ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ADDIS ABABA INSTITUTE OF TECHNOLOGY

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

INVESTIGATION INTO SOME OF THE ENGINEERING PROPERTIES OF SOILS FOUND IN ZIWAY TOWN ,ETHIOPIA

BY:

BEZZA TESFAYE TABOR

"A thesis submitted to the school of graduate studies of Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in civil and environmental engineering" (major in geotechnical engineering)

ADVISOR:

DR.-ING. SAMUEL TADESSE

FEBRUARY, 2015

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DECLARATION

I, the undersigned, declare that this thesis is my original work performed under the supervision of my research advisor Dr.ing Samuel Taddese and has not been presented as a thesis for a degree in any other university, and that all sources of materials used for this thesis have also been duly acknowledged.

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SYMBOLS AND ABBREVIATIONS

AASHTO -	American Association of Highway and Transportation Officials
ASTM -	American Society for Testing Materials standard
CL-	Lean clay
EAEA -	Journal of the Ethiopian Association of Engineers and Architects
LL -	Liquid limit
MDD –	Maximum dry density
ML –	Inorganic Silt
NMC -	Natural moisture content
OMC -	Optimum moisture content
PI -	Plastic Index
PL -	Plastic limit
SM -	Silty sand
SW-	sand-silt mixtures
TP -	Test pit
USCS -	Unified Soil Classification System
γd -	Dry unit weight
γw -	Wet unit weight
BS -	British Standard
MoWR-	Ministry of water resources
NUPI-	National urban planning institute

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ABSTRACT

Investigation of the ground conditions is used for the economical design of the sub structural elements. It is also necessary to obtained sufficient information on type, characteristics and distributions of a soil and rock underlying sites of proposed structures for feasibility and economic studies for a proposed project.

The objective of this thesis is to investigate the engineering properties of soil found in Ziway town. To achieve its objective disturbed and undisturbed samples from different parts of the town were collected and laboratory tests were done on the collected samples.

Grain size analysis tests revealed that, starting from few centimeters below the ground level to the depth of investigation which is three meters, the soil in Ziway town is mostly silts and silty sand. In which for silt soils of ziway town has clay content ranging from 6.72 to 10.93%, silt fraction 51.45 to 73.03%, sand fraction 15.16 to 40.4%, and gravel content from 0.84 to 1.88% and for silty sand soils clay content ranging from 0.66 to 4.41%, silt fraction 17.15 to 42.18%, sand fraction 52.06 to 81.3%, and gravel content from 0.89 to 1.6%

Within the depth of exploration, the specific gravity of the town ranges from 2.40 to 2.62. These values are low compared with Arora, 2003, this is because the soils are light weighted.

From the consistency limit test results, liquid limit ranges from 27–37 %, plastic limit from none plastic to limit ranges from 23 – 29% and plastic index from ranges 0-8%.

Compaction tests carried out on samples collected from the study area revealed that the maximum dry density (MDD) ranges from1.22 to 1.55 g/cm3 and the optimum moisture content ranges from 22.6 to 35.8 percent.

Shear strengh parameters from the graph of shear stress vesrsus displacement and maximum shear stress vesrsus applied vertical load respectively gives cohesion(C) and angle of internal friction (Φ). From those results the cohesion ranges from 2.90 to 20.15kPa and the angle of internal friction ranges from 19.8^0-28.4^0.

1. Introduction

1.1 Back ground of the problem

A geotechnical engineer determines and designs the type of foundation, earthwork, and/or pavement sub grades required for the intended man-made structures to be built. The success or failure of a foundation depends essentially on the reliability of the various soil parameters obtained from the field investigation and laboratory testing, and used as an input into the design of foundations.

In Civil engineering works like, preliminary design and in designing foundation, pavement, retaining structures, etc., geotechnical investigation on the engineering property of soil is very essential. Many researches were conducted and there are ongoing researches in most big cities of the country like Addis Ababa, Bahirdar, Mekele, Hawassa, Adama, etc.

Investigation of the underground conditions at a site is prerequisite to the economical design of the substructure elements. It is also necessary to obtain sufficient information for feasibility and economic studies of the proposed project. As well soil investigation is a must in the present age for the design of foundations of any project. The extent of the investigation depends upon the magnitude and importance of the project.

Insufficient geotechnical investigations, faulty interpretation of results, or failure to portray results in a clearly understandable manner may contribute to inappropriate designs; delays in construction schedules, costly construction modifications, and use of substandard borrow material, environmental damage to the site, post construction remedial work, and even failure of a structure and subsequent litigation. Therefore, to obtain information on type, characteristics and distributions of a soil, geotechnical investigations should be done on soil and rock underlying (and sometimes adjacent to) proposed structures.

Ziway is one of the fastest growing cities in the country and there is a big volume of construction works and recreation centers. It is the transit way on the road from the capital Addis Ababa to the capital of southern nations nationalities and peoples of Ethiopia, Hawassa. Due to its location and near distance from Addis Ababa, investors are attracted to construct in Ziway town and the nearby areas. However, the engineering property of the soil in the city is not studied. This research is therefore directed to the study of the physical and mechanical properties of soils i.e. investigating the index properties and identifying the characteristics of the soil.

1.2 Objectives of the Study

The general objective of the thesis is to investigate some of the engineering properties of the soils found on Ziway town.

1.2.1 Specific objectives

The specific objectives of this thesis work are the following:

- ✓ To investigate : -natural moisture content, field density, specific gravity, consistency limits, grain size analysis, compaction characteristics, and shear strength of soil by direct shear test etc.
- ✓ Classification of soil based on both according to ASHTO and ASTM
- ✓ To determine the range of values of index property of soil in different parts of the city.

1.3 Methodology

To achieve the above mentioned objectives seven sampling areas were selected. From the selected sampling areas pits were excavated to a maximum depth of three meters. Disturbed samples of soils were collected for laboratory testing.

In the field GPS readings were taken to locate the ordinate of sampling area. Visual Classification, field density and natural moisture content tests were done in the field.

The natural moisture content tests were performed by using balance and moisture cans at the site. After measuring the weight of empty can and can with moist soil the sample is brought to laboratory and put into drying oven. Therefore to know shear strength remold is prepared in laboratory using its field density, natural moisture content, direct shear test is done.

All the laboratory tests would be performed according to American Society for Testing Materials (ASTM) standard

1.4 Scope of the Study

The scope of this study is limited to investigating the index properties, compaction characteristics, and direct shear tests. The depth of investigation in this research is limited to the maximum depth of three meters.

1.5. Structure of the Thesis

This thesis work is divided in to six Chapters, each covering a specific topic of the research work. In this introductory Chapter the background of the problem, objective, methodology and scope of the thesis work and structure of the thesis are presented. Chapter two deals with a brief literature review. Chapter three deals with the description of area of (Ziway town) in which this research is done. The fourth Chapter deals with in-situ properties with sample description and the types of laboratory tests conducted and results obtained. The discussion on the laboratory results obtained from this work and comparison with previously done researches is covered in Chapter five. Chapter six is the conclusions and recommendations drawn from the research. Detailed soil profiles for each test pits, calculation of specific gravity test result, grain size and hydrometer analysis test results, liquid limit results, compaction test results, and direct shear test results are all included in the appendix.

2. Literature review

2.1. Soil formation and soil deposit

The simplest definition of a soil is an unconsolidated layer of weathered rock which lies upon bedrock. Soils are formed by the process of in-situ weathering and decomposition of parent rock. The three major weathering processes are physical, chemical and biological processes. In the weathering process, the parent rock and rock minerals break down, releasing internal energy and forming soils of lower internal energy that are stable. The properties of soil materials depend up on the properties of the rock materials which they are derived from. Physical processes increase surface area and fractures so that chemical attack takes place where as biological phenomena include both of them.

The varieties of soil materials encountered in engineering problems is almost limitless ranging from hard, dense, large pieces of rock through to gravel, sand, silt, and clay to organic deposit of soft compressible organic peat. At any given site, a number of different soil types can be present, and the composition may vary over intervals of a little as a few inches.

The major factors influencing the formation of soil are described as follows:-

2.1.1. Parent materials

Parent material constitute during the early and immediate stage of the Soil forming factors such as: parent rock, vegetation conditions, climate, topography and drainage conditions, chemical process weathering stages processes determine the type of soil formed. The nature of the parent materials is much more important during the above weathering stages than after intense weathering for long period of times.

There are two main variables in parent materials that affect soils: grain size and composition.
Grain size is the main determinant of soil texture. Soil texture influences the soil structure, consistency, cation exchange capacity, profile drainage, moisture retaining capacity, and organic content.

2.1.2. Vegetation conditions

Vegetation condition is highly dependent with climate (precipitation, soil, and air) and topography nature of the area. Areas with highly vegetation cover have less susceptibility to erosion. This means the probability of formation of residual tropical soil is less.

2.1.3. Climate

In mountainous tropical countries like Ethiopia altitude is by far the most important factor controlling climate. It affects distribution of both temperature and rainfall. Generally, regions between 1500-2300 meter a.m.s.l (categorized as "woina dega" or sub tropical climate) have temperature that range between 15-20^{0}c, areas between 500-1500 meters a.m.s.l ("kola" tropical climate) have 20-30^{0}c and areas below 500 meters a.m.s.l ("bereha" or desert climate) have a temperature 30^{o}c and above (NUPI, 1993).

Climate is the major factor governing the rate and type of soil formation .The major components of climate are the amount and distribution of precipitation, and temperature. Physical weathering is more pronounced in dry climates, while the extent and rate of chemical weathering is largely controlled by the availability of moisture and temperature. The temperature variation is adequately represented by mean annual temperature, which is nearly constant temperature. The clay minerals of the soil of the world changed in predictable way with distance from the equator. According to Van Hoff's principle the velocity of chemical reaction increases by a factor of 2 to 3 for every 10^{0}c rise in temperature.

Climate has a further effect on the properties of tropical residual soil. In sub humid tropical and subtropical areas water tables are often deeper than 5 to 10m and the effect of unsaturation; desiccation and seasonal or long term rewetting have to be taken into account in geotechnical design.

The two main rainfall parameter most widely available are the mean annual total and the length of dry season. The amount and distribution of precipitation affect the availability of moisture and relative humidity of the soil atmosphere; it influences the concentration or chemical activities of solution in the system.

2.1.4. Topography and drainage condition

Topography has a major influence on drainage characteristics which in turn is known to have a major effect on soil mineralogy. According to (Dagnachew D., 2011) Topography controls the rate of weathering by partly determining the amount of available water and the rate at which it moves down through the zone of weathering.

It also controls the effective edge of the profile by controlling the rate of erosion of a weathered material from the surface. Hence deeper profiles will generally be found in valleys and on gentle slopes rather than high ground or steep slopes.

Soil profiles developed from basic igneous rocks on hillsides the depth of weathering increases down the slopes where as kaolinite/hallosite are the predominant clay minerals at the top of the slope and smectite at the bottom of the slope.

2.2. Chemical weathering process:

2.2.1. Decomposition:

This includes the physical breakdown of the rock fabric and the chemical break down of the constitute minerals, usually rock forming minerals. Typical products are being clay minerals, oxides, hydroxides, and free silica. Under tropical condition reaction may occur more relatively quickly so that recently transported soils may subsequently be modified into soil materials. Decomposition according to (Zelalem, 2005), (Fekede, 2007) is physio-chemical breakdown of primary minerals and release of constitute elements (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O), which appear in simple ionic forms.

2.2.2. Leaching and Re-deposition:

This includes laterization process; involves removal of combined silica, alkaline earth, and alkalies. There is a consequent accumulation of oxides and hydroxides of sesquioxides and the leached materials may be redeposited and accumulated elsewhere in the soil profile.

Under condition of low chemical and soil-forming activity, physio-chemical weathering does not continue beyond the clay-forming stage and tends to produce end products consisting of clay minerals predominantly represented by kaolinite and occasionally by hydrated and hydrous oxide of iron and aluminum, (Zelalem, A.2005).

2.2.3. Dehydration/desiccation:

Process that the composition and distribution of the sesquioxides-rich minerals in a manner, which is generally not reversible upon wetting. Dehydration also influences the formation of clay minerals. That is, in the case of total dehydration, strongly cemented soils with a unique granular soil structure may be formed.

2.3. General types of soil

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

2.4. Soil particles size and shape

The size of particles may range from gravel to the finest possible. Their characteristics vary with size. Soil particles coarser than 0.075mm are visible to the naked eye or may be examined by means of a hand lenses. They constitute the coarser fraction of the soil. The coarser fraction is constituted of gravel and sand. The individual particles of gravel, fragments of rock, are composed of one or more minerals, whereas sand grains contain mostly one mineral material which is usually quartz. The individual grains of sand and gravel may be angular, sub angular, sub-rounded rounded or well-rounded. Gravel may contain may contain flat. Some sands contain a fairly high percentage of mica flakes that give them the properties of elasticity. Silt and clay constitute the finer fraction of particle.

2.5. Soil mineralogical composition:

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

Primary minerals: present in original rock from which soil is formed. These occur predominantly in sand and silt fractions, and are weathering resistant (quartz, feldspars).

Secondary minerals: formed by decomposition of primary minerals, and their subsequent weathering and recomposition into new ones (clay minerals).

Humus or organic matter: decomposed organic materials.

2.6 Index properties

The tests required for determination of engineering properties 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 behavior of soils should thus 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, Atterberg limits, free swell and specific gravity.

2.6.1 Particle-size distribution

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. Mechanical analysis is used for the coarse sized soils by using nest of sieve and hydrometer analysis is used for fine grained soils. For a soil-containing fine to coarse sized particles the combined analysis is employed.

2.6.2 Atterberg Limits

Atterberg Limits tests are used to confirm visual descriptions. They are performed on fine-grained soils (clays, silts) to determine the amount of water necessary to achieve a range of behavioral states. Atterberg limits tests should be performed on each representative soil, and additional tests are advisable to confirm grouping of apparently similar soils and where project complexity justifies additional testing. These test results have been correlated with other soil properties. The liquid limit (LL), plastic limit (PL) and shrinkage limit (SL) are Atterberg limits.

However, for classification purposes, the term Atterberg limits generally refers to the more common liquid and plastic limits only. The shrinkage limit test is less often included in common laboratory programs. The shrinkage limit test is performed when swelling behavior in soils are suspected that could influence design and construction.

Liquid Limit: the moisture content of a soil at the boundary between the liquid and plastic states. The liquid limit is determined by ascertaining the moisture content at which two halves of a soil cake will flow together for a distance of 0.5 inch along the bottom of the groove separating the halves, when the blows they are in is dropped between 15 to 35 times from a distance of 0.4 inches at the rate of 2 drops/second. A plot of the relationship between the water content and the number of drops is made using the results of the tests. The water content corresponding to the intersection of the line with the 25-drop abscissa is the liquid limit of the soil.

Plastic Limit: is the moisture content at the boundary between the plastic and semisolid states. The plastic limit is determined by ascertaining the lowest moisture content at which the material can be rolled into threads 3mm in diameter before crumbling.

Plasticity Index: is simply the numerical difference between the liquid limit and the plastic limit and indicates the magnitude of the range of moisture content over which the soil remains plastic.

$$PI = LL - PL \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

It is the measure of the cohesion qualities of the binder resulting from the clay content. Also it gives some indication of the amount of swelling and shrinkage that will result in the wetting and drying of that fraction tested. The plasticity index is nothing but a measure that gives the amount of water which must be added to change a soil from its plastic limit to its liquid limit. Generally the behavior of all soils and specifically clays considerably differs with the presence of water so one needs a reference index to clarify the effects.

The Atterberg limits and related indices have proved to be very useful for soil identification and classification. The limits are often used directly in specifications for controlling soil quality for use in fill and in semi empirical methods of design Soils are classified by AASHTO and USCS based on their Atterberg limits and on particle size as determined by sieving (ASTM D 4318-98).

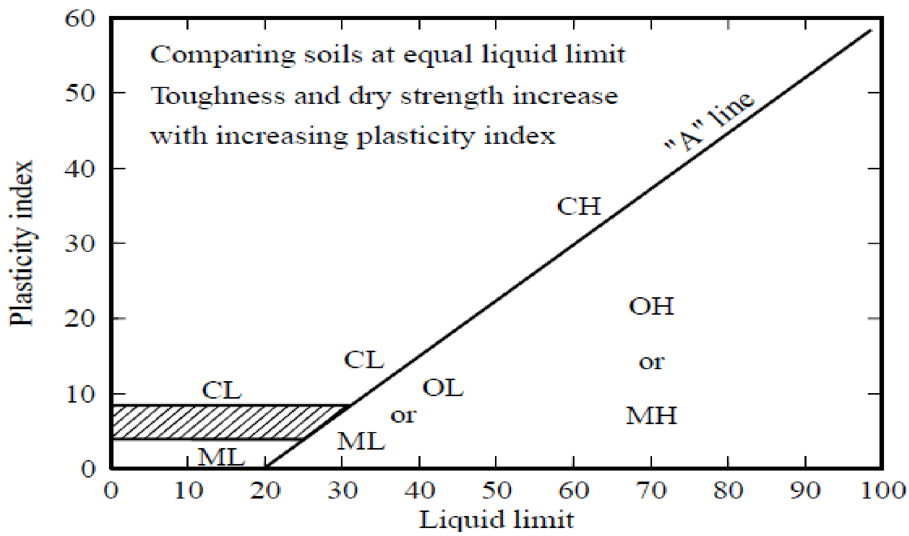


Fig.2.1Casagrande's Plasticity chart

2.6.3. Specific gravity

Specific gravity of the soil solids is useful in the determination of void-ratio and degree of saturation. It is also useful in computing the unit weight of the soil under different conditions and also in the determination of particle size by hydrometer analysis. Table 2.1 shows the specific gravity value of some soil type.

Table 2.1Specific gravities of some soil types (Arora, 2003)

S.No.	*Soil Type*	*Specific Gravity*
1	Gravel	2.65—2.68
2	Sand	2.65—2.68
3	Silty Sands	2.66—2.70
4	Silt	2.66—2.70
5	Inorganic Clays	2.68—2.80
6	Organic Soils	Variable, may fall below 2.00

2.7. 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.

Compaction is an entirely different process than consolidation, even though both the process causes a reduction in the volume.

Compaction is rapid process of reduction of volume by mechanical which expelled out air from the voids at the unaltered water content by means such as rolling, tamping and vibration, whereas consolidation is a gradual process of reduction of volume by squeezing out of water from the soil under sustained static loading.

Table 2.2 range of optimumu water content(Arora, 2003)

Sand	*Sandy silt or silty sand*	*Silt*	*Clay*
6 to 10%	8 to 12%	12 to 16%	14 to 20%

2.8 Shear Strength

Geotechnical design of embankments, cuts, walls, and foundations requires a thorough understanding of the strength properties of soil. The level of effort used to determine soil strength parameters varies, depending on the size and complexity of the project elements and consequences of failure. The shear strength of a soil is the maximum shearing stress the soil structure can resist before failure. Soils generally derive their strength from friction between particles (expressed as the angle of internal friction, Φ) or cohesion between particles (expressed as the cohesion, c in units of force/unit area), or both. These parameters are expressed in the form of total stress (c, Φ) or effective stress (c', Φ').The total stress on any soil layer is induced by the overburden pressure plus any applied loads.

The general design cases and applicable stress categories are summarized below:

Design Case Analysis	**Type and Strength Parameters**
Foundations	Total Stress –Un drained Shear Strengths
Excavation	Effective Stress –Drained Shear Strengths
Natural Slope	Effective Stress –Drained Shear Strengths

2.8.1 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.

Table 2.3 Typical values of drained angle of friction for sands and silts (Arora, 2003)

Soil type	ϕ' (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

3. Description of the study area

3.1. General

Ziway is a town and separate woreda (administrative structure) in central Ethiopia. It is located on the road connecting Addis Ababa to Nairobi in the Misraq Shewa Zone of the Oromia Region of Ethiopia. Ziway is located at latitude and longitude of $7^{o}56'$N $38^{o}43'$E and with an elevation of 1643 meters above sea level. It is about 163 kilometers away from Addis Ababa in southeast direction. Ziway has a total area of about 8000 hectares, which has been subdivided into 4 urban kebele (least administrative structure) administrations.

The economy of the Ziway town is based on small trade, fishing, and horticulture. Ziway is also home to a prison, a caustic soda factory, and share-flower Ethiopia.

The name Ziway officially reverted to its original Oromo language name, Batu, in 2000. Ziway had been serving as the capital city of Misraq shewa zone in Oromiya National Regional State during 2000-2005. With the reason of on the 10th of June 2005 that the Oromiya National Regional Government announced the move of the regional capital back to Addis Ababa, within this reason, back Adama as capital of misraq shewa and Batu as capital of Adamitulu jido kombolcha woreda.

The 2007 according to Gregorian calendar national census reported a total population for Ziway of 43,660, of whom 22,956 were men and 20,704 were women. The majority of the inhabitants said they practiced Ethiopian Orthodox Christianity, with 51.04% of the population reporting they observed this belief, while 24.69% of the population were Muslim, 0.42% practiced traditional beliefs, and 22.07% of the population were Protestant. The 1994 national census reported this town had a total population of 20,056 of whom 10,323 were males and 9,733 were females. The location of the research area, i.e. Ziway, on the map of Ethiopia is shown in figure 3.1.

Legend:

■ Ziway town

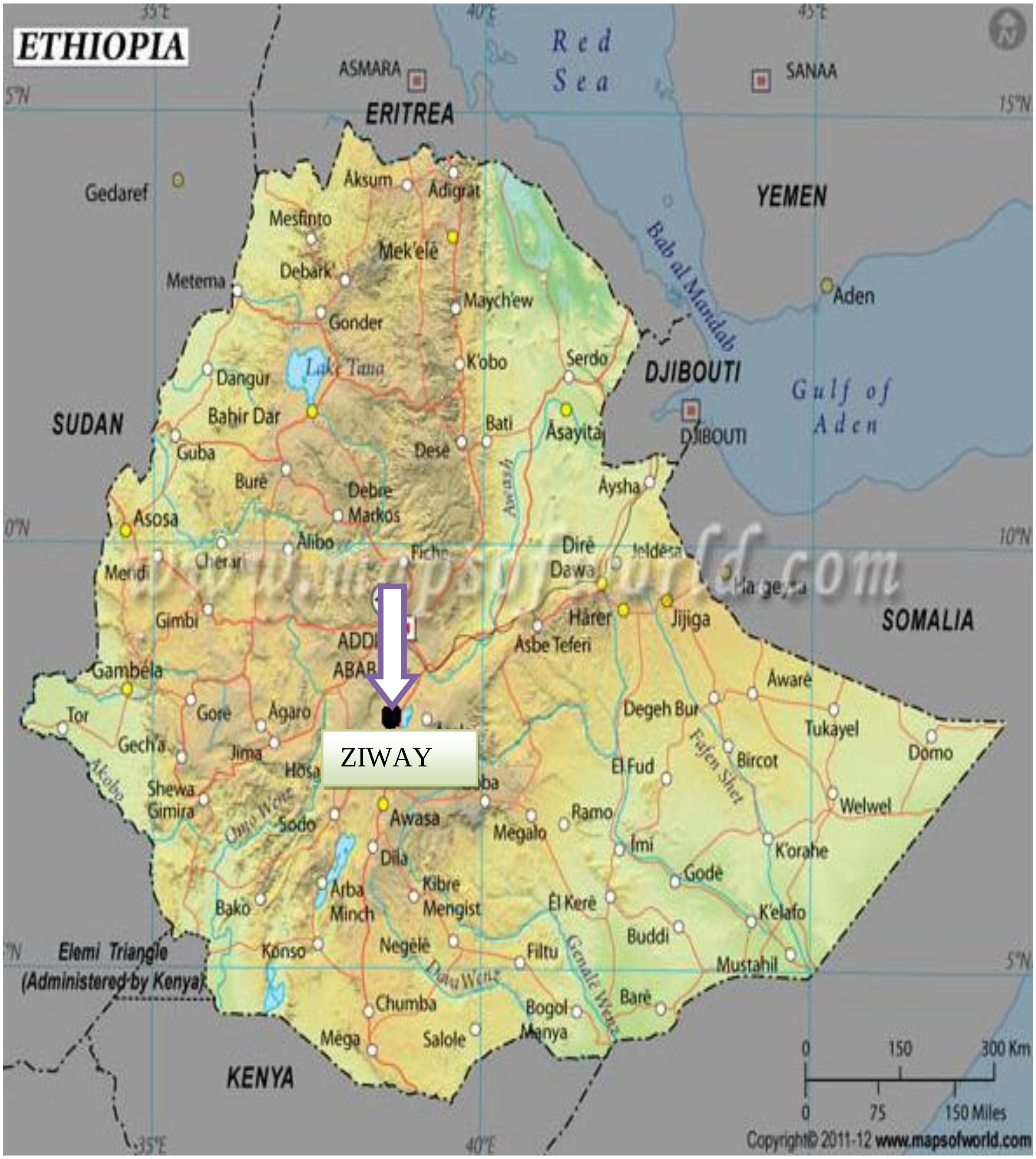


Fig 3.1 Location of the research area on the map of Ethiopia

3.2. Soil and Geology

The Great Rift Valley, formed about 20 million years ago, is the single largest geographical feature on the African continent. Its gradual expansion has been accompanied by a large amount of volcanic activity: the valley floor is studded with dormant and extinct volcanoes such as Fentale in Ethiopia.

The Rift Valley runs through Ethiopia from the Red Sea to the Kenya border. In northern Ethiopia it forms the Danakil Depression, an inaccessible and inhospitable desert that dips to the lowest point on the earth's surface. (see appendix H)

Along with the historical circuit in the north, the southern Rift valley is probably the most touristic part of Ethiopia, with easy access on public transport and fair tourist facilities.

The Ethiopian rift system which is part of the Great East African Rift valley System may be subdivided into three main sections. There are: the south western rift zone, the main Ethiopian rift, and Afar.

Ziway is part of the northernmost of Ethiopia's Rift Valley and dominated by flatlands. Ziway is regarded as seismically active area concerning earthquake hazards with the probability occurrence of 0.99 in every 100 years, i.e. as most of rift valley cities such as Adama, Mojo. (See appendix H)

Lake Ziway which is near to the town of Ziway is the northernmost of Ethiopia's Rift Valley lake and an ideal first stop on a tour of the Rift Valley. The lake is notable for its scenic qualities. It is ringed by steep volcanic hills and a dense bird population. The large island of Tullo Guddo is clearly visible from the mainland. On the highest peak the church of Debre Tsion is quite possibly the oldest active monastery in southern Ethiopia.

The soils in Ziway town are lithosols and mollic andosols. Lithosols are stony with very shallow depth and very susceptible to water erosion, while the andosols give good yield in crop production provided phosphorous fertilizer. Other soil type in the area is vertic cambisols.

TEST PIT LOCATION

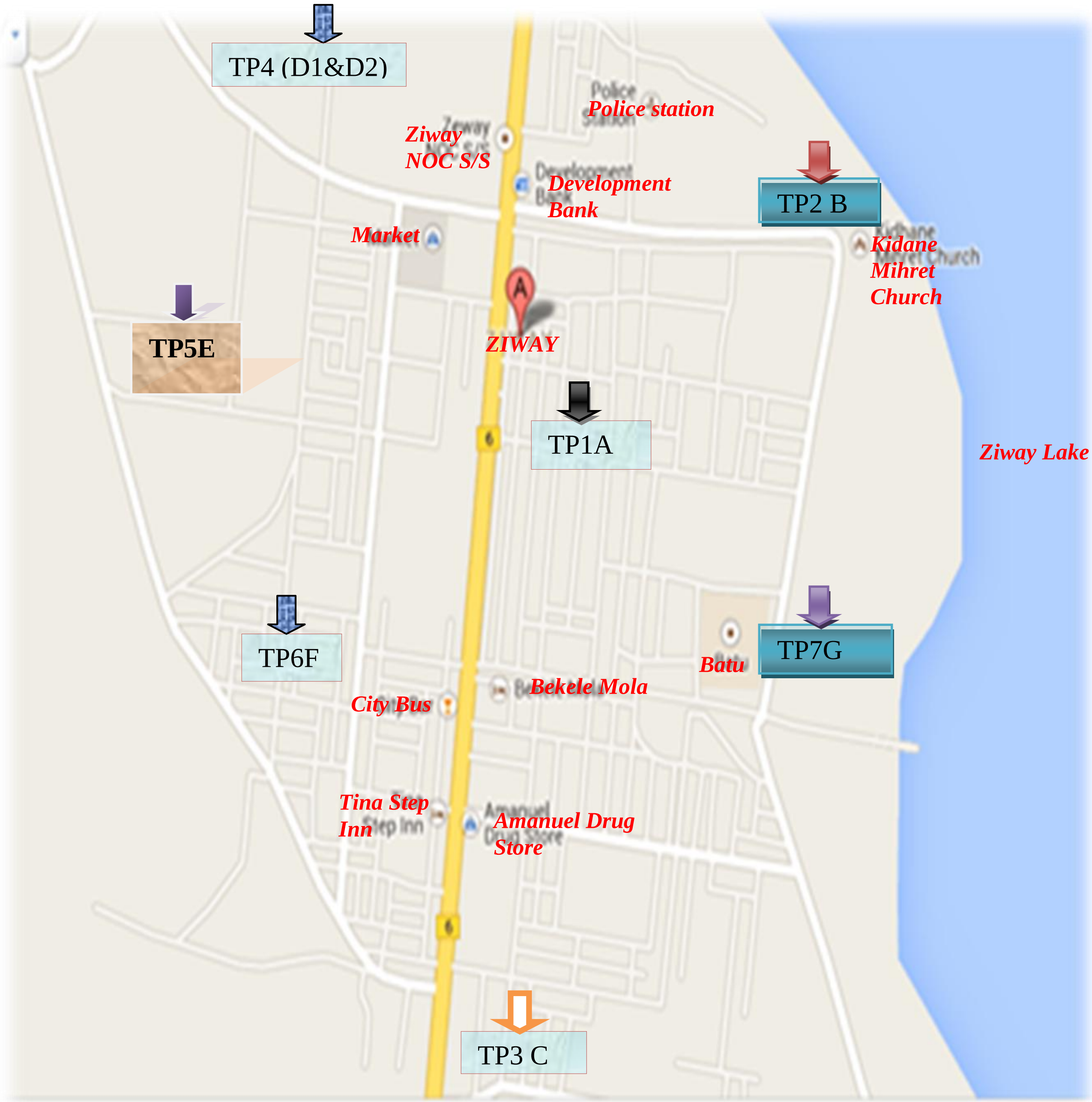


Fig. 3.2 Location of sampling areas shown on map of ZIWAY town (from Google earth map)

3.3. Topography and drainage conditions

The altitude of Ziway varies from about 1500m to 1670m above mean sea level. The two perennial rivers in the vicinity of Ziway are Meki River and Bulbula River which joins Ziway Lake.

3.4. Climate

3.4.1. Rainfall

The Rift Valley is lower and hotter than the highlands. And have an elevations are around 1500m and temperatures are rarely uncomfortably hot. The bulk of rain falls between June and September.

3.4.2. Temperature

The mean daily temperature at Ziway is 19.3°C. The highest temperatures occur between March and June prior to the start of the main rains, though seasonal variation in daily temperature is relatively slight. Spatial variations in temperature are largely results of differences in altitude. Mean daily temperatures fall with increasing altitude at a rate estimated to be within the range 0.55^0 – 0.65^0 C per 100 m, though the lapse rates are not uniform and actual temperature variations depend on exposure and seasonal weather characteristics.

While frost has not been recorded at Ziway, the minimum temperatures in the dry season frequently fall below 10°C and sometimes to 4°C. Temperature at ground level may therefore occasionally fall below freezing point, with implication for crop production. (MoWR)

4. In-situ Properties and Laboratory tests results

4.1. In-situ properties

4.1.1. Identification of Soil in the Study Area

The soil samples for this thesis work were collected from Ziway town. Before selecting sampling areas, discussion was taken on topography map of Ziway town with explanation from experts of municipality staffs for possible variation on soil types, visual site investigation and information from resident, and construction firms were also collected to consider the different soil types and to take sample evenly in the whole town. Accordingly, seven representative sampling areas were selected from different locations of the town as site investigation around the town confirmed. Those selected seven sampling test pits areas were considered enough for the town to investigate its engineering properties. Pits were excavated to the maximum depth of three meters. Since soil characteristics were determined along the profile for soil sample and have same profile except one test pits, it is preferred to take most of the sample at three meter since most shallow foundation depths are up to three meters and seasonal moisture fluctuation depth at the Ziway town taken to be at three meter. Only disturbed samples were taken because of the silt nature of the soil which makes recovering of undisturbed sample difficult. In the field visual soil description was made and sample for laboratory testing were collected. The global coordinates of sampling location is determined and presented in table 4.1.

Table 4.1 the location of test pits in global position system.

Test Pit	Location at the town	Longitude(in degrees)	Latitude(in degrees)	Elevation(meter)
TP1(A)	At adamitulu jido kombolcha speaker house	$7^{0}52^{'}06''$	$38^{0}41^{'}06^{''}$	1641
TP2(B)	Near lake back of kidan merit church	$7^{0}51^{'}0''$	$38^{0}43^{'}$	1635
TP3(C)	Around sherflower Ethiopia	$7^{0}56^{'}05''$	$38^{0}44^{'}02^{''}$	1638
TP4(D)	Around federal prison area	$7^{0}51^{'}09''$	$38^{0}42^{'}38^{''}$	1648
TP5(E)	In new road of butajira infront of Adventist	$7^{0}51^{'}08''$	$38^{0}42^{'}40^{''}$	1644
TP6(F)	St.George church	$7^{0}50^{'}04''$	$38^{0}43^{'}04^{''}$	1640
TP7(G)	Infront of Bethlehem hotel	$7^{0}52^{'}07''$	$38^{0}43^{'}01^{''}$	1633

4.1.2. Description of In-situ properties

From the entire test pits three basic properties were identified: in the top layer white shining sandy silt was identified, in the test pits are most are silts soils, silty sand, fine sands, and sand-silt mixtures; there is also some minimum amount of clay. (See App A. for soil profiles of each test pits). In the field part of the natural moisture content and field density tests were done.

4.1.2.1. Natural moisture content and In situ density

For most soils, the water content may be an 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. Since it was difficult to bring undisturbed samples to the laboratory, this test was done by using apparatus like moisture can, balance, core sampler and oven dry from Oromia agricultural research institute Ziway soil research center. The weight of the moisture can and the weight of can with moist soil was measured. Then the sample put it in to drying oven at a temperature of 105+5°c for 24 hours. Then after, the natural moisture content was determined

In situ density:-The bulk density is the ratio of mass of moist soil to the volume of the soil sample, and the dry density is the ratio of the mass of the dry soil to the volume the soil sample. The in-place density of soils is used to determine density of compacted soils used in the construction of structural fills, highway embankments, or earth dams. This test was done according to the Standard Reference: ASTM D 2937-00 – Standard

Test for Density of Soil in Place by the Drive-Cylinder Method. The natural moisture continent and in situ density of the samples around three meter is shown in Table 4.2. Field densities were taken only around three meters because these values were required for remolding sample in direct shear test.

Table 4.2 the In-situ density and natural moisture contents of soil samples

Test Pit number	Depth in meter	Natural moisture content (%)	In-situ density(g/cm3)
TP1(A)	@ 3	13.1	1.39
TP2(B)	@ 3	64.5	1.21
TP3(C)	@ 3	20.0	1.35
TP4(D2 &D1)	@ 2	24.3	1.41
	@ 3	25.1	1.49
TP5(E)	@ 3	28.2	1.20
TP6(F)	@ 3	46.8	1.23
TP7(G)	@ 3	31.6	1.43

4.2. Index properties

4.2.1. General

Basically, soil is more complex material. The complexity is contributed by its existence in almost innumerable varieties, by its combination of solid, liquid and gases. In many instances the solid particles vary in size from big boulders to colloidal size. Furthermore, the relative quantities of solid, liquid and gases in a given soil are found to change due to physical causes such as loading, seasonal variation and change of temperature. The physical properties of soils, which serve mainly for identification and classification, are commonly known as index properties.

A bulk soil is a soil as it exists in nature. The properties of soils are complex and variable. Every civil engineering work involves the determination of soil type and its associated engineering application; certain properties are more significant than others. The common problems faced by civil engineers are related to bearing capacity and compressibility of soil and seepage through the soil. The possible solution to these problems is arrived at based on the study of the physical and index properties of the soil.

Soil is a heterogeneous material. The properties and characteristics of soils vary from point to point. The tests required for determination of engineering properties are generally elaborate and time consuming. Sometimes the geotechnical engineer is interested to have some rough assessment of the engineering properties without conducting elaborate tests. This is possible if index properties are determined. The various properties of soils, which could be considered as index properties are:

1. Grain size analysis
2. Atterberg limits
3. Specific gravity

The ASTM testing procedure is used in the laboratory. Most of the literature for tropical soils is carried out using this method

4.2.2. Specific gravity

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil.

The specific gravity of the minerals affects the specific gravity of soils derived from them. 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.

According to ASTM D 854-98, two procedures for performing specific gravity are provided. These are Method-A, procedures for oven dried specimen and Method-B, procedure for moist specimen. For specimens of organic soils and highly plastic, fine-grained soils, Procedure B shall be the preferred method.

But in this research the specific gravities are determined using method A. The test results are shown in Table 4.3. Method-A give more reasonable value than that of Method-B, for this soil type and Method-A are used in other calculations like hydrometer analysis.

Table 4.3 Specific Gravity of the Soil of the Study Area

Serial no	Designation	Depth in meter	Specific Gravity(using oven dry sample)	Water used for testing
1	TP1(A)	@ 3	2.56	Tap water
2	TP2(B)	@ 3	2.48	Tap water
3	TP3(C)	@ 3	2.54	Tap water
4	TP4(D1)	@ 3	2.62	Tap water
5	TP4(D2)	@ 2	2.57	Tap water
6	TP5(E)	@ 3	2.40	Tap water
7	TP6(F)	@ 3	2.53	Tap water
8	TP7(G)	@ 3	2.56	Tap water

From the above table the specific gravity of ziway soils ranges from 2.40 to 2.62. (See the detail in appendix B)

4.2.3. Grain-size distribution of soil

4.2.3.1. General

Soil particles may consist of size ranges from boulders to fine-sized clays. 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.

The distribution of particle sizes larger than 75µm (retained on the No.200 sieve) is determined by sieving while the distribution of particle size smaller than 75 µ m (usually silt and clay) is determined by the sedimentation process using hydrometer analysis.

For different soil types at different depth, analysis can be carried out to determine the ranges of sizes in which the soil samples fall and their relative proportions.

After complete grain size analysis, the relative proportion of different size groups in each soil sample can be determined. The ranges of size especially the proportion of clay fraction is very important in case of expansive soils.

Soil samples that pass 2mm sieve size have been taken for analysis, after air drying and pulverizing. The analysis is done by wet sieving for composite analysis of both sieve and hydrometer.

The procedure followed to run this test is according to ASTM standard with designations D422-63 and D1140-97. According to ASTM D422-63 the distribution of particles, finer than 75µm can be done by hydrometer test and courser than 75µm by mechanical sieve.

The combined grain size distribution curve for particles retained on No.200 sieve and passing No.200 sieve is shown in fig 4.1. The gradation of soils in the study area varies considerably (Table 4.4).

Table 4.4 summery of grain size analysis result

Serial no	Designation	Depth(meter)	Percent amount of particle size			
			Gravel	Sand	Silt	Clay
1	TP-A	@ 3m	1.35	52.06	42.18	4.41
2	TP-B	@3m	1.11	72.84	25.68	1.21
3	TP-C	@3m	1.43	40.4	51.45	6.72
4	TP-D1	@3m	1.88	35.99	55.29	6.84
5	TP-D2	@ 2m	0.89	24.88	64.63	9.6
6	TP-E	@3m	0.89	81.30	17.15	0.66
7	TP-F	@3m	0.84	15.16	73.03	10.93
8	TP-G	@3m	1.6	53.08	42.02	3.3

From the grain size analysis results: for silt soils of ziway town has clay content ranging from 6.72 to 10.93%, silt fraction 51.45 to 73.03%, sand fraction 15.16 to 40.4%, and gravel content from 0.84 to 1.88% and for silty sand soils clay content ranging from 0.66 to 4.41%, silt fraction 17.15 to 42.18%, sand fraction 52.06 to 81.3%, and gravel content from 0.89 to 1.6% (See the detail in Appendix C).

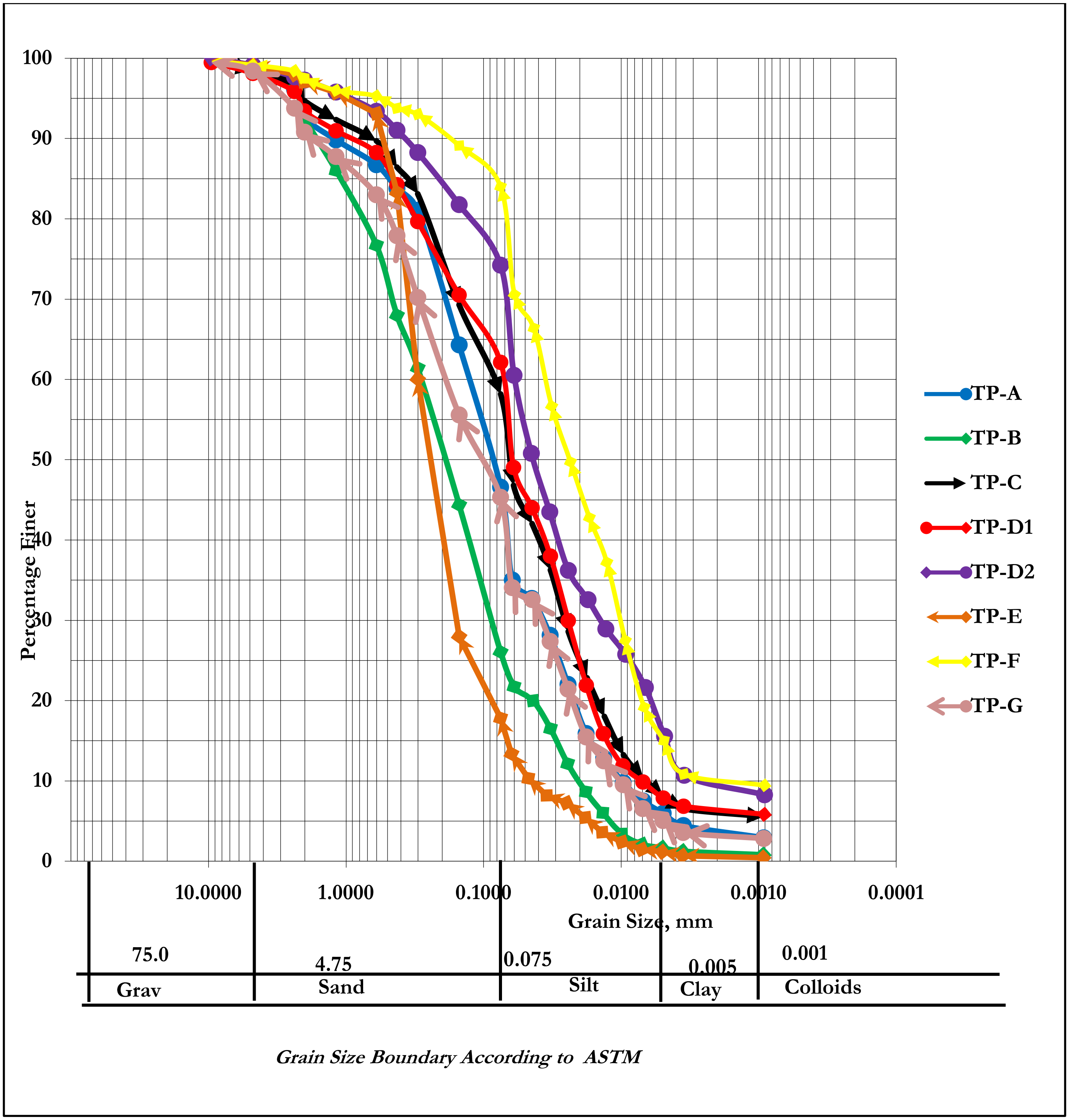


Fig 4.1 Grain size distribution curve for samples from test pits A to G

4.2.4. Atterberg Limits

4.2.4.1. General

Atterberg Limits are arbitrary boundaries through which a soil passes from liquid, to plastic, semi solid and solid states. These boundaries are defined by moisture contents.
They are used to determine the consistency of fine-grained soils.

The objective of the Atterberg limits test is to obtain basic index information about plasticity of the soil. It is the primary form of classification for cohesive soils.

Fine-grained soils are tested to determine the liquid, plastic and shrinkage limits, which are moisture contents that define boundaries between material consistency states. These standardized tests produce comparable numbers used for soil identification, classification and correlations to other properties.

The liquid (LL) and plastic (PL) limits define the water content boundaries between non-plastic, plastic and viscous fluid states (Fig 4.2). The plasticity index (PI) defines the complete range of plastic state. The smaller the shrinkage limits (SL), the more susceptible a soil is to volume change - that is, the smaller the SL, the less water is required to start the soil to change in volume. (See the detail in appendix D).

States	Limit	Consistency	Volume change
Liquid		Very soft	↑
………………w_l	Liquid limit……...	Soft	
Plastic		Stiff	Decrease in volume
………………w_p	Plastic limit……...	Very stiff	
Semi solid			↓
………………w_s	Shrinkage limit…..	Extremely stiff	
Solid		Hard	Constant volume

Fig 4.2 Different states and consistency of soils with Atterberg limits

The stages with water content looks like as follows:-

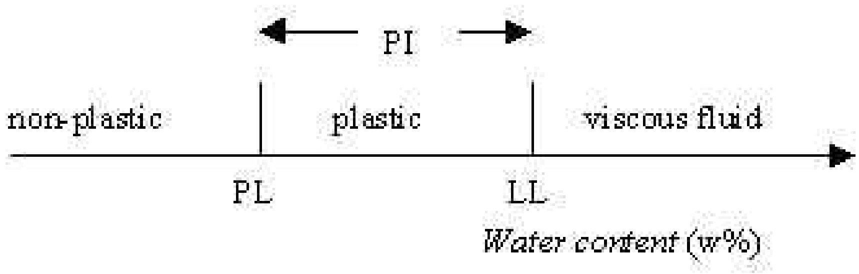


Fig 4.3 Atterberg limits illustration

4.2.4.2. Results

Atterberg Limits were determined for air-dried samples. It was done based on the Standard Reference: ASTM D 4318-98 –Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. The air- dried samples were prepared by spreading the specimen in the air until it dried. The room temperature was about 18-23ºc. The portions of the samples passing the No. 40 (0.425mm) sieve were used for the preparation of the sample for this test.

The liquid limit test on oven dry sample was done only on five representative samples.
The oven drying samples were prepared by putting the sample in an oven for 24 hours at a temperature of 110 ºc + 5º.

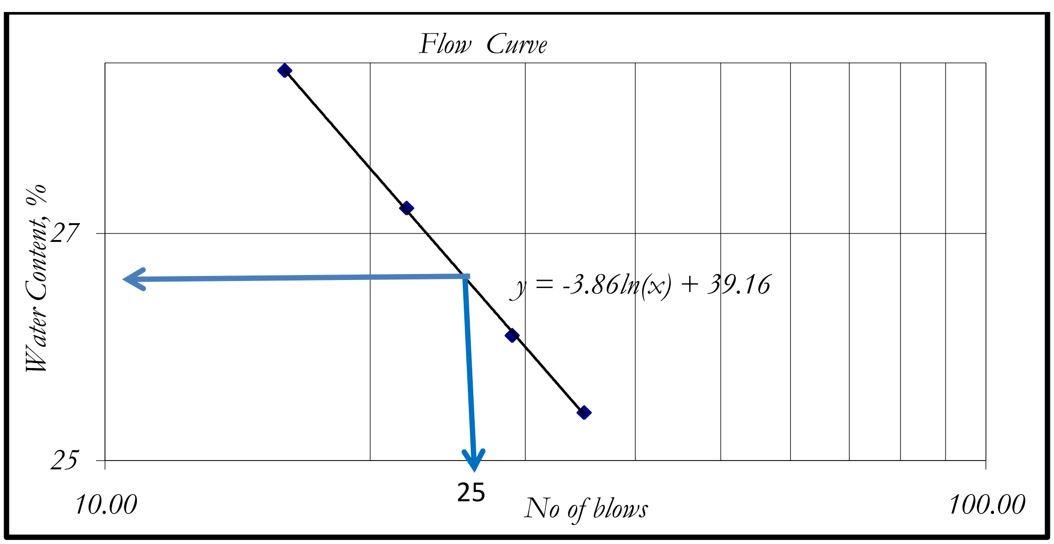


Fig 4.4 Typical flow curve

Table 4.5 Atterberg limits of the study area

Serial No	Designation	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	TP-C	31	27	4
2	TP-D1	27	23	4
3	TP-D2	31	25	6
4	TP-F	37	29	8

The Atterberg Limits for silt (TP-C, TP-D1, TP-D2, and TP-F) soils in Ziway town are summarized in Table 4.5 above. From this we can observe that liquid limit ranges from 27–37%, plastic limit ranges from 23–29% and plastic index from 4 to 8%.

4.3. Compaction test

4.3.1. General

Compaction places soils in a dense state and hence decreases further settlement; increases shear strength and decreases permeability. Mechanical compaction is one of the most common and cost effective means of stabilizing soils. During compaction air is expelled from the void spaces. Thus compaction results in an increase in the density of the soil. An extremely important task of geotechnical engineers is the performance and analysis of field control tests to assure that compacted fills are meeting the prescribed design specifications. Design specifications usually state the required density (as a percentage of the "maximum" density measured in a standard laboratory test), and the water content. In general, most engineering properties, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing the soil density. Results are used to determine appropriate methods of field compaction and to provide a standard by which to judge the acceptability of field compaction.

The optimum water content is the water content that results in the greatest density for a specified compactive effort. Compacting at water contents higher than (wet of) the optimum water content results in a relatively dispersed soil structure (parallel particle orientations) that is weaker, more ductile, less pervious, softer, more susceptible to shrinking, and less susceptible to swelling than soil compacted dry of optimum to the same density. The soil compacted lower than (dry of) the optimum water content typically results in a flocculated soil structure (random particle orientations) that has the opposite characteristics of the soil compacted wet of the optimum water content to the same density.

Two types of compaction tests routinely performed are: (1) The Standard Proctor Test, and (2) The Modified Proctor Test. In this thesis the Standard Proctor Test is used.

From the test results the maximum dry density (MDD) of Ziway ranges from1.22 to 1.55 g/cm3 and the optimum moisture content ranges 22.6 to 35.83 percent. The summary of the test result is shown in Table 4.6.

Generally course grained soils can be compacted to a higher dry density than fine gained soils for the some compaction effort. When some fines are added to the coarse grained soils to file the voids, the maximum dry density further increases, but it the amount of fines is too much, more than required to fill the voids, it results in reduction of dry density; well graded soils can attain higher dry density than poorly graded soils. High plasticity soils attain much less dry density than low plasticity clays for the some compactive effort. (See the detail in appendix E).

Table 4.6 summery of maximum dry density and optimum moisture content

Serial no	Designation	Depth (m)	MDD(g/cm^3)	OMC (%)
1	TP-A	@3	1.46	27.2
2	TP-B	@3	1.25	22.6
3	TP-C	@3	1.41	28.5
4	TP-D1	@3	1.55	27.5
5	TP-D2	@2	1.44	25.6
6	TP-E	@3	1.22	35.83
7	TP-F	@3	1.28	25
8	TP-G	@3	1.49	27.1

Compaction is the process by which the in-situ density of soil or aggregate is increased by driving out air. In-situ density increases with compaction and tends to increase with depth. For any soil, optimal water content exists at which it will achieve its maximum density. In-situ density is the weight of soil to the total soil volume ($V_{soil} + V_{water} + V_{air}$) but maximum dry density (compacted soil density) is the weight of soil to the volume soil plus volume water.

Therefore soils in the Ziway town which have high in-situ density are compacted to high maximum dry density.

4.4. Classification of the Soils

4.4.1. General

Many different disciplines find a soil classification based purely on particle-size classification 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.

Engineering soils are subdivided into two main groups as a function of their predominant sizes and associated plasticity. The coarse-grained soils are composed of sand size and larger particles. They are separated into size ranges by sieving of materials up to cobble size. Except for minor fractions of plastic fines, they characteristically are non-plastic. The fine grained soils consist predominantly of silt and clay-sized particles with differing degrees of plasticity measured by their Atterberg limits rather than by sieving and settling velocity methods.

The most widely used classification schemes are those that divide soils into an orderly, easily remembered system of groups, or classes, that have similar physical and engineering properties and that can be identified by simple and inexpensive tests.

These groups ideally provide estimates of both the engineering characteristics and performance of soils for design and construction engineers. The descriptions of soils within the groups of a given classification typically are represented by alphabetical or alphanumeric symbols for rapid identification in written material, graphic boring logs, and on engineering drawings. The continued use of a few engineering soil classification systems is the result of the provision in each for the needs of the Civil Engineer as well as the adaptability of the classification to the variety of soils encountered in engineering practice.

A soil classification system is an arrangement of different soils into groups having similar properties. The purpose of soil classification is to make possible the estimation of soil properties by association with soils of the same class whose properties are known and to provide the engineer with accurate method of soils description. The soils under investigation have been classified according to USCS and AASHTO M-145. These methods are among the widely used classification systems in our country. Average grain size classification according to ASTM, 1998

Gravel	76.2mm – 4.75mm
Sand	4.75mm – 0.075mm
Coarse sand	4.75mm – 2mm
Medium sand	2mm - 0.425mm
Fine sand	0.425 – 0.075
Silt size	0.074 to 0.005 mm
Clay size	<0.005 mm
Colloids	<0.001 mm

Average grain size classification according to USCS (Budhu, 2000)

Gravel	75mm - 4.75mm
Sand	4.75mm - 0.075mm
Silt	0.075mm - 0.002mm
Clay	< 0.002mm

Average grain size classification according to AASHO (Teferra, 1999)

Gravel	>2mm
Sand	2mm - 0.05mm
Silt	0.05mm - 0.002mm
Clay	< 0.002mm

4.4.2. 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.

For the cases under consideration; except the four samples collected from less weathered rocky areas (sample A, sample B, sample E, sample G). Grain size analysis of the entire samples revealed that more than 50% from each samples pass the No 200 sieve i.e. are sample C, D1, D2 and F. They are classified as fine-grained soils and are sub divided based on their Atterberg limit values.

By making use of laboratory determined Liquid Limit and Plasticity Indexes for a soil sample the proper group of the soil for the as received condition has been made by use of the plasticity chart, or A- line diagram, as illustrated by Figure 4.5.

Table 4.7 classification of soil based on unified soil classification system

Serial no	Designation	Depth(meter)	Percent amount of particle size				LL (%)	PL (%)	PI (%)	Classification According to USC
			Gravel	Sand	Silt	Clay				
1	TP-A	@3m	1.35	52.06	42.18	4.41	-	-	NP	SM
2	TP-B	@3m	1.11	72.84	25.68	1.21	-	-	NP	SM
3	TP-C	@3m	1.43	40.40	51.45	6.72	31	27	4	ML
4	TP-D1	@3m	1.88	35.99	55.29	6.84	27	23	4	ML
5	TP-D2	@2m	0.89	24.88	64.63	9.60	31	25	6	ML
6	TP-E	@3m	0.89	81.30	17.15	0.66	-	-	NP	SM
7	TP-F	@3m	0.84	15.16	73.03	10.93	37	29	8	ML
8	TP-G	@3m	1.60	53.08	42.02	3.30	-	-	NP	SM

According to USC classification scheme most of the soil of the study area falls in SM and ML, region which shows that the soil is non expansive. From the plot of plasticity chart in figure 4.5 and the classification soils on table 4.7 the soils found in Ziway town are silts, silty sands, very fine sands, and sand-silt mixtures.

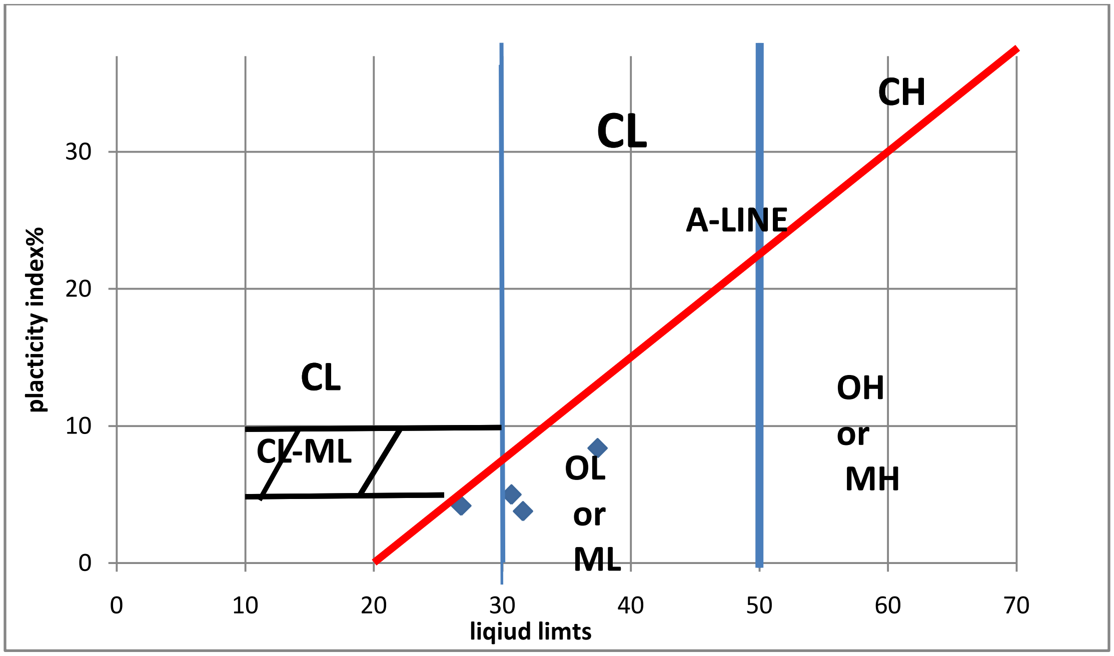


Fig 4.5 Plasticity chart of the study area according to Unified Soil Classification System

4.4.3. Classifications of soils based on AASHTO Classification system

It is a textural-plasticity classification that uses sieved fractions and Atterberg Limits for assignment of 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 USC system is retained to separate the finer fractions from sand.

The increased number of soil groups in the AASHTO classification compared with the USC system as well as the different upper size limits of sand makes comparisons of the two systems difficult.

The AASHTO system classifies soils into seven groups, A-1 through A-7-6. As per this system of soil classification, soils of Ziway town fall under A-2-4, A-3, and A-4 with group index, 0, 0, and 8 respectively.

Even though the AASHTO classification system is more specific, unlike the USC classification system the AASHTO system does not clearly set out the effects of drying temperature. The decrease by the clay fractions does not affect the group to which the soil was assigned. Though this is the fact, it is the AASHTO classification system, which deserves priority in classifying soils of Ziway town.

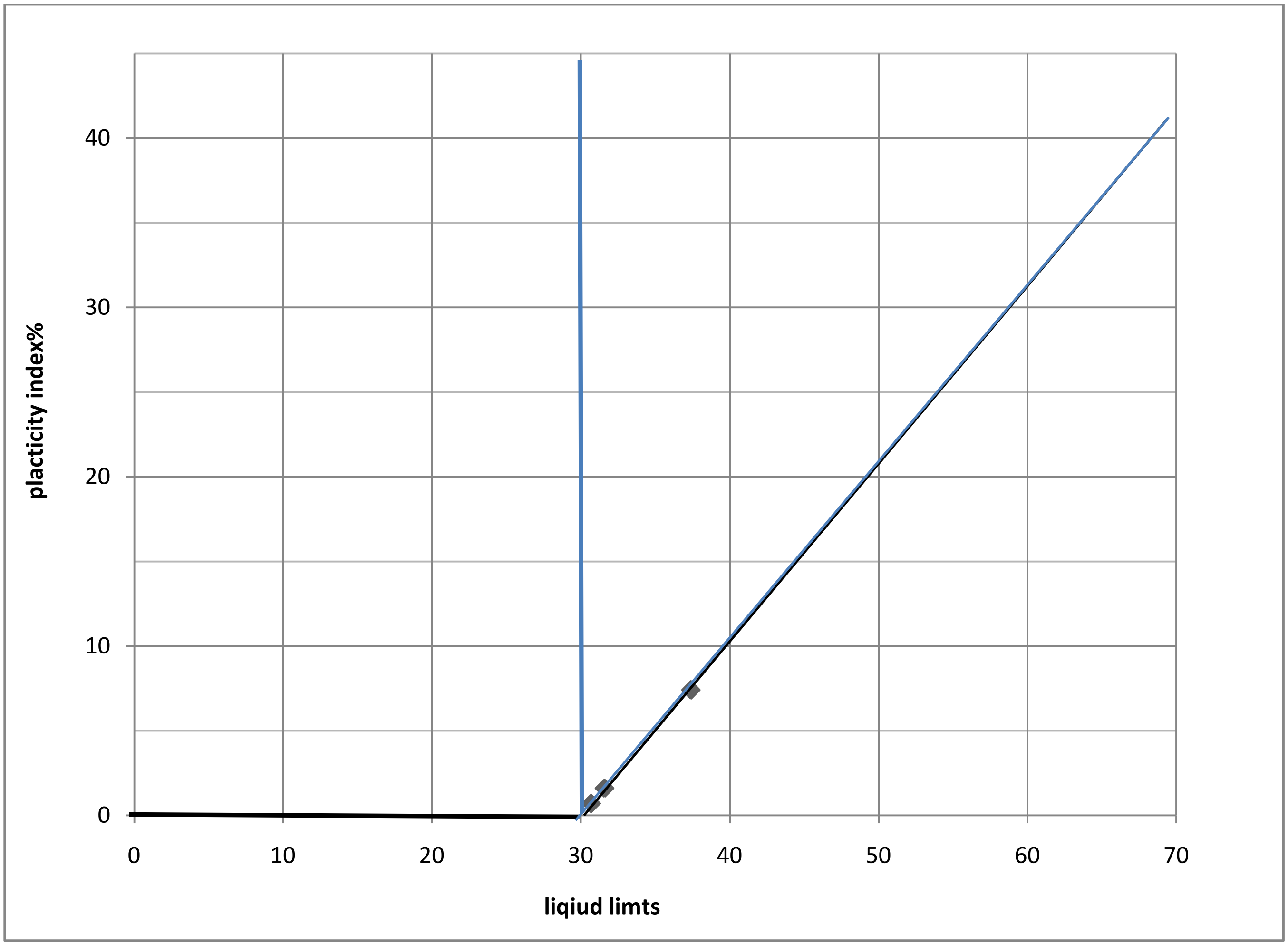


Fig 4.6 Plasticity chart of soil in the study area according to AASHTO system of classification

Table 4.8 Classifications of soils based on AASHTO Classification system

Serial No	Designat-ion	Percent passing on sieve			LL (%)	PL (%)	PI (%)	Group index	Group classification	Usual type of significant constitute materials	General rating assub-grade materials
		No. 10	No. 40	No. 200							
1	TP-A	92.64	83.78	46.59	-	-	NP	8(max)	A-4	Silty soils	fair
2	TP-B	92.56	67.98	26.05	-	-	NP	0	A-2-4	Silt or clayey gravel and sand	Good
3	TP-C	94.74	86.43	58.17	31	27	4	8(max)	A-4	Silty soils	fair
4	TP-D1	93.43	84.25	62.13	27	23	4	8(max)	A-4	Silty soils	fair
5	TP-D2	97.28	91.03	74.23	31	25	6	8(max)	A-4	Silty soils	fair
6	TP-E	97.03	83.31	17.81	-	-	NP	0	A-3	Fine sand	Good
7	TP-F	97.46	93.78	84.0	37	29	8	8(max)	A-4	Silty soils	fair
8	TP-G	90.8	77.90	45.32	-	-	NP	0	A-3	Fine sand	Good

4.5. DIRECT SHEAR TEST

4.5.1. General

The shear strength of soil mass is its property against sliding along internal 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 its simplicity and smoothness in operation and the rapidity of testing program. But this test has the disadvantage that lateral pressure and stress on other than the plane of shear are not known during test.

4.5.2. Significance

The test used to determine 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 compacted by artificially at its in situ moisture content and in-situ density.

- ✓ A direct shear device will be used to determine the shear strength parameters (i.e. angle of internal friction ($\emptyset$) and cohesion (C) of soil.
- ✓ From the plot of the shear stress versus the horizontal displacement, the maximum shear stress is obtained for a specific vertical confining stress.
- ✓ 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 ($\emptyset$) and cohesion (C) may be determined the graph.
- ✓ The shear strength can be computed from the following equation:

Total Shear stress = C + $\sigma \tan\emptyset$

$$\sigma = \frac{N}{A}$$

Where: N = normal vertical force

$\sigma = normal\ stress$ $\emptyset = angle\ of\ internal\ friction$

C= cohesion

Shear load = Proving reading * ring calibration factor (0.7N/dial)

Shear Stress = Shear Load / corrected area

Corrected area = Initial area (60 x 60) – (1-horizontal strain)

Horizontal strain (ϵ) = $\frac{\Delta L}{L0}$

4.5.3. Sample preparation:

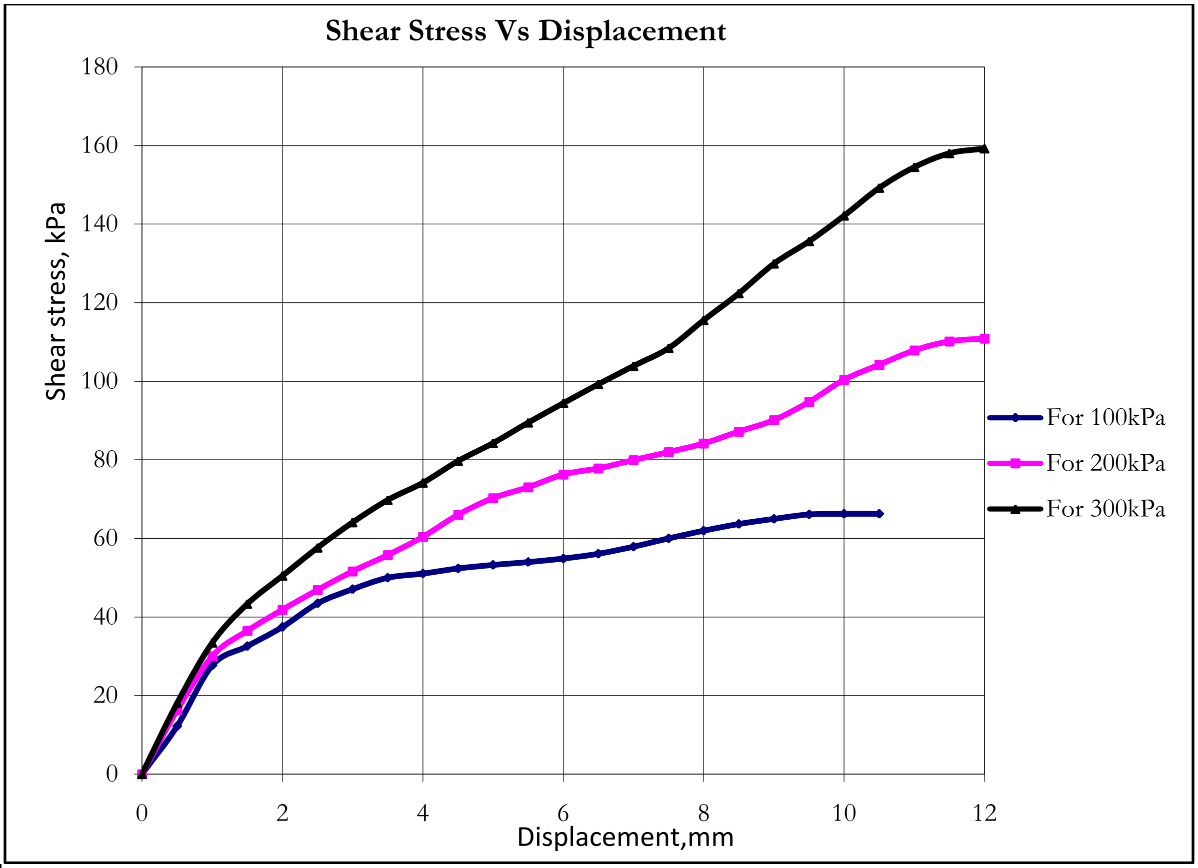
Direct shear test is done: field density and natural moisture content tests were done in the field. The natural moisture content tests were performed by using balance and moisture cans at the site. After measuring the weight of empty can and can with moist soil the sample is brought to laboratory and put into drying oven. Therefore to know shear strength remold is prepared in laboratory using its field density, natural moisture content, direct shear test is done.

Shear Strength Parameters Determination: The maximum shear stress at failure occurs before 15% strain attain during each test. Using the normal stress and the maximum shear stress at failure the value of cohesion (C) and angle of internal friction(Ø) will be determined as follows.

Shear strengh parameters from the graph of shear stress vesrsus displacement and maximum shear stress vesrsus and applied vertical load respectively gives cohesion(C) and angle of internal friction (Ø) as follows:(see detail in Appendix F)

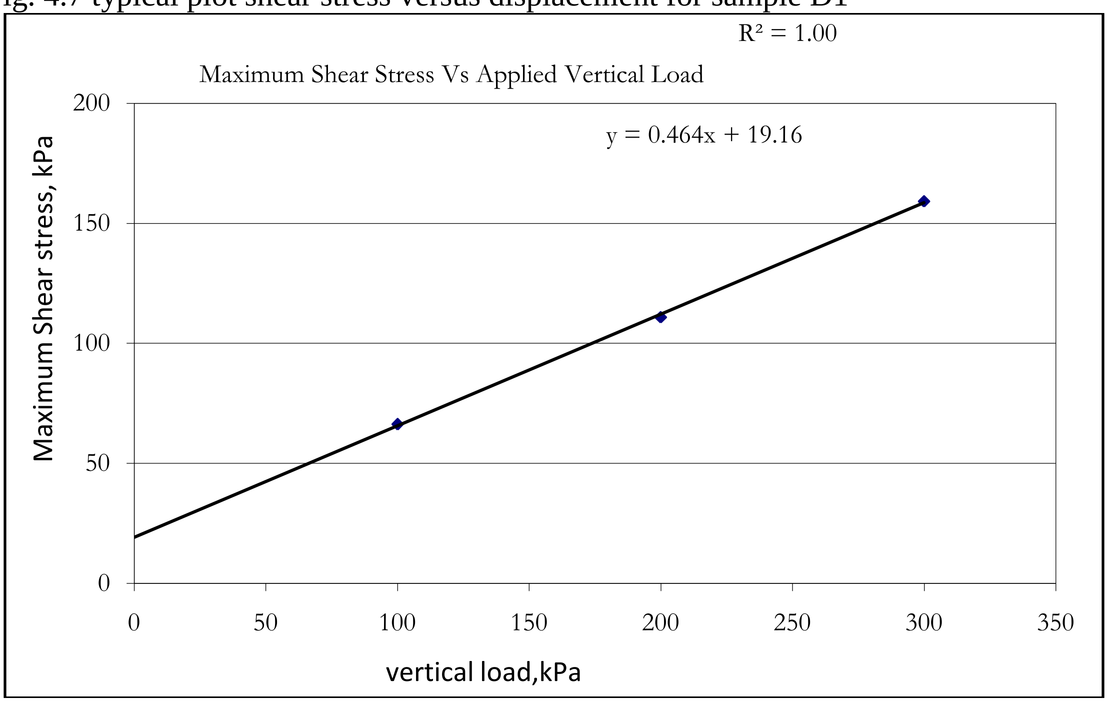
Table 4.9 summery of direct shear results i.e the cohesion and angle of internal friction.

Serial no	designation	Depth (m)	Cohesion (C) in kPa.	Angle of internal friction (Ø).in degrees
1	TP-A	@3	13.9	26.1
2	TP-B	@3	7.8	27.0
3	TP-C	@3	17.0	25.0
4	TP-D1	@3	19.2	24.9
5	TP-E	@3	2.9	28.4
6	TP-F	@3	20.2	19.8
7	TP-G	@3	9.8	26.6



Angle of internal friction, ϕ =24.9

Fig. 4.7 typical plot shear stress versus displacement for sample D1



Cohesion(KN/M^2)=19.16

Fig. 4.8 typical plot maximum shear stress versus applied vertical load for sample D1

5. Discussions of the laboratory test results and Comparisons with previously done researches

5.1. Discussions of the laboratory test results

The results obtained from the grain size analyses indicate that the dominant proportion of soil particle in the research area is silty sand and silt soils.

From Atterberg Limits test results the values of plastic index for silts is greater than silty sands. This reason is due to the silts soils have higher clay particle than silty sand soil.

The specific gravity of Ziway soil is from 2.4 to 2.62. According to Arora, 2003 the specific gravity of silt and silty sand soil is from 2.66 to 2.7, so the specific gravity of Ziway soil is low. This is may be because the soils in the study area much derived from light weighted rocks.

According to Unified Soil Classification System, the soil under investigation lies below the A-line in the region of sandy silt, inorganic silt and inorganic elastic silt. That means inorganic silt with low plasticity.

According to AASHTO Classification system, soils of Ziway town fall under A-2-4, A-3, and A-4 with group index, 0, 0, and 8 respectively. The soil under investigation have fair to good rating as sub-grade materials.

From compaction test results the Optimum moisture content of Ziway soil is from 22.6 to 35.83% this is relatively higher than the optimum moisture content of silt and silty sand soils of Arora, 2003(i.e. 8 to 16%). This deviation may be due to compaction methods and sample preparation.

The shear strength of cohensionless soils, such as sands and non-plastic silt, is mainly due to friction between particles. In dense sands, interlocking between particles also contributes significantly to the strength.

Except test pit TP6-F(Φ=19.8), the angle of internal friction (Φ) falls between 24.9^0 to 28.4^0, and from the litrature the angle of intenal friction for soils of silt to silty sand ranges from 26^0 to 35^0, it is relatively similar to the accepted reprentative values. The value of internal friction for TP6-F is lower than the litereture,this may be due to sample preparation.

5.2. Comparisons with previously done researches

For the soil under investigation; Index property were studied and a comparison was made with known silt and silty sand soils. Adama silt and silty sand soil studied by Abu Gemechu, (2011) and Dagnachew Debebe (2011).

Table 5.1 Index property Test Results in different parts of the country

	Thesis by Abu Gemechu, 2007	Thesis by Dagnachew,2011	Current thesis
Soil type	Silt & silty sand	Silt & silt sand	Silt, silty sand, sand-silt mixures
Location	Adama	Adama	Ziway
Clay Content (%)	14-58	5.4 – 40.5	0.66-10.93
Silt fraction (%)	14-61	17.6-60.7	17.15-73.03
Sand fraction (%)	25-56	14.5-54.6	15.16-81.3
Liquid Limit (%)	39-49.4	29-73	27-37
Plastic limit (%)	26-37.4	24-39	23-29
Plasticity Index (%)	10-15	5-34	4-8
Moisture content (%)	25-30.5	17.5-36.5	22.6-35.83
Specific Gravity	2.61-2.7	2.4-2.7	2.4-2.62
Compaction (g/cm3)	1.33-1.53	1.2-1.62	1.22-1.55
From plasticity chart	ML&SM	SM, ML, MH	SM & ML

Table 5.1 show the average values of various tests done at different parts of countries, i.e., Sieve analysis, Liquid Limit, Plastic Index and specific gravities showing different properties. As indicated in the above table Ziway soils show lower plasticity (clay content) as compared to Adama soil. The data indicate that there is a considerable similarity in the physical properties of Adama and Ziway town soils.

6. Conclusions and recommendations

6.1. Conclusion

Grain size analysis tests revealed that, starting from few centimeters below the ground level to the depth of investigation which is three meters, the soil in Ziway town is mostly silts and silty sand. In which for silt soils of ziway town has clay content ranging from 6.72 to 10.93%, silt fraction 51.45 to 73.03%, sand fraction 15.16 to 40.4%, and gravel content from 0.84 to 1.88% and for silty sand soils clay content ranging from 0.66 to 4.41%, silt fraction 17.15 to 42.18%, sand fraction 52.06 to 81.3%, and gravel content from 0.89 to 1.6%

Within the depth of exploration, the specific gravity of the town ranges from 2.40 to 2.62.

From compaction test results the maximum dry density (MDD) of Ziway ranges from1.22 to 1.55 g/cm3 and the optimum moisture content ranges 22.6 to 35.83 percent.

From the consistency limit test results, the Atterberg Limits for silt (TP-C, TP-D1, TP-D2, and TP-F) soils is conducted. And the liquid limit ranges from 27–37%, plastic limit ranges from 23–29% and plastic index from 4 to 8%.

Shear strengh parameters from the graph of shear stress vesrsus displacement and maximum shear stress vesrsus and applied vertical load respectively gives cohesion(C) and angle of internal friction (Φ), From this results the cohesion of Ziway ranges from 2.90-20.15kPa and the angle of internal friction ranges from 19.8^{0}-28.4^{o}.

6.2. Recommendation

- ✓ In this research samples of soil were collected only from seven test pits, by increasing the number of sampling area in-depth investigation should be done in future.
- ✓ The dynamic characteristics of soils with relation to respond of soil to earthquake should be studied in future. The Correlation of the index property with shear strength parameters may also be done.

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Appendix – A

(Log of test pits)

PROJECT:	MSC THESIS	DATE: May 8,2013
LOCATION:	Near Adamitulu Jidokombolcha speaker office	
TEST PIT No.:	TP1(A)	

DEPTH, m	Bore Hole Log	VISUAL SOIL DISCRIPTION	Field test type	Sampled for
-0.90		Fill		
-3.0	+ −+ − + −+ − + − + − +− + − + −+ − + − + −+ − + − + − +− +	High content silty soils with some sand content , elastic silts	Natural moisture content ,in-situ density	Natural moisture content, Grain size analysis, Consistency limit test, Compaction test, specific gravity test, direct shear test

TEST PIT SIZE, m 1.20 X 1.50 X3.0

LOCATION: LOGGED ZIWAY TOWN

LOGGED BY: BEZZA TESFAYE

TEST PIT NO : TP1(A)

PROJECT:	MSC THESIS	
LOCATION:	Near lake back of kidan meherit church	
TEST PIT No.:	TP2(B)	DATE: May 8,2013

DEPTH, m	Bore Hole Log	VISUAL SOIL DISCRIPTION	Field test type	Sampled for
-0.40		fill	Natural moisture content ,in-situ density	Natural moisture content, Grain size analysis, Consistency limit test, Compaction test, specific gravity test, direct shear test
-1.50	+ −+ − + −+ − + − + − +− + − +−+ −+ − + − + −+ − + −	Moist silty soil considered, with pumice type light sands seen.		
Below 1.50		Ground water considered		

TEST PIT SIZE, m 1.20 X 1.50 X1.5

LOCATION: LOGGED ZIWAY TOWN

LOGED BY: BEZZA TESFAYE

TEST PIT NO: TP2(B)

PROJECT:	MSC THESIS	Date:	May 8,2013
LOCATION:	Around sheer flower Ethiopia		
TEST PIT No.:	TP3(C)		

DEPTH, m	Bore Hole Log	VISUAL SOIL DISCRIPTION	Field test type	Sampled for
-0.80		**Fill**		
	+ +	**Silty soils, elastic silts and loose type termite tropical soil**	Natural moisture content ,in-situ density	Natural moisture content, Grain size analysis, Consistency limit test, Compaction test, specific gravity test, direct shear test

TEST PIT SIZE, m 1.20 X 1.50 X3.0

LOCATION: LOGGED ZIWAY TOWN

LOGED BY: BEZZA TESFAYE

TEST PIT NO TP3(C)

PROJECT:	MSC THESIS		
LOCATION:	Around Federal prison area		
TEST PIT No.:	TP4(D)		DATE: May 8,2013

DEPTH, m	Bore Hole Log	VISUAL SOIL DISCRIPTION	Field test type	Sampled for
-0.70		Fill		
-2.0	+ +	Silty soils , to some extent loose nature silty soils , have termite crystals , tropical residual soils	Natural moisture content ,in-situ density	Natural moisture content, Grain size analysis, Consistency limit test, Compaction test, specific gravity test, direct shear test
-3.0	+ + + + + + + + + + + + + + + + + + + +	Silty soils moist nature than the above, to some extent stiff nature silty soils considering to top layer , have termite crystals , tropical residual soils considered	Natural moisture content ,in-situ density	Natural moisture content, Grain size analysis, Consistency limit test, Compaction test, specific gravity test, direct shear test

TEST PIT SIZE, m	1.20 X 1.50 X3.0
LOCATION: LOGGED	ZIWAY TOWN
LOGED BY:	BEZZA TESFAYE
TEST PIT NO	TP4(D)

PROJECT:	MSC THESIS	
LOCATION:	On new road to Butajira in front of Adventist church	
TEST PIT No.:	TP5(E)	DATE: September,20,2013

DEPTH, m	Bore Hole Log	VISUAL SOIL DISCRIPTION	Field test type	Sampled for
-1.0		Fill		
-3.0	– – – – – – – – – – – – – – – – – – - - - - - -	Fine sands , pumice light sands, basaltic extrusive soil with light pumice soil	Natural moisture content ,in-situ density	Natural moisture content, Grain size analysis, Consistency limit test, Compaction test, specific gravity test, direct shear test

TEST PIT SIZE, m 1.20 X 1.50 X3.0

LOCATION: ZIWAY TOWN

Logged by : BEZZA TESFAYE

PROJECT:	MSC THESIS	DATE: September,20,2013
LOCATION:	Near Saint GEORGE Church	
TEST PIT No.:	TP6(F)	

DEPTH, m	Bore Hole Log	VISUAL SOIL DISCRIPTION	Field test type	Sampled for
-0.60		Fill		
-3.0	+ +	Elastic silt, high content of silty soils ,have some clay content, white shining silty soils, some termite nature tropical soil also seen	Natural moisture content ,in-situ density	Natural moisture content, Grain size analysis, Consistency limit test, Compaction test, specific gravity test, direct shear test

TEST PIT SIZE, m	1.20 X 1.50 X3.0
LOCATION: LOGGED	ZIWAY TOWN
LOGED BY:	BEZZA TESFAYE
TEST PIT NO	TP6(F)

PROJECT:	MSC THESIS	
LOCATION:	In front of Bethlehem hotel	
TEST PIT No.:	TP7(G)	DATE: September,20,2013

DEPTH, m	Bore Hole Log	VISUAL SOIL DISCRIPTION	Field test type	Sampled for
-0.65		Fill		
-3.0	+ −+ − + −+ − + − + − +− + − + +− −+−+− −+−+− − +− + −+ − +	Silty soils, Medium stiff silts , high moisture content silt soils	Natural moisture content ,in-situ density	Natural moisture content, Grain size analysis, Consistency limit test, Compaction test, specific gravity test, direct shear test

TEST PIT SIZE, m	1.20 X 1.50 X3.0
LOCATION: LOGGED	ZIWAY TOWN
LOGED BY:	BEZZA TESFAYE
TEST PIT NO	TP7(G)

Appendix – B

(Specific gravity test result)

For sample A

Determination No.	*1*	*2*
Pycnometer No.	*1*	*2*
Weight of pycnometer + soil + water, W_{pws} *(g)*	*163.9*	*163.6*
Temperature, T_x*(°c)*	*19*	*19*
Weight of pycnometer + water at T_x *,* $W_{pw}(atT_x)$ *(g)*	*148.48*	*148.58*
Weight of dry soil , w_s *(gm)*	*25*	*25*
Conversion factor , K	*1.0002*	*1.0002*
Specific gravity of soil at 20°c.	*2.61*	*2.51*
Average specific gravity of soil.	*2.56*	

For sample B

Determination No.	*1*	*2*
Pycnometer No.	*1*	*2*
Weight of pycnometer + soil + water, W_{pws} *(g)*	*163.3*	*163.5*
Temperature, T_x*(°c)*	*19*	*19*
Weight of pycnometer + water at T_x *,* $W_{pw}(atT_x)$ *(g)*	*148.48*	*148.58*
Weight of dry soil , w_s *(gm)*	*25*	*25*
Conversion factor , K	*1.0002*	*1.0002*
Specific gravity of soil at 20°c.	*2.47*	*2.48*
Average specific gravity of soil.	*2.48*	

For sample C

Determination No.	*1*	*2*
Pycnometer No.	*1*	*2*
Weight of pycnometer + soil + water, W_{pws} *(g)*	*164.1*	*163.5*
Temperature, T_x*(°c)*	*19*	*19*
Weight of pycnometer + water at T_x *,* W_{pw}*(at*T_x*) (g)*	*148.58*	*148.68*
Weight of dry soil , w_s *(gm)*	*25*	*25*
Conversion factor , K	*1.0002*	*1.0002*
Specific gravity of soil at 20°c.	*2.62*	*2.46*
Average specific gravity of soil.	*2.54*	

For sample D1

Determination No.	*1*	*2*
Pycnometer No.	*1*	*2*
Weight of pycnometer + soil + water, W_{pws} *(g)*	*164.1*	*163.9*
Temperature, T_x*(°c)*	*19*	*19*
Weight of pycnometer + water at T_x *,* W_{pw}*(at*T_x*) (g)*	*148.58*	*148.48*
Weight of dry soil , w_s *(gm)*	*25*	*25*
Conversion factor , K	*1.0002*	*1.0002*
Specific gravity of soil at 20°c.	*2.64*	*2.61*
Average specific gravity of soil.	*2.62*	

For sample D2

Determination No.	*1*	*2*
Pycnometer No.	*1*	*2*
Weight of pycnometer + soil + water, W_{pws} *(g)*	*163.9*	*163.8*
Temperature, T_x*(°c)*	*19*	*19*
Weight of pycnometer + water at T_x *,* $W_{pw}(at T_x)$ *(g)*	*148.58*	*148.58*
Weight of dry soil , w_s *(gm)*	*25*	*25*
Conversion factor , K	*1.0002*	*1.0002*
Specific gravity of soil at 20°c.	*2.58*	*2.56*
Average specific gravity of soil.	*2.57*	

For sample E

Determination No.	*1*	*2*
Pycnometer No.	*1*	*2*
Weight of pycnometer + soil + water, W_{pws} *(g)*	*163.3*	*162.9*
Temperature, T_x*(°c)*	*19*	*19*
Weight of pycnometer + water at T_x *,* $W_{pw}(at T_x)$ *(g)*	*148.58*	*148.48*
Weight of dry soil , w_s *(gm)*	*25*	*25*
Conversion factor , K	*1.0002*	*1.0002*
Specific gravity of soil at 20°c.	*2.43*	*2.36*
Average specific gravity of soil.	*2.40*	

For sample F

Determination No.	1	2
Pycnometer No.	1	2
Weight of pycnometer + soil + water, W_{pws} *(g)*	163.8	163.5
Temperature, T_x*(°c)*	19	19
Weight of pycnometer + water at T_x *,* $W_{pw}(at T_x)$ *(g)*	148.58	148.48
Weight of dry soil , w_s *(gm)*	25	25
Conversion factor , K	1.0002	1.0002
Specific gravity of soil at 20°c.	2.56	2.51
Average specific gravity of soil.	2.53	

For sample G

Determination No.	1	2
Pycnometer No.	1	2
Weight of pycnometer + soil + water, W_{pws} *(g)*	163.6	164.5
Temperature, T_x*(°c)*	19	19
Weight of pycnometer + water at T_x *,* $W_{pw}(at T_x)$ *(g)*	148.68	148.98
Weight of dry soil , w_s *(gm)*	25	25
Conversion factor , K	1.0002	1.0002
Specific gravity of soil at 20°c.	2.48	2.64
Average specific gravity of soil.	2.56	

Appendix – C

(Grain size and hydrometer analysis results)

FOR SAMPLE A

Sieve opening (mm)	Mass of sieve (g)	Mass of sieve with retained soil (g)	Mass of retained soil (g)	Percentage retained, %	Cumulative percentage retained, %	comulative Percentage passing, %
9.5	**463.2**	**466.1**	**2.9**	**0.29**	**0.29**	**99.71**
4.75	350.6	361.2	10.6	**1.06**	**1.35**	98.65
2.36	416.4	441.6	25.2	**2.52**	**3.87**	96.13
2	400.9	435.8	34.9	**3.49**	**7.36**	92.64
1.18	372.3	400.4	28.1	**2.81**	**10.17**	89.83
0.6	326.9	357.8	30.9	**3.09**	**13.26**	86.74
0.425	305.8	335.4	29.6	**2.96**	**16.22**	83.78
0.3	305.3	332.4	27.1	**2.71**	**18.93**	81.07
0.15	271.1	438.8	167.7	**16.77**	**35.7**	64.3000
0.075	261.3	438.4	177.1	**17.71**	**53.41**	46.5900
Pan	255.7	721.1	465.4	**46.54**	**99.95**	0.0500
Total	3266.3	4729	999.5	99.66		

Sample A
near Jido-kombolcha speaker house
1000

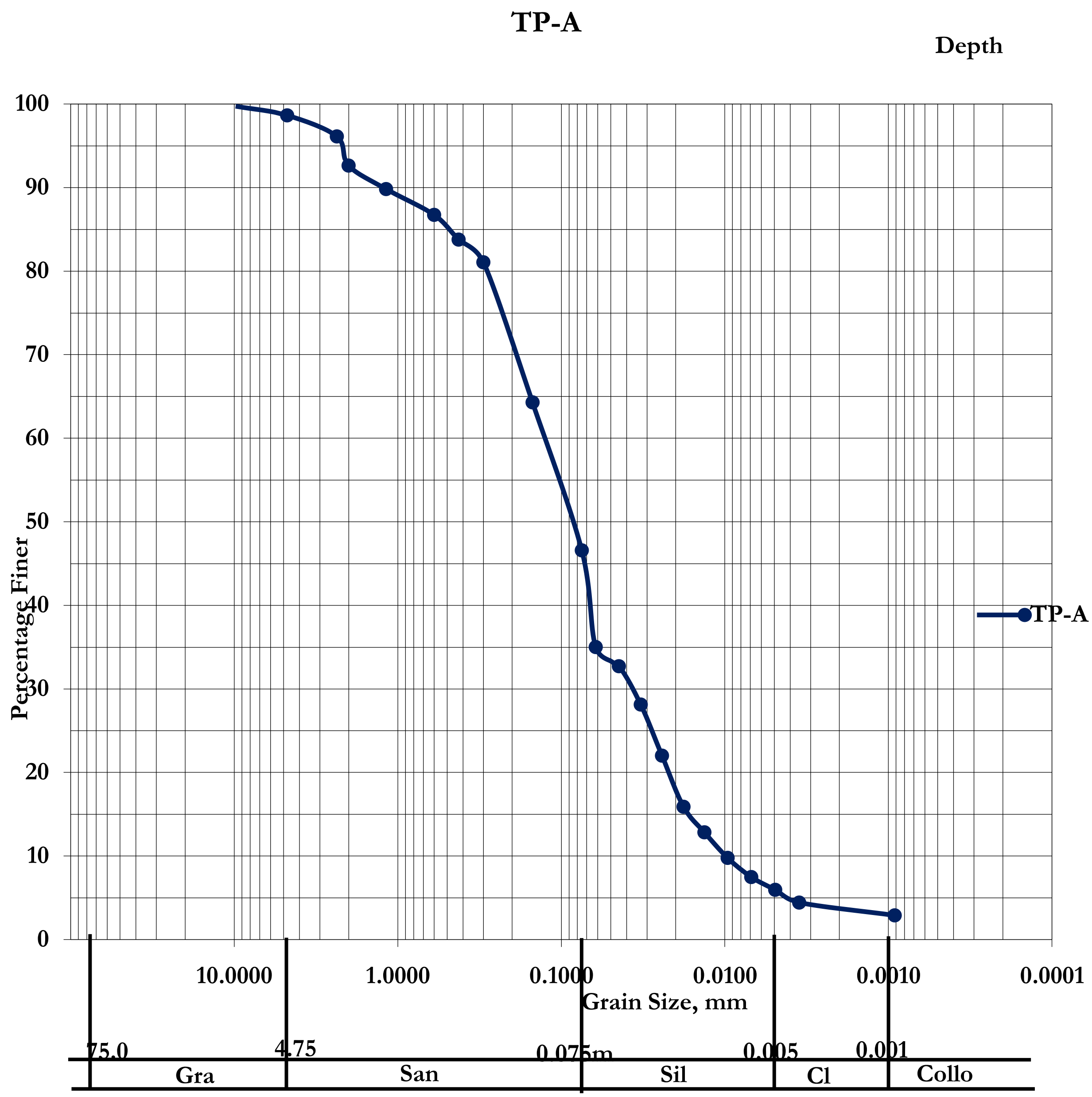
A.wash on pan

%gravel	1.35
%sand	52.06
%fine	46.59

Hydrometer Analysis for A

Specific Gravity of soil 2.56 Test Temperature, deg.c 18

Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)	Perc. Finer Combined (%)
0.5	1.0260	0.0031	1.0229	9.42	0.0142	0.0616	75.16	35.02
1	1.0245	0.0031	1.0214	9.82	0.0142	0.0445	70.24	32.72
2	1.0215	0.0031	1.0184	10.61	0.0142	0.0327	60.39	28.14
4	1.0175	0.0031	1.0144	11.67	0.0142	0.0243	47.26	22.02
8	1.0135	0.0031	1.0104	12.73	0.0142	0.0179	34.13	15.90
15	1.0115	0.0031	1.0084	13.26	0.0142	0.0134	27.57	12.84
30	1.0095	0.0031	1.0064	13.79	0.0142	0.0096	21.01	9.79
60	1.0080	0.0031	1.0049	14.18	0.0142	0.0069	16.08	7.49
120	1.0070	0.0031	1.0039	14.45	0.0142	0.0049	12.80	5.96
240	1.0060	0.0031	1.0029	14.71	0.0142	0.0035	9.52	4.43
3600	1.0050	0.0031	1.0019	14.98	0.0142	0.0009	6.24	2.91



Grain Size Boundary According to ASTM

For sample B

Sieve opening (mm)	Mass of sieve (g)	Mass of sieve with retained soil (g)	Mass of retained soil (g)	Percentage retained, %	Cumulative percentage retained, %	comulative Percentage passing, %		
9.5	**463.2**	**463.4**	**0.2**	**0.02**	**0.02**	**99.98**		
4.75	350.6	361.5	10.9	**1.09**	**1.11**	98.89		
2.36	416.4	446	29.6	**2.96**	**4.07**	95.93		
2	400.9	434.6	33.7	**3.37**	**7.44**	92.56		
1.18	372.3	437.6	65.3	**6.53**	**13.97**	86.03		
0.6	326.9	420.1	93.2	**9.32**	**23.29**	76.71		
0.425	305.8	393.1	87.3	**8.73**	**32.02**	67.98		
0.3	305.3	370.9	65.6	**6.56**	**38.58**	61.42		
0.15	271.1	441.5	170.4	**17.04**	**55.62**	44.3800	%gravel	1.11
0.075	261.3	444.6	183.3	**18.33**	**73.95**	26.0500	%sand	72.84
Pan	255.7	515.8	260.1	**26.01**	**99.96**	0.0400	%fine	26.05
Total	3266.3	4729.1	999.6	99.94				

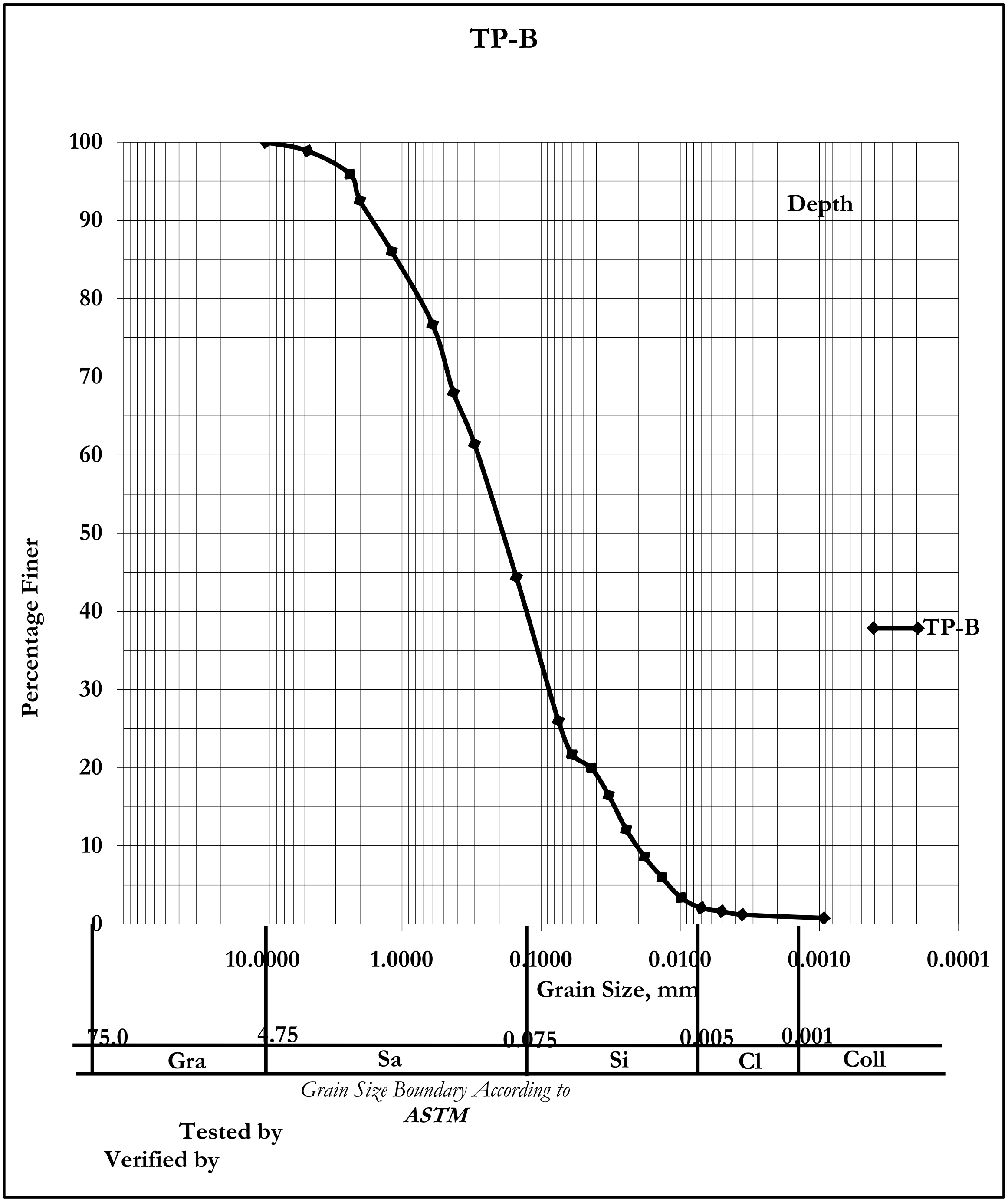
SAMPLE B
near lake back of kedanmehiret church

1000

Hydrometer Analysis for B

Specific Gravity of soil 2.48 Test Temperature, deg.c 19

Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)	Perc. Finer Combined (%)
0.5	1.0280	0.0031	1.0249	8.89	0.0142	0.0599	83.45	21.74
1	1.0260	0.0031	1.0229	9.42	0.0142	0.0436	76.75	19.99
2	1.0220	0.0031	1.0189	10.48	0.0142	0.0325	63.34	16.50
4	1.0170	0.0031	1.0139	11.80	0.0142	0.0244	46.58	12.14
8	1.0130	0.0031	1.0099	12.86	0.0142	0.0180	33.18	8.64
15	1.0100	0.0031	1.0069	13.65	0.0142	0.0135	23.12	6.02
30	1.0070	0.0031	1.0039	14.45	0.0142	0.0099	13.07	3.40
60	1.0055	0.0031	1.0024	14.85	0.0142	0.0071	8.04	2.10
120	1.0050	0.0031	1.0019	14.98	0.0142	0.0050	6.37	1.66
240	1.0045	0.0031	1.0014	15.11	0.0142	0.0036	4.69	1.22
3600	1.0040	0.0031	1.0009	15.24	0.0142	0.0009	3.02	0.79


TP-B
Depth
Percentage Finer
100
90
80
70
60
50
40
30
20
10
0
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Grain Size, mm
TP-B
75.0
4.75
0.075
0.005
0.001
Gra
Sa
Si
Cl
Coll
Grain Size Boundary According to
ASTM
Tested by
Verified by

FOR SAMPLE C

Sieve opening (mm)	Mass of sieve (g)	Mass of sieve with retained soil (g)	Mass of retained soil (g)	Percentage retained, %	Cumulative percentage retained, %	comulativePercentage passing, %
9.5	**463.2**	**468.1**	**4.9**	**0.49**	**0.49**	**99.51**
4.75	350.6	360	9.4	**0.94**	**1.43**	**98.57**
2.36	416.4	434.5	18.1	**1.81**	**3.24**	**96.76**
2	400.9	421.1	20.2	**2.02**	**5.26**	**94.74**
1.18	372.3	396.1	23.8	**2.38**	**7.64**	**92.36**
0.6	326.9	353.5	26.6	**2.66**	**10.3**	**89.7**
0.425	305.8	338.5	32.7	**3.27**	**13.57**	**86.43**
0.3	305.3	338.4	33.1	**3.31**	**16.88**	**83.12**
0.15	271.1	409.3	138.2	**13.82**	**30.7**	**69.3**
0.075	261.3	372.6	111.3	**11.13**	**41.83**	**58.17**
Pan	255.7	837	581.3	**58.13**	**99.96**	**0.04**
Total	3266.3	4729.1	999.6	**99.96**		

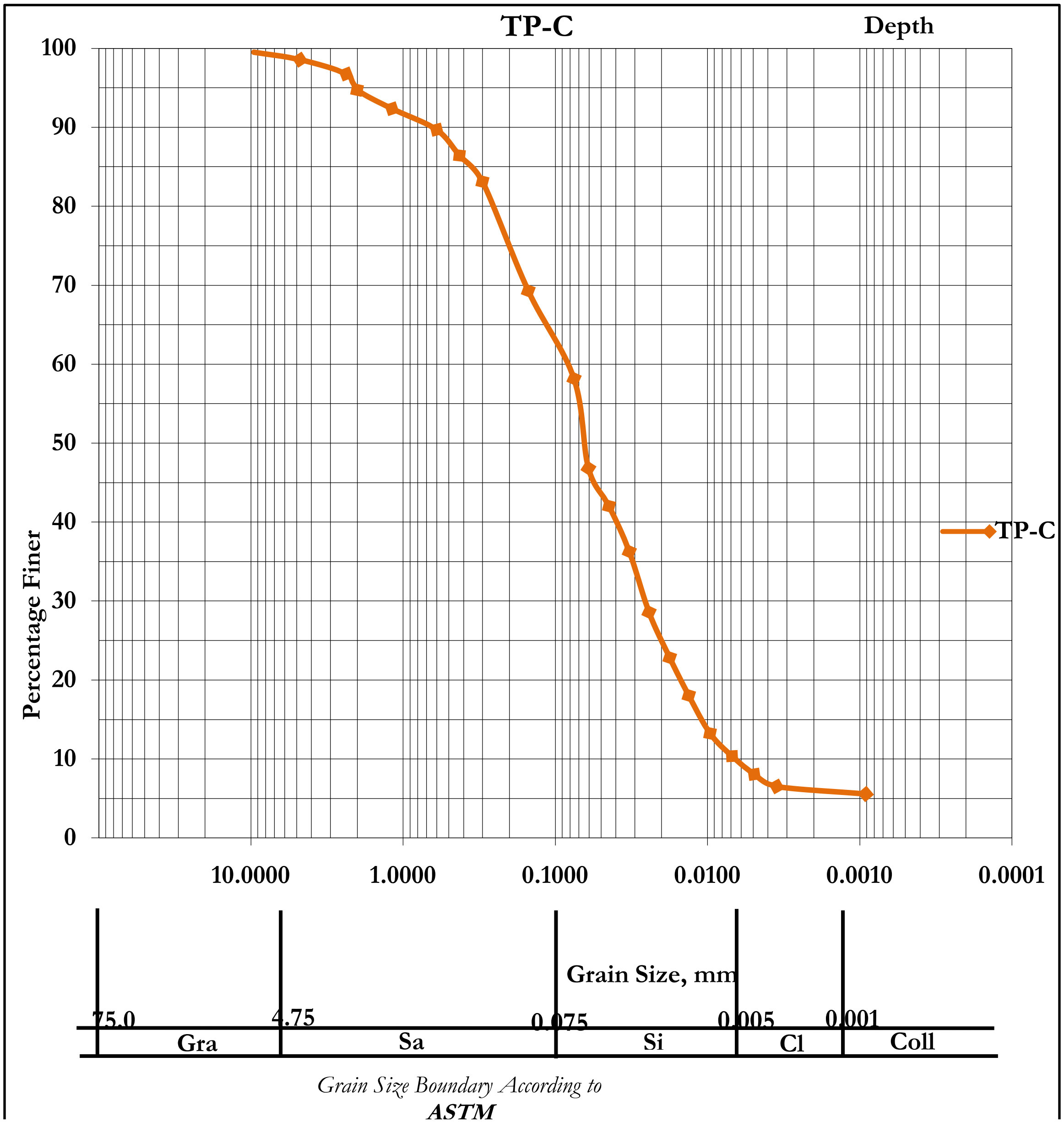
Sample C
near shear flower area
1000
sample in gm

%gravel	1.43
%sand	40.4
%fine	58.17

Hydrometer Analysis **for sample C**

Specific Gravity of soil 2.54 Test Temperature, deg.c 18.5

Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)	Perc. Finer Combined (%)
0.5	1.0275	0.0031	1.0244	9.03	0.0142	0.0603	80.49	46.82
1	1.0250	0.0031	1.0219	9.69	0.0142	0.0442	72.24	42.02
2	1.0220	0.0031	1.0189	10.48	0.0142	0.0325	62.35	36.27
4	1.0180	0.0031	1.0149	11.54	0.0142	0.0241	49.15	28.59
8	1.0150	0.0031	1.0119	12.33	0.0142	0.0176	39.25	22.83
15	1.0125	0.0031	1.0094	12.99	0.0142	0.0132	31.01	18.04
30	1.0100	0.0031	1.0069	13.65	0.0142	0.0096	22.76	13.24
60	1.0085	0.0031	1.0054	14.05	0.0142	0.0069	17.81	10.36
120	1.0073	0.0031	1.0042	14.37	0.0142	0.0049	13.85	8.06
240	1.0065	0.0031	1.0034	14.58	0.0142	0.0035	11.22	6.52
3600	1.0060	0.0031	1.0029	14.71	0.0142	0.0009	9.57	5.56


TP-C
Depth
Percentage Finer
100
90
80
70
60
50
40
30
20
10
0
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
TP-C
Grain Size, mm
75.0
4.75
0.075
0.005
0.001
Gra
Sa
Si
Cl
Coll
Grain Size Boundary According to
ASTM

FOR SAMPLE D1

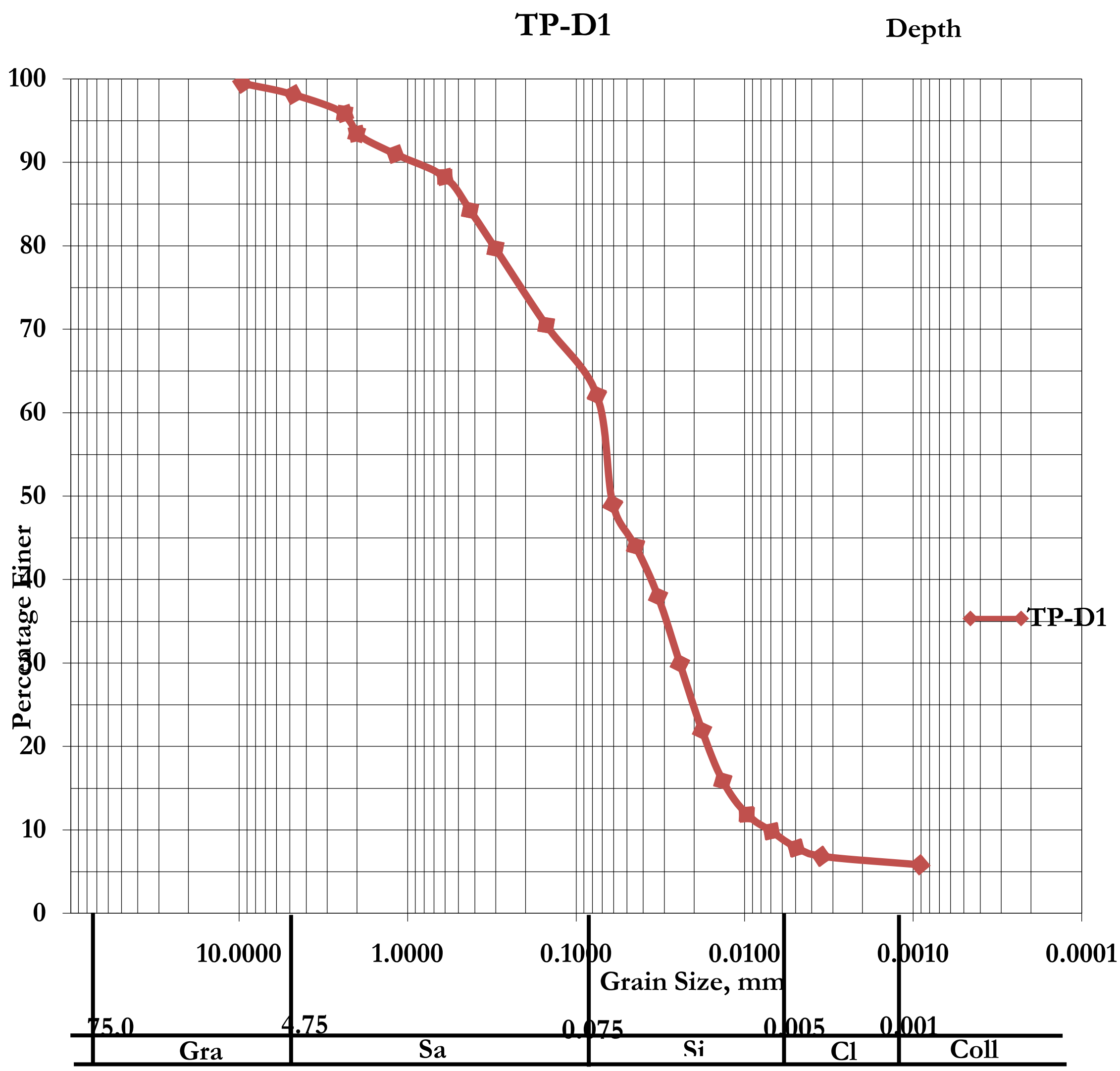
Sieve opening (mm)	Mass of sieve (g)	Mass of sieve with retained soil (g)	Mass of retained soil (g)	Percentage retained, %	Cumulative percentage retained, %	comulative Percentage passing, %
9.5	**463.2**	**468.5**	**5.3**	**0.53**	**0.53**	**99.47**
4.75	350.6	364.1	13.5	**1.35**	**1.88**	**98.12**
2.36	416.4	439	22.6	**2.26**	**4.14**	**95.86**
2	400.9	425.2	24.3	**2.43**	**6.57**	**93.43**
1.18	372.3	396.8	24.5	**2.45**	**9.02**	**90.98**
0.6	326.9	354.1	27.2	**2.72**	**11.74**	**88.26**
0.425	305.8	345.9	40.1	**4.01**	**15.75**	**84.25**
0.3	305.3	351.1	45.8	**4.58**	**20.33**	**79.67**
0.15	271.1	362.9	91.8	**9.18**	**29.51**	**70.49**
0.075	261.3	344.9	83.6	**8.36**	**37.87**	**62.13**
Pan	255.7	876.9	621.2	**62.12**	**99.99**	**0.01**
Total	3266.3	4729.4	999.9	99.99		

Sample D1
AROUND FEDERAL PRISONAL AREA
at
3meter

1000

%gravel	1.88
%sand	35.99
%fine	62.13

Hydrometer Analysis		**for D1**						
Specific Gravity of soil		2.62			Test Temperature, deg.c		18	
Elapsed	Actual	Composite	Corrected	Effective	Coefficient	Grain	Perc.	Perc. Finer
Time	Hydrometer	Correction	Hydrometer	Depth	K	Size	Finer	Combined
(min)	Reading		Reading	(cm)		(mm)	(%)	(%)
0.5	1.0275	0.0031	1.0244	9.03	0.0142	0.0603	78.92	49.04
1	1.0250	0.0031	1.0219	9.69	0.0142	0.0442	70.84	44.01
2	1.0220	0.0031	1.0189	10.48	0.0142	0.0325	61.13	37.98
4	1.0180	0.0031	1.0149	11.54	0.0142	0.0241	48.20	29.94
8	1.0140	0.0031	1.0109	12.60	0.0142	0.0178	35.26	21.91
15	1.0110	0.0031	1.0079	13.39	0.0142	0.0134	25.55	15.88
30	1.0090	0.0031	1.0059	13.92	0.0142	0.0097	19.08	11.86
60	1.0080	0.0031	1.0049	14.18	0.0142	0.0069	15.85	9.85
120	1.0070	0.0031	1.0039	14.45	0.0142	0.0049	12.61	7.84
240	1.0065	0.0031	1.0034	14.58	0.0142	0.0035	11.00	6.83
3600	1.0060	0.0031	1.0029	14.71	0.0142	0.0009	9.38	5.83



Grain Size Boundary According to ***ASTM***

FOR SAMPLE D2

Sieve opening (mm)	**Mass of sieve (g)**	**Mass of sieve with retained soil (g)**	**Mass of retained soil (g)**	**Percentage retained, %**	**Cumulative percentage retained, %**	**comulative Percentage passing, %**
9.5	**463.2**	**463.2**	**0**	**0**	**0**	**100**
4.75	350.6	359.5	8.9	**0.89**	**0.89**	99.11
2.36	416.4	430.7	14.3	**1.43**	**2.32**	97.68
2	400.9	404.9	4	**0.4**	**2.72**	97.28
1.18	372.3	387.2	14.9	**1.49**	**4.21**	95.79
0.6	326.9	350.9	24	**2.4**	**6.61**	93.39
0.425	305.8	329.4	23.6	**2.36**	**8.97**	91.03
0.3	305.3	333	27.7	**2.77**	**11.74**	88.26
0.15	271.1	336	64.9	**6.49**	**18.23**	81.7700
0.075	261.3	336.7	75.4	**7.54**	**25.77**	74.2300
Pan	255.7	998	742.3	**74.23**	**100**	0.0000
Total	3266.3	4266.3	1000	100		

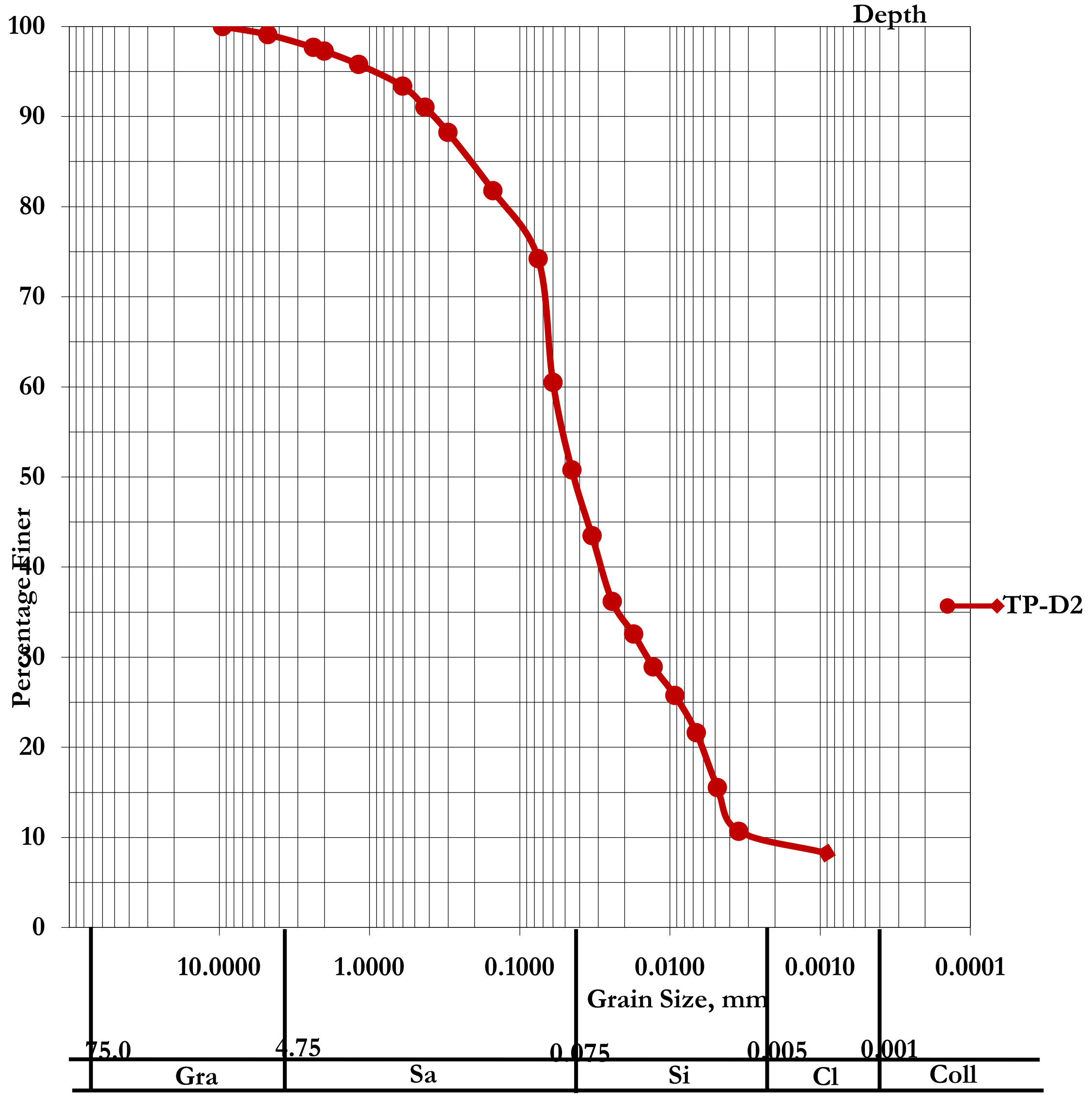
Sample D2 near federal at 2m

1000

%gravel	0.89
%sand	24.88
%fine	74.23

Hydrometer Analysis		for D2						
Specific Gravity of soil		2.57			Test Temperature, deg.c		18	
Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)	Perc. Finer Combined (%)
0.5	1.0280	0.0031	1.0249	8.89	0.0142	0.0599	81.52	60.51
1	1.0240	0.0031	1.0209	9.95	0.0142	0.0448	68.42	50.79
2	1.0210	0.0031	1.0179	10.75	0.0142	0.0329	58.60	43.50
4	1.0180	0.0031	1.0149	11.54	0.0142	0.0241	48.78	36.21
8	1.0165	0.0031	1.0134	11.94	0.0142	0.0173	43.87	32.56
15	1.0150	0.0031	1.0119	12.33	0.0142	0.0129	38.96	28.92
30	1.0137	0.0031	1.0106	12.68	0.0142	0.0092	34.70	25.76
60	1.0120	0.0031	1.0089	13.13	0.0142	0.0066	29.14	21.63
120	1.0095	0.0031	1.0064	13.79	0.0142	0.0048	20.95	15.55
240	1.0075	0.0031	1.0044	14.32	0.0142	0.0035	14.41	10.69
3600	1.0065	0.0031	1.0034	14.58	0.0142	0.0009	11.13	8.26

TP-D2



Grain Size Boundary According *to* ***ASTM***

FOR SAMPLE E

Sieve opening (mm)	Mass of sieve (g)	Mass of sieve with retained soil (g)	Mass of retained soil (g)	Percentage retained, %	Cumulative percentage retained, %	Cumulative Percentage passing, %
9.5	**454.9**	**457.2**	**2.3**	**0.23**	**0.23**	**99.77**
4.75	429.2	432.5	3.3	**0.66**	**0.89**	**99.11**
2.36	383.3	388.9	5.6	**1.12**	**2.01**	**97.99**
2	377.7	382.5	4.8	**0.96**	**2.97**	**97.03**
1.18	370.9	377.4	6.5	**1.3**	**4.27**	**95.73**
0.6	323.5	336.5	13	**2.6**	**6.87**	**93.13**
0.425	292.2	341.3	49.1	**9.82**	**16.69**	**83.31**
0.3	304.2	420.59	116.39	**23.278**	**39.968**	**60.032**
0.15	270.2	430.4	160.2	**32.04**	**72.008**	**27.992**
0.075	273.3	324.2	50.9	**10.18**	**82.188**	**17.812**
Pan	239.8	327.2	87.4	**17.48**	**99.668**	**0.332**
Total	3264.3	4218.69	499.49	**99.668**		

SAMPLE E
500
ROAD TO BUTAJIRA

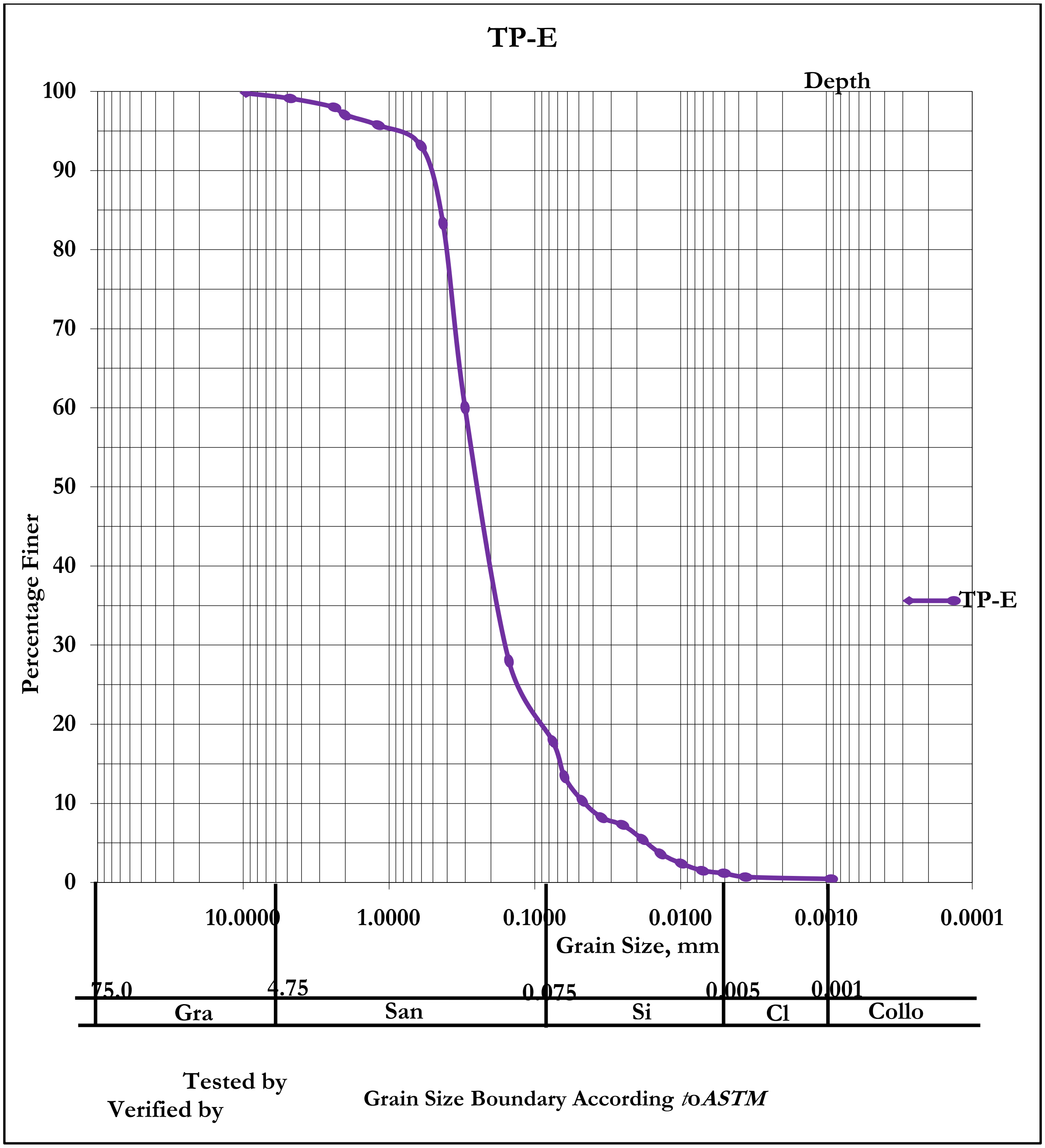
%gravel	0.89
%sand	81.298
%fine	17.812

HYDEROMETER ANAYSIS FOR SAMPLE E

Specific Gravity of soil 2.40

Test Temperature, deg.c 18

Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)	Perc. Finer Combined (%)
0.5	1.0250	0.0031	1.0219	9.69	0.0142	0.0625	75.09	13.37
1	1.0200	0.0031	1.0169	11.01	0.0142	0.0471	57.94	10.32
2	1.0165	0.0031	1.0134	11.94	0.0142	0.0347	45.94	8.18
4	1.0150	0.0031	1.0119	12.33	0.0142	0.0249	40.80	7.27
8	1.0120	0.0031	1.0089	13.13	0.0142	0.0182	30.51	5.44
15	1.0090	0.0031	1.0059	13.92	0.0142	0.0137	20.23	3.60
30	1.0070	0.0031	1.0039	14.45	0.0142	0.0099	13.37	2.38
60	1.0055	0.0031	1.0024	14.85	0.0142	0.0071	8.23	1.47
120	1.0050	0.0031	1.0019	14.98	0.0142	0.0050	6.51	1.16
240	1.0042	0.0031	1.0011	15.19	0.0142	0.0036	3.77	0.67
3600	1.0038	0.0031	1.0007	15.29	0.0142	0.0009	2.40	0.43


TP-E
Depth
100
90
80
70
60
50
40
30
20
10
0
Percentage Finer
TP-E
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Grain Size, mm
75.0
4.75
0.075
0.005
0.001
Gra
San
Si
Cl
Collo
Tested by
Verified by
Grain Size Boundary According *to* ***ASTM***

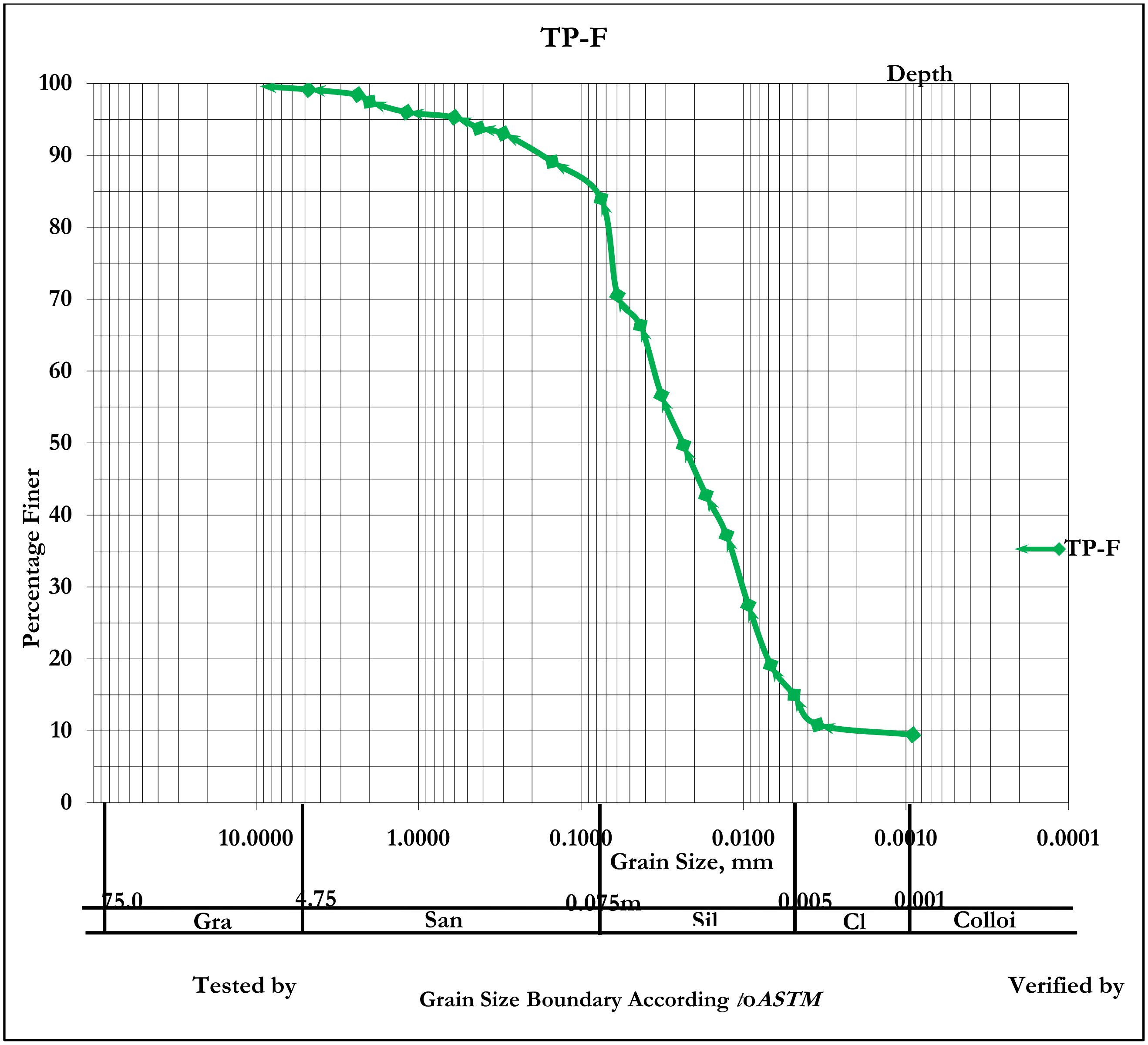
FOR SAMPLE F

Sieve opening (mm)	Mass of sieve (g)	Mass of sieve with retained soil (g)	Mass of retained soil (g)	Percentage retained, %	Cumulative percentage retained, %	Cumulative Percentage passing, %
9.5	454.9	456.8	1.9	0.38	0.38	99.62
4.75	429.3	431.6	2.3	0.46	0.84	99.16
2.36	383.1	386.7	3.6	0.72	1.56	98.44
2	377.7	382.6	4.9	0.98	2.54	97.46
1.18	370.9	378.2	7.3	1.46	4	96
0.6	325.6	329.1	3.5	0.7	4.7	95.3
0.425	292.2	299.8	7.6	1.52	6.22	93.78
0.3	304.2	307.9	3.7	0.74	6.96	93.04
0.15	270	289.6	19.6	3.92	10.88	89.12
0.075	273.3	298.9	25.6	5.12	16	84
Pan	417.6	836.9	419.3	83.86	99.86	0.14
Total	3898.8	4398.1	499.3	99.86		

Sample F
St.George compound
500

%gravel	0.84
%sand	15.16
%fine	84

Hydrometer Analysis for F								
Specific Gravity of soil		2.53			Test Temperature, deg.c		18.5	
Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)	Perc. Finer Combined (%)
0.5	1.0285	0.0031	1.0254	8.76	0.0142	0.0594	84.00	70.56
1	1.0270	0.0031	1.0239	9.16	0.0142	0.0430	79.04	66.40
2	1.0235	0.0031	1.0204	10.08	0.0142	0.0319	67.47	56.67
4	1.0210	0.0031	1.0179	10.75	0.0142	0.0233	59.20	49.73
8	1.0185	0.0031	1.0154	11.41	0.0142	0.0170	50.93	42.78
15	1.0165	0.0031	1.0134	11.94	0.0142	0.0127	44.32	37.23
30	1.0130	0.0031	1.0099	12.86	0.0142	0.0093	32.74	27.50
60	1.0100	0.0031	1.0069	13.65	0.0142	0.0068	22.82	19.17
120	1.0085	0.0031	1.0054	14.05	0.0142	0.0049	17.86	15.00
240	1.0070	0.0031	1.0039	14.45	0.0142	0.0035	12.90	10.83
3600	1.0065	0.0031	1.0034	14.58	0.0142	0.0009	11.24	9.45



TP-F
Depth
Percentage Finer
100
90
80
70
60
50
40
30
20
10
0
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Grain Size, mm
TP-F
75.0
4.75
0.075m
0.005
0.001
Gra
San
Sil
Cl
Colloi
Tested by
Grain Size Boundary According toASTM
Verified by

FOR SAMPLE G

Sieve opening (mm)	Mass of sieve (g)	Mass of sieve with retained soil (g)	Mass of retained soil (g)	Percentage retained, %	Cumulative percentage retained, %	comulativePercentage passing, %
9.5	**454.9**	**457.6**	**2.7**	**0.54**	**0.54**	**99.46**
4.75	429.3	434.6	**5.3**	**1.06**	**1.6**	**98.4**
2.36	383.4	406.5	**23.1**	**4.62**	**6.22**	**93.78**
2	377.5	392.4	**14.9**	**2.98**	**9.2**	**90.8**
1.18	370.8	386	**15.2**	**3.04**	**12.24**	**87.76**
0.6	325.6	349.4	**23.8**	**4.76**	**17**	**83**
0.425	291.8	317.3	**25.5**	**5.1**	**22.1**	**77.9**
0.3	304.2	342.7	**38.5**	**7.7**	**29.8**	**70.2**
0.15	270	343.1	**73.1**	**14.62**	**44.42**	**55.58**
0.075	273.3	324.6	**51.3**	**10.26**	**54.68**	**45.32**
Pan	417.6	643.5	**225.9**	**45.18**	**99.86**	**0.14**
Total	3898.4	4397.7	499.3	**99.86**		

Sample G
infront of bethelehem hotel

500

46

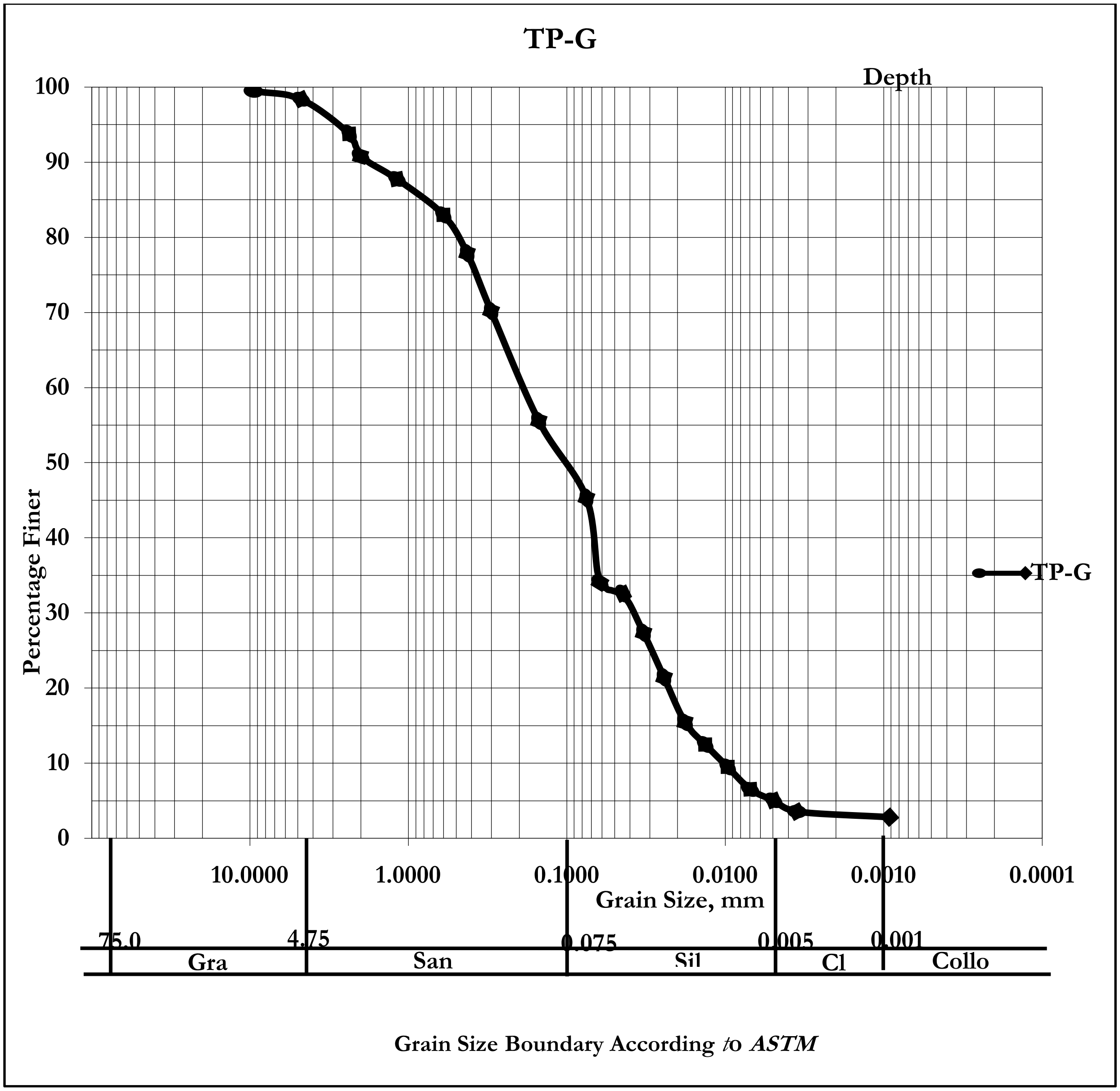
454

%gravel	1.6
%sand	53.08
%fine	45.32

Hydrometer Analysis for G

Specific Gravity of soil 2.56
Test Temperature, deg. c 18

Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)	Perc. Finer Combined (%)
0.5	1.0260	0.0031	1.0229	9.42	0.0142	0.0616	75.16	34.06
1	1.0250	0.0031	1.0219	9.69	0.0142	0.0442	71.88	32.57
2	1.0215	0.0031	1.0184	10.61	0.0142	0.0327	60.39	27.37
4	1.0175	0.0031	1.0144	11.67	0.0142	0.0243	47.26	21.42
8	1.0135	0.0031	1.0104	12.73	0.0142	0.0179	34.13	15.47
15	1.0115	0.0031	1.0084	13.26	0.0142	0.0134	27.57	12.49
30	1.0095	0.0031	1.0064	13.79	0.0142	0.0096	21.01	9.52
60	1.0075	0.0031	1.0044	14.32	0.0142	0.0069	14.44	6.54
120	1.0065	0.0031	1.0034	14.58	0.0142	0.0049	11.16	5.06
240	1.0055	0.0031	1.0024	14.85	0.0142	0.0035	7.88	3.57
3600	1.0050	0.0031	1.0019	14.98	0.0142	0.0009	6.24	2.83


TP-G
Depth
100
90
80
70
60
50
40
30
20
10
0
Percentage Finer
TP-G
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Grain Size, mm
75.0
4.75
0.075
0.005
0.001
Gra
San
Sil
Cl
Collo
Grain Size Boundary According to ASTM

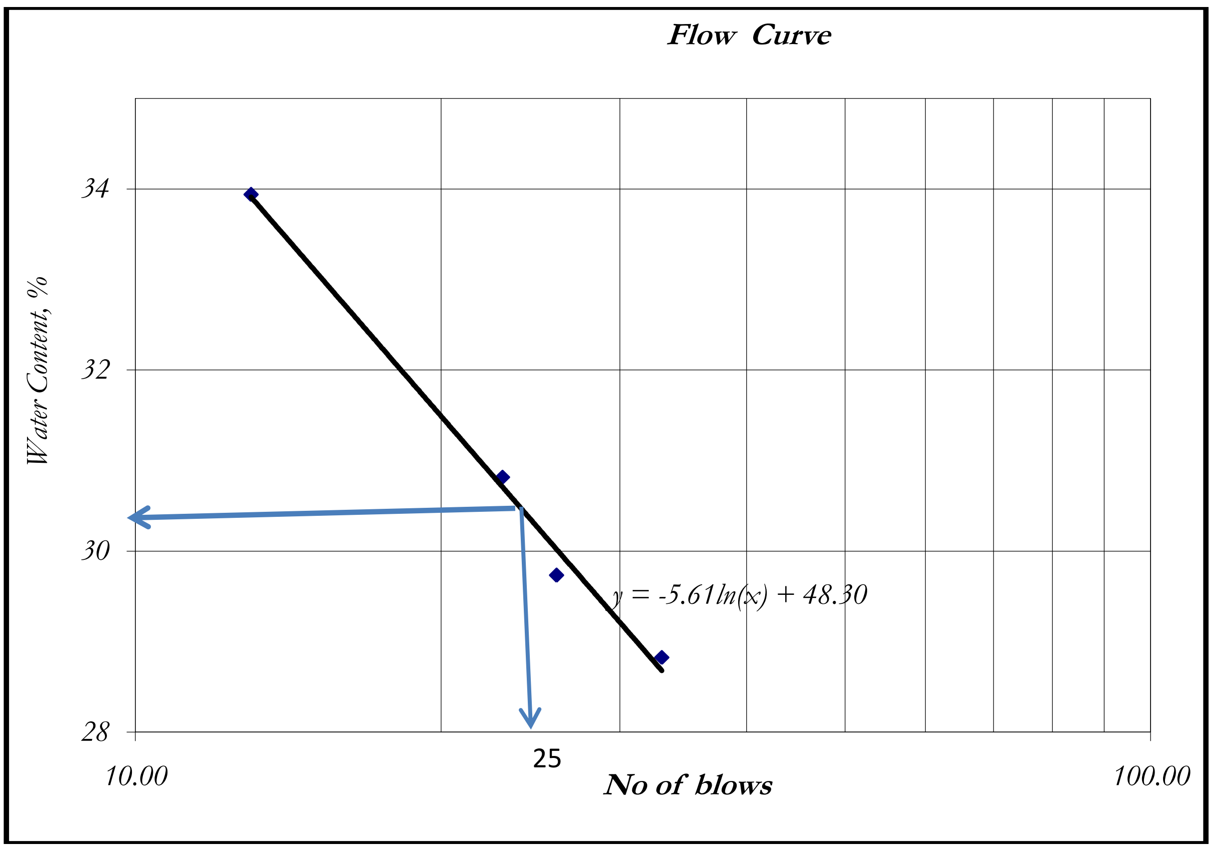
Appendix – D

(Liquid limit results)

Test Pit No: **C(SHARE AREA)**
Depth = **UPTO-3M**

	Liquid Limit				Plastic Limit	
Trial No	1	2	3	4	1	
Container No	R1	C1	Z1	B1	H4	
Mass of container, g	21.50	22.10	22.20	21.90	21.50	
Mass of container + Wet soil, g	65.70	63.70	61.25	58.10	34.30	
Mass of container + Dry soil, g	54.50	53.90	52.3	50.00	31.60	
Mass of water, g	11.20	9.80	8.95	8.10	2.70	
Mass of dry soil, g	33.00	31.80	30.10	28.10	10.10	
NO OF BLOW	13.00	23.00	26.00	33.00		
Water content, %	33.93939	30.81761	29.73422	28.82562	26.73267	

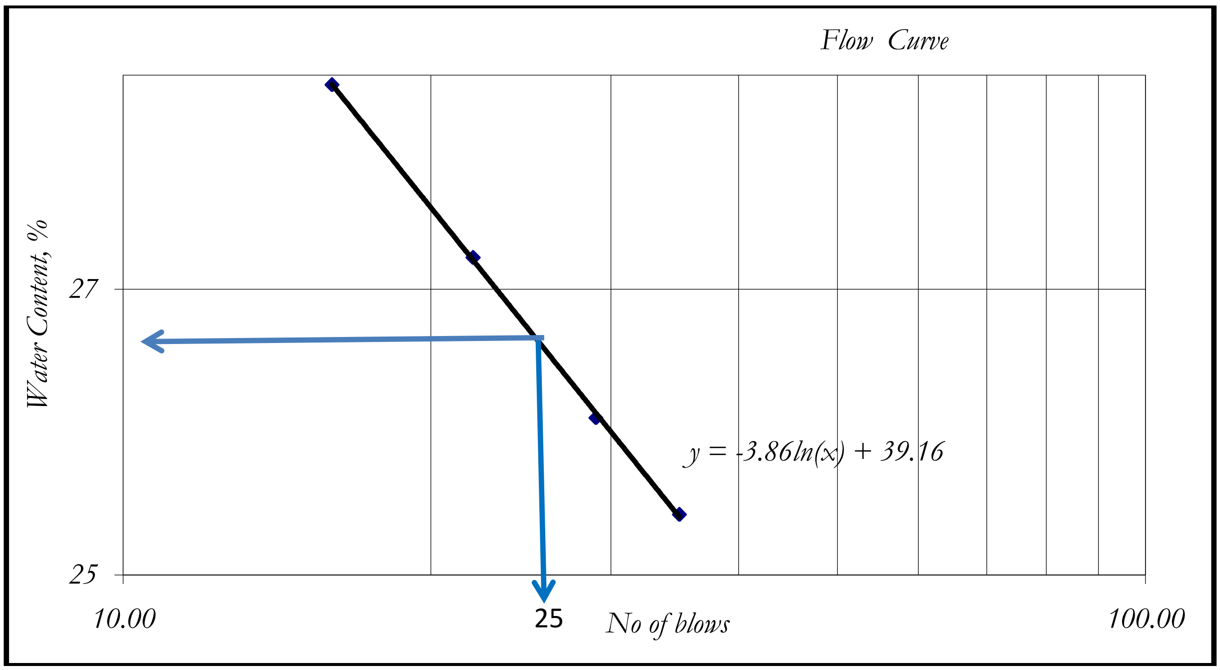
Liquid Limit, % = 31 **Plastic Limit, % 27** **PI, %= 4**



Test Pit No: D1(FEDERAL PRISON AREA)
Depth = UPTO-3M

	Liquid Limit				Plastic Limit	
Trial No	1	2	3	4	1	2
Container No	E2	C1	H5	R3	C6	74
Mass of container, g	22.00	21.90	22.30	22.10	22.30	22.10
Mass of container + Wet soil, g	48.20	44.80	44.50	42.15	34.90	38.20
Mass of container + Dry soil, g	42.40	39.90	40	38.00	32.60	35.2
Mass of water, g	5.80	4.90	4.50	4.15	2.30	3.00
Mass of dry soil, g	20.40	18.00	17.70	15.90	10.30	13.10
NO OF BLOW	16.00	22.00	35.00	29.00		
Water content, %	28.43137	27.22222	25.42373	26.10063	22.3301	22.90076

Liquid Limit, % = 27 **Plastic Limit, % 23** **PI, %= 4**

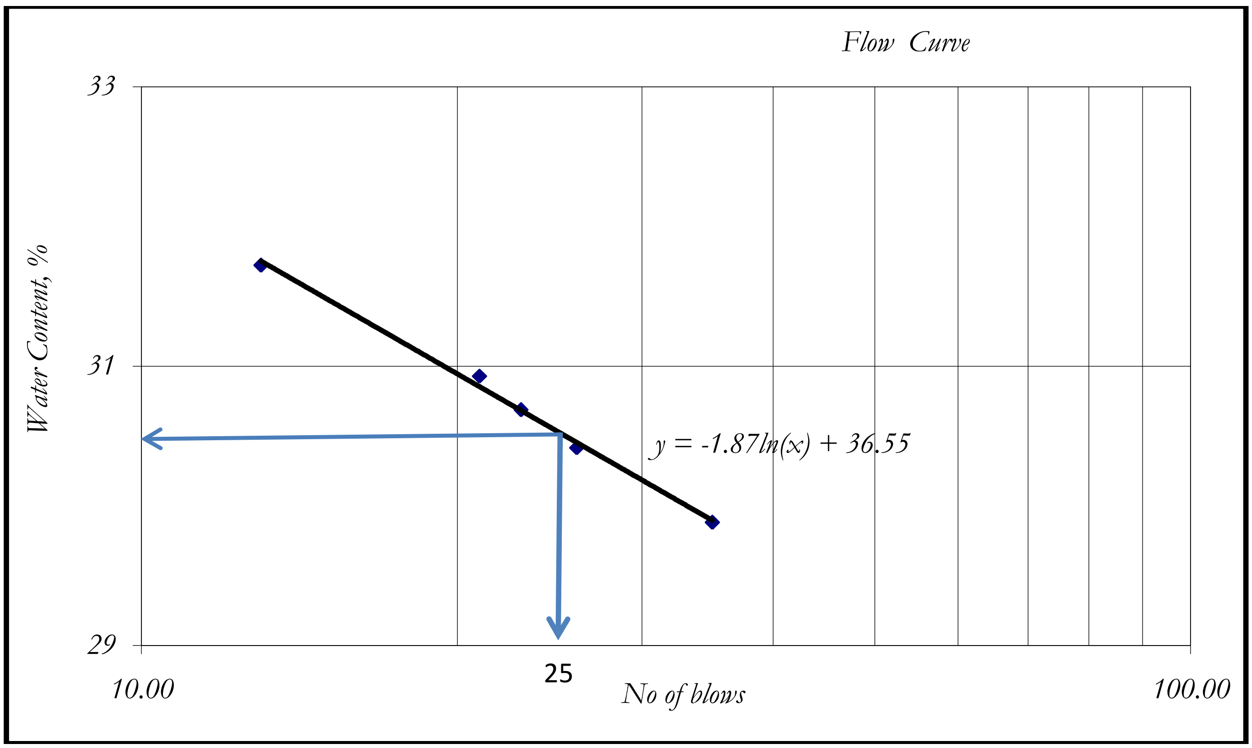


Test Pit No: D2(FEDERAL PRISON AREA) at

Depth = 2m

	Liquid Limit					Plastic Limit	
Trial No	1	2	3	4	5	1	2
Container No	E2	C1	R3	H5	74	C6	74
Mass of container, g	22.10	21.90	22.20	22.00	22.20	22.30	22.10
Mass of container + Wet soil, g	46.60	47.30	52.65	50.30	54.80	35.30	38.40
Mass of container + Dry soil, g	40.70	41.30	45.5	43.70	47.30	32.60	35.2
Mass of water, g	5.90	6.00	7.15	6.60	7.50	2.70	3.20
Mass of dry soil, g	18.60	19.40	23.30	21.70	25.10	10.30	13.10
NO OF BLOW	13.00	21.00	23.00	26.00	35.00		
Water content, %	31.72043	30.92784	30.6867	30.41475	29.88048	26.21359	24.42748

Liquid Limit, % = 31 **Plastic Limit, % 25** **PI, %= 6**

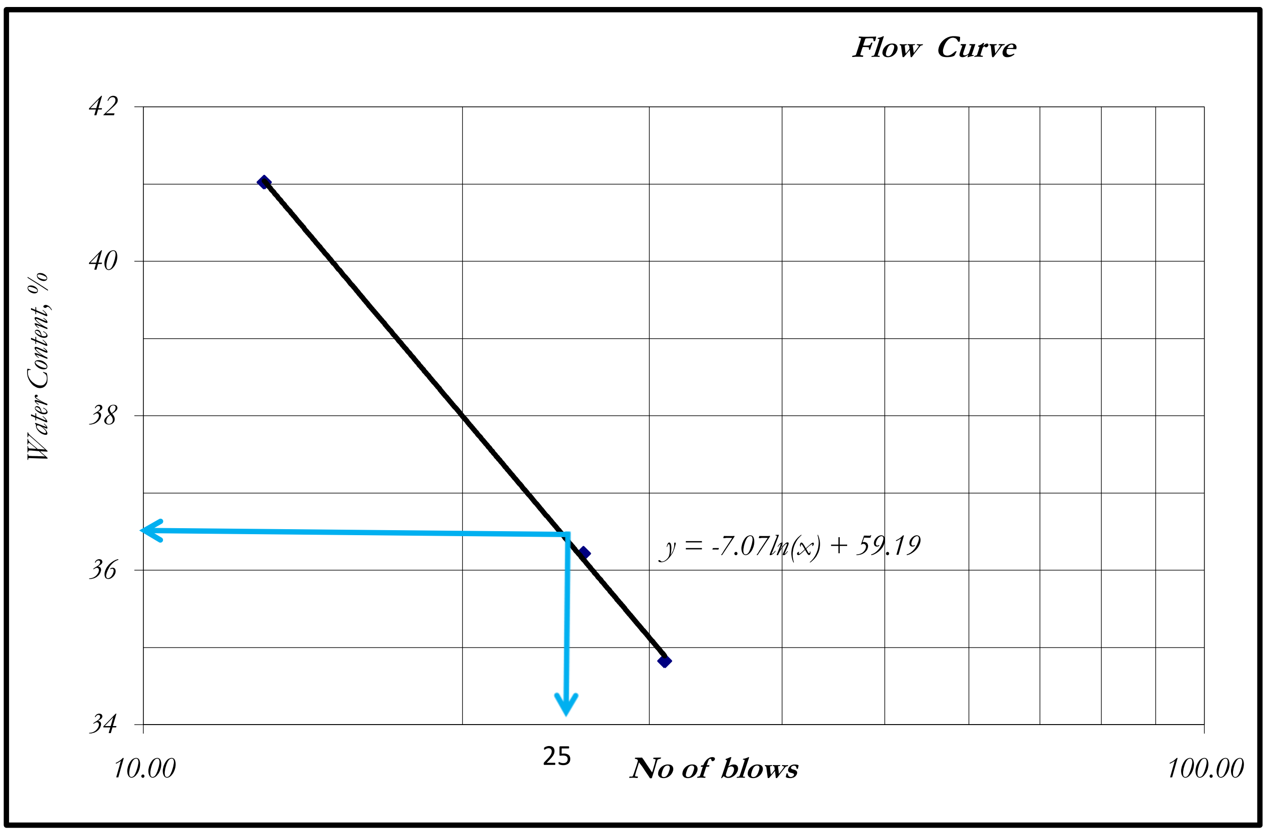


Test Pit No: TP6F(St. George church compounds)

Depth = at-3m

	Liquid Limit			Plastic Limit
Trial No	1	2	3	2
Container No	B1	G1	G2	94
Mass of container, g	22.00	21.80	22.10	22.20
Mass of container + Wet soil, g	44.00	47.00	49.20	29.85
Mass of container + Dry soil, g	37.60	40.30	42.2	28.13
Mass of water, g	6.40	6.70	7.00	1.72
Mass of dry soil, g	15.60	18.50	20.10	5.93
NO OF BLOW	13.00	26.00	31.00	
Water content, %	41.02564	36.21622	34.82587	29.00505902

Liquid Limit, % = 37   Plastic Limit, % 29   PI, %= 8



Appendix – E

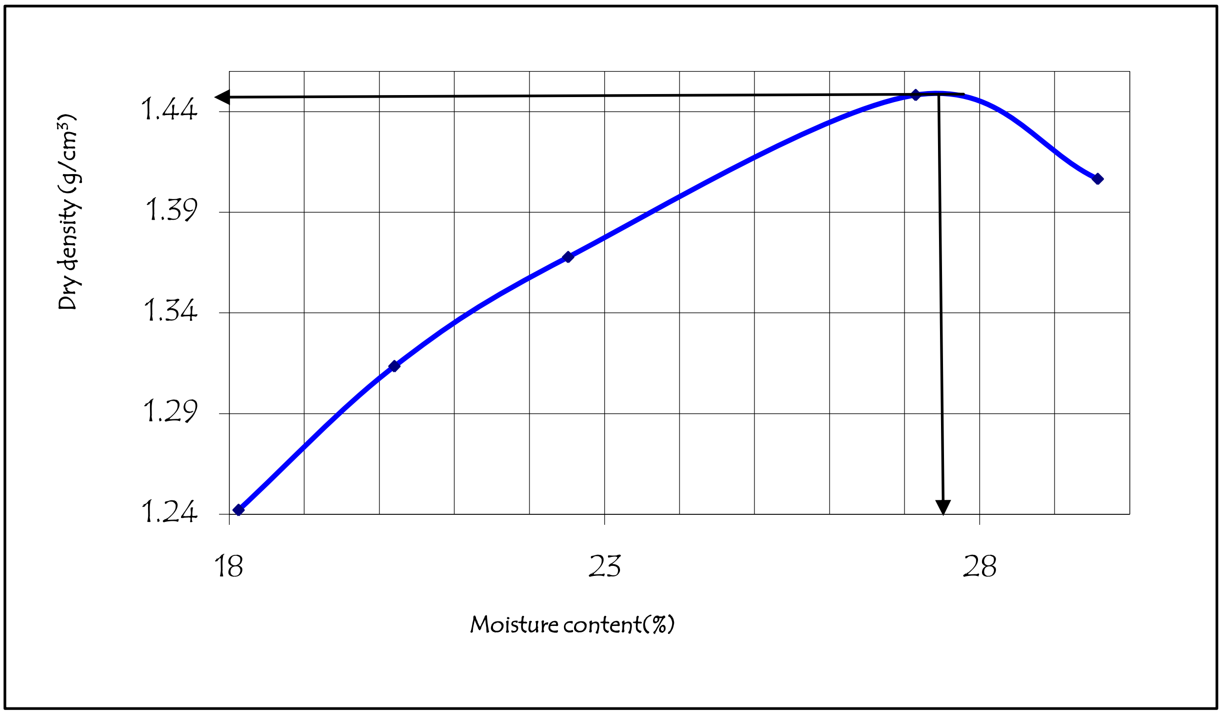
(Compaction test result)

Sample Pit No TP1A **Sample Depth, 3m :**

Moisture content Vs dry density comp. table

Determination No.	1	2	3	4	5
Mass of Mold, g	6308	6308	6308	6308	6308
Mass of mold+ Compacted Soil, g	7693	7800	7890	8050	8034
Mass of Compacted soil, g	1385	1492	1582	1742	1726
Volume of Mold,cm3	944	945	944	946	947
Bulk density, g/cm3	1.47	1.58	1.68	1.84	1.82
Water Contenet, %	18.12	20.20	22.52	27.15	29.57
Dry density, g/cm3	1.24	1.31	1.37	1.45	1.41

Max.dry dernsity,(mdd) = 1.46 Opt. moisture content, %(omc)=27.2



Water Content

Conatainer No	49	B2	42		
Mass of container, g	22.2	21.9	22.2	21.9	20.8
Mass of container + wet soil, g	95.2	70.1	80.15	94.5	69
Mass of ontainer + Dry soil, g	84	62	69.5	79	58
Mass of Water, g	11.2	8.1	10.65	15.5	11
Mass of Dry soil, g	61.8	40.1	47.3	57.1	37.2
Water content, %	18.12	20.20	22.52	27.15	29.57
Dry Unit Weight, g/cm3	1.24	1.31	1.37	1.45	1.41

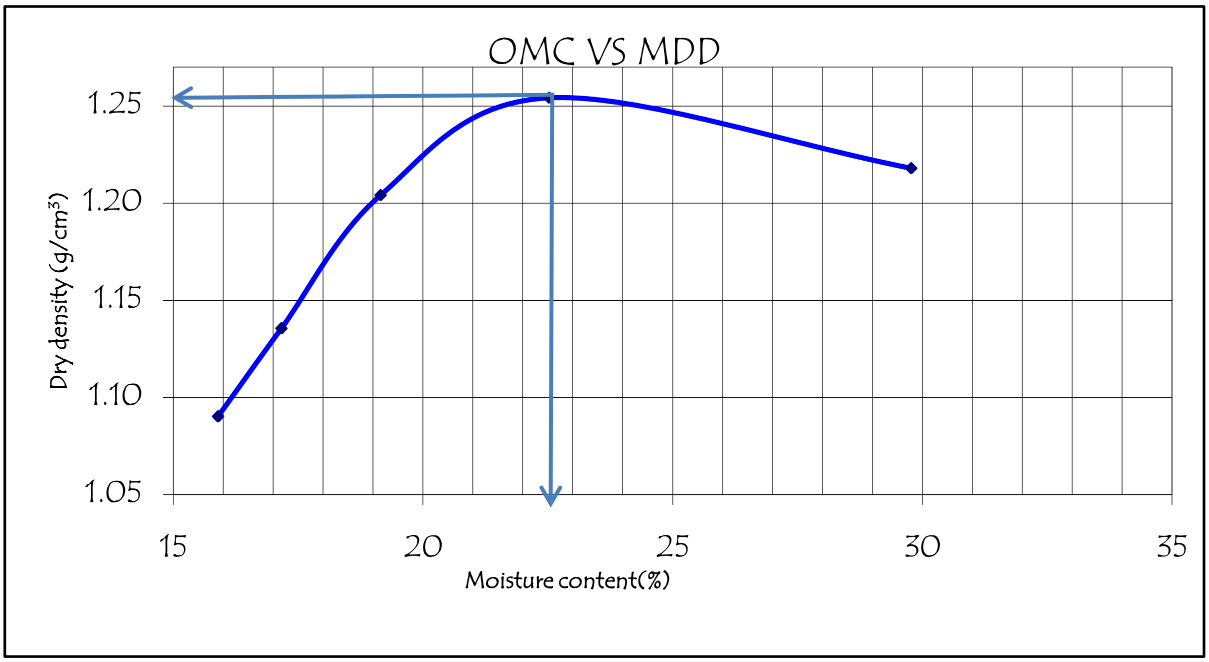
Sample Pit No TP2B **Sample Depth, 3m :**

Moisture content Vs dry density comp. table

Determination No.	1	2	3	4	5
Mass of Mold, g	4400	4400	4400	4400	4400
Mass of mold+ Compacted Soil, g	5551	5612	5707	5800	5840
Mass of Compacted soil, g	1151	1212	1307	1400	1440
Volume of Mold,cm3	911	911	911	911	911
Bulk density, g/cm3	1.26	1.33	1.43	1.54	1.58
Water Contenet, %	15.89	17.16	19.63	22.53	29.78
Dry density, g/cm3	1.09	1.14	1.20	1.25	1.22

Max.dry dernsity,(mdd) = 1.25

Opt. moisture content, %(omc)=22.6



Water Content

Conatainer No	49	B2	42	N2	B
Mass of container, g	22.1	22.2	22.3	22.3	22.2
Mass of container + wet soil, g	69.5	57.7	60.7	93	91.5
Mass of ontainer + Dry soil, g	63	52.5	54.4	80	75.6
Mass of Water, g	6.5	5.2	6.3	13	15.9
Mass of Dry soil, g	40.9	30.3	32.1	57.7	53.4
Water content, %	15.89	17.16	19.63	22.53	29.78
Dry Unit Weight, g/cm3	1.09	1.14	1.20	1.25	1.22

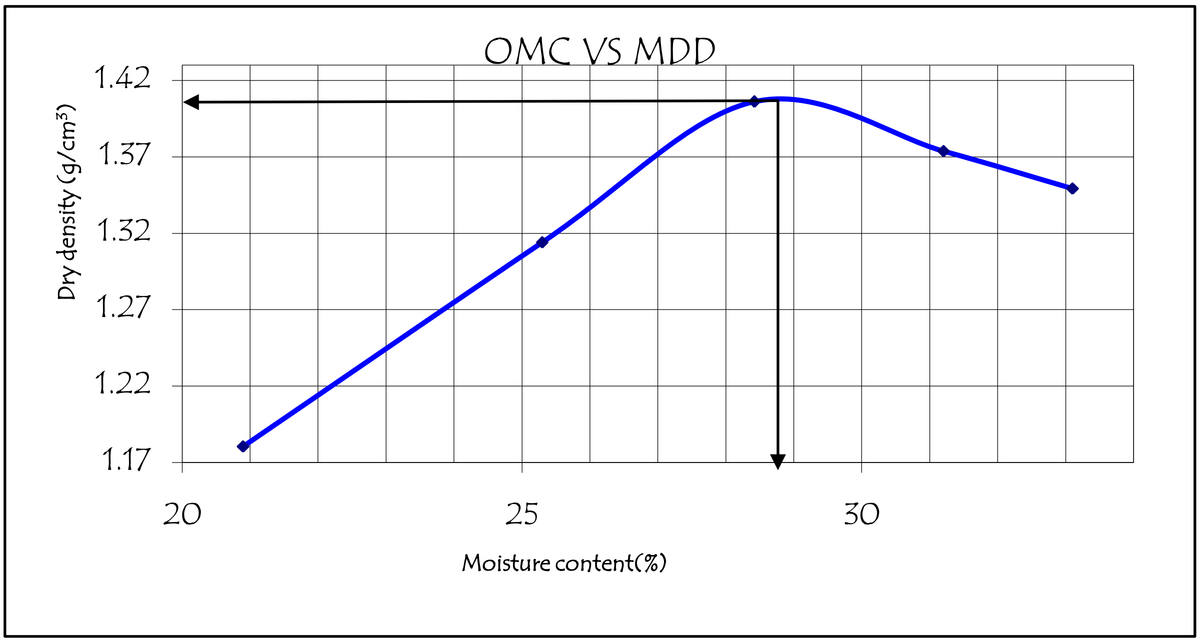
Sample Pit No TP3C **Sample Depth, 3m :**

Moisture content Vs dry density comp. table

Determination No.	1	1	3	4	5
Mass of Mold, g	4400	4400	4400	4400	4400
Mass of mold+ Compacted Soil, g	5700	5900	6045	6042	6036
Mass of Compacted soil, g	1300	1500	1645	1642	1636
Volume of Mold,cm3	911	911	911	911	911
Bulk density, g/cm3	1.43	1.65	1.81	1.80	1.80
Water Contenet, %	20.90	25.30	28.42	31.20	33.10
Dry density, g/cm3	1.18	1.31	1.41	1.37	1.35

Max.dry dernsity,(mdd) = 1.41

Opt. moisture content, %(omc)=28.5



Water Content

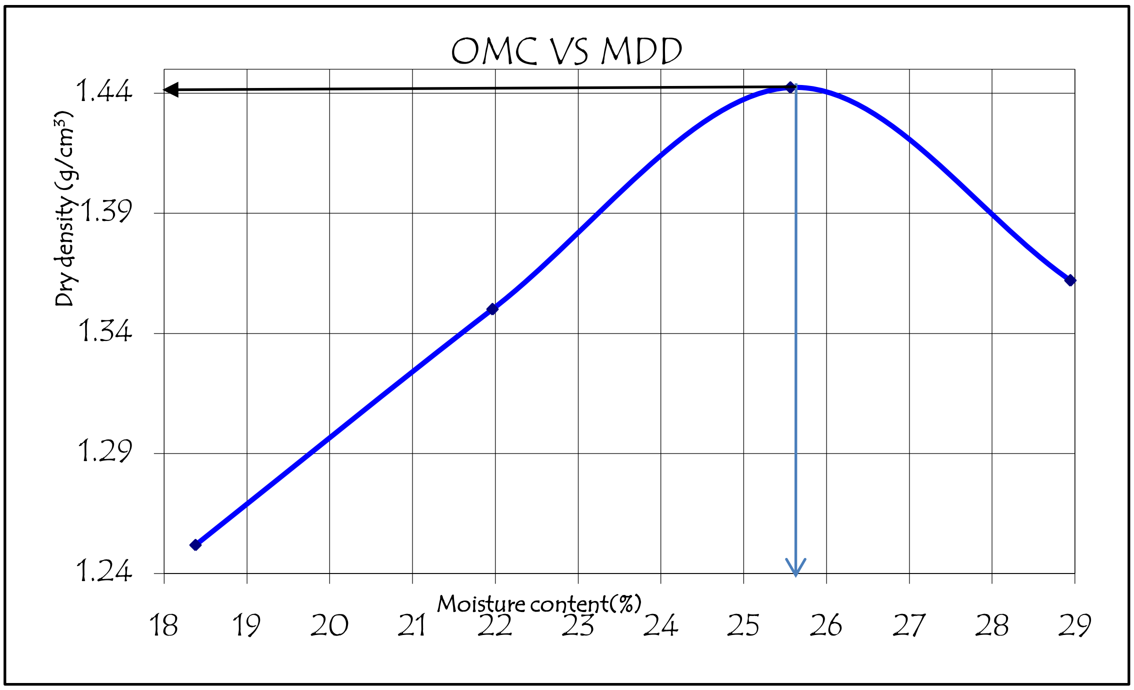
Conatainer No	77	49	42	D1	G12
Mass of container, g	21.5	22.1	22.2	22.2	21.9
Mass of container + wet soil, g	62	85.5	105.8	92	118
Mass of ontainer + Dry soil, g	55	72.7	87.3	75.4	94.1
Mass of Water, g	7	12.8	18.5	16.6	23.9
Mass of Dry soil, g	33.5	50.6	65.1	53.2	72.2
Water content, %	20.90	25.30	28.42	31.20	33.10
Dry Unit Weight, g/cm3	1.18	1.31	1.41	1.37	1.35

Sample Pit No TP4D2   Sample Depth, 2m :

Moisture content Vs dry density comp. table

Determination No.	*1*	*3*	4	5
Mass of Mold, g	*4400*	*4400*	*4400*	*4400*
Mass of mold+ Compacted Soil, g	*5750*	*5900*	6050	6000
Mass of Compacted soil, g	*1350*	*1500*	*1650*	*1600*
Volume of Mold,cm3	*911*	*911*	*911*	*911*
Bulk density, g/cm3	*1.48*	*1.65*	*1.81*	*1.76*
Water Contenet, %	*18.38*	*21.97*	*25.56*	*28.95*
Dry density, g/cm3	*1.25*	*1.35*	*1.44*	*1.36*

Max.dry dernsity,(mdd) = 1.44   Opt. moisture content, %(omc)=25.6



Water Content

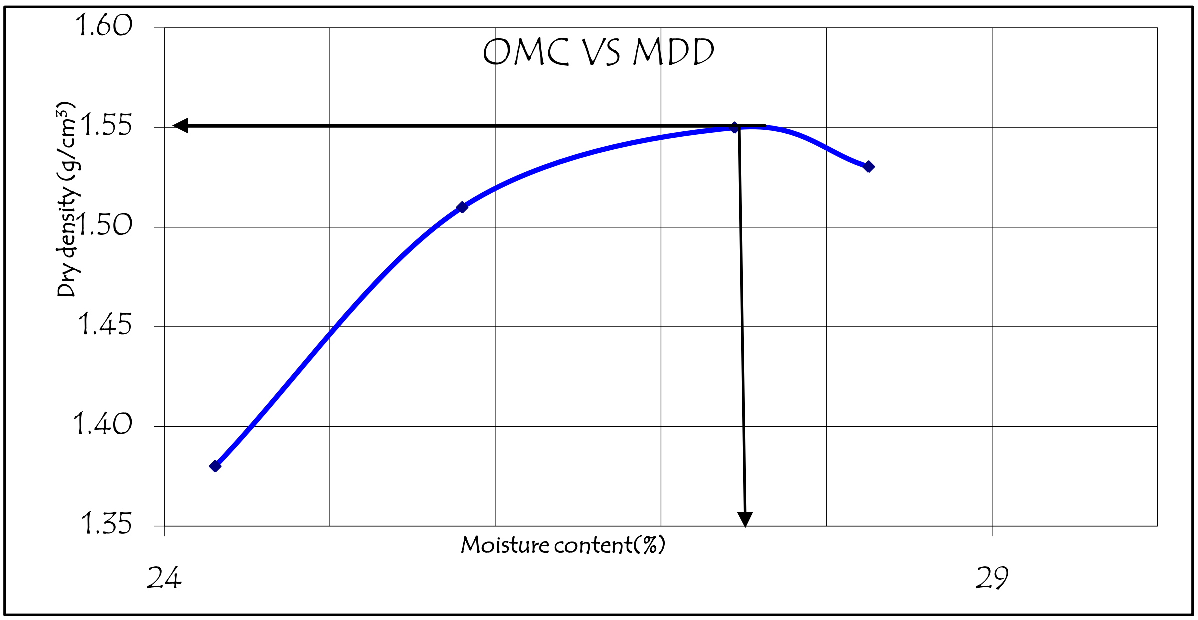
Conatainer No	49	42	12	3
Mass of container, g	22.1	22.2	22.2	21.9
Mass of container + wet soil, g	82	101.6	89	115
Mass of ontainer + Dry soil, g	72.7	87.3	75.4	94.1
Mass of Water, g	9.3	14.3	13.6	20.9
Mass of Dry soil, g	50.6	65.1	53.2	72.2
Water content, %	18.38	21.97	25.56	28.95
Dry Unit Weight, g/cm3	1.25	1.35	1.44	1.36

Sample Pit No TP4D1 **Sample Depth, 3m :**

Moisture content Vs dry density comp. table

Determination No.	*1*	*3*	4	5
Mass of Mold, g	*4400*	*4400*	*4400*	*4400*
Mass of mold+ Compacted Soil, g	*5975*	*6140*	6202	6188
Mass of Compacted soil, g	*1575*	*1740*	*1802*	*1788*
Volume of Mold,cm3	*911*	*911*	*911*	*911*
Bulk density, g/cm3	*1.73*	*1.91*	*1.98*	*1.96*
Water Contenet, %	*24.31*	*25.8*	*27.44*	*28.25*
Dry density, g/cm3	*1.38*	*1.51*	*1.55*	*1.53*

Max.dry dernsity,(mdd) = 1.55 Opt. moisture content, %(omc)=27.5



Water Content

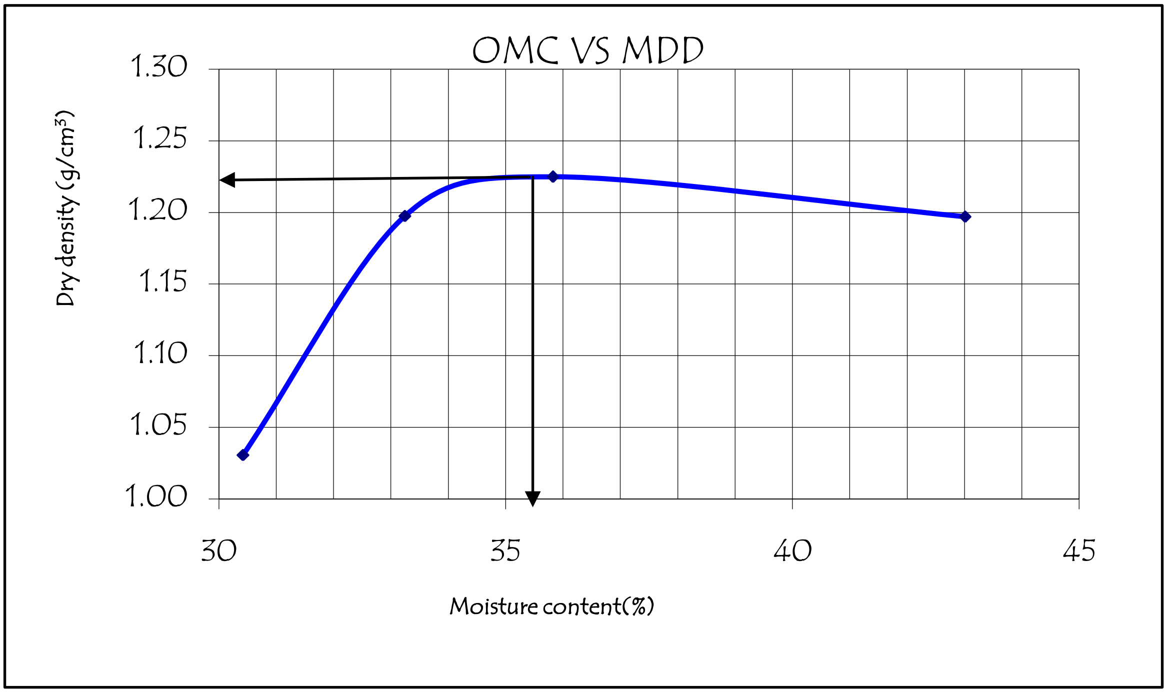
Conatainer No		49	42		
Mass of container, g		22.1	22.2	22.2	21.9
Mass of container + wet soil, g		85	103.7	90	114.5
Mass of ontainer + Dry soil, g		72.7	87.3	75.4	94.1
Mass of Water, g		12.3	16.4	14.6	20.4
Mass of Dry soil, g		50.6	65.1	53.2	72.2
Water content, %		24.31	25.19	27.44	28.25
Dry Unit Weight, g/cm3		1.39	1.53	1.55	1.53

Sample Pit No TP5E **Sample Depth, 3m :**

Moisture content Vs dry density comp. table

Determination No.	4	5	6	7
Mass of Mold, g	4508.9	4508.8	4509.6	4509.1
Mass of mold+ Compacted Soil, g	5777.8	6015	6080	6125
Mass of Compacted soil, g	1268.9	1506.2	1570.4	1615.9
Volume of Mold,cm3	944	944	944	944
Bulk density, g/cm3	1.34	1.60	1.66	1.71
Water Contenet, %	30.42	33.24	35.83	43.01
Dry density, g/cm3	1.03	1.20	1.22	1.20

Max.dry dernsity,(mdd) = 1.22 Opt. moisture content, %(omc)=35.83



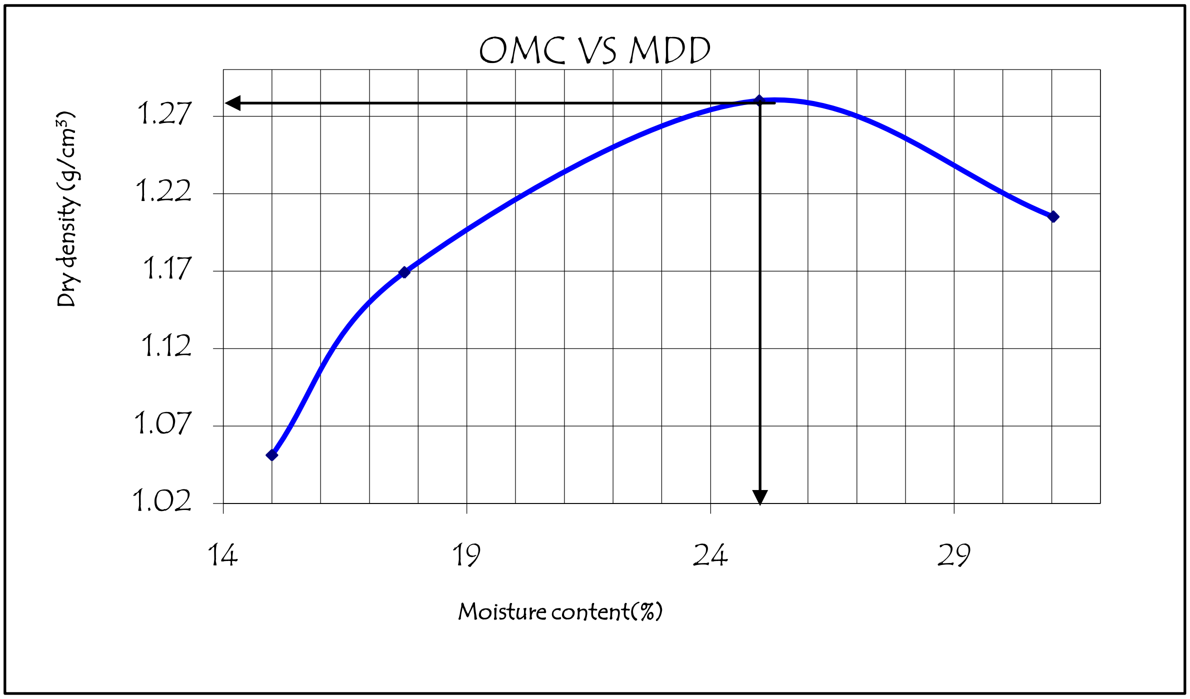
Water Content	A2	C1	N2	B2
Conatainer No	N2	C1	A1	B
Mass of container, g	22.2	22.2	21.9	22.1
Mass of container + wet soil, g	59.5	71.5	65.5	62
Mass of ontainer + Dry soil, g	50.8	59.2	54	50
Mass of Water, g	8.7	12.3	11.5	12
Mass of Dry soil, g	28.6	37	32.1	27.9
Water content, %	30.42	33.24	35.83	43.01
Dry Unit Weight, g/cm3	1.03	1.20	1.22	1.20

Sample Pit No TP6F Sample Depth, 3m :

Moisture content Vs dry density comp. table

Determination No.	H3	J8	M3	F3
Mass of Mold, g	4509.2	4509.5	4509.5	4509.5
Mass of mold+ Compacted Soil, g	5650.3	5808.6	6020	6000
Mass of Compacted soil, g	1141.1	1299.1	1510.5	1490.5
Volume of Mold,cm3	944	944	944	944
Bulk density, g/cm3	1.21	1.38	1.60	1.58
Water Contenet, %	15.00	17.72	25.00	31.03
Dry density, g/cm3	1.05	1.17	1.28	1.20

Max.dry dernsity,(mdd) = 1.28 Opt. moisture content, %(omc)=25



Water Content

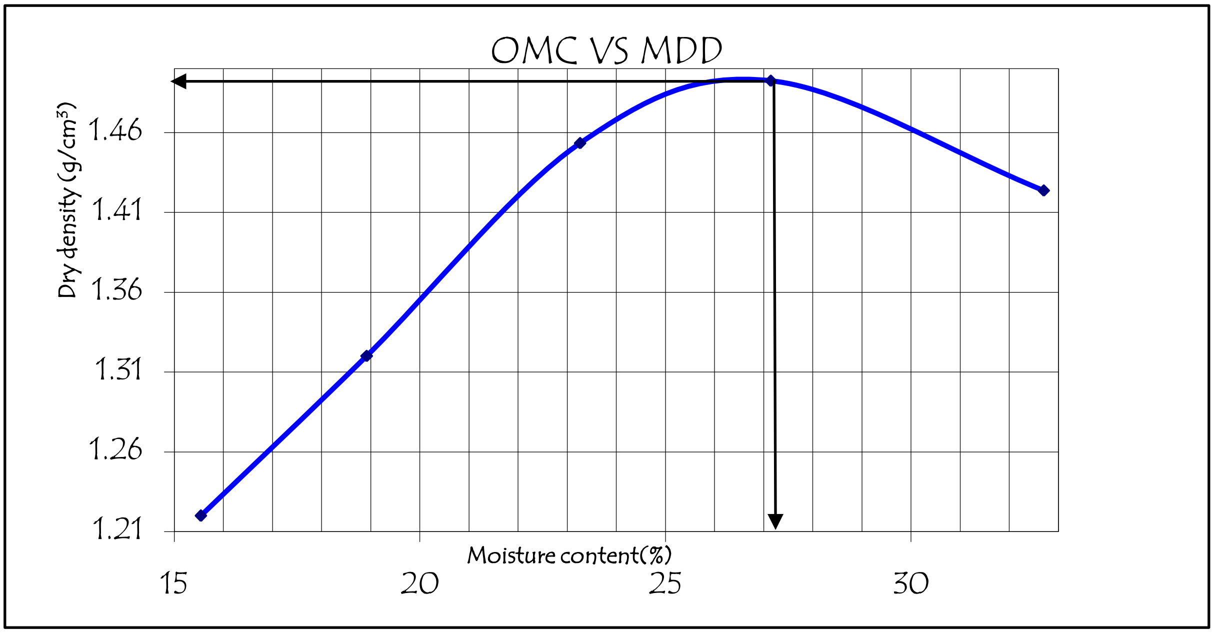
Conatainer No	49	B2	N2	B3
Mass of container, g	22	22.1	22	22
Mass of container + wet soil, g	45	52	44.5	60
Mass of ontainer + Dry soil, g	42	47.5	40	51
Mass of Water, g	3	4.5	4.5	9
Mass of Dry soil, g	20	25.4	18	29
Water content, %	15.00	17.72	25.00	31.03
Dry Unit Weight, g/cm3	1.05	1.17	1.28	1.20

Sample Pit No TP7G **Sample Depth, 3m :**

Moisture content Vs dry density comp. table

Determination No.	1	2	3	4	5
Mass of Mold, g	4508.5	4508.6	4508.8	4508.7	4509.5
Mass of mold+ Compacted Soil, g	5839	5990.5	6200	6300	6293
Mass of Compacted soil, g	1330.5	1481.9	1691.2	1791.3	1783.5
Volume of Mold,cm3	944	944	944	944	944
Bulk density, g/cm3	1.41	1.57	1.79	1.90	1.89
Water Contenet, %	15.54	18.92	23.26	27.15	32.70
Dry density, g/cm3	1.22	1.32	1.45	1.49	1.42

Max.dry dernsity,(mdd) = 1.49 Opt. moisture content, %(omc)=27.1



Water Content

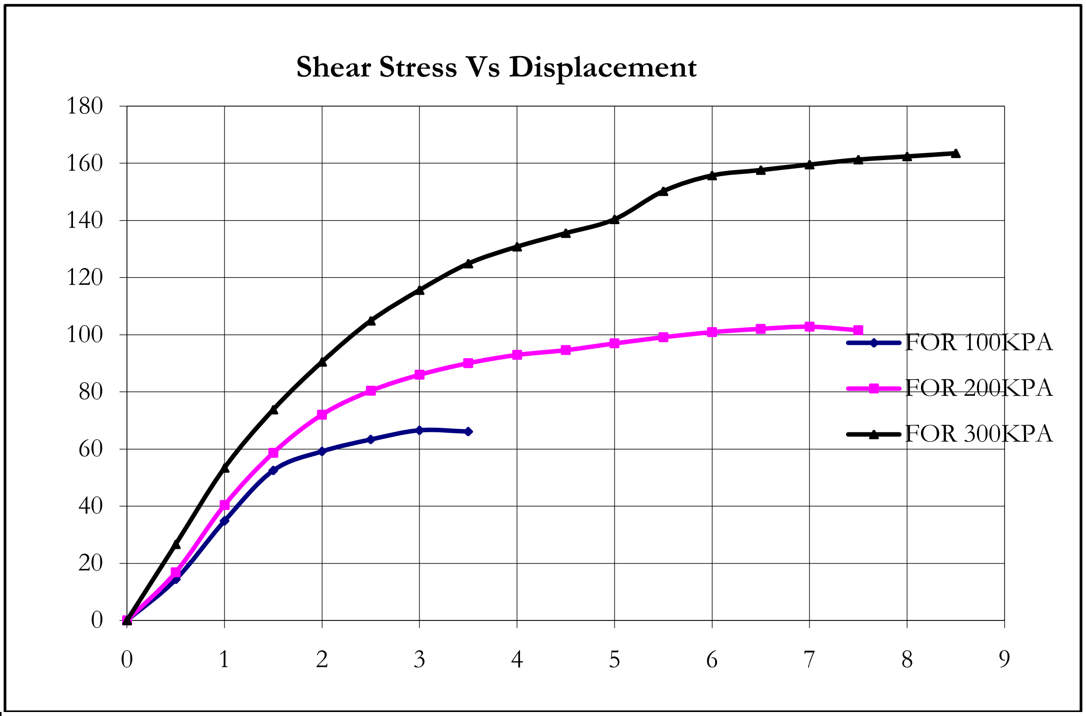
Conatainer No	77	40	49	B2	42
Mass of container, g	22	22.2	21.8	21.4	22
Mass of container + wet soil, g	56.2	57.4	78.5	94	78
Mass of ontainer + Dry soil, g	51.6	51.8	67.8	78.5	64.2
Mass of Water, g	4.6	5.6	10.7	15.5	13.8
Mass of Dry soil, g	29.6	29.6	46	57.1	42.2
Water content, %	15.54	18.92	23.26	27.15	32.70
Dry Unit Weight, g/cm3	1.22	1.32	1.45	1.49	1.42

Appendix – F

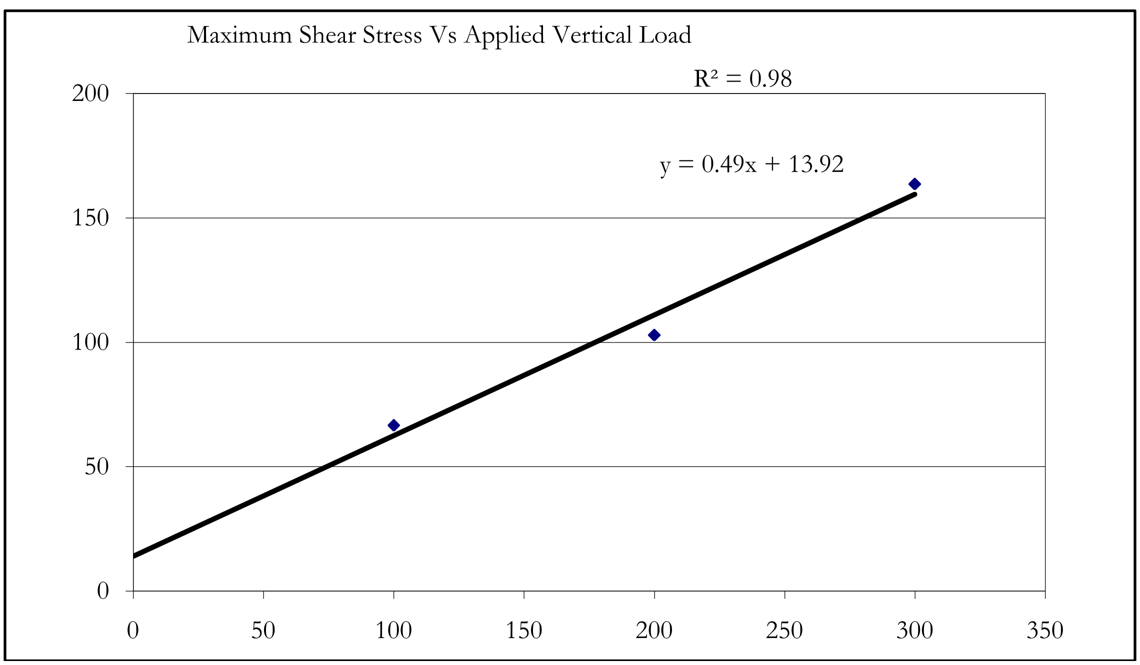
(Direct shear test result)

Sample No.	TP1A(Adamitulu jido)	Sample Source:	Test Pit	Depth, : 3m	
Thickness of sample:	25mm	Ring Calibration Factor:	0.70 N/div		
Length of sample :	60 mm	Rate of strain :	1.6 mm/min		
Width of sample:	60 mm	Sample Condition: Disturbed			

		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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	3570	73.00	51.10	14.31	86.00	60.20	16.86	136.00	95.20	26.67
1.0	3540	176.00	123.20	34.80	204.00	142.80	40.34	270.00	189.00	53.39
1.5	3510	263.00	184.10	52.45	294.00	205.80	58.63	370.00	259.00	73.79
2.0	3480	294.00	205.80	59.14	358.00	250.60	72.01	450.00	315.00	90.52
2.5	3450	312.00	218.40	63.30	396.00	277.20	80.35	517.00	361.90	104.90
3.0	3420	325.00	227.50	66.52	420.00	294.00	85.96	565.00	395.50	115.64
3.5	3390	320.00	224.00	66.08	436.00	305.20	90.03	605.00	423.50	124.93
4.0	3360				446.00	312.20	92.92	628.00	439.60	130.83
4.5	3330				450.00	315.00	94.59	645.00	451.50	135.59
5.0	3300				457.00	319.90	96.94	662.00	463.40	140.42
5.5	3270				463.00	324.10	99.11	702.00	491.40	150.28
6.0	3240				467.00	326.90	100.90	721.00	504.70	155.77
6.5	3210				468.00	327.60	102.06	723.00	506.10	157.66
7.0	3180				467.00	326.90	102.80	725.00	507.50	159.59
7.5	3150				457.00	319.90	101.56	726.00	508.20	161.33
8.0	3120							724.00	506.80	162.44
8.5	3090							722.00	505.40	163.56
		Maximum shear stress, kPa		**66.52**			**102.80**	*Maximum shear stress, kPa*		**163.56**



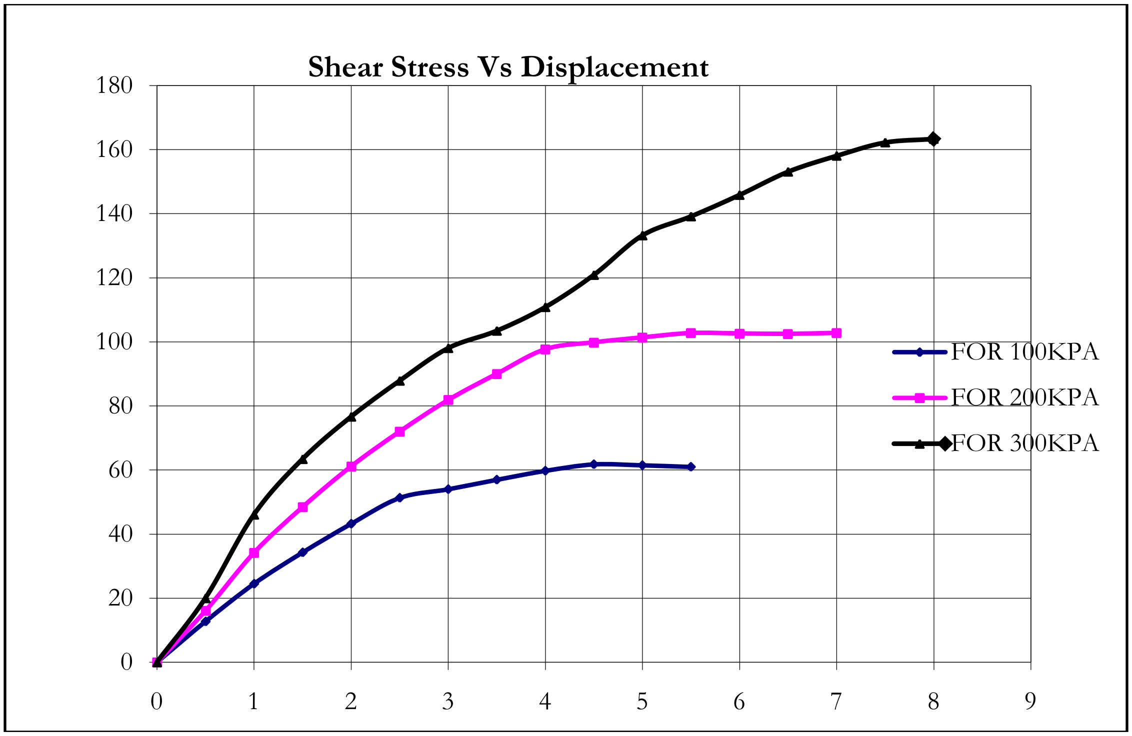
Angle of internal friction, ϕ = **26.1^0**



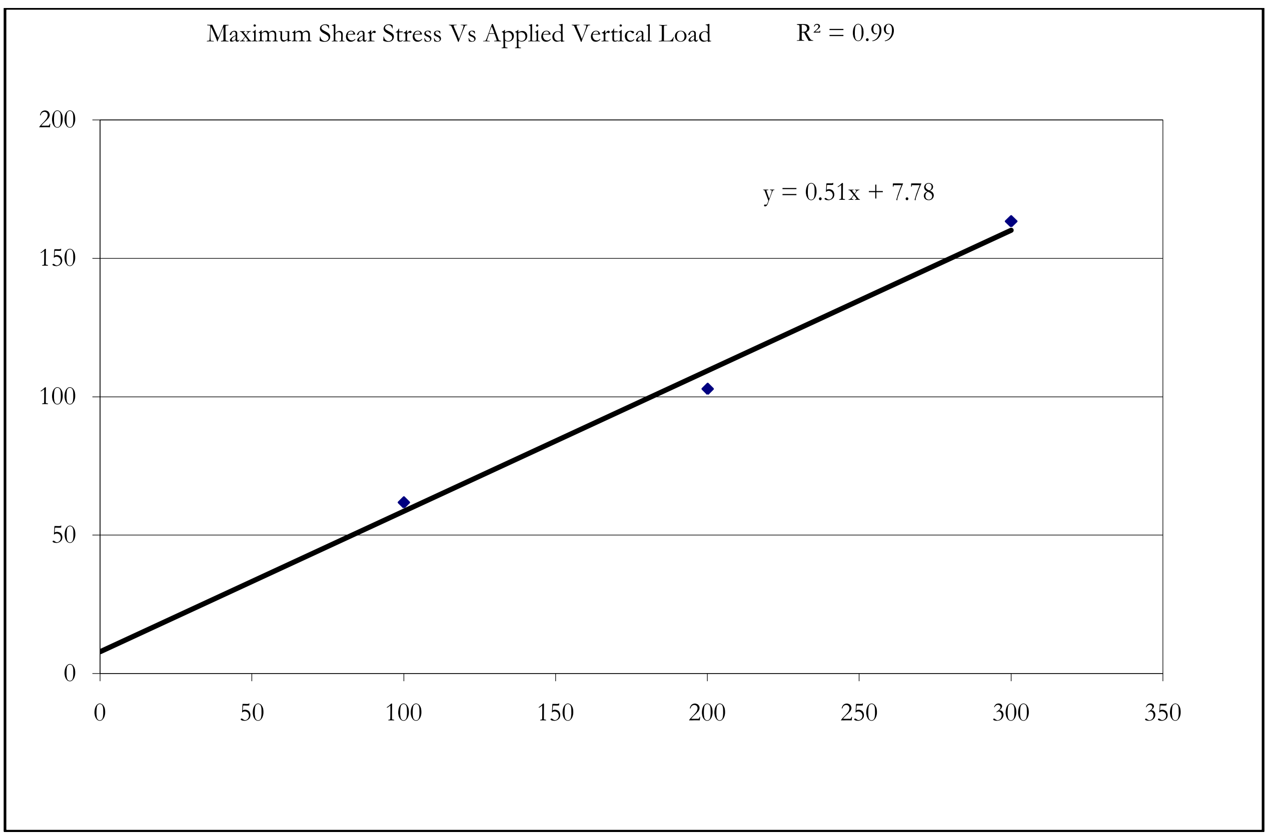
Cohesion , (KN/M^2)= **13.92**

Sample No.	TP2B(NEAR LAKE)	Sample Source: Test Pit	Depth, m : 3m
Thickness of sample:	36mm	Ring Calibration Factor: 0.70 N/div	
Length of sample :	60 mm	Rate of strain : 1.6 mm/min	
Width of sample:	60 mm	Sample Condition: Disturbed	

		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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	3570	65.00	45.50	12.75	82.00	57.40	16.08	102.00	71.40	20.00
1.0	3540	124.00	86.80	24.52	173.00	121.10	34.21	233.00	163.10	46.07
1.5	3510	172.00	120.40	34.30	243.00	170.10	48.46	318.00	222.60	63.42
2.0	3480	215.00	150.50	43.25	304.00	212.80	61.15	381.00	266.70	76.64
2.5	3450	253.00	177.10	51.33	355.00	248.50	72.03	433.00	303.10	87.86
3.0	3420	264.00	184.80	54.04	400.00	280.00	81.87	479.00	335.30	98.04
3.5	3390	276.00	193.20	56.99	436.00	305.20	90.03	501.00	350.70	103.45
4.0	3360	287.00	200.90	59.79	469.00	328.30	97.71	532.00	372.40	110.83
4.5	3330	294.00	205.80	61.80	475.00	332.50	99.85	575.00	402.50	120.87
5.0	3300	290.00	203.00	61.52	478.00	334.60	101.39	628.00	439.60	133.21
5.5	3270	285.00	199.50	61.01	480.00	336.00	102.75	650.00	455.00	139.14
6.0	3240				475.00	332.50	102.62	675.00	472.50	145.83
6.5	3210				470.00	329.00	102.49	702.00	491.40	153.08
7.0	3180				467.00	326.90	102.80	718.00	502.60	158.05
7.5	3150							730.00	511.00	162.22
8.0	3120							728.00	509.60	163.33
		Maximum shear stress, kPa		**61.80**			**102.80**	*Maximum shear stress, kPa*		**163.33**



Angle of internal friction, ϕ =27^0

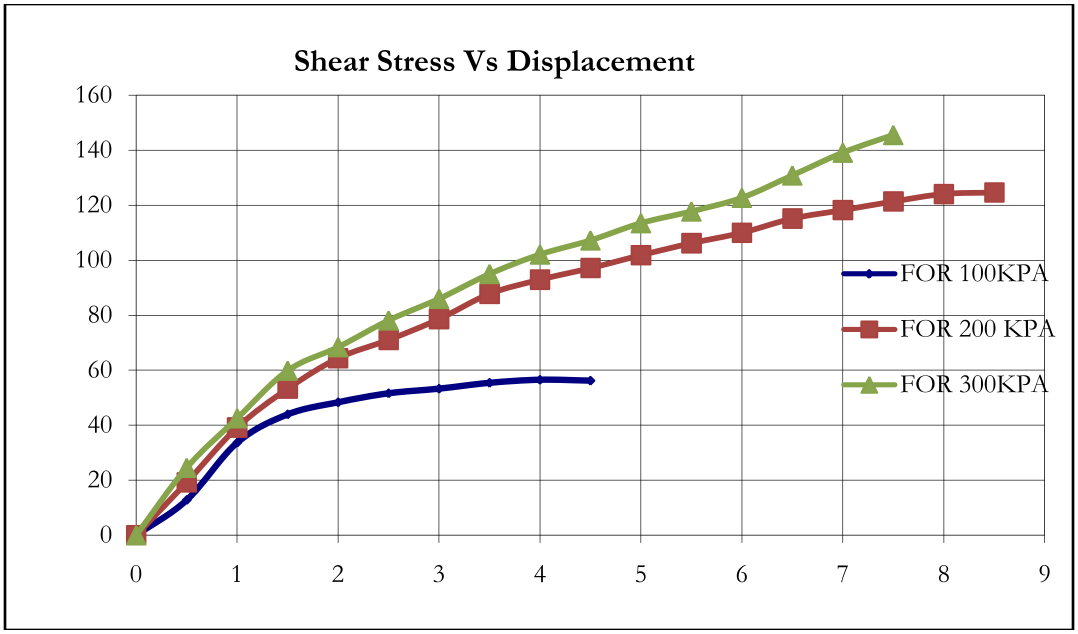


Cohesion , C (KN/M^2) = 7.78

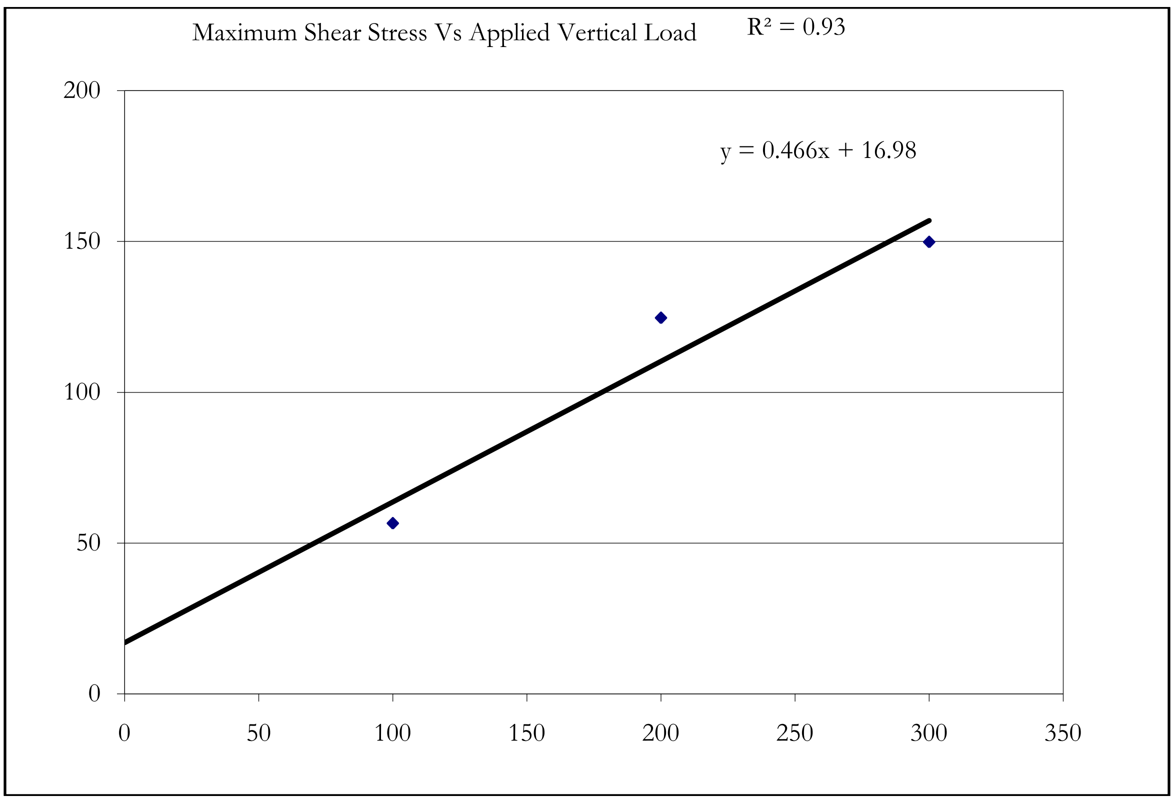
TP3C(F.AREA) SHARE

	Sample Source:	Test Pit	Depth, m : 3m
36mm	Ring Calibration Factor:	0.70 N/div	
60 mm	Rate of strain :	1.6 mm/min	
60 mm	Sample Condition: Disturbed		

	Applied Stress 100 kpa	Vertical		Applied Stress 200 kpa	Vertical		Applied Stress 300 kpa	Vertical
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]
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65.00	45.50	12.75	98.00	68.60	19.22	125.00	87.50	24.51
170.00	119.00	33.62	198.00	138.60	39.15	215.00	150.50	42.51
220.00	154.00	43.87	267.00	186.90	53.25	300.00	210.00	59.83
240.00	168.00	48.28	320.00	224.00	64.37	340.00	238.00	68.39
254.00	177.80	51.54	350.00	245.00	71.01	385.00	269.50	78.12
260.00	182.00	53.22	384.00	268.80	78.60	420.00	294.00	85.96
268.00	187.60	55.34	425.00	297.50	87.76	460.00	322.00	94.99
271.00	189.70	56.46	446.00	312.20	92.92	490.00	343.00	102.08
267.00	186.90	56.13	462.00	323.40	97.12	510.00	357.00	107.21
			480.00	336.00	101.82	535.00	374.50	113.48
			496.00	347.20	106.18	550.00	385.00	117.74
			509.00	356.30	109.97	568.00	397.60	122.72
			528.00	369.60	115.14	600.00	420.00	130.84
			537.00	375.90	118.21	632.00	442.40	139.12
			546.00	382.20	121.33	655.00	458.50	145.56
			553.00	387.10	124.07	666.00	466.20	149.42
			550.00	385.00	124.60	661.00	462.70	149.74
Maximum shear stress, kPa		**56.46**			**124.60**	*Maximum shear stress, kPa*		**149.74**



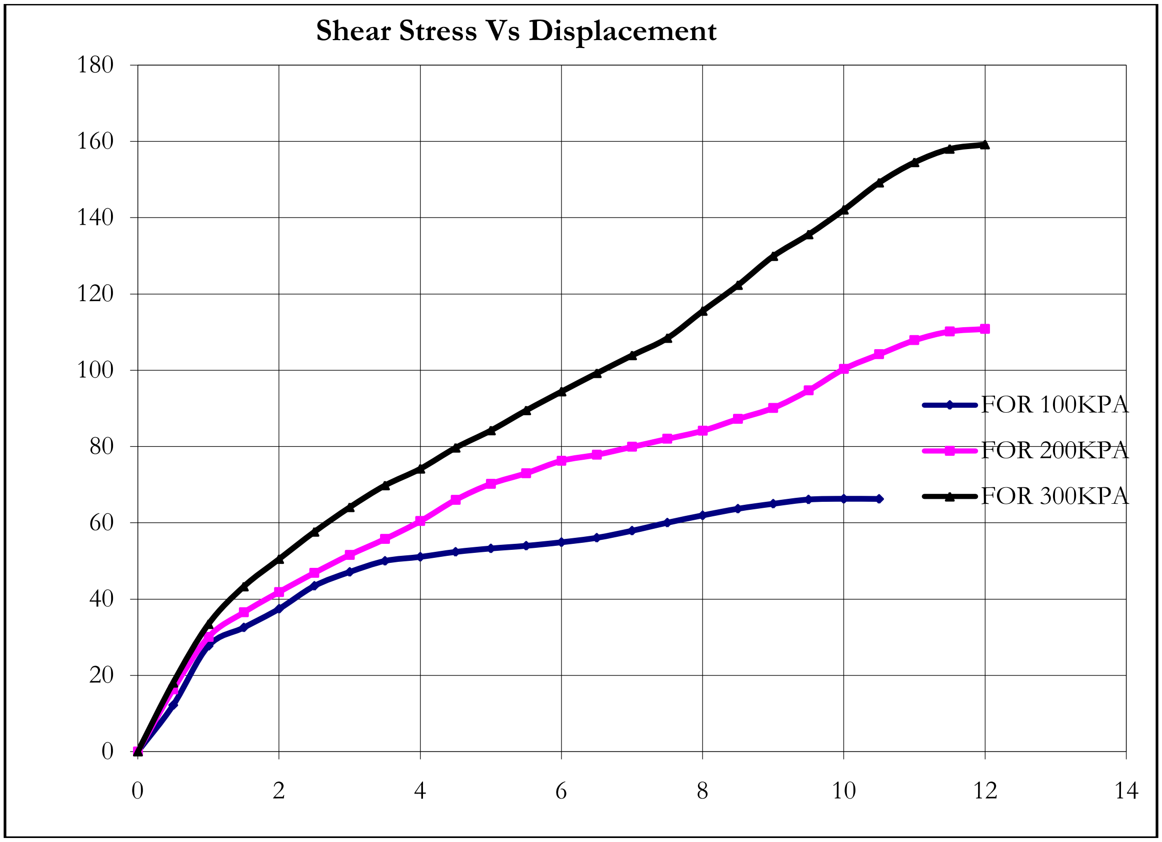
Angle of internal friction, ϕ =25^0



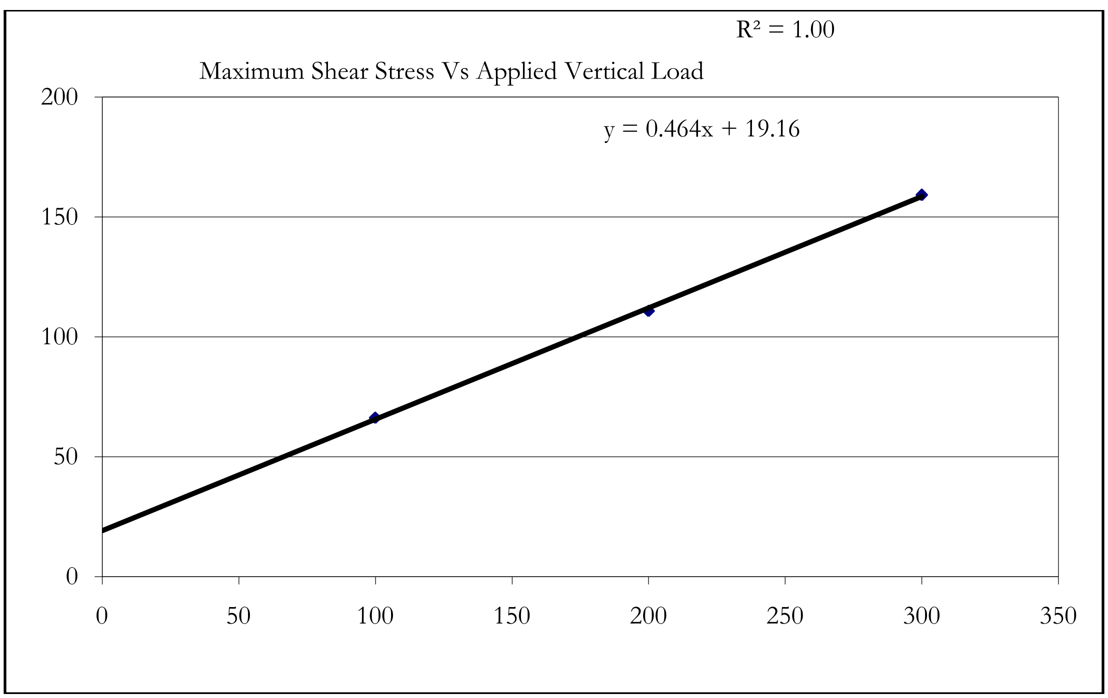
Cohesion , C(KN/M^2)=16.98

Sample No.	TP4D1(federal prison)	Sample Source:	Test Pit	Depth, m : 3m	
Thickness of sample:	36mm	Ring Calibration Factor:	0.70 N/div		
Length of sample :	60 mm	Rate of strain :	1.6 mm/min		
Width of sample:	60 mm	Sample Condition: Disturbed			

		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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	3570	62.00	43.40	12.16	83.00	58.10	16.27	92.00	64.40	18.04
1.0	3540	140.00	98.00	27.68	152.00	106.40	30.06	169.00	118.30	33.42
1.5	3510	163.00	114.10	32.51	183.00	128.10	36.50	217.00	151.90	43.28
2.0	3480	186.00	130.20	37.41	208.00	145.60	41.84	251.00	175.70	50.49
2.5	3450	214.00	149.80	43.42	231.00	161.70	46.87	284.00	198.80	57.62
3.0	3420	230.00	161.00	47.08	252.00	176.40	51.58	313.00	219.10	64.06
3.5	3390	242.00	169.40	49.97	270.00	189.00	55.75	338.00	236.60	69.79
4.0	3360	245.00	171.50	51.04	290.00	203.00	60.42	356.00	249.20	74.17
4.5	3330	249.00	174.30	52.34	314.00	219.80	66.01	379.00	265.30	79.67
5.0	3300	251.00	175.70	53.24	331.00	231.70	70.21	397.00	277.90	84.21
5.5	3270	252.00	176.40	53.94	341.00	238.70	73.00	418.00	292.60	89.48
6.0	3240	254.00	177.80	54.88	353.00	247.10	76.27	437.00	305.90	94.41
6.5	3210	257.00	179.90	56.04	357.00	249.90	77.85	455.00	318.50	99.22
7.0	3180	263.00	184.10	57.89	363.00	254.10	79.91	472.00	330.40	103.90
7.5	3150	270.00	189.00	60.00	369.00	258.30	82.00	488.00	341.60	108.44
8.0	3120	276.00	193.20	61.92	375.00	262.50	84.13	515.00	360.50	115.54
8.5	3090	281.00	196.70	63.66	385.00	269.50	87.22	540.00	378.00	122.33
9.0	3060	284.00	198.80	64.97	394.00	275.80	90.13	568.00	397.60	129.93
9.5	3030	286.00	200.20	66.07	410.00	287.00	94.72	587.00	410.90	135.61
10.0	3000	284.00	198.80	66.27	430.00	301.00	100.33	609.00	426.30	142.10
10.5	2970	281.00	196.70	66.23	442.00	309.40	104.18	633.00	443.10	149.19
11.0	2940				453.00	317.10	107.86	649.00	454.30	154.52
11.5	2910				458.00	320.60	110.17	657.00	459.90	158.04
12.0	2880				456.00	319.20	110.83	655.00	458.50	159.20
		Maximum shear stress, kPa		**66.27**			**110.83**	*Maximum shear stress, kPa*		**159.20**



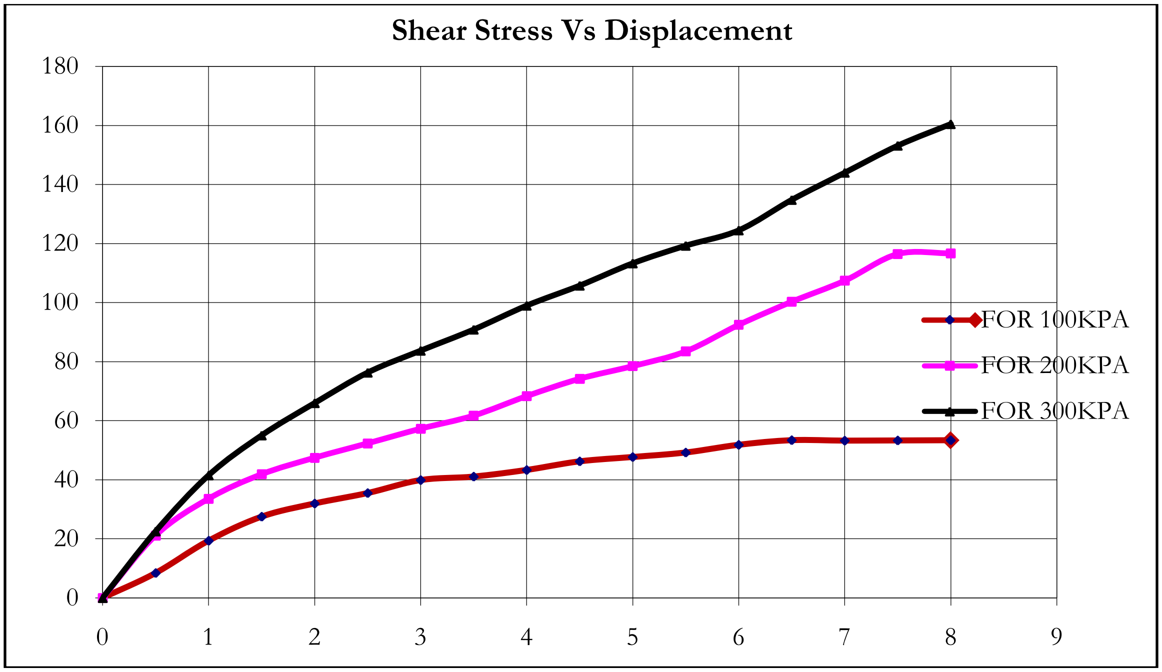
Angle of internal friction, ϕ =24.9



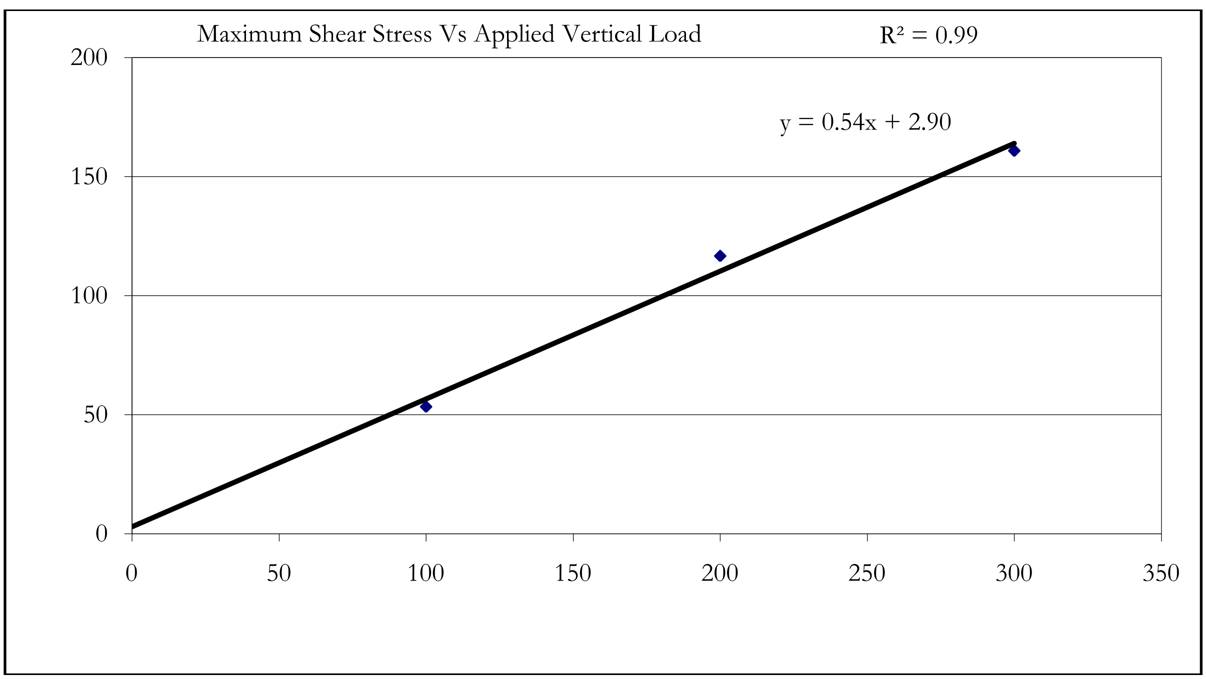
Cohesion(KN/M^2)=19.16

Sample No.	TP5E(ROAD TO BUTA JIRA)	Sample Source:	Test Pit	Depth, m :3m	
Thickness of sample:	25mm	Ring Calibration Factor:	0.70 N/div		
Length of sample :	60 mm	Rate of strain :	1.6 mm/min		
Width of sample:	60 mm	Sample Condition: disturbed			

		Applied Stress **100 kpa**	Vertical		Applied Stress **200 kpa**	Vertical		Applied Stress **300 kpa**	Vertical
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	3570	43.00	30.10	8.43	108.00	75.60	21.18	115.00	80.50	22.55
1.0	3540	98.00	68.60	19.38	170.00	119.00	33.62	210.00	147.00	41.53
1.5	3510	138.00	96.60	27.52	210.00	147.00	41.88	276.00	193.20	55.04
2.0	3480	159.00	111.30	31.98	236.00	165.20	47.47	328.00	229.60	65.98
2.5	3450	175.00	122.50	35.51	258.00	180.60	52.35	376.00	263.20	76.29
3.0	3420	195.00	136.50	39.91	280.00	196.00	57.31	409.00	286.30	83.71
3.5	3390	199.00	139.30	41.09	299.00	209.30	61.74	440.00	308.00	90.86
4.0	3360	208.00	145.60	43.33	328.00	229.60	68.33	475.00	332.50	98.96
4.5	3330	220.00	154.00	46.25	353.00	247.10	74.20	503.00	352.10	105.74
5.0	3300	225.00	157.50	47.73	370.00	259.00	78.48	534.00	373.80	113.27
5.5	3270	230.00	161.00	49.24	390.00	273.00	83.49	557.00	389.90	119.24
6.0	3240	240.00	168.00	51.85	428.00	299.60	92.47	576.00	403.20	124.44
6.5	3210	245.00	171.50	53.43	460.00	322.00	100.31	618.00	432.60	134.77
7.0	3180	242.00	169.40	53.27	488.00	341.60	107.42	654.00	457.80	143.96
7.5	3150	240.00	168.00	53.33	524.00	366.80	116.44	689.00	482.30	153.11
8.0	3120	238.00	166.60	53.40	520.00	364.00	116.67	715.00	500.50	160.42
8.5	3090							710.00	497.00	160.84
		Maximum shear stress, kPa	**53.43**				**116.67**	*Maximum shear stress, kPa*		**160.84**



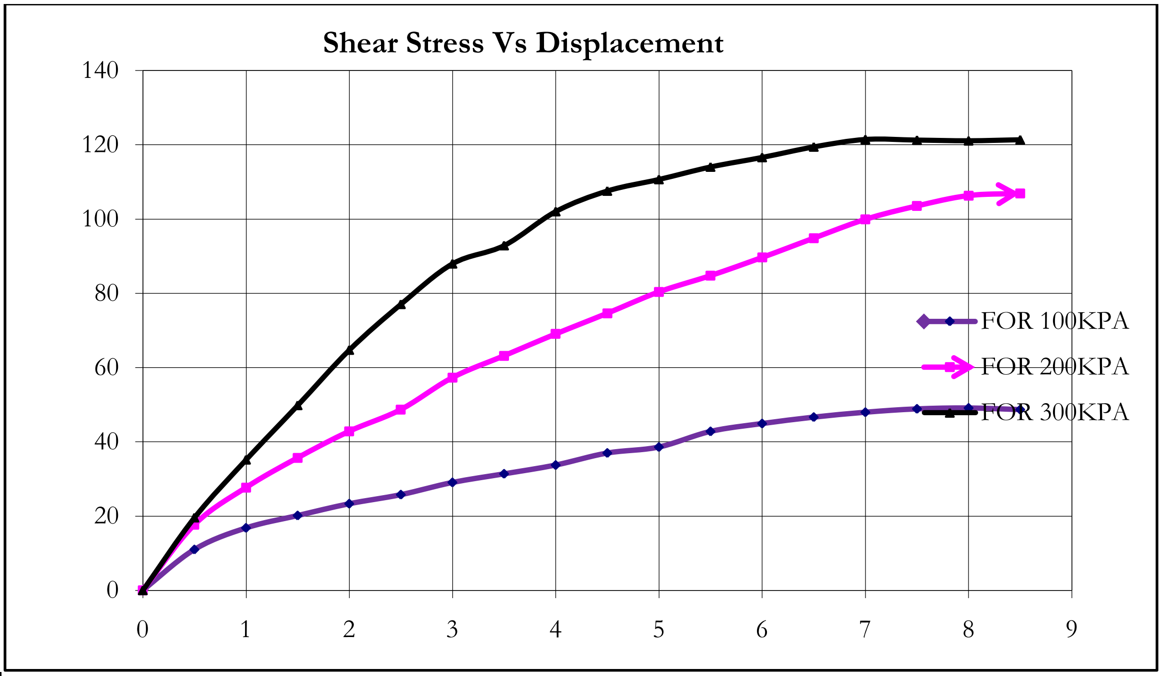
Angle of internal friction, ϕ =28.4⁰



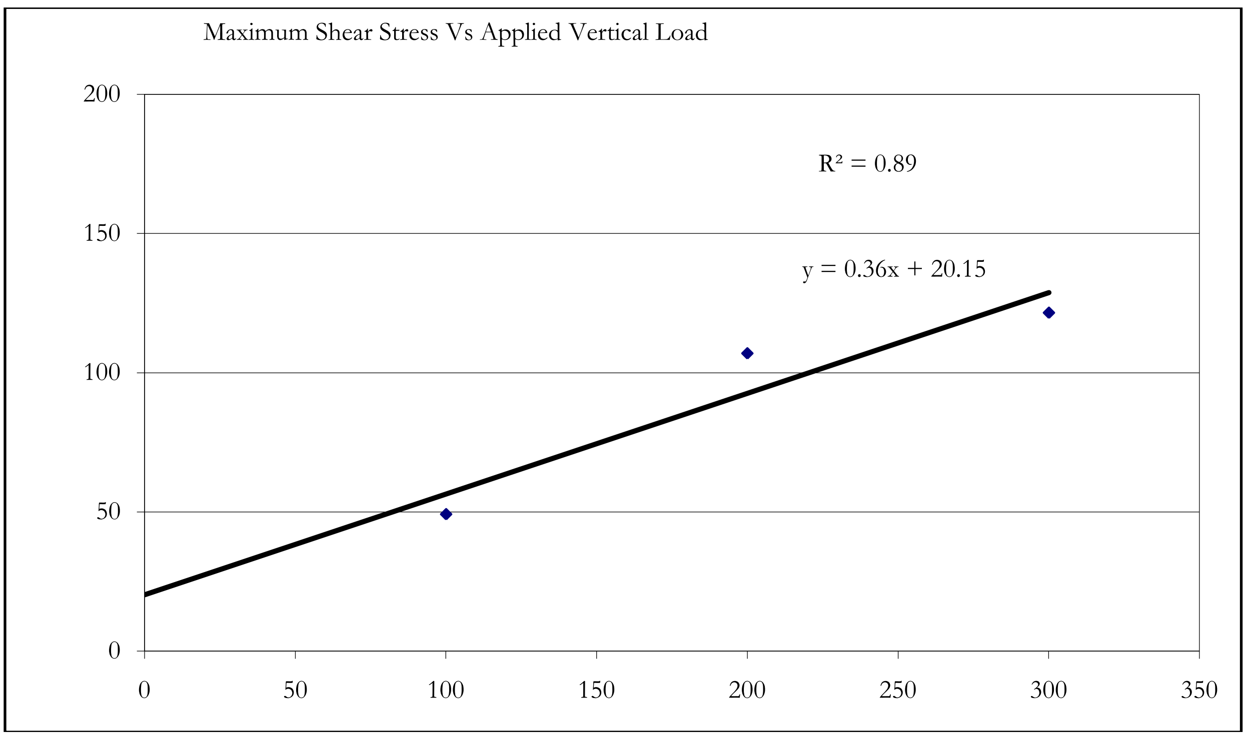
Cohesion , C(KN/M²)=2.90

Sample No.	TP6F(St.George compound)	Sample Source:	Test Pit	Depth, m : 3m	
Thickness of sample:	25mm	Ring Calibration Factor:	0.70 N/div		
Length of sample :	60 mm	Rate of strain :	1.6 mm/min		
Width of sample:	60 mm	Sample Condition: Disturbed			

		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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	3570	56.00	39.20	10.98	90.00	63.00	17.65	100.00	70.00	19.61
1.0	3540	85.00	59.50	16.81	140.00	98.00	27.68	178.00	124.60	35.20
1.5	3510	101.00	70.70	20.14	179.00	125.30	35.70	250.00	175.00	49.86
2.0	3480	116.00	81.20	23.33	213.00	149.10	42.84	322.00	225.40	64.77
2.5	3450	127.00	88.90	25.77	240.00	168.00	48.70	380.00	266.00	77.10
3.0	3420	142.00	99.40	29.06	280.00	196.00	57.31	430.00	301.00	88.01
3.5	3390	152.00	106.40	31.39	306.00	214.20	63.19	450.00	315.00	92.92
4.0	3360	162.00	113.40	33.75	331.50	232.05	69.06	490.00	343.00	102.08
4.5	3330	176.00	123.20	37.00	355.00	248.50	74.62	512.00	358.40	107.63
5.0	3300	182.00	127.40	38.61	379.00	265.30	80.39	522.00	365.40	110.73
5.5	3270	200.00	140.00	42.81	396.00	277.20	84.77	533.00	373.10	114.10
6.0	3240	208.00	145.60	44.94	415.00	290.50	89.66	540.00	378.00	116.67
6.5	3210	214.00	149.80	46.67	435.00	304.50	94.86	548.00	383.60	119.50
7.0	3180	218.00	152.60	47.99	454.00	317.80	99.94	552.00	386.40	121.51
7.5	3150	220.00	154.00	48.89	466.00	326.20	103.56	546.00	382.20	121.33
8.0	3120	219.00	153.30	49.13	474.00	331.80	106.35	540.00	378.00	121.15
8.5	3090	215.00	150.50	48.71	472.00	330.40	106.93	536.00	375.20	121.42
		Maximum shear stress, kPa		**49.13**			**106.93**	*Maximum shear stress, kPa*		**121.51**



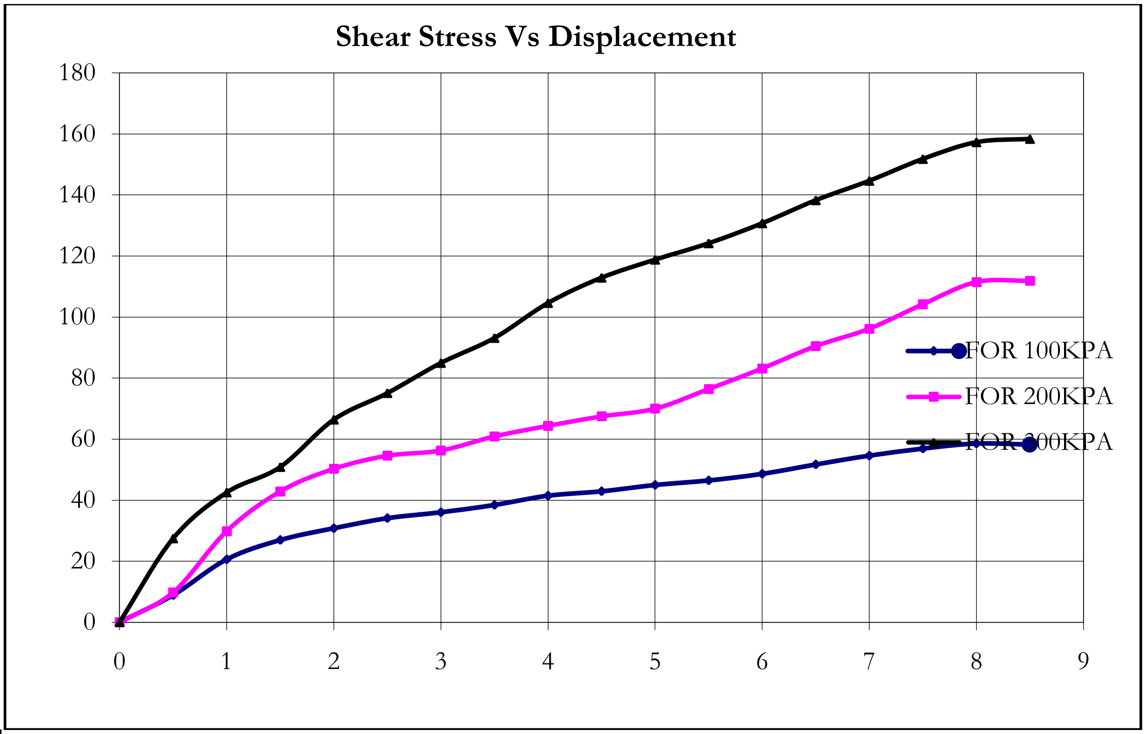
Angle of internal friction,ϕ =19.8^0



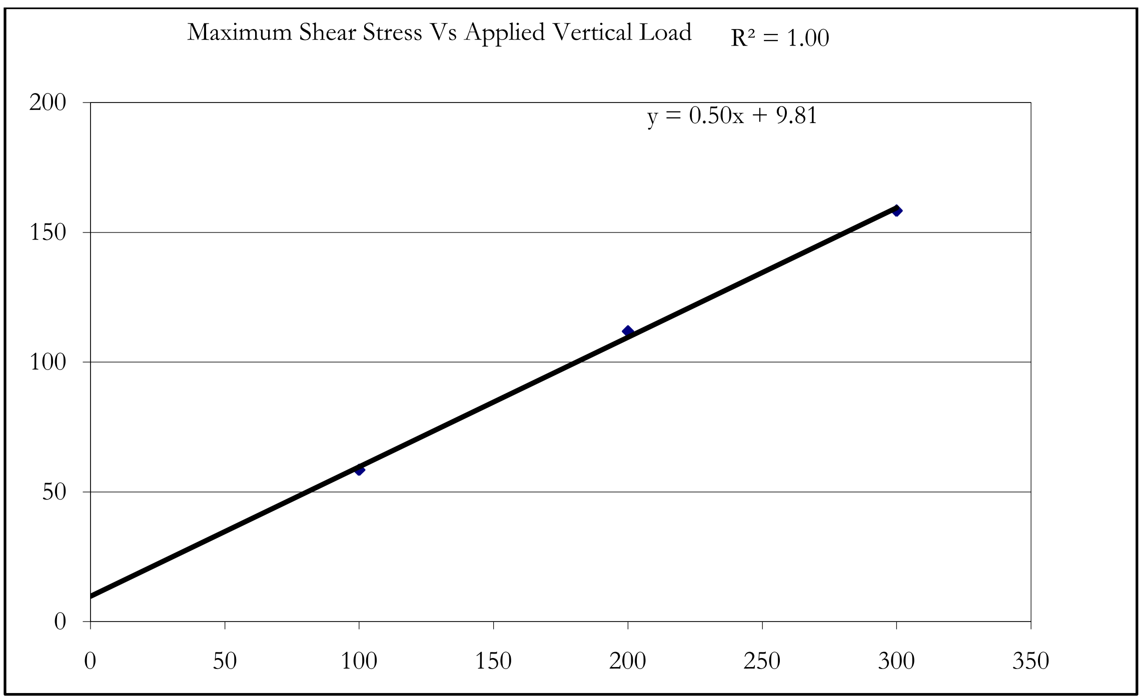
Cohesion, C(KN/M^2)= 20.15

Sample No.	TP7G(In front of Bethlehem hotel)	Sample Source:	Test Pit	Depth, m 3m:
Thickness of sample:	25mm	Ring Calibration Factor:	0.70 N/div	
Length of sample :	60 mm	Rate of strain :	1.6 mm/min	
Width of sample:	60 mm	Sample Condition: Disturbed		

		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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	3570	45.00	31.50	8.82	50.00	35.00	9.80	140.00	98.00	27.45
1.0	3540	104.00	72.80	20.56	151.00	105.70	29.86	215.00	150.50	42.51
1.5	3510	135.00	94.50	26.92	215.00	150.50	42.88	255.00	178.50	50.85
2.0	3480	153.00	107.10	30.78	250.00	175.00	50.29	330.00	231.00	66.38
2.5	3450	168.00	117.60	34.09	269.00	188.30	54.58	370.00	259.00	75.07
3.0	3420	176.00	123.20	36.02	275.00	192.50	56.29	415.00	290.50	84.94
3.5	3390	186.00	130.20	38.41	295.00	206.50	60.91	451.00	315.70	93.13
4.0	3360	199.00	139.30	41.46	309.00	216.30	64.38	502.00	351.40	104.58
4.5	3330	204.00	142.80	42.88	321.00	224.70	67.48	537.00	375.90	112.88
5.0	3300	212.00	148.40	44.97	330.00	231.00	70.00	560.00	392.00	118.79
5.5	3270	217.00	151.90	46.45	357.00	249.90	76.42	580.00	406.00	124.16
6.0	3240	225.00	157.50	48.61	385.00	269.50	83.18	605.00	423.50	130.71
6.5	3210	237.00	165.90	51.68	415.00	290.50	90.50	634.00	443.80	138.26
7.0	3180	248.00	173.60	54.59	437.00	305.90	96.19	657.00	459.90	144.62
7.5	3150	256.00	179.20	56.89	469.00	328.30	104.22	683.00	478.10	151.78
8.0	3120	261.00	182.70	58.56	497.00	347.90	111.51	701.00	490.70	157.28
8.5	3090	257.00	179.90	58.22	494.00	345.80	111.91	699.00	489.30	158.35
		Maximum shear stress, kPa		**58.56**			**111.91**	*Maximum shear stress, kPa*		**158.35**



Angle of internal friction, ϕ =26.6^0



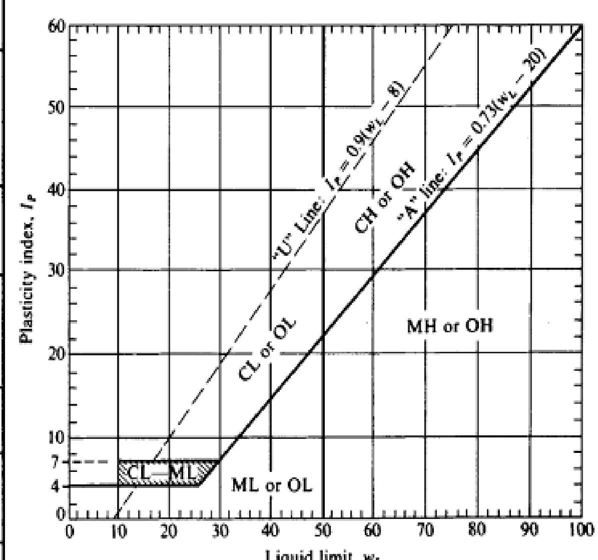
Cohesion , C (KN/M^2) =9.81

Appendix- G

(Chart used for soil classification in USCS & ASHTO)

Major divisions			Group symbols		Typical names	Laboratory classification criteria		
Coarse-grained soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW		Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentages of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5% GW, GP, SW, SP; More than 12% GM, GC, SM, SC; 5 to 12 % *Borderline* cases requiring dual symbols†	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{10}}$ between 1 and 3	
			GP		Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting C_u or C_c requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM*	d	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or I_P less than 4	Limits plotting in hatched zone with I_P between 4 and 7 are *borderline* cases requiring use of dual symbols.
				u				
			GC		Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above "A" line with I_P greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP		Poorly graded sands, gravelly sands, little or no fines		Not meeting C_u or C_c requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM*	d	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or I_P less than 4	Limits plotting in hatched zone with I_P between 4 and 7 are *borderline* cases requiring use of dual symbols.
				u				
			SC		Clayey sands, sand-clay mixtures		Atterberg limits above "A" line with I_P greater than 7	

Major divisions		Group symbols	Typical names	
Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50%)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity	For all soils plotting nearly on "A" line use dual symbols, i.e., I_P = 29.5, w_L = 60 gives CH-OH or CH-MH. When w_L is near 50 use CL/CH, ML/MH. Take "nearly on" as ±2 percent.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		OL	Organic silts and organic silty clays of low plasticity	
	Silts and clays (Liquid limit greater than 50%)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		CH	Inorganic clays of high plasticity, fat clays	
		OH	Organic clays of medium to high plasticity, organic silts	
Highly organic soils		Pt	Peat and other highly organic soils	



A-Chart

General Classification	*Granular materials (35% or less passing No. 200 Sieve (0.075 mm)*							*Silt-clay Materials More than 35% passing No. 200 Sieve (0.075 mm)*			
Group Classification	A–1		A–3	A–2				A–4	A–5	A–6	A–7
	A–1–a	A–1–b		A–2–4	A–2–5	A–2–6	A–2–7				A–7–5 A–7–6
(*a*) Sieve Analysis: Percent Passing											
(*i*) 2.00 mm (No. 10)	50 max										
(*ii*) 0.425 mm (No. 40)	30 max	50 max	51 min								
(*iii*) 0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
(*b*) Characteristics of fraction passing 0.425 mm (No. 40)											
(*i*) Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
(*ii*) Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
(*c*) Usual types of significant Constituent materials	Stone Fragments Gravel and sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
(*d*) General rating as subgrade.	Excellent to Good							Fair to Poor			

* If plasticity index is equal to or less than (liquid Limit—30), the soil is A—7—5 (*i.e.* PL > 30%)
If plasticity index is greater than (Liquid Limit—30), the soil is A—7—6 (*i.e.* PL < 30%)

Appendix- H

(Link sites)

Rift Valley | Link Ethiopia

www.linkethiopia.org/guide-to-ethiopia/travellers-guide/rift-valley-lakes/rift-valley/

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- Addis Ababa
- Historic Route
- East to Harar
- Rift Valley Lakes
- Travel Tips
- Ethiopia Info
- History
- Geography
- Wildlife
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- Facts & Figures
- The Pankhurst History Library
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Rift Valley

Rift Valley Lakes > Rift Valley | Nechisar | Omo & Mago | Gambella

Information supplied by 'Ethiopia: The Bradt Travel Guide – fifth edition' by Philip Briggs.

The Great Rift Valley, formed about 20 million years ago, is the single **largest geographical feature on the African continent**. Its gradual expansion has been accompanied by a large amount of volcanic activity: the valley floor is studded with dormant and extinct volcanoes such as Fenatle in Ethiopia.

The Rift Valley runs through Ethiopia from the Red Sea to the Kenya border. In northern Ethiopia it forms the Danakil Depression, an inaccessible and inhospitable desert that dips to the lowest point on the earth's surface.

Along with the historical circuit in the north, the southern Rift valley is probably the most touristed part of Ethiopia, with easy access on public transport and fair tourist facilities.

Climate

The Rift Valley is lower and hotter than the highlands, though in part of the Rift south of Addis Ababa elevations are around 1500m and temperatures are rarely uncomfortably hot. The bulk of rain falls between June and September.

Between Shashemene and Arba Minch you pass through the Walaita highlands, which are much chillier than other areas covered in this section. The far south is much hotter and drier than most accessible parts of Ethiopia.