ASSESSING THE STABILIZATION OF MARGINAL LATERITE SOILS USING STEEL SLAG AND QUARRY DUST FOR THE CONSTRUCTION OF A SUBBASE ROAD LAYER

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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 report focuses on the stabilization of marginal laterite soils using steel slag and quarry dust for the construction of a subbase road layer. Laterite soils, commonly found in tropical and subtropical regions, are characterized by their physical nature, chemical composition, and geological characteristics. The report highlights the challenges associated with using laterite soils in road construction, particularly their variability in quality and the need for stabilization to meet strength requirements. The research aims to assess the suitability of using steel slag, a byproduct of the steelmaking process, and quarry dust, a byproduct of stone crushing, as stabilizers to improve the engineering properties of laterite soils. The methodology section details the various tests conducted to evaluate the physical and mechanical properties of the soil samples, including the California Bearing Ratio (CBR), Atterberg limits, and particle size distribution. The results indicate that the addition of steel slag improves the load-bearing capacity of the soil sample by 160% at 40% of steel slag. Quarry dust reduces the liquid limit by 13%, plastic index by 27% and linear shrinkage by 33% at 10% of quarry dust in the blend. The report concludes that the use of these industrial byproducts not only enhances the performance of the soil but also offers environmental benefits by recycling waste materials and reducing the need for natural resources.

DECLARATION

I, KYALIGONZA GARY TIMOTHY, affirm that this report is my original work. Any external research used has been properly cited. This report has not been submitted to any other institution for any academic award.

Signature…………………………………………

Date…………………………………………………

APPROVAL

This report was compiled under the guidance of my supervisor and is now ready to be submitted to the Faculty of Engineering, Design and Technology, Uganda Christian University, in partial fulfillment of the requirements for an award of a Bachelor of Science in civil and environmental engineering for academic reward.

Approved by

SIGNATURE……………………………………………………………

DATE…………………………………………………………………………

MR. ZZIGWA MARVIN

(SUPERVISOR)

DEDICATION

I dedicate this research to my mother, Ms. Kisembo Victoria Basemera, who has been my biggest support throughout my academic journey. I also dedicate this report to my guardian, Mr. Kirungi Jackson Barnabas, who has financially supported me throughout my academic journey.

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LIST OF ABBREVIATIONS

AASHTO	AMERICAN ASSOCIATION OF STATE HIGHWAY TRANSPORTATION OFFICIAL SYSTEM
BS	BRITISH STANDARD
BSCEE	BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING
CBR	CALIFORNIA BEARING RATIO
CRR	CRUSHED ROCK
LL	LIQUID LIMIT
LS	LINEAR SHRINKAGE
MDD	MAXIMUM DRY DENSITY
MoWT	MINISTRY OF WORKS AND TRANSPORT
OMC	OPTIMUM MOISTURE CONTENT
PI	PLASTICITY INDEX
PL	PLASTIC LIMIT
UCU	UGANDA CHRISTIAN UNIVERSITY
USCS	UNIFIED SOIL CLASSIFICATION SYSTEM

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Lateritic soils are a leached residue that results from the natural process of laterization in tropical and sub-tropical regions around the world. Laterite soils are defined according to physical nature, chemical composition, geological characteristics, and morphology. The characteristics of laterite soil depend on numerous factors, such as origin process, atmosphere, rain magnitude, temperature, parent rock nature, bed surface properties, weathering course, etc. and it can be influenced by the synergetic effect of all these factors (Kumar et al., 2022).

Laterite soils are mainly composed of aluminum, silicon, and iron oxides and may contain crystalline phases such as quartz, kaolinite, halloysite, goethite, hematite, and ilmenite. The bulk density of laterite depends on its chemical composition, which typically varies widely from 0.9 to 3.6 g/cm3. It increases with iron content and decreases with alumina content (Kaze et al.,2022).

Laterite soils are used in the construction of the subgrade, subbase, and base layers of flexible pavements. This is because of their good strength properties; however, quality laterite soils may not be available in the local area of the road project and engineers are forced to improvise and stabilize the marginal laterite soils to improve them to meet the strength requirements for natural gravel used to construct the pavement layers (Sudla et al., 2018).

The most common stabilizers used for the stabilization of laterite soils are cement and lime for chemical stabilization and crushed rock for mechanical stabilization.

Cement stabilization is widely used because it is widely available, cost-friendly, highly durable, and quite weather-resistant. Granular soils with sufficient fines are ideally suited for cement stabilization as they require the least amount of cement. Cement stabilization however causes cracks in the soil due to hydration and the manufacturing process of cement leads to adverse effects on the environment.

Mechanical stabilization with crushed rock is another common method of stabilizing laterite soil due to the availability and proximity of crushed rock. However, stabilization using crushed rock distorts the particle size distribution of the soil and lowers the cohesiveness of the soil. Crushed rock is a non-renewable resource, and its continued mining makes it susceptible to depletion (Opara & Ejiogu, 2021).

Steel slag is a solid waste byproduct from industrial steel production generated from the conversion of iron to steel in a Furnace. Recycling of scrap steel is performed by the Electric Air Furnace which also generates slag but of varying properties. Other types include the ladle refining slag and casting residue. The slag is rich in calcium oxide which contributes to the cementitious properties of the slag. It also contains other oxides such as silicon, iron, aluminum, and magnesium which are impurities from the steel manufacturing process that undergo oxidation and are eliminated from the molten metal. These chemical properties vary depending on the steel grades used, furnace type, and pretreatment method used (Wandera, 2021). This enhances the soil strength through a series of chemical reactions forming calcium silicate hydrates having reacted with silicates in the soil. It is characterized by adhesive properties making it a suitable binder aggregate for unbound bases subbases, and pavement surface layers in road construction (Yi et al., 2012).

Quarry dust is a by-product formed as a result of the crushing and cutting of stone (Prakash & Hanumantha Rao, 2017). Quarry dust is a fine powdery material made of crushed rock particles, primarily comprising silica, feldspar, and other minerals depending on the parent rock type (Subramanian & Kannan, 2013). Quarry dust has been a widely used material in improving the properties of problematic soils to fit different engineering purposes.

1.2 STATEMENT OF THE PROBLEM

Uganda's climate is largely tropical, and a sizable portion of the soils in Uganda are lateritic in nature. To date, the instability, as well as the strength of laterite soils in the construction application, has been widely addressed by many scholars (Ezreig et al., 2022). Laterite soils are used in the construction of the subgrade, subbase, and base layers of flexible pavements(Townsend et al., n.d.).

However, quality laterite soils may not be available in the local area of the road project and engineers are forced to improvise and stabilize the marginal laterite soils to improve them to meet the strength requirements for natural gravel used to construct the pavement layers (Sudla et al., 2018). Case study of Nasuuti-Nakabago-Ntawo road where the material is obtained from Nsambwe borrow pit with a CBR value of 25%. In contrast, the required minimum CBR value for the Subbase layer is 45%. This discrepancy caused the engineers to stabilize the soil using varying percentages of crushed rock to mechanically modify the soil to meet the minimum requirements for the subbase layer.

However, this research intends to assess the suitability of stabilizing marginal laterite soils using crushed steel slag to meet the requirements for a subbase layer of a flexible pavement.

1.3 OBJECTIVES

1.3.1 Main objective

To assess the stabilization of marginal laterite soils using steel slag and quarry dust for the construction of a subbase layer of a flexible pavement.

1.3.2 Specific objectives

1. To determine the physical and mechanical properties of neat laterite soil.
2. To determine the physical properties of steel slag.
3. To determine the physical and mechanical properties of the laterite soil with varying compositions of steel slag and quarry dust.

1.4 JUSTIFICATION

Steel slag has a density between 3.3-3.6 g/cm^3. It is characterized as a hard material giving it a high level of strength with a bulk density of 1800-2000 kg/m^3 Los Angeles Abrasion of 20-25% and crushing value of 15% marking it a hard material. It is wear-resistant making it rough due to its high frictional and abrasion resistance. It is characterized by adhesive properties making it a suitable binder aggregate for unbound bases and subbases, a pavement surface layer in road construction. These characteristics depict a material that is well capable of improving the strength of the laterite soils by increasing the load-bearing capacity and enhancing the mechanical performance (Güneyisi et al., 2020).

Steel slag offers environmental benefits, as it is a byproduct of the steelmaking process and can help reduce the need for quarrying natural resources. Studies have shown that the use of steel slag in construction not only conserves natural aggregates but also diverts industrial waste from landfills contributing to sustainability in construction. This makes steel slag a viable alternative while minimizing the environmental impact of road construction (KCCA, 2016).

The addition of quarry dust to neat soil samples reduces the liquid limit, plastic limit, and plastic index of the sample due to the addition of a non-plastic material (Madhavi and Raghuveer, 2021). Since quarry dust is a nonplastic material, replacing a portion of plastic fines in the neat soil sample with quarry dust subsequently leads to a decrease in the liquid limit and plastic index of a soil sample (Dixit et al., 2016a).

1.5 SIGNIFICANCE OF THE STUDY

Soil stabilization techniques have been the focus of extensive research by numerous scholars, with a wide range of stabilizers being evaluated for their effectiveness in enhancing soil properties. The viability of different stabilizing agents has been well-established through these studies, addressing various soil types and conditions. This report seeks to explore and establish the potential of using steel slag as a mechanical stabilizer for improving the engineering properties of laterite soils. Specifically, the study aims to determine how steel slag can enhance the strength, durability, and overall performance of laterite soils, making them more suitable for construction and other geotechnical applications. This report will contribute to the growing body of knowledge on sustainable soil stabilization techniques using industrial by-products through detailed analysis.

1.6 SCOPE

Geographical scope

The case study of research is Nasuuti-Nakabago-Ntawo road in Mukono Municipality 0°22'21.7"N 32°45'04.4"E

Content scope

The study focused on analyzing the physical and mechanical properties of the material, i.e., California bearing ratio, plasticity characteristics, and particle size distribution of the final blended material.

Time scope

The study was carried out over a span of 6 months from October 2024 to March 2025.

CHAPTER 2:LITERATURE REVIEW

2.1 INTRODUCTION

This chapter highlights the existing body of knowledge related to the research concept. This chapter provides an analysis of various scholarly works like books, journals, and other academic materials that inform and guide the research topic.

2.2 SOIL STABILIZATION

Soil stabilization involves the alteration of soils to reinforce their physical properties. Soil stabilization aims to improve shear strength, shrink-swell properties, and other soil characteristics and therefore improve the load-bearing capacity. Soil stabilization can also be defined by the preservation or alteration of one or more soil properties to better the engineering characteristics and performance of the soil (Yakub et al., 2020).

During soil stabilization, stabilizers are added to the soil at varying percentages and the various parameter changes in the soil are noted.

Types of soil stabilization include:

1. Mechanical stabilization
2. Chemical stabilization
3. Compaction stabilization

2.2.1 Basic principles of soil stabilization

Different stabilization methods are generally governed by different factors and variables. However, some basic principles cut across all stabilization methods and are essential for stabilization to be successful (Archibong et al., 2020). These are:

1. **Evaluate the properties of the given type of soil.**

This is the first and most important part of soil stabilization which helps to identify the composition of the soil. This is because the engineering properties of soil are primarily governed by the composition of the soil. Therefore, by identifying the properties and composition of the soil, an effective stabilizer can be employed to enhance the engineering performance of the soil.

2. **Decide the most suitable, effective, and economical method of stabilization.**

This principle informs us to pick the best possible stabilizer that best supplements the lacking properties in the soil being stabilized. That's to say, a stabilizer employed for clay soils may not be as effective when employed for sandy soil.

3. **Design the soil blend considering stability and durability.**

This principle involves choosing the appropriate blend of neat soil and stabilizer that meets the stability and durability standards required for the purpose for which the soil is to be used.

4. **Determine the adequate construction procedure**

The adequate construction procedure ensures proper compaction of the stabilized layers of material.

2.2.2 Mechanical stabilization

Mechanical stabilization involves physically changing the properties of the soil to in turn affect the gradation, solidity, density, and other characteristics of the soil. This can be achieved by mixing and compacting two or more soils of different grades.

With respect to mechanical stabilization, soils can be grouped into two (Archibong et al., 2020).

Aggregates. These typically have particle sizes greater than 75 microns. They provide the skeletal framework for providing internal friction.

Binders. These typically have particle sizes of less than 75 microns. They primarily provide cohesion in the material.

Factors that affect mechanical stabilization.

- Strength of the aggregate used.
- Basic mineral composition of the blended soils.
- Gradation of the blended soil.
- Plasticity characteristics of the blended soils.

Mechanical stabilization using aggregates (CRR)

Aggregates improve the internal angle of friction in granular soil by increasing the number of contact points between particles due to their larger size and often angular shape, which creates more interlocking and resistance to shearing forces, effectively allowing the soil to withstand greater shear stress before failure (Nicks Jennifer & Adams Mick, 2013).

2.2.3 Chemical stabilization.

Chemical stabilization involves the addition of an additive that causes a chemical interaction between the soil particles and the additive causing an alteration in the physical and chemical properties of the soil(Das, n.d.).

Most common type of chemical stabilization includes cement stabilization and lime stabilization.

2.2.4 Compaction stabilization.

Compaction stabilization uses mechanical methods to force air voids out of the soil mass, creating soil that can support weight subsequently without needing to be compressed more right away (Adams, 2014). One of the main methods of stabilizing soil is dynamic compaction, which involves dropping a heavyweight onto the ground at regular intervals to essentially hammer away irregularities and guarantee a level surface (Adams, 2014). Another method that uses similar concepts is vibratory vibro-compaction, which accomplishes its objectives using vibration rather than deformation caused by kinetic force.

2.2.5 Studies on Soil Stabilization using steel slag

Previous research on soil stabilization using steel slag has been greatly focused on modification of lateritic soils to improve their plasticity. The application of steel slag in stabilizing expansive soils has also been researched.

Application of Adjusted Activated Steel Slag to improve problematic soils.

Soil stabilization to improve the plasticity of marginal soils has most commonly been done using cement. Chemical parameters based on the oxide composition in cement are very useful in describing the capability of cement to be used as a stabilizer for problematic soils (Wu et al., 2019).

After comparing the differences in the chemical compositions of the slag and cement clinker, the adjustment concept was introduced (Wu et al., 2019).

Component adjustment of steel slag involves the addition of metakaolin and lime to the steel slag. Metakaolin and lime supplied to the steel slags to improve the Si/Al/Ca phase and alkalinity. After component adjustment, the slag is then activated before mixing with problematic soils to improve the plasticity of the soils(Wu et al., 2019).

The results of the research showed an improvement in the California Bearing Ratio and Unconfined compressive strength of the soils. The research also showed a significant reduction in the plastic index and plastic limit of the soil.

However, research has also shown that ground steel slag reduces the plasticity of lateritic soils and lowers the optimum moisture content while increasing the maximum dry density of the soils but reduces the soaked CBR value of the soil with an increase in ground slag content(Longjohn et al., 2022).

Application of steel slag in stabilization of expansive soils

Steel slag has been used to stabilize expansive soils and results showed that steel slag was able to improve the geotechnical properties of the expansive soil. According to research carried out by (Kabeta, 2023), the addition of 25% of ground steel slag produced a significant drop in the liquid limit of the soil from 90.8% to 65.2% and the plastic limit dropped from 60.3% to 42.5%. Therefore, the plastic index dropped from 30.5% to 22.%.

The addition of 25% steel slag also reduced the free swell value of the soil from 104% to 58% and an increase in the California bearing ratio from 3.64% to 6.82%. The unconfined compressive strength of the soil also increased from 0.94Mpa to 2.6Mpa (Kabeta, 2023).

Application of steel slag in improving the bearing capacity of black cotton soils

Steel slag has also been used to improve the bearing capacity of weak black cotton soils. The addition of 50% steel slag to black cotton soils showed an increase in the soaked CBR of the soils from 1.75% to 5.88% (Bidkar et al., 2019).

The steel slag used in this case had a fineness modulus of 3.55 implying that the steel slag was crushed and classified as coarse sand rather than fine sand.

2.3 SUBBASE ROAD LAYER

The sub-base layer is the first layer constructed over the formation level(subgrade). It forms the first layer in the pavement structure. As part of the foundation of the upper pavement layers, the subbase layer serves to protect the flexible pavement by mitigating detrimental climatic effects and static or dynamic stress applied to the pavement structure (Nik Daud et al., 2019). The general specification for road and bridge works specifies minimum material requirements for a subbase layer for flexible pavements.

According to the Flexible Pavement Design Manual of Uganda, the materials for subbase construction are classified into two types, granular and cemented.

The granular subbase material is classified as G45 and G30 according to the General Specification for road and bridge works as shown in Tables 1 and 2 below. The tables specify the different physical and mechanical characteristics that a material must meet in order to be classified as a G45 or G30.

Table 1: Material specification for G45 Subbase granular material (sourced from General Specification for Highways and Bridges series 3000, 2005)

Material properties	Accepted values
CBR (%) BS1377 part4	>45 (after 4 days of soaking)
CBR swell (%) BS1377 part4	<0.5 measured at BS- heavy compaction
Atterberg limits	
Liquid limit BS1377 part2	<40
Plasticity index BS1377 part2	<14
Linear shrinkage BS1377 part2	<7
Grading	
Grading modulus BS1377 part2	>1.5

Table 2: Material specification for G30 Subbase granular material (sourced from General Specification for Highways and Bridges series 3000, 2005)

Material properties	Accepted values
CBR (%) BS1377 part4	>30 (after 4 days of soaking)
CBR swell (%) BS1377 part4	<1.0 measured at BS- heavy compaction
Atterberg limits	
Liquid limit BS1377 part2	<45
Plasticity index BS1377 part2	<16
Linear shrinkage BS1377 part2	<8
Grading	
Grading modulus BS1377 part2	>1.2

2.4 LATERITE SOILS

Laterite soils

Lateritic soils are leached residue resulting from the natural process of laterization in tropical and sub-tropical regions around the world. Laterite soils are defined according to physical nature, chemical composition, geological characteristics, and morphology. The characteristics of laterite soil depend on numerous factors, such as origin process, atmosphere, rain magnitude, temperature, parent rock nature, bed surface properties, weathering course, etc., and it can be influenced by the synergetic effect of all these factors (Santha Kumar et al., 2022).

Due to their abundance in tropical regions, laterite soils are commonly used in the road construction industry for the subgrade, subbase, and base layers of the road depending on the quality of the material and the design of the road.

Marginal soils

In road construction, marginal materials are materials that do not possess the required quality standards as per the prevailing highway standards, sufficient for their use as pavement structural components such as surfaces, subgrades, bases, or subbases (Cook & Gourley, 2003)

Marginal soils may be short of the required standards in terms of Atterberg limits, bearing capacity, or particle size distribution of the soils. This limits their performance as a particular pavement layer.

Classification of laterite soils

The characteristics of laterite soil depend on numerous factors, such as origin process, atmosphere, rain magnitude, temperature, parent rock nature, bed surface properties, weathering course, etc. (Santha Kumar et al., 2022).

Laterite soil classification can be done using the AASHTO or USCS soil classification systems. Both grade the soil and give its quality, clearly highlighting its performance as an engineering material (Archibong et al., 2020).

AASHTO soil classification system

Soil is classified into seven major groups, namely A-1 to A-7. Granular soils are categorized as A-1, A-2, and A-3 if at least 35% of the soil grains pass sieve number 200. More than 35% of soils with grains that pass sieve number 200 are categorized as belonging to categories A–4. A-5, A-6, and A-7. Groups A-4 and A-7 include most of the silt and clay. The criteria in the soil classification system are grain size.

USCS soil classification system

This system classifies the soils into two groups.

- Coarse-grained soils, such as pebbles and sand, are less than half percent of the total weight of the soil sample that passes filter no. 200. The first letter in this category is either G or S. S stands for sandy or sandy soil, and G for pebbles or pebble-rich soil (D Chandrasasi, S Marsudi and E Suhartanto, 2021).
- Fine-grained soil is soil that is more than half percent of the total weight of the soil sample that passes the No. 200 sieve. For this category, the initial letter M stands for inorganic silt. O stands for organic silt, and C for inorganic clay. The

PT symbol denotes peat, manure, and other soils with a high organic content (D Chandrasasi, S Marsudi and E Suhartanto, 2021).

2.5 STEEL SLAG

Steel slag is a byproduct of the steelmaking process produced when impurities are separated from molten steel in a furnace with about 15-20% of the total steel smelting attributed to steel slag (Lim et al., 2016). Different types of slag are produced depending on the type of steel production process which could be the basic oxygen furnace slag, electric arc furnace slag, or ladle furnace slag. Steel slag is rich in oxides such as calcium, magnesium, silicon, and iron, which provide it with unique mechanical and chemical properties (Lim et al., 2016).

In recent years, the use of steel slag in civil engineering and construction projects has raised concerns as to how it can be reused due to its durability, high strength, and potential to recycle these waste materials (KCCA, 2016).

Formation of steel slag

As steel is melted in the furnace, the impurities form a layer of slag on the surface of the molten steel (Nunes & Borges, 2021). This slag is rich in calcium oxide due to the addition of lime during the melting process. The lime acts as a flux, removing impurities like silica, phosphorous, and sulfur. The steel slag contains oxides that are impurities from the manufacturing process (Gopinath & Mehra, 2018).

The steel slag is then periodically removed from the surface of the molten steel, and this is done to ensure the purity of the steel and to collect the slag for further processing.

The steel slag is then cooled and solidified in air or by water quenching depending on the desired properties of the steel slag. Once solidified, the slag is then crushed to produce different sizes of aggregate and these various aggregates can then be used for different construction applications.

Chemical composition of steel slag.

The table below shows the chemical composition of the various types of steel slag which informs the corrosion potential of steel slag.

Table 3: Chemical composition of various types of steel slag in percentages (sourced from Liang, 2013)

Components	Basic oxygen furnace	Electric arc furnace (carbon steel)	Electric arc furnace (alloy/stainless)
SiO_2	8-20	9-20	24-32
Al_2O_3	1-6	2-9	3.0-7.5
FeO	10-35	15-30	1-6
CaO	30-55	35-60	39-45
MgO	5-15	5-15	8-15
MnO	2-8	3-8	0.4-2
TiO_2	0.4-2	N/A	N/A

From Table 4 above, steel slag is mainly comprised of mainly silicates and calcium oxide therefore the metallic oxides in the steel slag are not significant enough to cause significant durability concerns.

Types of steel slag include:

Basic oxygen furnace slag

This type of slag is produced during the conversion of pig iron into steel in a basic oxygen furnace. It is characterized by its density of 3,000-3,500 kg/m^3. It has low water absorption ranging from 1% to 4% making it suitable for applications where low permeability is critical. Its high calcium oxide content can lead to expansive behaviour which is a challenge in some construction applications but can be mitigated through proper aging and treatment (Cabrera et al., 2021).

Electric arc furnace slag

This type of slag is formed during the production of steel in electric arc furnaces, EAF slag has similar properties to BOF slag but contains more iron oxides and has higher stability. Its density and compressive strength have shown to be comparable to the BOF slag making it a suitable alternative for sub-base materials depending on the batch used during the steel production. EAF slag also demonstrates higher resistance to abrasion with Los Angeles abrasion values below 30% indicating its durability in road construction (Papayianni & Anastasiou, 2020).

Ladle furnace slag.

This type of slag is formed during the final refining of steel in the ladle furnace and is normally used in cement production due to its finer particles and lower mechanical strength. This makes it less suitable for use in road sub-base layers compared to BOF and EAF slags due to its lower load-bearing capacity and higher porosity (Singh et al., 2021).

Current uses of steel slag.

1) Steel slag is commonly used as a base material in road construction due to its high stability, resistance to deformation, and load-bearing capacity. Its angular shape provides excellent interlocking properties (Al-Shamsi et al., 2023).

2) Steel slag is used as an aggregate in hot-mix asphalt for surface layers of roads. Its rough surface texture provides an adhesive surface with asphalt binders, improving skid resistance and reducing wear from vehicle traffic. These asphalt mixtures with steel slag aggregates have been shown to extend the lifespan of roads (Güneyisi et al., 2020).

3) Steel slag is used to replace natural aggregates in concrete production improving compressive strength and reducing shrinkage. The high angularity and roughness of slag particles increase the bonding between the cement and aggregates, leading to improved concrete strength. Its high density also enhances the durability and wear resistance of concrete structures (Cabrera et al., 2021).

4) Steel slag is used as a supplementary cementitious material in cement production where it contributes to the reduction of clinker content which reduces CO_2 emissions. The calcium and silica content in steel slag provides pozzolanic activity enhancing the cement's strength and durability (Singh et al., 2021).

5) Steel slag is used as landfill covers, in soil stabilization and wastewater treatment. Its alkaline nature neutralizes acidic soils and stabilizes heavy metals preventing leaching into groundwater.

Availability of Steel slag

Table 3 below shows the total quantities of steel produced by different steel production industries around the country. Research shows that about 20 to 40 percent of steel slag is produced during the steel melting process.

Table 4: Steel melting production (Source: NPA, 2019)

Organization	Production of steel melting (tonnes per year)
Roofing Steel in Namanve	13,200
Steel and Tube	30,000
Tembo Steel in Lugazi	60,000
Tembo Steel in Iganga	36,000
Tian Tang	18,000
Pramukh Steel	25,000
Yogi Steel	28,000
Total	**210,200**

The steel melting process yields about 0.4 tonnes of steel slag for every tonne of the steel melted (Bhavan, 2018).

$$Steel\ slag\ mass = 210{,}000 \times 0.4 = \ 84{,}000\ tonnes\ per\ year$$

The bulk density of steel slag ranges from 1700 kg/m^3 to about 2000 kg/m^3. Hence, taking the density as 1,700 kg/m^3, the volume of steel slag available each year will be obtained as shown below.

$$Steel\ slag\ volume = \frac{84{,}000 \times 1{,}000}{1700} = 50{,}000\ m^3$$

Considering a one kilometer stretch of road with a thickness of 200 mm of subbase layer and road width 8 m, where the lane width is 3.5 m and shoulders are 0.5 m.

$$Volume\ of\ road = 0.2 \times 8 \times 1{,}000 = 1{,}600\ m^3\ per\ km$$

Taking the worst-case scenario to be 50 % steel slag addition to the mix in the subbase layer, then the length of road that can be achieved is obtained as shown below.

$$Length\ of\ road = \frac{50{,}000}{1{,}600 \times \frac{50}{100}} = 62.5\ km$$

This means that a 60km stretch of road with a 50% composition of steel slag in the subbase can be obtained from the available quantities of steel slag annually.

2.6 QUARRY DUST

Quarry dust is recognized as an effective and economical material for the improvement of weak soils that can be used for construction. Due to its fine particle size and excellent binding properties, it has been used to enhance the strength and stability of various soil types. Quarry dust is a cost-effective alternative to traditional materials and an environmentally sustainable option for construction projects (Onyelowe et al., 2012).

Studies have been conducted on the effect of quarry dust on the plasticity of soil. Results showed that as the percentage of stone dust increased, the liquid limit reduced at a faster rate and the plastic limit at a slower rate resulting in a decrease in the Plasticity index, i.e., there is a decrease in plasticity index (PI) with an increase in Stone dust content. The addition of Stone Dust increased the Maximum Dry density and reduced the Optimum Moisture Content up to 40% stone Dust content and 50% Stone dust content, a reversal of the MDD and OMC results (Dahal et al., 2022).

This is possibly attributed to the replacement of the plastic fines of the material with non-plastic quarry dust leading to a reduction in the liquid limit and plastic index of the soils.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

This chapter outlines the methods and techniques used to collect and analyze data for this study. The chapter also outlines the sources of the materials used during the research. Providing details about the approach and methods used ensures transparency and allows for replication of the study by future researchers.

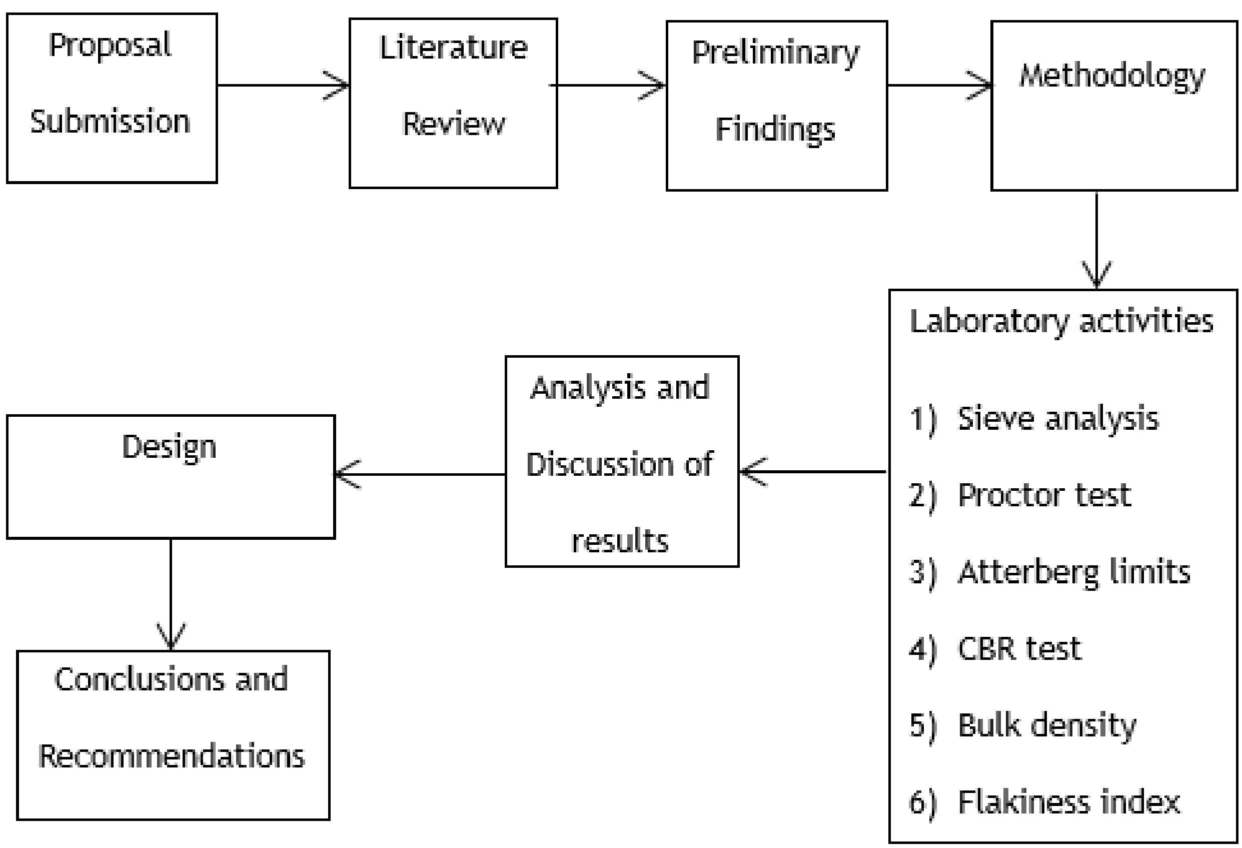


Figure 1: Research design

3.2 MATERIALS

Laterite soils

The laterite soils were obtained from a borrow pit owned by Stirling at Nyenje-Ntawo with coordinates 0°22'21.7"N 32°45'04.4"E. The borrow pit contained reddish brown soil, which is a characteristic of laterite soils rich in iron.

The sample was collected from three different spots within the borrow pit at depths of 1.5 m. The sample was collected in its disturbed form with a total weight of about 300 kgs and transported to Stirling testing laboratories in Mbalala.

Steel slag

The steel slag was obtained from Roofings Rolling Mills Ltd, a steel manufacturing company in Namamve, Kampala, Uganda. Roofings Rolling Mills Ltd uses an induction furnace in the steel production process.

A sample of about 150 kgs was collected from the industry and transported to Stirling Testing Laboratories in Mbalala.

The material was then manually crushed until particle sizes were not greater than 20mm using a mallet, as shown in the Figure 2 below.

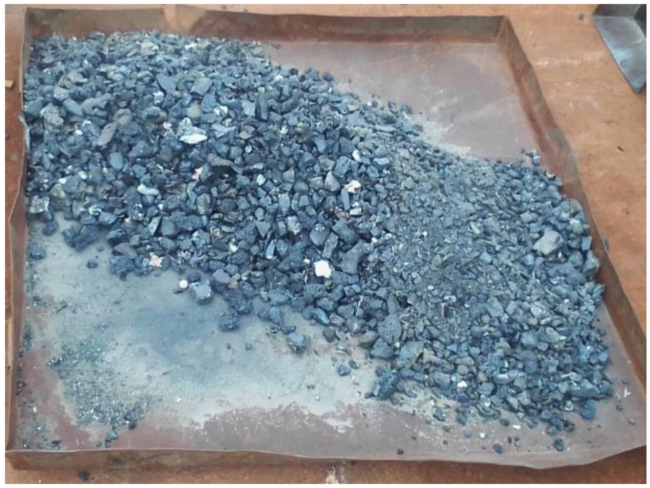


Figure 2: Crushed steel slag

Quarry dust

The quarry dust shown in Figure 3 below was obtained from MM Stone Quarry located at plot 1850 Buleeba, Jinja. The quarry dust collected was obtained from crushing granite stone and we collected about 40 kg of sample which was then transported Stirling testing Laboratories in Mbalala.

Figure 3: Granite dust

TEST PLANS

The test plans in Table 5 and 6 below show the material proportions for each blend, stating the different percentages by mass and the quantities of each material required to carry out the required tests on the material blend.

Table 5: Summary of the test plan for laterite soils with varying compositions of steel slag.

Sample composition	Material Proportions	Quantities	
		Steel slag	**Soil**
Neat soil	100% laterite soils	0 kgs	50 kgs
Steel slag + soil	40% steel slag + 60% laterite soil	20 kgs	30 kgs
Steel slag + soil	30% steel slag + 70% laterite soil	15 kgs	35 kgs
Steel slag + soil	20% steel slag + 80% laterite soil	10 kgs	40 kgs

Table 6: Summary of test plan for varying composition of laterite soil and quarry dust with fixed steel slag percentage at 40%

Sample composition	Material proportions	Quantities		
		Steel slag	**Laterite soil**	**Quarry dust**
SS + LS + QD	40% SS + 55% LS +5% QD	20 kgs	27.5kgs	2,5 kgs
SS + LS + QD	40% SS + 50% LS +10% QD	20 kgs	25 kgs	5 kgs
SS + LS + QD	40% SS + 45% LS +15% QD	20 kgs	22.5 kgs	7.5 kgs

SS – Steel slag

LS – Laterite soil

QD – Quarry dust

3.3 METHODS

3.3.1 Determining the physical-mechanical properties of the Laterite soils.

The physical-mechanical properties of the soil were determined to classify the soil and determine its performance without any stabilization.

Tests carried out included:

1. **Maximum dry density and Optimum moisture content relation (British Standard 1377 part 2).**

This test helped to obtain the relationship between the compacted dry density and moisture content. This was majorly important in identifying the optimum moisture content to be used when compacting the sample for the California Bearing Ratio Test.

Sample preparation

The test was carried out on the sample passing through the 20mm test sieve. A representative sample of 15 kgs was used for this test.

The sample was then quartered, and portions were picked in alternating quarters to ensure that the material particles were uniformly distributed. The sample was split into five equal portions of about 3 kg weight.

Apparatus

- 4.5 kg rammer

- Five 1-litre moulds. The moulds should be fitted with detachable baseplates and removable extensions
- Measuring cylinder
- Test sieves sizes 20 mm and 5 mm

Test procedure

For each portion, varying amounts of water were added to cover a range of moisture contents around the expected optimum moisture content.

The material was then compacted in standard cylindrical molds of about 1ltr volume.

All the samples were compacted in three layers, applying 62 evenly distributed blows to each layer using a 4.5 kg rammer.

The samples were trimmed to cut off the excess material so that the compacted material was flush with the mold.

The samples were then weighed, and representative samples were taken to the oven for moisture content determination at about 105ºC for 24 hours.

Calculation and plotting

- A graph of moisture vs density was drawn, and the peak point of the graph was taken as the maximum dry density.
- The moisture content at that point was taken as the optimum moisture content.

2. **California Bearing Ratio and California Bearing Ratio swell after 4 days of soaking (British Standard 1377 part 4).**

This test is the main factor in determining the strength of a material. The strength of a subgrade, subbase, and base course material is typically expressed in terms of their CBR value.

The one-point method was used in determining the CBR % of the soil due to limited availability of the steel slag during the time of testing, however, the three point method provides more reliable results.

Sample preparation.

The test was carried out on the sample passing through the 20mm test sieve of about 6 kgs. The sample was brought to optimum moisture content and thoroughly mixed thereafter sealed and soaked for at least 24 hours before tests were carried out.

Apparatus

- Test sieves 20mm and 5mm
- Three cylindrical molds with an internal diameter of 150 mm and a height of 127 mm. The molds were fitted with detachable baseplates and removable extensions.
- Two metal rammers, 2.5 kg and 4.5 kg.
- Perforated baseplates
- Perforated swell plates with adjustable stems to provide seating for a dial gauge.
- A dial gauge with 25 mm travel and reading to 0.01 mm.
- CBR compression machine with known proving ring factor.

- Annular surcharge discs for penetration test weighing 5 kg.

Test procedure

The test was carried out using the one-point method.

The sample at optimum moisture content was compacted into a standard 2 lts mold in five layers, applying 62 evenly distributed blows per layer using a 4.5 kg rammer.

The sample was then trimmed and fitted with a perforated baseplate. A filter paper was then placed on top of the sample, followed by perforated swell plates.

Annular surcharge discs weighing about 4.5 kg were then placed on the stem of the perforated swell plates. A dial gauge was thereafter mounted on the extension collar and adjusted to give a convenient zero reading.

The mold was then placed in the soaking tank with the water level just below the mold extension and left to soak for 4 days.

After 4 days of soaking, the sample was then taken for penetration using a CBR testing machine shown in Figure 4 below.

Figure 4: CBR testing machine

Calculations

- ✓ **Density calculations**

1. The volume of the mold V_m (cm^3) was obtained
2. Bulk density was calculated from;

$$bulk\ density = \left(\frac{mass\ of\ soil}{volume\ of\ the\ mould}\right) \times 1000$$

Mass of the soil was obtained from the mass of soil, mold, and baseplate – mass of mold and baseplate.

3. Dry density was then calculated from;

$$dry\ density = \left(\frac{100}{100 + moisture\ content}\right) \times bulk\ density$$

- ✓ **Swell calculation**

1. Swell in percentage was calculated from the equation below;

$$swell = \left(\frac{F - B}{127}\right) \times 100$$

Where

F is the dial gauge reading after 4 days of soaking

B is the dial gauge reading before soaking

- ✓ **Calculation for California bearing ratio.**

1. Penetration of 2.5 mm and 5.0 mm were used to calculate the CBR value.
2. CBR at 2.5 mm penetration was calculated from;

$$CBR(\%) = \frac{P \times 100}{13.2}$$

Where

P is the plunger force at 2.5 mm penetration in kN

3. CBR at 5.0mm penetration was calculated from;

$$CBR(\%) = \frac{P \times 100}{20.0}$$

Where

P is the plunger force at 5.0 mm penetration in kN.

NB: ***CBR at 2.5mm penetration was used for assessing the quality of the material***

3. **Atterberg limits (British Standard 1137 part 2) i.e. Liquid limit, Plastic limit, and linear shrinkage.**

These tests helped to understand the performance of the soil when interacting with moisture. The tests highlighted the moisture content at which the soil transitions from a solid to a plastic state and the moisture content at which the soil transitions from a plastic to a liquid state. These greatly informed the performance of the soil when moisture is added to the soil.

The Atterberg limits tests were carried out in **duplicates**, and the averages were calculated to get the final result.

i. **Liquid limit**

Sample preparation

The test was carried out on a soil sample passing through the 425 µm sieve of weight about **400 g**. The same sample was used to carry out the plastic limit test and linear shrinkage test.

The sample was placed on a glass plate and water was added before mixing thoroughly with the spatulas until the sample became a thick homogeneous paste. The sample was placed in an airtight bag and allowed to sit for 16-24 hours to allow the water to penetrate and soak the soil sample.

Apparatus required

- Test sieve of size 425 μm
- Flat glass platform
- Two spatulas
- A cone penetrometer (with a stainless steel cone 35 mm long with a smooth polished surface, angle of 30º, and mass of 80 g)
- Metal cup with 55 mm diameter and 40 mm depth with rim parallel to the flat base
- Apparatus for moisture content determination

Test procedure

After soaking the sample, the sample was tested by adjusting the moisture content and penetrating the sample using a cone penetrometer shown in Figure 5 below for five seconds.

Figure 5: Cone Penetrometer

A range of penetrations between 15.0 mm – 27.0 mm were recorded and representative samples were taken for moisture content determination in an oven at 105ºC for 24 hours.

Calculations

1. The moisture content was calculated for each specimen.

$$w = (\frac{m2 - m3}{m3 - m1}) \times 100$$

   Where

   m1 is the mass of the container (g)

   m2 is the mass of the container and wet soil (g)

   m3 is the mass of the container and dry soil (g)

2. The relationship between the moisture content and cone penetration was plotted with the moisture content as the abscissa and the cone penetration as the ordinates on linear scales.
3. The line of best fit was drawn

4. The liquid limit of the soil sample was the moisture content corresponding to the cone penetration of 20mm and was expressed to the nearest whole number.

ii. Plastic limit and plasticity index

Objective

Apparatus required

- Flat glass plate
- Two palette knives
- Apparatus for moisture content determination

Sample preparation

This test was carried out as a continuation of the liquid limit test. During the liquid limit test, a penetration test was done for a penetration of 20 mm. Part of this sample was set aside to dry partially at room temperature.

The sample set aside to dry was then used to carry out the plastic limit test.

Test procedure

The sample was rolled on the glass plate into threads of about 3 mm until they started to break. The particles were then placed in an oven at 105ºC for 24 hours to determine the moisture content.

Calculations

The average of the moisture contents for the portions of the sample was taken as the plastic limit. The value was rounded off to the nearest whole number.

Plasticity index

PI = Liquid Limit – Plastic Limit

iii. Linear shrinkage

Apparatus required

- Flat glass plate
- Two palette knives
- Drying oven capable of maintaining a temp of 105ºC - 110ºC
- Brass mold for linear shrinkage test
- Vernier calipers or steel rule with an accuracy of 0.5 mm

Sample preparation

This test was carried out as a continuation of the liquid limit test. The sample with a cone penetration of 20 mm was used for this test.

Test procedure

The sample was placed in a lubricated brass mold for linear shrinkage determination.

The sample was then placed in an oven at about 105ºC for 16 – 24 hours.

Calculations

The linear shrinkage was calculated from;

$$linear\ shrinkage(\%) = \left(1 - \frac{l}{d}\right) \times 100$$

Where

l is the length of the oven-dried sample

d is the original length of the specimen

NB: *Linear Shrinkage is measured to the nearest whole percentage*.

4. Particle size distribution (British Standard 1377 part 2)

This test helped to determine whether the soil consists of predominately gravel, sand, or silt, and to an extent which of the size ranges was likely to control the engineering performance of the soil.

The Particle size distribution test was carried out in **duplicates**, and the averages were calculated to get the final result.

Sample preparation

The sample was picked from the platform after sun drying for 12 to 16 hours and riffled to obtain a representative sample of a minimum mass of about 10 kg.

The sample weight was also noted down as the wet mass of the soil.

A representative sample was also picked for moisture content.

Apparatus required

- Test sieves: 37 mm, 20 mm, 14 mm, 10 mm, 5 mm, 3.35 mm, 1.18 mm, 600 μm, 300 μm, 75 μm.

- Drying oven
- Riffle boxes
- Sieve brushes

Calculations

- ✓ Calculated the cumulative mass retained
- ✓ Calculated the percentage mass retained
- ✓ Calculated the percentage of passing
- ✓ Plotted a graph of the grading sieve size against %passing.
- ✓ Grading modulus was calculated from;

$$gm = (300 - \% < 2\ mm - \% < 425\ \mu mm - \% < 75\ \mu mm) \div 100$$

3.3.2 Determining the physical properties of steel slag.

The physical properties of the steel slag to be determined include:

1. **Bulk density (ASTM C29/C29M)**

This test is an indicator of the quality of steel slag. Higher relative densities indicate stronger and more durable materials, therefore informing the suitability of the steel slag for use as a construction material.

Test procedure

The sample was poured into a graduated container of known volume until it filled one-third of the container.

The sample was then tamped using a metal rod, applying 25 strokes evenly distributed on the sample.

The process was repeated until the container was filled with the sample and the excess was trimmed off as shown in the figure 6 below.

Figure 6: Graduated container filled with steel slag.

The sample and container were then weighed and the net weight of the sample was calculated.

Calculation

Density is calculated from

$$D = \frac{Mass\ of\ soil\ sample}{volume\ of\ container}$$

2. **Particle size distribution (British Standard 812 part 103).**

This test helped in determining the particle size of the steel slag and how the different particle sizes are distributed within the sample.

Sample preparation

The sample was washed through the 75 µm sieve, letting the sample that passes through the sieve run to waste.

The sample was then transferred to a tray and placed in an oven to dry at 105ºC to 110ºC for about 16 hours.

Test procedure

After drying in the oven, the sample was weighed to determine its dry weight.

The sample was then sieved through the different sieve sizes while weighing the mass of the sample retained on the sieve.

Calculations

- ✓ Calculate the cumulative mass retained
- ✓ Calculate the percentage mass retained

- ✓ Calculate the percentage passing
- ✓ Plot a graph of the grading sieve size against %passing.
- ✓ Compare the percentage with the specified limits for CRR.

3.3.3 Physical-mechanical properties of the laterite soil with varying compositions of steel slag.

40%, 30%, and 20% steel slag were added to the laterite soil by mass as shown in the figure 7 below and tested to determine the percentage that gives the most satisfying results for a subbase material.

Figure 7: Steel slag added to the neat laterite soil in varying percentages

The percentages chosen were based on blending the material to fit within the grading envelope for G45 Subbase material.

The final percentage was chosen based on the most satisfactory results focusing on CBR % and CBR swell after 4 days of soaking.

The tests carried out to assess the performance of each blend included.

1. **Maximum dry density and optimum moisture content (British Standard 1377 part 2).**

This test helped to obtain the relationship between the compacted dry density and moisture content. This was majorly important in identifying the optimum moisture content to be used when compacting the sample for the California Bearing Ratio Test.

2. **California Bearing Ratio and California Bearing Ratio swell after 4 days of soaking. (British Standard 1377 part 4).**

This test is the main factor in determining the strength of a material. The strength of a subgrade, subbase, and base course material are typically expressed in terms of their CBR value.

3. **Atterberg Limits (British Standard 1137 part 2) i.e. Liquid limit, Plastic limit, and linear shrinkage.**

These tests helped to understand the performance of the soil when interacting with moisture. The tests highlighted the moisture content at which the soil transitions from a solid to a plastic state and the moisture content at which the soil transitions from a plastic to a liquid state. These greatly informed the performance of the soil when moisture is added to the soil.

4. **Particle size distribution (British Standard 812 part 103).**

This test helped in determining the particle size of the steel slag and how the different particle sizes are distributed within the sample.

3.3.4 Physical-mechanical properties of the laterite soil and steel slag with varying compositions of quarry dust

With the percentage of steel slag fixed, we then added varying percentages of quarry dust and repeated the same tests carried out on the steel slag + soil sample.

5%, 10%, and 15% quarry dust were added to 40% steel slag and laterite soil by mass and tested to determine the percentage that gives the most satisfying results for a subbase material. The percentage was chosen based on the most satisfactory results focusing on CBR% and CBR swell after 4 days of soaking.

Tests carried out to assess the performance of each blend included.

1. **Maximum dry density and optimum moisture content (British Standard 1377 part 2).**

This test helped to obtain the relationship between the compacted dry density and moisture content. This was majorly important in identifying the optimum moisture content to be used when compacting the sample for the California Bearing Ratio Test.

2. **California Bearing Ratio and California Bearing Ratio swell after 4 days of soaking. (British Standard 1377 part 4).**

This test is the main factor in determining the strength of a material. The strength of a subgrade, subbase, and base course material are typically expressed in terms of their CBR value.

3. **Atterberg Limits (British Standard 1137 part 2) i.e. Liquid limit, Plastic limit, and linear shrinkage.**

These tests helped to understand the performance of the soil when interacting with moisture. The tests highlighted the moisture content at which the soil transitions from a solid to a plastic state and the moisture content at which the soil transitions from a plastic to a liquid state.

4. Particle size distribution (British Standard 812 part 103).

This test helped in determining the particle size of the steel slag and how the different particle sizes are distributed within the sample.

CHAPTER 4:RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results from the various tests conducted and an analysis of the results obtained. The tests were carried out in the systematic order of the objectives using the methods described in Chapter 3.

4.2 NEAT SOIL SAMPLE

Table 7 below shows a summary of the neat soil sample physical and mechanical properties. These properties are compared to the ministry of water standard for G45 granular subbase material. The table highlights the areas where the neat sample does meet the minimum standards required for the G45 granular subbase material.

Table 7: Summary of neat soil sample results in comparison with standards from the MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material

Material Property	Material sample	Specification
Atterberg Limits		
LL	57.4	<40
PL	27.5	
PI	30.0	<14
LS	15.0	<7
Grading Modulus	0.42	>1.5
USCS classification	CH	
ASHTO classification	A-7-6	
Maximum Dry density	2.063	
Optimum moisture	12.8	
CBR %(after 4 days of	25	>45
CBR swell	0.75	<0.5

4.2.1 California bearing ratio

The CBR % of the sample after 4 days of soaking does not meet the minimum requirement for a G45 material of 45%. Therefore, the neat soil doesn't meet the standards.

The California bearing ratio is a penetration test in which the ratio of the penetration resistance of a particular soil sample to that of a standard crushed stone is calculated. The result is expressed as a percentage as per the equation (Ahmed et al., 2024).

California bearing ratio is a direct representation of a soil's load-bearing capacity. The load-bearing capacity of soil is determined by the internal angle of friction and cohesion of soil (Jain et al., 2023). Therefore, by improving either the cohesion or internal angle of friction of a material, one can improve the load-bearing capacity of soil.

CBR swell

The CBR swell of a material signifies a material's potential to expand in volume when exposed to moisture (Look, 2016). The degree of expansion of the material directly affects its ability to work as a pavement layer material. A material with a high CBR swell percentage is not fit for use in construction because this can lead to cracks and damage to the overlying pavement layers.

According to the MoWT general specification for roads and bridges in Uganda, the CBR swell of a granular G45 material should not exceed **0.5%**. Therefore, since the CBR swell of the material is **0.75**, the material is not fit for use as a G45 subbase.

4.2.2 Atterberg Limits

These are a set of measurements done to establish the moisture content at which fine-grained particles change state. From solid to semi-solid to plastic and then to a liquid state (Dhir et al., 2017).

4.2.2.1 Liquid limit

The liquid limit is the moisture content of a sample at which it starts to behave as a liquid (Rajapakse, 2016). It is the lowest amount of moisture in a fine-grained soil sample at which it will start to flow when a shearing force is applied.

The liquid limit of the material was **57.4%** which is above the limit of **40%** for a G45 subbase material according to the MoWT general specification for roads and bridges in Uganda.

4.2.2.2 Plastic limit and plastic index

The plastic limit of soil is the moisture content at which the soil can no longer be remolded without cracking (Kaliakin, 2017). This is the moisture content at which the soil turns from a semi-solid state to a plastic state.

A low plastic limit shows that a material starts to act like a plastic material when a little moisture is added to the soil. The plastic limit also informs the plastic index of a material which is the liquid limit – plastic limit.

The potential for swelling of a material can be indicated by a high liquid limit coupled with a high plasticity index (Netinger Grubeša et al., 2016). Therefore, a material with a high liquid limit and high plasticity index has a high potential for swelling which is undesirable for construction materials as it can lead to cracks in overlying pavement layers.

4.2.2.3 Linear shrinkage

The linear shrinkage/shrinkage limit is the moisture content at which fine-grained soil no longer changes volume upon drying (Kaliakin, 2017). The shrinkage limit is a useful determinant of the swelling and shrinkage potential of the fine-grained soil sample.

Generally, soils that have high swell potential tend to have a high shrinkage potential. This shows the relation between the plasticity index and the shrinkage limit of a sample. In practice, the linear shrinkage is usually half the plasticity index of a soil sample.

The linear shrinkage of the soil sample was **30.0%** which was significantly higher than the recommended standard of **14%** from the MoWT general specifications for road and bridge works 2005.

4.2.3 Particle size distribution

The particle size distribution curve shows the different percentage passing of each sieve diameter. The distribution curve can also shows whether the soil is poorly graded, gap graded and well graded. The distribution curve below shows the grading curve for the neat soil sample compared to the grading envelope for a G45 granular subbase material.

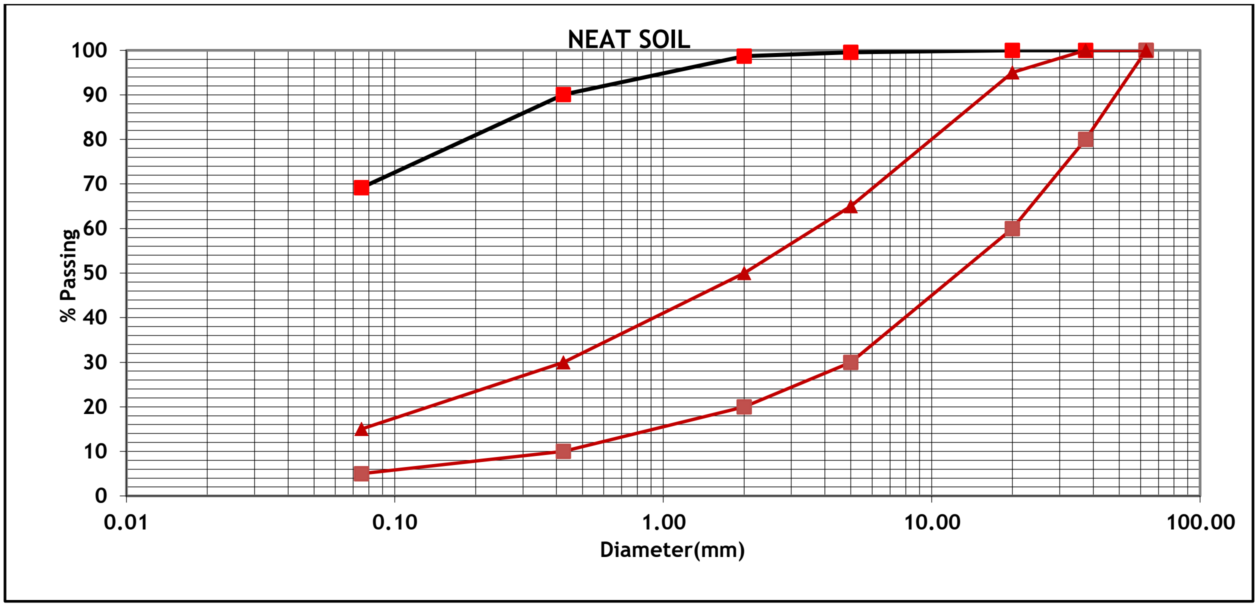


Figure 8: Particle size distribution curve for neat soil

The particle size distribution curve of the neat soil in Figure 8 showed that the material lacked coarse particles, possibly contributing to the soil's low bearing capacity. The lack of coarse particles in a soil sample leads to low internal angle of friction in a soil sample therefore a low load-bearing capacity of the soil.

Grading modulus

The grading modulus of the soil sample was found to be **0.42** which is below the standard of **1.5** from the MoWT general specifications for road and bridge works 2005.

The grading modulus highlights the relationship between the coarse and fine particles in a soil sample. The lower the grading modulus, the finer the sample. This shows that the sample is very fine and is not suitable for a G45 subbase material.

4.2.4 Classification of the Neat soil sample

Unified Soil Classification System

According to the Unified Soil Classification System (USCS), the soil sample can be classified as an **inorganic clay with high plasticity** i.e. **CH**

The sample has less than 50% retained on the 75μm sieve making it a fine-grained soil. The plasticity index of the sample falls above the A-line and is greater than 7 making the soil sample an inorganic clay sample (C).

The soil also has a Liquid limit greater than 50% which the system classifies as a sample with high plasticity (H).

American Association of State Highway Transportation Official System

According to the AASHTO classification system, soils with more than 35% passing the No. 200 sieve(75μm) are considered fine-grained soils or Clay to Clay to silt materials. These fall in the class of A-4, A-5, A-6, and A-7.

Soils with a liquid limit above 41% and a plasticity index above 11% are classified as A-7 materials. The A-7 class is further divided into A-7-5 and A-7-6 materials, A-7-5 having a liquid limit below 50% and A-7-6 having a liquid limit above 50%.

Therefore, with 69% passing the No. 200 sieve, a liquid limit of 57, and a plasticity index of 30, the soil is classified as an **A-7-6 material**.

According to the AASHTO system, this material is deemed **poor for use as a subgrade** material and therefore necessitates modification before applying the material on the road.

4.2.5 Maximum dry density and Optimum moisture content.

Maximum dry density is the Density that corresponds to the optimum moisture content of a soil sample. The maximum Dry density corresponds to the maximum density a soil sample can obtain when moisture is added to the sample. The maximum dry density also aids the determination of the degree of compaction of the field compacted layer.

The maximum dry density of the soil was **2.063 gm/cm^3** and the optimum moisture content of **12.8%**. This indicates that maximum compaction will be achieved at a moisture content of 12.8%.

CONCLUSION

From the results of the first objective, the material is found not to comply with any set standards and parameters set by the MoWT general specifications for a G45 granular subbase material. Therefore, this material needs to be stabilized to fit the specifications for G45 subbase material.

4.3 STEEL SLAG

The tests carried out on the steel slag included particle size distribution, flakiness index, and bulk density.

4.3.1 Particle size distribution

The particle size distribution curve shows the different percentage passing of each sieve diameter. The distribution curve can also shows whether the material is poorly graded, gap graded and well graded. The graph below shows the particle size distribution curve of the steel slag in comparison to the grading envelope for crushed rock used to modify problematic soils.

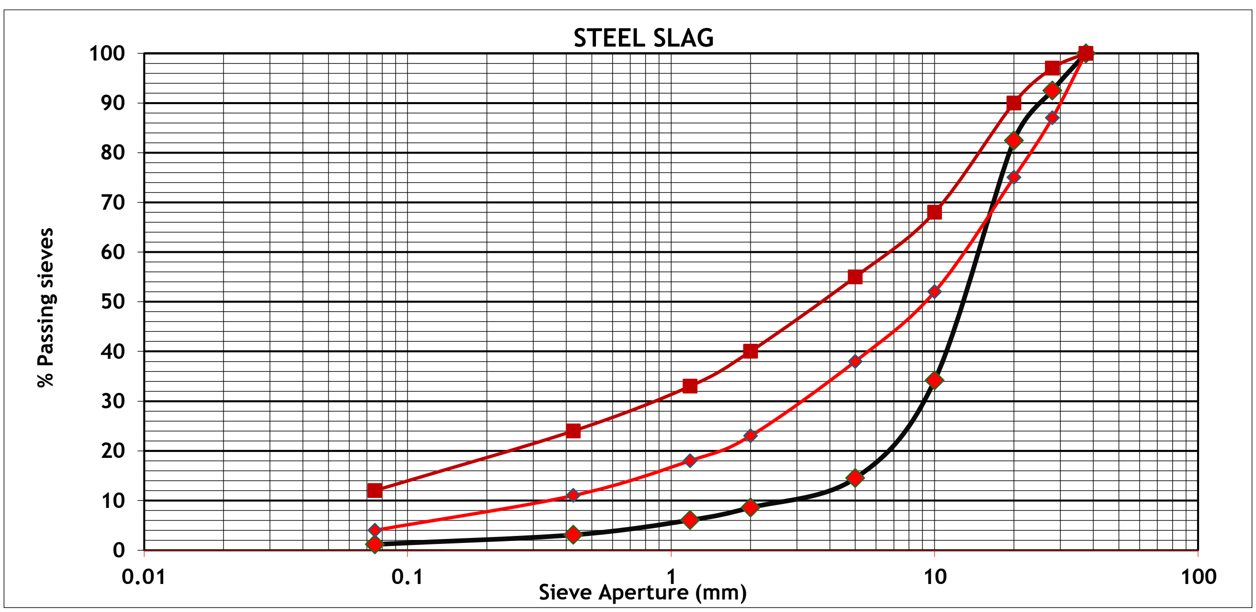


Figure 9: Particle size distribution curve for Steel slag

The particle size distribution of the steel slag was compared to the grading limits for crushed rock material which is usually used to modify problematic soils.

The curve in Figure 9 shows that the crushed steel slag is mainly comprised of mainly **coarse material** which makes it a suitable blend to fix the particle size gap in the neat laterite soil.

The coarse particles when blended with the neat soil will possibly increase the internal friction between particles in the soil and improve the CBR% of the soil. (Afrazi & Yazdani, 2021). This is because there is a direct relationship between the internal angle of friction and the presence of coarse particles within a soil sample (Rasti et al., 2021).

4.3.2 Flakiness index

This is basically the measure of the proportion of particles that are considered flaky i.e. whose thickness is significantly smaller than their length.

Flaky particles negatively affect the strength and durability of particles. This is due to their low interlocking capacity. These particles break down easily due to having a poor load-bearing capacity along their thin axis (Patel, 2024).

The flakiness of the steel slag was found to be **12.6 %** which is below the specification of **35 %** for crushed rock (CRR) in the MoWT general specifications for Road and Bridge works 2005.

4.3.3 Bulk density

The bulk density of the steel slag was **1705 kg/m^3.** Compared to the bulk density of the coarse aggregates, usually around **1200 kg/m^3 - 1750 kg/m^3** (Shahriar, n.d.), steel slag has a relatively equal bulk density to that of coarse crushed aggregates.

This shows that, based on density, the steel slag will perform similarly to crushed rock.

CONCLUSION

The tests carried out on the steel slag showed that the material was predominantly coarse grained, making it a suitable material to improve the internal angle of friction of the neat soil sample thus improving its load-bearing capacity.

4.4 LATERITE SOIL WITH VARYING COMPOSITIONS OF STEEL SLAG

Three samples of laterite soils + steel slag were prepared i.e. **40%, 30%,** and **20%.** The percentages were determined taking into consideration the effect on the particle size distribution of the soil sample and the economic implication of the blend. Tests carried out on the blends included CBR%, CBR swell, Atterberg Limits, Particle size distribution, and Maximum Dry Density.

4.4.1 Effect of steel slag on the Maximum dry density and optimum moisture content

Understanding the relationship between MDD and OMC is crucial for construction projects, as it helps in determining the appropriate moisture levels needed to achieve the desired soil compaction and stability. The graphs 10 and 11 below show the effect of addition of steel slag on the maximum dry density and optimum moisture content of the soil.

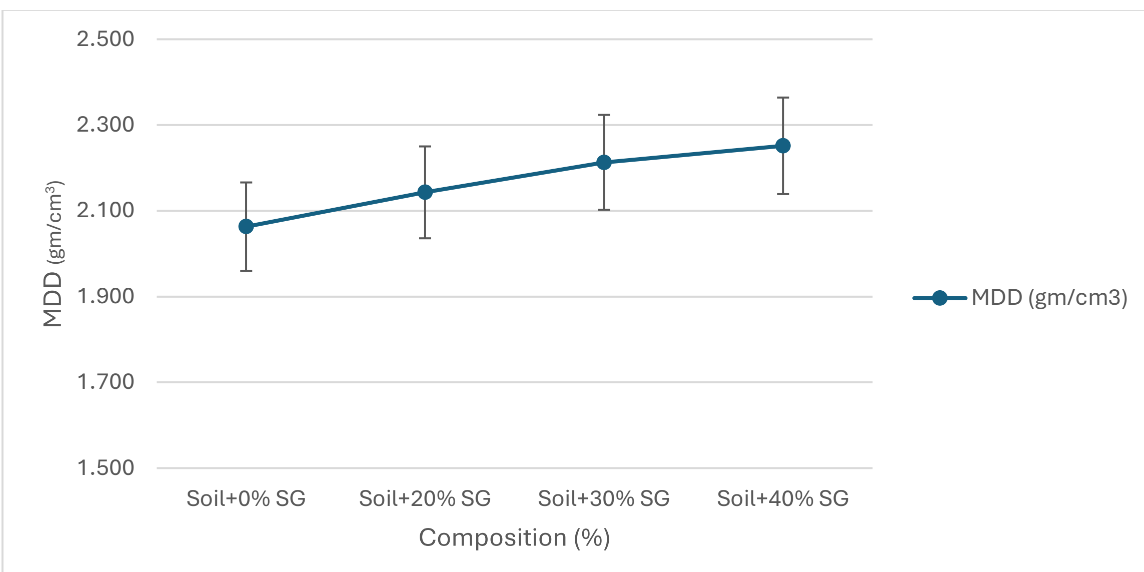


Figure 10: Maximum dry density at varying compositions of steel slag

From Figure 10 above, the slight increase in the maximum dry density of the soil with increasing percentages of steel slag could be attributed to the fact that steel slag has a higher specific gravity than neat soil (Akinwumi, 2014).

The steel slag has a higher relative density than the neat soil therefore, the blend achieves higher maximum dry density leading to a denser and stronger material.

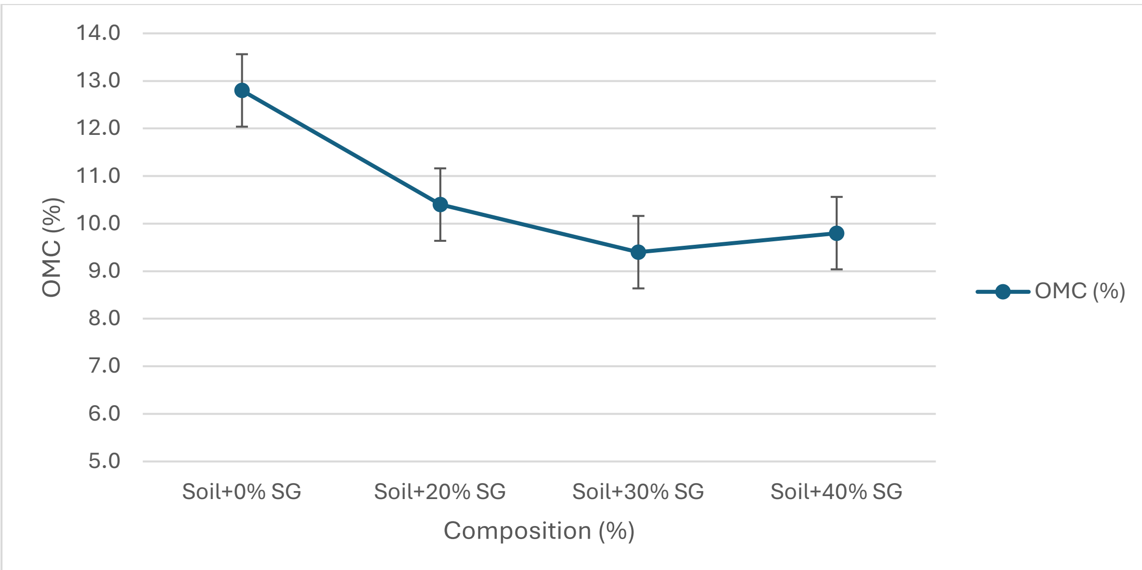


Figure 11: Optimum moisture content at varying compositions of steel slag

From Figure 10 above, the decrease in optimum moisture content with higher steel slag content before a slight increase can be attributed to a reduction in the size of the diffused water layer that resulted in the agglomeration (clumping together) of the clay size particles making the soil require less water to reach optimum (Akinwumi, 2014).

This implies that during compaction, less moisture is required to be added to the blend to achieve the required degree of compaction. This subsequently reduces the costs of road construction.

4.4.2 Effect of steel slag on the CBR% of the soil

The CBR value helps engineers design pavements that can withstand the expected traffic loads and environmental conditions, ensuring the longevity and stability of the road structure. CBR value of a soil is mainly determined by two factors, internal angle of friction and cohesion between particles. The graph below shows the effect of addition of steel slag on the CBR on the soil.

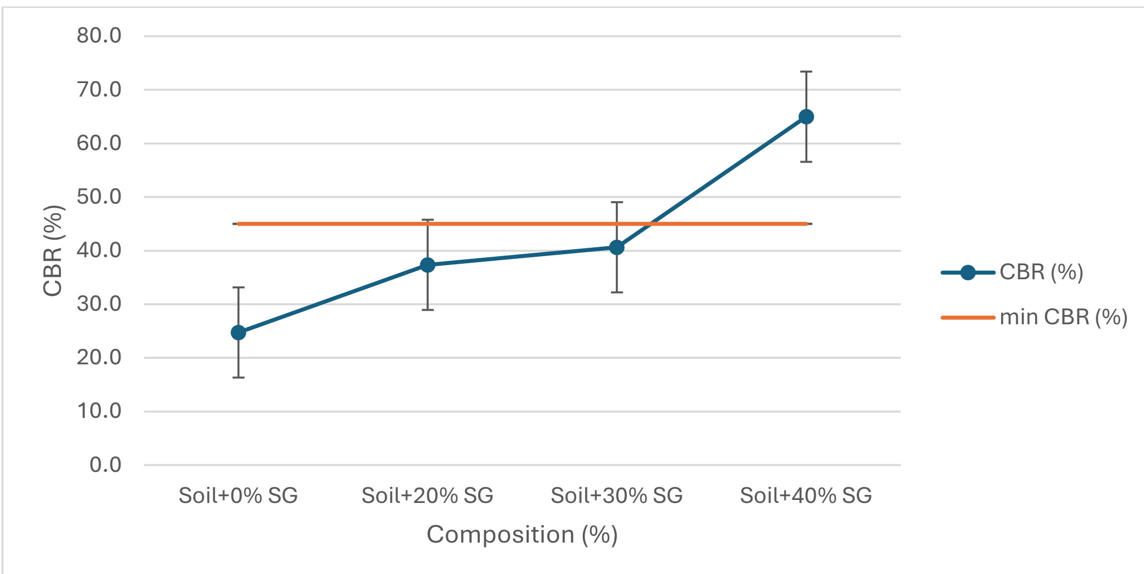


Figure 12: CBR % at varying compositions of steel slag

From Figure 12 above, the CBR % increased with an increase in steel slag percentage. This is possibly due to the increase in the percentage of coarse-grained particles in the soil blend.

There is a direct relationship between the percentage of coarse-grained particles and the internal angle of friction (Rasti et al., 2021). The increase in the internal angle of friction of the soil blend could consequently have led to the increase in the load-bearing capacity of the soil, thus an increase in the CBR%.

At **40%** steel slag composition, the CBR percentage increased to **65%** which is well above the minimum requirement for a G45 Subbase granular material.

4.4.3 Effect of steel slag on the CBR swell of the soil

CBR swell is a measure of the potential expansion of a soil sample when it is soaked in water. It is an important parameter in the California Bearing Ratio (CBR) test, which is used to evaluate the strength and load-bearing capacity of soils. The graph below shows the effect of steel slag on the CBR swell of the soil.

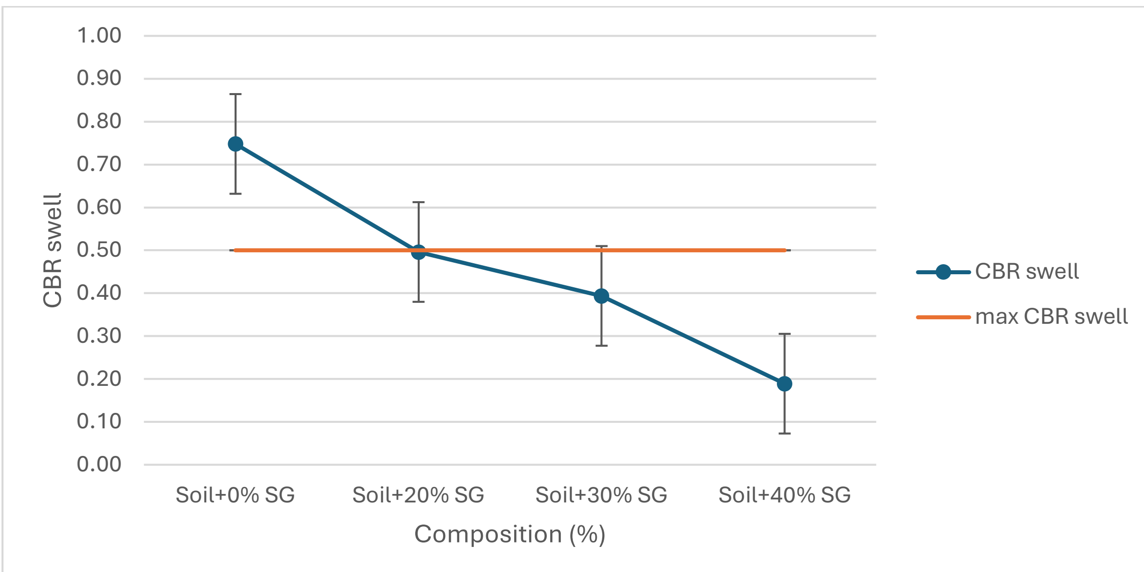


Figure 13: CBR swell at varying compositions of steel slag

From Figure 13, the CBR swell of the material reduces with an increasing percentage of steel slag. This is possibly attributed to the replacement of part of the plastic clay particles with non-plastic steel slag particles (Dixit et al., 2016).

The CBR swell of the material at 30% and 40% composition of steel slag both dropped below the maximum standard for a G45 subbase material.

4.4.4 Effect of steel slag on the Liquid limit of the soil sample

Liquid limit is a critical property of granular soils. It is the moisture content at which the soil changes from a plastic state to a liquid state. The graph below shows the effect of steel slag on the liquid limit of the material

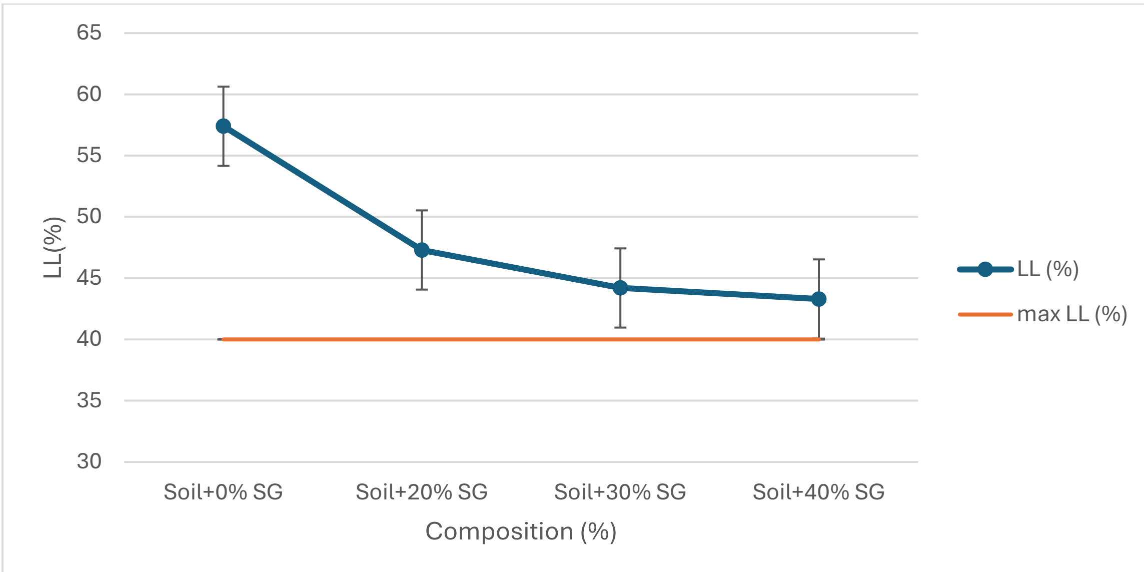


Figure 14: Liquid limit at varying compositions of steel slag

From Figure 14, the liquid limit generally decreased with an increase in steel slag percentage. This could be attributed to the replacement of the percentage of the plastic fines in the sample with the non-plastic fines of steel slag (Dixit et al., 2016).

However, the decrease was not sufficient to drop the liquid limit below the recommended standard according to the MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

4.4.5 Effect of steel Slag on the Plastic Index of the soil sample

The plasticity index is the numerical difference between the liquid limit and plastic limit of a soil, and it represents the range of water content over which a soil remains plastic. Meaning it can be molded without cracking or crumbling. The graph below shows the effect of steel slag on the plasticity index of the soil.

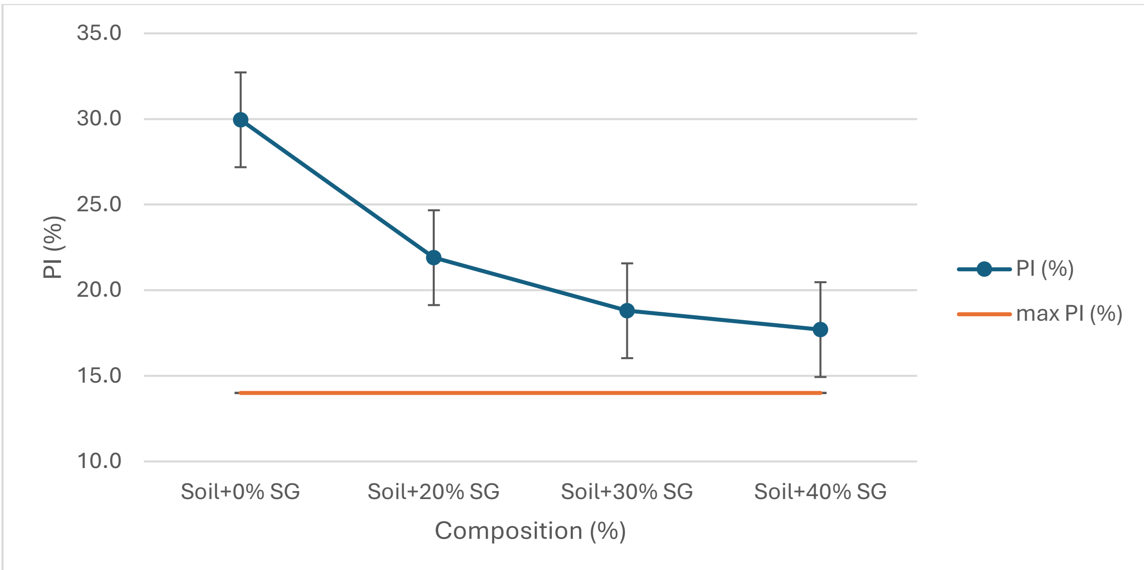


Figure 15: Plasticity limit of soil blends with varying compositions of steel slag

From Figure 15, the plasticity index generally decreased with an increase in steel slag percentage. This could also be attributed to the replacement of the percentage of the plastic fines in the sample with the non-plastic fines of steel slag (Dixit et al., 2016).

However, the decrease was not sufficient to drop the plastic index below the recommended standard according to the MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

4.4.6 Effect of steel slag on the Linear Shrinkage of the soil

Linear shrinkage is the reduction in length of a soil sample as it dries from its liquid limit to a completely dry state. The graph below shows the effect of steel slag on the linear shrinkage of the soil.

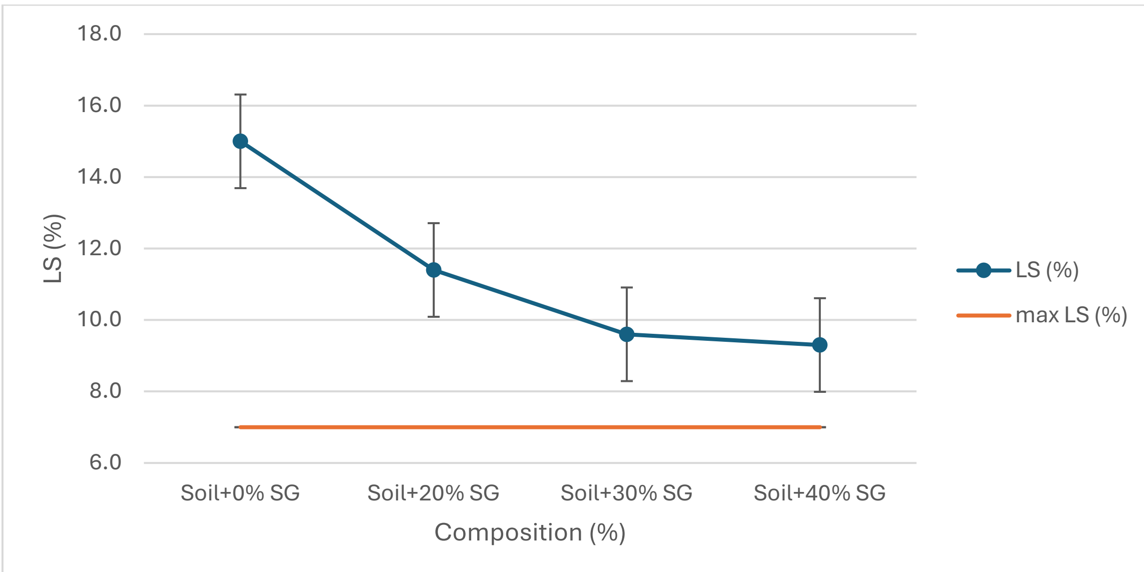


Figure 16: Linear shrinkage of the soil blends at varying compositions of steel slag

From Figure 16 the linear Shrinkage also had a general decrease with an increase in steel slag percentage. This could also be attributed to the replacement of the percentage of the plastic fines in the sample with the non-plastic fines of steel slag. The replacement of the clay plastic fines that have a high shrink-swell potential reduces the overall shrinkage potential of the material (British Geological Survey, 2023).

However, the decrease was not sufficient to drop the linear shrinkage below the recommended standard according to the MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

4.4.7 Effect of steel slag on the Grading modulus

The grading modulus is a numerical value that indicates the coarseness or fineness of a of a soil sample based on its size distribution. The graph below shows the effect of addition of steel slag to the grading modulus of the soil.

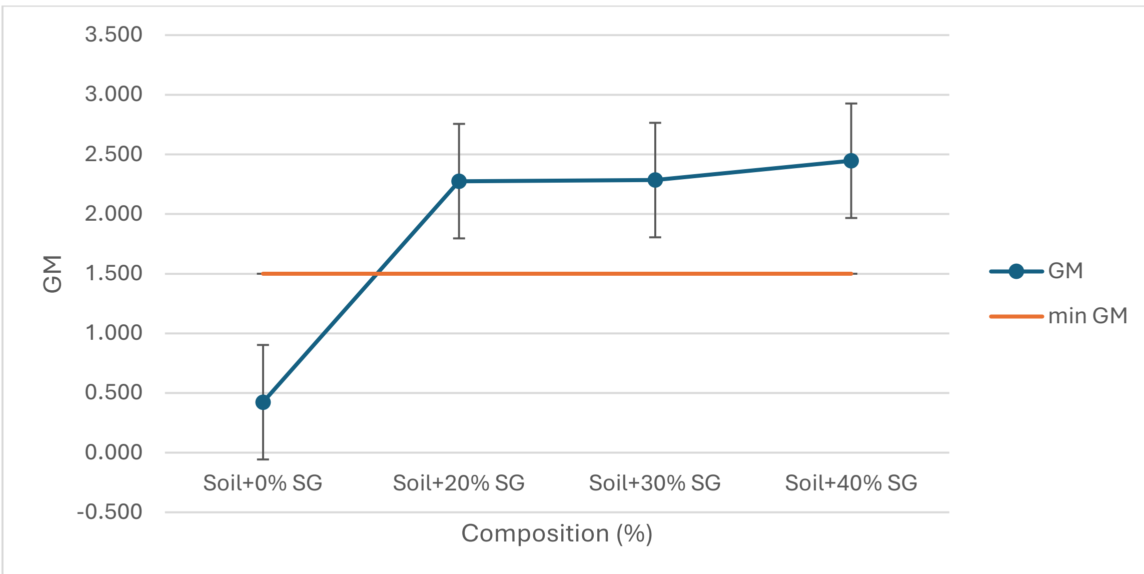


Figure 17: Grading modulus of laterite soil at varying compositions of steel slag

The increase in the grading modulus of the material in Figure 17 above, indicates a well-balanced and more uniform distribution between fine and coarse particles within the soil sample. This improvement enhances the soil's overall gradation, leading to better compaction, reduced void ratios, and improved load-bearing capacity. A well-graded soil mixture ensures optimal particle interlocking, which contributes to higher stability, reduced permeability, and enhanced engineering performance.

The grading modulus after blending the material meets the requirement for a G45 subbase material according to the MoWT general specifications for roads and bridges in Uganda.

CONCLUSION

Based on the results above, the addition of 40 % steel slag significantly improved the load-bearing capacity of the soil in terms of the CBR % by 160% and reduced the CBR swell by 70 %. This sufficiently lowered the CBR swell below the set standards for a G45 granular subbase material and increased the CBR of the material beyond the set minimum for a G45 subbase material, according to the MoWT general specifications for road and bridge construction.

4.5 LATERITE SOILS AND 40% STEEL SLAG WITH VARYING COMPOSITIONS OF QUARRY DUST

5%, 10%, and **15%** quarry dust were added to **40%** steel slag and laterite soil by mass and tested to determine the percentage that gives the most satisfying results for a subbase material. The design percentage was chosen based on the most satisfactory results focusing on CBR % and CBR swell after 4 days of soaking.

With the percentage of steel slag fixed, the mix percentages will then be chosen based on the most satisfactory results and economic implications of the blend.

4.5.1 Effect of quarry dust on Maximum Dry Density and optimum moisture content.

The graph below shows the effect of quarry dust on Maximum Dry Density and optimum moisture content

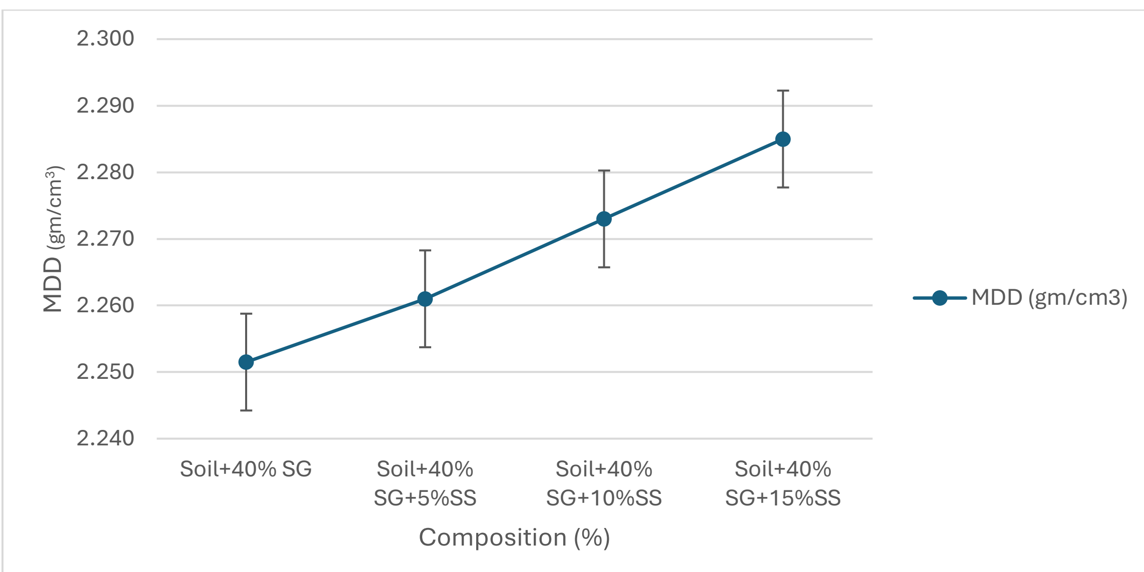


Figure 18: Maximum Dry Density at varying compositions of quarry dust

From Figure 18 above, the maximum dry density of the blended material increased as the percentage of quarry dust increased. This could be attributed to the fact that quarry dust has a higher specific gravity than the soil it replaced in the blend, therefore an increase in overall density is expected due to the difference in specific gravities (Senanayaka et al., 2024).

It should also be noted that the increase in the maximum dry density could also be attributed to the difference in particle size distribution curves of the neat soil and quarry dust (Chetia et al., 2018).

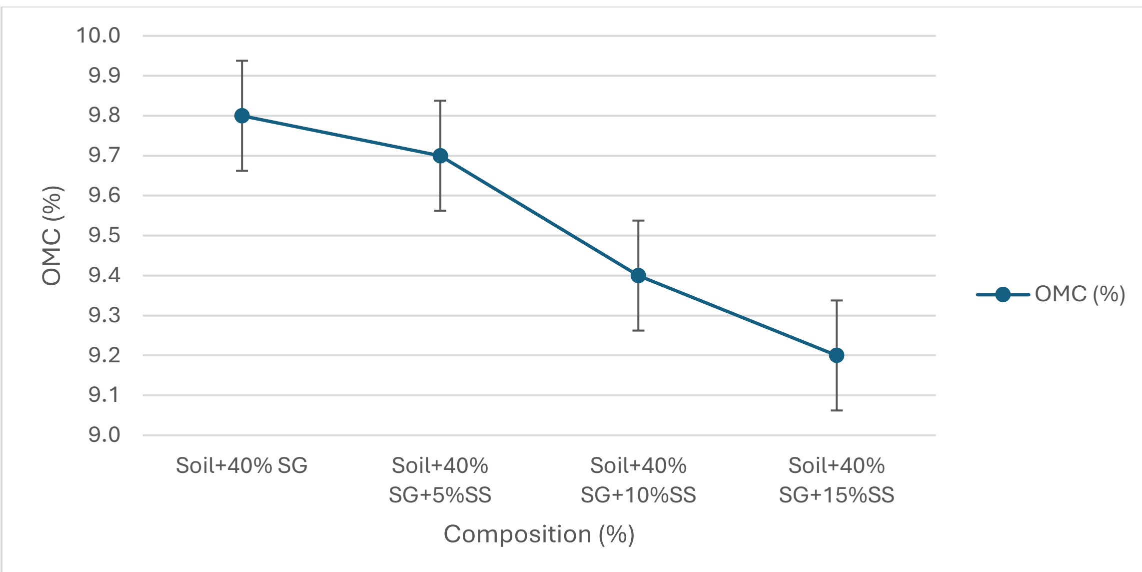


Figure 19: Optimum moisture content at varying compositions of quarry dust.

From Figure 18 above, the optimum moisture content of the blended material decreases with an increase in the quarry dust percentage. This is due to the reduction of the percentage of the clay particles in the material blend (Chetia et al., 2018). A reduction in the percentage of clay materials means that less water is required for a sample to reach its maximum dry density.

4.5.2 Effect of quarry dust on the CBR% of the material.

The graph below shows the effect of quarry dust on the CBR% of the material

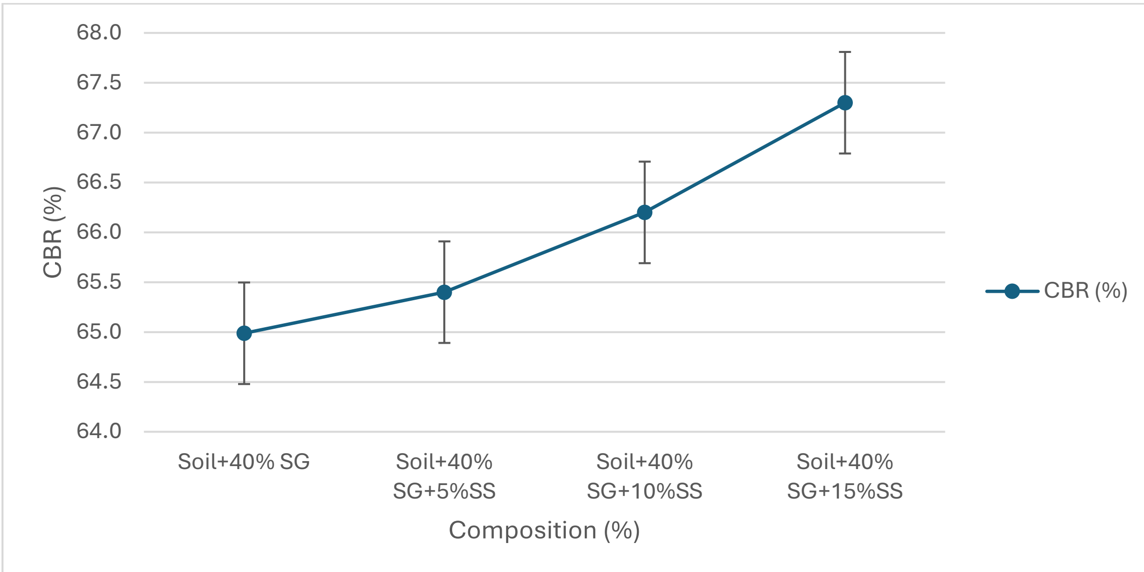


Figure 20: CBR% of the blended material at varying compositions of quarry dust

From Figure 20 above, it is noted that the CBR of the material blend increases slightly with an increase in the percentage of the quarry dust added to the material. This could be attributed to the improved gradation of the material therefore leading to improved strength and load-bearing characteristics (Kufre Etim et al., 2021).

Furthermore, the increase in the California Bearing ratio of the material blend could also be attributed to the annular shape of the quarry dust particles which leads to a slight increase in the internal angle of friction of the material leading to an increase in the load bearing capacity hence the increase in the CBR % of the material (Senanayaka et al., 2024).

The California bearing ratio could have also increased to the addition of a material with a higher specific gravity compared to that of neat soil leading to a denser material hence an increase in the California bearing ratio of the material.

4.5.3 Effect of quarry dust on the CBR swell of the material.

The graph below shows the effect of quarry dust on the CBR swell of the material

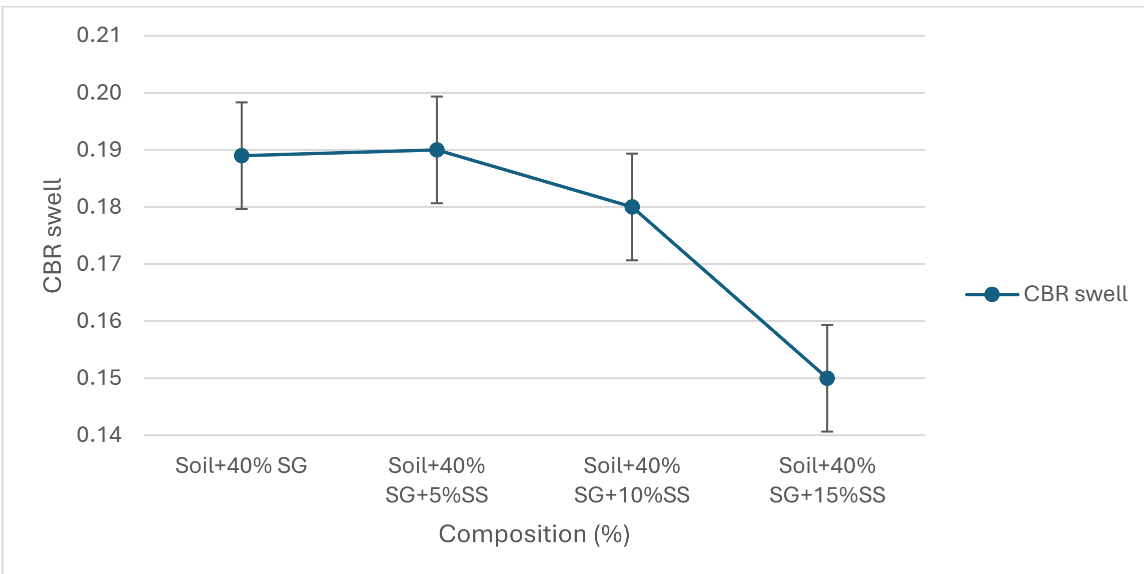


Figure 21: CBR swell of the blended material at varying compositions of quarry dust

From Figure 21, the CBR swell of the material reduced with an increase in the percentage of quarry dust added to the blend. This is due to the replacement of the plastic neat soil fines with the non-plastic quarry dust fines hence a reduction in the CBR swell of the material (Dixit et al., 2016).

4.5.4 Effect of quarry dust on the Liquid limit of the material.

The graph below shows the effect of quarry dust on the Liquid limit of the material.

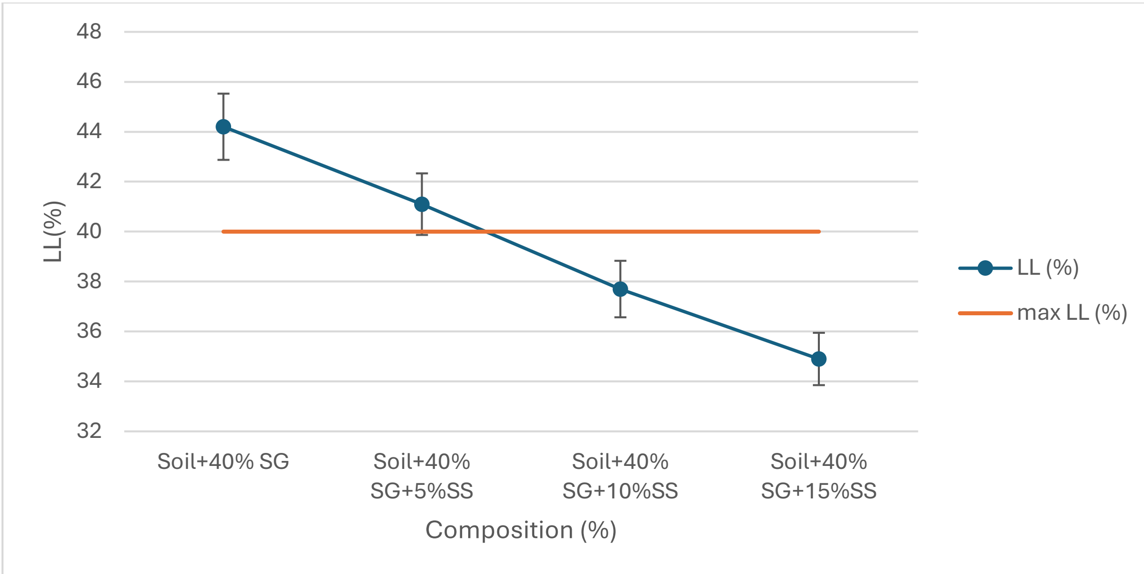


Figure 22: Liquid limit at varying compositions of quarry dust

From Figure 22, the liquid limit generally decreased with an increase in quarry dust percentage. This could be attributed to the replacement of the percentage of the plastic fines in the sample with the non-plastic fines of quarry dust (Dixit et al., 2016).

The **10%** quarry dust reduced the liquid limit by **13%**, sufficiently lowering it below the required standard according to the MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

4.5.5 Effect of quarry dust on the Plastic index of the material.

The graph below shows the effect of quarry dust on the Plastic index of the material.

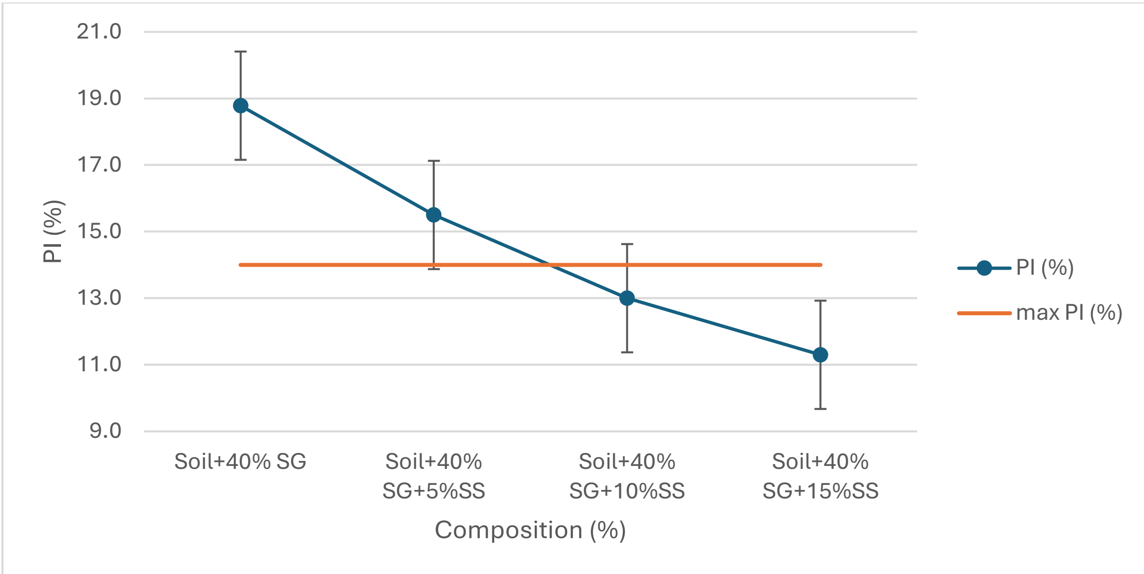


Figure 23: Plastic index at varying compositions of quarry dust

From Figure 23, the plastic index decreased with an increase in quarry dust percentage. This could be attributed to the replacement of the percentage of the plastic fines in the sample with the non-plastic fines of quarry dust (Dixit et al., 2016). This causes a decrease in the liquid limit followed by a more than proportional decrease in the plastic limit causing a decrease in the plastic index of the material.

The **10%** quarry dust reduced the plastic limit by **27%**, sufficiently lowering it below the required standard according to the MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

4.5.6 Effect of quarry dust on the linear shrinkage of the material

The graph below shows the effect of quarry dust on the linear shrinkage of the material

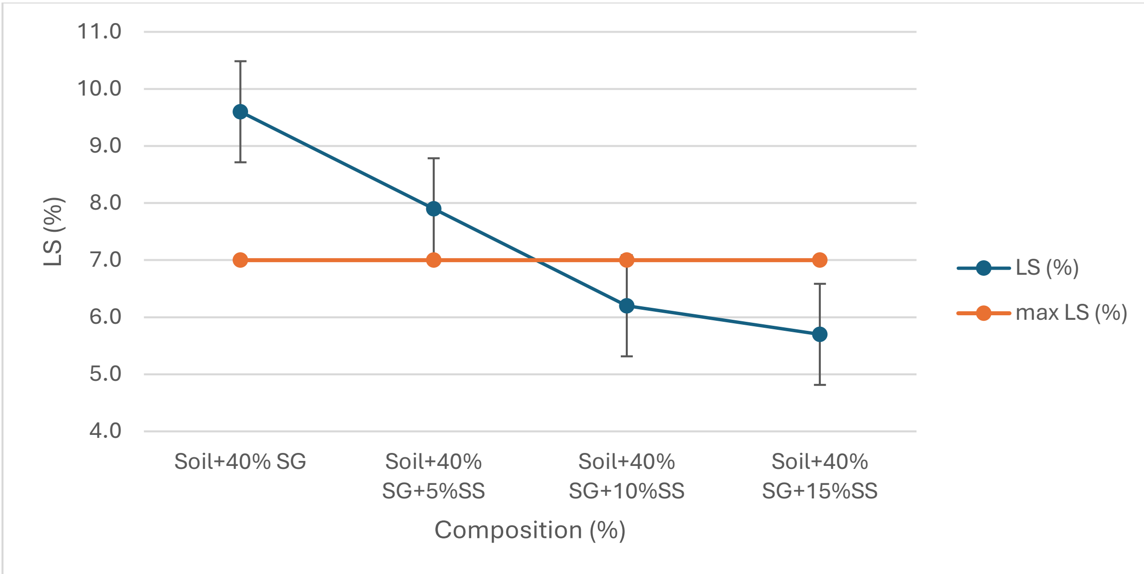


Figure 24: Linear shrinkage of the material at varying compositions of quarry dust

From Figure 24, the linear Shrinkage also had a general decrease with an increase in quarry dust percentage. This could also be attributed to the replacement of the percentage of the plastic fines in the sample with the non-plastic fines of quarry dust. The replacement of the clay plastic fines that have a high shrink-swell potential reduces the overall shrinkage potential of the material (British Geological Survey, 2023).

The **10%** quarry dust reduced the plastic limit by **33%**, sufficiently lowering it below the required standard according to the MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

4.5.7 Effect of quarry dust on the Grading modulus

The graph below shows the effect of quarry dust on the Grading modulus of the material blend.

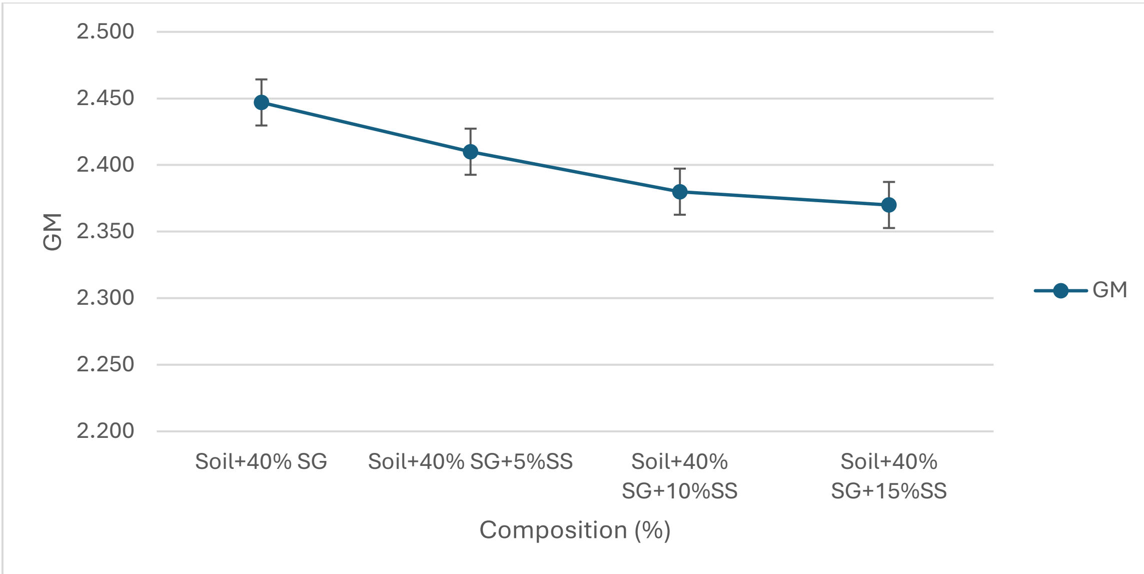


Figure 25: Grading modulus at varying compositions of quarry dust

From Figure 25 above, the grading modulus of the blended material decreased with an increase in quarry dust percentage. This is probably due to the percentage of fine material increasing, which eventually causes the grading modulus to drop. The grading modulus is the relationship between the percentage of fines to the percentage of coarse material within a particular sample. The finer a material, the lower the grading/fineness modulus of the sample, and the reverse is true (Chandran, 2023).

CONCLUSION

Based on the test results above, the addition of **10% quarry dust** into the blended material significantly improved its overall plastic characteristics. This enhancement ensures that the material now meets the material standards set by the Ministry of Works and Transport (MoWT) in Uganda for G45 granular subbase materials used in road and bridge construction. The addition of quarry dust effectively reduced the plasticity index by 27%, the liquid limit by 13%, and the linear shrinkage by 33%, thereby enhancing its suitability and performance as a subbase layer in accordance with the MoWT general specifications for road and bridge works.

4.6 DESIGN AND APPLICATION

Material preparation

Steel slag

- Obtain steel slag from the steel manufacturing process using an induction furnace.
- Crush the steel slag to obtain a material of minimum grading modulus of 2.81 and flakiness index of 12.6

Quarry dust

- Obtain the granite dust from a stone quarry with a grading modulus of 1.4 and ensure it's free from impurities.

The table below shows a summary of the fineness modulus of the steel slag and quarry dust used for modifying the laterite soils.

Table 8: The fineness modulus of the materials for stabilization

Material properties for stabilization	**Design Requirements**	
	Steel slag	**Quarry dust**
Grading: BS 1377: part 2		
Minimum Grading Modulus	2.81	1.39
Minimum Flakiness index	12.6	-

The table below shows the summary of the material properties before stabilization and after stabilization specifying the expected results after stabilization.

Table 9: The material specifications before and after stabilization

Material properties	**Before stabilization**	**After stabilization with 40% steel slag and 10% quarry dust**	**General specifications**
CBR: BS 1377: Part 4			
Minimum CBR (%) after 4 days soaking	25	66	45
Maximum CBR-swell (%) at BS-Heavy	0.75	0.2	0.5
Atterberg limits:			
Max Liquid Limit BS 1377: Part 2	57	38	40
Max Plasticity Index BS 1377: Part 2	30	13	14
Max Linear Shrinkage BS 1377: Part 2	15	6	7
Grading: BS 1377: Part 2			
Minimum Grading Modulus	0.4	2.4	1.5
Classification			
USCS	CH	GW	-
AASHTO	A-7-6	A-2-6	-

CASE STUDY APPLICATION

From the results above, the material blend of **40% steel slag, 10% quarry dust and 50% laterite soil** gave satisfactory results based on its physical and mechanical properties and economic implication

Design using the AASHTO method of design

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

Original pavement design

- 50mm Hot Mix Asphalt
- 200mm CRR Base
- 175mm G45 Subbase
- 150mm Improved Subgrade

Coefficients for each layer based on the material used

a_1 = 0.35, a_2 = 0.14 and a_3 = 0.11

Assuming drainage conditions of water being removed within 1 week and the pavement structure is exposed to moisture levels approaching saturation for a time greater than 25%, drainage coefficients for the subbase and base layer can be taken as **m_2 = m_3 = 0.8**

Therefore, the structural number can be obtained from

$$SN = (0.35 \times 50) + (0.14 \times 200 \times 0.8) + (0.11 \times 175 \times 0.8)$$

$$SN = 55.3$$

At 40% composition of steel slag, 10% quarry dust and 50% laterite soils, the blend had a CBR of **66.2%,** using AASHTO nomographs to get the new coefficient for a_3,

a_3 = 0.13

Calculating the new layer thickness when using the steel slag blend as the Subbase material.

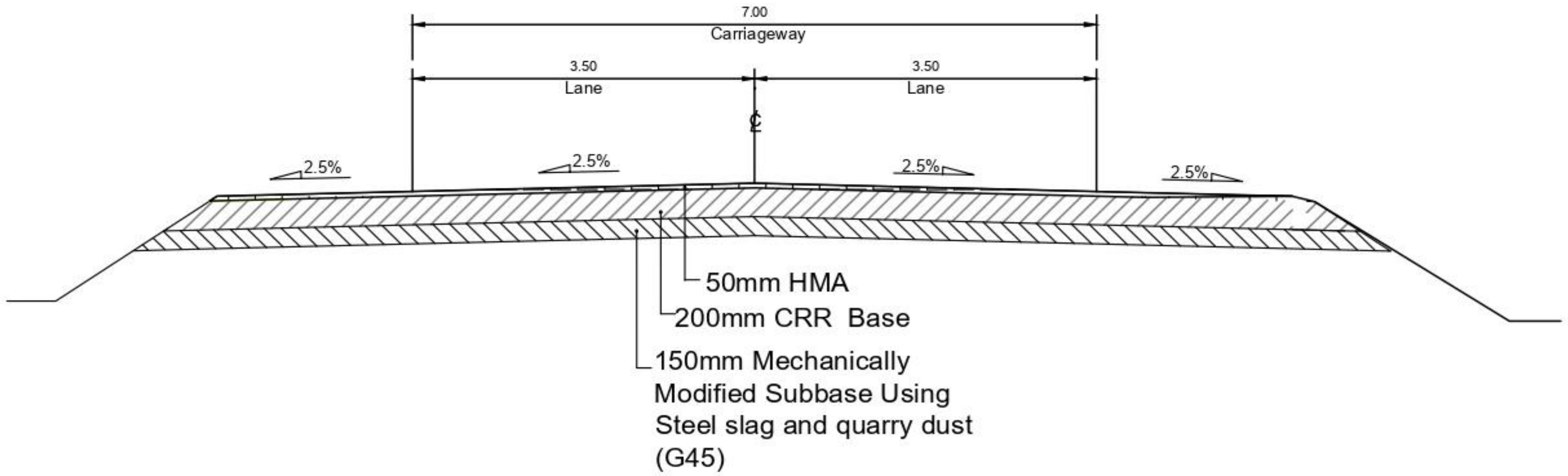
$$\mathbf{55.3 = 0.35 \times 50 + 0.14 \times 200 \times 0.8 + 0.13 \times D_3 \times 0.8}$$

$$\mathbf{D_3 = 148.1mm \approx 150mm}$$

This shows that the material depth for the sub-base reduces from **175mm to 150mm** when the blend is used as the subbase material.

New pavement design with modified subbase layer.

- 50mm Hot Mix Asphalt
- 200mm CRR Base
- 150mm Modified Subbase with steel slag and quarry dust



Typical Cross Section

Pavement Layers Details		
Pavement Layer Type	Thickness	Material and Level of Compaction
Surfacing	50mm	50mm of continuously graded asphalt (AC-14)
Base	200mm	200mm of new crushed stone base (CRR coarse type, min 102% of BS-Heavy Compaction according to BS 1377: Part 4
Sub-base	150mm	150 mm of Mechanically modified soil using 40% steel slag and 10% quarry dust to form an new sub-base - G45 (Min 98% of BS Heavy Compaction according to BS 1377: Part 4)

TYPICAL CROSS SECTION	
PROJECT TITLE	STABILIZATION OF LATERITE SOILS USING STEEL SLAG AND QUARRY DUST
AUTHOR	KYALIGONZA GARY TIMOTHY
REG NUMBER	S21B32 /067
SCALE	1:50 A3

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION

From the results of the first objective, the material is found not to comply with any set standards and parameters set by the MoWT general specifications for a G45 granular subbase material. Therefore, this material needs to be stabilized to fit the specifications for G45 subbase material.

The tests carried out on the steel slag showed that the material was predominantly coarse grained, making it a suitable material to improve the internal angle of friction of the neat soil sample thus improving its load-bearing capacity.

Based on the results of the third objective, the addition of 40 % steel slag significantly improved the load-bearing capacity of the soil in terms of the CBR % by 160% and reduced the CBR swell by 70 %. This sufficiently lowered the CBR swell below the set standards for a G45 granular subbase material and increased the CBR of the material beyond the set minimum for a G45 subbase material, according to the MoWT general specifications for road and bridge construction. However, the steel slag did not produce sufficient fines to lower the plasticity characteristics of the neat soil below the specified standards. Therefore, this necessitated addition of quarry dust to lower the plasticity characteristics of the material.

Based on the test results of the final objective, the addition of **10% quarry dust** into the blended material significantly improved its overall plastic characteristics. This enhancement ensures that the material now meets the material standards set by the

Ministry of Works and Transport (MoWT) in Uganda for G45 granular subbase materials used in road and bridge construction. The addition of quarry dust effectively reduced the plasticity index by 27%, the liquid limit by 13%, and the linear shrinkage by 33%, thereby enhancing its suitability and performance as a subbase layer in accordance with the MoWT general specifications for road and bridge works.

The overall study's findings demonstrate that steel slag and quarry dust can effectively stabilize laterite soils, making them suitable for use in subbase road layers. The improved soil properties include increased strength, reduced plasticity, and enhanced durability, which are essential for the construction of stable and long-lasting road infrastructure. The research also emphasizes the importance of sustainable construction practices that utilize industrial waste materials, thereby contributing to environmental conservation and resource efficiency.

RECOMMENDATIONS

Further research, however, should be carried out on alternative materials to substitute the quarry dust in the material blend and different methods of crushing the steel slag to produce sufficient fines.

Further research can also be carried out on how to activate the cementations properties of the CaO in the steel slag, which is in high percentages which can be used for chemical stabilization of weak soils to improve cohesion.

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APPENDIX A

Appendix 1: Riffling of steel slag

Appendix 2: Quartering of the steel slag

Appendix 3: Quartering neat soil

Appendix 4: Proctor compaction

Appendix 5: CBR compaction

Appendix 6: Soaking tank for CBR swell

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Page 1 of 1

Doc. Number :	4800013419	**Date** :	Jan 8, 2025
Plant :	2200	**Vehicle:No:**	UEX 576X
Storage Location:	2202	**Time** :	3:39:53 PM
To:M/s.	UGANDA CHRISTIAN UNIVERSITY	**Ref.No** :	709145180

Sl.No	Material No.	Item description	UOM	Quantity	Remarks
1		SLUG	KGS	25	FOR RESEARCH PURPOSE

ROOFINGS ROLLING MILLS LTD
GATE OUTWARD NO: 33
08 JAN 2025
OUTWARD TIME: 16:03
SIGNATURE:

Prepared By: RM0082

Verified By:

Authorised by: Yogendra Tripathi

08/01/25

Recieved By

Name:	ELVIS
Sign:	
Date:	2025-01-08

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Page 1 of 1

Doc. Number :	4800013470	Date :	Jan 15, 2025
Plant :	2200	Vehicle:No:	UFG 400L
Storage Location:	2202	Time :	12:51:39 PM
To:M/s.	UGANDA CHRISTIAN UNIVERSITY	Ref.No :	709145180

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1		SLUG	KGS	80	FOR RESEARCH PURPOSE

ROOFINGS ROLLING MILLS LTD
GATE OUTWARD NO: 25
15 JAN 2025
OUTWARD TIME: 13:12 pm
SIGNATURE:

15.01.2025

Prepared By: RM0082	Verified By:	Authorised by: Rajeesh Patikkuthazha

Recieved By

Name:	ELVIS SSEKALABA
Sign:	
Date:	2025-01-15

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

SUMMARY OF TEST RESULTS FOR LATERATE GRAVEL OF NEAT SAMPLE

LOCATION: NSAMBWE | Depth: 0.5m

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	AVERAGE
NSAMBWE	NEAT SAMPLE	28-12-24	100	100	100	100	99	90	69	0.42	57.5	27.5	30.0	15.0	2.063	12.8	25	0.75	0.75
			100	100	100	100	99	90	69	0.43	57.4	27.4	29.9	15.0	-	-	- - -	-	
			100	100	100	99.68	98.83	89.98	68.87	0.42	57.4	27.5	30.0	15.0	2.063	12.8	24.7	0.75	0.75
	AVERAGE		100	100	100	100	99	90	69	0.423	57.4	27.4	30.0	15.0	2.063	12.8	24.7	0.75	0.75

FOR LAB

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Lab Technician   Materials Engineer

STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
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PROJECT:	**ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION**

ATTERBERG LIMITS

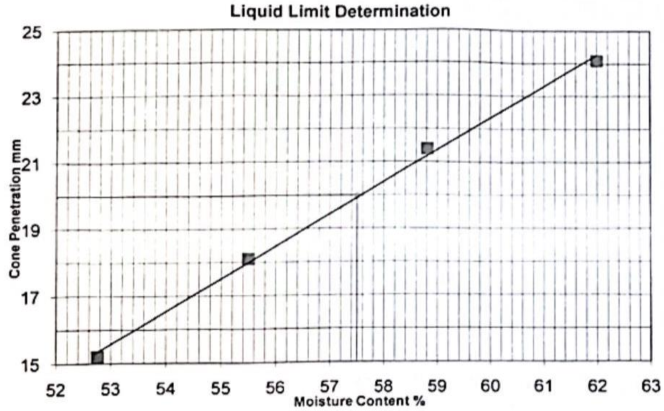
Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE		Technician:	Lab Team
mix	NEAT SAMPLE		Sample Date	28-Dec-2024
Test method	BS 1377: Part 2, 1990 4 3/4 4		Test Date	31-Dec-2024
LAYER	LATERATIC GRAVEL (NEAT)			
Depth:	0.5m			

PLASTIC LIMIT	Test No.	Q	SI		Average
Mass of wet soil + container (g)		41.19	46.59		43.89
Mass of dry soil + container (g)		36.99	41.46		39.225
Mass of container (g)		21.66	22.91		22.285
Mass of moisture (g)		4.2	5.1		4.665
Mass of dry soil (g)		15.33	18.55		16.94
Moisture content %		27.4	27.7		27.5
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.2	18.1	21.4	24.1
penetration (mm)		15.2	18.1	21.4	24.1
AVERAGE		15.2	18.1	21.4	24.1
Container No.		P166	P146	V	P145
Mass of wet soil + container (g)		53.97	64.00	65.79	51.69
Mass of dry soil + container (g)		37.81	43.67	44.07	34.69
Mass of container (g)		7.18	7.04	7.14	7.27
Mass of moisture (g)		16.16	20.33	21.72	17
Mass of dry soil (g)		30.63	36.63	36.93	27.42
Moisture content (%)		52.8	55.5	58.8	62.0
AVERAGE		52.8	55.5	58.8	62.0

Liquid Limit Determination



Liquid limit (%)	57.5
Plastic limit (%)	27.5
Plasticity Index (%)	30.0
Linear shrinkage	
Trough No.	Y
Trough length (cm)	14.0
Specimen length (cm)	11.9
L.shringage =	2.1
% L.shrinkage =	15.0

Remarks:

TESTING LAB		STUDENTS
Materials Engineer		
Lab Technician		

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PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

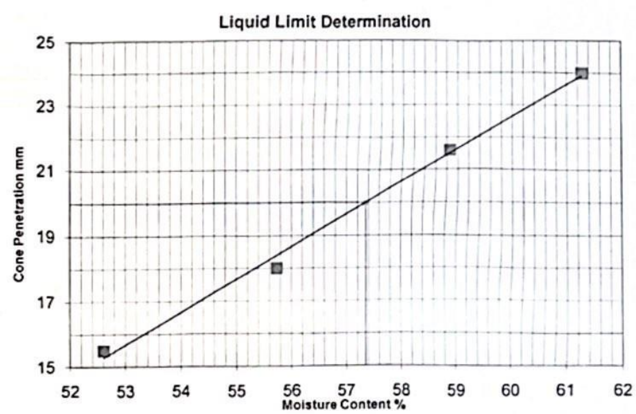
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE	Technician:	Lab Team
mix	NEAT SAMPLE	Sample Date	28-Dec-2024
Test method	BS 1377: Part 2: 1990 4 3/4 4	Test Date	31-Dec-2024
LAYER	LATERATIC GRAVEL (NEAT)		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	OG	4L		Average
Mass of wet soil + container (g)		40.14	44.21		42.175
Mass of dry soil + container (g)		36.08	39.59		37.835
Mass of container (g)		21.37	22.63		22
Mass of moisture (g)		4.06	4.6		4.34
Mass of dry soil (g)		14.71	16.96		15.835
Moisture content %		27.6	27.2		27.4
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.5	18	21.6	24.0
penetration (mm)		15.5	18.0	21.6	24.0
AVERAGE		15.5	18.0	21.6	24.0
Container No.		FOO	4B	AX	PP
Mass of wet soil + container (g)		50.34	52.85	61.20	43.72
Mass of dry soil + container (g)		35.49	36.33	41.20	29.81
Mass of container (g)		7.26	6.69	7.22	7.11
Mass of moisture (g)		14.85	16.52	20	13.91
Mass of dry soil (g)		28.23	29.64	33.98	22.7
Moisture content (%)		52.6	55.7	58.9	61.3
AVERAGE		52.6	55.7	58.9	61.3



Liquid limit (%)	57.4
Plastic limit (%)	27.4
Plasticity Index (%)	29.9

Linear shrinkage

Trough No.	Y
Trough length (cm)	14.0
Specimen length (cm)	11.9
L.shringage =	2.1
% L.shrinkage =	15.0

Remarks:

TESTING LAB

STIRLING CIVIL ENGINEERING LTD
Materials Engineer
07 FEB 2025
Lab Technician
P. O. BOX 796, KAMPALA (U)

STUDENTS

Institution	Students Names	Testing Lab
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ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28-Dec-24
mix:	NEAT SAMPLE	Casting date :	31-Dec-24
Source:	NSAMBWE	Testing Date :	4-Jan-25
Sample Description:	LATERATIC GRAVEL (NEAT)	Technician :	: Lab team
		Volume of Mould used (m^3)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	JH		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	2313		MDD (Mg/m^3)	2.063
Tin + oven dry soil sample (g)	2208		N.M.C (%)	7.5
Tin (g)	816		OMC (%)	12.8
Dry soil sample	1392		Added OMC (%)	5.3
Water (g)	105		Calculated dry wt of soil (g)	5547.4
N.M.C (%)	7.5		Water added (g)	**293**
Average (%)	7.5		**Water added (mL)**	**293**

Number of blows		62											
Number of layer		5											
Water Content Determination		Before Soaking		After Soaking									
Tare No		YU	-	PP	-								
Mass of wet sample + Tare	g	1888	-	2422	-								
Mass of dry sample + Tare	g	1775	-	2215	-								
Mass of Tare	g	809	-	808	-								
Mass of water	g	113	-	207	-								
Mass of dry sample	g	966	-	1407	-								
Water content	%	11.7	-	14.7	-								
Average water Content	%	11.7		14.7									
Density determination													
Mould No		YO											
Mass of mould + soil	g	12698		12858									
Mass of mould	g	7388		7388									
Mass of soil	g	5310		5470									
Volume of the mould	cm3	2305		2305									
Moist density	g/cm3	2.304		2.373									
Dry density	g/cm3	2.062		2.069									
Swell Determination													
Date		Hour		D.Gauge Reding									
Initial reading		96 hrs		9.6									
Final reading				10.55									
Height of the specimen				127									
Height of swell				0.95									
		Swelling(%)		0.75									

Observations	

For the Lab		For Students	
Lab. Technician	Materials Engineer	[signature]	[signature]

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Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth 0.5m	Sampling Date	28-Dec-24
mix:	NEAT SAMPLE	Penetration Date	4-Jan-25
Source:	NSAMBWE	Technician	: Lab team
Sample Description :	**LATERATIC GRAVEL (NEAT)**		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	YO		
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**	1	0.2	2	0.4								
0.5	**24**	1	0.2	3	0.6								
0.75	**35**	2	0.4	4	0.8								
1	**47**	2	0.4	5	1.0								
1.5	**71**	3	0.6	9	1.8								
2	**94**	6	1.2	13	2.7								
2.5	**118**	9	1.8	16	3.3								
3	**142**	10	2.1	18	3.7								
3.5	**165**	12	2.5	19	3.9								
4	**189**	13	2.7	20	4.1								
4.5	**213**	14	2.9	22	4.5								
5	**236**	14	2.9	24	4.9								
5.5	**260**	15	3.1	25	5.1								
6	**283**	15	3.1	26	5.3								
6.5	**307**	16	3.3	28	5.7								
7	**331**	16	3.3	29	6.0								
7.5	**354**	17	3.5	30	6.2								

Observations

For the Contractor		For Students	
Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD
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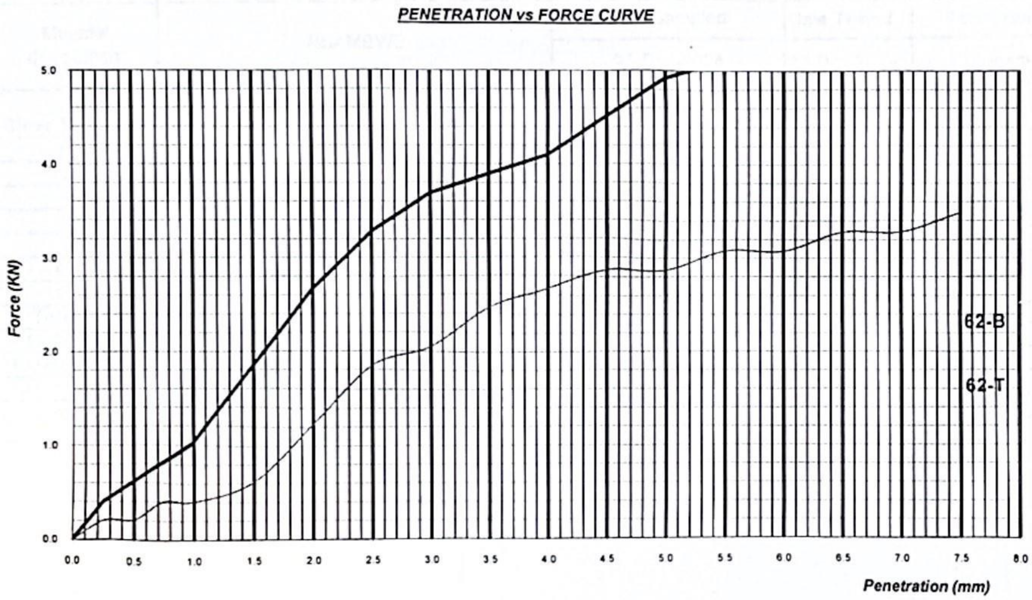
ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28-Dec-24
mix:	NEAT SAMPLE	Testing Date :	4-Jan-25
Source:	NSAMBWE	Technician	: Lab team
Sample Description:	LATERATIC GRAVEL (NEAT)		



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	3.3	1.8	25	14
5.0 mm Penetration	4.9	2.9	25	14
Average	4.1	2.4	24.7	14.2
Retained CBR	24.7			
Observations	CBR= 24.7			

For the Lab		For Students	
Lab. Technician	Materials Engineer		

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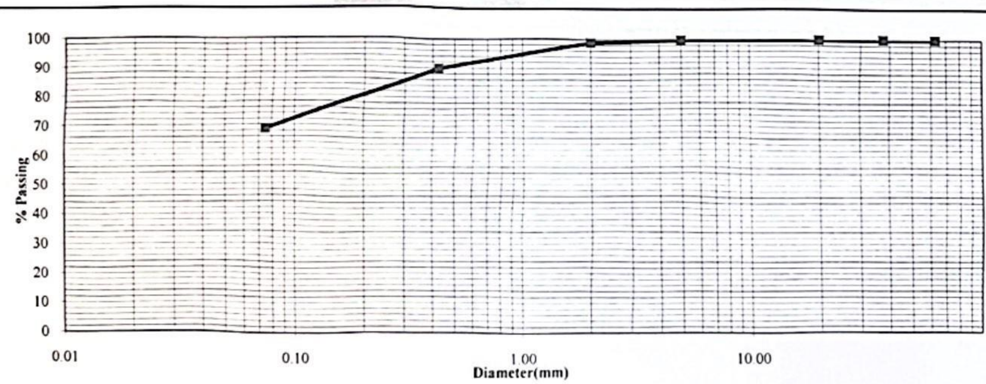
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE	Lab. Refernece No.:		
Location :(km)	NEAT SAMPLE	Dry wt. of sample before washing: (g)		4698.2
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		1508.0
Material description:	NSAMBWE	Date Sampled:	Date Tested:	Technician
		28-Dec-2024	30-Dec-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	0.0	0.0	100	60	95
5.0	9.5	0.2	100	30	65
2.00	40.7	0.9	99	20	50
0.425	426.3	9.1	90	10	30
0.075	999.0	21.3	69	5	15
Total fines	3222.7	68.6			
Bottom Pan	32.5				
Extracted fines	3190.2				
Total sample	4698.2				
Grading Modulus		0.43			



Testing Lab

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P. O. BOX 796, KAMPALA (U)

Lab Technician   Materials Engineer

STUDENTS

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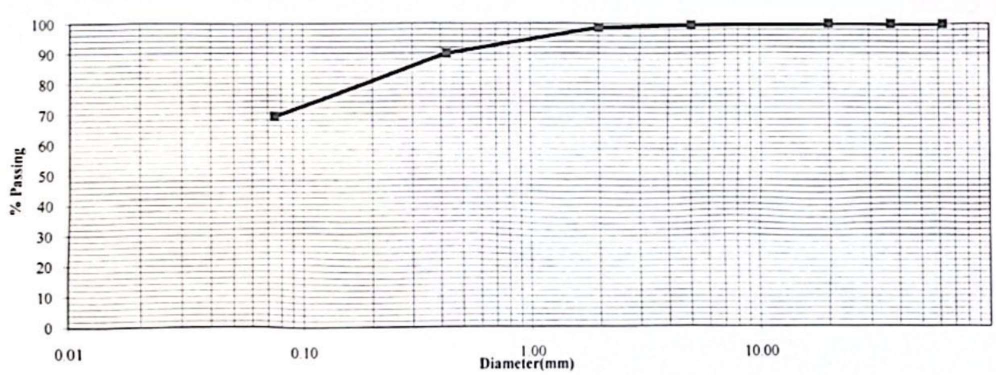
PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE	Lab. Refernece No.:		
Location :(km)	NEAT SAMPLE	Dry wt. of sample before washing: (g)		4896.3
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		1533.2
Material description:	NSAMBWE	Date Sampled:	Date Tested:	Technician
		28-Dec-2024	30-Dec-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	0.0	0.0	**100**	60	95
5.0	21.5	0.4	**100**	30	65
2.00	41.2	0.8	**99**	20	50
0.425	422.3	8.6	**90**	10	30
0.075	1025.4	20.9	**69**	5	15
Total fines	3385.9	69.2			
Bottom Pan	22.8				
Extracted fines	3363.1				
Total sample	4896.3				
Grading Modulus		**0.42**			



Testing Lab: STIRLING CIVIL ENGINEERING LTD

Lab Technician — Materials Engineer

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P. O. BOX 796, KAMPALA (U)

STUDENTS

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION				
Test Reference No.	Depth. 0.5m		Date Sampled	Date Tested	Technician
Mix	NEAT SAMPLE		28-Dec-24	30-Dec-24	Lab team
SOURCE :	NSAMBWE				
Material description:	LATERATIC GRAVEL (NEAT)		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	5	457	100	1,000

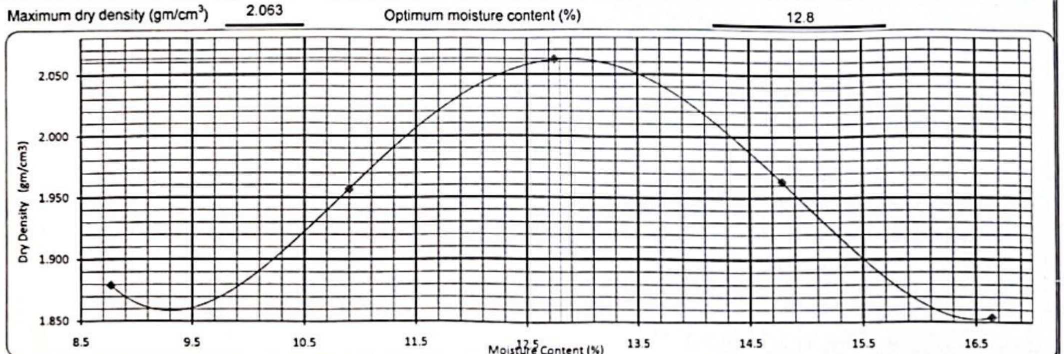
MOISTURE CONTENT DATA

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	5,969	6,095	6,250	6,178	6,087
Mass of Mould	gm	3,925	3,925	3,925	3,925	3,925
Mass of Compacted soil	gm	2044	2170	2325	2253	2162
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	2.044	2.170	2.325	2.253	2.162

DATA FOR PROCTOR CURVE

Container No.		MSJ	NQ	AA	SA	LP
Mass of wet soil + Container	gm	1,303.0	1,045.0	2,107.0	926.0	883.0
Mass of dry soil + container	gm	1,204.0	948.0	1,916.0	816.0	765.0
Mass of container	gm	75.0	58.0	418.0	72.0	56.0
Mass of water added	gm	99	97	191	110	118
Mass of dry soil	gm	1129	890	1498	744	709
Moisture content	%	8.8	10.9	12.8	14.8	16.6
Dry density	g/cm^3	1.879	1.957	2.062	1.963	1.854

Maximum dry density (gm/cm^3) 2.063 Optimum moisture content (%) 12.8



Remarks:

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

Lab Technician	Materials Engineer	STUDENTS	

INSTITUTION	STUDENTS		TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS S21B32/097 & KYALIGONZA GARY S21B32/067		Stirling
PROJECT	ASSESSING THE STABILIZATION OF LATERITE SOILS USING CRUSHED STEEL SLAG FOR THE CONSTRUCTION OF A SUBBASE ROAD LAYER		
	TESTING DATE		28-Jan-25
TEST NO	1		2
WEIGHT OF AGGREGATES (g)	5750		5759
VOLUME OF CONTAINER (m^3)	0.003375		0.003375
BULK DENSITY (Kg/m^3)	1703.704		1706.370
AVERAGE BULK DENSITY(Kg/m^3)	1706.4		

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

INSTITUTION	CLIENT	CONTRACTOR	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKKALABA ELVIS S21B32/097 & KYALIGONZA GARY S21B32/067		Stirling

PROJECT: ASSESSING THE STABILIZATION OF LATERITE SOILS USING CRUSHED STEEL SLAG FOR THE CONSTRUCTION OF A SUBBASE ROAD LAYER

TEST: GRADING OF CRUSHED STEEL SLAG

(BS 1377 - 2 - 1990)

LAYER :

LOCATION: MUKONO LAB

SUPPLIER :

SAMPLE No: AVERAGE OF 2

MATERIAL DESCRIP' STEEL SLAG

OPERATORS: LAB TEAM

TOTAL DRY WT. OF SAMPLE: 4906.4

TOTAL WT AFTER WASHING 4856.3

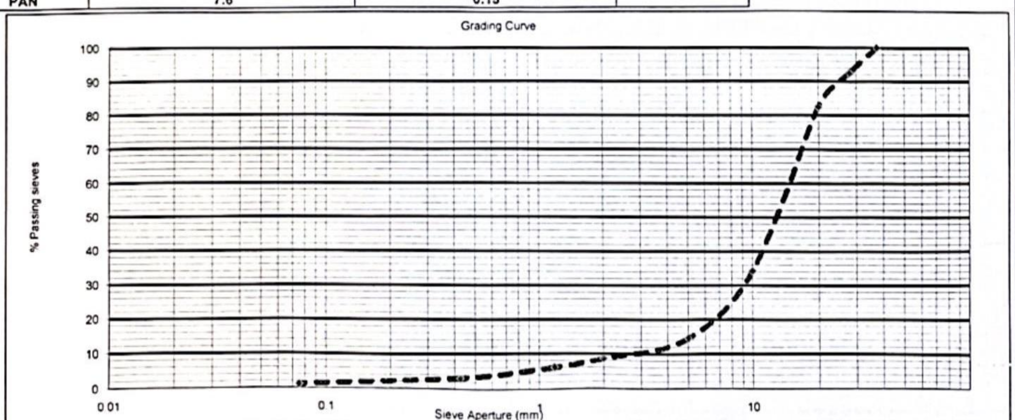
MOISTURE CONTENT:

WET OR DRY SIEVING: DRY

DATE SAMPLED: 15-Jan-25

DATE TESTED: 3-Feb-25

MAXIMUM SIEVE SIZE (mm)	WEIGHT RETAINED (gm)	PERCENTAGE RETAINED (%)		SPECIFIED LIMITS *table 3902/2)*	*(spec* (%)
37.5	0.0	0.00	100		
28.0	368.2	7.50	92		
20.0	494.8	10.08	82		
10.0	2366.1	48.22	34		
5.0	966.3	19.69	14		
2.0	290.3	5.92	9		
1.18	123.4	2.52	6		
0.425	146.2	2.98	3		
0.075	93.7	1.91	1		
PAN	7.6	0.15			



FOR TESTING LAB

STIRLING CIVIL ENGINEERING LTD
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INSTITUTION	CLIENT	CONTRACTOR	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKKALABA ELVIS S21B32/097 & KYALIGONZA GARY S21B32/067		Stirling

PROJECT:	ASSESSING THE STABILIZATION OF LATERITE SOILS USING CRUSHED STEEL SLAG FOR THE CONSTRUCTION OF A SUBBASE ROAD LAYER

TEST: FLAKINESS INDEX OF CRUSHED STEEL SLAG

(BS 812:105)

Field Ref.		Technician:	
Laboratory Ref:		Total dry wt. of the samplebefore wash	4906.4
Location:	MUKONO	Total dry wt of the sample after washin	4856.3
Sample No:	SAMPLE B	Wet or Wet sieving:	Wet Sieving
Material Description:	STEEL SLAG	Date sampled:	15-01-25
		Date tested:	03-02-25

PARTICLE SIZE DISTRIBUTION

MAXIMUM SIEVE SIZE (mm)	WEIGHT RETAINED (gm)	PERCENTAGE RETAINED (%)	PERCENTAGE PASSING(%)
37.5	0	0.0	100
28.0	368.15	7.5	92
20.0	494.8	10.1	82
10.0	2366.05	48.2	34

Where % retained on any of the above sieves is less than 5% that size is not tested for flakiness

BS sieve size (mm)		37.5	28.0	20.0	10.0	TOTAL
Weight retained	A	0		494.8	2366.05	2860.9
Riffled weight (if needed)	B			494.8	1808.1	
Correction factor	(A/B) = C			1.0	1.3	
Wt. Passing sieve	D			51.05	235.85	
Wt. Retained on sieve	E			443.75	1572.25	
Corrected Wt. Passing	(DxC) = F			51.1	308.6	359.7

FLAKNESS = $\frac{\text{TOTAL (F)}}{\text{TOTAL (A)}}$

12.6 %
(SPEC < 35 %)

TESTING LAB

STIRLING CIVIL ENGINEERING LTD
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INSITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS S21B32/097 & KYALIGONZA GARY S21B32/067	Stirling

GRANITE DUST SAMPLE FROM MM STONE QUARRY		
Testing date	18/02/2025	
Test No.	1	2
Weight of the pyknometer (M1)g	101.926	101.926
Pyknometer and granite dust (M2)g	235.049	235.053
Pyknometer and granite dust and water (M3)g	286.589	286.229
Pyknometer and water (M4)g	202.229	202.226
Specific gravity $Gs = \frac{M2-M1}{(M4-M1)-(M3-M2)}$	2.73	2.71
Average specific gravity Gs	2.72	
Density of granite dust (kgm^{-3})	2720	
Testing Lab		

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INSTITUTION	CLIENT	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS AND KYALIGONZA GARY	Stirling Stirling Civil Engineering Ltd

STIRLING MUKONO LABORATORY

PROJECT ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

GRADING FOR AGGREGATES

(BS)

LOCATION: Budondo subcounty

SUPPLIER: MM quarry factory

SAMPLE No:

MATERIAL DESCRIPTION: GRANITE QUARRY DUST

OPERATORS:

TOTAL DRY WT. OF SAMPLE: 5862.2

TOTAL DRY WT. OF SAMPLE AFTER: 5375.6

SAMPLE DATE :

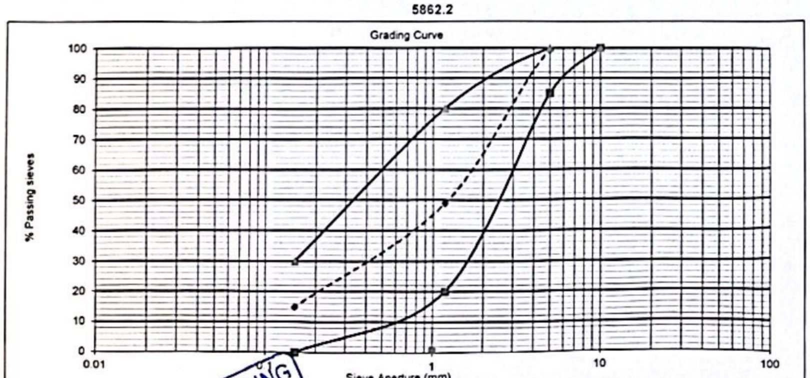
DATE SAMPLED: 14/12/2024

DATE TESTED: 15/02/2025

SAMPLE AVERAGE OF 2

MAXIMUM SIEVE SIZE (mm)	WEIGHT RETAINED (gm)	PERCENTAGE RETAINED (%)	PERCENTAGE PASSING (%)	SPECIFIED LIMITS *(spec table 4502/1)* (%)
10.0	0	0.0	100.0	100
5.000	25.7	0.4	99.4	85 - 100
1.180	2994.6	51.1	48.9	20 - 80
0.150	1959.2	33.4	14.9	0 - 30
PAN	396.1			
WIEGHT LOST DURING SIEVING	486.6			
TOTAL	5862.2			

5862.2



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For the Supplier

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

SUMMARY OF TEST RESULTS FOR LATERATE GRAVEL OF LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG

LOCATION: NSAMBWE BORROWPIT **Depth:** 0.5m

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	AVERAGE
NSAMBWE BORROW PIT	LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG	28/12/2024	100	98	91	47	29	16	9	2.46	47.5	25.3	22.2	11.4	2.143	10.4	37	0.50	0.50
			100	100	93	46	27	17	13	2.43	47.0	25.5	21.5	11.4	-	-	- - -	-	
			100	98.84	91.81	46.76	27.83	16.61	10.84	2.45	47.3	25.4	21.9	11.4	2.143	10.4	37.4	0.50	0.50
	AVERAGE		100	99	92	47	28	17	11	2.447	47.3	25.5	21.9	11.4	2.143	10.4	37.4	0.50	0.50

FOR LAB

STIRLING CIVIL ENGINEERING LTD

07 FEB 2025

P. O. BOX 796, KAMPALA (U)

Lab Technician Materials Engineer

STUDENTS

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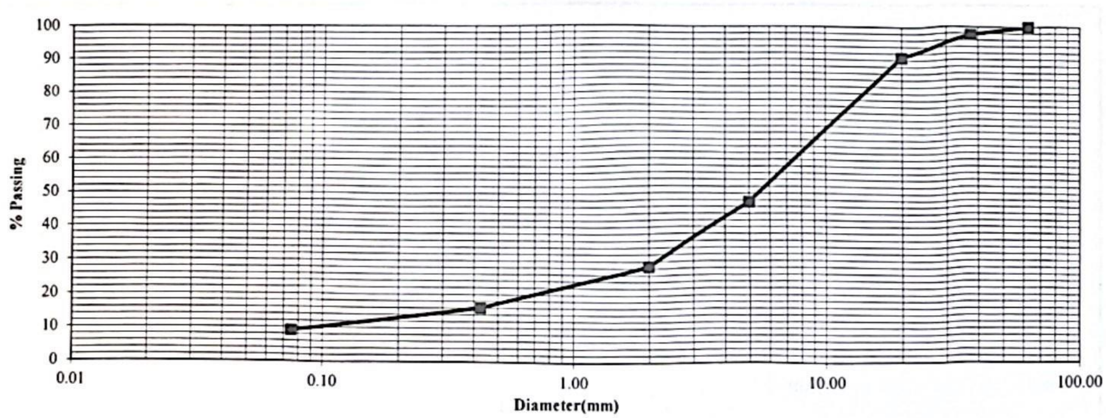
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	20% STEEL SLAG	Dry wt. of sample before washing: (g)		3845.9
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		3505.4
Material description:	LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	28/Jan/2025	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	100	100	100
37.5	89.3	2.3	98	80	100
20.0	267.6	7.0	91	60	95
5.0	1662.9	43.2	47	30	65
2.00	727.6	18.9	29	20	50
0.425	481.1	12.5	16	10	30
0.075	265.3	6.9	9	5	15
Total fines	352.1	9.2			
Bottom Pan	11.6				
Extracted fines	340.5				
Total sample	3845.9				
Grading Modulus		2.46			



Testing Lab

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

Lab Technician

Materials Engineer

STUDENTS

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UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

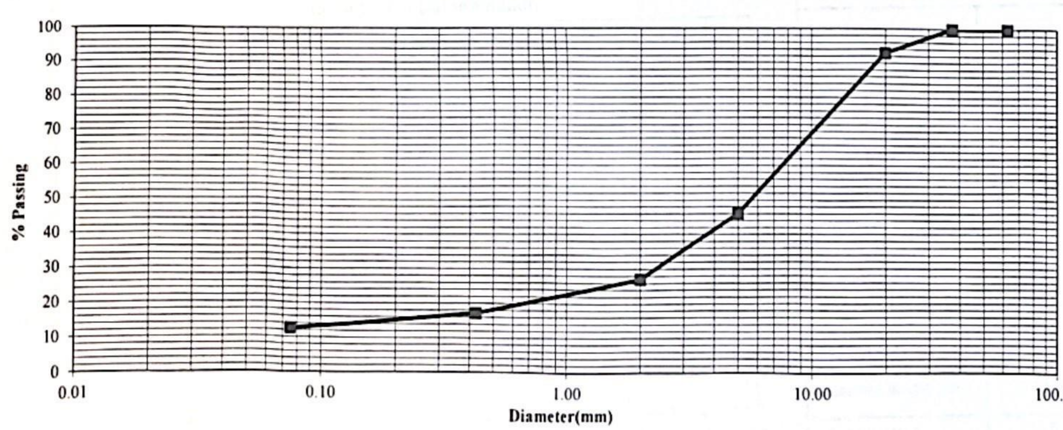
PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:	
Location :(km)	20% STEEL SLAG	Dry wt. of sample before washing: (g)	4198.9
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)	3705.7

Material description:	Date Sampled:	Date Tested:	Technician
LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG	28/Dec/2024	28/Jan/2025	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	298.1	7.1	**93**	60	95
5.0	1967.3	46.9	**46**	30	65
2.00	795.4	18.9	**27**	20	50
0.425	417.0	9.9	**17**	10	30
0.075	195.4	4.7	**13**	5	15
Total fines	525.7	12.5			
Bottom Pan	32.5				
Extracted fines	493.2				
Total sample	4198.9				
Grading Modulus		**2.43**			



Testing Lab STIRLING CIVIL ENGINEERING LTD 07 FEB

Lab Technician *Materials Engineer*

STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

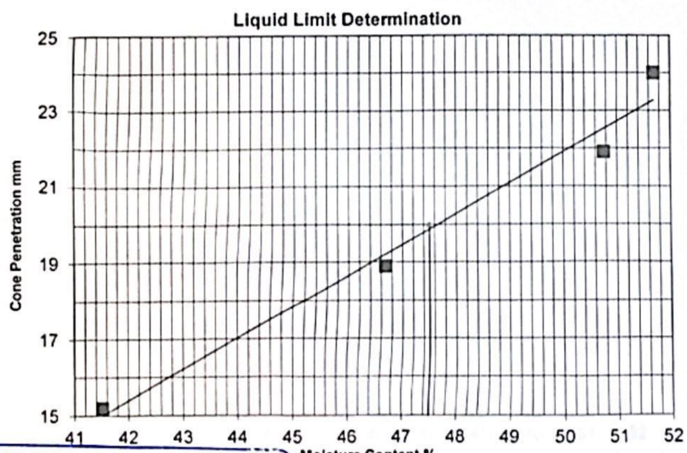
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	KAWANDA TOWN COUNCIL (WAKISO	Technician:	Lab Team
mix	20% STEEL SLAG	Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	29/Jan/2025
LAYER	LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	OO	JL		Average
Mass of wet soil + container (g)		38.76	35.12		36.94
Mass of dry soil + container (g)		35.28	32.61		33.945
Mass of container (g)		21.65	22.56		22.105
Mass of moisture (g)		3.48	2.5		2.995
Mass of dry soil (g)		13.63	10.05		11.84
Moisture content %		25.5	25.0		25.3
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	21.9	24.0
penetration (mm)		15.2	18.9	21.9	24.0
AVERAGE		15.2	18.9	21.9	24.0
Container No.		A	PI7	PI38	A15
Mass of wet soil + container (g)		48.06	51.57	43.95	49.65
Mass of dry soil + container (g)		36.08	37.35	31.56	35.14
Mass of container (g)		7.22	6.89	7.15	7.07
Mass of moisture (g)		11.98	14.22	12.39	14.51
Mass of dry soil (g)		28.86	30.46	24.41	28.07
Moisture content (%)		41.5	46.7	50.8	51.7
AVERAGE		41.5	46.7	50.8	51.7



Liquid limit (%)	47.5
Plastic limit (%)	25.3
Plasticity Index (%)	22.2
Linear shrinkage	
Trough No.	Y
Trough length (cm)	14.0
Specimen length (cm)	12.4
L.shringage =	1.6
% L.shrinkage =	11.4

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P. O. BOX 796, KAMPALA (U)

Remarks:

TESTING LAB		STUDENTS
Materials Engineer Lab Technician		

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	**ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION**

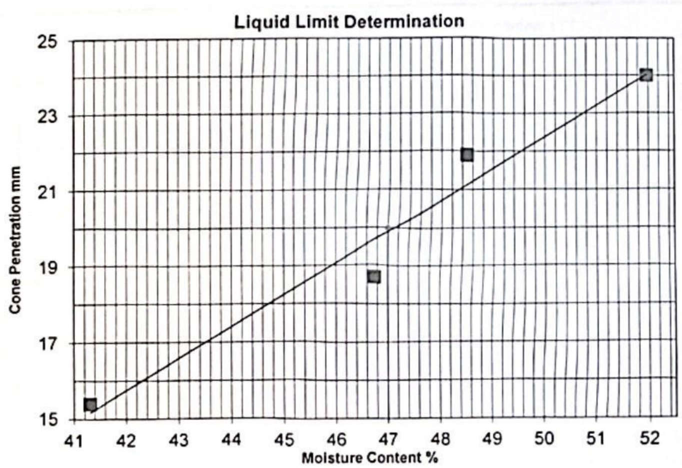
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	KAWANDA TOWN COUNCIL (WAKISO	Technician:	Lab Team
mix	20% STEEL SLAG	Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	29/Jan/2025
LAYER	LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	3	I4		Average
Mass of wet soil + container (g)		72	70.67		71.335
Mass of dry soil + container (g)		69.4	68.46		68.93
Mass of container (g)		59.24	59.77		59.505
Mass of moisture (g)		2.6	2.2		2.405
Mass of dry soil (g)		10.16	8.69		9.425
Moisture content %		25.6	25.4		25.5
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.4	18.7	21.9	24.0
penetration (mm)		15.4	18.7	21.9	24.0
AVERAGE		15.4	18.7	21.9	24.0
Container No.		PI43	PI66	PII2	PI26
Mass of wet soil + container (g)		46.47	62.05	48.58	45.91
Mass of dry soil + container (g)		34.95	44.53	34.98	32.61
Mass of container (g)		7.06	7.05	6.93	7.02
Mass of moisture (g)		11.52	17.52	13.6	13.3
Mass of dry soil (g)		27.89	37.48	28.05	25.59
Moisture content (%)		41.3	46.7	48.5	52.0
AVERAGE		41.3	46.7	48.5	52.0



Liquid limit (%)	47.0
Plastic limit (%)	25.5
Plasticity Index (%)	21.5
Linear shrinkage	
Trough No.	Y
Trough length (cm)	14.0
Specimen length (cm)	12.4
L.shringage =	1.6
% L.shrinkage =	11.4

Remarks:

TESTING LAB

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P. O. BOX 798, KAMPALA (U)

Materials Engineer

Lab Technician

STUDENTS

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION				
Test Reference No.	Depth. 0.5m		Date Sampled	Date Tested	Technician
Mix	20% STEEL SLAG		28/Dec/24	28/Jan/25	Lab team
SOURCE :	NSAMBWE BORROWPIT				
Material description:	LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG		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	5	457	100	1,000

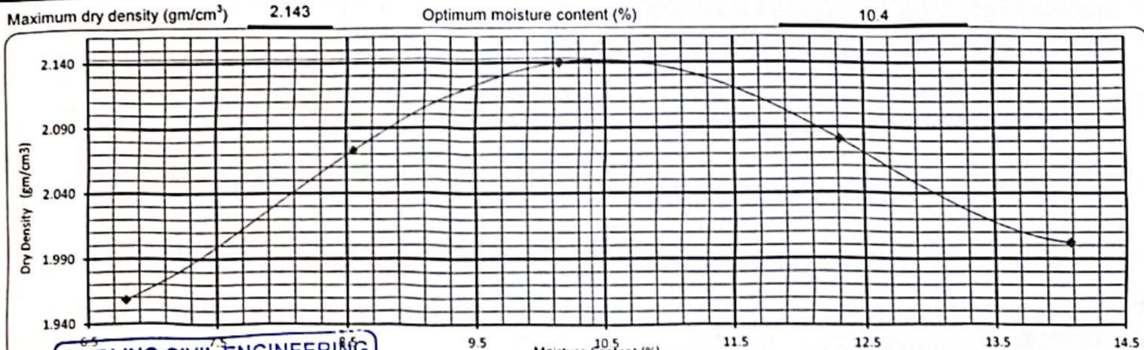
MOISTURE CONTENT DATA

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	6,364	6,523	6,630	6,610	6,557
Mass of Mould	gm	4,273	4,273	4,273	4,273	4,273
Mass of Compacted soil	gm	2091	2250	2357	2337	2284
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	2.091	2.250	2.357	2.337	2.284

DATA FOR PROCTOR CURVE

Container No.		Z6T	KJ	YY	MANU	AA
Mass of wet soil + Container	gm	2,537.0	2,307.0	2,532.0	1,905.0	1,772.0
Mass of dry soil + container	gm	2,427.0	2,188.0	2,371.0	1,756.0	1,605.0
Mass of container	gm	808.0	797.0	784.0	546.0	419.0
Mass of water added	gm	110	119	161	149	167
Mass of dry soil	gm	1619	1391	1587	1210	1186
Moisture content	%	6.8	8.6	10.1	12.3	14.1
Dry density	g/cm^3	1.958	2.073	2.140	2.081	2.002

Maximum dry density (gm/cm^3) 2.143 Optimum moisture content (%) 10.4



FOR TESTING LAB		STUDENTS	
Lab Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P. O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	20% STEEL SLAG	Casting date :	31/Dec/24
Source:	NSAMBWE BORROWPIT	Testing Date :	4/Jan/25
Sample Description:	LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG	Technician :	: Lab team
		Volume of Mould used (m³)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	LDU		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	1991		MDD (Mg/m³)	2.143
Tin + oven dry soil sample (g)	1963		N.M.C (%)	1.8
Tin (g)	419		OMC (%)	10.4
Dry soil sample	1544		Added OMC (%)	8.6
Water (g)	28		Calculated dry wt of soil (g)	5891.2
N.M.C (%)	1.8		Water added (g)	506
Average (%)	1.8		**Water added (mL)**	**506**

Number of blows		62					
Number of layer		5					
Water Content Determination		Before Soaking		After Soaking			
Tare No		KCR	-	Y2Y	-		
Mass of wet sample + Tare	g	1169	-	2780	-		
Mass of dry sample + Tare	g	1110	-	2575	-		
Mass of Tare	g	421	-	815	-		
Mass of water	g	59	-	205	-		
Mass of dry sample	g	689	-	1760	-		
Water content	%	8.6	-	11.6	-		
Average water Content	%	8.6		11.6			
Density determination							
Mould No		MM					
Mass of mould + soil	g	11697		11868			
Mass of mould	g	6160		6160			
Mass of soil	g	5537		5708			
Volume of the mould	cm3	2305		2305			
Moist density	g/cm3	2.402		2.476			
Dry density	g/cm3	2.213		2.218			
Swell Determination							
Date		Hour		D.Gauge Reding			
Initial reading		96 hrs		8.65			
Final reading				9.28			
Height of the specimen				127			
Height of swell				0.63			
		Swelling(%)		0.50			

Observation

For the Lab		For Students	
Lab Technician	Materials Engineer		

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

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date	28/Dec/24
mix:	20% STEEL SLAG	Penetration Date	4/Jan/25
Source:	NSAMBWE BORROWPIT	Technician	: : Lab team
Sample Description :	: LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	MM		
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**	2	0.4	2	0.4
0.5	**24**	4	0.8	5	1.0
0.75	**35**	8	1.6	7	1.4
1	**47**	11	2.3	10	2.1
1.5	**71**	13	2.7	14	2.9
2	**94**	17	3.5	19	3.9
2.5	**118**	20	4.1	23	4.7
3	**142**	24	4.9	26	5.3
3.5	**165**	28	5.7	29	6.0
4	**189**	29	6.0	33	6.8
4.5	**213**	31	6.4	36	7.4
5	**236**	34	7.0	38	7.8
5.5	**260**	36	7.4	40	8.2
6	**283**	38	7.8	41	8.4
6.5	**307**	40	8.2	44	9.0
7	**331**	41	8.4	46	9.4
7.5	**354**	42	8.6	48	9.8

Observations

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P.O. BOX 706, KAMPALA

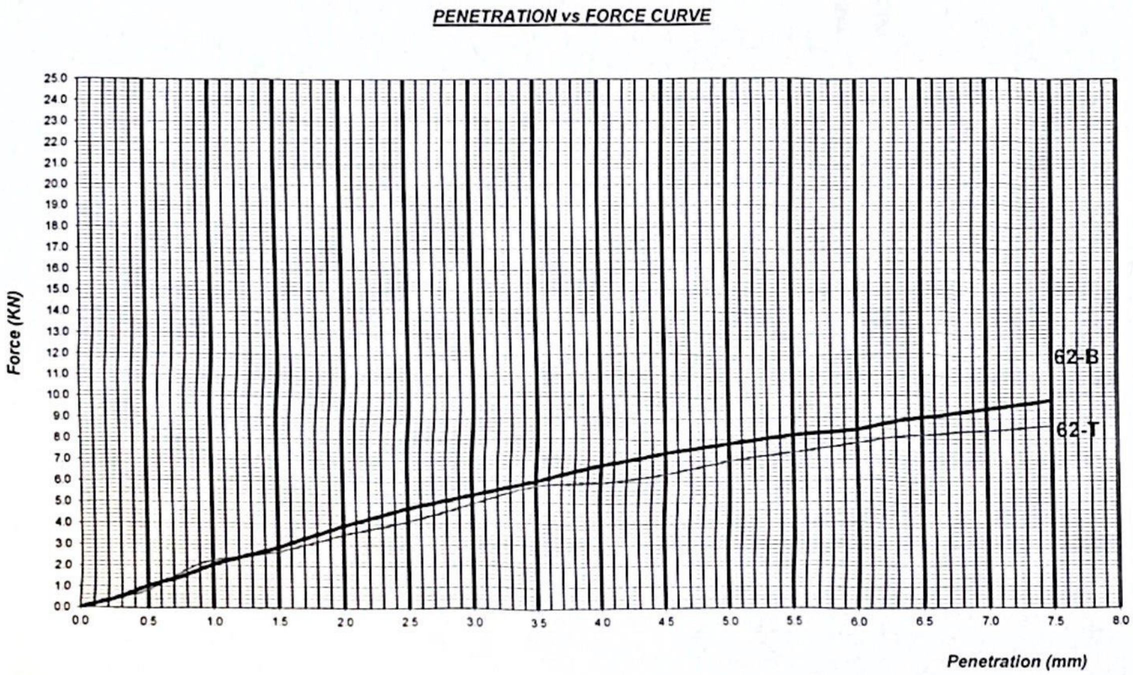
For the Contractor		For Students	
Lab Technician	Materials Engineer		

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date : 28/Dec/24
mix:	20% STEEL SLAG	Testing Date : 4/Jan/25
Source:	NSAMBWE BORROWPIT	Technician : Lab team
Sample Description:	LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG	



	62 blows											
	Force		CBR									
	Bottom	Top	Bottom	Top								
2.5 mm Penetration	4.7	4.1	36	31								
5.0 mm Penetration	7.8	7.0	39	35								
Average	6.3	5.5	37.4	33.0								
Retained CBR	37.4											
Observations	CBR= 37.4											

For the Lab		For Students	
Lab. Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

SUMMARY OF TEST RESULTS FOR LATERATE GRAVEL OF LATERATIC GRAVEL MODIFIED WITH 30% STEEL SLAG

LOCATION: NSAMBWE BORROWPIT | Depth: 0.5m

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	AVERAGE
NSAMBWE BORROW PIT	LATERATIC GRAVEL MODIFIED WITH 30% STEEL SLAG	28/12/2024	100	100	95	55	35	22	16	2.27	43	25.6	17.4	9.3	2.213	9.4	41	0.39	0.39
			100	100	97	55	35	21	14	2.30	43.6	25.7	17.9	9.3	-	-	- - -	-	
			100	100	95.76	54.9	34.95	21.66	14.86	2.29	43.3	25.6	17.7	9.3	2.213	9.4	40.6	0.39	0.39
	AVERAGE		100	100	96	55	35	22	15	2.285	43.3	25.7	17.7	9.3	2.213	9.4	40.6	0.39	0.39

FOR LAB

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P. O. BOX 796, KAMPALA (U)

Lab Technician   Materials Engineer

STUDENTS

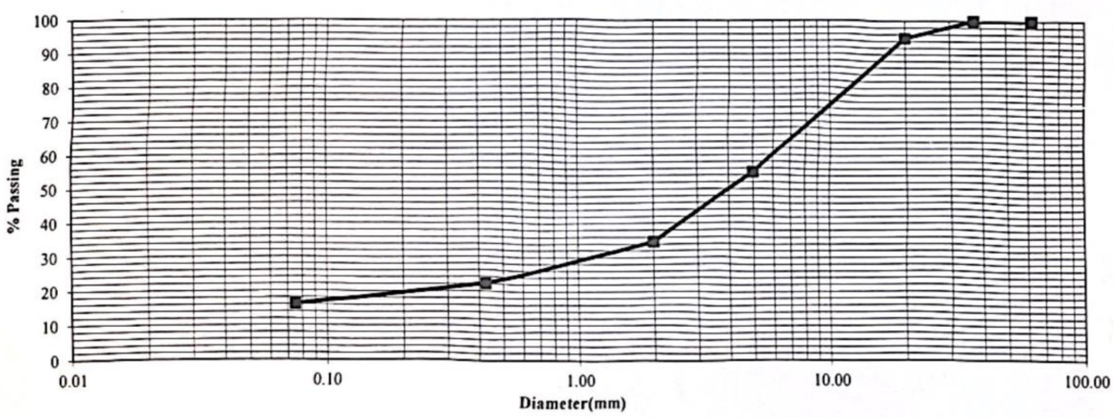
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	30% STEEL SLAG	Dry wt. of sample before washing: (g)		6377.7
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		5357.6
Material description:	NSAMBWE BORROWPIT	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	28/Jan/2025	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	328.6	5.2	**95**	60	95
5.0	2547.7	39.9	**55**	30	65
2.00	1288.9	20.2	**35**	20	50
0.425	803.2	12.6	**22**	10	30
0.075	380.7	6.0	**16**	5	15
Total fines	1028.6	16.1			
Bottom Pan	8.5				
Extracted fines	1020.1				
Total sample	6377.7				
Grading Modulus		**2.27**			



STIRLING CIVIL ENGINEERING LTD
Testing Lab
07 FEB 2025
Lab Technician
Materials Engineer
P. O. BOX 796, KAMPALA (U)

STUDENTS

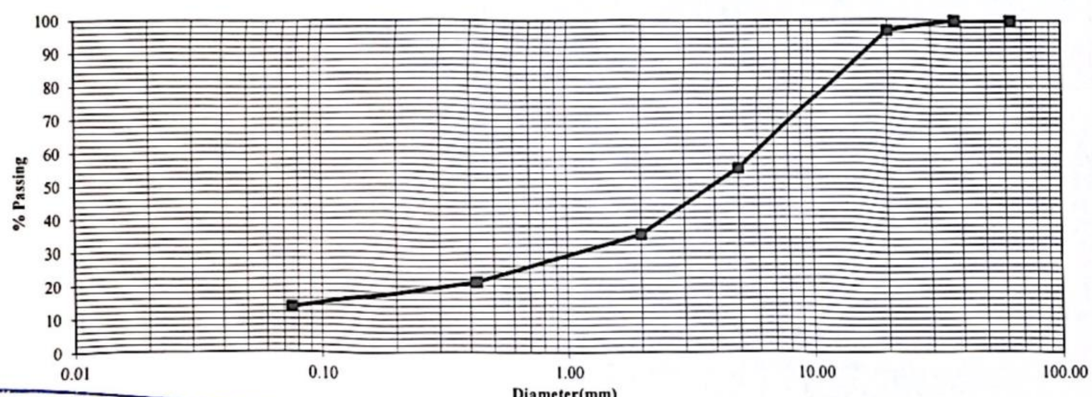
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	30% STEEL SLAG	Dry wt. of sample before washing: (g)		5751.8
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		4988.0
Material description:	NSAMBWE BORROWPIT	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	28/Jan/2025	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	190.9	3.3	**97**	60	95
5.0	2402.7	41.8	**55**	30	65
2.00	1132.7	19.7	**35**	20	50
0.425	804.9	14.0	**21**	10	30
0.075	439.3	7.6	**14**	5	15
Total fines	781.3	13.6			
Bottom Pan	17.5				
Extracted fines	763.8				
Total sample	5751.8				
Grading Modulus		**2.30**			



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07 FEB 2025
P.O. BOX 796, KAMPALA (U)

Testing Lab		STUDENTS	
Lab Technician	Materials Engineer		

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	**ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION**

ATTERBERG LIMITS

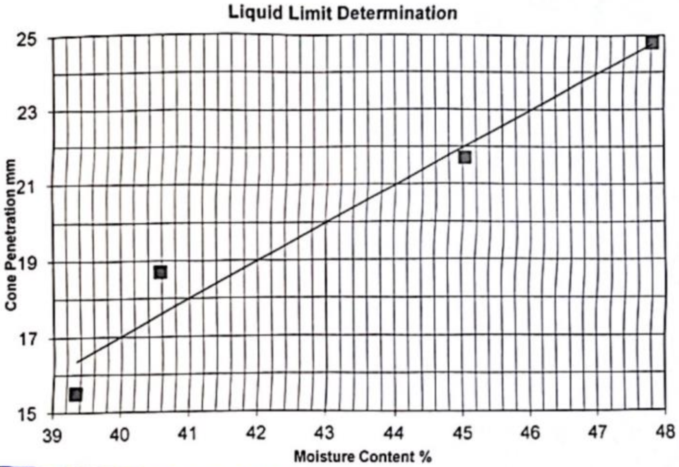
Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT	Technician:	Lab Team
mix	30% STEEL SLAG	Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	31/Dec/2024
LAYER	LATERATIC GRAVEL MODIFIED WITH 30% STEEL SLAG		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	I3	Q		Average
Mass of wet soil + container (g)		35.32	32.59		33.955
Mass of dry soil + container (g)		32.69	30.38		31.535
Mass of container (g)		22.46	21.68		22.07
Mass of moisture (g)		2.63	2.2		2.42
Mass of dry soil (g)		10.23	8.7		9.465
Moisture content %		25.7	25.4		25.6
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.5	18.7	21.7	24.8
penetration (mm)		15.5	18.7	21.7	24.8
AVERAGE		15.5	18.7	21.7	24.8
Container No.		PI56	BE	PI28	PI600
Mass of wet soil + container (g)		55.89	65.30	62.31	51.48
Mass of dry soil + container (g)		42.08	48.46	45.17	37.12
Mass of container (g)		6.97	6.96	7.11	7.09
Mass of moisture (g)		13.81	16.84	17.14	14.36
Mass of dry soil (g)		35.11	41.5	38.06	30.03
Moisture content (%)		39.3	40.6	45.0	47.8
AVERAGE		39.3	40.6	45.0	47.8

Liquid Limit Determination



Liquid limit (%)	43.0
Plastic limit (%)	25.6
Plasticity Index (%)	17.4
Linear shrinkage	
Trough No.	4
Trough length (cm)	14.0
Specimen length (cm)	12.7
L.shringage =	1.3
% L.shrinkage =	9.3

Remarks:

STIRLING CIVIL ENGINEERING LTD

TESTING LAB

Materials Engineer.

P. O. BOX 796, KAMPALA (U)

Lab Technician

STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

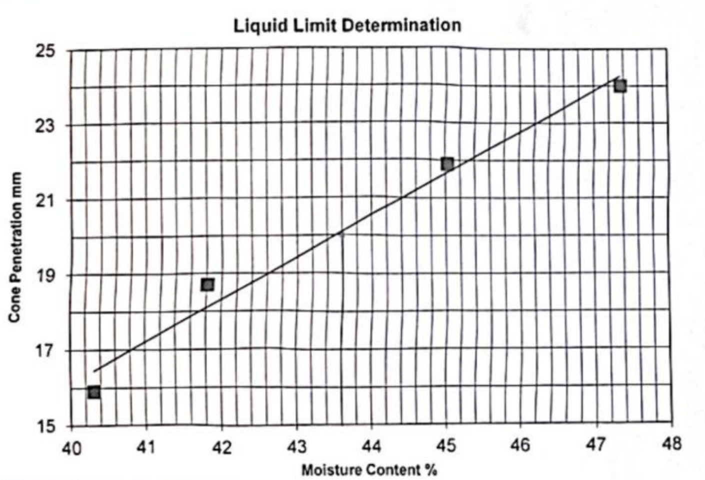
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT		Technician:	Lab Team
mix	30% STEEL SLAG		Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4		Test Date	31/Dec/2024
LAYER	LATERATIC GRAVEL MODIFIED WITH 30% STEEL SLAG			
Depth:	0.5m			

PLASTIC LIMIT	Test No.	RAD	4L		Average
Mass of wet soil + container (g)		43.17	31.91		37.54
Mass of dry soil + container (g)		38.88	29.93		34.405
Mass of container (g)		21.97	22.33		22.15
Mass of moisture (g)		4.29	2.0		3.135
Mass of dry soil (g)		16.91	7.6		12.255
Moisture content %		25.4	26.1		25.7
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.9	18.7	21.9	24.0
penetration (mm)		15.9	18.7	21.9	24.0
AVERAGE		15.9	18.7	21.9	24.0
Container No.		4B	MB	PIMO	PI52
Mass of wet soil + container (g)		54.18	63.71	50.95	59.09
Mass of dry soil + container (g)		40.70	47.04	37.35	42.40
Mass of container (g)		7.26	7.17	7.15	7.16
Mass of moisture (g)		13.48	16.67	13.6	16.69
Mass of dry soil (g)		33.44	39.87	30.2	35.24
Moisture content (%)		40.3	41.8	45.0	47.4
AVERAGE		40.3	41.8	45.0	47.4



Liquid limit (%)	43.6
Plastic limit (%)	25.7
Plasticity Index (%)	17.9
Linear shrinkage	
Trough No.	4
Trough length (cm)	14.0
Specimen length (cm)	12.7
L.shringage =	1.3
% L.shrinkage =	9.3

Remarks:

TESTING LAB

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

Lab Technician

STUDENTS

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	30% STEEL SLAG	Casting date :	31/Dec/24
Source:	NSAMBWE BORROWPIT	Testing Date :	4/Jan/25
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 30% STEEL SLAG	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)	2426		MDD (Mg/m^3)	2.213
Tin + oven dry soil sample (g)	2404		N.M.C (%)	1.3
Tin (g)	767		OMC (%)	9.4
Dry soil sample	1637		Added OMC (%)	8.1
Water (g)	22		Calculated dry wt of soil (g)	5919.4
N.M.C (%)	1.3		Water added (g)	477
Average (%)	1.3		**Water added (mL)**	477

Number of blows		62					
Number of layer		5					
Water Content Determination		Before Soaking		After Soaking			
Tare No		ZIK	-	BAR	-		
Mass of wet sample + Tare	g	765	-	3135	-		
Mass of dry sample + Tare	g	705	-	2895	-		
Mass of Tare	g	67	-	805	-		
Mass of water	g	60	-	240	-		
Mass of dry sample	g	638	-	2090	-		
Water content	%	9.4	-	11.5	-		
Average water Content	%	9.4		11.5			
Density determination							
Mould No		NO					
Mass of mould + soil	g	12257		12373			
Mass of mould	g	6687		6687			
Mass of soil	g	5570		5686			
Volume of the mould	cm3	2305		2305			
Moist density	g/cm3	2.416		2.467			
Dry density	g/cm3	2.209		2.213			
Swell Determination							
Date		Hour		D.Gauge Reding			
Initial reading		96 hrs		8.5			
Final reading				9			
Height of the specimen				127			
Height of swell				0.5			
		Swelling (%)		0.39			

Observations

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P. O. BOX 796, KAMPALA (U)

For the Lab		For Students	
Lab Technician	Materials Engineer		

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date	28/Dec/24
mix:	30% STEEL SLAG	Penetration Date	4/Jan/25
Source:	NSAMBWE BORROWPIT	Technician	:: Lab team
Sample Description :	: LATERATIC GRAVEL MODIFIED WITH 30% STEEL SLAG		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	NO		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.2312	0.2312	0.2312

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	2	0.5	3	0.7
0.5	24	4	0.9	5	1.2
0.75	35	6	1.4	6	1.4
1	47	7	1.6	8	1.8
1.5	71	10	2.3	11	2.5
2	94	13	3.0	14	3.2
2.5	118	17	3.9	20	4.6
3	142	21	4.9	24	5.5
3.5	165	27	6.2	28	6.5
4	189	33	7.6	33	7.6
4.5	213	39	9.0	36	8.3
5	236	44	10.2	40	9.2
5.5	260	49	11.3	43	9.9
6	283	54	12.5	44	10.2
6.5	307	59	13.6	47	10.9
7	331	64	14.8	50	11.6
7.5	354	69	16.0	52	12.0

Observations

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P.O. BOX 796, KAMPALA

For the Contractor		For Students
Lab Technician	Materials Engineer	

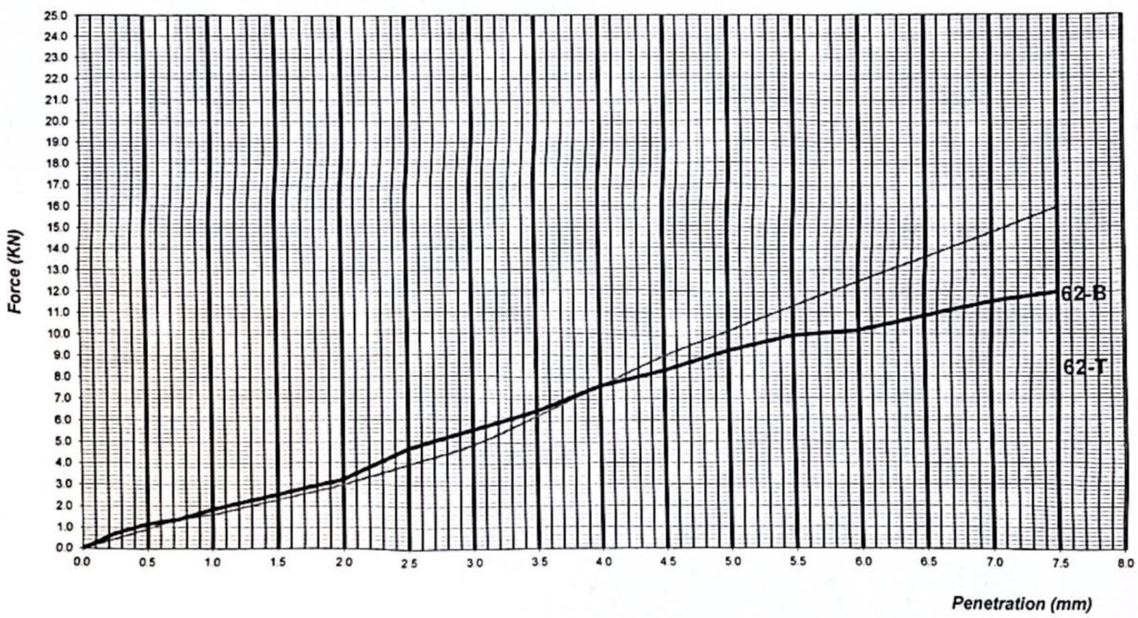
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	30% STEEL SLAG	Testing Date :	4/Jan/25
Source:	NSAMBWE BORROWPIT	Technician	: Lab team
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 30% STEEL SLAG		

PENETRATION vs FORCE CURVE



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	4.6	3.9	35	30
5.0 mm Penetration	9.2	10.2	46	51
Average	6.9	7.1	40.6	40.3
Retained CBR	40.6			

Observations CBR= 40.6

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For the Lab		For Students	
Lab Technician	Materials Engineer		

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

SUMMARY OF TEST RESULTS FOR LATERATE GRAVEL OF LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG

LOCATION: NSAMBWE BORROWPIT — Depth: 0.5m

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	AVERAGE
NSAMBWE BORROWPIT	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	28-12-24	100	100	92	51	34	23	17	2.26	44.2	25.3	18.9	9.6	2.252	9.8	65	0.19	0.19
			100	100	94	49	33	22	16	2.29	44.1	25.5	18.6	9.6	-	-	- - -	-	
			100	100	93.02	50.17	33.36	22.32	16.77	2.28	44.2	25.4	18.8	9.6	2.252	9.8	65.0	0.19	0.19
	AVERAGE		100	100	93	50	33	22	17	2.276	44.2	25.5	18.8	9.6	2.252	9.8	65.0	0.19	0.19

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STUDENTS

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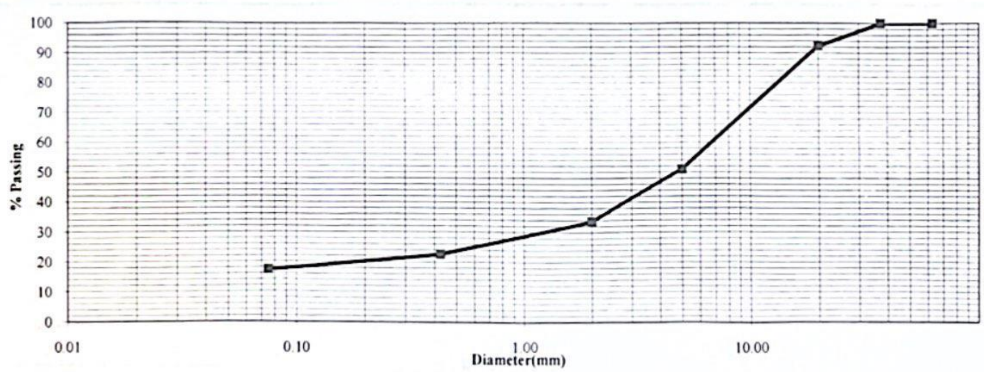
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	Dry wt. of sample before washing: (g)		5656.4
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		4684.7
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	Date Sampled:	Date Tested:	Technician
		28-Dec-2024	28-Jan-2025	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	430.0	7.6	**92**	60	95
5.0	2339.6	41.4	**51**	30	65
2.00	979.5	17.3	**34**	20	50
0.425	625.5	11.1	**23**	10	30
0.075	303.9	5.4	**17**	5	15
Total fines	977.9	17.3			
Bottom Pan	6.2				
Extracted fines	971.7				
Total sample	5656.4				
Grading Modulus		**2.26**			



Testing Lab

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P. O. BOX 796, KAMPALA (U)

Lab Technician　　Materials Engineer

STUDENTS

INSTITUTION	STUDENTS NAMES	TESTING LAB
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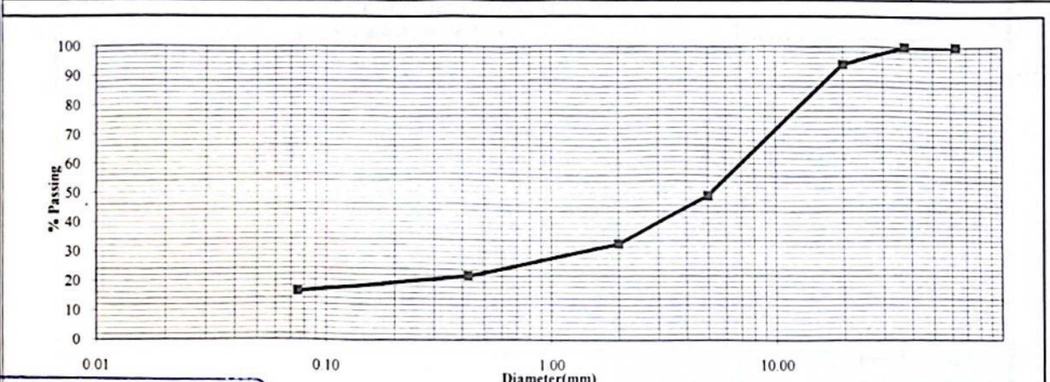
PROJECT : **ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION**

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	Dry wt. of sample before washing: (g)		5130.4
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		4300.6
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	Date Sampled:	Date Tested:	Technician
		28-Dec-2024	28-Jan-2025	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	326.3	6.4	**94**	60	95
5.0	2274.1	44.3	**49**	30	65
2.00	837.4	16.3	**33**	20	50
0.425	565.0	11.0	**22**	10	30
0.075	293.4	5.7	**16**	5	15
Total fines	834.2	16.3			
Bottom Pan	4.4				
Extracted fines	829.8				
Total sample	5130.4				
Grading Modulus		**2.29**			



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Testing Lab
07 FEB 2025
P. O. BOX 796, KAMPALA (U)

Lab Technician

Materials Engineer

STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

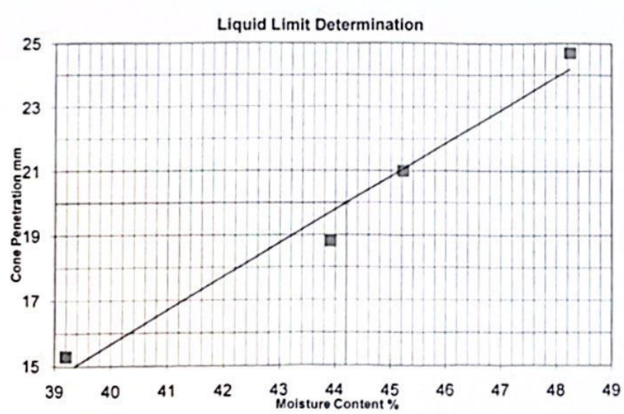
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT	Technician:	Lab Team
mix	ATERATIC GRAVEL MODIFIED WITH 40% STEEL SLA(	Sample Date	28-Dec-2024
Test method	BS 1377: Part 2, 1990 4.3/4.4	Test Date	29-Jan-2025
LAYER	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	PNU	LL		Average
Mass of wet soil + container (g)		37.78	36.56		37.17
Mass of dry soil + container (g)		34.77	33.69		34.23
Mass of container (g)		22.84	22.36		22.6
Mass of moisture (g)		3.01	2.9		2.94
Mass of dry soil (g)		11.93	11.33		11.63
Moisture content %		25.2	25.3		25.3
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.3	18.8	21	24.7
penetration (mm)		15.3	18.8	21.0	24.7
AVERAGE		15.3	18.8	21.0	24.7
Container No.		PIOE	A7	KF	PI82
Mass of wet soil + container (g)		58.20	61.27	68.12	66.84
Mass of dry soil + container (g)		43.80	45.44	50.70	47.38
Mass of container (g)		7.07	9.39	12.18	7.05
Mass of moisture (g)		14.4	15.83	17.42	19.46
Mass of dry soil (g)		36.73	36.05	38.52	40.33
Moisture content (%)		39.2	43.9	45.2	48.3
AVERAGE		39.2	43.9	45.2	48.3



Liquid limit (%)	44.2
Plastic limit (%)	25.3
Plasticity Index (%)	18.9
Linear shrinkage	
Trough No.	3
Trough length (cm)	14.0
Specimen length (cm)	12.7
L.shringage =	1.4
% L.shrinkage =	9.6

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

STUDENTS

STIRLING CIVIL ENGINEERING LTD
FEB 2025
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

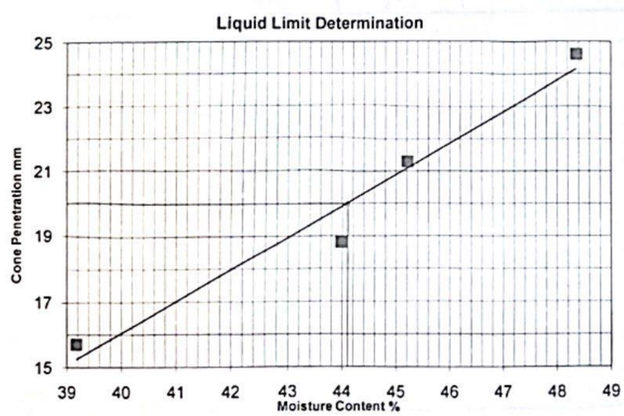
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT	Technician:	Lab Team
mix	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLA(	Sample Date	28-Dec-2024
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	29-Jan-2025
LAYER	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	VP	DT		Average
Mass of wet soil + container (g)		39.78	39.79		39.785
Mass of dry soil + container (g)		36.08	36.33		36.205
Mass of container (g)		21.52	22.76		22.14
Mass of moisture (g)		3.7	3.5		3.58
Mass of dry soil (g)		14.56	13.57		14.065
Moisture content %		25.4	25.5		25.5
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.7	18.8	21.3	24.6
penetration (mm)		15.7	18.8	21.3	24.6
AVERAGE		15.7	18.8	21.3	24.6
Container No.		A4	ME	PI32	6E
Mass of wet soil + container (g)		40.99	64.90	71.53	67.30
Mass of dry soil + container (g)		31.40	47.21	51.46	47.69
Mass of container (g)		6.92	6.99	7.07	7.14
Mass of moisture (g)		9.59	17.69	20.07	19.61
Mass of dry soil (g)		24.48	40.22	44.39	40.55
Moisture content (%)		39.2	44.0	45.2	48.4
AVERAGE		39.2	44.0	45.2	48.4



Liquid limit (%)	44.1
Plastic limit (%)	25.5
Plasticity Index (%)	18.6
Linear shrinkage	
Trough No.	3
Trough length (cm)	14.0
Specimen length (cm)	12.7
L.shringage =	1.4
% L.shrinkage =	9.6

Remarks

TESTING LAB	STUDENTS
Materials Engineer	
Lab Technician	

STIRLING CIVIL ENGINEERING
07 FEB 2025
P.O. BOX ..., KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION				
Test Reference No.	Depth. 0.5m		Date Sampled	Date Tested	Technician
Mix	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG		28-Dec-24	28-Jan-25	Lab team
SOURCE :	NSAMBWE BORROWPIT				
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG		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	5	457	100	1,000

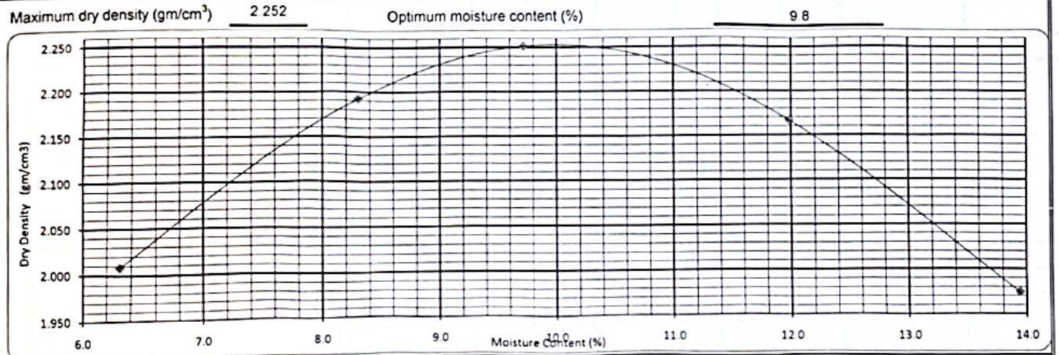
MOISTURE CONTENT DATA

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	6,408	6,647	6,743	6,699	6,522
Mass of Mould	gm	4,273	4,273	4,273	4,273	4,273
Mass of Compacted soil	gm	2135	2374	2470	2426	2249
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	2.135	2.374	2.470	2.426	2.249

DATA FOR PROCTOR CURVE

Container No.		UMT	2I	BKX	BA	HP
Mass of wet soil + Container	gm	2,536.0	2,755.0	2,688.0	2,527.0	1,727.0
Mass of dry soil + container	gm	2,433.0	2,605.0	2,521.0	2,339.0	1,534.0
Mass of container	gm	800.0	799.0	802.0	770.0	150.0
Mass of water added	gm	103	150	167	188	193
Mass of dry soil	gm	1633	1806	1719	1569	1384
Moisture content	%	6.3	8.3	9.7	12.0	13.9
Dry density	g/cm^3	2.008	2.192	2.251	2.166	1.974

Maximum dry density (gm/cm^3) 2.252 Optimum moisture content (%) 9.8



FOR TESTING LAB	STUDENTS	
Lab Technician		

STIRLING CIVIL ENGINEERING LTD
Materials Engineer
07 FEB 2025
P. O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28-Dec-24
mix:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	Casting date :	30-Jan-25
Source:	NSAMBWE BORROWPIT	Testing Date :	3-Feb-25
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	Technician :	Lab team
		Volume of Mould used (m^3)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	DAD		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	1509		MDD (Mg/m^3)	2.252
Tin + oven dry soil sample (g)	1482		N.M.C (%)	2.0
Tin (g)	119		OMC (%)	9.8
Dry soil sample	1363		Added OMC (%)	7.8
Water (g)	27		Calculated dry wt of soil (g)	5881.1
N.M.C (%)	2.0		Water added (g)	460
Average (%)	2.0		**Water added (mL)**	**460**

Number of blows		62																
Number of layer		5																
Water Content Determination		Before Soaking		After Soaking														
Tare No		HP2	-	YY	-													
Mass of wet sample + Tare	g	567	-	3060	-													
Mass of dry sample + Tare	g	527	-	2826	-													
Mass of Tare	g	59	-	780	-													
Mass of water	g	40	-	234	-													
Mass of dry sample	g	468	-	2046	-													
Water content	%	8.5	-	11.4	-													
Average water Content	%	8.5		11.4														
Density determination																		
Mould No		OK																
Mass of mould + soil	g	11812		11976														
Mass of mould	g	6127		6127														
Mass of soil	g	5685		5849														
Volume of the mould	cm3	2305		2305														
Moist density	g/cm3	2.466		2.538														
Dry density	g/cm3	2.272		2.277														
Swell Determination																		
Date		Hour		D.Gauge Reding														
Initial reading		96 hrs		9.15														
Final reading				9.39														
Height of the specimen				127														
Height of swell				0.24														
		Swelling(%)		**0.19**														

Observations

For the LTD		**For Students**	
Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P.O. BOX 708 KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date	28-Dec-24
mix:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	Penetration Date	3-Feb-25
Source:	NSAMBWE BORROWPIT	Technician :	: Lab team
Sample Description :	: **LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG**		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	OK		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.3120	0.3120	0.3120

Speed : ....mm/min.

Penetration of the plunger (mm)	Time (s)	Top Reading •10³mm	Top Force (KN)	Bottom Reading •10³mm	Bottom Force (KN)
0	0	0	0.0	0	0.0
0.25	12	1	0.3	3	0.9
0.5	24	2	0.6	4	1.2
0.75	35	4	1.2	6	1.9
1	47	5	1.6	8	2.5
1.5	71	9	2.8	11	3.4
2	94	14	4.4	15	4.7
2.5	118	19	5.9	20	6.2
3	142	25	7.8	27	8.4
3.5	165	30	9.4	33	10.3
4	189	35	10.9	40	12.5
4.5	213	41	12.8	46	14.4
5	236	43	13.4	53	16.5
5.5	260	48	15.0	58	18.1
6	283	54	16.8	60	18.7
6.5	307	59	18.4	63	19.7
7	331	64	20.0	65	20.3
7.5	354	68	21.2	68	21.2

Observations

For the Contractor		For Students	
Lab. Technician	*Materials Engineer*		

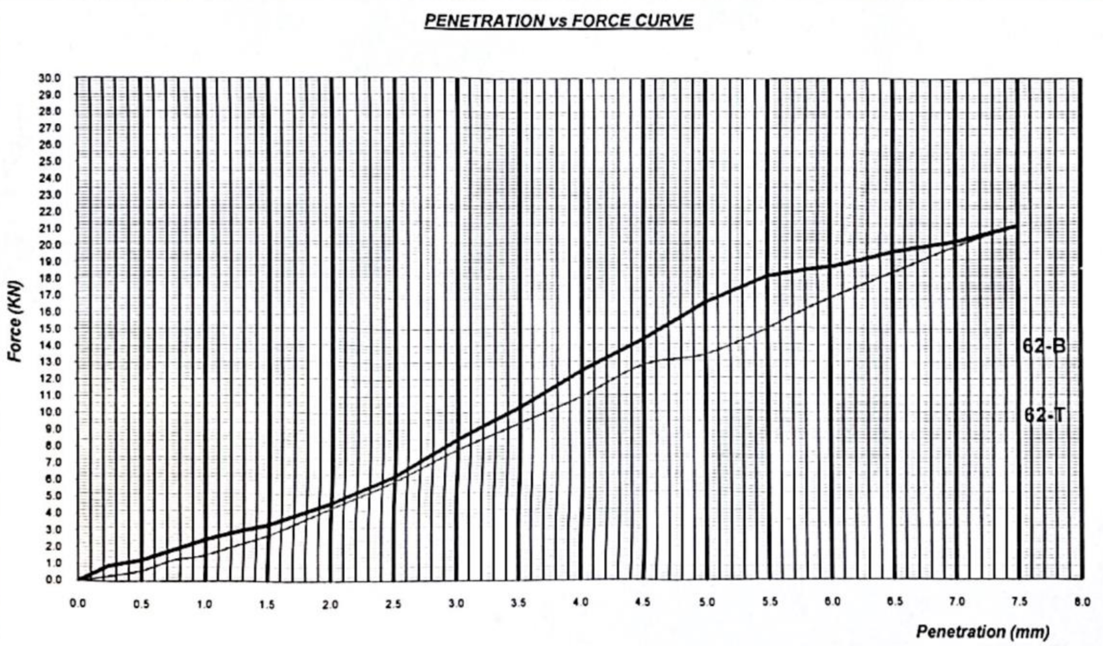
STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
P. O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth 0.5m	Sampling Date :	28-Dec-24
mix:	LATERATIC GRAVEL MODIFIED WITH 40% STE	Testing Date :	3-Feb-25
Source:	NSAMBWE BORROWPIT	Technician	: Lab team
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG		



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	6.2	5.9	47	45
5.0 mm Penetration	16.5	13.4	83	67
Average	11.4	9.7	65.0	56.0
Retained CBR	65.0			
Observations	CBR= 65.0			

		For Students
Lab. Technician	STIRLING CIVIL ENGINEERING LTD Materials Engineer 07 FEB 2025	

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

SUMMARY OF TEST RESULTS FOR LATERATE GRAVEL OF 40% STEEL SLAG & 5% QUARRY DUST

LOCATION: NSAMBWE BORROWPIT **Depth:** 0.5m

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	AVERAGE
NSAMBWE BORROW PIT	40% STEEL SLAG & 5% QUARRY DUST	28/12/2024	100	98	92	46	30	19	10	2.41	41.1	25.6	15.5	7.9	2.261	9.7	65	0.19	0.19
			100	98	91	46	30	19	10	2.41	41.1	25.6	15.5	7.9	-	-	- - -	-	
			100	98	91.5	46	30	19	10	2.41	41.1	25.6	15.5	7.9	2.261	9.7	65.4	0.19	0.19
	AVERAGE		100	98	92	46	30	19	10	2.410	41.1	25.6	15.5	7.9	2.261	9.7	65.4	0.19	0.19

FOR LAB

STIRLING CIVIL ENGINEERING LTD P.O. BOX 7... KAMPALA (U)

Lab Technician

Materials Engineer

STUDENTS

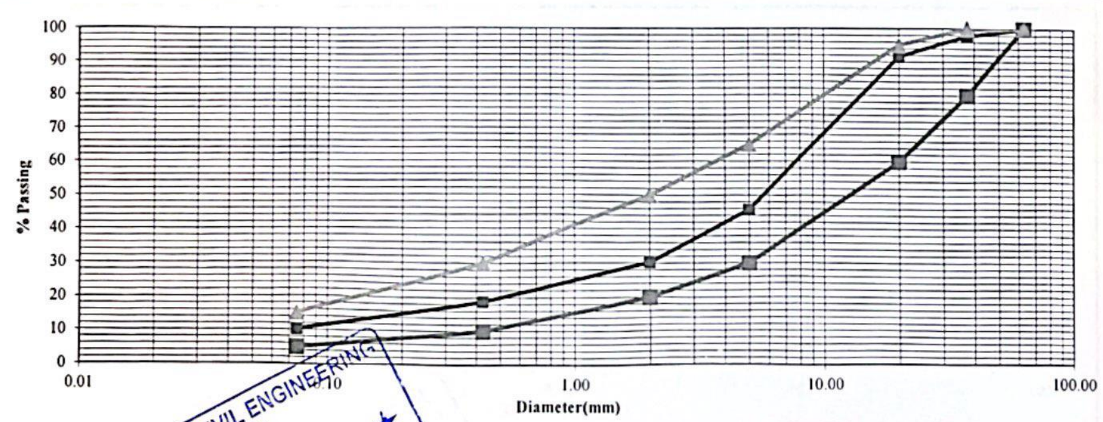
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	40% STEEL SLAG & 5% QUARRY DUST	Dry wt. of sample before washing: (g)		4021.3
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		3620.6
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 5% QUARRY DUST	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	17/Feb/2025	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	87.1	2.2	**98**	80	100
20.0	253.2	6.3	**92**	60	95
5.0	1842.7	45.8	**46**	30	65
2.00	627.6	15.6	**30**	20	50
0.425	453.1	11.3	**19**	10	30
0.075	345.3	8.6	**10**	5	15
Total fines	412.3	10.3			
Bottom Pan	11.6				
Extracted fines	400.7				
Total sample	4021.3				
Grading Modulus		**2.41**			



Testing Lab

STIRLING CIVIL ENGINEERING LTD
KAMPALA (U)

Lab Technician *Materials Engineer*

STUDENTS

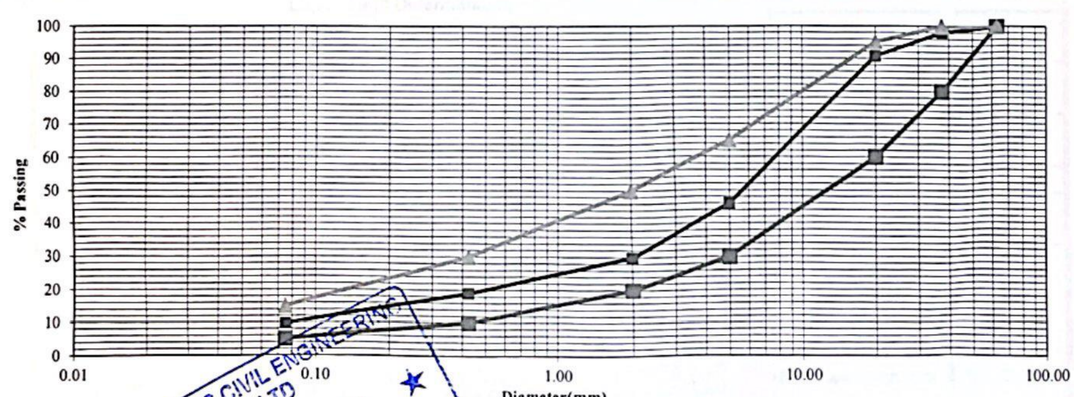
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	40% STEEL SLAG & 5% QUARRY DUST	Dry wt. of sample before washing: (g)		3808.1
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		3472.3
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 5% QUARRY DUST	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	17/Feb/2025	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	75.3	2.0	**98**	80	100
20.0	278.3	7.3	**91**	60	95
5.0	1702.1	44.7	**46**	30	65
2.00	615.4	16.2	**30**	20	50
0.425	413.3	10.9	**19**	10	30
0.075	355.4	9.3	**10**	5	15
Total fines	368.3	9.7			
Bottom Pan	32.5				
Extracted fines	335.8				
Total sample	3808.1				
Grading Modulus		**2.41**			



STIRLING CIVIL ENGINEERING LTD ... KAMPALA (U)

Testing Lab	STUDENTS
Lab Technician *Materials Engineer*	

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

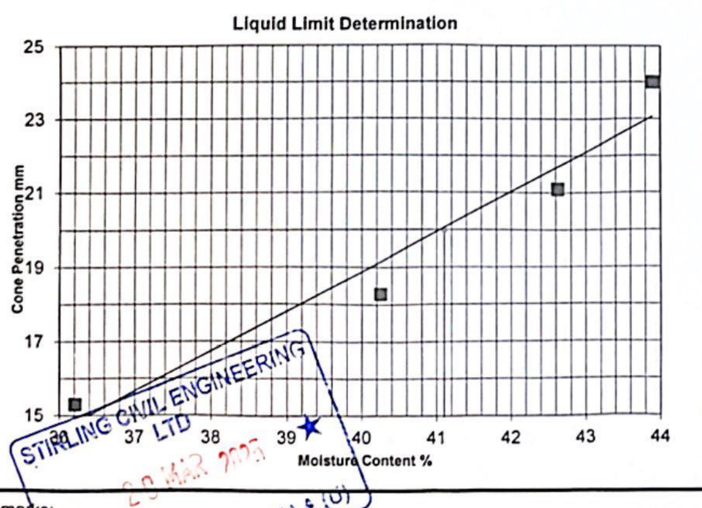
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT	Technician:	Lab Team
mix	LATERATIC GRAVEL WITH SS & QD	Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	17/Feb/2025
LAYER	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 5% QUARRY DUST		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	PNU	LL		Average
Mass of wet soil + container (g)		36.06	37.33		36.695
Mass of dry soil + container (g)		33.77	34.69		34.23
Mass of container (g)		24.84	24.36		24.6
Mass of moisture (g)		2.29	2.6		2.465
Mass of dry soil (g)		8.93	10.33		9.63
Moisture content %		25.6	25.6		25.6
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	21.1	24.0
penetration (mm)		15.3	18.3	21.1	24.0
AVERAGE		15.3	18.3	21.1	24.0
Container No.		PIOE	A7	KF	PI82
Mass of wet soil + container (g)		57.10	60.37	67.12	64.94
Mass of dry soil + container (g)		43.80	45.74	50.70	47.28
Mass of container (g)		7.07	9.39	12.18	7.05
Mass of moisture (g)		13.3	14.63	16.42	17.66
Mass of dry soil (g)		36.73	36.35	38.52	40.23
Moisture content (%)		36.2	40.2	42.6	43.9
AVERAGE		36.2	40.2	42.6	43.9



Liquid limit (%)	41.1
Plastic limit (%)	25.6
Plasticity Index (%)	15.5
Linear shrinkage	
Trough No.	3
Trough length (cm)	14.0
Specimen length (cm)	12.9
L.shringage =	1.1
% L.shrinkage =	7.9

Remarks:

TESTING LAB		STUDENTS
Materials Engineer		
Lab Technician		

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

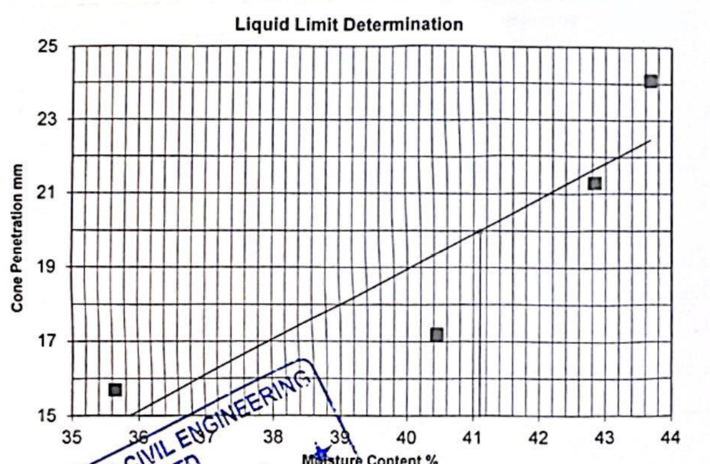
PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT		Technician:	Lab Team	
mix	LATERATIC GRAVEL WITH SS & QD		Sample Date	28/Dec/2024	
Test method	BS 1377: Part 2, 1990:4.3/4.4		Test Date	17/Feb/2025	
LAYER	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 5% QUARRY DUST				
Depth:	0.5m				
PLASTIC LIMIT	Test No.	VP	DT		Average
Mass of wet soil + container (g)		39.78	39.79		39.785
Mass of dry soil + container (g)		36.08	36.33		36.205
Mass of container (g)		21.52	22.76		22.14
Mass of moisture (g)		3.7	3.5		3.58
Mass of dry soil (g)		14.56	13.57		14.065
Moisture content %		25.4	25.5		25.5
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.7	17.2	21.3	24.1
penetration (mm)		15.7	17.2	21.3	24.1
AVERAGE		15.7	17.2	21.3	24.1
Container No.		A4	ME	PI32	6E
Mass of wet soil + container (g)		39.99	63.90	71.23	65.30
Mass of dry soil + container (g)		31.30	47.51	51.99	47.62
Mass of container (g)		6.92	6.99	7.07	7.14
Mass of moisture (g)		8.69	16.39	19.24	17.68
Mass of dry soil (g)		24.38	40.52	44.92	40.48
Moisture content (%)		35.6	40.4	42.8	43.7
AVERAGE		35.6	40.4	42.8	43.7



Liquid limit (%)	41.1
Plastic limit (%)	25.5
Plasticity Index (%)	15.6
Linear shrinkage	
Trough No.	3
Trough length (cm)	14.0
Specimen length (cm)	12.9
L.shringage =	1.1
% L.shrinkage =	7.9

Remarks:

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

TESTING LAB		STUDENTS
Materials Engineer		
Lab Technician		

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION					
Test Reference No.		Depth. 0.5m		Date Sampled	Date Tested	Technician
Mix	40% STEEL SLAG & 5% QARRY DUST			28/Dec/24	17/Feb/25	Lab team
SOURCE :	NSAMBWE BORROWPIT					
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 5% QARRY DUST			Natural moisture (%) :	2.0	

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	5	457	100	1,000

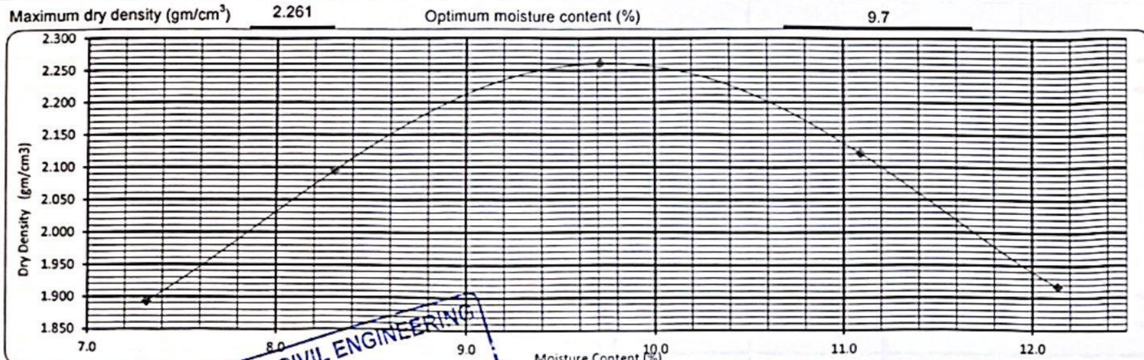
MOISTURE CONTENT DATA

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	6,304	6,542	6,753	6,629	6,422
Mass of Mould	gm	4,273	4,273	4,273	4,273	4,273
Mass of Compacted soil	gm	2031	2269	2480.3	2356	2149
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	2.031	2.269	2.480	2.356	2.149

DATA FOR PROCTOR CURVE

Container No.		UMT	2I	BKX	BA	HP
Mass of wet soil + Container	gm	2,531.0	2,755.0	2,688.0	2,513.0	1,730.0
Mass of dry soil + container	gm	2,413.0	2,605.0	2,521.0	2,339.0	1,559.0
Mass of container	gm	800.0	799.0	802.0	770.0	150.0
Mass of water added	gm	118.0	150	167	174	171
Mass of dry soil	gm	1613	1806	1719	1569	1409
Moisture content	%	7.3	8.3	9.7	11.1	12.1
Dry density	g/cm^3	1.893	2.095	2.261	2.121	1.916

Maximum dry density (gm/cm^3) 2.261 Optimum moisture content (%) 9.7



FOR TESTING LAB		STUDENTS
Lab Technician	Materials Engineer	

STIRLING CIVIL ENGINEERING LTD P. O. BOX 785, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	40% STEEL SLAG & 5% QUARRY DUST	Casting date :	20/Feb/25
Source:	NSAMBWE BORROWPIT	Testing Date :	24/Feb/25
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 5% QUARRY DUST	Technician :	: Lab team
		Volume of Mould used (m^3)	2305

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	WDE		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	2105		MDD (Mg/m^3)	2.261
Tin + oven dry soil sample (g)	2070		N.M.C (%)	2.2
Tin (g)	450		OMC (%)	9.7
Dry soil sample	1620		Added OMC (%)	7.5
Water (g)	35		Calculated dry wt of soil (g)	5870.4
N.M.C (%)	2.2		Water added (g)	**443**
Average (%)	2.2		**Water added (mL)**	**443**

Number of blows		62									
Number of layer		5									
Water Content Determination		Before Soaking		After Soaking							
Tare No		FER	-	RWE	-						
Mass of wet sample + Tare	g	1195	-	2805	-						
Mass of dry sample + Tare	g	1132	-	2600	-						
Mass of Tare	g	430	-	820	-						
Mass of water	g	63	-	205	-						
Mass of dry sample	g	702	-	1780	-						
Water content	%	9.0	-	11.5	-						
Average water Content	%	9.0		11.5							
Density determination											
Mould No		OK									
Mass of mould + soil	g	11820		11840							
Mass of mould	g	6160		6160							
Mass of soil	g	5660		5680							
Volume of the mould	cm3	2305		2305							
Moist density	g/cm3	2.456		2.464							
Dry density	g/cm3	2.253		2.210							
Swell Determination											
Date		Hour		D.Gauge Reding							
Initial reading		96 hrs		9.15							
Final reading				9.39							
Height of the specimen				127							
Height of swell				0.24							
		Swelling(%)		0.19							

Observations

For the Lab		For Students	
Lab. Technician	*Materials Engineer*		

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

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date	28/Dec/24
mix:	40% STEEL SLAG & 5% QUARRY DUST	Penetration Date	24/Feb/25
Source:	NSAMBWE BORROWPIT	Technician	: : Lab team
Sample Description :	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 5% QUARRY DUST		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	OK		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.3120	0.3120	0.3120

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	0.3	2	0.6								
0.5	24	2	0.6	4	1.2								
0.75	35	3	0.9	5	1.6								
1	47	7	2.2	9	2.8								
1.5	71	10	3.1	12	3.7								
2	94	13	4.1	15	4.7								
2.5	118	21	6.6	23	7.2								
3	142	26	8.1	30	9.4								
3.5	165	31	9.7	32	10.0								
4	189	35	10.9	41	12.8								
4.5	213	42	13.1	47	14.7								
5	236	45	14.0	49	15.3								
5.5	260	50	15.6	58	18.1								
6	283	51	15.9	60	18.7								
6.5	307	57	17.8	61	19.0								
7	331	63	19.7	64	[illegible]								
7.5	354	68	21.2	67	20.9								

Observations

For the Lab		For Students	
Lab. Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD ... 96, KAMPALA (U)

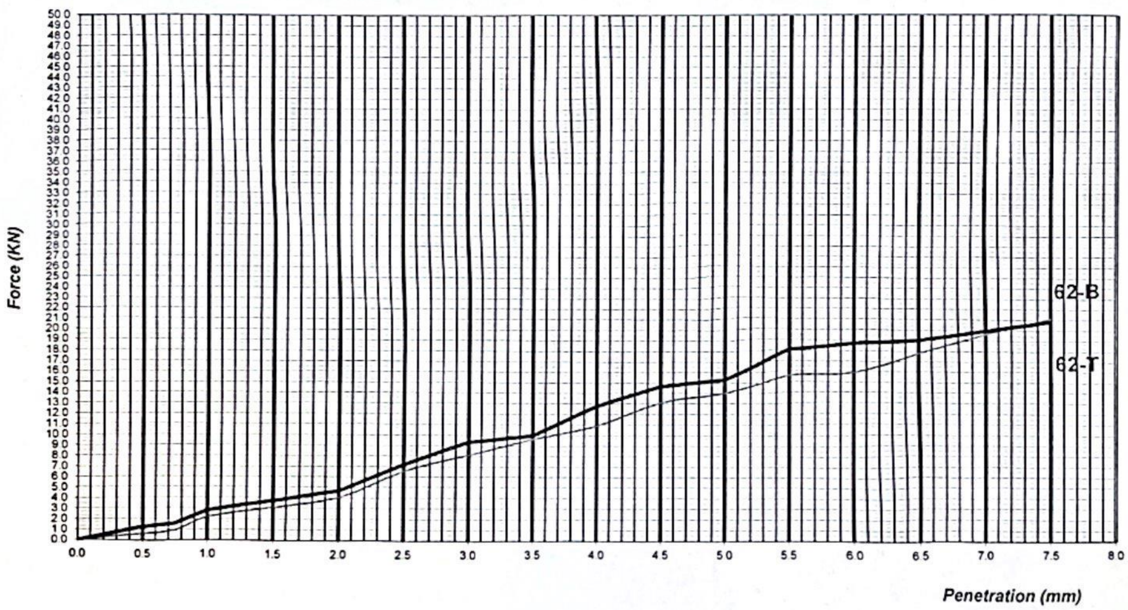
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	40% STEEL SLAG & 5% QUARRY DUST	Testing Date :	24/Feb/25
Source:	NSAMBWE BORROWPIT	Technician	: Lab team
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 5% QUARRY DUST		

PENETRATION vs FORCE CURVE



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	7.2	6.6	54	49
5.0 mm Penetration	15.3	14.0	77	70
Average	11.2	10.3		59.9
Retained CBR		65.4		
Observations	CBR= 65.4			

For the Lab		For Students	
Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD P.O. BOX 36, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

SUMMARY OF TEST RESULTS FOR LATERATE GRAVEL OF 40% STEEL SLAG & 10% QUARRY DUST

LOCATION: NSAMBWE BORROWPIT   **Depth:** 0.5m

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	AVERAGE
NSAMBWE BORROW PIT	40% STEEL SLAG & 10% QUARRY DUST	28/12/2024	100	99	91	46	28	23	11	2.38	37.7	25.6	12.1	6.2	2.273	9.4	66	0.18	0.18
			100	100	91	46	28	23	11	2.38	37.7	25.6	12.1	6.2	-	-	- - -	-	
			100	99.5	91	46	28	22.83	11	2.38	37.7	24.7	13.0	6.2	2.273	9.4	66.2	0.18	0.18
	AVERAGE		100	100	91	46	28	23	11	2.382	37.7	25.6	13.0	6.2	2.273	9.4	66.2	0.18	0.18

FOR LAB

Lab Technician

STIRLING CIVIL ENGINEERING LTD
20 MAR 2025
P. O. Box ... KAMPALA (U)
Materials Engineer

STUDENTS

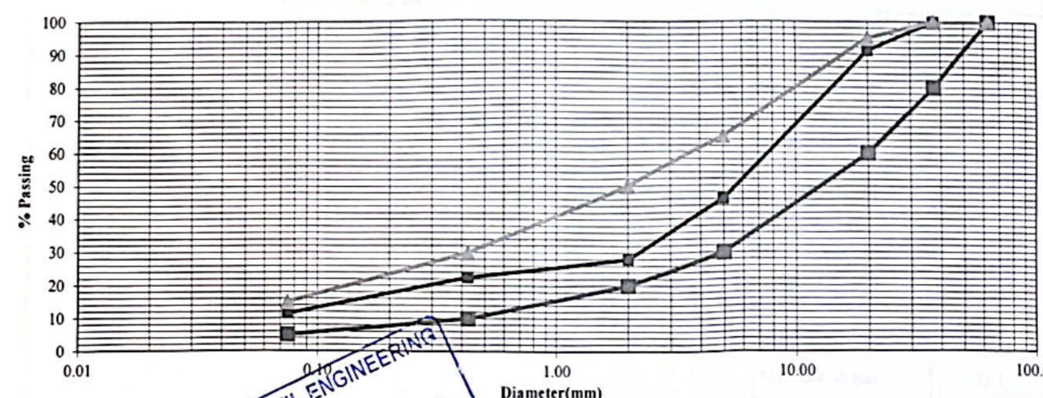
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	40% STEEL SLAG & 10% QARRY DUST	Dry wt. of sample before washing: (g)		4830.4
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		4280.7
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 10% QARRY DUST	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	17/Feb/2025	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	426.7	8.8	**91**	60	95
5.0	2173.4	45.0	**46**	30	65
2.00	877.4	18.2	**28**	20	50
0.425	265.4	5.5	**23**	10	30
0.075	533.4	11.0	**11**	5	15
Total fines	554.1	11.5			
Bottom Pan	4.4				
Extracted fines	549.7				
Total sample	4830.4				
Grading Modulus		2.38			



Testing Lab		STUDENTS	
Lab Technician	Materials Engineer		

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

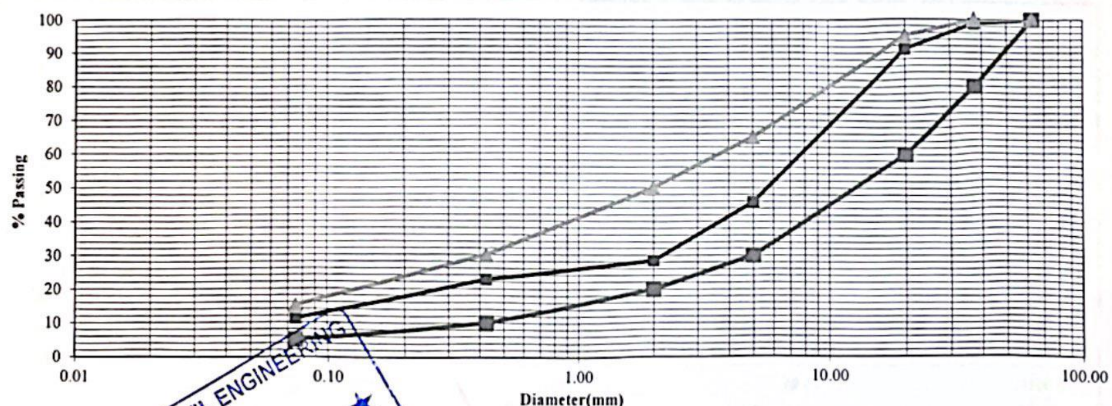
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	40% STEEL SLAG & 10% QARRY DUST	Dry wt. of sample before washing: (g)		5356.4
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		4760.7
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 10% QARRY DUST	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	17/Feb/2025	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	63.3	1.2	**99**	80	100
20.0	421.5	7.9	**91**	60	95
5.0	2419.2	45.2	**46**	30	65
2.00	929.5	17.4	**28**	20	50
0.425	307.1	5.7	**23**	10	30
0.075	613.9	11.5	**11**	5	15
Total fines	601.9	11.2			
Bottom Pan	6.2				
Extracted fines	595.7				
Total sample	5356.4				
Grading Modulus		**2.38**			



Testing Lab:	STUDENTS
Lab Technician / Materials Engineer	

STIRLING CIVIL ENGINEERING LTD
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INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	**ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION**

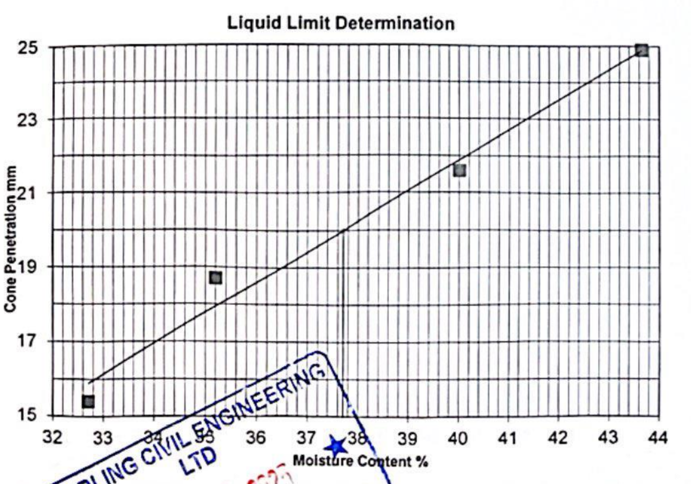
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT	Technician:	Lab Team
mix	LATERATIC GRAVEL WITH SS & 10% QD	Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	17/Feb/2025
LAYER	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 10% QUARRY DUST		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	I3	Q		Average
Mass of wet soil + container (g)		35.58	32.6		34.09
Mass of dry soil + container (g)		32.68	30.38		31.53
Mass of container (g)		21.36	21.69		21.525
Mass of moisture (g)		2.9	2.2		2.56
Mass of dry soil (g)		11.32	8.69		10.005
Moisture content %		25.6	25.5		25.6
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.4	18.7	21.6	24.9
penetration (mm)		15.4	18.7	21.6	24.9
AVERAGE		15.4	18.7	21.6	24.9
Container No.		PI56	BE	PI28	PI600
Mass of wet soil + container (g)		54.89	58.39	58.10	49.48
Mass of dry soil + container (g)		43.08	45.00	43.53	36.60
Mass of container (g)		6.97	6.96	7.11	7.09
Mass of moisture (g)		11.81	13.39	14.57	12.88
Mass of dry soil (g)		36.11	38.04	36.42	29.51
Moisture content (%)		32.7	35.2	40.0	43.6
AVERAGE		32.7	35.2	40.0	43.6



Liquid limit (%)	37.7
Plastic limit (%)	25.6
Plasticity Index (%)	12.1
Linear shrinkage	
Trough No.	4
Trough length (cm)	14.0
Specimen length (cm)	13.1
L.shringage =	0.9
% L.shrinkage =	6.2

Remarks:

TESTING LAB Materials Engineer: Lab Technician		STUDENTS

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	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

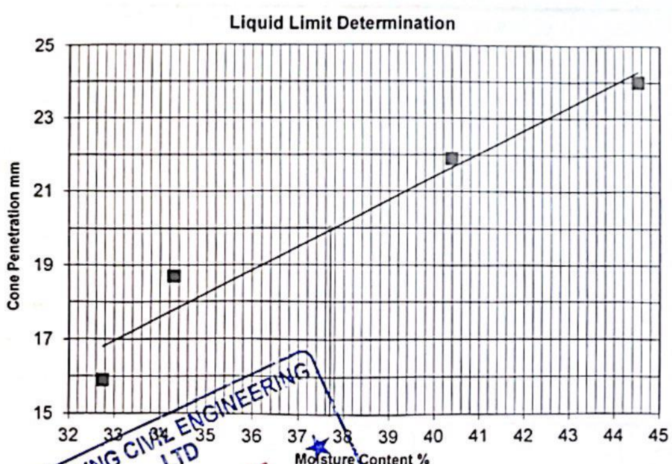
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT	Technician:	Lab Team
mix	LATERATIC GRAVEL WITH SS & 10% QD	Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	17/Feb/2025
LAYER	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 10% QUARRY DUST		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	RAD	4L		Average
Mass of wet soil + container (g)		43.07	31.75		37.41
Mass of dry soil + container (g)		38.87	29.89		34.38
Mass of container (g)		21.97	22.33		22.15
Mass of moisture (g)		4.2	1.9		3.03
Mass of dry soil (g)		16.9	7.56		12.23
Moisture content %		24.9	24.6		24.7
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.9	18.7	21.9	24.0
penetration (mm)		15.9	18.7	21.9	24.0
AVERAGE		15.9	18.7	21.9	24.0
Container No.		4B	MB	PIMO	PI52
Mass of wet soil + container (g)		52.18	60.71	50.95	58.09
Mass of dry soil + container (g)		41.10	47.04	38.35	42.40
Mass of container (g)		7.26	7.17	7.15	7.16
Mass of moisture (g)		11.08	13.67	12.6	15.69
Mass of dry soil (g)		33.84	39.87	31.2	35.24
Moisture content (%)		32.7	34.3	40.4	44.5
AVERAGE		32.7	34.3	40.4	44.5



Liquid limit (%)	37.7
Plastic limit (%)	24.7
Plasticity Index (%)	13.0
Linear shrinkage	
Trough No.	4
Trough length (cm)	14.0
Specimen length (cm)	13.1
L.shringage =	0.9
% L.shrinkage =	6.2

Remarks:

TESTING LAB		STUDENTS
Materials Engineer:		
Lab Technician		

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

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	**Stirling**

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

Test Reference No.	Depth. 0.5m	Date Sampled	Date Tested	Technician
Mix	40% STEEL SLAG & 10% QUARRY DUST	28/Dec/24	17/Feb/25	Lab team
SOURCE :	NSAMBWE BORROWPIT			
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 10% QUARRY DUST	Natural moisture (%) :	2.0	

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	5	457	100	1,000

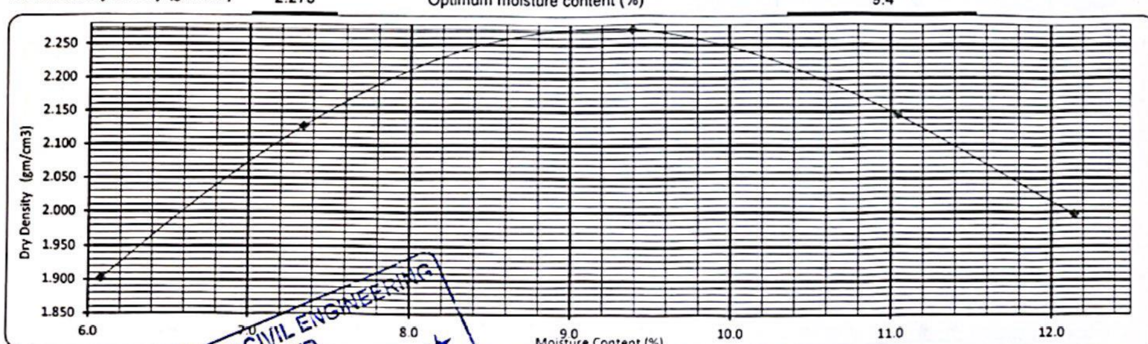
MOISTURE CONTENT DATA

Test No.		1	2	3	4	5
Tin No.		A	A	A	A	A
Water Added	cm^3	140	200	260	320	380
Mass of Compacted soil + mould	gm	6,291	6,557	6,759	6,654	6,511
Mass of Mould	gm	4,273	4,273	4,273	4,273	4,273
Mass of Compacted soil	gm	2018	2284	2486	2381	2238
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	2.018	2.284	2.486	2.381	2.238

DATA FOR PROCTOR CURVE

Container No.		MJR	BAR	EVE	RWE	KAU
Mass of wet soil + Container	gm	2,849.0	2,792.0	2,440.0	2,475.0	3,253.0
Mass of dry soil + container	gm	2,731.0	2,656.0	2,296.0	2,310.0	2,987.0
Mass of container	gm	790.0	803.0	763.0	816.0	797.0
Mass of water added	gm	118	136	144	165	266
Mass of dry soil	gm	1941	1853	1533	1494	2190
Moisture content	%	6.1	7.3	9.4	11.0	12.1
Dry density	g/cm^3	1.902	2.128	2.273	2.144	1.996

Maximum dry density (gm/cm^3) 2.273 Optimum moisture content (%) 9.4



FOR TESTING LAB			STUDENTS
Lab Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD
20 MAR 2025
P.O. BOX

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	40% STEEL SLAG & 10% QUARRY DUST	Casting date :	20/Feb/25
Source:	NSAMBWE BORROWPIT	Testing Date :	24/Feb/25
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 10% QUARRY DUST	Technician :	: Lab team
		Volume of Mould used (m^3)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	DAQ		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	1987		MDD (Mg/m^3)	2.273
Tin + oven dry soil sample (g)	1956		N.M.C (%)	2.0
Tin (g)	410		OMC (%)	9.4
Dry soil sample	1546		Added OMC (%)	7.4
Water (g)	31		Calculated dry wt of soil (g)	5879.7
N.M.C (%)	2.0		Water added (g)	435
Average (%)	2.0		**Water added (mL)**	**435**

Number of blows		62											
Number of layer		5											
Water Content Determination		Before Soaking		After Soaking									
Tare No		YEW	-	WWS	-								
Mass of wet sample + Tare	g	1210	-	2625	-								
Mass of dry sample + Tare	g	1148	-	2625	-								
Mass of Tare	g	435	-	825	-								
Mass of water	g	62	-	205	-								
Mass of dry sample	g	713	-	1800	-								
Water content	%	8.7	-	11.4	-								
Average water Content	%	8.7		11.4									
Density determination													
Mould No		OK											
Mass of mould + soil	g	11850		11900									
Mass of mould	g	6160		6160									
Mass of soil	g	5690		5740									
Volume of the mould	cm3	2305		2305									
Moist density	g/cm3	2.469		2.490									
Dry density	g/cm3	2.271		2.236									
Swell Determination													
Date		Hour		D.Gauge Reding									
Initial reading		96 hrs		9.13									
Final reading				9.36									
Height of the specimen				127									
Height of swell				0.23									
		Swelling(%)		0.18									
Observations													

For the Lab		**For Students**	
Lab Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD P.O. BOX 766, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	**Stirling**

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date	28/Dec/24
mix:	40% STEEL SLAG & 10% QUARRY DUST	Penetration Date	24/Feb/25
Source:	NSAMBWE BORROWPIT	Technician	: : Lab team
Sample Description :	: LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 10% QUARRY DUST		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	OK		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.3120	0.3120	0.3120

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**	1	0.3	3	0.9								
0.5	**24**	2	0.6	4	1.2								
0.75	**35**	4	1.2	6	1.9								
1	**47**	5	1.6	8	2.5								
1.5	**71**	9	2.8	11	3.4								
2	**94**	14	4.4	17	5.3								
2.5	**118**	20	6.2	23	7.2								
3	**142**	25	7.8	27	8.4								
3.5	**165**	30	9.4	33	10.3								
4	**189**	35	10.9	40	12.5								
4.5	**213**	41	12.8	46	14.4								
5	**236**	47	14.7	50	15.6								
5.5	**260**	48	15.0	58	18.1								
6	**283**	54	16.8	60	18.7								
6.5	**307**	59	18.4	63	19.7								
7	**331**	64	20.0	65	20.3								
7.5	**354**	68	21.2	68	21.2								

Observations

For the Lab		For Students	
Lab. Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD
20 MAR 2025
P.O. BOX ... KAMPALA (U)

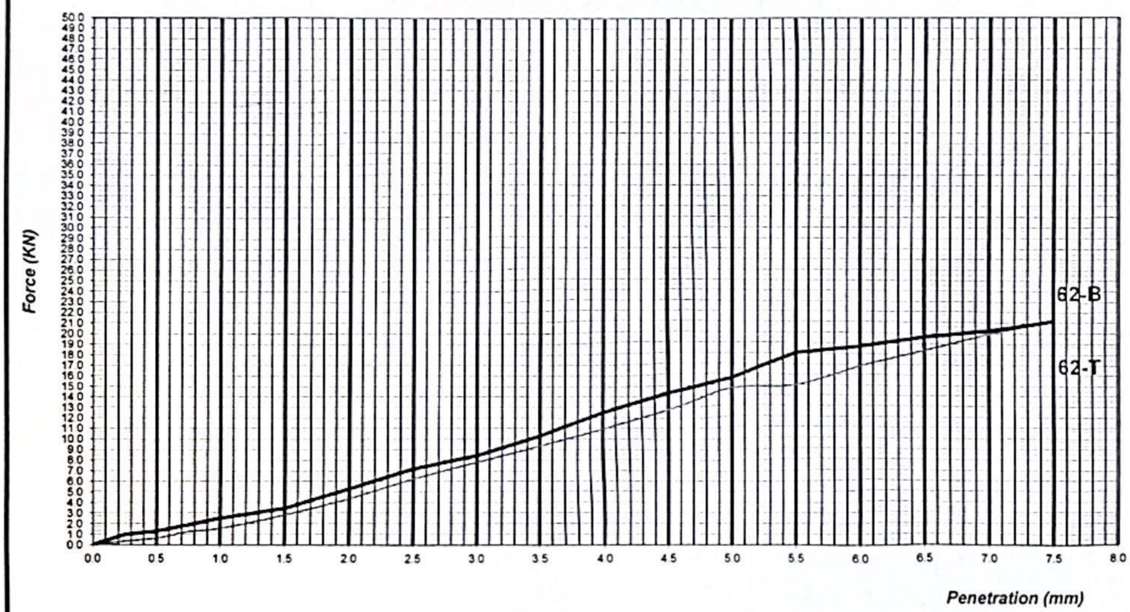
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	40% STEEL SLAG & 10% QUARRY DUST	Testing Date :	24/Feb/25
Source:	NSAMBWE BORROWPIT	Technician	: Lab team
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 10% QUARRY DUST		

PENETRATION vs FORCE CURVE



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	7.2	6.2	[illegible]	47
5.0 mm Penetration	15.6	14.7	78	73
Average	11.4	10.5	66.2	60.3
Retained CBR	66.2			

Observations CBR = 66.2

For the Lab		For Students	
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	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

SUMMARY OF TEST RESULTS FOR LATERATE GRAVEL OF 40% STEEL SLAG & 15% QUARRY DUST

LOCATION: NSAMBWE BORROWPIT **Depth:** 0.5m

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	AVERAGE
NSAMBWE BORROW PIT	40% STEEL SLAG & 15% QUARRY DUST	28/12/2024	100	100	91	46	28	23	13	2.36	34.9	23.6	11.3	5.7	2.285	9.2	67	0.15	0.15
			100	99	91	46	28	23	12	2.37	34.9	23.6	11.3	5.7	-	-	- - -	-	
			100	99.5	91	46	28	22.83	12.5	2.37	34.9	23.6	11.3	5.7	2.285	9.2	67.3	0.15	0.15
	AVERAGE		100	100	91	46	28	23	13	2.367	34.9	23.6	11.3	5.7	2.285	9.2	67.3	0.15	0.15

FOR LAB

Lab Technician

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

STUDENTS

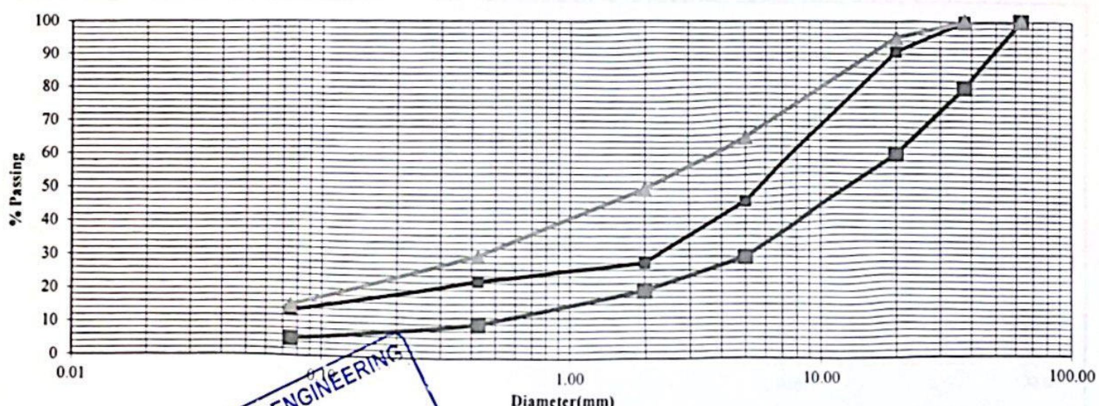
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	40% STEEL SLAG & 15% QARRY DUST	Dry wt. of sample before washing: (g)		5394.2
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		4677.2
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 15% QARRY DUST	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	17/Feb/2025	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	498.2	9.2	91	60	95
5.0	2387.7	44.3	46	30	65
2.00	988.9	18.3	28	20	50
0.425	303.2	5.6	23	10	30
0.075	490.7	9.1	13	5	15
Total fines	725.5	13.4			
Bottom Pan	8.5				
Extracted fines	717.0				
Total sample	5394.2				
Grading Modulus		2.36			



Testing Lab

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

Lab Technician *Materials Engineer*

STUDENTS

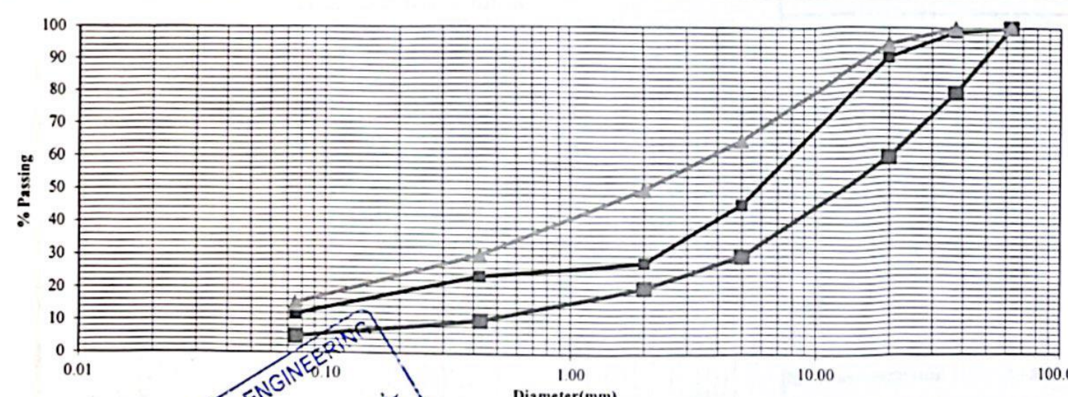
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	40% STEEL SLAG & 15% QARRY DUST	Dry wt. of sample before washing: (g)		5025.2
Depth: (m)	0.5m	Dry wt. of sample after washing: (g)		4453.0
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 15% QARRY DUST	Date Sampled:	Date Tested:	Technician
		28/Dec/2024	17/Feb/2025	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	63.0	1.3	**99**	80	100
20.0	392.9	7.8	**91**	60	95
5.0	2282.7	45.4	**46**	30	65
2.00	892.7	17.8	**28**	20	50
0.425	214.9	4.3	**23**	10	30
0.075	589.3	11.7	**12**	5	15
Total fines	589.7	11.7			
Bottom Pan	17.5				
Extracted fines	572.2				
Total sample	5025.2				
Grading Modulus		**2.37**			



Testing Lab | STUDENTS

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

Lab Technician | *Materials Engineer*

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	**ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION**

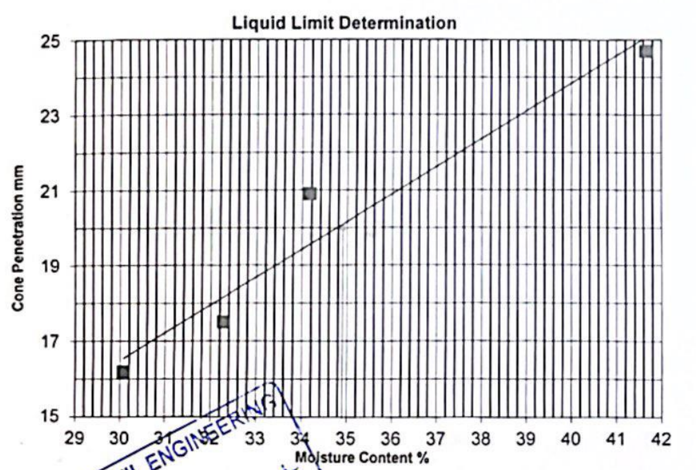
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROW PIT	Technician:	Lab Team
mix	LATERATIC GRAVEL WITH SS & 15% QD	Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	17/Feb/2025
LAYER	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 15% QUARRY DUST		
Depth:	0.5m		

PLASTIC LIMIT	Test No.	OO	JL		Average
Mass of wet soil + container (g)		36.6	37.1		36.85
Mass of dry soil + container (g)		33.73	34.35		34.04
Mass of container (g)		21.64	22.58		22.11
Mass of moisture (g)		2.87	2.8		2.81
Mass of dry soil (g)		12.09	11.77		11.93
Moisture content %		23.7	23.4		23.6
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		16.2	17.5	20.9	24.7
penetration (mm)		16.2	17.5	20.9	24.7
AVERAGE		16.2	17.5	20.9	24.7
Container No.		A	PI7	PI38	A15
Mass of wet soil + container (g)		46.06	40.57	39.90	39.75
Mass of dry soil + container (g)		37.08	32.35	31.56	30.14
Mass of container (g)		7.22	6.89	7.15	7.07
Mass of moisture (g)		8.98	8.22	8.34	9.61
Mass of dry soil (g)		29.86	25.46	24.41	23.07
Moisture content (%)		30.1	32.3	34.2	41.7
AVERAGE		30.1	32.3	34.2	41.7



Liquid limit (%)	34.9
Plastic limit (%)	23.6
Plasticity Index (%)	11.3
Linear shrinkage	
Trough No.	Y
Trough length (cm)	14.0
Specimen length (cm)	13.2
L.shringage =	0.8
% L.shrinkage =	5.7

Remarks:

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

TESTING LAB		STUDENTS
Materials Engineer		
Lab Technician		

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

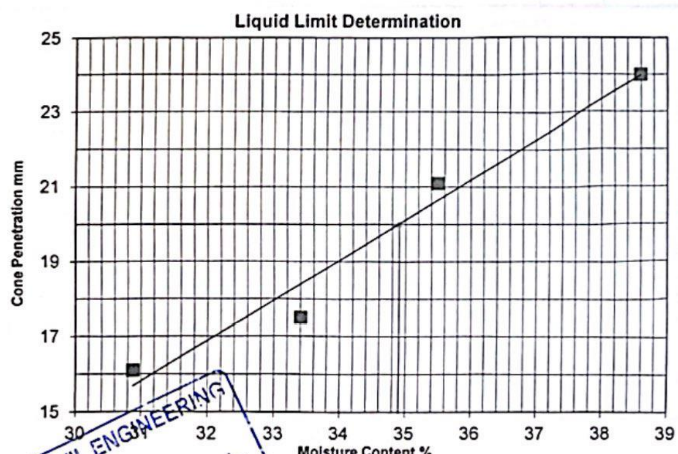
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROW PIT		Technician:	Lab Team
mix	LATERATIC GRAVEL WITH SS & 15% QD		Sample Date	28/Dec/2024
Test method	BS 1377: Part 2, 1990:4.3/4.4		Test Date	17/Feb/2025
LAYER	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 15% QUARRY DUST			
Depth:	0.5m			

PLASTIC LIMIT	Test No.	3	I4		Average
Mass of wet soil + container (g)		71.1	70.5		70.8
Mass of dry soil + container (g)		68.82	68.46		68.64
Mass of container (g)		59.24	59.77		59.505
Mass of moisture (g)		2.28	2.0		2.16
Mass of dry soil (g)		9.58	8.69		9.135
Moisture content %		23.8	23.5		23.6
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		16.1	17.5	21.1	24.0
penetration (mm)		16.1	17.5	21.1	24.0
AVERAGE		16.1	17.5	21.1	24.0
Container No.		PI43	PI66	PII2	PI26
Mass of wet soil + container (g)		44.87	57.05	43.58	41.10
Mass of dry soil + container (g)		35.95	44.53	33.98	31.61
Mass of container (g)		7.06	7.05	6.93	7.02
Mass of moisture (g)		8.92	12.52	9.6	9.49
Mass of dry soil (g)		28.89	37.48	27.05	24.59
Moisture content (%)		30.9	33.4	35.5	38.6
AVERAGE		30.9	33.4	35.5	38.6



Liquid limit (%)	34.9
Plastic limit (%)	23.6
Plasticity Index (%)	11.3
Linear shrinkage	
Trough No.	Y
Trough length (cm)	14.0
Specimen length (cm)	13.2
L.shringage =	0.8
% L.shrinkage =	5.7

Remarks:

TESTING LAB		STUDENTS
Materials Engineer		
Lab Technician		

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

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

PROJECT: ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

Test Reference No.	Depth. 0.5m	Date Sampled	Date Tested	Technician
Mix	40% STEEL SLAG & 15% QUARRY DUST	28/Dec/24	17/Feb/25	Lab team
SOURCE :	NSAMBWE BORROWPIT			
Material description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 15% QUARRY DUST	Natural moisture (%) :	2.0	

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	5	457	100	1,000

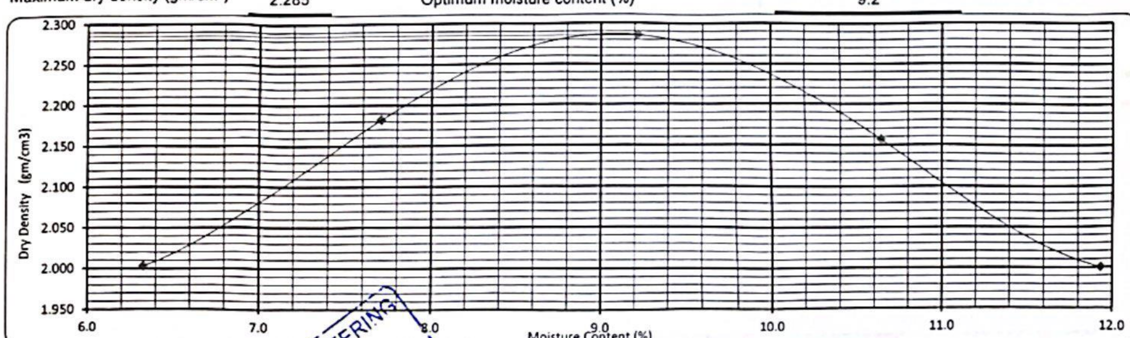
MOISTURE CONTENT DATA

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	6,403	6,623	6,769	6,659	6,512
Mass of Mould	gm	4,273	4,273	4,273	4,273	4,273
Mass of Compacted soil	gm	2130	2350	2496	2386	2239
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	2.130	2.350	2.496	2.386	2.239

DATA FOR PROCTOR CURVE

Container No.		UMT	2I	BKX	BA	HP
Mass of wet soil + Container	gm	2,532.0	2,755.0	2,684.0	2,527.0	1,720.0
Mass of dry soil + container	gm	2,429.0	2,615.0	2,526.0	2,359.0	1,554.0
Mass of container	gm	801.1	798.3	812.0	780.0	163.0
Mass of water added	gm	103	140	158	168	166
Mass of dry soil	gm	1627.9	1816.7	1714	1579	1391
Moisture content	%	6.3	7.7	9.2	10.6	11.9
Dry density	g/cm^3	2.003	2.182	2.285	2.157	2.000

Maximum dry density (gm/cm^3) 2.285 Optimum moisture content (%) 9.2



FOR TESTING LAB		STUDENTS	
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	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	40% STEEL SLAG & 15% QUARRY DUST	Casting date :	20/Feb/25
Source:	NSAMBWE BORROWPIT	Testing Date :	24/Feb/25
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 15% QUARRY DUST	Technician :	: Lab team
		Volume of Mould used (m^3)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	PSX		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	2200		MDD (Mg/m^3)	2.285
Tin + oven dry soil sample (g)	2162		N.M.C (%)	2.2
Tin (g)	460		OMC (%)	9.2
Dry soil sample	1702		Added OMC (%)	7.0
Water (g)	38		Calculated dry wt of soil (g)	5866.0
N.M.C (%)	2.2		Water added (g)	**409**
Average (%)	2.2		**Water added (mL)**	**409**

Number of blows		**62**										
Number of layer		5										
Water Content Determination		Before Soaking		After Soaking								
Tare No		HP2	-	YY	-							
Mass of wet sample + Tare	g	1230	-	2850	-							
Mass of dry sample + Tare	g	1170	-	2650	-							
Mass of Tare	g	440	-	830	-							
Mass of water	g	60	-	200	-							
Mass of dry sample	g	730	-	1820	-							
Water content	%	8.2	-	11.0	-							
Average water Content	%	8.2		11.0								
Density determination												
Mould No		OK										
Mass of mould + soil	g	11715		11950								
Mass of mould	g	6133		6133								
Mass of soil	g	5582		5817								
Volume of the mould	cm3	2305		2305								
Moist density	g/cm3	2.422		2.524								
Dry density	g/cm3	2.238		2.274								
Swell Determination												
Date		Hour		D.Gauge Reding								
Initial reading		96 hrs		8.75								
Final reading				8.94								
Height of the specimen				127								
Height of swell				0.19								
		Swelling(%)		0.15								
Observations												

For the Lab		For Students	
Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD 20 MAR 2025 P.O. BOX ... KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date	28/Dec/24
mix:	40% STEEL SLAG & 15% QUARRY DUST	Penetration Date	24/Feb/25
Source:	NSAMBWE BORROWPIT	Technician	: : Lab team
Sample Description :	: LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 15% QUARRY DUST		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	OK		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.3120	0.3120	0.3120

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**	1	0.3	3	0.9
0.5	**24**	2	0.6	4	1.2
0.75	**35**	4	1.2	6	1.9
1	**47**	5	1.6	8	2.5
1.5	**71**	9	2.8	11	3.4
2	**94**	14	4.4	15	4.7
2.5	**118**	20	6.2	22	6.9
3	**142**	25	7.8	27	8.4
3.5	**165**	30	9.4	33	10.3
4	**189**	35	10.9	40	12.5
4.5	**213**	41	12.8	46	14.4
5	**236**	47	14.7	53	16.5
5.5	**260**	48	15.0	58	18.1
6	**283**	54	16.8	60	18.7
6.5	**307**	59	18.4	63	19.7
7	**331**	64	20.0	65	20.3
7.5	**354**		21.2	68	21.2

Observations

For the Lab		For Students	
Lab. Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD
20 MAR 2025
P.O. BOX 36, KAMPALA (U)

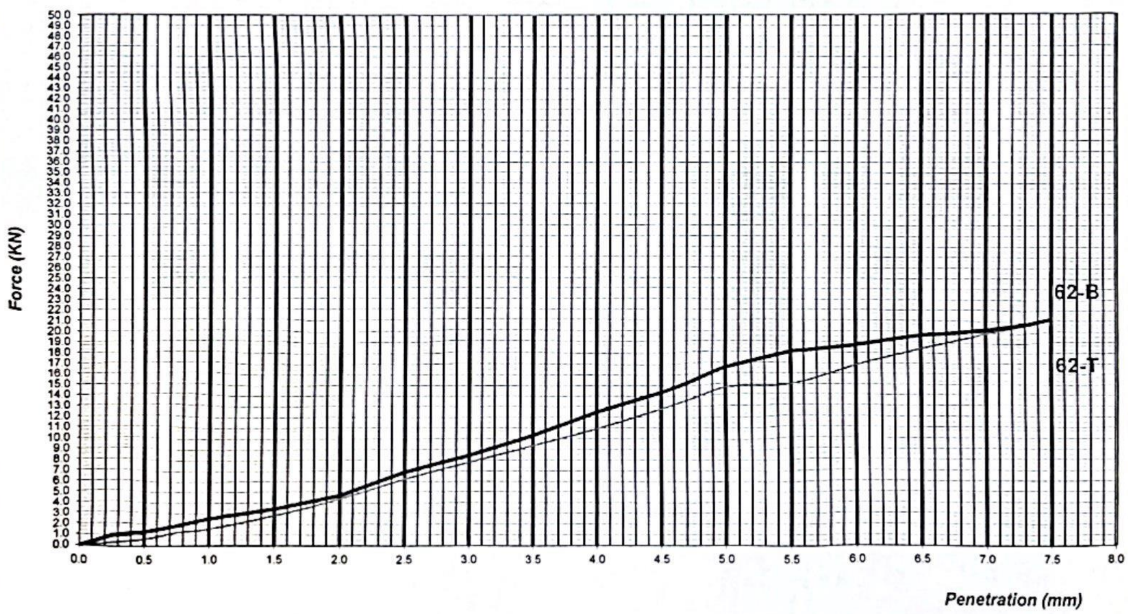
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Depth. 0.5m	Sampling Date :	28/Dec/24
mix:	40% STEEL SLAG & 15% QUARRY DUST	Testing Date :	24/Feb/25
Source:	NSAMBWE BORROWPIT	Technician	: Lab team
Sample Description:	LATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG & 15% QUARRY DUST		

PENETRATION vs FORCE CURVE



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	6.9	6.2	52	47
5.0 mm Penetration	16.5	14.7	83	73
Average	11.7	10.5	67.3	60.3
Retained CBR	67.3			
Observations	CBR= 67.3			

STIRLING CIVIL ENGINEERING LTD, KAMPALA (U) 20 MAR 2025

For the Lab		For Students	
Lab. Technician	*Materials Engineer*		

ANNEX

Table 5.1. AASHTO Classification System

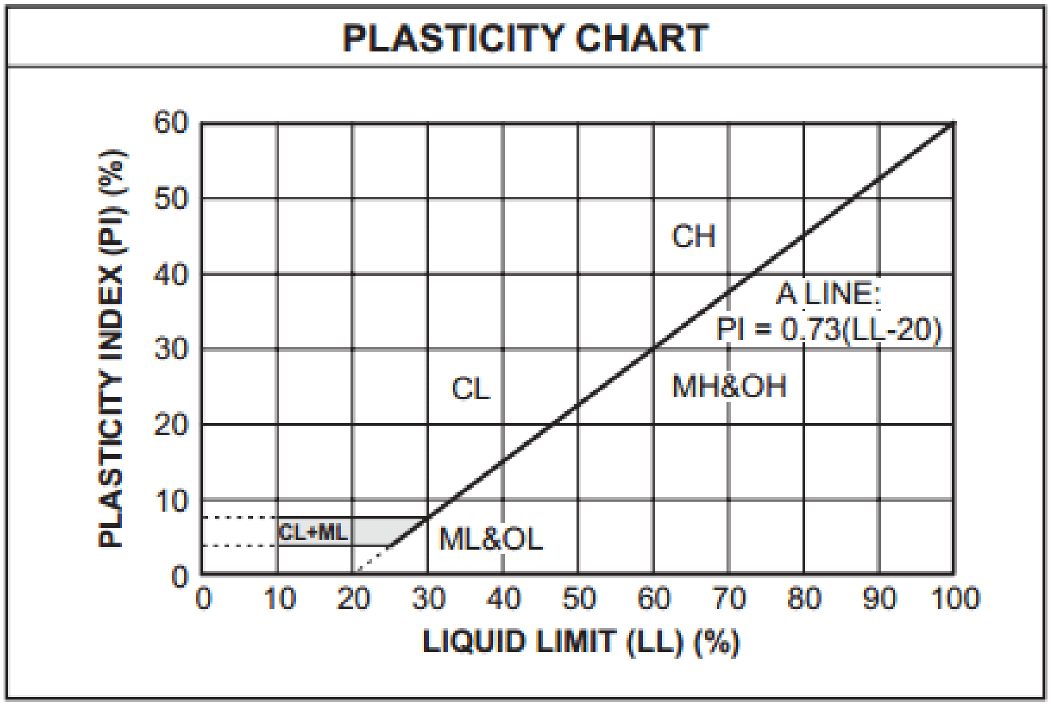
General Classification	Granular materials (35% or less passing No. 200 Sieve (0.075 mm))							Silt-clay Materials More than 35% passing No. 200 Sieve (0.075 mm)			
Group Classification	A—1		A—3	A—2				A—4	A—5	A—6	A—7
	A—1—a	A—1—b		A—2—4	A—2—5	A—2—6	A—2—7				A—7—5 A—7—6
(a) Sieve Analysis: Percent Passing											
(i) 2.00 mm (No. 10)	50 max										
(ii) 0.425 mm (No. 40)	30 max	50 max	51 min								
(iii) 0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
(b) Characteristics of fraction passing 0.425 mm (No. 40)											
(i) Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
(ii) Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
(c) Usual types of significant Constituent materials	Stone Fragments Gravel and sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
(d) General rating as subgrade.	Excellent to Good							Fair to Poor			

* If plasticity index is equal to or less than (liquid Limit—30), the soil is A—7—5 (i.e. PL > 30%)
If plasticity index is greater than (Liquid Limit—30), the soil is A—7—6 (i.e. PL < 30%)

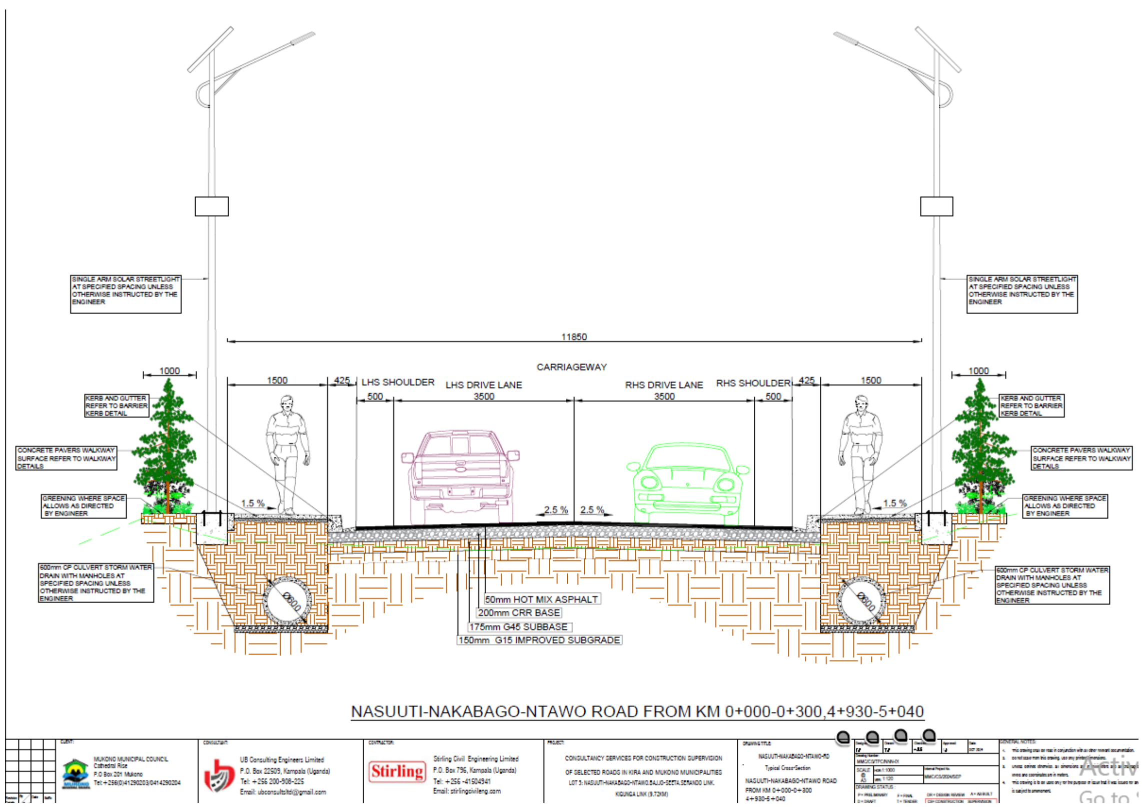
Annex 1: AASHTO Classification Chart

Major Division			Symbol	Brief description of soil types	Laboratory test results
Coarse grained soils, more than 50% material larger than No. 200 sieve size (0.074 mm)	Gravel, "G" more than half of coarse fraction larger than 4.76 mm sieve	Clean gravel with little or no fines* (less than 5%)	GW	Well graded gravels and gravels sand mixtures	Uniformity coefficient- $Cu = D_{60}/D_{10} > 6$ Gradation coefficient, $Cg = D^2_{30}/D_{60}\ D_{10} = 1$ to 3
			GP	Poorly graded gravels and gravel -sand mixtures	Not meeting the Cu and Cg requirement of GW
		Gravel with appreciable proportion of fines* (more than 12%)	GM	Silty gravel and gravel sand mixtures	
			GC	Clayey gravels and gravel-sand-silt mixtures	
	Sands, "S" more than half of coarse fraction smaller than 4.76 mm	Clean sand with little or no fines* (Less than 5%)	SW	Well graded sand and gravelly sands	Cu < 4 Cg = 1 to 3
			SP	Poorly graded sands and gravelly sand	Not meeting the Cu and Cg requirements of SW
		Sands with appreciable proportion of fines* (more than 12%)	SM	Silty sand and sand-silt mixtures	
			SC	Clayey sand and sand clay mixtures	
Fine grained soils, more than 50% materials smaller than No. 200 sieve size (0.074 mm)	Silts and clays with liquid limit less than 50 – "L"		ML	Inorganic silts, very fine rock floor, clayey silt or fine sand	Classification by plasticity chart (Fig. 6.2)
			CL	Inorganic clays, gravelly sandy or silty	
			OL	Organic silt and silty clays	
	Silts and clays with liquid limit greater than 50 – "H"		MH	Inorganic silt elastic and Micaceous silts	
			CH	Inorganic fat clays	*Fines are those materials smaller than No. 200 sieve size or 0.074mm size
			OH	Organic silt and clays	
Highly organic soils			Pt	Peat and other highly organic soils	

Annex 2: USCS Classification chart



Annex 3: USCS Plasticity Chart



Annex 4: Original Pavement structure of Nasuuti-Nakabago-Ntawo road