

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

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## ABSTRACT

Expansive soils are known for their unpredictable expansion and contraction, low permeability, poor load transfer mechanism, high volume changes with variation in moisture content and high compressibility which renders them unsuitable for construction unless stabilized. Owing to the effect of environmental and physical factors to the efficient performance of the traditional methods of cement and lime such as pH, temperature and presence of sulphates, the research carried out aimed at investigating the physical process of adding an inert material (river sand) to expandible soils to stabilize them, a locally available material within the scope of study. The soil sample was blended with varying proportions of river sand (0%, 10%, 20% and 30%). From the tests carried out on the neat soils, the soils were categorized as inorganic clays with high levels of plasticity with reference to the USCS. Incorporating river sand into the expansive soil, significant improvements in strength, reduction in plasticity index as well as swelling potential were seen. The application of 20% river sand increased the CBR of the neat soils from 8% to 29.1% and the plasticity index from 31.2% to 22.5% which satisfies the MoWT subgrade (G15 material) specifications requirements. Thus, the mix proportion of 20% river sand and 80% neat soils was considered as the optimum stabilizer content for expansive soils for subgrade.

**DECLARATION**

I **ATEMO ENEKU JOAN** declare that the work included in this report is entirely original, free of plagiarism, and hasn't been submitted for consideration for any awards to any other organization.

Signature..... Date.....

**ATEMO ENEKU JOAN S20B32/313**

**APPROVAL**

With my permission as the academic supervisor, this report has been turned in for review.

Signature.....Date.....

**MS. JOSEPHINE RITAH NAKYEYUNE**

**ACADEMIC SUPERVISOR**

## **DEDICATION**

In appreciation of my family's inspiration, encouragement and support during this academic journey, I dedicate this work to them.

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With deep appreciation, I thank the Almighty God, whose favor made it possible for this study endeavor to be successfully completed

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## ABBREVIATIONS AND ACRONYMS

BS	British Institute of Standards
CBR	California Bearing Ratio
G15	Gravel material with minimum CBR value of 15% after 4 days soaking
LS	Linear Shrinkage
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PI	Plasticity Index
PL	Plastic Limit
PSD	Particle Size Distribution
USCS	Unified Soil Classification System

## CHAPTER ONE: INTRODUCTION

### 1.1 Background

Expansive soils are characterized by unpredictable expansion and contraction, low permeability, poor load transfer mechanism, high changes in volume owing to the variation in moisture content, and high compressibility (Amadi, 2018). The substantial amount of montmorillonite clay mineral available in expansive soil attributes to the high swelling and shrinkage properties (Etim, 2017). Expansive soils world over exhibit serious geotechnical and structural engineering challenges (Jones, 2017). This is seen by the various damage to buildings, roads and other structures built on expansive soils (AIR061; Anand J. Puppala & Araviand Pedarla, 2017). The damage by expansive subgrade in pavement structures is estimated to be in billions of dollars, which is remarkably more than damages caused by floods (Lopez-Laza, 2017) . In addition, the annual average maintenance cost of structures built on expansive soils is estimated to range from \$9 to \$15 billion making the costs much expensive (Tanyıldızı, 2023).

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 (Kavish S. M., 2014) especially in area that are susceptible to expansive soils. These soils can also, be found in semi-arid or arid soils where with even relatively low expansiveness, are known to inflict considerable harm (Lee D. & Ian J., 2012). For instance, in Uganda, the semi-arid Karamoja sub region in the North East is known to have most of its land cover occupied by expansive soils (A. A. Kibuka & S. Jjuuko, 2023), as seen in figure 1 below.

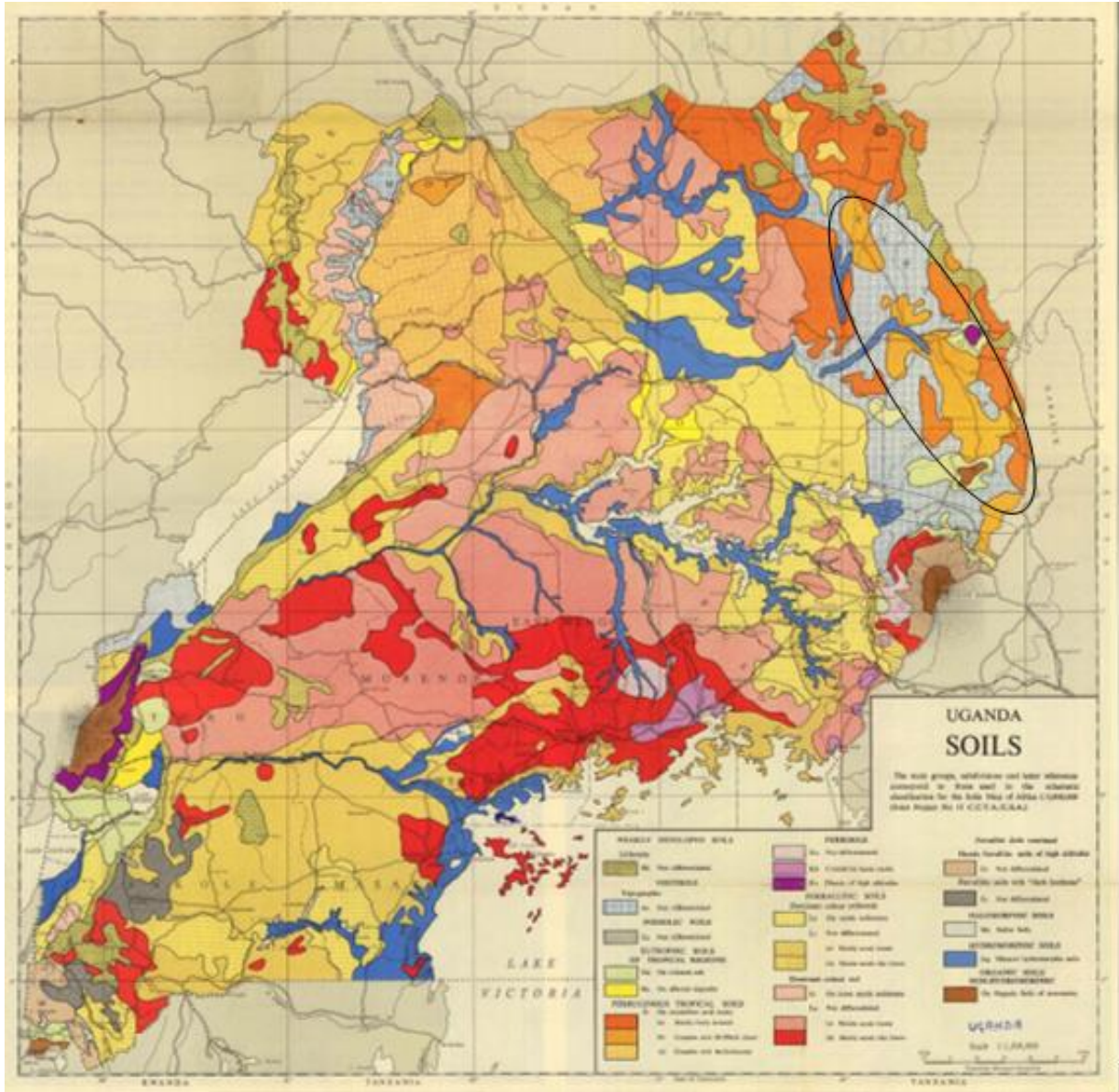


Figure 1: Pattern of the soil distribution in Uganda. (European Commission, 2020)

Though the replacement of problematic soils by suitable soil and compacting among the most recommended techniques for enhancing soil, the costs involved in this method are extremely high especially where the problematic soils are seen to occupy vast stretch of land. Thus, researchers are prompted to look-up for alternative methods such as soil stabilization with different additives which has proven to be effective. This research therefore intends to investigate the effectiveness of using river sand as a soil stabilizer

for expansive soils. The research involved laboratory testing to evaluate the engineering qualities of expansive soils when blended together with river sand. The research is intended to contribute to the development of sustainable solutions for expansive soil stabilization in Uganda.

## **1.2 Problem statement**

The swelling and shrinkage of subgrade layer composed of expansive soils results into pavement failure in form of the differential settlements and cracking (Narasimha R., 2020). 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 C. O., 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 23-30 which indicates a greater potential for soil to undergo significant volume changes as a result of variations in moisture content. The liquid limit ranged from 46-56 which implies that the soils pose greater moisture sensitivity. The proportion of particles passing the sieve No. 200 ranged from

70-85% which shows that most of the soil's particle sizes are fines, and the California Bearing Ratio value ranged from 1-2 at the 95 % compaction which means that the soil has poor load-bearing capacity, which is a characteristic of expansive soils. This research therefore intends to investigate the effect of blending river sand with of expansive soils for their stabilization.



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 the stabilization of expansive soils.

#### **1.3.2 Specific objectives**

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

### **1.4 Research questions**

1. What are the engineering characteristics of expansive soils?

2. What are the engineering qualities of river sand?
3. What are the engineering qualities of the river sand stabilized soil?

### **1.5 Justification**

Areas such as North eastern Uganda where most of soil cover is expansive (Nagasha, 2019; Egeru A., 2015), 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 (Melling H.C., 2017). In order to save these costs for transportation of material for the other pavement layers, engineers result to stabilization or modification of the existing problematic soils. Owing to the presence of rivers such as Depeth, Okere, Kitorosi, Moroto, Kangole and Acolcol and other streams (Swidiq M., 2014) in the Karamoja sub-region, are known to have a lot of river sand deposit especially during the dry spells when they dry up and all that remains of the once water rich channels is sand (A. A. Kibuka & S. Jjuuko, 2023; Water Journalists Africa, 2020), this can also be seen in fig.3 below, which shows a number of 7 major rivers which include; River Depeth, River Okere, River Kitorosi, River Okot, River Moroto, River Kangole and River Acolcol which flow within the Karamoja region.

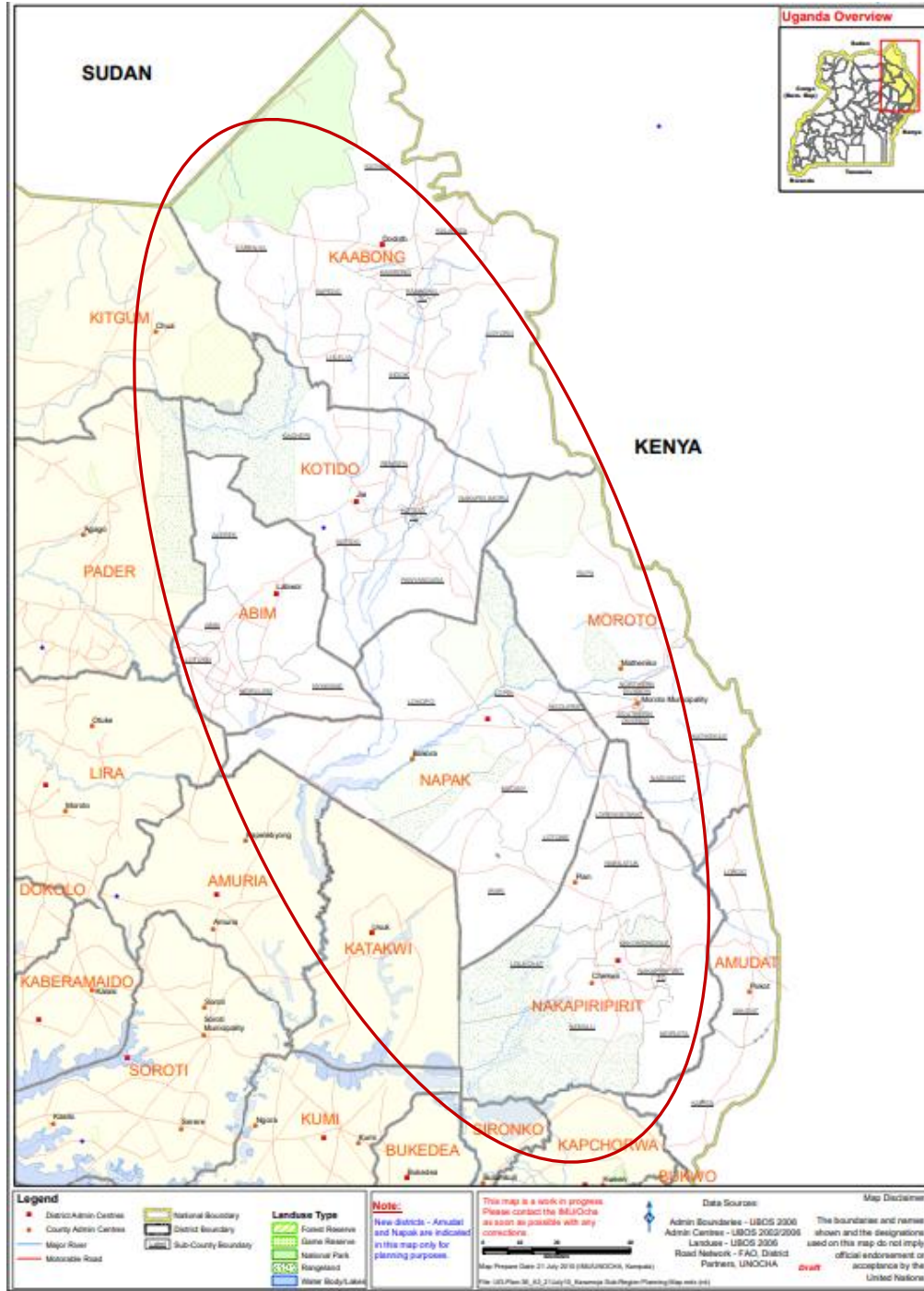


Figure 3: Map Karamoja sub-region, Uganda showing major rivers and streams (Alan & Samuel, 2021).

This locally available material when employed to stabilize the expanding soils address the challenge of looking for suitable soils from borrow pit in other regions.

The primary basis for the stabilization of soils is its composition (Afrain, 2017) since the behavior of sands and clays exhibit different properties, sandy granular particles contribute to strength and hardness of the soil. However, since they lack of cohesiveness and binding qualities between their grains, they are susceptible to erosion. On the other hand, clay soils possess adequate properties for binding grains together but lacks the shear strength especially when fully soaked. Thus, though moisture is problematic with clay soils, it avails cohesion to the sandy particles. A composite material with improved engineering qualities is typically formed when the two different types of soil are blended together in appropriate proportions (Archibong G. A., 2020).

## **1.6 Project scope**

### **1.6.1 Geographical scope**

The study's carried out within the geographical scope of Moroto-Nadunget section which lies along the Soroti-Moroto road, in North Eastern Uganda. The river sand was collected from River Kangole.

### **1.6.2 Content scope**

The study centered on investigating expansive soil stabilization by blending it with river sand, with Moroto-Nadunget road section as the case study. The soil samples were extracted and transported in air tight bags to the Sterling material Laboratory in Mukono from where the tests will be conducted.

### **1.6.3 Time scope**

The research project was conducted with in a period of 6 month, from October, 2023 to April, 2024.

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Introduction

This chapter discusses the theories that inform the basis of this research. It gives a general overview of what expansive soils are and their properties, subgrade and different techniques and methods of soil stabilization.

### 2.2 Soil

Soils are the unconsolidated layers that cover the Earth's surface and consist of particles with different sizes and shapes having minor bonds between them. Thus, soil forms a structure that can easily undergo deformation when subjected to forces (Harold M. Vans Es, 2017). Soil, as oppose to other materials used in construction is very sensitive to changes in moisture content. Thus, a number of the road failures are usually influenced by its behavior (Kisunge J., 2012). Most stabilization is undertaken for fine soils which include; silty, clayey and organic soils (Afrain, 2017). Stabilization of fine-grained soils or granular materials are the easiest since they have a substantial surface area relative to their particle dimension. In comparison to other fine soils, clay soils possess a wide surface area as a result of their elongated, particle shape (J. David Rogers, 2019). Silty soils are sensitive to minute changes in moisture thus are challenging to stabilize. Peat soils and organic soils are known to have a rich water content, high organic content and porosity (Nadhirah M.Z., 2018).

### 2.3 Expansive soils

Expansive soils are soils which are vulnerable to changes in volume which results from variation in moisture content. Due to the significant amount of swelling clay minerals

found in these soils, as the amount of moisture in them increases, they expand greatly and as they lose moisture, they shrink extensively leaving large void in the soil (Dharmendra B., 2022).

Expansive soils are usually experienced in the semi-arid and arid regions of the world. This is attributed to the low rainfall experienced in these areas. This inhibits the active montmorillonite clay mineral which is responsible for the high swell-shrinkage potential, from degrading into the clay kinds with minimal activity such as kaolinite and illite (Lee D Jones, 2012).

The swelling and shrinkage cycles experienced by expansive soils as a result of moisture variations pose significant recurrent stresses on the road structure bringing about early pavement failure. The soils tend to become exhausted and lose their potential to withstand structural loads and also pose elevated compressibility levels (John D., 2016). Thus, the engineering properties of these soils require improvement. A number of soil improvements such as soil replacement and chemical stabilization are carried out. However, for larger spans of areas covered with expansive soils, soil replacement is greatly expensive to achieve. In addition, some of the methods do not put into account the aspect of environmental compatibility (Ali, 2016). Thus, the use of river sand which is locally available and environmentally friendly.

### **2.3.1 Pavement and expansive soils**

Reducing the stress levels transmitted to the subgrade to permissible levels within which the soils wouldn't sustain significant deformation is one of the key functions of the pavement. Pavements pose a greater level of vulnerability to expansive soil damage in comparison to other engineering structures built on expansive soils. This is due to

their relatively lightweight and cover a comparatively vast area (Lee D Jones, 2012). Severe unevenness along significant lengths, longitudinal and lateral cracking resulting from substantial localized destructions are some of the major forms of deterioration caused to pavements built on soils characterized by expansiveness.

### **2.3.2 Mineralogical aspect of expansive soils**

The swell-shrinkage behavior exhibited by expanding soils is caused by the presence of clay mineral, montmorillonite. The arrangement of the clay crystal sheets and the molecular structure gives them a strong attraction to retain water molecules within the crystalline layers. Water molecules possess an electrical dipole structure which bring about a chemical-electric pull of its molecules to the very tiny clay sheets through the process of adsorption. Compared to other clay minerals, montmorillonite has the ability to absorb significantly more water molecules between its clay sheets (Guru P.P., 2023). Therefore, it has a high swell-shrink potential.

## **2.2 Subgrade**

Subgrade also referred to as the formation level is the native /insitu material underneath a pavement. For pavement structures, it's the subgrade that constitutes the foundation material, thus the characteristics possessed by the subgrade influence the performance of the pavement. 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 which in turn increases the construction costs incurred in the pavement construction. The subgrade properties and drainage are key influences to pavement deformation.

The subgrade strength is normally examined by the California Bearing Ratio (CBR) test. The CBR value obtained is attributed to the type of soil, moisture content and density. The strength and durability of the subgrade poses a great impact when it comes to the design and performance of the pavement (Muhammed Tanyildizi, 2023). In road construction, the greatest percentage of the pavement layers constitute of the soil or gravelly material. To achieve the required strength, the soils used in the pavement construction should meet the required specification (Afrain, 2017). Table 1 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

### **2.3 Soil stabilization**

The process of changing one or more characteristics to improve a soil’s performance and engineering qualities is referred to as soil stabilization. The soil shear strength can be increased through stabilization which controls its shrinkage-swell properties and in turn improves on its bearing capacity. Soil stabilization also lowers the soil’s permeability and compressibility which in turn increases the soil’s shear strength hence minimizing the settling of structures built on them (Afrain, 2017). Stabilization is not a

guarantee for that every soil property within the soil can be improved. However, the choice on which properties of the soil to improve influences the decision on the stabilization technological usage. The key soil qualities of concern to engineers include; strength, permeability, stable volume, compressibility and durability (Ali A. F., 2017)

### **2.3.1 Basic Principals of stabilizing soil**

A number of stabilization methods are influenced by distinct variables and factors. However, it's generally acknowledged that before any soil stabilization method is used, certain criteria should be considered (Archibong G. A., 2020) which include;

- I. Evaluating the soil's properties; this is the initial step for stabilization of any soil and it gives an overview of the engineering properties possessed by the soil which in turn guides on the selection of the appropriate stabilization method to be employed.
- II. Deciding the best affordable, efficient and appropriate stabilizing technique which will supplement or improve the properties identified.
- III. The soil mix design.
- IV. Taking into account the building process by effectively compacting the layers that are stabilized.

### **2.3.2 Soil stabilization classification**

Basing on which additives are to be incorporated, soil stabilization is grouped into two groups;

- I. Stabilization of the native soils without incorporating any additives
- II. Stabilization of the native soils with the incorporation of additives

### **2.3.2.1 Types of additives**

These include additives such as; cementing, modifiers, water retarding, water retaining, and water proofing agents. Each of the additives behave differently hence each has particular appropriate application and restriction (Archibong G. A., 2020).

Generally, cementing agents such as Portland cement, lime, lime-pozzolana and sodium silicates have been extensively employed to enhance existing gravel roads as well as stabilizing natural soils for road subgrade. However, one of the major downsides of using materials with cementing qualities in stabilizing soil is its cost, which in turn usually leads to the addition of small amounts of substance to the soil (Archibong G. A., 2020). As a result, the soil is merely modified rather than undergoing actual cementing mechanism.

Table 2 : summery of types of additives source: (Archibong G. A., 2020)

<b>Stabilization</b>	<b>Additives</b>
Mechanical	None
Cementing Agents	<ul style="list-style-type: none"> <li>• Cement</li> <li>• Lime</li> <li>• Lime-pozzolana</li> <li>• Sodium silicate</li> </ul>
Modifiers	<ul style="list-style-type: none"> <li>• Cement</li> <li>• Lime</li> <li>• Bitumen</li> </ul>
Water proofing agents	<ul style="list-style-type: none"> <li>• Bitumen</li> <li>• Membranes</li> </ul>
Water retarding agents	<ul style="list-style-type: none"> <li>• Organic cationic compounds</li> </ul>
Water retaining agents	<ul style="list-style-type: none"> <li>• Calcium chloride</li> <li>• Sodium chloride</li> </ul>
Miscellaneous chemicals	<ul style="list-style-type: none"> <li>• Resins</li> <li>• Calcium acrylate</li> </ul>

## 2.3 Soil stabilization methods

### 2.3.3.1 Lime *stabilization*

Lime has been utilized for centuries due to its ability to enhance the soil's ideal water content, shrinkage limit and strength limit and strength while lowering its swelling potential liquid limit, plasticity index and maximum dry density (Pei X., 2015) thus

enhances the subgrade soils to be compacted and worked. As sufficient amounts water and lime are added to the soil, its pH rises allowing the particles of the clay to dissociate. With the release of the silica and alumina, the calcium in the lime reacts with particles of clay forming calcium-silicate-hydrates and calcium-aluminate-hydrates. These compounds formed possess cementing properties comparable to those present in Portland cement. Consequently, the soil changes into a hard impermeable layer that can support more weight. However, the rate at which the stabilization process occurs is dependent on the type clay present in the soil. Thus, a mellowing period of about 4 days is allowed to obtain a uniform and friable soil mix. Lime stabilization enhances engineering properties of soil such as strength, permanent deformation, and reduction in swelling. These improvements are usually noticed in clays with moderate to high plasticity (Ali A. F., 2017).

#### **2.3.3.2 Cement stabilization**

The commonly employed chemical stabilization techniques is the use of cement forming a soil-cement material. Cement stabilization involves the mixing of pulverized Portland cement with soil together with water and the mixture then compacted to create a robust material with enhanced strength, durability and low moisture fluctuations (Anggraini V., 2014). Hydration takes place when cement and water are combined forming compound of calcium silicate hydrate and calcium aluminate hydrate with the release of excess calcium hydroxide (Khan TA, 2015). With the exception of soils with a PI value greater than 30 and those having an organic content higher than 2%, cement has shown to be an efficient means of stabilizing all soil types. However, with prior

addition of lime before cement is mixed to soils having very high PI can be done to keep the soils more workable (Firoozi AA T. M., 2014; Ronoh V, 2014).

As compared to lime, cement hydrates more quickly than lime does, resulting in an instantaneous increase in strength. Therefore, when utilizing cement stabilization, there is no requirement for a mellowing time, the stabilized mix is compacted after 2 hours of initial mixing. Over time, the material's strength improves (Ali A. F., 2017). In addition, facts such as high temperature, low humidity and delayed compaction often result in insufficient strength increase (Ismail A, 2014).

### **2.3.3.3 Stabilization using fly ash**

During the combustion of coal, fly ash is generated as a by-product of the process (Bose B., 2012). Fly ash is an aluminous, pozzolan-siliceous material. Fly ash constitutes of two classes; class F fly ash and class C fly ash. Class F fly ash doesn't self-cement, it requires an activator of either lime or cement, which is why it's not often used. (Firoozi AA T. M., 2015). Using class C fly ash and lime, a criterion was created to determine the structural layer coefficient for the flexible pavement's base layer (Rupnow TD, 2015), results indicated that the base layer lowered when the two additives were added, when combined with lime, fly ash can be used to stabilize most coas- and medium-grained soils with a PI of no more than 25.

### **Impacts of chemical stabilization on the environment**

Currently the world is experiencing a major challenge of global warming, and carbon dioxide is contributing greatly to the phenomenon (Du Y, 2015). During cement manufacturing large amounts of carbon dioxide is emitted which contributes to about 10% of total carbon dioxide emission (Gao T, 2015). In addition, during lime

stabilization, calcium carbonate is calcinated during the process of producing material that contain calcium (Ibetehaj T. J., 2014), which happens at high temperatures and releases carbon dioxide into the atmosphere which negatively impacts the environment. The stabilization of soil using cement near aquatic areas may rise the pH of water, which will probably affect plant development and change the species composition (Archibong G. A., 2020). Furthermore, using it during stabilization may cause a localized rise in dust particles impacting the well-being of those using it. Fresh cement may also contain traces of hexavalent chromium, which is an allergen to certain individuals which impacts their well-being. Proper attention should be given to the implications of the stabilization decision on the environment, taking into account both the short- and long-term impacts, even though some of those effects can be mitigated.

#### **2.3.3.4 Mechanical stabilization**

In order to create a composite material that meets the necessary soil qualities and has superior properties to any of its constituents, mechanical stabilization is achieved by combining soils of two or more gradation. The method combines the engineering properties of each of the blended materials to the soil mixture. With regard to mechanical stabilization, these soils can broadly be divided into two groups (Arora K. R., 2012);

- I. Aggregates; strong, well graded and angular sand and gravel particles characterize these soils. These give the soil a skeletal structure that addresses its internal friction and incompressibility.

- II. Binders; they are soils composed mainly of clays and silts and are distinguished by an average grain size of less than 75 microns. They avail cohesion, plasticity and imperviousness to the soil.

The soils when thoroughly mixed, obtain an improved gradation of the blended soil having properties of both materials in one mix (Arora K. R., 2012). Through compaction, the void ratio of the mixture is reduced. In some cases, it's been noted that certain soils display "show-skip grading". This implies that the particle size distribution curve will display a horizontal section within the particle size range showing absence of particles in that specific size range. In this case, adding the missing size particle range results in the application of mechanical stabilization. Cohesionless soils will be combined with cohesive soils for improved gradation and compaction (Archibong G. A., 2020).

#### **Factors affecting mechanical stabilization**

- I. Aggregate strength; the stability of mixed soil increases with the increase in strength of aggregates.
- II. Mineral composition; the stability of the blended mix is largely dependent on the mineral composition of the soil mix.
- III. Gradation of the mixture; increasing mechanical stability of the soil mix requires proper gradation of the soil mix. This is achieved by finer binder particles being well encapsulated in the coarser grain pore spaces.

Fuller's law can be used to guide the design of soil mixes and it stipulates that the granular soil mass achieves a very high density after compaction if the distribution of particle size is as follows;

$$\text{percentage of particle passing any sieve} = 100 \times \sqrt{D/D_{max}}$$

Where; D= opening of a particle size,  $D_{max}$ = size of the largest particle

Although according to (Arora K. R., 2012), ideally the mixture should contain roughly 25% binder, but it's crucial to have more particles pass the 75-micron sieve than what Fuler's calculations suggest.

- IV. Plasticity characteristics of the soil mixt; the plasticity of the soil mixture should meet the requirements for the intended use. For intense according to MoWT, general specifications, 2005.

Table 3: plasticity specification for different soil categories (MoWT, 2005)

soil	Maximum plasticity index BS 1377: Part 2
G7	30
G15	25
G30	16
G45	14
G60	10
G80	8

- V. Adequate compaction of soil mixture; in the field, the compaction level determines the soil's mechanical stability.

One of the easiest ways to stabilize soil is through mechanical means. Usually, subgrade qualities are improved with it. The environmental impact of this technology is negligible (Archibong G. A., 2020).

#### **2.3.4 Engineering properties of river sand**

Sand is an extensively utilized building material worldwide. River sand in particular is a common source of sand used for construction works. According estimates by the industry, river sand contributes to more than 60% of the overall sand used in construction world over (Dinh, 2022). River sand is a naturally occurring material often found at the bottom of river channels that is widely used in the field of engineering for its unique physical properties which include;

- i. Particle size distribution: it consists of a varying range of particle sizes, ranging from fine sand to coarse sand. The grain size distribution of river sand is important since to a large extent it influences its strength and durability. (Bosboom J., 2021; Jayakody S., 2020).
- ii. Bulk density: this property influences the weight and volume of the material it is added to. The river sand's bulk density basically ranges from 1.4 to 1.6 g/cm<sup>3</sup> (Bosboom J., 2021).
- iii. Absolute density: this is expressed as unit volume of sand and serves as a measure of its compactness. River sand's absolute density varies from 2,4 to 2.7 g/cm<sup>3</sup> (Bosboom J., 2021).

River sand is an all-purpose material that has a number of applications in construction and other engineering fields. Due to its mechanical and physical

properties, it makes it the most preferred for the stabilization of expansive soils (Muhindo W. M. A., 2023).

#### **2.3.4.1 Formation process of river sand**

The naturally occurring sequence of geological events results in the production of river sand. Rocks weathering is the initial stage in the process, which involves the breaking down of rocks into smaller particles by factors such as wind, water and temperature variations. This is followed by transportation of these particles by river or stream. Water serves as an essential component in the transportation, bringing together the particles and smoothening them out. Sand and other silt are deposited along the river bed when river's flow slows down. Sand particles are sorted by size and density in these lower energy regions. Lower layers get compacted over time by the weight of the uppermost sediment layers, which build up over time (Bello-Palacios & Almenningen, 2021). This compaction, coupled with potential cementation by minerals like silica or calcium carbonate, binds the sand grains together. With pressure and compaction, loose sand sediment transforms into sandstone through lithification. Over time, exposed sandstones undergo erosion, releasing sand particles back into the sediment cycle and continuing the geological journey of river sand. (Yang & Shi, 2019).

#### **2.3.5 Role of river sand in soil stabilization**

Sand exhibits high load bearing capacity under confined conditions and can be added to cohesive soils in differing amounts as an additive which brings about alteration in the plasticity properties, strength and compaction of the soil mix (Khemissa M., 2015). Kallaros and Athanasapoulou (Kallaros G. & Athanasapoulou A., 2016), findings showed a considerable increase in the soil's strength with the addition of sand up to 60% of the

soil's weight and a discernible change in the Atterberg limits with a 42% reduction in linear shrinkage. As a result, the mix was suggested for use as a subgrade when building flexible pavements on country roads with minimal traffic.

River sand is frequently used in soil stabilization methods because of 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 (Kallaros G. & Athanasapoulou A., 2016).

## **CHAPTER THREE: METHODOLOGY**

### **3.1 Introduction**

This chapter accounts for the methods that were used to acquire the materials, the sampling and the laboratory tests that were performed to obtain the objectives of the research project. The findings to aid explain the research concept were obtained with reference to the standard tests and procedures that were executed during the study and are further explained below.

### **3.2 Material acquisition and preparation**

#### **3.2.1 Expansive soils**

The disturbed samples of expansive soils were obtained using hoes and shovels along the Moroto Nadunget road section at a depth of 1-1.5m at varying locations during the field survey. The expansive soils were obtained by open excavation to a depth of 0-1m below the ground level. The soil sample was then collected and packed in air tight bags and labels attached indicating the sampling date, soil description and sampling depth. This was then transported to the laboratory for testing.

#### **3.2.2 River sand**

About 60 kg of river sand was obtained from River Kangole using shovels which is located at coordinates 2°18'54''N and 34°36'49''E in Moroto. The sand was placed in sampling bags and moved to the material's laboratory at Stirling where it was air dried and then tested for various engineering properties.

### 3.3 Sample preparation

#### 3.3.1 Soil sample

Both the soil sample and sand were spread uniformly on separate trays and left to air dry for about 3 days and then partitioned for various tests.



*Figure 4: sand being dried*



*Figure 5: disturbed sample of expansive soil being dried*

### **3.4 Experiments**

To examine the different engineering properties of the material as indicated in the methodology, a number of tests were carried out, which include;

#### **3.4.1 Tests on expansive soils**

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

The test was carried out to assess the relative portions of different size particles in the soil material. From this, it was determined that the soil consisted of predominantly fine particle sizes and thus the engineering qualities of the soil are likely to be influenced by these particles. The method of wet sieving was preferably used since most soils are cohesive and it's a more accurate means of grading the soil as oppose to dry sieving.

##### **3.4.1.2 Liquid limit test using cone penetration method with reference to BS. 1377 part 2:1990**

The soil transitions from a liquid to a plastic condition at a moisture concentration known as the liquid limit. The moisture content that corresponded to the 20mm cone penetration was determined as the liquid limit. The test results were used in the identify and classify the fine-grained cohesive soils.



*Figure 6:sample preparation for the Atterberg limit test*

#### **3.4.1.3 Plastic limit with reference to BS. 1377: part 2:1990**

The soil turns plastic at a moisture content referred to as the plasticity limit. The soil's plasticity index was calculated using the liquid limit and plastic limit test values. Which is calculated as the difference between the liquid limit,  $W_L$  and the plastic limit,  $W_P$ .

$$I_p = W_L - W_P$$

The plasticity index when plotted against the liquid limit on the plasticity chart, can be used to categorize expansive soils.

#### **3.4.1.4 Linear shrinkage test with reference to BS. 1377: part 2 1990**

The test works under the basis that the soil types that retain water undergo significant reduction in size when they lose the water contained within. Shrinkage in soil occurs due to drying and it is highly experienced in clays than in silts and sands. The reduction in the length of a wet soil sample upon drying is referred to as linear shrinkage and it's calculated using linear measurement in relation to a standard half-cylinder mould of the soil sample fraction passing a  $425\mu m$  test sieve. The test quantifies the extent of shrinkage likely to be experienced especially when dealing with expansive soils.



*Figure 7: linear shrinkage molds containing soil sample*

#### **3.4.1.5 Compaction test (proctor) with reference to BS. 1377: part 4:1990**

The test was conducted with the aim of obtaining the correlation between the compacted density and soil moisture content. The test provides a guide for specifications on field compaction. A soil's achievable dry density is determined by the moisture content and the level of compaction that is applied. For that kind of compaction, the moisture content that corresponds with the maximum dry density is the optimum moisture content.

#### **3.4.1.6 California bearing ration, using the one-point method with reference to BS. 1377 part4:1990**

The test is used to ascertain the strength of the soil especially when designing for pavement material of natural gravel. The strength of materials of natural gravel is exhibited in terms of their CBR value. The CBR value was determined as the resistance to the conventional cylindrical plunger with 50mm diameter penetrating 2.5mm.

### **3.4.2 Tests on the river sand**

The river sand used during the study was tested to check for the various engineering properties to ensure that it adheres with the required specifications and standards for its intended use. For the research study, the tests carried out included; bulk specific gravity, grain size analysis, water absorption and silt content.

#### **3.4.2.1 Specific gravity test with reference to ASTM C 128-97**

The test was conducted as a measure of the material's quality, aggregates with a low specific gravity are often characterized as weaker than those with high specific gravity. It informs of the sand's potential to support structural loads and its porosity. The substantial specific gravity of sand is about 2.65. For road construction the specific gravity of fine aggregates normally used ranges from 2.5-3.0 with an average of about 2.68.

#### **3.4.2.2 Grain size analysis as per ASTM C 128**

The grading of sand was classified considering the percentage of sand that passed through the different sieve sizes; sand with a uniform particle size distribution is classified as well graded, whereas sand that contains a wide range of particle sizes is classified as poorly grade. The test was conducted with the aim of determining the particle size distribution of the sand since it reflects on the sand's particle size and shape. These parameters are responsible for its strength, stability and porosity.



*Figure 8: grain size analysis test for the river sand*

#### **3.4.2.3 Water absorption with reference to ASTM C 128-97**

The test was conducted to deduce the measure of strength of the sand. The test provides an overview of strength of aggregated. Aggregates with higher water absorption are more porous and thus regarded as unsuitable. With reference to BS. 812-2, the maximum permissible water absorption value is 3%.

#### **3.4.2.4 Silt content with reference to ASTM C 40**

The test was carried out to determine the amount of silt particles present in the sand. Silts refer to fine -grained particles that are smaller than sand particles but larger than clay particles. They are known to have an effect on the strength of sand and can result into poor compaction, reduced shear strength and increased settlement. The ASTM standard D2419-14 limits the silt content of sand used for construction purpose to a maximum of 10%. However, for river sand, the permissible silt content is less than 8%, more than this reduces the bonding capacity of raw materials affecting the durability of the work.

### **3.4.3 Stabilized mix**

For the stabilized mix, the same tests as those performed on the neat soils were carried out but this time varying the proportions of soil and sand. This was conducted to ascertain the impact of sand on the plasticity index, compaction and strength properties of the soil and from which determined the optimum mix proportion of the two materials that would give the engineering properties required for subgrade material.

#### **3.4.3.1 Sample preparation**

The neat soils to be treated were spread and broken down to the required loose thickness as specified in the section 3700 of the MoWT General Specifications, 2005. The river sand was then spread over the prepared soil at required rate and the two materials were dry mixed by means of ploughs until uniformly mixed. The mix material was then partitioned and tested for various properties.

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

The test was carried out to determine the particle size distribution of the varying blended mixes of the soil and river sand. However, particular emphasis was on the particles retained on the sieve No. 200 as this determines the fine fraction of the composition.

#### **3.4.3.3 Liquid limit test using cone penetration method with reference to BS. 1377 part 2:1990**

The test was carried out to ascertain the variation of the liquid limit with the varying blended mixes.

#### **3.4.3.4 Plastic limit with reference to BS. 1377: part 2:1990**

The plastic limit was determined for varying blended mixes. Results obtained from the test were used in conjunction with the liquid limit results to calculate for the plasticity index of each of the blended mix. The plasticity index,  $I_p$  is the difference between the liquid limit,  $W_L$  and the plastic limit,  $W_P$ .

$$I_p = W_L - W_P$$

#### **3.4.3.5 Linear shrinkage test with reference to BS. 1377: part 2 1990**

To quantify the extent of shrinkage likely to be exhibited by the varying blended mixes, the linear shrinkage test was conducted. The length and diameter of the dry samples were measured using a venire caliper.

#### **3.4.3.6 Compaction test (proctor) with reference to BS. 1377: part 4:1990**

To determine both the maximum dry density and optimum moisture content of the varying blended mixes, the proctor test was conducted.

#### **3.4.3.7 California bearing ration, using the one-point method with reference to BS. 1377 part4:1990**

The CBR test was performed to evaluate the strength of the varying blended mixes. Since the stabilization method used in the research study is entirely mechanical stabilization, the strength of the stabilized mix is best determined using the CBR test with reference to series 3700, (MoWT, 2005). This is because the material being added to the neat soil is inert and is thus not expected to have any form of chemical reaction with the soil and thus no curing is required for the soil to achieve maximum strength. Instead, the strength developed by the material is instant.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

The test results deduced from the various tests conducted during the research investigation are covered in this chapter.

4.2 Engineering properties of the expansive soils.

4.2.1 Particle size distribution

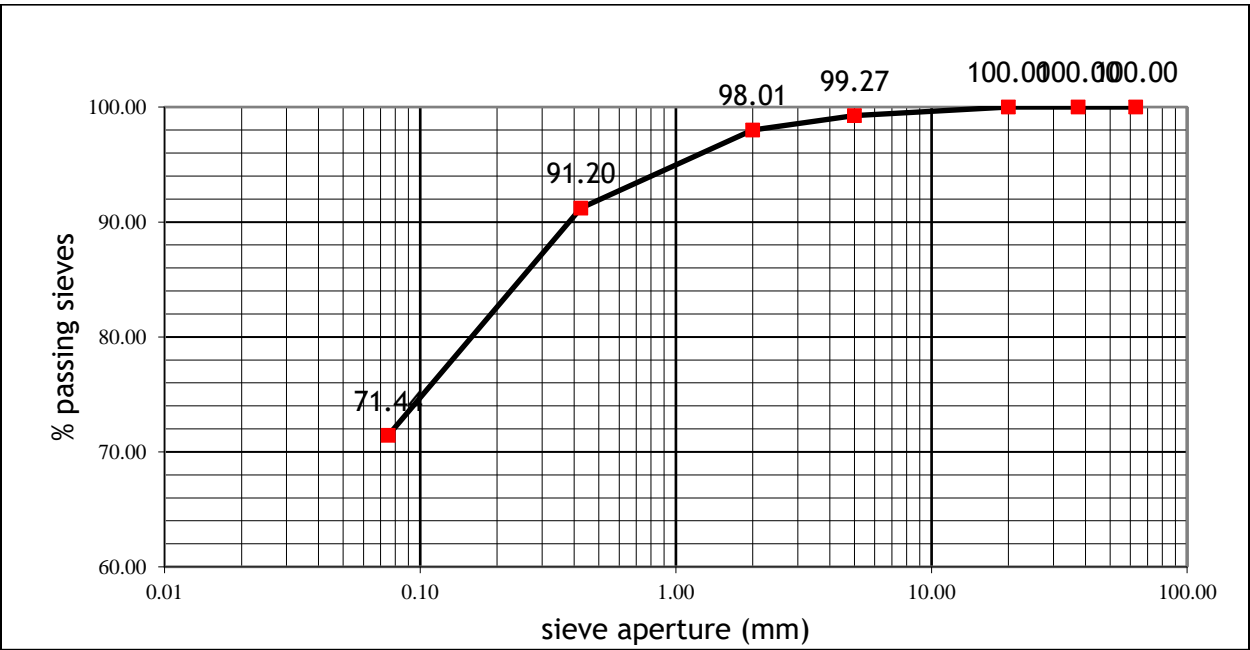


Figure 9: particle size distribution of the neat soil

The curve above represents the full range particle sizes in the fraction of the soils used for research, from the smallest soil particle size to the largest. From the graph, it's seen that the fine fraction; percentage passing the 75µm sieve size is 71.44% and the coarse fraction; the percentage retained on the 75µm is 28.56%. This implies that the soils are fine grained with reference to the Unified Soil Classification System (USCS).

Soils with finer particles are usually more sensitive to water content (Andrew Lees, 2022).

#### 4.2.3 Liquid limit

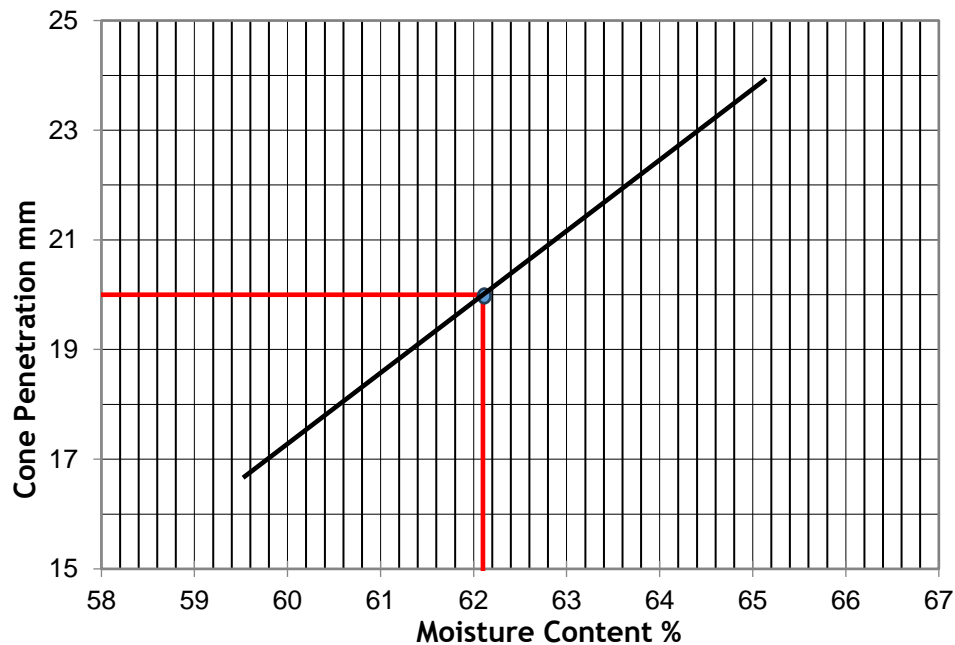


Figure 10: liquid limit graph

The graph plotted represents the correlation between the moisture content and the cone penetration. The liquid limit of the soil sample is 62% which is the moisture content correlating to a cone penetration of 20mm. with reference to the Unified Soil Classification System (USCS), the soil was considered to have a high plasticity since its liquid limit is greater than 50%.

#### 4.2.4 Plastic limit and plasticity index

The moisture content at which the soil transitions from plastic to semi-solid was determined to be 31.0%. Having both the liquid limit and plastic limit parameters of the soil, the plasticity Index, (PI) was then calculate from the equation;

$$PI = W_L - W_P$$

$$PI = 62 - 31$$

$$PI = 31\%$$

#### 4.2.5 Linear shrinkage

The linear shrinkage was determined to be 18%. This signifies that the soils are likely to experience a shrinkage of about 18% when exposed to dry conditions.

#### 4.2.6 Soil classification

The soil was classified with reference to the Unified System of soil Classification (USCS) and the plasticity chart.

*Table 4: Unified Soil Classification System (Zzigwa M., 2022)*

	Prefix (Main terms)	Suffix (Qualifying term)
Coarse grained soils (more than half retained on a 75µm sieve)	G = Gravel (more than half the coarse fraction in gravel range)	Coarse grained having less than 5% passing a 75µm sieve <ul style="list-style-type: none"> <li>• W = well graded (<math>C_u &gt; 4</math> (for gravel) or <math>&gt; 6</math> (for sand); <math>1 &lt; C_c &lt; 3</math>)</li> <li>• P = Poorly graded (not meeting all grading requirements for suffix W)</li> </ul>
	S = Sand (less than half the coarse fraction in gravel range)	Coarse grained having more than 12% passing a 75µm sieve <ul style="list-style-type: none"> <li>• C = With clay (PI above the A line and <math>PI &gt; 7</math>)</li> <li>• M = With Silt (PI above the A line or <math>PI &lt; 4</math>)</li> </ul>
Fine grained (Less than half retained on a 75µm sieve)	C = Inorganic Clay (PI above the A line and $PI > 7$ )	L = Low plasticity ( $LL < 50\%$ )
	M = Silt & O = Organic Clay (PI above the A line and $PI < 4$ )	H = High plasticity ( $LL > 50\%$ )
Highly organic soils	Pt = Peat	

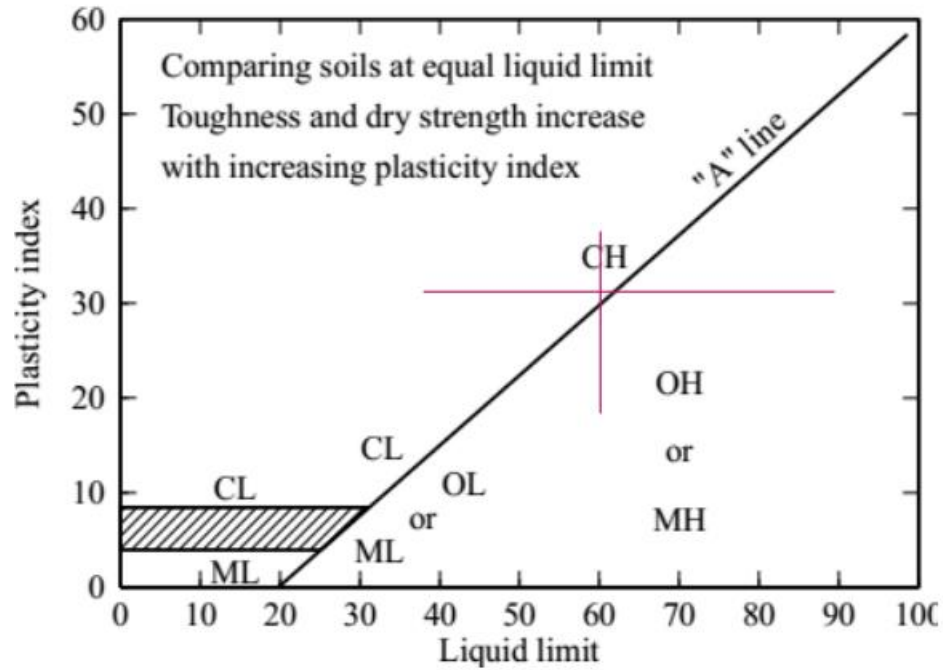


Figure 11: plasticity chart (Zzigwa M., 2022)

When the plasticity index, 31% and the liquid limit 62% of the soil were located on the plasticity chart, the point was seen to lie above the A-line. This confirms that the soil is a CH soil; inorganic clay with high plasticity.

#### 4.2.7 Proctor test

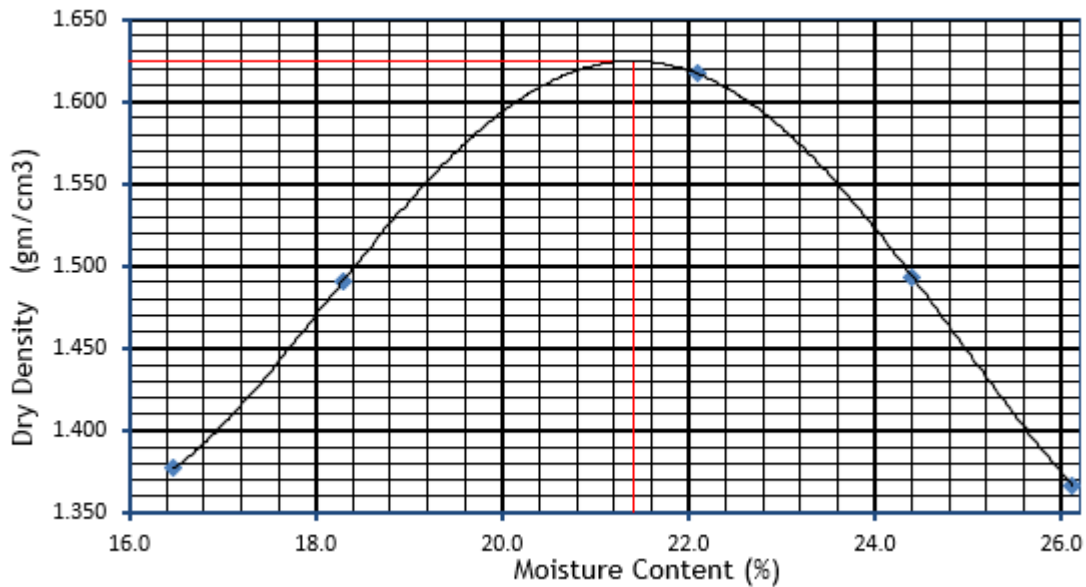


Figure 12: Graph of the proctor test

The relationship between the soil's dry density and moisture content is displayed on the graph above. The MDD,  $1.625 \text{ g/cm}^3$  was determined as the dry density that corresponded to the peak of the curve. The OMC, 21.4% was determined as the moisture content correlating with to the maximum dry density.

#### 4.2.8 California Bearing Ratio (CBR)

The compacted CBR mould achieved a dry density of  $1.688 \text{ g/cm}^3$  which is approximately equal to the maximum dry density,  $1.652 \text{ g/cm}^3$  determined from the proctor test which implies that the dry density was maintained.

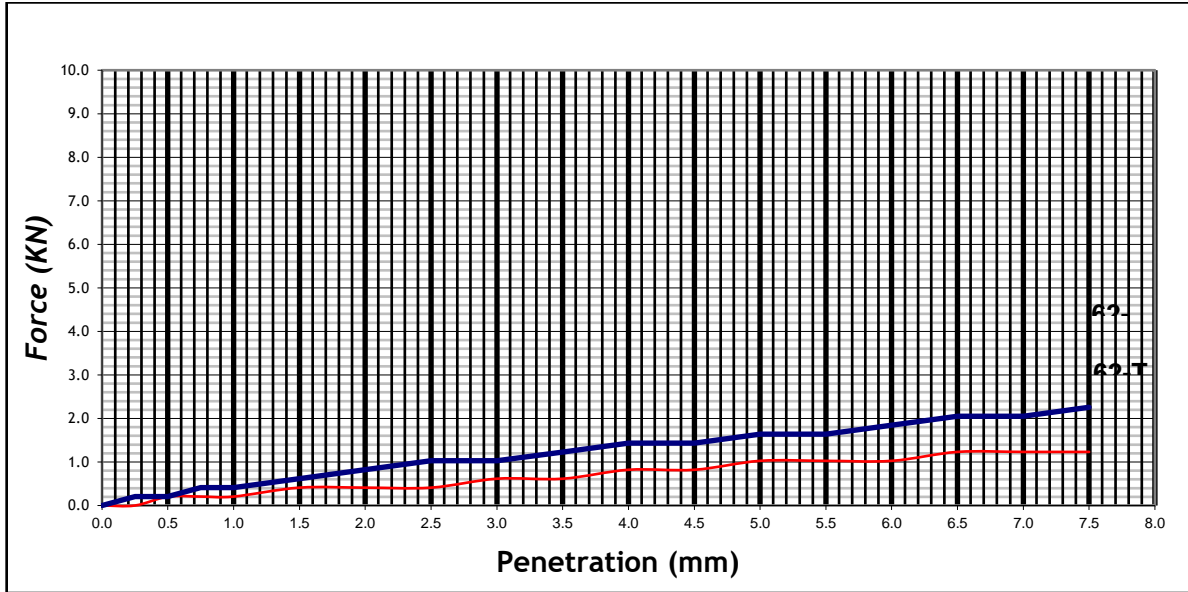


Figure 13: Force against penetration graph

The graph represents the relationship between the force and penetration. The CBR was determined by substituting the value of force at the 2.5mm and 5.0mm into the equation;

$$CBR (\%) = P \times \frac{100}{13.2} \quad \text{at a penetration of 2.5mm}$$

$$CBR (\%) = P \times \frac{100}{20.0} \quad \text{at a penetration of 5.0m}$$

With reference to CML, the CBR for the soil was determined to 8%, which is less than 15%: the minimum CBR value for subgrade with reference to MoWT, General Specifications, 2005.

### 4.3 Engineering properties of the river sand

#### 4.3.1 Grading test

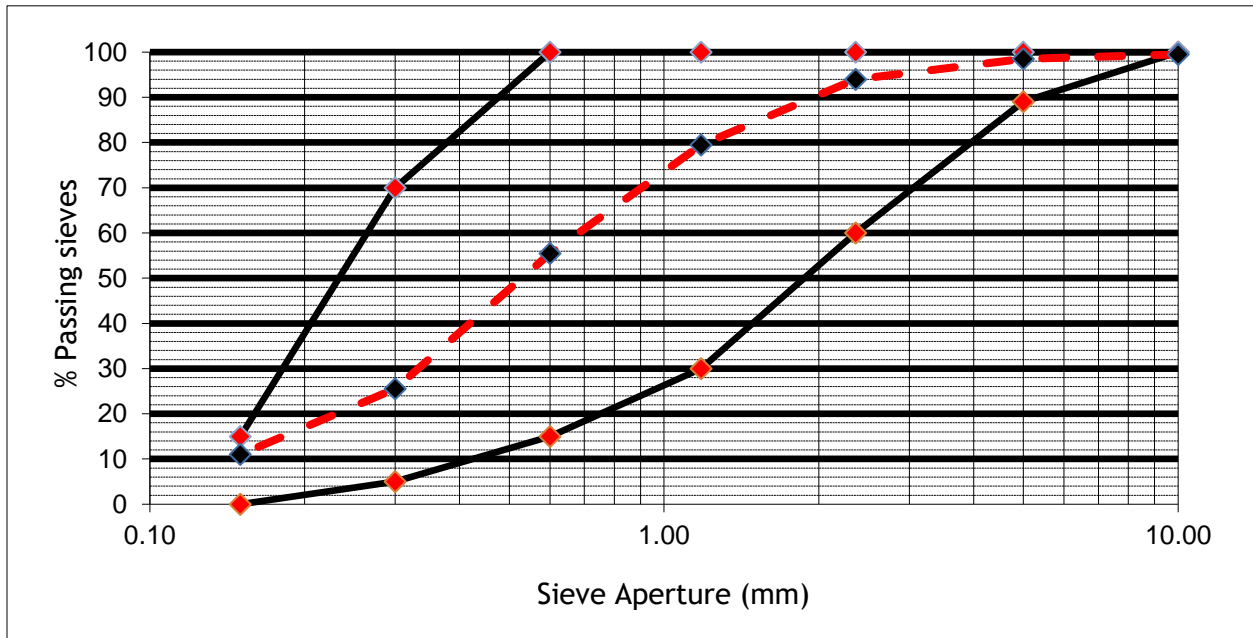


Figure 14: grading curve of the river sand

The graph represents the relationship between the percentage passing against the sieve size. From the graph it's seen that grading curve of the river sand denoted in red colour lies within the grading envelop. This implies that the river sand is well graded and hence possesses good quality required for stabilization of the expansive soils (MoWT, 2005).

### 4.3.2 Water absorption, silt content and bulk specific gravity

Table 5: test results of water absorption, silt content and bulk specific gravity

Engineering property	Test value	Permissible value	standard	units
Water absorption	1.6	3max	ASTM C 128-97	%
Silt content	3.0	8max	ASTM C 40	%
Bulk specific gravity	2.5	2.4-3.0	ASTM C 128-97	Dimensionless

The test results of the water absorption, silt content and bulk specific gravity all lie within the permissible requirements for good quality sand. This implies that the river sand used in the study possessed good qualities required for the stabilization of the expansive soils.

### 4.4 Engineering properties of the river sand stabilized soil

#### 4.4.1 Particle size distribution

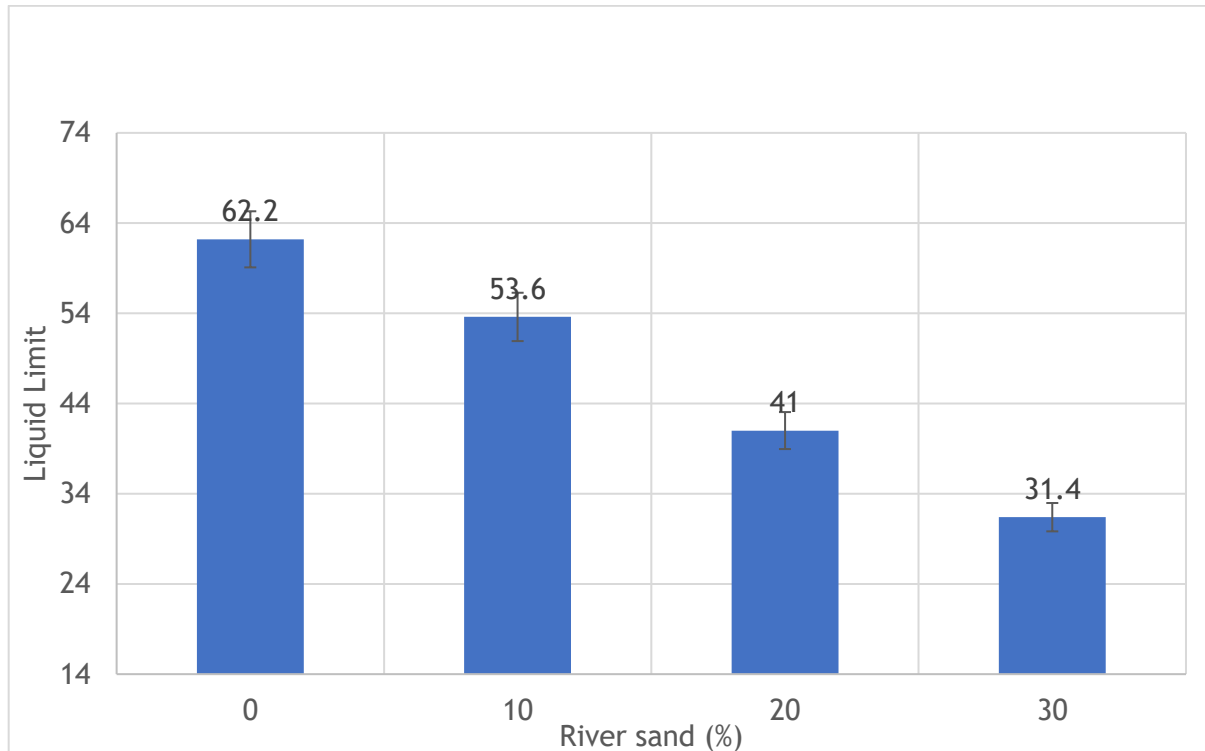
Table 6: Fine fraction with increase in the content of river sand

PERCENTAGE OF RIVER SAND CONTENT (%)	FINE FRACTION (PERCENTAGE PASSING 75 $\mu$ m SIEVE) (%)
0	71.45
10	58.35
20	41.45
30	32

With the addition of sand, the grading curves of the blended mixes improved. This was observed in the decrease percentage of through the  $75\mu m$  sieve size, since the finer clay particles were substituted by the coarse particles of the river sand. Usually, the size and arrangement of the soil's particles will tend to influence its properties. Soils that are characterized by larger size particles are attributed to be stronger as a result of the higher interparticle friction. On the other hand, soils with finer particles are usually more sensitive to water content. For soils comprising of a differing range of particle sizes, the gaps that exist between the larger particles are partially filled by the smaller particles creating a dense material when compacted. This results into a material with high strength and good engineering properties. Soil is said to be well graded if it constitutes of a wide particle distribution with no significant size gap (Andrew Lees, 2022).

## 4.4.2 Atterberg limits

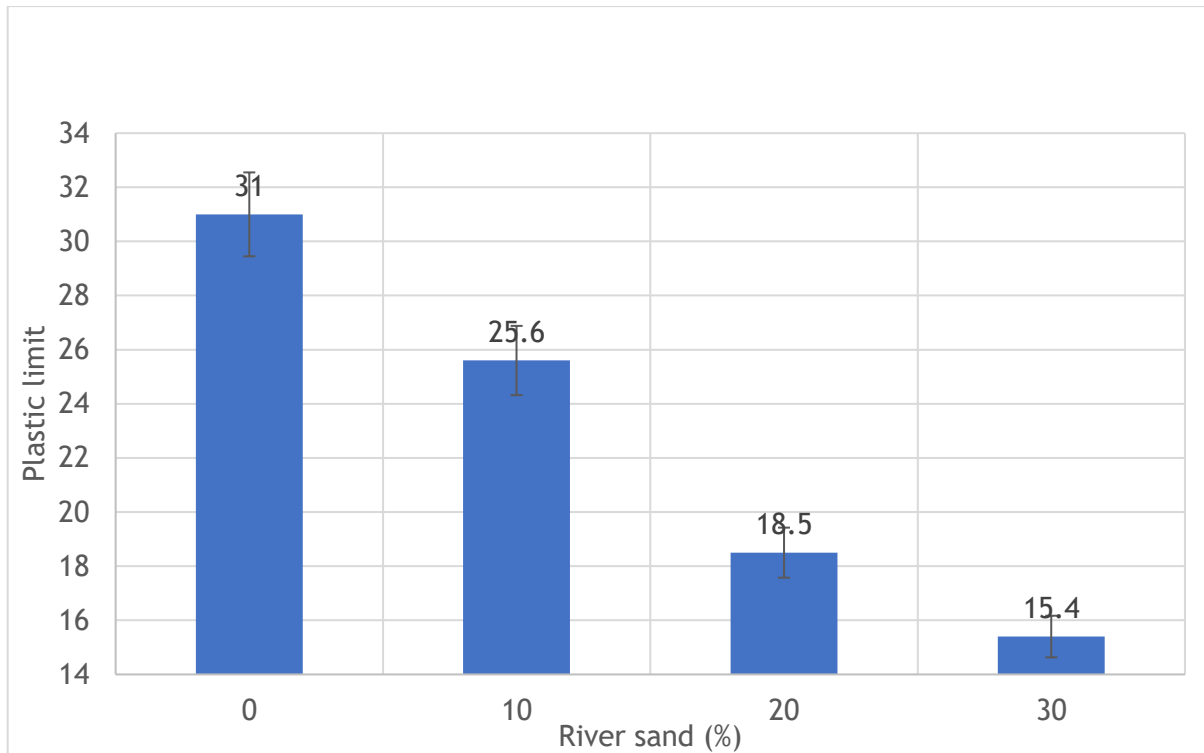
### 4.4.2.1 Liquid limit



*Figure 15: Liquid limit with increase in the river sand content*

The liquid limit values of the soil sample with varying percentages of river sand; 0%, 10%, 20% and 30% were 62.2%, 53.6%, 41%, and 31.4% respectively. This trend shows a considerable lowering in the liquid limit of the neat soils with increase in the portion of the river sand. This is attributed increasing reduction in the soil's fine fraction with the increase of coarse fraction by the addition of the river sand. Indicating that the fine particles were gradually replaced by the coarse particles of the river sand thus improvement in the soil's gradation. With reduced percentage of fine particles, the sensitivity of the soil to moisture is also reduced thus a decrease in the water retention ability of the soil (Andrew Lees, 2022; A. A. Kibuka & S. Jjuuko, 2023).

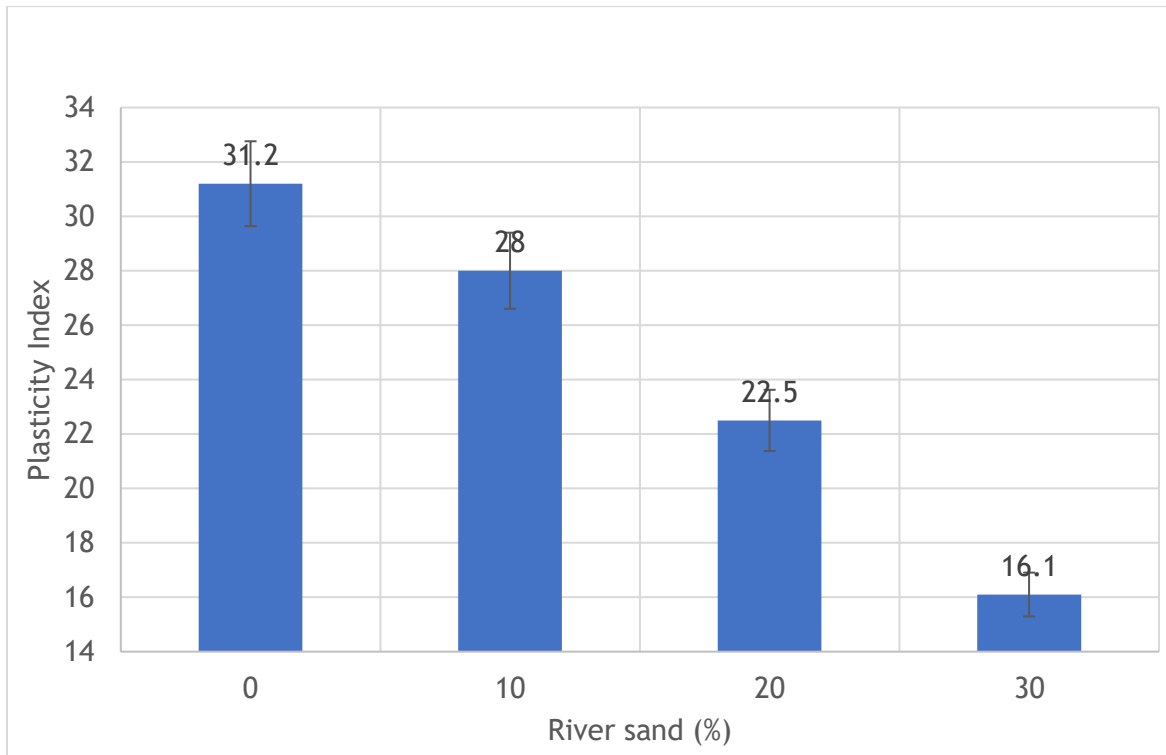
#### 4.4.2.2 Plastic limit



*Figure 16: A graph of plastic limit against river sand percentage*

The plastic limit reduced considerably: 31 % with 0% river sand, 25.6% with 10% river sand, 18.5% with 20% river sand and 15.4% with 30% river sand. The trend indicates a decrease in the plastic limit with increase in the river sand fraction. This trend 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).

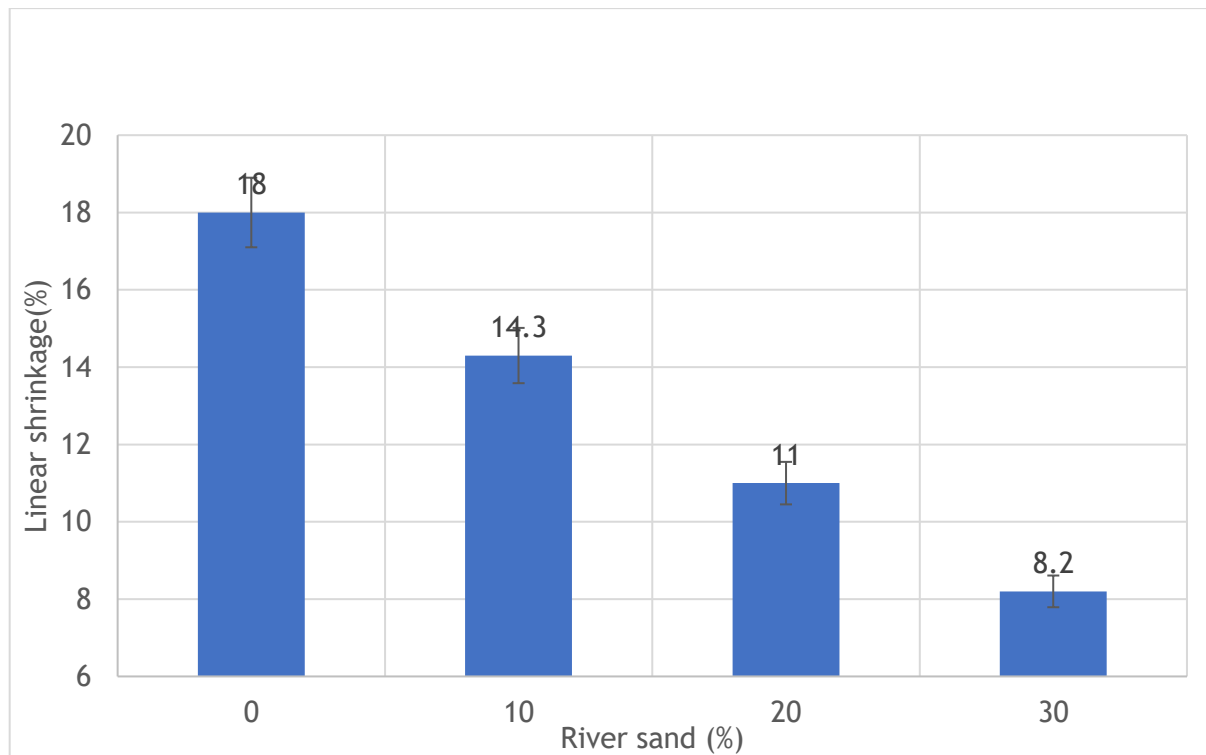
#### 4.4.2.3 Plasticity index



*Figure 17: A graph of the plasticity index against the river sand content*

The PI of the neat soil is observed to reduce greatly with the addition of the river sand content. This is due to the grading of the soil which improves from fine-grained to fine and coarse-grained, and with the decrease in the fine particles, the moisture retention ability of the soil also reduces substantially. This indicates a substantial decrease in the plasticity property of the soil with the increasing content of the river sand (Salima A., 2022).

#### 4.4.2.4 Linear shrinkage

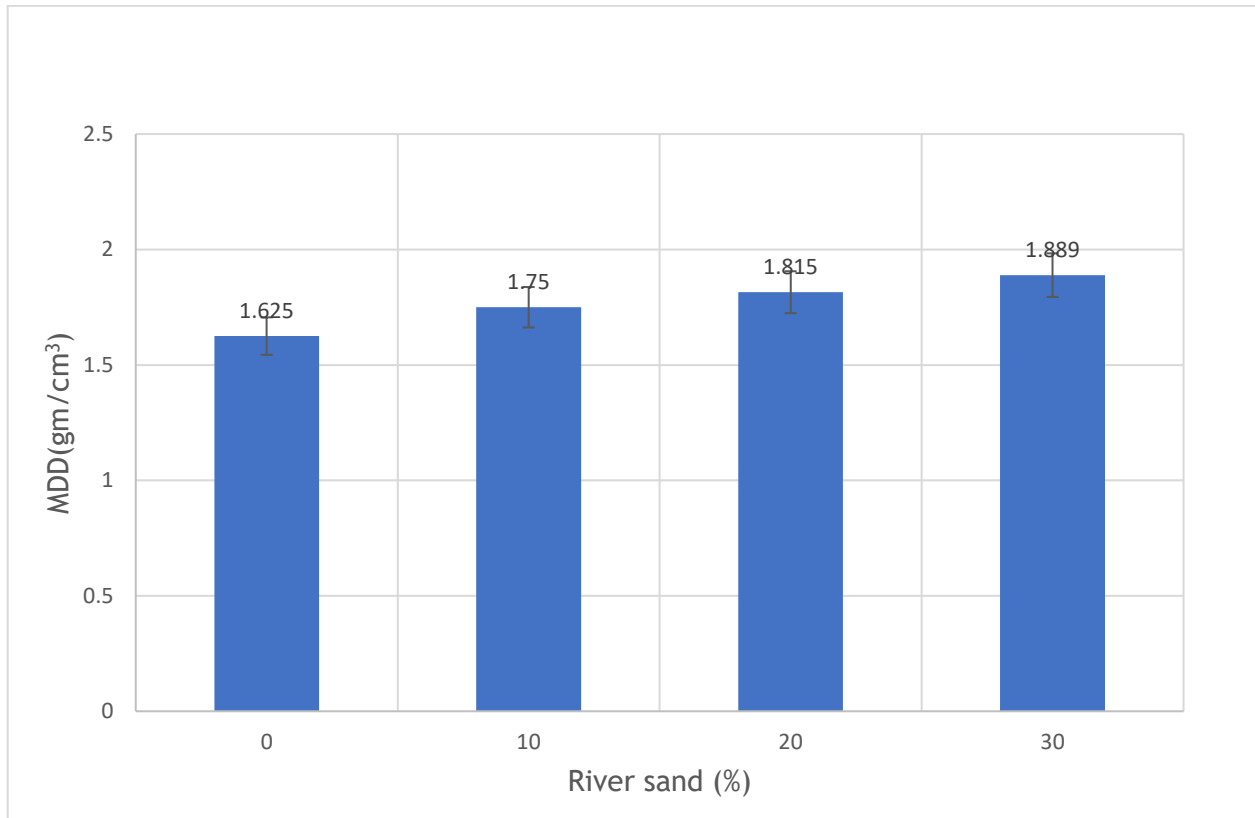


*Figure 18: A graph of linear shrinkage against river sand percentage*

The linear shrinkage of the soil also reduces substantially with the increase in the river sand fraction. This is attributed to the gradual enhancement in the soil texture with the addition of the river sand (Dongdong L., 2021; Kallaros G. & Athanasapoulou A., 2016). The fine particles of the soil which attribute to the high plasticity property of the soil are replaced by the non- plastic river sand hence reduction in the linear shrinkage exhibited by the soil.

#### 4.4.5 The Maximum Dry Density and Optimum Moisture Content

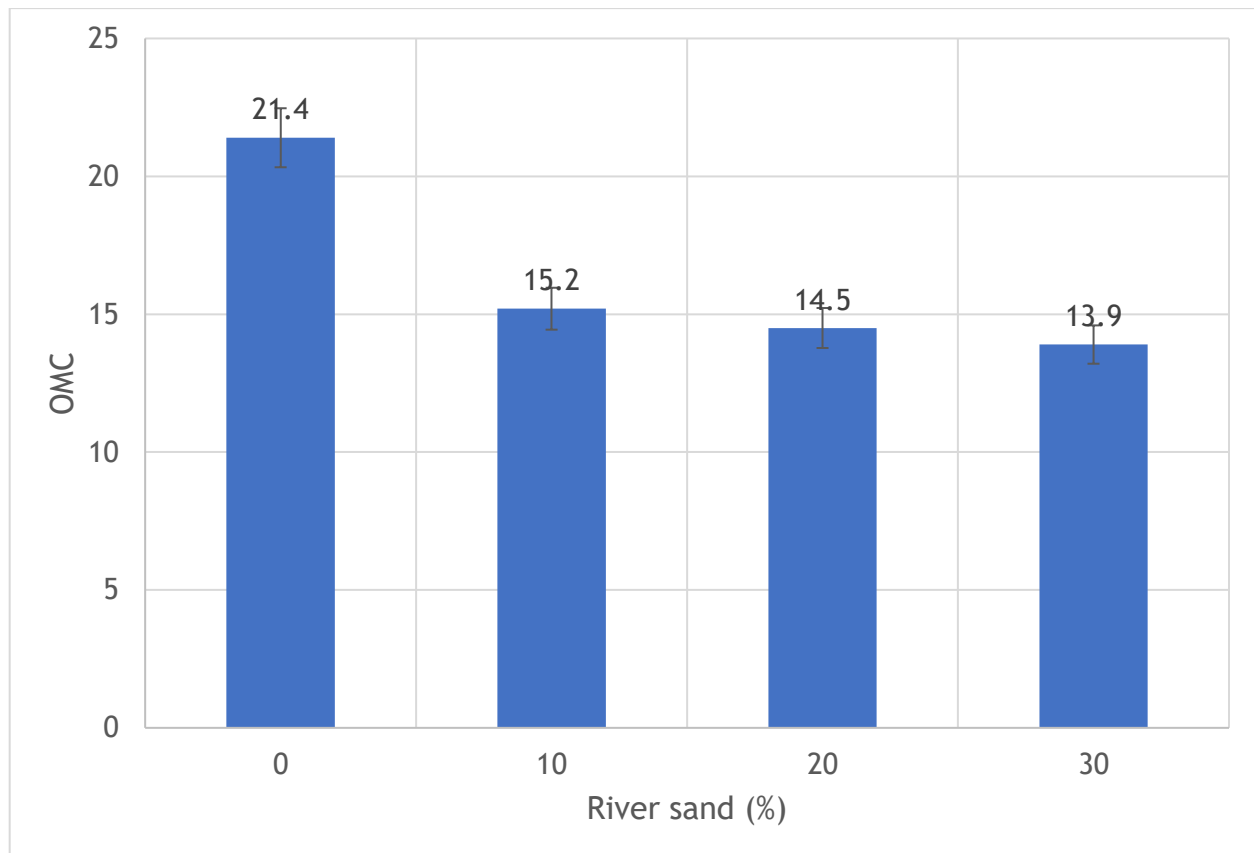
##### 4.4.5.1 Maximum Dry Density



*Figure 19: A graph of MDD against river sand percentage*

As the percentage of the river sand increases, the MDD increases consistently with increase in the river sand fraction. The variation in the MDD is due to the improved grading of the blended mixes with the addition of the river sand. Well graded soils exhibit higher MDD than poorly graded soils. As the river sand content increases, the dry density also increases which intern enhances the compaction properties exhibited by the material thus an increase in the MDD (lyad A., 2021; Tugume B., 2019).

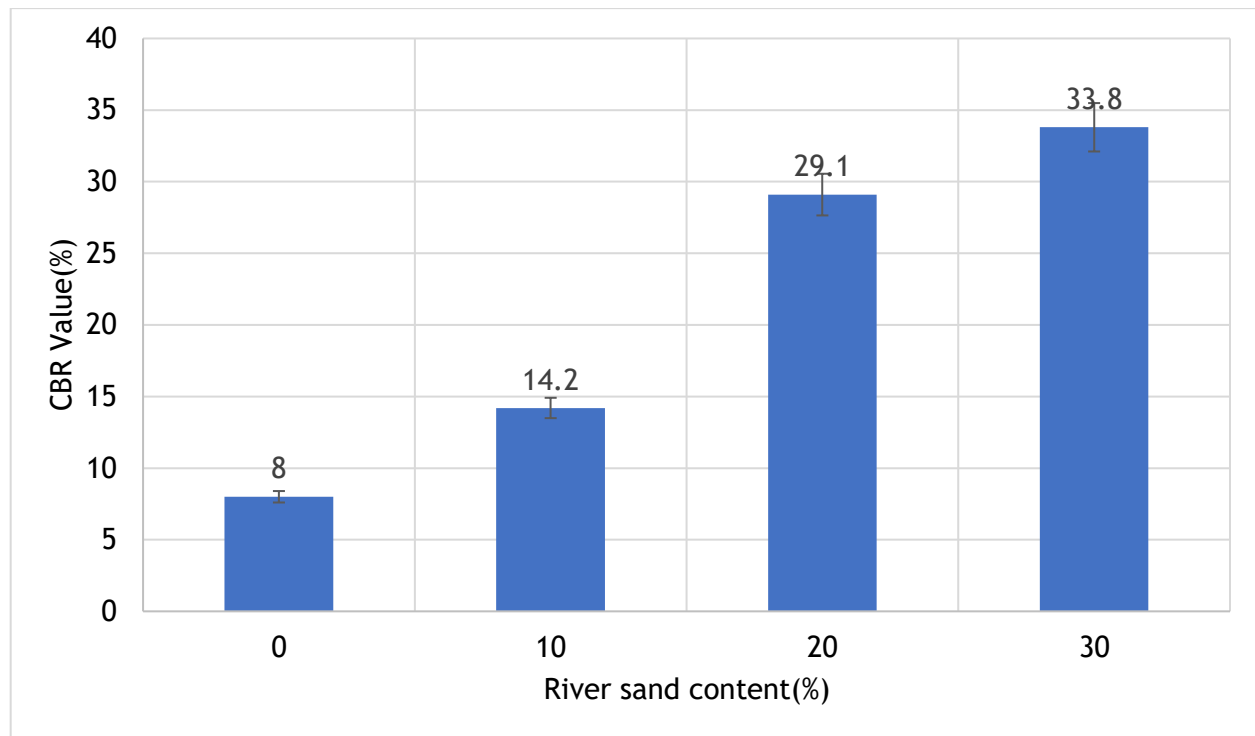
#### 4.4.5.2 Optimum Moisture Content



*Figure 20: A graph of OMC against river sand content*

The graph shows the impact of increasing river sand fraction on OMC of the neat soils. There is a remarkable decrease in the OMC as the percentage of sand was increased. The variation in the OMC is due to the variation in the soil's plasticity properties with the addition of the content of the river sand. Finer soils exhibit higher OMC (A. A. Kibuka & S. Jjuuko, 2023) with the increase in the content of river sand, there is a considerable decrease in the fine fraction hence a decrease in the soil's plasticity properties thus decrease in the OMC. Decrease in soil's plasticity properties results into reduced ability of the soil to retain water (Iyad A., 2021).

#### 4.4.6 The California Bearing Ratio (CBR)

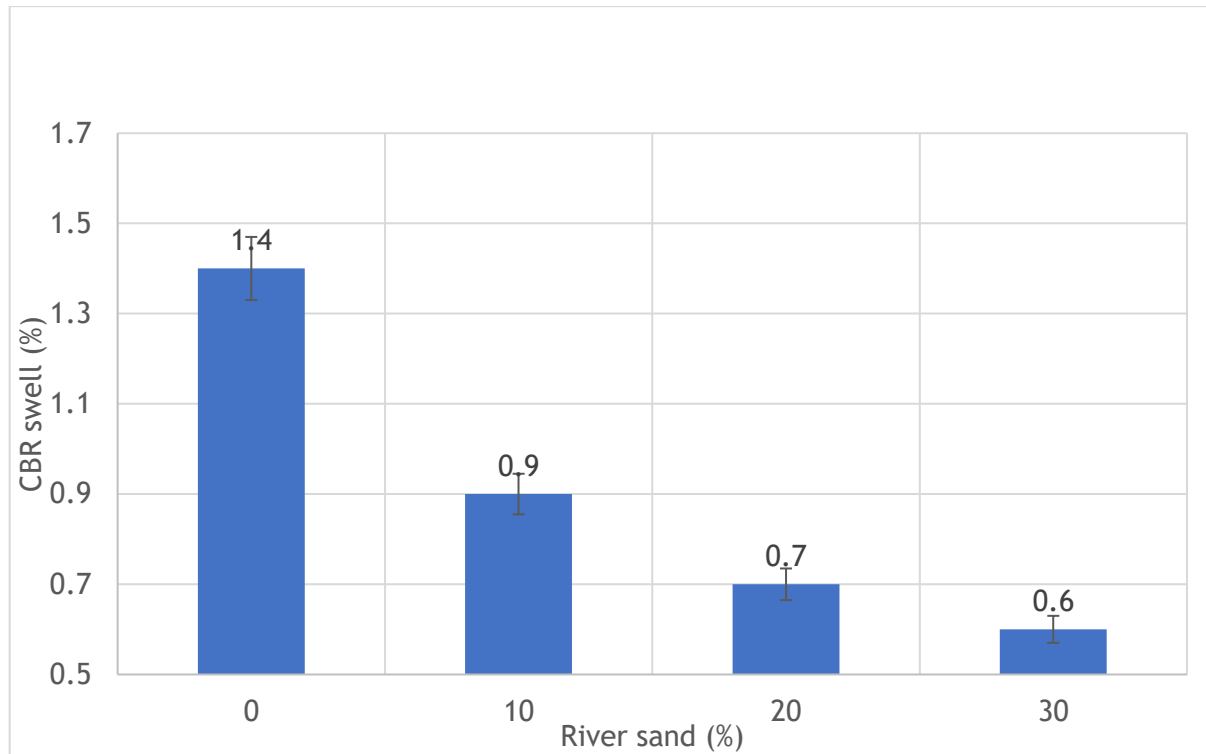


*Figure 21: A graph of the CBR value with increasing river sand content*

The graph reveals a gentle rise in the CBR value with the increase in the fraction of the river sand. The increase in the CBR value from 8% to 14.2% to 29.1% to 33.8% with the addition of 0%, 10%, 20%, and 30% of river sand respectively is attributed to the rearrangement of the soil particles within the material from fine-grained soil to an increasingly granular nature. The river sand provides the skeletal framework which in turn provides internal friction and incompressibility to the soil mix while the soil provides the much-needed cohesion, plasticity and imperviousness resulting into an interlocked structure between the soil particles (Arora K. R., 2012). The material's strength property thus increases due to increasing density of the material. The high the

density of the material, the greater its resistance to penetration force and thus increase in the CBR values (A. A. Kibuka & S. Jjuuko, 2023).

#### 4.4.7 CBR swell



*Figure 22: A graph of CBR swell against river sand percentage*

There was a progressive reduction in the CBR swell percentages of the soil samples with increasing percentage of river sand ranging from 0 to 30%. The swelling percentages were reduced as follows; 1.4%, 0.9%, 0.7% and 0.6% for the river sand portions of 0%, 10%, 20% and 30% respectively. This is attributed to the reduction of the plasticity of the soil indicating a reduction decrease in water retention ability of the soil. This depicts an improvement in the swell potential of the material when exposed to adverse wet conditions (Babu V.R., 2016).

## 4.5 Mix design

With reference to the analyzed results above, the optimum mix for the expansive soil-river sand mix was decided on based on;

- I. The plasticity index and CBR value with reference to the MoWT General specifications. The mix proportion of 20% river sand and 80% expansive soil was considered as the optimum mix and economical for use. The PI value for the mix proportion was 22.5% which is below the required maximum of 25% and the CBR value of 29.1 which is above the required minimum CBR value for G15 subgrade material.
- II. The CBR swell was 0.7% which is below the maximum CBR swell value of 1.5%.
- III. The percentage passing the 75 $\mu$ m sieve size was 41.45% which is below 50% which classifies the stabilized mix as not being highly plastic with reference to USCS.

*Table 7: summery of the expansive soil-river sand mix proportion*

Percentage of materials by mass		Test results							
		Atterberg limits							
Expansive soil (%)	River Sand (%)	LL(%)	PL(%)	PI (%)	LS(%)	MDD (gm/cm <sup>3</sup> )	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

## CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

The expansive soils were classified as fine grained since the fine fraction was determined as 71.44% which is greater than 50% with reference to USCS. The liquid limit was determined as 62% which indicates that the soil has high plasticity and the plastic limit was 31% giving plasticity index of 31%. With reference to the USCS the soils were classified as CH; inorganic clay with high plasticity which confirms that the soils are expansive. The MDD was determined as 1.625g/cm<sup>3</sup> and OMC was determined as 21.4%, with a CBR of 8% for the soil compacted at a dry density of 1.688 g/cm<sup>3</sup>. The CBR swell was determined as 1.4%. Therefore, there is a need to stabilize the soils so as to achieve the required specifications for subgrade soils.

The grading curve of the river sand was observed to lie within the grading envelop indicating that the river sand is well graded. The water absorption, 1.6 % < 3, the silt content 3.0% < 8% and the bulk specific gravity, 2.5 lies within the permissible range of 2.4-3.0, this indicates that the river sand used in the research study possessed good qualities for the stabilization of the expansive soil.

With the addition of differing percentages of sand to the neat soils, a substantial improvement in the soil's strength, reduction in the plasticity and swell potential were observed. There was a general decrease in the Atterberg limits with increasing percentage of sand: the LL reduced by 21.2%, the plastic limit decreased by 12.5%, the plasticity index reduced by 8.7% and linear shrinkage reduced by 7% with the addition of 20% river sand whereas the MDD increased by 0.19g/cm and OMC decrease by 6.9%. The CBR value increased by 21.1% and CBR swell reduced by 0.7% with the addition of

20% river sand to the neat soils. With reference to MoWT General specification, 2005, the optimum mix proportion for expansive soil-river sand considered was 20% river sand.

## **5.2 Recommendations**

Basing on the laboratory test result obtained from the research study, it is recommended that;

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

Conducting additional research 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.

Testing the erosion and weathering resistance of river sand-stabilized soils, especially in regions prone to extreme weather conditions. This can provide valuable insights into the durability and longevity of the stabilization technique.

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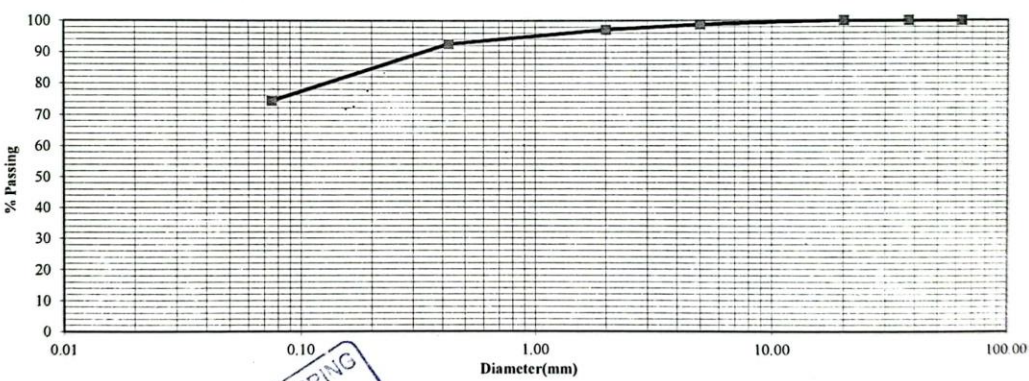
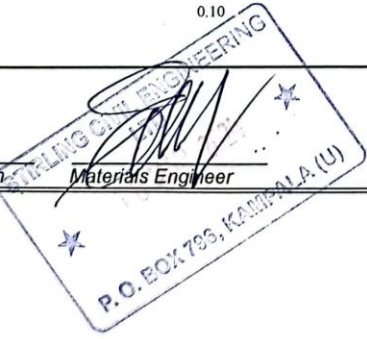


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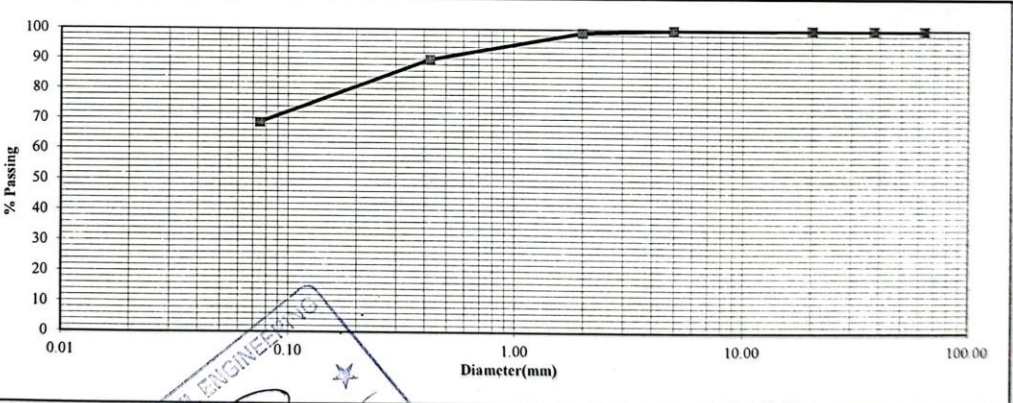



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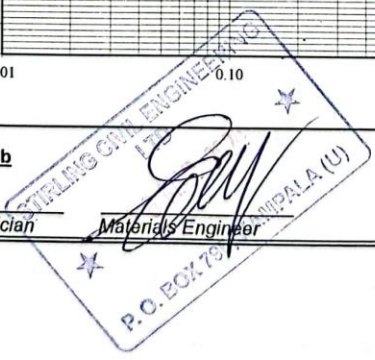
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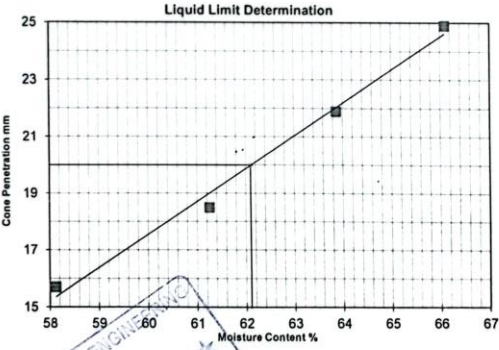



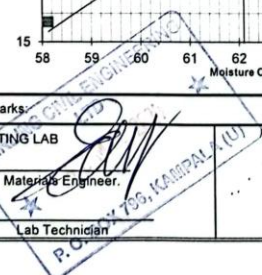
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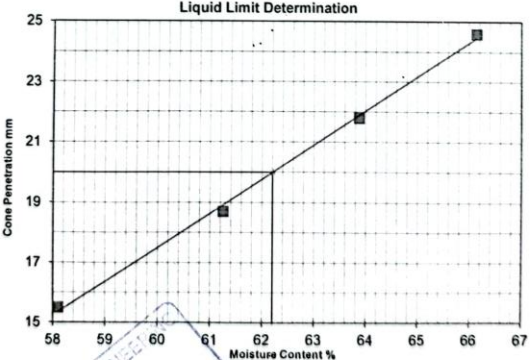
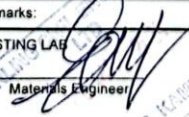

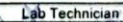




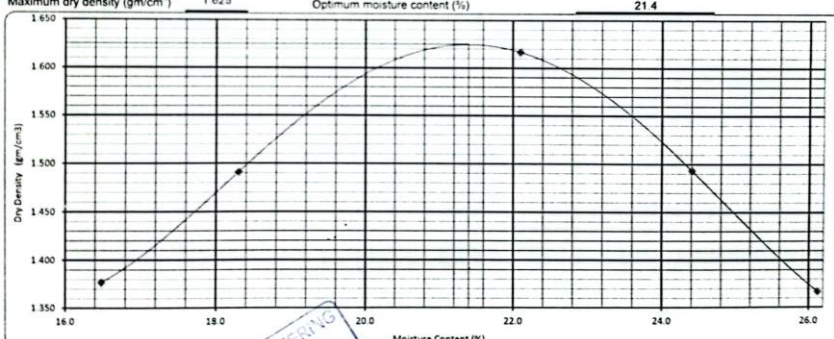



INSTITUTION		STUDENTS NAMES		TESTING LAB	
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMO ENEKU JOAN ( S20B32/313)</b>		<b>Stirling</b>	
<b>PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
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
<b>Total fines</b>	3570.5	74.3			
<b>Bottom Pan</b>	5.1				
<b>Extracted fines</b>	3565.4				
<b>Total sample</b>	4806.4				
<b>Grading Modulus</b>		<b>0.36</b>			
					
<b>Testing Lab</b>			<b>STUDENTS</b>		
					
Lab Technician		Materials Engineer			

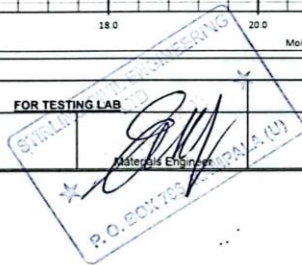
INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMO ENEKU JOAN ( S20B32/313)</b>		<b>Stirling</b>	
<b>PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
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
<b>Total fines</b>	3222.7	68.6			
<b>Bottom Pan</b>	32.5				
<b>Extracted fines</b>	3190.2				
<b>Total sample</b>	4698.2				
<b>Grading Modulus</b>		<b>0.43</b>			
					
<b>Testing Lab</b>			<b>STUDENTS</b>		
Lab Technician 		Materials Engineer 			


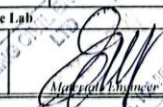



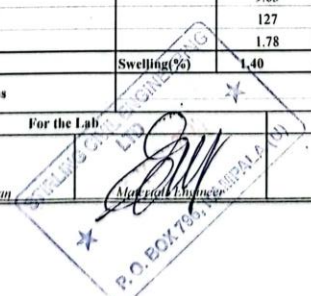
INSTITUTION		STUDENTS		TESTING LAB																			
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		<b>Stirling</b>																			
PROJECT:		INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS																					
<b>ATTERBERG LIMITS</b>																							
<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																					
<b>PLASTIC LIMIT</b>		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																							
<b>LIQUID LIMIT</b>		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																							
<b>Liquid Limit Determination</b>																							
				<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.			STUDENTS  																				
																							

INSTITUTION		STUDENTS		TESTING LAB		
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Church of God Member of the World of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN (S20B32/313)</b>		<b>Stirling</b>		
<b>PROJECT:</b>		<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>				
<b>ATTERBERG LIMITS</b>						
<i>Liquid limit (cone penetrometer) and plastic limit</i>						
<b>SOURCE :</b>		MOROTO DISTRICT		<b>Technician:</b>	<b>Lab Team</b>	
mix		NEAT SAMPLE		<b>Sample Date</b>	15/Dec/2023	
<b>Test method</b>		BS 1377: Part 2, 1990 4.3/4.4		<b>Test Date</b>	18/Dec/2023	
<b>LAYER</b>		EXPANSIVE SOILS				
<b>Depth</b>		0.5m				
<b>PLASTIC LIMIT</b>		<b>Test No.</b>	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	
<b>AVERAGE</b>						
<b>LIQUID LIMIT</b>		<b>Test No.</b>	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
<b>AVERAGE</b>			15.5	18.7	21.8	24.6
<b>Container No.</b>		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)		16.82	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	
<b>AVERAGE</b>			58.1	61.3	63.9	66.1
		<b>Liquid limit (%)</b>		62.2		
		<b>Plastic limit (%)</b>		31.2		
		<b>Plasticity Index (%)</b>		31.0		
		<b>Linear shrinkage</b>				
		<b>Trough No.</b>		4		
		<b>Trough length (cm)</b>		14.0		
		<b>Specimen length (cm)</b>		11.5		
		<b>L.shrinkage =</b>		2.5		
		<b>% L.shrinkage =</b>		18.0		
<b>Remarks:</b>						
<b>TESTING LAB</b>				<b>STUDENTS</b>		
 Materials Engineer				 _____		
 Lab Technician				 _____		

INSTITUTION		STUDENTS NAMES			TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)			<b>Stirling</b>	
PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS						
Test Reference No	Depth	0.5m	Date Sampled	Date Tested	Technician	
Mix	NEAT SAMPLE		15/Dec/23	17/Dec/23	Lab team	
SOURCE	MOROTO DISTRICT					
Material description:	EXPANSIVE SOILS		Natural moisture (%)	11.0		
<b>TEST DATA</b>						
Weight of rammer (Kg)	No. of blows per layer	No. of layers	Height of drop (mm)	Diameter of mould(mm)	Volume of mould (cm <sup>3</sup> )	
4.5	27	5	457	100	1,000	
<b>MOISTURE CONTENT DATA</b>						
Test No	1	2	3	4	5	
Tin No	A	A	A	A	A	
Water Added	cm <sup>3</sup>	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	cm <sup>3</sup>	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm <sup>3</sup>	1.604	1.764	1.974	1.858	1.724
<b>DATA FOR PROCTOR CURVE</b>						
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/cm <sup>3</sup>	1.377	1.491	1.617	1.494	1.367
Maximum dry density (g/cm <sup>3</sup> )	1.625		Optimum moisture content (%)		21.4	
						
Remarks:						
FOR TESTING LAB			STUDENTS			
Lab Technician	 Materials Engineer					



Institution		Students Names		Testing Lab	
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20032/010) &amp; ATEMIO ENEKU JOAN (S20032/313)</b>		<b>Stirling</b>	
<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>					
<b>CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)</b>					
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 <sup>3</sup> ) 2305	
<b>Natural moisture of air dried sample</b>			<b>Volume of water added</b>		
Tin No.	NMT		Mass of air dried soil (g)	6000	
Tin + air dried soil sample (g)	2364		MDD (Mg/m <sup>3</sup> )	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				
<b>Water Content Determination</b>			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	
<b>Density determination</b>					
Mould No	21				
Mass of mould + soil	g	12068		12178	
Mass of mould	g	7490		7490	
Mass of soil	g	4578		4688	
Volume of the mould	cm <sup>3</sup>	2305		2305	
Moist density	g/cm <sup>3</sup>	1.986		2.034	
Dry density	g/cm <sup>3</sup>	1.685		1.691	
<b>Swell Determination</b>					
Date	1 Hour	D.Gauge Reading			
Initial reading	96 hrs	7.85			
Final reading		9.63			
Height of the specimen		127			
Height of swell		1.78			
	Swelling (%)	1.40			
<b>Observations</b>					
For the Lab			For Students		
Lab. Technician					





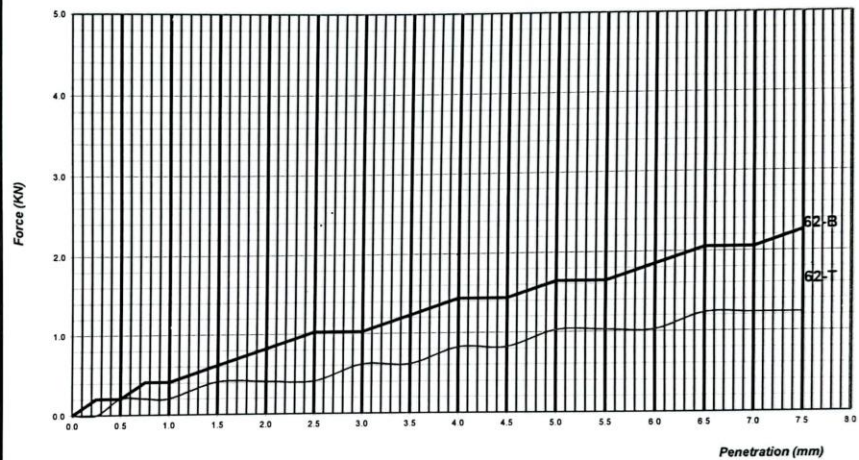
<b>Institution</b> UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>	<b>Students Names</b> MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)	<b>Testing Lab</b> <b>Stirling</b>
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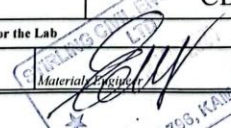

**INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS**

**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				CBR= 8.0
	For the Lab		For Students	
Lab. Technician	 Material Engineer			



Appendix B: Laboratory tests on the river sand used


INSTITUTION	STUDENTS	TESTING LAB	
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Learning in the Heart of Africa</small>	<b>MWINE AMBROSE (S20B32/010) &amp; ATEMO ENEKU JOAN ( S20B32/313)</b>	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <b>Stirling</b> </div>	
SAMPLE DISCRPTION:	<b>SAND</b>	Sampling Date:	16-Jan-24
SAMPLE SOURCE:	<b>MOROTO</b>	Testing Date:	17-Jan-24
TEST	<b>DETERMINATION OF SILT CONTE</b>		
TEST METHOD	<b>ASTM C40</b>		
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 % $(V3/V1) \times 100$	3.2	2.8



FOR TESTING LAB

**STIRLING CIVIL ENGINEERING LTD**




29 JAN 2024


P.O. BOX 796, KAMPALA (U)



INSTITUTION	STUDENTS		TESTING LAB
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Field of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMO ENEKU JOAN ( S20B32/313)		<b>Stirling</b>  STIRLING
PROJECT	INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS		
<b>SPECIFIC GRAVITY &amp; WATER ABSORPTION FINE AGGREGATES</b> (AASHTO : T84—00) ASTM DESIGNATION : C128—97			
SOURCE: MOROTO	OPERATOR:		
SAMPLE No	SAMPLING DATE		16-Jan-24
SAMPLE DESCRIPTION: Natural sand	TESTING DATE:		17-Jan-24
<b>TEST NO</b>			
	<b>A</b>		<b>B</b>
[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 (B+S-C)	2.488	2.465
Bulk Specific Gravity on saturated surface dry basis	S (B+S-C)	2.526	2.505
Apparent Specific Gravity	A (B+A-C)	2.586	2.567
Water Absorption(%)=	100(S-A) A	1.5	1.5
<b>AVERAGE RESULTS</b>			
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 Centre of Excellence in the East of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN ( S20B32/313)		<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <b>Stirling</b> </div>	
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			
					
<div style="border: 2px solid blue; padding: 5px; transform: rotate(-15deg); display: inline-block;"> <b>FOR TESTING LAB</b>  <b>STIRLING CIVIL ENGINEERING LTD</b>  <small>25 JAN 2024</small>  <b>P. O. BOX 785, KAMPALA (U)</b> </div> <div style="margin-left: 20px;">  </div>					

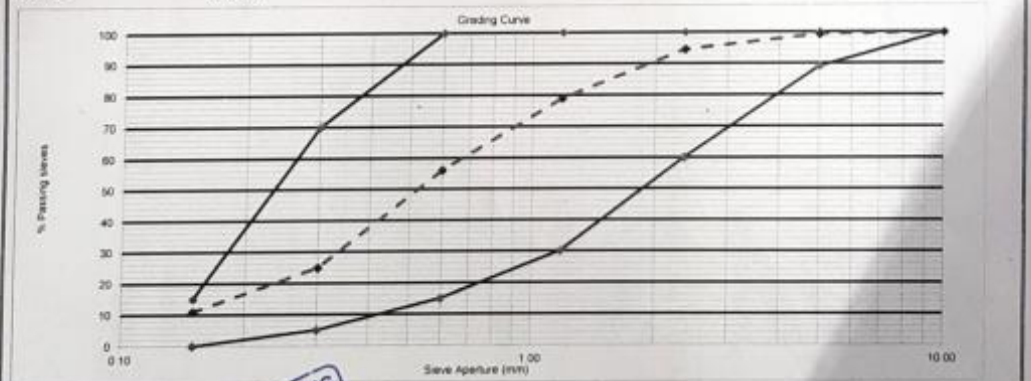
<b>INSTITUTION</b>	<b>STUDENTS</b>	<b>TESTING LAB</b>
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>	<b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN ( S20B32/313)</b>	<b>Stirling</b>

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




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

**TOTAL** 5384.7





**FOR TESTING LAB**






**STIRLING CIVIL ENGINEERING LTD**  
 19 JAN 24  
 P. O. BOX 795, KAMPALA (U)

<b>INSTITUTION</b>	UCANDA CHRISTIAN UNIVERSITY <small>A CHRISTIAN UNIVERSITY IN THE HEART OF AFRICA</small>		<b>STUDENTS</b>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)	<b>TESTING LAB</b>	Stirling
<b>PROJECT</b>	INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS		<b>TESTING DATE</b>	17-Jan-24		
<b>SAND SAMPLE 1</b>						
<b>TEST NO</b>	1	2	3			
<b>WEIGHT OF SAND</b>	4806	4842	4781			
<b>VOLUME OF CONTAINER</b>	0.27	0.27	0.27			
<b>BULK DENSITY (g/cm<sup>3</sup>)</b>	1.780	1.793	1.771			
<b>AVERAGE BULK DENSITY (g/cm<sup>3</sup>)</b>	<b>1.781</b>					
<b>TESTING LAB</b> <b>STIRLING CIVIL ENGINEERING LAB</b>  P. O. BOX 796, KAMPALA (U)						

# Appendix C: Laboratory test results on the stabilized soil

INSTITUTION		STUDENTS		TESTING LAB																		
 <b>LUCINDA CHRISTIAN UNIVERSITY</b> <small>A Division of the University of North Carolina</small>		<b>MMWNE AMBROSE (S20832010) &amp; ATENGO ENEKU</b> <b>JOAN (S20832731)</b>		<b>Stirling</b>																		
<b>PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>																						
<b>SUMMARY OF ALL TEST RESULTS</b>																						
LOCATION	BLENDED %	SAMPLING DATE	GRADING										ATTERBURG LIMITS					MDD	OMC	CBR	CAR SWELL	CAR AVERAGE
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC	CBR					
			100.0	100.0	100.0	98.7	97.1	92.5	74.3	0.4	62.1	30.8	31.3	18.0	1425	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			
			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	63.7	40.0	1.0	40.9	18.6	22.3	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	-	-	-	-	-			
			100.0	100.0	100.0	98.8	92.5	62.8	29.4	1.2	31.4	15.3	16.1	8.2	1889	11.3	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	-	-	-	-	-			
<b>FOR LAB</b>																						
<b>LAB TECHNICIAN</b>						<b>KAMALIS EMMANUEL</b>																


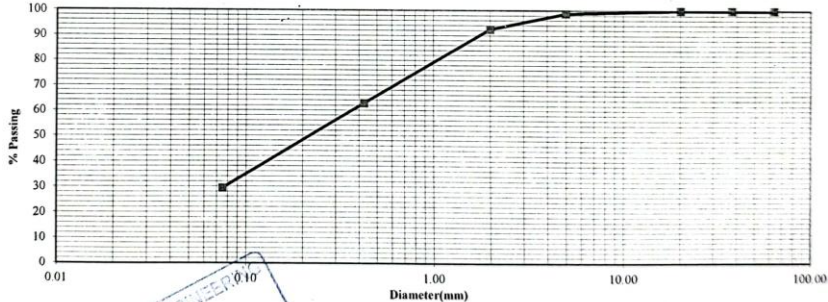


INSTITUTION	STUDENTS	TESTING LAB
 UGANDA CHRISTIAN UNIVERSITY A Member of the Council of Higher Education	MWINE AMBROSE (S20B322010) & ATENO ENUKU JOANI (S20B32213)	<div style="border: 1px solid black; padding: 5px; display: inline-block;">Stirling</div>

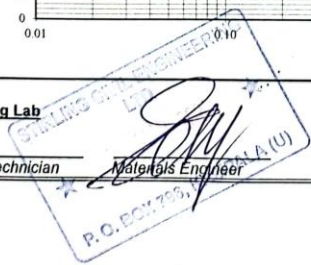
PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS


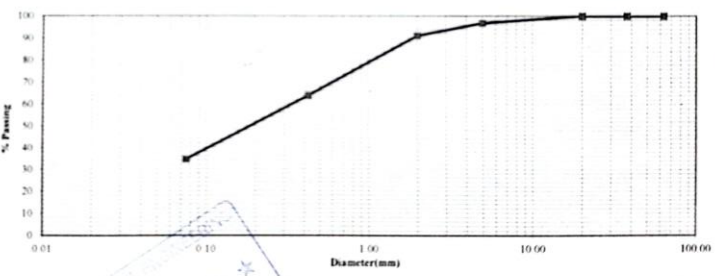




SUMMARY OF TEST RESULTS FOR EXPANSIVE MATERIAL OF EXPANSIVE SOIL MODIFIED WITH 30% SAND


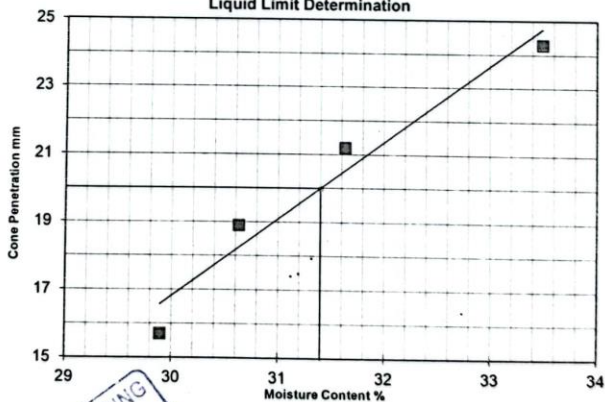
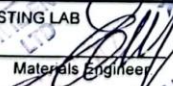
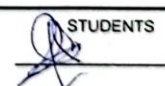
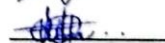
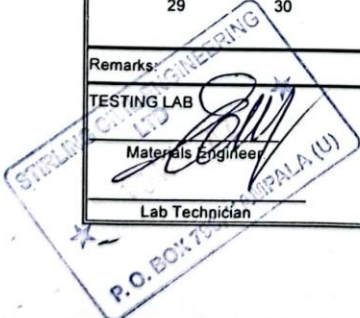
LOCATION	RENDED %	SAMPLING DATE	GRAADING						ATTERBERG LIMITS						MDD		CRB	CAR SWELL	CAR AVERAGE
			37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC				
EXPANSIVE SOIL MODIFIED WITH 30% SAND	100	100	100	99	92	63	29	1.15	31.4	15.3	16.1	8.2	1.889	13.3	33.8	0.55	0.55		
	100	100	100	97	91	64	35	1.11	31.4	15.4	16.0	8.2	-	-	-	-	-		
	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	1.130	31.4	15.4	16.1	8.2	1.889	13.3	33.8	0.55	0.55


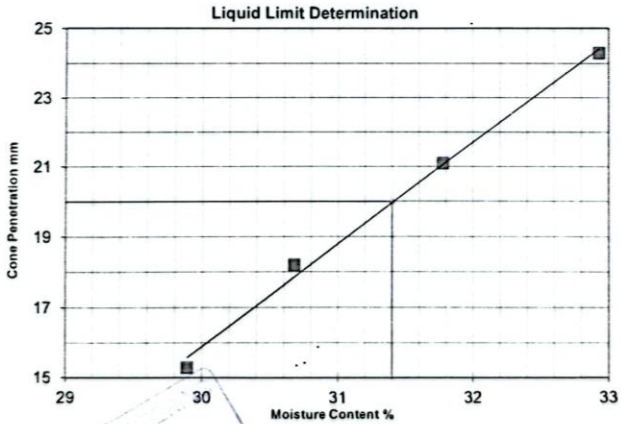
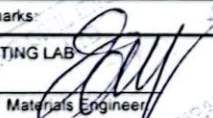
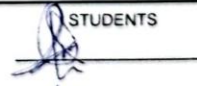
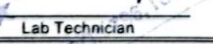

Lab Technician:    
 Lab Technician:    
 Lab Technician: 


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)		<b>Stirling</b>	
<b>PROJECT :</b> INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
Location :			Lab. Reference No.:		
MOROTO DISTRICT					
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			
					
<b>Testing Lab</b>  Lab Technician			<b>STUDENTS</b> 		



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)		<b>Stirling</b>	
<b>PROJECT :</b> INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
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
<b>Total fines</b>	1236.7	34.6			
<b>Bottom Pan</b>	41.7				
<b>Extracted fines</b>	1197.0				
<b>Total sample</b>	3583.5				
<b>Grading Modulus</b>		<b>1.11</b>			
					
<b>Testing Lab</b>			<b>STUDENTS</b>		
Lab Technician:  Materials Engineer: 			 		

INSTITUTION		STUDENTS		TESTING LAB		
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMO ENEKU JOAN (S20B32/313)</b>		<b>Stirling</b>		
<b>PROJECT:</b>		<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>				
<b>ATTERBERG LIMITS</b>						
<i>Liquid limit (cone penetrometer) and plastic limit</i>						
<b>SOURCE :</b>		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	
<b>LAYER</b>		EXPANSIVE SOILS				
Depth:	0.5m					
<b>PLASTIC LIMIT</b>		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	
<b>AVERAGE</b>						
<b>LIQUID LIMIT</b>		Test No.	1	2	3	4
Initial gauge reading (mm)			0	0	0	0
Final gauge reading (mm)			15.7	18.9	21.2	24.3
penetration (mm)			15.7	18.9	21.2	24.3
<b>AVERAGE</b>			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	
<b>AVERAGE</b>			29.9	30.6	31.6	33.5
<b>Liquid Limit Determination</b>						
						
				<b>Liquid limit (%)</b>	31.4	
				<b>Plastic limit (%)</b>	15.3	
				<b>Plasticity Index (%)</b>	16.1	
<b>Linear shrinkage</b>						
				Trough No.	1	
				Trough length (cm)	14.0	
				Specimen length (cm)	12.9	
				L.shrinkage =	1.2	
				% L.shrinkage =	8.2	
<b>Remarks:</b>						
<b>TESTING LAB</b>  Materials Engineer				<b>STUDENTS</b>  		
						

INSTITUTION		STUDENTS		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)		<b>Stirling</b>		
<b>PROJECT:</b>		INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS				
<b>ATTERBERG LIMITS</b>						
<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				
<b>PLASTIC LIMIT</b>		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						
<b>LIQUID LIMIT</b>		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
<b>Liquid Limit Determination</b>						
						
				Liquid limit (%)	31.4	
				Plastic limit (%)	15.4	
				Plasticity Index (%)	16.0	
<b>Linear shrinkage</b>						
				Trough No	1	
				Trough length (cm)	14.0	
				Specimen length (cm)	12.9	
				L shrinkage =	1.2	
				% L shrinkage =	8.2	
Remarks:						
TESTING LAB		STUDENTS				
 Materials Engineer		 _____				
 Lab Technician		 _____				

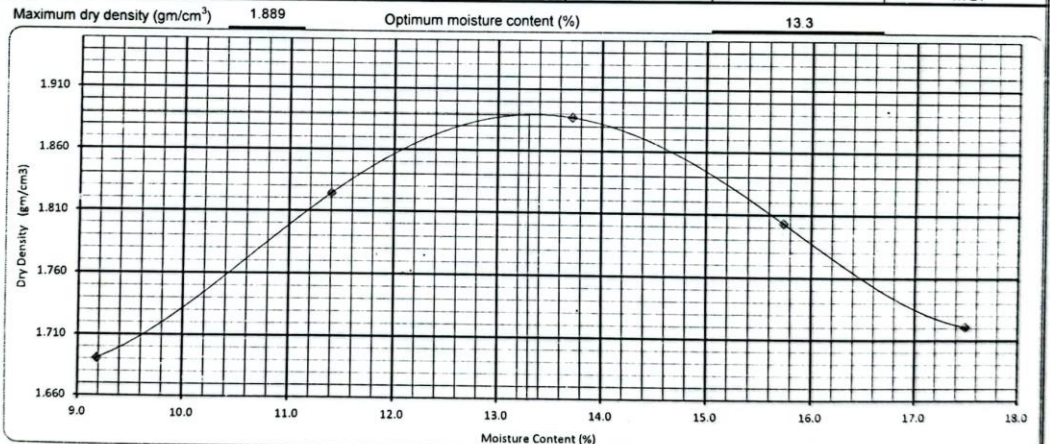
<b>INSTITUTION</b>	<b>STUDENTS NAMES</b>	<b>TESTING LAB</b>
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Service of Africa</small>	<b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN (S20B32/313)</b>	<b>Stirling</b>

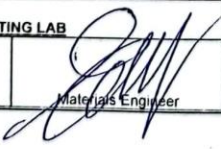


<b>PROJECT:</b>	<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>			
Test Reference No	Depth 0.5m	Date Sampled	Date Tested	Technician
Mix	EXPANSIVE SOIL MODIFIED WITH 30% SAND	15/Dec/23	5/Feb/24	Lab team
SOURCE	MOROTO DISTRICT			
Material description:	EXPANSIVE SOILS	Natural moisture (%)	11.0	


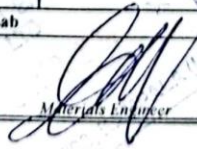
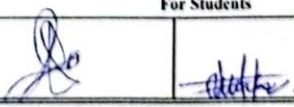
TEST DATA					
Weight of rammer (Kg)	No. of blows per layer	No of layers	Height of drop (mm)	Diameter of mould(mm)	Volume of mould (cm <sup>3</sup> )
4.5	27	5	457	100	1,000


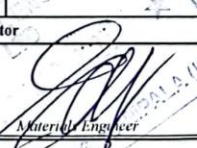

MOISTURE CONTENT DATA					
Test No.	1	2	3	4	5
Tin No	A	A	A	A	A
Water Added	cm <sup>3</sup> 140	240	340	440	540
Mass of Compacted soil + mould	gm 6,119	6,305	6,419	6,360	6,295
Mass of Mould	gm 4,273	4,273	4,273	4,273	4,273
Mass of Compacted soil	gm 1846	2032	2146	2087	2022
Volume of mould	cm <sup>3</sup> 1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm <sup>3</sup> 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 <sup>3</sup> 1.691	1.824	1.887	1.803	1.721



<b>Remarks:</b>	
<b>FOR TESTING LAB</b>	<b>STUDENTS</b>
Lab Technician:  Materials Engineer: 	

<b>Institution</b>  <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Vision of Excellence in the Heart of Africa</small>		<b>Students Names</b> MWINE AMBROSE (S20B32/010) & ATEMONEKEU JOAN (S20B32/313)		<b>Testing Lab</b> <div style="border: 2px solid black; padding: 5px; display: inline-block;"> <b>Stirling</b> </div>	
<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>					
<b>CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)</b>					
Test sample reference :		Depth : 0.5m		Sampling Date : 15/Dec/23	
Mix :		EXPANSIVE SOIL MODIFIED WITH 30% SAND		Casting date : 16/Feb/24	
Source :		MOROTO DISTRICT		Testing Date : 14/Feb/24	
Sample Description :		EXPANSIVE SOILS		Technician : Lab team	
				Volume of Mould used (m <sup>3</sup> ) : 2305	
<b>Natural moisture of air dried sample</b>			<b>Volume of water added</b>		
Tin No	21		Mass of air dried soil (g)	699	
Tin + air dried soil sample (g)	2459		MDD (Mg/m <sup>3</sup> )	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	
<b>Average (%)</b>		6.0	<b>Water added (mL)</b>	520	
Number of blows		62			
Number of layer		5			
<b>Water Content Determination</b>		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		
<b>Density determination</b>		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 <sup>3</sup>	2305	2305		
Moist density	g/cm <sup>3</sup>	2.183	2.185		
Dry density	g/cm <sup>3</sup>	1.898	1.898		
<b>Swell Determination</b>					
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		
<b>Observations</b>					
<b>For the Lab</b>			<b>For Students</b>		
Lab. Technician		 Materials Engineer			

Institution	Students Names		Testing Lab		
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>	<b>MWINE AMBROSE (S20B32/010) &amp; ATEMO ENEKU JOAN (S20B32/313)</b>		<b>Stirling</b>		
<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>					
<b>CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)</b>					
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				
Number of layers	5		5	5	
Mould No	21				
Capacity of the Proving Ring (KN)	50		50	50	
Proving Ring Constant (KN/div.)	0.2052		0.2052	0.2052	
Speed: .....mm min.	Top		Bottom		
Penetration of the plunger (mm)	Time (s)	Reading *10 <sup>3</sup> mm	Force (KN)	Reading *10 <sup>3</sup> mm	Force (KN)
0	0	0	0.0	0	0.0
0.25	12	1	0.2	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				

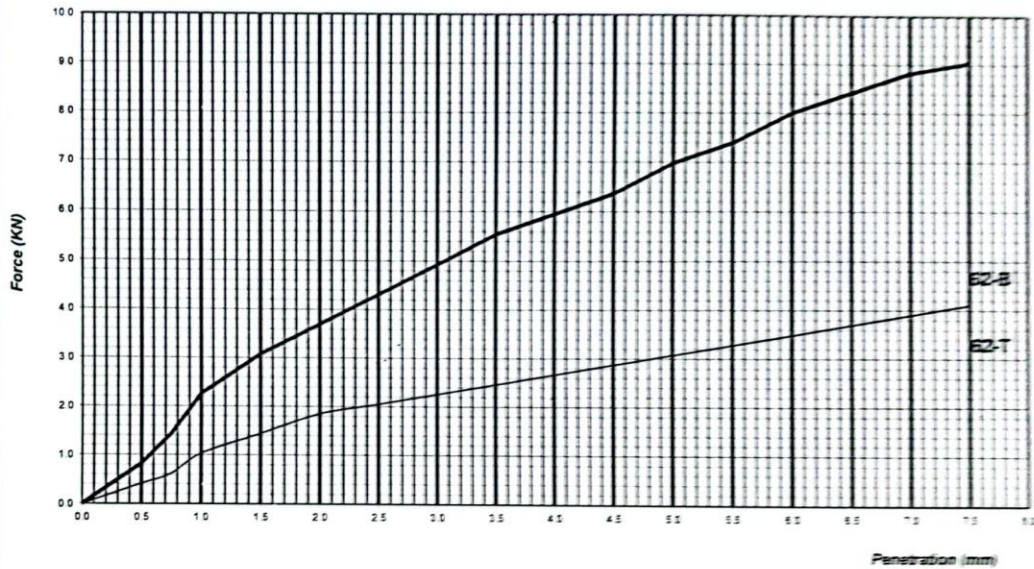
<b>Institution</b>	<b>Students Names</b>	<b>Testing Lab</b>
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>	<b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN (S20B32/313)</b>	<b>Stirling</b>


**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: 14/9/24
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			

<b>INSTITUTION</b>	<b>STUDENTS</b>	<b>TESTING LAB</b>
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Member of Uganda's 4th Sector of H.E.O.s</small>	MWINE AMBROSE (S20B321010) & ATEMU ENEKU JOAN (S20B32313)	<div style="border: 1px solid black; padding: 5px; display: inline-block;"><b>Stirling</b></div>

**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**


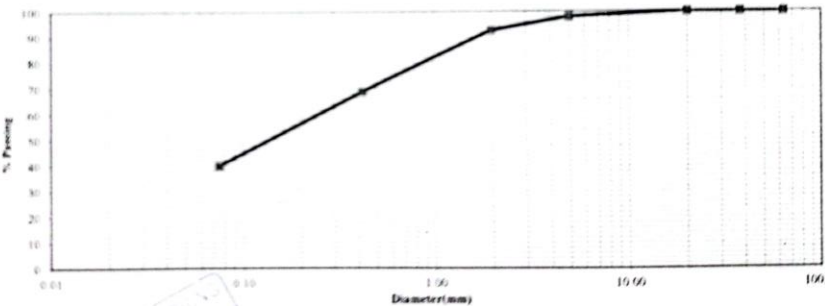
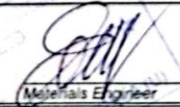

LOCATION	BLENDED %	SAMPLING DATE	GRADING										ATTERBERG LIMITS			MDD			CBR	CBR SWELL
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC	MDD	OMC		
MOROTO DISTRICT	100	100	100	100	98	93	69	40	0.99	40.9	18.6	22.3	11.0	1.815	14.5	29.1	0.67	0.67		
	100	100	100	95	91	68	43	0.98	41.0	18.3	22.7	11.0	-	-	-	-	-	-		
	<b>100</b>	<b>100</b>	<b>100</b>	<b>96.66</b>	<b>91.87</b>	<b>68.53</b>	<b>41.48</b>	<b>0.98</b>	<b>40.9</b>	<b>18.4</b>	<b>22.5</b>	<b>11.0</b>	<b>1.815</b>	<b>14.5</b>	<b>29.1</b>	<b>0.67</b>	<b>0.67</b>			
MOROTO DISTRICT			12/15/2023																	
<b>AVERAGE</b>			100	100	100	97	92	69	41	0.981	40.9	18.3	22.5	11.0	1.815	14.5	29.1	0.67	0.67	

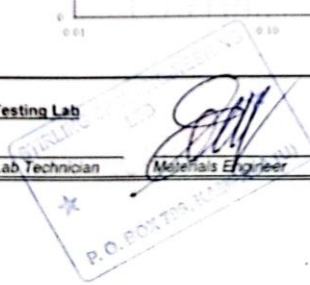
FOR LAB


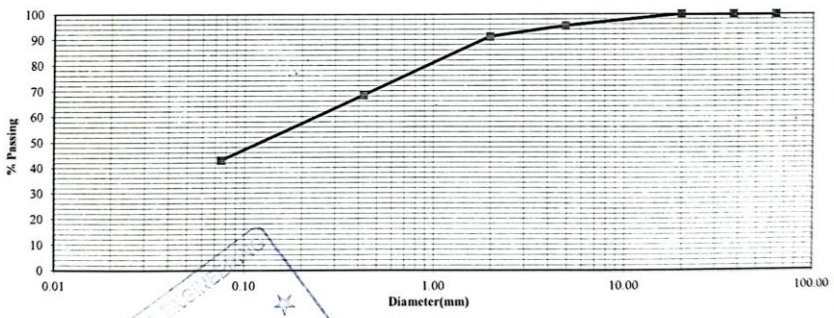



STUDENTS


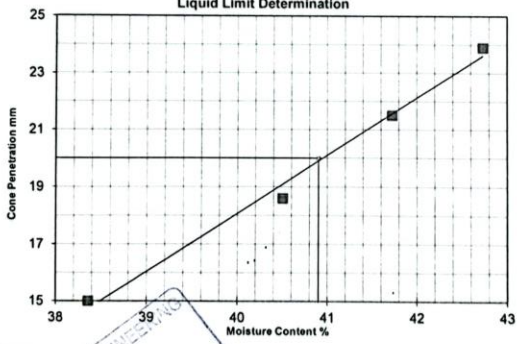
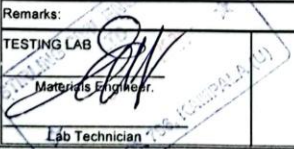
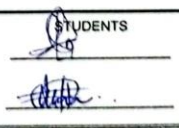




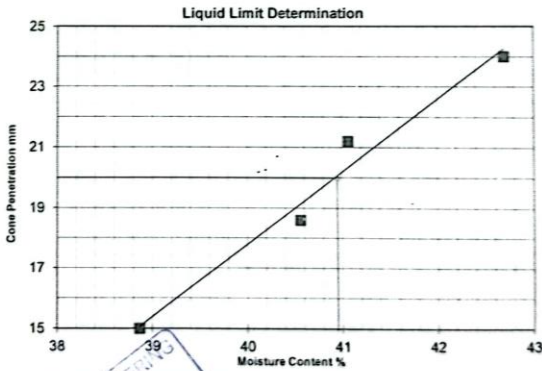
Lab Technician


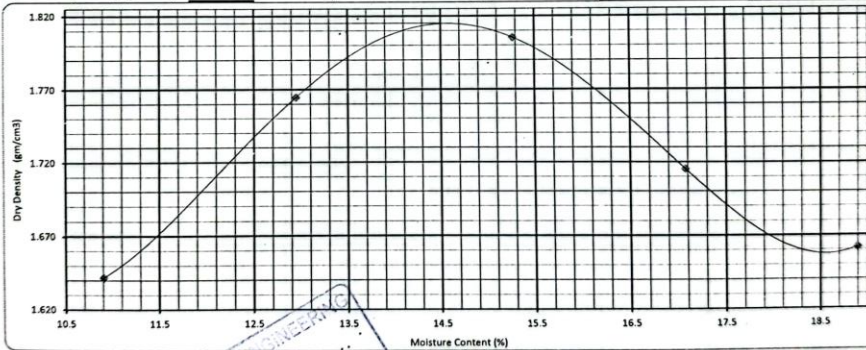
INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		<b>Stirling</b>	
<b>PROJECT :</b> INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
Location: MOROTO DISTRICT			Lab Reference No:		
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	1549.1	40.0			
Bottom Pan	37.7				
Extracted fines	1511.4				
Total sample	3871.6				
Grading Modulus		0.99			
					
<b>Testing Lab</b>  Lab Technician			<b>STUDENTS</b> 		


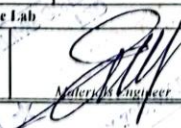








INSTITUTION		STUDENTS NAMES		TESTING LAB	
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMO ENEKU JOAN ( S20B32/313)</b>		<b>Stirling</b>	
<b>PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
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:	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	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
<b>Total fines</b>	1524.5	42.9			
<b>Bottom Pan</b>	27.0				
<b>Extracted fines</b>	1497.5				
<b>Total sample</b>	3550.1				
<b>Grading Modulus</b>		0.98			
					
Testing Lab			STUDENTS		
 Lab Technician <u>Materials Engineer</u>			 		


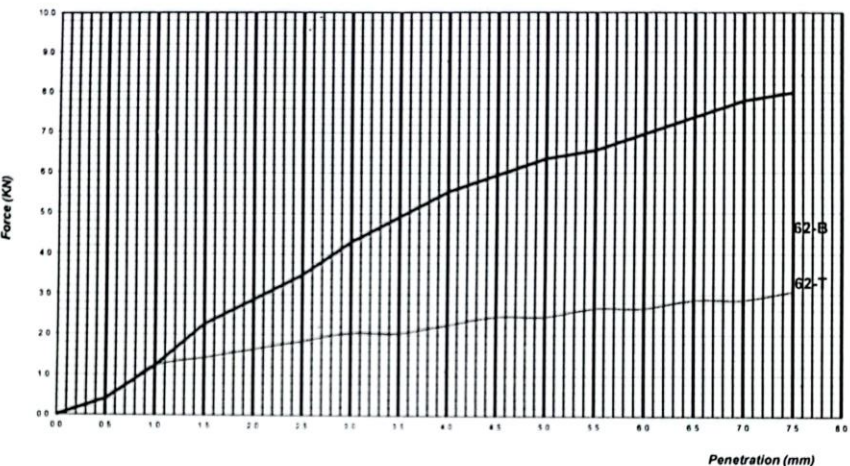
INSTITUTION		STUDENTS		TESTING LAB		
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN (S20B32/313)</b>		<b>Stirling</b>		
<b>PROJECT:</b>		<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>				
<b>ATTERBERG LIMITS</b>						
<i>Liquid limit (cone penetrometer) and plastic limit</i>						
<b>SOURCE :</b>		MOROTO 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				
<b>PLASTIC LIMIT</b>						
	Test No.	13	RAD		Average	
	Mass of wet soil + container (g)	30.69	33.31		32	
	Mass of dry soil + container (g)	29.38	31.57		30.475	
	Mass of container (g)	22.48	21.98		22.23	
	Mass of moisture (g)	1.31	1.7		1.525	
	Mass of dry soil (g)	0.9	0.59		0.245	
	Moisture content %	19.0	18.1		18.6	
<b>AVERAGE</b>						
<b>LIQUID LIMIT</b>						
	Test No.	1	2	3	4	
	Initial gauge reading (mm)	0	0	0	0	
	Final gauge reading (mm)	15.0	18.6	21.5	23.9	
	penetration (mm)	15.0	18.6	21.5	23.9	
	<b>AVERAGE</b>	15.0	18.6	21.5	23.9	
<b>Container No.</b>						
		PI33	MB	PI2H	BC	
	Mass of wet soil + container (g)	50.29	36.71	55.07	46.12	
	Mass of dry soil + container (g)	38.28	28.14	42.24	34.42	
	Mass of container (g)	6.97	6.98	11.49	7.04	
	Mass of moisture (g)	12.01	8.57	12.83	11.7	
	Mass of dry soil (g)	31.31	21.16	30.75	27.38	
	Moisture content (%)	38.4	40.5	41.7	42.7	
	<b>AVERAGE</b>	38.4	40.5	41.7	42.7	
<b>Liquid Limit Determination</b>						
						
				Liquid limit (%)		40.9
				Plastic limit (%)		18.6
				Plasticity Index (%)		22.3
<b>Linear shrinkage</b>						
				Trough No.		4
				Trough length (cm)		14.0
				Specimen length (cm)		12.5
				L.shrinkage =		1.5
				% L.shrinkage =		11.0
<b>Remarks:</b>						
<b>TESTING LAB</b>  Materials Engineer.			<b>STUDENTS</b> 			
<b>Lab Technician</b> 						


INSTITUTION		STUDENTS		TESTING LAB	
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN (S20B32/313)</b>		<b>Stirling</b>	
<b>PROJECT:</b>		<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>			
<b>ATTERBERG LIMITS</b>					
<i>Liquid limit (cone penetrometer) and plastic limit</i>					
<b>SOURCE</b>		MOROTO 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
<b>LAYER</b>		EXPANSIVE SOILS			
Depth		0.5m			
<b>PLASTIC LIMIT</b>		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)		21.26	22.57		21.915
Mass of moisture (g)		1.48	1.3		1.36
Mass of dry soil (g)		7.98	6.9		7.44
Moisture content %		18.3	19.3		18.3
<b>AVERAGE</b>					
<b>LIQUID LIMIT</b>		Test No	1	2	3
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
<b>AVERAGE</b>		15.0	18.6	21.2	24.0
Container No		P1VFN	P1811	FOO	FORD
Mass of wet soil + container (g)		43.43	56.43	60.57	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	6.80
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	40.6	41.1	42.7
<b>AVERAGE</b>		38.9	40.6	41.1	42.7
		Liquid limit (%)		41.0	
		Plastic limit (%)		18.3	
		Plasticity Index (%)		22.7	
		Linear shrinkage			
		Trough No.		4	
		Trough length (cm)		14.0	
		Specimen length (cm)		12.5	
		L shrinkage =		1.5	
		% L shrinkage =		11.0	
<b>Remarks:</b>					
<b>TESTING LAB</b> Materials Engineering Lab Technician				<b>STUDENTS</b>  	

INSTITUTION	STUDENTS NAMES		TESTING LAB		
 LUCANDA CHRISTIAN UNIVERSITY <small>A School of Education &amp; The Heart of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		<b>Stirling</b>		
<b>PROJECT:</b> 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/Feb/24	Lab team	
SOURCE	MOROTO DISTRICT		Natural moisture (%)		
Material description:	EXPANSIVE SOILS		11.0		
<b>TEST DATA</b>					
Weight of rammer (Kg)	No. of blows per layer	No. of layers	Height of drop (mm)	Diameter of mould (mm)	Volume of mould (cm <sup>3</sup> )
4.5	27	5	457	100	1,000
<b>MOISTURE CONTENT DATA</b>					
Test No.	1	2	3	4	5
Tin No.	A	A	A	A	A
Water Added	cm <sup>3</sup>	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 <sup>3</sup>	1,000	1,000	1,000	1,000
Wet density of soil	g/cm <sup>3</sup>	1.821	1.993	2.081	2.008
<b>DATA FOR PROCTOR CURVE</b>					
Container No.	BKN	CR7	UCU	BBC	YBY
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 <sup>3</sup>	1.642	1.765	1.805	1.715
Maximum dry density (g/cm <sup>3</sup> )	1.815		Optimum moisture content (%)		
14.5					
					
<b>Remarks:</b>					
<b>FOR TESTING LAB</b>			<b>STUDENTS</b>		
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)		<b>Stirling</b>	
<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>					
<b>CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)</b>					
Test sample reference :		Depth: 0.5m		Sampling Date: 15/Dec/23	
mix:		EXPANSIVE SOIL MODIFIED WITH 20% SAND		Casting date: 6/Feb/24	
Source:		MOROTO DISTRICT		Testing Date: 10/Feb/24	
Sample Description		EXPANSIVE SOILS		Technician: Lab team	
				Volume of Mould used (m <sup>3</sup> ) 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 <sup>3</sup> )	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			
<b>Water Content Determination</b>		Before Soaking	After Soaking		
Tare No		Y6Y -	FDC -		
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		
<b>Density determination</b>		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 <sup>3</sup>	2305	2305		
Moist density	g/cm <sup>3</sup>	2.154	2.159		
Dry density	g/cm <sup>3</sup>	1.873	1.873		
<b>Swell Determination</b>					
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		
<b>Observations</b>					
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) & ATEMO ENEKU JOAN (S20B32/313)	<b>Stirling</b>
<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>		
<b>CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)</b>		
Test sample reference	Depth 0.5m	Sampling Date 15 Dec 23
Mix	EXPANSIVE SOIL MODIFIED 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 Driving 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 Force *10 <sup>3</sup> /mm (KN)
0	0	0 0.0
0.25	12	1 0.2
0.5	24	2 0.4
0.75	35	4 0.8
1	47	6 1.2
1.5	71	7 1.4
2	94	8 1.6
2.5	118	9 1.8
3	142	10 2.1
3.5	165	10 2.1
4	189	11 2.3
4.5	213	12 2.5
5	236	12 2.5
5.5	260	13 2.7
6	283	13 2.7
6.5	307	14 2.9
7	331	14 2.9
7.5	354	15 3.1
Observations		
For the Contractor		For Students
 <small>Lab Technician</small>		 

Institution	Students Names	Testing Lab
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)	<b>Stirling</b>
<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>		
<b>CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)</b>		
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	
<b>PENETRATION vs FORCE CURVE</b>		
		
	62 Blows	
	Force      CBR	
	Bottom	Top
2.5 mm Penetration	3.5	1.8
5.0 mm Penetration	6.4	2.5
Average	4.9	2.2
Retained CBR	29.1	
Observations	<b>CBR = 29.1</b>	
	For the Lab	For Students
Lab Technician	Materials Engineer	

<b>INSTITUTION</b>	<b>STUDENTS</b>	<b>TESTING LAB</b>
 UCANDA CHRISTIAN UNIVERSITY <small>A School of Excellence in the Heart of Africa</small>	MWINE AMBROSE (S20B321010) & ATEMU ENEKU JOAN (S20B321313)	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <b>Stirling</b> </div>


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


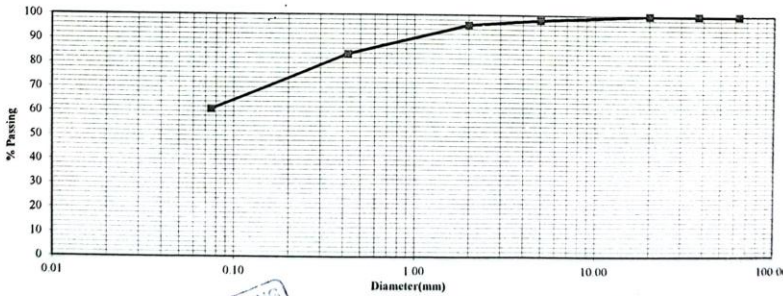

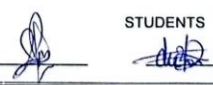
**SUMMARY OF TEST RESULTS FOR EXPANSIVE MATERIAL OF EXPANSIVE SOIL MODIFIED WITH 10% SAND**

LOCATION	BLENDED %	SAMPLING DATE	GRADING					ATTERBERG LIMITS					Depth: 0.5m		CAR	CAR SWELL	AVERAGE		
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS				MDD	OMC
EXPANSIVE MODIFIED WITH 10% SAND	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	-	-	-	-	-		
	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		
MOROTO DISTRICT		12/15/2023																	
AVERAGE			100	100	100	98	96	83	58	0.632	53.6	25.5	28.0	14.3	1.750	15.0	14.2	0.91	0.91


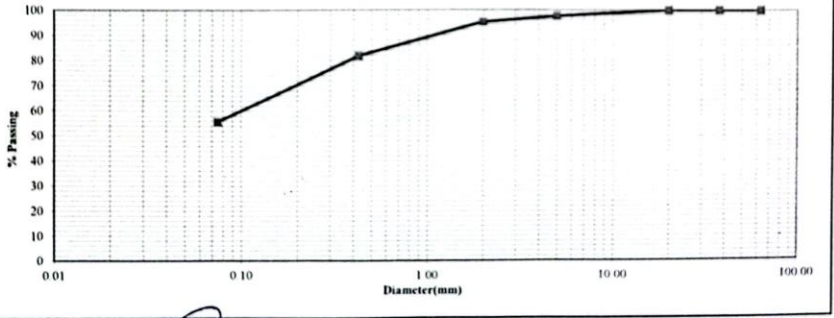




**FOR LAB**


Lab Technician:  **Lab Engineer**

STUDENTS:  

INSTITUTION		STUDENTS NAMES		TESTING LAB	
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMO ENEKU JOAN ( S20B32/313)</b>		<b>Stirling</b>	
<b>PROJECT : INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
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
<b>Total fines</b>	<b>3026.4</b>	<b>61.0</b>			
<b>Bottom Pan</b>	<b>57.4</b>				
<b>Extracted fines</b>	<b>2969.0</b>				
<b>Total sample</b>	<b>4963.0</b>				
<b>Grading Modulus</b>		<b>0.59</b>			
					
<b>Testing Lab</b>			<b>STUDENTS</b>		
 Lab Technician			 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)		<b>Stirling</b>	
<b>PROJECT :</b> INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
<b>Location :</b> MOROTO DISTRICT			<b>Lab Reference No</b>		
<b>Location :(km)</b>	EXPANSIVE SOIL MODIFIED WITH 10% SAND		<b>Dry wt. of sample before washing (g)</b>	4358.5	
<b>Depth: (m)</b>	0.5m		<b>Dry wt. of sample after washing (g)</b>	1991.0	
<b>Material description:</b>	MOROTO DISTRICT		<b>Date Sampled</b>	<b>Date Tested</b>	<b>Technician</b>
			15/Dec/2023	5/Feb/2024	Lab team
<b>Sieve Size (mm)</b>	<b>Weight Retained (g)</b>	<b>Retained (%)</b>	<b>Passing (%)</b>	<b>Grading Limits (G60 &amp; 80)</b>	
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
<b>Total fines</b>	2428.3	55.7			
<b>Bottom Pan</b>	60.8				
<b>Extracted fines</b>	2367.5				
<b>Total sample</b>	4358.5				
<b>Grading Modulus</b>		<b>0.67</b>			
					
<b>Testing Lab</b>			<b>STUDENTS</b>		
 Lab Technician		 Materials Engineer		 	

<b>INSTITUTION</b>  <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Trust of Excellence in the Heart of Africa</small>	<b>STUDENTS</b> <b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN (S20B32/313)</b>	<b>TESTING LAB</b> <div style="border: 1px solid black; padding: 2px; display: inline-block;"><b>Stirling</b></div>
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**PROJECT:** INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS

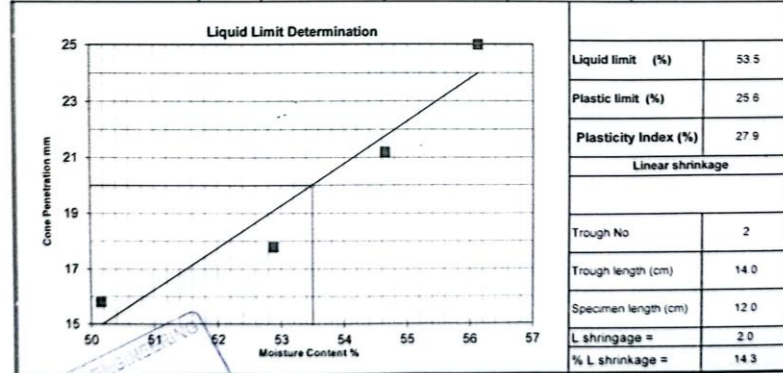
**ATTERBERG LIMITS**

*Liquid limit (cone penetrometer) and plastic limit*





<b>SOURCE:</b>	MOROTO DISTRICT	<b>Technician:</b>	Lab Team
<b>mix</b>	EXPANSIVE SOIL MODIFIED WITH 10% SAND	<b>Sample Date</b>	15/Dec/2023
<b>Test method</b>	BS 1377 Part 2, 1990 4 3/4.4	<b>Test Date</b>	18/Dec/2023
<b>LAYER</b>	EXPANSIVE SOILS		
<b>Depth:</b>	0.5m		


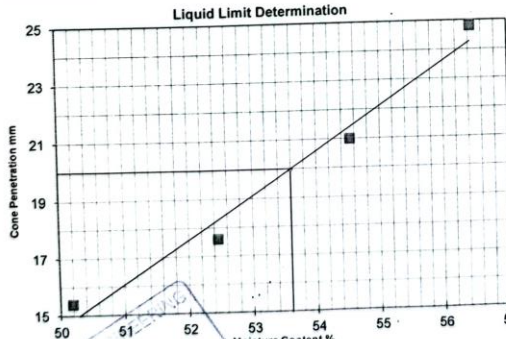
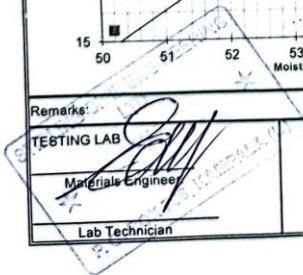
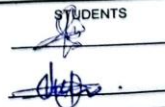
<b>PLASTIC LIMIT</b>		Test No.	RAD	JL	Average
Mass of wet soil + container (g)			38.12	39.62	38.87
Mass of dry soil + container (g)			34.8	36.16	35.48
Mass of container (g)			21.96	22.54	22.25
Mass of moisture (g)			3.32	3.5	3.39
Mass of dry soil (g)			12.84	13.62	13.23
Moisture content %			25.9	25.4	25.6
<b>AVERAGE</b>					


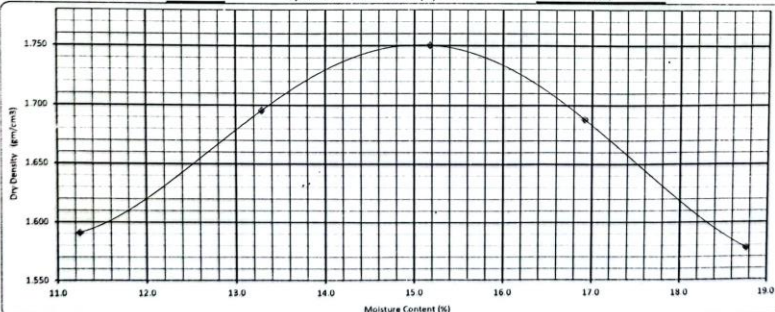
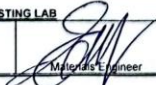


<b>LIQUID LIMIT</b>		Test No.	1	2	3	4
Initial gauge reading (mm)			0	0	0	0
Final gauge reading (mm)			15.8	17.8	21.2	25.0
penetration (mm)			15.8	17.8	21.2	25.0
<b>AVERAGE</b>			15.8	17.8	21.2	25.0
<b>Container No.</b>		FORD	FOO	PI33	PI2H	
Mass of wet soil + container (g)		49.84	48.18	56.84	53.66	
Mass 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	
<b>AVERAGE</b>			50.2	52.9	54.6	56.1










**Remarks:**

TESTING LAB  Material Engineer	<b>STUDENTS</b>  Student
	 Lab Technician

INSTITUTION		STUDENTS		TESTING LAB		
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A College of Excellence in the Heart of Africa</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN (S20B32/313)</b>		<b>Stirling</b>		
<b>PROJECT:</b>		<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>				
<b>ATTERBERG LIMITS</b>						
<i>Liquid limit (cone penetrometer) and plastic limit</i>						
<b>SOURCE :</b>		MOROTO DISTRICT		Technician:		
mix		EXPANSIVE SOIL MODIFIED WITH 10% SAND		Sample Date		
Test method		BS 1377: Part 2, 1990.4.3/4.4		Test Date		
LAYER		EXPANSIVE SOILS				
Depth:		0.5m				
<b>PLASTIC LIMIT</b>		Test No.	13	44	Average	
Mass of wet soil + container (g)			41.68	40.06	40.87	
Mass of dry soil + container (g)			37.75	36.25	37	
Mass of container (g)			22.46	21.23	21.845	
Mass of moisture (g)			3.93	3.8	3.87	
Mass of dry soil (g)			15.29	15.02	15.155	
Moisture content %			25.7	25.4	25.5	
<b>AVERAGE</b>						
<b>LIQUID LIMIT</b>		Test No.	1	2	3	4
Initial gauge reading (mm)			0	0	0	0
Final gauge reading (mm)			15.4	17.6	21	24.8
penetration (mm)			15.4	17.6	21.0	24.8
<b>AVERAGE</b>			15.4	17.6	21.0	24.8
Container No.		MB		BC		PIH
Mass of wet soil + container (g)			42.07	51.40	46.96	46.46
Mass of dry soil + container (g)			30.34	36.14	32.89	32.20
Mass of container (g)			6.97	7.05	7.09	6.93
Mass of moisture (g)			11.73	15.26	14.07	14.26
Mass of dry soil (g)			23.37	29.09	25.8	25.27
Moisture content (%)			50.2	52.5	54.5	56.4
<b>AVERAGE</b>						
			50.2	52.5	54.5	56.4
		Liquid limit (%)		53.6		
		Plastic limit (%)		25.5		
		Plasticity Index (%)		28.1		
		<b>Linear shrinkage</b>				
		Trough No		2		
		Trough length (cm)		14.0		
		Specimen length (cm)		12.0		
		L shrinkage =		2.0		
		% L shrinkage =		14.3		
Remarks:						
TESTING LAB						
Materials Engineer						
Lab Technician		<b>STUDENTS</b> 				

INSTITUTION		STUDENTS NAMES			TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>ESTABLISHED IN 1980</small>		<b>MWINE AMBROSE (S20B32/010) &amp; ATEMU ENEKU JOAN (S20B32/313)</b>			<b>Stirling</b>	
<b>PROJECT: INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>						
Test Reference No	Depth	0.5m	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 <sup>3</sup> )	
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 <sup>3</sup>	120	220	320	420	520
Mass of Compacted soil + mould	gm	4,985	5,136	5,231	5,189	5,089
Mass of Mould	gm	3,215	3,215	3,215	3,215	3,215
Mass of Compacted soil	gm	1770	1921	2016	1974	1874
Volume of mould	cm <sup>3</sup>	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm <sup>3</sup>	1.770	1.921	2.016	1.974	1.874
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	2,198.0
Mass of dry soil + container	gm	2,268.0	1,982.0	1,828.0	1,919.0	1,977.0
Mass of container	gm	801.0	763.0	767.0	784.0	799.0
Mass of water added	gm	165	162	161	192	221
Mass of dry soil	gm	1467	1219	1061	1135	1178
Moisture content	%	11.2	13.3	15.2	16.9	18.8
Dry density	g/cm <sup>3</sup>	1.591	1.696	1.750	1.688	1.578
Maximum dry density (g/cm <sup>3</sup> )	1.750		Optimum moisture content (%)		15.0	
						
<b>Remarks:</b>						
<b>FOR TESTING LAB</b>			<b>STUDENTS</b>			
Lab Technician 			 			

Institution	Students Names		Testing Lab	
 UGANDA CHRISTIAN UNIVERSITY <small>A Division of Faithlife &amp; the Board of Africa</small>	MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)		<b>Stirling</b>	
<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>				
<b>CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)</b>				
Test sample reference :	Depth : 0.5m		Sampling Date :	15/Dec/23
mix:	EXPANSIVE SOIL MODIFIED WITH 10% SAND		Casting date :	6/Feb/24
Source:	MOROTO DISTRICT		Testing Date :	10/Feb/24
Sample Description:	EXPANSIVE SOILS		Technician :	Lab team
			Volume of Mould used (m <sup>3</sup> )	2305
Natural moisture of air dried sample			Volume of water added	
Tin No	ACB		Mass of air dried soil (g)	699
Tin + air dried soil sample (g)	2908		MDD (Mg/m <sup>3</sup> )	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			
<b>Water Content Determination</b>		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	-
<b>Density determination</b>				
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 <sup>3</sup>	2305	2305	
Moist density	g/cm <sup>3</sup>	2.089	2.112	
Dry density	g/cm <sup>3</sup>	1.781	1.784	
<b>Swell Determination</b>				
Date	Hour	D Gauge Reading		
Initial reading	96 hrs	20.04		
Final reading		21.19		
Height of the specimen		127		
Height of swell		4.15		
	Swelling(%)	0.91		
<b>Observations</b>				
For the Lab			For Students	
 Lab Technician Materials Engineer				

Institution		Students Names				Testing Lab	
 UGANDA CHRISTIAN UNIVERSITY <small>A Division of the University of the North</small>		MWINE AMBROSE (S20B32/010) & ATEMU ENEKU JOAN (S20B32/313)				<b>Stirling</b>	
<b>INVESTIGATING THE USE OF RIVER SAND IN THE STABILISATION OF EXPANSIVE SOILS</b>							
<b>CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)</b>							
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		5	
Mould No		NN					
Capacity of the Proving Ring (KN)		50		50		50	
Proving Ring Constant (KN/div.)		0.2052		0.2052		0.2052	
Speed: mm/min		Top		Bottom			
Penetration of the plunger (mm)	Time (s)	Reading *10 <sup>3</sup> /mm	Force (KN)	Reading *10 <sup>3</sup> /mm	Force (KN)		
0	0	0	0.0	0	0.0		
0.25	12	1	0.2	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		 <small>Lab. Technician</small>		 <small>Student</small>		 <small>Student</small>	



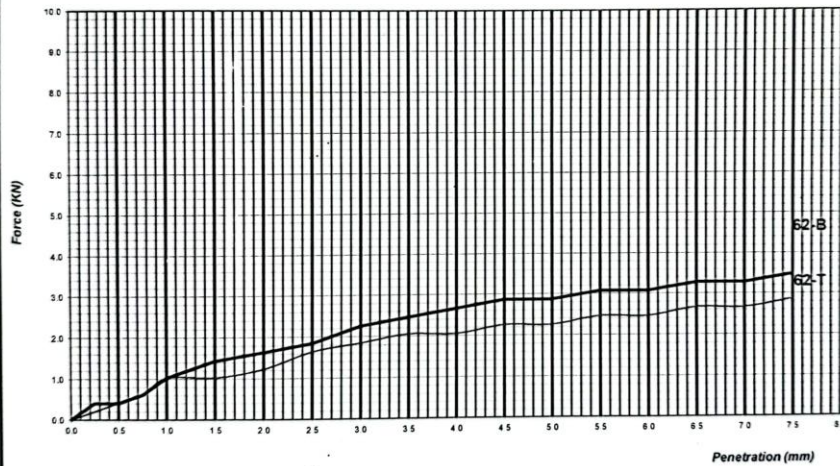
<b>Institution</b> UGANDA CHRISTIAN UNIVERSITY <small>A Church of Excellence in the Heart of Africa</small>	<b>Students Names</b> MWINE AMBROSE (S20B32/010) & ATEMIO ENEKU JOAN (S20B32/313)	<b>Testing Lab</b> <b>Stirling</b>
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**INVESTIGATING THE USE 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:	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	<i>[Signature]</i>		<i>[Signature]</i>	