ASSESSING THE STABILIZATION OF LATERITE SOILS USING STEEL SLAG AND QUARRY DUST FOR ROAD SUBBASE

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S21B32/097

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

April, 2025

UGANDA CHRISTIAN UNIVERSITY

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ABSTRACT

Lateritic soils are often weak and unsuitable for road construction without stabilisation. This study assesses the suitability of stabilising lateritic soil using steel slag and quarry dust, focusing on the Nasuuti-Nakabago-Ntawo road, where soil from the Nsambwe borrow pit had a CBR of 24.7 %, below the required 45 % for a G45 granular subbase material. Proctor test, CBR, Atterberg limits, and particle size distribution, were performed on varying percentages of laterite, steel slag, and quarry dust. The results showed that 40 % steel slag addition increased the CBR by 160 % and reduced CBR swell by 70 %, improving load-bearing capacity. 10 % quarry dust with 40 % steel slag effectively reduced the plasticity index by 27 %, liquid limit by 13 %, and linear shrinkage by 33 %, enhancing workability and durability. These findings confirm that a combination of steel slag and quarry dust can significantly improve laterite soil properties, making it suitable for subbase applications in road construction.

DECLARATION

I, SSEKKALABA ELVIS, hereby declare that this is my original work, is not plagiarized and has not been submitted to any other institution for any award.

Signature: Date:

……………………………………………………… ……………………………………………………….

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S21B32/097

APPROVAL

I certify that this report is for **SSEKKALABA ELVIS** and I fully accept that he has been under supervision and so submitted is the Final Research and Design report to the Faculty of Engineering, Design and Technology, Uganda Christian University in partial fulfilment of the requirements for an award of a Bachelor of Science in Civil and Environmental Engineering.

Signature: Date:

……………………………………………………… ……………………………………………………….

MR. MARVIN ZZIGWA

(Academic Supervisor)

DEDICATION

I dedicate this research to my parents, who have been my biggest support and motivation throughout my academic journey.

ACKNOWLEDGMENT

I thank the Almighty God for enabling me to carry out this research project.

I would also like to thank my parents for their continued support during this research project, for it would not have been possible without their support.

I would like to extend my gratitude to Mr. Marvin Zzigwa, my research supervisor, for the guidance, assistance, advice and time that he dedicated to this research project.

Appreciation goes out to Mr. Kyaligonza Gary, my project partner, for being collaborative and active throughout this research process.

Finally, I would like to thank the Faculty of Engineering Design and Technology at Uganda Christian University for supporting us with the required guidance and supervision throughout the research.

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AASHTO	American Association of State Highway Transportation Official System
BOF	Basic Oxygen Furnace
BS	British Standard
CBR	California Beating Ratio
EAF	Electric Arc Furnace
Eq.	Equation
GM	Gradation Modulus
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
QD	Quarry Dust
SS	Steel Slag
UCU	Uganda Christian University
USCS	Unified Soil Classification System

CHAPTER ONE: INTRODUCTION

1.0 Introduction

This section contains the background and purpose of this research. It provides scientific justification for the used materials during the study.

1.1 Background

In many tropical and subtropical regions around the world, a unique type of soil forms over time due to intense weathering and leaching processes. This soil, known as lateritic soil, develops through a natural phenomenon called laterization where minerals are gradually stripped away, leaving behind a rich concentration of iron and aluminium oxides. They have been widely studied due to their distinct properties and significance in engineering works. They are classified based on their morphology, geological features, physical and chemical nature. Factors that affect these soil parameters include the weathering course, parent rock type, temperature, precipitation intensity, bed surface features, weathering process, atmosphere, and origin process (Kumar et al., 2022). Crystalline phases including quartz, kaolinite, halloysite, goethite, hematite, and ilmenite may be found in laterite soils, which are mostly made up of iron, silicon, and aluminium oxides. The chemical nature of laterite determines its bulk density, which normally ranges from 0.9 to 3.6 g/cm^3. It rises with iron amounts and falls with alumina concentration (Cyriaque et al., 2022).

The foundation, subbase, and subgrade layers of flexible pavements are built using laterite soils. Due to their high strength qualities, engineers may have to stabilize and improvise marginal laterite soils in order to meet the strength requirements for natural gravel used to build the pavement layers, as quality laterite soils may not be readily available in the area of the road project (Sudla et al., 2018).

Cement and lime stabilisation is used extensively due to its accessibility, affordability, durability, and weather resistance. Since cement stabilisation uses the least quantity of cement, granular soils with enough fines are optimal. However, cement stabilisation results in soil cracks because of hydration, and the cement production process has negative environmental implications. Laterite soils have been mechanically stabilized with crushed rock material. It impacts the soil by altering gradation and reduces the soil cohesion. Crushed rock material mining makes it prone to exhaustion since it’s a non-renewable resource (Denis & Ejiogu, 2021).

Steel slag is a byproduct of industrial steel manufacturing, formed during the process of converting iron into steel in a Basic Oxygen Furnace (Aldeeky & Al Hattamleh, 2017). An Electric Arc Furnace, which is used to recycle scrap steel, also produces slag, but with distinct characteristics. Other forms of slag include ladle refining slag and casting waste (Yu et al., 2021). The slag contains significant amounts of calcium oxide, which provides cement-like properties, along with other oxides such as silicon, iron, aluminium, and magnesium. These oxides are impurities from the steelmaking process that are oxidized and removed from the molten metal (Wandera, 2021). The chemical reactions between the slag and soil increase soil strength by forming calcium silicate hydrates that bond with silicates in the soil. Its adhesive nature makes it an effective binder for unbound bases, subbases, and surface layers in road construction (Yi et al., 2012).

Quarry dust is a by-product formed because of the crushing and cutting of stone (Beju & Mandal, 2018). It is a fine powdery material made of crushed rock particles, primarily comprising silica, feldspar, and other minerals depending on the parent rock type. It has been a widely used material in improving the properties of problematic soils to fit different engineering purposes. (Subramanian & Kannan, 2013).

1.2 Problem statement

A significant percentage of Uganda's soils are lateritic in composition. They are usually weak and not readily used for most construction works. Numerous studies have been performed on the stability and strength of laterite soils in road construction to date with various approaches (Wu, Liu, Rao, Wang, & Wang, 2021).

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 24.7 %. The required minimum CBR value for the Subbase layer is 45 % for a G45 material. This deficiency requires 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.

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

1.3.3 Research questions

1. What are the physical and mechanical properties of laterite soil?
2. What are the physical properties of the steel slag and quarry dust?
3. What are the physical and mechanical properties of the laterite soils with varying compositions of steel slag and quarry dust?

1.4 Justification

Steel slag has Los Angeles abrasion of 20–25 %, a crushing value of 15 % and a bulk density of 1700–2000 kg/m^3 making it a hard material compared to the soil. It Because of its strong resistance to abrasion and friction, it is tough and resistant to wear providing significant strength to soil. It is an appropriate binder aggregate for unbound bases and subbases, a pavement surface layer in road construction, due to its adhesive qualities. These features show a material that may effectively increase the mechanical performance and load-bearing capacity of laterite soils, hence strengthening them (Güneyisi et al., 2020).

It is a byproduct of the steelmaking process and is expected to decrease the demand for natural resource extraction which is an advantage for the environment (Kabeta & Lemma, 2023). Research has demonstrated that using steel slag in construction contributes to sustainability in the building industry by preventing industrial waste from ending up in landfills and conserving natural aggregates. Because of this, steel slag is a good substitute that reduces the negative effects of road building on the environment (Hemanta et al., 2024).

Quarry dust is a non-plastic substance which it lowers the sample's liquid limit, plastic limit, and plastic index when added to the soil samples. This is because it replaces some of the plastic particles in the neat soil sample reducing plasticity (Athanassios, 2014).

1.5 Significance of the study

The study determines if steel slag and quarry dust may be used as a mechanical stabiliser to enhance the laterite soils' engineering qualities. It specifically seeks to ascertain how steel slag and quarry dust might improve laterite soils' strength, resilience, and overall performance rendering them more appropriate for use in building and other geotechnical applications. It brings out the sustainable soil stabilisation methods while utilising industrial byproducts through in-depth investigation.

1.6 Geographical scope

The case study of research is Nasuuti-Nakabago-Ntawo road with borrow pit located at coordinates 0°22'21.7"N 32°45'04.4"E.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This section contains the present body of knowledge in line with this research project. It analyses various literature such as, journal articles that were used to inform the research process.

2.1 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 (Ayoola & Philip, 2023). During soil stabilization, stabilizers are added to the soil at varying percentages and the various parameter changes in the soil are noted (Ojuri et al., 2022). This can be through mechanical or chemical stabilization techniques.

2.1.1 Principles of soil stabilization

Different stabilization methods are governed by several factors and variables. However, some basic principles cut across all stabilization methods and are essential for stabilization to be successful. The identification of the properties and composition of the soil in crucial for soil stabilization. This is because they inform their engineering properties and whether a stabilizer can be employed to enhance the engineering performance of these marginal soil (Archibong et al., 2020).

A suitable stabilizer is selected based on its effective and economical method of stabilization. This ensures that priority is placed on the property deficiencies in the soil being stabilized. The soil blend is then designed considering stability and durability of the mix. These are compared to the standards required depending on the purpose for the soil. Finally, an adequate construction procedure is obtained to ensure proper compaction of the stabilized layers (Archibong et al., 2020).

2.1.2 Mechanical stabilization

It involves physical alteration of the soil's features which influences the soil's properties. It is achieved by mixing and compacting two or more soils of varying grades. It depends on the gradation, mineral composition and plasticity characteristics of the blended soils. They might be aggregate or binders. Aggregates provide the skeletal framework for providing internal friction while binders provide cohesion in the material (Rajput & Minkina, 2024).

2.1.3 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. Most common type of chemical stabilization includes cement stabilization and lime stabilization (Mahyar & Shalchian, 2023).

2.1.4 Studies on soil stabilization using steel slag.

This section contains the previous research on the mechanical stabilization of various problematic soil types such as expansive and black cotton soils using steel slag.

2.1.4.1 Application in 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 increased the CBR from 3.64 % to 6.82 %. The UCS of the soil also increased from 0.94 MPa to 2.6 MPa (Cikmit et al., 2019).

2.1.4.2 Application in 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 increased the 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 a coarse sand rather than a fine sand.

2.2 Subbase layer

The subbase layer is the first layer constructed on the road's subgrade layer. This forms the first layer in the pavement structure. The minimum material requirements for a subbase layer for flexible pavements are specified based on various country requirements. The subbase material is classified as a G45 material according to the General specifications of MoWT for road and bridge works as shown in **Table 1**.

Table 1: Specifications for G45 subbase granular material (Source: MoWT, 2005)

Material properties	**G45 material**
CBR (%) BS1377 part4	Greater than 45
CBR swell (%) BS1377 part4	Greater than 0.5
Atterberg limits	
Liquid limit (%) BS1377 part2	Less than 40
Plasticity index (%) BS1377 part2	Less than 14
Linear shrinkage (%) BS1377 part2	Less than 7
Grading	
Grading modulus BS1377 part2	Greater than 1.5

The guidelines shown in the **Table 1** above ensure quality control for G45 subbase granular material for road to be implement in Uganda.

2.3 Laterite soils

Lateritic soils are leached residue resulting from the natural process of laterization in tropical and sub-tropical regions around the world (Ayodele et al., 2024). 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 among others. These soils can be influenced by the synergetic effect of all these factors (Santha et al., 2022).

Due to their abundance in tropical regions, laterite soils are commonly used in the road construction for the subgrade, subbase, and base layers of the road depending on the quality of the material and the design of the road (Erol et al., 2021).

2.3.1 Classification

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).

1) **AASHTO:**

A-1 through A-7 are the seven main categories into which soil is divided. If at least 35 % of the soil grains pass sieve number 200, the granular soils are classified as A-1, A-2, and A-3. The groups A-4 comprise more than 35 % of soils with grains that pass sieve number 200. A-5, A-6, and A-7. Most of the silt and clay are found in groups A-4 and A-7. Grain size is one of the parameters used in the soil categorization system (Chandrasasi et al., 2021).

2) **USCS**

It divides soils into two major classes: coarse and fine-grained soils., which are ones in which less than half of the sample's weight passes through the No. 200 sieve. The first letter in this category denotes the predominant particle type: "G" denotes gravel-rich soil (pebbles), whereas "S" denotes sandy soils. Fine-grained soils have more than 50 % of their total weight passing through the No. 200 sieve. These soils are further subdivided based on composition. The initial letter "M" refers to inorganic silt, "C" denotes inorganic clay, and "O" indicates organic silt. For highly organic soils, such as peat and manure, the symbol "PT" is used (Pahno & Valdez, 2024).

2.4 Steel slag

About 15–25 % of all steel melting is recognized as to steel slag. This is the remaining product after the steelmaking process (Zhang et al., 2021). It is created when the impurities in the molten steel are removed having left the furnace. Depending on the kind of steel manufacturing process, several kinds of slag are created. Its abundance of oxides, including calcium, magnesium, silicon, and iron, gives it unique mechanical and chemical properties. The usage of steel slag in architectural and civil engineering projects has raised concerns about its potential for reuse in recent years due to its exceptional strength, durability, and recycling potential (Kabeta & Lemma, 2023).

2.4.1 Steel slag formation

Steel slag is formed as steel is melted in a furnace where the impurities form a layer of slag on the surface of the molten steel. 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 sulphur. The steel slag contains oxides that are impurities from the manufacturing process (Nunes & Borges, 2021). The steel slag is then periodically removed from the molten steel surface, and this is done to ensure the purity of the steel and to collect the slag for further processing. It is then cooled and solidified in air or by water quenching depending on the desired properties of the steel slag (Palankar, Ravi Shankar, & Mithun, 2015). Once solidified, the slag is then crushed to produce varied sizes of aggregate for different construction applications (Gopinath & Mehra, 2018).

2.4.2 Steel slag corrosion resistance

Corrosion resistance is a crucial consideration when utilizing steel slag in construction. Its mineral makeup gives it an elevated level of corrosion resistance since it has less than about 10 % iron oxide content to cause significant durability issues that would arise from interaction with water. The high calcium and magnesium silicate composition significantly lowers the material's susceptibility to corrosion (Khalid et al., 2022).

2.4.3 Types of steel slag

a) Basic oxygen furnace slag

This kind of slag is created in a simple oxygen furnace when pig iron is turned into steel leaving behind the BOF slag. It is distinguished by having a density between 3,000 and 3,500 kg/m^3. It is appropriate for applications where low permeability is crucial due to its low water absorption, which ranges from 1 % to 4 %. Its expansive behaviour, which can be problematic in some building applications because to its high calcium oxide concentration, can be lessened with the right age and care (Cabrera et al., 2021).

b) Electric arc furnace slag

This kind slag, known as EAF slag, is created when steel is made in electric arc furnaces. It is more stable and includes more iron oxides than BOF slag. Depending on the batch used to produce the steel, its density and compressive strength have been shown to be equivalent to those of BOF slag, making it a good substitute for sub-base materials. With Los Angeles abrasion values below 30 %, EAF slag also exhibits greater resistance to abrasion, demonstrating its endurance in road building (Papayianni & Anastasiou, 2020).

c) **Ladle furnace slag.**

This type of slag is typically employed in the manufacturing of cement because of its smaller particles and lesser mechanical strength. It is created in the last refining of steel when in the ladle furnace. Because of its larger porosity and lower load-bearing ability, it is less appropriate for usage in road sub-base layers than BOF and EAF slags (Singh et al., 2021).

2.4.4 Availability of steel slag

Steel production in Uganda was sourced from the information obtained from the National Planning Authority platform as shown in **Table 2** below.

Table 2: Steel production in Uganda (Source: National Planning Authority, 2019)

Organization	**Annual steel melting production (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**

In the steel melting process, produces about 40 % of the steel melted forms slag (Bhavan, 2018). The annual mass of steel slag was obtained as shown in **Eq. (2.1).**

$$Steel\ slag\ mass = 210{,}000 \times 0.4 = \ 84{,}000\ tonnes\ per\ year \qquad \text{Eq. (2.1)}$$

Where the annual steel was approximated to 210,000 tonnes from **Table 2**. Steel slag volume was got from **Eq. (2.2)** taking the steel slag density as 1,700 kg/m^3.

$$Steel\ slag\ volume = \frac{84{,}000 \times 1{,}000}{1700} = 50{,}000\ m^3\ per\ year \qquad \text{Eq. (2.2)}$$

The volume of road for a one-kilometre length of single lane road was obtained in **Eq. (2.3)**. It was assumed to have a width 200 mm subbase layer thickness and 8 m road width taking a 3.5 m lane width and 0.5 m shoulders.

$$Volume\ of\ road = 0.2 \times 8 \times 1{,}000 = 1{,}600\ m^3\ per\ km \qquad \text{Eq. (2.3)}$$

Length of road from addition of 50 % steel slag was obtained from **Eq. (2.4)** below.

$$Length\ of\ road = \frac{50{,}000}{1{,}600 \times \frac{50}{100}} = 62.5\ km \qquad \text{Eq. (2.4)}$$

Based on the computed values from **Eq. (2.1) - (2.4)**, 60 km length of single lane road with 200 mm subbase layer thickness and 8 m road width having a 3.5 m lane width and 0.5 m shoulders with a 50 % steel slag in the subbase can be obtained from the available quantities of steel slag annually.

2.4.5 Applications of steel slag

The properties of steel slag have been widely studied and utilised to inform its use in various areas as discussed below.

Steel slag has major performance and environmental advantages when used to make cement and concrete. Because of its high angularity and surface roughness, which strengthen the interaction between cement and aggregates, it increases compressive strength and decrease shrinkage. Concrete buildings' resilience to wear and tear is also influenced by its density (Cabrera et al., 2021).

Hot-mix asphalt for road surface layers uses steel slag as an aggregate. With asphalt binders, rough surface roughness creates an adhesive surface that increases skid resistance and lessens wear from driving. It has been demonstrated that these asphalt mixes including steel slag aggregates increase the longevity of roadways (Güneyisi et al., 2020).

It is an additional material in the cement manufacturing process. It lowers the amount of clinker and, consequently, CO_2 emissions. The calcium and silica in slag provide pozzolanic activity, which boosts the strength and durability of cement (Khin et al., 2025). These uses show how steel slag may enhance material qualities and promote environmentally friendly building methods.

2.5 Quarry dust

Quarry dust has a fine particle size and has been used to improve the plasticity of soil boosting their strength and stability without negatively impacting the environment for various construction projects (Onyelowe et al., 2012). Studies have showed that as the percentage of quarry dust in soil is increased, the liquid limit reduced at a faster than the plastic limit which decreased the plasticity index. The maximum dry density increased as the optimum moisture content reduced the up to 40 % stone dust. However, there was a noted a reverse of the properties at 50 % stone dust. The changes could be attributed to the non-plastic quarry dust which substituted the plastic fines of the soil matrix leading to a reduced plasticity (Dahal et al., 2022).

CHAPTER THREE: METHODOLOGY

3.0 Introduction

This section contains details on the approach used to test and understand data obtained from the study. It shows the materials used for the research and where they were obtained. This will enable future researchers to reproduce this study.

3.1 Research design

The research followed a systematic procedure as shown in **Figure 1** and was informed by previous studies that entailed using steel slag in various areas.

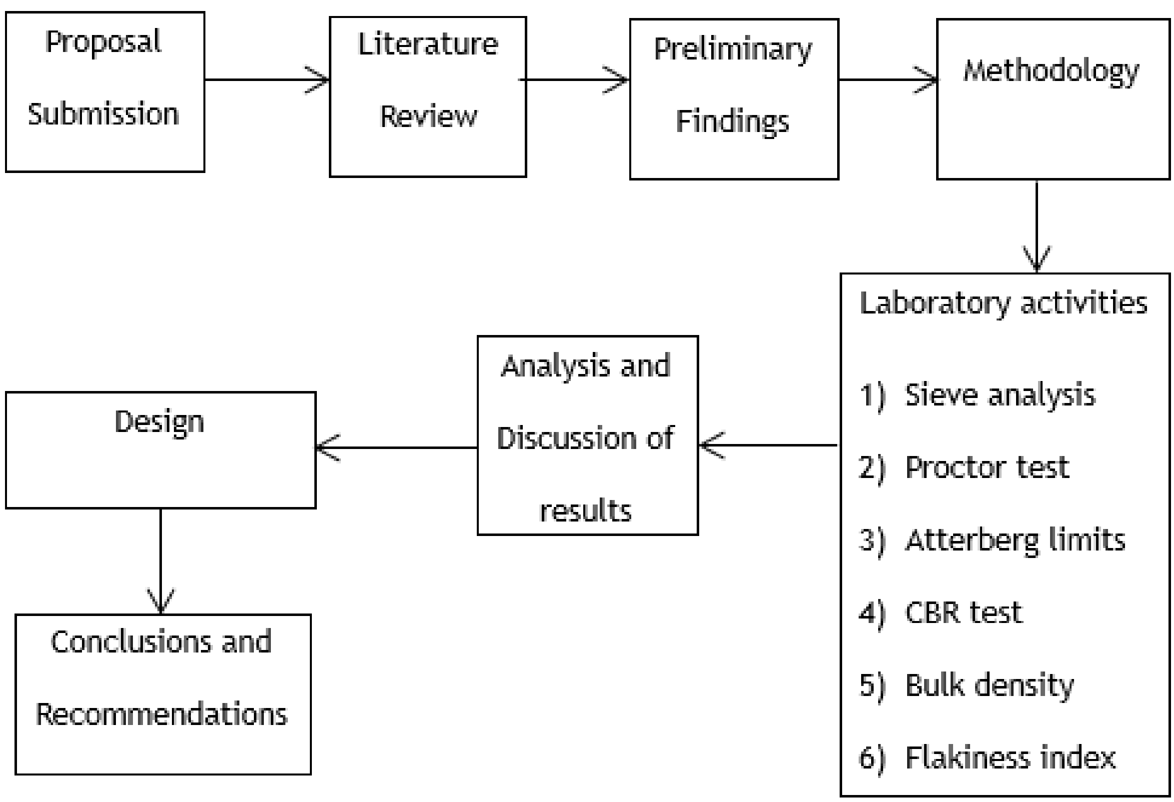


Figure 1: Research design

The research design in **Figure 1** contains the general plan and steps taken for the research project from the proposal submission to the recommendations.

3.2 Materials

The laterite soils were obtained from a borrow pit owned by Stirling 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.

The steel slag was obtained from Roofings Rolling Mills Ltd, a steel manufacturing company in Namanve, 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, Mukono as shown in **Figure 22** in Appendix A. The material was then manually crushed until particle sizes were not greater than 20mm using a mallet, as shown in the **Figure 2** below. The quarry dust was obtained from MM stone quarry in Jinja and taken tom the lab as shown in **Figure 3.**

Figure 2: Crushed steel slag material.

Figure 3: Granite dust material.

The experimentation started as soon as materials in under study were obtained as shown in **Figure 2&3** while at the lab.

3.3 Methods

The methods that were used were in line with the research project's objectives with the goal of assessing the suitability of using steel slag and quarry dust in stabilizing weak laterite soils.

3.3.1 Physical and mechanical properties of the laterite soils.

The physical and mechanical properties of the neat laterite soil were first obtained as shown in **Figure 3** above have performed some desk study and used in the classification of the soil and determination of its performance before any stabilization. The tests that were conducted are as described below.

a) **Proctor test (BS 1377 part 4)**

This test aids in determining the correlation between maximum dry density and optimum moisture content. The ideal moisture content that was obtained from this test was later used when compacting the sample for the CBR test.

Sample preparation

The test was carried out on the sample passing through the 20 mm test sieve. The sample was then quartered as shown in **Figure 18** in Appendix A 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 5 kg weight.

Procedure

1. For each portion, varying amounts of water were added to cover a range of moisture contents around the expected optimum moisture content.
2. The material was then compacted in standard cylindrical moulds of about 1ltr volume.

3. All the samples were compacted in three layers, applying 62 evenly distributed blows to each layer using a 4.5 kg rammer.
4. The samples were trimmed to cut off the excess material so that the compacted material was flush with the mould.
5. The samples were then weighed as shown in **Figure 19** in Appendix A, and representative samples were taken to the oven as shown in **Figure 21** in Appendix A. This was for moisture content determination at about 105 ºC for 24 hours.

Calculations

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.

b) California Bearing Ratio (BS 1377 part 4)

This test was 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. 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 of about 6 kg passing through the 20 mm test sieve. 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.

Test procedure

1. The sample at optimum moisture content was compacted into a standard 2 litre mould in five layers, applying 62 evenly distributed blows per layer using a 4.5 kg rammer.
2. 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.
3. Annular surcharge discs weighing about 4.5 kg were then placed on the stem of the perforated swell plates.
4. A dial gauge was thereafter mounted on the extension collar and adjusted to give a convenient zero reading.
5. The mould was then placed in the soaking tank with the water level just below the mould extension and left to soak for 4 days as shown in **Figure 20** in Appendix A.
6. The sample was then taken for penetration using a CBR testing machine shown in **Figure 4** below.

Figure 4: CBR testing machine.

Calculations

The penetration values obtained from the CBR testing machine in **Figure 4** were recorded and used for the computations in **Eq. (3.1) - (3.3)** below.

The CBR swell percentage was determined to assess the expansion characteristics of the soil upon soaking. It was calculated using **Eq. (3.1)** below:

$$CBR\ swell = \left(\frac{F - B}{127}\right) \times 100 \qquad \text{Eq. (3.1)}$$

where F was the dial gauge reading after four days of soaking, and B was the dial gauge reading before soaking. The obtained swell percentage from **Eq. (3.1)** provided insight into the soil's potential volumetric expansion when exposed to moisture.

The CBR was determined by obtaining the penetration loads at 2.5 mm and 5.0 mm, which were then used to calculate the CBR values. The CBR at 2.5 mm penetration was calculated using **Eq. (3.2)**, where P represents the plunger force at 2.5 mm penetration.

$$CBR(\%) = \frac{P \times 100}{13.2} \qquad \text{Eq. (3.2)}$$

Similarly, the CBR at 5.0 mm penetration was determined using **Eq. (3.3)**, where P is the plunger force at 5.0 mm penetration.

$$CBR(\%) = \frac{P \times 100}{20.0} \qquad \text{Eq. (3.3)}$$

The CBR at 2.5 mm penetration from **Eq. (3.2)**, was used for assessing the strength quality of the material. The CBR at 5 mm penetration from **Eq. (3.3)**, was used to verify the validity of the CBR value obtained at 2.5 mm penetration for use in the subgrade evaluation.

Atterberg limits (BS 1137 part 2)

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 from a plastic to a liquid state. These informed the performance of the soil when moisture is added to the soil. 5 kg of sample was used for these tests.

i. **Liquid limit**

The liquid limit test was done to establish the moisture content at which soil passes from the liquid state to the plastic state. The variations in the moisture content in soil may have a significant effect on its shear strength, especially on fine-grained soils.

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.

Test procedure

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

Figure 5: Cone penetrometer.

2. A range of penetrations between 15.0 mm – 27.0 mm were recorded a cone penetrometer in **Figure 5** and representative samples were taken for moisture content determination in an oven at 105 °C for 24 hours.

Calculations

Moisture content was calculated for each specimen was obtained from **Eq. (3.4)** where m_1 was the mass of the container, m_2 was the mass of the container and wet soil and m_3 was the mass of the container and dry soil.

$$w = \left(\frac{m_2 - m_3}{m_3 - m_1}\right) \times 100 \qquad \text{Eq. (3.4)}$$

The relationship between the moisture content obtained from **Eq. (3.4)** and cone penetration was plotted with the moisture content as the abscissa and the cone penetration as the ordinates on linear scales. The line of best fit was drawn, and the liquid limit of the soil sample was the moisture content corresponding to the cone penetration of 20 mm and was expressed to the nearest whole number.

ii. Plastic limit and plasticity index

The plastic limit test was done to determine the moisture content at which soil becomes too dry to be plastic. It was further used to determine the plasticity index of a soil sample. The plasticity index is the difference between the liquid limit and the plastic limit. It is the range of moisture content in which soil is plastic. The finer the soil, the greater the plasticity index.

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 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.

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 105 °C 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 was obtained from the difference between the liquid limit and plastic limit.

iii. Linear shrinkage

This test was done to determine how much a soil sample would decrease in volume after prolonged drying beyond the plastic limit. This also helped in understanding the converse condition of expansion due to wetting.

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.

Procedure

1. The sample was placed in a lubricated brass mould for linear shrinkage determination.
2. The sample was then placed in an oven at about 105 ºC for 16 – 24 hours.

Calculations

The linear shrinkage was calculated from **Eq. (3.5)** below.

$$linear\ shrinkage(\%) = \left(1 - \frac{l}{d}\right) \times 100 \qquad \text{Eq. (3.5)}$$

where **Eq. (3.5)** had *l* for the length of the oven-dried sample and *d* for the original length of the specimen to determine the change in length due to loss of moisture.

c) Particle size distribution (BS 1377 part 2)

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

Sample preparation

The sample of about 10 kg 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 2.5 kg. The sample weight was also noted down as the wet mass of the soil. A representative sample was also picked for moisture content.

Procedure

1. The soil sample was then passed through a series of sieves arranged vertically upwards according to their sizes.
2. The mass retained on each sieve was obtained and used for the following calculations.

Calculations

The cumulative mass retained was calculated, followed by the determination of the percentage mass retained and the percentage passing. A graph was then plotted with the grading sieve size on the x-axis and the percentage passing on the y-axis. Finally, the grading modulus was calculated to assess the particle size distribution.

3.3.2 Physical properties of steel slag and quarry dust.

a) **Bulk density (ASTM C29/C29M)**

This test was used to inform the quality of steel slag. This is because high values relative densities compared to the soil are attributed to stronger and more durable materials use, hence proving it suitability as a construction material.

Test procedure

1. The sample was poured into a graduated container of known volume of 0.003375 m^3 until it fills one third of the container.
2. The sample was then tamped using a metal rod applying 25 stokes evenly distributed on the sample.
3. 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: Mould filled with steel slag.

4. The sample and container in **Figure 6** were then weighed and the net weight of the sample calculated.

Calculations

The volume of the mould was obtained and used to determine the bulk density. The bulk density was then calculated using **Eq. (3.6)** below, which relates mass and volume to density.

$$bulk\ density = \left(\frac{mass\ of\ soil}{volume\ of\ the\ mould}\right) \quad \text{Eq. (3.6)}$$

The mass of the soil in **Eq. (3.6)** was derived from the difference between the mass of the soil, mould, and baseplate, and the mass of the mould and baseplate.

b) Particle size distribution (BS 1377 part 2).

This test was used in obtaining the particle sizes steel slag as well as those of the quarry dust in various experimental setups to determine their particle distribution in their respective samples obtained.

Sample preparation

The sample of about 10 kg each was washed through the 75 µm sieve and the portion of that passed through the sieve was discarded. The sample was then transferred to a tray and placed in an oven to dry at 105 °C to 110 °C for about 16 hours.

Test procedure

1. After drying in the oven, the sample was weighed to determine its dry weight.
2. The sample was then sieved through the different sieve sizes while weighing the mass of the sample retained on the sieve.

Calculations

1. Calculation of the cumulative mass retained, percentage mass retained, and percentage passing was performed.
2. Plotted a graph of sieve size against percentage passing.
3. Compared the percentages with the standard limits for crushed rock.

3.3.3 Physical and mechanical properties of the modified laterite soil.

To find the proportion that produces the best results for a subbase material, various amounts of steel slag and crushed rock were applied to the laterite soil and evaluated. Based on the blend's economic implications and the most gratifying results, the mix design was be selected. Tests were conducted to evaluate each blend's performance. 40 %, 30 %, and 20 % steel slag were added to the laterite soil by mass as shown in **Figure 7** below and tested to determine the percentage that gave the satisfactory results for a G45 subbase material.

Figure 7: Varying percentages of steel slag added to laterite soil.

40 % steel slag gave satisfactory strength results from the samples in **Figure 7**, although didn't meet the plasticity requirements and hence the addition of quarry dust propositions**. Table 3** below shows a summary of the test plan for laterite soils with varying compositions of steel slag and quarry dust.

Table 3: Test plan for laterite soil modification

Sample composition	Steel slag	Laterite soil	Quarry dust
20 % steel slag	10 kg	40 kg	0 kg
30 % steel slag	15 kg	35 kg	0 kg
40 % steel slag	20 kg	30 kg	0 kg
40 % steel slag + 5 % quarry dust	20 kg	27.5 kg	2.5 kg
40 % steel slag + 10 % quarry dust	20 kg	25 kg	5 kg
40 % steel slag + 15 % quarry dust	20 kg	22.5 kg	7.5 kg

The quantities obtained in the **Table 3** informed the amounts of each material required to be required to conduct the various sets of tests at varying sample compositions. 5 %, 10 %, and 15 % quarry dust were then added to 40 % steel slag and laterite soil by mass and tested to determine the percentage that gave the satisfying plasticity results for a subbase material. The final design percentage was chosen based on the satisfactory strength and plasticity results.

Tests carried out on each blend included the following as describe before:

a) Maximum dry density and optimum moisture content (BS 1377 part 2) that helped in determining the correlation between moisture content and compacted dry density. The optimum moisture content obtained was used when compacting the sample for the CBR Test.
b) CBR and CBR swell after 4 days of soaking. (BS 1377 part 4) that was used to determine the strength of a material. The strength of the subbase material is typically expressed in terms of their CBR value.

c) Atterberg Limits (BS 1137 part 2) where the linear shrinkage, plastic limit, and liquid limit obtained and used in understanding how the soil behaves with different moisture conditions. It undergoes changes from a solid to a plastic condition as well as the moisture content at which it becomes liquid significantly impacting on how well the soil performs after being moistened.
d) Particle size distribution (BS 1137 part 2) that helped to determine the extent to which of the size ranges and likely to control the engineering performance of the soil.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This section contains the discussion of results for the various tests carried out in line with the research objectives.

4.1 Neat soil sample

Results for the material properties for the neat soil sample were obtained and compared with the MoWT general specifications for road and bridge works for a G45 subbase material as shown in **Table 4** below.

Table 4: Summary of the neat soil sample test results.

Material property	Neat soil sample	G45 subbase specifications
MDD (g/cm^3)	2.063	-
OMC (%)	12.8	-
CBR (%)	24.7	> 45
CBR swell (%)	0.75	< 0.5
Liquid limit (%)	57.4	< 40
Plastic limit (%)	27.4	-
Plasticity index (%)	30.0	< 14
Linear shrinkage (%)	15.0	< 7
Grading modulus	0.423	> 1.5
USCS classification	CH	
AASHTO classification	A-7-6	

Based on the neat soil sample test results summarized in **Table 4**, the soil didn't meet the minimum requirements for a G45 material.

4.1.1 Gradation

The soil sample was classified as an inorganic clay with high plasticity with CH according USCS. This is because the sample had less than 50 % retained on the 75 µm 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 had a liquid limit greater than 50 % which the system classifies as a sample with high plasticity (H).

The soil sample was classified as an A-7-6 material according to the AASHTO. This is because the soils had more than 35 % passing the 75 µm sieve and was 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. The soil had a liquid limit above 41 % and plasticity index above 11 % and was 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 was classified as an A-7-6 material. This material was therefore considered poor for use as a subgrade material requiring modification before applying the material on the road. This could be attributed to the lack of coarse particles which are crucial in boosting the load bearing capacity of the soil by increasing the internal angle of friction in a soil sample (Senanayaka et al., 2024).

The grading modulus of the soil sample was found to be 0.423 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 was fine and not suitable for use as a G45 subbase material without modification (Chandran, 2023).

4.1.2 Atterberg limits

Atterberg limits 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).

a) Liquid limit

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

b) Plastic limit and plastic index

The plastic limit of soil is the moisture content at which the soil can no longer be remoulded 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 of the soil sample was 27.4 %. The plastic limit informs the plastic index of a material which is the difference between the liquid limit and plastic limit.

The plastic index 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.

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

c) Linear shrinkage

Linear shrinkage is the moisture content at which a 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. The linear shrinkage of the soil sample was 15.0 % which was significantly higher than the recommended standard of 7 % from the MoWT general specifications for road and bridge works 2005.

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 (Kaliakin, 2017).

4.1.3 Maximum dry density

The maximum dry density corresponds to the maximum density a soil sample can obtain when moisture is added to the sample and occurs at the optimum moisture content. It also aids in determination of the degree of compaction of the field compacted layer (Senanayaka et al., 2024).

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

4.1.4 California Bearing Ratio

CBR 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 (Safkat et al., 2024).

The CBR % of the sample after 4 days of soaking was 24.7 % which does not meet the minimum requirement for a G45 material of 45 %. Therefore, the neat soil doesn't meet the standards. CBR 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.

4.1.5 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 could 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.

Therefore, 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.

4.2 Steel slag and quarry dust

Tests were carried out on the steel slag and quarry dust to determine the physical properties. These included the particle size distribution for both materials, and the flakiness index and bulk density for steel slag. This section therefore intends to discuss the results obtained from these tests.

4.2.1 Particle size distribution

The particle size distribution of the steel slag was compared to the standard grading limits for crushed rock material as shown in **Figure 8** below. These limits are used to obtain a well graded stabilized state of the soil material while modifying the soils.

The quarry dust grading was performed, and the curve was as shown in **Figure 28** in the Appendix B.

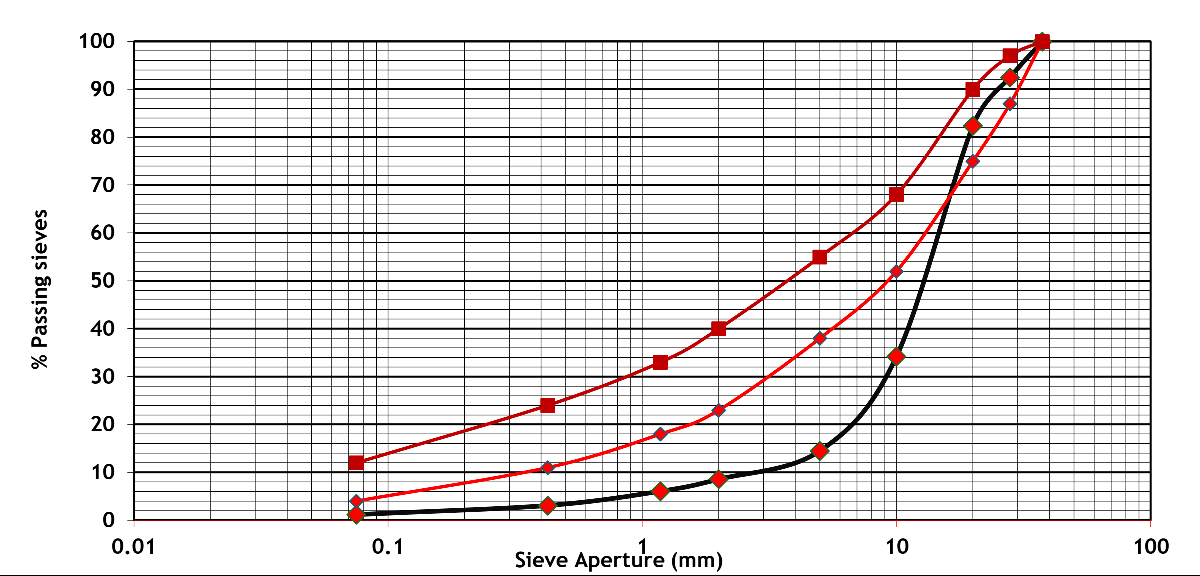


Figure 8: Gradation of steel slag.

The curves in **Figure 8** show that the crushed steel slag is comprised of coarse material. This makes it a suitable material to blend with the soil which was fined-grained as shown in **Table 5** below. The material was therefore expected to fix the particle size gap in the neat laterite soil.

The coarse particles when blended with the neat soil increased the internal friction between particles in the soil improving 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).

4.2.2 Flakiness index

This is the measure of proportion of particles that whose thickness is significantly smaller than their length. The flakiness of the steel slag was found to be 12.6 % which is below the specification of 35 % for crushed rock in the MoWT general specifications for Road and Bridge works 2005. This means that 12.6 % of the steel slag had their thickness significantly smaller than their length but was within the required standard.

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).

4.2.3 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.), the steel slag had an equal bulk density to that of coarse crushed aggregates. This showed that based on density, the steel slag would perform similarly to crushed rock.

Therefore, 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.

4.3 Modified laterite soil

Three samples of laterite soils and steel slag were prepared with 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 were 40 % gave satisfactory strength results for the CBR and CBR swell.

5 %, 10 %, and 15 % quarry dust by mass were then added to three samples with fixed 40 % steel slag by mass and laterite soil. These were tested to determine the

percentage that satisfied the strength and plasticity requirements for a G45 subbase material as shown in **Figure 9 - 16** below.

4.3.1 Maximum dry density of the modified laterite soil.

Figure 9 shows the variation in maximum dry density of the soil with increasing percentages of steel slag and quarry dust. The observed trend highlights the influence of material properties such as specific gravity and particle size distribution on soil compaction behaviour.

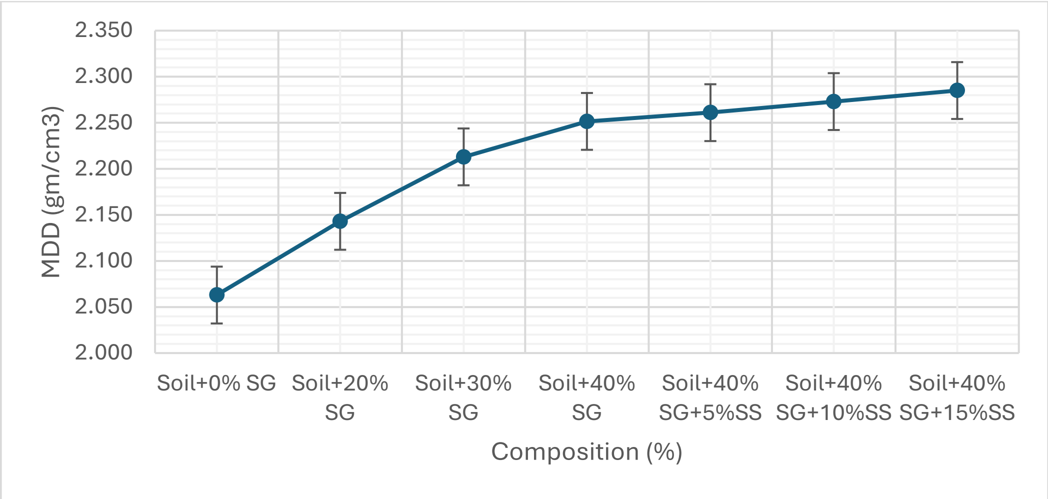


Figure 9: Maximum dry density at varying material compositions.

From **Figure 9**, there was a general increase in the maximum dry density. It gradually increased with increasing percentages of steel slag. This could be attributed to the fact that steel slag has a higher specific gravity than neat soil (Akinwumi, 2014). Additionally, the steel slag possesses a higher relative density, resulting in a denser blend with an increased maximum dry density.

Furthermore, a slight increase in maximum dry density was observed with increasing percentages of quarry dust at a constant 40 % steel slag content. This trend can be linked to the higher specific gravity of quarry dust compared to the soil it replaced, leading to an overall increase in density (Senanayaka et al., 2024). Additionally, the difference in particle size distribution between quarry dust and neat soil contributed to the density increase as quarry dust particles were slightly coarser (Chetia et al., 2018).

4.3.2 Optimum moisture content of the modified laterite soil.

Figure 10 shows the variation in optimum moisture content of the soil with increasing percentages of steel slag and quarry dust. The observed trend highlights the impact of material composition on the water demand required for achieving optimal compaction.

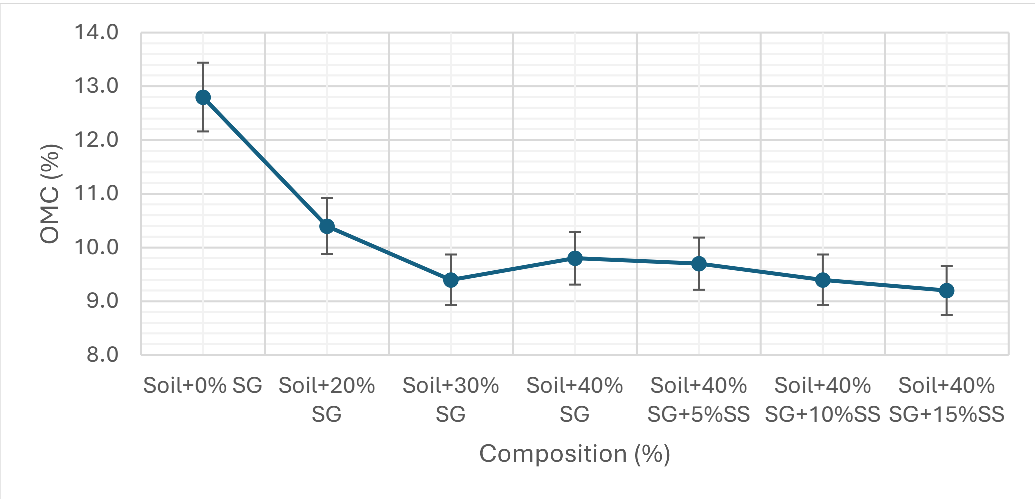


Figure 10: Optimum moisture content at varying material compositions.

From **Figure 10**, there was a general decrease in the optimum moisture content. The initial decrease with increasing steel slag content, followed by a slight increase, can be attributed to a reduction in the size of the diffused water layer. This reduction leads to the agglomeration of clay-sized particles, making the soil require less water to reach its optimum state (Akinwumi, 2014). As a result, less moisture is needed during compaction which can lower the overall cost of road construction.

Furthermore, the optimum moisture content of the blended material slightly decreases with an increase in quarry dust percentage. This is due to the reduction in the proportion of clay particles in the blend (Chetia et al., 2018). Since clay materials retain more water, their reduction means that less water is required for the sample to achieve its maximum dry density.

4.3.3 Atterberg limits of the modified laterite soil.

These discuss the results related to how the sample behaved under different moisture conditions.

4.3.3.1 Liquid limit

Figure 11 shows the variation in liquid limit with increasing percentages of steel slag and quarry dust. The changes observed reflect the impact of replacing plastic fines in the soil with non-plastic fines from these stabilizing materials.

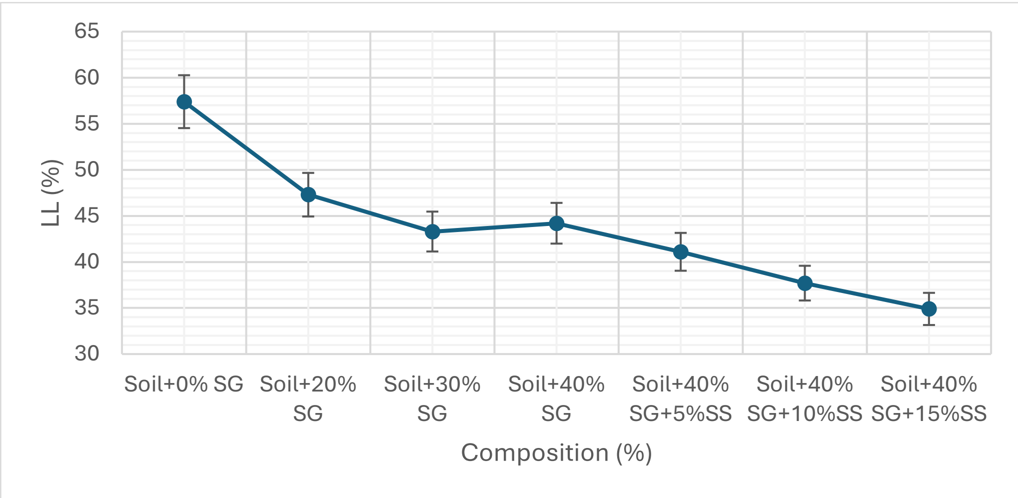


Figure 11: Liquid limit at varying material compositions.

From **Figure 11**, the liquid limit decreased as the percentage of steel slag increased. This reduction can be attributed to the replacement of plastic fines in the sample with the non-plastic fines of steel slag (Dixit et al., 2016). However, despite this decrease, the liquid limit remained above the maximum 40 % liquid limit required by MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

Similarly, an increase in quarry dust percentage also led to a gradual decrease in the liquid limit. This trend is due to the substitution of plastic fines with the non-plastic fines of quarry dust (Dixit et al., 2016). Notably, the addition of 10 % quarry dust reduced the liquid limit by 13 %, bringing it sufficiently below the required standard as per the MoWT specifications for a G45 granular subbase material.

4.3.3.2 Plastic index

Figure 12 shows the variation in the plasticity index with increasing percentages of steel slag and quarry dust. The observed trend reflects the effect of replacing plastic fines with non-plastic fines, influencing the soil's overall plasticity.

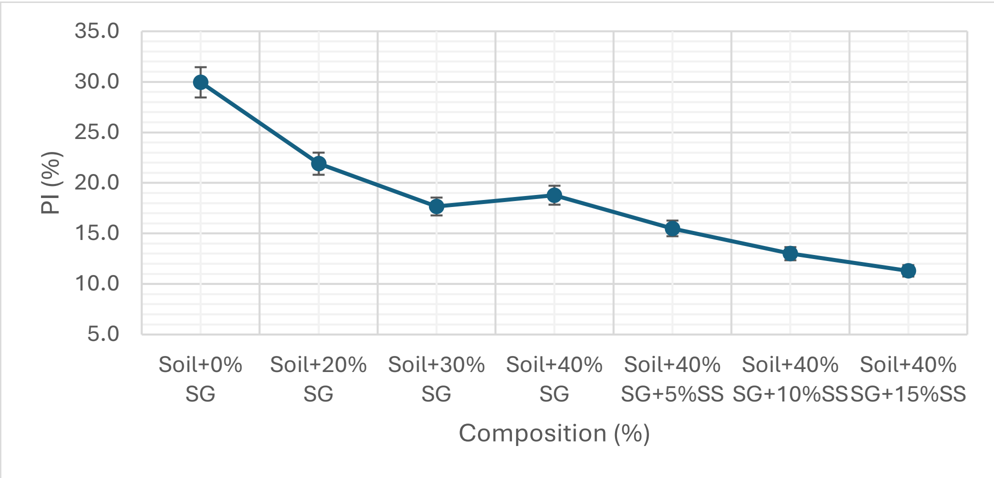


Figure 12: Plastic index at varying material compositions.

From **Figure 12**, the plasticity index generally decreased as the percentage of steel slag increased. This reduction can be attributed to the replacement of plastic fines in the sample with the non-plastic fines of steel slag (Dixit et al., 2016). However, despite the decrease, the plasticity index remained above the 14 % plastic index maximum limit specified in the MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

Similarly, an increase in quarry dust percentage resulted in a decrease in the plasticity index. This can be explained by the replacement of plastic fines with the non-plastic fines of quarry dust (Dixit et al., 2016), leading to a reduction in the liquid limit followed by a more than proportional decrease in the plastic limit. Consequently, this caused a decrease in the plasticity index of the material. Notably, the addition of 10 % quarry dust reduced the plastic limit by 27 %, sufficiently bringing it below the required standard as per the MoWT specifications for a G45 granular subbase material.

4.3.3.3 Linear shrinkage

Figure 13 shows the variation in linear shrinkage with increasing percentages of steel slag and quarry dust. The observed trend highlights the effect of replacing clay plastic fines which have high shrink-swell potential, with non-plastic fines, thereby influencing the overall shrinkage behaviour of the material.

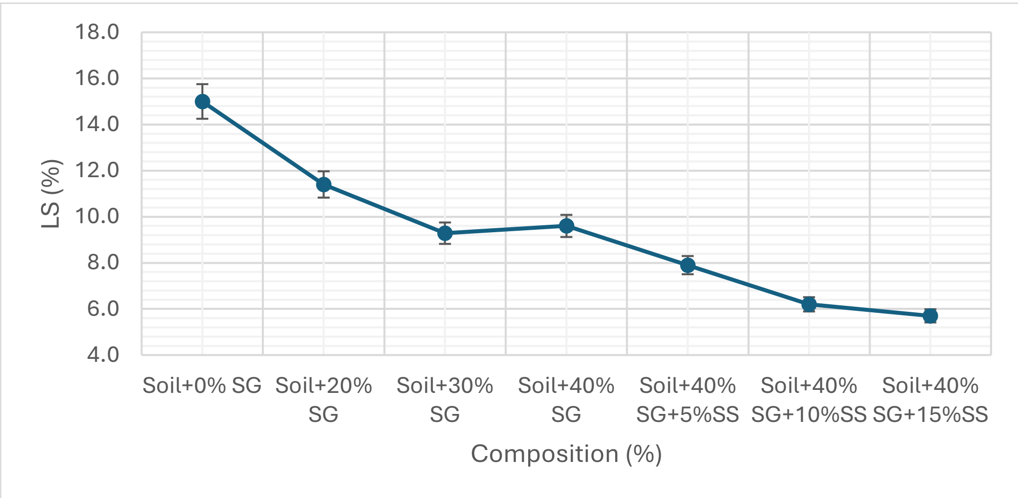


Figure 13: Linear shrinkage at varying material compositions.

From **Figure 13**, the linear shrinkage generally decreased with an increase in steel slag percentage. This reduction can be attributed to the replacement of plastic fines in the sample with the non-plastic fines of steel slag. The removal of clay plastic fines, which exhibit high shrink-swell potential, contributed to lowering the overall shrinkage of the material (British Geological Survey, 2023). However, the decrease was not sufficient to bring the linear shrinkage below the set standard of 7 % maximum linear shrinkage by MoWT general specifications for roads and bridges in Uganda for a G45 granular subbase material.

Similarly, an increase in quarry dust percentage also resulted in a decrease in linear shrinkage. This trend is attributed to the replacement of plastic fines with non-plastic quarry dust fines, reducing the proportion of clay materials responsible for high shrink-swell behaviour (British Geological Survey, 2023). Notably, the addition of 10 % quarry dust reduced the plastic limit by 33 %, sufficiently bringing the linear shrinkage below the required standard as per the MoWT specifications for a G45 granular subbase material.

4.3.4 CBR of the modified laterite soil.

Figure 14 illustrates the variation in the CBR percentage with increasing percentages of steel slag and quarry dust. The observed trend reflects the impact of coarse-grained particle content and internal friction on the load-bearing capacity.

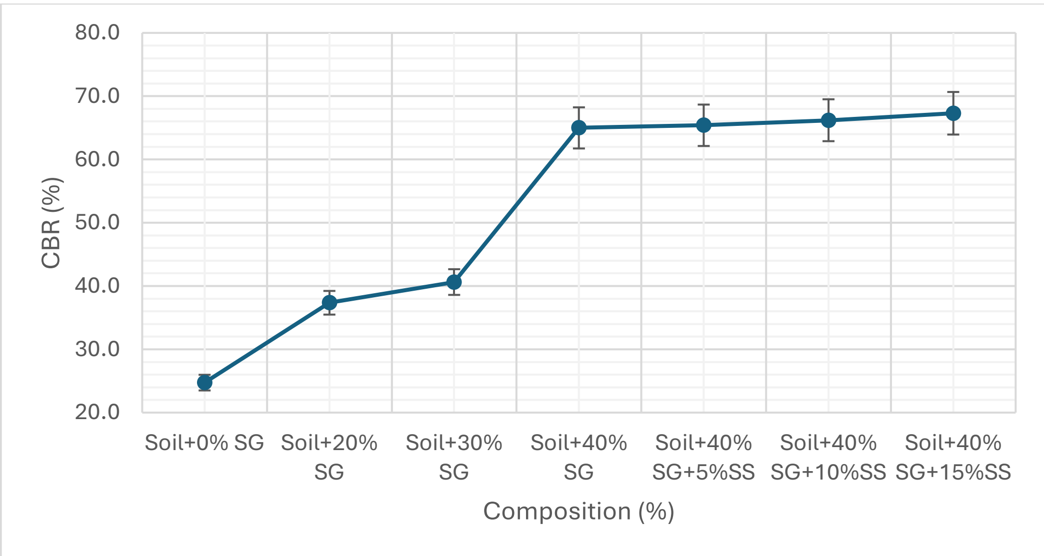


Figure 14: CBR of laterite soil at varying material composition.

From **Figure 14**, the CBR percentage gradually increased with an increase in steel slag content. This can be attributed to the higher proportion of coarse-grained particles in the soil blend, which is related to an increase in the internal angle of friction (Rasti et al., 2021). The resulting improvement in shear strength led to an enhanced load-bearing capacity, thereby increasing the CBR percentage. At 40 % steel slag composition, the CBR increased to 65 %, surpassing the minimum requirement for a G45 subbase granular material.

Additionally, a slight increase in the CBR was observed with the addition of quarry dust. This improvement can be linked to the enhanced gradation of the material, which contributed to better strength and load-bearing characteristics (Kufre Etim et al., 2021). Furthermore, the annular shape of quarry dust particles may have increased the internal angle of friction, further boosting the load-bearing capacity (Senanayaka et al., 2024). The CBR increase can also be associated with the addition of a material with a higher specific gravity than neat soil, resulting in a denser blend and, consequently, an improved CBR.

4.3.5 CBR swell of the modified laterite soil.

Figure 15 illustrates the variation in CBR swell with increasing percentages of steel slag and quarry dust. The observed trend highlights the effect of replacing plastic clay fines with non-plastic fines leading to a reduction in the material's swelling potential.

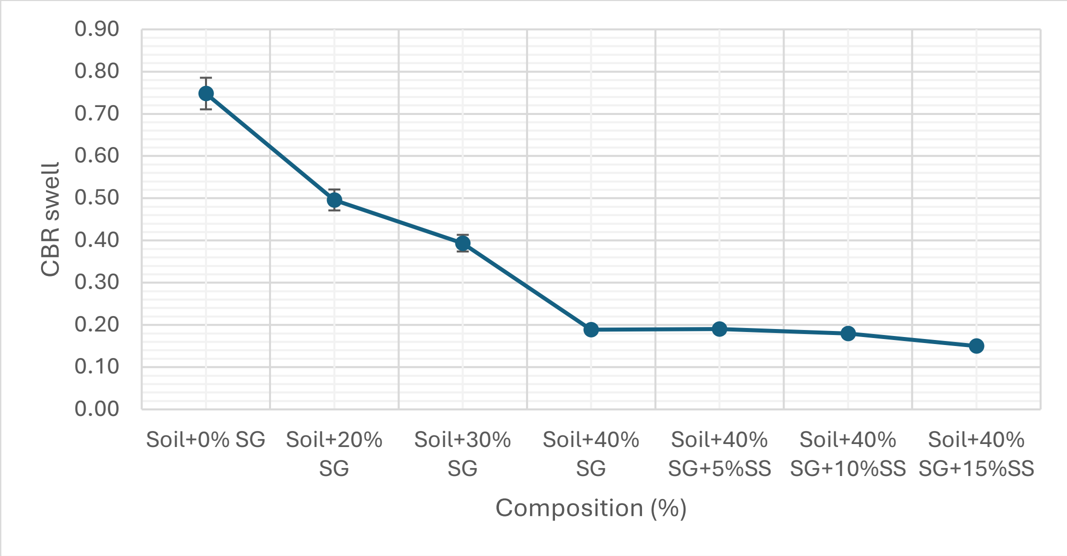


Figure 15:CBR swell of laterite soil at varying material composition.

From **Figure 15**, the CBR swell of the material gradually decreased as the percentage of steel slag increased. This reduction can be attributed to the replacement of plastic clay particles with non-plastic steel slag particles, which have lower shrink-swell potential (Dixit et al., 2016). Notably, at 30 % and 40 % steel slag composition, the CBR swell dropped below the maximum standard required for a G45 subbase material, indicating improved stability and reduced expansion.

Similarly, the CBR swell slightly decreased with an increase in quarry dust percentage. This trend is due to the substitution of plastic fines in the neat soil with non-plastic quarry dust fines, which significantly reduces the swelling potential of the material (Dixit et al., 2016). This reduction enhances the overall stability of the soil blend, making it more suitable for road subbase applications.

4.3.6 Grading modulus of the modified laterite soil.

Figure 16 illustrates the variation in grading modulus with increasing percentages of steel slag and quarry dust. The grading modulus reflects the balance between fine and coarse particles within the soil blend which influences compaction, void ratios, and overall load-bearing capacity.

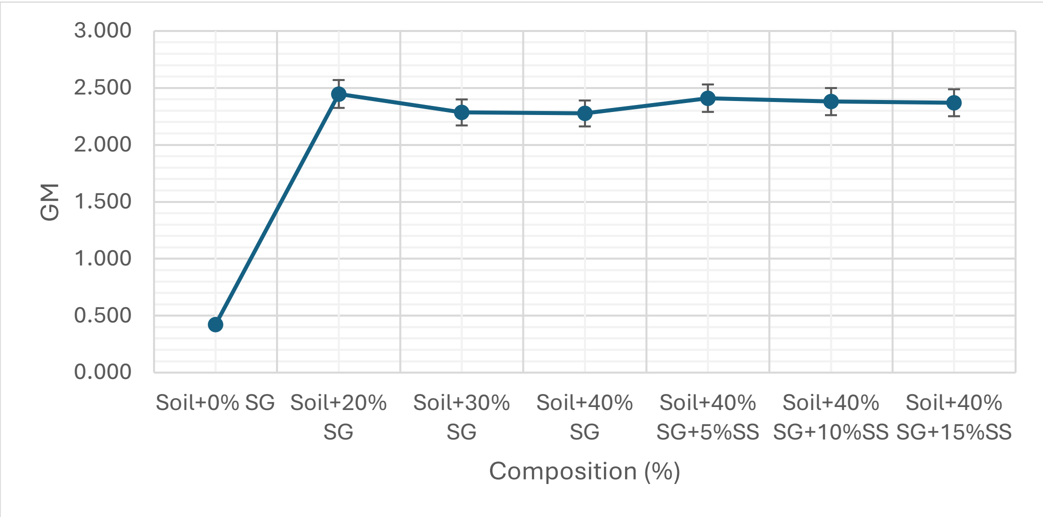


Figure 16: Grading modulus of at varying material compositions.

From **Figure 16**, an increase in the grading modulus indicates a well-balanced and more uniform distribution of fine and coarse particles in the soil sample. This improvement enhances soil gradation, leading to better compaction, reduced void ratios, and improved load-bearing capacity. A well-graded soil mixture ensures optimal particle interlocking, contributing to higher stability, reduced permeability, and enhanced engineering performance. After blending, the grading modulus of the material met the MoWT general specifications for a G45 subbase material in Uganda.

However, as the quarry dust percentage increased, the grading modulus of the blended material slightly decreased. This trend is due to the increasing proportion of fine material that is non plastic replacing the plastic soil fines hence reducing the overall grading modulus. Since the grading modulus represents the ratio of fine to coarse particles, an increase in finer material leads to a lower modulus while coarser materials result in a higher value (Chandran, 2023). This shift in particle distribution affects the soil's compaction behaviour and engineering properties.

4.4 Summary of the results and discussion

Based on all the obtained results as shown in **Table 5** below, 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.

Table 5: Summary of all results

Composition (%)	MDD gm/cm^3	OMC (%)	LL (%)	PI (%)	LS (%)	CBR (%)	CBR swell	GM
Soil	2.063	12.8	57.4	30.0	15.0	24.7	0.75	0.423
20 % SG	2.143	10.4	47.3	21.9	11.4	37.4	0.50	2.447
30 % SG	2.213	9.4	43.3	17.7	9.3	40.6	0.39	2.285
40 % SG	2.252	9.8	44.2	18.8	9.6	65.0	0.19	2.276
40 % SG +5 % SS	2.261	9.7	41.1	15.5	7.9	65.4	0.19	2.41
40 % SG +10 % SS	2.273	9.4	37.7	13	6.2	66.2	0.18	2.38
40 % SG +15 % SS	2.285	9.2	34.9	11.3	5.7	67.3	0.15	2.37

The addition of 10 % quarry dust into the blended material significantly improved its overall plastic characteristics as shown in **Table 5** above. This enhancement ensured that the material meets the material standards set by 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.

4.5 Design

This sub-section shows how this research can be applied in the stabilization of laterite soils for a G45 subbase road layer using steel slag and quarry dust. It acts as a quality control measure to ensure the integrity of the stabilized subbase layer based on the obtained results from this research.

4.5.1 Material preparation

For the implementation of this research, the material shall be obtained and prepared in line with the following guidelines as summarized in **Table 6** below.

4.5.1.1 Steel slag

- The steel slag shall be obtained from the waste of a steel melting plant using an induction furnace. Ensure the removal of impurities such as ashes.
- The obtained steel slag shall then be crushed to obtain a material of a minimum grading modulus of 2.81 and flakiness index of 12.6

4.5.1.2 Quarry dust

- The granite dust shall be obtained from a stone quarry, with a minimum grading modulus of 1.4 and ensure it's free from impurities.

Table 6: Steel slag and quarry dust specifications

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 steel slag and quarry dust obtained should meet the criteria specified in the **Table 6** above before use in the stabilization of the laterite soil for the subbase road layer.

The minimum properties for the neat laterite soil should meet the criteria specified in **Table 7** below before stabilization. This is to ensure that satisfactory results are obtained upon stabilizing the soil with **40 %** steel slag and **10 %** quarry dust.

Table 7: 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	-

The general material specifications compared with the guidelines are shown in **Table 7** above. It shows that the layer will meet the required general requirements according to the MoWT when stabilized at 40 % steel slag and 10 % quarry dust. This ensures quality control in line with the national guidelines.

4.5.2 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. The AASHTO method of design with as shown in **Eq. (3.7)** below was used for the computations.

$$\boldsymbol{SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3} \qquad \text{Eq. (3.7)}$$

Original pavement design as shown in **Figure 17** in the Annex.

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

Coefficients for each layer based on the material used.

$$\mathbf{a_1 = 0.35}$$

$$\mathbf{a_2 = 0.14}$$

$$\mathbf{a_3 = 0.11}$$

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 below.

$$m_2 = m_3 = 0.8$$

Therefore, the structural number in **Eq. (3.9)** was be obtained from the substitution into **Eq. (3.7)** above that is shown in **Eq. (3.8)** below.

$$\boldsymbol{SN = (0.35 \times 50) + (0.14 \times 200 \times 0.8) + (0.11 \times 175 \times 0.8)} \qquad \text{Eq. (3.8)}$$

$$\boldsymbol{SN = 55.3} \qquad \text{Eq. (3.9)}$$

At 40 % composition of steel slag, 10 % quarry dust and 50 % laterite soils, the blend had a CBR of 66 %, 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 was performed as shown in **Eq. (3.10) - (3.11).**

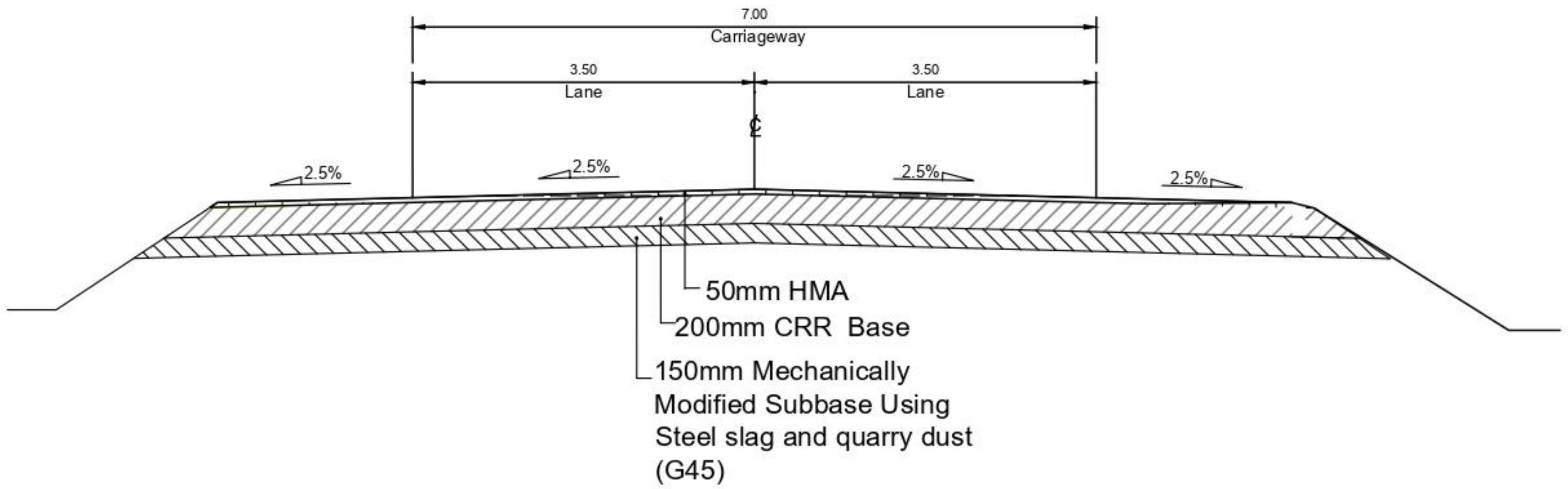
$$\boldsymbol{55.3 = 0.35 \times 50 + 0.14 \times 200 \times 0.8 + 0.13 \times D_3 \times 0.8} \qquad \text{Eq. (3.10)}$$

$$\boldsymbol{D_3 = 148.1mm \approx 150mm} \qquad \text{Eq. (3.11)}$$

From **Eq. (3.11)**, it 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.

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

These dimensions therefore inform the generated design drawing in **Figure 17** shown below.



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	SSEKKALABA ELVIS
REG NUMBER	S21B32 /097
SCALE	1:50 A3

Figure 17: Design drawing

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This section contains the conclusions from the findings of this research project based on each of the objectives. It also identifies the areas for further research under the recommendations that can be utilized by future scholars.

5.1 Conclusions

The results for the first objective showed that the neat soil was did not to comply with MoWT general specifications for a G45 granular subbase material. It was found that the CBR was 24.7 %, CBR swell was 0.75 %, liquid limit was 57.4 %, plasticity index was 30.0 % and a linear shrinkage of 15.0 %. The soil was further classified as an A-7-6 material according to AASHTO and CH according to USCS with a grading modulus of 0.423. Therefore, this soil needed to be stabilized to meet the required standards for G45 subbase material in road construction before its use.

The results for the second objective showed that the steel slag material was coarse grained with a bulk density of 1706 kg/m^3 and flakiness index of 12.6% which met the specified standard for aggregates to be used in the road subbase layer. This informed its suitability in improving the internal angle of friction of the neat soil sample which improves its load-bearing capacity. The quarry dust was found to be fine-grained with a grading modulus of 1.39 informing its use in reducing the plasticity of the blend.

Based on the results of the third objective, the addition of 40 % steel slag significantly increased the load-bearing capacity of the soil in terms of the CBR % by 160 % and reduced the CBR swell by 70 %. The obtained values met the required standards for strength unlike for the plasticity properties. The addition of 10 % quarry dust into the blended material 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 G45 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 shows the importance of sustainable construction practices using industrial waste materials which contributes to environmental conservation and resource efficiency.

5.2 Recommendations

The use of alternative materials to substitute the quarry dust in the material blend based on the availability of the material is highly recommended. Various methods of crushing the steel slag rather than manual approaches should be adopted so as produce sufficient fines for the blend.

Further studies should be carried out on how to activate the cementations properties of the calcium oxide in the steel slag. This is because it is in high percentages and can be used for chemical stabilization of weak soils to improve cohesion.

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APPENDICES

Appendix A: Laboratory pictures taken during tests.

Figure 18: Quartering of neat sample for testing

Figure 19: Weighing of proctor sample mould after compaction

Figure 20: CBR samples ready for soaking

Figure 21: Oven drying of samples

Figure 22: Steel slag from Roofings steel melting plant waste

Figure 23: Crushed steel slag

Figure 24: Riffling of steel slag process.

Figure 25: Steel slag bulk density test

Figure 26: Blending with varying material percentages

Figure 27: Quarry dust quartering.

Appendix B: Laboratory results

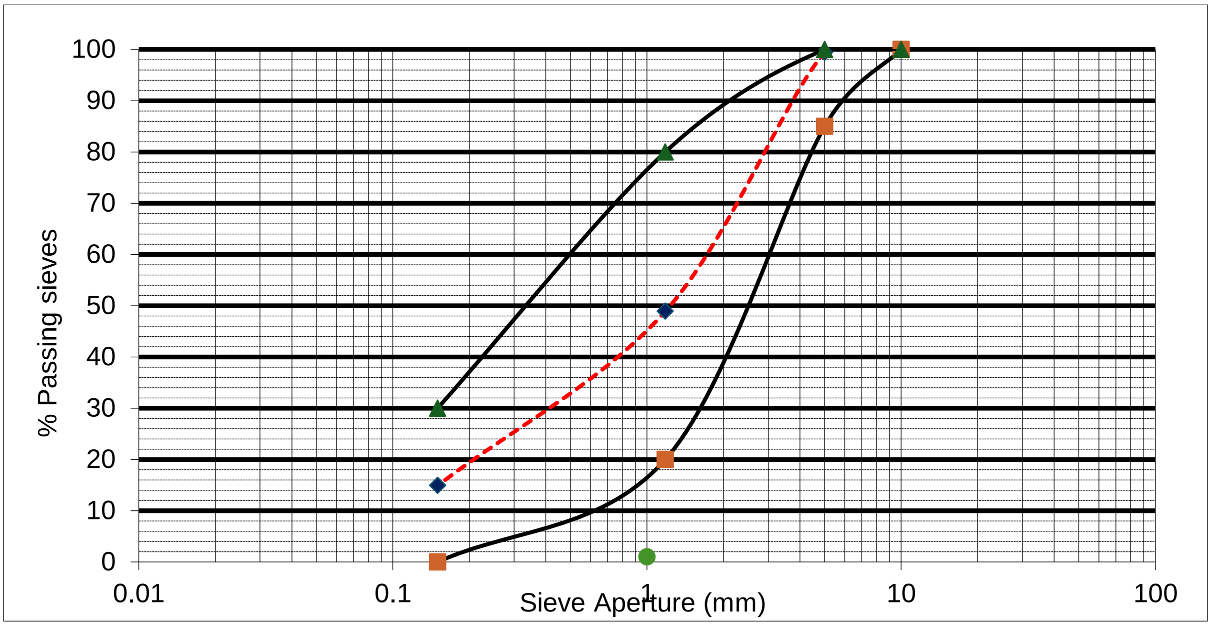

Figure 28: Grading curve for the quarry dust.

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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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NON-RETURNABLE MATERIAL GATE PASS

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	

Sl No	Material No.	Item description	UOM	Quantity	Remarks
1		SLUG	KGS	80	FOR RESEARCH PURPOSE

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

15-01-2025

Prepared By: RM0082

Verified By:

Authorised by: Rajeesh Patikkuthazha

Recieved By

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

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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

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	12.5	24.7	0.75	0.75

FOR LAB

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Materials Engineer

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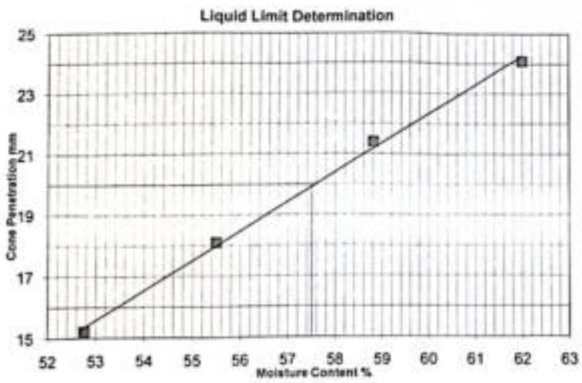
PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

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 (%)	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
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**

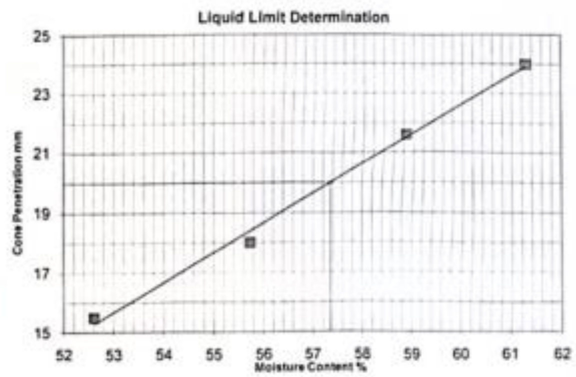
ATTERBERG LIMITS

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:

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Lab Technician

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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			

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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	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/dev.)	0.2052	0.2052	0.2052

Speed mm/min		Top		Bottom	
Penetration of the plunger (mm)	Time (s)	Reading $*10^3$mm	Force (KN)	Reading $*10^3$mm	Force (KN)
0	**0**	0	0.0	0	0.0
0.25	**12**	1	0.2	2	0.4
0.5	**24**	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		

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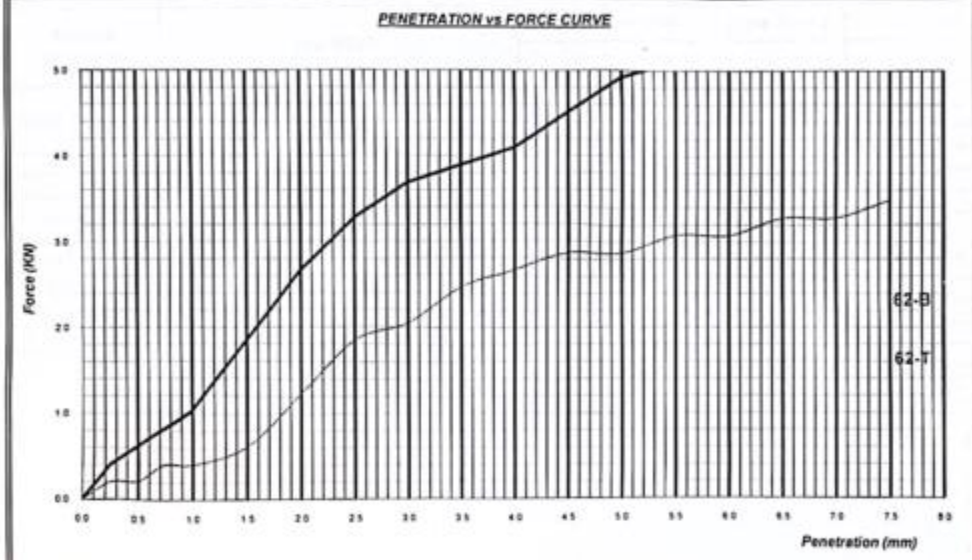
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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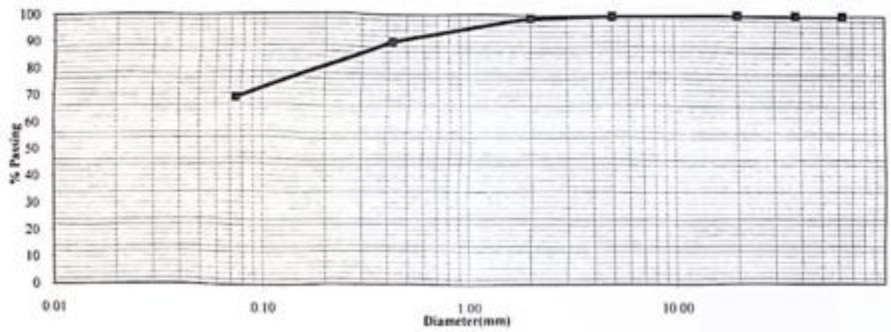
PROJECT : ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

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

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Lab Technician

Materials Engineer

07 FEB 2025

P. O. BOX 796, KAMPALA (U)

STUDENTS

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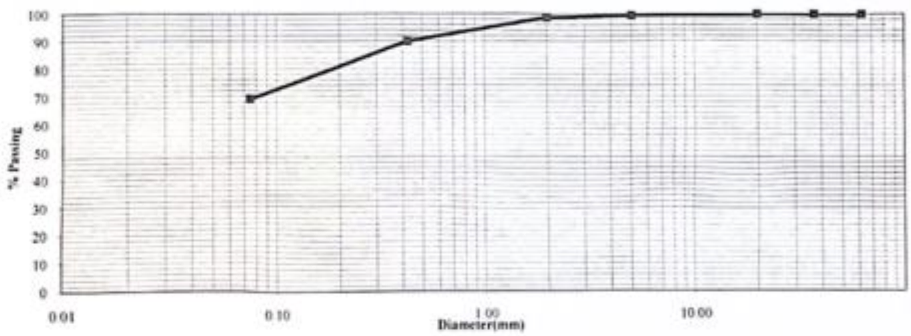
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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

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

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

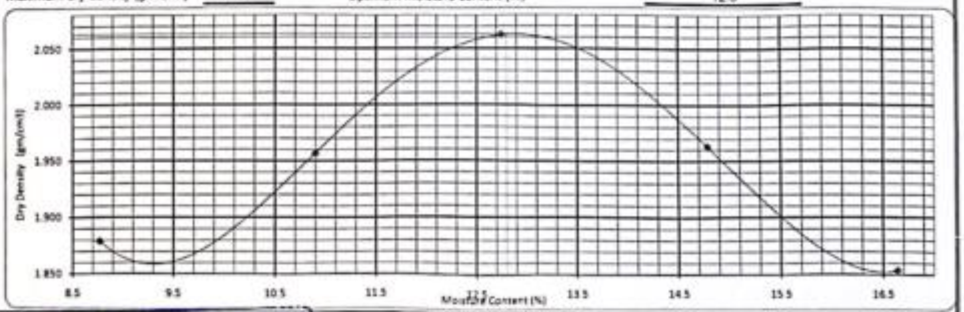
MOISTURE CONTENT DATA

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

Lab Technician	Materials Engineer	STUDENTS	

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

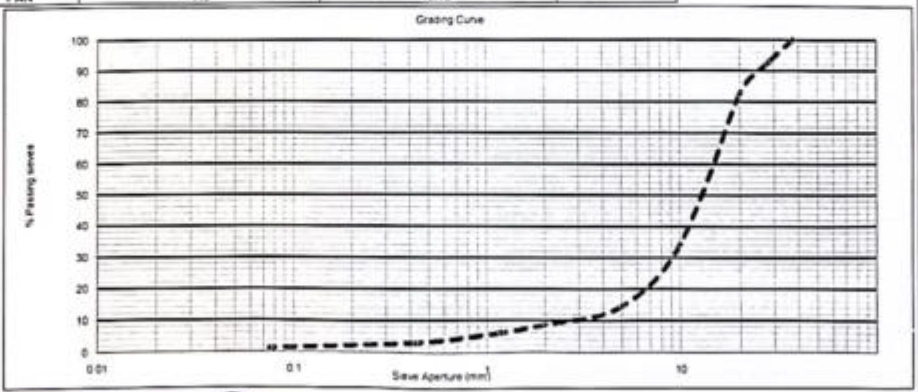
PROJECT: ASSESSING THE STABILIZATION OF LATERITE SOILS USING CRUSHED STEEL SLAG FOR THE CONSTRUCTION OF A SUBBASE ROAD LAYER

TEST: GRADING OF CRUSHED STEEL SLAG

(BS 1377 - 2 - 1990)

LAYER :		OPERATORS:	LAB TEAM
LOCATION:	MUKONO LAB	TOTAL DRY WT. OF SAMPLE:	4906.4
SUPPLIER :		TOTAL WT AFTER WASHING	4856.3
SAMPLE No:	AVERAGE OF 2	MOISTURE CONTENT:	
MATERIAL DESCRIP	STEEL SLAG	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 2902/2)	(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

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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	1806.1	
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 = $\frac{\text{TOTAL (F)}}{\text{TOTAL (A)}}$

$\frac{12.6}{\text{(SPEC < 35 \%)}}$ %

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		

STIRLING CIVIL ENGINEERING LTD
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INSTITUTION	CLIENT	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY	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

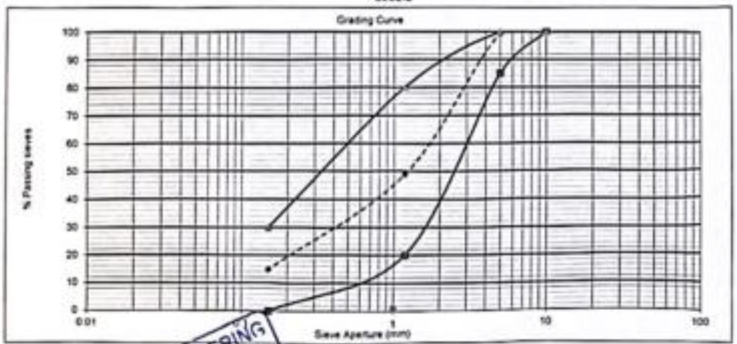
GRADING FOR AGGREGATES

(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			
WEIGHT LOST DURING SIEVING	486.6			
TOTAL	5862.2			

5862.2



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KAMPALA (U)

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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

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

Lab Technician Materials Engineer

STUDENTS

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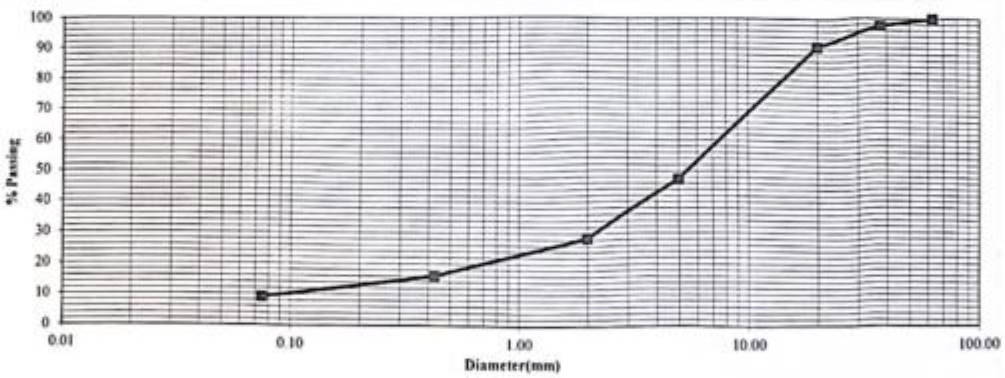
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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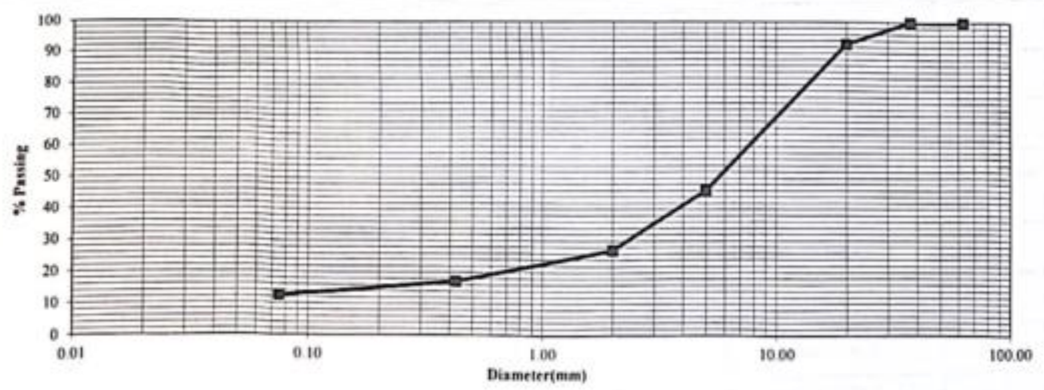
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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)	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:	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	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

Scanned with CamScanner

INSTITUTION	STUDENTS	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**

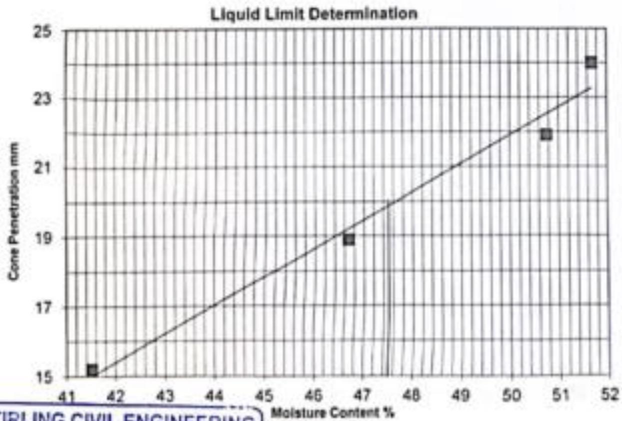
ATTERBERG LIMITS

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

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

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

STUDENTS

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INSTITUTION	STUDENTS	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**

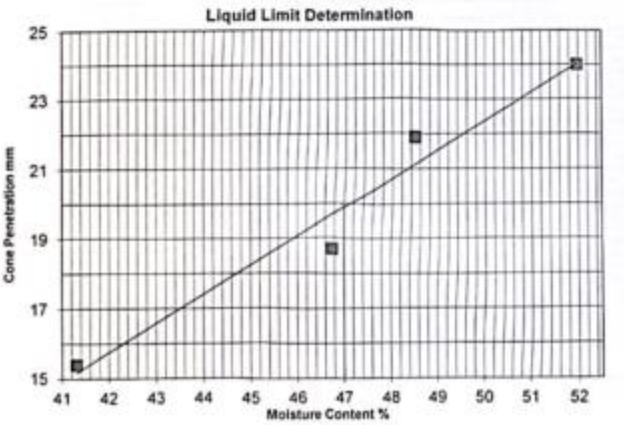
ATTERBERG LIMITS

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	STUDENTS
Materials Engineer	
Lab Technician	

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

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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

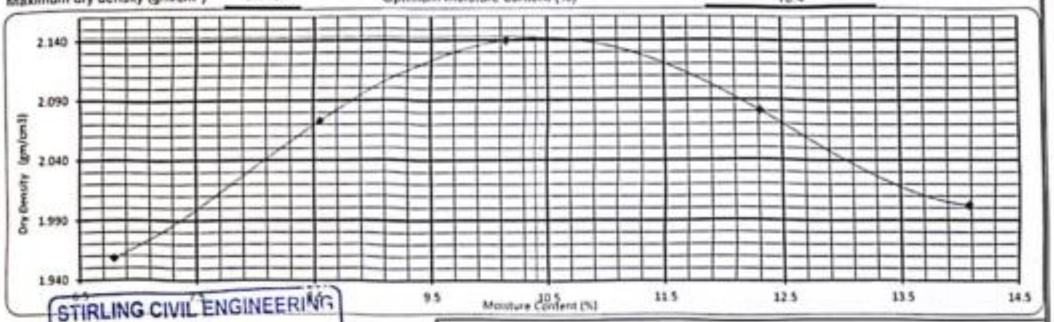
MOISTURE CONTENT DATA

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



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FOR TESTING LAB		STUDENTS	
Lab Technician	Materials Engineer		

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Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	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 (m^3)	**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/m^3)	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	
Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD
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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:	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 $*10^{3}$mm	Force (KN)	Reading $*10^{3}$mm	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

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For the Contractor	For Students
Lab Technician / Materials Engineer	

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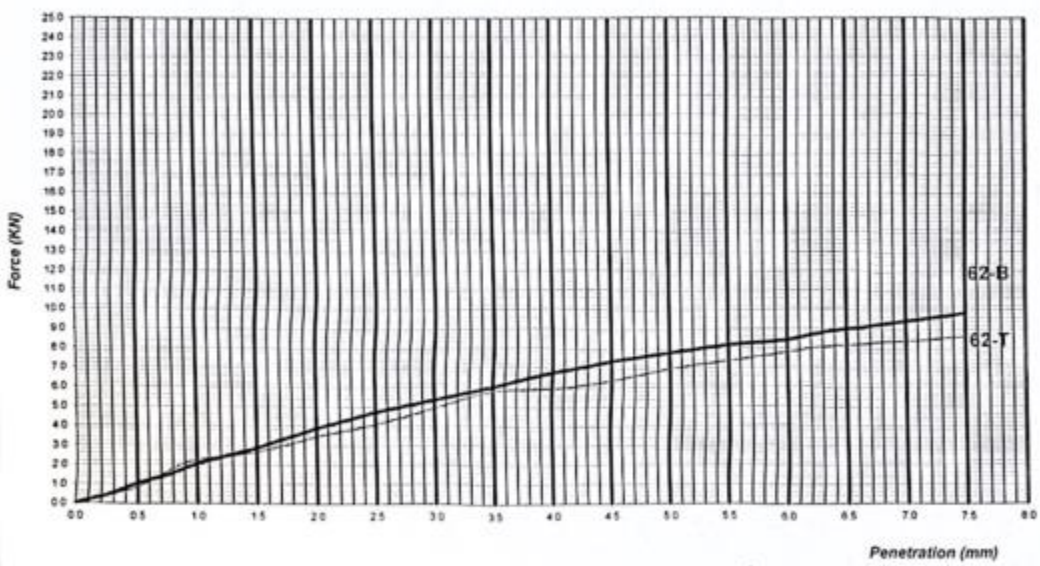
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	**Stirling**

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:	20% STEEL SLAG	Testing Date :	4/Jan/25
Source:	NSAMBWE BORROWPIT	Technician	: Lab team
Sample Description:	LATERATE GRAVEL MODIFIED WITH 20% STEEL SLAG		

PENETRATION vs FORCE CURVE



	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		

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INSTITUTION	STUDENTS	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

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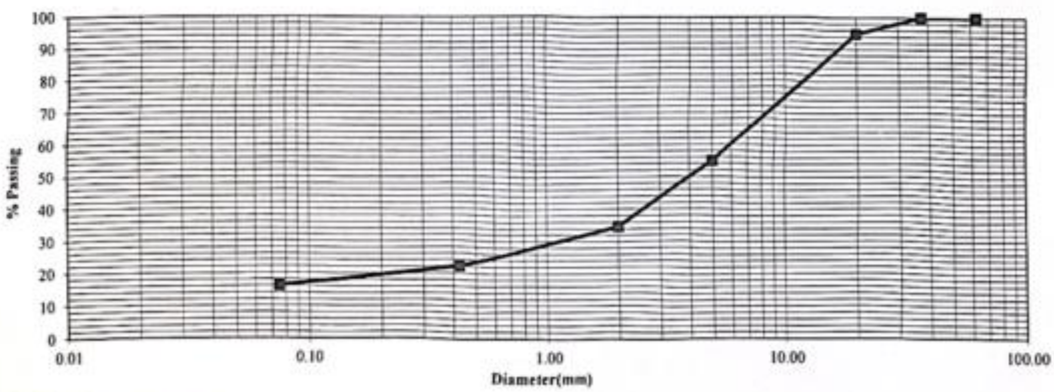
PROJECT :	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Location :	NSAMBWE BORROWPIT	Lab. Refernece No.:		
Location :(km)	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			



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Testing Lab
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Lab Technician
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P. O. BOX 796, KAMPALA (U)

STUDENTS

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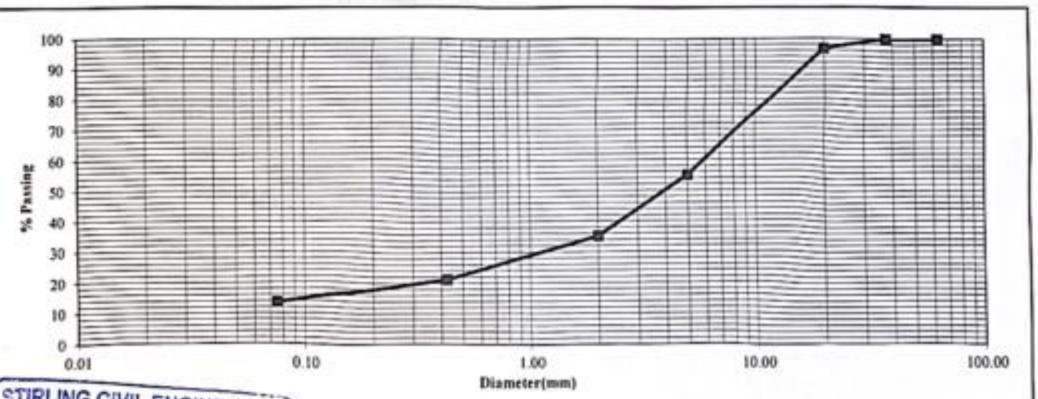
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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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Testing Lab

Lab Technician

Materials Engineer

STUDENTS

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INSTITUTION	STUDENTS	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**

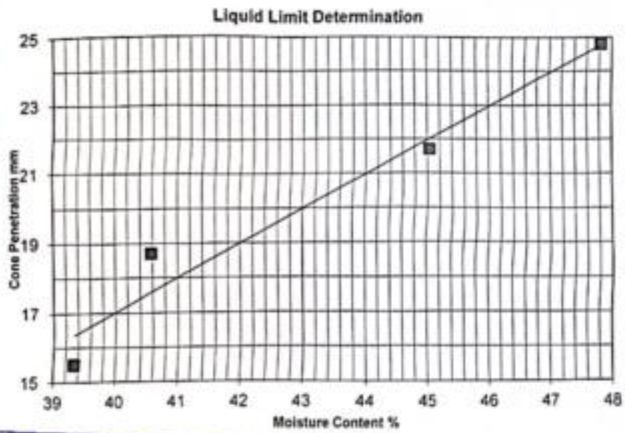
ATTERBERG LIMITS

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 (%)	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:

TESTING LAB

STIRLING CIVIL ENGINEERING LTD

Materials Engineer

P. O. BOX 796, KAMPALA (U)

Lab Technician

STUDENTS

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

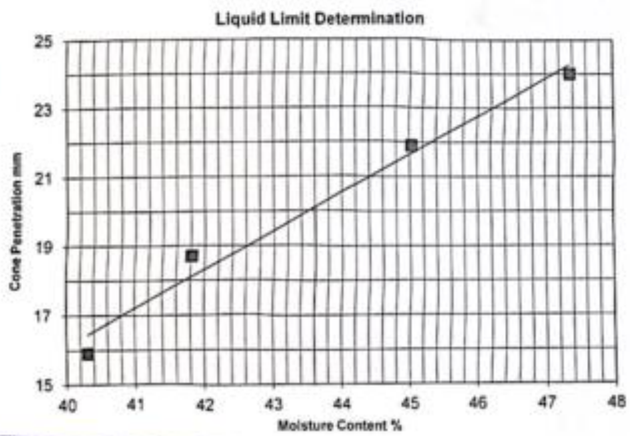
PROJECT:	ASSESSING THE USE OF STEEL SLAG TO STABILISE LATERITE SOILS FOR SUBBASE LAYER IN ROAD CONSTRUCTION

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

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Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	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

For the Lab		For Students	
Lab Technician	Materials Engineer		

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

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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: 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 $*10^3$mm	Force (KN)	Reading $*10^3$mm	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:

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07 FEB 2025
P.O. BOX 796, KAMPALA

For the Contractor		For Students	
Lab Technician	Materials Engineer		

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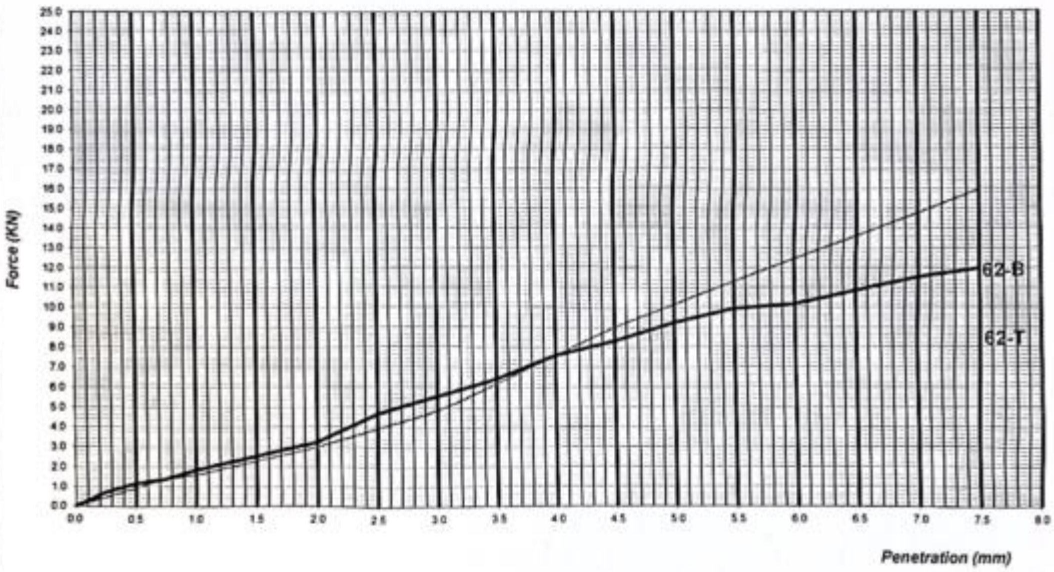
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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		

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INSTITUTION	STUDENTS	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

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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FOR LAB
07 FEB 2025
Lab Technician
Materials Engineer
P. O. BOX 796, KAMPALA (U)

STUDENTS

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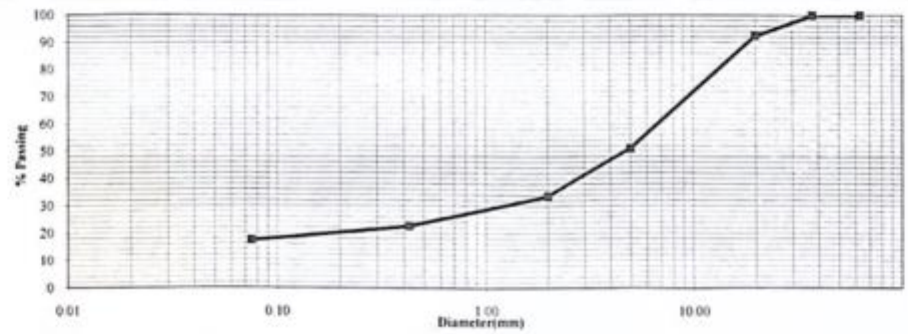
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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

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

STIRLING CIVIL ENGINEERING LTD

Lab Technician

Materials Engineer

P. O. BOX 796, KAMPALA (U)

STUDENTS

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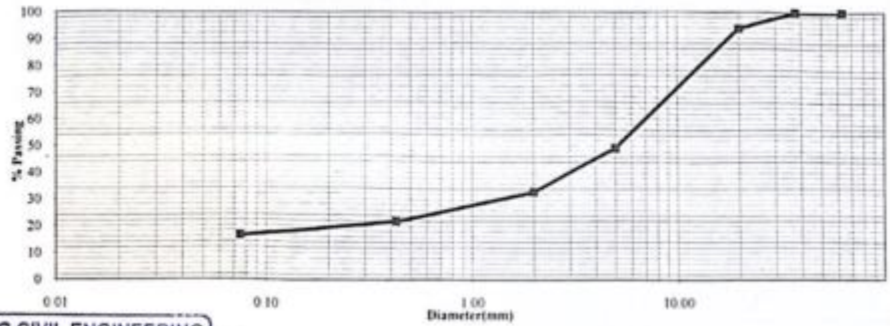
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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

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	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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

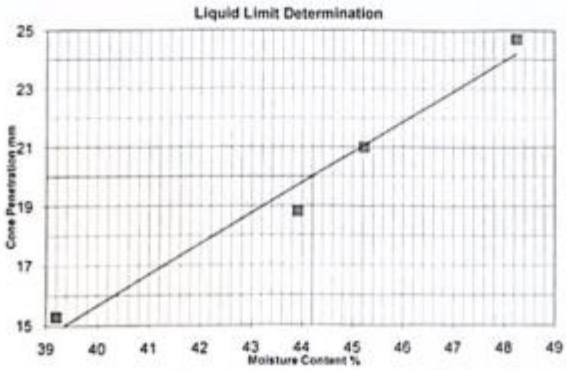
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	NSAMBWE BORROWPIT	Technician	Lab Team
mix	ATERATIC GRAVEL MODIFIED WITH 40% STEEL SLAG	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		PIDE	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

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

STUDENTS

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INSTITUTION	STUDENTS	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

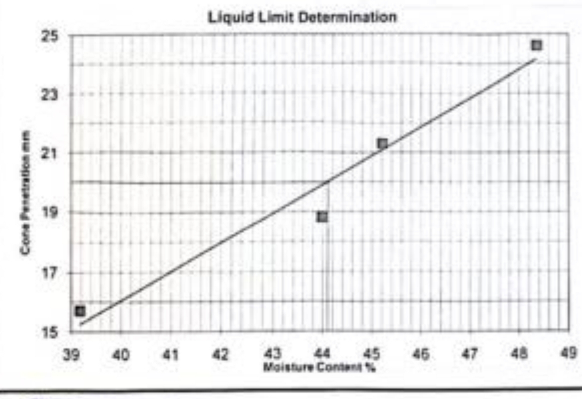
ATTERBERG LIMITS

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	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

Materials Engineer

Lab Technician

STIRLING CIVIL ENGINEERING LTD
07 FEB 2025
KAMPALA (U)

STUDENTS

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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

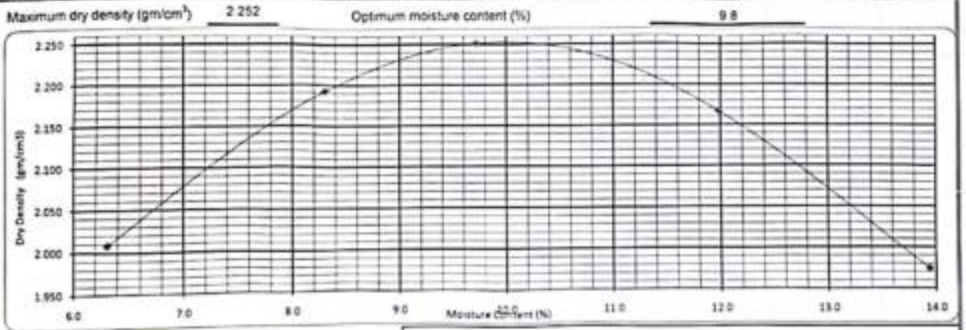
MOISTURE CONTENT DATA

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	21	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)

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Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	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		

STIRLING CIVIL ENGINEERING LTD

07 FEB 2025

P.O. BOX 505, KAMPALA (U)

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

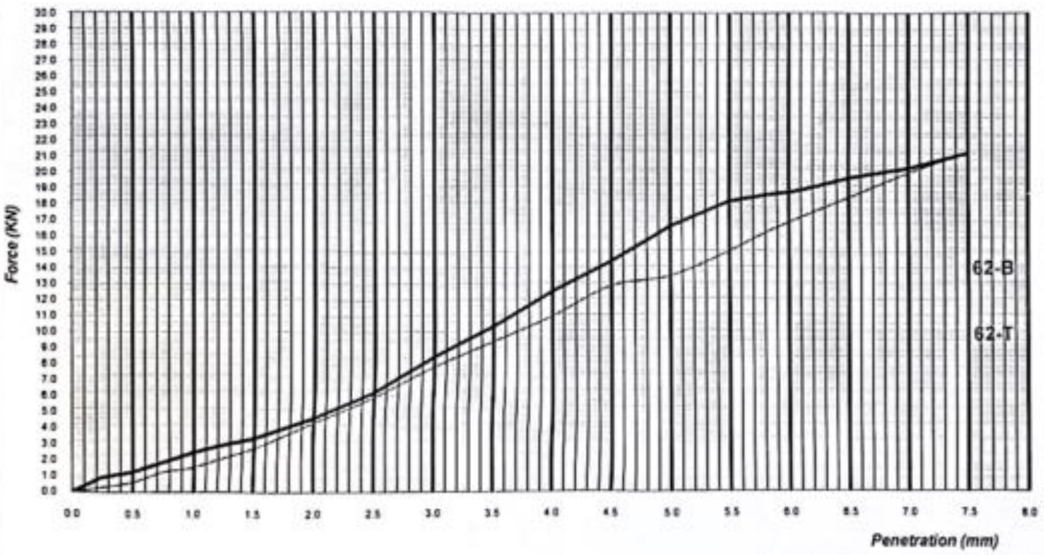
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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		

PENETRATION vs FORCE CURVE



	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		

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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

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
Materials Engineer
P.O. BOX [illegible] KAMPALA (U)

Lab Technician

STUDENTS

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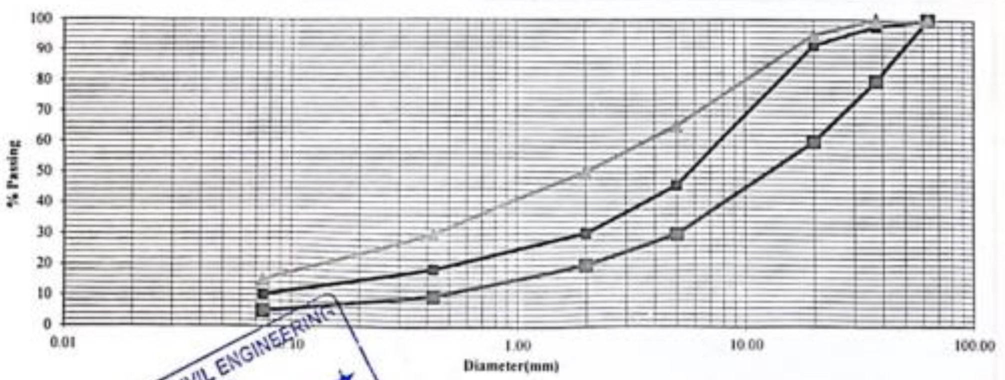
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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

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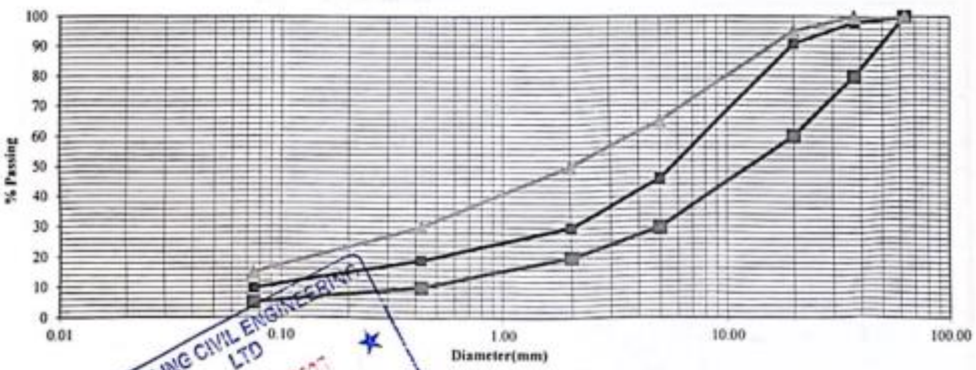
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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

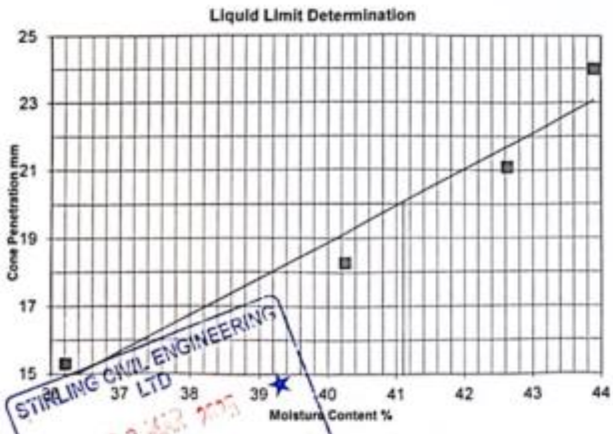
ATTERBERG LIMITS

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		

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

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

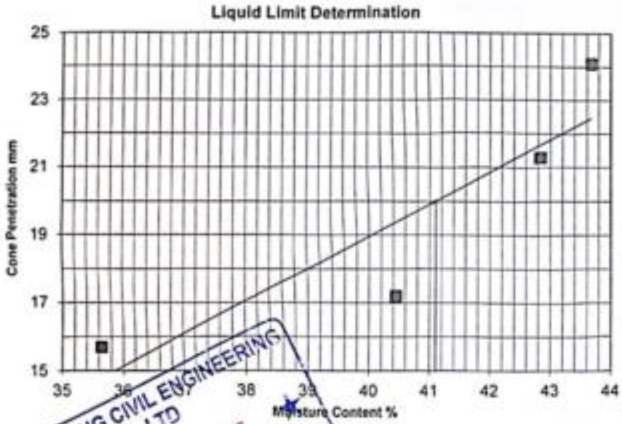
ATTERBERG LIMITS

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

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TESTING LAB	STUDENTS
Materials Engineer	
Lab Technician	

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INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	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

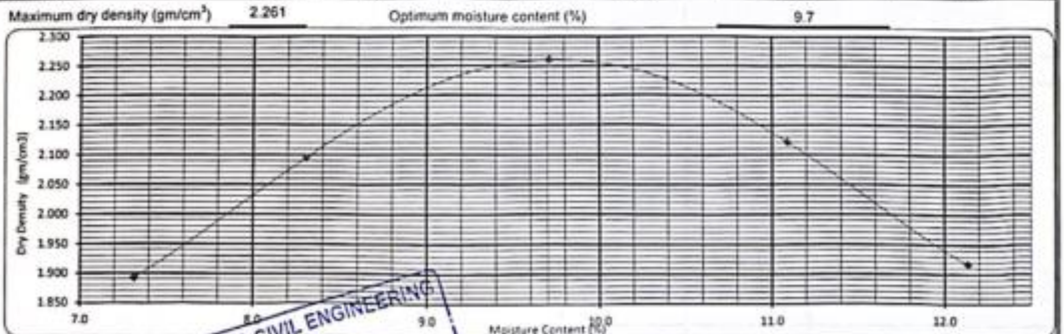
MOISTURE CONTENT DATA

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		

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

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Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	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*		

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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 *10³mm	Force (KN)	Reading *10³mm	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	[illegible]	[illegible]	20.9								

Observations			
For the Lab			**For the Students**
Lab. Technician			

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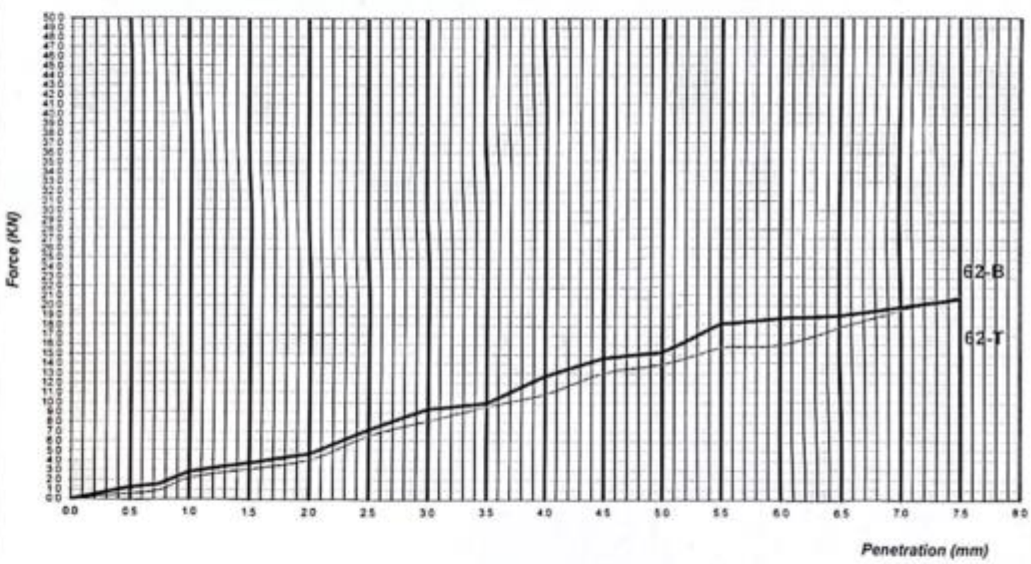
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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	[illegible]
Average	11.2	10.3	[illegible]	59.9
Retained CBR	65.4			
Observations	CBR= 65.4			

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

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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

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	4[illegible]	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

STIRLING CIVIL ENGINEERING LTD
KAMPALA (U)

Lab Technician

Materials Engineer

STUDENTS

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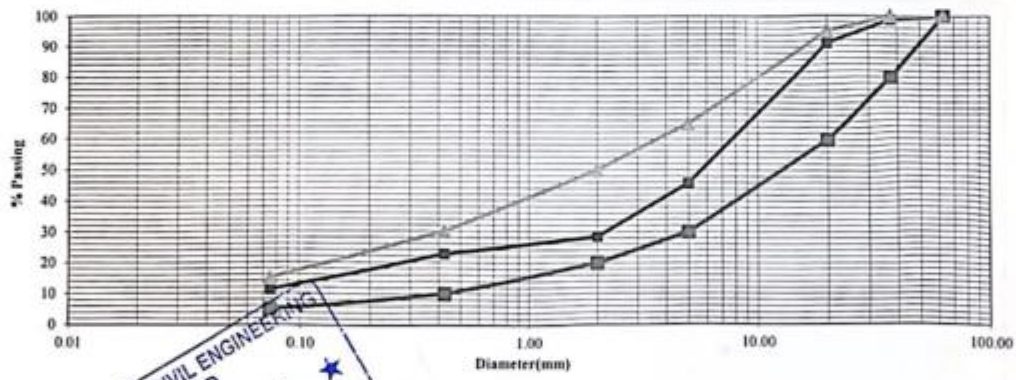
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD

P.O. BOX ... KAMPALA (U)

STUDENTS

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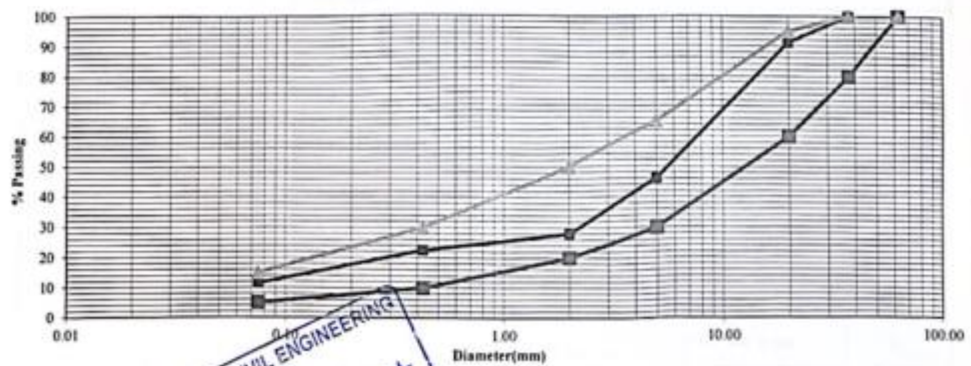
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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

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

Lab Technician

Materials Engineer

STUDENTS

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

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

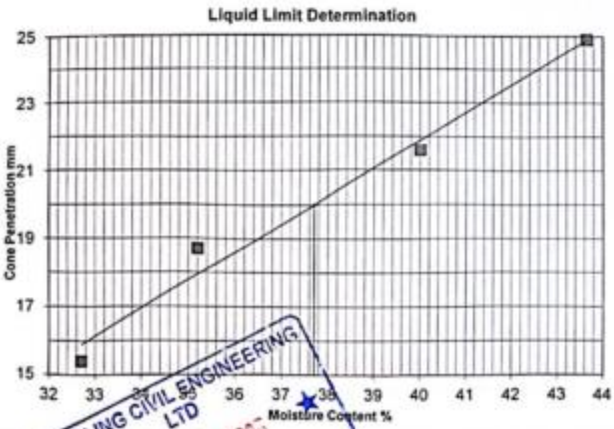
ATTERBERG LIMITS

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		STUDENTS
Materials Engineer		
Lab Technician		

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

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

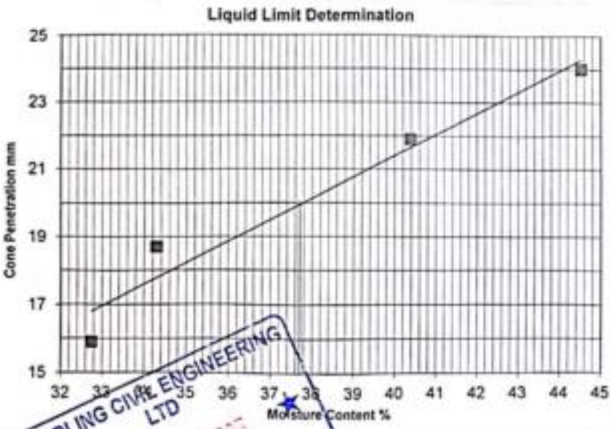
ATTERBERG LIMITS

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		

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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

SOIL TESTING LAB		STUDENTS
Lab Technician	Materials Engineer	

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Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	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						
Observation										

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

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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 $*10^3$mm	Force (KN)	Reading $*10^3$mm	Force (KN)
0	0	0	0.0	0	0.0
0.25	12	1	0.3	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	[illegible]	[illegible]	21.2

Observations

For the Lab	For Students
Lab. Technician	

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Materials Engineer
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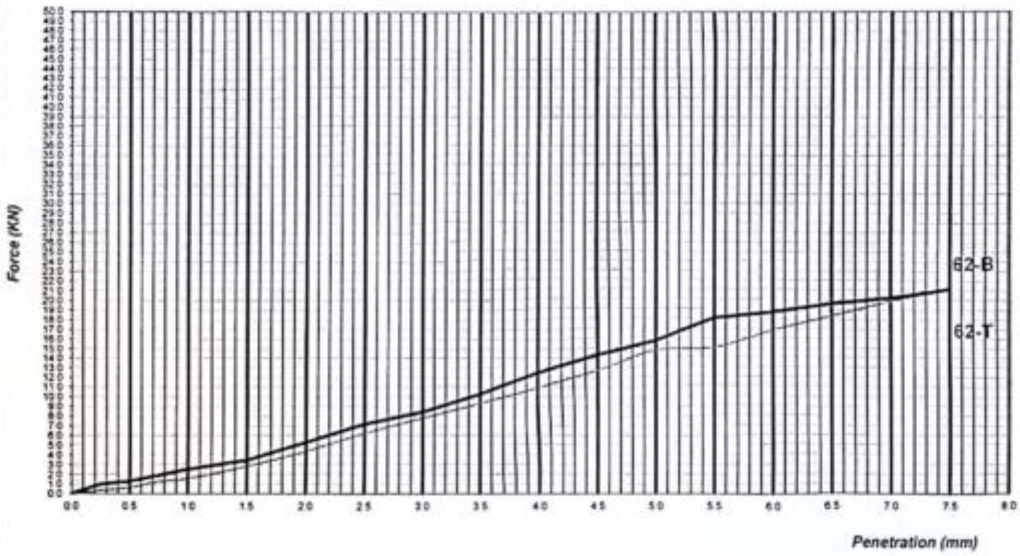
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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	[illegible]	78	[illegible]
Average	11.4	[illegible]0.5	66.2	60.3
Retained CBR	66.2			
Observations	CBR = 66.2			

For the Lab		For Students	
Lab. Technician	Materials Engineer		

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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

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 785, KAMPALA (U)

STUDENTS

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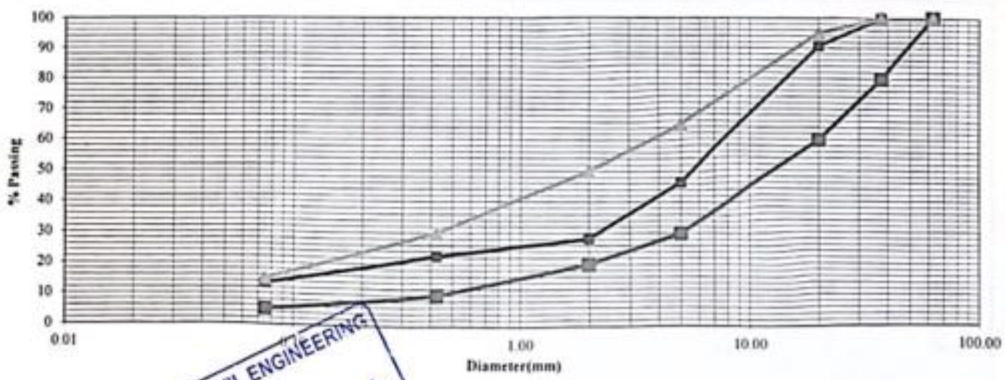
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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	STUDENTS
Lab Technician / Materials Engineer	

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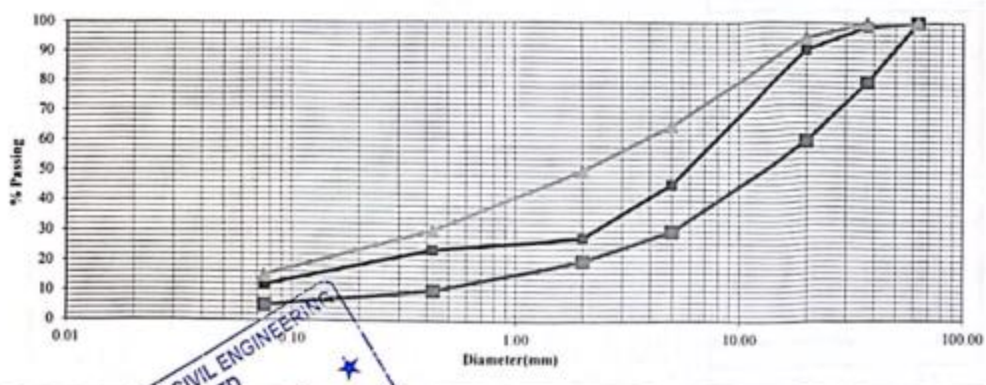
INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	SSEKKALABA ELVIS & KYALIGONZA GARY	Stirling

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

STIRLING CIVIL ENGINEERING LTD
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Lab Technician   Materials Engineer

STUDENTS

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

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

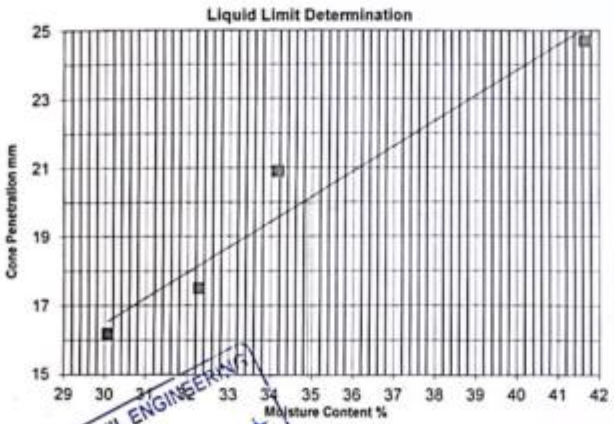
ATTERBERG LIMITS

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

TESTING LAB

Materials Engineer

Lab Technician

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

STUDENTS

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

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

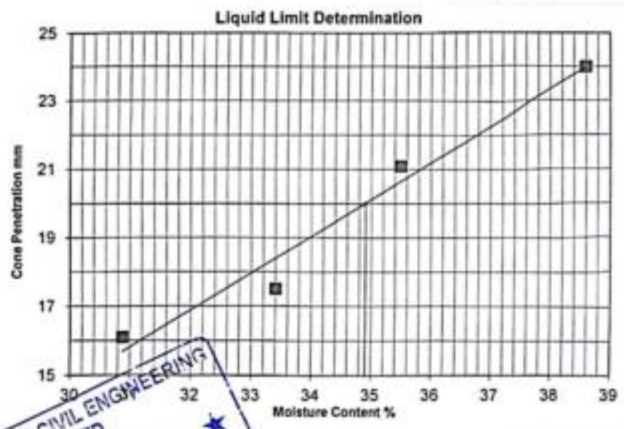
ATTERBERG LIMITS

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	14		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:

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

TESTING LAB		STUDENTS
Materials Engineer		
Lab Technician		

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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

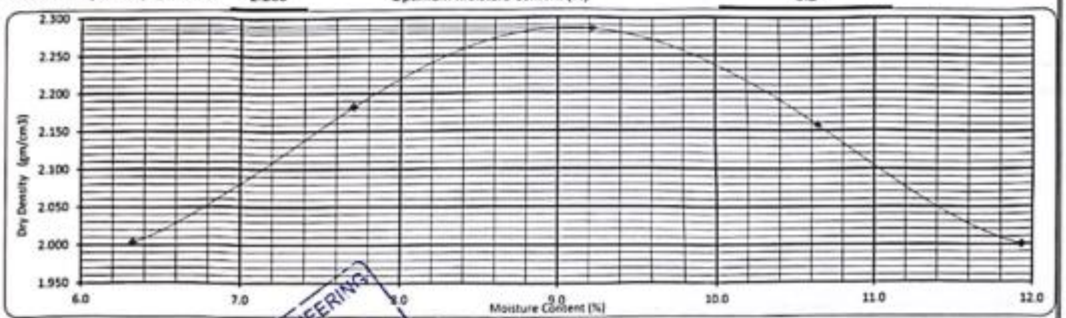
MOISTURE CONTENT DATA

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	21	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	

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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 (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*	

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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:	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 $*10^3$mm	Force (KN)	Reading $*10^3$mm	Force (KN)
0	0	0	0.0	0	0.0
0.25	12	1	0.3	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	[illegible]	65	20.3
7.5	354	[illegible]	21.2	[illegible]	21.2

Observations

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

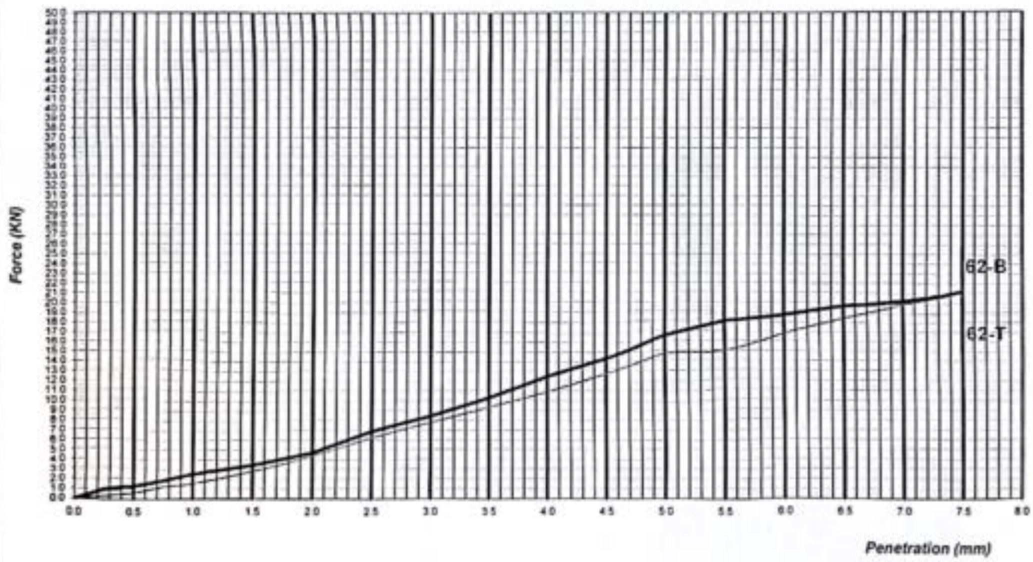
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	SSEKALABA ELVIS & KYALIGONZA GARY	Stirling

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	[illegible]	73
Average	11.7	[illegible]	67.3	60.[illegible]
Retained CBR	67.3			
Observations	CBR= 67.3			

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For the Lab		For Students	
Lab. Technician	Materials Engineer		

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ANNEX

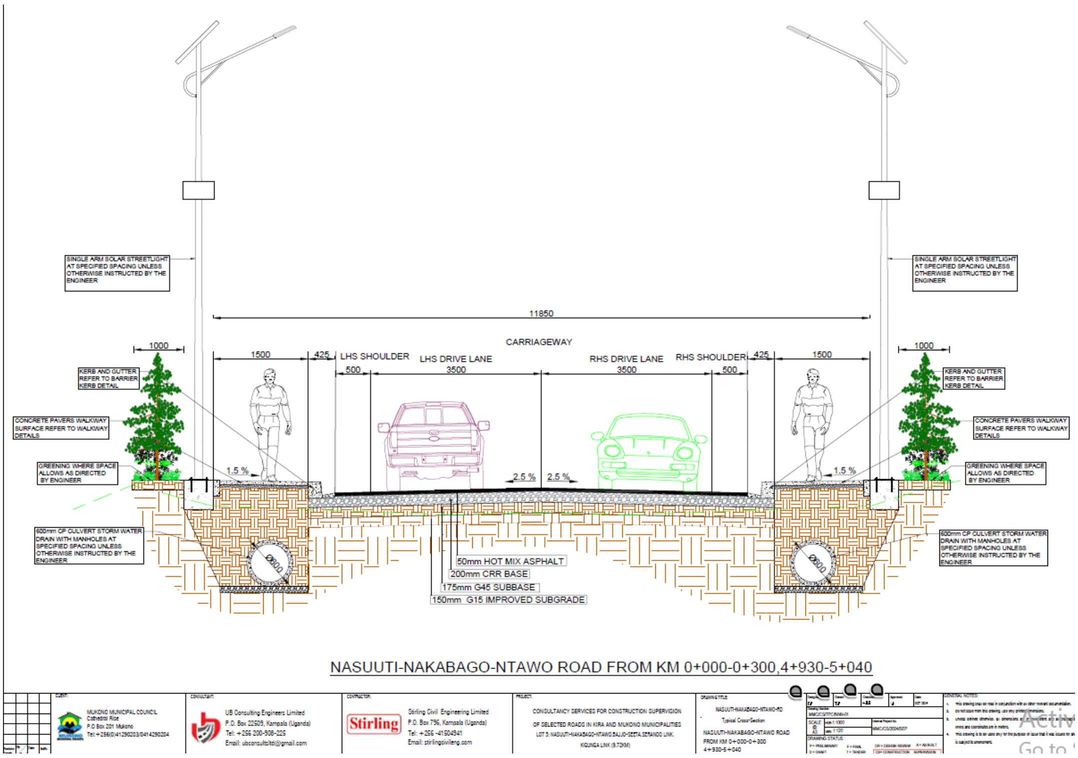

Figure 29: Original Nasuuti-Nakabago-Ntawo road design.

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%)

Figure 30: AASHTO classification.

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	*Fines are those materials smaller than No. 200 sieve size or 0.074mm size
			CH	Inorganic fat clays	
			OH	Organic silt and clays	
Highly organic soils			Pt	Peat and other highly organic soils	

. 31: USCS classification.

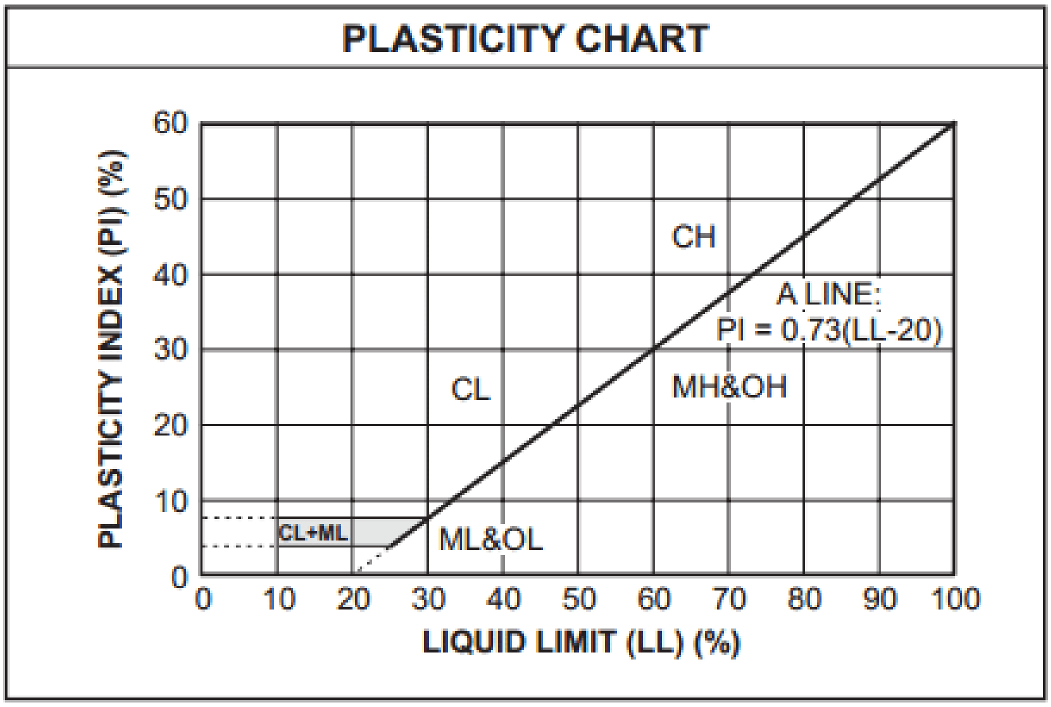

Figure 32: USCS plasticity.