

**INVESTIGATING THE USE OF RIVER SAND IN STABILISING EXPANSIVE SOILS
CASE STUDY: MOROTO-NADUNGET PAVEMENT SECTION**

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S20B32/010

**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, 2024



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ABSTRACT

The research carried out was aimed at improving the properties of expansive soils while using river sand for use in the subgrade soil layer. The research was guided by three specific objectives which included determining the engineering properties of the neat soils, determining the engineering properties of river sand and lastly determining the engineering properties of the river sand stabilized mix. The case study of the research was Moroto-Nadunget road section located in Moroto District and the river sand was bought along the banks of river Kangole from the locals. Furthermore, the study discussed about the sampling and preparation of the materials used. Different laboratory tests were carried out at Sterling laboratory while following the specific objectives stated in reference with the required standards of British Standards, General Specification MOW and others. Lastly different tests of CBR, MDD, PI were carried out on the stabilized river sand mix and at optimum river sand content of 20%, the mix had an MDD value of 1.889gm/cm³, CBR value of 33.8%, PI value of 16.1% which all lied in the required range for a subgrade soil layer. Hence making river sand a good mechanical stabilizer for expansive soils. For this research, some conclusions were drawn and as well recommendations for further research were given.

DECLARATION

I, **MWINE AMBROSE** hereby declare that this is my original work, is not plagiarised and has not been submitted any other institution for any award.

Signature:

Date:

MWINE AMBROSE

S20B20/010

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APPROVAL

I therefore approve that this report belongs to Mwine Ambrose bearing registration number S20B32/010 with this research project report being done under my supervision and is ready to be handed over to the Faculty of Engineering, Design and Technology in order for him to peruse a degree in Civil and Environmental Engineering at Uganda Christian University.

Signature:.....

Date:

JOSEPHINE RITAH NAKYEYUNE

Academic Supervisor

DEDICATION

I dedicate this work to my parents Mr. Tumwine Charles and Mrs. Tumwine Naome.

ACKNOWLEDGEMENTS

I first of all acknowledge God the almighty for enabling me to be able to finish this internship safe and sound. Thank you very much mummy and daddy Mr. and Mrs. Tumwine Charles and Naome who were behind the money, care that I received during this final year project. I would also like to thank my project partner Atemo Joan for working hand in hand with me to ensure that this research project comes to life. I also thank my academic supervisor Ms. Josephine Ritah Nakyeyune for guiding me during the course of my research. A special thank you to Mr. Martin and Mr. Kabiru at Sterling labs as well for helping and guiding me during the laboratory tests for my results.

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LIST OF ACRONYMS

BS	British Standard
CBR	California Bearing Ratio
DCP	Dynamic Cone Penetration
LL	Liquid Limit
MDD	Maximum Dry Density
OMC	Optimum Moisture Content.
PI	Plasticity Index
PL	Plastic Limit
PSD	Particle Size Distribution
SG	Specific Gravity
SL	Shrinkage Limit
SPT	Standard Penetration Test
USC	Unified Soil Classification

CHAPTER ONE: INTRODUCTION

1.1 Background

Relatively low bearing capacity, poor permeability, high compressibility, and a large volume change with changes in moisture conditions are characteristics of expansive soils (Jefferson & Lee D, 2012). The considerable amount of montmorillonite clay mineral present in expansive soil attributes to the high swelling and shrinkage properties (Etim, 2017). Because of their lattice structure, which permits water molecules to be absorbed between the layers, these clays have an expansive quality. The significant harm done to infrastructure—such as buildings, roads, and other manmade structures located on broad soil terrains—highlights these difficulties (Puppala & Congress, 2019). The detrimental impact of expansive soils is particularly evident in pavement structures, where the damage is estimated to reach staggering figures in the billions of dollars, surpassing even the economic losses attributed to natural disasters like floods (Lopez-Laza, et al., 2017).

Subgrade soils, or the soil beneath roads, are a major source of concern in Uganda. Changes in moisture cause the soil to expand and compress, causing cracks and uneven roads. Due to this instability, expensive repairs are required on a regular basis, which causes traffic jams and road closures. Structures constructed on expansive soils typically require \$9 to \$15 billion in upkeep each year, which is a very high cost (Tanyıldızı & Gökalp, 2023).

In Moroto district, the abundant number of rivers present and possess a very large amount of river sand provide a source of river sand that can act as an alternative for the unavailable borrow pit material which must be sourced from more distant places making the projects much more expensive in terms of transporting the borrow pit material and buying the borrow pit material. A need to mine this river sand and

use it in stabilising the expansive soils looks to be a much more viable reason to favour this research.

Owing to the increase in population coupled with the reduction of available land, a number of civil engineering structures are being established on weak or soft soils since the areas are all sitted on expansive soils making it hard to avoid the need to stabilise the soils (Kavish S, 2014). These soils can also, be found in arid or semi-arid soils where soils of even moderate expansiveness are seen to cause significant damage (Jefferson & Lee D, 2012). This research aims to investigate the effectiveness of using river sand as soil stabilizer for expansive soils in Uganda. The research will involve laboratory testing to evaluate the engineering properties of expansive soils treated with river sand. The tests will include the determination of soil strength, swelling potential, and permeability, among others. The results will be compared with those obtained from untreated expansive soils to assess the effectiveness of the soil stabilizers. This research will contribute to the development of sustainable and cost-effective solutions for the stabilization of expansive soils in Uganda. The findings of this research will be relevant for engineers, contractors, and policymakers involved in construction and infrastructure development in Uganda and other regions with similar soil conditions.

1.2 Problem statement

The swelling and shrinkage of subgrade layer composed of expansive soils results into pavement failure inform of the differential settlements and cracking (Ikechukwu, et al., 2021). Roads established on expansive subgrade soils have failed to fulfill their intended functions of accessibility and mobility, owing to their poor condition resulting from the pavement failure, to which the nature of the soil contributes to some extent (Ikeagwuani, 2019).

From the site visits carried out during the period between July-August, 2023, the section between Nadunget and Moroto town of the Soroti- Moroto road was seen to have experienced failure in the pavement evidenced by the cracks, extensive depressions and upheavals in the bituminous surfacing as shown in fig 1; below. From preliminary tests conducted on soil samples from different locations along the failed section at chainages of Km 0+900, Km 1+100, Km 4+400 and Km 7+000 while using the AASHTO standards, the Plastic Index values ranged from 23-32 which indicated a greater potential for soil to undergo significant volume changes (swelling and shrinking) with changes in moisture content. Liquid limit ranged from 56-64 which signified greater moisture sensitivity of the soils hence more prone to expansion. Percentage of particle passing the No. 200 sieve ranging from 70-85% and very low California Bearing Ratio value ranging from 1-2 at the 95 % compaction which meant that the soil has poor loadbearing capacity, which is a characteristic of expansive soils. A geological map showing the weak soils present in Moroto area gives a picture of the soil pattern in the location. This pattern points out the fact that the soils in this area of Moroto- Nadunget road section have extremely weak soils with a high clay content as demonstrated in the key on the map below;

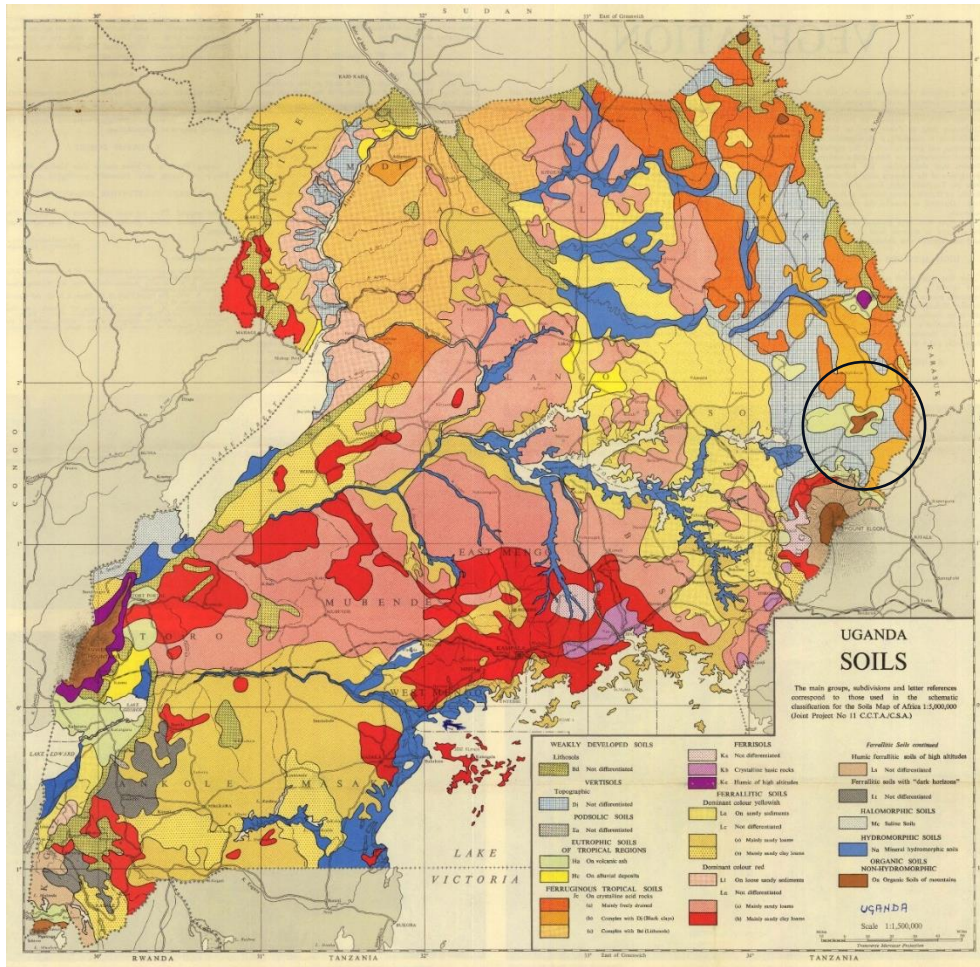


Figure 1 Pattern of the soil distribution in Uganda.

Source (European Commission, 2020).

The area highlighted with a circle on the map shows that the area of Moroto has soils is rich in high clay content making it highly expansive.

There is an interest to investigate the action of sand and other materials in stabilization trials (Fang, et al., 2019). This research therefore intends to investigate the use of river sand in the stabilization of expansive soils.



Figure 2 Pavement failure of one or the road sections of the Soroti Moroto road taken during one of the site visits.

1.3 Objectives

1.3.1 Main objective

To investigate the use of river sand in stabilising expansive soils.

1.3.2 Specific objective

1. To determine the engineering properties of the expansive soil.
2. To determine the engineering properties of river sand.
3. To determine the engineering properties of the river sand stabilized soil.

1.3.3 Research questions

1. What are the engineering properties of expansive soils?
2. What are the engineering properties of river sand?
3. What the engineering properties of the river sand stabilized soil?

1.4 Justification

Areas such as North eastern Uganda were most of soil cover is expansive, face the challenge of replacement of the problematic soils by suitable soil to obtain stable

subgrade layer onto which the other pavement layers are to be constructed. This is due to the high costs incurred in transportation of material from the borrow pit coupled with the long stretches for which the soil is to be replaced (Nagudi, 2020). In order to save these costs for transportation of material for the other pavement layers, engineers resort to stabilization or modification of the existing problematic soils. Owing to the presence of abundant rivers in the area which have a lot of river sand deposit (Kibuka, A.A & Jjuuko, 2023). This locally available material can be used to stabilize the expansive soil thus solve the challenge of looking for suitable soils from borrow pit in other regions. (Elsawy & Schanz, 2017).

Using the hydrological map of Karamoja Turkana region, a number of 7 major rivers namely River Moroto, River Kangole, River Depeth, River Kitorosi, River Acolcol, River Okere and River Okot (Swidiq M., 2014). These rivers dry up during the dry season leaving behind a large deposit of river sand that can be used for stabilising expansive soils (A. A. Kibuka & S. Jjuuko, 2023; Water Journalists Africa, 2020). Below is a hydrological map of the rivers in Moroto District as shown in the area highlighted;

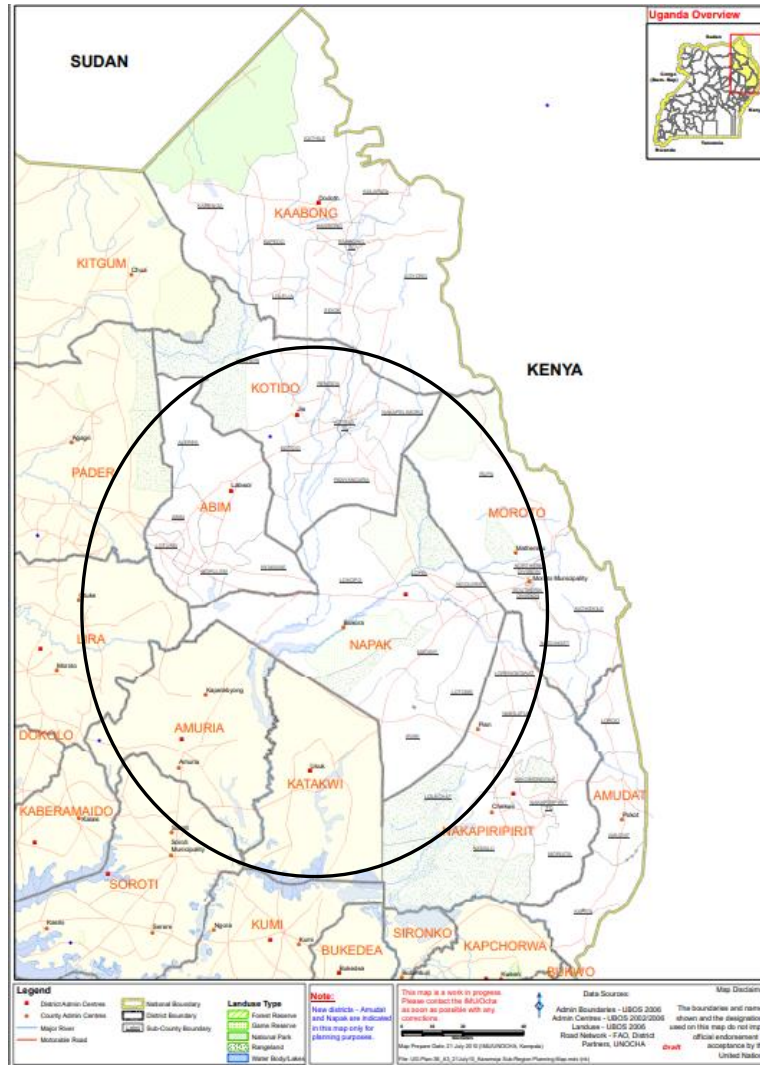


Figure 3 Map Karamoja sub-region, Uganda. Map of rivers in Moroto district Uganda.

Source: (Alan & Samuel, 2021).

River sand exhibits high load bearing capacity under confined conditions and can be used in varying proportions as an admixture to cohesive soils altering properties of plasticity, compaction and strength of the mixture (Khemissa, M, 2015). River sand decreases the plasticity of expansive soils through changes in particle size distribution and inter-particle interactions since plasticity in soils is associated with their ability to deform without fracturing (Zhang, et al., 2022). Expansive soils, rich in fine-grained clay particles, exhibit high plasticity due to the small size of these

particles and their ability to attract and hold water molecules, leading to swelling and shrinkage behaviors. When river sand is introduced to these soils it alters their composition by adding coarser and non-cohesive particles lowering the soil's overall plasticity because the sand particles do not exhibit the same water-attracting characteristics as clay.

The addition of sand also disrupts the close packing of clay particles, reducing their ability to bond tightly and form strong, water-retaining structures (Cuthbertson, et al., 2018). This modification reduces the soil's capacity to absorb and retain water, which is a significant contributor to the plasticity of clay-rich soils. Consequently, by diluting the fine-grained clay content and altering the soil structure, river sand effectively decreases the plasticity of expansive soils.

Additionally, river sand also has a well-graded particle size distribution which will be more effective in filling the voids between clay particles hence adding much-needed drainage and increasing the soil's permeability, allowing excess water to flow through the soil more easily. When used river sand will improve its drainage, the soil grading, strength and reduce the risk of surface cracking (Chian & Bi, 2021).

1.5 Scope

1.5.1 Geographical Scope

The soil sample was picked from Moroto-Nadunget road section located in Moroto District.

1.5.2 Content Scope

This research was focused on stabilising expansive soils with river sand by carrying out tests carried from Sterling laboratory to determine the weak properties present in the soil to be improved. The river sand from River Kangole was as well tested to

determine its properties and see whether it could be used to stabilise the expansive soils at Moroto-Nadunget road section.

1.5.3 Time Scope

The research project was conducted from October 2023 to April 2024 making a total of 6 months.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Soils are complex natural resources with varying physical and chemical properties. They are comprised of mineral particles, organic matter, water, and air, and their composition greatly influences their engineering behavior. The study of soil mechanics is crucial in various civil engineering projects, especially in construction, as the stability and durability of structures depend significantly on the properties of the underlying soil (Aboudi Mana, et al., 2017).

2.1.1 Expansive Soils

Expansive soils, also known as shrink-swell soils, are types of clay soils that significantly change in volume with changes in moisture content (Jefferson & Lee D, 2012). This property makes them highly problematic for construction projects, as they can exert immense pressure on foundations during wet periods and shrink during dry periods, leading to structural damage. The expansive nature of these soils is primarily due to the presence of minerals like smectite clays, which have a high affinity for water molecules, causing the soil to swell when hydrated and shrink when dehydrated. Both illite and montmorillonite are widespread in nature, though they tend to occur in different geological settings. Illite is commonly found in sedimentary rocks such as shale and in weathered volcanic rocks. On the other hand, montmorillonite is often abundant in soils derived from volcanic ash deposits and sedimentary rocks like bentonite. These minerals play essential roles in soil formation and composition, with their presence influencing the physical and chemical properties of the surrounding environment

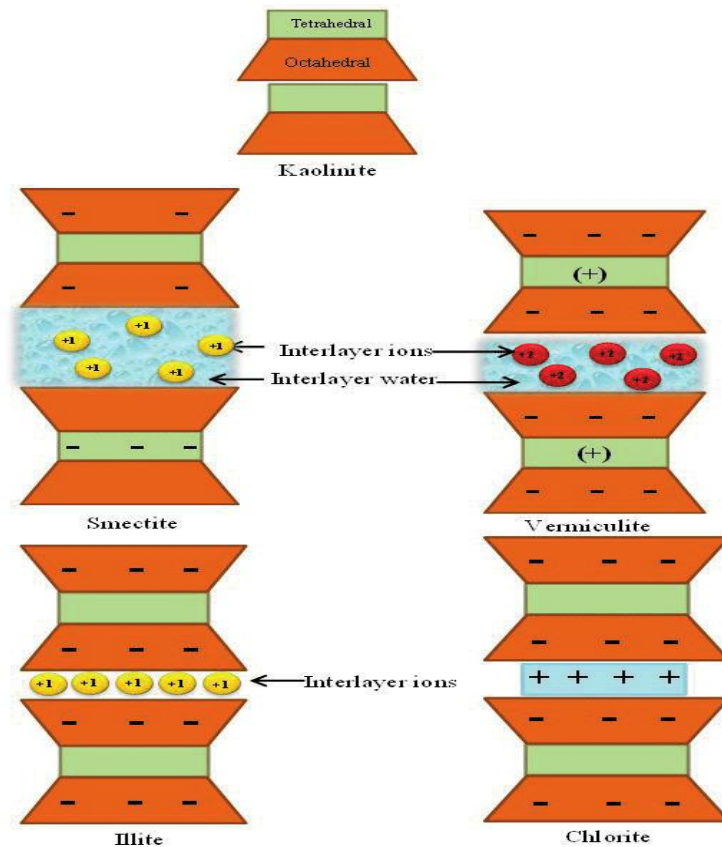


Figure 4 Structure of Kaolinite, Illite, Chlorite of clay.

Source (Firoozi & Baghini, 2016).

2.1.2 Subgrade

Subgrade soil, in the context of civil and geotechnical engineering, refers to the natural or compacted layer of soil that lies beneath a pavement structure, such as roads, highways, or other construction projects. It serves as the foundation for the overlying pavement and plays a crucial role in distributing loads from traffic and external forces (Kazmee & Tutumluer, 2015). The subgrade must possess sufficient load-bearing capacity to support the weight of vehicles and structures, preventing excessive settlement and deformation. Engineers focus on achieving proper compaction of the subgrade, managing moisture content, and ensuring uniformity in soil properties to enhance its stability and strength. The type of soil, whether it's clay, silt, sand, or gravel, influences its engineering characteristics, and in some

cases, additional treatments or improvements may be applied to optimize the subgrade's performance. Overall, the quality of the subgrade soil is fundamental to the long-term durability and stability of the entire pavement structure (Jegatheesan & Gnanendran, 2016). The performance of subgrade depends on upon the load bearing capacity, moisture content, strength of the subgrade soil and the additional base layers. The properties of the subgrade are key in the design of the pavement, thus weak subgrade material require higher thickness to protect it from pavement load. The subgrade properties and drainage are key influences to pavement deformation. The subgrade strength is normally assessed in terms of the California Bearing Ratio (CBR) which is dependent on the soil type, moisture content and its density (Nandiraju & Palat, 2020).

The table below summaries the minimum properties required for a soil to qualify as a subgrade material in pavement design.

Table 1 Specifications of subgrade material

Properties	standard
Soaked CBR after 4 days	15% minimum
Material class	G15 minimum
Plasticity index	6% max

Source; MoWT General Specifications, 2005

2.2.1 Categories of subgrade

There are three categories of subgrade and they include;

2.2.1.1 Category 1

These are subgrades in which the water table is sufficiently close to the ground surface to control the subgrade moisture content (Romanoschi . S.A, 2017).

1. In non-plastic soils the water table will dominate the subgrade moisture content when it rises to within 1 m of the road surface,
2. In sandy clays ($PI < 20$ per cent), when it rises to within 3m of the road surface,
3. In heavy clays ($PI > 40$ per cent), within 7m of the road surface.

2.2.1.2 Category 2

These subgrades are those with deep water tables and where rainfall is sufficient to produce significant changes in moisture conditions under the road. The rainfall in such areas is usually greater than 250 mm per year and is often seasonal (Romanoschi . S.A, 2017).

2.2.1.3 Category 3

These are subgrades in areas with no permanent water table near the ground surface and where the climate is dry throughout most of the year with an annual rainfall of 250 mm or less (Romanoschi . S.A, 2017).

2.2.2 Tests carried out to determine strength of subgrade.

Different tests can be carried out to determine the strength of subgrade and they include the following below (Shabbab Ajmi, et al., 2015).

2.2.2.1 Standard Penetration Test (SPT)

The Standard Penetration Test (SPT) is a widely used in-situ soil testing method to assess the subsurface conditions and the relative density of soils. It involves driving a thick-walled sampler (split-barrel sampler) into the ground at regular intervals using a standard weight dropped from a specific height. The number of blows required for the sampler to penetrate the soil by 300 mm is recorded and termed the "blow count" or "N-value." The SPT provides information about soil resistance at different depths, which aids in stratifying soil layers, evaluating soil consistency, determining soil bearing capacity, and assessing liquefaction potential. It is

commonly utilized in geotechnical investigations for foundation design, retaining walls, and evaluating the stability of slopes and embankments (Yusof & Zabidi, 2018).

The standard penetration test as already stated above enables engineers to obtain and know the parameters of soil in-situ e.g. to know the approximate strength of cohesive soils. It helps them to obtain the bearing capacity of soil and CBR of the soil in-situ.

The end goal of SPT is to obtain the SPT N value which is the sum of the number of blows required to drive the split spoon sampler into the drilled bore hole for the last 300mm every 150 mm (Osman. S, 2021).

It is from the SPT N Value that the bearing capacity and CBR of the soil in-situ is obtained.

2.2.2.2 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test evaluates the load-bearing capacity of subgrade soils for pavement design and construction. It involves subjecting a soil sample compacted at specified moisture content and density to incremental loading using a standard piston. The test measures the penetration resistance of the soil and compares it to the penetration of a standard material (typically crushed stone) to determine the CBR value. Higher CBR values indicate greater strength and better load-bearing capacity of the soil. CBR testing is crucial in designing flexible pavements, road construction, and determining the necessary thickness of pavement layers, ensuring adequate support and durability for traffic loads (Fondjo & Theron, 2021).

2.2.2.3 Dynamic Cone Penetrometer (DCP)

The Dynamic Cone Penetrometer (DCP) is a portable field test used to assess the in-situ strength and compactness of soils, particularly for preliminary evaluations of pavement subgrades, embankments, and shallow foundations. It involves driving a steel cone into the soil using repeated blows from a hammer dropped from a fixed height, measuring the penetration depth for each blow. The DCP provides a rapid assessment of the soil's stiffness, compactness, and bearing capacity by correlating the penetration depth to the number of blows. It is a quick, cost-effective method for assessing the relative strength of soils in the field and is often used for initial site investigations, quality control during construction, and in road maintenance to identify areas needing improvement or reinforcement (Zimar & Robert, 2022).

2.3 STABILISATION

Soil stabilization is the alteration of soils to enhance their physical properties by improving the engineering properties of soil, making it more stable, durable, and suitable for construction purposes (Michael, et al., 2014).

2.3.1 Guide for selection of stabilizers.

There are different parameters followed when selecting a chemical stabilizer (General Specification MOW, 2005).

For a material more than 25% passing through a 0.075mm sieve;

1. If the material is less than 10% use cement preferably.
2. If the material is between 10% and 20% use lime and or cement.
3. If the material is more than 20% use lime preferably.

2.3.2 Methods for Stabilizing Expansive Soils.

2.3.2.1 Chemical Stabilization

1. Hydrated Lime stabilisation

Hydrated lime, or calcium hydroxide, is a widely used chemical additive for soil stabilization. The process begins with the careful mixing of lime with the soil at pre-determined proportions based on engineering requirements. Lime reacts with the clay minerals in the soil, initiating pozzolanic reactions. In this reaction, lime reacts with the silica (SiO_2) and alumina (Al_2O_3) present in clay minerals to form calcium silicate hydrates and calcium aluminate hydrates, similar to the hydration products in Portland cement. This effectively reduces the plasticity and swell-shrink behavior of the soil. When mixed with expansive soils, hydrated lime reacts with clay minerals, modifying their properties (Siddharth, et al., 2019). It reduces the plasticity and swelling potential of clay soils, making them more stable for construction. The chemical reaction between hydrated lime and clay minerals alters the mineralogy of the soil, enhancing its loadbearing capacity and reducing its susceptibility to moisture changes. The overall stabilization mechanism involves a combination of pozzolanic reactions and lime hydration, resulting in the formation of stable compounds that enhance the geotechnical properties of expansive soils (Poulose & Babu, 2018).

% OF LIME	L.L	PL	PI
0%	49.8%	18.7%	31.1
2%	11.9%	4.57%	7.33
4%	10.86%	5.54%	5.32
6%	11.72%	5.85%	5.87
8%	16.82%	6.46%	10.36

Figure 5 Different percentages of lime and how much they improved the expansive soil when blended.

Source (Beetham & Dijkstra, 2015).

2. Cement stabilisation

Stabilizing expansive soil using cement is a widely employed geotechnical engineering technique that aims to mitigate the detrimental effects of soil expansion and contraction. Expansive soils, often rich in clay minerals, exhibit significant volume changes in response to variations in moisture content, leading to undesirable swelling and shrinkage behavior. Cement stabilization involves the addition of cementitious materials to the soil, typically in the form of Portland cement, to enhance its engineering properties such as by reducing the plasticity and also creating an agglomerated structure of calcium silicate hydrates which bound the surrounding particles strongly hence reducing its susceptibility to moisture-induced movements (Mahedi, et al., 2018).

The process begins by thoroughly mixing the cement with the expansive soil at predetermined proportions based on engineering specifications. The cementitious material binds with the clay particles, creating a more stable matrix that is less prone to volume changes (Chikyala, et al., 2023). The chemical reactions between the cement and soil particles result in the formation of cement hydrates, which strengthen the soil structure and improve its load-bearing capacity. This treatment effectively reduces the soil's plasticity and swelling potential, transforming it into a more stable and resilient foundation material.

Additionally, cement stabilization enhances the soil's resistance to erosion and improves its durability over time. The treated soil becomes less susceptible to water penetration, minimizing the adverse effects of moisture fluctuations. The success of cement stabilization depends on factors such as the type and dosage of cement used, proper mixing techniques, and adequate curing conditions. According to past research, cement has been added to lime while stabilizing expansive soils to curb

the challenge of sulphate attack that is responsible for failure of subgrade soils stabilized by lime alone. The cement acts as a pozzolan which reacts with the excess calcium ions that remained unreacted after the hydration process (Puppala, et al., 2014).

This method is commonly employed in road construction, foundation engineering, and other civil engineering projects to create a solid and reliable foundation on expansive soils. Overall, cement stabilization offers a cost-effective and sustainable solution to address the challenges posed by expansive soils in geotechnical engineering.

3. Fly Ash stabilisation

The utilization of fly ash for stabilizing expansive soils is a well-established geotechnical practice that involves several key steps to mitigate the detrimental effects of soil expansion and contraction (Mahdi, et al., 2020). The process is typically carried out in the following detailed manner;

Soil Analysis: Before stabilization, a comprehensive analysis of the expansive soil's properties is conducted. This includes assessments of plasticity, grain size distribution, mineralogy, and moisture content. Understanding the soil's characteristics is crucial for determining the appropriate dosage and treatment methodology (Zhou & Giustozzi, 2022).

Selection of Fly Ash Type: Different types of fly ash exist, primarily Class C and Class F, each with distinct chemical compositions. The selection depends on factors such as the soil type and project requirements. Class C fly ash contains a significant amount of lime, contributing to both pozzolanic and cementitious reactions. Class F fly ash is low in lime but high in silica and alumina, enhancing its pozzolanic characteristics (Mahdi, et al., 2020).

Mix Design: Based on the soil analysis and fly ash type, a mix design is established to determine the optimal ratio of fly ash to soil. This ratio influences the chemical reactions and physical properties of the stabilized soil. Laboratory tests, including compaction and unconfined compressive strength tests, help establish the most effective mix design.

Application of Fly Ash: The selected fly ash is uniformly mixed with the expansive soil using conventional construction equipment, such as graders or mixers. The mixing process ensures thorough distribution of fly ash throughout the soil matrix.

Curing: After mixing, the stabilized soil is subjected to a curing period, allowing the chemical reactions between the fly ash and soil minerals to take place. Curing duration is crucial for the development of strength and stability in the treated soil.

Testing and Quality Control: The stabilized soil is subjected to various laboratory tests, including California Bearing Ratio (CBR) tests, triaxial tests, and swell-shrink tests, to assess changes in engineering properties such as strength, compressibility, and volumetric stability. Quality control measures are implemented to ensure the effectiveness of the stabilization process (Zhou & Giustozzi, 2022).

2.3.2.2 Mechanical stabilization

Owing to the fact that most of the chemical stabilization techniques are costly and are inhibited by a number of environmental conditions such as temperature, sulphides, freeze-thaw and dry-wet effect and organic matter (Sherwood P., 2016), for example, calcium-based stabilizers such as lime and cement are susceptible to sulphate conditions (Sridharan A., 2023).

Mechanical stabilization is accomplished by mixing or blending soil of two or more gradation to obtain a material that meets the required soil properties. The main objective is to improve the stability and load bearing capacity of soil. Mechanical

stabilization produces the desired engineering properties by compaction of the soil aggregate particles to achieve a dense soil mass. Additional fines may be blended before compaction to form a uniform, well-graded, dense soil-aggregate mixture after compaction. The choice of methods should be based on the gradation of the material.

Mechanical stabilization on the other hand is the process of enhancing the properties of soil by changing its gradation and thus not susceptible to environmental conditions. The soil's stability in this method relies on the inherent properties of the soil material. Stabilization is accomplished by mixing or blending two or more types of natural soils of more gradation to obtain a composite material which is superior to any of its components (Habita A., 2017).

2.3.3 Engineering Properties of river sand.

Some of the properties possessed by river sand include (Wijepala & Jayakody, 2019).

1. Porosity

River sand typically has a high porosity, allowing water and air to pass through easily.

This characteristic aids in drainage and reduces the risk of waterlogging in the soil (Wijepala & Jayakody, 2019).

2. Density

The density of river sand is relatively high, contributing to the stability of the soil structure when used as a stabilizing agent. Compacted sand enhances the load-bearing capacity of the soil (Wijepala & Jayakody, 2019).

3. Cohesion and Internal Friction

River sand particles generally have low cohesion but exhibit internal friction, which provides stability to the soil mass. This internal frictional resistance is vital in preventing soil erosion and landslides (Wijepala & Jayakody, 2019).

2.3.3.1 Composition of river sand.

The chemical composition of river sand can vary depending on its geological source. However, typical river sand is primarily composed of silica, which is usually in the form of quartz. The main components of river sand include (Pearson & Verney, 2021).

1. Quartz: This is a dominant component of river sand that is a hard and transparent mineral resistant to weathering.
2. Aluminum Oxide: River sand may contain varying amounts of aluminum oxide, which is commonly present as minerals like feldspar or clay minerals (Pearson & Verney, 2021).
3. Iron Oxide: The presence of iron oxide imparts a color to the sand with different shades of beige to light brown or red depending on the amount of iron present.
4. Calcium Oxide: The small amounts of calcium oxide may be present in river sand especially in minerals like calcite.
5. Magnesium Oxide: Similarly, small amounts of magnesium oxide may be found in river sand, often associated with minerals like olivine.
6. Potassium Oxide and Sodium Oxide: These alkali oxides may be present in minor amounts, commonly associated with feldspar minerals.
7. It's important to note that the exact composition of river sand can vary widely based on the geological characteristics of the riverbed from which it is sourced. Local variations in mineral content, weathering processes, and

geological history can influence the specific composition of river sand in different regions. Analytical techniques such as X-ray diffraction (XRD) or chemical analysis can provide more precise information about the mineral content of a particular sample of river sand (Schneider & Hornung, 2016).

2.3.3.2 Formation process of river sand.

River sand originates through a natural progression of geological processes. It all begins with the weathering of rocks, where external forces like wind, water, and temperature changes break down rocks into smaller particles. These weathered rock pieces, including sand-sized grains, are then carried downstream by rivers or streams. During this journey, water acts as a vital agent, smoothing and rounding the particles. As the river's flow slows down, sediment, including sand, is deposited along the riverbed. In these lower energy areas, sand particles undergo sorting based on size and density. Over time, additional layers of sediment accumulate, and the weight of the overlying material compacts the lower layers (Bello-Palacios & Almenningen, 2021). This compaction, along with potential cementation by minerals like silica or calcium carbonate, binds the sand grains together. With ongoing pressure and compaction, loose sand sediment transforms into sandstone through a process called lithification. Eventually, exposed sandstones undergo erosion, releasing sand particles back into the sediment cycle and continuing the geological journey of river sand (Yang & Shi, 2019).

2.3.3.3 Role of river sand in soil Stabilization

Sand is a naturally occurring granular material. Since it exhibits high load bearing capacity in confined conditions, it can be used in varying proportions as an admixture to cohesive soils altering properties of plasticity, compaction and strength of the mixture (Khemissa M., 2015). According to findings there was a substantial

improvement in strength with the addition of sand percentage up to 60% by weight of soil, as well as noticeable alteration in Atterberg limits, with decrease in linear shrinkage by 42% (Kallaros G. & Athanasapoulou A., 2016). Thus recommended the mix to be used as subgrade for construction of flexible pavements in rural roads with low traffic volume.

River sand is commonly used in soil stabilization techniques due to its excellent drainage properties, high compaction ability, and compatibility with various soil types. When mixed with expansive soils, river sand improves the soil's engineering properties, mitigating issues related to swelling and shrinkage (Khemissa, M, 2015).

CHAPTER THREE: METHODOLOGY

3.0 Introduction

This chapter gives a brief account on how the materials will be acquired, the sampling and the laboratory tests in order to achieve the objectives of the research project. In order to yield results to aid explain the research phenomenon, standard tests and procedures will be executed during the study and are further broken down below.

3.1 Material acquisition and preparation

3.1.1 Expansive soil

The expansive soil samples were extracted from the Moroto-Nadunget road section of the Soroti- Moroto road, with each sample weighing approximately 200kg, it was then securely packed in air-tight sacks immediately after collection, ensuring that the samples remain uncontaminated and undisturbed during transportation. These sacks were carefully labeled with crucial information, including the date of sampling, the specific depth at which the samples were collected during open excavation (0m to 1m below ground level), and a concise description of the soil's color, texture, and moisture content. Careful attention was taken to prevent spillage and maintain the integrity of the samples during transportation to the Sterling laboratory. Upon arrival at the laboratory, the sealed sacks were opened under controlled conditions to avoid any potential contamination. Subsequently, the soil samples were spread uniformly on trays to undergo a thorough air-drying process, allowing them to reach a consistent moisture level. Following the drying process, any lumps or aggregates within the soil samples were carefully broken down into smaller particles to prepare the samples adequately for the subsequent tests. These systematic procedures guaranteed the reliability and accuracy of the soil analyses

conducted at the laboratory, ensuring that the results were a representative of the actual soil conditions at the specified locations and depths.

3.1.2 River sand

60 kilograms of sand were bought from the miners located at the banks of River Kangole with co-ordinates 2° 18' 54" N and 34° 36' 49" E were after the sand was transported to the Sterling laboratory in Mukono after being carefully packed and sealed in appropriate containers.

3.2 Sample preparation

3.2.1 Soil sample

The soil sample was spread on trays and left to air dry for about 3 days and partitioned for various tests.



Figure 6 Air drying of the river sand.

3.3 Experiments

In order to achieve the objective of the study, various tests will be carried out.

3.3.1 Tests on the expansive soils.

3.3.1.1 Particle size distribution using the wet sieving method with reference to BS 1377: part 2:1990

The test was to aid in the classification of the soil since it provided an overview of the relative portions of the different sizes of particles present in the soil sample. From this we could determine whether the soil consists of predominantly gravel, sand, silt or clay particle sizes and which of these particles is likely to influence the engineering properties of the soil.



Figure 7 Weighing of the sample retained on the sieves during gradation.

3.3.1.2 Liquid limit test using cone penetration method as per BS. 1377 part 2:1990

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



Figure 8 Preparation of the sample for the atterberg limits.

3.3.1.3 Plastic limit with reference with BS. 1377: part 2:1990

The plastic limit was the moisture content for which the soil became plastic. It was used together with the liquid limit to determine the plasticity index. The plasticity index when plotted against the liquid limit on the plasticity chart provided a means of classifying cohesive soils. The plasticity index was the difference between the liquid limit and the plastic limit.

3.3.1.4 Linear shrinkage test with reference to BS. 1377: part 2 1990

Shrinkage in soil occurs due to drying and it is significant in clays and less experienced in silts and sands. Linear shrinkage is decrease in the length of wet soil after drying. The test is a way of quantifying the amount of shrinkage likely to be experienced especially when dealing with expansive soils.

The test provided a means of quantifying the amount of shrinkage that is likely to be experienced by the soil. The shrinkage limit test works under the principle that the water retaining soil type undergoes significant decrease in size when the water contained within dries up. The level of shrinkage can be measured relative to a standard half cylindrical shrinkage mould 140mm long with 40mm diameter.

3.3.1.5 Compaction test (proctor) with reference to BS. 1377: part 4:1990

The degree of compaction applied together with the moisture content determined the dry density which could be achieved for a soil.

The moisture content which gave the highest dry density was referred to as the optimum moisture content for that type of compaction. The test aimed at obtaining the relationship between the compacted density and soil moisture content. The test provided a guide for specifications on field compaction.

3.3.1.6 California bearing ratio, using the one-point method with reference to BS. 1377 part4:1990

To test for strength of a soil sample the CBR test was used especially when designing for pavement material of natural gravel. The strength of materials of natural gravel was expressed in terms of their CBR value. The CBR value was the resistance chosen at a penetration of 2.5mm or 5mm of a standard cylindrical plunger of 50mm diameter, expressed as a percentage of the known resistance of the plunger to 2.5mm in penetration in crushed aggregate.



Figure 9 Four days soaking of CBR.

3.3.1.7 CBR swell with reference to BS. 1377 part4:1990.

The CBR swell methodology, investigated the systematic analysis of expansive subgrade soils to determine their swell potential. Laboratory testing, encompassing careful sample preparation and comprehensive data collection, was conducted to evaluate the relationship between California Bearing Ratio (CBR) values and soil swell under varying moisture conditions. The study aimed to establish a reliable method for assessing subgrade soil stability, providing valuable insights into the soil's ability to withstand swelling pressures.

In this test, a soil specimen was compacted at standard Proctor moisture content and density is subjected to increasing compressive loads at a constant rate.



Figure 10 Trimming of the mould after compaction.

3.3.2 Tests on sand

Sand was tested to ensure that it meets the required specifications and standards for its intended use. For the research study, the tests considered include; specific gravity, grain size analysis, finess modulus and silt content.

3.3.2.1 Bulk specific gravity test in reference with ASTM C 128-97

Bulk specific gravity is the ratio of weight of a given volume of aggregates to the weight of an equal volume of water. When it comes to road construction the specific gravity of fine aggregates normally used ranges from 2.4-3.0 with an average of

about 2.68. It is a measure of the quality of the material aggregates having low specific gravity are generally weaker than those with high specific gravity. It informed of the sand's potential to support structural loads and its porosity.

3.3.2.2 Grain size analysis in reference with BS 882-1992

The test was conducted to determine the particle size distribution of the sand. It reflected on the sand's particle size and shape, and these parameters were responsible for its strength, stability and porosity. The grading of sand was classified considering the percentage of sand that passed through the different sieve sizes. Sand that has a uniform particle size distribution is classified as well graded, on the other hand sand that contains a wide range of particle sizes is classified as poorly grade.

3.3.2.3 Silt content in reference with ASTM C40

The test was conducted to determine the amount of silt particles present in the sand. Silts refers to fine -grained particles that are smaller than sand particles but lager than clay particles. They are known to affect the strength of sand and can result into poor compaction, reduced shear strength and increased settlement. The ASTM standard limits the silt content of sand used for construction purpose to a maximum of 8%.

3.3.2.4 Water Absorption in reference with ASTM C 128-97

Water absorption test on river sand involved immersing a sample of the sand in water and measuring the amount of water absorbed over a specific period. The process was carried out by placing a known quantity of dry river sand into a container and adding water until the sand was fully submerged. After a predetermined soaking time, typically ranging from a few minutes to several hours, the sand was removed from the water, and any excess water on the surface was carefully drained. The wet

sand was then weighed to determine the increase in weight, indicating the amount of water absorbed. This test provided valuable information about the porosity and permeability of the river sand, which is crucial for various engineering and construction applications, such as determining its suitability for concrete or mortar mixes, filtration systems, or landscaping projects.

3.3.3 Experiments on stabilised mix

3.3.3.1 Particle size distribution using the wet sieving method with reference to BS 1377: part 2:1990

Since the test gave a general picture of the relative amounts of the various sizes of particles contained in the soil sample, it helped with the stabilised soil mix classification. This allowed us to ascertain whether the river sand was able to stabilize the blended mix and whether the soil is now mostly composed of gravel, sand, silt, or still more clay particle sizes.

3.3.3.2 Liquid limit test using cone penetration method as per BS. 1377 part 2:1990

The liquid limit was the moisture content for which the stabilised soil mix passed from liquid state to plastic state. It enabled the identification and classification of the stabilized soil mix.

3.3.3.3 Plastic limit with reference with BS. 1377: part 2:1990

The moisture content at which the stabilized soil mixture turned plastic was known as the plastic limit. To calculate the plasticity index, it was combined with the liquid limit. Cohesive soils could be categorized using the plasticity index by plotting it against the liquid limit on the plasticity chart. The difference between the liquid and plastic limits was known as the plasticity index.

3.3.3.4 Linear shrinkage test with reference to BS. 1377: part 2 1990

Shrinkage in soil occurs due to drying and it is significant in clays and less experienced in silts and sands. Linear shrinkage is decrease in the length of wet soil after drying. The test is a way of quantifying the amount of shrinkage likely to be experienced especially when dealing with expansive soils.

The test provided a means of quantifying the amount of shrinkage that is likely to be experienced by the soil. The shrinkage limit test works under the principle that the water retaining soil type undergoes significant decrease in size when the water contained within dries up. The level of shrinkage can be measured relative to a standard half cylindrical shrinkage mould 140mm long with 40mm diameter.

3.3.3.5 Compaction test (proctor) with reference to BS. 1377: part 4:1990

The degree of compaction applied together with the moisture content determined the dry density which could be achieved for the stabilized soil mix.

The moisture content which gave the highest dry density was referred to as the optimum moisture content for that type of compaction. The test aimed at obtaining the relationship between the compacted density and soil moisture content. The test provided a guide for specifications on field compaction.

3.3.3.6 California bearing ratio, using the one point method in reference with BS. 1377 part4:1990

The CBR test was utilized, particularly when developing for stabilized mix material, to determine the strength of a soil sample. The CBR value of stabilized mix materials was used to express their strength. The CBR value was the resistance, given as a percentage of the known resistance of the plunger to 2.5mm in penetration in crushed aggregate, selected at a penetration of 2.5mm or 5mm of a conventional cylindrical plunger of 50mm diameter.

It informed of the highest axial compressive stress that, in the absence of constraining tension, a cohesive soil specimen could bear. It is a measurement for stabilised soil mix strength. The specimen that had been prepared, mixed, compacted, and cured was subjected to increasing loads until it failed.

3.3.3.7 CBR swell with reference to BS 1377 part4:1990.

The river sand stabilized mix's swell potential was examined through a thorough investigation using the CBR swell approach. The association between California Bearing Ratio (CBR) values and soil swell under various moisture conditions was assessed through laboratory research that involved meticulous sample preparation and thorough data gathering. In addition to offering important insights into the soil's capacity to tolerate swelling pressures, the study sought to develop a dependable technique for evaluating subgrade soil stability.

CHAPTER FOUR: RESULTS AND DISCUSSIONS.

4.0 Introduction

This chapter explains the test results and analysis of the different experimental works while stabilizing expansive soils with river sand.

4.1 Engineering properties of the expansive soils.

4.1.1 PARTICLE SIZE DISTRIBUTION

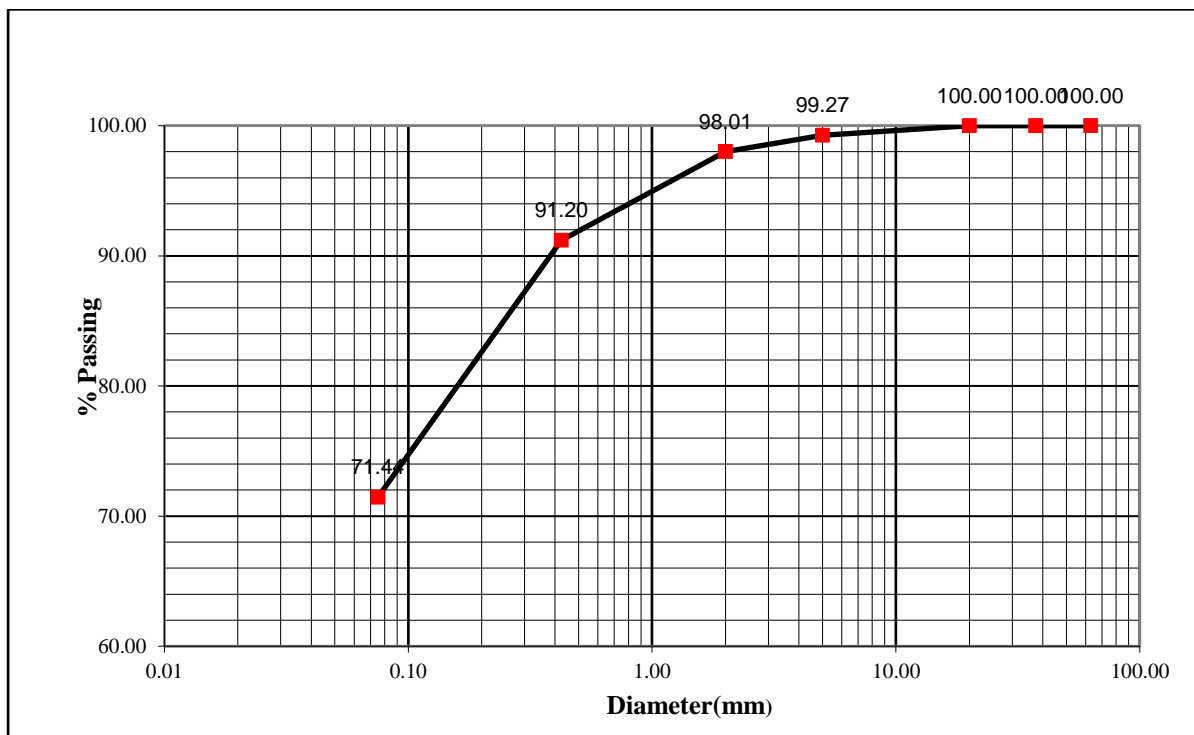


Figure 11 A graph of the PSD of the neat soil sample.

The shape of the curve appears like a c shape rather than a straight horizontal line is because it represents a full range of different particle sizes of the neat soil sample unlike if there was a uniform particle size in the whole neat sample where it would appear as one straight line.

At sieve size 0.075mm, the percentage passing is 71.44% while the percentage retained is 28.56% indicating that the particles are more of fine grained than coarse since the percentage of 71.44% passing is larger than percentage of 28.56% retained.

In accordance to the Unified Soil Classification System (USCS), the soil was determined to be fine grained since the percentage passing through the 0.075mm sieve (71.44%) was more than that retained on the 0.075mm sieve (28.56%).

Criteria for assigning group symbols				Group symbol
Coarse-grained soils More than 50% of retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels	$C_u \geq 4$ and $1 \leq C_c \leq 3^c$	GW
		Less than 5% fines ^a	$C_u < 4$ and/or $1 > C_c > 3^c$	GP
	Sands 50% or more of coarse fraction passes No. 4 sieve	Gravels with Fines	$PI < 4$ or plots below "A" line (Figure 5.3)	GM
		More than 12% fines ^{a,d}	$PI > 7$ and plots on or above "A" line (Figure 5.3)	GC
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands	$C_u \geq 6$ and $1 \leq C_c \leq 3^c$	SW
		Less than 5% fines ^b	$C_u < 6$ and/or $1 > C_c > 3^c$	SP
Sands with Fines		$PI < 4$ or plots below "A" line (Figure 5.3)	SM	
	More than 12% fines ^{b,d}	$PI > 7$ and plots on or above "A" line (Figure 5.3)	SC	
Fine-grained soils 50% or more passes No. 200 sieve	Silts and clays Liquid limit less than 50	Inorganic	$PI > 7$ and plots on or above "A" line (Figure 5.3) ^e $PI < 4$ or plots below "A" line (Figure 5.3) ^e	CL ML
		Organic	$\frac{\text{Liquid limit — oven dried}}{\text{Liquid limit — not dried}} < 0.75$; see Figure 5.3; OL zone	OL
	Silts and clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line (Figure 5.3) PI plots below "A" line (Figure 5.3)	CH MH
		Organic	$\frac{\text{Liquid limit — oven dried}}{\text{Liquid limit — not dried}} < 0.75$; see Figure 5.3; OH zone	OH
	Highly Organic Soils	Primarily organic matter, dark in color, and organic odor		Pt

^aGravels with 5 to 12% fine require dual symbols: GW-GM, GW-GC, GP-GM, GP-GC.

^bSands with 5 to 12% fines require dual symbols: SW-SM, SW-SC, SP-SM, SP-SC.

$$^c C_u = \frac{D_{60}}{D_{10}}; \quad C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}}$$

^dIf $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol GC-GM or SC-SM.

^eIf $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol CL-ML.

Figure 12 Unified Classification System

Source (Das, 2019).

4.1.2 GRADING MODULUS.

A high grading modulus signifies that a wide range of particle sizes fall within the gravel fraction while a low grading modulus signifies that the soil has a more distribution of fine particles.

The value 0.41 is lower than 0.5 signifying that the soil has a more distribution of fine particles (RG, et al., 2019).

4.1.3 LIQUID LIMIT

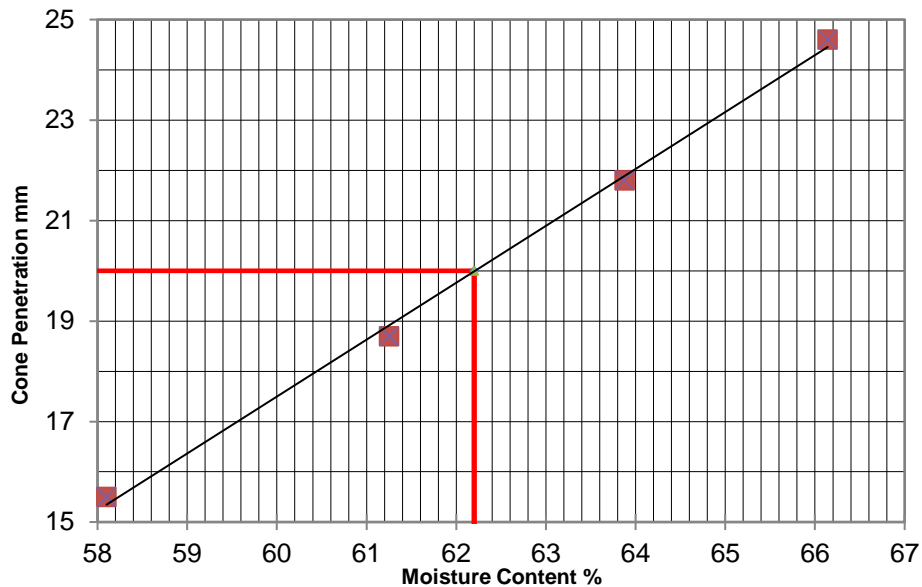


Figure 13 Liquid limit of the neat soil sample.

The liquid limit is a property of soils that represents the moisture content at which a soil changes from plastic state to liquid state. In this case the moisture content at which the neat soil sample changes state from semi solid to liquid is at 62.2% which is greater than 50%, with reference to table 2 indicates that the soils are of high plasticity. Thus the soil absorbs a lot of water hence causing the swelling effect in the soil.

4.1.4 PLASTIC LIMIT

This is property of soil that represents the moisture content at which the soil while transition from a plastic to a semi solid state. The plastic limit is 31.0% which indicates that the soil transitions from plastic to semi solid at 31.0% of moisture content.

4.1.5 LINEAR SHRINKAGE

This is a property that gives an understanding about how the change in length and height of the soil is affected after it has lost all its moisture content. The value of

linear shrinkage is 18.0% which indicates that the soil undergoes high degree of shrinkage in conditions of very high temperatures.

4.1.6 PLASTICITY INDEX

This is the difference between the Liquid Limit and the Plastic Limit of a soil sample. The relevancy of plastic index is that it helps determine the plasticity of the soil sample. A higher plasticity index indicating that the soil has a substantial plasticity and undergoes significant volume changes with variation in moisture content while the lower plasticity index indicates the soil has a lower plasticity and undergoes less volume changes with variation in moisture content.

$$\begin{aligned}\text{Plastic Index} &= 62.2\% - 31.0\% \\ &= \underline{31.2\%}\end{aligned}$$

From the standards, the required Plasticity index should be a maximum of 25% which doesn't comply with the 31.2% of the tested neat soils. Therefore, the plasticity of the soil needs to be reduced to fall within the range (General Specification MOW, 2005).

Using the graph below, the Plasticity index corresponding to the liquid limit was above the A line;

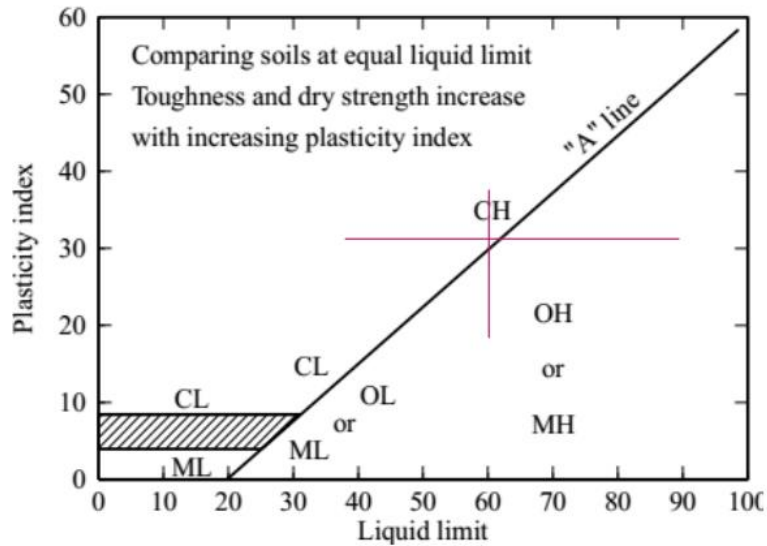


Figure 14 An A line chart. Source (Das, 2019).

The plasticity index was as well above 7% indicating that it is an inorganic clay hence being given a prefix “C”. Lastly, the liquid limit of the soil is 62.2% which is greater than 50% hence it is classified to be of high plasticity thus attaining a suffix “H”.

The soil is classified as a fine-grained inorganic clay of high plasticity.

4.1.7 PROCTOR TEST.

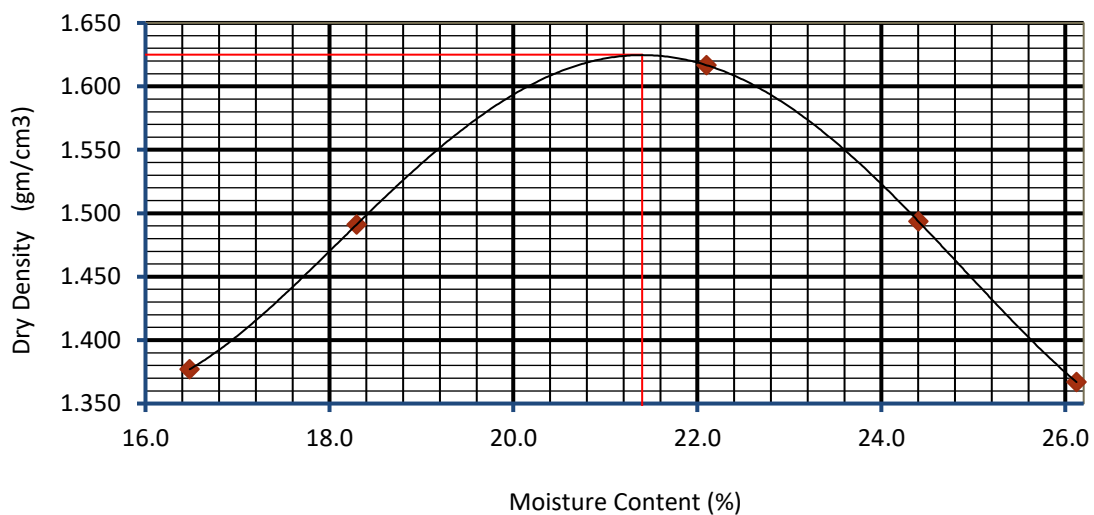


Figure 15 Graph of dry density against moisture content.

4.1.7.1 MAXIMUM DRY DENSITY

A plot of dry density against moisture content was drawn and the peak value of the graph is extended to the dry density axis and that value represents the maximum dry density which is 1.625gm/cm³.

4.1.7.2 OPTIMUM MOISTURE CONTENT.

The point having the peak value of dry density on the graph is extended to the moisture content axis which gives a value of 21.4% which gives the optimum moisture content.

4.2 CALIFORNIA BEARING RATIO

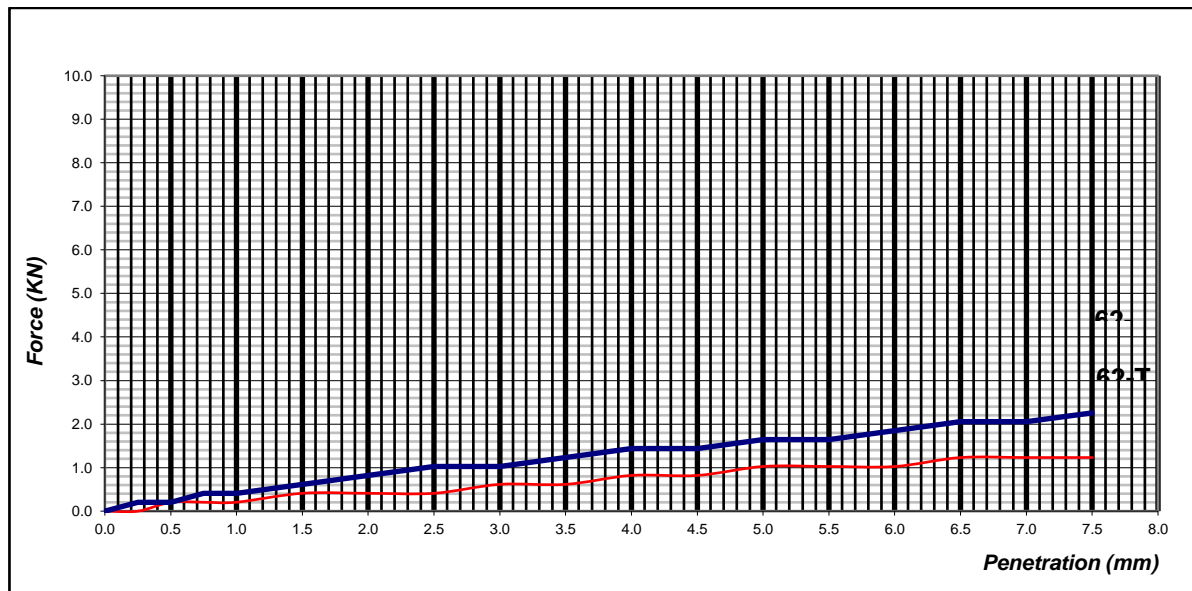


Figure 16 A plot of Force against penetration

At 2.5mm penetration force for bottom and top was 1.0KN and 0.4KN respectively.

$$\begin{aligned} CBR_{bottom} &= \frac{1.0}{13.2} \times 100 \\ &= \underline{8.0\%} \end{aligned}$$

$$\begin{aligned} CBR_{top} &= \frac{0.4}{13.2} \times 100 \\ &= \underline{3.0\%} \end{aligned}$$

The CBR value obtained during the one-point test at the penetration of 2.5mm was 8.0% after 4 days of soaking which is lower than the required CBR of a subgrade

material which is 15% after 4 days of soaking (General Specification MOW, 2005). Therefore, the soil must be stabilized to improve the CBR of the existing expansive subgrade soils.

4.2.1 CBR SWELL

This helps to monitor how much the soil sample swells. The value 1.40% is how much the neat soil sample was able to swell under adverse wet conditions. The standard CBR swell should be a maximum of 1.5% which complies with the standards (General Specification MOW, 2005).

However the soil needs to be improved because the CBR swell is at the verge of the minimum limits.

4.3 ENGINEERING PROPERTIES OF THE RIVER SAND.

4.3.1 Grading

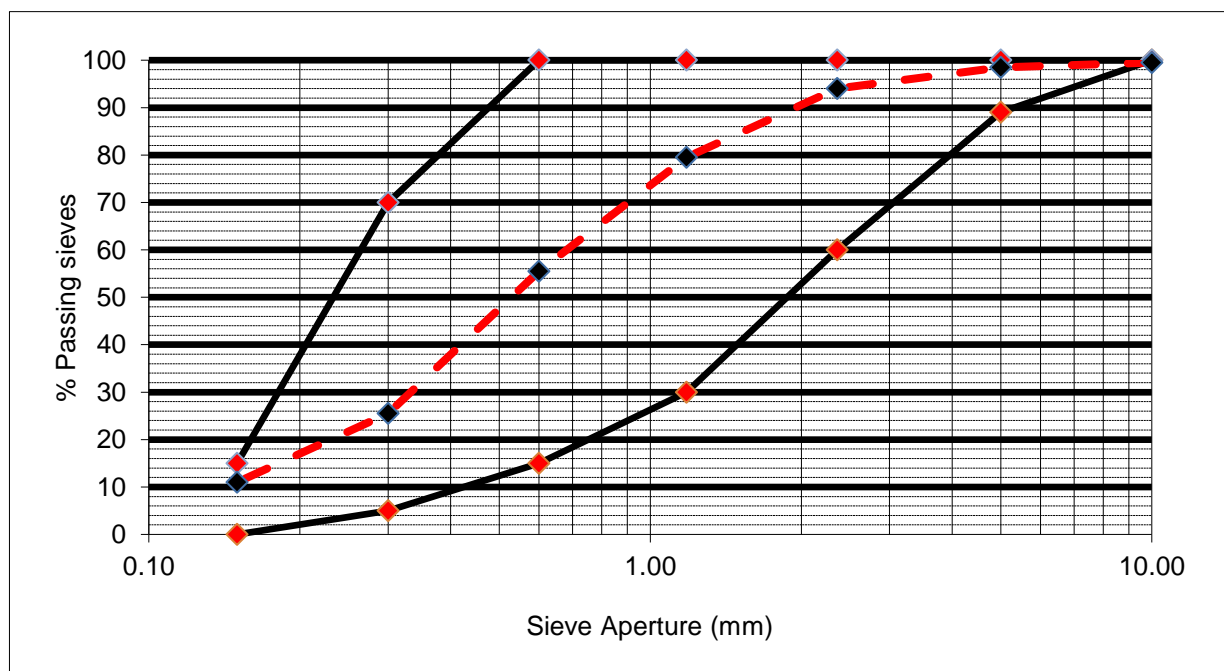


Figure 17 Grading curve for river sand.

The grading curve for the river sand lies within the grading envelope for fine aggregates in reference with (BS, 1992). This means the river sand qualifies to be used as a mechanical stabilizer for the expansive soils in accordance to the standards

since it has well graded particle sizes allowing it to fine content in the expansive soils and reduce the overall plasticity of the soil when blended together (ASTM, 1997).

Table 2 Summary of test results conducted on the river sand

Engineering property	Test result	Standard	Units
Water Absorption	1.6	Maximum of 3%	%
Silt content	3.0	Maximum of 8%	%
Bulk specific gravity	2.5	2.4 - 3.0	Dimensionless

The test results of the sand fall in the range of the required standard indicating that the sand is of good quality and can therefore be used to stabilise the expansive soils.

4.3.2 Silt content

The value for silt content was 3.0% indicated the amount of silt in the river sand which was also falling in the allowable range therefore allowing the river sand to be used as a stabilizer for expansive soils (ASTM, 1997).

4.3.3 Water absorption

The value 1.6% indicates the amount of water absorbed by the river sand. In reference to the standards, the obtained test result of 1.6% is within the required range for water absorption (ASTM, 1997). Therefore qualifying the river sand as a good stabilizer for expansive soils.

4.3.4 Bulk specific gravity

The value 2.5 indicates the ratio of weight of a given volume of aggregates to the weight of an equal volume of water. In reference to the standards, the obtained test result falls within the range of 2.4 to 3.0 hence qualifying the river sand to be used as a stabilizer in the expansive soils (ASTM, 1997).

4.4 ENGINEERING PROPERTIES OF RIVER SAND STABILIZED MIX.

4.4.1 Atterberg limits

4.4.1.1 Liquid Limit

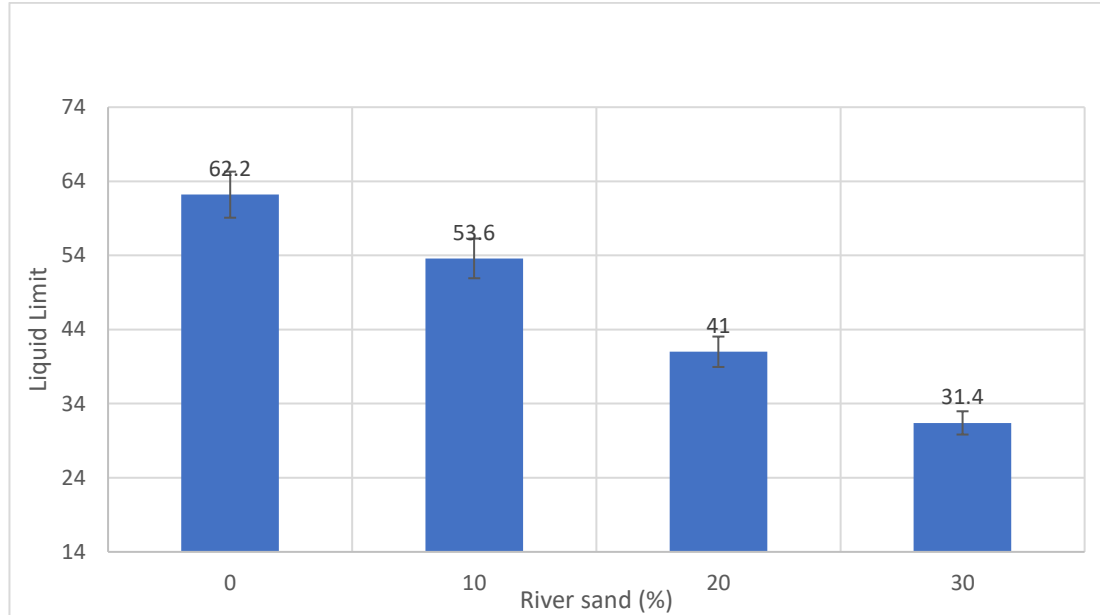


Figure 18 A graph of Liquid Limit against river sand percentages.

The trend of the Liquid Limit increases with increase in river sand content.

At 10% sand content, there is a moderate reduction in liquid limit primarily due to the dilution effect and some improvement in drainage, leading to a slight decrease in plasticity. With an increase to 20% sand content, the dilution effect becomes more significant, further reducing the clay content and plasticity of the soil mixture. Additionally, drainage is significantly improved, promoting more efficient water movement and contributing to a notable decrease in liquid limit. Finally, at 30% sand content, the dilution effect is maximized, resulting in a substantial reduction in clay content and plasticity. Drainage is optimized, facilitating rapid water flow and decreasing the water content required for liquid limit attainment (Ikeagwuani & Nwonu, 2019). Moreover, the alteration of particle size distribution and soil structure becomes more pronounced, leading to a pronounced decrease in liquid limit

compared to lower sand percentages. Overall, as the percentage of river sand increases from 10% to 20% and then to 30%, the trend of decreasing liquid limit intensifies due to the cumulative effects of dilution, improved drainage, and changes in soil structure (Soltani & Taheri, 2017).

4.4.1.2 Plastic limit

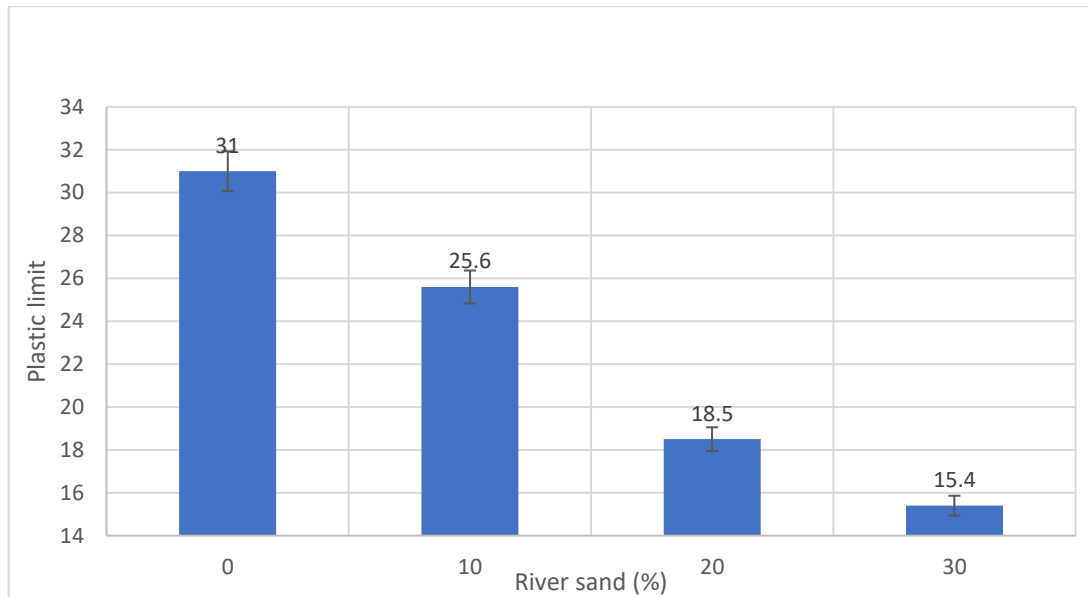


Figure 19 A graph of Plastic Limit against river sand content.

The plastic limit reduced considerably with increase in the content of the river sand content which is due to the reduced fines in the material with the addition of the coarse river sand thus reduction in the plastic nature of the soil (Fondjo & Theron, 2021).

4.4.1.3 Plastic index

The plasticity index (PI) is a fundamental measure in geotechnical engineering indicating the range of moisture content over which a fine-grained soil exhibits plastic behavior. It is determined by calculating the numerical difference between the liquid limit (LL), the moisture content at which the soil transitions from a plastic to a liquid state, and the plastic limit (PL), the moisture content at which the soil can no longer be molded into a thread without crumbling.

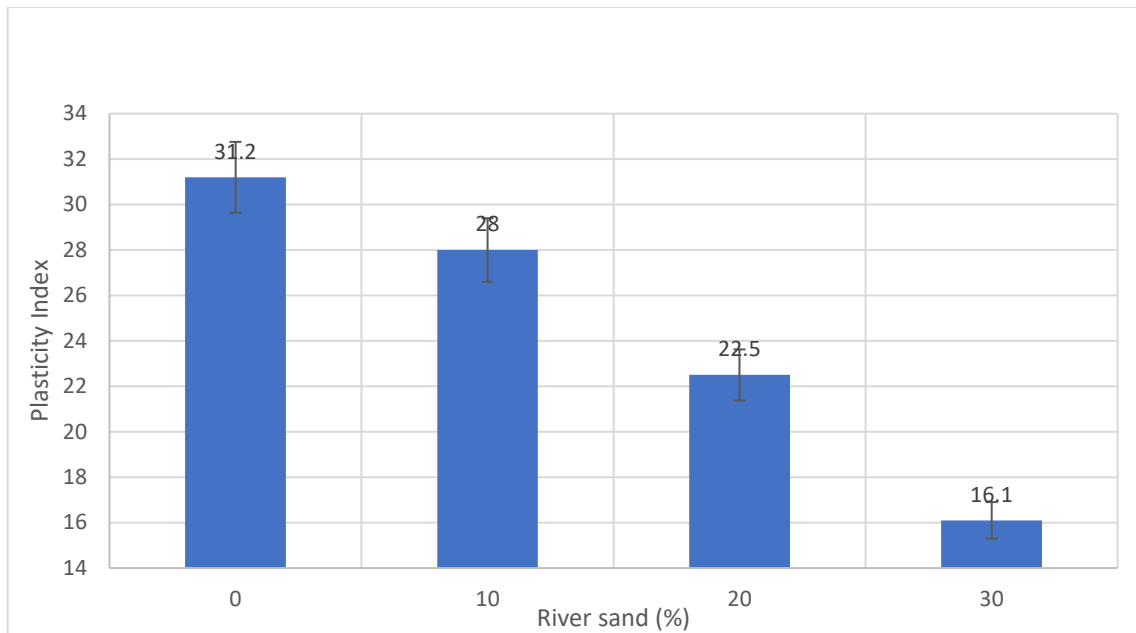


Figure 20 A graph of Plasticity Index against River sand content.

From the graph mixing the neat soil sample with 10% sand causes a slight fall in the PI value of the material while the increase in the percentage of sand up to 20% causes a gentle fall in the PI value and further addition of sand up to 30% causes a sharp drop as well in the PI value of the neat sample.

This trend is because adding sand to the soil results in the reduction of overall fines, making the soil less plastic. Therefore making the number of bonds between the clay particles to decrease as the sand-clay particle bond increases. In addition, the sand particles are more angular in shape than the clay particles, which can result in an interlocking structure that decreases the plasticity of the soil and increases its strength (Mousavi & Karamvand, 2017).

4.4.1.4 Linear shrinkage

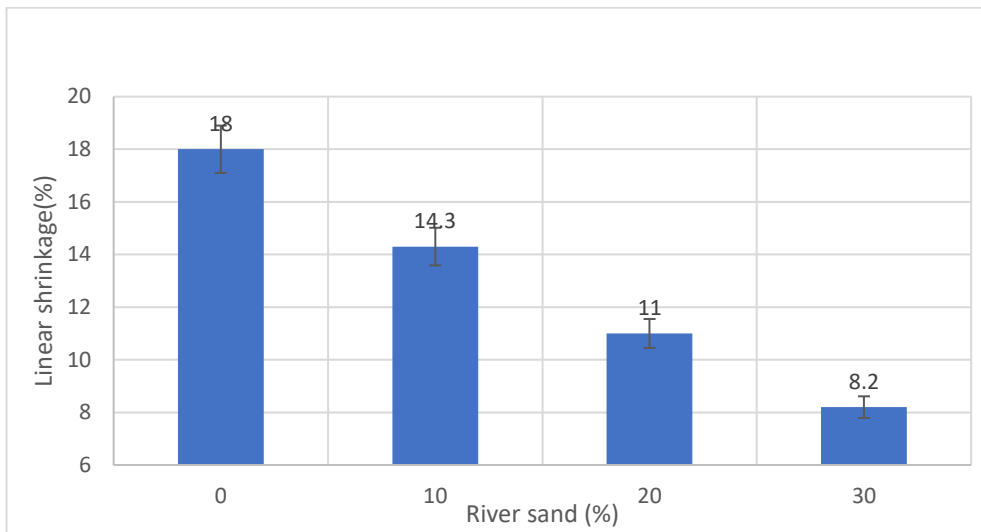


Figure 21 A graph of Linear Shrinkage against river sand percentages.

The linear shrinkage of the soil also reduces substantially with the increase in the river sand content.

This is attributed to the gradual improvement in the soil texture with the addition of the river sand (Mousavi & Karamvand, 2017).

4.4.2 Proctor test

4.4.2.1 Maximum Dry Density

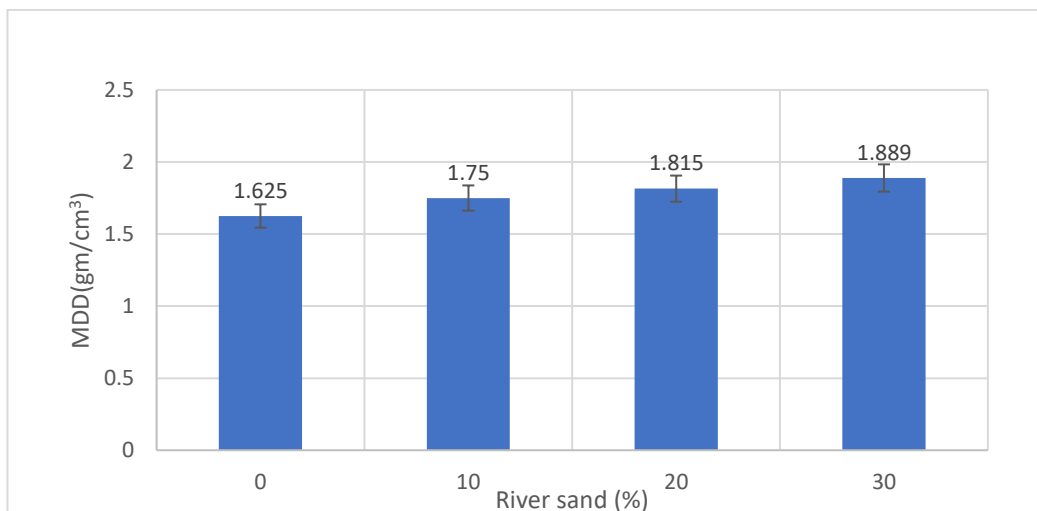


Figure 22 A graph of MDD against river sand percentages used.

The trend in the graph shows an increase in Maximum Dry Density (MDD) observed with the sequential addition of 10%, 20%, and 30% of river sand to stabilize expansive soils which can be attributed to a combination of factors. Initially, with the addition of 10% river sand, the mixture experiences improved particle packing due to the interlocking nature of the sand particles, leading to a reduction in voids and enhanced compaction efficiency. This results in a moderate increase in MDD. As the percentage of river sand is further increased to 20%, the mixture's cohesion and drainage properties improve significantly, reducing the swelling potential of the expansive soils and further enhancing compaction efforts. This results in a more substantial increase in MDD as the mixture becomes denser and more stable. Finally, at 30% river sand addition, the mixture's particle characteristics, including shape and size distribution, are optimized, leading to maximum particle interlocking and improved drainage. This allows for the most efficient compaction, resulting in the highest MDD among the three stages of sand addition. In summary, the incremental increase in MDD with successive additions of river sand is a result of progressively improved particle packing, enhanced cohesion, reduced swelling potential, and optimized drainage, ultimately leading to a denser and more stable material (Kollaros & Athanasopoulou, 2016).

4.4.2.2 Optimum Moisture Content

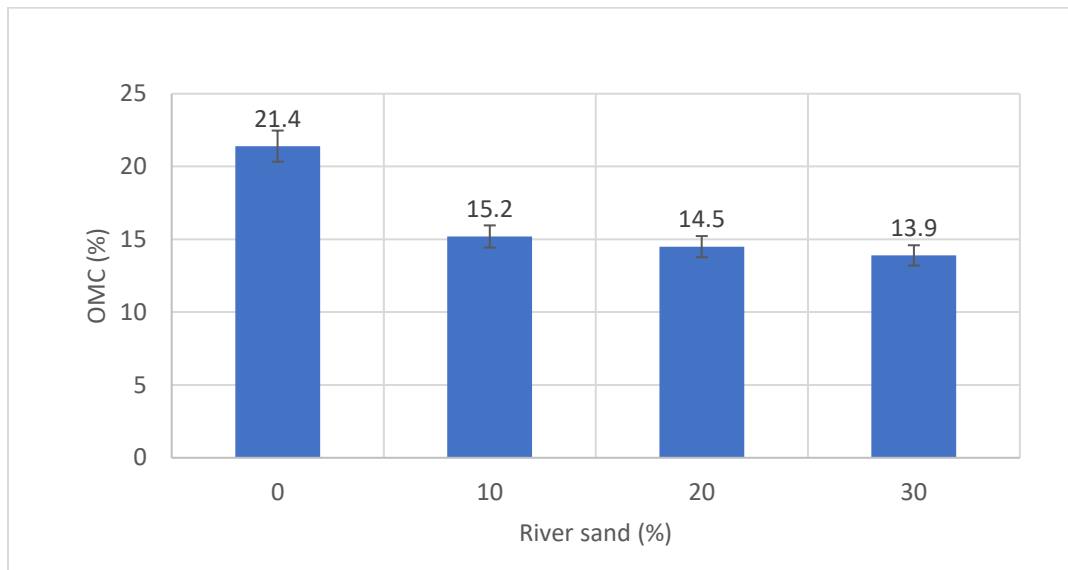


Figure 23 A graph of OMC against river sand percentages.

The trend of the OMC sharply decreased with addition of 10% river sand content followed by a gentle decrease with addition of 20% river sand content and then at addition of 30% river sand content the OMC slightly dropped.

The OMC decreased in trend from 21.4% to 13.9% because the addition of the stabilizer reduced the soil's porosity making it less permeable to water. This meant that less water could penetrate the soil, resulting in a reduction in the OMC as the trend continued (Cheng & Huang, 2018). Additionally, the process of soil stabilization led to an increase in the soil's strength and stiffness, which further reduced its compressibility and made it more resistant to deformation. This caused the soil to require less water to achieve the same level of compaction and MDD, resulting in a lower optimum moisture content (Ash-Shu'ara & Wale, 2018).

4.4.3 CBR test

4.4.3.1 CBR Value

The modification of soils in which case now the expansive soil is the soil binder undergoing a mechanical stabilisation type. River sand is inert and doesn't react

with the expansive soil but it rather possesses unique properties of providing much-needed internal friction and incompressibility therefore improving the properties of the expansive soils. In such a case the CBR test results are enough to give conclusive strength property of the stabilized mix unlike the soil stabilized chemically which requires time for the chemicals to react and stabilise the soil making it fall under the Unconfined Compressive Strength test (General Specification MOW, 2005).

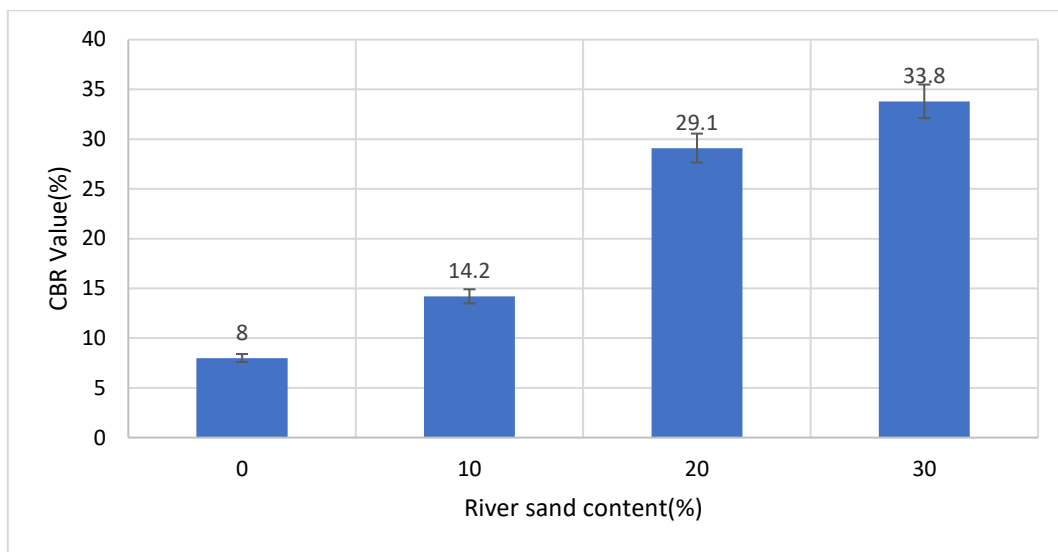


Figure 24 A graph of CBR against river sand content.

The CBR value gently increases with addition of 10% river sand and sharply increases with an addition of 20% river sand. The trend at addition of 30% river sand then rises slightly.

The graph shows that as the amount of river sand increases, the CBR value gradually rises. With the addition of 0%, 10%, 20%, and 30% of river sand, respectively, the CBR value increased from 8% to 14.2% to 29.1% to 33.8%. This rise is ascribed to the soil particles within the material rearranging from fine-grained soil to a more granular nature. The soil offers the much-needed cohesiveness, flexibility, and imperviousness, resulting in an interlocking structure between the soil particles, while the river sand supplies the skeletal framework, which in turn gives internal

friction and incompressibility to the soil mix. As a result, the material's strength attribute increases as its density rises. The greater density of the material, the higher the CBR values are due to its increased resistance to penetrating force (Sudrajat & Isradi, 2023).

4.4.3.2 CBR swell

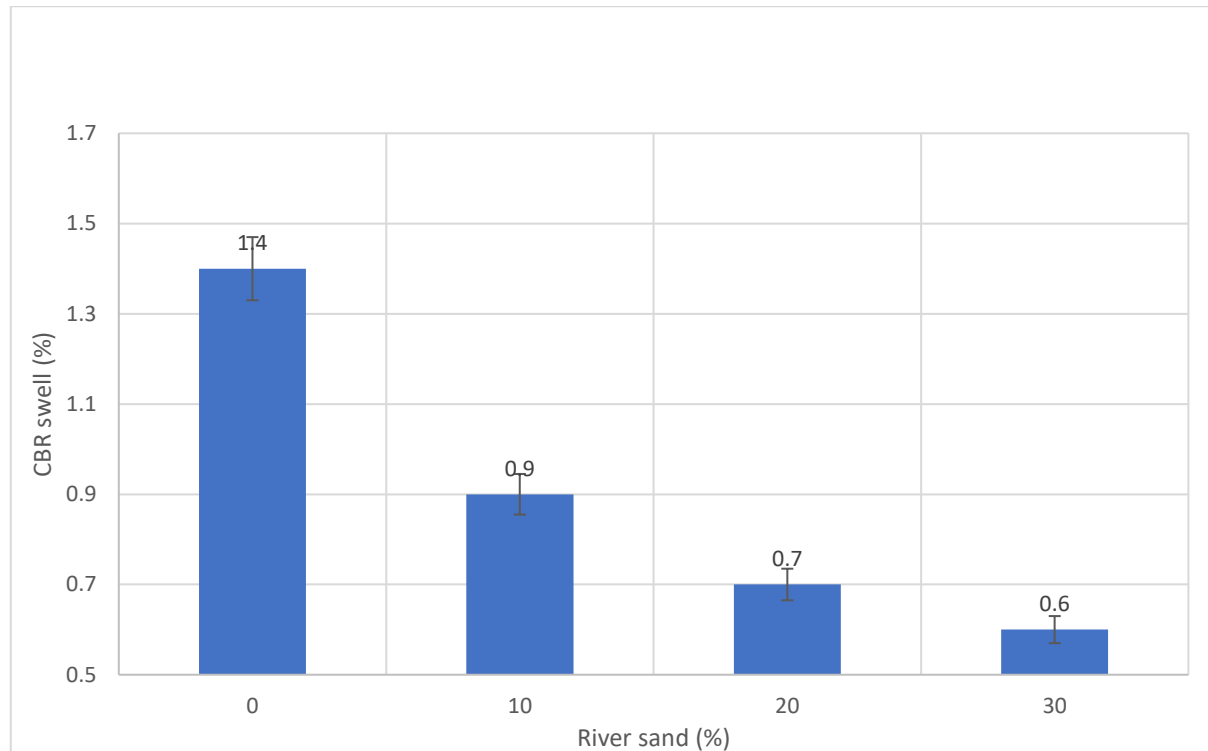


Figure 25 A graph of CBR swell against river sand percentages.

The trend of CBR Swell decreases with increase in river sand content from 0% to 10% to 20% to 30% respectively.

This is due to reduction of the plasticity of the soil indicating a decrease in its water retention ability (Soltani & Taheri, 2017).

4.5 Design proportions.

This design proportion tends to guide people that may apply river sand for stabilization of subgrade use. The river sand shall be used for the subgrade soils

having the following properties; Plasticity index above 7 and a Liquid limit above 50% as well as those materials with CBR values less than 15.

Table 3 Summary of the proportion mix design.

Percentage of materials by mass		Test results							
		Atterberg limits							
Expansive soil (%)	River Sand (%)	LL(%)	PL(%)	PI (%)	LS(%)	MDD (gm/cm ³)	OMC(%)	CBR (%)	CBR Swell (%)
100	0	62.2	31.0	31.2	18.0	1.625	21.4	8.0	1.4
90	10	53.6	25.6	28.0	14.3	1.750	15	14.2	0.9
80	20	41.0	18.5	22.5	11.0	1.815	14.5	29.1	0.7
70	30	31.4	15.4	16.1	8.2	1.889	13.9	33.8	0.6

Table 4 Relationship between the test results and standard requirements for subgrade material

Parameter	Test standard	Value	Test result
CBR	BS 1377 : Part 4	Minimum 15%	29.1%
CBR swell	BS 1377 : Part 4	Maximum 1.5%	0.7%
PI	BS 1377 : Part 2	Maximum of 25%	22.5%

Comparing the requirements for G15 material for subgrade with the test results of the subgrade soils in table 3, the mixed proportion of 20% river sand and 80% expansive soil fulfills all the requirements and is taken as the optimum river sand content.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study focused on the use of river sand to stabilise expansive soils for subgrade construction and the following conclusions were drawn based on the test results and discussions;

It was found that the soil collected from the Moroto-Nandugent road section was classified as a “CH”; inorganic clays of high plasticity with a plasticity index of 31.2%, 71.44% fines passing the 0.075 mm sieve, a liquid limit of 62.2% and Linear shrinkage of 18%. While the strength properties gave the MDD as 1.625gm/cm³ with an OMC of 21.4%, CBR of 8% compacted to a dry density of 1.688gm/cm³, and CBR swell of 1.4%. The neat soil does not meet the minimum requirements for subgrade construction as per the (General Specification MOW, 2005).

The observation of the river sand's grading curve lying in line with the grading envelope suggests that the sand is properly graded. Given that the bulk specific gravity of 2.5, the silt content of 3.0% 8%, and the water absorption of 1.6% < 3 all fall within the acceptable range of 2.4-3.0, the river sand employed in the research study appears to have favorable properties for stabilising the expansive soil in reference to (ASTM, 1997).

Lastly, different percentages of river sand at 10%, 20% and 30% were able to increase the strength parameters i.e. CBR of 20% river sand after 4 days of curing was 29.1% which met the minimum requirements as required by (General Specification MOW, 2005). In summary there was a general reduction in the atterberg limits, OMC, CBR swell and an increase in the MDD and CBR with increasing percentages of river sand. This therefore indicated that river sand can be added to cohesive soils in different amounts to change the mixture's strength, compaction, and plasticity. It also

demonstrated a high load-bearing capability in restricted spaces given that a soil's flexibility is determined by its capacity to undergo deformation without breaking allowing the river sand to reduce the plasticity of expansive soils by altering the distribution of particle sizes and the interactions between individual particles. Because fine-grained clay particles are small in size and can draw and retain water molecules, expansive soils that include a high concentration of these particles display great flexibility, resulting in swelling and shrinking tendencies. The addition of coarser, non-cohesive particles from river sand changes the composition of these soils, reducing their overall flexibility because the sand particles don't have the same ability to draw water as clay. Comparing the requirements for G15 material for subgrade with the test results of the subgrade soils, the mixed proportion of 20% river sand and 80% expansive soil fulfills all the requirements and is taken as the optimum river sand content.

5.2 Recommendation

More research be done on the use of other sand types, such as lake sand and lateritic sand with different gradations.

Additional research should be conducted to explore the long-term effects of river sand stabilization on expansive subgrade soils because investigating the durability and sustainability of this technique over an extended period could provide valuable insights for future infrastructure projects.

Performing a comprehensive cost-benefit analysis to evaluate the economic feasibility of using river sand for soil stabilization. This should include an assessment of initial costs, maintenance expenses, and potential savings over the project's lifecycle.

Tests on the erosion and weathering resistance of river sand-stabilized soils, especially in regions prone to extreme weather conditions should be carried out to provide valuable insights into the durability and longevity of the stabilization technique.

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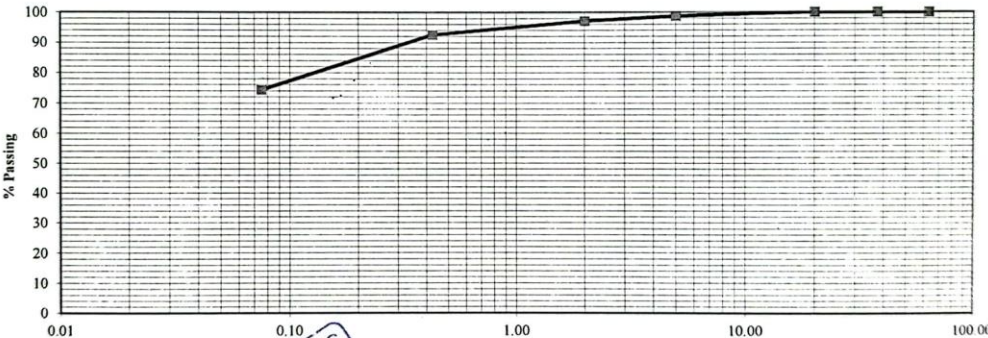
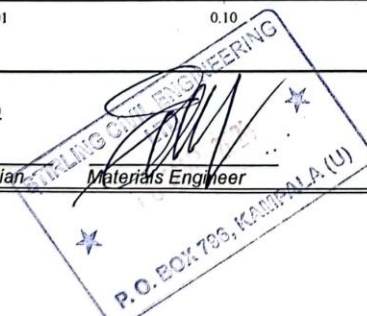
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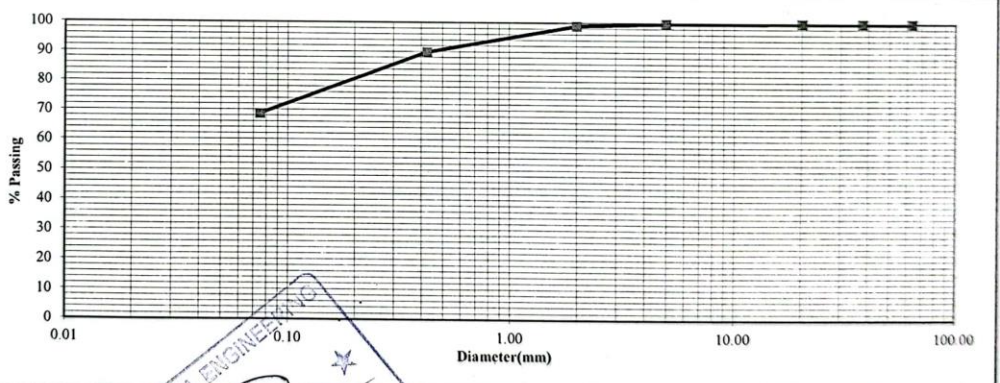
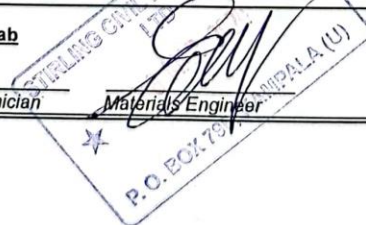
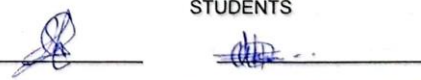
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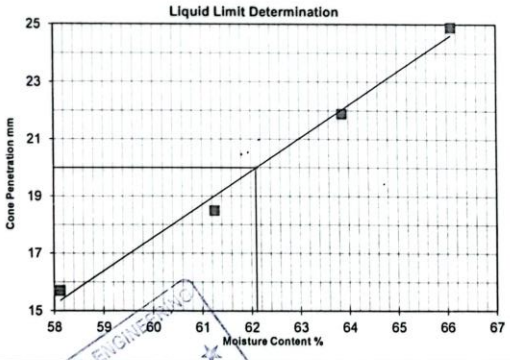
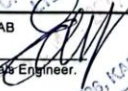


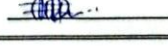
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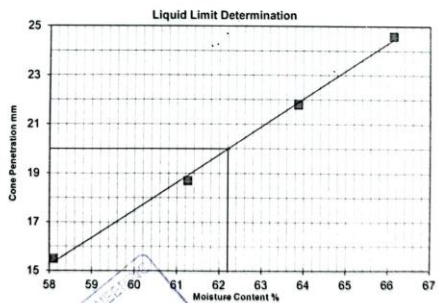
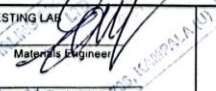
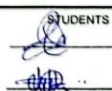

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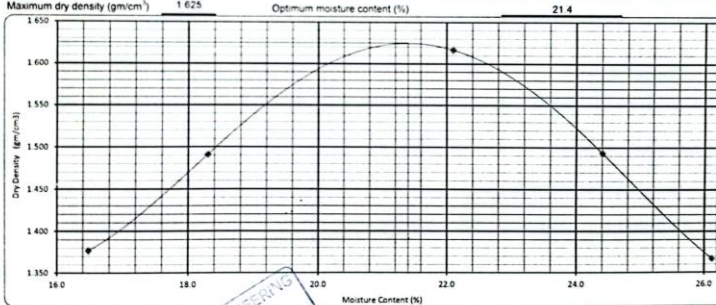
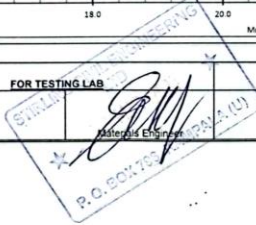


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INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN (S20B32/313)		Stirling	
PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)					
Location : MOROTO DISTRICT			Lab. Reference No.:		
Location : (km)	NEAT SAMPLE		Dry wt. of sample before washing: (g)	4806.4	
Depth: (m)	0.5m		Dry wt. of sample after washing: (g)	1241.0	
Material description:	MOROTO DISTRICT		Date Sampled:	Date Tested:	Technician
			15/Dec/2023	17/Dec/2023	Lab team
Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	100	100	100
37.5	0.0	0.0	100	80	100
20.0	0.0	0.0	100	60	95
5.0	60.3	1.3	99	30	65
2.00	79.9	1.7	97	20	50
0.425	218.1	4.5	93	10	30
0.075	877.6	18.3	74	5	15
Total fines	3570.5	74.3			
Bottom Pan	5.1				
Extracted fines	3565.4				
Total sample	4806.4				
Grading Modulus		0.36			
					
Testing Lab			STUDENTS		
 Lab Technician: _____ Materials Engineer: _____			_____ _____		

INSTITUTION  UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		STUDENTS NAMES MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN (S20B32/313)		TESTING LAB <div style="border: 2px solid black; padding: 5px; display: inline-block;">Stirling</div>	
PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)					
Location : MOROTO DISTRICT			Lab. Reference 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:	MOROTO DISTRICT		Date Sampled:	Date Tested:	Technician
			15/Dec/2023	17/Dec/2023	Lab team
Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	100	100	100
37.5	0.0	0.0	100	80	100
20.0	0.0	0.0	100	60	95
5.0	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 Lab Technician			STUDENTS		
 P.O. BOX 79...					

INSTITUTION		STUDENTS		TESTING LAB																			
 UGANDA CHRISTIAN UNIVERSITY <small>A Center of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN (S20B32/313)		Stirling																			
PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS																							
ATTERBERG LIMITS																							
<i>Liquid limit (cone penetrometer) and plastic limit</i>																							
SOURCE :		MOROTO DISTRICT		Technician: Lab Team																			
mix		NEAT SAMPLE		Sample Date: 15/Dec/2023																			
Test method		BS 1377: Part 2, 1990 4.3/4.4		Test Date: 18/Dec/2023																			
LAYER		EXPANSIVE SOILS																					
Depth		0.5m																					
PLASTIC LIMIT																							
	Test No.	PL	SO		Average																		
Mass of wet soil + container (g)		28.75	28.61		28.68																		
Mass of dry soil + container (g)		27.26	27.31		27.285																		
Mass of container (g)		22.61	22.91		22.76																		
Mass of moisture (g)		1.49	1.3		1.395																		
Mass of dry soil (g)		4.65	4.4		4.525																		
Moisture content %		32.0	29.5		30.8																		
AVERAGE																							
LIQUID LIMIT																							
	Test No.	1	2	3	4																		
Initial gauge reading (mm)		0	0	0	0																		
Final gauge reading (mm)		15.7	18.5	21.9	24.9																		
penetration (mm)		15.7	18.5	21.9	24.9																		
AVERAGE		15.7	18.5	21.9	24.9																		
Container No.		BE	PI66	PI8	MB																		
Mass of wet soil + container (g)		43.53	40.31	49.10	47.65																		
Mass of dry soil + container (g)		30.12	27.68	32.73	31.47																		
Mass of container (g)		7.05	7.06	7.10	6.99																		
Mass of moisture (g)		13.41	12.63	16.37	16.18																		
Mass of dry soil (g)		23.07	20.62	25.63	24.48																		
Moisture content (%)		58.1	61.3	63.9	66.1																		
AVERAGE		58.1	61.3	63.9	66.1																		
Liquid Limit Determination																							
					<table border="1"> <tr> <td>Liquid limit (%)</td> <td>62.1</td> </tr> <tr> <td>Plastic limit (%)</td> <td>30.8</td> </tr> <tr> <td>Plasticity Index (%)</td> <td>31.3</td> </tr> <tr> <td colspan="2" style="text-align: center;">Linear shrinkage</td> </tr> <tr> <td>Trough No.</td> <td>4</td> </tr> <tr> <td>Trough length (cm)</td> <td>14.0</td> </tr> <tr> <td>Specimen length (cm)</td> <td>11.5</td> </tr> <tr> <td>L shrinkage =</td> <td>2.5</td> </tr> <tr> <td>% L shrinkage =</td> <td>18.0</td> </tr> </table>	Liquid limit (%)	62.1	Plastic limit (%)	30.8	Plasticity Index (%)	31.3	Linear shrinkage		Trough No.	4	Trough length (cm)	14.0	Specimen length (cm)	11.5	L shrinkage =	2.5	% L shrinkage =	18.0
Liquid limit (%)	62.1																						
Plastic limit (%)	30.8																						
Plasticity Index (%)	31.3																						
Linear shrinkage																							
Trough No.	4																						
Trough length (cm)	14.0																						
Specimen length (cm)	11.5																						
L shrinkage =	2.5																						
% L shrinkage =	18.0																						
Remarks:																							
TESTING LAB Materials Engineer.  Lab Technician  P. O. BOX 759, KAMPALA (U)			STUDENTS  																				

INSTITUTION		STUDENTS		TESTING LAB		
 UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling		
PROJECT:		INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS				
ATTERBERG LIMITS						
<i>Liquid limit (cone penetrometer) and plastic limit</i>						
SOURCE:		MUROTO DISTRICT		Technician:		
mix		NEAT SAMPLE		Lab Team		
Test method		BS 1377: Part 2, 1990 4.3/4.4		Sample Date		
LAYER		EXPANSIVE SOILS		Test Date		
Depth		0.5m				
PLASTIC LIMIT		Test No.	KK	PL	Average	
Mass of wet soil + container (g)			32.84	34.07	33.455	
Mass of dry soil + container (g)			30.35	31.34	30.845	
Mass of container (g)			22.32	22.64	22.48	
Mass of moisture (g)			2.49	2.7	2.61	
Mass of dry soil (g)			8.03	8.7	8.365	
Moisture content %			31.0	31.4	31.2	
AVERAGE						
LIQUID LIMIT		Test No.	1	2	3	4
Initial gauge reading (mm)			0	0	0	0
Final gauge reading (mm)			15.5	18.7	21.8	24.6
penetration (mm)			15.5	18.7	21.8	24.6
AVERAGE			15.5	18.7	21.8	24.6
Container No.			IA	PI33	PI19	PL
Mass of wet soil + container (g)			52.79	43.62	47.87	40.66
Mass of dry soil + container (g)			35.97	29.71	31.92	27.22
Mass of container (g)			7.02	7.00	6.95	6.90
Mass of moisture (g)			16.62	13.91	15.95	13.44
Mass of dry soil (g)			28.95	22.71	24.97	20.32
Moisture content (%)			58.1	61.3	63.9	66.1
AVERAGE			58.1	61.3	63.9	66.1
 <p style="text-align: center;">Liquid Limit Determination</p> <p>Cone Penetration mm</p> <p>Moisture Content %</p>		Liquid limit (%)		62.2		
		Plastic limit (%)		31.2		
		Plasticity Index (%)		31.0		
		Linear shrinkage				
		Trough No.		4		
		Trough length (cm)		14.0		
		Specimen length (cm)		11.5		
		L shrinkage =		2.5		
		% L shrinkage =		18.0		
Remarks:						
TESTING LAB  Materials Engineer			STUDENTS 			
Lab Technician 						

INSTITUTION		STUDENTS NAMES			TESTING LAB	
 UCANDA CHRISTIAN UNIVERSITY <small>A School of Education & the Arts of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)			<div style="border: 1px solid black; padding: 2px; display: inline-block;">Stirling</div>	
PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS						
Test Reference No		Depth 0.5m		Date Sampled		Technician
Mix		NEAT SAMPLE		15/Dec/23		Lab team
SOURCE MOROTO DISTRICT						
Material description: EXPANSIVE SOILS				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 (cm³)	
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 (cm³)	120	220	320	420	520	
Mass of Compacted soil + mould (gm)	5.886	6.046	6.256	6.140	6.006	
Mass of Mould (gm)	4.282	4.282	4.282	4.282	4.282	
Mass of Compacted soil (gm)	1604	1764	1974	1858	1724	
Volume of mould (cm³)	1.000	1.000	1.000	1.000	1.000	
Wet density of soil (g/cm³)	1.604	1.764	1.974	1.858	1.724	
DATA FOR PROCTOR CURVE						
Container No	BOJ	UCJ	CR7	Z6T	Y6Y	
Mass of wet soil + Container (gm)	2.680.0	2.863.0	2.444.0	2.740.0	2.673.0	
Mass of dry soil + container (gm)	2.414.0	2.545.0	2.141.0	2.361.0	2.289.0	
Mass of container (gm)	800.0	807.0	770.0	808.0	819.0	
Mass of water added (gm)	266	318	303	379	384	
Mass of dry soil (gm)	1614	1738	1371	1553	1470	
Moisture content (%)	16.5	18.3	22.1	24.4	26.1	
Dry density (g/cm³)	1.377	1.491	1.617	1.494	1.367	
Maximum dry density (g/cm ³) 1.625 Optimum moisture content (%) 21.4						
						
Remarks:						
FOR TESTING LAB			STUDENTS			
Lab Technician	 <small>P.O. SONTOS</small>					

Institution UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		Students Names MWINE AMBROSE (S20B32010) & ATEMU ENEKU JOAN (S20B32013)		Testing Lab Stirling	
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)					
Test sample reference :		Depth: 0.5m		Sampling Date: 15/Dec/23	
MIX:		NEAT SAMPLE		Casting date: 3/Jan/24	
Source: MOROTO DISTRICT				Testing Date: 7/Jan/24	
Sample Description: EXPANSIVE SOILS				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)	2364		MDD (Mg/m ³)	1.625	
Tin + oven dry soil sample (g)	2287		N.M.C (%)	5.1	
Tin (g)	776		OMC (%)	21.4	
Dry soil sample	1511		Added OMC (%)	16.3	
Water (g)	77		Calculated dry wt of soil (g)	5694.2	
N.M.C (%)	5.1		Water added (g)	931	
Average (%)	5.1		Water added (mL)	931	
Number of blows	62				
Number of layer	5				
Water Content Determination			Before Soaking	After Soaking	
Tare No	BOJ	-	CR7	-	
Mass of wet sample + Tare	g	2053	-	2490	-
Mass of dry sample + Tare	g	1863	-	2200	-
Mass of Tare	g	800	-	770	-
Mass of water	g	190	-	290	-
Mass of dry sample	g	1063	-	1430	-
Water content	%	17.9	-	20.3	-
Average water Content	%	17.9		20.3	
Density determination			21		
Mould No					
Mass of mould + soil	g	12068		12178	
Mass of mould	g	7490		7490	
Mass of soil	g	4578		4688	
Volume of the mould	cm ³	2305		2305	
Moist density	g/cm ³	1.986		2.034	
Dry density	g/cm ³	1.685		1.691	
Swell Determination					
Date	Hour		D Gauge Reading		
Initial reading	96 hrs		7.85		
Final reading			9.63		
Height of the specimen			127		
Height of swell			1.78		
	Swell(ing)(%)		1.40		
Observations					
For the Lab			For Students		
Lab. Technician			Student		

Institution UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the World of Africa</small>		Students Names MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Testing Lab Stirling	
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)					
Test sample reference : mix : NEAT SAMPLE		Depth : 0.5m		Sampling Date : 15/Dec/23	
Source : MOROTO DISTRICT				Penetration Date : 7/Jan/24	
Sample Description : EXPANSIVE SOILS				Technician : Lab team	
Number of blows per layer		62			
Number of layers		5		5	
Mould No		21		5	
Capacity of the Proving Ring (KN)		50		50	
Proving Ring Constant (KN/div.)		0.2052		0.2052	
Speed : mm/min		0.2052		0.2052	
Penetration of the plunger (mm)	Time (s)	Top		Bottom	
		Reading *10 ⁻³ mm	Force (KN)	Reading *10 ⁻³ mm	Force (KN)
0	0	0	0.0	0	0.0
0.25	12	0	0.0	1	0.2
0.5	24	1	0.2	1	0.2
0.75	35	1	0.2	2	0.4
1	47	1	0.2	2	0.4
1.5	71	2	0.4	3	0.6
2	94	2	0.4	4	0.8
2.5	118	2	0.4	5	1.0
3	142	3	0.6	5	1.0
3.5	165	3	0.6	6	1.2
4	189	4	0.8	7	1.4
4.5	213	4	0.8	7	1.4
5	236	5	1.0	8	1.6
5.5	260	5	1.0	8	1.6
6	283	5	1.0	9	1.8
6.5	307	6	1.2	10	2.1
7	331	6	1.2	10	2.1
7.5	354	6	1.2	11	2.3
Observations					
For the Contractor			For Students		
Lab. Technician					


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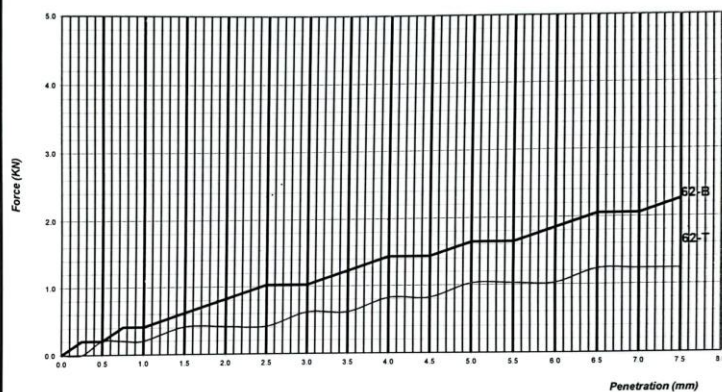
Institution UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>	Students Names MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/013)	Testing Lab Stirling
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INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference:	Depth: 0.5m	Sampling Date: 15/Dec/23
Mix: NEAT SAMPLE		Testing Date: 7/Jan/24
Source: MOROTO DISTRICT		Technician: Lab team
Sample Description: EXPANSIVE SOILS		

PENETRATION vs FORCE CURVE




	62 blows								
	Force		CBR						
	Bottom	Top	Bottom	Top					
2.5 mm Penetration	1.0	0.4	8	3					
5.0 mm Penetration	1.6	1.0	8	5					
Average	1.3	0.7	8.0	4.1					
Retained CBR					8.0				
Observations	<p align="center">CBR = 8.0</p>								


For the Lab	For Students
Lab. Technician	




Appendix B: Laboratory tests on the river sand used


INSTITUTION	STUDENTS	TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Learning & Service of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)	Stirling	
SAMPLE DIScription:	SAND	Sampling Date:	16-Jan-24
SAMPLE SOURCE:	MOROTO	Testing Date:	17-Jan-24
TEST	DETERMINATION OF SILT CONTEET		
TEST METHOD	ASTM C40		
S.no	Description	Sample 1	Sample 1
1	Volume of sample Sand (V2)	56.2	60
2	Volume of silt layer + Sand sample(V1)	58	61.7
3	Volume of silt layer (V3)	1.8	1.7
4	Percentage of silt % $(V3/V1)*100$	3.2	2.8

FOR TESTING LAB




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INSTITUTION	STUDENTS	TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN (S20B32/313)	<div style="border: 1px solid black; padding: 2px; display: inline-block;">Stirling</div> STIRLING	
PROJECT	INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS		
SPECIFIC GRAVITY & WATER ABSORPTION FINE AGGREGATES <small>(AASHTO ; T84—00) ASTM DESIGNATION ; C128—97</small>			
SOURCE: MOROTO		OPERATOR:	
SAMPLE No		SAMPLING DATE: 16-Jan-24	
SAMPLE DESCRIPTION: Natural sand		TESTING DATE: 17-Jan-24	
TEST NO			
[A] wt. of oven dry sample in air	(gm)	525	480.5
[B] wt. of pycnometer filled with water	(gm)	1804.2	1760.9
[C] wt. of pycnometer with specimen and water	(gm)	2126.2	2054.2
[S] wt of saturated surface dry sample	(gm)	533	488.2
Bulk Specific Gravity on oven dry basis	A	2.488	2.465
	(B+S-C)		
Bulk Specific Gravity on saturated surface dry basis	S	2.526	2.505
	(B+S-C)		
Apparent Specific Gravity	A	2.586	2.567
	(B+A-C)		
Water Absorption(%)=	100(S-A)	1.5	1.6
	A		
AVERAGE RESULTS			
BULK SPECIFIC GRAVITY		2.477	
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS		2.515	
APPARENT SPECIFIC GRAVITY		2.576	
WATER ABSORPTION		1.6	
FOR TESTING LAB			

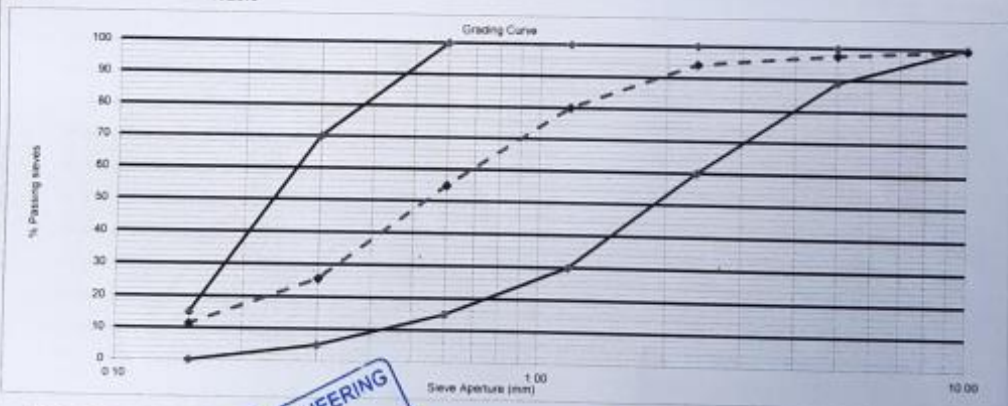







INSTITUTION	STUDENTS	TESTING LAB
 UGANDA CHRISTIAN UNIVERSITY <small>A College of Excellence in the East of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)	Stirling
PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS		
TEST: GRADING FOR SAND (BS 882 - 1992)		
MATERIAL :	NATURAL SAND	OPERATORS: LAB TEAM
MATERIAL SOURCE:	MOROTO	TOTAL DRY WT. OF SAMPLE: 4859.5
SAMPLE No:	SAMPLE A	TOTAL WT AFTER WASHING 4523.6
MATERIAL DESCRIPTION:	NATURAL SAND	MOISTURE CONTENT:
		WET OR DRY SIEVING: WET
		DATE SAMPLED: 16-Jan-24
		DATE TESTED: 17-Jan-24


MAXIMUM SIEVE SIZE (mm)	WEIGHT RETAINED (gm)	PERCENTAGE RETAINED (%)	PERCENTAGE PASSING (%)	BS 882:1992 Table 4. (%)
10.00	25.1	0.52	99	100
5	92.3	1.90	98	89-100
2.36	163.9	3.37	94	60 - 100
1.18	690.5	14.21	80	30 - 100
0.600	1221.3	25.13	55	15 - 100
0.300	1421.6	29.25	26	5 - 70
0.150	689.7	14.19	11	0 - 15
PAN	219.2			

TOTAL 4523.6



FOR TESTING LAB

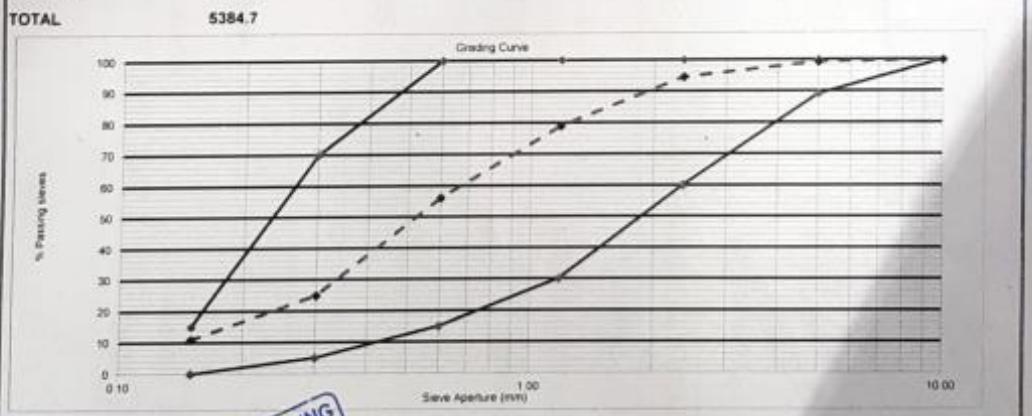



INSTITUTION	STUDENTS	TESTING LAB
 UGANDA CHRISTIAN UNIVERSITY <small>A Division of Southern & Eastern Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)	Stirling

PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS

TEST: GRADING FOR SAND (BS 882 - 1992)	
MATERIAL : NATURAL SAND	OPERATORS: LAB TEAM
MATERIAL SOURCE: MOROTO	TOTAL DRY WT. OF SAMPLE: 5867.2
SUPPLIER : STIRLING	TOTAL WT AFTER WASHING 5384.7
SAMPLE No: SAMPLE B	MOISTURE CONTENT:
MATERIAL DESCRIPTION: NATURAL SAND	WET OR DRY SIEVING: WET
	DATE SAMPLED: 16-Jan-24
	DATE TESTED: 17-Jan-24

MAXIMUM SIEVE SIZE (mm)	WEIGHT RETAINED (gm)	PERCENTAGE RETAINED (%)	PERCENTAGE PASSING (%)	BS 882:1992 Table 4. (%)
10.00	12.5	0.21	100	100
5	27.7	0.47	99	89-100
2.36	286.7	4.89	94	60 - 100
1.18	914.1	15.58	79	30 - 100
0.600	1334.8	22.75	56	15 - 100
0.300	1834.8	31.27	25	5 - 70
0.150	814.1	13.88	11	0 - 15
PAN	160.0			





FOR TESTING LAB

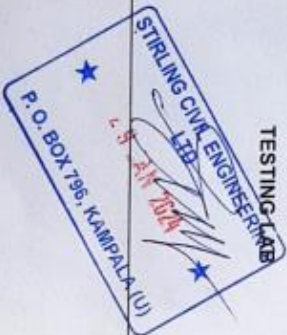
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INSTITUTION	STUDENTS			TESTING LAB
 UGANDA CHRISTIAN UNIVERSITY <small>A Christ-Centered University of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)			<div style="border: 1px solid black; padding: 2px; display: inline-block;">Stirling</div>
PROJECT	INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS			
	TESTING DATE	17-Jan-24		
	SAND SAMPLE 1			
TEST NO	1	2	3	
WEIGHT OF SAND	4806	4842	4781	
VOLUME OF CONTAINER	0.27	0.27	0.27	
BULK DENSITY (g/cm ³)	1.780	1.793	1.771	
AVERAGE BULK DENSITY(g/cm ³)	1.781			




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Appendix C: Laboratory test results on the stabilized soil

INSTITUTION		STUDENTS		TESTING LAB																
UCANDA CHRISTIAN UNIVERSITY <small>UNIVERSITY OF THE GREAT RIVERS</small>		MWINE AMBROSE (S20B232010) & ATEMU ENERU JOANI (S20B23213)		Stirling																
PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS																				
SUMMARY OF ALL TEST RESULTS																				
LOCATION	BLENDED %	SAMPLING DATE	GRAVING					ATTERBERG LIMITS					MDD		CBR		CBR SWELL	CBR AVERAGE		
			1	2	3	4	5	PL	PI	US	MDD	OMC	CBR	SWELL						
0	100% SAND	100.0	100.0	100.0	98.7	97.1	92.5	74.3	0.4	62.1	30.8	31.3	18.0	1625	21.4	8	-	1.4	1.4	
		100.0	100.0	100.0	99.8	98.9	89.9	68.6	0.4	62.2	31.2	31.0	18.0	-	-	-	-	-	-	
		100.0	100.0	100.0	98.0	95.8	83.8	61.0	0.6	53.5	25.6	27.9	14.3	1750	15	-	-	14	0.9	0.9
	20% SAND	100.0	100.0	100.0	97.6	95.2	81.9	55.7	0.7	53.6	25.5	28.1	14.3	-	-	-	-	-	-	-
		100.0	100.0	100.0	97.9	92.6	68.7	40.0	1.0	40.9	18.6	21.3	11.0	1315	14.5	-	-	29	0.7	0.7
		100.0	100.0	100.0	95.4	91.2	68.4	42.9	1.0	41.0	18.3	22.7	11.0	-	-	-	-	-	-	-
	30% SAND	100.0	100.0	100.0	98.8	92.5	62.8	29.4	1.2	31.4	15.3	16.1	8.2	1389	13.3	-	-	34	0.6	0.6
		100.0	100.0	100.0	96.8	91.1	63.7	34.6	1.1	31.4	15.4	16.0	8.2	-	-	-	-	-	-	-
		100.0	100.0	100.0	96.8	91.1	63.7	34.6	1.1	31.4	15.4	16.0	8.2	-	-	-	-	-	-	-

Lab Technician

 Mwanika E. E. E. E.

 UGANDA CHRISTIAN UNIVERSITY <small>Uganda's Premier Christian University</small>	STUDENTS MWINE AMBROSE (S20B2010) & ATENO ENYU JOAN (S20B20213)	TESTING LAB <div style="border: 1px solid black; padding: 5px; display: inline-block;">Stirling</div>
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PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS


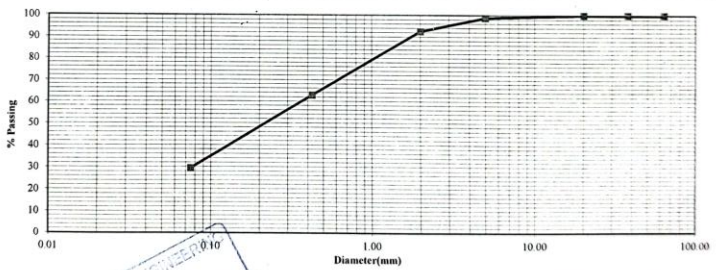

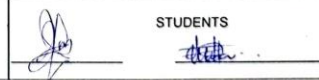
SUMMARY OF TEST RESULTS FOR EXPANSIVE MATERIAL OF EXPANSIVE SOIL MODIFIED WITH 30% SAND

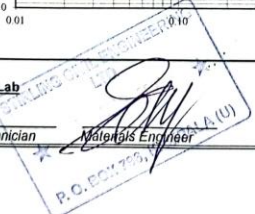
LOCATION BLEND %	SAMPLING DATE	GRADING					ATTEMBERG LIMITS					MOOD		CBR	CBR SWELL	CBR AVERAGE	
		37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD				OMC
EXPANSIVE SOIL	100	100	100	99	92	63	29	115	31.4	15.3	16.1	8.2	1.889	13.3	33.8	0.55	0.55
	100	100	100	97	91	64	35	111	31.4	15.4	16.0	8.2	-	-	-	-	-
MOROTO MODIFIED WITH 30% SAND	100	100	100	97.76	91.77	63.28	32	1.13	31.4	15.3	16.1	8.2	1.889	13.3	33.8	0.55	0.55
MOROTO DISTRICT	12/15/2023																
AVERAGE	100	100	100	98	92	63	32	1.10	31.4	15.4	16.1	8.2	1.889	13.3	33.8	0.55	0.55


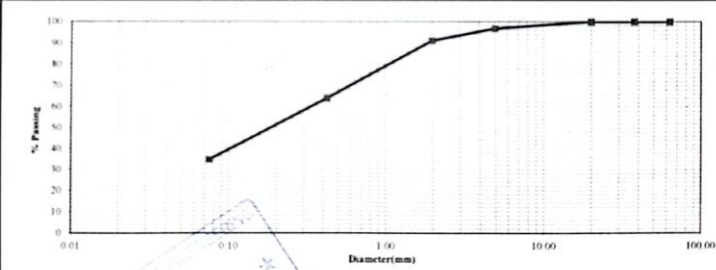

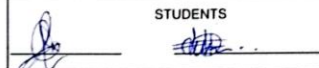
FOR LAB


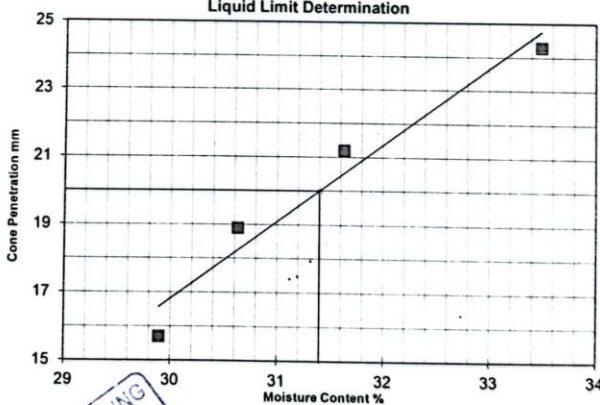
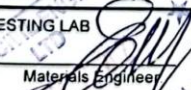
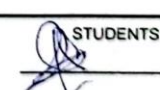

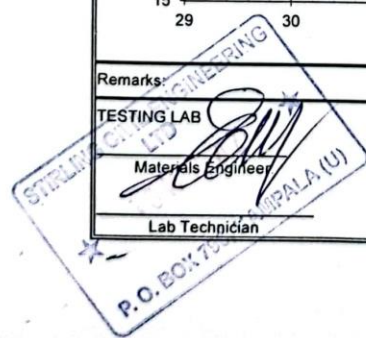
LAB TECHNICIAN: *[Signature]*


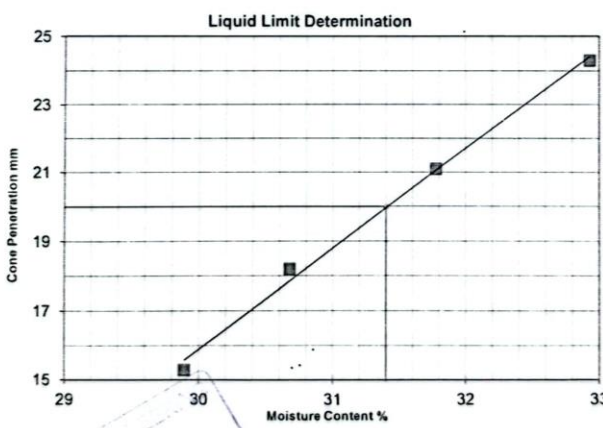
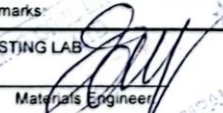


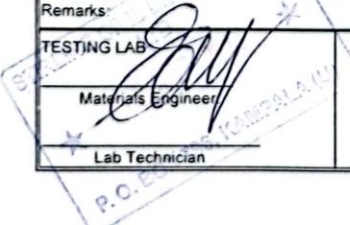
STUDENTS: *[Signature]*


INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling	
PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)					
Location :		MOROTO DISTRICT		Lab. Reference No.:	
Location : (km)	EXPANSIVE SOIL MODIFIED WITH 30% SAND		Dry wt. of sample before washing: (g)	2786	
Depth: (m)	0.5m		Dry wt. of sample after washing: (g)	2028.1	
Material description:	MOROTO DISTRICT		Date Sampled:	Date Tested:	Technician
			15/Dec/2023	5/Feb/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	34.7	1.2	99	30	65
2.00	175.2	6.3	92	20	50
0.425	826.1	29.7	63	10	30
0.075	930.1	33.4	29	5	15
Total fines	819.9	29.4			
Bottom Pan	62.0				
Extracted fines	757.9				
Total sample	2786.0				
Grading Modulus		1.15			
					
Testing Lab		STUDENTS			
 Lab Technician		 STUDENTS			



INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Church of Scotland in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN (S20B32/313)		Stirling	
PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)					
Location: MOROTO DISTRICT			Lab Reference No.:		
Location (km)	EXPANSIVE SOIL MODIFIED WITH 30% SAND		Dry wt. of sample before washing: (g)	3583.5	
Depth (m)	0.5m		Dry wt. of sample after washing: (g)	2386.5	
Material description:	MOROTO DISTRICT		Date Sampled:	Date Tested:	Technician
			15/Dec/2023	5/Feb/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	116.1	3.2	97	30	65
2.00	204.0	5.7	91	20	50
0.425	979.1	27.3	64	10	30
0.075	1045.6	29.2	35	5	15
Total fines	1238.7	34.6			
Bottom Pan	41.7				
Extracted fines	1197.0				
Total sample	3583.5				
Grading Modulus		1.11			
					
Testing Lab  Lab Technician <i>Materials Engineer</i>			STUDENTS 		

INSTITUTION  UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		STUDENTS MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		TESTING LAB <div style="border: 2px solid black; padding: 5px; display: inline-block;">Stirling</div>	
PROJECT:		INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS			
ATTERBERG LIMITS					
<i>Liquid limit (cone penetrometer) and plastic limit</i>					
SOURCE :		MOROTO DISTRICT		Technician:	Lab Team
mix		EXPANSIVE SOIL MODIFIED WITH 30% SAND		Sample Date	15/Dec/2023
Test method		BS 1377: Part 2, 1990 4 3/4 4		Test Date	6/Feb/2024
LAYER		EXPANSIVE SOILS			
Depth:		0.5m			
PLASTIC LIMIT		Test No.	I4	KL	Average
Mass of wet soil + container (g)		39.12	36.04		37.58
Mass of dry soil + container (g)		36.95	34.23		35.59
Mass of container (g)		22.84	22.27		22.555
Mass of moisture (g)		2.17	1.8		1.99
Mass of dry soil (g)		14.11	11.96		13.035
Moisture content %		15.4	15.1		15.3
AVERAGE					
LIQUID LIMIT		Test No	1	2	3
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.7	18.9	21.2	24.3
penetration (mm)		15.7	18.9	21.2	24.3
AVERAGE		15.7	18.9	21.2	24.3
Container No.		A7	AO	PI26	KO
Mass of wet soil + container (g)		43.28	49.10	49.23	48.90
Mass of dry soil + container (g)		35.46	39.21	39.08	38.38
Mass of container (g)		9.30	6.92	6.99	6.97
Mass of moisture (g)		7.82	9.89	10.15	10.52
Mass of dry soil (g)		26.16	32.29	32.09	31.41
Moisture content (%)		29.9	30.6	31.6	33.5
AVERAGE					
		29.9	30.6	31.6	33.5
Liquid Limit Determination					
				Liquid limit (%) 31.4 Plastic limit (%) 15.3 Plasticity Index (%) 16.1 Linear shrinkage	
				Trough No. 1	
				Trough length (cm) 14.0	
				Specimen length (cm) 12.9	
				L.shrinkage = 1.2	
				% L.shrinkage = 8.2	
Remarks:					
TESTING LAB  Materials Engineer				STUDENTS  _____  _____	
		Lab Technician			

INSTITUTION		STUDENTS		TESTING LAB																				
 UGANDA CHRISTIAN UNIVERSITY <small>A School of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling																				
PROJECT:		INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS																						
ATTERBERG LIMITS																								
<i>Liquid limit (cone penetrometer) and plastic limit</i>																								
SOURCE:		MOROTO DISTRICT		Technician:	Lab Team																			
mix		EXPANSIVE SOIL MODIFIED WITH 30% SAND		Sample Date	15/Dec/2023																			
Test method		BS 1377 Part 2, 1990 4.3/4.4		Test Date	6/Feb/2024																			
LAYER		EXPANSIVE SOILS																						
Depth		0.5m																						
PLASTIC LIMIT		Test No	PN	Y4	Average																			
Mass of wet soil + container (g)		36.04	35.48		35.76																			
Mass of dry soil + container (g)		34.23	33.56		33.895																			
Mass of container (g)		22.27	21.23		21.75																			
Mass of moisture (g)		1.81	1.9		1.865																			
Mass of dry soil (g)		11.96	12.33		12.145																			
Moisture content %		15.1	15.6		15.4																			
AVERAGE																								
LIQUID LIMIT		Test No	1	2	3	4																		
Initial gauge reading (mm)			0	0	0	0																		
Final gauge reading (mm)		15.3	18.2	21.1	24.3																			
penetration (mm)		15.3	18.2	21.1	24.3																			
AVERAGE		15.3	18.2	21.1	24.3																			
Container No.		PI42	PI811	AB	FOO																			
Mass of wet soil + container (g)		41.59	51.48	48.91	52.92																			
Mass of dry soil + container (g)		33.66	41.06	38.78	41.51																			
Mass of container (g)		7.13	7.09	6.90	6.86																			
Mass of moisture (g)		7.93	10.42	10.13	11.41																			
Mass of dry soil (g)		26.53	33.97	31.88	34.65																			
Moisture content (%)		29.9	30.7	31.8	32.9																			
AVERAGE		29.9	30.7	31.8	32.9																			
						<table border="1"> <tr> <td>Liquid limit (%)</td> <td>31.4</td> </tr> <tr> <td>Plastic limit (%)</td> <td>15.4</td> </tr> <tr> <td>Plasticity Index (%)</td> <td>16.0</td> </tr> <tr> <td colspan="2" style="text-align: center;">Linear shrinkage</td> </tr> <tr> <td>Trough No.</td> <td>1</td> </tr> <tr> <td>Trough length (cm)</td> <td>14.0</td> </tr> <tr> <td>Specimen length (cm)</td> <td>12.9</td> </tr> <tr> <td>L shrinkage =</td> <td>1.2</td> </tr> <tr> <td>% L shrinkage =</td> <td>3.2</td> </tr> </table>	Liquid limit (%)	31.4	Plastic limit (%)	15.4	Plasticity Index (%)	16.0	Linear shrinkage		Trough No.	1	Trough length (cm)	14.0	Specimen length (cm)	12.9	L shrinkage =	1.2	% L shrinkage =	3.2
Liquid limit (%)	31.4																							
Plastic limit (%)	15.4																							
Plasticity Index (%)	16.0																							
Linear shrinkage																								
Trough No.	1																							
Trough length (cm)	14.0																							
Specimen length (cm)	12.9																							
L shrinkage =	1.2																							
% L shrinkage =	3.2																							
Remarks:																								
TESTING LAB  Materials Engineer		STUDENTS  																						
																								

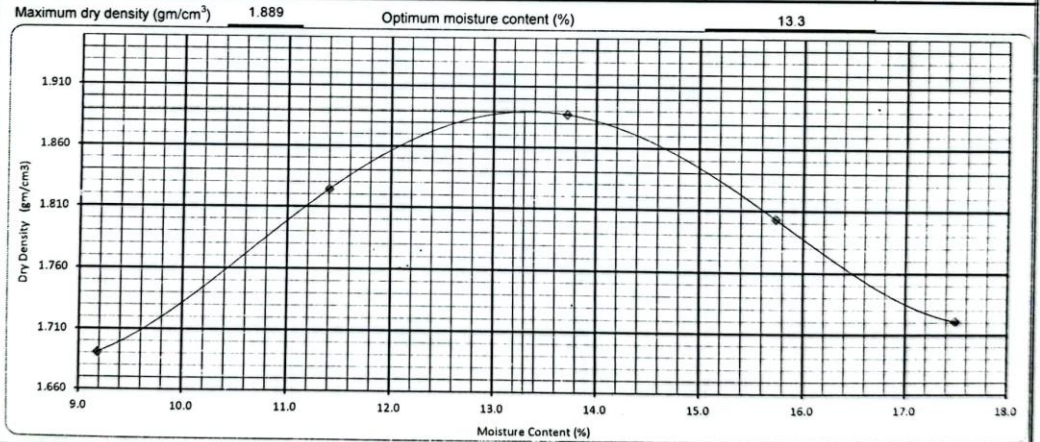
INSTITUTION	STUDENTS NAMES	TESTING LAB
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)	Stirling

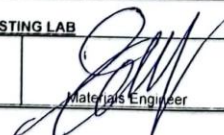

PROJECT:	INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS			
Test Reference No	Depth	Date Sampled	Date Tested	Technician
Mix	0.5m	15/Dec/23	5/Feb/24	Lab team
SOURCE	MOROTO DISTRICT			
Material description:	EXPANSIVE SOILS	Natural moisture (%)	11.0	


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


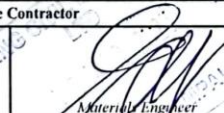


MOISTURE CONTENT DATA						
Test No		1	2	3	4	5
Tin No		A	A	A	A	A
Water Added	cm ³	140	240	340	440	540
Mass of Compacted soil + mould	gm	6,119	6,305	6,419	6,360	6,295
Mass of Mould	gm	4,273	4,273	4,273	4,273	4,273
Mass of Compacted soil	gm	1846	2032	2146	2087	2022
Volume of mould	cm ³	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm ³	1.846	2.032	2.146	2.087	2.022


DATA FOR PROCTOR CURVE						
Container No.		UPC	FDC	Z6T	BAK	MJR
Mass of wet soil + Container	gm	2,140.0	2,047.0	2,460.0	2,026.0	2,268.0
Mass of dry soil + container	gm	2,028.0	1,920.0	2,261.0	1,860.0	2,048.0
Mass of container	gm	808.0	806.0	810.0	805.0	790.0
Mass of water added	gm	112	127	199	166	220
Mass of dry soil	gm	1220	1114	1451	1055	1258
Moisture content	%	9.2	11.4	13.7	15.7	17.5
Dry density	g/cm ³	1.691	1.824	1.887	1.803	1.721



Remarks:	
FOR TESTING LAB	STUDENTS
 Lab Technician	 Students

Institution		Students Names		Testing Lab	
 UGANDA CHRISTIAN UNIVERSITY <small>A Church of Christ in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENERU JOAN (S20B32/313)		Stirling	
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)					
Test sample reference :		Depth: 0.5m		Sampling Date : 15/Dec/23	
mix		EXPANSIVE SOIL MODIFIED WITH 30% SAND		Casting date : 10/Feb/24	
Source		MOROTO DISTRICT		Testing Date : 14/Feb/24	
Sample Description		EXPANSIVE SOILS		Technician : Lab team	
				Volume of Mould used (m ³) 2305	
Natural moisture of air dried sample			Volume of water added		
Tin No	21			Mass of air dried soil (g)	699
Tin + air dried soil sample (g)	2459			MDD (Mg/m ³)	1.889
Tin + oven dry soil sample (g)	2365			N.M.C (%)	6.0
Tin (g)	800			OMC (%)	15.2
Dry soil sample	1565			Added OMC (%)	9.2
Water (g)	94			Calculated dry wt of soil (g)	5639.6
N.M.C (%)	6.0			Water added (g)	520
Average (%)	6.0			Water added (mL)	520
Number of blows		62			
Number of layer		5			
Water Content Determination		Before Soaking	After Soaking		
Tare No		ACB -	ACB -		
Mass of wet sample + Tare	g	1877 -	2351 -		
Mass of dry sample + Tare	g	1734 -	2145 -		
Mass of Tare	g	782 -	782 -		
Mass of water	g	143 -	206 -		
Mass of dry sample	g	952 -	1363 -		
Water content	%	15.0 -	15.1 -		
Average water Content	%	15.0	15.1		
Density determination		21			
Mould No					
Mass of mould + soil	g	12589	12594		
Mass of mould	g	7558	7558		
Mass of soil	g	5031	5036		
Volume of the mould	cm ³	2305	2305		
Moist density	g/cm ³	2.183	2.185		
Dry density	g/cm ³	1.898	1.898		
Swell Determination					
Date	Hour	D Gauge Reading			
Initial reading	96 hrs	6.3			
Final reading		7			
Height of the specimen		127			
Height of swell		0.7			
		Swelling(%)	0.55		
Observations					
For the Lab			For Students		
Lab Technician		Materials Engineer			

Institution		Students Names				Testing Lab	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)				Stirling	
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS							
CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)							
Test sample reference :		Depth: 0.5m		Sampling Date: 15/Dec/23			
mix:		EXPANSIVE SOIL, MODIFIED WITH 30% SAND				Penetration Date: 14/Feb/24	
Source:		MOROTO DISTRICT				Technician: Lab team	
Sample Description :		EXPANSIVE SOILS					
Number of blows per layer		62		5		5	
Number of layers		5		5		5	
Mould No		21		50		50	
Capacity of the Proving Ring (KN)		50		0.2052		0.2052	
Proving Ring Constant (KN/div.)		0.2052		0.2052		0.2052	
Speed:mm min.		Top		Bottom			
Penetration of the plunger (mm)		Time (s)	Reading *10 ³ mm	Force (KN)	Reading *10 ³ mm	Force (KN)	
0		0	0	0.0	0	0.0	
0.25		12	1	0.2	2	0.4	
0.5		24	2	0.4	4	0.8	
0.75		35	3	0.6	7	1.4	
1		47	5	1.0	11	2.3	
1.5		71	7	1.4	15	3.1	
2		94	9	1.8	18	3.7	
2.5		118	10	2.1	21	4.3	
3		142	11	2.3	24	4.9	
3.5		165	12	2.5	27	5.5	
4		189	13	2.7	29	6.0	
4.5		213	14	2.9	31	6.4	
5		236	15	3.1	34	7.0	
5.5		260	16	3.3	36	7.4	
6		283	17	3.5	39	8.0	
6.5		307	18	3.7	41	8.4	
7		331	19	3.9	43	8.8	
7.5		354	20	4.1	44	9.0	
Observations							
For the Contractor				For Students			
Lab. Technician		 Material Engineer					

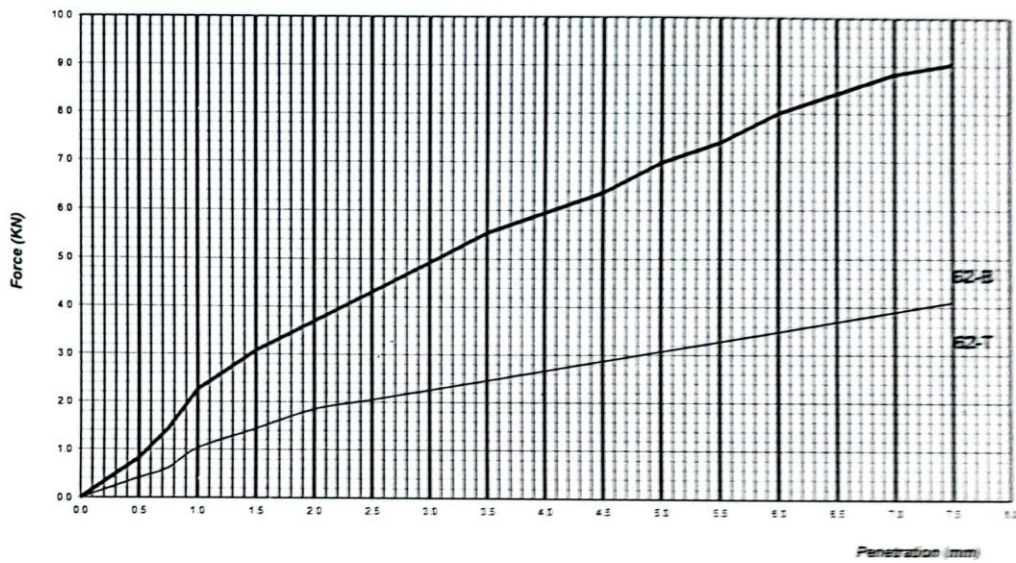
Institution	Students Names	Testing Lab
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)	Stirling

INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS


CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference	Depth 0.5m	Sampling Date 15/Dec/23
mix	EXPANSIVE SOIL MODIFIED WITH 30% SAND	Testing Date 14/Feb/24
Source	MOROTO DISTRICT	Technician Lab team
Sample Description	EXPANSIVE SOILS	

PENETRATION vs FORCE CURVE



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	4.3	2.1	33	15
5.0 mm Penetration	7.0	3.1	35	15
Average	5.6	2.6	33.8	15.5
Retained CBR	33.8			
Observations	CBR= 33.8			
For the Lab	For Students			
Lab. Technician	Materials Engineer			

INSTITUTION	STUDENTS	TESTING LAB
 UGANDA CHRISTIAN UNIVERSITY <small>A Member of Universities & Institutions of Higher Learning in Uganda</small>	MWINE AMBROSE (S208327010) & ATEMU ENEKU JOAN (S208323213)	Stirling

PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS

SUMMARY OF TEST RESULTS FOR EXPANSIVE MATERIAL OF EXPANSIVE SOIL MODIFIED WITH 20% SAND

LOCATION	BLENDED %	SAMPLING DATE	GRADING					ATTERBERG LIMITS					Depth: 0.5m							
			63	37.5	20	5	2	0.415	0.075	GM	LL	PL	PI	LS	MDD	OMC	MDD	OMC	CBR	CBR SWELL
EXPANSIVE SOIL MODIFIED WITH 20% SAND	100	100	100	100	100	98	93	69	40	0.59	40.9	18.6	22.3	11.0	1.815	14.5	29.1	-	0.57	0.57
	100	100	100	100	100	95	91	68	43	0.58	41.0	18.3	22.7	11.0	-	-	-	-	-	-
	100	100	100	100	100	96.66	91.87	68.53	41.48	0.98	40.9	18.4	22.5	11.0	1.815	14.5	29.1	-	0.57	0.57
	MOROTO DISTRICT		12/15/2023																	
AVERAGE			100	100	100	97	92	69	41	0.981	40.9	18.3	22.5	11.0	1.815	14.5	29.1	-	0.57	0.57


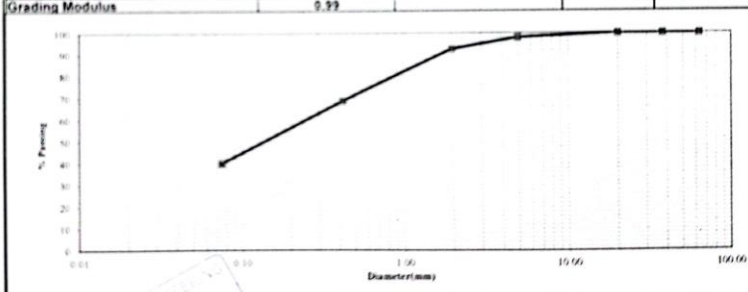
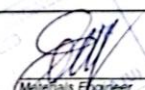


FOR LAB


Lab Technician

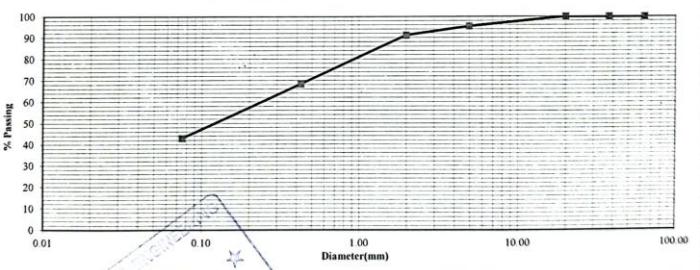

 P.O. BOX 12345, KAMPALA (U) KY
 Registered Professional Engineer




STUDENTS


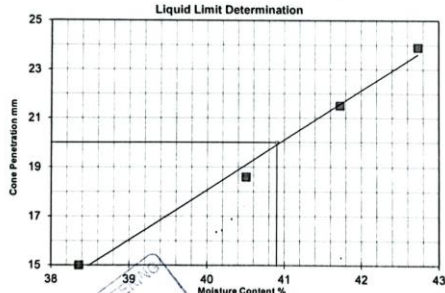
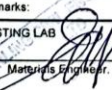




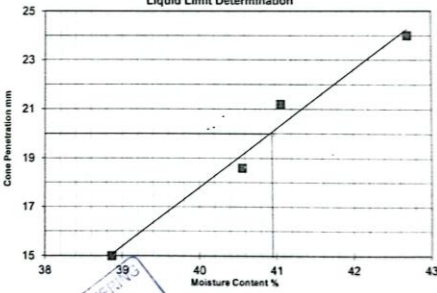
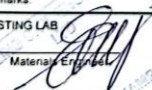
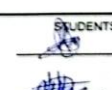
INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN (S20B32/313)		Stirling	
PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 99)					
Location			Lab Reference No.		
MOROTO DISTRICT					
Location (km)	EXPANSIVE SOIL MODIFIED WITH 20% SAND		Dry wt. of sample before washing (g)	3871.6	
Depth (m)	0.5m		Dry wt. of sample after washing (g)	2360.2	
Material description	MOROTO DISTRICT		Date Sampled	Date Tested	Technician
			15/Dec/2023	5/Feb/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	81.0	2.1	98	30	65
2.00	207.1	5.3	93	20	50
0.425	923.4	23.9	69	10	30
0.075	1111.0	28.7	40	5	15
Total fines	1549.5	40.0			
Bottom Pan	37.7				
Extracted fines	1111.4				
Total sample	3871.6				
Grading Modulus		9.99			
					
Testing Lab			STUDENTS		
Lab Technician 			 		

INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling	
PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)					
Location : MOROTO DISTRICT			Lab. Reference No.:		
Location : (km) EXPANSIVE SOIL MODIFIED WITH 20% SAND		Dry wt. of sample before washing: (g)		3550.1	
Depth: (m) 0.5m		Dry wt. of sample after washing: (g)		2052.6	
Material description: MOROTO DISTRICT		Date Sampled: 15/Dec/2023		Date Tested: 5/Feb/2024	
				Technician 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	162.9	4.6	95	30	65
2.00	150.1	4.2	91	20	50
0.425	810.4	22.8	68	10	30
0.075	902.2	25.4	43	5	15
Total fines	1524.5	42.9			
Bottom Pan	27.0				
Extracted fines	1497.5				
Total sample	3550.1				
Grading Modulus		0.98			


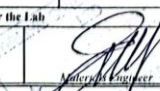




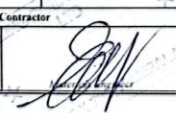

Testing Lab Lab Technician  Materials Engineer	STUDENTS  
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INSTITUTION		STUDENTS		TESTING LAB																																																	
 UGANDA CHRISTIAN UNIVERSITY <small>A College of the Church & the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling																																																	
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Test method		BS 1377 Part 2, 1990 4 3/4 4		Sample Date																																																	
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Depth:		0.6m		7/1 ebr/2024																																																	
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INSTITUTION		STUDENTS		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY A College of Education & the Arts of Africa		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling	
PROJECT:		INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS			
ATTERBERG LIMITS					
<i>Liquid limit (cone penetrometer) and plastic limit</i>					
SOURCE	MICROTO DISTRICT		Technician	Lab Team	
mix	EXPANSIVE SOIL MODIFIED WITH 20% SAND		Sample Date	15/Dec/2023	
Test method	BS 1377 Part 2, 1990 4.3/4.4		Test Date	7/Feb/2024	
LAYER	EXPANSIVE SOILS				
Depth	0.5m				
PLASTIC LIMIT	Test No	44	JL	Average	
Mass of wet soil + container (g)		30.7	30.73	30.715	
Mass of dry soil + container (g)		29.24	29.47	29.355	
Mass of container (g)		21.29	22.57	21.915	
Mass of moisture (g)		1.46	1.3	1.36	
Mass of dry soil (g)		7.98	6.9	7.44	
Moisture content %		18.3	18.3	18.3	
AVERAGE					
LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.0	18.6	21.2	24.0
penetration (mm)		15.0	18.6	21.2	24.0
AVERAGE					
		15.0	18.6	21.2	24.0
Container No	P1VPN	P1811	FOO	FORD	
Mass of wet soil + container (g)	43.43	56.43	50.57	59.84	
Mass of dry soil + container (g)	33.22	42.19	44.94	43.97	
Mass of container (g)	6.95	7.08	6.88	6.90	
Mass of moisture (g)	10.21	14.24	15.63	15.87	
Mass of dry soil (g)	26.27	35.11	38.06	37.17	
Moisture content (%)	38.9	40.8	41.1	42.7	
AVERAGE					
		38.9	40.8	41.1	42.7
Liquid Limit Determination					
					
				Liquid limit (%)	41.0
				Plastic limit (%)	18.3
				Plasticity Index (%)	22.7
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				Trough No.	4
				Trough length (cm)	14.0
				Specimen length (cm)	12.5
				L shrinkage =	1.5
				% L shrinkage =	11.2
Remarks:					
TESTING LAB Material Engineer  Lab Technician			STUDENTS 		

INSTITUTION		STUDENTS NAMES			TESTING LAB	
UGANDA CHRISTIAN UNIVERSITY		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/013)			Stirling	
PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS						
Test Reference No	Depth	Date Sampled	Date Tested	Technician		
Mix	EXPANSIVE SOIL MODIFIED WITH 20% SAND	15/Dec/23	5/Febr/24	Lab team		
SOURCE	MOROTO DISTRICT	Natural moisture (%)		11.0		
Material description: EXPANSIVE SOILS						
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	120	220	320	420	
Mass of Compacted soil + mould	gm	5,036	5,208	5,296	5,223	
Mass of Mould	gm	3,215	3,215	3,215	3,215	
Mass of Compacted soil	gm	1821	1993	2081	2008	
Volume of mould	cm ³	1,000	1,000	1,000	1,000	
Wet density of soil	g/cm ³	1.821	1.993	2.081	2.008	
DATA FOR PROCTOR CURVE						
Container No.	BKN	CR7	UCU	BBC	YSY	
Mass of wet soil + Container	gm	1,991.0	2,105.0	1,948.0	2,290.0	
Mass of dry soil + container	gm	1,874.0	1,952.0	1,797.0	2,074.0	
Mass of container	gm	801.0	770.0	808.0	809.0	
Mass of water added	gm	117	153	151	216	
Mass of dry soil	gm	1073	1182	989	1265	
Moisture content	%	10.9	12.9	15.3	17.1	
Dry density	g/cm ³	1.642	1.765	1.805	1.715	
Maximum dry density (g/cm ³)	1.815		Optimum moisture content (%)		14.5	
Remarks:						
FOR TESTING LAB			STUDENTS			
Lab Technician	Materials Engineer			STUDENTS		

Institution		Students Names		Testing Lab	
 UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa		MWINE AMBROSE (S20B12/010) & ATEMIO ENEKU JOAN (S20B12/011)		Stirling	
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)					
Test sample reference		Depth: 0.5m		Sampling Date: 15/Dec/23	
mix: EXPANSIVE SOIL MODIFIED WITH 20% SAND		Source: MOROTO DISTRICT		Casting date: 6/feb/24	
Sample Description: EXPANSIVE SOILS				Testing Date: 10/feb/24	
				Technician: Lab team	
				Volume of Mould used (m ³): 2305	
Natural moisture of air dried sample			Volume of water added		
Tin No	BA		Mass of air dried soil (g)	6690	
Tin + air dried soil sample (g)	2596		MDD (Mg/m ³)	1 815	
Tin + oven dry soil sample (g)	2476		N.M.C (%)	7.0	
Tin (g)	768		OMC (%)	14.5	
Dry soil sample	1708		Added OMC (%)	7.5	
Water (g)	120		Calculated dry wt of soil (g)	5578.5	
N.M.C (%)	7.0		Water added (g)	419	
Average (%)	7.0		Water added (mL)	419	
Number of blows	62				
Number of layer	5				
Water Content Determination			Before Soaking	After Soaking	
Tare No	Y6Y	-	F1DC	-	
Mass of wet sample + Tare	g	2106	-	2309	-
Mass of dry sample + Tare	g	1938	-	2110	-
Mass of Tare	g	819	-	805	-
Mass of water	g	168	-	199	-
Mass of dry sample	g	1119	-	1305	-
Water content	%	15.0	-	15.2	-
Average water Content	%	15.0		15.2	
Density determination			AST		
Mould No					
Mass of mould + soil	g	11684		11696	
Mass of mould	g	6719		6719	
Mass of soil	g	4965		4977	
Volume of the mould	cm ³	2305		2305	
Moist density	g/cm ³	2.154		2.159	
Dry density	g/cm ³	1.873		1.873	
Swell Determination					
Date	Hour	D.Gauge Reading			
Initial reading	96 hrs	12.65			
Final reading		13.5			
Height of the specimen		127			
Height of swell		0.85			
	Swelling (%)	0.67			
Observations					
For the Lab			For Students		
Lab Technician		 Materials Engineer		 Student	

Institution		Students Names		Testing Lab		
 UGANDA CHRISTIAN UNIVERSITY <small>A Vision of Education for the World</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling		
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS						
CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)						
Test sample reference		Depth: 0.5m		Sampling Date: 15/Nov/23		
mix: EXPANSIVE SOIL AMENDED WITH 20% SAND				Penetration Date: 10/Feb/24		
Source: MOROTO DISTRICT				Technician: Lab team		
Sample Description: EXPANSIVE SOILS						
Number of blows per layer		62				
Number of layers		5		5		
Mould No		AST				
Capacity of the Pressing Ring (KN)		50		50		
Pressing Ring Constant (KN/dia ²)		0.2052		0.2052		
Speed: mm/min		Top		Bottom		
Penetration of the plunger (mm)		Time (s)	Reading *10 ⁻³ mm (KN)	Force (KN)	Reading *10 ⁻³ mm (KN)	Force (KN)
0		0	0	0.0	0	0.0
0.25		12	1	0.2	1	0.2
0.5		24	2	0.4	2	0.4
0.75		35	4	0.8	4	0.8
1		47	6	1.2	6	1.2
1.5		71	7	1.4	11	2.3
2		94	8	1.6	14	2.9
2.5		115	9	1.8	17	3.5
3		142	10	2.1	21	4.3
3.5		165	10	2.1	24	4.9
4		189	11	2.3	27	5.5
4.5		213	12	2.5	29	6.0
5		236	12	2.5	31	6.4
5.5		260	13	2.7	32	6.6
6		283	13	2.7	34	7.0
6.5		307	14	2.9	36	7.4
7		331	14	2.9	38	7.8
7.5		354	15	3.1	39	8.0
Observations						
For the Contractor			For Students			
 Lab Technician			 Student			

Institution UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		Students Names MWINE AMBROSE (S20R32/010) & ATEMU ENEKU JOAN (S20R32/313)		Testing Lab Stirling	
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)					
Test sample reference		Depth 0.5m		Sampling Date 15/Dec/23	
mix		EXPANSIVE SOIL MODIFIED WITH 20% SAND		Testing Date 10/feb/24	
Source		MOROTO DISTRICT		Technician Lab team	
Sample Description		EXPANSIVE SOILS			
PENETRATION vs FORCE CURVE					
		62 Blows			
		Force		CBR	
		Bottom	Top	Bottom	Top
2.5 mm Penetration		3.5	1.8	20	14
5.0 mm Penetration		6.4	2.5	32	12
Average		4.9	2.2	29.1	13.1
Retained CBR		29.1			
Observations		CBR= 29.1			
For the Lab		For Students			
Lab Technician		Materials Engineer			



INSTITUTION	UCANDA CHRISTIAN UNIVERSITY <small>A Member of the Association of Universities of Uganda</small>	STUDENTS	MWINE AMBROSE (S20B32010) & ATEMU ENEKU JOHN (S20B32013)	TESTING LAB	Stirling
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PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS


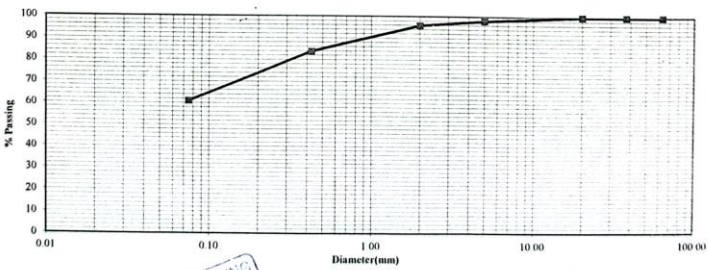



SUMMARY OF TEST RESULTS FOR EXPANSIVE MATERIAL OF EXPANSIVE SOIL MODIFIED WITH 10% SAND

LOCATION	BLENDED %	SAMPLING DATE	GRADING					ATTERBERG LIMITS					MOQD		CBR	CBR SWELL	AVERAGE					
			1	2	3	4	5	LL	PL	PI	LS	MDD	OMC									
MOROTO DISTRICT	EXPANSIVE SOIL MODIFIED WITH 10% SAND	12/15/2023	63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC	14.2	62	0.91			
			100	100	100	98	96	84	61	0.59	53.5	25.6	27.9	14.3	1,750	15.0				14.2	0.91	0.91
			100	100	100	98	95	82	56	0.67	53.6	25.5	28.1	14.3	-	-				-	-	-
AVERAGE			100	100	100	97.8	95.54	82.87	58.35	0.63	53.6	25.6	28.0	14.3	1,750	15.0	14.2	0.91	0.91			


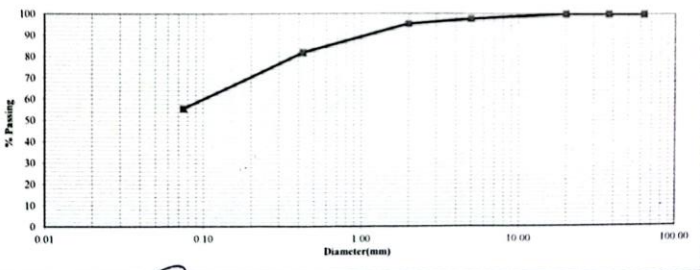



FOR LAB


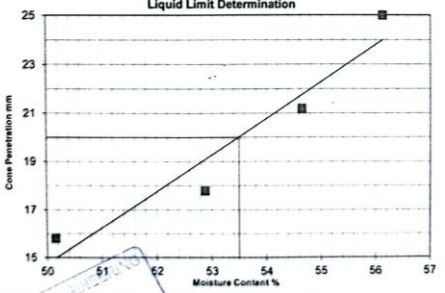

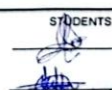
LAB Technician:  MWINE AMBROSE


STUDENTS:  


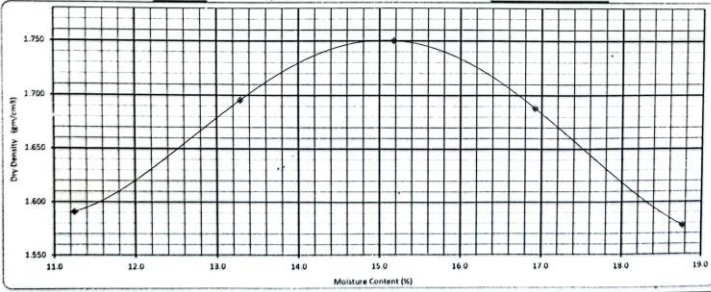
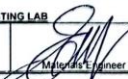


INSTITUTION  UGANDA CHRISTIAN UNIVERSITY <small>A Church of South Africa in the Heart of Africa</small>		STUDENTS NAMES MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN (S20B32/313)		TESTING LAB <div style="border: 1px solid black; padding: 2px; display: inline-block;">Stirling</div>	
PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)					
Location : MOROTO DISTRICT			Lab. Reference No.:		
Location (km)	EXPANSIVE SOIL MODIFIED WITH 10% SAND		Dry wt. of sample before washing: (g)	4963	
Depth: (m)	0.5m		Dry wt. of sample after washing: (g)	1994.0	
Material description:	MOROTO DISTRICT		Date Sampled:	Date Tested:	Technician
			15/Dec/2023	5/Feb/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	97.4	2.0	98	30	65
2.00	108.9	2.2	96	20	50
0.425	596.2	12.0	84	10	30
0.075	1134.1	22.9	61	5	15
Total fines	3026.4	61.0			
Bottom Pan	57.4				
Extracted fines	2969.0				
Total sample	4963.0				
Grading Modulus		0.59			
					
Testing Lab Lab Technician  Materials Engineer			STUDENTS  		




 P.O. BOX 796, KAMPALA (U)


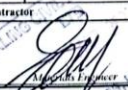

INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN (S20B32/313)		Stirling	
PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)					
Location :		MOROTO DISTRICT		Lab Reference No	
Location (km)	EXPANSIVE SOIL MODIFIED WITH 10% SAND		Dry wt of sample before washing (g)	4358.5	
Depth (m)	0.5m		Dry wt of sample after washing (g)	1991.0	
Material description:	MOROTO DISTRICT		Date Sampled	Date Tested	Technician
			15/Dec/2023	5/Feb/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	106.0	2.4	98	30	65
2.00	101.3	2.3	95	20	50
0.425	581.2	13.3	82	10	30
0.075	1141.7	26.2	56	5	15
Total fines	2428.3	55.7			
Bottom Pan	60.8				
Extracted fines	2367.5				
Total sample	4358.5				
Grading Modulus		0.67			
					
Testing Lab  Lab Technician <i>Materials Engineer</i>			STUDENTS  		

INSTITUTION		STUDENTS		TESTING LAB		
 UGANDA CHRISTIAN UNIVERSITY <small>A University of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling		
PROJECT:		INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS				
ATTERBERG LIMITS						
Liquid limit (cone penetrometer) and plastic limit						
SOURCE: MOROTO DISTRICT		Technician:		Lab Team		
EXPANSIVE SOIL MODIFIED WITH 10% SAND		Sample Date		15/Dec/2023		
Test method: BS 1377 Part 2, 1990 4.3/4.4		Test Date		19/Dec/2023		
LAYER: EXPANSIVE SOILS						
Depth: 0.5m						
PLASTIC LIMIT		Test No.	RAD	JL	Average	
Mass of wet soil + container (g)			38.12	39.82	38.87	
Mass of dry soil + container (g)			34.8	36.16	35.48	
Mass of container (g)			21.96	22.54	22.25	
Mass of moisture (g)			3.32	3.5	3.39	
Mass of dry soil (g)			12.84	13.82	13.23	
Moisture content %			25.9	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)			15.8	17.8	21.2	25.0
penetration (mm)			15.8	17.8	21.2	25.0
AVERAGE			15.8	17.8	21.2	25.0
Container No.		FORD	FOO	PI33	PI2H	
Mass of wet soil + container (g)		49.84	45.18	56.84	53.66	
Mass of dry soil + container (g)		35.47	32.69	39.21	36.85	
Mass of container (g)		6.82	6.89	6.95	6.90	
Mass of moisture (g)		14.37	13.59	17.63	16.81	
Mass of dry soil (g)		28.65	25.7	32.26	29.95	
Moisture content (%)		50.2	52.9	54.6	56.1	
AVERAGE			50.2	52.9	54.6	56.1
		Liquid limit (%)		53.5		
		Plastic limit (%)		25.6		
		Plasticity Index (%)		27.9		
		Linear shrinkage				
Trough No		2				
Trough length (cm)		14.0				
Specimen length (cm)		12.0				
L shrinkage =		2.0				
% L shrinkage =		14.3				
Remarks:						
TESTING LAB  M. Engineer Lab Technician		STUDENTS 				

INSTITUTION		STUDENTS		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Christ-Centered, Life-Long Learning Institution</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling	
PROJECT:		INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS			
ATTERBERG LIMITS					
<i>Liquid limit (cone penetrometer) and plastic limit</i>					
SOURCE :		MOROTO DISTRICT		Technician: Lab Team	
mix		EXPANSIVE SOIL MODIFIED WITH 10% SAND		Sample Date 15/Dec/2023	
Test method		BS 1377: Part 2, 1990.4.3/4.4		Test Date 18/Dec/2023	
LAYER		EXPANSIVE SOILS			
Depth:		0.5m			
PLASTIC LIMIT		Test No. 13		44	
Mass of wet soil + container (g)		41.68		40.06	
Mass of dry soil + container (g)		37.75		36.25	
Mass of container (g)		22.46		21.23	
Mass of moisture (g)		3.93		3.8	
Mass of dry soil (g)		15.29		15.02	
Moisture content %		25.7		25.4	
AVERAGE					
LIQUID LIMIT		Test No. 1		2	
Initial gauge reading (mm)		0		0	
Final gauge reading (mm)		15.4		17.6	
penetration (mm)		15.4		17.6	
AVERAGE		15.4		17.6	
Container No.		MB		BC	
Mass of wet soil + container (g)		42.07		51.40	
Mass of dry soil + container (g)		30.34		36.14	
Mass of container (g)		6.97		7.05	
Mass of moisture (g)		11.73		15.26	
Mass of dry soil (g)		23.37		29.09	
Moisture content (%)		50.2		52.5	
AVERAGE		50.2		52.5	
		54.5		56.4	
		21.0		24.8	
		PII8		PIH	
Mass of wet soil + container (g)		46.96		46.46	
Mass of dry soil + container (g)		32.89		32.20	
Mass of container (g)		7.09		6.93	
Mass of moisture (g)		14.07		14.26	
Mass of dry soil (g)		25.8		25.27	
Moisture content (%)		54.5		56.4	
AVERAGE		54.5		56.4	
		21.0		24.8	
		PII8		PIH	
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Mass of container (g)		7.09		6.93	
Mass of moisture (g)		14.07		14.26	
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Moisture content (%)		54.5		56.4	
AVERAGE		54.5		56.4	
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		PII8		PIH	
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AVERAGE		54.5		56.4	
		21.0		24.8	
		PII8		PIH	
Mass of wet soil + container (g)		46.96		46.46	
Mass of dry soil + container (g)		32.89		32.20	
Mass of container (g)		7.09		6.93	
Mass of moisture (g)		14.07		14.26	
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		21.0		24.8	
		PII8		PIH	
Mass of wet soil + container (g)		46.96		46.46	
Mass of dry soil + container (g)		32.89		32.20	
Mass of container (g)		7.09		6.93	
Mass of moisture (g)		14.07		14.26	
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INSTITUTION	STUDENTS NAMES		TESTING LAB		
 UGANDA CHRISTIAN UNIVERSITY	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		Stirling		
PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
Test Reference No	Depth	Date Sampled	Date Tested	Technician	
Mix	EXPANSIVE SOIL MODIFIED WITH 10% SAND	15/Dec/23	5/Feb/24	Lab team	
SOURCE	MOROTO DISTRICT				
Material description:	EXPANSIVE SOILS	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	120	220	320	420
Mass of Compacted soil + mould	gm	4,985	5,136	5,231	5,189
Mass of Mould	gm	3,215	3,215	3,215	3,215
Mass of Compacted soil	gm	1770	1921	2016	1974
Volume of mould	cm ³	1,000	1,000	1,000	1,000
Wet density of soil	g/cm ³	1.770	1.921	2.016	1.974
DATA FOR PROCTOR CURVE					
Container No.	KAU	CMD	NMT	YY	KT
Mass of wet soil + Container	gm	2,433.0	2,144.0	1,989.0	2,111.0
Mass of dry soil + container	gm	2,268.0	1,982.0	1,828.0	1,919.0
Mass of container	gm	801.0	763.0	767.0	784.0
Mass of water added	gm	165	162	161	192
Mass of dry soil	gm	1467	1219	1061	1135
Moisture content	%	11.2	13.3	15.2	16.9
Dry density	g/cm ³	1.591	1.696	1.750	1.688
Maximum dry density (g/cm ³)	1.750		Optimum moisture content (%)		15.0
					
Remarks:					
FOR TESTING LAB			STUDENTS		
Lab Technician					

Institution	Students Names		Testing Lab	
 UGANDA CHRISTIAN UNIVERSITY <small>A Division of the Church of the Holy Spirit of Africa</small>	MWINE AMBROSE (S100121019) & ATEMO ENEKU JOAN (S100121011)		Stirling	
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS				
CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)				
Test sample reference :	Depth : 0.5m		Sampling Date :	15/Dec/23
mix:	EXPANSIVE SOIL MODIFIED WITH 10% SAND		Casting date :	6/Dec/24
Source	MOROOTO DISTRICT		Testing Date :	10/Dec/24
Sample Description	EXPANSIVE SOILS		Technician :	Lab team
			Volume of Mould used (m ³)	2305
Natural moisture of air dried sample			Volume of water added	
Tin No	ACB		Mass of air dried soil (g)	6990
Tin + air dried soil sample (g)	2908		MDD (Mg/m ³)	1.750
Tin + oven dry soil sample (g)	2730		N.M.C (%)	9.2
Tin (g)	787		OMC (%)	13.9
Dry soil sample	1943		Added OMC (%)	4.7
Water (g)	178		Calculated dry wt of soil (g)	5459.3
N.M.C (%)	9.2		Water added (g)	260
Average (%)	9.2		Water added (mL)	260
Number of blows	62			
Number of layer	5			
Water Content Determination		Before Soaking	After Soaking	
Tare No	21	-	NRM	-
Mass of wet sample + Tare	g	2020	-	2353
Mass of dry sample + Tare	g	1841	-	2111
Mass of Tare	g	805	-	797
Mass of water	g	179	-	242
Mass of dry sample	g	1036	-	1314
Water content	%	17.3	-	18.4
Average water Content	%	17.3	-	18.4
Density determination				
Mould No	NN			
Mass of mould + soil	g	11460		11515
Mass of mould	g	6646		6646
Mass of soil	g	4814		4869
Volume of the mould	cm ³	2305		2305
Moist density	g/cm ³	2.089		2.112
Dry density	g/cm ³	1.781		1.784
Swell Determination				
Date	Hour	D Gauge Reading		
Initial reading	96 hrs	20.04		
Final reading		21.19		
Height of the specimen		127		
Height of swell		1.15		
	Swelling (%)	0.91		
Observations				
For the Lab		For Students		
Lab. Technician				

Institution		Students Names		Testing Lab	
 UGANDA CHRISTIAN UNIVERSITY <small>A Division of the University of the South Pacific</small>		MWINE AMBROSE (S20B32/010) & ATEMIO ENEKU JOAN (S20B32/313)		Stirling	
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)					
Test sample reference :		Depth 0.5m		Sampling Date 15/Dec/23	
mix: EXPANSIVE SOIL MODIFIED WITH 10% SAND				Penetration Date 10/Feb/24	
Source: MOROTO DISTRICT				Technician :: Lab team	
Sample Description: EXPANSIVE SOILS					
Number of blows per layer		62			
Number of layers		5		5	
Mould No		NN			
Capacity of the Proving Ring (KN)		50		50	
Proving Ring Constant (KN/div.)		0.2052		0.2052	
Speed: mm/min					
		Top		Bottom	
Penetration of the plunger (mm)	Time (s)	Reading *10 ³ mm	Force (KN)	Reading *10 ³ mm	Force (KN)
0	0	0	0.0	0	0.0
0.25	12	1	0.2	2	0.4
0.5	24	2	0.4	2	0.4
0.75	35	3	0.6	3	0.6
1	47	5	1.0	5	1.0
1.5	71	5	1.0	7	1.4
2	94	6	1.2	8	1.6
2.5	118	8	1.6	9	1.8
3	142	9	1.8	11	2.3
3.5	165	10	2.1	12	2.5
4	189	10	2.1	13	2.7
4.5	213	11	2.3	14	2.9
5	236	11	2.3	14	2.9
5.5	260	12	2.5	15	3.1
6	283	12	2.5	15	3.1
6.5	307	13	2.7	16	3.3
7	331	13	2.7	16	3.3
7.5	354	14	2.9	17	3.5
Observations					
For the Contractor			For Students		
Lab Technician 					



Institution UGANDA CHRISTIAN UNIVERSITY <small>A University of Excellence in the Heart of Africa</small>	Students Names MWINE AMBROSE (S20B32/010) & ATEMIO ENEKU JOAN (S20B32/313)	Testing Lab Stirling		
INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS				
CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)				
Test sample reference	Depth: 0.5m	Sampling Date: 15/Dec/23		
mix	EXPANSIVE SOIL MODIFIED WITH 10% SAND	Testing Date: 10/Feb/24		
Source	MOROTO DISTRICT	Technician: Lab team		
Sample Description	EXPANSIVE SOILS			
PENETRATION vs FORCE CURVE				
	62 blows			
	Force			
	CBR			
	Bottom	Top	Bottom	Top
2.5 mm Penetration	1.8	1.6	14	12
5.0 mm Penetration	2.9	2.3	14	11
Average	2.4	1.9	14.2	11.9
Retained CBR	14.2			
Observations	CBR = 14.2			
	For the Lab		For Students	
Lab Technician	Materials		P.O. BOX 755, KAMPALA (U)	