ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILIZATION OF WEAK SUBGRADE SOILS

GARRY MCARNOLD

S20B32/033

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

April, 2024

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa

ABSTRACT

Weak subgrade soils are usually expansive in nature characterized by swelling and shrinkage tendencies at different moisture contents, making then unsuitable for engineering projects like road construction without proper stabilization or reinforcement. Over the years, cement and lime have played a role as common stabilizers for improvement of such soils. However, in Uganda, the cost of these additives have been escalating creating a need to come up with alternative solutions. Henceforth, this research aims to assess the viability of river sand and saw dust ash as efficient stabilizers for the weak subgrade soils. Through analytical experimentation, the percentages of river sand were varied with increasing percentages of 15%, and saw dust ash was varied in reducing percentages of 3%. The objectives of the research were accomplished through a number of laboratory tests, such as gradation analysis, atterberg limits, proctor compaction test, and California Bearing Ratio (CBR) test. The discoveries after carrying out the tests disclosed the soil is clayey with high plasticity, calling for the need for stabilization. More so, the incorporation of river sand and sawdust ash resulted in a considerable decrease in the plasticity index, from 30.5% to 5.3%. Furthermore, the of addition of river sand sawdust ash led to a significant increase in the maximum dry density and a decrease in the optimum moisture content as its proportion was augmented. The optimum percentages of river sand and saw dust ash were 45% and 3% respectively. These end results disclose the prospects of river sand and sawdust ash as an economical alternative to traditional stabilizers like as cement and lime.

DECLARATION

I, **MCARNOLD GARRY** hereby declare that my research presented in this report is an original record and has not been presented to other institutions or universities expecting to receive any academic awards or recognition.

MCARNOLD GARRY

S20B32/033

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

APPROVAL

I hereby certify that this research study of MCARNOLD GARRY, at Uganda Christian University from September 2023 to April 2024 was oversaw under my supervision and guidance, and this report is approved for submission to Uganda Christian University's Department of Engineering and Environment.

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

MR. HENRY SEJJEMBA

ACADEMIC SUPERVISOR

ACKNOWLEDGEMENTS

To start with, I want to sincerely thank the Almighty God for giving me the ability to be strong and knowledge I deeply needed to undertake my final year project and come up with this report.

For the success I attained in this project, I am entirely grateful and thankful to my supervisor Mr. Henry Sejjemba, as he readily permitted me to occupy his valuable time from the start of this research project till its conclusion. His advice, support, and suggestions gave me the insight I needed to understand the study topic and made it possible for the task to be completed meaningfully and quickly.

I am very much grateful for my project partner Nambooze Justine Shilla who was very supportive and collaborative within all the project activities. It was a pleasure working with her.

TABLE OF CONTENTS

ABSTRACT i

DECLARATION ii

APPROVAL iii

ACKNOWLEDGEMENTS iv

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER ONE: INTRODUCTION 1

1.1 Background 1

1.2 Problem statement 3

1.3 Objectives 4

1.3.1 Main objective 4

1.3.2 Specific Objective 4

1.4 Research questions 4

1.5 Scope 4

1.6 Justification 5

1.7 Knowledge gap 6

CHAPTER TWO: LITERATURE REVIEW 7

2.1 Introduction 7

2.2 Soil 7

2.3 Weak subgrade soils. 7

2.4 Mechanism of weak subgrade soils 8

2.5 Clay minerals 8

2.6 Soil Stabilization 10

2.7 MATERIALS 13

2.6.1 Stabilization using sawdust ash 13
2.6.2 Stabilization using river sand 14
CHAPTER THREE: METHODOLOGY 16
3.1 Introduction 16
3.2 Materials 16
3.3 Sample preparation and blending 17
3.4 Tests to be carried out 17
CHAPTER FOUR: RESULTS AND DISCUSSIONS 23
4.1 Introduction 23
4.2 SIEVE ANALYSIS AND CLASSIFICATION. 24
4.2.1 AASHTO Soil Classification System 26
4.2.2 USCS soil classification system 26
4.3 ATTERBERG LIMITS 28
4.4 COMPACTION TEST 30
4.5 CALIFORNIA BEARING RATIO (CBR) 31
4.6 CHEMICAL COMPOSITION OF SAWDUST ASH. 33
4.7 PROPERTIES OF RIVER SAND 34
4.7.1 Grading of the river sand 34
4.8 CHEMICAL PROPERTIES OF THE NEAT SOILS 37
4.8 Effect of river sand and saw dust ash on the atterberg limits of the soil. 38
4.9 Effect of river sand and saw dust ash on proctor values of the soil 42
4.10 Effect of river sand and saw dust ash strength characteristics of the soil 43
4.11 DESIGN MATRIX 45
Analysis of results for the optimum mix of river sand and saw dust ash added to the soil. 46

4.12 Shear strength test on the optimum mix. 51
CHAPTER 5: CONCLUSION AND RECOMMENDATION.. 53
CONCLUSION 53
RECOMMENDATIONS... 54
REFERENCES 55

LIST OF TABLES

Table 1: Chemical composition of weak subgrade soils 10
Table 2: Chemical composition of sawdust ash. 14
Table 3: Summary of results 23
Table 4: Summary for the grading results on the neat soil 24
Table 5: AASHTO 35th edition 2015 28
Table 6: Obtained atterberg limit results and corresponding standards 28
Table 7: Asphalt Institute (1962) 32
Table 8: Chemical composition of sawdust ash after the XRF test 33
Table 9: Grading results for the river sand 35
Table 10: Other engineering properties of the river sand. 36
Table 11: Chemical composition of saw dust ash 37
Table 12: Atterberg limit values for varying percentages of river sand and saw dust ash 38
Table 13: Design matrix.. 45
Table 14: Values obtained after using the optimum percentages compared with the Standards 46
Table 15: Grading results for the stabilized soil with the optimum percentages 47
Table 16: Comparison of the type of subgrade soils and Grading Index 51
Table 17: Shear strength parameters 52

LIST OF FIGURES

Figure 1: Drying a neat sample of the weak soils. 16
Figure 2: Carrying out a particle size distribution test.................................... 18
Figure 3: Carrying out a proctor compaction test.. 21
Figure 4: Moulds placed in a soaking tank.. 22
Figure 5: Percentage passing against sieve sizes... 25
Figure 6: AASHTO Classification chart 26
Figure 7: Casagrande's plasticity chart (USCS)... 27
Figure 8: A graph of cone penetration against moisture content......................... 29
Figure 9: A graph of dry density against moisture content. 31
Figure 10: types of pozzolans in accordance to ASTM C618 34
Figure 11: A graph of percentage passing against sieve sizes. 35
Figure 12: A graph of liquid limit against percentage variations 39
Figure 13: A graph of plasticity index against percentage variations 40
Figure 14: A graph of linear shrinkage against percentage variation 41
Figure 15: A graph of OMC against percentage variations 42
Figure 16: A graph of MDD against percentage variations 42
Figure 17: A graph of CBR against percentage variations.................................. 43
Figure 18: A graph of Unconfined compressive strength against percentage variations 44
Figure 19: AASHTO classification chart... 49
Fig 20: Casagrande's plasticity chart... 50

LIST OF ABBREVIATIONS

PI	Plasticity index
LL	Liquid limit
PL	Plastic limit
USCS	Unified Soil Classification System
UCS	Unconfined compressive strength
AASHTO	American Society of State Highway and Transport Official
ASTM	American Society for Testing and Materials
OMC	Optimum moisture content
CBR	California bearing ratio
MoWT	Ministry of Works and Transport
MDD	Maximum dry density
BS	British Standard
MC	Moisture content
LAB	Laboratory
SD	Saw dust
SDA	Saw dust ash

CHAPTER ONE: INTRODUCTION

1.1 Background

Weak subgrade soils are present throughout the world especially in regions that experience semi-arid and arid climatic conditions where annual evaporation exceeds annual precipitation, according to Christos 2022 some of the places that are largely affected by these soils are Canada, United States from North America, Argentina from South America, Spain, China, and several Countries in Africa including Uganda. The distinctive black or grey color, deep or wide shrinkage fractures, high dry strength and low wet strength, stickiness, and poor traffic ability when wet are characteristics of these soils. Problematic subgrade soils with low strength and beating capacity are known as weak subgrade soils. Engineers working on such soils encounter a multitude of challenges. These types of soils are not strong enough to withstand the loads that the structure will bear during construction or during its useful life (Ajay Upadhyay, 2016).

These kinds of soils are found in humid environments where the soils have high plasticity index which is usually above 40 (Jones, 2012). They have a high content of montmorillonite clay minerals that easily take in and retain water for a long time therefore causing damage to the structure. These weak subgrade soils swell when they take in water and they shrink when they lose water, these cyclic volume changes cause crack to form. According to Mintek Team, 2021 he explains how swelling and shrinkage occurs in these soils and states that these soils under about 30% increase when they expand.

Because weak subgrade soils' poor engineering performance has compelled researchers to enhance these soils' characteristics, soil stabilization is a useful technique for enhancing soil qualities and the functionality of structures built on them. (T. Geeta Rani, 2014). The major aim of the soil stabilization is to improve the strength and stiffness of the weak soil. Previous scholars have made significant efforts to strengthen and stabilize weak subgrade soils. Soil stabilization is the alteration of soils to reinforce their physical properties. It can increase the shear strength of the soil od the soil, control swelling and shrinkage properties of the soil and therefore increasing the load bearing capacity of the soil. It strengthens the engineering characteristics of the soil hence improving its performance. Soil stabilization can be achieved through a variety of techniques, such as replacing deficient soil with better soil, blending it with better soil or material, using solid waste from various industries, adding fibrous material to strengthen the soil, or using chemical additives to improve soil properties and characteristics (G. Muthumari, 2018).

The most popular chemical stabilizers are lime and cement, which through pozzolanic reactions increase the strength properties of expansive soils. However, using these stabilizers has proven to be very expensive and unsustainable due to the significant amounts of carbon dioxide produced during cement production. (Abbey et al., 2017). This has inspired research into the use of unconventional stabilizers such rice husk ash, sugarcane bagasse ash, cow dung ash, fly ash, and plastic dust among others to stabilize expansive soils whose disposal would otherwise be troublesome.

1.2 Problem statement

Development through urbanization has taken place over the years creating more employment opportunities for the citizens and because of this, many roads have been constructed and they ought to be in properly constructed. Weak subgrade soils are seen to be a major problem on the 27 km stretch of Kisamba road Busunjju (MoWT, 2022). Major sections of the road pass through swamps and as vehicle pass through these areas heaving is seen to take place leaving the road in a sorry state. This has increased the time road users spend traveling and the vehicle operating costs as vehicles are seen to break down. Heaving occurs due to the presence of clay minerals in the soil that undergo cyclic volume changes when there is variation in water content. There is heavy settlement in the case that heavy vehicles use the road which comes about due to shrinkage and swelling. The road develops potholes, and cracks continuously.

Soil stabilization refers to the process of changing a soil's characteristics by chemical or mechanical means to produce a better soil mixture with the necessary strength features. The procedure may involve the blending or mixing of soils to attain a desired material that is well graded, has a low plasticity and act as a binder for cementation of the soil particles (Arun, 2014). These weak subgrade soils must therefore undergo stabilization in order to improve their gradation, drainage strength as well as reducing their swelling potential.

1.3 Objectives

1.3.1 Main objective

Assessing the use of river sand and sawdust ash as stabilizing materials for weak subgrade soils.

1.3.2 Specific Objective

1. To determine the engineering properties of the neat soil.
2. To determine the engineering properties of river sand and sawdust ash to be used as a stabilizer.
3. To determine the variation in strength values with different percentages of river sand and sawdust ash added to the soil.

1.4 Research questions

1. What are the engineering properties of the neat soil?
2. What are the engineering properties of river sand and sawdust ash to be used as a stabilizer?
3. What is variation in strength values with different percentages of river sand and sawdust ash added to the soil?

1.5 Scope

This research deals with the improving of engineering and geotechnical properties of the weak subgrade soils on the Kisamba road Busunjju. The engineering properties of these problematic soils are to be improved using river sand that was obtained from Lwera and sawdust ash that was obtained from local carpentry workshops in Mukono.

This study is to be carried out for a period of nine months which is from August 2023 to April 2024.

1.6 Justification

River sand is inert and granular in nature therefore, due to its strength in confined conditions it has potential as a filler material when mixed with the expansive soil (Roy, 2013). During stabilization of fine-grained soils there should be uniform gradation of materials that are coarser so that the composite mix has both friction and cohesion. When mixed in varying proportions, since the sand particles are made of angular shapes, they interlock with the soil particles hence the sand is an admixture to the soils that are cohesive. The interlocking of the particles alters various properties of the soil such as compaction, bearing capacity, and plasticity (Khemissa et al., 2015; Louarfi et al., 2012). However, because of the high clay content in the soil during wet conditions it is very hard for the soil to remain bonded effectively with the sand and therefore there is a need for the sawdust ash to added (S. C. Chukwu et al., 2017).

Sawdust ash is pozzolanic in nature containing about 10-15% silica, 8-15% alumina and 25-40% calcium oxide which are available for cationic exchange when mixed with the expansive soil in presence of water (Manguana, 2022). Flocculation and agglomeration of the particles takes place and compounds such as calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H) are formed which are cementitious materials increasing the strength of the soil (Adey, 2017) therefore strongly bonding the particles together. Addition of sawdust ash improves the strength properties of the problematic soils but also increases the fines, therefore introduction of river sand helps to improve the gradation and improve the atterberg limits.

1.7 Knowledge gap

Over the years, previous researchers and scholars have studied the used of river sand to improve the properties of expansive clayey soils and having examined the properties of the stabilized soil the CBR value was seen to increase and the plasticity index reduce. Nevertheless, since river sand is a mechanical soil stabilizer when used in expansive soils, it doesn't remain effectively bonded with the soil particles especially during in wet conditions (S. C. Chukwu et al., 2017) and therefore this calls for the need study the use of sawdust ash as a chemical stabilizer to effectively bond the particles together therefore increasing the CBR value of the soil further. The river sand plays a role in reducing the atterberg limits of the expansive soils whereas the sawdust ash is to chemically increase the bonding of the particles and increasing the strength of the soil.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter details literature on the different types of a subgrade, properties, composition and characteristics of weak subgrade soils. Furthermore, it provides details on the different types of stabilization; chemical and mechanical stabilization.

Details on the stabilizing materials: river sand and saw dust ash used in this study are also provided in this chapter.

2.2 Soil

Life on Earth is made possible by the complex mixture of minerals, organic matter, gases, liquids, and many living organisms that makes up soil. Soil is continually changing due to a variety of physical, chemical, and biological processes, including weathering and related erosion. Stabilization is essential in soft soils (silty, clayey peat, or organic soils) in order to attain the appropriate engineering and geotechnical properties. (J. David Rogers, 2018). Sherwood claims that fine-grained granular soils are the easiest to stabilize due to their large surface area in relation to particle diameter. Compared to other soil types, clay soil has a higher surface area due to its flat and elongated particle morphologies. However, because silty materials are sensitive to even minute fluctuations in moisture, stabilizing them may prove challenging.

2.3 Weak subgrade soils.

Weak subgrade soils are those that expand greatly when exposed to water and contract when the water evaporates. These soils swell when they take in water and shrink when they lose the water, a phenomenon generally attributed with variations and seasonal moisture changes. Such volume changes of weak subgrade soils caused instability in shape is influenced by several factors such as their mineralogy, clay content, fabric structure, moisture content, density, pore water chemistry and loading conditions (Michael T, 2016). Different civil engineering constructions built on them sustain damage as a result of the soil's alternating swell-shrink characteristic. The extent of the harm caused by expanding soil has been well-documented in international literature (Sabat, 2018).

2.4 Mechanism of weak subgrade soils

The primary reason for the cyclic volume changes because of the existence of montmorillonite clay minerals. In montmorillonite (2:1, silica/alumina unit), the tips of tetrahedral share oxygen and hydroxyls with the octahedral sheet, making it a single layer (Babita singh, 2014). Water and exchangeable cations can readily enter and separate the primary layers because of the structure's charge shortage and the weaker Van der Waals link between two consecutive silica sheets. Therefore, a soil rich in montmorillonite is more susceptible to swelling due to its affinity for holding moisture (Saini R, 2018). As a result of the water evaporating, it is susceptible to significant contraction, which can cause noticeable shrinkage and settlement.

2.5 Clay minerals

Majority of the soil classifications systems describe clay particles as having an effective diameter of about 0.003mm or less. However, clay minerals aren’t only determined by the particle size (A, 2017). Mineralogical composition is probably the crucial fine-grained soil grain characteristic. The electrical forces acting on a particle's surface are typically much stronger than the gravity force for small particles (Chen, 2018).

Clay minerals are categorized into three most outstanding groups namely: illite montmorillonite, and kaolinite which are crystalline hydrous aluminosilicates. Majority of the expansive soil problems possess montmorillonite clay minerals causing the engineering problems.

“Montmorillonite” is used currently both as a group name for all clay minerals with an expanding lattice, except vermiculite, and also as a specific mineral name (Abdulla sharo, 2019). Taking in of water by the clay particles leads to swelling. From the mineralogical perspective, the magnitude of expansion is basically dependent on the type and amounts of the clay minerals that are present, their internal structure, their exchangeable ions, and electrolyte content of aqueous phase.

Montmorillonite is a three-layers mineral having a single octahendral sheet sandwiched between two tetrahendral sheets to give a 2 to 1 lattice structure.

Illite has a similar structure with that of monmorillonite, but some of the silican atoms are replaced by aluminum, and in addition, potassium ions are present between the tetrahendral sheet and adjacent crystals (Taha, 2020).

Table 1: Chemical composition of weak subgrade soils (Taha, 2020).

Element	Percentage composition
Silica	63.17
Alumina	19.36
Ferric	4.32
Titanium	0
Pottasium	1.73
Sodium	8.73
Magnesium	1.79
Calcium	0.67
Loss of ignition	0.23

2.6 Soil Stabilization

Soil stabilization is basically a technique of enhancing the properties of the soil by introducing and blending other materials. Soil stabilization is necessary whenever the soil to be used for construction is weak and unable to support the structural load. It focuses on lowering the permeability and compressibility of the soil mass in earth structures as well as elevating its shear strength thereby reducing the settlement of structures. Stabilizing agents (binder materials) are incorporated in the weak soils during soil stabilization to improve their geotechnical and engineering properties such as compressibility, strength, gradation, permeability, and durability (Afrin, 2017).

Types of soil stabilization.

A variety of soil stabilization techniques have been used over the years which can be broadly classified into two major groups, i.e. mechanical and chemical (A.R. Estabragh, 2014)

Chemical soil stabilization

It can be accomplished by adding a chemical component to the expansive soil with the intention of improving the soil's characteristics. Chemical stabilization agents are often calcium-based and include fly ash, cement, lime, and bitumen.

They experience both short- and long-term chemical changes when exposed to water, which improves the soil matrix overall in terms of swell reduction, shear strength, and resistance to the effects of wetting and drying (Adams, 2021). According to Afrin (2017), cation exchange, flocculation, agglomeration, pozzolanic reaction, and carbonate cementation are the stabilizing mechanisms for chemical stabilizers. The majority of the time, these chemicals are sprayed into soil after being combined with water and maybe blended and compacted.

Mechanisms of chemical stabilization

The following is a summary of stabilizing mechanisms that use fly ash, sawdust ash, cement, or lime:

- Cation exchange: calcium cations from the available calcium hydroxide replace sodium, magnesium, and other cations.
- Agglomeration and flocculation: the clay particles agglomerate to reduce plasticity and increase effective grain size, so fortifying the matrix. As the plastic

soil texture gradually transforms into non-plastic materials, these two processes help to decrease the adsorbed water layer, increase interparticle friction, and improve workability (Adamu Beyene, 2022).

- Pozzolanic reaction: silicates and aluminates are soluble at the clay surface due to the high pH environment produced by the accessible calcium hydroxide. These materials then react with calcium ions to form cementitious products that are mostly made of majorly calcium aluminate hydrates and calcium silicate hydrates.
- Carbonate cementation: calcium carbonate precipitates are generated when carbon dioxide from the atmosphere reacts with calcium oxide, which binds the soil particles together

Mechanical Stabilization

This technique aims and involves improving the properties of the neat soil by changing its gradation. This procedure involves compacting the soil and densification by application of mechanical energy and force by help of sorts of rollers, rammers, vibration techniques and at time blasting. The firmness of the soil in this technique depends on the genetic and in built characteristics of the soil material (Ali Akbar Firoozi, 2017). More than one type of natural soils is blended to achieve a composite material which possesses better engineering properties like strength and durability and meets the required standards and specifications.

2.7 MATERIALS

2.6.1 Stabilization using sawdust ash

Sawdust is obtained from local carpentry workshops it being a by-product of timber and wood-cutting industries. Sawdust ash has high levels of silica content, indicating it possesses pozzolanic properties. Previous scholars have indicated that incorporating sawdust ash with materials such as lime and cement with are cementitious with pozzolanic activity could surely help improve (K. Adebayo, n.d.). Therefore, it produces cement compounds in the presence of water and calcium hydroxide (Abubaker Ahmed, 2023).

Following soil stabilization with sawdust ash, lime/cement, studies and research have disclosed a considerable reduction in the swelling potentials of the soils leading to a significant improvements in the mechanical properties like strength and durability (Akinwumi I, 2023).

In other ways, the rising energy demand has led to a variety coal-fired power stations. Following this development, the practical utilization and safe disposal of large amounts of sawdust ash is a concern. This results in a serious issues of pollution to the ecosystem. Therefore, as a stabilizing material and admixture with soil, saw dust ash has not only brought up great indications for improving the soil properties but also safeguarding the environment.

The units of silicate (SiO_2) and aluminate (Al_2O_3) present in the expansive soils will react with the calcium (Ca^{2+}) and hydroxide (OH^-) during the course of pozzolanic reactions. Consequently, active cementation materials such calcium silicate hydroxides

(CSH) and aluminate hydroxides (CAH) were formed (M.P. Adari, n.d.). These resulting chemical compounds are absolute cementitious materials that are insoluble in water. A gel substance called calcium silicate hydrate constricts the clay particles and lessens the amount of air spaces in the soil. These cementitious materials continuously change from a gel to a crystalline state, forming an interlocking structure that prevents these weal subgrade soils from swelling due to the initial surface reduction the particles of clay (T. Chompoorat, 2019).

Table 2: Chemical composition of sawdust ash.

Constituents	**% by mass**
Silicon dioxide	66.57
Aluminum oxide	21.60
Iron oxide	1.41
Calcium oxide	2.41
Sodium oxide	1.41
Potassium oxide	2.79

2.6.2 Stabilization using river sand

River in Uganda have deposits of river sand along their shores for example River Kaffu. During stabilization, river sand particles are made of angular shapes which makes it easy for them to easily interlock with the soil particle. According to Chicmela, 2023, when river sand when used to stabilize clayey soils the CBR value improved from 5% to

18% which is above the standard for a subgrade material according to the Ministry of Works and Transport, however, the plasticity index remained above 25.

A Ugandan scholar Jjuuko et al, 2011 revealed that at sand blends of 20– 100%, the maximum dry density (MDD) increased from 1867 to 2357 kg/m3 and the optimum moisture content (OMC) reduced from 16.5 to 8.5%, respectively, while the unconfined compressive strength decreased from 787 to 95 kPa at sand blends of 20– 60%.

A research by another scholar (Chavali et al., 2014) show that adding sand up to 30% increased the maximum dry density (MDD) of clay-sand mixtures, but after that point it decreased. According to the same analysis, the ideal moisture level of the sand declined up to 30% before slightly increasing.

Mixing coarser sand admixture particles with the finer soil particles in accordance with the stabilizing strategies ensures that a consistent gradation of soil particles is produced, and the composite mix that results have both cohesion and friction. Furthermore, the soil demonstrates improved load carrying ability when correctly mixed, placed, and compacted. Sand can be used as an admixture to the soils that are cohesive, it alters the plasticity index and strength of the soil (Roy, 2013).

CHAPTER THREE: METHODOLOGY

3.1 Introduction

To attain the objectives of the research, the samples are to be collected in triplicates from various points along the road stretch. Then they are to be transported to the laboratory for testing.

3.2 Materials

Weak subgrade soils.

The weak subgrade soil considered to be upgraded in the study will be collected along Kisamba road in Busunjju. The soil samples were fetched from a depth of 1.5 m beneath the ground surface close to the damaged road segment. As a result, the samples that were gathered belong to the road subgrade and share the same physical characteristics as the damaged pavement's foundation.

Figure 1: Drying a neat sample of the weak soils.

River sand.

In the research, river sand will be used as a mechanical stabilizer to stabilize the expansive soils. It will be obtained from t

he sand deposits in Lwera located along in Mpigi district.

Sawdust ash

The sawdust made use of in this study was obtained from local carpentry workshops in Mukono. The saw dust was then burnt in a furnace at a controlled temperature of 700^0C and then left to cool to produce the ash.

3.3 Sample preparation and blending

With the aid of manual excavation tools, test pits that were dug up to a depth of 1.5 meters yielded weak and expanding soil samples. To prevent significant moisture loss, the collected samples will be stored in airtight bags before being sent to a lab for analysis.

The sawdust obtained from local carpentry workshops then burnt in a furnace at a controlled temperature of 700^0C and then left to cool.

3.4 Tests to be carried out

To achieve the objectives in this research, a variety of tests will be carried out both on the neat weak subgrade soils before stabilization, on sawdust ash and river sand, and also the mixture of the weak subgrade soils and the stabilizer.

These tests will be carried out at different percentages of the stabilizer mixed with the weak subgrade soils and they include the following:

PARTICLE SIZE DISTRIBUTION – WET SIEVING (Reference BS 1377: Part 2: 1990)

Objective

For soils, especially coarse soils, a particle size distribution analysis is an essential classification test since it shows the relative amounts of various particle sizes. This allows one to ascertain whether the soil is mostly composed of gravel, sand, silt, or clay sizes and, to a lesser degree, which of these size ranges is most likely to regulate the soil's engineering features.

Sample preparation

The test sample was obtained by oven drying for at least 12 hours. The representative sample will then be riffled or quartered to give a minimum mass of about 2.5 kg.

Figure 2: Carrying out a particle size distribution test

ATTERBERG LIMITS (Reference BS 1377: Part 2: 1990)

The atterberg limits that include liquid limit, plastic limit and plasticity index were carried out.

LIQUID LIMIT (CONE PENETROMETER METHOD)

Objective

PLASTIC LIMIT

Objective.

The moisture content at which a soil transitions from a liquid to a plastic form is known as the liquid limit, and it has been determined empirically. When the plastic limit is also known, the liquid limit can be used to distinguish and categorize cohesive soils with fine grains. Shear strength of a soil can be significantly impacted by changes in moisture content, particularly in fine-grained soils.

This test, which is based on measuring the penetration of a standard cone into the soil, will determine the liquid limit of a sample in its natural state passing through a 425µm sieve.

PLASTICITY INDEX

The difference between the liquid and plastic limits is known as the plasticity index. The range of moisture content in which a soil is plastic is measured by its plasticity index; the higher the plasticity index, the finer the soil.

$PI = LL - PL$

LINEAR SHRINKAGE

OBJECTIVE

In clayey soils, shrinkage due to drying is severe if the drying process is continued over the plastic limit. In addition to continuing to shrink in volume, the wet soil exhibits similar expansion. The amount of shrinkage that clayey soils are likely to experience can be measured using the linear shrinkage value. It also applies to the opposite situation of expanding as a result of moisture.

DRY DENSITY MOISTURE CONTENT RELATIONSHIP

Objective

This test involves two hand compactive effort levels to find the link between soil moisture content and compacted dry density. The test serves as a reference for field compaction guidelines. Using a 2.5 kg rammer for a light compaction test and a 4.5 kg rammer for a heavy compaction test, respectively, are the two methods.

The test compares the improvement in the density of the sample, which describes the amount of moisture required during compaction in order to achieve the maximum dry density of the soil.

To use this test, we will first make sure that the soil sample should pass through the 20mm test sieve as specified by the standards.

Figure 3: Carrying out a proctor compaction test

CALIFORNIA BEARING RATIO (CBR)

Objective

The primary determinant of the necessary thickness of flexible pavements for highways and airfields is the strength of the subgrade. The California Bearing Ratio (CBR) value of subgrade, subbase, and base course materials is used to express their strength. When designing with natural gravel pavement materials, the CBR-value is a must. The CBR test will be carried out on material passing the 20mm sieve.

Figure 4: Moulds placed in a soaking tank

UNCONFINED COMPRESSIVE STRENGTH (BS1377: Part 4:1990: ASTM D2166)

The unconfined compressive strength (UCS) test is a laboratory method that will be used to determine the shear strength of the soil that won't contain any confinement. The test is often used to evaluate the strength properties of cohesive soil.

Main principle

UCS of stabilized material is the load in KN/m^2 required to crush a cylindrical specimen 127mm high and 152.4mm diameter to total failure at a rate of load of 140kpa/s.

X-RAY FLORESCENCE TEST

The components taken into consideration for the investigation were characterized using chemical analysis. An X-ray florescence (XRF) test will be performed to ascertain the sawdust ash's chemical composition. X-ray florescence analysis is basically carried out to determine the mineralogical phases present in different materials i.e. sawdust ash and river sand.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Introduction

This segment of the report focusses on the demonstration of the results and their analysis. The geotechnical properties of the neat soils, chemical properties of sawdust ash and the properties of the river sand are presented. The test that were conducted include particle size distribution, atterberg limits, proctor compaction tests, California bearing ratio tests (CBR) and the Unconfined Compressive Strength test.

The obtained results were then compared to the standard values specified by the Ministry of Works and Transport, AASHTO, ASTM and the General Specifications for Roads and Bridges.

Results on the neat sample

Lab tests were conducted from Stirling Laboratory located in Mbalala, Mukono on the neat expansive soil samples collected from Kisamba road in Busunjju, to evaluate various physical properties in their natural state. These properties encompassed Particle Size Distribution, Atterberg Limits, Maximum Dry Density, and California Bearing Ratio (CBR)

Table 3: Summary of results

GM	LL	PL	PI	LS	OMC	MDD	CBR	CBR SWELL	AVERAGE
0.68	50.3	19.9	30.4	15.0	14.4	1.807	6	1.00	1.00
0.67	50.8	20.2	30.6	15.0					
0.68	**50.6**	**20.2**	**30.5**	**15.0**	**14.4**	**1.80**	**6**	**1.00**	**1.00**

4.2 SIEVE ANALYSIS AND CLASSIFICATION.

A particle size distribution test was carried out using wet sieving and the oven dried sample was then passed through sieves of different sizes. The results were tabulated including the sieve sizes and the percentage passing each sieve size.

Table 4: Summary for the grading results on the neat soil

Sieve sizes	63	37.7	20	5	2	0.425	0.075
Percentage passing (%)	100	100	100	99	99	92	57

A graph of percentage passing against sieve sizes was plotted and the grading analysis was done to later calculate the grading modulus and group index of the soil. The soil was also classified using AASHTO and USCS.

The neat sample was observed to have 57% fines and this high percentage of fines partially contributed to the high plasticity displayed by the soil. The results from the sieve analysis are summarized in the table below.

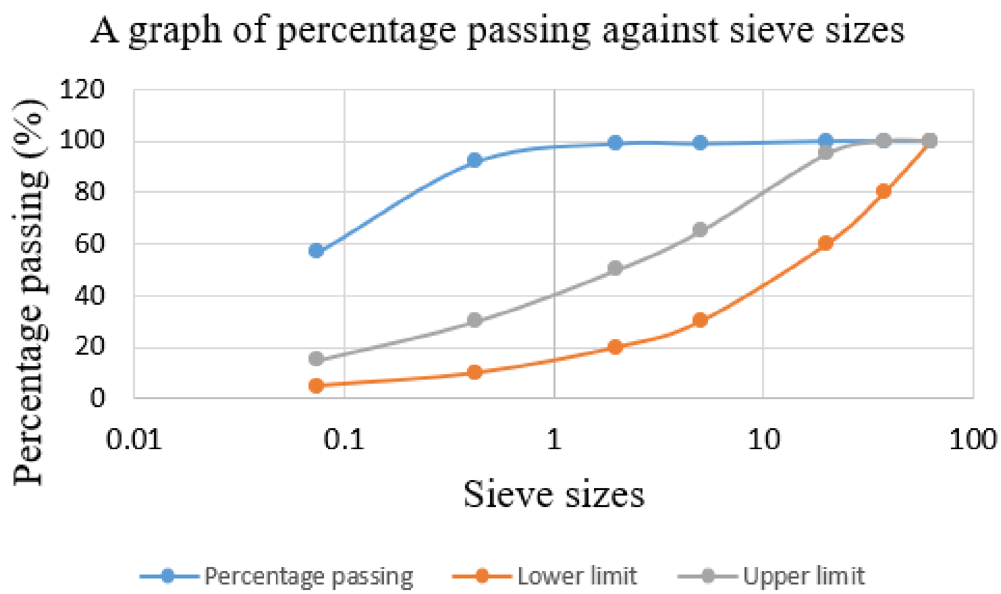


Figure 5: Percentage of neat sample passing against sieve sizes.

From the graph, 43% of the soil is coarse grains and 57%is fines. Therefore, the soil is mainly composed of fines (silt and clay) as indicated by the high percentage of fines. These large quantities of fine particles in the soil are accountable for the swell and shrinkage tendencies of the soil since fine grained soils tend to be subtle to water content, therefore referred to as cohesive soils

The soil is also poorly graded since it has a small distribution range, between 0.075mm and 1mm sieve evidenced by a gradual increase in the curve before it later became constant.

However, for a soil sample to be considered as well grades, it should comprise of particles distributed over a wide range consisting of both coarse-grained and fine-grained particles that fill the voids hence resulting into a material of a material of high density and increased strength.

4.2.1 AASHTO Soil Classification System

Since 45% of the soil passes the 0.075mm sieve, and the liquid limit is greater than 40, the soil falls under the A-7-6 (Fine-grained soils, high plasticity) category. This confirms the soil's poor drainage and low bearing capacity.

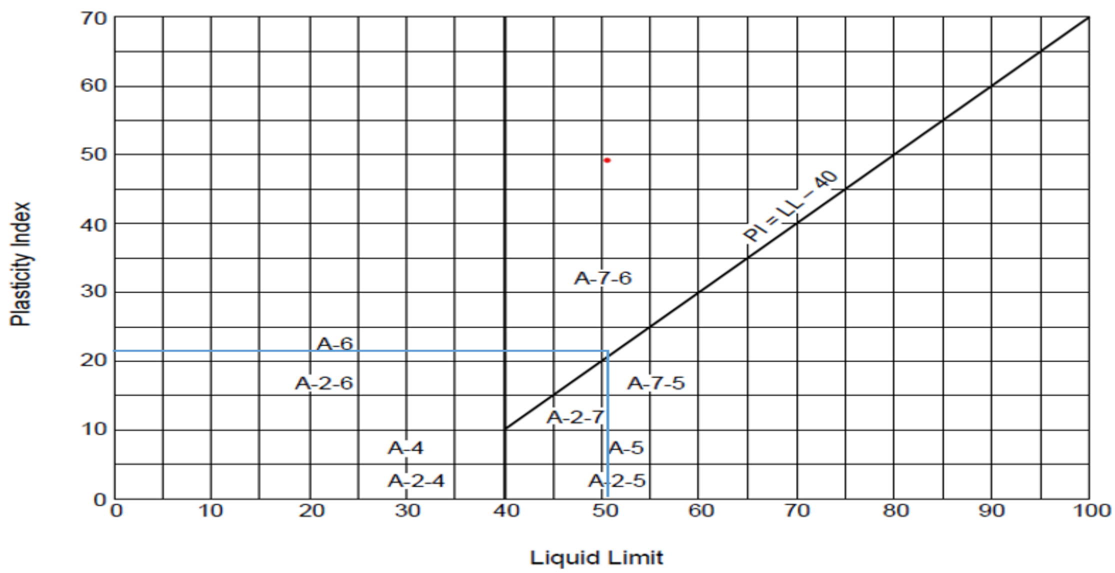


Figure 6: AASHTO Classification chart

4.2.2 USCS soil classification system

Using the obtained plasticity index of 30.5 and liquid limit of 50.6%, the soil is lies above the A-line and is classified as CH (clayey soil with a high plasticity) as shown in the Casagrande's plasticity chart. This indicates a highly plastic clay with significant potential for shrinkage and swelling therefore it does not qualify for it to be used for a subgrade material.

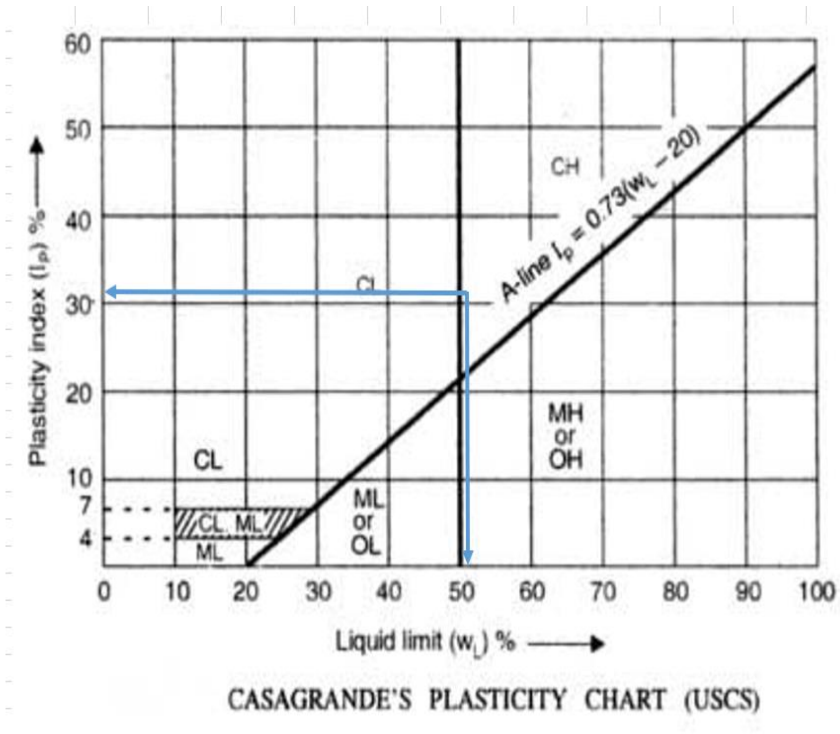


Figure 7: Casagrande's plasticity chart (USCS)

Grading modulus

The grading modulus shows the relationship between a coarse grains and fine grains in the soil. A grading modulus(GM) was obtained as 0.678 indicating that the soil doesn't qualify to be used for a subgrade material since its grading modulus is below 1.0. (GM must typically be greater 1.0 for a material to be used as a subgrade).

Group Index

Where F is the percentage fines that pass sieve No. 200,

$$GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

$$GI = (57 - 35)[0.2 + 0.005(50.6 - 40)] + 0.01(57 - 15)(30.5 - 10)$$

$$\boldsymbol{GI = 9}$$

Table 5: AASHTO 35th edition 2015

Type of subgrade soil	**Group Index**
Good	0-1
Fair	2-4
Poor	5-9
Very poor	10-20

The soil is classified as poor since its grading modulus lies between 5 to 9

4.3 ATTERBERG LIMITS

The critical water contents of fine-grained soils, such silt and clay, when they change from a solid to a liquid are commonly measured using Atterberg limits. They are a reliable method of estimating the silt and clay soils' engineering characteristics. The shrinkage limit, plastic limit, liquid limit, and plasticity index are the atterberg limits.

Laboratory tests were carried out to determine the atterberg limits and the values obtained were compared to the standard specifications as shown in the table below.

Table 6: Obtained atterberg limit results and corresponding standards

Test	**Result**	**Standards**
Liquid limit (%)	50.6	41% Maximum (ASTM D3282)
Plastic limit (%)	20.2	
Linear shrinkage (%)	15.0	
Plasticity Index(%)	30.5	25% Maximum (MoWT 200

LIQUID LIMIT DETERMINATION

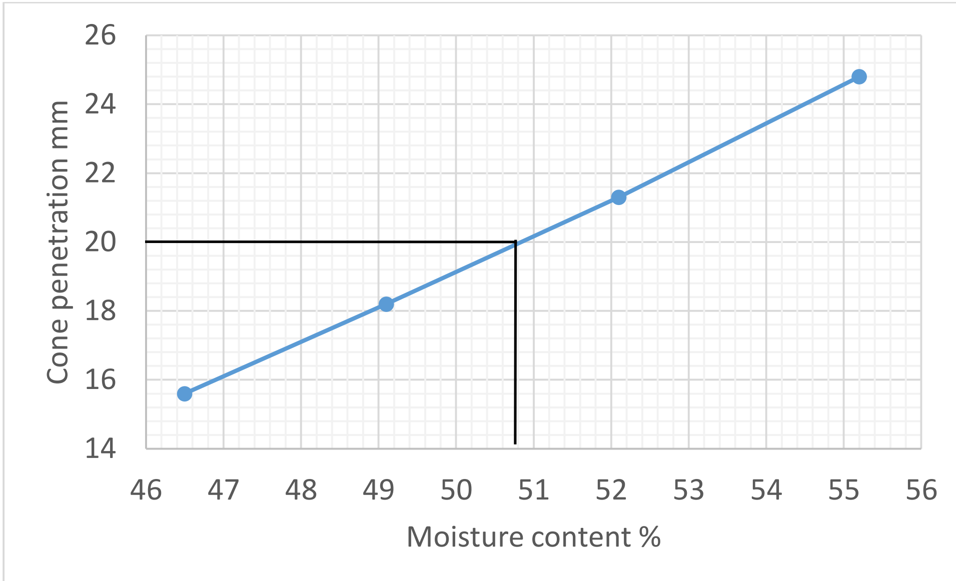


Figure 8: Cone penetration against moisture content.

The liquid limit was determined by carrying out the cone penetration test, and the moisture content at a cone penetration of 20mm. According the graph plotted, the liquid limit was obtained as 50.6%.

Liquid Limit (LL) of 50.6% indicates high plasticity, indicative of potentially problematic behavior under wet conditions. The obtained liquid limit is above the ASTM standards which dictates that for a subgrade, the liquid limit should not exceed 41%, therefore this means the soil has to be stabilized for it to conform to the standards.

A plastic limit (PI) of 30.5%: This was obtained after carrying out lab tests and this is greater than the maximum PI value of 25% as specified by MoWT, 2004, for a G15 upper subgrade layer. This therefore means the soil possesses poor engineering properties and should not be used as a subgrade material unless it has been stabilized. This indicates significant potential for shrinkage and swelling with moisture changes. And with a PI of

30.5%, the soil has low shear strength and does not qualify to be used as a subgrade material.

Using the liquid limit (50.6) and the Plasticity Index (30.5), according to the Plasticity chart for the British Standards Soil Classification. The soil is CH, meaning it's a cohesive soil that exhibits high plasticity. The higher the liquid limit, the higher the compressibility of the soil and the lower the strength of the soil. Hence stabilization is required to attain values that conform to the standards and specifications.

Linear Shrinkage of 15.0%: This further confirms the high plasticity, exceeding the typical limit of 8% for acceptable construction soils. A Linear Shrinkage of 15.0% lies within the marginal chance for cracking due to swelling and shrinking

4.4 COMPACTION TEST

The test was carried out aiming to obtain the optimum moisture content and the maximum dry density of the sampled soil. The Optimum moisture content is the water content that attains the maximum dry density of the soil

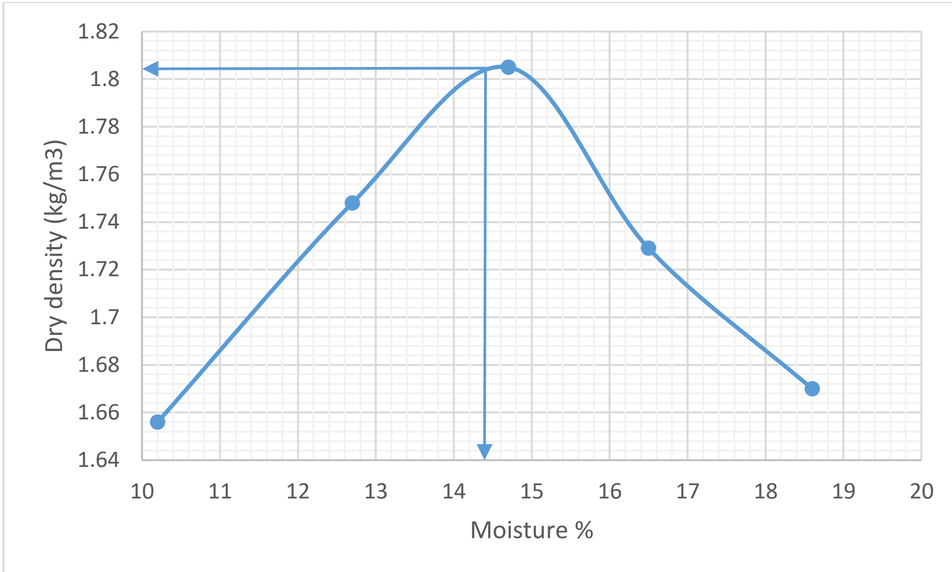


Figure 9: Dry density against moisture content.

From the graph plotted, an optimum moisture content of 14.4% was obtained and its corresponding maximum dry density of 1.807%.

An OMC of 14.4% is attributed to the increase swelling nature of the soil with MDD of 1.807. This implies that since the value of the MDD is small, more water is still present in the soil sample which contributes to swelling and settlement of the natural soil.

4.5 CALIFORNIA BEARING RATIO (CBR)

The CBR is the strength value of soil to be used in the road pavement and for the neat soil sample, it was carried out in accordance with the BS 1377: Part 4: 1990. The soil sample was first soaked for four days and the test was then conducted after. The CBR value for the neat sample was 6%.

This value on comparison with the general requirements for a G15 subgrade material after 4 days of soaking is below the standards of 15% according to MoWT, 2004 and this was brought about by the high percentage of fines in the soil. This calls for improvement of the soil properties through stabilization to meet the standards to be used a G15 subgrade material.

Also according to the Asphalt Institute, the soil is classified as poor since its CBR value lies between 3-7%. This CBR value indicates that the soil possesses a low bearing capacity which therefore makes it incapable of bearing heavy traffic loads.

Table 7: Asphalt Institute (1962)

CBR	**Soil type**
0-3	Very poor
3-7	Poor
7-20	Fair
20-50	Good

Conclusively, for the first objective, which was to obtain the engineering properties of the neat expansive soils, lad tests were carried out and an observation was made that the soil possessed poor engineering properties for a G15 subgrade material, as it had a high plasticity, high liquid limit, and a low bearing capacity. On comparison of the results obtained from the tests, with the general specifications for a G15 subgrade material, we observed that the soil did not conform to the set standards and thus needed to be stabilized before it could be used as a subgrade material.

Stabilization with river sand and sawdust ash can enhance soil strength and bearing capacity.

4.6 CHEMICAL COMPOSITION OF SAWDUST ASH.

The sawdust was burnt in a furnace at controlled temperatures of 500^0C. It was then allowed to cool and a sample was taken to the laboratory to test its chemical compositions using the X-ray florescence test. The elements that were focused on were silicon oxide, calcium oxide and aluminum (III) oxide since they are key elements in formation of a gels (calcium silicate hydrate and calcium aluminate hydrate) which increase the bonding and strength of the soil.

Table 8: Chemical composition of sawdust ash after the XRF test

Chemical composition	Percentage composition
Silicon dioxide	67.87
Calcium oxide	10.47
Aluminum (III) oxide	8.63
Iron (III) oxide	4.54
Manganese (II) oxide	4.53
Potassium oxide	2.80
Phosphorus pent oxide	0.19
Titanium dioxide	0.07

The chemical composition study of sawdust ash, as shown in the table, indicates that sawdust ash is a viable pozzolanic material due to its significant silica (67.87%), calcium oxide (10.47%), and alumina (8.63%) contents. As to the specifications of ASTM C 618-15, materials are classified as pozzolans if the combined proportion of silica, alumina, and ferric oxide above 70%. The total percentage of these components in the context of this investigation is higher than 70%. Sawdust ash is established by this characterisation conformal as a pozzolanic substance, indicating its possible use in stabilizing soil.

The high percentage of silicon dioxide and Calcium oxide in the pozzolan is an indication of a high production of calcium silicate hydrate $(C-S-H)$ and calcium aluminate hydrate $(C-A-H)$ which increase the strength of the weak subgrade soils when mixed with the sawdust ash.

The sawdust ash used as a stabilizer conforms to these requirements, hence it qualifies to be used as a stabilizer of weak subgrade soils as per the ASTM standards.

Table showing types of pozzolans in accordance to ASTM C618

Properties	**Class N type pozzolan**	**Class F type pozzolan**	**Class C type pozzolan**
Min. $SiO_2 + Al_2O_3 + Fe_2O$ (%)	70.0	70.0	50.0
Max. Sulfur trioxide (SO_3) (%)	4.0	5.0	5.0
Max. $Na_2O + 0.658\ K_2O$	1.5	1.5	1.5
Max. loss on ignition	10.0	6.0	6.0

Figure 10: types of pozzolans in accordance to ASTM C618

4.7 PROPERTIES OF RIVER SAND

4.7.1 Grading of the river sand

A particle size distribution test using wet sieving was carried out and the sample was oven dried, and passed through sieves of different sizes.

Table 9: Grading results for the river sand

Maximum sieve size (mm)	Percentage passing (%)	BS 882:1992 Table 4 (%)
10.00	100	100
5	99	89-100
2.36	96	60-100
1.16	78	30-100
0.600	50	15-100
0.300	20	5-70
0.150	5	0-15

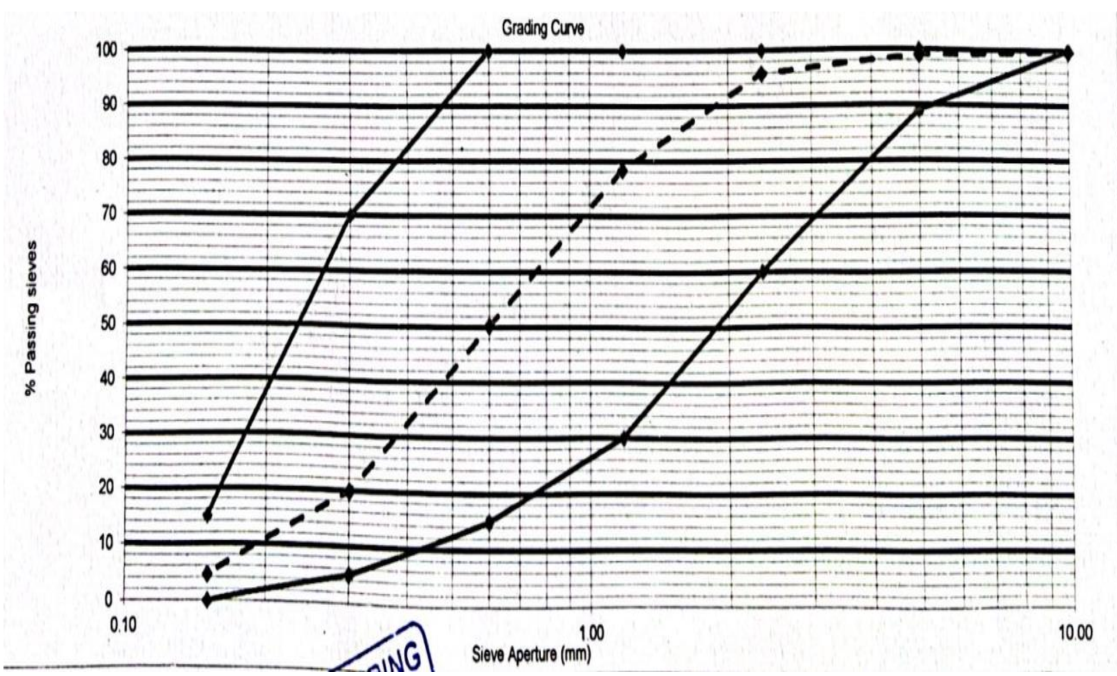


Figure 11: Percentage of sand passing against sieve sizes.

The sand is classified to be well graded since its grading curve lies between the grading envelope. This therefore means that it can be used as a stabilizer of weak subgrade soil and help improve the atterberg limits of the weak soils.

The coefficient of uniformity, C_u and coefficient of curvature, C_c were also calculated as shown below:

Where, D_{60} = grain diameter at 60% passing

D_{30} = grain diameter at 30% passing

D_{10} = grain diameter at 10% passing

$$Coefficient\ of\ uniformity,\ C_U = \frac{D_{60}}{D_{10}} = \frac{0.79}{0.16} = 5$$

$$Coefficient\ of\ curvature,\ C_C = \frac{D_{30}^2}{D_{10} \times D_{60}} = \frac{0.38^2}{0.19 \times 0.75} = 1.01$$

Accordingly, sands are well graded if the C_c is between 1 and 3.

Table 10: Other engineering properties of the river sand.

Property	Value obtained	Standard
Specific gravity	2.798	ASTM C128, required is between 2.4 and 3
Silt content	2.55	ASTM C33-86, required is less than 8%
Water absorption	2.4	ASTM T 255, required is between 0.2 to 4%

This therefore concludes that the river sand to be used in this research conforms to all the standards and specification.

4.8 CHEMICAL PROPERTIES OF THE NEAT SOILS

XRF test for neat soil

An X-ray florescence (XRF) test also carried out for the neat soils to determine its composition and the results also indicate high amounts of silica, alumina and calcium oxide and therefore the soil contains high amounts of clay in it.

The high atterberg limits of the, high plasticity index which is 30.5% which is above the required which is supposed to be 25% and the high liquid limit that is 50.6% which is also above the required also confirmed the expansive nature of the soil.

Table 11: Chemical composition of saw dust ash

Chemical composition	Percentage composition
Silicon dioxide	41.50
Calcium oxide	19.85
Manganese (II) oxide	15.45
Aluminum (III) oxide	10.9
Iron (III) oxide	8.78
Potassium oxide	1.25
Phosphorus pent oxide	1.05
Titanium dioxide	0.02

The soil swell also indicates that it has the ability to take in water and retain it for a long time and thereby increasing in volume. Also, according to literature, montmorillonite clay has about 49.40% silica, 19.70% alumina and 1.50% calcium oxide which were the major components of the soil (Alfard, 2019). The soil was therefore containing clayey soils and is therefore expansive in nature.

4.8 Effect of river sand and saw dust ash on the atterberg limits of the soil.

Table 12: Atterberg limit values for varying percentages of river sand and saw dust ash

Percentage variations	**LL (%)**	**PI (%)**	**LS (%)**
0% river sand and 12% saw dust ash	26.5	9.1	9.1
15% river sand and 9% saw dust ash	24.8	7.0	7
30% river sand and 6% saw dust ash	24.2	6.4	6.45
45% river sand and 3% saw dust ash	23.3	5.3	5.25
60% river sand and 0% saw dust ash	22.8	Non-Plastic	Non-Plastic

The above table indicated the results of the Atterberg limit values when different percentages of saw dust ash and river sand are added to the neat sample.

Effect of river sand and saw dust ash on the liquid limit of the soil.

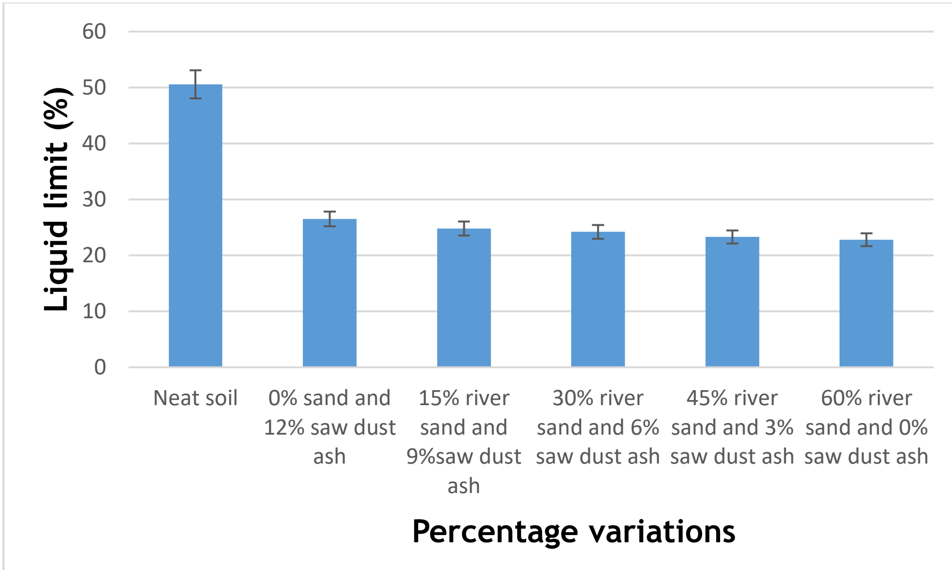


Figure 12: A graph of liquid limit against percentage variations

The graph shows the variation of the liquid limit with increasing percentages of river sand and decreasing percentages of saw dust ash. There was an evident decrease in liquid limit values from 50.6% to 22.8%. This decrease was attributed to the reduced water exhibited by the samples when mixed with the stabilizer since the sample contains more river sand which is non plastic in nature and less saw dust ash is added to the soil and therefore resulting in diminished liquid limit and soil plasticity. As a result, the notable reduction in the liquid limit implies a significant reduction of the compressibility and swelling tendencies of the stabilized soil.

Effect of river sand and saw dust ash on the plasticity index of the soil.

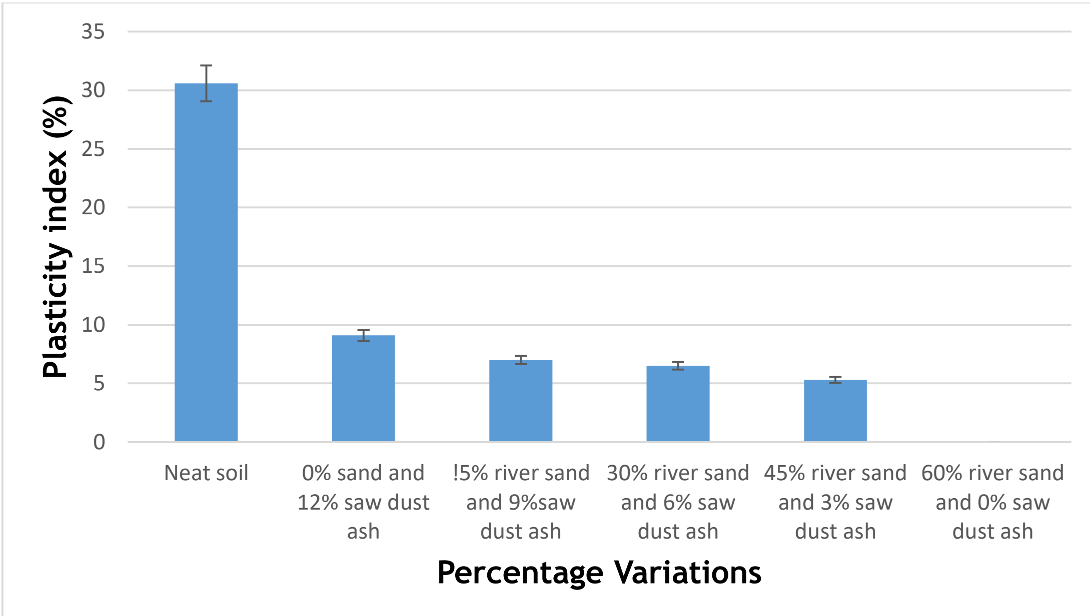


Figure 13: A graph of plasticity index against percentage variations

Similarly, the plastic index that is another significant index property of the weak subgrade soils decreased with increase in amount of river sand and decreasing amounts of saw dust ash. The initial plastic index of the soil in its natural state was 30.5%. With addition of river sand and saw dust ash, the resulting plastic index value reduced to 5.3%. This was attributed to the non-plastic nature of the sand. As more river sand was added in the sample, it became harder for the sample to be rolled into the threads of 3mm diameter as the test was carried. However, with 60% river sand and 0% saw dust ash, the sample could not be rolled and therefore it became non-plastic at that point.

Effect of river sand and saw dust ash on the linear shrinkage of the soil.

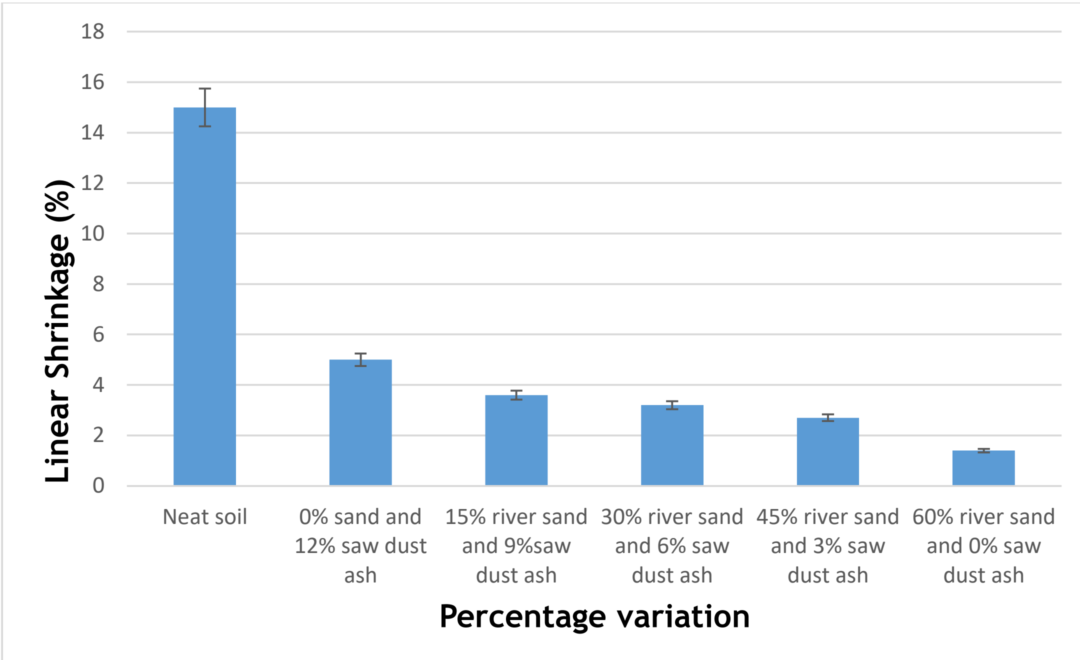


Figure 14: A graph of linear shrinkage against percentage variation

From the of the graph, there is a decreasing trend in the Linear Shrinkage value from 15.0% to 1.3% with increase in the river sand added to the soil. This is attributed to the addition of a mechanical stabilizer (river sand) which is granular in nature. When added to the expansive soil which mainly comprise of the fines, the fines fill the voids. This leads to a reduction in the water intake since there are less fines which can hold the water and therefore it is noted that as more sand is added to the soil, there is less shrinkage in the sample.

4.9 Effect of river sand and saw dust ash on proctor values of the soil

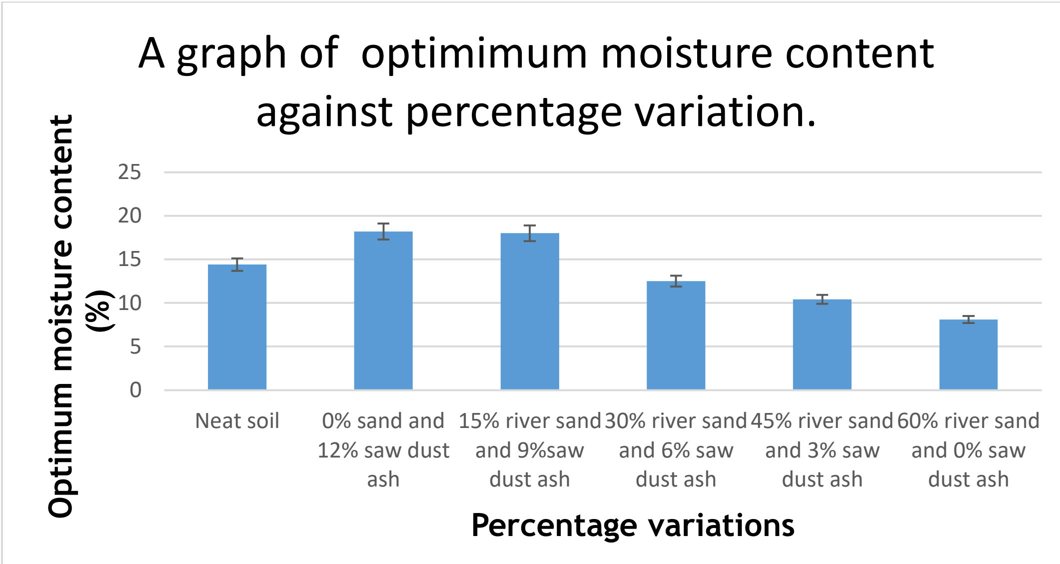


Figure 15: A graph of OMC against percentage variations

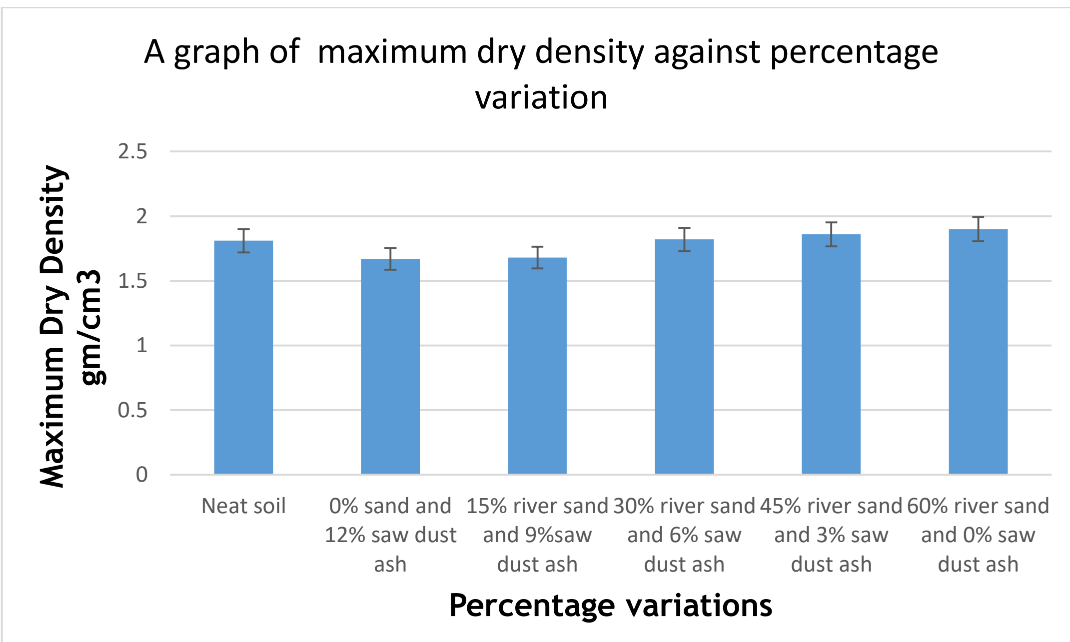


Figure 16: A graph of MDD against percentage variations

The combined effect of river sand and saw dust ash on maximum dry density and optimum moisture content of the weak soils is shown by the graph above respectively. From the trend of the graphs, the maximum dry density kept on increasing with increase in river sand and reduction in sawdust ash while the optimum moisture content of the gradually decreased. The MDD of the soil increased from 1.667g/cm^3 to 1.898g/cm^3 because increasing the percentages of river sand increased the coarse fraction of the soil and therefore improving the size distribution and gradation of the soil. The particles of the river sand are angular shaped interlocking with the soil particles which comprise of the fines. These fines fill the voids and hence lead to formation of a densely packed soil sample forming a material of high density. Additionally, the reduction in the soil's OMC was attributed to the saw dust's capacity to lower porosity and fill the voids in the soil.

4.10 Effect of river sand and saw dust ash strength characteristics of the soil

Effect of river sand and saw dust ash on the CBR of the soil.

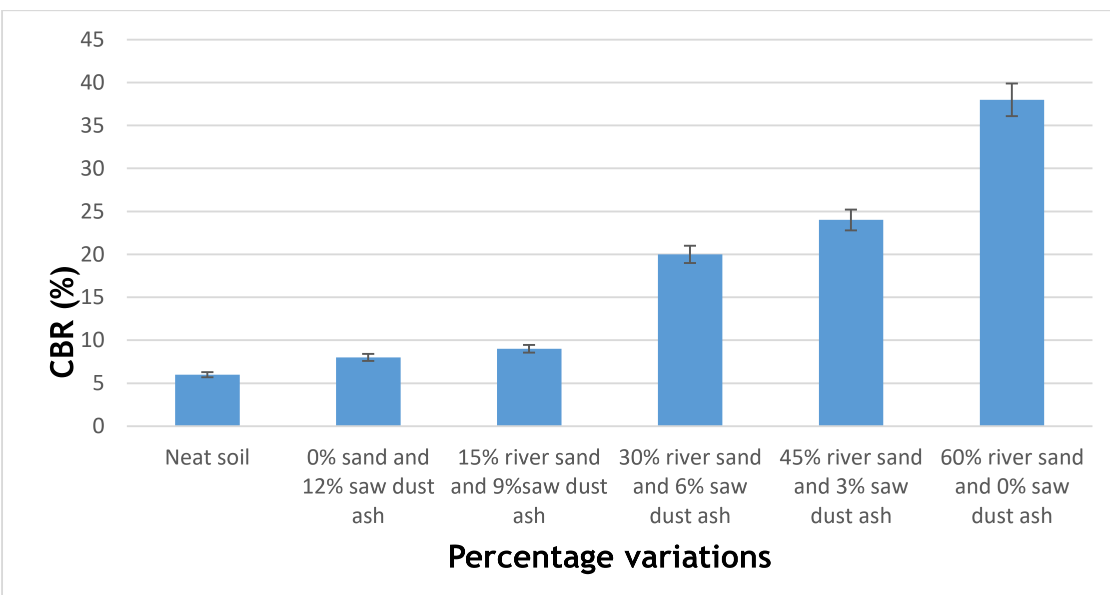


Figure 17: A graph of CBR against percentage variations

There is a noticeable increase in the CBR values from 8% to 38% for the stabilized soil with varying percentages of river sand and saw dust ash. This increase was directly associated to the pozzolanic reactions brought about by addition on saw dust ash where the calcium oxide from the saw dust ash reacts in the presence of water with the silicates and aluminates in the soil and saw dust ash to form cementitious materials which is in form of a gel like calcium silicate hydrate and calcium aluminate hydrate that increase the binding the particles together. Progressive increase in river sand dosage apparently enhances the strength qualities of the weak subgrade soil by improving the gradation of the soil hence reducing percentage fines and this river sand is bonded to the soil particles strongly. However, beyond a certain point, adding more river sand and sawdust ash reduces the strength due to excess particles and the production of excess silica, which raises the porosity of the expanding soils.

Effect of river sand and saw dust ash on the Unconfined Compressive Strength of the soil.

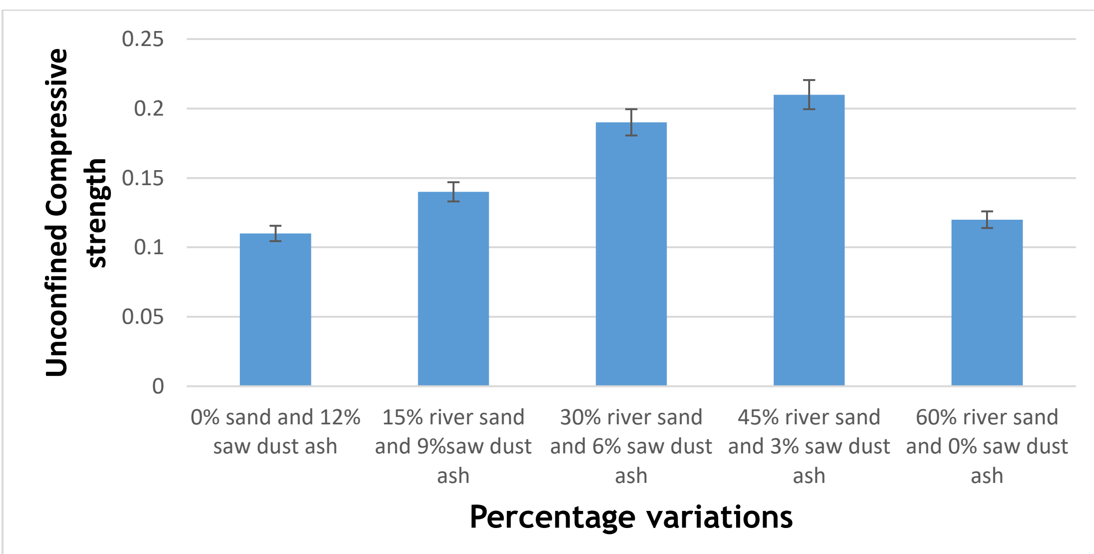


Figure 18: A graph of Unconfined compressive strength against percentage variations

From the trend of the graph, the unconfined compressive strength of the soil increases with increase in river sand and saw dust ash and is seen to later drop. The maximum UCS value recorded was attained at 45% river sand and 3% saw dust ash. The following rise in the UCS is explained by the addition of river sand to improve gradation and the formation of cementitious compounds between the pozzolans in sawdust ash and the calcium oxide in the soil. The excess river sand in the soil, which creates weak bonds between the soil and the cementitious compounds generated causing the decline in UCS values observed with the addition of 60% river sand and 0% sawdust ash.

4.11 DESIGN MATRIX

Table 13: Design matrix

Soil	River sand	Saw dust ash	LL	PL	PI	LS	MDD	OMC	CBR	CBR swell	UCS	
100	0	0	50.6	20.1	30.5	15	1.807	14.4	6	1	-	
88	0	12	26.5	17.4	9.1	5	1.667	18.2	8	0.65	0.11	
76	15	9	24.8	17.7	7.0	3.6	1.682	18	9	0.6	0.14	
64	30	6	24.2	17.8	6.45	3.2	1.819	12.5	20	0.33	0.19	
52	**45**	**3**	**23.3**	**18**	**5.3**	**2.7**	**1.857**	**10.4**	**24**	**0.46**	**0.21**	**Optimum**
40	60	0	23.0	NON-PLASTIC		1.4	1.898	8.1	38	0.16	**0.12**	

Analysis of results for the optimum mix of river sand and saw dust ash added to the soil.

The optimum mix attained was 45% river sand and 3% saw dust ash which gave the best engineering properties of the soil. The river sand added to the soil, improved on the gradation of the soil since it has angular shaped particles that interlock with the weak soils. The saw dust ash acts as a chemical stabilizer to improve on the bonding of the soil. s

Table 14: Values obtained after using the optimum percentages compared with the Standards

Soil properties	Value obtained	Standard/Requirements
Liquid limit	23.3	<41
Plastic index	18	<25
Shrinkage limit	1.4	<8%
CBR	24%	<15%

From the results obtained, the Atterberg limits reduces and they therefore do not take in a lot of water making the swell potential reduce. Therefore, the stabilized soil with 45% river sand and 3% saw dust ash is an optimum mix design to use since it gives the values that fit within the standard to be used as a G15 subgrade material.

Particle size distribution of the optimum soil sample attained.

For 45% river sand and 3% saw dust ash.

Table 15: Grading results for the stabilized soil with the optimum percentages

Sieve size	63	37.5	20	5	2	0.425	0.075
Percentage passing	100	100	100	98.8	96.8	76.3	26.4

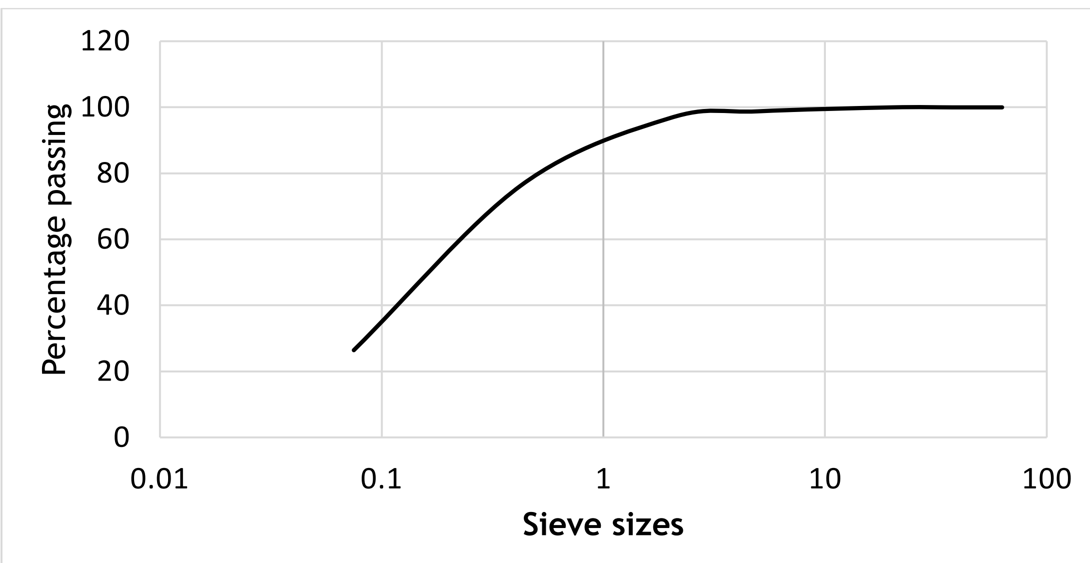


Fig 7: Grading curve of the stabilized soil with the optimum percentages

From the grading curve, the sample comprises of 26.4% fines and 73.6% coarse grained particles, hence resulting in a coarse-grained soil as evidenced by more particles in the coarse fraction being present in the soil sample. The large percentage of coarse particles in the soil are a reason for the reduction in the swell properties of the stabilized soil sample since the samples are no longer sensitive to water and are more cohesionless. Also, the distribution of these particles in the soil indicates a lot about the strength properties of the soil.

From the graph, it can be observed that the particles occupy a wide distribution range, between 0.075mm and 10mm and hence the soil is well graded.

Grading modulus

The soil's grading modulus was determined to be 1.006. The grading modulus shows whether the particles are uniformly distributed or not. With the addition of saw dust ash and river sand as stabilizers, the GM is seen to increase from 0.678 to 1.006 and this is because with the addition of more granular particles, there is an increase in the percentage retained on the last sieves that is 2mm, 0.425mm and 0.075mm sieve sizes. A high GM indicates presence of more particles in the coarse fraction. Also, the GM meets the requirements as per Ministry of Works and Transport General Specifications which require that a subgrade material must have a minimum of 1.

Atterberg limit results.

There was an improvement in the atterberg limits as the liquid limit of the soil sample that was stabilized with 45% river sand and 3% saw dust ash was obtained as 23.3 after carrying out the cone penetration test showing an improvement in the soil properties. The plastic limit was obtained as 17.8% which gives a plasticity index of 5.5% which all conform to the standards and requirements.

Classifying the soil using AASHTO

The stabilized soils from the study are classified as a coarse-grained soil according to the AASHTO soil classification for highways (1967) since it contains less than 35% passing the 0.075mm sieve and therefore it comprising of mainly large particles. The stabilized soil sample is an excellent to good clayey gravel and sand which falls under the category of A-2-6. It can therefore be used as a good subgrade material. Subgroup A-2-6 includes those materials with low plasticity indexes and are do not undergo high volume changes hence have a high bearing capacity.

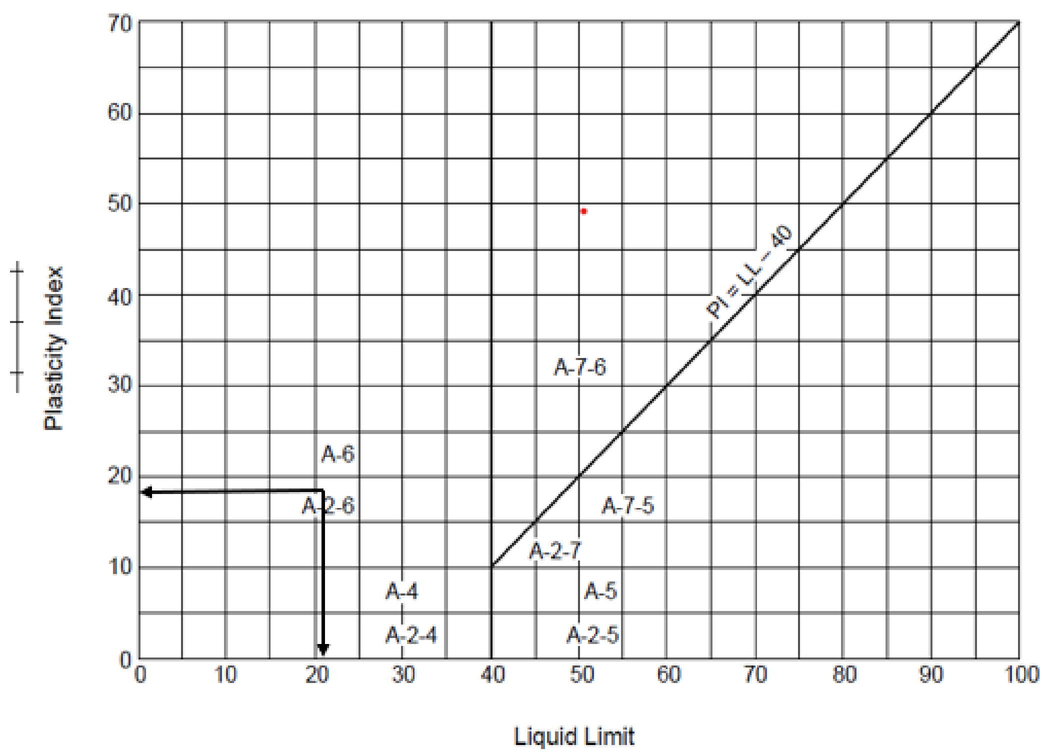


Figure 19: AASHTO classification chart

Classifying the soil using USCS

Having classified the soil using USCS with less than 50% passing sieve No. 200, the soil sample is classed as CL soils which are inorganic clays with low plasticity of 5.5%

USCS soil classification system chart

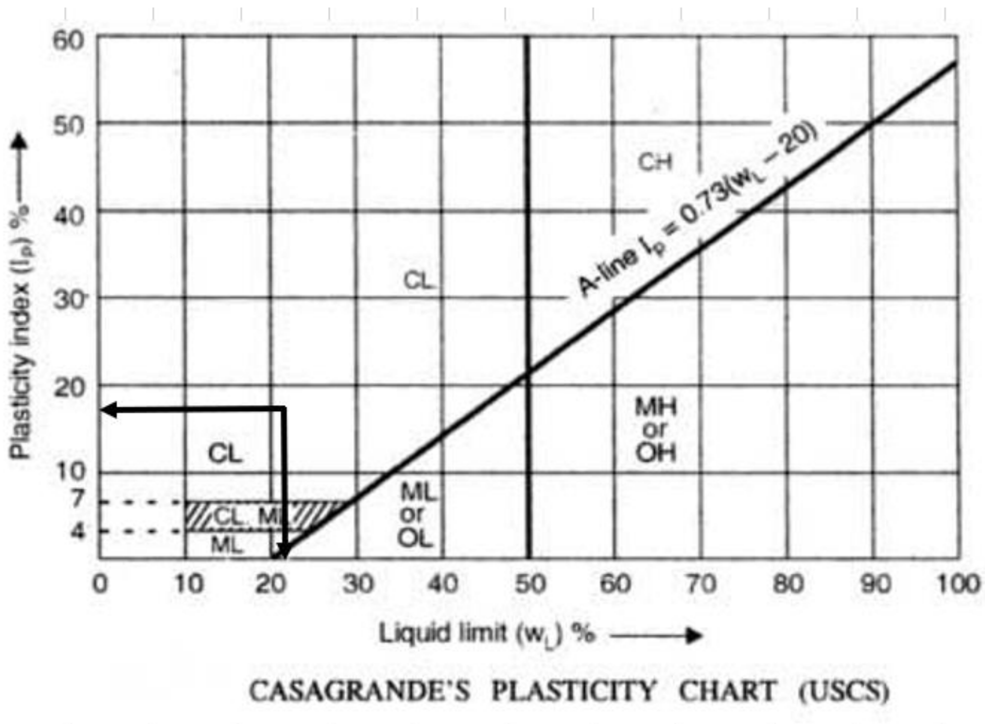


Fig 20: Casagrande's plasticity chart

For clayey materials, determination of GI is important to identify the change or the improvement that has occurred after the stabilization of the soil sample. From the equation below, the GI was obtained where F is the percentage fines that pass sieve No. 200

$$GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

$$GI = (23.7 - 35)[0.2 + 0.005(23.3 - 40)] + 0.01(23.7 - 15)(5.2 - 10)$$

$$GI = 3$$

However, according to the standards, the group index of the soil standards indicates the soil type as the follows to be used as a subgrade material.

Table 16: Comparison of the type of subgrade soils and Grading Index

Type of subgrade soil	Group index
Good	0-1
Fair	2-4
Poor	5-9
Very poor	10-20

Since the $GI = 3$ therefore the soil is fair and can therefore be used as a subgrade material since it meets the requirements for construction of a subgrade layer on the road according to the Ministry of Works, Housing and Communication, General Specifications for National Roads of 2004.

A CBR value of 24% of the stabilized soil with 45% river sand and 3% saw dust ash was obtained which qualifies to be a G15 materials which can be used as subgrade materials in road construction.

4.12 Shear strength test on the optimum mix.

The test was conducted to determine the effective shear strength parameters of the optimum mixture of the soil and the stabilizers, ie cohesion, and angle of internal friction. The shear strength parameters are used in determining the bearing capacity of the soils and stability of the slope.

Table 17: Shear strength parameters

Bulk density	**Normal Stress**	**Shear strength**	**Cohesion**	**Angle of internal friction**
Mg/m^3	kPa	kPa	kPa	9(Degrees)
1.960	50.0	38.0	2.0	36.6
	100.0	78.0		
	200.0	150.0		

The value obtained was attributed to the fact that during the increase in river sand and saw dust ash, the materials bridged the gaps between the soil particles, leading to an increase in the number of the interlocking points of the soil particles. The bridging effect reduced the movement of the soil particles thus increasing soil stability and shear strength. Furthermore, the matrix formed in the soil reduced the pore size, thereby decreasing the void ratio of the soil and increasing its maximum density.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

CONCLUSION

Upon testing, the neat soil didn't conform to the requirements for G15 subgrade material according to the ministry of works general specifications for road and bridge works 2005 and was classified as a clayey soil with a high plasticity and an A-7-6 material according USCS and AASHTO respectively. Its atterberg limits were very high indicating swelling and shrinkage properties and a CBR value was obtained as 6% meaning it was a poor soil therefore they needed to be stabilized so this purpose

The composition of the saw dust ash made it a class C agro-pozzolan according to the ASTM standard since the sum of the percentage of silicon dioxide, Aluminum dioxide and iron (III) oxide was greater than 50% and was fit to be used as a stabilizer. The river sand was well graded and also met the standards to be used as a stabilizer for the weak soils.

With the addition of 45% river sand and 3% saw dust ash, an optimum mix design was achieved, the atterberg limits of the soil decreases, the CBR value improved to 24% which conformed to the standards and the soil achieved its properties for a G15 subgrade material.

RECOMMENDATIONS

In this research, the saw dust ash that was used as a mixture of ash from both the soft and hard wood trees, therefore research should be conducted on the effect of using only soft or hardwood trees so obtain the effect of each on the engineering characteristics of the weak soil.

The obtained optimum percentages of 45% river sand and 3% saw dust ash gives a UCS value of 0.21 MPA after stabilization which is still below the standards, therefore further research should be conducted on how to ensure the optimum percentages give results to a UCS value to meet the required standards.

From the research conducted, since there is an increasing trend in the UCS values of the soil from the mix design used, and at 45% river sand and 3% saw dust ash and all the soil parameters are within the required range except the UCS value, then a range for the amount of river sand and saw dust ash to be added was chosen to be between 45% to 50% river sand and 3% saw dust ash. The UCS value shows the potential to increase to reach the standard which is 0.25 for a G15 subgrade material.

REFERENCES

1.A.R. Estabragh, H. R. A. J., 2014. Treatment of an expansive soil by mechanical and chemical techniques.

A, A., 2017. *International Journal of Engineeing esearch-online 2321-7755.* .

Abdulla sharo, Y. A., 2019. Improving Properties of Expansive Soil Using Cement, Quick Lime and Cement-Lime Blend.. *international review of civil engineering.*

Abubaker Ahmed, J. Y., 2023. Improvement of expansive soil characteristics stabilized with sawdust ash, high calcium fly ash and cement.

Adams, T., 2021. Three Broad Types of Soil Stabilization.

Adamu Beyene, Y. T., 2022. Experimental study on potential suitability of natural lime and waste ceramic dust in modifying properties of highly plastic clay.

Afrin, H., 2017. A Review on Different Types Soil Stabilization Techniques.

Afrin, H., 2017. A Review on Different Types Soil Stabilization Techniques. *International Journal of Transportation Engineering and Technology.*

Ajay Upadhyay, S. K., 2016. REVIEW ON SOIL STABILIZATION USING CERAMIC WASTE.

Akinwumi I, O. O., 2023. Engineering properties of tropical clay and bentonite modified with sawdust.

Ali Akbar Firoozi, C. G. O. A. A. F. &. M. S. B., 2017. Fundamentals of soil stabilization.

Arun, K. U. &. K. B. B., 2014. SUBGRADE STABILIZATION WITH QUARRY DUST-AN INDUSTRIAL WASTE.. *International Journal of Research in Engineering and Technology Vol. 03 Issue: 08, 409-412.* .

Babita singh, R. k., 2014. Evaluation of Geotechnical properties of clayey soil blended with waste materials. *Jordan Journal of civil engineering, volume-8.*

Chen, F. H., 2018. Foundation on expansive soils..

G. Muthumari, R. N. A. J. D. R., 2018. Comparative Study on Stabilization of Expansive Soil using cement kiln dust and ceramic dust..

J. David Rogers, R. O. a. R. B. R., 2018. DAMAGE TO FOUNDATIONS FROM EXPANSIVE SOILS.

K. Adebayo, F. B., n.d. Effect of saw dust ash on index and engineering properties of a weak lateritic soil.

M.N. Rahmat, N. I. M. R., 2015. Strength properties of sustainable palm oil fuel ash (POFA)—stabilized landfill.

M.P. Adari, A. P., n.d. Cation exchange capacity (CEC) and unconfined capacity and unconfined compressive strength (UCS) of soils under the influence of lime and fly ash.

Michael T, S. S. K. A., 2016. Expansive soil stabilization using industrial solid wastes a review. *International Journal of Advanced Technology in Engineering and Science. DOI:*

.

Sabat, A. K., 2018. Stabilization of Expansive Soil Using Waste Ceramic Dust.

Saini R, P. D. S. S., 2018. *International Journal of Advance Research Science and Engineering.*

T. Chompoorat, S. L. S. S. V. K. P. J. P. J., 2019. Mechanical properties and microstructures of stabilised dredged expansive soil from coal mine.

T. Geeta Rani, C. S., 2014. *Strength behavior of expansive soil treated with tile waste.*

Taha, M. M., 2020. Influence of Polypropylene Fibre (PF) Reinforcement on Mechanical Properties of Clay Soil.

Tesfaye, A. B. Y., 2020. Experimental study on potential suitability of natural lime and waste.

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	NAMBOOZE JUSTINE SHILLA (S20B32/214) & MCARNOLD GARRY (S20B32/033)	Stirling

PROJECT: ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILISATION OF WEAK SUBGRADE SOILS

SUMMARY OF TEST RESULTS FOR NEAT MATERIAL AT NEAT SAMPLE

LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS				MDD			CBR		CBR SWELL	
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC				62	AVERAGE
NEAT SAMPLE	EXPANSIVE SOILS	12/10/2023	100	100	100	100	99	91	56	0.53	50.3	19.9	30.4	15.0	1.807	14.4		5.9		1.00	1.00
			100	100	100	99	99	92	57	0.52	50.8	20.2	30.6	15.0	-	-	-	-	-	-	
			100	**100**	**100**	**99.45**	**99.11**	**91.58**	**56.78**	**0.53**	**50.6**	**20.1**	**30.5**	**15.0**	**1.807**	**14.4**		**6**		**1.00**	**1.00**
	AVERAGE		100	100	100	99	99	92	57	0.525	50.6	20.2	30.5	15.0	1.807	14.4		5.9		1.00	1.00

FOR LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
02 F... 2024
P.O. BOX 796, KAMPALA (U)

FOR STUDENTS

Telephone
+256 (0) 414 250 464 (Gen)
+256 (0) 414 250 474
Email: dgal@mia.go.ug
Website: www.mia.go.ug

In any Correspondence on this subject please quote No.......... **GE 038/2024**

FOR GOD AND MY COUNTRY

THE REPUBLIC OF UGANDA

MINISTRY OF INTERNAL AFFAIRS
DIRECTORATE OF GOVERNMENT ANALYTICAL LABORATORY
Plot No. 2 Lourdel Road
Wandegeya,
P.O. BOX 105639
Kampala - Uganda

02nd February 2024

MS. NAMBOOZE JUSTINE SHILLAH AND MR Mc ARNOLD GARRY
REG NO. S20B32/214 & S20B32/033
UGANDA CHRISTIAN UNIVERSITY
P.O BOX 4,
MUKONO-UGANDA
Tel: 256-778-051449

REPORT OF ANALYSIS

Description of the Samples

One sample in a black polythene bag containing saw dust ash sample was submitted by Ms. Nambooze Justine, on 25th January 2024, and analysed on 31st January 2024. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Saw dust Ash sample packed in a black polythene bag.	01	Sample "A" GE 038/2024

Analysis Requested

Elemental analysis

Method of Analysis

Elemental analysis was done using the XRF Method.

Results of Analysis

The above sample has been analyzed with the following results as below,

Parameter	Units	Results Saw dust Ash sample GE 038/2024
Silicon dioxide	% m/m	67.87
Calcium Oxide	% m/m	10.47
Aluminum Oxide	% m/m	8.63
Iron (III) Oxide	% m/m	4.54
Manganese (II)Oxide	% m/m	4.53
Potassium Oxide	% m/m	2.80
Phosphorous pent oxide	% m/m	0.19
Titanium di oxide	% m/m	0.07

Remarks

1. Results relate to sample analyzed and are reported as on received basis.

[signature] 02/02/2024

Semalago Fredrick
Government Analyst

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	NAMBOOZE JUSTINE SHILLA (S20B32/214) & MCARNOLD GARRY (S20B32/033)	Stirling

PROJECT: ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILISATION OF WEAK SUBGRADE SOILS

SUMMARY OF ALL THE TEST RESULTS FOR WEAK SUBGRADE SOILS STABILISED WITH RIVER SAND & SAWDUST

LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS				MDD		UCS	CBR	CBR SWELL
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC		62Blows	62
	NEAT		100	100	100	100	99	91	56	0.53	50.3	19.9	30.4	15.0	1.807	14.4		5.9	1.00
			100	100	100	99	99	92	57	0.52	50.8	20.2	30.6	15.0	-	-		-	-
	EXPANSIVE SOILS STABILISED WITH 0% RIVER SAND & 12% SAWDUST		100	100	100	99	98	90	42	0.693	26.6	17.4	9.2	5.0	1.667	18.2		8	0.65
			100	100	100	99	98	91	41	0.693	26.4	17.4	9.0	5.0	-	-	0.11	-	-
	EXPANSIVE SOILS STABILISED WITH 15% RIVER SAND & 9% SAWDUST		100	100	100	98	97	81	34	0.872	24.5	17.4	7.0	3.6	1.682	18.0		9	0.6
			100	100	100	99	97	82	38	0.826	25.0	18.0	7.0	3.6	-	-	0.14	-	-
0	EXPANSIVE SOILS STABILISED WITH 30% RIVER SAND & 6% SAWDUST	12/9/2023	100.0	100.0	100.0	99.6	98.0	75.0	31.3	0.957	24.2	17.9	6.3	3.2	1.819	12.5		20	0.33
			100.0	100.0	100.0	99.4	97.7	73.8	33.5	0.950	24.2	17.6	6.6	3.2	-	-	0.19	-	-
	EXPANSIVE SOILS STABILISED WITH 45% RIVER SAND & 3% SAWDUST		100.0	100.0	100.0	99.3	96.3	72.3	29.0	1.024	23.3	18.0	5.3	2.7	1.857	10.4		24	0.46
			100.0	100.0	100.0	98.3	97.2	80.3	23.7	0.988	23.3	18.0	5.2	2.7	-	-	0.21	-	-
	EXPANSIVE SOILS STABILISED WITH 60% RIVER SAND ONLY		100.0	100.0	100.0	99.6	96.8	58.8	17.6	1.268	23.0	NON PLASTIC		1.4	1.898	8.1		38	0.16
			100.0	100.0	100.0	99.2	96.4	57.7	11.9	1.339	22.6			1.4	-	-	0.12	-	-

FOR LAB

Lab Technician | Materials Engineer

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

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	NAMBOOZE JUSTINE SHILLA (S20B32/214) & MCARNOLD GARRY (S20B32/033)	Stirling

PROJECT: ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILISATION OF WEAK SUBGRADE SOILS

SUMMARY OF TEST RESULTS FOR NEAT MATERIAL AT WEAK SUBGRADE SOILS STABILISED WITH 0% RIVER SAND & 12'

LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS				MDD		CBR	CBR SWELL	
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC	/	62	AVERAGE
WEAK SUBGRAD			100	100	100	99	98	90	42	0.69	26.6	17.4	9.2	5.0	1.667	18.2	8	0.65	0.65
			100	100	100	99	98	91	41	0.69	26.4	17.4	9.0	5.0	-	-	-	-	
	EXPANSIVE SOILS		**100**	**100**	**100**	**99.12**	**98.21**	**90.67**	**41.8**	**0.69**	**26.5**	**17.4**	**9.1**	**5.0**	**1.667**	**18.2**	**8**	**0.65**	**0.65**
		12/10/2023																	
	AVERAGE		100	100	100	99	98	91	42	0.693	26.5	17.4	9.1	5.0	1.667	18.2	7.7	0.65	0.65

FOR LAB

Lab Technician | Materials Engineer

FOR STUDENTS

STIRLING CIVIL ENGINEERING
P.O. BOX 798, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	NAMBOOZE JUSTINE SHILLA (S20B32/214) & MCARNOLD GARRY (S20B32/033)	Stirling

PROJECT: ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILISATION OF WEAK SUBGRADE SOILS

SUMMARY OF TEST RESULTS FOR WEAK SUBGRADE SOILS STABILISED WITH 15% RIVER SAND & 9

LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS				MDD			CBR		CBR SWELL	
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC				62	AVERAGE
WEAK SUBGRADE SOILS STABILISED WITH 15% RIVER SAND & 9% SAWDUST	WEAK SUBGRADE SOILS	12/10/2023	100	100	100	98	97	81	34	0.87	24.45	17.4	7.0	3.6	1.682	18.0		9.3		0.59	0.59
			100	100	100	99	97	82	38	0.83	25.0	18.0	7.0	3.6	-	-	-	-	-	-	
			100	**100**	**100**	**98.57**	**97.03**	**81.69**	**36.39**	**0.85**	**24.7**	**17.7**	**7.0**	**3.6**	**1.682**	**18.0**		**9**		**0.59**	**0.59**
	AVERAGE		100	100	100	99	97	82	36	0.849	24.7	18.0	7.0	3.6	1.682	18.0		9.3		0.59	0.59

FOR LAB

Lab Technician

Materials Engineer

FOR STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	NAMBOOZE JUSTINE SHILLA (S20B32/214) & MCARNOLD GARRY (S20B32/033)	Stirling

PROJECT: ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILISATION OF WEAK SUBGRADE SOILS

SUMMARY OF TEST RESULTS FOR NEAT MATERIAL AT WEAK SUBGRADE SOILS STABILISED WITH 30% RIVER SAND & 6

LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS				MDD			CBR		CBR SWELL	
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC				62	AVERAGE
WEAK SUBGRAD	WEAK SUBGRADE	12/10/2023	100	100	100	100	98	75	31	0.96	24.2	17.9	6.3	3.2	1.819	12.5		19.8		0.33	0.33
			100	100	100	99	98	74	34	0.95	24.2	17.6	6.6	3.2	-	-	-	-	-	-	
			100	**100**	**100**	**99.51**	**97.85**	**74.39**	**32.43**	**0.95**	**24.2**	**17.7**	**6.5**	**3.2**	**1.819**	**12.5**		**20**		**0.33**	**0.33**
	AVERAGE		100	100	100	100	98	74	32	0.953	24.2	17.6	6.5	3.2	1.819	12.5		19.8		0.33	0.33

FOR LAB

Lab Technician

Materials Engineer

FOR STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	NAMBOOZE JUSTINE SHILLA (S20B32/214) & MCARNOLD GARRY (S20B32/033)	Stirling

PROJECT: ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILISATION OF WEAK SUBGRADE SOILS

SUMMARY OF TEST RESULTS FOR WEAK SUBGRADE STABILISED WITH 45% RIVER SAND & 3% SAW

LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS				MDD			CBR		CBR SWELL	
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC				62	AVERAGE
WEAK SUBGRADE STABILISED WITH 45% RIVER SAND & 3% SAWDUST	WEAK SUBGRADE SOILS	12/10/2023	100	100	100	99	96	72	29	1.02	23.3	18.0	5.3	2.7	1.857	10.4		23.7		0.46	0.46
			100	100	100	98	97	80	24	0.99	23.3	18.0	5.2	2.7	- -	-	-	-	-	-	
			100	100	100	98.83	96.75	76.32	26.34	1.01	23.3	18.0	5.2	2.7	1.857	10.4		24		0.46	0.46
																				/	
	AVERAGE		100	100	100	99	97	76	26	1.006	23.3	18.0	5.2	2.7	1.857	10.4		23.7		0.46	0.46

FOR LAB

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

Lab Technician

Materials Engineer

FOR STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	NAMBOOZE JUSTINE SHILLA (S20B32/214) & MCARNOLD GARRY (S20B32/033)	Stirling

PROJECT: ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILISATION OF WEAK SUBGRADE SOILS

SUMMARY OF TEST RESULTS FOR WEAK SUBGRADE SOILS STABILISED WITH 60% RIVER SAND ON

LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS				MDD			CBR		CBR SWELL	
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC				62	AVERAGE
WEAK SUBGRAD	WEAK SUBGRADE	12/10/2023	100	100	100	100	97	59	18	1.27	23	NON PLASTIC		1.4	1.898	8.1		37.8		0.16	0.16
			100	100	100	99	96	58	12	1.34	22.6	NON PLASTIC		1.4	-	-	-	-	-	-	
			100	100	100	99.44	96.63	58.27	14.78	1.30	22.8	NON PLASTIC		1.4	1.898	8.1		38		0.16	0.16
	AVERAGE		100	100	100	99	97	58	15	1.303	22.8	NON PLASTIC	0.0	1.4	1.898	8.1		37.8		0.16	0.16

FOR LAB

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

Lab Technician

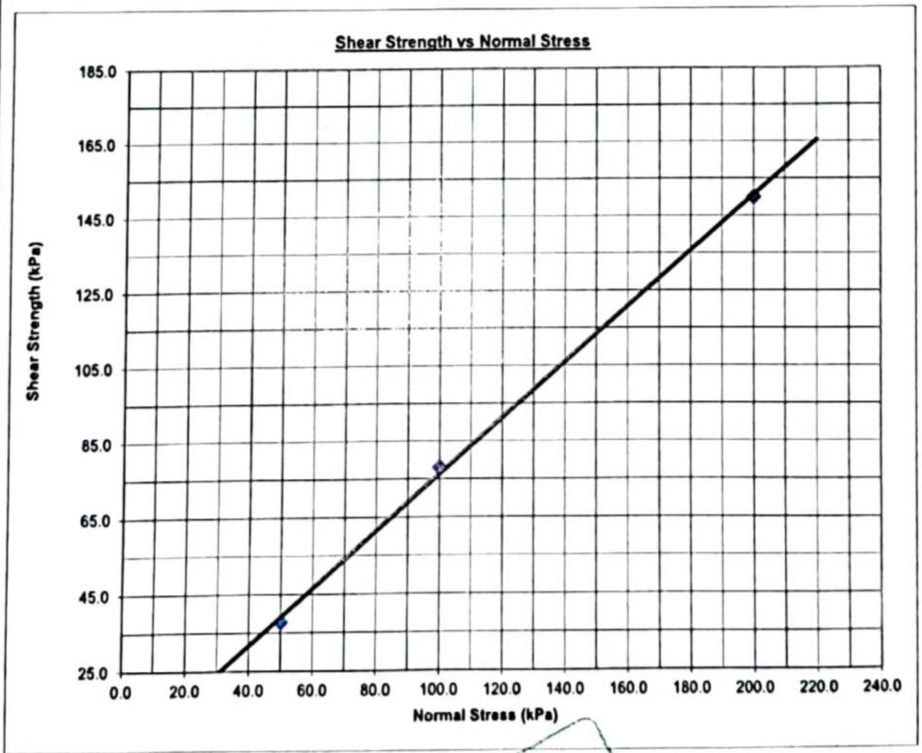
Materials Engineer

FOR STUDENTS

GETLAB LTD
YOUR RELIABLE ENGINEERING LABORATORY

DIRECT SHEAR BOX TEST OF SOILS (BS EN ISO 178922-9:2017)				
TITLE:	ASSESSING THE USE OF RIVER SAND AND SAW DUST ASH IN THE STABILIZATION OF WEAK SUBGRADE SOILS	Task:	Final Year project	
University:	Uganda CHRISTIAN UNIVERSITY	Students Details	NAMBOOZE JUSTINE SHILLA S20B32/214	MCARNOLD GARRY S20B32/033
Sample Source:	Busunju			
Sample Type:	sandy CLAYS for subgrade layer modified with 45% River sand and 3% saw dust ash	Depth (m):	1.0 -1.5	
Date Tested:	27-Mar-24			
Material Type:	Moulded Sample.			

Bulk Density	Normal Stress	Shear Strength	Cohesion	Angle of Internal Friction
γ_b	δ_n	τ_s	C	ϕ
Mg/m^3	kPa	kPa	kPa	(Degree)
1.960	50.0	38.0	2.0	36.6
	100.0	78.0		
	200.0	150.0		



Tested by:

NAMBOOZE JUSTINE SHILLA & MCARNOLD GARRY

Approved by:

Sen. Laboratory Engineer (O.T)

GETLAB LTD 28 MAR 2024 Geotechnical Engineering & Technology Laboratory Ltd P. O. Box 100001, Kasangati