Investigation on the Index and Some of Engineering Properties of Soils Found in Iteya Town,Ethiopia.

Tamirat Zewde Tola

A Thesis Submitted to

The Department of Civil Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirements for the Degree of Master's in Civil Engineering (Specialization in Geotechnical Engineering)

Office of Graduate Studies

Adama Science and Technology University

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Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled "Investigation on the Index and Some of Engineering Properties of Soils Found in Iteya Town, Ethiopia" is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Tamirat Zewde	______________________	____________________
Name of the Student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Investigation on the Index and Some of Engineering Properties of Soils Found in Iteya Town, Ethiopia" prepared under my guidance by Tamirat zewde submitted in partial fulfillment of the requirements for the degree of Mater"s of Science in Civil Engineering (Specialization in Geotechnical Engineering). Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures.

<u>Argaw Asha (PhD)</u>

Advisor Signature Date

APPROVAL SHEET

I, the advisor of the thesis entitled "Investigation on the Index and Some of Engineering Properties of Soils Found in Iteya Town, Ethiopia" developed by Tamirat zewde, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Argaw Asha (PhD)

Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Tamirat Zewde have read and evaluated the thesis entitled "Investigation on the Index and Some of Engineering Properties of Soils Found in Iteya Town, Ethiopia" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Civil Engineering (Specialization in Geotechnical Engineering).

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TABLE OF CONTENTS

Contents……………………………………………………………………………………page

LIST OF TABLE

LIST OF FIGURES AND ILUSTRATIONS

LIST OF ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society of Testing and Materials
ASTU	Adama Science and Technology University
TP	Test Pit
OD	Oven Dry
LL	Liquid Limit
MDD	Maximum Dry Density
PL	Plastic Limit
PI	Plastic Index
OMC	Optimum Moisture Content
SC	Clayey sand
SM	Silty Sand
USCS	Unified Soil Classification System
GS	Specific gravity
NP	None plastic

ABSTRACT

This study focuses on investigating the engineering properties of soil in Iteya town to provide necessary geotechnical data for construction projects. The undisturbed samples were used to determine natural moisture contents, while disturbed samples were used for free swell tests, grain size analysis, Atterberg limit tests, specific gravity tests, and compaction tests. Samples prepared from compacted soil were used for direct shear tests using the standard Proctor test. According to the engineering properties test results, the grain size analysis showed that the dominant soil particles in the study area are coarse-grained soils with clay content ranging from 0.7-6%, silt fraction 7.88-15.4%, sand fraction 62-86.36%, and gravel fraction 1.8-27.20%. The Atterberg limits indicated that the liquid limit ranges from 14% to 20.3%, the plastic limit from 13.91% to 17.92%, and the plastic index from non-plastic to 4.73%. These results suggest that the soils are non-plastic to low plastic and less susceptible to compressibility. The specific gravity ranges from 2.64-2.68, typical for sandy soils. The free swell test revealed a free swell value ranging from 1.8% to 18.1%, indicating all soil samples are non-expansive. The moisture content of the soils ranges from 14% to 26.92%, indicating that the soil is mainly coarse-grained. The compaction test showed that the optimum moisture content (OMC) and maximum dry density (MDD) vary from 17.7% to 27.77% and 1.42 to 1.55 g/cm³, respectively, indicative of coarse-grained soil particles with higher density than fine soil particles. The shear strength parameters, cohesion (C) and internal friction angle (ϕ), determined from the direct shear test, vary from 1.019 to 7.95 kPa and 22.7° to 29.7°, respectively. Based on these tests, the soil in the study area is classified as silty sand (SM) and poorly graded sand with clay and gravel soil as per the Unified Soil Classification System (USCS) and as A-2-4 and A-3 according to the American Association of State Highway and Transportation Officials (AASHTO) soil classification system. The soil is suitable for roadway pavement as per the AASHTO classification. The results indicated that the soils in the area possess desirable engineering characteristics, including good shear strength, low compressibility, low plasticity, and less susceptibility to shrinkage and swelling with variations in moisture content. The study provides valuable geotechnical data that can be applied to ensure the stability and safety of structures in Iteya town.

***Key words**: Engineering properties of soil and index properties of soil.*

CHAPTER ONE

INTRODUCTION

1.1.Background the research

Site investigation or sub surface exploration is done for obtaining the information about subsurface condition at the site of proposed structural system (dams, buildings, highways and, roads etc.).

Site investigation consists of determining the profile of the natural soil deposition at the site taking the soil samples and determining the engineering properties of soils.

One of the important activities is proper design of structure. The proper design of civil engineering structures like foundation of buildings, retaining walls, high ways, etc. in turn requires adequate knowledge of sub surface conditions at the sites of the structures. Many failures to highway, buildings, and other structures founded on soils are mainly due to the lack of proper investigation of substructure engineering properties of soil condition (Arora, 2003).

Geotechnical investigation of engineering and index property of soil at a site is prerequisite to the economical design of the substructure elements. It is also necessary to obtain sufficient information on the detail engineering and index properties of soil at different depth. The extent of the investigation depends upon the magnitude and importance of the project (Debebe, 2011). In addition; the properties of soils vary from place to place depending on climate, topography, parent material, soil fabric and degree of weathering. For developing countries like Ethiopia which is developing at high growth rate the construction industry is also growing rapidly. Detailed geotechnical investigation on the engineering property of soil is very essential. Because these data are very important for civil engineers in preliminary design and in designing foundation, pavement, retaining structures, etc. for future construction projects in the country.

In the study area, the engineering property of the soil of the town like shear strength and basic engineering properties of soils i.e. investigating the index property as well as swelling characteristics of the soil in the town is not studied therefore the study is used to fill this gap. The present work is to fill this gap by investigating the engineering properties and understanding the behavior of the soil undelaying the town. In addition it is expected to recommend technically and economically feasible remedial measure to improve the behavior of the soil if it is not suitable for construction works.

1.2.Statement of the problem

Investigation of engineering properties of soil is essential for the economical design of sub structural elements as almost everything we build i.e. buildings, bridges, dams and others are in, on or within soils or rocks. It is also necessary to obtain sufficient information for feasibility and economic studies of the proposed project.

In a country like Ethiopia which is developing at high growth rate, many construction works are undergoing at present and will be done in the future. Geotechnical investigation on the engineering properties of soil is very essential, because these data are very important for civil engineers in preliminary design and in the design of foundation, pavement, retaining structures, etc. for future construction projects in the country. Many researches were done and there are ongoing researches in most big cities of the country like Addis Ababa, Bahir Dar, Mekele, Hawasa; etc.

However, the engineering property of the soil in Iteya town has not yet been studied. This research is therefore directed to the study of the engineering properties of soils in Iteya town.

1.3.Objective of the Study

1.3.1. General Objective

The general objective of this research was to study Index and some of engineering properties of soils found in Iteya Town.

1.3.2. Specific Objective

- To investigate the Index and some of the engineering properties of soil in Iteya town like: natural moisture content, specific gravity, grain size analysis, free swell, shear strength and compaction characteristics.
- To classify the soils according to both AASHTO and USCS.

1.4.Significance of the study

The research shall investigate the Index and some of engineering properties of soils found in Iteya Town and in this town; there are many expansion projects of building, road construction and different civil works. Settlement, shear failure, structural crack, potholes, drainage and surface defects problems are among common building and road defect (problems) in which the main cause is the selection of qualified subsurface condition during construction. The present worked was filling this gap by investigating the engineering properties and understanding the behavior of the soil undelaying the town.

1.5.Scope of the study

The scope of this study is limited to investigating the index properties; shear strength, compaction, and swelling properties. Totally twenty samples were collected from ten test pits. Due to the budget constraint, the depth of investigation in this research is limited to the maximum depth of three meters.

1.6.Structure of the Thesis

The thesis has been divided in to five chapters. The first chapter is the introductory part which includes the general background, statement of the problem, objective, and significance of the study and scope of the study. The second chapter is deals with a brief literature review including general expression soil deposit, mineralogy of soils, soil particle size and shape, identification and classification of soils. In the third chapter, description of the sampling area is covered which includes geology, climate, topography, soil characteristics and methodology. The fourth chapter results and discussions of the laboratory test and Comparison of test results with previous test results conducted by other researchers on different. In chapter five conclusions from test results and recommendation is presented. Appendices and references are attached at the end of the thesis.

CHAPTER TWO

LITERATURE REVIEW

2.1.General

Soil is defined as a natural aggregate of mineral grains, with or without organic constituents that can be separated by gentle mechanical means such as agitation in water. By contrast rock is considered to be a natural aggregate of mineral grains connected by strong and permanent cohesive force. The process of weathering of rock decreases the cohesive force binding the mineral grains and leads to the disintegration of bigger masses to smaller and smaller particles. Soils are formed by the process of weathering of the parent rock (Debebe, 2011).

Soils are formed from the physical and chemical weathering of rocks. Physical weathering involves reduction of size without any change in the original composition of the parent rock. The main agent responsible for this processes are exfoliation, unloading, erosion, freezing and thawing. Chemical weathering causes both reduction in size and chemical alteration of the original parent rock. The main agents responsible for chemical weathering are hydration, carbonation and oxidation. Often chemical and physical weathering takes place in concert (ASTM, 2004).

Chemical weathering is much more important than physical weathering in soil formation. Soils at a particular site can be residual (that is weathered in place) or transported (moved by water, wind, glacier, etc.) and the geologic history of a particular deposit significantly affects its engineering behavior (Oromia urbn Planning Institute, 2010).

2.2.General Types of Soils

According to their grain size, soil particles are classified as cobbles, gravel, sand, silt and clay. Grains having diameters in the range of 4.75 to 76.2 mm are called gravel. If the grains are visible to the naked eye, but are less than about 4.75 mm in size the soil is described as sand. The lower limit of visibility of grains for the naked eyes is about 0.075 mm. Soil grains ranging from 0.075 to 0.002 mm are termed as silt and those that are finer than 0.002 mm as clay. This classification is purely based on size which does not indicate the properties of fine grained materials (Murty, 1990).

Table2.1 Particle size Range (Murty, 1990)

Particle Name	**Size Range**
Gravel	4.75-76.2mm
Sand	<4.75mm
Silt	0.075mm-0.002mm
Clay	<0.002mm

2.2.1. Residual and Transported Soil

Residual soils: are those that remain at the place of their formation as a result of the weathering of parent rocks. The depth of residual soils depends primarily on climatic conditions and the time of exposure. In some areas, this depth might be considerable. In temperate zones Residual soils are commonly stiff and stable. (Murty,1990). Residual soils include topsoil and laterites. Laterites are formed by chemical weathering under warm, humid tropical conditions when the rain water leaches out the soluble rock material leaving behind the insoluble hydroxide of iron and aluminum, giving them their characteristic red-brown color. (Indrawan, I,Rahardjo, H et al. , 2006) An important characteristic of residual soil is that the sizes of grains are indefinite. For example, when a residual sample is sieved, the amount passing any given sieve size depends greatly on the time and energy expended in shaking, because of the partially disintegrated condition. (R.M, 1990)

Transported soils: are soils that are found at locations far removed from their place of formation. The transporting agents of such soils are glaciers, wind and water. These soils include gravels, sands, silts and clays. As a stream or river loses its velocity it tends to some of the particles that it is carrying, dropping the larger, heavier particles first. Hence, on higher reaches of a river gravel and sand are found whilst on the lower parts silts and clays predominate. Common descriptive terms such as gravels, sands, silts, and clays are used to identify specific textures in soils. One can refer to these soil textures as soil types; that is, Sands and gravels are grouped together as coarse-grained soils. Clays and silts are fine-grained soils. To characterize fine-grained soils, one needs further information on the types of minerals present and their contents. The response of fine-grained soils to loads, known as the mechanical behavior, depends on the type of predominant minerals present Many of these transported soils are loose and soft to a depth of several hundred feet. Therefore, difficulties with foundations and other types of construction are generally associated with transported soils (Murty, 1990).

2.3.Soil Structure

The structure of a soil may be defined as the manner of arrangement and state of aggregation of soil grains. In a broader sense, consideration of mineralogical composition, electrical properties, orientation and shape of soil grains, nature and properties of soil water and the interaction of soil water and soil grains, also may be included in the study of soil structure, which is typical for transported or sediments soils (William D.K and Robert D.H, 1981).

The following types of structure are commonly studied:

(a) Single-grained structure (b) Honey-comb structure (c) Flocculent structure

2.3.1. Single-grained Structure

Single-grained structure is characteristic of coarse grained soils with a particle size greater than 0.02 mm. Gravitational forces pre-dominate the surface forces and hence grain to grain contact results. The deposition may occur in a loose state, with large voids or in a sense state, with less of voids (William D.K and Robert D.H, 1981).

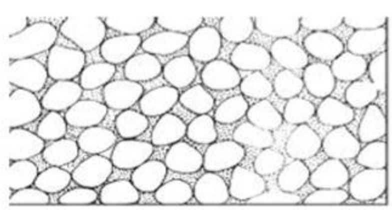


Figure2.1 Single-grain Structure (Website, 2015)

2.3.2. Honey-comb Structure

This structure can occur only in fine-grained soils, especially in silt and rock flour. Due to the relatively smaller size of grains, besides gravitational forces, inter-particle surface forces also play an important role in the process of settling down. The structure can be broken down by external disturbances. (William. D and Robert 1981).

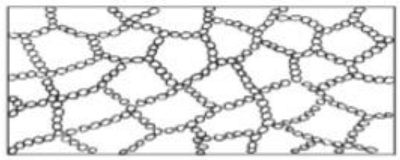


Figure2.2 Honey-comp structures (Website, 2015)

2.3.3. Flocculent Structure

This structure is characteristic of fine-grained soils such as clays. Flocculent structures are formed by settlement of flocks of clay particles. Clays that have flocculent structures are light weight and possess high void ratios

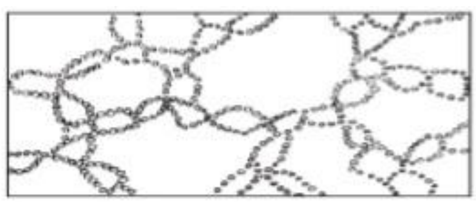


Figure2.3Flocculent structure (Website, 2015)

2.4.Soil Particle Size and Shape

The size of particles may range from grav el to the finest size possible. Their characteristics vary with the size. Soil particles coarser than 0.075mm are visible to the naked eye or may be examined by means of a hand lens. They constitute the coarser fractions of the soils. Grains size finer than 0.075mm is contains the finer fractions of soils. The shape of grains smaller than 1μ can be determined by means of an electron microscope. The molecular structure of particles can be investigated by means of X-ray analysis. The shape of particles present in a soil mass is equally as important as the particle size distribution because it has significant influence on the physical properties of a given soil. However, not much attention is paid to particle shape because it is more difficult to measure. The individual grains of gravel and sand may be angular, sub-angular, sub-rounded, rounded or well-rounded. Silt and clay constitute the finer fractions of the soil. The particles may be angular, flake shaped or sometimes needle-like (Murty, 1990).

2.5.Soil Mineralogical Composition

Mineral particles are inorganic materials derived from rocks and minerals. They are extremely variable in size and composition.

- **Primary minerals**: present in original rock from which soil is formed. These occur predominantly in sand and silt fractions, and are weathering resistant (quartz, feldspars).
- **Secondary minerals**: formed by decomposition of primary minerals, and their Subsequent weathering and re composition into new ones (clay minerals).
- **Humus** or **organic matter** (decomposed organic materials). (Debebe, 2011) .

2.6.Index Properties

Index properties are basic for distinguishing soils. Index properties may be divided into two main categories namely, soil grain properties and soil aggregate properties. The soil grain properties are the properties of the individual grains as expressed by size, shape, and mineralogical characteristics. The soil aggregate properties are the properties of the soil mass as a whole. The most significant aggregate property of cohesion less soils is the relative density, whereas that of cohesive soils is the consistency (Alemayehu Teferra and Mesfine Leikun, 1999)

A bulk soil, as it exists in nature, is more or less randomly assembled of soil particles, water and air. The properties of soils are complex and variable. Every civil engineering work involves the determination of soil type and its associated engineering application; certain properties are more significant than others. The common problems faced by civil engineers are related to bearing capacity and compressibility of soil and seepage through the soil. The possible solution to these problems is arrived at based on the study of the physical and index properties of the soil (Krishna, 2002). Soil is a heterogeneous material. The properties and characteristics of soils vary from point to point. The tests required for determination of engineering properties are generally elaborate and time consuming. Sometimes the geotechnical engineer is interested to have some rough assessment of the engineering properties without conducting elaborate tests. This is possible if index properties are determined. The properties of soils which are not of primary interest to the geotechnical engineer but which are indicative of the engineering properties are called index properties (Arora, 2003)

2.6.1. Moisture Content

Moisture content of soils refers to the total amount of water contained in a soil either as free water or capillary water. It is always expressed as a percentage of the weight of solids in the soil (Tadesse.A, 2015) Natural moisture content of a soil is affected by climate, vegetation cover of the area and other artificial factors. Hence the same soil could have different moisture contents in different seasons of a year and in different times. Since such type of moisture content is likely to fluctuate any time it may not indicate the general property of the soil.

2.6.2. Atterberg Limits

Atterberg limit is a water content at which the soil changes from one state to the other state. They are performed on fine-grained soils (clays, silts) to determine the amount of water necessary to achieve a range of behavioral states. (Bowles,J.E, 1996) In1911, a Swedish engineer Atterberg mentioned that a fined grained soil can exist in liquid, plastic, semi-soiled and solid state (Arora, 2003).The liquid limit (LL), plastic limit (PL) and shrinkage limit (SL) are Atterberg limits.

Liquid limit: the liquid limit (LL) is a water content at which the soil changes from liquid state to plastic state. Principally LL is defined as the water content at which the soil pat cut using standard groove closes for about a distance of 13mm (1/2in) at 25 numbers of blows of the liquid limit machine. The conventional liquid limit test is conducted according to AASHTOT89 or ASTM D4318 test procedures.

Plastic limit: It is a water content at which the soil changes its state from plastic to semi-solid. The soil mold begins to crumble when rolled in to thread of soil of 3mm diameter. The conventional plastic limit test is carried out as per the procedure of AASHTOT 90 or ASTM D4318. The shear strength at the plastic limit is about 100 times that of the liquid limit.

Shrinkage limit: It is the water content at which the soil changes from semi-solid state to solid state. It is the smallest water content at which the soil is saturated

Plasticity index (PI): it is the amount of water that must be added to change a soil from its plastic limit to liquid limit. It is the numerical difference between liquid limit and plastic limit. (PI=LL-PL). If either plastic limit or liquid limit cannot be determined, the soil is non-plastic. When the plastic limit is greater than the liquid limit, the plasticity is considered as zero (Arora, 2003). The Atterberg limits and related indices have proved to be very useful for soil identification and classification. The limits are often used directly in specifications for controlling soil quality for use in fill and in semi empirical methods of design Soils are classified by AASHTO and USCS based on their Atterberg limits and on particle size as determined by sieving (ASTM D 4318).

Table2.2 Typical values of natural water content in saturated state (Murty, 1990)

Plasticity index	Plasticity
0	Non-plastic
<7	Low plastic
7-17	Medium plastic
>17	High plastic

Table2.3 Typical consistency limits for soil (Arora, 2003)

Soil type	Liquid limits (%)	Plastic limits (%)	Plastic index (%)
Sand	Non-plastic	Non-plastic	Non-plastic
Silt	30-40	20-25	10-15
Clay	40-150	25-50	15-100

2.6.3. Grain Size Analysis

Clay is a fine grained soil with a placidity index equal to or greater than four (John J, 2009). Gravel is a particle of rock that pas a 3 in (75mm) and retained on 4.75mm U.S Standard sieve. Sand is a particle of rock that will pass a No 4 (4.75mm) and retained on No- 200 (75µm U.S standard sieve. Silt is soil passing a No- 200 (75µm) U.S standard sieve and non-plastic or slightly plastic (ASTM, D, 2000). For course grained materials, the grain size distribution is determine by passing soil sample either by wet or dry shaken through a series of sieve placed in decreasing opening size order and a pan at the bottom of the stock. Then the percent passing on each sieve is used for further identifying the distribution and gradation of different sizes. Particles size analysis tests are conducted according to ASTM D 422-63. In addition, the distribution of different soil particles in a given soil is determined by sedimentation process using hydrometers test for soil passing No-200 (0.075mm) sieve (ASTM, D, 2000).

2.6.4. Specific gravity

Specific gravity of the soil solids is useful in the determination of void-ratio and degree of saturation. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature (Krishna, 2002)

This method is described in ASTM D 854-00 - Standard Test for Specific Gravity of Soil Solids by Water Pycnometer the stated temperature. In soil mechanics, the main important of the test result is used in the phase relationship of air, water, and solids in a given volume of the soil. But specific gravity is not useful as a criterion for soil classification because the variation is rather small from mineral to mineral (Krishna, 2002).

Table2.4 General ranges of Gs for different soil (Das, Soil mechanics laboratory manuals, 2002)

Soil type	Range of Gc
Sand	2.63-2.67
Silt	2.65-2.7
Clay and silt clay	2.67-2.9
Organic soil	Less than 2

2.7.Soil Classification

There are a wide variety of soils covering earth. It is difficult to study the behavior of individual soils. It is desirable to classify the soils in to broad groups of similar behavior and study the behavior of groups. Soils having similar behavior can be grouped together to form a particular group under different standardized classification system. A soil is classified according to index properties such as particle size and plasticity characteristics (Arora, 2003).

There are different classification methods such as USCS and AASHTO classification system which are used to specify a certain soil type that is suitable for a specific application. These classification systems divide the soils in to two groups: cohesive or fine grained soils and cohesion less or coarse grained soils. For coarse grained materials, the grain size distribution is determining by passing soil sample either by wet or dry shaking through a series of sieve placed in decreasing opening size order and a pan at the bottom of the stock. Then the percent passing on each sieve is used for further identifying the distribution and gradation of different sizes. Particles size analysis tests are conducted according to ASTM D 422-63. In addition, the distribution of different soil particles in a given soil is determined by sedimentation process using hydrometers test for soil passing No-200 (0.075mm) sieve (ASTM, D, 2000). Currently, two elaborate classification systems are commonly used by soil engineers. Both systems take into consideration the particle size distribution and Atterberg limits.

2.7.1. AASHTO Classification System

AASHTO classification system is useful for classifying both coarse and fine grained soils. The particle size distribution and the plasticity characteristics are required to classify a soil in AASHTO. In these system the soils are divided in to seven types, designated as A-1 and A-7 are further subdivided in to two categories and the soil A-2 in to four categories. The soil with the lowest number is the most suitable for subgrade. For instance, A-1 is better than the soil A-4.

According to AASHTO, granular soils are soils in which 35% or less are finer than the No. 200 sieve (0.075 mm). Silt-clay soils are soils in which more than 35% are finer than the No. 200 sieve (Budhu, 2015).

2.7.2. Unified Soil Classification System (USCS)

USCS is the most popular system for determining the suitability of soils for general use based on the particle size distribution and plasticity characteristics. In this system the soils are classified in to two categories as coarse grained soils, if more than 50% of the soil retained on No. 200 (0.075mm) sieve and fine grained soils, if more than 50% of the soil passes No. 200 sieve.

Coarse grained soils are further divided in to eight groups and fine grained soils are divided in to seven groups. The last highly organic soils are identified by visual inspection (Das, Advanced soil mechanics, 1997).

2.8.Compaction of Soil

Compaction means pressing the soil particles close to each other by mechanical methods. Air during compaction is expelled from the void space in the soil mass and, therefore the mass density is increased. Compaction of soil mass is done to improve its engineering properties. Compaction generally increases the shear strength of soil, and hence the stability and bearing capacity. It is also useful in reducing the compressibility and permeability of the soil. Design specifications usually state the required density (as a percentage of the “maximum” density measured in a standard laboratory test), and the water content as optimum moisture contents of soils using ASTM D698 method A (Arora, 2003).

Table2.5 Range of optimum water content (Arora, 2003)

Soil type	Sand	Sandy silt	Silt	Clay
Optimum Moisture Content	6 to 10%	8 to 12%	12 to16%	14 to 20%

Table2.6 Typical values of dry density (Arora, 2003)

Soil type	State of soil	Dry density((g/cm3)
Gravel	Loosest	1.6
	Densest	2.0
Coarse sand, Medium sand	Loosest	1.5
	Densest	1.9
Uniform, fine sand	Loosest	1.4
	Densest	1.9
Coarse silt	Loosest	1.3
	Densest	1.8
Fine silt	Softest	1.3
	Hardest	1.9

Two types of compaction tests are routinely performed: **Standard Proctor Test** (lower compaction effort), and **Modified Proctor Test** (higher compaction effort). Most of the time standard Proctor test is used but, the modified proctor test may be used when greater soil unit weight is required. (Zewdie, 2004)

Table2.7 summary of standard proctor and modified proctor compaction test specifications ASTM d- 698 and ASTM d-1557 respectively

Procedure		Procedure A	Procedure B	Procedure C
Material		≤20% Retained on No.4 Sieve	>20% Retained on No.4 ≤20% Retained on 9.5mm Sieve	>20% Retained 9.5mm <30% Retained 19mm Sieve
Material to be used		Passing 4.75 mm Sieve	Passing 9.5 mm sieve	Passing 19.0 mm sieve
Mold diameter		10.16cm(4inch)	10.16cm(4 inch)	15.25cm(6inch)
Volume of mold		944 cm^3	944 cm^3	2123 cm^3
Blow per layer		25	25	56
Layer	Standard Proctor	Three	Three	Three
	Modified Proctor	Five	Five	Five
Height of drop	Standard Proctor	30.5cm	30.5cm	30.5cm
	Modified Proctor	45.7cm	45.7cm	45.7cm
Weight of rammer	Standard Proctor	2.45Kg	2.45Kg	2.45Kg
	Modified Proctor	4.54Kg	4.54Kg	4.54Kg

2.9.Shear Strength

2.9.1. General

One of the most important and basic engineering properties of soil is its shear strength or ability to resist sliding along internal surfaces within a mass. Geotechnical design of embankments, cuts, walls, and foundations requires a thorough understanding of the strength properties of soil. The stability of a cut, the slope of an earth dam, the foundations of structures, the natural slopes of hillsides and other structures built on soil depend upon the shearing resistance offered by the soil along the probable surfaces of slippage. The safety of any geotechnical structure is dependent on the strength of the soil. Shear strength of a soil is the property that enables a soil to remain in equilibrium when its surface is not level. Shear strength is required to make estimates of the load-bearing capacity of soils and the stability of geotechnical structures, and in analyzing the stress–strain characteristics of soils (Arora, 2003) .

Three types of laboratory tests are commonly used to determine shear strength characteristics of soils. These tests are the direct shear test, the tri-axial compression test and the unconfined compression test. The direct shear test will used in this study to determine the shear strength parameters as all the soils under the study are coarse grained soil. The shear strength of a soil is the maximum shearing stress the soil structure can resist before failure. Soils generally derive their strength from friction between particles (expressed as the angle of internal friction, Φ) or cohesion between particles (expressed as the cohesion, c in units of force/unit area), or both. These parameters are expressed in the form of total stress (c, Φ) or effective stress (c‽, Φ‽).The total stress on any soil layer is induced by the overburden pressure plus any applied loads.

2.9.2. Direct Shear Test

Direct shear test is conducted on a soil specimen in a shear box which is split into two halves along a horizontal plane. The shear box is made of brass or gunmetal. It is square or circular in plan. In situations which need the shearing strength of a soil, direct shear test applied. The typical internal friction angle for sand and silt are tabulated in Table 8.

Table2.8 Typical values of drained angle of friction for sands and silts (Arora, 2003)

Soil type	Ø”(deg)
Sand: Rounded grains	
Loose	27-30
Medium	30-35
Dense	35-38
Sand: Angular grains	
Loos	30-35
Medium	35-40
Dense	40-45
Gravel with some sand	34-48
Silts	26-35

CHAPTER THREE

MATERIALS AND METHODS

3.1.Study Area

Iteya is located in eastern Arsi in the Oromia Region. It is one of the largest and most populated towns in Oromia National Regional State. This town has a latitude and longitude of 08°08′N 39°14′E respectively. The altitude of Iteya is about 1500 to 2170 meters above sea level. It is about 150 kilometers away from Addis Ababa in southeast direction. The topography of Iteya town is relatively flat and in the direction of Asela with a gentle slope exit and other part of the town and only land adjacent to the Dera Mountain is susceptible to slope failure. It has a moderate climate condition and a dominant granular soil type. (Oromia urban Planning Institute, 2010)

Figure3.1 Location of the study area (Website, 2015)

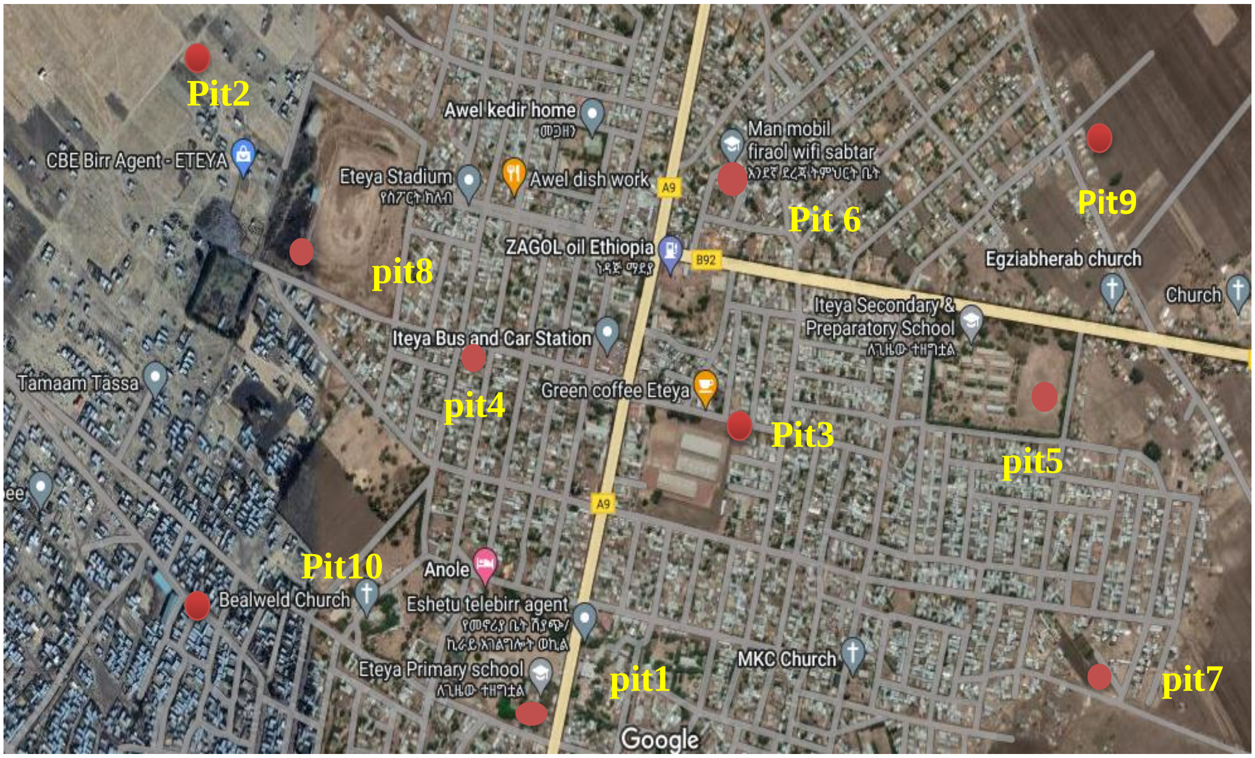


Figure3.2 Pit Location of the research area on the map of Ethiopia (Website, 2015)

3.2.Soil and Geology

Soil forms through complex interaction of several factors. The most important factors in soil formation are parent material, time, climate, organisms, and Relief (land forms and topography) The Ethiopian rift system which is part of the East African Rift System may be subdivided into three main sections. There are: the south western rift zone, the main Ethiopian rift, and Afar. Iteya is part of the central Rift Valley and dominated by flatlands stretching. (Macaulay land use research inistitute, 2012)

3.3.Climate

3.3.1. Temperature

The climate in Ethiopia is mainly influenced by altitude. There are three principle climate in Ethiopia; topical rain climate, dry climate and warm temperature. Mean maximum and mean minimum temperature vary spatially temporary. Generally mean maximum temperature is higher from March to May and minimum temperature is lower from November to December as comprised to other months. The lowest mean minimum temperature mostly occurs over the highland of the country. In a mountainous tropical country like Ethiopia altitude is by far the most important factor in controlling climate. It affects distribution of both temperature and rainfall. Generally, regions above 2500 meters a.m.s.l. (categorized as dega' or cool to cool temperature) have temperatures that range between 10^0c-16^0c, areas between 1500– 2500 meters a.s.l. (i.e. 'weina dega' or warm to cool temperature) have 16^0c and 20^0c areas below 500 to 1500 meters a.m.s.l. (i.e. 'kolla' or warm to hot) have a temperature of 20^0c and30^0 .

The town of Iteya, with an altitude ranging from 1500-2170 meters a.m.s.l, therefore the study area (Iteya town) is found in ‘weina dega’. (Ethiopian coffee exporters association, 2012)

3.3.2. Rainfall

The records of National Meteorological Service Agency from Iteya observatory substation show that the mean annual rainfall the rainy season is only in months of July and August followed by rainfall of almost equal to or below evaporation rate of the city. Around 50% of the rainfall arrives in these two months.

3.4.Research Methodology

To achieve the above objectives of this thesis researches, accomplished on different activities were conducted in different three stages such as Pre-field work, Field work and Post field work.

Pre-field work

Literatures have been reviewed at the beginning of the work were the major activities in the first stage is investigation of the index property and engineering properties of the soil, referring, Different books, journals, different thesis and gathering important data (geological map and topographic).

Field work

Selecting the Location of the sampling area and the test pits and Disturbed and undisturbed samples of soils were collected for laboratory testing. GPS reading was taken to locate the ordinate of sampling area. Undisturbed samples were handled carefully to prevent sample disturbance, and prevent a loss of moisture during transportation to the laboratory.

Post field work

Proper data Organization and collected field data and Laboratory test are conducted for different test below. Drying of soil samples oven dried for twenty four hours and for air dry depending whether condition.

Major activities in the stage of Post field work

- Natural moisture content
- Specific gravity test
- Atterberg limit tests
- Grain size analysis
- Free swell test
- Standard compaction test
- Shear strength test (Direct shear teat)

Figure3.3 Atterberg limit tests

Figure3.4 Standard compaction tests

All the above tests were done according to American Society for Testing Materials (ASTM) standard.

Finally the results have been compared to known literature values and discussed.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1.In-situ properties

4.1.1. Identification of soil in the study area

The soil specimens for this study were collected from Iteya town. Before selecting sampling areas, visual site investigation and information from resident, and construction firms were collected to consider the different soil types and to take sample in the whole town. After reconnaissance survey and gathering of information about a soil type in the whole town, ten sampling areas were selected from different locations of the town. The soil cover of the study area not varies from place to place. Test pits were excavated to the maximum depth of three meters. Both disturbed and undisturbed soil samples were taken at a depth of 1.5m and 3m from the test pits to determine the engineering and index properties of the soils. Each tests listed on objectives were done for all samples taken.

Table 4.1 Sampling depth and location of sampling area

Test Pit	Location	Northing(m)	Easting(m)	Elevation(m)
TP-1	Iteya Elementary School	919435.152	536375.39	1669 amsl
TP-2	Around mosque	919254.787	536182.106	1670.70 amsl
TP-3	Iteya TVET college	919877.77	536189.297	1684.1 amsl
TP-4	Bus station	918869.287	535697.00	1688.70 amsl
TP-5	High school	920089.184	534689.291	1670.5 amsl
TP-6	Megerisa elemetry school	920983.271	534070.596	1651.60 amsl
TP-7	Around hospital	920270.478	535355.424	1683.40 amsl
TP-8	Stadium	920570.838	535384.698	1680.30 amsl
TP-9	Techenic	898956.779	536022.779	1697.46 amsl
TP-10	Around bealeweld cherch	899346.138	535565.138	1600.87 amsl

4.1.2. In-situ properties Description

From each test pits disturbed and undisturbed samples were taken to laboratory. Disturbed samples are used to determine classification tests and shearing resistance. Undisturbed samples are used to determine in- situ properties of the soil such as natural moisture content, in situ density.

4.1.2.1.Natural moisture content

For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of (Krishna, 2002)

Natural moisture content of the soil is determined in the laboratory by using undisturbed sample. This test was done by using moisture can, drying oven and balance. This laboratory test is done by referring ASTM D 2216-98 standard. In the laboratory the weight of the moisture can and the weight of can with moist soil was measured. Then the sample was put in to drying oven at a temperature of 105+5°c for 24 hours. The loss of mass due to drying is considered to be water. The water content is calculated using the mass of water and the mass of the dry specimen. Natural moisture content of soils of the study area ranges from 14.20-24.82%. The natural moisture content of each sample is summarized in Table 4.2.

Table 4.2 Summary of natural moisture contents of the studied soils

Site location	Depth(m)	Natural Moisture contents (%)
TP1-1	0 to 1.5	22.68
TP1-2	1.5 to 3	26.92
TP2-1	0 to 1.5	20.69
TP2-2	1.5 to 2.6	19.62
TP3-1	0 to 1.5	17.44
TP3-2	1.5 to 3	20.32
TP4-1	0 to 1.5	19.83
TP4-2	1.5 to 3	19.46

TP5-1	0 to 1.5	23.34
TP5-2	1.5 to 3	14.57
TP6-1	0 to 1.5	24.82
TP6-2	1.5 to 3	24.63
TP7-1	0 to 1.5	23.23
TP7-2	1.5 to 3	14.20
TP8-1	0 to 1.5	23.29
TP8-2	1.5 to 3	16..29
TP9-1	0 to 1.5	17.36
TP9-2	1.5 to 3	22.45
TP10-1	0 to 1.5	24.72
TP10-2	1.5 to 3	20.39

4.2.Index properties

4.2.1. General

Soils are classified and identified based on index properties. The properties and characteristics of soils vary from point to point. The tests required for determination of engineering properties are generally elaborate and time consuming. Sometimes the geotechnical engineer may need some rough assessment of the engineering properties without elaborate tests. This is possible if index properties are determined. The properties of soils which are not of primary interest to the geotechnical engineer but are indicative of the engineering properties are called index properties.

Index tests include the water content (also known as moisture content), specific gravity tests, unit weight determinations, and particle size distributions and Atterberg limits, which are used to classify the soil (Arora, 2003)

4.2.2. Specific gravity

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil (Krishna, 2002) the specific gravity of most rock and soil forming minerals varies from 2.50 (some Feldspars) and 2.65 (Quartz) to 3.5 (Augite or Olivine). Gypsum has a smaller value of 2.3 and salt (NaCl) has 2.1. Some iron minerals may have higher values, for instance, magnetite has 5.2 (Murty, 1990)

According to ASTM D 854-00 standard test for specific gravity of studied soils is determined by using Water Pycnometer. Totally specific gravity of the soils collected from the ten pits is summarized in Table 4.3. This specific gravity test of the studied soils ranges from 2.65 to 2.68, which is typical for sandy soils .The details information of the all experimental data to determine the specific gravity are expressed in appendix B.

Table 4.3 the specific gravity of the studied soils

pit	Sampling depth(m)	Condition	Specific gravity	Water used for testing
TP1-1	1.5	OD	2.65	Tap water
TP1-2	3	OD	2.65	Tap water
TP2-1	1.2	OD	2.67	“
TP2-2	2.6	OD	2.64	“
TP3-1	1.5	OD	2.67	“
TP3-2	3	OD	2.68	“
TP4-1	1.5	OD	2.65	“
TP4-2	3	OD	2.67	“
TP5-1	1.5	OD	2.64	“
TP5-2	3	OD	2.67	“
TP6-1	1.5	OD	2.66	“
TP6-2	3	OD	2.66	“
TP7-1	1.5	OD	2.67	“
TP7-2	3	OD	2.68	“

TP8-1	1.5	OD	2.65	“
TP8-2	3	OD	2.67	“
TP9-1	1.5	OD	2.67	“
TP9-2	3	OD	2.68	“
TP10-1	1.5	OD	2.65	“
TP10-2	3	OD	2.67	“

4.2.3. Grain-size distribution of soil

4.2.3.1.General

The size of soil particle and their distribution throughout the soil mass are important factors which influence soil properties and performance. Particle size is expressed in term of single diameter. For the larger particles this is taken as being equal to the size of the smallest square hole of a sieve through which the particle will pass (Teferra A.and M.Leikun, 1999)

The test was conducted according to ASTM D422-63, the distribution of particles finer than 75μm can be done by hydrometer test and courser than 75μm by mechanical sieve. The data are presented on a semi-log plot of percent finer vs. particle diameters and combined with the data from a sieve analysis of the soil sample retained on the No.200 and sieve passing No.200 hydrometer test is shown in Figure 4.1 It can be seen that the soils for almost all samples are coarse-grained. The gradation of soils in the study area varies significantly (Table 4.4). From the grain size analysis results showed that, which have clay content range from 0.7 – 6%, silt fraction range from 7.88 –15.40 %, sand fraction range from 62.09– 86.36% and gravel content range from 1.8 – 27.20. From this test result the soil was coarse grained soil due to percentage course than 0.075mm sieve is greater than 50 percent. From grain size analyses (fig 4.1) sand which is uniform sand soil particle with small amount of fine and gravel percentage therefore, the soils are poorly graded sand. (Addiszemen.T, 2015)

Table 4.4 Summary of grain size analysis result

		percent amount of particle size			
Site location	Depth(m)	Gravel (%)	Sand (%)	Silts (%)	Clay (%)
TP1-1	1.5	3.2	81.1	11.21	4.49
TP1-2	3	3.9	79.5	11.98	4.62
TP2-1	1.5	3.3	78.4	13.31	4.99
TP2-2	2.6	1.8	76.8	15.4	6
TP3-1	1.5	4.11	79.39	11.32	5.18
TP3-2	3	8.11	77.49	10.33	4.07
TP4-1	1.5	3.33	81.6	10.53	4.57
TP4-2	3	2.31	82.09	11.69	2.9
TP5-1	1.5	5.31	79.98	11.72	2.99
TP5-2	3	20.6	68.3	8.35	2.75
TP6-1	1.5	17.3	86.36	8.98	2.93
TP6-2	3	26.31	62.97	8.55	2.17
TP7-1	1.5	27	62.9	9.4	0.7
TP7-2	3	27.21	62.09	8.62	2.08
TP8-1	1.5	27.47	62.23	9.81	0.49
TP8-2	3	27.21	62.9	7.88	2.01
TP9-1	1.5	6.82	72.8	11.6	4.82
TP9-2	3	9.8	78.11	8.12	3.6
TP10-1	1.5	3.4	69.3	14.23	5.7
TP10-2	3	6.5	60.8	14.74	5.9

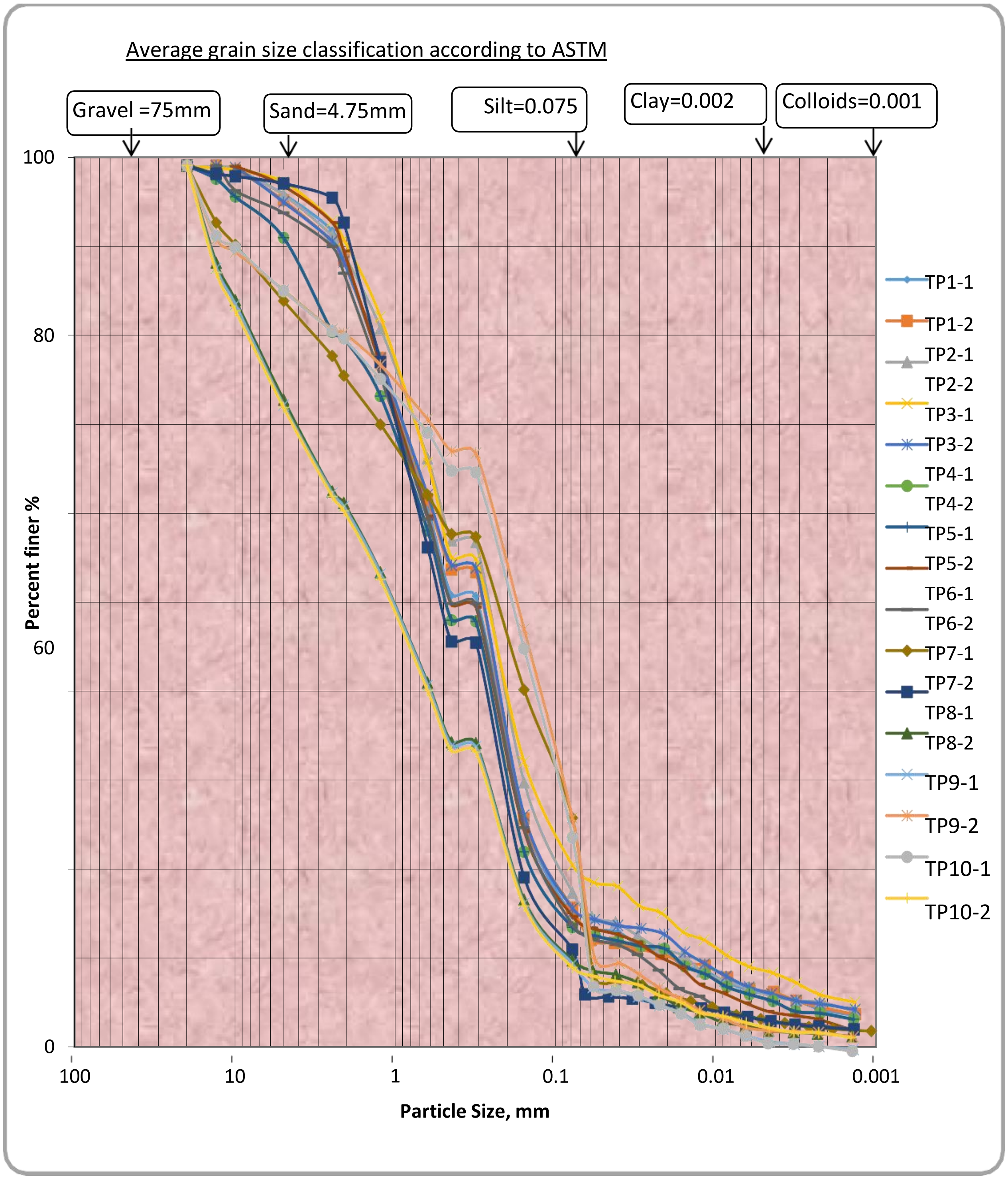


Figure4.1 Grain size distribution curve of the studied soil sample

4.2.4. Atterberg limit test

The Swedish Scientist, Atterberg (1911), developed a method of describing quantitatively the effect of varying water content on the consistency of fine-grained soils. He established the four states of soil consistency, which are called the liquid, the plastic, the semi-solid, and the solid states. He also proposed a series of tests for determining the boundaries known as Atterberg limits between the physical states of soil. Each boundary or limit is defined by the water content that produces a specified consistency. The liquid state is produced when a fine grained soil is mixed with a large quantity of water. In such state the soil behaves like a liquid. That is, it flows freely like a liquid and has no resistance to deformation. If, however, its water content is gradually reduced, it will begin to show a small shearing strength. The limit at which soil suspension passes from no strength to a very small strength is the liquid limit. The limit is defined by moisture content of soil at that point (Alemayehu Teferra and Mesfine Leikun, 1999)

At moisture content lower than its liquid limit, the soil is in a plastic state. If the sample is subjected to a further decrease in moisture content, it will eventually lose its plasticity. The moisture content at which the sample, when it is rolled into a thread, starts to crumble rather than distort plastically, is called its plastic limit.

After the plastic limit, the soil displays the properties of semi-solid. With a further decrease in moisture content, the soil sample will finally reach a point where it can no longer change in volume. At this point, the soil is said to have reached its shrinkage limit (Alemayehu Teferra and Mesfine Leikun, 1999)

Atterberg Limits were determined for air-dried samples. It was done based on the Standard Reference: ASTM D 4318-98 –Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. The air-dried soil sample were prepared by spreading the material out in trays the laboratory and leaving it open to the air for at least 15days or equivalent put inside oven at a temperature of 500C for at least 5 days until they were dried thoroughly. The room temperature was about 20oC. The portions of the samples passing the No. 40 (0.425mm) sieve were used for the preparation of the sample for this test.

The atterberg limits result for the studied soils are presented table 4.5. From the Atterberg limit test result showed that, which liquid limit (LL) in percent range from 14 –20.38%, plastic limit in percent range from 13.91 –17.86 %, plasticity index (PI) in percent range from non-plastic to 4.73.

Table 4.5 Atterberg limit test result

Test pit	Sample depth(m)	Test condition	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
TP1-1	1.5	Oven dried	20.38	17.86	2.52
TP1-2	3	Oven dried	20.21	16.68	3.52
TP2-1	1.5	Oven dried	18.53	14.77	3.76
TP2-2	2.6	Oven dried	20.32	15.60	4.73
TP3-1	1.5	Oven dried	16.85	13.91	2.9
TP3-2	3	Oven dried	16.01	15.34	0.67
TP4-1	1.5	Oven dried	16.5	16.52	0.0
TP4-2	3	Oven dried	-	-	NP
TP5-1	1.5	Oven dried	-	-	NP
TP5-2	3	Oven dried	-	-	NP
TP6-1	1.5	Oven dried	17.97	17.77	0.2
TP6-2	3	Oven dried	14	14.17	0.0
TP7-1	1.5	Oven dried	-	-	NP
TP7-2	3	Oven dried	-	-	NP
TP8-1	1.5	Oven dried	-	-	NP
TP8-2	3	Oven dried	-	-	NP
TP9-1	1.5	Oven dried	-	-	NP

TP9-2	3	Oven dried	-	-	NP
TP10-1	1.5	Oven dried	-	-	NP
TP10-2	3	Oven dried	-	-	NP

4.2.5. Free Swelling tests

This test is performed by slowly pouring 10cm^3 of oven dry soil which has passed the No.40 (0.425mm) sieve in to 100cm^3 graduated cylinder filled with distilled (tap) water. After 24 hours, final volume of the suspension being read. Hence, free swell is given by the difference between the final and initial volume, expressed as a percentage of initial volume. To calculate the volumetric swelling of the soil, the following formula is used. (Equation4.1)

$$\frac{(Final\ volume\ -\ Initian\ volume\ of\ soil)}{Initial\ volume} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .4.1$$

The laboratory test results of Free swell test of the studied oven dried samples are summarized in Table 4.6. From the test result one can see that the free swell of the soil under investigation for this specific area ranges from 1.8% to 18.1%. Those soils having free swell less than 50% are considered as non-expansive, with free swell between 50%-100% are considered as marginal and soils having free swell greater than 100% are considered as expansive (leikun,T.A., 1999)Hence all soil samples under investigations are non-expansive soils.

Table 4.6 Free swelling of the studied soils

Site location	Sampling depth(m)	Test condition	Water used for testing	Volume initial (ml)	Volume final (ml)	Swelling (%)
TP1-1	1.5	oven dry	Tap water	10	11	1.0
TP1-2	3	“	“	10	11	1.0
TP2-1	1.2	“	“	10	11.81	1.81
TP2-2	2.6	“	“	10	11.5	1.5
TP3-1	1.5	“	“	10	11.7	1.7

TP3-2	3	“	“	10	11	1.0
TP4-1	1.5	“	“	10	10.8	0.8
TP4-2	3	“		10	10.18	0.18
TP5-1	1.5	“	“	10	10.7	0.7
TP5-2	3	”	“	10	10.5	0.5
TP6-1	1.5	“	“	10	11.5	1.5
TP6-2	3	“	“	10	10.7	1.7
TP7-1	1.5	”	“	10	10.5	0.5
TP7-2	3	“	“	10	10.4	0.4
TP8-1	1.5	“	“	10	10.5	0.5
TP8-2	3	“	“	10	10.6	0.6
TP9-1	1.5	“	“	10	11	1.0
TP9-2	3	“	“	10	10.58	0.58
TP10-1	1.5	“	“	10	11.2	1.2
TP10-2	3	“	“	10	10.4	0.4

4.3.Compaction test

Compaction test is used to determine compaction characteristics of the soils. The function of Compaction is generally increases the bearing capacity, shear strength of soil, and hence the stability and reduces the compressibility and permeability of the soil.

Compaction test is laboratory test. The characteristic of the compaction soil under investigation is studied using the standard Procter test or light compaction test. Soil passing No.4 (4.75mm) sieve air-dried soil is prepared and compacted in three layers with each layer compacted by 25 blows .

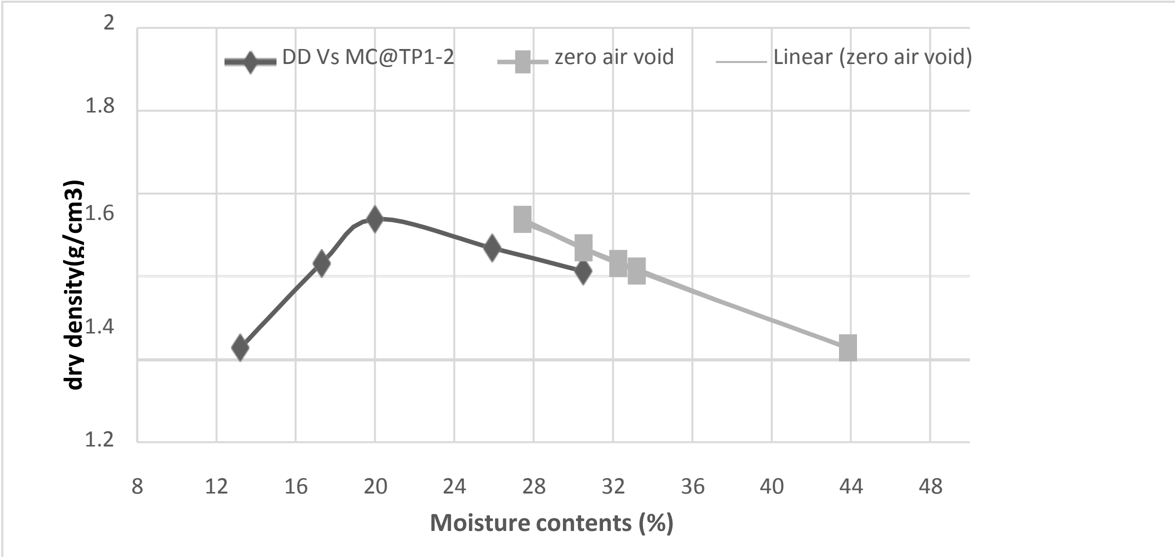
Table4.7 Dry density computation for TP1-2 @ 3m

Sampling depth……………………3m GS= 2.65

Determination No.	1	2	3	4	5
Mass of Mold, g	4405	4405	4405	4405	4405
Mass of mold + Compacted Soil, g	5717.1	5990	6148	6151	6145
Mass of Compacted soil, g	1312.1	1585	1743	1746	1740
Volume of Mold, cm3	944	944	944	945	946
Bulk density, g/cm3	1.44	1.53	1.79	1.74	1.72
Water Contenet, %	13.208	17.308	20	14	18
Dry density, g/cm3	1.2278	1.4313	1.538	1.468	1.412

Table 4.8 Typical Water content computation for TP1-2 @ 3m

Conatainer No	B1	E3	A1	B2	C2
Mass of container, g	15.5	15.5	15.75	15.55	15.25
Mass of container + wet soil, g	75.5	76.5	75.75	83.55	92.25
Mass of Container + Dry soil, g	68.5	67.99	65.65	69.05	74.25
Mass of Water, g	7.1	8.99	10.1	14.1	18
Mass of Dry soil, g	53	52.01	49.9	53.5	59
Water content, %	13.39	17.28	20.24	26.35	30.5



Maximum dry density (g/cm^3) = 1.52 Optimum moisture contents (%) =20

Figure4.2 Typical dry density vs. moisture contents curve for TP1-2 @ 3m

The laboratory test result is summarized in Table 4.7 the Results of compaction test for the OMC and MDD values vary from 17.77 to 27.7% and 1.42 to 1.6 g/cm^3, respectively the details for the calculation are included in appendix-E.

Table 4.9 Summary for MDD and OMC of the soil

Site location	Depth(m)	Test condition	MDD(g/cm3)	OMC (%)
TP1-1	1.5	air dry	1.55	22
TP1-2	3	air dry	1.52	20
TP2-1	1.2	air dry	1.6	17.77
TP2-2	2.6	air dry	1.52	17.9
TP3-1	1.5	air dry	1.47	22
TP3-2	3	air dry	1.413	26
TP4-1	1.5	air dry	1.47	24
TP4-2	3	air dry	1.51	20
TP5-1	1.5	air dry	1.51	20
TP5-2	3	air dry	1.43	23
TP6-1	1.5	air dry	1.43	26

TP6-2	3	air dry	1.48	21.9
TP7-1	1.5	air dry	1.48	20
TP7-2	3	air dry	1.42	27.27
TP8-1	1.5	air dry	1.49	18
TP8-2	3	air dry	1.46	20
TP9-1	1.5	air dry	1.5	22
TP9-2	3	air dry	1.41	25
TP10-1	1.5	air dry	1.6	18
TP10-2	3	air dry	1.5	18

4.4.Classification of the Soils

4.4.1. General Considerations for Classification of Soils

A soil classification system is an arrangement of different soils into groups having similar properties. Those soils under investigation have been classified according to both USCS and AASHTO M-145. These methods are among the widely used classification systems in our country (Braja.M.Das, 2004)

4.4.2. Classification of soils based on Unified Soil Classification System (USCS)

Soils are divided into two major groups, coarse-grained and fine-grained soils, using the No. 200 sieve as the size criterion. When more than half of the soil sample is larger than the No. 200 sieve, it is classified as coarse grained and is further subdivided by sieving and gradation. When more than half of the soil sample is finer than the No. 200 sieve, it is classified as fine-grained and is subdivided primarily based on liquid limit values and degree of plasticity. From the Grain size analysis result, the entire samples revealed that the percentage passing No 200 sieve size for all the studied soils is < 50 %(Table 4.10), implying they are coarse-grained soils. According to the USCS the soil are coarse grained soil mainly contains silty sand(SM) and poorly graded sand with clay and gravel (table4.10). This classification uses the symbols (SP, SM, SC,) based on the indicated percentages passing the No.200 and No.4 sieves, and the atterberg limit values (Murty, 1990)

Table 4.10 Classification of soil based on unified soil classification system

Serial No	Designation	Depth (m)	% pass No 200	Percentage amount of particle size				LL (%)	PL (%)	PI (%)	Classification according to USCS
				Gravel (%)	Sand (%)	Silt (%)	Clay (%)				
1	TP1-1	1.5	15.70	3.20	81.10	11.21	4.49	20.38	17.86	2.52	SM
2	TP1-2	3m	16.60	3.90	79.50	11.98	4.62	20.21	16.68	3.52	SM
3	TP2-1	1.5	18.30	3.30	78.40	13.31	4.99	18.53	14.77	3.76	SM
4	TP2-2	3	21.40	1.80	76.80	15.40	6.00	20.32	15.60	4.73	SM
5	TP3-1	1.5	16.50	4.11	79.39	11.32	5.18	16.85	13.91	2.9	SM
6	TP3-2	3	14.40	8.11	77.49	10.33	4.78	16.01	15.34	0.67	SM
7	TP4-1	1.5	15.10	3.30	81.60	10.53	3.07	16.5	16.52	0.0	SM
8	TP4-2	3	15.60	2.31	82.09	12.70	3.91	_	_	NP	SM
9	TP5-1	1.5	14.71	5.31	79.98	11.72	2.99	_	_	NP	SM
10	TP5-2	3	11.10	20.60	68.30	8.35	2.75	_	_	NP	SP-SC
11	TP6-1	1.5	11.91	1.73	86.36	8.98	2.93	17.91	17.77	0.2	SM
12	TP6-2	3	10.72	26.31	62.97	8.55	2.17	14	14.17	0.00	SP-SC
13	TP7-1	1.5	10.10	27.00	62.90	9.40	0.70	_	_	NP	SP-SC
14	TP7-2	3	10.70	27.21	62.09	8.62	2.08	_	_	NP	SP-SC
15	TP8-1	1.5	10.30	27.47	62.23	9.81	0.49	_	_	NP	SP-SC
16	TP8-2	3	9.89	27.21	62.90	7.88	2.01	_	_	NP	SP-SC
17	TP9-1	1.5	4.28	6.82	72.8	11.6	4.82	_	_	NP	SM
18	TP9-2	3	12.52	9.8	78.11	8.12	3.6	_	_	NP	SM
19	TP10-1	1.5	17.30	3.4	69.3	14.23	5.7	_	_	NP	SM
20	TP10-2	3	19.00	6.5	60.8	14.74	5.9	_	_	NP	SM

4.4.3. Classifications of soils based on AASHTO Classification system

In this classification system, soil is classified into seven major groups: A-1 through A-7. Soils classified under groups A-1, A-2, and A-3 are granular materials of which 35% or less of the particles pass through the No. 200 sieve. Soils of which more than 35% pass through the No. 200 sieve are classified under groups A-4, A-5, A-6, and A-7. These soils are mostly clay and silt-type materials (Braja, 2006) the soil properties that are used for this classification system are; particle size distribution, Liquid limit and Plastic index obtained from laboratory and to check the quality of the soil defined by group index. This index can help to make the performance of the soil for engineering application, such as highway and airfield construction. According to this thesis all group index values indicate 0. A group index of zero indicates a good subgrade. The group index is appended to the soil type determined from AASHTO table .The smaller the value of a group index, the better the soil is in that category. From the Table 4.11 and figure 4.3 the soils under the study area are categorized in A-2-4 and A-3. According to this classification system, the usual type of material is suitable for supporting roadway pavement (Braja, 2006)

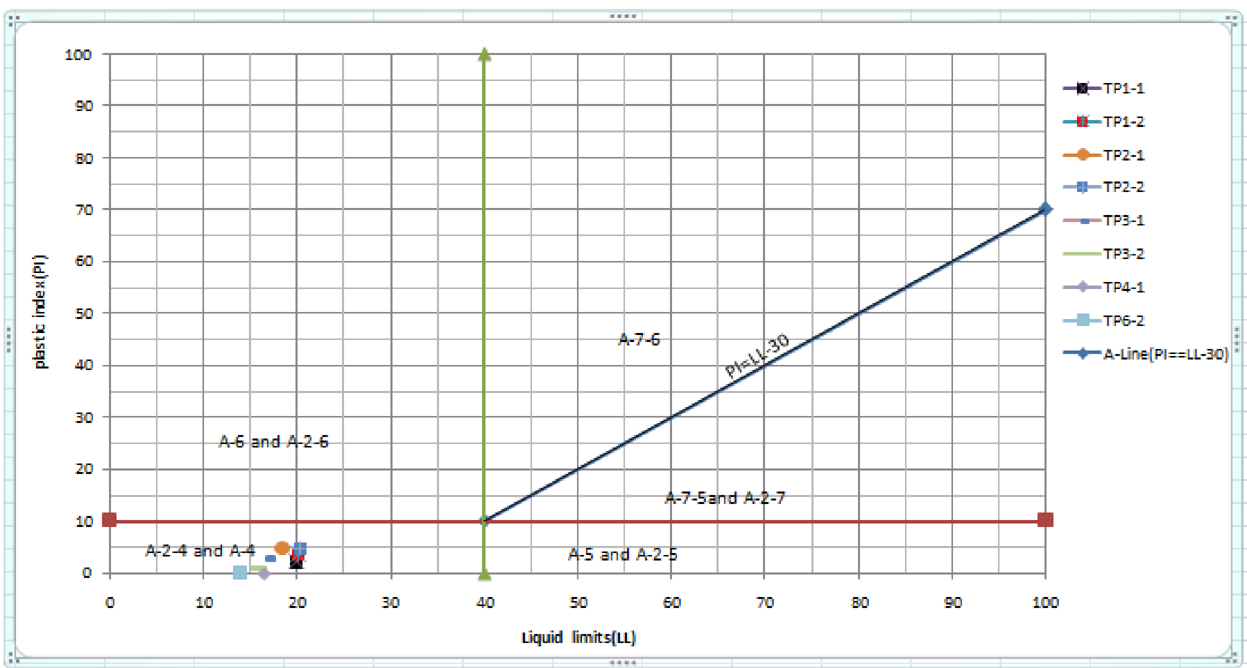


Figure4.3 Plasticity chart of study area according to AASHTO soil classification

Table 4.11 Classification of soil based on AASHTO

Test Pit	Depth (m)	Atterberg Test result		Percentage passing in Sieve number			AASHTO Soil Classification	Usual type of Significant materials	General Rating as sub-grade Materials
		LL	PI	10 (2mm)	40 (0.425mm)	200 (0.075mm)			
TP1- 1	1.5	20	2.1	89.60	51.70	15.70	A-2-4(0)	Silty or clayey gravel andsand	Good
TP1-2	3	20.2	3.5	89.40	54.60	16.60	A-2-4(0)	"	"
TP2-1	0 to 1.2	18.5	3.7	90.10	57.90	18.30	A-2-4(0)	"	"
TP2-2	1.2 to 3	20.3	4.7	91.59	55.90	21.40	A-2-4(0)	"	"
TP3-1	0 to 1.2	16.8	2.9	89.20	55.10	16.50	A-2-4(0)	"	"
TP3-2	1.2 to 3	16.00	0.7	80.60	48.89	14.40	A-2-4(0)	"	"
TP4-1	0 to 1.2	16.5	0.0	89.40	51.20	15.10	A-3(0)	Fine sand	"
TP4-2	1.2 to 3	_	NP	90.39	50.61	15.60	A-3(0)	Fine sand	"
TP5-1	0 to 1.2	_	NP	87.90	50.81	14.71	A-3(0)	Fine sand	"
TP5-2	1.2 to 3	_	NP	67.70	46.40	11.10	A-3(0)	Fine sand	"
TP6- 1	0 to 1.2	18	0.22	93.79	46.61	11.91	A-2-4(0)	Silty or clayey gravelandsand	"
TP6-2	1.2 to 3	14	0.00	62.11	35.29	10.72	A-3(0)	Fine sand	"

TP7-1	0 to 1.2	_	NP	61.56	34.62	10.10	A-3(0)	Fine sand	“
TP7-2	1.2 to 3	_	NP	60.98	34.80	10.70	A-3(0)	Fine sand	“
TP8-1	0 to 1.2	_	NP	60.57	34.71	10.30	A-3(0)	Fine sand	“
TP8-2	1.2 to 3	_	NP	61.20	34.20	9.89	A-3(0)	Fine sand	“
TP9-1	1.5	_	NP	76.98	42.88	4.28	A-2-4(0)	Siltyorclayey gravelandsan	“
TP9-2	3	_	NP	78.72	47.91	12.52	A-2-4(0)	“	“
TP10-1	1.5	_	NP	89.10	56.90	17.30	A-2-4(0)	“	“
TP10-2	3	_	NP	89.29	64.20	19.00	A-2-4(0)	“	“

4.4.4. Classification based on activity

Skempton (1953) showed that for soils with a particular mineralogy, the plasticity index is linearly related to the amount of the clay fraction. He coined the term called activity (A) to describe the importance of the clay fraction on the plasticity index (Das, Soil mechanics laboratory manuals, 2002)(Equation4.2)

$$A = \frac{PI}{(Clay\ firaction)}(\%) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.2$$

Range for activity soil classification is summarized in Table 4.12. Depending upon this classification soils are classified into three types. The results of activity numbers are presented in Table 21. Activities of soils of the study area are computed based on results obtained from hydrometer analysis (% of clay fraction) and Atterberg"s limit (Accordingly all soils of the study area are inactive (Figure 4.3 and Table 4.13)

Table 4.12 ranges for activity soil classification (Das, Soil mechanics laboratory manuals, 2002)

S/N	Activity	Soil type
1	<0.75	In active
2	0.75-1.25	Normal
3	>1.25	Active

Table 4.13 Skempton activity numbers of investigated soils

Test pit	Depth	PI	% clay	activity(A)	Remark
TP-1	1.5	2.52	4.49	0.56	Inactive
	3	3.52	4.62	0.74	Inactive
TP-2	1.5	3.7	4.99	0.75	Inactive
	3	4.73	6	0.746	Inactive
TP-3	1.5	2.9	5.18	0.560	Inactive
	3	0.67	4.07	0.165	Inactive
	1.5	0.0	4.57	0	Inactive

TP-4	1.5	NP	2.9	0	Inactive
TP-5	3	NP	2.99	0	Inactive
	1.5	NP	2.75	0	Inactive
TP-6	3	0.22	2.93	0.075	In active
	1.5	0.00	2.17	0.000	Inactive
TP-7	3	NP	0.7	0	Inactive
	1.5	NP	2.08	0	Inactive
TP-8	3	NP	0.49	0	Inactive
	1.5	NP	2.01	0	Inactive
TP-9	1.5	NP	4.82	0	Inactive
	3	NP	3.6	0	Inactive
TP-10	1.5	NP	5.7	0	Inactive
	3	NP	5.9	0	Inactive

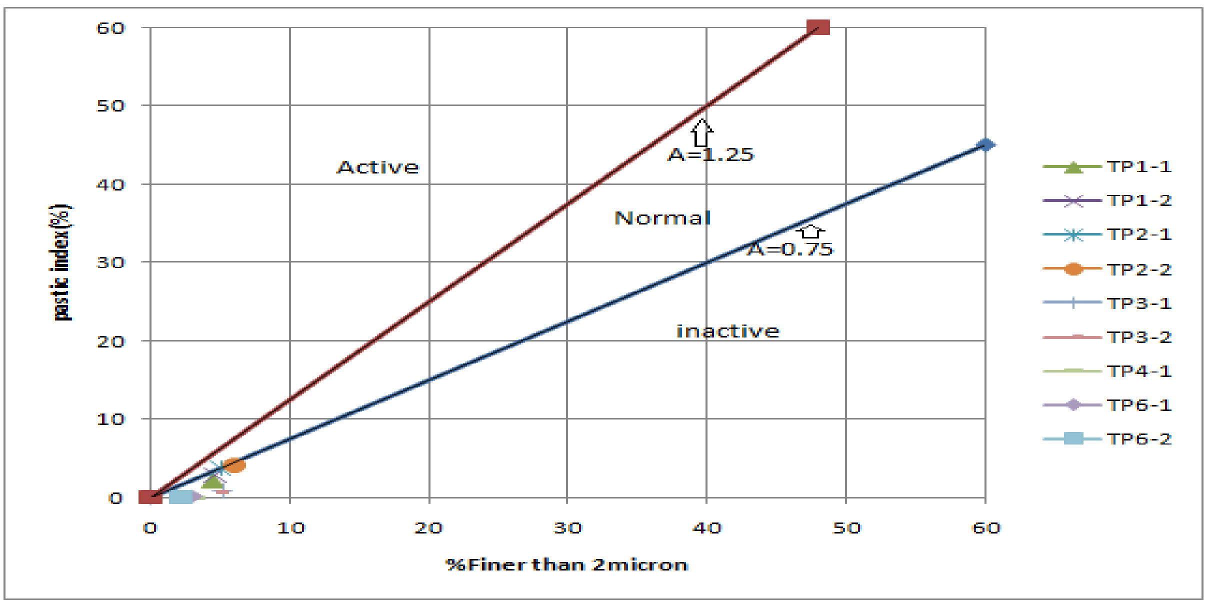


Figure 4.4 Classification of soil according to activity

4.5.Direct shear test

4.5.1. General

The shear strength of soil mass is its property against sliding along inside planes within itself. The stability of slope in an earth dam or hills embankment and the foundations of structures built on different types of soil depend up on the shearing resistance offered by the soil along the possible slippage surface. Shear parameters are like angle of internal friction and cohesion also used in computing the safe bearing capacity of the foundation soils and the earth pressure behind retaining walls. In a situations which needs the shearing strength of a soil direct shear test is applied. The test can be performed on an undisturbed sample or remolded samples. The main advantage of direct shear test is it is quick, inexpensive and suitable to determine the shear strength parameters of both cohesive and non-cohesive soils and But the disadvantage that lateral pressure and stress on other than the plane of shear are not known during test

4.5.2. Significance

This test is performed on a disturbed sample after remolded (compacted) by artificially at optimum moisture content. During compaction, the soil is filled in molded in three equal layer of soil and compacted by a 24.4N hammer falling a distance of 0.305meters. Each layer is subjected to 25 drops of the hammer. The sample is then placed in shear box and the excess part is removed and level off the top. The selected vertical load, then, applied and the soil sheared while recording horizontal displacement and shear load.

- ❖ From the plot, a straight-line approximation of the Mohr-Coulomb failure envelope curve can be drawn. Angle of internal friction (Ø) and cohesion (C) may be determined the graph (Figure 4.6).
- ❖ After the experiment is run several times for various vertical-confining stresses, a plot of the maximum shear stresses versus the vertical (normal) confining stresses for each of the tests is produced.
- ❖ From the plot of the shear stress versus the horizontal displacement, the maximum shear stress is obtained for a specific vertical confining stress (Figure 4.5)
- ❖ The shear strength can be calculate from the following equation

Total Shear stress = C + $\sigma tan\emptyset$ and σ=N/A Where: N = normal vertical force

σ=$normal\ stress$, $\emptyset$=$angleof\ nternal\ friction$ and C= cohesion

The output data for direct shear strength test results for the studied samples are tabulated in Table 4.15.The angle of internal friction (∅) of the studied soils is between 22.72 to 29.95°(Table 4.15), which is in accordance with literature data (i.e. the angle of internal friction of silt to silty sand ranges from 26° to 35°). The shear strength of granular soils, such as, poorly graded sand with clay and gravel, fine sands is mainly due to friction between particles. The cohesion value ranges from 7.950 to 1.019kPa, which appears to be a function of fine fraction, particularly clay content.

Table 4.14 Direct shear results of TP1-2 at Itaya elementary school

Thickness of sample=25mm	ring calibration factors=0.70N/div		stress (kpa)	weght of soil	
Length of sample= 60 mm	Rate of strain=	1.6 mm/min	100	158.8	gm
Width of sample= 60 mm	Optimum moisture content (%)	22	200	159	gm
			300	161	gm

		Applied vertical stress ***100 kpa***			*Applied vertical stress* ***200 kpa***			*Applied vertical stress* ***300 kpa***		
Horizontal Displacement[mm]	Corrected Area [mm2]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]
0.0	3600	0	0	0	0	0	0	0	0	0
1.0	3540	46	32.2	9.0960452	69	48.3	13.6441	114	79.8	22.5424
1.5	3510	144	100.8	28.717949	180	126	35.8974	251	175.7	50.057
2.0	3480	234	163.8	47.068966	275	192.5	55.3161	346	242.2	69.5977
2.5	3450	267	186.9	54.173913	338	236.6	68.5797	410	287	83.1884
3.0	3420	284	198.8	58.128655	369	258.3	75.5263	472	330.4	96.6082
3.5	3390	295	206.5	60.914454	391	273.7	80.7375	509	356.3	105.103
4.0	3360	302	211.4	62.916667	405	283.5	84.375	533	373.1	111.042

4.5	3330	296	207.2	62.222222	423	296.1	88.9189	576	403.2	121.081
5.0	3300				430	301	91.2121	599	419.3	127.061
5.5	3270				441	308.7	94.4037	611	427.7	130.795
6.0	3240				445	311.5	96.142	639	447.3	138.056
6.5	3210				452	316.4	98.567	691	483.7	150.685
7.0	3180				455	318.5	100.157	705	493.5	155.189
7.5	3150				451	315.7	100.222	709	496.3	157.556
8.0	3120				445	311.5	99.8397	719	503.3	161.314
8.5	3090				442	309.4	100.129	723	506.1	163.786
9.0	3060							717	501.9	164.02
9.5	3030							709	496.3	163.795
				62.91667			**100.22**			**164.02**

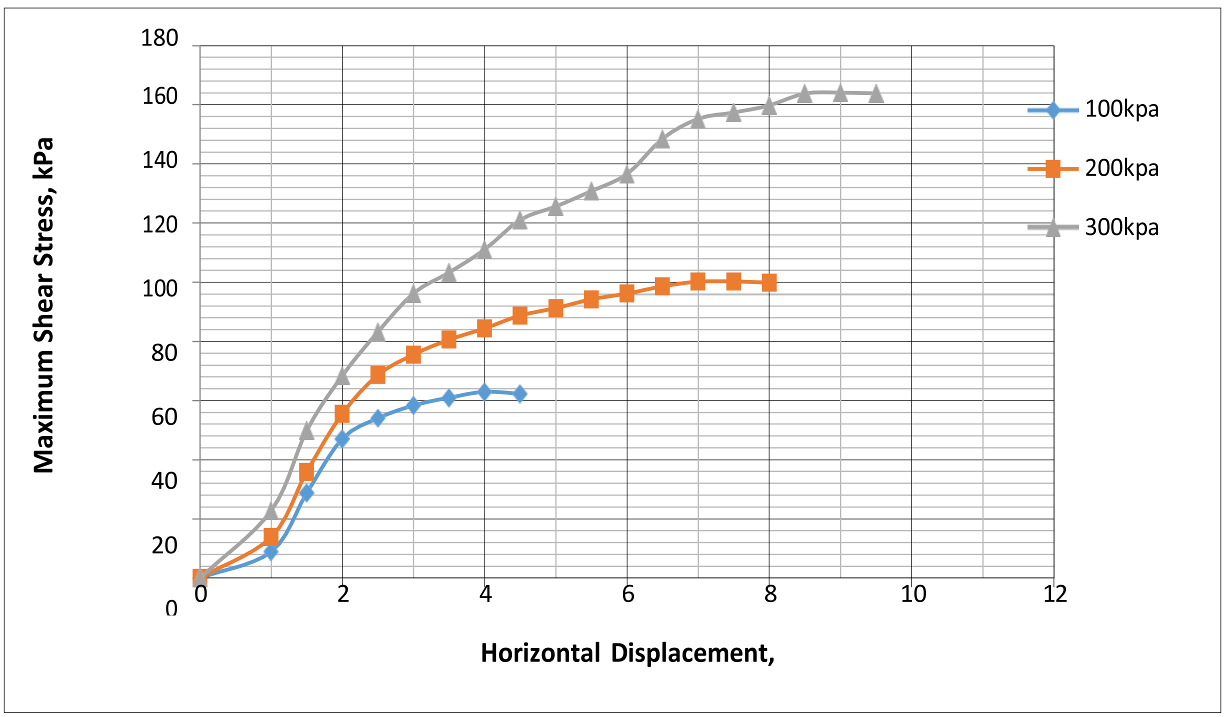


Figure4.5 Typical plot of shear stress versus displacement for sample TP1-2

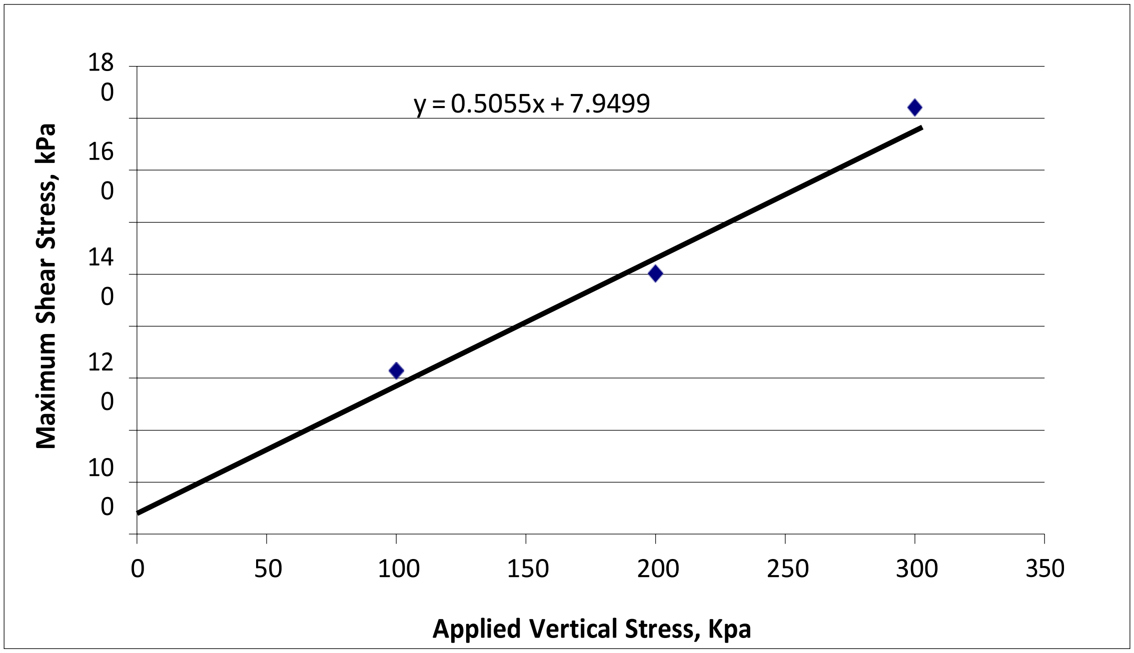


Figure4.6 Typical plot of maximum shear stress versus applied vertical load for sample TP1-2

(C=**7.949kpa** Ø =$\tan^{-1}$ (0.505) =**26.790°**

Table 4.15 Summary of direct shear results i.e. the cohesion and angle of internal friction

Serial No	Designation	Depth (m)	Cohesion(C)in kpa	Angle of internal friction (Ø) In degree
1	TP1-2	3	7.95	26.79
2	TP2-2	3	6.82	29.59
3	TP3-2	3	4.603	28.07
4	TP4-2	3	5.11	27.09
5	TP5-2	3	3.893	24.61
6	TP6-2	3	1.019	25.07
7	TP7-2	3	1.125	22.72
8	TP8-2	3	2.113	28.899
9	TP10-2	3	4.21	28.61

10	TP9-2	3	6.22	29.95

4.6.Comparison of test results with previous investigated research near to study area

Information obtained from the results tested in laboratory is used to provide an indicator of general engineering behavior of soil in study area. From this laboratory from the laboratory tests were obtained expansive soils.

The natural moisture content of the samples ranges from 14.2 – 26.92%. This indicates that the underground water level in all parts of the town is located far from ground surface And this result is indicate that the soil contain mainly coarse fraction of soil.

Specific gravity test results for oven dried samples at a temperature of 105+5 oc are summarized in Table 4.3. From the test result one can see that the Specific gravity of the soil under investigation ranges from 2.64 to 2.68. This result summarize that the soil are between the range of sand and silty.

The grain size analysis result is shown in figures 4.1 and table 4.4. The results obtained from the grain size analyses indicate that the dominant proportion of soil particle in the research area is sand, which has clay content ranging from Clay= 0.7-6%, silt fraction 7.88-15.4%, sand fraction 62 to 86.36% and gravel content from 1.8-27.20%.

Based on Unified Soil Classification System, the soils investigated in the study area are classified under SC, SP and SM. According to USCS the soil of the study area are coarse grained soil mainly contains silty sand and poorly graded sand with clay and gravel .the soil samples investigated under this thesis found within non-plastic to Low plastic.

Activity number of the soils ranges from 0 to 0.95. This indicates that the soils in the research area are inactive. Free swell test results for oven dried samples at a temperature of $105+5^{oc}$ are summarized in Table 4.6. From the test result one can see that the free swell of the soil under investigation ranges from 1.8% to 18.1%. The free swell tests tell us how much the increase in volume of soil subject to submergence in water. The soil samples found in study area are classified as non-expansive value less than 50 % (Alemayehu Teferra and Mesfine Leikun, 1999) the result of Atterberg Limit of the soil samples analysis were evaluated using a representative on oven dried soil samples are shown on Table 4.5. From these testes the soil under investigation is inorganic. The soil in the study area has the LL= 14 to 20.3 %(< 30% which is low plastic), PL= 13.91 to 17.86% % and PI from NP to 4.73%. This result is indicating that the soil where non- plastic to low plastic due to plastic index is less than 7.

According to AASHTO soil classification system, soil investigated in Iteya town is classified under A-2-4, A-3. Generally the soil coarse grained soil mainly contain A-3(fine sand) and A-2-4 (Silty or clay gravel and sand) with group index of Zero this classification indicates that the suitability of soils as subgrade material are good.

Optimum moisture content and the maximum dry density of the study area is Summarized in Table 4.7. From the test results the maximum dry density (MDD) of Iteya ranges from1.42 to1.55 g/cm3 and the optimum moisture content ranges 17.7 to 27.77 percent. Therefore the soils are compact with medium OMC related to other fine grained soil.

Table 4.16 Comparison of test results with previous investigated research near to study area

Thesis type	Dagnachew,2011	Gemechu, 2007	Current studies
Location	Adama	Adama	Iteya
Clay Content (%)	14-58	5.4 – 40.5	0.7-6%,
Silt fraction (%)	14-61	17.6-60.7	7.88-15.4%
Sand fraction (%)	25-56	14.5-54.6	62-86.36%.
Liquid Limit (%)	39-49.4	29-73	13.91 to 17.88%
Plastic limit (%)	26-37.4	24-39	NP to20.38%
Plasticity Index (%)	10-15	5-34	NP to 4.7%
Moisture content (%)	25-30.5	17.5-36.5	14.2 – 26.92%.
Specific Gravity	2.61-2.7	2.4-2.7	2.65- 2.68
Compaction (g/cm3)	1.33-1.53	1.2-1.62	1.8 to 18.
From plasticity chart	ML&SM	SM, ML, MH	SM,SP

CONCLUSION AND RECOMMENDATION

5.1.Conclusion

1. According to this study the most common types of soil found in Etaya town are dominantly composed of coarse grained soil starting from few centimeters below the ground level to the depth of investigation which is three meters (according to AASHTO soil classification Silty or clayey gravel and sand (A-2-4) and fine sand(A-3)) with small fine fraction and According to USCS expression most of the soil of the study area falls in silty sand (SM),and sand with poorly graded with clay and gravel soil type(SP-SC).
2. Grain size analysis tests revealed that, starting from few centimeters below the ground level to the depth of investigation which is three meters, the soil in Etaya town in which the percentage of the clay content ranging from 0.7-6%, silt fraction 7.88-15.4%, sand fraction 62-86.36%, and gravel fraction 1.8-27.20%.
3. All the soils samples in the study area have free swell value of less than 50%. The soils under investigation are non-plastic to low plastic. The water holding capacity of the soil is also lower as indicated by activity (A) value less than 0.75. This shows the soil in the study area is non-expansive with free swell value ranging from 1.8-18.1%.
4. The soils in the study area have low Atterberg limit values which show the soils are low plastic. From this consistency limit test results the liquid limit of the area ranges from 14- 38% plastic limit rages from 13.91-17.86% and plastic index from non-plastic to 4.73%.
5. From compaction test results the maximum dry density (MDD) of the soils ranges from 1.42 to 1.55 g/cm3 and optimum moisture content ranges from 17.7 to 27.77 %.
6. The result for OMC is relatively higher than the optimum moisture content of fine sand and silty sand soils reported in literature which could be due to the presence of small clay fraction. The shear strength parameters i.e. cohesion and angle of internal friction vary from 1.019 to 7.95 kPa and 22.72 to 29.95°, respectively.

Generally, the result of this research indicates the engineering characteristics of soil in the study area is good shear strength ,bearing capacity and low compressibility, low plasticity and less susceptible to shrinkage and swelling with variation of moisture content.

5.2. Recommendation

In this research, samples of soil were collected only from ten test pits it is therefore, Recommended to increase the number of sampling area in-depth investigation.

Further detailed investigation has to be carried out to find UCS of the soil using the insitu Moisture content.

Establishing the empirical correlation between CBR and shear strength parameters Monitoring have to be an area for further research

The dynamic characteristics of soils with relation to respond of soil to earthquake should be studied in future. The Correlation of the index property with shear strength parameters may also be done

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APPENDIX

Appendix – A (Log of test pits)

Project Msc thesis Location Iteya elementary school Test pit Code TP-1			Date :25/7/2015	
Depth(m)	Bore Hole Log	visual soil description	Field test type	Sampled for
-0.95	+ - + - +- + -	Fill	Natural moisture contents	Natural moisture contents, Grain size analysis, Specific gravity, consistency limits, standard compaction test, shear strength test(Direct shear test)
-3	+-+-+- +-+-+- +-+-+- +-+-+-	Course grained soil		
Test pit size=1.5x1.5x 3m Location Logged: Itaya town eastern Ethiopia				

Project Msc thesis Location Around mosque Test pit Code TP2	Date : Date :27/7/2015

Depth(m)	Bore Hole Log	Visual Soil Description	Field test type	Sampled for
-0.95	+ - + - +- + - + - + -+- + -	Fill	Natural moisture contents	Natural moisture contents, Grain size analysis, Specific gravity, consistency limits, standard compaction test, Shear strength test(Direct shear test)
-3	+ - + - +- + - + - + -+- + - + - + - + - +-	Course grained soil with some of large difficult rock to excavate		
Test pit size=<u>1.5x1.5x 3m</u> Location Logged: Iteya town eastern Ethiopia				

Project MSc thesis Location near bus station Test pit Code TP-4			Date :01/8/2010	
Depth(m)	Bore Hole Log	visual soil description	Field test type	Sampled for
-0.95	+ - + - +- + - + - + - +- + - + - + - + - +- +-+-+--+- + - + - + -	Fill	Natural moisture contents	Natural moisture contents, Grain size analysis, Specific gravity, consistency limits, standard compaction test, Shear strength test. (Direct shear test)

	+ - +-+-+- +--			
-3	+ - + - +- + - + - + - +- + - + - + -	Fine to course Sand with less amount of gravel percentage		

Test pit size=1.5x1.5x 3m Location Logged: Iteya Town Ethiopia	

For test pit, TP 3, TP 5, TP6, TP 7, TP 8, TP 9 and TP 10 the soil from visual classification are the s.

Appendix – B (Specific gravity test result)

B - 1. The detailed test results for Specific gravity test

<u>For test pit 1</u>

Sample type…………………………..disturbed

Table B-1: Specific gravity test results

Test pit code	TP-1

Depth	0 to 1.5m		1.5 to 3m	
Determination No.	1	2	1	2
Pycnometer No.	1	2	1	2
Weight of pycnometer + water filled to mark at Tx , Wpw(atTx) W1(g)	159	159	159	159
Weight of pycnometer + soil + water, Wpws,W2 (g)	166.56	166.4	166.5	166.54
Weight of dry soil , Ws (g)	12	12	12	12
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	4.44	4.6	4.5	4.46
Temperature, Tx(oc)	24	24	24	24
Gs at(T1 in °c)	2.7027	2.608	2.67	2.63
Correction Factor (K)	0.9991	0.9991	0.9991	0.9991
Specific gravity of soil at 20°c.	2.700	2.605	2.68	2.62
Average specific gravity of soil.	2.65		2.65	

For test pit 2

Sample type .... disturbed

Table B-2: Specific gravity test results

test pit code	TP-2			
Depth	0 to 1.5m		1.5 to 3m	
Determination No.	1	2	1	2
Pycnometer No.	1	2	1	2
Weight of pycnometer + water filled to mark at Tx , Wpw(atTx) W1(g)	159	159	159	159
Weight of pycnometer + soil + water, Wpws,W2 (g)	166.15	167.47	166.45	167.1
Weight of dry soil , Ws (g)	12	13	12	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)- W2	4.85	4.53	4.55	3.9
Temperature, Tx(oc)	26	26	26	26

Gs at(T1 in °c)	2.474	2.8697	2.637	2.6530
Correction Factor (K)	0.9986	0.9986	0.9986	0.9986
Specific gravity of soil at 20°c.	2.4705	2.8656	2.633	2.649
Average specific gravity of soil.	2.67		2.64	

For test pit 3

Sample type……………………….. Disturbed

Table B-3: Specific gravity test results

Test pit code	TP3			
Depth	0 to 1.5m		1.5 to 3m	
Determination No.	1	2	1	2
Pycnometer No.	1	2	1	2
Weight of pycnometer + water filled to mark at Tx , Wpw(atTx) W1(g)	159	159	159	159
Weight of pycnometer + soil + water, Wpws,W2 (g)	167.6	167.95	167.61	168.1
Weight of dry soil , Ws (g)	14	14	14	14
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	5.4	50.5	5.39	4.9
Temperature, Tx(oc)	24	24	24	24
Gs at(T1 in °c)	2.59	2.77	2.59	2.857143
Correction Factor (K)	0.9988	0.9988	0.9988	0.9988
Specific gravity of soil at 20°c.	2.586	2.768	2.58	2.55
Average specific gravity of soil.	2.67		2.61	

For test pit 7

Sample type……………….. Disturbed

test pit code	TP-7			
Depth	0 to 1.2m		1.2 to 3m	
Determination No.	1	2	1	2
Pycnometer No.	1	2	1	2
Weight of pycnometer + soil + water, Wpws,W2 (g)	167.65	167.9	167.7	167.89
Weight of pycnometer + water filled to mark at Tx , Wpw(atTx) W1(g)	159	159	159	159
Weight of dry soil , Ws (g)	14	14	14	14
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	5.35	5.5	5.5	5.7
Temperature, Tx(oc)	25	25	25	25
Gs at(T1 in °c)	2.616	2.745	2.641	2.739
Correction Factor (K)	0.9988	0.9988	0.9988	0.9988
Specific gravity of soil at 20°c.	2.63	2.72	2.6373	2.736
Average specific gravity of soil.	2.675		2.68	

For test pit 8

Sample type……………….. Disturbed

test pit code	TP-8			
Depth	0 to 1.2m		1.2 to 3m	
Determination No.	1	2	1	2
Pycnometer No.	1	2	1	2
Weight of pycnometer + soil + water, Wpws,W2 (g)	165.95	167	165.89	167.12
Weight of pycnometer + water filled to mark at Tx , Wpw(atTx) W1(g)	159	159	159	159
Weight of dry soil , Ws (g)	11	13	11	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	4	5	4.85	4.88
Temperature, Tx(oc)	23	23	23	23

Gs at(T1 in °c)	2.716	2.6	2.67	2.66
Correction Factor (K)	0.9993	0.9993	0.9993	0.9993
Specific gravity of soil at 20°c.	2.74	2.60	2.68	2.66
Average specific gravity of soil.	2.65		2.67	

For test pit 9

Sample type……………….. Disturbed

Test pit code	TP-9			
Depth	0 to 1.5m		1.5 to 3m	
Determination No.	1	2	1	2
Pycnometer No.	1	2	1	2
Weight of pycnometer + water filled to mark at Tx , Wpw(atTx) W1(g)	159	159	159	159
Weight of pycnometer + soil + water, Wpws,W2 (g)	167.9	167.5	167.16	168.11
Weight of dry soil , Ws (g)	14	14	14	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	5.4	50.5	5.39	4.9
Temperature, Tx(oc)	24	24	24	24
Gs at(T1 in °c)	2.59	2.77	2.59	2.857143
Correction Factor (K)	0.9988	0.9988	0.9988	0.9988
Specific gravity of soil at 20°c.	2.586	2.768	2.58	2.85
Average specific gravity of soil.	2.67		2.68	

For test pit 10

Sample type………………. disturbed

Test pit code	TP-10			
Depth	0 to 1.5m		1.5 to 3m	
Determination No.	1	2	1	2

Pycnometer No.	1	2	1	2
Weight of pycnometer + water filled to mark at Tx , Wpw(atTx) W1(g)	159	159	159	159
Weight of pycnometer + soil + water, Wpws,W2 (g)	166.29	166.65	166.01	166.95
Weight of dry soil , Ws (g)	12	12	12	12
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	4.72	4.25	5.85	4.05
Temperature, Tx(oc)	26	26	26	26
Gs at(T1 in °c)	2.547	2.76	2.405	2.963
Correction Factor (K)	0.9986	0.9986	0.9986	0.9986
Specific gravity of soil at 20°c.	2.54	2.76	2.4.01	2.95
Average specific gravity of soil.	2.65		2.67	

Appendix – C (Atterberg limit test results and charts)

C - 1. The detailed test results for Atterberg limit

TP1-1 @ 1.5m

Sample type…………………………disturbed

Sampling depth…………………….. 1.5m

Table C-1-1: Liquid limit and Plastic limit test results

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A15	A21	C31	D22	A6	D2
Mass of container,gm	15.6	15.5	15.4	15.5	16.0	15.4
Mass of container +wet soil,gm	38.6	34.5	40.4	39.5	26	27.25
Mass of container +dry soil,gm	33.6	31.5	36.4	36.5	25	24.91
Mass of water, gm	5	3	4	3	1	2.34
Mass of dry soil, gm	18	16	21	21	9	9.51
Water content(ω), %	27.78	18.75	19.05	14.29	11.11	24.6
No of blows	19	24	28	32	17.85	

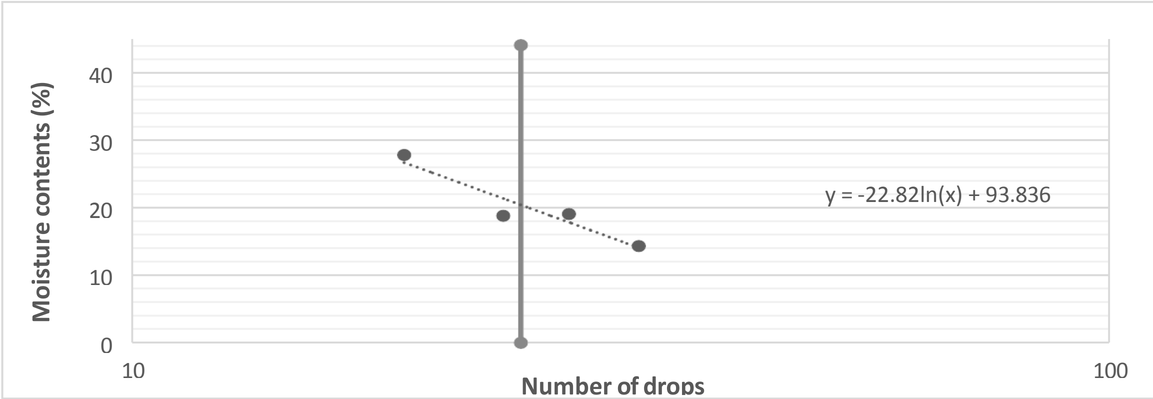


Fig C - 1 water content vs. log (N) graph

Liquid limits (LL) =20.38%, plastic limit (PL) = 17.86%, plastic index (PI) =2.52%

TP1-2 @ 3m

Sample type………………………..disturbed
Sampling depth……………………. 3m
Testing condition…………………... oven dried
Table C-1-2: Liquid limit and Plastic limit test results

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A2	C3	K5	D5	L3	L2
Mass of container,gm	15.6	15.5	15.7	15.7	15.5	15.6
Mass of container +wet soil,gm	30.6	30.5	31.4	29.7	26	27.27
Mass of container +dry soil,gm	27.6	28.5	28.5	28.7	24.5	25.6
Mass of water, gm	3	2	2.9	1	1.5	1.67
Mass of dry soil, gm	12	13	12.8	13	9	10
Water content(ω), %	25	15.38	20.77	7.69	16.67	16.7
No of blows	23	29	24	33	16.68	

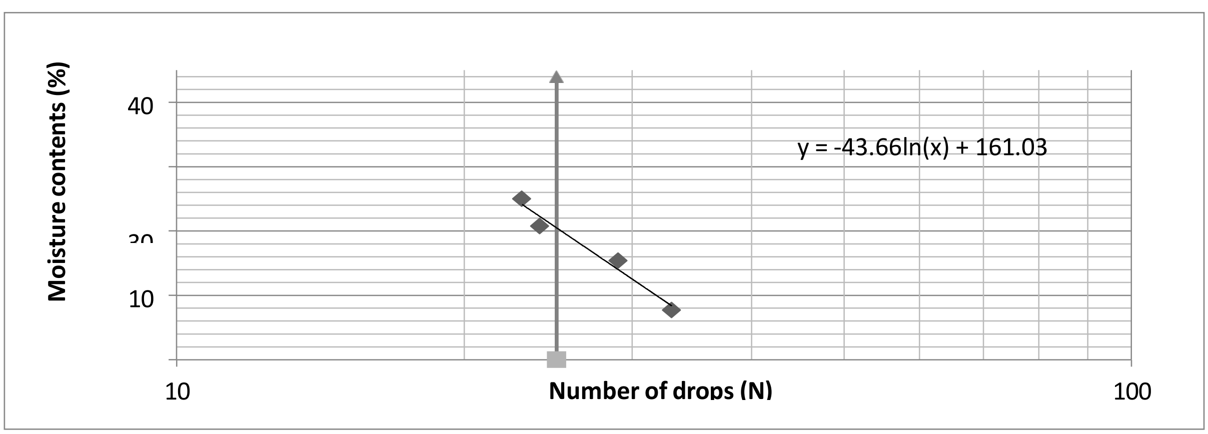


Fig C-1-2 water content vs. log (N) graph

Liquid limits (LL) =20.21%, plastic limit (PL) = 16.687%plastic index (PI) =3.523%

TP2-1 @ 1.5m

Sample type………………..disturbed

Sampling depth……………. 1.5m

Table C-1-3: Liquid limit and Plastic limit test results

	Liquid Limit				Plastic Limit	
Container No	A4	B2	C3	D21	H3	D4
Mass of container,gm	15.6	15.6	15.5	15.5	15.5	15.7
Mass of container +wet soil,gm	31.6	31.6	28.5	29.1	24.7	28.3
Mass of container +dry soil,gm	27.6	29.6	25.5	28.52	23.5	26.7
Mass of water, gm	4	2	3	0.6	1.2	1.6
Mass of dry soil, gm	12	14	10	13.02	4.3	11
Water content(ω), %	33.34	14.30	30.2	4.622	15.00	14.55
No of blows	17	28	23	32	14.77	

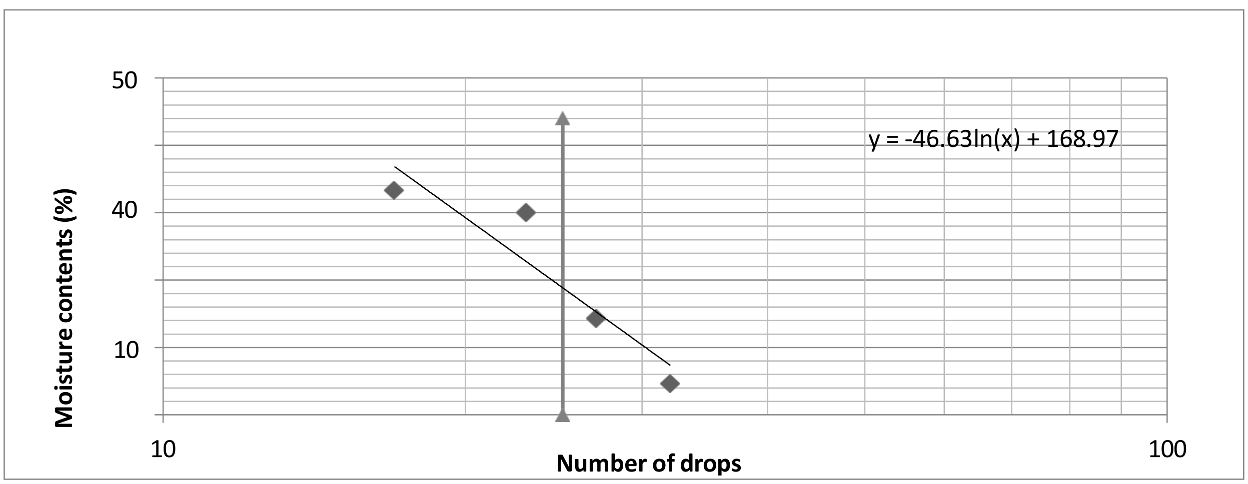


Fig C-1-3 water content vs. log (N) graph

Liquid limits (LL) =18.56%, plastic limit (PL) = 14.77%, plastic index (PI) =3.79%

Appendix – D (Grain size and hydrometer analysis results)

D. The detailed test results for sieve and hydrometer

TP1-2 @ 3m

Weight of Dry Sample: 1000 gm.

Test type: ASTM (dry sieve analysis)

Table –D-1 Dry sieve analysis result for TP1-2 at 3m

Sieve opening(mm)	Mass of sieve(g)	wt of sieve +soil	wtretained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	445	0	0.00	0.00	100.00
9.5	442	447	5	0.50	0.50	99.50
4.75	441	475	34	3.40	3.90	96.10
2.36	405	451	46	4.60	8.50	91.50
2	467	488	21	2.10	10.60	89.40
1.18	434	544	110	11.00	21.60	78.40
0.6	407	566	159	15.90	37.50	62.50
0.425	367	446	79	7.90	45.40	54.60
0.3	372	375	3	0.30	45.70	54.30
0.15	343	620	277	27.70	73.40	26.60
0.075	335	435	100	10.00	83.40	16.60
0	240	405	165	16.50	99.90	0.10

Table D-2 Hydrometer analysis result for TP1-2 at 3m

Elapsed time (min)	Temp °C	Actual hydro. Rdg(Ra)	Hyd. Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr. Hydr. Rdg (.Rc)	% Finer (p)	% Adjusted Finer PA
0	25	41	42	9.6	0.0128	-	1.3	0.994	34.3	68.1884	11.32
0.5	25	38	39	10.1	0.0128	0.057627	1.3	0.994	39.3	78.1284	12.97
1	25	37	38	10.2	0.0128	0.040950	1.3	0.994	38.3	76.1404	12.64

2	25	35	36	10.6	0.0128	0.029518	1.3	0.994	36.3	72.1644	11.97
4	26	33	34	10.9	0.0127	0.020934	1.65	0.994	34.65	68.8842	11.43
8	26	30	31	11.4	0.0127	0.015138	1.65	0.994	31.65	62.9202	10.44
15	26	29	30	11.5	0.0127	0.011104	1.65	0.994	30.65	60.9322	10.11
30	26	25	26	12.2	0.0127	0.008087	1.65	0.994	26.65	52.9802	8.795
60	26	21	22	12.9	0.0127	0.005880	1.65	0.994	22.65	45.0282	7.475
120	26	20	21	13	0.0127	0.004174	1.65	0.994	21.65	43.0402	7.145
240	26	17	18	13.5	0.0127	0.003007	1.65	0.994	18.65	37.0762	6.155
480	28	14	15	14	0.0125	0.002128	2.5	0.994	16.5	32.802	5.445
1440	24	13	14	14.2	0.0129	0.001288	1	0.994	14	27.832	4.620

Table –D 1-3 Dry sieve analysis result for TP2-1 sample depth @0 to 1.5

Astm sieve (mm)	weight of seive	wt of seive +soil	wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	445	0	0.00	0.00	100.00
9.5	442	446	4	0.40	0.40	99.60
4.75	441	470	29	2.90	3.30	96.70
2.36	405	451	46	4.60	7.90	92.10
2	467	487	20	2.00	9.90	90.10
1.18	434	518	84	8.40	18.30	81.70
0.6	407	553	146	14.60	32.90	67.10
0.425	367	459	92	9.20	42.10	57.90
0.3	372	374	2	0.20	42.30	57.70
0.15	343	613	270	27.00	69.30	30.70
0.075	335	459	124	12.40	81.70	18.30
0	252	435	183	18.30	100.00	0.00

Table D-4 Hydrometer analysis result for TP2-1 sample depth @1.5

Elapsed time (min)	Temp °C	Actual hydro .Rdg (Ra)	Hyd. Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr. Hydr. Rdg.Rc	% finer(p)	% Adjusted Finer PA
0	23	45	46	8.9	0.0131	-	0.7	0.996	37.7	75.0984	13.74
1	24	40	41	9.7	0.0139	0.04028	1	0.996	41	81.672	14.95
2	24	36	37	10.4	0.0129	0.029494	1	0.996	37	73.704	13.49
4	24	32	33	11.1	0.0129	0.021546	1	0.996	33	65.736	12.03
8	24	30	31	11.4	0.0129	0.015439	1	0.996	31	61.752	11.30
15	24	25	26	12.2	0.0129	0.011664	1	0.996	26	51.792	9.478
30	24	22	23	12.7	0.012	0.008415	1	0.996	23	45.816	8.384
60	24	20	21	13	0.0129	0.006020	1	0.996	21	41.832	7.655
120	25	17	18	13.5	0.0128	0.004288	1.3	0.996	18.3	36.4536	6.671
240	27	15	16	13.8	0.0125	0.00299	2	0.996	17	33.864	6.197
480	28	14	15	14	0.0125	0.002132	2.5	0.996	13.86	27.6092	5.052
1440	23	13	14	14.2	0.0131	0.001299	0.7	0.996	13.7	27.2904	4.994

Table –D-5 Dry sieve analysis result for TP2-2 sample depth @ 1.5 to 3m

Astm sieve (mm)	weight of seive	wt of seive +soil	wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	448	3	0.30	0.30	99.70
9.5	442	444	2	0.20	0.50	99.50
4.75	441	454	13	1.30	1.80	98.20
2.36	405	449.1	44.1	4.41	6.21	93.79
2	467	488	21	2.10	8.31	91.69
1.18	434	521	87	8.70	17.01	82.99
0.6	407	570.9	163.9	16.39	33.40	66.60
0.425	367	474	107	10.70	44.10	55.90
0.3	372	373	1	0.10	44.20	55.80

0.15	343	571	228	22.80	67.00	33.00
0.075	335	451	116	11.60	78.60	21.40
0	241	455	214	21.40	100.00	0.00

Table D-6 Hydrometer analysis result for TP2-2 sample depth @ 1.5 to 3m Gs=2.65

Elaps ed time (min)	Te m p °C	Actual hydro. Rdg (Ra)	Hyd. Corr. for menis cus	L from Tabl e 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr. Hy dr. Rdg. (Rc)	% finer(p)	% Adjust ed Finer PA
0	25	48	49	8.4	0.013	-	1.3	1.002	41.3	82.765	17.71
1	25	43	44	9.2	0.013	0.0391	1.3	1.002	44.3	88.777	18.99
2	25	38	39	10.1	0.013	0.0289	1.3	1.002	39.3	78.757	16.85
4	25	36	37	10.4	0.013	0.0208	1.3	1.002	37.3	74.749	15.99
8	25	31	32	11.2	0.013	0.0152	1.3	1.002	32.3	64.729	13.85
15	25	29	30	11.5	0.013	0.0112	1.3	1.002	30.3	60.721	12.99
30	25	25	26	12.2	0.013	0.0082	1.3	1.002	26.3	52.705	11.28
60	25	22	23	12.7	0.013	0.0059	1.3	1.002	23.3	46.693	9.992
120	26	20	21	13	0.0127	0.0041	1.65	1.002	21.65	43.386	9.285
240	27	17	18	13.5	0.0126	0.0029	2	1.002	19	38.076	8.148
480	27	14	15	14	0.0126	0.0021	2	1.002	13.35	26.753	5.725
1440	24	13	14	14.2	0.013	0.0012	1	1.002	14	28.056	6.004

Table –D-7 Dry sieve analysis result for TP3-1 sample depth @0 to1.5m

ASTM sieve (mm)	weight of seive	wt of seive +soil	wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	445	0	0.00	0.00	100.00
9.5	442	444.1	2.1	0.21	0.21	99.79
4.75	441	480	39	3.90	4.11	95.89

2.36	405	449	44	4.40	8.51	91.49
2	467	489.9	22.9	2.29	10.80	89.20
1.18	434	543	109	10.90	21.70	78.30
0.6	407	560	153	15.30	37.00	63.00
0.425	367	446	79	7.90	44.90	55.10
0.3	372	375.1	3.1	0.31	45.21	54.79
0.15	343	621	278	27.80	73.01	26.99
0.075	335	439.9	104.9	10.49	83.50	16.50
0	241	406	165	16.50	100.00	0.00

Table D-8 Hydrometer analysis result for TP3-1 sample depth @0 to1.5m

Elapsed time (min)	Temp °C	Actual hydro. Rdg(Ra)	Hyd.Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr. Hydr. Rdg.(Rc)	% finer (p)	% Adjusted Finer PA
0	25	50	51	8.1	0.0128	-	1.3	1	43.3	86.6	14.29
1	25	43	44	9.2	0.0128	0.039	1.3	1	44.3	88.6	14.61
2	25	42	43	9.4	0.0128	0.027	1.3	1	43.3	86.6	14.29
4	25	40	41	9.7	0.0128	0.020	1.3	1	41.3	82.6	13.63
8	25	34	35	10.7	0.0128	0.014	1.3	1	35.3	70.6	11.64
15	25	30	31	11.4	0.0128	0.011	1.3	1	31.3	62.6	10.33
30	24	26	27	12	0.0130	0.008	1	1	27	54	8.91
60	25	22	23	12.7	0.0128	0.006	1.3	1	23.3	46.6	7.689
120	24	20	21	13	0.0130	0.004	1	1	21	42	6.93
240	26	17	18	13.5	0.0127	0.003	1.65	1	18.65	37.3	6.154
480	26	16	17	13.7	0.0127	0.002	1.65	1	14.97	29.9	4.940
1440	23	15	16	13.8	0.0131	0.001	0.7	1	15.7	31.4	5.181

Table –D-10 Dry sieve analysis result for TP4-1 sample depth @0 to1.2m

Sieve opening (mm)	Mass of sieve (g)	Mass of sieve with retained soil (g	Mass of retained soil (g)	Percentage retained, %	Cumulative percentage retained, %	Percentage of passing, %
19	435	435	0	0.00	0.00	100.00
12.5	444	444	0	0.00	0.00	100.00
9.5	442	446	4	0.40	0.40	99.60
4.75	440	469	29	2.90	3.30	96.70
2.36	405	446	41	4.10	7.40	92.60
2	465	497	32	3.20	10.60	89.40
1.18	434	556	122	12.20	22.80	77.20
0.6	407	569	162	16.20	39.00	61.00
0.425	365	463	98	9.80	48.80	51.20
0.3	373	373	0	0.00	48.80	51.20
0.15	342	594	252	25.20	74.00	26.00
0.075	334	443	109	10.90	84.90	15.10
pan	240	391	151	15.10	100.00	0.00
Total			1000	100		

Table D-11 Hydrometer analysis result for TP4-1 sample depth @0 to1.2m Gs=2.67

Elapsed time (min)	Tem (°C)	Actual H. dro. Rdg (Ra)	Hyd. Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr. Hydr. Rdg. (Rc)	% finer (p)	% Adjusted Finer (PA)
0	23	52	53	8.3	0.01309	-	0.7	0.996	44.7	89.042	13.44
1	23	42	43	9.4	0.01309	0.0401	0.7	0.996	42.7	85.058	12.84
2	23	38	39	10.1	0.01309	0.0294	0.7	0.996	38.7	77.090	11.64
4	23	32	33	11.1	0.01309	0.0218	0.7	0.996	32.7	65.138	9.836
8	23	25	26	12.2	0.01309	0.0161	0.7	0.996	25.7	51.194	7.730
15	23	22	23	12.7	0.01309	0.0120	0.7	0.996	22.7	45.218	6.828
30	23	18	19	13.5	0.01309	0.0087	0.7	0.996	18.7	37.250	5.625

60	23	17	18	13.8	0.01309	0.0062	0.7	0.996	17.7	35.258	5.324
120	24	16	17	14.3	0.01293	0.0044	1	0.996	17	33.864	5.113
240	25	16	17	14.5	0.01278	0.0031	1.3	0.996	17.3	34.462	5.204
480	26	15	16	14.7	0.01264	0.0022	1.65	0.996	14.05	27.988	4.226
1440	21	15	16	14.7	0.01353	0.0013	0.2	0.996	15.2	30.278	4.572

Table –D-12 Dry sieve analysis result for TP4-2 sample depth @0 to1.2m

ASTM SIEVE(mm)	weight of seive	wt of seive +soil	wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	444	444	0	0.00	0.00	100.00
9.5	442	443.1	1.1	0.11	0.11	99.89
4.75	440	462	22	2.20	2.31	97.69
2.36	405	446	41	4.10	6.41	93.59
2	465	497	32	3.20	9.61	90.39
1.18	434	562.9	128.9	12.89	22.50	77.50
0.6	406	575	169	16.90	39.40	60.60
0.425	365	464.9	99.9	9.99	49.39	50.61
0.3	373	375	2	0.20	49.59	50.41
0.15	342	594.1	252.1	25.21	74.80	25.20
0.075	334	430	96	9.60	84.40	15.60
0	240	396	156	15.60	100.00	0.00

Table –D-16 Dry sieve analysis result for TP5-2 sample depth @ 1.5 to 3m

ASTM SIEVE (mm)	weight of seive	wt of seive +soil	wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00

12.5	445	520	75	7.50	7.50	92.50
9.5	442	482	40	4.00	11.50	88.50
4.75	441	532	91	9.10	20.60	79.40
2.36	405	486	81	8.10	28.70	71.30
2	384	420	36	3.60	32.30	67.70
1.18	434	490	56	5.60	37.90	62.10
0.6	407	501	94	9.40	47.30	52.70
0.425	367	430	63	6.30	53.60	46.40
0.3	372	376	4	0.40	54.00	46.00
0.15	343	536	193	19.30	73.30	26.70
0.075	335	491	156	15.60	88.90	11.10
0	240	351	111	11.10	100.00	0.00

Table D-17 Hydrometer analysis result for for TP5-2 sample depth @ 1.5to 3m Gs=2.67

Elapse d time (min)	Temp °C	Actual hydro. Rdg (Ra)	Hyd. Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr.H ydr. Rd g .Rc	% finer (p)	% Adjusted FinerPA
0	25	40	41	7.1	0.01326	-	1.3	1.018	33.3	67.80	7.458
1	25	36	37	8.6	0.01326	0.03889	1.3	1.018	37.3	75.94	8.354
2	25	34	35	8.6	0.01326	0.0275	1.3	1.018	35.3	71.87	7.906
4	25	30	31	8.6	0.01326	0.01944	1.3	1.018	31.3	63.73	7.010
8	25	26	27	8.6	0.01326	0.01375	1.3	1.018	27.3	55.58	6.114
15	25	23	24	8.6	0.01326	0.01004	1.3	1.018	24.3	49.47	5.442
30	25	19	20	8.6	0.01326	0.0071	1.3	1.018	20.3	41.33	4.546
60	25	17	18	8.6	0.01326	0.00502	1.3	1.018	18.3	37.26	4.098
120	25	15	16	8.6	0.01326	0.00355	1.3	1.018	16.3	33.19	3.651

240	25	13	14	8.6	0.01326	0.00251	1.3	1.018	14.3	29.11	3.203
480	26	12	13	8.6	0.01326	0.00177	1.3	1.018	10.62	21.62	2.378
1440	20	11	12	8.6	0.01326	0.00102	1.3	1.018	12.3	25.04	2.755

Table –D-18 Dry sieve analysis result for TP6-1 sample depth @1.5m

ASTM SIEVE (mm)	weight of seive	wt of seive +soil	wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	454	9	0.90	0.90	99.10
9.5	442	442	0	0.00	0.90	99.10
4.75	441	449.3	8.3	0.83	1.73	98.27
2.36	405	421.9	16.9	1.69	3.42	96.58
2	467	494.9	27.9	2.79	6.21	93.79
1.18	434	591.2	157.2	15.72	21.93	78.07
0.6	407	615.5	208.5	20.85	42.78	57.22
0.425	36	473.1	106.1	10.61	53.39	46.61
0.3	372	374.1	2.1	0.21	53.60	46.40
0.15	343	606.9	263.9	26.39	79.99	20.01
0.075	335	416	81	8.10	88.09	11.91
0	241	360.1	119.1	11.91	100.00	0.00

Table D-19 Hydrometer analysis result for for TP6-1 sample depth @0 to1.5m Gs=2.68

Elapsed time (min)	Temp °C	Actual hydro. Rdg(Ra)	Hyd. Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr.Hyd r. Rdg (.Rc)	%finer (p)	%Adjusted Finer (PA)
0	24	30	31	11.4	0.0129	-	1	0.994	23	45.724	5.441
1	24	27	28	11.9	0.0129	0.0445	1	0.994	28	55.664	6.624

2	24	26	27	12	0.0129	0.0316	1	0.994	27	53.676	6.387
4	24	24	25	12.4	0.0129	0.0227	1	0.994	25	49.700	5.914
8	24	22	23	12.7	0.0129	0.0162	1	0.994	23	45.724	5.441
15	25	21	22	12.9	0.01275	0.0118	1.3	0.994	22.3	44.332	5.276
30	25	19	20	13.2	0.01275	0.0085	1.3	0.994	20.3	40.356	4.802
60	25	17	18	13.5	0.01275	0.0060	1.3	0.994	18.3	36.380	4.329
120	25	15	16	13.8	0.01275	0.0043	1.3	0.994	16.3	32.404	3.856
240	26	13	14	14.2	0.01261	0.0031	1.65	0.994	14.65	29.124	3.466
480	26	12	13	14.3	0.01261	0.0022	1.65	0.994	10.97	21.808	2.595
1440	22	12	13	14.3	0.0132	0.0013	0.4	0.994	12.4	24.651	2.933

Table –D-22 Dry sieve analysis result for TP7-1 sample depth @1.5m

astm sieve(mm)	weight of seive	wt of sieve +soil	Wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	560.1	115.1	11.51	11.51	88.49
9.5	442	483.1	41.1	4.11	15.62	84.38
4.75	441	554.8	113.8	11.38	27.00	73.00
2.36	405	504.3	99.3	9.93	36.93	63.07
2	467	482.1	15.1	1.51	38.44	61.56
1.18	434	510.1	76.1	7.61	46.05	53.95
0.6	407	532.1	125.1	12.51	58.56	41.44
0.425	367	435.2	68.2	6.82	65.38	34.62
0.3	372	372.9	0.9	0.09	65.47	34.53
0.15	343	519.2	176.2	17.62	83.09	16.91
0.075	335	403.1	68.1	6.81	89.90	10.10
0	240	341	101	10.10	100.00	0.00

Table D-23 Hydrometer analysis result for for TP7-1 sample depth @1.5m   Gs=2.68

Elapsed time (min	Temp °C	Actual hydro. Rdg (Ra)	Hyd. Corr. For meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr. Hydr. Rdg (.Rc)	%finer (p)	%Adjusted Finer (PA)
0	22	51	52	7.9	0.0132	-	0.4	0.994	43.4	6.27	8.88
1	22	43	44	9.2	0.0132	0.0400	0.4	0.994	35.4	70.37	7.24
2	22	40	41	9.7	0.0132	0.0291	0.4	0.994	32.4	64.41	6.63
4	22	35	36	10.6	0.0132	0.0215	0.4	0.994	27.4	54.47	5.61
8	22	31	32	11.2	0.0132	0.0156	0.4	0.994	23.4	46.519	4.79
15	22	25	26	12.2	0.0132	0.0119	0.4	0.994	17.4	34.59	3.56
30	22	22	23	12.7	0.0132	0.0086	0.4	0.994	14.4	28.62	2.94
60	23	18	19	13.3	0.0130	0.0061	0.7	0.994	10.7	21.27	2.19
120	23	15	16	13.8	0.0130	0.0044	0.7	0.994	7.7	15.308	1.57
240	25	13	14	14.2	0.0127	0.0031	1.3	0.994	6.3	12.52	1.29
480	27	11	12	14.5	0.0124	0.0022	2	0.994	5	9.940	1.02
1440	22	11	12	14.5	0.0132	0.0013	0.4	0.994	3.4	6.759	0.69

Table –D-26 Dry sieve analysis result for TP8-1 sample depth @0 to 3m

ASTM SIEVE (Mm)	Weight Of Seive	Wt Of Seive +Soil	Wt Retained(Gm)	%Retained	Cum % Retained	%Pass
19	435	435	0	0.00	0.00	100.00
12.5	445	565	120	12.00	12.00	88.00
9.5	442	487.1	45.1	4.51	16.51	83.49
4.75	441	548	107	10.70	27.21	72.79
2.36	405	500.1	95.1	9.51	36.72	63.28
2	467	490	23	2.30	39.02	60.98
1.18	434	508.9	74.9	7.49	46.51	53.49
0.6	407	520.7	113.7	11.37	57.88	42.12
0.425	367	440.2	73.2	7.32	65.20	34.80
0.3	372	373	1	0.10	65.30	34.70
0.15	343	518	175	17.50	82.80	17.20

0.075	335	400	65	6.50	89.30	10.70
0	241	348	107	10.70	100.00	0.00

Table D-27 Hydrometer analysis result for for TP8-1 sample depth @0 to 1.5m Gs=2.65

Elap sed time (min)	Temp (°C)	Actual hydro. Rdg (Ra)	Hyd.Corr. for meni scus	L from Table 1	K from Table 2	D (mm)	CT From table3	a from Table4	Corr. Hydr. Rdg (Rc)	%finer (p)	%Adjusted Finer (PA)
0	23	50	51	8.1	0.0131	-	0.7	1	_	_	_
1	23	43	44	9.2	0.0131	0.0399	0.7	1	35.7	71.40	7.354
2	23	40	41	9.7	0.0131	0.0290	0.7	1	32.7	65.40	6.736
4	23	35	36	10.6	0.0131	0.0214	0.7	1	27.7	55.40	5.706
8	23	30	31	11.4	0.0131	0.0157	0.7	1	22.7	45.40	4.676
15	23	24	25	12.4	0.0131	0.0120	0.7	1	16.7	33.40	3.440
30	23	22	23	12.7	0.0131	0.0086	0.7	1	14.7	29.40	3.028
60	23	18	19	13.3	0.0131	0.0062	0.7	1	10.7	21.40	2.204
120	23	14	15	14	0.0131	0.0045	0.7	1	6.7	13.40	1.380
240	25	13	14	14.2	0.018	0.0031	1.3	1	6.3	12.60	1.298
480	27	11	12	14.5	0.0125	0.0022	2	1	5	10.00	1.030
1440	22	10	11	14.7	0.0133	0.0013	0.4	1	2.4	4.800	0.494

Table –D-28 Dry sieve analysis result for TP8-2 sample depth @ 3m

Astm sieve (mm)	Weight Of Seive	Wt Of Seive +Soil	Wt Retained(Gm)	%Retained	Cum % Retained	%Pass
19	435	435	0	0.00	0.00	100.00
12.5	445	565	120	12.00	12.00	88.00
9.5	442	485.1	43.1	4.31	16.31	83.69
4.75	441	550	109	10.90	27.21	72.79
2.36	405	504.9	99.9	9.99	37.20	62.80
2	467	483	16	1.60	38.80	61.20

1.18	434	510.1	76.1	7.61	46.41	53.59
0.6	407	532.9	125.9	12.59	59.00	41.00
0.425	367	435	68	6.80	65.80	34.20
0.3	372	372.9	0.9	0.09	65.89	34.11
0.15	343	516.2	173.2	17.32	83.21	16.79
0.075	335	404	69	6.90	90.11	9.89
0	240	338.9	98.9	9.89	100.00	0.00

Table D-29 Hydrometer analysis result for for TP8-2 sample depth @ 1.5 to 3m Gs=2.67

Elapsed time (min)	Temp °C	Actual hydro. Rdg (Ra)	Hyd. Corr. for meniscus	Lfrom Table 1	K from Table 2	D (mm)	CT From table3	a from Table4	Corr. Hy dr. Rdg(.Rc)	%finer (p)	%Adjusted Finer(PA)
0	22	48	49	8.4	0.0132	-	0.4	0.996	40.4	80.47	7.96
1	22	42	43	9.4	0.0132	0.0405	0.4	0.996	42.4	84.46	8.36
2	22	40	41	9.7	0.0132	0.0291	0.4	0.996	40.4	80.47	7.96
4	22	34	35	10.7	0.0132	0.0216	0.4	0.996	34.4	68.52	6.78
8	22	30	31	11.4	0.0132	0.0158	0.4	0.996	30.4	60.55	5.99
15	22	24	25	12.4	0.0132	0.0120	0.4	0.996	24.4	48.60	4.81
30	22	22	23	12.7	0.0132	0.0086	0.4	0.996	22.4	44.62	4.41
60	23	18	19	13.3	0.0130	0.0061	0.7	0.996	18.7	37.25	3.68
120	23	15	16	13.8	0.0130	0.0044	0.7	0.996	15.7	31.27	3.09
240	25	12	13	14.3	0.0127	0.0031	1.3	0.996	13.3	26.49	2.62
480	27	11	12	14.5	0.0125	0.0021	2	0.996	13	25.89	2.56
1440	21	10	11	14.7	0.0135	0.0013	0.2	0.996	10.2	20.31	2.01

Table –D-30 Dry sieve analysis result for TP9-1 sample depth @0 to1.5m

astm sieve(mm)	weight of seive	wt of sieve +soil	Wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00

12.5	445	567	122	12.2	12.2	87.5
9.5	442	444.1	2.1	0.21	12.32	87.68
4.75	441	480	39	3.90	16.22	83.78
2.36	405	449	44	4.40	20.62	79.38
2	467	491	24	2.4	23.02	76.98
1.18	434	543	109	10.90	33.92	66.08
0.6	407	560	153	15.30	49.22	50.78
0.425	367	446	79	7.90	57.12	42.88
0.3	372	375.1	3.1	0.31	57.43	42.57
0.15	343	621	278	27.80	85.23	14.77
0.075	335	439.9	104.9	10.49	95.72	4.28
0	241	283.8	42.8	4.28	100.00	0.00

Table D-33 Hydrometer analysis result for TP9-2 sample depth @1.5to 3 Gs=2.68

Elapsed time (min)	Temp° C	Actual hydro. Rdg (Ra)	Hyd. Corr. for meniscus	Lfrom Table 1	K from Table 2	D (mm)	CT From table3	a from Table 4	Corr. Hydr. Rdg. (Rc)	%Finer (p)	%Adjusted Finer PA
0	24	49	50	8.3	0.0129	-	1	0.994	42	83.50	12.02
1	24	44	45	9.1	0.0129	0.0389	1	0.994	45	89.46	12.88
2	24	42	43	9.4	0.0129	0.0280	1	0.994	43	85.48	12.31
4	24	41	42	9.6	0.0129	0.0200	1	0.994	42	83.50	12.02
8	24	34	35	10.7	0.0129	0.0149	1	0.994	35	69.58	10.02
15	24	31	32	11.2	0.0129	0.0111	1	0.994	32	63.62	9.161
30	24	26	27	12	0.0129	0.0082	1	0.994	27	53.68	7.729
60	24	23	24	12.5	0.0129	0.0059	1	0.994	24	47.71	6.871
120	25	20	21	13	0.0127	0.0042	1.3	0.994	21.3	42.34	6.098
240	25	16	17	13	0.0127	0.0030	1.3	0.994	17.3	34.39	4.953
480	26	15	16	13.8	0.0126	0.0021	1.65	0.994	0.013	27.79	4.002
1440	21	14	15	14	0.0133	0.0013	0.2	0.994	14.2	28.23	4.065

Table –D 34 Dry sieve analysis result for TP10-1 sample depth @0 to 1.5m

ASTM Sieve(mm)	weight of seive	wt of seive+soil	wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	445	0	0.00	0.00	100.00
9.5	442	456	14	1.40	1.40	99.60
4.75	441	470	29	2.90	4.30	95.70
2.36	405	451	46	4.60	8.90	91.10
2	467	487	20	2.00	10.90	89.10
1.18	434	518	84	8.40	19.30	80.70
0.6	407	553	146	14.60	33.90	66.10
0.425	367	459	92	9.20	43.10	56.90
0.3	372	374	2	0.20	43.30	56.70
0.15	343	613	270	27.00	70.30	29.70
0.075	335	459	124	12.40	82.70	17.30
0	252	425	173	17.30	100.00	0.00

Table D-35 Hydrometer analysis result for TP10-1 sample depth @1.5

Elapsed time (min)	Temp °C	Actual hydro Rdg (Ra)	Hyd. Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	afrom Table 4	Corr. Hydr. Rdg. Rc	%finer(p)	% Adjusted Finer PA
0	23	45	46	8.9	0.0131	-	0.7	0.996	37.7	75.0984	13.74
1	24	40	41	9.7	0.0139	0.04028	1	0.996	41	81.672	14.95
2	24	36	37	10.4	0.0129	0.029494	1	0.996	37	73.704	13.49
4	24	32	33	11.1	0.0129	0.021546	1	0.996	33	65.736	12.03
8	24	30	31	11.4	0.0129	0.015439	1	0.996	31	61.752	11.30
15	24	25	26	12.2	0.0129	0.011664	1	0.996	26	51.792	9.478
30	24	22	23	12.7	0.012	0.008415	1	0.996	23	45.816	8.384
60	24	20	21	13	0.0129	0.006020	1	0.996	21	41.832	7.655

120	25	17	18	13.5	0.0128	0.004288	1.3	0.996	18.3	36.4536	6.671
240	27	15	16	13.8	0.0125	0.00299	2	0.996	17	33.864	6.197
480	28	14	15	14	0.0125	0.002132	2.5	0.996	13.86	27.60912	5.052
1440	23	13	14	14.2	0.0131	0.001299	0.7	0.996	13.7	27.2904	4.994

Table –D36 Dry sieve analysis result for TP10-2 sample depth @ 1.5 to 3m

Astm Sieve (mm)	weight of seive	wt of seive+soil	wt retained(gm)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	454	9	0.90	0.90	99.10
9.5	442	444	2	0.20	2.90	97.10
4.75	441	454	13	1.30	4.20	95.80
2.36	405	449.1	44.1	4.41	8.61	91.39
2	467	488	21	2.10	10.71	89.29
1.18	434	521	87	8.70	19.41	80.59
0.6	407	570.9	163.9	16.39	35.80	64.20
0.425	367	474	107	10.70	46.50	64.20
0.3	372	373	1	0.10	46.60	53.40
0.15	343	571	228	22.80	69.40	30.60
0.075	335	451	116	11.60	81.00	19.00
0	241	431	190.0	19.00	100.00	0.00

Table D-37 Hydrometer analysis result for TP10-2 sample depth @ 1.5 to 3m Gs=2.65

Elapsed time (min)	Temp °C	Actual hydro. Rdg (Ra)	Hyd. Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr. Hy dr. Rdg. (Rc)	%finer (p)	%Adjusted Finer PA
0	25	48	49	8.4	0.013	-	1.3	1.002	41.3	82.765	17.71
1	25	43	44	9.2	0.013	0.0391	1.3	1.002	44.3	88.777	18.99

2	25	38	39	10.1	0.013	0.0289	1.3	1.002	39.3	78.757	16.85
4	25	36	37	10.4	0.013	0.0208	1.3	1.002	37.3	74.749	15.99
8	25	31	32	11.2	0.013	0.0152	1.3	1.002	32.3	64.729	13.85
15	25	29	30	11.5	0.013	0.0112	1.3	1.002	30.3	60.721	12.99
30	25	25	26	12.2	0.013	0.0082	1.3	1.002	26.3	52.705	11.28
60	25	22	23	12.7	0.013	0.0059	1.3	1.002	23.3	46.693	9.992
120	26	20	21	13	0.0127	0.0041	1.65	1.002	21.65	43.386	9.285
240	27	17	18	13.5	0.0126	0.0029	2	1.002	19	38.076	8.148
480	27	14	15	14	0.0126	0.0021	2	1.002	13.35	26.753	5.725
1440	24	13	14	14.2	0.013	0.0012	1	1.002	14	28.056	6.004

Appendix – E (Standard Compaction test result)

E The detailed test results for Standard Compaction test

TP1-1 @1.5m GS=2.65

Sampling depth……………………. 1.5m

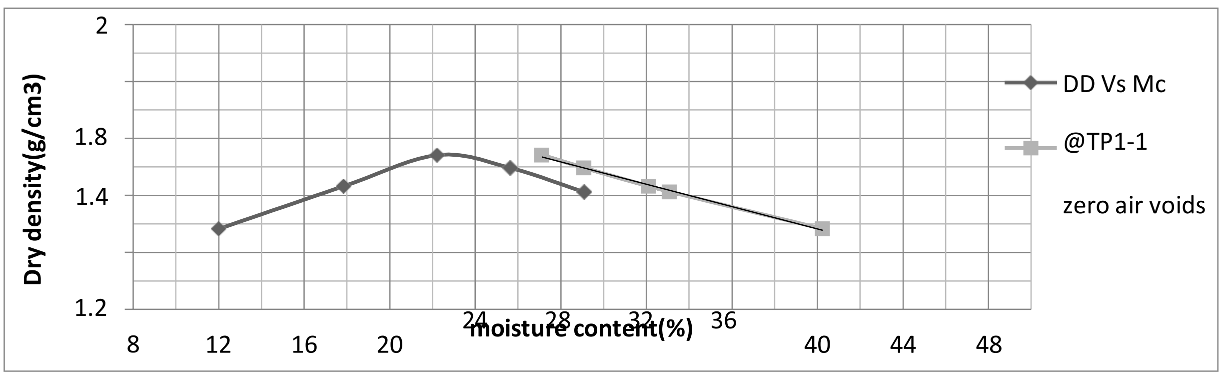
Table E-1: Moisture content vs. dry density computation

Determination No.	1	2	3	4	5
Mass of Mold, g	4405	4405	4405	4405	4405
Mass of mold + Compacted Soil, g	5761.5	5998.1	6183	6179.9	6125.9
Mass of Compacted soil, g	1356.5	1593.1	1779	1774.9	1788
Volume of Mold, cm3	944	944	944	945	946
Bulk density, g/cm3	1.45	1.64	1.80	1.70	1.68
Water Contenet, %	12	17.83	22.22	25.64	29.09
Dry density, g/cm3	1.283	1.4322	1.55419	1.4965	1.467

Table E-2: Water content computation

Conatainer No	B1	D3	R3	B2	C2
Mass of container, g	15.6	15.65	15.55	15.55	15.45
Mass of container + wet soil, g	71.60	59.65	59.65	64.55	86.45
Mass of ontainer + Dry soil, g	65.5	51.75	52.98	54.59	70.46
Mass of Water, g	6.1	7.9	6.661	9.96	15.99
Mass of Dry soil, g	49.9	36.1	37.439	39.09	55.01

Water content, %	12.22	21.88	17.79	25.47	26.09
Dry Unit Weight, g/cm3	1.26	1.35	1.40	1.18	1.16



Maximum dry density (g/cm^3) =1.55, Optimum moisture contents (%) =22

TP2-1 @ 1.5m

Sampling depth……………………………1.5m GS= 2.67

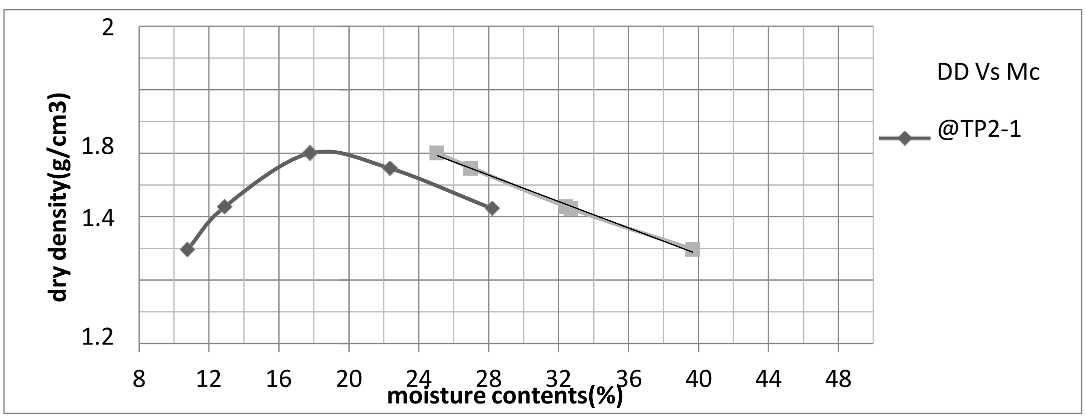
Table E-5 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	B4	A1	B1	D2	D1
MC = Mass of empty, clean can(grams)	7	9	9	10	8

MCMS = Mass of can, and moist soil (grams)	63.5	51.9	51.4	57.6	78.52
MCDS = Mass of can, and dry soil (grams)	58	47	45	48.9	63
MS = Mass of soil solids (grams)	51	38	36	38.9	55
MW = Mass of pore water (grams)	5.5	4.9	6.4	8.7	15.52
W = Water content, w%	10.784	12.895	17.778	22.365	28.22

Table E-6: Density computation

Determination No.	1	2	3	4	5
W = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	10.784	12.895	17.778	22.365	28.22
Mass of compacted soil and mold (grams)	5760.9	5930	6184	6197.9	6130
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1355.9	1525	1779	1792.9	1725
Wet density, ρ , (g/cm3)	1.4363	1.6155	1.8845	1.8993	1.828
Dry density, ρd , (g/cm3)	1.2965	1.4309	1.6001	1.5521	1.425



Maximum dry density (g/cm^3) =1.6, Optimum moisture contents (%) =17.77

TP3-2@3m

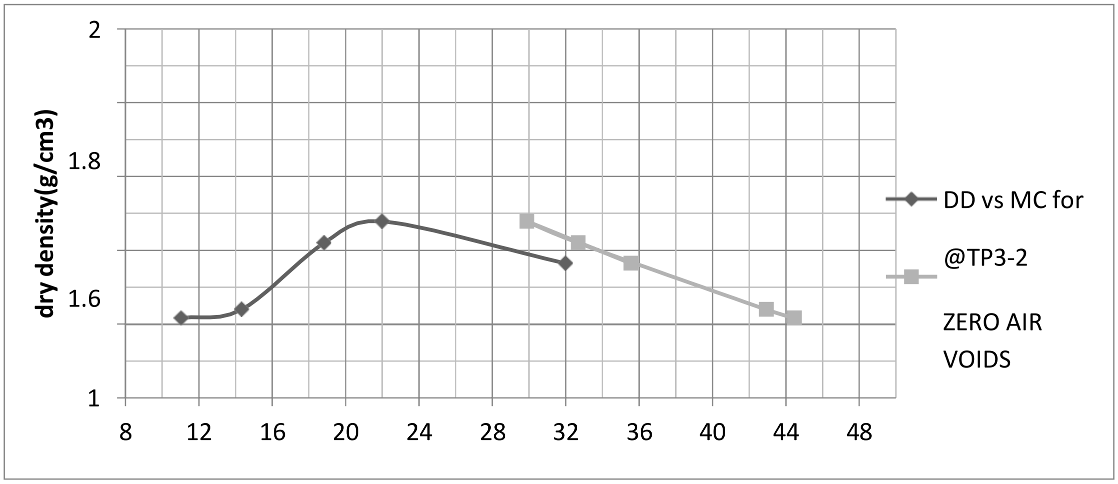
Sampling depth……………………………3m GS= 2.68

Table E-11 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	G2	D2	K1	D1	L1
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	63.2	54.99	77.9	73.1	97
MCDS = Mass of can, and dry soil (grams)	57	48	64	59	74
MS = Mass of soil solids (grams)	48	39	55	52	66
MW = Mass of pore water (grams)	6.2	6.99	13.9	14.1	23
W = Water content, w%	12.917	17.923	25.273	27.115	34.85

Table E-12: Density computation

Compacted Soil - Sample no.	1	2	3	4	5
W = Assumed water content, w%	8	16	22	26	30
Actual average water content, w%	12.917	17.923	25.273	27.115	34.85
Mass of compacted soil and mold (grams)	5663.5	5808	6075.8	6101	6079
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1258.5	1403	1670.8	1696	1674
Wet density, ρ , (g/cm3)	1.3332	1.4862	1.7699	1.7966	1.773
Dry density, ρd , (g/cm3)	1.1807	1.2603	1.4128	1.4134	1.315
For drawing saturation line(zero air void line s=100)					
Dry density, ρd (g/cm3)	1.1806	1.2603	1.412	1.413	1.3150
Saturated moisture contents (%)	47.3852	42.03	33.46	33.43	38.73



Maximum dry density (g/cm^3) =1.47, Optimum moisture contents (%) =22

TP4-1@1.5

Sampling depth……………………………1.5m GS= 2.65

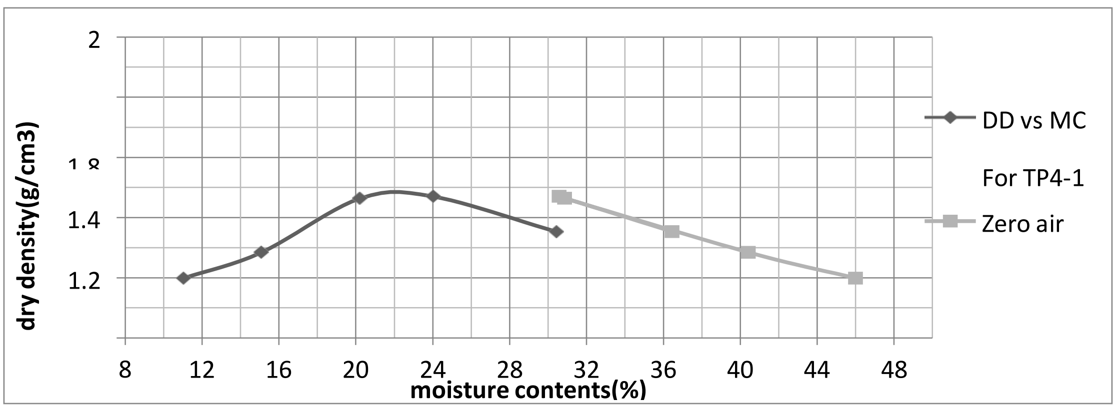
Table E-13 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	G1	D2	M3	B2	D11
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	62.3	54	75	71.5	94.1
MCDS = Mass of can, and dry soil (grams)	57	48.1	63.9	59	74
MS = Mass of soil solids (grams)	48	39.1	54.9	52	66
MW = Mass of pore water (grams)	5.3	5.9	11.1	12.5	20.1
W = Water content, w%	11.042	15.09	20.219	24.038	30.45

Table E-14: Density computation

Compacted Soil - Sample no.	1	2	3	4	5
W = Assumed water content, w%	8	12	16	20	26

Actual average water content, w%	11.042	15.09	20.219	24.038	30.45
Mass of compacted soil and mold (grams)	5661	5800	6065.9	6126	6071
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1256	1395	1660.9	1721	1666
Wet density, ρ , (g/cm3)	1.3305	1.4778	1.7594	1.8231	1.765
Dry density, ρd , (g/cm3)	1.1982	1.284	1.4635	1.4698	1.353
For drawing saturation line(zero air void line s=100)					
Dry density, ρd (g/cm3)	1.1982	1.284	1.463	1.469	1.352
Saturated moisture contents (%)	46.004	40.42	30.8	30.58	36.46



Maximum dry density (g/cm^3) =1.47, Optimum moisture contents (%) =24

TP4-2@3m

Sampling depth……………………………3m GS= 2.67

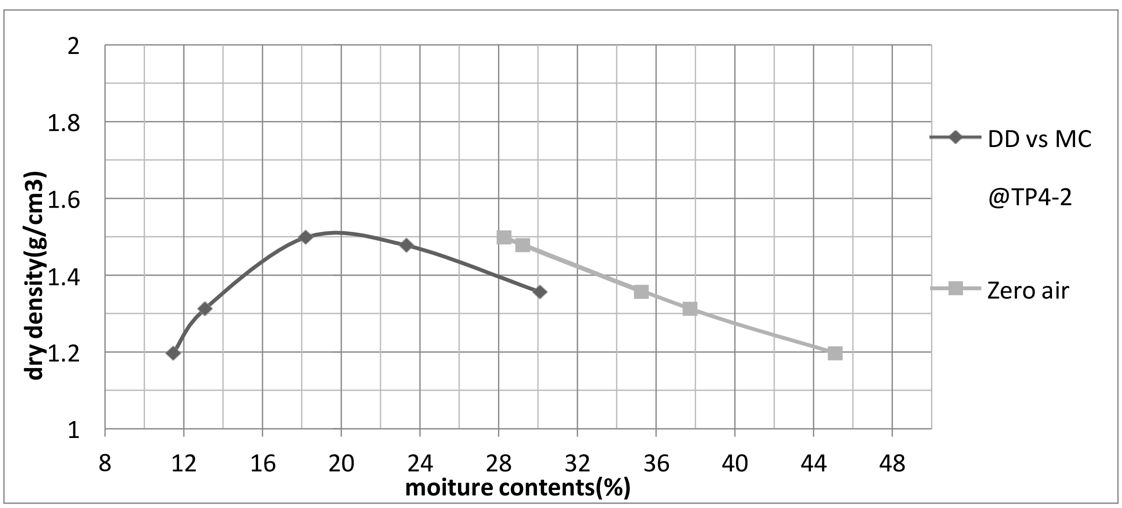
Table E-15 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	M1	D1	D1	A1	A2
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	62.5	53.1	74.01	71	94
MCDS = Mass of can, and dry soil (grams)	57	48	64	58.9	74.1
MS = Mass of soil solids (grams)	48	39	55	51.9	66.1

MW = Mass of pore water (grams)	5.5	5.1	10.01	12.1	19.9
W = Water content, w%	11.458	13.077	18.2	23.314	30.11

Table E-16: Density computation

Compacted Soil - Sample no.	1	2	3	4	5
W = Assumed water content, w%	8	10	16	20	26
Actual average water content, w%	11.458	13.077	18.2	23.314	30.11
Mass of compacted soil and mold (grams)	5664	5806	6077	6125	6071
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1259	1401	1672	1720	1666
Wet density, ρ , (g/cm3)	1.3337	1.4841	1.7712	1.822	1.765
Dry density, ρd , (g/cm3)	1.1966	1.3125	1.4985	1.4776	1.356
For saturation line(zero air void line s=100)					
Dry density, ρd (g/cm3)	1.1965	1.3124	1.498	1.4775	1.356
Saturated moisture contents (%)	45.110	37.730	28.273	29.21	35.2599



Maximum dry density (g/cm^3) =1.47, Optimum moisture contents (%) =20

TP5-1@1.5

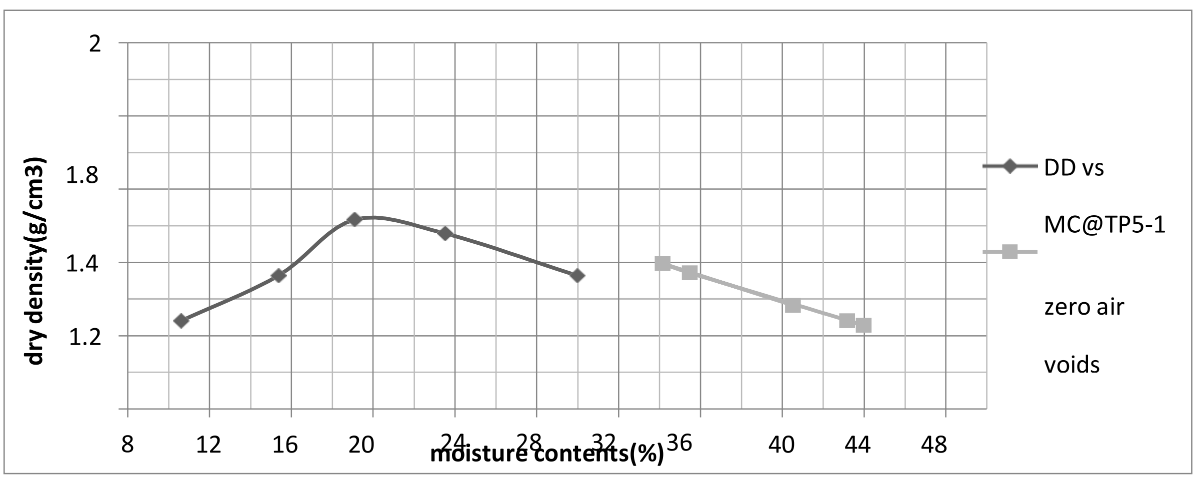
Sampling depth……………………………1.5m GS= 2.64

Table E-17 Water content computation

Moisture can number - number	R1	R2	R3	R4	T1
MC = Mass of empty, clean can(grams)	8	7	9	8	7
MCMS = Mass of can, and moist soil (grams)	62.2	54.3	74.5	71	94.1
MCDS = Mass of can, and dry soil (grams)	57	48	64	59	74
MS = Mass of soil solids (grams)	49	41	55	51	67
MW = Mass of pore water (grams)	5.2	6.3	10.5	12	20.1
W = Water content, w%	10.612	15.366	19.091	23.529	30

Table E-18: Density computation

Compacted Soil - Sample no.	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	10.612	15.366	19.091	23.529	30
Mass of compacted soil and mold (grams)	5700	5890	6110	6129	6078
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1295	1485	1705	1724	1673
Wet density, ρ , (g/cm3)	1.3718	1.5731	1.8061	1.8263	1.772
Dry density, ρd , (g/cm3)	1.2402	1.3636	1.5166	1.4784	1.363
For saturation line(zero air void line s=100)					
Dry density, ρd (g/cm3)	1.24	1.228	1.37122	1.39656	1.28
Saturated moisture contents (%)	43.18	43.981	35.4742	34.1513	40.53



Maximum dry density (g/cm^3) =1.51, Optimum moisture contents (%) =20

TP6-1@1.5

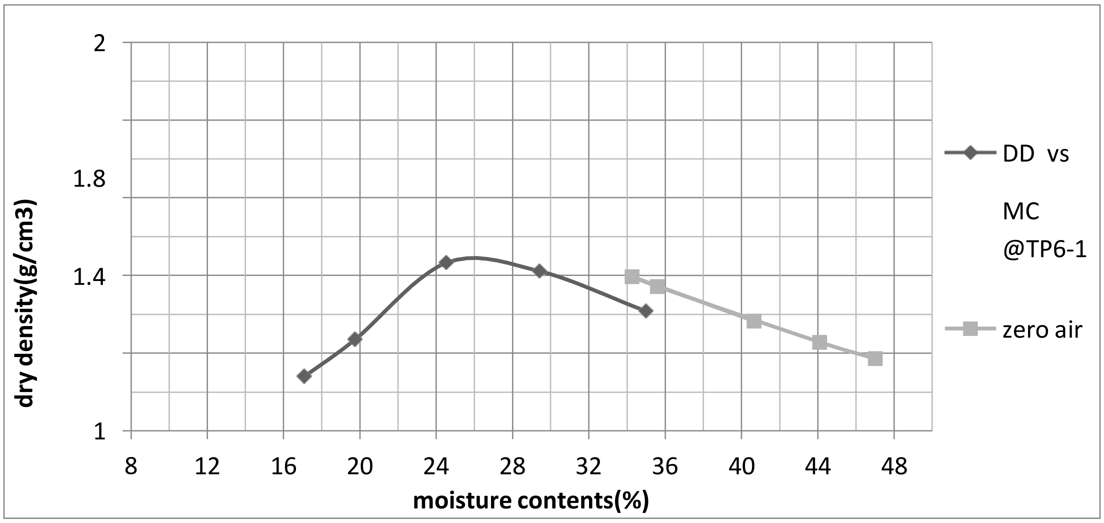
Sampling depth……………………………1.5m GS= 2.66

Table E-21 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	D2	M1	G1	K2	A1
MC = Mass of empty, clean can(grams)	8	7	9	7	8
MCMS = Mass of can, and moist soil (grams)	64.2	56.1	77.5	73	97.1
MCDS = Mass of can, and dry soil (grams)	56	48	64	58	74
MS = Mass of soil solids (grams)	48	41	55	51	66
MW = Mass of pore water (grams)	8.2	8.1	13.5	15	23.1
W = Water content, w%	17.083	19.756	24.545	29.412	35

Table E-22: Density computation

Compacted Soil - Sample no.	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	17.083	19.756	24.545	29.412	35
Mass of compacted soil and mold (grams)	5665	5802	6090	6129	6072
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1260	1397	1685	1724	1667
Wet density, ρ , (g/cm3)	1.3347	1.4799	1.785	1.8263	1.766
Dry density, ρd , (g/cm3)	1.14	1.2357	1.4332	1.4112	1.308
For saturation line(zero air void line s=100)					
Dry density, ρd (g/cm3)	1.18549	1.2279	1.3712	1.3965	1.2822
Saturated moisture contents (%)	47.0392	44.121	35.614	34.291	40.67



Maximum dry density (g/cm^3) =1.43, Optimum moisture contents (%) =26

TP6-2@3m

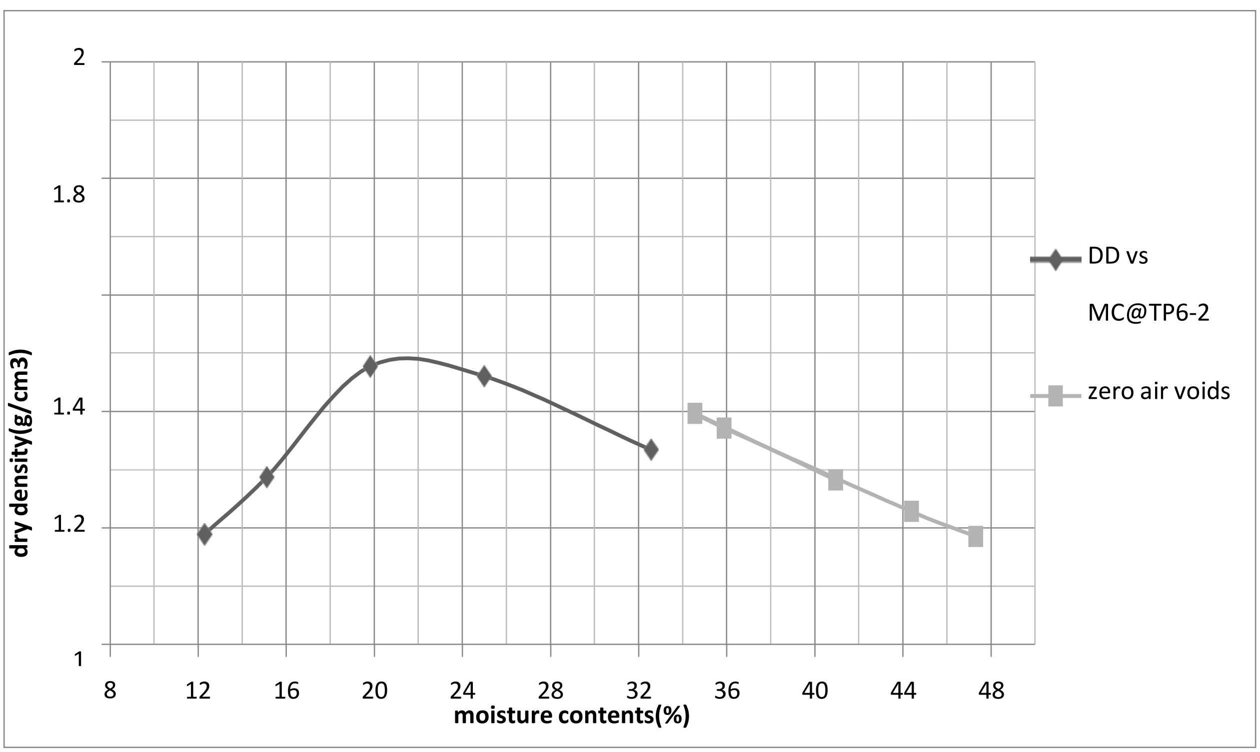
Sampling depth……………………………3m   GS=   2.66

Table E-22 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	M1	B2	A1	D1	D2
MC = Mass of empty, clean can(grams)	9	8	9	7	7
MCMS = Mass of can, and moist soil (grams)	62.9	52.9	74.9	72	94.5
MCDS = Mass of can, and dry soil (grams)	57	47	64	59	73
MS = Mass of soil solids (grams)	48	39	55	52	66
MW = Mass of pore water (grams)	5.9	5.9	10.9	13	21.5
W = Water content, w%	12.292	15.128	19.818	25	32.58

Table E-22: Density computation

Compacted Soil - Sample no.	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	12.292	15.128	19.818	25	32.58
Mass of compacted soil and mold (grams)	5665	5804	6076	6128	6074
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1260	1399	1671	1723	1669
Wet density, ρ , (g/cm3)	1.3347	1.482	1.7701	1.8252	1.768
Dry density, ρd , (g/cm3)	1.1886	1.2873	1.4773	1.4602	1.334
For saturation line(zero air void line s=100)					
Dry density, ρd (g/cm3)	1.18864	1.287	1.477	1.4601	1.3336
Saturated moisture contents (%)	46.816	40.37	30.375	31.171	37.672



Maximum dry density (g/cm^3) =1.48, Optimum moisture contents (%) =21.9

TP8-1@1.5

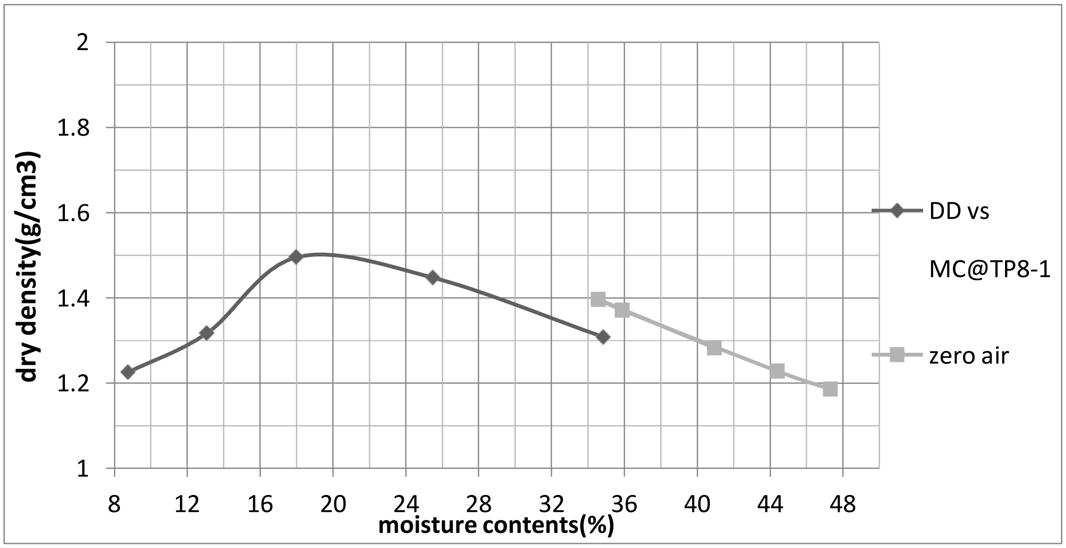
Sampling depth……………………………1.5m GS= 2.65

Table E-27 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	B1	A1	L2	D1	D2
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	61.2	53.1	73.9	71	97
MCDS = Mass of can, and dry soil (grams)	57	48	64	58	74
MS = Mass of soil solids (grams)	48	39	55	51	66
MW = Mass of pore water (grams)	4.2	5.1	9.9	13	23
W = Water content, w%	8.75	13.077	18	25.49	34.85

Table E-28 Density computation

Compacted Soil - Sample no.	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	8.75	13.077	18	25.49	34.85
Mass of compacted soil and mold (grams)	5663	5811	6071	6120	6071
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1258	1406	1666	1715	1666
Wet density, ρ , (g/cm3)	1.3326	1.4894	1.7648	1.8167	1.764
Dry density, ρd , (g/cm3)	1.2254	1.3172	1.4956	1.4477	1.308



Maximum dry density (g/cm^3) =1.49, Optimum moisture contents (%) =18

TP9-2@3m

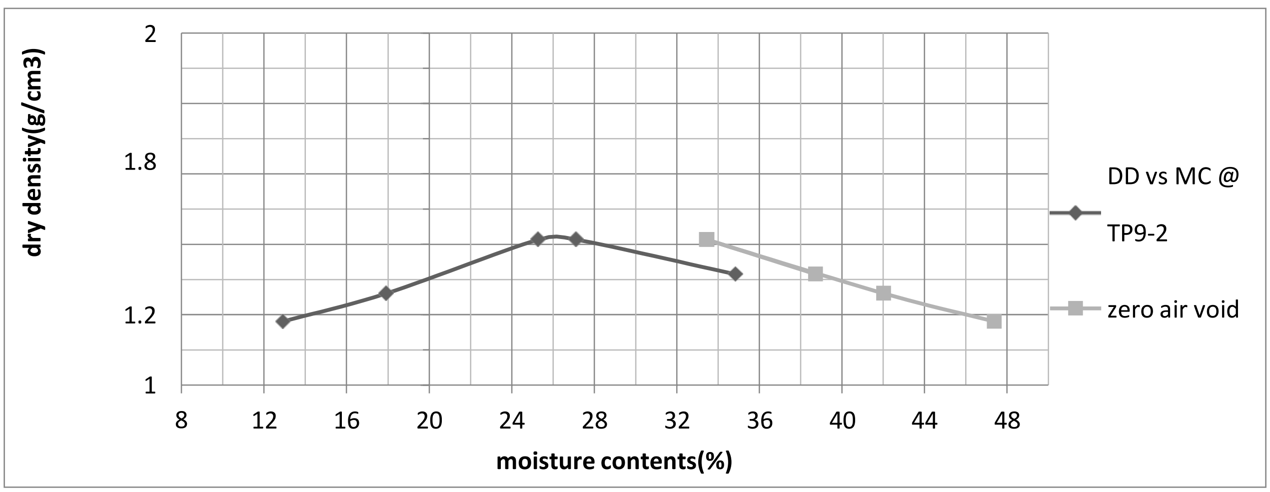
Sampling depth……………………………3m GS= 2.68

Table E-11 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	G2	D2	K1	D1	L1
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	63.2	54.99	77.9	73.1	97
MCDS = Mass of can, and dry soil (grams)	57	48	64	59	74
MS = Mass of soil solids (grams)	48	39	55	52	66
MW = Mass of pore water (grams)	6.2	6.99	13.9	14.1	23
W = Water content, w%	11.17	16.3	25.3	27.5	33.25

Table E-12: Density computation

Compacted Soil - Sample no.	1	2	3	4	5
W = Assumed water content, w%	8	16	22	26	30
Actual average water content, w%	11.17	16.3	25.3	27.5	33.25
Mass of compacted soil and mold (grams)	5663.5	5808	6075.8	6101	6079
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1258.5	1403	1670.8	1696	1674
Wet density, ρ , (g/cm3)	1.3332	1.4862	1.7699	1.7966	1.773
Dry density, ρd , (g/cm3)	1.1807	1.2603	1.4128	1.4134	1.315
For drawing saturation line(zero air void line s=100)					
Dry density, ρd (g/cm3)	1.1806	1.2603	1.412	1.413	1.3150
Saturated moisture contents (%)	47.3852	42.03	33.46	33.43	38.73



Maximum dry density (g/cm^3) =1.41, Optimum moisture contents (%) =25

TP10-1@1.5

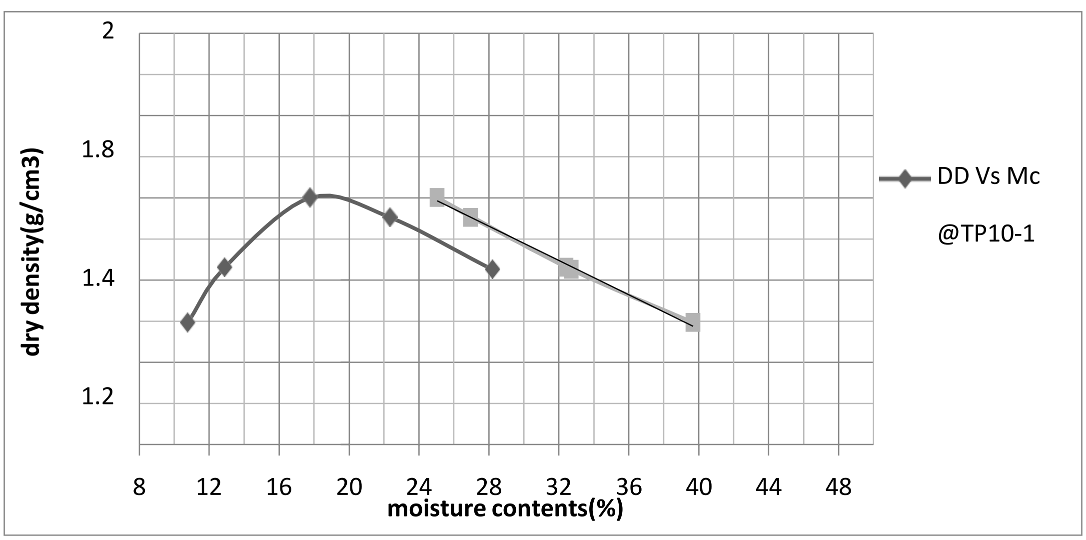
Sampling depth……………………………1.5m GS= 2.67

Table E-5 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	B4	A1	B1	D2	D1
MC = Mass of empty, clean can(grams)	7	9	9	10	8
MCMS = Mass of can, and moist soil (grams)	63.5	51.9	51.4	57.6	78.52
MCDS = Mass of can, and dry soil (grams)	58	47	45	48.9	63
MS = Mass of soil solids (grams)	51	38	36	38.9	55
MW = Mass of pore water (grams)	5.5	4.9	6.4	8.7	15.52
W = Water content, w%	10.764	11.995	18.12	21.85	28.22

Table E-6: Density computation

Determination No.	1	2	3	4	5
W = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	10.764	11.995	18.12	21.85	28.22
Mass of compacted soil and mold (grams)	5760.9	5930	6184	6197.9	6130
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1355.9	1525	1779	1792.9	1725
Wet density, ρ , (g/cm3)	1.4363	1.6155	1.8845	1.8993	1.828
Dry density, ρd , (g/cm3)	1.2965	1.4309	1.6001	1.5521	1.425
For saturation line(zero air void line s=100)					
Dry density, ρd (g/cm3)	1.2965	1.4309	1.6000	1.55212	1.425
Saturated moisture contents (%)	39.677	32.430	25.043	26.974	32.70



Maximum dry density (g/cm^3) =1.41, Optimum moisture contents (%) =18

TP10-2@3m

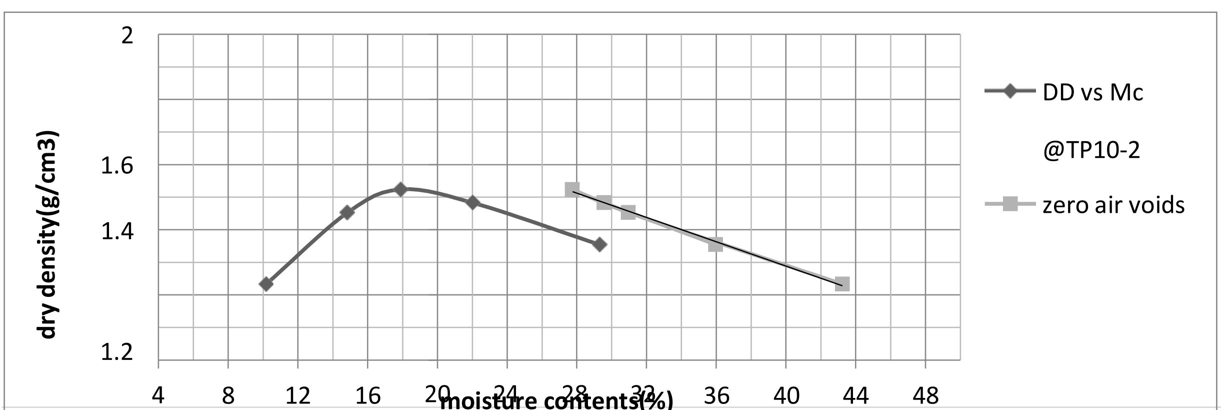
Sampling depth……………………………3m GS= 2.64

Table E-7 Water content computation

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	B2	L1	G1	D1	G1
MC = Mass of empty, clean can(grams)	60	61	60	60	61
MCMS = Mass of can, and moist soil (grams)	123.9	117.5	118.95	132	158
MCDS = Mass of can, and dry soil (grams)	118	110.2	110	119	136
MS = Mass of soil solids (grams)	58	49.2	50	59	75.01
MW = Mass of pore water (grams)	5.9	7.3	8.95	13	21.99
W = Water content, w%	11.02	13.137	17.9	22.034	28.92

Table E-8: Density computation

Compacted Soil - Sample no.	1	2	3	4	5
W= Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	11.02	13.137	17.9	22.034	28.92
Mass of compacted soil and mold (grams)	5687.2	5979.9	6101	6113	6058
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1282.2	1574.9	1696	1708	1653
Wet density, ρ , (g/cm3)	1.3583	1.6683	1.7966	1.8093	1.751
Dry density, ρd , (g/cm3)	1.2329	1.4528	1.5238	1.4826	1.35
Dry density, ρd (g/cm3)	1.232851	1.4527726	1.523842	1.482639	1.354
Saturated moisture contents (%)	43.2339	30.955109	27.7448	29.56852	35.97

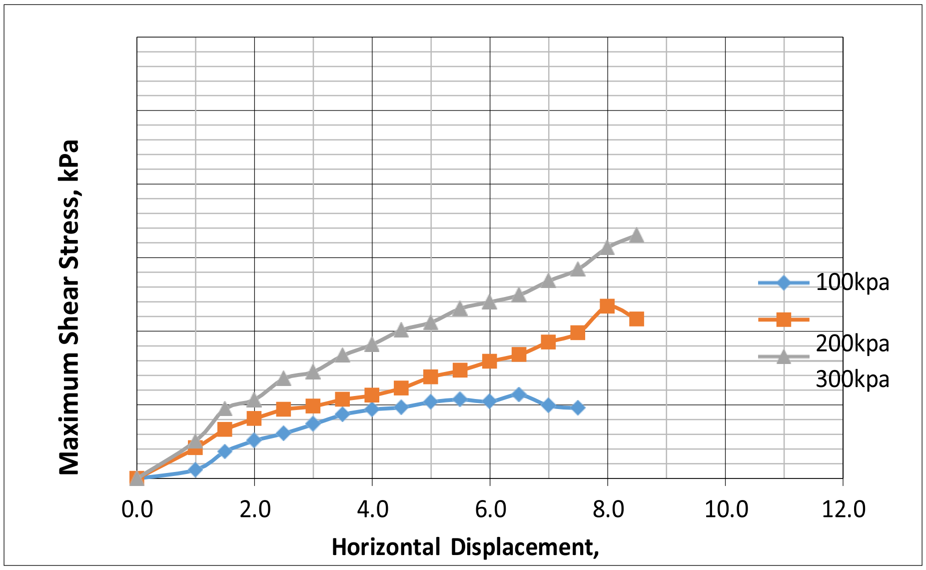


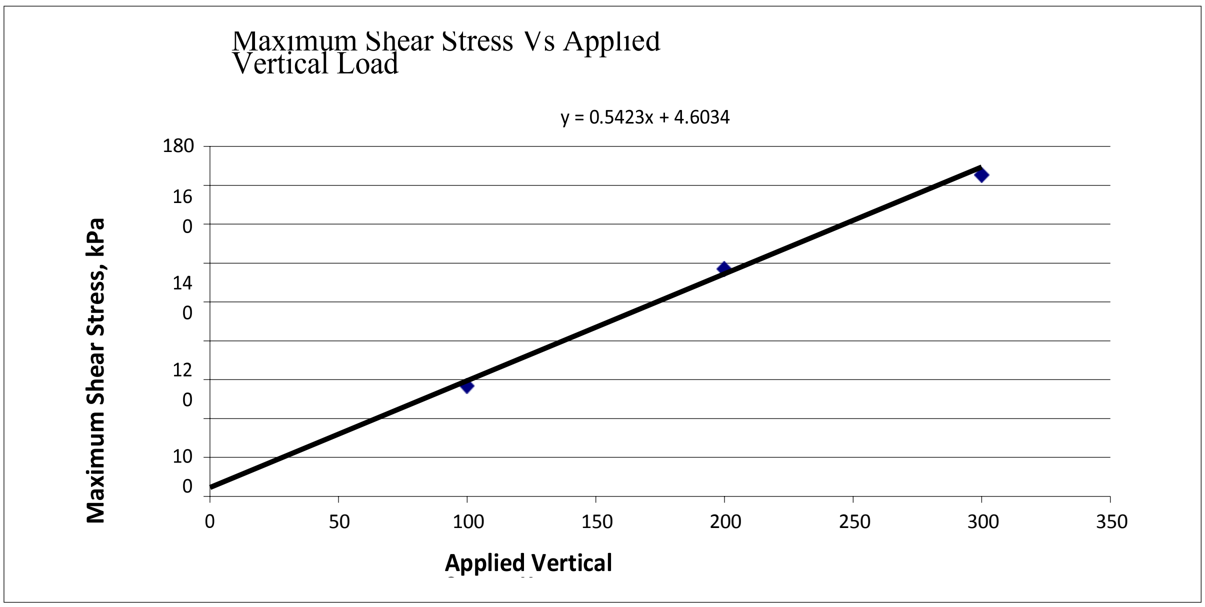
Appendix- F (Direct shear test)

Sample code and Depth =TP3-2@ 3m at iteya TVET college

thickness of sample=	25mm	ring calibration factors=0.70N/div		*stress(kpa)*
Length of sample	*60 mm*	*Rate of strain 1.6 mm/min*		*100*
Width of sample	*60 mm*	*optimum Moisture content(%)*	19	*200*
				300

		Applied Vertical Stress ***100 kpa***			*Applied Vertical Stress* ***200 kpa***			*Applied Vertical Stress* ***300 kpa***		
Horizontal Displacement [mm]	Corrected Area [mm2]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]
0.0	3600	0	0	0	0	0	0	0	0	0
1.0	3540	30	21	5.9322034	105	73.5	20.7627	129	90.3	25.5085
1.5	3510	92	64.4	18.347578	167	116.9	33.3048	238	166.6	47.4644
2.0	3480	128	89.6	25.747126	202	141.4	40.6322	266	186.2	53.5057
2.5	3450	151	105.7	30.637681	231	161.7	46.8696	335	234.5	67.971
3.0	3420	180	126	36.842105	240	168	49.1228	354	247.8	72.4561
3.5	3390	210	147	43.362832	260	182	53.6873	405	283.5	83.6283
4.0	3360	225	157.5	46.875	271	189.7	56.4583	437	305.9	91.0417
4.5	3330	230	161	48.348348	292	204.4	61.3814	480	336	100.901
5.0	3300	245	171.5	51.969697	325	227.5	68.9394	500	350	106.061
5.5	3270	251	175.7	53.730887	343	240.1	73.4251	540	378	115.596
6.0	3240	242	169.4	52.283951	368	257.6	79.5062	555	388.5	119.907
6.5	3210	261	182.7	56.915888	386	270.2	84.1745	572	400.4	124.735
7.0	3180	225	157.5	49.528302	421	294.7	92.673	610	427	134.277
7.5	3150	215	150.5	47.777778	445	311.5	98.8889	640	448	142.222
8.0	3120				521	364.7	116.891	700	490	157.051
8.5	3090				478	334.6	108.285	730	511	165.372
				56.91589			**116.89**			**165.37**





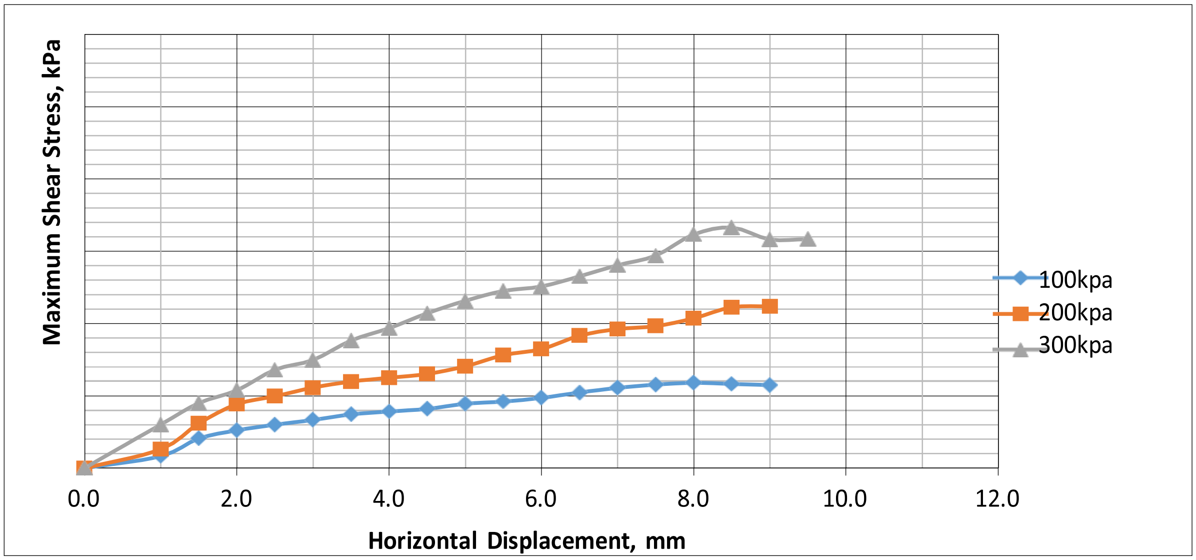
TP3-2@3m,C= **4.603KN/m2** Ø =than^{-1}(0.5423) = **28.47^{o}**

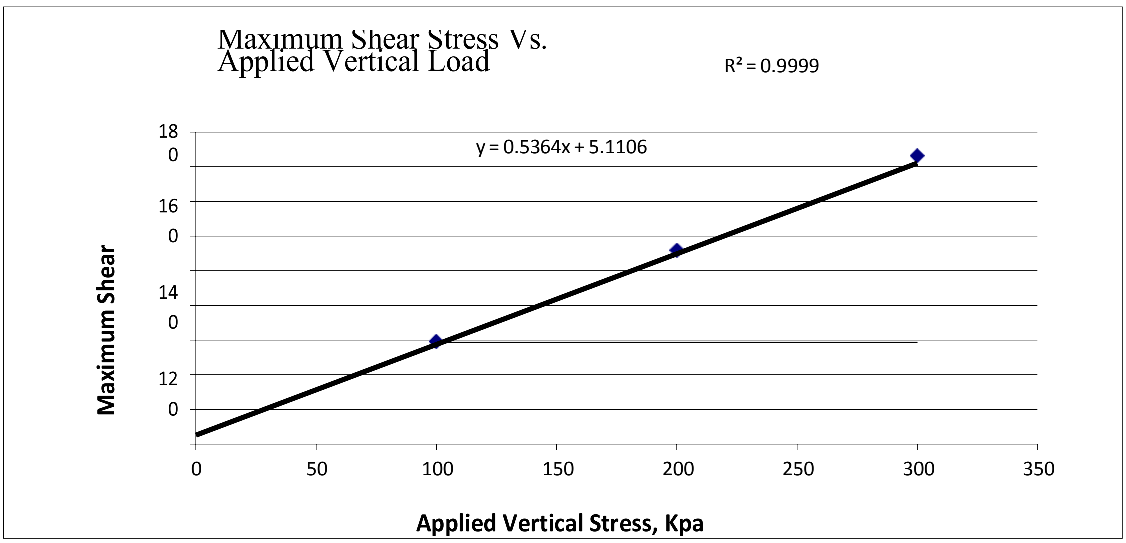
Sample code and Depth= TP4-2@3m at Bus station

Thickness of sample=25mm		ring calibration factors=0.70N/div		stress (kpa)	weght of soil		
Length of sampl	60 mm	Rate of strain	1.6 mm/min	100	158.8	gm	
Width of sample=	60 mm	optimum Moisture content	18	200	159	gm	

300 161 gm

		Applied Vertical Stress ***100kpa***			*Applied Vertical Stress* ***200kpa***			*Applied Vertical Stress* ***300 kpa***		
Horizontal Displacement[mm]	Corrected Area [mm2]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]	Proving Ring Reading	Shear Load [N]	Shear Stress [kPa]
0.0	3600	0	0	0	0	0	0	0	0	0
1.0	3540	42	29.4	8.3050847	66	46.2	13.0508	152	106.4	30.0565
1.5	3510	103	72.1	20.541311	155	108.5	30.9117	225	157.5	44.8718
2.0	3480	130	91	26.149425	220	154	44.2529	267	186.9	53.7069
2.5	3450	148	103.6	30.028986	245	171.5	49.7101	335	234.5	67.971
3.0	3420	163	114.1	33.362573	272	190.4	55.6725	365	255.5	74.7076
3.5	3390	180	126	37.168142	290	203	59.882	427	298.9	88.1711
4.0	3360	188	131.6	39.166667	300	210	62.5	464	324.8	96.6667
4.5	3330	195	136.5	40.990991	310	217	65.1652	509	356.3	106.997
5.0	3300	210	147	44.545455	332	232.4	70.4242	545	381.5	115.606
5.5	3270	215	150.5	46.024465	365	255.5	78.1346	572	400.4	122.446
6.0	3240	225	157.5	48.611111	381	266.7	82.3148	581	406.7	125.525
6.5	3210	240	168	52.336449	420	294	91.5888	608	425.6	132.586
7.0	3180	252	176.4	55.471698	437	305.9	96.195	637	445.9	140.22
7.5	3150	260	182	57.777778	442	309.4	98.2222	661	462.7	146.889
8.0	3120	263	184.1	59.00641	462	323.4	103.654	720	504	161.538
8.5	3090	257	179.9	58.220065	491	343.7	111.23	734	513.8	166.278
9.0	3060	251	175.7	57.418301	489	342.3	111.863	691	483.7	158.072
9.5	3030							685	479.5	158.251
				59.00641			**111.86**			**166.28**





TP4-2@3m, C= **5.11 KN/m2** Ø =than^{-1}(0.51106) = **27.09°**

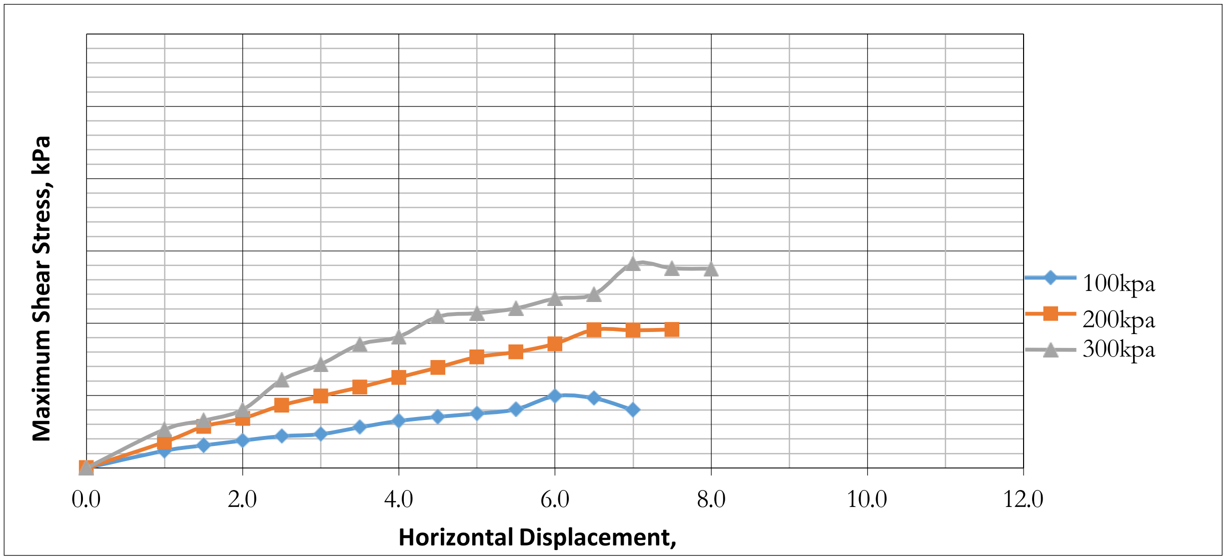
Sample Code And Depth =TP5-2@3m at high school

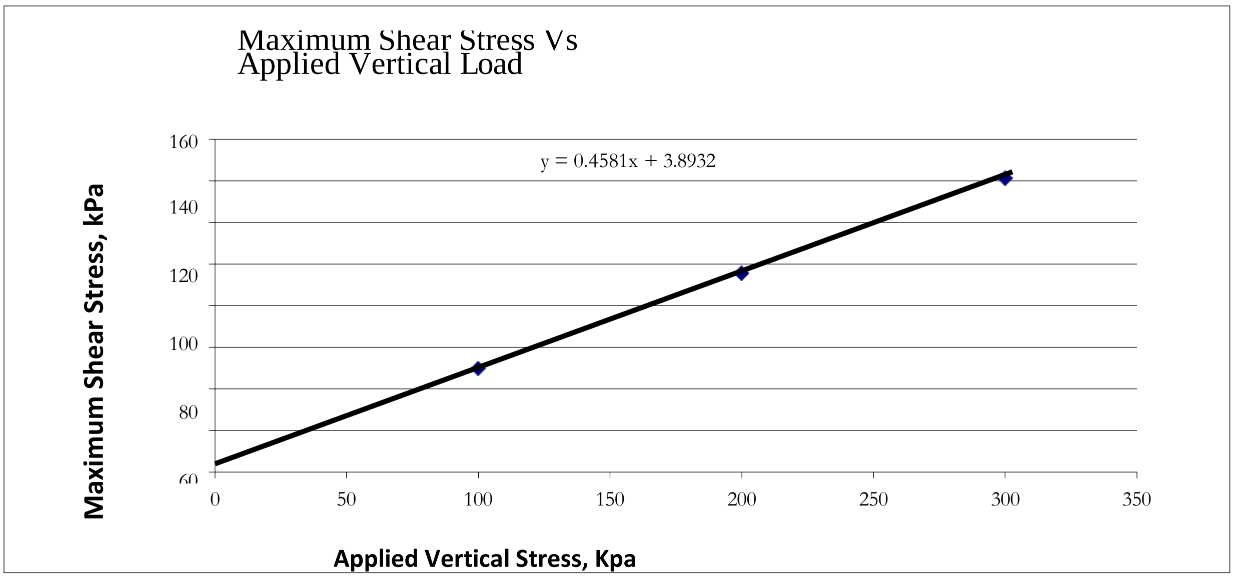
Thickness of Sample25mm Ring Calibration Factors=0.70n/Div

Length Of Sample *60 Mm* *Rate Of Strain 1.6 Mm/Min*

Width Of Sample *60 Mm* *Optimum Moisture Content(%)* 22

		Applied Vertical Stress ***100kpa***			*Applied Vertical Stress* ***200 kpa***			*Applied Vertical Stress* ***300 kpa***		
Horizontal Displacement[mm]	Corrected Area[mm2]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]
0.0	3600	0	0	0	0	0	0	0	0	0
1.0	3540	54	37.8	10.677966	83	58.1	16.4124	120	84	23.7288
1.5	3510	73	51.1	14.558405	137	95.9	27.3219	158	110.6	31.51
2.0	3480	95	66.5	19.109195	169	118.3	33.9943	200	140	40.2299
2.5	3450	113	79.1	22.927536	210	147	42.6087	290	203	58.8406
3.0	3420	119	83.3	24.356725	239	167.3	48.9181	350	245	71.6374
3.5	3390	132	92.4	27.256637	265	185.5	54.7198	410	287	84.6608
4.0	3360	149	104.3	31.041667	296	207.2	61.6667	435	304.5	90.625
4.5	3330	161	112.7	33.843844	321	224.7	67.4775	500	350	105.105
5.0	3300	169	118.3	35.848485	348	243.6	73.8182	504	352.8	106.909
5.5	3270	173	121.1	37.033639	373	261.1	79.8471	515	360.5	110.245
6.0	3240	178	124.6	38.45679	384	268.8	82.963	536	375.2	115.802
6.5	3210	172	120.4	37.507788	418	292.6	91.1526	543	380.1	118.411
7.0	3180				427	298.9	93.9937	549	384.3	120.849
7.5	3150							550	385	122.222
8.0	3120							543	380.1	121.827
				38.45679			**93.994**			**122.22**



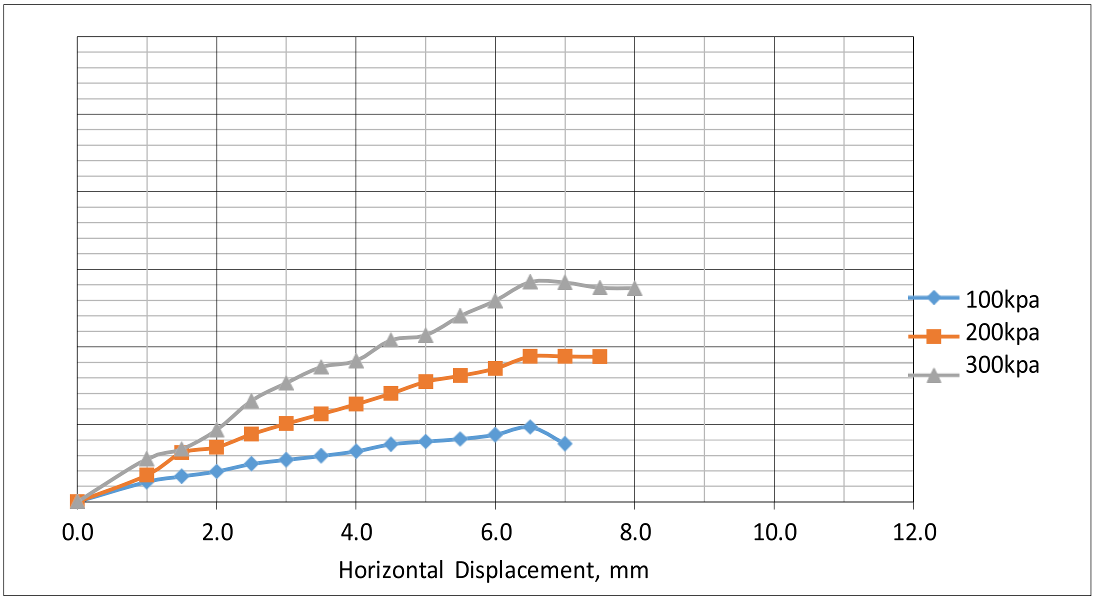


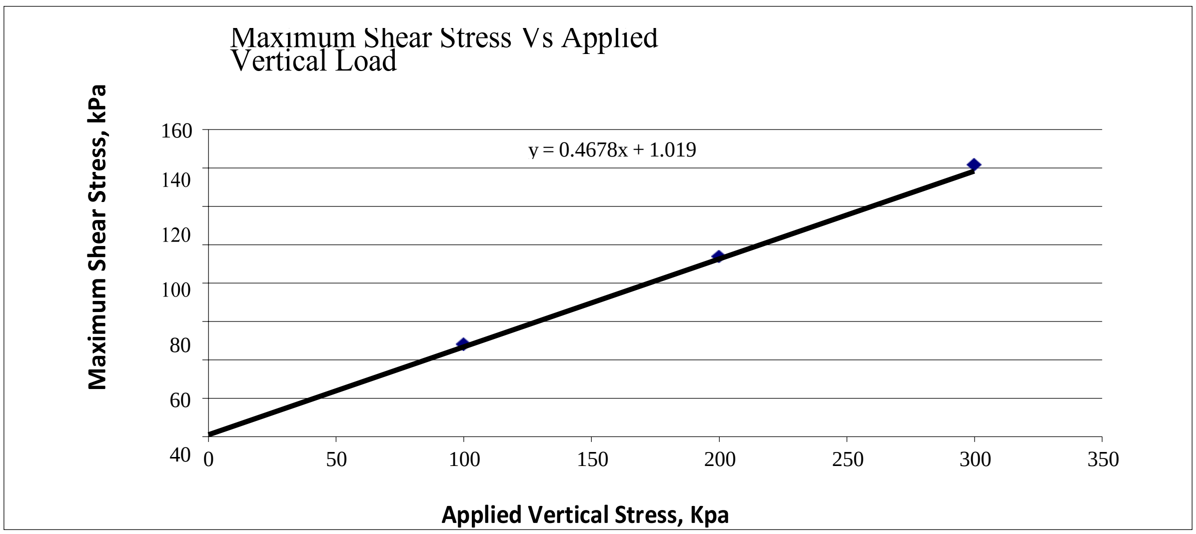
TP5-2@3m, C= **3.8932 KN/m2** Ø =than^{-1}(0. 4581) =**24.61^{o}**

Sample Code And Depth =TP6-2 @3m

Thickness Of Sample=	25mm	Ring Calibration Factors=0.70n/Div
Length Of Sample	*60 Mm*	*Rate Of Strain 1.6 Mm/Min*
Width Of Sample	*60 Mm*	*Optimum Moisture Content(%)* 22

		Applied Vertical Stress ***100kpa***			*Applied Vertical Stress* ***200 kpa***			*Applied Vertical Stress* ***300 kpa***		
Horizontal Displacement[mm]	Corrected Area[mm2]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]
0.0	3600	0	0	0	0	0	0	0	0	0
1.0	3540	65	45.5	12.853107	87	60.9	17.2034	140	98	27.6836
1.5	3510	82	57.4	16.353276	159	111.3	31.7094	170	119	33.9031
2.0	3480	97	67.9	19.511494	175	122.5	35.2011	230	161	46.2644
2.5	3450	120	84	24.347826	215	150.5	43.6232	321	224.7	65.1304
3.0	3420	132	92.4	27.017544	246	172.2	50.3509	374	261.8	76.5497
3.5	3390	143	100.1	29.528024	274	191.8	56.5782	421	294.7	86.9322
4.0	3360	156	109.2	32.5	302	211.4	62.9167	436	305.2	90.8333
4.5	3330	176	123.2	36.996997	332	232.4	69.7898	496	347.2	104.264
5.0	3300	183	128.1	38.818182	365	255.5	77.4242	506	354.2	107.333
5.5	3270	189	132.3	40.458716	380	266	81.3456	560	392	119.878
6.0	3240	200	140	43.209877	398	278.6	85.9877	600	420	129.63
6.5	3210	221	154.7	48.193146	430	301	93.7695	650	455	141.745
7.0	3180	170	119	37.421384	426	298.2	93.7736	642	449.4	141.321
7.5	3150				421	294.7	93.5556	621	434.7	138
8.0	3120							614	429.8	137.756
				48.19315			**93.774**			**141.74**





<u>TP6-2@3m</u>, C= **<u>1.019 KN/m2</u>** Ø =than^{-1}(0.4678) = **<u>25.07^{o}</u>**

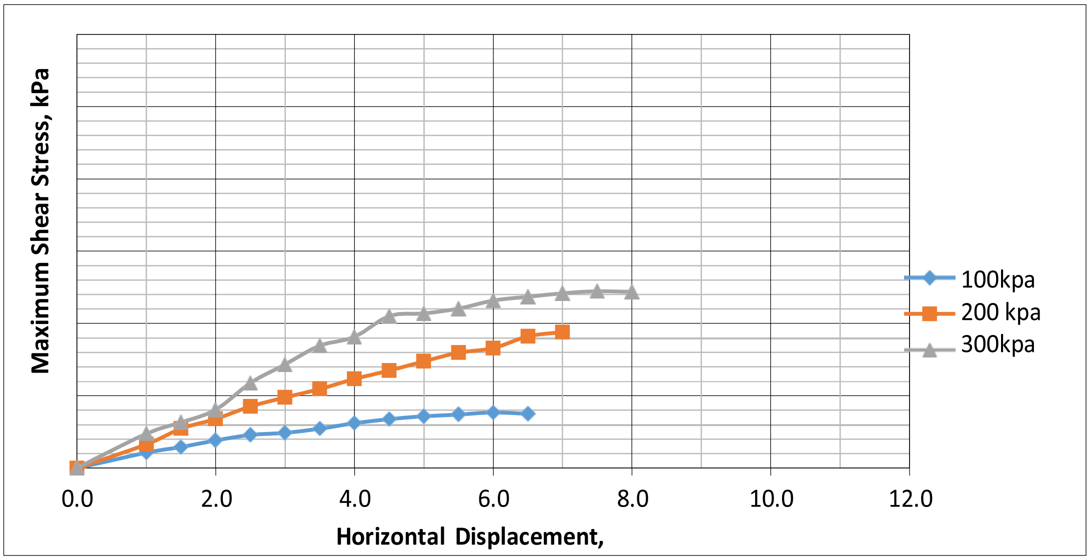
Sample <u>Code And Depth =TP7-2@3m</u>

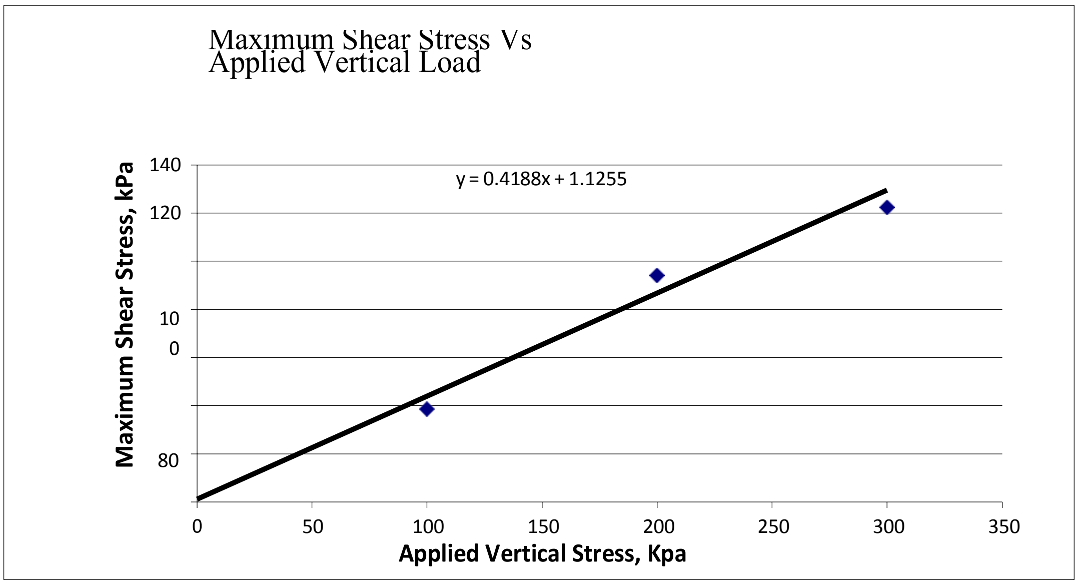
Thickness of Sample25mm Ring Calibration Factors=0.70n/Div

Length Of Sample 60 Mm Rate Of Strain 1.6 Mm/Min

Width Of Sample 60 Mm Optimum Moisture Content(%) 22

		Applied Vertical Stress ***100kpa***			*Applied Vertical Stress* ***200 kpa***			*Applied Vertical Stress* ***300 kpa***		
Horizontal Displacement[mm]	Corrected Area[mm2]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]
0.0	3600	0	0	0	0	0	0	0	0	0
1.0	3540	54	37.8	10.677966	83	58.1	16.4124	120	84	23.7288
1.5	3510	73	51.1	14.558405	137	95.9	27.3219	158	110.6	31.51
2.0	3480	95	66.5	19.109195	169	118.3	33.9943	200	140	40.2299
2.5	3450	113	79.1	22.927536	210	147	42.6087	290	203	58.8406
3.0	3420	119	83.3	24.356725	239	167.3	48.9181	350	245	71.6374
3.5	3390	132	92.4	27.256637	265	185.5	54.7198	410	287	84.6608
4.0	3360	149	104.3	31.041667	296	207.2	61.6667	435	304.5	90.625
4.5	3330	161	112.7	33.843844	321	224.7	67.4775	500	350	105.105
5.0	3300	169	118.3	35.848485	348	243.6	73.8182	504	352.8	106.909
5.5	3270	173	121.1	37.033639	373	261.1	79.8471	515	360.5	110.245
6.0	3240	178	124.6	38.45679	384	268.8	82.963	536	375.2	115.802
6.5	3210	172	120.4	37.507788	418	292.6	91.1526	543	380.1	118.411
7.0	3180				427	298.9	93.9937	549	384.3	120.849
7.5	3150							550	385	122.222
8.0	3120							543	380.1	121.827
				38.45679			**93.994**			**122.22**





TP7-2@1.5, C= **1.125 KN/m2** Ø =than^{-1}(0.4188) =**22.72º**

Sample Code And Depth =TP8-2@3m

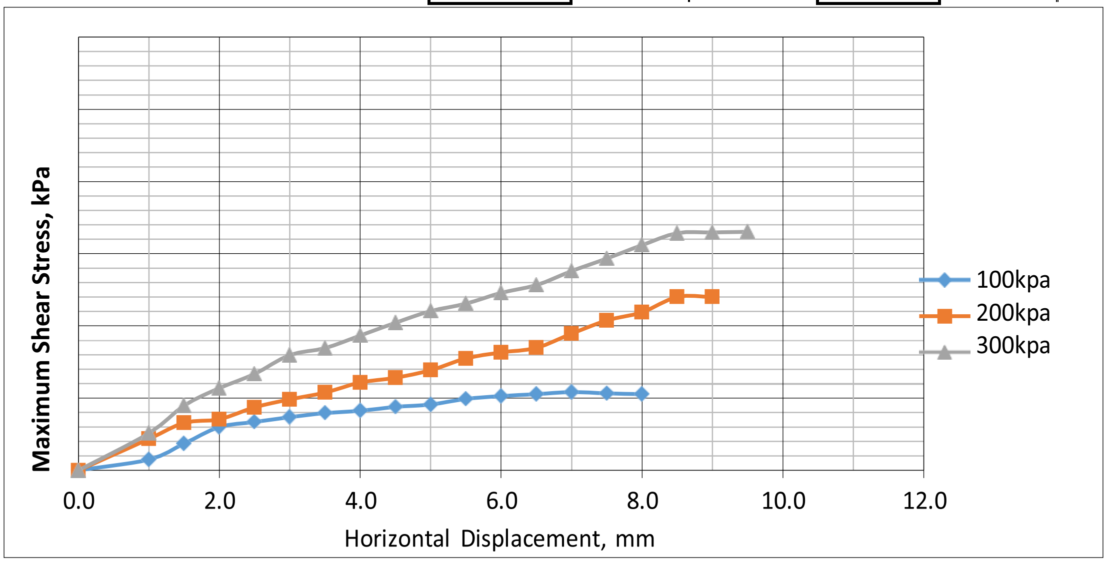
ThicknessOfSample= 25mm Ring Calibration Factors=0.70n/Div

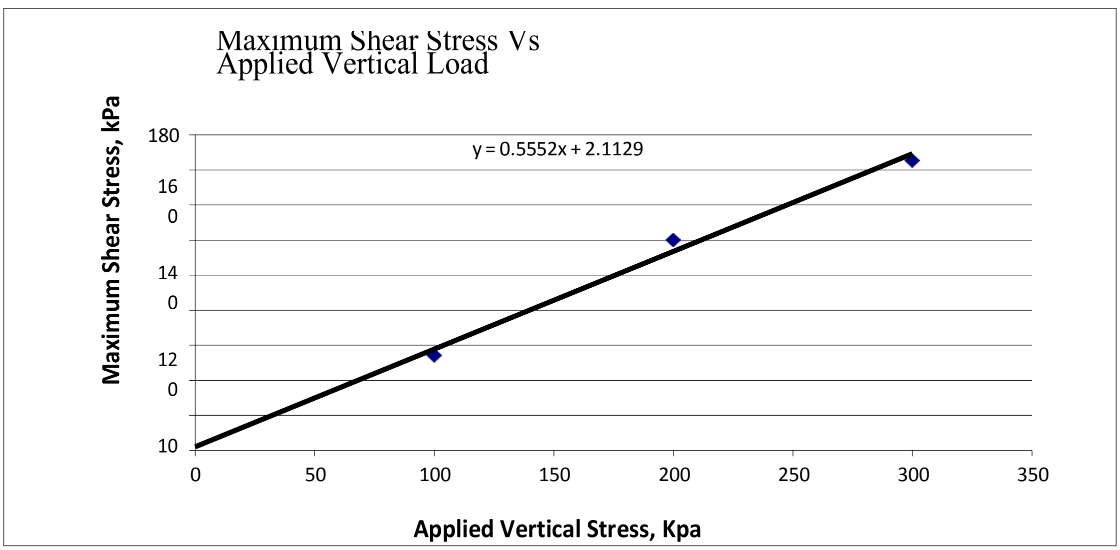
Length Of Sample *60 Mm* *Rate Of Strain 1.6 Mm/Min*

Width Of Sample *60 Mm* *Optimum Moisture Content(%)* 22

		Applied Vertical Stress ***100kpa***			*Applied Vertical Stress* ***200 kpa***			*Applied Vertical Stress* ***300 kpa***		
Horizontal Displacement[mm]	Corrected Area[mm2]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]	Proving RingReading	Shear Load[N]	Shear Stress[kPa]
0.0	3600	0	0	0	0	0	0	0	0	0
1.0	3540	38	26.6	7.5141243	110	77	21.7514	130	91	25.7062
1.5	3510	93	65.1	18.547009	165	115.5	32.906	225	157.5	44.8718
2.0	3480	149	104.3	29.971264	176	123.2	35.4023	283	198.1	56.9253
2.5	3450	165	115.5	33.478261	215	150.5	43.6232	329	230.3	66.7536
3.0	3420	180	126	36.842105	240	168	49.1228	390	273	79.8246
3.5	3390	192	134.4	39.646018	261	182.7	53.8938	410	287	84.6608
4.0	3360	198	138.6	41.25	292	204.4	60.8333	448	313.6	93.3333
4.5	3330	209	146.3	43.933934	305	213.5	64.1141	486	340.2	102.162
5.0	3300	215	150.5	45.606061	327	228.9	69.3636	520	364	110.303
5.5	3270	231	161.7	49.449541	362	253.4	77.4924	539	377.3	115.382
6.0	3240	238	166.6	51.419753	378	264.6	81.6667	569	398.3	122.932
6.5	3210	242	169.4	52.772586	389	272.3	84.8287	588	411.6	128.224
7.0	3180	246	172.2	54.150943	430	301	94.6541	627	438.9	138.019
7.5	3150	240	168	53.333333	467	326.9	103.778	660	462	146.667
8.0	3120	235	164.5	52.724359	488	341.6	109.487	695	486.5	155.929
8.5	3090				530	371	120.065	725	507.5	164.239
9.0	3060				525	367.5	120.098	720	504	164.706

9.5	3030							715	500.5	165.182
				54.15094			**120.1**			**165.18**





TP8-2@3m, C= **2.113. KN/m2** Ø =than^{-1}(0.5052) = **28.899^{o}**