ADAMA SCIENCE AND TECHNOLGY UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CIVIL ENGINEERING

INVESTIGATION ON SOME ENGINEERING PROPERTIES OF SOILS OF DERA TOWN

A Thesis Submitted to the School of Graduate Studies of Adama Science and Technology University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Civil Engineering (Geotechnical Engineering)

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Adama. Ethiopia

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DECLARATION

I state that this thesis is my original work performed under the supervision of my research advisor Dr.Yedata Chemdesa and has not been presented as a thesis for a degree in any other university, and that all sources of materials used for this idea have also been acknowledged.

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ABBREVIATIONS AND SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society of Testing and Materials
ASTU	Adama Science and Technology University
CBR	California bearing ratio test
Cc	Coefficient of curvature
Cu	Coefficient of curvature
LL	Liquid Limit
MDD	Maximum Dry Density
N	Number of drops
NP	None plastic
OMC	Optimum Moisture Content
PI	Plastic index
PL	Plastic Limit
SC	Clayey sand
SM	Silty Sand
USCS	Unified Soil Classification System
TP	Test pit

ABSTRACT

Dera town is geographically located in the eastern Ethiopia and it is the transit on the road from the capital town of Addis Ababa and Adama to Assela.Due to its location, investors are attracted to construct in the town. A lot of civil engineering structures are under construction; however, as many town of Ethiopia, the engineering properties of the soil underlying town are not well known with respect to the intended urban development plan. This study is, therefore, conducted with the intention to assess the index properties and some of the engineering characteristics of soil of the town. The undisturbed samples for determination of natural moisture contents and disturbed samples for free swell test, grain size analysis, Atterberg limit test, specific gravity, compaction, sample prepared from compacted sample for direct shear test using standard Procter test.

The grain size analysis test result showed that the dominant proportion of soil particle in the study area is coarse-grained soils, which have clay content ranging from 0.7-6%, silt faction 7.89-15.4%, sand fraction 62-86.10% and gravel fraction 1.8-27.20%. According to atterberg limit test, the liquid limit ranges from 14 to 20.3 %, plastic limit ranges from 14.17 to 17.92% % and plastic index from non-plastic to 4.7%.The specific gravity ranges from 2.60-2.68. Free swell value in percent ranges from 1-20%. The moisture content of the soils ranges from 14-26.92% and the optimum moisture content (OMC) and maximum dry density (MDD) varies from 18 to 26% and 1.4 to1.6 g/cm^3, respectively. The shear strength parameters, cohesion (C) and internal friction angle (ϕ), determined from direct shear test varies from 1.019 to 7.95 kPa and 22.7° to 29.7°, respectively. The samples were collected from the site had been conducted in laboratory and classified according to USCS and AASHTO.

The soil in the study was silty sand(SM) and poorly graded sand with clay and gravel soil as per USCS and A-2-4 and A-3 as per AASHTO and the soil is suitable for road way pavement as per AASHTO soil classification system. Generally the result of this study indicates that the soils of the study area possess desirable engineering characteristics i.e. low compressibility, good shear strength, low plasticity and less susceptible to shrinkage and swelling with variation of moisture content. The outcome of this thesis may be applicable in different civil Engineering sectors, especially for preliminary investigations and prefeasibility study of Civil Engineering works such as foundation work, Earth dams, Earth fills, and other works that involve soils.

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the problem

For the country like Ethiopia, wherever population increase at higher rate needs to assign huge amount of resources for construction works to convene the growing demand for shelter and other related facilities such as road networks. This effort should be accompanied by strict and professionally ethical quality assurance and supervision of construction. 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., 2004).The success or failure of a foundation depends essentially on the reliability of the various soil parameters obtained from the field investigation and laboratory tests, as it is used as an input into the design of foundations for all types of large and small building.

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 topography, climate, parent material, the fabric (internal structure) and degree of weathering. The investigation is; therefore, need to be carried out locally for different towns. Dera is one of the fast growing towns in our country and it is the transit on the road from the capital town Addis Ababa and Adama to the Assela. It is about 120km far from Addis Ababa. Due to its location and near distance from Adama and other recreation center like Sodere, investors are attracted to construct in the town. However, the engineering property of the soil of the town like shear strength, which is one of the fundamental parameter for computation of bearing capacity and prerequisite for proper design of engineering structures, is not studied.

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 Objectives of the Study

1.2.1. General objective

The general objective of the study is to investigate, analyze and characterize some of the engineering properties of soils underlying the Dera town. This can be achieved by careful and through scientific look at the test and investigation results that have been collected during both preliminary and detailed study.

1.2.2. Specific objectives

- To investigate the index properties of the soil like: specific gravity, natural moisture content, consistency limits, and grain size analysis, swelling potential and compaction characteristics.
- To classify the soils according to both AASHTO and USCS.
- To determine the shear strength characteristic of soils in the town.

1.3 Methodology

To achieve the above objectives, different activities were conducted in different three stages such as Pre-field work, Field work and Post field work.

Pre-field work

Literature review of previous related works with regard to investigation of the index property and engineering properties of the soil, gathering important data (topographic and geological map), different books, technical papers, journals and different thesis at pre field work are reviewed at the beginning of the work were the major activities in the first stage.

Field work

The Location of the sampling area is selected and the test pits were bored at different selected locations and disturbed and undisturbed samples were collected. GPS reading would be taken to locate the coordinate of the sampling site at this stage. The samples were handled carefully to prevent sample disturbance, change in cross section, or loss of water content during transportation to the laboratory.

Post field work

Proper data Organization and integration of the collected field data and Laboratory test are conducted for different test below. The soil samples oven dried for drying for twenty four hours or air dry before conducting the following laboratory tests:

Atterberg Limits: The liquid limit, plastic limit, and plasticity index for each type of soil was determined according to ASTM D-4318-98 (Standard Test Method for Liquid Limit, Plastic Limit and Plasticity Index of Soils). The standard four-point method for determining the liquid limit was used for all tests.

Grain Size Analysis: was conducted according to ASTM D 422-63- Standard Test Method for Particle-Size Analysis of Soils. The grain size distribution for soil particles finer than 0.075mm was determined using 152H Hydrometer (Standard Test Method for Amount of Material in the Soil Finer than the No. 200 Sieve).

Specific Gravity: The specific gravity of each type of soil was determined according to ASTM D-854-00(Standard Test Method for Specific Gravity of Soils). The precision and bias of each pair of tests were investigated and all are within the ASTM accepted range.
The compaction test and the direct shear test also conducted from the dry sample in laboratory using standard proctor compaction test and direct shear box, respectively

All the tests were conducted according to American Society for Testing Materials (ASTM) standards indicated in Table 1.1

Table 1.1. American Society for Testing Material standards for different lab tests

Test code	Description
ASTM D 422	Test Method for Particle-Size Analysis of Soils
ASTM D 698,metho A	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (600kN-m/m3))
ASTM D 2216	Test Method for Laboratory Determination of Water(Moisture) Content of Soil and Rock
ASTM D 2487	Classification of Soils for Engineering Purposes(Unified Soil Classification System)
ASTM D 2488	Practice for Description and Identification of Soils(Visual-Manual Procedure)
ASTM D 4318	Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTMD 854-98	Test Method for specific gravity
ASTM D-4220	Standard Practice for Preserving and Transporting of Soil samples

1.4 Organization of the Study

This thesis work is organized under five chapters. The first chapter is introduction part which includes the back ground, objective of the study and methodology of different activity while conducting the thesis work. Chapter two deals with review of the literatures for studying the accepted theories and practices in the related topics. Chapter three describes the field investigation and soil sampling procedure which includes site selection for sampling, visual soil identification and sampling methods, and description of study area. In chapter four, laboratory tests conducted and discussion on the laboratory results obtained from this work and comparison with previously done researches is covered in chapter four. Chapter five covers the conclusions and recommendations drawn from the research. Finally, data for the direct shear test results, compaction, atterbrg limits, specific gravity, and log test for soil profiles and test result for each test pits are included in appendix.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Index Properties

The tests required for determination of engineering properties (permeability, compressibility and shear strength) are generally elaborated and time consuming. Sometimes the geotechnical engineers are 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 should be understood by conducting tests on physical attributes of the soil particle and soil aggregate constituents. The physical properties of soils which serve mainly for identification and classification purpose are commonly known as index properties which can be determined by simple laboratory tests. Index property tests are grain size analysis, specific gravity, Atterberg limits and free swell. (Arora., 2004) .Index properties of cohesive soils are used to characterize the physical and mechanical behaviors of soils by using moisture content, specific gravity, particle size distribution, Atterberg limits and moisture density relationships (Fredrics, 1983).

2.1.1. Grain Size Analysis

Grain size analysis is used to determine the effective diameter of the soil particles that constitute and strongly affect the uniformity characteristics of the soil mass. For coarse grained materials, the grain size distribution is determine 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, 2000).

2.1.2. Natural Moisture Content

The water content is the ratio of the mass of water to the mass of dry solid. It is the most common measure of characterizing the condition of clay, important for classification purpose, general description and describing consistency (John J.Germaine et al., 2009). The procedure of determination of water content is measuring of the mass of moist specimen, over drying, allowing the specimen to cool. This method is described in ASTM D2216. Change in moisture content is the most influential parameter that affects the property of soils. In fine grained (cohesive) soils, the consistence of a given soil type depends on its water content. The moisture content test is conducted in laboratory as per the procedures of ASTM D2216. Most natural soils, which are sandy and gravelly in nature, may have water contents up to about 15 to 20%. In natural fine-grained (silty or clayey) soils, water contents up to about 50 to 80% can be found. However, peat and highly organic soils with water contents up to about 500% are not uncommon (Das, 2002).

Table 2.1 Typical Values of Natural Water Content in a, Saturated State

Soil	Natural water contents in saturated state (%)
Loose uniform sand	25-30
Dense uniform sand	12-16
Loose angular-grained silty sand	25
Dense angular-grained silty sand	15
Stiff Clay	20
Soft Clay	30-50
Soft inorganic clay	80-130
Glacial till	10

2.1.3Atterberg Limits

Atterberg limit is a water content at which the soil changes from one state to the other state. In1911, a Swedish engineer Atterberg mentioned that a fined grained soil can exist in liquid, plastic, semi-solid and solid state (Arora., 2004).

At the same water content, different soils may have different consistency limit. Thus consistence limits are very important index properties of fine grained soils. The three Atterberg limits such as liquid limit, plastic limit and shrinkage limits are the boundary at which three phases such as liquid to plastic, plastic to semi-plastic and semi plastic to solid is changed respectively.

Liquid limit: the liquid limit (LL) is a water content at which the soil changes from liquid state to plastic state. The liquid limit is determined in the laboratory by either casagrande's or by cone penetration method. In the present work, the test was conducted by Casagrande method. According to this method, 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 ASTM D4318 test procedures. About 120gm of an air drained sample passing 425µm (No-40) sieve is used to conduct the test (Arora., 2004).The liquid limit of soil depends up on the type of clay minerals constitute the soil.

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 ASTM D4318. The shear strength at the plastic limit is about 100 times that of the liquid limit. (Arora., 2004).

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., 2004) .

The greater the plasticity index meaning that the soil is more plastic, compressible and the greater volume change characteristic of the soil (table 2.2).

Table 2.2 Typical Values of Natural Water Content in a, Saturated State (Murthy, 1990)

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

Table 2.3 Typical Atterberg Limits for Soils (Budhu, 1999)

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

2.1.4 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 (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, 20˚C is typically used as the reference temperature because this is the most common application temperature. 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). The typical specific gravity value for different types of soils is summarized in Table 2.4.

Table 2.4 General ranges of Gs for different soils (Das, 2002).

Soil type	Range of Gs
Sand	2.63-2.67
Silts	2.65-2.7
Clay and silty clay	2.67-2.9
Organic soil	Less than 2

At least three specific gravity tests should be conducted for obtaining correct result, these values should not varies by more than 2 to 3% (Das, 2002).

2.2 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., 2004)

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 determine 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, 2000).

Currently, two elaborate classification systems are commonly used by soil engineers. Both systems take into consideration the particle size distribution and Atterberg limits. They are the American Association of State Highway and Transportation Officials (AASHTO) classification system and Unified Soil Classification system (USCS). The USCS classify the soil into two major types of soil i.e. coarse and fine grained soil depending on particle size which pass in sieve size for number 200(0.075mm),according to chart on appendix(G}

In AASHTO classification system, the soils are rated according to their suitability for support roadway pavement. It is a textural-plasticity classification that uses Atterberg Limits test results such as liquid limits and plastics index of the soil and sieve analysis like percentage passing in number 10, 40, and 200 sieves which has the size of 2mm, 0.425mm and 0.075mm respectively. It classifies the soils to seven main groups and several subgroups. The classification is more specific than the USC system. In the limits placed on Silt-Clay (fine-grained) soils as required by soil gradations, rather than using the No.4 sieve (4.75 mm) of the USC system as the upper limit of the sand-size range, the AASHTO classification uses the No. 10 sieve (2.0 mm) as the upper size limit of sand. However, the No. 200 sieve (0.075 mm) used in the (Arora, 2004). USC system is retained to separate the finer fractions from sand.

2.3 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, 2004).

Table 2.5 Range of optimum water content (Arora, 2003)

Soil type	sand	Sandy silt or silty sand	Silt	Clay
Optimum Moisture contents	6 to 10%	8 to 12%	12 to 16%	14 to 20%

Table 2.6 Typical values of dry density (Arora., 2004)

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

2.4 Shear Strength

2.4.1 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. 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. There is hardly a problem in the field of engineering which does not involve the shear properties of the soil in some manner or the other. The safety of any geotechnical structure is dependent on the strength of the soil. If the soil fails, a structure founded on it can collapse, endangering lives and causing economic damage. Shear strength of a soil is the internal frictional resistance of a soil to shearing forces. 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., 2004).

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 is used in this study to determine the shear strength parameters as all the soils under the study are coarse grained soil.

2.4.2 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 test can be performed on an undisturbed sample or remolded samples. The main advantage of direct shear test is its simplicity and smoothness in operation and the rapidity of testing program. But this test has the disadvantage that lateral pressure and stress on planes other than the plane of shear are not known during test (Arora, 2004). In addition, the sample is forced to fail along predetermined failure plane which may not be the weakest plane in the soil mass. The typical internal friction angle for sand and silt are tabulated in Table 2.2.

Table 2.7.Typical values of drained angle of friction for sands and silts (Arora, 2004).

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

CHAPTER THREE

3. FIELD INVESTIGATION AND SOIL SAMPLING

3.1. Identification of Soil in the Study Area

The sampling areas (test pit location) were selected with great care that all soil types in the study area must be properly represented and distributed evenly in the whole town. The selection of sampling site was based on visual observation during reconnaissance site survey and information collected from Dera town resident and construction firms. The soil sample were collected from eight site of the town Aroressa , Technic school,Gabriel church,high school,bus station ,Cambiargitu,Abebech nursery school ,near tele. Pits were excavated up to a depth of three meter on the selected sampling stations and a total of sixteen representative distributed and undisturbed samples were collected. The soil samples were stored in plastic bag immediately after sampling to prevent loss of moisture. The global coordinates of sampling location i.e. northing, easting and elevations are tabulated in Table 3.1. The spatial distributions of the sampling stations are distributed over the Dodota district as shown in Figure 3.1 due to shape file for Dera town were not found on Arc GIS; therefore the samples concentrated at close distance related to district.

Table 3.1 Global coordinates of sampling areas

Test Pit	Location	Northing(m)	Easting(m)	Elevation (m)
TP-1	Aroressa	919435.152	536375.39	1669 amsl
TP-2	Technic school	919254.787	536182.106	1670.70 amsl
TP-3	Gabriel church	919877.77	536189.297	1684.1 amsl
TP-4	High school	918869.287	535697.00	1688.70 amsl
TP-5	Bus station	920089.184	534689.291	1670.5 amsl
TP-6	Cambiargitu	920983.271	534070.596	1651.60 amsl
TP-7	Abebech nursery school	920270.478	535355.424	1683.40 amsl
TP-8	Tele	920570.838	535384.698	1680.30 amsl

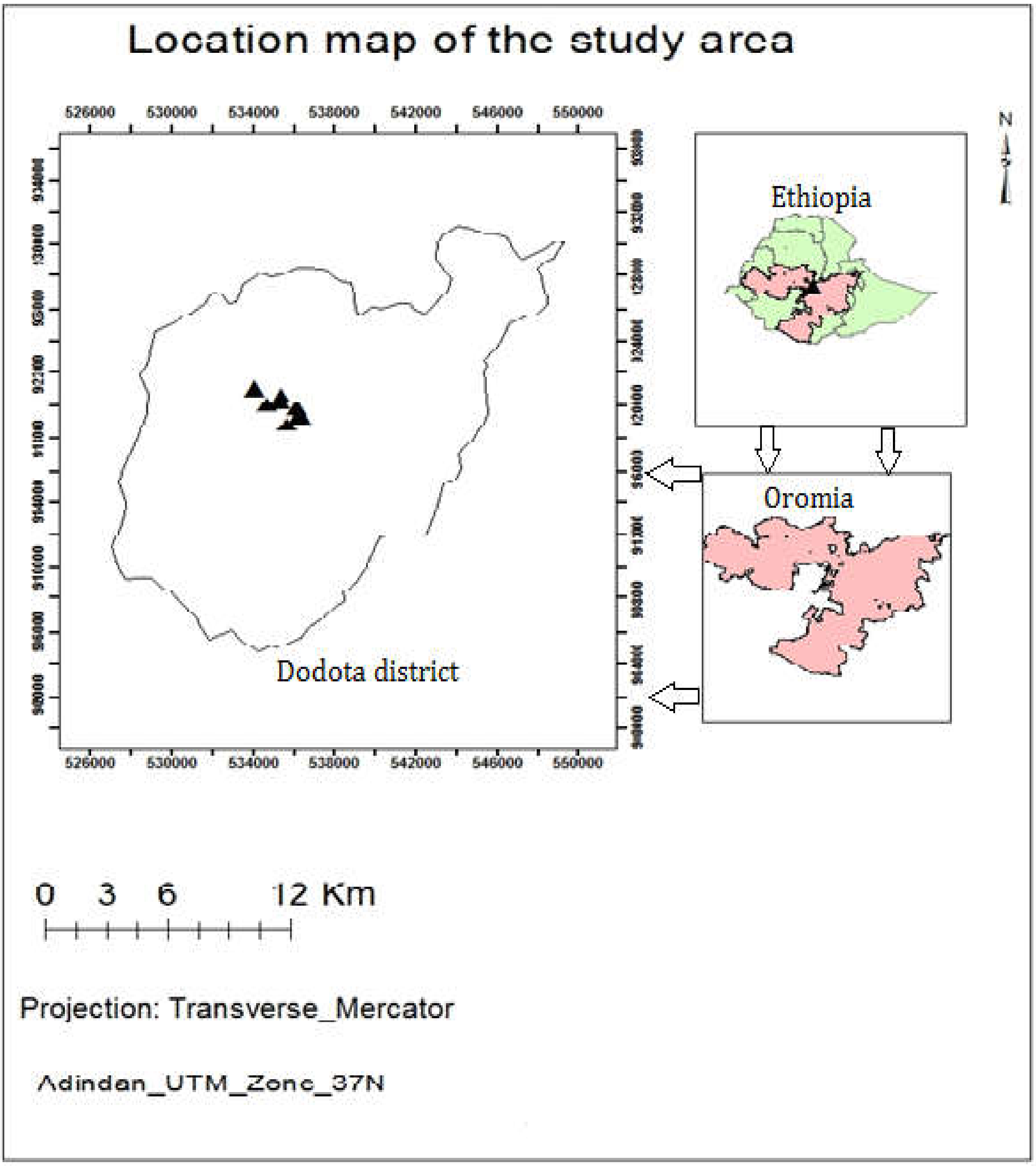


Fig 3.1. Location map of the study area in Dera town on the Dodota district shape file

3.2. Visual Identification of Soils in the Field

Field identification of soils was carried out according to the ASTM D-2488 "Standard Practice for Description and Identification of Soils". The field description and classification of soil were based on the size and distribution of coarse-grained particles and on the behavior of fine-grained particles. The first step used in describing soil under the visual-manual method was to determine whether the soil is fine-grained or coarse-grained by visually observing the soil sample to be taken. The other is the plasticity nature when water is added. Most of the studied soils showed no plasticity as it immediately crumbled when it remolded without forming ball or thread.

3.3. Sampling Methods and Sample Preservation

Clear and accurate data are required to describe the soil profile and sample locations (US Army Corps of Engineers, 1970) .Test pits were excavated using hand tools with plan area of 1.5m by 1.5m and representative disturbed and undisturbed samples were taken. The disturbed samples had been handled and preserved to prevent contamination by foreign material and to ensure that the in situ soil conditions are preserved.

Fig 3.2 test pit representative for 1.5mx1.5m

An attempt was made to collect samples that should be representative of the in situ soil at the depth from which the sample was taken. The preserving and transporting of the samples were done according to ASTM D-4220-95 (standard Practice for Preserving and Transporting of Soil samples).

Identification: All soil samples were properly marked to accurately identify the origin of the sample. The name of the sampling area and the depth of sampling were written on each sampling container with waterproof permanent marker. Packing of samples: in general, disturbed samples do not require special transport safety measures (US Army Corps of Engineers, 1970). However, the sample containers were protected from breakage and exposure to excessive moisture, which may cause deterioration of the labels and the sampling bags.

Methods of transportation: The most satisfactory method of sample transportation is vehicle that can be loaded at the exploration site and driven directly to the testing laboratory (US Army Corps of Engineers, 1970). Since the sampling area in Dera town and Adama soil laboratory not much far, sample transportation was not any problem because it requires not more than fourteen minutes for transporting samples from the sampling area to the Soil laboratory of Adama Science and Technology University (ASTU). Thus, there was no fear of exposing the sample to excessive heat and cold.

3.4. General description of Dera town

Dera town lies within Awash basin water shed region. It is situated on the main arterial road of Adama to Asala at about 25km from Adama. Specifically it is located at the toe of Dera Mountain to the west. The topography of town is relatively flat with a gentle slope at the direction of Asela 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).The flat landscape of Dera has a width of some 4.1km from the Awash Bishollaa peasant association in the north, where the land is fragmented by deep gullies to Dilfakar peasant association in the south, and from the foot of mount Dilfakar in the east to west extreme has a length of 2.64km, where Dera town is situated. According to the past development plan of the town the urbanized land is about 392 ha. But it is important to look the actual or virtual boundary and urbanized land to understand the existing reality of the town. From this perspective, the existing urbanized land of the town is estimated to be 587ha, which the virtual area significantly exceed the development plan area by 195ha (Oromia Urban Planning Institute, 2010).

CHAPTER FOUR

4. In-situ Properties and Laboratory tests results and discussion

4.1. In-situ properties

4.1.1 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 soil (Krishna, 2002).

This test was done by using moisture can, drying oven and balance. 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. Then after, the natural moisture content was determined. The natural moisture content of the soils taken from the eight pits for each profile is tabulated in Table 4.1 and this result indicate that the soil at the study area were mainly coarse grained soil. The natural moisture contents for coarse grained soil are between 15 to 20% (Das, 2002). natural moisture contents for TP1-1, TP1-2,TP2-1,TP3-2,TP5-1,TP6-1,TP6-2,TP7-1 and TP8-1 are between 20 to 27% this due to the soil are loose uniform sand percentage in the soil is larger than the rest test pit(table 2.1)

Table 4.1. Summary of natural moisture contents of the studied soils.

Site location	Depth(m)	Natural Moisture contents (%)
TP1-1	1.5	22.69
TP1-2	3m	26.92
TP2-1	0 to 1.2	20.75
TP2-2	1.2 to 3m	19.67
TP3-1	0 to 1.2m	17.46
TP3-2	1.2 to 3m	20.96
TP4-1	0 to 1.2m	19.84
TP4-2	1.2 to 3m	19.46
TP5-1	0 to 1.2m	23.37
TP5-2	1.2 to 3m	14.57
TP6-1	0 to 1.2	24.81
TP6-2	1.2 to 3	24.65
TP7-1	0 to 1.2	23.21
TP7-2	1.2 to 3	14.21
TP8-1	0 to 1.2	23.33
TP8-2	1.2 to 3	16.49

4.2. Index properties

4.2.1. General

The soils are a heterogeneous material in nature. 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 engineers were 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., 2004).According to Punimia, et al, the index properties of soils are water content, specific gravity, particle size distribution, consistency limits, , free- swell

4.2.2. Specific gravity of soil

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 (Murthy, 1990).

In the present study, the specific gravity of the studied soils determined according to ASTM D 854-00, Standard Test for Specific Gravity of Soil Solids by using Water Pycnometer. The specific gravity of the soils collected from the eight pits are summarized in Table 4.2. The specific gravity of the studied soils ranges from 2.64 to 2.68, which is typical for sandy soils (Table 2.1).The similar result for specific gravity shown as table 4.2 this is due the soil properties are similar which is A-3(fine sand) soil types. The details of the all experimental data to determine the specific gravity are included in appendix B.

Table 4.2. The specific gravity of the studied soils

Serial No	Designation	Depth(m)	Gs
1	TP1-1	1.5	2.65
2	TP1-2	3m	2.66
3	TP2-1	0 to 1.2	2.67
4	TP2-2	1.2 to 3m	2.64
5	TP3-1	0 to 1.2m	2.65
6	TP3-2	1.2 to 3m	2.68
7	TP4-1	0 to 1.2m	2.67
8	TP4-2	1.2 to 3m	2.60
9	TP5-1	0 to 1.2m	2.67
10	TP5-2	1.2 to 3m	2.67
11	TP6-1	0 to 1.2	2.68
12	TP6-2	1.2 to 3	2.68
13	TP7-1	0 to 1.2	2.68
14	TP7-2	1.2 to 3	2.68
15	TP8-1	0 to 1.2	2.65
16	TP8-2	1.2 to 3	2.67

4.2.3 Free Swelling tests

This test is performed by slowly pouring 10ml of oven dry soil which has passed the No.40 (0.425mm) sieve in to 100 ml 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 (Equation 4.1).

Free swell= (Final volume -Initial volume of the soil)/(initial volume)*100% ……..4.1

Free swell test results of the studied oven dried samples are summarized in Table 4.3. From the test result one can see that the free swell of the soil under investigation ranges from 1% to 20%. Those soils having a free swell less than 50% are considered not likely to show expansive property (Leikun, 1999). Hence all soil samples under investigations are non-expansive soils.

Table 4.3. Free swelling potential of the studied soils

Site location	Depth(m)	Test condition	Volume initial (ml)	Volume final (ml)	Swelling potential (%)	Water used in test
TP1-1	1.5	oven dry	10	11	10	distilled water
TP1-2	3m	oven dry	10	11	10	distilled water
TP2-1	0 to 1.2	oven dry	10	12	20	distilled water
TP2-2	1.2 to 3m	oven dry	10	12	20	distilled water
TP3-1	0 to 1.2m	oven dry	10	11.7	17	distilled water
TP3-2	1.2 to 3m	oven dry	10	11	10	distilled water
TP4-1	0 to 1.2m	oven dry	10	10.8	8	distilled water
TP4-2	1.2 to 3m	oven dry	10	10.1	1	distilled water
TP5-1	0 to 1.2m	oven dry	10	10.1	1	distilled water
TP5-2	1.2 to 3m	oven dry	10	10.4	4	distilled water
TP6-1	0 to 1.2	oven dry	10	11.5	15	distilled water
TP6-2	1.2 to 3	oven dry	10	11.7	17	distilled water
TP7-1	0 to 1.2	oven dry	10	10.5	5	distilled water
TP7-2	1.2 to 3	oven dry	10	10.4	4	distilled water
TP8-1	0 to 1.2	oven dry	10	10.5	5	distilled water
TP8-2	1.2 to 3	oven dry	10	10.6	6	distilled water

4.2.4. Grain-size distribution of soil

4.2.4.1. General

Grain size analysis was performed on essentially all geotechnical particulate materials ranging from clay to boulders. Grain size analysis refers to discerning the percentage of particles (by dry mass) within a specified particle size range across all the sizes represented for the sample. The distribution of particle sizes is used to distinguish the maximum particle size and the major portion of the particle sizes, as well as to characterize the soil, such as by the Unified Soil Classification System (USCS).

The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution required in classifying the soil. Grain size Analysis test is used to determine the percentage of different grain sizes contained within a soil. Two methods were used to find the particle-size distribution of the soil samples: sieve analysis, for particle sizes larger than 0.075 mm (No. 200) in diameter; and hydrometer analysis for particle-sizes smaller than 0.075 mm in diameter. During hydrometer analysis sodium hexametaphosphate (NaPO3) or Calgon was used as a dispersion agent, and all analysis was determined based on ASTM (D 421 & 422) procedure. The diameter or size range is adopted from ASTM as follows: >4.75 mm (No.4) gravel; 4.75 up to 0.075 mm (No.200) sand; 0.075 up to 0.002 mm silt and < 0.002 mm clay.

4.2.4.2. Test procedure and results

The procedure followed to conduct this test is ASTM standard with Designations D422. According to ASTM D422the distribution of particles, finer than 75µm can be done by hydrometer test and coarser than 75µm by mechanical sieve. Therefore, the samples collected from the site were air or oven dried first. The weight of the sample was measured and then mechanical sieving was done on samples of soil by using dry sieve method.

The weight of the sample which retained on each sieves was measured and percentage passing for each sieve size calculated for drawing gradation curve (Table 4.4).The sample of soil passing No. 200 was transferred to the pan and 50grams of soil was taken for hydrometer test and soaked for 24 hours by adding dispersing agent (sodium hexameta phosphate). At the end of soaking, the sample was dispersed further using stirring apparatus. Then it's poured into 1000ml cylinder and stirred again for a period of 1 min by covering it with the palm. The procedures mentioned above were followed for grain size analysis for all the sixteen samples. The combined grain size distribution curve for particles retained on No.200 Sieve and passing No.200 sieve is shown in Figure 4.1.

The grain size analysis test result showed that the dominant proportion of soil particle in the research area is coarse-grained soils, which have clay content ranging from 0.7-6%, silt faction 7.89-15.4% sand fraction 62-86.10% and gravel fraction 1.8-27.20% (Table 4.4).from the grain size analyses the soil were coarse grained soil due to percentage finer than 0.075mm sieve is less than 50 percent. The soils are poorly graded sand (fig 4.1) which is uniform sand soil particle with small amount of fine and gravel percentage.

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	3.20	81.10	11.21	4.49
TP1-2	3m	3.90	79.50	11.98	4.62
TP2-1	0 to 1.2	3.30	78.40	13.31	4.99
TP2-2	1.2 to 3m	1.80	76.80	15.40	6.00
TP3-1	0 to 1.2m	4.10	79.40	11.32	5.18
TP3-2	1.2 to 3m	8.10	77.50	9.62	4.78
TP4-1	0 to 1.2m	3.30	81.60	12.03	3.07
TP4-2	1.2 to 3m	2.30	82.10	11.69	3.91
TP5-1	0 to 1.2m	5.30	80.00	11.71	2.99
TP5-2	1.2 to 3m	21.30	67.70	8.25	2.75
TP6-1	0 to 1.2	2.00	86.10	8.97	2.93
TP6-2	1.2 to 3	26.30	63.00	8.53	2.17
TP7-1	0 to 1.2	26.90	62.80	9.60	0.70
TP7-2	1.2 to 3	27.20	62.00	8.72	2.08
TP8-1	0 to 1.2	27.20	62.50	9.81	0.49
TP8-2	1.2 to 3	27.20	62.90	7.89	2.01

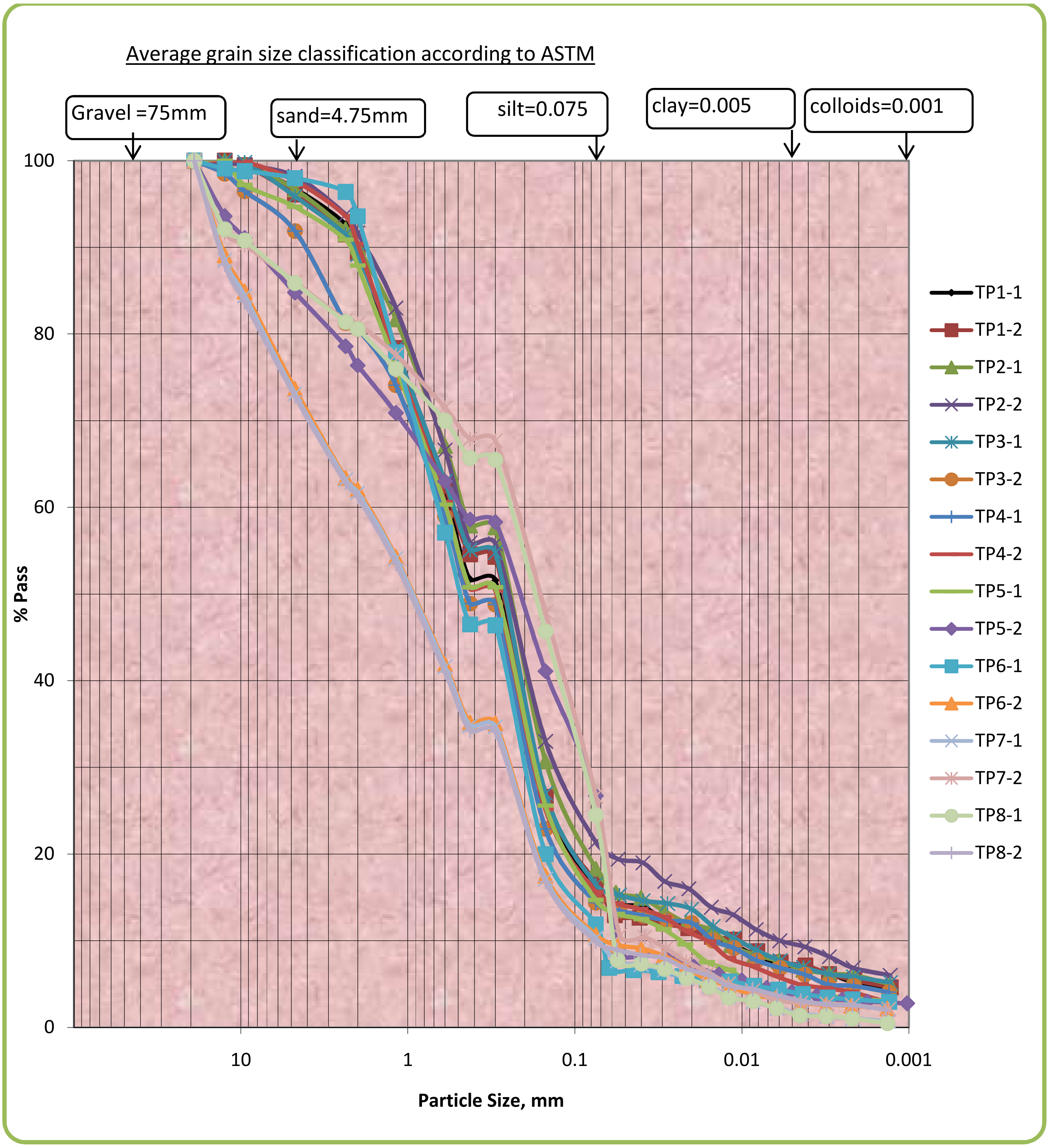


Fig.4.1. Grain size distribution curve of the studied soil samples

4.2.5. Atterberg limits

The liquid limit, plastic limit and shrinkage limits of soils are collectively referred to as the Atterberg Limits. For soil classification and identification of fine grained soils, however, the liquid limits and plastic limits in combination with plasticity index are commonly used. The plasticity index, which represent the range of water content at which the soil shows plastic behavior, is key parameter for identify the engineering property of soils. The larger the plasticity index, the greater will be the engineering problems associated with using the soil as an engineering material, such as foundation support for residential building and road sub grades.

The atterberg limits result for the studied soils are presented table 4.5. The liquid limit (LL), plastic limit (PL) and plasticity index (PI) in percent range from 14 to 20.3, 14.17 to 17.92 and non-plastic to 4.7, respectively. From this result the soil are non-plastic to low plastic which is less susceptible to compressible. High plastic soils are highly compressible soil ((Arora, 2004)

Table 4.5. Atterberg limit test result

Site location	Depth(m)	LL	PL	PI
TP1-1	1.5	20	17.92	2.1
TP1-2	3m	20.2	16.68	3.5
TP2-1	0 to 1.2	18.5	14.77	3.7
TP2-2	1.2 to 3m	20.3	15.60	4.7
TP3-1	0 to 1.2m	16.8	13.93	2.9
TP3-2	1.2 to 3m	16.00	15.34	0.7
TP4-1	0 to 1.2m	16.5	16.52	0.0
TP4-2	1.2 to 3m	_	_	NP
TP5-1	0 to 1.2m	_	_	NP
TP5-2	1.2 to 3m	_	_	NP
TP6-1	0 to 1.2	18	17.78	0.22
TP6-2	1.2 to 3	14	14.17	0.00
TP7-1	0 to 1.2	_	_	NP
TP7-2	1.2 to 3	_	_	NP
TP8-1	0 to 1.2	_	_	NP
TP8-2	1.2 to 3	_	_	NP

4.3. Compaction test

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

The compaction characteristic of the soil under investigation is studied using the standard Procter test or light compaction test. As indicated in Table 4.6, The OMC and MDD values vary from 18 to 26% and 1.4 to 1.6 g/cm^3, respectively. The details for the calculation are included in appendix-E and also these results are the indicative of coarse grained soil particle which has higher density than the fine soil particle (as table 2.6) the soils are loose uniform fine sand to loose gravel.

Table 4.6 summary for OMC and MDD of the soil

Site location	Depth(m)	Test condition	MDD(g/cm3)	OMC (%)
TP1-1	1.5	air dry	1.55	22
TP1-2	3m	air dry	1.53	20
TP2-1	0 to 1.2	air dry	1.6	19
TP2-2	1.2 to 3m	air dry	1.53	18
TP3-1	0 to 1.2m	air dry	1.48	22
TP3-2	1.2 to 3m	air dry	1.42	26
TP4-1	0 to 1.2m	air dry	1.47	21.7
TP4-2	1.2 to 3m	air dry	1.51	20
TP5-1	0 to 1.2m	air dry	1.5	20
TP5-2	1.2 to 3m	air dry	1.43	23
TP6-1	0 to 1.2	air dry	1.44	26
TP6-2	1.2 to 3	air dry	1.4	22
TP7-1	0 to 1.2	air dry	1.48	20
TP7-2	1.2 to 3	air dry	1.42	26
TP8-1	0 to 1.2	air dry	1.5	19
TP8-2	1.2 to 3	air dry	1.49	19

4.4. Classification of the Soils

4.4.1. General Considerations for Classification of Soils

Many different disciplines find a soil classification based purely on particle-size satisfactory for their professional needs, but Civil Engineer requires a classification that has engineering applications. The demand led to the development of a number of engineering soil classifications. All widely used engineering soil classifications involve a combination of particle size and measures of plasticity and texture. The 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.

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

The USCS system is a textural-plasticity classification scheme. 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. The presence of organic material is an additional classification factor for fine-grained soils. Paired letter symbols are used for each soil group in the USC system. The first symbol refers to, the predominant particle size (with the exception of organics). The second symbol for coarse-grained soils refer to gradation for clean (little or no fines) soils and the presence of silt and clay-size particles for soils with appreciable amounts of fines. The second symbol for fine-grained soils subdivides on the basis of low (L) or high (H) 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 %, 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 (table4.7).

Table 4.7. Classification of soil based on unified soil classification system (USCS)

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	17.92	2.1	SM
2	TP1-2	3m	16.60	3.90	79.50	11.98	4.62	20.2	16.68	3.5	SM
3	TP2-1	0 to 1.2	18.30	3.30	78.40	13.31	4.99	18.5	14.77	3.7	SM
4	TP2-2	1.2 to 3m	21.40	1.80	76.80	15.40	6.00	20.3	15.60	4.7	SM
5	TP3-1	0 to 1.2m	16.50	4.10	79.40	11.32	5.18	16.8	13.93	2.9	SM
6	TP3-2	1.2 to 3m	14.40	8.10	77.50	9.62	4.78	16.00	15.34	0.7	SM
7	TP4-1	0 to 1.2m	15.10	3.30	81.60	12.03	3.07	16.5	16.52	0.0	SM
8	TP4-2	1.2 to 3m	15.60	2.30	82.10	11.69	3.91	_	_	NP	SM
9	TP5-1	0 to 1.2m	14.70	5.30	80.00	11.71	2.99	_	_	NP	SM
10	TP5-2	1.2 to 3m	11.00	21.30	67.70	8.25	2.75	_	_	NP	SP-SC
11	TP6-1	0 to 1.2	11.90	2.00	86.10	8.97	2.93	18	17.78	0.22	SM
12	TP6-2	1.2 to 3	10.70	26.30	63.00	8.53	2.17	14	14.17	0.00	SP-SC
13	TP7-1	0 to 1.2	10.30	26.90	62.80	9.60	0.70	_	_	NP	SP-SC
14	TP7-2	1.2 to 3	10.80	27.20	62.00	8.72	2.08	_	_	NP	SP-SC
15	TP8-1	0 to 1.2	10.30	27.20	62.50	9.81	0.49	_	_	NP	SP-SC
16	TP8-2	1.2 to 3	9.90	27.20	62.90	7.89	2.01	_	_	NP	SP-SC

4.4.3. Classifications of soils based on AASHTO Classification system

In this classification system, the soils are rated according to their suitability for support roadway pavement. In this classification system, soil is classified into seven major groups:A-1 through A-7.Soils classified under A-1,A-2 and A-3 are granular materials whereas soils classified under A-4,A-5,A-6 and A-7 are finer materials which is mostly silt and clay type materials.

The classification is based on particle size analysis, liquid limit and plasticity index obtained from laboratory. According to this classification system, the soils of the study area are fall under A-2-4 and A-3(Figure 4.2 and Table 4.8) with group index 0. The result suggests the soils in the study area are suitable for supporting roadway pavement.

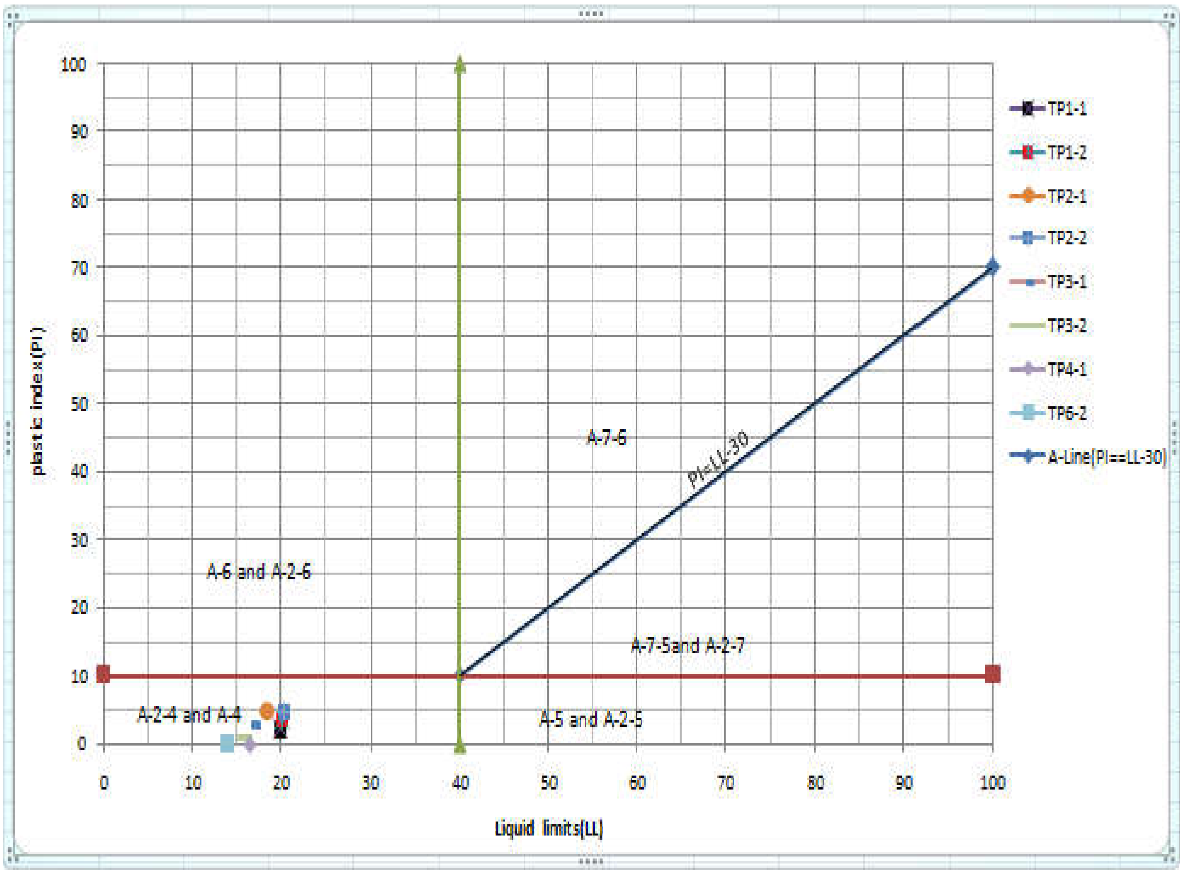


Fig 4.2. Plasticity chart of study area according to AASHTO soil classification

Table 4.8. 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	89.70	51.70	15.70	A-2-4(0)	Silty or clayey gravel and sand	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	91.70	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	48.90	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	90.40	50.60	15.60	A-3(0)	Fine sand	"
TP5-1	0 to 1.2	_	NP	87.90	50.80	14.70	A-3(0)	Fine sand	"
TP5-2	1.2 to 3	_	NP	67.10	46.00	11.00	A-3(0)	Fine sand	"
TP6-1	0 to 1.2	18	0.22	93.60	46.50	11.90	A-2-4(0)	Silty or clayey gravel and sand	"
TP6-2	1.2 to 3	14	0.00	62.10	35.20	10.70	A-3(0)	Fine sand	"
TP7-1	0 to 1.2	_	NP	61.70	34.80	10.30	A-3(0)	Fine sand	"
TP7-2	1.2 to 3	_	NP	61.00	34.90	10.80	A-3(0)	Fine sand	"
TP8-1	0 to 1.2	_	NP	60.90	34.70	10.30	A-3(0)	Fine sand	"
TP8-2	1.2 to 3	_	NP	61.20	34.20	9.90	A-3(0)	Fine sand	"

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, 2002),(Equation 4.2). The range of classification based on activity are summarized in Table 4.10.Activities of soils of the study area are computed based on results obtained from hydrometer analysis (% of clay fraction) and Atterberg's limit (PI).Accordingly all soils of the study area are inactive (Figure 4.3 and Table 4.10).

A=PI/(clay fraction)(%) ………………………………4.2

Table 4.9 ranges for activity soil classification (Das, 2002).

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

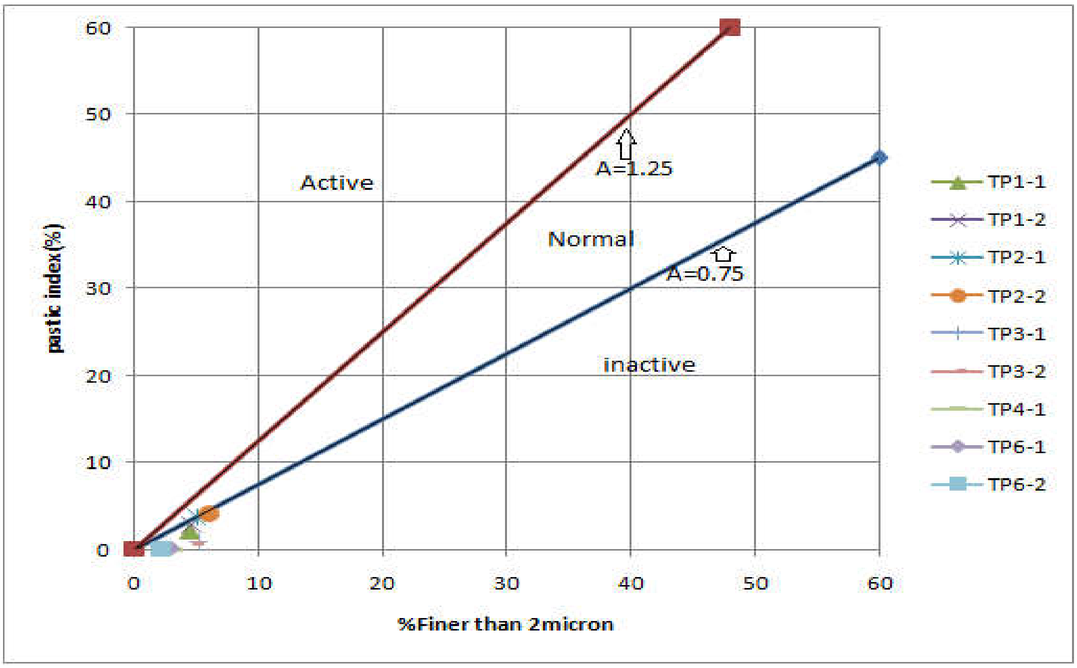


Fig 4.3. Classification of soil according to activity

Table 4.10. Activity of soils of the study area

Test pit	Depth	PI	% clay	activity(A)	Remark
TP1-1	1.5	2.1	4.49	0.47	Inactive
TP1-2	3m	3.5	4.62	0.74	Inactive
TP2-1	0 to 1.2	3.7	4.99	0.74	Inactive
TP2-2	1.2 to 3m	4.7	6	0.745	Inactive
TP3-1	0 to 1.2m	2.9	5.18	0.56	Inactive
TP3-2	1.2 to 3m	0.7	4.78	0.146	Inactive
TP4-1	0 to 1.2m	0.0	3.07	0	Inactive
TP4-2	1.2 to 3m	NP	3.91	0	Inactive
TP5-1	0 to 1.2m	NP	2.99	0	Inactive
TP5-2	1.2 to 3m	NP	2.75	0	Inactive
TP6-1	0 to 1.2	0.22	2.93	0.076	In active
TP6-2	1.2 to 3	0.00	2.17	0.000	Inactive
TP7-1	0 to 1.2	NP	0.7	0	Inactive
TP7-2	1.2 to 3	NP	2.08	0	Inactive
TP8-1	0 to 1.2	NP	0.49	0	Inactive
TP8-2	1.2 to 3	NP	2.01	0	Inactive

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 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 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.

4.5.2. Sample preparation and test

This test is used to determine shear strength parameters (i.e. the angle of internal friction and cohesion) of the soil with the shear stress-strain characteristics of soil sample. 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 of the shear stress versus the horizontal displacement, the maximum shear stress is obtained for a specific vertical confining stress (Figure 4.4).
- 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, a straight-line approximation of the Mohr-Coulomb failure envelope curve can be drawn. Angle of internal friction ( ) and cohesion (C) may be determined the graph (Figure 4.5).
- The shear strength can be calculated from the following equation

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

$\sigma = normal stress$, $= angle of internal friction$ and C= cohesion

The output data for direct shear strength test results for the studied samples are tabulated in Table 4.11.The angle of internal friction ( ) of the studied soils is between 22.68 to 29.68°(Table 4.12), 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 7.9 to 1.019kPa, which appears to be a function of fine fraction, particularly clay content.

Table 4.11 output data for direct shear strength test

sample code and	depth=	TP1-2	At Aroresa		
thickness of sample=	25mm		ring calibration factors=0.70N/div	*stress(kpa)*	*weight 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	45	31.5	8.8983	70	49	13.841	115	80.5	22.74
1.5	3510	144	100.8	28.7179	180	126	35.897	250	175	49.857
2.0	3480	234	163.8	47.0689	276	193.2	55.517	340	238	68.39
2.5	3450	266	186.2	53.971	338	236.6	68.58	410	287	83.18
3.0	3420	285	199.5	58.333	369	258.3	75.52	470	329	96.198
3.5	3390	295	206.5	60.914	390	273	80.53	500	350	103.24
4.0	3360	302	211.4	62.916	405	283.5	84.37	533	373.1	111.04
4.5	3330	296	207.2	62.222	422	295.4	88.708	576	403.2	121.08
5.0	3300				430	301	91.212	592	414.4	125.57
5.5	3270				440	308	94.189	611	427.7	130.79
6.0	3240				445	311.5	96.142	632	442.4	136.54
6.5	3210				452	316.4	98.567	681	476.7	148.50
7.0	3180				455	318.5	100.157	705	493.5	155.18
7.5	3150				451	315.7	100.222	708	495.6	157.33
8.0	3120				445	311.5	99.839	712	498.4	159.74
8.5	3090							723	506.1	163.78
9.0	3060							717	501.9	164.02
9.5	3030							709	496.3	163.795
				62.91667			**100.22**			**164.02**

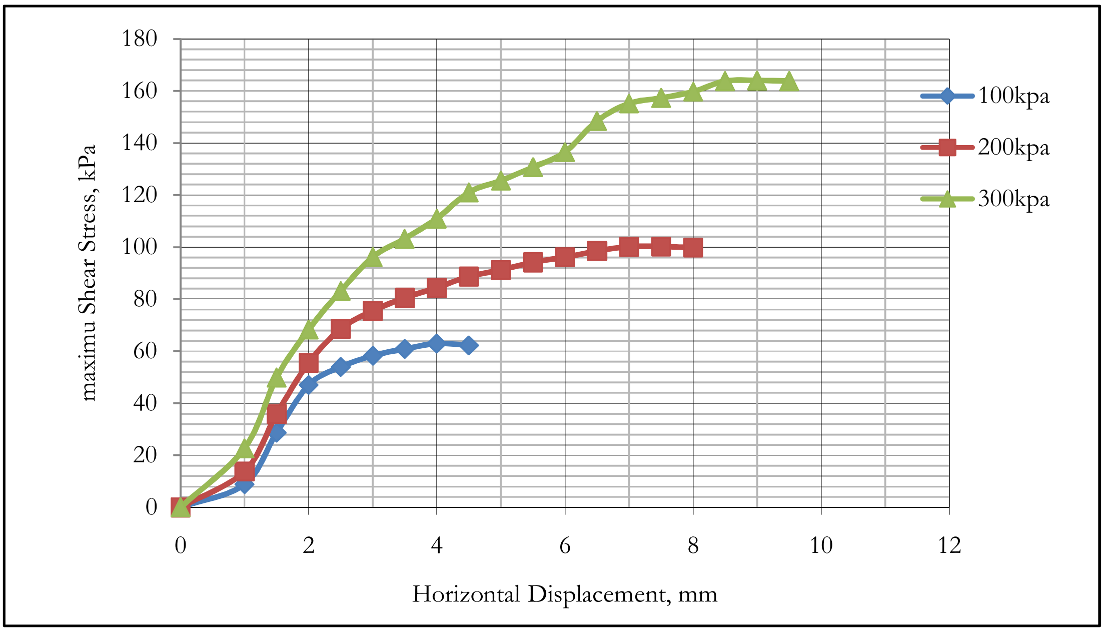


Fig. 4.4. Typical plot shear stress versus displacement for sample TP1-2

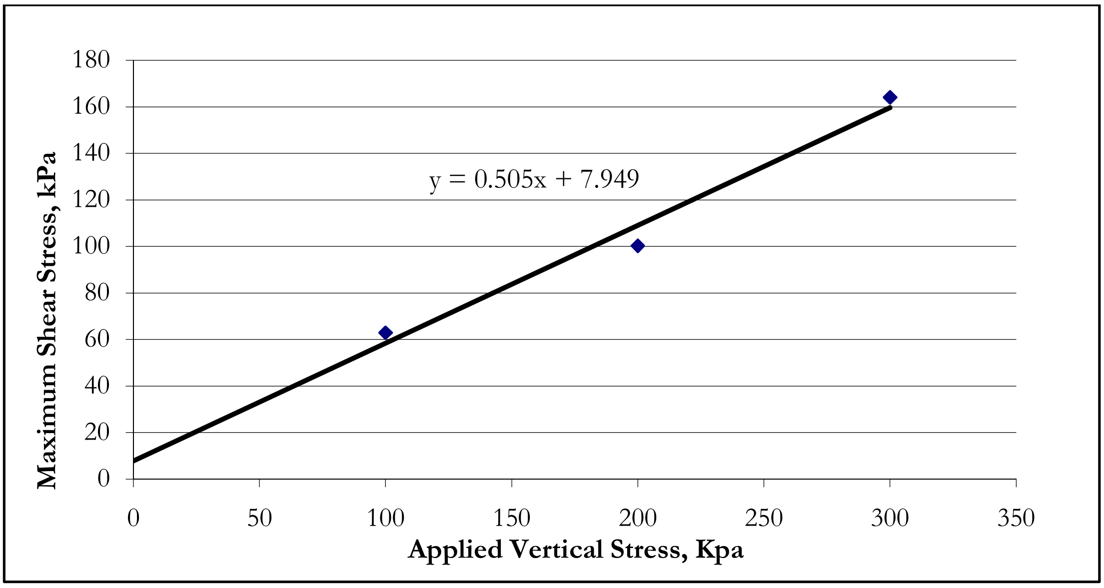


Fig. 4.5.Typical plot maximum shear stress versus applied vertical load for sample TP1-2(C=7.949kpa, =than-1(0.505) =26.790)

Table 4.12 summery 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 ( ) in degree
1	TP1-2	3	7.949	26.8
2	TP2-2	1.2 to 3	6.816	29.68
3	TP3-2	1.2 to 3	4.603	28.46
4	TP4-2	1.2 to 3	5.11	28.19
5	TP5-2	1.2 to 3	3.893	24.6
6	TP6-2	1.2 to 3	1.019	25
7	TP7-2	1.2 to 3	1.125	22.68
8	TP8-2	1.2 to 3	2.112	29

4.6. Comparisons with previously done researches

For the soil under investigation, a comparison was made with known silty sand soils reported in previous work. From this results the silt sand soils are also in Adama but there is a variation of index properties of this two of soils are due the percentage of clay in these town are different. The comparisons of the two towns are selected because of similar types of soils.

Table 4.13.Comparison of index property of the study with previous works

Thesis type	Dagnachew,2011	Gemechu, 2015	This work
Location	Adama	Adama	Dera
Clay Content (%)	14-58	5.4 – 40.5	0.7-6%,
Silt fraction (%)	14-61	17.6-60.7	7.89-15.4%
Sand fraction (%)	25-56	14.5-54.6	62-86.10%.
Liquid Limit (%)	39-49.4	29-73	14 to 20 %
Plastic limit (%)	26-37.4	24-39	14.17 to 17.92%
Plasticity Index (%)	10-15	5-34	NP to 4.7%
Moisture content (%)	25-30.5	17.5-36.5	14.21-26.92%
Specific Gravity	2.61-2.7	2.4-2.7	2.6-2.68
Compaction (g/cm3)	1.33-1.53	1.2-1.62	1.4 to 1.6
From plasticity chart	ML&SM	SM, ML, MH	SM,SP-SC

CHAPTER FIVE

5. Conclusions and Recommendations

5.1. Conclusion

1. The result from the above test are revealed that, starting from few centimeters below the ground level to the depth of investigation which is three meters, the soil in this town is dominantly composed of coarse grained soil (According to USCS scheme 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), and according to AASHTO soil classification Silty or clayey gravel and sand (A-2-4)and fine sand(A-3)) with small fine fraction.
2. The clay content ranging from 0.7-6%, silt fraction 7.89-15.4%, sand fraction 62-86.10%, and gravel fraction 1.8-27.20%. The liquid limit of the soils ranges from 14% to 20% and plastic limit ranges from 14.2% to 17.9%. Similarly the plasticity index ranges from non-plastic to 4.7%.The maximum dry density (MDD) of the soils ranges from 1.4 to 1.6 g/cm^3 and optimum moisture content ranges from 18 to 26%.
3. 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 7.9 kPa and 22.7 to 29.7°, respectively.
4. 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. Free swell ranges from 1-20%, which shows that the studied soils are non-expansive and don’t pose significant damage on engineering structure
5. Generally, the result of this study indicates that the soils of the study area possess desirable engineering characteristics i.e. low compressibility, good shear strength, 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 eight test pits, it is, therefore, recommended to increase the number of sampling area to accurately cover all the soil in the town.
- In the present work, due to cost and time constraint the CBR for the soil under investigation is not determined. Therefore, it is recommended to conduct CBR test and determine the empirical correlation between CBR and shear strength parameters.
- The dynamic characteristics of soils with relation to respond of soil to earthquake should be studied using geophysical method without sampling the soils are better to study in the future and the Correlation of the index property with shear strength parameters also consider.

7. References

1. Arora, K. (2004). *soil mechanical and foundation engineering.* Delhi: re–print standard publisher distributors,najsarak,6th edition Page 15,19,26,30.

2. *ASTM, , Special Procedures for Testing Soil and Rock for Civil Engineering.*

3. ASTM, D. (2000). *American Society for Testing and Material D 2487-00 Standard Practice for Classification for soils for engineering purpose (Unified Classification System) , Annual Book of ASTM Standard Volume 04.08,.* West Conshohocken, Pennsylvania,.

4. Das, B. M. (2002). *Soil mechanics laboratory manuals,* 6th edition Page 5,9,15,35,41,51,81,99.

5. Debebe, D. (2011). *Investigation on some of the engineering characteristics of soil in Adama town.* A.A.U,Ethiopia: M.Sc. Thesis.

6. Fredrics, M. (1983). *Standard hand book for civil engineering, M.Standard Hand Book For Civil Engineers.* new York: McGraw- Hill book company.

7. John J.Germaine et al. (2009). *Geotechnical Laboratory Measurements for Engineers.*

8. Krishna, R. (2002). *Engineering Properties of Soils Based on Laboratory Testing.* UIC.

9. Leikun, T. A. (1999). *Soil Mechanics.* Addis Ababa: Faculty of Technology Addis Ababa university.

10. Murthy, V. N. (1990). *Geotechnical Engineering: Principles and Practices of Soil mechanics and foundation engineering.* new york: Marcel Dekker,inc.

11. Oromia Urban Planning Institute. (2010). *Oromia Urban Planning InstituteReport on Dera Structure Plan preparation project.* Addis Ababa.

12. US Army Corps of Engineers. (1970). *US Army Corps of Engineers. Laboratory soils testing. Engineer Manual, Dept. of the Army.* Washington, D.C.

13. Budhu.M.(1999),soil mechanics and foundations.

Appendix –A (Some of log of test pits)

<table>
<tr><td colspan="3">Project <u>Msc thesis</u>
Location <u>Aroresa site</u>
Test pit Code <u>TP1-1 and TP2-2 aroressa</u></td><td colspan="2">Date :25/1/2008</td></tr>
<tr><td>Depth(m)</td><td>Bore Hole Log</td><td>visual soil description</td><td>Field test type</td><td>Sampled for</td></tr>
<tr><td>-0.8</td><td>+ - + -
+- + -</td><td>Fill</td><td rowspan="2">Natural moisture contents</td><td rowspan="2">Natural moisture contents,
Grain size analysis,
Specific gravity,
consistency limits,
standard compaction test,
shear strength test(Direct shear test)</td></tr>
<tr><td>-3</td><td>+-+-+-+-
+-+-+-+-
+-+-+-+-</td><td>Course grained soil</td></tr>
<tr><td colspan="3">Test pit size=<u>1.5x1.5x 3m</u>
Location Logged: <u>Dera town eastern Ethiopia</u></td><td colspan="2"></td></tr>
</table>

For test pit TP 2, TP 4, TP 6, TP 7 and TP 8 the soil from visual classification are the same

<table>
<tr><td colspan="3">Project Msc thesis
Location Gabriel church
Test pit Code TP3</td><td colspan="2">Date : Date :26/1/2008</td></tr>
<tr><td>Depth(m)</td><td>Bore Hole Log</td><td>VISUAL SOIL DISCRIPTION</td><td>Field test type</td><td>Sampled for</td></tr>
<tr><td>-0.8</td><td>+ - + - +- + -
+ - + -+- + -</td><td>Fill</td><td rowspan="2">Natural moisture contents</td><td rowspan="2">Natural moisture contents, Grain size analysis, Specific gravity, consistency limits, standard compaction test, shaer strength test(Direct shear test)</td></tr>
<tr><td>-3</td><td>+ - + - +- + -
+ - + -+- + -
+ - + - + - +-</td><td>Course grained soil with some of large difficult rock to excavate</td></tr>
<tr><td colspan="3">Test pit size=1.5x1.5x 3m
Location Logged: Dera town eastern Ethiopia</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td colspan="3">Project Msc thesis
Location near bus station
Test pit Code TP 5</td><td colspan="2">Date :29/1/2008</td></tr>
<tr><td>Depth(m)</td><td>Bore Hole Log</td><td>visual soil description</td><td>Field test type</td><td>Sampled for</td></tr>
<tr><td>-0.8</td><td>+ - + - +- +
- + - + -+- +
- + - + - + -
+-+-+-+--+-
+ - + - + - +
- +-+-+-+--</td><td>Fill</td><td rowspan="2">Natural moisture contents</td><td rowspan="2">Natural moisture contents,
Grain size analysis,
Specific gravity,
consistency limits,
standard compaction test,
Shear strength test.</td></tr>
<tr><td>-3</td><td>+ - + - +- +
- + - + -+- +
- + - + -</td><td>fine to course sand with less amount of gravel percentage</td></tr>
<tr><td colspan="3">Test pit size=1.5x1.5x 3m
Location Logged: Dera town eastern Ethiopia</td><td colspan="2"></td></tr>
</table>

Appendix – B (Specific gravity test result)

location: at aroresa

test pit code	TP1-1		TP1-2	
Depth	0 to 1.2m		1.2 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)	167.2	167	167.15	167.1
Weight of dry soil , Ws (g)	13	13	13	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	4.8	5	4.85	4.9
Temperature, Tx(oc)	23	23	23	23
Gs at(T1 in °c)	2.708	2.6	2.680	2.653
Conversion factor(A)	0.9993	0.9993	0.9993	0.9993
Specific gravity of soil at 20°c.	2.71	2.60	2.68	2.65
Average specific gravity of soil.	2.65		2.66	

location:at technic school

test pit code	TP2-1		TP2-2	
Depth	0 to 1.2m		1.2 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)	166.75	167.46	166.45	167.1
Weight of dry soil , Ws (g)	13	13	12	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	5.25	4.54	4.55	4.9
Temperature, Tx(oc)	25	25	25	25
Gs at(T1 in °c)	2.476	2.8634	2.637	2.653061
Conversion factor(A)	0.9988	0.9988	0.9988	0.9988
Specific gravity of soil at 20°c.	2.47	2.86	2.63	2.65
Average specific gravity of soil.	2.67		2.64	

location:at Gabriel church

test pit code	TP3-1		TP3-2	
Depth	0 to 1.2m		1.2 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)	167.00	167.2	166.80	167.45
Weight of dry soil , Ws (g)	13	13	13	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	5	4.8	5.2	4.55
Temperature, Tx(oc)	23	23	23	23
Gs at(T1 in °c)	2.600	2.7083	2.500	2.857143
Conversion factor(A)	0.9993	0.9993	0.9993	0.9993
Specific gravity of soil at 20°c.	2.60	2.71	2.50	2.86
Average specific gravity of soil.	2.65		2.68	

location:at high school

test pit code	TP4-1		TP4-2	
Depth	0 to 1.2m		1.2 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)	166.30	166.7	165.15	167.2
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	4.7	4.3	5.85	3.8
Temperature, Tx(oc)	23	23	23	23
Gs at(T1 in °c)	2.553	2.7907	2.051	3.157895
Conversion factor(A)	0.9993	0.9993	0.9993	0.9993
Specific gravity of soil at 20°c.	2.55	2.79	2.05	3.16
Average specific gravity of soil.	2.67		2.60	

location:at abebech Nursery school

test pit code	TP5-1		TP5-2	
Depth	0 to 1.2m		1.2 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)	166.2	165.5	167.16	167.1
Weight of dry soil , Ws (g)	11	11	13	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	3.8	4.5	4.84	4.9
Temperature, Tx(oc)	24	24	24	24
Gs at(T1 in °c)	2.895	2.4444	2.686	2.653061
Conversion factor(A)	0.9991	0.9991	0.9991	0.9991
Specific gravity of soil at 20°c.	2.89	2.44	2.68	2.65
Average specific gravity of soil.	2.67		2.67	

location:at cambiargitu

test pit code	TP6-1		TP6-2	
Depth	0 to 1.2m		1.2 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)	166.55	167.12	167.00	167.3
Weight of dry soil , Ws (g)	12	13	13	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	4.45	4.88	5	4.7
Temperature, Tx(oc)	22	22	22	22
Gs at(T1 in °c)	2.697	2.6639	2.600	2.765957
Conversion factor(A)	0.9996	0.9996	0.9996	0.9996
Specific gravity of soil at 20°c.	2.70	2.66	2.60	2.76
Average specific gravity of soil.	2.68		2.68	

location:at bus station

test pit code	TP7-1		TP7-2	
Depth	0 to 1.2m		1.2 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)	168.3	168.5	168.5	168.3
Weight of dry soil , Ws (g)	15	15	15	15
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	5.7	5.5	5.5	5.7
Temperature, Tx(oc)	26	26	26	26
Gs at(T1 in °c)	2.632	2.7273	2.727	2.631579
Conversion factor(A)	0.9986	0.9986	0.9986	0.9986
Specific gravity of soil at 20°c.	2.63	2.72	2.72	2.63
Average specific gravity of soil.	2.68		2.68	

location:at tele

test pit code	TP8-1		TP8-2	
Depth	0 to 1.2m		1.2 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)	167.2	167	167.15	167.12
Weight of dry soil , Ws (g)	13	13	13	13
mass of equal volume of water as the soil solid,Ww(g)=(W1+Ws)-W2	4.8	5	4.85	4.88
Temperature, Tx(oc)	23	23	23	23
Gs at(T1 in °c)	2.708	2.6	2.680	2.663934
Conversion factor(A)	0.9993	0.9993	0.9993	0.9993
Specific gravity of soil at 20°c.	2.71	2.60	2.68	2.66
Average specific gravity of soil.	2.65		2.67	

Appendix – C (Grain size and hydrometer analysis results)

Note: for all sample the total weight is 1000gram and test type is: ASTM (dry sieve analysis)

Test pits No: TP1-2 sample depth 3m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	543.3	109.3	10.93	21.53	78.47
0.6	407	566	159	15.90	37.43	62.57
0.425	367	446	79	7.90	45.33	54.67
0.3	372	375	3	0.30	45.63	54.37
0.15	343	620	277	27.70	73.33	26.67
0.075	335	435	100	10.00	83.33	16.67
Pan	240	405	166	16.60	99.93	0.00
Total			999.3	100.00		

Hydrometer analysis test result (152H) Gs=2.66

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

Test pits No: TP2-1 sample depth 0 to 1.2m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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
Pan	252	435	183	18.30	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) Gs=2.67

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	27.60912	5.052
1440	23	13	14	14.2	0.0131	0.001299	0.7	0.996	13.7	27.2904	4.994

Test pits N<u>o: </u>TP2-2 sample depth 1.2 to 3m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	28.7	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
Pan	252	435	183	18.30	100.00	0.00
Total			999.97	100		

Hydrometer analysis test result (152H) Gs=2.64

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	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

Test pits No: TP3-1 sample depth 0 to1.2m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	2	0.20	0.20	99.80
4.75	441	480	39	3.90	4.10	95.90
2.36	405	449	44	4.40	8.50	91.50
2	467	490	23	2.30	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	3	0.30	45.20	54.80
0.15	343	621	278	27.80	73.00	27.00
0.075	335	440	105	10.50	83.50	16.50
pan	241	406	165	16.50	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) 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. 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

Test pits No: TP3-2 sample depth 1.2 to 3m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	460	15	1.50	1.50	98.50
9.5	442	462	20	2.00	3.50	96.50
4.75	441	487	46	4.60	8.10	91.90
2.36	405	511	106	10.60	18.70	81.30
2	467	474	7	0.70	19.40	80.60
1.18	434	499	65	6.50	25.90	74.10
0.6	407	558	151	15.10	41.00	59.00
0.425	367	468	101	10.10	51.10	48.90
0.3	372	373	1	0.10	51.20	48.80
0.15	343	602	259	25.90	77.10	22.90
0.075	335	420	85	8.50	85.60	14.40
pan	241	385	144	14.40	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) 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	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

Test pits No: TP4-1 sample depth 0 to1.2m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	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		

Hydrometer analysis test result (152H) Gs=2.67

Elapsed time (min)	Temp (°C)	Actual hdro. 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

Test pits No: TP4-2 sample depth 0 to1.2m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	0.10	0.10	99.90
4.75	440	462	22	2.20	2.30	97.70
2.36	405	446	41	4.10	6.40	93.60
2	465	497	32	3.20	9.60	90.40
1.18	434	563	129	12.90	22.50	77.50
0.6	406	575	169	16.90	39.40	60.60
0.425	365	465	100	10.00	49.40	50.60
0.3	373	375	2	0.20	49.60	50.40
0.15	342	594	252	25.20	74.80	25.20
0.075	334	430	96	9.60	84.40	15.60
pan	240	396	156	15.60	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) Gs=2.60

Elapsed time (min)	Temp °C	Actual hydro. Rdg (Ra)	Hyd. Corr. for menisci-us	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	0.0134	-	0.4	1.01	43.4	87.668	13.676
1	22	43	44	9.2	0.0134	0.041	0.4	1.01	43.4	87.668	13.676
2	22	40	41	9.7	0.0134	0.029	0.4	1.01	40.4	81.608	12.731
4	22	35	36	10.6	0.0134	0.022	0.4	1.01	35.4	71.508	11.155
8	22	31	32	11.2	0.0134	0.016	0.4	1.01	31.4	63.428	9.895
15	22	25	26	12.2	0.0134	0.012	0.4	1.01	25.4	51.308	8.004
30	22	22	23	12.7	0.0134	0.009	0.4	1.01	22.4	45.248	7.059
60	23	18	19	13.3	0.0132	0.006	0.7	1.01	18.7	37.774	5.893
120	23	15	16	13.8	0.0132	0.004	0.7	1.01	15.7	31.714	4.947
240	25	13	14	14.2	0.0131	0.003	1.3	1.01	14.3	28.886	4.506
480	27	11	12	14.5	0.0128	0.002	2	1.01	10.33	20.867	3.255
1440	21	9	10	14.7	0.0135	0.0014	0.2	1.01	9.2	18.584	2.899

Test pits No: TP5-1 sample depth 0 to1.2m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	470	28	2.80	2.80	97.20
4.75	440	465	25	2.50	5.30	94.70
2.36	405	443	38	3.80	9.10	90.90
2	465	495	30	3.00	12.10	87.90
1.18	434	550	116	11.60	23.70	76.30
0.6	406	566	160	16.00	39.70	60.30
0.425	365	460	95	9.50	49.20	50.80
0.3	373	373	0	0.00	49.20	50.80
0.15	342	594	252	25.20	74.40	25.60
0.075	334	443	109	10.90	85.30	14.70
pan	240	387	147	14.70	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) Gs=2.67

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	49	50	8.3	0.01309	-	0.7	0.996	41.7	83.1	12.2
1	23	42	43	9.4	0.01309	0.0401	0.7	0.996	42.7	85. 1	12.5
2	23	38	39	10.1	0.01309	0.0294	0.7	0.996	38.7	77. 1	11.3
4	23	32	33	11.1	0.01309	0.0218	0.7	0.996	32.7	65.1	9.57
8	23	25	26	12.2	0.01309	0.0161	0.7	0.996	25.7	51.1	7.52
15	23	22	23	12.7	0.01309	0.0120	0.7	0.996	22.7	45.2	6.64
30	23	17	18	13.5	0.01309	0.00878	0.7	0.996	17.7	35.2	5.18
60	23	15	16	13.8	0.01309	0.0062	0.7	0.996	15.7	31.2	4.59
120	24	12	13	14.3	0.01293	0.0044	1	0.996	13	25.9	3.80
240	25	11	12	14.5	0.01278	0.0031	1.3	0.996	12.3	24.5	3.60
480	26	10	11	14.7	0.01264	0.0022	1.65	0.996	8.98	17.89	2.63
1440	21	10	11	14.7	0.01336	0.0013	0.2	0.996	10.2	20.3	2.98

Test pits No: TP5-2 sample depth 1.2 to 3m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	509	64	6.40	6.40	93.60
9.5	442	467	25	2.50	8.90	91.10
4.75	441	504	63	6.30	15.20	84.80
2.36	405	467	62	6.20	21.40	78.60
2	384	406	22	2.20	23.60	76.40
1.18	434	489	55	5.50	29.10	70.90
0.6	407	486	79	7.90	37.00	63.00
0.425	367	411	44	4.40	41.40	58.60
0.3	372	375	3	0.30	41.70	58.30
0.15	343	515	172	17.20	58.90	41.10
0.075	335	479	144	14.40	73.30	26.70
pan	240	507	267	26.70	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) Gs=2.67

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	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

Test pits No: TP6-1 sample depth 0 to1.2m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	445	3	0.30	1.20	98.80
4.75	441	449	8	0.80	2.00	98.00
2.36	405	421	16	1.60	3.60	96.40
2	467	495	28	2.80	6.40	93.60
1.18	434	591	157	15.70	22.10	77.90
0.6	407	615	208	20.80	42.90	57.10
0.425	367	473	106	10.60	53.50	46.50
0.3	372	373	1	0.10	53.60	46.40
0.15	343	607	264	26.40	80.00	20.00
0.075	335	416	81	8.10	88.10	11.90
pan	241	360	119	11.90	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) 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	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

Test pits No: TP6-2 sample depth 1.2 to 3m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	554	109	10.90	10.90	89.10
9.5	442	484	42	4.20	15.10	84.90
4.75	441	553	112	11.20	26.30	73.70
2.36	405	508	103	10.30	36.60	63.40
2	467	480	13	1.30	37.90	62.10
1.18	434	512	78	7.80	45.70	54.30
0.6	407	531	124	12.40	58.10	41.90
0.425	367	434	67	6.70	64.80	35.20
0.3	372	373	1	0.10	64.90	35.10
0.15	343	519	176	17.60	82.50	17.50
0.075	335	403	68	6.80	89.30	10.70
pan	241	348	107	10.70	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) 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	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

Test pits No: TP7-1 sample depth 0 to 1.2m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	560	115	11.50	11.50	88.50
9.5	442	483	41	4.10	15.60	84.40
4.75	441	554	113	11.30	26.90	73.10
2.36	405	504	99	9.90	36.80	63.20
2	467	482	15	1.50	38.30	61.70
1.18	434	510	76	7.60	45.90	54.10
0.6	407	532	125	12.50	58.40	41.60
0.425	367	435	68	6.80	65.20	34.80
0.3	372	373	1	0.10	65.30	34.70
0.15	343	519	176	17.60	82.90	17.10
0.075	335	403	68	6.80	89.70	10.30
pan	240	343	103	10.30	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) 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

pits No: TP7-2 sample depth 1.2 to 3m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	45	4.50	16.50	83.50
4.75	441	548	107	10.70	27.20	72.80
2.36	405	500	95	9.50	36.70	63.30
2	467	490	23	2.30	39.00	61.00
1.18	434	509	75	7.50	46.50	53.50
0.6	407	520	113	11.30	57.80	42.20
0.425	367	440	73	7.30	65.10	34.90
0.3	372	373	1	0.10	65.20	34.80
0.15	343	518	175	17.50	82.70	17.30
0.075	335	400	65	6.50	89.20	10.80
pan	241	349	108	10.80	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) 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	52	53	7.8	0.0132	-	0.4	0.994	44.4	88.26	9.533
1	22	48	49	8.4	0.0132	0.0383	0.4	0.994	48.4	96.21	10.392
2	22	42	43	9.4	0.0132	0.0286	0.4	0.994	42.4	84.29	9.103
4	22	35	36	10.6	0.0132	0.0215	0.4	0.994	35.4	70.37	7.601
8	22	29	30	11.5	0.0132	0.0158	0.4	0.994	29.4	58.44	6.312
15	22	23	24	12.5	0.0132	0.0120	0.4	0.994	23.4	46.51	5.024
30	23	19	20	13.2	0.0130	0.0087	0.7	0.994	19.7	39.16	4.230
60	23	14	15	14	0.0130	0.0063	0.7	0.994	14.7	29.22	3.156
120	24	12	13	14.3	0.0129	0.0045	1	0.994	13	25.84	2.791
240	26	11	12	14.5	0.0126	0.0031	1.65	0.994	12.65	25.14	2.716
480	27	10	11	14.7	0.0124	0.0022	2	0.994	9.35	18.58	2.007
1440	23	9	10	14.8	0.0130	0.0013	0.7	0.994	9.7	19.28	2.083

Test pits No: TP8-1 sample depth 0 to 1.2m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%retained	cum % retained	%pass
19	435	435	0	0.00	0.00	100.00
12.5	445	560	115	11.50	11.50	88.50
9.5	442	490	48	4.80	16.30	83.70
4.75	441	550	109	10.90	27.20	72.80
2.36	405	508	103	10.30	37.50	62.50
2	467	483	16	1.60	39.10	60.90
1.18	434	510	76	7.60	46.70	53.30
0.6	407	530	123	12.30	59.00	41.00
0.425	367	430	63	6.30	65.30	34.70
0.3	372	373	1	0.10	65.40	34.60
0.15	343	516	173	17.30	82.70	17.30
0.075	335	405	70	7.00	89.70	10.30
pan	252	355	103	10.30	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) 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. 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	0.0128	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

Test pits No: TP8-2 sample depth 1.2 to 3m

ASTM SIEVE (mm)	weight of sieve(g)	wt of seive +soil(g)	Wt retained(g)	%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	43	4.30	16.30	83.70
4.75	441	550	109	10.90	27.20	72.80
2.36	405	505	100	10.00	37.20	62.80
2	467	483	16	1.60	38.80	61.20
1.18	434	511	77	7.70	46.50	53.50
0.6	407	532	125	12.50	59.00	41.00
0.425	367	435	68	6.80	65.80	34.20
z	372	373	1	0.10	65.90	34.10
0.15	343	516	173	17.30	83.20	16.80
0.075	335	404	69	6.90	90.10	9.90
pan	240	339	99	9.90	100.00	0.00
Total			1000	100		

Hydrometer analysis test result (152H) Gs=2.67

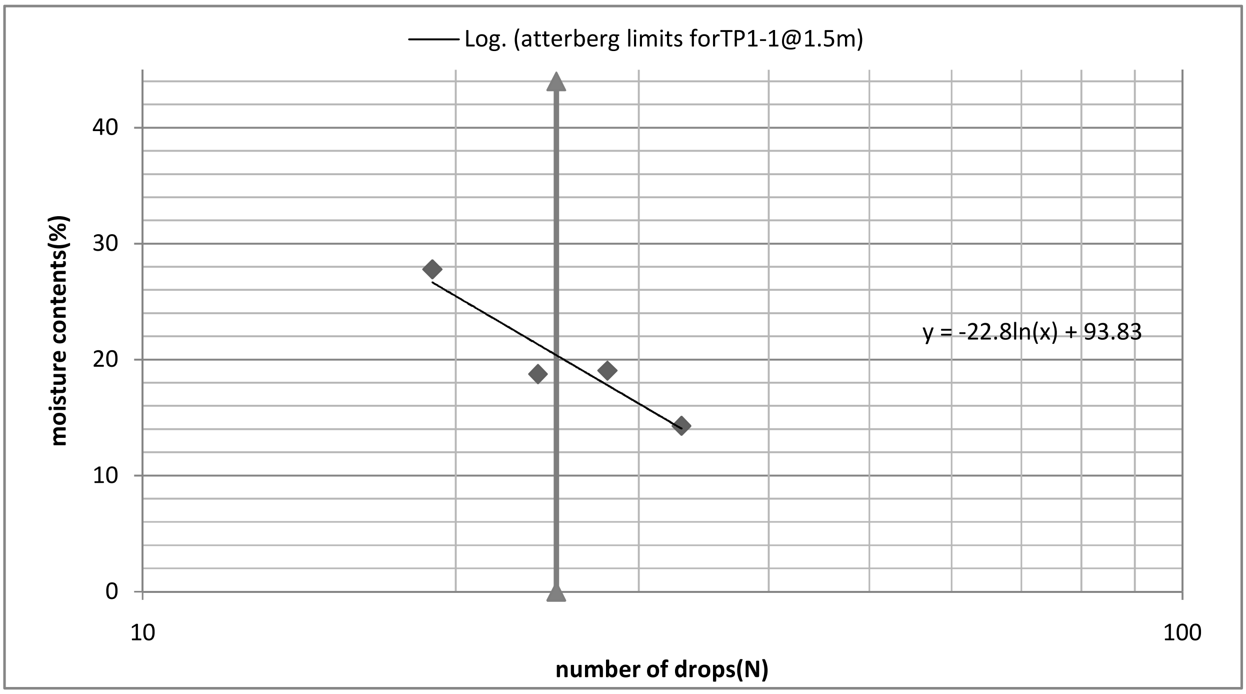
Elapsed time (min)	Temp °C	Actual hydro. Rdg (Ra)	Hyd. Corr. for meniscus	L from Table 1	K from Table 2	D (mm)	CT From table 3	a from Table 4	Corr.Hydr.Rdg (.Rc)	%finer(p)	% Adjusted Finer (PA)
0	22	48	49	8.4	0.0132	-	0.4	0.996	40.4	80.47	7.96
1	22	42	43	9.4	0.0132	0.0405	0.4	0.996	42.4	84.46	8.36
2	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

Appendix – D (Liquid limit results and plastic limit test)

Test pit: TP1-1aroresa

Depth: 1.5m

	Liquid limits(LL)				Plastic limit(PL)	
Trial No	1	2	3	4	1	2
Container No	K-1-1	K-1-2	K-1-3	K-1-4	K-1-1	K-1-2
Mass of container(g)	60	60	58	58	94	94
Mass of container + wet soil(g)	83	79	83	82	104	105.85
Mass of container + dry soil(g)	78	76	79	79	103	103.5
Mass of dry soil(g)	18	16	21	21	9	9.5
Mass of water(g)	5	3	4	3	1	2.35
Water contents (%)	27.78	18.75	19.05	14.29	11.11	24.74
Number of drops(N)	19	24	28	33	PL=17.92	

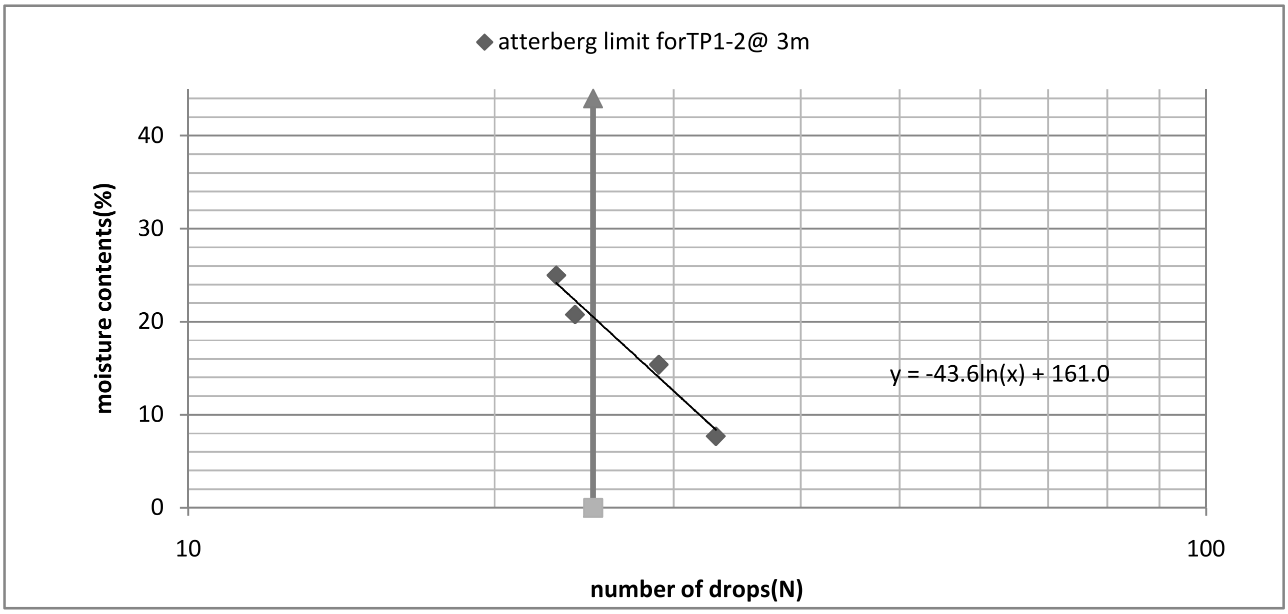


Liquid limits (LL) =20%, plastic limit (PL) = 17.92%, plastic index (PI) =2.08%

Test pit: TP1-2aroresa

Depth: 3m

	Liquid limits(LL)				Plastic limit(PL)	
Trial No	1	2	3	4	1	2
Container No	k-1-1	k-1-2	k-1-3	k-1-4	k-1-1	k-1-2
Mass of container(g)	61	61	61	61	61	61
Mass of container + wet soil(g)	76	76.7	76	75	71.5	72.67
Mass of container + dry soil(g)	73	74	74	74	70	71
Mass of dry soil(g)	12	13	13	13	9	10
Mass of water(g)	3	2.7	2	1	1.5	1.67
Water contents (%)	25	20.77	15.38	7.69	16.67	16.7
Number of drops(N)	23	24	29	33	16.68	

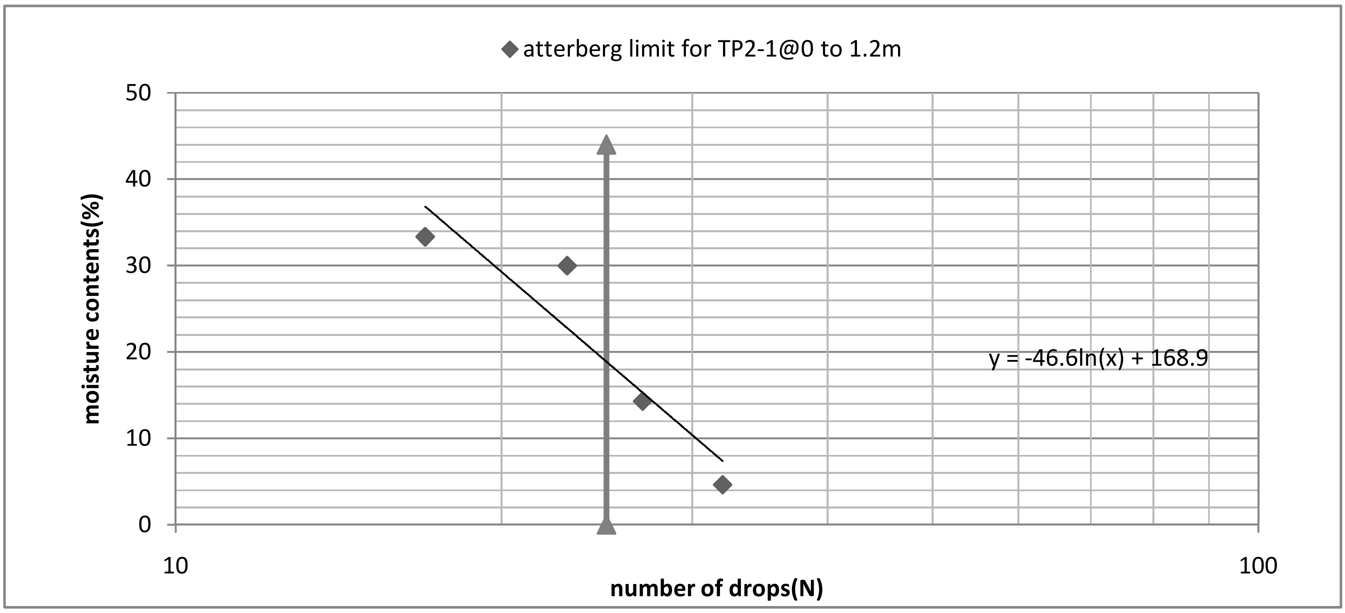


Liquid limits (LL) =20.2%, plastic limit (PL) = 16.68%plastic index (PI) =3.52%

Test pit: TP2-1technic College

Depth: 0 to 1.2m

	Liquid limits(LL)				Plastic limit(PL)	
Trial No	1	2	3	4	1	2
Container No	K-2-1	K-2-2	K-2-3	K-2-4	K-2-1	K-2-2
Mass of container(g)	8	7	7	61	7	62
Mass of container + wet soil(g)	24	20	23	74.6	19.6	71.2
Mass of container + dry soil(g)	20	17	21	74	18	70
Mass of dry soil(g)	12	10	14	13	11	8
Mass of water(g)	4	3	2	0.6	1.6	1.2
Water contents (%)	33.33	30	14.29	4.62	14.55	15.00
Number of drops(N)	17	23	27	32	14.77	

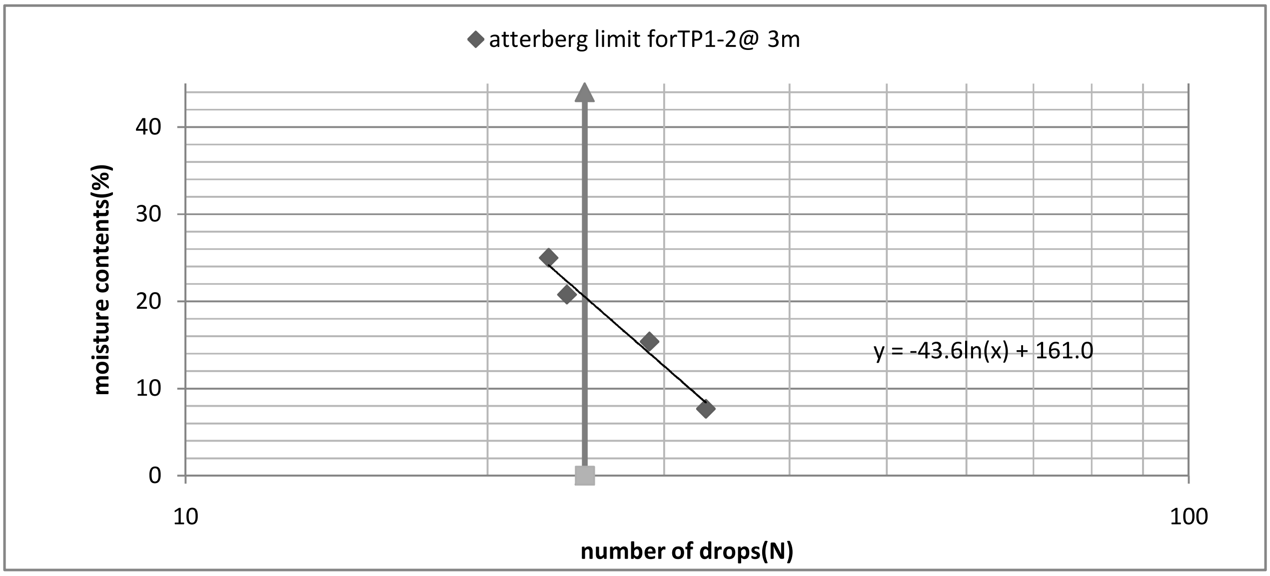


Liquid limits (LL) =18.5%, plastic limit (PL) = 14.77%, plastic index (PI) =3.73%

Test pit: TP2-2technic College

Depth: 1.2 to 3m

	Liquid limits(LL)				Plastic limit(PL)	
Trial No	1	2	3	4	1	2
Container No	K-2-1	K-2-2	K-2-3	K-2-4	K-2-1	K-2-2
Mass of container(g)	8	62	97	93	61	61
Mass of container + wet soil(g)	26	80	110	108	70.5	71.12
Mass of container + dry soil(g)	22	77	108	106	69	70
Mass of dry soil(g)	14	15	11	13	8	9
Mass of water(g)	4	3	2	2	1.5	1.12
Water contents (%)	28.57	20	18.18	15.38	18.75	12.44
Number of drops(N)	16	24	28	34	15.60	

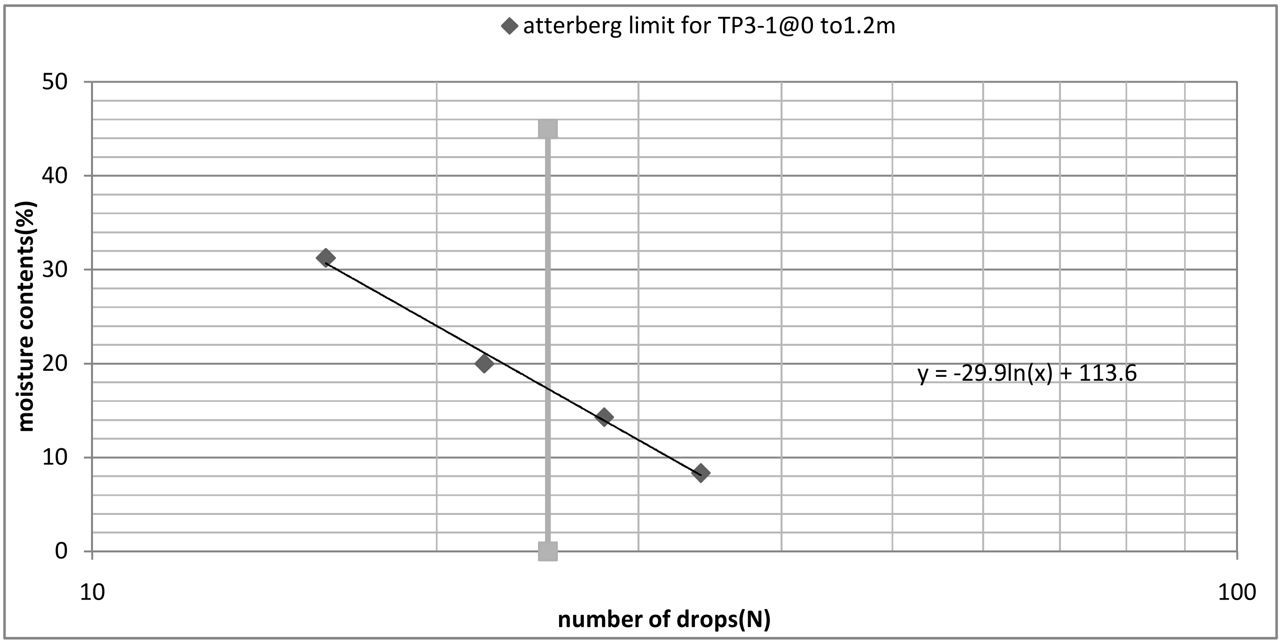


Liquid limits (LL) =20.3%, plastic limit (PL) = 15.6%, plastic index (PI) =4.7%

Test pit: TP3-1 Gabriel church

Depth: 0 t0 1.2m

	Liquid limits(LL)				Plastic limit(PL)	
Trial No	1	2	3	4	1	2
Container No	K-3-1	K-3-2	K-3-3	K-3-4	K-3-1	K-3-2
Mass of container(g)	61	61	60	62	93	61
Mass of container + wet soil(g)	82	79	76	75	105	70.5
Mass of container + dry soil(g)	77	76	74	74	104	69
Mass of dry soil(g)	16	15	14	12	11	8
Mass of water(g)	5	3	2	1	1	1.5
Water contents (%)	31.25	20	14.29	8.33	9.09	18.75
Number of drops(N)	16	22	28	34	13.92	

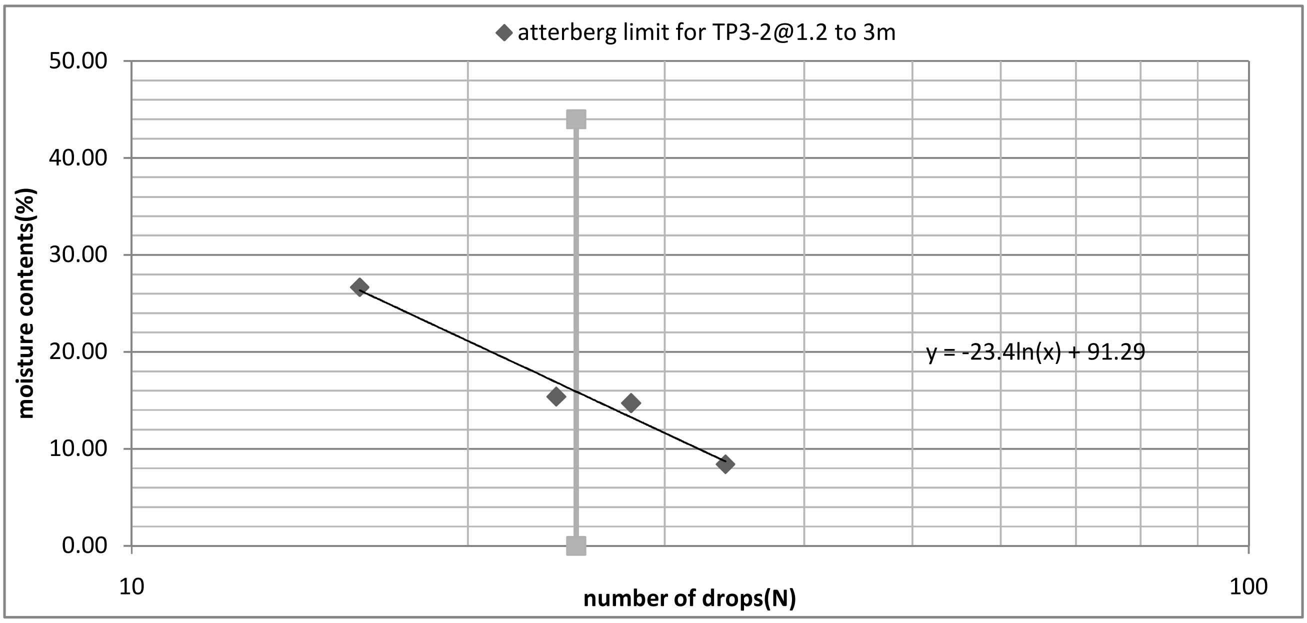


Liquid limits (LL) =16.8%, plastic limit (PL) = 13.92%, plastic index (PI) =2.88%

Test pit: TP3-2Gabriel church

Depth: 1.2 to 3m

	Liquid limits(LL)				Plastic limit(PL)	
Trial No	1	2	3	4	1	2
Container No	K-3-1	K-3-2	K-3-3	K-3-4	K-3-1	K-3-2
Mass of container(g)	62	61	61	62	97	97
Mass of container + wet soil(g)	81	76	80.5	82.6	110	115
Mass of container + dry soil(g)	77	74	78	81	108	113
Mass of dry soil(g)	15	13	17	19	11	16
Mass of water(g)	4	2	2.5	1.6	2	2
Water contents (%)	26.67	15.38	14.71	8.42	18.18	12.50
Number of drops(N)	16	24	28	34	15.34	

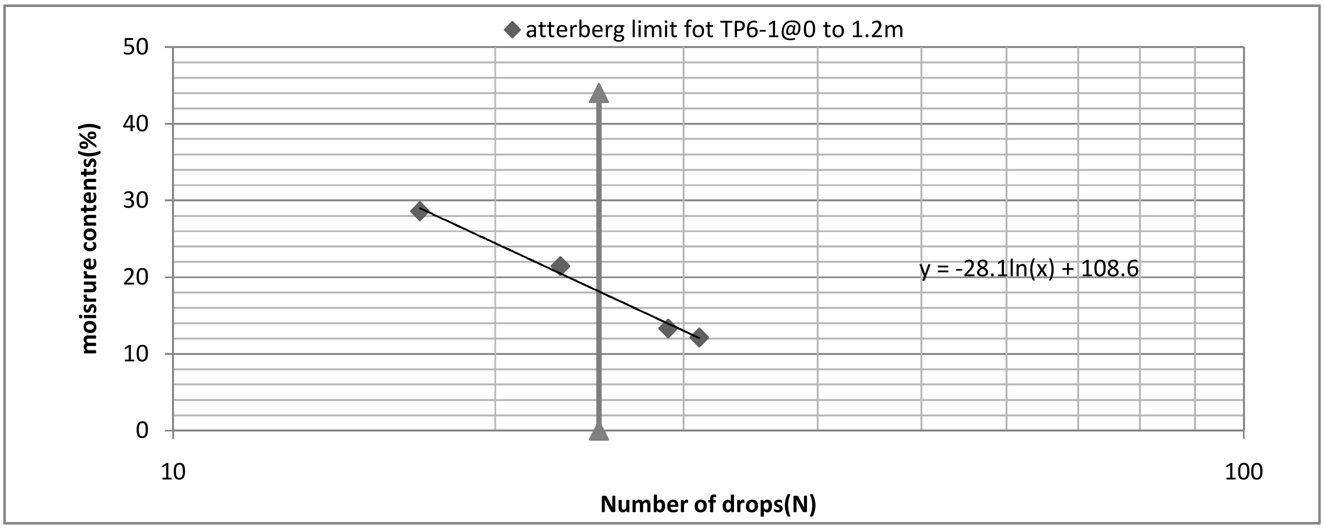


Liquid limits (LL) =16%, plastic limit (PL) = 15.34%, plastic index (PI) =0.66%

Test pit: TP6-1Cambiargitu

Depth: 0 to 1.2m

	Liquid limits(LL)				Plastic limit(PL)	
Trial No	1	2	3	4	1	2
Container No	k-6-1	k-6-2	k-6-3	k-6-4	k-6-1	k-6-2
Mass of container(g)	61	62	60	61	62	61
Mass of container + wet soil(g)	79	79	77	76.7	68.8	72
Mass of container + dry soil(g)	75	76	75	75	68	70
Mass of dry soil(g)	14	14	15	14	6	9
Mass of water(g)	4	3	2	1.7	0.8	2
Water contents (%)	28.57	21.42	13.33	12.14	13.33	22.22
Number of drops(N)	17	23	29	31	17.78	



Liquid limits (LL) =18%, plastic limit (PL) = 17.78%, plastic index (PI) =0.2

Appendix – E(Standard Compaction test result)

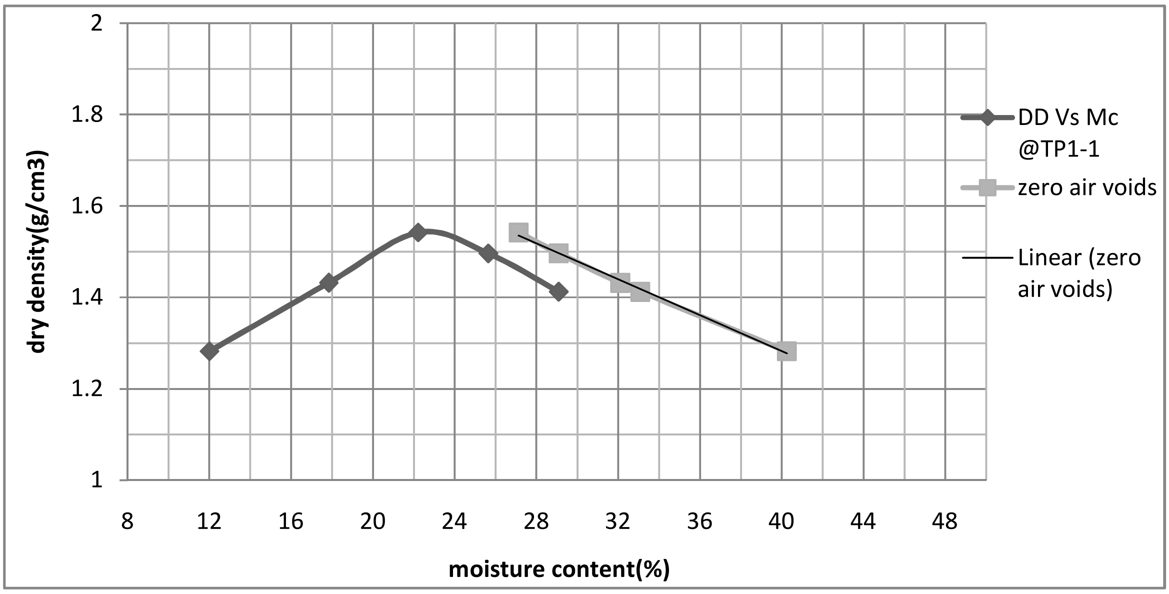
Sample Pit No TP1-1 Sample Depth 1.5m:
Moisture content Vs dry density comp. table GS= 2.65

Water Content Determination:

Compacted Soil – Sample No	1	2	3	4	5
Moisture can number - number	K-1-1	K-1-2	K-1-3	K-1-4	K-1-5
MC = Mass of empty, clean can(grams)	7	9	9	10	8
MCMS = Mass of can, and moist soil (grams)	63	53	53	59	79
MCDS = Mass of can, and dry soil (grams)	57	46.34	45	49	63
MS = Mass of soil solids (grams)	50	37.34	36	39	55
MW = Mass of pore water (grams)	6	6.66	8	10	16
W = Water content, w%	12	17.836	22.222	25.641	29.09

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	24
Actual average water content, w%	12	17.836	22.222	25.641	29.09
Mass of compacted soil and mold (grams)	5761	5998	6184	6180	6126
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1356	1593	1779	1775	1721
Wet density, ρ , (g/cm3)	1.4364	1.6875	1.8845	1.8803	1.823
Dry density, ρd , (g/cm3)	1.2825	1.4321	1.5419	1.4966	1.412
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.2825363	1.432074	1.541891	1.496563	1.4123
Saturated moisture contents(%)	40.234652	32.09295	27.11956	29.08394	33.073



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

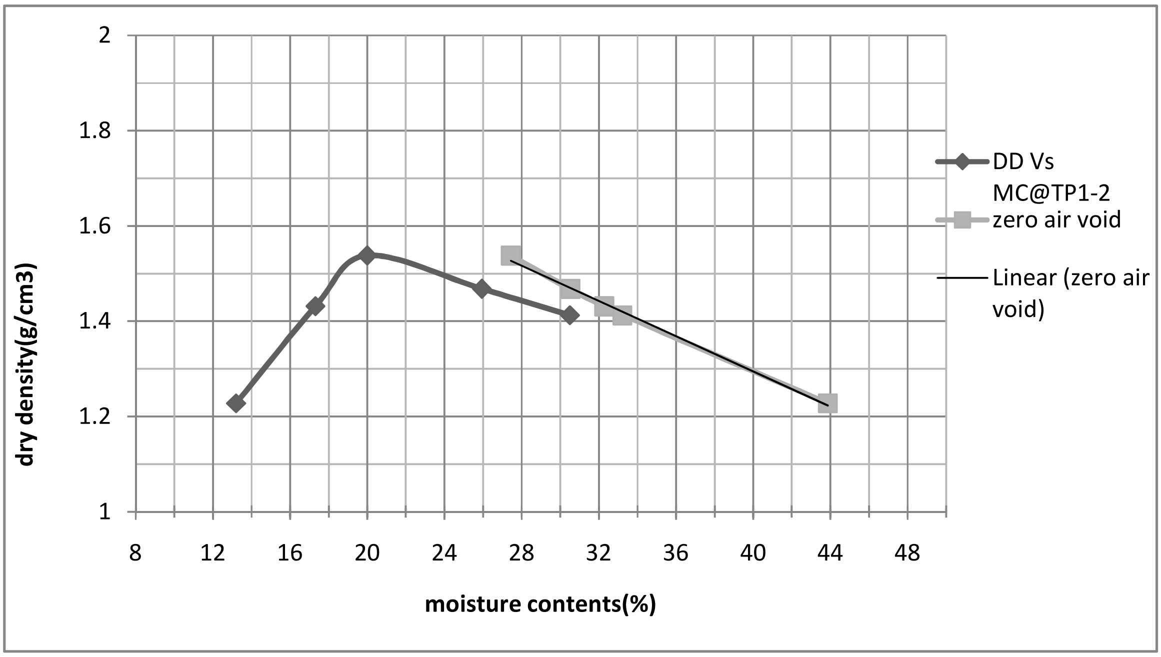
Sample Pit No TP1-2 Sample Depth 3m:GS=2.66
Moisture content Vs dry density table

Water Content Determination:

Compacted Soil – Sample No	1	2	3	4	5
Moisture can number - number	K-1-1	K-1-2	K-1-3	K-1-4	K-1-5
MC = Mass of empty, clean can(grams)	62	61	61	62	93
MCMS = Mass of can, and moist soil (grams)	122	122	121	130	170
MCDS = Mass of can, and dry soil (grams)	115	113	111	116	152
MS = Mass of soil solids (grams)	53	52	50	54	59
MW = Mass of pore water (grams)	7	9	10	14	18
W = Water content, w%	13.208	17.308	20	25.926	30.51

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	14	20	26
Actual average water content, w%	13.208	17.308	20	25.926	30.51
Mass of compacted soil and mold (grams)	5717	5990	6147	6150	6145
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1312	1585	1742	1745	1740
Wet density, ρ , (g/cm3)	1.3898	1.679	1.8453	1.8485	1.843
Dry density, ρd , (g/cm3)	1.2277	1.4313	1.5378	1.4679	1.412
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.2276836	1.4313	1.537782	1.46794	1.4123
Saturated moisture contents (%)	43.860226	32.27255	27.43472	30.52869	33.211



Maximum dry density (g/cm^3) =1.53, Optimum moisture contents (%) =20

Sample Pit No TP2-1Sample Depth 0 to 1.2m: Gs=2.67

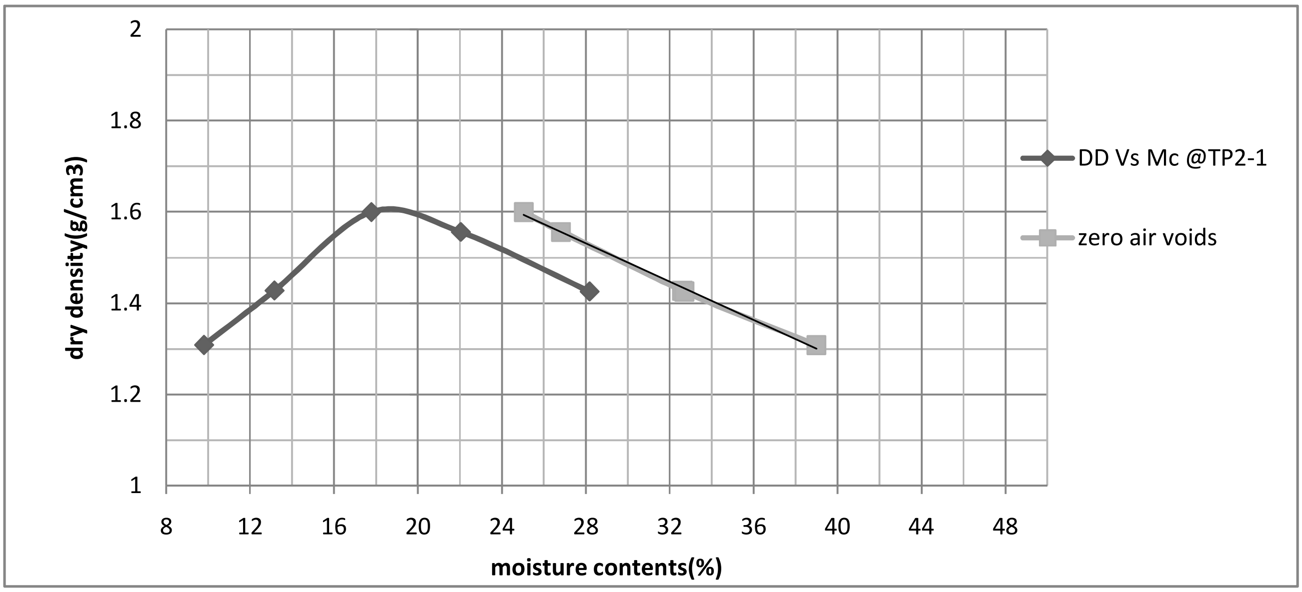
Moisture content Vs dry density comp. table

sample depth=0 to 1.2m Water Content Determination:

Compacted Soil – Sample No	1	2	3	4	5
Moisture can number - number	K-2-1	K-2-2	K-2-3	K-2-4	K-2-5
MC = Mass of empty, clean can(grams)	7	9	9	10	8
MCMS = Mass of can, and moist soil (grams)	63	52	51.4	57.6	78.5
MCDS = Mass of can, and dry soil (grams)	58	47	45	49	63
MS = Mass of soil solids (grams)	51	38	36	39	55
MW = Mass of pore water (grams)	5	5	6.4	8.6	15.5
W = Water content, w%	9.8039	13.158	17.778	22.051	28.18

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	9.8039	13.158	17.778	22.051	28.18
Mass of compacted soil and mold (grams)	5761	5930	6184	6198	6130
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1356	1525	1779	1793	1725
Wet density, ρ , (g/cm3)	1.4364	1.6155	1.8845	1.8994	1.827
Dry density, ρd , (g/cm3)	1.3082	1.4276	1.6001	1.5562	1.426
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.3082	1.42762	1.600075951	1.5562019	1.425577
Saturated moisture contents (%)	38.988	32.5934	25.04384977	26.805829	32.69385



Maximum dry density (g/cm^3) =1.6, Optimum moisture contents (%) =19

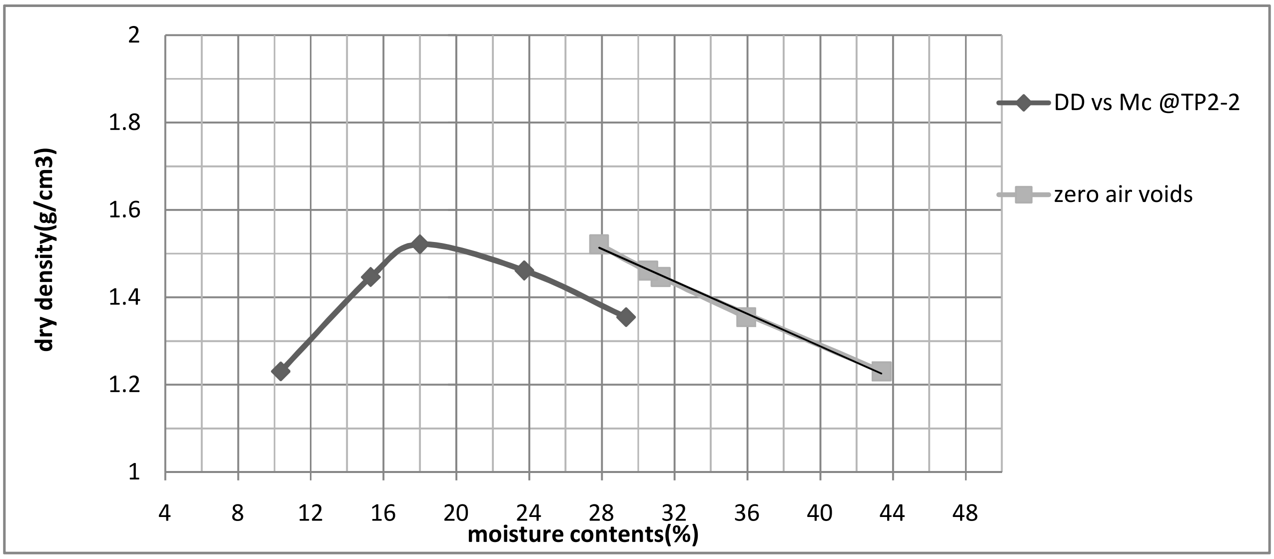
Sample Pit No TP2-2   Sample Depth 1.2 to 3m:Gs=2.64

Moisture content Vs dry density comp. table Moisture contents determination

Compacted Soil – Sample No	1	2	3	4	5
Moisture can number - number	K-2-1	K-2-2	K-2-3	K-2-4	K-2-5
MC = Mass of empty, clean can(grams)	60	61	60	60	61
MCMS = Mass of can, and moist soil (grams)	124	117.5	119	133	158
MCDS = Mass of can, and dry soil (grams)	118	110	110	119	136
MS = Mass of soil solids (grams)	58	49	50	59	75
MW = Mass of pore water (grams)	6	7.5	9	14	22
W = Water content, w%	10.345	15.306	18	23.729	29.33

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	10.345	15.306	18	23.729	29.33
Mass of compacted soil and mold (grams)	5687	5980	6100	6112	6059
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1282	1575	1695	1707	1654
Wet density, ρ , (g/cm3)	1.3581	1.6684	1.7956	1.8083	1.752
Dry density, ρd , (g/cm3)	1.2307	1.447	1.5217	1.4615	1.355
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.230733581	1.4469589	1.521653	1.461473	1.354731
Saturated moisture contents(%)	43.37356566	31.231675	27.83921	30.54535	35.93661



Maximum dry density (g/cm^3) =1.53, Optimum moisture contents (%) =18

Sample Pit No TP3-1   Sample Depth 0 to 1.2m: Gs=2.65

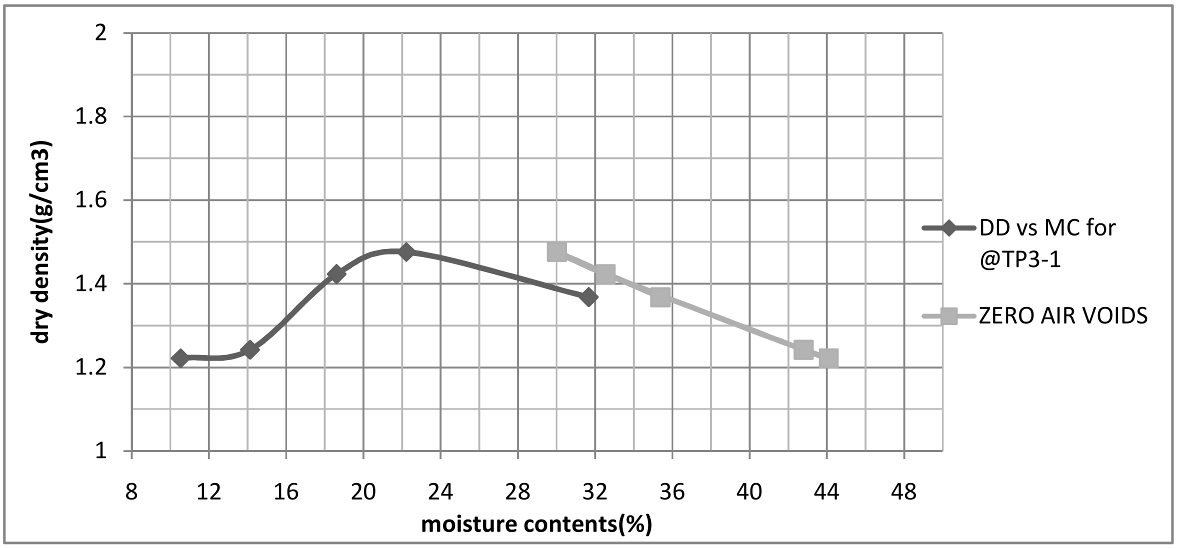
Moisture content Vs dry density comp. table

Moisture contents determination

Compacted Soil – Sample No	1	2	3	4	5
Moisture can number – number	K-3-1	K-3-2	K-3-3	K-3-4	K-3-5
MC = Mass of empty, clean can(grams)	60	60	61	61	96
MCMS = Mass of can, and moist soil (grams)	102	112.5	112	116	175
MCDS = Mass of can, and dry soil (grams)	98	106	104	106	156
MS = Mass of soil solids (grams)	38	46	43	45	60
MW = Mass of pore water (grams)	4	6.5	8	10	19
W = Water content, w%	10.526	14.13	18.605	22.222	31.67

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	28
Actual average water content, w%	10.526	14.13	18.605	22.222	31.67
Mass of compacted soil and mold (grams)	5680	5743	5998	6108	6105
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1275	1338	1593	1703	1700
Wet density, ρ , (g/cm3)	1.3506	1.4174	1.6875	1.804	1.801
Dry density, ρd , (g/cm3)	1.222	1.2419	1.4228	1.476	1.368
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.222	1.242	1.423	1.476	1.368
Saturated moisture contents(%)	44.097	42.787	32.548	30.014	35.378



Maximum dry density (g/cm^3) =1.48, Optimum moisture contents (%) =22

Sample Pit No TP3-2 Sample Depth 1.2 to 3m:

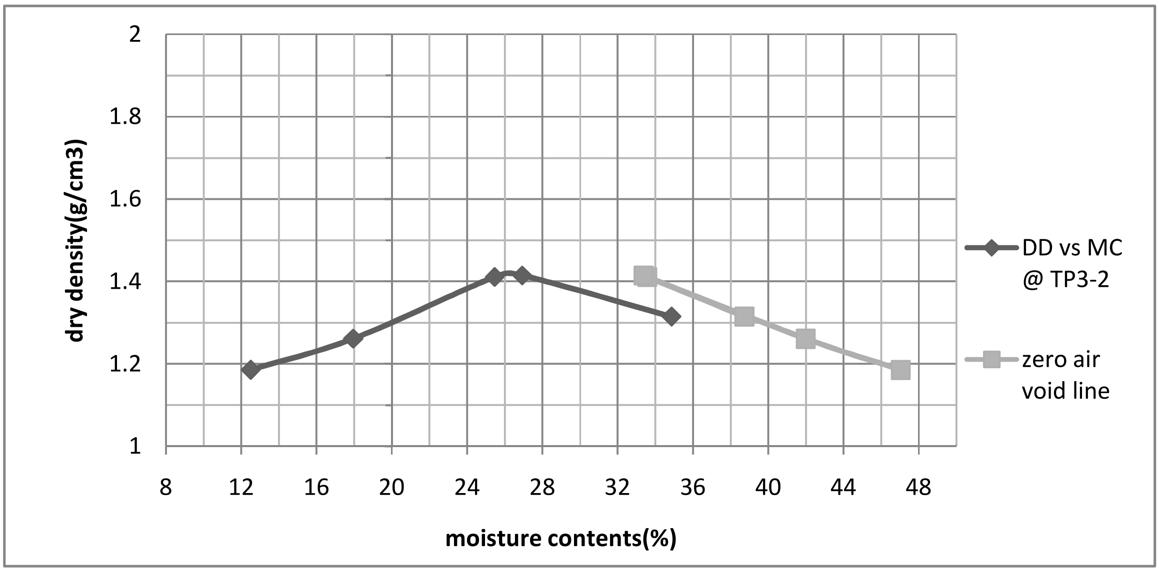
Moisture content Vs dry density comp. tableGs=2.68

Water Content Determination:

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K-3-1	K-3-2	K-3-3	K-3-4	K-3-5
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	63	55	78	73	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	7	14	14	23
W = Water content, w%	12.5	17.949	25.455	26.923	34.85

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	16	22	26	30
Actual average water content, w%	12.5	17.949	25.455	26.923	34.85
Mass of compacted soil and mold (grams)	5664	5802	6076	6100	6074
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1259	1397	1671	1695	1669
Wet density, ρ , (g/cm3)	1.3337	1.4799	1.7701	1.7956	1.768
Dry density, ρd , (g/cm3)	1.1855	1.2547	1.411	1.4147	1.311
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.185499058	1.2546748	1.410971	1.414676	1.311107
Saturated moisture contents (%)	47.03922801	42.388493	33.55975	33.37411	38.95797



Maximum dry density (g/cm^3) =1.42, Optimum moisture contents (%) =26

Sample Pit No TP4-1 Sample Depth 0 to 1.2m:

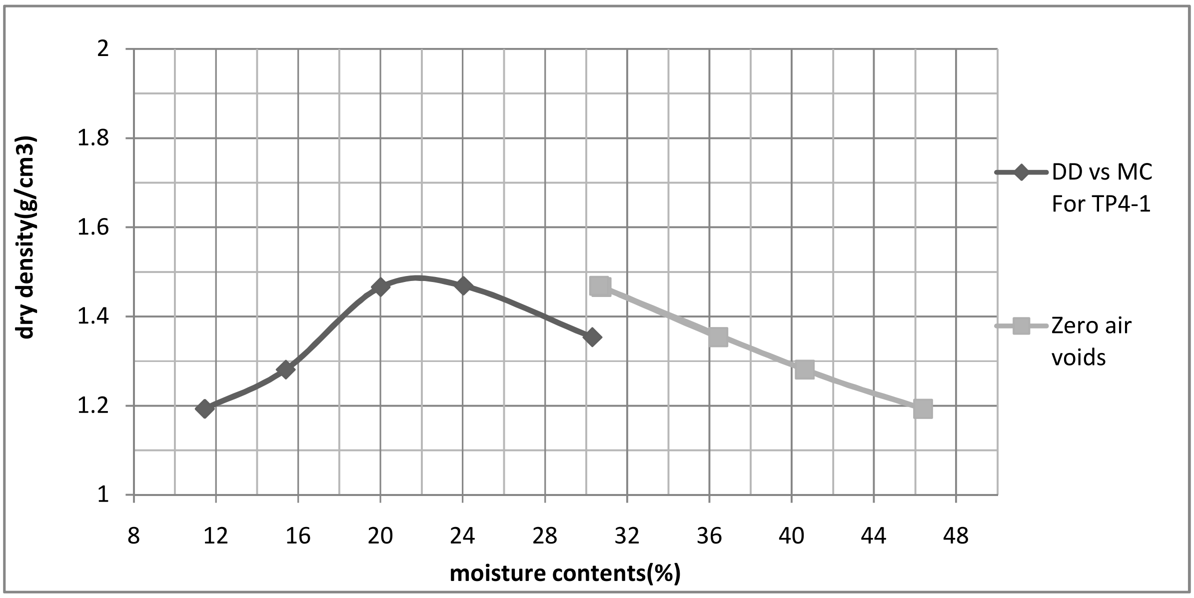
Moisture content Vs dry density comp. table Gs=2.67

Water Content Determination:

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K-4-1	K-4-2	K-4-3	K-4-4	K-4-5
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	62.5	54	75	71.5	94
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)	5.5	6	11	12.5	20
W = Water content, w%	11.458	15.385	20	24.038	30.3

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	11.458	15.385	20	24.038	30.3
Mass of compacted soil and mold (grams)	5660	5800	6066	6125	6070
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1255	1395	1661	1720	1665
Wet density, ρ , (g/cm3)	1.3294	1.4778	1.7595	1.822	1.764
Dry density, ρd , (g/cm3)	1.1928	1.2807	1.4663	1.4689	1.354
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.19278	1.280720339	1.4662782	1.468927	1.353592
Saturated moisture contents (%)	46.3848	40.62787521	30.746696	30.62374	36.42433



Maximum dry density (g/cm^3) =1.47, Optimum moisture contents (%) =21.7

Sample Pit No TP4-2 Sample Depth 1.2 to 3m:

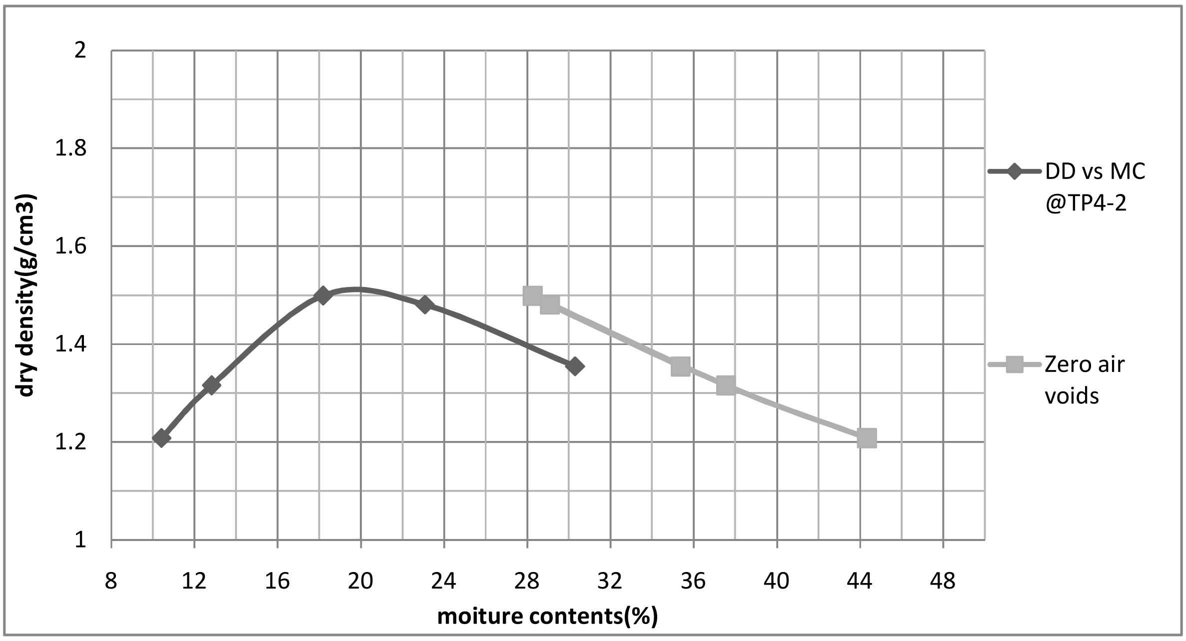
Moisture content Vs dry density comp. table Gs=2.6

Water Content Determination:

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K-4-1	K-4-2	K-4-3	K-4-4	K-4-5
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	62	53	74	71	94
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)	5	5	10	12	20
W = Water content, w%	10.417	12.821	18.182	23.077	30.3

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	10.417	12.821	18.182	23.077	30.3
Mass of compacted soil and mold (grams)	5668	5802	6076	6129	6078
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1259	1397	1671	1724	1669
Wet density, ρ , (g/cm3)	1.3337	1.4799	1.7701	1.8263	1.768
Dry density, ρd , (g/cm3)	1.2079	1.3117	1.4978	1.4838	1.357
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.20787	1.311705508	1.4977999	1.483845	1.356844
Saturated moisture contents (%)	44.329	37.77508581	28.303055	28.93093	35.23892



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

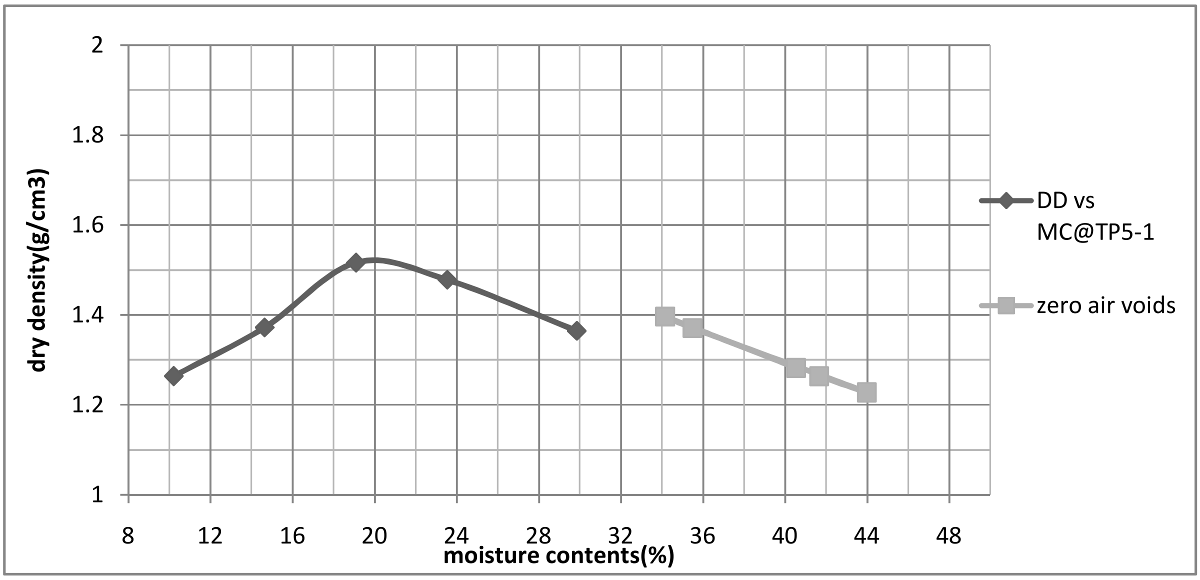
Sample Pit No TP5-1 Sample Depth 0 to 1.2m:

Moisture content Vs dry density comp. table Gs=2.67Water Content Determination

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K-5-1	K-5-2	K-5-3	K-5-4	K-5-5
MC = Mass of empty, clean can(grams)	8	7	9	8	7
MCMS = Mass of can, and moist soil (grams)	62	54	74.5	71	94
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	6	10.5	12	20
W = Water content, w%	10.204	14.634	19.091	23.529	29.85

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	10.204	14.634	19.091	23.529	29.85
Mass of compacted soil and mold (grams)	5700	5890	6100	6129	6074
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1295	1485	1695	1724	1669
Wet density, ρ , (g/cm3)	1.3718	1.5731	1.7956	1.8263	1.768
Dry density, ρd , (g/cm3)	1.2448	1.3723	1.5077	1.4784	1.362
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.245	1.228	1.37123	1.396560319	1.2822919
Saturated moisture contents (%)	42.88	43.981	35.4743	34.15131407	40.532182



Maximum dry density (g/cm^3) =1.5, Optimum moisture contents (%) =20

Sample Pit No TP5-2 Sample Depth 1.2 to 3m:

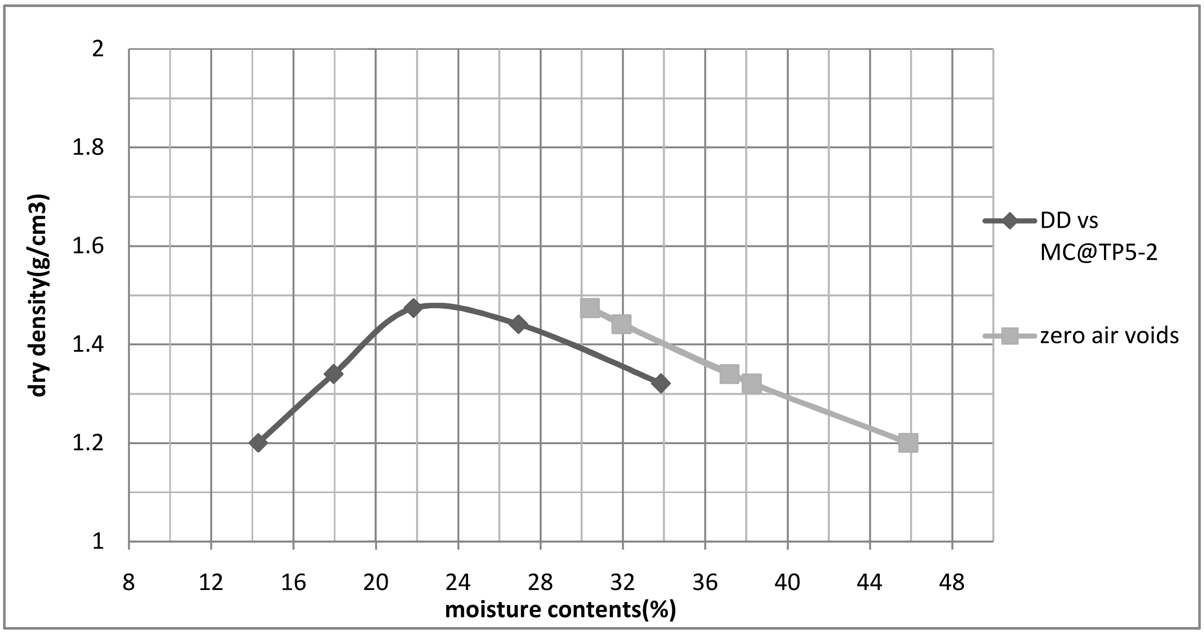
Moisture content Vs dry density comp. table Gs=2.67

Water Content Determination:

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K-5-1	K-5-2	K-5-3	K-5-4	K-5-5
MC = Mass of empty, clean can(grams)	7	9	9	7	9
MCMS = Mass of can, and moist soil (grams)	63	55	76	73	96
MCDS = Mass of can, and dry soil (grams)	56	48	64	59	74
MS = Mass of soil solids (grams)	49	39	55	52	65
MW = Mass of pore water (grams)	7	7	12	14	22
W = Water content, w%	14.286	17.949	21.818	26.923	33.85

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	14.286	17.949	21.818	26.923	33.85
Mass of compacted soil and mold (grams)	5720	5890	6100	6129	6074
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1295	1485	1695	1724	1669
Wet density, ρ , (g/cm3)	1.3718	1.5731	1.7956	1.8263	1.768
Dry density, ρd , (g/cm3)	1.2003	1.3337	1.474	1.4389	1.321
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.2	1.3337	1.47396	1.438880329	1.3209259
Saturated moisture contents (%)	45.86	37.526	30.3913	32.04529943	38.251292



Maximum dry density (g/cm^3) =1.48, Optimum moisture contents (%) =23

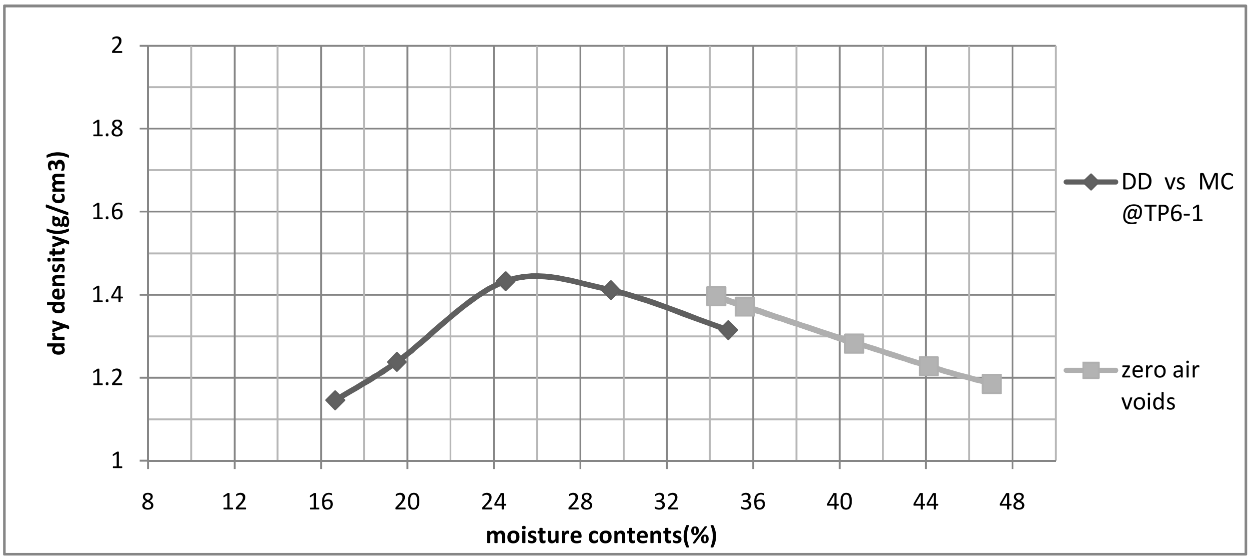
Sample Pit No TP6-1 Sample Depth 0 to 1.2m: Gs=2.68

Moisture content Vs dry density comp. table water contents determination

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K-6-1	K-6-2	K-6-3	K-6-4	K-6-5
MC = Mass of empty, clean can(grams)	8	7	9	7	8
MCMS = Mass of can, and moist soil (grams)	64	56	77.5	73	97
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	8	13.5	15	23
W = Water content, w%	16.667	19.512	24.545	29.412	34.85

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	16.667	19.512	24.545	29.412	34.85
Mass of compacted soil and mold (grams)	5664	5802	6090	6129	6074
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1259	1397	1685	1724	1669
Wet density, ρ , (g/cm3)	1.3337	1.4799	1.785	1.8263	1.768
Dry density, ρd , (g/cm3)	1.1432	1.2383	1.4332	1.4112	1.311
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.1855	1.227979625	1.3712252	1.39656	1.282292
Saturated moisture contents (%)	47.0392	44.12114309	35.614047	34.29106	40.67193



Maximum dry density (g/cm^3) =1.44, Optimum moisture contents (%) =26

Sample Pit No TP6-2 Sample Depth 1.2 to 3m: Gs=2.68

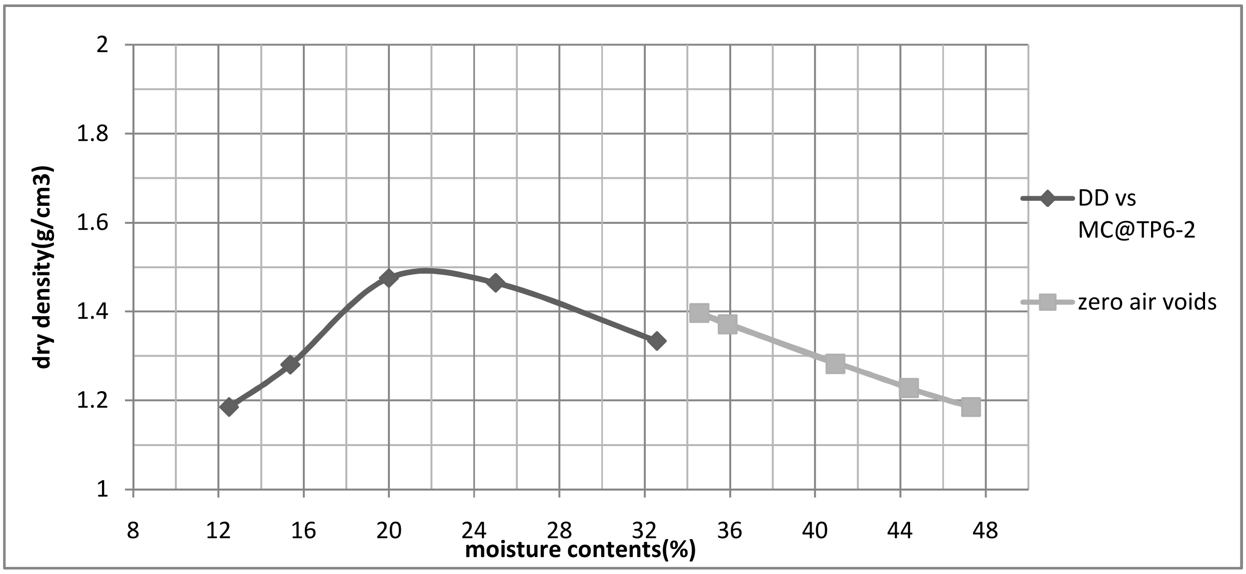
Moisture content Vs dry density comp. table

Moisture contents determination

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K-6-1	K-6-2	K-6-3	K-6-4	K-6-5
MC = Mass of empty, clean can(grams)	9	8	9	7	7
MCMS = Mass of can, and moist soil (grams)	63	53	75	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)	6	6	11	13	21.5
W = Water content, w%	12.5	15.385	20	25	32.58

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	12.5	15.385	20	25	32.58
Mass of compacted soil and mold (grams)	5669	5802	6076	6129	6074
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1259	1397	1671	1724	1669
Wet density, ρ , (g/cm3)	1.3337	1.4799	1.7701	1.8263	1.768
Dry density, ρd , (g/cm3)	1.1855	1.2826	1.4751	1.461	1.334
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.1854991	1.282556	1.475106	1.461017	1.3336
Saturated moisture contents (%)	47.039228	40.65584	30.47831	31.13204	37.672



Maximum dry density (g/cm^3) =1.49, Optimum moisture contents (%) =22

Sample Pit No TP7-1 Sample Depth 0 to 1.2m: Gs=2.68

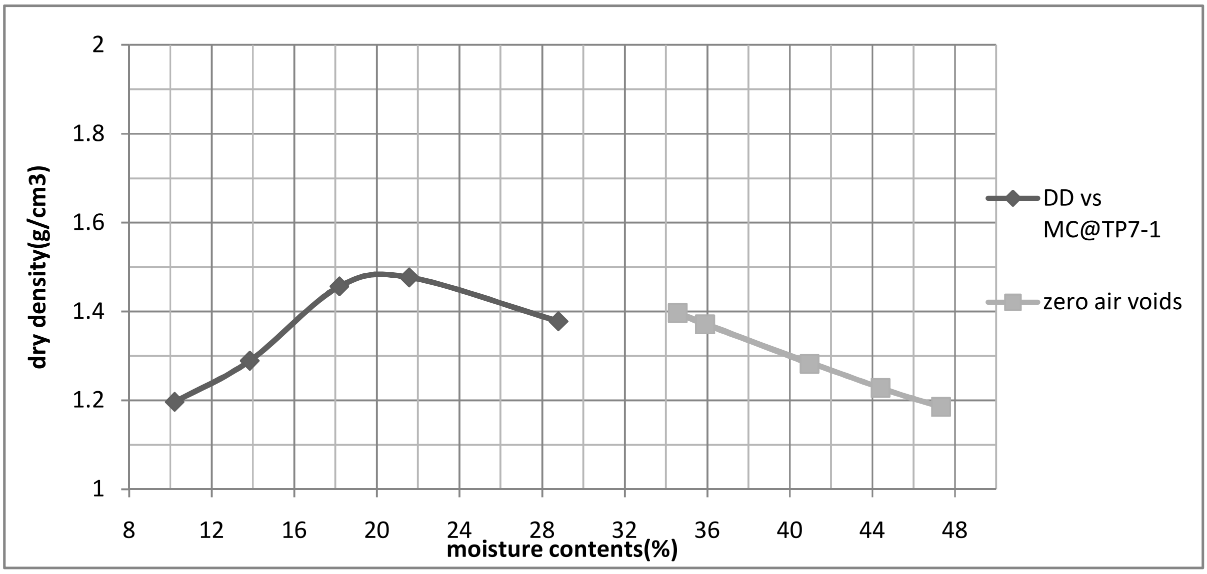
Moisture content Vs dry density comp. table

Water Content Determination:

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K-7-1	K-7-2	K-7-3	K-7-4	K-7-5
MC = Mass of empty, clean can(grams)	8	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	62	53.4	74	69	93
MCDS = Mass of can, and dry soil (grams)	57	48	64	58	74
MS = Mass of soil solids (grams)	49	39	55	51	66
MW = Mass of pore water (grams)	5	5.4	10	11	19
W = Water content, w%	10.204	13.846	18.182	21.569	28.79

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	10.204	13.846	18.182	21.569	28.79
Mass of compacted soil and mold (grams)	5650	5790	6030	6100	6080
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1245	1385	1625	1695	1675
Wet density, ρ , (g/cm3)	1.3189	1.4672	1.7214	1.7956	1.774
Dry density, ρd , (g/cm3)	1.1967	1.2887	1.4566	1.477	1.378
For drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.1855	1.22798	1.37122523	1.396560	1.28229
Saturated moisture contents(%)	47.316	44.3975	35.89044243	34.567461	40.94833



Maximum dry density (g/cm^3) =1.485, Optimum moisture contents (%) =20

Sample Pit No TP7-2 Sample Depth 0 to 1.2m: Gs=2.68

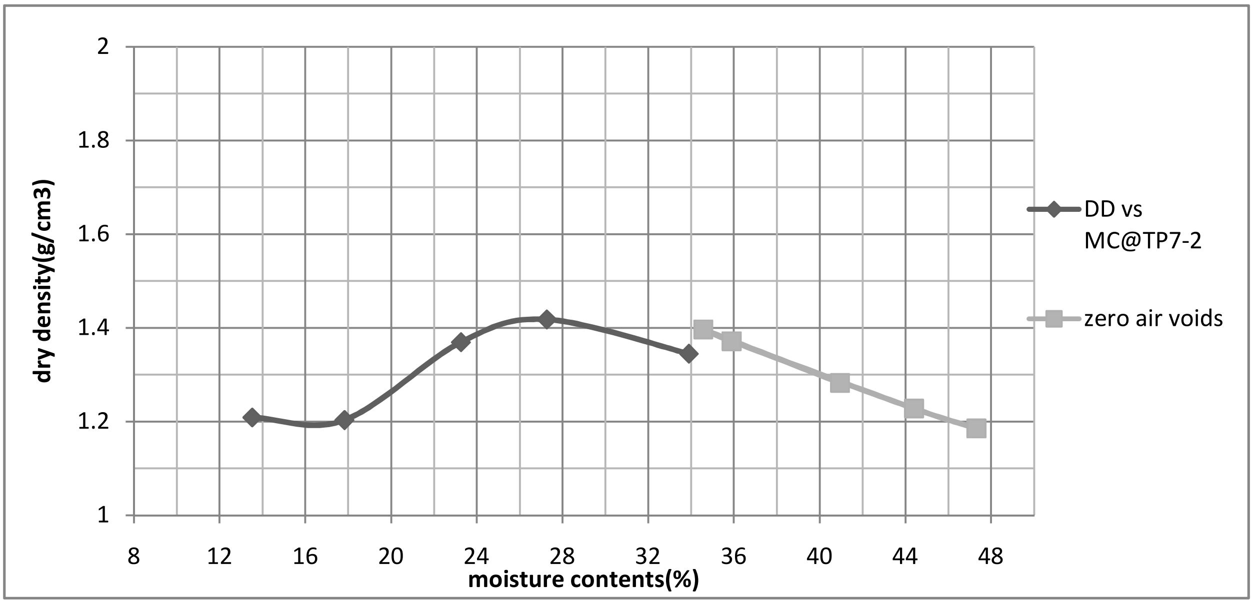
Moisture content Vs dry density comp. table

Water Content Determination

Compacted Soil - Sample	1	2	3	4	5
Moisture can number - number	K--7-1	K-7-2	K-7-3	K-7-4	K-7-5
MC = Mass of empty, clean can(grams)	61	60	61	61	96
MCMS = Mass of can, and moist soil (grams)	103	114.2	114	117	175
MCDS = Mass of can, and dry soil (grams)	98	106	104	105	155
MS = Mass of soil solids (grams)	37	46	43	44	59
MW = Mass of pore water (grams)	5	8.2	10	12	20
W = Water content, w%	13.514	17.826	23.256	27.273	33.9

Density determination

Determination No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	13.514	17.826	23.256	27.273	33.9
Mass of compacted soil and mold (grams)	5710	5743	5998	6108	6105
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1295	1338	1593	1703	1700
Wet density, ρ , (g/cm3)	1.3718	1.4174	1.6875	1.804	1.801
Dry density, ρd , (g/cm3)	1.2085	1.2029	1.3691	1.4174	1.345
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.1854991	1.22798	1.371225	1.39656	1.2823
Saturated moisture contents(%)	47.315624	44.39754	35.89044	34.56746	40.948



Maximum dry density (g/cm^3) =1.42, Optimum moisture contents (%) =26

Sample Pit No TP8-1 Sample Depth 0 to 1.2m:

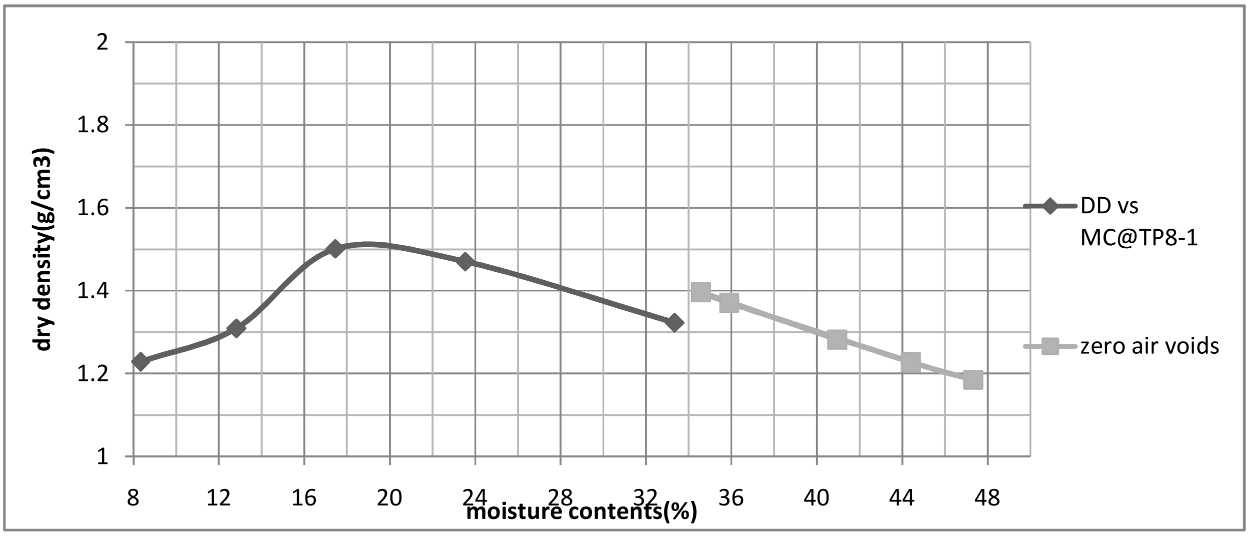
Moisture content Vs dry density comp. table

Water contents determination

Compacted Soil – Sample No	1	2	3	4	5
Moisture can number - number	K--8-1	K-8-2	K-8-3	K-8-4	K-8-5
MC = Mass of empty, clean can(grams)	9	9	9	7	8
MCMS = Mass of can, and moist soil (grams)	61	53	73.6	70	96
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	5	9.6	12	22
W = Water content, w%	8.3333	12.821	17.455	23.529	33.33

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	8.3333	12.821	17.455	23.529	33.33
Mass of compacted soil and mold (grams)	5660	5800	6070	6120	6070
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1255	1395	1665	1715	1665
Wet density, ρ , (g/cm3)	1.3294	1.4778	1.7638	1.8167	1.764
Dry density, ρd , (g/cm3)	1.2272	1.3098	1.5017	1.4707	1.323
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.18549906	1.22798	1.3712	1.396560319	1.282292
Saturated moisture contents (%)	47.3156238	44.39754	35.89	34.56746055	40.94833



Maximum dry density (g/cm^3) =1.52, Optimum moisture contents (%) =19

Sample Pit No TP8-2 Sample Depth 1.2 to 3m:

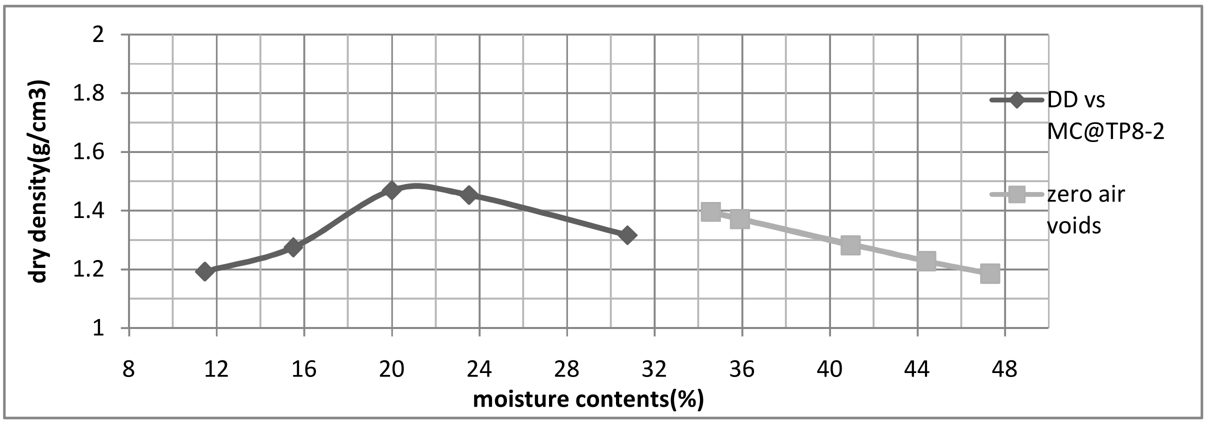
Moisture content Vs dry density comp. table

Water contents determination

Compacted Soil – Sample No	1	2	3	4	5
Moisture can number - number	K--8-1	K-8-2	K-8-3	K-8-4	K-8-5
MC = Mass of empty, clean can(grams)	9	8	9	7	8
MCMS = Mass of can, and moist soil (grams)	62.5	54.2	75	70	93
MCDS = Mass of can, and dry soil (grams)	57	48	64	58	73
MS = Mass of soil solids (grams)	48	40	55	51	65
MW = Mass of pore water (grams)	5.5	6.2	11	12	20
W = Water content, w%	11.458	15.5	20	23.529	30.77

Density determination

Compacted Soil – Sample No	1	2	3	4	5
w = Assumed water content, w%	8	12	16	20	26
Actual average water content, w%	11.458	15.5	20	23.529	30.77
Mass of compacted soil and mold (grams)	5660	5795	6070	6100	6030
Mass of mold (grams)	4405	4405	4405	4405	4405
Wet mass of soil in mold (grams)	1255	1390	1665	1695	1625
Wet density, ρ , (g/cm3)	1.3294	1.4725	1.7638	1.7956	1.721
Dry density, ρd , (g/cm3)	1.1928	1.2749	1.4698	1.4535	1.316
for drawing saturation line(zero air void line s=100)					
Dry density, ρd , (g/cm3)	1.18549906	1.22798	1.3712	1.396560319	1.282292
Saturated moisture contents (%)	47.3156238	44.39754	35.89	34.56746055	40.94833



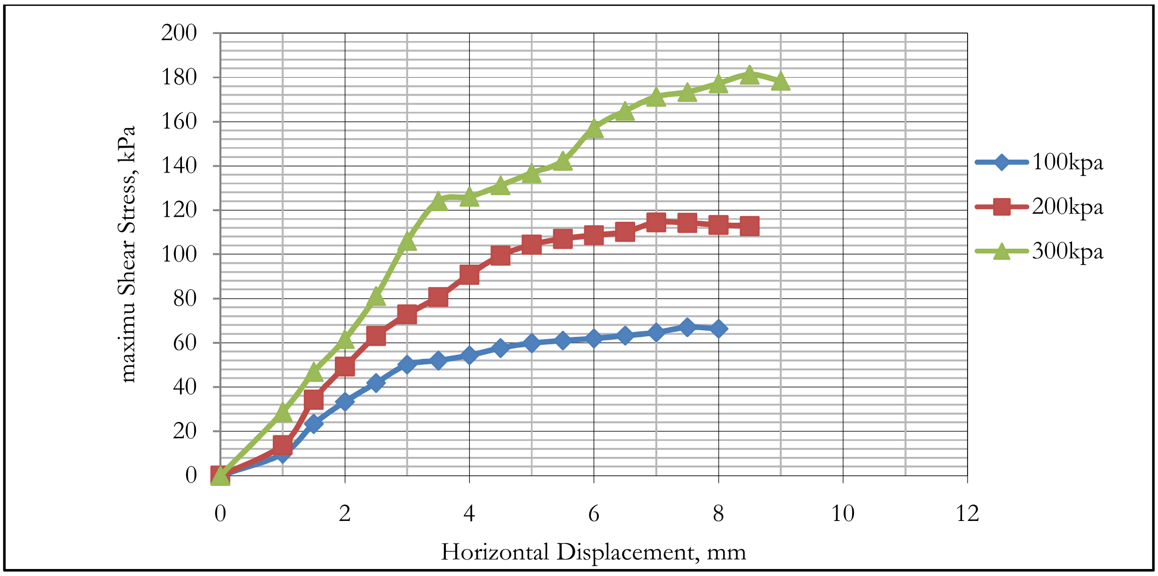
Maximum dry density (g/cm^3) =1.52, Optimum moisture contents (%) =19

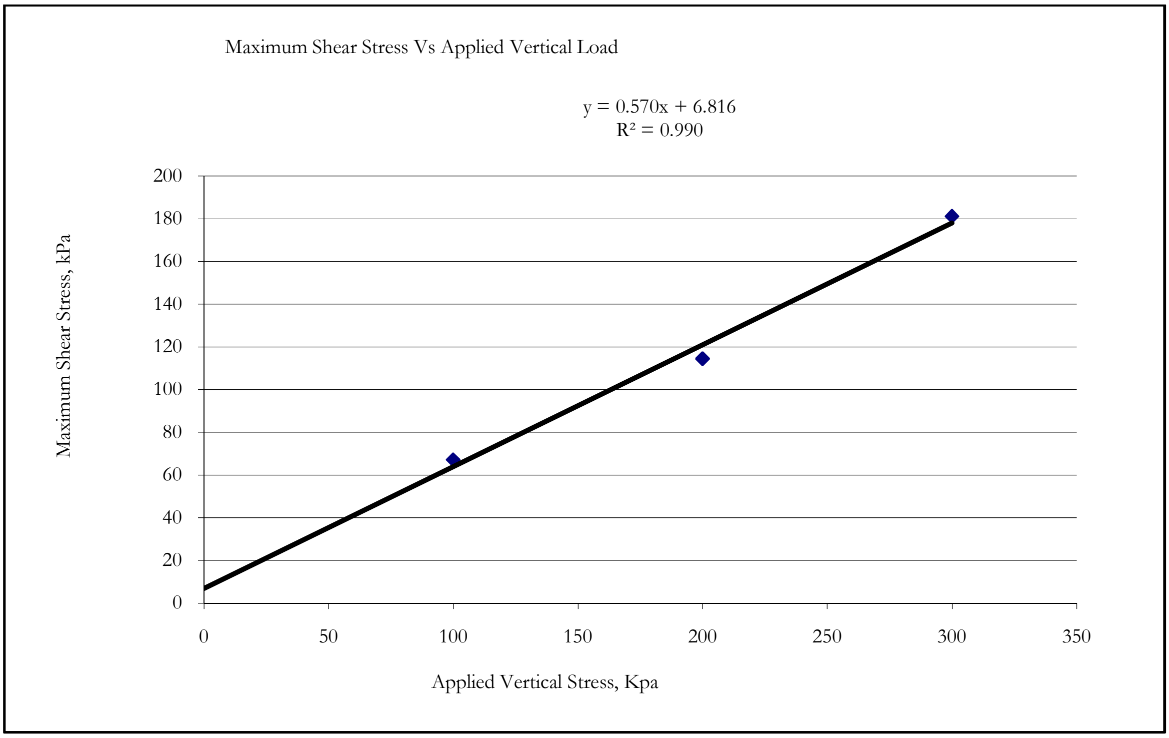
Appendix- F (Direct shear test)

sample code and depth =TP2-21.2 to 3m(technic school)

thickness of sample=	25mm	Ring calibrationfactors=0.70N/div	
Length of sample	60 mm	Rate of strain	1.6 mm/min
Width of sample	60 mm	Optimum Moisture content (%)	18

		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	50	35	9.887005	70	49	13.841808	145	101.5	28.672
1.5	3510	117	81.9	23.33333	172	120.4	34.301994	235	164.5	46.866
2.0	3480	166	116.2	33.39080	245	171.5	49.281609	307	214.9	61.7528
2.5	3450	206	144.2	41.79710	311	217.7	63.101449	400	280	81.159
3.0	3420	245	171.5	50.14619	356	249.2	72.865497	518	362.6	106.023
3.5	3390	252	176.4	52.03539	391	273.7	80.737463	601	420.7	124.10
4.0	3360	261	182.7	54.375	436	305.2	90.833333	605	423.5	126.041
4.5	3330	274	191.8	57.597598	473	331.1	99.429429	624	436.8	131.17
5.0	3300	282	197.4	59.81818	492	344.4	104.36364	645	451.5	136.81
5.5	3270	285	199.5	61.00917	500	350	107.03364	665	465.5	142.35
6.0	3240	287	200.9	62.00617	503	352.1	108.67284	727	508.9	157.07
6.5	3210	290	203	63.239875	505	353.5	110.12461	756	529.2	164.85
7.0	3180	294	205.8	64.71698	520	364	114.46541	778	544.6	171.26
7.5	3150	302	211.4	67.11111	514	359.8	114.22222	780	546	173.33
8.0	3120	296	207.2	66.41025	505	353.5	113.30128	790	553	177.24
8.5	3090				498	348.6	112.81553	800	560	181.23
9.0	3060							780	546	178.43
Maximum				**67.11111**			**114.4654**			**181.2298**



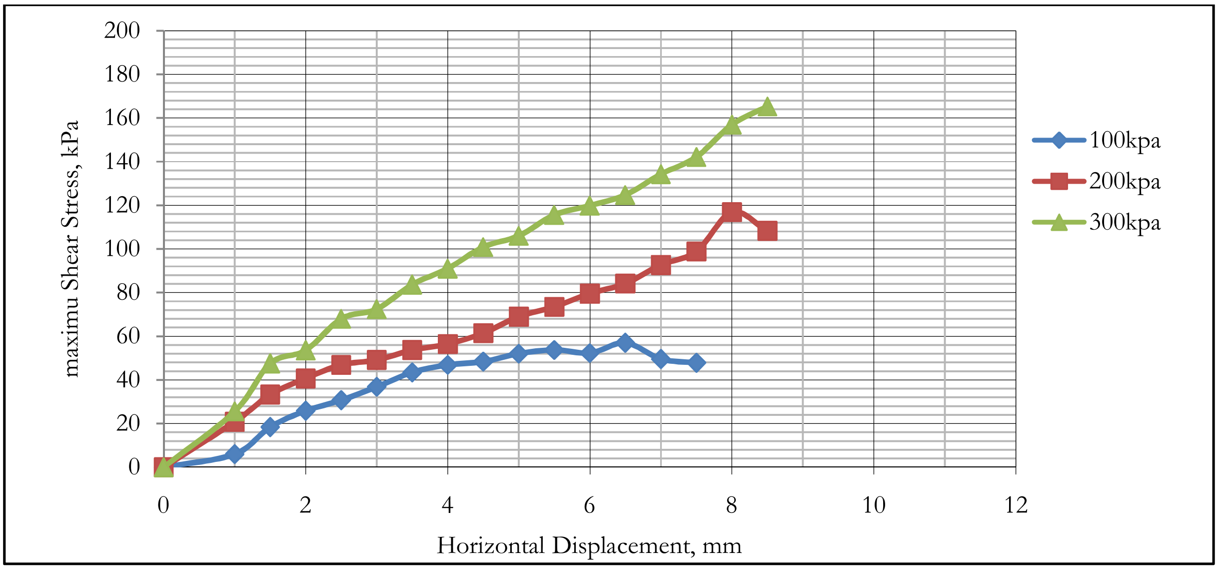


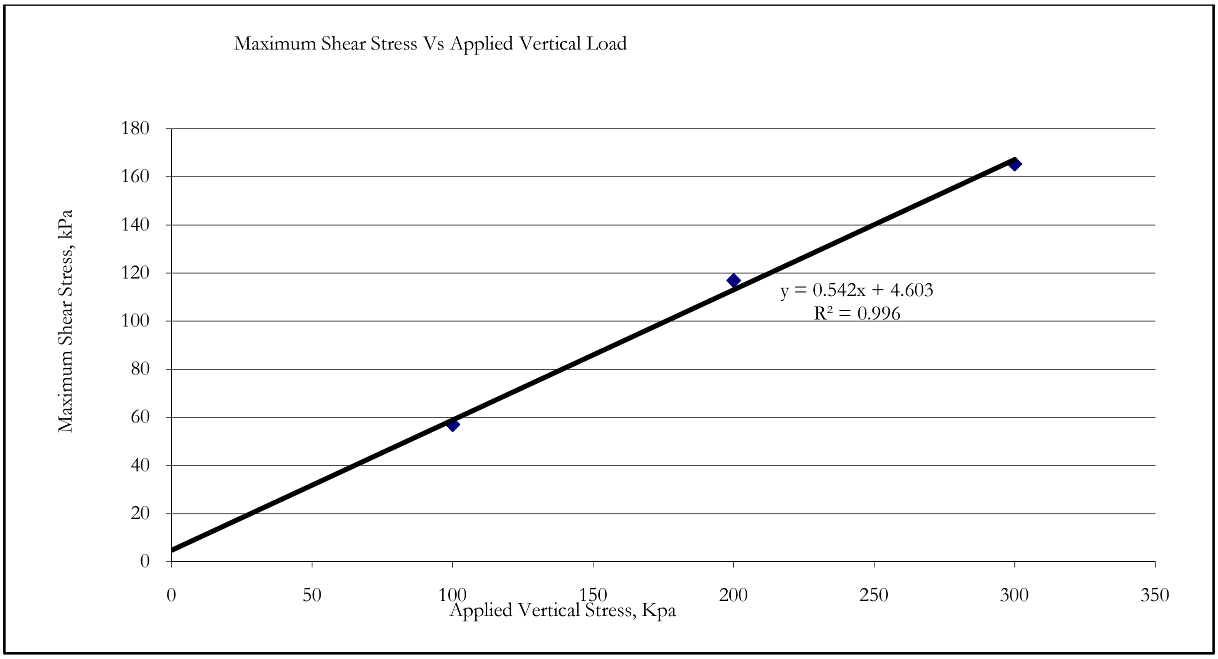
TP2-2technic school,C=6.816kpa, =than^{-1}(0.57) =29.68^{0}

sample code and depth =TP3-21.2 to 3m(gabriel church)

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(%)	=26	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	5.93220	105	73.5	20.762	129	90.3	25.508
1.5	3510	92	64.4	18.3475	167	116.9	33.304	238	166.6	47.464
2.0	3480	128	89.6	25.7471	202	141.4	40.632	266	186.2	53.505
2.5	3450	151	105.7	30.6376	231	161.7	46.869	335	234.5	67.971
3.0	3420	180	126	36.8421	240	168	49.122	354	247.8	72.456
3.5	3390	210	147	43.3628	260	182	53.687	405	283.5	83.628
4.0	3360	225	157.5	46.875	271	189.7	56.458	437	305.9	91.041
4.5	3330	230	161	48.3483	292	204.4	61.381	480	336	100.90
5.0	3300	245	171.5	51.9696	325	227.5	68.939	500	350	106.06
5.5	3270	251	175.7	53.7308	343	240.1	73.425	540	378	115.59
6.0	3240	242	169.4	52.2839	368	257.6	79.506	555	388.5	119.90
6.5	3210	261	182.7	56.9158	386	270.2	84.174	572	400.4	124.73
7.0	3180	225	157.5	49.5283	421	294.7	92.673	610	427	134.27
7.5	3150	215	150.5	47.7777	445	311.5	98.888	640	448	142.22
8.0	3120				521	364.7	116.89	700	490	157.05
8.5	3090				478	334.6	108.28	730	511	165.37
Maximum				**56.91589**			**116.89**			**165.37**



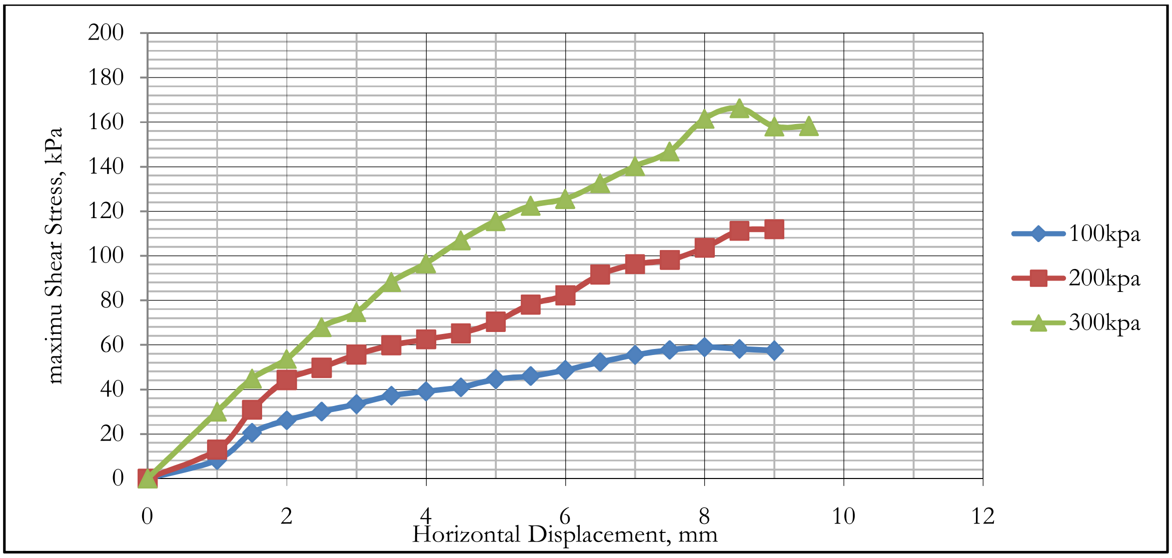


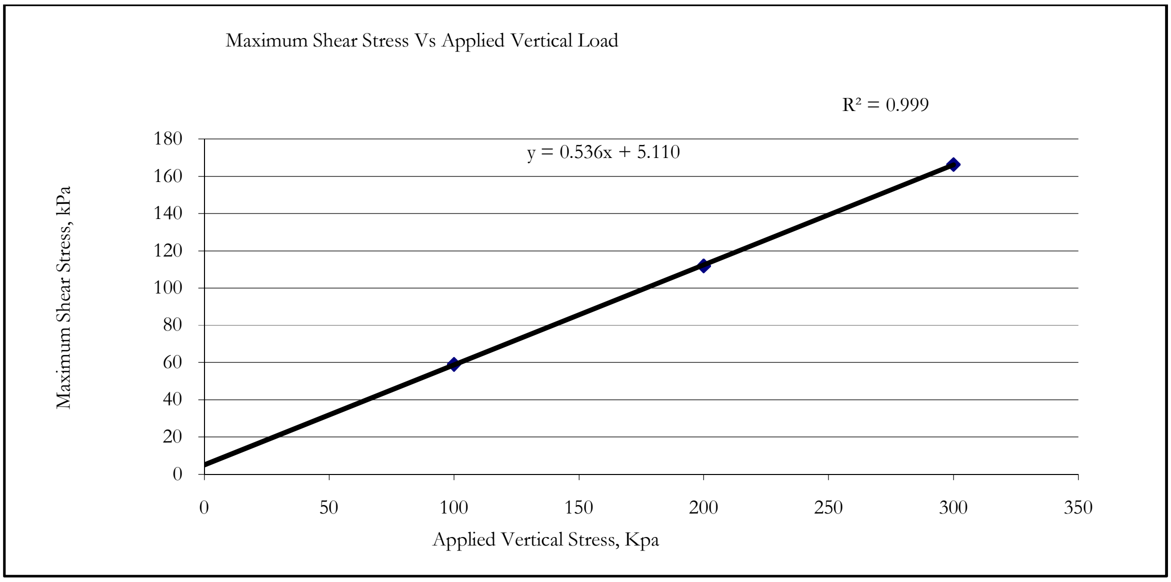
TP3-2gabriel church,C=4.603kpa, =than^{-1}(0.542) =28.46^{0}

sample code and depth =TP4-21.2 to 3m(high school)

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 (%)	20	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	42	29.4	8.305084	66	46.2	13.0508	152	106.4	30.0565
1.5	3510	103	72.1	20.54131	155	108.5	30.9117	225	157.5	44.8718
2.0	3480	130	91	26.14942	220	154	44.2529	267	186.9	53.7069
2.5	3450	148	103.6	30.02898	245	171.5	49.7101	335	234.5	67.971
3.0	3420	163	114.1	33.36257	272	190.4	55.6725	365	255.5	74.7076
3.5	3390	180	126	37.16814	290	203	59.882	427	298.9	88.1711
4.0	3360	188	131.6	39.16666	300	210	62.5	464	324.8	96.6667
4.5	3330	195	136.5	40.99099	310	217	65.1652	509	356.3	106.997
5.0	3300	210	147	44.54545	332	232.4	70.4242	545	381.5	115.606
5.5	3270	215	150.5	46.02446	365	255.5	78.1346	572	400.4	122.446
6.0	3240	225	157.5	48.61111	381	266.7	82.3148	581	406.7	125.525
6.5	3210	240	168	52.33644	420	294	91.5888	608	425.6	132.586
7.0	3180	252	176.4	55.47169	437	305.9	96.195	637	445.9	140.22
7.5	3150	260	182	57.77777	442	309.4	98.2222	661	462.7	146.889
8.0	3120	263	184.1	59.0064	462	323.4	103.654	720	504	161.538
8.5	3090	257	179.9	58.22006	491	343.7	111.23	734	513.8	166.278
9.0	3060	251	175.7	57.41830	489	342.3	111.863	691	483.7	158.072
9.5	3030							685	479.5	158.251
Maximum				**59.00641**			**111.86**			**166.28**



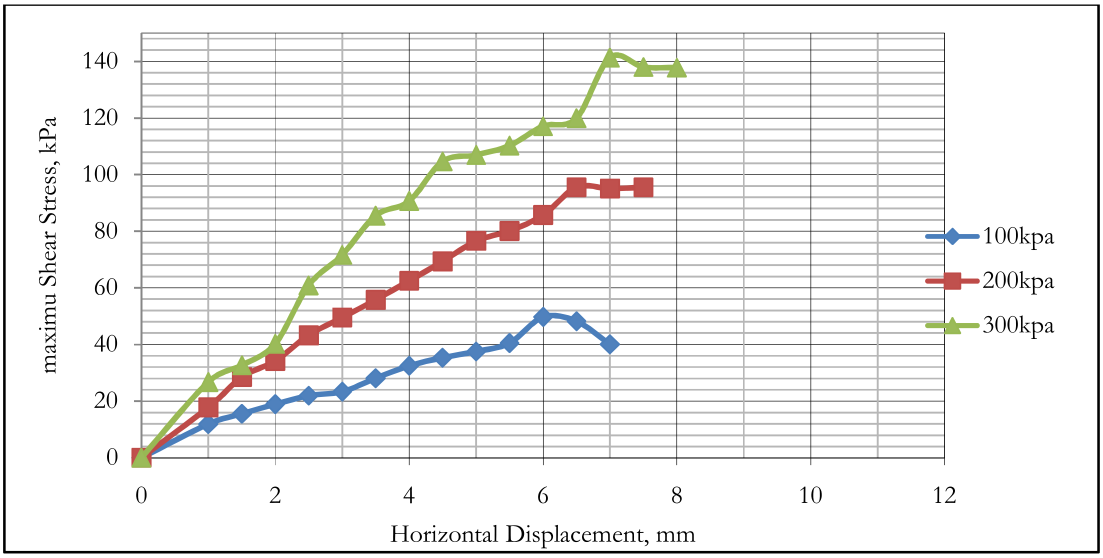


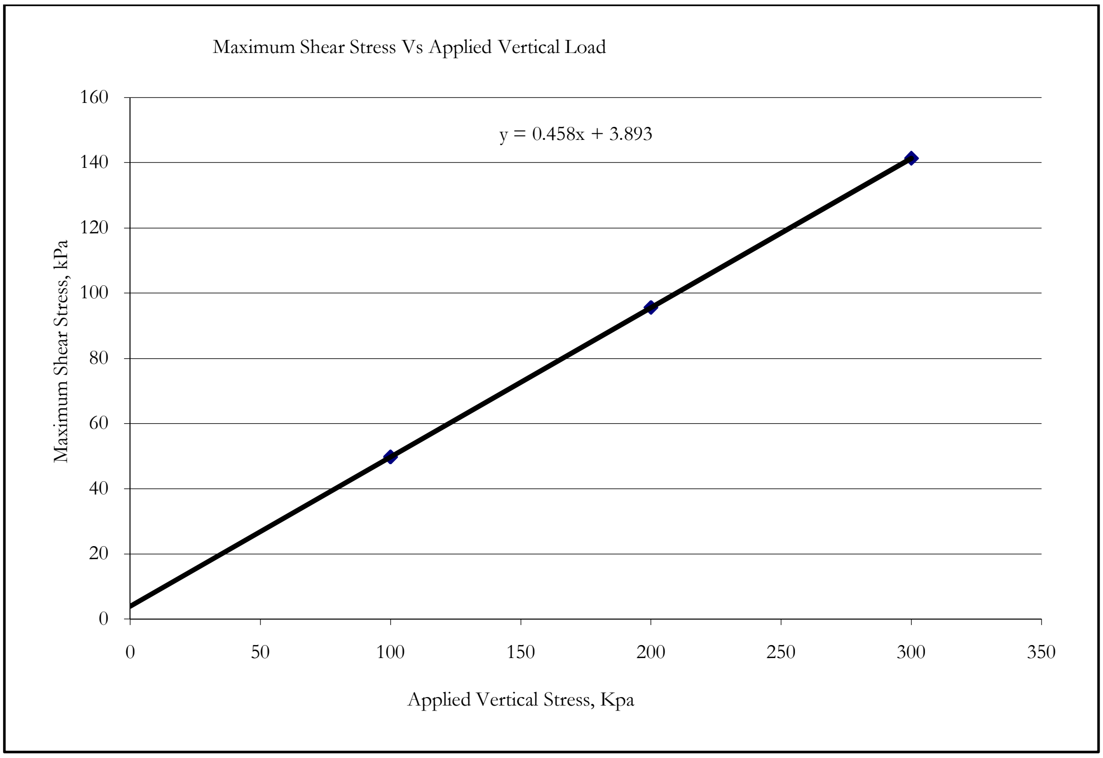
TP4-2high school, C=5.11kpa, =than^{-1}(0.418)=28.19^{0}

sample code and depth =TP5-21.2 to 3m(at bus station)

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(%)	23	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	60	42	11.864407	90	63	17.796	135	94.5	26.694
1.5	3510	78	54.6	15.555556	143	100.1	28.518	164	114.8	32.706
2.0	3480	94	65.8	18.908046	170	119	34.195	200	140	40.229
2.5	3450	108	75.6	21.913043	213	149.1	43.217	300	210	60.869
3.0	3420	114	79.8	23.333333	242	169.4	49.532	350	245	71.637
3.5	3390	136	95.2	28.082596	270	189	55.752	414	289.8	85.486
4.0	3360	156	109.2	32.5	300	210	62.5	435	304.5	90.625
4.5	3330	168	117.6	35.315315	330	231	69.369	498	348.6	104.68
5.0	3300	177	123.9	37.545455	361	252.7	76.575	504	352.8	106.90
5.5	3270	189	132.3	40.458716	374	261.8	80.061	515	360.5	110.24
6.0	3240	230	161	49.691358	397	277.9	85.771	542	379.4	117.09
6.5	3210	221	154.7	48.193146	438	306.6	95.514	550	385	119.93
7.0	3180	182	127.4	40.062893	432	302.4	95.0943	642	449.4	141.32
7.5	3150				430	301	95.555	621	434.7	138
8.0	3120							614	429.8	137.75
Maximum				**49.69136**			**95.556**			**141.32**



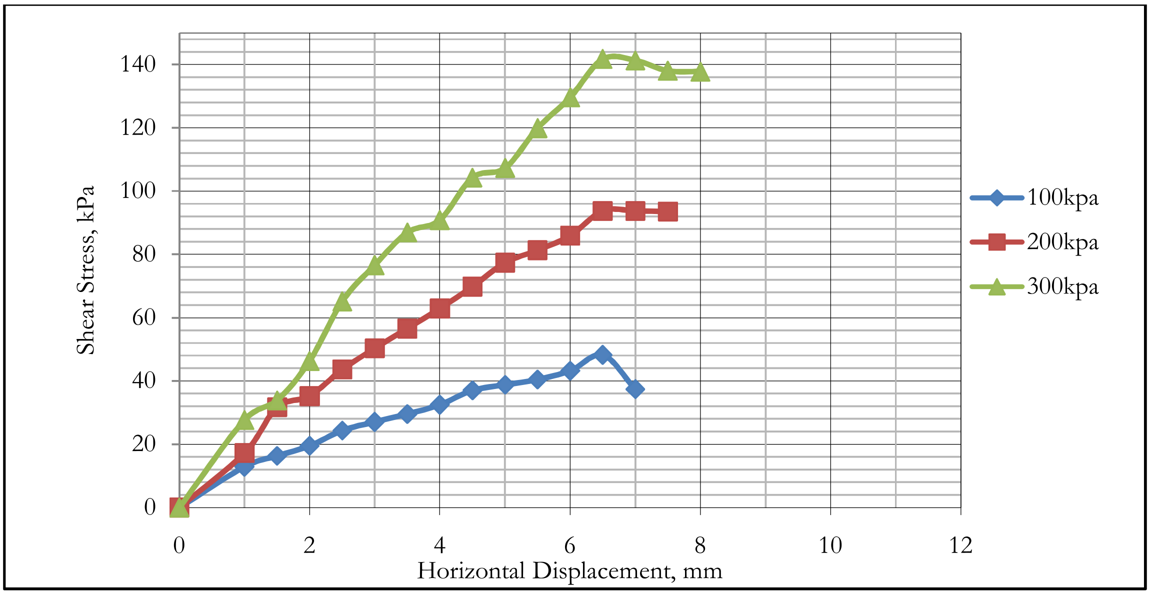


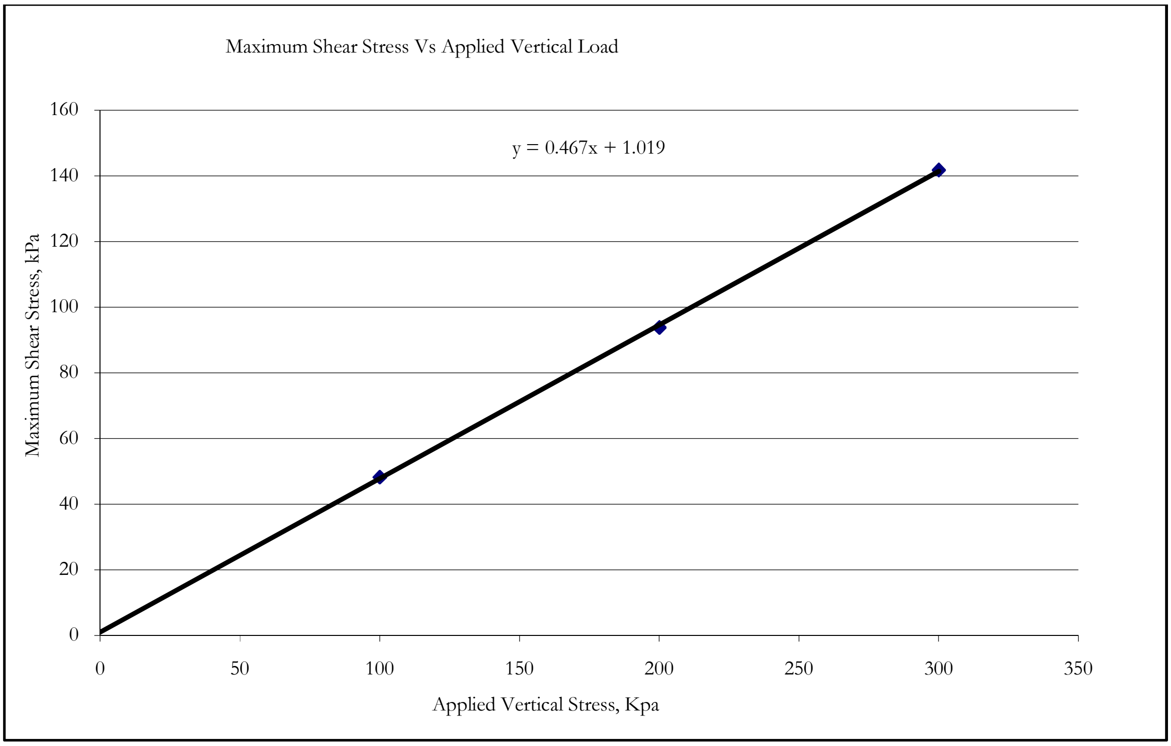
TP5-2bus station, C=3.893kpa, $=\text{than}^{-1}(0.418) = 24.6^{0}$

sample code and depth =TP6-21.2 to 3m(cambiargitu)

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 **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	65	45.5	12.85310	87	60.9	17.203	140	98	27.683
1.5	3510	82	57.4	16.35327	159	111.3	31.709	170	119	33.903
2.0	3480	97	67.9	19.5114	175	122.5	35.201	230	161	46.264
2.5	3450	120	84	24.34782	215	150.5	43.623	321	224.7	65.130
3.0	3420	132	92.4	27.01754	246	172.2	50.350	374	261.8	76.549
3.5	3390	143	100.1	29.52802	274	191.8	56.578	421	294.7	86.932
4.0	3360	156	109.2	32.5	302	211.4	62.916	436	305.2	90.833
4.5	3330	176	123.2	36.99699	332	232.4	69.789	496	347.2	104.26
5.0	3300	183	128.1	38.81818	365	255.5	77.424	506	354.2	107.333
5.5	3270	189	132.3	40.45871	380	266	81.345	560	392	119.87
6.0	3240	200	140	43.20987	398	278.6	85.987	600	420	129.63
6.5	3210	221	154.7	48.19314	430	301	93.769	650	455	141.74
7.0	3180	170	119	37.42138	426	298.2	93.773	642	449.4	141.32
7.5	3150				421	294.7	93.555	621	434.7	138
8.0	3120							614	429.8	137.75
Maximum				**48.19315**			**93.774**			**141.74**



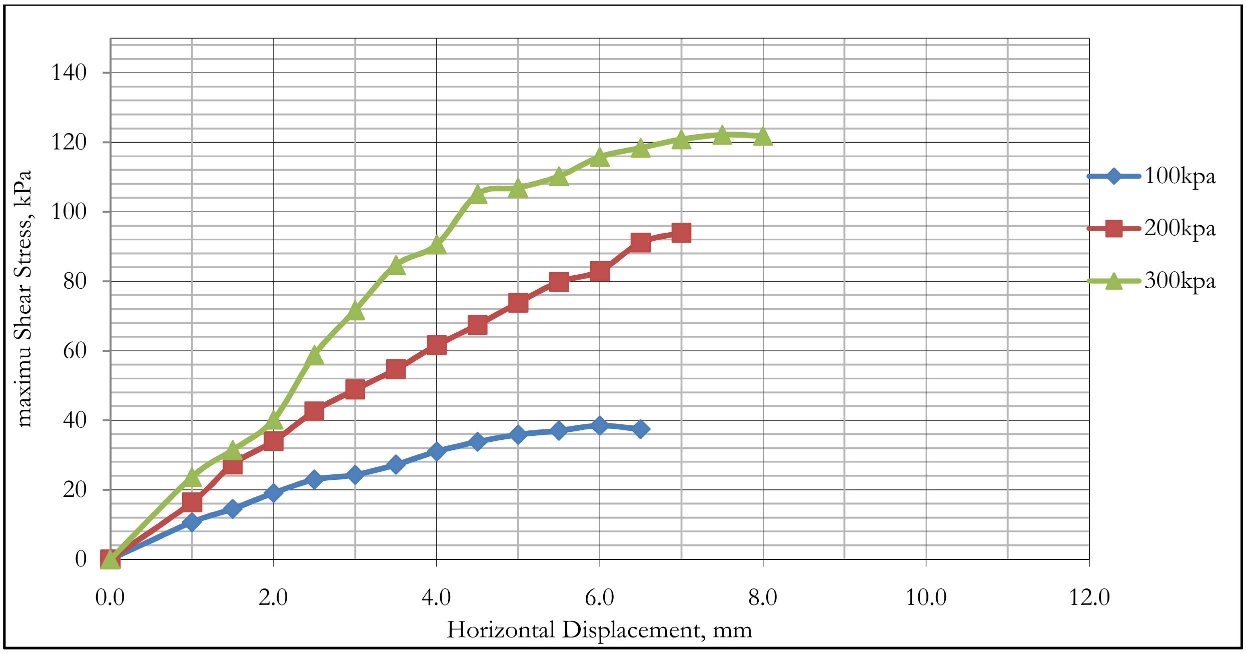


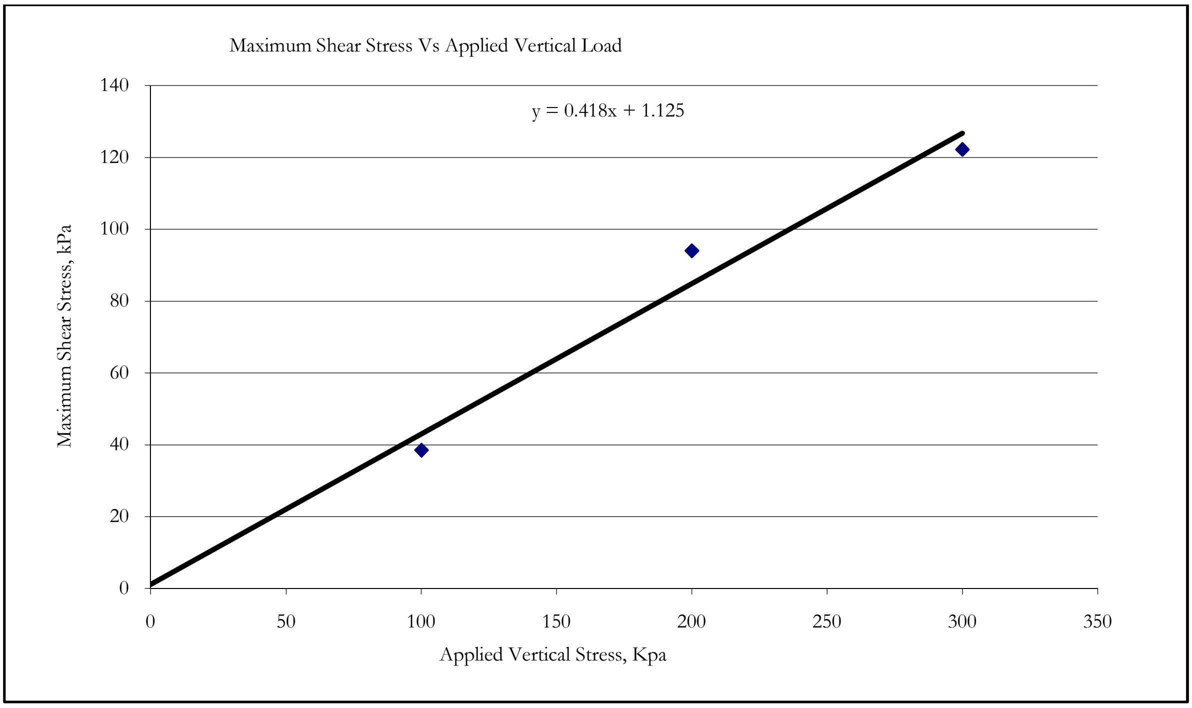
TP6-2cambi argitu, C=1.019kpa, $=\text{than}^{-1}(0.467) = 25^{0}$

sample code and depth =TP7-21.2 to 3m(abebecholmaDa,immani school)

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(%) 26

		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	54	37.8	10.67796	83	58.1	16.412	120	84	23.728
1.5	3510	73	51.1	14.55840	137	95.9	27.321	158	110.6	31.51
2.0	3480	95	66.5	19.10919	169	118.3	33.994	200	140	40.229
2.5	3450	113	79.1	22.92753	210	147	42.608	290	203	58.840
3.0	3420	119	83.3	24.35672	239	167.3	48.918	350	245	71.637
3.5	3390	132	92.4	27.25663	265	185.5	54.719	410	287	84.660
4.0	3360	149	104.3	31.04166	296	207.2	61.666	435	304.5	90.625
4.5	3330	161	112.7	33.84384	321	224.7	67.477	481	336.7	101.11
5.0	3300	169	118.3	35.84848	348	243.6	73.818	504	352.8	106.90
5.5	3270	173	121.1	37.03363	373	261.1	79.847	515	360.5	110.24
6.0	3240	178	124.6	38.45679	384	268.8	82.963	536	375.2	115.80
6.5	3210	172	120.4	37.50778	418	292.6	91.152	543	380.1	118.41
7.0	3180				427	298.9	93.993	549	384.3	120.84
7.5	3150							550	385	122.22
8.0	3120							543	380.1	121.82
Maximum				**38.45679**			**93.994**			**122.22**



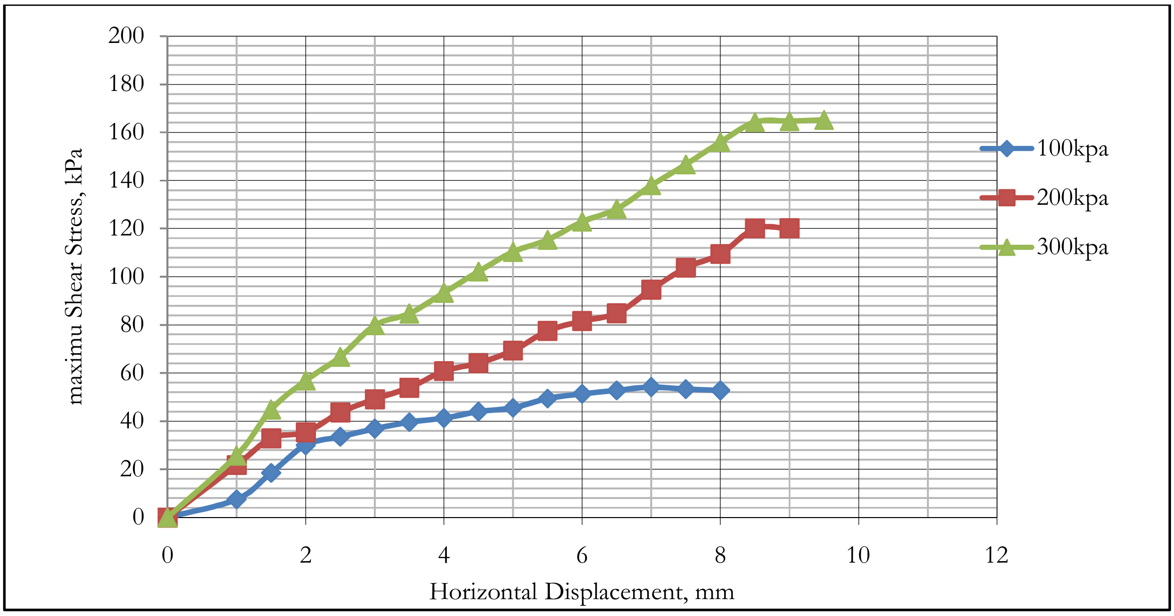


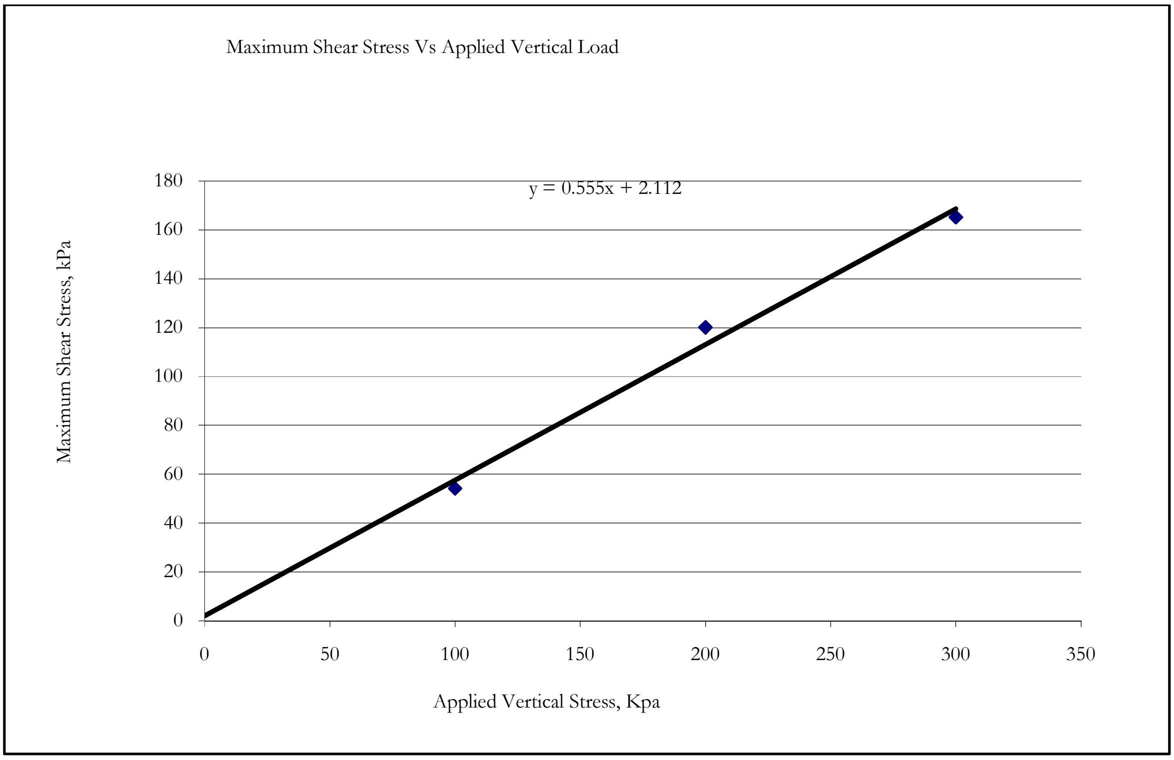
TP7-2abebech Nursery school, C=1.125kpa, =than^{-1}(0.418) =22.68^{0}

sample code and depth =TP8-21.2 to 3m(at tele)

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	38	26.6	7.514124	110	77	21.751	130	91	25.706
1.5	3510	93	65.1	18.54700	165	115.5	32.906	225	157.5	44.871
2.0	3480	149	104.3	29.97126	176	123.2	35.402	283	198.1	56.925
2.5	3450	165	115.5	33.47826	215	150.5	43.623	329	230.3	66.753
3.0	3420	180	126	36.84210	240	168	49.122	390	273	79.824
3.5	3390	192	134.4	39.64601	261	182.7	53.893	410	287	84.660
4.0	3360	198	138.6	41.25	292	204.4	60.8333	448	313.6	93.3333
4.5	3330	209	146.3	43.93393	305	213.5	64.114	486	340.2	102.16
5.0	3300	215	150.5	45.60606	327	228.9	69.363	520	364	110.30
5.5	3270	231	161.7	49.44954	362	253.4	77.492	539	377.3	115.38
6.0	3240	238	166.6	51.41975	378	264.6	81.666	569	398.3	122.93
6.5	3210	242	169.4	52.77258	389	272.3	84.828	588	411.6	128.22
7.0	3180	246	172.2	54.15094	430	301	94.654	627	438.9	138.01
7.5	3150	240	168	53.33333	467	326.9	103.77	660	462	146.66
8.0	3120	235	164.5	52.72435	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
Maximum				**54.15094**			**120.1**			**165.18**





TP8-2 tele, C=2.112kpa, =than^{-1}(0.555) =29