INVESTIGATION INTO THE COLLAPSE POTENTIAL OF SUBBASE MATERIAL IN THE TROPICS REGION

CASE STUDY: THE GREATER KAMPALA METROPOLITAN AREA

BY

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A THESIS/DISSERTATION SUBMITTED TO KYAMBOGO UNIVERSITY DIRECTORATE OF RESEARCH AND GRADUATE TRAINING IN PARTIAL FULFILMENT FOR THE DEGREE OF MASTERS OF SCIENCE IN STRUCTURAL ENGINEERING OF KYAMBOGO UNIVERSITY

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for submission to the Directorate of Research and Graduate Training of Kyambogo University, a research dissertation entitled: **"Investigation into the collapse potential of subbase material in the Tropics region (A case study of the Greater Kampala Metropolitan Area)",** in fulfillment of the requirements for the award of Master of Science in Structural Engineering Degree of Kyambogo University.

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DECLARATION

I, Mbwali Mary Christine, hereby declare that this submission is my work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material that has been accepted for the award of any other degree of the university or other institute of higher learning, except where due acknowledgment has been made in the text and reference list.

Signature: ………………………………………………….

Date: ……………………………………………………….

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DEDICATION

I dedicate this thesis to my parents for their endless support, affection, and encouragement throughout my educational journey. I fervently hope that this accomplishment will serve as a realization of their aspirations for my academic and personal growth.

ABSTRACT

Road construction in tropical regions such as the Greater Kampala Metropolitan Area (GKMA) faces persistent challenges from hydro-consolidation, which can weaken subbase layers and compromise pavement durability. This study aimed to evaluate the collapse potential of subbase materials in the GKMA and recommend measures to enhance their performance for sustainable road infrastructure. Representative samples were subjected to physical-mechanical tests [Maximum Dry Density (MDD), California Bearing Ratio (CBR), Atterberg limits and Particle Size Distribution (PSD)], chemical analysis (chloride, sulphate, and pH content) and conventional oedometer testing under wetting conditions to determine hydro-consolidation behavior. The oedometer test results showed that subbase soils at Natural Moisture Content (NMC) exhibited medium to high collapse potential, exceeding 3% under higher applied stresses, indicating susceptibility to hydro-consolidation when saturated under load. However, samples compacted at Optimum Moisture Content (OMC) displayed collapse potentials below 2%, demonstrating that proper compaction significantly reduces collapse risk. These results confirm that collapse potential is stress-dependent and highlight the importance of achieving optimum moisture content during construction to enhance subbase stability. Based on the findings, the study recommends further evaluation of subbase materials under higher applied stresses to better simulate traffic conditions, expanding investigations beyond the GKMA to capture broader geological variability, and examining other road failure mechanisms such as drainage efficiency and construction practices. Overall, this research provides a practical evidence base on hydro-consolidation behavior of subbase materials, enabling engineers and policymakers in Uganda to design, construct, and maintain pavements that are durable, resilient, and cost-effective in tropical environments.

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LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing Materials
BS	British Standards
BSCS	British Standard Classification System
CBR	California Bearing Ratio
CHG	Clay of High Plasticity
DOT	Double Oedometer Test
g/L	grams per litre
GK	Gayaza-Kalagi
GKMA	Greater Kampala Metropolitan Area
GM	Grading Modulus
IRI	International Roughness Index
KMN	Kampala-Mukono-Njeru
LL	Liquid Limit
MDD	Maximum Dry Density
mg/kg	milligrams per kilogram
MoWT	Ministry of Works and Transport
UNRA	National Roads Authority
NMC	Natural Moisture Content
OMC	Optimum Moisture Content
PSD	Particle Size Distribution
ROI	Returns on Investment

SSB	Silver Springs-Bweyogerere
USA	United States of America

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Transport, a means of moving people and goods, serves as the foundation of both domestic and global trade (Khayesi and Nafukho, 2016), Therefore, the expansion and maintenance of transport networks and the expansion of the economy complement each other (Duval, 2007). Transport is an all-prevailing industry that facilitates all phases of production and distribution of goods (Gassner, Lederer and Fellner, 2020). Efficient transportation systems yield favorable economic and social outcomes, creating a ripple effect that expands benefits, including enhanced market accessibility, increased employment opportunities, tourism and additional investments (Blanquart and Koning, 2017).The development of transportation systems leads to improved personal mobility, decreased travel time and expanded choices for individuals in terms of where to reside, work and shop (Ogryzek *et al.*, 2020)

Furthermore, transportation improvements contribute to the reduction of production and distribution costs for goods, consequently promoting national economic growth (Banister and Berechman, 2001). A well-rounded transportation system, encompassing a robust network of roadways, railways, waterways and airways, is essential to achieve these benefits (Flick, 2018). Road transport system has become an increasingly dominant mode of movement and one of the most important modes of transport with many desirable characteristics such as flexibility, door-to-door services and greater accessibility to remote areas (Kadiyali, 2013). However, many of these countries are still grappling with road failure tendencies some of whose causes remain uncertain. Road failure occurs when the road layers no longer hold their original shape and develop material stress (Canestrari and Ingrassia, 2020) which leads to failure issues.

The road network in Uganda, specifically in the Greater Kampala Metropolitan Area (GKMA), is affected by several road failures, of which one cannot be sure of their actual causes. Some of the known causes of road failure are: inadequate preliminary geological investigation, poor design of roads, poor materials, bad supervision and workmanship, lack of routine and periodic maintenance, harsh weather conditions, poor site locations, improper use and overloading and inadequate sanction for highway failure (Afolayan and Abidoye, 2017). These road failures include: potholes, cracks, rutting, depressions, raveling, upheavals, subsidence, shoving, edge damage and many more (Kwikiriza, 2016). In the case of potholes, patching has been done to repair the failed areas, but they often reappear shortly thereafter (Ghosh *et al.*, 2018).

Other studies have attributed the causes of failure to poor/inappropriate choice of materials used during road construction, particluarly sub-base materials, water intrusion, stress from heavy vehicles, seasonal expansion and contraction, sun exposure, insufficient strength of bituminous mixes, overloading, poor drainage and natural disaster (Imran *et al.*, 2015).

Proper maintenance is essential to prevent failed areas from spreading or increasing (Adams *et al.*, 2014). In absence of timely maintenance, failed areas gradually enlarge, leading to traffic congestion, increased accidents, higher vehicle operating costs and discomfort to the road users (Zimmerman and Peshkin, 2004).

Economic activities such as resource management, production, distribution and consumption of goods and services predominantly occur in the GKMA. Produce from smaller towns finds a market in the GKMA; however, the poor road networks along these corridors hinders to traffic movements, resulting in higher vehicle operating costs, increased travel time and more accidents (Olagunju, 2015).

Much research has focused on testing the quality of the road construction materials through laboratory experiments such as the California Bearing Ratio (CBR), Maximum Dry Density (MDD), Atterberg limits and Particle Size Distribution (PSD), (stabilized and un-stabilized) with some studies focusing on subgrade materials. However, less attention is paid to the collapsible potential of the soils used in the road structures, particularly subbase materials. For example, Houston, Houston and Spadola (1988) and Houston *et al.* (2002) discussed problems caused collapsible soil on highways in the United States of America (USA); Soliman and Hanna (2010) examined the performance of reinforced collapsible soil; Livneh and Livneh (2012) focused their study on collapse-settlement of heterogeneous soil subgrade; Gaaver (2012) researched on the geotechnical properties of Egyptian collapsible soils; Noor *et al.* (2013) investigated the behavior of a numerical models of piles in collapsible soil subjected to inundation; Ali (2015) studied the performance of partially replaced collapsible soil; Hanna and Soliman (2017) experimentally investigated a foundation on collapsible soils, Ayeldeen *et al.* (2017) looked at the possibility of using xanthum gum and guar gum biopolymers to enhance mechanical behaviors of collapsible soil; Singh (2018) analyzed concrete pavements laid on stabilized collapsible soils, Cameron and Nuntasarn (2006) did, however, discuss the pavement engineering parameters of Thai collapsible soil that was used for road subbase; all these to mention but a few.

Day (2001) defined collapsible soils as soils that experience significant and sudden volume reduction upon exposure to moisture. This collapsing process is referred to as hydro-collapse, hydro-consolidation, or hydro-compression (Huat *et al.*, 2008). These soils may consist of unconsolidated or cemented materials and are often naturally dry (Kalantari, 2013). Collapse behavior can also occur in fill material due to reduced negative pore water pressure (suction), upon wetting (Jotisankasa, 2005). A decrease in dry density followed by an increased vertical pressure may increase the collapse potential. (Mansour *et al.*, 2008). Collapsible soils can resist substantial vertical pressure under small compression, but upon wetting, even without additional vertical load, larger settlement is observed (Houston and Houston, 1997).

While previous studies have assessed the quality of road construction materials and subgrade soils, limited attention has been given to the collapse potential of subbase materials, particularly under hydro-consolidation conditions. This gap is significant because subbase failures can critically affect pavement performance, especially in tropical climates such as the GKMA. Therefore, this study systematically investigates the hydro-consolidation behavior of locally sourced subbase materials to provide reliable data for sustainable pavement design and construction.

In line with this, the study specifically aims to determine whether the observed road failures in the GKMA result from hydro-consolidation occurring within the construction layers.

1.2 Problem Statement

Several road networks in the GKMA continue to experience premature failure, with potholes being the most widespread defect. Uganda National Roads Authority (UNRA, 2021) reported that nearly 60% of urban roads in Kampala exhibit moderate to severe distress, with potholes accounting for over 40% of maintenance interventions. This deterioration is strongly linked to moisture ingress into pavement layers, which compromises structural strength. Although tests such as soaked CBR are commonly used to evaluate materials under wet conditions, failures remain frequent along sections exposed to continuous cycles of wetting and drying. These cycles are often triggered by seasonal weather variations, poor drainage, and human activities such as water spillage and leakages. Despite the recognition of moisture as a critical factor in pavement deterioration, limited research has examined the hydro-consolidation potential of subbase soils in Uganda. This study therefore investigates whether road failures in the GKMA are associated with hydro-consolidation, addressing this critical gap.

1.3 Research Objectives

1.3.1 Main Objective

The main objective of this study was to minimize subbase road failure resulting from hydro-consolidation (collapsible potential).

1.3.2 Specific Objectives.

The specific objectives were:

i. To assess the suitability of the existing road pavement material as a subbase material by classification through physical-mechanical tests [PSD, CBR, MDD, Atterberg Limits] and chemical tests [Sulphate & Chloride Content, pH Value];

ii. To determine the collapse potential of the material under natural and saturated conditions using results from the conventional oedometer test; and

iii. To assess mitigation measures to reduce hydro-consolidation effects and improve subbase performance.

1.4 Research Questions

i. What is the physical-mechanical composition and chemical composition of the selected existing road pavement material?

ii. What is the collapse potential of the material under natural and saturated conditions using results from the conventional oedometer test?

iii. What are the mitigation measures to reduce hydro-consolidation effects and improve subbase performance?

1.5 Research Justification

The stability of road pavements in the GKMA has become a critical concern due to increasing traffic volumes, particularly heavy vehicles, which now exceed the minimum levels recommended by the Ministry of Works and Transport (MoWT, 2021). Poorly planned road networks, inadequate maintenance, and the concentration of economic and social activities in the region further worsen pavement deterioration. Field observations reveal various forms of road distress, including potholes, rutting, edge failures, alligator cracking, subsidence, and both shallow and deep gullies, all of which indicate structural weaknesses within the pavement layers (UNRA, 2022).

Soil characteristics also play a fundamental role in pavement performance. Subbase soils in the region are often non-uniform, rarely homogeneous, and display significant variations in physical and mechanical properties. Such variability influences their behaviour under changing moisture conditions, leading to phenomena such as hydro-consolidation and sudden collapse of the pavement foundation. Research has shown that repeated wetting–drying cycles significantly alter the mechanical behaviour of compacted soils, reducing their strength and resilience while increasing their susceptibility to collapse (Rosenbalm and Zapata, 2017; Abbey *et al.*, 2023). Despite their critical role in overall pavement stability, the collapse potential of these subbase materials has not been sufficiently quantified for tropical soils subjected to high rainfall and heavy traffic loads.

This research is therefore justified on both practical and academic grounds. By assessing the collapse potential of subbase materials under controlled wetting conditions, the study provides essential data to predict soil behaviour, inform sustainable pavement design, and guide material selection. The findings will also contribute to reducing maintenance costs, improving road safety, and supporting evidence-based infrastructure planning in tropical regions.

1.6 Significance of the Study

The implementation of the research findings by the concerned authorities will enhance the performance of pavement layers, leading to several practical benefits. These include lower vehicle operating costs, reduced road maintenance expenditures due to less frequent interventions, and higher Returns on Investment (ROI) for government infrastructure projects. Road users will also benefit from time savings, improved ride quality through pavements with recommended surface roughness levels as per the International Roughness Index (IRI), and reduced accident rates associated with better-constructed pavements. Furthermore, the study promotes improved stormwater management, thereby minimising structural damage to the pavement base and surface caused by poor drainage within the GKMA.

Beyond these practical outcomes, the study contributes to the academic and professional body of knowledge by addressing a key gap: the limited quantification of collapse potential of subbase materials in tropical environments, particularly under wetting–drying conditions. Existing literature has focused extensively on expansive soils and subgrade performance, but comparatively less attention has been directed to subbase layers in regions with intense rainfall and high traffic demands. This research provides empirical evidence and insights into the behaviour of such soils, offering a scientific basis for more sustainable pavement design in tropical contexts.

In addition, the findings hold significant policy relevance, as they can guide the MoWT and other stakeholders in adopting more reliable design standards and specifications. They may also inform updates to pavement design manuals to account for soil collapse potential under variable moisture conditions. Finally, the study provides a foundation for future research into material improvement techniques, alternative stabilisation methods, and numerical modelling of collapse potential in tropical soils.

1.7 Research Scope

1.7.1 Content Scope

The study was limited to the assessment of subbase materials from failed road sections, focusing on physical-mechanical characterisation through particle size distribution (PSD), maximum dry density (MDD), California Bearing Ratio (CBR), and Atterberg limits; chemical assessment of chlorides, sulphates, and pH; and evaluation of collapse potential using conventional oedometer tests on remolded samples at both natural and optimum moisture contents. The scope also included interpreting the results to establish the suitability of the materials, their stability under saturated and unsaturated conditions, and to recommend feasible interventions for stabilising subbase layers.

1.7.2 Time Scope

The research was conducted over twenty-four months (January 2023 – January 2025), with a supplementary investigation into the temporal deterioration of pavement structures, considering the influence of seasonal variations and climatic factors on road performance.

1.7.3 Geographical Scope

The study was confined to the Greater Kampala Metropolitan Area (GKMA), a region characterised by expansive soils, seasonal rainfall, and a diverse road network. The focus was on primary and secondary roads that are prone to failure, with a location map provided to illustrate the road network and highlight the classes of interest within the study area.

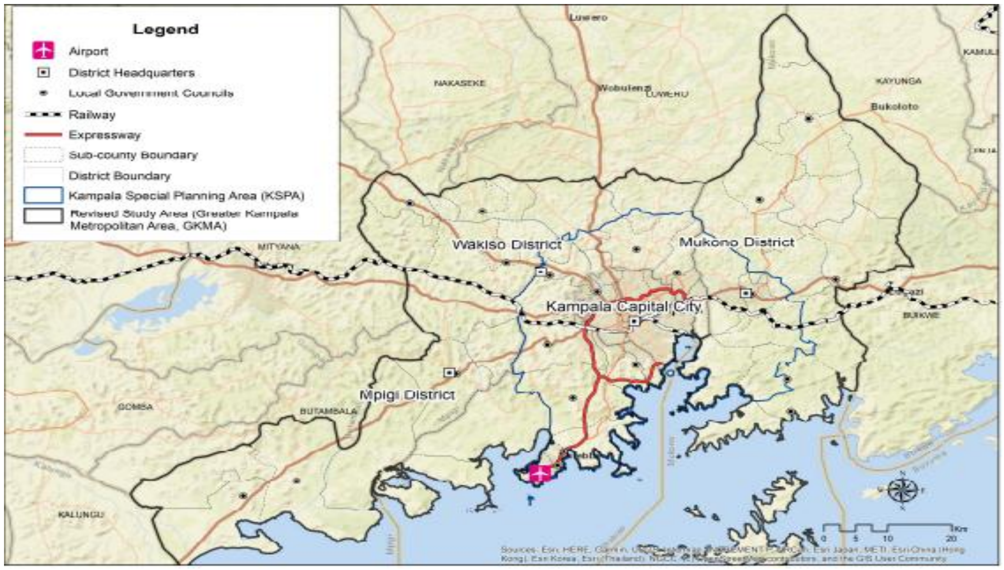


Figure 1.1: Map showing the Greater Kampala Metropolitan Area

1.7.4 Feasibility of the Study

The study was carefully limited to a practical and attainable scale, ensuring that the objectives could be accomplished within the available resources, laboratory capabilities, and allocated timeframe. This approach maintained methodological soundness while ensuring the findings remain directly applicable to road engineering challenges in tropical environments.

1.8 Conceptual Framework

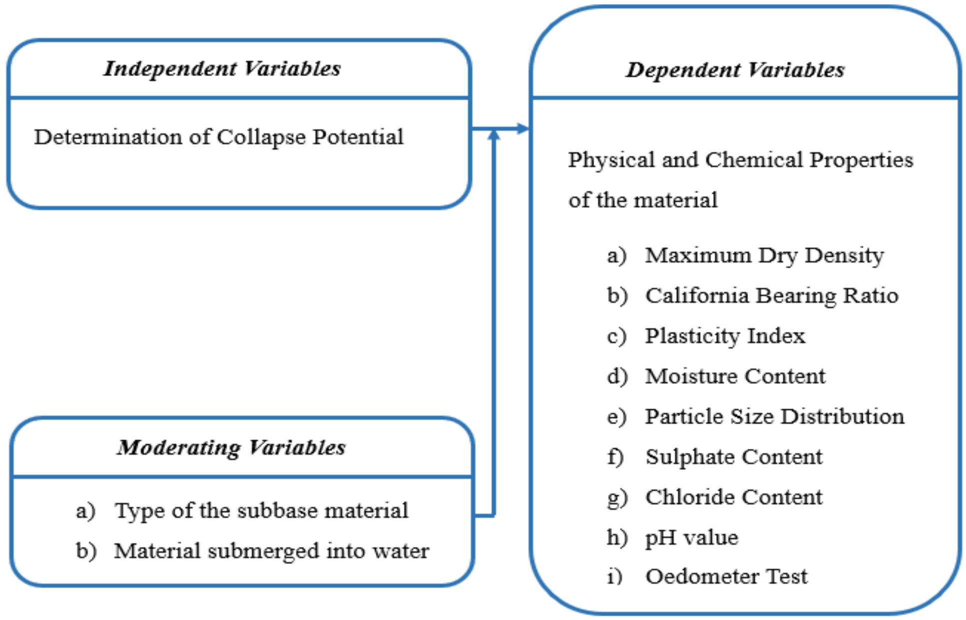


Figure 1.2: Conceptual Framework

The independent variable, collapse potential, was influenced by the type of subbase material and its exposure to moisture (moderating variables). The dependent variables comprised the material's physical and chemical properties, including MDD, CBR, PI, Moisture Content, PSD, Sulphate and Chloride Content, Ph Value, and Oedometer test results. From a scientific perspective, it was expected that soils with higher plasticity, lower density, or higher soluble content would show greater collapse potential, particularly under wetting conditions. The moderating variables either strengthend or reduced these effects, establishing measurable links between material properties and pavement performance.

1.9 Layout of the Dissertation

This dissertation is organised into five chapters. Chapter One introduces the study, presenting the background, problem statement, objectives, research questions, justification, significance, scope, and layout. Chapter Two provides a review of relevant literature, focusing on the concepts of soil behaviour, hydro-consolidation, pavement performance, and gaps in existing studies. Chapter Three outlines the research methodology, detailing the experimental design, sampling procedures, and laboratory testing methods employed. Chapter Four presents and analyses the research findings, supported by tables, figures, and discussions. Chapter Five concludes the study by summarising the key findings, drawing conclusions, and providing recommendations for practice, policy, and further research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Subbase materials are crucial for infrastructure stability and load-bearing capacity (Shirazi *et al.*, 2020). Various evaluation methods are available, including sieve analysis, Atterberg limits, Proctor compaction, California Bearing Ratio and plate load tests. Each method has its advantages and limitations, and their accuracy and reliability have been studied.

This literature review aims to provide an overview of subbase material evaluation methods, the factors influencing their collapse potental and the relationship between applied stresses and pavement design. Both theoretical and empirical studies are reviewed to highlight strengths and weaknesses in existing knowledge, identify areas of consensus and divergence and ultimately establish the research gap that this study seeks to address.

2.2 The Subbase and Subbase Materials

2.2.1 Definition and role of subbase and subbase materials in pavement design

The subbase is a layer that is positioned directly under the pavement and typically comprises recycled materials, gravel, or crushed aggregate (Corporation, 2013). Subbase materials are placed between the base course and the subgrade to provide additional support and stability to the pavement structure (Officials, 1993).

The main purpose of the subbase layer is to offer structural reinforcement for the upper pavement layers while also acting as a frost barrier and inhibiting the infiltration of subgrade fines to the upper layers (Giroud *et al.*, 2023). Additionally, subbase can enhance drainage capabilities (Chu *et al.*, 2023) and evenly distribute traffic loads over the subgrade, thereby reducing stresses on weaker soils.

Figure 2.1: Basic Flexible pavement structure showing the subbase course/layer (Hoffman, 2008:(Costa, 2022)

2.2.2 Common types of Subbase Materials and their Properties

Table 2.1: Types of Subbase Materials and their Properties (Kumar *et al.*, 2006)

Subbase Material	**Properties**	**Common Uses**
Crushed stone	Angular, unevenly shaped rocks; durable; excellent drainage and compaction	Base material for concrete and asphalt pavements
Gravel	Smooth, rounded stones; good compaction and drainage	Base material for unpaved roads and parking areas
Sand	Granular; good compaction and drainage	Base material for concrete and asphalt pavements
Recycled concrete aggregate	Crushed concrete; favorable drainage and compaction	Base material for concrete and asphalt pavements
Crushed slag	A by-product of steel production; favorable compaction and drainage	Base material for parking areas and unpaved roads
Geosynthetic materials	Geotextiles and geogrids; even load distribution and effective drainage	Base material for unpaved roads and parking areas

2.3 Collapse Potential of Subbase Materials

2.3.1 Causes and Mechanisms of Subbase Collapse

Subbase collapse arises from factors such as:

a) **Poor soil conditions:** Subbase collapse can happen due to weak, compressible, or settlement-prone soils. Such conditions may lead to the sinking or settling of subbase materials, ultimately failing the pavement structure (Roche *et al.*, 2001).

b) **Inadequate drainage:** Water accumulating in the subbase layer can weaken the subbase material and reduce its load-bearing capacity. Inadequate drainage can also cause subbase materials to become saturated, leading to instability and collapse (Mallick and El-Korchi, 2022).

c) **Overloading:** Subbase materials can fail when subjected to excessive loads. This can occur when heavy vehicles or equipment are operated on the pavement, causing the subbase to compress and deform (Assogba *et al.*, 2021).

d) **Poor subbase material quality:** Subbase materials that are of poor quality or not compacted properly during construction can also lead to subbase collapse. This can cause the pavement to settle and become uneven, resulting in poor ride quality and potential safety hazards (Huang, 2004).

The mechanisms of subbase collapse can vary depending on the specific cause. In some cases, the subbase material may experience plastic deformation or shear failure, leading to instability and collapse. In other cases, the subbase material may experience uneven settlement or consolidation, causing the pavement itself to sink or become uneven. The specific mechanism of subbase collapse will depend on the underlying cause and the characteristics of the subbase material (Mamlouk and Zaniewski, 2006).

2.3.2 Factors Affecting the Collapse Potential of Subbase Materials

The collapse potential of subbase materials can be affected by several factors, including:

a) **Soil Type:** The type of soil that makes up the subbase can have a significant impact on its collapse potential. Highly compressible soils, such as organic soils, can lead to significant settlement and deformation, while well-graded granular materials are more stable and less susceptible to collapse (Zhussupbekov *et al.*, 2022).

b) **Moisture Content:** Moisture content in the subbase is another important factor. Excessive moisture can cause soil particles to become unstable, leading to settlement and deformation, while a lack of moisture can cause soil to become brittle and prone to cracking (Nazzal *et al.*, 2020).

c) **Density:** The density of the subbase material can affect its ability to resist deformation. Materials that are compacted to a high density are less likely to experience significant settlement (Lu *et al.*, 2021).

d) **Thickness:** The thickness of the subbase layer can also affect its ability to support overlying loads (Baadiga *et al.*, 2021). A thicker subbase layer can distribute loads more evenly, reducing the potential for collapse.

e) **Loading:** The magnitude and frequency of loading can also have an impact on the collapse potential of subbase materials. Heavy loads or frequent traffic can cause excessive deformation and settlement, while lighter loads or less frequent traffic may not cause significant deformation (Alaneme *et al.*, 2021).

f) **Drainage:** Adequate drainage is important for preventing excessive moisture from accumulating in the subbase material. Poor drainage can lead to instability and collapse (Alaneme *et al.*, 2021).

g) **Climate:** Environmental factors such as temperature and precipitation can affect the collapse potential of subbase materials. In areas with frequent freeze-thaw cycles, for example, the expansion and contraction of soil can lead to cracking and instability (Jotisankasa, 2005).

2.3.3 Relationship Between Subbase Properties and Collapse Potential

The potential for subbase collapse can be directly affected by the properties of the subbase materials, including factors such as soil type, moisture content, density, thickness, loading, drainage, and climate (Huang, 2004). Soil types with high compressibility, such as organic soils, have a higher risk of collapse, while well-graded granular materials are more stable and less likely to collapse (Das, 2021). Moisture content, density and thickness are also important factors to consider, as high moisture levels, low density and inadequate thickness can increase the subbase's compressibility and risk of deformation.

Repeated heavy loads can also weaken the subbase and lead to permanent deformation, while proper drainage is crucial to prevent water accumulation and maintain the subbase's strength (Luo et al., 2017). Climate is another important factor to consider, as freeze-thaw cycles and other environmental conditions can cause significant damage and increase the risk of collapse (Roberts, 2008).

To minimize the potential for subbase collapse and ensure long-term stability, it's crucial to carefully analyze and optimize the subbase materials, as well as implement appropriate construction practices, regular monitoring and maintenance (Wistuba and Walther, 2013). By taking a comprehensive approach that considers all relevant factors, it's possible to minimize the risk of subbase collapse and ensure the integrity of the infrastructure.

2.4 Evaluation methods

2.4.1 Overview of Common Methods Used to Evaluate Subbase Materials

There are several methods used to evaluate subbase materials, including:

a) **Sieve Analysis:** This method involves passing a sample of the subbase material through a series of sieves with progressively smaller openings (BS 1377: Part 2: 1990). The amount of material retained on each sieve is measured, and this data are used to determine the particle size distribution of the material.

Advantages: Simple and cost-effective method to determine particle size distribution of materials. Provides information on the gradation and uniformity of subbase materials.

Limitations: Only provides information on particle size distribution and does not account for other properties such as plasticity, compressibility or strength.

b) **Atterberg Limits:** This method involves determining the moisture content at which a soil transitions between different states, such as from a solid to a plastic or liquid state. These data can be used to assess the soil's plasticity and compressibility (BS EN 1377: Part 2: 1990).

Advantages: Provides information on the plasticity and compressibility of subbase materials. Can be used to classify soils according to their properties.

Limitations: Only provides information on soil properties related to moisture content and does not account for other factors that affect performance such as particle size distribution or strength.

c) **Proctor Compaction Test:** This test involves compacting a soil sample using a standard amount of energy and measuring the resulting density. These data can be used to determine the maximum dry density and optimum moisture content of the material. (BS 1377: Part 4: 1990)

Advantages: Provides information on the maximum dry density and optimum moisture content of subbase materials, which are important parameters for designing and evaluating subbase materials for various engineering applications.

Limitations: Does not account for the effects of repeated loading, freeze-thaw cycles, or other environmental conditions that can affect the performance of subbase materials.

d) **California Bearing Ratio Test:** This test involves measuring the resistance of a soil sample to penetration by a standard plunger (BS 1377: Part 9: 1990). The CBR value is calculated as the ratio of the force required to penetrate the sample to the force required to penetrate a standard material under the same conditions. This value is used to evaluate the material's load-bearing capacity.

Advantages: Provides information on the load-bearing capacity of subbase materials under specific conditions, which is important for pavement and road design.

Limitations: Only provides information on the load-bearing capacity of subbase materials under specific conditions and does not account for other factors that affect performance, such as moisture content or environmental conditions.

e) **Plate Load Test:** This test involves measuring the deflection of a plate placed on the subbase material under successive standard loads. The resulting data can be used to calculate the modulus of the subgrade reaction, which is a measure of the material's stiffness and load-bearing capacity (Consoli *et al.*, 2003).

Advantages: Provides information on the stiffness and load-bearing capacity of subbase materials under specific conditions, which is important for pavement and road design.

Limitations: Can be expensive and time-consuming to conduct. The results may be affected by the size and shape of the plate used, and the conditions of the testing site may not be representative of actual field conditions during operation.

The choice of the most suitable test method or methods to evaluate subbase materials depends on the characteristics of the specific material being analyzed and the intended application of the subbase. Adherence to established testing protocols is crucial to ensure dependable and precise results.

f) **Chloride Content Test:** There are two methods for determining a soil sample's chloride salt content that is soluble in water and soluble in acid. Both processes are derived from Volhard's technique. The soil is either immersed in water or an acid salt of an element that forms an insoluble chloride (BS 1377: Part 3: 1990).

g) **Sulphate Content Test:** Sulphate content is determined by either an ion exchange or gravimetric method. The extract in each case may be treated with diluted hydrochloric acid and barium chloride solution added after which a precipitate is collected, dried and weighed or it may be transferred to an ion-exchange column and the eluate titrated with standardized sodium hydroxide solution (BS 812-118: 1988).

h) **pH Value:** This is the logarithm to base 10 of the reciprocals of the concentration of hydrogen ions in an aqueous solution. It provides a measure of the acidity or alkalinity of the solution on a scale reading from 0 to 14, on which 7 represents neutrality. pH was determined by the electrometric method (BS 1377: Part 3: 1990).

i) **Oedometer Test:** This is a method of determination of the consolidation characteristics of soils when subjected to changes in the applied effective stress, the permeability characteristics of sands, the susceptibility of clays to internal erosion by water and the susceptibility of soils to heave in freezing conditions (BS 1377: Part 5: 1990).

2.4.2 Severity of Collapse Potential

Table 2.2: The severity of the collapse potential according to (Jennings and Knight, 1975) and ASTM (D5333-2003)

Jennings and Knight, 1975		ASTM (D5333-2003) standard	
Ic, (%) at σv=200 kPa	Severity of problem	Ic, (%) at σv=200 kPa	Degree of collapse
< 1 **1-5** **5-10** > 10	Negligible /No Moderate trouble Moderate to Severe Severe trouble	< 2 $2 \leq I_c < 6$ $6 \leq I_c < 10$ > 10.0	Low/Slight Moderate Moderately High High

The severity of the soil collapse potential is a measure of the likelihood that soil will experience significant volume reduction when subjected to wetting or loading. This potential is crucial in geotechnical engineering, particularly for areas with prevalent collapsible soils, as these can cause severe structural damage.

a) (Jennings and Knight, 1975) Classification:

Jennings and Knight (1975) provided a classification system for collapse potential based on the results of collapse tests. The severity of the collapse potential is categorized as follows:

0% - 1%: No problem (Negligible)

1% - 5%: Moderate trouble (Moderate)

5% - 10%: Trouble (Moderate to Severe)

>10%: Severe trouble (Severe)

This classification is based on the percent collapse, which is the change in height of a soil specimen under a given load when wetted.

b) ASTM D5333-03 (2003) Classification:

ASTM D5333-03, titled "Standard Test Method for Measurement of Collapse Potential of Soils," also provides guidelines for assessing collapse potential, though it is more focused on the test procedure. The standard suggests the following interpretation based on the collapse index (I_c):

I_c < 2%: Low collapse potential

2% ≤ I_c < 6%: Moderate collapse potential

6% ≤ I_c < 10%: Moderately high collapse potential

I_c ≥ 10%: High collapse potential

This classification was used to interpret the results of a collapse test on the subbase material, typically performed on samples subjected to a specified overburden pressure (200 kPa) and then inundated with water.

Why 200 kPa?

ASTM D5333-03 and Jennings and Knight (1975) consider 200 kPa as the standard overburden pressure for assessing soil collapse potential because it represents a realistic stress level commonly exerted by buildings, pavements and other structures. This pressure is sufficient to trigger collapse in susceptible soils, making the test results relevant to real-world conditions. Standardizing at 200 kPa ensures consistent, comparable results across different tests, effectively identifying soils with potential collapse risks without overestimating issues in less critical scenarios. This balance between practicality and safety helps prevent structural failures by accurately assessing soil stability under typical construction loads.

Summary:

a) Jennings and Knight (1975): Focus on a simpler classification system primarily based on field observations.
b) ASTM D5333-03: Provides a more detailed interpretation based on laboratory testing, with clear thresholds for different levels of collapse potential.

Both systems are essential for evaluating soil conditions and making informed decisions in geotechnical engineering projects.

2.4.3 Collapse Potential Classification

The collapse potential of soils is a critical factor in assessing the risk of soil subsidence or settlement when a material is exposed to moisture, often due to flooding, leakage, or changes in groundwater levels. The classifications given by ASTM D5333-03 provided a structured way to evaluate this risk, with different levels indicating varying degrees of concern and necessary intervention.

a) I_c < 2%: Low Collapse Potential:

Soils with a collapse index (I_c) of less than 2% are considered to have low collapse potential. This means that when the soil is wetted, it experiences minimal volume reduction.

Structures or foundations built on these soils are unlikely to suffer significant settlement or damage due to wetting. The risk of subsidence is minimal.

Generally, no special precautions are needed beyond standard geotechnical practices. The soil is considered stable and safe for typical construction activities.

b) 2% ≤ I_c < 6%: Moderate Collapse Potential:

Soils within this range are considered to have moderate collapse potential. There is a measurable risk of soil volume reduction when wetted, but it is not excessively high.

Structures may experience some settlement, which could lead to minor cracks or misalignments. However, the extent of damage is usually manageable and may not pose severe structural risks.

Engineering solutions such as soil improvement (e.g., compaction, stabilization), careful drainage design, or using deep foundations to transfer loads to more stable soils might be recommended to mitigate risks.

c) 6% ≤ I_c < 10%: Moderately High Collapse Potential

Soils with a collapse index in this range have a moderately high potential for collapse. The likelihood of significant volume reduction upon wetting increases, leading to a greater risk of structural damage.

Settlement can be more pronounced, leading to noticeable structural damage such as major cracks, tilting, or even partial failure of foundations. This can compromise the safety and usability of the structure.

More intensive geotechnical solutions are necessary. These may include soil replacement, chemical stabilization, deep foundation systems (like piles or piers), or designing structures that can tolerate some movement without catastrophic failure.

d) $I_c \geq 10\%$: High Collapse Potential

Soils with a collapse index of 10% or greater are classified as having high collapse potential. This indicates a severe risk of large-scale soil volume reduction upon wetting.

Severe settlement can occur, potentially leading to the collapse or serious damage of structures. This level of collapse potential poses a significant risk to safety and structural integrity.

Extensive mitigation measures are essential. Options include removing and replacing the problematic soil, using specialized foundation systems that bypass the collapsible layer (e.g., deep piles), or ground improvement techniques such as grouting or lime/cement stabilization. Additionally, ensuring that water does not infiltrate the soil (through proper drainage design) is crucial.

e) Key Considerations:

i. **Geotechnical Investigation:** Understanding the collapse potential of soils at a site is vital before construction. This involves conducting collapse tests and analyzing the results to determine the necessary engineering approach.

ii. **Water Management:** Effective drainage and water management strategies are essential to prevent water from reaching collapsible soils, thereby reducing the risk of triggering soil collapse.

iii. **Monitoring:** Regular monitoring of structures/roads built on soils with moderate to high collapse potential is important to detect early signs of settlement and to implement corrective measures promptly.

Understanding these classifications and their implications allows engineers and construction professionals to make informed decisions about foundation design, soil treatment, and overall project feasibility, ensuring the safety and longevity of structures /roads constructed on potentially collapsible soils.

2.4.4 Acceptable Collapse Percentage

For subbase materials, which are typically used beneath roadways, pavements, and foundations to provide structural support, the acceptable percentage of collapse is generally very low. This is because any significant collapse could compromise the integrity of the structure above.

a) Typically Acceptable Range

0% - 1% Collapse: This is generally considered acceptable for subbase materials. At this range, the material exhibits negligible collapse potential, meaning it will remain stable when subjected to moisture and loading conditions. This ensures that the subbase will provide a reliable foundation for the layers above it.

1% - 2% Collapse: While some engineers may consider this range acceptable, it is often viewed with caution. If collapse in this range is observed, it may necessitate additional measures such as compaction, stabilization, or selecting a more suitable material to ensure the subbase performs as required.

b) Importance of Low Collapse Potential

Structural Stability: The subbase layer supports the load of the structure or pavement above. Any significant collapse in the subbase can lead to settlement, cracking, or even failure of the surface layer.

Durability: A subbase with a very low collapse potential will maintain its structural integrity over time, even when exposed to moisture, which is crucial for the long-term performance of the infrastructure.

c) Summary:

For subbase materials, the acceptable collapse percentage is typically in the 0% - 1% range. This ensures minimal risk to the structural integrity and long-term performance of the infrastructure. If collapse potential is detected to be greater than 1%, further analysis and potential material modification or replacement are recommended.

2.4.5 Vehicle requirements

According to the **statutory instruments 2017 no.45 of the Uganda National Roads Authority (vehicle dimensions and load control) regulations**, the permissible maximum gross vehicle weight is 56 metric tonnes and any single axle of the vehicle should not transmit more than 75 percent of the laden weight on the road surface.

Also to ensure that the vehicle has good traction, at least 20 % of the vehicle weight must fall on the steered axles.

Thus it means $0.2 \times 56 = 11.20$ will be carried by the steer axles;

$0.8 \times 56 = 44.8$ metric tonnes will be carried by the rear axles, since the major consideration during the design is the worst-case scenario, I considered the rear axles wheel loading.

Therefore the wheel load of the rear axles is given by;

From; $\text{Load(Force)}, \text{F} = \text{mg}$

$\text{F} = 44.8 \times 9.8 \times 1000 = 439.04\ \text{kN}$

Considering the worst-case scenario,

Wheel load, $\text{Q} = \frac{75}{100} \times 439.04 = 329.28\text{kN}$, per the **statutory instrument 2017 of the Uganda National Roads Authority.**

2.4.6 Load distribution to the road pavement

Wheel load is distributed to the pavement layers as a uniformly distributed load since the thickness is $> 0.6\text{m}$, using mode **1 of EN 1991-2 clause 4.9.1**, tandem load considering contact area of $(0.4\text{m} \times 0.4\text{m})$, force of 329.28kN.

Using a 2:1 load increment method recommended by **BD31-01 2003**, other recommendations are at a disposal angle of 30 to the vertical for a well-compacted fill **(EN 1991-2:2003)**.

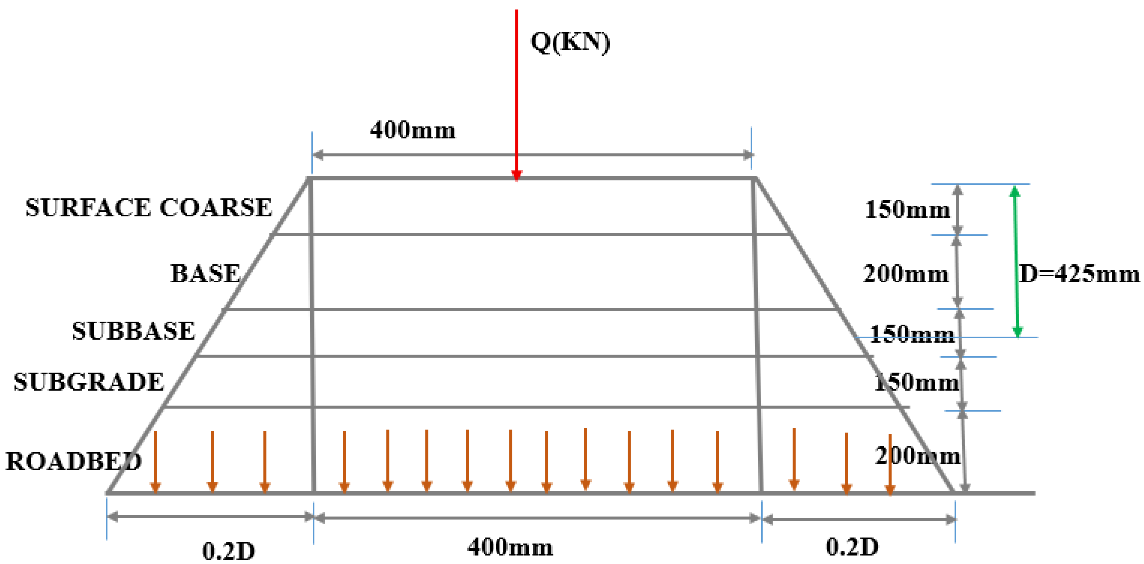


Figure 2.2: Wheel load distribution in the Road Pavement *(Adapted from Transport Research Laboratory, Overseas Road Note 4, 1993; UNRA, General Specifications for Road and Bridge Works, 2010).*

Therefore the equivalent increase in stress from each wheel to the subbase layer, q is given by Equation 2.1 below;

$$q = \frac{Q}{(0.4 + D)^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

Where;

q = The increase in stress due to wheel loading (Q) at any depth

Q = Wheel Loading (kN)

D = Depth (m) from surface to centre of the subbase layer

Therefore, the increase in stress, q from the road surface up to the middle of the subbase layer will be calculated as below;

$$q = \frac{329.28}{(0.4 + 0.425)^2}$$

$$q = 480kN/m^2$$

2.5 Pavement Design and Applied Stresses

Vehicle loading is a critical determinant of pavement performance, particularly in tropical contexts where weak or moisture-sensitive soils are common. Uganda's statutory axle-load regulations limit gross vehicle weight to 56 tonnes, with rear axles carrying the largest proportion of traffic loads (UNRA, 2017). In practice, dual-wheel axle loads can exert stresses approaching 480 kPa on subbase layers, far exceeding the 200 kPa typically applied in laboratory oedometer tests (Uganda Road Design Manual, 2010; JICA, 2016). Light vehicles exert stresses below 100 kPa, typically keeping most soils stable with only minor deformation in those with moderate collapse potential. Medium-weight vehicles, applying stresses between 100 and 200 kPa, can cause noticeable settlement in soils with moderate collapse potential. Heavy vehicles, with stresses above 200 kPa, pose a significant risk to soils with high collapse potential, potentially leading to serious structural issues in road pavements (Uganda Road Design Manual, 2010; JICA, 2016; UNRA, 2017).

This discrepancy suggests that laboratory simulations may underestimate field collapse risks, underscoring the importance of testing under stress conditions representative of actual axle loads.

2.6 Empirical Literature Review

Several studies have investigated the collapse behaviour of soils under different environmental and loading conditions. In Brazil, Zanin *et al.* (2024) reported that gradual increases in moisture significantly enhanced the collapse potential of clayey sand soils, highlighting the sensitivity of tropical materials to wetting. Similarly, studies in Malaysia by Abdul Wahab *et al.* (2023) demonstrated that matric suction and saturation control play a critical role in collapse behaviour of cement-treated lateritic soils, especially under conditions simulating heavy rainfall. These findings are highly relevant to equatorial climates such as Uganda, where intense rainfall events are common.

Conceptual advances have also been made in understanding the mechanisms of collapse. Hamdy (2024) emphasised that collapse can be triggered either by increased applied stress or by the reduction in soil strength due to wetting, providing a theoretical framework for hydro-consolidation in metastable soils. Further, numerical modelling by Alassal *et al.* (2023) confirmed that soils subjected to higher pre-soaking stresses exhibit more severe collapse, while those with lower initial moisture content are also more susceptible due to increased matric suction.

In summary, while these empirical studies shed light on collapse mechanisms in tropical and moisture-sensitive soils, they primarily focus on regions outside Uganda. Moreover, most laboratory tests apply stress levels of about 200 kPa, which underestimate the actual axle loads experienced on heavily trafficked roads. There is also limited exploration of how rainfall, drainage, and compaction interact with hydro-consolidation in Ugandan subbase soils. This highlights a critical gap, which the present study addresses by assessing the collapse potential of subbase materials in the Greater Kampala Metropolitan Area under realistic traffic and climatic conditions.

2.7 Research Gap

Although subbase materials have been widely investigated, limited research has addressed their collapse potential under realistic traffic stresses in tropical environments. Many existing studies rely on geotechnical classifications and laboratory tests conducted at stress levels of around 200 kPa, which underestimate the field conditions typically experienced under heavy axle loads on tropical roads. Furthermore, Uganda-specific empirical evidence remains scarce, with most insights borrowed from neighbouring countries whose geological and climatic conditions may not be directly comparable. The combined influence of intense rainfall, drainage efficiency, and compaction quality on the hydro-consolidation behaviour of subbase soils in Uganda has received little focused attention, despite being critical to pavement performance. As a result, there is a lack of tailored testing approaches and locally relevant guidelines for evaluating collapse resistance and improving subbase performance under these conditions. This study therefore seeks to bridge these gaps by investigating the collapse potential of subbase materials in the Greater Kampala Metropolitan Area and by proposing context-specific measures to enhance road design and long-term pavement durability.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter introduces the experimental framework, material source, laboratory sample handling and methodologies employed in this research project. American Society for Testing Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), and British Standards (BS), commonly used for material testing in Uganda, were used in the testing procedures. It outlines the materials, equipment, sample preparation and laboratory testing techniques that were utilized to achieve the study's objectives. The methodology section encompasses measures such as field sampling, in-situ and laboratory testing, along with thorough data analysis.

The following activities were conducted as shown in **Figure 3.1**:

a) Conformance with the standardized testing procedures as outlined in ASTM, AASHTO and British Standards.

b) Execution of single and double oedometer tests per the guidelines outlined in the BS 1377-5:1990.

c) Analysis of results that were obtained from the tests that were conducted and the preparation of possible recommendations based on the findings.

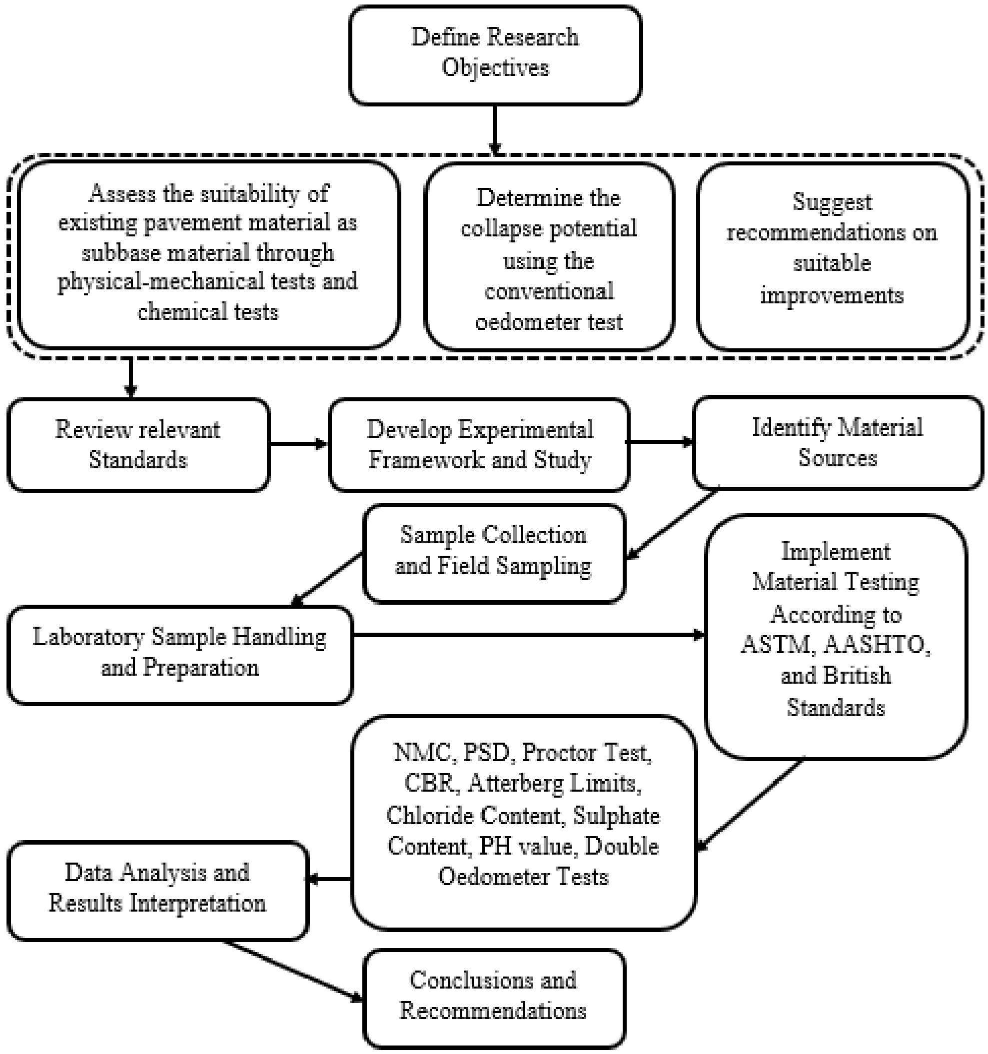


Figure 3.1: Research Schematic Diagram showing methodological procedure

3.2 Research Design and Approach

3.2.1 Research Design

The study adopted a mixed research design combining experimental, descriptive, and analytical approaches. The experimental aspect involved laboratory testing of subbase soils to determine their physical, chemical, and mechanical properties, as well as collapse potential. The descriptive component documented field conditions of failing pavements, guided by construction records and visual observations. The analytical element interpreted laboratory results using consolidation theory and international standards. This integrated design ensured a comprehensive understanding of material behavior under both field and laboratory conditions, while the use of ASTM and British Standards enhanced reliability, comparability, and applicability to local pavement design.

3.2.2 Research Approach

The study adopted a quantitative experimental approach, complemented by field sampling and analytical interpretation. Representative samples of existing road pavement subbase material were collected and subjected to laboratory testing. Physical and chemical tests were conducted to evaluate their strength and stiffness properties, while collapse potential was determined using the conventional oedometer test. The tests were performed on specimens under both unsaturated and saturated states at Natural Moisture Content (NMC) and Optimum Moisture Content (OMC). The outcomes provided insights into material performance and informed recommendations for suitable improvements to existing road pavements as in **Figure 3.1**

3.3 Materials

This study's materials were soil subbase material from already failing roads. Soil samples were obtained from the subbase layers of already failing roads within the study area. To ensure accurate separation from the base and subgrade, sampling was conducted under the supervision of a Uganda National Roads Authority (UNRA) Engineer, guided by road design specifications, layer thicknesses, and construction records of each considered road. Visual and textural distinctions, together with depth-controlled excavation, minimized contamination and ensured the collection of representative subbase material.

The selected subbase material was predominantly gravel, which is commonly used in pavement construction within the Greater Kampala Metropolitan Area. Prior to testing, the gravel samples were air-dried at room temperature, after which large aggregates, roots, and organic matter were carefully removed to maintain uniformity. The dried gravel was then manually broken down into smaller pieces where necessary, followed by sieving through standard laboratory test sieves to achieve the required particle size fractions for specific laboratory tests. This preparation ensured consistency, accuracy, and reliability in subsequent physical, mechanical, and chemical testing procedures.

3.4 Population and Sample

3.4.1 Population

The focus of the research was on the subbase material used in road construction in the GKMA. The study involved collecting three samples from different road sections that were already failing, located in the different parts of the GKMA. This approach aimed to ensure that the different conditions of the subbase material used in road construction in the area were represented in the study. Various tests including in-situ and laboratory tests were conducted to determine the composition of the subbase material samples and how they behave when in contact with water.

3.4.2 Sample and Sampling Strategies

Three samples of sub-base material used in road construction in the GKMA were collected from different road sections. The sampling strategy involved selecting road sections located in the different parts of the GKMA to ensure that the study represented the different conditions of sub-base material used in road construction in the area.

To select the road sections, Roads failing in the GKMA were considered. The roads that were considered were: the Gayaza-Kalagi (GK) road, Kampala-Mukono-Njeru (KMN) road and Silver Springs-Bweyogerere (SSB) road. The samples were collected specifically from sections of these roads that had failed. This approach helped ensure that the samples collected were representative of the entire study population.

The samples were collected using the grab sampling technique, which involved taking small, representative samples of the sub-base material from the road sections. To minimize bias, multiple grab samples, three, to be specific, were taken from each road section and combined to form a composite sample that represented the overall sub-base material at that location. The composite samples were then transported to the laboratory for further analysis. The population and sample are broken down as in **Table *3.1***

Table 3.1: Breakdown of the population and sample

Sample Ref.No.	Source	Location	Depth (m)	Soil Description
GK-01	Gayaza-Kalagi Road Trial Pit-01	KM: 4+300 LHS	0.215-0.415	Gravel Subbase
3GK-02	Gayaza-Kalagi Road Trial Pit-02	KM: 6+400 RHS	0.215-0.415	Gravel Subbase
GK-03	Gayaza-Kalagi Road Trial Pit-03	KM: 8+000 LHS	0.215-0.415	Gravel Subbase
KMN-01	Kamapala-Mukono-Njeru Road Trial Pit-01	KM: 1+050 LHS	0.250-0.450	Gravel Subbase
KMN-02	Kamapala-Mukono-Njeru Road Trial Pit-02	KM: 1+800 LHS	0.250-0.450	Gravel Subbase
KMN-03	Kamapala-Mukono-Njeru Road Trial Pit-03	KM: 2+320 RHS	0.430-0.630	Gravel Subbase
SSB-01	SilverSprings-Bweyogere Trial Pit-01	KM: 0+400 LHS	0.230-0.430	Silty Sandy Gravel Subbase
SSB-02	SilverSprings-Bweyogere Trial Pit-02	KM: 0+800 LHS	0.230-0.430	Silty Sandy Gravel Subbase
SSB-03	SilverSprings-Bweyogere Trial Pit-03	KM: 2+450 RHS	0.250-0.450	Gravel Subbase

3.5 Description of study area

The Greater Kampala Metropolitan Area (GKMA) spans approximately 8,451.9 km², encompassing Kampala City and its neighboring districts of Wakiso, Mukono, Mpigi, Buikwe, and Luweero. As of 2019, the population of the GKMA was estimated at 6.71 million people (UBOS, 2019; Wikipedia, 2025). This region is

Uganda’s most significant commercial and industrial hub, contributing more than 60% of the national GDP and about 70% of the country’s industrial output (NPA, 2020).

3.6 Data collection

The data collection process for this research involved the collection of sub-base material samples from different road sections in the GKMA. The selection of road samples within the same area was guided by both practicality and accessibility. The Uganda National Roads Authority (UNRA–Kampala) designated the specific failed road sections where permission was granted to excavate and obtain samples. These were the failing roads that were accessible for investigation and were considered representative of the local pavement failures that motivated this study. The sub-base material samples were tested in the laboratory to determine their physical and chemical properties and in-situ tests were conducted to measure the subbase material's behavior under various conditions. Inspections were also carried out on the road sections to identify any visible signs of damage or degradation in the sub-base material. Data from primary and secondary sources were analyzed to provide a comprehensive understanding of sub-base material used in road construction in the GKMA.

3.7 Sources of Data

Overall, a combination of primary and secondary data sources was used to analyze the sub-base material samples and obtain a comprehensive understanding of the sub-base material used in road construction in the GKMA.

3.7.1 Primary Data Sources

Primary data sources included in-situ and laboratory tests to determine the physical and chemical properties of the sub-base material samples. Inspections of the road sections were also conducted to identify any visible signs of damage or degradation in the sub-base material. These data sources were essential for obtaining information directly from the study samples.

3.7.2 Secondary data sources

Secondary data sources for the research included peer-reviewed journal articles, government reports, relevant textbooks and reference materials, literature reviews, and websites of professional organizations and industry associations. These data sources provided existing research on sub-base material used in road construction, information on sub-base material specifications, construction practices and standards, as well as a comprehensive understanding of sub-base material and its use in road construction. These data sources were essential for obtaining relevant information and background knowledge about the research topic.

3.8 Data Analysis

The qualitative and quantitative data for the PSD, CBR, compaction (Proctor test), Atterberg limits, chemical tests and oedometer tests, that were gathered were analyzed using descriptive statistical methods such as mean, mode, medium and range from the Microsoft Excel program before drawing conclusions and presentation of the final report.

3.9 Standards and Rationale for Selection

The laboratory procedures in this study were guided primarily by British Standards (BS 1377: 1990 series), with complementary reference to ASTM standards where necessary. The BS 1377: 1990 standards were selected because they are internationally recognized and widely adopted in Uganda and other Commonwealth countries for soil classification and geotechnical testing. Their comprehensive coverage of soil physical, mechanical, and chemical properties provided a consistent framework for comparing the results across different tests.

Specifically, BS 1377: Part 2:1990 was employed for index property tests (Moisture Content, PSD, and Atterberg Limits), ensuring conformity with conventional soil classification practices. BS 1377: Part 3:1990 was used for chemical testing (Chloride Content, Sulphate Content, and pH Values), given its reliability in identifying aggressive agents affecting pavement durability. BS 1377: Part 4:1990 was followed for strength and compaction tests (CBR and Proctor Tests), which are directly relevant to pavement material performance assessment. For consolidation and collapse potential determination, BS 1377: Part 5:1990 was strictly applied, as it provides clear protocols for oedometer testing.

In addition, the ASTM D5333 (Standard Test Method for Measurement of Collapse Potential of Soils) was referenced solely for the classification of collapse severity. While the testing procedure itself adhered to BS 1377:1990, ASTM D5333 offered a practical classification system for interpreting the degree of collapse potential, thereby enhancing the relevance and comparability of the results with international literature.

3.9.1 The choice of these standards was therefore motivated by three considerations:

a) Relevance to local practice – BS 1377:1990 is the default standard in Uganda for road and geotechnical investigations.

b) Comparability of results – Use of widely recognized standards ensures results are consistent with previous research and global practice.

c) Complementary classification – ASTM D5333 was included to enhance interpretability of collapse severity, bridging British and American approaches to soil collapse assessment.

3.10 Methods/Laboratory Tests

Various tests were conducted in the laboratory on molded soil samples to assess their material properties. The subsequent sections detail the specific tests undertaken, including those for subbase soils. The procedures for each test type are outlined in the following subsections **3.10.1-3.10.9**

3.10.1 Moisture Content

The purpose of this test was to determine the amount of water within the pore space between the soil grains in a soil sample as a percentage of the dry soil mass which is removable by oven-drying. The test was conducted in accordance with BS 1377: Part 2:1990. 100g of each of the nine samples of subbase soil, three from each road were placed in nine moisture tins and the weight was recorded. The soil samples were then placed in a 105 °C oven for 24 hours. The dry mass of the samples was measured by using a weighing scale after cooling to determine the quantity of water that was present in the soil. The moisture content was recorded as the average of the moisture content of the three samples from each road. The details of the results are presented in Chapter Four.

3.10.2 Particle Size Distribution

This type of test was essential for soil classification. The test was carried out in accordance with BS 1337: Part 2: 1990 as shown in **Figure G. 5: a.** Soaked samples in preparation for wet sieving**, b.** Wet sieving with a sieve of **0.075 mm** aperture sieve, **c.** BS sieves with decreasing aperture that was used for dry sieving, **d.** Dry sieving, **e, and f.** Weighing the material retained on each sieve**.** Wet sieving with a sieve of 0.075 mm aperture was carried out to separate silt and clay soil fractions from the samples for the test. Dry sieving was then performed after the materials had been dried in an oven at 105 °C. For sieving, BS sieves with decreasing aperture from 37.5mm, 28.0mm, 20.0mm, 14.0mm, 10.0mm, 6.3mm, 5.0mm, 2.0mm, 1.18mm, 0.600mm, 0.425mm, 0.300mm, 0.150mm and 0.075mm were used. The percentages that passed each sieve were then determined using cumulative quantities in percentages calculated from retained material weights. Material percentages passing were plotted against sieve size on a logarithmic scale to obtain the particle size distribution curve. The Grading Modulus (GM) is often used to classify material types according to particle size distribution. The grading modulus is defined as the cumulative percentage by mass of material in a representative sample of soil passing the 2 mm, 0.425 mm, and 0.075 mm sieves divided by 100. The grading modulus was determined using Error! Reference source not found..

$$GM = \left[3 - \left(\frac{\mu + \alpha + \beta}{100}\right)\right] \quad \text{.................. (3.1)}$$

where, μ, α, *and* β are percentages of particle sizes passing sieves 2 mm, 0.425 mm, and 0.075 mm apertures respectively.

3.10.3 Atterberg Limits

The determination of Atterberg limits was used to classify soil. The subbase soil samples were first sieved through a 425-micron test sieve for this test, which was carried out following BS 1377: Part 2:1990. After that, about 500g of each soil sample was weighed and put in an airtight bag.

a) Liquid Limit test (Cone penetrometer method)

The liquid limit (LL) identifies variations in the moisture content of expansive soils. Variations in the moisture content in a soil may have a significant effect on its shear strength, especially on fine-grained soils (expansive soils). It is based on the measurement of penetration into the soil of a standardized cone. The test was conducted in accordance with BS 1377: Part 2:1990**.**

The soil samples that were weighed and kept in an air-tight bag were soaked for 24 hours after which the experiment was conducted using the cone penetrometer method. Four test points were used at cone penetrations of 15 mm, 18 mm, 21 mm and 24 mm. Each soil sample was progressively saturated with water, completely mixed and then placed in metal cups for 5 seconds of penetration for each test point. After these penetrations soil samples were placed in moisture content tins to determine the moisture content at each penetration. The soils' liquid limits were obtained from the plotted graphs of penetration versus moisture content at a 20 mm penetration. Typical results were presented in Chapter Four and more detailed in **Appendix A.**

b) Plastic Limit and Plasticity Index

This was used together with the Liquid Limit to determine the variations in the Plasticity Index of the different samples.

The plastic limit test was conducted as a continuance of the liquid limit test. The soil samples were prepared as part of the liquid limit test, 40g of each of the soil samples were placed on the glass plates and allowed to dry partially until plastic enough to be rolled into balls. The procedure of the test was based on BS 1377: Part 2:1990. The balls were divided into smaller samples, each of which was formed into a thread with fingers that were rolled further until the formed thread was approximately 3mm in diameter. This process was repeated until the threads began to crumble. The crumbled particles of each sample were then transferred to tins for the determination of moisture content. This moisture content was taken as the plastic limit. Typical results were presented in Chapter Four and more detailed in **Appendix A**

c) Linear Shrinkage

Shrinkage due to drying is significant in expansive soils hence this method shows variation of shrinkage of expansive soils when subjected to moisture.

Linear shrinkage was performed to predict the amount of soil shrinkage expected. Each of the soil samples was placed in standard molds of 140 mm and allowed to stand for 24 hours to prevent early cracking. The soil samples were subsequently dried in an oven for 24 hours at 105 °C. The length of the block of soil was then measured with a vernier caliper to ascertain the percentage length difference. Typical results were presented in Chapter Four and more detailed in **Appendix A.**

3.10.4 California Bearing Ratio Test

This method covered the laboratory determination of the CBR of compacted samples of soil using the three-point method as a means of assessing the strength of subbase soils in highway construction. The CBR value is the resistance to penetration of 2.5mm and 5.0mm of a standard cylindrical plunger of 50mm diameter, expressed as a percentage of the known resistance of the plunger to 2.5mm in penetration in crushed aggregate, (taken as 13.8KN and 20KN respectively).

The CBR test was carried out in accordance with BS 1377: Part 4: 1990 Sub-clause 7.4. The test helped to classify the soil samples based on strength. Using a 2.5 kg rammer for light compaction and a 4.5 kg rammer for both intermediate and heavy compaction, each of the soil samples was compacted in three moulds. Three layers of soil samples were compacted for light compaction using a 2.5 kg rammer for 10 blows for each layer, 5 layers for intermediate compaction using a 4.5 kg rammer with 30 blows for each layer and 5 layers for heavy compaction using a 4.5 kg rammer with 65 blows per layer**.** After that, the molds were prepared for soaking and put in the soaking tank for four days. The CBR compression machine was finally used to take penetrations of the saturated moulds.

3.10.5 Proctor Test

This test aimed to find the relationship between the soil moisture content and compacted dry density. This test was performed in accordance with BS 1377: Part 4:1990. Following the soil samples' preparation, each of the soil samples was brought to their Optimum Moisture Content by progressively adding water until a 50-50 mixture of soil and water was obtained using a measuring cylinder filled to the 1000 cc mark. By subtracting the water levels in the measuring cylinder at the start, which were 1000 cc, and the final level, the OMC was estimated. Two values on either side of the estimated OMC i.e., ±50 cc were used to obtain 5 test points. The soil samples were then placed in a 1-liter mould and compacted with 27 blows of a 4.5 kg rammer for each layer for 5 layers. After compaction, soil samples were taken from each test point to determine the moisture contents. Typical results were presented in Chapter Four and more detailed in

Appendix C.

3.10.6 Chloride Content

The primary aim of the chloride content test was to ascertain the chloride levels in subbase soil, and the experimental methodology adhered to the guidelines outlined in BS 1377: Part 3 (1990). The procedure commenced with the collection of representative soil samples from the subbase layer at the designated sites, ensuring the absence of stones and organic matter. Subsequently, a soil extract was prepared by mixing a measured amount of soil with distilled water, followed by filtration to obtain a clear solution. The chloride content determination involved a titration method utilizing a silver nitrate solution of known concentration. A measured volume of the soil extract was titrated with the silver nitrate solution, forming a white precipitate of silver chloride. The endpoint was indicated by a color change, and the chloride content was calculated based on the volume and concentration of the silver nitrate solution. To ensure accuracy, blank titrations with distilled water were performed for quality control. The results were reported in grams per liter (g/L) or milligrams per kilogram (mg/kg), providing valuable insights into the chloride content of the subbase soil in accordance with the specified standard. The results are presented in **Table 4.5**.

3.10.7 Sulphate Content

The objective of the sulphate content test was to determine the sulfate levels in the subbase soil, following the procedural guidelines set forth by BS 1377-4:1990, section 4.3. The experimental process began with the careful collection of soil samples from the subbase layer at the designated site, ensuring the exclusion of stones and organic matter. The subsequent preparation of a soil extract involved mixing a measured quantity of soil with distilled water and filtering the solution for clarity. The sulphate content was determined through a titration method using a barium chloride solution. A known volume of the soil extract was titrated with the barium chloride solution, leading to the formation of a white precipitate of barium sulphate. The endpoint was identified by a distinct change in the solution's appearance. The sulphate content was then calculated based on the volume and concentration of the barium chloride solution. Quality control measures included performing blank titrations with distilled water to account for any impurities. The results were reported in g/L or mg/kg, providing information on the sulphate content of the subbase soil. The results are presented in **Table 4.5.**

3.10.8 PH Value Test

The objective of the pH value test was to assess the acidity or alkalinity of the subbase soils following BS 1377-3:1990, section 3.5. The experimental procedure was initiated with the meticulous collection of representative soil samples from the subbase layer at the designated site, ensuring the exclusion of stones and organic matter. Subsequently, a soil-water suspension/slurry was prepared by mixing a measured amount of soil with distilled water. The pH value determination was carried out using a calibrated pH meter or indicator paper. For the pH meter method, the electrode of the pH meter was immersed in the soil-water suspension/slurry, and the pH reading was recorded after stabilization. In the case of indicator paper, the soil-water suspension was applied to the paper, and the resulting color change was compared to a pH scale. To ensure accuracy, the pH meter was calibrated with standard buffer solutions and blank tests were performed. The obtained pH values provided essential information about the acidity or alkalinity of the subbase soil, contributing to a comprehensive understanding of its chemical properties. The results are presented in **Table 4.5.**

3.10.9 Collapsible Potential (Consolidation)

The collapse potential was determined using the double oedometer test (DOT) method according to Jennings and Knight (1975) and Houston and Houston (1997).

The test was carried out in accordance with BS 1377: Part 5: 1990. The soil samples were sieved through the 5mm aperture sieve and obtained 2.5kg for each sample.

An MDD curve was obtained for each sample to obtain the optimum moisture content. The samples were then remolded at NMC and OMC.

3.10.10 Sample Preparation

The first step was to determine the target densities after sieving the material through the 5mm sieve.

The soil samples passing through the 5mm sieve from each borrow area were subjected to a compaction test according to BS 1377: Part 4: section 3: sub-section 3.5.4.2: 1990, to determine the corresponding densities at the Natural Moisture Content and Optimum Moisture Content obtained from the compaction curves. The corresponding densities after compaction of the materials passing through the 5mm sieve are shown in **Table 3.2:** Dry densities at both NMC and OMC after sieving through a 5mm sieve.

Table 3.2: Dry densities at both NMC and OMC after sieving through a 5mm sieve

Sample Reference	NMC (%)	Dry density (kg/m^3)	OMC (%)	Dry Density (kg/m^3
GK-01	13.2	1.82	10.5	1.840
GK-02	8.8	1.88	9.8	1.960
GK-03	9.0	1.905	9.1	1.986
KMN-01	11.3	1.850	10.7	1.870
KMN-02	12.4	1.790	13.1	1.801
KMN-03	11.1	1.769	13.3	1.910

SSB-01	9.1	1.860	8.7	1.880
SSB-02	9.4	1.838	9	1.861
SSB-03	0.7	1.864	9.3	1.887

When the dry densities were obtained as shown in **Table 3.2**, the wet densities at both natural moisture content and optimum moisture content were calculated according to the Error! Reference source not found.**.** The specimens from soil s amples passing the 5mm sieve, for the collapsible potential test were then prepared according to D698 (Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lb/ft^3(600 kN-m/m^3)).

$$\rho = \frac{100\rho}{(100 + w)} \quad \text{………………….} (3.2)$$

The compaction effort in Error! Reference source not found. **3.3** was used to obtain the number of blows used to achieve the target wet densities.

$$E = \frac{(\theta \times \omega \times \varepsilon)}{v} \quad \text{……………….. } (3.3)$$

where; E is the compactive effort, θ is the number of blows, ω is the number of layers, ε is the weight of the hammer and v is the volume of the mould

The soil samples from each borrow area were compacted in the standard proctor moulds at both optimum and natural moisture content to the target densities.

Six specimens were prepared from each road i.e. three at natural moisture content and the other at optimum moisture content as shown in the photos in

Appendix G: **Photos**

After obtaining the compacted specimens which were 18 in number from all three roads i.e. 9 at natural moisture content and 9 at optimum moisture content, these samples were subjected to a double oedometer test.

a) Single oedometer test

The remolded samples at natural moisture content and optimum moisture content were loaded in the conventional oedometers to a stress level ranging between 50kPa and 800kPa and then flooded with pure water to induce collapse. Soil specimens were carefully placed within the oedometer cell equipped with automated loading and measurement capabilities. Vertical stress was applied incrementally and the associated settlement of the soil specimen was automatically recorded at each load increment. The results were reported as compression curves, offering detailed insights into the consolidation behavior of the subbase soil with the advantages of automation in the testing process.

b) Double oedometer test

For the double oedometer test with the automatic oedometer, soil samples were prepared and loaded at various moisture conditions, including NMC, OMC, and saturated and unsaturated states. This was conducted according to BS 1377 Part 5, BS EN ISO 17892-5:2017. The compacted/remolded soil samples were extracted from the proctor moulds and the procedures were followed as presented in BS 1377 Part 5. One specimen from the same compacted sample was tested at unsaturated conditions and another at saturated conditions. The process was repeated for all 18 compacted samples prepared from all three roads.

This followed the extraction of raw data from the oedometer consolidation software and loaded into the ACE consolidation analysis software.

The results of the oedometer consolidation tests both at natural and optimum moisture content under saturated and unsaturated conditions from the oedometer analysis software are shown in Chapter Four and more details in

Appendix E.

Each sample was loaded in oedometers, at NMC, one fully saturated and the other unsaturated. The same sample was also loaded at OMC, one fully saturated and the other unsaturated. This was done before the test began. The loaded samples were then subjected to identical loading. Four stress-strain curves for saturated and unsaturated at NMC and OMC were plotted for each of the samples. The difference between the compression curves is the amount of deformation that would occur at any stress level at which the soil gets saturated. The automated oedometer facilitated precise control over vertical and lateral stresses, and settlement and lateral deformation were automatically recorded during the test. Loading at different moisture conditions allowed for a comprehensive understanding of the soil's

response to varying water content. Quality control measures included verifying the proper calibration of the automatic oedometer and adherence to standard protocols for double oedometer testing. The results were reported as stress-strain relationships, providing valuable insights into the consolidation behavior of the subbase soil under different moisture conditions, with the added advantages of automation in terms of accuracy and efficiency.

3.11 Determination of Collapse Potential

The oedometer consolidation results i.e. the void ratios of the saturated and the unsaturated conditions were plotted against the applied pressure for both natural and optimum moisture content as shown in

***Appendix F*.**

The collapsible potential at 200kPa, 400kPa and 800kPa was determined from Error! Reference source not found.

$$I_c = \frac{e_B - e_I}{1 + e_o} \text{ x } 100 \qquad \text{………………. (3.4)}$$

Where:

I_c = collapse potential; denotes the percent-relative value of collapse measured at any stress level,

$e_B - e_I$ = the void ratio at the appropriate stress level before wetting,

e_o = the initial void ratio.

3.12 Chapter Summary

This Chapter delineates the methodology employed to investigate the physical and chemical properties and collapse potential of selected road pavement subbase materials in the GKMA. Adhering to British standards, the study incorporated quantitative and qualitative methods, including field sampling, in-situ and laboratory testing and data analysis. Utilizing a grab sampling strategy, diverse conditions were represented in the collected soil samples from failing roads. Laboratory tests covered aspects such as moisture content, particle size distribution, Atterberg limits, CBR, Proctor, chloride and sulfate content, pH value, and consolidation tests. The comprehensive research design aimed to determine collapse potential and recommend improvements for existing road pavements in the tropical region, contributing valuable insights to the field.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter gives the results that were obtained from the research, with all data analysis conducted using Excel. The chapter also highlights novel insights and discoveries derived from rigorous investigations, particularly regarding the categorization of the subbase material. It provides an analysis of the subbase material's properties, offering crucial information about its composition, behavior and susceptibility to collapse in tropical settings.

The results include Particle Size Distribution, Maximum Dry Density, CBR, chemical content analysis (Sulphate, Chloride, and pH) and specialized Oedometer tests.

This detailed profile not only defines structural characteristics but also explores potential vulnerabilities and collapse tendencies in tropical conditions. The interpretation of this information sheds light on the interplay between material properties and collapse potential, offering significant implications for construction practices in tropical regions.

4.2 Physical and Mechanical Properties

The Laboratory tests were carried out on the subbase material to determine their physical-mechanical properties according to the different available standards and to check for the materials' suitability and compliance with the MoWT general specification 2005 for roads and bridges (Bagonza, 2005). The physical and mechanical properties of the subbase material were determined to get a clear knowledge of the material before subjecting it to any other desired conditions. The key material properties that were of much interest included PSD, Atterberg limits, CBR, MDD and OMC. These properties were particularly selected for this study because of their help to characterize the sampled materials. The physical and mechanical test results are summarized in

Table ***4.3*** and **Table 4.4**.

4.2.1 Moisture Content

The procedure described the natural moisture content condition of the soils. The test was carried out following BS 1377-2 (1990). **Table 4.1,**

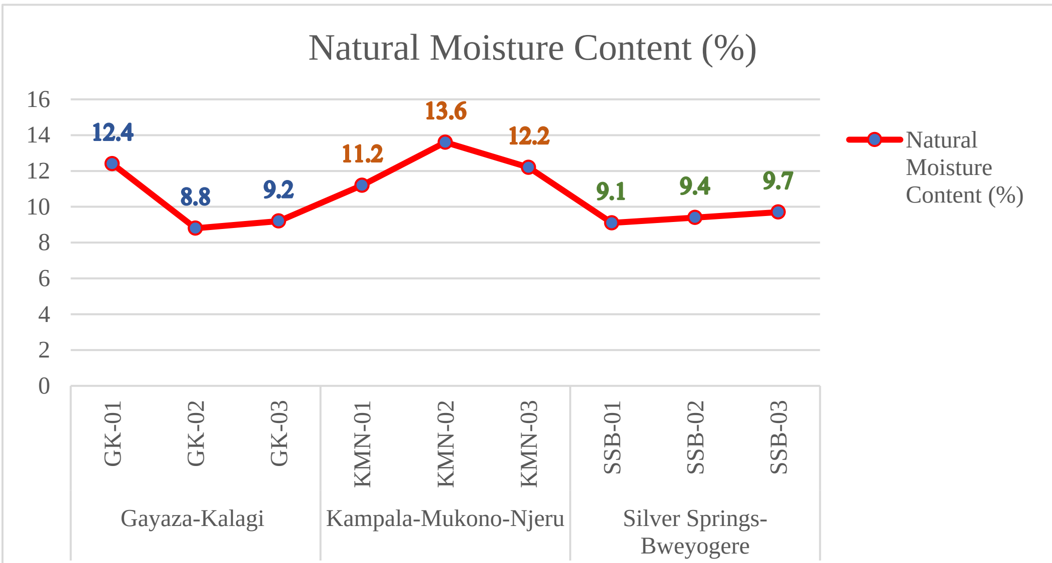


Figure **4.1*:* Natural** Moisture Content for the material from each of the three points from each road.

Table ***4.2*** shows the natural moisture content of the different materials from the three roads.

Table 4.1: Natural Moisture Content for the material from each of the three points from each road

Road Name	Sample Reference	Natural Moisture Content (%)
Gayaza-Kalagi	GK-01	12.40
	GK-02	8.80
	GK-03	9.20
Kampala-Mukono-Njeru	KMN-01	11.20

	KMN-02	13.6
	KMN-03	12.2
Silver Springs-Bweyogere	SSB-01	9.1
	SSB-02	9.4
	SSB-03	9.7

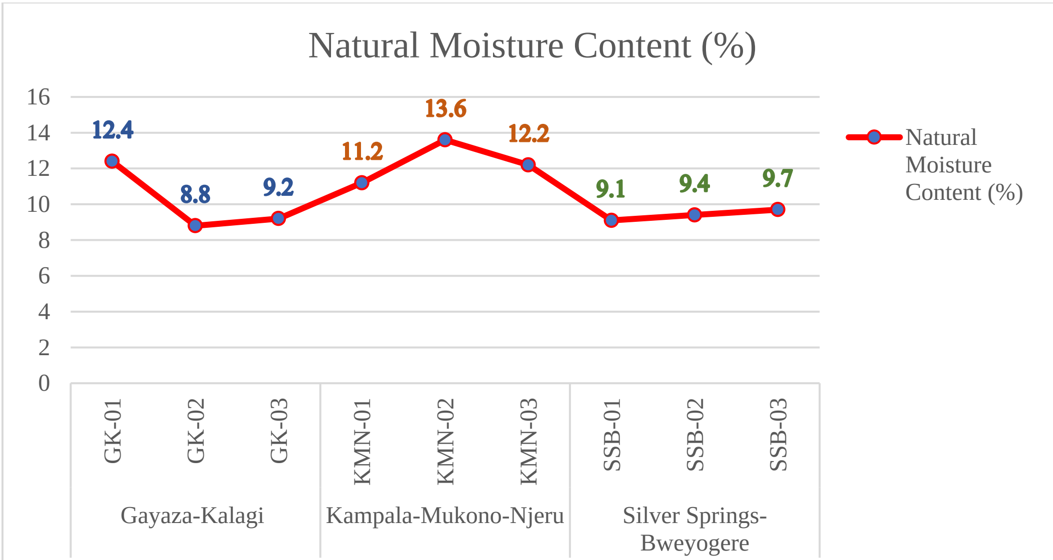


Figure 4.1: Natural Moisture Content for the material from each of the three points from each road.

Table 4.2: Natural Moisture Content for the material from the three Roads

Road Name	**Sample Ref.No.**	**Average Natural Moisture Content (%)**
Gayaza-Kalagi	GK	10.1
Kmapal-Mukono-Njeru	KMN	12.3
Silver Springs-Bweyogere	SSB	9.4

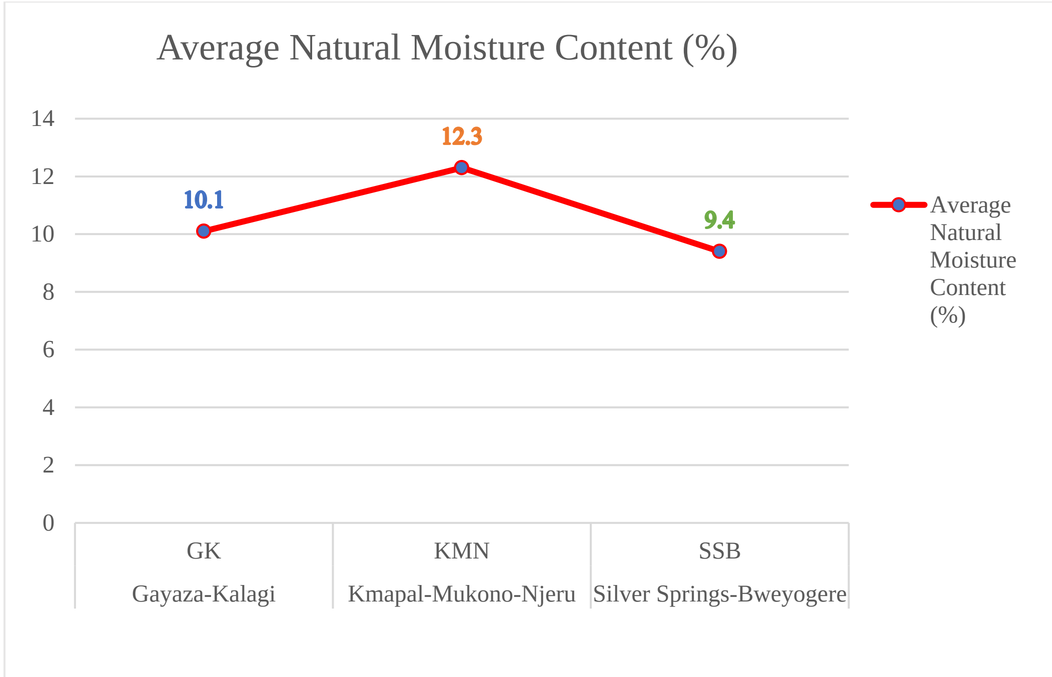


Figure 4.2: Average Natural Moisture Content for the material from the three Roads

4.2.2 Grading Characteristics

Particle size analysis was conducted on the subbase material samples from each trial pit across the three roads using the specified sieves outlined in the General Specifications for Roads and Bridge Works of Uganda. The grading process followed the BS 1377 Part 2: 1990 standards.

The particle size distribution analysis conducted on the samples from the three roads at various chainages provided valuable insights into the variation of grading moduli across the project area. See ***Table A. 1: PSD test results for the three roads at the different chainages*** and

Table A. 2: Average particle size distribution of each of the three roads as in **APPENDIX A**. The results indicated a correlation between particle size distribution and the corresponding grading modulus (GM), highlighting the following key observations:

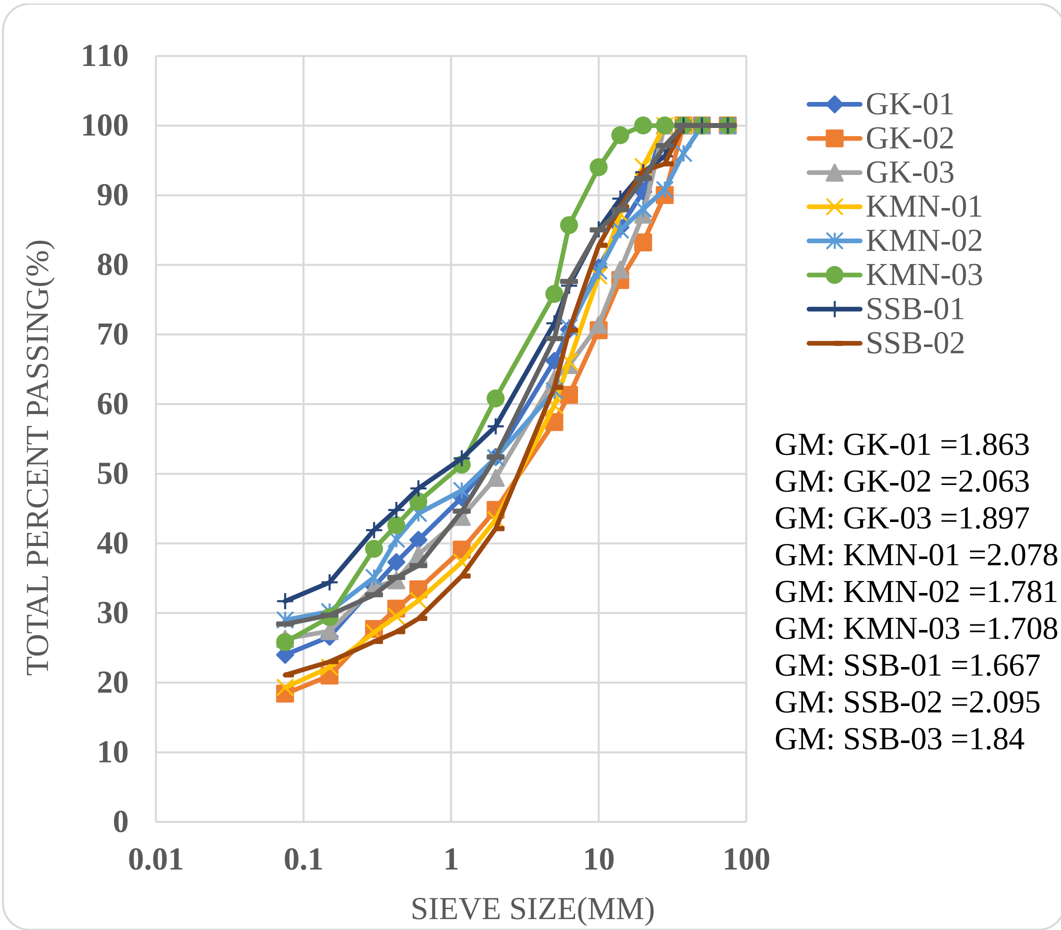


Figure 4.3: Particle size distribution curves

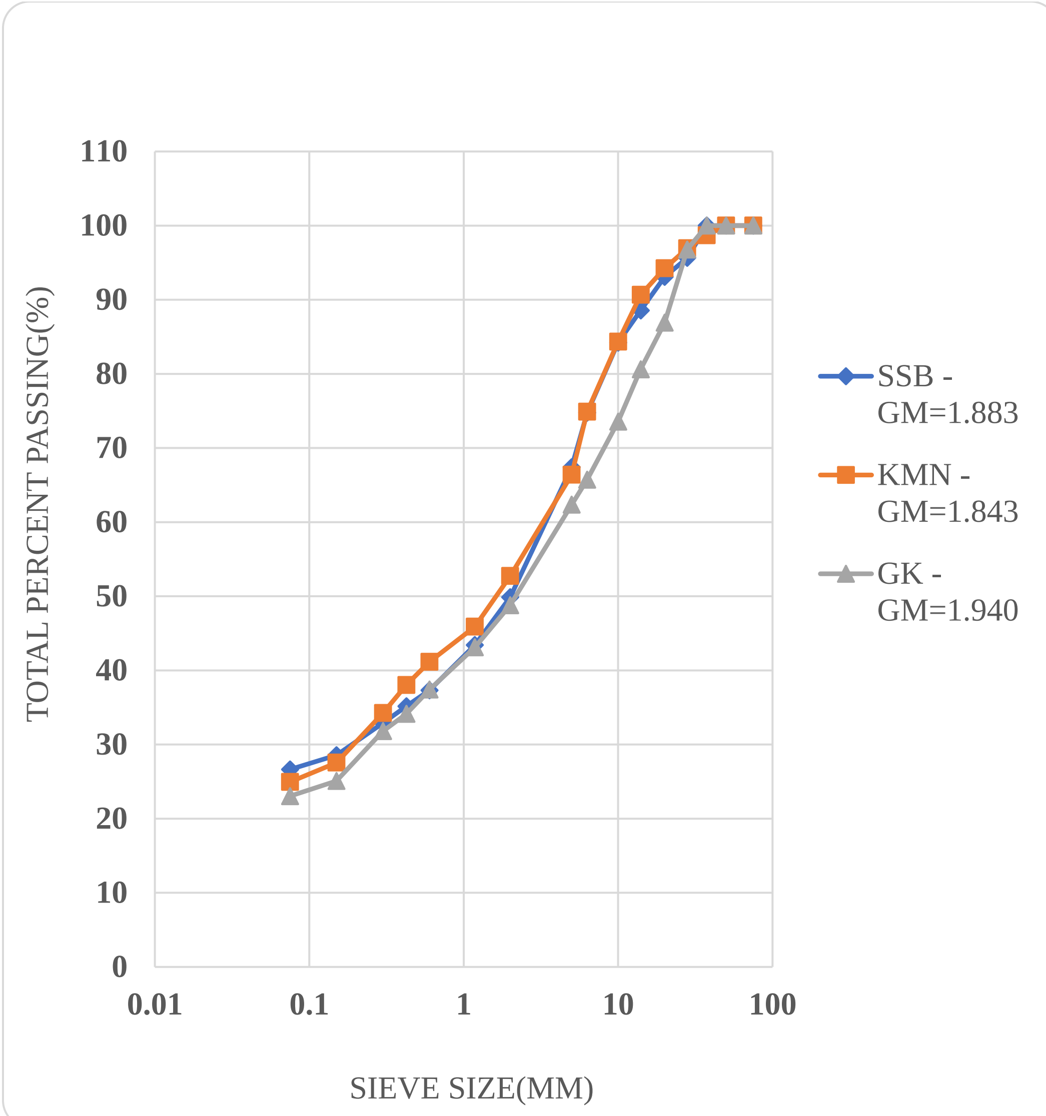


Figure 4.4: Gradation curves for the average PSD of each of the three roads

The grading test carried out showed that the material qualified as a subbase material because the grading moduli for all the samples from the three roads at the different chainages were within the specified ranges.

The particle size distribution curve indicated that the material for GK consisted of 23% fine material and 77% coarse material of which 28% was sand and 49% was gravel. The particle size distribution curve indicated that the material for KMN consisted of 25% fine material and 75% coarse material of which 30.1% was sand and 45% was gravel. The particle size distribution curve indicated that the material for SSB consisted of 27% fine material and 73% coarse material of which 24.4% was sand and 49% was gravel. According to the AASHTO soil classification system, the soil samples for GK, KMN and SSB are classified as A-2-6. The GM for the subbase material for GK, KMN and SSB is 1.940, 1.843 and 1.883 respectively.

The particle size distribution results highlight varied compositions among SSB, KMN and GK subbase materials, with differences in fines content and grading modulus. SSB displays a slightly lower grading modulus and higher fines content compared to KMN and GK, potentially indicating a wider range of particle sizes and lesser stability. Higher fines in SSB might hint at reduced compaction and drainage, elevating collapsible potential. Conversely, KMN and GK, with comparatively lower fines and marginally higher grading modulus, might possess better stability. However, while these differences imply potential collapsible tendencies, a detailed analysis considering additional factors like soil composition and compaction behavior is vital for precise collapsible potential assessment.

4.2.3 Compaction Characteristics

In this research, standardized methods in BS 1377 Part 4: 1990 were utilised to determine the maximum dry density attainable at optimal moisture content. The Proctor test results obtained in this study played a crucial role, serving as key indicators of the material's compaction potential. This emphasized the test's significance in grasping soil behavior and its direct influence on achieving stable compaction, pivotal in assessing the collapse potential of the material.

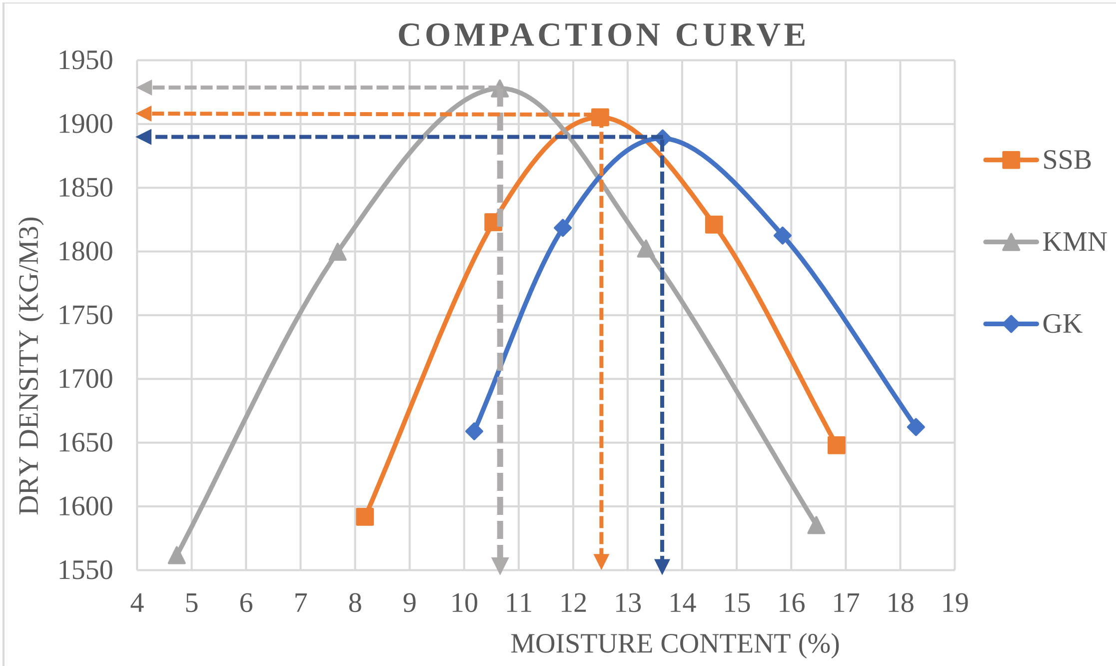


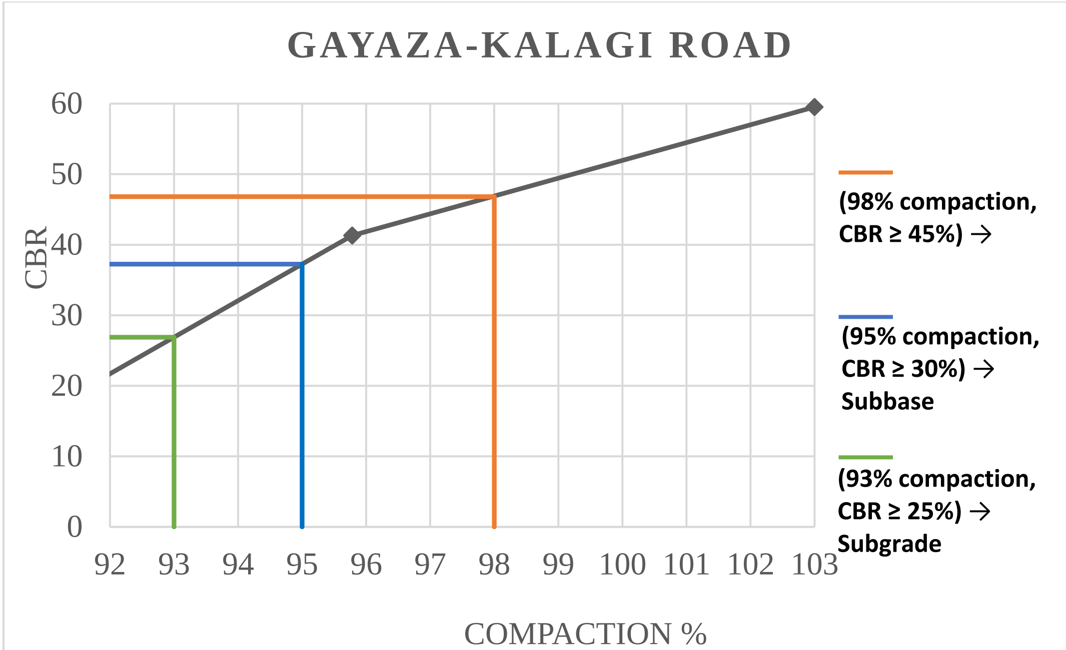
Figure 4.5: Average MDD and OMC curves for each of the three roads

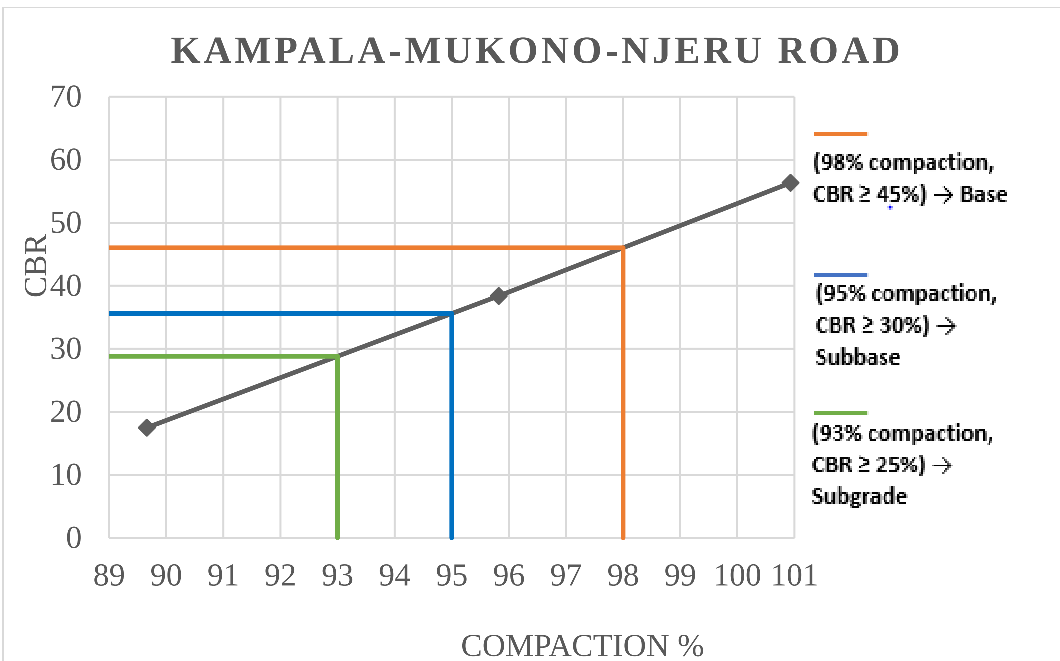
The proctor test outcomes for GK, KMN and SSB roads subbase materials emphasized variations in Maximum Dry Density and Optimum Moisture Content, key factors in assessing collapse potential. GK's MDD at 1890 kg/m³ and OMC at 13.60% suggest potentially lower compaction ability, impacting stability.

Conversely, KMN's MDD of 1930 kg/m³ and 10.65% OMC hint at better compaction and heightened stability. SSB exhibits 1910 kg/m³ MDD and 12.30% OMC, indicating moderate compaction. Higher MDD and optimal OMC, as in KMN, typically signify superior compaction, potentially reducing collapse risk. In contrast, lower MDD and higher OMC in GK might indicate decreased stability and a potentially elevated collapse risk. These distinctions underscore compaction disparities that may influence structural integrity and collapse potential among the subbase materials on these roads.

4.2.4 Strength Characteristics

Performing the CBR test was crucial for understanding the soil's load-bearing capacity and was conducted according to BS 1377: Part-4 (1990). The CBR test helps assess how the subbase material can withstand loads and stresses, which is directly linked to its stability and ability to resist collapse. By evaluating the CBR values, it was possible to determine the materials' strength and potential to withstand the pressures and strains commonly experienced in tropical environments due to water ingress into the subbase. These results in **Figure 4.6** were essential in predicting the subbase material's performance and susceptibility to collapse under various conditions, especially when continuously subjected to ingress of water.


GAYAZA-KALAGI ROAD
CBR
60
50
40
30
20
10
0
92 93 94 95 96 97 98 99 100 101 102 103
COMPACTION %
(98% compaction, CBR ≥ 45%) →
(95% compaction, CBR ≥ 30%) → Subbase
(93% compaction, CBR ≥ 25%) → Subgrade


KAMPALA-MUKONO-NJERU ROAD
CBR
70
60
50
40
30
20
10
0
89 90 91 92 93 94 95 96 97 98 99 100 101
COMPACTION %
(98% compaction, CBR ≥ 45%) → Base
(95% compaction, CBR ≥ 30%) → Subbase
(93% compaction, CBR ≥ 25%) → Subgrade

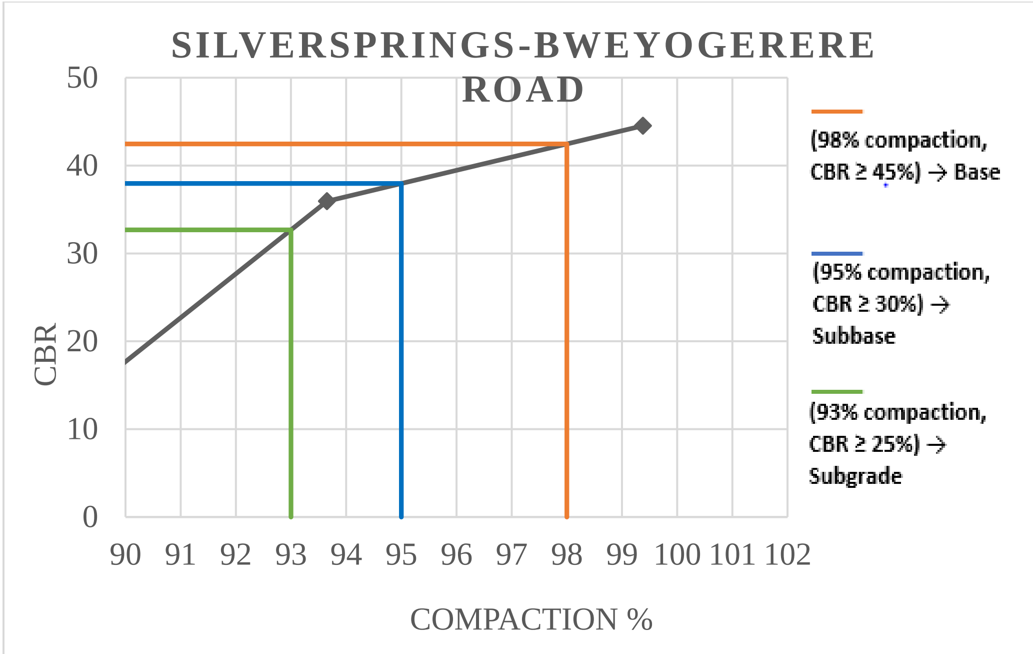


Figure 4.6: Average CBR curves for the three roads

The CBR results above provided essential insights into the load-bearing capacities of subbase materials across GK, KMN and SSB. Specifically, GK's modified gravel subbase exhibits escalating CBR values (27% at 93% MDD, 37% at 95% MDD and 47% at 98% MDD), indicating heightened load-bearing potential and resistance to deformation under soaked conditions. Similarly, KMN's gravel subbase shows consistent strength (29% at 93% MDD, 36% at 95% MDD and 46% at 98% MDD), suggesting reliable stability even at varied moisture levels. Conversely, SSB's Silty Sandy Gravel Subbase records relatively stable CBR values (33% at 93% MDD, 38% at 95% MDD and 42% at 98% MDD), indicating consistent load-bearing strength across different moisture conditions. These findings are pivotal in evaluating collapse potential, highlighting the distinct load-bearing capacities of these materials in tropical conditions.

Following the General Specifications for Road and Bridge Works, Ministry of Works and Transport (2004), the subbase material for GK, KMN and SSB qualifies for a G30 material since their CBR at 95% of MDD is less than 45 but greater than 30.

4.2.5 Plasticity Characteristics

The Atterberg limits to determine the plasticity of the soil samples were carried out according to BS 1377-2 (1990). **Table 4.4** shows the Atterberg limits of the tested subbase materials. It can be observed from **Table 4.4** that the soil material exhibited high plasticity with a liquid limit of 61.3% and a plasticity index of 30.1%. These values indicated that the soil material exhibited some volume change during saturation.

According to the British Standard Classification System (BSCS) the soil sample is classified as gravelly clay of high plasticity (CHG). The detailed results are presented in **Appendix A**.

Table 4.3: Summary of the Physical properties of the subbase material

Subbase area properties	Test Results											
	GK -01	GK -02	GK -03	KMN -01	KMN -02	KMN -03	SSB -01	SSB -02	SSB -03	Spec. Requirements		Remarks
LL (%)	32.4	25.7	33.6	27.6	36.3	32.3	38.1	38.1	35.4	Max	45	Passed
PL (%)	16.9	13.6	19.7	14.6	21.8	17.1	23.3	22.3	21.6	-	-	NP
PI (%)	15.5	12.1	13.8	13	14.5	15.3	14.8	15.8	13.7	Max	16	Passed
LS (%)	7.9	6	6.8	6.5	7.7	7.5	7.2	7.6	6.9	Max	8	Passed
CBR (%)	51	45	42	47	40	48	38	42	38	Min	30	Passed
MDD (kg/m^3)	1940	1870	1840	2002	1780	2002	1880	1870	1920	-	-	NP
OMC (%)	10.8	16	16.4	9.8	12.2	10.3	14.6	11.8	11	-	-	NP
Gravel (%)	47.6	55.2	50.6	56.6	47.7	39.2	43.2	57.9	47.6	-	-	NP
Sand (%)	28.4	26.4	23.1	24.1	23.3	35	25.1	21	24	-	-	NP
Silty/Clay (%)	24	18.4	26.3	19.3	29	25.8	31.7	21.1	28.4	-	-	NP
GM	1.863	2.063	1.897	2.078	1.781	1.708	1.667	2.095	1.840	-	-	NP

Table 4.4: Summary of the averages of Physical-Mechanical test results of the subbase material

Test Parameters	GK	KMN	SSB	Specifications	Standards
Average Results					
NMC (%)	10.3	11.6	9.4		BS 1377: Part 2 (1990)
Particle Size Distribution					
Gravel (%)	51	48	50	GM ≥ 1.2	BS 1377: Part 2 (1990)
Sand (%)	26	27	23		
Silt and Clay (%)	30	25	27		
Grading Modulus	1.94	1.856	1.867		
Proctor Test					
MDD (kg/m3)	1890	1930	1900		BS 1377: Part 4 (1990)
OMC (%)	13.6	10.65	12.3		
California Bearing Ratio					
CBR at 93%	27	29	33	(CBR at 95% MDD, BS Heavy for subbase layer of G30) Min 30 after 4 days of soaking	BS 1377: Part 4 (1990)
CBR at 95%	37	36	38		
CBR at 98%	47	46	42		
Atterberg Limits					
Liquid Limit, LL (%)	30.6	48.1	37.2	LL ≤ 45	BS 1377: Part 2 (1990)
Plastic Limit, PL (%)	16.7	17.8	22.4		
Plasticity Index, PI (%)	13.8	14.3	14.8	PI ≤ 16	
Linear Shrinkage, LS (%)	6.9	7.2	7.2	LS ≤ 8	

4.3 Chemical composition/properties

The chemical properties of the different materials on the selected roads are presented in **Table 4.5:** Chemical Composition of the different material samples and according to the General Specifications for Road and Bridge Works, Ministry of Works and Transport (2004), they were all within the acceptable limits.

Table 4.5: Chemical Composition of the different material samples

Test	GK 01	GK 02	GK 03	KMN 01	KMN 02	KMN 03	SSB 01	SSB 02	SSB 03
	Chemical composition (%)								
Sulphate Content	0.048	0.047	0.045	0.035	0.033	0.035	0.032	0.031	0.031
Chloride Content	0.078	0.066	0.054	0.012	0.010	0.008	0.009	0.0013	0.011
PH value	8.047	8.033	8.09	8.200	8.15	8.11	8.090	8.07	8.01

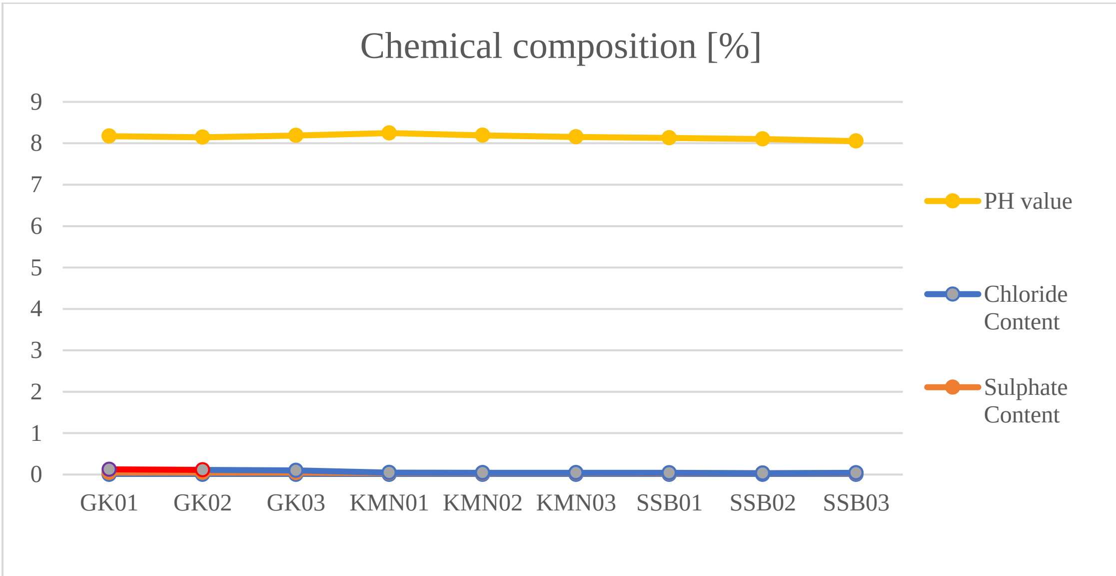


Figure 4.7: Chemical Composition of the different material samples

Table 4.6: Average Chemical Composition of the different material samples

Test	GK	KMN	SSB	Specifications	Standards
	Chemical Composition (%)				
Sulphate Content	0.047	0.034	0.031	< 0.5%	BS EN 1744-1
Chloride Content	0.067	0.011	0.007	< 1.0%	BS 1377: Part 3 (1990)
PH value	8.057	8.153	8.057	7 < PH < 9	BS 1377-3: 2018+A1: 2021

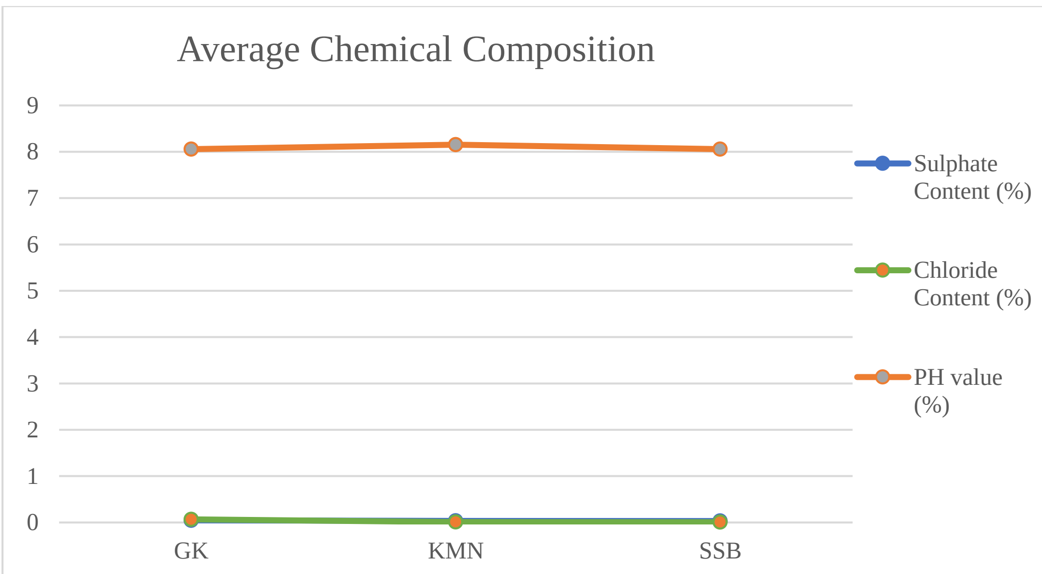


Figure 4.8: Average Chemical Composition

4.4 Collapsible potential (Consolidation properties)

Collapsible potential indicates the degree of abrupt fall in the volume of soil, in this case subbase layer as a result of being wetted. The test was conducted on soil samples collected from all the roads and the findings are represented in **Table 4.7**, **Figure 4.9** and

Appendix *E*. Remarks on the severity of the collapsible potential values obtained were based on

Table *2.2*, extracted from Jennings and Knight (1975) and ASTM D5333, 2003.

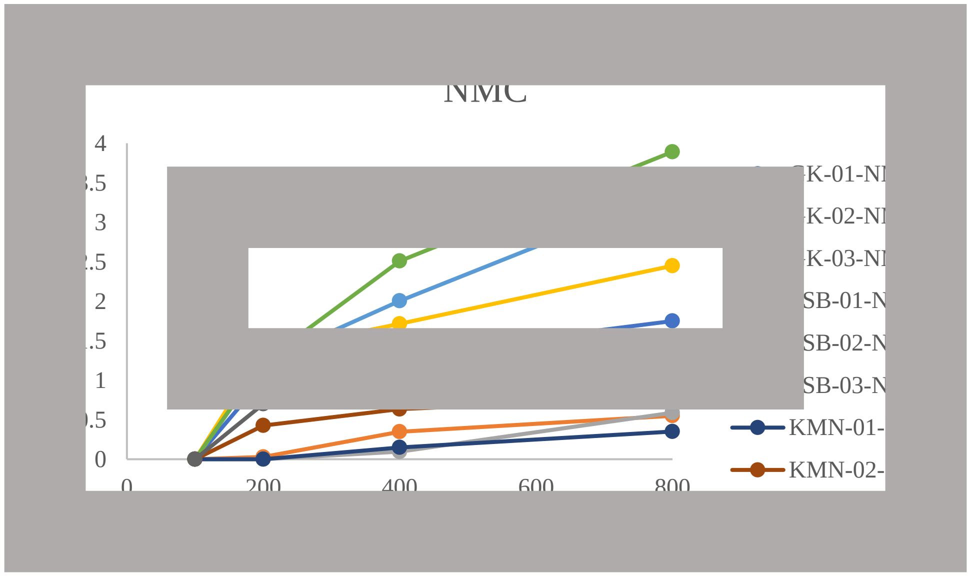
Table 4.7: Collapsible potential results

Sample No.	**Sample Reference**	**Collapsible potential values (%) at different Applied Pressures**			
		100 kPa	**200 kPa**	**400 kPa**	**800 kPa**
1	GK-01-NMC	0	1.01653	1.313135	1.749285
2	GK-01-OMC	0	0.403355	0.763155	1.203637
3	GK-02-NMC	0	0.029098	0.347779	0.549951
4	GK-02-OMC	0	0.008244	0.027375	0.022385
5	GK-03-NMC	0	0	0.095181	0588612
6	GK-03-OMC	0	0	0	0.188685
7	SSB-01-NMC	0	1.358342	1.713678	2.449115
8	SSB-01-OMC	0	0.967281	1.536851	1.473195
9	SSB-02-NMC	0	1.227851	2.004522	3.379429
10	SSB-02-OMC	0	1.118257	1.53777	1.675378
11	SSB-03-NMC	0	1.232062	2.508568	3.891606
12	SSB-03-OMC	0	1.119563	1.539028	1.930598
13	KMN-01-NMC	0	0	0.14908	0350596
14	KMN-01-OMC	0	0	0.38931	0.454664
15	KMN-02-NMC	0	0.427147	0.634092	0.78068
16	KMN-02-OMC	0	0.367263	0.422882	0.707492
17	KMN-03-NMC	0	0.700316	0.909216	1.243033

Sample No.	Sample Reference	Collapsible potential values (%) at different Applied Pressures			
		100 kPa	200 kPa	400 kPa	800 kPa
18	KMN-03-OMC	0	0.556796	0.74008	0.902895

The collapsible potential values for Gayaza Kalagi at optimum moisture content according to **Table 4.7,** indicated they were within an acceptable range and could not impair the road pavement, The collapsible potential values for Silver Springs Bweyogerere, however, showed that the collapsible potential values were within moderate trouble state thus could impair the road pavement. Further, Kampala Njeru road collapsible potential values at optimum moisture content indicated that the collapsible potential values were within the acceptable state and could not impair the road pavement.

However, all roads showed that could there be any deficiency in meeting the subbase requirement during its construction, the pavement could be affected by the collapsible potential of the subbase layer as all the values at natural moisture content were in a concern state.



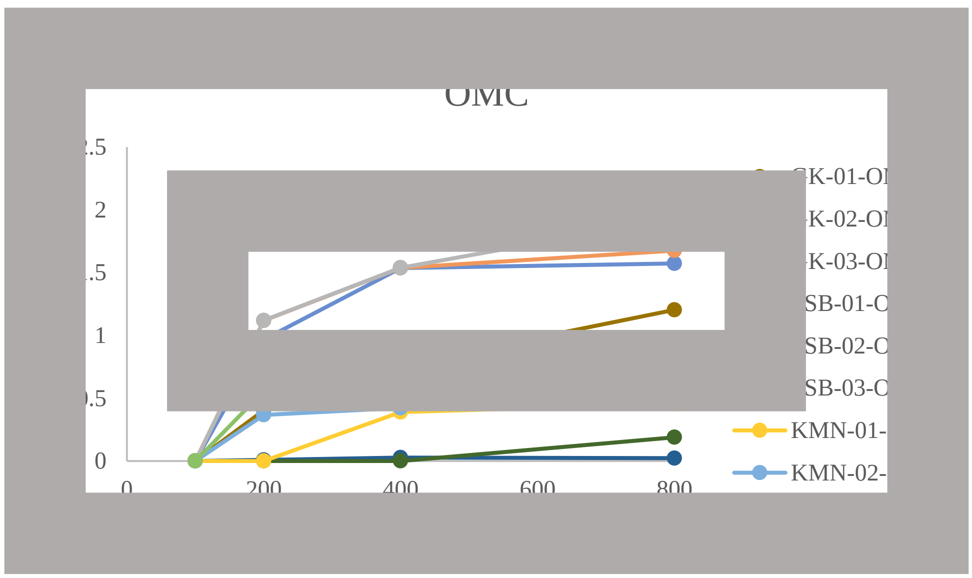


Figure 4.9: Collapsible potential at NMC and OMC

The oedometer test results in **Figure *4.9*** show that subbase soils tested at natural moisture content exhibited medium to high collapse potential, with values exceeding 3% under higher applied stresses. This indicates severe susceptibility to hydro-consolidation when these soils become saturated under load. In contrast, samples compacted at optimum moisture content showed collapse potentials below 2%, demonstrating the effectiveness of proper compaction in reducing collapse risk.

The results highlight that collapse potential is stress-dependent and emphasize the importance of achieving OMC during construction to enhance subbase stability and prevent premature pavement failure.

4.4.1 Severity of Collapse Potential

Table 4.8: The severity of the collapse potential according to *(Jennings and Knight, 1975)* and ASTM (D5333-2003)

Jennings and Knight (1975)		ASTM (D5333-2003) standard	
Ic, (%) at σv=200 kPa	Severity of problem	Ic, (%) at σv=200 kPa	Degree of collapse
< 1	Negligible /No	< 2	Low/Slight
1-5	Moderate trouble	$2 \leq I_c < 6$	Moderate
5-10	Moderate to Severe	$6 \leq I_c < 10$	Moderately High
> 10	Severe trouble	> 10.0	High

4.5 Relationship between PI, MDD, CBR, PSD, and Collapsible Potential

The data in **Table 4.9:** At Natural Moisture Content and

Table 4.10: At Optimum Moisture Content below present the collapsible potential of various subbase soil samples under different applied pressures and at different parameters, both at natural moisture content (NMC) and optimum moisture content (OMC).

Table 4.9: At Natural Moisture Content

Sample Reference	Collapsible potential values at different Applied Pressure (kPa)				PI (%)	CBR (%)	MDD (kg/m^3)	PSD			
	100	**200**	**400**	**800**				**Gravel (%)**	**Sand (%)**	**Silty/Clay (%)**	**GM**
GK-01-NMC	0	1.01653	1.313135	1.749285	15.5	51	1940	47.6	28.4	24	1.863
GK-02-NMC	0	0.029098	0.347779	0.549951	12.1	45	1870	55.2	26.4	18.4	2.063
GK-03-NMC	0	0	0.095181	0.588612	13.8	42	1840	50.6	23.1	26.3	1.897
SSB-01-NMC	0	1.358342	1.713678	2.449115	14.8	38	1880	43.2	25.1	31.7	1.667
SSB-02-NMC	0	1.227851	2.004522	3.379429	15.8	42	1870	57.9	21	21.1	2.095
SSB-03-NMC	0	1.232062	2.508568	3.891606	13.7	38	1920	47.6	24	28.4	1.84
KMN-01-NMC	0	0	0.14908	3.50596	13	47	2002	56.6	24.1	19.3	2.078
KMN-02-NMC	0	0.427147	0.634092	0.78068	14.5	40	1780	47.7	23.3	29	1.781
KMN-03-NMC	0	0.700316	0.909216	1.243033	15.3	48	2002	39.2	35	25.8	1.708

Table 4.10: At Optimum Moisture Content

Sample Reference	Collapsible potential values at different Applied Pressure (kPa)				PI (%)	CBR (%)	MDD (kg/m^3)	PSD			
	100	**200**	**400**	**800**				**Gravel (%)**	**Sand (%)**	**Silty/Clay (%)**	**GM**
GK-01-OMC	0	0.403355	0.763155	1.203637	15.5	51	1940	47.6	28.4	24	1.863
GK-02-OMC	0	0.008244	0.027375	0.022385	12.1	45	1870	55.2	26.4	18.4	2.063
GK-03-OMC	0	0	0	0.188685	13.8	42	1840	50.6	23.1	26.3	1.897
SSB-01-OMC	0	0.967281	1.536851	1.473195	14.8	38	1880	43.2	25.1	31.7	1.667
SSB-02-OMC	0	1.118257	1.53777	1.675378	15.8	42	1870	57.9	21	21.1	2.095
SSB-03-OMC	0	1.119563	1.539028	1.930598	13.7	38	1920	47.6	24	28.4	1.84
KMN-01-OMC	0	0	0.38931	0.454664	13	47	2002	56.6	24.1	19.3	2.078
KMN-02-OMC	0	0.367263	0.422882	0.707492	14.5	40	1780	47.7	23.3	29	1.781
KMN-03-OMC	0	0.556796	0.74008	0.902895	15.3	48	2002	39.2	35	25.8	1.708

4.5.1 Natural Moisture Content (NMC)

At NMC, the collapsible potential of the soils generally increased with applied pressure. Samples like SSB-03-NMC and SSB-02-NMC showed significant collapsibility at higher pressures, reaching values of 3.891606% and 3.379429% at 800 kPa, respectively. This trend was consistent across soils with higher Plasticity Index (PI) and lower California Bearing Ratio (CBR), indicating that more plastic and weaker soils tended to collapse more under load. The Maximum Dry Density (MDD) and Particle Size Distribution (PSD) also showed influence on collapsibility, with higher MDD and gravel content generally leading to lower collapsible potential.

4.5.2 Optimum Moisture Content (OMC)

At OMC, the collapsible potential of the soils was significantly reduced across all samples. For example, GK-02-OMC showed minimal collapsibility even at 800 kPa, with a value of only 0.022385%, compared to its NMC counterpart. The reduction in collapsibility at OMC was likely due to the increased soil density and cohesion, which improves the soil's resistance to structural failure. Even samples with higher PI and lower CBR, such as SSB-02-OMC, exhibited much lower collapsible potential compared to their NMC values.

4.5.3 Comparison

Overall, the collapsible potential of soils was much lower at OMC than at NMC. This indicated that achieving optimum moisture content during soil compaction can significantly enhance soil stability and reduce the risk of collapse under load. The correlations observed at NMC between collapsibility, PI, CBR, MDD and PSD still held at OMC, but the magnitudes of collapsibility were generally lower, reflecting the improved soil properties at OMC.

This analysis highlighted the importance of moisture content control in construction and geotechnical applications to ensure soil stability and minimize potential collapsibility.

4.6 Collapsible Potential results at 200 kPa versus its severity

Table 4.11: Severity of collapse at 200 kPa

Sample Reference	Collapsible potential values		Severity	
	100	**200**	**Jennings and Knight, 1975**	**ASTM (D5333-2003) standard**
GK-01-NMC	0	1.01653	Moderate Trouble	Low/Slight
GK-01-OMC	0	0.403355	Negligible/ No Trouble	Low/Slight
GK-02-NMC	0	0.029098	Negligible/ No Trouble	Low/Slight
GK-02-OMC	0	0.008244	Negligible/ No Trouble	Low/Slight
GK-03-NMC	0	0	Negligible/ No Trouble	Low/Slight
GK-03-OMC	0	0	Negligible/ No Trouble	Low/Slight
SSB-01-NMC	0	1.358342	Moderate Trouble	Low/Slight
SSB-01-OMC	0	0.967281	Negligible/ No Trouble	Low/Slight
SSB-02-NMC	0	1.227851	Moderate Trouble	Low/Slight
SSB-02-OMC	0	1.118257	Moderate Trouble	Low/Slight
SSB-03-NMC	0	1.232062	Moderate Trouble	Low/Slight

Sample Reference	Collapsible potential values		Severity	
	100	**200**	**Jennings and Knight, 1975**	**ASTM (D5333-2003) standard**
SSB-03-OMC	0	1.119563	Moderate Trouble	Low/Slight
KMN-01-NMC	0	0	Negligible/ No Trouble	Low/Slight
KMN-01-OMC	0	0	Negligible/ No Trouble	Low/Slight
KMN-02-NMC	0	0.427147	Negligible/ No Trouble	Low/Slight
KMN-02-OMC	0	0.367263	Negligible/ No Trouble	Low/Slight
KMN-03-NMC	0	0.700316	Negligible/ No Trouble	Low/Slight
KMN-03-OMC	0	0.556796	Negligible/ No Trouble	Low/Slight

The assessment of collapse potential for the various soil samples revealed that most samples exhibited a low risk of collapse. Under both NMC and OMC conditions, the majority of samples fell within the "Negligible/No Trouble" category according to (Jennings and Knight, 1975) and were classified as "Low/Slight" according to the ASTM D5333-03 (2003) standard. However, a few samples under NMC conditions, such as GK-01, SSB-01, SSB-02, and SSB-03, showed a "Moderate Trouble" classification by Jennings and Knight (1975), though they still remained in the "Low/Slight" category under the ASTM standard. Overall, the soils were considered stable with minimal collapse risk.

4.7 Collapse Potential at 400 kPa and 800 kPa

Table 4.12: Severity of collapse at 400 kPa and 800 kPa

Sample Reference	Collapse potential values (%)		Severity			
	400 kPa	800 kPa	Jennings and Knight, 1975 at 400 kPa	ASTM (D5333-2003) standard at 400 kPa	Jennings and Knight, 1975 at 800 kPa	ASTM (D5333-2003) standard at 800 kPa
GK-01-NMC	1.313135	1.749285	Moderate Trouble	Low/Slight	Moderate Trouble	Low/Slight
GK-01-OMC	0.763155	1.203637	Negligible/ No Trouble	Low/Slight	Moderate Trouble	Low/Slight
GK-02-NMC	0.347779	0.549951	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight
GK-02-OMC	0.027375	0.022385	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight
GK-03-NMC	0.095181	0.588612	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight
GK-03-OMC	0	0.188685	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight
SSB-01-NMC	1.713678	2.449115	Moderate Trouble	Low/Slight	Moderate Trouble	Moderate
SSB-01-OMC	1.536851	1.473195	Moderate Trouble	Low/Slight	Moderate Trouble	Low/Slight
SSB-02-NMC	2.004522	3.379429	Moderate Trouble	Moderate	Moderate Trouble	Moderate
SSB-02-OMC	1.53777	1.675378	Moderate Trouble	Low/Slight	Moderate Trouble	Low/Slight

SSB-03-NMC	2.508568	3.891606	Moderate Trouble	Moderate	Moderate Trouble	Moderate
SSB-03-OMC	1.539028	1.930598	Moderate Trouble	Low/Slight	Moderate Trouble	Low/Slight
KMN-01-NMC	0.14908	0.350596	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight
KMN-01-OMC	0.38931	0.454664	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight
KMN-02-NMC	0.634092	0.78068	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight
KMN-02-OMC	0.422882	0.707492	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight
KMN-03-NMC	0.909216	1.243033	Negligible/ No Trouble	Low/Slight	Moderate Trouble	Low/Slight
KMN-03-OMC	0.74008	0.902895	Negligible/ No Trouble	Low/Slight	Negligible/ No Trouble	Low/Slight

The results showed that while assessing collapse potential at 200 kPa was standard, evaluating soils at higher pressures, such as 400 kPa and 800 kPa, is critical for road design in the Greater Kampala Metropolitan Area (GKMA). For instance, samples like SSB-02-NMC and SSB-03-NMC exhibited "Moderate Trouble" under 400 kPa and escalated to higher collapse potential under 800 kPa, according to Jennings and Knight (1975). This trend underscores the need to design road structures that can handle these higher pressures, as roads in the GKMA frequently face heavy traffic and large vehicle loads that exert significant stress on subbases and subgrades. By considering these higher pressures, engineers could enhance the safety, structural integrity and longevity of roads, particularly in areas where soil conditions are variable and may be more susceptible to collapse under heavy loads.

4.8 Suitable recommendations for improvements

4.8.1 Rigorous Material Selection

Since soils with higher fines content and lower CBR values showed greater collapse at NMC, there is need to implement stringent material classification protocols, encompassing comprehensive physical-mechanical and chemical tests, to ensure that only materials meeting the required specifications are used as subbase materials. Prioritizing materials with low fine content and high California Bearing Ratio (CBR) values to reduce the risk of collapse (AL-Rawas, 2000).

4.8.2 Compaction and Density Control

The test results demonstrated that samples compacted at OMC performed significantly better, with collapse potentials below 2%. Therefore, there is need to ensure optimal compaction during construction by enforcing strict quality control measures to achieve consistent Maximum Dry Density (MDD) across the site. This would significantly enhance the load-bearing capacity and stability of the subbase, mitigating the risks associated with hydro-consolidation (Mansour *et al.*, 2008).

4.8.3 Effective Drainage and Moisture Management

Collapse was triggered when soils were saturated. Therefore, there is need to design and implement robust drainage systems to prevent water infiltration into the subbase layer, particularly in areas prone to hydro-consolidation. Moisture control measures, such as geotextiles and sub-surface drainage should be incorporated to maintain the integrity of the subbase material under varying environmental conditions (Zornberg *et al.*, 2017; Das, 2021).

4.8.4 Use of Soil Stabilizers

For subbase materials with identified collapse potential, the application of soil stabilizers like lime or cement should be considered. These stabilizers could reduce susceptibility to hydro-consolidation and enhance the overall performance of the subbase (Puppala, 2016; Adjabi, Nouaouria and Djebabla, 2021).

4.8.5 Regular Monitoring and Preventive Maintenance

Since the study established that collapse susceptibility varies with compaction condition and stress levels, regular monitoring of road conditions, especially in areas where the subbase materials have shown higher collapse potential should be conducted. Preventive maintenance strategies to address early signs of distress should be implemented, ensuring long-term road durability (Tran *et al.*, 2025).

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This study evaluated the impact of hydro-consolidation on the stability of subbase materials in the Greater Kampala Metropolitan Area, analyzing soil samples from three roads. Through classification, compaction, CBR and double oedometer tests, the research assessed the collapsible potential of these materials, conclusions were made together with recommendations for enhancing road construction practices.

5.2 Summary of the Dissertation

This dissertation investigated the collapse potential of subbase materials within the Greater Kampala Metropolitan Area (GKMA), where tropical climatic conditions and heavy traffic loads pose significant risks to road durability. The study commenced by establishing the background and significance of soil collapse in tropical regions, identifying critical gaps in existing research. A comprehensive methodology was employed, incorporating physical and mechanical tests (Maximum Dry Density, California Bearing Ratio, Atterberg Limits, and Particle Size Distribution), chemical analyses (chloride, sulphate, and pH content), and oedometer testing under wetting conditions to simulate hydro-consolidation.

The results indicated that subbase soils compacted at natural moisture content exhibited medium to high collapse potential, whereas soils compacted at optimum moisture content displayed negligible collapse potential. These findings underscore the critical influence of compaction quality and applied stress levels on soil behavior. The dissertation concludes with practical recommendations, including rigorous material selection, strict density control, improved drainage, soil stabilization, and ongoing monitoring. Collectively, the study provides actionable insights for enhancing pavement performance and durability in Uganda's tropical environment.

5.3 Conclusions

These conclusions highlight the critical need for careful material selection, thorough compaction, and effective moisture control to ensure the stability and durability of road subbase materials in areas prone to hydro-consolidation.

5.3.1 Suitability of Existing Subbase Materials

The subbase materials from the studied roads met the physical requirements stipulated in the General Specifications for Roads and Bridge Works (MoWT, 2010), including adequate Maximum Dry Density (MDD), California Bearing Ratio (CBR) above 30%, Atterberg Limits within acceptable ranges and Particle Size Distribution (PSD). Chemical tests further confirmed compliance, with Chloride Content, Sulphate Content, and pH values within permissible limits. Despite these satisfactory results, certain materials exhibited properties that could compromise stability under hydro-consolidation, especially in wet conditions.

5.3.2 Collapse Potential of Subbase Materials

The conventional oedometer tests revealed varying degrees of collapse potential across the materials, with significant concerns under wetting conditions typical of high groundwater areas or poor drainage. The collapse potential values for low-capacity roads indicated negligible risks, aligning with standards from Jennings and

Knight (1975) and ASTM D5333 (2003). However, for high-capacity roads, the collapse potential in tropical regions presented a substantial risk, potentially affecting the design life and long-term stability of the pavement.

5.3.3 Impact of Hydro-Consolidation

Hydro-consolidation was found to significantly influence the stability of subbase materials, particularly those with higher fine content and suboptimal compaction levels. The study highlighted the critical need for proper material selection, precise moisture control and effective drainage systems to mitigate the risks associated with hydro-consolidation, especially in high-volume traffic roads. Failure to prepare the subbase at the correct moisture levels and densities could exacerbate the collapse potential, leading to early pavement failure.

5.4 Limitations of the Study

Despite its contributions, the study has several limitations. First, the experimental program was confined to subbase materials from selected sites within the GKMA, which may limit the generalizability of the findings to other regions of Uganda. Second, the oedometer tests applied a maximum stress of 800 kPa, which, while substantial, may not fully represent extreme axle loads experienced on heavily trafficked roads. Third, laboratory testing cannot entirely replicate long-term field conditions, particularly the combined effects of rainfall, drainage performance, and repeated traffic loading. Finally, the study focused primarily on hydro-consolidation, whereas other factors contributing to road failures such as construction practices and maintenance regimes were outside the scope of this research.

5.5 Recommendations

These recommendations aim to provide a comprehensive approach to mitigating the impact of hydro-consolidation on-road stability, ensuring safer and more durable infrastructure. Based on the findings of this research, the following recommendations are proposed to enhance the stability and longevity of road subbase materials, particularly in regions susceptible to hydro-consolidation:

5.5.1 Evaluation of Subbase Materials under Higher Applied Stresses

There is need to evaluate subbase materials under higher applied stresses during laboratory testing to better simulate actual traffic loads. In this study, the maximum load applied in the oedometer tests was 800kPa; however, typical traffic loads on the road may exceed this value. Testing under higher stresses could provide a more realistic assessment of collapse potential, ensuring that laboratory results closely reflect field conditions and offering a more reliable basis for pavement design.

5.5.2 Further Research Beyond the Greater Kampala Metropolitan Area

There is need for further investigations of subbase materials beyond the Greater Kampala Metropolitan Area. Expanding the study to other regions could determine whether the collapse behaviors observed here are locally specific or representative of wider geological conditions, and could support development of region-specific material selection and treatment guidelines.

5.5.3 Further Research on Factors Leading to Recurring Road Failures

There is need for further research into the underlying factors that contribute to recurring road failures. While this study focused on the collapse potential of subbase materials, other aspects such as drainage efficiency, construction practices, traffic loading, and maintenance strategies should further be investigated to establish a more comprehensive understanding of road deterioration mechanisms.

5.5.4 Further Research and Testing

Further research into advanced methods for predicting hydro-consolidation behavior in subbase materials and the long-term performance of stabilized materials under different environmental conditions should be encouraged. Additionally, there should be mandatory collapse potential tests for all soil materials used in road construction, especially in equatorial regions where seasonal waterlogging may occur.

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APPENDIX

Appendix A: Particle Size Distribution

Table A. 1: PSD test results for the three roads at the different chainages

Sample Ref. No.	GK -01	GK -02	GK -03	KMN -01	KMN -02	KMN -03	SSB -01	SSB -02	SSB -03
Chainage	4+300	6+400	8+000	1+050	1+800	2+320	0+400	0+800	2+450
Side	LHS	RHS	LHS	LHS	LHS	RHS	LHS	LHS	RHS
Sieve Sizes	Percent Passing Sieve (mm)								
75	100	100	100	100	100	100	100	100	100
50	100	100	100	100	100	100	100	100	100
37.5	100	100	100	100	96.0	100	100	100	100
28	100	90.0	100	100	90.8	100	95.6	94.5	97.1
20	90.5	83.2	87.2	94.1	88.0	100	93.3	93.5	92.4
14	85.4	77.8	79.3	87.3	85.0	98.6	89.5	88.3	87.9
10	79.6	70.6	71.4	78.4	79.1	94.0	85.1	82.8	85.0
6.3	70.7	61.3	65.6	66.1	71.0	85.7	77.0	70.6	77.6
5	66.2	57.4	63.6	59.8	61.9	75.8	71.6	62.4	69.4
2	52.4	44.8	49.4	43.4	52.3	60.8	56.8	42.1	52.4
1.18	46.6	39.1	43.8	37.3	47.6	51.3	52.2	35.3	44.6
0.6	40.5	33.4	38.4	31.8	44.3	46.0	47.9	29.2	36.8
0.425	37.3	30.6	34.7	29.5	40.6	42.6	44.8	27.3	35.1
0.3	33.8	27.7	33.7	27.2	35.1	39.2	41.9	25.9	32.6
0.15	26.6	21.0	27.4	22.2	30.2	29.4	34.4	23.0	29.7
0.075	24.0	18.4	26.3	19.3	29.0	25.8	31.7	21.1	28.4
GM	1.863	2.063	1.897	2.078	1.781	1.708	1.667	2.095	1.84

Table A. 2: Average particle size distribution of each of the three roads

Sieve size (mm)	**SSB**	**KMN**	**GK**
	% Passing	% Passing	% Passing
75	100	100	100
50	100	100	100
37.5	100	98.7	100
28	95.6	96.9	96.8
20	93.1	94.2	86.9
14	88.6	90.7	80.6
10	84.2	84.3	73.5
6.3	74.8	74.9	65.7
5	67.4	66.4	62.4
2	49.9	52.7	48.8
1.18	43.4	45.9	43.1
0.600	37.3	41.2	37.4
0.425	35.2	38.0	34.1
0.300	32.9	34.2	31.8
0.150	28.6	27.6	25.1
0.075	26.6	24.9	23.0
GM	**1.883**	**1.843**	**1.940**

Appendix B: Atterberg Limits

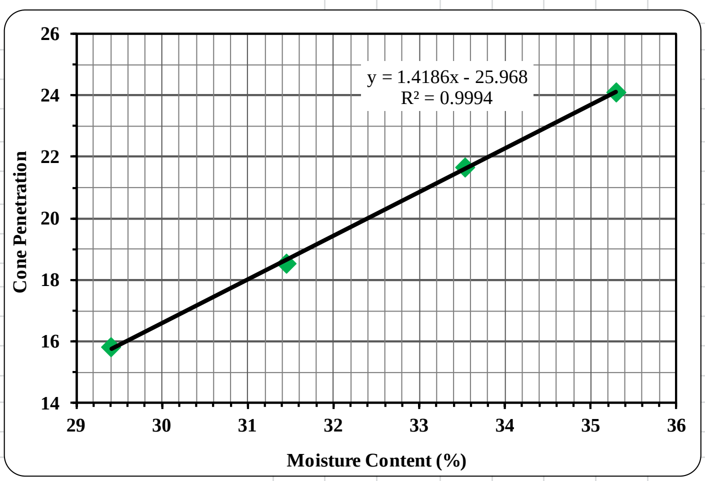
Table B. 1: GK-01 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	GK-01	**Testing Date:**	16/Oct/23
Depth (m):	0.215-0.415	**Location**	KM: 4+300 LHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								**PLASTIC LIMIT**		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.81	15.81	18.53	18.53	21.67	21.67	24.10	24.10			
Average penetration mm	15.8		18.5		21.7		24.1				
Container No.	**AM**	**140**	**53**	**190**	**AH**	**B9**	**127**	**125**	**105**	**SG3**	
Mass of wet soil + container (a)	30.44	30.10	32.60	32.98	34.60	34.98	36.27	36.13	24.76	24.53	
Mass of dry soil + container (b)	26.63	26.34	28.05	28.17	29.28	29.65	30.34	30.32	23.04	22.90	
Mass of container (c)	13.69	13.54	13.56	12.90	13.43	13.74	13.54	13.86	12.84	13.30	
Mass of moisture (d = a-b)	3.81	3.76	4.55	4.81	5.32	5.33	5.93	5.81	1.72	1.63	
Mass of dry soil (e = b-c)	12.94	12.80	14.49	15.27	15.85	15.91	16.80	16.46	10.20	9.60	
Moisture content (w =100X(d)/(e)	29.44	29.38	31.40	31.50	33.56	33.50	35.30	35.30	16.86	16.98	
Average Moisture content	29.4		31.5		33.5		35.3		16.9		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		^oC
c) washed on 0.425 mm		
d) oven dried	105-110	^oC
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	32.4	%
Plastic limit		
PL	16.9	%
Plastic Index		
PI	15.5	%

LINEAR SHRINKAGE

Initial length $L_{o,}$ mm	139.9	mm	Oven-dried length $L_{D\,,}$ mm	128.9	mm
Linear shrinkage, LS = $100X(1-L_D/L_o)$ %	7.9	%	Shrinkage Product, SP=LSX %<425 µm	0	

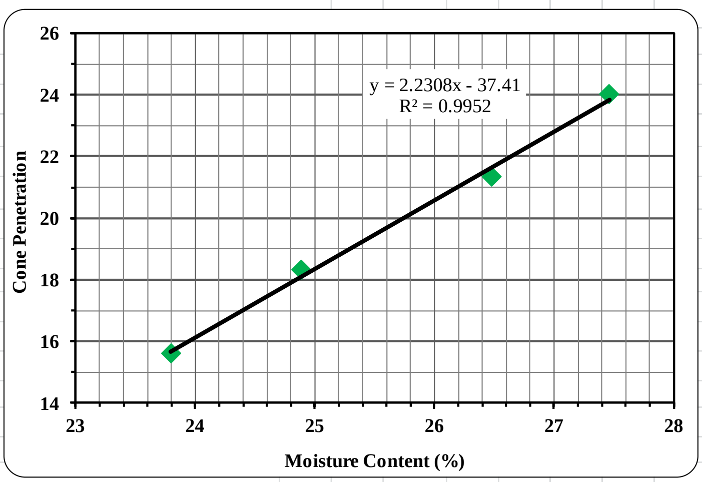
Table B. 2: GK-02 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	GK-02	**Testing Date:**	16/Oct/23
Depth (m):	0.215-0.415	**Location**	KM: 6+400 RHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								**PLASTIC LIMIT**		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.61	15.61	18.32	18.32	21.33	21.33	24.03	24.03			
Average penetration mm	15.6		18.3		21.3		24.0				
Container No.	**NW**	**152**	**BM7**	**102**	**113**	**103**	**177**	**142**	**BD**	**26**	
Mass of wet soil + container (a)	30.96	30.15	32.71	32.32	34.67	34.65	36.31	36.13	24.51	24.54	
Mass of dry soil + container (b)	27.50	26.80	28.90	28.35	30.12	30.12	31.29	31.28	23.16	23.09	
Mass of container (c)	12.95	12.73	13.55	12.44	12.96	12.99	13.04	13.59	13.17	12.52	
Mass of moisture (d = a-b)	3.46	3.35	3.81	3.97	4.55	4.53	5.02	4.85	1.35	1.45	
Mass of dry soil (e = b-c)	14.55	14.07	15.35	15.91	17.16	17.13	18.25	17.69	9.99	10.57	
Moisture content (w =100X(d)/(e)	23.78	23.81	24.82	24.95	26.52	26.44	27.51	27.42	13.51	13.72	
Average Moisture content	23.8		24.9		26.5		27.5		13.6		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		°C
c) washed on 0.425 mm		
d) oven dried	105-110	°C
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	25.7	%
Plastic limit		
PL	13.6	%
Plastic Index		
PI	12.1	%

LINEAR SHRINKAGE

Initial length $L_{o,}$ mm	140	mm	Oven-dried length $L_{D\,,}$ mm	131.1	mm
Linear shrinkage, LS = 100X(1-L_D/L_o) %	6.0	%	Shrinkage Product, SP=LSX %<425 μm	0	

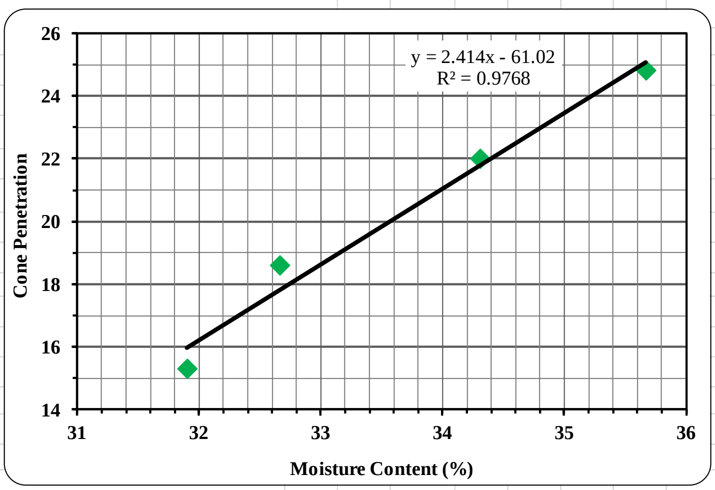
Table B. 3: GK-03 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	GK-03	**Testing Date:**	16/Oct/23
Depth (m):	0.215-0.415	**Location**	KM: 8+000 LHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								**PLASTIC LIMIT**		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.30	15.30	18.60	18.60	22.00	22.00	24.80	24.80			
Average penetration mm	15.3		18.6		22.0		24.8				
Container No.	PI56	PII2	BE	PIBB	P157	IA	P146	600	JN	RAD	
Mass of wet soil + container (a)	65.79	61.98	62.92	62.92	63.75	63.07	58.97	64.40	49.71	48.32	
Mass of dry soil + container (b)	51.59	48.64	49.19	49.14	49.26	48.83	45.39	49.36	45.15	44.05	
Mass of container (c)	7.09	6.81	7.19	6.92	7.02	7.33	7.35	7.16	22.44	21.99	
Mass of moisture (d = a-b)	14.20	13.34	13.73	13.78	14.49	14.24	13.58	15.04	4.56	4.27	
Mass of dry soil (e = b-c)	44.50	41.83	42.00	42.22	42.24	41.50	38.04	42.20	22.71	22.06	
Moisture content (w =100X(d)/(e)	31.91	31.89	32.69	32.64	34.30	34.31	35.70	35.64	20.08	19.36	
Average Moisture content	31.9		32.7		34.3		35.7		19.7		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		°C
c) washed on 0.425 mm		
d) oven dried	105-110	°C
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	33.6	%
Plastic limit		
PL	19.7	%
Plastic Index		
PI	13.8	%

LINEAR SHRINKAGE

Initial length L_o, mm	140	mm	Oven-dried length L_D, mm	130	mm
Linear shrinkage, LS = 100X(1-L_D/L_o) %	6.8	%	Shrinkage Product, SP=LSX %<425 μm	0	

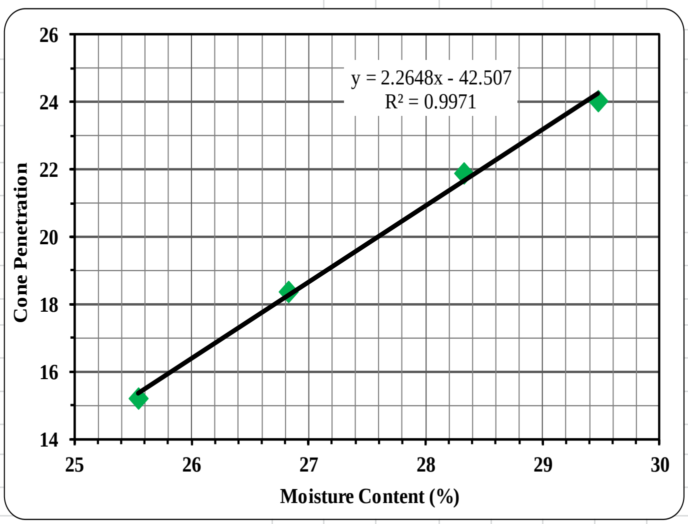
Table B. 4: KMN-01 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	KMN-01	**Testing Date:**	16/Oct/23
Depth (m):	0.250 -0.450	**Location**	KM: 1+050 LHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								**PLASTIC LIMIT**		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.20	15.20	18.38	18.38	21.88	21.88	24.04	24.04			
Average penetration mm	15.2		18.4		21.9		24.0				
Container No.	**128**	**36**	**29**	**16**	**87**	**WT**	**SG2**	**T7**	**96**	**222**	
Mass of wet soil + container (a)	30.94	30.59	32.33	32.59	34.34	34.51	36.58	36.87	24.09	24.02	
Mass of dry soil + container (b)	27.18	26.98	28.18	28.34	29.41	29.82	31.08	31.38	22.67	22.59	
Mass of container (c)	12.45	12.86	12.68	12.53	11.98	13.29	12.36	12.81	12.82	12.98	
Mass of moisture (d = a-b)	3.76	3.61	4.15	4.25	4.93	4.69	5.50	5.49	1.42	1.43	
Mass of dry soil (e = b-c)	14.73	14.12	15.50	15.81	17.43	16.53	18.72	18.57	9.85	9.61	
Moisture content (w =100X(d)/(e)	25.53	25.57	26.77	26.88	28.28	28.37	29.38	29.56	14.42	14.88	
Average Moisture content	25.5		26.8		28.3		29.5		14.6		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		°C
c) washed on 0.425 mm		
d) oven dried	105-110	°C
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	27.6	%
Plastic limit		
PL	14.6	%
Plastic Index		
PI	13.0	%

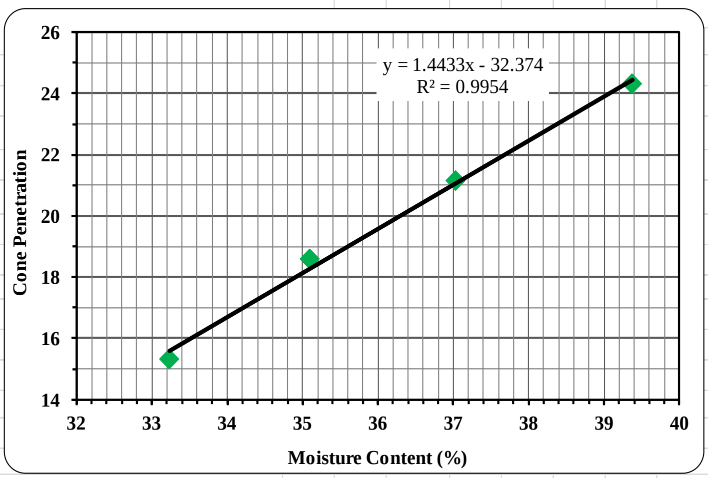
Table B. 5: KMN-02 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	KMN-02	**Testing Date:**	16/Oct/23
Depth (m):	0.250 -0.450	**Location**	KM: 1+800 LHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								**PLASTIC LIMIT**		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.33	15.33	18.61	18.61	21.15	21.15	24.31	24.31			
Average penetration mm	15.3		18.6		21.2		24.3				
Container No.	**55**	**129**	**148**	**68**	**L9**	**145**	**49**	**KB**	**SG8**	**154**	
Mass of wet soil + container (a)	30.68	30.56	32.13	32.33	34.70	34.52	36.41	36.98	25.13	25.41	
Mass of dry soil + container (b)	26.34	26.27	26.93	27.13	28.91	28.79	29.98	30.13	22.98	23.07	
Mass of container (c)	13.29	13.35	12.09	12.34	13.23	13.36	13.55	12.84	12.61	12.86	
Mass of moisture (d = a-b)	4.34	4.29	5.20	5.20	5.79	5.73	6.43	6.85	2.15	2.34	
Mass of dry soil (e = b-c)	13.05	12.92	14.84	14.79	15.68	15.43	16.43	17.29	10.37	10.21	
Moisture content (w =100X(d)/(e)	33.26	33.20	35.04	35.16	36.93	37.14	39.14	39.62	20.73	22.92	
Average Moisture content	33.2		35.1		37.0		39.4		21.8		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		°C
c) washed on 0.425 mm		
d) oven dried	105-110	°C
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	36.3	%
Plastic limit		
PL	21.8	%
Plastic Index		
PI	14.5	%

LINEAR SHRINKAGE

Initial length L_o, mm	140.1	mm	Oven-dried length L_D, mm	129.3	mm
Linear shrinkage, LS = 100X(1-L_D/L_o) %	7.7	%	Shrinkage Product, SP=LSX %<425 µm	0	

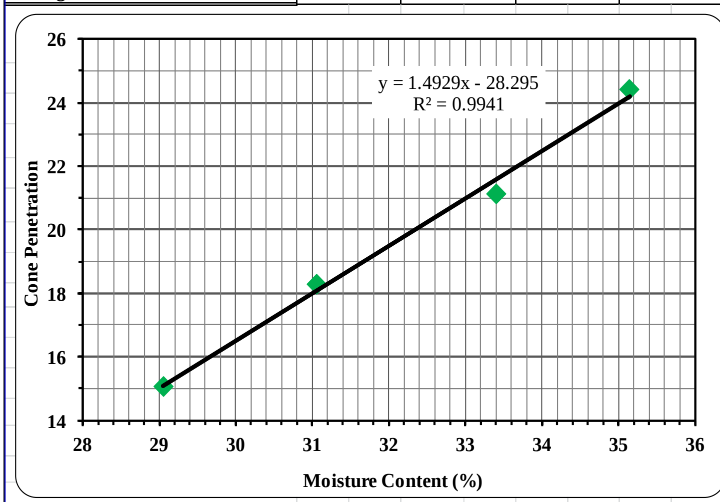
Table B. 6: KMN-03 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	KMN-03	**Testing Date:**	16/Oct/23
Depth (m):	0.250 -0.450	**Location**	KM: 2+320 RHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								PLASTIC LIMIT		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.06	15.06	18.27	18.27	21.14	21.14	24.41	24.41			
Average penetration mm	15.1		18.3		21.1		24.4				
Container No.	**60**	**BH8**	**T6**	**134**	**B9**	**X6**	**189**	**167**	**56**	**MM**	
Mass of wet soil + container (a)	30.65	30.81	32.83	32.53	34.61	34.27	36.15	36.10	24.24	24.87	
Mass of dry soil + container (b)	26.67	26.94	28.39	27.99	29.33	29.09	30.06	30.22	22.49	23.18	
Mass of container (c)	13.01	13.58	14.10	13.36	13.50	13.60	12.70	13.52	12.21	13.29	
Mass of moisture (d = a-b)	3.98	3.87	4.44	4.54	5.28	5.18	6.09	5.88	1.75	1.69	
Mass of dry soil (e = b-c)	13.66	13.36	14.29	14.63	15.83	15.49	17.36	16.70	10.28	9.89	
Moisture content (w =100X(d)/(e)	29.14	28.97	31.07	31.03	33.35	33.44	35.08	35.21	17.02	17.09	
Average Moisture content	29.1		31.1		33.4		35.1		17.1		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		°C
c) washed on 0.425 mm		
d) oven dried	105-110	°C
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	32.3	%
Plastic limit		
PL	17.1	%
Plastic Index		
PI	15.3	%

LINEAR SHRINKAGE

Initial length L_o, mm	139.4	mm	Oven-dried length L_D, mm	129	mm
Linear shrinkage, LS = 100X(1-L_D/L_o) %	7.5	%	Shrinkage Product, SP=LSX %<425 µm	0	

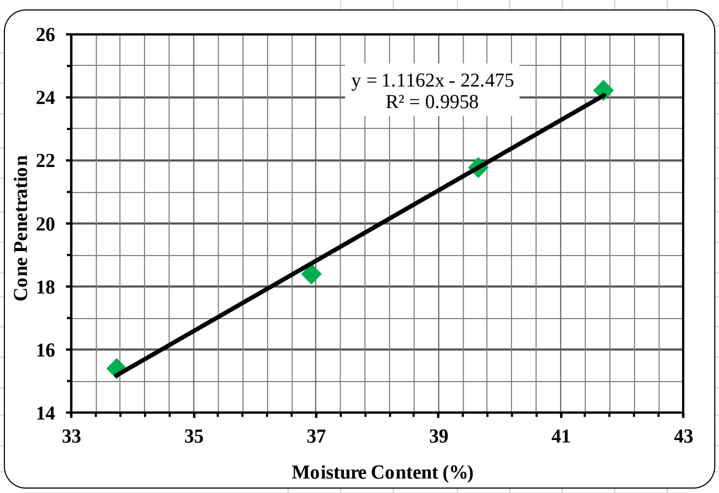
Table B. 7: SSB-01 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	SSB-01	**Testing Date:**	16/Oct/23
Depth (m):	0.250 -0.450	**Location**	KM: 0+400 LHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								**PLASTIC LIMIT**		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.39	15.39	18.40	18.40	21.76	21.76	24.23	24.23			
Average penetration mm	15.4		18.4		21.8		24.2				
Container No.	**19**	**75**	**59**	**132**	**TN**	**AC**	**78**	**41**	**BM6**	**160**	
Mass of wet soil + container (a)	30.49	30.21	32.48	32.53	34.39	34.58	36.37	36.43	23.53	23.45	
Mass of dry soil + container (b)	26.05	25.96	27.32	27.30	28.33	28.39	29.48	29.38	21.40	21.48	
Mass of container (c)	12.92	13.33	13.35	13.13	13.06	12.77	12.96	12.47	12.28	12.98	
Mass of moisture (d = a-b)	4.44	4.25	5.16	5.23	6.06	6.19	6.89	7.05	2.13	1.97	
Mass of dry soil (e = b-c)	13.13	12.63	13.97	14.17	15.27	15.62	16.52	16.91	9.12	8.50	
Moisture content (w =100X(d)/(e)	33.82	33.65	36.94	36.91	39.69	39.63	41.71	41.69	23.36	23.18	
Average Moisture content	33.7		36.9		39.7		41.7		23.3		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		°C
c) washed on 0.425 mm		
d) oven dried	105-110	°C
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	38.1	%
Plastic limit		
PL	23.3	%
Plastic Index		
PI	14.8	%

LINEAR SHRINKAGE

Initial length L_o, mm	140	mm	Oven-dried length L_D, mm	129.9	mm
Linear shrinkage, LS = 100X(1-L_D/L_o) %	7.2	%	Shrinkage Product, SP=LSX %<425 µm	0	

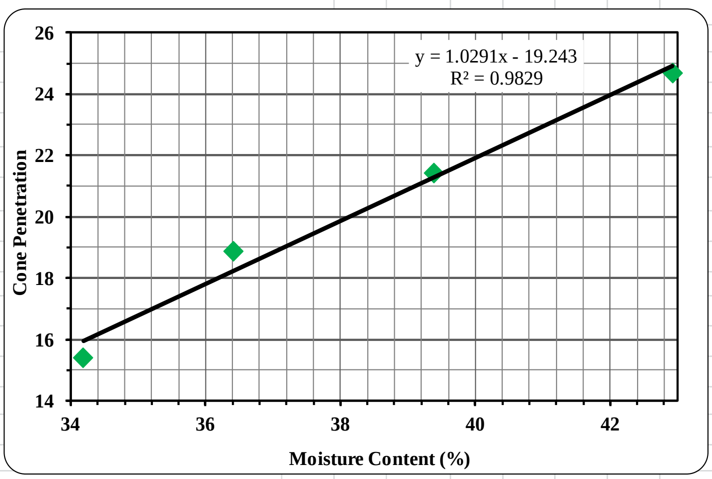
Table B. 8: SSB-02 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	SSB-02	**Testing Date:**	16/Oct/23
Depth (m):	0.250 -0.450	**Location**	KM: 0+800 LHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								**PLASTIC LIMIT**		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.40	15.40	18.88	18.88	21.43	21.43	24.68	24.68			
Average penetration mm	15.4		18.9		21.4		24.7				
Container No.	**63**	**90**	**63**	**22**	**80**	**86**	**BH7**	**187**	**164**	**176**	
Mass of wet soil + container (a)	30.07	30.44	32.74	32.88	34.08	34.91	36.67	36.43	22.41	22.84	
Mass of dry soil + container (b)	25.77	26.15	27.38	27.73	28.23	28.82	29.73	29.32	20.49	20.84	
Mass of container (c)	13.35	13.44	12.71	13.54	13.26	13.48	13.39	12.92	11.94	11.80	
Mass of moisture (d = a-b)	4.30	4.29	5.36	5.15	5.85	6.09	6.94	7.11	1.92	2.00	
Mass of dry soil (e = b-c)	12.42	12.71	14.67	14.19	14.97	15.34	16.34	16.40	8.55	9.04	
Moisture content (w =100X(d)/(e)	34.62	33.75	36.54	36.29	39.08	39.70	42.49	43.35	22.46	22.12	
Average Moisture content	34.2		36.4		39.4		42.9		22.3		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		°C
c) washed on 0.425 mm		
d) oven dried	105-110	°C
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	38.1	%
Plastic limit		
PL	22.3	%
Plastic Index		
PI	15.8	%

LINEAR SHRINKAGE

Initial length L_o, mm	140.2	mm	Oven-dried length L_D, mm	129.6	mm
Linear shrinkage, LS = 100X(1-L_D/L_o) %	7.6	%	Shrinkage Product, SP=LSX %<425 µm	0	

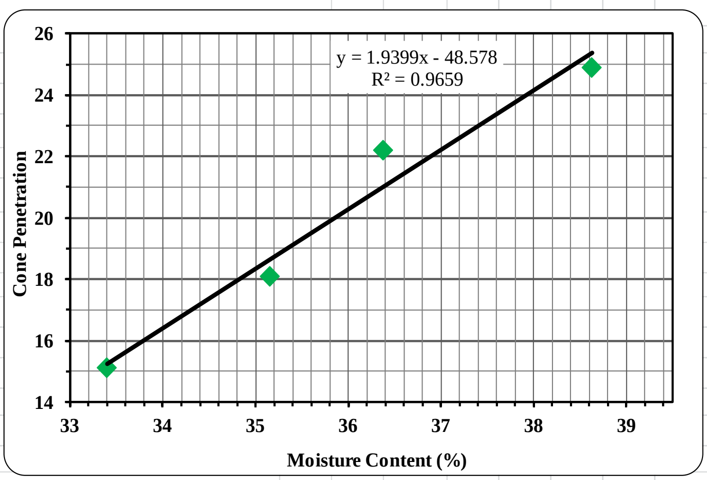
Table B. 9: SSB-03 Plasticity Index Results

DETERMINIATION OF LIQUID LIMIT & PLASTIC LIMIT

BS 1377-2:1990

Project:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
Task	Research Dissertation		
University	KYAMBOGO	**Faculty**	ENGINEERING
Sample Reference	SSB-03	**Testing Date:**	16/Oct/23
Depth (m):	0.250 -0.450	**Location**	KM: 2+450 RHS
Student	Mbwali Mary Christine	**Reg, No**	21/U/GMES/14326/PE

	LIQUID LIMIT								**PLASTIC LIMIT**		
TEST NO.	**1**		**2**		**3**		**4**		**1**	**2**	**Average**
Initial dial gauge reading mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Final dial gauge reading mm	15.10	15.10	18.00	18.20	22.30	22.10	25.00	24.80			
Average penetration mm	15.1		18.1		22.2		24.9				
Container No.	PI19	KO	P18	PI82	P133	PIBB	PD	PI6OO	DT	I3	
Mass of wet soil + container (a)	69.80	60.60	62.12	63.68	60.79	58.20	59.68	70.90	41.88	40.31	
Mass of dry soil + container (b)	54.26	47.34	47.83	49.15	46.57	44.69	45.16	53.25	38.55	37.07	
Mass of container (c)	7.08	6.99	6.77	7.03	7.04	6.94	6.92	7.15	22.76	22.45	
Mass of moisture (d = a-b)	15.54	13.26	14.29	14.53	14.22	13.51	14.52	17.65	3.33	3.24	
Mass of dry soil (e = b-c)	47.18	40.35	41.06	42.12	39.53	37.75	38.24	46.10	15.79	14.62	
Moisture content (w =100X(d)/(e)	32.94	32.86	34.80	34.50	35.97	35.79	37.97	38.29	21.09	22.16	
Average Moisture content	32.9		34.6		35.9		38.1		21.6		



Natural moisture content		
		%
Sample Preparation		
a) as received		
b) air dried		°C
c) washed on 0.425 mm		
d) oven dried	105-110	°C
e) unknown		
Proportion pasing 0.425 mm		
		%
Liquid limit;		
LL	35.4	%
Plastic limit		
PL	21.6	%
Plastic Index		
PI	13.7	%

LINEAR SHRINKAGE

Initial length L_o, mm	140.2	mm	Oven-dried length L_D, mm	130.5	mm
Linear shrinkage, LS = 100X(1-L_D/L_o) %	6.9	%	Shrinkage Product, SP=LSX %<425 µm	0	

Appendix C: Proctor Test Results

Table C. 1: MDD and OMC for the different three roads at different chainages

Sample Ref. No.	Location	Soil Description	Compaction	
			MDD (kg/m^3)	OMC (%)
GK-01	KM: 4+300 LHS	Gravel Subbase modified with CRR	1940	10.8
GK-02	KM: 6+400 RHS	Gravel Subbase modified with CRR	1870	16.0
GK-03	KM: 8+000 LHS	Gravel Subbase modified with CRR	1840	16.4
KMN-01	KM: 1+050 LHS	Gravel Subbase	2002	9.8
KMN-02	KM: 1+800 LHS	Gravel Subbase	1780	12.2
KMN-03	KM: 2+320 RHS	Gravel Subbase	2002	10.3
SSB-01	KM: 0+400 LHS	Silty Sandy Gravel Subbase	1880	14.6
SSB-02	KM: 0+800 LHS	Silty Sandy Gravel Subbase	1870	11.8
SSB-03	KM: 2+450 RHS	Gravel Subbase	1920	11

Table C. 2: Average MDD and OMC for each of the three roads

Sample Ref. No.	Source	Soil Description	Compaction	
			MDD (kg/m^3)	OMC (%)
GK	Gayaza-Kalagi Road	Gravel Subbase modified with CRR	1890	13.60
KMN	Kamapala-Mukono-Njeru Road	Gravel Subbase	1930	10.65
SSB	SilverSprings-Bweyogerere Road	Silty Sandy Gravel Subbase	1900	12.30

Table C. 3: GK-01 MDD and OMC Results

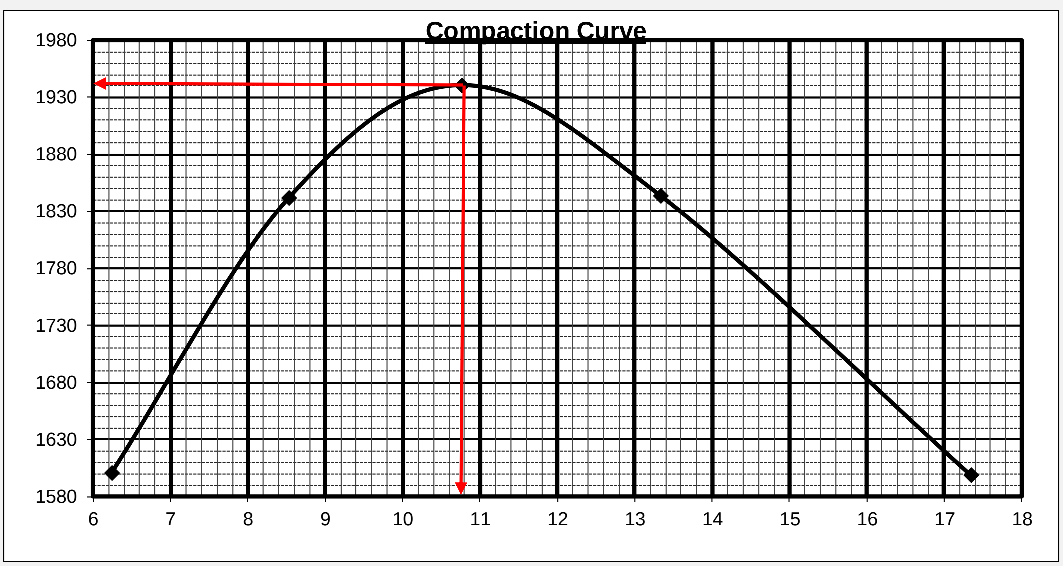
PROJECT:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
TASK:	Research Dissertation		

COMPACTION TEST
MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION
BS 1377: Part 4: 1990

UNIVERSITY:	KYAMBOGO	DEPARTMENT:	CIVIL AND BUILDING ENGINEERING
FACULTY:	ENGINEERING	STUDENT:	Mbwali Mary Christine
SAMPLE REFERENCE:	GK-01	Reg No.:	21/U/GMES/14326/PE
SAMPLE LOCATION:	KM: 4+300 LHS		
DEPTH (m):	0.215-0.415	TESTING DATE	11-Oct-23

Bulk density determination						
TEST No	UNIT	1	2	3	4	4
WATER ADDED, g	g	**0**	**105**	**225**	**345**	**465**
WEIGHT OF MOULD+SAMPLE	g	5038	5335	5485	5425	5213
WEIGHT OF MOULD	g	3345	3345	3345	3345	3345
WEIGHT OF SAMPLE	g	1693	1990	2140	2080	1868
VOLUME OF MOULD	cm^3	1000	1000	1000	1000	1000
WET DENSITY	kg/m^3	1693	1990	2140	2080	1868
DRY DENSITY	kg/m^3	**1601**	**1842**	**1941**	**1843**	**1599**

Moisture determination											
CONTAINER No	UNIT	**B39**	**B30**	**M007**	**M065**	**M032**	**M179**	**M132**	**M049**	**A08**	**M110**
WT OF WET SOLI+TIN	g	225	265	315	320	375	360	445	450	585	570
WT OF DRY SOIL+TIN	g	217.1	255	297.2	301	346.7	334.3	405	405.2	509.9	503
WT OF MOISTURE	g	7.9	10	17.8	19	28.3	25.7	40	44.8	75.1	67
WT OF TIN	g	80	80	70	70	80	75	75	75	80	90
WT OF DRY SOIL	g	137.1	175	227.2	231	266.7	259.3	330	330.2	429.9	413
MOISTURE CONTENT	%	5.8	5.7	7.8	8.2	10.6	9.9	12.1	13.6	17.5	16.2
AVERAGE MOISTURE CONTENT	**%**	**5.7**		**8.0**		**10.3**		**12.8**		**16.8**	



MDD: 1940 kg/m3 **OMC: 10.8 %**

Table C. 4: GK-02 MDD and OMC Results

PROJECT:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study
TASK:	Research Dissertation

COMPACTION TEST
MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION
BS 1377: Part 4: 1990

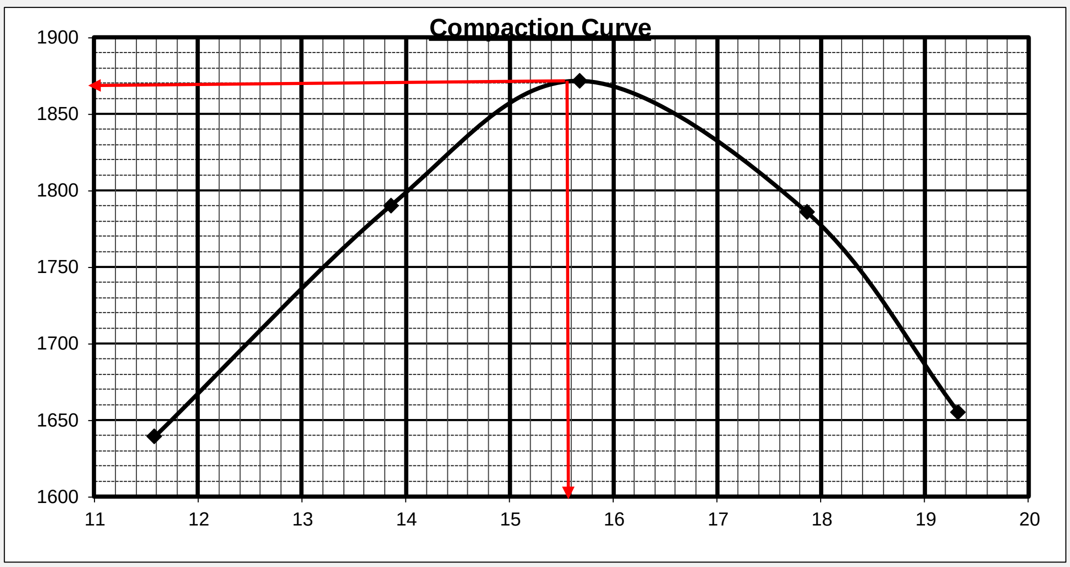
UNIVERSITY:	KYAMBOGO	DEPARTMENT:	CIVIL AND BUILDING ENGINEERING
FACULTY:	ENGINEERING	STUDENT:	Mbwali Mary Christine
SAMPLE REFERENCE:	GK-02	Reg No.:	21/U/GMES/14326/PE
SAMPLE LOCATION:	KM: 6+400 RHS		
DEPTH (m):	0.215-0.415	TESTING DATE	11-Oct-23

Bulk density determination

TEST No	UNIT	1	2	3	4	4
WATER ADDED, g	g	**0**	**70**	**190**	**310**	**430**
WEIGHT OF MOULD+SAMPLE	g	5174	5383	5510	5450	5320
WEIGHT OF MOULD	g	3345	3345	3345	3345	3345
WEIGHT OF SAMPLE	g	1829	2038	2165	2105	1975
VOLUME OF MOULD	cm^3	1000	1000	1000	1000	1000
WET DENSITY	kg/m^3	1829	2038	2165	2105	1975
DRY DENSITY	kg/m^3	**1639**	**1790**	**1872**	**1786**	**1655**

Moisture determination

CONTAINER No	UNIT	m073	M091	M031	B45	M102	M139	M078	M094	M026	M089
WT OF WET SOLI+TIN	g	368.5	280	280	365	345	425	445	600	575	710.5
WT OF DRY SOIL+TIN	g	338	259	255	330	308	380	392	520	492.9	609
WT OF MOISTURE	g	30.5	21	25	35	37	45	53	80	82.1	101.5
WT OF TIN	g	77	76	75.5	76	85	75	90	80	75	75
WT OF DRY SOIL	g	261	183	179.5	254	223	305	302	440	417.9	534
MOISTURE CONTENT	%	11.7	11.5	13.9	13.8	16.6	14.8	17.5	18.2	19.6	19.0
AVERAGE MOISTURE CONTENT	%	**11.6**		**13.9**		**15.7**		**17.9**		**19.3**	



MDD: 1870 kg/m3 **OMC: 16.0 %**

Table C. 5: GK-03 MDD and OMC Results

PROJECT:	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**		
TASK:	**Research Dissertation**		

COMPACTION TEST

MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION

BS 1377: Part 4: 1990

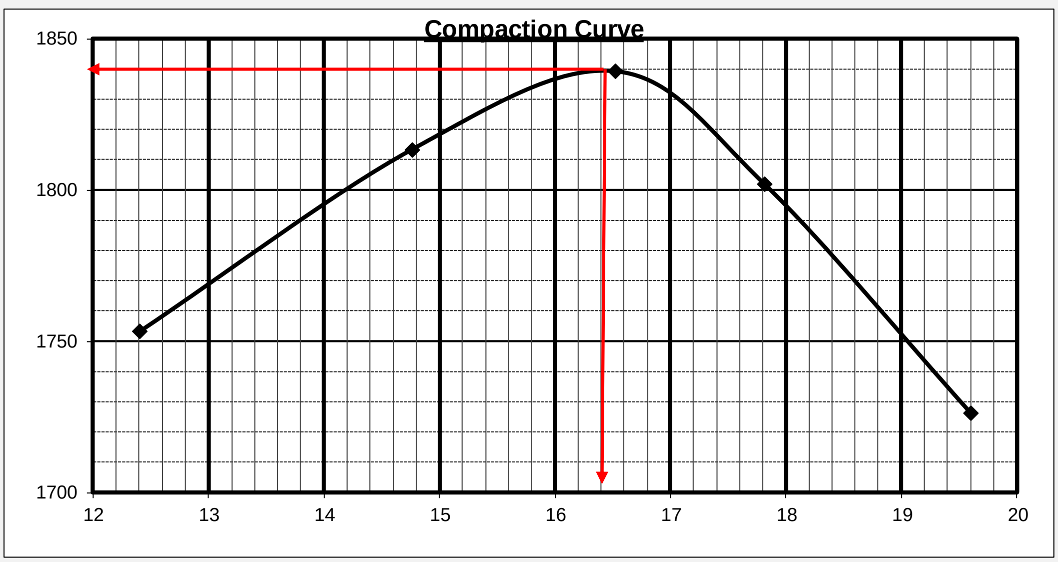
UNIVERSITY:	KYAMBOGO	**DEPARTMENT:**	**CIVIL AND BUILDING ENGINEERING**
FACULTY:	ENGINEERING	**STUDENT:**	Mbwali Mary Christine
SAMPLE REFERENCE:	GK-03	**Reg No.:**	21/U/GMES/14326/PE
SAMPLE LOCATION:	KM: 8+000 LHS		
DEPTH (m):	0.215-0.415	**TESTING DATE**	11-Oct-23

Bulk density determination

TEST No	UNIT	1	2	3	4	4
WATER ADDED, g	g	166	226	286	346	406
WEIGHT OF MOULD+SAMPLE	g	5,394	5,504	5,566	5,546	5,488
WEIGHT OF MOULD	g	3,432	3,432	3,432	3,432	3,432
WEIGHT OF SAMPLE	g	1962	2072	2134	2114	2056
VOLUME OF MOULD	cm^3	1000	1000	1000	1000	1000
WET DENSITY	kg/m^3	1962	2072	2134	2114	2056
DRY DENSITY	kg/m^3	**1753**	**1813**	**1839**	**1802**	**1726**

Moisture determination

CONTAINER No	UNIT	KK19	TT19	AA	GR8	BB19	A3	B19	A1	A2	FF
WT OF WET SOLI+TIN	g	340	320	282	270	268	254	278	274	248	226
WT OF DRY SOIL+TIN	g	311	295	256	246	242	230	246	250	220	202
WT OF MOISTURE	g	29	25	26	24	26	24	32	24	28	24
WT OF TIN	g	77	76	75.5	76	85	75	90	80	75	75
WT OF DRY SOIL	g	234	219	180.5	170	157	155	156	170	145	127
MOISTURE CONTENT	%	12.4	11.4	14.4	14.1	16.6	15.5	20.5	14.1	19.3	18.9
AVERAGE MOISTURE CONTENT	**%**	**11.9**		**14.3**		**16.0**		**17.3**		**19.1**	



MDD: 1840 kg/m3 **OMC: 16.40 %**

Table C. 6: KMN-01 MDD and OMC Results

PROJECT:	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**
TASK:	**Research Dissertation**

COMPACTION TEST
MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION
BS 1377: Part 4: 1990

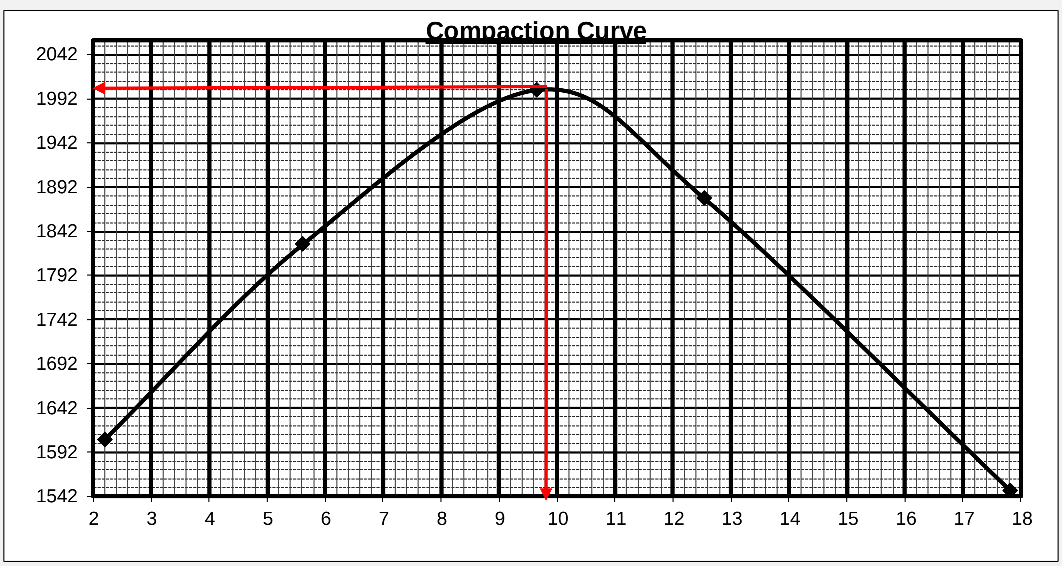
UNIVERSITY:	KYAMBOGO	**DEPARTMENT:**	**CIVIL AND BUILDING ENGINEERING**
FACULTY:	ENGINEERING	**STUDENT:**	Mbwali Mary Christine
SAMPLE REFERENCE:	KMN-01	**Reg No.:**	21/U/GMES/14326/PE
SAMPLE LOCATION:	KM: 1+050 LHS		
DEPTH (m):	0.250-0.450	**TESTING DATE**	11-Oct-23

Bulk density determination

TEST No	UNIT	1	2	3	4	4
WATER ADDED, g	g	**0**	**100**	**200**	**300**	**400**
WEIGHT OF MOULD+SAMPLE	g	4987	5275	5540	5460	5170
WEIGHT OF MOULD	g	3345	3345	3345	3345	3345
WEIGHT OF SAMPLE	g	1642	1930	2195	2115	1825
VOLUME OF MOULD	cm^3	1000	1000	1000	1000	1000
WET DENSITY	kg/m^3	1642	1930	2195	2115	1825
DRY DENSITY	kg/m^3	**1607**	**1827**	**2002**	**1879**	**1549**

Moisture determination

CONTAINER No	UNIT	**M046**	**MO76**	**MOO9**	**MI66**	**MO62**	**M044**	**M023**	**M130**	**M13**	**M052**
WT OF WET SOLI+TIN	g	230	200	295	290	385	340	435	455	525	520
WT OF DRY SOIL+TIN	g	225.3	198.3	282.6	279	359.4	316.2	396.2	411.9	455.5	454.2
WT OF MOISTURE	g	4.7	1.7	12.4	11	25.6	23.8	38.8	43.1	69.5	65.8
WT OF TIN	g	70	75	75	70	75	85	85	70	75	75
WT OF DRY SOIL	g	155.3	123.3	207.6	209	284.4	231.2	311.2	341.9	380.5	379.2
MOISTURE CONTENT	%	3.0	1.4	6.0	5.3	9.0	10.3	12.5	12.6	18.3	17.4
AVERAGE MOISTURE CONTENT	**%**	**2.2**		**5.6**		**9.6**		**12.5**		**17.8**	



MDD: 2002 kg/m3 **OMC: 9.8 %**

Table C. 7: KMN-02 MDD and OMC Results

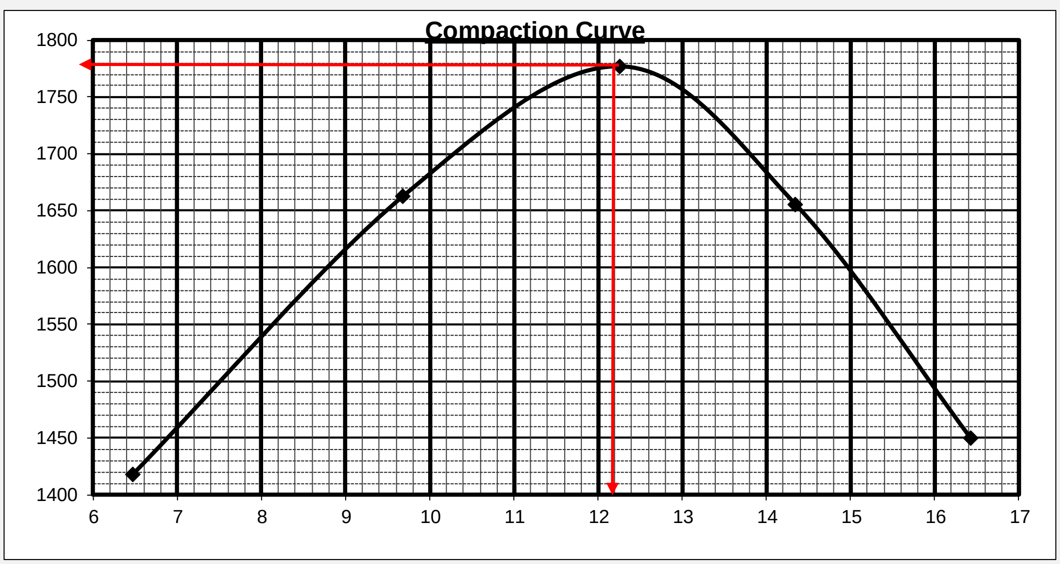
PROJECT:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study			
TASK:	Research Dissertation			

COMPACTION TEST
MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION
BS 1377: Part 4: 1990

UNIVERSITY:	KYAMBOGO	DEPARTMENT:	CIVIL AND BUILDING ENGINEERING
FACULTY:	ENGINEERING	STUDENT:	Mbwali Mary Christine
SAMPLE REFERENCE:	KMN-02	Reg No.:	21/U/GMES/14326/PE
SAMPLE LOCATION:	KM: 4+300 LHS		
DEPTH (m):	0.250-0.450	TESTING DATE	11-Oct-23

Bulk density determination						
TEST No	UNIT	1	2	3	4	4
WATER ADDED, g	g	**0**	**50**	**100**	**150**	**200**
WEIGHT OF MOULD+SAMPLE	g	4855	5169	5340	5238	5033
WEIGHT OF MOULD	g	3345	3345	3345	3345	3345
WEIGHT OF SAMPLE	g	1510	1824	1995	1893	1688
VOLUME OF MOULD	cm^3	1000	1000	1000	1000	1000
WET DENSITY	kg/m^3	1510	1824	1995	1893	1688
DRY DENSITY	kg/m^3	**1418**	**1663**	**1777**	**1655**	**1450**

Moisture determination											
CONTAINER No	UNIT	MO12	M184	M064	M144	B18	MO39	M127	M129	M013	M135
WT OF WET SOLI+TIN	g	205	230	245	275	315	310	395	370	490	490
WT OF DRY SOIL+TIN	g	198.5	219.3	229.8	258	289.9	284.3	353.1	334	431.4	434.3
WT OF MOISTURE	g	6.5	10.7	15.2	17	25.1	25.7	41.9	36	58.6	55.7
WT OF TIN	g	75	80	75	80	85	75	70	75	85	85
WT OF DRY SOIL	g	123.5	139.3	154.8	178	204.9	209.3	283.1	259	346.4	349.3
MOISTURE CONTENT	%	5.3	7.7	9.8	9.6	12.2	12.3	14.8	13.9	16.9	15.9
AVERAGE MOISTURE CONTENT	%	**6.5**		**9.7**		**12.3**		**14.4**		**16.4**	



MDD: 1780 kg/m3 **OMC: 12.2 %**

Table C. 8: KMN-03 MDD and OMC Results

PROJECT:	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**		
TASK:	**Research Dissertation**		

COMPACTION TEST
MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION
BS 1377: Part 4: 1990

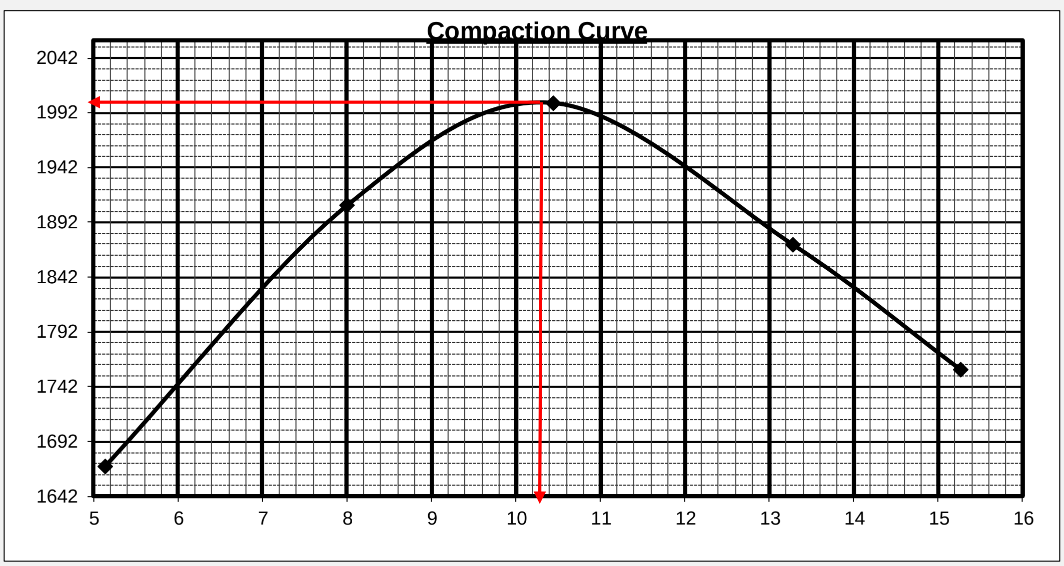
UNIVERSITY:	KYAMBOGO	**DEPARTMENT:**	**CIVIL AND BUILDING ENGINEERING**
FACULTY:	ENGINEERING	**STUDENT:**	Mbwali Mary Christine
SAMPLE REFERENCE:	KMN-03	**Reg No.:**	21/U/GMES/14326/PE
SAMPLE LOCATION:	KM: 3+320 RHS		
DEPTH (m):	0.250-0.450	**TESTING DATE**	11-Oct-23

Bulk density determination

TEST No	UNIT	1	2	3	4	4
WATER ADDED, g	g	**0**	**60**	**120**	**180**	**240**
WEIGHT OF MOULD+SAMPLE	g	5115	5420	5570	5480	5386
WEIGHT OF MOULD	g	3360	3360	3360	3360	3360
WEIGHT OF SAMPLE	g	1755	2060	2210	2120	2026
VOLUME OF MOULD	cm^3	1000	1000	1000	1000	1000
WET DENSITY	kg/m^3	1755	2060	2210	2120	2026
DRY DENSITY	kg/m^3	**1669**	**1907**	**2001**	**1871**	**1758**

Moisture determination

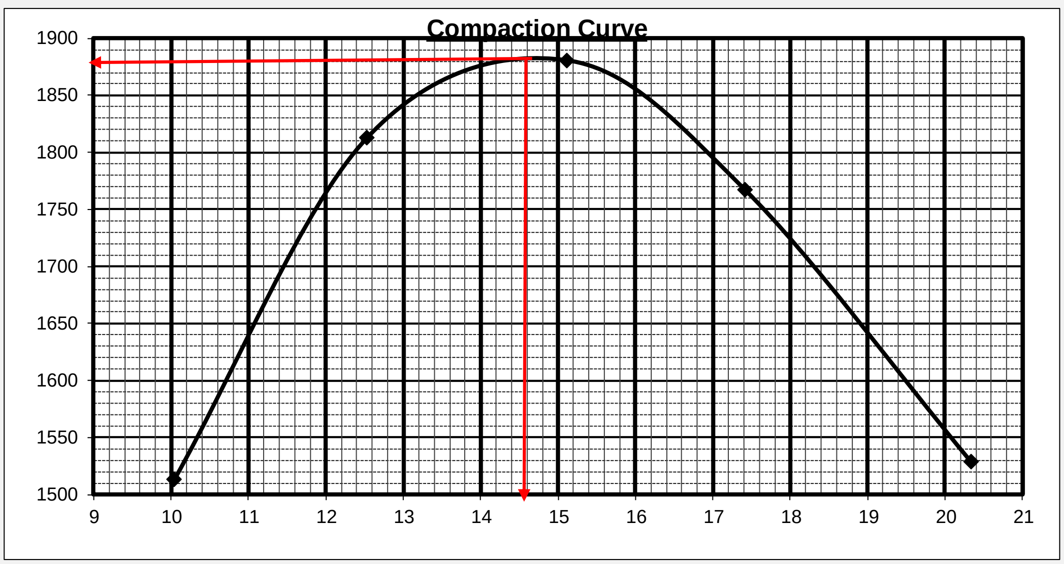
CONTAINER No	UNIT	A027	MO33	M173	M119	M105	B19	A040	M157	MOO1	M034
WT OF WET SOLI+TIN	g	323	325	400	415	450	450	505	500	560	570
WT OF DRY SOIL+TIN	g	313.8	310.3	378.6	387.4	417.1	413	455.9	449.4	493.3	509.7
WT OF MOISTURE	g	9.2	14.7	21.4	27.6	32.9	37	49.1	50.6	66.7	60.3
WT OF TIN	g	85	75	80	75	75	85	80	75	85	85
WT OF DRY SOIL	g	228.8	235.3	298.6	312.4	342.1	328	375.9	374.4	408.3	424.7
MOISTURE CONTENT	%	4.0	6.2	7.2	8.8	9.6	11.3	13.1	13.5	16.3	14.2
AVERAGE MOISTURE CONTENT	**%**	**5.1**		**8.0**		**10.4**		**13.3**		**15.3**	



MDD: 2002 kg/m3 **OMC: 10.3 %**

Table C. 9: SSB-01 MDD and OMC Results

PROJECT:	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**										
TASK:	**Research Dissertation**										
COMPACTION TEST MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION BS 1377: Part 4: 1990											
UNIVERSITY:	KYAMBOGO			**DEPARTMENT:**		**CIVIL AND BUILDING ENGINEERING**					
FACULTY:	ENGINEERING					**STUDENT:**		Mbwali Mary Christine			
SAMPLE REFERENCE:	SSB-01					**Reg No.:**		21/U/GMES/14326/PE			
SAMPLE LOCATION:	KM: 0+400 LHS										
DEPTH (m):	0.250-0.450					**TESTING DATE**		11-Oct-23			
Bulk density determination											
TEST No	UNIT	1		2		3		4		4	
WATER ADDED, g	g	**50**		**100**		**150**		**200**		**250**	
WEIGHT OF MOULD+SAMPLE	g	5025		5400		5525		5435		5200	
WEIGHT OF MOULD	g	3360		3360		3360		3360		3360	
WEIGHT OF SAMPLE	g	1665		2040		2165		2075		1840	
VOLUME OF MOULD	cm^3	1000		1000		1000		1000		1000	
WET DENSITY	kg/m^3	1665		2040		2165		2075		1840	
DRY DENSITY	kg/m^3	**1513**		**1813**		**1881**		**1767**		**1529**	
Moisture determination											
CONTAINER No	UNIT	**M16**	**M188**	**M059**	**M072**	**A042**	**M125**	**M143**	**M192**	**A024**	**MII7**
WT OF WET SOLI+TIN	g	320	345	375	385	405	425	465	440	505	500
WT OF DRY SOIL+TIN	g	296	322.2	342.5	349	362	378.7	407	386	432	427.7
WT OF MOISTURE	g	24	22.8	32.5	36	43	46.3	58	54	73	72.3
WT OF TIN	g	75	75	70	75	75	75	75	75	70	75
WT OF DRY SOIL	g	221	247.2	272.5	274	287	303.7	332	311	362	352.7
MOISTURE CONTENT	%	10.9	9.2	11.9	13.1	15.0	15.2	17.5	17.4	20.2	20.5
AVERAGE MOISTURE CONTENT	**%**	**10.0**		**12.5**		**15.1**		**17.4**		**20.3**	



MDD: 1880 kg/m3 **OMC: 14.6 %**

Table C. 10: SSB-02 MDD and OMC Results

PROJECT:	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**
TASK:	**Research Dissertation**

COMPACTION TEST

MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION

BS 1377: Part 4: 1990

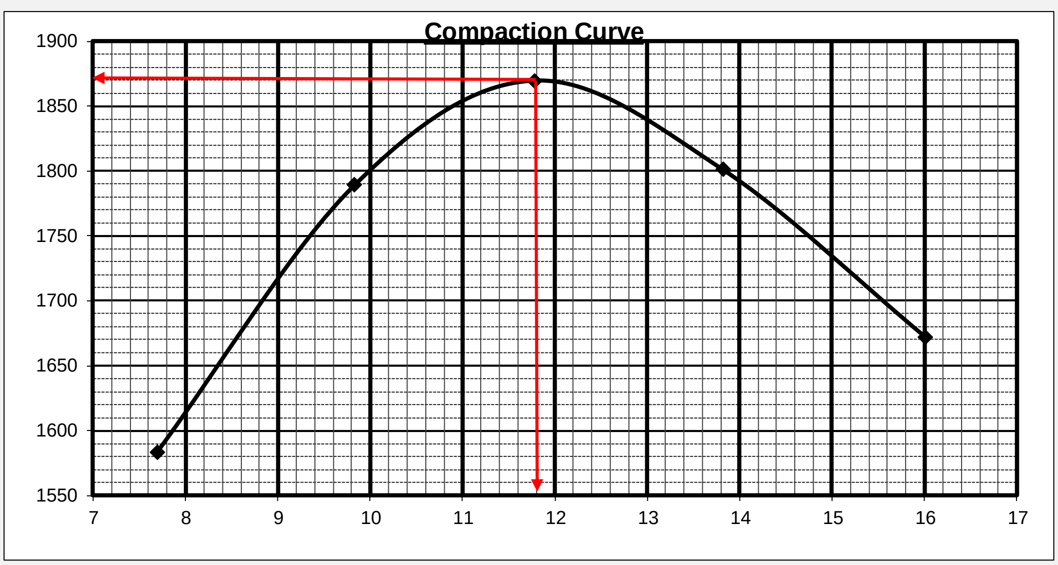
UNIVERSITY:	KYAMBOGO	**DEPARTMENT:**	**CIVIL AND BUILDING ENGINEERING**
FACULTY:	ENGINEERING	**STUDENT:**	Mbwali Mary Christine
SAMPLE REFERENCE:	SSB-02	**Reg No.:**	21/U/GMES/14326/PE
SAMPLE LOCATION:	KM: 0+800 LHS		
DEPTH (m):	0.250-0.450	**TESTING DATE**	11-Oct-23
Sample Description:		**Location/Source:**	

Bulk density determination

TEST No	UNIT	1	2	3	4	4
WATER ADDED, g	g	**50**	**100**	**150**	**200**	**250**
WEIGHT OF MOULD+SAMPLE	g	5065	5325	5450	5410	5300
WEIGHT OF MOULD	g	3360	3360	3360	3360	3360
WEIGHT OF SAMPLE	g	1705	1965	2090	2050	1940
VOLUME OF MOULD	cm^3	1000	1000	1000	1000	1000
WET DENSITY	kg/m^3	1705	1965	2090	2050	1940
DRY DENSITY	kg/m^3	**1583**	**1789**	**1870**	**1801**	**1672**

Moisture determination

CONTAINER No	UNIT	A030	A196	B44	B40	M195	A028	M114	M084	M026	M089
WT OF WET SOLI+TIN	g	320	300	355	350	445	435	485	490	675.5	710.5
WT OF DRY SOIL+TIN	g	302.9	283.2	330.7	327.3	405.7	398.4	434.2	443.7	593.2	622.5
WT OF MOISTURE	g	17.1	16.8	24.3	22.7	39.3	36.6	50.8	46.3	82.3	88
WT OF TIN	g	75	70	90	90	75	85	85	90	77	75
WT OF DRY SOIL	g	227.9	213.2	240.7	237.3	330.7	313.4	349.2	353.7	516.2	547.5
MOISTURE CONTENT	%	7.5	7.9	10.1	9.6	11.9	11.7	14.5	13.1	15.9	16.1
AVERAGE MOISTURE CONTENT	%	**7.7**		**9.8**		**11.8**		**13.8**		**16.0**	



MDD: 1870 kg/m3 **OMC: 11.8 %**

Table C. 11: SSB-03 MDD and OMC Results

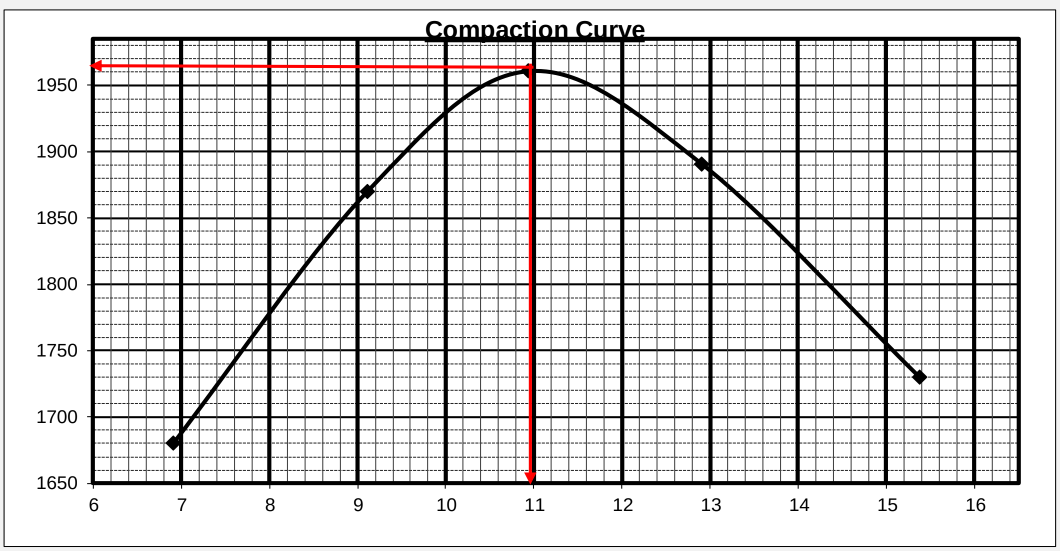
PROJECT:	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study		
TASK:	Research Dissertation		

COMPACTION TEST
MAXIMUM DRY DENSITY (MDD) AND OPTIMUM MOISTURE CONTENT (OMC) DETERMINATION
BS 1377: Part 4: 1990

UNIVERSITY:	KYAMBOGO	DEPARTMENT:	CIVIL AND BUILDING ENGINEERING
FACULTY:	ENGINEERING	STUDENT:	Mbwali Mary Christine
SAMPLE REFERENCE:	SSB-03	Reg No.:	21/U/GMES/14326/PE
SAMPLE LOCATION:	KM: 2+450 RHS		
DEPTH (m):	0.250-0.450	TESTING DATE	11-Oct-23
Sample Description:		Location/Source:	

Bulk density determination						
TEST No	UNIT	1	2	3	4	4
WATER ADDED, g	g	**50**	**100**	**150**	**200**	**250**
WEIGHT OF MOULD+SAMPLE	g	5156	5400	5535	5495	5356
WEIGHT OF MOULD	g	3360	3360	3360	3360	3360
WEIGHT OF SAMPLE	g	1796	2040	2175	2135	1996
VOLUME OF MOULD	cm^3	1000	1000	1000	1000	1000
WET DENSITY	kg/m^3	1796	2040	2175	2135	1996
DRY DENSITY	kg/m^3	**1680**	**1870**	**1961**	**1891**	**1730**

Moisture determination											
CONTAINER No	UNIT	KT	YY	XZM	BOJ	NMT	Z6T	FDC	BOJ	MJR	2I
WT OF WET SOLI+TIN	g	345	325	380	375	470	460	510	515	701	736
WT OF DRY SOIL+TIN	g	327.9	308.2	355.7	351.3	430.7	423.4	459.2	468.7	618.2	647.5
WT OF MOISTURE	g	17.1	16.8	24.3	23.7	39.3	36.6	50.8	46.3	82.8	88.5
WT OF TIN	g	75	70	90	90	75	85	85	90	77	75
WT OF DRY SOIL	g	252.9	238.2	265.7	261.3	355.7	338.4	374.2	378.7	541.2	572.5
MOISTURE CONTENT	%	6.8	7.1	9.1	9.1	11.0	10.8	13.6	12.2	15.3	15.5
AVERAGE MOISTURE CONTENT	**%**	**6.9**		**9.1**		**10.9**		**12.9**		**15.4**	



MDD: 1965 kg/m3 **OMC: 11.0 %**

Appendix D: California Bearing Ratio Results

Table D. 1: CBR of each of the three roads at different chainages

Lab. Sample Ref.No.	Location	Depth (m)	Soil Description	CBR 4days Soaked		
				MDD percent		
				93%	95%	98%
GK-01	KM: 4+300 LHS	0.215-0.415	Gravel Subbase modified with CRR	15	31	51
GK-02	KM: 6+400 RHS	0.215-0.415	Gravel Subbase modified with CRR	29	35	45
GK-03	KM: 8+000 LHS	0.215-0.415	Gravel Subbase modified with CRR	27	36	42
KMN-01	KM: 1+050 LHS	0.250-0.450	Gravel Subbase	32	39	47
KMN-02	KM: 1+800 LHS	0.250-0.450	Gravel Subbase	25	31	40
KMN-03	KM: 2+320 RHS	0.430-0.630	Gravel Subbase	27	35	48
SSB-01	KM: 0+400 LHS	0.230-0.430	Silty Sandy Gravel Subbase	22	32	38
SSB-02	KM: 0+800 LHS	0.230-0.430	Silty Sandy Gravel Subbase	22	31	42
SSB-03	KM: 2+450 RHS	0.250-0.450	Gravel Subbase	23	32	38

Table D. 2: Average CBR and NMC for the three roads

Sample Ref.No.	Source	Soil Description	CBR 4days Soaked MDD percent		
			93%	95%	98%
GK	Gayaza-Kalagi Road	Gravel Subbase modified with CRR	27	37	47
KMN	Kampala-Mukono-Njeru Road	Gravel Subbase	29	36	46
SSB	SilverSprings-Bweyogerere Road	Silty Sandy Gravel Subbase	33	38	42

Table D. 3: GK-01 CBR Penetration Results

PROJECT :	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study			
TASK:	Research Dissertation	UNIVERSITY:	KYAMBOGO	Serial No.:

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 4+300 LHS		Depth (m):	0.215-0.415	Testing Date:	*12/10/23*	
FACULTY:	ENGINERING	DEPARTMENT:	CIVIL & BUILDING ENGINEERING	STUDENT:	Mbwali Mary	21/U/GMES/1432 6/PE	
Sample Ref No.	GK-01		Soaking Period	4	Proving Ring Factor	0.0217	

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
8.3	*8.4*	*8.4*	*10.8*	*2.4*	*18100*	*442*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	M154	MO91	M154	MO91	M154	MO91
Mass of container, g	80.00	75.00	80.00	75.00	80.00	75.00
Mass of wet soil +container, g	390.00	355.00	390.00	355.00	390.00	355.00
Mass of dry soil +container, g	366.30	333.20	366.30	333.20	366.30	333.20
Moisture content	8.3	8.4	8.3	8.4	8.3	8.4
Avergae moisture content	8.4		8.4		8.4	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	N023	N041	N056
Volume of mould, cm^3	2305.0	2305.0	2305.0
Mass of mould, g	6645.0	6595.0	6505.0
Mass of mould + Soil, g	11135.0	11315.0	11490.0
Mass of soil, g	4490.0	4720.0	4985.0
Dry Density, kg/m^3	1.798	1.890	1.996
Target Density	1.940	1.940	1.940
% Compaction	92.7	97.4	102.9

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
11.9	**49.8**	**62.7**

TESTING

Penetration (mm)	Dial Gauge Reading LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom	Equivalent Force in kN LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	9	50	28	102	30	122	0.20	1.09	0.61	2.21	0.65	2.65
1.0	20	70	58	195	100	260	0.43	1.52	1.26	4.23	2.17	5.64
1.5	30	85	120	265	184	359	0.65	1.84	2.60	5.75	3.99	7.79
2.0	36	91	221	311	245	415	0.78	1.97	4.80	6.75	5.32	9.01
2.5	40	105	260	348	285	480	0.87	2.28	5.64	7.55	6.18	10.42
3.0	48	120	295	384	332	550	1.04	2.60	6.40	8.33	7.20	11.94
3.5	52	132	328	393	380	611	1.13	2.86	7.12	8.53	8.25	13.26
4.0	60	143	340	416	440	672	1.30	3.10	7.38	9.03	9.55	14.58
4.5	64	153	350	444	503	715	1.39	3.32	7.60	9.63	10.92	15.52
5.0	68	160	366	456	547	770	1.48	3.47	7.94	9.90	11.87	16.71
5.5	72	170	378	471	584	810	1.56	3.69	8.20	10.22	12.67	17.58
6.0	75	182	384	496	620	860	1.63	3.95	8.33	10.76	13.45	18.66
6.5	78	190	397	517	650	886	1.69	4.12	8.61	11.22	14.11	19.23
7.0	80	205	408	540	685	930	1.74	4.45	8.85	11.72	14.86	20.18
7.5	93	235	415	557	711	960	2.02	5.10	9.01	12.09	15.43	20.83
8.0	96	260	423	600	737	990	2.08	5.64	9.18	13.02	15.99	21.48

CALCULATION OF CBR %

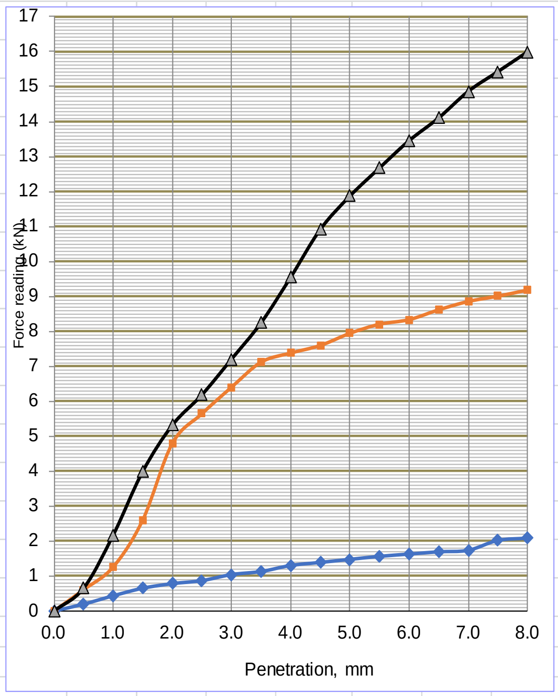
	LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
CBR at 2.5 mm penetration	6.6	17.2	42.6	57.0	46.7	78.7
CBR at 5.0 mm penetration	7.4	17.4	39.8	49.6	59.5	83.7
M	11.9		49.8		62.7	

Table D. 4: GK-01 CBR Results

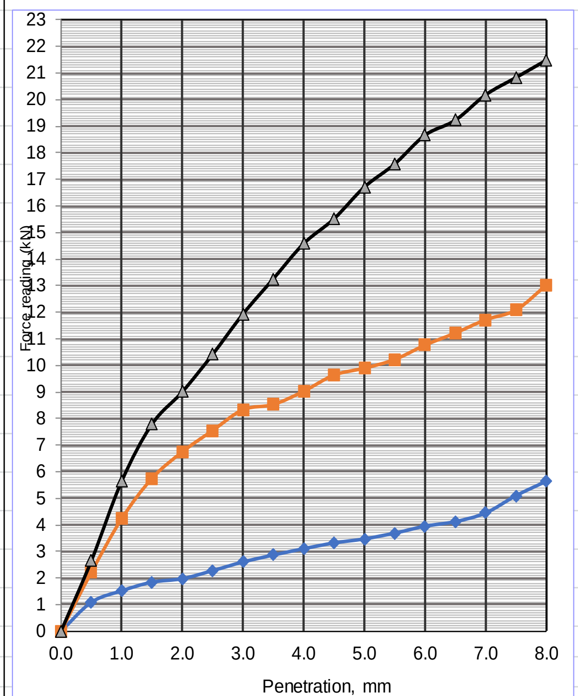
CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

Top Face Penetration

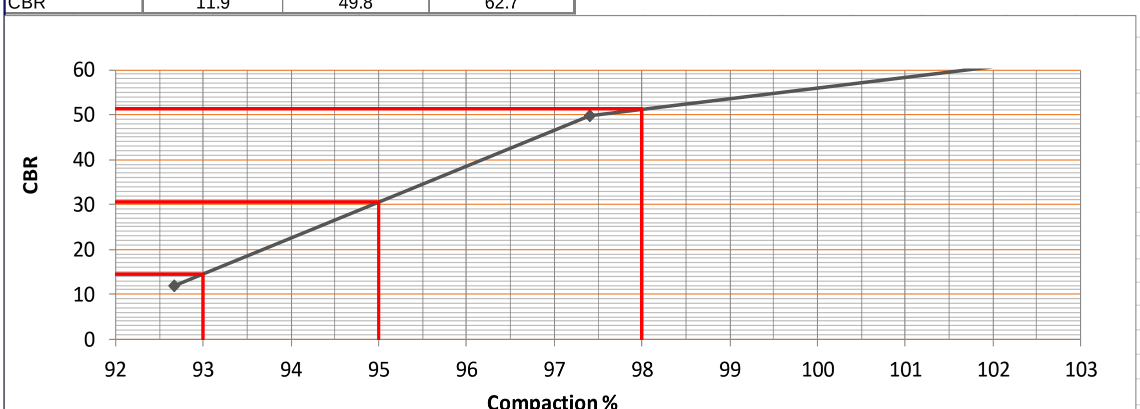


Bottom Face Penetration



Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	92.7	97.4	102.9
CBR	11.9	49.8	62.7



CBR @ 98% MDD	51
CBR @ 95% MDD	31
CBR @ 93% MDD	15

Table D. 5: GK-02 CBR Penetration Results

PROJECT :	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**				
TASK:	Research Dissertation	**UNIVERSITY:**	KYAMBOGO	**Serial No.:**	

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 6+400 RHS		Depth (m):	0.215-0.415		Testing Date:	*12/10/23*
FACULTY:	ENGINERING	**DEPARTMENT:**	CIVIL & BUILDING ENGINEERING	**STUDENT:**	Mbwali Mary		**21/U/GMES/14326/PE**
Sample Ref No.	GK-02		Soaking Period	4	Proving Ring Factor		**0.0217**

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
7.5	*8.7*	*8.1*	*16.0*	*7.9*	*18100*	*1429*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	MO77	AO15	MO77	AO15	MO77	AO15
Mass of container, g	80.00	75.00	80.00	75.00	80.00	75.00
Mass of wet soil +container, g	355.00	305.00	355.00	305.00	355.00	305.00
Mass of dry soil +container, g	335.90	286.50	335.90	286.50	335.90	286.50
Moisture content	7.5	8.7	7.5	8.7	7.5	8.7
Avergae moisture content	8.1		8.1		8.1	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	NO3A	NO16	NO51B
Volume of mould, cm^3	2305.0	2305.0	2305.0
Mass of mould, g	6375.0	6220.0	6490.0
Mass of mould + Soil, g	10600.0	10680.0	11225.0
Mass of soil, g	4225.0	4460.0	4735.0
Dry Density, kg/m^3	1.696	1.790	1.900
Target Density	1.870	1.870	1.870
% Compaction	90.7	95.7	101.6

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
20.7	**37.7**	**57.4**

TESTING

Penetration (mm)	Dial Gauge Reading LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom	Equivalent Force in kN LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	6	80	15	100	35	200	0.13	1.74	0.33	2.17	0.76	4.34
1.0	9	102	38	160	62	280	0.20	2.21	0.82	3.47	1.35	6.08
1.5	17	142	62	205	93	371	0.37	3.08	1.35	4.45	2.02	8.05
2.0	23	185	80	270	133	450	0.50	4.01	1.74	5.86	2.89	9.77
2.5	28	225	110	350	178	523	0.61	4.88	2.39	7.60	3.86	11.35
3.0	33	265	134	410	215	569	0.72	5.75	2.91	8.90	4.67	12.35
3.5	39	292	156	465	250	612	0.85	6.34	3.39	10.09	5.43	13.28
4.0	44	314	179	525	290	665	0.95	6.81	3.88	11.39	6.29	14.43
4.5	49	344	190	570	325	718	1.06	7.46	4.12	12.37	7.05	15.58
5.0	54	380	218	605	348	778	1.17	8.25	4.73	13.13	7.55	16.88
5.5	58	414	245	642	382	837	1.26	8.98	5.32	13.93	8.29	18.16
6.0	62	450	270	692	415	896	1.35	9.77	5.86	15.02	9.01	19.44
6.5	67	469	290	735	438	938	1.45	10.18	6.29	15.95	9.50	20.35
7.0	72	488	305	770	555	1055	1.56	10.59	6.62	16.71	12.04	22.89
7.5	75	500	315	799	570	1124	1.63	10.85	6.84	17.34	12.37	24.39
8.0	78	533	330	835	581	1196	1.69	11.57	7.16	18.12	12.61	25.95

CALCULATION OF CBR %

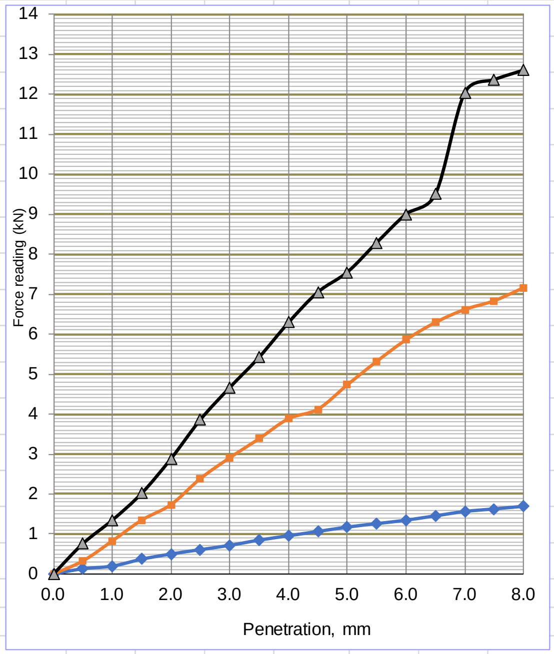
	LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
CBR at 2.5 mm penetration	4.6	36.9	18.0	57.4	29.2	85.7
CBR at 5.0 mm penetration	5.9	41.3	23.7	65.8	37.8	84.6
M	20.7		37.7		57.4	

Table D. 6: GK-02 CBR Results

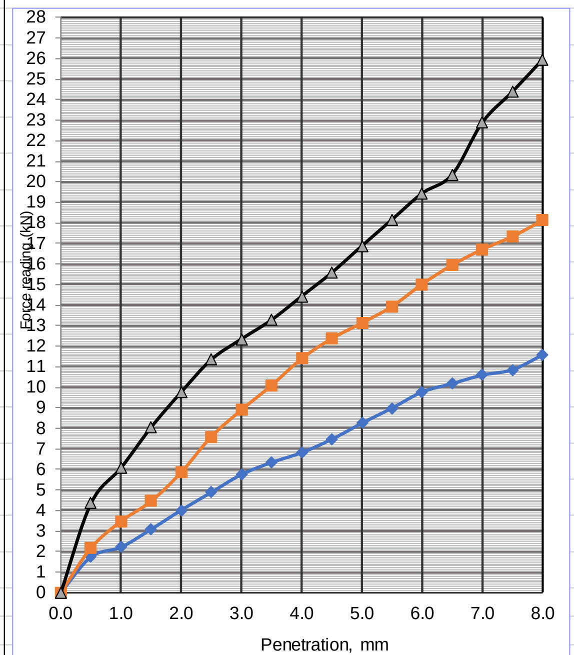
CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

Top Face Penetration

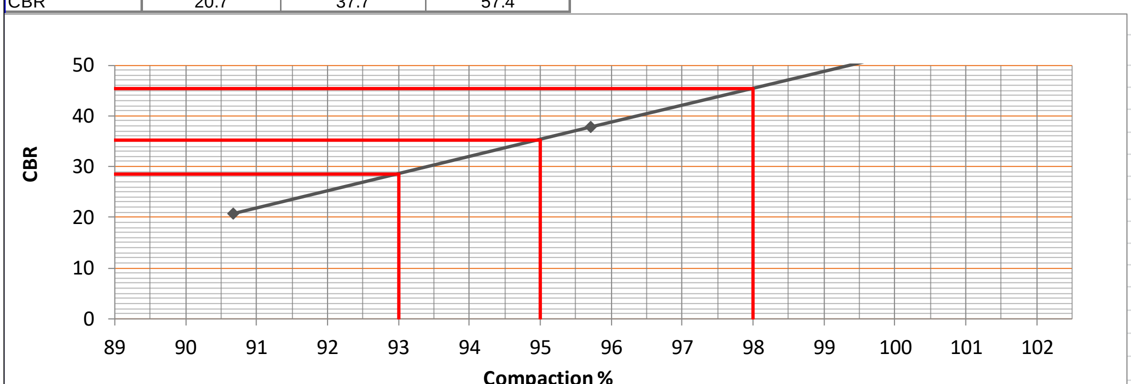


Bottom Face Penetration



Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	90.7	95.7	101.6
CBR	20.7	37.7	57.4



CBR @ 98% MDD	45
CBR @ 95% MDD	35
CBR @ 93% MDD	29

Table D. 7: GK-03 CBR Penetration Results

PROJECT :	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**			
TASK:	Research Dissertation	**UNIVERSITY:**	KYAMBOGO	**Serial No.:**

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 8+000 LHS		Depth (m):	0.215-0.415		Testing Date:	*12/10/23*
FACULTY:	ENGINERING	**DEPARTMENT:**	CIVIL & BUILDING ENGINEERING	**STUDENT:**	Mbwali Mary		**21/U/GMES/14326/PE**
Sample Ref No.	GK-03		Soaking Period	4	Proving Ring Factor		0.0217

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
7.2	*8.4*	*7.8*	*16.4*	*8.6*	*18100*	*1562*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	AKA	XC	AKA	XC	AKA	XC
Mass of container, g	80.00	75.00	80.00	75.00	80.00	75.00
Mass of wet soil +container, g	365.00	315.00	365.00	315.00	365.00	315.00
Mass of dry soil +container, g	345.90	296.50	345.90	296.50	345.90	296.50
Moisture content	7.2	8.4	7.2	8.4	7.2	8.4
Avergae moisture content	7.8		7.8		7.8	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	GJ	NO20	NO5
Volume of mould, cm^3	2305.0	2305.0	2305.0
Mass of mould, g	6585.0	6430.0	6480.0
Mass of mould + Soil, g	10700.0	10780.0	11325.0
Mass of soil, g	4115.0	4350.0	4845.0
Dry Density, kg/m^3	1.657	1.751	1.950
Target Density	1.840	1.840	1.840
% Compaction	90.0	95.2	106.0

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
14.3	**36.4**	**58.4**

TESTING

Penetration (mm)	Dial Gauge Reading LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom	Equivalent Force in kN LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	22	60	54	135	64	190	0.48	1.30	1.17	2.93	1.39	4.12
1.0	26	86	65	158	96	260	0.56	1.87	1.41	3.43	2.08	5.64
1.5	28	103	93	223	133	315	0.61	2.24	2.02	4.84	2.89	6.84
2.0	35	119	111	267	170	395	0.76	2.58	2.41	5.79	3.69	8.57
2.5	40	134	127	317	212	501	0.87	2.91	2.76	6.88	4.60	10.87
3.0	45	148	158	357	268	528	0.98	3.21	3.43	7.75	5.82	11.46
3.5	49	174	178	385	294	585	1.06	3.78	3.86	8.35	6.38	12.69
4.0	53	199	204	421	323	627	1.15	4.32	4.43	9.14	7.01	13.61
4.5	57	204	224	457	354	660	1.24	4.43	4.86	9.92	7.68	14.32
5.0	60	212	243	500	393	690	1.30	4.60	5.27	10.85	8.53	14.97
5.5	63	235	261	530	427	746	1.37	5.10	5.66	11.50	9.27	16.19
6.0	66	241	281	567	471	790	1.43	5.23	6.10	12.30	10.22	17.14
6.5	68	250	291	605	513	835	1.48	5.43	6.31	13.13	11.13	18.12
7.0	70	275	304	627	545	890	1.52	5.97	6.60	13.61	11.83	19.31
7.5	71	290	317	645	588	925	1.54	6.29	6.88	14.00	12.76	20.07
8.0	72	315	329	663	623	965	1.56	6.84	7.14	14.39	13.52	20.94

CALCULATION OF CBR %

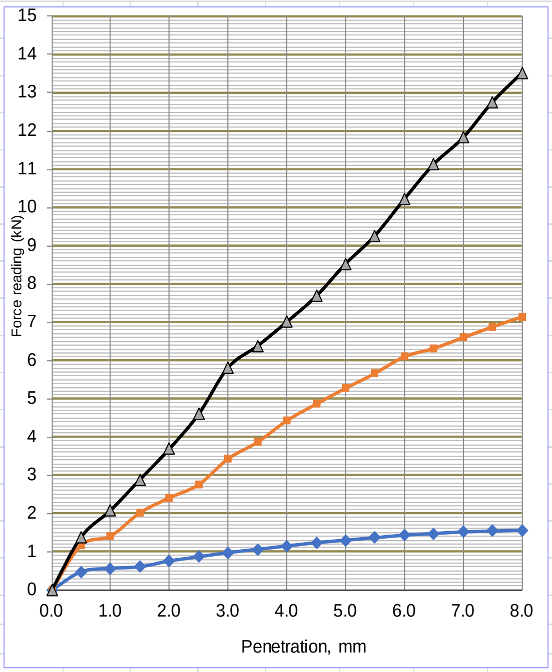
	LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
CBR at 2.5 mm penetration	6.6	22.0	20.8	52.0	34.7	82.1
CBR at 5.0 mm penetration	6.5	23.0	26.4	54.4	42.7	75.0
M	14.3		36.4		58.4	

Table D. 8: GK-03 CBR Results

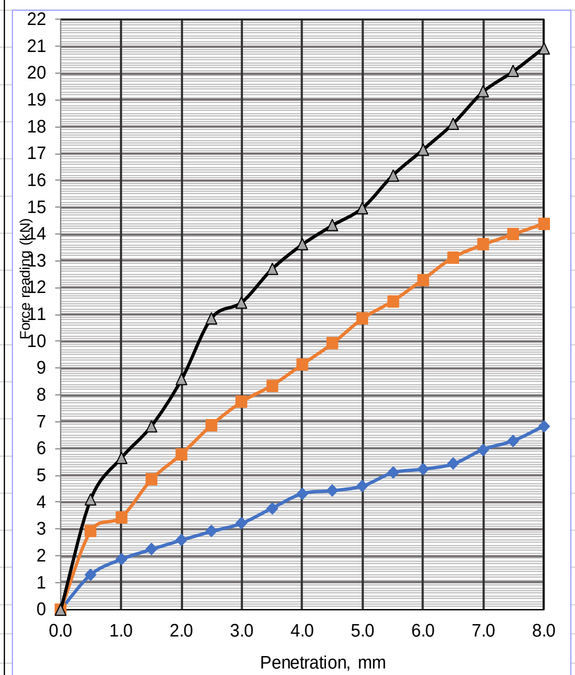
CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

Top Face Penetration

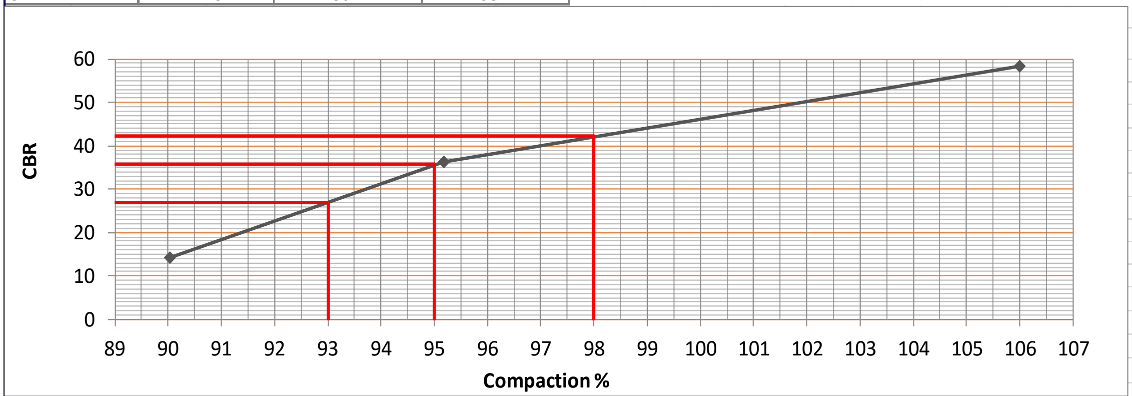


Bottom Face Penetration



Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	90.0	95.2	106.0
CBR	14.3	36.4	58.4



CBR @ 98% MDD	42
CBR @ 95% MDD	36
CBR @ 93% MDD	27

Table D. 9: KMN-01 CBR Penetration Results

PROJECT :	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**				
TASK:	Research Dissertation	**UNIVERSITY:**	KYAMBOGO	**Serial No.:**	

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 1+050 LHS		Depth (m):	0.250-0.450		Testing Date:	*12/10/23*
FACULTY:	ENGINERING	**DEPARTMENT:**	CIVIL & BUILDING ENGINEERING	**STUDENT:**	Mbwali Mary		**21/U/GMES/14326/PE**
Sample Ref No.	KMN-01		Soaking Period	4	Proving Ring Factor		0.0217

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
6.8	*5.5*	*6.2*	*9.8*	*3.6*	*18100*	*660*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	MO82	M104	MO82	M104	MO82	M104
Mass of container, g	75.00	75.00	75.00	75.00	75.00	75.00
Mass of wet soil +container, g	370.00	380.00	370.00	380.00	370.00	380.00
Mass of dry soil +container, g	351.10	364.20	351.10	364.20	351.10	364.20
Moisture content	6.8	5.5	6.8	5.5	6.8	5.5
Avergae moisture content	6.2		6.2		6.2	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	CT	NO41	NO2
Volume of mould, cm^3	2303.0	2303.0	2303.0
Mass of mould, g	6705.0	6480.0	6670.0
Mass of mould + Soil, g	11095.0	11185.0	11575.0
Mass of soil, g	4390.0	4705.0	4905.0
Dry Density, kg/m^3	1.796	1.925	2.006
Target Density	2.002	2.002	2.002
% Compaction	89.7	96.1	100.2

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
21.6	**42.2**	**52.0**

TESTING

Penetration (mm)	Dial Gauge Reading						Equivalent Force in kN					
	LIGHT		INTRM.		HEAVY		LIGHT		INTRM.		HEAVY	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	9	25	40	75	35	95	0.20	0.54	0.87	1.63	0.76	2.06
1.0	30	50	88	126	93	168	0.65	1.09	1.91	2.73	2.02	3.65
1.5	65	80	110	206	140	230	1.41	1.74	2.39	4.47	3.04	4.99
2.0	99	108	170	265	188	286	2.15	2.34	3.69	5.75	4.08	6.21
2.5	119	145	200	315	234	400	2.58	3.15	4.34	6.84	5.08	8.68
3.0	136	170	225	378	280	440	2.95	3.69	4.88	8.20	6.08	9.55
3.5	153	189	255	400	324	492	3.32	4.10	5.53	8.68	7.03	10.68
4.0	170	210	282	450	365	540	3.69	4.56	6.12	9.77	7.92	11.72
4.5	185	230	301	495	410	590	4.01	4.99	6.53	10.74	8.90	12.80
5.0	195	241	355	555	446	620	4.23	5.23	7.70	12.04	9.68	13.45
5.5	209	254	389	570	480	650	4.54	5.51	8.44	12.37	10.42	14.11
6.0	219	286	420	615	515	693	4.75	6.21	9.11	13.35	11.18	15.04
6.5	230	308	445	660	550	740	4.99	6.68	9.66	14.32	11.94	16.06
7.0	239	330	480	700	605	778	5.19	7.16	10.42	15.19	13.13	16.88
7.5	248	351	500	730	635	820	5.38	7.62	10.85	15.84	13.78	17.79
8.0	260	369	521	775	658	858	5.64	8.01	11.31	16.82	14.28	18.62

CALCULATION OF CBR %

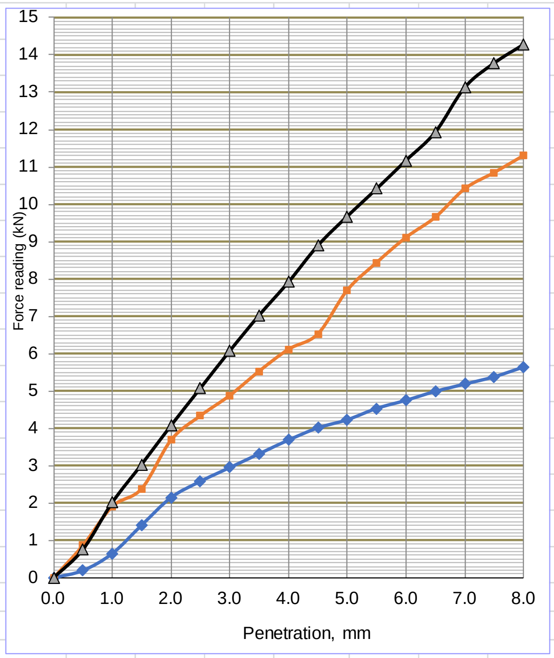
CBR at 2.5 mm penetration	19.5	23.8	32.8	51.6	38.4	65.6
CBR at 5.0 mm penetration	21.2	26.2	38.6	60.3	48.5	67.4
M	21.6		42.2		52.0	

Table D. 10: KMN-01 CBR Results

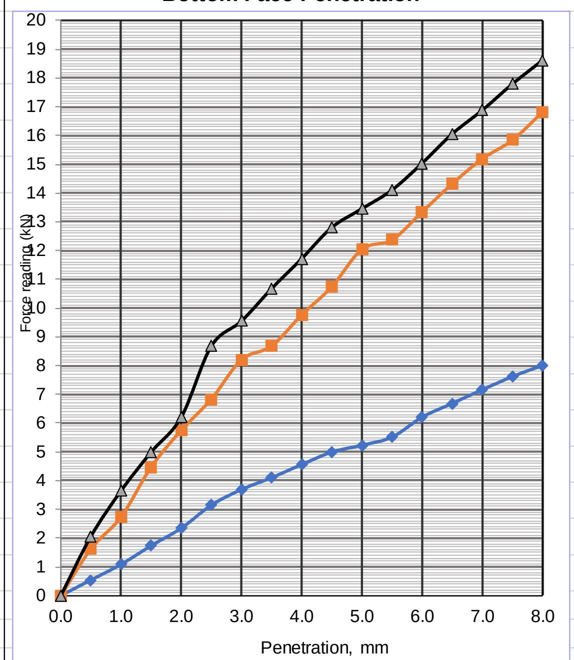
CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

Top Face Penetration

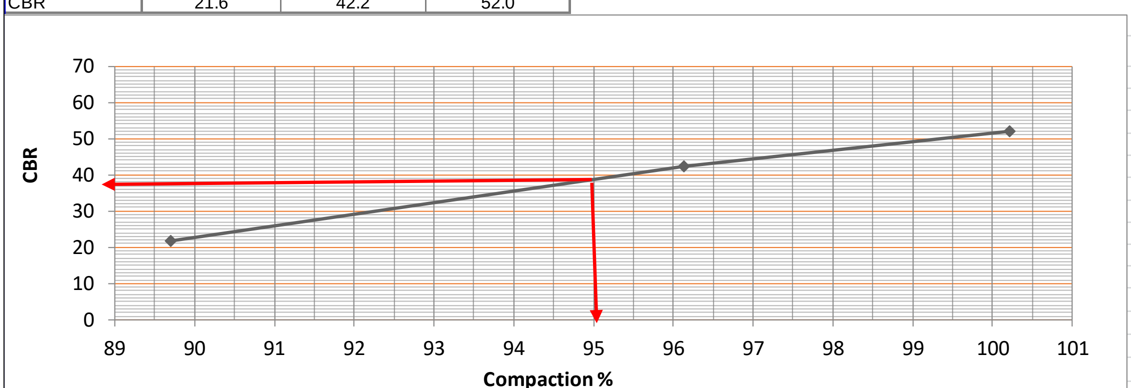


Bottom Face Penetration



Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	89.7	96.1	100.2
CBR	21.6	42.2	52.0



CBR @ 98% MDD	47
CBR @ 95% MDD	39
CBR @ 93% MDD	32

Table D. 11: KMN-02 CBR Penetration Results

PROJECT :	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**				
TASK:	Research Dissertation	**UNIVERSITY:**	KYAMBOGO	**Serial No.:**	

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 4+300 LHS		Depth (m):	0.250-0.450		Testing Date:	*12/10/23*
FACULTY:	ENGINERING	**DEPARTMENT:**	CIVIL & BUILDING ENGINEERING	**STUDENT:**	Mbwali Mary		**21/U/GMES/14326/PE**
Sample Ref No.	KMN-02		Soaking Period	4	Proving Ring Factor		0.0217

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
9.1	*8.9*	*9.0*	*12.2*	*3.2*	*18100*	*578*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	M022	B29	M022	B29	M022	B29
Mass of container, g	75.00	85.00	75.00	85.00	75.00	85.00
Mass of wet soil +container, g	390.00	365.00	390.00	365.00	390.00	365.00
Mass of dry soil +container, g	363.60	342.20	363.60	342.20	363.60	342.20
Moisture content	9.1	8.9	9.1	8.9	9.1	8.9
Avergae moisture content	9.0		9.0		9.0	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	N096	N126	N20
Volume of mould, cm^3	2303.0	2303.0	2303.0
Mass of mould, g	6300.0	6755.0	6670.0
Mass of mould + Soil, g	10286.3	11025.0	11205.0
Mass of soil, g	3986.3	4270.0	4535.0
Dry Density, kg/m^3	1.588	1.701	1.806
Target Density	1.780	1.780	1.780
% Compaction	89.2	95.6	101.5

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
14.0	**32.5**	**51.2**

TESTING

Penetration (mm)	Dial Gauge Reading LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom	Equivalent Force in kN LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	10	30	30	124	50	105	0.22	0.65	0.65	2.69	1.09	2.28
1.0	15	56	66	130	80	210	0.33	1.22	1.43	2.82	1.74	4.56
1.5	25	68	78	160	120	314	0.54	1.48	1.69	3.47	2.60	6.81
2.0	50	86	98	210	155	405	1.09	1.87	2.13	4.56	3.36	8.79
2.5	71	100	116	280	180	445	1.54	2.17	2.52	6.08	3.91	9.66
3.0	89	111	130	329	225	512	1.93	2.41	2.82	7.14	4.88	11.11
3.5	101	122	145	375	252	583	2.19	2.65	3.15	8.14	5.47	12.65
4.0	115	131	164	408	275	658	2.50	2.84	3.56	8.85	5.97	14.28
4.5	125	139	184	445	320	700	2.71	3.02	3.99	9.66	6.94	15.19
5.0	135	147	198	482	371	751	2.93	3.19	4.30	10.46	8.05	16.30
5.5	144	155	214	522	407	800	3.12	3.36	4.64	11.33	8.83	17.36
6.0	152	162	223	560	446	846	3.30	3.52	4.84	12.15	9.68	18.36
6.5	160	170	244	595	481	882	3.47	3.69	5.29	12.91	10.44	19.14
7.0	166	180	258	630	517	925	3.60	3.91	5.60	13.67	11.22	20.07
7.5	174	190	270	665	549	962	3.78	4.12	5.86	14.43	11.91	20.88
8.0	180	202	282	685	615	994	3.91	4.38	6.12	14.86	13.35	21.57

CALCULATION OF CBR %

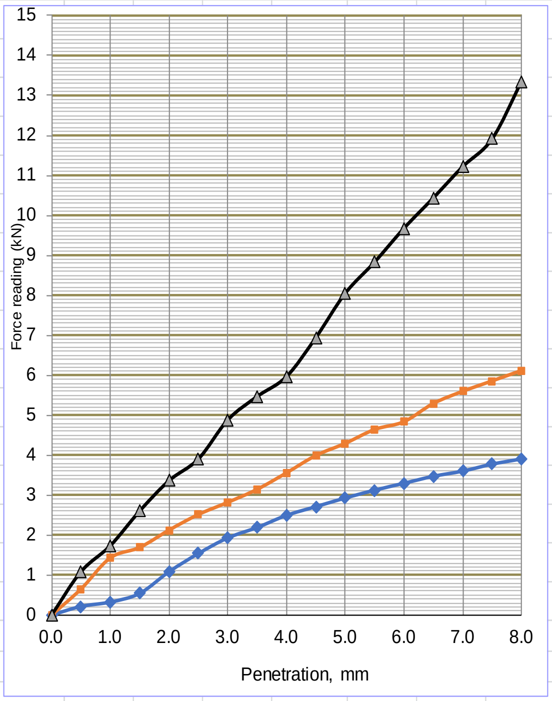
	LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
CBR at 2.5 mm penetration	11.6	16.4	19.0	45.9	29.5	72.9
CBR at 5.0 mm penetration	14.7	16.0	21.5	52.4	40.3	81.6
M	14.0		32.5		51.2	

Table D. 12: KMN-02 CBR Results

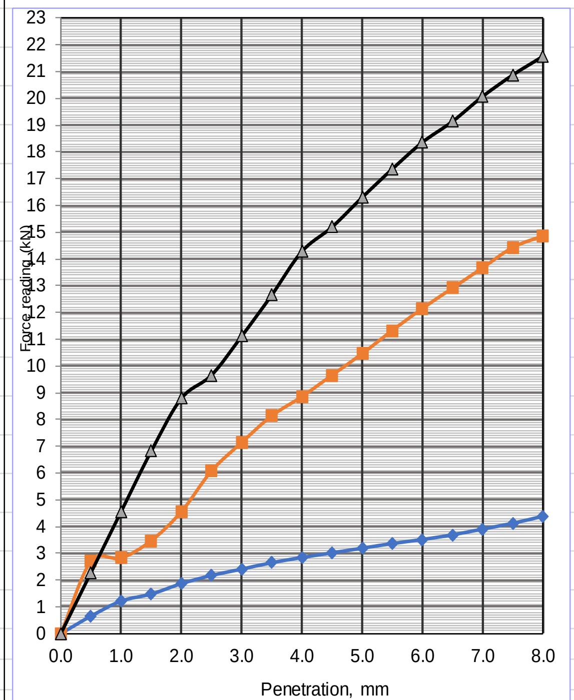
CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

Top Face Penetration

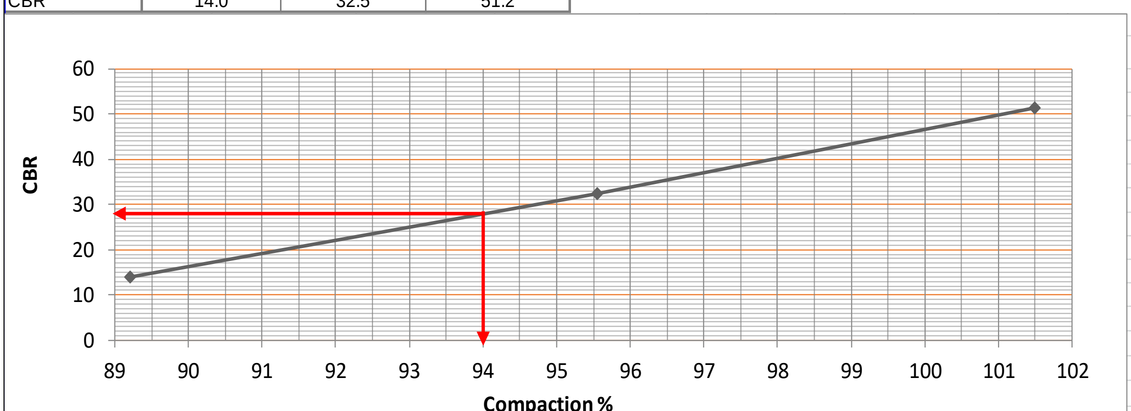


Bottom Face Penetration



Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	89.2	95.6	101.5
CBR	14.0	32.5	51.2



CBR @ 98% MDD	40
CBR @ 95% MDD	31
CBR @ 93% MDD	25

Table D. 13: KMN-03 CBR Penetration Results

PROJECT :	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**				
TASK:	Research Dissertation	**UNIVERSITY:**	KYAMBOGO	**Serial No.:**	

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 3+320 RHS	Depth (m):	0.250-0.450	Testing Date:	*12/10/23*
FACULTY:	ENGINERING	**DEPARTMENT:**	CIVIL & BUILDING ENGINEERING	**STUDENT:** Mbwali Mary	**21/U/GMES/14326/PE**
Sample Ref No.	KMN-03	Soaking Period	4	Proving Ring Factor	0.0217

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
8.8	*8.7*	*8.7*	*10.3*	*1.6*	*18100*	*287*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	M204	B22	M204	B22	M204	B22
Mass of container, g	85.00	85.00	85.00	85.00	85.00	85.00
Mass of wet soil +container, g	400.00	360.00	400.00	360.00	400.00	360.00
Mass of dry soil +container, g	374.60	338.10	374.60	338.10	374.60	338.10
Moisture content	8.8	8.7	8.8	8.7	8.8	8.7
Avergae moisture content	8.7		8.7		8.7	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	N032	N063	NO28A
Volume of mould, cm^3	2303.0	2303.0	2303.0
Mass of mould, g	6365.0	6540.0	6290.0
Mass of mould + Soil, g	10905.0	11369.0	11390.0
Mass of soil, g	4540.0	4829.0	5100.0
Dry Density, kg/m^3	1.813	1.929	2.037
Target Density	2.002	2.002	2.002
% Compaction	90.6	96.3	101.8

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
16.8	**40.5**	**65.8**

TESTING

Penetration (mm)	Dial Gauge Reading LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom	Equivalent Force in kN LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	5	60	80	90	85	164	0.11	1.30	1.74	1.95	1.84	3.56
1.0	6	82	99	110	121	256	0.13	1.78	2.15	2.39	2.63	5.56
1.5	7	110	120	140	174	308	0.15	2.39	2.60	3.04	3.78	6.68
2.0	8	150	176	209	257	419	0.17	3.26	3.82	4.54	5.58	9.09
2.5	10	195	218	276	336	467	0.22	4.23	4.73	5.99	7.29	10.13
3.0	12	221	285	287	405	545	0.26	4.80	6.18	6.23	8.79	11.83
3.5	14	240	308	315	462	613	0.30	5.21	6.68	6.84	10.03	13.30
4.0	17	262	324	334	516	680	0.37	5.69	7.03	7.25	11.20	14.76
4.5	20	280	337	356	555	733	0.43	6.08	7.31	7.73	12.04	15.91
5.0	23	305	353	374	594	767	0.50	6.62	7.66	8.12	12.89	16.64
5.5	27	319	365	397	624	796	0.59	6.92	7.92	8.61	13.54	17.27
6.0	29	343	378	410	650	818	0.63	7.44	8.20	8.90	14.11	17.75
6.5	32	365	390	425	674	836	0.69	7.92	8.46	9.22	14.63	18.14
7.0	35	386	404	438	697	845	0.76	8.38	8.77	9.50	15.12	18.34
7.5	39	400	414	455	714	853	0.85	8.68	8.98	9.87	15.49	18.51
8.0	41	417	424	472	733	865	0.89	9.05	9.20	10.24	15.91	18.77

CALCULATION OF CBR %

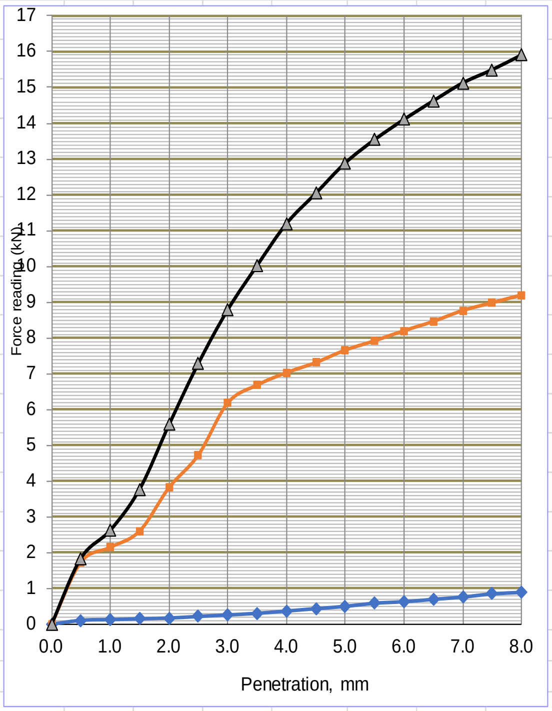
	LIGHT		INTRM.		HEAVY	
CBR at 2.5 mm penetration	1.6	32.0	35.7	45.2	55.1	76.5
CBR at 5.0 mm penetration	2.5	33.2	38.4	40.7	64.6	83.4
M	16.8		40.5		65.8	

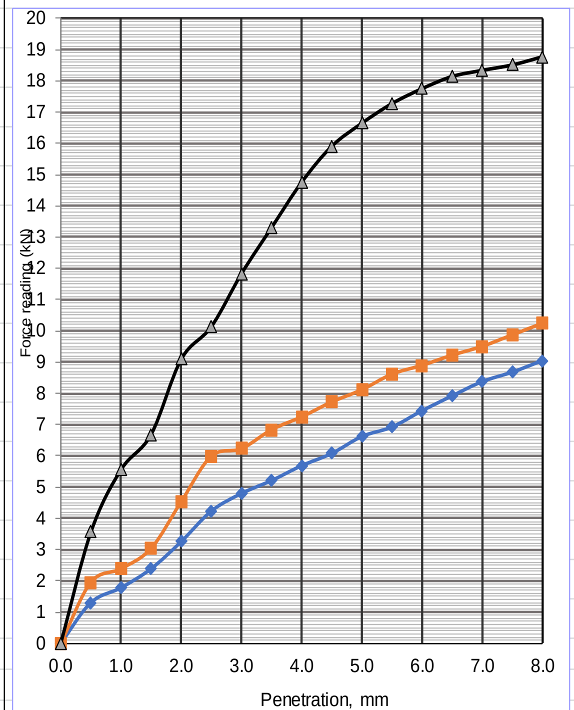
Table D. 14: KMN-03 CBR Results

CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

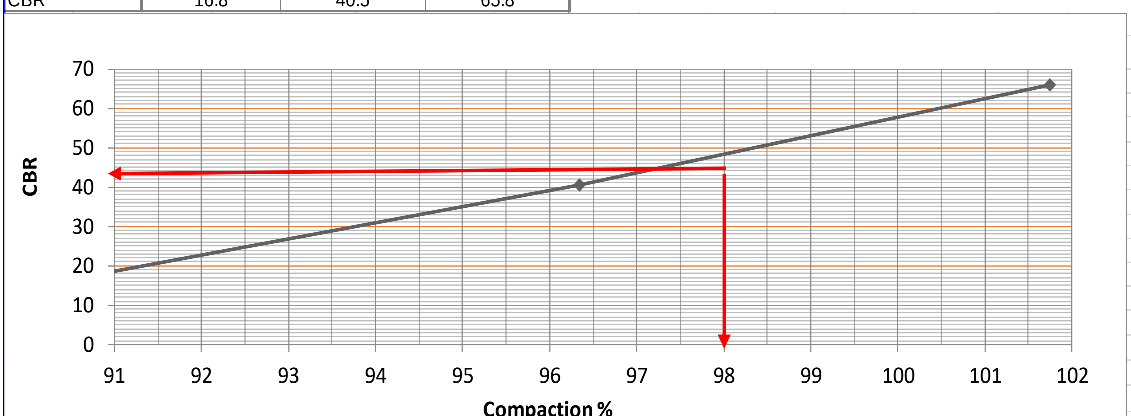
Top Face Penetration	**Bottom Face Penetration**





Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	90.6	96.3	101.8
CBR	16.8	40.5	65.8



CBR @ 98% MDD	48
CBR @ 95% MDD	35
CBR @ 93% MDD	27

Table D. 15: SSB-01 CBR Penetration Results

PROJECT :	Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study				
TASK:	Research Dissertation	UNIVERSITY:	KYAMBOGO	Serial No.:	

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 0+400 LHS		Depth (m):	0.250-0.450		Testing Date:	*12/10/23*
FACULTY:	ENGINERING	DEPARTMENT:	CIVIL & BUILDING ENGINEERING	STUDENT:	Mbwali Mary		21/U/GMES/14326/PE
Sample Ref No.	SSB-01		Soaking Period	4	Proving Ring Factor		0.0125

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
14.2	*11.6*	*12.9*	*14.6*	*1.7*	*18100*	*307*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	MO96	M029	MO96	M029	MO96	M029
Mass of container, g	75.00	70.00	75.00	70.00	75.00	70.00
Mass of wet soil +container, g	365.00	355.00	365.00	355.00	365.00	355.00
Mass of dry soil +container, g	328.90	325.40	328.90	325.40	328.90	325.40
Moisture content	14.2	11.6	14.2	11.6	14.2	11.6
Avergae moisture content	12.9		12.9		12.9	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	N058	NO8	NO5
Volume of mould, cm^3	2303.0	2303.0	2303.0
Mass of mould, g	6470.0	6745.0	6565.0
Mass of mould + Soil, g	10892.0	11376.0	11520.0
Mass of soil, g	4422.0	4631.0	4955.0
Dry Density, kg/m^3	1.701	1.781	1.906
Target Density	1.880	1.880	1.880
% Compaction	90.5	94.7	101.4

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
8.2	**31.0**	**45.8**

TESTING

Penetration (mm)	Dial Gauge Reading LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom	Equivalent Force in kN LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	4	80	19	490	40	445	0.05	1.00	0.24	6.13	0.50	5.56
1.0	9	102	37	510	91	550	0.11	1.28	0.46	6.38	1.14	6.88
1.5	15	120	52	531	110	650	0.19	1.50	0.65	6.64	1.38	8.13
2.0	20	143	66	558	132	741	0.25	1.79	0.83	6.98	1.65	9.26
2.5	23	151	79	578	145	825	0.29	1.89	0.99	7.23	1.81	10.31
3.0	26	165	94	595	161	905	0.33	2.06	1.18	7.44	2.01	11.31
3.5	30	173	106	615	178	990	0.38	2.16	1.33	7.69	2.23	12.38
4.0	34	192	120	634	195	1060	0.43	2.40	1.50	7.93	2.44	13.25
4.5	37	202	134	655	212	1120	0.46	2.53	1.68	8.19	2.65	14.00
5.0	40	215	147	670	230	1140	0.50	2.69	1.84	8.38	2.88	14.25
5.5	43	230	160	685	244	1165	0.54	2.88	2.00	8.56	3.05	14.56
6.0	47	240	170	690	256	1180	0.59	3.00	2.13	8.63	3.20	14.75
6.5	50	251	182	720	267	1197	0.63	3.14	2.28	9.00	3.34	14.96
7.0	56	262	191	740	278	1228	0.70	3.28	2.39	9.25	3.48	15.35
7.5	60	270	200	760	292	1252	0.75	3.38	2.50	9.50	3.65	15.65
8.0	62	280	210	783	306	1281	0.78	3.50	2.63	9.79	3.83	16.01

CALCULATION OF CBR %

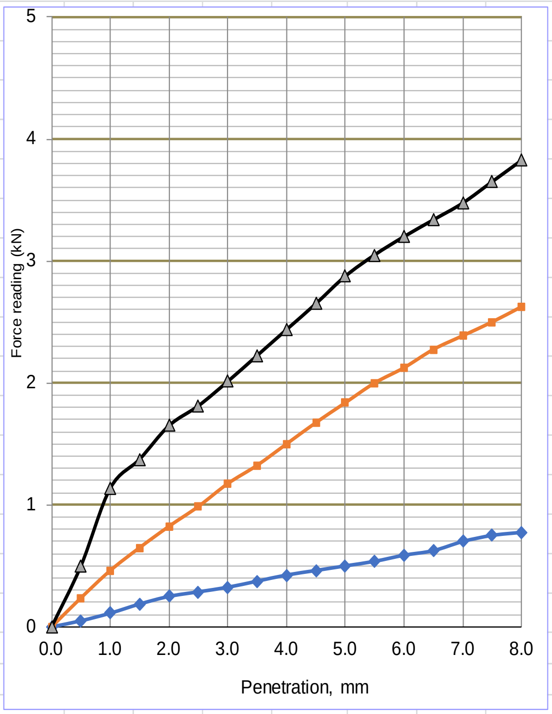
	LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
CBR at 2.5 mm penetration	2.2	14.3	7.5	54.6	13.7	77.9
CBR at 5.0 mm penetration	2.5	13.5	9.2	42.0	14.4	71.4
M	8.2		31.0		45.8	

Table D. 16: SSB-01 CBR Results

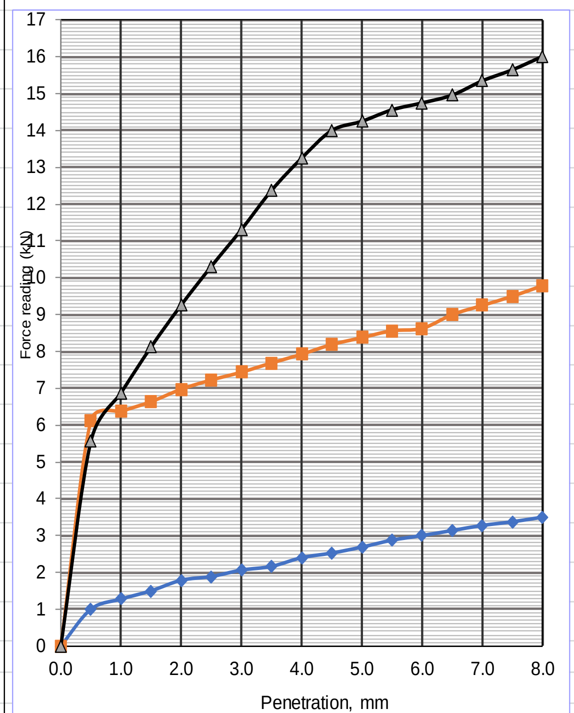
CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

Top Face Penetration

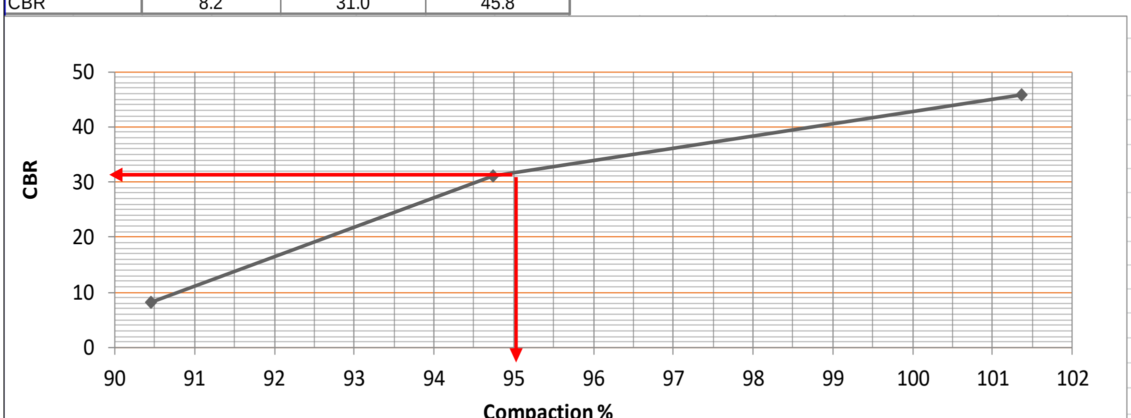


Bottom Face Penetration



Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	90.5	94.7	101.4
CBR	8.2	31.0	45.8



CBR @ 98% MDD	38
CBR @ 95% MDD	32
CBR @ 93% MDD	22

Table D. 17: SSB-02 CBR Penetration Results

PROJECT :	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**			
TASK:	Research Dissertation	**UNIVERSITY:**	KYAMBOGO	**Serial No.:**

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 0+800 LHS		Depth (m):	0.250-0.450		Testing Date:	*12/10/23*
FACULTY:	ENGINERING	**DEPARTMENT:**	CIVIL & BUILDING ENGINEERING	**STUDENT:**	Mbwali Mary		**21/U/GMES/14326/PE**
Sample Ref No.	SSB-02		Soaking Period	4	Proving Ring Factor		**0.0125**

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
10.0	*9.8*	*9.9*	*11.8*	*1.9*	*18100*	*336*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	M359	AOO7	M359	AOO7	M359	AOO7
Mass of container, g	75.00	85.00	75.00	85.00	75.00	85.00
Mass of wet soil +container, g	350.00	365.00	350.00	365.00	350.00	365.00
Mass of dry soil +container, g	324.90	339.90	324.90	339.90	324.90	339.90
Moisture content	10.0	9.8	10.0	9.8	10.0	9.8
Avergae moisture content	9.9		9.9		9.9	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	40	NO39	34
Volume of mould, cm^3	2303.0	2303.0	2303.0
Mass of mould, g	6618.0	6690.0	6625.0
Mass of mould + Soil, g	10785.0	11105.0	11275.0
Mass of soil, g	4167.0	4415.0	4650.0
Dry Density, kg/m^3	1.646	1.744	1.836
Target Density	1.799	1.799	1.799
% Compaction	91.5	96.9	102.1

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
14.3	**40.5**	**46.5**

TESTING

Penetration (mm)	Dial Gauge Reading LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom	Equivalent Force in kN LIGHT Top	LIGHT Bottom	INTRM. Top	INTRM. Bottom	HEAVY Top	HEAVY Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	14	189	58	190	35	310	0.18	2.36	0.73	2.38	0.44	3.88
1.0	25	215	125	295	100	400	0.31	2.69	1.56	3.69	1.25	5.00
1.5	31	236	268	385	165	500	0.39	2.95	3.35	4.81	2.06	6.25
2.0	39	246	298	460	216	610	0.49	3.08	3.73	5.75	2.70	7.63
2.5	45	258	317	540	274	710	0.56	3.23	3.96	6.75	3.43	8.88
3.0	54	278	330	600	325	805	0.68	3.48	4.13	7.50	4.06	10.06
3.5	59	299	340	666	370	900	0.74	3.74	4.25	8.33	4.63	11.25
4.0	69	316	352	715	420	1000	0.86	3.95	4.40	8.94	5.25	12.50
4.5	71	341	370	782	468	1063	0.89	4.26	4.63	9.78	5.85	13.29
5.0	79	365	380	852	512	1105	0.99	4.56	4.75	10.65	6.40	13.81
5.5	88	382	390	900	560	1186	1.10	4.78	4.88	11.25	7.00	14.83
6.0	91	410	401	939	600	1262	1.14	5.13	5.01	11.74	7.50	15.78
6.5	98	465	410	975	640	1302	1.23	5.81	5.13	12.19	8.00	16.28
7.0	106	485	421	1012	681	1363	1.33	6.06	5.26	12.65	8.51	17.04
7.5	112	499	430	1042	720	1401	1.40	6.24	5.38	13.03	9.00	17.51
8.0	117	520	438	1086	762	1440	1.46	6.50	5.48	13.58	9.53	18.00

CALCULATION OF CBR %

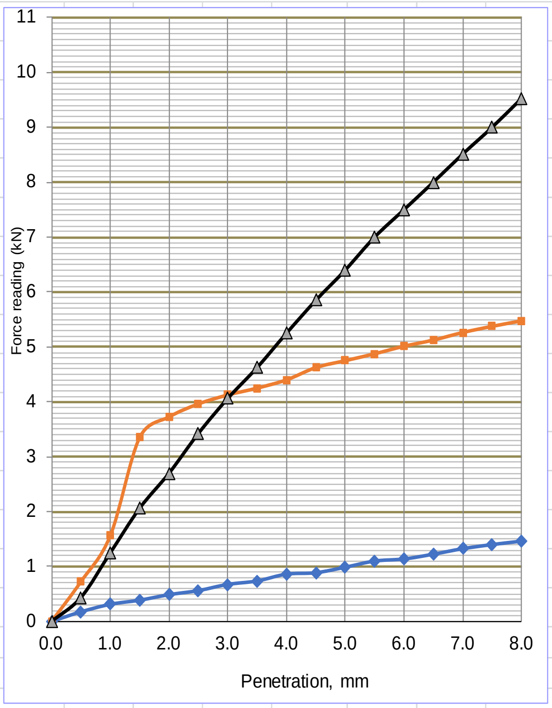
CBR at 2.5 mm penetration	4.2	24.4	29.9	51.0	25.9	67.0
CBR at 5.0 mm penetration	4.9	22.9	23.8	53.4	32.1	69.2
M	14.3		40.5		46.5	

Table D. 18: SSB-02 CBR Results

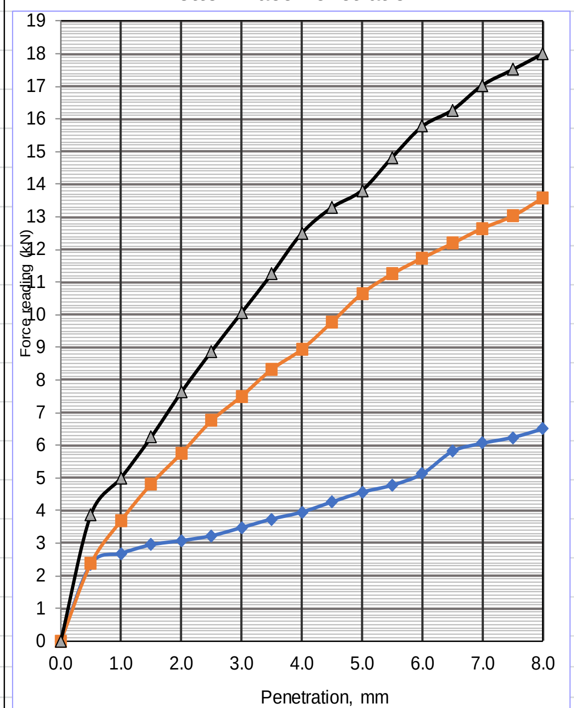
CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

Top Face Penetration

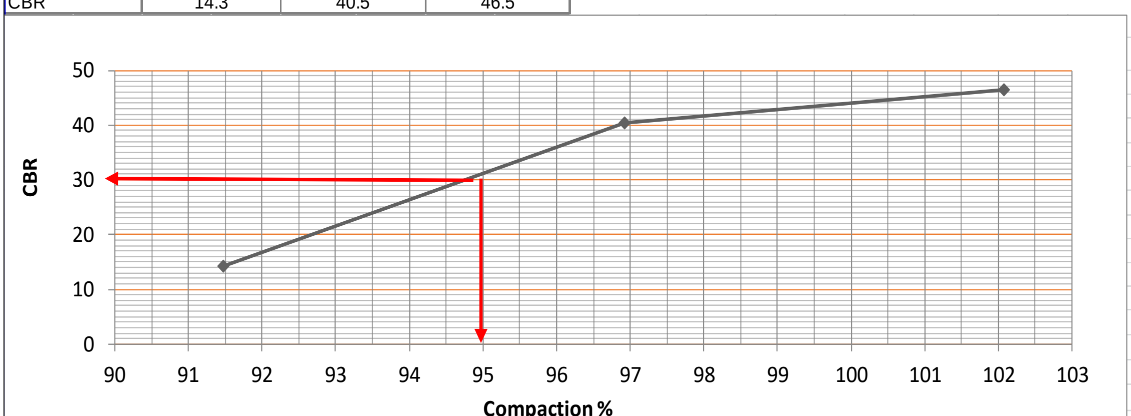


Bottom Face Penetration



Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	91.5	96.9	102.1
CBR	14.3	40.5	46.5



CBR @ 98% MDD	42
CBR @ 95% MDD	31
CBR @ 93% MDD	22

Table D. 19: SSB-03 CBR Penetration Results

PROJECT :	**Investigating into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study**			
TASK:	Research Dissertation	**UNIVERSITY:**	KYAMBOGO	**Serial No.:**

CBR TEST: REF TEST METHOD : BS 1377- 4 (1990)

Sample Location:	KM: 2+450 RHS		Depth (m):	0.250-0.450		Testing Date:	*12/10/23*
FACULTY:	ENGINERING	**DEPARTMENT:**	CIVIL & BUILDING ENGINEERING	**STUDENT:**	Mbwali Mary		**21/U/GMES/1432 6/PE**
Sample Ref No.	SSB-03		Soaking Period	4	Proving Ring Factor		**0.0125**

Water to be added

Present MC, %		Average MC %	Target OMC, %	Target OMC - MC (%)	*Mass of soil, g*	Water to be added,mL
13.0	*13.5*	*13.2*	*11.8*	*-1.4*	*18100*	*-259*

Moisture content before moulding

	LIGHT		*INTRM.*		*HEAVY*	
Container No.	MM	AXE	MM	AXE	MM	AXE
Mass of container, g	85.00	90.00	85.00	90.00	85.00	90.00
Mass of wet soil +container, g	486.00	502.00	486.00	502.00	486.00	502.00
Mass of dry soil +container, g	440.00	453.00	440.00	453.00	440.00	453.00
Moisture content	13.0	13.5	13.0	13.5	13.0	13.5
Avergae moisture content	13.2		13.2		13.2	

Density Determination

	LIGHT	*INTRM.*	*HEAVY*
Mould No.	K2	M22	MK6
Volume of mould, cm^3	2303.0	2303.0	2303.0
Mass of mould, g	6025.0	6522.0	6802.0
Mass of mould + Soil, g	10532.0	11325.0	11893.0
Mass of soil, g	4507.0	4803.0	5091.0
Dry Density, kg/m^3	1.728	1.842	1.952
Target Density	1.920	1.920	1.920
% Compaction	90.0	95.9	101.7

Accepted CBR

LIGHT	*INTRM.*	*HEAVY*
8.9	**36.3**	**41.4**

TESTING

Penetration (mm)	Dial Gauge Reading						Equivalent Force in kN					
	LIGHT		INTRM.		HEAVY		LIGHT		INTRM.		HEAVY	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	10	33	75	85	79	125	0.13	0.41	0.94	1.06	0.99	1.56
1.0	20	62	100	125	130	188	0.25	0.78	1.25	1.56	1.63	2.35
1.5	33	81	155	220	230	275	0.41	1.01	1.94	2.75	2.88	3.44
2.0	49	102	225	385	330	352	0.61	1.28	2.81	4.81	4.13	4.40
2.5	69	120	295	475	428	448	0.86	1.50	3.69	5.94	5.35	5.60
3.0	85	145	366	540	510	542	1.06	1.81	4.58	6.75	6.38	6.78
3.5	92	163	440	597	600	630	1.15	2.04	5.50	7.46	7.50	7.88
4.0	103	180	495	635	686	700	1.29	2.25	6.19	7.94	8.58	8.75
4.5	115	196	525	685	772	789	1.44	2.45	6.56	8.56	9.65	9.86
5.0	125	215	550	720	825	850	1.56	2.69	6.88	9.00	10.31	10.63
5.5	135	230	574	750	867	915	1.69	2.88	7.18	9.38	10.84	11.44
6.0	144	245	600	783	899	968	1.80	3.06	7.50	9.79	11.24	12.10
6.5	154	261	625	800	915	998	1.93	3.26	7.81	10.00	11.44	12.48
7.0	162	275	645	818	930	1025	2.03	3.44	8.06	10.23	11.63	12.81
7.5	172	292	665	856	945	1075	2.15	3.65	8.31	10.70	11.81	13.44
8.0	180	309	680	895	958	1105	2.25	3.86	8.50	11.19	11.98	13.81

CALCULATION OF CBR %

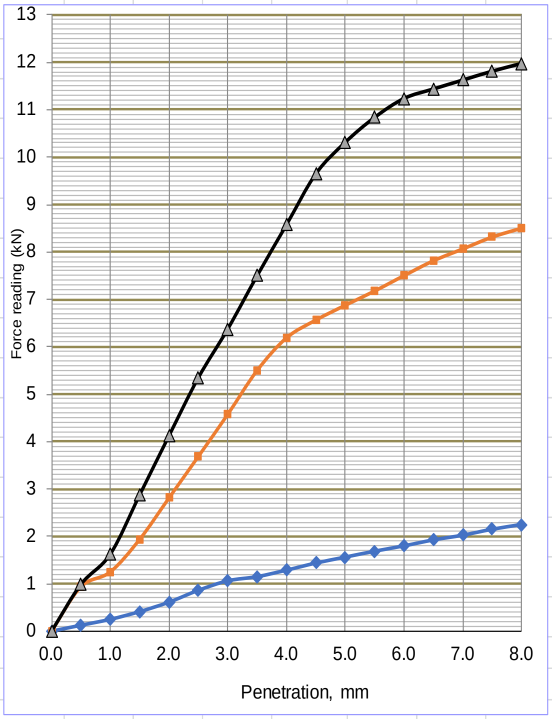
CBR at 2.5 mm penetration	6.5	11.3	27.9	44.8	40.4	42.3
CBR at 5.0 mm penetration	7.8	13.5	34.4	45.1	51.7	53.2
M	8.9		36.3		41.4	

Table D. 20: SSB-03 CBR Results

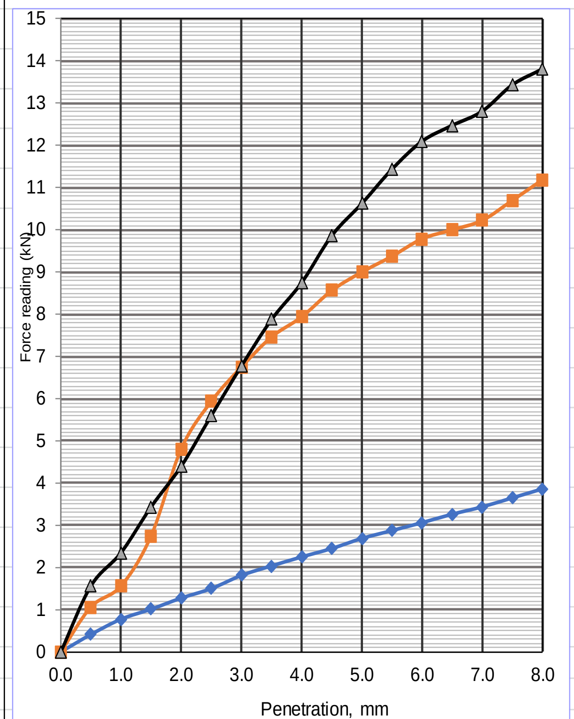
CBR TEST

REF TEST METHOD: BS 1377- 4 (1990)

Top Face Penetration

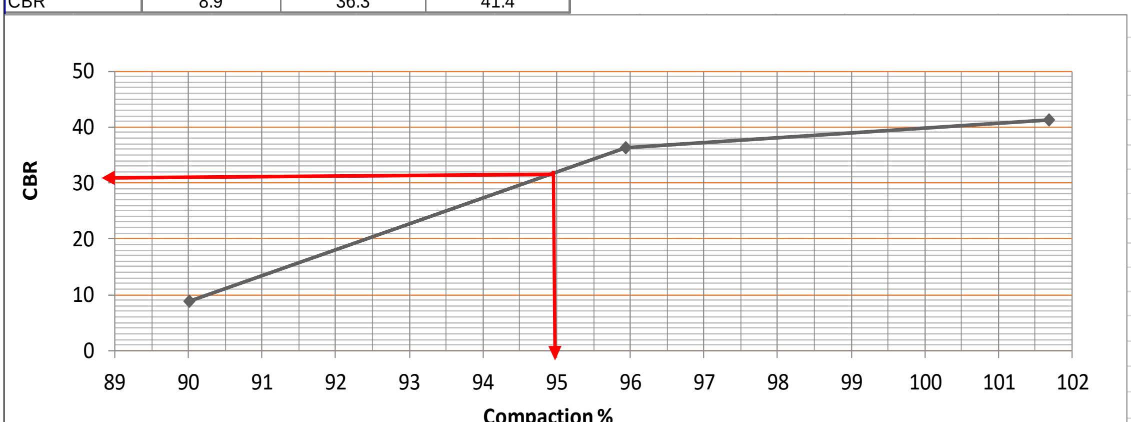


Bottom Face Penetration



Three point Graph

	LIGHT	INTRIM	HEAVY
DENSITY RATIO	90.0	95.9	101.7
CBR	8.9	36.3	41.4



CBR @ 98% MDD	38
CBR @ 95% MDD	32
CBR @ 93% MDD	23

Appendix E: Oedometer Test Results

Table E. 1: GK-01 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *21/Oct/23*

Sample source: GK-01 -nmc sat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Gayaza Karagi road ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*13.2*	
Water Content (Measured) (%)	*12.4*	*14.4*
Bulk Density (Mg/m^3)	*2.062*	
Dry Density (Mg/m^3)	*1.820*	*2.040*
Dry Unit Weight (kN/m^3)	*17.8*	*20.0*
Void Ratio	*0.482*	*0.389*
Degree of Saturation (%)	*69.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.93*	*0.482000*	*3.9E-01*	*0.140*	*7.143*	*5.38E-10*
25 - 50	*00:58*	*19.53*	*0.452434*	*0.6606*	*0.801*	*1.249*	*5.19E-09*
50 - 100	*00:58*	*19.10*	*0.420645*	*0.3666*	*0.439*	*2.276*	*1.58E-09*
100 - 200	*00:58*	*18.60*	*0.383225*	*0.1550*	*0.264*	*3.783*	*4.02E-10*
200 - 400	*00:58*	*18.10*	*0.346241*	*0.0893*	*0.134*	*7.452*	*1.17E-10*
400 - 800	*00:58*	*17.47*	*0.299418*	*0.1622*	*0.087*	*11.456*	*1.39E-10*
800 - 400	*00:58*	*17.53*					
400 - 100	*00:58*	*17.55*		-	-	-	-
100 - 50	*00:58*	*17.62*					
50 - 25	*03:56*	*17.808*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 2: GK-01 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*21/Oct/23*
Sample source:	GK-01 -nmc unsat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Gayaza Karagi road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*13.2*	
Water Content (Measured) (%)	*13.4*	*12.3*
Bulk Density (Mg/m^3)	*2.096*	
Dry Density (Mg/m^3)	*1.800*	*1.990*
Dry Unit Weight (kN/m^3)	*17.7*	*19.5*
Void Ratio	*0.458*	*0.358*
Degree of Saturation (%)	*73.0*	*93*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.90*	*0.458000*	*1.6E-01*	*0.192*	*5.208*	*3.08E-10*
25 - 50	*00:58*	*19.71*	*0.444076*	*0.2561*	*0.384*	*2.605*	*9.64E-10*
50 - 100	*00:58*	*19.45*	*0.424962*	*0.1864*	*0.266*	*3.759*	*4.86E-10*
100 - 200	*00:58*	*19.08*	*0.398076*	*0.5774*	*0.190*	*5.274*	*1.07E-09*
200 - 400	*00:58*	*18.64*	*0.365745*	*0.2744*	*0.135*	*7.382*	*3.65E-10*
400 - 800	*00:58*	*18.08*	*0.324745*	*0.1443*	*0.084*	*11.844*	*1.20E-10*
800 - 400	*00:58*	*17.99*					
400 - 100	*00:58*	*18.02*		-	-	-	-
100 - 50	*00:58*	*18.06*					
50 - 25	*03:56*	*18.148*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 3: GK-01 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*		
Task:	*Research Dissertation*	**University:** Kyambogo	Testing Date: *21/Oct/23*
Sample source:	GK-01 -omc sat	**Faculty:** Engineering	Specimen Depth (m): *0.2 -0.45*
Location:	Gayaza Karagi road	***Student:*** *Mbwali Mary Christine*	Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	20	
Inner Diameter (mm)	80	
Water Content (Trimmings) (%)	10.5	
Water Content (Measured) (%)	12.3	12.9
Bulk Density (Mg/m^3)	2.030	
Dry Density (Mg/m^3)	1.840	1.990
Dry Unit Weight (kN/m^3)	18.0	19.5
Void Ratio	0.470	0.348
Degree of Saturation (%)	71.0	100

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	00:58	19.90	0.470000	1.2E-01	0.194	5.155	2.21E-10
25 - 50	00:58	19.76	0.459269	0.3652	0.293	3.408	1.05E-09
50 - 100	00:58	19.52	0.441703	0.2868	0.242	4.133	6.81E-10
100 - 200	00:58	19.16	0.415537	0.1005	0.182	5.483	1.80E-10
200 - 400	00:58	18.82	0.390032	0.2725	0.091	11.044	2.42E-10
400 - 800	00:58	18.39	0.359015	0.2013	0.056	17.834	1.11E-10
800 - 400	00:58	18.15					
400 - 100	00:58	18.24		-	-	-	-
100 - 50	00:58	18.30					
50 - 25	03:56	18.445					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 4: GK-01 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *21/Oct/23*

Sample source: GK-01 -omc unsat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Gayaza Karagi road ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*10.4*	
Water Content (Measured) (%)	*10.8*	*9.9*
Bulk Density (Mg/m^3)	*2.051*	
Dry Density (Mg/m^3)	*1.860*	*1.940*
Dry Unit Weight (kN/m^3)	*18.2*	*19.0*
Void Ratio	*0.453*	*0.390*
Degree of Saturation (%)	*64.0*	*69*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.90*	*0.453000*	*1.1E-01*	*0.210*	*4.762*	*2.21E-10*
25 - 50	*00:58*	*19.81*	*0.446607*	*0.1683*	*0.177*	*5.652*	*2.92E-10*
50 - 100	*00:58*	*19.66*	*0.435637*	*0.1659*	*0.152*	*6.559*	*2.48E-10*
100 - 200	*00:58*	*19.46*	*0.421397*	*0.1510*	*0.100*	*10.029*	*1.48E-10*
200 - 400	*00:58*	*19.18*	*0.401121*	*0.5049*	*0.072*	*13.945*	*3.55E-10*
400 - 800	*00:58*	*18.84*	*0.376427*	*0.4064*	*0.044*	*22.572*	*1.77E-10*
800 - 400	*00:58*	*18.89*					
400 - 100	*00:58*	*18.96*		-	-	-	-
100 - 50	*00:58*	*19.01*					
50 - 25	*03:56*	*19.141*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 5: GK-02 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*22/Oct/23*
Sample source:	GK-02 -nmc sat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Gayaza Karagi road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*8.7*	
Water Content (Measured) (%)	*8.8*	*11.8*
Bulk Density (Mg/m^3)	*2.040*	
Dry Density (Mg/m^3)	*1.880*	*2.080*
Dry Unit Weight (kN/m^3)	*18.4*	*20.4*
Void Ratio	*0.439*	*0.319*
Degree of Saturation (%)	*54.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.87*	*0.439000*	*1.1E-01*	*0.258*	*3.876*	*2.85E-10*
25 - 50	*00:58*	*19.66*	*0.423603*	*0.1455*	*0.431*	*2.321*	*6.15E-10*
50 - 100	*00:58*	*19.31*	*0.398276*	*0.2315*	*0.358*	*2.792*	*8.13E-10*
100 - 200	*00:58*	*18.88*	*0.367841*	*0.2195*	*0.219*	*4.564*	*4.72E-10*
200 - 400	*00:58*	*18.36*	*0.330111*	*0.0814*	*0.139*	*7.201*	*1.11E-10*
400 - 800	*00:58*	*17.76*	*0.286970*	*0.2601*	*0.082*	*12.247*	*2.08E-10*
800 - 400	*00:58*	*17.82*					
400 - 100	*00:58*	*17.88*		-	-	-	-
100 - 50	*00:58*	*17.94*					
50 - 25	*03:56*	*18.068*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 6: GK-02 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*		
Task: *Research Dissertation*	**University:** Kyambogo	Testing Date: *22/Oct/23*	
Sample source: GK-02 -nmc unsat	**Faculty:** Engineering	Specimen Depth (m): *0.2 -0.45*	
Location: Gayaza Karagi road	***Student:*** *Mbwali Mary Christine*	Sample Condition *Moulded*	

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*8.7*	
Water Content (Measured) (%)	*9.7*	*8.0*
Bulk Density (Mg/m^3)	*2.045*	
Dry Density (Mg/m^3)	*1.880*	*2.080*
Dry Unit Weight (kN/m^3)	*18.4*	*20.3*
Void Ratio	*0.435*	*0.301*
Degree of Saturation (%)	*60.0*	*75*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.90*	*0.435000*	*6.2E-02*	*0.192*	*5.208*	*1.16E-10*
25 - 50	*00:58*	*19.70*	*0.420004*	*0.0593*	*0.420*	*2.381*	*2.44E-10*
50 - 100	*00:58*	*19.30*	*0.391950*	*0.0631*	*0.397*	*2.519*	*2.46E-10*
100 - 200	*00:58*	*18.93*	*0.365259*	*0.0639*	*0.193*	*5.189*	*1.21E-10*
200 - 400	*00:58*	*18.44*	*0.330102*	*0.0329*	*0.129*	*7.727*	*4.18E-11*
400 - 800	*00:58*	*17.95*	*0.294779*	*0.1398*	*0.067*	*14.984*	*9.15E-11*
800 - 400	*00:58*	*17.96*					
400 - 100	*00:58*	*17.98*		-	-	-	-
100 - 50	*00:58*	*18.03*					
50 - 25	*03:56*	*18.129*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 7: GK-02 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

Tested in accordance with BS 1377: Part 5:1990

TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*22/Oct/23*
Sample source:	GK-02 -omc sat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Gayaza Karagi road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*8.8*	
Water Content (Measured) (%)	*6.3*	*10.2*
Bulk Density (Mg/m^3)	*2.085*	
Dry Density (Mg/m^3)	*1.960*	*2.100*
Dry Unit Weight (kN/m^3)	*19.2*	*20.6*
Void Ratio	*0.409*	*0.275*
Degree of Saturation (%)	*45.0*	*97*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.96*	*0.409000*	*1.5E-01*	*0.082*	*12.195*	*1.20E-10*
25 - 50	*00:58*	*19.75*	*0.394346*	*0.2292*	*0.417*	*2.399*	*9.37E-10*
50 - 100	*00:58*	*19.53*	*0.378425*	*0.3730*	*0.229*	*4.370*	*8.37E-10*
100 - 200	*00:58*	*19.25*	*0.358981*	*0.3693*	*0.141*	*7.074*	*5.12E-10*
200 - 400	*00:58*	*18.89*	*0.333759*	*0.2840*	*0.093*	*10.754*	*2.59E-10*
400 - 800	*00:58*	*18.50*	*0.306002*	*0.1735*	*0.052*	*19.179*	*8.87E-11*
800 - 400	*00:58*	*18.47*					
400 - 100	*00:58*	*18.50*		-	-	-	-
100 - 50	*00:58*	*18.55*					
50 - 25	*03:56*	*18.614*					

c_v Coefficient of Consolidation

m_v Coefficient of Volume Compressibility

$1/m_v$ Constrained Modulus

k Coefficient of Permeability

Table E. 8: GK-02 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*22/Oct/23*
Sample source:	GK-02 -omc unsat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Gayaza Karagi road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa): *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*8.8*	
Water Content (Measured) (%)	*9.2*	*8.0*
Bulk Density (Mg/m^3)	*2.095*	
Dry Density (Mg/m^3)	*1.930*	*2.090*
Dry Unit Weight (kN/m^3)	*18.9*	*20.4*
Void Ratio	*0.402*	*0.294*
Degree of Saturation (%)	*62.0*	*73*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.83*	*0.402000*	*5.9E-02*	*0.332*	*3.012*	*1.92E-10*
25 - 50	*00:58*	*19.68*	*0.391135*	*0.0854*	*0.313*	*3.199*	*2.62E-10*
50 - 100	*00:58*	*19.45*	*0.374731*	*0.1517*	*0.238*	*4.205*	*3.54E-10*
100 - 200	*00:58*	*19.22*	*0.359099*	*0.1611*	*0.115*	*8.720*	*1.81E-10*
200 - 400	*00:58*	*18.87*	*0.334143*	*0.0526*	*0.093*	*10.799*	*4.77E-11*
400 - 800	*00:58*	*18.47*	*0.306314*	*0.2290*	*0.053*	*19.009*	*1.18E-10*
800 - 400	*00:58*	*18.30*					
400 - 100	*00:58*	*18.35*		-	-	-	-
100 - 50	*00:58*	*18.38*					
50 - 25	*03:56*	*18.464*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 9: GK-03 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

Tested in accordance with BS 1377: Part 5:1990

TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*23/Oct/23*
Sample source:	GK-03 -nmc sat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Gayaza Karagi road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.0*	
Water Content (Measured) (%)	*9.2*	*12.1*
Bulk Density (Mg/m^3)	*2.040*	
Dry Density (Mg/m³)	*1.905*	*2.056*
Dry Unit Weight (kN/m³)	*18.7*	*20.2*
Void Ratio	*0.442*	*0.327*
Degree of Saturation (%)	*56.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.88*	*0.442000*	*1.2E-01*	*0.230*	*4.339*	*2.65E-10*
25 - 50	*00:58*	*19.67*	*0.426470*	*0.1490*	*0.433*	*2.308*	*6.33E-10*
50 - 100	*00:58*	*19.32*	*0.401088*	*0.2273*	*0.358*	*2.794*	*7.98E-10*
100 - 200	*00:58*	*18.90*	*0.370661*	*0.2234*	*0.218*	*4.577*	*4.79E-10*
200 - 400	*00:58*	*18.37*	*0.332868*	*0.0956*	*0.139*	*7.210*	*1.30E-10*
400 - 800	*00:58*	*17.77*	*0.289574*	*0.2429*	*0.082*	*12.238*	*1.95E-10*
800 - 400	*00:58*	*17.85*					
400 - 100	*00:58*	*17.90*		-	-	-	-
100 - 50	*00:58*	*17.97*					
50 - 25	*03:56*	*18.081*					

c_v Coefficient of Consolidation

m_v Coefficient of Volume Compressibility

$1/m_v$ Constrained Modulus

k Coefficient of Permeability

Table E. 10: GK-03 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*23/Oct/23*
Sample source:	GK-03 -nmc unsat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Gayaza Karagi road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa): *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.0*	
Water Content (Measured) (%)	*9.2*	*8.2*
Bulk Density (Mg/m^3)	*2.053*	
Dry Density (Mg/m³)	*1.905*	*2.058*
Dry Unit Weight (kN/m³)	*18.7*	*20.2*
Void Ratio	*0.433*	*0.303*
Degree of Saturation (%)	*63.0*	*76*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	00:58	19.92	0.433000	7.2E-02	0.164	6.079	1.16E-10
25 - 50	00:58	19.65	0.413868	0.0727	0.536	1.865	3.82E-10
50 - 100	00:58	19.32	0.389907	0.0759	0.340	2.938	2.54E-10
100 - 200	00:58	18.95	0.363324	0.0725	0.192	5.206	1.37E-10
200 - 400	00:58	18.54	0.334394	0.0427	0.129	7.736	5.41E-11
400 - 800	00:58	18.03	0.297473	0.0754	0.067	14.969	4.94E-11
800 - 400	00:58	17.98					
400 - 100	00:58	17.99		-	-	-	-
100 - 50	00:58	18.05					
50 - 25	03:56	18.142					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 11: GK-03 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*		
Task: *Research Dissertation*	**University:** Kyambogo	Testing Date: *23/Oct/23*	
Sample source: GK-03 -omc sat	**Faculty:** Engineering	Specimen Depth (m): *0.2 -0.45*	
Location: Gayaza Karagi road	***Student:*** *Mbwali Mary Christine*	Sample Condition *Moulded*	

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.1*	
Water Content (Measured) (%)	*6.7*	*10.5*
Bulk Density (Mg/m^3)	*2.086*	
Dry Density (Mg/m^3)	*1.986*	*2.086*
Dry Unit Weight (kN/m^3)	*19.5*	*20.5*
Void Ratio	*0.412*	*0.284*
Degree of Saturation (%)	*50.0*	*98*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.97*	*0.412000*	*1.5E-01*	*0.054*	*18.351*	*7.97E-11*
25 - 50	*00:58*	*19.76*	*0.397216*	*0.2295*	*0.419*	*2.385*	*9.44E-10*
50 - 100	*00:58*	*19.54*	*0.381258*	*0.3735*	*0.229*	*4.372*	*8.38E-10*
100 - 200	*00:58*	*19.23*	*0.359724*	*0.3692*	*0.156*	*6.405*	*5.65E-10*
200 - 400	*00:58*	*18.88*	*0.335172*	*0.2837*	*0.090*	*11.060*	*2.52E-10*
400 - 800	*00:58*	*18.48*	*0.306588*	*0.1733*	*0.054*	*18.657*	*9.11E-11*
800 - 400	*00:58*	*18.49*					
400 - 100	*00:58*	*18.51*		-	-	-	-
100 - 50	*00:58*	*18.57*					
50 - 25	*03:56*	*18.627*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 12: GK-03 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

Tested in accordance with BS 1377: Part 5:1990

TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*		
Task:	*Research Dissertation*	**University:** Kyambogo	Testing Date: *23/Oct/23*
Sample source:	GK-03 -omc unsat	**Faculty:** Engineering	Specimen Depth (m): *0.2 -0.45*
Location:	Gayaza Karagi road	***Student:*** *Mbwali Mary Christine*	Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.1*	
Water Content (Measured) (%)	*9.6*	*8.3*
Bulk Density (Mg/m^3)	*2.097*	
Dry Density (Mg/m³)	*1.953*	*2.047*
Dry Unit Weight (kN/m³)	*19.2*	*20.1*
Void Ratio	*0.405*	*0.297*
Degree of Saturation (%)	*65.0*	*76*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.85*	*0.405200*	*7.0E-02*	*0.304*	*3.284*	*2.08E-10*
25 - 50	*00:58*	*19.69*	*0.394211*	*0.0789*	*0.315*	*3.173*	*2.44E-10*
50 - 100	*00:58*	*19.46*	*0.377768*	*0.1656*	*0.238*	*4.207*	*3.86E-10*
100 - 200	*00:58*	*19.15*	*0.355846*	*0.1717*	*0.160*	*6.236*	*2.70E-10*
200 - 400	*00:58*	*18.83*	*0.333660*	*0.0584*	*0.082*	*12.126*	*4.72E-11*
400 - 800	*00:58*	*18.48*	*0.309219*	*0.1999*	*0.046*	*21.651*	*9.06E-11*
800 - 400	*00:58*	*18.32*					
400 - 100	*00:58*	*18.36*		-	-	-	-
100 - 50	*00:58*	*18.41*					
50 - 25	*03:56*	*18.477*					

c_v Coefficient of Consolidation

m_v Coefficient of Volume Compressibility

$1/m_v$ Constrained Modulus

k Coefficient of Permeability

Table E. 13: KMN-01 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*
Task:	*Research Dissertation*
University:	Kyambogo
Testing Date:	*23/Oct/23*
Sample source:	KMN-01 -nmc sat
Faculty:	Engineering
Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru
Student:	*Mbwali Mary Christine*
Sample Condition	*Moulded*
Testing Prep. Method:	*Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity:	*2.70*
Preconsolidation Pressure (kPa)	*N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*11.3*	
Water Content (Measured) (%)	*11.2*	*12.4*
Bulk Density (Mg/m^3)	*2.099*	
Dry Density (Mg/m^3)	*1.850*	*2.030*
Dry Unit Weight (kN/m^3)	*18.1*	*19.9*
Void Ratio	*0.432*	*0.335*
Degree of Saturation (%)	*66.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.90*	*0.432000*	*1.5E-01*	*0.200*	*5.000*	*2.95E-10*
25 - 50	*00:58*	*19.66*	*0.414458*	*0.1141*	*0.492*	*2.031*	*5.51E-10*
50 - 100	*00:58*	*19.32*	*0.390544*	*0.1856*	*0.340*	*2.942*	*6.19E-10*
100 - 200	*00:58*	*18.83*	*0.355173*	*0.1436*	*0.256*	*3.911*	*3.60E-10*
200 - 400	*00:58*	*18.35*	*0.321178*	*0.3604*	*0.126*	*7.930*	*4.46E-10*
400 - 800	*00:58*	*17.82*	*0.283237*	*0.2482*	*0.072*	*13.853*	*1.76E-10*
800 - 400	*00:58*	*18.07*					
400 - 100	*00:58*	*18.15*		-	-	-	-
100 - 50	*00:58*	*18.16*					
50 - 25	*03:56*	*18.262*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 14: KMN-01 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *23/Oct/23*

Sample source: KMN-01 -nmc unsat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Kamplala Mukono Njeru ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	20	
Inner Diameter (mm)	80	
Water Content (Trimmings) (%)	11.3	
Water Content (Measured) (%)	11.0	8.6
Bulk Density (Mg/m^3)	2.115	
Dry Density (Mg/m^3)	1.890	2.100
Dry Unit Weight (kN/m^3)	18.5	20.5
Void Ratio	0.421	0.289
Degree of Saturation (%)	70.0	100

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	00:58	19.98	0.421000	7.9E-02	0.050	20.000	3.87E-11
25 - 50	00:58	19.78	0.407188	0.0666	0.389	2.569	2.54E-10
50 - 100	00:58	19.43	0.382207	0.2491	0.355	2.813	8.69E-10
100 - 200	00:58	19.01	0.352324	0.2869	0.229	4.368	6.44E-10
200 - 400	00:58	18.61	0.323974	0.4464	0.124	8.075	5.42E-10
400 - 800	00:58	18.11	0.288459	0.2936	0.057	17.524	1.64E-10
800 - 400	00:58	17.87					
400 - 100	00:58	17.90		-	-	-	-
100 - 50	00:58	17.94					
50 - 25	03:56	18.032					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 15: KMN-01 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*24/Oct/23*
Sample source:	KMN-01 -nmc unsat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*10.7*	
Water Content (Measured) (%)	*10.8*	*11.4*
Bulk Density (Mg/m^3)	*2.047*	
Dry Density (Mg/m^3)	*1.870*	*2.090*
Dry Unit Weight (kN/m^3)	*18.4*	*20.5*
Void Ratio	*0.460*	*0.308*
Degree of Saturation (%)	*66.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.61*	*0.460000*	*1.5E-01*	*0.782*	*1.279*	*1.16E-09*
25 - 50	*00:58*	*19.34*	*0.440582*	*0.2744*	*0.543*	*1.843*	*1.46E-09*
50 - 100	*00:58*	*18.95*	*0.412112*	*0.1566*	*0.403*	*2.480*	*6.20E-10*
100 - 200	*00:58*	*18.55*	*0.382839*	*0.0547*	*0.212*	*4.726*	*1.14E-10*
200 - 400	*00:58*	*18.07*	*0.347580*	*0.0486*	*0.130*	*7.682*	*6.21E-11*
400 - 800	*00:58*	*17.62*	*0.314949*	*0.3112*	*0.062*	*16.169*	*1.89E-10*
800 - 400	*00:58*	*17.84*					
400 - 100	*00:58*	*17.86*		-	-	-	-
100 - 50	*00:58*	*17.89*					
50 - 25	*03:56*	*17.946*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 16: KMN-01 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*24/Oct/23*
Sample source:	KMN-01 -omc unsat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*10.7*	
Water Content (Measured) (%)	*11.4*	*10.0*
Bulk Density (Mg/m^3)	*2.063*	
Dry Density (Mg/m^3)	*1.860*	*2.070*
Dry Unit Weight (kN/m^3)	*18.3*	*20.3*
Void Ratio	*0.449*	*0.304*
Degree of Saturation (%)	*69.0*	*89*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.95*	*0.449000*	*6.7E-02*	*0.096*	*10.417*	*6.35E-11*
25 - 50	*00:58*	*19.76*	*0.435017*	*0.0617*	*0.387*	*2.584*	*2.34E-10*
50 - 100	*00:58*	*19.38*	*0.407776*	*0.0944*	*0.381*	*2.628*	*3.53E-10*
100 - 200	*00:58*	*19.05*	*0.383498*	*0.1387*	*0.173*	*5.784*	*2.35E-10*
200 - 400	*00:58*	*18.63*	*0.353221*	*0.2117*	*0.110*	*9.116*	*2.28E-10*
400 - 800	*00:58*	*18.19*	*0.321474*	*0.2028*	*0.059*	*17.006*	*1.17E-10*
800 - 400	*00:58*	*17.87*					
400 - 100	*00:58*	*17.87*		-	-	-	-
100 - 50	*00:58*	*17.92*					
50 - 25	*03:56*	*18.003*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 17: KMN-02 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *24/Oct/23*

Sample source: KMN-02 -nmc sat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Kamplala Mukono Njeru ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	20	
Inner Diameter (mm)	80	
Water Content (Trimmings) (%)	12.4	
Water Content (Measured) (%)	13.6	13.5
Bulk Density (Mg/m^3)	2.049	
Dry Density (Mg/m^3)	1.790	2.140
Dry Unit Weight (kN/m^3)	17.5	21.0
Void Ratio	0.481	0.365
Degree of Saturation (%)	75.0	100

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	00:58	19.95	0.481000	4.3E-02	0.094	10.638	4.01E-11
25 - 50	00:58	19.35	0.436496	0.0742	1.205	0.830	8.77E-10
50 - 100	00:58	18.73	0.390511	0.0874	0.642	1.558	5.51E-10
100 - 200	00:58	18.10	0.343556	0.0835	0.339	2.954	2.77E-10
200 - 400	00:58	17.35	0.288248	0.2255	0.206	4.846	4.57E-10
400 - 800	00:58	16.54	0.228490	0.1227	0.116	8.600	1.40E-10
800 - 400	00:58	16.42					
400 - 100	00:58	16.46		-	-	-	-
100 - 50	00:58	16.53					
50 - 25	03:56	16.710					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 18: KMN-02 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*24/Oct/23*
Sample source:	KMN-02 -nmc unsat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*12.4*	
Water Content (Measured) (%)	*13.3*	*11.5*
Bulk Density (Mg/m^3)	*2.064*	
Dry Density (Mg/m^3)	*1.790*	*2.140*
Dry Unit Weight (kN/m^3)	*17.5*	*21.0*
Void Ratio	*0.470*	*0.237*
Degree of Saturation (%)	*74.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.70*	*0.470000*	*5.6E-02*	*0.604*	*1.656*	*3.32E-10*
25 - 50	*00:58*	*19.28*	*0.439130*	*0.0831*	*0.853*	*1.173*	*6.95E-10*
50 - 100	*00:58*	*18.72*	*0.397970*	*0.1430*	*0.581*	*1.721*	*8.15E-10*
100 - 200	*00:58*	*18.06*	*0.349835*	*0.1458*	*0.350*	*2.858*	*5.00E-10*
200 - 400	*00:58*	*17.35*	*0.297569*	*0.0454*	*0.197*	*5.080*	*8.77E-11*
400 - 800	*00:58*	*16.57*	*0.239725*	*0.1890*	*0.113*	*8.819*	*2.10E-10*
800 - 400	*00:58*	*16.70*					
400 - 100	*00:58*	*16.69*		-	-	-	-
100 - 50	*00:58*	*16.67*					
50 - 25	*03:56*	*16.704*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 19: KMN-02 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*
Task:	*Research Dissertation*
University:	Kyambogo
Testing Date:	*24/Oct/23*
Sample source:	KMN-02 -omc sat
Faculty:	Engineering
Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru
Student:	*Mbwali Mary Christine*
Sample Condition	*Moulded*
Testing Prep. Method:	*Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity:	*2.70*
Preconsolidation Pressure (kPa)	*N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*13.1*	
Water Content (Measured) (%)	*14.5*	*13.6*
Bulk Density (Mg/m^3)	*2.021*	
Dry Density (Mg/m^3)	*1.790*	*2.010*
Dry Unit Weight (kN/m^3)	*17.5*	*19.7*
Void Ratio	*0.511*	*0.357*
Degree of Saturation (%)	*77.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.52*	*0.511000*	*6.3E-02*	*0.970*	*1.031*	*5.97E-10*
25 - 50	*00:58*	*19.26*	*0.491584*	*0.1569*	*0.527*	*1.898*	*8.11E-10*
50 - 100	*00:58*	*18.89*	*0.463404*	*0.0985*	*0.387*	*2.582*	*3.74E-10*
100 - 200	*00:58*	*18.40*	*0.426611*	*0.5544*	*0.258*	*3.878*	*1.40E-09*
200 - 400	*00:58*	*17.93*	*0.391555*	*0.1895*	*0.126*	*7.930*	*2.34E-10*
400 - 800	*00:58*	*17.39*	*0.350758*	*0.2543*	*0.075*	*13.284*	*1.88E-10*
800 - 400	*00:58*	*17.53*					
400 - 100	*00:58*	*17.64*		-	-	-	-
100 - 50	*00:58*	*17.70*					
50 - 25	*03:56*	*17.785*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 20: KMN-02 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*24/Oct/23*
Sample source:	KMN-02 -omc unsat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*13.1*	
Water Content (Measured) (%)	*13.7*	*11.8*
Bulk Density (Mg/m^3)	*2.056*	
Dry Density (Mg/m^3)	*1.820*	*1.890*
Dry Unit Weight (kN/m^3)	*17.8*	*18.5*
Void Ratio	*0.485*	*0.423*
Degree of Saturation (%)	*77.0*	*74*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.80*	*0.485000*	*2.2E-01*	*0.392*	*2.551*	*8.59E-10*
25 - 50	*00:58*	*19.64*	*0.472749*	*0.2086*	*0.333*	*3.001*	*6.82E-10*
50 - 100	*00:58*	*19.42*	*0.456340*	*0.2656*	*0.225*	*4.443*	*5.86E-10*
100 - 200	*00:58*	*19.09*	*0.432066*	*0.4683*	*0.154*	*6.473*	*7.10E-10*
200 - 400	*00:58*	*18.63*	*0.397608*	*0.1390*	*0.121*	*8.294*	*1.64E-10*
400 - 800	*00:58*	*18.14*	*0.361173*	*0.1772*	*0.066*	*15.116*	*1.15E-10*
800 - 400	*00:58*	*18.94*					
400 - 100	*00:58*	*19.03*		-	-	-	-
100 - 50	*00:58*	*19.11*					
50 - 25	*03:56*	*19.233*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 21: KMN-03 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*24/Oct/23*
Sample source:	KMN-03 -nmc sat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*11.1*	
Water Content (Measured) (%)	*12.2*	*11.5*
Bulk Density (Mg/m^3)	*2.108*	
Dry Density (Mg/m^3)	*1.910*	*2.060*
Dry Unit Weight (kN/m^3)	*18.7*	*20.2*
Void Ratio	*0.423*	*0.311*
Degree of Saturation (%)	*80.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.84*	*0.423000*	*1.5E-01*	*0.324*	*3.086*	*4.84E-10*
25 - 50	*00:58*	*19.46*	*0.396176*	*0.0640*	*0.760*	*1.316*	*4.77E-10*
50 - 100	*00:58*	*19.04*	*0.366365*	*0.0694*	*0.431*	*2.322*	*2.93E-10*
100 - 200	*00:58*	*18.70*	*0.341676*	*0.0618*	*0.182*	*5.488*	*1.10E-10*
200 - 400	*00:58*	*18.29*	*0.312504*	*0.1894*	*0.110*	*9.120*	*2.04E-10*
400 - 800	*00:58*	*17.85*	*0.281554*	*0.3785*	*0.059*	*16.814*	*2.21E-10*
800 - 400	*00:58*	*18.49*					
400 - 100	*00:58*	*18.50*		-	-	-	-
100 - 50	*00:58*	*18.53*					
50 - 25	*03:56*	*18.545*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 22: KMN-03 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*
Task:	*Research Dissertation*
University:	Kyambogo
Testing Date:	*24/Oct/23*
Sample source:	KMN-03 -omc unsat
Faculty:	Engineering
Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru
Student:	*Mbwali Mary Christine*
Sample Condition	*Moulded*
Testing Prep. Method:	*Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity:	*2.70*
Preconsolidation Pressure (kPa)	*N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*11.1*	
Water Content (Measured) (%)	*12.3*	*10.7*
Bulk Density (Mg/m^3)	*2.127*	
Dry Density (Mg/m^3)	*1.920*	*2.120*
Dry Unit Weight (kN/m^3)	*18.8*	*20.8*
Void Ratio	*0.410*	*0.273*
Degree of Saturation (%)	*81.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.87*	*0.410000*	*3.7E-01*	*0.266*	*3.759*	*9.73E-10*
25 - 50	*00:58*	*19.64*	*0.393644*	*0.1549*	*0.467*	*2.141*	*7.10E-10*
50 - 100	*00:58*	*19.38*	*0.375949*	*0.1712*	*0.358*	*2.797*	*6.00E-10*
100 - 200	*00:58*	*19.10*	*0.355694*	*0.2421*	*0.164*	*6.083*	*3.90E-10*
200 - 400	*00:58*	*18.67*	*0.325259*	*0.1503*	*0.098*	*10.197*	*1.45E-10*
400 - 800	*00:58*	*18.29*	*0.298927*	*0.1698*	*0.054*	*18.434*	*9.03E-11*
800 - 400	*00:58*	*17.71*					
400 - 100	*00:58*	*17.76*		-	-	-	-
100 - 50	*00:58*	*17.86*					
50 - 25	*03:56*	*18.066*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 23: KMN-03 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *20/Oct/23*

Sample source: KMN-03 -omc sat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Kamplala Mukono Njeru ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	20	
Inner Diameter (mm)	80	
Water Content (Trimmings) (%)	13.3	
Water Content (Measured) (%)	13.1	13.6
Bulk Density (Mg/m^3)	1.977	
Dry Density (Mg/m^3)	1.760	2.140
Dry Unit Weight (kN/m^3)	17.2	20.9
Void Ratio	0.547	0.264
Degree of Saturation (%)	66.0	100

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	00:58	19.86	0.547000	4.9E-02	0.282	3.546	1.37E-10
25 - 50	00:58	19.40	0.511187	0.0592	0.933	1.072	5.41E-10
50 - 100	00:58	18.67	0.454799	0.0849	0.752	1.330	6.26E-10
100 - 200	00:58	17.94	0.398875	0.1067	0.387	2.582	4.06E-10
200 - 400	00:58	17.10	0.333553	0.2154	0.235	4.250	4.97E-10
400 - 800	00:58	16.25	0.267767	0.1944	0.124	8.042	2.37E-10
800 - 400	00:58	16.11					
400 - 100	00:58	16.19		-	-	-	-
100 - 50	00:58	16.29					
50 - 25	03:56	16.450					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 24: KMN-03 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*
Task:	*Research Dissertation*
University:	Kyambogo
Testing Date:	*20/Oct/23*
Sample source:	KMN-03 -omc unsat
Faculty:	Engineering
Specimen Depth (m):	*0.2 -0.45*
Location:	Kamplala Mukono Njeru
Student:	*Mbwali Mary Christine*
Sample Condition	*Moulded*
Testing Prep. Method:	*Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity:	*2.70*
Preconsolidation Pressure (kPa)	*N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*13.3*	
Water Content (Measured) (%)	*13.0*	*12.4*
Bulk Density (Mg/m^3)	*1.994*	
Dry Density (Mg/m^3)	*1.760*	*2.130*
Dry Unit Weight (kN/m^3)	*17.2*	*20.8*
Void Ratio	*0.534*	*0.269*
Degree of Saturation (%)	*66.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.58*	*0.534000*	*8.7E-02*	*0.842*	*1.188*	*7.21E-10*
25 - 50	*00:58*	*19.30*	*0.512524*	*0.1033*	*0.572*	*1.748*	*5.80E-10*
50 - 100	*00:58*	*18.70*	*0.466581*	*0.1074*	*0.517*	*1.934*	*5.45E-10*
100 - 200	*00:58*	*17.89*	*0.404377*	*0.0928*	*0.394*	*2.537*	*3.59E-10*
200 - 400	*00:58*	*17.10*	*0.344168*	*0.0382*	*0.226*	*4.432*	*8.46E-11*
400 - 800	*00:58*	*16.34*	*0.285492*	*0.0701*	*0.111*	*9.016*	*7.63E-11*
800 - 400	*00:58*	*16.56*					
400 - 100	*00:58*	*16.54*		-	-	-	-
100 - 50	*00:58*	*16.52*					
50 - 25	*03:56*	*16.548*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 25: SSB-01 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

Tested in accordance with BS 1377: Part 5:1990

TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*		
Task:	*Research Dissertation*	**University:** Kyambogo	Testing Date: *25/Oct/23*
Sample source:	SSB-01 -nmc sat	**Faculty:** Engineering	Specimen Depth (m): *0.2 -0.45*
Location:	Silver Springs Bweyogerere road	***Student:*** *Mbwali Mary Christine*	Sample Condition *Moulded*
Testing Prep. Method:	*Tested Directly in a Ring from a Ring Lined Sampler*		
Specific Gravity:	*2.70*		

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.1*	
Water Content (Measured) (%)	*11.5*	*10.4*
Bulk Density (Mg/m^3)	*1.988*	
Dry Density (Mg/m^3)	*1.820*	*2.170*
Dry Unit Weight (kN/m^3)	*17.9*	*21.3*
Void Ratio	*0.482*	*0.281*
Degree of Saturation (%)	*65.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.55*	*0.482000*	*1.2E-01*	*0.904*	*1.106*	*1.06E-09*
25 - 50	*00:58*	*19.15*	*0.452212*	*0.2211*	*0.823*	*1.216*	*1.78E-09*
50 - 100	*00:58*	*18.55*	*0.408196*	*0.1535*	*0.620*	*1.612*	*9.34E-10*
100 - 200	*00:58*	*17.97*	*0.364774*	*0.0823*	*0.316*	*3.166*	*2.55E-10*
200 - 400	*00:58*	*17.35*	*0.319202*	*0.3326*	*0.171*	*5.843*	*5.58E-10*
400 - 800	*00:58*	*16.65*	*0.267110*	*0.2315*	*0.101*	*9.873*	*2.30E-10*
800 - 400	*00:58*	*16.61*					
400 - 100	*00:58*	*16.64*		-	-	-	-
100 - 50	*00:58*	*16.69*					
50 - 25	*03:56*	*16.799*					

c_v Coefficient of Consolidation

m_v Coefficient of Volume Compressibility

$1/m_v$ Constrained Modulus

k Coefficient of Permeability

Table E. 26: SSB-01 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*		
Task:	*Research Dissertation*	**University:** Kyambogo	Testing Date: *25/Oct/23*
Sample source:	SSB-01 -nmc unsat	**Faculty:** Engineering	Specimen Depth (m): *0.2 -0.45*
Location:	Silver Springs Bweyogerere road	***Student:*** *Mbwali Mary Christine*	Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.1*	
Water Content (Measured) (%)	*8.5*	*8.2*
Bulk Density (Mg/m^3)	*2.018*	
Dry Density (Mg/m^3)	*1.860*	*2.040*
Dry Unit Weight (kN/m^3)	*18.2*	*19.9*
Void Ratio	*0.460*	*0.327*
Degree of Saturation (%)	*51.0*	*67*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.68*	*0.460000*	*2.3E-01*	*0.640*	*1.563*	*1.46E-09*
25 - 50	*00:58*	*19.37*	*0.437662*	*0.0633*	*0.622*	*1.608*	*3.86E-10*
50 - 100	*00:58*	*19.06*	*0.414813*	*0.1599*	*0.323*	*3.095*	*5.07E-10*
100 - 200	*00:58*	*18.65*	*0.384606*	*0.0618*	*0.217*	*4.606*	*1.32E-10*
200 - 400	*00:58*	*18.09*	*0.344222*	*0.0523*	*0.148*	*6.742*	*7.61E-11*
400 - 800	*00:58*	*17.52*	*0.302320*	*0.1196*	*0.079*	*12.609*	*9.30E-11*
800 - 400	*00:58*	*18.10*					
400 - 100	*00:58*	*18.13*		-	-	-	-
100 - 50	*00:58*	*18.20*					
50 - 25	*03:56*	*18.297*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 27: SSB-01 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*25/Oct/23*
Sample source:	SSB-01 -omc sat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Silver Springs Bweyogerere road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*8.7*	
Water Content (Measured) (%)	*9.3*	*11.4*
Bulk Density (Mg/m^3)	*1.991*	
Dry Density (Mg/m^3)	*1.840*	*2.190*
Dry Unit Weight (kN/m^3)	*18.1*	*21.5*
Void Ratio	*0.474*	*0.308*
Degree of Saturation (%)	*54.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.12*	*0.474000*	*7.2E-02*	*1.756*	*0.569*	*1.25E-09*
25 - 50	*00:58*	*18.70*	*0.442678*	*0.1946*	*0.889*	*1.125*	*1.70E-09*
50 - 100	*00:58*	*18.19*	*0.405164*	*0.3527*	*0.544*	*1.837*	*1.88E-09*
100 - 200	*00:58*	*17.65*	*0.365366*	*0.3842*	*0.297*	*3.368*	*1.12E-09*
200 - 400	*00:58*	*17.08*	*0.323136*	*0.1521*	*0.162*	*6.160*	*2.42E-10*
400 - 800	*00:58*	*16.51*	*0.281127*	*0.3373*	*0.083*	*11.982*	*2.76E-10*
800 - 400	*00:58*	*16.60*					
400 - 100	*00:58*	*16.67*		-	-	-	-
100 - 50	*00:58*	*16.71*					
50 - 25	*03:56*	*16.821*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 28: SSB-01 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*25/Oct/23*
Sample source:	SSB-01 -omc unsat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Silver Springs Bweyogerere road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity: *2.70*

Preconsolidation Pressure (kPa): *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*8.7*	
Water Content (Measured) (%)	*9.2*	*8.2*
Bulk Density (Mg/m^3)	*2.005*	
Dry Density (Mg/m³)	*1.840*	*1.960*
Dry Unit Weight (kN/m³)	*18.1*	*19.3*
Void Ratio	*0.464*	*0.221*
Degree of Saturation (%)	*54.0*	*59*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	1/m_v (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.96*	*0.464000*	*1.6E-01*	*0.080*	*12.500*	*1.24E-10*
25 - 50	*00:58*	*19.66*	*0.442260*	*0.1380*	*0.595*	*1.680*	*8.06E-10*
50 - 100	*00:58*	*19.25*	*0.412079*	*0.1553*	*0.419*	*2.385*	*6.39E-10*
100 - 200	*00:58*	*18.81*	*0.379527*	*0.4333*	*0.231*	*4.329*	*9.82E-10*
200 - 400	*00:58*	*18.34*	*0.345636*	*0.0998*	*0.123*	*8.124*	*1.21E-10*
400 - 800	*00:58*	*17.75*	*0.302374*	*0.2219*	*0.081*	*12.415*	*1.75E-10*
800 - 400	*00:58*	*18.57*					
400 - 100	*00:58*	*18.61*		-	-	-	-
100 - 50	*00:58*	*18.54*					
50 - 25	*03:56*	*18.682*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
1/m_v Constrained Modulus
k Coefficient of Permeability

Table E. 29: SSB-02 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *25/Oct/23*

Sample source: SSB-02 -nmc sat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Silver Springs Bweyogerere road ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.4*	
Water Content (Measured) (%)	*11.8*	*10.5*
Bulk Density (Mg/m^3)	*2.055*	
Dry Density (Mg/m^3)	*1.838*	*2.176*
Dry Unit Weight (kN/m^3)	*18.0*	*21.3*
Void Ratio	*0.484*	*0.284*
Degree of Saturation (%)	*66.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.56*	*0.484000*	*1.2E-01*	*0.871*	*1.149*	*1.03E-09*
25 - 50	*00:58*	*19.06*	*0.446500*	*0.2036*	*1.033*	*0.968*	*2.06E-09*
50 - 100	*00:58*	*18.47*	*0.402442*	*0.1595*	*0.623*	*1.605*	*9.75E-10*
100 - 200	*00:58*	*17.88*	*0.358951*	*0.0842*	*0.317*	*3.150*	*2.62E-10*
200 - 400	*00:58*	*17.27*	*0.313384*	*0.2706*	*0.172*	*5.823*	*4.56E-10*
400 - 800	*00:58*	*16.56*	*0.261111*	*0.2179*	*0.102*	*9.803*	*2.18E-10*
800 - 400	*00:58*	*16.64*					
400 - 100	*00:58*	*16.65*		-	-	-	-
100 - 50	*00:58*	*16.71*					
50 - 25	*03:56*	*16.813*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 30: SSB-02 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*
Task:	*Research Dissertation*
University:	Kyambogo
Testing Date:	*25/Oct/23*
Sample source:	SSB-02 -nmc unsat
Faculty:	Engineering
Specimen Depth (m):	*0.2 -0.45*
Location:	Silver Springs Bweyogerere road
Student:	*Mbwali Mary Christine*
Sample Condition	*Moulded*
Testing Prep. Method:	*Tested Directly in a Ring from a Ring Lined Sampler*
Specific Gravity:	*2.70*
Preconsolidation Pressure (kPa)	*N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.4*	
Water Content (Measured) (%)	*8.8*	*8.3*
Bulk Density (Mg/m^3)	*2.035*	
Dry Density (Mg/m^3)	*1.878*	*2.051*
Dry Unit Weight (kN/m^3)	*18.4*	*20.1*
Void Ratio	*0.452*	*0.330*
Degree of Saturation (%)	*55.0*	*68*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	*00:58*	*19.70*	*0.452000*	*2.3E-01*	*0.607*	*1.649*	*1.36E-09*
25 - 50	*00:58*	*19.39*	*0.429539*	*0.0833*	*0.628*	*1.592*	*5.13E-10*
50 - 100	*00:58*	*19.07*	*0.406831*	*0.1534*	*0.323*	*3.099*	*4.86E-10*
100 - 200	*00:58*	*18.66*	*0.376779*	*0.0691*	*0.217*	*4.608*	*1.47E-10*
200 - 400	*00:58*	*18.19*	*0.342489*	*0.0723*	*0.127*	*7.902*	*8.98E-11*
400 - 800	*00:58*	*17.73*	*0.309421*	*0.1055*	*0.063*	*15.973*	*6.48E-11*
800 - 400	*00:58*	*18.12*					
400 - 100	*00:58*	*18.14*		-	-	-	-
100 - 50	*00:58*	*18.22*					
50 - 25	*03:56*	*18.311*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 31: SSB-02 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

Tested in accordance with BS 1377: Part 5:1990

TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *26/Oct/23*

Sample source: SSB-02 -omc sat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Silver Springs Bweyogerere road ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.0*	
Water Content (Measured) (%)	*9.6*	*11.8*
Bulk Density (Mg/m^3)	*1.994*	
Dry Density (Mg/m^3)	*1.861*	*2.205*
Dry Unit Weight (kN/m^3)	*18.3*	*21.6*
Void Ratio	*0.476*	*0.319*
Degree of Saturation (%)	*56.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.14*	*0.476000*	*1.1E-01*	*1.723*	*0.581*	*1.88E-09*
25 - 50	*00:58*	*18.71*	*0.444385*	*0.1710*	*0.895*	*1.117*	*1.50E-09*
50 - 100	*00:58*	*18.20*	*0.406837*	*0.2595*	*0.544*	*1.839*	*1.38E-09*
100 - 200	*00:58*	*17.66*	*0.366975*	*0.2121*	*0.297*	*3.370*	*6.17E-10*
200 - 400	*00:58*	*17.09*	*0.324753*	*0.1471*	*0.162*	*6.174*	*2.34E-10*
400 - 800	*00:58*	*16.58*	*0.287006*	*0.2034*	*0.075*	*13.364*	*1.49E-10*
800 - 400	*00:58*	*16.63*					
400 - 100	*00:58*	*16.68*		-	-	-	-
100 - 50	*00:58*	*16.74*					
50 - 25	*03:56*	*16.835*					

c_v Coefficient of Consolidation

m_v Coefficient of Volume Compressibility

$1/m_v$ Constrained Modulus

k Coefficient of Permeability

Table E. 32: SSB-02 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *26/Oct/23*

Sample source: SSB-02 -omc unsat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Silver Springs Bweyogerere road ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	20	
Inner Diameter (mm)	80	
Water Content (Trimmings) (%)	9.0	
Water Content (Measured) (%)	9.5	8.3
Bulk Density (Mg/m^3)	2.008	
Dry Density (Mg/m^3)	1.862	1.976
Dry Unit Weight (kN/m^3)	18.3	19.4
Void Ratio	0.466	0.378
Degree of Saturation (%)	55.0	60

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	00:58	19.98	0.466000	1.8E-01	0.047	21.489	8.09E-11
25 - 50	00:58	19.68	0.443982	0.1403	0.601	1.663	8.28E-10
50 - 100	00:58	19.32	0.417903	0.1577	0.362	2.765	5.59E-10
100 - 200	00:58	18.85	0.383369	0.3451	0.244	4.101	8.26E-10
200 - 400	00:58	18.36	0.347297	0.0971	0.131	7.661	1.24E-10
400 - 800	00:58	17.86	0.311198	0.2156	0.067	14.910	1.42E-10
800 - 400	00:58	18.60					
400 - 100	00:58	18.62		-	-	-	-
100 - 50	00:58	18.57					
50 - 25	03:56	18.696					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 33: SSB-03 NMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *26/Oct/23*

Sample source: SSB-03 -nmc sat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Silver Springs Bweyogerere road ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.7*	
Water Content (Measured) (%)	*12.2*	*10.8*
Bulk Density (Mg/m^3)	*1.991*	
Dry Density (Mg/m^3)	*1.864*	*2.144*
Dry Unit Weight (kN/m^3)	*18.3*	*21.0*
Void Ratio	*0.487*	*0.292*
Degree of Saturation (%)	*68.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.58*	*0.487000*	*1.5E-01*	*0.843*	*1.186*	*1.27E-09*
25 - 50	*00:58*	*19.07*	*0.449321*	*0.0865*	*1.035*	*0.966*	*8.79E-10*
50 - 100	*00:58*	*18.48*	*0.405170*	*0.1527*	*0.623*	*1.606*	*9.33E-10*
100 - 200	*00:58*	*17.89*	*0.361665*	*0.1536*	*0.317*	*3.158*	*4.77E-10*
200 - 400	*00:58*	*17.28*	*0.316022*	*0.0701*	*0.172*	*5.829*	*1.18E-10*
400 - 800	*00:58*	*16.57*	*0.263579*	*0.1825*	*0.102*	*9.799*	*1.83E-10*
800 - 400	*00:58*	*16.66*					
400 - 100	*00:58*	*16.67*		-	-	-	-
100 - 50	*00:58*	*16.74*					
50 - 25	*03:56*	*16.826*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 34: SSB-03 NMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING

Tested in accordance with BS 1377: Part 5:1990

TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*		
Task:	*Research Dissertation*	**University:** Kyambogo	Testing Date: *26/Oct/23*
Sample source:	SSB-03 -nmc unsat	**Faculty:** Engineering	Specimen Depth (m): *0.2 -0.45*
Location:	Silver Springs Bweyogerere road	***Student:*** *Mbwali Mary Christine*	Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

DESCRIPTION	**INITIAL CONDITIONS**	**FINAL CONDITIONS**
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.7*	
Water Content (Measured) (%)	*9.2*	*8.5*
Bulk Density (Mg/m^3)	*2.036*	
Dry Density (Mg/m^3)	*1.905*	*2.028*
Dry Unit Weight (kN/m^3)	*18.7*	*19.9*
Void Ratio	*0.455*	*0.333*
Degree of Saturation (%)	*58.0*	*70*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	*k* (m/s)
5 - 25	*00:58*	*19.71*	*0.455000*	*1.2E-01*	*0.579*	*1.727*	*7.10E-10*
25 - 50	*00:58*	*19.40*	*0.432390*	*0.0932*	*0.631*	*1.586*	*5.77E-10*
50 - 100	*00:58*	*19.09*	*0.409633*	*0.1496*	*0.322*	*3.101*	*4.73E-10*
100 - 200	*00:58*	*18.67*	*0.379591*	*0.0750*	*0.216*	*4.622*	*1.59E-10*
200 - 400	*00:58*	*18.30*	*0.352522*	*0.0787*	*0.100*	*10.037*	*7.69E-11*
400 - 800	*00:58*	*17.85*	*0.319322*	*0.1146*	*0.062*	*16.042*	*7.01E-11*
800 - 400	*00:58*	*18.15*					
400 - 100	*00:58*	*18.16*		-	-	-	-
100 - 50	*00:58*	*18.25*					
50 - 25	*03:56*	*18.324*					

c_v Coefficient of Consolidation

m_v Coefficient of Volume Compressibility

$1/m_v$ Constrained Modulus

k Coefficient of Permeability

Table E. 35: SSB-03 OMC Saturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name:	*Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*				
Task:	*Research Dissertation*	**University:**	Kyambogo	Testing Date:	*26/Oct/23*
Sample source:	SSB-03 -omc sat	**Faculty:**	Engineering	Specimen Depth (m):	*0.2 -0.45*
Location:	Silver Springs Bweyogerere road	***Student:***	*Mbwali Mary Christine*	Sample Condition	*Moulded*
Testing Prep. Method:	*Tested Directly in a Ring from a Ring Lined Sampler*				
Specific Gravity:	*2.70*				

Preconsolidation Pressure (kPa)	*N/A*

DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.3*	
Water Content (Measured) (%)	*10.0*	*12.1*
Bulk Density (Mg/m³)	*1.994*	
Dry Density (Mg/m³)	*1.887*	*2.196*
Dry Unit Weight (kN/m³)	*18.5*	*21.5*
Void Ratio	*0.479*	*0.327*
Degree of Saturation (%)	*60.0*	*100*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm²/sec)	m_v (m²/MN)	$1/m_v$ (MN/m²)	*k* (m/s)
5 - 25	*00:58*	*19.15*	*0.479000*	*1.3E-01*	*1.695*	*0.590*	*2.24E-09*
25 - 50	*00:58*	*18.72*	*0.447217*	*0.1946*	*0.898*	*1.114*	*1.71E-09*
50 - 100	*00:58*	*18.21*	*0.409590*	*0.2115*	*0.544*	*1.840*	*1.13E-09*
100 - 200	*00:58*	*17.67*	*0.369721*	*0.1920*	*0.296*	*3.378*	*5.58E-10*
200 - 400	*00:58*	*17.10*	*0.327430*	*0.1685*	*0.162*	*6.181*	*2.67E-10*
400 - 800	*00:58*	*16.59*	*0.289541*	*0.2154*	*0.075*	*13.352*	*1.58E-10*
800 - 400	*00:58*	*16.65*					
400 - 100	*00:58*	*16.69*		-	-	-	-
100 - 50	*00:58*	*16.76*					
50 - 25	*03:56*	*16.848*					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Table E. 36: SSB-03 OMC Unsaturated Oedometer Test Results

DETERMINATION OF ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS USING INCREMENTAL LOADING
Tested in accordance with BS 1377: Part 5:1990
TEST REPORT

Project Name: *Investigation into the collapsible potential of subbase materials in the tropical region with the greater kampala metropolitan area case study*

Task: *Research Dissertation* **University:** Kyambogo Testing Date: *26/Oct/23*

Sample source: SSB-03 -omc unsat **Faculty:** Engineering Specimen Depth (m): *0.2 -0.45*

Location: Silver Springs Bweyogerere road ***Student:*** *Mbwali Mary Christine* Sample Condition *Moulded*

Testing Prep. Method: *Tested Directly in a Ring from a Ring Lined Sampler*

Specific Gravity: *2.70*

Preconsolidation Pressure (kPa) *N/A*

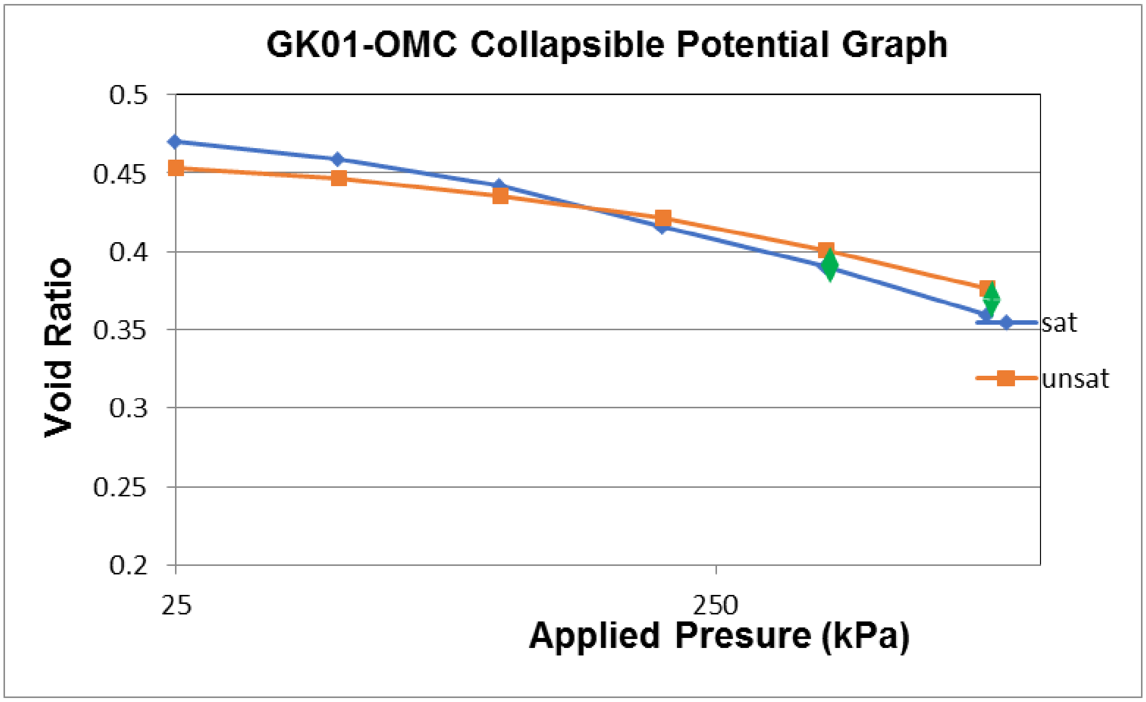
DESCRIPTION	INITIAL CONDITIONS	FINAL CONDITIONS
Height (mm)	*20*	
Inner Diameter (mm)	*80*	
Water Content (Trimmings) (%)	*9.3*	
Water Content (Measured) (%)	*9.9*	*8.6*
Bulk Density (Mg/m^3)	*2.009*	
Dry Density (Mg/m^3)	*1.889*	*1.948*
Dry Unit Weight (kN/m^3)	*18.5*	*19.1*
Void Ratio	*0.469*	*0.381*
Degree of Saturation (%)	*58.0*	*64*

Test Method Used to Calculate Coefficient of Consolidation: *Square root of time method*

Pressure Stage (kPa)	Load Increment Duration (hh:mm)	Height at End of Increment (mm)	Void Ratio	c_v (mm^2/sec)	m_v (m^2/MN)	$1/m_v$ (MN/m^2)	k (m/s)
5 - 25	00:58	19.99	0.469000	1.7E-02	0.019	52.552	3.14E-12
25 - 50	00:58	19.69	0.446834	0.1490	0.604	1.656	8.83E-10
50 - 100	00:58	19.33	0.420699	0.1688	0.361	2.767	5.98E-10
100 - 200	00:58	18.86	0.386167	0.2909	0.243	4.112	6.94E-10
200 - 400	00:58	18.37	0.350038	0.1772	0.130	7.670	2.27E-10
400 - 800	00:58	17.93	0.317473	0.1983	0.060	16.574	1.17E-10
800 - 400	00:58	18.62					
400 - 100	00:58	18.63		-	-	-	-
100 - 50	00:58	18.59					
50 - 25	03:56	18.709					

c_v Coefficient of Consolidation
m_v Coefficient of Volume Compressibility
$1/m_v$ Constrained Modulus
k Coefficient of Permeability

Appendix F: Collapsible Potential Graphs for all the roads



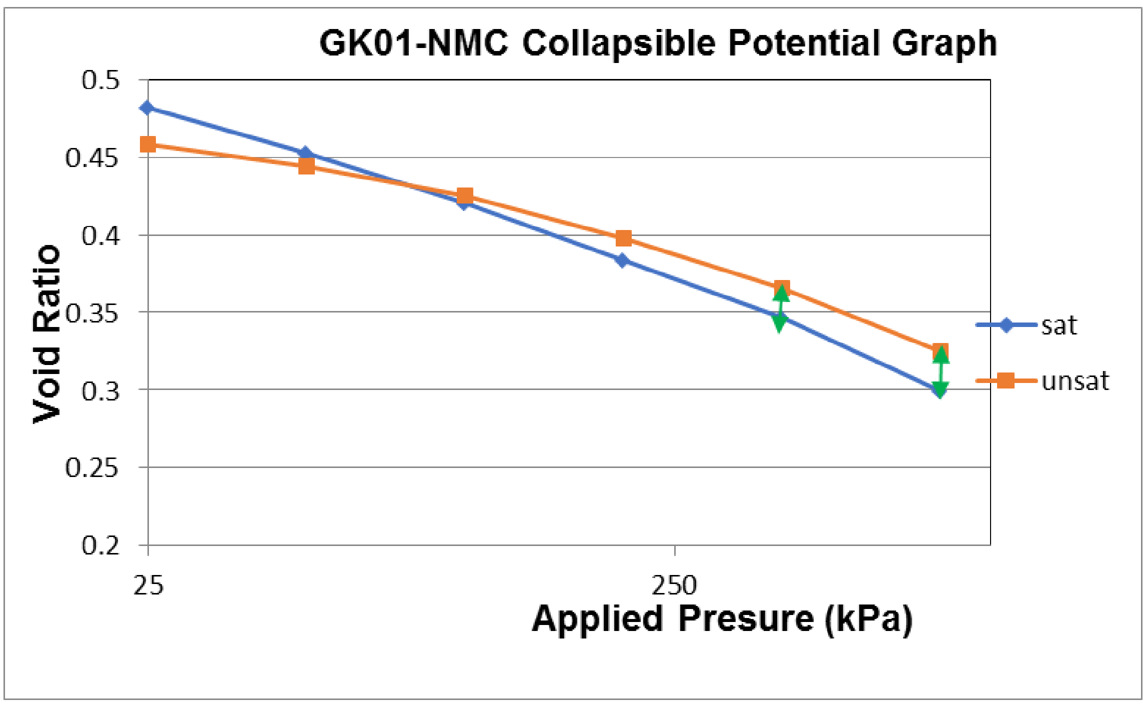
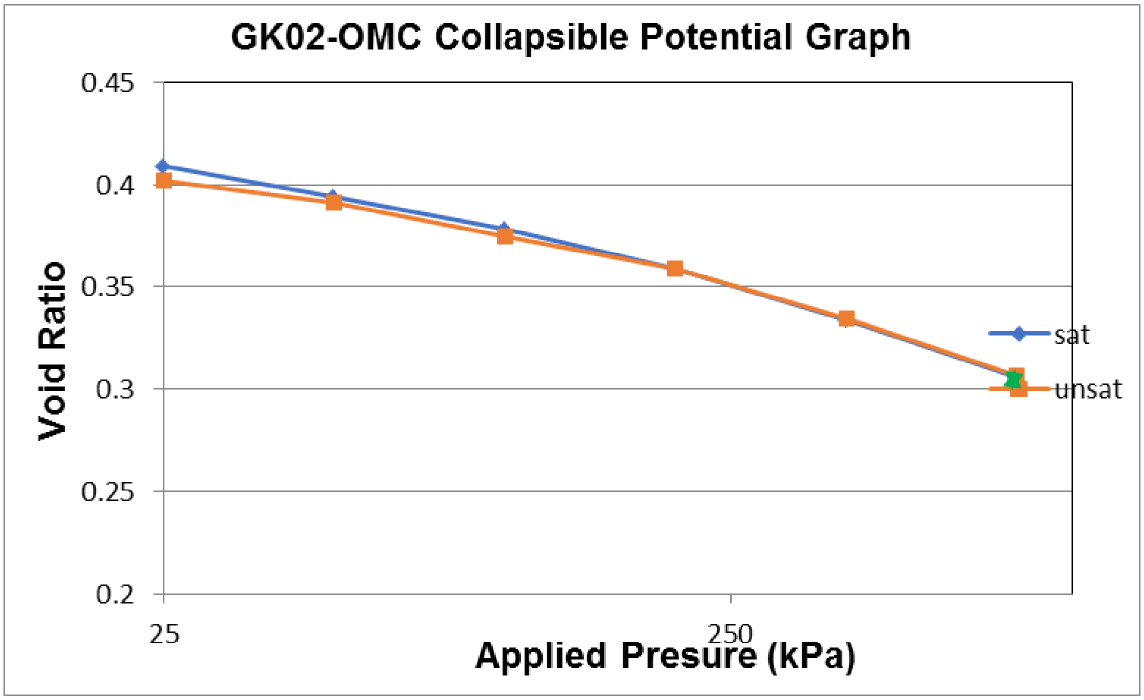


Figure F. 1: GK-01, OMC, and NMC Collapsible Potential Graphs



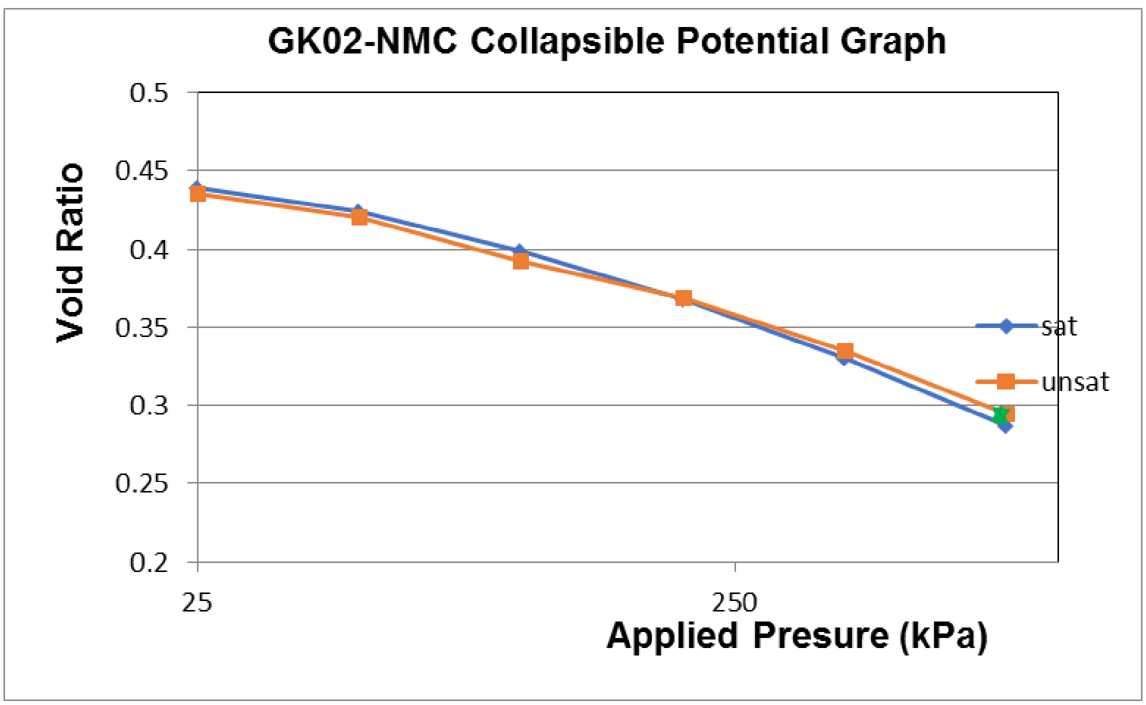
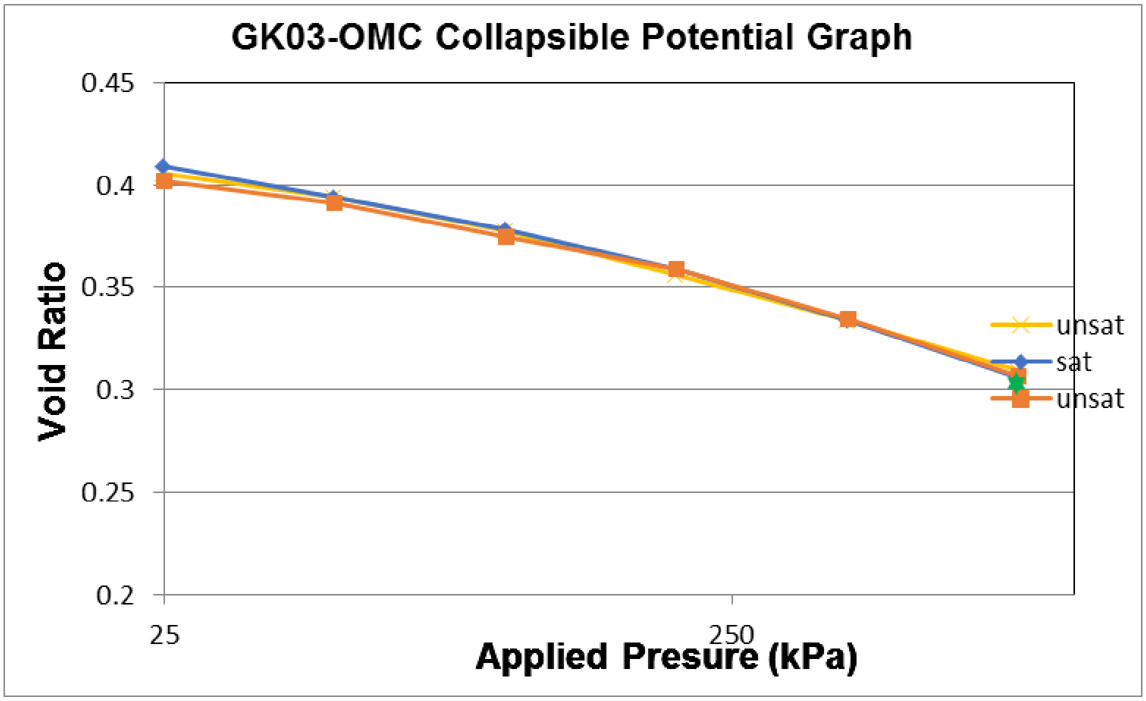


Figure F. 2: GK-02, OMC and NMC Collapsible Potential Graphs



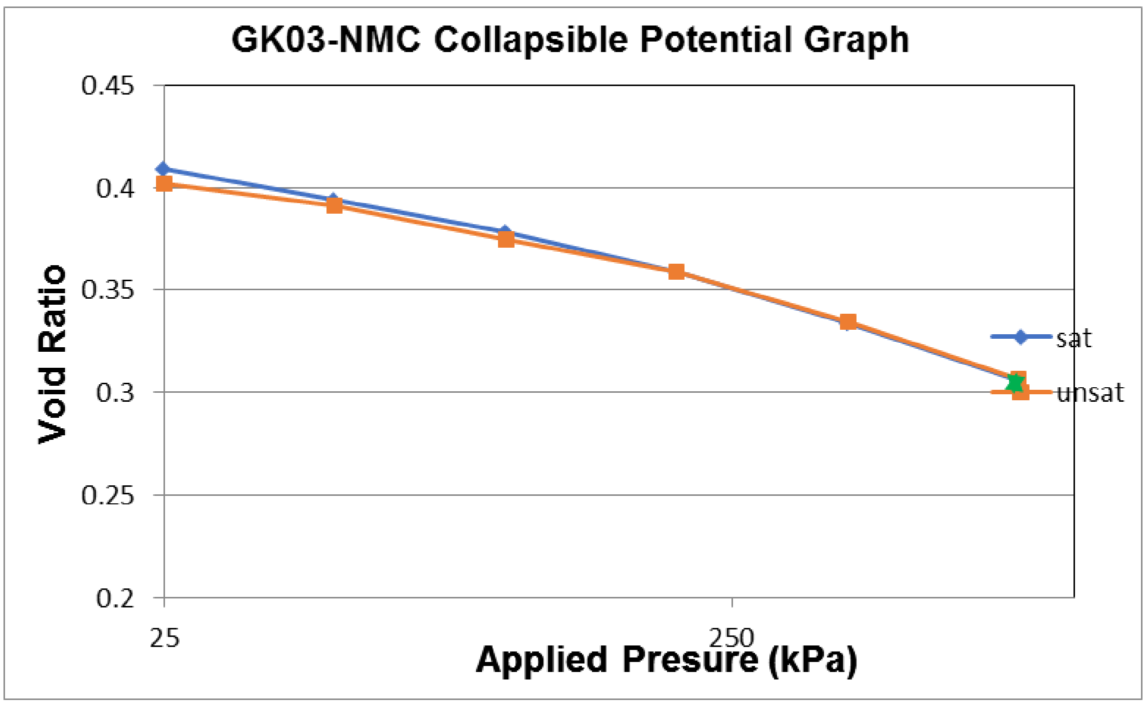
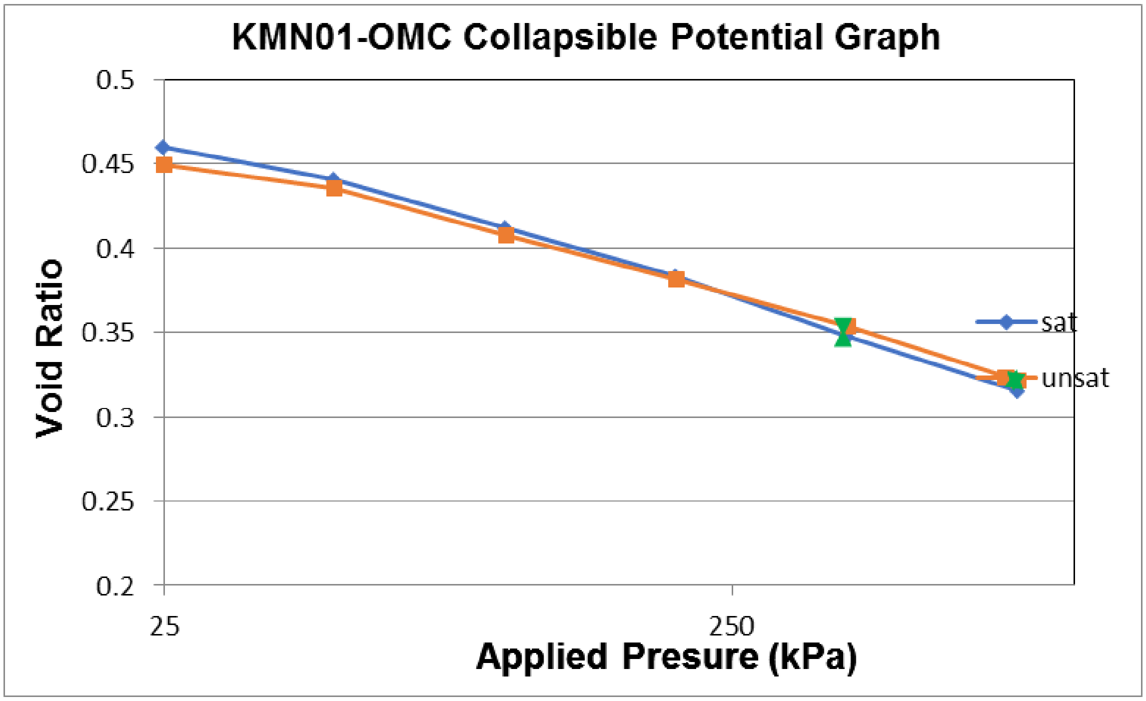


Figure F. 3: GK-03, OMC and NMC Collapsible Potential Graphs



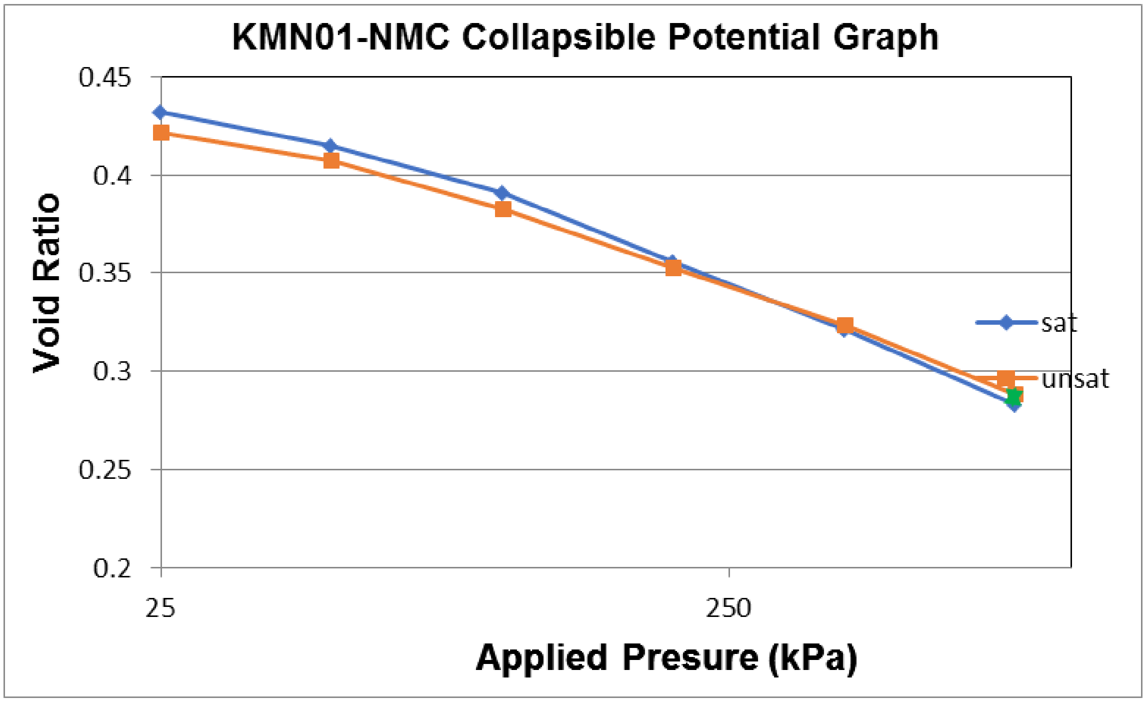
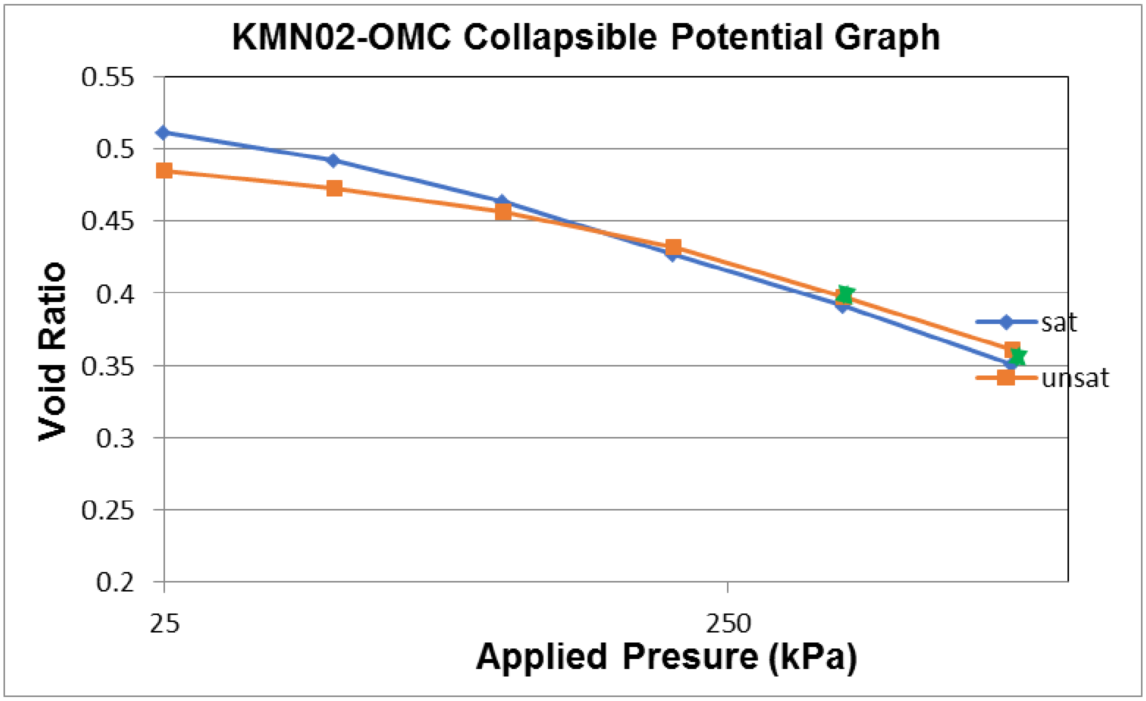


Figure F. 4: KMN-01, OMC and NMC Collapsible Potential Graphs



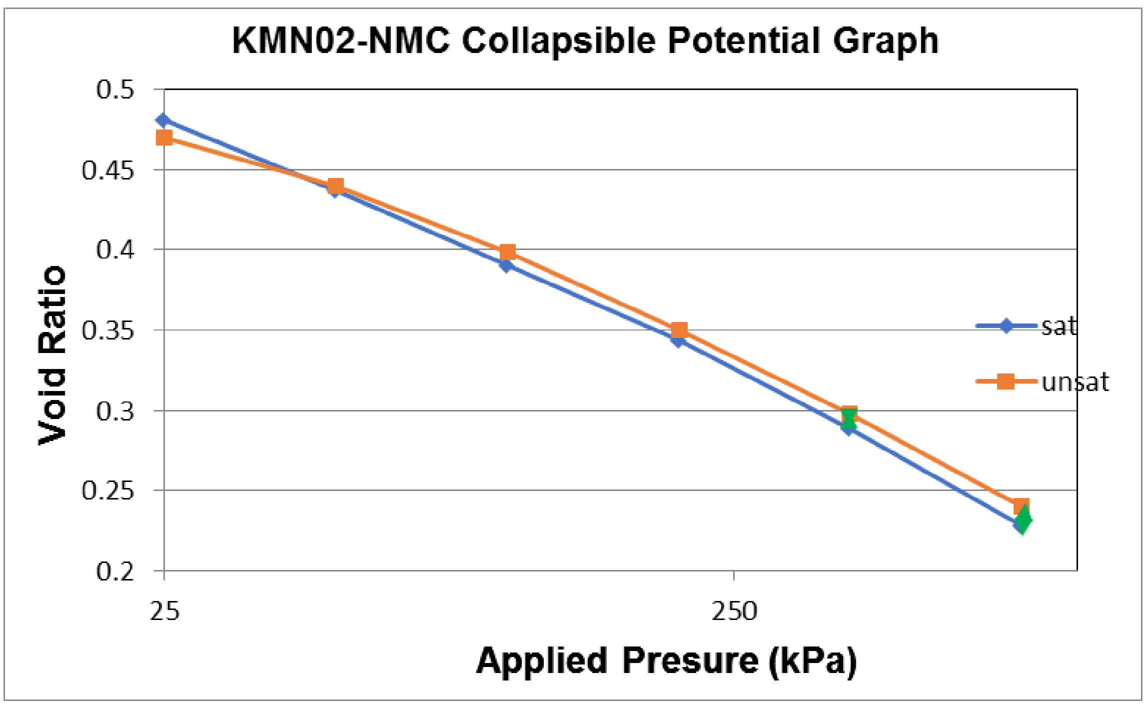
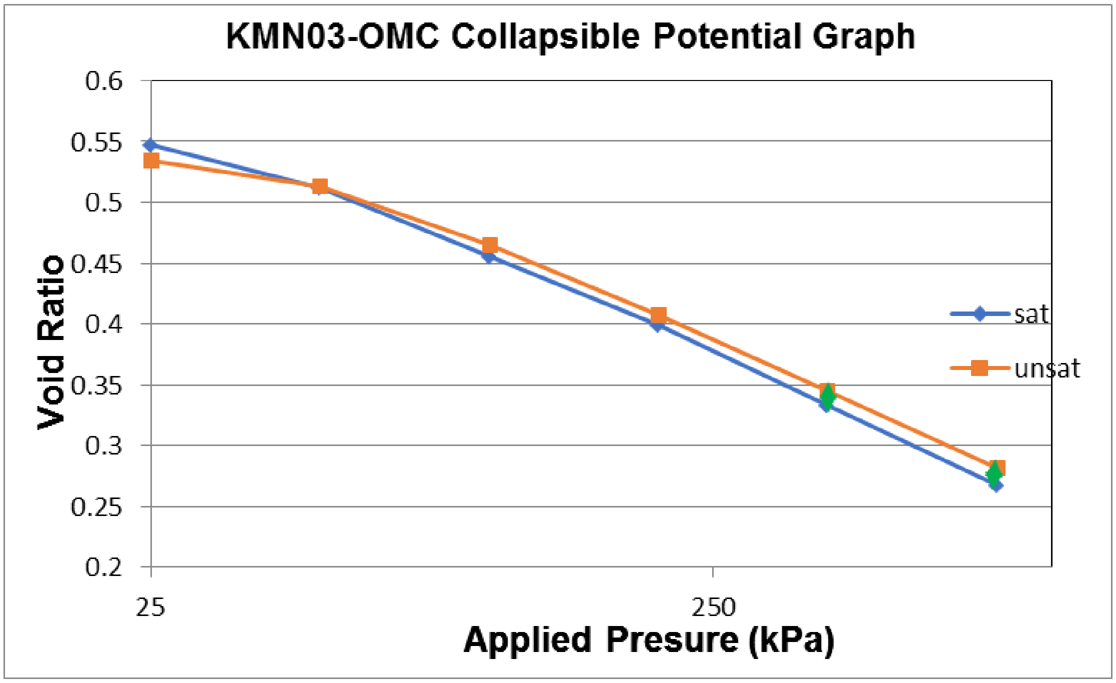


Figure F. 5: KMN-02, OMC and NMC Collapsible Potential Graphs



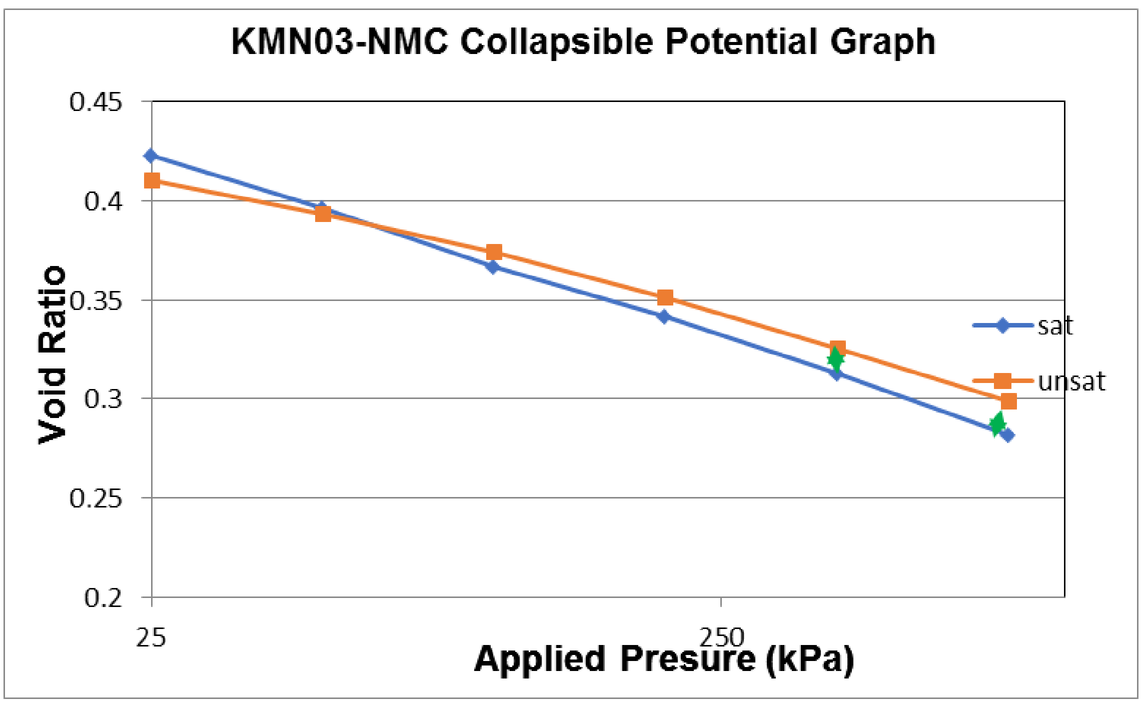
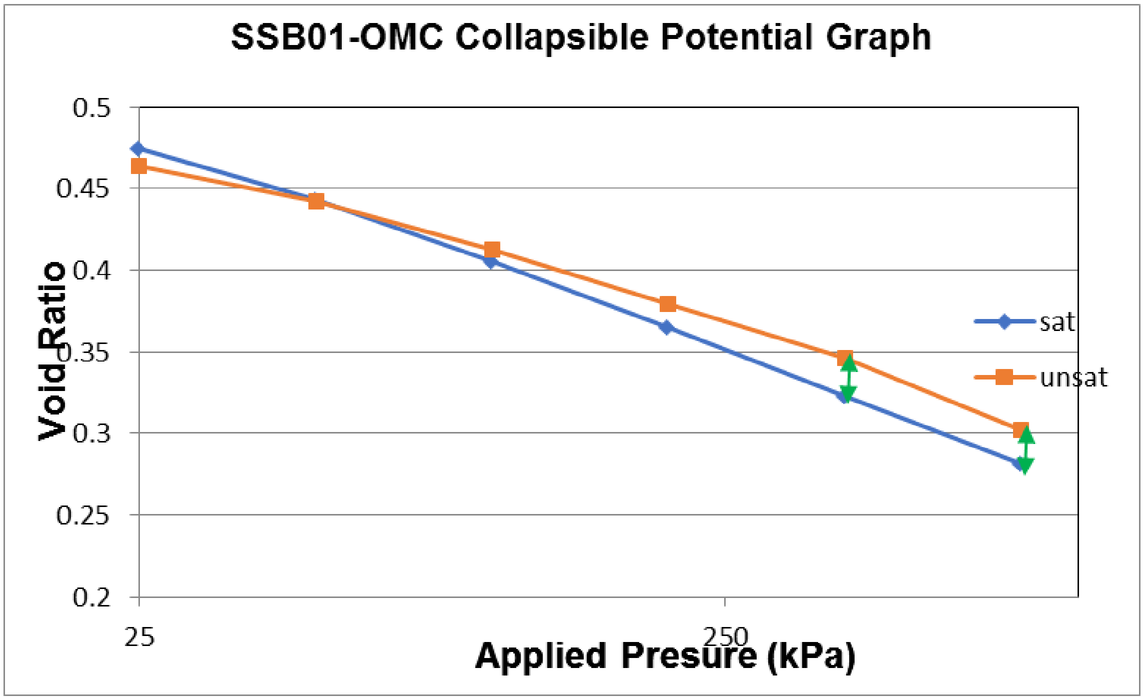


Figure F. 6: KMN-03, OMC and NMC Collapsible Potential Graphs



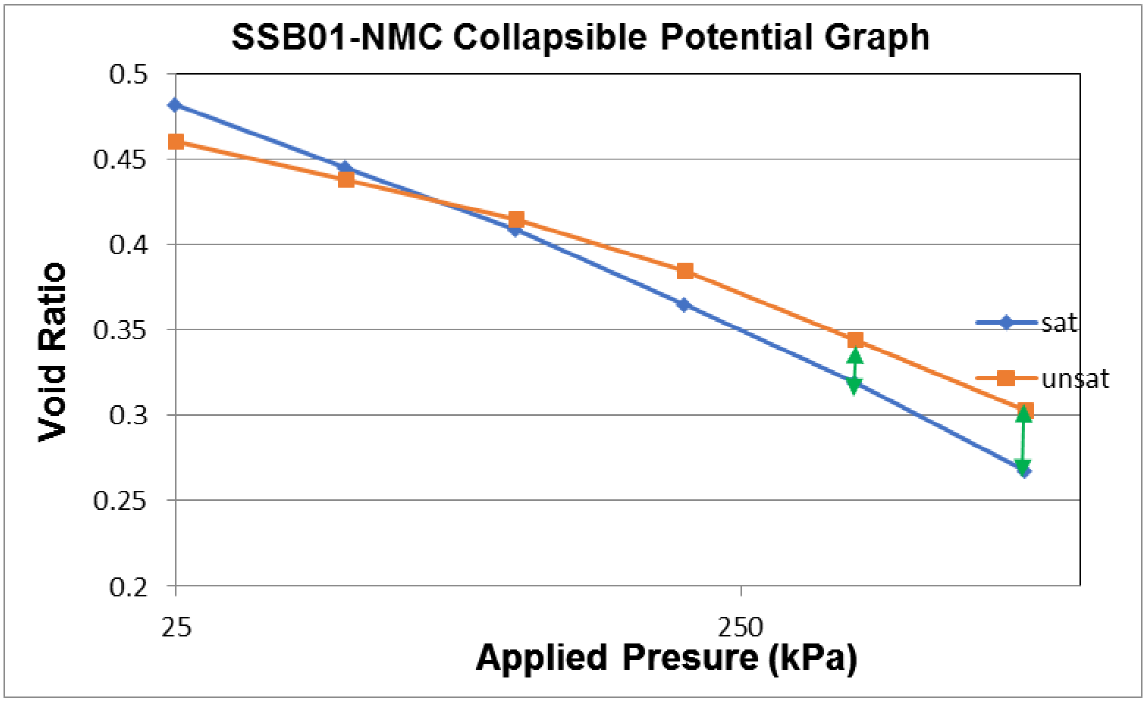


Figure F. 7: SSB-01, OMC and NMC Collapsible Potential Graphs

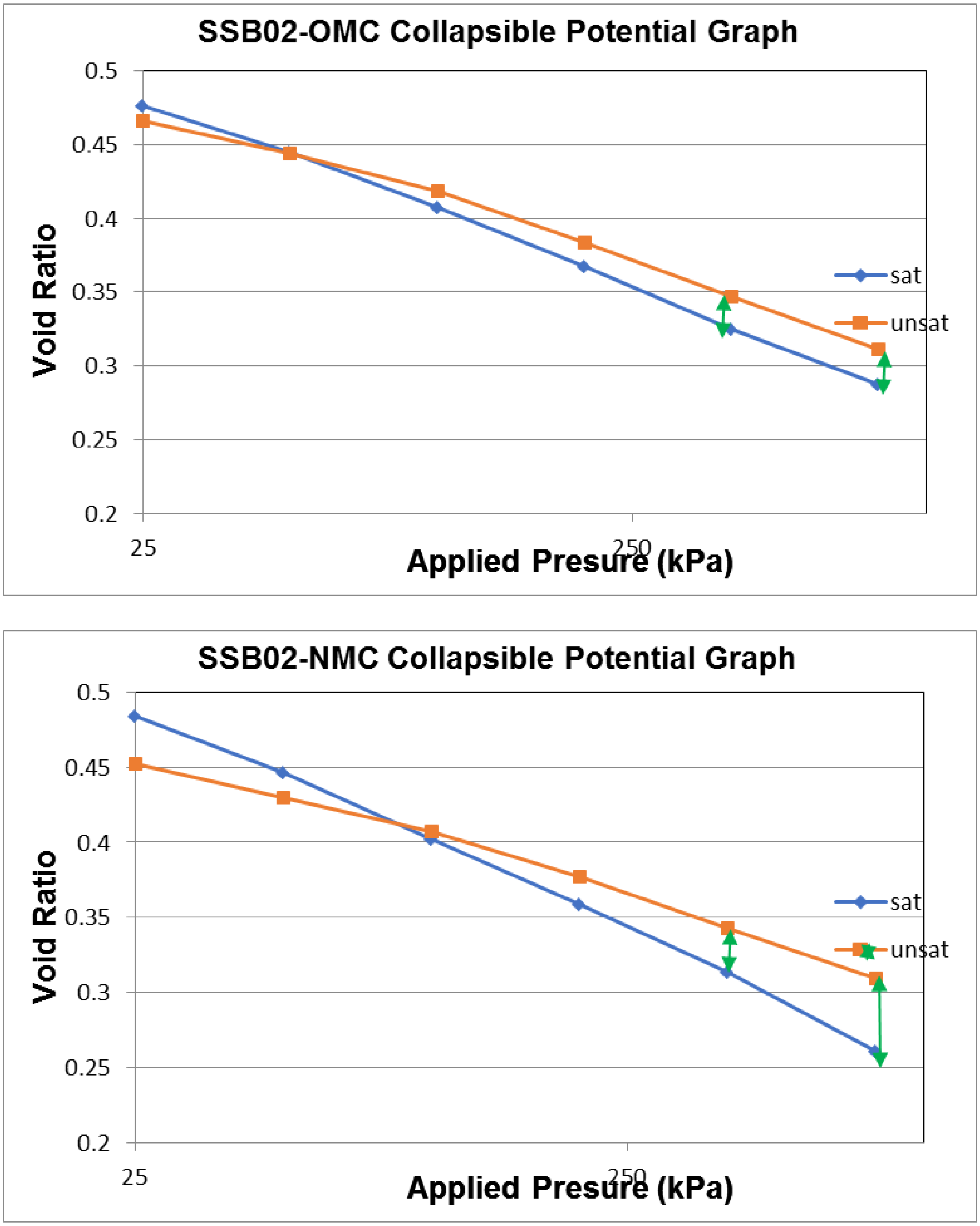
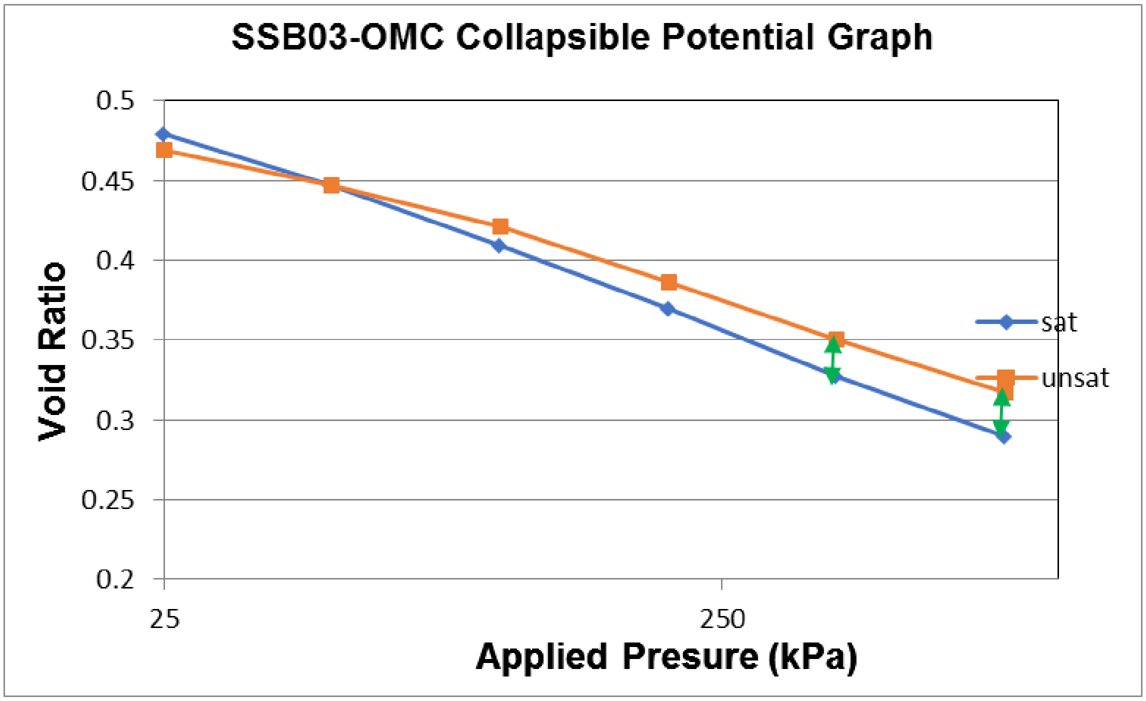


Figure F. 8: SSB-02, OMCand NMC Collapsible Potential Graphs



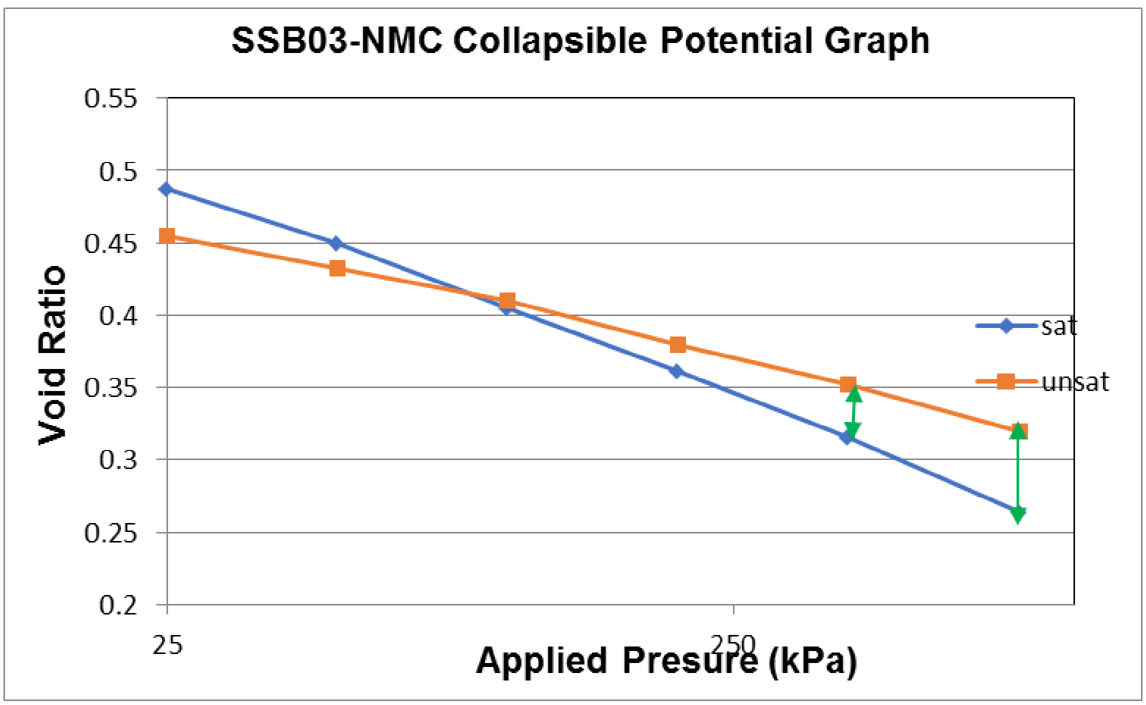


Figure F. 9: SSB-03, OMC and NMC Collapsible Potential Graphs

Appendix G: Photos

Figure G. 1: *An axe and a spade*

Figure G. 2: *Measuring Tape*

Figure G. 3: *Sample bags that were used, both with and without samples*

Figure G. 4: *The team that helped with sampling in their PPE*

Figure G. 5: a. *Soaked samples in preparation for wet sieving**, b.*** *Wet sieving with a sieve of **0.075 mm** aperture sieve, **c.*** *BS sieves with decreasing aperture that was used for dry sieving, **d.*** *Dry sieving, **e, and f.*** *Weighing the material retained on each sieve*

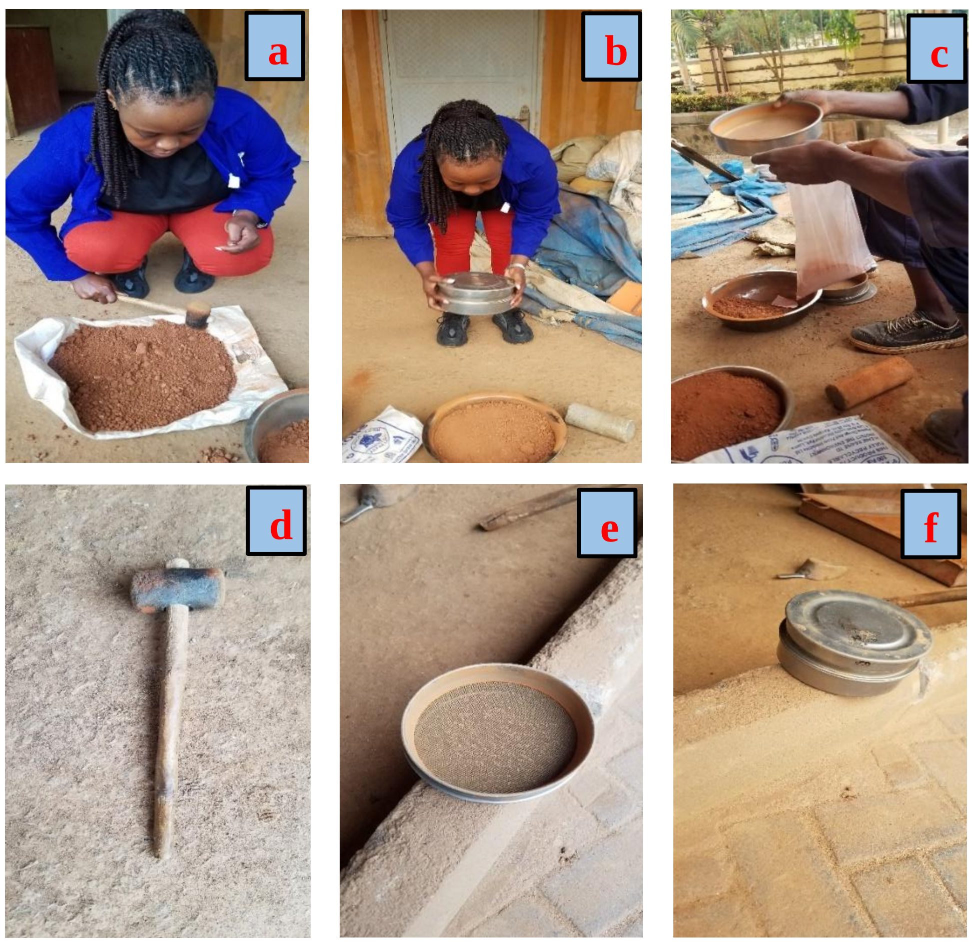


***Figure G. 6: a.** Crushing using a rubber mallet, **b.** Sieving through 425-micron test sieve, **c.** Sample being put in an airtight bag after sieving, **d.** Rubber mallet, **e and f.** 425-micron test sieve*

***Figure G. 7: a.** Preparation of the samples, **b.** One of the soil samples kept in an air-tight bag and soaked for 24 hours after which the experiment was conducted using the cone penetrometer method, **c.** Samples soaked for 24 hours, **e.** Oven*

Figure G. 8: *Linear Shrinkage mould*

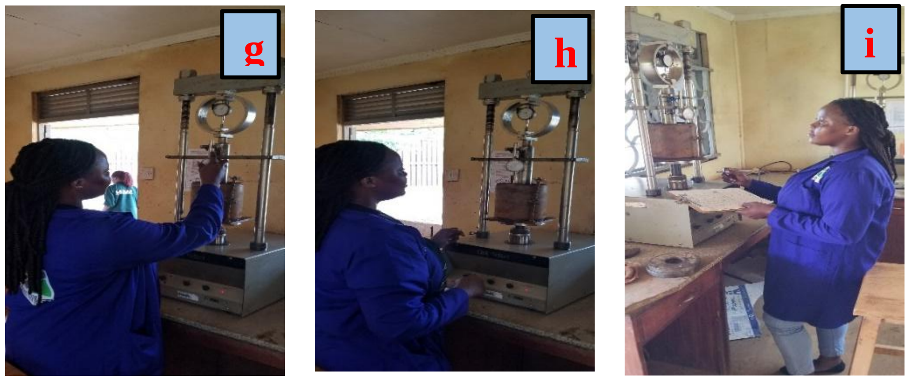


Figure G. 9: ***a.*** *Preparing the sample by adding water to achieve the optimum,* ***b.*** *Oiling the moulds and adding filter papers,* ***c.*** *compaction in 5 layers for each mould,* ***d.*** *trimming the sample after compaction,* ***e.*** *Sample after trimming,* ***f.*** *Soaked samples,* ***g&h&i.*** *Penetration of the samples using a cone penetrometer*

Figure G. 10: a. *Preparation of the sample by sieving through the 20mm and 5mm aperture sieve,* ***b.*** *Measuring cylinder used to track the amount of water added to the sample,* ***c.*** *Weighing the sample to be used at each point,* ***d.*** *Oiling the mould to avoid sticking of the sample to the mould,* ***e&f.*** *compaction in layers 5 layers- 27 blows on each layer,* ***g.*** *4.5kg rammer,* ***h.*** *Moisture tin,* ***i****. Oven drying moistures for 24 hours.*

Figure G. 11: *Remolded samples/compacted specimen for double oedometer*

Figure G. 12: a. *Unsaturated loaded sample,* ***b.*** *Saturated loaded sample,* ***c. d. e.*** *Porous Stone* ***f.*** *Loading Pad* ***g. h.*** *Cutting Ring,* ***i.*** *Moisture tin.*

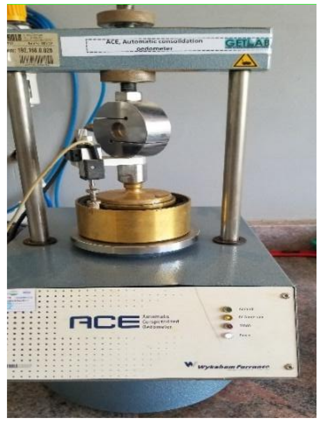


Figure G. 13: *Loaded sample in the conventional oedometer or the single oedometer test*

Figure G. 14: *Loaded samples for double oedometer test at NMC, one saturated and the other unsaturated*

Figure 5.1: *A section of one of the sampled roads with potholes in the GKMA*

KYAMBOGO UNIVERSITY

Department of Civil and Environmental Engineering

P. O. BOX 1, KYAMBOGO – P. O. BOX 7181 KAMPALA, UGANDA
Website: www.kyu.ac.ug, Email: civil@kyu.ac.ug
TEL: +256-41-4287340, FAX: +256-41-4289056/4222643

April 20, 2023

UGANDA NATIONAL ROADS AUTHORITY
RECEIVED
Name:
24 APR 2023
P.O.BOX 7885, KAMPALA
KAMPALA STATION

The Station Manager
UNRA Station, Kampala
Plot 28/30, 6th Street Industrial Area
Kampala - Uganda

Dear Sir,

RE: REQUEST TO COLLECT SUB-BASE MATERIAL SAMPLES FROM THE UNDER-MENTIONED ROADS

Ms. Mbwali Mary Christine is a student of Kyambogo University undertaking a Master of Science in Structural Engineering from the Department of Civil and Environmental Engineering. She is conducting a research study on "*Investigating the collapse potential of the sub-base material in the tropics region: A case study of the Greater Kampala Metropolitan Area*". The researcher is being supervised and co-supervised by Dr. Bulolo Sam and Dr. Ssenyondo Vicent respectively.

This research is very vital regarding the need to decrease road failure and improve the road layer performance. I hereby write to your office to request you to allow the researcher to collect three (3) sub-base material samples from each of the following links; Gayaza - Kalagi Road, Kyaliwajjala - Kira Road, Silver Springs - Bweyogerere Road, and Jinja Road. Several laboratory tests will be done on the samples to achieve results that will be used to suggest recommendations for suitable improvements.

I shall be grateful for your cooperation and support towards this research.

Yours Sincerely,

20.04.23

THE HEAD OF DEPARTMENT
CIVIL & ENVIRONMENTAL
ENGINEERING
KYAMBOGO UNIVERSITY

Dr. Onyutha Charles
Head of Department of Civil and Environmental Engineering

CC. Eng. Dr. Anne Nakagiri - Dean, Faculty of Engineering
Dr. Ssenyondo Vicent – Research Coordinator, Department of Civil and Environmental Engineering
Dr. Bulolo Sam – Department of Civil and Environmental Engineering, Kyambogo University

The specific objectives of this study are;

a) To carry out physical and chemical composition tests on the selected existing road pavement material both in-situ and in the laboratory. (Proctor test, CBR, Atterberg Limits, PSD, DCP, Carbonate content, Sulphate content, PH value, Chloride content)
b) To determine the collapse potential of the material using the conventional oedometer test.
c) To suggest recommendations on suitable improvements.

Uganda National Roads Authority
6th Street Industrial Area
P.O. Box 7885
Kampala – Uganda.
Telephone: +256 485 420 006/ +256 414 318 621

In any correspondence on this subject
Please quote No. **UNRA/KLA/Admin/2022-23/066**

9th May 2023

Ms Mbwali Mary Christine
Kyambogo University
Department of Civil and Environmental Engineering
P.O.Box 7181
Kampala Uganda

Dear Madam

RE: REQUEST TO COLLECT SUB-BASE MATERIAL SAMPLES FROM SELECTED ROADS:

Reference is made to the letter dated 20th April 2023 that was received on 24th April 2023 requesting for permission to collect samples of sub-base material on the UNRA roads namely; Gayaza-Kalagi, Kyaliwajjala-Kira, Silver Springs –Bweyogerere and Kampla-Jinja roads.

Uganda National Roads Authority promotes engineering research and we therefore have no have objection in carrying out the tests as long as they are purely for this study purposes. Any deviation to that, you will be liable to any repercussions.

You are therefore cleared to the pick the samples on the selected roads and make sure the pits are backfilled using the right materials. You will be assisted by our **Maintenance Technician Mr. Ayebare Junior** in locating the selected road links and ensuring that the trial pits are properly reinstated.

UGANDA NATIONAL ROADS AUTHORITY (UNRA) P.O. BOX 7885, KAMPALA TEL: 0414 235838 6th STREET. INDUSTRIAL AREA

Yours,

Eng. Jacob K. Asiimwe
Station Manager- Kampala

Cc: Regional Manager Central - UNRA

1 | P a g e

KYAMBOGO UNIVERSITY
Department of Civil and Environmental Engineering
P. O. BOX 1, KYAMBOGO – P. O. BOX 7181 KAMPALA, UGANDA
Website: www.kyu.ac.ug, Email: civil@kyu.ac.ug
TEL: +256-41-4287340, FAX: +256-41-4289056/4222643

October 3, 2023

The Managing Director,
Geotechnical Engineering and Technology Laboratory (GETLAB) Limited,
Plot 1234, Block 197, Kitetika Cell
Kasangati Town Council, Uganda

Dear Sir,

RE: <u>REQUEST TO CARRY OUT RESEARCH TESTS FROM GETLAB LABORATORY</u>

Ms Mbwali Mary Christine is a student of Kyambogo University undertaking a Master of Science in Structural Engineering from the Department of Civil and Environmental Engineering. She is conducting a research study on the collapse potential of the sub-base material in the tropical region: A case study of the Greater Kampala Metropolitan Area.

I hereby write to your office requesting permission to conduct tests on one-dimensional consolidation, compaction, CBR, Atterberg limits, PSD, and a few chemical tests on soils.

The necessary support to enable the researcher to conduct the laboratory tests and complete her research will be duly acknowledged in the dissemination of the results.

I shall be grateful for your cooperation and support.

Yours Sincerely,

Dr. Bulolo Sam
Research Coordinator, Department of Civil and Environmental Engineering

CC. Dean, Faculty of Engineering
Head of Department of Civil and Building Engineering

GETLAB LTD
YOUR RELIABLE ENGINEERING LABORATORY
03 OCT 2023
RECEIVED

GETLAB
YOUR RELIABLEENGINEERINGLABORATORY

Plot 1234, Plot 197 Namirembe Hillside Road, P.O Box 100001,Kasangati Kampala
Tel: +256-392-175-833
Email: info@getlab.co.ug
Web: www.getlab.co.ug

F/COM/01 ISSUE 01

2nd September 2023

Ref: G/Internship/2023/07

To: Ms. Mbwali Mary Christine

Study Program: Master of Science in Structural Engineering

Attention:

Research Coordinator

Department of Civil and Environmental Engineering

Kyambogo University

Dear Sir,

RE: Research Placement

We write to inform you that your application for research placement has been accepted.

This research engagement will be subjected to Geotechnical Engineering and Technology Laboratory (GETLAB) LTD personnel Rules and Procedures, and Code of Conduct.

Getlab Ltd views the engagement as being an educational opportunity for you, rather than a part-time job.

As such, your research will include conducting tests one- dimensional consolidation, compaction, CBR, Atterberg limits, PSD and a few chemical tests on soil as well as focus primarily on learning and developing new skills and gaining a deeper understanding of concepts through hand-on application of the knowledge you learned in class.

Date of commencement:

Your date of commencement shall be 3rd September, 2023.

Engagement Duration:

This research engagement will be 6 weeks which will end on 15th October, 2023.

Validity of research

This research placement will be valid for only one week from the date of commencement. Beyond this time, the student will have forfeited his/her place.

Geotechnical Engineering and Technology Laboratory (GETLAB) Limited

GETLAB
YOUR RELIABLEENGINEERINGLABORATORY

Plot 1234, Plot 197 Namirembe Hillside Road, P.O Box 100001,Kasangati Kampala
Tel: +256-392-175-833
Email: info@getlab.co.ug
Web: www.getlab.co.ug

F/COM/01 ISSUE 01

Training hours

You will be required to research for a minimum of 40 hours per week, your research hours being 8:00hrs to 13:00hrs and 14:00 hrs to 17:00hrs from Monday to Friday.

Only official public holidays will be recognized as non-working days. You must seek permission for any working day, that for any reason you will be away from your research station.

Deployment

You will be deployed in all the Geotechnical Engineering and Technology Laboratory sections according to the agreed research program.

Secrecy

Except for purposes of academic reporting, you shall keep secret any company information that may come to your knowledge in the course of your research. You shall continue to be bound by this obligation even after leaving or completing your internship.

Thank you.

GETLAB LTD
02 SEP 2023
Geotechnical Engineering & Technology Laboratory Ltd

Sincerely yours,

Internship Coordinator,
Senior Laboratory Engineer
Ochan Terry Adei
CC.
Managing Director
(Eng. Ivan Masuba)

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INVESTIGATION INTO THE COLLAPSE POTENTIAL OF SUBBASE MATERIAL IN THE TROPICS REGION

CASE STUDY: THE GREATER KAMPALA METROPOLITAN AREA

BY

MBWALI MARY CHRISTINE

(BEng. Civil Engineering, NDU)

21/U/GMES/14326/PE

A THESIS/DISSERTATION SUBMITTED TO KYAMBOGO UNIVERSITY DIRECTORATE OF RESEARCH AND GRADUATE TRAINING IN PARTIAL FULFILMENT FOR THE DEGREE OF MASTERS OF SCIENCE IN STRUCTURAL ENGINEERING OF KYAMBOGO UNIVERSITY

OCTOBER, 2025

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TESTIMONIAL

Print Date: Wed, Oct 15, 2025 3:06 PM

NAME:	MBWALI MARY CHRISTINE	DATE OF BIRTH:	1994-12-25
REG. NO.:	21/U/GMES/14326/PE	FACULTY :	DIRECTORATE OF RESEARCH AND GRADUATE TRAINING
STUDENT NO.:	2100814326	PROGRAM:	MASTER OF SCIENCE IN STRUCTURAL ENGINEERING
GENDER:	FEMALE		

YEAR 1 - SEMESTER I — 2021/2022

CODE	TITLE	MARK	CU	GRADE	GD POINT	REMARK
TCE6101	RESEARCH METHODS	70.0	3	B	4.0	NP
TCS6101	FINITE ELEMENT ANALYSIS	75.0	4	B+	4.5	NP
TCS6102	ADVANCED SOIL MECHANICS	71.0	4	B	4.0	NP
TCS6103	ADVANCED STRUCTURAL MECHANICS	61.0	3	C	3.0	NP
TCS6104	STRUCTURAL DYNAMICS AND EARTHQUAKE ENGINEERING	64.0	3	C	3.0	NP
TCS6105	ADVANCED PROJECT PLANNING AND MANAGEMENT	70.0	3	B	4.0	NP
SEMESTER REMARK: NP			CTCU: 20	GPA: 3.80		

YEAR 1 - SEMESTER II — 2021/2022

CODE	TITLE	MARK	CU	GRADE	GD POINT	REMARK
TCM6201	INFRASTRUCTURE MAINTENANCE AND MANAGEMENT	70.0	4	B	4.0	NP
TCS6201	PLASTIC AND NONLINEAR ANALYSIS	73.0	4	B	4.0	NP
TCS6202	PRE-STRESSED CONCRETE DESIGN	72.0	4	B	4.0	NP
TCS6203	ADVANCED REINFORCED CONCRETE DESIGN	70.0	4	B	4.0	NP
TCS6204	DESIGN OF STEEL STRUCTURES	61.0	3	C	3.0	NP
SEMESTER REMARK: NP			CTCU: 39	GPA: 3.84		CGPA: 3.82

YEAR 2 - SEMESTER I — 2022/2023

CODE	TITLE	MARK	CU	GRADE	GD POINT	REMARK
TCS6400	PROJECT UNIT I (PROPOSAL DEVELOPMENT)	74.0	10	B	4.0	NP
SEMESTER REMARK: NP			CTCU: 49	GPA: 4.00		CGPA: 3.86

Minimum Graduation Load(CUs):65

Total Credit Units:49

KYAMBOGO UNIVERSITY
15 OCT 2025
OFFICE OF THE DEAN
FACULTY OF ENGINEERING

Faculty Dean's Signature

NOTE: THE RESULTS ON TH[illegible] ARE PROVISIONAL AND MUST BEAR A STAMP FROM THE REGISTRAR. A FULL TRANSCRIPT IS ISSUED BY THE ACADEMIC REGISTRAR.
THE MEDIUM OF INSTRUCTION IS ENGLISH.

NORMAL PROGRESS: NP | RETAKE PAPERS: RT | CONCEDED PASS: CP | AUDITED COURSE: (AU)

This is a Testimonial as at Oct 15, 2025 and is Valid with a stamp and signature. Any alterations of this document makes it invalid

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