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JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

GEOTECHNICAL ENGINEERING STREAM

STABILIZATION OF EXPANSIVE SOIL FOR SUBGRADE USING CEMENT: A CASE OF GURAGE ZONE, ABESHIGE WOREDA

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Civil Engineering (Geotechnical Engineering)

By:

ABEBE BEKELE

December, 2021

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DECLARATION

I declare that this thesis entitled "**STABILIZATION OF EXPANSIVE SOIL FOR SUBGRADE USING CEMENT: A CASE OF GURAGE ZONE, ABESHIGE WOREDA**" is my original work, and has not been presented any other person for an award of a degree in any University or elsewhere. All sources of material used for this thesis have to be duly acknowledged.

Mr. Abebe Bekele

Candidate: Signature ________ Date 18/02/2022

As a thesis Research Advisor, we hereby certify that we have read and evaluate this MSc. thesis prepared under our guidance, by Mr. Abebe Bekele Ashebo "**STABILIZATION OF EXPANSIVE SOIL FOR SUBGRADE USING CEMENT: A CASE OF GURAGE ZONE, ABESHIGE WOREDA".** *We* recommended *that it be submitted as fulfilling the thesis requirement.*

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As member of board of examiners of the MSc Thesis open defense examination, we certify that we have read, evaluated the thesis prepared by Abebe Bekele Ashebo and examined the candidate. We recommended that the thesis could be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Civil Engineering (Geotechnical Engineering).

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ABSTRACT

Soil stabilization is one of the ground improvement methods of treating expansive soils. The expansive soil is a serious threat as it possesses seasonal variations on moisture content.Most parts of Ethiopia are covered by expansive soils. This type of soil leads to severe damage to pavements and foundations of structures. A lot of infrastructures like pavements and buildings were damaged due to this problem.Hence, the soil on which the structuresare to be built must be capable of withstanding the load imposed on it. In order to minimize this problem, it needs to be stabilized. Therefore, this research aims to evaluate the effect of an addition of cement to improve the expansive soils for subgrade use and to determine the optimum percentages of cement for stabilizing expansive soils in the study area. To achieve the objective of this research experimental method was applied after collecting representative soil samples. Three soil samples were collected from three different Keble's found in Abeshige Woreda, Gurage Zone, Ethiopia and index and engineering properties of soils wereconducted on original soils followingAmerican Association of Highway and Transportation Office (AASHTO) procedure.To improve the weak subgrade soil obtained from study area natural soil was mixed with different percentages of cement by weight starting from 4 up to 16% of cement and itseffects on Atterberg limits, free swell index, Modified proctor test, California Bearing Ratio, and swell were studied.Based on laboratory test results from natural soils before treatment the soils obtained from study area were considered as expansive clay soils. The result indicatedthat the proportion of fines passing no 200 sieve 95.45,92.33, and 92.2%, liquid limit 99.6, 89.80, and 95.90%, and plasticity index 59, 59.80, and 61.4%, the free swell index of 110, 90.9, and 90%, the California Bearing Ratio and percent swell with 0.6, 0.8, 0.90% and 13.70, 12, and 10.80% for Abuko, Bedo, and Fintjeju Keble soil samples respectively. Soil samples are classified into A-7-5 as per the American Association of Highway and Transportation Office (AASHTO)and high plasticity clay soil (CH) as perUnified Soil Classification System (USCS) classification system. An addition of cement on natural soil decreases the liquid limit, increases plastic limit and decreases plasticity indexes (PI) by 71.02, 89.80, and 88.11% for (Abuko, Bedo, and Fintjeju Keble) respectively. The maximum dry density (MDD) shows a slight increase and the optimum moisture content (OMC) shows a decrease in the treatment of weak subgrade soil with addition of cement. California Bearing Ratio values increased from 0.6 to 45.20%, 0.8 to 57.9%, and from 0.9 to 54.5% for Abuko, Bedo, and Fintjeju Keble's soil samples, respectively.It has been confirmed that 12% cement is an effective chemical stabilizer to improve both the index and strength properties of the soil of the study area.Despite the fact that this thesis work is limited in terms of time and budget, it is hoped that the finding will serve as a good starting point of the future.

***Keywords**: Expansive soils, Cement, stabilization, subgrade*

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ACRONYMS

AASHTO	American Association of Highway and Transportation Office
ASTM	American Society of Testing and Materials
YB	Bulk density of soil
CBR	California Bearing Ratio
DFS	Differential Free Swell
YD	Dry density of soil
ERA	Ethiopian Road Authority
FSI	Free Swell Index
FST	Free Swell Test
G	Gram
IS	Indian Standard
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
JIT	Jimma University Institute of Technology
LL	Liquid Limit
M.A.L	Mean Above Sea Level
MDD	Maximum Dry Density
Mc	Mass of Can
NMC	Natural Moisture Content
OMC	Optimum Moisture Content
PI	Plasticity Index
PL	Plasticity Limit
Gs	Specific gravity
USCS	Unified Soil Classification System
Vk	Volume of kerosene
Vw	Volume of water
Wds	Weight of dry soil
Wws	Weight of wet soil

1. INTRODUCTION

1.1 Back Ground of the Study

In the field of Civil Engineering, nearly all projects are built on, or into, the ground.However, the soil on which the structure must be able to take the load imposed on it must be able to hold that load. Thus, during the planning, design, and construction of these projects' engineers must give great attention. All geotechnical engineers must understand the properties of soils and identify the soil types. Expansive soils are clayey minerals which exhibit significant volume changes when subjected to moisture variations [1].The presence of montmorillonite contributes to high swell-shrink potentials [2].In the tropical region, these soils could be lateritic soils, black cotton soils, collapsible soils or any other tropical soils[2].

In many parts of the world, this soil is problematic and causes extensive damage to Civil Engineering structures. Since then, documented evidence of the existence and problems associated with expansive soils has occurred in countries like Australia, Africa, India, and the USA [3]. Expansive soils are widely spread in African countries, occurring in South Africa, Kenya, Mozambique, Morocco, Ghana, Nigeria, Ethiopia, etc. In Ethiopia, the following trunk roads like Addis-Ambo, Addis-Woliso, and Addis-Debrebrihan, and some parts of Mekele, Gondar, Bahir Dar, and Gambella are also known to be covered by expansive soils [4].

Soil stabilization means any process which leads to change and improves the soil properties, so engineers can use it in their construction without failure [5]. Several methods are used to improve the properties of soils, such as the stability, strength, and load bearing capacity, as well as durability.Therefore, the aim at soil stabilization is that improve soil strengthand toincrease the soil particles' water proof[6]. Even though, the common solutions to encountering such problems include excavation and replacement of soil, or chemical stabilization. Since, the excavation and replacement of soil becomes very expensive, especially when usable soils have to be hauled a significant distance[5].The problematic soil is removed and replaced by good quality materials or treated using mechanical or chemical stabilization. Moreover, soil stabilization can be accomplished by several methods, such as mechanical stabilization as well as chemical stabilization methods [5].In order to treat this problem, stabilization should be implemented with different stabilizing additives to achieve the required specification of road sub-grade materials.

However,severalsoils which exhibit swells and shrinking characteristics have expansive clay minerals, such as smectite, that absorb water, the more of this clay a soil contains, the higher its swelling potential and the more water it can absorb [9]. The feasible alternative to counter this problem is either to improve the locally available black cotton or to shrink-swell soil materials with stabilizing agents such as cement[6]. Hence, black cotton soils are clay soils with high plasticity,which are commonly black or gray in color.These soils possess a high plasticity index [7] and their color varies from dark grey to black. A difficult problem ofCivil Engineering exists when the subgrade is found to be clay soil.In practice, the problem associated with swelling (expansive soils) contributes to the establishment and development of various techniques for improving their low engineering performance[8, 9].

These soils occurred in (Abeshige Woreda), particularly in Abuko, Bedo, and Fintejeju(Keble’s), and their surrounding areas.

Since, much literaturehas been reviewed for the effectiveness and to what percentage content of cement as a stabilizer to improve different problematic soils in different part of the world [12].However, in several locations in tropical countries, such as Africa and India, black cotton soils exist [12].This soil show very strong swelling and shrinkage characteristics under changing moisture conditions[13, 14]. The main objective of thisis to investigate the stabilization potential for expansive soil for subgrade using cement a case of (Abeshige Woreda), particularly three (Keble’s) reported above.

However, someresearches have been done on blending lime with cement, fly ash andsand with cement there is little improvement but the presentedresearch work have been focused using cement alone to improve engineering properties of soilfound in the study area this shows that better improvement rather than other available materials. The study area is new not done before. The expansive soil found in this study area was very problematic soil and needs good material to improve it that is why the researcher had chosen cement rather than other material. The other main reason that made the researchers decide to study the Gurage Zone in (Abeshige Woreda) especially in Abuko, Bedo, and Fintjeju (Keble’s), is that: repeatedly failure of existing road subgrade soils during the rainy season of different stations to bring solution to solve theproblem the study area.Therefore, the findings can be used as guide to select chemical additives (stabilizer), and amount based on engineering properties of soils and the desire strength (CBR) and even if,it has its own scientific contributions to improve engineering properties of expansive soils found in the study area.

1.2 Statement of the Problem

The swell and shrinkage distinctiveness of expansive soil causes significant damage to structures such as buildings and pavements [1]. The strength of subgrade soil is a major factor for the performance of asphalt pavement. So, the movement of the subgrade is one of the causes of road pavement failure. Road failure of study area or Abeshige Woreda road could be in the form of cracks, potholes, surface deformation, surface defects which make the road network unsafe and not suitable to the road users. On the other hand, during the construction of road, the existing soil material should require special attention to be used as a subgrade of pavement in order to reduce the problem due to expansiveness. Since, volumetric changes weaken the subgrade by inducing cracking which metes out damage to the overly structures [3].

Since, black cotton soils have complicated behavior and are generally characterized by detrimental volume changes when subjected to moisture fluctuations [17]. The aerial coverage of expansive soils in Ethiopia are estimated to be 18.9 million hectares[18].The swelling potential forblack cotton soil highly dependentonsoil properties, environmental factors, and stress conditions [19]. Instead of borrowing a suitable soil from long distance it is economical to use locally available expansive soil after stabilization with cost effective local materials to bring immediate solution to overcome challenges. Moreover, most soil which is found in Abeshige Woreda has high plasticity index and low CBR value. As a result, they make pavement structure failure.

The aim of this study was to investigate the engineering properties of stabilizing of expansive soil for subgrade using cement a case of Gurage Zone, Abeshige Woreda in addition to this to minimize the environmental hazards. Attempt made to analyze the causes of failure of roads constructed on poor subgrade soils had been investigated by representative test pit samples from the selected sites for the study area. The study focused on Abeshige Woreda Particularly three Keble’s road.

1.3 Research Question

The study main goal is to answer the following research question:

1) What are the index and engineering properties of natural soils found in the study area?
2) What are the effects of an addition of cement to the expansive soils of the study area?
3) What is the optimum percentage of cement to stabilize expansive soils found in the study area?

1.4 Objectives

1.4.1 General Objective

The aim of the study isto investigate stabilization potential of expansive soil for subgrade using cement in Gurage Zone of Abeshige Woreda, particularly three Keble's.

1.4.2 Specific Objectives

The specific objectives of the study are;

- To determine the index and engineering properties of natural soils found in the study area.
- To evaluate the effect of the addition of cement in improving the expansive soils of study area.
- To determine the optimum percentage of cement for stabilizing the expansive soils of the study area.

1.5 Scope of the Study

This study aimed at improving the problematic soils found in the Abeshige Woreda, particularly Abuko, Bedo, and Fintjeju Keble's roads, by using cement. The study concentrated on determining the physical properties of natural soils before treatment, the effect of the addition of cement by varying percentagesof 4 to 16% by weight, and evaluating the optimum percentage of cement used to stabilize the expansive soils found in the study area. To achieve the objectives of this study, both index and engineering properties of soils were conducted following both AASHTO and ASTM testing standards. All tests were conducted in the Geotechnical Engineering or Soil laboratory of Jimma Institute of Technology (JIT) and the Jimma University College of Agriculture and Veterinary Medicine soil laboratory (JUCAVM). Then the results were compared with ERA specifications. Finally, the results of the analysis, discussion, conclusion, and recommendation were discussed.

1.6 Significance of the Study

The purpose of stabilizing cement is to improve the geotechnical properties and in order to get a safe, stable and durable structure. Contractors, consultants and owners will be benefit from the study as a source of information for building construction and road construction projects, in the case of Gurage Zone, (Abeshige Woreda), the area of required soil improvement and the existence of expansive soils.As a result, this study has aided construction firms and the researchers in better understanding and estimating the behaviorofthe expansive soil found in (AbeshigeWoreda). The findings can be used as guide to select chemical additives (stabilizer) and amount based on engineering properties of soils and the desire strength (CBR) and even if, it has its own scientific contributions to improve engineering properties of expansive soils found in the study area. In addition, other researchers will use the findings as a literature review and reference for further research into the stabilization of expansive soil for subgrade using cement a case of Gurage Zone, (Abeshige Woreda).

1.7 Limitation of the Study

Experimental study of expansive soil geotechnical characteristics is abroad experimental analysis. Therefore, the study has got certain limitations. This study was aimed to focus only stabilization of expansive soil for subgrade, and limited to Gurage Zone, Abeshige Woreda particularly three Keble’s only due to difficult to transport the materials (Samples) from study area. The study was conducted by taking only limited geotechnical properties of expansive soil (Atterberg limits, free swell, moisture density relation, CBR and CBR swell potential on stabilization by cement.) In addition, the study is not including the chemical properties of soil due to time.

1.8 The thesis Organization

The thesis is structured into five main sections, along with an appendix incorporated at the end of the thesis. The first part deals with the background of the research and why the research has been conducted. It states the background of the study, the reasons for carrying out this research, the problem statement, and objectives of the study. The second partliterature reviews relating expansive soil and thestabilization mechanisms that can accompany it. The thirdsection explains the study area, research methodology, and types of tests proposed to be conducted. Section four explains in detailhow laboratory tests results and findings are briefly tabulated. Under section five,conclusions and recommendations were conducted.

2. REVIEW OF LITERATURE

2.1 Source of Expansive Soils

Expansive soils, occurring in arid and semi-arid climate of regions of the world causes serious problems in civil engineering structures. Such soils swell when given access to water and shrink when they dry out. Expansive soils have a complicated behavior and are generally characterized by detrimental volume changes when subjected to moisture fluctuations [1].These problematic soils do not possess enough strength to support the wheel loads placed upon them, either during construction or during the service life of the pavement [3, 34]. These soils must be, therefore, treated to provide a stable subgrade or a working platform for the construction of the pavement. Soils containing a high concentration of clay mineralsconsiderable will exhibit high swelling and shrinkage characteristics [13, 16]. If not properly handled, it is the most problematic soil.

Detail information of the expansive soil will aid in the development of a method for improving the soil's nature. The amount and type of clay mineral particles in the soil influence how expansive the soil is.The parent materials for expansive soils can be classified into two. The first group comprises basic igneous rocks. This group comprises minerals named feldspar and pyroxene. The decomposition of the mineral forms an important mineral called smectite (montmorillonite) and other secondary mineral. The formation of montmorillonite was probably the volcanic eruptions sending up clouds of ash felt on the plains and the seas with the ashes to be altered to montmorillonite [13]. The presence of montmorillonite clay in these soils imparts them high swell-shrink potentials.

So far, damage to buildings, roads, and railways built on expanding soils has been documented. This is owing to the expansive soil's swell-shrink tendencies when exposed to changes in moisture.To solve this problem, stabilization should implement with different stabilizing additives to achieve the required specification of sub-soil materials [34]. As a result of this, a variety of factors, most light buildings built on expansive soils are subjected to moisture change. One of the causes of moisture change is a faulty drainage system. This causes the expansive soils to swell[11, 13]. To overcome, this problem treating the expansive soil with cement is very important in improving the engineering properties of soil. In addition to this, in order to get good bearing capacity of the soil in the study area this stabilization method is very important.

Subgrades are usually consisted of locally available deposits that sometimes might be very weak or very wet with low strength /stiffness to support the pavements traffic loading. The strength of subgrade soil is a major factor for the performance of asphalt pavement. Roads constructed on expansive soil areas known by as bad conditions and unpredictable behavior for which the nature of the sol contributes to some extent. The failures of pavement, in the form of heave, depression, cracking, and unevenness are most likely to happen by expansive soil in the subgrade [1, 34].So, the movement of the subgrade is one of the causes of road pavement failure.This characteristic causes considerable construction defects if not adequately tookinto consideration. In this case; expansive soils are those clay soils which exhibit significant volume changes as a result of soil moisture variation [23]. During construction it is recommended that all subgrades should be compacted to a relative density of at least 95% of the MDD achieved in Modified Proctor Test. Compaction not only improves the subgrade bearing strength but also reduces permeability and subsequent compaction by traffic.

The performance of a pavement depends on the quality of its subgrade and existing condition of road bed. The performance of a pavement depends on the quality of its subgrade and existing condition of road bed [24, 34]. Since,documented evidence of the existence and problems associated with expansive soils has occurred in countries like Australia, Africa, India, andthe USA [3]. Hence, expansive soils are widely spread in African content, occurring in South Africa, Kenya, Mozambique, Morocco, Ghana, Nigeria, Ethiopia, etc. In Ethiopia, the following trunk roads like Addis-Ambo, Addis-Woliso, and Addis-Debrebrihan, and some parts of Mekele, Gondar, Bahir Dar, and Gambella are also known to be covered by expansive soils [4].

The expansive soil found in the study area was very problematic soil and needs good material to improve it that is why the researcher had chosen cement rather than other material. The other main reasons that made the researchers decide to study the Gurage Zone in Abeshige Woreda especially in Abuko, Bedo, and Fintjeju Kebles, is that: repeatedly failure of existing road subgrade soils during the rainy season of different stations to bring solution to the problem withthe study area.Therefore, the findings can be used as guide to select chemical additives or stabilizer and amount based on engineering properties of soils and the desire strength (CBR). To overcome, this problem treating the expansive soil with cement is very important in improving the engineering properties of soil. In addition to this, in order to get good bearing capacity of the soil in the study area this stabilization method is very important.

Soil stabilization means any process which leads to change and improves the soil properties, so engineers can use it in their construction without failure. Several methods are used to improve the properties of soils, such as; stability, strength, and load bearing capacity, as well as durability.As in other countries, black cotton soil is a problem of Ethiopia as well. There are several roads whose failures were attributed to volumetric change in expansive soil [25].Soil stabilization is defined as physical or chemical treatment to maintain stability or to improved soil material possessing the desired engineering properties [7]. The process may include blending of soils to achieve a desired gradation or mixing of available additives that may alter the gradation, texture, plasticity or act as a binder for cementation of the soil[19].Since, cement is one of the most common additives used as a stabilizing agent for expansive soil. Even though, changing seasonal conditions is usually responsible for these fluctuations in soil moisture content. The variation in the soil's volume causes vertical or horizontal deformation of the ground[25, 32].Since then foundations constructed on black cotton soils are subjected to large uplifting forces caused by the swelling. Most of the structural damage due to expansive soils from the differential rather than the total movements towardsthe foundation soils as swelling[26].

According to the researcher[14] his review construction of pavement on weak or soft subgrade soil is risky because such soil is susceptible to differential settlements, poor shearing strength, and high compressibility. According to [34] suggested that the strength of road subgrade for flexible pavement is commonly assessed in terms of CBR and this is dependent on the type of soil, its density, and its moisture content. In addition to this, the strength or CBR values of the subgrade soil beneath the completed road pavement are usually difficult [35].

The expansive soil can result in enormous damage to buildings and roads [16]. A summary of these issues is provided by [29] in his review of how different countries deal with expansive soil problems. Even though, the extent or depth of this zone may depend on the geo-climatic conditions of the region [29]. However, the reduction in the volume change of expansive soils can be done by one of the several methods that are practiced.Since, it is often more economical to treat subgrade soils. So that, pavement designs are considered based on an include sub-grade construction on embankments and in slopes. Consequently, when dealing with black cotton soils a number of approaches should be considered and included as follows.

- Choose an alternative route and avoid expansive soil.
- Remove and replace expansive soil with a non-expansive alternative
- Physically alter expansive soils through disturbance and re-compaction
- Stabilization through chemical additives, such cement treatment
- Control water content changes although very difficult over the life of pavement

2.1.1 Composition of Clay Mineralogy

Clay minerals contribute to the expansiveness of soils and have a diameter of less than 0.002mm. Clay has the great rolls for expansive behavior of the soil. Clays are composed of extremely small crystalline particles of one or more members of a small group of minerals. These minerals are essentially hydrous aluminum silicates, with magnesium or iron replacing wholly or partially for the aluminum. Therefore, the most important grain property of fine grain soil is its mineralogical composition [29]. These bonds are either ionic or covalent, and actual bonds in silica and aluminium sheets are combinations of these two types of bonds[28].

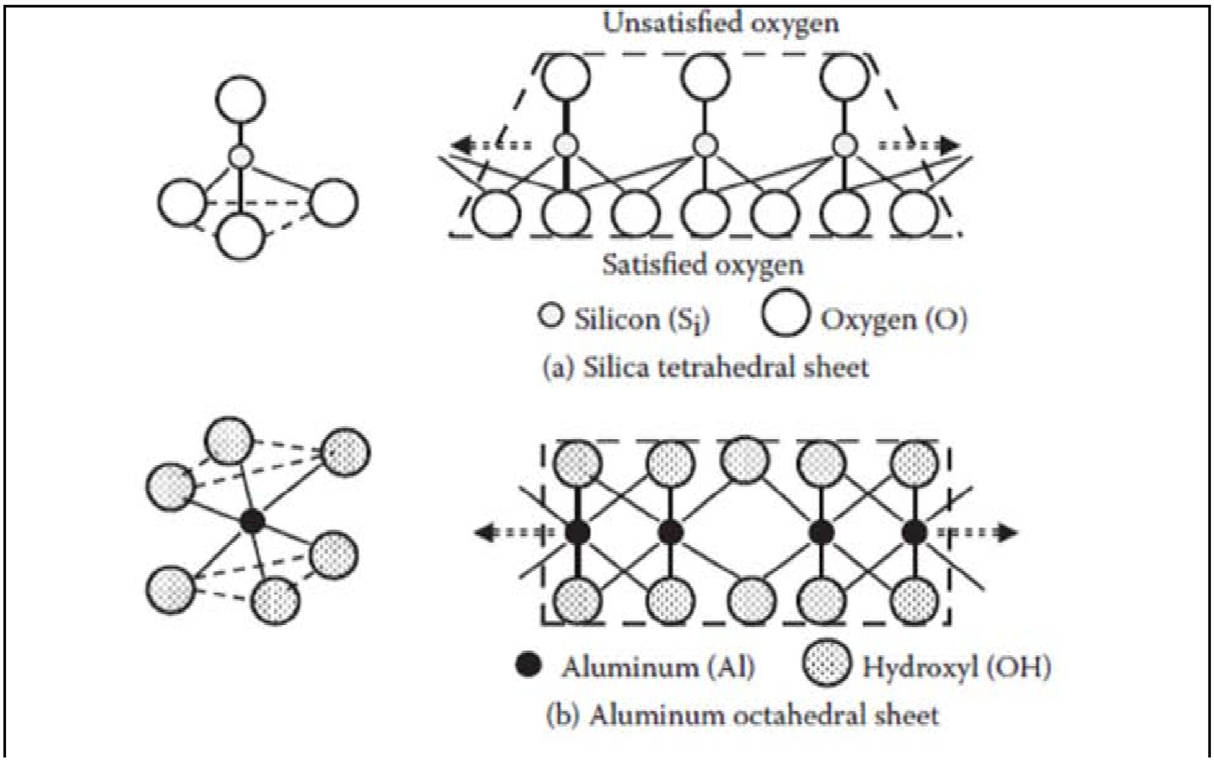


Figure 2-1 Silica tetrahedral sheets and Aluminum octahedron sheets

Most minerals of interest in geotechnical engineers are composed of oxygen and silicon. Silicates are a group of minerals with a structural unit called the Silica Tetrahedral[28]. The three most important groups of clay minerals are montmorillonite, illite, and kaolinite, which are crystalline hydrous alumina-silicates with the help of X-ray technology minerals are identified [21].

2.1.1.1 Kaolinite Group

The general mineral structural formula of Kaolinite group is$Al_4Si_4O_{10}(OH)_8$. Kaolinite is the common clay in humid tropical region and the least active of the three clay minerals [5]. Kaolinite is another group of clay mineralogy that consists of one silica sheet and one alumna (1:1). The layers of these structures are held together by hydrogen bond. Kaolinite has few or no exchangeable and interlayer bonds are relatively preventing any hydrogen between layers and allowing many layers to build up [13].

2.1.1.2 Montmorillonite Group

Montmorillonite is more colloidal than kaolinite and more active mineral [28]. The general mineral structural formula of Kaolinite group is$Al_4Si_8O_{10}(OH)_4nH_2O$. The structural arrangement of this mineral is composed of two silica tetrahedral sheets with a central alumina octahedral sheet (2:1). Water can enter between the sheets, causing them to expand significantly and thus the structure can break into $10A^0$ thick structural units. Soils containing a considerable amount of montmorillonite minerals will exhibit high swelling and shrinkage characteristics [13]. Bentonite clay mineral belongs to the montmorillonite group and the general chemical formula is Al_2 [Mg] (Si_4O_{10}) $(OH)_2$+ XH_{20}. Weak Vander Waals forces to hold layers together and the bonding of these sheets is rather weak, resulting in a rather unstable mineral, especially when wet [16]. In fact, this type of clay mineral displays a significant affinity with water, with subsequent swelling and expansion [13].

2.1.1.3 Illite Group

Illite is medium active mica like clay minerals and a predominant constituent of many shells. The potassium ion (K+) occurs between to unit layers.The general mineral structural formula of illitegroup isKy(AlFe2.Mg4.Mg6)Si8-yAly(OH)O20. It does not swell as much with the presence of water as montmorillonite [8].In addition to this in illite group, the layers are separated by potassium ion, whereas, above mentioned clay minerals the layers are separated by loosely held water and exchangeable metallic ions [20]. Unlike montmorillonites particles, which are extremely small and have a great affinity with water, illite particles will normally aggregate and thereby develop less affinity for water. The layers of illite clay minerals are linked together by fairly weak bonding with potassium ions held between them [31, 32].

2.1.2 Characteristics of Expansive Soils

Generally, the expansive soils are found in the highlands and lowland of the Ethiopia. The characteristics and nature of expansive soilsis different. These weak subgradessoilwhich absorbs water heavily, swell, become soft and lose strength [32]. These soils are easily compressible when wetted and possess a tendency to heave during wet conditions and shrink away from volume and develop cracks during dry seasons [35]. Also, expansive soils in relation to their free swell index (FSI) are called highly expansive soils when the free swell index exceeds 50% and such black cotton or expansive soil undergo volumetric changes leading to several pavement distortion, and general in factthat seasonal wetting and drying [13].

The general characteristics of Black Cotton as follows:Easy to recognize these soils in the field during either in dry or wet seasons.Shrinkage cracks are visible to the ground surface during dry seasons.The maximum width of these cracks may be up to 20mm or more and they are travel deep into the ground.Black cotton soils requirea hammer to break.During rainy seasons, these soils become very sticky and very difficult to traverse.Even though, the key aspects of black cotton soils behavior are soil vulnerability water induced volume change.According to the researcher [33]review the swell-shrink potential for expansive soils is determined by initial water content and dry density. Generally, the larger the amount of these minerals presents in the soil, the greater expansive potential. Fine grain soils can absorb large quantities of water after rainfall, becoming sticky and heavy.

2.1.3 Identification of Expansive Soils

Expansive soils can be recognized by using mineralogical identification, indirect properties and direct expansion potential tests. Since, expansiveness of a soil is governed by the type and proportion of clay minerals it contains. Knowing the type and proportion of the clay mineral in a soil gives an indication on the swelling potential. Even though, from observed that the extremely small size of clay grains the minerals difficult to distinguish in either hand specimen or in graphic microscope. Due to a steep increase in construction activities in recent times, there is a need for a quick and simple method to facilitate civil engineers in evaluating and identifying the expansiveness and swelling potential of soils [13]. The identification of potential swelling or shrinking away from subsoil problems is an important tool for the selection of suitable foundations.

2.1.3.1 Field Identification

Expansive soils are often like clay, becoming very sticky when wetted and hard and brittle when dry. However, some of the important field identification methods that indicate the potential for expansiveness of soil are: a shiny fingernail, the wet sample of the soil is sticky and it is relatively difficult to clean the soil from the, appearance of in nearby usually have colors of black or gray.

2.1.3.2 Experimental Identification

Generally, there are three different methods of identifying expansive soil in laboratory.

i.Direct Method

The recommended the direct method of expansion potential measurement to recognize expansive soils since the test is simple to perform and does not require any expensive laboratory equipment. According to him, X-ray diffraction is principally used in determining the proportions of various minerals present in colloidal clay if supported by different thermal analysis and skimming electron microscopic it provides good results [17].

ii. Indirect Methods

This method is used to investigate the swelling potential of a soil by examining other parameters, which indirectly given information about the soil property. These include property tests, Cation Exchange Capacity (CEC), and Potential Volume Change (PVC) test [35].

iii.Mineralogical Methods

Type of clay mineral is a fundamental factor, which determines the expansive behavior of a soil. Mineralogical test is used to identify these minerals. There are a lot of factors that contribute to the swelling potential for the clay that has like the negative electric charges on the surface of the clay mineral, the strength of the interlayer bonding, and the cationexchange's ability. The most common of these techniques such as: Differential Thermal Analysis, X-Ray Diffraction, Dye Adsorption and Chemical Analysis. These different mineralogical identification methods are important to a research laboratory in exploring the basic properties of clays; they are impracticable and uneconomical for practicing engineers [13, 16].

2.2 Engineering Properties of Expansive Soil

2.2.1 Moisture Content

Expansive soil has higher affinity with water and the higher the more swell it exhibits [1]. Generally, the moisture content of the soil is the ratioof the mass of water in the sample and the mass of solid material [33]. The water content of the material is used in expressing the phase relationship air, water and solid in given volume of material. The natural moisture content of the soil is affected by, vegetation cover of the area and other artificial factors. The moisture content of subgrade soil is governed by the climate and depth of the water table below the road surface. Hence, the strength of the subgrade is classified into six subgrade strength classes [34].

According to the researcher [26], review the fine grain soils, the consistency which is a term used to indicate the degree of firmness of cohesive soils, of a given soil type depends on its water content and it can be very soft, soft, very stiff and hard. When the water content increases the consistency will be soft and as water decreases, it becomes hard the water content of the soil along with its liquid limit and plastic limits are used to express its relative termed liquidity index.

Table 2-1 Typical moisture contents of soils

Material	Moisture content
Gravel	2-10
Sand	5-15
Silt	5-40
Clay	10-50
Organic or peat	>50

2.2.2 Compaction of Soil

Compaction is the process whereby the volume of air in the soil is reduced. The compaction is normally achieved through the use of compaction equipment [9]. During this process solid particle become more closely spaced. This reduction of air volume of a mixture produces a corresponding increase in material unit weight, or density. Compaction is the greatest determining factor of dense graded pavement performance. Inadequate compaction results in a pavement with decreased stiffness, reduced fatigue life, accelerated aging / decreased durability, rutting, and moisture damage [18].

Compaction is a process that brings an increase in soil density, accompanied by a decrease in air volume with no change in water content [27]. The degree of compaction is measured by dry unit weight and depends on the water content and compaction effort (Weight of the hammer, number of impacts, the weight of roller and number of passes) for a given compaction effort, the maximum dry density occurs at optimum water content.

In this research study Ihave performed modified proctor test (AASHTO T-180). Mechanical compaction is one of the most common and cost effectives means the porosity (void ratio) of the soil and thus increases density. In general, most engineering properties of soil such as strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing soil density.

Also, the effects of compaction on the expansive soil: reduce the compressibility of the soil, thereby decreasing the tendency towards settlement of structures founded on these soils, increase the dry density of the soil, thus increasing its shear strength and bearing capacity.

Compaction of soil is measured in terms of the dry density of the soil which is the weight of soil solids per unit volume of the soil.Compacting soil waters content higher than or the optimum moisture content irrelatively dispersed soil structure or parallel particle orientations.

2.2.2.1 Density-Moisture Content-Strength Relationships of the subgrade

During road construction, the dry density of the subgrade soil and its moisture content modified from original state by compaction at the subgrade level (in cuts and by compaction of the excavated materials used in embankments). In addition to this, water content is adjusted to reach a maximum level of compaction [40]. Hence, the density of the compacted subgrade soil will remain approximately constant except for some residual compaction and certain moisture sensitive soils required in the design standard [34]. This relationship must be determined in the density of subgrade soil can be controlled within limits by compaction at suitable moisture content of the time of construction.

Table 2-2Subgrade strength classes

Classes	CBR Ranges (%)
S1	<3
S2	3-4
S3	5-7
S 4	8-14
S 5	15-30
S 6	>30

However, this structural standard manual requires which requires the strength of subgrade soil for design must be assigned to the six strength classes. However, from the above table according to subgrade strength class with S1 needs special treatment. Also, according to a researcher [35] the lower CBR values (less than 10), lead to the deflection of the subgrade material under traffic loadings.

2.2.3 Atterberge Limits

Swedish soils scientists Albert Atterberg originally defined seven "Limits of Consistency" to classify fine grain but in current engineering practice, only two the liquid and plastic limits are commonly used. A fine grain soil can exist on solid, semi-solid, plastic and viscous fluid state depending on its water content [8]. However, the liquid limit and plastic limits are widely used for engineering classification of fine grain soils.

The liquid limit and plasticity index of the soil are both used in determining the need for and type of subgrade stabilization. The liquid limitis used to classify the soil and the plasticity index is used as an indicator for the degree of stabilization that will be required and the most likely stabilization method that will be used. Soil with a plasticity index higher than 12% will typically require some form into stabilization according to[11].

i. Liquid Limit (LL)

Liquid limit of a soil is the boundary of plastic and liquid state. Liquid limit is determined in the laboratory by the Casagrande apparatus test.

ii.Plastic Limit (PL)

The plastic limits are a change in water is accompanied by a change volume of the soil mass. The plastic limits are the boundary of plastic and semisolid state. According to the Casagrande apparatus, the soil begins to disintegrate when rolled into threads of a specified size (3mm).

iii. Plasticity Index (PI)

The range of water contents between the liquid limit and plastic limit, which is an important measure of plastic behavior, is called the plasticity index. Plasticity index indicates the degree of plasticity of the soil. The greater the difference between the liquid limit and the plastic limits, the greater the plasticity of the soil. Cohesion less soilshas zero plasticity indexes. Such soils are termed as non-plastic soil.

2.2.4 Specific Gravity (Gs)

The specific gravity of the soil was expressed as the ratio of mass in the air of a given volume of soil particles of the weight in the air of an equal volume of distilled water at standard temperature. The specific gravity of the soil is used in calculating the phase relationships of soil water, and solids in a given volume of the soil. Specific gravity of soils an important quantity that is frequently used in the calculation of percentage finer and diameter of the soil grains in hydrometer analysis.

Table 2-3The specific gravity of the soil

Types of soils	Specific gravity
Gravel	2.65-2.68
Sand	2.65-2.69
Silty sands	2.66-2.7
Inorganic clays	2.67-2.8
Organic soils	<2.0

2.2.5 Free Swell Test

A free swell test of the soil is the increase in the volume of soil without any external constraints on submerged water. Such soils have the possibility the structure when the groundwater table reaches the influence zone. It is therefore, always essential to investigate the swelling or expansive nature of these soils which are likely to possess undesirable expansion characteristics.

i.**Free Swell Index (FSI)**

The free swell index is the volume of the soil without any external constraint when subjected to submergence in water. This approach based on the free swell's ratio, defined as ratio sediment volume of soil in distilled water to that in kerosene or carbon tetrachloride. To work out this problem, the free swell index was proposed by [36]. This method is based on the ratio of the equilibrium soil volume of the dry soil. To ready, the sediment 10gm soil must be oven dried and mixed thoroughly with distilled water in 100ml measuring jar then allow settling.

2.2.6 Grain Size Analysis

According to the researcher[37]was carried soil consists mostly of different sized soil particles as a major constituent ingredient. The determination of the fraction of particles will help to identify the soil type as well as to estimate many engineering properties such as strength and permeability and also to identify whether the soil is suitable for construction projects such as highways, dam, or as black or for filter design. The two methods mostly used to determine grain size distribution are sieving analysis for coarse grain soil (size coarser than 0.075mm) and hydrometer analysis for fine grainsoil whose size finer than 0.075mm.

The suitability criterion for the airfield and embankment construction has been based on grain size distribution. The prediction of permeability can be done using to grain size analysis. The proper gradation of filter material is established particle size distribution.The grain size test usually uses for classification of soil according to AASHTO classification system. Hydrometer Analysis: The soil which passes through #200(0.075mm) sievesnot used mechanical sieving test because the particles to be small and cannot be passing through the screens individually. Those particles are performed by hydrometer analysis as per ASTM D 1140 standard. This is done soil with water and sodium hexametaphosphate (as a dispersing agent) for 24 hours to slurry of dispersed soil particles. The soil particles are initially suspended in the liquid mixture, but settle over time.

2.3 Classification of Soils

The soil can be classified as AASHTO and (USCS) soil classification system

2.3.1 American Association of State Highway and Transportation Officials (AASHTO)

Soil classification is the arrangement of soil into groups which have similar behavior [38]. The main objective of any soil classification system is predicting the engineering properties and behavior of a soil based on a few simple laboratories or field tests. According to the [38] soil classification system was developed in 1928 by the U.S Bureau of Public Roads, which is now called the American Association of State Highway and Transportation Officials (AASHTO). The AASHTO system uses similar but the driving lines have an equation of the form PI=LL- 30. It generally classified soil broadly into granular materials and silt-clay.

The soil classified under groups A-1, A-2 and A-3 are granular materials with 35% or less passing through a No. 200 sieve but A-1 and A-3 are non-plastic. Soil with more 35% passing No.200 sieve is classified under group, A-4, A-5, A-6, andA-7.[38]. These soils are mostly silt and clay type materials.

2.3.2 Unified Soil Classification System (USCS)

The USCS was developed cooperatively by the U.S Army Corps of Engineers (USA) [39]. The USCS classification was published Army Corps. It has since been adopted by the American Society for Testing and Materials (ASTM) as the standard classification of soils for engineering purposes. The success of the USC is indicated by its routine use worldwide and its acceptance for international geotechnical communication [39].

The USCS system is a textural plasticity classification scheme. Soils are divided into two major coarse grains and fine grain soils. When more than half of the soil sample is smaller than the N0.200 sieves, it is classified as fine grain soil and is primarily based on the liquid limit values and degree of plasticity.Paired letter symbols are used for each soil group of the USCS system. The first symbol refers to the predominant particle size (with the exception of organics). The second symbol for fine grain soils refer to gradation for clean (little or no fines) soils and the presence of silt and clay particles for soils with appreciable amounts of fines [39].

The second symbol for fine grain soils areon the basis of low (L)or high (H) plasticity [40]. The USCS system includes typical soil names the classification system. Soil that is intermediate between two groups may be identified symbolically by a combined notation such as SM-ML and SC-CL. The basis of the USCS system is the liquid limit and plasticity index of soil. The plasticity chart is the plot of PI inordinate and in abscissa that describes the properties of clay and silt soils in terms of Atterberg Limits.

2.4 Soil Stabilization

Soil stabilization deals with mechanical, physical-chemical and chemical methods to make the stabilized soil serve its purpose.Expansive soils, due to their poor swell-shrink characteristics, possess a challenge to geotechnical engineers in handling them during the construction activities in or on them. In order to improve the engineering properties of such soils, they need to be stabilized. The stabilization process, essentially involves the excavation of the in-situ soil and compacting the treated soil [25].

Common reasons for the need for stabilizations [42] are: Provide a working platform for construction of subsequent layers by drying out wet areas and or temporarily increasing strength properties. Reduce shrink/swell of expansive soils or existing materials. Increase strength to provide long term support for the pavement structure. Reduce pavement thickness and improve durability. Utilize local materials and upgrade materials, for the reduction of construction cost by effectively.

2.4.1 Mechanisms of Stabilization

Soil stabilization is one of the ground improvement methods of treating expansive soils. Soil stabilization mechanism is the method used to change one or more engineering properties of soil so as to improve the desired performance. The twoused methods of stabilization of soils by chemical or mechanical [42].

2.4.1.1 Chemical Stabilization

Chemical stabilization is additive stabilization achieved by the addition of proper percentages of cement, lime, fly ash or combination of these materials to the soil. The addition of chemicals to the soil improves the geotechnical properties of soils.The selection of type and determination of the percentages of additive should be dependent upon the soil classification in which the soil desired. However, the study was concerned with the stabilization of road subgrade materials. The additive used in this study is cement.

Therefore, it could be considered first stabilizing agent or hydraulic binders because it can be used alone to bring about the stabilizing action.Since, this could be considered during mix design to the desired strength. Calcium silicates, C3S and C2S are the most cementitious properties of ordinary Portland cement which responsible for strength development [43]. Kent Newman and Jeb S. Tingle in their study of previous research reports, Portland cement was used as the stabilizers control for comparison of properties to the polymers and was used at concentration of 2.75%, 6% and 9.5.

The beneficial effects of cement on the performance of soils have been widely documented [43].However, the findings of different researchers on the Portland cement compacted properties as well as strength and modulus has been entirely consistent. The more specific general guide based on the fines content which states the upper limit of P.I for selecting soil for cement stabilization. Base of this system, soils with AASHTO classification A-2 and A-3 are perfect for stabilization with cement, but cement can be successfully used to treat A-4 through A-7 soils as well.The Portland Cement Association (PCA) established guidelines on stabilizing a wide range of soils from gravels to clays. Portland cement can be used to improve or modify the quality of the soil into a cemented mass with increased strength and durability. In addition to this, cement for subgrade soil treatment can be economical, fast, and sustainable solutions to several soil problems encountered before or during construction [15].

2.4.1.2 Mechanical Stabilization

Mechanical stabilization is a technic that improves the engineering properties of subgrade soil without altering any chemical stabilizers or admixtures. This method is used to improve stability weak subgrade and shear strength characteristics of the soil through compaction, replacement unsuitable material with non-expansive fill, addition of aggregates, soil reinforcement and mixing or blending soils with different gradations to obtain a material that met the required specification [34].

2.5 Factors Affecting Expansive Soil Swelling and Shrinkage

The expansive soil's swelling and shrinkage affecting factors are like Initial water content, Clay mineralogy, Dry density, Particle size, Climate arid Location of water table.

Table 2-4Some factors affecting expansive soils property

Factors Affecting Expansive Soil's Swelling and Shrinkage as follows	
Initial water content	Small amount of initial water content on the other hand indicates small degree of saturation. The tendency towards soil to observe water will increase and this condition increases swelling potential.
Clay mineralogy	Clay soils which have clay minerals with higher swelling potential like Montmorillonite have hinge swelling potential, as the amount of clay mineral with high swell potential increases the swelling potential of the soil increases.
Dry density	The higher the value of initial dry density implies, closer particle spacing have large swelling potential.
Particle sizes	Fine particles of a soil existdensely and the finer the particle the higher will be its expansion potential.
Climate arid	This reduction of water contents may lead to increase swelling potential for clay.
Location of water tables	Fluctuating the location of water tables causes variation on water content of the depth of the clay stratum, and the water content variation affects the soil swell-shrinkage property.

2.6 Literature Survey from different laboratory experiments & Analysis on the study area

According to the researchers [42] in published experimental research work title soil stabilization for road construction: comparative analysis of a three prolongs approach where the comparative effect of cement, sodium chloride and brick dust on clay soil found at location during road construction [42], was carried out using various percentage of 2%, 6%, 10% and 14% cement content mixed with clay soils. As the ratio of the lateritic soil increase such higher value of minimum dry density, low permeability and high free swelling potential for the expansive soil properties decrease. After his experimental investigation, the result of compaction tests for indicating that the MDD black cotton soils increase as the lateritic soil increase mixed percentage weight increase and the optimum moisture content of the soil decrease as the ratio of lateritic soil ratio increases.

According to researcher [43] studied an experimental study on the performance of the lateritic soil mixed with problematic soil in India. Even though, the design of mixed soil is required for appropriate use of subgrade soil mix for civil engineering works which may be expansive and lateritic or leeched soil to get desirable compaction, permeability, and free swelling potential, the result revealed that mixed soil engineering properties had higher than the engineering properties of expansive soil which change the properties of the expansive soil; as the ratio of the lateritic soil increase such higher value of minimum dry density, low permeability and high free swelling potential of the expansive soil properties decreases. After his experiment investigation, the result of compaction tests to indicate that the MDD black cotton soils increase as the lateritic soil increase mixed percentage weight increase and the OMC of the soil decreases as ratio of lateritic soil increase.

According to the researcher[44] have worked on lime – stabilized black cotton soil and brick powder mixture as sub base material stated that the lime-stabilized black cotton soil proportion with brick powder will help to help to obtain the better CBR value. The mixture of 20% brick powders and 80% lime-stabilized black cotton soil under resulted in an increase in the CBR value by about 135% in comparison with lime-stabilized black cotton soil.) As it is the promising material to use the mixture of brick powder and lime-stabilized black cotton soil as sub base material in flexible pavements. Therefore, from their statement the lime-stabilized of black cotton soil and bricks powder mixture used as sub-base material.

According to the researcher [45] Studied about investigation into some of the engineering properties of soils in DebreBerhan Town. He obtained from grain size analysis result the soil found in DebreBerhan Town is dominantly silt and clay types. AASTHO classification system shows the soils are classified in either of the A-6 or A-7 (A-7-5, A-7-6). The soil is poor to be used for sub grade material as per the AASTHO recommendation of suitability of soils as subgrade material. Free swell test results of soils under investigation shows that the soil expansiveness property ranges from low on marginal degree of expansiveness. According to the researcher [46] investigation of engineering properties of soil found in Ziway, he concluded the following results of based on laboratory test. Grain size analysis tests revealed that, starting from few centimetres below ground level to depth of investigation which is three meters, the soil in Ziway town is mostly silts and silty sand. Therefore, the silt soils of Ziway town have clay content ranging from 6.72 to 10.93%, silt fraction 51.45 to 73.03%, sand fraction 15.16 to 40.4%, and gravel content from 0.84 to 1.88% and for silty sand soils clay content ranging from 0.66 to 4.41%, silt fraction 17.15 to 42.18%, sand fraction 52.02 to 81.3%, and gravel content from 0.89 to 1.6% within the depth of exploration, the specific gravity of the town ranges from 2.40 to 2.62. These values are low compared with [45] this is because the soils are light weighted. From the consistency limit test results, liquid limit ranges from 27-37%, plastic limit from none plastic to limit ranges from 23-29% and plastic index from ranges 0-8%.

According to the researcher [50] studied on the swelling properties of black cotton soils mixed with the sand column; they performed experimental work in the laboratory. The result shows that the size of sand column and initial moisture contents in expansive soil influence the swelling properties. A large size sand column decreases swelling as compared to a smaller one. It is also seen that swelling is greatly reduced with the increase in moisture content. Finally, this research is to understanding that if the sand column is installed in the black cotton soil in saturated condition maximum volume stability can be obtained.

According to the researcher [51] studied on geotechnical properties of stabilized expansive soil quarry dust mixes. This study discussed the suitability of waste material that is quarry dust for stabilization of expansive soil. Quarry dust is mixed with expansive soil sample of different proportions and their influence on the geotechnical properties of expansive soil was studied. In this paper, the test results such as shear strength parameters, soaked CBR and differential free swell obtained on expansive clays mixed with different proportions of quarry dust are obtain and the result indicates that it is observed that at optimum percentage, i.e., 10% quarry dust, there is a marked improvement in the strength of soil.

According to the researcher [52]studied on stabilization of Black Cotton Soil with Sand and Cement as a subgrade for pavement in their study experimentally found that the addition of sand and cement mix results in the improvement of soaked CBR values while using sand as increasing order and reaches up to 40% and the constantly mix cement with natural soil. It is also observed that the free swelling index goes on decreasing from the increase in sand amount.

According tothe researcher [53] performed the experimental study on the investigates the suitability of using waste glass (WG) as an admixture to cement stabilized black cotton soil (BCS) for roads, fills an embankment. The soil was stabilized with 0, 2, 4, 6, and 8% cement and 0, 5, 10, 15, and 20% WG by weight of the dry soil. Laboratory tests were carried out using the Standard Proctor (SP) compaction efforts, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), and compaction characteristics test to evaluate the effectiveness of WG on Ordinary Portland Cement (OPC) stabilized BCS. The results obtained showed a decrease in the plasticity index (PI), liquid limit (LL), plastic limit (PL), and increase MDD with an increase in WG content in all cement proportions used and as compared to the values obtained for the natural soil.

2.7 Critical Review of Literature

Since, the commonly improvement attained from soil stabilization can be summarized as follows:

- Quality improvement: The most common enhancements achieved through stabilization include reduction of plasticity index or swelling potential and increases in durability and strength with a better soil gradation. In wet weather, stabilization may be used to provide a working platform for construction operations.
    - Thickness reduction: The strength and stiffness of a soil can be improved through the use of chemical additives to permit a reduction in design thickness of the stabilized material compared with an unstabilized or unbounded material. The design thickness can be reduced if the strength, stability and durability requirement of a base or sub-base course is indicated to suitable by further analysis.

2.8 Summary of the Literature Review

Expansive soils, occurring in arid and semi-arid climate of regions of the world causes serious problems in civil engineering structures. Such soils swell when given access to water and shrink when they dry out. The strength of subgrade soil is a major factor for the performance of asphalt pavement. So, the movement of the subgrade is one of the causes of road pavement failure. Road failure of study area could be in the form of cracks, potholes, surface deformation, surface defects which make the road network unsafe and not suitable to the road users. The performance of a pavement depends on the quality of its subgrade and existing condition of road bed. The performance of a pavement depends on the quality of its subgrade and existing condition of road bed [34, 16].

The following important point has been observed from the review of the above literature of stabilization of expansive soil for subgrade using chemical additives or stabilizer and also soil material as follows.

- The expansive soil has stabilized using different types of the soil and soil material such as cement, lateritic, sand, non-swelling soil are used; improve the engineering properties of the expansive soil for the stabilization of the expansive soil.
- From the experimental study of the above review, research shows that the engineering properties of expansive soil improved and it is more or less in all mixing ratio of expansive soil are used for road construction.
- Generally, the literature review revealed that the blending of expansive soil with other soil material is less cost, friendly to the environment and adjust as wanted by fixing the ratio of mixing based on the design strength required from the soil.
- Generally, the specification was reviewed according to the [34] design standard specifications.
- Finally, to eliminate the danger from such of these soils, the properties of the subgrade may need to be improved, either mechanically, chemically, or both to provide a platform for the construction of subsequent layers and to provide adequate support for the pavement over its design life.

3. MATERIALS AND METHODS

3.1 Study Area Description

The study area is found in South-western Ethiopia, Gurage Zone, Abeshige Woreda is located about 155km south west of Addis Ababa; Jimma asphalt highway and 233km from Hawassa town. The location of the research area extends 80^{0}27’30’’N and 38^{0}10’50’’ E Latitude and longitudes respectively. The topography of the study area is variable, rugged, hilly and mountainous at the middle part of the project whereas flat at the beginning and end of project. The climate of the Abeshige Woreda ranges from cool to warm. The annual average temperature of the study area is 21 ^{0}C.The area of study receives small amount of rainfall between March and April while the heavy rain occurs mainly to July to September. The maximum depth of disturbed soil sample is 1.5 m.

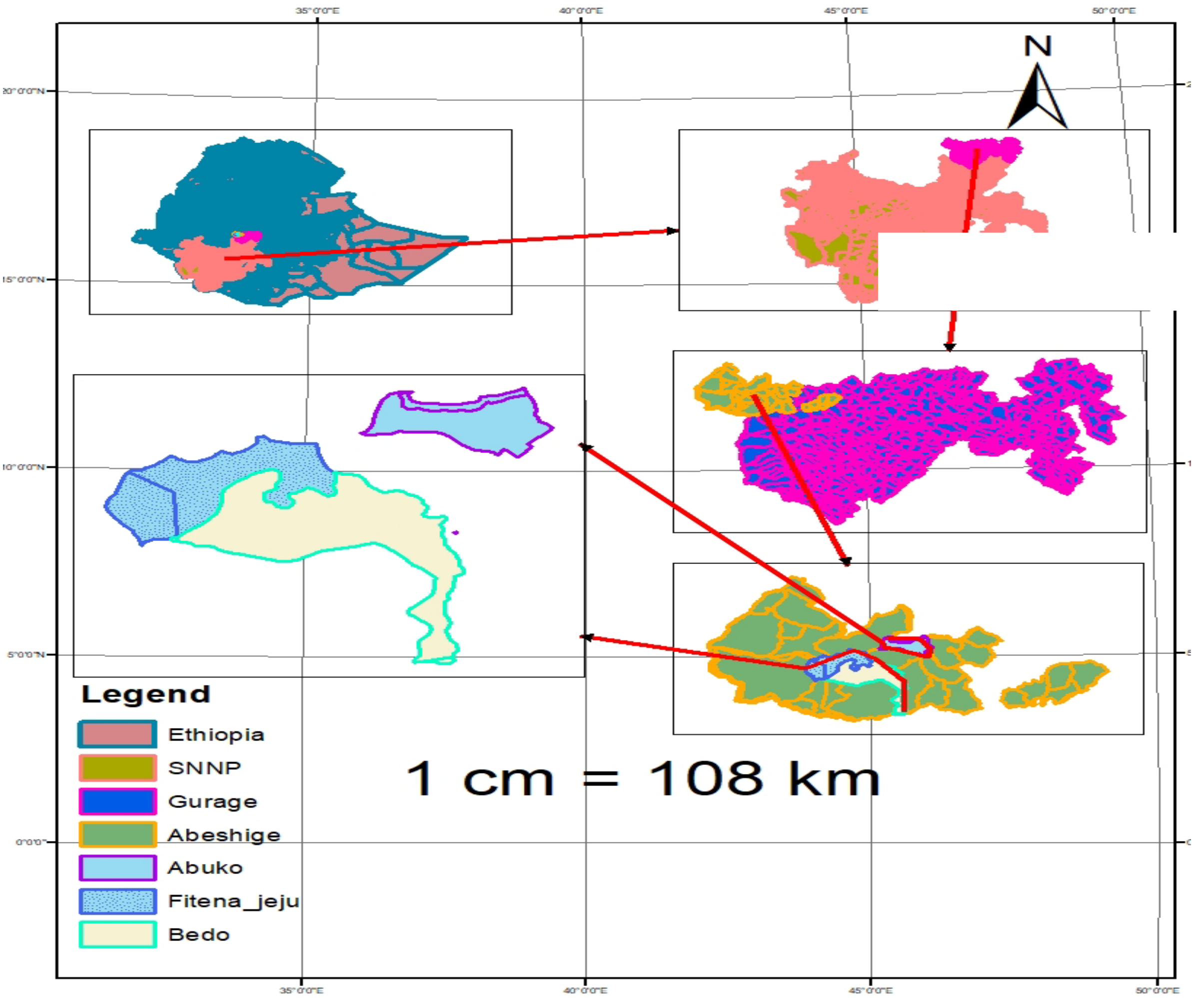


Figure 3-1 Location Map of (Abeshige Woreda, 2021)

3.2 Materials

3.2.1 Expansive soil

The soil sample used for the study fromAbeshige Woreda)particularly researched area from pit excavation depth of1.5m in order to avoid organic matter. The researcher was used the materials to study this research were expansive soil and cement.

Figure 3-2 Visual investigation into expansive subgrade soils observed (April: 15/ 8/2013 3:45)

3.2.2 Cement

Cement is one of chemical additive that can be used to stabilize the expansiveness to improve soil engineering properties as well as the mechanical characteristics of the soil like degree of compaction. The researcher bought cement from the market.

3.3 Studydesign

In this research the experimental study designs were used. That means the experimental research method is always based on experiment work with description and analysis. For the accomplishment of this research objective, the secondary data onto the related study was reviewed and the researcher primary data was collected from each test pit, then different laboratory tests were conducted.The laboratory tests wereconducted according to AASHTO and ASTM standard testing procedures were performed for the accomplishment of this research objective.

The test designed to accomplish the research objective was stabilization of expansive soil for subgrade using cement and soil with different percentages of additives such cement. In laboratory different tests were performed such as natural moisture, grain sizes analysis and hydrometer analysis, free swell test, Atterberg limit (LL &PL),Classification test, proctor compaction (Modified proctor), CBR and CBR swell tests for subgrade soil with different proportion of cement. Finally, the results were compared with design standards [34].

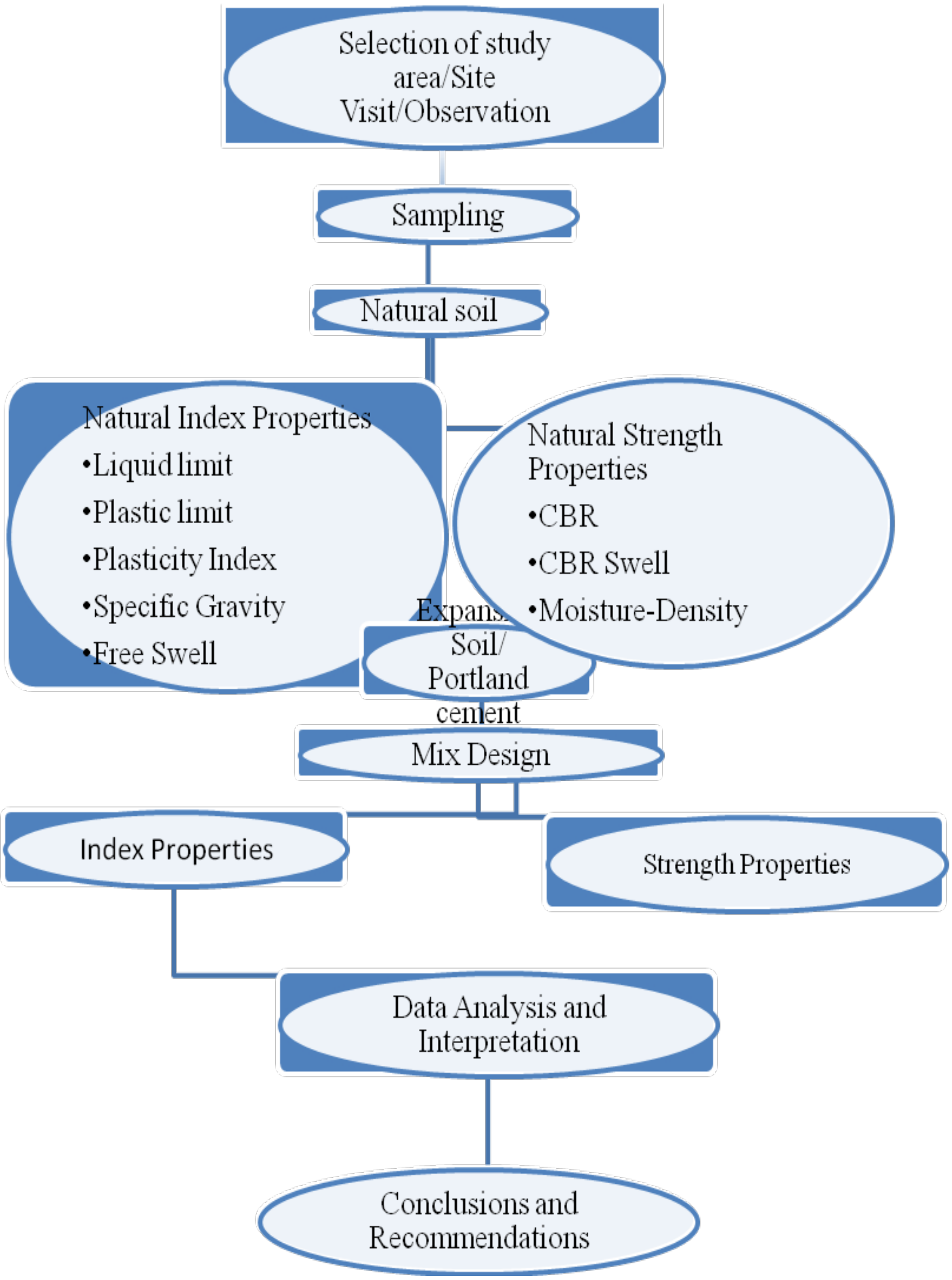


Figure 3-3 Flow chart of research methods

3.4 Study Population

The study population of this study the material used in this research; those are expansive subgrade soil and cement.

3.5 Data Collection

The data collection was carried out from two different data sources, primary and secondary data sources. The researcher primary data was collected from each test pit, then different laboratory tests were conducted and the result was recorded. The secondary data was collected from different works of literature, journals, scientific researches; books, websites, and were reviewed to analyse the research.

3.6 Sample Technique

The sampling techniques used for this research were a purposive sampling. The experimental investigation into the study area was executed particularly on the weak subgrade soil sample, since this study pick out the sample in relation to some criteria, which are considered important to particular study.

3.7 Sample Collection

The soil samples were collected from Abeshige Woreda around Abuko, Bedo, and Fintejeju along the road sides. The collected sample was disturbed and taken from 1.5m depth. Cement was bought from market and also disturbed soils samples were collectedfrom study area and taken into Jimma Institute of Technology Geotechnical Engineering laboratory test and JUCAVM soil laboratory.

3.8 Sample Preparation and Mixing Ratio

Sample preparation of treatment and testing, the sample was prepared in accordance with the method described in ASTM C702-86[49]. This method involves air drying of samples and/or oven drying at 105^0 C. The sample was taken from the study area and the moisture of the soil was placed into the inside plastic bags.

The natural moisture content of the soil was kept and into the laboratory test inserted oven-dried. The first group involves preparing uniform samples of Atterberg limits, free swell, classification, and the other for compaction and California bearing ratio tests. Based on the theories and laboratory test performed, the results obtained will be analysed, compared and discussed thoroughly. The soil was stabilized with cement percentages of 4, 6, 8, 10,12, 14, and 16 by dry weight of the soils.

Table 3-1 Sample preparations and mixing ratio

Percentage of cement (%)	Subgrade Expansive soils
4	96
6	94
8	92
10	90
12	88
14	86
16	84

3.9 Study Variables

3.9.1 Dependent Variables

The dependent variable of the research is the engineering properties of stabilized expansive soils (CBR, Atterberg limit, Compaction (MDD, OMC) and CBR swell).

3.9.2 Independent Variables

Independent variables are the presumed cause of dependent variablewhich includes dosage of cement.

3.10 Data Processing and Analysis

For the accomplishment of this research objective, the data was processed according to the following tasks. Those are: data handling and recording were prepared for laboratory tests, all data were properly observed and recorded using standard format, by arranging and the results, and then the relationship was noted. And also tools were used for data analysis and an interpretation was done using MS-Excels, and Origin Pro 8.5 Software.

3.11 Laboratory Test performed and Test Methodology

The laboratory tests of this research study included grain size analysis and hydrometer test analysis, specific gravity, free swell, Atterberg limit, modified proctor test and CBR test.

3.11.1 Natural Moisture Content

The natural moisture content of the laboratory test is performed to determine the water content. The oven drying method was used to determine the moisture of the soil samples. According to AASHTO T-265 [48] Standard Test Method of laboratory determination, the moisture content of the soil was determined. Two sets of samples were dried to a constant temperature using oven-dry at a temperature of 105^0C.

3.11.2 Grain Size Analysis

In this study wet sample preparation in accordance with (ASTM D 422-63) Standard Test Method of particle size analysis was applied. The mechanical analysis was used for coarse sized soils by using a set of the sieve and whereas hydrometer analysis is used for fine grain soils. Here sodium hexametaphosphate was used as a dispersing agent. For soils comprising coarser and finer sizes, both mechanical and hydrometer testing methods were performed.

3.11.3 Atterberg Limits

Atterberg limits were determined for air dried samples. It was done on standard reference: AASHTO T-89 and 90 or ASTM 4318 Standard Test Method for liquid limit, plastic limit, and plasticity index of the soils. The test was computed by using the Casagrande apparatus. The representative samples were air-dried and the sample soil of 250g passing through a No. 40 (0.425mm) sieve was used for the preparation of the sample for this test. The same procedures were carried out for the treated soil with an increment of cement. The plasticity index was computed for each soil based on the liquid limit and plastic limit obtained.

3.11.4 Specific Gravity

The test was to determine the specific gravity of the soil by using a pynometer. Based on the soil type specific gravity may be unusually high or low. However, specific gravity is the ratio of the mass of a unit volume of soil at a standard temperature of the mass of the same volume of gas-free distilled water at a stated temperature.

The test was conducted according to AASHTO T 100-93 for specific gravity of soil solids by water by pycnometer procedure. Since the specific gravity results are to be used for determination of particle size of the hydrometric analysis portion of AASHTO T-88, intended that the specific gravity test is done on the portion of the soil which passes 0.075mm (No.

200) sieves size. The room temperature was about 19-24^{0}C. The specific gravity of the soil refers mass of solid matter of a given soil sample as compared to an equal volume of water.

3.11.5Free Swell Test

To study the swelling properties of the soils, the simplest test conducted is free swell test. According to standard [48] the test was conducted by slowly pouring 10grams of oven dry soil, which passed No.40 (0.425mm) sieves into a 100ml graduated cylinder with distilled water and kerosene. Free swell test results from oven dried samples of a temperature of 105^{0}C.

3.11.6ModifiedProctor Test

This laboratory test is performed to determine the relationship between the moisture content and the dry density of the soil in a specified compaction effort. There are two types of compaction tests: Standard and Modified compaction test. In this study, I performed a modified proctor compaction test. In general, most engineering properties, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, would be improved by increasing soil density.

The modified proctor tests conducted according to AASHTO T-99 procedures are employed to conduct the compaction test. This method employed for the particles of the soil retained on the sieve No.4 (4.75mm). Densities are calculated from unit weights measured the laboratory divided by gravity due to the earth. Hence, this test was done on the soil, and then various Portland cements on the natural soil and MDD and OMC were determined.

3.11.7California Bearing Ratio

California bearing ratio is a common comprehensive test of present practiced in the design of pavement to survey the stiffness modulus and shear quality of subgrade material. Nowadays, the CBR test is the most widespread method of determining the bearing strength of the pavement materials and fundamental to pavement design practice.The results of these are used with the empirical curves to determine the thickness of the pavement and its component layers. However, CBR is expressed to force exerted by plungers and the depth of penetration specimen; it is aimed at determining the relationship between force and penetration. The method uses material passing 9.5mm sieve size and provides the CBR value of the material at optimum moisture content.

The CBR test indirectly measures the shearing resistance of soil under controlled moisture and density conditions. To determine the strength and swelling potential of the subgrade soil has been carried out by soaking four days (96 hours) and swell testing procedure. CBR is determined compaction level with 65 blows to 95% maximum dry density (MDD).The initial dials reading of the dial indicator on the soaked CBR mold taken just after soaking the sample. At the end of 96 hours of the final dial reading of the dial indicator is taken.

3.12 Soil Classification

The soil was classified according to the AASHTO soil classification system using particle size distribution and Atterberg Limits and as well as according to the USCS classification system. Soil classification provides a method of identifying soils in a particular group that would likely exhibit similar characteristics. According AASHTO classification soils into seven major groups: A-1 through A-7 the major groups divided into subgroups. USCS system also classifies the soil based on grain gradation, plasticity and by group symbols and group names.

3.13 Mixing soil and Stabilizer

After water addition, the appropriate amounts of stabilizer were then added to the mixture and blended thoroughly for three to five minutes. The mixture was set at the lowest speed, and water and stabilizer were each added slowly to promote uniform blending and prevent clumping of the soil and or stabilizer[49].

4. RESULTS AND DISCUSSIONS

This chapter deals with the laboratory test results from natural soils and the effect of addition of cement on the original soils to improve the engineering properties of expansive soils found in the study area.

4.1 Natural Moisture Content Determination

Natural Moisture content wasdetermined for three samples and its values range of 40 to 54%. Detail result of NMC was presented in appendix.

4.2 Engineering Properties of Natural Soils

The laboratory test carried out on natural soils has been focused to investigate the grading, Liquid Limits (LL), plasticity Index (PI), specific gravity, maximum dry density (MDD), optimum moisture content (OMC), soil strength (CBR), and the potential to swell tothe soils. The index and engineering properties conducted on natural soil before treating it with cement were presented on the Table 4.1 shown below.

The results shown on the below table, revealing that the soils found this study area were dominated by expansive soils. The most dominant soil type was clay soils which have high expansiveness properties when incorporated into other test results like free swell index and the CBR values. All the results obtained from three test pits shows that the natural soils have expansive properties, which is problematic soil for engineering uses. Hence, it is recommended to improving the engineering properties of expansive soil found in this study area by using locally available materials like cement.

Table 4-1 Summaries of laboratory tests results from natural soils

Properties	Property	Values		
		Abuko Keble	Bedo Keble	Fintjeju Keble
Grain Size	Coarse (%)	0.00	1.03	0.98
	Sand (%)	4.55	6.64	6.82
	Silt (%)	45.20	40.21	38.21
	Clay (%)	50.26	52.13	53.99
Atterberg's Limit	Liquid Limit (%)	99.60	89.80	95.90
	Plasticity Index (%)	59.00	59.80	61.4
Specific Gravity	Gs	2.71	2.73	2.71
Compaction Test	MDD (kN/cu.m)	1.52	1.55	1.53
	OMC (%)	22	26	24
Swelling Test	Free Swell Index (%)	110	90.91	90
CBR (%)		0.6	0.8	0.9

4.2.1 Grain size determination on Natural Soil

The particle size determination conducted on this study reveals that the soils of study area were dominated by fine grain soils. The gradation of the soil sample was conducted both mechanical (sieve) and hydrometer tests. The gradation analysis to be done through mechanical sieve for the material retained on #200 sieves and hydrometer analysis for material pass through #200 sieves. The hydrometer test was conducted by taking 50gm of soil sample which passing #200 (0.075mm) sieve and soaked for 24 hours in chemical solution (Sodium Hexa-Meta Phosphate) to disintegrate the large particle.Even if a little amount of gravel and sand soils obtained from the test results silt and clay soils were the most dominant soils in study area. The tabular experimental results are presented in appendix and the particle sizes distribution curves are shown in figure 4.1.

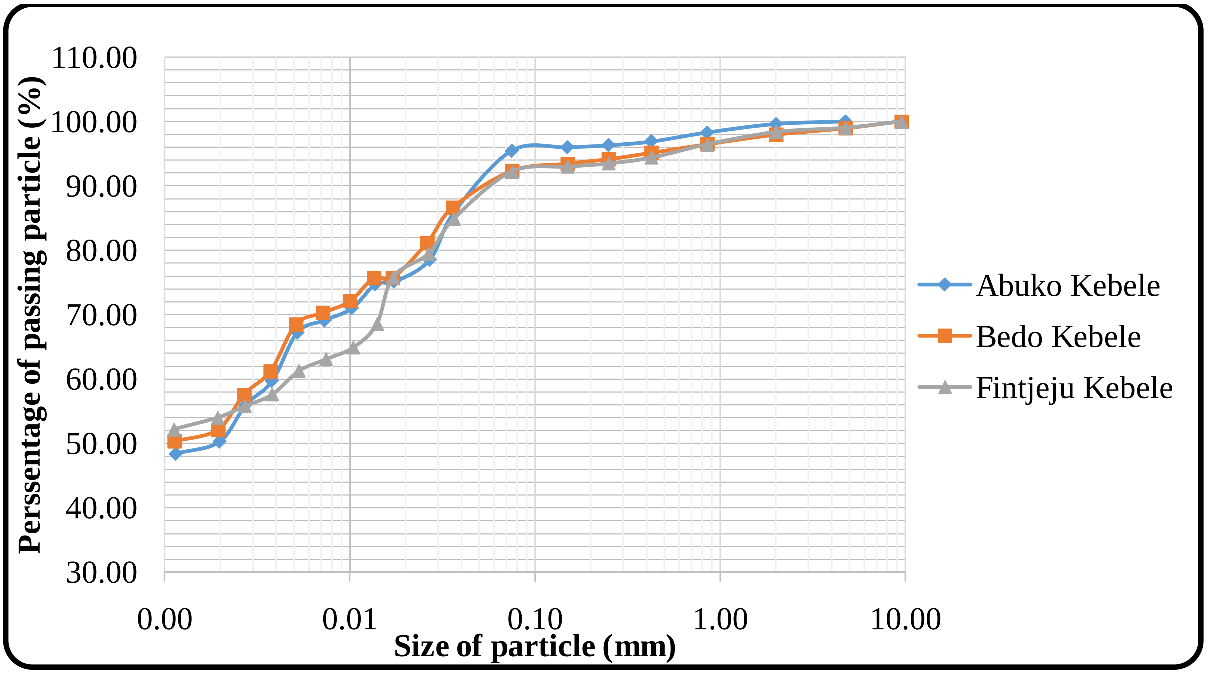


Figure 4-1 combined grain sizes determination Curve

The soil sample obtained from(Abuko Keble)is black clay, and almost 95.45% of the soil is passing through No.200 sieve and the soil obtained from (Bedo Keble) is grey, and almost 92.33%of the soil is passing through No.200 sieve as shown in figure 4.1 above. The soils obtained from (Fintjeju Keble)were also dominated by fine grain soils and above 92.20% of soils were passing through No. 200 sieve sizes. Therefore, the given soil sample was a fine silty and clay soil.

4.2.2 Atterberg Limits Determination

The results obtained from Atterberg Limits test was shown in the table 4.2 given below. The LL (%) values were 99.60, 89.80, and 95.90% for Abuko, Bedo, and Fintjeju (Keble's) respectively. The PL (%) and PI in the three soil samples were 40.60 and 59% for (Abuko Keble), 30.10, and 59.80% for (Bedo Keble), and 34.40 and 61.40% for Fintjeju Keble respectively. The results obtained from this test agrees with the observations made by the Ministry of Works and Urban Development of Ethiopia [55] and they stated that all greyish and/or brownish clays in Ethiopia with plasticity indices (PI) greater than 25% can be identified as expansive soils.

Table 4-2 Summary of Atterberg limits to the natural subgrade soil

Test pit Location	Atterberg Limit Test on Natural Untreated soil		
	Liquid Limit (%)	Plastic Limit (%)	Plastic Index
Abuko Keble	99.60	40.60	59.00
Bedo Keble	89.80	30.10	59.80
Fintjeju Keble	95.90	34.40	61.40

4.2.3 Specific Gravity Determination

The result of Specific gravity obtained in this study was varyingfrom 2.71 to 2.73. And the type soils found in this study area were categorized under expansive clay soils.

4.2.4 Free swell Determination

The free swell Index of soils of study area was tabulated in theTable 4.3 shown below

Table 4-3 Summary of free swell test of the natural subgrade soil

Sample Location	Free swells (%)
Abuko Keble	110
Bedo Keble	90.91
Fintjeju Keble	90

This result indicated that the three soils were highly expansive soils. It was supported by [13]. Soils are called highly expansive when the free swell index exceeds 50% and such soils undergo volumetric changes leading to pavement distortion, cracking and general unevenness due to seasonal wetting and drying.

4.2.5 Compaction Determination

Modified Proctor tests were conducted on the soil to determine the relationship between the moisture content and dry density of specific compaction effort according to AASHTO T99-97. The soil sample obtained from Abuko Keble has optimum moisture content 22% and the maximum dry density is 1.52gm/cm^3. The soil samples taken from Bedo Keble have optimum moisture content of 26% and the maximum dry density is 1.55gm/cm^3. Also the soil samples taken from (Fintjeju Keble) have optimum moisture content of 24% and the maximum dry density is 1.53gm/cm^3 as shown on figure 4.5, 4.6 & 4.7. The results of MDD and OMC test computed for the collected samples were written in Table 4.7

4.2.6 CBR Test Results

Strength of the soil has also been determined. A CBR was conducted for 65 Blows, 30 Blows and 10 Blows and, summary of results are presented in table 4.8 blow. According to laboratory result as presented in table 4.8, soil samples taken from Abuko and Bedo (Keble) had 0.6and 0.8% soaked CBR value with 13.7 and 12%swell respectively and soil sample taken from (Fintjeju Keble) had 0.90% CBR value with 10.80% CBR swell. From the soaked CBR test, it was found that the natural soil has low CBR value, as compared [34] three of natural soil samples does not satisfy the minimum requirements as sub-grade material. Also, CBR swells values are above the specified maximum value of 2%, hence this soil needs to be treated before use.

4.3 Soil Classification

4.3.1 AASHTO Method of Soil Classification for the Study Area

The AASHTO system uses similar techniques as that of USCS but the dividing line has an Equation of the form PI= LL-30. It generally classifies a soil broadly into granular material and silt-clay material. The granular material is further divided into three groups which are Called A-1, A-2 and A-3. The silt-clay material is in turn divided into four groups namely, A-4, A-5, A-6 and A-7. As it can be observed from AASHTO Classification system

Table 4-4 Soil Classification

Location of Sample	Atterberg Limits			Soil Classification	
	LL	PL	PI	USCS	AASHTO
Abuko Keble	99.60	40.60	59.00	CH	A-7-5
Bedo Keble	89.80	30.10	59.80	CH	A-7-5
Fintjeju Keble	95.90	34.40	61.40	CH	A-7-5

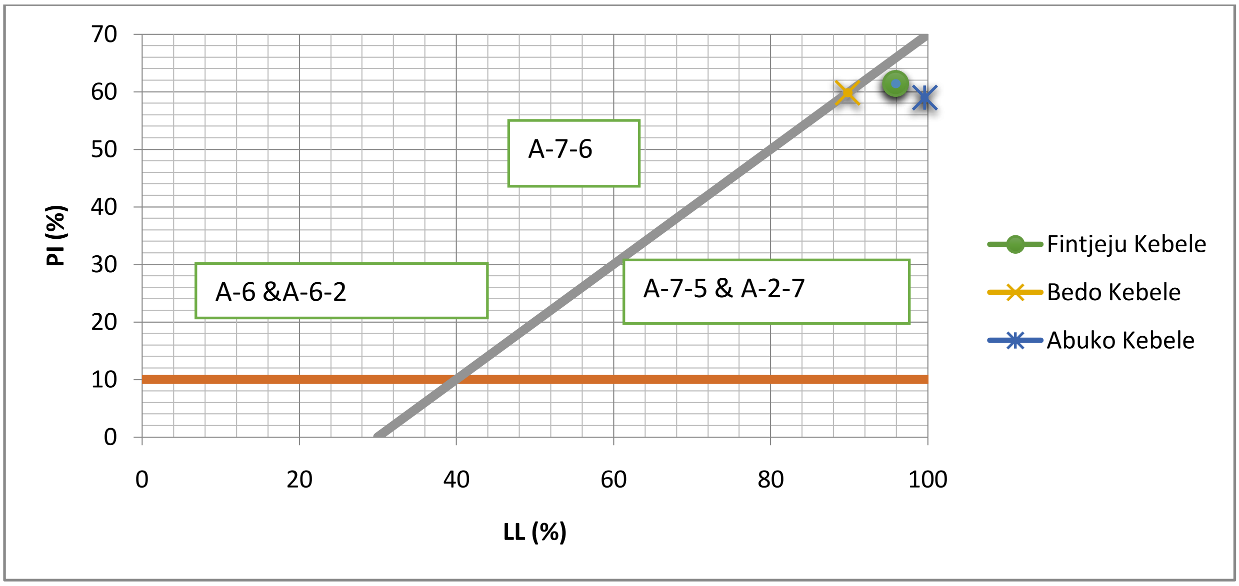


Figure 4-2 Soils to classification charts according AASHTO system

As results of Atterberg limit test result soils obtained from three test pits have different Liquid limit and plastic Index, however according to AASHTO soil classification system three soil samples have classified under group A-7-5. Thus, the natural subgrade material is unsuitable to be used as subgrade material without employing some improvement methods.

4.3.2 USCS Method of Soil Classification for the Study Area

According to USCS, if the Liquid limits are greater or equal to 50% the soil can be clay, silt, or organic depends on whether the soil coordinates plot of above or below the A line. Since both soil sample has Liquid limit more than 50% and above A-Line, so they are Classify under high to very high CH.

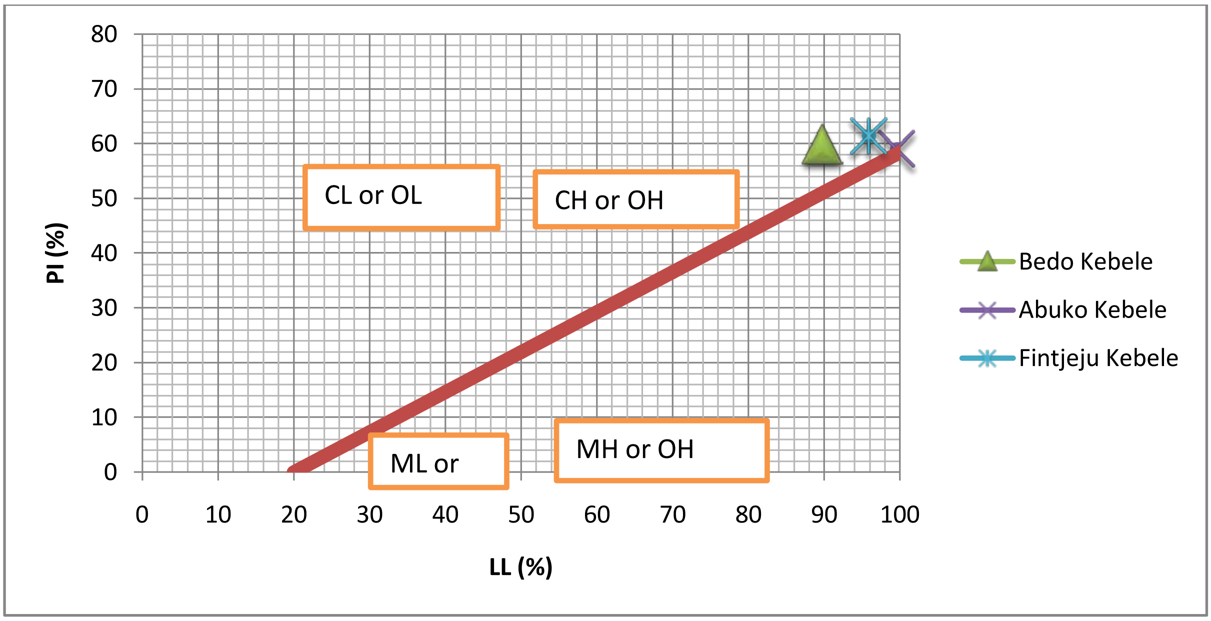


Figure 4-3 Plasticity chart of the studied soil using USCS

4.4 Chemical and Mineralogical Identification

The mineralogy of the natural soil samples was determined using indirect methods of plasticity index and liquid limit chart as reviewed on literature review of this report.

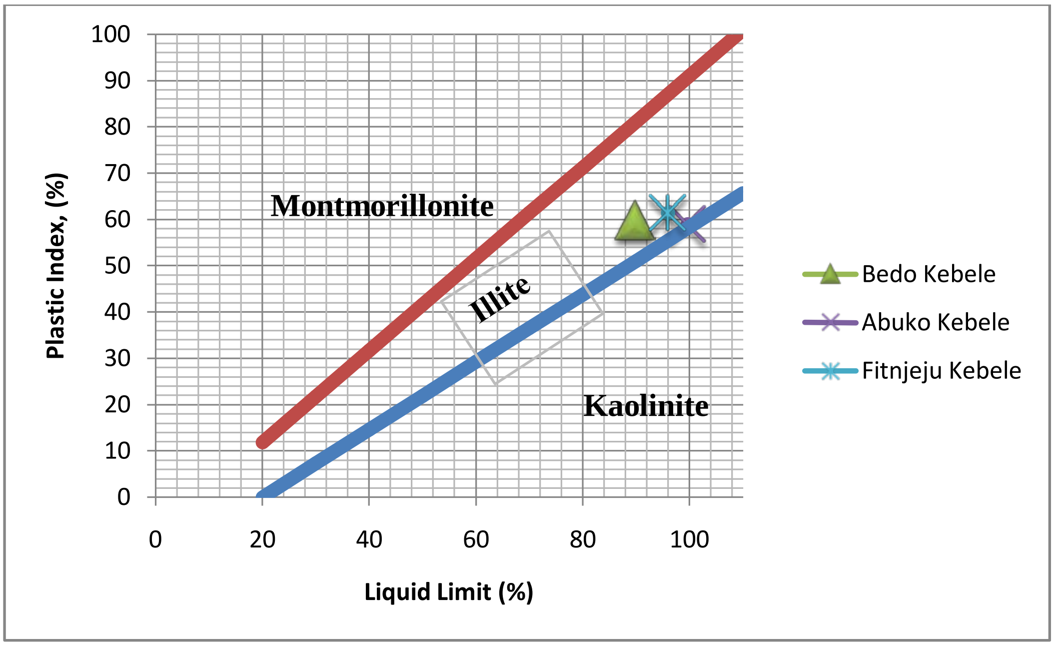


Figure 4-4 Mineralogical Identification of Expansive Soils using Indirect Method

4.5 Summaries of laboratory tests results from natural soils

According to the laboratory test results of the natural subgrade soil sample obtained during the study, the proportion of fines passing no 200 sieve 95.45, 92.33 and 92.20%, liquid limit 99.60, 89.80, and 95.90% and plasticity index 59, 59.80, and 61.40% for Abuko, Bedo, and Fintjeju (Keble) soil samples respectively. Soils samples are classified in to A-7-5 as per the AASHTO and CH as per the USCS classification system.

The liquid limit and plasticity index values are very much greater than the ERA requirements, i.e., liquid limit less than 60% and plasticity index less than 30%. Accordingly, three of soil samples show excess values in each parameter, and the soil in general thus had expansive property. The free swell index of 110, 90.91 and 90% for Abuko Keble, Bedo Keble and Fintjeju Keble soil sample, respectively, also revealed that the soils are expansive soil since its free swell index is greater than 50%. Furthermore, the CBR and CBR percent swell with 0.6, 0.8, 0.9% and 13.70, 12, 10.80% for Abuko Keble, Bedo Keble, and Fintjeju Keble soil samples respectively indicate that the soils have a low load-bearing capacity and high swelling potential when compared to [34] specifications of CBR > 3% and per cent swell of less than 2% which makes it unsuitable for construction without any suitable treatment measure.

However, the comparisons between the [34]design manual and laboratory results of the soil show that the soil sample did not fulfil the requirements as a sub-grade and is determined to be unsuitable for sub-grade in road construction. Therefore, the subgrade soil should be treated with appropriate improving methods before use as a road subgrade.

4.6 Effect of Addition of Cement on Engineering Properties

4.6.1 Effect of addition of cement on Atterberg Limits

Table 4.5 presents the results of Atterberg limits determined under different additive contents. The PI variations on both untreated and treated soils are shown in figure 4.5.

From the test data it was observed that addition of cement to natural soil decreases Liquid Limit and Plasticity Index values. After modification PI reduced from a value of 59 to 17.1%, 59.80 to 6.1%, and from 61.40 to 7.3% for Abuko, Bedo and Fintjeju Keble respectively after an improvement with 16% cement. Hence cement has a great impact on reduction of PI.

Blending expansive soil with cement was satisfying [34] standard specification for Sub-grade construction.

Table 4-5 Atterberg limits test result of treated & untreated expansive clay soils

Sample No.	Addition of Cement by different percentage		LL (%)	PL (%)	PI (%)	ERA[34] Requirement For PI in (%)	Remark
	Natural soil	Cement (%)					
Abuko Keble	NS	0	99.60	40.60	59	< 30	Poor
	NS	4	98.6	50.3	48.3		Poor
	NS	6	97.5	53.1	44.4		Poor
	NS	8	95.7	55.9	39.8		Poor
	NS	10	91.2	57.3	34.40		Poor
	NS	12	88.6	59.5	29.1		Satisfied
	NS	14	84.4	59.8	24.6		Satisfied
	NS	16	78.7	61.6	17.1		Satisfied
Bedo Keble	NS	0	89.80	30.1	59.80	< 30	Poor
	NS	4	86	39.6	46.4		Poor
	NS	6	83.4	47.3	36.1		Poor
	NS	8	80.2	49.1	31		Poor
	NS	10	77.2	50.5	26.7		Satisfied
	NS	12	73.7	52.8	20.9		Satisfied
	NS	14	64.9	52.4	12.4		Satisfied
	NS	16	60.4	54.4	6.1		Satisfied
Fintjeju Keble	NS	0	95.90	34.40	61.40	< 30	Poor
	NS	4	91.8	44	47.9		Poor
	NS	6	89.3	49.7	39.6		Poor
	NS	8	86.2	52	34.2		Poor
	NS	10	83.3	54.9	28.4		Satisfied
	NS	12	78.9	57.2	21.8		Satisfied
	NS	14	69.2	60.1	9.1		Satisfied
	NS	16	64.8	57.5	7.3		Satisfied

The decrease in PI indicates an improvement in the workability of the soil. The higher the PI is, the greater the quantum of water that can be imbibed by the soil is, and hence the greater its swell potential would be. It is obvious that an addition of 12% of cement was sufficient to enhance the workability of the soil by reducing the PI by 71.02, 89.80, and 88.11% for Abuko, Bedo and Fintjeju Keble respectively. The soil classification also changed after the natural soil was treated by cement. After the addition of the cement, the soil falls in the class of MH soil. All mixtures after addition of 10 to 12% cement moves the soil class as CH to MH. This renders the soil satisfactory for most construction operations even under severe environmental conditions.

4.6.2 Effect of addition of cement on Free swells Index

The free swell tests were conducted by mixing with cement at different proportion of percentages by dry weight of soil sample. The Effects of cement on free swell index of the soil samples tabulated in table 4.6 for three soil samples.

Table 4-6 Free swell index test results after treating expansive soils with cement

Cement Percentage	Test Pit Location		
	Abuko Keble Free Swell Index	Bedo Keble Free Swell Index	Fintjeju Keble Free Swell Index
0	110.00	90.91	90.00
4	72.73	70.00	75.00
6	60.00	63.64	52.38
8	45.45	40.91	36.36
10	36.36	30.00	40.00
12	30.00	27.27	30.00
14	25.00	25.00	20.00
16	20.00	22.73	18.18

The free swell test reveals that a significant reduction in the swell potential for the soil sample was observed by adding a different proportion of cement. The free swell index value decreased from 110, 90.91 and 90%, to 20, 22.73, and 18.18% for Abuko, Bedo and Fintjeju

(Keble) soil samples, respectively, which was a significant change. The degree of expansion was decreased by 81.82, 75, and 79.80% for addition of cement from 0 to 16% for Abuko, Bedo and Fintjeju (Keble) soil samples, respectively. For the addition of 12% of cement to expansive soils, the free swell index decreased by 72.73, 70, and 66.67% for Abuko, Bedo, and Fintjeju (Keble) soil samples, respectively.

A soil that has a free swell index above 50% is considered a highly expansive soil and is not recommended for engineering to use [13].But, the addition of cement to expansive soils in this study shows that the addition of 8% of cement enables the problematic soils found in the study area to be used as subgrade materials. Hence, the result obtained is guaranteed. The soil stabilized using cement shows a low degree of expansion as compared to untreated soil. As a result, the soil has a free swell to the allowable requirements.

4.6.3 The Effects of Addition of cement on Compaction

A modified proctor test was conducted by varying the cement content under consideration to determine the maximum dry density and optimum moisture content of the soils. The most common measure of compaction of soil is its density. Soil density and optimum moisture content should be determined according to ASTM D-1557. The optimum moisturecontent and maximum dry density of stabilized soils are presented in Table 4.7 below,and the value of the laboratory data analysis is attached tothe Appendix.

Table 4-7 Compaction tests results after treating expansive soils with cement

Cement Percentage	Abuko Keble		Bedo Keble		Fintjeju Keble	
	Maximum Dry Density (g/cm^3)	Optimum Water Content (%)	Maximum Dry Density (g/cm^3)	Optimum Water Content (%)	Maximum Dry Density (g/cm^3)	Optimum Water Content (%)
0	1.52	22.00	1.550	26.00	1.530	24.00
4	1.54	21.00	1.580	24.00	1.565	22.00
6	1.56	20.00	1.600	21.50	1.580	21.00
8	1.58	19.00	1.635	21.00	1.615	20.50
10	1.63	18.50	1.660	16.50	1.640	17.00
12	1.64	17.00	1.690	15.00	1.670	15.00
14	1.65	17.00	1.700	14.00	1.695	14.50

16	1.66	16.00	1.750	14.00	1.730	14.00

The result of optimum moisture content and maximum dry density showed that stabilization proportion has increased optimum moisture content but maximum dry density has decreased. The laboratory test results show that the maximum dry density of the soil samples ranged from 1.52g/cm^3 to 1.66g/cm^3, 1.55g/cm^3 to 1.75g/cm^3, 1.53g/cm^3 to 1.73g/cm^3 (increasing performance) and optimum moisture content (OMC) were ranges between 22 to 16%, 26 to 14%, 24 to 14% (decreasing performance) for Abuko, Bedo, and Fintjeju (Keble)soil samples respectively.

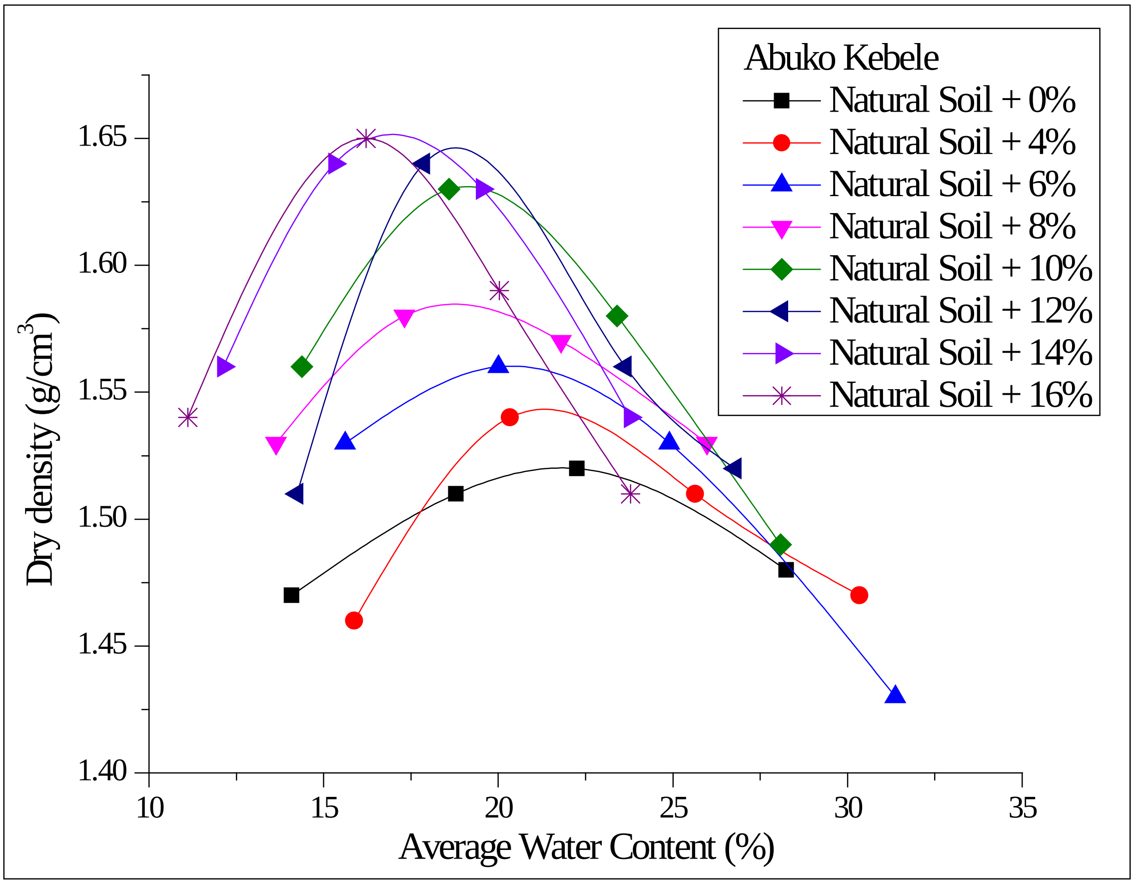


Figure 4-5 Summary of OMC and MDD of treated soil sample for Abuko Keble test pit

It is also observed that with an increase in cement dosage in the soil samples, there is a further decrease in OMC values. The fall in density is due to the quick reaction against cement with the soil, which alters the Base Exchange aggregation and flocculation, thereby resulting in an increased void ratio of the mixture. This subsequently leads to increases in the density of the overall mixture.

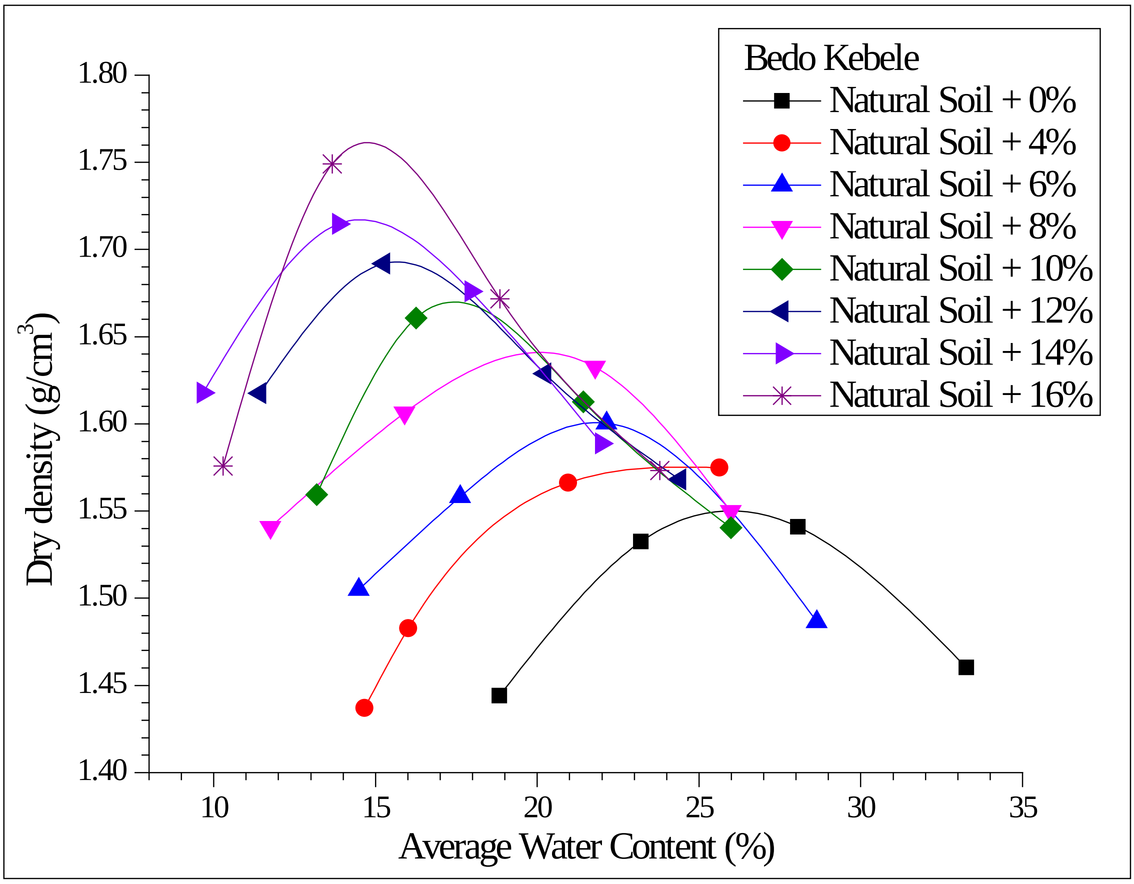


Figure 4-6 Summary of OMC and MDD of treated soil sample for the Bedo Keble test pit

It can be observed from Figure 4.7 that OMC decreases of the increase in Cement in mix mode stabilization. While the MDD decreases as cement content increases in expansive soil stabilization.

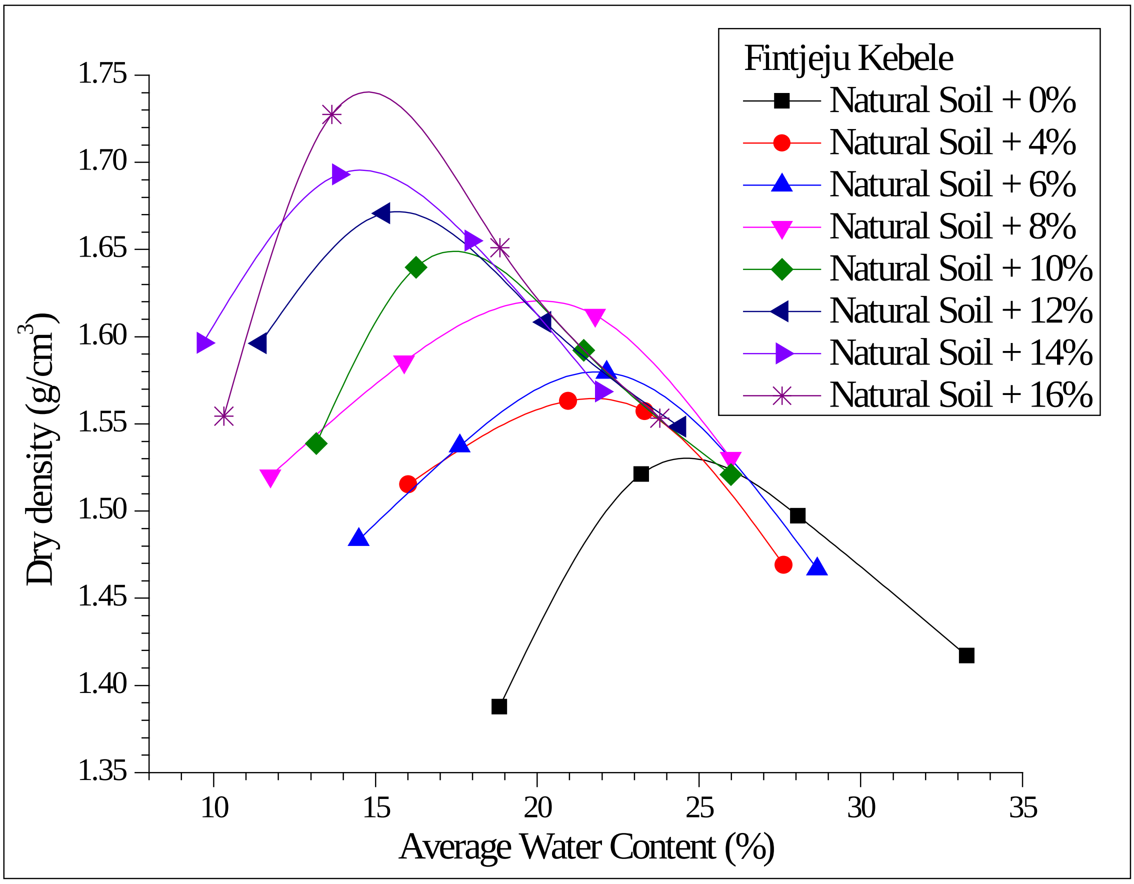


Figure 4-7 Summary of OMC and MDD of treated soil sample for the Fintjeju Keble test pit

The result of optimum moisturecontent and maximum dry density showed asstabilization proportion increased optimum moisture content decreased butmaximum dry density increased. This concept is the same as [54] concept. He concluded that the addition of chemical stabilizers to subgrade soils has decreased the OMC and has increased MDD of stabilized subgrade expansive soils.

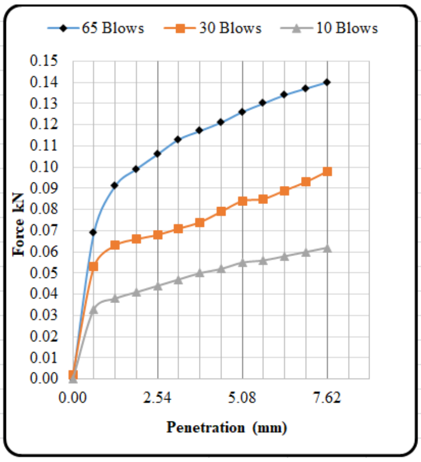
4.6.4 Effects of the Addition of Cement on CBR Values

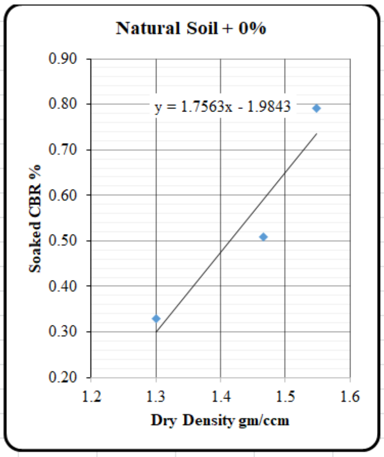
The soaked CBR of the BC soil used in this study is 0.6, 0.8 & 0.9% for Abuko, Bedo and Fintjeju (Keble) soil samples, respectively. According to [34], sub-grade materials having a CBR value of less than 3% need a special treatment. The soils stabilized by cement showed an improvement in strength. CBR is one of the parameters used to measure strength. The test resultsfrom the stabilized and natural sub-grade were presented in Table 4.8 below.

Table 4-8 CBR values of treated and untreated soils

Percentage of Cement (%)	Test Pit Location		
	Abuko Keble	Bedo Keble	Fintjeju Keble
	CBR % at 95 % of MDD	CBR % at 95 % of MDD	CBR % at 95 % of MDD
0%	0.6	0.8	0.9
4%	2.56	3.4	3.1
6%	4.1	5.4	4.9
8%	9.1	11.8	10.7
10%	11.7	15.7	14.2
12%	19.5	27.1	24.6
14%	30.9	38.4	35.9
16%	45.2	57.9	54.5

As the cement stabilized expansive soil shown on Table 4.8 above, the CBR values increased from 0.6 to 45.20%, 0.8 to 57.9% and from 0.9 to 54.5% for Abuko, Bedo and Fintjeju (Keble's) soil samples, respectively. The CBR values were increased by 98.67, 98.62, and 98.35% for Abuko, Bedo and Fintjeju (Keble's) soil samples, respectively. After the addition of 8% of cementto natural soil, the properties of natural expansive soil changed from an unsatisfied condition to a satisfied condition due to the fact that, at this mix percentage, the values of CBRare significantly greater than the recommended CBR values by [34].





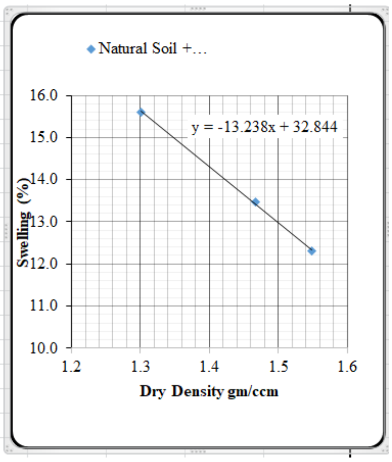


Figure 4-8 Soaked CBR Vs MDD   Figure 4-9 CBR Swelling Vs MDD

The CBR swells test was also performed on varying combinations of soil-cement mixtures. The CBR swellsto untreated soil is found to be 13.7, 12 and 10.8% for Abuko, Bedo, and Fintjeju (Keble's) soil samples, respectively, mentioned in Table 4.9. This shows high swelling capacity. The amount of swelling and the magnitude of swelling pressure depend on the soil structure and fabric, the clay minerals presented in the soil, and the physio-chemical aspects of the soil such as cementation, cation valence, presence of organic matter and salt concentration. In detail CBR and CBR Swell has been shown in Appendix part of this paper.

Table 4-9 Swell from the CBR tests

Percentage of Mixture		Natural Soil								
		Cement%	0	4	6	8	10	12	14	16
Sample Name	Abuko Keble	Swell%	13.7	9.4	5.2	2.8	2.2	1.2	0.6	0.4
		Remarks	Poor					Satisfied		
	Bedo Keble	Swell%	12	8	3.8	0.8	0.3	0.3	0.2	0.1
		Remarks	Poor			Satisfied				
	Fintjeju Keble	Swell%	10.8	7.8	3.7	0.9	0.3	0.3	0.2	0.1
		Remarks	Poor			Satisfied				

4.7 Summary of the Effect of Cement on Engineering Properties of Expansive Soils and Selection of Appropriate Percentage of Cement.

The result of laboratory tests for this study reveals that, engineering properties were increased for an increment of cement by percentage. The problematic expansive soil was significantly improved on poor condition to satisfied condition for subgrade construction by mixing with a different percentage of cement with before construction. For different tests, different percentages of cement improve the properties of natural soil. In Atterberg limit tests, the plasticity index of the soil was improved after the addition of cement of 12, 10, and 10% for Abuko, Bedo, and Fintjeju (Keble's), respectively. In free swell index tests, an addition of 8% of cement to expansive natural soil improves the recommended free swell values of [34] criteria for the three (Keble's). The most important parameter in subgrade designs, CBR values, also improved after the addition of 8% of cement to expansive natural soils in the three (Keble's) soil samples. For Abuko (Keble) soil samples, the CBR swells tobecome satisfied after the addition of 12% of cement to natural soils, while for the rest of (Keble's), the CBR swells tobecamesatisfied after the addition of 8% of cement.

Therefore, based on the above analysis, the maximum results were achieved at 8% and 12% of cement by weight. Even if most parameters achieve the ERA requirement at 8% and some parameters achieve the ERA requirement at 12% of cement by weight, the optimumPercentage of addition of cement to improve the study's expansive soil was taken as 12% of cement by weight.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The problematic soils obtained from three (Keble's) in (Abeshige Woreda) were stabilized by using cement as additives with different percentagesof this study. Based on the laboratory test results the following points were forwarded as a conclusion of this study.

- Based on laboratory test results from natural soils before treatment the soils obtained from study area were considered as expansive clay soils.
- The test results from Atterberg limit of revealing that the General soils classification systems AASHTO and USCS shows for three samples are A-7-5 and CH respectively; this indicates that the soils are poor and unsuitable to use as a sub grade road construction material unless it improved.
- An addition of cement on natural soil decreases the Liquid limit, increase the plastic limit, and decrease the plasticity index of the soil. The MDD shows a slight increase

and OMC shows a decrease in the treatment of weak subgrade soil with addition of cement.

- As a mixture of cement with soil increases the free swell index become decrease and fulfil Free swell index values recommended by ERA after an addition of 8% of cement.
- CBR values increase as the addition of %cement increase in natural soil.
- An addition of percentage of cement decreases the CBR Swell of soils and increase the strength of soils found in the study area.
- Hence, after treating the expansive soils, the engineering properties of soils obtained from three (Keble's)fulfil the required or recommended values by ERA of subgrade construction material.
- Generally, based on the conducted analysis the optimum percentage of cement to stabilize the expansive soils of study area was obtained at 12% of cement by weight.

5.2 Recommendations

Beside the findings of this study, the following recommendation was forwarded;

- This study was conducted only on three test pits. Additional soil sample should be necessary to come up with good results.
- It is recommended to conducting stabilization by taking large number of samples characterizing the whole study area. Therefore, the findings should be considered as indicative.

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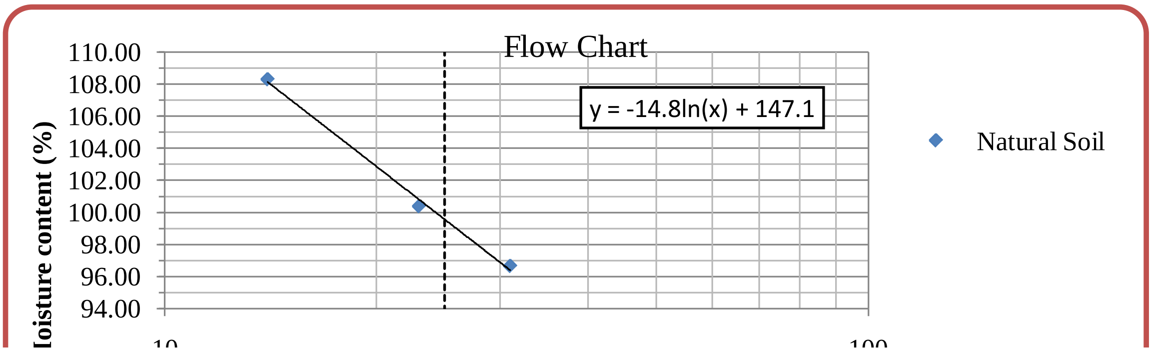
APPENDIX. Laboratory Test Results

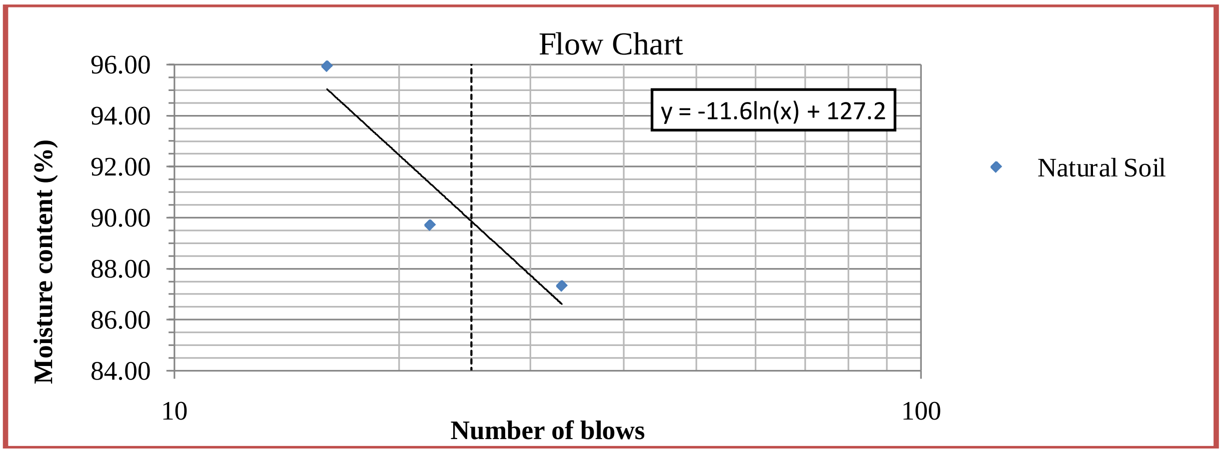
1. ATTERBERG LIMIT TEST

Test pit Location	AbukoKeble				
Material Type	Natural Soil				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	31	23	14		
Trial No	01	02	03	01	02
Wt. of Container, (g)	17.57	18.22	18.47	17.43	18.53
Wt. of container + wet soil, (g)	43.68	40.24	37.97	24.63	30.41
Wt. of container + dry soil, (g)	30.85	29.21	27.83	22.59	26.92
Wt. of water, (g)	12.83	11.03	10.14	2.04	3.49
Wt. of dry soil, (g)	13.28	10.99	9.36	5.16	8.39
Moisture container, (%)	96.64	100.37	108.30	39.53	41.60

Liquid Limit, %	99.6	Ave. Plastic Limit, %	40.6	Plastic Index, %	59.0

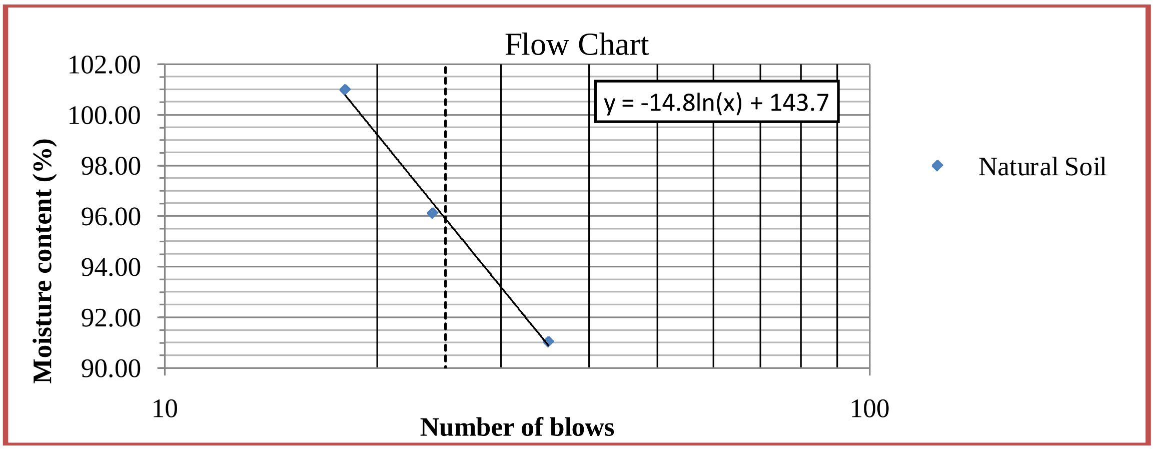


Test pit Location	BedoKeble						
Material Type	Natural Soil						
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)			
Number of blows	33	22	16				
Trial No	01	02	03	01	02		
Wt. of Container, (g)	16.52	17.13	17.36	16.38	17.42		
Wt. of container + wet soil, (g)	41.06	37.83	35.70	23.15	28.59		
Wt. of container + dry soil, (g)	29.62	28.04	26.72	21.69	25.84		
Wt. of water, (g)	11.44	9.79	8.98	1.46	2.75		
Wt. of dry soil, (g)	13.10	10.91	9.36	5.31	8.42		
Moisture container, (%)	87.33	89.70	95.94	27.50	32.66		
Liquid Limit, %	89.8	Ave. Plastic Limit, %	30.1	Plastic Index, %	59.8		

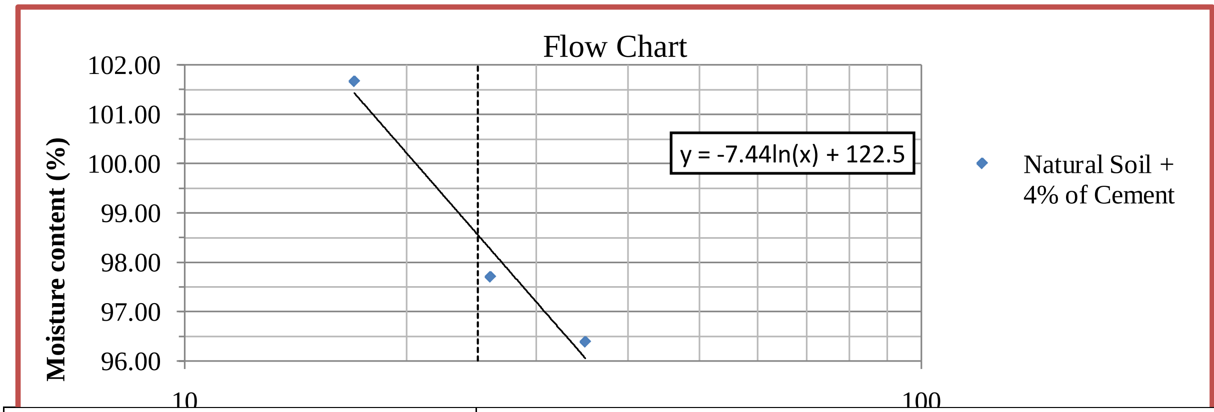


Test pit Location	FintjejuKeble				
Material Type	Natural Soil				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	35	24	18		
Trial No	01	02	03	01	02
Wt. of Container, (g)	18.50	19.19	19.44	18.35	19.51
Wt. of container + wet soil, (g)	45.99	42.37	39.98	25.93	32.02
Wt. of container + dry soil, (g)	32.89	31.01	29.66	24.01	28.78

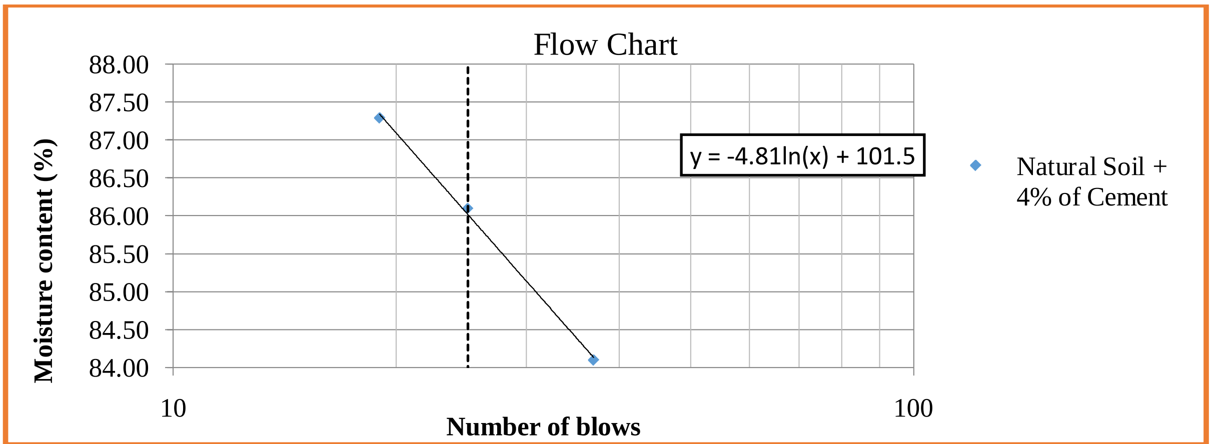
Wt. of water, (g)	13.10	11.36	10.32	1.92	3.24
Wt. of dry soil, (g)	14.39	11.82	10.22	5.66	9.27
Moisture container, (%)	91.04	96.11	100.98	33.92	34.95
Liquid Limit, %	95.9	Ave. Plastic Limit, %	34.4	Plastic Index, %	61.4



Test pit Location	AbukoKeble				
Material Type	Natural Soil + 4% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	35	26	17		
Trial No	01	02	03	01	02
Wt. of Container, (g)	17.05	17.60	17.41	16.48	17.03
Wt. of container + wet soil, (g)	32.82	33.12	30.74	24.99	28.44
Wt. of container + dry soil, (g)	25.08	25.45	24.02	22.10	24.68
Wt. of water, (g)	7.74	7.67	6.72	2.89	3.76
Wt. of dry soil, (g)	8.03	7.85	6.61	5.62	7.65
Moisture container, (%)	96.39	97.71	101.66	51.42	49.15
Liquid Limit, %	98.6	Ave. Plastic Limit, %	50.3	Plastic Index, %	48.3

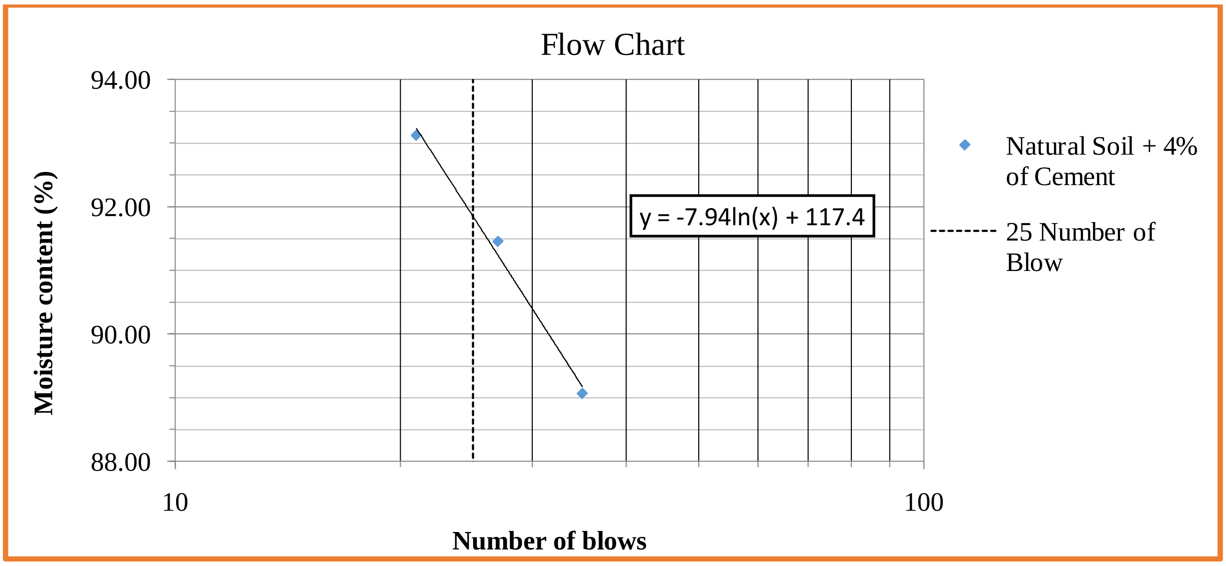


Test pit Location	BedoKeble				
Material Type	Natural Soil + 4% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	37	25	19		
Trial No	01	02	03	01	02
Wt. of Container, (g)	16.03	16.54	16.37	15.49	16.01
Wt. of container + wet soil, (g)	30.85	31.13	28.90	23.49	26.73
Wt. of container + dry soil, (g)	24.08	24.38	23.06	21.22	23.69
Wt. of water, (g)	6.77	6.75	5.84	2.27	3.04
Wt. of dry soil, (g)	8.05	7.84	6.69	5.73	7.68
Moisture container, (%)	84.10	86.10	87.29	39.62	39.58
Liquid Limit, %	86.0	Ave. Plastic Limit, %	39.6	Plastic Index, %	46.4

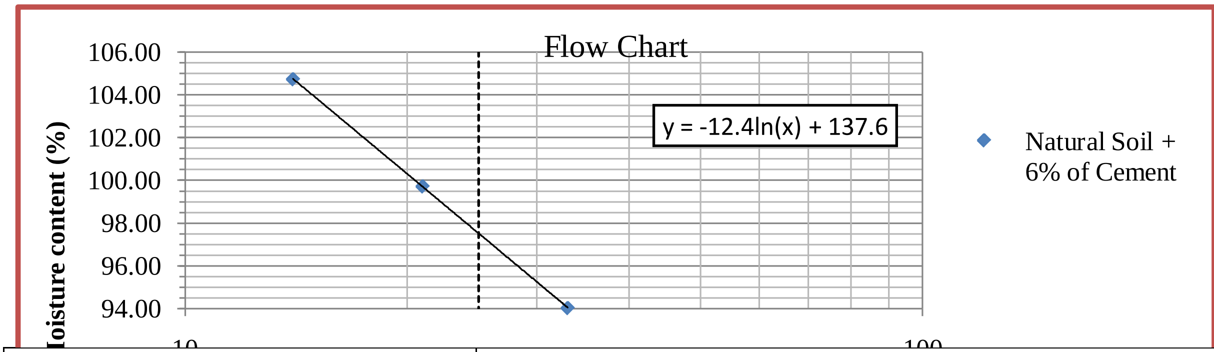


Test pit Location	FintjejuKeble				
Material Type	Natural Soil + 4% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	35	27	21		
Trial No	01	02	03	01	02

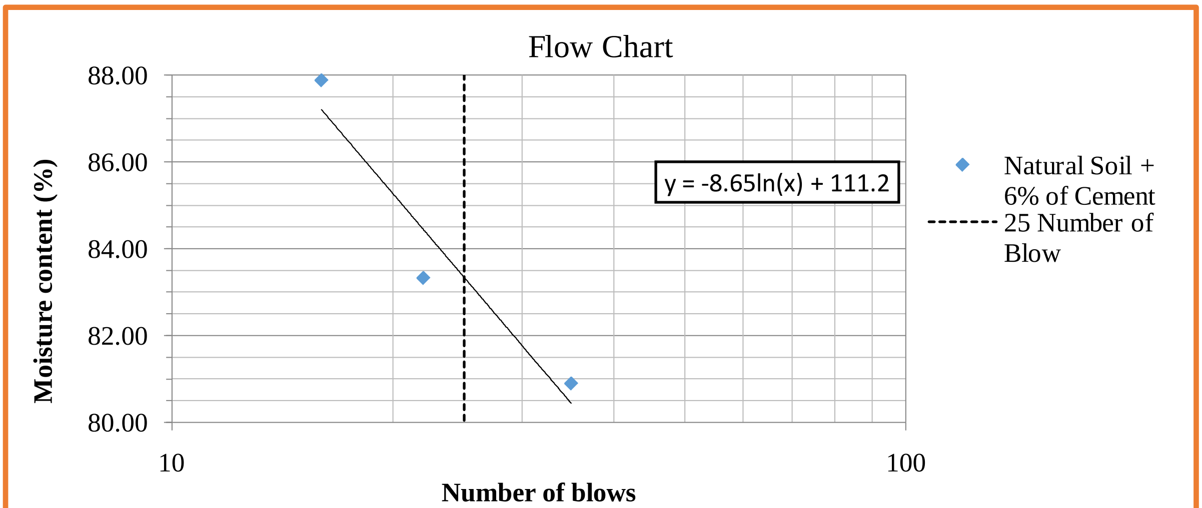
Wt. of Container, (g)		17.95	18.52	18.33	17.35	17.93
Wt. of container + wet soil, (g)		34.55	34.87	32.37	26.31	29.94
Wt. of container + dry soil, (g)		26.73	27.06	25.60	23.55	26.30
Moisture container, (%)		89.07	91.45	93.12	44.39	43.54
Liquid Limit, %	91.8	Ave. Plastic Limit, %	44.0	Plastic Index, %		47.9



Test pit Location	AbukoKeble				
Material Type	Natural Soil + 6% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	33	21	14		
Trial No	01	02	03	01	02
Wt. of Container, (g)	18.21	17.45	18.38	6.73	6.05
Wt. of container + wet soil, (g)	32.82	31.37	33.55	18.93	17.23
Wt. of container + dry soil, (g)	25.74	24.42	25.79	14.83	13.24
Wt. of water, (g)	7.08	6.95	7.76	4.10	3.99
Wt. of dry soil, (g)	7.53	6.97	7.41	8.10	7.19
Moisture container, (%)	94.02	99.71	104.72	50.62	55.49
Liquid Limit, % 97.5	Ave. Plastic Limit, %	53.1	Plastic Index, %		44.4

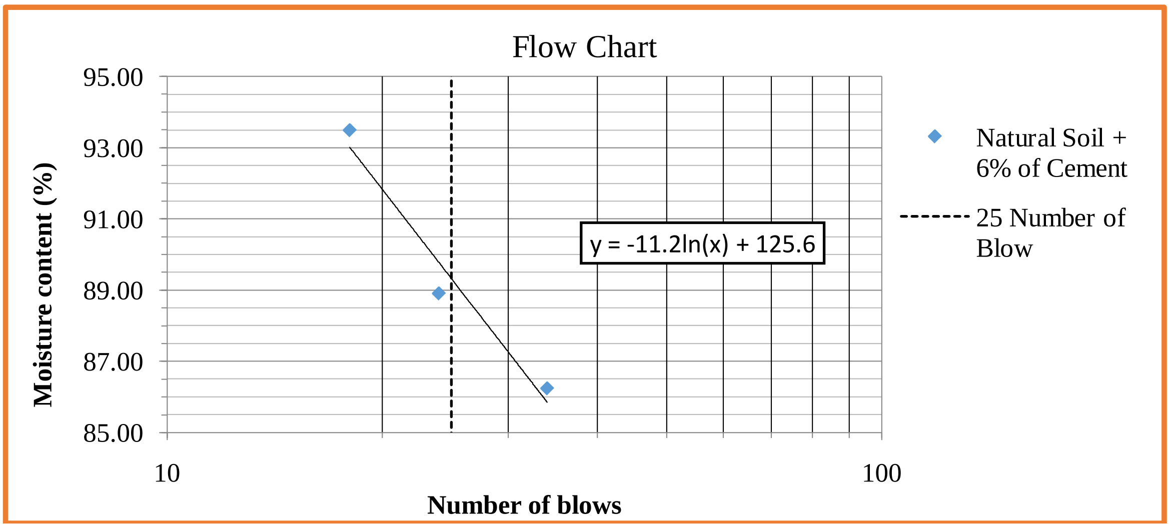


Test pit Location	BedoKeble				
Material Type	Natural Soil + 6% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	35	22	16		
Trial No	01	02	03	01	02
Wt. of Container, (g)	17.12	16.40	17.28	6.33	5.69
Wt. of container + wet soil, (g)	30.85	29.49	31.54	17.79	16.20
Wt. of container + dry soil, (g)	24.71	23.54	24.87	14.24	12.71
Wt. of water, (g)	6.14	5.95	6.67	3.55	3.49
Wt. of dry soil, (g)	7.59	7.14	7.59	7.91	7.02
Moisture container, (%)	80.90	83.33	87.88	44.88	49.72
Liquid Limit, %	83.4	Ave. Plastic Limit, %	47.3	Plastic Index, %	36.1

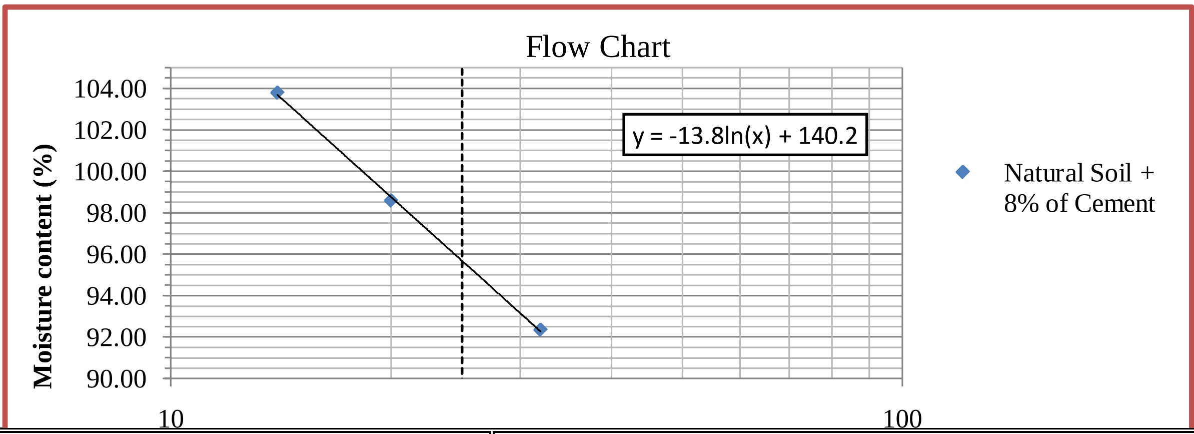


Test pit Location	FintjejuKeble				
Material Type	Natural Soil + 6% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	34	24	18		
Trial No	01	02	03	01	02
Wt. of Container, (g)	19.17	18.37	19.35	7.09	6.38

Wt. of container + wet soil, (g)			34.55	33.03		35.33	19.92		18.14
Wt. of container + dry soil, (g)			27.43	26.13		27.61	15.81		14.11
Wt. of water, (g)			7.12	6.90		7.72	4.11		4.04
Wt. of dry soil, (g)			8.26	7.76		8.26	8.72		7.73
Moisture container, (%)			86.24	88.91		93.50	47.13		52.23
Liquid Limit, %	89.3	Ave. Plastic Limit, %			49.7			Plastic Index, %	39.6

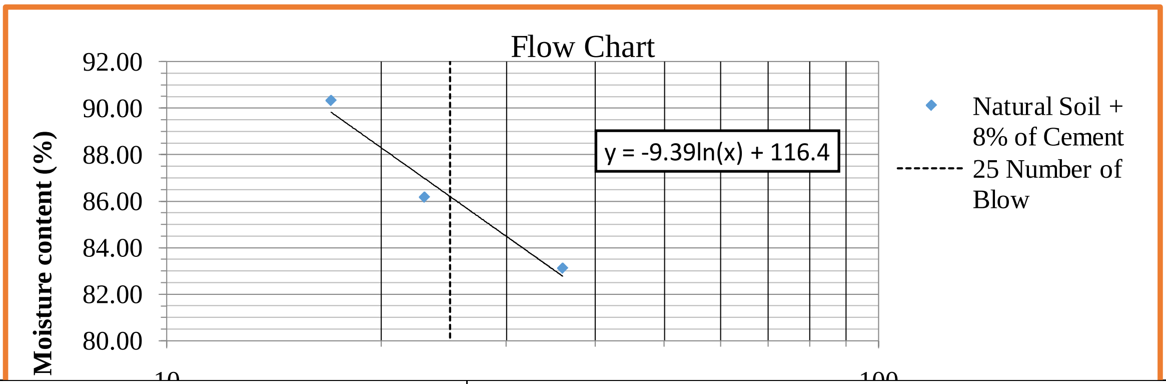


Test pit Location	AbukoKeble				
Material Type	Natural Soil + 8% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	32	20	14		
Trial No	01	02	03	01	02
Wt. of Container, (g)	17.18	17.72	16.77	5.76	6.47
Wt. of container + wet soil, (g)	33.26	31.20	30.16	19.59	12.56
Wt. of container + dry soil, (g)	25.54	24.51	23.34	14.60	10.39
Wt. of water, (g)	7.72	6.69	6.82	4.99	2.17
Wt. of dry soil, (g)	8.36	6.79	6.57	8.84	3.92
Moisture container, (%)	92.34	98.59	103.81	56.45	55.36
Liquid Limit, % 95.7	Ave. Plastic Limit, % 55.9			Plastic Index, % 39.8	

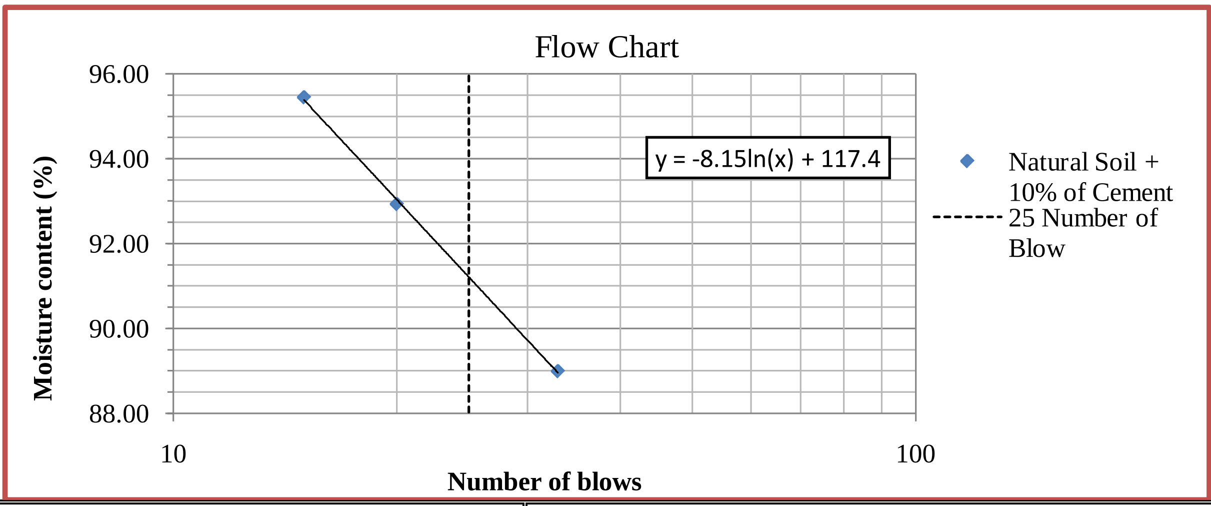


Test pit Location	BedoKeble				
Material Type	Natural Soil + 8% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	34	21	15		
Trial No	01	02	03	01	02
Wt. of Container, (g)	16.15	17.66	15.76	5.41	6.08
Wt. of container + wet soil, (g)	31.26	29.03	28.35	18.41	11.81
Wt. of container + dry soil, (g)	24.62	23.97	22.57	14.02	9.97
Moisture container, (%)	78.39	80.19	84.88	50.99	47.30
Liquid Limit, % 80.2	Ave. Plastic Limit, %	49.1	Plastic Index, %		31.0

Test pit Location	FintjejuKeble				
Material Type	Natural Soil + 8% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	36	23	17		
Trial No	01	02	03	01	02
Wt. of Container, (g)	18.09	19.78	17.65	6.06	6.81
Wt. of container + wet soil, (g)	35.01	32.51	31.75	20.62	13.23
Wt. of container + dry soil, (g)	27.33	26.62	25.06	15.56	11.07
Moisture container, (%)	83.11	86.16	90.32	53.21	50.74
Liquid Limit, % 86.2	Ave. Plastic Limit, %	52.0	Plastic Index, %		34.2

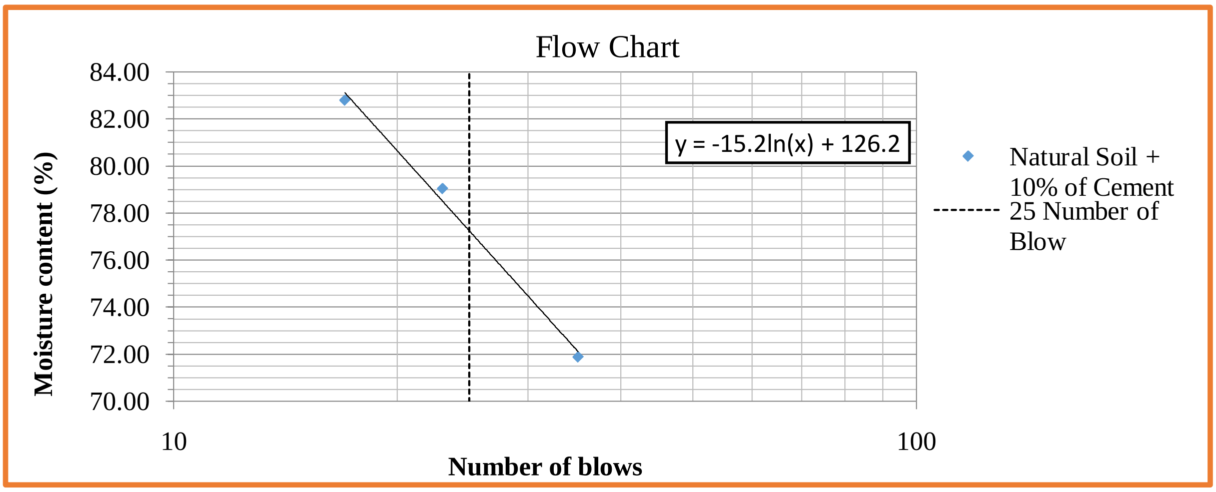


Test pit Location	AbukoKeble				
Material Type	Natural Soil + 10% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	33	20	15		
Trial No	01	02	03	01	02
Wt. of Container, (g)	17.57	17.42	17.49	5.57	6.13
Wt. of container + wet soil, (g)	31.82	33.78	32.52	14.37	13.82
Wt. of container + dry soil, (g)	25.11	25.90	25.18	11.11	11.07
Wt. of water, (g)	6.71	7.88	7.34	3.26	2.75
Wt. of dry soil, (g)	7.54	8.48	7.69	5.54	4.94
Moisture container, (%)	88.99	92.92	95.45	58.84	55.67
Liquid Limit, %	91.2	Ave. Plastic Limit, %	57.3	Plastic Index, %	34.0

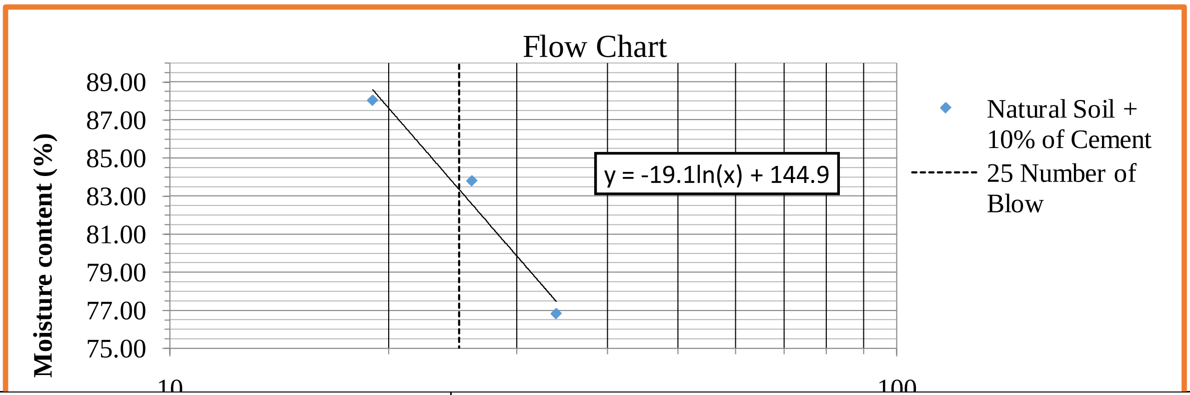


Test pit Location	BedoKeble			
Material Type	Natural Soil + 10% of Cement			
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)
Number of blows	35	23	17	

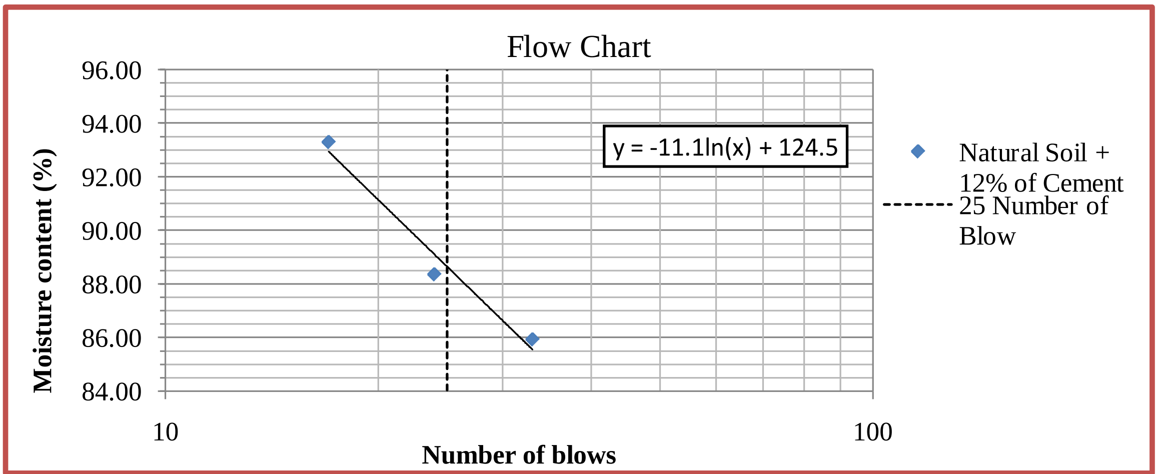
Trial No		01		02	03	01	02
Wt. of Container, (g)		16.52		16.37	16.44	5.24	5.76
Wt. of container + wet soil, (g)		29.91		31.75	30.57	13.51	12.99
Wt. of container + dry soil, (g)		24.31		24.96	24.17	10.67	10.62
Moisture container, (%)		71.89		79.05	82.79	52.30	48.77
Liquid Limit, %	77.2	Ave. Plastic Limit, %		50.5		Plastic Index, %	26.7



Test pit Location				FintjejuKeble				
Material Type				Natural Soil + 10% of Cement				
Determination				Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows				34	26	19		
Trial No				01	02	03	01	02
Wt. of Container, (g)				18.50	18.33	18.41	5.87	6.45
Wt. of container + wet soil, (g)				33.50	35.56	34.24	15.13	14.55
Wt. of container + dry soil, (g)				26.98	27.71	26.83	11.84	11.68
Wt. of water, (g)				6.52	7.85	7.41	3.29	2.87
Wt. of dry soil, (g)				8.48	9.37	8.42	5.98	5.23
Moisture container, (%)				76.81	83.80	88.03	55.01	54.87
				-19.1273	144.9117			
Liquid Limit, %		83.3	Ave. Plastic Limit, %		54.9	Plastic Index, %		28.4

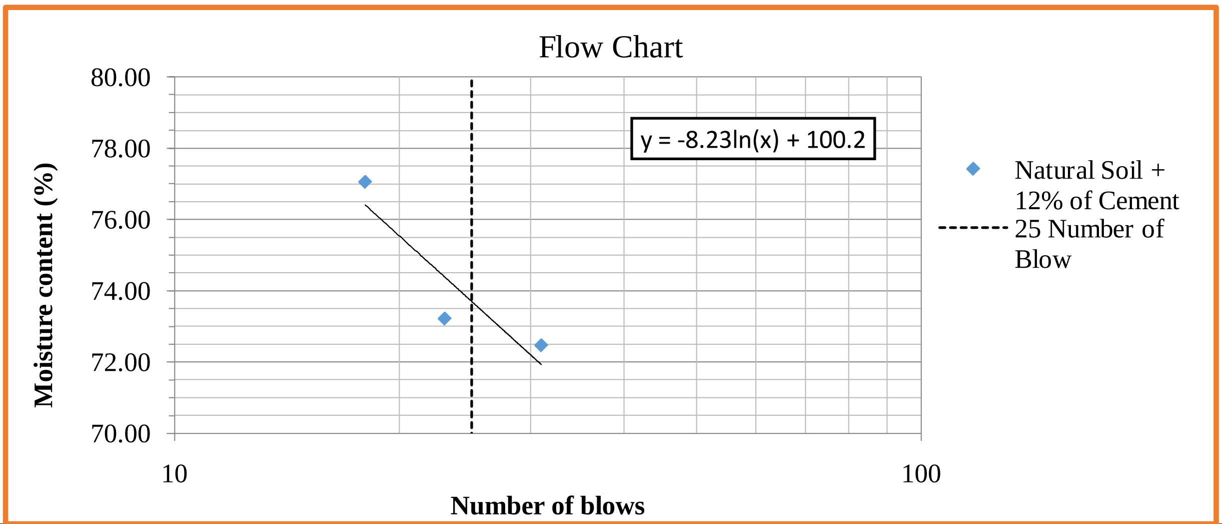


Test pit Location	AbukoKeble				
Material Type	Natural Soil + 12% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	33	24	17		
Trial No	01	02	03	01	02
Wt. of Container, (g)	17.15	17.52	18.04	5.72	5.76
Wt. of container + wet soil, (g)	33.40	30.46	32.73	13.20	15.40
Wt. of container + dry soil, (g)	25.89	24.39	25.64	10.45	11.75
Wt. of water, (g)	7.51	6.07	7.09	2.75	3.65
Wt. of dry soil, (g)	8.74	6.87	7.60	4.73	5.99
Moisture container, (%)	85.93	88.36	93.29	58.14	60.93
		-11.1444	124.5100		
Liquid Limit, %	88.6	Ave. Plastic Limit, %	59.5	Plastic Index, %	29.1

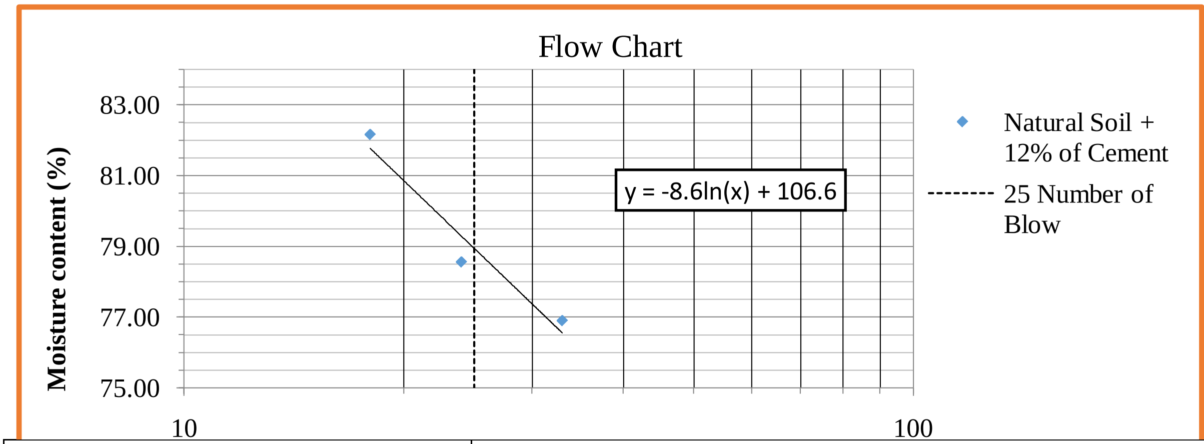


Test pit Location	BedoKeble	
Material Type	Natural Soil + 12% of Cement	
Determination	Liquid Limit (AASHTO T-89)	Plastic Limit

Number of blows		31		23		18	(AASHTO T-90)	
Trial No		01		02		03	01	02
Wt. of Container, (g)		16.12		16.47		16.96	5.38	5.41
Wt. of container + wet soil, (g)		31.40		28.63		30.77	12.41	14.48
Wt. of container + dry soil, (g)		24.98		23.49		24.76	10.03	11.28
Wt. of water, (g)		6.42		5.14		6.01	2.38	3.20
Wt. of dry soil, (g)		8.86		7.02		7.80	4.65	5.87
Moisture container, (%)		72.46		73.22		77.05	51.18	54.51
Liquid Limit, %	73.7	Ave. Plastic Limit, %		52.8		Plastic Index, %		20.9

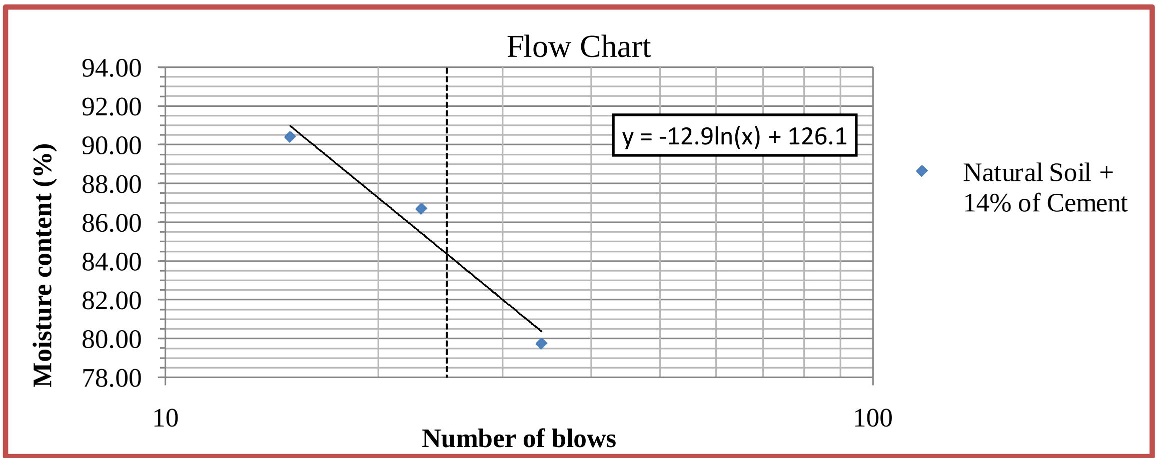


Test pit Location	FintjejuKeble			
Material Type	Natural Soil + 12% of Cement			
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	33	24	18		
Trial No	01	02	03	01	02
Wt. of Container, (g)	18.05	18.45	19.00	6.03	6.06
Wt. of container + wet soil, (g)	35.17	32.07	34.46	13.90	16.22
Wt. of container + dry soil, (g)	27.73	26.07	27.49	11.03	12.53
Wt. of water, (g)	7.44	5.99	6.98	2.87	3.69
Wt. of dry soil, (g)	9.67	7.63	8.49	5.00	6.47
Moisture container, (%)	76.91	78.55	82.16	57.33	57.03
Liquid Limit, % 78.9	Ave. Plastic Limit, % 57.2		Plastic Index, %	21.8	



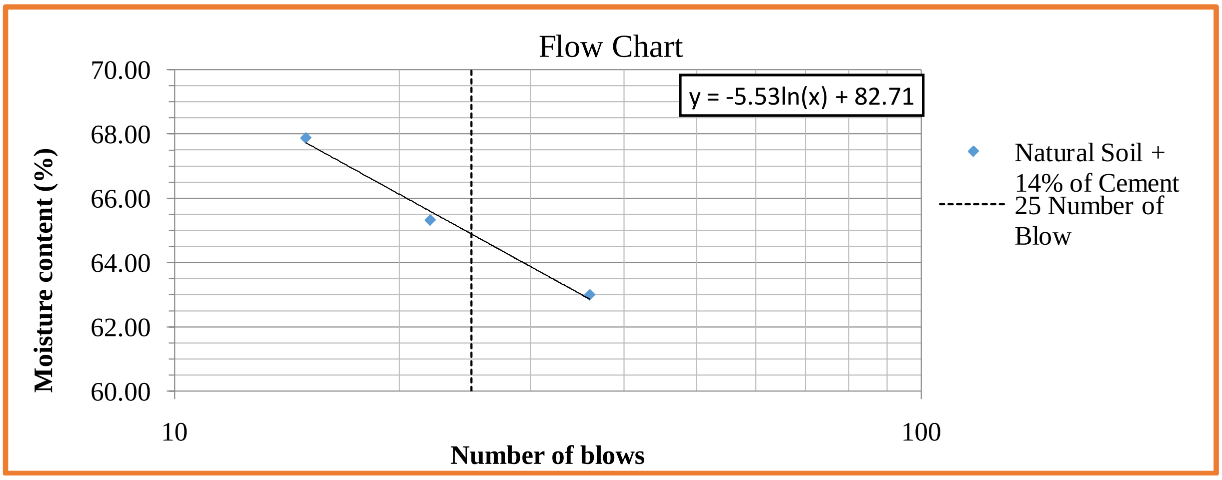
Test pit Location	AbukoKeble				
Material Type	Natural Soil + 14% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	34	23	15		
Trial No	01	02	03	01	02
Wt. of Container, (g)	17.93	17.86	17.44	6.17	5.83
Wt. of container + wet soil, (g)	31.14	32.16	30.73	13.83	13.30
Wt. of container + dry soil, (g)	25.28	25.52	24.42	11.01	10.46
Wt. of water, (g)	5.86	6.64	6.31	2.82	2.84
Wt. of dry soil, (g)	7.35	7.66	6.98	4.84	4.63
Moisture container, (%)	79.73	86.68	90.40	58.26	61.34

Liquid Limit, %	84.4	Ave. Plastic Limit, %	59.8	Plastic Index, %	24.6

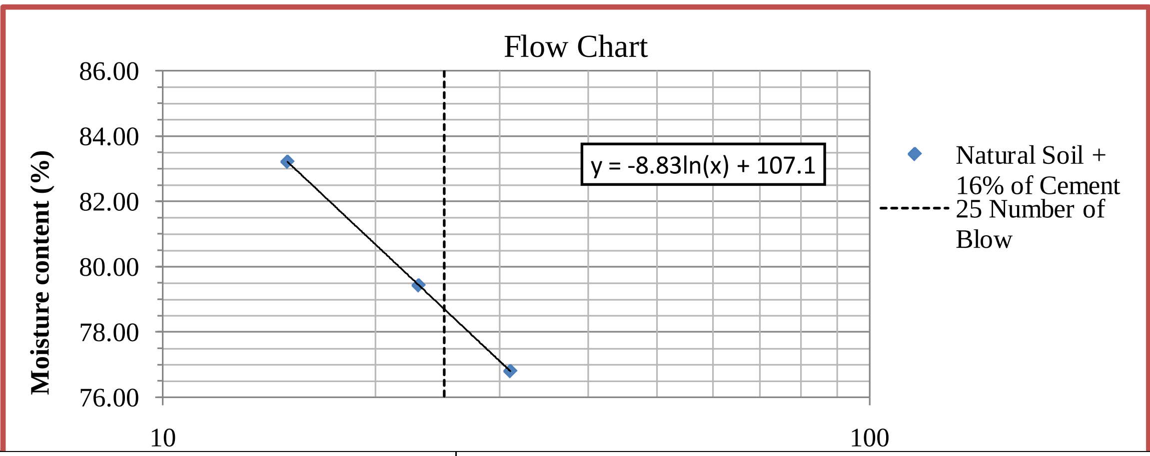


Test pit Location	BedoKeble				
Material Type	Natural Soil + 14% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	36	22	15		
Trial No	01	02	03	01	02

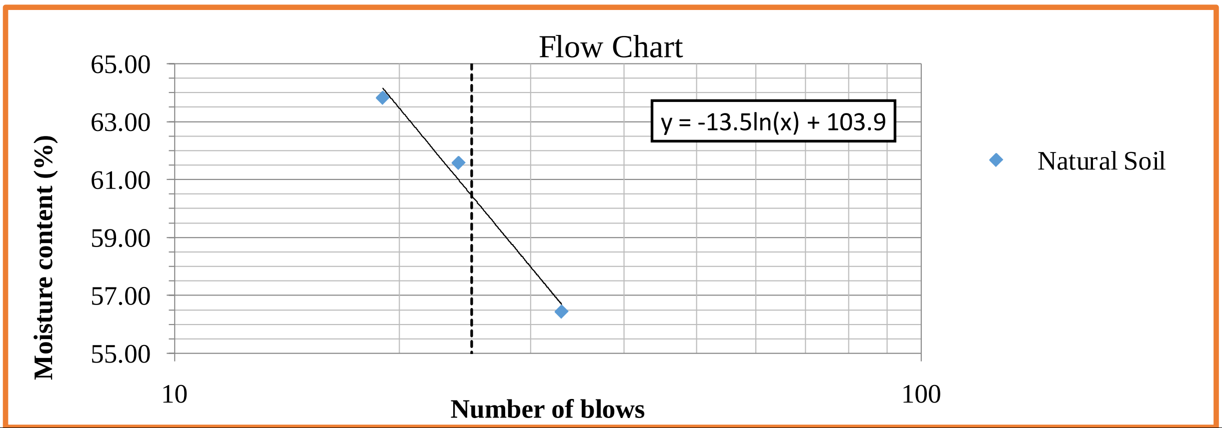
Wt. of Container, (g)		16.85	16.79	16.40	5.80		5.48
Wt. of container + wet soil, (g)		29.27	30.23	28.89	13.00		12.50
Wt. of container + dry soil, (g)		24.47	24.92	23.84	10.57		10.04
Wt. of water, (g)		4.80	5.31	5.05	2.43		2.46
Wt. of dry soil, (g)		7.62	8.13	7.44	4.77		4.56
Moisture container, (%)		62.99	65.31	67.88	50.94		53.95
Liquid Limit, %	64.9	Ave. Plastic Limit, %		52.4	Plastic Index, %		12.4



Test pit Location	AbukoKeble				
Material Type	Natural Soil + 16% of Cement				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	31	23	15		
Trial No	01	02	03	01	02
Wt. of Container, (g)	17.66	17.48	18.36	5.78	5.51
Wt. of container + wet soil, (g)	32.37	31.44	33.75	13.45	13.13
Wt. of container + dry soil, (g)	25.98	25.26	26.76	10.54	10.21
Wt. of water, (g)	6.39	6.18	6.99	2.91	2.92
Wt. of dry soil, (g)	8.32	7.78	8.40	4.76	4.70
Moisture container, (%)	76.80	79.43	83.21	61.13	62.13
Liquid Limit, % 78.7	Ave. Plastic Limit, %	61.6	Plastic Index, %		17.1



Test pit Location	Natural Soil + 16% of Cement				
Material Type	Natural Soil				
Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	33	24	19		
Trial No	01	02	03	01	02
Wt. of Container, (g)	16.60	16.43	17.26	5.43	5.18
Wt. of container + wet soil, (g)	30.43	29.55	31.73	12.64	12.34
Wt. of container + dry soil, (g)	25.44	24.55	26.09	10.12	9.80
Wt. of water, (g)	4.99	5.00	5.64	2.52	2.54
Wt. of dry soil, (g)	8.84	8.12	8.83	4.69	4.62
Moisture container, (%)	56.45	61.58	63.82	53.73	54.98
Liquid Limit, %	60.4	Ave. Plastic Limit, %	54.4	Plastic Index, %	6.1



Test pit Location	FintjejuKeble
Material Type	Natural Soil + 16% of Cement

Determination	Liquid Limit (AASHTO T-89)			Plastic Limit (AASHTO T-90)	
Number of blows	35	26	21		
Trial No	01	02	03	01	02
Wt. of Container, (g)	18.59	18.41	19.33	6.09	5.81
Wt. of container + wet soil, (g)	34.08	33.10	35.53	14.16	13.83
Wt. of container + dry soil, (g)	28.24	27.39	29.00	11.23	10.88
Wt. of water, (g)	5.84	5.71	6.53	2.93	2.95
Wt. of dry soil, (g)	9.65	8.98	9.67	5.15	5.07
Moisture container, (%)	60.57	63.60	67.58	56.86	58.10
	-13.4933	108.2586			
Liquid Limit, %	64.8	Ave. Plastic Limit, %	57.5	Plastic Index, %	7.3

2.1 WET SEIVE Analysis Results

Pit Number	**AbukoKeble**			
Sieve Size	Mass of Retaing (g)	Percentage of Retaing (%)	Cumulative of Percentage Retaining	passing particle
9.50	0	0.00	0.00	100.00
4.75	0	0.00	0.00	100.00
2.00	4.28	0.43	0.43	99.57
0.850	12.916	1.29	1.72	98.28
0.425	13.671	1.37	3.09	96.91
0.250	6.001	0.60	3.69	96.31
0.150	3.407	0.34	4.03	95.97
0.075	5.187	0.52	4.55	95.45
Pan	954.538	190.91	195.45	
Total	1000			

Pit Number	**BedoKeble**			
Sieve Size	Mass of Retaing (g)	Percentage of Retaing (%)	Cumulative of Percentage Retaining	passing particle

9.50	0	0.00	0.00	100.00
4.75	10.3	1.03	1.03	98.97
2.00	9.87	0.99	2.02	97.98
0.850	15.1	1.51	3.53	96.47
0.425	13.4	1.34	4.87	95.13
0.250	9.74	0.97	5.84	94.16
0.150	7.23	0.72	6.56	93.44
0.075	11.02	1.10	7.67	92.33
Pan	923.34	184.67	192.33	

Pit Number	**FintjejuKeble**			
Sieve Size	Mass of Retaing (g)	Percentage of Retaing (%)	Cumulative of Percentage Retaining	passing particle
9.50	0	0.00	0.00	100.00
4.75	9.80	0.98	0.98	99.02
2.00	6.42	0.64	1.62	98.38
0.850	19.37	1.94	3.56	96.44
0.425	20.51	2.05	5.61	94.39
0.250	9.00	0.90	6.51	93.49
0.150	5.11	0.51	7.02	92.98
0.075	7.78	0.78	7.80	92.20
Pan	922.007	184.40	192.20	
Total	1000			

2.2 HYDROMETER ANALYSIS RESULT

Hydrometer analysis for AbukoKeble soil samples

Elapsed time t in, min	Actual Hydrometer Reading	Eff.depthL(cm)	Temperature (c0)	K	C_T	Par.diameter D (mm)	Value of 'a' for Gs	Corrected hydrometer reading for	% Finer D, P(%)=Rd+a/Mo	corrected (Pa)
1	49	8.1	23	0.01292084	0.7	0.0368	0.985983	45.7	90.1	86.02
2	45	8.8	23	0.01292084	0.7	0.0270	0.985983	41.7	82.2	78.49
5	43.2	9.0	23	0.01292084	0.7	0.0174	0.985983	39.9	78.7	75.10
8	43	9.1	23	0.01292084	0.7	0.0138	0.985983	39.7	78.3	74.73
15	41	9.4	23	0.01292084	0.7	0.0102	0.985983	37.7	74.3	70.96
30	40	9.6	23	0.01292084	0.7	0.0073	0.985983	36.7	72.4	69.08
60	39	9.7	23	0.01292084	0.7	0.0052	0.985983	35.7	70.4	67.20
120	35	10.4	23	0.01292084	0.7	0.0038	0.985983	31.7	62.5	59.67
240	33	10.7	23	0.01292084	0.7	0.0027	0.985983	29.7	58.6	55.90

480	30	11.2	23	0.01292084	0.7	0.0020	0.985983	26.7	52.7	50.26
1440	29	11.4	23	0.01292084	0.7	0.0011	0.985983	25.7	50.7	48.38

Hydrometer analysis for BedoKeble soil samples

Elapsed time t in, min	Actual Hydrometer Reading	Eff.depth,L (cm)	Temperature (c0)	K	CT	Par.diameter D (mm)	Value of 'a' for Gs	Corrected hydrometer reading for	% Finer D,P(%)=Rd+a/Mo	corrected (Pa)
1	51	7.8	23	0.012879251	0.7	0.0359	0.98355	47.7	93.8	86.64
2	48	8.3	23	0.012879251	0.7	0.0262	0.98355	44.7	87.9	81.19
5	45	8.8	23	0.012879251	0.7	0.0170	0.98355	41.7	82.0	75.74
8	45	8.8	23	0.012879251	0.7	0.0135	0.98355	41.7	82.0	75.74
15	43	9.1	23	0.012879251	0.7	0.0100	0.98355	39.7	78.1	72.11
30	42	9.2	23	0.012879251	0.7	0.0071	0.98355	38.7	76.1	70.29
60	41	9.4	23	0.012879251	0.7	0.0051	0.98355	37.7	74.2	68.47
120	37	10.1	23	0.012879251	0.7	0.0037	0.98355	33.7	66.3	61.21
240	35	10.4	23	0.012879251	0.7	0.0027	0.98355	31.7	62.4	57.58
480	32	10.9	23	0.012879251	0.7	0.0019	0.98355	28.7	56.5	52.13
1440	31	11.0	23	0.012879251	0.7	0.0011	0.98355	27.7	54.5	50.31

Hydrometer analysis for FintjejuKeble soil samples

Elapsed time t in, min	Actual Hydrometer Reading	Eff.depth,L (cm)	Temperature (c0)	K	CT	Par.diameter D (mm)	Value of 'a' for Gs	Corrected hydrometer reading for persentpartic l	% Finer D,P(%)=Rd+a/Mo	corrected (Pa)
0										
1	50	7.9	23	0.012919	0.7	0.0364	0.985868	46.7	92.1	84.90
2	47	8.4	23	0.012919	0.7	0.0265	0.985868	43.7	86.2	79.44
5	45	8.8	23	0.012919	0.7	0.0171	0.985868	41.7	82.2	75.81
8	41	9.4	23	0.012919	0.7	0.0140	0.985868	37.7	74.3	68.54
15	39	9.7	23	0.012919	0.7	0.0104	0.985868	35.7	70.4	64.90
30	38	9.9	23	0.012919	0.7	0.0074	0.985868	34.7	68.4	63.08
60	37	10.1	23	0.012919	0.7	0.0053	0.985868	33.7	66.4	61.27
120	35	10.4	23	0.012919	0.7	0.0038	0.985868	31.7	62.5	57.63
240	34	10.6	23	0.012919	0.7	0.0027	0.985868	30.7	60.5	55.81
480	33	10.7	23	0.012919	0.7	0.0019	0.985868	29.7	58.6	53.99
1440	32	10.9	23	0.012919	0.7	0.0011	0.985868	28.7	56.6	52.18

Specific gravity analysis results

Test pit Location	AbukoKeble		
Test Pit No	Sample 1		
Code of Pycnometer	2	6	AB
Mass of Pycnometer	20.011	17.087	22.242
Mass of Pycnometer with Dry Soil	29.395	25.952	30.984
Mass of Pycnometer with Dry Soil and Water	51.926	49.031	83.492
Mass of Pycnometer and Water	46.005	43.43	77.961
Temperature of Pycnometer with Water (T^0_{ci})	24	24	24
Density of water at (T^0_{ci})	0.99732	0.99732	0.99732
Temperature of Pycnometer with Soil and Water (T^0_{cx})	24	24	24
Density of water at (T^0_{cx})	0.99732	0.99732	0.99732
Corrected Mass of Pycnometer and Water	46.005	43.43	77.961
Correction Factor, K at 20^0_c	0.9991	0.9991	0.9991
Specific Gravity, Gs at 20^0_c	2.7074	2.7135	2.7201
Average Specific Gravity, Gs at 20^0_c	**2.71**		

Test pit Location	BedoKeble		
Test Pit No	Sample 1		
Code of Pycnometer	1	2	3
Mass of Pycnometer	19.611	16.745	21.797
Mass of Pycnometer with Dry Soil	28.807	25.433	30.364
Mass of Pycnometer with Dry Soil and Water	50.887	48.050	81.822
Mass of Pycnometer and Water	45.085	42.561	76.402
Temperature of Pycnometer with Water (T^0_{ci})	21	21	21
Density of water at (T^0_{ci})	0.99802	0.99802	0.99802
Temperature of Pycnometer with Soil and Water (T^0_{cx})	22	22	22
Density of water at (T^0_{cx})	0.9978	0.9978	0.9978
Corrected Mass of Pycnometer and Water	45.07496	42.55202	76.38494
Correction Factor, K at 20^0_c	0.9996	0.9996	0.9996
Specific Gravity, Gs at 20^0_c	2.7167	2.7229	2.7361
Average Specific Gravity, Gs at 20^0_c	**2.73**		

2. Compaction Test Results

Test pit Location	AbukoKebele				
Percentage of cement	**Natural Soil + 0%**				
Mass of mold, (gm)	5463.4	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	17.92	17.5	49.67	17.43	
	18.76	17.53	37.75	17.57	
Mass of can +wet soil	116.38	88.01	140.27	84.16	
	106.85	88.63	120.15	80.99	
Mass of can +dry soil	104.15	76.95	123.88	69.38	
	96.05	77.29	105.05	67.1	
water content	14.18	18.60	22.09	28.45	
	13.97	18.98	22.44	28.04	
Average water content, (%)	**14.08**	**18.79**	**22.26**	**28.25**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	9016.7	9269.2	9404.1	9480.1	
Bulk density, (g/cm^3)	1.67	1.79	1.86	1.89	
Dry density, (g/cm^3)	1.47	1.51	1.52	1.48	
Maximum Dry Density (g/cm^3)	***1.52***	***Optimum Water Content (%)***			***22***

Test pit Location	BedoKebele				
Percentage of cement	**Natural Soil + 0%**				
Mass of mold, (gm)	6037.1	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	19.174	18.725	53.149	18.65	
	20.073	18.757	40.395	18.8	
Mass of can +wet soil	124.527	94.177	150.089	90.051	
	114.33	94.834	128.565	86.659	
Mass of can +dry soil	107.275	80.08	128.835	72.155	
	99.892	80.386	109.252	69.784	
water content	19.58	22.98	28.08	33.45	
	18.09	23.44	28.05	33.10	
Average water content, (%)	**18.84**	**23.21**	**28.06**	**33.27**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	9106.8	9472.2	9652.6	9595.1	

Dry density, (g/cm^3)	1.44	1.53	1.54	1.46	
Maximum Dry Density (g/cm^3)	***1.55***	***Optimum Water Content (%)***			***26***

Test pit Location	FintjejuKebele				
Percentage of cement	**Natural Soil + 0%**				
Mass of mold, (gm)	6061.2	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	17.45	17.04	48.37	16.97	
	18.27	17.07	36.76	17.11	
Mass of can +wet soil	113.32	85.7	136.58	81.95	
	104.04	86.3	116.99	78.86	
Mass of can +dry soil	97.62	72.87	117.24	65.66	
	90.9	73.15	99.42	63.5	
water content	19.58	22.98	28.08	33.46	
	18.09	23.45	28.04	33.11	
Average water content, (%)	**18.84**	**23.21**	**28.06**	**33.28**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	9562.1	10040.5	10131.8	10070.8	
Dry density, (g/cm^3)	1.39	1.52	1.50	1.42	
Maximum Dry Density (g/cm^3)	***1.53***	***Optimum Water Content (%)***			***24***

Test pit Location	AbukoKebele				
Percentage of cement	**Natural Soil + 4% Cement**				
Mass of mold, (gm)	2717.8	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	28.08	49.719	31.477	17.489	41.322
	17.91	17.483	18.504	37.745	17.556
Mass of can +wet soil	110.34	153.464	149.332	93.215	117.753
	89.72	101.138	95.623	130.836	65.706
Mass of can +dry soil	99.98	138.963	128.894	77.679	100.28
	80.39	89.91	82.934	111.94	54.3
water content	14.41	16.25	20.98	25.81	29.64
	14.93	15.50	19.69	25.47	31.04
Average water content, (%)	**14.67**	**15.88**	**20.34**	**25.64**	**30.34**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6165	6317.5	6644.5	6751.5	6793.5
Bulk density, (g/cm^3)	1.62	1.70	1.85	1.90	1.92
Dry density, (g/cm^3)	1.42	1.46	1.54	1.51	1.47
Maximum Dry Density (g/cm^3)	***1.54***	***Optimum Water Content (%)***			***21***

Test pit Location	BedoKebele				
Percentage of cement	**Natural Soil + 4% Cement**				
Mass of mold, (gm)	2728.7	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	30.05	53.2	33.68	18.71	44.21
	19.16	18.71	19.8	40.39	18.78
Mass of can +wet soil	118.06	164.21	159.79	99.74	126
	96	108.22	102.32	139.99	70.31
Mass of can +dry soil	106.98	148.59	137.91	83.12	107.3
	86.02	96.1	88.04	119.78	58.1
water content	14.40	16.37	20.99	25.80	29.64
	14.93	15.66	20.93	25.46	31.05
Average water content, (%)	**14.66**	**16.02**	**20.96**	**25.63**	**30.35**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6226.7	6380.7	6750.9	6929	6861.4
Dry density, (g/cm^3)	1.44	1.48	1.57	1.57	1.49
Maximum Dry Density (g/cm^3)	***1.58***	***Optimum Water Content (%)***			***24***

Test pit Location	FintjejuKebele				
Percentage of cement	**Natural Soil + 4% Cement**				
Mass of mold, (gm)	2739.6	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	27.35	48.41	30.65	17.03	40.23
	17.44	17.03	18.02	36.75	17.09
Mass of can +wet soil	107.43	149.43	145.41	90.76	114.66
	87.36	98.48	93.11	127.39	63.98
Mass of can +dry soil	97.35	135.22	125.5	75.64	97.64
	78.28	87.45	80.12	109	52.87
water content	14.40	16.37	20.99	23.48	26.97
	14.92	15.66	20.92	23.17	28.26
Average water content, (%)	**14.66**	**16.02**	**20.95**	**23.32**	**27.62**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6102.2	6472.1	6753.4	6816.9	6720.2
Dry density, (g/cm^3)	1.38	1.52	1.56	1.56	1.47
Maximum Dry Density (g/cm^3)	***1.565***	***Optimum Water Content (%)***			***22***

Test pit Location	BedoKebele				
Percentage of cement	**Natural Soil + 6% Cement**				
Mass of mold, (gm)	2730.9	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	19.74	19.1	18.37	39.08	18.96
	30.48	18.9	19.68	39.22	19.33
Mass of can +wet soil	117.42	69.65	101.43	123.05	87.91
	132.55	68.9	88.34	116.82	84.24
Mass of can +dry soil	104.95	61.93	86.13	103.96	69.97
	119.76	61.56	76.09	99.91	67.25
water content	14.63	18.02	22.58	29.42	35.17
	14.33	17.21	21.72	27.86	35.45
Average water content, (%)	**14.48**	**17.62**	**22.15**	**28.64**	**35.31**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6386.3	6619.9	6879.2	6788.7	6688.2
Bulk density, (g/cm^3)	1.72	1.83	1.96	1.91	1.87
Dry density, (g/cm^3)	1.50	1.56	1.60	1.49	1.38
Maximum Dry Density (g/cm^3)	***1.60***	***Optimum Water Content (%)***			***21.5***

Test pit Location	FintjejuKebele				
Percentage of cement	**Natural Soil + 6% Cement**				
Mass of mold, (gm)	2741.8	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	17.96	17.38	16.72	35.56	17.25
	27.74	17.2	17.91	35.69	17.59
Mass of can +wet soil	106.85	63.38	92.3	111.98	80
	120.62	62.7	80.39	106.31	76.66
Mass of can +dry soil	95.5	56.36	78.38	94.6	63.67
	108.98	56.02	69.24	90.92	61.2
water content	14.64	18.01	22.58	29.44	35.18
	14.33	17.21	21.72	27.87	35.45
Average water content, (%)	**14.48**	**17.61**	**22.15**	**28.65**	**35.31**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6348	6580.2	6837.9	6748	6648.1
Bulk density, (g/cm^3)	1.70	1.81	1.93	1.89	1.84
Dry density, (g/cm^3)	1.48	1.54	1.58	1.47	1.36
Maximum Dry Density (g/cm^3)	***1.58***	***Optimum Water Content (%)***			***21***

Test pit Location	AbukoKebele
Percentage of cement	**Natural Soil + 8% Cement**

Mass of mold, (gm)	2717.8	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	27.87	17.468	17.153	18.235	17.09
	17.56	17.555	17.666	17.575	17.208
Mass of can +wet soil	86.56	108.207	81.03	99.118	85.484
	85.83	107.034	78.668	99.569	97.599
Mass of can +dry soil	79.66	94.856	69.597	82.609	70.054
	77.47	93.799	67.75	82.486	79.002
water content	13.32	17.25	21.80	25.65	29.13
	13.95	17.36	21.80	26.32	30.10
Average water content, (%)	**13.64**	**17.31**	**21.80**	**25.98**	**29.61**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6420.2	6644.5	6782	6806	6727.5
Bulk density, (g/cm^3)	1.74	1.85	1.91	1.93	1.89
Dry density, (g/cm^3)	1.53	1.58	1.57	1.53	1.46
Maximum Dry Density (g/cm^3)	***1.58***	***Optimum Water Content (%)***			***19***

Test pit Location	BedoKebele				
Percentage of cement	**Natural Soil + 8% Cement**				
Mass of mold, (gm)	2728.7	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	29.82	18.69	18.35	19.51	18.29
	18.79	18.78	18.9	18.81	18.41
Mass of can +wet soil	92.62	115.78	86.7	106.06	91.47
	91.84	114.53	84.17	106.54	104.43
Mass of can +dry soil	86.24	102.5	74.47	88.39	74.96
	83.89	101.36	72.49	88.26	84.53
water content	11.31	15.85	21.79	25.65	29.13
	12.21	15.95	21.80	26.32	30.10
Average water content, (%)	**11.76**	**15.90**	**21.79**	**25.99**	**29.62**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6384.4	6680.9	6949.8	6874.1	6794.8
Bulk density, (g/cm^3)	1.72	1.86	1.99	1.95	1.92
Dry density, (g/cm^3)	1.54	1.61	1.63	1.55	1.48
Maximum Dry Density (g/cm^3)	***1.635***	***Optimum Water Content (%)***			***21***

Test pit Location	FintjejuKebele		
Percentage of cement	**Natural Soil + 8% Cement**		
Mass of mold, (gm)	2739.6	Volume of mold, (cm^3)	2123

Determination of water content					
Trials	01	02	03	04	05
Mass of can	27.14	17.01	16.7	17.75	16.64
	17.1	17.09	17.2	17.12	16.75
Mass of can +wet soil	84.28	105.36	78.9	96.51	83.24
	83.57	104.22	76.59	96.95	95.03
Mass of can +dry soil	78.48	93.28	67.77	80.43	68.21
	76.34	92.24	65.97	80.32	76.92
water content	11.30	15.84	21.79	25.65	29.14
	12.20	15.94	21.78	26.31	30.10
Average water content, (%)	**11.75**	**15.89**	**21.78**	**25.98**	**29.62**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6346.1	6640.8	6908.1	6832.9	6754
Bulk density, (g/cm^3)	1.70	1.84	1.96	1.93	1.89
Dry density, (g/cm^3)	1.52	1.59	1.61	1.53	1.46
Maximum Dry Density (g/cm^3)	***1.615***	***Optimum Water Content (%)***			***20.5***

Test pit Location	AbukoKebele				
Percentage of cement	**Natural Soil + 10% Cement**				
Mass of mold, (gm)	2722	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	37.754	17.492	18.496	41.322	
	49.72	17.546	17.437	31.449	
Mass of can +wet soil	175.206	100.345	86.388	143.035	
	207.267	99.597	91.638	154.324	
Mass of can +dry soil	157.455	86.817	73.707	120.398	
	187.997	87.273	77.357	127.792	
water content	14.83	19.51	22.97	28.63	
	13.94	17.67	23.83	27.54	
Average water content, (%)	**14.38**	**18.59**	**23.40**	**28.08**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6514.5	6823.5	6861.5	6785	
Bulk density, (g/cm^3)	1.79	1.93	1.95	1.91	
Dry density, (g/cm^3)	1.56	1.63	1.58	1.49	
Maximum Dry Density (g/cm^3)	***1.63***	***Optimum Water Content (%)***			***18.5***

Test pit Location	BedoKebele				
Percentage of cement	**Natural Soil + 10% Cement**				
Mass of mold, (gm)	2732.9	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05

Mass of can	40.4	18.72	19.79	44.21	
	53.2	18.77	18.66	33.65	
Mass of can +wet soil	187.47	107.37	92.44	153.05	
	221.78	106.57	98.05	165.13	
Mass of can +dry soil	169.48	94.89	79.87	130.83	
	203.16	94.38	83.77	137.74	
water content	13.94	16.38	20.92	25.65	
	12.42	16.12	21.93	26.31	
Average water content, (%)	**13.18**	**16.25**	**21.43**	**25.98**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil,	6479.	6831.7	6890.1	6852.9	0
Dry density, (g/cm^3)	1.56	1.66	1.61	1.54	
Maximum Dry Density (g/cm^3)	***1.66***	***Optimum Water Content (%)***			***16.5***

Test pit Location	FintjejuKebele				
Percentage of cement	**Natural Soil + 10% Cement**				
Mass of mold, (gm)	2743.8	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	36.76	17.04	18.01	40.23	
	48.41	17.08	16.98	30.62	
Mass of can +wet soil	170.6	97.71	84.12	139.28	
	201.82	96.98	89.23	150.27	
Mass of can +dry soil	154.23	86.35	72.68	119.06	
	184.88	85.89	76.23	125.34	
water content	13.94	16.39	20.93	25.65	
	12.41	16.12	21.94	26.32	
Average water content, (%)	**13.17**	**16.25**	**21.43**	**25.98**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6440.7	6790.7	6848.8	6811.8	
Bulk density, (g/cm^3)	1.74	1.91	1.93	1.92	
Dry density, (g/cm^3)	1.54	1.64	1.59	1.52	
Maximum Dry Density (g/cm^3)	***1.64***	***Optimum Water Content (%)***			***17***

Test pit Location	AbukoKebele				
Percentage of cement	**Natural Soil + 12% Cement**				
Mass of mold, (gm)	2717.4	Volume of mold, (cm^3)			2123
Determination of water content					
Trials		02	03	04	05
Mass of can	17.65	17.875	18.396	17.72	36.539
	19.6	17.668	17.174	18.054	36.522
Mass of can +wet soil	57.14	97.56	102.452	81.087	152.777
	64.83	103.392	96.416	79.145	139.272

Mass of can +dry soil	52.43	85.455	86.356	67.681	124.131
	58.95	90.43	81.292	66.264	113.906
water content	13.54	17.91	23.68	26.83	32.70
	14.94	17.81	23.59	26.72	32.78
Average water content, (%)	**14.24**	**17.86**	**23.64**	**26.78**	**32.74**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6391	6820	6818	6802	6673
Bulk density, (g/cm^3)	1.73	1.93	1.93	1.92	1.86
Dry density, (g/cm^3)	1.51	1.64	1.56	1.52	1.40
Maximum Dry Density (g/cm^3)	***1.64***	***Optimum Water Content (%)***			***17***

Test pit Location	BedoKebele				
Percentage of cement	**Natural Soil + 12% Cement**				
Mass of mold, (gm)	2728.3	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	18.89	19.13	19.68	18.96	
	20.97	18.9	18.38	19.32	
Mass of can +wet soil	61.14	104.39	109.62	86.76	
	69.37	110.63	103.17	84.69	
Mass of can +dry soil	57.1	92.94	94.4	73.42	
	64.08	98.66	88.98	71.9	
water content	10.57	15.51	20.37	24.50	
	12.27	15.01	20.10	24.32	
Average water content, (%)	**11.42**	**15.26**	**20.23**	**24.41**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6554.9	6868.2	6886.2	6870	
Bulk density, (g/cm^3)	1.80	1.95	1.96	1.95	
Dry density, (g/cm^3)	1.62	1.69	1.63	1.57	
Maximum Dry Density (g/cm^3)	***1.69***	***Optimum Water Content (%)***			***15***

Test pit Location	FintjejuKebele				
Percentage of cement	**Natural Soil + 12% Cement**				
Mass of mold, (gm)	2739.2	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	17.19	17.41	17.91	17.25	
	19.08	17.2	16.73	17.58	
Mass of can +wet soil	55.64	94.99	99.75	78.95	
	63.13	100.67	93.88	77.07	
Mass of can +dry soil	51.96	84.58	85.9	66.81	
	58.31	89.78	80.97	65.43	
water content	10.58	15.50	20.37	24.50	
	12.29	15.00	20.10	24.33	

Average water content, (%)	**11.44**	**15.25**	**20.23**	**24.41**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6515.6	6827	6844.9	6828.8	
Bulk density, (g/cm^3)	1.78	1.93	1.93	1.93	
Dry density, (g/cm^3)	1.60	1.67	1.61	1.55	
Maximum Dry Density (g/cm^3)	***1.67***	***Optimum Water Content (%)***			***15***

Test pit Location	AbukoKebele				
Percentage of cement	**Natural Soil + 14% Cement**				
Mass of mold, (gm)	2722	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	16.03	18.218	17.161	17.176	18.066
	19.3	18.4	17.863	17.558	17.465
Mass of can +wet soil	60.96	117.668	98.064	95.196	109.497
	68.28	128.219	102.479	95.775	106.087
Mass of can +dry soil	56.13	104.841	84.938	79.873	89.98
	62.95	113.219	88.55	81.084	87.258
water content	12.04	14.81	19.37	24.44	27.14
	12.21	15.82	19.71	23.13	26.98
Average water content, (%)	**12.13**	**15.31**	**19.54**	**23.78**	**27.06**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6435.4	6740	6861.1	6779.3	6729.5
Bulk density, (g/cm^3)	1.75	1.89	1.95	1.91	1.89
Dry density, (g/cm^3)	1.56	1.64	1.63	1.54	1.49
Maximum Dry Density (g/cm^3)	***1.65***	***Optimum Water Content (%)***			***17***

Test pit Location	BedoKebele				
Percentage of cement	**Natural Soil + 14% Cement**				
Mass of mold, (gm)	2732.9	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	17.15	19.49	18.36	18.38	
	20.65	19.69	19.11	18.79	
Mass of can +wet soil	65.23	125.9	104.93	101.86	
	73.06	137.19	109.65	102.48	
Mass of can +dry soil	61.06	113.18	91.88	86.46	
	68.36	122.64	95.75	87.76	
water content	9.50	13.58	17.75	22.62	
	9.85	14.13	18.14	21.34	
Average water content, (%)	**9.67**	**13.85**	**17.94**	**21.98**	
Determination of Bulk density and Dry density					

Mass of mold + Compacted soil, (gm)	6499.8	6877.4	6929.7	6847.1	
Bulk density, (g/cm^3)	1.77	1.95	1.98	1.94	
Dry density, (g/cm^3)	1.62	1.71	1.68	1.59	
Maximum Dry Density (g/cm^3)	***1.7***	***Optimum Water Content (%)***			***14***

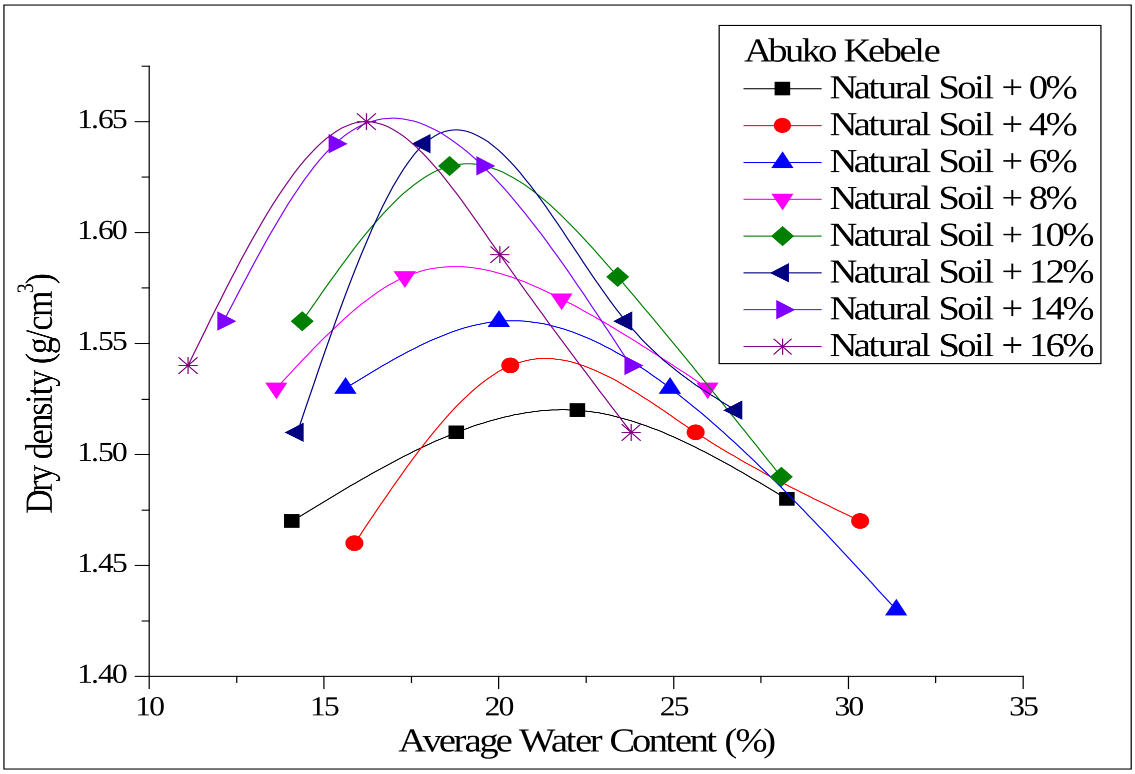
Test pit Location	FintjejuKebele				
Percentage of cement	**Natural Soil + 14% Cement**				
Mass of mold, (gm)	2743.8	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	15.61	17.74	16.71	16.73	
	18.79	17.92	17.39	17.1	
Mass of can +wet soil	59.36	114.57	95.49	92.69	
	66.48	124.84	99.78	93.26	
Mass of can +dry soil	55.56	102.99	83.61	78.68	
	62.21	111.6	87.13	79.86	
water content	9.51	13.58	17.76	22.62	
	9.83	14.13	18.14	21.35	
Average water content, (%)	**9.67**	**13.86**	**17.95**	**21.98**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6460.8	6836.1	6888.1	6806	
Bulk density, (g/cm^3)	1.75	1.93	1.95	1.91	
Dry density, (g/cm^3)	1.60	1.69	1.66	1.57	
Maximum Dry Density (g/cm^3)	***1.695***	***Optimum Water Content (%)***			***14.5***

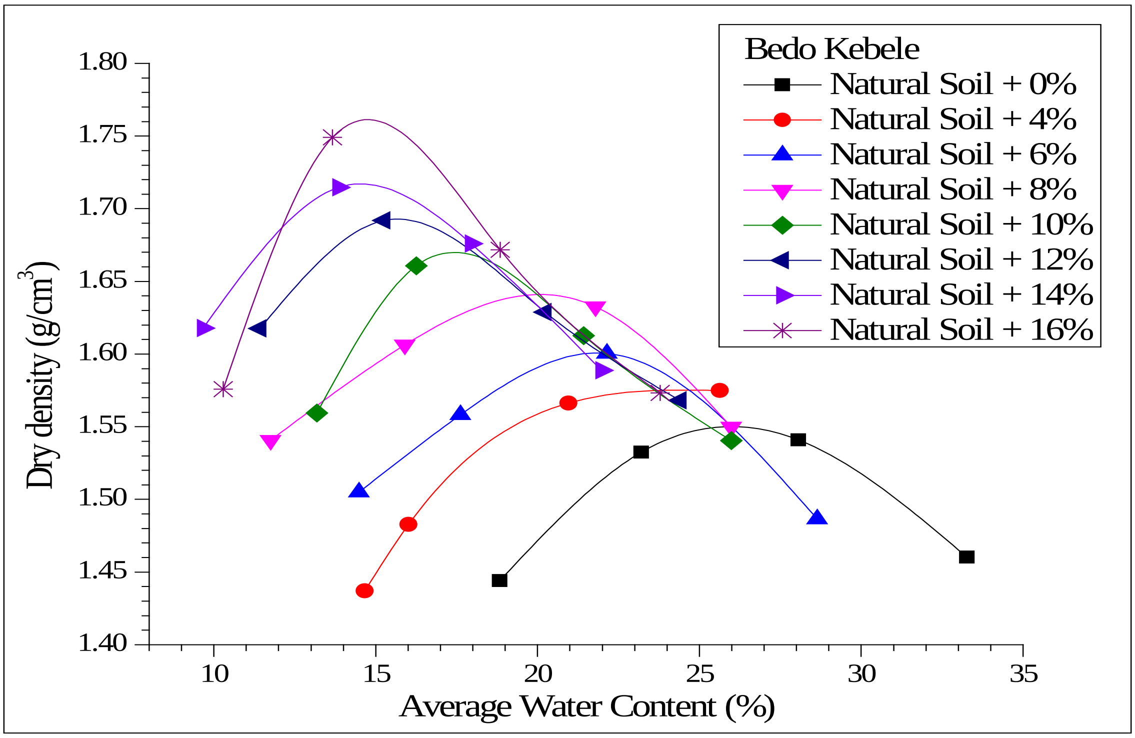
Test pit Location	AbukoKebele				
Percentage of cement	**Natural Soil + 16% Cement**				
Mass of mold, (gm)	2722	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	6.16	36.569	17.467	17.459	17.69
	5.6	36.604	17.566	17.556	17.736
Mass of can +wet soil	38.54	155.026	131.56	94.187	73.618
	46.65	177.522	136.099	94.612	85.88
Mass of can +dry soil	35.48	138.767	111.322	79.522	63.058
	42.32	157.523	117.597	79.723	70.573
water content	10.44	15.91	21.56	23.63	23.28
	11.79	16.54	18.50	23.95	28.97
Average water content, (%)	**11.11**	**16.22**	**20.03**	**23.79**	**26.12**
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6358.9	6805.6	6763.6	6700.3	6722.1
Bulk density, (g/cm^3)	1.71	1.92	1.90	1.87	1.88

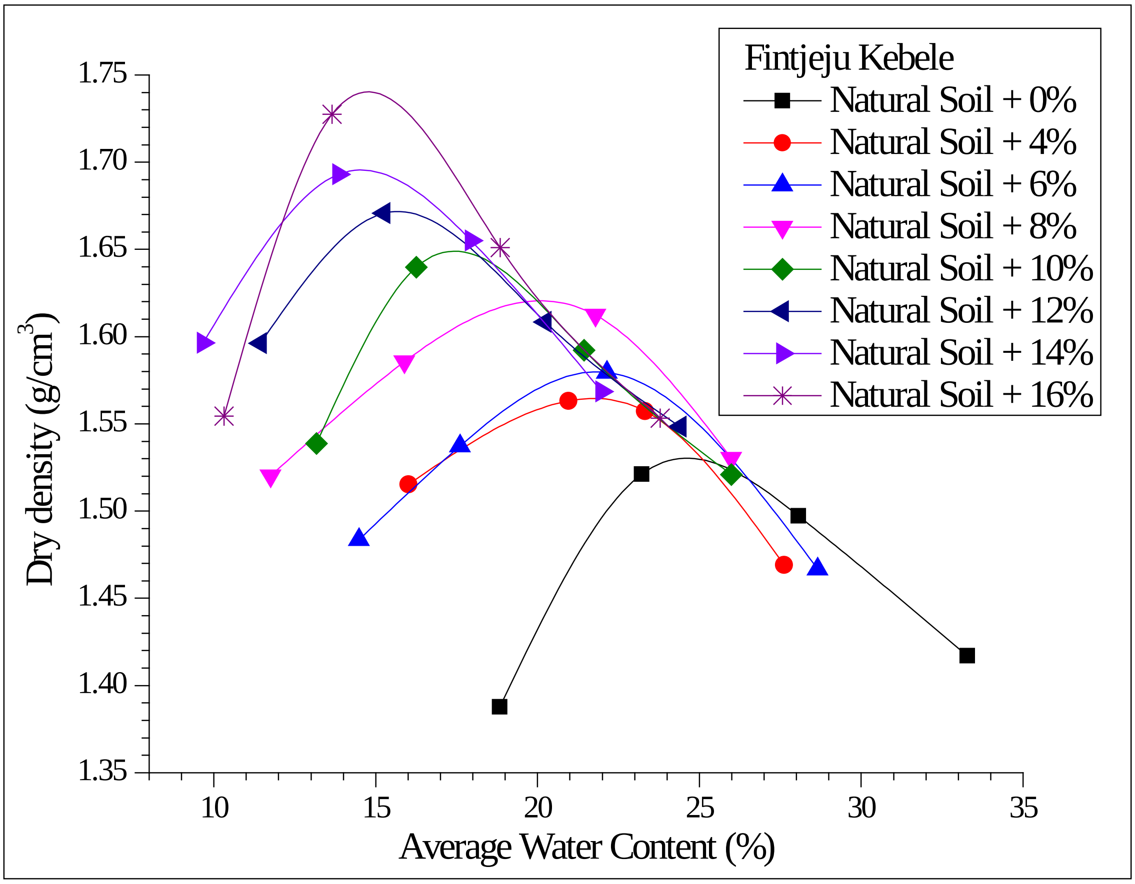
Dry density, (g/cm^3)	1.54	1.65	1.59	1.51	1.49
Maximum Dry Density (g/cm^3)	***1.66***	***Optimum Water Content (%)***			***16***

Test pit Location	BedoKebele				
Percentage of cement	**Natural Soil + 16% Cement**				
Mass of mold, (gm)	2732.9	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	6.59	39.13	18.69	18.68	
	5.99	39.17	18.8	18.78	
Mass of can +wet soil	41.24	165.88	140.77	100.78	
	49.92	189.95	145.63	101.23	
Mass of can +dry soil	37.96	149.48	121.11	85.09	
	45.88	173.25	125.83	85.3	
water content	10.46	14.86	19.20	23.63	
	10.13	12.46	18.50	23.95	
Average water content, (%)	**10.29**	**13.66**	**18.85**	**23.79**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6422.5	6953.7	6951.2	6867.3	
Bulk density, (g/cm^3)	1.74	1.99	1.99	1.95	
Dry density, (g/cm^3)	1.58	1.75	1.67	1.57	
Maximum Dry Density (g/cm^3)	***1.75***	***Optimum Water Content (%)***			***14***

Test pit Location	FintjejuKebele				
Percentage of cement	**Natural Soil + 16% Cement**				
Mass of mold, (gm)	2743.8	Volume of mold, (cm^3)			2123
Determination of water content					
Trials	01	02	03	04	05
Mass of can	6	35.61	17.01	17	
	5.45	35.64	17.11	17.09	
Mass of can +wet soil	37.53	150.95	128.1	91.71	
	45.43	172.85	132.52	92.12	
Mass of can +dry soil	34.54	136.03	110.21	77.43	
	41.75	157.66	114.51	77.62	
water content	10.48	14.86	19.20	23.63	
	10.14	12.45	18.49	23.96	
Average water content, (%)	**10.31**	**13.65**	**18.84**	**23.79**	
Determination of Bulk density and Dry density					
Mass of mold + Compacted soil, (gm)	6384	6912	6909.5	6826.1	
Bulk density, (g/cm^3)	1.71	1.96	1.96	1.92	
Dry density, (g/cm^3)	1.55	1.73	1.65	1.55	
Maximum Dry Density (g/cm^3)	***1.73***	***Optimum Water Content (%)***			***14***


Abuko Kebele
Natural Soil + 0%
Natural Soil + 4%
Natural Soil + 6%
Natural Soil + 8%
Natural Soil + 10%
Natural Soil + 12%
Natural Soil + 14%
Natural Soil + 16%
Dry density (g/cm3)
1.65
1.60
1.55
1.50
1.45
1.40
10
15
20
25
30
35
Average Water Content (%)


Bedo Kebele
Natural Soil + 0%
Natural Soil + 4%
Natural Soil + 6%
Natural Soil + 8%
Natural Soil + 10%
Natural Soil + 12%
Natural Soil + 14%
Natural Soil + 16%
Dry density (g/cm3)
Average Water Content (%)
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
10
15
20
25
30
35


Fintjeju Kebele
Natural Soil + 0%
Natural Soil + 4%
Natural Soil + 6%
Natural Soil + 8%
Natural Soil + 10%
Natural Soil + 12%
Natural Soil + 14%
Natural Soil + 16%
Dry density (g/cm3)
Average Water Content (%)
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
10
15
20
25
30
35

3. CBR Test Results

Test pit Lacotion	Abuko Kebele	Percentage of cement	**Natural Soil + 0%**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13355	13745.5	13117	13603.9	12689.5	13423.4
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4057.1	4447.6	3830.3	4317.2	3402.8	4136.7
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	1.910	2.094	1.803	2.033	1.602	1.948
Dry density of soil (g/ccm)	1.55	1.64	1.47	1.49	1.30	1.27

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	137.5		141.9	106.2	150.4		122.1	159.4	144.0		149.9	138.8
Mass of dry soil + Container, (g)	118.3		117.8	87.3	128.6		103.8	125.2	123.4		110.0	106.3
Mass of container, (g)	35.6		29.7	17.7	33.6		37.2	31.4	34.6		34.9	36.6
Mass of water, (g)	19.3		24.1	18.9	21.8		18.3	34.2	20.5		39.9	32.5
Mass of drysoil, (g)	82.7		88.1	69.6	95.0		66.6	93.8	88.8		75.1	69.7
Moisture content, (%)	23.3		27.4	27.1	22.9		27.4	36.4	23.1		53.2	46.7
Average moisture content, (%)	23.3		27.4		22.9		36.4		23.1		53.2	

CBR Penetration Determination

Penetration after 96 hrs Soaking Period | Surcharge Weight:-4.55 KG | Ring Calibration Factor (KN/Div.)= 1.0

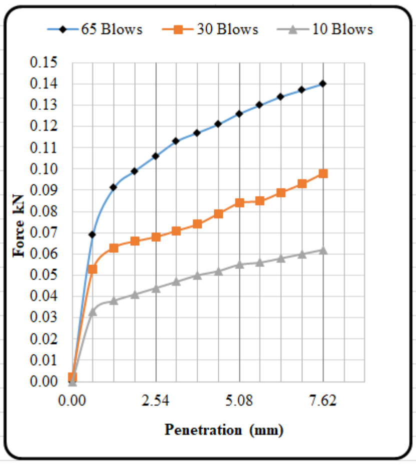
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.002		0.00	0.00	
0.64	0.069		0.64	0.053		0.64	0.03	
1.27	0.091		1.27	0.063		1.27	0.04	
1.91	0.099		1.91	0.066		1.91	0.04	
2.54	0.106	**0.79**	2.54	0.068	**0.51**	2.54	0.04	**0.33**
3.18	0.113		3.18	0.071		3.18	0.05	
3.81	0.117		3.81	0.074		3.81	0.05	
4.45	0.121		4.45	0.079		4.45	0.05	
5.08	0.126	**0.63**	5.08	0.084	**0.42**	5.08	0.06	**0.28**
5.72	0.130		5.72	0.085		5.72	0.06	
6.35	0.134		6.35	0.089		6.35	0.06	
6.99	0.137		6.99	0.093		6.99	0.06	
7.62	0.140		7.62	0.098		7.62	0.06	

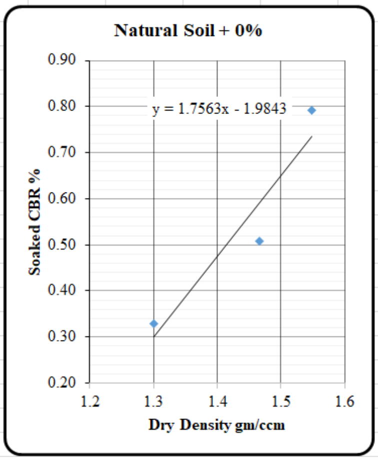
Swelling Determination

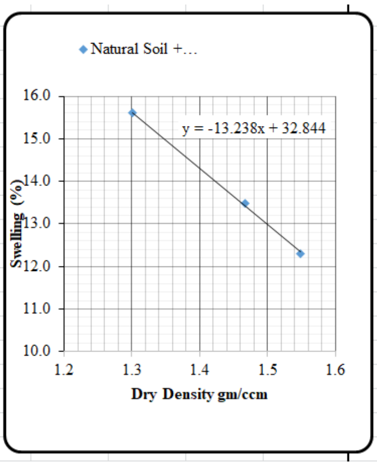
65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	2.35	12.31
Final reading, (mm)	16.9	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	1.02	13.48
Final reading, (mm)	16.9	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	0	15.60
Final reading, (mm)	18.4	
Modified MDD (g/ccm)		**1.52**
Optimum moisture content, %		22.00
Modified MDD at 95% (g/ccm)		**1.444**

Penetration (mm)	**Corrected reading Load (kN)**			**Corrected CBR (%)**			**No.of blows**	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**	Swell in %
	65 Blows	**30 Blows**	**10 Blows**	**65 Blows**	**30 Blows**	**10 Blows**	**10**	**23.1**	**1.30**	**0.33**	**86**	**16**
2.54mm	**0.11**	**0.07**	**0.04**	**0.79**	**0.51**	**0.33**	**30**	**22.9**	**1.47**	**0.51**	**96**	**13**
5.08mm	**0.13**	**0.08**	**0.06**	**0.63**	**0.42**	**0.28**	**65**	**23.3**	**1.55**	**0.79**	**102**	**12**

CBR % at 95 % of Maximum Dry Density	**0.6**	**CBR Swelling (%)**	**13.7**





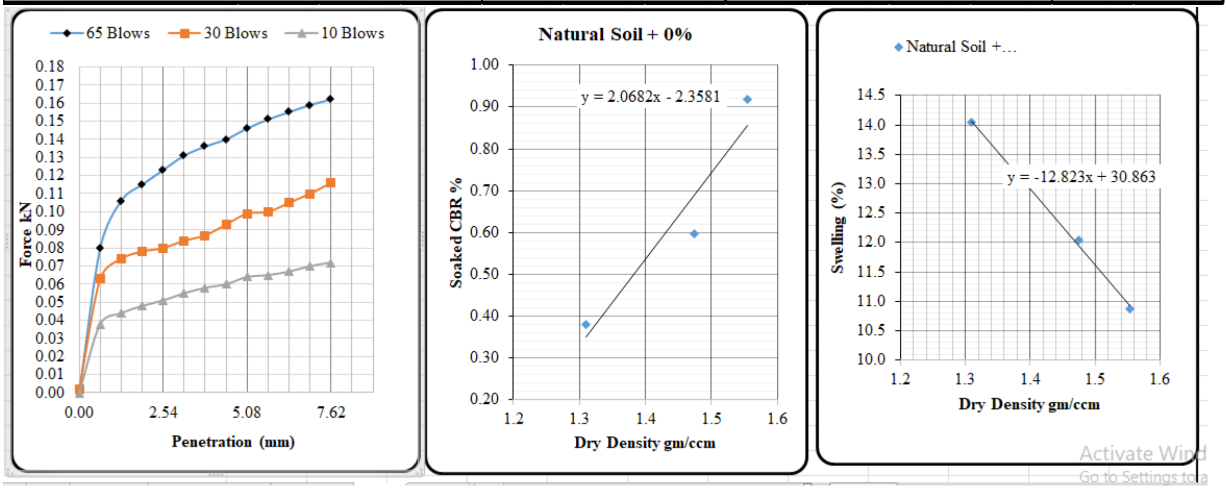


Test pit Lacotion	Bedo Kebele		Percentage of cement		Natural Soil + 0%	
Compaction Determination						
COMPACTION DATA	**65 Blows**		**30 Blows**		**10 Blows**	
	Before soak	**After soak**	**Before soak**	**After soak**	**Before soak**	**After soak**
Mass of soil + Mould, (g)	13435.1	13428	13195.7	13485.5	12765.6	13503.9
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4137.2	4130.1	3909	4198.8	3478.9	4217.2
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	1.948	1.944	1.840	1.977	1.638	1.985
Dry density of soil (g/ccm)	1.55	1.54	1.47	1.46	1.31	1.31

Moisture Determination												
MOISTURE CONTENT DATA	**65 Blows**				**30 Blows**				**10 Blows**			
	Before soak		**After soak**		**Before soak**		**After soak**		**Before soak**		**After soak**	
Mass of wet soil + Container,	140.29		144.75	108.32	153.41		124.53	162.62	146.85		152.94	141.58
Mass of dry soil + Container,	119.20		120.76	89.52	129.63		103.83	128.38	124.42		112.76	108.91
Mass of container, (g)	35.93		30.00	17.91	33.95		37.55	31.76	34.94		35.27	36.97
Mass of water, (g)	21.09		23.99	18.80	23.78		20.70	34.24	22.43		40.18	32.67
Mass of drysoil, (g)	83.27		90.76	71.61	95.68		66.28	96.62	89.48		77.49	71.94
Moisture content, (%)	25.33		26.43	26.25	24.85		31.23	35.44	25.07		51.85	45.41
Average moisture content, (%	25.3		26.4		24.9		35.4		25.1		51.9	

CBR Penetration Determination									**Swelling Determination**		
enetration after 96 hrs Soaking Perio			Surcharge Weight:-4.55 KG		g Calibration Factor (KN/Di			1.0	**65 Blows**		
65 Blows			**30 Blows**			**10 Blows**			Height of mold (mm)	118	Swell %
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	Initial reading, (mm)	2.35	10.88
0.00	0.000		0.00	0.002		0.00	0.000		Final reading, (mm)	15.2	
0.64	0.080		0.64	0.063		0.64	0.038		**30 Blows**		
1.27	0.106		1.27	0.074		1.27	0.044		Height of mold (mm)	118	Swell in %
1.91	0.115		1.91	0.078		1.91	0.048		Initial reading, (mm)	1.02	12.05
2.54	0.123	**0.92**	2.54	0.080	**0.60**	2.54	0.051	**0.38**	Final reading, (mm)	15.2	
3.18	0.131		3.18	0.084		3.18	0.055		**10 Blows**		
3.81	0.136		3.81	0.087		3.81	0.058		Height of mold (mm)	118	Swell in %
4.45	0.140		4.45	0.093		4.45	0.060		Initial reading, (mm)	0	14.04
5.08	0.146	**0.73**	5.08	0.099	**0.50**	5.08	0.064	**0.32**	Final reading, (mm)	16.6	
5.72	0.151		5.72	0.100		5.72	0.065				
6.35	0.155		6.35	0.105		6.35	0.067		Modified MDD (g/ccm)		1.55
6.99	0.159		6.99	0.110		6.99	0.070		Optimum moisture content, %		26.00
7.62	0.162		7.62	0.116		7.62	0.072		**Modified MDD at 95% (g/c**		**1.473**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	25.1	1.31	0.38	86	14
2.54mm	0.12	0.08	0.05	0.92	0.60	0.38	30	24.9	1.47	0.60	97	12
5.08mm	0.15	0.10	0.06	0.73	0.50	0.32	65	25.3	1.55	0.92	102	11
									2.068224	-2.3580525	-12.822823	30.86294634
CBR % at 95 % of Maximum Dry Density				0.8			CBR Swelling (%)				12.0	



Test pit Lacotion	Fintjeju Kebele	Percentage of cement	**Natural Soil + 0%**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13381.4	12958	13142.9	13013.5	12714.5	13031.3
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4083.5	3660.1	3856.2	3726.8	3427.8	3744.6
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	1.923	1.723	1.816	1.755	1.614	1.763
Dry density of soil (g/ccm)	1.55	1.36	1.46	1.29	1.30	1.15

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	143.10		146.92	109.94	156.48		126.40	165.06	149.79		155.23	143.70
Mass of dry soil + Container, (g)	122.18		121.97	90.42	132.87		104.87	129.66	127.53		113.89	110.00
Mass of container, (g)	36.29		30.15	18.00	34.29		37.74	31.92	35.29		35.45	37.15
Mass of water, (g)	20.92		24.95	19.52	23.61		21.53	35.40	22.26		41.34	33.70
Mass of drysoil, (g)	85.89		91.82	72.42	98.58		67.13	97.74	92.24		78.44	72.85
Moisture content, (%)	24.36		27.17	26.95	23.95		32.07	36.22	24.13		52.70	46.26
Average moisture content, (%)	24.4		27.2		24.0		36.2		24.1		52.7	

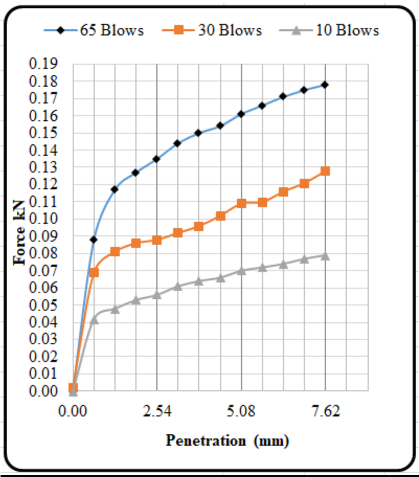
CBR Penetration Determination

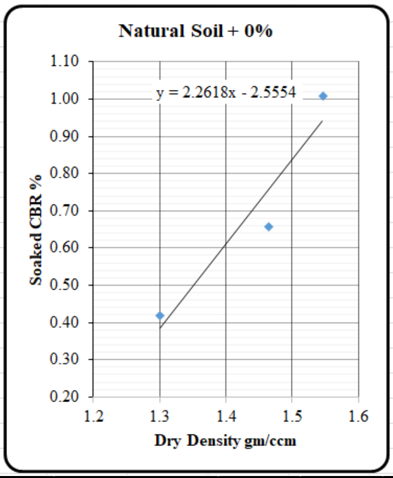
Penetration after 96 hrs Soaking Period			Surcharge Weight:-4.55 KG			Ring Calibration Factor (KN/Div.)=		1.0
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.002		0.00	0.000	
0.64	0.088		0.64	0.069		0.64	0.042	
1.27	0.117		1.27	0.081		1.27	0.048	
1.91	0.127		1.91	0.086		1.91	0.053	
2.54	0.135	**1.01**	2.54	0.088	**0.66**	2.54	0.056	**0.42**
3.18	0.144		3.18	0.092		3.18	0.061	
3.81	0.150		3.81	0.096		3.81	0.064	
4.45	0.154		4.45	0.102		4.45	0.066	
5.08	0.161	**0.81**	5.08	0.109	**0.55**	5.08	0.070	**0.35**
5.72	0.166		5.72	0.110		5.72	0.072	
6.35	0.171		6.35	0.116		6.35	0.074	
6.99	0.175		6.99	0.121		6.99	0.077	
7.62	0.178		7.62	0.128		7.62	0.079	

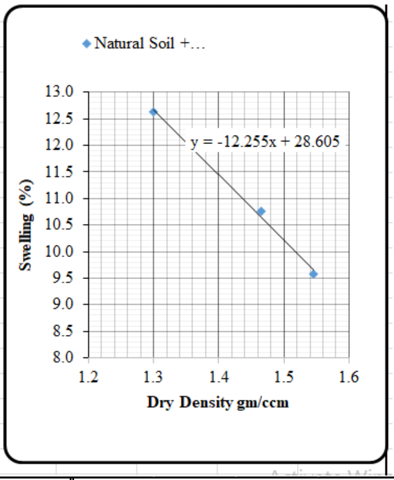
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	2.35	9.59
Final reading, (mm)	13.7	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	1.02	10.76
Final reading, (mm)	13.71	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	0.00	12.64
Final reading, (mm)	14.91	
Modified MDD (g/ccm)		1.53
Optimum moisture content, %		24.00
Modified MDD at 95% (g/ccm)		**1.454**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	24.1	1.30	0.42	86	13
2.54mm	0.14	0.09	0.06	1.01	0.66	0.42	30	24.0	1.46	0.66	96	11
5.08mm	0.16	0.11	0.07	0.81	0.55	0.35	65	24.4	1.55	1.01	102	10
									2.261835	-2.5553681	-12.255386	28.60464747
CBR % at 95 % of Maximum Dry Density				0.9			CBR Swelling (%)				10.8	







Test pit Lacotion	Abuko Kebele	Percentage of cement	**Natural Soil + 4% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13539	14058.3	13109.5	13788.8	12715	13464.1
Mass Mould, (g)	9425	9425	9358	9358	9416	9416
Mass of Soil, (g)	4114	4633.3	3751.5	4430.8	3299	4048.1
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	1.937	2.181	1.766	2.086	1.553	1.906
Dry density of soil (g/ccm)	1.60	1.58	1.46	1.46	1.28	1.26

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g	164.2		68.4	78.2	102.5		70.0	99.3	133.4		81.1	128.5
Mass of dry soil + Container, (g	141.5		54.9	61.3	87.9		54.4	80.4	114.7		59.4	103.5
Mass of container, (g)	33.2		18.0	18.1	18.5		18.5	36.0	25.8		17.7	54.4
Mass of water, (g)	22.7		13.4	17.0	14.6		15.6	18.9	18.7		21.6	25.0
Mass of drysoil, (g)	108.3		37.0	43.2	69.5		35.9	44.4	88.9		41.7	49.1
Moisture content, (%)	21.0		36.3	39.3	21.1		43.4	42.6	21.0		51.9	50.9
Average moisture content, (%)	21.0		37.8		21.1		43.0		21.0		51.4	

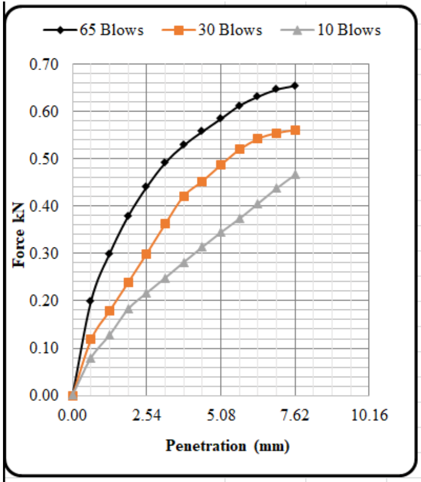
CBR Penetration Determination

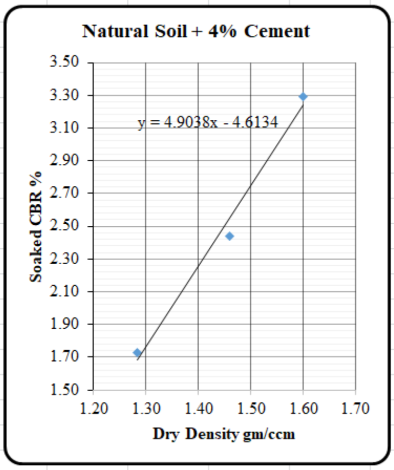
Penetration after 96 hrs Soaking Period			Surcharge Weight:-4.55 KG			Ring Calibration Factor (KN/Div.)=		1.0
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.00		0.00	0.00		0.00	0.00	
0.64	0.20		0.64	0.12		0.64	0.08	
1.27	0.30		1.27	0.18		1.27	0.13	
1.91	0.38		1.91	0.24		1.91	0.18	
2.54	0.44	**3.29**	2.54	0.30	**2.24**	2.54	0.22	**1.62**
3.18	0.49		3.18	0.36		3.18	0.25	
3.81	0.53		3.81	0.42		3.81	0.28	
4.45	0.56		4.45	0.45		4.45	0.31	
5.08	0.59	**2.93**	5.08	0.49	**2.44**	5.08	0.35	**1.73**
5.72	0.61		5.72	0.52		5.72	0.37	
6.35	0.63		6.35	0.54		6.35	0.41	
6.99	0.65		6.99	0.56		6.99	0.44	
7.62	0.66		7.62	0.56		7.62	0.47	

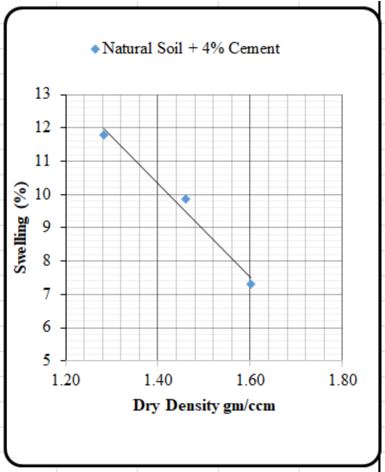
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	5.98	7.31
Final reading, (mm)	14.6	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	7.87	9.86
Final reading, (mm)	19.5	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	8.97	11.81
Final reading, (mm)	22.9	
Modified MDD (g/ccm)		1.54
Optimum moisture content, %		21.00
Modified MDD at 95% (g/ccm)		**1.463**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	21.0	1.28	1.7	83	12
2.54mm	0.44	0.30	0.22	3.29	2.24	1.62	30	21.1	1.46	2.4	95	10
5.08mm	0.59	0.49	0.35	2.93	2.44	1.73	65	21.0	1.60	3.3	104	7
CBR % at 95 % of Maximum Dry Density				2.6			CBR Swelling (%)				9.4	







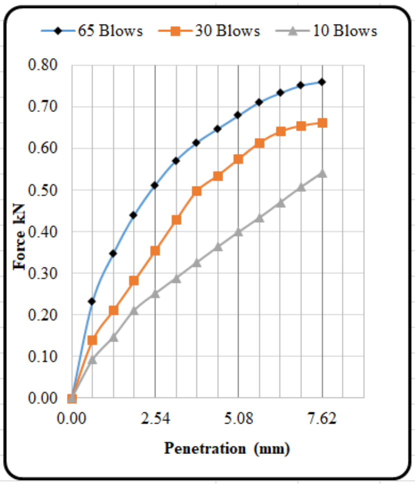
Test pit Lacotion	Bedo Kebele		Percentage of cement		**Natural Soil + 4% Cement**	
Compaction Determination						
COMPACTION DATA	**65 Blows**		**30 Blows**		**10 Blows**	
	Before soak	**After soak**	**Before soak**	**After soak**	**Before soak**	**After soak**
Mass of soil + Mould, (g)	13620.2	14058.3	13188.2	13871.5	12791.3	13544.9
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4322.3	4760.4	3901.5	4584.8	3504.6	4258.2
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.035	2.241	1.837	2.159	1.650	2.005
Dry density of soil (g/ccm)	1.66	1.66	1.50	1.53	1.34	1.33

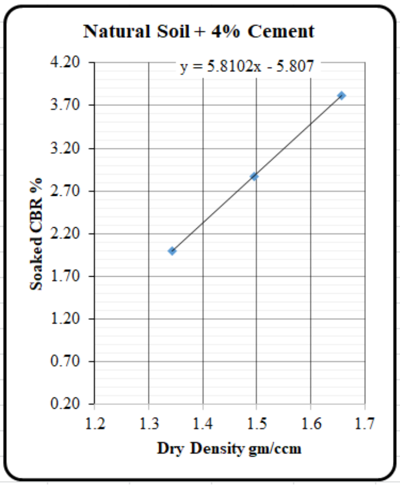
Moisture Determination												
MOISTURE CONTENT DATA	**65 Blows**				**30 Blows**				**10 Blows**			
	Before soak		**After soak**		**Before soak**		**After soak**		**Before soak**		**After soak**	
Mass of wet soil + Container, (g	167.48		69.75	79.80	104.60		71.38	101.28	136.04		82.68	131.07
Mass of dry soil + Container, (g)	142.62		56.32	62.80	88.63		55.75	82.41	115.62		60.90	106.08
Mass of container, (g)	33.50		18.14	18.23	18.66		18.69	36.36	26.08		17.91	54.95
Mass of water, (g)	24.86		13.43	17.00	15.97		15.63	18.87	20.42		21.78	24.99
Mass of drysoil, (g)	109.12		38.18	44.57	69.97		37.06	46.05	89.54		42.99	51.13
Moisture content, (%)	22.78		35.18	38.14	22.82		42.17	40.98	22.81		50.66	48.88
Average moisture content, (%)	22.8		35.2		22.8		41.0		22.8		50.7	

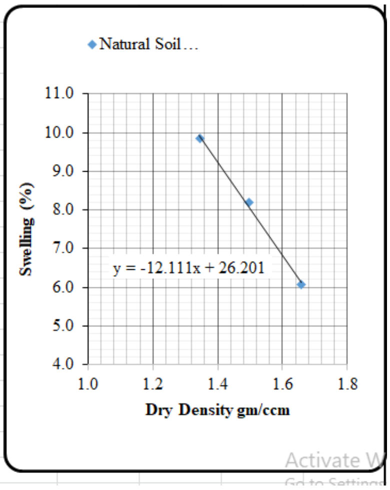
CBR Penetration Determination								
Penetration after 96 hrs Soaking Period		**Surcharge Weight:-4.55 KG**			**Ring Calibration Factor (KN/Div.)=**		**1.0**	
65 Blows			**30 Blows**			**10 Blows**		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.001	
0.64	0.232		0.64	0.139		0.64	0.093	
1.27	0.348		1.27	0.211		1.27	0.148	
1.91	0.440		1.91	0.282		1.91	0.212	
2.54	0.512	**3.82**	2.54	0.354	**2.64**	2.54	0.252	**1.88**
3.18	0.571		3.18	0.428		3.18	0.289	
3.81	0.614		3.81	0.498		3.81	0.327	
4.45	0.647		4.45	0.535		4.45	0.364	
5.08	0.679	**3.40**	5.08	0.575	**2.88**	5.08	0.400	**2.00**
5.72	0.711		5.72	0.614		5.72	0.434	
6.35	0.733		6.35	0.641		6.35	0.471	
6.99	0.751		6.99	0.655		6.99	0.508	
7.62	0.760		7.62	0.662		7.62	0.542	

Swelling Determination		
65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	5.98	6.07
Final reading, (mm)	13.1	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	7.87	8.21
Final reading, (mm)	17.6	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	8.97	9.86
Final reading, (mm)	20.6	
Modified MDD (g/ccm)		1.58
Optimum moisture content, %		24.00
Modified MDD at 95% (g/ccm)		**1.501**

Penetration (mm)	**Corrected reading Load (kN)**			**Corrected CBR (%)**			**No.of blows**	**MCBS %**	**DDBS g/cm3**	**Corrercrt CBR %**	**% OF Compaction**	**Swell in %**
	65 Blows	**30 Blows**	**10 Blows**	**65 Blows**	**30 Blows**	**10 Blows**	**10**	**22.8**	**1.34**	**2.00**	**87**	**10**
2.54mm	**0.51**	**0.35**	**0.25**	**3.82**	**2.64**	**1.88**	**30**	**22.8**	**1.50**	**2.88**	**97**	**8**
5.08mm	**0.68**	**0.58**	**0.40**	**3.40**	**2.88**	**2.00**	**65**	**22.8**	**1.66**	**3.82**	**108**	**6**
									5.8101535	-5.8070311	-12.111236	26.200761
CBR % at 95 % of Maximum Dry Density					**3.4**		**CBR Swelling (%)**				**8.0**	


65 Blows
30 Blows
10 Blows
Force kN
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
2.54
5.08
7.62
Penetration (mm)


Natural Soil + 4% Cement
y = 5.8102x - 5.807
Soaked CBR %
4.20
3.70
3.20
2.70
2.20
1.70
1.20
0.70
0.20
1.2
1.3
1.4
1.5
1.6
1.7
Dry Density gm/ccm


Natural Soil…
y = -12.111x + 26.201
Swelling (%)
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
1.0
1.2
1.4
1.6
1.8
Dry Density gm/ccm

Test pit Lacotion	Fintjeju Kebele	Percentage of cement	**Natural Soil + 4% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13565.7	13566.3	13056.3	13386	12740.1	13070.8
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4267.8	4268.4	3769.6	4099.3	3453.4	3784.1
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.009	2.010	1.775	1.930	1.626	1.782
Dry density of soil (g/ccm)	1.65	1.48	1.45	1.36	1.33	1.18

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g	170.83		70.80	81.00	106.69		72.45	102.80	138.76		83.92	133.04
Mass of dry soil + Container, (g)	146.19		56.88	63.43	90.85		56.31	83.23	118.51		61.51	107.14
Mass of container, (g)	33.84		18.23	18.32	18.85		18.78	36.54	26.34		18.00	55.22
Mass of water, (g)	24.64		13.92	17.57	15.84		16.14	19.57	20.25		22.41	25.90
Mass of drysoil, (g)	112.35		38.65	45.11	72.00		37.53	46.69	92.17		43.51	51.92
Moisture content, (%)	21.93		36.02	38.95	22.00		43.01	41.91	21.97		51.51	49.88
Average moisture content, (%)	21.9		36.0		22.0		41.9		22.0		51.5	

CBR Penetration Determination

Penetration after 96 hrs Soaking Period | Surcharge Weight:-4.55 KG | Ring Calibration Factor (KN/Div.)= 1.0

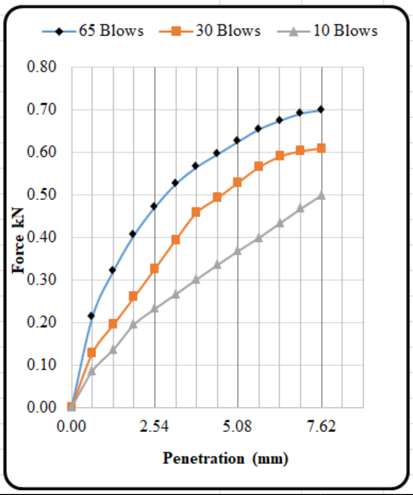
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.001	
0.64	0.213		0.64	0.128		0.64	0.086	
1.27	0.320		1.27	0.194		1.27	0.136	
1.91	0.405		1.91	0.259		1.91	0.195	
2.54	0.471	**3.52**	2.54	0.326	**2.44**	2.54	0.232	**1.73**
3.18	0.525		3.18	0.394		3.18	0.266	
3.81	0.565		3.81	0.458		3.81	0.301	
4.45	0.595		4.45	0.492		4.45	0.335	
5.08	0.625	**3.13**	5.08	0.529	**2.65**	5.08	0.368	**1.84**
5.72	0.654		5.72	0.565		5.72	0.399	
6.35	0.674		6.35	0.590		6.35	0.433	
6.99	0.691		6.99	0.603		6.99	0.467	
7.62	0.699		7.62	0.609		7.62	0.499	

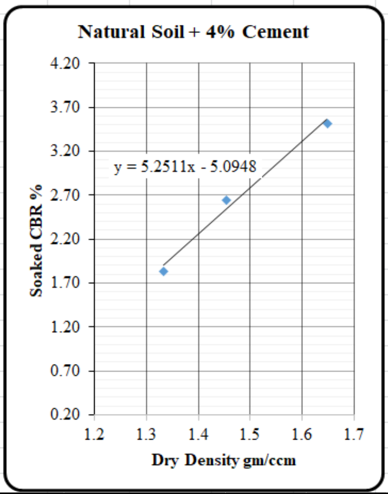
Swelling Determination

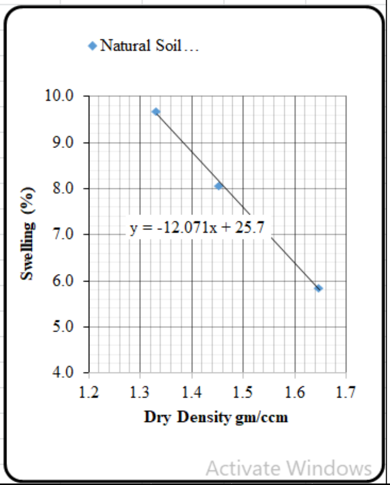
65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	5.98	5.85
Final reading, (mm)	12.9	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	7.71	8.05
Final reading, (mm)	17.21	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	8.79	9.67
Final reading, (mm)	20.20	
Modified MDD (g/ccm)		1.57
Optimum moisture content, %		22.00
Modified MDD at 95% (g/ccm)		**1.487**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	22.0	1.33	1.84	87	10
2.54mm	0.47	0.33	0.23	3.52	2.44	1.73	30	22.0	1.45	2.65	94	8
5.08mm	0.63	0.53	0.37	3.13	2.65	1.84	65	21.9	1.65	3.52	107	6
									5.2510906	-5.094806	-12.070594	25.700299

CBR % at 95 % of Maximum Dry Density	3.1	CBR Swelling (%)	7.8







Test pit Lacotion	Abuko Kebele	Percentage of cement	**Natural Soil + 6% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	**After soak**	**Before soak**	**After soak**	**Before soak**	**After soak**
Mass of soil + Mould, (g)	13583	14074.3	13155	13774.6	12754	13492.9
Mass Mould, (g)	9466	9466	9394	9394	9439	9439
Mass of Soil, (g)	4117	4608.3	3761	4380.6	3315	4053.9
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	1.938	2.170	1.771	2.062	1.561	1.909
Dry density of soil (g/ccm)	1.61	1.57	1.47	1.43	1.30	1.25

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		**After soak**		**Before soak**		**After soak**		**Before soak**		**After soak**	
Mass of wet soil + Container, (g)	112.4		140.6	108.3	123.9		70.4	63.6	118.1		76.8	89.5
Mass of dry soil + Container, (g)	96.3		111.9	89.0	105.9		54.1	49.8	101.1		55.8	65.0
Mass of container, (g)	18.2		36.5	37.7	17.6		17.6	18.2	17.9		17.2	18.4
Mass of water, (g)	16.0		28.6	19.3	18.0		16.3	13.8	17.0		20.9	24.4
Mass of drysoil, (g)	78.1		75.4	51.2	88.3		36.5	31.5	83.2		38.6	46.7
Moisture content, (%)	20.5		38.0	37.6	20.3		44.6	43.9	20.4		54.2	52.4
Average moisture content, (%)	20.5		37.8		20.3		44.3		20.4		53.3	

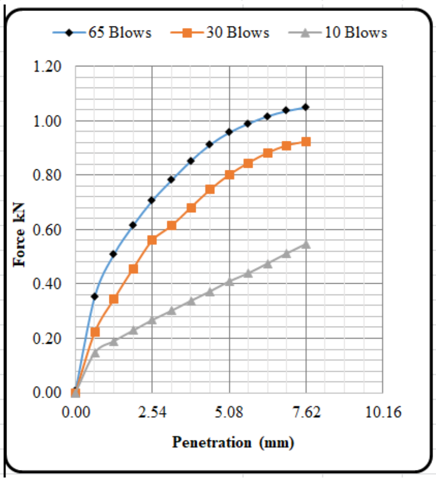
CBR Penetration Determination

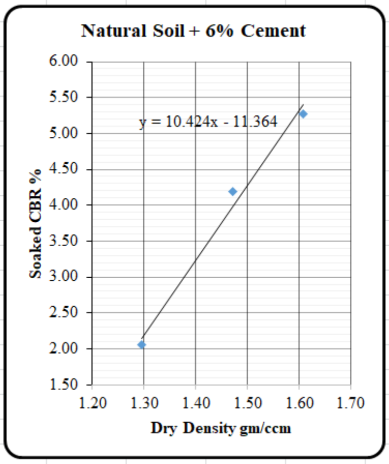
Penetration after 96 hrs Soaking Period			Surcharge Weight:-4.55 KG			Ring Calibration Factor (KN/Div.)=		**1.0**
65 Blows			**30 Blows**			**10 Blows**		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.01		0.00	0.0		0.00	0.00	
0.64	0.35		0.64	0.2		0.64	0.15	
1.27	0.51		1.27	0.3		1.27	0.19	
1.91	0.62		1.91	0.5		1.91	0.23	
2.54	0.71	**5.28**	2.54	0.6	**4.19**	2.54	0.27	**2.00**
3.18	0.78		3.18	0.6		3.18	0.30	
3.81	0.85		3.81	0.7		3.81	0.34	
4.45	0.91		4.45	0.7		4.45	0.37	
5.08	0.96	**4.79**	5.08	0.8	**4.02**	5.08	0.41	**2.05**
5.72	0.99		5.72	0.8		5.72	0.44	
6.35	1.02		6.35	0.9		6.35	0.48	
6.99	1.04		6.99	0.9		6.99	0.51	
7.62	1.05		7.62	0.9		7.62	0.55	

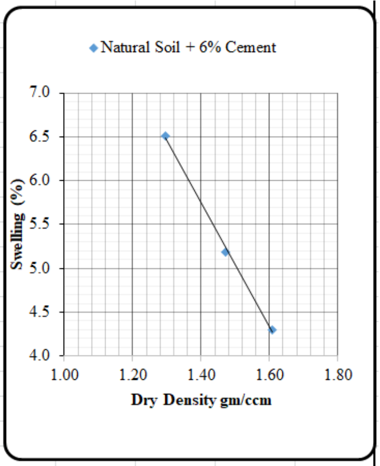
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	9.12	4.31
Final reading, (mm)	14.2	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	11.57	5.19
Final reading, (mm)	17.7	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	18.02	6.51
Final reading, (mm)	25.7	
Modified MDD (g/ccm)		1.56
Optimum moisture content, %		20.00
Modified MDD at 95% (g/ccm)		**1.482**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	20.4	1.30	2.1	83	7
2.54mm	0.71	0.56	0.27	5.28	4.19	2.00	30	20.3	1.47	4.2	94	5
5.08mm	0.96	0.80	0.41	4.79	4.02	2.05	65	20.5	1.61	5.3	103	4
CBR % at 95 % of Maximum Dry Density				4.1			CBR Swelling (%)				5.2	







Test pit Lacotion	Fintjeju Kebele	Percentage of cement	**Natural Soil + 6% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13609.8	13663.1	13181	13372.2	12779.2	13098.8
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4311.9	4365.2	3894.3	4085.5	3492.5	3812.1
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.030	2.055	1.833	1.923	1.644	1.795
Dry density of soil (g/ccm)	1.68	1.49	1.52	1.34	1.37	1.17

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	116.92		145.53	112.08	128.86		72.86	65.85	122.89		79.47	92.63
Mass of dry soil + Container, (g)	99.92		115.87	92.12	109.61		56.00	51.51	105.50		57.78	67.32
Mass of container, (g)	18.59		37.06	38.31	17.92		17.88	18.50	18.26		17.43	18.64
Mass of water, (g)	17.00		29.66	19.96	19.25		16.86	14.34	17.39		21.69	25.31
Mass of drysoil, (g)	81.33		78.81	53.81	91.69		38.12	33.01	87.24		40.35	48.68
Moisture content, (%)	20.90		37.63	37.09	20.99		44.23	43.44	19.93		53.75	51.99
Average moisture content, (%)	20.9		37.6		21.0		43.4		19.9		53.8	

CBR Penetration Determination

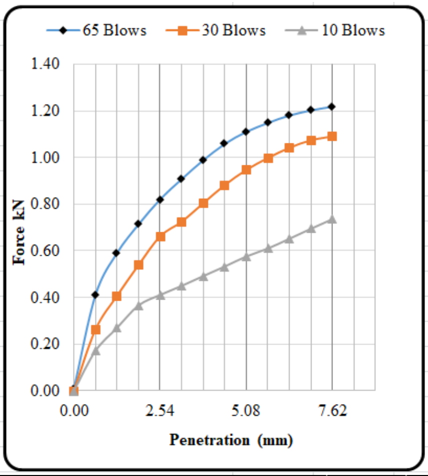
Penetration after 96 hrs Soaking Period	Surcharge Weight:-4.55 KG	Ring Calibration Factor (KN/Div.)=	1.0

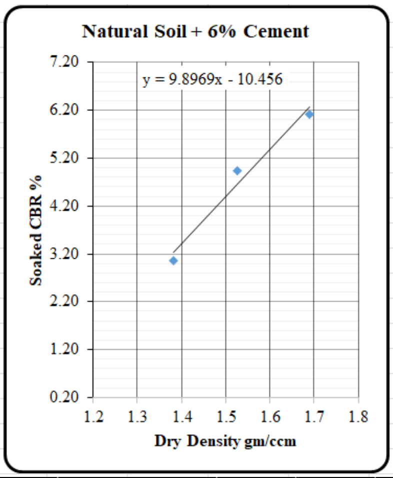
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.006		0.00	0.000		0.00	0.000	
0.64	0.376		0.64	0.241		0.64	0.157	
1.27	0.543		1.27	0.374		1.27	0.248	
1.91	0.656		1.91	0.496		1.91	0.337	
2.54	0.754	**5.63**	2.54	0.609	**4.55**	2.54	0.378	**2.82**
3.18	0.834		3.18	0.667		3.18	0.414	
3.81	0.909		3.81	0.740		3.81	0.453	
4.45	0.973		4.45	0.811		4.45	0.490	
5.08	1.021	**5.11**	5.08	0.871	**4.36**	5.08	0.530	**2.65**
5.72	1.056		5.72	0.918		5.72	0.561	
6.35	1.086		6.35	0.959		6.35	0.600	
6.99	1.106		6.99	0.988		6.99	0.639	
7.62	1.121		7.62	1.004		7.62	0.677	

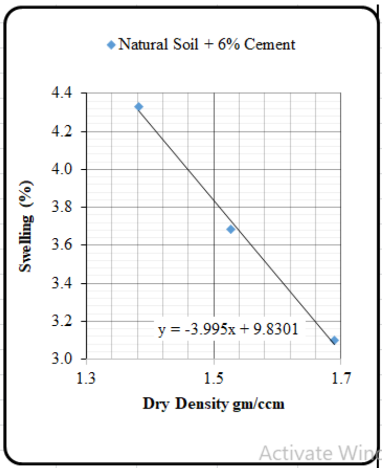
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	9.12	2.89
Final reading, (mm)	12.52	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	11.34	3.61
Final reading, (mm)	15.60	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	17.66	4.24
Final reading, (mm)	22.67	
Modified MDD (g/ccm)		1.58
Optimum moisture content, %		21.00
Modified MDD at 95% (g/ccm)		**1.501**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	19.9	1.37	2.82	88	4
2.54mm	0.75	0.61	0.38	5.63	4.55	2.82	30	21.0	1.52	4.55	97	4
5.08mm	1.02	0.87	0.53	5.11	4.36	2.65	65	20.9	1.68	5.63	108	3
									9.0610347	-9.4538778	-4.4111864	10.293868
CBR % at 95 % of Maximum Dry Density				4.9			CBR Swelling (%)				3.7	







Test pit Lacotion	Abuko Kebele	Percentage of cement	**Natural Soil + 8% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13598	14142.1	13219.5	13975.9	12766	13573.4
Mass Mould, (g)	9451	9451	9394.5	9394.5	9338	9338
Mass of Soil, (g)	4147	4691.1	3825	4581.4	3428	4235.4
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	1.952	2.209	1.801	2.157	1.614	1.994
Dry density of soil (g/ccm)	1.62	1.59	1.50	1.47	1.34	1.30

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	93.3		101.5	87.3	116.2		113.1	111.9	104.7		87.0	108.2
Mass of dry soil + Container, (g)	80.5		78.3	67.9	99.7		87.8	86.5	90.1		63.2	76.7
Mass of container, (g)	18.0		17.5	18.0	16.8		33.8	33.2	17.4		18.2	18.1
Mass of water, (g)	12.7		23.2	19.4	16.4		25.3	25.3	14.6		23.8	31.5
Mass of drysoil, (g)	62.5		60.8	50.0	82.9		54.0	53.3	72.7		45.1	58.6
Moisture content, (%)	20.4		38.2	38.8	19.8		46.9	47.4	20.1		52.7	53.8
Average moisture content, (%)	20.4		38.5		19.8		47.2		20.1		53.3	

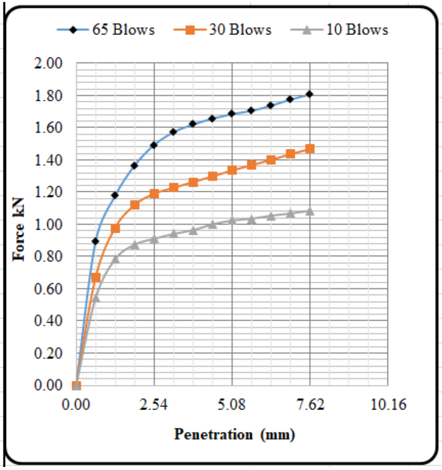
CBR Penetration Determination

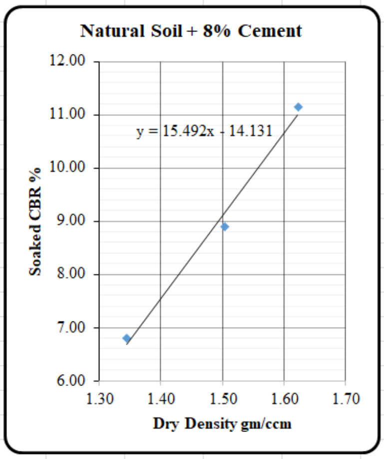
Penetration after 96 hrs Soaking Period		Surcharge Weight:-4.55 KG			Ring Calibration Factor (KN/Div.)=		1.0	
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.00		0.00	0.00		0.00	0.00	
0.64	0.89		0.64	0.67		0.64	0.54	
1.27	1.18		1.27	0.98		1.27	0.78	
1.91	1.37		1.91	1.12		1.91	0.87	
2.54	1.49	**11.15**	2.54	1.19	**8.89**	2.54	0.91	**6.81**
3.18	1.57		3.18	1.23		3.18	0.94	
3.81	1.62		3.81	1.26		3.81	0.96	
4.45	1.66		4.45	1.30		4.45	1.00	
5.08	1.69	**8.43**	5.08	1.34	**6.68**	5.08	1.02	**5.12**
5.72	1.71		5.72	1.37		5.72	1.04	
6.35	1.74		6.35	1.40		6.35	1.05	
6.99	1.78		6.99	1.44		6.99	1.07	
7.62	1.81		7.62	1.47		7.62	1.09	

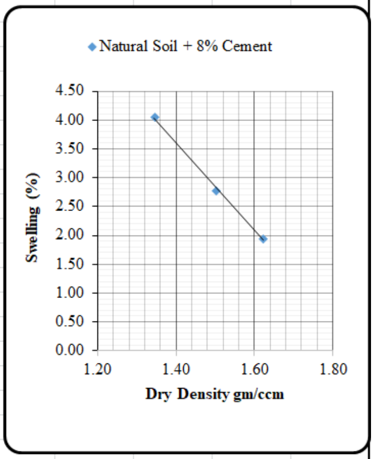
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	16.91	1.94
Final reading, (mm)	19.2	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	24.15	2.78
Final reading, (mm)	27.4	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	22.82	4.05
Final reading, (mm)	27.6	
Modified MDD (g/ccm)		1.58
Optimum moisture content, %		19.00
Modified MDD at 95% (g/ccm)		**1.501**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	20.1	1.34	6.8	85	4
2.54mm	1.49	1.19	0.91	11.15	8.89	6.81	30	19.8	1.50	8.9	95	3
5.08mm	1.69	1.34	1.02	8.43	6.68	5.12	65	20.4	1.62	11.1	103	2
CBR % at 95 % of Maximum Dry Density				9.1			CBR Swelling (%)				2.8	







Test Pit Lacotion	Fintjeju Kebele	Percentage of cement	**Natural Soil + 8% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13624.9	13674.4	13245.6	13513.8	12791.2	13124.5
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4327	4376.5	3958.9	4227.1	3504.5	3837.8
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.037	2.060	1.864	1.990	1.650	1.807
Dry density of soil (g/ccm)	1.70	1.49	1.54	1.35	1.38	1.19

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	97.03		105.04	90.41	120.87		117.11	115.80	108.95		90.06	112.06
Mass of dry soil + Container, (g)	83.93		81.02	70.33	103.04		90.91	89.60	94.15		65.46	79.42
Mass of container, (g)	18.39		17.72	18.23	17.12		34.34	33.71	17.76		18.42	18.38
Mass of water, (g)	13.10		24.02	20.08	17.83		26.20	26.20	14.80		24.60	32.64
Mass of drysoil, (g)	65.54		63.30	52.10	85.92		56.57	55.89	76.39		47.04	61.04
Moisture content, (%)	19.99		37.95	38.54	20.75		46.31	46.88	19.37		52.30	53.47
Average moisture content, (%)	20.0		37.9		20.8		46.9		19.4		52.3	

CBR Penetration Determination

Penetration after 96 hrs Soaking Period | Surcharge Weight:-4.55 KG | Ring Calibration Factor (KN/Div.)= **1.0**

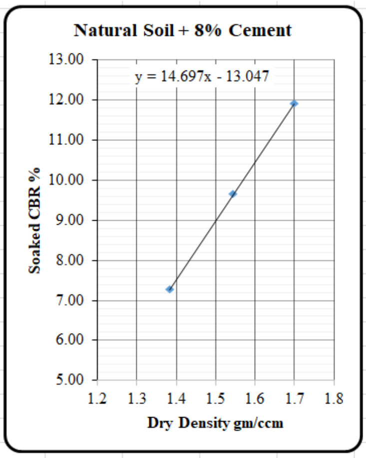
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.952		0.64	0.728		0.64	0.578	
1.27	1.255		1.27	1.061		1.27	0.834	
1.91	1.456		1.91	1.216		1.91	0.933	
2.54	1.593	**11.90**	2.54	1.292	**9.65**	2.54	0.972	**7.26**
3.18	1.678		3.18	1.332		3.18	1.005	
3.81	1.729		3.81	1.371		3.81	1.029	
4.45	1.768		4.45	1.409		4.45	1.067	
5.08	1.799	**9.00**	5.08	1.449	**7.25**	5.08	1.093	**5.47**
5.72	1.820		5.72	1.484		5.72	1.105	
6.35	1.854		6.35	1.520		6.35	1.125	
6.99	1.894		6.99	1.558		6.99	1.140	
7.62	1.928		7.62	1.593		7.62	1.158	

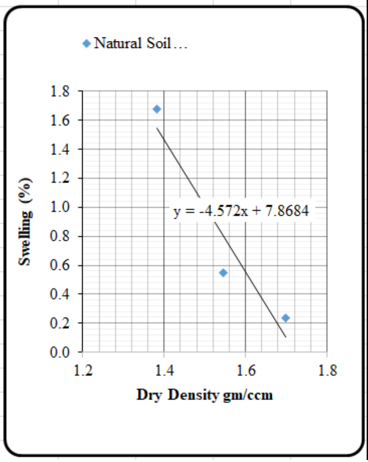
Swelling Determination

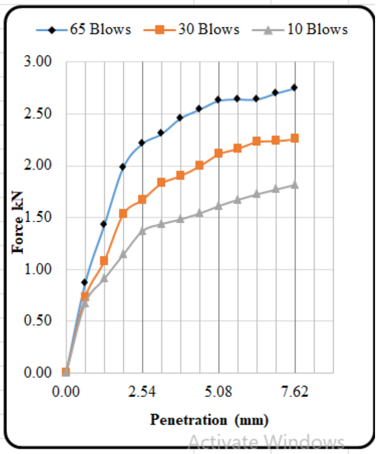
65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	16.91	0.24
Final reading, (mm)	17.19	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	23.55	0.55
Final reading, (mm)	24.19	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	22.36	1.68
Final reading, (mm)	24.34	
Modified MDD (g/ccm)		1.62
Optimum moisture content, %		20.50
Modified MDD at 95% (g/ccm)		**1.534**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correct CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	19.4	1.38	7.26	87	2
2.54mm	1.59	1.29	0.97	11.90	9.65	7.26	30	20.8	1.54	9.65	98	1
5.08mm	1.80	1.45	1.09	9.00	7.25	5.47	65	20.0	1.70	11.90	107	0
									14.697338	-13.046838	-4.5720174	7.8684435

CBR % at 95 % of Maximum Dry Density	10.7	CBR Swelling (%)	0.9







Test pit Lacotion	Abuko Kebele			Percentage of cement		Natural Soil + 10% Cement
Compaction Determination						
COMPACTION DATA	**65 Blows**		**30 Blows**		**10 Blows**	
	Before soak	**After soak**	**Before soak**	**After soak**	**Before soak**	**After soak**
Mass of soil + Mould, (g)	13748	14295.9	13394.5	14008.1	13105	13768.9
Mass Mould, (g)	9488.5	9488.5	9410	9410	9509	9509
Mass of Soil, (g)	4259.5	4807.4	3984.5	4598.1	3596	4259.9
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.005	2.263	1.876	2.165	1.693	2.006
Dry density of soil (g/ccm)	1.66	1.59	1.57	1.48	1.41	1.33

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (	141.0		66.3	71.9	150.9		81.9	71.7	146.0		76.7	73.4
Mass of dry soil + Container, (	123.0		51.8	56.0	132.2		61.5	55.1	127.6		57.0	54.9
Mass of container, (g)	36.6		18.0	17.5	37.8		18.4	17.9	37.2		17.7	18.1
Mass of water, (g)	18.0		14.5	15.9	18.7		20.4	16.5	18.4		19.7	18.5
Mass of drysoil, (g)	86.4		33.9	38.6	94.3		43.1	37.3	90.4		39.2	36.8
Moisture content, (%)	20.9		42.8	41.2	19.9		47.3	44.4	20.3		50.3	50.2
Average moisture content, (%)	20.9		42.0		19.9		45.9		20.3		50.3	

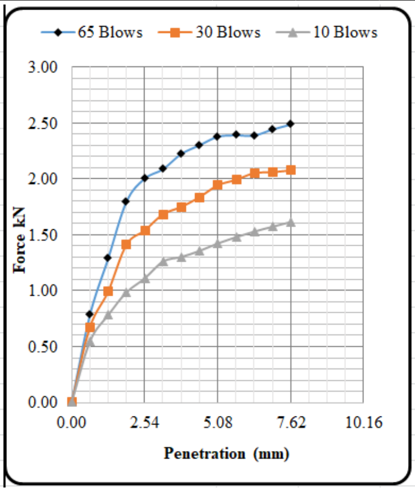
CBR Penetration Determination

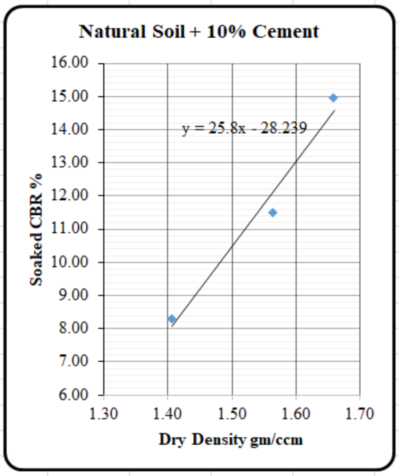
Penetration after 96 hrs Soaking Period		Surcharge Weight:-4.55 KG			Ring Calibration Factor (KN/Div.)=		1.0	
65 Blows			**30 Blows**			**10 Blows**		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.00		0.00	0.0		0.00	0.00	
0.64	0.78		0.64	0.7		0.64	0.55	
1.27	1.29		1.27	1.0		1.27	0.78	
1.91	1.80		1.91	1.4		1.91	0.99	
2.54	2.00	**14.97**	2.54	1.5	**11.50**	2.54	1.11	**8.29**
3.18	2.09		3.18	1.7		3.18	1.26	
3.81	2.22		3.81	1.8		3.81	1.30	
4.45	2.30		4.45	1.8		4.45	1.36	
5.08	2.38	**11.90**	5.08	1.9	**9.73**	5.08	1.42	**7.13**
5.72	2.39		5.72	2.0		5.72	1.48	
6.35	2.39		6.35	2.1		6.35	1.53	
6.99	2.44		6.99	2.1		6.99	1.57	
7.62	2.49		7.62	2.1		7.62	1.62	

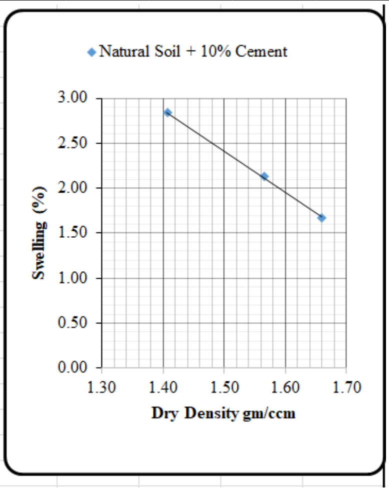
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	12.93	1.67
Final reading, (mm)	14.9	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	19.65	2.14
Final reading, (mm)	22.2	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	26.25	2.84
Final reading, (mm)	29.6	
Modified MDD (g/ccm)		1.63
Optimum moisture content, %		19.00
Modified MDD at 95% (g/ccm)		**1.549**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	20.3	1.41	8.3	86	2.84
2.54mm	2.00	1.54	1.11	14.97	11.50	8.29	30	19.9	1.57	11.5	96	2.14
5.08mm	2.38	1.94	1.42	11.90	9.73	7.13	65	20.9	1.66	15.0	102	1.67
CBR % at 95 % of Maximum Dry Density				11.7			CBR Swelling (%)				2.2	







Test Pit Lacotion	Fintjeju Kebele	Percentage of cement	**Natural Soil + 10% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13675.6	13878.3	13022.6	13598.9	12832.1	13366.7
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4377.7	4580.4	3735.9	4312.2	3545.4	4080
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.061	2.156	1.759	2.030	1.669	1.921
Dry density of soil (g/ccm)	1.77	1.52	1.53	1.41	1.44	1.28

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (	146.70		68.66	74.46	157.02		84.83	74.22	151.86		79.40	76.01
Mass of dry soil + Container, (	131.15		53.66	58.01	141.70		63.69	57.09	135.92		58.96	56.86
Mass of container, (g)	37.29		18.22	17.72	38.60		18.65	18.16	37.95		18.00	18.40
Mass of water, (g)	15.55		15.00	16.45	15.32		21.14	17.13	15.94		20.44	19.15
Mass of drysoil, (g)	93.86		35.44	40.29	103.10		45.04	38.93	97.97		40.96	38.46
Moisture content, (%)	16.57		42.33	40.83	14.86		46.94	44.00	16.27		49.90	49.79
Average moisture content, (%)	16.6		42.3		14.9		44.0		16.3		49.9	

CBR Penetration Determination

Penetration after 96 hrs Soaking Period | Surcharge Weight:-4.55 KG | Ring Calibration Factor (KN/Div.)= **1.0**

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.001		0.00	0.000	
0.64	0.864		0.64	0.730		0.64	0.674	
1.27	1.422		1.27	1.078		1.27	0.909	
1.91	1.983		1.91	1.534		1.91	1.144	
2.54	2.212	**16.52**	2.54	1.672	**12.49**	2.54	1.369	**10.23**
3.18	2.305		3.18	1.829		3.18	1.438	
3.81	2.456		3.81	1.901		3.81	1.483	
4.45	2.541		4.45	1.995		4.45	1.540	
5.08	2.626	**13.14**	5.08	2.110	**10.56**	5.08	1.612	**8.07**
5.72	2.639		5.72	2.164		5.72	1.672	
6.35	2.639		6.35	2.229		6.35	1.725	
6.99	2.697		6.99	2.238		6.99	1.771	
7.62	2.746		7.62	2.255		7.62	1.816	

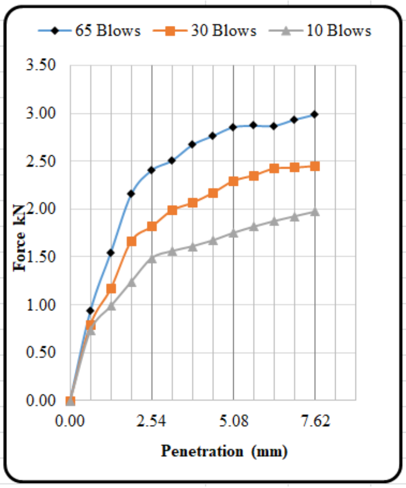
Swelling Determination

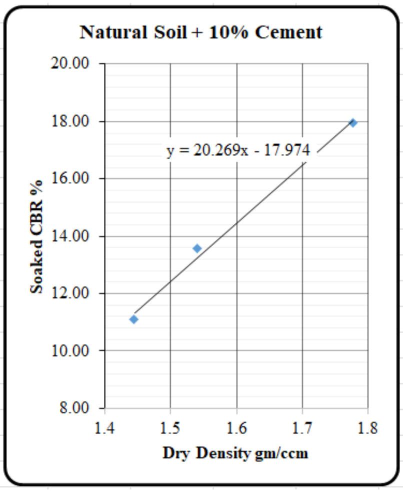
65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	11.64	0.19
Final reading, (mm)	11.86	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	19.16	0.36
Final reading, (mm)	19.59	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	25.68	0.36
Final reading, (mm)	26.1	

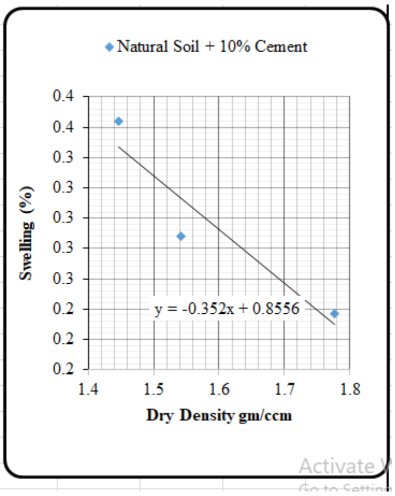
Modified MDD (g/ccm)	1.64
Optimum moisture content, %	17.00
Modified MDD at 95% (g/ccm)	**1.558**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	16.3	1.44	10.23	88	0
2.54mm	2.21	1.67	1.37	16.52	12.49	10.23	30	14.9	1.53	12.49	94	0
5.08mm	2.63	2.11	1.61	13.14	10.56	8.07	65	16.6	1.77	16.52	108	0
									18.578343	-16.242675	-0.5763401	1.2147628

CBR % at 95 % of Maximum Dry Density	14.2	CBR Swelling (%)	0.3





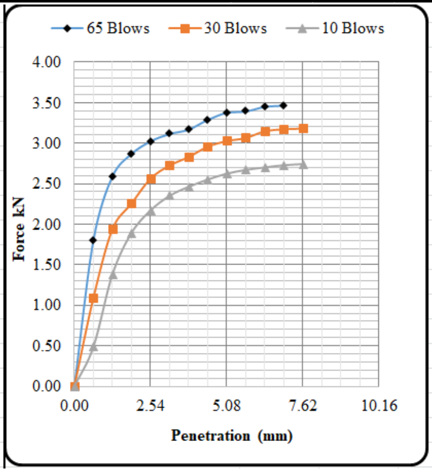


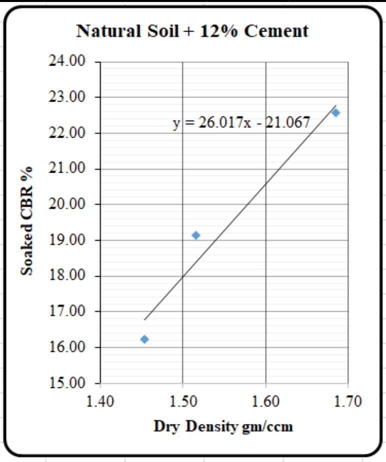
Test pit Lacotion	Abuko Kebele		Percentage of cement		**Natural Soil + 12% Cement**	
Compaction Determination						
COMPACTION DATA	**65 Blows**		**30 Blows**		**10 Blows**	
	Before soak	**After soak**	**Before soak**	**After soak**	**Before soak**	**After soak**
Mass of soil + Mould, (g)	13629	14012.4	13236.5	13848.7	13099.5	13700.1
Mass Mould, (g)	9370	9370	9395.8	9395.8	9420	9420
Mass of Soil, (g)	4259	4642.4	3840.7	4452.9	3679.5	4280.1
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.005	2.186	1.808	2.096	1.732	2.015
Dry density of soil (g/ccm)	1.69	1.55	1.52	1.44	1.45	1.31

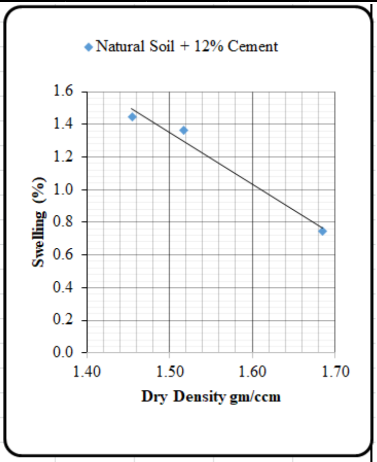
Moisture Determination												
MOISTURE CONTENT DATA	**65 Blows**				**30 Blows**				**10 Blows**			
	Before soak		**After soak**		**Before soak**		**After soak**		**Before soak**		**After soak**	
Mass of wet soil + Container, (g)	121.2		144.8	102.8	153.1		63.1	73.5	137.2		114.4	108.8
Mass of dry soil + Container, (g)	106.1		113.7	83.5	134.0		48.8	56.0	120.1		87.1	81.7
Mass of container, (g)	26.7		37.7	36.6	34.9		17.5	17.6	30.8		36.5	31.5
Mass of water, (g)	15.1		31.1	19.3	19.1		14.3	17.5	17.1		27.3	27.1
Mass of drysoil, (g)	79.4		75.9	46.9	99.1		31.3	38.4	89.3		50.5	50.2
Moisture content, (%)	19.0		41.0	41.1	19.2		45.8	45.6	19.1		54.1	54.0
Average moisture content, (%)	19.0		41.0		19.2		45.7		19.1		54.1	

CBR Penetration Determination									**Swelling Determination**		
Penetration after 96 hrs Soaking Period			**Surcharge Weight:-4.55 KG**		**Ring Calibration Factor (KN/Div.)=**			**1.0**	**65 Blows**		
65 Blows			**30 Blows**			**10 Blows**			Height of mold (mm)	118	Swell %
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	Initial reading, (mm)	21.52	0.75
0.00	0.00		0.00	0.0		0.00	0.00		Final reading, (mm)	22.4	
0.64	1.80		0.64	1.1		0.64	0.49		**30 Blows**		
1.27	2.59		1.27	1.9		1.27	1.38		Height of mold (mm)	118	Swell in %
1.91	2.87		1.91	2.3		1.91	1.89		Initial reading, (mm)	13.98	1.36
2.54	3.02	**22.57**	2.54	2.6	**19.14**	2.54	2.17	**16.22**	Final reading, (mm)	15.6	
3.18	3.11		3.18	2.7		3.18	2.35		**10 Blows**		
3.81	3.17		3.81	2.8		3.81	2.46		Height of mold (mm)	118	Swell in %
4.45	3.29		4.45	3.0		4.45	2.55		Initial reading, (mm)	12.04	1.45
5.08	3.37	**16.89**	5.08	3.0	**15.14**	5.08	2.62	**13.13**	Final reading, (mm)	13.8	
5.72	3.39		5.72	3.1		5.72	2.67				
6.35	3.45		6.35	3.1		6.35	2.70		Modified MDD (g/ccm)		1.64
6.99	3.46		6.99	3.2		6.99	2.73		Optimum moisture content, %		17.00
7.62			7.62	3.2		7.62	2.74		**Modified MDD at 95% (g/ccm)**		**1.558**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	19.1	1.45	16.2	89	1.45
2.54mm	3.02	2.56	2.17	22.57	19.14	16.22	30	19.2	1.52	19.1	92	1.36
5.08mm	3.37	3.03	2.62	16.89	15.14	13.13	65	19.0	1.69	22.6	103	0.75
CBR % at 95 % of Maximum Dry Density				19.5			CBR Swelling (%)				1.2	







Test pit Lacotion	Bedo Kebele	Percentage of cement	**Natural Soil + 12% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13560.9	13942.3	13170.3	13779.5	13034	13631.6
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4263	4644.4	3883.6	4492.8	3747.3	4344.9
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.007	2.187	1.828	2.115	1.764	2.046
Dry density of soil (g/ccm)	1.74	1.62	1.59	1.52	1.53	1.40

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	123.63		147.68	104.85	156.18		64.34	74.97	139.91		116.69	110.95
Mass of dry soil + Container, (g)	110.89		119.35	87.68	140.08		51.19	58.77	125.49		91.41	85.76
Mass of container, (g)	26.95		38.12	36.93	35.25		17.65	17.74	31.10		36.89	31.79
Mass of water, (g)	12.74		28.33	17.17	16.10		13.15	16.20	14.42		25.28	25.19
Mass of drysoil, (g)	83.94		81.23	50.75	104.83		33.54	41.03	94.39		54.52	53.97
Moisture content, (%)	15.18		34.88	33.83	15.36		39.21	39.48	15.28		46.37	46.67
Average moisture content, (%)	15.2		34.9		15.4		39.5		15.3		46.4	

CBR Penetration Determination

Penetration after 96 hrs Soaking Period | Surcharge Weight:-4.55 KG | Ring Calibration Factor (KN/Div.)= 1.0

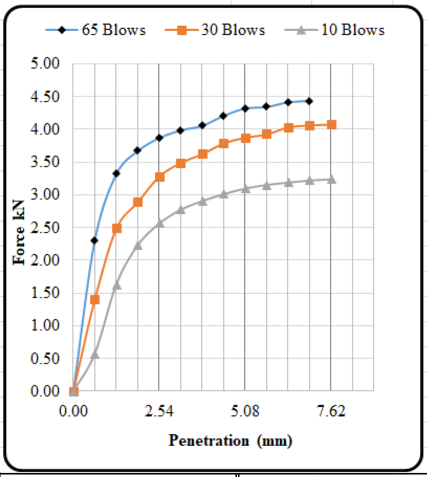
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	2.304		0.64	1.398		0.64	0.576	
1.27	3.314		1.27	2.483		1.27	1.632	
1.91	3.669		1.91	2.887		1.91	2.233	
2.54	3.867	**28.89**	2.54	3.279	**24.50**	2.54	2.562	**19.14**
3.18	3.985		3.18	3.487		3.18	2.773	
3.81	4.054		3.81	3.622		3.81	2.905	
4.45	4.207		4.45	3.784		4.45	3.011	
5.08	4.319	**21.61**	5.08	3.873	**19.38**	5.08	3.096	**15.49**
5.72	4.341		5.72	3.923		5.72	3.152	
6.35	4.413		6.35	4.028		6.35	3.188	
6.99	4.433		6.99	4.061		6.99	3.220	
7.62	0.000		7.62	4.070		7.62	3.237	

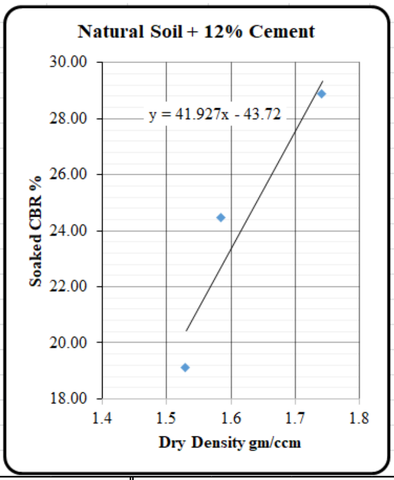
Swelling Determination

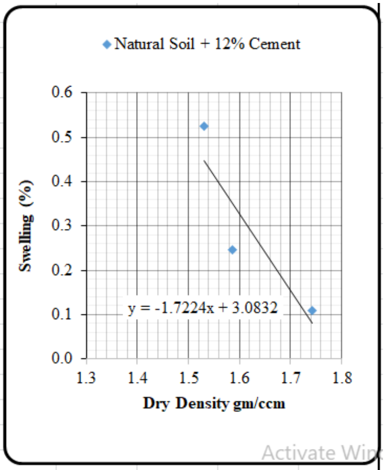
65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	19.5832	0.11
Final reading, (mm)	19.7	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	13.74	0.25
Final reading, (mm)	14.0	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	13.41	0.53
Final reading, (mm)	14.0	
Modified MDD (g/ccm)		1.69
Optimum moisture content, %		15.00
Modified MDD at 95% (g/ccm)		**1.606**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	15.3	1.53	19.14	93	0.53
2.54mm	3.87	3.28	2.56	28.89	24.50	19.14	30	15.4	1.59	24.50	97	0.25
5.08mm	4.32	3.87	3.10	21.61	19.38	15.49	65	15.2	1.74	28.89	106	0.11
									41.926824	-43.719648	-1.7224318	3.0832294

CBR % at 95 % of Maximum Dry Density	27.1	CBR Swelling (%)	0.3







Test Pit Lacotion	Fintjeju Kebele	Percentage of cement	**Natural Soil + 12% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13506.7	13454.3	13117.6	13297.2	12981.9	13154.5
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4208.8	4156.4	3830.9	4010.5	3695.2	3867.8
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	1.982	1.957	1.804	1.888	1.740	1.821
Dry density of soil (g/ccm)	1.73	1.44	1.57	1.35	1.52	1.24

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	126.10		149.90	106.42	159.30		65.31	76.09	142.71		118.44	112.61
Mass of dry soil + Container, (g)	113.66		120.54	88.56	143.58		51.70	59.36	128.63		92.32	86.62
Mass of container, (g)	27.22		38.31	37.11	35.60		17.74	17.83	31.41		37.07	31.95
Mass of water, (g)	12.44		29.36	17.86	15.72		13.61	16.73	14.08		26.12	25.99
Mass of drysoil, (g)	86.44		82.23	51.45	107.98		33.96	41.53	97.22		55.25	54.67
Moisture content, (%)	14.39		35.70	34.71	14.56		40.08	40.28	14.48		47.28	47.54
Average moisture content, (%)	14.4		35.7		14.6		40.3		14.5		47.3	

CBR Penetration Determination

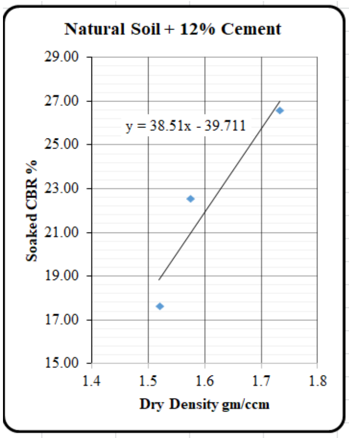
Penetration after 96 hrs Soaking Period | Surcharge Weight:-4.55 KG | Ring Calibration Factor (KN/Div.)= 1.0

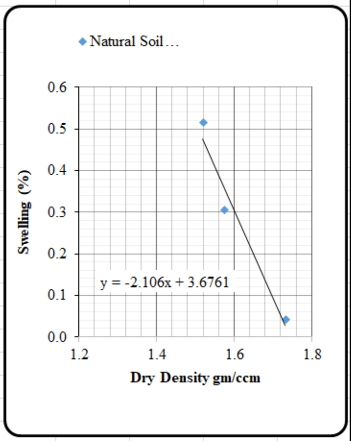
65 Blows			30 Blows			10 Blows		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	2.120		0.64	1.286		0.64	0.530	
1.27	3.049		1.27	2.284		1.27	1.501	
1.91	3.375		1.91	2.656		1.91	2.054	
2.54	3.558	**26.58**	2.54	3.017	**22.54**	2.54	2.357	**17.61**
3.18	3.666		3.18	3.208		3.18	2.551	
3.81	3.730		3.81	3.332		3.81	2.673	
4.45	3.870		4.45	3.481		4.45	2.770	
5.08	3.973	**19.88**	5.08	3.563	**17.83**	5.08	2.848	**14.25**
5.72	3.994		5.72	3.609		5.72	2.900	
6.35	4.060		6.35	3.706		6.35	2.933	
6.99	4.078		6.99	3.736		6.99	2.962	
7.62	0.000		7.62	3.744		7.62	2.978	

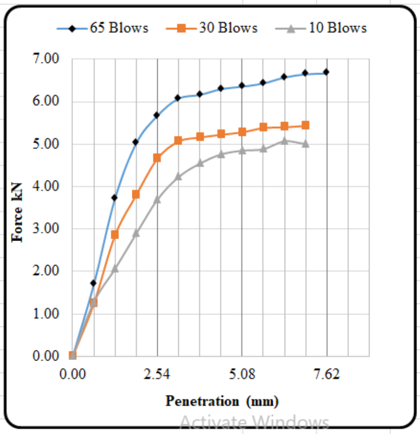
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	19.58	0.04
Final reading, (mm)	19.6	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	13.39	0.31
Final reading, (mm)	13.8	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	13.14	0.52
Final reading, (mm)	13.8	
Modified MDD (g/ccm)		1.67
Optimum moisture content, %		15.00
Modified MDD at 95% (g/ccm)		**1.587**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	14.5	1.52	17.61	93	1
2.54mm	3.56	3.02	2.36	26.58	22.54	17.61	30	14.6	1.57	22.54	96	0
5.08mm	3.97	3.56	2.85	19.88	17.83	14.25	65	14.4	1.73	26.58	106	0
									38.509674	-39.71115	-2.1059526	3.6761336
CBR % at 95 % of Maximum Dry Density					24.6			CBR Swelling (%)			0.3	





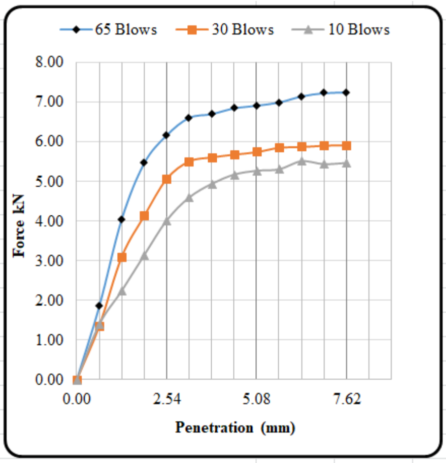


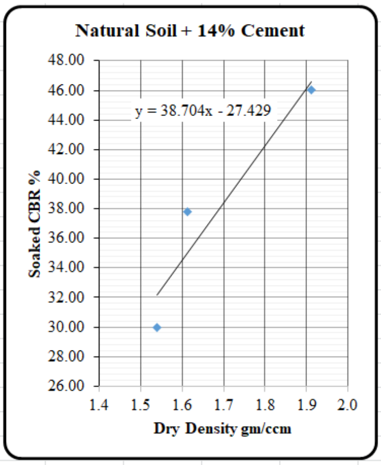
Test pit Lacotion	Abuko Kebele		Percentage of cement		**Natural Soil + 14% Cement**	
Compaction Determination						
COMPACTION DATA	**65 Blows**		**30 Blows**		**10 Blows**	
	Before soak	**After soak**	**Before soak**	**After soak**	**Before soak**	**After soak**
Mass of soil + Mould, (g)	13869.5	14137.5	13140.5	13806.1	12957.5	13492.8
Mass Mould, (g)	9569	9569	9296.5	9296.5	9292.5	9292.5
Mass of Soil, (g)	4300.5	4568.5	3844	4509.6	3665	4200.3
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.025	2.151	1.810	2.123	1.726	1.978
Dry density of soil (g/ccm)	1.71	1.60	1.54	1.54	1.47	1.37

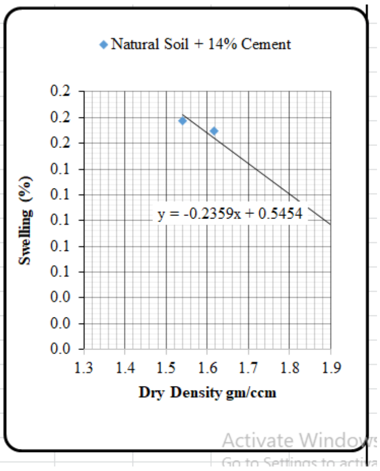
Moisture Determination												
MOISTURE CONTENT DATA	**65 Blows**				**30 Blows**				**10 Blows**			
	Before soak		**After soak**		**Before soak**		**After soak**		**Before soak**		**After soak**	
Mass of wet soil + Container, (g)	118.3		71.1	99.5	160.0		78.3	87.6	139.2		116.6	100.4
Mass of dry soil + Container, (g)	105.9		57.1	78.6	140.6		61.6	67.8	123.2		91.6	78.5
Mass of container, (g)	37.2		17.6	17.2	29.7		17.2	17.1	33.4		34.9	29.7
Mass of water, (g)	12.5		14.0	20.9	19.4		16.7	19.7	15.9		25.0	21.9
Mass of drysoil, (g)	68.7		39.4	61.4	110.9		44.4	50.8	89.8		56.6	48.8
Moisture content, (%)	18.2		35.6	33.9	17.5		37.6	38.9	17.7		44.2	45.0
Average moisture content, (%)	18.2		34.8		17.5		38.2		17.7		44.6	

CBR Penetration Determination									**Swelling Determination**		
Penetration after 96 hrs Soaking Period		**Surcharge Weight:-4.55 KG**		**Ring Calibration Factor (KN/Div.)=**			**1.0**		**65 Blows**		
65 Blows			**30 Blows**			**10 Blows**			Height of mold (mm)	118	Swell %
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	Initial reading, (mm)	17.97	0.37
0.00	0.00		0.00	0.0		0.00	0.00		Final reading, (mm)	18.4	
0.64	1.42		0.64	1.1		0.64	1.20		**30 Blows**		
1.27	3.11		1.27	2.6		1.27	1.93		Height of mold (mm)	118	Swell in %
1.91	4.20		1.91	3.5		1.91	2.71		Initial reading, (mm)	15.85	0.64
2.54	4.74	**35.40**	2.54	4.3	**32.05**	2.54	3.46	**25.87**	Final reading, (mm)	16.6	
3.18	5.08		3.18	4.7		3.18	3.96		**10 Blows**		
3.81	5.15		3.81	4.8		3.81	4.26		Height of mold (mm)	118	Swell in %
4.45	5.26		4.45	4.8		4.45	4.46		Initial reading, (mm)	11.91	0.82
5.08	5.31	**26.59**	5.08	4.9	**24.34**	5.08	4.54	**22.74**	Final reading, (mm)	12.9	
5.72	5.38		5.72	5.0		5.72	4.57				
6.35	5.49		6.35	5.0		6.35	4.75		Modified MDD (g/ccm)		1.65
6.99	5.56		6.99	5.0		6.99	4.69		Optimum moisture content, %		17.00
7.62	5.57		7.62						**Modified MDD at 95% (g/ccm)**		**1.568**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	**30 Blows**	**10 Blows**	**65 Blows**	**30 Blows**	**10 Blows**	**10**	**17.7**	**1.47**	**25.9**	**89**	**0.8**
2.54mm	**4.74**	**4.29**	**3.46**	**35.40**	**32.05**	**25.87**	**30**	**17.5**	**1.54**	**32.0**	**93**	**0.6**
5.08mm	**5.31**	**4.86**	**4.54**	**26.59**	**24.34**	**22.74**	**65**	**18.2**	**1.71**	**35.4**	**104**	**0.4**
CBR % at 95 % of Maximum Dry Density				**30.9**			**CBR Swelling (%)**				**0.6**	


65 Blows
30 Blows
10 Blows
Force kN
Penetration (mm)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
0.00
2.54
5.08
7.62


Natural Soil + 14% Cement
y = 38.704x - 27.429
Soaked CBR %
Dry Density gm/ccm
26.00
28.00
30.00
32.00
34.00
36.00
38.00
40.00
42.00
44.00
46.00
48.00
1.4
1.5
1.6
1.7
1.8
1.9
2.0


Natural Soil + 14% Cement
y = -0.2359x + 0.5454
Swelling (%)
Dry Density gm/ccm
0.0
0.0
0.0
0.1
0.1
0.1
0.1
0.1
0.2
0.2
0.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9

Test pit Lacotion	Bedo Kebele		Percentage of cement		**Natural Soil + 14% Cement**	
Compaction Determination						
COMPACTION DATA	**65 Blows**		**30 Blows**		**10 Blows**	
	Before soak	**After soak**	**Before soak**	**After soak**	**Before soak**	**After soak**
Mass of soil + Mould, (g)	13952.7	14222.3	13219.3	13888.9	13035.2	13573.8
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4654.8	4924.4	3932.6	4602.2	3748.5	4287.1
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.192	2.318	1.852	2.167	1.765	2.018
Dry density of soil (g/ccm)	1.91	1.74	1.62	1.58	1.54	1.42

Moisture Determination

MOISTURE CONTENT DATA	**65 Blows**				**30 Blows**				**10 Blows**			
	Before soak		**After soak**		**Before soak**		**After soak**		**Before soak**		**After soak**	
Mass of wet soil + Container, (g)	120.69		72.51	101.48	120.69		79.83	89.34	120.69		118.89	102.41
Mass of dry soil + Container, (g)	110.09		58.77	80.99	110.09		63.44	69.88	110.09		94.30	80.81
Mass of container, (g)	37.54		17.79	17.36	37.54		17.39	17.24	37.54		35.27	30.00
Mass of water, (g)	10.60		13.74	20.49	10.60		16.39	19.46	10.60		24.59	21.60
Mass of drysoil, (g)	72.55		40.98	63.63	72.55		46.05	52.64	72.55		59.03	50.81
Moisture content, (%)	14.61		33.53	32.20	14.61		35.59	36.97	14.61		41.66	42.51
Average moisture content, (%)	14.6		33.5		14.6		37.0		14.6		41.7	

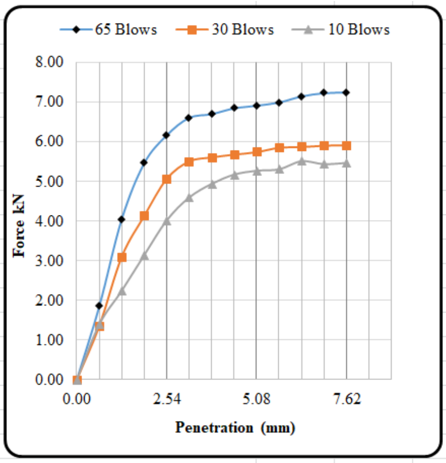
CBR Penetration Determination

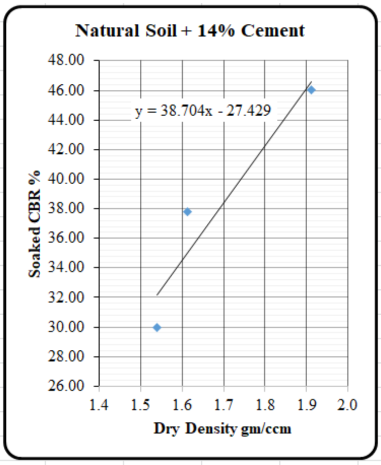
Penetration after 96 hrs Soaking Period		**Surcharge Weight:-4.55 KG**			**Ring Calibration Factor (KN/Div.)=**			**1.0**
65 Blows			**30 Blows**			**10 Blows**		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.002	
0.64	1.846		0.64	1.353		0.64	1.394	
1.27	4.046		1.27	3.099		1.27	2.244	
1.91	5.457		1.91	4.129		1.91	3.143	
2.54	6.161	**46.03**	2.54	5.062	**37.82**	2.54	4.016	**30.00**
3.18	6.601		3.18	5.503		3.18	4.595	
3.81	6.696		3.81	5.607		3.81	4.938	
4.45	6.842		4.45	5.676		4.45	5.172	
5.08	6.908	**34.57**	5.08	5.738	**28.72**	5.08	5.270	**26.37**
5.72	6.989		5.72	5.848		5.72	5.306	
6.35	7.142		6.35	5.867		6.35	5.510	
6.99	7.224		6.99	5.901		6.99	5.437	
7.62	7.242		7.62	5.913		7.62	5.467	

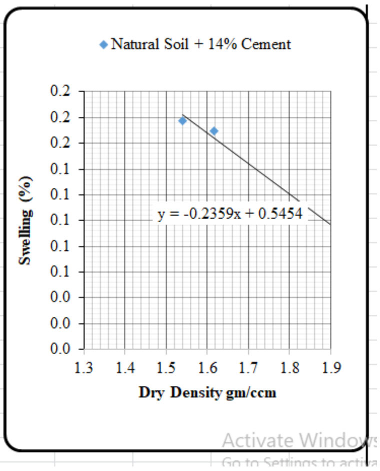
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	5.12	0.09
Final reading, (mm)	5.23	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	2.34	0.17
Final reading, (mm)	2.54	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	0.27	0.18
Final reading, (mm)	0.48	
Modified MDD (g/ccm)		1.70
Optimum moisture content, %		14.00
Modified MDD at 95% (g/ccm)		**1.615**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	**30 Blows**	**10 Blows**	**65 Blows**	**30 Blows**	**10 Blows**	**10**	**14.6**	**1.54**	**30.00**	**93**	**0.18**
2.54mm	**6.16**	**5.06**	**4.02**	**46.03**	**37.82**	**30.00**	**30**	**14.6**	**1.62**	**37.82**	**98**	**0.17**
5.08mm	**6.91**	**5.74**	**5.27**	**34.57**	**28.72**	**26.37**	**65**	**14.6**	**1.91**	**46.03**	**116**	**0.09**
									38.703699	-27.42905	-0.2359431	0.5454378
CBR % at 95 % of Maximum Dry Density				**38.4**			**CBR Swelling (%)**				**0.2**	







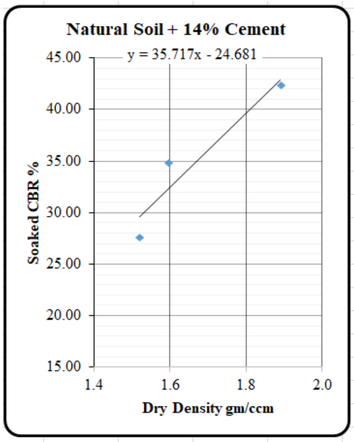
Test Pit Lacotion	Fintjeju Kebele		Percentage of cement		Natural Soil + 14% Cement	
Compaction Determination						
COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13896.9	13724.5	13166.4	13402.8	12983.1	13098.7
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4599	4426.6	3879.7	4116.1	3696.4	3812
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.165	2.084	1.827	1.938	1.740	1.795
Dry density of soil (g/ccm)	1.89	1.55	1.60	1.41	1.52	1.26

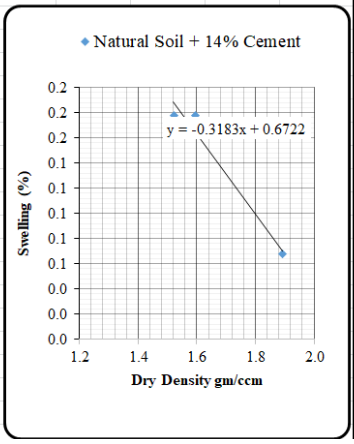
Moisture Determination												
MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	123.10		73.60	103.00	123.10		81.03	90.68	123.10		120.67	103.95
Mass of dry soil + Container, (g)	112.29		59.36	81.80	112.29		64.07	70.58	112.29		95.24	81.62
Mass of container, (g)	37.84		17.88	17.45	37.84		17.48	17.33	37.84		35.45	30.15
Mass of water, (g)	10.81		14.24	21.20	10.81		16.96	20.10	10.81		25.43	22.33
Mass of drysoil, (g)	74.45		41.48	64.35	74.45		46.59	53.25	74.45		59.79	51.47
Moisture content, (%)	14.52		34.33	32.94	14.52		36.40	37.75	14.52		42.53	43.38
Average moisture content, (%)	14.5		34.3		14.5		37.7		14.5		42.5	

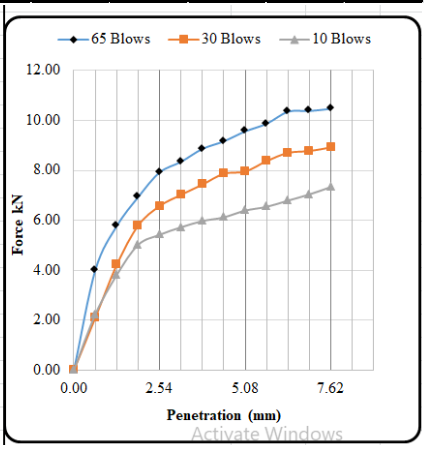
CBR Penetration Determination								
Penetration after 96 hrs Soaking Period		Surcharge Weight:-4.55 KG		Ring Calibration Factor (KN/Div.)=		1.0		
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.002	
0.64	1.698		0.64	1.245		0.64	1.282	
1.27	3.722		1.27	2.851		1.27	2.064	
1.91	5.020		1.91	3.799		1.91	2.892	
2.54	5.668	**42.34**	2.54	4.657	**34.79**	2.54	3.695	**27.60**
3.18	6.073		3.18	5.063		3.18	4.227	
3.81	6.160		3.81	5.158		3.81	4.543	
4.45	6.295		4.45	5.222		4.45	4.758	
5.08	6.355	**31.80**	5.08	5.279	**26.42**	5.08	4.848	**24.26**
5.72	6.430		5.72	5.380		5.72	4.882	
6.35	6.571		6.35	5.398		6.35	5.069	
6.99	6.646		6.99	5.429		6.99	5.002	
7.62	6.663		7.62	5.440		7.62	5.030	

Swelling Determination		
65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	5.12	0.07
Final reading, (mm)	5.2	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	2.28	0.18
Final reading, (mm)	2.5	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	0.26	0.18
Final reading, (mm)	0.5	
Modified MDD (g/ccm)		1.70
Optimum moisture content, %		14.50
Modified MDD at 95% (g/ccm)		**1.610**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	14.5	1.52	27.60	92	0
2.54mm	5.67	4.66	3.70	42.34	34.79	27.60	30	14.5	1.60	34.79	97	0
5.08mm	6.36	5.28	4.85	31.80	26.42	24.26	65	14.5	1.89	42.34	115	0
									35.717366	-24.680946	-0.3182528	0.6722354
CBR % at 95 % of Maximum Dry Density				35.9			CBR Swelling (%)				0.2	







Test pit Lacotion	Abuko Kebele	Percentage of cement	**Natural Soil + 16% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13675	13876.4	13230	13872.3	12838	13550.6
Mass Mould, (g)	9309.5	9309.5	9399	9399	9308	9308
Mass of Soil, (g)	4365.5	4566.9	3831	4473.3	3530	4242.6
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.055	2.150	1.804	2.106	1.662	1.997
Dry density of soil (g/ccm)	1.75	1.57	1.54	1.55	1.42	1.41

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	91.8		84.5	80.1	131.8		64.4	88.1	111.8		92.3	82.3
Mass of dry soil + Container, (g)	80.9		66.5	63.4	115.2		52.5	68.9	98.1		75.4	66.5
Mass of container, (g)	17.9		17.7	18.0	17.7		17.9	16.8	17.8		37.3	26.7
Mass of water, (g)	10.9		18.1	16.7	16.6		11.9	19.2	13.8		16.9	15.8
Mass of drysoil, (g)	63.0		48.8	45.3	97.6		34.6	52.1	80.3		38.1	39.8
Moisture content, (%)	17.3		37.1	36.8	17.0		34.3	36.8	17.1		44.3	39.7
Average moisture content, (%)	17.3		36.9		17.0		35.5		17.1		42.0	

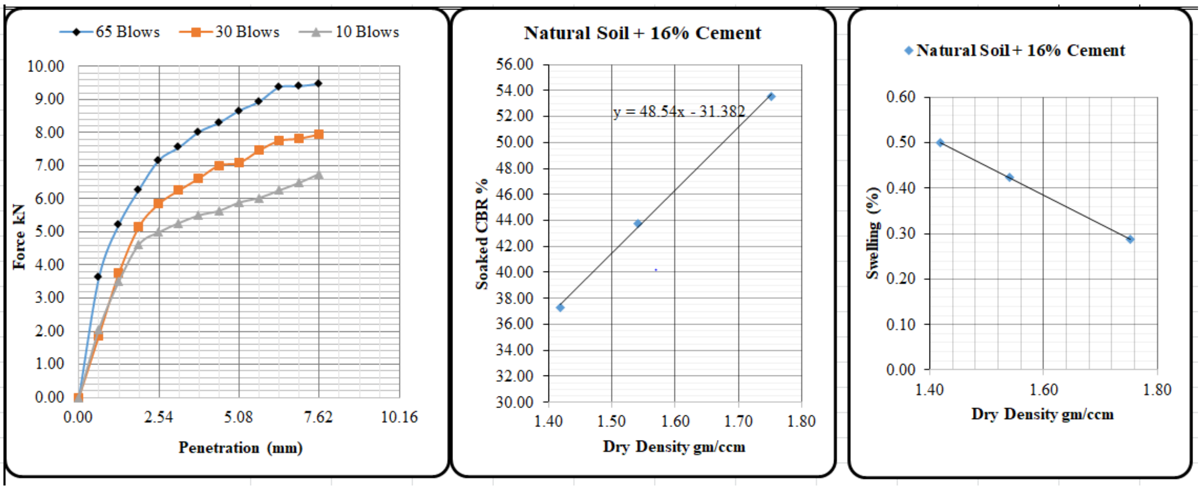
CBR Penetration Determination

Penetration after 96 hrs Soaking Period		Surcharge Weight:-4.55 KG			Ring Calibration Factor (KN/Div.)=			1.0
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.00		0.00	0.0		0.00	0.00	
0.64	3.63		0.64	1.9		0.64	2.06	
1.27	5.23		1.27	3.8		1.27	3.51	
1.91	6.28		1.91	5.2		1.91	4.63	
2.54	7.17	**53.57**	2.54	5.9	**43.73**	2.54	4.99	**37.31**
3.18	7.56		3.18	6.3		3.18	5.27	
3.81	8.03		3.81	6.6		3.81	5.50	
4.45	8.30		4.45	7.0		4.45	5.64	
5.08	8.66	**43.35**	5.08	7.1	**35.48**	5.08	5.89	**29.47**
5.72	8.94		5.72	7.5		5.72	6.03	
6.35	9.37		6.35	7.8		6.35	6.26	
6.99	9.40		6.99	7.8		6.99	6.49	
7.62	9.48		7.62	8.0		7.62	6.76	

Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	16.98	0.29
Final reading, (mm)	17.3	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	14.2	0.42
Final reading, (mm)	14.7	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	11.57	0.50
Final reading, (mm)	12.2	
Modified MDD (g/ccm)		1.66
Optimum moisture content, %		16.00
Modified MDD at 95% (g/ccm)		**1.577**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	17.1	1.42	37.3	85	0.5
2.54mm	7.17	5.85	4.99	53.57	43.73	37.31	30	17.0	1.54	43.7	93	0.4
5.08mm	8.66	7.09	5.89	43.35	35.48	29.47	65	17.3	1.75	53.6	106	0.3
CBR % at 95 % of Maximum Dry Density				45.2			CBR Swelling (%)				0.4	



65 Blows
30 Blows
10 Blows
Force kN
Penetration (mm)
Natural Soil + 16% Cement
y = 48.54x - 31.382
Soaked CBR %
Dry Density gm/ccm
Natural Soil + 16% Cement
Swelling (%)
Dry Density gm/ccm

Test pit Lacotion	Bedo Kebele	Percentage of cement	**Natural Soil + 16% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13757.1	13959.7	13309.4	13955.5	12915	13631.9
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4459.2	4661.8	4022.7	4668.8	3628.3	4345.2
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.099	2.195	1.894	2.198	1.708	2.046
Dry density of soil (g/ccm)	1.86	1.75	1.68	1.65	1.51	1.48

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	93.64		86.23	81.65	134.48		65.66	89.83	114.06		94.11	83.93
Mass of dry soil + Container, (g)	84.95		72.43	69.07	121.00		54.60	71.67	102.97		78.39	69.15
Mass of container, (g)	18.04		17.84	18.22	17.83		18.05	16.96	17.94		37.62	26.96
Mass of water, (g)	8.69		13.80	12.58	13.48		11.06	18.16	11.09		15.72	14.78
Mass of drysoil, (g)	66.91		54.59	50.85	103.17		36.55	54.71	85.03		40.77	42.19
Moisture content, (%)	12.99		25.28	24.74	13.07		30.26	33.19	13.04		38.56	35.03
Average moisture content, (%)	13.0		25.3		13.1		33.2		13.0		38.6	

CBR Penetration Determination

Penetration after 96 hrs Soaking Period | Surcharge Weight:-4.55 KG | Ring Calibration Factor (KN/Div.)= 1.0

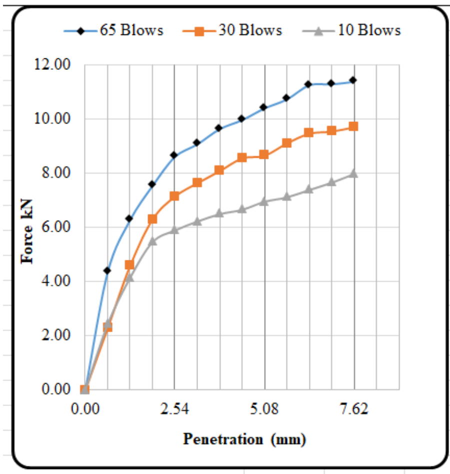
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	4.352		0.64	2.285		0.64	2.430	
1.27	6.271		1.27	4.585		1.27	4.147	
1.91	7.534		1.91	6.293		1.91	5.459	
2.54	8.605	**64.28**	2.54	7.142	**53.35**	2.54	5.893	**44.02**
3.18	9.069		3.18	7.634		3.18	6.221	
3.81	9.631		3.81	8.080		3.81	6.494	
4.45	9.962		4.45	8.551		4.45	6.654	
5.08	10.395	**52.02**	5.08	8.649	**43.28**	5.08	6.950	**34.78**
5.72	10.727		5.72	9.104		5.72	7.114	
6.35	11.248		6.35	9.462		6.35	7.385	
6.99	11.282		6.99	9.539		6.99	7.654	
7.62	11.378		7.62	9.700		7.62	7.976	

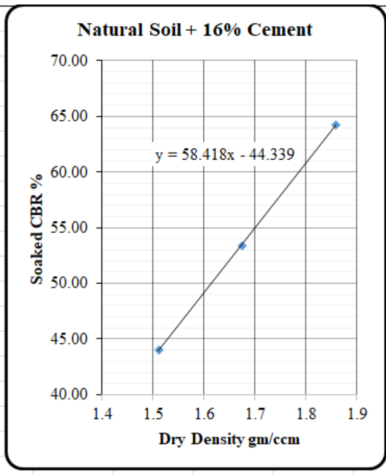
Swelling Determination

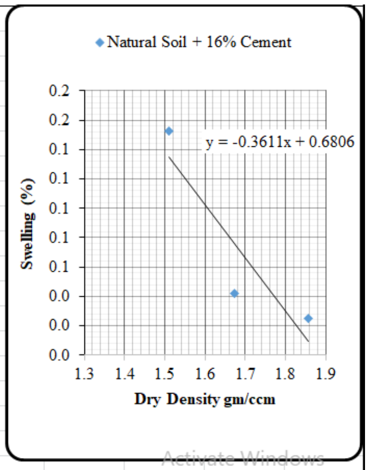
65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	12.17	0.03
Final reading, (mm)	12.2	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	14.41	0.04
Final reading, (mm)	14.5	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	8.32	0.15
Final reading, (mm)	8.5	
Modified MDD (g/ccm)		1.75
Optimum moisture content, %		14.00
Modified MDD at 95% (g/ccm)		**1.663**

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	13.0	1.51	44.02	91	0
2.54mm	8.61	7.14	5.89	64.28	53.35	44.02	30	13.1	1.68	53.35	101	0
5.08mm	10.40	8.65	6.95	52.02	43.28	34.78	65	13.0	1.86	64.28	112	0
									58.417846	-44.339055	-0.3610723	0.6805683

CBR % at 95 % of Maximum Dry Density	57.9	CBR Swelling (%)	0.1







Test Pit Lacotion	Fintjeju Kebele	Percentage of cement	**Natural Soil + 16% Cement**

Compaction Determination

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mass of soil + Mould, (g)	13702.1	13471.1	13256.2	13467.1	12863.3	13154.8
Mass Mould, (g)	9297.9	9297.9	9286.7	9286.7	9286.7	9286.7
Mass of Soil, (g)	4404.2	4173.2	3969.5	4180.4	3576.6	3868.1
Volume of Mould, (ccm)	2124	2124	2124	2124	2124	2124
Wet density of soil, (g/ccm)	2.074	1.965	1.869	1.968	1.684	1.821
Dry density of soil (g/ccm)	1.81	1.56	1.63	1.47	1.47	1.31

Moisture Determination

MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Mass of wet soil + Container, (g)	95.51		87.52	82.87	137.17		66.64	91.18	116.34		95.52	85.19
Mass of dry soil + Container, (g)	85.80		73.15	69.76	122.21		55.15	72.39	104.00		79.17	69.84
Mass of container, (g)	18.22		17.93	18.31	18.01		18.14	17.04	18.12		37.81	27.09
Mass of water, (g)	9.71		14.37	13.11	14.96		11.49	18.79	12.34		16.35	15.35
Mass of drysoil, (g)	67.58		55.22	51.45	104.20		37.01	55.35	85.88		41.36	42.75
Moisture content, (%)	14.37		26.02	25.48	14.36		31.05	33.95	14.37		39.53	35.91
Average moisture content, (%)	14.4		26.0		14.4		33.9		14.4		39.5	

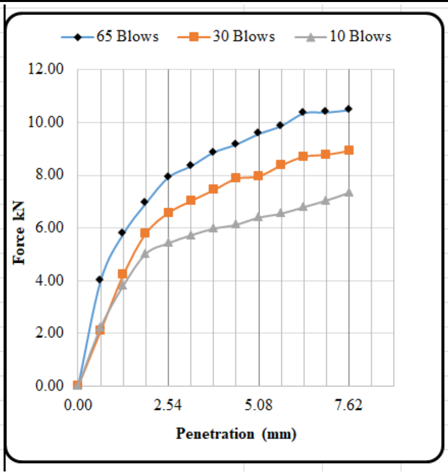
CBR Penetration Determination

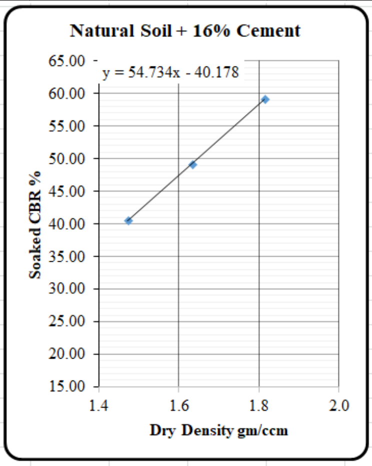
Penetration after 96 hrs Soaking Period		Surcharge Weight:-4.55 KG			Ring Calibration Factor (KN/Div.)=			1.0
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	4.004		0.64	2.102		0.64	2.236	
1.27	5.769		1.27	4.218		1.27	3.815	
1.91	6.931		1.91	5.790		1.91	5.022	
2.54	7.917	**59.14**	2.54	6.571	**49.09**	2.54	5.422	**40.51**
3.18	8.343		3.18	7.023		3.18	5.723	
3.81	8.861		3.81	7.434		3.81	5.974	
4.45	9.165		4.45	7.867		4.45	6.122	
5.08	9.563	**47.86**	5.08	7.957	**39.82**	5.08	6.394	**32.00**
5.72	9.869		5.72	8.376		5.72	6.545	
6.35	10.348		6.35	8.705		6.35	6.794	
6.99	10.379		6.99	8.776		6.99	7.042	
7.62	10.468		7.62	8.924		7.62	7.338	

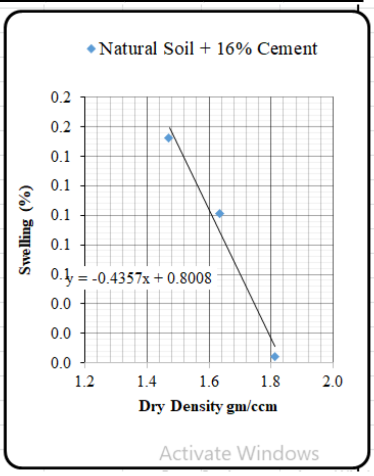
Swelling Determination

65 Blows		
Height of mold (mm)	118	Swell %
Initial reading, (mm)	12.17	0.00
Final reading, (mm)	12.18	
30 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	14.05	0.10
Final reading, (mm)	14.2	
10 Blows		
Height of mold (mm)	118	Swell in %
Initial reading, (mm)	8.15	0.15
Final reading, (mm)	8.3	
Modified MDD (g/ccm)	1.73	
Optimum moisture content, %	14.00	
Modified MDD at 95% (g/ccm)	**1.644**	

Penetration (mm)	Corrected reading Load (kN)			Corrected CBR (%)			No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction	Swell in %
	65 Blows	30 Blows	10 Blows	65 Blows	30 Blows	10 Blows	10	14.4	1.47	40.51	89	0
2.54mm	7.92	6.57	5.42	59.14	49.09	40.51	30	14.4	1.63	49.09	98	0
5.08mm	9.56	7.96	6.39	47.86	39.82	32.00	65	14.4	1.81	59.14	109	0
									54.734056	-40.177933	-0.4356803	0.8007895
CBR % at 95 % of Maximum Dry Density				54.5			CBR Swelling (%)				0.1	

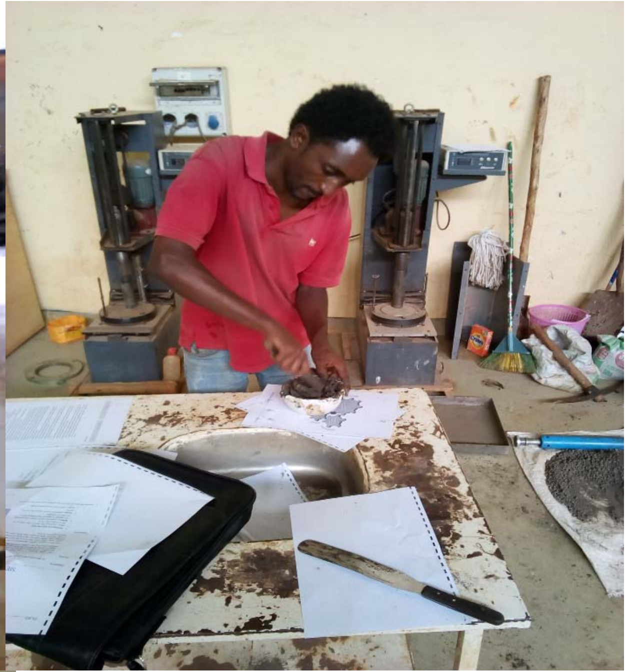






APPENDIX 2. Some Photos Taken During soil sampling and Laboratory testing


May: 28/ 9/2013 3:30 AM

June: 15/10/2013 4:30PM

June : 22/10/2013 2:30 AM

July: 10/ 11/2013 3:20 AM July: 25/ 11/2013 2:30 AM