ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Bio-Enzyme Stabilization Of Red Clay Soil

Prepared By: Dagnachew Seifu

A THESIS SUBMITTED TO THE SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING OF ADDIS ABABA INSTITUTE OF TECHNOLOGY, ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN CIVIL ENGINEERING (GEOTECHNICAL ENGINEERING)

April , 2021

Addis Ababa, Ethiopia

Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Bio-Enzyme Stabilization of Red Clay Soil

By

Dagnachew Seifu

Approved by Board of Examiners

Dr. Mesele Haile (Advisor)	____________ Signature	____________ Date
Dr. Henok Fikre (External Examiner)	____________ Signature	____________ Date
Dr. Tezera Firew (Internal Examiner)	____________ Signature	____________ Date
____________ (Chairman)	____________ Signature	____________ Date

Abstract

Enzyme based liquid soil stabilizers have emerged as an alternative soil stabilization technique and are being introduced to the road construction industry, with an objective to improve the geotechnical properties of soils and ultimately reduce the overall cost of the projects. However, evidence to support the effectiveness of these products as stabilizer is based on manufacturer's claims in their marketing brochures and manuals. Thus there is a need for an independent assessment of these products. Accordingly, this study is performed to evaluate the effect of TerraZyme which is an Enzyme based liquid stabilizer in improving the engineering properties of a red clay soil.

Soil samples were collected from five different location in the northern part of Addis Ababa, and different laboratory tests were conducted on the soil samples with and without the application of TerraZyme. These tests include Particle Size Distribution, Plasticity Index, CBR and Unconfined Compressive Strength tests.

The result obtained shows a slight increment in the UCS and CBR tests of the soil but the improvement is very small to warrant a large scale application of TerraZyme for red clay soil. Therefore, the type of soils in which the TerraZyme application can produce an optimal result should be investigated before applying TerraZyme on a large scale projects.

ACKNOWLEDGEMENT

I would like to express my heartfelt thanks to my advisor Dr Mesele Haile for his professional guidance and valuable support, I would also like to express my appreciation to NET Consulting Engineers Plc management and the laboratory staff members for their support, encouragement and allowing me to use the laboratory to conduct laboratory tests.

At last but not the list my best gratitude goes to my wife W/o Hirut Worku for her support and encouragement throughout the study.

Table of Content

List of Table

List of Figures

ABBREVIATIONS AND DEFINITIONS

AAU	Addis Ababa University
ERA	Ethiopian Roads Authority
RSDP	Road Sector Development Program
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BS	British Standard
CBR	California Bearing Ratio
UCS	Unconfined Compressive Strength
Km	Kilo meter
m	meter
MDD	Maximum Dry Density
mg	Milligram (one thousandth of a gram)
mm	Millimetre (one thousandth of a meter)
OMC	Optimum Moisture Content
kPa	SI unit of pressure (kPa = Kilo-Pascal)
kN	SI unit of load (kN = Kilo-Newton)
Ǻ^0	Angstrom Measuring Unit of length (1 Angstrom = 10^{-10} m)
pH	Power of H (= symbol for hydrogen), measure of the acidity or alkalinity of a solution
PI	Plasticity Index
SI	System International (The international System of Units of Measurement)
USCS	Unified Soil Classification System

1 INTRODUCTION

Soils available for construction often do not meet the requirement for construction. The process by which the properties of the soil are improved so as to meet the construction requirement is called stabilization. In its broadest sense, soil stabilization may also be defined as the method used to change one or more properties of soil so as to improve the desired performance of the soil [Teferra, A. and. Likin M. (1999)].

In the fourth Road Sector Development Program (RSDP) and the Growth and Transformation Plan of the country, it is intended that all kebeles and weredas to be connected with an all weathered road network. Accordingly, around 70,000 km of road is expected to be built within the next five years. This shows that a huge amount of money will be invested to construct these roads and they have to be maintained so that comfort, convenience and safety are provided to the travelling public.

Hence, Cost effectiveness of the roads to be constructed is vital for economic growth of the country. There is an urgent need to identify new methods and materials to improve the road structure and to expand the road network. Commonly used materials may be fast depleting or may not be available in an economically viable distance. Therefore, this may lead to an increase in the cost of construction.

When poor quality soil is available at the construction site, the best option is to modify the properties of the soil so that it meets the pavement design requirements. This has led to the development of soil stabilization techniques. Since the nature and properties of natural soil vary widely, a suitable stabilization technique has to be adopted for a particular situation after considering the soil properties.

Soil improvement by mechanical or chemical means is widely adopted. In order to stabilize soils for improving strength and durability, a number of chemical additives, both inorganic and organic, have also been used. Recently Bio-Enzymes have emerged as a new chemical for soil stabilization. Bio-Enzymes are chemical, organic, and liquid concentrated substances which are used to improve the stability of soil to be used for construction.

Recently, enzyme – based liquid stabilizers have been introduced to the road construction industry. However, evidence of support of the effectiveness of these products as stabilizer is based on manufacturer's claims in their marketing brochures and manuals. Thus there is a need for independent assessment of these products. Since the goal of soil stabilization is to improve the properties of the treated materials, stabilization should provide improvement in the material properties that contribute to better performance of the treated material compared to the untreated material. Therefore, the assessment of the effectiveness of the treatment method or used product in the soil stabilization can be achieved by determining change in the properties of the treated material. In this study the effectiveness of the enzyme – based product (TerraZyme) was determined through the measurement of Atterberg limits, Californian Bearing Ratio and Unconfined Compressive Strength tests.

Therefore, this thesis mainly concentrates on stabilizing soils that are used for road construction and hence the main focus will be to assess the performance of the stabilizing chemical enzyme on red clay soil. In light of this, the thesis may be extended to evaluate the use of the stabilized soils as a sub base and improved sub grade material for gravel paved roads by using a chemical enzyme (TerraZyme) which was previously submitted to the University (AAU/AAIT) by the supplier for an academic research purpose.

1.1 Objectives

1.1.1 General Objectives

The main objective of the thesis was to investigate the performance of TerraZyme (which is a chemical enzyme) on red clay soils and to better understand its potential use for road construction. Laboratory experiments were performed to determine if these products improve the material properties of sub grade soils and if they offer superior mechanical properties compared to the un- stabilized control specimen.

1.1.2 Specific Objectives

The specific objectives of the thesis are:

1. Determining Red clay soil.
2. Identification of which properties of the soil can be improved.
3. Evaluating the stabilized soils property if it can be used as a sub base or other pavement layer.

1.2 Methodology

To accomplish the intended objective of the proposed thesis, the following methodologies will be performed.

- A thorough literature review were made on the existing documents and similar works performed by different researchers.
- The required samples were collected from the field that suites the intended purpose and objectives of the thesis.
- The red clay soils obtained from field were tested in the laboratory to determine engineering properties like specific gravity, grain size distribution, consistency limits, compaction and CBR and UCS without stabilization.
- The same tests had been performed in the laboratory after the soils has been stabilized with the specified chemical enzyme.
- Analysis and discussions had been made on the experimental results to determine whether the stabilizing chemical improves the engineering properties of the given soil or not.
- Comparison of the engineering properties of the TerraZyme treated soil were made with that of the Ethiopian Roads Authority specification to assess the application of the stabilized soil for sub base or any other pavement layer.

2 LITERATURE REVIEW

2.1 General

The coarse – grained soils generally contain the minerals quartz and field spar. These minerals are strong and electrically inert. The behaviour of such soils does not depend up on the nature of the mineral present. The behaviour of fine grained soils on the other hand depends to a large extent on the nature and characteristics of the minerals present. Therefore the most significant properties of clay depend on the type of minerals. It is these minerals that impart cohesion and plasticity of the clay soils (Arora, 2004).

Most soil classification systems defines clay particles as having an effective diameter of two micron (0.002mm) or less. Particle size alone does not determine clay mineral. Probably the most important property of fine grained soils is the mineralogical composition. For small size particles, the electrical forces acting on the surface of the particles are much greater than the gravitational force (Chen, 1998).

2.2 Gravitational force and Surface Forces

The gravitational force in a soil particle is proportional to its mass and as the specific gravity of particles is approximately constant, the gravitational force is proportional to the volume of the particle, the volume depends upon the particle size thus the gravitational force depends on a particle size in other words, the larger the particle size the greater would be the gravitational force (Arora, 2004).

On the other hand bonding or surface forces between particles depends upon the surface area of the particles and not up on the volume. The surface area also depends upon the particle size. However the surface forces become more important only when the particle size decreases, the effect of surface forces on a particle becomes more predominant than gravitational force (Arora, 2004).

A material in which the surface forces are predominant is known as a colloid .the term colloid has been derived from Greek word Kolla and Oidos, meaning a gluey material and alike .for colloids the ratio of surface area to the volume is very large. The clayey soils with particle size of smaller than 2 micron size are generally colloidal in nature. The colloids have very large specific surface (Arora, 2004)

2.3 Clay soil formation

The clay minerals are formed through a complicated process from an assortment of the parent materials. The parent materials include feldspars, micas, and limestone. The alteration process on land is referred as weathering (Chen 1998). The three major agencies of weathering being physical, chemical and biological processes. In the weathering process the parent rock and rock minerals break down, releasing internal energy and forming substances having a lower internal energy which are therefore more stable. Physical process (e.g. Stress release by erosion, differential thermal strain and ice and salt crystallization pressure) disintegrates the rock, exposed fresh surface to the chemical attack and increases the permeability of the material to the percolation of chemically reactive fluids. Chemical Process, This chiefly comprises hydrolysis; cation exchange and oxidation alter the original rock mineral to form more stable clay minerals. Biological weathering includes both physical action (e.g. splitting by roots wedging) and chemical action (e.g. bacteriological oxidation, chelation and reduction of iron and sulphur compounds (Nelson, 1991).

Hydrolysis is considered to be the most important of the chemical weathering processes. It occurs when a salt combines with water to form an acid and a base. In rock weathering, the salt is usually a silicate and the product of the reaction is a clay mineral. Oxidation is usually preceded by hydrolysis and affects rocks containing iron sulphates, carbonates and silicate. The product of oxidation usually has a large specific volume than the parent minerals and thus expansion due to oxidation contributes to the physical comminution of rock (Nelson, 1991).

2.3.1 Clay minerals

A material in which the influence of the surface charges is predominant is said to be in the colloidal state. The colloidal particles of soil consist primarily of clay minerals that were derived from rock minerals by weathering, that have crystal structures differing from those of the parent minerals. All the clay minerals are crystalline hydrous Aluminosilicates having a lattice structure in which the atoms are arranged in several layers, similar to the pages of a book (Terzaghi, et al. 1883-1963).

The basic building blocks of the clay minerals are the Silica tetrahedron and the Alumina octahedron. These blocks form tetrahedral and octahedral layers (Fig.2-1 & 2-2), different combinations of which produce a unit sheet of the various types of clay minerals. The arrangement and the chemical composition of these layers determine the type of clay mineral (Terzaghi, et al. 1883-1963)

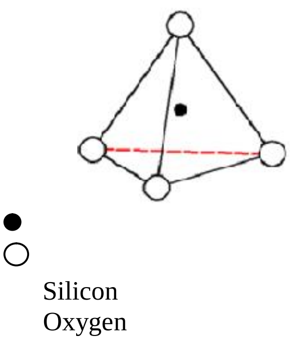


Figure 2-1: Si- Tetrahedron

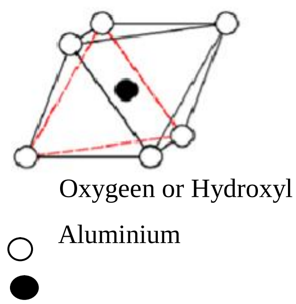


Figure 2-2 Al- Octahedral

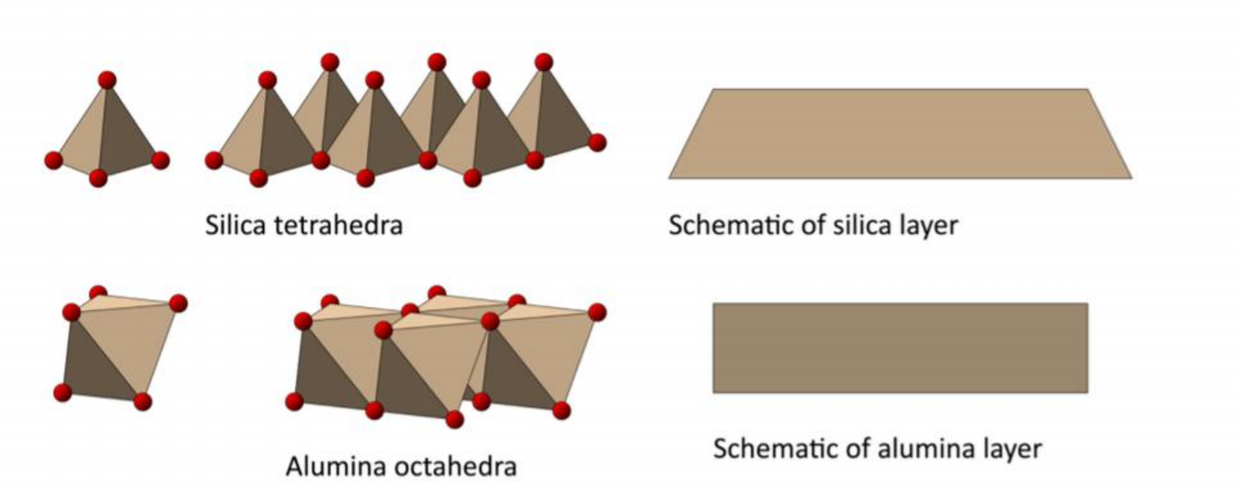


Figure 2-3 Schematic diagram of Silica Tetrahedra and Al Octahedral

The three most important groups of clay minerals are Kaolinite, Illite, and Montmorillonite. However, there are a number of clay minerals which are crystalline Aluminosilicates. Such as Halloysite and Vermiculite.

2.3.1.1 Kaolinite

Kaolinite is composed of a single Silica tetrahedron sheet and single Aluminium octahedral sheet combined in a unit so as the tips of the silica tetrahedron and one of the layers of the octahedral sheet form a common layer. The association of a silica tetrahedral sheet with aluminium octahedral sheet forms one layer of kaolinite. The thickness of Kaolinite layer is about 7Ǻ. The kaolinite mineral is formed by stacking the layers of 7Ǻ thick one above the other with the base of silica sheet bonding the hydroxyls of the octahedral sheet by Hydrogen bond. Since the hydrogen bonds are relatively strong, the mineral is stable and water cannot enter between the sheets to expand the unit cells. The Kaolinite minerals generally have a hexagonal shape with the sides of the hexagon between 5000 Ǻ to 10000 Ǻ (Arora, 2004).

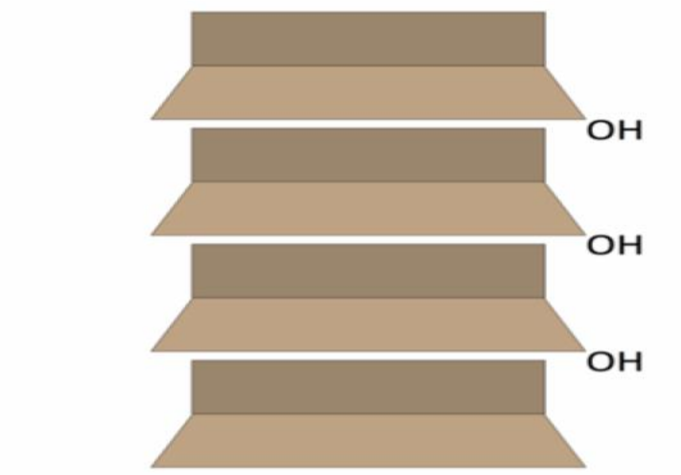


Figure 2-4: Kaolinite 1:1 Clay mineral

2.3.1.2 Illite

Illite is made up of octahedral sheet bonding with two silica sheets: one at the top and another at the bottom. The Illite layers are bonded by potassium ions. Illite particles range from 50Ǻ to 500Ǻ in thickness and lateral dimension of 1000Ǻ to 5000Ǻ which is same as that of Montmorillonite and have specific surface area of about 80m^2/gm (Arora, 2004).

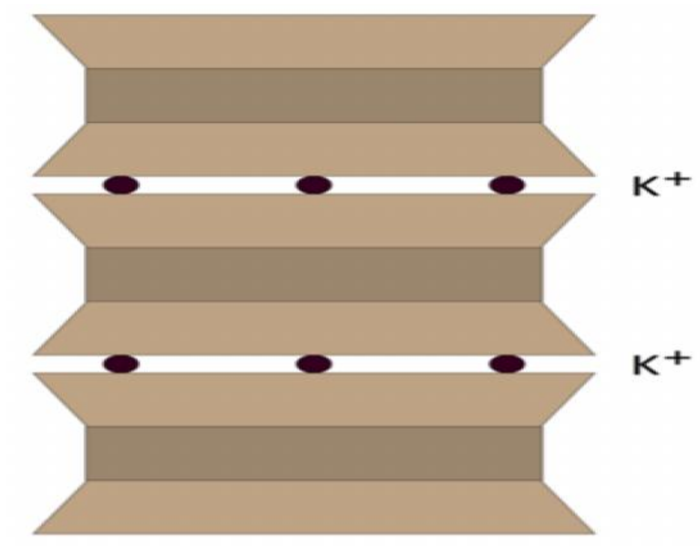


Figure 2-5: Illite Clay Mineral

2.3.1.3 Montmorillonite

Montmorillonite has similar structure to illite. The structure has one octahedral sheet sandwiched between two silica sheets and bonded with weak Van der Waals forces. Large amount of water is attracted in to the space between the layers and causing the layers to expand significantly. Montmorillonite particles have the lateral dimension of 1000Ǻ to 5000Ǻ and thickness of 10 Ǻ to 50 Ǻ, and its specific area is about 800m^2 /gm (Arora, 2004).

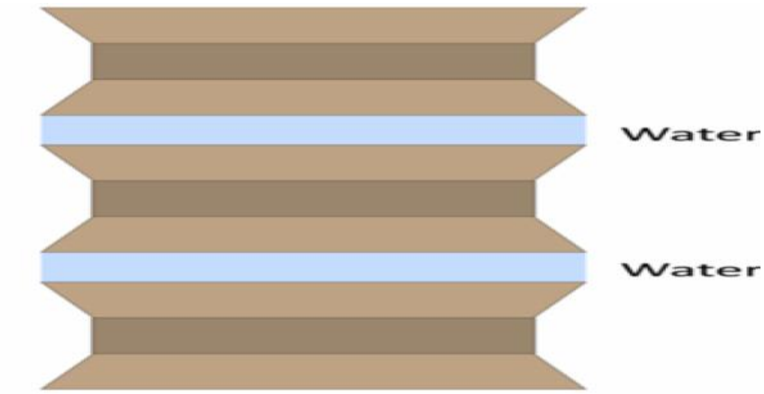


Figure 2-6Montmorinolite 2:1 Clay mineral

2.3.2 Mineral Composition of Ethiopian Red Clay soils

Red clay soils are very common throughout the tropical and sub –tropical regions of the world. However, it is a misconception to consider them as forming a distinct clearly defined soil type as they encompasses a wide variety of soils whose material and engineering properties vary considerably.

According to the study of Morin and Parry (1971) the Ethiopian red clay soils are formed as residual from basaltic volcanic rocks in places with plenty of rainfall and good drainage. The principal clay minerals that constitute the Ethiopian red clay are Kaolinite and Halloysite with an accessory Montmorillonite. The Ethiopian red clay is found to be acidic, which is similar to that of other tropical soils. The cation exchange capacity is from 30 to 77 milli-equivalents per 100g. The Ethiopian red clay soils do not show wide range index properties as other tropical soils. They have also generally lower clay contents, liquid limits and plasticity indices (Morin, W.J., and Parry, W.T., 1971).

Table 2-1: Properties of Ethiopian red clay soils (Morin and Parry 1971)[7].

Properties	**Values/Results**
Parent Rock	Olivine basalt, Basalt, Trachyte,
Rain fall, mm/yr	1220-2340
Temperature, ^{o}c	13.8-20
Drainage	Fair – good
Principal Clay minerals	Kaolinite, Hallysite, Montmorillonite
PH Value	5.1-6.8
Principal Cations	Calcium, Magnesium, Potassium
Cation Exchange capacity, m.e./100g	30-77
Clay (2μ), %	34-76
Liquid Limit, %	44-66
Plasticity Index, %	14-30
Shrinkage Limit, %	10-30
Specific gravity	2.61-2.91
Organic Content, %	1-4
Compaction Test: Max Density g/cc	1.185-1.698,
Optimum Moisture Content, %	38-29
CBR Test Value	6-9
Unconfined Compressive Strength, kpa.	147-251

In clay water mixture positively charged ions (cations) are present around the clay particles, creating a film of water around the clay particle that remains attached or adsorbed on the clay surface. The adsorbed water or double layer gives clay particles their plasticity. In some cases the clay can swell and the size of double layer increases, but it can be reduced by drying. Therefore, to truly improve the soil properties, it is necessary to permanently reduce the thickness of double layer. Cation exchange processes can accomplish this. By utilizing fermentation processes, specific micro-organisms can produce stabilizing enzyme in large quantity. These soil-stabilizing enzymes catalyse the reactions between the clay and the organic cations and accelerate the cationic exchange without becoming part of the end product (Ravi 2009).

2.3.2.1 Cation exchange

Clay minerals have the property of absorbing certain anions and cations and retaining them in an exchangeable state. The exchangeable ions are held around the outside of the Silica-Alumina clay mineral structural unit, and the exchange reaction does not affect the structure of the Silica-Alumina pocket. The existence of such charges is indicated by the ability of clay minerals to absorb ions from the solution. Cations (positive ions are more readily absorbed than anions (negative ions); hence negative charges must be predominant on the clay surface. A cation such as Na^+ is readily attracted from a salt solution and attached to a clay surface. However the absorbed Na^+ ion is not permanently attached; it can be replaced by K^+ ions if the clay is placed in a solution of potassium chloride KCL. The process of replacement by excess cations is called cat ion exchange. The cation exchange capacity is the charge or electrical attraction for cation per unit mass as measured in mill equivalent per 100grams of soil (Arora, 2004).

2.3.2.2 Plasticity of Soils

The plasticity of a soil is its ability to undergo deformation without cracking or fracturing .A plastic soil can be remoulded into various shapes when it is wet. Plasticity is an important index property of fine-grained soils, especially clayey soils. Plasticity in soils is due to the presence of clay minerals. The clay particles carry a negative charge on their surface and the water molecules are dipolar and are attracted to the clay surface. The phenomenon is known as adsorption (not absorption) of water, and the water attracted to the clay surface is called adsorbed water. Plasticity of the soil is due to adsorbed water.

The clay particles are separated by layers of adsorbed water which allow them to slip over one another. When the soil is subjected to deformation the particles do not return to their original positions, with the result that the deformations are plastic (irreversible). As the water content of the soil is reduced, the plasticity of the soil is reduced. Ultimately the soil becomes dry when the particles are cemented together as a solid mass(Arora, 2004).

Therefore the presence of adsorbed water is necessary to impart plasticity characteristics of the soil the soil does not become plastic when it is mixed with a non-polarizing liquid, such as kerosene or paraffin oil. Theses liquids do not have electromagnetic properties to react with clay minerals.

2.4 Soil Stabilization

Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable and suitable for the intended purpose. It is required when the soil available for construction is unsuitable for the intended purpose. In its broadest sense, stabilization includes compaction, pre consolidation, drainage, mixing with other soils and addition of chemicals. In general soil stabilization may also be defined as the method used to change one or more properties of soil so as to improve the desired performance of the soil. Broadly, soil stabilization techniques can be classified in two main groups.

2.4.1 Mechanical stabilization

Here, the stability of the soil is increased by blending the available soil with imported soil or aggregate, so as to obtain a desired particle-size distribution, and compacting the mixture to a desired density. Compacting a soil at appropriate moisture content itself is a form of mechanical stabilization.

2.4.2 Chemical Stabilization

Mixing or injecting additives such as Lime, Cement, Sodium Silicate, Calcium Chloride, bituminous materials with or in the soil can increase stability of the soil. Chemicals stabilization is the general term implying the use of chemicals for bringing about stabilization.

A cementing material or a chemical is added to a natural soil for the purpose of stabilization. The decreasing availability and increasing cost of construction materials and uncertain economic climates force engineers to consider more economical methods for building roads. An obvious solution is to use locally available materials. However, all too often, these materials fall outside of required specifications. This situation becomes even more critical when an increasing demand for roads in underdeveloped rural areas and informal settlements comes into play (Raul et al.2005)

The use of soil stabilization products for the stabilization of fine-grained soils using traditional methods of stabilization such as cement, lime and bituminous materials is quite wide spread across the world. However, as technology and the understanding of the soil Stabilization mechanisms improves; additional stabilization products have been developed. Bio-Enzymes are among them.

2.4.2.1 Bio-Enzymes

An enzyme is by definition an organic catalyst that speeds up a chemical reaction without becoming part of the end product. The enzyme combines with the large organic molecules to form a reactant intermediary, which exchange ions with the clay structure, breaking down the lattice and causing the cover-up effect, which prevents further absorption of water and the loss of density. The enzyme is regenerated by the reaction and goes to react again. Because the ions are large, little osmotic migration takes place and a good mixing process is required (Raul et al.2005)

Bio-Enzyme is a natural, non-toxic, non-flammable, non-corrosive liquid enzyme formulation fermented from vegetable extracts that improves the engineering properties of soil, facilitates higher soil compaction and increases strength. Enzymes catalyze the reactions between the clay and the organic cations and accelerate the cationic exchange process to reduce absorbed layer thickness(Raul et al.2005)

2.4.2.2 Enzymes as a Soil Stabilizer

The enzymes are adsorbed by the clay lattice, and then released upon exchange with metals cat ions. They have an important effect on the clay lattice, initially causing them to expand and then to tighten. The enzymes can be absorbed also by colloids enabling them to be transported through the soil electrolyte media. The enzymes also help the soil bacteria to release hydrogen ions, resulting in pH gradients at the surfaces of the clay particles, which assist in breaking up the structure of the clay (Raul et al.2005).

The idea of using enzyme stabilization for roads was developed from enzyme products used for treatment of soil to improve horticultural applications. A modification to the process produced a material, which was suitable for stabilization of poor subgrade soil for road traffic. When is added to a soil, the enzymes increase the wetting and bonding capacity of the soil particles. The enzyme allows soil materials to become more easily wet and more densely compacted. Also, it improves the chemical bonding that helps to fuse the soil particles together, creating a more permanent structure that is more resistant to weathering, wear and water penetration(Raul et al.2005)

2.4.2.2.1 The Concept of Enzyme Stabilization

Enzyme stabilization is commonly demonstrated by termites and ants in Latin America, Africa and Asia. "Ant saliva", full of enzymes, is used to build soil structures which are rock hard and meters high. These structures are known to stand firm despite heavy tropical rain seasons (Raul et al.2005)

2.4.2.2.1.1 TerraZyme

According to the manufacturer’s application manual, TerraZyme liquid stabilizer is specifically formulated to modify the engineering properties of soil and aggregate mixtures by catalysing natural chemical reactions in the soil, converting poor subgrade soil into more water and load resistant forms to improve the structural properties of cohesive soils.

TerraZyme is a bio enzyme concentrate made from the fermentation of plant-based organic matter. The catalytic enzymes in TerraZyme are natural protein molecules that speed up chemical reactions. These catalysts accelerate changes in the road materials to form new chemical and physical structures. Many materials change their forms over long periods of time, but transformations that would have taken years to accomplish can be completed within very short periods when the appropriate catalytic enzymes are added under the right conditions

2.4.2.2.1.2 TerraZyme Physical Properties

TerraZyme is non-toxic, harmless to humans, animals, marine life, and the environment. It is non-irritating, non-flammable, and non-corrosive. TerraZyme contains no combustible or corrosive materials, and can be safely used near open flame or in poorly ventilated areas. It contains no bacteria nor known allergens. TerraZyme has been tested safe by both independent and government scientific agencies. Some of the basic physical properties are tabulated as follows. Table 2-2

Table 2-2 Physical properties of TerrZyme

Color	Smell	Flammability	Corrosively	Specific Gravity
Brown	Slightly sweet smell	Non Flammable	Non Corrosive	1.4146

2.4.3 Review of Previous Studies on Enzyme Based Soil Stabilization

A number of studies have been made in different parts of the world to assess the use of bio enzymes for roads construction and many of them are not published and are limited to a specific area, such as soil type and specific chemical enzymes. However, most of the research papers focus their study either in laboratory investigation or field performance investigation. Therefore the reviews of previous studies were made in these two parts.

2.4.3.1 Laboratory Based Assessments

Wright-Fox (1993) carried out a study to assess the stabilization potential of enzymes [3]. Standard soil tests were performed for the study as no specific standards are available for enzyme-stabilized materials. Results from strength and index tests (e.g. liquid and plastic limit) conducted by Wright-Fox showed an increase in the unconfined compressive strength of the stabilized material as compared to control specimens. There was a 15% increase in the undrained shear strength of the stabilized material. The soil used was silty clay with a liquid limit of 66% and plasticity index of 42%. The index tests performed did not show any variation from the control specimen. Thus it was concluded that the enzymes might not offer waterproofing qualities using the recommended rate of application. Wright-Fox (1993) concluded that enzymes may provide some additional shear strength for some soils and that the soil stabilization with enzymes should be considered for various applications but only on a case-by-case basis [5].

Magangira M.B.(2009) conducted a study on Evaluation of the effect of enzyme-based liquid chemical stabilizers on sub grade soils. The aim of the study effect of two enzyme based liquid chemicals as soil stabilizers. Tests were made on two types of soils with a plasticity index of

35% and 7%. The maximum plasticity reduction obtained after treatment of both soils was less than 5% and therefore not significant. However, slight improvement in the maximum dry density was obtained following treatment by one product on one of the soil samples. Unconfined Compressive strength tests were made after the samples were left to cure in plastic bags for 7, 21,28days the result revealed a mixed effect on strength. Those instances where there was an increase in strength, it was less than 50% with increase in concentration level of the two enzymes-based stabilizers and age for both soils after treatment. Thus it was concluded that more independent investigations on the effects of the stabilizers in order to enhance their acceptance in road construction.

(Raul .et .al 2005) Conducted a study to assess the effect of Enzyme based chemicals in titled "Preliminary Laboratory Investigation of Enzyme Solutions as a Soil Stabilizer." Resilient modulus testing was performed and the effect of time on the performance was also evaluated by running tests on specimens cured for various times. The result obtained in this project showed that the addition of enzyme A does not improve substantially the resilient modulus of soil I. but increases by 54% the resilient modulus of soil II. In the other hand the addition of enzyme B to soil I and II had a pronounced effect on the resilient modulus. The stiffness of soil I was increased in average by 69% and by 77% for soil II. The type of soil had an effect on the effectiveness of the treatments. Percentages of fines, chemical composition among other are properties that affect the stabilization mechanism. It was found that the resilient modulus increased as the curing time increases for all mixtures of soils and enzymes. It was also noticed that an increment in the application rate suggested by the manufacturers does not improve the effectiveness of the stabilization process.

Shear strength tests were performed on 26 specimens using two different confining pressures 4 and 8 psi. The limited number of specimens tested show that at least 4 months of curing time are needed to observe improvement in the shear strength. It was observed that enzyme A increases the shear strength of soil I by 9%, and by 23% for soil II. In the other hand enzyme B increases the shear strength by 31% for soil I and 39% for soil II.

Sanjeet S. et al.(2018) have made an attempted to study soil stabilization using Bio-Enzyme. In his study he had considered the properties of soil stabilized with the Terrazyme and compared the result with that of Geotechnical Properties of the native Soil, in order to use this technology for Geotechnical applications. Laboratory investigations are carried out in two stages. In the first stage the soil characterization is done. In the second stage, Terrazyme is added to the soil in two dosages, 0.05% and 0.1% and studies are conducted. Tests are conducted with soil alone as well as soil stabilized with terraZyme containing di erent dosages.

A series of Standard Proctor tests, Soaked and Unsoaked California Bearing Ratio (CBR) test, and Unconfined Compressive Strength tests were conducted on locally available clayey soil mixed with di erent proportions of Terrazyme in order to study the improvement of strength properties of Terrazyme stabilized soil. The specimen are compacted to their respective MDD at optimum moisture content. Results show that the terraZyme can successfully be used to stabilize the soil. Significant improvement was found in both Soaked CBR and Unconfined Compressive Strength.

The study concluded that TerraZyme is a satisfactory stabilizing agent for clayey soils. The utilization of the enzyme like TerraZyme is an alternative to reduce construction cost of the roads particularly in low volume roads.

Divya V et al. (2020) have made an attempt to make a comparative study on a natural weak soil using different stabilization materials including Bio-Enzyme which are obtained from vegetable extracts, and check whether this materials have improved the mechanical characteristics of the natural weak soil. And analysis of the different techniques/materials used for improvement of embankment/sub grade resting on expansive soil.

The improvement in the compressive strength characteristics of expansive soils when stabilized using materials like lime, rice husk ash, stone dust, fiber and bio-enzyme had been compared and studied in this work. On comparison it is observed when the stabilizing agent is pozzolanic in nature, curing period plays a crucial role as far as improvement factor is concerned.

Final the researchers concluded that effectiveness of TerraZyme is dependent upon the curing period rather than dosage. TerraZyme has only marginal or slight influence on the optimum moisture content and maximum dry density. Performance of lime is comparable to that of enzyme treated Black Cotton soil.

Athira S. et. al. (2017) an attempt have been made to stabilize the soil with readily available bio-enzyme, which will be highly beneficial for engineers. TerraZyme, a bio-enzyme is a material which drastically improve the properties of the soil, is eco-friendly and economical for long run. This paper deals with the study of the effect of Laterite soil, collected from Aduvaserry of Ernakulam district, was mixed with TerraZyme for different dosages and different curing period. It was found that with time TerraZyme have significant impact on improving unconfined compressive strength (UCC) and California bearing ratio (CBR) values of the soil.

2.4.3.2 Field Performance Assessments

Roger W. et. Al. (2005) conducted study to assess the performance of Road Stabilizer Product at Buenos Aires National Wildlife Refuge, Seven dust control products were installed and monitored for two years. Performance monitoring of each product occurred at 6-month intervals for a 24-month period beginning in March 2003, six months after the products were applied. Each monitoring event consisted of a visual inspection for dust control, wash boarding, ravelling, and potholing, rutting, and leaching. The evaluation team also performed on-site physical testing consisting of Dynamic Cone Penetrometer (DCP) measurements, Silt Load evaluations, Nuclear Density Gauge readings, and GeoGage Soil Stiffness tests. The results of these observations are summarized in Table2-2. In general, the higher the number reported, the better the performance. And concludes that although varying levels of performance can be distinguished among the products at this particular project site, the order of observed performance may not be the same on another project where conditions such as specific soil type, climate, level of traffic, and rate of product application are different [12] The rating and performance of the electrochemical enzyme products, Permazyme and TerraZyme, deserve some special qualification. These electrochemical products are formulated to perform and react with materials containing clay particles. They are dependent on fine clay mineralogy to reach and achieve maximum performance for dust abatement and soil stabilization. Because the material used for borrow on this source were a “non-plastic” material containing no clay particles, these two products would probably not be optimal choices even though costs may be lower.

Table 2-3 Visual and physical value summery

Test Section	Product	Visual Overall Average Score (x10)	Physical Overall Normalized Rank	Overall Average Score	Relative Cost	Relative Application Rate
I	**Mag/Lig**	65	90	77	medium	high
II	**Caliber**	73	92	83	medium	high
III	**Soil Cement**	55	76	65	High	medium
IV	**Permazyme**	50	78	64	Low	Low
V	**TerraZyme**	55	78	66	Low	Low
VI	**Lignosulfonate**	56	84	70	medium	high
VII	**Mag/Cl**	54	89	71	medium	high

Rubens B. et al.(2001) conducted a study on objective performance measurement of actual road sites treated with an organic soil stabilizer(particularly TerraZyme) in brazil and recorded an increased CBR value or capacity to support traffic loading to more than fifteen times that of the soil not treated with the soil stabilizer. The treated pavement preserved the structural integrity of the surface (no permanent deformation or plastic effects) with increased cohesion of the base layer material and consequent increase in CBR. And hence recommends soil stabilizers should be used more widely in improving road sub-base and base soils and receiving important savings in paved road construction. Considerable cost savings about 30% were shown.

LI Yue-jun et al. (2016) conducted a Study on application of TerraZyme in road base course of road. The test was made on a road which is located in Qiaoyi country, Wangcheng County. It is narrow, sunken and 3km long. The topography, environment around the road as well as the condition of subgrade is complex. The drainage system is old and had not been repaired for so long, part of which is ineffective that the pipe culverts used for drainage system is silted up and blocked. The traffic volume in this county is low mainly consists of tractor and small car, also the vehicle weighting 20 ton pass through occasionally. Accordingly a series of deflection tests were conducted on the both of TerraZyme solidified soil and non-solidified.

The researcher concluded that TerraZyme can solidify the soil effectively. The advantage of solidification soil is high strength, low cost, high stability and no pollution, thus, it illustrates a good prospect of application and extension. Recommends for further studies in order to form a sound technique of TerraZyme solidification soil for paving road.

2.4.3.3 Field Trials in Ethiopia:

Tewodros A. (2010) has done study in Ethiopia on expansive soils. He constructed a test section on a road with expansive subgrade soil in the Chancho –Ginchi road. Different types of soil stabilization techniques have been used (Mechanical, chemical stabilization and lime). The expansive sub grade was mechanically stabilized by mixing it with non – plastic gravel with a proportion of 50% by volume, and compacted to the required density. The expansive soil was treated with semi-processed lime with an application rate of 10% by weight, further the expansive sub grade was treated with a combination of hydrated lime and a TerraZyme. Nine trial sections were constructed by using these different materials. This comparative study on different trial sections reveals that TerraZyme stabilization gives better results (Ravi et al. 2019). However the study did not show the effect of TerraZyme alone as a soil stabilizing agent. Hence, it would be very difficult to conclude TerraZyme can be used to stabilize expansive soils while using lime with a concentration of the highest order.

Although the documents are not published yet, Ethiopian Roads Authority have made a study on the performance of the TerraZyme in a trial section near Chancho about 85 km in north direction from Addis Ababa. TerraZyme was applied on a black cotton soil, and the result is not satisfactory. In fact, the ability of TerraZyme treatment to raise very low CBR values to stabilized values 100% to 200% may often not be sufficient to make the treated material attractive for road construction without the addition of sand or gravel. Low strength, highly plastic soils are suitable for TerraZyme treatment when combined with coarse structural material. Therefore it is expected that the application of TerraZyme alone on a black cotton soil may not result in a satisfactory performance.

3 METHODOLOGY AND EXPERIMENTAL INVESTIGATIONS

3.1 General

The general methodology employed in this study includes reconnaissance survey based on the available geological map and other documents which is followed by field investigation which basically involves the selection of test pit location and collection of samples from the selected areas. Subsequently, the samples were tested in the laboratory and the results were analysed. The following section presents the detail activities performed and test results obtained from laboratory investigation.

3.1.1 Geology of the area

According to the geological map of Addis Ababa, the northern part of the city mainly comprises of three type of geological formations; Namely, Intoto Mixed Rock, Quaternary Olivine Basalt and Repi basalt (Asseged et al, 2007)

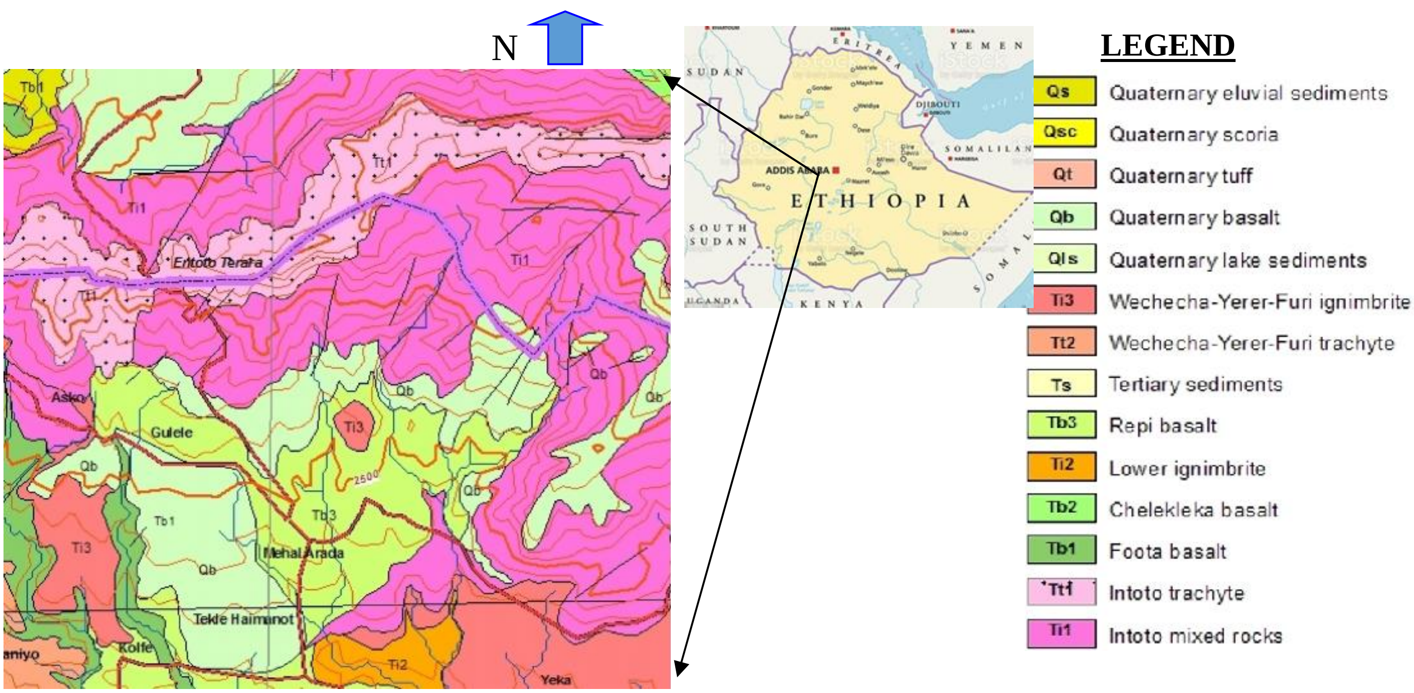


Figure 3-1Extracted from Geological map of Addis Ababa

3.1.1.1 Intoto Mixed Rock (Ti1)

This unit consists of trachyte, ignimbrite, pyroclastic rocks and sediments. All the rocks are highly weathered and jointed with few layers of agglomerate at some places. This unit develops a thick red soil and in some places it is covered by patches of quaternary basalt. A thick red clay soil is also observed along the contacts of Cheleleka basalt units.

3.1.1.2 Quaternary Olivine Basalt (Qb)

This unit is exposed in the northern central and southern central part of Addis Ababa. This basalt is dark grey in colour on fresh out crops and becomes reddish up on weathering.

3.1.1.3 Repi basalt (Tb3)

This unit is found generally in the central and eastern part of Addis Ababa. This rock is porphyritic and aphanitic with the top part mostly vesicular. Weathering of the rock forms different colours of mainly dark brown.

3.2 Field Investigation

As stated in the objective of this study, the objective of the paper focuses on investigation of the performance of TerraZyme on red clay soil. Therefore the first step was to identify locations which are suitable for the formation of red clay soils. It was learned that the northern part of Addis Ababa is known for red clay soil deposits. Accordingly, visual inspections of the sites have been performed and sampling locations were selected before test pitting of the sub grade soil has commenced. Most of the test pit locations were selected from an ongoing project area which was very helpful in reducing the time to obtain permission from the local authorities as well as to reduce financial expenses from excavation of test pits.

Based on the geological map of Addis Ababa and visual inspection, it is known that the northern part of Addis Ababa is suitable for the formation of red clay soils. To accommodate variations in the engineering properties of red clay soils five different locations were selected for sampling.

3.3 Soil Sampling

Soil sampling was conducted with proposed preliminary plan of the selected sites. Sampling points were selected systematically which best represent the section under consideration. In this respect two test pits were excavated from each location and two samples were collected from each test pit from a depth of 1 and 2 meters. Accordingly a total of 20 disturbed samples were collected and tested in the laboratory.

Almost all test pits show that from a depth of 0.5m up to 2m; the area is covered with reddish silty clay soil and as the depth increases, the texture of the soil continues to be the same with a slight change in its stiffness.

Table 3-1: Description of the soil samples

S.No	Location	No. Sample
1	Total Addisu Gebeya	5
2	Semen Gebeya	5
3	Kechene Hidasie Health Center	5
4	Kolfe Police training Center	5
5	Intoto Technical and Vocational poly technique college	5

3.4 Experimental Investigation

To assess the suitability of Bio-Enzyme as soil stabilizer for red clay soils, laboratory tests were conducted to determine the engineering properties and strength characteristics of the collected soil samples with and without stabilization. The soil samples considered for study were first tested for engineering properties and samples were then tested for strength parameters such as CBR and Unconfined Compressive Strength without stabilization, and then with stabilization for a curing period of 7days 21days and 30days. In the above tests the Bio-Enzyme named TerraZyme was used for stabilization, all the tests were performed as per standard practice described below.

Table 3-2: Standard test procedures used

S.No.	Type of Test	Test Method Employed
1	Moisture Content	AASHTO T-99
2	Determining Liquid Limits of soil	AASHTO T-89
3	Plastic limit and Plasticity index	AASHTO T-90
4	Particle Size Analysis (Hydrometer Method)	AASHTO T 88-93
5	Modified Proctor Compaction	ASTM D-1557
6	Californian Bearing Ratio Test	ASTM D-1883
7	Unconfined Compressive Strength	AASHTO T 208-92
8	Specific Gravity	AASHTO T 100

3.4.1 Moisture Content (*w*)

The soil samples as received from the field was allowed to be dried thoroughly in air and the moisture of the air dried samples were determined using an oven drying technique. The sample has been allowed to be dried in an oven for about 24 hours at 105°C and the moisture content is determined as follows.

$$w = \frac{A - B}{B - C} \times 100$$

Where *w* = percentage of moisture in the specimen, based on oven dry mass of soil

A = Mass of container and wet mass of soil.

B = Mass of container and dry mass of soil

C = Mass of container.

Accordingly this has been help full in determining the water requirement of the remoulded samples for CBR and Unconfined Compressive Strength tests.

3.4.2 Specific Gravity (G_s)

G_s is the a ratio of the mass in air of a given volume of material at a stated temperature to the mass of in air of the same volume of gas free distilled water at a stated temperature. Standard test methodology designated as AASHTO T-100 has been employed in the investigation of specific gravity (G_s) of the sampled soils. The test have been performed to five samples one from each location. Typical test results of one of the samples are presented as follows.

Table 3-3: Typical test result

SPECIFIC GRAVITY Of SOIL(AASHTO T 100)			
Location :	Total Addisu Gebeya(Test pit 1)		
Depth	2m		
Description	**Unit**	**Sample 1**	**Sample 2**
Mass of Soil(A)	gm	10.52	10.38
Mass of Pycnometer + Sample Filled With Water(B)	gm	178.45	185.38
Mass of Pycnometer Filled with Water Only(C)	gm	171.97	178.99
Bulk Specific Gravity(A/(A+C-B))		2.604	2.602
	Average	2.60	

Table 3-4: Summary of Specific Gravity test results for un-stabilized soil

S.No	Location	Specific Gravity (G_S)
1	Total Addisu Gebeya	2.61
2	Semen Gebeya	2.57
3	Kechene Hidasie Health Center	2.62
4	Kolfe Police training Center	2.64
5	Intoto Technical and Vocational poly technique college	2.60

3.4.3 Liquid Limits and Plastic Limit Tests

The consistency of fine grained soils is its physical states in which it exists. It is used to denote the degree of firmness of a soil. Consistency of a soil is indicated by terms such as soft, firm or hard. A Swedish agriculture engineer Atterberg (1911) mentioned that a fine grained soil can exist in four states namely, liquid, plastic, semi –solid and solid state. The water content at which the soil changes from one state to the other are known as consistency limit or Atterberg limits.

This is an important physical property of fine grained soils, since most of the problems of clayey soils are highly associated with their plasticity. Accordingly the liquid limit and plastic limit tests for both untreated as well as treated soils have been tested as per AASHTO T-89 &T-90 and the result is presented in the preceding sections.

Table 3-5: Typical Atterberg limits and sieve analysis test and soil classification

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	26	20			
Container No.		P	A-7	B-1	A-11	B-10	
Mass of Container	g	17.66	17.58	17.72	17.61	17.65	
Mass of Wet Soil + Container	g	33.27	35.79	38.83	32.40	31.84	
Mass of Dry Soil + Container	g	27.12	28.52	30.29	28.43	28.03	
Mass of Water in Specimen	g	6.15	7.27	8.54	3.97	3.81	
Mass of Dry Soil	g	9.46	10.94	12.57	10.82	10.38	
Moisture Content	%	65.0	66.5	67.9	36.7	36.7	
					Average PL, %		**36.7**

Initial Mass= 161 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.23	1	99
№ 40	1.5	1	98
№ 200	3.46	2	96

LL	PI	AASHTO Soil Class.
67	30	A-7-5 [20]

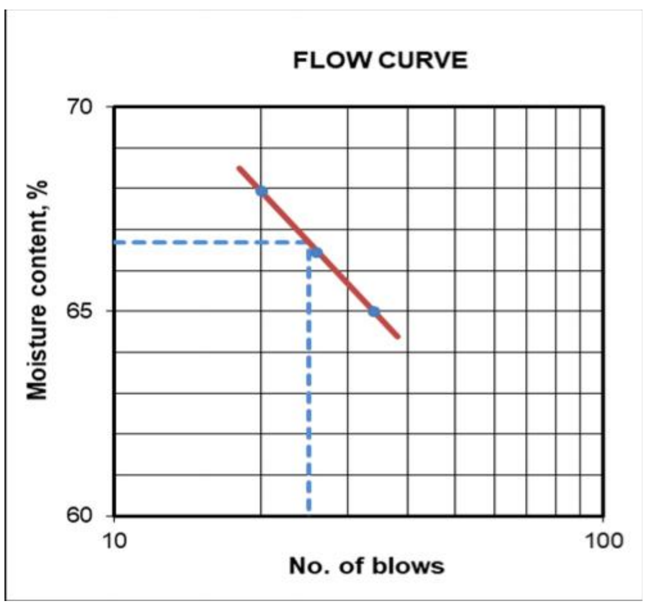


Table 3-6; **Summary of Liquid limits and Plasticity index of non-stabilized soil**

S.No	Location	Test pit No.	Depth(m)	Atterberg limits	
				LL (%)	PI (%)
1	Total Addisu Gebeya	1	1	65	28
		1	2	69	31
		2	1	52	24
		2	2	56	26
		3	2	57	25
2	Semen Gebeya	1	1	77	38
		1	2	73	31
		2	1	83	41
		2	2	79	40
		3	2	65	29
3	Kechene Hidasie Health Center	2	2	67	30
		1	1	57	23
		2	1	66	31
		1	2	60	27
		3	2	64	28
4	Kolfe Police training Center	1	1	72	32
		1	2	71	35
		2	1	65	29
		2	2	60	28
		3	2	62	30
5	Intoto Technical and Vocational poly technique college	1	1	81	36
		1	2	81	41
		2	1	83	41
		2	2	83	41
		3	2	62	31

3.4.4 Particle Size Analysis of soils

It is a method of separation of soils in to different fractions based on particle size. It expresses quantitatively the proportions, by mass, of various sizes of particles present in the soil. It is shown on a particle size distribution curve. The particle size analysis is normally made in two stages:

1. Sieve analysis
2. Sedimentation analysis (Hydrometer Analysis)

The first analysis is made for course - grained soils (for particles greater than 0.075mm) which can easily pass through a set of sieves. The second analysis is made for fine grained soils (for particle size less than 0.075mm). As a soil mass may contain the particles of both types of soils, a combined analysis comprising both analysis may be required for some soils. Accordingly sieve analysis test have been performed to all the twenty samples and hydrometer test is made for five samples, one from each location. And the result is presented in the fig 3-2 and table 3-8.

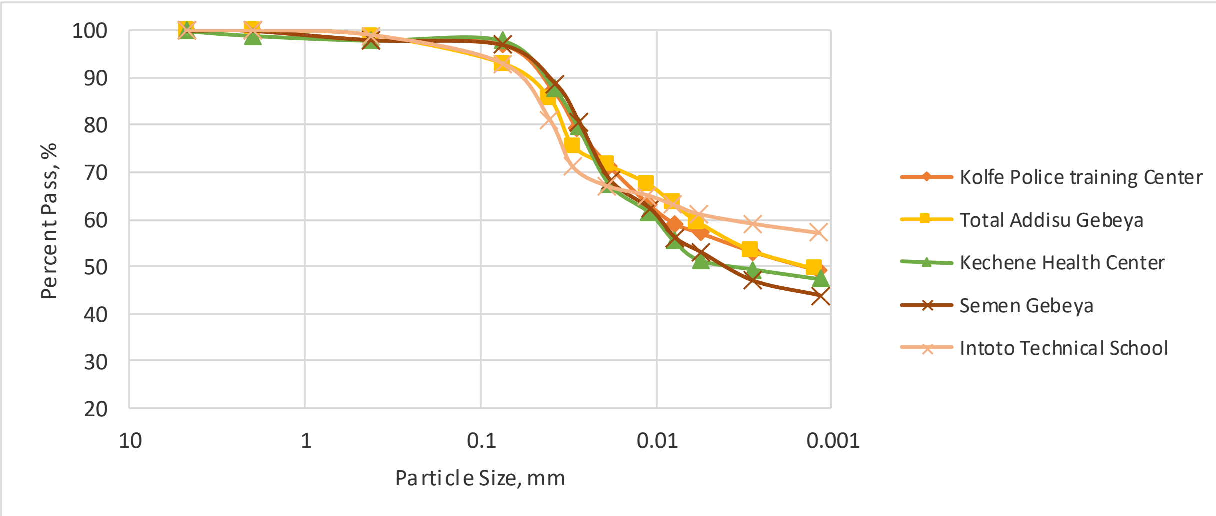


Figure 3-2 Summary of Hydrometer Test

Table 3-7: Summery of the Combined Hydrometer and sieve analysis result

S.No	Location	Sieve Analysis(% pass)			Hydrometer analysis(%Pass)	
		2mm	0.425mm	0.075mm	2 µm(Clay)	Silt
1	Total Addisu Gebeya	100	99	93	51	42
2	Semen Gebeya	98	98	97	46	51
3	Kechene Hidasie Health Center	99	98	98	50	48
4	Kolfe Police training Center	100	98	97	52	45
5	Intoto Technical and Vocational poly technique college	100	99	93	55	46

3.4.5 Soil Classification Systems

The purpose of any classification system is to categorize soils by relating their appearance and behavior with previously established engineering properties and performance. Attributes of a good classification system include simplicity, reproducibility under variable conditions, and applicability to all soils likely to be encountered. And hence two standard soil classification systems are used to classify the soil samples AASHTO M 145 and Unified Soil Classification System (ASTM D-2487)

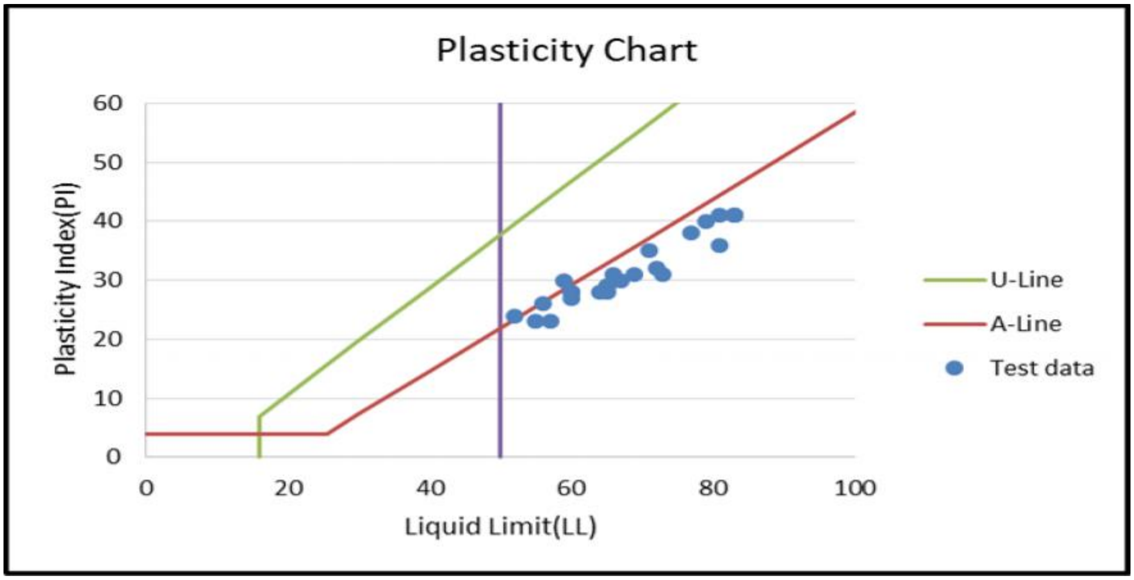


Figure 3-3: Plasticity chart extracted from (ASTM D-2487)

As it can be observe from the plasticity chart which was extracted from ASTM D-2487 most of the samples fall under A-line this indicates that the soils can be classified as MH or OH. However the soils cannot be classified as OH (organic soils) since there is no indication to classify the soils as organic soil. Therefore most of the soils are classified as MH –Elastic silt with an exception of two samples, which fall above A-Line and classified as CH fat –Clay. Table 3.9 presents the Summary of Liquid limit and plasticity index and classification of the non-stabilized soil samples.

Table 3-8; **Summary of Liquid limit and plasticity index and classification of the non -stabilized soil samples**

S No.	Station	Test Pit No.	Depth	Sieve Analysis AASHTO T 11, T 27			Atterberg Limits AASHTO T 89, T 90		AASHTO Classification AASHTO M145
				2 mm	0.425 mm	0.075 mm	LL %	PI %	
1	Total Addisu Gebeyas	A	1	99	98	96	65	28	A-7-5[20]
2	Total Addisu Gebeyas	A	2	100	100	97	69	31	A-7-5[20]
3	Total Addisu Gebeyas	B	1	100	100	97	52	24	A-7-6[20]
4	Total Addisu Gebeyas	B	2	100	100	98	56	26	A-7-5[20]
5	Total Addisu Gebeyas	C	2	100	99	93	55	23	A-7-5[20]
6	Semen Gebeya	A	1	100	99	98	77	38	A-7-5[20]
7	Semen Gebeya	A	2	100	99	98	73	31	A-7-5[20]
8	Semen Gebeya	B	1	98	96	94	83	41	A-7-5[20]
9	Semen Gebeya	B	2	98	97	94	79	40	A-7-5[20]
10	Semen Gebeya	C	2	98	98	97	65	29	A-7-5[20]
11	Kechene Hidasie Health center	A	1	100	100	97	57	23	A-7-5[20]
12	Kechene Hidasie Health center	A	2	100	99	96	60	27	A-7-5[20]
13	Kechene Hidasie Health center	B	1	99	98	96	66	31	A-7-5[20]
14	Kechene Hidasie Health center	B	2	99	98	96	67	30	A-7-5[20]
15	Kechene Hidasie Health center	C	2	99	99	98	64	28	A-7-5[20]
16	Kolfe Police training Center	A	1	100	99	96	72	32	A-7-5[20]
17	Kolfe Police training Center	A	2	100	99	96	71	35	A-7-5[20]
18	Kolfe Police training Center	B	1	99	95	89	65	29	A-7-5[20]
19	Kolfe Police training Center	B	2	99	95	88	60	28	A-7-5[20]
20	Kolfe Police training Center	C	2	94	91	88	60	28	A-7-5[20]
21	Intoto Technical l and Vocational Poly Technique College	A	1	100	100	97	57	23	A-7-5[20]

S No.	Station	Test Pit No.	Depth	Sieve Analysis AASHTO T 11, T 27			Atterberg Limits AASHTO T 89, T 90		AASHTO Classification AASHTO M145
				2 mm	0.425 mm	0.075 mm	LL %	PI %	
22	Intoto Technical l and Vocational Poly Technique College	A	2	100	99	96	60	27	A-7-5[20]
23	Intoto Technical l and Vocational Poly Technique College	B	1	99	98	96	66	31	A-7-5[20]
24	Intoto Technical l and Vocational Poly Technique College	B	2	99	98	96	67	30	A-7-5[20]
25	Intoto Technical l and Vocational Poly Technique College	C	2	100	99	93	62	31	A-7-6[20]

3.4.6 Comparison of test results with previous studies

As it can be clearly observed when the soil classification is made according to AASHTO soil classification system, all of the soil samples are classified as A-7 and fifteen out of twenty three samples falls under A-7-5 and the rest are A-7-6. LL of the soil samples ranges from 52 to 83, PI from 23 to 41. The Specific gravity of the soil samples ranges from 2.57 to 2.64.

Comparison of the previous studies made on red clay soil from Addis Ababa is presented in the table below.

Table 3-9: Comparison of previous Studies

S.No	Researchers	Year	Locations	LL(%)	PI(%)	Gs(%)
1	Samuel Tadesse	1989	Kolfe and Semen Gebeya Mazegajia	59-75	15-47	2.66-2.77
2	Tesfaye Neare	2004	Different Places in Addis Ababa where red Clay soil Exists	47-82	23-55	N/A
3	Merihune Lukas	2010	Kolfe and Semen Gebeya Mazegajia	61-72	34-39	2.61-2.9
4	Ermias Genaye	2014	Different Places in Addis Aababa where red Clay soil Exists	54-72	22-38	2.67-2.76
5	Ashenafi Mulugeta	2016	Shiromeda ,Semen Mazegaja, Gulelle and Asco	43-66	15-31	2.55-2.65
6	Current Study		Total Addisu Gebeya, Kechene and Intoto, Kolfe and Semen Gebeya	52-83	23-41	2.57-2.64

3.4.7 Compaction Test

The objective of this phase of testing was to determine whether the chemical products have any influence on the compaction characteristics of the red clay soil. According to the Application Instructions manual of TerraZyme. The enzyme has an additional benefit of improving the compaction i.e. acting as a compaction aid. TerraZyme treatment increases soil density and reduces OMC by 2 - 3% in the laboratory, this can have a beneficial effect on the construction process in two ways:

i) A higher density can be achieved for a standard compaction effort, or less effort would be necessary to achieve the required compaction.

ii) Less water would be necessary to achieve the specified density under a given compaction effort.

Laboratory test was carried out to assess the potential improvement in density as a result of compacting material with the addition of TerraZyme. Initially, the five control specimens were compacted using a standard test method for laboratory compaction characteristics of the soil using Modified Effort (ASTM D-1557) without TerraZyme.

The Optimum moisture content (OMC) and Maximum Dry Density (MDD) that is obtained from this compaction test were used to remold the samples for CBR and UCS testing purpose. Summary of the test results are presented in the Table 3-10.

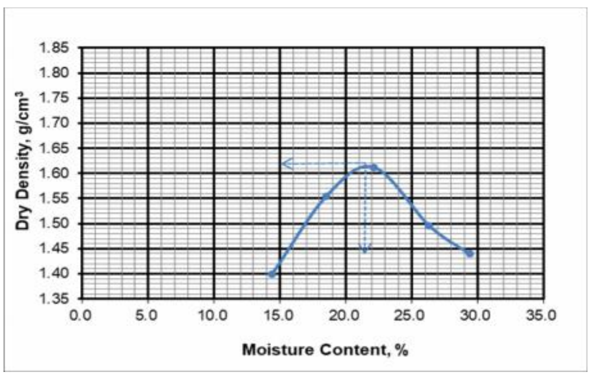
Table 3-10: Summary of Specific Gravity, Optimum Moisture Content and Maximum Dry Density

S.No	Location	Specific Gravity (G_S)	OMC (%)	MDD(gm/cm^3)
1	Total Addisu Gebeya	2.61	22.5	1.62
2	Semen Gebeya	2.57	22.5	1.54
3	Kechene Hidasie Health Center	2.62	23.5	1.52
4	Kolfe Police training Center	2.64	20.5	1.51
5	Intoto Technical and Vocational poly technique college	2.60	21.5	1.61

Table 3-11: Typical compaction test result of the moisture density relations

TEST METHOD: ASTM D-1557

			1	2	3	4	5
Bulk Density	Mass of Mould + Soil	g	4823	5052	5170	5095	5070
	Mass of Mould	g	3312	3312	3312	3312	3312
	Mass of Wet Soil	g	1511	1740	1858	1783	1758
	Volume of Mould	cm^3	944	944	944	944	944
	Bulk Density	g/cm^3	1.601	1.843	1.968	1.889	1.862
Moisture Content	Container No.		OH	38	51	36	34
	Mass of Container	g	44.5	43.4	43.6	42	44.1
	Mass of Container + Wet Soil	g	222.6	285.2	247.3	218.5	291.9
	Mass of Container + Dry Soil	g	200.2	247.4	210.4	181.7	235.6
	Moisture Content	%	14.4	18.5	22.1	26.3	29.4
	Dry Density	g/cm^3	1.40	1.56	1.61	1.49	1.44



MDD= 1.61 g/cm^3

OMC= 21.5 %

3.4.8 Californian Bearing Ratio (CBR)

CBR test is used to evaluate the potential strength of sub grade, sub base and base course materials for use in roads air field pavements. The test is a standardize penetration test in which a plunger with specific dimensions penetrates a compacted soil at fixed rate of penetration. As the penetration continues, the force required to maintain the penetration rate is recorded at a suitable interval. The CBR value is expressed as a percentage of a standard load at fixed penetration depth of 0.1” (2.54mm) and 0.2” (5.08mm).

It was developed by Californian Division of Highway as a method of classifying and evaluating sub- grade and sub base materials for flexible pavement. It is an empirical test and has been used to determine the materials property for pavement design. It is a penetration test where in a standard piston having an area of 3in2 (50mm diameter) is used to penetrate the soil at a standard rate of 1.25mm/min. the pressure to penetrate 0.1” and 0.2in” shall be compared with the bearing value of standard crushed rock at the respective depth of penetration and the grater of the two will be taken as CBR value of the Material.

In short, a portion of a soil sample which is large enough for one CBR mould had been taken and the required amount of water to bring the soil to its Optimum Moisture Content level is added after that the moisturized soil is compacted in to a CBR mould using an effort that brings the soil to its Maximum Dry Density using a standard procedure. The compacted soil, in the CBR mould is then, socked for four days and then penetration test will commences as it is explained above.

Accordingly, CBR tests have been performed on five samples, one from each location for stabilized and non- stabilized specimen. Summary of the test results on the un-stabilized soil are presented on table.

Table 3-12: Summery of test results for un-stabilized soil

S.No	Location	CBR(%)	Swell (%)
1	Total Addisu Gebeya	9	2.84
2	Semen Gebeya	8	3.26
3	Kechene Hidasie Health Center	7	4.22
4	Kolfe Police training Center	6	4.58
5	Intoto Technical and Vocational poly technique college	9	3.04

In general the CBR results of the non-stabilized soil samples collected from those five different locations ranges between 6 and 9 percent with a swelling percentage between 4.58 to 2.84 %. These results were used to evaluate the effect of the TerraZyme in the same soil samples selected.

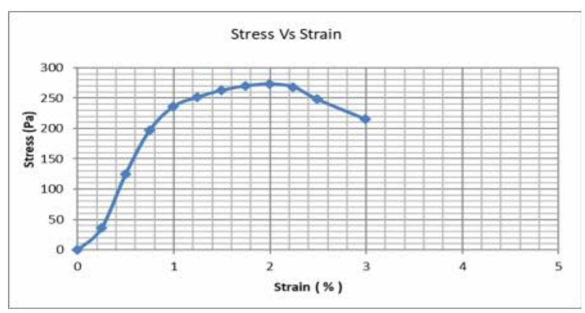
3.4.9 Unconfined Compressive Strength (UCS)

UCS is compressive stress at which an unconfined cylindrical specimen of the soil will fail in a simple compression test. In this test method, unconfined compressive strength is taken as the maximum load attained per unit area or the load per unit area at 15 percent axial strain, whichever is secured first during the performance of the test is taken as the Unconfined Compressive Strength result of the material. The shear strength is then calculated to be half of the Compressive stress at failure. Table 3-13 presents a typical test result for a single UCS test.

A portion of a soil sample which is large enough for one UCS mould had been taken and the required amount of water to bring the soil to its Optimum Moisture Content level is added, after that a specific amount of the moisturized soil is compacted in to a UCS mould in three layers so as to brings the soil to its Maximum Dry Density level. The compacted soil, in the UCS mould is then tested for its compressive strength in an unconfined condition. Atypical test result and analysis is presented in the following Table 3-15

Table 3-13 Typical Test Result for UCS

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4
Moisture Content (%) =	22.8
Bulk Unit Weight (kg/m^3)=	1989.58



q_u =	251.14	kpa
C = $q_u/2$ =	125.57	kpa
Strain at failure =	2.24	(%)

Accordingly, UCS tests were conducted on remolded specimen on five different samples, one from each location. The samples were remolded to attain the maximum dry density and optimum moisture content from the compaction test result. Table 3-16 presents summary Unconfined Compressive Strength test results.

Table 3-14 Unconfined Compressive Strength (UCS)

S.No	Location	UCS(Pa)
1	Total Addisu Gebeya	251
2	Semen Gebeya	247
3	Kechene Hidasie Health Center	239
4	Kolfe Police training Center	231
5	Intoto Technical and Vocational poly technique college	259

3.4.10 Summary of Test Result on the Control Specimen

The soil samples shows (Table 3-9) a liquid limit values between 52-83% and plasticity index between 23-41% most of the soil samples have been classified as A-7-5(20) according to AASHTO soil classification system with an exception of one sample which was classified as A-7-6(20). And also according to Unified soli classification systems they fall under MH-Elastic silts class with an exception of one sample which falls under CH-fat clay.

The sieve analysis and hydrometer test result (Table 3-8) shows that the clay portion of the samples rages from 48-61% and the silt portion ranges from 32-49%. Therefore one can conclude that the soil type collected for the investigation can be classified as red clay soil.

3.5 Laboratory Investigation of Stabilized Soil

According to TerraZyme Soil Stabilizer Application Instructions manual, TerraZyme stabilization can improve final cured California Bearing Ratio (CBR) value as well as reduce permeability and safe guard against the harmful loss of structural particles in the treated layer. TerraZyme treatment of the soils can also eliminate pumping action of silt and clay from below the base and sub base layers to protect the integrity of the road structure. In general TerraZyme can improve the engineering properties of most soil types. The main improved property is the strength, depending on the soil type and density. (TerraZyme Manual).

Laboratory or field testing provide most authoritative information for determining the most economical TerraZyme dosages to yield the specified strength levels in the target structural layer of the road design. CBR values and economic factors are considered the most important information in selecting TerraZyme dosages for stabilization. For this particular purpose a dosage recommended by the manufacturing company has been used.

Accordingly the following procedure were applied to stabilize the soils in the laboratory as it was stipulated in the application instructions manuals. These procedures were used so as to insure in obtaining an aqueous solution equivalent to 1(TerraZyme):500 (Water)

1. Pulverize each soil sample so that any clods are broken-up and the soil can be treated uniformly.
2. Place each soil sample to be treated in a separate plastic bag.
3. Take the spray bottle provided and fill it with clean 240ml water
4. Add 10 drops of TerraZyme from glass dropper bottle into the bottle which contains 240 ml of water. 10 drops will provide an aqueous solution equivalent to a 1 (TZ):500 (Water)
5. Shake the bottle well to ensure uniform distribution of the solution.
6. Spray the soil with the TerraZyme solution with the required amount so as to achieve the optimum moisture content (OMC) and mix the soil until the moisture is well distributed and becomes moist enough and create a cohesive clump when squeezed.
7. After wards, the soils shall be compacted to the required density for the respective tests.

Accordingly a TerraZyme stabilized soils have been tested to determine whether the treated soils engineering properties have improved or not and also to determine which properties are affected by the application of TerraZyme.

3.5.1 Consistency Limits

Soil analysis classified according to AASHTO Soil Classification System (grain size distribution, Atterburg limits, moisture density relations, California Bearing Ratio, organic content) are all key Information to project success as per the recommendation of the manufacturer manual. Accordingly, TerraZyme stabilized soils were tested for Liquid limit and plastic limit after 7days of curing. The results are shown in Table 3-15.

Table 3-15: Atterberg limits test result of the stabilized soil

Location	Test pit No.	Depth(m)	Atterberg limits	
			LL (%)	PI (%)
Total Addisu Gebeya	A	1	64	26
	A	2	64	31
	B	1	51	22
	B	2	56	24
	C	2	52	21
Semen Gebeya	A	1	73	34
	A	2	69	30
	B	1	81	40
	B	2	75	39
	C	2	63	27
Kechene Hidasie Health Center	A	1	55	21
	A	2	59	25
	B	1	61	30
	B	2	64	31
	C	2	63	27
Kolfe Police training Center	A	1	75	31
	A	2	73	31
	B	1	64	27
	B	2	60	28
	C	2	58	26
Intoto Technical and Vocational poly technique college	A	1	56	21
	A	2	60	26
	B	1	65	31
	B	2	66	27
	C	2	61	26

3.5.2 CBR Tests with TerraZyme

The samples were treated with pre-determined concentration of enzyme at optimum moisture content. CBR molds were prepared by modified proctor's method and kept in air tight bags for the specified curing time that is 7, 21 or 30 days. Later these molds were kept in soaked condition for 4 days and then tested for CBR. The results of tested soil with various curing days are given in Table 3-17

Table 3-16: CBR test result of stabilized soil

S.No.	Location	7Days		21Days		30Days	
		CBR (%)	Swell (%)	CBR (%)	Swell (%)	CBR (%)	Swell (%)
1	Total Addisu Gebeya	10	3.54	11	3.21	13	3.12
2	Semen Gebeya	9	4.47	10	4.43	11	4.31
3	Kechene Hidasie Health Center	7	5.86	8	5.74	10	5.14
4	Kolfe Police training Center	8	4.81	8	4.52	10	4.46
5	Intoto Technical and Vocational poly technique college	9	3.23	10	3.32	12	3.44

3.5.3 Unconfined Compressive Strength (UCS)

In general terms, the determination of unconfined compressive strength followed test method AASHTO T-208. However the test method applies to non-stabilized soils therefore modification to the test are necessary when dealing with non-traditional stabilizers as the stabilizer may need more than 7 days to develop strength. The prepared samples were placed in a plastic bag and kept in a desiccators for the specified curing period and tested.

The samples were tested at the end of each curing time that is 7days, 21days and 30days. Since this has been the requirement of the producer (to cure the samples at least for 30days before the test is performed).Table 3-19 presents the UCS test results for five samples at different curing time.

Table 3-17: **Unconfined strength test result of the stabilized soil**

S.No	Location	UCS (Pa)		
		7days	21days	30days
1	Total Addisu Gebeya	312	357	378
2	Kechene Hidasie Health Center	303	359	372
3	Semen Gebeya	296	318	353
4	Kolfe Police training Center	300	343	415
5	Intoto Technical and Vocational poly technique college	284	305	376

4 DISCUSSION ON THE TEST RESULTS

4.1 General

As an integral part of the study, a series of tests were conducted on both untreated and treated soil samples so as to analyze and evaluate the effect of TerraZyme with that of red clay soil samples. Accordingly, this chapter comprises mainly analysis and discussions of the test results that are obtained from the laboratory works. Some of the recommended tests that are important for evaluation the effect of TerraZyme includes soil classification according to AASHTO soil classification system, grain size distribution, Atterberg limits, moisture density relations, CBR and Unconfined Compressive Strength (UCS).

4.1.1 Atterberg limits

Atterberg limits tests are one of the tests that is required for evaluation of the effect of TerraZyme. Hence, a series of Atterberg limit tests were conducted in the laboratory so as to assess the effect of the TerraZyme on the plasticity of the soils for both treated and untreated soils.

4.1.1.1 Total Addisu Gebeya

One of the samples collected Total Addisu Gebeya had been classified as CH- Fat Clay whereas all the other soil samples were classified as MH-Elastic silt. The liquid limit test results obtained for the untreated (Non-stabilized) soil ranges from 52-69 and the plasticity index test result ranges from 23-31. After the application of TerraZyme the maximum reduction observed in the Plasticity index were 2%. Hence no significant change is observed on the Atterberg limit test results of the soil samples collected from Total Addisu Gebeya. The table 4-1 below shows summery of test result for both stabilized and non-stabilized soil sample from Total Addisu Gebeya

Table 4-1 Summer of Atterberg limit Test result for samples from Total Addisu Gebeya

S. N	Station	TP	D (m)	Sieve Analysis AASHTO T 11, T 27			Atterberg Limits (non Stabilized) AASHTO T 89, T 90		Atterberg Limits (Stabilized) AASHTO T 89, T 91		AASHTO Classification AASHTO M145	Unified soil Classification System ASTM D 2487
				2 mm	0.425 mm	0.075 mm	LL %	PI %	LL %	PI %		
1	Total Addisu Gebeyas	A	1	99	98	96	65	28	64	26	A-7-5[20]	MH-Elastic Silt
2	Total Addisu Gebeyas	A	2	100	100	97	69	31	64	31	A-7-5[20]	MH-Elastic Silt
3	Total Addisu Gebeyas	B	1	100	100	97	52	24	51	22	A-7-6[20]	CH -Fat Clay
4	Total Addisu Gebeyas	B	2	100	100	98	56	26	56	24	A-7-5[20]	MH-Elastic Silt
5	Total Addisu Gebeyas	C	2	100	99	93	55	23	52	21	A-7-5[20]	MH-Elastic Silt

4.1.1.2 Semen Gebeya

All of the samples collected Semen Gebeya had been classified as MH-Elastic silt. The liquid limit test results obtained for the untreated (Non stabilized) soil Ranges from 83-65 and the plasticity index test result ranges from 29-41. After the application of TerraZyme the maximum reduction observed in the Plasticity index were 4%. Hence no significant change is observed on the Atterberg limit test results of the soil samples collected from Semen Gebeya. The table (4-2) below shows summery of test result for both stabilized and non-stabilized soil sample from Semen Gebeya.

Table 4-2 Summer of Atterberg limit Test result for samples from Semen Gebeya

S No.	Station	Test Pit No.	Depth (m)	Sieve Analysis AASHTO T 11, T 27			Atterberg Limits (non Stabilized) AASHTO T 89, T 90		Atterberg Limits (Stabilized) AASHTO T 89, T 91		AASHTO Classification AASHTO M145	Unified soil Classification System ASTM D 2487
				2 mm	0.425 mm	0.075 mm	LL %	PI %	LL %	PI %		
1	Semen Gebeya	A	1	100	99	98	77	38	73	34	A-7-5[20]	MH-Elastic Silt
2	Semen Gebeya	A	2	100	99	98	73	31	69	30	A-7-5[20]	MH-Elastic Silt
3	Semen Gebeya	B	1	98	96	94	83	41	81	40	A-7-5[20]	MH-Elastic Silt
4	Semen Gebeya	B	2	98	97	94	79	40	75	39	A-7-5[20]	MH-Elastic Silt
5	Semen Gebeya	C	2	98	98	97	65	29	63	27	A-7-5[20]	MH-Elastic Silt

4.1.1.3 Kechene Hidasie Health Center

All of the samples collected Kechene Hidasie Health center had been classified as MH-Elastic silt. The liquid limit test results obtained for the untreated (Non stabilized) soil Ranges from 57-67 and the plasticity index test result ranges from 23-31. After the application of TerraZyme the maximum reduction observed in the Plasticity index were 2%. Hence no significant change is observed on the Atterberg limit test results of the soil samples collected from Kechene Hidasie Health center. The table (4-3) below shows summery of test result for both stabilized and non-stabilized soil sample from Semen Gebeya

Table 4-3 Summer of Atterberg limit Test result for samples from Kechene Hidasie Health Center

S No.	Station	Test Pit No.	Depth	Sieve Analysis AASHTO T 11, T 27			Atterberg Limits (non Stabilized) AASHTO T 89, T 90		Atterberg Limits (Stabilized) AASHTO T 89, T 91		AASHTO Classification AASHTO M145	Unified soil Classification System ASTM D 2487
				2 mm	0.425 mm	0.075 mm	LL %	PI %	LL %	PI %		
1	Kechene Hidasie Health center	A	1	100	100	97	57	23	55	21	A-7-5[20]	MH-Elastic Silt
2	Kechene Hidasie Health center	A	2	100	99	96	60	27	59	25	A-7-5[20]	MH-Elastic Silt
3	Kechene Hidasie Health center	B	1	99	98	96	66	31	61	30	A-7-5[20]	MH-Elastic Silt
4	Kechene Hidasie Health center	B	2	99	98	96	67	30	64	31	A-7-5[20]	MH-Elastic Silt
5	Kechene Hidasie Health center	C	2	99	99	98	64	28	63	27	A-7-5[20]	MH-Elastic Silt

4.1.1.4 Kolfe Police Training Center

All of the samples collected Kolfe Police training Center had been classified as MH-Elastic silt. The liquid limit test results obtained for the untreated (Non stabilized) soil Ranges from 60-72 and the plasticity index test result ranges from 35-28. After the application of TerraZyme the maximum reduction observed in the Plasticity index were 4%. Hence no significant change is observed on the Atterberg limit test results of the soil samples collected from Kolfe Police training Center. The table (4-4) below shows summery of test result for both stabilized and non-stabilized soil sample from Semen Gebeya

Table 4-4 Summer of Atterberg limit Test result for samples from Kolfe Police training Center

S No.	Station	Test Pit No.	Depth	Sieve Analysis			Atterberg Limits (non Stabilized)		Atterberg Limits (Stabilized)		AASHTO Classification AASHTO M145	Unified soil Classification System ASTM D 2487
				AASHTO T 11, T 27			AASHTO T 89, T 90		AASHTO T 89, T 90			
				2 mm	0.425 mm	0.075 mm	LL %	PI %	LL %	PI %		
1	Kolfe Police training Center	A	1	100	99	96	72	32	75	31	A-7-5[20]	MH-Elastic Silt
2	Kolfe Police training Center	A	2	100	99	96	71	35	73	31	A-7-5[20]	MH-Elastic Silt
3	Kolfe Police training Center	B	1	99	95	89	65	29	64	27	A-7-5[20]	MH-Elastic Silt
4	Kolfe Police training Center	B	2	99	95	88	60	28	60	28	A-7-5[20]	MH-Elastic Silt
5	Kolfe Police training Center	C	2	94	91	88	60	28	58	26	A-7-5[20]	CH-Fat Clay

4.1.1.5 Intoto Technical and Vocational Poly Technique College

One of the samples collected Intoto Technical and Vocational Poly Technique College compound had been classified as CH- Fat Clay whereas all the other soil samples were classified as MH-Elastic silt.. The liquid limit test results obtained for the untreated (Non stabilized) soil Ranges from 67-57 and the plasticity index test result ranges from 31-23. After the application of TerraZyme the maximum reduction observed in the Plasticity index were 5%. Hence no significant change is observed on the Atterberg limit test results of the soil samples collected from Kolfe Police training Center. The table (4-5) below shows summery of test result for both stabilized and non-stabilized soil sample from Intoto Technical and Vocational Poly Technique College

Table 4-5 Summer of Atterberg limit Test result for samples from Intoto Technical and Vocational Poly

S No.	Station	TP	D (m)	Sieve Analysis			Atterberg Limits (non Stabilized)		Atterberg Limits (Stabilized)		AASHTO Classification AASHTO M145	Unified soil Classification System ASTM D 2487
				AASHTO T 11, T 27			AASHTO T 89, T 90		AASHTO T 89, T 90			
				2	0.425	0.075	LL	PI	LL	PI		
				mm	mm	mm	%	%	%	%		
1	Intoto Technical I and Vocational Poly Technique College	A	1	100	100	97	57	23	56	21	A-7-5[20]	MH-Elastic Silt
2	Intoto Technical I and Vocational Poly Technique College	A	2	100	99	96	60	27	60	26	A-7-5[20]	MH-Elastic Silt
3	Intoto Technical I and Vocational Poly Technique College	B	1	99	98	96	66	31	65	31	A-7-5[20]	MH-Elastic Silt
4	Intoto Technical I and Vocational Poly Technique College	B	2	99	98	96	67	30	66	27	A-7-5[20]	MH-Elastic Silt
5	Intoto Technical I and Vocational Poly Technique College	C	2	100	99	93	62	31	61	26	A-7-6[20]	MH-Elastic Silt

As a summary, the liquid limit for untreated soils ranges between 83 and 52% and after treatment the maximum reduction in liquid limit observed is 5 %. Only five soil samples shows a reduction above 4%. The rest shows a reduction ranging between 3% & 1%. Therefore, no significant reduction is observed in the liquid limit of the tested soil samples. Fig: 4-1 shows the comparison made between liquid limits of treated and untreated soils

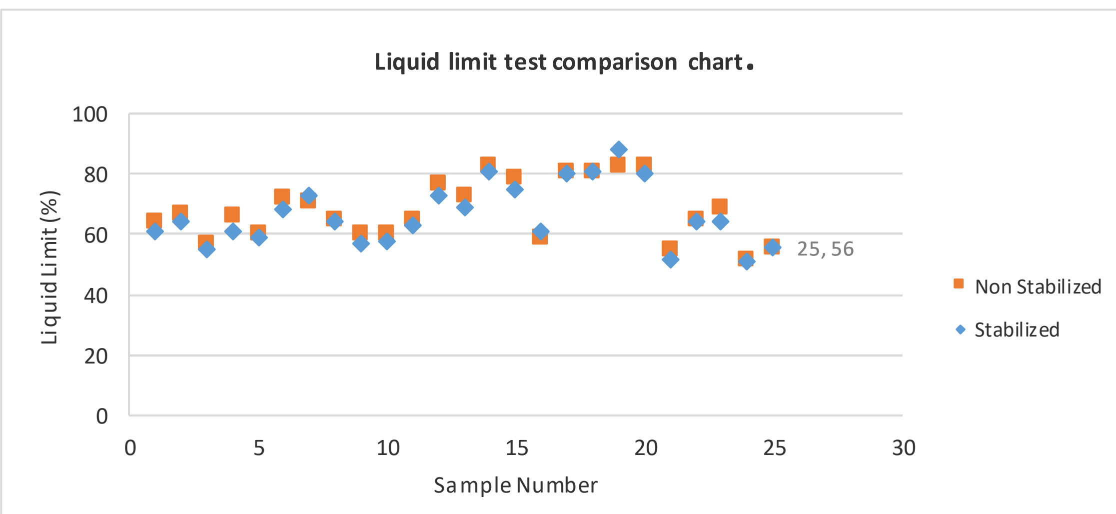


Figure 4-1 Liquid limit comparison Chart

The same is true for plasticity index of tested soils, for untreated soils the plasticity index of the soil ranges between 23 and 41 % and after treatment the maximum reduction observed is about 4% in three sample and the other shows a maximum of 2% and 1% reduction. Therefore, there is no significant reduction is observed in the plasticity index of the treated soil so as to make the soils fit as a sub base material.

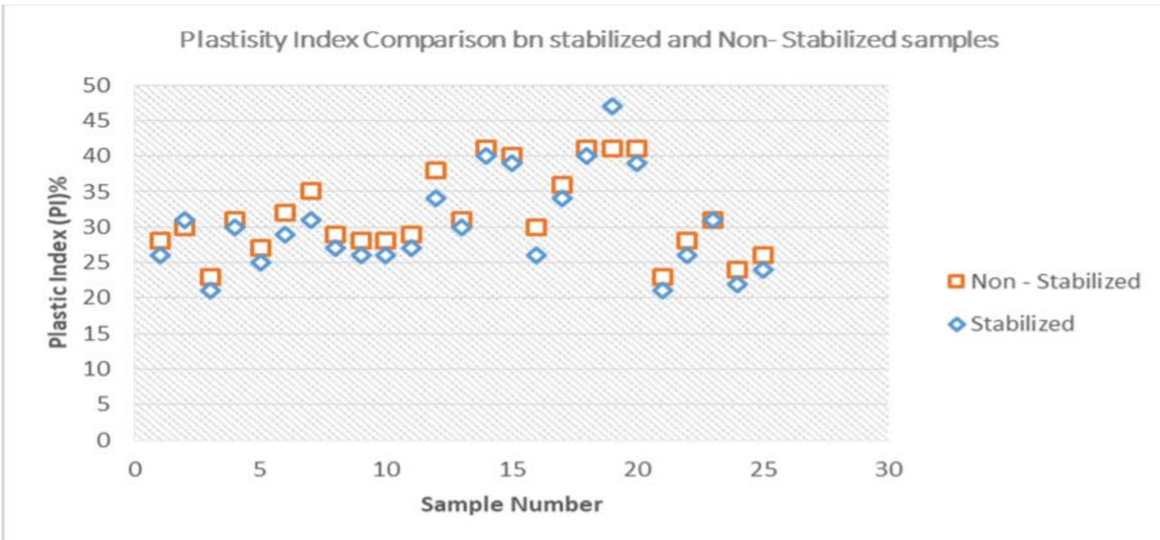


Figure 4-2: Plasticity index comparison for stabilized and non-stabilized soils

In general, the applications of the chemical enzyme (TerraZyme) did not result in any significant reduction in the plasticity of red clay soils.

4.2 Compaction

Comparison of moisture density relationship of the selected soil samples were made using maximum dry densities (MDD) and optimum moisture contents (OMC) of the red clay soils. Accordingly for non-stabilized soils the results obtained from standard test method AASHTO T-193) that is using Modified Proctor Test. For the stabilized soils the dry density and Moisture content results are obtained while remolding the sample for CBR test using the same effort and moisture content to obtain a similar MDD. The results of the two compaction are presented in the Table 4-1.

And hence it can be observed from the chart that in all the stabilized soils there is a small improvement in their maximum dry density associated with a minor reduction in their moisture content.

Table 4-6: Comparison of compaction test result

S.No	Location	Non stabilized soil		Stabilized soil(Average)	
		MDD (gm/cm3)	OMC (%)	MDD (gm/cm3)	OMC (%)
1	Total Addisu Gebeya	1.62	22.5	1.65	21.97
2	Kechene Hidasie Health Center	1.52	23.5	1.56	22.66
3	Semen Gebeya	1.54	22.5	1.58	22.02
4	Kolfe Police training Center	1.51	20.5	1.54	19.89
5	Intoto Technical and Vocational poly technique college	1.62	21.5	1.65	20.68

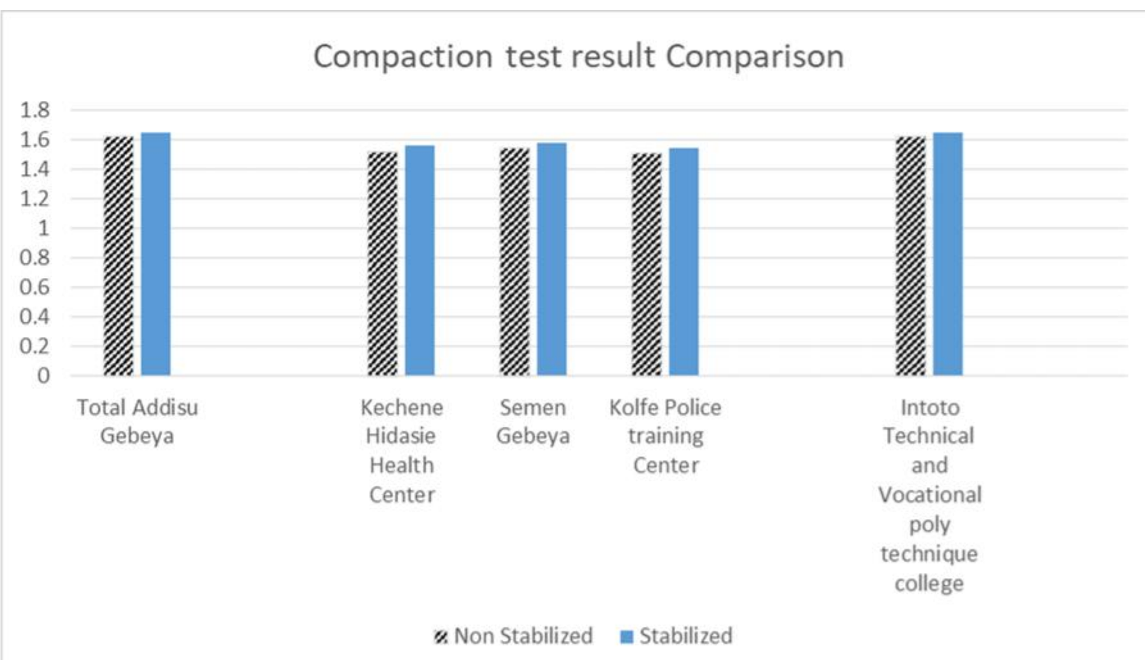


Figure 4-3: Comparison of compaction test result

4.3 Californian Bearing Ratio (CBR)

CBR values are used to assess the suitability of the given sub grade, sub base or base course materials for the intended purpose. Since CBR is value of it represents the penetration resistance of the given material with respect to a standard crushed aggregate it is a measure of the strength property of the material.

As TerraZyme Soil Stabilizer Application Instructions indicates the main property of the soil that is expected to be improved is the strength property of the material, depending on the soil type and density Hence the CBR Value of the stabilized soil is expected to increase. As it can be observed from the chart the CBR value of the stabilized soils after 30days of curing time is increased.

In general the following points were noted from the test result

- The CBR test result shows small increment as compared to the untreated soil.
- The maximum increment observed in the CBR value is 4% which is below the expected value therefore the result obtained are not satisfactory as compared to the expected result.
- Based on the test results it was found that CBR values of the treated soil increases as the curing period increases.

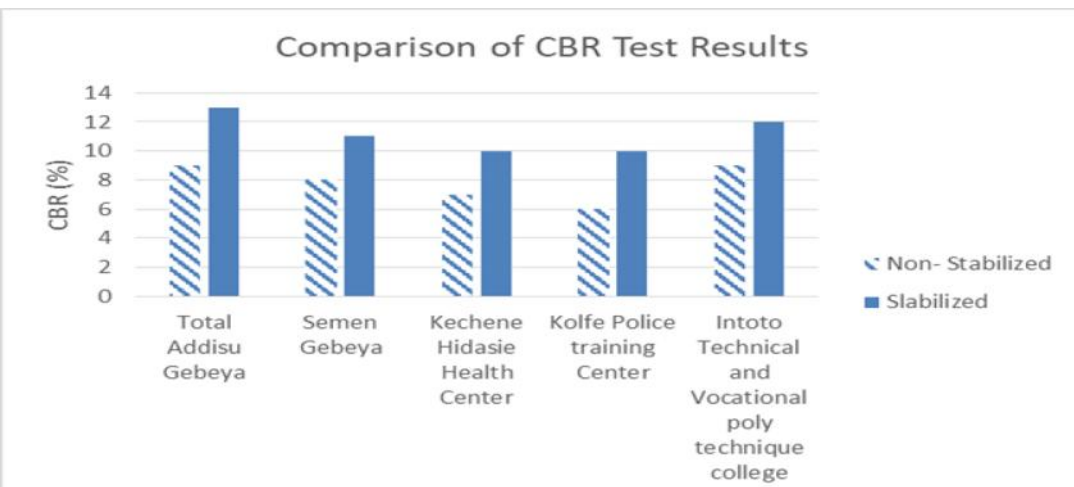


Figure 4-4: Comparison of CBR Values for Stabilized and Non Stabilized soil

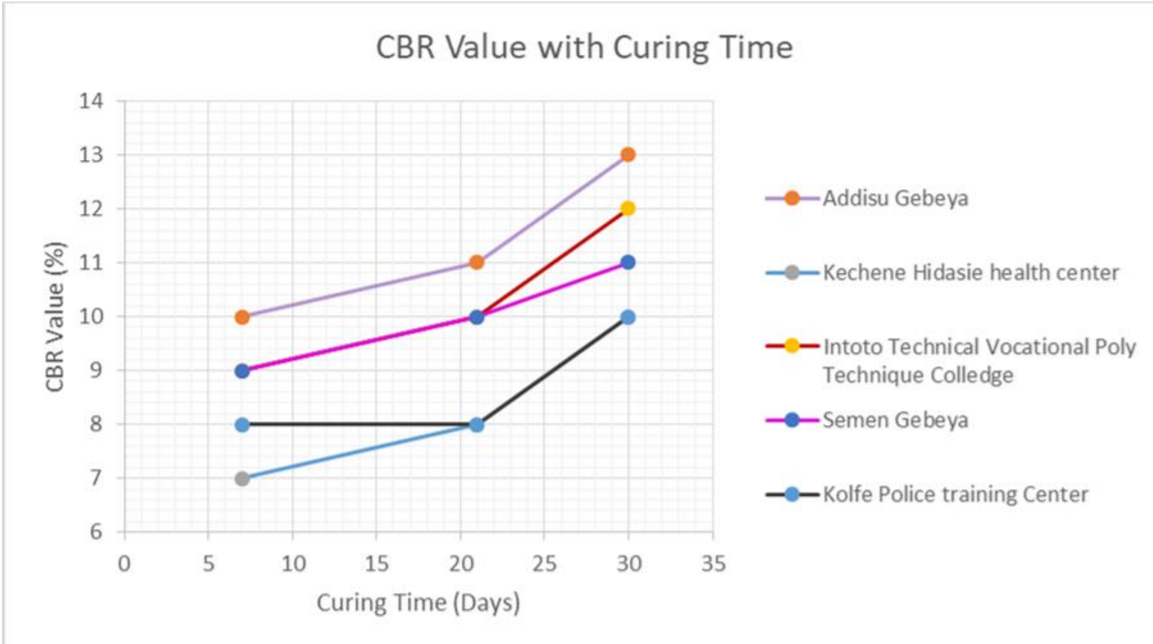


Figure 4-5: Effect of Curing Period on CBR

4.4 Unconfined Compressive Strength (UCS)

The unconfined compressive strength test was used as an indicator to assess the strength improvement of the soil treated with TerraZyme. The effect of the treatment on the unconfined compressive strength is shown in the figure 4-6. The results of the treated of red clay soil for a curing period of 7days 21days and 30days is shown in Table 3-16. The result shows that there is a significant increment in the unconfined compressive strength value of an enzyme treated soil as compared to non-stabilized soil.

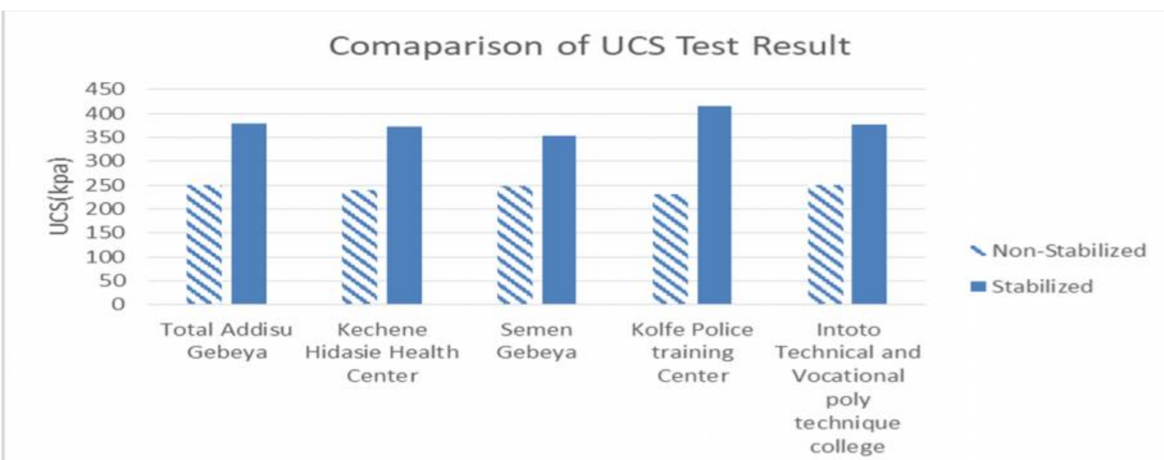


Figure 4-6: Comparison of UCS Results for Stabilized and Non Stabilized soil samples

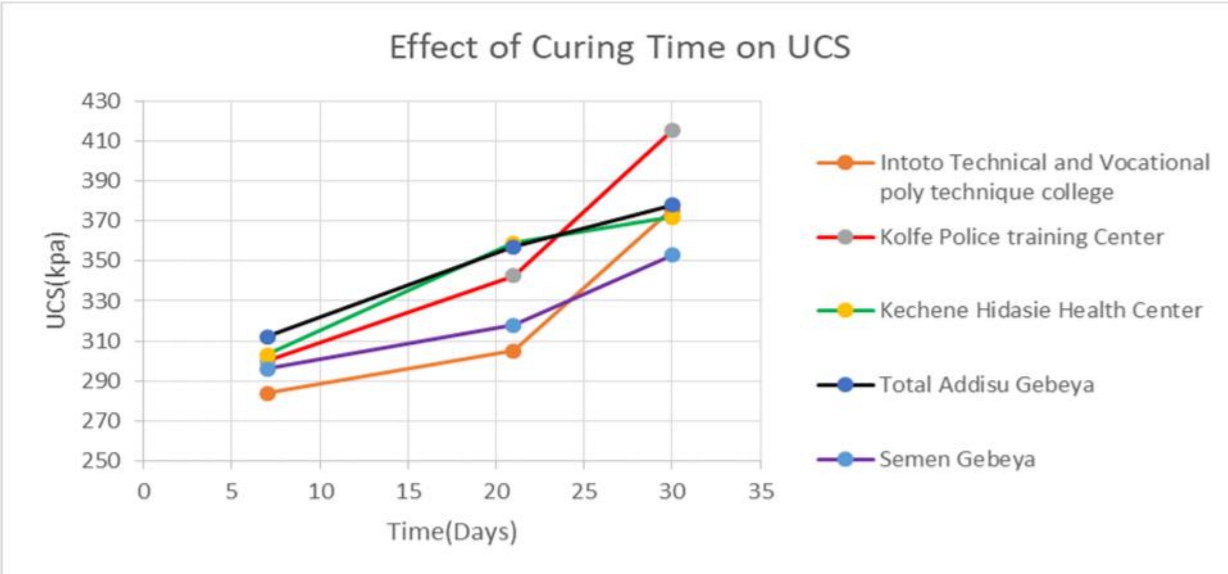


Figure 4-7: Effect of Curing time on UCS

In General the following points were noted from the test result

- Based on the test results it was found that unconfined compressive strength value of the treated soil is increased.
- The result shows an increment with that of the curing period increases.
- The increment ranges from 55Pa to 116Pa by treating the soil with enzyme for a curing period of 30days.

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The objective of this thesis is to assess the performance of TerraZyme on a red clay soil and to better understand its potential value for road construction. Accordingly a number of laboratory tests have been performed and the results were analyzed and discussed in the previous section of the report. Based on the analysis performed on the experimental data obtained in this study the following conclusions were drawn:

- The application of TerraZyme on a red clay soil did not show any significant reduction on the plasticity index of the soil.
- The maximum dry density of the TerraZyme treated soil shows a significant increment as compared to that of untreated soils.
- The CBR value of TerraZyme treated red clay soil shows a small increment after a 30days curing time. The improvement obtained in the CBR value of red clay soil is not satisfactory.
- The Unconfined Compressive Strength value of TerraZyme treated red clay soil shows a significant increase as compared to untreated soils.
- In both the CBR and UCS test the results show an increment as the curing time increases.
- The results show that application of TerraZyme on red clay soil will not result in a significant improvement in the engineering properties of the red clay soil.
- The previously published literature on the effectiveness of these product categories also notes that product performance varies in relation to soil type, composition, climate, and traffic. Therefore, the ineffectiveness of the TerraZyme on red clay soil might be attributed to the soil type.

5.2 RECOMMENDATION

- The type of soils in which the TerraZyme application can produce an optimal result should be investigated before the application of the treatment on project bases.
- The investigation of this enzyme based chemicals are highly dependent on the soil type therefore it is advisable to make further investigation on different soil types
- Extend the laboratory testing to investigate its performance on soils with medium plasticity and having different proportion of gravel.

REFERENCE

1. Chen, F.H. (1998). Foundations on Expansive Soils. New York: Elsevier Science Publishers.
2. Nelson J. D., and D. J. Miller, (1991). Expansive Soils Problems and Practice in Foundation And Pavement Engineering. New York: Courier Companies, Inc.
3. Teferra, A. and. Likin M. (1999). Soil Mechanics. Addis Ababa: Addis Ababa University.
4. Arora, Dr.K.R. (2004) Soil Mechanics and Foundation Engineering
5. Wright Fox, R. Macfarlane, J. G. Bibbens, R. F. (1993). Alternate Chemical Soil Stabilizers. Minor Research Report. CalTrans.
6. Terzaghi, 1883-1 963. Soil mechanics in engineering practice/Karl Terzaghi, Ralph B. Peck, Gholamreza Mesri.-3rd Ed.
7. Morin, W.J., and W.T. Parry, (1971) Geotechnical Properties of Ethiopian Volcanic Soils, Geotechnique, Vol. 21, No 3, PP223-232.
8. Ravi Shankar A.U, HarshaKumarRai & Ramesha MithanthayaI. (2009). 'Bio-Enzyme Stabilized Lateritic Soil As A Highway Material Paper No. 553'
9. Raul V., O. M Mihai, Ray Hozalski, Tim Clyne. (2005)Preliminary Laboratory Investigation of Enzyme Solutions As A Soil Stabilizer. Work Order 79
10. Magangira M.B.(2009). 'Evaluation of the effects of enzyme- Based liquid Chemical stabilizers on subgrade soils' CSIR, Built Enviroment, Pretoria
11. Dr. Rubens Brazetti* and Dr. Sheldon R. Murphy,(2001) **'**Objective Performance Measurement Of Actual Road Sites Treated With An Organic Soil Stabilizer'
12. Roger W. Surdahl, J. H. Woll, and R. Marquez (2005). 'Road Stabilizer Product Performance Buenos Aires National Wildlife Refuge Publication No. FHWA-CFL/TD-05-011 October 2005'
13. Asseged G., Muluget H/Mariam, K.Mariam Gashaw, (2007) Geological Map of Addis Ababa City
14. AASHTO (2001),'Standard Specification for Transportation materials and methods of sampling and Testing'
15. Ravi S., Jagdish T. Shahu Vasant H. (2019). 'Geotechnics for Transport Infrastructure, Recent Development ,Up Coming Technology and new Concepts, Volume 2'

16. Divya V and Asha M N, (2020).' Evaluation of Sustainable Methods for Embankment Stabilization'
17. Athira S, B K Safana and Keerthi Sabu, (2017). ' Soil Stabilization using TerraZyme for Road Construction'
18. Sanjeet Sahoo, G. Sridevi, (2018). 'Soil stabilization using bio-enzyme'
19. LI Yue-Jun , LI Liang and DAN Han-Cheng, (2016). ' Study on application of TerraZyme in road base course of road'
20. Samuel T. (1989). 'Investigation into some of the Engineering properties of Addis Ababa Red clay soil' Maters Thesis, Addis Ababa University.
21. Tesfaye N. (2004), 'Determination of Parameters for the Tangent Modulus Approach,' M.Sc. Thesis, Addis Ababa University.
22. Merihun L. (2004), 'a study on the effect of remoulding on the mechanical behaviour of Addis Ababa red clay soil,' MSc Thesis, Addis Ababa University.
23. Ermias G.(2014), 'Predicting the Value of CBR from DCP for Addis Ababa Red Clay', M.Sc. Thesis, Addis Ababa University
24. Ashenafi M.(2016), 'Soaked CBR Value Determination From Laboratory DCP Test For Addis Ababa Red Clay Soil', M.Sc. Thesis, Addis Ababa University

APPENDIX

I- Test Result for Non- Stabilized Soil

SPECIFIC GRAVITY OF SOIL (TEST METHOD:AASHTO T 100)				
Location	Total Addisu Gebeya			
Depth	2m			
Specimen Reference		Unit	Sample 1	Sample 2
Mass of Soil	A	gm	10.27	10.59
Mass of Pycnometer + Sample Filled With Water	B	gm	185.44	178.8
Mass of Pycnometer Filled with Water Only	C	gm	179.1	172.27
Bulk Specific Gravity (A/A+C-B)	D		2.613	2.608
		Average	2.61	

Location	Semen Gebeya			
Depth	2m			
Specimen Reference		Unit	Sample 1	Sample 2
Mass of Soil	A	g	10.4	10.43
Mass of Pycnometer + Sample Filled With Water	B	g	185.46	185.34
Mass of Pycnometer Filled with Water Only	C	g	179.1	178.99
Bulk Specific Gravity	D	g	2.574	2.556
		Average	2.57	

Location	Kechene Hidasie Health Center			
Depth	2m			
Specimen Reference		Unit	Sample 1	Sample 2
Mass of Soil	A	gm	10.77	10.65
Mass of Pycnometer + Sample Filled With Water	B	gm	182.57	183.41
Mass of Pycnometer Filled with Water Only	C	gm	175.9	176.82
Bulk Specific Gravity	D		2.627	2.623
		Average	2.62	

Location	Kolfe Police training Center			
Depth	2m			
Specimen Reference			1	2
Mass of Soil	A	g	10.81	10.68
Mass of Pycnometer + Sample Filled With Water	B	g	182.61	183.46
Mass of Pycnometer Filled with Water Only	C	g	175.9	176.82
Bulk Specific Gravity	D	g	2.637	2.644
		Average	2.64	

Location	Intoto Technical and Vocational poly			
Depth	2m			
Specimen Reference		Unit	Sample 1	Sample 2
Mass of Soil	A	gm	10.52	10.38
Mass of Pycnometer + Sample Filled With Water	B	gm	178.45	185.38
Mass of Pycnometer Filled with Water Only	C	gm	171.97	178.99
Bulk Specific Gravity	D		2.604	2.602
		Average	2.60	

	Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering	
Laboratory Test Result		

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** C
Sampled /Tested by: Dagnachew Seifu **Depth:** 2m
Location: Total Addisu Gebeya
Terrazyme application: **Non**

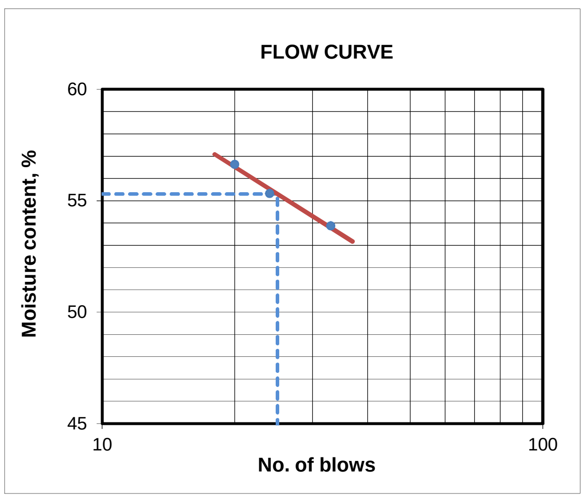
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	24	20			
Container No.		I	O	A18	Z11	AZ	
Mass of Container	g	18.35	17.77	17.86	23.86	20.69	
Mass of Wet Soil + Container	g	29.89	30.32	30.25	30.74	27.06	
Mass of Dry Soil + Container	g	25.85	25.85	25.77	29.05	25.53	
Mass of Water in Specimen	g	4.04	4.47	4.48	1.69	1.53	
Mass of Dry Soil	g	7.50	8.08	7.91	5.19	4.84	
Moisture Content	%	53.9	55.3	56.6	32.6	31.6	
					Average PL, %		**32.1**

Initial Mass= 179.15 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0.07	0	100
№ 40	1.93	1	99
№ 200	11.26	6	93

LL	PI	AASHTO Soil Class.
55	23	A-7-5 [20]



Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** C

Sampled /Tested by: Dagnachew Seifu **Depth:** 1m

Location: Semen Gebeya

Terrazyme application: **Non**

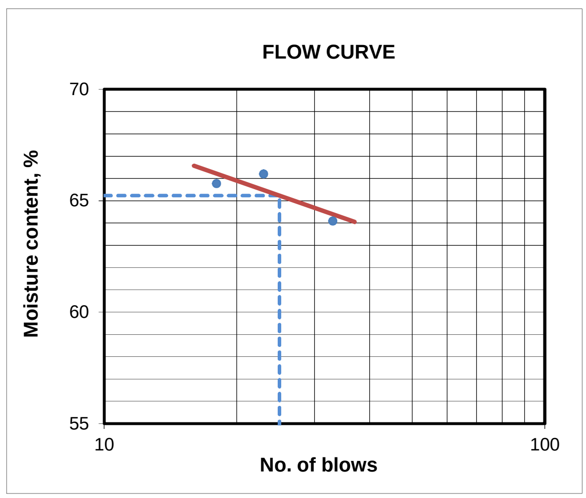
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	23	18			
Container No.		H	A16	A8	Y6	AM	
Mass of Container	g	17.79	17.76	17.87	23.8	20.63	
Mass of Wet Soil + Container	g	30.77	31.04	30.27	31.32	27.27	
Mass of Dry Soil + Container	g	25.70	25.75	25.35	29.32	25.55	
Mass of Water in Specimen	g	5.07	5.29	4.92	2.00	1.72	
Mass of Dry Soil	g	7.91	7.99	7.48	5.52	4.92	
Moisture Content	%	64.1	66.2	65.8	36.2	35.0	
					Average PL, %		**35.6**

Initial Mass= 174.57 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	3.59	2	98
№ 40	0.28	0	98
№ 200	1.67	1	97

LL	PI	AASHTO Soil Class.
65	29	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Intoto Technical and Vocational Poly techmic College
Terrazyme application: **Non**

Test Pit No. C
Depth: 2m

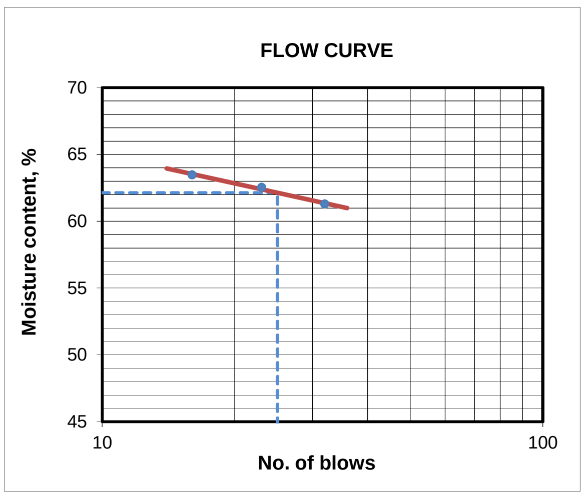
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	23	16			
Container No.		A70	M	T	Y9	AD	
Mass of Container	g	17.69	18.03	17.6	23.69	23.53	
Mass of Wet Soil + Container	g	30.69	30.74	31.74	30.12	30.04	
Mass of Dry Soil + Container	g	25.75	25.85	26.25	28.57	28.53	
Mass of Water in Specimen	g	4.94	4.89	5.49	1.55	1.51	
Mass of Dry Soil	g	8.06	7.82	8.65	4.88	5.00	
Moisture Content	%	61.3	62.5	63.5	31.8	30.2	
					Average PL, %		**31.0**

Initial Mass= 178.23 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0	0	100
№ 40	1.69	1	99
№ 200	9.9	6	93

LL	PI	AASHTO Soil Class.
62	31	A-7-5 [20]



	ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING	
Laboratory Test Result		

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** B

Sampled /Tested by: Dagnachew Seifu **Depth:** 2m

Location: Intoto Technical and Vocational poly technique college

Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

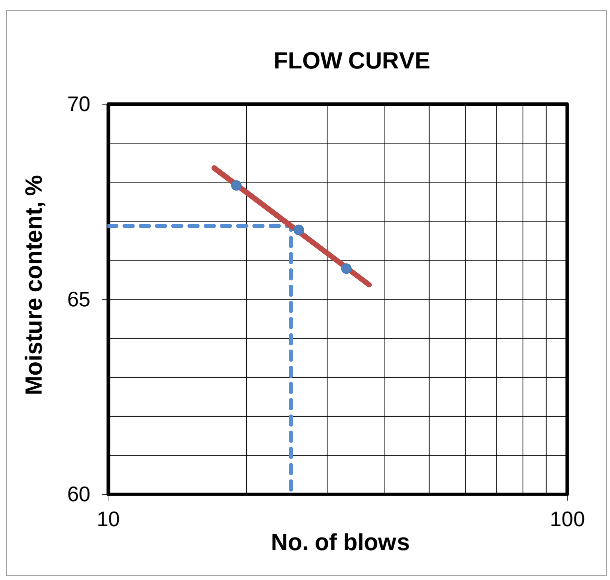
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	19			
Container No.		A-13	A-2	A-19	Z-3	Z-6	
Mass of Container	g	18.25	17.85	17.93	23.52	23.02	
Mass of Wet Soil + Container	g	30.85	33.31	34.00	29.41	28.78	
Mass of Dry Soil + Container	g	25.85	27.12	27.50	27.83	27.21	
Mass of Water in Specimen	g	5.00	6.19	6.50	1.58	1.57	
Mass of Dry Soil	g	7.60	9.27	9.57	4.31	4.19	
Moisture Content	%	65.8	66.8	67.9	36.7	37.5	
					Average PL, %		**37.1**

Initial Mass= 150.1 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.50	1	99
№ 40	1.50	1	98
№ 200	3	2	96

LL	PI	AASHTO Soil Class.
67	30	A-7-5 [20]



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. A
Sampled /Tested by: Dagnachew Seifu
Depth: 1m
Location: Intoto Technical and Vocational poly technique college
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

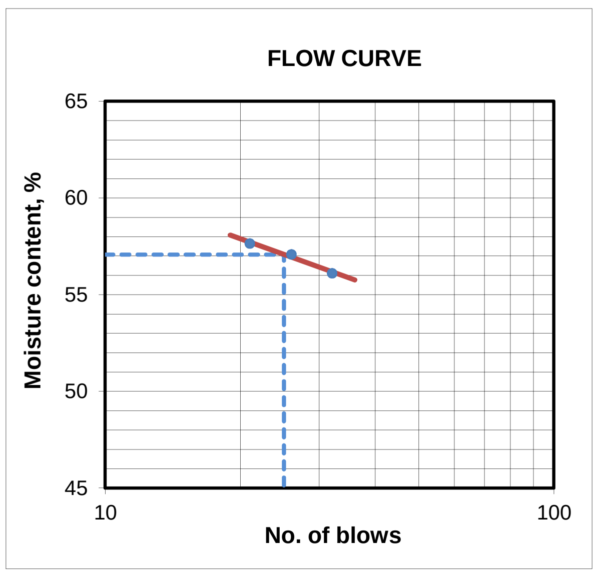
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	26	21			
Container No.		A-18	A-8	A-16	Z-7	Z-9	
Mass of Container	g	17.8	17.81	17.7	23.52	23.43	
Mass of Wet Soil + Container	g	28.26	32.56	35.12	30.78	32.22	
Mass of Dry Soil + Container	g	24.50	27.20	28.75	28.90	30.06	
Mass of Water in Specimen	g	3.76	5.36	6.37	1.88	2.16	
Mass of Dry Soil	g	6.70	9.39	11.05	5.38	6.63	
Moisture Content	%	56.1	57.1	57.6	34.9	32.6	
					Average PL, %		**33.8**

Initial Mass= 301 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0	0	100
№ 40	0	0	100
№ 200	9.03	3	97

LL	PI	AASHTO Soil Class.
57	23	A-7-5 [20]



	ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING	
	Laboratory Test Result	

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A

Sampled /Tested by: Dagnachew Seifu **Depth:** 2m

Location: Intoto Technical and Vocational poly technique college

Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

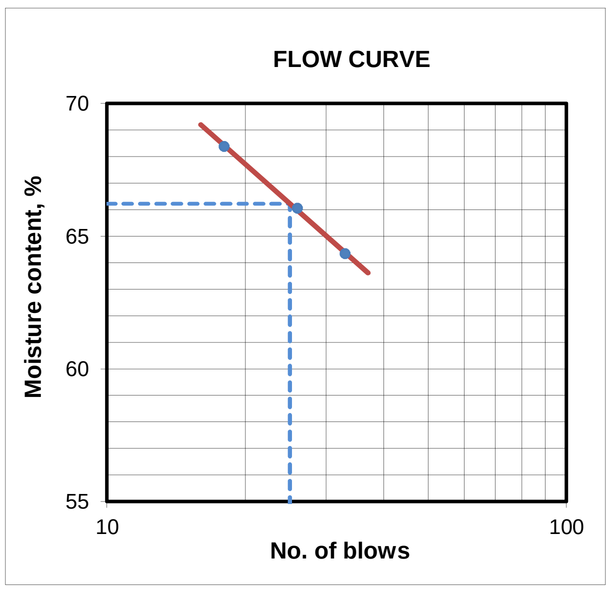
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	18			
Container No.		O	B-1	A-8	AL	Z-15	
Mass of Container	g	17.72	17.77	17.78	23.52	23.75	
Mass of Wet Soil + Container	g	32.51	36.6	36.42	41.04	41.84	
Mass of Dry Soil + Container	g	26.72	29.11	28.85	36.54	37.05	
Mass of Water in Specimen	g	5.79	7.49	7.57	4.50	4.79	
Mass of Dry Soil	g	9.00	11.34	11.07	13.02	13.30	
Moisture Content	%	64.3	66.0	68.4	34.6	36.0	
					Average PL, %		**35.3**

Initial Mass= 152.7 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.53	1	99
№ 40	1.53	1	98
№ 200	3.1	2	96

LL	PI	AASHTO Soil Class.
66	31	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 1m
Location: Intoto Technical and Vocational poly technique college
Terrazyme application: Non

ATTERBERG LIMITS AND SOIL CLASSIFICATION

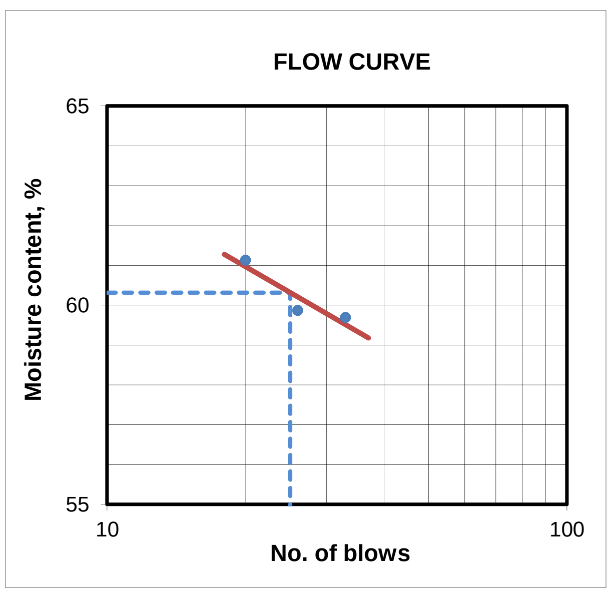
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	20			
Container No.		B-6	A-20	BD	Z-8	AB	
Mass of Container	g	17.68	17.59	17.58	20.51	23.12	
Mass of Wet Soil + Container	g	34.00	34.52	33.00	29.04	31.25	
Mass of Dry Soil + Container	g	27.90	28.18	27.15	26.93	29.21	
Mass of Water in Specimen	g	6.10	6.34	5.85	2.11	2.04	
Mass of Dry Soil	g	10.22	10.59	9.57	6.42	6.09	
Moisture Content	%	59.7	59.9	61.1	32.9	33.5	
					Average PL, %		**33.2**

Initial Mass= 203.6 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0	0	100
№ 40	2.04	1	99
№ 200	6.11	3	96

LL	PI	AASHTO Soil Class.
60	27	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. A
Sampled /Tested by: Dagnachew Seifu
Depth: 1m
Location: Total Addisu Gebeya
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

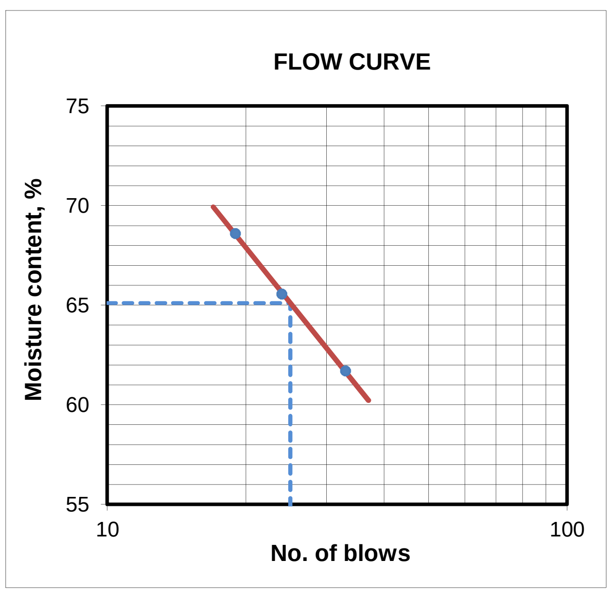
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	24	19			
Container No.		A-17	S	B-5	Z-14	Y-9	
Mass of Container	g	17.76	17.72	17.75	23.62	23.57	
Mass of Wet Soil + Container	g	33.88	33.48	32.94	44.61	43.11	
Mass of Dry Soil + Container	g	27.73	27.24	26.76	38.92	37.79	
Mass of Water in Specimen	g	6.15	6.24	6.18	5.69	5.32	
Mass of Dry Soil	g	9.97	9.52	9.01	15.30	14.22	
Moisture Content	%	61.7	65.5	68.6	37.2	37.4	
					Average PL, %		**37.3**

Initial Mass= 154.3 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.54	1	99
№ 40	1.54	1	98
№ 200	3.09	2	96

LL	PI	AASHTO Soil Class.
65	28	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A

Sampled /Tested by: Dagnachew Seifu **Depth:** 1m

Location: Total Addisu Gebeya

Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

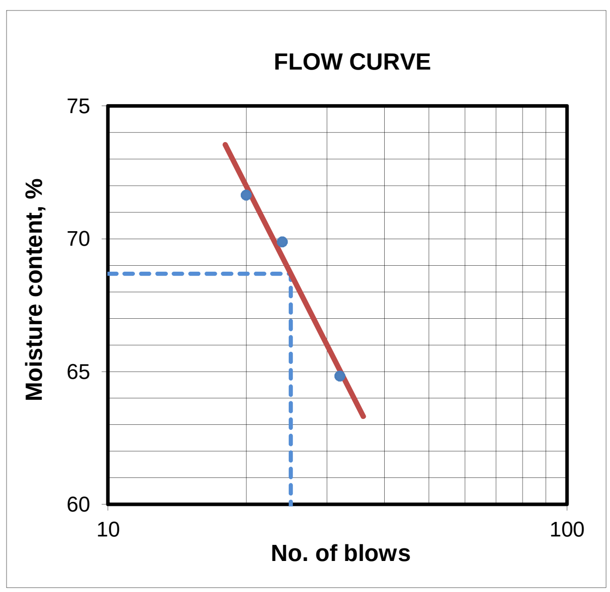
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	24	20			
Container No.		B-8	N	A-7	Y-4	Z-1	
Mass of Container	g	17.69	17.94	17.59	23.36	23.51	
Mass of Wet Soil + Container	g	33.20	38.852	36.35	31.36	30.78	
Mass of Dry Soil + Container	g	27.10	30.25	28.52	29.16	28.77	
Mass of Water in Specimen	g	6.10	8.60	7.83	2.20	2.01	
Mass of Dry Soil	g	9.41	12.31	10.93	5.80	5.26	
Moisture Content	%	64.8	69.9	71.6	37.9	38.2	
					Average PL, %		**38.1**

Initial Mass= 164.3 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0	0	100
№ 40	0	0	100
№ 200	4.93	3	97

LL	PI	AASHTO Soil Class.
69	31	A-7-5 [20]



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil — **Test Pit No.** A

Sampled /Tested by: Dagnachew Seifu — **Depth:** 2m

Location: Total Addisu Gebeya

Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

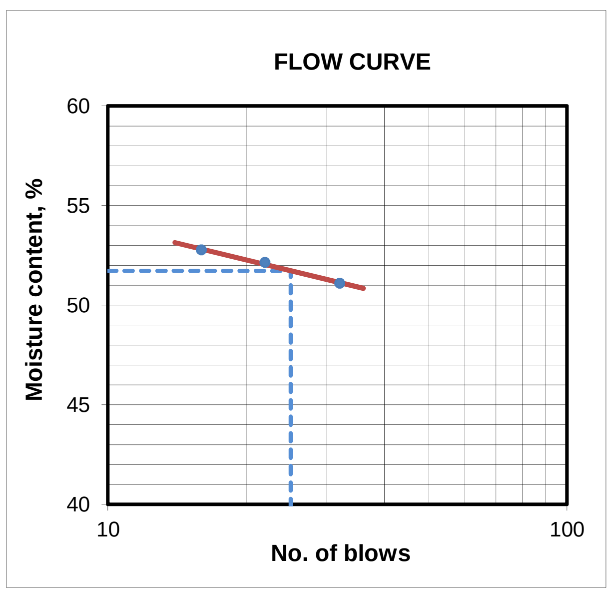
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	22	16			
Container No.		A-14	L	A	AW	AI	
Mass of Container	g	17.8	17.97	17.73	23.41	23.51	
Mass of Wet Soil + Container	g	29.57	31.48	31.25	33.91	34.34	
Mass of Dry Soil + Container	g	25.59	26.85	26.58	31.64	31.95	
Mass of Water in Specimen	g	3.98	4.63	4.67	2.27	2.39	
Mass of Dry Soil	g	7.79	8.88	8.85	8.23	8.44	
Moisture Content	%	51.1	52.1	52.8	27.6	28.3	
					Average PL, %		**27.9**

Initial Mass= 152.7 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0	0	100
№ 40	0	0	100
№ 200	4.58	3	97

LL	PI	AASHTO Soil Class.
52	24	A-7-6 [20]



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Total Addisu Gebeya
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

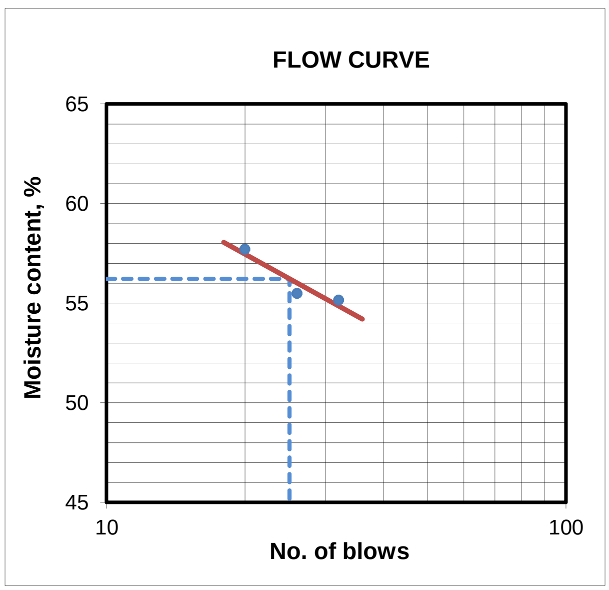
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	26	20			
Container No.		A-3	J	VV	Z-4	AR	
Mass of Container	g	17.68	18.3	7.09	20.18	23.35	
Mass of Wet Soil + Container	g	31.52	33.18	29.50	41.50	44.68	
Mass of Dry Soil + Container	g	26.60	27.87	21.30	36.53	39.85	
Mass of Water in Specimen	g	4.92	5.31	8.20	4.97	4.83	
Mass of Dry Soil	g	8.92	9.57	14.21	16.35	16.50	
Moisture Content	%	55.2	55.5	57.7	30.4	29.3	
						Average PL, %	**29.8**

Initial Mass= 163.8 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0	0	100
№ 40	0	0	100
№ 200	3.28	2	98

LL	PI	AASHTO Soil Class.
56	26	A-7-5 [20]



Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Kechene Hidasie Health Center
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

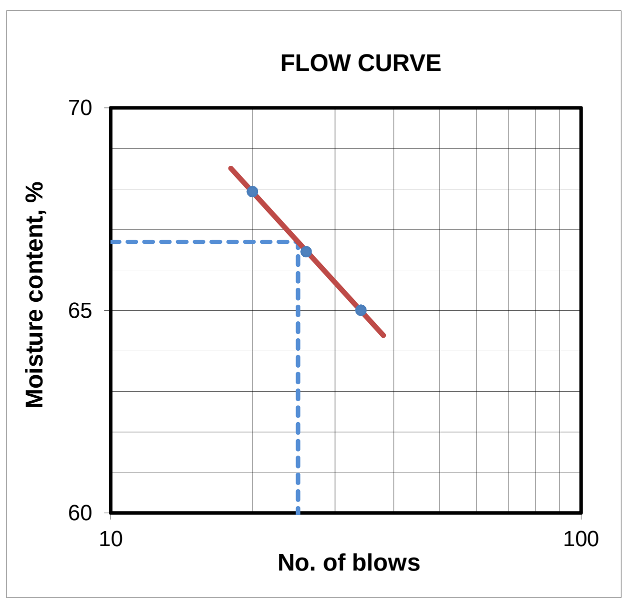
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	26	20			
Container No.		P	A-7	B-1	A-11	B-10	
Mass of Container	g	17.66	17.58	17.72	17.61	17.65	
Mass of Wet Soil + Container	g	33.27	35.79	38.83	32.40	31.84	
Mass of Dry Soil + Container	g	27.12	28.52	30.29	28.43	28.03	
Mass of Water in Specimen	g	6.15	7.27	8.54	3.97	3.81	
Mass of Dry Soil	g	9.46	10.94	12.57	10.82	10.38	
Moisture Content	%	65.0	66.5	67.9	36.7	36.7	
					Average PL, %		**36.7**

Initial Mass= 161 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.23	1	99
№ 40	1.5	1	98
№ 200	3.46	2	96

LL	PI	AASHTO Soil Class.
67	30	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A
Sampled /Tested by: Dagnachew Seifu **Depth:** 1m
Location: Kechene Hidasie Health Center
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

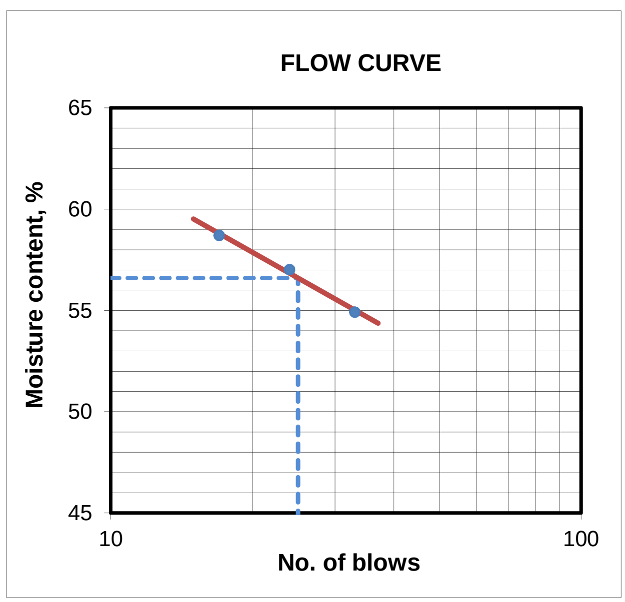
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	24	17			
Container No.		AC	Z-13	AR	AL	AY	
Mass of Container	g	20.08	23.08	23.25	23.43	23.24	
Mass of Wet Soil + Container	g	42.25	49.57	46.20	40.87	40.88	
Mass of Dry Soil + Container	g	34.39	39.95	37.71	36.40	36.45	
Mass of Water in Specimen	g	7.86	9.62	8.49	4.47	4.43	
Mass of Dry Soil	g	14.31	16.87	14.46	12.97	13.21	
Moisture Content	%	54.9	57.0	58.7	34.5	33.5	
					Average PL, %		**34.0**

Initial Mass= 154 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0	0	100
№ 40	0.65	0	100
№ 200	4.27	3	97

LL	PI	AASHTO Soil Class.
57	23	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. A
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Kechene Hidasie Health Center
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

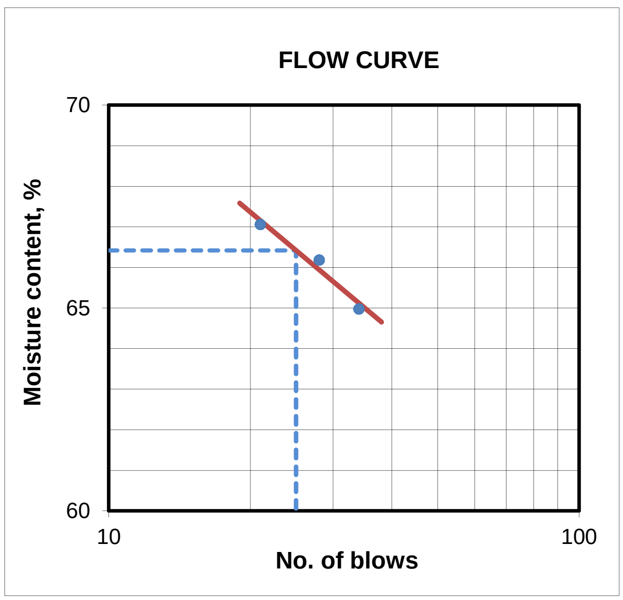
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	28	21			
Container No.		A-15	B-3	R	Z-6	AN	
Mass of Container	g	17.89	17.64	17.73	22.93	20.03	
Mass of Wet Soil + Container	g	34.52	34.79	37.36	33.99	30.14	
Mass of Dry Soil + Container	g	27.97	27.96	29.48	31.08	27.52	
Mass of Water in Specimen	g	6.55	6.83	7.88	2.91	2.62	
Mass of Dry Soil	g	10.08	10.32	11.75	8.15	7.49	
Moisture Content	%	65.0	66.2	67.1	35.7	35.0	
					Average PL, %		**35.3**

Initial Mass= 151 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.27	1	99
№ 40	1.11	1	98
№ 200	2.96	2	96

LL	PI	AASHTO Soil Class.
66	31	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 1m
Location: Kechene Hidasie Health Center
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

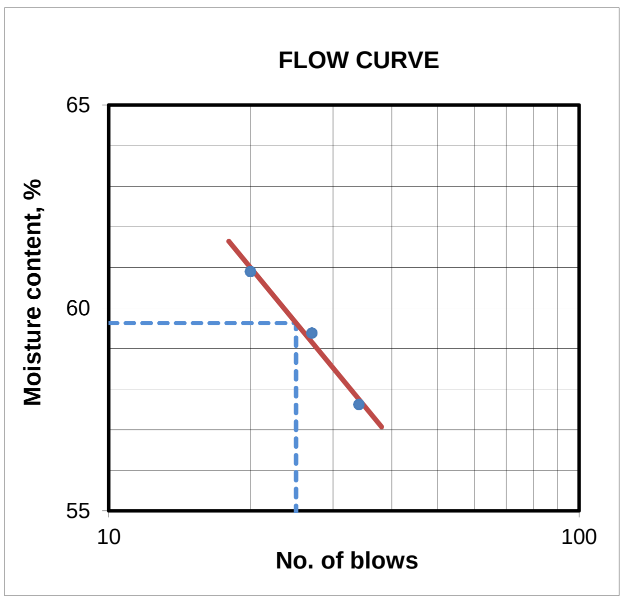
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	27	20			
Container No.		S	A-12	A-20	N	B-4	
Mass of Container	g	17.68	17.71	17.55	17.9	18.12	
Mass of Wet Soil + Container	g	33.60	35.37	35.41	30.70	31.84	
Mass of Dry Soil + Container	g	27.78	28.79	28.65	27.51	28.41	
Mass of Water in Specimen	g	5.82	6.58	6.76	3.19	3.43	
Mass of Dry Soil	g	10.10	11.08	11.10	9.61	10.29	
Moisture Content	%	57.6	59.4	60.9	33.2	33.3	
					Average PL, %		**33.3**

Initial Mass= 149 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0.14	0	100
№ 40	0.89	1	99
№ 200	5.12	3	96

LL	PI	AASHTO Soil Class.
60	27	A-7-5 [20]



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil

Test Pit No. A

Sampled /Tested by: Dagnachew Seifu

Depth: 1m

Location: Kolfe Police training Center

Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

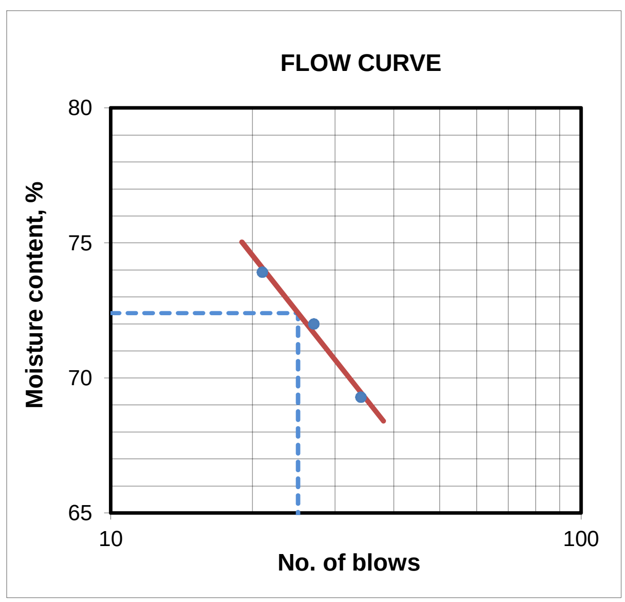
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	27	21			
Container No.		G	A-14	A-17	A-13	A-16	
Mass of Container	g	17.83	17.77	17.7	18.23	17.66	
Mass of Wet Soil + Container	g	35.20	34.73	36.17	36.15	33.98	
Mass of Dry Soil + Container	g	28.09	27.63	28.32	31.07	29.31	
Mass of Water in Specimen	g	7.11	7.10	7.85	5.08	4.67	
Mass of Dry Soil	g	10.26	9.86	10.62	12.84	11.65	
Moisture Content	%	69.3	72.0	73.9	39.6	40.1	
					Average PL, %		**39.8**

Initial Mass= 154 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0.72	0	100
№ 40	1.36	1	99
№ 200	3.9	3	96

LL	PI	AASHTO Soil Class.
72	32	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 1m
Location: Kolfe Police training Center
Terrazyme application: Non

ATTERBERG LIMITS AND SOIL CLASSIFICATION

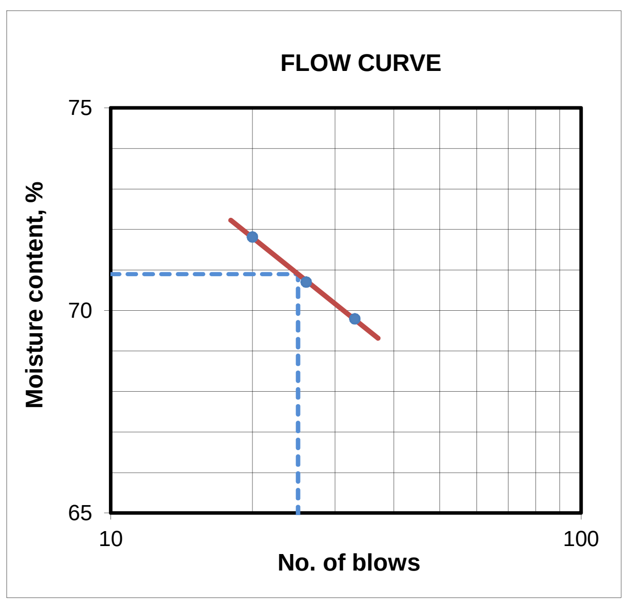
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	20			
Container No.		A	L	A9	AH	AW	
Mass of Container	g	17.7	17.92	17.91	20.32	23.28	
Mass of Wet Soil + Container	g	35.24	34.82	37.48	32.07	35.93	
Mass of Dry Soil + Container	g	28.03	27.82	29.30	28.99	32.61	
Mass of Water in Specimen	g	7.21	7.00	8.18	3.08	3.32	
Mass of Dry Soil	g	10.33	9.90	11.39	8.67	9.33	
Moisture Content	%	69.8	70.7	71.8	35.5	35.6	
					Average PL, %		**35.6**

Initial Mass= 154 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0.69	0	100
№ 40	1.24	1	99
№ 200	3.52	2	96

LL	PI	AASHTO Soil Class.
71	35	A-7-5 [20]



	Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering	

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A

Sampled /Tested by: Dagnachew Seifu **Depth:** 2m

Location: Kolfe Police training Center

Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

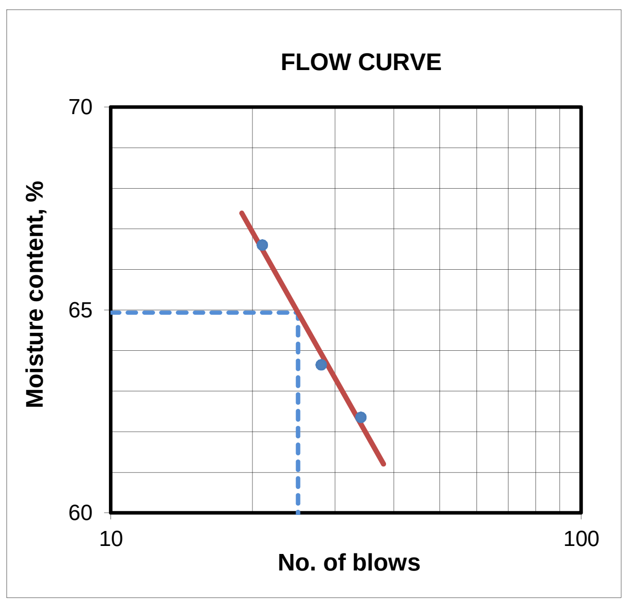
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	28	21			
Container No.		B6	AY	T	AM	Y-3	
Mass of Container	g	17.63	18.05	17.52	20.47	23.15	
Mass of Wet Soil + Container	g	33.59	36.33	35.88	38.61	38.77	
Mass of Dry Soil + Container	g	27.46	29.22	28.54	33.82	34.65	
Mass of Water in Specimen	g	6.13	7.11	7.34	4.79	4.12	
Mass of Dry Soil	g	9.83	11.17	11.02	13.35	11.50	
Moisture Content	%	62.4	63.7	66.6	35.9	35.8	
					Average PL, %		**35.9**

Initial Mass= 158 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.92	1	99
№ 40	5.44	3	95
№ 200	10.6	7	89

LL	PI	AASHTO Soil Class.
65	29	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Kolfe Police training Center
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

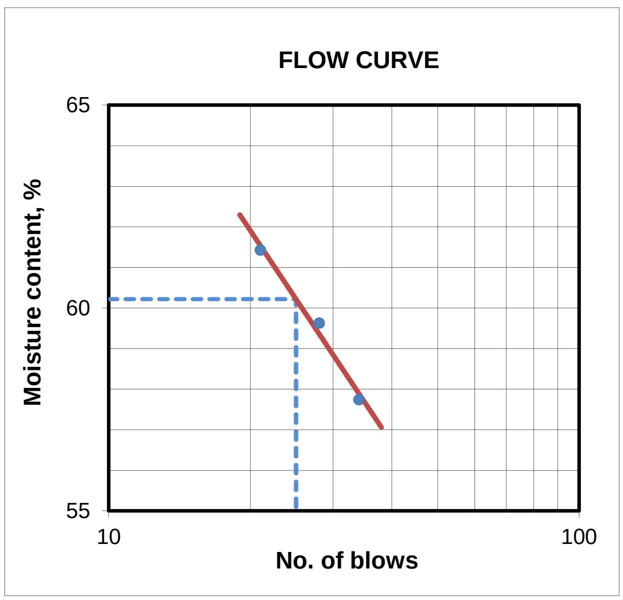
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	28	21			
Container No.		Z-15	Z-12	Y8	CC	AT	
Mass of Container	g	23.45	20.36	22.97	12.95	12.9	
Mass of Wet Soil + Container	g	42.30	35.11	42.60	24.39	23.56	
Mass of Dry Soil + Container	g	35.40	29.60	35.13	21.60	20.95	
Mass of Water in Specimen	g	6.90	5.51	7.47	2.79	2.61	
Mass of Dry Soil	g	11.95	9.24	12.16	8.65	8.05	
Moisture Content	%	57.7	59.6	61.4	32.3	32.4	
					Average PL, %		**32.3**

Initial Mass= 152 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.27	1	99
№ 40	5.92	4	95
№ 200	11.25	7	88

LL	PI	AASHTO Soil Class.
60	28	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. A
Sampled /Tested by: Dagnachew Seifu
Depth: 1m
Location: Semen Gebeya
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

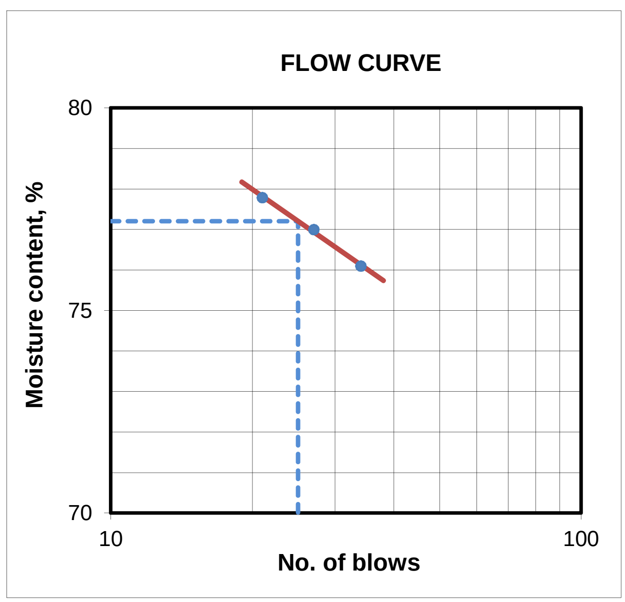
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	27	21			
Container No.		A-19	A5	B-5	AG	Y-9	
Mass of Container	g	17.9	17.55	17.75	23.38	23.38	
Mass of Wet Soil + Container	g	36.39	33.48	36.24	35.12	33.77	
Mass of Dry Soil + Container	g	28.40	26.55	28.15	31.85	30.84	
Mass of Water in Specimen	g	7.99	6.93	8.09	3.27	2.93	
Mass of Dry Soil	g	10.50	9.00	10.40	8.47	7.46	
Moisture Content	%	76.1	77.0	77.8	38.6	39.3	
					Average PL, %		**38.9**

Initial Mass= 153 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0.58	0	100
№ 40	0.75	0	99
№ 200	2.42	2	98

LL	PI	AASHTO Soil Class.
77	38	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** B

Sampled /Tested by: Dagnachew Seifu **Depth:** 1m

Location: Semen Gebeya

Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

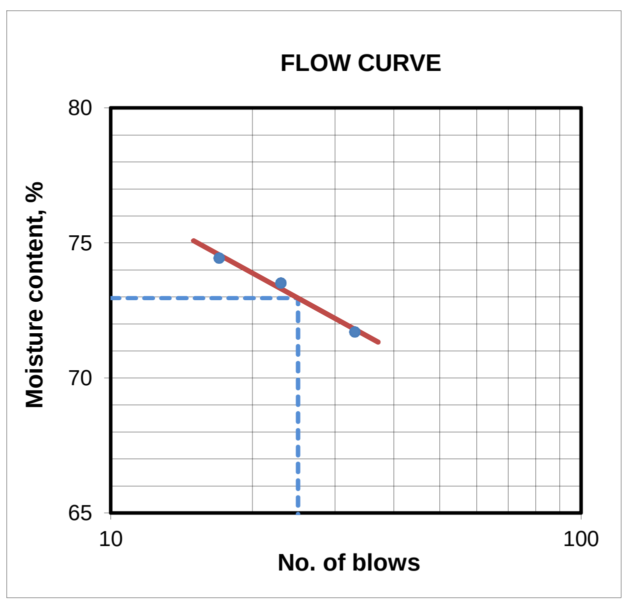
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	23	17			
Container No.		Y-2	Y-5	AU	O	B-9	
Mass of Container	g	23.11	23.25	20.38	17.68	17.75	
Mass of Wet Soil + Container	g	45.93	44.94	40.65	28.66	31.1	
Mass of Dry Soil + Container	g	36.40	35.75	32.00	25.46	27.14	
Mass of Water in Specimen	g	9.53	9.19	8.65	3.20	3.96	
Mass of Dry Soil	g	13.29	12.50	11.62	7.78	9.39	
Moisture Content	%	71.7	73.5	74.4	41.1	42.2	
					Average PL, %		**41.7**

Initial Mass= 155 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0.44	0	100
№ 40	0.68	0	99
№ 200	2.24	1	98

LL	PI	AASHTO Soil Class.
73	31	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Semen Gebeya
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

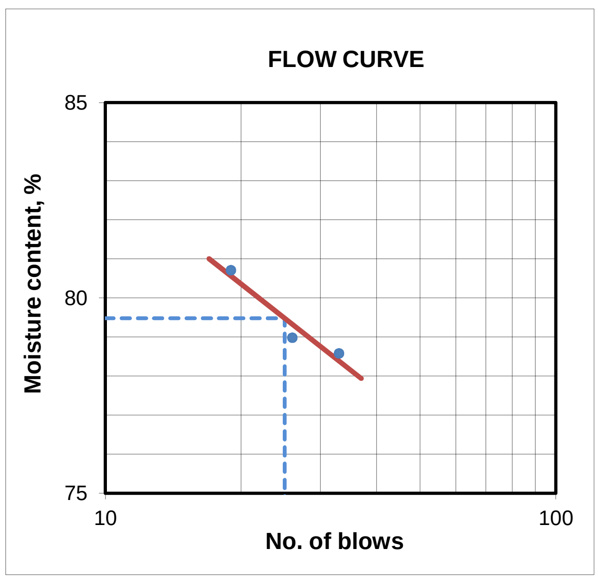
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	19			
Container No.		P	B-10	N	AF	AC	
Mass of Container	g	17.69	17.69	17.96	23.57	20.25	
Mass of Wet Soil + Container	g	28.78	29.7	37.82	29.02	27.63	
Mass of Dry Soil + Container	g	23.90	24.40	28.95	27.52	25.53	
Mass of Water in Specimen	g	4.88	5.30	8.87	1.50	2.10	
Mass of Dry Soil	g	6.21	6.71	10.99	3.95	5.28	
Moisture Content	%	78.6	79.0	80.7	38.0	39.8	
					Average PL, %		**38.9**

Initial Mass= 174.6 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	3.00	2	98
№ 40	2.24	1	97
№ 200	5.24	3	94

LL	PI	AASHTO Soil Class.
79	40	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. A
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Semen Gebeya
Terrazyme application: **Non**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

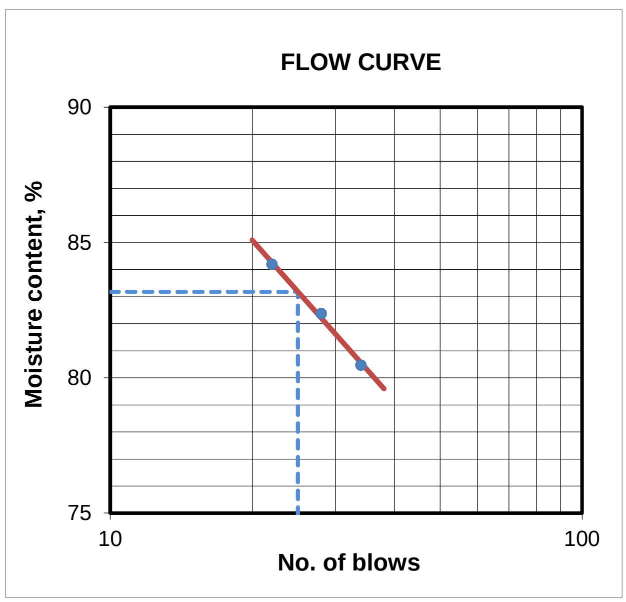
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	28	22			
Container No.		Y-7	Z-11	Y-6	F	A-2	
Mass of Container	g	23.12	23.48	23.44	17.56	17.81	
Mass of Wet Soil + Container	g	37.99	40.97	41.97	31.47	28.92	
Mass of Dry Soil + Container	g	31.36	33.07	33.50	27.32	25.63	
Mass of Water in Specimen	g	6.63	7.90	8.47	4.15	3.29	
Mass of Dry Soil	g	8.24	9.59	10.06	9.76	7.82	
Moisture Content	%	80.5	82.4	84.2	42.5	42.1	
					Average PL, %		**42.3**

Initial Mass= 157 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	3.24	2	98
№ 40	2.73	2	96
№ 200	3.23	2	94

LL	PI	AASHTO Soil Class.
83	41	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil **Test Pit No.:** B

Sampled/Tested by: Dagnachew Seifu **Depth:** 1m

Location: Total Addisu Gebeya

Terazayem Application: Non

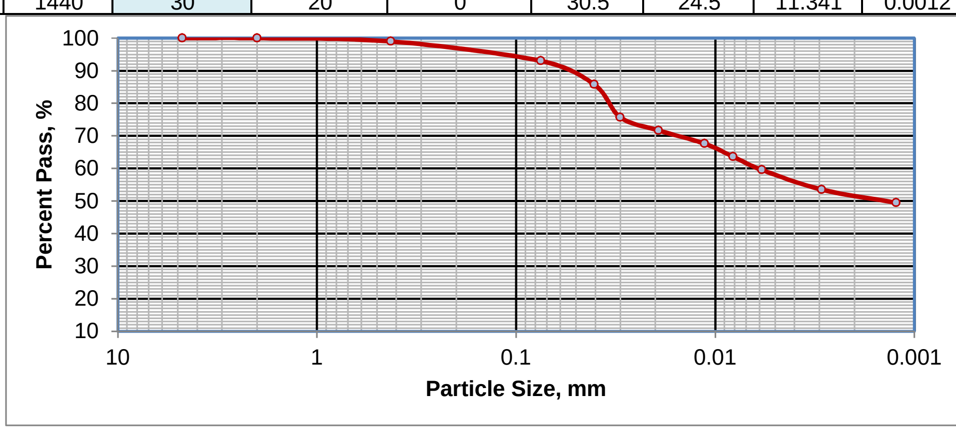
PARTICLE SIZE ANALYSIS (HYROMETER METHOD)

TEST METHOD: AASHTO T 88

Hyrometer No.	152H, 115
Sedimentation cylinder No.	1
Meniscus correction, C_m	0.5
Despersing agent correction, C_d	6
Volume of Bulb, cc	55.3

Percent of soil passing 2mm sieve	100	%
Specific gravity of the soil, G_s	2.61	
Mass of wet soil in suspention	50	g
Initial moisture content	0	%
Dry mass in suspension, M_o	50	g

Date	Time	Time Elapsed in min	Hydrometer Reading	Temprature	Temprature Correction	Corrected Hyrometer Reading		Effective Depth	Grain Size in mm	Percent by Weight Finer	Adjusted Percent Finer
		t	R	T^0C	C_t	R'	R"	L	D	P	%
9/17/2019	10:15AM	1	48	20	0	48.5	42.5	8.497	0.0405	86	86
9/17/2019		2	43	20	0	43.5	37.5	9.287	0.0300	76	76
9/17/2019		5	41	20	0	41.5	35.5	9.603	0.0193	72	72
9/17/2019		15	39	20	0	39.5	33.5	9.919	0.0113	68	68
9/17/2019		30	37	20	0	37.5	31.5	10.235	0.0081	64	64
9/17/2019		60	35	20	0	35.5	29.5	10.551	0.0058	60	60
9/17/2019		250	32	20	0	32.5	26.5	11.025	0.0029	53	53
9/18/2019		1440	30	20	0	30.5	24.5	11.341	0.0012	49	49



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil **Test Pit No.:** A

Sampled/Tested by: Dagnachew Seifu **Depth:** 1m

Location: Semen Gebeya

Terazayem Application: Non

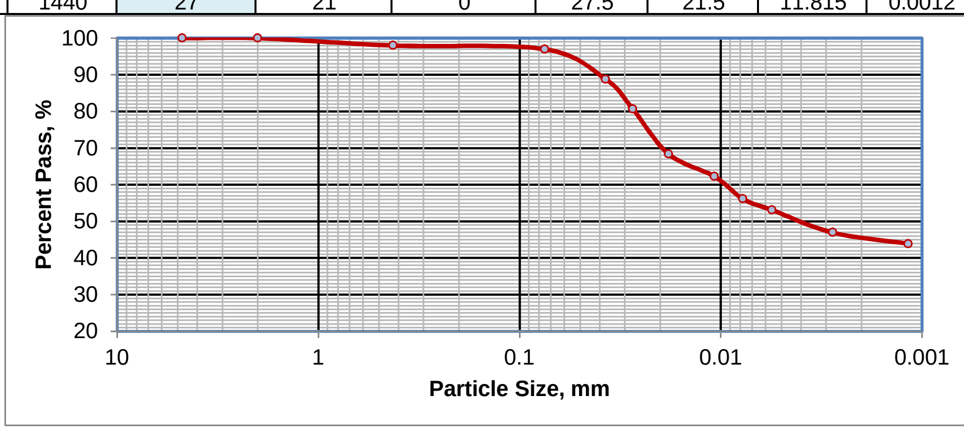
PARTICLE SIZE ANALYSIS (HYROMETER METHOD)

TEST METHOD: AASHTO T 88

Hyrometer No.	152H, 115
Sedimentation cylinder No.	1
Meniscus correction, C_m	0.5
Despersing agent correction, C_d	6
Volume of Bulb, cc	55.3

Percent of soil passing 2mm sieve	100	%
Specific gravity of the soil, G_s	2.57	
Mass of wet soil in suspention	50	g
Initial moisture content	0	%
Dry mass in suspension, M_o	50	g

Date	Time	Time Elapsed in min	Hydrometer Reading	Temprature	Temprature Correction	Corrected Hyrometer Reading		Effective Depth	Grain Size in mm	Percent by Weight Finer	Adjusted Percent Finer
		t	R	T^0C	C_t	R'	R"	L	D	P	%
9/17/2019	0.49861	1	49	21.5	0	49.5	43.5	8.339	0.0373	89	89
9/17/2019		2	45	21.5	0	45.5	39.5	8.971	0.0273	81	81
9/17/2019		5	39	21.5	0	39.5	33.5	9.919	0.0182	68	68
9/17/2019		15	36	21.5	0	36.5	30.5	10.393	0.0107	62	62
9/17/2019		30	33	21.5	0	33.5	27.5	10.867	0.0078	56	56
9/17/2019		60	31.5	21.5	0	32	26	11.104	0.0056	53	53
9/17/2019		250	28.5	22.5	0	29	23	11.578	0.0028	47	47
9/18/2019		1440	27	21	0	27.5	21.5	11.815	0.0012	44	44



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	**C**
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	**2m**
Location:	Kolfe Police training Center		
Terazayem Application:	Non		

PARTICLE SIZE ANALYSIS (HYROMETER METHOD)

TEST METHOD: AASHTO T 88

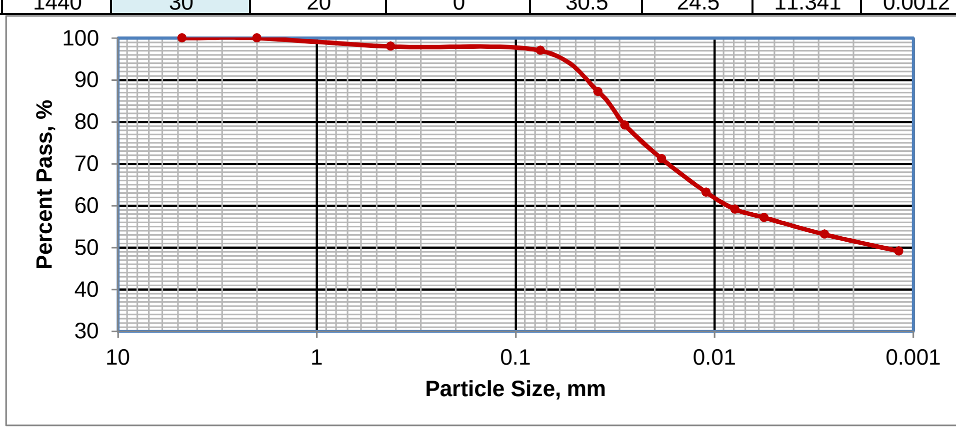
Kolfe Police Training Center

T.P= C Depth= 2m

Hyrometer No.	152H, 115
Sedimentation cylinder No.	1
Meniscus correction, C_m	0.5
Despersing agent correction, C_d	6
Volume of Bulb, cc	55.3

Percent of soil passing 2mm sieve	100	%
Specific gravity of the soil, G_s	2.64	
Mass of wet soil in suspention	50	g
Initial moisture content	0	%
Dry mass in suspension, M_o	50	g

Date	Time	Time Elapsed in min	Hydrometer Reading	Temprature	Temprature Correction	Corrected Hyrometer Reading		Effective Depth	Grain Size in mm	Percent by Weight Finer	Adjusted Percent Finer
		t	R	T^0C	C_t	R'	R"	L	D	P	%
9/17/2019	10:15AM	1	49	20	0	49.5	43.5	8.339	0.0384	87	87
9/17/2019		2	45	20	0	45.5	39.5	8.971	0.0281	79	79
9/17/2019		5	41	20	0	41.5	35.5	9.603	0.0184	71	71
9/17/2019		15	37	20	0	37.5	31.5	10.235	0.0110	63	63
9/17/2019		30	35	20	0	35.5	29.5	10.551	0.0079	59	59
9/17/2019		60	34	20	0	34.5	28.5	10.709	0.0056	57	57
9/17/2019		250	32	20	0	32.5	26.5	11.025	0.0028	53	53
9/18/2019		1440	30	20	0	30.5	24.5	11.341	0.0012	49	49



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

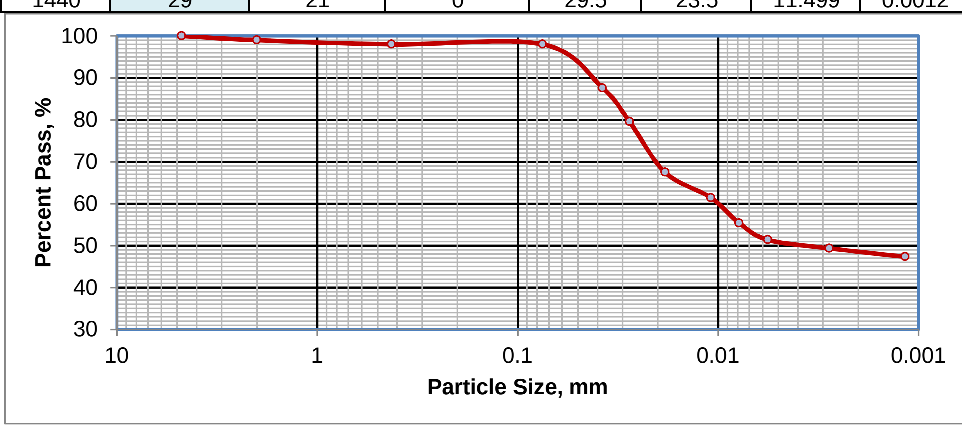
Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	**C**
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	**2m**
Location:	Kechene Hidasie Health Center		
Terazayem Application:	Non		

PARTICLE SIZE ANALYSIS (HYROMETER METHOD)
TEST METHOD: AASHTO T 88

Hyrometer No.	152H, 115
Sedimentation cylinder No.	1
Meniscus correction, C_m	0.5
Despersing agent correction, C_d	6
Volume of Bulb, cc	55.3

Percent of soil passing 2mm sieve	100	%
Specific gravity of the soil, G_s	2.62	
Mass of wet soil in suspention	50	g
Initial moisture content	0	%
Dry mass in suspension, M_o	50	g

Date	Time	Time Elapsed in min	Hydrometer Reading	Temprature	Temprature Correction	Corrected Hyrometer Reading		Effective Depth	Grain Size in mm	Percent by Weight Finer	Adjusted Percent Finer
		t	R	T^0C	C_t	R'	R"	L	D	P	%
9/17/2019	11:58 AM	1	49	21.5	0	49.5	43.5	8.339	0.0377	88	88
9/17/2019		2	45	21.5	0	45.5	39.5	8.971	0.0277	80	80
9/17/2019		5	39	21.5	0	39.5	33.5	9.919	0.0184	67	67
9/17/2019		15	36	21.5	0	36.5	30.5	10.393	0.0109	61	61
9/17/2019		30	33	21.5	0	33.5	27.5	10.867	0.0079	55	55
9/17/2019		60	31	21.5	0	31.5	25.5	11.183	0.0056	51	51
9/17/2019		250	30	22.5	0	30.5	24.5	11.341	0.0028	49	49
9/18/2019		1440	29	21	0	29.5	23.5	11.499	0.0012	47	47



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

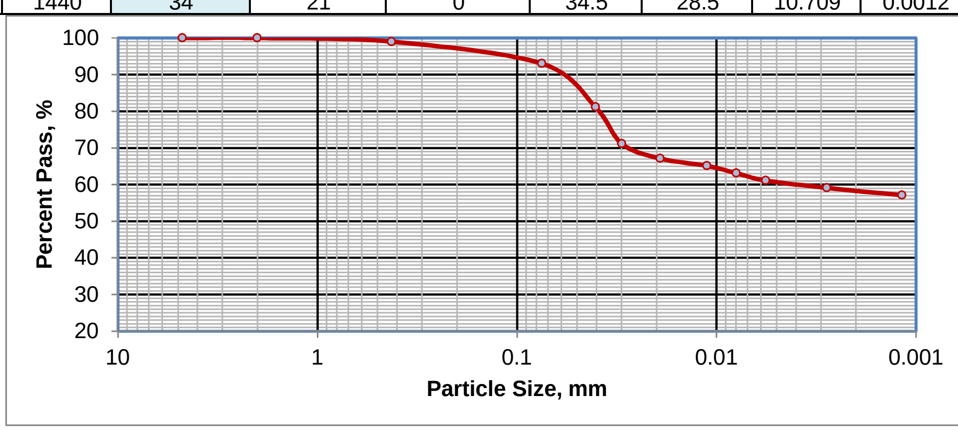
Titel: Chemical Stabilization Of Red Clay Soil — **Test Pit No.:** C
Sampled/Tested by: Dagnachew Seifu — **Depth:** 2m
Location: Intoto Technical and Vocational poly technique college
Terazayem Application: Non

PARTICLE SIZE ANALYSIS (HYROMETER METHOD)
TEST METHOD: AASHTO T 88

Hyrometer No.	152H, 115
Sedimentation cylinder No.	1
Meniscus correction, C_m	0.5
Despersing agent correction, C_d	6
Volume of Bulb, cc	55.3

Percent of soil passing 2mm sieve	99	%
Specific gravity of the soil, G_s	2.60	
Mass of wet soil in suspention	50	g
Initial moisture content	0	%
Dry mass in suspension, M_o	50	g

Date	Time	Time Elapsed in min	Hydrometer Reading	Temprature	Temprature Correction	Corrected Hyrometer Reading		Effective Depth	Grain Size in mm	Percent by Weight Finer	Adjusted Percent Finer
		t	R	T^0C	C_t	R'	R"	L	D	P	%
9/17/2019	10:15AM	1	46	20	0	46.5	40.5	8.813	0.0404	82	81
9/17/2019		2	41	20	0	41.5	35.5	9.603	0.0298	72	71
9/17/2019		5	39	21	0	39.5	33.5	9.919	0.0192	68	67
9/17/2019		15	38	21	0	38.5	32.5	10.077	0.0112	66	65
9/17/2019		30	37	21	0	37.5	31.5	10.235	0.0079	64	63
9/17/2019		60	36	22	0	36.5	30.5	10.393	0.0057	62	61
9/17/2019		250	35	23	0	35.5	29.5	10.551	0.0028	60	59
9/18/2019		1440	34	21	0	34.5	28.5	10.709	0.0012	58	57



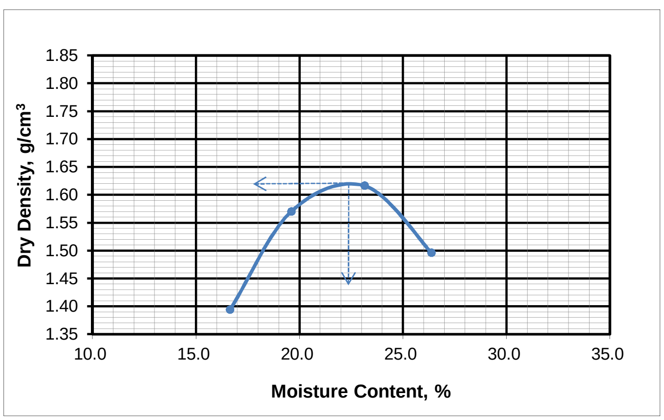
ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil
Test Pit No.: C
Sampled/Tested by: Dagnachew Seifu
Depth: 2m
Location: Total Addisu Gebeya
Terazayem Application: Non

TEST METHOD:AASHTO T 180

			1	2	3	4	
Bulk Density	Mass of Mould + Soil	g	4850	5088	5194	5100	
	Mass of Mould	g	3315	3315	3315	3315	
	Mass of Wet Soil	g	1535	1773	1879	1785	
	Volume of Mould	cm^3	944	944	944	944	
	Bulk Density	g/cm^3	1.626	1.878	1.990	1.891	
Moisture Content	Container No.		46	90	A15	40	0
	Mass of Container	g	44.4	44.3	43.1	44.1	45.7
	Mass of Container + Wet Soil	g	176.8	190.7	212.8	219.0	180.3
	Mass of Container + Dry Soil	g	157.9	166.7	180.9	182.5	164.7
	Moisture Content	%	16.7	19.6	23.1	26.4	13.1
	Dry Density	g/cm^3	1.39	1.57	1.62	1.50	



Maximum Dry Density= 1.62 g/cm^3
Optimum Moisture Content= 22.5 %

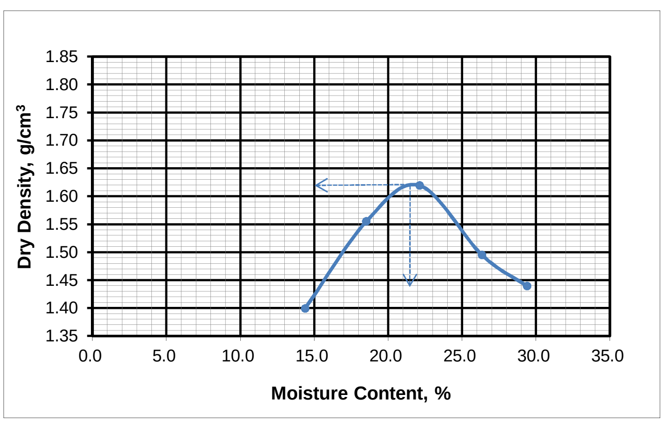
Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Intoto Technical and Vocational poly technique college		
Terazayem Application:	Stabilized		

TEST METHOD:AASHTO T 180

			1	2	3	4	
Bulk Density	Mass of Mould + Soil	g	4823	5052	5179	5095	5070
	Mass of Mould	g	3312	3312	3312	3312	3312
	Mass of Wet Soil	g	1511	1740	1867	1783	1758
	Volume of Mould	cm^3	944	944	944	944	944
	Bulk Density	g/cm^3	1.601	1.843	1.978	1.889	1.862
Moisture Content	Container No.		OH	38	51	36	34
	Mass of Container	g	44.5	43.4	43.6	42	44.1
	Mass of Container + Wet Soil	g	222.6	285.2	247.3	218.5	291.9
	Mass of Container + Dry Soil	g	200.2	247.4	210.4	181.7	235.6
	Moisture Content	%	14.4	18.5	22.1	26.3	29.4
	Dry Density	g/cm^3	1.40	1.56	1.62	1.49	1.44



Maximum Dry Density= 1.61 g/cm^3
Optimum Moisture Content= 21.5 %

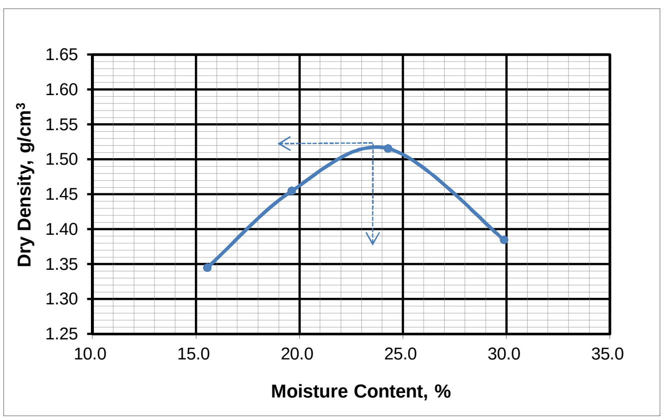
ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil
Test Pit No.: C
Sampled/Tested by: Dagnachew Seifu
Depth: 2m
Location: Kechene Hidasie Health Center
Terazayem Application: Non

TEST METHOD:AASHTO T 180

			1	2	3	4	
Bulk Density	Mass of Mould + Soil	g	4779	4955	5090	5010	
	Mass of Mould	g	3312	3312	3312	3312	
	Mass of Wet Soil	g	1467	1643	1778	1698	
	Volume of Mould	cm^3	944	944	944	944	
	Bulk Density	g/cm^3	1.554	1.740	1.883	1.799	
Moisture Content	Container No.		KN	17	77	98	1
	Mass of Container	g	45.9	42.4	43.2	44	42.8
	Mass of Container + Wet Soil	g	243.6	165.5	231.6	215.7	234.4
	Mass of Container + Dry Soil	g	217.0	145.3	194.8	176.2	212.6
	Moisture Content	%	15.5	19.6	24.3	29.9	12.8
	Dry Density	g/cm^3	1.34	1.45	1.52	1.38	



Maximum Dry Density= 1.52 g/cm^3
Optimum Moisture Content= 23.5 %

Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

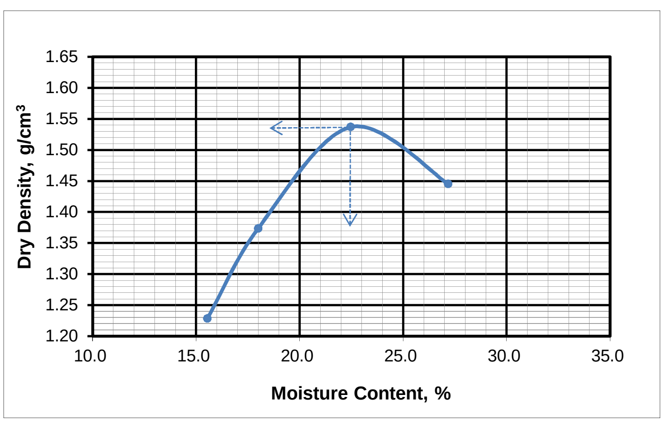
Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil
Sampled/Tested by: Dagnachew Seifu
Location: Semen Gebeya
Terazayem Application: Non

Test Pit No.: C
Depth: 2m

TEST METHOD:AASHTO T 180

			1	2	3	4	
	Mass of Mould + Soil	g	4655	4845	5092	5050	
	Mass of Mould	g	3315	3315	3315	3315	
	Mass of Wet Soil	g	1340	1530	1777	1735	
	Volume of Mould	cm^3	944	944	944	944	
	Bulk Density	g/cm^3	1.419	1.621	1.882	1.838	
Moisture Content	Container No.		KN	21.A	82	28	778
	Mass of Container	g	45.9	43.7	44.2	42.2	43.8
	Mass of Container + Wet Soil	g	243.6	216.1	198.4	218.6	291.5
	Mass of Container + Dry Soil	g	217.0	189.8	170.1	180.9	260.9
	Moisture Content	%	15.5	18.0	22.5	27.2	14.1
	Dry Density	g/cm^3	1.23	1.37	1.54	1.45	



Maximum Dry Density= 1.54 g/cm^3
Optimum Moisture Content= 22.5 %

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil **Test Pit No.:** C
Sampled/Tested by: Dagnachew Seifu **Depth:** 2m
Location: Total Addisu Gebeya
Terazayem Application: Stabilized

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		F1	
Mass of Mould	g	6222	
Mass of Mould + Soil	g	10493	
Mass of Soil	g	4271	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	2.011	
Dry Density	g/cm^3	1.65	-

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	4.54kg
Days Soaked	4

Rammer	4.54kg
Layer	5
Volume,cm^3	2124
Height,mm	116.43
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

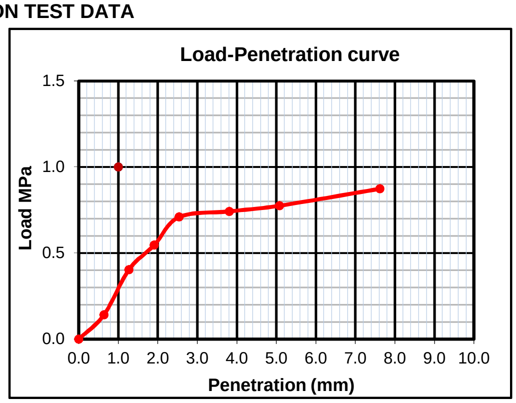
MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		26	
Mass of Container	g	43.2	
Mass of Container + Wet Soil	g	263.8	
Mass of Container + Dry Soil	g	224	
Moisture Content	%	22.01	

SWELL

Number of Blows	56
Reading Before Soaking, mm	3.49
Reading After Soaking, mm	7.61
Percent Swell	3.54

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	13	0.14		
1.27	37	0.40		
1.91	50	0.55		
2.54	65	0.71	0.7	10.3
3.81	68	0.74		
5.08	71	0.78	0.8	7.5
7.62	80	0.87		
10.16				
12.7				



CBR at 100% Standard Compaction= **10** % Corresponding Swell= **3.54** %

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Kechene Hidasie Health Center		
Terazayem Application:	Non		

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		RE	
Mass of Mould	g	6168	
Mass of Mould + Soil	g	10154	10419
Mass of Soil	g	3986	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.877	
Dry Density	g/cm^3	1.54	-

SOAKING CONDITION

Unsoaked	
Soaked	**v**
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

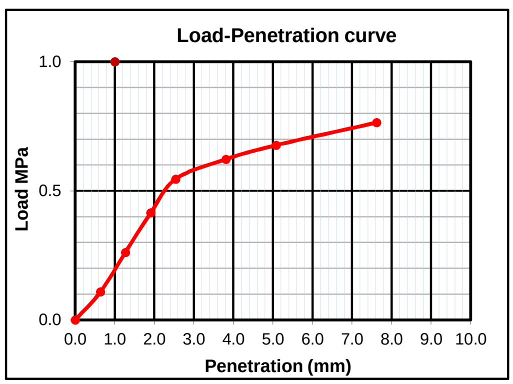
MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		52	
Mass of Container	g	45.7	
Mass of Container + Wet Soil	g	192.1	
Mass of Container + Dry Soil	g	165.7	
Moisture Content	%	22.00	

SWELL

Number of Blows	56
Reading Before Soaking, mm	2.73
Reading After Soaking, mm	6.52
Percent Swell	3.26

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	10	0.11		
1.27	24	0.26		
1.91	38	0.41		
2.54	50	0.55	0.5	7.9
3.81	57	0.62		
5.08	62	0.68	0.7	6.6
7.62	70	0.76		
10.16				
12.7				



CBR at 100% Standard Compaction= **7** %   Corresponding Swell= **3.26** %

Tested By	**Checked By**	**Approved By**
Lab. Technician	**Material Engineer**	**General Manager**

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil — **Test Pit No.:** C
Sampled/Tested by: Dagnachew Seifu — **Depth:** 2m
Location: Kolfe Police training Center
Terazayem Application: Non

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		C-2	
Mass of Mould	g	6227	
Mass of Mould + Soil	g	10413	
Mass of Soil	g	4186	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.971	
Dry Density	g/cm^3	1.62	

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		B-17	
Mass of Container	g	56	
Mass of Container + Wet Soil	g	311.8	
Mass of Container + Dry Soil	g	266	
Moisture Content	%	21.81	

SWELL

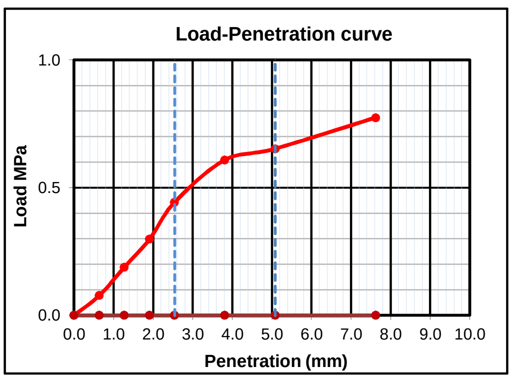
Number of Blows	56
Reading Before Soaking, mm	0.09
Reading After Soaking, mm	5.42
Percent Swell	4.58

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.4 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	7	0.08		
1.27	17	0.19		
1.91	27	0.30		
2.54	40	0.44	0.4	6.4
3.81	55	0.61		
5.08	59	0.65	0.7	6.3
7.62	70	0.77		
10.16				
12.7				



CBR at 100% Standard Compaction= **6** %   Corresponding Swell= **4.58** %

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil **Test Pit No.:** C
Sampled/Tested by: Dagnachew Seifu **Depth:** 2m
Location: Semen Gebeya
Terazayem Application: Non

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		JQ	
Mass of Mould	g	6519	
Mass of Mould + Soil	g	10459	10702
Mass of Soil	g	3940	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.855	
Dry Density	g/cm^3	1.52	-

SOAKING CONDITION

Unsoaked	
Soaked	**v**
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		48	
Mass of Container	g	45.1	
Mass of Container + Wet Soil	g	240.8	
Mass of Container + Dry Soil	g	205.1	
Moisture Content	%	22.31	

SWELL

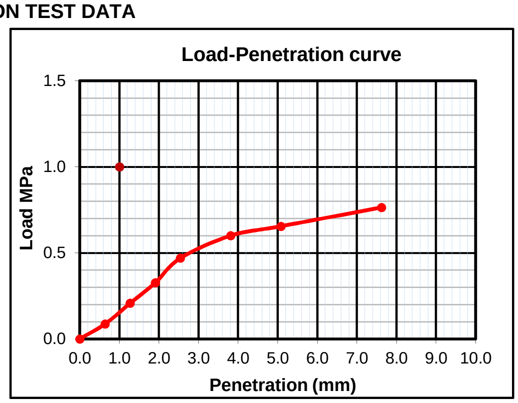
Number of Blows	56
Reading Before Soaking, mm	3.63
Reading After Soaking, mm	8.54
Percent Swell	4.22

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	8	0.09		
1.27	19	0.21		
1.91	30	0.33		
2.54	43	0.47	0.5	6.8
3.81	55	0.60		
5.08	60	0.66	0.7	6.4
7.62	70	0.76		
10.16				
12.7				



CBR at 100% Standard Compaction= **7** %   Corresponding Swell= **4.22** %

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Total Addisu Gebeya		
Terazayem Application:	Non		

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		F1	
Mass of Mould	g	6222	
Mass of Mould + Soil	g	10493	
Mass of Soil	g	4271	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	2.011	
Dry Density	g/cm^3	1.65	-

SOAKING CONDITION

Unsoaked	
Soaked	**v**
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		26	
Mass of Container	g	43.2	
Mass of Container + Wet Soil	g	263.8	
Mass of Container + Dry Soil	g	224	
Moisture Content	%	22.01	

SWELL

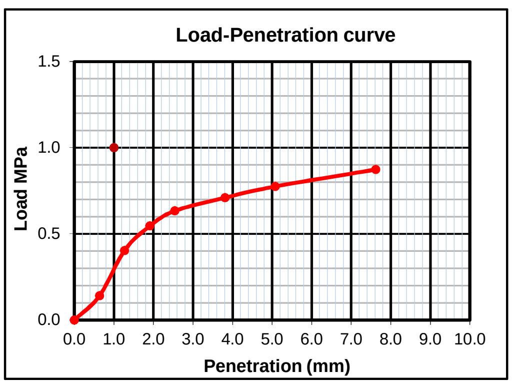
Number of Blows	56
Reading Before Soaking, mm	3.49
Reading After Soaking, mm	6.8
Percent Swell	2.84

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	13	0.14		
1.27	37	0.40		
1.91	50	0.55		
2.54	58	0.63	0.6	9.2
3.81	65	0.71		
5.08	71	0.78	0.8	7.5
7.62	80	0.87		
10.16				
12.7				



CBR at 100% Standard Compaction= **9** %

Corresponding Swell= **2.84** %

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A
Sampled /Tested Dagnachew Seifu **Depth:** 2m
Location: Total Addisu Gebeya
Terrazyme applicat **Non** **Date :**

Unconfined Compressive Strength of Soils

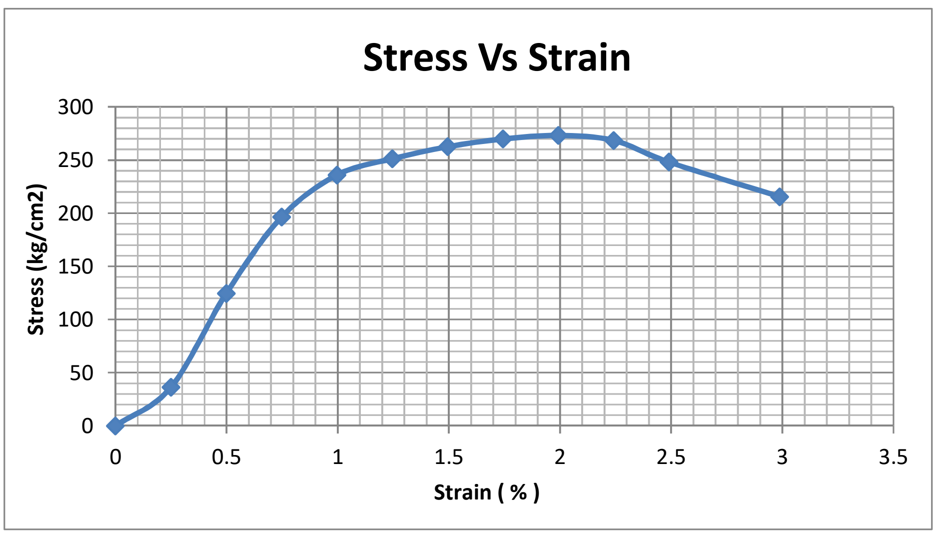
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3)	208.4

Curing Time :-	Non

Moisture Content (%):-	22.81
Bulk Unit Weight (g/cm^3):-	1.99

qu = **251.14 Pa**
C = qu/2 = **125.57 Pa**
Strain at failure = **2.24 (%)**



	ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING	

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. C
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Kechene Hidasie Health Center
Terrazyme application: **Non**
Date :

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

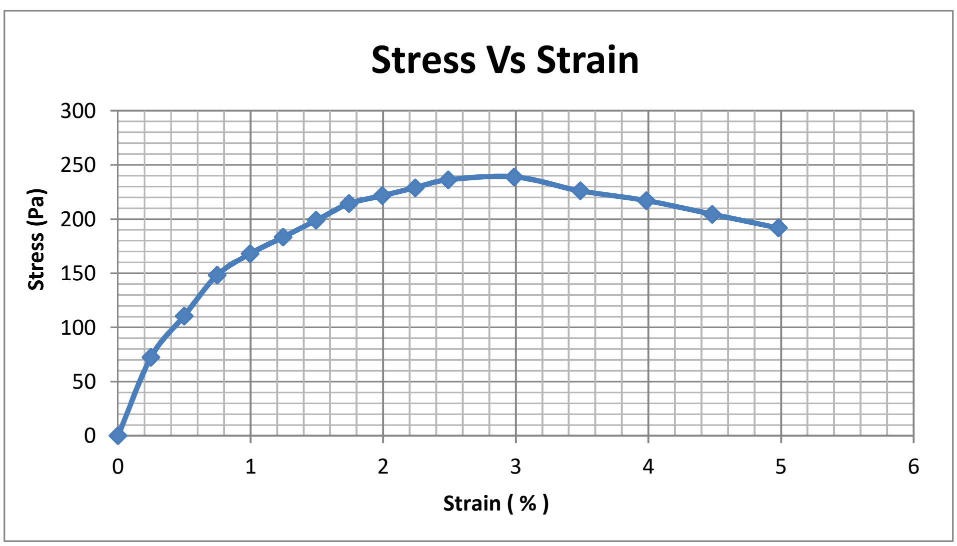
Curing Time :-	Non

Moisture Content (%):-	23.75
Bulk Unit Weight (g/cm^3):-	1.88

qu = 239.00 kg/cm^2

C = qu/2 = 119.50 kg/cm^2

Strain at failure = 2.98 (%)



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Kolfe Police training Center
Terrazyme application: **Non**

Test Pit No. C
Depth: 2m
Date :

Unconfined Compressive Strength of Soils

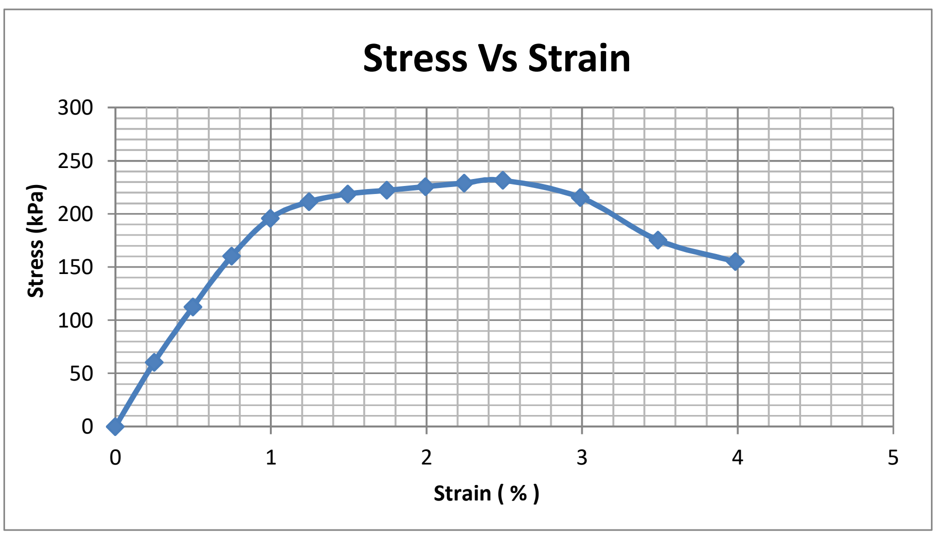
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	Non

Moisture Content (%):-	20.38
Bulk Unit Weight (g/cm^3):-	1.82

qu = **231.53 kPa**
C = qu/2 = **115.77 kPa**
Strain at failure = **2.49 (%)**



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Semen Gebeya
Terrazyme application: **Non**

Test Pit No. B
Depth: 2m
Date :

Unconfined Compressive Strength of Soils

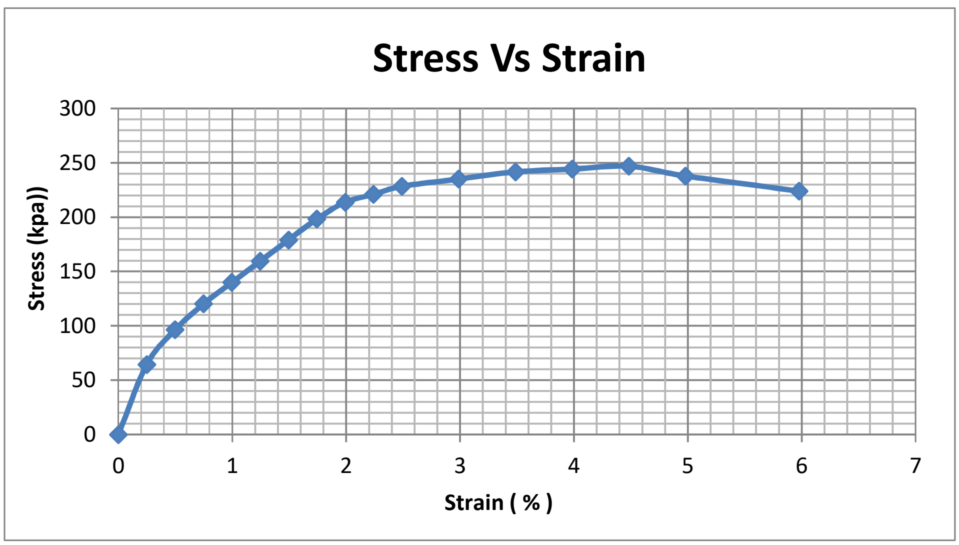
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	Non

Moisture Content (%):-	23.10
Bulk Unit Weight (g/cm^3):-	1.96

qu = **247 kpa**
C = qu/2 = **123 kpa**
Strain at failure = **4.48 (%)**



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Intoto Technical and Vocational poly technique college
Terrazyme application: **Non**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

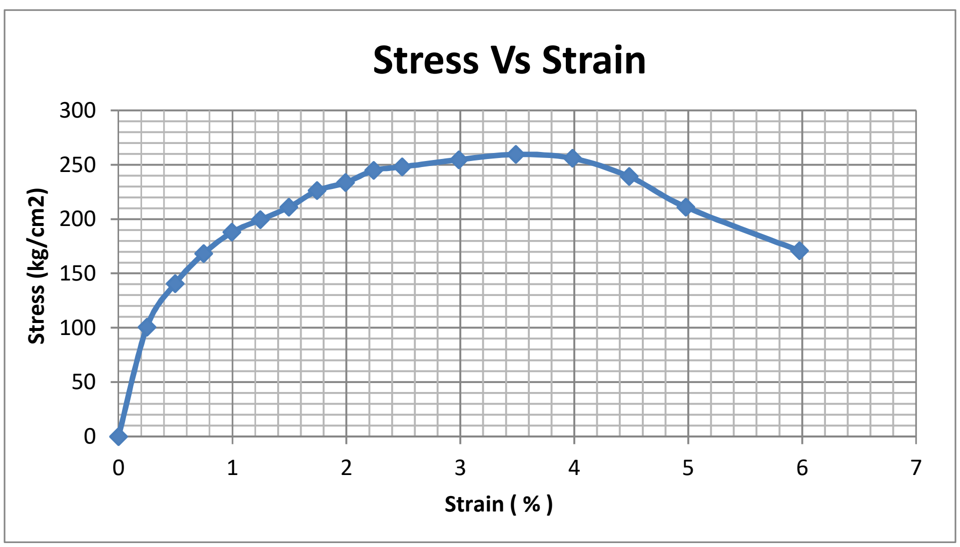
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	Non

Moisture Content (%):-	21.35
Bulk Unit Weight (g/cm^3):-	1.97

qu = **260 kpa**
C = qu/2 = **129.78 kpa**
Strain at failure = **3.49 (%)**



II-Test Result for Stabilized Soil

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. C
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Total Addisu Gebeya
Terrazyme application: **Stabilized**

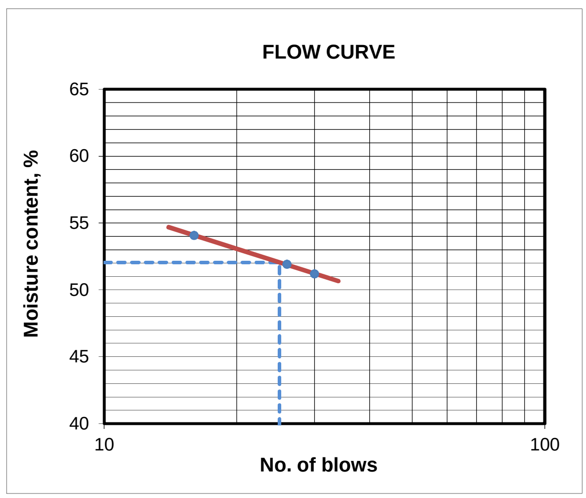
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		30	26	16			
Container No.		B10	R	A1	Z15	AW	
Mass of Container	g	17.73	17.8	17.96	23.89	23.64	
Mass of Wet Soil + Container	g	29.78	30.03	31.01	34.80	34.34	
Mass of Dry Soil + Container	g	25.70	25.85	26.43	32.20	31.78	
Mass of Water in Specimen	g	4.08	4.18	4.58	2.60	2.56	
Mass of Dry Soil	g	7.97	8.05	8.47	8.31	8.14	
Moisture Content	%	51.2	51.9	54.1	31.3	31.4	
					Average PL, %		**31.4**

Initial Mass= 179.15 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0.07	0	100
№ 40	1.93	1	99
№ 200	11.26	6	93

LL	PI	AASHTO Soil Class.
52	21	A-7-5 [20]



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** C
Sampled /Tested by: Dagnachew Seifu **Depth:** 2m
Location: Intoto Technical and Vocational Poly techmic College
Terrazyme application: **Stabilized**

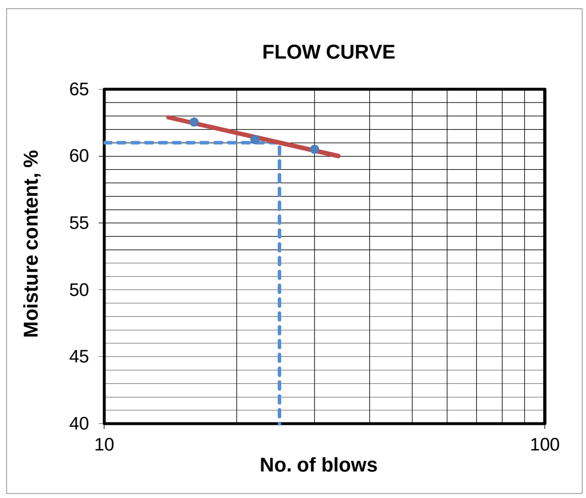
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		30	22	16			
Container No.		A10	A12	B4	AL	Z5	
Mass of Container	g	17.95	17.81	18.21	23.85	23.53	
Mass of Wet Soil + Container	g	33.76	31.37	35.83	33.11	33.27	
Mass of Dry Soil + Container	g	27.80	26.22	29.05	30.75	30.7	
Mass of Water in Specimen	g	5.96	5.15	6.78	2.36	2.57	
Mass of Dry Soil	g	9.85	8.41	10.84	6.90	7.17	
Moisture Content	%	60.5	61.2	62.5	34.2	35.8	
					Average PL, %		**35.0**

Initial Mass= 178.23 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	0	0	100
№ 40	1.69	1	99
№ 200	9.9	6	93

LL	PI	AASHTO Soil Class.
61	26	A-7-5 [20]



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** C
Sampled /Tested by: Dagnachew Seifu **Depth:** 2m
Location: Kolfe Police training Center
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

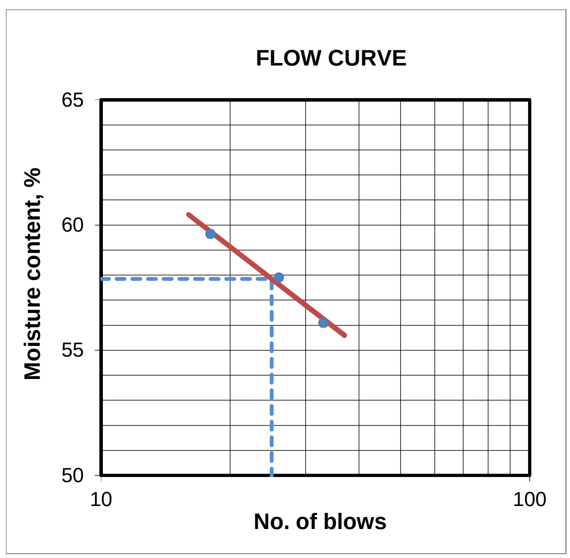
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	18			
Container No.		A-13	A4	K	Y3	Y8	
Mass of Container	g	18.31	18.14	17.76	23.45	23.3	
Mass of Wet Soil + Container	g	31.14	31.64	36.90	32.58	40.69	
Mass of Dry Soil + Container	g	26.53	26.69	29.75	30.21	36.75	
Mass of Water in Specimen	g	4.61	4.95	7.15	2.37	3.94	
Mass of Dry Soil	g	8.22	8.55	11.99	6.76	13.45	
Moisture Content	%	56.1	57.9	59.6	35.1	29.3	
						Average PL, %	**32.2**

Initial Mass= 160.2 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	4.92	3	97
№ 40	17.47	11	86
№ 200	15.35	10	76

LL	PI	AASHTO Soil Class.
58	26	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. C
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Intoto Technical and Vocational Poly techmic College
Terrazyme application: **Stabilized**

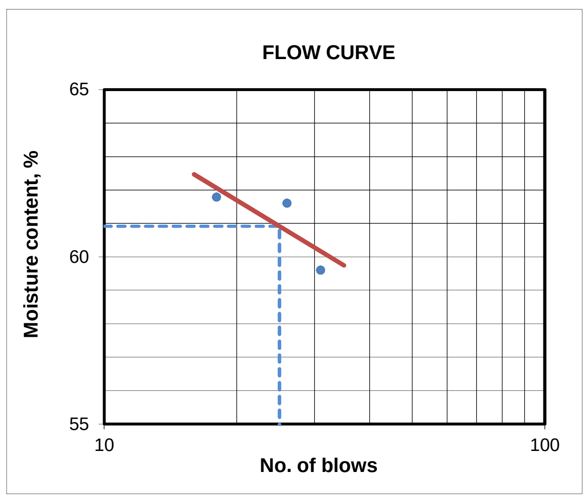
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		31	26	18			
Container No.		A4	E	A14	Z6	A5	
Mass of Container	g	18.12	17.86	17.86	23.39	23.85	
Mass of Wet Soil + Container	g	30.25	30.32	30.69	34.01	33.7	
Mass of Dry Soil + Container	g	25.72	25.57	25.79	31.18	31.25	
Mass of Water in Specimen	g	4.53	4.75	4.90	2.83	2.45	
Mass of Dry Soil	g	7.60	7.71	7.93	7.79	7.40	
Moisture Content	%	59.6	61.6	61.8	36.3	33.1	
					Average PL, %		**34.7**

Initial Mass= 174.88 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	1.45	1	99
№ 40	0.31	0	99
№ 200	1.75	1	98

LL	PI	AASHTO Soil Class.
61	26	A-7-5 [20]



Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** C

Sampled /Tested by: Dagnachew Seifu **Depth:** 2m

Location: Semen Gebeya

Terrazyme application: **Stabilized**

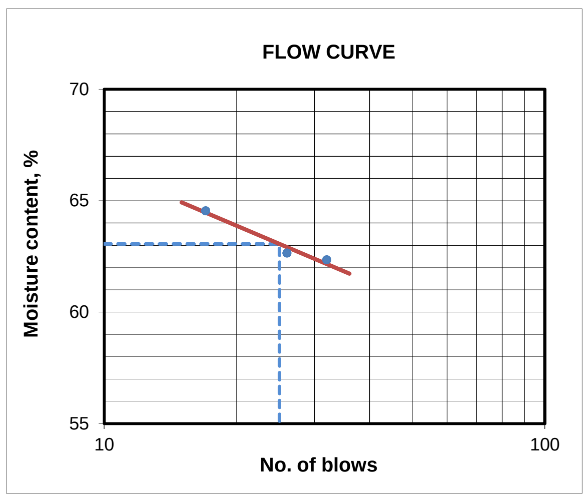
TEST METHODS: AASHTO T 89, T90 & M145

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	26	17			
Container No.		A9	C	B8	Y9	AC	
Mass of Container	g	17.98	17.76	17.71	23.71	20.4	
Mass of Wet Soil + Container	g	33.76	31.65	31.73	31.99	29.38	
Mass of Dry Soil + Container	g	27.70	26.30	26.23	29.80	27	
Mass of Water in Specimen	g	6.06	5.35	5.50	2.19	2.38	
Mass of Dry Soil	g	9.72	8.54	8.52	6.09	6.60	
Moisture Content	%	62.3	62.6	64.6	36.0	36.1	
					Average PL, %		**36.0**

Initial Mass= 174.57 g

Sieve No.	Mass Ret.	% Retain.	% Pass.
№ 10	3.59	2	98
№ 40	0.28	0	98
№ 200	1.67	1	97

LL	PI	AASHTO Soil Class.
63	27	A-7-5 [20]



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

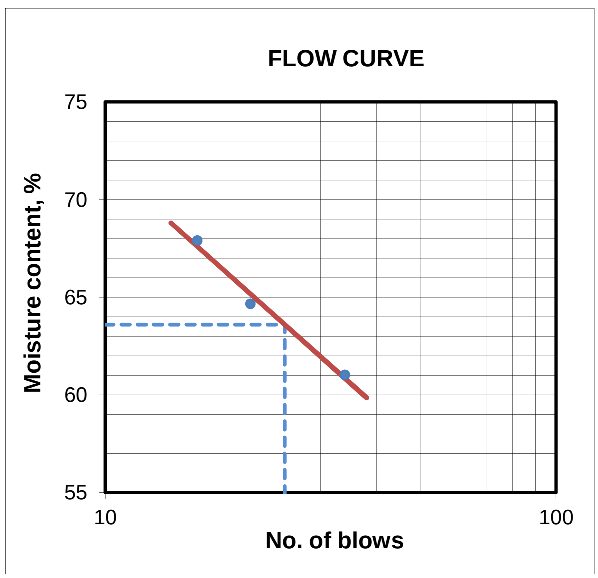
Title : Chemical stailzation of Red Clay Soil **Test Pit No.** B
Sampled /Tested by: Dagnachew Seifu **Depth:** 2m
Location: Kechene Hidasie Health Center
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	21	16			
Container No.		A-20	B-1	N	AY	Z-1	
Mass of Container	g	17.56	17.79	17.96	23.34	23.49	
Mass of Wet Soil + Container	g	29.46	29.35	34.03	32.32	31.34	
Mass of Dry Soil + Container	g	24.95	24.81	27.53	30.09	29.38	
Mass of Water in Specimen	g	4.51	4.54	6.50	2.23	1.96	
Mass of Dry Soil	g	7.39	7.02	9.57	6.75	5.89	
Moisture Content	%	61.0	64.7	67.9	33.0	33.3	
					Average PL, %		**33.2**

LL	PI
64	31



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A

Sampled /Tested by: Dagnachew Seifu **Depth:** 1m

Location: Kechene Hidasie Health Center

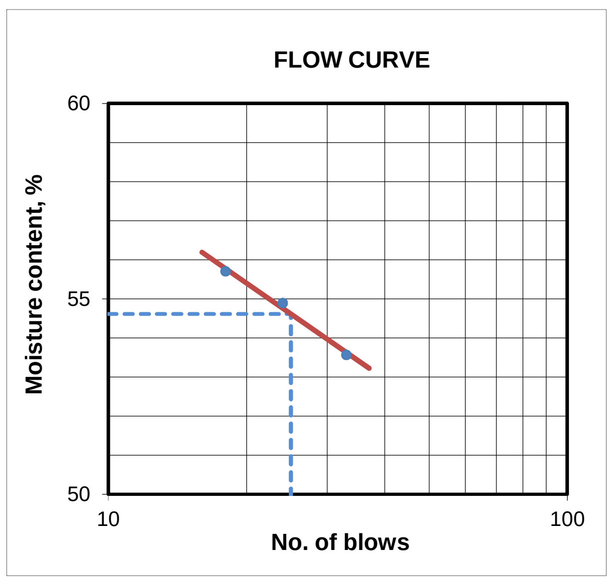
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	24	18			
Container No.		A-12	A-6	A-19	AB	Y-3	
Mass of Container	g	17.74	17.68	17.93	23.11	23.22	
Mass of Wet Soil + Container	g	29.58	29.87	35.40	30.10	32.41	
Mass of Dry Soil + Container	g	25.45	25.55	29.15	28.35	30.06	
Mass of Water in Specimen	g	4.13	4.32	6.25	1.75	2.35	
Mass of Dry Soil	g	7.71	7.87	11.22	5.24	6.84	
Moisture Content	%	53.6	54.9	55.7	33.4	34.4	
					Average PL, %		**33.9**

LL	PI
55	21



Laboratory Test Result

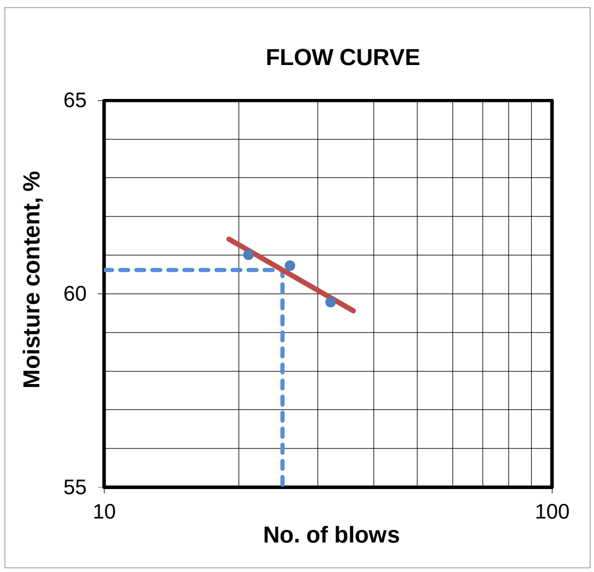
Title : Chemical stailzation of Red Clay Soil **Test Pit No.** B
Sampled /Tested by: Dagnachew Seifu **Depth:** 1m
Location: Kechene Hidasie Health Center
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	26	21			
Container No.		A-14	O	A-5	Z-11	Y-2	
Mass of Container	g	17.8	17.7	17.54	23.55	23.16	
Mass of Wet Soil + Container	g	29.72	30.43	30.92	30.04	29.85	
Mass of Dry Soil + Container	g	25.26	25.62	25.85	28.49	28.28	
Mass of Water in Specimen	g	4.46	4.81	5.07	1.55	1.57	
Mass of Dry Soil	g	7.46	7.92	8.31	4.94	5.12	
Moisture Content	%	59.8	60.7	61.0	31.4	30.7	
					Average PL, %		**31.0**

LL	PI
61	30



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

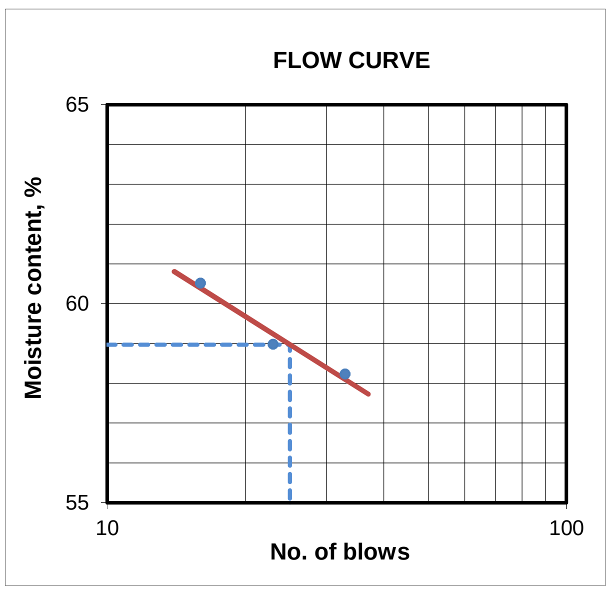
Title : Chemical stailzation of Red Clay Soil
Test Pit No. A
Sampled /Tested by: Dagnachew Seifu
Depth: 1m
Location: Kechene Hidasie Health Center
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	23	16			
Container No.		B-9	B-2	A-8	Z-3	AH	
Mass of Container	g	17.79	17.96	17.78	23.52	20.42	
Mass of Wet Soil + Container	g	29.91	30.01	32.82	30.89	29.12	
Mass of Dry Soil + Container	g	25.45	25.54	27.15	29.01	26.88	
Mass of Water in Specimen	g	4.46	4.47	5.67	1.88	2.24	
Mass of Dry Soil	g	7.66	7.58	9.37	5.49	6.46	
Moisture Content	%	58.2	59.0	60.5	34.2	34.7	
					Average PL, %		**34.5**

LL	PI
59	25



	Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering	
Laboratory Test Result		

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A

Sampled /Tested by: Dagnachew Seifu **Depth:** 1m

Location: Kolfe Police training Center

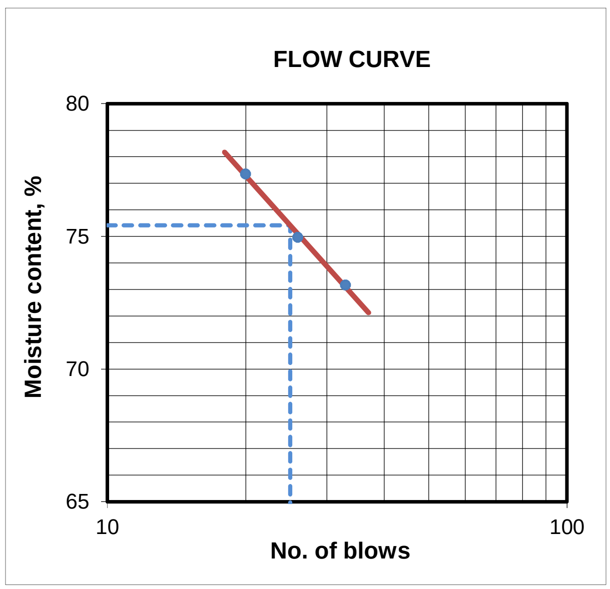
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	20			
Container No.		AS	K	BD	AK	AN	
Mass of Container	g	17.57	17.76	17.58	23.46	20.11	
Mass of Wet Soil + Container	g	35.63	35.71	35.35	26.49	28.98	
Mass of Dry Soil + Container	g	28.00	28.02	27.60	25.56	26.27	
Mass of Water in Specimen	g	7.63	7.69	7.75	0.93	2.71	
Mass of Dry Soil	g	10.43	10.26	10.02	2.10	6.16	
Moisture Content	%	73.2	75.0	77.3	44.3	44.0	
					Average PL, %		**44.1**

LL	PI
75	31



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A

Sampled /Tested by: Dagnachew Seifu **Depth:** 2m

Location: Kolfe Police training Center

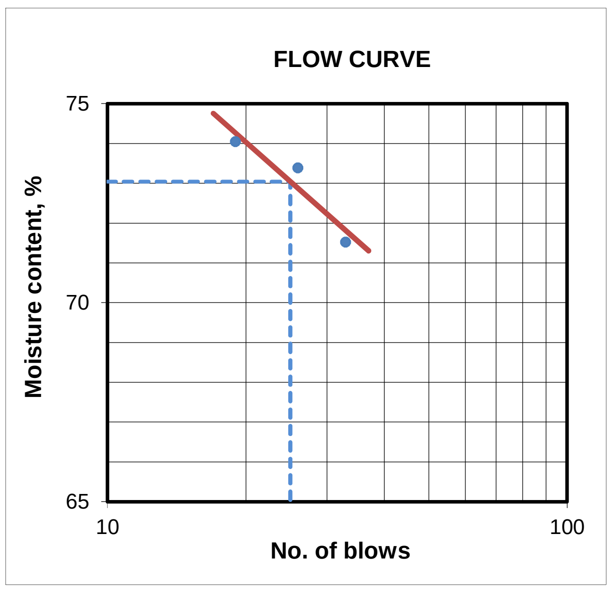
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	19			
Container No.		A-12	A	F	Z-9	Z-4	
Mass of Container	g	17.72	17.75	17.59	23.42	20.16	
Mass of Wet Soil + Container	g	31.51	32.73	37.97	30.62	28.44	
Mass of Dry Soil + Container	g	25.76	26.39	29.30	28.49	25.98	
Mass of Water in Specimen	g	5.75	6.34	8.67	2.13	2.46	
Mass of Dry Soil	g	8.04	8.64	11.71	5.07	5.82	
Moisture Content	%	71.5	73.4	74.0	42.0	42.3	
					Average PL, %		**42.1**

LL	PI
73	31



	Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering	
Laboratory Test Result		

Title : Chemical stailzation of Red Clay Soil

Test Pit No. B

Sampled /Tested by: Dagnachew Seifu

Depth: 1m

Location: Kolfe Police training Center

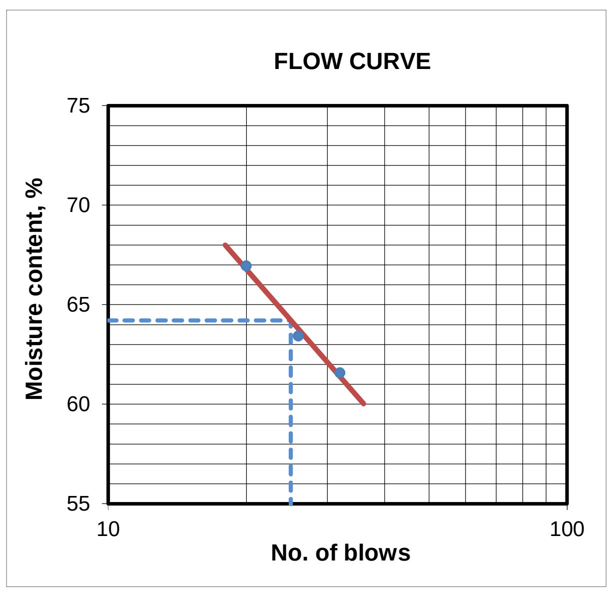
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	26	20			
Container No.		B-9	B-1	B	Y-3	Y-6	
Mass of Container	g	17.8	17.78	17.92	23.21	23.56	
Mass of Wet Soil + Container	g	33.23	32.52	34.68	29.96	30.98	
Mass of Dry Soil + Container	g	27.35	26.80	27.96	28.13	29.02	
Mass of Water in Specimen	g	5.88	5.72	6.72	1.83	1.96	
Mass of Dry Soil	g	9.55	9.02	10.04	4.92	5.46	
Moisture Content	%	61.6	63.4	66.9	37.2	35.9	
					Average PL, %		**36.5**

LL	PI
64	27



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** B

Sampled /Tested by: Dagnachew Seifu **Depth:** 2m

Location: Kolfe Police training Center

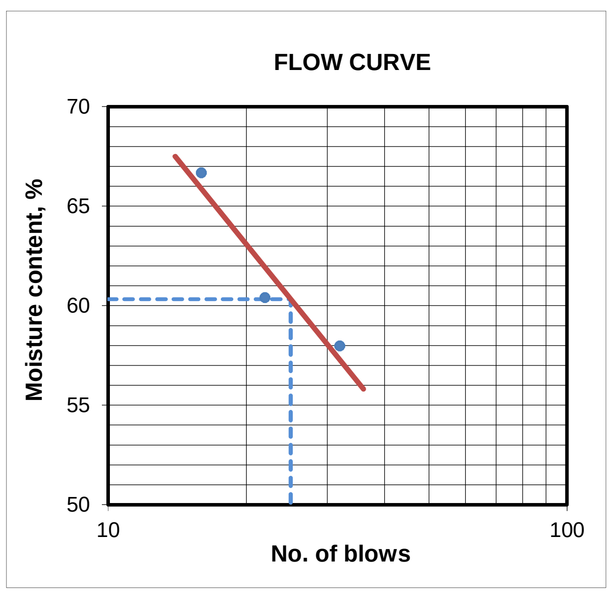
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	22	16			
Container No.		P	Q	A	Y-8	AR	
Mass of Container	g	17.72	18.22	17.73	23.03	23.33	
Mass of Wet Soil + Container	g	30.01	29.8	31.98	29.16	27.85	
Mass of Dry Soil + Container	g	25.50	25.44	26.28	27.66	26.76	
Mass of Water in Specimen	g	4.51	4.36	5.70	1.50	1.09	
Mass of Dry Soil	g	7.78	7.22	8.55	4.63	3.43	
Moisture Content	%	58.0	60.4	66.7	32.4	31.8	
					Average PL, %		**32.1**

LL	PI
60	28



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

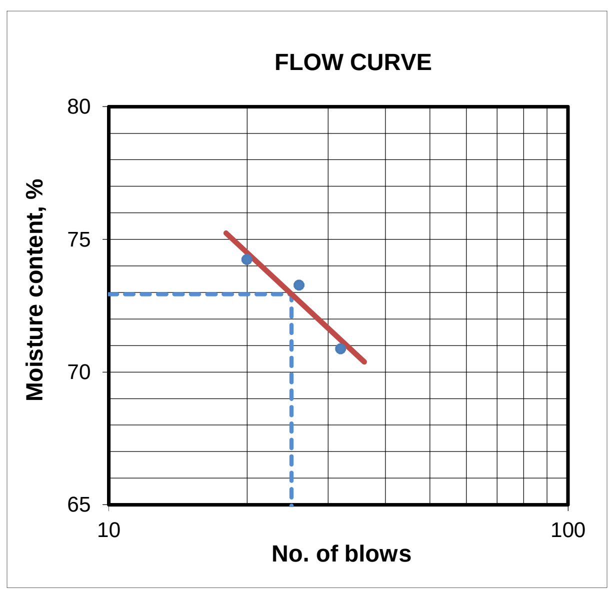
Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A
Sampled /Tested by: Dagnachew Seifu **Depth:** 1m
Location: Semen Gebeya
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	26	20			
Container No.		A-8	A-5	VV	A-21	Z-11	
Mass of Container	g	17.83	20.56	7.09	20.48	23.57	
Mass of Wet Soil + Container	g	32.61	29.31	34.81	29.15	32.34	
Mass of Dry Soil + Container	g	26.48	25.61	23.00	26.70	29.88	
Mass of Water in Specimen	g	6.13	3.70	11.81	2.45	2.46	
Mass of Dry Soil	g	8.65	5.05	15.91	6.22	6.31	
Moisture Content	%	70.9	73.3	74.2	39.4	39.0	
					Average PL, %		**39.2**

LL	PI
73	34



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

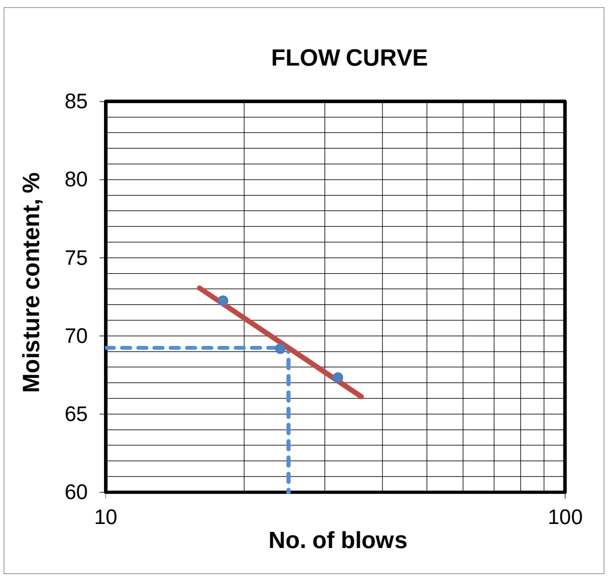
Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A
Sampled /Tested by: Dagnachew Seifu **Depth:** 1m
Location: Semen Gebeya
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		32	24	18			
Container No.		C	A-11	B-7	Y-9	AG	
Mass of Container	g	17.69	17.63	17.84	23.52	23.53	
Mass of Wet Soil + Container	g	32.7	32.94	32.93	30.91	31.02	
Mass of Dry Soil + Container	g	26.66	26.68	26.60	28.83	28.92	
Mass of Water in Specimen	g	6.04	6.26	6.33	2.08	2.10	
Mass of Dry Soil	g	8.97	9.05	8.76	5.31	5.39	
Moisture Content	%	67.3	69.2	72.3	39.2	39.0	
					Average PL, %		**39.1**

LL	PI
69	30



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** B

Sampled /Tested by: Dagnachew Seifu **Depth:** 1m

Location: Semen Gebeya

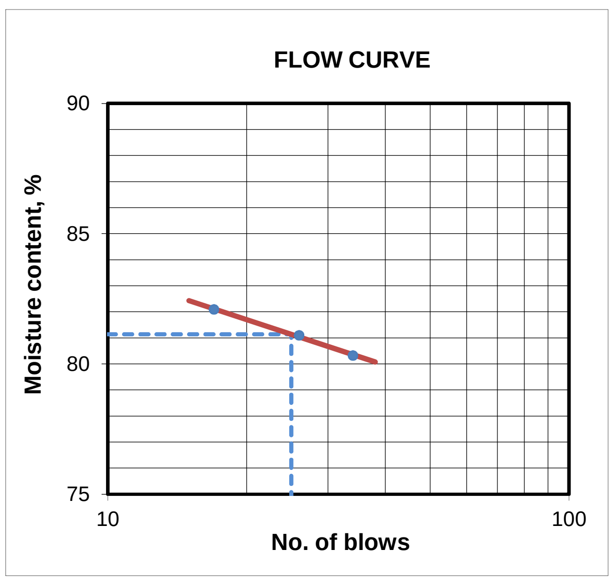
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		34	26	17			
Container No.		B-6	B-2	M	AE	Z-3	
Mass of Container	g	17.67	17.96	17.92	23.36	23.53	
Mass of Wet Soil + Container	g	33.25	33.19	38.46	31.02	31.29	
Mass of Dry Soil + Container	g	26.31	26.37	29.20	28.79	29.03	
Mass of Water in Specimen	g	6.94	6.82	9.26	2.23	2.26	
Mass of Dry Soil	g	8.64	8.41	11.28	5.43	5.50	
Moisture Content	%	80.3	81.1	82.1	41.1	41.1	
					Average PL, %		**41.1**

LL	PI
81	40



	Addis Ababa University Addis Ababa Institute of Technology School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** B

Sampled /Tested by: Dagnachew Seifu **Depth:** 2m

Location: Semen Gebeya

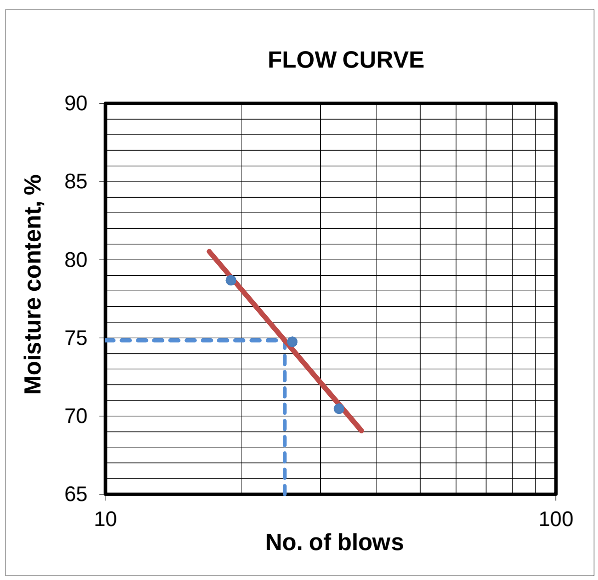
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	19			
Container No.		T	H	A-12	AV	AC	
Mass of Container	g	17.58	17.78	17.79	23.64	20.28	
Mass of Wet Soil + Container	g	29.82	29.96	28.35	30.65	26.66	
Mass of Dry Soil + Container	g	24.76	24.75	23.70	28.78	24.95	
Mass of Water in Specimen	g	5.06	5.21	4.65	1.87	1.71	
Mass of Dry Soil	g	7.18	6.97	5.91	5.14	4.67	
Moisture Content	%	70.5	74.7	78.7	36.4	36.6	
					Average PL, %		**36.5**

LL	PI
75	39



Laboratory Test Result

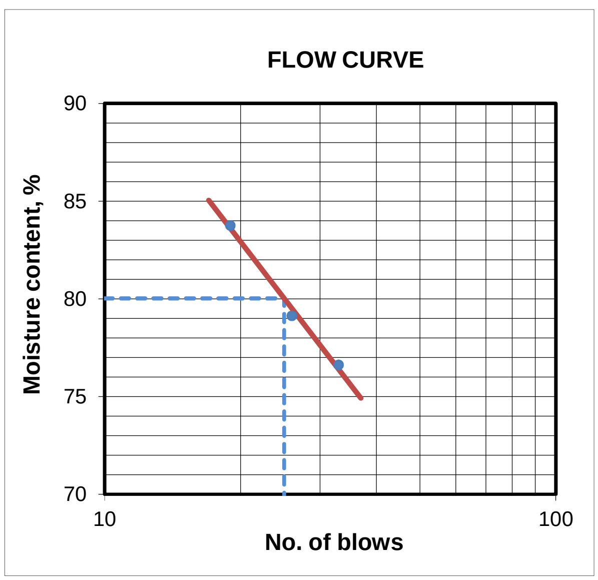
Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A
Sampled /Tested by: Dagnachew Seifu **Depth:** 1m
Location: Intoto Technical and Vocational poly technique college
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	19			
Container No.		B3	A5	A-12	AO	27A	
Mass of Container	g	17.67	17.67	17.79	13	12.89	
Mass of Wet Soil + Container	g	30.97	33.38	28.65	18.03	20.44	
Mass of Dry Soil + Container	g	25.20	26.44	23.70	16.44	18.05	
Mass of Water in Specimen	g	5.77	6.94	4.95	1.59	2.39	
Mass of Dry Soil	g	7.53	8.77	5.91	3.44	5.16	
Moisture Content	%	76.6	79.1	83.8	46.2	46.3	
					Average PL, %		**46.3**

LL	PI
80	34



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A

Sampled /Tested by: Dagnachew Seifu **Depth:** 1m

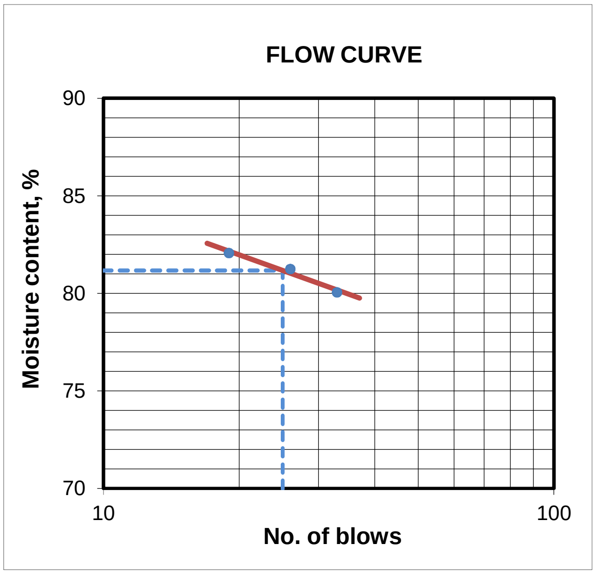
Location: Intoto Technical and Vocational poly technique college

Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	19			
Container No.		Q	B9	GH	Y1	AU	
Mass of Container	g	18.28	17.9	18.28	23.67	20.62	
Mass of Wet Soil + Container	g	32.72	35.39	32.70	31.68	27.51	
Mass of Dry Soil + Container	g	26.30	27.55	26.20	29.34	25.55	
Mass of Water in Specimen	g	6.42	7.84	6.50	2.34	1.96	
Mass of Dry Soil	g	8.02	9.65	7.92	5.67	4.93	
Moisture Content	%	80.0	81.2	82.1	41.3	39.8	
					Average PL, %		**40.5**



LL	PI
81	40

	Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering	
Laboratory Test Result		

Title : Chemical stailzation of Red Clay Soil **Test Pit No.** B

Sampled /Tested by: Dagnachew Seifu **Depth:** 1m

Location: Intoto Technical and Vocational poly technique college

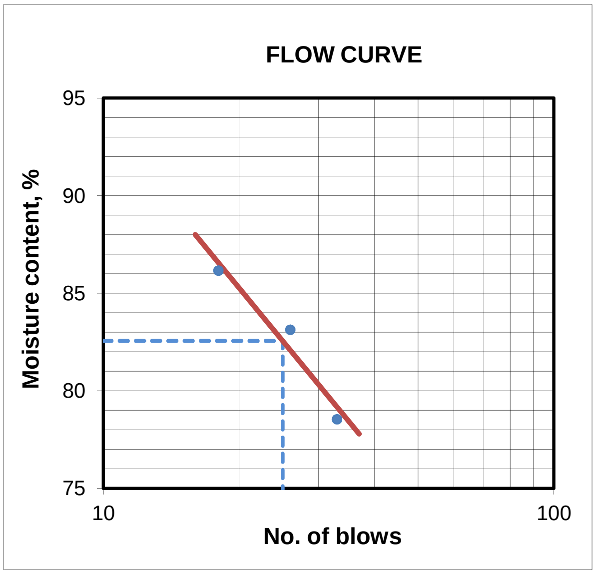
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	18			
Container No.		B1	N	A-11	AB	AD	
Mass of Container	g	17.81	18.18	17.67	23.22	23.76	
Mass of Wet Soil + Container	g	31.54	34.24	30.31	29.47	31.04	
Mass of Dry Soil + Container	g	25.50	26.95	24.46	27.66	28.94	
Mass of Water in Specimen	g	6.04	7.29	5.85	1.81	2.10	
Mass of Dry Soil	g	7.69	8.77	6.79	4.44	5.18	
Moisture Content	%	78.5	83.1	86.2	40.8	40.5	
					Average PL, %		**40.7**

LL	PI
83	42



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

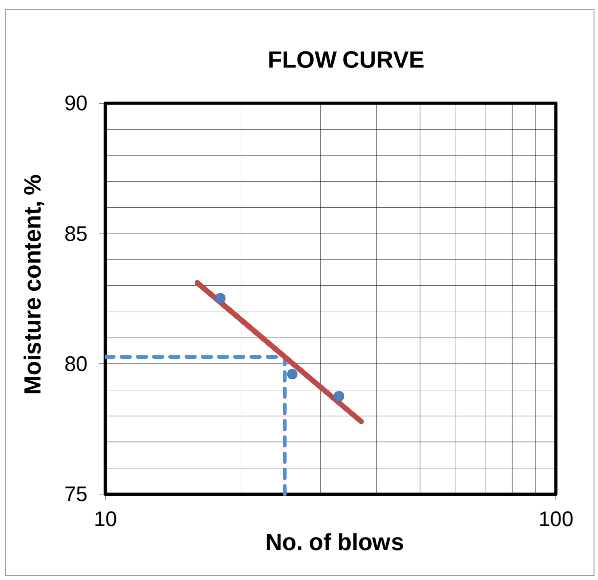
Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Intoto Technical and Vocational poly technique college
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	18			
Container No.		B6	N	A-7	Y9	AJ	
Mass of Container	g	17.68	18.18	17.62	23.74	23.68	
Mass of Wet Soil + Container	g	30.98	32.8	34.65	30.05	30.53	
Mass of Dry Soil + Container	g	25.12	26.32	26.95	28.22	28.56	
Mass of Water in Specimen	g	5.86	6.48	7.70	1.83	1.97	
Mass of Dry Soil	g	7.44	8.14	9.33	4.48	4.88	
Moisture Content	%	78.8	79.6	82.5	40.8	40.4	
					Average PL, %		**40.6**

LL	PI
80	39



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil — **Test Pit No.** B

Sampled /Tested by: Dagnachew Seifu — **Depth:** 1m

Location: Total Addisu Gebeya

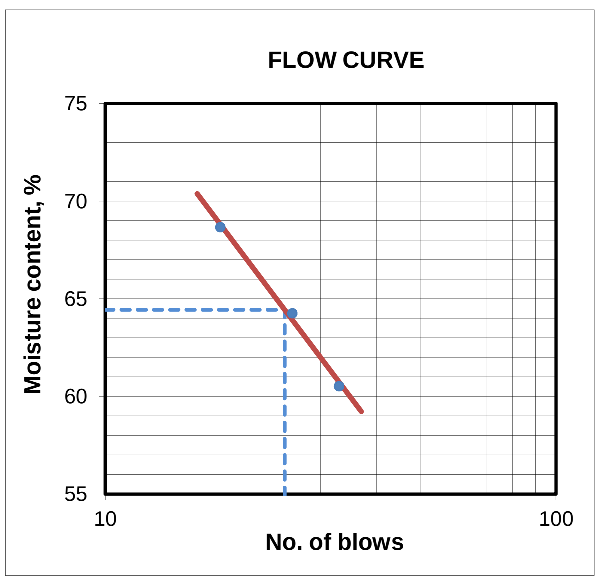
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	18			
Container No.		A3	A-15	A-7	Y5	Y2	
Mass of Container	g	17.72	17.95	17.62	23.52	23.49	
Mass of Wet Soil + Container	g	29.84	31.42	33.56	31.59	31.14	
Mass of Dry Soil + Container	g	25.27	26.15	27.07	29.38	29.01	
Mass of Water in Specimen	g	4.57	5.27	6.49	2.21	2.13	
Mass of Dry Soil	g	7.55	8.20	9.45	5.86	5.52	
Moisture Content	%	60.5	64.3	68.7	37.7	38.6	
					Average PL, %		**38.2**

LL	PI
64	26



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

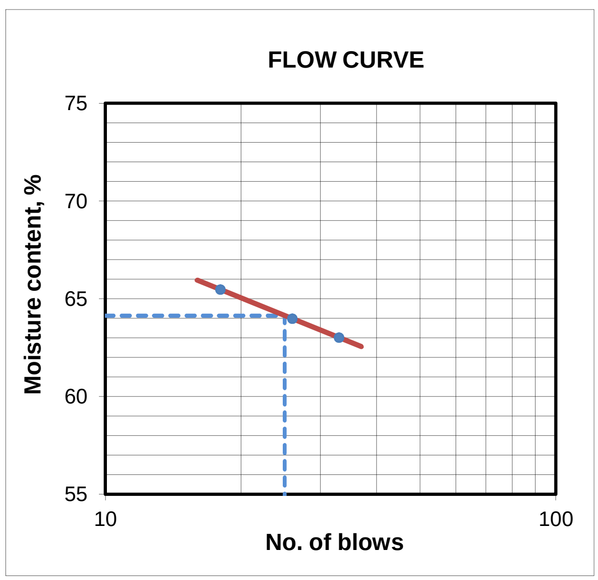
Title : Chemical stailzation of Red Clay Soil **Test Pit No.** A
Sampled /Tested by: Dagnachew Seifu **Depth:** 2m
Location: Total Addisu Gebeya
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	18			
Container No.		A-13	A4	K	Y3	Y8	
Mass of Container	g	18.31	18.14	17.76	23.45	23.3	
Mass of Wet Soil + Container	g	31.71	32.16	37.60	31.11	29.85	
Mass of Dry Soil + Container	g	26.53	26.69	29.75	29.21	28.21	
Mass of Water in Specimen	g	5.18	5.47	7.85	1.90	1.64	
Mass of Dry Soil	g	8.22	8.55	11.99	5.76	4.91	
Moisture Content	%	63.0	64.0	65.5	33.0	33.4	
					Average PL, %		**33.2**

LL	PI
64	31



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

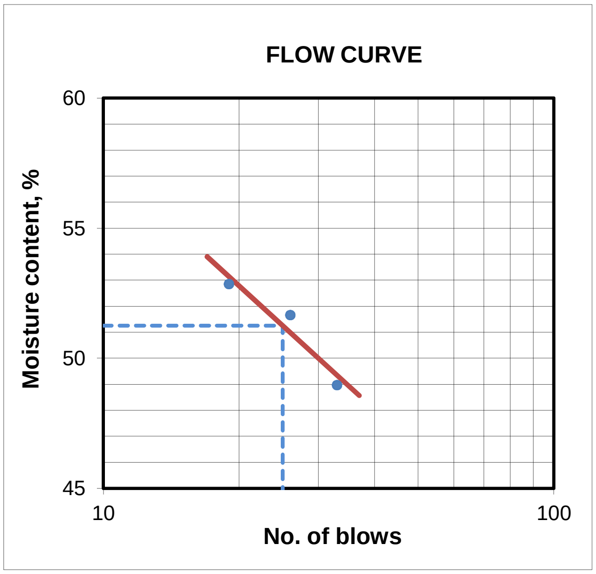
Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 1m
Location: Total Addisu Gebeya
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	19			
Container No.		B10	B7	CK3	Z5	AH	
Mass of Container	g	17.76	17.94	7.17	23.37	20.76	
Mass of Wet Soil + Container	g	27.13	27.04	26.20	29.59	28.48	
Mass of Dry Soil + Container	g	24.05	23.94	19.62	28.23	26.74	
Mass of Water in Specimen	g	3.08	3.10	6.58	1.36	1.74	
Mass of Dry Soil	g	6.29	6.00	12.45	4.86	5.98	
Moisture Content	%	49.0	51.7	52.9	28.0	29.1	
					Average PL, %		**28.5**

LL	PI
51	22



Laboratory Test Result

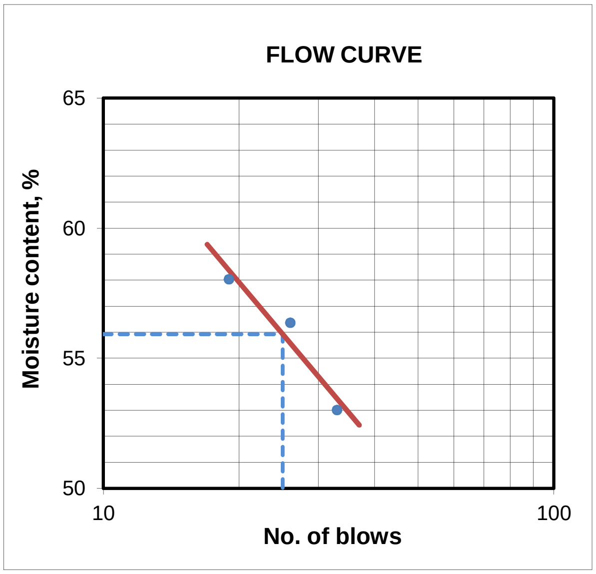
Title : Chemical stailzation of Red Clay Soil
Test Pit No. B
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Total Addisu Gebeya
Terrazyme application: **Stabilized**

ATTERBERG LIMITS AND SOIL CLASSIFICATION

TEST METHODS: AASHTO T 89 & T90

		Liquid Limit (LL)			Plastic Limit (PL)		
No. of blows		33	26	19			
Container No.		A-1	A-20	A	Z15	ZA-11	
Mass of Container	g	17.94	17.62	17.79	23.89	23.91	
Mass of Wet Soil + Container	g	31.42	28.55	27.81	29.75	30.29	
Mass of Dry Soil + Container	g	26.75	24.61	24.13	28.32	28.74	
Mass of Water in Specimen	g	4.67	3.94	3.68	1.43	1.55	
Mass of Dry Soil	g	8.81	6.99	6.34	4.43	4.83	
Moisture Content	%	53.0	56.4	58.0	32.3	32.1	
					Average PL, %		**32.2**

LL	PI
56	24



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil | **Test Pit No.:** C
Sampled/Tested by: Dagnachew Seifu | **Depth:** 2m
Location: Total Addisu Gebeya
Terazayem Application: Stabilized

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		F1	
Mass of Mould	g	6222	
Mass of Mould + Soil	g	10493	
Mass of Soil	g	4271	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	2.011	
Dry Density	g/cm^3	1.65	-

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

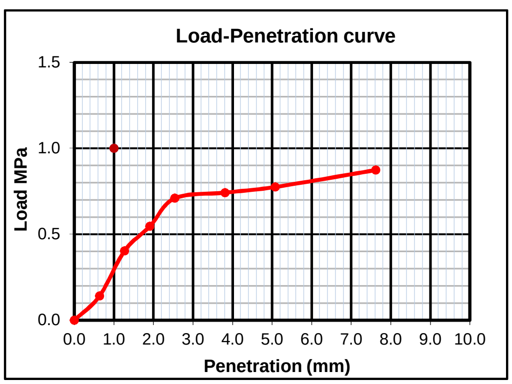
MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		26	
Mass of Container	g	43.2	
Mass of Container + Wet Soil	g	263.8	
Mass of Container + Dry Soil	g	224	
Moisture Content	%	22.01	

SWELL

Number of Blows	56
Reading Before Soaking, mm	3.49
Reading After Soaking, mm	7.61
Percent Swell	3.54

PENETRATION TEST DATA

Penetration	56 Blows			
mm	Dial Read. div	Load Mpa	Corr. Load Mpa	CBR %
0	0	0.00		
0.64	13	0.14		
1.27	37	0.40		
1.91	50	0.55		
2.54	65	0.71	0.7	10.3
3.81	68	0.74		
5.08	71	0.78	0.8	7.5
7.62	80	0.87		
10.16				
12.7				



CBR at 100% Standard Compaction= **10** %   Corresponding Swell= **3.54** %

Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil
Test Pit No.: C
Sampled/Tested by: Dagnachew Seifu
Depth: 2m
Location: Semen Gebeya
Terazayem Application: Stabilized

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		JQ	
Mass of Mould	g	6519	
Mass of Mould + Soil	g	10629	10702
Mass of Soil	g	4110	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.935	
Dry Density	g/cm^3	1.58	-

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		48	
Mass of Container	g	45.1	
Mass of Container + Wet Soil	g	240.8	
Mass of Container + Dry Soil	g	205.1	
Moisture Content	%	22.31	

SWELL

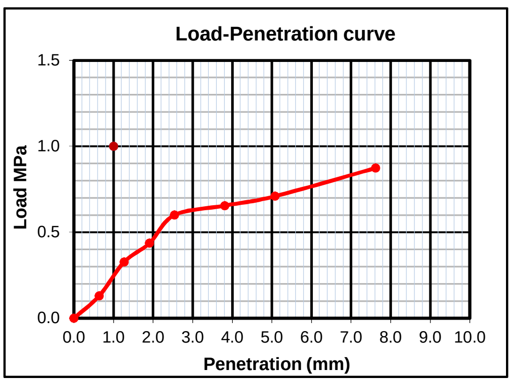
Number of Blows	56
Reading Before Soaking, mm	3.63
Reading After Soaking, mm	8.83
Percent Swell	4.47

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
mm	Dial Read. div	Load Mpa	Corr. Load Mpa	CBR %
0	0	0.00		
0.64	12	0.13		
1.27	30	0.33		
1.91	40	0.44		
2.54	55	0.60	0.6	8.7
3.81	60	0.66		
5.08	65	0.71	0.7	6.9
7.62	80	0.87		
10.16				
12.7				



CBR at 100% Standard Compaction= **9** %

Corresponding Swell= **4.47** %

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Intoto Technical and Vocational poly technique college		
Terazayem Application:	Stabilized		

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		A2	
Mass of Mould	g	6155	
Mass of Mould + Soil	g	10457	10378
Mass of Soil	g	4302	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	2.025	
Dry Density	g/cm^3	1.68	-

SOAKING CONDITION

Unsoaked	
Soaked	**v**
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

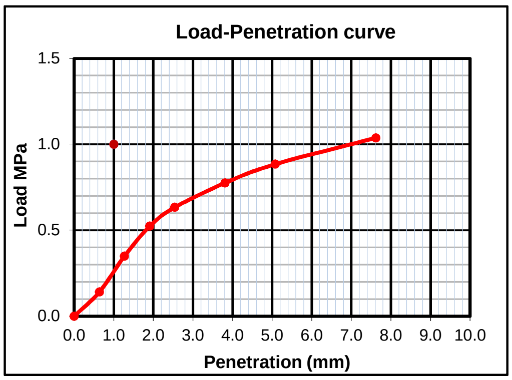
MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		64	
Mass of Container	g	44	
Mass of Container + Wet Soil	g	227.1	
Mass of Container + Dry Soil	g	195.7	
Moisture Content	%	20.70	

SWELL

Number of Blows	56
Reading Before Soaking, mm	4.89
Reading After Soaking, mm	8.65
Percent Swell	3.23

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	13	0.14		
1.27	32	0.35		
1.91	48	0.52		
2.54	58	0.63	0.6	9.2
3.81	71	0.78		
5.08	81	0.88	0.9	8.6
7.62	95	1.04		
10.16				
12.7				



CBR at 100% Standard Compaction= **9** %   Corresponding Swell= **3.23** %

Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Kechene Hidasie Health Center		
Terazayem Application:	Stabilized		

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		RE	
Mass of Mould	g	6168	
Mass of Mould + Soil	g	10234	
Mass of Soil	g	4066	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.914	
Dry Density	g/cm^3	1.56	-

SOAKING CONDITION

Unsoaked	
Soaked	**v**
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		52	
Mass of Container	g	45.7	
Mass of Container + Wet Soil	g	192.9	
Mass of Container + Dry Soil	g	165.7	
Moisture Content	%	22.67	

SWELL

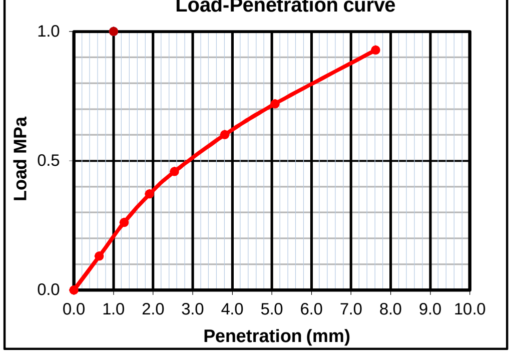
Number of Blows	56
Reading Before Soaking, mm	2.73
Reading After Soaking, mm	9.55
Percent Swell	5.86

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	12	0.13		
1.27	24	0.26		
1.91	34	0.37		
2.54	42	0.46	0.5	6.6
3.81	55	0.60		
5.08	66	0.72	0.7	7.0
7.62	85	0.93		
10.16				
12.7				



CBR at 100% Standard Compaction= **7** %   Corresponding Swell= **5.86** %

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil
Test Pit No.: C
Sampled/Tested by: Dagnachew Seifu
Depth: 2m
Location: Total Addisu Gebeya
Curing Time 21 days
Terazayem Application: Stabilized

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		F1	
Mass of Mould	g	6222	
Mass of Mould + Soil	g	10481	
Mass of Soil	g	4259	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	2.005	
Dry Density	g/cm^3	1.64	-

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	4.54kg
Days Soaked	4

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		26	
Mass of Container	g	43.2	
Mass of Container + Wet Soil	g	264.1	
Mass of Container + Dry Soil	g	224	
Moisture Content	%	22.18	

SWELL

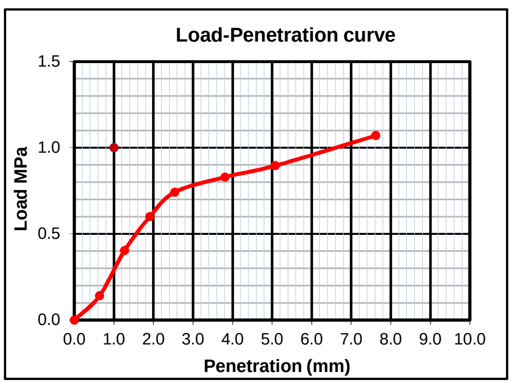
Number of Blows	56
Reading Before Soaking, mm	3.49
Reading After Soaking, mm	7.23
Percent Swell	3.21

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	2124
Height,mm	116.43
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	13	0.14		
1.27	37	0.40		
1.91	55	0.60		
2.54	68	0.74	0.7	10.8
3.81	76	0.83		
5.08	82	0.90	0.9	8.7
7.62	98	1.07		
10.16				
12.7				



CBR at 100% Standard Compaction= **11** %

Corresponding Swell= **3.21** %

Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Semen Gebeya	**Curing Time**	21 days
Terazayem Application:	Stabilized		

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		E	
Mass of Mould	g	6202	
Mass of Mould + Soil	g	10262	10702
Mass of Soil	g	4060	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.911	
Dry Density	g/cm^3	1.57	-

SOAKING CONDITION

Unsoaked	
Soaked	**v**
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		48	
Mass of Container	g	45.1	
Mass of Container + Wet Soil	g	239.9	
Mass of Container + Dry Soil	g	205.1	
Moisture Content	%	21.75	

SWELL

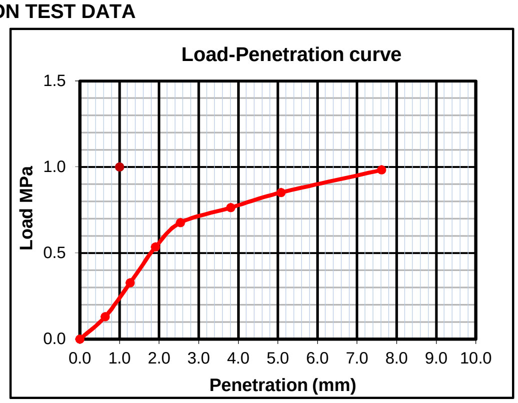
Number of Blows	56
Reading Before Soaking, mm	3.63
Reading After Soaking, mm	8.79
Percent Swell	4.43

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	12	0.13		
1.27	30	0.33		
1.91	49	0.54		
2.54	62	0.68	0.7	9.8
3.81	70	0.76		
5.08	78	0.85	0.9	8.3
7.62	90	0.98		
10.16				
12.7				



CBR at 100% Standard Compaction= **10** %   Corresponding Swell= **4.43** %

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Intoto Technical and Vocational poly technique college	**Curing Time**	21 days
Terazayem Application:	Stabilized		

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		E	
Mass of Mould	g	6202	
Mass of Mould + Soil	g	10417	
Mass of Soil	g	4215	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.984	
Dry Density	g/cm^3	1.65	-

Curing Time 21 Days

SOAKING CONDITION

Unsoaked	
Soaked	**v**
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		A-24	
Mass of Container	g	58.6	
Mass of Container + Wet Soil	g	223.9	
Mass of Container + Dry Soil	g	195.7	
Moisture Content	%	20.57	

SWELL

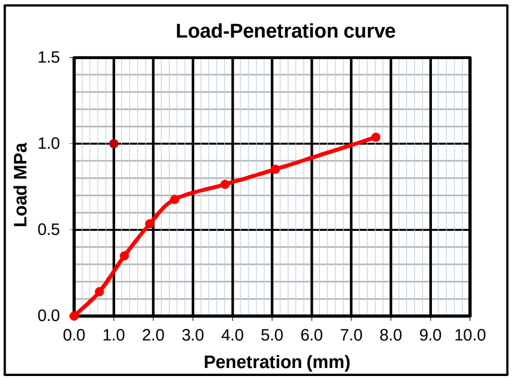
Number of Blows	56
Reading Before Soaking, mm	4.89
Reading After Soaking, mm	8.75
Percent Swell	3.32

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
mm	Dial Read. div	Load Mpa	Corr. Load Mpa	CBR %
0	0	0.00		
0.64	13	0.14		
1.27	32	0.35		
1.91	49	0.54		
2.54	62	0.68	0.7	9.8
3.81	70	0.76		
5.08	78	0.85	0.9	8.3
7.62	95	1.04		
10.16				
12.7				



CBR at 100% Standard Compaction= **10** %

Corresponding Swell= **3.32** %

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Kechene Hidasie Health Center	**Curing Time**	21 days
Terazayem Application:	Stabilized		

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		A-5	
Mass of Mould	g	6183	
Mass of Mould + Soil	g	10197	
Mass of Soil	g	4014	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.890	
Dry Density	g/cm^3	1.55	-

SOAKING CONDITION

Unsoaked	
Soaked	**v**
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

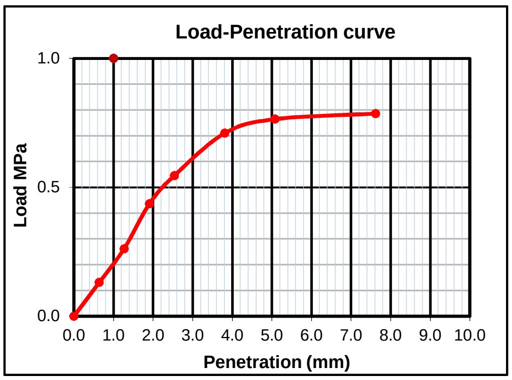
MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		52	
Mass of Container	g	45.7	
Mass of Container + Wet Soil	g	192.2	
Mass of Container + Dry Soil	g	165.7	
Moisture Content	%	22.08	

SWELL

Number of Blows	56
Reading Before Soaking, mm	2.73
Reading After Soaking, mm	9.41
Percent Swell	5.74

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	12	0.13		
1.27	24	0.26		
1.91	40	0.44		
2.54	50	0.55	0.5	7.9
3.81	65	0.71		
5.08	70	0.76	0.8	7.4
7.62	72	0.79		
10.16				
12.7				



CBR at 100% Standard Compaction= **8** % Corresponding Swell= **5.74** %

	ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING	
	Laboratory Test Result	

Titel: Chemical Stabilization Of Red Clay Soil — **Test Pit No.:** C
Sampled/Tested by: Dagnachew Seifu — **Depth:** 2m
Location: Total Addisu Gebeya — **Curing Time** 30 Days
Terazayem Application: Stabilized

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		KI	
Mass of Mould	g	6107	
Mass of Mould + Soil	g	10360	
Mass of Soil	g	4253	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	2.002	
Dry Density	g/cm^3	1.65	-

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		TD	
Mass of Container	g	50.1	
Mass of Container + Wet Soil	g	261.7	
Mass of Container + Dry Soil	g	224	
Moisture Content	%	21.68	

SWELL

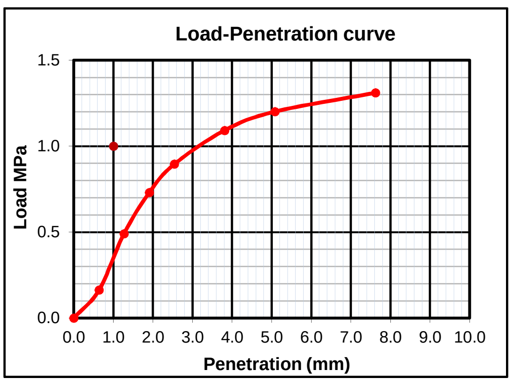
Number of Blows	56
Reading Before Soaking, mm	3.49
Reading After Soaking, mm	7.12
Percent Swell	3.12

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	15	0.16		
1.27	45	0.49		
1.91	67	0.73		
2.54	82	0.90	0.9	13.0
3.81	100	1.09		
5.08	110	1.20	1.2	11.7
7.62	120	1.31		
10.16				
12.7				



CBR at 100% Standard Compaction= **13** %   Corresponding Swell= **3.12** %

Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel:	Chemical Stabilization Of Red Clay Soil	**Test Pit No.:**	C
Sampled/Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Intoto Technical and Vocational poly technique college	**Curing Time**	30 Days
Terazayem Application:	Stabilized		

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		A-15	
Mass of Mould	g	6191	
Mass of Mould + Soil	g	10396	
Mass of Soil	g	4205	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.980	
Dry Density	g/cm^3	1.64	-

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

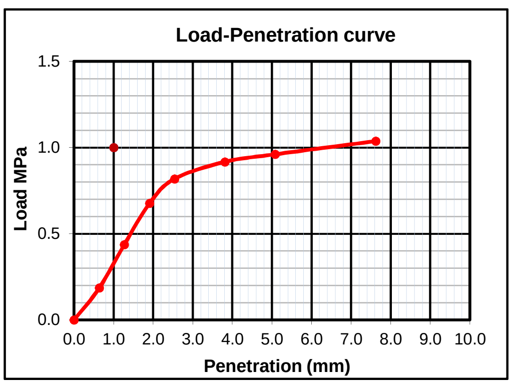
MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		A-31	
Mass of Container	g	52.4	
Mass of Container + Wet Soil	g	225.48	
Mass of Container + Dry Soil	g	195.7	
Moisture Content	%	20.78	

SWELL

Number of Blows	56
Reading Before Soaking, mm	5.95
Reading After Soaking, mm	9.96
Percent Swell	3.44

PENETRATION TEST DATA

Penetration	56 Blows			
mm	Dial Read. div	Load Mpa	Corr. Load Mpa	CBR %
0	0	0.00		
0.64	17	0.19		
1.27	40	0.44		
1.91	62	0.68		
2.54	75	0.82	0.8	11.9
3.81	84	0.92		
5.08	88	0.96	1.0	9.3
7.62	95	1.04		
10.16				
12.7				



CBR at 100% Standard Compaction= **12** %   Corresponding Swell= **3.44** %

Addis Ababa University Addis Ababa Institute of Technology School of Civil and Environmental Engineering	

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil
Sampled/Tested by: Dagnachew Seifu
Location: Semen Gebeya
Terazayem Application: Stabilized

Test Pit No.: C
Depth: 2m
Curing Time 30 Days

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		KI	
Mass of Mould	g	6107	
Mass of Mould + Soil	g	10240	
Mass of Soil	g	4133	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.946	
Dry Density	g/cm^3	1.59	-

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		TD	
Mass of Container	g	50.1	
Mass of Container + Wet Soil	g	239.2	
Mass of Container + Dry Soil	g	205.1	
Moisture Content	%	22.00	

SWELL

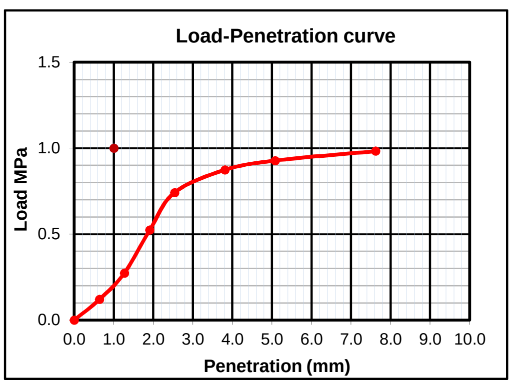
Number of Blows	56
Reading Before Soaking, mm	3.43
Reading After Soaking, mm	8.45
Percent Swell	4.31

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume, cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
mm	div	Mpa	Mpa	%
0	0	0.00		
0.64	11	0.12		
1.27	25	0.27		
1.91	48	0.52		
2.54	68	0.74	0.7	10.8
3.81	80	0.87		
5.08	85	0.93	0.9	9.0
7.62	90	0.98		
10.16				
12.7				



CBR at 100% Standard Compaction= **11** % Corresponding Swell= **4.31** %

Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Titel: Chemical Stabilization Of Red Clay Soil
Sampled/Tested by: Dagnachew Seifu
Location: Kechene Hidasie Health Center
Terazayem Application: Stabilized
Test Pit No.: C
Depth: 2m
Curing Time 30 Days

CALIFORNIA BEARING RATIO TEST

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		56 Blows	
		Before	After
Mould Number		KI	
Mass of Mould	g	6107	
Mass of Mould + Soil	g	10220	
Mass of Soil	g	4113	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.936	
Dry Density	g/cm^3	1.57	-

SOAKING CONDITION

Unsoaked	
Soaked	v
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

MOISTURE CONTENT DETERMINATION		56 Blows	
		Before	After
Container Number		TD	
Mass of Container	g	50.1	
Mass of Container + Wet Soil	g	192.7	
Mass of Container + Dry Soil	g	165.7	
Moisture Content	%	23.36	

SWELL

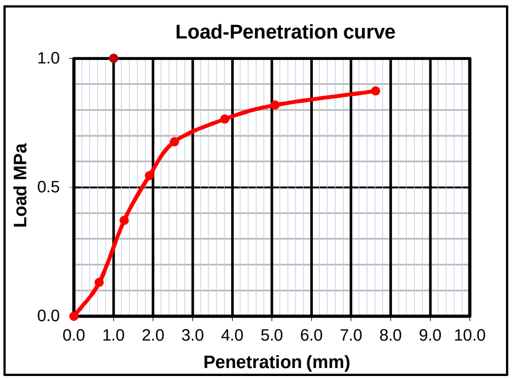
Number of Blows	56
Reading Before Soaking, mm	8.25
Reading After Soaking, mm	14.24
Percent Swell	5.14

CALIBRATION/STANDARD DATA

Rammer	4.54kg
Layer	5
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	7921
Ring Factor	21.13 N/div
Load @2.54	6.9
Load @5.08	10.3

PENETRATION TEST DATA

Penetration	56 Blows			
mm	Dial Read. div	Load Mpa	Corr. Load Mpa	CBR %
0	0	0.00		
0.64	12	0.13		
1.27	34	0.37		
1.91	50	0.55		
2.54	62	0.68	0.7	9.8
3.81	70	0.76		
5.08	75	0.82	0.8	8.0
7.62	80	0.87		
10.16				
12.7				



CBR at 100% Standard Compaction= **10** %

Corresponding Swell= **5.14** %

	ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING	

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil

Sampled /Tested by: Dagnachew Seifu

Location: Kechene Hidasie Health Center

Terrazyme application: **Stabilized**

Test Pit No. C

Depth: 2m

Date :

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

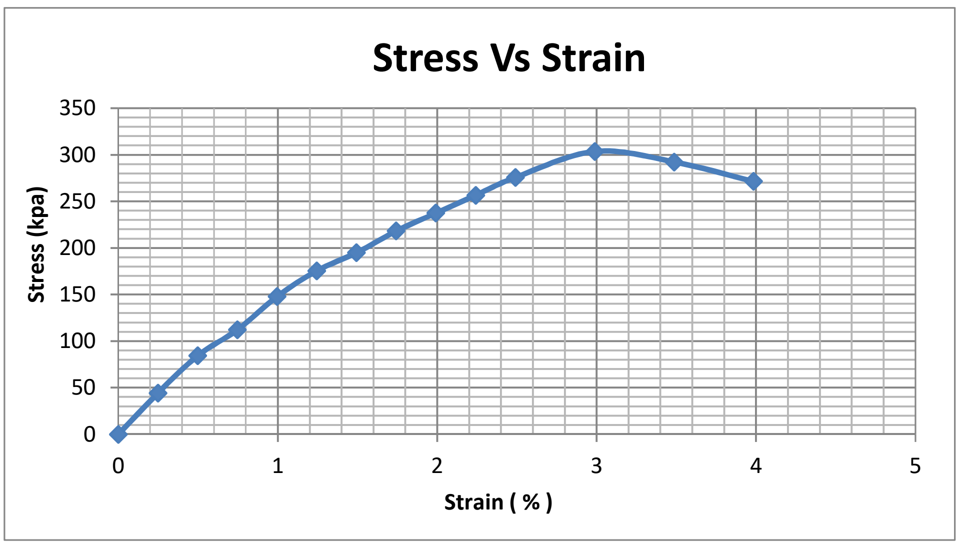
Curing Time :-	7days

Moisture Content (%):-	23.10
Bulk Unit Weight (g/cm^3):-	1.96

qu = **2.26 kpa**

C = qu/2 = **1.13 kpa**

Strain at failure = **2.99 (%)**



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. C
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Kechene Hidasie Health Center
Terrazyme application: **Stabilized**

Unconfined Compressive Strength of Soils

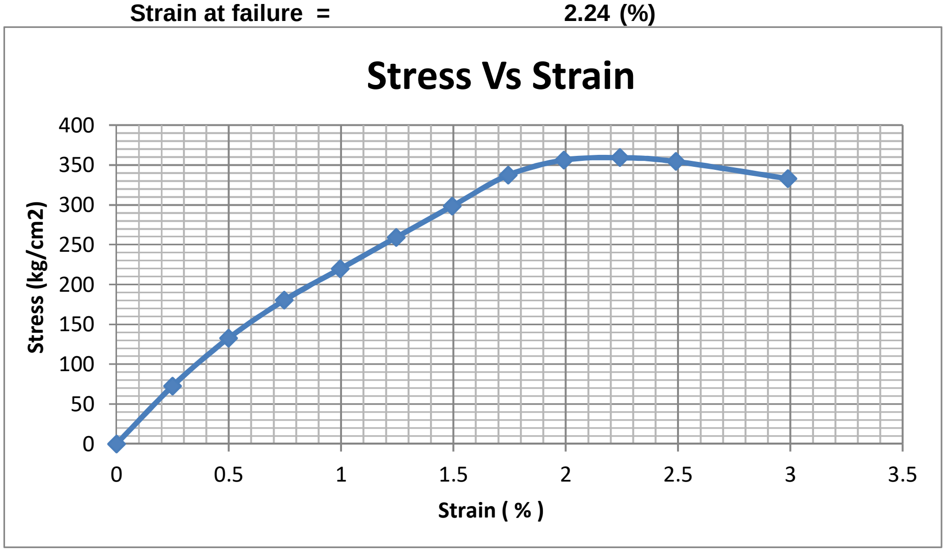
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	21days

Moisture Content (%):-	23.10
Bulk Unit Weight (g/cm^3):-	1.96

qu = **359 kpa**
C = qu/2 = **180 kpa**
Strain at failure = **2.24 (%)**



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Kechene Hidasie Health Center
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

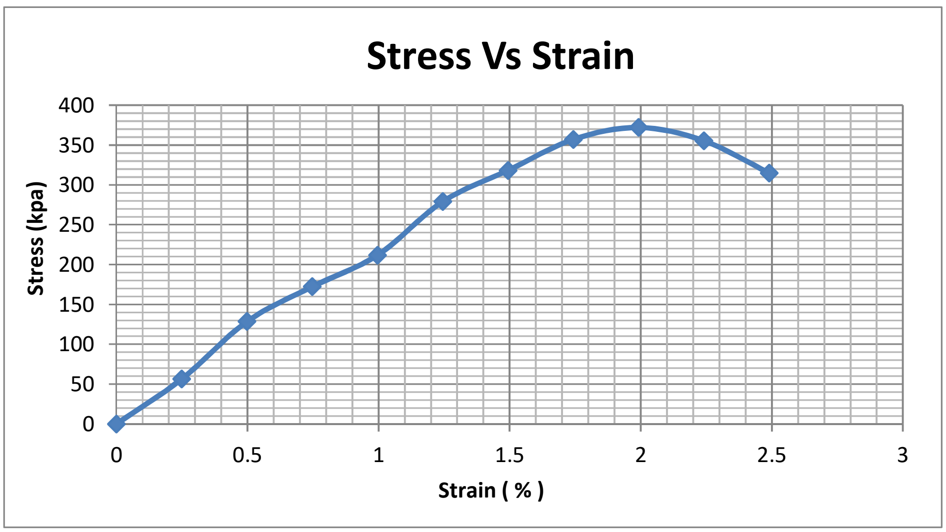
Curing Time :-	30days

Moisture Content (%):-	23.10
Bulk Unit Weight (g/cm^3):-	1.96

qu = **372 kpa**

C = qu/2 = **186 kpa**

Strain at failure = **1.99 (%)**



	Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering	

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Kolfe Police training Center
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

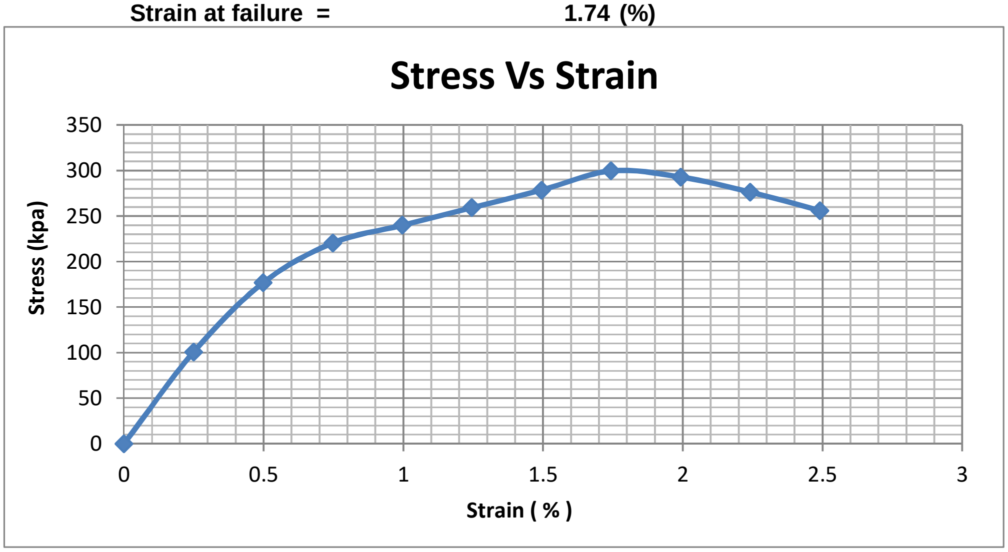
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	7days

Moisture Content (%):-	31.33
Bulk Unit Weight (g/cm^3):-	1.77

qu = **300 kpa**
C = qu/2 = **150 kpa**
Strain at failure = **1.74 (%)**



	ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING	

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil

Test Pit No. C

Sampled /Tested by: Dagnachew Seifu

Depth: 2m

Location: Kolfe Police training Center

Terrazyme application: **Stabilized**

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

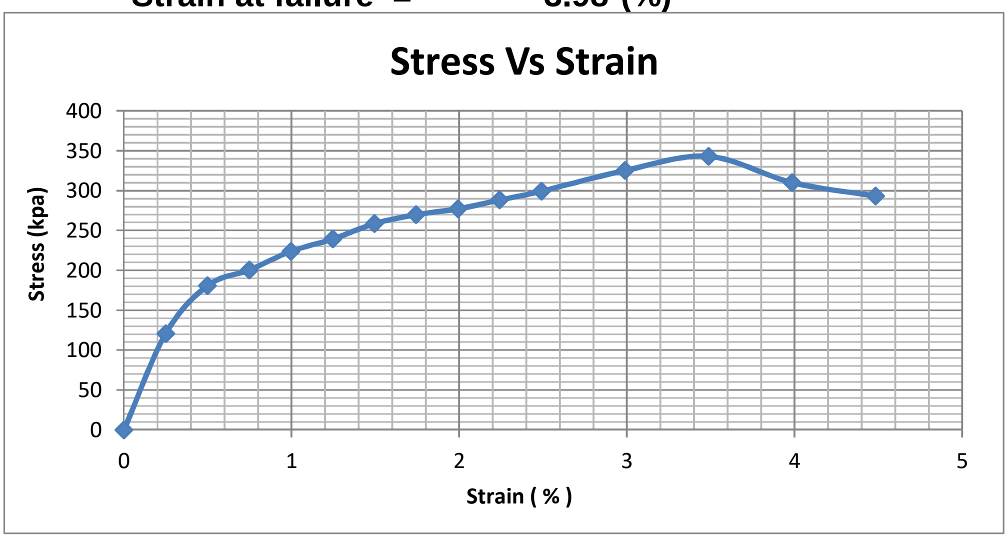
Curing Time :-	21days

Moisture Content (%):-	31.33
Bulk Unit Weight (g/cm^3):-	1.77

qu = 343 kpa

C = qu/2 = 171 kpa

Strain at failure = 3.98 (%)



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Kolfe Police training Center
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

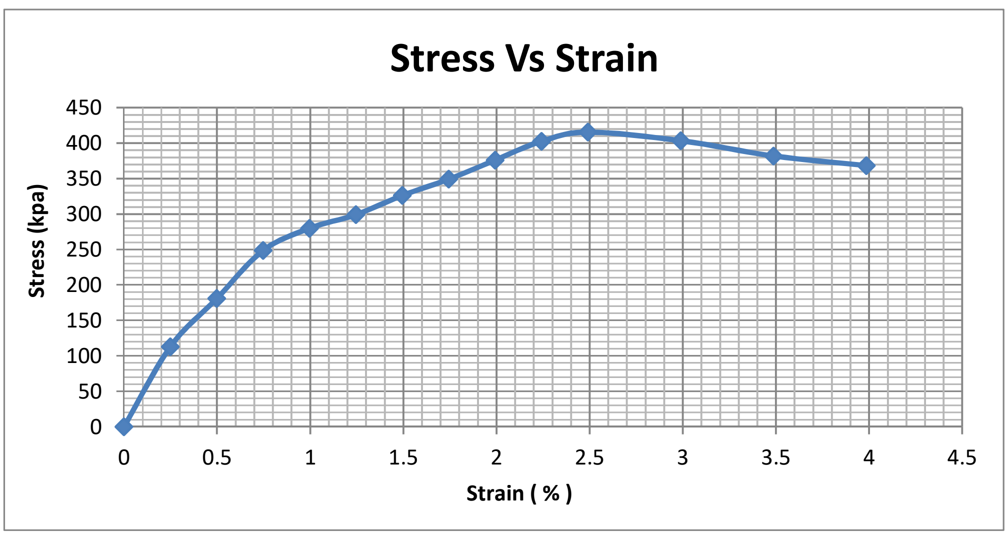
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	30days

Moisture Content (%):-	31.33
Bulk Unit Weight (g/cm^3):-	1.77

qu = **415 kpa**
C = qu/2 = **208 kpa**
Strain at failure = **2.49 (%)**



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Semen Gebeya
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

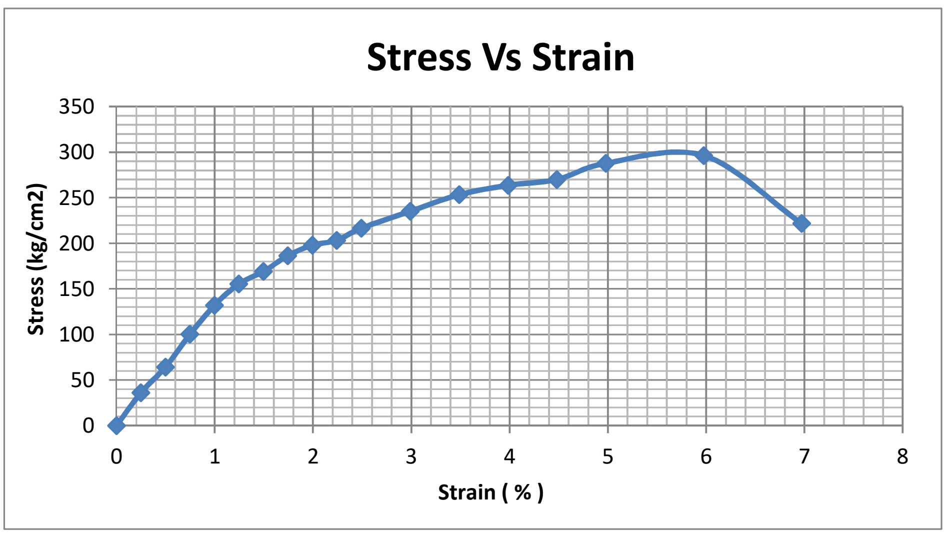
Curing Time :-	7days

Moisture Content (%):-	27.00
Bulk Unit Weight (g/cm^3):-	1.84

qu = **296 kpa**

C = qu/2 = **148 kpa**

Strain at failure = **5.99 (%)**



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Semen Gebeya
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

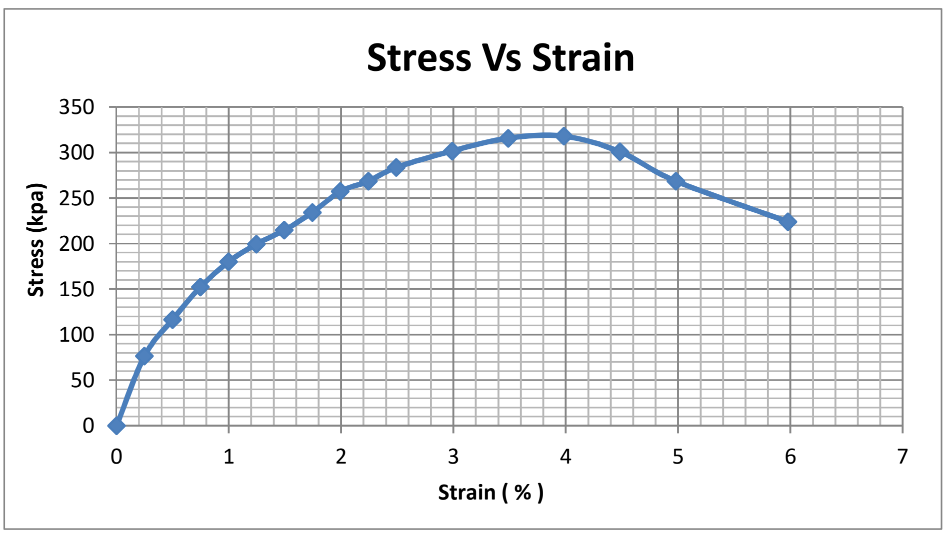
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	21days

Moisture Content (%):-	27.00
Bulk Unit Weight (g/cm^3):-	1.84

qu = **318 kpa**
C = qu/2 = **159 kpa**
Strain at failure = **3.98 (%)**



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Test Pit No. C
Sampled /Tested by: Dagnachew Seifu
Depth: 2m
Location: Semen Gebeya
Terrazyme application: **Stabilizer**
Date :

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

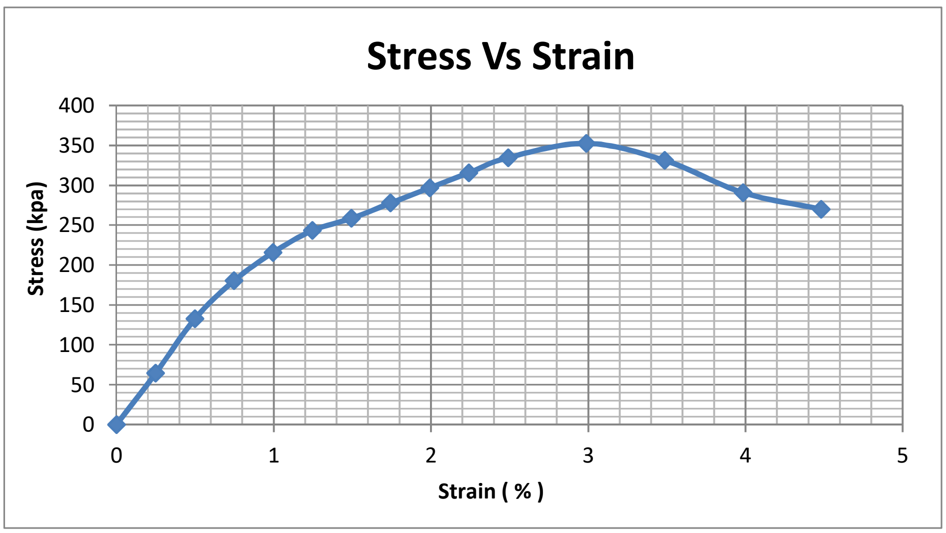
Curing Time :-	30days

Moisture Content (%):-	27.00
Bulk Unit Weight (g/cm^3):-	1.84

qu = **353 kpa**

C = qu/2 = **176 kpa**

Strain at failure = **2.99 (%)**



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Intoto Technical and Vocational poly technique college
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

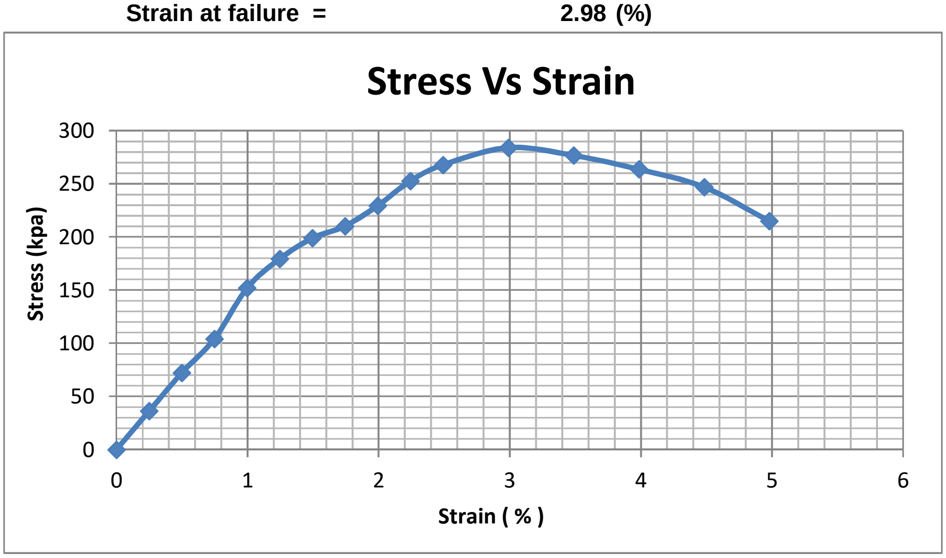
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	7days

Moisture Content (%):-	27.11
Bulk Unit Weight (g/cm^3):-	1.87

qu = **284 kpa**
C = qu/2 = **142 kpa**
Strain at failure = **2.98 (%)**



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title :	Chemical stailzation of Red Clay Soil	**Test Pit No.**	C
Sampled /Tested by:	Dagnachew Seifu	**Depth:**	2m
Location:	Intoto Technical and Vocational poly technique college		
Terrazyme application:	**Stabilized**		

Unconfined Compressive Strength of Soils

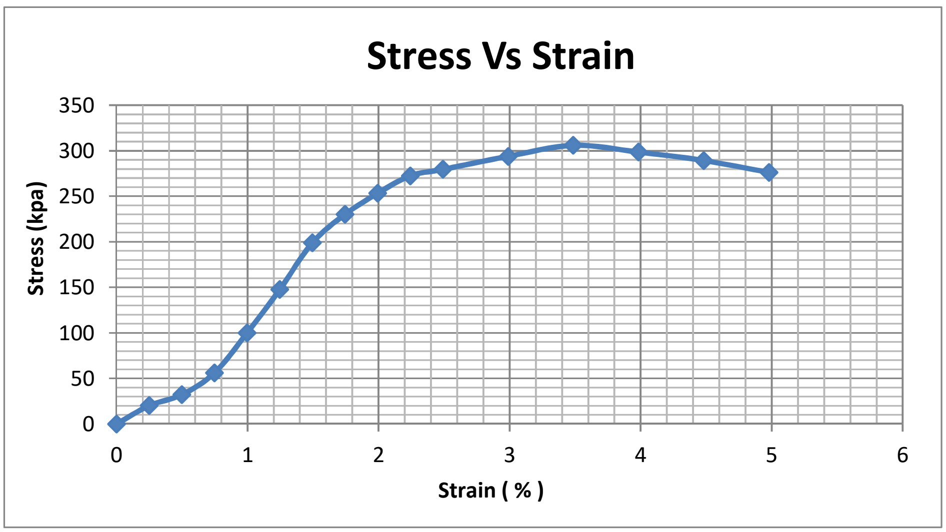
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	21days

Moisture Content (%):-	27.11
Bulk Unit Weight (g/cm^3):-	1.87

qu =	**305.95**	**kpa**
C = qu/2 =	**152.97**	**kpa**
Strain at failure =	**3.49**	**(%)**



Addis Ababa University
Addis Ababa Institute of technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Intoto Technical and Vocational poly technique college
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

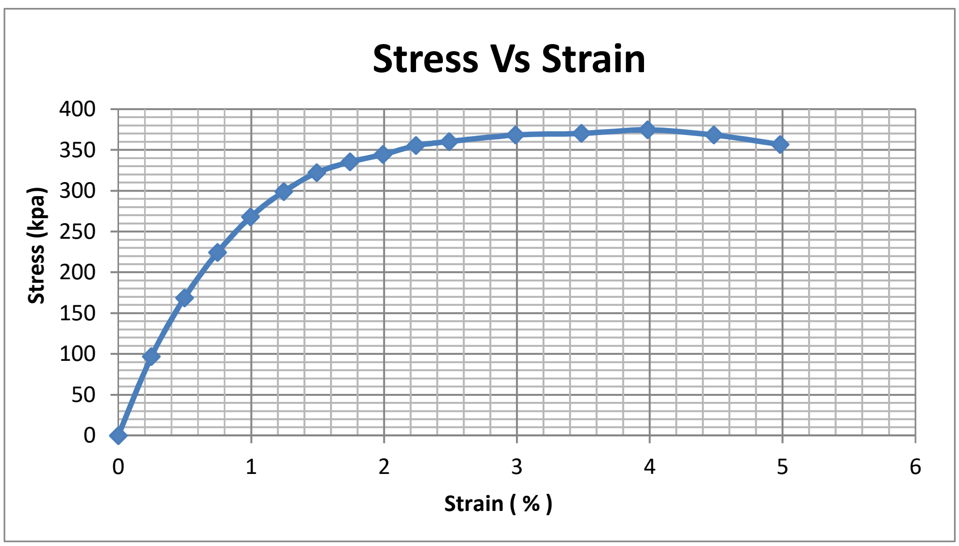
TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	30 days

Moisture Content (%):-	27.11
Bulk Unit Weight (g/cm^3):-	1.87

qu = **375 kpa**
C = qu/2 = **187 kpa**
Strain at failure = **3.98 (%)**



	Addis Ababa University Addis Ababa Institute of technology School of Civil and Environmental Engineering	

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Total Addisu Gebeya
Terrazyme application: **Stabilized**

Test Pit No. B
Depth: 2m

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

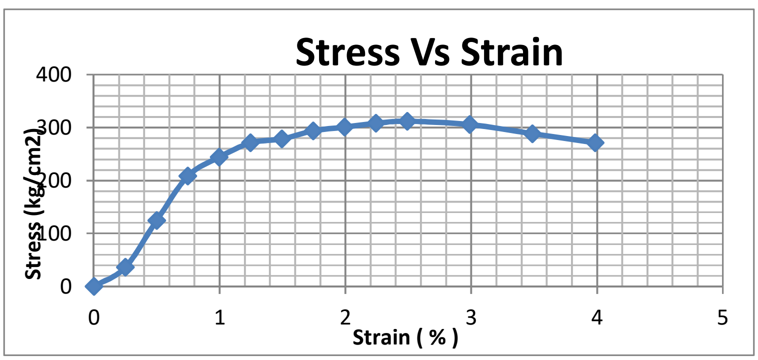
Curing Time :-	7days

Moisture Content (%):-	25.76
Bulk Unit Weight (g/cm^3):-	1.94

qu = **312 kpa**

C = qu/2 = **156 kpa**

Strain at failure = **2.49 (%)**



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Total Addisu Gebeya
Terrazyme application: **Stabilized**

Test Pit No. B
Depth: 2m

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

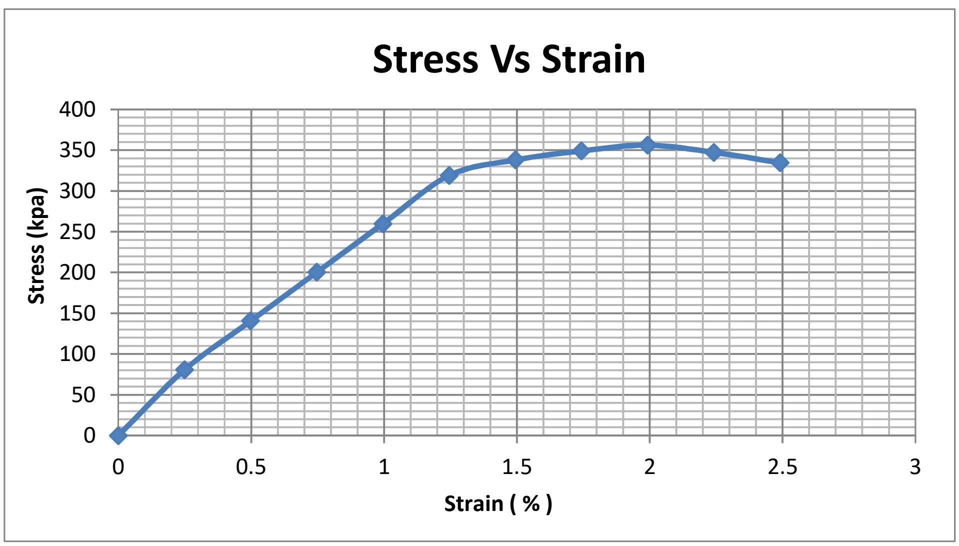
Curing Time :-	21days

Moisture Content (%):-	25.8
Bulk Unit Weight (g/cm^3):-	1.94

qu = **356 kpa**

C = qu/2 = **178 kpa**

Strain at failure = **1.99 (%)**



	ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING	

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Total Addisu Gebeya
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

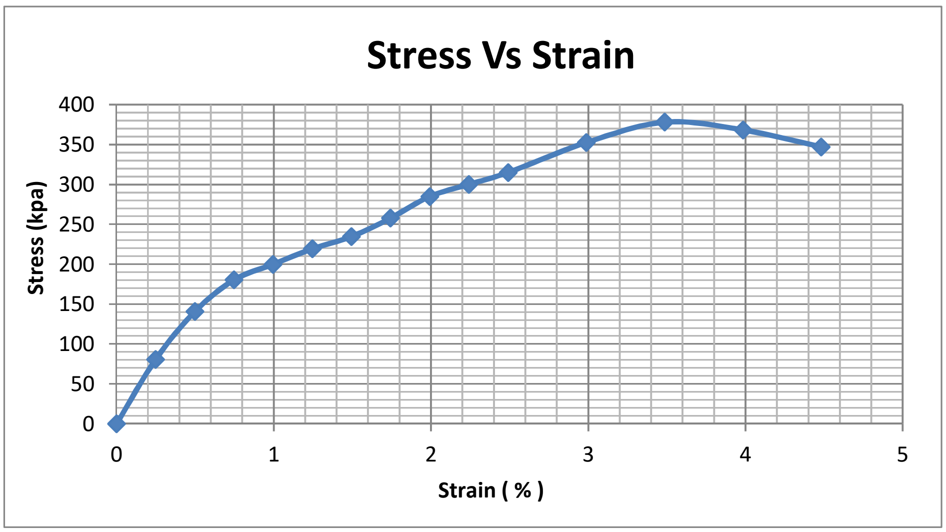
Curing Time :-	30days

Moisture Content (%):-	25.76
Bulk Unit Weight (g/cm^3):-	1.94

qu = **378 kpa**

C = qu/2 = **189 kpa**

Strain at failure = **3.49 (%)**



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Laboratory Test Result

Title : Chemical stailzation of Red Clay Soil
Sampled /Tested by: Dagnachew Seifu
Location: Total Addisu Gebeya
Terrazyme application: **Stabilized**

Test Pit No. C
Depth: 2m

Unconfined Compressive Strength of Soils

TEST METHODS: AASHTO T 208-92

Diameter of Sample (cm):	5.1
Height of Sample (cm):	10.2
Area of Sample (cm^2):	20.4
Volume of Test Sample (cm^3):	208.4

Curing Time :-	30days

Moisture Content (%):-	25.76
Bulk Unit Weight (g/cm^3):-	1.94

qu = **378 kpa**
C = qu/2 = **189 kpa**
Strain at failure = **3.49 (%)**