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Pozzolanic Potentials of Fresh Cow Dung and Cow Dung Ash for Gravel Roads Construction

BY

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DECLARATION

I, Anthony Mugendi Nyagah, hereby declare that this thesis is my original work. To the best of my knowledge, the work presented here has not been presented for a thesis in any other university.

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CERTIFICATION

This thesis has been submitted for review and approved by the university supervisor(s).

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DEDICATION

I dedicate this work to my parents and friends who have taught me persistence, determination and work smart. Who has loved and cherished me all through my life, taught me to embrace passion, humility, patience and above all to fear the Lord in everything that I do

Also, I would like to dedicate this report to my young brother Late Police Constable (L/PC) Kelvin M. Njoka who passed away in the line of duty on 06/12/2019 following an Al-Shabaab attack at Wajir on his way back to work.

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ABSTRACT

Among third-world countries, gravel and earth roads form an excessively large portion of the road network when compared to paved roads. In Kenya, earth roads comprise about 47% of the road network, gravel roads 38% and surface-dressed and premixed asphalt roads 11 and 4% respectively (KENHA, 2019). It is important to note that paving roads is an expensive exercise, though pertinent, that competes for the deficient resources in the usually strained economies resulting in their easy neglect.

Over the years, there has been an overreliance on cement as the primary chemical stabilizer, which has contributed to the low development of gravel and earth s due to cost reasons. In addition, the manufacture of cement is an environment-polluting activity that adds to the carbon footprint due to the gaseous pollutants released during the cement production process. This research investigated FCD and CDA as alternative stabilizers as they are readily available and eco-friendly. The effects of FCD and CDA were determined at various percentages for FCD (0%, 3%, 6%, 9%, and 12%) and CDA (0%, 3%, 6%, 9%, 12%, and 15%) both by weight was used. The index properties, compaction properties, plasticity requirements and bearing strength CBR and UCS were determined.

The results show that for the mechanical stabilization with FCD, the MDD decreases with an increase in the percentage of FCD stabilizer, while OMC increased with the increase in dosages of FCD. The CBR test results showed an increase with the increase in FCD dosages where a maximum result of 54% was attained with 6% FCD replacement, further increase in FCD dosages lowered the CBR value while the UCS test results showed a maximum value was attained with 6% FCD replacement and with further increase in FCD decreased the UCS values. The chemical stabilization with CDA, the MDD showed a decrease with an increase in dosages of CDA while OMC increased with the increase in amounts of CDA. The test results for CBR showed an increase with the increase of CDA dosages while the UCS test results showed an increase with the increase of CDA dosages and attained a maximum with 6% CDA dosage and a further increase in CDA dosages showed a decrease in UCS results.

Both FCD and CDA are inexpensive, readily obtainable, sustainable and eco-friendly. This will help low and middle-income countries in paving their gravel roads.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
CBR	California Bearing Ratio
CDA	Cow Dung Ash
FCD	Fresh Cow Dung
KENHA	Kenya National Highways Authority
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
UCS	Unconfined Compressive Strength
XRF	X-ray Fluorescence
SG	Specific Gravity

CHAPTER 1: INTRODUCTION

1.0 Background

The main reason why some roads remain surfaced but not paved is primarily due to the economics of scale. This is because, it is less expensive to build roadways out of compacted earth or gravel rather than concrete, which would satisfy the need to carry vehicles over without the ramping costs of pavement which are often not justifiable in areas receiving very little heavy vehicular traffic. However, the challenge associated with this is dirt and gravel roads are not as resilient as a paved surfaces. The loose aggregate nature of their surfaces makes them vulnerable to gradual erosion by the wind. Sudden torrential rains can rapidly accelerate the erosion of the road's surface, making the roadway difficult or impossible to traverse. Because of this, roads made from gravel and dirt are rarely a smooth ride, and gradual erosion is often enough to create a bumpy surface. This is usually worsened in the wake of a downpour, which would develop potholes and unpassable areas of mud (Burchcom, 2021).

A study carried out by the Korea Institute of Civil Engineering and Building Technology, on the use of soil-stabilized roads as a cost-effective alternative to traditional paving (Technology, 2018). The study was carried out in urban and rural areas in Southeast Asian countries, including Thailand and Malaysia, and they found that rural areas suffered from poor road infrastructure. They also found out that the soil in countryside areas was alike, weathered and was simply washed away by a slight quantity of rainfall that causes settlement and slurry, rendering the farm roads impassable. The cost to cover the road with tarmac or concrete was high and the government could not afford it hence the need to find other cost-effective methods to stabilize the roads (Technology, 2018). The service life of concrete paved farm roads was estimated to be two years due to the soft roadbed and the maintenance expenses for such roads were high every year. The alternative to asphalt or concrete roads were surface stabilized soil with a mixture of cement, pozzolan, lime and inorganic salt in an absolute ratio, which coagulates when it reacts with cement and additives. The result is, it forms long-term, strong stable ground in a short time on any type of soft base (Technology, 2018).

The majority of rural roads in Sub-Saharan Africa are unpaved (gravel & earth) roads (Ngezahayo, 2019). These roads act as links on day-to-day activities and benefits to the rural communities, they ack as links to farms, and access to social amenities like hospitals, and trade centres and they are used in transporting farm produce to the market. The key challenges faced by the rural roads in Sub-Saharan Africa during construction and maintenance activities are Lack of funding and engineering technology. Following these challenges, these roads are generally in a destitute condition. During the rainy season, they become nearly impassable, this is due to erosion processes that severely damage them. As a result, the communities using these roads suffer due to the poor transport of both goods and services. The overall result is that the country's development is hindered due to the inaccessibility of the farms to transport farm produce and people to market on time (Ngezahayo, 2019).

Mwaipungu and Allopi (2014) surveyed the quality control of the gravel materials used in the maintenance of gravel roads. they aimed to find out if the approvals and environmental impact assessment were sought by the organizations tasked with the maintenance of the gravel roads laid down by the Ministry responsible for mining before opening new borrow pits to harvest gravel soil. The results showed 70% of the respondents said that they do not look for approval and do not conduct environmental impact assessments, while 9.5% do environmental impact assessments through contractors who have been awarded construction or maintenance works. Another 40% of the respondents said they do not determine the geological nature of these borrow pits due to the scarcity of materials laboratories with such capacity. The active laboratories for conducting such tests are in Dodoma and Dar es Salaam regions (Mwaipungu, 2014).

According to Kenya National Highways Authority (KENHA), Kenya has about 63,575 km out of 177,800km of the classified road network. Table 1-1 gives a summary of the classified road network in Kenya as of 2019 from 41,800km at independence in 1963 (KENHA, 2019).

Gravel and earth roads form the major category of roads in Kenya. About 85% of the total road network is gravel and earth roads (KENHA, 2019). In Kenya, lateritic gravel is used to build gravel and earth roads.

Table 1-1: Road Classifications in Kenya (KENHA, 2019)

No	Road Class	Surface Type and Length (km)				Total
		Premix	Surface dressing	Gravel	Earth	
1.	International Trunk Roads (A)	1,245	1,564	715	95	3,619
2.	National Roads (B)	350	1,166	819	346	2,681
3.	Primary Roads I	643	2,198	3,602	1,553	7,996
4.	Secondary Roads (D)	77	1,183	5,702	4,088	11,050
5.	Minor Roads I	166	542	8,216	17,983	26,907
6.	Special Purpose Roads	25	115	4,930	6,254	11,324
	All classes	2,506	6,768	23,984	30,319	63,577

Gravels roads require frequent periodic maintenance as compared to paved roads. The effects of rain are more on gravel roads, especially when poorly drained. The major challenges associated with gravel roads are poor drainage and lack of proper compaction which results in rutting. Good drainage and proper compaction of the gravel roads can help to withstand the traffic loads.

Heavy amounts of rainfall on unpaved roads, can result in an uncomfortable drive. According to the report by the Federal Highway Administration (FHWA) the formation of periodic, transverse ripples in the surface of gravel also known as washboarding, is caused by; driving behaviours, dryness, inferior quality of gravel and lack of cover on the road surface. There is a need for correct classification of the gravel soil in terms of quality and strength of the gravel soil, as this will help to eliminate the corrugations and rebuild with a precise choice of sound quality gravel material to inhibit their restructuring.

In addition, dust on gravel roads is very common as shown in Plate 1-1. Dust control remains the biggest challenge facing most of the unpaved roads in rural areas, thus if these roads are well paved this will result in;

1. Decrease frequent periodic maintenance,
2. Alleviate well-being concerns, and
3. To avoid dust-related damage to wayside flora.

Plate 1-1: Dust on gravel roads (Google)

As days go by, there is a high demand for durable gravel roads, for this to happen there is a need to stabilize the gravel soil to be used. There exist two types of stabilization of the material conventional stabilizers like cement and lime and non-conventional stabilizers like, fly ash. Conventional stabilizers have been studied and well-documented in their application. However, for non-conventional stabilizers there exists less research on their application. More stabilizers are under research. Therefore, this research Investigates the pozzolanic ability of both FCD CDA aimed at stabilizing the gravel soil to be used on gravel pavement construction.

FCD possesses binding properties and controls dust as used in rural homes. Based on the chemical composition, Duna & Omoniyi, (2014) classified CDA as a class N pozzolan. Hence, this study seeks to investigate the pozzolanic ability of FCD as well as CDA for gravel pavement construction.

1.1 Problem Statement

Lack of funding is the greatest challenge facing rural roads in Sub-Saharan Africa are (Ngezahayo, 2019). The reliability of conventional stabilizers like cement and lime has led to the low development of rural roads. This is because they are expensive and hence they are not affordable to the majority of the local (county) governments. There have been numerous technological advancements in the stabilization of soils to date. Many stabilizers like polymers, resins, fibers, chlorides, geosynthetics, cement, lime, fly ash, and bitumen are being used in soil stabilization no matter how costly and "non-green" they are. Their production releases greenhouse gases that lead to climate change and the raw materials like limestone and iron ore being natural resources their continuous mining diminishes over time.

However, little is known about the use of non-traditional green sustainable stabilizers such as FCD and CDA. Further research needs to be carried out to govern the adequacy of non-traditional soil stabilizers and their effectiveness in the modification of engineering properties of soil. Some research has shown that CDA can be used in concrete. Fewer studies have been done on soil stabilization with CDA. No research exists to document the performance of FCD on soil stabilization. The use of FCD and CDA are less expensive, naturally occurring, and low energy consumption in their production and transportation hence sustainable materials. They can be produced annually and their contribution towards climate change is minimal.

Hence, this study is aimed at stabilizing lateritic soil with FCD and CDA to improve its engineering properties in the construction of gravel and earth roads.

1.2 Research Objective

The research objective of this research is to evaluate and optimize the pozzolanic potentials of fresh cow dung and cow dung ash for gravel road construction.

1.2.1 The specific objectives of this research are:

1. To determine the effects of FCD and CDA on the grading of lateritic gravel as a soil stabilizer.
2. To determine the effects of FCD and CDA on compaction properties maximum dry densities (MDD), and optimum moisture content (OMC) of lateritic gravel as a soil stabilizer.
3. To determine the effects of FCD and CDA on bearing strengths CBR, and UCS of lateritic gravel as a stabilizer.
4. To determine the effects of FCD and CDA on the plasticity requirements of lateritic gravel as a soil stabilizer.

1.3 Research Questions

1. Does the use of FCD and CDA as a stabilizer improve the grading of the lateritic gravel?
2. Does the use of FCD and CDA as a stabilizer improve the compaction properties of the lateritic gravel?
3. Does the use of FCD and CDA as a stabilizer improve the bearing strengths, CBR, and UCS of the lateritic gravel?
4. Does the use of FCD and CDA as a stabilizer improve the plasticity requirements of the lateritic gravel?

1.4 The Scope of Study

The scope of this study is to investigate the index properties of the lateritic gravel, chemical and physical characterization of FCD & CDA, Compaction tests, CBR, UCS, and grading which were done on neat and stabilized lateritic gravel soil.

1.5 The Justification for the Study

This research aims to solve the problems associated with duts on unpaved roads in rural areas like respiratory and cardiovascular health problems, irritation to eyes, skin and throat to the road users and the effects on the plants planted on the way side which leads to low harvest when the dust is so much. The above causes losses to both economic and social activities.

1.6 The Limitations of the Study

At the time of writing this thesis, there was no material available on the ways the preparation for the FCD as a stabilizer on lateritic gravel roads. Also, the preparation of CDA was done in two stages, the FCD cakes were first burnt in the open air, then the ash was collected and taken to the kiln and burnt at 500^0c for 8 hours then cooled overnight. The main reason for first burning the FCD cakes in the open air was the smoke, this was because the kiln is located at the main campus of the University of Nairobi this meant the mechanical laboratory and the offices around the laboratory would have out-of-bounce for the entire period. The other point was I was allowed to use the kiln during the day only this was because the kiln required close supervision.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

Cement and lime are the conventional whose properties are well documented and their efficiency has been verified through research and practical application. This literature evaluation aims to explore the works of other researchers in investigating the stabilization of soils using non-traditional stabilizers on engineering properties of soil, this research aims to review the stabilization of soils using non-traditional stabilizers.

2.1 Soil Stabilization

Soil stabilization is a chemical or physical treatment of soil to improve its properties modifying its natural characteristics. Soil stabilization can be achieved in two ways, mechanical or chemical methods.

Mechanical stabilization is the physical process by which the physical properties of the soil structure are altered. Chemical stabilization is attained through chemical reactions between chemical addition (cementitious matter) plus soil limestones (pozzolanic materials) towards the required result. Soil stabilization is done for strength (load-bearing capacity) improvement, dust control, and soil waterproofing (Mwanga, 2015).

2.2 Conventional Soil Stabilizers

2.2.1 Lime Stabilization

Soil-lime stabilization is mixing soil with lime (calcium oxide-CaO) in the correct proportion. The lime reacts well with clay soils, particularly with a modest to high plasticity index (PI>15). Lime can modify almost all fine-grained soils however the best modification is in clay soils relative to extreme plasticity. Alteration occurs when calcium cations from hydrated lime (calcium hydroxide-$Ca(OH)_2$) replace the cations present in the clay minerals, this reaction is enabled by the alkaline condition of the lime-water system. This reaction yields the following aids; Plasticity decrease, decrease in moisture-holding capacity (aeration), a bulge lessening, Enhanced stability and the capacity to build a dense working platform (Mwanga, 2015).

Soils stabilized with lime are supposed to be tested for: California bearing ratio (CBR), unconfined compressive strength (UCS), atterberg limits and particle size distribution.

The addition of 4 to 6% of lime is usually required to reduce the Plasticity index to less than 20, increase the shrinkage limit, reduction in the swell, increase CBR (10 for 7 days cure and 15 for 28 days cure) and modification of particle size distribution to similar to that of silt. Soil-lime stabilization is comparatively expensive in treating bulk clay soils, consequently, there are problems in acquiring a uniform and intimate mix (Ministry of Transport and Communications, 1987).

2.2.2 Portland Cement

Soil-cement stabilization is mixing soil and cement in correct proportions with water, compressing towards the required density and then curing. When a well-graded aggregate with adequate fines fills the voids if the coarse aggregates are stabilized with cement, the binder will improve the following properties: strength, compressibility, penetrability, swelling ability, ice vulnerability and responsiveness to changes in moisture content. Cement-stabilized materials are rigid or semi-rigid hence CBR is meaningless. The requirements for cement-stabilized soils are shown in Figure 2-1.

Chart B3	CEMENT-STABILIZED MATERIALS FOR BASE	Chart B3
MATERIAL REQUIREMENTS		
Materials Before Treatment		Cement
Experience has shown that materials which Comply with the following requirement are generally suitable for improvement.		Ordinary Portland Cement(KS 02-21) without any addition. Amounts usually required: Plastic Gravel 5 – 8% Clayey sands 5 – 7%
Grading Maximum size 2 - 40mm Passing 0.075 mm sieve Max. 35% Uniformly coefficient Min. 10 Plasticity Index: Max. 25 Plasticity Modulus: Mix in place Min. 1,500 Mix in plant Max. 700		
Soaked CBR Min 30 Organic matter: Max. 0.5%		
Treated Material		
UCS of laboratory mix at 95% MDD (Modified AASHTO) and 7 days cure + 7 days soak: min. 1,800 kN/m^2 Plasticity Index: Max. 6%, Plasticity Modulus Max. 250 (Calculated)		
TRAFFIC LIMITATIONS none		

Figure 2-1: Cement Stabilized Material (Ministry of Transport and Communications, 1987)

The UCS is the most convenient test for soil-cement mixtures. A minimum of UCS 1,800kN/m^2 is required on the laboratory mix, compacted at 95% MDD (modified AASHTO) after 7 days cure and 7 days soak (Ministry of Transport and Communications, 1987).

2.2.3 Fly-ash

Fly-ash is a by-product of burning coal. it contains amorphous oxide (mainly SiO_2, Al_2O_3), and metal oxides i.e. TiO_2, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, SO_3 and organic carbons hence, it has pozzolanic properties (Andavan & Pagadala, 2020).

Type “C” and type “F” are the two types of fly ash. This categorization is founded on chemical composition. Fly ash type “C” contains more than 20% of lime but has high silicate content, and does not require an activator while Class F fly ash has less than 7% lime (CaO) but has low silicate content. The standard adopted in choosing fly ash as a soil stabilizing agent is well described in (ASTM C593-19, 2019).

2.3 Non-traditional stabilizers

An evaluation of the results of a few types of research conducted on non-traditional stabilizers namely salt, polymers, molasses, bio-enzymes, and ashes of agro-by-products. to examine the performance of soil stabilization.

2.3.1 Salts

Abood, *et al*. (2007) investigated the effect of stabilizing silty clay using salts as a stabilizer in the ratios of 2, 4, and 8% by dry weight of NaCl, $MgCl_2$ & $CaCl_2$. The silty clay soil sample (from the south of Iraq) was taken one metre deep below the ground surface. The compaction properties were conducted according to ASTM (D 1557), and consistency limits and compressive strength were examined. MDD improved from 17.5 kN/m^3 to 19.0 kN/m^3 and OMC reduced from 15% to 13%. The Atterberg Limits were carried out using the Cassagrande apparatus according to ASTM (D423-66). decreased with the increase in salt content. The UCS conducted according to ASTM (D2166-65) increased as the salt content increased (Abood, et al., 2007).

Jaffer, (2013) also investigated the results of adding chloride salts (NaCl, $MgCl_2$ and $CaCl_2$) to a sample of silty clay soil (from the south of Iraq). Where the percentage (2%, 4%, and 8%) of salt were added to the soil then the following studies were carried out, the effect of salts on the compaction characteristics carried out conferring to ASTM (D 1557), atterberg limits were carried out using the Cassagrande apparatus according to ASTM (D423-66), and unconfined compressive strength (UCS) conducted according to ASTM (D2166-65). The results showed the compaction properties showed there was an increase in MDD and a decrease in OMC as the salt content was increased. The liquid limit, plastic limit, and plasticity index decreased with increasing salt content. The unconfined compressive strength (UCS) increased with the increase in salt content (Jafer, 2013).

2.3.2 Polymers

Guo Liuhui (2014) evaluated the effects of biopolymer, the results were the sand stabilized with Polymer the shear strength increased compared to that of 8% cement-stabilized sand, and a healing potential was evident. The study also showed that the biopolymer being more eco-friendly, may provide a more sustainable alternative to traditional stabilization methods like cement and lime and still offer both environmental and economic benefits (Guo, 2014).

Naseer *et al*. (2018) investigated the use of acrylic polymer for the stabilization of clayey soil, six different formulations were studied containing different percentages ranging from 0%, 2%, 4%, 6% 8% & 10% of acrylic polymer and cured for 3, 7 & 14 days. The maximum dry density (MDD) was attained with a 6% concentration of acrylic polymer. It was noted that the liquid limit (LL) decreases as the amount of the acrylic polymer increases. Whereas, the plastic limit (PL) increases with increasing the acrylic concentration. The maximum unconfined compressive strength (UCS) was attained with 6% replacement with acrylic polymer, whereas the California bearing ratio (CBR) attained a maximum increment at 6% addition of stabilizer compared to the untreated soil. After 14 days of curing and testing, the above results were attained (Naseer, et al., 2018).

Torio-Kaimo *et al*. (2020) studied the effects of UCS on clay strengthened with kerosene-treated coir fiber. The results were, Coir fiber had the highest tensile strength but it also had a very slow rate of biodegradation among natural fibers. The preliminary soil test performed classified the material as high-plasticity clay (CH), and kerosene reduced the moisture intake of coir by 170%. The samples with fiber concentrations ranging from 0% to 2% by dry weight of soil were tested for UCS in optimum moisture and dry states. At 1.5% fibre content, the coir enhanced the strength and stress-strain response of high-plasticity clay by 52% as compared to unreinforced samples, the ductility in the coir-reinforced samples tested at optimum moisture conditions. There was an increase in the elastic modulus, by 78%. (Torio-Kaimo, et al., 2020).

2.3.3 Molasses

M'Ndegwa, (2011) investigated the improvement of expansive clay soil using cane molasses as a stabilizer material. The molasses content in the soil ranging from 4 to 14 % by weight of air-dried soil. The specific gravity (SG) of the molasses was 1.46. The optimum cane molasses used in stabilizing the expansive clay soil was 8%. This gave the highest value of CBR. It was also found that when expansive clay soils were mixed with molasses, the swelling of the expansive clay soil was reduced (M'Ndegwa, 2011).

Ravi *et al.* (2015) studied the effect of molasses on strength of soil both compressible Clay (CI) and Highly Compressible Clay (CH). The results showed that with 6% of molasses, the UCS of both CI and CH increased by 94%. CBR also increased by 6.37% when 6% of molasses was added. With the increased values of both UCS and CBR, showed that molasses took part in the enhancement of soil cohesion. (Ravi, et al., 2015).

Mwanga, (2015), investigated the molasses as a stabilizer in the stabilization of silt clay to be used as the inner zone for small dam embankment construction, the soil was improved by adding 5.0%, 5.5%, 6.0% 6.5%, 7.0% and 7.5% of molasses. The silt clay stabilized by adding 6.5% molasses showed an improvement of MDD from 18.5 kN/m^3 to 19.40 kN/m^3, and the bulk density increased from 21.0 kN/m^3 to 21.34 kN/m^3. The improvement in MDD and bulk density of the soil could be attributed to an increase in cohesion and a fill of voids in the soil. The OMC of the soil dropped from 12.0% to 10.0% with the increase in molasses. The recommended percentage of molasses to be used in stabilizing the silt clay to be used for a dam embarkment construction ranges between 6% - 6.5%. (Mwanga, 2015).

Prudhvi & Kameswar rao. (2017) investigated the stabilization of gravel soil by using molasses-lime with different amounts of molasses-lime 0%, 5%, 10%, 15%, 20% and 25%. An optimum of 10% of molasses was found to increase the MDD of soil from 1,890 Kg/m^3 to 1,933 Kg/m^3. The OMC of soil increased from 10.0% to 12.0% with the increase in molasses-lime percentage. The above results have shown that the stabilization of soil with molasses and lime increased the strength properties of soil by using 7% to 10% of molasses and lime (Prudhvi & Kameswar rao, 2017).

Amunga (2020) investigated the stabilization of lateritic gravel using molasses as a stabilizer for unpaved rural roads, the roads studied were in Butere and Mumias both in Kakamega County. 1%, 2%, 3% and 4% were the mix ratios of the molasses by dry weight of the laterite gravel. The lateritic gravel mixed with 2% of the molasses by dry weight the results showed the MDD increased from 1712 to 2100 Kg/m^3, the strength properties improved both UCS increased from 154 to 272 kN/m^3 and the CBR improved from 19 to 62 %. The plasticity index dropped from 20 to 13. This improvement was attributed to the increase in density of the stabilized laterite gravel soil, which was brought about by the improved binding capacity ad this increased the strength of the soil mass. (Amunga, 2020).

2.3.4 Bio-enzymes

Agarwal *et al*. (2014) investigated the stabilization of black cotton soil using the Terrazyme bio-enzyme. The UCS was determined by adding the Terrazyme bio-enzyme to the black cotton soil at various dosages as (0.0, 0.25ml, 0.5ml, 0.75ml, 1.0ml, 2.0ml, 3.0ml, and 4.0ml/per 5kg of soil) then the stabilized soil was allowed one and seven days of curing. The results showed that a sample stabilized with 1ml/per 5kg of bio-enzyme, and cured for 7 days, gave higher strength values of the treated soil samples. Therefore the optimum dosage of Terrazyme bio-enzyme was 1ml/per 5kg of soil (Agarwal, et al., 2014).

Panchal *et al*. (2017) studied the effect of ground improvement using Terrazyme a bio-enzyme used for improving the CBR value in road construction. Terrazyme is made from the fermentation of plants, vegetable extract and fruit extract which makes it a natural, non-toxic and liquid enzyme. Terrazyme was used as a soil stabilizer to improve the CBR value in road construction materials. The Terrazyme dosages were taken as 500ml/m^3, 700ml/m^3, 900ml/m^3 and 1000ml/m^3 per m^3 of the soil sample. After stabilization, the samples were cured for 7, 14 and 28 days respectively, after which the results were analyzed. The highest CBR value was observed with the third dosage (900ml/m^3) with two weeks (14 days) curing periods and percentage increment as compared to the untreated soil sample (Panchal, et al., 2017).

Mugada & Nagaraj. (2019) studied the effect of Terrazyme bio-enzyme on plasticity and UCS characteristics of earthen construction material. The dosages of the enzymes used were 0.025, 0.039, 0.050, and 0.065ml/kg of soil. The stabilized samples were cured for 7, 14, 30 and 60 days. The results showed that the plastic and shrinkage limits increased with the increase in enzyme dosage and the curing period. Whereas the liquid limit decreased with an increase in dosage of enzyme and curing period, the UCS increased with the increase of Terrazyme bio-enzyme and the prolonged curing time, another observation made was that the sealed curing condition of the soil was found to be more effective than wet curing method (Muguda & Nagaraj, 2019).

2.3.5 Ashes of Agro-byproducts

Soil stabilization by use of different stabilizers namely; rice husk ash (RHA), sugarcane bagasse ash (SCBA), and CDA was studied. RHA, SCBA and CDA were blended with untreated soil in the ratios of 0%, 2.5%, 5%, 7.5%, 10%, and 12.5% by weight. After testing the MDD of the soil reduces while the OMC increases following stabilization. This can be attributed to the increase in mix proportion and reduction in the amount of free silt, the clay portion and coarser materials with a large establishment of surface area, while the decrease in MDD can be attributed to the addition of ash which had a lower specific gravity to that of the soil. The unsoaked and soaked CBR and UCS achieved an optimum at 7.5% of ash. The unsoaked CBR improvement may have been brought about by the creation of calcium silicates after the reaction of silica from ash from the mixed stabilizers and calcium from the alluvial soil. whereas the soaked CBR and UCS were accredited to the gradual formation of cementitious compounds between the ashes of the mixed stabilizers and calcium hydroxide contained in the alluvial soil.

The decrease in the soaked CBR after 7.5% ash content could be attributed to the excess ash that was not used in the reaction, which therefore inhabits spaces within the sample and therefore reduces bonds in the soil–ash mixtures. (Yadav, et al., 2017).

2.3.6 Groundnut Shell Ash

A study was carried out on the stabilization of black cotton soil using groundnut shell ash (GSA) as a stabilizer. The classification of regur soil using the AASHTO soil classification system was classified as A-7-6. The study was carried out in Nigeria to advance the engineering properties of black cotton soil. The results showed that as the OMC increased with the increase of GSA as a stabilizer, on the other hand, the MDD was decreasing with the increase in GSA as a stabilizer at the standard Proctor compaction energy. The peak CBR obtained was 6% at 8% GSA which was lower than the 80% CBR standard recommended for untreated base course materials. Hence the above value failed the recommended criterion for subgrade materials. The UCS at 7 days was lower than the 1034kN/m^2 evaluation standard recommended by TRRL (1977) for adequate stabilization. It was therefore recommended that groundnut shell ash could be used as an admixture with a more potent stabilizer compacted at standard Proctor compaction to reduce the cost of stabilization (Ijimdiya, et al., 2012).

The results of the atterberg limits presented showed the liquid limit increased from 83 % natural black cotton soil to 103 % stabilized black cotton soil with 10% GSA stabilizer. The improvement in liquid limit could be attributed to the flocculation and aggregation of the clay particles and the additional reduction in surface area and increase in strength. The plastic limits of GSA-treated black cotton soil decreased from 44% to 23% for soil stabilized with 2% GSA increased gradually with an increase in dosages of GSA and this could be attributed to the increase in the amount of fines content. This alteration of soil character occurred due to bi-valent calcium ions supplied by the GSA replacing less firmly attached monovalent ions in the double layer surrounding the clay particles. This according to O'Flaherty (1974) tends to decrease the thickness of the double layer and to depress the zeta potential (that is, a measure of the effectiveness of the particle's negative charges in repelling a second particle) thereby causing flocculation and agglomeration. (Ijimdiya, et al., 2012).

2.3.7 Bagasse Ash

Amit *et al*. (2014) investigated the low bearing capacity, low permeability, and high compressibility of black cotton soil. The chemical characterization of the bagasse ash was as shown in Table 2-2. According to ASTM C618 (2001), for any material to be considered to have pozzolanic properties, the combination of Al_2O_3, SiO_2 and Fe_2O_3 should be above 70% as a minimum. For the bagasse ash, it was found that the combination was 80.61% which was greater than the 70% minimum recommended as recommended in ASTM C618 (2001). The percentage composition of MgO was 0.85% which was less than the 5% stated in the standard and Na_2O was spotted at 1.05% a value below 1.5% and this showed a pozzolanic action according to ASTM C618 (2001).

Table 2-1: Chemical composition of Bagasse Ash (Suryavanshi, et al., 2014)

Chemical composition Bagasse Ash Oxide (%)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O
64.38	11.67	4.56	10.26	0.85	3.57	1.05

The specific gravity (SG) of bagasse ash was found to be 1.306, and the stabilization of black cotton soil with bagasse ash was carried out by blending the soil with different percentages of bagasse ash (3%, 6%, 9% and 12%). The effective percentage replacement of bagasse ash was found to be 6%. The MDD increased by 6 %, CBR increased by 42 % and compressive strength increased by 44 %. The blend suggested by this research is black cotton soil + 6% replacement by bagasse ash, without any addition of bonding or chemical material, this would be an economic approach (Suryavanshi, et al., 2014).

2.4 Applications of Fresh Cow Dung

Yalley and Manu (2013) investigated the strength and durability properties of earth brick stabilized with cow dung. Where the local soil (from the Sunyani Polytechnic area of Ghana) was used. The compressive strength of the earth bricks improved with 20% cow dung by dry weight as a stabilizer. The bricks also had a dry and wet compressive strength of 6.64 and 2.27 MPa respectively. The compressive strength increased by 25% in the dry compressive strength of bricks stabilized with 20% cow dung content as compared to the unstabilized earth brick. The 20% cow dung content resulted in lower permeability of water into the brick. And the abrasive resistance increased with 20% cow dung content.

After immersion in water for 10 minutes, the compressive strength of the stabilized bricks decreased, despite the optimum Cow dung content, this showed the design of the stabilized earth bricks not come into direct conduct with rainwater if they were to last in any construction (Yalley & Manu, 2013).

Millogo, *et al*. (2016) investigated the effects of cow dung on micro-structural changes in earth blocks (adobes) X-ray diffraction (XRD) was used among other methods. They aimed to evaluate the effects of these changes on the physical properties (water absorption and linear shrinkage) and mechanical properties (flexural and compressive strengths) of adobe blocks. The results showed that cow dung reacted with kaolinite and fine quartz to produce insoluble silicate amine, which joined the isolated soil particles together. Moreover, the significant presence of fibres in cow dung prevents the propagation of cracks in the adobes and thus reinforces the material. The above phenomena make the adobe microstructure homogeneous with an apparent reduction of the porosity. The major effect of cow-dung additions is a significant improvement in the water-resistance of adobe, which led to the conclusion that adobes stabilized by cow-dung were suitable as building materials in wet environments (Millogo, et al., 2016).

Mbereyaho, *et al*. (2020) investigated the cohesive soil mixed with cow dung as a replacement for cement to be used for simple plastering works, the cohesive soil was extracted from one of the local sites (in Rwanda) mixed with various percentages of cow dung 10%, 20%, 30% & 40%. The cohesive soil was sieved to extract organic matter, and then the Atterberg limits test was conducted to establish the cohesive status of the soils. The cow dung was mixed with the cohesive and the respective cubes of 100mmx100mmx100mm 12 cubes in total, 3 cubes for each sample were moulded. The cohesive soil average specific gravity was 2.603 and this value was in line with standards as it should range between 2.6 - 2.8 following (ASTM D 854-92).

The mixture was then compacted manually using a metallic tamping rod severally over one layer and they were kept for 3 days in water for the water absorption test. Later they were dried for 28 days in an open-air space before they were tested accordingly. The liquid limit (W_L) was 40.785%, the plastic liquid (W_P) was 23.0% and the plasticity index (I_P) was 17.785%. The best water absorption for all cubes was found to be 19.82 on average which corresponded to 20% of cow dung content.

In the cohesive soil mortar mixed with cow dung from 10% to 20%, the shrinkage increased from 24.6 to 25.3%, and then it decreased to 24 and 23% respectively at 30% and 40% of the cow dung content. The durability test was conducted visually and it showed that no cracks in the plastered mortar were well attached to the wall. The content of 20% of cow dung could be considered a low-cost alternative construction material to cement mortar for some structural members under normal conditions this is because it showed better properties and higher durability. To avoid earlier shrinkage and cracks in mortar due to spontaneous drying by the sun, this mortar should not be left in an open area for at least an earlier stage of seven days (Mbereyaho, et al., 2020).

Most rural homes in Kenya use cow dung smear coating, bi-monthly in keeping their homes clean and dust-free as shown; Plates 2-1 show the mixing of the materials required which are water, dudu dust (to prevent insects and worms invasion into the house) and the cow dung. Plates 2-2 & 2-3 show the mixing of the materials before smearing them on the mud house. Plate 2-4 shows the actual smearing of the mixed material in the house and finally Plate 2-5 shows after smearing the mixed material it is left for a while to dry before stepping on it.

Plate 2-1: Step 1 -Materials (Sand, FCD, Water & Dudu Dust) (Google)

Plate 2-2: Step 2 -Mixing the material (Google)

Plate 2-3: Step 3 -Mixing the materials slowly with water (Google)

Plate 2-4: Step 4 -Smearing the dung evenly (Google)

Plate 2-5: Step 5 -Drying (Google)

Miner and Smith (1975), and NACA (1989) carried out a chemical composition of both manure and urine for different farmed animals namely; cows, oxen, pigs, chickens and horses as shown in Table 2-2. From the results, the percentage of organic material for all the animals was the highest and this is an indication that the binding properties in the respective manure and urine could be a result of the organic material which are act as a binder.

Table 2-2: Chemical composition of manures and urines of different farmed animals

	Dairy cattle	Beef cattle	Ox	Pig	Chicken layers	Chicken broiler	Horse	Milk cow dung	Cow dung	Pig manure	Cow urine	Pig urine
Dry as % of fresh manure	12.7	11.6	25	9.2	25.2	25.2	20.9	15	10-15	15	5-7	7
Dry matter (%)	100	100	100	100	100	100	100	15	10-15	15	5-7	7
Organic material (%)	82.5	85	85	80	70	70	80	11.4	14.6	15	2.3	2.5
Total nitrogen (%)	3.9	4.9	4.5	7.5	5.4	6.8	2.9	0.36	0.30-0.45	0.50-0.60	0.60-1.20	0.30-0.50
Total phosphorous (%)	0.7	1.6	0.7	2.5	2.1	1.5	0.5	0.32	0.15-0.25	0.45-0.60	trace	0.07-0.15
Total potassium (%)	2.6	3.6	3.2	4.9	2.3	2.1	1.8	0.2	0.32	0.35-0.50	1.30-1.40	0.20-0.70
Biological oxygen demand $^{5\ days}$	16.5	23	9	33	27	-	-	-	-	-	-	-
Chemical oxygen demand	88	95	11.8	95	90	-	-	-	-	-	-	-
Source[1]	1	1	1	1	1	1	1	2	2	2	2	2

Source: (1) Miner and Smith (1975); (2) NACA (1989).

2.5 Applications of Cow Dung Ash

Ojedokun *et al*. (2014) studied the outcomes of adding CDA as a partial replacement of cement in several ratios by weight (0%, 10%, 20% and 30%) of cement a total of 16 cubes were cast whose sizes were 150mmx150mmx150mm. The cubes were cured for a period of 7, 14, 21 and 28 days respectively before compressive strengths testing. CDA concrete was recommended for use only when 10% of CDA with a strength of 21.11N/mm^2 at 28 days of curing as shown in Table 2-3, and the workability as shown in Table 2-4. The initial and final setting time increased with an increase in the dosages of CDA and workability decreased with an increase in the dosages of CDA. The bulk density decreased with an increase in the dosages of CDA (Ojedokun, et al., 2014).

Table 2-3: Cube strength of cubes for each curing period (Ojedokun, et al., 2014)

Curing Period	0%	10%	20%	30%
7 days	14.44 N/mm^3	13.56 N/mm^3	6.67 N/mm^3	5.11 N/mm^3
14 days	15.56 N/mm^3	15.20 N/mm^3	9.24 N/mm^3	5.42 N/mm^3
21 days	17.42 N/mm^3	17.11 N/mm^3	10.13 N/mm^3	5.78 N/mm^3
28 days	21.33 N/mm^3	21.11 N/mm^3	11.11 N/mm^3	6.00 N/mm^3

Table 2-4: Workability results (Ojedokun, et al., 2014)

% of CDA	Slump (mm)
0%	40
10%	48
20%	80
30%	100

Omoniyi, *et al*. (2014) investigated the use of CDA as an additional cementitious material in concrete. The cement was replaced at 5%, 10, 15%, 20%, 25% and 30% of CDA. The physical properties like specific gravity (SG) for CDA was 2.55 while that for OPC (Ashaka cement) was 3.15. The chemical properties of the CDA and OPC were as shown in Table 2-5 which showed that, The index properties of CDA were found to be 76.91%. This value is greater than the 75% minimum specified by STM C 618-12 class N pozzolana. The combined percentage of alkali (Na_2O+K_2O) was 3.5% this being a low percentage value, it reduced the possibility of the destruction of the aggregate alkali reaction as this would have caused the disintegration of concrete. The strength gain and the setting time of concrete were observed to be affected by the high alkalis percentage. It was also observed that the present Sulphur trioxide (SO_3) of 1.4% was less than the 4%

specified by ASTM C618-12 this showed the durability was improved and the expansion of the paste was prevented. This showed that CDA reacted with ordinary Portland cement, which made the concrete compressive strength acceptable.

Table 2-5: Chemical composition (Omoniyi, et al., 2014)

Oxide Composition	Weight (%)	
	CDA	Ashaka Cement
S_iO_2	69.65	20.26
Al_2O_3	4.27	6.30
Fe_2O_3	2.99	3.26
CaO	12.55	65.51
MgO	2.12	0.96
SO_3	1.36	0.69
K_2O	2.94	0.88
Na_2O	0.57	0.89
P_2O_5	1.48	0.25
Mn_2O_3	0.63	0.21
TiO_2	0.33	0.24
$SiO_2+AlO_3+Fe_2O_3$	76.91	29.82

A total number of 105 cubes were prepared of size 150mmx150mmx150mm, among the tests carried out were; the initial and final setting time and slump test carried out on the fresh cement / CDA blended paste and concrete. The cubes were then cured for 7, 14, 28, 60 and 90 days and thereafter the compressive strength was tested for each cube. The results showed that as the percentage of CDA dosage was increased, both the initial and final setting times also increased from 12.2% - 59.3% and 2.74% - 43.90% respectively. This illustrated that CDA acted as a retarder. As the CDA content was increased, the workability of concrete also decreased. This was because additional water was required to maintain the steadiness of the concrete as the CDA dosage was increased.

The compressive strength results showed a decrease in crushing strength as the dosages of CDA increased regardless of the curing age. The results also showed there was no significant difference in crushing strength between the control concrete and those containing up to 15% CDA at a 5% level of significance.

Samson & Tope, (2014) also investigated the pozzolanic potentials of CDA. The summation of SiO_2, Al_2O_3 and Fe_2O_3 in CDA exceeded the 70% minimum specified by ASTMC 618-12 as shown in Table 2-6 below. The test results indicated that CDA prolongs the setting time and reduces the compressive strength with the increase in dosages of CDA.

Both the physical properties and the SG of CDA obtained was 2.55 a value lower than that of OPC (Ashaka cement) of 3.15 but it was above the required values which lie between 2.0 - 2.40 as specified in ASTM C618 (1978) for pozzolanic material. Due to the difference in specific gravity, it implied that more quantity of CDA was needed to replace an equal weight of Ashaka cement. CDA was seen to be finer than OPC and certainly increased the surface area of cementitious materials available for hydration (Samson & Tope, 2014).

Table 2-6: Chemical Composition of CDA from several sources and OPC (Samson & Tope, 2014)

Oxide Composition (%)	Percentage Composition					
	Source 1	**Source 2**	**Source 3**	**Source 4**	**Average**	**OPC**
S_iO_2	69.76	69.65	61.786	61.866	65.7655	20.26
Al_2O_3	4.74	4.27	5.206	3.614	4.4575	6.30
Fe_2O_3	3.18	2.99	3.978	2.502	3.1625	3.26
CaO	13.25	12.55	13.307	12.852	12.98975	65.51
MgO	2.12	2.22	1.779	1.952	2.01775	0.96
SO_3	0.89	1.36	0.705	0.807	0.9405	0.69
K_2O	2.71	2.94	2.674	3.011	2.83375	0.88
Na_2O	0.611	0.56	0.388	0.485	0.511	0.89
P_2O_5	1.37	1.48	1.215	1.466	1.38275	0.25
Mn_2O_3	0.62	0.63	0.565	0.582	0.59925	0.21
TiO_2	0.38	0.34	0.443	0.312	0.36875	0.24
$CaCO_3$	23.64	22.40	23.751	22.938	23.18225	-
$SiO_2+AlO_3+Fe_2O_3$	77.68	76.91	70.97	67.982	73.3855	-

Gurjar & Bhadouriya, (2015) did a study on the production of concrete with CDA and rice husks ash (RHA) as a partial replacement of ordinary portland cement (OPC) in an M:15 mix proportional ratio of 1:2:4 was used. The consistency limit, setting time, and workability of CDA and RHA with ordinary portland cement were tested. Cement was replaced with CDA and RHA by weight in portions of 5%, 10%, 15%, 20% & 25% respectively in concrete. The concrete cubes were of standard size 150mmx150mmx150mm and a Compressive strength test was done after curing for 7, 14, and 28 days. The results showed that the maximum compressive strength was achieved with optimum content of CDA and RHA at 5% replacement as shown in Table 2-7. The workability decreased with an increase in dosages of both the CDA and RHA as a binder in concrete. The setting time increased with increasing replacement in cement (Gurjar & Bhadouriya, 2015)

Table 2-7: Compressive strength (Gurjar & Bhadouriya, 2015)

CDA+RHA REPLACEMENT%	COMPRESSIVE STRENGTH (N/mm^2)		
	7 Days	14 Days	28 Days
0%	16.4	23.0	29.1
5%	27.2	32.2	36.7
10%	26.2	31.6	35.7
15%	25.7	30.4	34.5
20%	24.5	29.9	32.1
25%	22.8	28.2	30.9

Fredrick *et al*. (2018) characterized the chemical properties of CDA as shown in Table 2-8 and found out that the combination of Al_2O_3, SiO_2 and Fe_2O_3 was 78% which was more than than the 70% specified in ASTM C618 (2001), calcium trioxocarbonate of 24% was detected and this contributed to the strength of the concrete. The percentage sulphur as MgO was 2.1 % which was less than the 5% specified in the standard and Na_2O was detected at 0.6% less than 1.5% which conforms to ASTM C618 (2001) and showed high pozzolanic action.

Table 2-8: Chemical properties of CDA (Fredrick, et al., 2018)

Chemical composition Elemental Oxide (%)											
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	P_2O_5	Mn_2O_5	TiO_2	$CaCO_3$
69.75	4.74	3.17	13.25	2.11	0.89	2.70	0.61	1.37	0.62	0.38	0.19

Another research was done to determine the permeability properties of cylindrical concrete samples with a diameter of 75mm and 100mm long, made with CDA as a binder. The specimens were tested after 28, 56, and 90 days of curing. Another set of cylindrical having a diameter of 100mm and 50mm height were prepared for a sorptivity test, they were tested at 28 and 56 days of curing. Concrete cube samples of class 25 N/mm^2 design strength with a water-to-cement ratio of 0.6 were prepared with ordinary Portland cement (OPC) and the OPC was partially replaced with CDA at 0%, 10%, 20% and 30% by weight. The results showed early strength for the control samples as compared with that of the CDA-stabilized samples as shown in Figure 2-2. Crushing strength test carried out on 100mmx100mmx100mm after 7, 28, 56 and 90 days of curing.

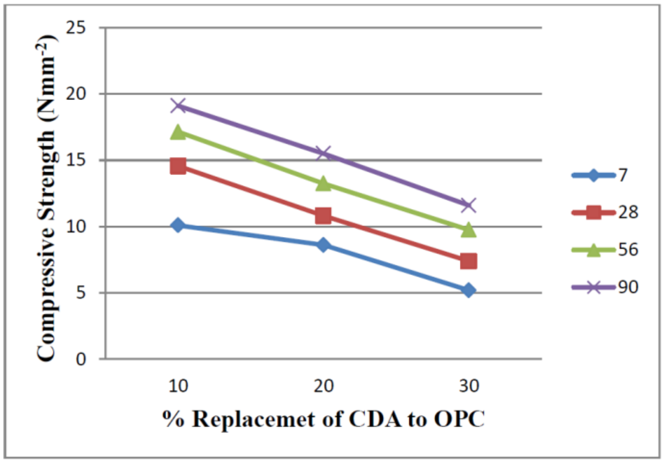

Figure 2-2: Compressive Strength vs % Replacement of CDA (Fredrick, et al., 2018).

The presence of CDA as a filler showed low early strength development compared to the control samples, this was because the CDA as a filler is a pozzolan that is known to reduce the early strength of concrete due to its slow rate of hydration. When CDA and OPC were mixed, the crushing strength increased after a long period of curing. From the results, the bending strength decreased with an increase in CDA dosages. CDA increased the capillary suction of concrete hence, the absorption of water into the cube increased this intern affected the durability of the concrete negatively. Permeability decreased with a longer period of curing then it increased as the dosages of CDA were increased. The high results for flexural strength, compressive strength, sorptivity, and water permeability were obtained with an optimal replacement for CDA as 10%. In conclusion, CDA is a good pozzolanic material, that can achieve up to 94% design strength within 28 days of curing, but with 10% of CDA partially replaced with the OPC the water absorption of moisture into concrete would be negligible. On the physical properties, the SG of CDA was determined as 2.28. This conforms to the requirements in ASTM C618 (1978) for pozzolanic materials. Though less than that of OPC which was 3.15. This implied that the concrete produced with a partial replacement using CDA had less weight as compared to that of 100 % OPC (Fredrick, et al., 2018).Kumar & Dr A. Anbuchezian, (2018) did a research project for use of CDA, alumina and lime as a full replacement for cement in concrete production. It was found out CDA can only be replaced at 10%-20% of cement since the further replacement of CDA, will require more water (Kumar & Anbuchezian, 2018)

Sruthy *et al*. (2017) studied the crushing strength of concrete made with CDA and glass fibre as a binder. This was to minimize greenhouse gas emissions to the atmosphere. The CDA was added at various percentages (6%, 8%, 10%, 12% and 14%) by weight of cement. 0.5% glass fibre being an economically strong material, was added this was to strengthen the CDA concrete and make it more durable in addition, glass fibre has excellent bending strength, and resists cracks. With these properties, glass fibre can be used as an alternative material for producing concrete to be used in construction. The concrete class 25 was done and the results showed with an 8% replacement of cement with cow dung ash, increased the compressive strength (Sruthy, et al., 2017).

2.6 Optimization of Gravel soils Engineering Properties

The material requirements, traffic limitations and construction procedures for gravel roads are summarized in Figure 2-3 as defined by the Ministry of Transport and Communications.

<table>
<tr><td>Chart GWC</td><td colspan="3">GRAVEL WEARING COURSE</td><td>Chart GWC</td></tr>
<tr><td colspan="3">Grading after compaction</td><td></td><td>Plasticity requirements</td></tr>
<tr><td rowspan="2">Sieve (mm)</td><td colspan="2">% by weight passing</td><td></td><td rowspan="2">Plasticity modulus: min. 200 max 1,200
Plasticity index:
-Wet areas Min. 5 Max. 20
-Dry areas min. 20 max. 30</td></tr>
<tr><td>Class 1</td><td>Class 2</td><td></td></tr>
<tr><td>37.5</td><td>-</td><td>100</td><td></td><td></td></tr>
<tr><td>28</td><td>100</td><td>95-100</td><td></td><td>Bearing strength requirement</td></tr>
<tr><td>20</td><td>95-100</td><td>85-100</td><td></td><td rowspan="2">CBR at 95% MDD (Modified AASHTO) and 4 days soak: Min. 20</td></tr>
<tr><td>14</td><td>80-100</td><td>65-100</td><td></td></tr>
<tr><td>10</td><td>65-100</td><td>55-100</td><td></td><td></td></tr>
<tr><td>5</td><td>45-85</td><td>35-92</td><td></td><td>MECHANICAL STABILIZATION</td></tr>
<tr><td>2</td><td>30-68</td><td>23-77</td><td></td><td rowspan="5">These requirements also apply to mixture of the natural gravel and sand or up to 30% of stone (crushed or not)</td></tr>
<tr><td>1</td><td>25-56</td><td>18-62</td><td></td></tr>
<tr><td>0.425</td><td>18-44</td><td>14-50</td><td></td></tr>
<tr><td>0.075</td><td>12-32</td><td>10-40</td><td></td></tr>
</table>

Figure 2-3 Gravel Wearing Course Specifications (Ministry of Transport and Communications, 1987)

According to the research done by the U.S Department of Transportation made by South Dakota Local Transport Assistance on the design and maintenance of manual for gravel roads. Table 2-9 below shows that a good gravel material to be used on gravel roads the percentage of fines passing the 200 No. sieve should range between (4-15%) and the plasticity index should also range between (4-12%) (Program, 2000).

Table 2-9: Good Gravel Material for Surface Gravel roads (Program, 2000)

Sieve No.	Percentage passing
20mm	100
14mm	
4.75mm	50-78
2.36mm	37-67
0.425mm	13-35
0.075mm	4-15
Plasticity Index	4-12

2.7 Critique of the Existing Literature

From the literature review, we get valuable information where the use of different natural materials has been studied on how to use them as a soil stabilizer and the results have given positive results. Among the materials studied are salts (NaCl, $CaCl_2$ and $MgCl_2$) molasses, and bio-enzymes, among other materials, studied.

2.7.1 Mechanical Stabilization using Fresh Cow Dung

On the study of stabilization using cow dung various studies have been done; Peter and Dorothy (2013) carried out a study in Ghana on the Strength and Durability Properties of cow dung Stabilized Earth Bricks by burning the bricks in the kiln the cow dung being a combustible material it was burnt in the process leaving pores in the bricks that's why after water immersion, the voids in the bricks left after burning were filled with water this made the strength of the bricks to drop. Hence it was found that the bricks stabilized with cow dung were not suitable in wet areas. Younoussa et al., (2016) did research titled; Earth blocks stabilized by cow dung' the study was done in Burkina Faso (Ouagadougou area) on lateritic clay, Leopold et al., (2020) did research where he replaced cement with cow dung in producing mortar for simple plastering works on cohesive soils in Rwanda. The above studies concentrated on stabilizing cohesive soils to make bricks for building construction whereas, In my study, cow dung is used to stabilize lateritic gravel soil on unpaved roads where I will carry out the following tests; Compaction Properties (MDD & OMC), strength properties (CBR & UCS), grading and atterberg limits. The stabilization of lateritic gravel using cow dung to be used on gravel and earth roads was an area not exhaustively covered in the reports studied at the time of writing this thesis. These led to research on the possibilities of stabilizing the lateritic gravel using cow dung to be used on earth and gravel roads in rural areas.

2.7.2 Chemical stabilization using Cow Dung Ash (CDA)

Ojedokun *et al*. (2014) studied CDA as a partial replacement of cement in the concrete-making process, Omoniyi *et al*. (2014) in their study titled, 'Compressive strength characteristic of cow dung ash (CDA) blended cement concrete, Duna & Omoniyi (2014) in their report titled; 'Investigating the pozzolanic potentials of CDA in cement paste mortars', Inderveer & Gautam (2015) Performed a Research on Study on the use of CDA and RHA as partial replacement of ordinary cement (OPC) in concrete production, Sruthy *et al*. (2017) carried out a research on the compressive strength of concrete made with CDA and glass fibre as a binder. The above studies showed that the CDA was used alone or mixed with other materials in the production of concrete, BUT in my study, CDA is used without blending it with any other material to stabilize the lateritic gravel to be used on gravel and earth roads mostly found in rural areas. The stabilization of lateritic gravel using CDA was an area not well covered in the literature review material found at the time of compiling this report, this study intends to study the possibility of stabilizing the lateritic gravel using CDA as a chemical stabilizer.

Ijimdiya *et al*. (2012) Investigated the stabilization of black cotton soil using groundnut shell ash (GSA), Amit *et al*. (2014) did a study titled; 'Stabilization of expansive soils with bagasse ash' for a material to be used as a base course in road construction. In my study, I am stabilizing the lateritic gravel soil with CDA and I will carry out the following tests; Compaction Properties (MDD & OMC), Strength Properties (CBR & UCS), grading and atterberg limits. Where the stabilized material is to be used as a gravel-wearing course (GWC) on unpaved rural roads in Kenya.

2.8 Summary and Conceptual Framework

2.8.1 Mechanical Stabilization

From the studies highlighted above, the information we get is that FCD is mixed with different types of cohesive soils, and stabilization of the said soils occurs this is evident by the improvement in the strength properties of the stabilized soils. At the time of writing this thesis, there was no material found on lateritic soils stabilized with fresh cow dung to be used on unpaved roads in rural areas.

2.8.2 Chemical Stabilization

From the studies above CDA on full or partial replacement of ordinary portland cement (OPC) in the production of concrete showed there was an increase in strength properties like compressive strength after a prolonged period of curing time. Other materials studied were groundnut shell ash (GSA) as a stabilizer of expansive soils to be used as a road base and found that this stabilization decreased the maximum dry density (MDD), California Bearing Ratio strength(CBR) and unconfined compressive strength (UCS). Stabilization of expansive soils (black cotton soil) using bagasse ash found that this increased both CBR and the weight-bearing ability of the soil. The MDD and UCS of the stabilized expansive soil were also increased after stabilization. This study aims to find out the ability of both FCD and CDA in stabilizing the lateritic gravel soils on earth and gravel roads without the addition of any other additive. Figure 2-4 & Figure 2-5, illustrates the procedure to adopt in stabilizing the gravel soils for unpaved roads in rural areas.

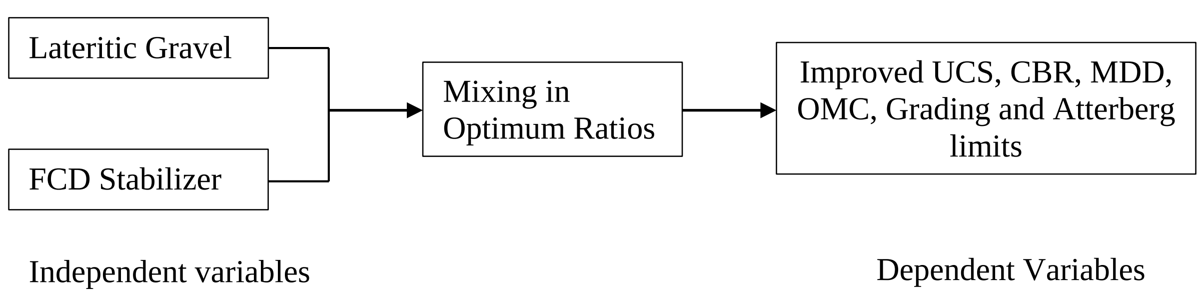

Figure 2-4: Conceptual framework for mechanical stabilization

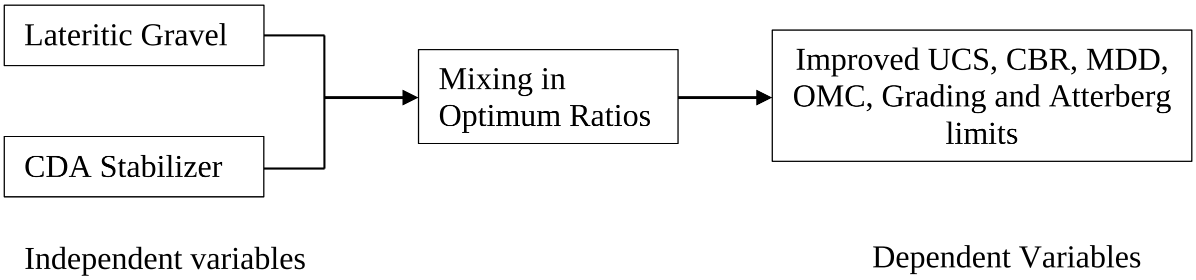

Figure 2-5: Conceptual framework for chemical stabilization

The use of both FCD and CDA as a stabilization material for the lateritic gravel soils as a road construction material is more economical and environmentally friendly in comparison with other conventional methods of soil stabilization. At the time of writing this thesis, the majority of the studies have laid more emphasis on improved pavement layers for paved roads by the use of conventional stabilizers like lime and cement. This research aims to find out how to improve the gravel course material by mixing the optimal ratios of FCD and CDA to the lateritic gravel to improve the earth and gravel roads in rural areas to serve the community for a much longer time without reservicing.

CHAPTER 3: MATERIALS AND METHODS

3.0 Introduction

This chapter explains the collection, preparation and analysis of the materials to be used for the entire laboratory tests. The aim is to determine the strength of the lateritic gravel sample when stabilized with different amounts of both fresh cow dung (FCD) and cow dung ash (CDA). It describes the materials that will be used and methods adopted to get the samples from the field, and the tests to be carried out in the laboratory on the materials. This chapter explains the methodology and sampling approach to be used for the lateritic gravel.

3.1 Materials Collection and Preparation

3.1.1 Lateritic Gravel Soil

The lateritic clay sample used for this investigation was collected from a quarry at Kamiti, Kiambu County (37M 268108.00 m E 9871211.00 m S) as shown in Figure 3-1 at a depth of 1.2m using the method of disturbed sampling. The sample collected was packed in sampling bags and transported to the University of Nairobi (Transportation and soil Mechanics laboratory) where upon arrival the lateritic gravel sample is homogenously mixed and air-dried for 24 hours. After drying the soil, clods are crushed gently and grounded with the help of a wooden pestle and mortar then the sample is passed through 20mm sieve No. and the retained material on the sieve was discarded. The sufficient quantity is safely stored in plastic bags for use during the entire laboratory testing work.

3.1.2 Fresh Cow Dung (FCD)

The dried cow dung is collected from the Upper Kabete Campus (College of Agriculture and Veterinary Sciences) at the dairy farm. The caked samples were collected from the grazing fields. The cakes are pounded lightly using a pestle and mortar. Foreign materials like natural vegetable matter, sticks and stones are removed through sieving (sieve number 20mm) as shown in plates 3-1 and 3-2, Part of this prepared material is used directly as FCD.

Figure 3-1: Sampling Location in Membley (Google)

Plate 3-1: Removing of foreign materials

Plate 3-2: Sieving using a 20mm sieve

3.1.3 Cow Dung Ash (CDA)

Cow dung ash part of the prepared dried cakes used for the FCD is calcined at 500^0C (Kiln at Mechanical laboratory, UON main campus) as shown in Plate 3-3, after removing from the kiln, it is allowed to cool overnight as shown in Plate 3-4. Then that sample is taken to the Ministry of Petroleum and Mining situated in an Industrial area on Machakos road, for grinding (using the pulverization machine) and then sieved through B.S. sieve No. 200 (75µm) before usage as shown in Plate 3-5.


Plate 3-3: Burning in Kiln


Plate 3-4: Cooling after Burning in a kiln


Plate 3-5: Final product after sieving

3.2 Materials Index Properties and Characterization

The index properties on laterite gravel are done to classify the lateritic gravel in accordance to AASHTO, while the FCD material is taken to the College of Agriculture & Veterinary Sciences (CAVS) Upper Kabete Campus laboratory to analyse its chemical composition like organic matter, organic carbon, among other chemical elements present in the FCD. The cow dung ash (CDA) is done by both Physical and Chemical Methods. Chemical analysis of the ash was done using the X-ray Fluorescence (XRF) machine. While the specific gravity of CDA is determined following ASTM C188-1995.

3.3 Method of Testing

Figure 3-2 shows the flow chart to be used in conducting the tests. The research laboratory investigations will be done on the natural soil and the stabilized material (both Mechanical and Chemical) stabilization involve the following;

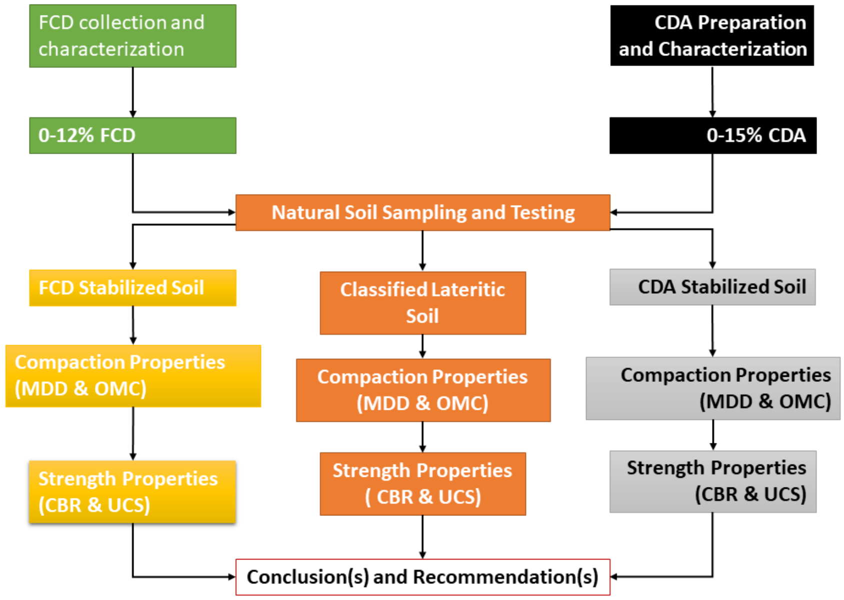

Figure 3-2: Methodology Flow Chart

3.4 Determination of Compaction Properties (MDD & OMC)

The standard compaction test was done using a 4.5kg rammer following AASHTO T180. Mould size 101.6mm diameterx116.4mm (volume 950mm^3) was used. A sample passing the 20 mm test sieve was roughly 20kg then the sieved sample was divided into five samples each weighing 4kg. each sample was entirely mixed with different amounts of water to get the right mixture of moisture contents, after mixing with water they were closed in an airtight container and let to cure for 4 hours before working on them. Moulds were filled in five layers by applying 25 blows for each layer using the 4.5 kg compaction rammer. This was to determine the MDD and OMC of the laterite gravel.

3.4.1 Mechanical Stabilization using FCD

The lateritic gravel soils were mixed with FCD stabilizer at various percentages of (0%, 3%, 6%, 9% and 12%) by weight. The test aimed to determine the MDD and OMC of the laterite gravel. The air-dried sample was subdivided to get the representative sample of 6 kg by the quartering method (BS 1377-4, 1990).

3.4.2 Chemical Stabilization using CDA

The effects of CDA at (0%, 3%, 6%, 9%, 12% and 15%) by weight. The test aimed to determine both the MDD and OMC of the stabilized lateritic gravel. The air-dried sample was subdivided to get the representative sample of 6 kg by the quartering method (BS 1377-4, 1990).

3.5 Determination of Strength Properties (CBR & UCS)

3.5.1 California Bearing Ratio

The effects of FCD stabilizer on lateritic gravel were determined at various percentages (0%, 3%, 6%, 9% and 12%) and CDA stabilizer at (0%, 3%, 6%, 9%, 12% and 15%) both by weight. The CBR test was performed in the laboratory following AASHTO T193:1990 the aim was to determine the index strength and bearing capacity of the material. The material passing the 20 mm sieve was prepared for the test, and then the sample was stored for 24 hours in a secured place before compaction into the moulds. The moisture content of the material sample was determined using the heavy compaction test. and. The material was compacted statically in CBR mould at 95% MDD and OMC. The material was soaked for 4 days in perforated moulds with surcharge this was to determine the rate of water absorption and the degree of swell for the neat and FCD stabilized sample, while the CDA stabilized samples were cured for seven days and soaked for seven days. The samples were removed from the water, surcharge weights removed and samples were drained for 15 minutes before CBR penetration.

Plate 3-6: FCD stabilizer

Plate 3-7: Mixing FCD with soil

Plate 3-8: Water mesurement

Plate 3-9: Moulding

Plate 3-10: Water draining

Plate 3-11: CBR Testing

Plate 3-12: Moulds after Testing

As shown in Plates 3-6 to 3-9 show the measuring, mixing and moulding for the CBR test. Plates 3-10 show the draining of water for the soaked CBR samples for about 15 minutes before testing as shown in Plate 3-11. The applied force to the plunger from each dial gauge reading at each penetration at intervals of 2.5 mm was recorded. The ring factor was used to convert the gauge readings into force (kN). A graph of force on the plunger against penetration was plotted and a smooth curve was drawn through the points. The forces corresponding to 2.5mm and 5.0mm were calculated from the shown equations. The higher value of the two was taken as the CBR of the material.

- CBR value at 2.5mm: $= \frac{Force\ at\ 2.5mm\ x\ 100}{13.2\ (KN)}$ (3.1)
- CBR value at 5.0mm: $= \frac{Force\ at\ 5.0mm\ x\ 100}{20.0\ (KN)}$ (3.2)

3.5.2 Unconfined Compressive Strength (UCS)

The effects of FCD (mechanical stabilization) at (0%, 3%, 6%, 9% and 12%) and CDA at (0%, 3%, 6%, 9%, 12% and 15%) both by weight on lateritic gravel was determined. The UCS tests were carried out per BS 1924:1990. To determine the optimum amount of the stabilizer, seven specimens (for mechanical stabilization) and Three specimens (for chemical stabilization) were used for each stabilizer content. Plate 3-13 shows the CDA stabilizer, Plate 3-14 shows the mixing of the lateritic gravel with the CDA stabilizer and Plate 3-15 shows the final mix of the lateritic gravel and CDA awaiting water and then moulding.

Plate 3-13: CDA stabilizer

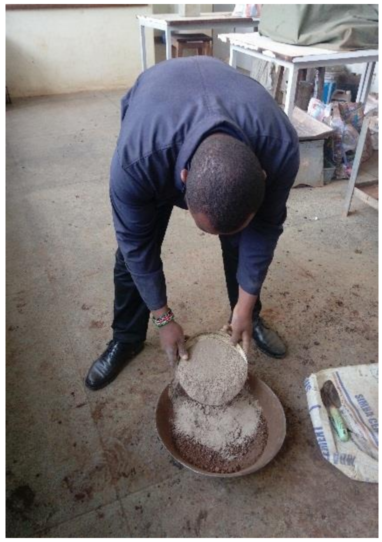

Plate 3-14: Mixing CDA with soil

Plate 3-15: Final mixture ready for moulding

Plate 3-16 shows the final sample this is after compaction and now the sample is being removed from the mould. Plate 3-17 shows the UCS testing and Plate 3-18 shows the failed samples after UCS testing.

Plate 3-16: UCS sample preparation

Plate 3-17: UCS Testing

Plate 3-18: UCS Failed samples after Testing

The dial readings were converted to the appropriate load and length units, and these values were recorded on the datasheet in the deformation and total load columns. The sample cross-sectional area and strain were computed. The corrected area (for both neat and FCD stabilized samples) was determined using the formula:

$$A = A_0 (1- e) \qquad (3.3)$$

for CDA stabilized sample the original area (A_o) was used to calculate the UCS.

3.6 Determination of Grading and Atterberg limits

3.6.1 Particle Size Distribution

The sieve analysis of the lateritic gravel soil was carried out as per BS 1377, Part 2; 1990. A representative sample weighing 2.5 kg was obtained by riffling, this sample was air-dried for twelve hours. Wet sieving was carried out to remove the silt and clay-sized particles, and then dry sieving was done to remove the remaining course materials. down to the fine sand size. The sieve sizes used ranged between sizes 0.075 mm to 10 mm. they were arranged from the smallest to the largest size in ascending order from the receiver pan. The sample was poured on the top sieve and hand shaken. The cumulative percentage retained on each sieve was determined using the following equation;

$$\%\ retained = \frac{m_2 \times 100}{m_1} \qquad (3.4)$$

Where m_1 = mass of the test sample after cooling

m_2 = mass of the retained sample on each sieve

The data obtained were presented in the form of a graph plotted on a grading chart.

3.6.2 Atterberg Limits

These tests were done in the laboratory according to BS 1377; Part 2; 1990. The samples were prepared to determine the plastic limits and liquid limits, from which the plasticity index was determined.

The cone penetrometer method (definitive method) was used and the test samples weighing about 400g as shown on Plate 3-19 which pass the 425 µm sieve were used and the material retained on the mentioned sieve was discarded (BS 1377-2, 1990). Both the liquid limit and plastic limit for neat lateritic gravel and the stabilized material at various percentages were determined.

3.6.2.1 Apparatus

A Penetrometer complying with BS 1377-2:1990, a cone of stainless steel approximately 35 mm long, with a smooth, polished surface and an angle of 30 ± 1°., A metal cup 55 ± 2) mm in diameter and (40 ± 2) mm deep with the rim parallel to the flat base, A flat glass plate 10 mm thick and 500 mm square, Two spatulas, An evaporating dish, of about 150 mm diameter as shown on Plate 3-20 and Plate 3-21, Apparatus for moisture content determination, A wash bottle containing distilled water, a straight-bladed spatula and a stopwatch.

Plate 3-19: Sieved Sample

Plate 3-20: Atterberg Limits apparatus

Plate 3-21: Penetrometer apparatus

Plate 3-22: Mixing

Plate 3-23: Cup filled with sample

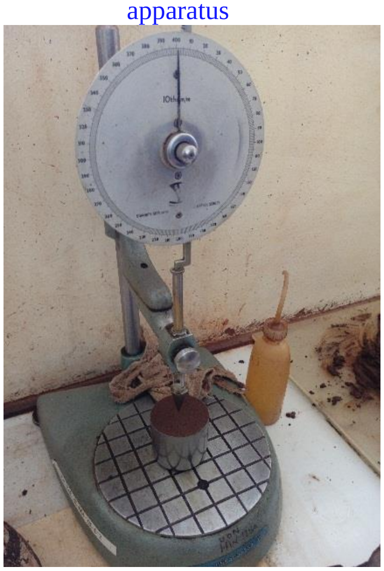

Plate 3-24: Testing for Liquid Limit

Plate 3-25: Rolling the samples

Plate 3-26: Sample for plastic limit

3.6.2.2 Liquid Limit

After recording the cone penetration four times to determine the liquid limits, the moisture content of each sample was recorded after oven drying for 12 hours. The cone penetration on the (y-axis) and moisture content on the (x-axis) was plotted on a linear scale. From the linear graph, the moisture content corresponding to a penetration of 20 mm was interpolated. This value was recorded as the liquid limit (w_L) of the soil sample (BS 1377-2, 1990) Repeat the above procedure for both Neat and stabilized material.

3.6.2.3 Plastic Limit

The plastic limit of the soil sample is the lowest moisture content at which the soil is plastic. The sample was from the soil in its natural state and passed the 425 μm test sieve. The moisture content of each sample was recorded. The plastic limit computed was the average of the water contents (w_P) (BS 1377-2, 1990)

3.6.2.4 Plasticity Index

The Plasticity Index (I_P) is the difference between the Liquid Limit (w_L) and the Plastic Limit

(w_P) and is calculated from the equation: $I_P = w_L - w_P$ (BS 1377-2, 1990) (3.5)

3.6.2.5 Linear Shrinkage

The linear shrinkage is the decrease in length of a soil sample when oven-dried, starting with the moisture content of the sample at the liquid limit.

Percentage of linear shrinkage (w_S) = $\left(1 - \frac{L_D}{L_0}\right) 100$ (3.6)

Where; L_o is the Original length (in mm)

L_D is the length of the oven-dried specimen (in mm)

3.6.2.6 Plasticity Modulus

Is defined as the product of linear shrinkage (LS) and percentage passing BS No 40 sieve (i.e., % < 425μm):

SM = LS (% < 425μm) (3.7)

CHAPTER 4: RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents the results and the discussions of the test results obtained on both the neat lateritic gravel material and the stabilized laterite gravel mixed with FCD and CDA stabilizers in varying percentages. These results were presented in either tabular or graphical presentations. The obtained results were then compared with the specific standard values as recommended in the Gravel Wearing Course chart by the Ministry of Transport and Infrastructure Road Design Manual Part III (1987) and the South Dakota Standard Specifications a good gravel material to be used on gravel roads.

4.1 Index Properties and the characterization of the materials

4.1.1 Index Properties of Lateritic Gravel

The engineering and the geotechnical properties were carried out on the laterite gravel using the standard methods where a series of standardized tests were carried out in the laboratory using the laboratory equipment and the results are shown in Table 4-1. The aim was to assist in the classification of the lateritic gravel as per the AASHTO Classification.

Table 4-1: Index properties of Lateritic Gravel

Test Description	Results	Method
Soil sample collected from (Name and coordinates)	Kamiti (37M 268108.00 m E 9871211.00 mS)	BS 1377-1, 1990
Sieve analysis:	Figure 2	BS 1377-2, 1990
Natural moisture content (%)	9.2	BS 1377-2, 1990
Percentage passing B.S Sieve No. 200	39.3	BS 1377-2, 1990
Liquid Limit (%)	69	BS 1377-2, 1990
Plastic Limit (%)	35	BS 1377-2, 1990
Plasticity Index (%)	34	BS 1377-2, 1990
Shrinkage Index %	15	BS 1377-2, 1990
Free Swell %	0.18	BS 1377: 1990
Group Index	29.15(29)	BS 1377: 1990
AASHTO Classification	A-7-6	AASHTO
Unified system of classification (USC)	CH	ASTM D2487-11
Maximum Dry Density (kg/m^3)	1674	BS 1377-4, 1990
Optimum Moisture Content %	24.74	BS 1377-4, 1990
Unconfined Compressive Strength (kN/m^2)	257	ASTM D2166
California Bearing Ratio (%)		BS 1377-5: 1990
Unsoaked	99	BS 1377-5: 1990
Soaked	39	BS 1377-5: 1990
Specific Gravity	1.82	BS 1377-2: 1990
Colour	Brown	BS 1377-2: 1990

4.1.2 Characterization of the FCD sample

Following the analysis of the FCD material, the results showed that it contained, organic matter 31.80%, organic carbon 18.50% and Nitrogen 1.35%. The other minor elements of the FCD material are shown in Table 4-2. This was to establish the chemical composition of the FCD and the binding components present in FCD that will be responsible for binding the lateritic gravel during the stabilization (mechanical stabilization)

Table 4-2: Chemical composition of FCD sample

Parameters	Units	Values	Method
pH	-	10.20	1.2.5 (water)
Ec	dS/m	2.5	1.2.5 (water)
Nitrogen	%	1.35	Kjedhal
Organic Carbon	%	18.50	Walkley black
Organic matter	%	31.80	Calculated
Potassium	ppm	3250	Flame photometer
Phosphorous	ppm	720.2	Calorimetric
Sodium	ppm	600	Atomic absorption
Calcium	ppm	2350	Atomic absorption
Magnesium	ppm	938	Atomic absorption
Copper	ppm	90	Atomic absorption
Manganese	ppm	194	Atomic absorption
Zinc	ppm	108	Atomic absorption
Iron	ppm	620	Atomic absorption
Aluminium	ppm	Trace	Atomic absorption
Sulphate - S	ppm	0.20	Atomic absorption
Specific gravity		1.48	-

Key: pH- Hydrogen potential, Ec- Electro conductivity, ppm- parts per million

4.1.3 Characterization of CDA sample

Table 4-3 shows the results from the material characterization of the CDA sample done using X-ray Fluorescence (XRF) for CDA. The CDA material sample is composed of the following; silicon oxide 46.96%, aluminium oxide 8.53% and iron oxide 5.52% among other oxides as shown in Table 4-3 below.

Duna & Omoniyi (2014), Omoniyi, et al., (2014) and Fredrick et al., (2018), in their research, found that the combination of Al_2O_3, SiO_2 and Fe_2O_3 was 73.39%, 76.91% & 77.66% respectively which was higher than the recommended 70% as per the ASTM C618 (2001)

Table 4-3: Chemical composition of CDA sample.

Oxide Composition (%)	Nyagah	Duna & Omoniyi(2014)	Omoniyi et al.,(2014)	Fredrick, et al.,(2018)
SiO_2	45.96	65.7655	69.65	69.75
Al_2O_3	8.53	4.4575	4.27	4.74
Fe_2O_3	5.52	3.1625	2.99	3.17
CaO	11.85	12.98975	12.55	13.25
MgO	5.17	2.01775	2.12	2.11
SO_3	1.02	0.9405	1.36	0.89
K_2O	11.79	2.83375	2.94	2.70
Na_2O	-	0.511	0.57	0.61
P_2O_5	6.66	1.38275	1.48	1.37
Mn_2O_3	0.45	0.59925	0.63	0.62
TiO_2	0.55	0.36875	0.33	0.38
$CaCO_3$	-	23.18225	-	0.19
$CaSO_4$	-	-	-	-
$SiO_2+AlO_3+Fe_2O_3$	60.01	73.3855	76.91	77.66
Characterization method	XRF,	XRF	XRF	-

4.2 Effects of FCD and CDA Stabilizer on Compaction

Figures 4-1and 4-2 below show the results from the compaction for the stabilized gravel soil (mechanical stabilization) using FCD. The OMC and MDD at different dosages of FCD indicate that OMC increases with an increase of FCD stabilizer from 24.47% at 0% (NEAT) FCD stabilizer to 29.5% with 12% FCD. This can be attributed to the FCD stabilizer being increased which is a fine material more water content is required for compaction. Fines have a high surface area to volume ratio which absorbs more water.

The MDD decreases from 1666 kg/m^3 of the untreated gravel soil (NEAT) to 1474 kg/m^3 at 12% FCD. This can be explained by the fact that we are replacing natural gravel with a lighter material where FCD is (1420 kg/m^3) compared to natural gravel which is (1820 kg/m^3) thus the low densities of the stabilized material.

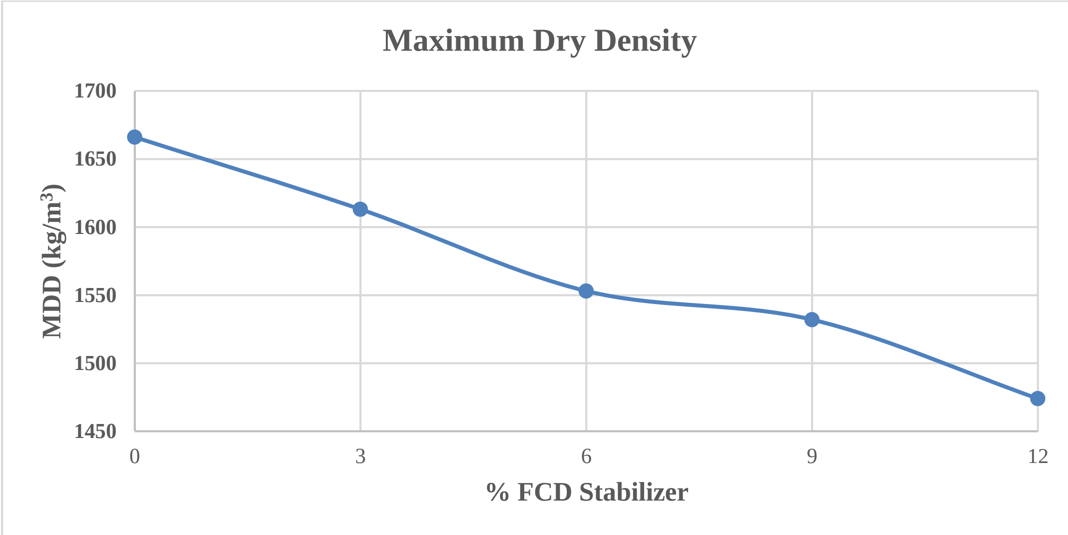

Figure 4-1: Maximum dry density (MDD) values for FCD stabilized material.

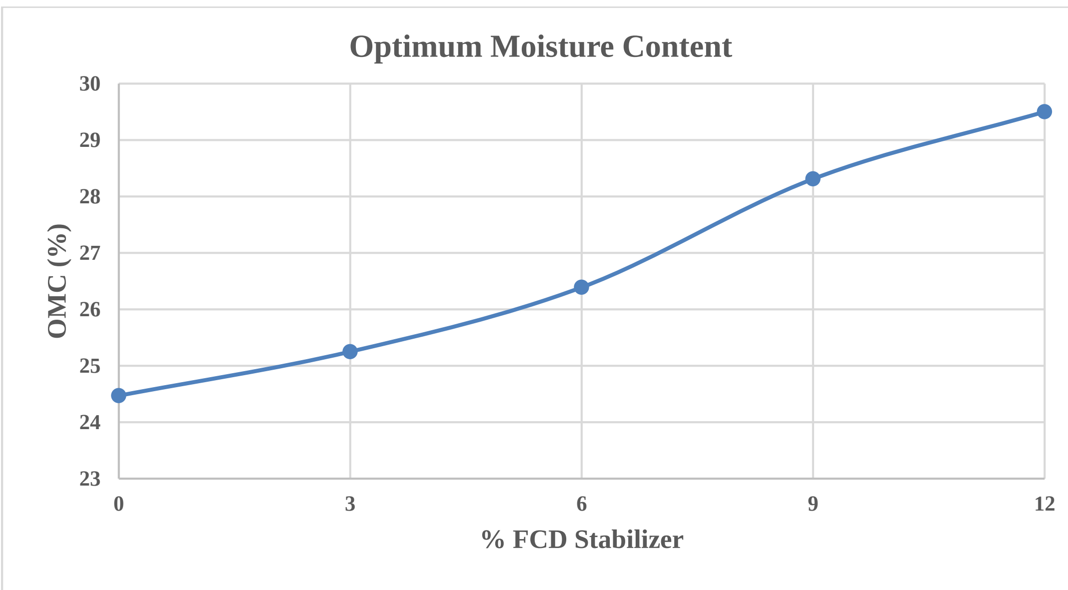

Figure 4-2: Optimum moisture content values for FCD stabilized material.

Figures 4-3 and 4-4 show the results from the compaction for the stabilized gravel soil (chemical stabilization) using the CDA. The OMC and MDD at different dosages of CDA indicate that OMC increases with an increase of CDA stabilizer from 24.47% at 0% % CDA stabilizer to 27.80% with 15% CDA. This can be attributed to the CDA stabilizer is increased which is a fine material more water content is required for compaction. Fines have a high surface area to volume ratio which absorbs more water.

The MDD decreases from 1666 kg/m^3 of the untreated gravel soil (NEAT) to 1560 kg/m^3 at 15% CDA. This can be explained by the fact that we are replacing natural gravel with a lighter material where CDA is (2164 kg/m^3) compared to natural gravel which is (1820 kg/m^3) thus the low densities of the stabilized material. Figures 4-1and 4-2 below show the results from the compaction for the stabilized gravel soil (chemical stabilization) using CDA.

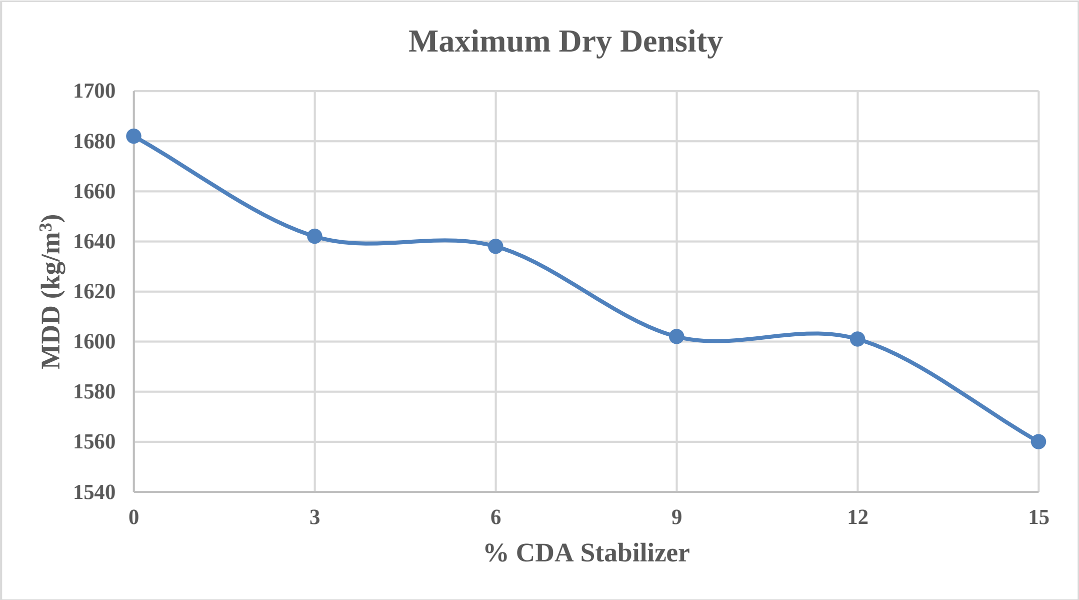

Figure 4-3: Optimum moisture content values for CDA stabilized material.

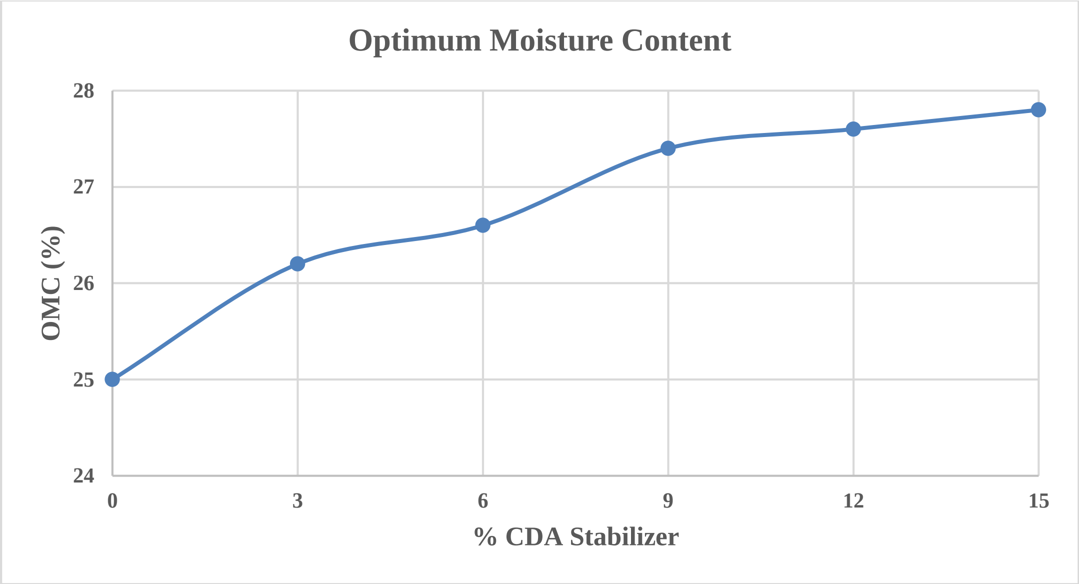

Figure 4-4: Optimum moisture content for CDA stabilized material.

4.3 Effects of FCD and CDA Stabilizer on Lateritic Gravel Strength Properties.

Figures 4-5 and 4-6 below show the lateritic gravel soil strength results after mechanical stabilization using FCD. The results show that UCS and values increase with an increase in FCD content up to a maximum of 300 kN/m^2 for UCS and 54% for CBR at 6% FCD. This can be attributed to the fibres in FCD which binds the gravel hence increasing in strength and a further increase in FCD dosages leads to a decrease in UCS. This is due to the increase in the fines from FCD.

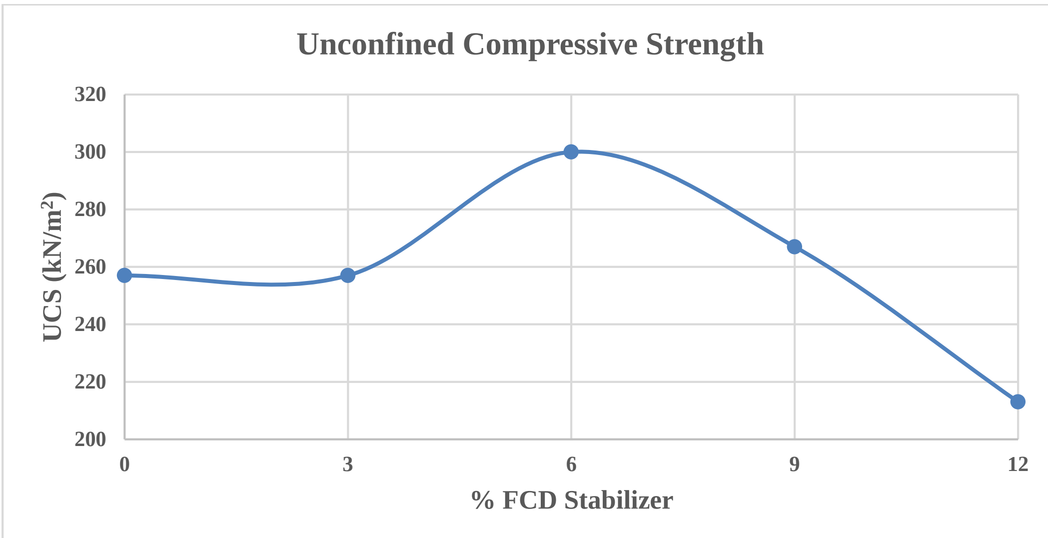

Figure 4-5: Unconfined compressive strength values for FCD stabilized material.

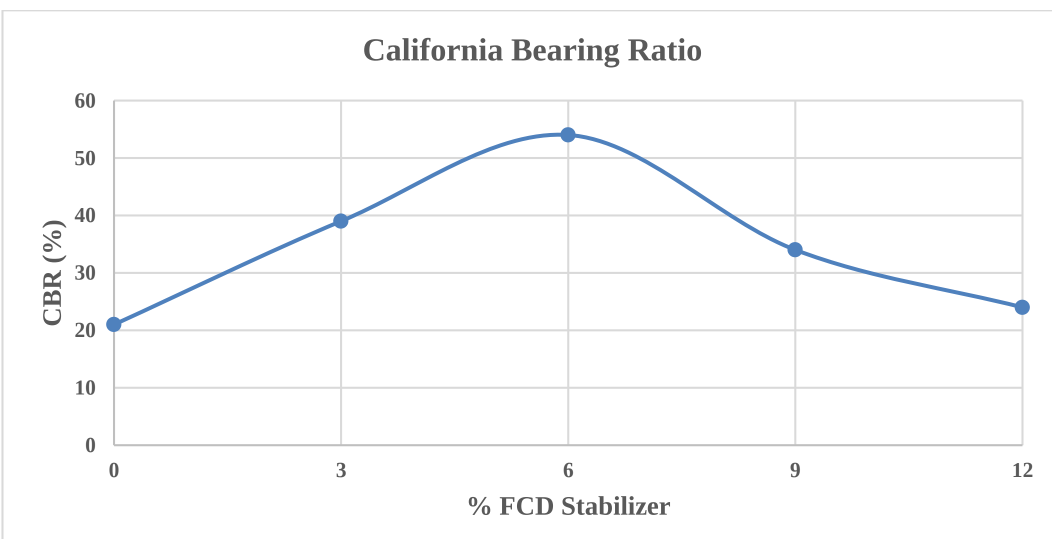

Figure 4-6: California bearing ratio values for FCD stabilized material.

Figure 4-7 shows the lateritic gravel soil strength CBR results after the chemical stabilization using the CDA. The results show that the CBR values increase with the increase in CDA dosages, this can be accredited to the more the CDA stabilizer (being a chemical stabilizer) is added the more the particles of the lateritic gravel will be bonded together since this is a chemical reaction.

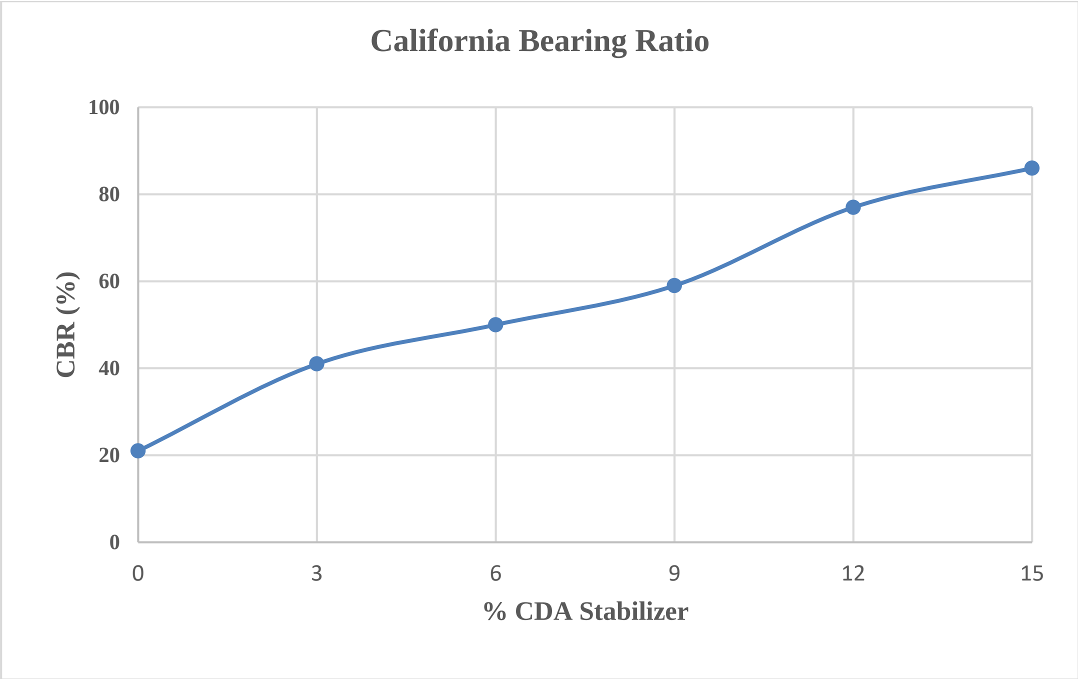

Figure 4-7: California bearing ratio values for CDA stabilized material.

Figure 4-8 shows the lateritic gravel soil strength UCS results after the chemical stabilization using the CDA. The results show that UCS increases with the increase in CDA dosages up to 9% CDA where we attain a maximum value of 496 kN/m^2. Further increase in CDA leads to lower values of UCS. This can be attributed to the more the CDA the more the fines which require more water.

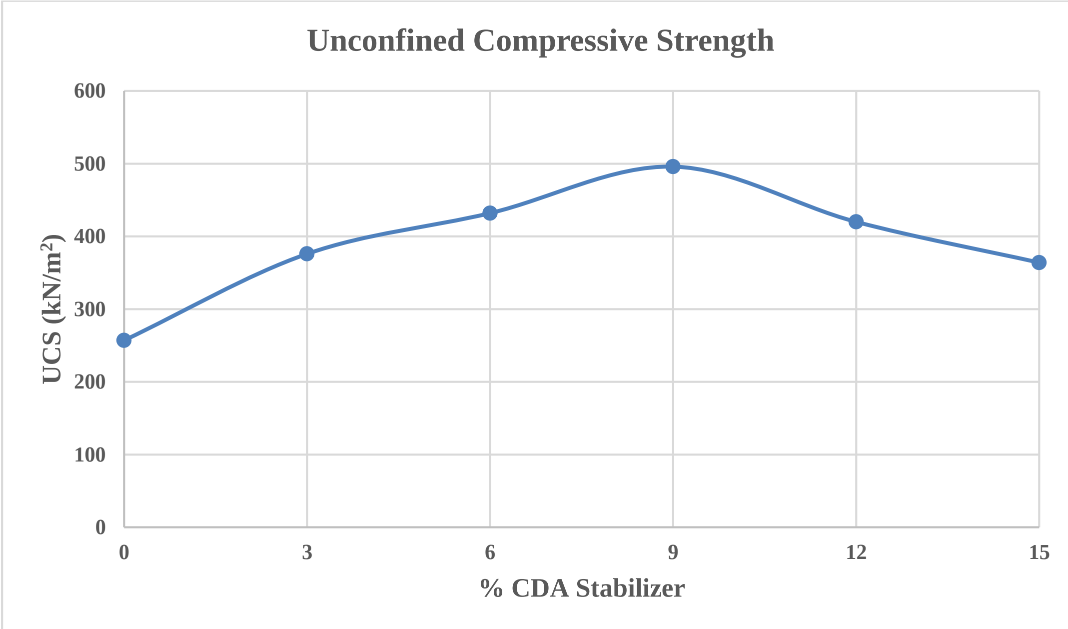

Figure 4-8: Unconfined compressive strength values for CDA stabilized material.

4.4 Effects of FCD and CDA Stabilizer on Lateritic Gravel Atterberg limits.

Table 4-4 shows the atterberg limits results after mechanical stabilization using FCD. For FCD stabilized material the liquid limit increases from 69% NEAT to 73% with 3% FCD stabilizer. This can be attributed to as the FCD stabilizer is added more water is required this explains why the liquid limit values rise, and then the values drop from 73% with 3% FCD to 70% with both 9% & 12% FCD. This can be attributed to as the FCD stabilizer material is added, the voids are replaced by the fibres in the FCD stabilizer which could not hold much water hence the decrease in liquid limit values. The values then increase from 70% with both 6% & 12% FCD to 74% with 12% FCD, this can be attributed to the FCD stabilizer added more water was required since the voids are filled with the fibres meaning the excess FCD material required more water.

The plastic limit increases from 35% NEAT to 37% with both 6% and 9% FCD to 40% with both 9% & 12% FCD. This can be attributed to as the FCD material is added more water was required to change the material from a solid state to a plastic state. The reason for the values in both 9% and 12% FCD to remain the same can be explained as at 6% FCD the material was enough to bond more fines together and to fill the voids. This meant that the material could not hold water hence the reason for the constant values of plastic limit.

The plasticity index is dependent on the liquid limit and plastic limit, therefore the higher the values of the liquid limit and the lower the values of the plastic limit, the higher the values of the plasticity index and vice versa.

Linear shrinkage is the decrease in length of a wet soil sample after drying, therefore from our results Table 4-4 below shows the linear shrinkage increases from the NEAT sample to 3% FCD stabilized sample, then it is maintained at 6% FCD stabilized sample. This is attributed to the FCD material added to it and the water used during the moulding, even after drying, the FCD material filled in the voids left after drying.

After the 6%, FCD stabilized material the linear shrinkage then further reduced up to 13 with the 12% FCD stabilized material after drying, this can be attributed to as the material dried, part of the excess FCD material also dried up thus leaving behind more voids.

Table 4-4: FCD Stabilized Material Atterberg Limits

Stabilized material	Liquid limit	Plastic limit	Plasticity Index	Linear shrinkage
NEAT	69	35	34	15
3% FCD	73	37	36	17
6% FCD	70	37	33	17
9% FCD	70	40	30	14
12% FCD	74	40	34	13

Table 4-5 shows the results after the chemical stabilization using the CDA. The liquid limit for CDA stabilized material shows a decrease with the increase in dosages of the CDA stabilizer from 69% NEAT to 62% with 15% CDA stabilizer. This can be attributed to as the CDA stabilizer material was added, more fines were bonded together hence the sample could not have much water.

The plastic limit increases from 35% NEAT to 36% with both 3% and 6% CDA stabilizer. This can be attributed to more water being required as the dosages of CDA were added to the soil sample for both 3% and 6% CDA to have similar values, it meant that the additional 6% CDA was not sufficient to bond more particles and required a similar amount of water as 3% CDA. The plastic limit then dropped from 36% with 6% CDA to 31% with 15% CDA. This can be attributed to as the CDA material was increased, more fines we bonded together hence a low surface area to volume ratio and less the sample could retain less water.

The plasticity index is dependent on the liquid limit and plastic limit, therefore the higher the values of the liquid limit and the lower the values of the plastic limit, the higher the values of the plasticity index and vice versa.

Linear shrinkage is the decrease in length of a wet soil sample after drying, therefore from our results Table 4-5 below shows the linear shrinkage increases from the NEAT sample to 3% CDA stabilized sample, then it is maintained at 6% CDA stabilized sample. This is attributed to as the CDA material is added more water is required after drying, as water evaporates more voids are left hence the increase in linear shrinkage.

After the 6% CDA stabilized material the linear shrinkage then further reduced up to 13 with both the 12% and 15% CDA stabilized material after drying, this can be attributed to the as the CDA material was added more fines were bonded together and after drying, the voids were already filled by the CDA hence the reason for reduction of the linear shrinkage.

Table 4-5: CDA Stabilized Material Atterberg Limits

Stabilized material	Liquid limit	Plastic limit	Plasticity Index	Linear shrinkage
NEAT	69	35	34	15
3% CDA	66	36	29	17
6% CDA	65	36	29	17
9% CDA	62	32	30	14
12% CDA	63	33	29	13
15% CDA	62	31	30	13

4.5 Effects of FCD and CDA Stabilizer on Grading of the Lateritic Gravel

Figure 4-9 shows the % of fines increases with the increase in the dosages of the FCD material from 41.1% with 3% FCD material to 46.6% with 12% of FCD. This can be attributed to as the FCD was added, fewer particles of clay were bonded together hence which meant more fines were left unbonded together hence the reason for the increase in the % of fines.

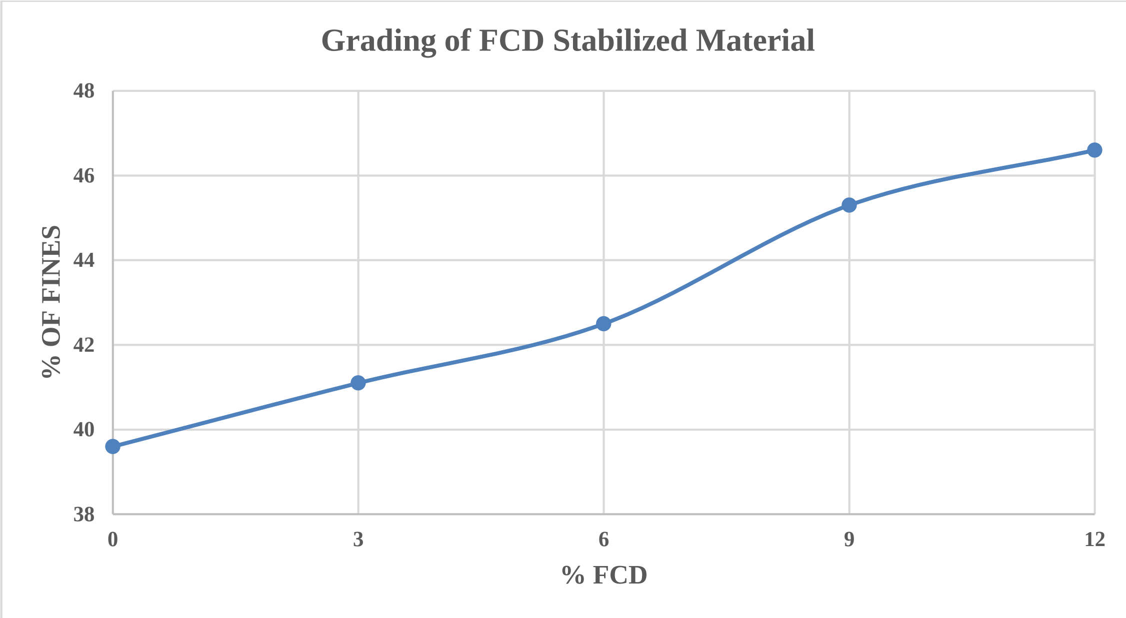

Figure 4-9: Grading values for FCD stabilized material.

Figure 4-10 shows the % of fines decreases with the increase in the dosages of the CDA material to 39.1% with 3% CDA material then the fines reduce up to 37.2% with 6% of CDA. This can be attributed to at 6% of CDA, there is enough material to bind the gravel particles together thus less % of fines. Then the % of fines increases from 39.1 with 6% of CDA to 44.5% with 15% of CDA material. This can be attributed to as the dosages of CDA are increased, the CDA does not have any clay particles to bind together since the majority of the clay bonding through the chemical reaction took place with 6% of CDA as a stabilizer. This meant the excess CDA material was left unused hence the reason for the increase in the percentage of fines.

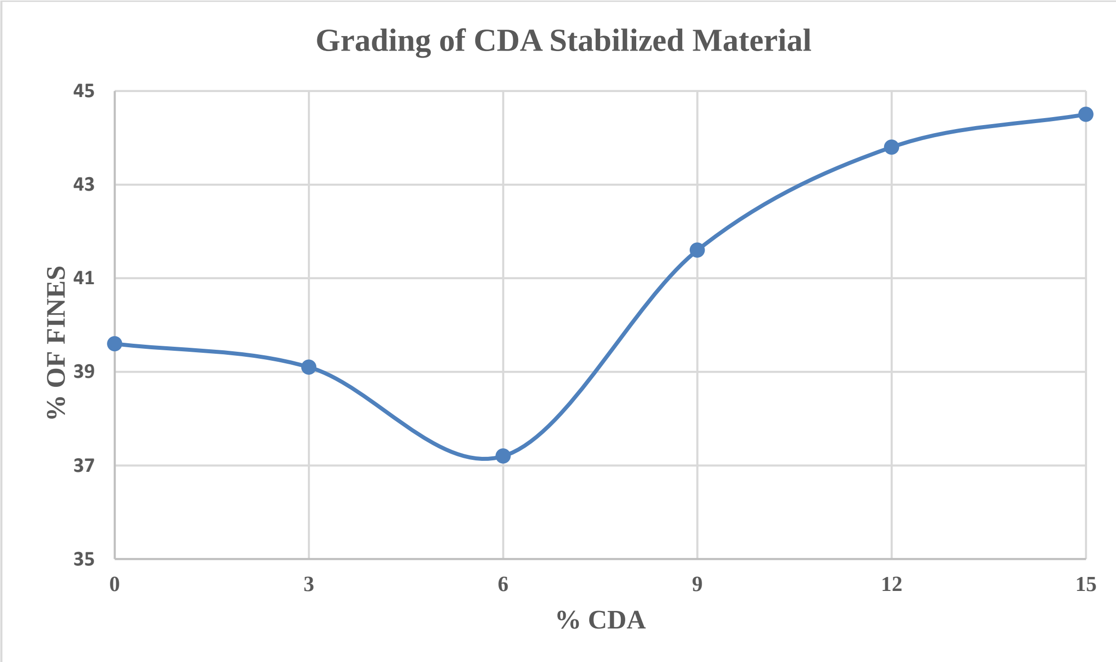

Figure 4-10: Grading values for CDA stabilized material.

4.6 Suitability of FCD as a Stabilizer

The results obtained from the chemical analysis of the FCD sample, the results obtained show that the percentage of organic matter is 31.8% among other elements found in the sample. These results were compared to the results that were obtained by Miner & Smith (1975) also NACA (1989) had done a similar test and found that the percentage of organic material was 82.5% for the dairy cattle, the key binding material is the organic matter as a by-product after the digestion. The FCD was considered a stabilizer after careful study of its use in plastering the mad houses back in the villages to prevent dust.

4.7 Suitability of CDA as a Stabilizer

The chemical characterization of the CDA material results shows that the combination of Al_2O_3, SiO_2 and Fe_2O_3 was 60.01% which was less than 70% minimum according to ASTM C618 (2001) though the difference could have occurred during the material preparation as mentioned in the limitations of the study.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The optimum amount of both FCD and CDA to be adopted for the stabilization of lateritic soil was 6%.

1. The grading properties for the stabilized lateritic soil using the FCD was 42.5% (mechanical Stabilization) and for CDA-stabilized material was 37.2% (chemical stabilization). From the road design specification manual part III GWC chart the CDA stabilized material passed the grading test as class 2 material which requires the percentage (%) passing the 200mm sieve No. ranges between (10-40%). But the mechanically stabilized material failed the grading.

   According to the South Dakota Standard Specifications a good gravel material to be used on gravel roads, the percentage of fines passing the 200 No. sieve should range from (4-15%). Our material both FCD and CDA stabilized material failed since the values obtained were out of the recommended range.

2. The MDD for both FCD and CDA stabilized material was 1553kg/m^3 and 1638kg/m^3 respectively theses values were lower compared to the NEAT sample.

   The OMC for both FCD and CDA stabilized material was 26.4% and 26.6% respectively.

3. The CBR for both FCD and CDA stabilized material passes the required minimum of 20% CBR (mechanical stabilized) and 30% CBR (chemical stabilized). This is according to the road's design manual part III Chart B3 GWC chart.

   The UCS for mechanically stabilized material is not a requirement while for the CDA chemical stabilized the material has 432 kN/m^2 which fails the required minimum of 1,800 kN/m^2. This is according to the roads design manual part III Chart B3 for cement stabilized material for the base.

4. The plasticity requirements were as follows;

   For FCD-stabilized material plasticity index was 33% whereas for the CDA-stabilized material was 29%. The CDA stabilized material passed the test according to the road design manual part III Chart GWC under dry areas which ranges between (min 20 & max 30). The mechanically stabilized did not meet the requirements as per the Chart GWC.

According to the South Dakota Standard Specifications a good gravel material to be used on gravel roads, the plasticity index should range from (4-12%). Our material failed since both FCD and CDA stabilized material was out of the recommended range.

5.2 Recommendations

1. The cattle manure in most of our homes is mostly used as manure in the farms but from our research, we have found out that it can be used to improve the strength characteristics of the lateritic gravel soil used on unpaved and earth roads in most rural areas as the manure both as FCD or CDA promotes stabilization of the lateritic gravel soil.

2. Scientific studies should be carried out to determine how long the FCD and CDA gravel soil would last since the FCD is an organic material and CDA is organic though undergone some chemical change, especially in adverse weather conditions i.e rainy season.

3. Pilot studies are required before the utilization of FCD and CDA stabilization on gravel road construction.

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APPENDICES

Appendix A Chemical Characterization for the Samples

Appendix A1 Chemical Composition of FCD Sample

UNIVERSITY OF NAIROBI

COLLEGE OF AGRICULTURE & VETERINARY SCIENCES

Department of Land Resource Management & Agricultural Technology

Telephone: 631225 (DL) 3592736-9 Ext.27021 P.O. BOX 29053-00625

Fax: 631225 Email: larmat@uonbi.ac.ke Nairobi, Kenya

Certificate of Analysis

Sample name : Manure Sample A

Date received : January 2020

Sample source :

LABORATORY RESULTS

Manure Analytical Data

	Sample ID	Anthony	
Parameters	**Lab No**	**091**	**Method**
pH		10.20	1.2.5 (water)
Ec	dS/m	2.50	1.2.5 (water)
Nitrogen	%	1.35	Kjedhal
Organic Carbon	%	18.5	Walkley black
Organic matter	%	31.80	Calculated
Potassium	ppm	3250	Flame photometer
Phosphorus	ppm	720.2	calorimetric
Sodium	Ppm	600.0	Flame photometer
Calcium	Ppm	2350.0	Atomic absorption
Magnesium	Ppm	938.0	Atomic absorption
copper	Ppm	90.0	Atomic absorption
Manganese	Ppm	194	Atomic absorption
Zinc	Ppm	108	Atomic absorption
Iron	Ppm	620	Atomic absorption
Aluminum	Ppm	Trace	Atomic absorption
Sulphate-S	ppm	0.20	colorimetric
Specific density	g/cm3	2.01	

NAME: J Kimotho **Signature**........ **Date** 20/1/2020

SOIL /WATER LABORATORY

Dept. of Land Res. Mgt. & Agric. Tech. (LARMAT) University of Nairobi P. O. Box 29053 - 00625, NAIROBI - KENYA.

Appendix B Chemical Composition of CDA Sample

REPUBLIC OF KENYA

MINISTRY OF PETROLEUM AND MINING

STATE DEPARTMENT OF MINING

MADINI HOUSE
MACHAKOS ROAD
P.O. Box 30009-00100 GPO
NAIROBI

e-mail:cg@mining.go.ke
When replying please quote ref No & date

Ref. No.ORIGINAL CERT NO. 1851/20

Date…3rd August, 2020

ASSAY CERTIFICATE

SENDER'S NAME	**:**	**ANTHONY MUGENDI NYAGAH**
DATE	**:**	**24.07.2020**
SAMPLE TYPE	**:**	**COWDUNG ASH**
SAMPLE NO	**:**	**1851/20**
SENDER'S REF	**:**	**SAMPLE A**

RESULT

The sample was analyzed by XRF and gave the following chemical composition.

CHEMICAL COMPOSITION:

Silica as SiO_2…………………………	45.96%
Potassium as K_2O……………………	11.79%
Calcium as CaO…………………	11.85%
Aluminium as Al_2O_3………………	8.53%
Phosphorus as P_2O_5…………………	6.66%
Iron as Fe_2O_3………………………	5.52%
Magnesium as MgO……………………	5.17%
Chlorine as Cl………………………	1.97%
Sulphur as S……………………………	1.02%
Titanium as TiO…………………	0.55%
Manganese as MnO…………………	0.45%
Zinc as Zn…………………………	0.13%
Zirconium as Zr……………………………	0.12%
Copper as Cu………………………….	0.08%
Strontium as Sr…………………………	0.08%

EDWARD MWANGI
FOR: DIRECTOR OF GEOLOGICAL SURVEYS.

The results are based on test sample only.

FOR DIRECTOR OF GEOLOGICAL SURVEYS
03 AUG 2020
P. O. Box 30009-00100
NAIROBI

REPUBLIC OF KENYA

MINISTRY OF PETROLEUM AND MINING

STATE DEPARTMENT OF MINING

MADINI HOUSE
MACHAKOS ROAD
P.O. Box 30009-00100 GPO
NAIROBI

e-mail:cg@mining.go.ke
When replying please quote ref No & date

Ref. No.ORIGINAL CERT NO. 1852/20

Date…3rd August, 2020

ASSAY CERTIFICATE

SENDER'S NAME : ANTHONY MUGENDI NYAGAH
DATE : 24.07.2020
SAMPLE TYPE : COWDUNG ASH
SAMPLE NO : 1852/20
SENDER'S REF : SAMPLE B

RESULT

The sample was analyzed by XRF and gave the following chemical composition.

CHEMICAL COMPOSITION:

Silica as SiO_2	41.12%
Potassium as K_2O	15.83%
Calcium as CaO	11.58%
Phosphorus as P_2O_5	8.36%
Aluminium as Al_2O_3	7.17%
Magnesium as MgO	5.19%
Iron as Fe_2O_3	3.80%
Chlorine as Cl	3.65%
Sulphur as S	2.10%
Titanium as TiO	0.36%
Manganese as MnO	0.33%
Zinc as Zn	0.19%
Copper as Cu	0.09%
Zirconium as Zr	0.08%
Strontium as Sr	0.07%
Gold as Au	0.004%

EDWARD MWANGI
FOR: DIRECTOR OF GEOLOGICAL SURVEYS.

The results are based on test sample only.

FOR DIRECTOR OF GEOLOGICAL SURVEY
03 AUG 2020
P. O. Box 30009-00100
NAIROBI

Appendix B Specific Gravity for the Samples

Appendix B1 Specific Gravity for FCD Sample

University of Nairobi

Department of Civil & Construction Engineering

(Soil Mechanics Laboratory)

SPECIFIC GRAVITY

Student	*Anthony Mugendi Nyagah*				
Project	*Mechanical Stabilization of Lateritic Gravel Using FCD*				
Depth (m)		**Test pit ID:**		**Sample. No.**	
Test date:	27-Jul-20	**Sample Description:**			
Specification	According to BS 1377:1990 Part			**Location:**	

Sample Number							**Murram**	**FCD**		
Bottle Number							X	G		
Mass of empty bottle (W_1)							61.3	59.8		
Mass of bottle + Soil (W_2)							72.2	69.4		
Mass of bottle + Soil+ Water (W_3)							179.7	168.6		
Mass of bottle full of Water (W_4)							174.8	165.5		
Mass of Water used ($W_3 - W_2$)							107.5	99.2		
Mass of soil used ($W_2 - W_1$)							10.9	9.6		
Volume of Soil $(W_4 - W_1) - (W_3 - W_2)$							6	6.5		
Specific Gravity of Soil $GS = \frac{(W2 - W1)}{(W4 - W1) - (W3 - W2)}$							**1.817**	**1.477**		
Average Gs										

TECHNOLOGIST	**Mathew Mburu**	Verified :	**Elly Oyier**
Date	**27-Jul-20**		
Observations:			
Conform to the specifications			

Appendix B2 Specific Gravity for CDA Sample

University of Nairobi

Department of Civil & Construction Engineering

(Soil Mechanics Laboratory)

SPECIFIC GRAVITY

STUDENT	Anthony Mugendi Nyagah				
PROJECT	Chemical Stabilization of Lateritic Gravel using the CDA				
Depth (m)		Test pit ID:		Sample. No.	
Test date:	25-Sep-20	Sample Description:			
Specification	According to BS 1377:1990 Part			Location:	

Sample Number							CDA SAMPLE A	CDA SAMPLE B		
Bottle Number							C	B		
Mass of empty bottle (W_1)							64.6	65.3		
Mass of bottle + Soil (W_2)							76.8	75.4		
Mass of bottle + Soil+ Water (W_3)							184	184.5		
Mass of bottle full of Water (W_4)							177.4	179.1		
Mass of Water used ($W_3 - W_2$)							107.2	109.1		
Mass of soil used ($W_2 - W_1$)							12.2	10.1		
Volume of Soil ($W_4 - W_1$)- ($W_3 - W_2$)							5.6	4.7		
Specific Gravity of Soil $$GS = \frac{(W2 - W1)}{(W4 - W1) - (W3 - W2)}$$							**2.179**	**2.149**		
Average Gs							**2.164**			

TECHNOLOGIST	**Mathew Mburu**	Verified :	**Elly Oyier**
Date	**25-Sep-20**		
Observations:			
Conform to the specifications			

Appendix C NEAT Sample

Appendix C1 Compaction Properties (MDD & OMC)

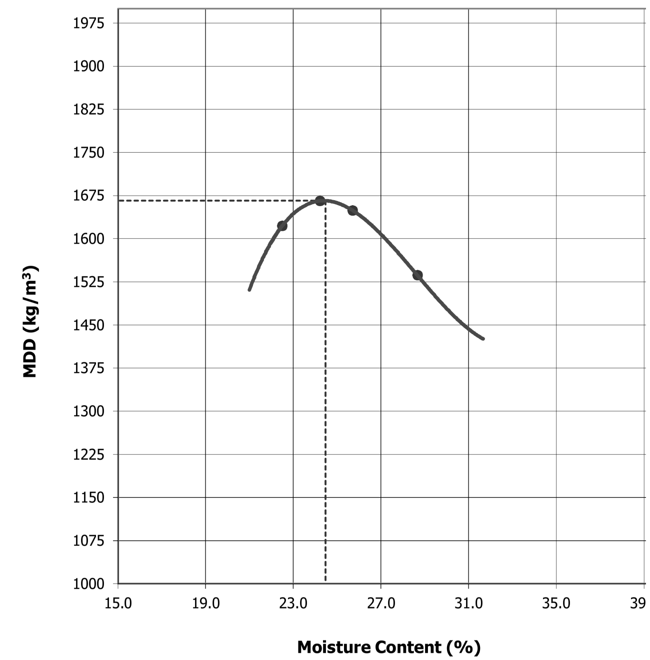
UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

Moisture - Density

Sample Type	**Lateritic Gravel**			
Sample source	**Membley Quarry, Kiambu County**			
Sample Date	**28-Nov-19**	**Sample No**	**NEAT**	**Depth**
Test date	**28-Nov-19**	**Sample Description**	**Lateritic Gravel**	
Specification	In accordance with BS 1377: 1990			

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**			
Test No	NMC	1	2	3	4		
Wt of mould + wet material (g)		6600	6678	6682	6590		
Wt wet material (g)		1900	1978	1982	1890		
Wet density (kg/m^3)		1987	2069	2073	1977		
Moisture content							
Container No	62	213	134	145	140		
Wt of container + wet material (g)	290.30	349.10	357.58	329.25	335.30		
Wt of container (g)	94.60	92.60	103.70	106.00	104.10		
Wt of container + dry material (g)	256.50	302.00	308.10	283.60	283.80		
Wt dry material (g)	161.90	209.40	204.40	177.60	179.70		
Wt of moisture (g)	33.80	47.10	49.48	45.65	51.50		
Moisture content (%)	20.88	22.49	24.21	25.70	28.66		
Dry density (kg/m^3)		1623	1666	1649	1537		



Optimum Moisture Content (%)	**24.47**
Maximum Dry Density (kg/m^3)	**1666**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	30-Nov-19		
Observations:			
Conform to the specifications			

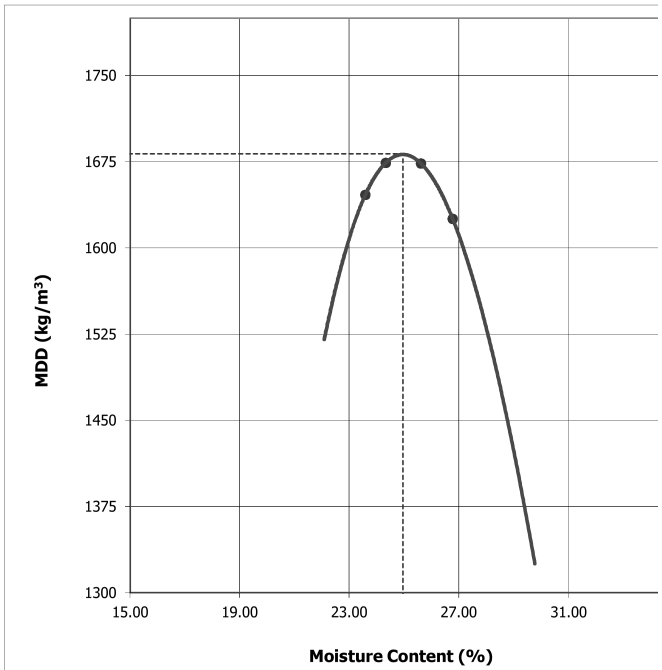
UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

Moisture - Density

Sample Type	**Lateritic Gravel**		
Sample source	**Membley Quarry, Kiambu County**		
Sample Date	**23-Sep-20**	**Sample No**	**Depth**
Test date	**23-Sep-20**	**Sample Description**	NEAT
Specification	In accordance with BS 1377: 1990		

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**			
Test No	NMC	1	2	3	4		
Wt of mould + wet material (g)		6645	6690	6710	6670		
Wt wet material (g)		1945	1990	2010	1970		
Wet density (kg/m³)		2035	2082	2103	2061		
Moisture content							
Container No	164	62	223	51	68		
Wt of container + wet material (g)	317.40	156.20	149.80	170.70	154.30		
Wt of container (g)	108.00	94.90	79.80	94.70	91.80		
Wt of container + dry material (g)	299.70	144.50	136.10	155.20	141.10		
Wt dry material (g)	191.70	49.60	56.30	60.50	49.30		
Wt of moisture (g)	17.70	11.70	13.70	15.50	13.20		
Moisture content (%)	9.23	23.59	24.33	25.62	26.77		
Dry density (kg/m³)		1646	1674	1674	1625		



Optimum Moisture Content (%)	**25.0**
Maximum Dry Density (kg/m³)	**1682**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	24-Sep-20		
Observations:			
Conform to the specifications			

Appendix C2 Strength Properties (UCS & CBR)

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

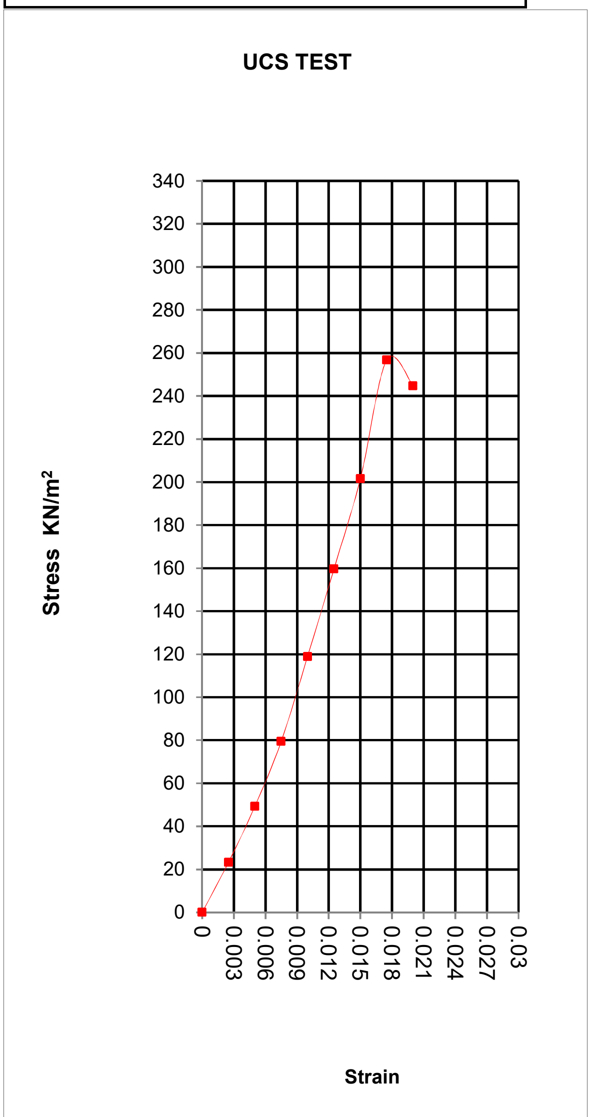
WORKING SHEET

UCS TEST

Project: Chemical Stabilization of Lateritic Gravel	**Date: 29-Sept-2019**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
Type	UNSTABILIZED	MDD	1682
Stabilizer	NEAT	OMC	25
%	0	NMC	9.2



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.42176	23
0.64	0.0050	0.995	0.01819	0.89624	49
0.95	0.0075	0.9925	0.01824	1.4498	79
1.27	0.0100	0.99	0.01828	2.1747	119
1.59	0.0125	0.9875	0.01833	2.92596	160
1.91	0.0150	0.9850	0.01838	3.70358	202
2.22	0.0175	0.9825	0.01842	4.73162	257
2.54	0.0200	0.9800	0.01847	4.52074	245

MOULDING MOISTURE CONTENT	
Tin No.	23A
Tin +Wet soil	196.4
Tin + Dry soil	167.2
Wt of Tin	27.3
Wt of Moisture	29.2
Wt. of dry soil	139.9
Moisture content	20.9

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		257 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew &Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

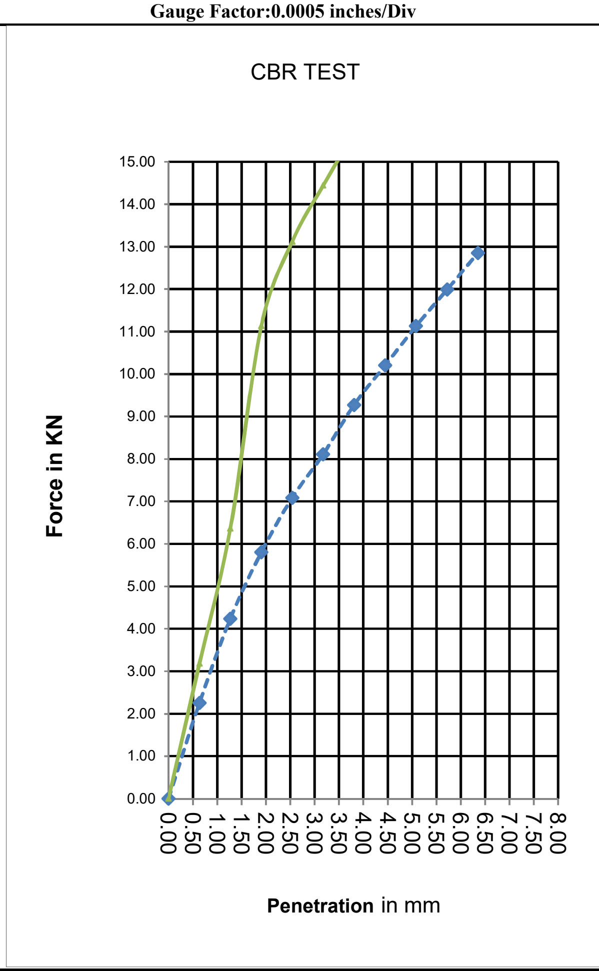
CBR TEST
(AASHTO T193:1990)

NEAT (Unsoaked)

Project: Stabilization of Lateritic Gravel		**Tested:** 27/07/2020	**Date soaked:**
Student.: Anthony Mugendi Nyagah		**Mould No.:**	**Date Moulded:** 27/07/2020

SWELL DATA			
Initial gauge Reading	**(div)**	0	
Final gauge Reading	**(div)**	18	
Difference	**(div)**	18	
Ring Factor		0.01	
Gauge Factor:0.0005 inches/Div			

SAMPLE DETAILS			
Type	~~Stabilized~~/unstabilized	MDD	1666
Stabilizer	Nil	OMC	24.47
%		NMC	9.2
Swell %	0.18		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	2.25253	3.18			
1.27	4.24006	6.3601			
1.91	5.80359	11.13			
2.54	7.08886	13.118	13.2	54	99
3.18	8.10912	14.443			
3.81	9.27514	15.635			
4.45	10.2027	16.523			
5.08	11.1302	17.358	20.0	56	87
5.72	11.9914	17.557			
6.35	12.8527	17.769			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	63
Tin +Wet soil	167.8
Tin + Dry soil	153.7
Wt of Tin	92.8
Wt of Moisture	14.1
Wt. of dry soil	75
Moisture content	18.80

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			99	54
5	20			87	56
		CBR = 99%		Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

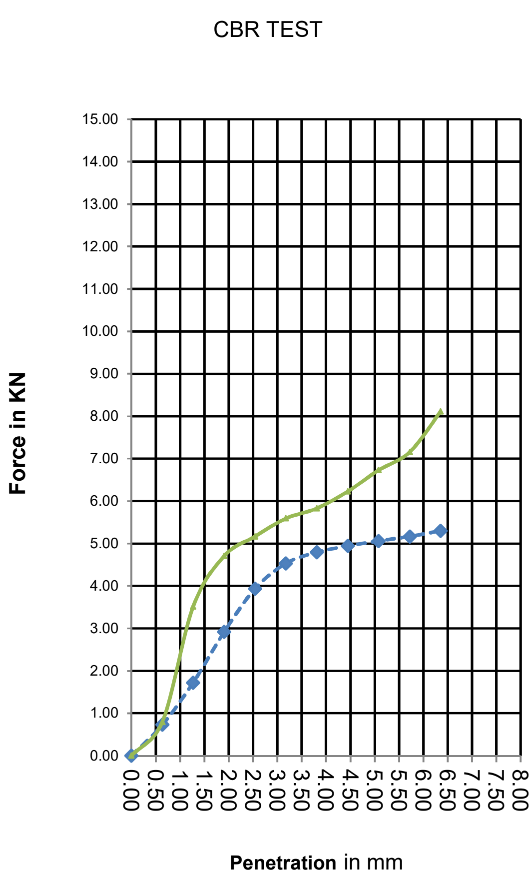
CBR TEST
(AASHTO T193:1990)

NEAT (Soaked)

Project: Stabilization of Lateritic Gravel	**Tested:** 03/12/2019	**Date soaked:**	29/11/2019
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	18
Difference	**(div)**	18
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	~~Stabilized~~/unstabilized	**MDD**	1666
Stabilizer	Nil	**OMC**	24.47
%		**NMC**	20.9
Swell %	0.18		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.72876	0.795			
1.27	1.72253	3.5113			
1.91	2.91504	4.7038			
2.54	3.93531	5.1676	13.2	30	39
3.18	4.53157	5.5916			
3.81	4.79657	5.8301			
4.45	4.94232	6.2276			
5.08	5.06158	6.7311	20.0	25	34
5.72	5.16758	7.1551			
6.35	5.30008	8.1091			

Moulding Data		
Wt.of Mould + Wet soil	**g**	
Wt. of Mould	**g**	
Moisture Content	**%**	
Wet Density	**Kg/m^3**	
Dry Density	**Kg/m^3**	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	208
Tin +Wet soil	214
Tin + Dry soil	187.2
Wt of Tin	78.7
Wt of Moisture	26.8
Wt. of dry soil	135.3
Moisture content	19.81

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		39	30
5	20		34	25
		CBR = 39%	**Checked:**	Martin Mburu

Appendix C3 Atterberg Limits

Plasticity Indices

PROJECT	Lateritic Gravel				
STUDENT	Anthony Mugendi Nyagah				
DEPTH		Sample No	NEAT	Sample time	
Test date	28-Nov-19	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		**32**	**8**	**10**	**17**	**K2**	**13**
Penetration (mm)		**15.1**	**17.3**	**19.9**	**22.2**		
Wt of Container + Wet Soil (g)		**54**	**63.2**	**76.1**	**87.3**	**16.9**	**16.9**
Wt of Container + Dry Soil (g)		**45**	**49.6**	**57.5**	**62.8**	**14.9**	**14.8**
Wt of Container (g)		**30**	**28.2**	**29.7**	**28.3**	**9.1**	**9**
Wt of Moistuer (g)		**9**	**13.6**	**18.6**	**24.5**	**2**	**2.1**
Wt of Dry Soil (g)		**15**	**21.4**	**27.8**	**34.5**	**5.8**	**5.8**
Moisture Content (%)		**60.00**	**63.55**	**66.91**	**71.01**	**34.48**	**36.21**

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	119
		No 2	140		**No 2**	119

$y = 27.938\ln(x) - 16.045$
$R^2 = 0.9908$

Liquid Limit	**67**
Plastic Limit	**35**
Plasticity Index	**32**
Linear Shrinkage (%)	**15**

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	30-Sep-20		
Observations:			

Conform to the specifications

Plasticity Indices

PROJECT	Lateritic Gravel				
STUDENT	Anthony Mugendi Nyagah				
DEPTH		Sample No	NEAT Sample B	Sample time	
Test date	24-Sep-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		1	9	24	41	T4	B
Penetration (mm)		15.5	17	20.4	22.5		
Wt of Container + Wet Soil (g)		54.7	65.6	76.7	89.6	14.8	14.8
Wt of Container + Dry Soil (g)		46	51.8	58.3	65.2	13.4	13.3
Wt of Container (g)		30.2	29.1	29.5	29.5	9.1	8.4
Wt of Moistuer (g)		8.7	13.8	18.4	24.4	1.4	1.5
Wt of Dry Soil (g)		15.8	22.7	28.8	35.7	4.3	4.9
Moisture Content (%)		55.06	60.79	63.89	68.35	32.56	30.61

Linear Shrinkage	Initial Length (mm)	No1	140	Final Length (mm)	No 1	119
		No 2	140		No 2	119

$y = 32.017\ln(x) - 31.651$
$R^2 = 0.9444$

Liquid Limit	64
Plastic Limit	32
Plasticity Index	32
Linear Shrinkage (%)	15

Technician	Mathew Mburu	Verified :	Elly Oyier
Date	28-Sep-20		
Observations:			

Conform to the specifications

Appendix C4 Grading

UNIVERSITY OF NAIROBI
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

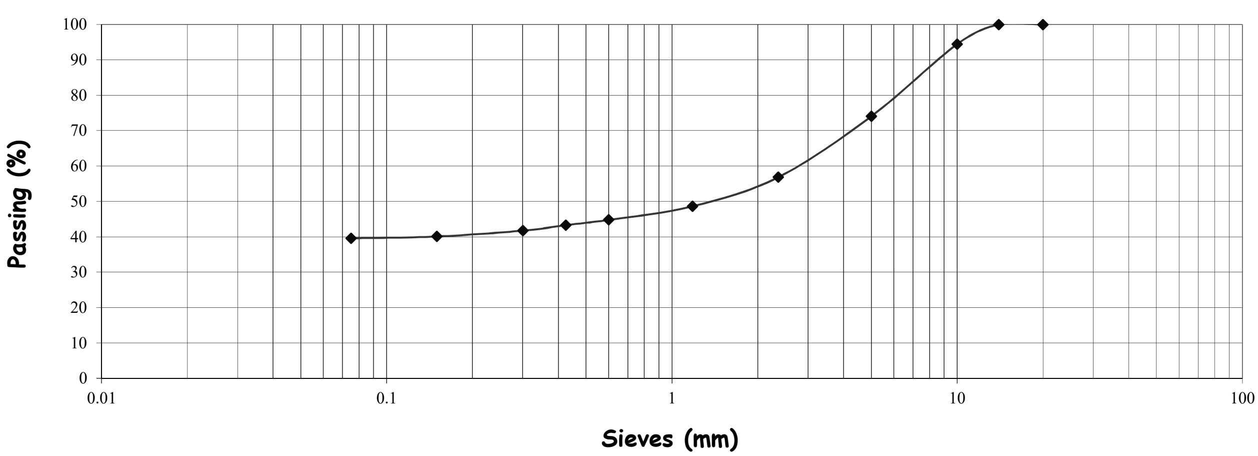
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley quarry, Kiambu County**				
Depth (m)		**SAMPLE No.**	**NEAT Sample A**	**Sr. No.**	
Test date:	27-Nov-19	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**Lateritic Gravel**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	79.2
Washed dry sample mass + pan	(gm)		Fine percent	(%)	39.6
Washed dry sample mass	(gm)	120.8	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria Min(%)	Acceptance Criteria Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	11.1	**5.6**	**94.5**		
5	40.8	**20.4**	**74.1**		
2.36	34.4	**17.2**	**56.9**		
1.18	16.5	**8.3**	**48.6**		
0.6	7.6	**3.8**	**44.8**		
0.425	3	**1.5**	**43.3**		
0.3	3.1	**1.6**	**41.8**		
0.15	3.3	**1.7**	**40.1**		
0.075	1	**0.5**	**39.6**		
	79.2	**39.6**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	mathew Mburu		**Verified :Lab. Incharge**	**Martin Mburu**	
Date					

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

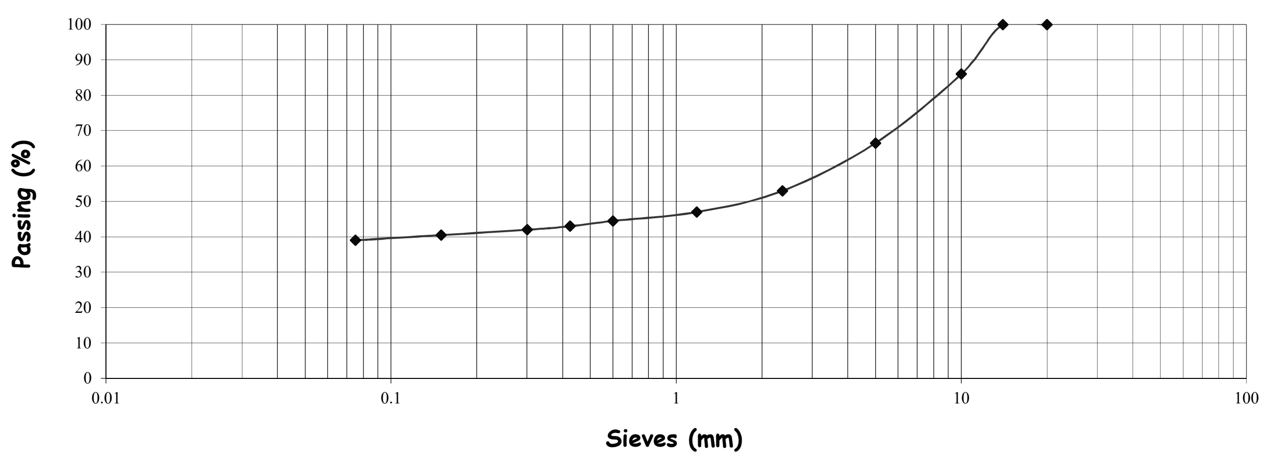
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley quarry, Kiambu County**				
Depth (m)		**SAMPLE No.**	**NEAT Sample B**	**Sr. No.**	
Test date:	25-Sep-20	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**Lateritic Gravel**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	78
Washed dry sample mass + pan	(gm)		Fine percent	(%)	39.0
Washed dry sample mass	(gm)	122	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria Min(%)	Acceptance Criteria Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	28	**14.0**	**86.0**		
5	39	**19.5**	**66.5**		
2.36	27	**13.5**	**53.0**		
1.18	12	**6.0**	**47.0**		
0.6	5	**2.5**	**44.5**		
0.425	3	**1.5**	**43.0**		
0.3	2	**1.0**	**42.0**		
0.15	3	**1.5**	**40.5**		
0.075	3	**1.5**	**39.0**		
	78	**39.0**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°	Scale N° :	
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Martin Mburu**		
Date					

Observations:

Conform to the specifications

NEAT Sample Summary Results

	Sample 1	Sample 2	Average Value
Compaction Results			
MDD	1666 kg/m^3	1682 kg/m^3	1674 kg/m^3
OMC	24.47%	25.0%	24.74%
Strength Properties			
UCS	257kN/m^2	257kN/m^2	257kN/m^2
CBR (Unsoaked)	99%	-	99%
CBR (Soaked)	39%	39%	39%
Atterberg Limits			
Liquid Limit (LL)	67	64	66
Plastic Limit (PL)	35	32	34
Plasticity Index (PI)	32	32	32
Linear Shrinkage	15	15	15
Grading			
	39.6	39	39.3

Appendix D FCD Stabilized Samples

Appendix D1 Compaction Properties (MDD & OMC)

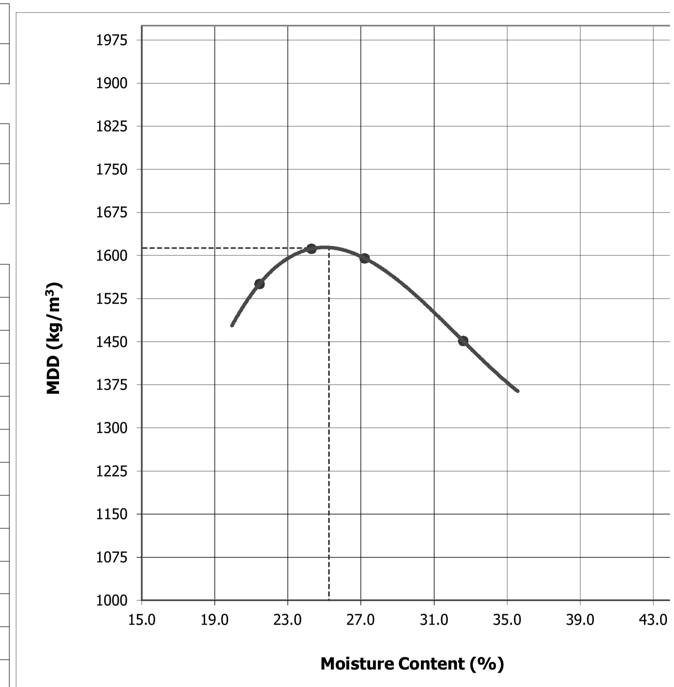
UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

Moisture - Density

Sample Type	**Mechanical Stabilization of Lateritic Gravel using FCD**		
Sample source	**Membley Quarry, Kiambu County & Upper Kabete Campus (Dairy farm) UON (FCD)**		
Sample Date	**03-Jan-20**	**Sample No**	**Depth**
Test date	**03-Jan-20**	**Sample Description**	**3% FCD**
Specification	In accordance with BS 1377: 1990		

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**			
Test No	NMC	1	2	3	4		
Wt of mould + wet material (g)		6500	6615	6640	6540		
Wt wet material (g)		1800	1915	1940	1840		
Wet density (kg/m^3)		1883	2003	2029	1925		
Moisture content							
Container No		50	107	53	223		
Wt of container + wet material (g)		282.70	276.80	263.00	255.70		
Wt of container (g)		92.40	95.10	91.80	79.50		
Wt of container + dry material (g)		249.10	241.30	226.40	212.40		
Wt dry material (g)		156.70	146.20	134.60	132.90		
Wt of moisture (g)		33.60	35.50	36.60	43.30		
Moisture content (%)		21.44	24.28	27.19	32.58		
Dry density (kg/m^3)		1550	1612	1595	1452		



Optimum Moisture Content (%)	**25.25**
Maximum Dry Density (kg/m^3)	**1613**

Technician	Mathew Mburu	Verified :	**Martin mburu**
Date	04-Jan-20		
Observations:			
Conform to the specifications			

UNIVERSITY OF NAIROBI
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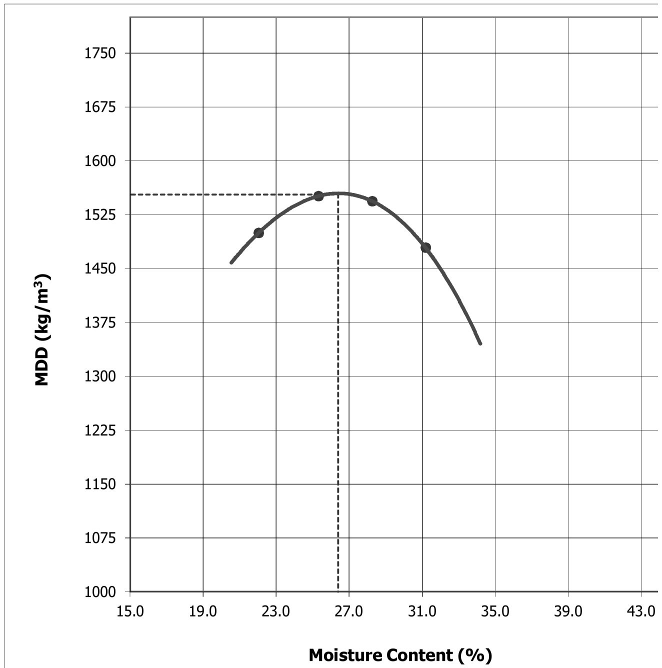
Moisture - Density

Sample Type	**Mechanical Stabilization of Lateritic Gravel using FCD**			
Sample source	**Membley Quarry, Kiambu County & Upper Kabete Campus (Dairy farm) UON (FCD)**			
Sample Date	**07-Jan-20**	**Sample No**	**Depth**	
hew	**07-Jan-20**	**Sample Description**	**6% FCD**	
Specification	In accordance with BS 1377: 1990			

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**			
Test No	NMC	1	2	3	4		
Wt of mould + wet material (g)		6450	6558	6593	6555		
Wt wet material (g)		1750	1858	1893	1855		
Wet density (kg/m^3)		1831	1944	1980	1940		
Moisture content							
Container No		181	213	198	222		
Wt of container + wet material (g)		212.00	295.00	211.50	211.20		
Wt of container (g)		79.70	92.50	84.90	79.10		
Wt of container + dry material (g)		188.10	254.10	183.60	179.80		
Wt dry material (g)		108.40	161.60	98.70	100.70		
Wt of moisture (g)		23.90	40.90	27.90	31.40		
Moisture content (%)		22.05	25.31	28.27	31.18		
Dry density (kg/m^3)		1500	1551	1544	1479		



Optimum Moisture Content (%)	**26.39**
Maximum Dry Density (kg/m^3)	**1553**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	08-Jan-20		
Observations:			
Conform to the specifications			

UNIVERSITY OF NAIROBI

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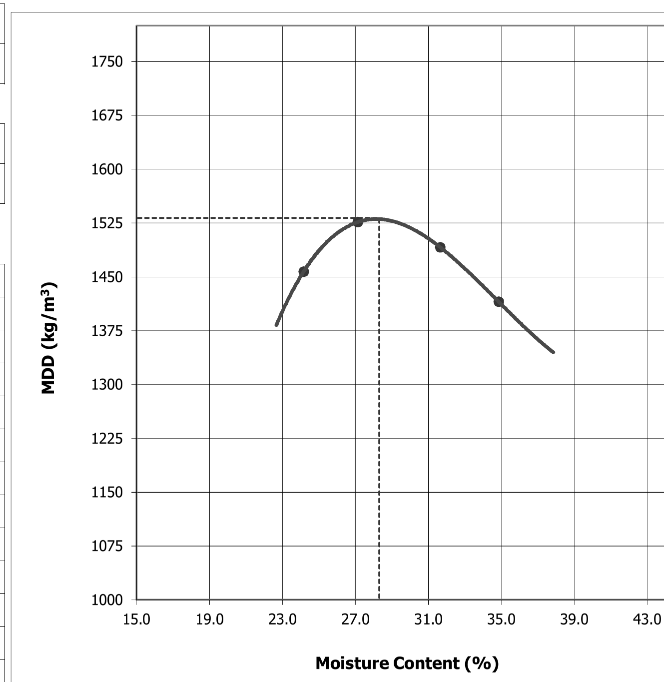
Moisture - Density

Sample Type	**Mechanical Stabilization of Lateritic Gravel using FCD**		
Sample source	**Membley Quarry, Kiambu County & Upper Kabete (Dairy farm) UON (FCD)**		
Sample Date	**07-Jan-20**	**Sample No**	**Depth**
Test date	**07-Jan-20**	**Sample Description**	**9% FCD**
Specification	In accordance with BS 1377: 1990		

Wt of Mould (g)	**4700**	**Volume of Mould (l)**	**0.956**				
Test No	NMC	1	2	3	4		
Wt of mould + wet material (g)		6430	6555	6577	6525		
Wt wet material (g)		1730	1855	1877	1825		
Wet density (kg/m^3)		1810	1940	1963	1909		
Moisture content							
Container No		50	58	61	68		
Wt of container + wet material (g)		264.20	271.80	278.80	250.40		
Wt of container (g)		92.60	93.70	93.70	92.50		
Wt of container + dry material (g)		230.80	233.80	234.30	209.60		
Wt dry material (g)		138.20	140.10	140.60	117.10		
Wt of moisture (g)		33.40	38.00	44.50	40.80		
Moisture content (%)		24.17	27.12	31.65	34.84		
Dry density (kg/m^3)		1457	1526	1491	1416		



Optimum Moisture Content (%)	**28.31**
Maximum Dry Density (kg/m^3)	**1532**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	08-Jan-20		
Observations:			
Conform to the specifications			

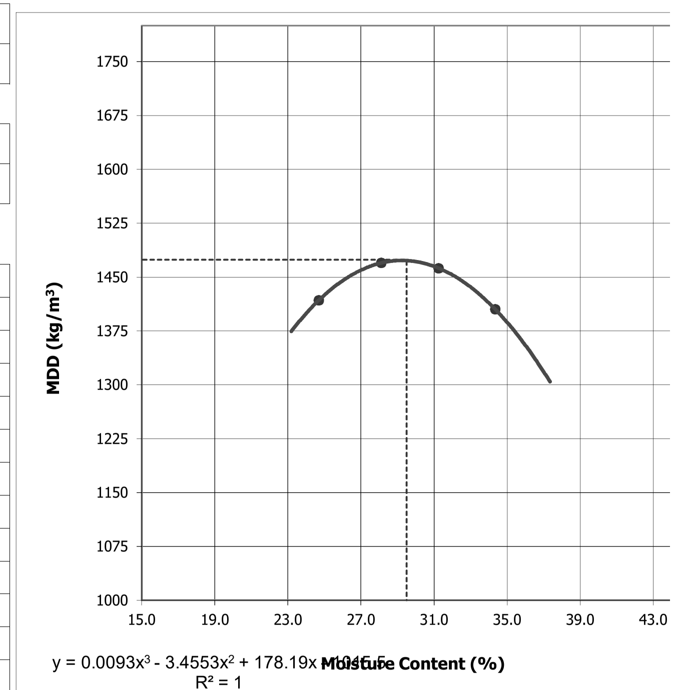
UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

Moisture - Density

Sample Type	**Mechanical Stabilization of Lateritic Gravel using FCD**		
Sample source	**Membley Quarry, Kiambu County & Upper Kabete Campus (Dairy farm) UON (FCD)**		
Sample Date	**07-Jan-20**	**Sample No**	**Depth**
Test date	**07-Jan-20**	**Sample Description**	**12% FCD**
Specification	In accordance with BS 1377: 1990		

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**			
Test No	NMC	1	2	3	4		
Wt of mould + wet material (g)		6390	6500	6535	6505		
Wt wet material (g)		1690	1800	1835	1805		
Wet density (kg/m^3)		1768	1883	1919	1888		
Moisture content							
Container No		223	208	63	216		
Wt of container + wet material (g)		211.40	209.60	250.00	198.40		
Wt of container (g)		79.60	78.80	92.90	79.10		
Wt of container + dry material (g)		185.30	180.90	212.60	167.90		
Wt dry material (g)		105.70	102.10	119.70	88.80		
Wt of moisture (g)		26.10	28.70	37.40	30.50		
Moisture content (%)		24.69	28.11	31.24	34.35		
Dry density (kg/m^3)		1418	1470	1463	1405		



Optimum Moisture Content (%)	**29.5**
Maximum Dry Density (kg/m^3)	**1474**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	08-Jan-20		
Observations:			
Conform to the specifications			

Appendix D2 Strength Properties (UCS)

UNIVERSITY OF NAIROBI

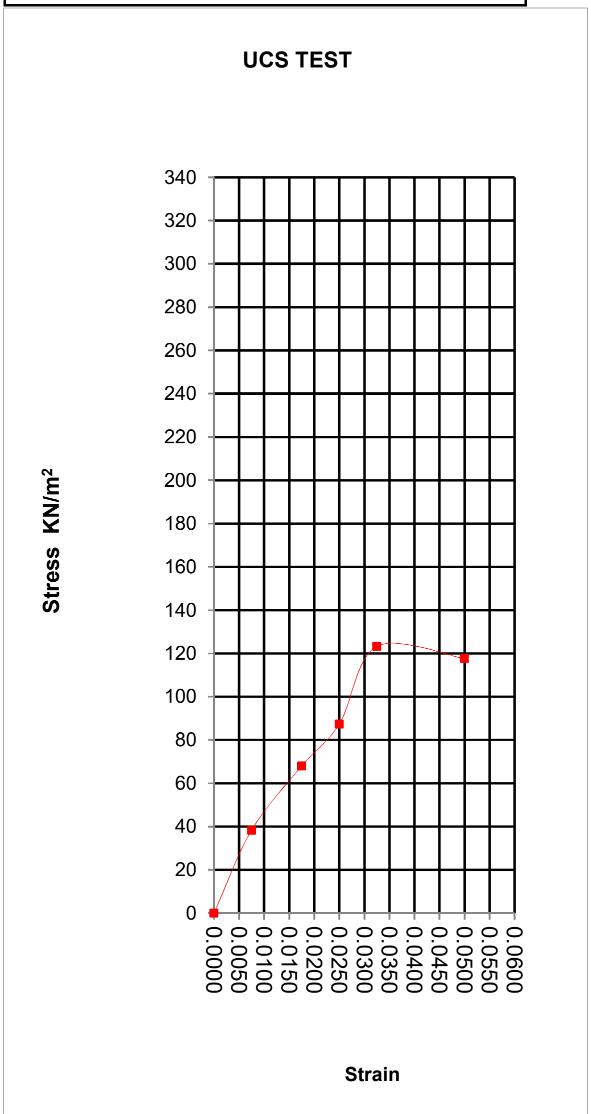
(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

SPECIMEN 1

Project: Mechanical Stabilization of Lateritic Gravel	**Date:17-Jan-2020**	**No. of days cured:**	0		
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0		
DATA		**SAMPLE DETAILS**		**MDD**	1613
Do =152mm		**Type**	**STABILIZED**	**OMC**	25.25
Lo mm	127	**Stabilizer**	**3% FCD**	**NMC**	9.2
Ao =(152x152x3.14)/4 m^2	0.0181	**%**	0		
Volume = AoLo m^3	0.00275				
Stabilizer = NON					



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	0.69854	38
2.22	0.0175	0.9825	0.01842	1.2521	68
3.18	0.0250	0.975	0.01856	1.62114	87
4.13	0.0325	0.9675	0.01871	2.3065	123
6.35	0.0500	0.95	0.01905	2.2406	118
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	249.8
Tin + Dry soil	217
Wt of Tin	93.6
Wt of Moisture	32.8
Wt. of dry soil	123.4
Moisture content	26.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		123 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

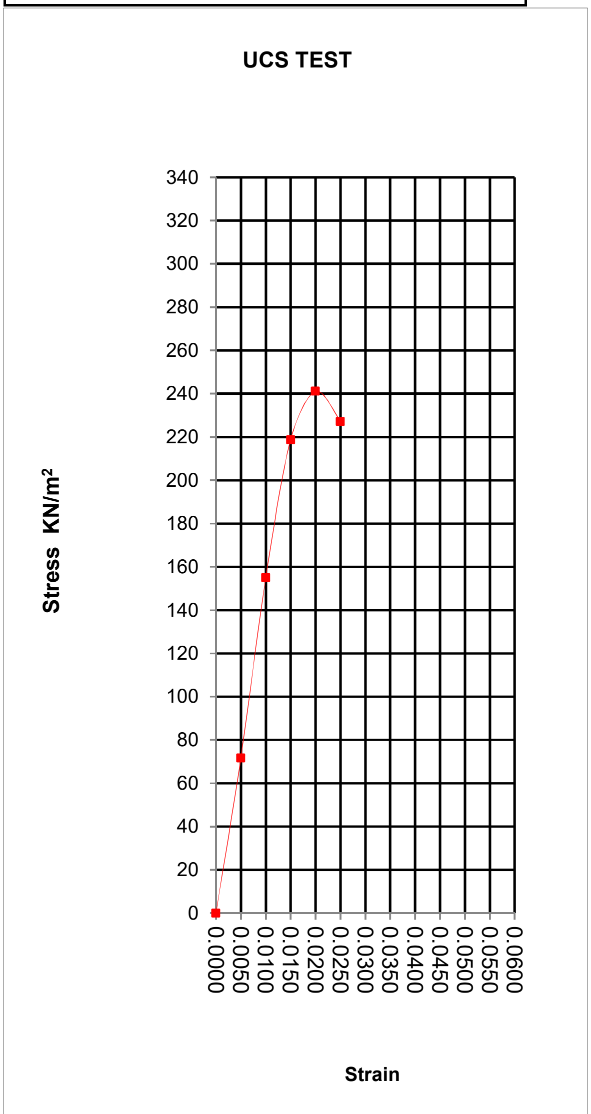
SPECIMEN 2

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 17-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1613
Type	STABILIZED	OMC	25.25
Stabilizer	3% FCD	NMC	9.2
%	0		

Defl. (mm)	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.64	0.0050	0.995	0.01819	1.30482	72
1.27	0.0100	0.99	0.01828	2.8337	155
1.91	0.0150	0.985	0.01838	4.0199	219
2.54	0.0200	0.98	0.01847	4.45484	241
3.18	0.0250	0.975	0.01856	4.2176	227
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0



MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	249.8
Tin + Dry soil	217
Wt of Tin	93.6
Wt of Moisture	32.8
Wt. of dry soil	123.4
Moisture content	26.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		241 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

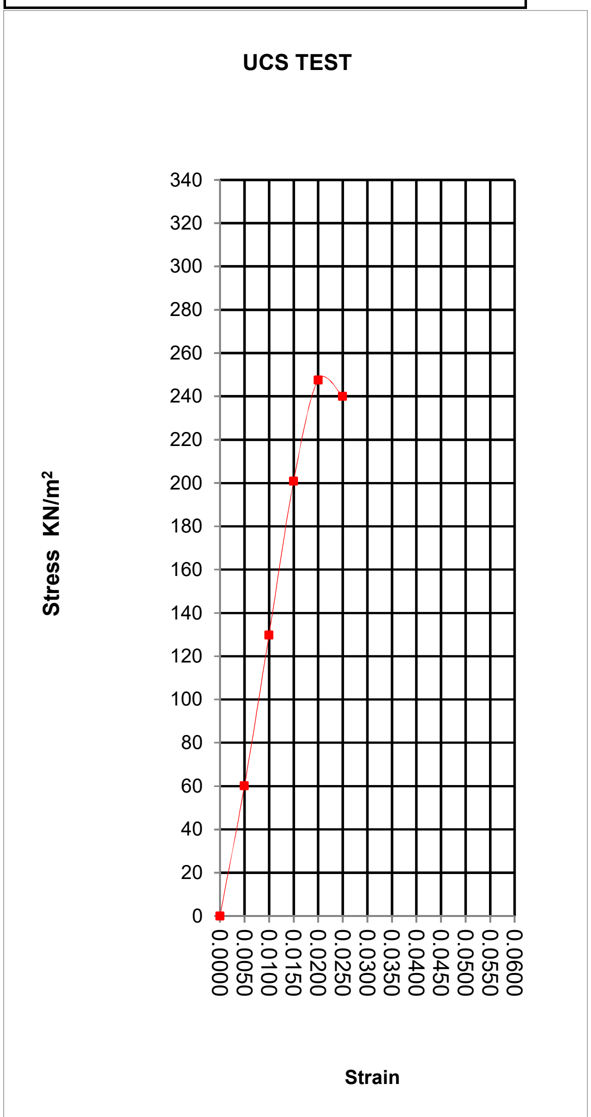
SPECIMEN 3

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 17-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA		
Do =152mm		
Lo	mm	127
Ao =(152x152x3.14)/4	m^2	0.0181
Volume = AoLo	m^3	0.00275
Stabilizer = NON		

SAMPLE DETAILS			
		MDD	1613
Type	**STABILIZED**	**OMC**	25.25
Stabilizer	**3% FCD**	**NMC**	9.2
%	**0**		

Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.64	0.0050	0.995	0.01819	1.09394	60
1.27	0.0100	0.99	0.01828	2.3724	130
1.91	0.0150	0.985	0.01838	3.6904	201
2.54	0.0200	0.98	0.01847	4.57346	248
3.18	0.0250	0.975	0.01856	4.45484	240
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0



MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	249.8
Tin + Dry soil	217
Wt of Tin	93.6
Wt of Moisture	32.8
Wt. of dry soil	123.4
Moisture content	26.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		248 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

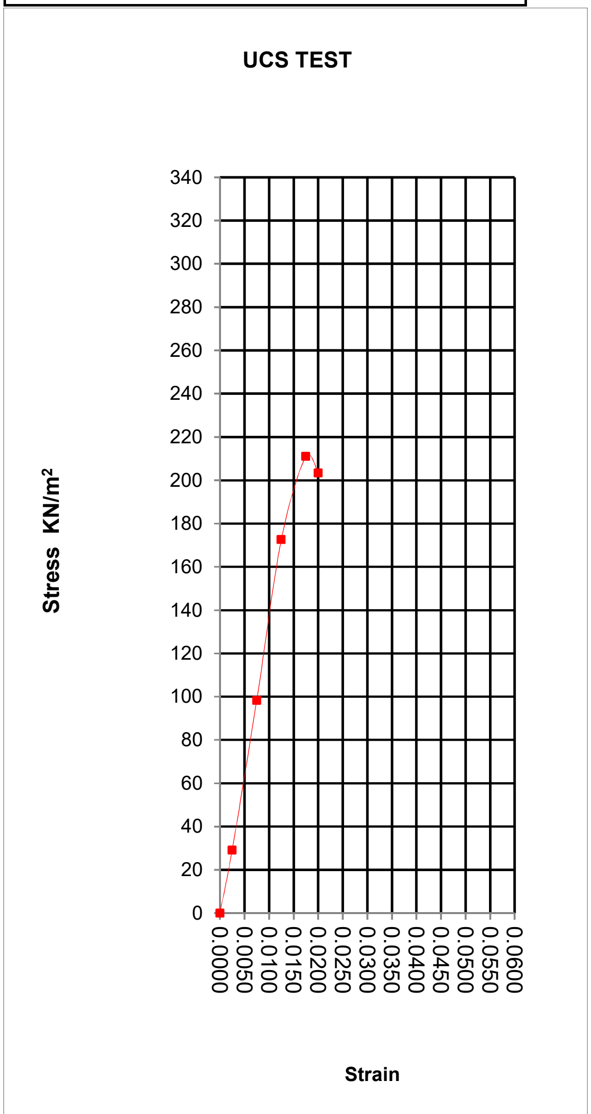
SPECIMEN 4

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 17-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1613
Type	**STABILIZED**	**OMC**	25.25
Stabilizer	**3% FCD**	**NMC**	9.2
%	**0**		

Defl. mm	**Deflection** E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.5272	29
0.95	0.0075	0.9925	0.01824	1.79248	98
1.59	0.0125	0.9875	0.01833	3.1632	173
2.22	0.0175	0.9825	0.01842	3.8881	211
2.54	0.0200	0.98	0.01847	3.7563	203
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0



MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	249.8
Tin + Dry soil	217
Wt of Tin	93.6
Wt of Moisture	32.8
Wt. of dry soil	123.4
Moisture content	26.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		211 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

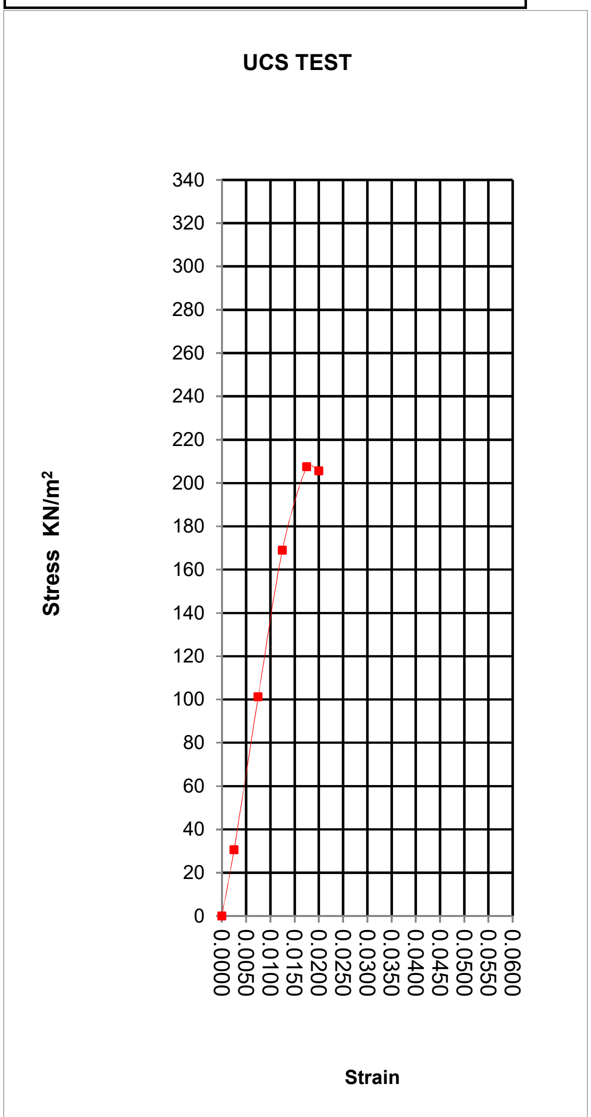
UCS TEST

SPECIMEN 5

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 17-Jan-2020**	**No. of days cured:**	0	
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0	

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1613
Type	STABILIZED	OMC	25.25
Stabilizer	3% FCD	NMC	9.2
%	0		



Defl. (mm)	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.55356	31
0.95	0.0075	0.9925	0.01824	1.8452	101
1.59	0.0125	0.9875	0.01833	3.0973	169
2.22	0.0175	0.9825	0.01842	3.8222	207
2.54	0.0200	0.98	0.01847	3.79584	206
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	249.8
Tin + Dry soil	217
Wt of Tin	93.6
Wt of Moisture	32.8
Wt. of dry soil	123.4
Moisture content	26.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		207 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

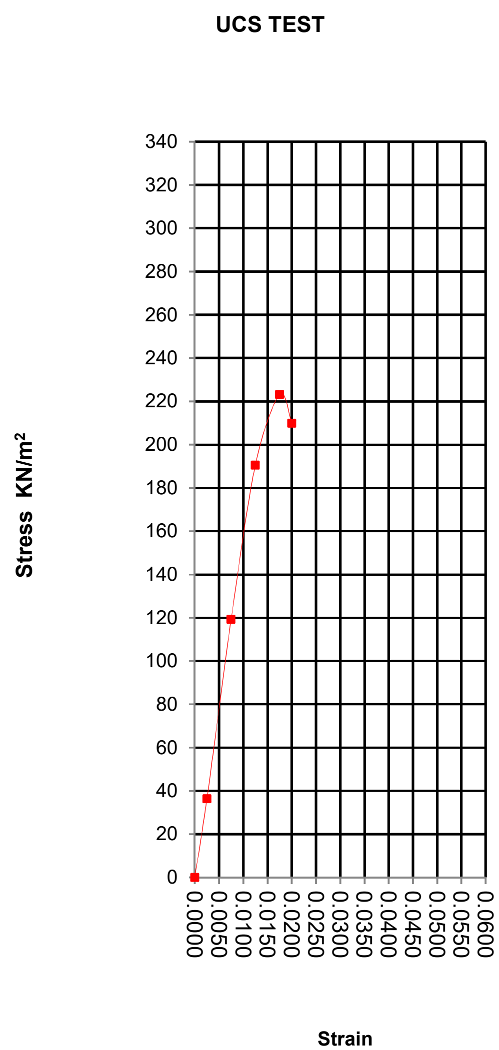
UCS TEST

SPECIMEN 6

Project: Mechanical Stabilization of Lateritic Gravel		**Date: 17-Jan-2020**	**No. of days cured:**	0
Client: Anthony Mugendi Nyagah		**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1613
Type	STABILIZED	OMC	25.25
Stabilizer	3% FCD	NMC	9.2
%	0		



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.659	36
0.95	0.0075	0.9925	0.01824	2.1747	119
1.59	0.0125	0.9875	0.01833	3.4927	191
2.22	0.0175	0.9825	0.01842	4.11216	223
2.54	0.0200	0.98	0.01847	3.87492	210
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	249.8
Tin + Dry soil	217
Wt of Tin	93.6
Wt of Moisture	32.8
Wt. of dry soil	123.4
Moisture content	26.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		223 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Mburu | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

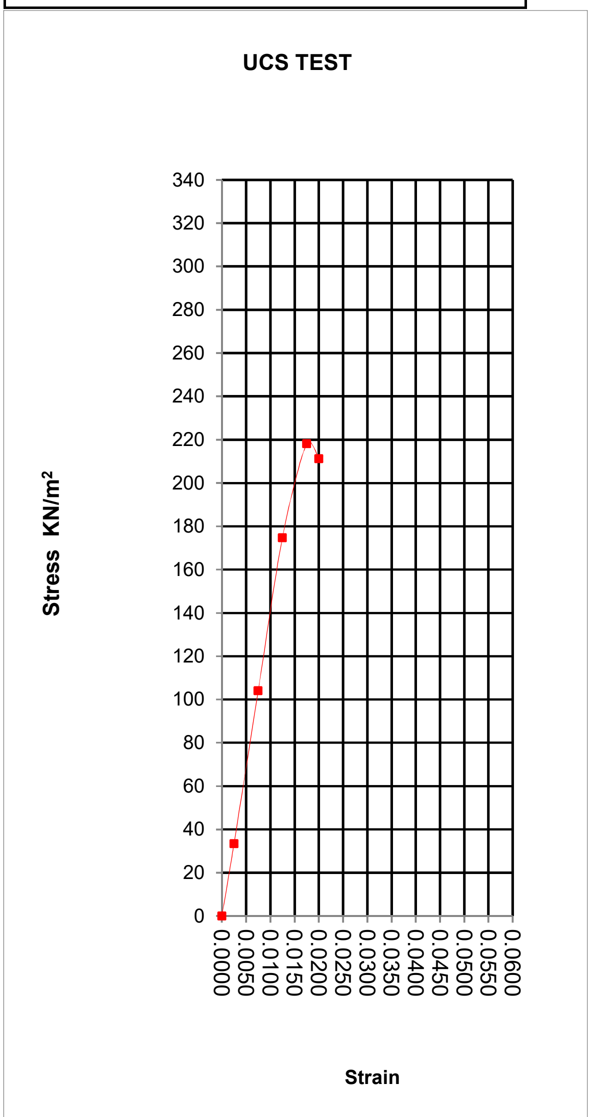
UCS TEST

SPECIMEN 7

Project: Mechanical Stabilization of lateritic Gravel	**Date: 17-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1613
Type	**STABILIZED**	**OMC**	25.25
Stabilizer	**3% FCD**	**NMC**	9.2
%	**0**		



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.60628	33
0.95	0.0075	0.9925	0.01824	1.89792	104
1.59	0.0125	0.9875	0.01833	3.20274	175
2.22	0.0175	0.9825	0.01842	4.0199	218
2.54	0.0200	0.98	0.01847	3.90128	211
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	249.8
Tin + Dry soil	217
Wt of Tin	93.6
Wt of Moisture	32.8
Wt. of dry soil	123.4
Moisture content	26.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		218 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

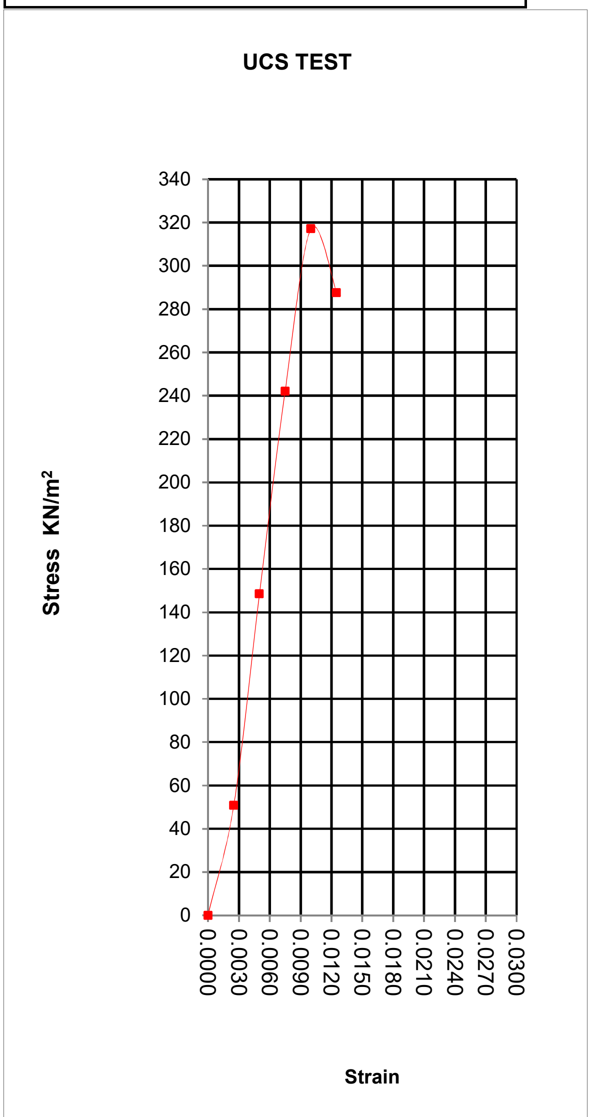
UCS TEST

SPECIMEN 1

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 06-Jan-2020**	**No. of days cured:**	0	
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0	

DATA				
Do =152mm				
Lo mm	127			
Ao =(152x152x3.14)/4 m^2	0.0181			
Volume = AoLo m^3	0.00275			
Stabilizer = NON				

SAMPLE DETAILS			
		MDD	1553
Type	**STABILIZED**	**OMC**	26.39
Stabilizer	**6% FCD**	**NMC**	9.2
%	**0**		



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.9226	51
0.64	0.0050	0.995	0.01819	2.7019	149
0.95	0.0075	0.9925	0.01824	4.4153	242
1.27	0.0100	0.99	0.01828	5.7992	317
1.59	0.0125	0.9875	0.01833	5.272	288
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	257
Tin + Dry soil	219.3
Wt of Tin	93.6
Wt of Moisture	37.7
Wt. of dry soil	125.7
Moisture content	30.0

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		317 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

SPECIMEN 2

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 06-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

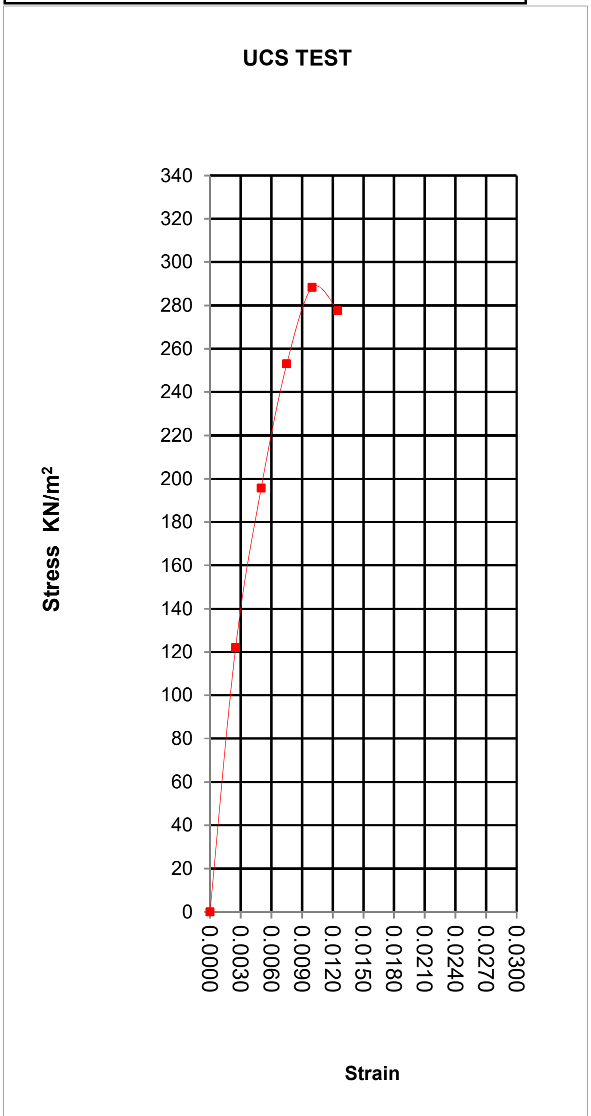
DATA

Do =152mm		
Lo	**mm**	127
Ao =(152x152x3.14)/4	**m^2**	0.0181
Volume = AoLo	**m^3**	0.00275
Stabilizer = NON		

SAMPLE DETAILS

Type	**STABILIZED**	**MDD**	1553
Stabilizer	**6% FCD**	**OMC**	26.39
%	**0**	**NMC**	9.2

Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	2.21424	122
0.64	0.0050	0.995	0.01819	3.5586	196
0.95	0.0075	0.9925	0.01824	4.613	253
1.27	0.0100	0.99	0.01828	5.272	288
1.59	0.0125	0.9875	0.01833	5.08748	278
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0



MOULDING MOISTURE CONTENT

Tin No.	61
Tin +Wet soil	257
Tin + Dry soil	219.3
Wt of Tin	93.6
Wt of Moisture	37.7
Wt. of dry soil	125.7
Moisture content	30.0

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		288 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

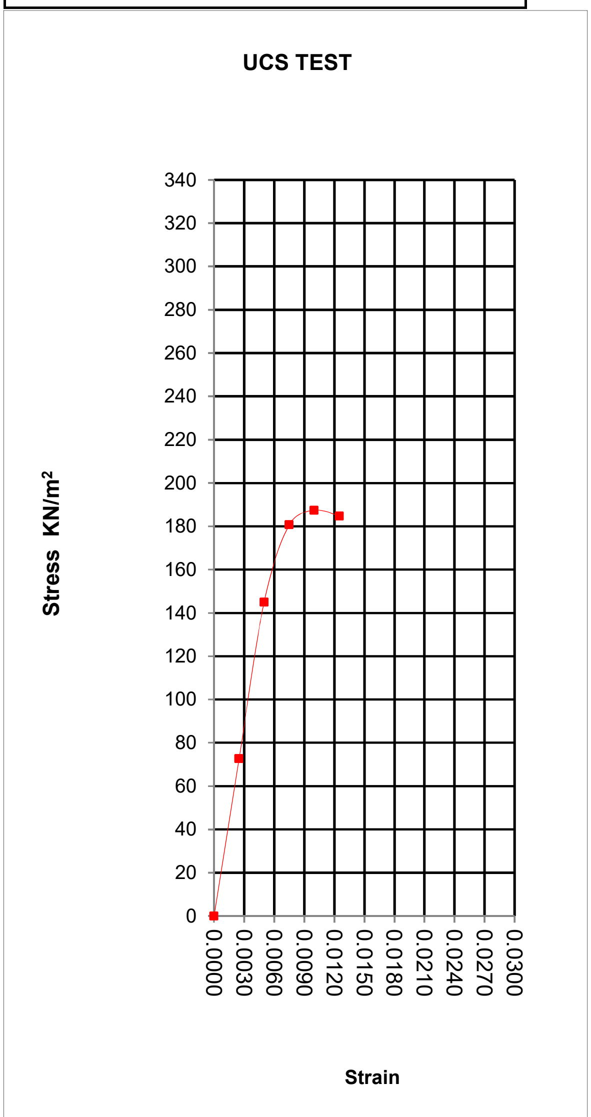
UCS TEST

SPECIMEN 3

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 06-Jan-2020**	**No. of days cured:**	0	
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0	

DATA			SAMPLE DETAILS		
Do =152mm				**MDD**	1553
Lo mm	127	**Type**	**STABILIZED**	**OMC**	26.39
Ao =(152x152x3.14)/4 m^2	0.0181	**Stabilizer**	**6% FCD**	**NMC**	9.2
Volume = AoLo m^3	0.00275	**%**	**0**		
Stabilizer = NON					

Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.318	73
0.64	0.0050	0.995	0.01819	2.636	145
0.95	0.0075	0.9925	0.01824	3.295	181
1.27	0.0100	0.99	0.01828	3.4268	187
1.59	0.0125	0.9875	0.01833	3.38726	185
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0



MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	257
Tin + Dry soil	219.3
Wt of Tin	93.6
Wt of Moisture	37.7
Wt. of dry soil	125.7
Moisture content	30.0

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		**187 KN/m^2**
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

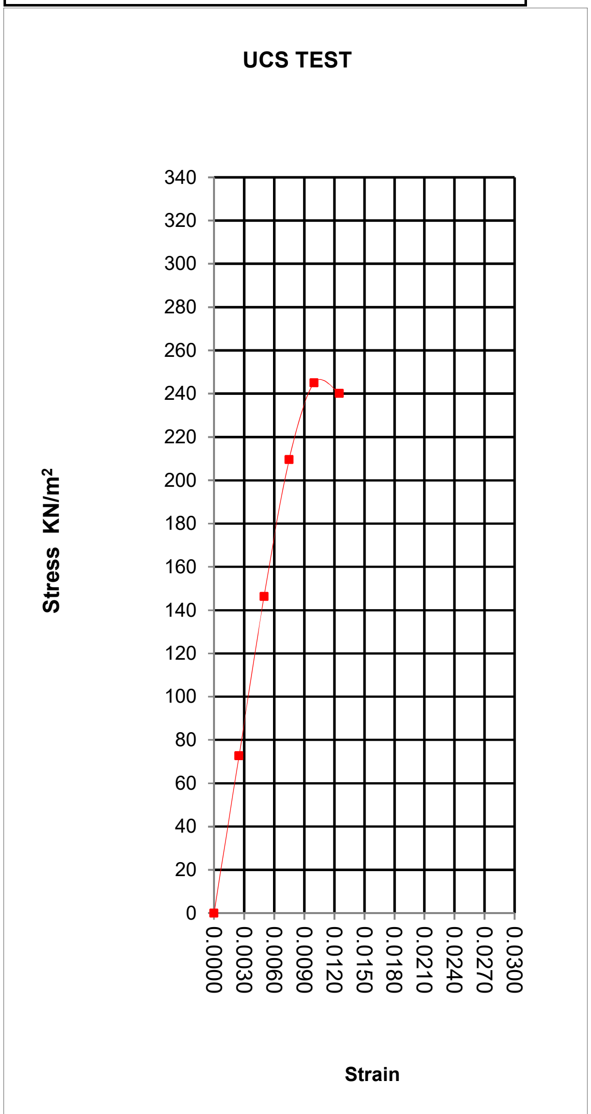
WORKING SHEET

UCS TEST

SPECIMEN 4

Project: Mechanical Stabilization of Lateritic Gravel		**Date: 06-Jan-2020**	**No. of days cured:**	0	
Student: Anthony Mugendi Nyagah		**Mould No.:**	**No. of days soaked:**	0	

DATA		SAMPLE DETAILS			
Do =152mm				**MDD**	1553
Lo mm	127	**Type**	**STABILIZED**	**OMC**	26.39
Ao =(152x152x3.14)/4 m^2	0.0181	**Stabilizer**	**3% FCD**	**NMC**	9.2
Volume = AoLo m^3	0.00275	**%**	0		
Stabilizer = NON					



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.318	73
0.64	0.0050	0.995	0.01819	2.66236	146
0.95	0.0075	0.9925	0.01824	3.8222	210
1.27	0.0100	0.99	0.01828	4.4812	245
1.59	0.0125	0.9875	0.01833	4.40212	240
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	257
Tin + Dry soil	219.3
Wt of Tin	93.6
Wt of Moisture	37.7
Wt. of dry soil	125.7
Moisture content	30.0

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		245 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

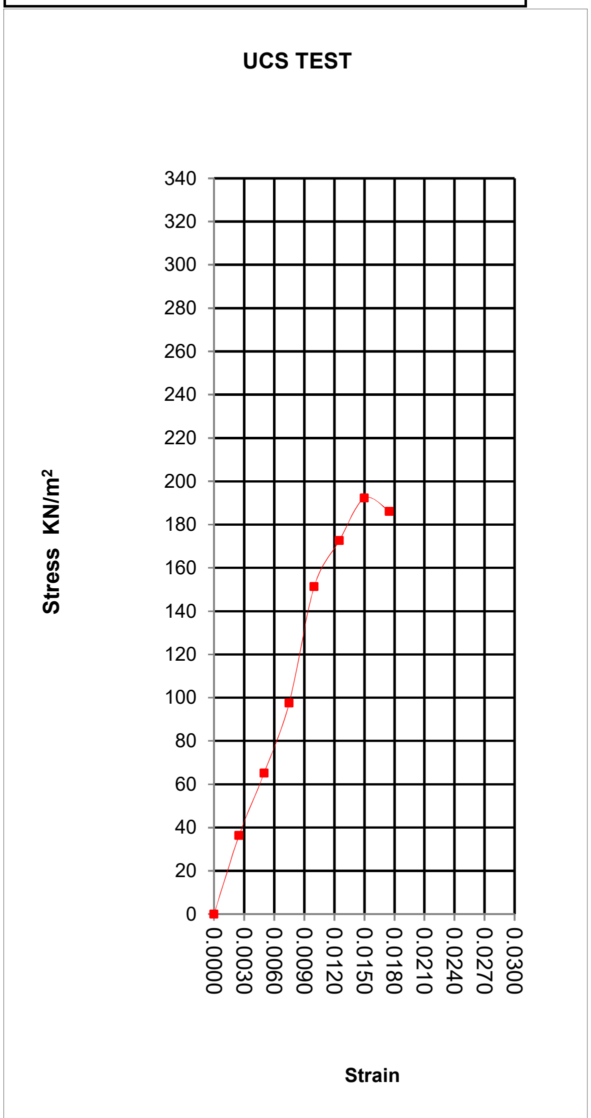
UCS TEST

SPECIMEN 5

Project: Mechanical Stabilization of lateritic Gravel		**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1553
Stabilizer	6% FCD	OMC	26.39
%	0	NMC	9.2



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.659	36
0.64	0.0050	0.995	0.01819	1.1862	65
0.95	0.0075	0.9925	0.01824	1.7793	98
1.27	0.0100	0.99	0.01828	2.7678	151
1.59	0.0125	0.9875	0.01833	3.1632	173
1.91	0.0150	0.9850	0.01838	3.53224	192
2.22	0.0175	0.9825	0.01842	3.4268	186
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	257
Tin + Dry soil	219.3
Wt of Tin	93.6
Wt of Moisture	37.7
Wt. of dry soil	125.7
Moisture content	30.0

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		192 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

SPECIMEN 6

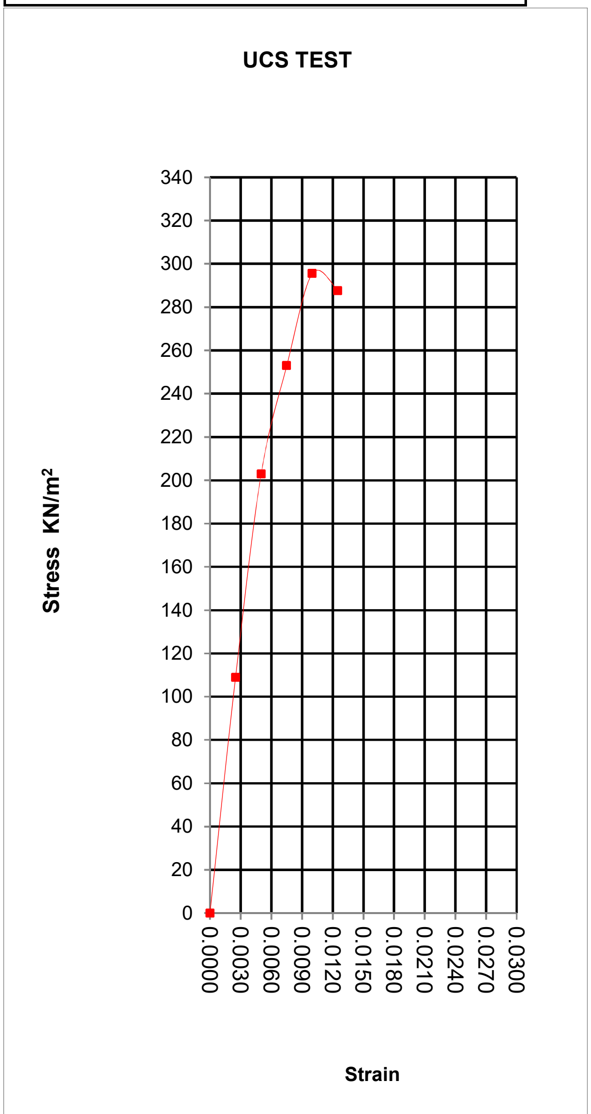
Project: Mechanical Stabilization of Lateritic Gravel	**Date: 06-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA

Do =152mm		
Lo	mm	127
Ao =(152x152x3.14)/4	m^2	0.0181
Volume = AoLo	m^3	0.00275
Stabilizer = NON		

SAMPLE DETAILS

Type	STABILIZED	MDD	1553
Stabilizer	6% FCD	OMC	26.39
%	0	NMC	9.2



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.977	109
0.64	0.0050	0.995	0.01819	3.6904	203
0.95	0.0075	0.9925	0.01824	4.613	253
1.27	0.0100	0.99	0.01828	5.4038	296
1.59	0.0125	0.9875	0.01833	5.272	288
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT

Tin No.	61
Tin +Wet soil	257
Tin + Dry soil	219.3
Wt of Tin	93.6
Wt of Moisture	37.7
Wt. of dry soil	125.7
Moisture content	30.0

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		296 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

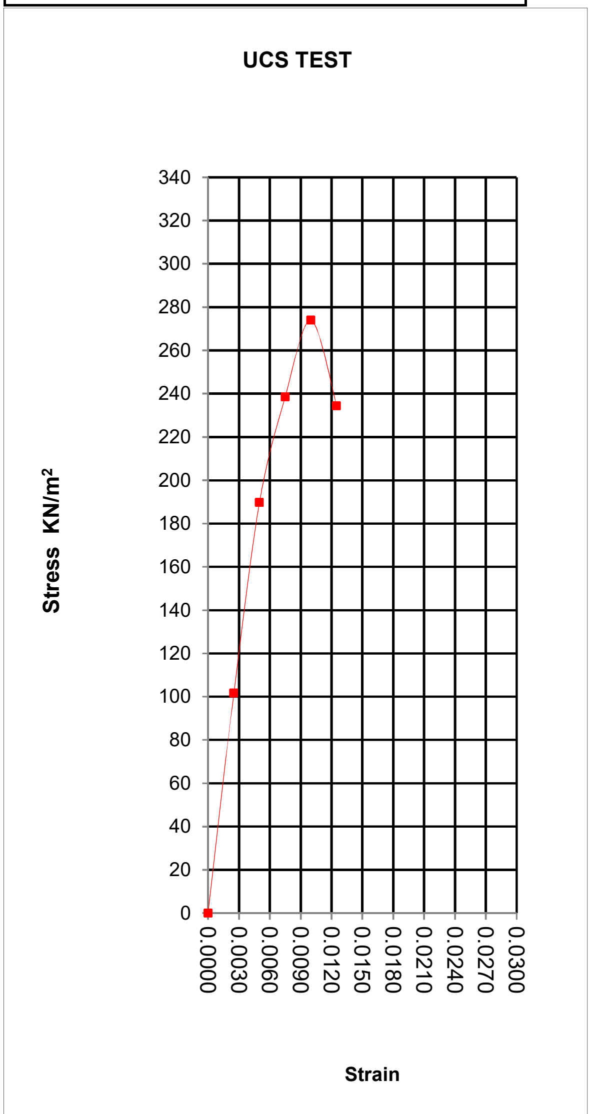
SPECIMEN 7

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 06-Jan-2020**	**No. of days cured:**	0
Client: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA			
Do =152mm			
Lo	mm	127	
Ao =(152x152x3.14)/4	m^2	0.0181	
Volume = AoLo	m^3	0.00275	
Stabilizer = NON			

SAMPLE DETAILS			
Type	STABILIZED	MDD	1553
Stabilizer	6% FCD	OMC	26.39
%	0	NMC	9.2

Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.8452	102
0.64	0.0050	0.995	0.01819	3.45316	190
0.95	0.0075	0.9925	0.01824	4.3494	238
1.27	0.0100	0.99	0.01828	5.0084	274
1.59	0.0125	0.9875	0.01833	4.29668	234
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0



MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	257
Tin + Dry soil	219.3
Wt of Tin	93.6
Wt of Moisture	37.7
Wt. of dry soil	125.7
Moisture content	30.0

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		274 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

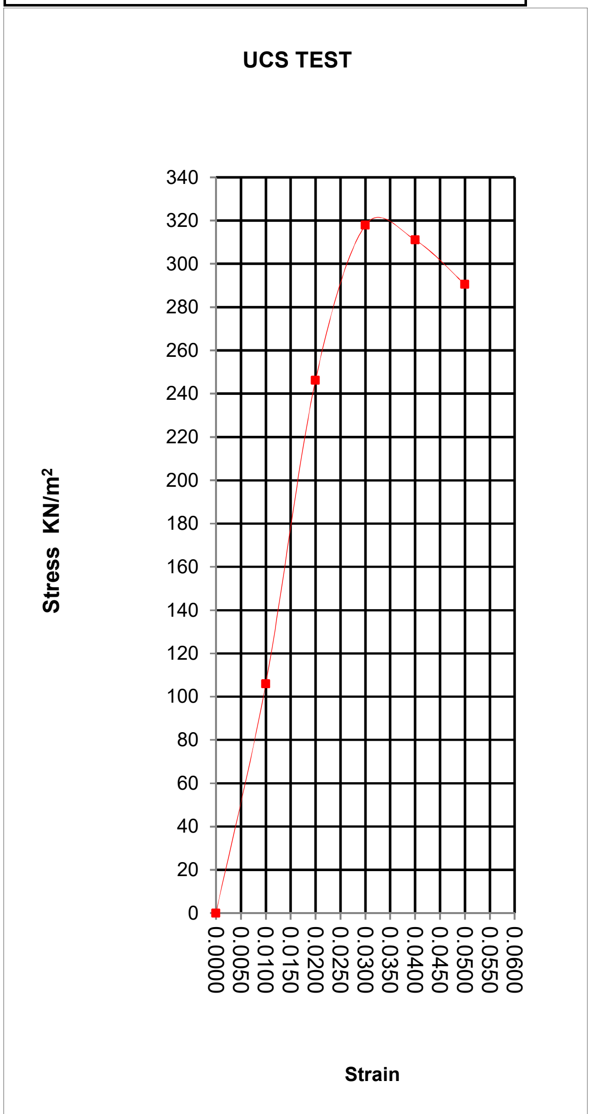
WORKING SHEET

UCS TEST

SPECIMEN 1

Project: Mechanical Stabilization of Lateritic Gravel		**Date: 22-Jan-2020**	**No. of days cured:**	0	
Student: Anthony Mugendi Nyagah		**Mould No.:**	**No. of days soaked:**	0	

DATA			SAMPLE DETAILS		
Do =152mm				MDD	1532
Lo mm	127	Type	STABILIZED	OMC	28.31
Ao =(152x152x3.14)/4 m^2	0.0181	Stabilizer	9% FCD	NMC	9.2
Volume = AoLo m^3	0.00275	%	0		
Stabilizer = NON					



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
1.27	0.0100	0.99	0.01828	1.93746	106
2.54	0.0200	0.98	0.01847	4.5471	246
3.81	0.0300	0.97	0.01866	5.931	318
5.08	0.0400	0.96	0.01885	5.8651	311
6.35	0.0500	0.95	0.01905	5.5356	291
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.9

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		318 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew % Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

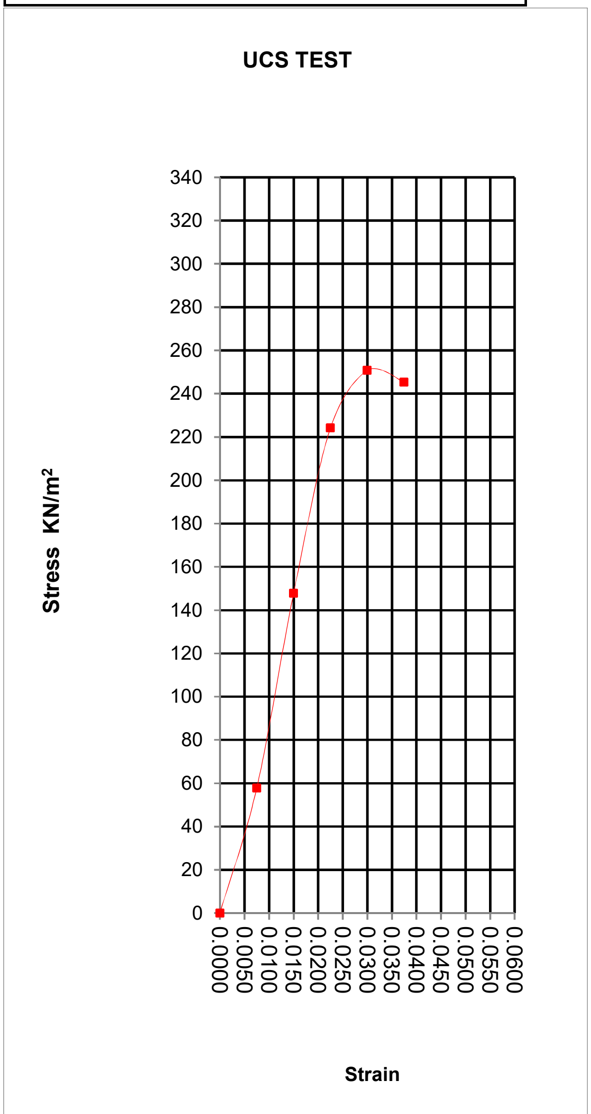
UCS TEST

SPECIMEN 2

Project: Mechanical Stabilization of lateritic Gravel	**Date: 22-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1532
Type	STABILIZED	OMC	28.31
Stabilizer	9% FCD	NMC	9.2
%	0		



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.0544	58
1.91	0.0150	0.985	0.01838	2.71508	148
2.86	0.0225	0.9775	0.01852	4.1517	224
3.81	0.0300	0.97	0.01866	4.6789	251
4.76	0.0375	0.9625	0.01881	4.613	245
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.9

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		251 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

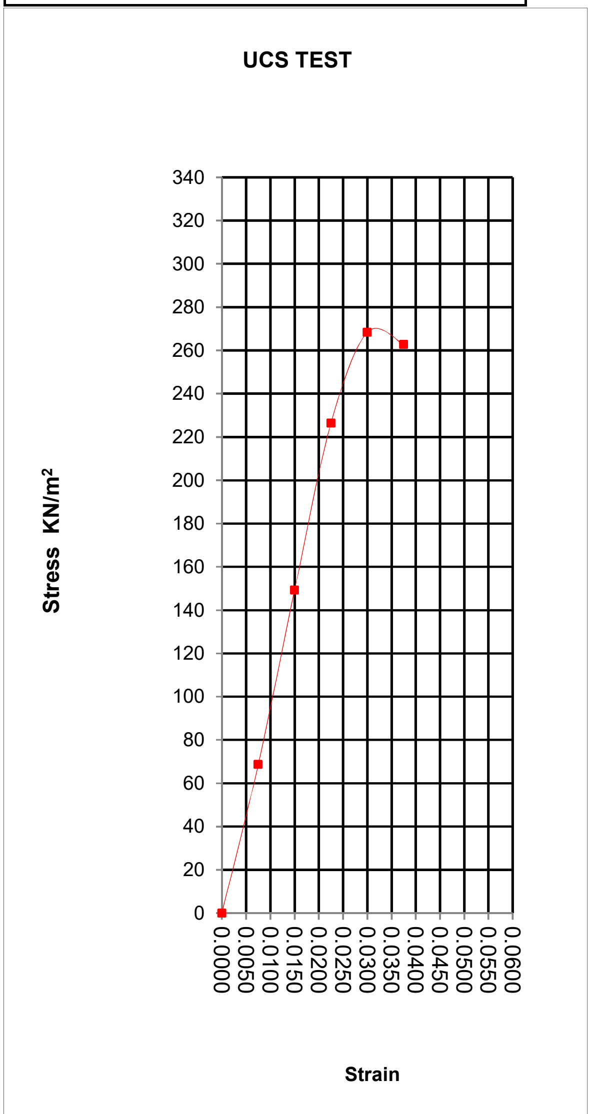
WORKING SHEET

UCS TEST

SPECIMEN 3

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 22-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA						
		SAMPLE DETAILS		MDD	1532
Do =152mm		Type	STABILIZED	OMC	28.31
Lo mm	127	Stabilizer	9% FCD	NMC	9.2
Ao =(152x152x3.14)/4 m^2	0.0181	%	0		
Volume = AoLo m^3	0.00275				
Stabilizer = NON					



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.2521	69
1.91	0.0150	0.985	0.01838	2.74144	149
2.86	0.0225	0.9775	0.01852	4.19124	226
3.81	0.0300	0.97	0.01866	5.0084	268
4.76	0.0375	0.9625	0.01881	4.9425	263
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.9

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		268 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

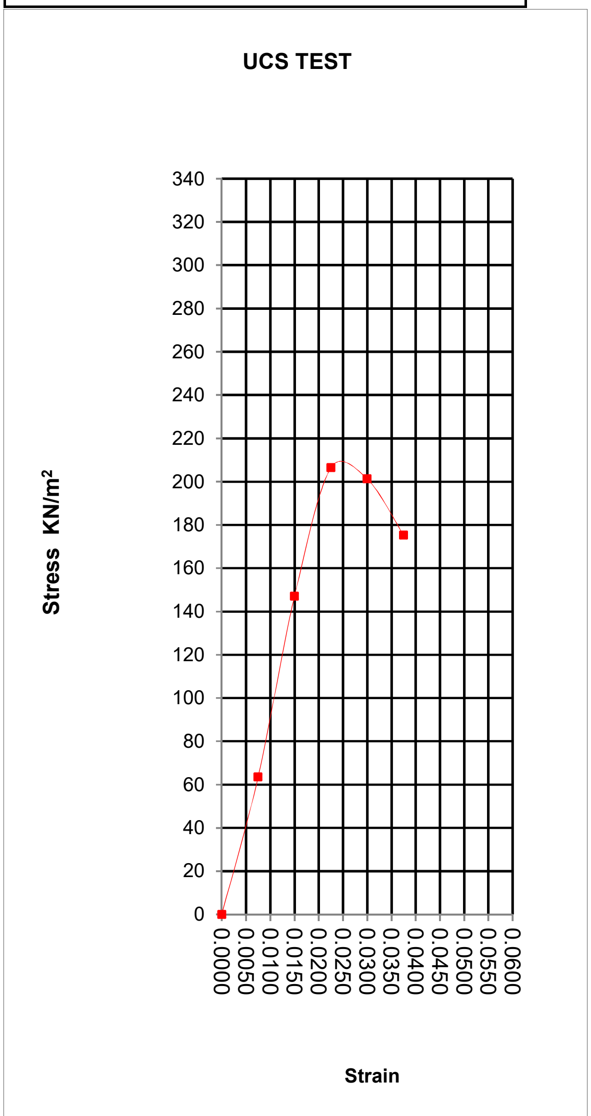
UCS TEST

SPECIMEN 4

Project: Mechanical stabilization of Lateritic Gravel	**Date: 22-Jan-2020**	**No. of days cured:**	0
student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1532
Stabilizer	9% FCD	OMC	28.31
%	0	NMC	9.2



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.15984	64
1.91	0.0150	0.985	0.01838	2.7019	147
2.86	0.0225	0.9775	0.01852	3.8222	206
3.81	0.0300	0.97	0.01866	3.7563	201
4.76	0.0375	0.9625	0.01881	3.295	175
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.9

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		206 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

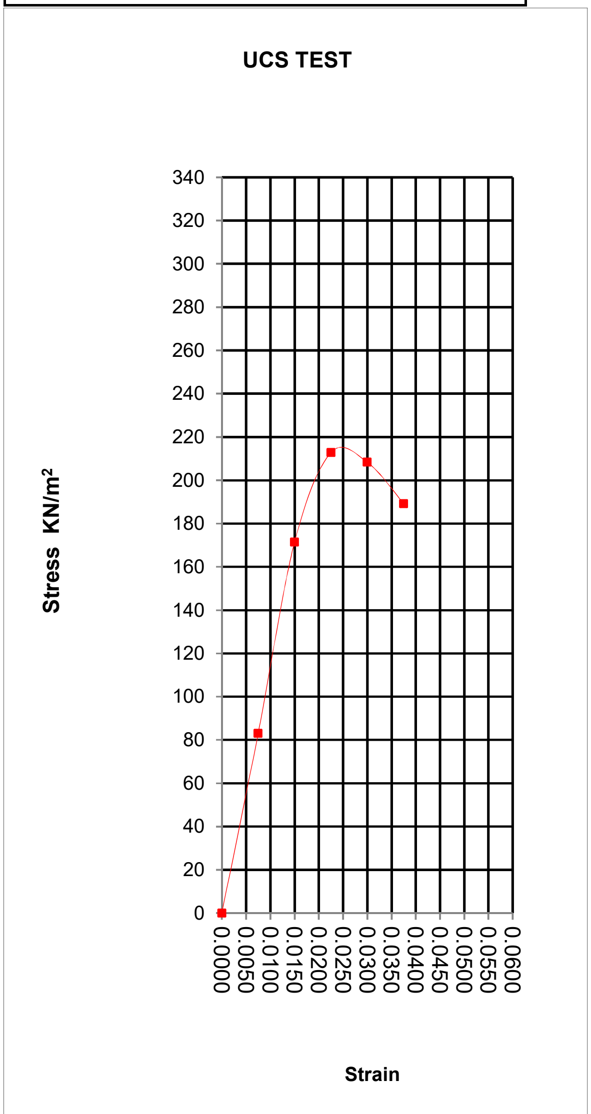
UCS TEST

SPECIMEN 5

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 22-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
Type	**STABILIZED**	**MDD**	1532
Stabilizer	**9% FCD**	**OMC**	28.31
%	**0**	**NMC**	9.2



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.5157	83
1.91	0.0150	0.985	0.01838	3.15002	171
2.86	0.0225	0.9775	0.01852	3.94082	213
3.81	0.0300	0.97	0.01866	3.8881	208
4.76	0.0375	0.9625	0.01881	3.5586	189
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	227.3
Tin + Dry soil	191.2
Wt of Tin	78.1
Wt of Moisture	36.1
Wt. of dry soil	113.1
Moisture content	31.9

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		213 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

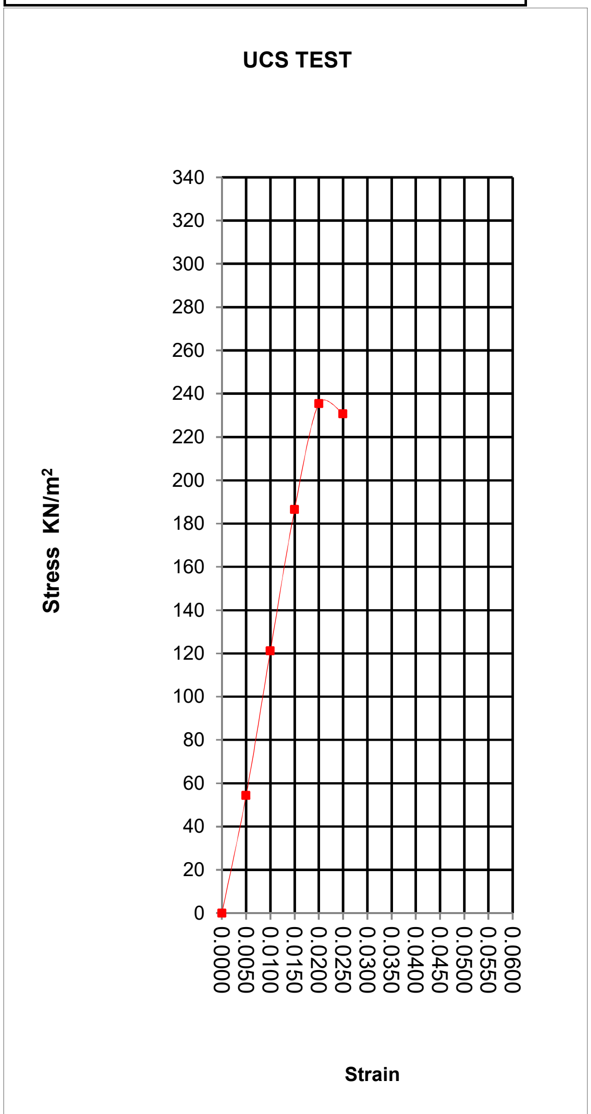
UCS TEST

SPECIMEN 6

Project: Mechanical Stabilization of Lateritic Gravel	Date: 22-Jan-2020	No. of days cured:	0
Student: Anthony Mugendi Nyagah	Mould No.:	No. of days soaked:	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1532
Stabilizer	9% FCD	OMC	28.31
%	0	NMC	9.2



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.64	0.0050	0.995	0.01819	0.9885	54
1.27	0.0100	0.99	0.01828	2.21424	121
1.91	0.0150	0.985	0.01838	3.4268	186
2.54	0.0200	0.98	0.01847	4.3494	235
3.18	0.0250	0.975	0.01856	4.2835	231
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	227.3
Tin + Dry soil	191.2
Wt of Tin	78.1
Wt of Moisture	36.1
Wt. of dry soil	113.1
Moisture content	31.9

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		235 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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WORKING SHEET

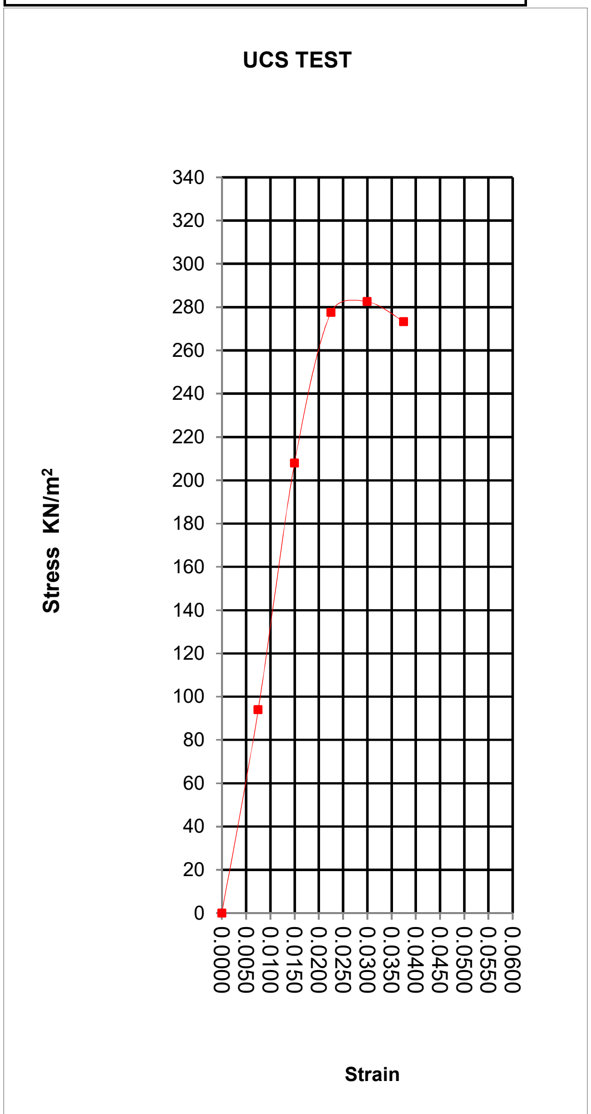
UCS TEST

SPECIMEN 7

Project: Mechanical stabilization of Lateritic Gravel	**Date: 22-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1532
Type	STABILIZED	OMC	28.31
Stabilizer	9% FCD	NMC	9.2
%	0		



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.7134	94
1.91	0.0150	0.985	0.01838	3.8222	208
2.86	0.0225	0.9775	0.01852	5.1402	278
3.81	0.0300	0.97	0.01866	5.272	283
4.76	0.0375	0.9625	0.01881	5.1402	273
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	227.3
Tin + Dry soil	191.2
Wt of Tin	78.1
Wt of Moisture	36.1
Wt. of dry soil	113.1
Moisture content	31.9

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		283 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

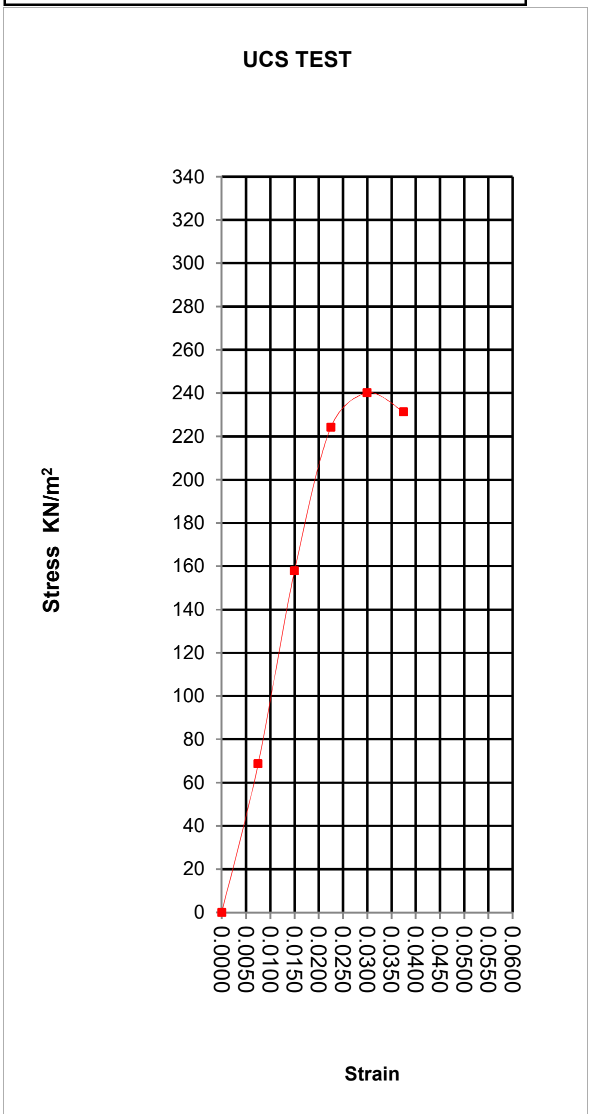
UCS TEST

SPECIMEN 1

Project: Mechanical Stabilization of Lateritic Gravel	**Date:23-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1474
Stabilizer	12% FCD	OMC	29.43
%	0	NMC	9.2



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.2521	69
1.91	0.0150	0.985	0.01838	2.8996	158
2.86	0.0225	0.9775	0.01852	4.1517	224
3.81	0.0300	0.97	0.01866	4.4812	240
4.76	0.0375	0.9625	0.01881	4.3494	231
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	195
Tin +Wet soil	215.1
Tin + Dry soil	183.6
Wt of Tin	76
Wt of Moisture	31.5
Wt. of dry soil	107.6
Moisture content	29.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		240 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

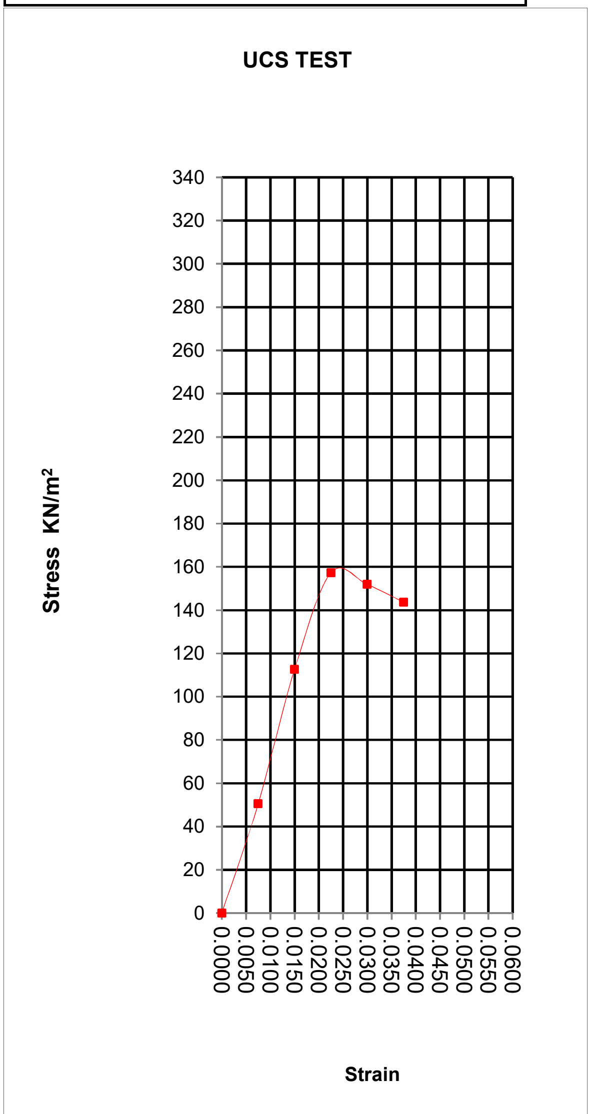
UCS TEST

SPECIMEN 2

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 23-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1474
Stabilizer	12% FCD	OMC	29.43
%	0	NMC	9.2



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	0.9226	51
1.91	0.0150	0.985	0.01838	2.06926	113
2.86	0.0225	0.9775	0.01852	2.91278	157
3.81	0.0300	0.97	0.01866	2.8337	152
4.76	0.0375	0.9625	0.01881	2.7019	144
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	195
Tin +Wet soil	215.1
Tin + Dry soil	183.6
Wt of Tin	76
Wt of Moisture	31.5
Wt. of dry soil	107.6
Moisture content	29.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		157 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

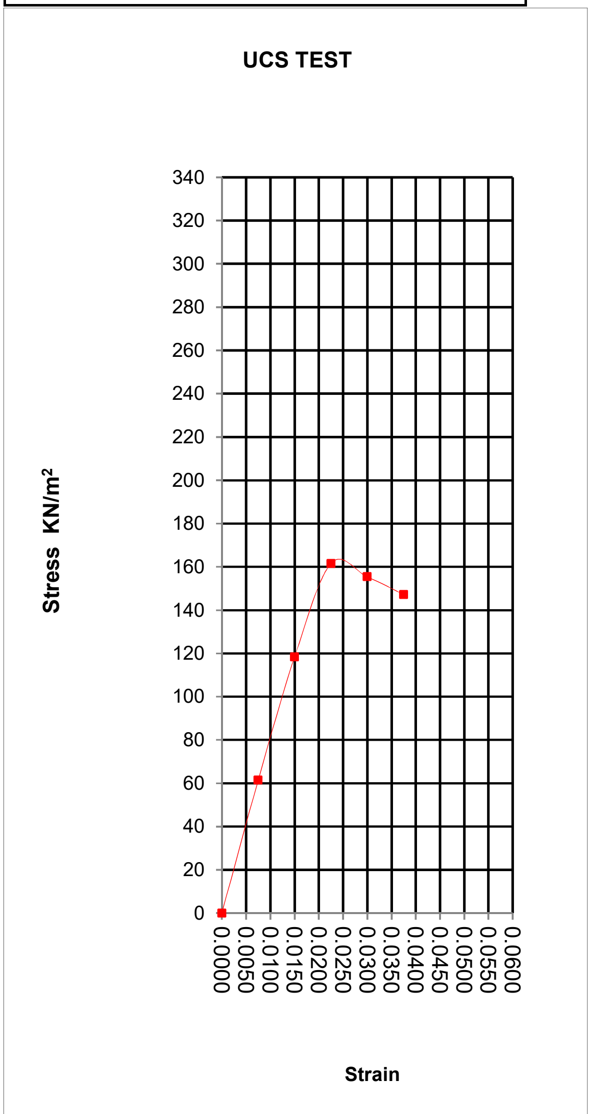
UCS TEST

SPECIMEN 3

Project: Mechanical Stabilization of lateritic Gravel	**Date: 23-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA						
Do =152mm		**SAMPLE DETAILS**		**MDD**	1474
Lo mm	127	**Type**	**STABILIZED**	**OMC**	29.43
Ao =(152x152x3.14)/4 m^2	0.0181	**Stabilizer**	**12% FCD**	**NMC**	9.2
Volume = AoLo m^3	0.00275	**%**	0		
Stabilizer = NON					

Defl. mm	**Deflection** E=L/L0	1-E	A=(Ao)/1-E	**Stress** Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.1203	61
1.91	0.0150	0.985	0.01838	2.1747	118
2.86	0.0225	0.9775	0.01852	2.99186	162
3.81	0.0300	0.97	0.01866	2.8996	155
4.76	0.0375	0.9625	0.01881	2.7678	147
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0



MOULDING MOISTURE CONTENT	
Tin No.	195
Tin +Wet soil	215.1
Tin + Dry soil	183.6
Wt of Tin	76
Wt of Moisture	31.5
Wt. of dry soil	107.6
Moisture content	29.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		**155 KN/m^2**
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

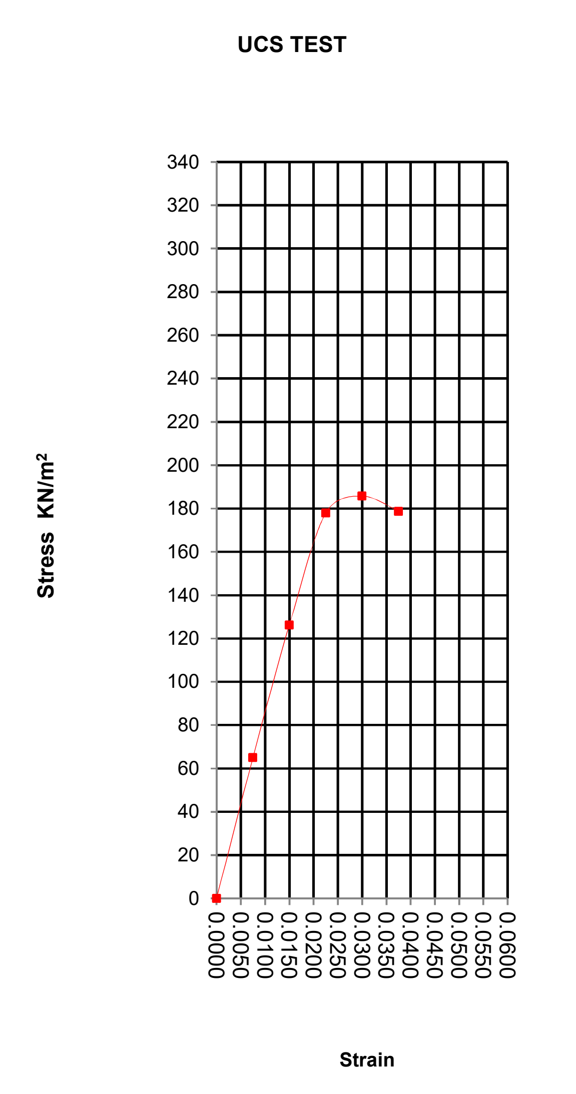
UCS TEST

SPECIMEN 4

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 23-jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA			
Do =152mm			
Lo	mm	127	
Ao =(152x152x3.14)/4	m^2	0.0181	
Volume = AoLo	m^3	0.00275	
Stabilizer = NON			

SAMPLE DETAILS			
Type	STABILIZED	MDD	1474
Stabilizer	12% FCD	OMC	29.43
%	0	NMC	9.2



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.1862	65
1.91	0.0150	0.985	0.01838	2.31968	126
2.86	0.0225	0.9775	0.01852	3.295	178
3.81	0.0300	0.97	0.01866	3.46634	186
4.76	0.0375	0.9625	0.01881	3.3609	179
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	195
Tin +Wet soil	215.1
Tin + Dry soil	183.6
Wt of Tin	76
Wt of Moisture	31.5
Wt. of dry soil	107.6
Moisture content	29.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		186 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

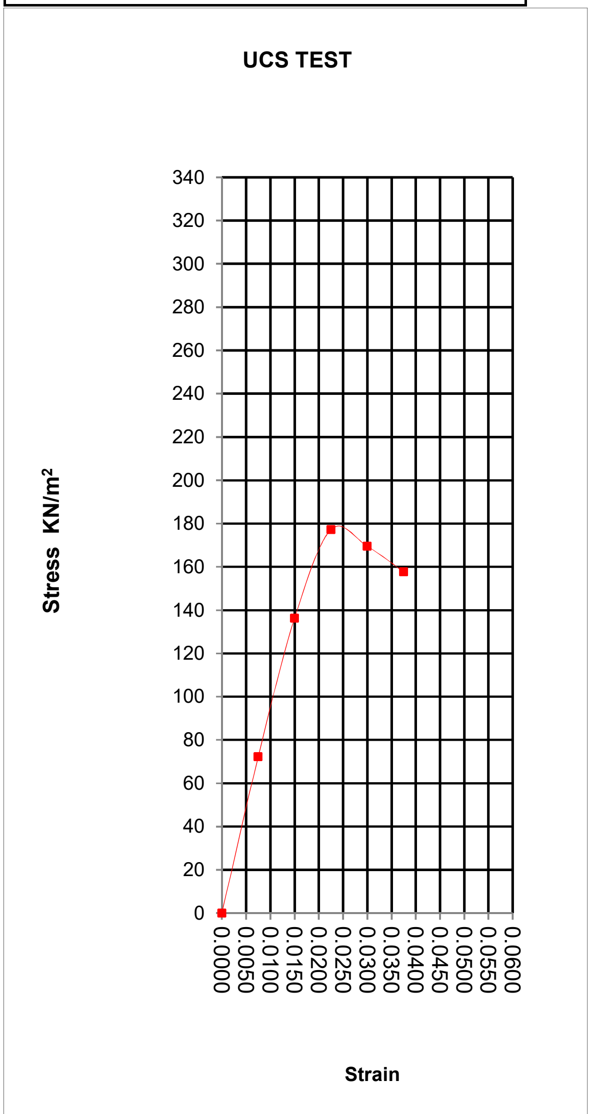
UCS TEST

SPECIMEN 5

Project: Mechanical Stabilization of Lateritic Gravel	**Date: 23-Jan-2020**	**No. of days cured:**	0	
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0	

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1474
Type	STABILIZED	OMC	29.43
Stabilizer	12% FCD	NMC	19.3
%	0		



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.318	72
1.91	0.0150	0.985	0.01838	2.5042	136
2.86	0.0225	0.9775	0.01852	3.28182	177
3.81	0.0300	0.97	0.01866	3.1632	170
4.76	0.0375	0.9625	0.01881	2.9655	158
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	195
Tin +Wet soil	215.1
Tin + Dry soil	183.6
Wt of Tin	76
Wt of Moisture	31.5
Wt. of dry soil	107.6
Moisture content	29.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		177 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

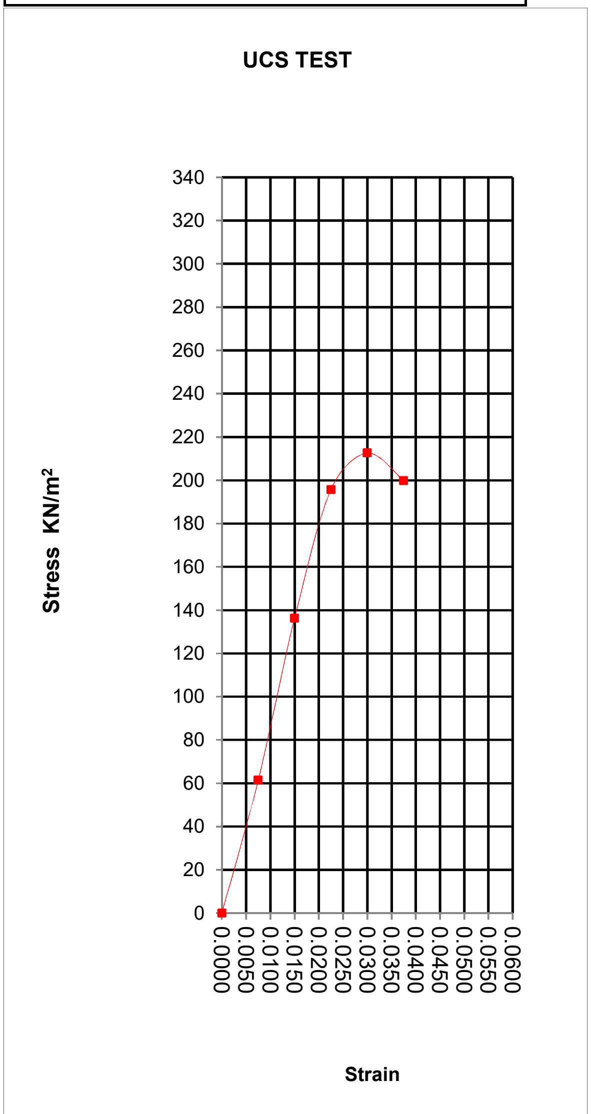
SPECIMEN 6

Project: Mechanical stabilization of Lateritic Gravel	**Date: 23-Jan-2020**	**No. of days cured:**	0
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = NON	

SAMPLE DETAILS			
		MDD	1474
Type	STABILIZED	OMC	29.43
Stabilizer	12% FCD	NMC	19.3
%	0		

Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.1203	61
1.91	0.0150	0.985	0.01838	2.5042	136
2.86	0.0225	0.9775	0.01852	3.6245	196
3.81	0.0300	0.97	0.01866	3.96718	213
4.76	0.0375	0.9625	0.01881	3.7563	200
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0



MOULDING MOISTURE CONTENT	
Tin No.	195
Tin +Wet soil	215.1
Tin + Dry soil	183.6
Wt of Tin	76
Wt of Moisture	31.5
Wt. of dry soil	107.6
Moisture content	29.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		213 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

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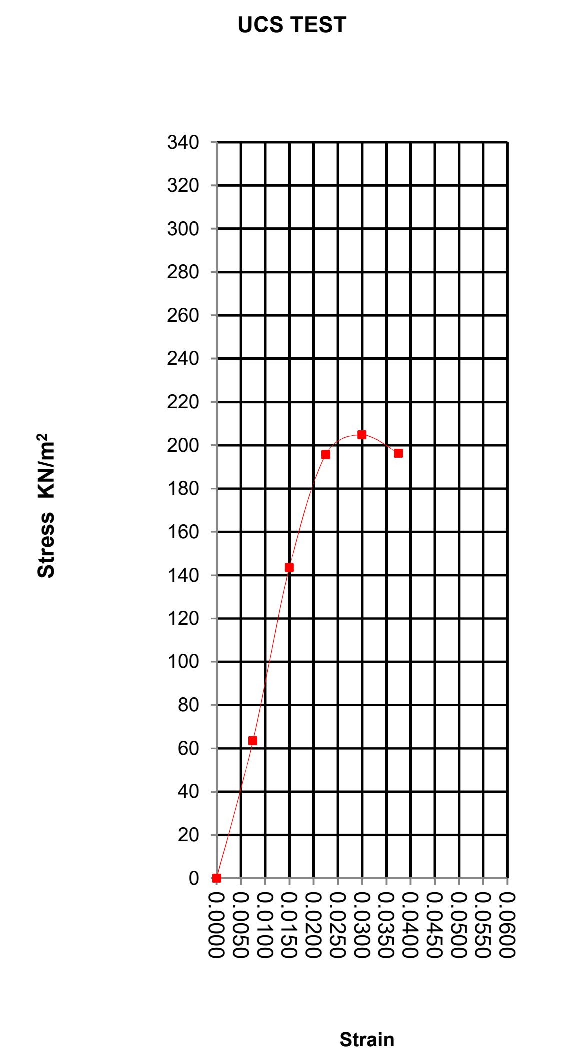
(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

SPECIMEN 7

Project: Mechanical Stabilization of lateritic Gravel		**Date: 23-Jan-2020**	**No. of days cured:**	0	
Student: Anthony Mugendi Nyagah		**Mould No.:**	**No. of days soaked:**	0	
DATA			**SAMPLE DETAILS**	**MDD**	1474
Do =152mm		**Type**	**STABILIZED**	**OMC**	29.43
Lo mm	127	**Stabilizer**	**12% FCD**	**NMC**	9.2
Ao =(152x152x3.14)/4 m^2	0.0181	**%**	0		
Volume = AoLo m^3	0.00275				
Stabilizer = NON					



Defl. (mm)	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.95	0.0075	0.9925	0.01824	1.15984	64
1.91	0.0150	0.985	0.01838	2.636	143
2.86	0.0225	0.9775	0.01852	3.6245	196
3.81	0.0300	0.97	0.01866	3.8222	205
4.76	0.0375	0.9625	0.01881	3.6904	196
0.00	0.0000	1.0000	0.01810	0	0
0.00	0	1.0000	0.01810	0	0
0.00	0.0000	1.0000	0.01810	0	0

MOULDING MOISTURE CONTENT	
Tin No.	195
Tin +Wet soil	215.1
Tin + Dry soil	183.6
Wt of Tin	76
Wt of Moisture	31.5
Wt. of dry soil	107.6
Moisture content	29.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		205 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

Appendix D3 Strength Properties (CBR)

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(HIGHWAYS LABORATORY)

WORKING SHEET

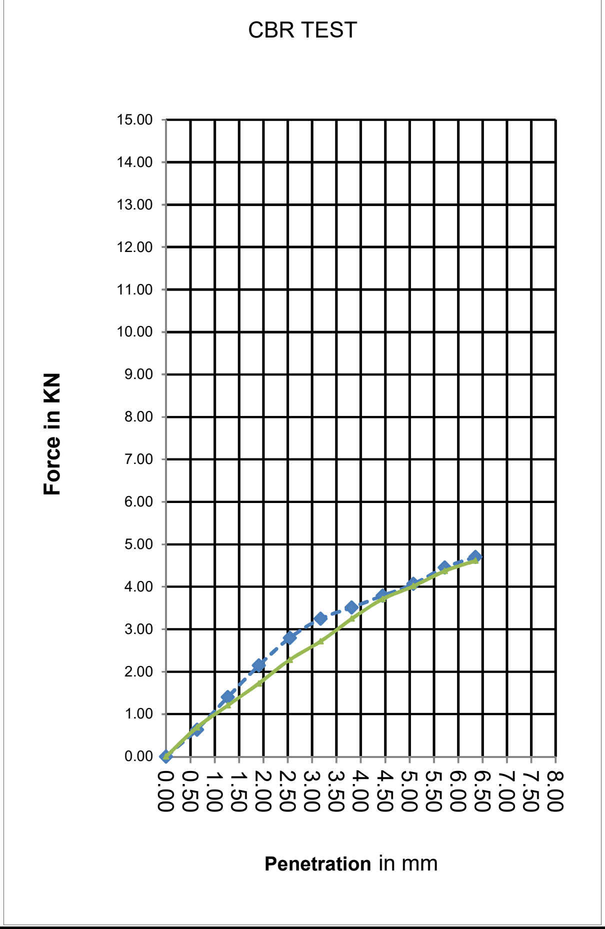
CBR TEST
(AASHTO T193:1990)

3% FCD SAMPLE 1

Project: Mechanical stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	18
Difference	**(div)**	18
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1613
Stabilizer	FCD	OMC	25.25
%		NMC	9.2
Swell %	0.18		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.63601	0.689			
1.27	1.40452	1.2058			
1.91	2.14653	1.7225			
2.54	2.79579	2.279	13.2	21	17
3.18	3.2463	2.7163			
3.81	3.5113	3.2463			
4.45	3.78956	3.7101			
5.08	4.06781	4.0148	20.0	20	20
5.72	4.45207	4.3726			
6.35	4.70382	4.6111			

Moulding Data		
Wt.of Mould + Wet soil	**g**	
Wt. of Mould	**g**	
Moisture Content	**%**	
Wet Density	**Kg/m³**	
Dry Density	**Kg/m³**	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	239
Tin + Dry soil	205.8
Wt of Tin	78.3
Wt of Moisture	33.2
Wt. of dry soil	127.5
Moisture content	26.04

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			17	21
5	20			20	20
		CBR =21%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST
(AASHTO T193:1990)

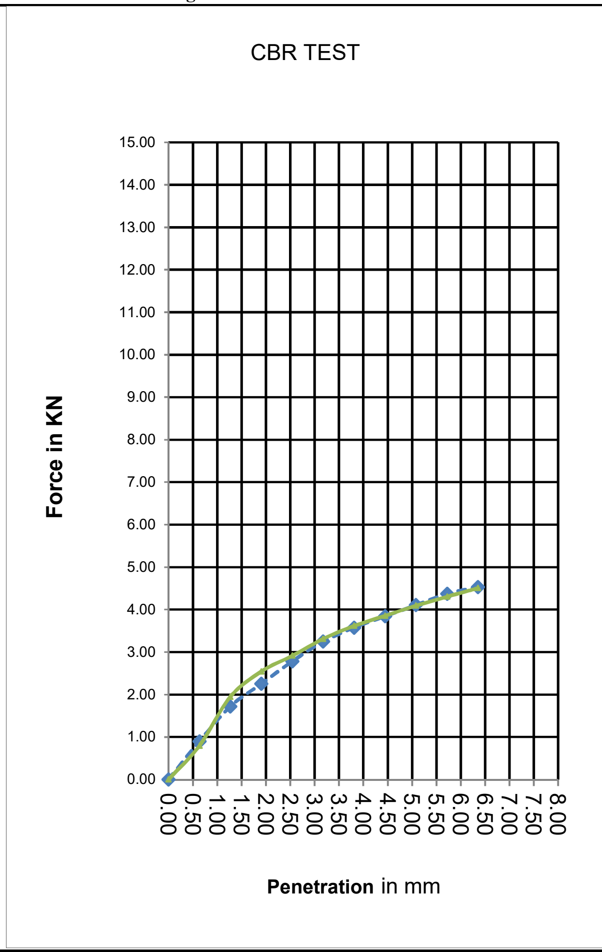
3% FCD SAMPLE 2

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	18
Difference	**(div)**	18
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1613
Stabilizer	FCD	OMC	25.25
%		NMC	9.2
Swell %	0.18		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.90101	0.795			
1.27	1.72253	1.9478			
1.91	2.25253	2.544			
2.54	2.78254	2.915	13.2	21	22
3.18	3.2463	3.3126			
3.81	3.57755	3.6173			
4.45	3.84256	3.8558			
5.08	4.10756	4.0943	20.0	21	20
5.72	4.37257	4.3063			
6.35	4.53157	4.5051			



Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	239
Tin + Dry soil	205.8
Wt of Tin	78.3
Wt of Moisture	33.2
Wt. of dry soil	127.5
Moisture content	26.04

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			22	21
5	20			20	21
		CBR =22%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

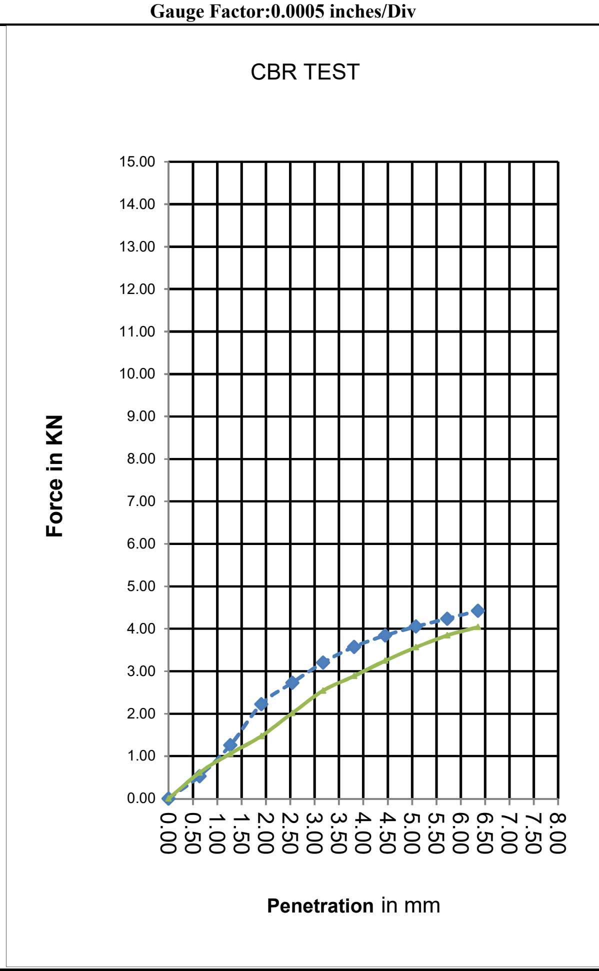
CBR TEST
(AASHTO T193:1990)

3% FCD SAMPLE 3

Project: Mechanical Stabilization of lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Client.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	18
Difference	(div)	18
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1613
Stabilizer	FCD	OMC	25.25
%		NMC	9.2
Swell %	0.18		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.53001	0.6095			
1.27	1.25877	1.06			
1.91	2.22603	1.4708			
2.54	2.72954	2.014	13.2	21	15
3.18	3.20655	2.544			
3.81	3.57755	2.8885			
4.45	3.84256	3.2463			
5.08	4.05456	3.5643	20.0	20	18
5.72	4.24006	3.8426			
6.35	4.42557	4.0413			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	239
Tin + Dry soil	205.8
Wt of Tin	78.3
Wt of Moisture	33.2
Wt. of dry soil	127.5
Moisture content	26.04

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		15	21
5	20		18	20
		CBR =21%	Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

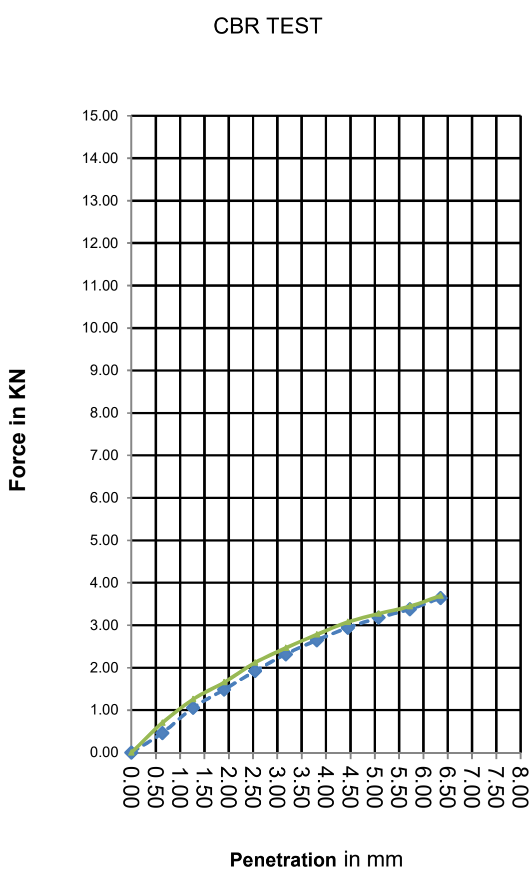
CBR TEST
(AASHTO T193:1990)

3% FCD SAMPLE 4

Project: Mechanical stabilization of lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	18
Difference	**(div)**	18
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1613
Stabilizer	FCD	OMC	25.25
%		NMC	9.2
Swell %	0.18		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.46376	0.7023			
1.27	1.06002	1.2588			
1.91	1.48402	1.6563			
2.54	1.92128	2.12	13.2	15	16
3.18	2.31879	2.4645			
3.81	2.65004	2.7825			
4.45	2.94154	3.074			
5.08	3.18005	3.2728	20.0	16	16
5.72	3.3788	3.4451			
6.35	3.64381	3.6968			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	239
Tin + Dry soil	205.8
Wt of Tin	78.3
Wt of Moisture	33.2
Wt. of dry soil	127.5
Moisture content	26.04

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			16	15
5	20			16	16
		CBR =16%		Checked:	Martin Mburu

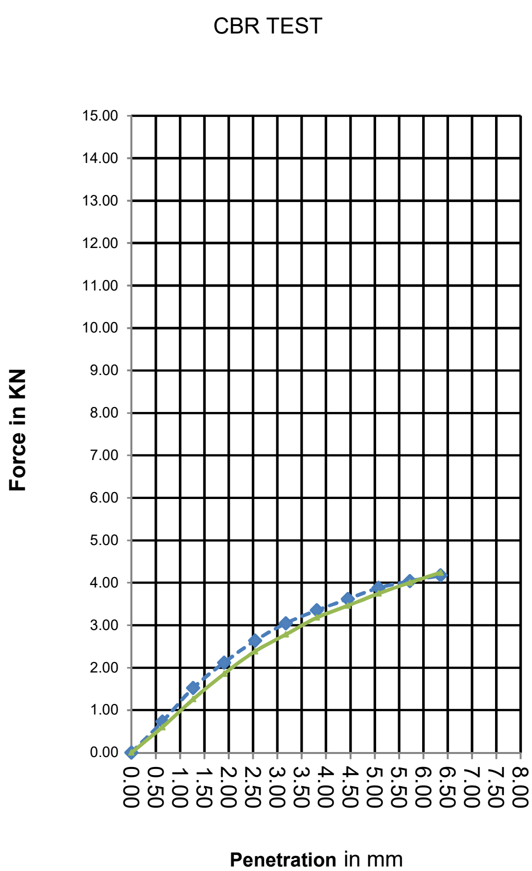
UNIVERSITY OF NAIROBI (HIGHWAYS LABORATORY)	WORKING SHEET CBR TEST (AASHTO T193:1990)

3% FCD SAMPLE 5

Project: Mechanical stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA			SAMPLE DETAILS			
Initial gauge Reading (div)	0		Type	STABILIZED	MDD	1613
Final gauge Reading (div)	18		Stabilizer	FCD	OMC	25.25
Difference (div)	18		%		NMC	9.2
Ring Factor	0.01		Swell %	0.18		

Gauge Factor:0.0005 inches/Div



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.72876	0.5963			
1.27	1.52377	1.2588			
1.91	2.12003	1.855			
2.54	2.63679	2.385	13.2	20	18
3.18	3.04755	2.7825			
3.81	3.3523	3.18			
4.45	3.6173	3.4583			
5.08	3.88231	3.7498	20.0	19	19
5.72	4.04131	4.0016			
6.35	4.17381	4.2401			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
% MDD		

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	239
Tin + Dry soil	205.8
Wt of Tin	78.3
Wt of Moisture	33.2
Wt. of dry soil	127.5
Moisture content	26.04

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			18	20
5	20			19	19
		CBR =20%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

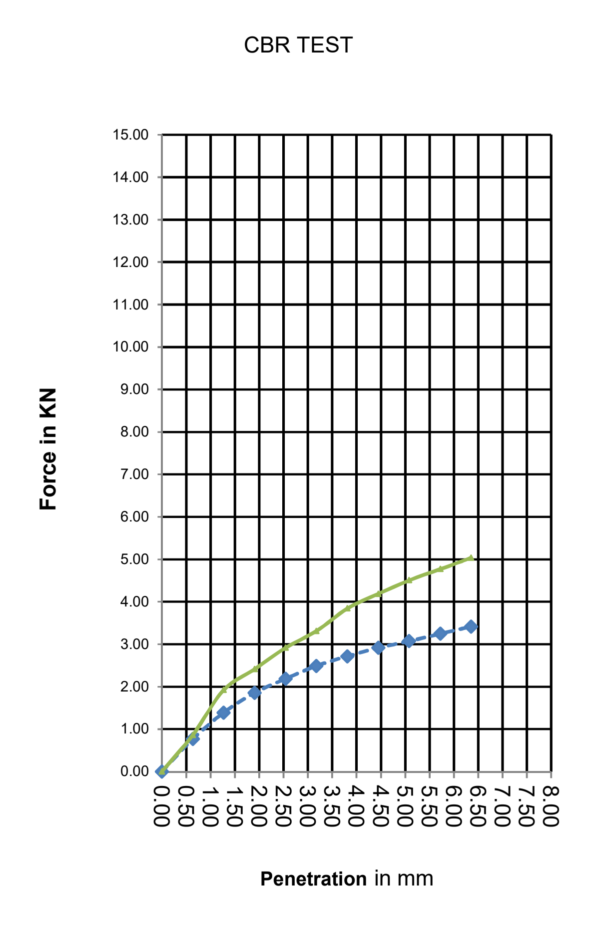
CBR TEST
(AASHTO T193:1990)

3% FCD SAMPLE 6

Project: Mechanical stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	18
Difference	(div)	18
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1613
Stabilizer	FCD	OMC	25.25
%		NMC	9.2
Swell %	0.18		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.76851	0.8613			
1.27	1.39127	1.9213			
1.91	1.85503	2.4115			
2.54	2.18628	2.915	13.2	17	22
3.18	2.49104	3.3126			
3.81	2.71629	3.8426			
4.45	2.91504	4.1871			
5.08	3.07405	4.5051	20.0	15	23
5.72	3.2463	4.7701			
6.35	3.41855	5.0351			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
% MDD		

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	239
Tin + Dry soil	205.8
Wt of Tin	78.3
Wt of Moisture	33.2
Wt. of dry soil	127.5
Moisture content	26.04

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		22	17
5	20		23	15
		CBR =23%	Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

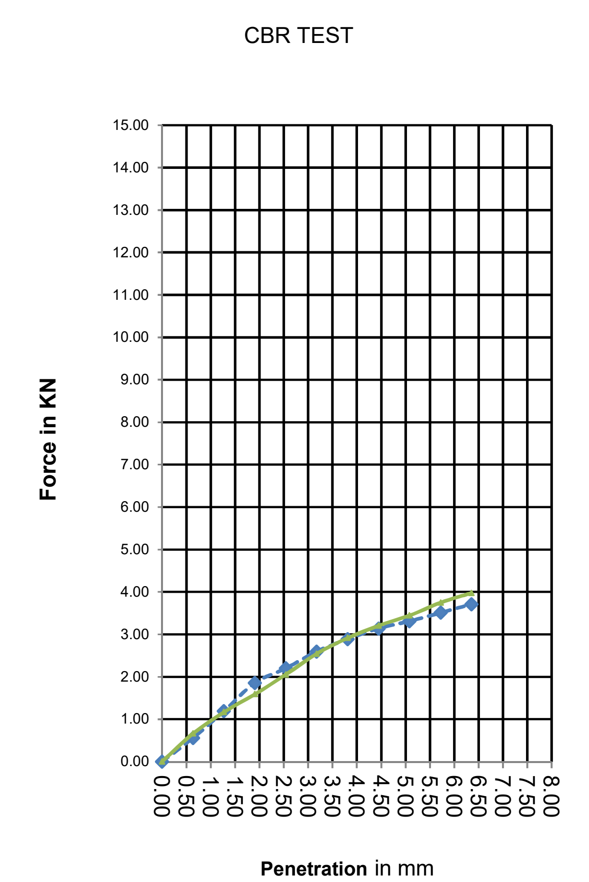
WORKING SHEET

CBR TEST
(AASHTO T193:1990)

3% FCD SAMPLE 7

Project: Mechanical Stabilization of Lateritic Gravel using FCD		**Tested:** 21/1/2020		**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah		**Mould No.:**		**Date Moulded:**	17/01/2020

SWELL DATA		SAMPLE DETAILS			
Initial gauge Reading (div)	0	Type	STABILIZED	MDD	1613
Final gauge Reading (div)	18	Stabilizer	FCD	OMC	25.25
Difference (div)	18	%		NMC	9.2
Ring Factor	0.01	Swell %	0.18		
Gauge Factor:0.0005 inches/Div					



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.55651	0.6625			
1.27	1.19252	1.166			
1.91	1.85503	1.59			
2.54	2.19953	2.0538	13.2	17	16
3.18	2.59704	2.544			
3.81	2.88854	2.915			
4.45	3.1403	3.2065			
5.08	3.31255	3.4451	20.0	17	17
5.72	3.5113	3.7498			
6.35	3.71006	3.9751			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	239
Tin + Dry soil	205.8
Wt of Tin	78.3
Wt of Moisture	33.2
Wt. of dry soil	127.5
Moisture content	26.04

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		16	17
5	20		17	17
		CBR =17%	Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

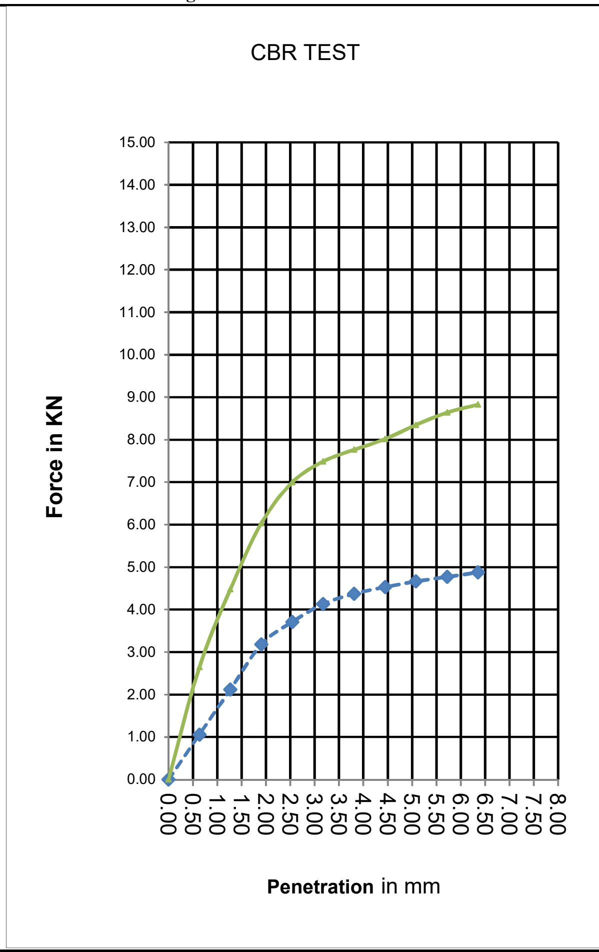
CBR TEST
(AASHTO T193:1990)

6% FCD SAMPLE 1

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 17/12/2019	**Date soaked:**	29/11/2019
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	12
Difference	**(div)**	12
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	OMC	26.39
Stabilizer	FCD	NMC	9.2
%			
Swell %	0.12		
		MDD	1553



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.06002	2.65			
1.27	2.12003	4.4786			
1.91	3.18005	6.0288			
2.54	3.71006	6.9961	13.2	28	53
3.18	4.13406	7.4864			
3.81	4.37257	7.7646			
4.45	4.53157	8.0164			
5.08	4.66407	8.3476	20.0	23	42
5.72	4.77007	8.6391			
6.35	4.87607	8.8246			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	214.3
Tin + Dry soil	184.6
Wt of Tin	78.8
Wt of Moisture	33.6
Wt. of dry soil	127.1
Moisture content	26.44

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			53	28
5	20			42	23
		CBR =53%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

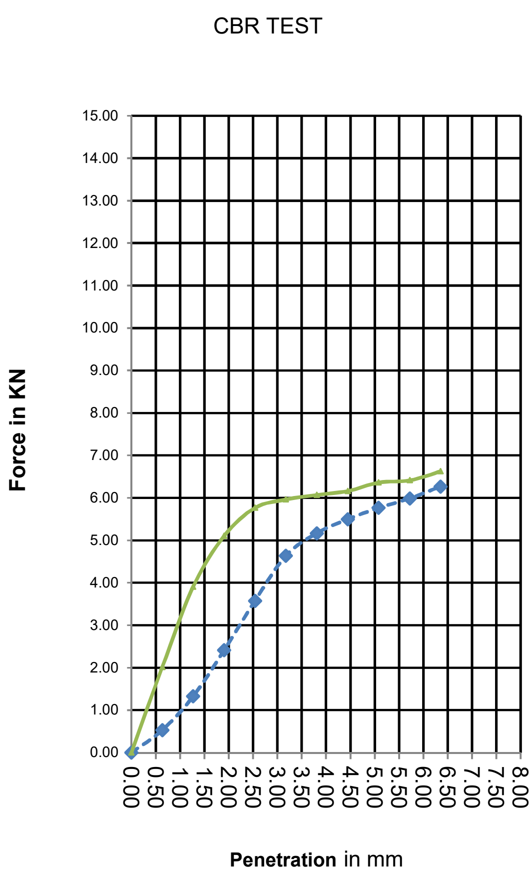
CBR TEST
(AASHTO T193:1990)

6% FCD SAMPLE 2

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 17/12/2019	**Date soaked:**	29/11/2019
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	12
Difference	(div)	12
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1553
Stabilizer	FCD	OMC	26.39
%		NMC	9.2
Swell %	0.12		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.53001	2.014			
1.27	1.32502	3.9088			
1.91	2.41154	5.1013			
2.54	3.57755	5.7638	13.2	27	44
3.18	4.63757	5.9626			
3.81	5.16758	6.0686			
4.45	5.49883	6.1613			
5.08	5.76384	6.3601	20.0	29	32
5.72	5.98909	6.4131			
6.35	6.26734	6.6251			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	214.3
Tin + Dry soil	184.6
Wt of Tin	78.8
Wt of Moisture	33.6
Wt. of dry soil	127.1
Moisture content	26.44

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			44	27
5	20			32	29
		CBR =44%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST
(AASHTO T193:1990)

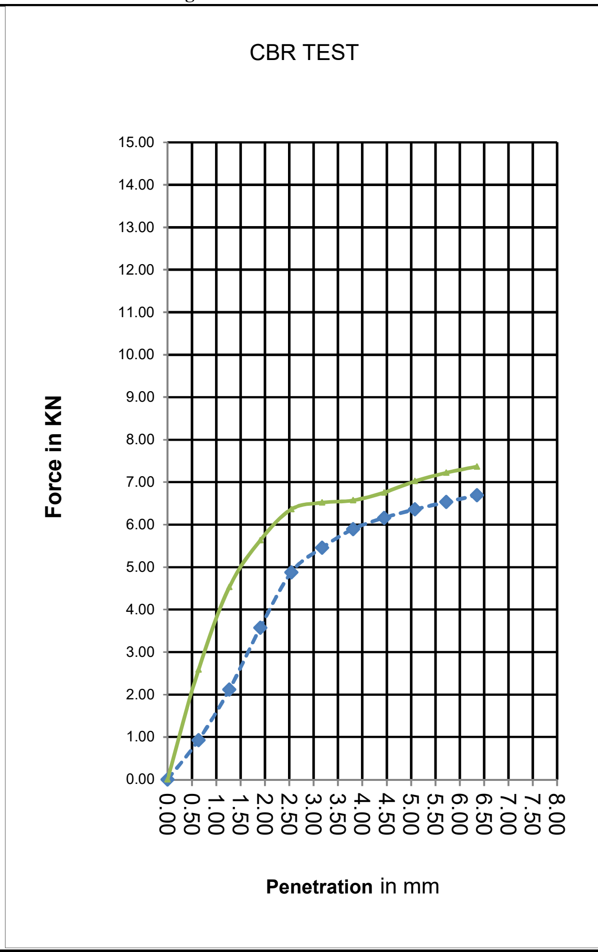
6% FCD SAMPLE 3

Project: Mechanical stabilization of Lateritic Gravel using FCD	**Tested:** 17/12/2019	**Date soaked:**	29/11/2019
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	12
Difference	(div)	12
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
		MDD	1553
Type	STABILIZED	OMC	26.39
Stabilizer	FCD	NMC	9.2
%			
Swell %	0.12		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.92751	2.5838			
1.27	2.12003	4.5316			
1.91	3.57755	5.6313			
2.54	4.87607	6.3601	13.2	37	48
3.18	5.45908	6.5191			
3.81	5.89634	6.5721			
4.45	6.16134	6.7576			
5.08	6.3601	7.0226	20.0	32	35
5.72	6.53235	7.2214			
6.35	6.69135	7.3671			



Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	214.3
Tin + Dry soil	184.6
Wt of Tin	78.8
Wt of Moisture	33.6
Wt. of dry soil	127.1
Moisture content	26.44

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			48	37
5	20			35	32
		CBR =48%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

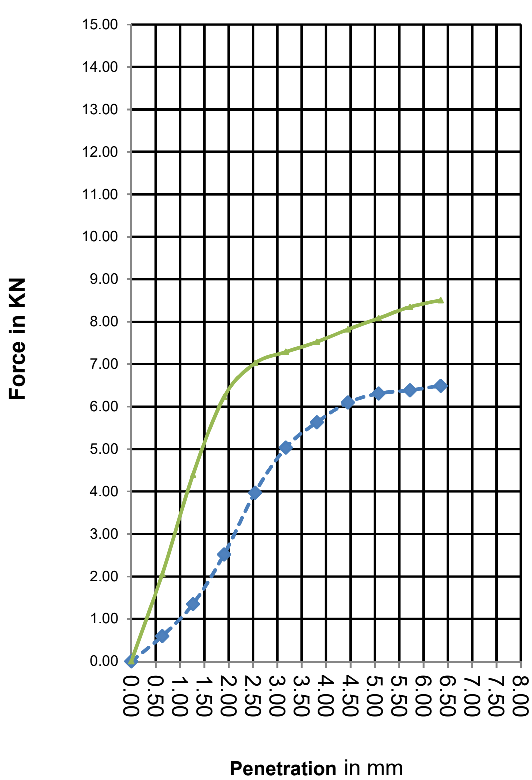
CBR TEST
(AASHTO T193:1990)

6% FCD SAMPLE 4

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 17/12/2019	**Date soaked:**	29/11/2019
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	12
Difference	**(div)**	12
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1553
Stabilizer	FCD	OMC	26.39
%		NMC	9.2
Swell %	0.12		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.59626	2.0538			
1.27	1.35152	4.3991			
1.91	2.51754	6.2276			
2.54	3.97506	7.0226	13.2	30	53
3.18	5.03508	7.2876			
3.81	5.63134	7.5261			
4.45	6.09509	7.8176			
5.08	6.3071	8.0826	20.0	32	40
5.72	6.3866	8.3476			
6.35	6.4926	8.5066			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	214.3
Tin + Dry soil	184.6
Wt of Tin	78.8
Wt of Moisture	33.6
Wt. of dry soil	127.1
Moisture content	26.44

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			53	30
5	20			40	32
		CBR =53%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

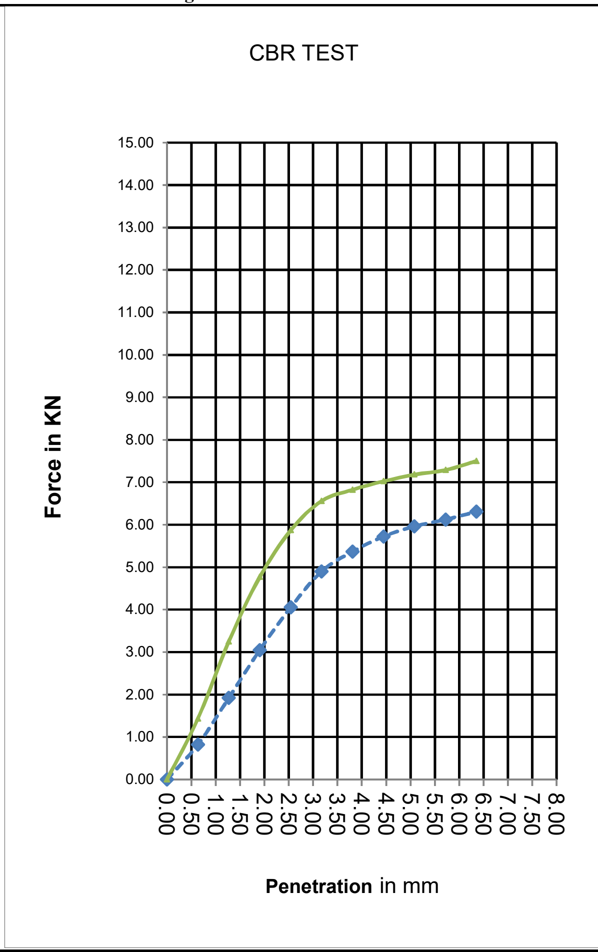
CBR TEST
(AASHTO T193:1990)

6% FCD SAMPLE 5

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 17/12/2019	**Date soaked:**	29/11/2019
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	12
Difference	**(div)**	12
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1553
Stabilizer	FCD	OMC	26.39
%		NMC	9.2
Swell %	0.12		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.82151	1.431			
1.27	1.92128	3.2463			
1.91	3.04755	4.7701			
2.54	4.05456	5.8698	13.2	31	44
3.18	4.90257	6.5588			
3.81	5.36633	6.8239			
4.45	5.72409	7.0226			
5.08	5.96259	7.1816	20.0	30	36
5.72	6.12159	7.2876			
6.35	6.3071	7.4996			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	214.3
Tin + Dry soil	184.6
Wt of Tin	78.8
Wt of Moisture	33.6
Wt. of dry soil	127.1
Moisture content	26.44

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			44	31
5	20			36	30
		CBR =44%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST

(AASHTO T193:1990)

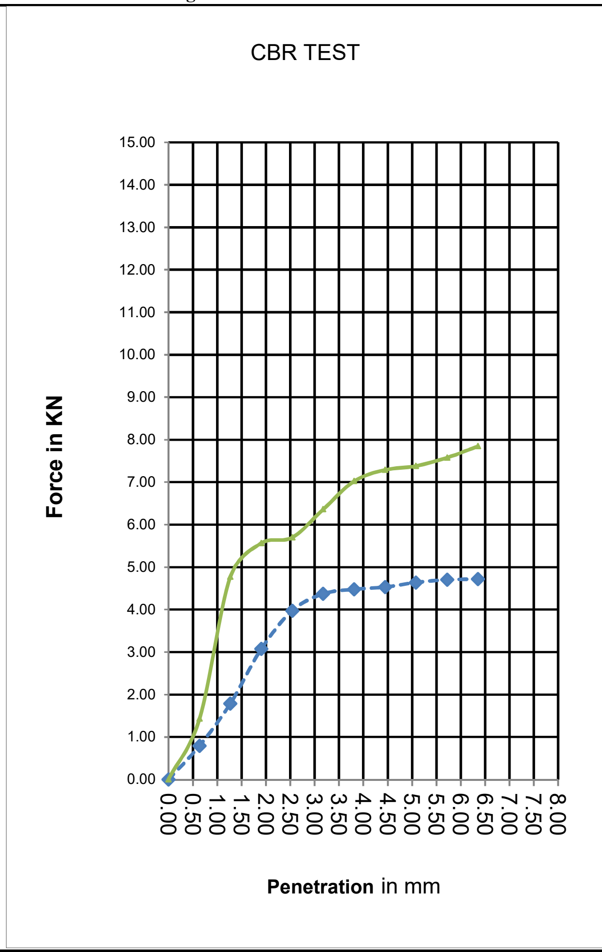
6% FCD SAMPLE 6

Project: Mechanical Stabilization of Lateritic Gravel Using FCD	**Tested:** 17/12/2019	**Date soaked:**	29/11/2019
student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	12
Difference	(div)	12
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1553
Stabilizer	FCD	OMC	26.39
%		NMC	9.2
Swell %	0.12		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.79501	1.431			
1.27	1.78878	4.7701			
1.91	3.07405	5.5651			
2.54	3.97506	5.6976	13.2	30	43
3.18	4.37257	6.3601			
3.81	4.47857	7.0226			
4.45	4.53157	7.2876			
5.08	4.63757	7.3804	20.0	23	37
5.72	4.70382	7.5791			
6.35	4.71707	7.8441			



Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	214.3
Tin + Dry soil	184.6
Wt of Tin	78.3
Wt of Moisture	33.6
Wt. of dry soil	127.1
Moisture content	26.44

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			43	30
5	20			37	23
		CBR =43%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

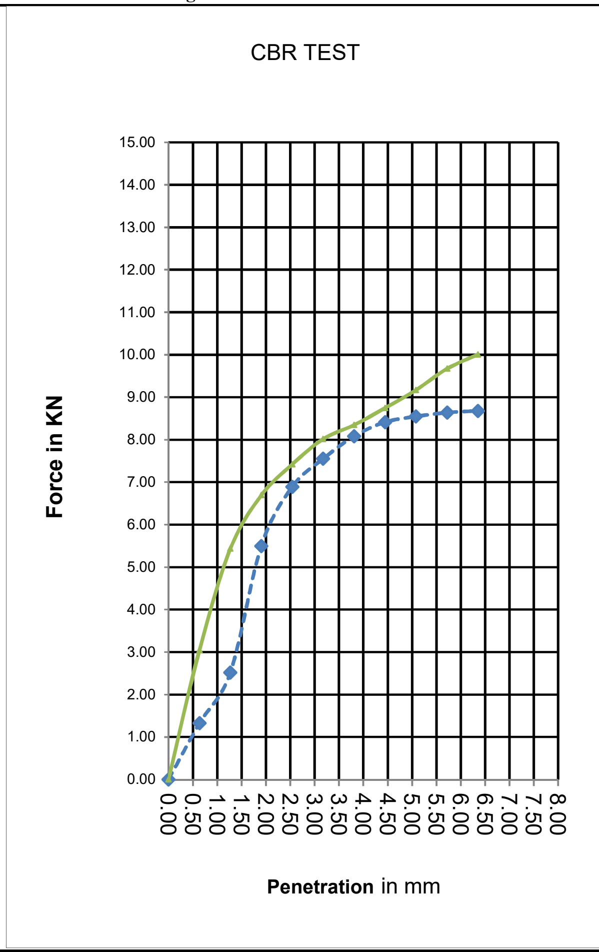
CBR TEST
(AASHTO T193:1990)

6% FCD SAMPLE 7

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 17/12/2019	**Date soaked:**	29/11/2019
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	12
Difference	(div)	12
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1553
Stabilizer	FCD	OMC	26.39
%		NMC	9.2
Swell %	0.12		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.32502	3.0475			
1.27	2.51754	5.4326			
1.91	5.49883	6.6914			
2.54	6.8901	7.4201	13.2	52	56
3.18	7.55261	8.0164			
3.81	8.08262	8.3476			
4.45	8.41388	8.7451			
5.08	8.54638	9.1691	20.0	43	46
5.72	8.63913	9.6726			
6.35	8.67888	10.004			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	214.3
Tin + Dry soil	184.6
Wt of Tin	78.8
Wt of Moisture	33.6
Wt. of dry soil	127.1
Moisture content	26.44

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			56	52
5	20			46	43
		CBR =56 %		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST
(AASHTO T193:1990)

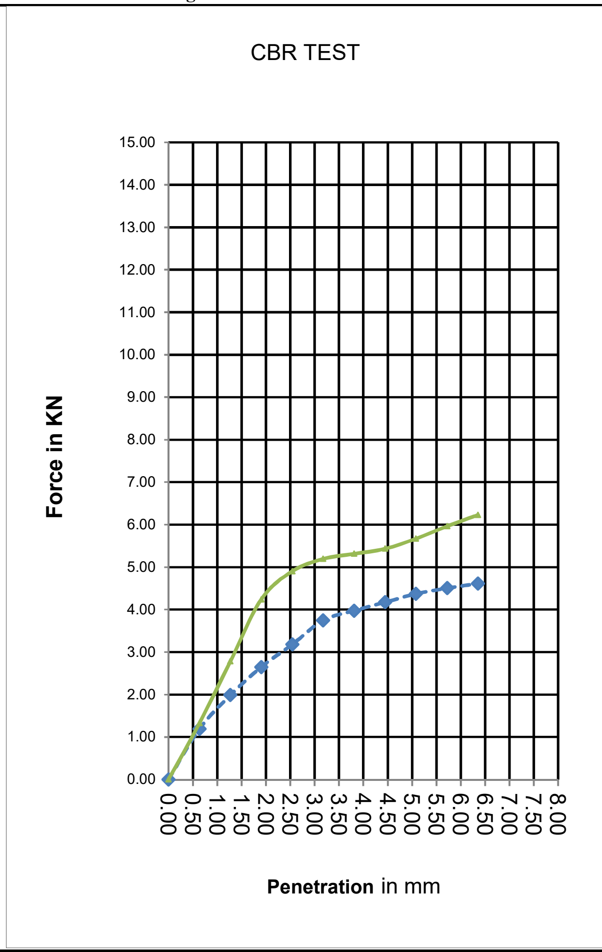
9% FCD SAMPLE 1

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	22
Difference	**(div)**	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
		MDD	1532
Type	STABILIZED	OMC	28.31
Stabilizer	FCD	NMC	14.3
%			
Swell %	0.22		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.19252	1.325			
1.27	1.98753	2.7825			
1.91	2.65004	4.2401			
2.54	3.18005	4.9026	13.2	24	37
3.18	3.74981	5.1941			
3.81	3.97506	5.3133			
4.45	4.17381	5.4326			
5.08	4.37257	5.6711	20.0	22	28
5.72	4.50507	5.9626			
6.35	4.61107	6.2276			



Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.93

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		37	24
5	20		28	22
		CBR =37%	**Checked:**	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

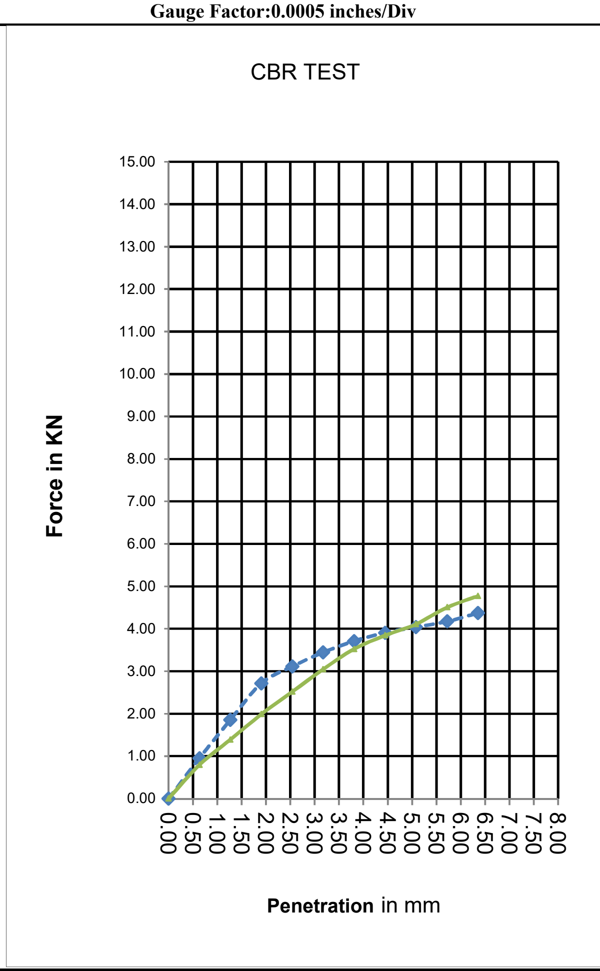
CBR TEST
(AASHTO T193:1990)

9% FCD SAMPLE 2

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA			SAMPLE DETAILS			
					MDD	1532
Initial gauge Reading	**(div)**	0	**Type**	**STABILIZED**	**OMC**	28.31
Final gauge Reading	**(div)**	22	**Stabilizer**	**FCD**	**NMC**	14.3
Difference	**(div)**	22	**%**			
Ring Factor		0.01	**Swell %**	0.22		

Gauge Factor:0.0005 inches/Div



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.95401	0.795			
1.27	1.85503	1.3913			
1.91	2.71629	1.9875			
2.54	3.1138	2.5175	13.2	24	19
3.18	3.44505	3.0475			
3.81	3.71006	3.5246			
4.45	3.90881	3.8426			
5.08	4.04131	4.1076	20.0	20	21
5.72	4.17381	4.5051			
6.35	4.37257	4.7701			

Moulding Data		
Wt.of Mould + Wet soil	**g**	
Wt. of Mould	**g**	
Moisture Content	**%**	
Wet Density	**Kg/m^3**	
Dry Density	**Kg/m^3**	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.93

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			19	24
5	20			21	20
		CBR =24%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

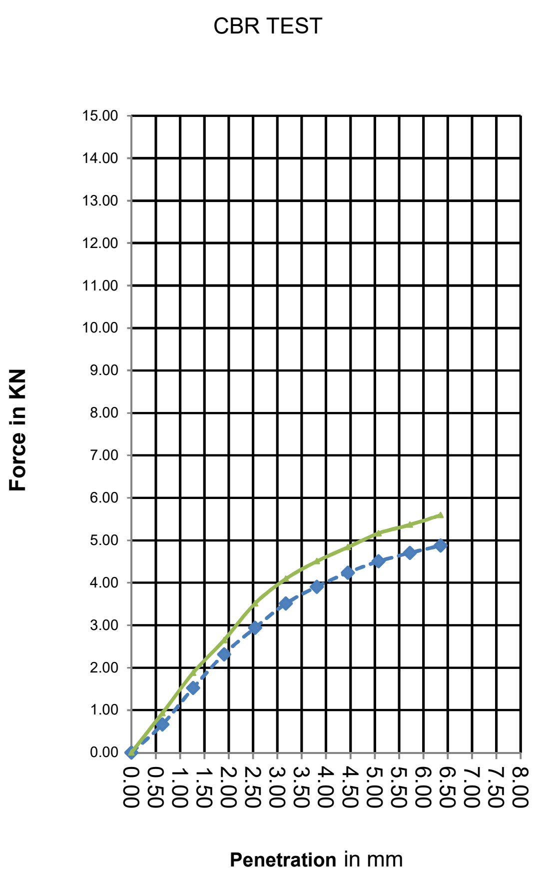
CBR TEST
(AASHTO T193:1990)

9% FCD SAMPLE 3

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	22
Difference	(div)	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1532
Stabilizer	FCD	OMC	28.31
%		NMC	14.3
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.66251	0.9275			
1.27	1.52377	1.8815			
1.91	2.31879	2.65			
2.54	2.94154	3.5113	13.2	22	27
3.18	3.5113	4.0943			
3.81	3.90881	4.5051			
4.45	4.24006	4.8363			
5.08	4.50507	5.1676	20.0	23	26
5.72	4.70382	5.3663			
6.35	4.87607	5.5916			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.93

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			27	22
5	20			26	23
		CBR =27%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

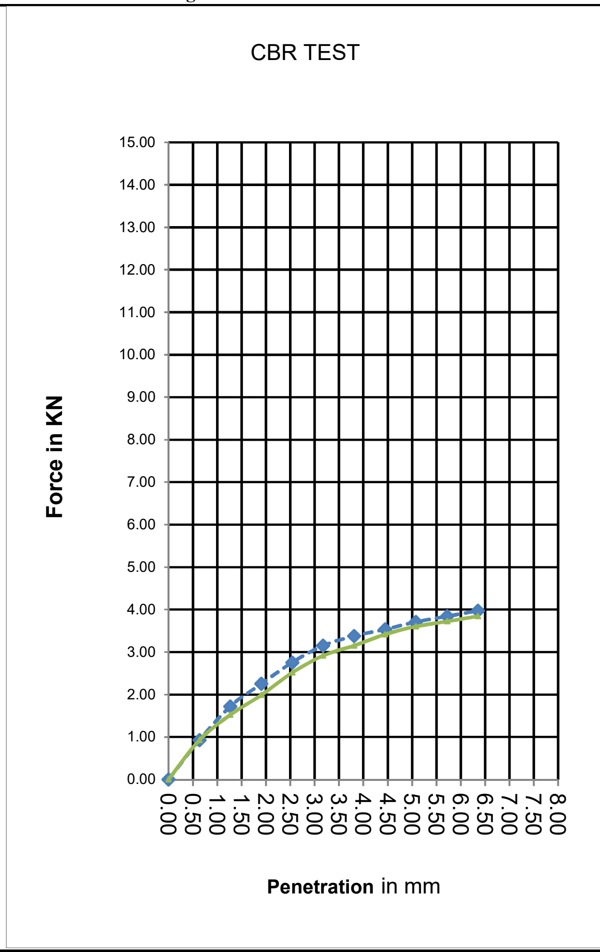
CBR TEST
(AASHTO T193:1990)

9% FCD SAMPLE 4

Project: Mechanical stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	22
Difference	(div)	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1532
Stabilizer	FCD	OMC	28.31
%		NMC	14.3
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.92751	0.9275			
1.27	1.72253	1.5238			
1.91	2.25253	1.9875			
2.54	2.75604	2.5175	13.2	21	19
3.18	3.15355	2.915			
3.81	3.3788	3.1535			
4.45	3.5378	3.4186			
5.08	3.71006	3.6041	20.0	19	18
5.72	3.84256	3.7233			
6.35	3.97506	3.8426			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.93

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			19	21
5	20			18	19
		CBR =21%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

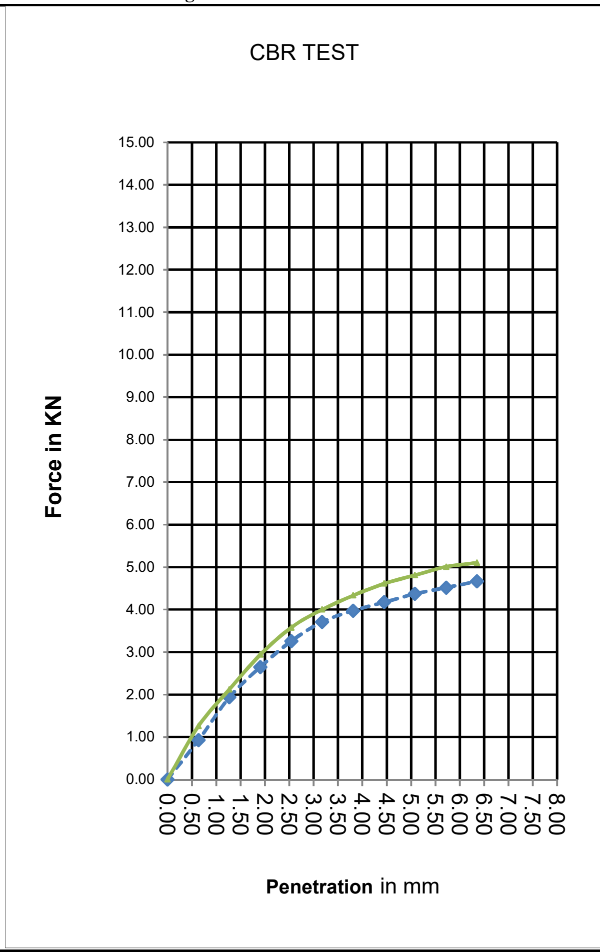
CBR TEST
(AASHTO T193:1990)

9% FCD SAMPLE 5

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA	
Initial gauge Reading (div)	0
Final gauge Reading (div)	22
Difference (div)	22
Ring Factor	0.01
Gauge Factor:0.0005 inches/Div	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1532
Stabilizer	FCD	OMC	28.31
%		NMC	14.3
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.92751	1.2588			
1.27	1.93453	2.12			
1.91	2.65004	2.9415			
2.54	3.25955	3.5776	13.2	25	27
3.18	3.71006	4.0016			
3.81	3.97506	4.3328			
4.45	4.17381	4.6111			
5.08	4.37257	4.8098	20.0	22	24
5.72	4.51832	5.0086			
6.35	4.66407	5.1013			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	227.3
Tin + Dry soil	191.2
Wt of Tin	78.1
Wt of Moisture	36.1
Wt. of dry soil	113.1
Moisture content	31.92

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			27	25
5	20			24	22
		CBR =27%		Checked:	Martin Mburu

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WORKING SHEET

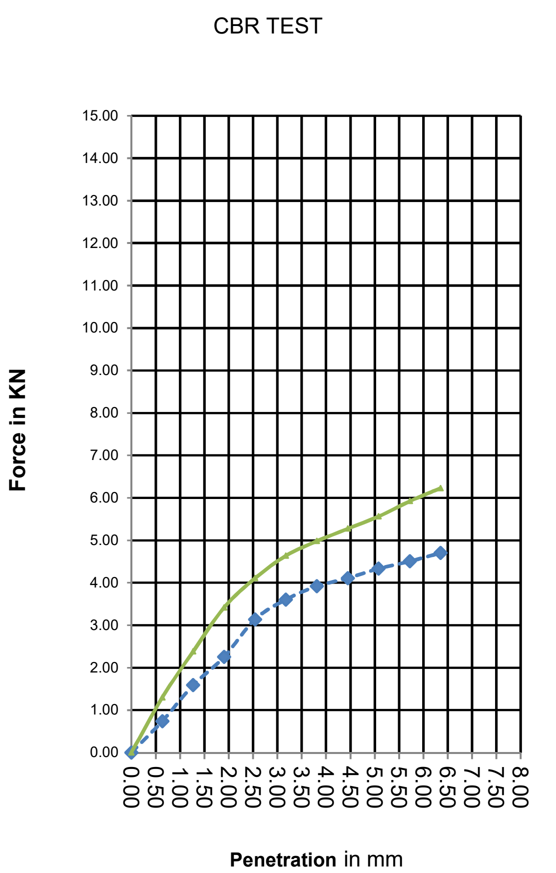
CBR TEST
(AASHTO T193:1990)

9% FCD SAMPLE 6

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Client.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA						
			SAMPLE DETAILS		**MDD**	1532
Initial gauge Reading (div)	0		**Type**	**STABILIZED**	**OMC**	28.31
Final gauge Reading (div)	22		**Stabilizer**	**FCD**	**NMC**	14.3
Difference (div)	22		**%**			
Ring Factor	0.01		**Swell %**	0.22		
Gauge Factor:0.0005 inches/Div						

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.74201	1.2985			
1.27	1.59002	2.385			
1.91	2.25253	3.4186			
2.54	3.1403	4.1076	13.2	24	31
3.18	3.60405	4.6376			
3.81	3.92206	4.9821			
4.45	4.10756	5.2736			
5.08	4.33282	5.5651	20.0	22	28
5.72	4.50507	5.9228			
6.35	4.70382	6.2276			



Moulding Data		
Wt.of Mould + Wet soil	**g**	
Wt. of Mould	**g**	
Moisture Content	**%**	
Wet Density	**Kg/m^3**	
Dry Density	**Kg/m^3**	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	227.3
Tin + Dry soil	191.2
Wt of Tin	78.1
Wt of Moisture	36.1
Wt. of dry soil	113.1
Moisture content	31.92

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		31	24
5	20		28	22
		CBR =31%	**Checked:**	Martin Mburu

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WORKING SHEET

CBR TEST

(AASHTO T193:1990)

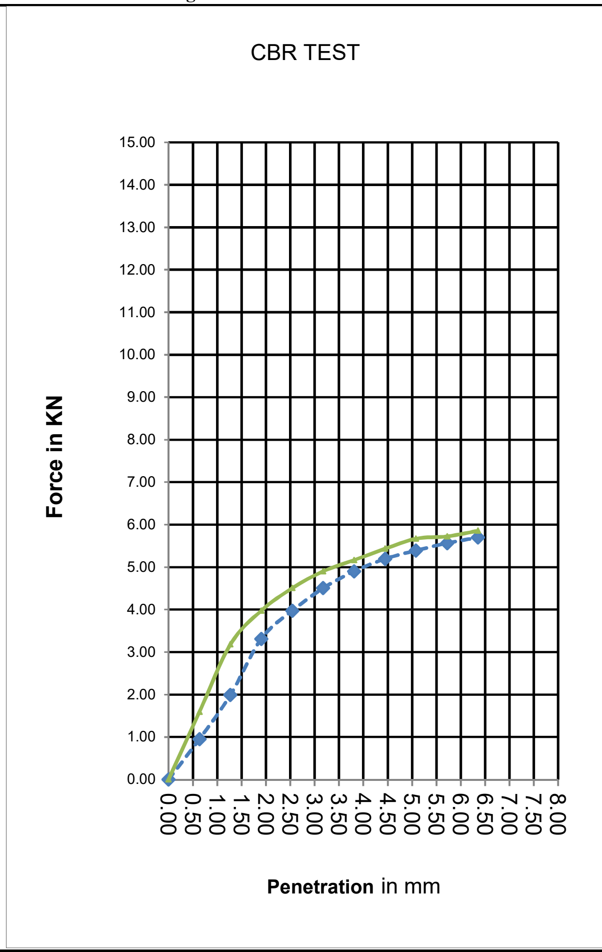
9% FCD SAMPLE 7

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 21/1/2020	**Date soaked:**	17/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	17/01/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	22
Difference	(div)	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1532
Stabilizer	FCD	OMC	28.31
%		NMC	14.3
Swell %	0.22		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.95401	1.59			
1.27	1.98753	3.18			
1.91	3.31255	3.9751			
2.54	3.97506	4.5051	13.2	30	34
3.18	4.50507	4.9026			
3.81	4.90257	5.1676			
4.45	5.19408	5.4326			
5.08	5.39283	5.6711	20.0	27	28
5.72	5.56508	5.7241			
6.35	5.69759	5.8566			



Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	201
Tin +Wet soil	227.3
Tin + Dry soil	191.2
Wt of Tin	78.1
Wt of Moisture	36.1
Wt. of dry soil	113.1
Moisture content	31.92

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		34	30
5	20		28	27
		CBR =34%	Checked:	Martin Mburu

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WORKING SHEET

CBR TEST
(AASHTO T193:1990)

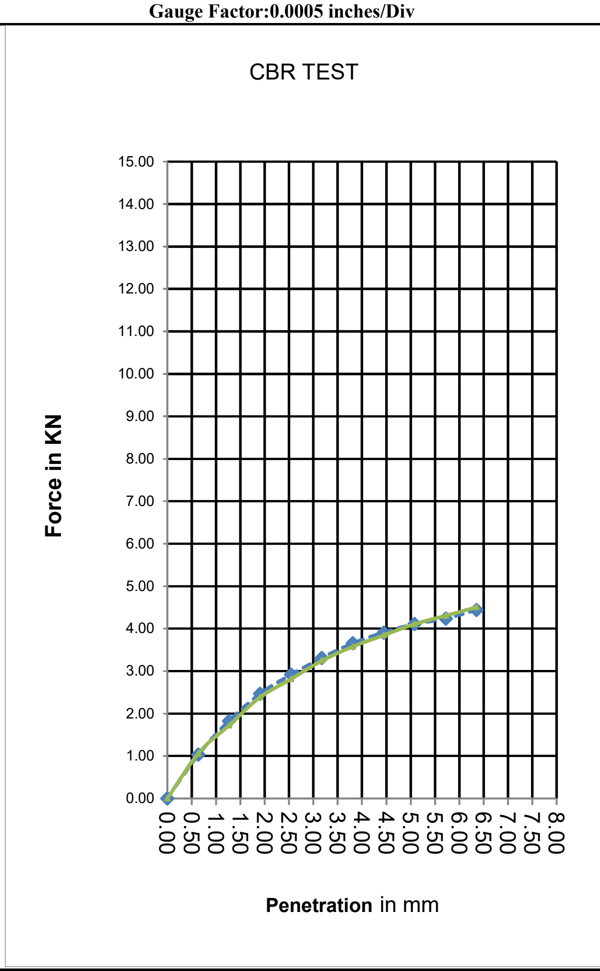
12% FCD SAMPLE 1

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 28/1/2020	**Date soaked:**	24/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/01/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	22
Difference	**(div)**	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
		MDD	1474
Type	**STABILIZED**	**OMC**	29.43
Stabilizer	**FCD**	**NMC**	9.2
%			
Swell %	0.22		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.03352	1.06			
1.27	1.82853	1.7225			
1.91	2.46454	2.385			
2.54	2.91504	2.809	13.2	22	21
3.18	3.31255	3.2463			
3.81	3.65706	3.5776			
4.45	3.90881	3.8426			
5.08	4.10756	4.1076	20.0	21	21
5.72	4.24006	4.3063			
6.35	4.43882	4.5051			



Moulding Data		
Wt.of Mould + Wet soil	**g**	
Wt. of Mould	**g**	
Moisture Content	**%**	
Wet Density	**Kg/m^3**	
Dry Density	**Kg/m^3**	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	223.8
Tin + Dry soil	187.7
Wt of Tin	78.6
Wt of Moisture	36.1
Wt. of dry soil	109.1
Moisture content	33.09

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			22	21
5	20			21	21
		CBR =22%		**Checked:**	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST
(AASHTO T193:1990)

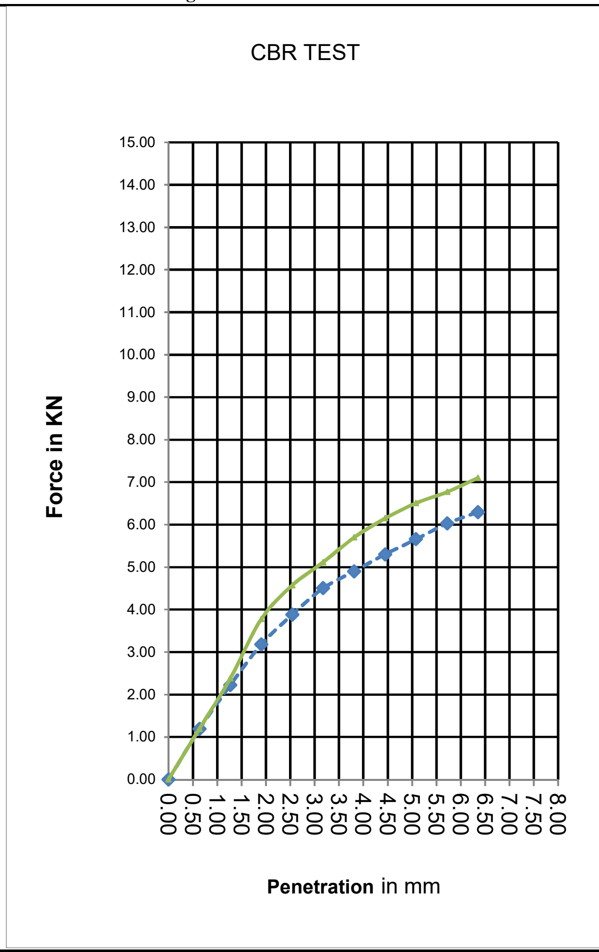
12% FCD SAMPLE 2

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 28/1/2020	**Date soaked:**	24/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/01/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	22
Difference	(div)	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1474
Stabilizer	FCD	OMC	29.43
%		NMC	9.2
Swell %	0.22		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.19252	1.1925			
1.27	2.22603	2.385			
1.91	3.18005	3.7763			
2.54	3.88231	4.5713	13.2	29	35
3.18	4.50507	5.1146			
3.81	4.90257	5.6976			
4.45	5.30008	6.1481			
5.08	5.65784	6.5058	20.0	28	33
5.72	6.02884	6.7709			
6.35	6.29385	7.1021			



Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	213
Tin +Wet soil	232
Tin + Dry soil	196.6
Wt of Tin	92.8
Wt of Moisture	35.4
Wt. of dry soil	103.8
Moisture content	34.10

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			29	35
5	20			28	33
		CBR =35%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

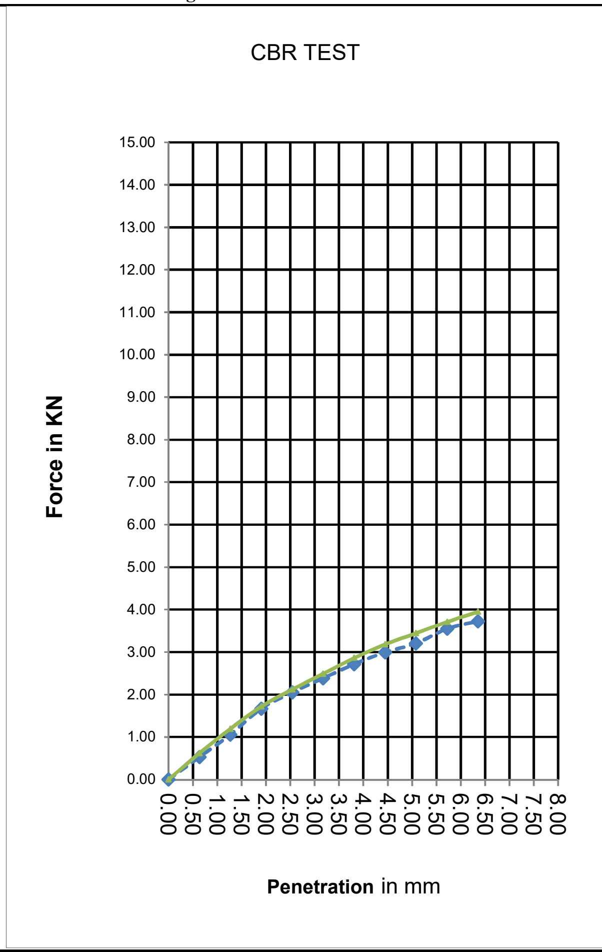
CBR TEST
(AASHTO T193:1990)

12% FCD SAMPLE 3

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 28/1/2020	**Date soaked:**	24/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/01/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	22
Difference	(div)	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1474
Stabilizer	FCD	OMC	29.43
%		NMC	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.53001	0.6228			
1.27	1.06002	1.1925			
1.91	1.66953	1.7225			
2.54	2.05378	2.12	13.2	16	16
3.18	2.38504	2.491			
3.81	2.71629	2.862			
4.45	2.99455	3.18			
5.08	3.20655	3.4451	20.0	16	17
5.72	3.55105	3.7101			
6.35	3.72331	3.9486			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	223.8
Tin + Dry soil	187.7
Wt of Tin	78.6
Wt of Moisture	36.1
Wt. of dry soil	109.1
Moisture content	33.09

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		16	16
5	20		16	17
		CBR =17%	**Checked:**	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

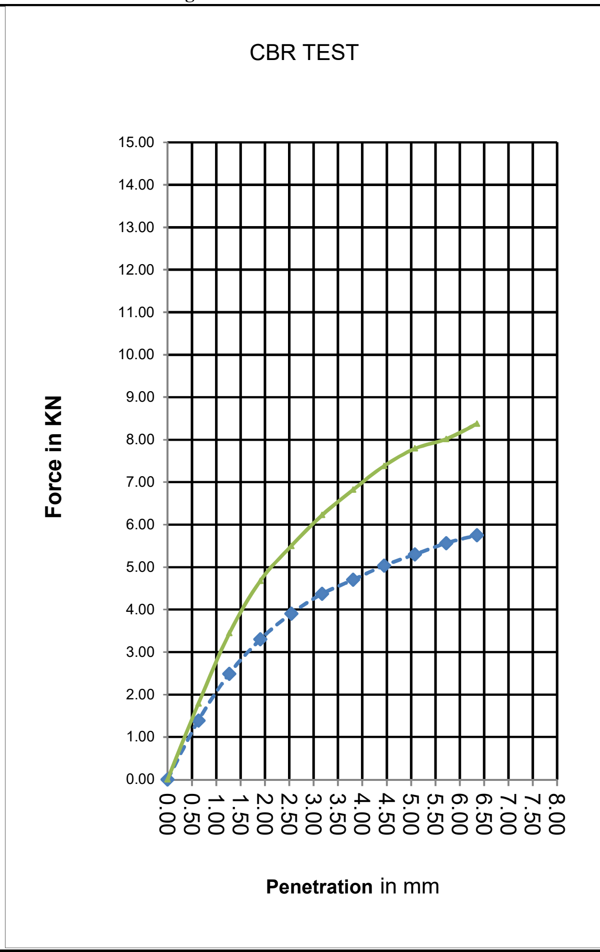
CBR TEST
(AASHTO T193:1990)

12% FCD SAMPLE 4

Project: Mechanical stabilization of Lateritic Gravel using FCD	**Tested:** 28/1/2020	**Date soaked:**	24/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/01/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	22
Difference	(div)	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1474
Stabilizer	FCD	OMC	29.43
%		NMC	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.39127	1.7888			
1.27	2.49104	3.4451			
1.91	3.2993	4.6773			
2.54	3.90881	5.4988	13.2	30	42
3.18	4.37257	6.2276			
3.81	4.70382	6.8239			
4.45	5.03508	7.3804			
5.08	5.30008	7.7911	20.0	27	39
5.72	5.56508	8.0164			
6.35	5.75059	8.3741			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	223.8
Tin + Dry soil	187.7
Wt of Tin	78.6
Wt of Moisture	36.1
Wt. of dry soil	109.1
Moisture content	33.09

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			30	42
5	20			27	39
		CBR = 42%		Checked:	Martin Mburu

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WORKING SHEET

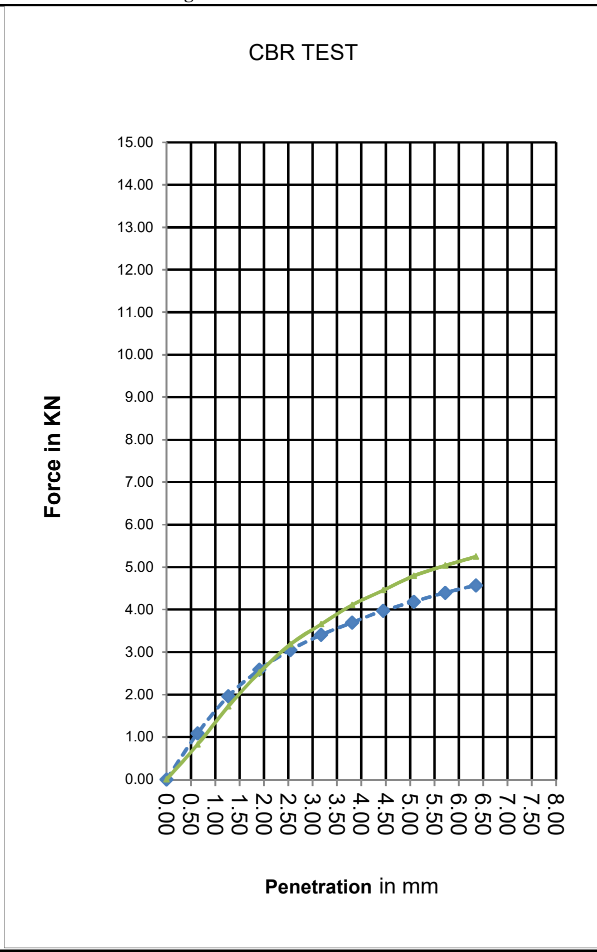
CBR TEST
(AASHTO T193:1990)

12% FCD SAMPLE 5

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 28/1/2020	**Date soaked:**	24/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/01/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	22
Difference	**(div)**	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1474
Stabilizer	FCD	OMC	29.43
%		NMC	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.08652	0.8215			
1.27	1.96103	1.7225			
1.91	2.58379	2.5175			
2.54	3.04755	3.18	13.2	23	24
3.18	3.4053	3.6571			
3.81	3.69681	4.1076			
4.45	3.97506	4.4521			
5.08	4.18706	4.7966	20.0	21	24
5.72	4.39907	5.0351			
6.35	4.57132	5.2471			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	213
Tin +Wet soil	232
Tin + Dry soil	196.6
Wt of Tin	92.8
Wt of Moisture	35.4
Wt. of dry soil	103.8
Moisture content	34.10

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			23	24
5	20			21	24
		CBR =24%		Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

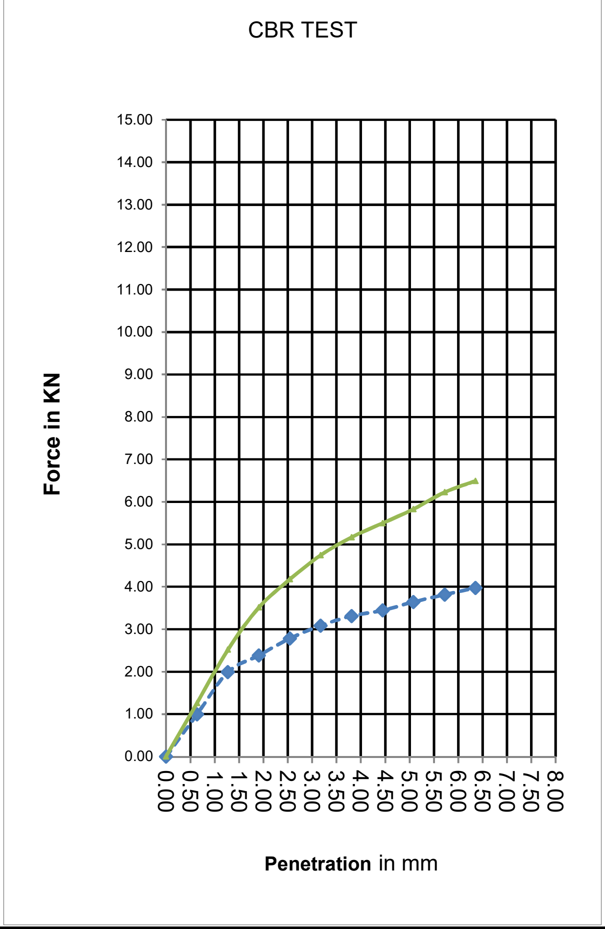
CBR TEST
(AASHTO T193:1990)

12% FCD SAMPLE 6

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 28/1/2020	**Date soaked:**	24/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/01/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	22
Difference	**(div)**	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1474
Stabilizer	FCD	OMC	29.43
%		NMC	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.99377	1.2588			
1.27	1.98753	2.5175			
1.91	2.38504	3.5113			
2.54	2.78254	4.1738	13.2	21	32
3.18	3.0873	4.7436			
3.81	3.31255	5.1676			
4.45	3.44505	5.4988			
5.08	3.64381	5.8301	20.0	18	29
5.72	3.81606	6.2276			
6.35	3.97506	6.4926			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	223.8
Tin + Dry soil	187.7
Wt of Tin	78.6
Wt of Moisture	36.1
Wt. of dry soil	109.1
Moisture content	33.09

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			32	24
5	20			28	22
		CBR =32%		**Checked:**	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

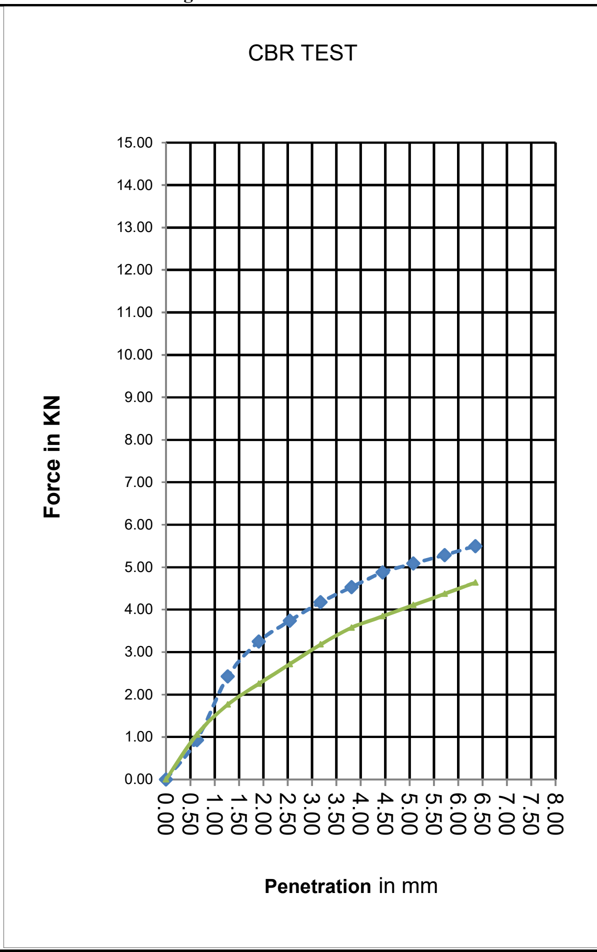
CBR TEST
(AASHTO T193:1990)

12% FCD SAMPLE 7

Project: Mechanical Stabilization of Lateritic Gravel using FCD	**Tested:** 28/1/2020	**Date soaked:**	24/01/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/01/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	22
Difference	**(div)**	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	**STABILIZED**	**MDD**	1474
Stabilizer	**FCD**	**OMC**	29.43
%		**NMC**	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.92751	1.06			
1.27	2.42479	1.7623			
1.91	3.2463	2.2525			
2.54	3.73656	2.7163	13.2	28	21
3.18	4.17381	3.18			
3.81	4.53157	3.5776			
4.45	4.87607	3.8426			
5.08	5.08808	4.1076	20.0	25	21
5.72	5.28683	4.3726			
6.35	5.49883	4.6376			

Moulding Data		
Wt.of Mould + Wet soil	**g**	
Wt. of Mould	**g**	
Moisture Content	**%**	
Wet Density	**Kg/m^3**	
Dry Density	**Kg/m^3**	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	213
Tin +Wet soil	232
Tin + Dry soil	196.6
Wt of Tin	92.8
Wt of Moisture	35.4
Wt. of dry soil	103.8
Moisture content	34.10

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		28	21
5	20		25	21
		CBR =28%	**Checked:**	Martin Mburu

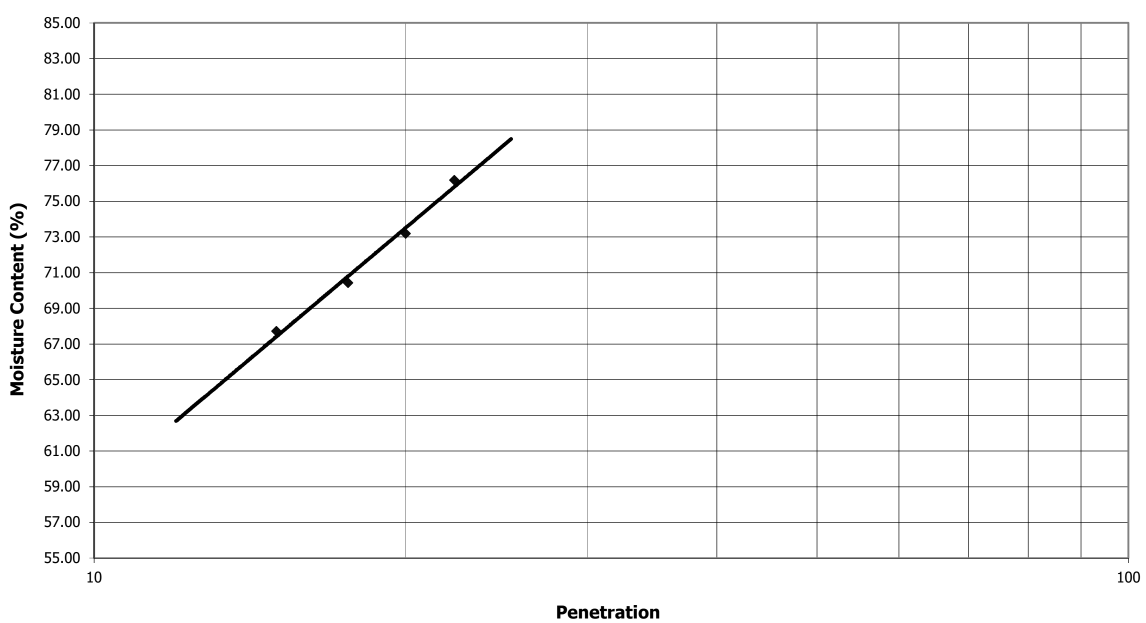
Appendix D4 Atterberg Limits

Plasticity Indices

PROJECT	Mechanical Stabilization of Lateritic Gravel using FCD				
STUDENT	Anthony mugendi Nyagah				
DEPTH		Sample No	3% STAB	Sample time	
Test date	03-Jan-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		**15**	**26**	**38**	**8**	**7F**	**2B**
Penetration (mm)		**15**	**17.6**	**20**	**22.3**		
Wt of Container + Wet Soil (g)		**50.5**	**62.3**	**72**	**83.7**	**16**	**16**
Wt of Container + Dry Soil (g)		**41.9**	**49.2**	**53.7**	**59.7**	**14.1**	**14.1**
Wt of Container (g)		**29.2**	**30.6**	**28.7**	**28.2**	**9**	**9**
Wt of Moistuer (g)		**8.6**	**13.1**	**18.3**	**24**	**1.9**	**1.9**
Wt of Dry Soil (g)		**12.7**	**18.6**	**25**	**31.5**	**5.1**	**5.1**
Moisture Content (%)		**67.72**	**70.43**	**73.20**	**76.19**	**37.25**	**37.25**

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	116
		No 2	140		**No 2**	116



Liquid Limit	**73**
Plastic Limit	**37**
Plasticity Index	**36**
Linear Shrinkage (%)	**17**

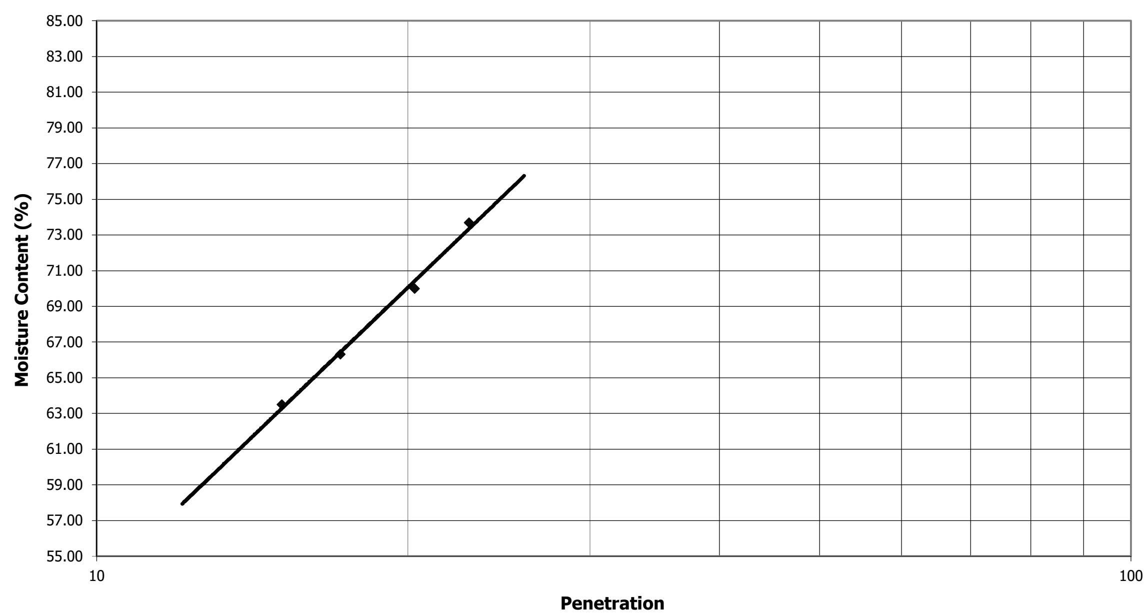
Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	06-Jan-20		
Observations:			
Conform to the specifications			

Plasticity Indices

PROJECT	Mechanical stabilization of Lateritic Gravel using FCD				
STUDENT	Anthony Mugendi Nyagah				
DEPTH		Sample No	6% STAB	Sample time	
Test date	20-Feb-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		**10**	**17**	**13**	**7**	**AA**	**R**
Penetration (mm)		**15.1**	**17.2**	**20.3**	**22.9**		
Wt of Container + Wet Soil (g)		**50.1**	**59.2**	**70**	**90.4**	**15.2**	**15.2**
Wt of Container + Dry Soil (g)		**42.1**	**46.8**	**53.2**	**63.8**	**13.6**	**13.6**
Wt of Container (g)		**29.5**	**28.1**	**29.2**	**27.7**	**9.2**	**9.3**
Wt of Moistuer (g)		**8**	**12.4**	**16.8**	**26.6**	**1.6**	**1.6**
Wt of Dry Soil (g)		**12.6**	**18.7**	**24**	**36.1**	**4.4**	**4.3**
Moisture Content (%)		**63.49**	**66.31**	**70.00**	**73.68**	**36.36**	**37.21**

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	116
		No 2	140		**No 2**	116



Liquid Limit	**70**
Plastic Limit	**37**
Plasticity Index	**33**
Linear Shrinkage (%)	**17**

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	21-Feb-20		
Observations:			

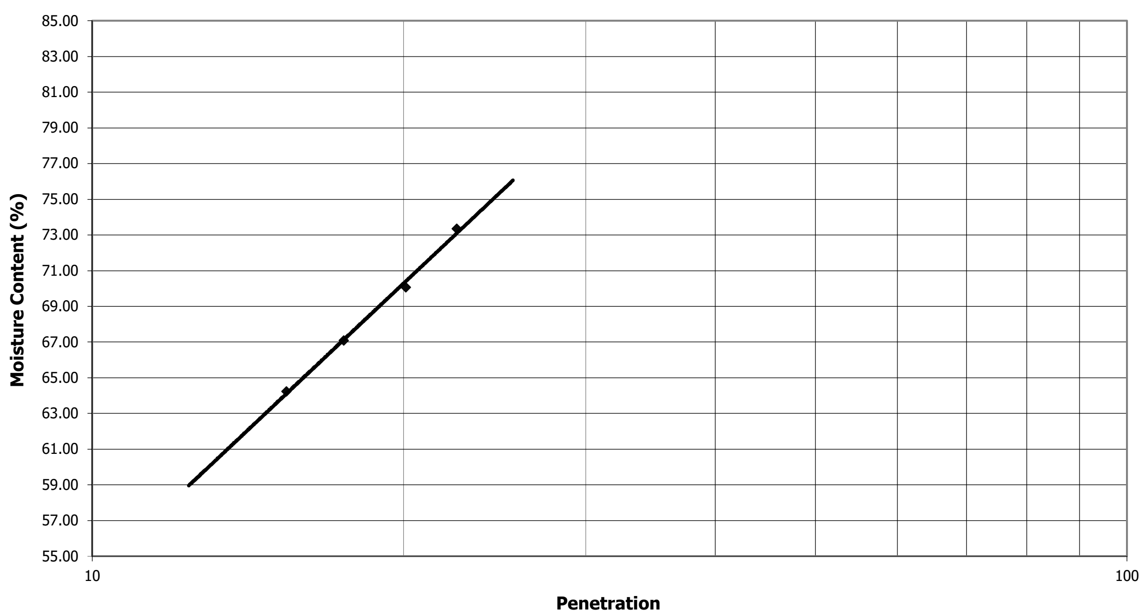
Conform to the specifications

Plasticity Indices

PROJECT	Mechanical Stabilization of Lateritic Gravel using FCD				
STUDENT	Anthony Mugendi Nyagah				
DEPTH		Sample No	9% STAB	Sample time	
Test date	20-Feb-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		**11**	**27**	**32**	**46**	**K2**	**13**
Penetration (mm)		**15.4**	**17.5**	**20.1**	**22.5**		
Wt of Container + Wet Soil (g)		**53.9**	**65.9**	**78**	**87.1**	**14.8**	**14.8**
Wt of Container + Dry Soil (g)		**44.2**	**50**	**58.1**	**62.6**	**13.2**	**13.1**
Wt of Container (g)		**29.1**	**26.3**	**29.7**	**29.2**	**9.2**	**8.9**
Wt of Moistuer (g)		**9.7**	**15.9**	**19.9**	**24.5**	**1.6**	**1.7**
Wt of Dry Soil (g)		**15.1**	**23.7**	**28.4**	**33.4**	**4**	**4.2**
Moisture Content (%)		**64.24**	**67.09**	**70.07**	**73.35**	**40.00**	**40.48**

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	120
		No 2	140		**No 2**	120



Liquid Limit	**70**
Plastic Limit	**40**
Plasticity Index	**30**
Linear Shrinkage (%)	**14**

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	21-Feb-20		
Observations:			

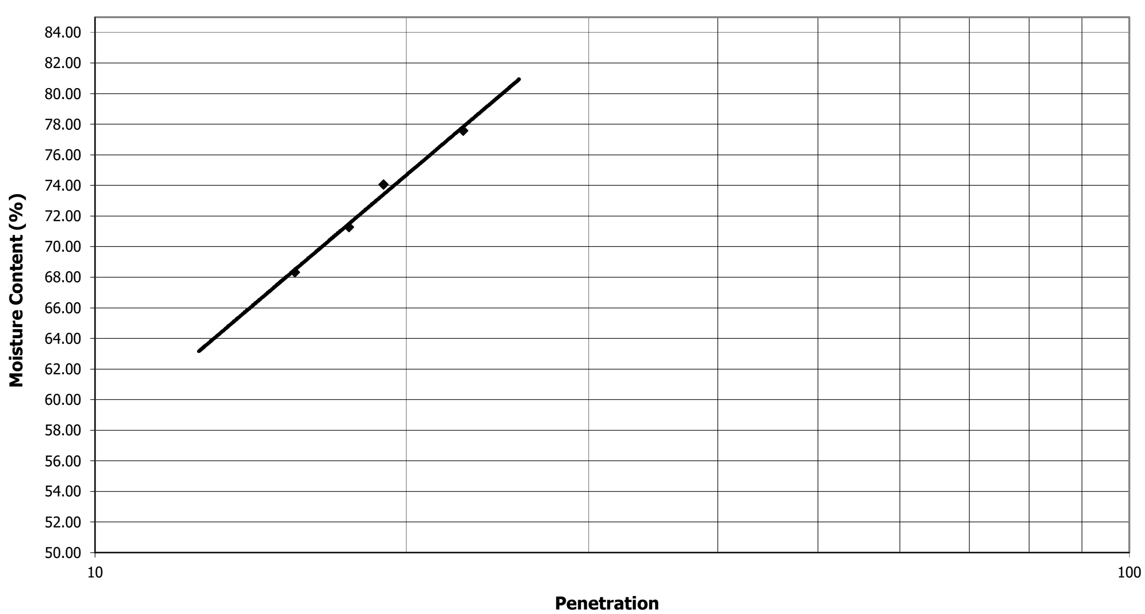
Conform to the specifications

Plasticity Indices

PROJECT	Mechanical Stabilization of Latertic Gravel using FCD				
STUDENT	Anthony Mugendi Nyagah				
DEPTH		Sample No	12% STAB	Sample time	
Test date	20-Feb-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		**2**	**30**	**33**	**24**	**DD**	**Q**
Penetration (mm)		**15.6**	**17.6**	**19**	**22.7**		
Wt of Container + Wet Soil (g)		**48.1**	**59.8**	**70.3**	**87.7**	**15.3**	**15.3**
Wt of Container + Dry Soil (g)		**39.9**	**45.9**	**52.6**	**62.1**	**13.6**	**13.6**
Wt of Container (g)		**27.9**	**26.4**	**28.7**	**29.1**	**9.5**	**9.3**
Wt of Moistuer (g)		**8.2**	**13.9**	**17.7**	**25.6**	**1.7**	**1.7**
Wt of Dry Soil (g)		**12**	**19.5**	**23.9**	**33**	**4.1**	**4.3**
Moisture Content (%)		**68.33**	**71.28**	**74.06**	**77.58**	**41.46**	**39.53**

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	122
		No 2	140		**No 2**	122



Liquid Limit	**74**
Plastic Limit	**40**
Plasticity Index	**34**
Linear Shrinkage (%)	**13**

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	21-Feb-20		
Observations:			

Conform to the specifications

Appendix D5 Grading

UNIVERSITY OF NAIROBI
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

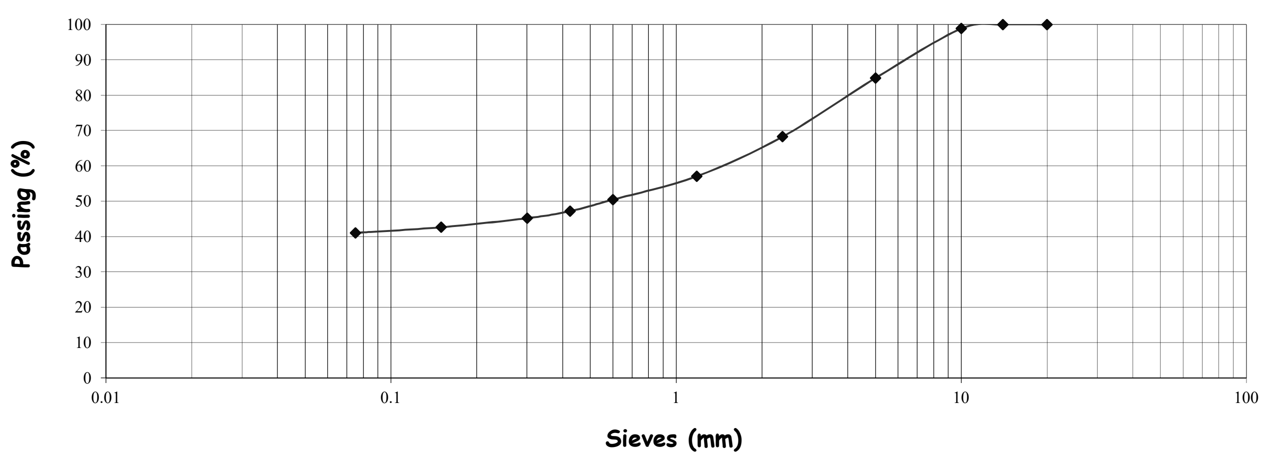
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley Quarry, Kiambu County (Lateritic Gravel) Upper Kabete Campus (Dairy Farm) UoN (FCD)**				
Depth (m)		**SAMPLE No.**	**3% FCD**	**Sr. No.**	
Test date:	30-Jan-20	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**FCD Mechanical Stabilized Sample**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	82.1
Washed dry sample mass + pan	(gm)		Fine percent	(%)	41.1
Washed dry sample mass	(gm)	117.9	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria Min(%)	Acceptance Criteria Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	2.3	**1.2**	**98.9**		
5	28	**14.0**	**84.9**		
2.36	33.2	**16.6**	**68.3**		
1.18	22.4	**11.2**	**57.1**		
0.6	13.2	**6.6**	**50.5**		
0.425	6.5	**3.3**	**47.2**		
0.3	4	**2.0**	**45.2**		
0.15	5.1	**2.6**	**42.7**		
0.075	3.2	**1.6**	**41.1**		
	82.1	**41.1**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Martin Mburu**		
Date	30-Jan-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

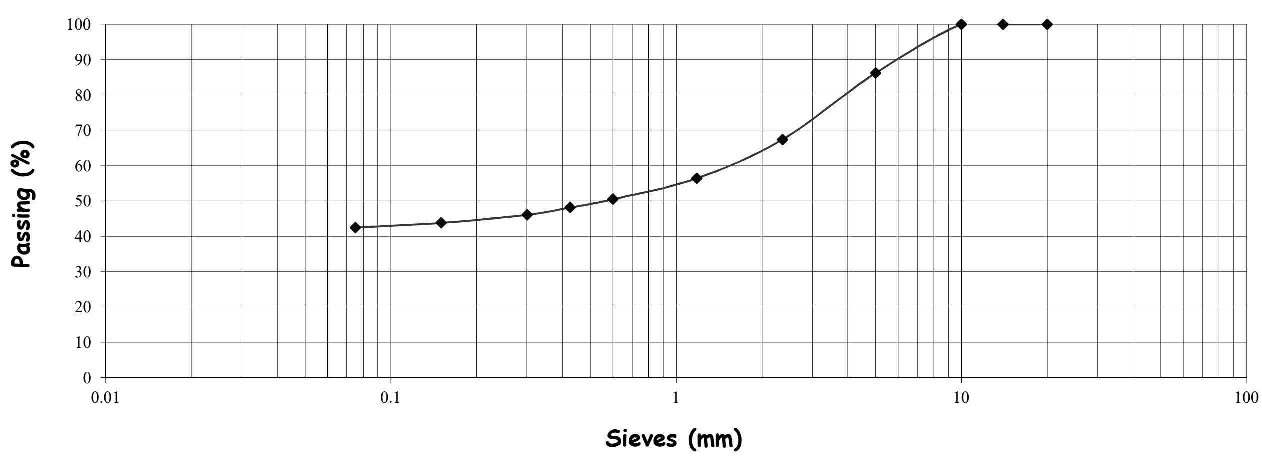
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley Quarry, Kiambu County (Lateritic Gravel) Upper Kabete Campus (Dairy Farm) UoN (FCD)**				
Depth (m)		**SAMPLE No.**	**6% FCD**	**Sr. No.**	
Test date:	24-Jan-20	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**FCD Mechanical Stabilized Sample**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	85
Washed dry sample mass + pan	(gm)		Fine percent	(%)	42.5
Washed dry sample mass	(gm)	115	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria Min(%)	Acceptance Criteria Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	0	**0.0**	**100.0**		
5	27.6	**13.8**	**86.2**		
2.36	37.6	**18.8**	**67.4**		
1.18	22	**11.0**	**56.4**		
0.6	11.8	**5.9**	**50.5**		
0.425	4.7	**2.4**	**48.2**		
0.3	4.1	**2.1**	**46.1**		
0.15	4.6	**2.3**	**43.8**		
0.075	2.6	**1.3**	**42.5**		
	85	**42.5**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Martin Mburu**		
Date	24-Jan-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

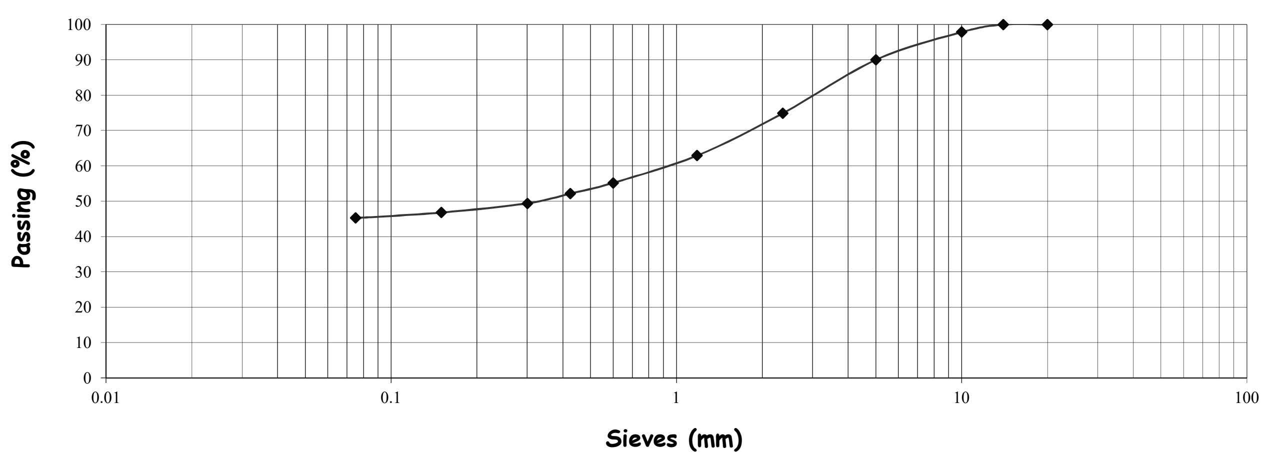
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**		
Sample source	**Membley Quarry, Kiambu County (Lateritic Gravel) Upper Kabete Campus (Dairy Farm) UoN (FCD)**		
Depth (m)	**SAMPLE No.** **9% FCD**	**Sr. No.**	
Test date:	03-Jan-20	**Location:**	
Specification	According to BS 1377:1990.	**Sample Description:**	**FCD Mechanical Stabilized Sample**

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	90.5
Washed dry sample mass + pan	(gm)		Fine percent	(%)	45.3
Washed dry sample mass	(gm)	109.5	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria Min(%)	Acceptance Criteria Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	4.3	**2.2**	**97.9**		
5	15.7	**7.9**	**90.0**		
2.36	30.2	**15.1**	**74.9**		
1.18	24	**12.0**	**62.9**		
0.6	15.4	**7.7**	**55.2**		
0.425	6	**3.0**	**52.2**		
0.3	5.6	**2.8**	**49.4**		
0.15	5.2	**2.6**	**46.8**		
0.075	3.1	**1.6**	**45.3**		
	90.5	**45.3**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Martin Mburu**		
Date	03-Jan-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

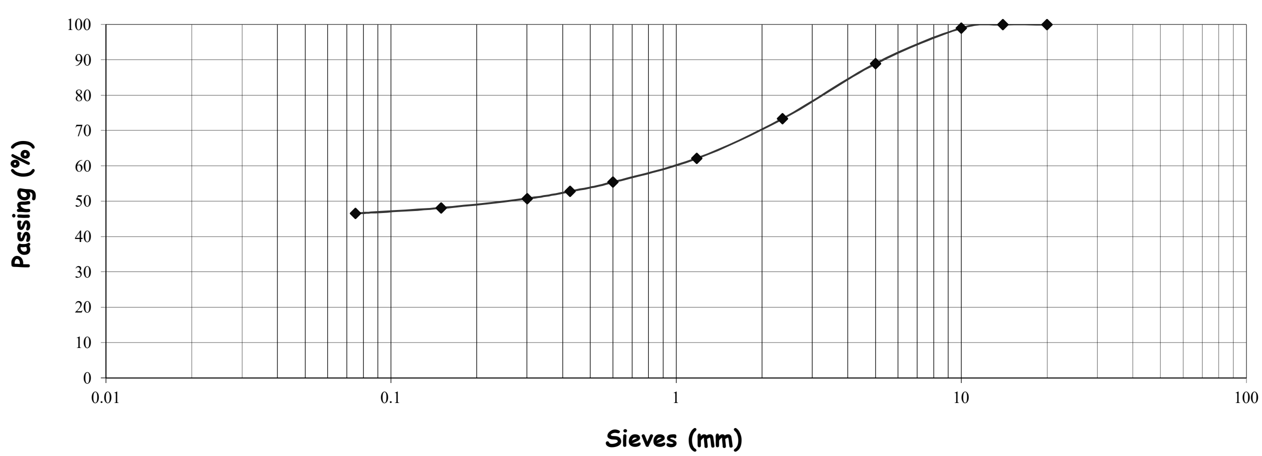
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**
Sample source	**Membley Quarry, Kiambu County (Lateritic Gravel) Upper Kabete Campus (Dairy Farm) UoN**
Depth (m)	**SAMPLE No.** **12% FCD** **Sr. No.**
Test date:	24-Jan-20 **Location:**
Specification	According to BS 1377:1990. **Sample Description:** **FCD Mechanical Stabilized Sample**

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	93.1
Washed dry sample mass + pan	(gm)		Fine percent	(%)	46.6
Washed dry sample mass	(gm)	106.9	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	2	**1.0**	**99.0**		
5	20.1	**10.1**	**89.0**		
2.36	31.2	**15.6**	**73.4**		
1.18	22.5	**11.3**	**62.1**		
0.6	13.4	**6.7**	**55.4**		
0.425	5.2	**2.6**	**52.8**		
0.3	4.1	**2.1**	**50.8**		
0.15	5.3	**2.7**	**48.1**		
0.075	3.1	**1.6**	**46.6**		
	93.1	**46.6**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Martin Mburu**		
Date	24-Jan-20				

Observations:

Conform to the specifications

Summary of FCD Stabilized Results

Compaction Properties

Stabilized Material	MDD (kg/m^3)	OMC (%)
3% FCD Stabilized	1613	25.25
6% FCD Stabilized	1553	26.39
9% FCD Stabilized	1532	28.31
12% FCD Stabilized	1474	29.50

Strength Properties UCS (kN/m^2)

FCD	Sample1	Sample2	Sample3	Sample4	Sample5	Sample6	Sample7	Average
3%	~~123~~	241	248	~~211~~	~~207~~	~~223~~	~~218~~	245
6%	317	288	~~187~~	~~245~~	~~192~~	296	~~274~~	300
9%	~~318~~	251	268	~~206~~	~~213~~	~~235~~	283	267
12%	240	~~157~~	~~155~~	186	~~177~~	213	~~205~~	213

Strength Properties CBR (%)

FCD	Sample1	Sample2	Sample3	Sample4	Sample5	Sample6	Sample7	Average
3%	21	22	21	~~16~~	20	23	~~17~~	22
6%	53	~~44~~	~~48~~	53	~~44~~	~~43~~	56	54
9%	37	~~24~~	~~27~~	~~21~~	~~27~~	31	34	34
12%	22	~~35~~	~~17~~	~~42~~	24	~~32~~	28	25

Atterberg Limits

FCD	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
3%	73	37	36	17
6%	70	37	33	17
9%	70	40	30	14
12%	74	40	34	13

Grading

FCD	% of fines
3%	41.1
6%	42.5
9%	45.3
12%	46.6

Appendix E CDA Stabilized Samples

Appendix E1 Compaction Properties (MDD & OMC)

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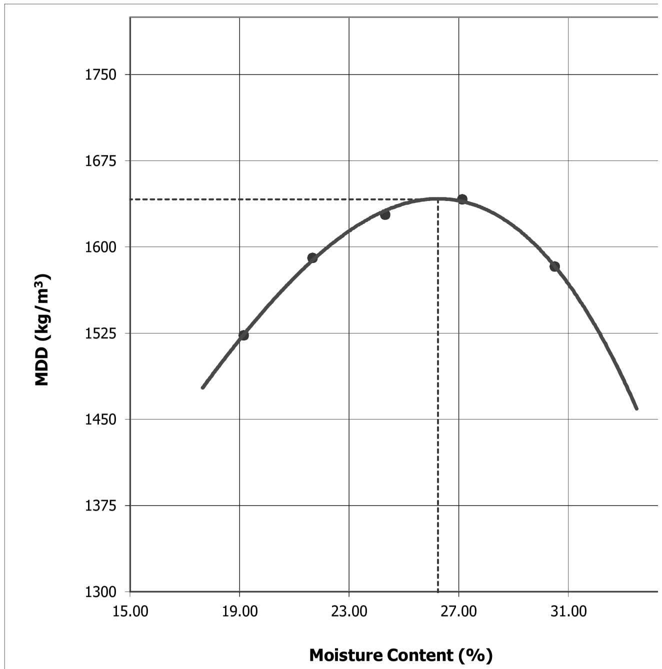
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

Moisture - Density

Sample Type	**Chemical stabilization of the Lateritic Gravel**			
Sample source	**Membley Quarry,Kiambu County (Natural Gravel)&Upper Kabete Campus (Dairy farm) UON (CDA)**			
Sample Date	**10-Mar-20**	**Sample No**	**Depth**	
Test date	**10-Mar-20**	**Sample Description**	**3% CDA**	
Specification	In accordance with BS 1377: 1990			

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**		
Test No	NMC	1	2	3	4	5
Wt of mould + wet material (g)		6435	6550	6635	6695	6675
Wt wet material (g)		1735	1850	1935	1995	1975
Wet density (kg/m³)		1815	1935	2024	2087	2066
Moisture content						
Container No	195	223	197	204	184	216
Wt of container + wet material (g)	244.10	135.70	151.70	164.70	150.60	163.50
Wt of container (g)	78.60	79.70	78.10	79.80	78.90	79.20
Wt of container + dry material (g)	223.20	126.70	138.60	148.10	135.30	143.80
Wt dry material (g)	144.60	47.00	60.50	68.30	56.40	64.60
Wt of moisture (g)	20.90	9.00	13.10	16.60	15.30	19.70
Moisture content (%)	14.45	19.15	21.65	24.30	27.13	30.50
Dry density (kg/m³)		1523	1591	1628	1642	1583



Optimum Moisture Content (%)	**26.2**
Maximum Dry Density (kg/m³)	**1642**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	11-Mar-20		
Observations:			
Conform to the specifications			

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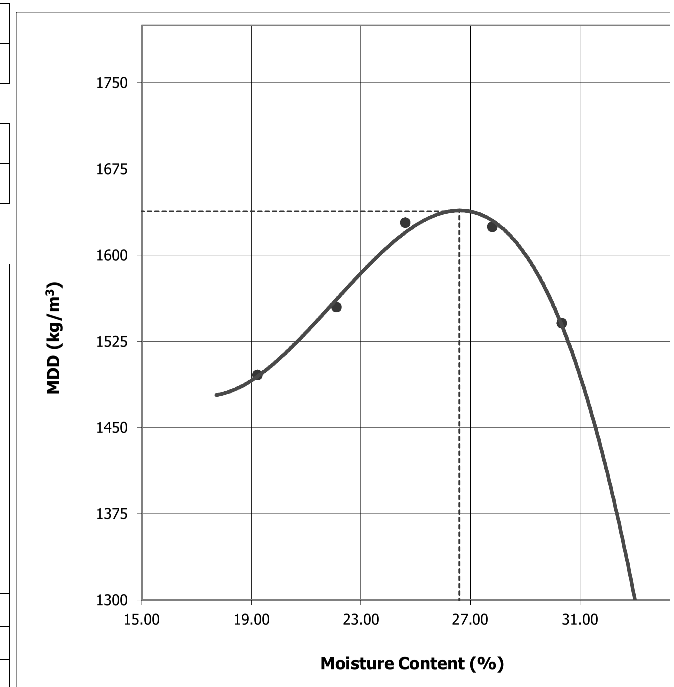
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

Moisture - Density

Sample Type	**Chemical Stabilization of the Lateritic Gravel**			
Sample source	**Membley Quarry, Kiambu County (Natural Gravel) & Upper Kabete Campus (Dairy Farm) UON (CDA)**			
Sample Date	**10-Mar-20**	**Sample No**	**Depth**	
Test date	**10-Mar-20**	**Sample Description**	**6% CDA**	
Specification	In accordance with BS 1377: 1990			

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**			
Test No	NMC	1	2	3	4	5	
Wt of mould + wet material (g)		6405	6515	6640	6685	6620	
Wt wet material (g)		1705	1815	1940	1985	1920	
Wet density (kg/m^3)		1783	1899	2029	2076	2008	
Moisture content							
Container No	195	62	222	183	107	198	
Wt of container + wet material (g)	244.10	164.80	153.80	168.10	169.80	161.50	
Wt of container (g)	78.60	94.70	79.20	79.00	95.30	85.00	
Wt of container + dry material (g)	223.20	153.50	140.30	150.50	153.60	143.70	
Wt dry material (g)	144.60	58.80	61.10	71.50	58.30	58.70	
Wt of moisture (g)	20.90	11.30	13.50	17.60	16.20	17.80	
Moisture content (%)	14.45	19.22	22.09	24.62	27.79	30.32	
Dry density (kg/m^3)		1496	1555	1628	1625	1541	



Optimum Moisture Content (%)	**26.6**
Maximum Dry Density (kg/m^3)	**1638**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	11-Mar-20		
Observations:			
Conform to the specifications			

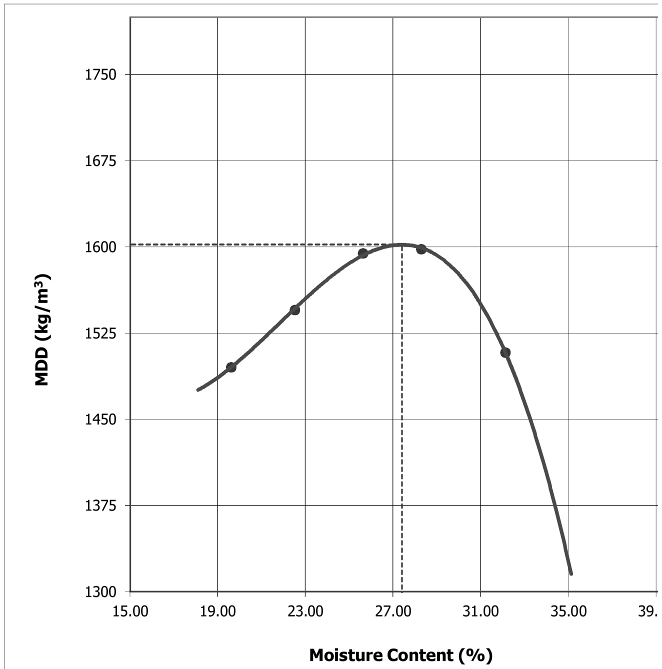
UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

Moisture - Density

Sample Type	**Chemical Stabilization of Lateritic Gravel**		
Sample source	**Membley Quarry, kiambu County (Natural Gravel) & Upper Kabete Campus (Dairy Farm) UON (CDA)**		
Sample Date	**10-Mar-20**	**Sample No**	**Depth**
Test date	**10-Mar-20**	**Sample Description**	**9% CDA**
Specification	In accordance with BS 1377: 1990		

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**		
Test No	NMC	1	2	3	4	5
Wt of mould + wet material (g)		6410	6510	6615	6660	6605
Wt wet material (g)		1710	1810	1915	1960	1905
Wet density (kg/m^3)		1789	1893	2003	2050	1993
Moisture content						
Container No	195	208	201	181	58	63
Wt of container + wet material (g)	244.10	157.50	161.00	149.40	169.10	173.60
Wt of container (g)	78.60	78.80	78.30	79.80	93.80	93.00
Wt of container + dry material (g)	223.20	144.60	145.80	135.20	152.50	154.00
Wt dry material (g)	144.60	65.80	67.50	55.40	58.70	61.00
Wt of moisture (g)	20.90	12.90	15.20	14.20	16.60	19.60
Moisture content (%)	14.45	19.60	22.52	25.63	28.28	32.13
Dry density (kg/m^3)		1496	1545	1594	1598	1508



Optimum Moisture Content (%)	**27.4**
Maximum Dry Density (kg/m^3)	**1602**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	11-Mar-20		
Observations:			
Conform to the specifications			

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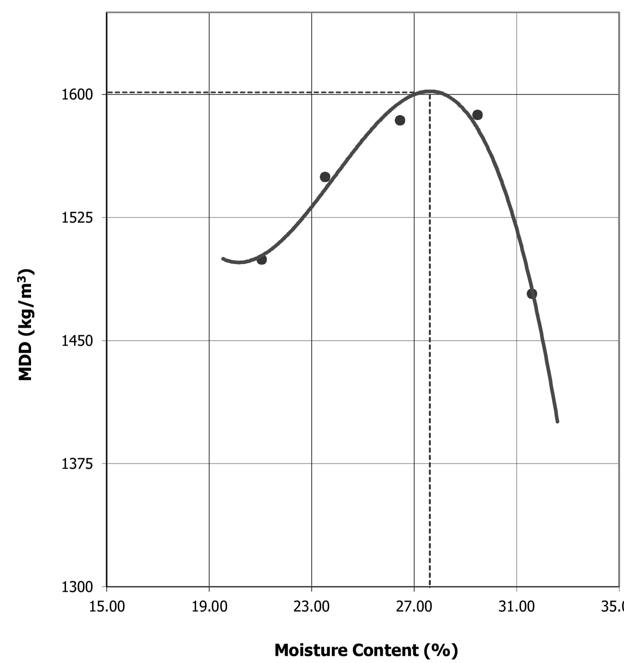
Moisture - Density

Sample Type	**Chemical Stabilization of the Lateritic Gravel**		
Sample source	**Membley Quarry, Kiambu County (Natural Gravel) & Upper Kabete Campus (Dairy Farm) UON (CDA)**		
Sample Date	**10-Mar-20**	**Sample No**	**Depth**
Test date	**10-Mar-20**	**Sample Description**	**12% CDA**
Specification	In accordance with BS 1377: 1990		

Wt of Mould (g)	**4700**	**Volume of Mould (l)**	**0.956**			
Test No	NMC	1	2	3	4	5
Wt of mould + wet material (g)		6435	6530	6615	6665	6560
Wt wet material (g)		1735	1830	1915	1965	1860
Wet density (kg/m³)		1815	1914	2003	2055	1946
Moisture content						
Container No	195	98	106	133	165	171
Wt of container + wet material (g)	244.10	196.70	199.10	221.70	197.30	230.80
Wt of container (g)	78.60	110.40	111.40	109.80	108.10	110.00
Wt of container + dry material (g)	223.20	181.70	182.40	198.30	177.00	201.80
Wt dry material (g)	144.60	71.30	71.00	88.50	68.90	91.80
Wt of moisture (g)	20.90	15.00	16.70	23.40	20.30	29.00
Moisture content (%)	14.45	21.04	23.52	26.44	29.46	31.59
Dry density (kg/m³)		1499	1550	1584	1588	1479



Optimum Moisture Content (%)	**27.6**
Maximum Dry Density (kg/m³)	**1601**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	11-Mar-20		
Observations:			
Conform to the specifications			

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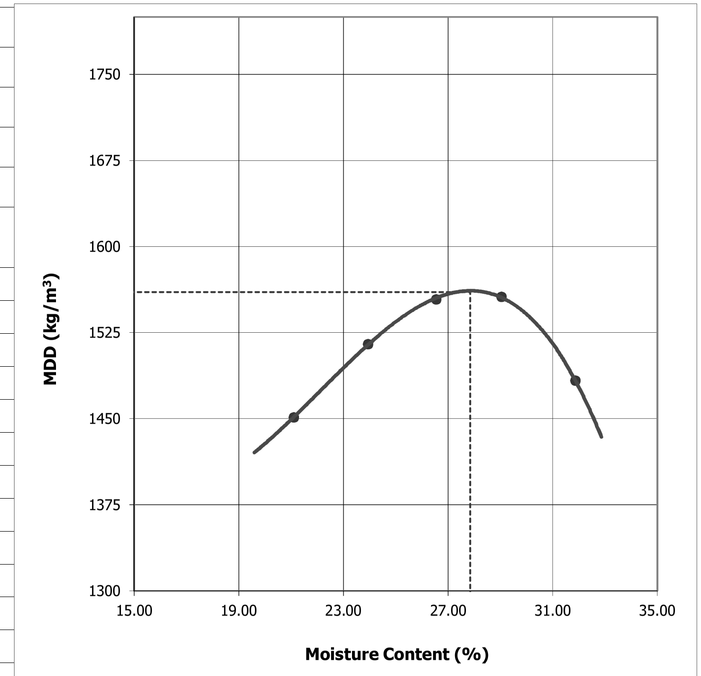
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

Moisture - Density

Sample Type	**Chemical Stabilization of the Lateritic Gravel**		
Sample source	**Membley Quarry,Kiambu County (Natural Gravel) & Upper Kabete Campus (Dairy Farm) UON (CDA)**		
Sample Date	**10-Mar-20**	**Sample No**	**Depth**
Test date	**10-Mar-20**	**Sample Description**	**15% CDA**
Specification	In accordance with BS 1377: 1990		

Wt of Mould (g)	**4700**	**Volume of Mould (l)**		**0.956**		
Test No	NMC	1	2	3	4	5
Wt of mould + wet material (g)		6380	6495	6580	6620	6570
Wt wet material (g)		1680	1795	1880	1920	1870
Wet density (kg/m^3)		1757	1878	1967	2008	1956
Moisture content						
Container No	195	151	50	161	134	146
Wt of container + wet material (g)	244.10	197.50	203.00	214.10	221.10	199.40
Wt of container (g)	78.60	109.10	92.70	105.90	103.80	106.70
Wt of container + dry material (g)	223.20	182.10	181.70	191.40	194.70	177.00
Wt dry material (g)	144.60	73.00	89.00	85.50	90.90	70.30
Wt of moisture (g)	20.90	15.40	21.30	22.70	26.40	22.40
Moisture content (%)	14.45	21.10	23.93	26.55	29.04	31.86
Dry density (kg/m^3)		1451	1515	1554	1556	1483



Optimum Moisture Content (%)	**27.8**
Maximum Dry Density (kg/m^3)	**1560**

Technician	Mathew Mburu	Verified :	**Martin Mburu**
Date	11-Mar-20		
Observations:			
Conform to the specifications			

Appendix E2 Strength Properties (UCS)

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

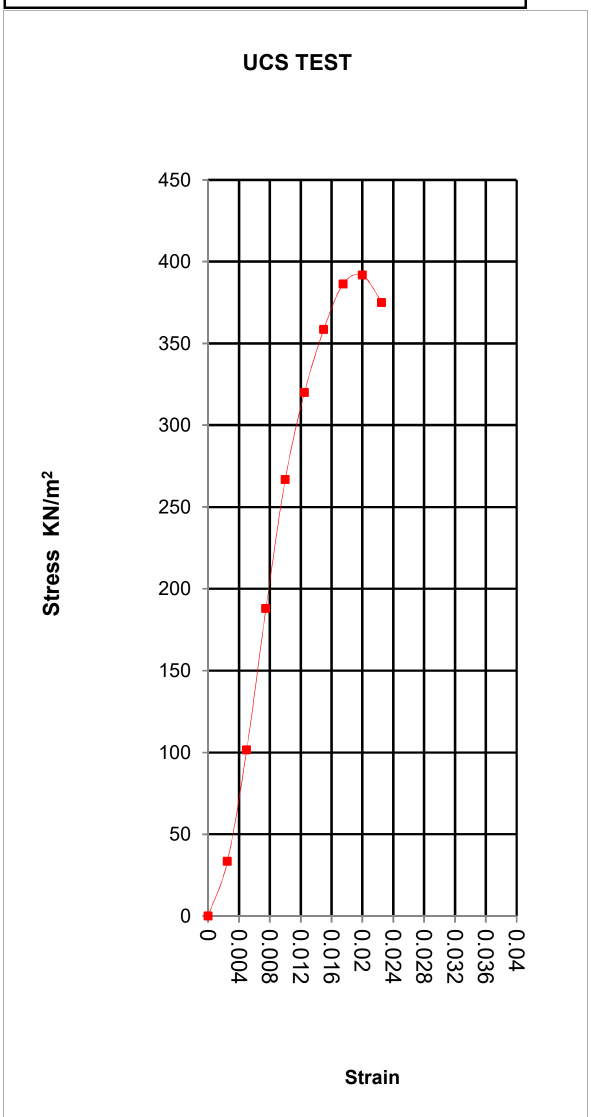
UCS TEST

SPECIMEN 1

Project: Chemical Stabilization of Lateritic Gravel	**Date: 21-Sept-2020**	**No. of days cured:**	7
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = CDA	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1642
Stabilizer	3% CDA	OMC	26.2
%	0	NMC	9.2



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.60628	33
0.64	0.0050	0.995	0.01819	1.8452	101
0.95	0.0075	0.9925	0.01824	3.4268	188
1.27	0.0100	0.99	0.01828	4.8766	267
1.59	0.0125	0.9875	0.01833	5.8651	320
1.91	0.0150	0.9850	0.01838	6.59	359
2.22	0.0175	0.9825	0.01842	7.1172	386
2.54	0.0200	0.9800	0.01847	7.23582	392
2.86	0.0225	0.9775	0.01852	6.94586	375

MOULDING MOISTURE CONTENT	
Tin No.	181
Tin +Wet soil	136.7
Tin + Dry soil	121.4
Wt of Tin	78.4
Wt of Moisture	15.3
Wt. of dry soil	43
Moisture content	35.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		392 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

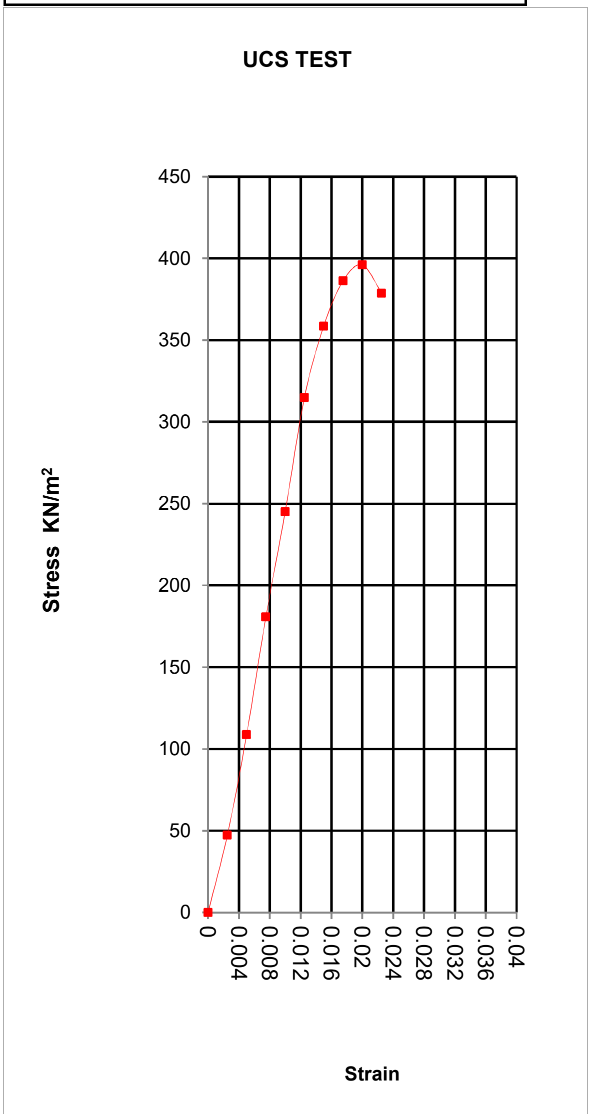
WORKING SHEET

UCS TEST

SPECIMEN 2

Project: Chemical Stabilization of Lateritic Gravel		Date: 21-Sept-2020	No. of days cured:	7	
Student: Anthony Mugendi Nyagah		Mould No.:	No. of days soaked:	0	

DATA			SAMPLE DETAILS		
Do =152mm				MDD	1642
		Type	STABILIZED	OMC	26.2
Lo mm	127	Stabilizer	3% CDA	NMC	9.2
Ao =(152x152x3.14)/4 m^2	0.0181	%	0		
Volume = AoLo m^3	0.00275				
Stabilizer = CDA					



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.8567	47
0.64	0.0050	0.995	0.01819	1.977	109
0.95	0.0075	0.9925	0.01824	3.295	181
1.27	0.0100	0.99	0.01828	4.4812	245
1.59	0.0125	0.9875	0.01833	5.77284	315
1.91	0.0150	0.9850	0.01838	6.59	359
2.22	0.0175	0.9825	0.01842	7.1172	386
2.54	0.0200	0.9800	0.01847	7.3149	396
2.86	0.0225	0.9775	0.01852	7.01176	379

MOULDING MOISTURE CONTENT	
Tin No.	181
Tin +Wet soil	136.7
Tin + Dry soil	121.4
Wt of Tin	78.4
Wt of Moisture	15.3
Wt. of dry soil	43
Moisture content	35.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		396 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

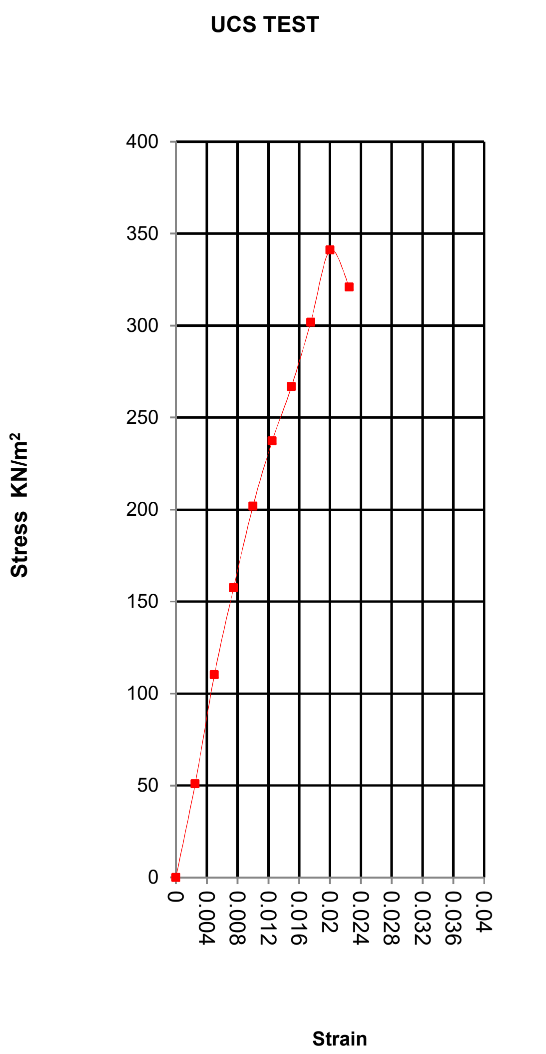
UCS TEST

SPECIMEN 3

Project: Chemical Stabilization of Lateritic Gravel	Date: 21-Sept-2020	No. of days cured:	7
Student: Anthony Mugendi Nyagah	Mould No.:	No. of days soaked:	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = CDA	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1642
Stabilizer	3% CDA	OMC	26.2
%	0	NMC	9.2



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.9226	51
0.64	0.0050	0.995	0.01819	2.00336	110
0.95	0.0075	0.9925	0.01824	2.87324	158
1.27	0.0100	0.99	0.01828	3.6904	202
1.59	0.0125	0.9875	0.01833	4.3494	237
1.91	0.0150	0.9850	0.01838	4.90296	267
2.22	0.0175	0.9825	0.01842	5.56196	302
2.54	0.0200	0.9800	0.01847	6.30004	341
2.86	0.0225	0.9775	0.01852	5.94418	321

MOULDING MOISTURE CONTENT	
Tin No.	181
Tin +Wet soil	136.7
Tin + Dry soil	121.4
Wt of Tin	78.4
Wt of Moisture	15.3
Wt. of dry soil	43
Moisture content	35.6

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		341 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

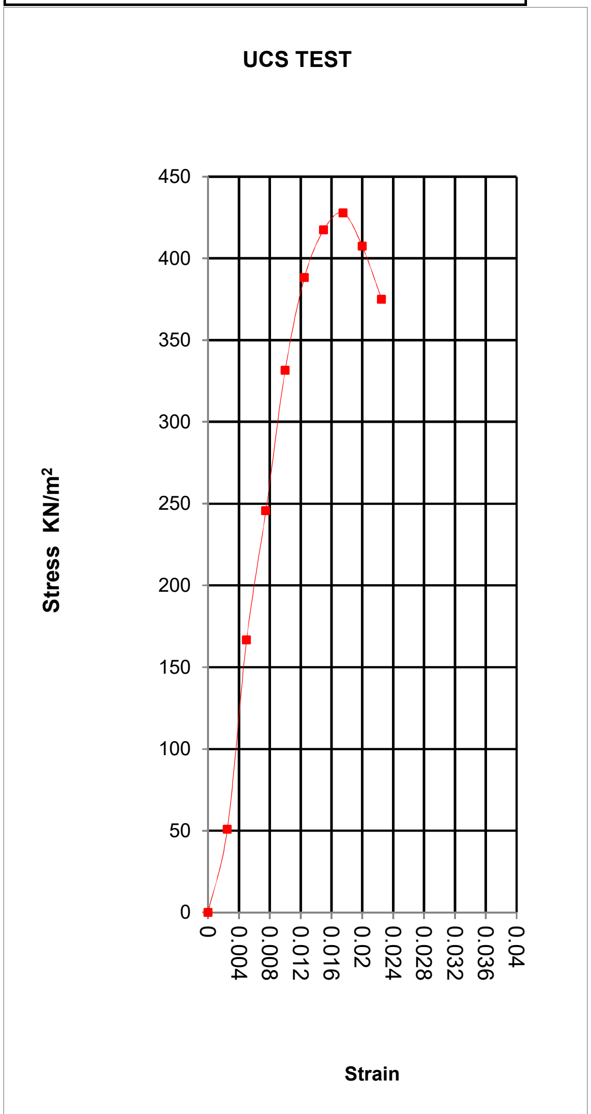
UCS TEST

SPECIMEN 1

Project: Chemical Stabilization of Lateritic Gravel	**Date: 21-Sept-2020**	**No. of days cured:**	7
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA			SAMPLE DETAILS			
Do =152mm					**MDD**	1638
Lo mm	127	**Type**	**STABILIZED**		**OMC**	26.6
		Stabilizer	**6% CDA**		**NMC**	9.2
Ao =(152x152x3.14)/4 m^2	0.0181	**%**	0			
Volume = AoLo m^3	0.00275					
Stabilizer = CDA						

Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.9226	51
0.64	0.0050	0.995	0.01819	3.0314	167
0.95	0.0075	0.9925	0.01824	4.4812	246
1.27	0.0100	0.99	0.01828	6.0628	332
1.59	0.0125	0.9875	0.01833	7.1172	388
1.91	0.0150	0.9850	0.01838	7.67076	417
2.22	0.0175	0.9825	0.01842	7.88164	428
2.54	0.0200	0.9800	0.01847	7.52578	407
2.86	0.0225	0.9775	0.01852	6.94586	375



MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	142.8
Tin + Dry soil	129.1
Wt of Tin	92.3
Wt of Moisture	13.7
Wt. of dry soil	36.8
Moisture content	37.2

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		428 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

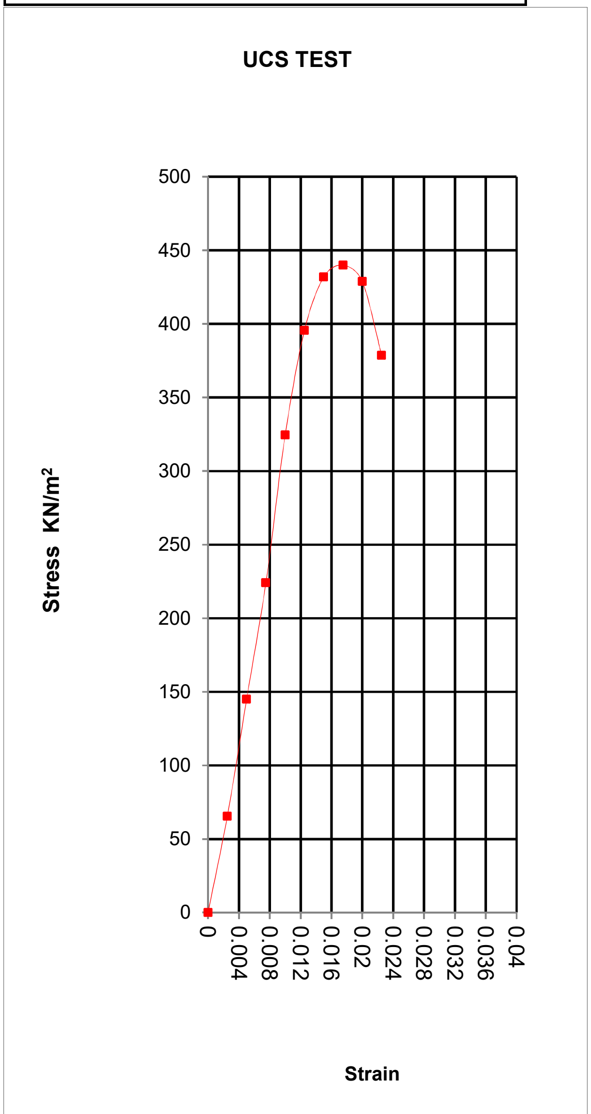
UCS TEST

SPECIMEN 2

Project: Chemical Stabilization of Lateritic Gravel	**Date: 21/09/2020**	**No. of days cured:**	7
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = CDA	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1638
Stabilizer	6% CDA	OMC	26.6
%	0	NMC	9.2



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.1862	65
0.64	0.0050	0.995	0.01819	2.636	145
0.95	0.0075	0.9925	0.01824	4.0858	224
1.27	0.0100	0.99	0.01828	5.931	324
1.59	0.0125	0.9875	0.01833	7.249	395
1.91	0.0150	0.9850	0.01838	7.93436	432
2.22	0.0175	0.9825	0.01842	8.1057	440
2.54	0.0200	0.9800	0.01847	7.92118	429
2.86	0.0225	0.9775	0.01852	7.01176	379

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	142.8
Tin + Dry soil	129.1
Wt of Tin	92.3
Wt of Moisture	13.7
Wt. of dry soil	36.8
Moisture content	37.2

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		440 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

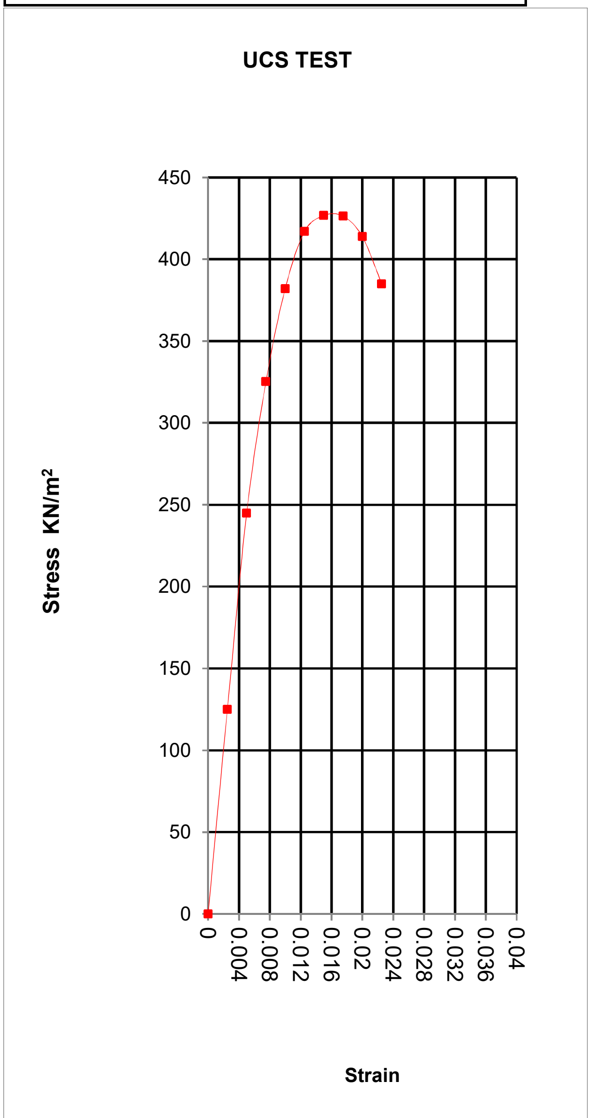
UCS TEST

SPECIMEN 3

Project: Chemical Stabilization of Lateritic Gravel	**Date: 21-Sept-2020**	**No. of days cured:**	7
student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA		
Do =152mm		
Lo	**mm**	127
Ao =(152x152x3.14)/4	**m^2**	0.0181
Volume = AoLo	**m^3**	0.00275
Stabilizer = CDA		

SAMPLE DETAILS			
Type	**STABILIZED**	**MDD**	1638
Stabilizer	6% CDA	**OMC**	26.6
%	0	**NMC**	9.2



Defl. mm	**Deflection** E=L/L0	1-E	A=(Ao)/1-E	**Stress** Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	2.26696	125
0.64	0.0050	0.995	0.01819	4.45484	245
0.95	0.0075	0.9925	0.01824	5.931	325
1.27	0.0100	0.99	0.01828	6.9854	382
1.59	0.0125	0.9875	0.01833	7.6444	417
1.91	0.0150	0.9850	0.01838	7.8421	427
2.22	0.0175	0.9825	0.01842	7.85528	426
2.54	0.0200	0.9800	0.01847	7.6444	414
2.86	0.0225	0.9775	0.01852	7.13038	385

MOULDING MOISTURE CONTENT	
Tin No.	61
Tin +Wet soil	142.8
Tin + Dry soil	129.1
Wt of Tin	92.3
Wt of Moisture	13.7
Wt. of dry soil	36.8
Moisture content	37.2

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		427 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

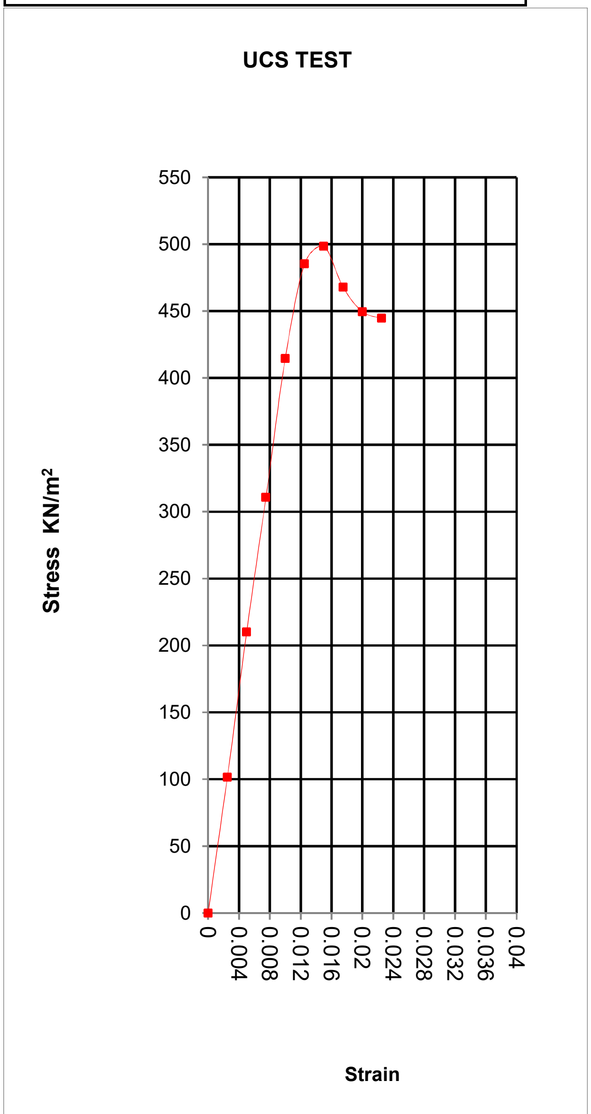
UCS TEST

SPECIMEN 1

Project: Chemical Stabilization of Lateritic Gravel	Date: 21-Sept-2020	No. of days cured:	7
Student: Anthony Mugendi Nyagah	Mould No.:	No. of days soaked:	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = CDA	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1602
Stabilizer	9% CDA	OMC	27.4
%	0	NMC	9.2



Defl.	Deflection			Stress	
mm	E=L/L0	1-E	A=(Ao)/1-E	Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.8452	102
0.64	0.0050	0.995	0.01819	3.8222	210
0.95	0.0075	0.9925	0.01824	5.6674	311
1.27	0.0100	0.99	0.01828	7.5785	415
1.59	0.0125	0.9875	0.01833	8.8965	485
1.91	0.0150	0.9850	0.01838	9.1601	498
2.22	0.0175	0.9825	0.01842	8.61972	468
2.54	0.0200	0.9800	0.01847	8.3034	450
2.86	0.0225	0.9775	0.01852	8.2375	445

MOULDING MOISTURE CONTENT	
Tin No.	24
Tin +Wet soil	196.5
Tin + Dry soil	180.5
Wt of Tin	95
Wt of Moisture	16
Wt. of dry soil	85.5
Moisture content	18.7

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		498 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

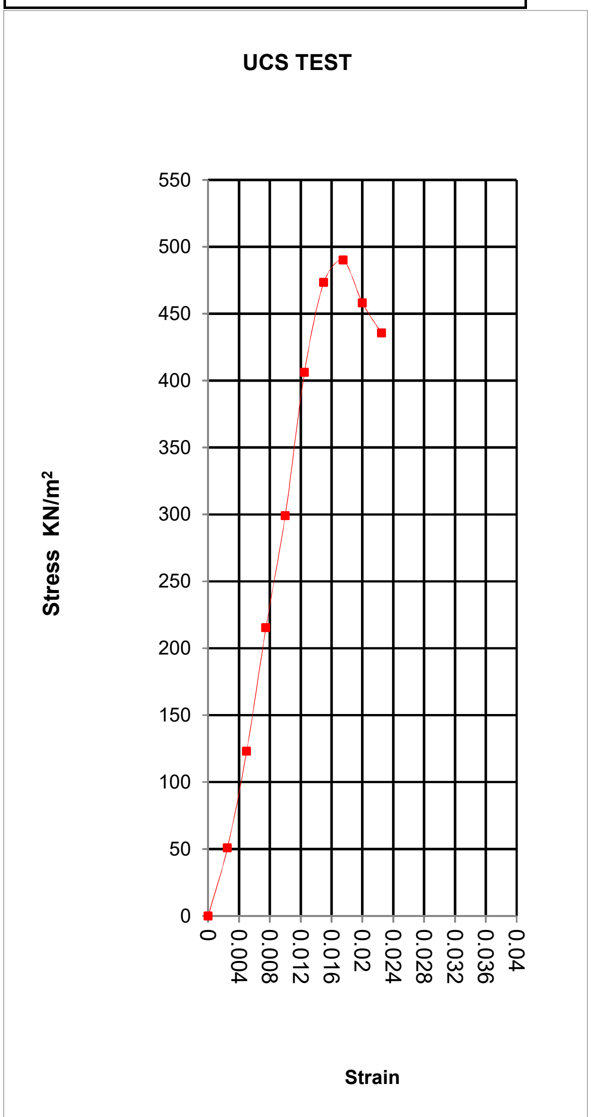
UCS TEST

SPECIMEN 2

Project: Chemical Stabilization of Lateritic Gravel			**No. of days cured:**	7	
Student: Anthony Mugendi Nyagah		**Mould No.:**	**No. of days soaked:**	0	

DATA		SAMPLE DETAILS			
Do =152mm				**MDD**	1602
Lo mm	127	**Type**	**STABILIZED**	**OMC**	27.4
Ao =(152x152x3.14)/4 m^2	0.0181	**Stabilizer**	9% CDA	**NMC**	9.2
Volume = AoLo m^3	0.00275	**%**	0		
Stabilizer = CDA					

Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	0.9226	51
0.64	0.0050	0.995	0.01819	2.2406	123
0.95	0.0075	0.9925	0.01824	3.92764	215
1.27	0.0100	0.99	0.01828	5.4697	299
1.59	0.0125	0.9875	0.01833	7.4467	406
1.91	0.0150	0.9850	0.01838	8.6988	473
2.22	0.0175	0.9825	0.01842	9.0283	490
2.54	0.0200	0.9800	0.01847	8.46156	458
2.86	0.0225	0.9775	0.01852	8.06616	436



MOULDING MOISTURE CONTENT	
Tin No.	24
Tin +Wet soil	196.5
Tin + Dry soil	180.5
Wt of Tin	95
Wt of Moisture	16
Wt. of dry soil	85.5
Moisture content	18.7

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		490 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

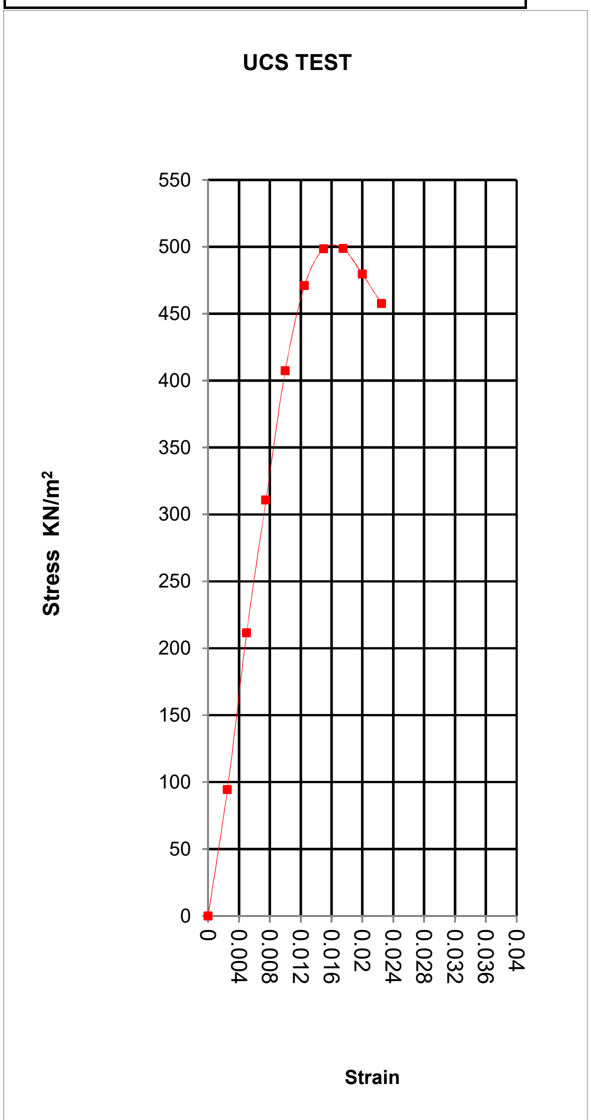
SPECIMEN 3

Project: Chemical Stabilization of Lateritic Gravel	**Date: 21-Sept-2020**	**No. of days cured:**	7
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = CDA	

SAMPLE DETAILS			
Type	STABILIZED	OMC	27.4
Stabilizer	9% CDA	NMC	9.2
%	0		
		MDD	1602

Defl. (mm)	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.7134	94
0.64	0.0050	0.995	0.01819	3.84856	212
0.95	0.0075	0.9925	0.01824	5.6674	311
1.27	0.0100	0.99	0.01828	7.4467	407
1.59	0.0125	0.9875	0.01833	8.6329	471
1.91	0.0150	0.9850	0.01838	9.1601	498
2.22	0.0175	0.9825	0.01842	9.18646	499
2.54	0.0200	0.9800	0.01847	8.85696	480
2.86	0.0225	0.9775	0.01852	8.47474	458



MOULDING MOISTURE CONTENT	
Tin No.	24
Tin +Wet soil	196.5
Tin + Dry soil	180.5
Wt of Tin	95
Wt of Moisture	16
Wt. of dry soil	85.5
Moisture content	18.7

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		499 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

SPECIMEN 1

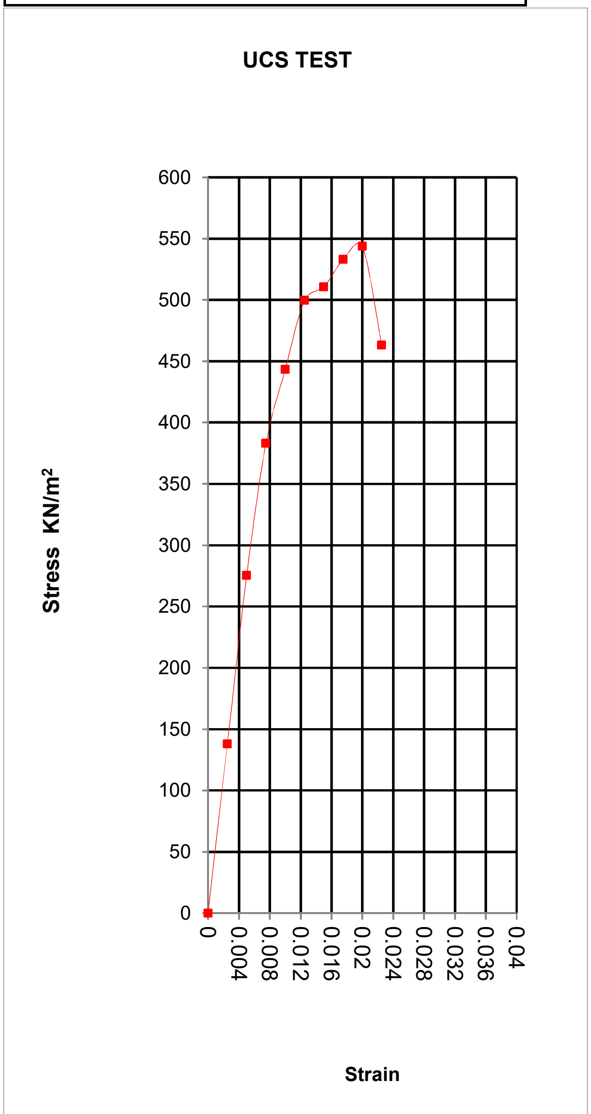
Project: Chemical Stabilization of Lateritic Gravel	**Date: 21-Sept-2020**	**No. of days cured:**	7
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA	
Do =152mm	
Lo mm	127
Ao =(152x152x3.14)/4 m^2	0.0181
Volume = AoLo m^3	0.00275
Stabilizer = CDA	

SAMPLE DETAILS			
Type	STABILIZED	**OMC**	27.6
Stabilizer	12% CDA	**NMC**	9.2
%	0		

MDD 1601

Defl. (mm)	E=L/L0	1-E	A=(Ao)/1-E	Load (KN)	Q (KN/m^2)
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	2.5042	138
0.64	0.0050	0.995	0.01819	5.0084	275
0.95	0.0075	0.9925	0.01824	6.9854	383
1.27	0.0100	0.99	0.01828	8.1057	443
1.59	0.0125	0.9875	0.01833	9.1601	500
1.91	0.0150	0.9850	0.01838	9.38416	511
2.22	0.0175	0.9825	0.01842	9.8191	533
2.54	0.0200	0.9800	0.01847	10.04316	544
2.86	0.0225	0.9775	0.01852	8.58018	463



MOULDING MOISTURE CONTENT	
Tin No.	62
Tin +Wet soil	159
Tin + Dry soil	142
Wt of Tin	93.1
Wt of Moisture	17
Wt. of dry soil	48.9
Moisture content	34.8

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		544 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

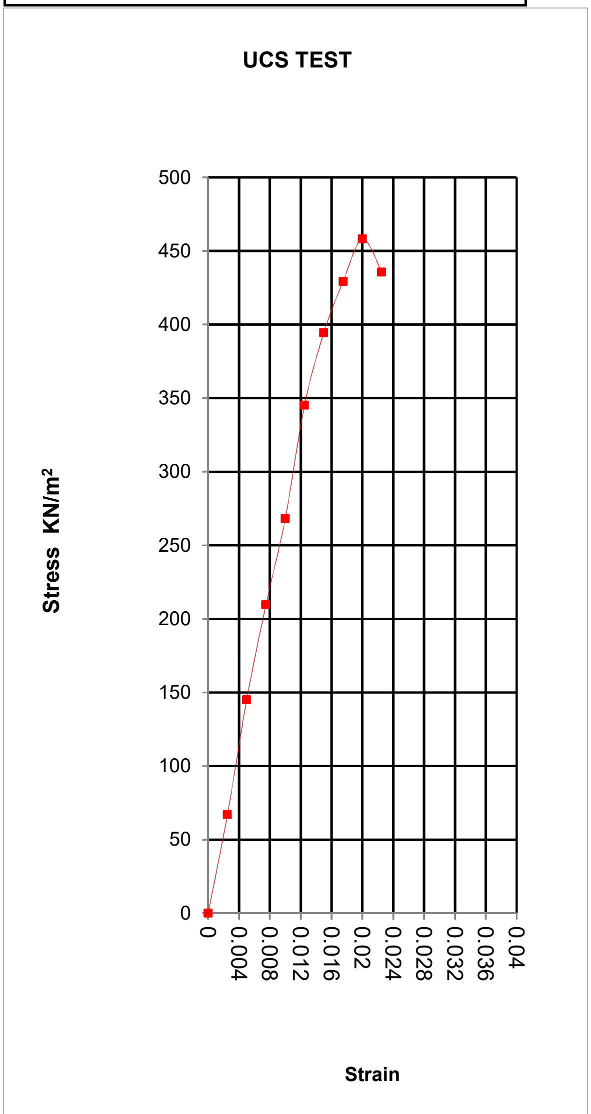
(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

SPECIMEN 2

Project: Chemical Stabilization of Lateritic Gravel		Date: 21-Sept-2020	No. of days cured:	7	
Student: Anthony Mugendi Nyagah		Mould No.:	No. of days soaked:	0	
DATA		SAMPLE DETAILS		MDD	1601
Do =152mm		Type	STABILIZED	OMC	27.6
Lo mm	127	Stabilizer	12% CDA	NMC	9.2
Ao =(152x152x3.14)/4 m^2	0.0181	%	0		
Volume = AoLo m^3	0.00275				
Stabilizer = CDA					



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.21256	67
0.64	0.0050	0.995	0.01819	2.636	145
0.95	0.0075	0.9925	0.01824	3.8222	210
1.27	0.0100	0.99	0.01828	4.90296	268
1.59	0.0125	0.9875	0.01833	6.3264	345
1.91	0.0150	0.9850	0.01838	7.249	394
2.22	0.0175	0.9825	0.01842	7.908	429
2.54	0.0200	0.9800	0.01847	8.46156	458
2.86	0.0225	0.9775	0.01852	8.06616	436

MOULDING MOISTURE CONTENT	
Tin No.	62
Tin +Wet soil	159
Tin + Dry soil	142
Wt of Tin	93.1
Wt of Moisture	17
Wt. of dry soil	48.9
Moisture content	34.8

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		458 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

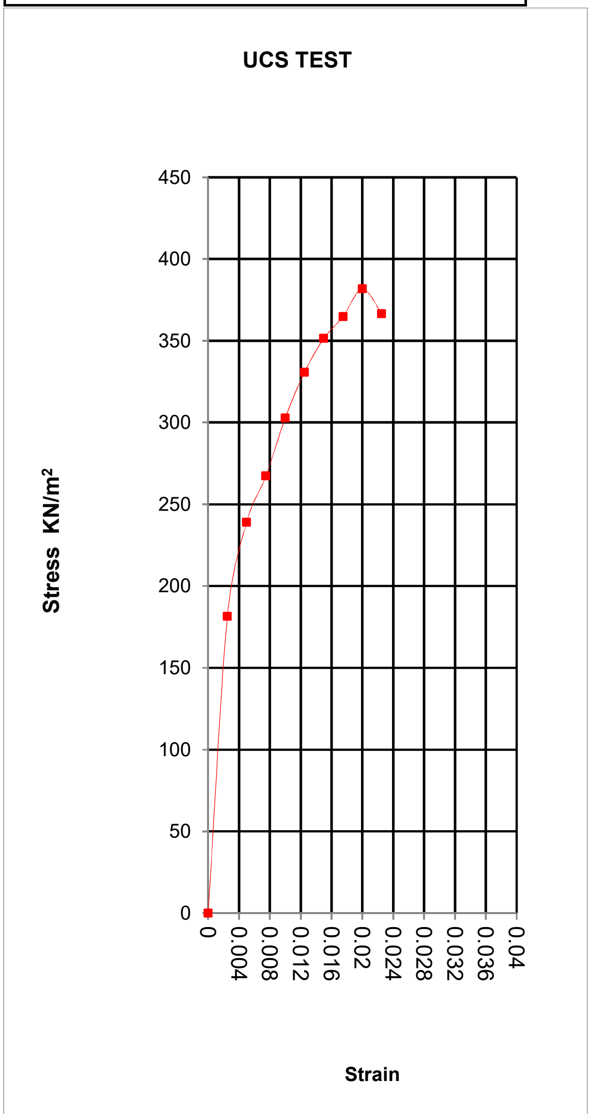
UCS TEST

SPECIMEN 3

Project: Chemical Stabilization of Lateritic Gravel	**Date: 21-Sept-2020**	**No. of days cured:**	7
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA		
Do =152mm		
Lo mm	127	
Ao =(152x152x3.14)/4 m^2	0.0181	
Volume = AoLo m^3	0.00275	
Stabilizer = CDA		

SAMPLE DETAILS			
Type	**STABILIZED**	**MDD**	1601
Stabilizer	**12% CDA**	**OMC**	27.6
%	**0**	**NMC**	9.2



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	3.295	182
0.64	0.0050	0.995	0.01819	4.3494	239
0.95	0.0075	0.9925	0.01824	4.8766	267
1.27	0.0100	0.99	0.01828	5.5356	303
1.59	0.0125	0.9875	0.01833	6.0628	331
1.91	0.0150	0.9850	0.01838	6.4582	351
2.22	0.0175	0.9825	0.01842	6.7218	365
2.54	0.0200	0.9800	0.01847	7.0513	382
2.86	0.0225	0.9775	0.01852	6.7877	367

MOULDING MOISTURE CONTENT	
Tin No.	62
Tin +Wet soil	159
Tin + Dry soil	142
Wt of Tin	93.1
Wt of Moisture	17
Wt. of dry soil	48.9
Moisture content	34.8

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		382 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew & Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

UCS TEST

SPECIMEN 1

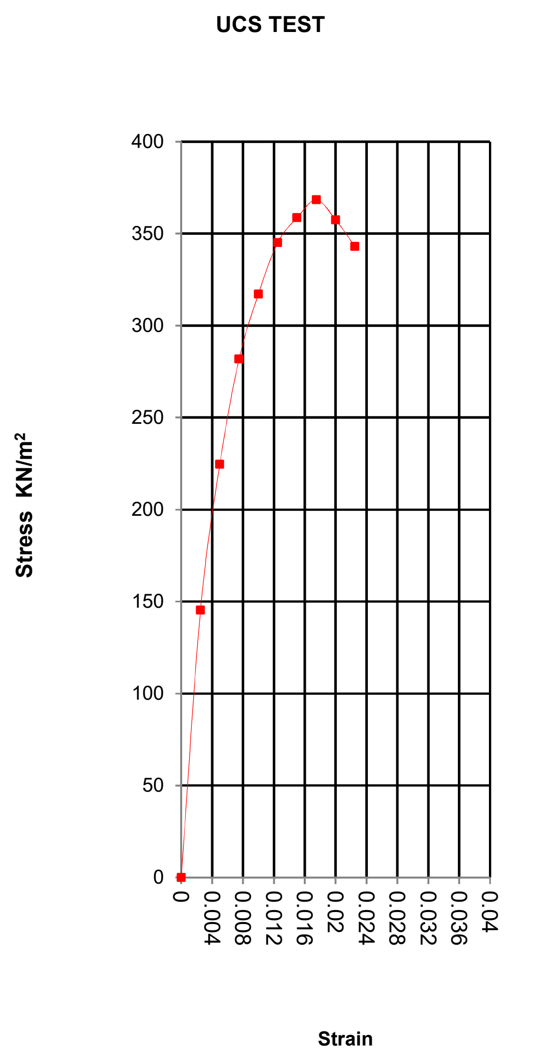
Project: Chemical Stabilization of Lateritic Gravel	Date: 21-Sept-2020	No. of days cured:	7
Student: Anthony Mugendi Nyagah	Mould No.:	No. of days soaked:	0

DATA

Do =152mm		
Lo	mm	127
Ao =(152x152x3.14)/4	m^2	0.0181
Volume = AoLo	m^3	0.00275
Stabilizer = CDA		

SAMPLE DETAILS

Type	STABILIZED	MDD	1560
Stabilizer	15% CDA	OMC	27.8
%	0	NMC	9.2



Defl. mm	E=L/L0	1-E	A=(Ao)/1-E	Load KN	Stress Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	2.636	145
0.64	0.0050	0.995	0.01819	4.0858	225
0.95	0.0075	0.9925	0.01824	5.1402	282
1.27	0.0100	0.99	0.01828	5.7992	317
1.59	0.0125	0.9875	0.01833	6.3264	345
1.91	0.0150	0.9850	0.01838	6.59	359
2.22	0.0175	0.9825	0.01842	6.7877	368
2.54	0.0200	0.9800	0.01847	6.60318	358
2.86	0.0225	0.9775	0.01852	6.35276	343

MOULDING MOISTURE CONTENT

Tin No.	140
Tin +Wet soil	166.3
Tin + Dry soil	149.8
Wt of Tin	104.4
Wt of Moisture	16.5
Wt. of dry soil	45.4
Moisture content	36.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		368 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew &Nyagah | Checked By: Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

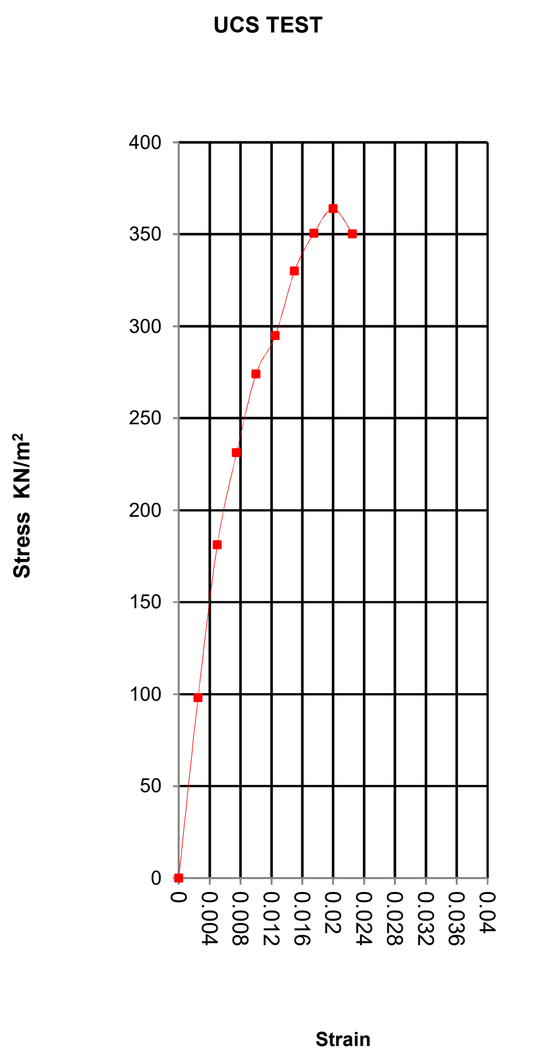
UCS TEST

SPECIMEN 2

Project: Chemical Stabilization of lateritic Gravel	Date: 21-Sept-2020	No. of days cured:	7
Student: Anthony Mugendi Nyagah	Mould No.:	No. of days soaked:	0

DATA		
Do =152mm		
Lo mm		127
Ao =(152x152x3.14)/4 m^2		0.0181
Volume = AoLo m^3		0.00275
Stabilizer = CDA		

SAMPLE DETAILS			
		MDD	1560
Type	STABILIZED	OMC	27.8
Stabilizer	15% CDA	NMC	9.2
%	0		



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.7793	98
0.64	0.0050	0.995	0.01819	3.295	181
0.95	0.0075	0.9925	0.01824	4.2176	231
1.27	0.0100	0.99	0.01828	5.0084	274
1.59	0.0125	0.9875	0.01833	5.4038	295
1.91	0.0150	0.9850	0.01838	6.0628	330
2.22	0.0175	0.9825	0.01842	6.4582	351
2.54	0.0200	0.9800	0.01847	6.7218	364
2.86	0.0225	0.9775	0.01852	6.48456	350

MOULDING MOISTURE CONTENT	
Tin No.	140
Tin +Wet soil	166.3
Tin + Dry soil	149.8
Wt of Tin	104.4
Wt of Moisture	16.5
Wt. of dry soil	45.4
Moisture content	36.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		364 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew &Nyagah | Checked By: Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

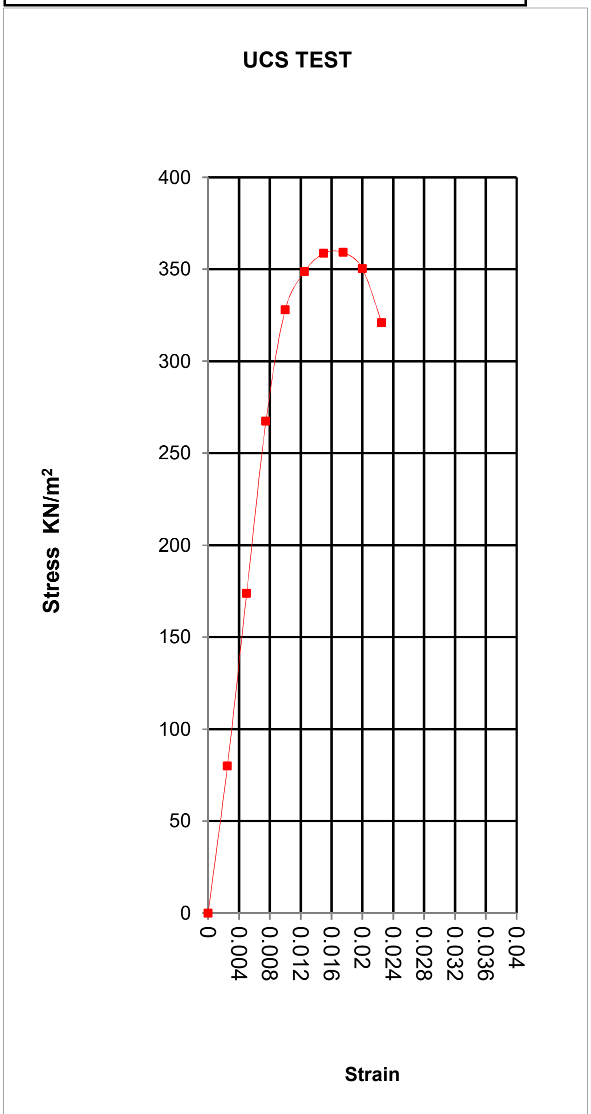
UCS TEST

SPECIMEN 3

Project: Chemical Stabilization of Lateritic Gravel	**Date: 21-Sept-2020**	**No. of days cured:**	7
Student: Anthony Mugendi Nyagah	**Mould No.:**	**No. of days soaked:**	0

DATA					
Do =152mm					
Lo mm	127				
Ao =(152x152x3.14)/4 m^2	0.0181				
Volume = AoLo m^3	0.00275				
Stabilizer = CDA					

SAMPLE DETAILS			
		MDD	1560
Type	**STABILIZED**	**OMC**	27.8
Stabilizer	**15% CDA**	**NMC**	9.2
%	**0**		



Defl. mm	Deflection E=L/L0	1-E	A=(Ao)/1-E	Stress Load KN	Q KN/m^2
0.00	0.0000	1	0.01810	0	0
0.32	0.0025	0.9975	0.01815	1.4498	80
0.64	0.0050	0.995	0.01819	3.1632	174
0.95	0.0075	0.9925	0.01824	4.8766	267
1.27	0.0100	0.99	0.01828	5.9969	328
1.59	0.0125	0.9875	0.01833	6.3923	349
1.91	0.0150	0.9850	0.01838	6.59	359
2.22	0.0175	0.9825	0.01842	6.61636	359
2.54	0.0200	0.9800	0.01847	6.47138	350
2.86	0.0225	0.9775	0.01852	5.94418	321

MOULDING MOISTURE CONTENT	
Tin No.	140
Tin +Wet soil	166.3
Tin + Dry soil	149.8
Wt of Tin	104.4
Wt of Moisture	16.5
Wt. of dry soil	45.4
Moisture content	36.3

RESULTS

Results	Specification	Result
Unconfined Compressive Strength		359 KN/m^2
Estimated Elastic Modulus		

Tested By: Mathew &Nyagah | Checked By: Martin Mburu

Appendix E3 Strength Properties (CBR)

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(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST
(AASHTO T193:1990)

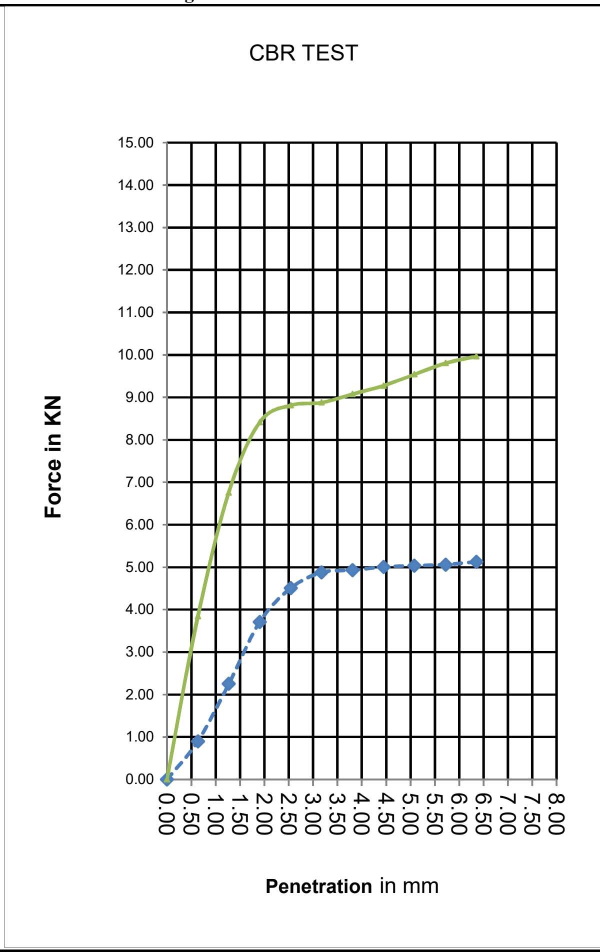
3% CDA SAMPLE 1

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 07/09/2020	**Date soaked:**	31/08/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/08/2020

SWELL DATA		
Initial gauge Reading	(div)	3.89
Final gauge Reading	(div)	4.79
Difference	(div)	0.9
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1642
Stabilizer	CDA	OMC	26.2
%		NMC	9.2
Swell %	0.009		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.90101	3.8426			
1.27	2.25253	6.7576			
1.91	3.71006	8.4139			
2.54	4.50507	8.8114	13.2	34	67
3.18	4.87607	8.8776			
3.81	4.92907	9.0764			
4.45	5.00858	9.2751			
5.08	5.03508	9.5401	20.0	25	48
5.72	5.06158	9.8051			
6.35	5.12783	9.9642			



Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	58
Tin +Wet soil	148.3
Tin + Dry soil	136.8
Wt of Tin	93.7
Wt of Moisture	11.5
Wt. of dry soil	43.1
Moisture content	26.67

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		67	34
5	20		48	25
		CBR = 67%	Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST
(AASHTO T193:1990)

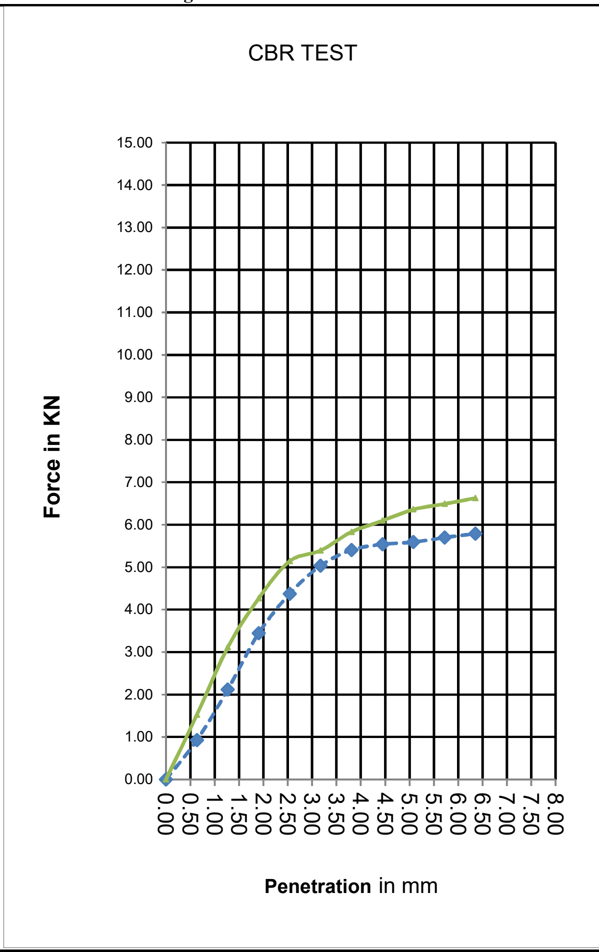
3% CDA SAMPLE 2

Project: Chemical Stabilization of lateritic Gravel		**Tested:** 07/09/2020	**Date soaked:** 31/08/2020
Student.: Anthony Mugendi Nyagah		**Mould No.:**	**Date Moulded:** 24/08/2020

SWELL DATA		
Initial gauge Reading	(div)	7.62
Final gauge Reading	(div)	7.81
Difference	(div)	0.19
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1642
Stabilizer	CDA	OMC	26.2
%		NMC	9.2
Swell %	0.0019		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.92751	1.5238			
1.27	2.12003	3.1138			
1.91	3.44505	4.2666			
2.54	4.37257	5.1411	13.2	33	39
3.18	5.03508	5.3928			
3.81	5.40608	5.8301			
4.45	5.53858	6.0951			
5.08	5.59158	6.3601	20.0	28	32
5.72	5.69759	6.4926			
6.35	5.79034	6.6251			



Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	53
Tin +Wet soil	163.4
Tin + Dry soil	148.4
Wt of Tin	91.9
Wt of Moisture	15
Wt. of dry soil	56.5
Moisture content	26.37

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		39	33
5	20		32	28
		CBR = 39%	Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST

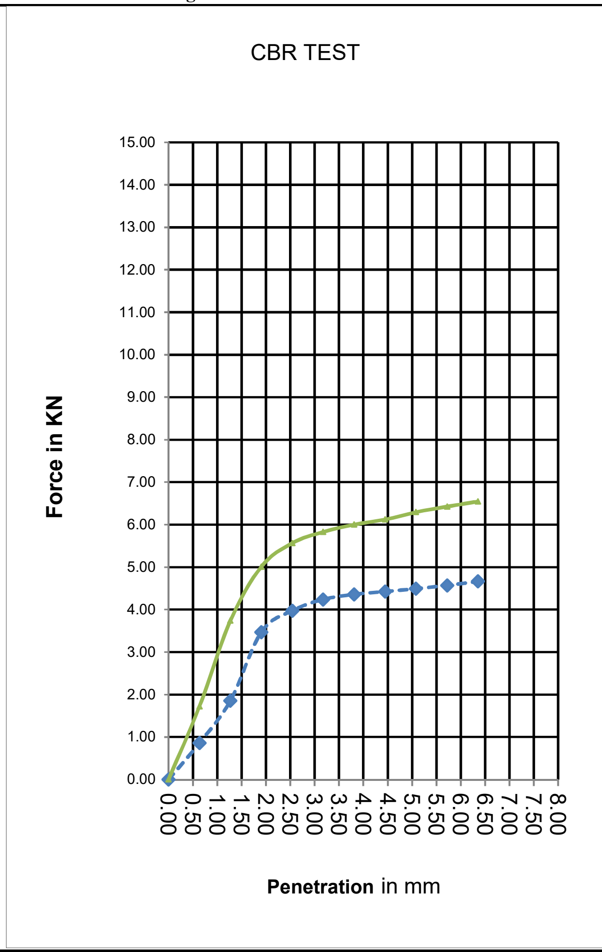
(AASHTO T193:1990)

3% CDA SAMPLE 3

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 07/09/2020	**Date soaked:**	31/08/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	29/11/2019

SWELL DATA		
Initial gauge Reading	**(div)**	3.06
Final gauge Reading	**(div)**	3.06
Difference	**(div)**	0
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
		MDD	1642
Type	**STABILIZED**	**OMC**	26.2
Stabilizer	**CDA**	**NMC**	9.2
%			
Swell %	0		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.86126	1.7225			
1.27	1.85503	3.7366			
1.91	3.47155	5.0086			
2.54	3.97506	5.5651	13.2	30	42
3.18	4.24006	5.8301			
3.81	4.35932	6.0023			
4.45	4.42557	6.1216			
5.08	4.49182	6.2938	20.0	22	31
5.72	4.57132	6.4263			
6.35	4.66407	6.5456			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	53
Tin +Wet soil	163.4
Tin + Dry soil	148.4
Wt of Tin	91.9
Wt of Moisture	15
Wt. of dry soil	56.5
Moisture content	26.37

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			42	30
5	20			31	22
		CBR =42%		Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

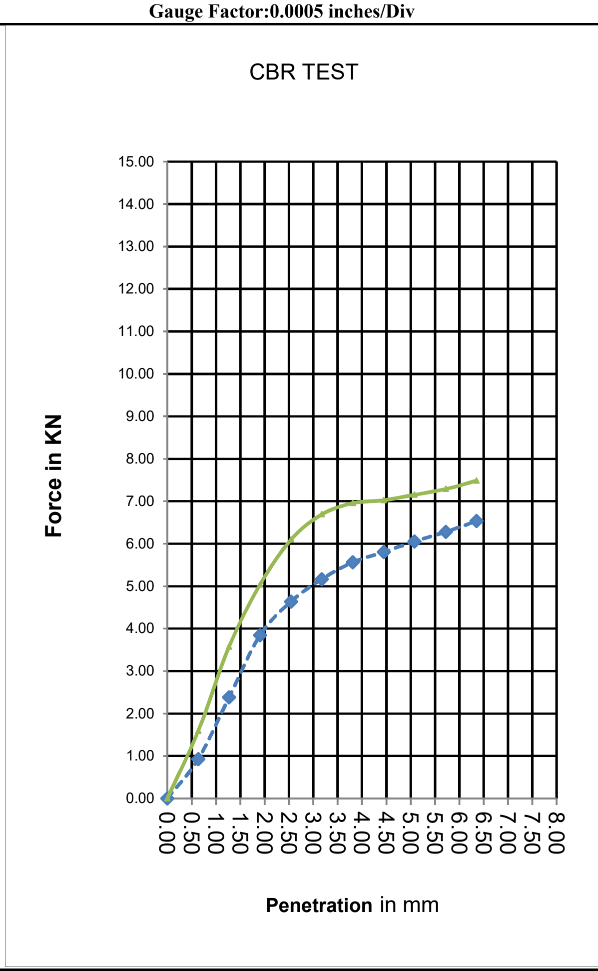
CBR TEST
(AASHTO T193:1990)

6% CDA SAMPLE 1

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 07/09/2020	**Date soaked:**	31/08/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/08/2020

SWELL DATA		
Initial gauge Reading	(div)	4.24
Final gauge Reading	(div)	4.82
Difference	(div)	0.58
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1638
Stabilizer	CDA	OMC	26.6
%		NMC	9.2
Swell %	0.0058		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.92751	1.59			
1.27	2.38504	3.5776			
1.91	3.84256	5.0351			
2.54	4.63757	6.0951	13.2	35	46
3.18	5.16758	6.6914			
3.81	5.56508	6.9564			
4.45	5.80359	7.0226			
5.08	6.05534	7.1551	20.0	30	36
5.72	6.28059	7.2876			
6.35	6.53235	7.4864			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	215.6
Tin + Dry soil	186.5
Wt of Tin	78.6
Wt of Moisture	29.1
Wt. of dry soil	107.9
Moisture content	26.97

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			46	35
5	20			36	30
		CBR = 46%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

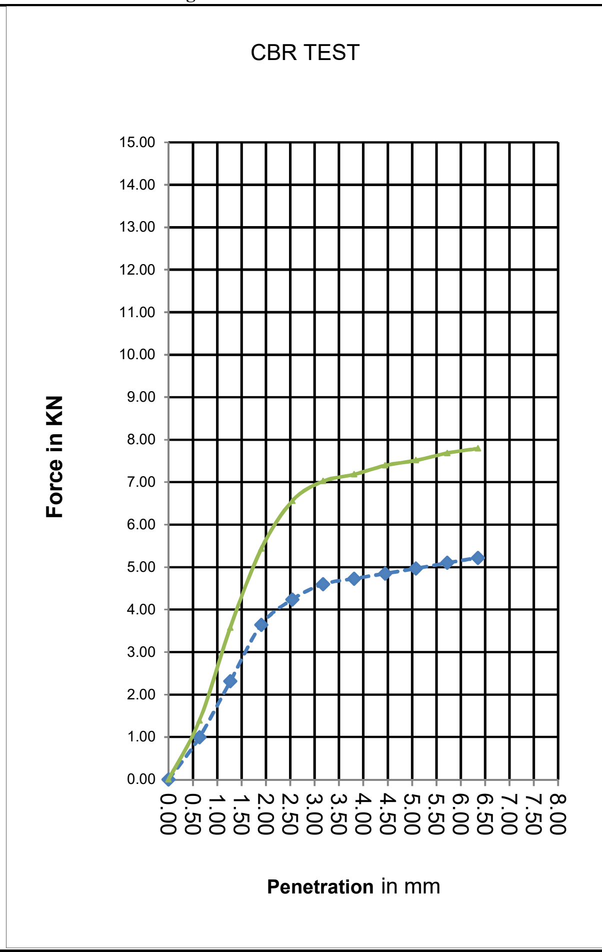
CBR TEST
(AASHTO T193:1990)

6% CDA SAMPLE 2

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 07/09/2020	**Date soaked:**	31/08/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/08/2020

SWELL DATA		
Initial gauge Reading	(div)	0.03
Final gauge Reading	(div)	6.3
Difference	(div)	6.27
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1638
Stabilizer	CDA	OMC	26.6
%		NMC	9.2
Swell %	0.0627		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.99377	1.3913			
1.27	2.31879	3.5776			
1.91	3.64381	5.4326			
2.54	4.24006	6.5588	13.2	32	50
3.18	4.59782	7.0226			
3.81	4.73032	7.1816			
4.45	4.84957	7.3936			
5.08	4.96883	7.5129	20.0	25	38
5.72	5.10133	7.6851			
6.35	5.22058	7.7911			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	215.6
Tin + Dry soil	186.5
Wt of Tin	78.6
Wt of Moisture	29.1
Wt. of dry soil	107.9
Moisture content	26.97

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			50	32
5	20			38	25
		CBR = 50%		Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

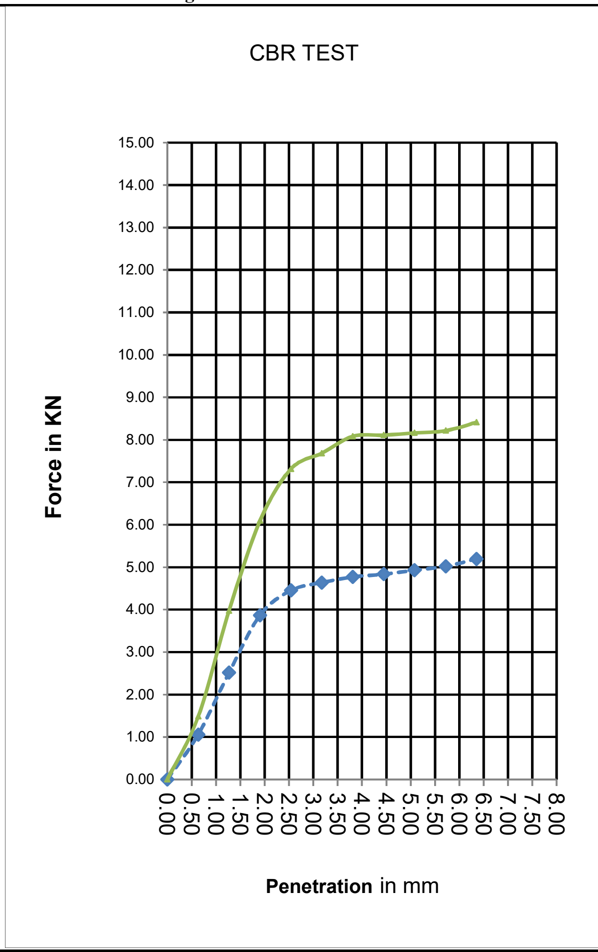
CBR TEST
(AASHTO T193:1990)

6% CDA SAMPLE 3

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 07/09/2020	**Date soaked:**	31/08/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/08/2020

SWELL DATA		
Initial gauge Reading	(div)	5.5
Final gauge Reading	(div)	6.32
Difference	(div)	0.82
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1638
Stabilizer	CDA	OMC	26.6
%		NMC	9.2
Swell %	0.0082		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.06002	1.484			
1.27	2.51754	3.9751			
1.91	3.86906	6.0951			
2.54	4.45207	7.3141	13.2	34	55
3.18	4.63757	7.6851			
3.81	4.77007	8.0826			
4.45	4.83632	8.1091			
5.08	4.92907	8.1621	20.0	25	41
5.72	5.02183	8.2151			
6.35	5.19408	8.4139			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	215.6
Tin + Dry soil	186.5
Wt of Tin	78.6
Wt of Moisture	29.1
Wt. of dry soil	107.9
Moisture content	26.97

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			55	34
5	20			41	25
		CBR = 55%		Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

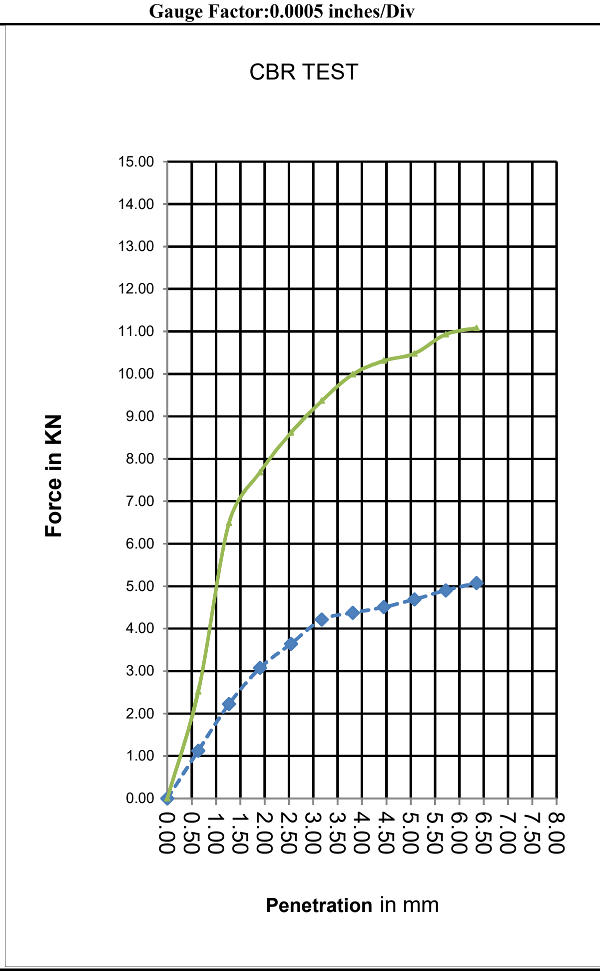
CBR TEST
(AASHTO T193:1990)

9% CDA SAMPLE 1

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 07/09/2020	**Date soaked:**	31/08/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/08/2020

SWELL DATA		
Initial gauge Reading	(div)	2.06
Final gauge Reading	(div)	2.99
Difference	(div)	0.93
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1602
Stabilizer	CDA	OMC	27.4
%		NMC	9.2
Swell %	0.0093		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.12627	2.5175			
1.27	2.22603	6.4926			
1.91	3.07405	7.6851			
2.54	3.64381	8.6126	13.2	28	65
3.18	4.21356	9.3679			
3.81	4.37257	9.9907			
4.45	4.50507	10.309			
5.08	4.69057	10.481	20.0	23	52
5.72	4.90257	10.931			
6.35	5.07483	11.077			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
% MDD		

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.93

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		65	28
5	20		52	23
		CBR = 65%	Checked:	Martin Mburu

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(HIGHWAYS LABORATORY)

WORKING SHEET

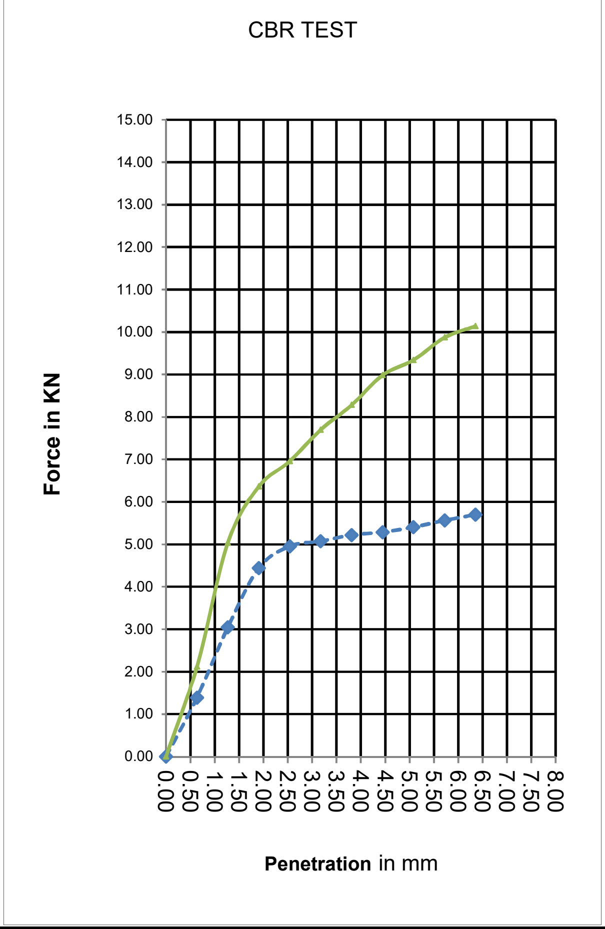
CBR TEST
(AASHTO T193:1990)

9% CDA SAMPLE 2

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 07/09/2020	**Date soaked:**	24/08/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	24/08/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	22
Difference	**(div)**	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1602
Stabilizer	CDA	OMC	27.4
%		NMC	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.39127	2.12			
1.27	3.04755	5.0351			
1.91	4.43882	6.3601			
2.54	4.95557	6.9564	13.2	38	53
3.18	5.07483	7.6984			
3.81	5.22058	8.2814			
4.45	5.28683	8.9836			
5.08	5.40608	9.3414	20.0	27	47
5.72	5.56508	9.8714			
6.35	5.69759	10.136			

Moulding Data		
Wt.of Mould + Wet soil	**g**	
Wt. of Mould	**g**	
Moisture Content	**%**	
Wet Density	**Kg/m^3**	
Dry Density	**Kg/m^3**	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.93

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			53	38
5	20			47	27
		CBR = 53%		**Checked:**	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST
(AASHTO T193:1990)

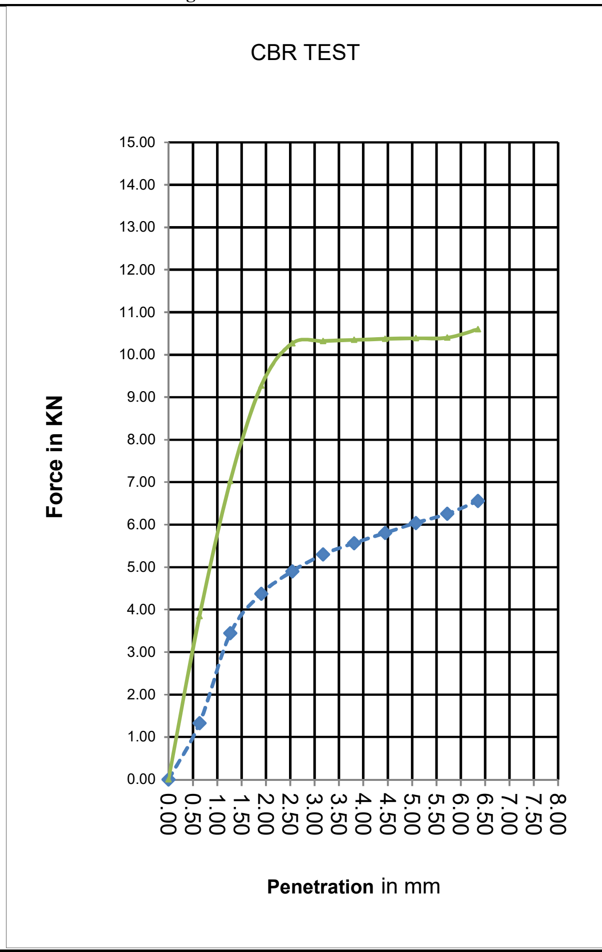
9% CDA SAMPLE 3

Project: Chemical Stabilization of Lateritic Gravel		**Tested:** 07/09/2020	**Date soaked:** 31/08/2020
Student.: Anthony Mugendi Nyagah		**Mould No.:**	**Date Moulded:** 24/08/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0.6
Final gauge Reading	**(div)**	9.02
Difference	**(div)**	8.42
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	**STABILIZED**	**MDD**	1602
Stabilizer	**CDA**	**OMC**	27.4
%		**NMC**	9.2
Swell %	0.0842		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.32502	3.8426			
1.27	3.44505	7.0226			
1.91	4.37257	9.2751			
2.54	4.90257	10.269	13.2	37	78
3.18	5.30008	10.322			
3.81	5.56508	10.348			
4.45	5.80359	10.375			
5.08	6.04209	10.388	20.0	30	52
5.72	6.25409	10.401			
6.35	6.55885	10.6			



Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	107
Tin +Wet soil	227.5
Tin + Dry soil	196.2
Wt of Tin	95
Wt of Moisture	31.3
Wt. of dry soil	101.2
Moisture content	30.93

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		78	37
5	20		52	30
		CBR =78%	**Checked:**	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST
(AASHTO T193:1990)

12% CDA SAMPLE 1

Project: Chemical stabilization of Lateritic Gravel	**Tested:** 10/09/2020	**Date soaked:**	03/09/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	27/08/2020

SWELL DATA

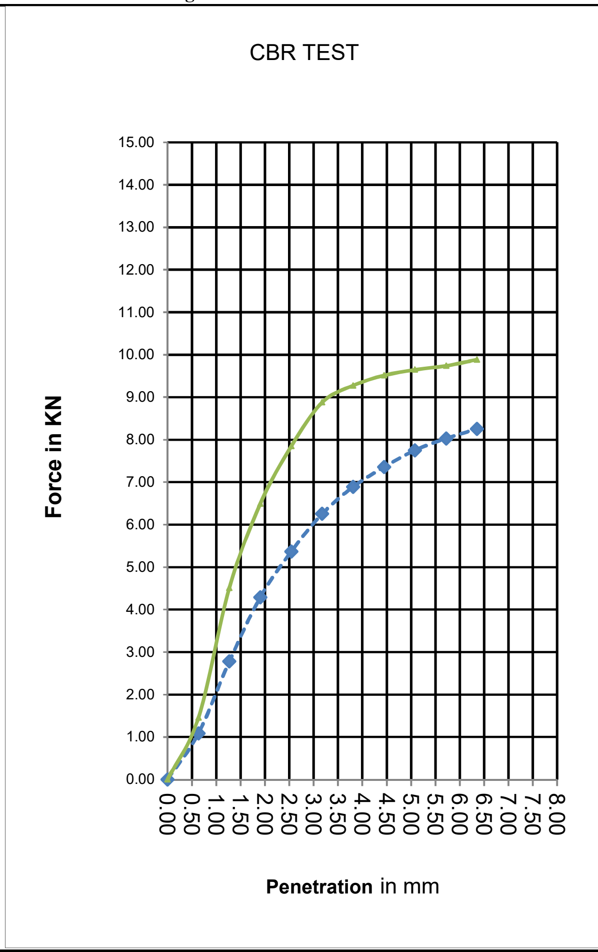
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	22
Difference	(div)	22
Ring Factor		0.01

Gauge Factor:0.0005 inches/Div

SAMPLE DETAILS

Type	STABILIZED	MDD	1601
Stabilizer	CDA	OMC	27.6
%		NMC	9.2
Swell %	0.22		

Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.08652	1.4575			
1.27	2.78254	4.5051			
1.91	4.29306	6.4926			
2.54	5.36633	7.8441	13.2	41	59
3.18	6.25409	8.8776			
3.81	6.8901	9.2751			
4.45	7.35386	9.5136			
5.08	7.75137	9.6461	20.0	39	48
5.72	8.02962	9.7389			
6.35	8.25487	9.8846			



Moulding Data

Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT

Tin No.	184
Tin +Wet soil	223.8
Tin + Dry soil	187.7
Wt of Tin	78.6
Wt of Moisture	36.1
Wt. of dry soil	109.1
Moisture content	33.09

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			59	41
5	20			48	39
		CBR = 59%		Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

CBR TEST

(AASHTO T193:1990)

12% CDA SAMPLE 2

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 10/09/2020	**Date soaked:**	03/09/2020
Client.: Anthony MugendiI Nyagah	**Mould No.:**	**Date Moulded:**	27/08/2020

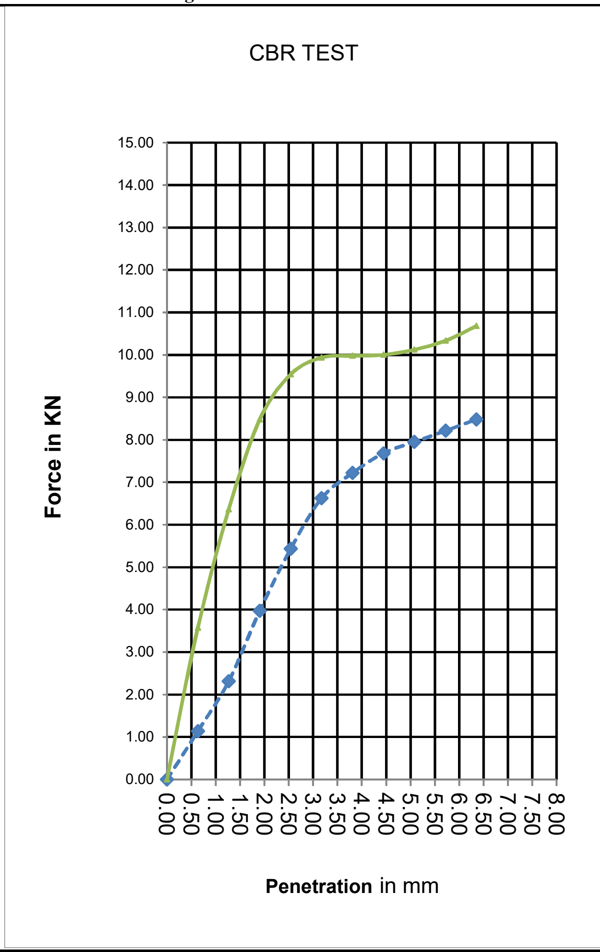
SWELL DATA

Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	22
Difference	**(div)**	22
Ring Factor		0.01

Gauge Factor:0.0005 inches/Div

SAMPLE DETAILS

Type	**STABILIZED**	**MDD**	1601
Stabilizer	**CDA**	**OMC**	27.6
%		**NMC**	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.13952	3.5776			
1.27	2.31879	6.3601			
1.91	3.97506	8.4801			
2.54	5.43258	9.5401	13.2	41	72
3.18	6.6251	9.9377			
3.81	7.22136	9.9774			
4.45	7.68512	10.004			
5.08	7.95012	10.123	20.0	40	51
5.72	8.21512	10.335			
6.35	8.48013	10.68			

Moulding Data

Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT

Tin No.	213
Tin +Wet soil	232
Tin + Dry soil	196.6
Wt of Tin	92.8
Wt of Moisture	35.4
Wt. of dry soil	103.8
Moisture content	34.10

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		72	41
5	20		51	40
		CBR = 72%	**Checked:**	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

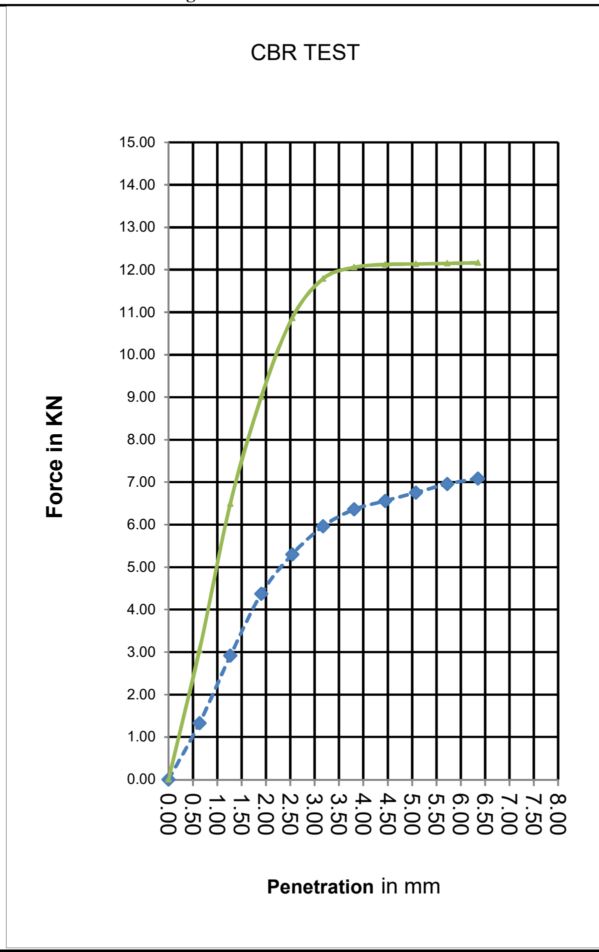
WORKING SHEET

CBR TEST
(AASHTO T193:1990)

12% CDA SAMPLE 3

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 10/09/2020	**Date soaked:**	03/09/2020
Student.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	27/08/2020

SWELL DATA			SAMPLE DETAILS			
Initial gauge Reading (div)	0		Type	STABILIZED	OMC	27.6
Final gauge Reading (div)	22		Stabilizer	CDA	NMC	9.2
Difference (div)	22		%			
Ring Factor	0.01		Swell %	0.22		
Gauge Factor:0.0005 inches/Div					MDD	1601



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.32502	3.0475			
1.27	2.91504	6.4926			
1.91	4.37257	9.0101			
2.54	5.30008	10.865	13.2	40	82
3.18	5.96259	11.793			
3.81	6.3601	12.058			
4.45	6.55885	12.124			
5.08	6.7576	12.137	20.0	34	61
5.72	6.95636	12.15			
6.35	7.08886	12.164			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	223.8
Tin + Dry soil	187.7
Wt of Tin	78.6
Wt of Moisture	36.1
Wt. of dry soil	109.1
Moisture content	33.09

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		82	40
5	20		61	34
		CBR =82%	Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

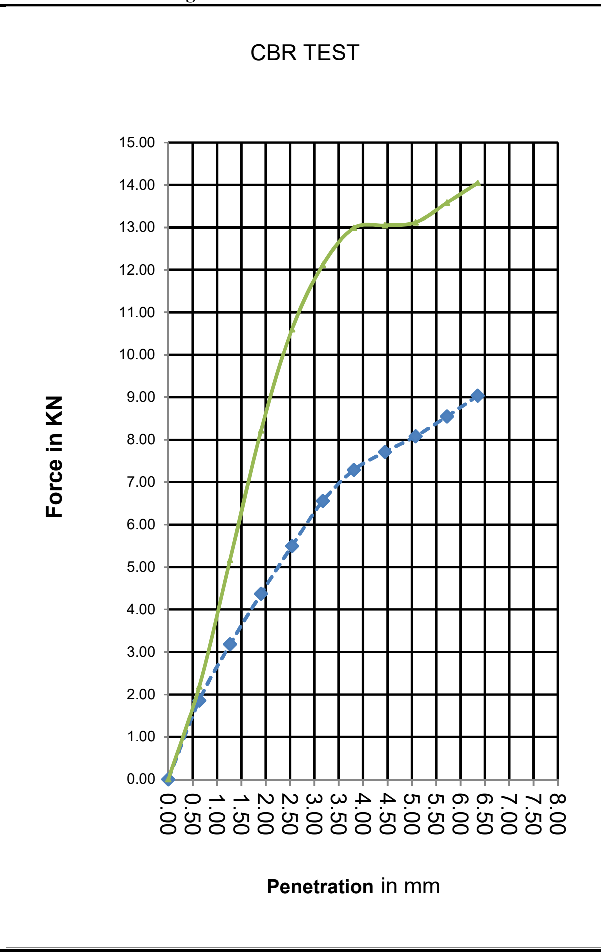
CBR TEST
(AASHTO T193:1990)

15% CDA SAMPLE 1

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 10/09/2020	**Date soaked:**	03/09/2020
Client.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	27/08/2020

SWELL DATA		
Initial gauge Reading	(div)	0
Final gauge Reading	(div)	22
Difference	(div)	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1560
Stabilizer	CDA	OMC	27.8
%		NMC	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.85503	2.1863			
1.27	3.18005	5.1676			
1.91	4.37257	8.2151			
2.54	5.49883	10.6	13.2	42	80
3.18	6.55885	12.124			
3.81	7.28761	12.985			
4.45	7.71162	13.051			
5.08	8.08262	13.118	20.0	40	66
5.72	8.54638	13.581			
6.35	9.03664	14.045			

Moulding Data		
Wt.of Mould + Wet soil	g	
Wt. of Mould	g	
Moisture Content	%	
Wet Density	Kg/m^3	
Dry Density	Kg/m^3	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	223.8
Tin + Dry soil	187.7
Wt of Tin	78.6
Wt of Moisture	36.1
Wt. of dry soil	109.1
Moisture content	33.09

RESULTS

Penetration(mm)	Standard Force(KN)	Specification		CBR%(top)	CBR%(bott.)
2.5	13.2			80	42
5	20			66	40
		CBR = 80%		Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

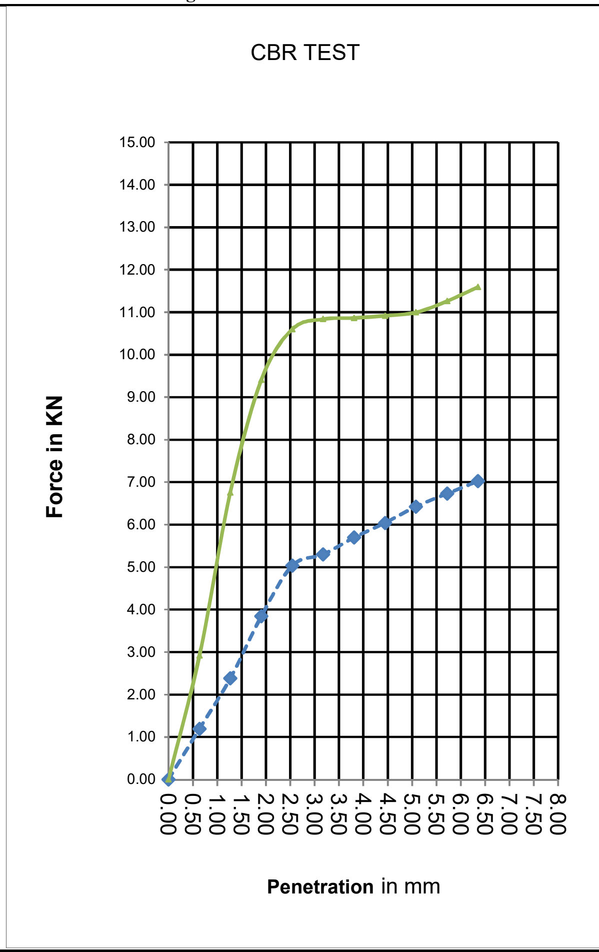
CBR TEST
(AASHTO T193:1990)

15% CDA SAMPLE 2

Project: Chemical Stabilization of Lateritic Gravel	**Tested:** 10/09/2020	**Date soaked:**	03/09/2020
Client.: Anthony Mugendi Nyagah	**Mould No.:**	**Date Moulded:**	27/08/2020

SWELL DATA	
Initial gauge Reading (div)	0
Final gauge Reading (div)	22
Difference (div)	22
Ring Factor	0.01
Gauge Factor:0.0005 inches/Div	

SAMPLE DETAILS			
Type	STABILIZED	MDD	1560
Stabilizer	CDA	OMC	27.8
%		NMC	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	1.19252	2.915			
1.27	2.38504	6.7576			
1.91	3.84256	9.4076			
2.54	5.03508	10.6	13.2	38	80
3.18	5.30008	10.839			
3.81	5.69759	10.865			
4.45	6.04209	10.918			
5.08	6.42635	10.998	20.0	32	55
5.72	6.7311	11.263			
6.35	7.02261	11.594			

Moulding Data	
Wt.of Mould + Wet soil g	
Wt. of Mould g	
Moisture Content %	
Wet Density Kg/m^3	
Dry Density Kg/m^3	
% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	213
Tin +Wet soil	232
Tin + Dry soil	196.6
Wt of Tin	92.8
Wt of Moisture	35.4
Wt. of dry soil	103.8
Moisture content	34.10

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		80	38
5	20		55	32
		CBR = 80%	Checked:	Martin Mburu

UNIVERSITY OF NAIROBI

(HIGHWAYS LABORATORY)

WORKING SHEET

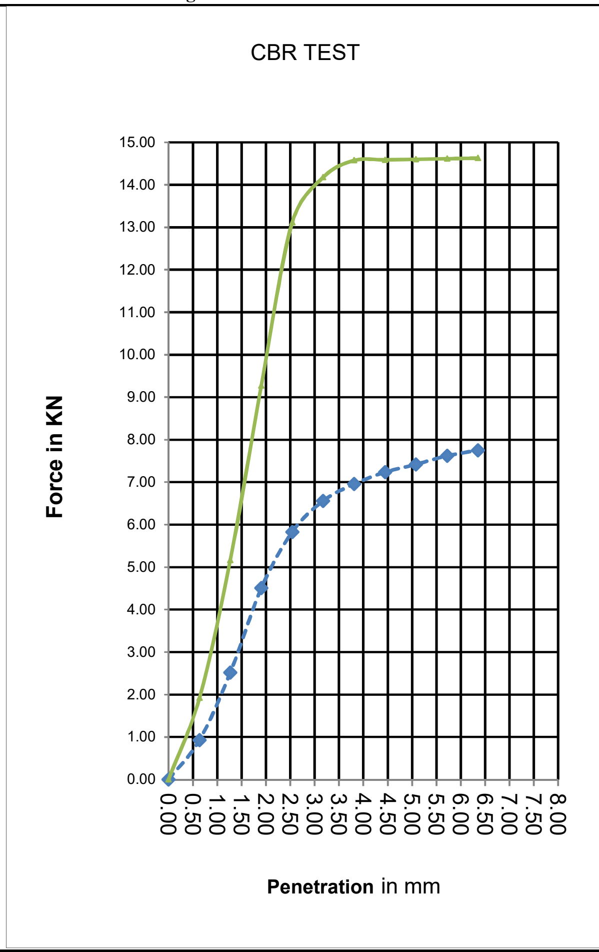
CBR TEST
(AASHTO T193:1990)

15% CDA SAMPLE 3

Project: Chemical Stabilization of Lateritic Gravel		**Tested:** 10/09/2020	**Date soaked:** 03/09/2020
Client.: Anthony Mugendi Nyagah		**Mould No.:**	**Date Moulded:** 27/08/2020

SWELL DATA		
Initial gauge Reading	**(div)**	0
Final gauge Reading	**(div)**	22
Difference	**(div)**	22
Ring Factor		0.01
Gauge Factor:0.0005 inches/Div		

SAMPLE DETAILS			
Type	STABILIZED	MDD	1560
Stabilizer	CDA	OMC	27.8
%		NMC	9.2
Swell %	0.22		



Penetration of the plunger (mm)	Bot (KN)	Top (KN)	Standard Load(KN)	CBR% Bott.	CBR% Top
0.00	0	0			
0.64	0.92751	1.9213			
1.27	2.51754	5.1676			
1.91	4.50507	9.2751			
2.54	5.83009	13.118	13.2	44	99
3.18	6.55885	14.178			
3.81	6.95636	14.575			
4.45	7.23461	14.588			
5.08	7.42011	14.602	20.0	37	73
5.72	7.61887	14.615			
6.35	7.75137	14.628			

Moulding Data		
Wt.of Mould + Wet soil	**g**	
Wt. of Mould	**g**	
Moisture Content	**%**	
Wet Density	**Kg/m^3**	
Dry Density	**Kg/m^3**	
	% MDD	

MOULDING MOISTURE CONTENT	
Tin No.	184
Tin +Wet soil	223.8
Tin + Dry soil	187.7
Wt of Tin	78.6
Wt of Moisture	36.1
Wt. of dry soil	109.1
Moisture content	33.09

RESULTS

Penetration(mm)	Standard Force(KN)	Specification	CBR%(top)	CBR%(bott.)
2.5	13.2		99	44
5	20		73	37
		CBR = 99%	Checked:	Martin Mburu

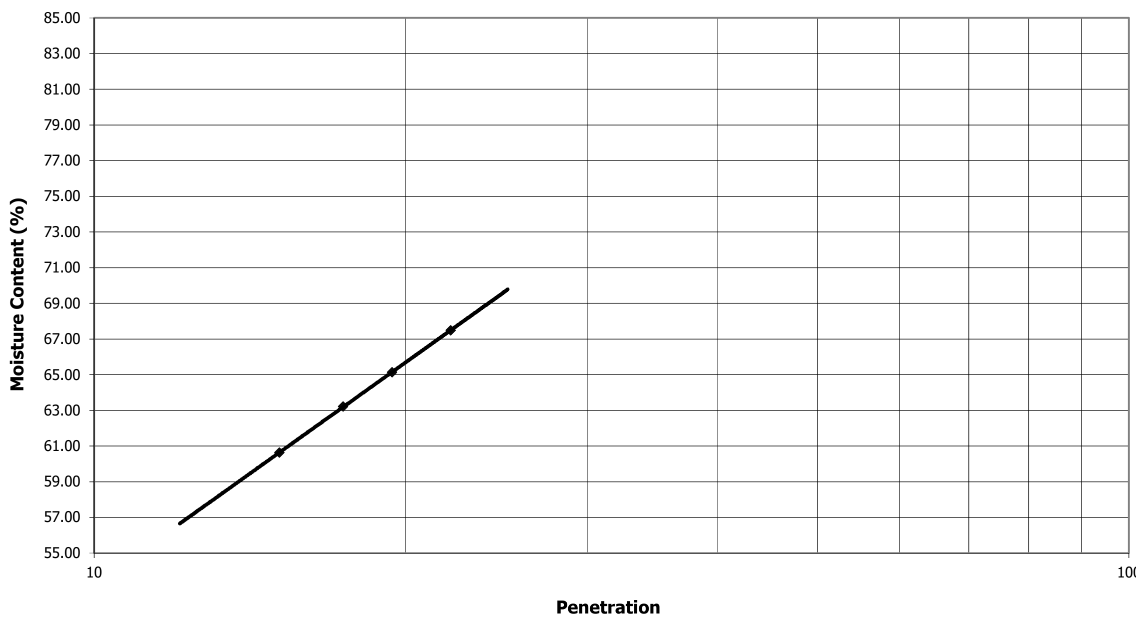
Appendix E4 Atterberg Limits

Plasticity Indices

PROJECT	Chemical Stabilization of Lateritic Gravel using the CDA				
STUDENT	Anthony Mugendi Nyagah				
DEPTH		Sample No	3% STAB	Sample time	
Test date	22-Sep-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		**29**	**4**	**15**	**1**	**J**	**T4**
Penetration (mm)		**15.1**	**17.4**	**19.4**	**22.1**		
Wt of Container + Wet Soil (g)		**53.5**	**74.2**	**82.9**	**91.5**	**15**	**15**
Wt of Container + Dry Soil (g)		**43.8**	**56.5**	**61.6**	**66.8**	**13.5**	**13.4**
Wt of Container (g)		**27.8**	**28.5**	**28.9**	**30.2**	**9.3**	**9.1**
Wt of Moistuer (g)		**9.7**	**17.7**	**21.3**	**24.7**	**1.5**	**1.6**
Wt of Dry Soil (g)		**16**	**28**	**32.7**	**36.6**	**4.2**	**4.3**
Moisture Content (%)		**60.63**	**63.21**	**65.14**	**67.49**	**35.71**	**37.21**

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	116
		No 2	140		**No 2**	116



Liquid Limit	**66**
Plastic Limit	**36**
Plasticity Index	**29**
Linear Shrinkage (%)	**17**

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	24-Sep-20		
Observations:			

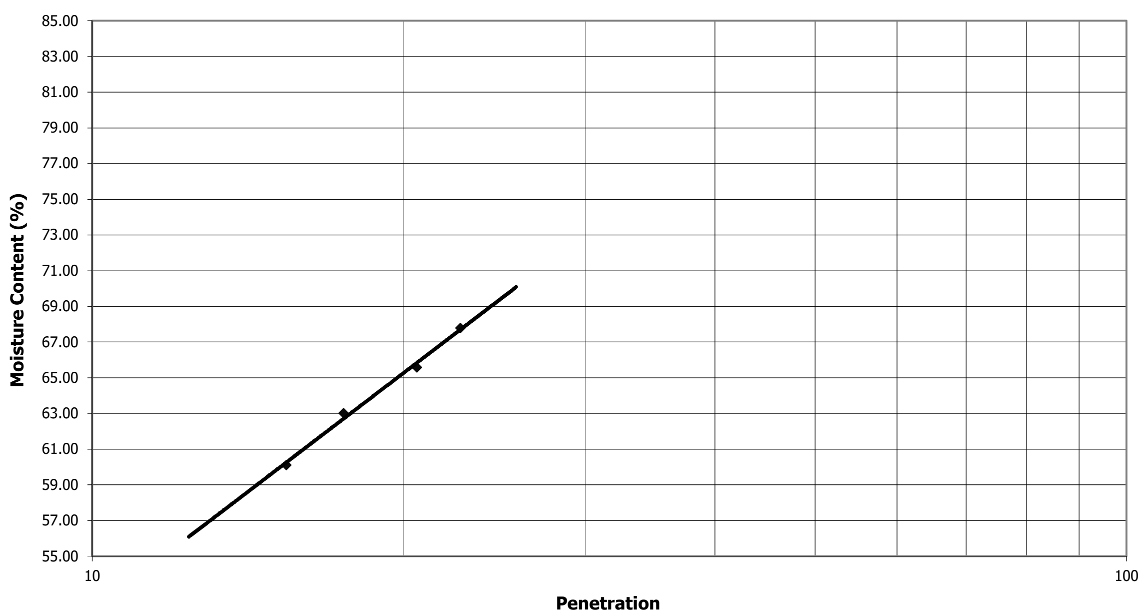
Conform to the specifications

Plasticity Indices

PROJECT	Chemical Stabilization of Lateritic Gravel Using the CDA				
STUDENT	Anthony Mugendi Nyagah				
DEPTH		Sample No	6% STAB	Sample time	
Test date	22-Sep-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		**41**	**33**	**30**	**10**	**B**	**R**
Penetration (mm)		**15.4**	**17.5**	**20.6**	**22.7**		
Wt of Container + Wet Soil (g)		**57.1**	**68.6**	**79.2**	**89**	**16.7**	**16.7**
Wt of Container + Dry Soil (g)		**46.7**	**53.1**	**59**	**65**	**14.3**	**14.7**
Wt of Container (g)		**29.4**	**28.5**	**28.2**	**29.6**	**7.5**	**9.2**
Wt of Moistuer (g)		**10.4**	**15.5**	**20.2**	**24**	**2.4**	**2**
Wt of Dry Soil (g)		**17.3**	**24.6**	**30.8**	**35.4**	**6.8**	**5.5**
Moisture Content (%)		**60.12**	**63.01**	**65.58**	**67.80**	**35.29**	**36.36**

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	116
		No 2	140		**No 2**	116



Liquid Limit	**65**
Plastic Limit	**36**
Plasticity Index	**29**
Linear Shrinkage (%)	**17**

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	24-Sep-20		
Observations:			

Conform to the specifications

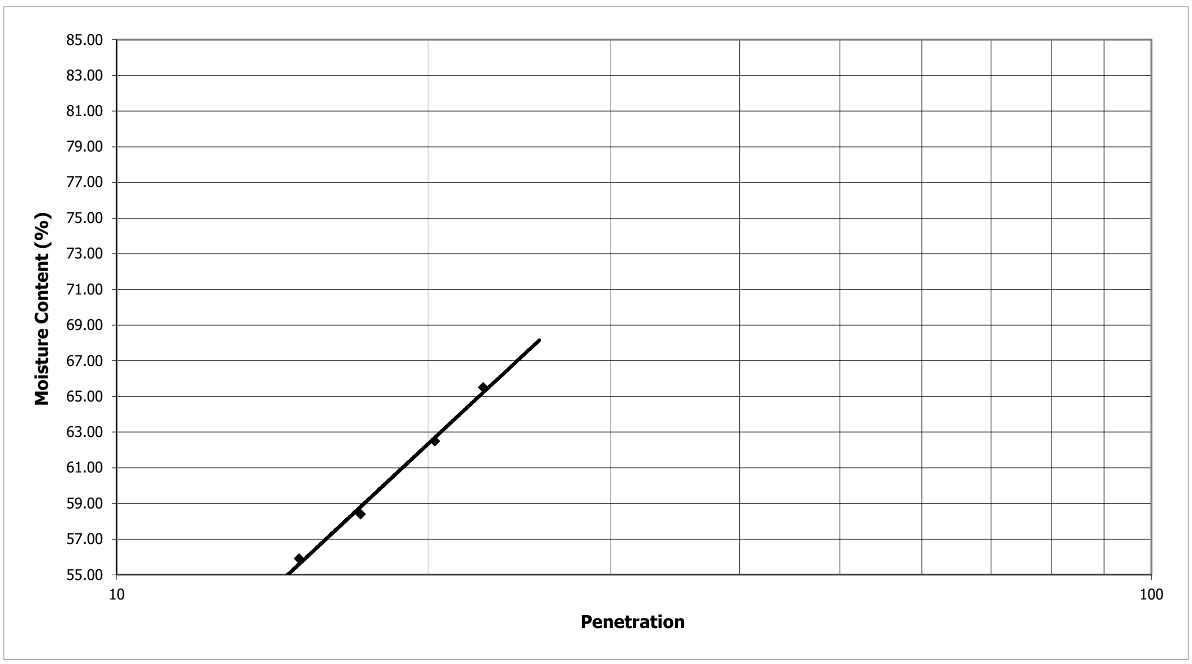
Plasticity Indices

PROJECT	Chemical Stabilization of Lateritic Gravel using the CDA
STUDENT	Anthony Mugendi Nyagah

DEPTH		Sample No	9% STAB	Sample time	
Test date	23-Sep-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		13	26	5	29	13	1P
Penetration (mm)		15	17.2	20.3	22.6		
Wt of Container + Wet Soil (g)		57.8	68.4	80.8	89.7	12.7	12.7
Wt of Container + Dry Soil (g)		47.4	54.5	61.8	65.2	11.8	11.6
Wt of Container (g)		28.8	30.7	31.4	27.8	9	8.1
Wt of Moistuer (g)		10.4	13.9	19	24.5	0.9	1.1
Wt of Dry Soil (g)		18.6	23.8	30.4	37.4	2.8	3.5
Moisture Content (%)		55.91	58.40	62.50	65.51	32.14	31.43

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	120
		No 2	140		**No 2**	120



Liquid Limit	62
Plastic Limit	32
Plasticity Index	30
Linear Shrinkage (%)	14

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	25-Sep-20		
Observations:			

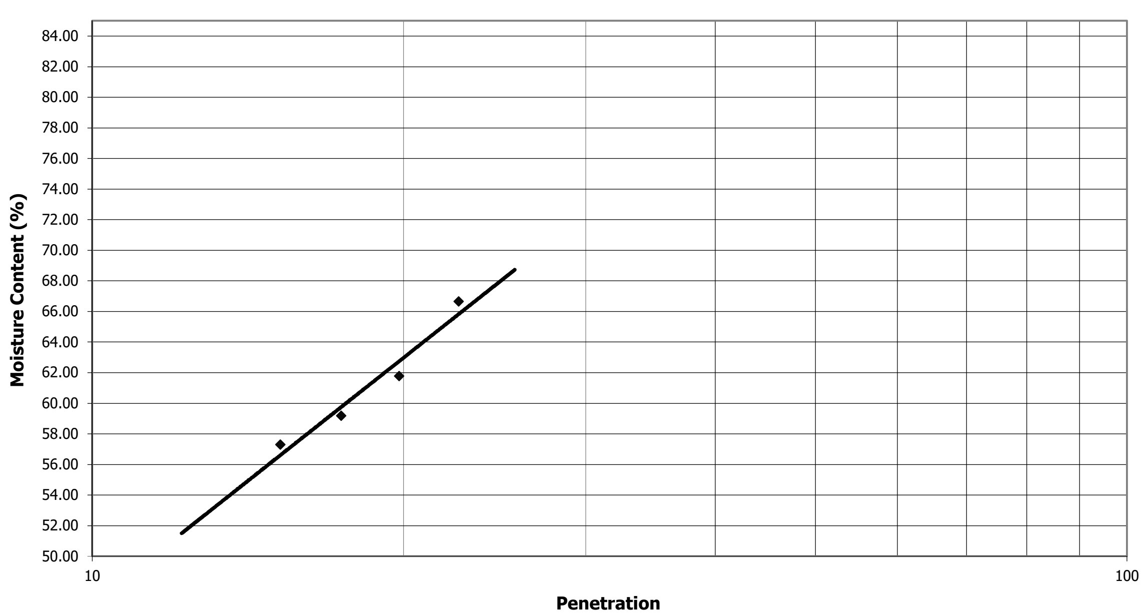
Conform to the specifications

Plasticity Indices

PROJECT	Chemical Stabilization of Lateritic Gravel using the CDA				
CHAINAGE	Anthony Mugendi Nyagah				
DEPTH		Sample No	12% STAB	Sample time	
Test date	23-Sep-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		**33**	**17**	**TX**	**46**	**R**	**ZB**
Penetration (mm)		**15.2**	**17.4**	**19.8**	**22.6**		
Wt of Container + Wet Soil (g)		**42.6**	**55.5**	**61.3**	**79.2**	**14.5**	**14.5**
Wt of Container + Dry Soil (g)		**37.5**	**45.2**	**44**	**59.2**	**13.2**	**13.1**
Wt of Container (g)		**28.6**	**27.8**	**16**	**29.2**	**9.2**	**9**
Wt of Moistuer (g)		**5.1**	**10.3**	**17.3**	**20**	**1.3**	**1.4**
Wt of Dry Soil (g)		**8.9**	**17.4**	**28**	**30**	**4**	**4.1**
Moisture Content (%)		**57.30**	**59.20**	**61.79**	**66.67**	**32.50**	**34.15**

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	122
		No 2	140		**No 2**	122



Liquid Limit	**63**
Plastic Limit	**33**
Plasticity Index	**29**
Linear Shrinkage (%)	**13**

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	25-Sep-20		
Observations:			

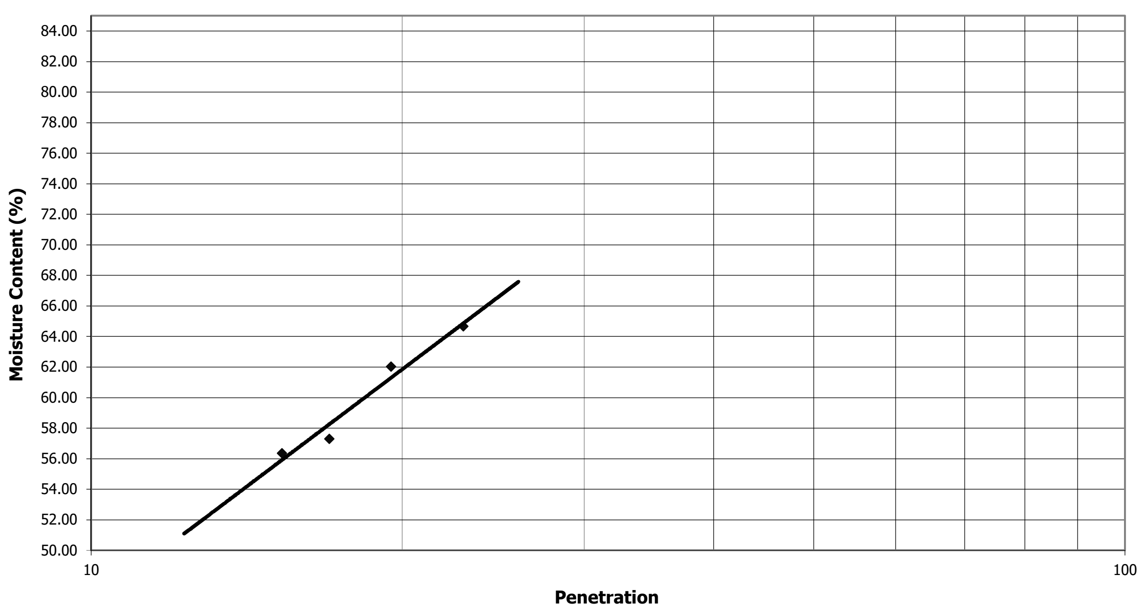
Conform to the specifications

Plasticity Indices

PROJECT	Chemical Stabilization of Lateritic Gravel using the CDA				
STUDENT	Anthony Mugendi Nyagah				
DEPTH		Sample No	15% STAB	Sample time	
Test date	23-Sep-20	Lab Ref No			
Specification	In accordance with BS 1377: 1990				

		Liquid Limit				Plastic Limit	
Container No		15	32	3	2	XL	7F
Penetration (mm)		15.3	17	19.5	22.9		
Wt of Container + Wet Soil (g)		48.1	59.6	69.5	79.3	12.7	12.7
Wt of Container + Dry Soil (g)		41	48.6	54.3	58.8	11.9	11.8
Wt of Container (g)		28.4	29.4	29.8	27.1	9.3	9
Wt of Moistuer (g)		7.1	11	15.2	20.5	0.8	0.9
Wt of Dry Soil (g)		12.6	19.2	24.5	31.7	2.6	2.8
Moisture Content (%)		56.35	57.29	62.04	64.67	30.77	32.14

Linear Shrinkage	**Initial Length (mm)**	**No1**	140	**Final Length (mm)**	**No 1**	122
		No 2	140		**No 2**	122



Liquid Limit	62
Plastic Limit	31
Plasticity Index	30
Linear Shrinkage (%)	13

Technician	Mathew Mburu	**Verified :**	Elly Oyier
Date	25-Sep-20		
Observations:			

Conform to the specifications

Appendix E5 Grading

UNIVERSITY OF NAIROBI
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

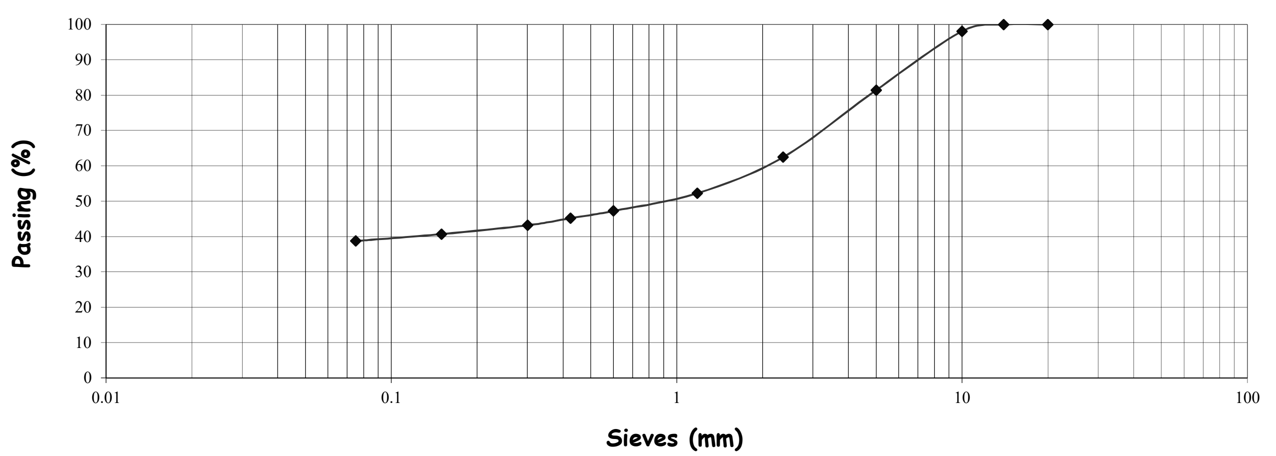
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**				
Depth (m)		**SAMPLE No.**	**3% CDA SAMPLE A**	**Sr. No.**	
Test date:	25-Sep-20	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**Lateritic Gravel soil Stabilized with CDA**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	77.5
Washed dry sample mass + pan	(gm)		Fine percent	(%)	38.8
Washed dry sample mass	(gm)	122.5	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	3.8	**1.9**	**98.1**		
5	33.3	**16.7**	**81.5**		
2.36	38	**19.0**	**62.5**		
1.18	20.4	**10.2**	**52.3**		
0.6	10	**5.0**	**47.3**		
0.425	4.1	**2.1**	**45.2**		
0.3	4	**2.0**	**43.2**		
0.15	5	**2.5**	**40.7**		
0.075	3.9	**2.0**	**38.8**		
	77.5	**38.8**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Elly Oyier**		
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

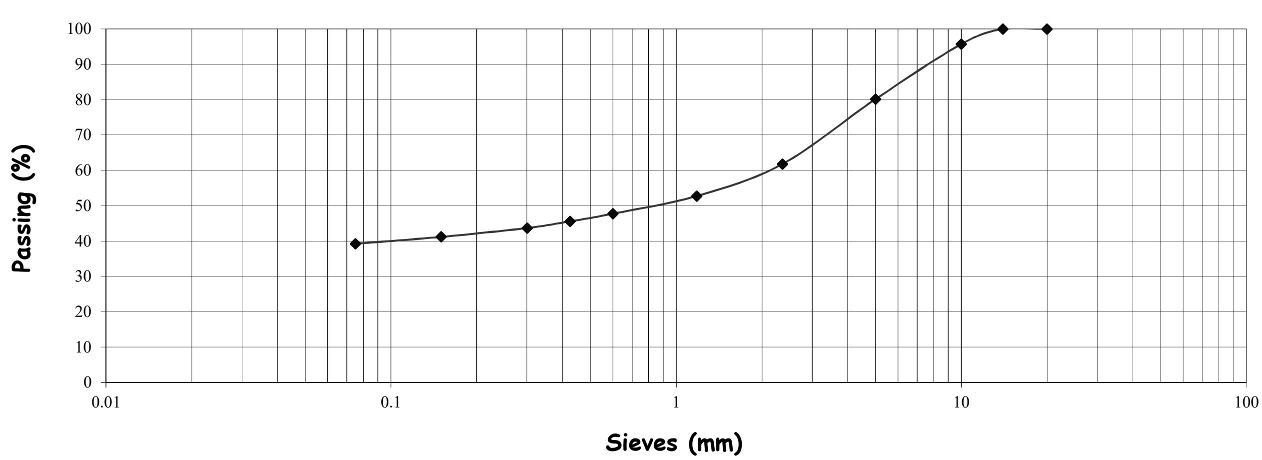
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**			
Sample source	**Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**			
Depth (m)	**SAMPLE No.**	**3% CDA SAMPLE B**	**Sr. No.**	
Test date:	25-Sep-20	**Location:**		
Specification	According to BS 1377:1990.	**Sample Description:**	**Lateritic Gravel soil Stabilized with CDA**	

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	78.5
Washed dry sample mass + pan	(gm)		Fine percent	(%)	39.3
Washed dry sample mass	(gm)	121.5	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	8.5	**4.3**	**95.8**		
5	31.2	**15.6**	**80.2**		
2.36	36.7	**18.4**	**61.8**		
1.18	18.1	**9.1**	**52.8**		
0.6	10	**5.0**	**47.8**		
0.425	4.3	**2.2**	**45.6**		
0.3	3.8	**1.9**	**43.7**		
0.15	5	**2.5**	**41.2**		
0.075	3.9	**2.0**	**39.3**		
	78.5	**39.3**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Elly Oyier**		
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

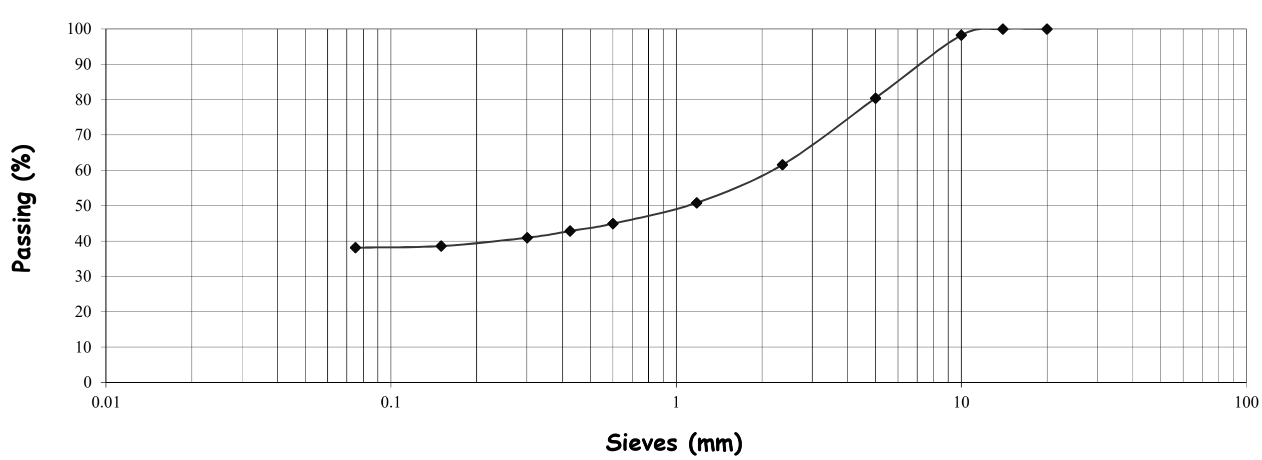
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**				
Depth (m)		**SAMPLE No.**	**6% CDA SAMPLE A**	**Sr. No.**	
Test date:	25-Sep-20	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**lateritic Gravel soil Stabilized with CDA**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	76.3
Washed dry sample mass + pan	(gm)		Fine percent	(%)	38.2
Washed dry sample mass	(gm)	123.7	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	3.5	**1.8**	**98.3**		
5	35.6	**17.8**	**80.5**		
2.36	37.7	**18.9**	**61.6**		
1.18	21.5	**10.8**	**50.9**		
0.6	11.8	**5.9**	**45.0**		
0.425	4.2	**2.1**	**42.9**		
0.3	3.8	**1.9**	**41.0**		
0.15	4.7	**2.4**	**38.6**		
0.075	0.9	**0.5**	**38.2**		
	76.3	**38.2**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Elly Oyier**		
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

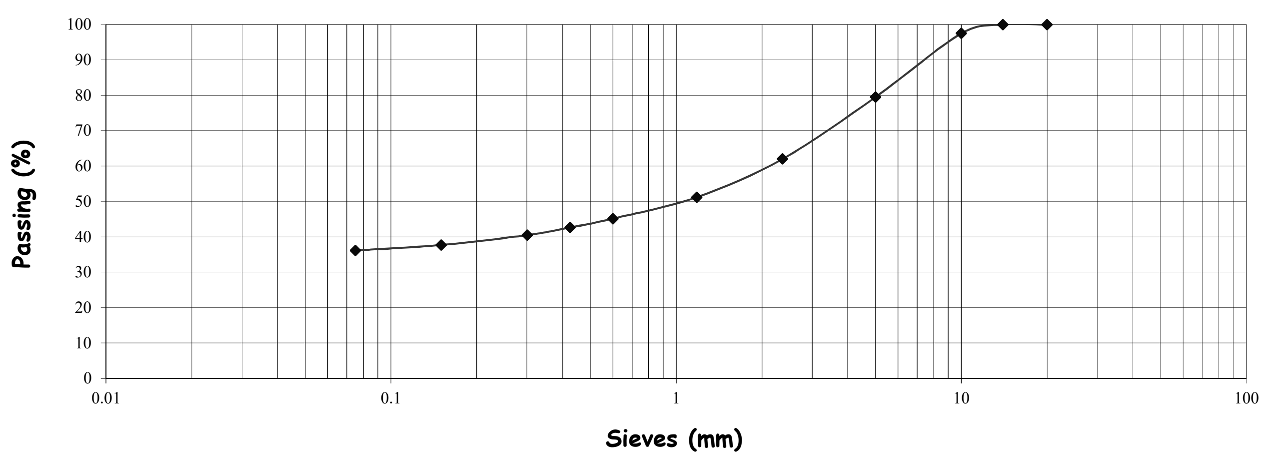
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**				
Depth (m)		**SAMPLE No.**	**6% CDA SAMPLE B**	**Sr. No.**	
Test date:	25-Sep-20	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**Lateritic Gravel soil Stabilized with CDA**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	72.3
Washed dry sample mass + pan	(gm)		Fine percent	(%)	36.2
Washed dry sample mass	(gm)	127.7	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria Min(%)	Acceptance Criteria Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	5	**2.5**	**97.5**		
5	36	**18.0**	**79.5**		
2.36	35	**17.5**	**62.0**		
1.18	21.6	**10.8**	**51.2**		
0.6	12.1	**6.1**	**45.2**		
0.425	5	**2.5**	**42.7**		
0.3	4.3	**2.2**	**40.5**		
0.15	5.6	**2.8**	**37.7**		
0.075	3.1	**1.6**	**36.2**		
	72.3	**36.2**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**		**Elly Oyier**	
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

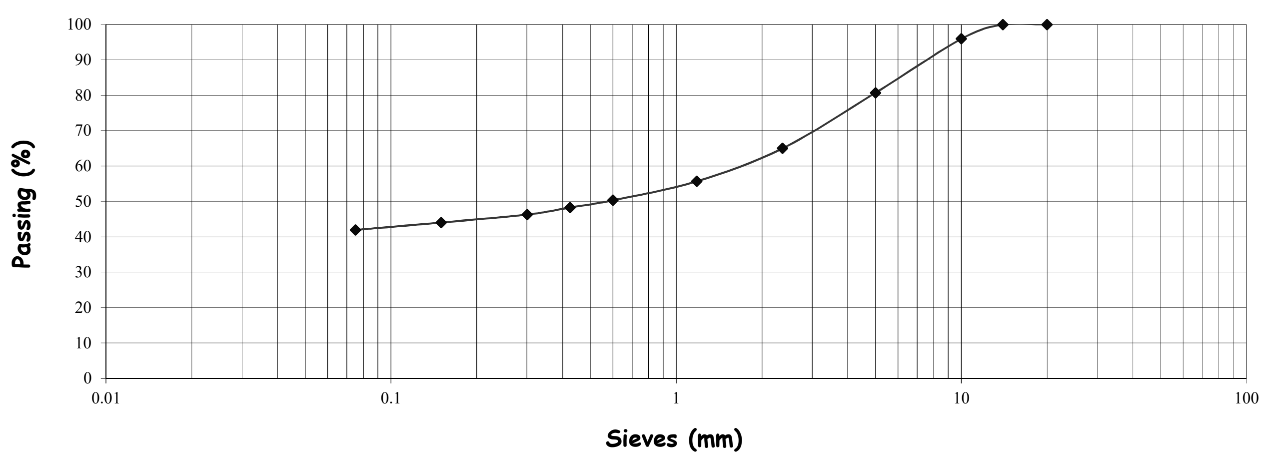
SIEVE ANALYSIS

Student	Anthony Mugendi Nyagah
Sample source	Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)
Depth (m)	SAMPLE No. 9% CDA SAMPLE A Sr. No.
Test date:	25-Sep-20 Location:
Specification	According to BS 1377:1990. Sample Description: Lateritic Gravel soil Stabilized with CDA

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	83.9
Washed dry sample mass + pan	(gm)		Fine percent	(%)	42.0
Washed dry sample mass	(gm)	116.1	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	8.1	**4.1**	**96.0**		
5	30.5	**15.3**	**80.7**		
2.36	31.4	**15.7**	**65.0**		
1.18	18.6	**9.3**	**55.7**		
0.6	10.7	**5.4**	**50.4**		
0.425	4.1	**2.1**	**48.3**		
0.3	4	**2.0**	**46.3**		
0.15	4.5	**2.3**	**44.1**		
0.075	4.2	**2.1**	**42.0**		
	83.9	**42.0**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu		Verified :Lab. Incharge	Elly Oyier	
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

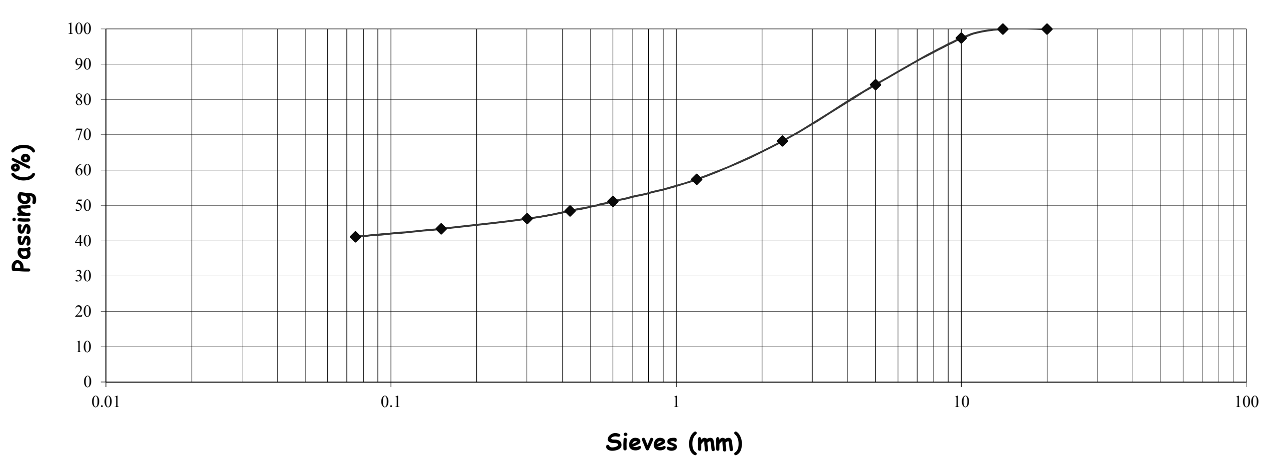
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**
Sample source	**Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**
Depth (m)	**SAMPLE No.** **9% CDA SAMPLE B** **Sr. No.**
Test date:	25-Sep-20 **Location:**
Specification	According to BS 1377:1990. **Sample Description:** **Lateritic Gravel soil Stabilized with CDA**

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	82.3
Washed dry sample mass + pan	(gm)		Fine percent	(%)	41.2
Washed dry sample mass	(gm)	117.7	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	5.2	**2.6**	**97.4**		
5	26.3	**13.2**	**84.3**		
2.36	32	**16.0**	**68.3**		
1.18	21.7	**10.9**	**57.4**		
0.6	12.5	**6.3**	**51.2**		
0.425	5.3	**2.7**	**48.5**		
0.3	4.5	**2.3**	**46.3**		
0.15	5.7	**2.9**	**43.4**		
0.075	4.5	**2.3**	**41.2**		
	82.3	**41.2**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu		**Verified :Lab. Incharge**	**Elly Oyier**	
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

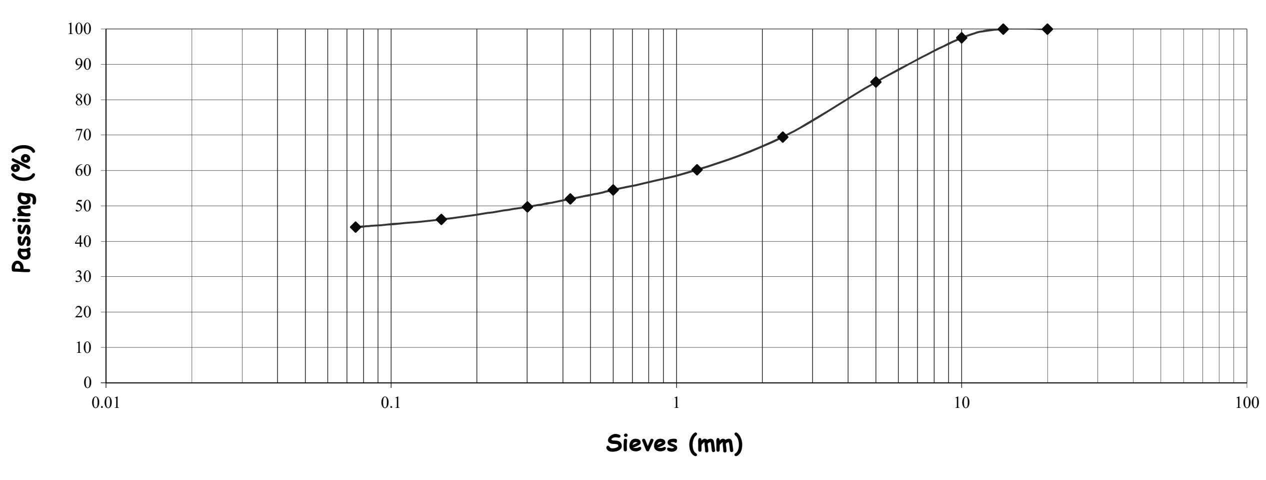
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**				
Depth (m)		**SAMPLE No.**	**12% CDA SAMPLE A**	**Sr. No.**	
Test date:	25-Sep-20	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**Lateritic Gravel soil Stabilized with CDA**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	88
Washed dry sample mass + pan	(gm)		Fine percent	(%)	44.0
Washed dry sample mass	(gm)	112	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	5	**2.5**	**97.5**		
5	25	**12.5**	**85.0**		
2.36	31	**15.5**	**69.5**		
1.18	18.6	**9.3**	**60.2**		
0.6	11.4	**5.7**	**54.5**		
0.425	5	**2.5**	**52.0**		
0.3	4.5	**2.3**	**49.8**		
0.15	7.1	**3.6**	**46.2**		
0.075	4.4	**2.2**	**44.0**		
	88	**44.0**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu		**Verified :Lab. Incharge**	**Elly Oyier**	
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

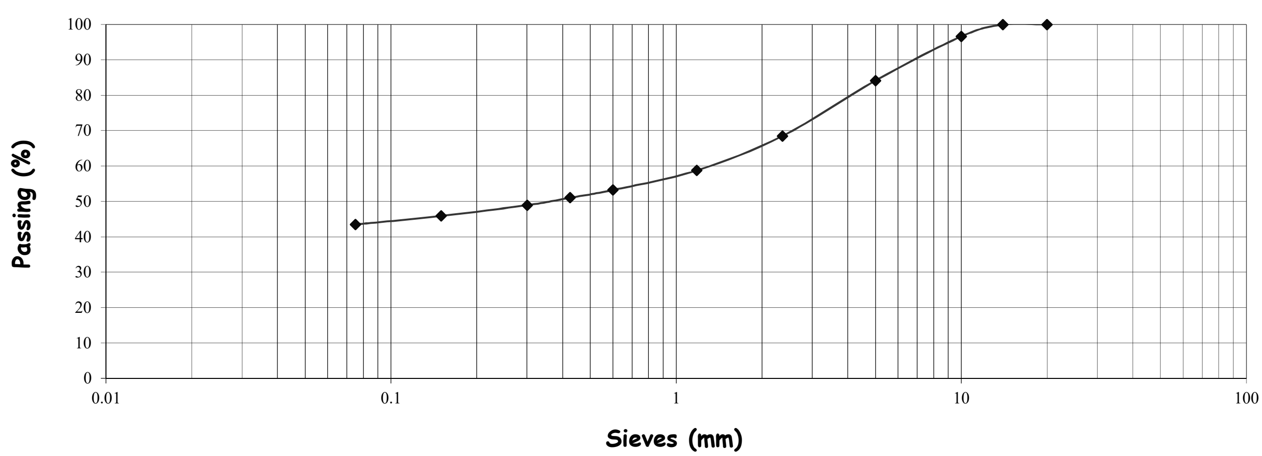
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**
Sample source	**Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**
Depth (m)	**SAMPLE No.** **12% CDA SAMPLE B** **Sr. No.**
Test date:	25-Sep-20 **Location:**
Specification	According to BS 1377:1990. **Sample Description:** **Lateritic Gravel soil Stabilized with CDA**

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	87
Washed dry sample mass + pan	(gm)		Fine percent	(%)	43.5
Washed dry sample mass	(gm)	113	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	6.7	**3.4**	**96.7**		
5	25	**12.5**	**84.2**		
2.36	31.3	**15.7**	**68.5**		
1.18	19.5	**9.8**	**58.8**		
0.6	11	**5.5**	**53.3**		
0.425	4.4	**2.2**	**51.1**		
0.3	4.2	**2.1**	**49.0**		
0.15	6.1	**3.1**	**45.9**		
0.075	4.8	**2.4**	**43.5**		
	87	**43.5**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Elly Oyier**		
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

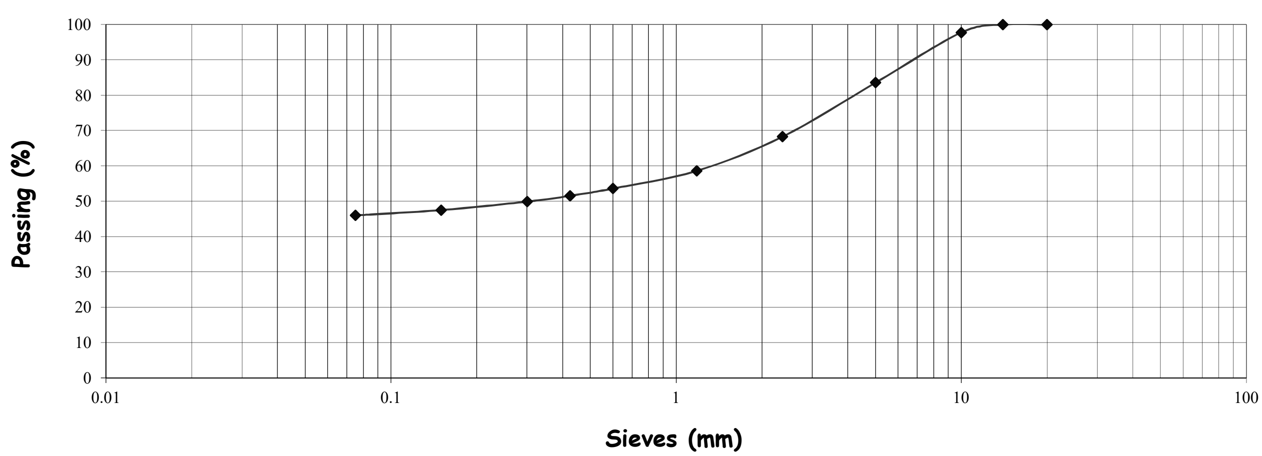
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**				
Sample source	**Membley quarry kiambu County (lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**				
Depth (m)		**SAMPLE No.**	**15% CDA SAMPLE A**	**Sr. No.**	
Test date:	25-Sep-20	**Location:**			
Specification	According to BS 1377:1990.	**Sample Description:**	**Lateritic Gravel soil Stabilized with CDA**		

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	92
Washed dry sample mass + pan	(gm)		Fine percent	(%)	46.0
Washed dry sample mass	(gm)	108	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria Min(%)	Acceptance Criteria Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	4.5	**2.3**	**97.8**		
5	28.4	**14.2**	**83.6**		
2.36	30.6	**15.3**	**68.3**		
1.18	19.3	**9.7**	**58.6**		
0.6	10	**5.0**	**53.6**		
0.425	4.1	**2.1**	**51.6**		
0.3	3.3	**1.7**	**49.9**		
0.15	4.8	**2.4**	**47.5**		
0.075	3	**1.5**	**46.0**		
	92	**46.0**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu	**Verified :Lab. Incharge**	**Elly Oyier**		
Date	25-Sep-20				

Observations:

Conform to the specifications

UNIVERSITY OF NAIROBI

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

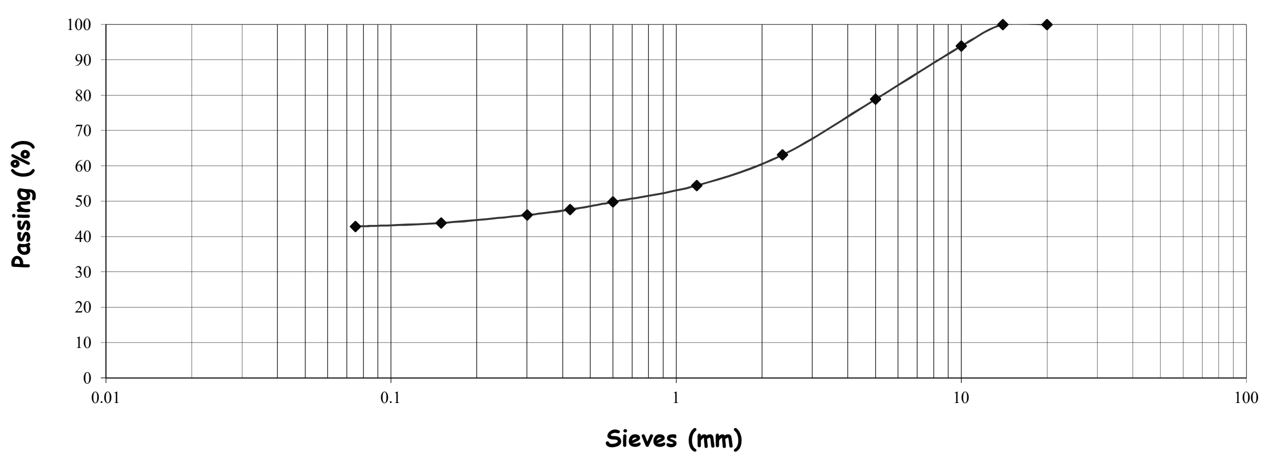
SIEVE ANALYSIS

Student	**Anthony Mugendi Nyagah**
Sample source	**Membley quarry kiambu County (Lateritic Gravel) & Upper Kabete Campus (Dairy Farm) UoN (CDA)**
Depth (m)	**SAMPLE No.** **15% CDA SAMPLE B** **Sr. No.**
Test date:	25-Sep-20 **Location:**
Specification	According to BS 1377:1990. **Sample Description:** **Lateritic Gravel soil Stabilized with CDA**

Pan mass	(gm)	0			
Initial dry sample mass + pan	(gm)				
Initial dry sample mass	(gm)	200	Fine mass	(gm)	85.7
Washed dry sample mass + pan	(gm)		Fine percent	(%)	42.9
Washed dry sample mass	(gm)	114.3	Acceptance Criteria	(%)	

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
20	0	**0.0**	**100.0**		
14	0	**0.0**	**100.0**		
10	12.2	**6.1**	**93.9**		
5	30.1	**15.1**	**78.9**		
2.36	31.5	**15.8**	**63.1**		
1.18	17.3	**8.7**	**54.5**		
0.6	9.3	**4.7**	**49.8**		
0.425	4.3	**2.2**	**47.7**		
0.3	3.1	**1.6**	**46.1**		
0.15	4.5	**2.3**	**43.9**		
0.075	2	**1.0**	**42.9**		
	85.7	**42.9**			
	200				

GRADING CURVE



Equipment	Sieve set N° :		Shaker N°		Scale N° :
Technician	Mathew Mburu		**Verified :Lab. Incharge**		**Elly Oyier**
Date	25-Sep-20				

Observations:

Conform to the specifications

Summary of CDA Stabilized Results

Compaction Properties

Stabilized Material	MDD (kg/m^3)	OMC (%)
3% CDA Stabilized	1642	26.20
6% CDA Stabilized	1638	26.60
9% CDA Stabilized	1602	27.40
12% CDA Stabilized	1601	27.60
15% CDA Stabilized	1560	27.80

Strength Properties UCS (kN/m^2)

CDA	Sample 1	Sample 2	Sample 3	Average
3%	392	396	341	376
6%	428	440	427	432
9%	498	490	499	496
12%	~~544~~	458	382	420
15%	368	364	359	364

Strength Properties CBR (%)

CDA	Sample 1	Sample 2	Sample 3	Average
3%	~~67~~	39	42	41
6%	46	50	55	50
9%	65	53	~~78~~	59
12%	~~59~~	72	82	77
15%	80	80	99	86

Atterberg Limits

FCD	Liquid Limit	Plastic Limit	Plasticity Index	Linear Shrinkage
3%	66	36	29	17
6%	65	36	29	17
9%	62	32	30	14
12%	63	33	29	13
15%	62	31	30	13

Grading (% of fines)

CDA	Sample A	Sample B	Average Value
3%	38.8	39.3	39.1
6%	38.2	36.2	37.2
9%	42.0	41.2	41.6
12%	44.0	43.5	43.8
15%	46.0	42.9	44.5