ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING

INVESTIGATION ON THE ENGINEERING PROPERTIES OF SOILS FOUND IN BURAYU TOWN

BY:

WUBSHET HIRPASA

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DECLARATION

I, the undersigned, declare that the work in the project entitled "Investigation on the Engineering Properties of Soil Found in Burayu Town" has been performed by me in the Department of Civil Engineering, Faculty of Technology, under the supervision of my research advisor Dr-Ing Samuel Tadesse. The information derived from literature has been duly acknowledged in the text and list of references provided. No part of this project was previously presented for another degree at any university.

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SYMBOLS AND ABBREVIATIONS

AASHTO – American Association of state Highway and transportation officials

Ac –Activity number

ASTM – American standard of testing materials

Cc – Compression index

C_V – Coefficient of consolidation

CH – Inorganic clay with high plasticity

e –Void ratio

Gs – Specific gravity

LL – Liquid limit

M.a.s.l – Mean Annual Sea Level

MDD – Maximum Dry Density

MH – Inorganic silt with high plasticity

NMC – Natural moisture content

Pc – Pre-consolidation pressure

Po – Over-burden pressure

PI – Plasticity index

PL – Plastic limit

OMC – Optimum Moisture Content

OUPI – Oromia Urban Plan institute

TP – Test pit

UCS – Unconfined compressive strength

USCS – Unified soil classification system

ABSTRACT

Soil is the ultimate foundation material which supports the structure. The proper functioning of the structure will, therefore, depend on the engineering properties of the underlying soil.

The objectives of this research is to investigate the engineering properties of soils found in the town by conducting different types of laboratory tests and to prepare soil map of Burayu town.This research is useful in providing necessary data or information that can be used in designing civil engineering structures in Burayu town.

Laboratory tests carried out on disturbed and undisturbed samples revealed that the natural moisture content ranges from 30.8-33.7%,specific gravity of the soils ranges from 2.70-2.82%.

Results of Atterberg limits tests show that of soils of Burayu town have liquid limits ranging from 66.1-72.1%, plastic limit ranges from 30.6–34.1 % and plastic index from 35.5–39.8%.This indicate that soils of the study area is highly plastic.

The grain size distribution indicates all soil samples have clay material more than 50%. Therefore clay type of soil is dominantly located in the study area.

The free swell test result indicates that soils of the study area are nonexpansive which means degree of swell of the soils is non-swelling. The degrees of activity of most of the study area soils are Inactive with maximum Activity index of 0.74.

Soils of the study area are classified according to USCS and AASHTO.USCS indicates one main type of soils, which is highly plastic clay soil (CH). According to AASHTO classification soils of the study area is A-7-5, which means clay soil with poor quality as a subgrade material.

The Compaction test result showed that maximum dry density (MDD) of the study area ranges from 1.31 to 1.38 g/cm^3 and the optimum moisture content (OMC) ranges 30.4 to 35.0%.

The unconfined compressive strength test result and liquidity index indicates the soil consistency of the study area fall in hard state.

Finally the consolidation test result shows that the soil exists naturally in a condition of over-consolidated, which has O.C.R >1, therefore the soil had been subjected to a pressure in excess of the present pressure.

CHAPTER ONE

1. INTRODUCTION

1.1. Back ground of the problem

Engineering properties of soils play a significant role in civil engineering construction works particularly in road constructions, foundations, embankments and dams to mention a few.These made imperative, the testing of soil, on which a foundation or super structure is to be laid. This would determine its geotechnical suitability as a construction material. In recent times, the alarming rate at which lives are being lost due to collapsed buildings and road failures calls for a solution. The solution could be brought by critical geotechnical testing of the engineering soil.

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.Foundations are designed and constructed for the structures of various sizes such as high-rise buildings, bridges,medium to large commercial buildings, and smaller structures where the soil conditions do not allow code-based design.

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. Public building officials may require soil data together with the recommendations of the geotechnical consultant prior to issuing a building permit, particularly if there is a chance that the project will endanger the public health or safety or degrade the environment (Bowles, 1996).

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 obtained information on type, characteristics and distributions of a soil, geotechnical investigations should be done on soil and rock underlying (and sometimes adjacent to) a site of proposed structures.

In a country like Ethiopia which is developing at high growth rate and which needs many construction works in the future, geotechnical investigation on the engineering property of soil is very essential.Because these data are very important for civil engineers in preliminary design and in designing foundation, pavement, retaining structures, etc for future construction projects in the country.

Many researches were done in most part of Ethiopia. But there was no research done in Burayu town. Today Burayu town is famous investment zone which is found in oromia region. It has a structure plan which was prepared in 2006 by the regional office Bureau of works and urban development. These areas need an extended construction of buildings and road, which necessitates this research on investigation of the engineering properties of Burayu soils.

This research is therefore directed to the study of the physical and mechanical properties of soils i.e.investigating the index property and consolidation characteristic, identifying the characteristics of the soil and preparing soil map of the city.

1.2. Objectives of the Study

The Objectives of this thesis work are the following:

- to investigate the engineering properties of the Burayu soils namely: natural moisture content, specific gravity, consistency limits, grain size analysis, swelling potential, consolidation and compaction characteristics etc.
- to determine the range of values of index property of soil in different parts of the city.
- to determine the consolidation characteristic and strength of soils in the city. `
- to prepare soil map of the town.

1.3. Methodology

To achieve the above mentioned objectives ten sampling areas were selected. From the selected sampling areas subsurface exploration was performed by boring test pits up to 3 m depth beneath existing sub grade manually. Disturbed and Undisturbed samples of soils were collected for laboratory testing. In the field GPS reading was taken to locate the ordinate of sampling area.

A detailed field investigation was performed on the site in accordance with the schedule. A total of 10 test pits was bored and 20 samples taken for disturbed samples according to the following distribution.

Table 1.1: Test Pit Distribution

Kebeles	No of test pits	No of samples to be taken
Gefersa Buryau	1	2
Buryau keta	1	2
Leku keta	2	4
Gefersa Guji	2	4
Gefersa Nono	2	4
Melka Gefersa	2	4
Total	10	20

Then, from the samples collected the following laboratory tests were done.

- Specific gravity test
- Atterberg limit tests
- Grain size analysis
- Free swell test
- Standard compaction test
- Shear strength test (unconfined compressive strength test)
- One-dimensional consolidation test

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

1.4. Scope of the Study

The scope of the study is limited to investigating the index properties,shear parameter determination,compaction and consolidation characteristic of the soil. Due to the budget constraint, the depth of investigation in this research is limited to the maximum depth of three meters since it is difficult to excavate and sampling manually beyond this depth.

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 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. Discussion of laboratory test results, Comparison with previously done research and soil map of the study area is covered in chapter five. Finally conclusions and recommendations drawn from the research area are presented in Chapter six.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Soil formation and soil deposits

In engineering soil is defined as an unconsolidated material, composed of solid particle produced by disintegration of rocks. They are formed by the process of weathering of the parent rock. The weathering of the rocks might be by mechanical disintegration, and/or chemical decomposition. The properties of the soil materials depend upon the properties of the rocks from which they are derived (Murthy, 1990).

The variety 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 deposits of soft compressible peat. To compound the complexity, all of these materials may occur over a range of densities and water contents. At any given site, a number of different soil types may be present, and the composition may vary over intervals of a little as a few inches (James, 1976).

It has long been appreciated that the engineering classification of soils is greatly facilitated by taking into account the soil-forming processes by which nature has created the various types of soil conditions. Similar combinations of soil-forming processes in different parts of the world have been found to lead to materials of similar index properties and similar engineering characteristics (Taylor, 1990).The main factors affecting the formations of soil are: Parent materials i.e. Geology of the area, topography and drainage, climate and biological influences.

2.1.1. Parent materials

There are two main variables in parent materials that affect soils: grain size and composition. Grain size is the main determinant of soil texture. Texture influences the soil structure, consistency, cation exchange capacity, profile drainage, moisture retaining capacity and organic content (Girma, 1962). Soil composition is composed of mineral matter and organic matter and contains pore spaces filled with water or air and soluble nutrients. Organic matter serves as a binder for mineral particles, contributing to soil structure so soil composition is one of the aids to the formation of soil.

2.1.2. Topography and Drainage

Topography has a major influence on drainage characteristics which in turn have major effect on soil mineralogy. Its control over soil properties is particularly strong in tropical environment reflecting the importance of lateral movement of water and soil materials (Taylor, 1990).

2.1.3. Climate

Climate is the principal factor governing the rate and type of soil formation. The two important components of climate are the amount and distribution of precipitation, and temperature. The temperature variable is adequately represented by mean annual temperature, which doesn't differ greatly from the nearly constant temperature in the lower part of the regolith. The two main rain fall parameters most widely available are the mean annual total and the length of the dry season. The amount and distribution of precipitation affects the availability of moisture and the relative humidity of the soil atmosphere; it influences the concentration or chemical activities of solutions in the system (Gilloth, 1995).

2.1.4. Biological influence

Soil formation is also impacted by biological influence such as plants, animals, bacteria and fungi. Plants help recycle nutrients by decaying as well as by taking up nutrients. Plants also put down roots into the soil, which helps anchor the soil in place and prevent erosion.

2.2. General types of soils

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

Table 2.1: Particle Size Range

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

2.3. Soil particle size and shape

The size of particles may range from gravel to the finest size possible. Their characteristics vary with the size. Soil particles coarser than 0.075mm are visible to the naked eye or may be examined by means of a hand lens. They constitute the coarser fractions of the soils. The coarser fractions of soils consist of gravel and sand. The individual particles of gravel, which are fragments of rock, are composed of one or more minerals, whereas sand grains contain mostly one mineral which is usually quartz. The individual grains of gravel and sand may be angular, sub angular, sub-rounded, rounded or well-rounded. Gravel may contain grains which may be flat. Some sands contain a fairly high percentage of mica flakes that give them the property of elasticity. Silt and clay constitute the finer fractions of the soil. Any one grain of this fraction generally consists of only one mineral. The particles may be angular, flake-shaped or sometimes needle-like (Murthy, 1990).

2.4. Soil texture

Common descriptive terms such as gravels, sands, silts and clays are used to identify specific texture in soils. Texture refers to the appearance or feel of a soil. Sands and gravels are grouped together as coarse grained soil. Clays and silts are fine grained soils. Coarse grained soils feel gritty and hard. Fine grained soils feel smooth (Budhu, 2000).

2.5. Mineralogy of clay

The minerals of clays are formed by the weathering of rocks. Most clay minerals of interest to geotechnical engineers are composed of oxygen and silicon which are the two most abundant elements on earth.Silicates are a group of minerals with a structural unit called the silica tetrahedron. A central silica cation is surrounded by four oxygen anions,one at each corner of the tetrahedron. Silica tetrahedrons combine to form sheets, called silicate sheets. Silicate sheets may contain other structural units such as alumina sheets. Alumina sheets are formed by a combination of alumina minerals,which consist of an aluminum ion surrounded by six oxygen or hydroxyl atoms in an octahedron (Budhu, 2000).

The main groups of clay crystalline materials that make up clays are the minerals kaolinite, illite and montmorillonite.

2.5.1. Kaolinite

Kaolinite has a structure that consists of one silica sheet and one alumna sheet bonded together in to a layer about 0.72nm (nm = 10^{-9}m) thick and stacked repeatedly (Fig 2.1.a). The layers are held together by hydrogen bonds (Budhu, 2000). Kaolinite has a few or no exchangeable cation, and the interlayer bonds are relatively strong preventing any hydration between layers and allowing many layers to build up. Kaolinite is relatively stable and water is unable to penetrate between the layers.Consequently Kaolinite shows little swelling on wetting (Teferra, et al., 1999). Kaolinites are found in soils that have undergone considerable weathering in warm, moist climates. They have low liquid limit and a low activity. Another member of the Kaolinite group appearing in some tropical soils is called halloysite, in which water molecules separate the layers. The halloysites are distinguished by one additional water molecule to the basic kaolinite. In contrast to most other clays, which are flaky, halloysite particles are tabular or rod like.

2.5.2. Illite

The illites are somewhat similar to montmorillonites in the structural units, but are different in their chemical composition.In illite, the layers are separated by potassium ion, where as in montmorillonite the layers are separated by loosely held water and exchangeable metallic ions (Fig 2.1.b). Unlike montmorillonite particles, which are extremely small and have a great affinity for water, the illite particles will normally aggregate and there by develop less affinity for water than montmorillonites. Correspondingly,their expansion properties are less. The cation exchange capacity of illite is less than that of montmorillonite. The inner layer bonding by the potassium ions is sufficiently strong. Illites usually occur as a very small, flaky particles mixed with other clay and non-clay materials (samuel.T.).

2.5.3. Montmorillonite

Montmorillonites are made up of sheet like unit comprising an alumna octahedral sheet between two silica tetrahedral sheets, as shown in Fig. 2.1(c).As the electrons rotate around the nucleus of an atom there will be times when there are more electrons on one side of the atom than the other, giving rise to a weak instantaneous dipole.Weak Vander Waals forces hold layers together and the bonding of these sheets is rather weak,resulting in a rather unstable mineral, especially when wet.In fact,montmorillonite display a significant affinity for water, with subsequent swelling and expansion. Its excessive swelling capacity may seriously endanger the stability of overlying structures and road pavements. Bentonite is part of the montmorillonite clay family, usually formed from the weathering of volcanic ash (samuel.T.).

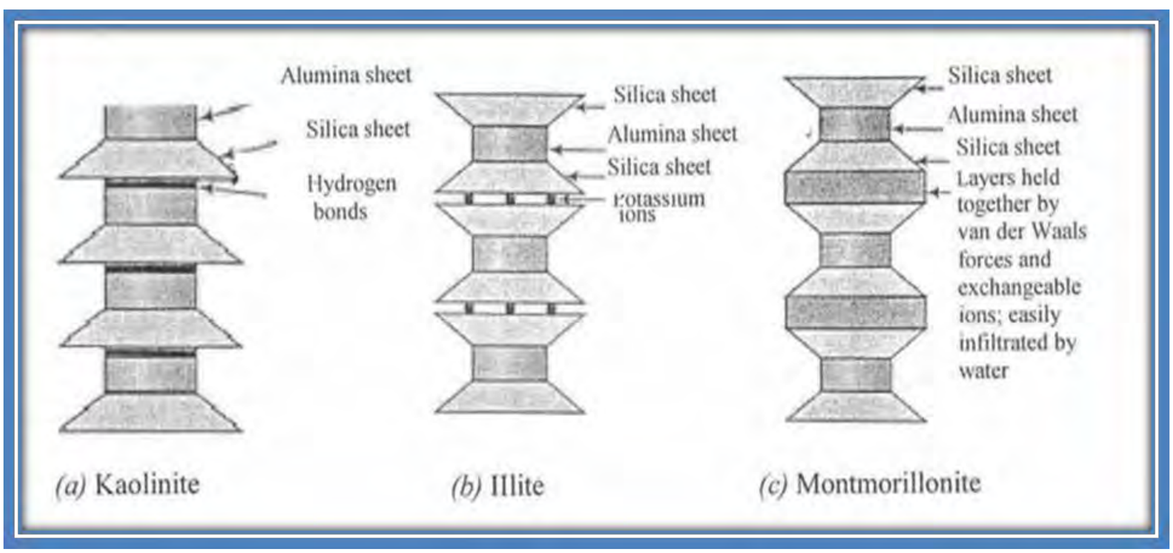


Figure 2.1: Structure of Kaolinite, Illite, and Montmorillonite

2.6. Review of Previous Research

Investigation of soils is very important in providing necessary data or information that can be used in designing civil engineering structures. Many investigators have studied on soils of Ethiopia.

Morin and Perry (1971) studied the origin and mineralogical composition of Ethiopian red clay soils. According to their study Ethiopian red clay soils are principally residual, derived from the weathering of volcanic rocks. The parent rock for black and red clays in Ethiopia is mainly olivine basalt, basalt and trachyte.

Ethiopian red clay soils have developed where rain fall is plentiful and drainage is good, and contain Kaolinite and Halloysite as the principal clay minerals, but Montmorillonite is also frequently present in significant amounts. The red color of the Ethiopian soils indicates the presence of iron.

Hailemariam (1992) has studied about investigation into shear strength characteristics of red clay soils of Addis Ababa. Based on experimental results of index property test soil under investigation are not expansive and no significant variations in the investigated depths as well as in different pits were found. The comparison of Addis Ababa red clay soil and lateritic soils of West Africa shows that the red clay soils investigated are not lateritic.

Samuel (1989) has studied about investigation in to some of engineering properties of Addis Ababa red clay soils. Based on experimental results from 13 samples around Kolfe, Rufael and Semen Gebeya areas he found out the depth of red clay soil in Addis Ababa ranges from few centimeters to about 10 meters. In the area covered by the study, however, the thickness of the soil is found to be one and half meter in Semen Gebeya and Rufael areas and more than 3m in Kolfe area and finally index property test result indicates the soil is not potentially expansive.

Ayenew (2004) has studied about investigation into shear strength characteristics of expansive soil of Ethiopia. Based on experimental results the shear strength of expansive soil ranges from 30-150kPa in cohesion and 3-25 degree in angle of internal frication in UU test on unsaturated soil. For saturated soil sample in UU test the cohesion ranges from 55-94kPa. There is a decrease in strength in saturated samples, which shows that the degree of saturation and the suction pressure can have major influence on the shear strength of expansive soil.

Mesfin (2004) has studied about investigation on index properties of expansive soils of Ethiopia. Based on experimental results from 125 samples shows high clay content, high to extremely high plasticity ranges. From the test result, the expansive soil of Ethiopia is classified as to extremely high swelling potential. Hence, these soils are unsuitable as construction material and should be considered as problematic foundation soils.

CHAPTER 3

3. DESCRIPTION OF THE STUDY AREA

3.1. General

Oromia special zone surrounding Finfine is the name given to a zone which was established in August 2008 as one of the eighteen zones of Oromia National Regional State. This Zone is located in the central part of Oromia National Regional State and the administrative center of the zone is located in Addis Ababa city. Burayu town is one of the nine municipal town administrations in Oromia Special Zone Surrounding Finfine where the research is conducted. It is bounded by Addis Ababa City in the east, by Addis-Bah and Finfine Fire Wood Development Projects in the north, by Gefersa Water Reservoir (Dam) in the West, and by Gefersa Siga Meda in the South and northwest.

Burayu town is located in Oromia National Regional State in the western fringe of Addis Ababa, along the Addis Ababa-Ambo road; 15km away from the center of Addis Ababa measured from Piazza. Astronomically the town extends roughly from $90^{o}02'$ to $90^{o}02'30''$ North latitudes and $38^{o}03'30''$ to $38^{o}41'30''$ East longitudes. According to census, the population of Burayu town was 4,138 in 1984; 10,027 in 1994, 63,873 in 2007 and 100,200 in 2010 (estimated). Burayu town administration has estimated that the population of the town has grown to more than 150,000 in 2014 showing that the town is growing very fast. Location of the research area on the map of Ethiopia is shown in figure 3.1 below.

3.2. Naming

The name Burayu is reportedly derived from one of the indigenous trees of the region. The term “Burayu” is an Oromiffa word which means “Tiqure Inchet” (it literally means black wood) in Amharic. The forest, which also consists of other indigenous trees like “Tid”, “Woira”, “Kosso” etc., used to the home of a large variety of wild animals including Buffaloes, Lion, Giraffe, Tigers, etc. However, due to population increase and intensification of farming activities, significant deforestation occurred in the area that resulted in the migration of the wild animals (OUPI, 2006).

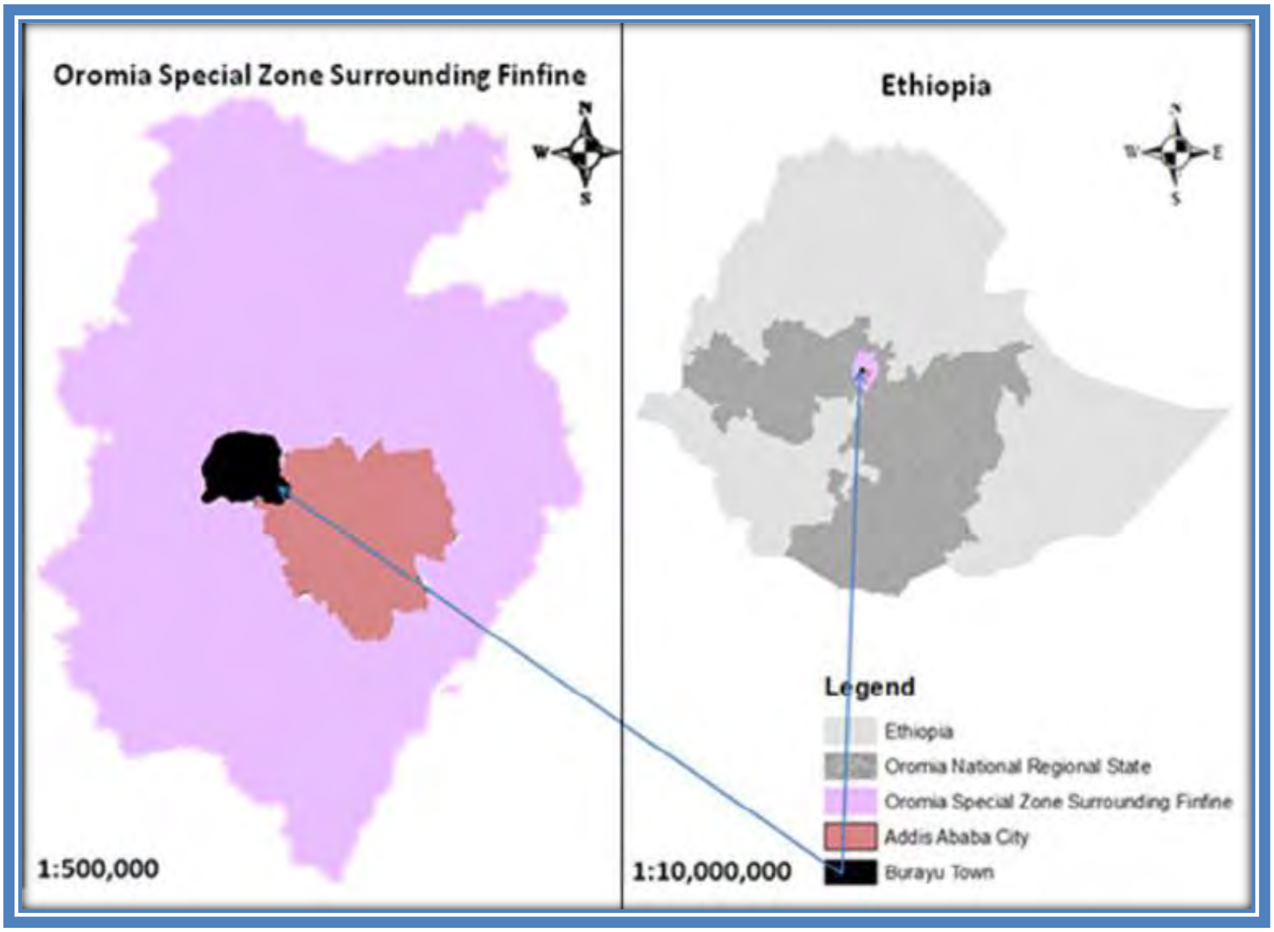


Figure 3.1: Location of the research area on the map of Ethiopia (Source: Based on Maps from Oromia National Regional State, Bureau of Finance and Economic Development, 2012)

3.3. Geology

The present topographic setting of the area is the result of internal geologic processes (volcano-tectonic activity) and external or surface processes such as weathering and erosion by rivers or streams, and gully development.

Burayu town and its environs are made up of volcanic rocks of Tertiary and Quaternary age. Localized recent alluvial deposits in the area are rarely observed and are only found along Gafarssa stream above the junction with Seqo stream. Concerning volcanic rocks, basalts the thickness of which ranges from 0 to 3 meters are found exposed at many places in the study area. This unit is found as massive large intact boulders. The trashy basalt is dark gray in color, very hard and resistant to weathering as compared to the brittle and relatively easily weathered aphanite basalts of dark black color. At many localities these massive blocks and boulders are found buried under the reddish brown soil, which is the weathering product of this rock unit. As compared to the basalt unit the ignimbrites are thick and characterized by columnar joints as observed in the quarry face. Both of these rock units are widely used as construction materials in the area (OUPI, 2006).

3.4. Soil type

Soil development and the nature of the soils in the area are mainly controlled by geology, topography and hence drainage. In well drained table land areas, the predominant soil type is red and easily eroded. Whereas, in some areas like those found northwest of St Marry church and the eastern tip of Tatek-Siga Meda, the soil is clayey. The occurrence of alluvial soils is very limited, which is only found along narrow river banks or flood plains. The Town is mainly covered with reddish brown silty clay soil (of friable nature which is highly leached).

Brick clay, the raw material for the production of brick, is found in and around the town. It is mainly the weathering product of acidic rocks of the Intoto silicics/rhyolites. The Ambo-Kassam regional fault, which has formed the Intoto mountain chain, is the major structure and there are also local fractures and flow structures in the ignimbrite rocks (OUPI, 2006).

3.4. Topography and drainage conditions

As the town is situated at the southwestern foot of Entoto ridge, most of the existing built up areas of the town lies on rugged terrain (land profile with steep slopes, deep streams or river valleys with steep gradients, deep river/stream banks, gullies and ridges) with limited flat lands.

On the other hand, most of the proposed expansion areas are characterized by gentle slopes and Undulated plains (in the northwestern directions) with limited steep slopes and deep gorges (in the southern directions) along Burayu and Tinshu Akaki rivers.

Altitude of the town ranges from 2600 meter above sea level (m.a.s.l.) at Entoto Ridge to 2450 m.a.s.l at Tinshu Akaki River valley. The town is found within the Awash River drainage basin, and it is particularly drained by Tinishu Akaki River. A number of perennial rivers and/or streams are found within the catchments of Tinishu Akakai River of which Burayu, Leku and Seqo are the major ones. The discharges of these streams are relatively small during dry seasons, whereas the volume of these rivers/steams drastically increases during summer season (June-September) and inundates the low gradient areas close to their banks. Therefore, adequate buffer zone should be reserved along the river banks (OUPI, 2006).

3.5. Climate

As data on the climatic condition of Burayu town is not readily available, an attempt has been made to adapt the climatic condition of Addis Ababa where the nearest metrological station is located (OUPI, 2006) as shown in table 3.1 below.

Table 3.1 Climate of the study area

No.	Climate	Values	Description
1	Rainfall	1,188mm (mean annual rainfall)	The highest mean annual rainfall concentration occurs from June to September i.e. 70%-80%.
2	Temperature	14^0c (mean annual temperature) 22^0c (mean annual maximum) 6^0c (mean annual minimum)	Value showed that it is a characteristic of a warm temperate climate.
3	Humidity	79% in August to 49% in December (mean monthly relative humidity)	Values showed that the area is very comfortable for human life.

CHAPTER 4

4. IN-SITU PROPERTIES AND LABORATORY TEST RESULTS

4.1. In-situ properties

4.1.1. Identification of soil in the study area

Before selecting sampling areas, visual site investigation and information from resident, and construction firms were collected to consider the different soil types and to take sample evenly in the whole town. After observation of the soil type in the whole town, ten sampling areas were selected from different locations of the town. Pits were excavated to the maximum depth of three meters by direct excavation manually, but in some areas boulders were encountered making the digging difficult. Both disturbed and undisturbed samples were taken. In the field visual soil description was made and sample for laboratory testing were collected. The global coordinates of sampling location i.e. northing, easting and elevations are shown in Table 4.1.

Table 4.1: Global coordinates of sampling areas

Test Pit	Location	Northing	Easting	Elevation(m)
TP-1	Gefersa Buryau	457922	1004419	2524
TP-2	Buryau keta	462512	1004200	2547
TP-3	Gefersa Guji	460044	1001363	2615
TP-4	Gefersa Guji	456788	1000991	2627
TP-5	Gefersa Nono	461502	997341	2647
TP-6	Gefersa Nono	458443	998377	2637
TP-7	Melka Gefersa	465636	998303	2536
TP-8	Melka Gefersa	464349	997057	2500
TP-9	Leku keta	465229	1001703	2595
TP-10	Leku keta	462950	1000055	2619

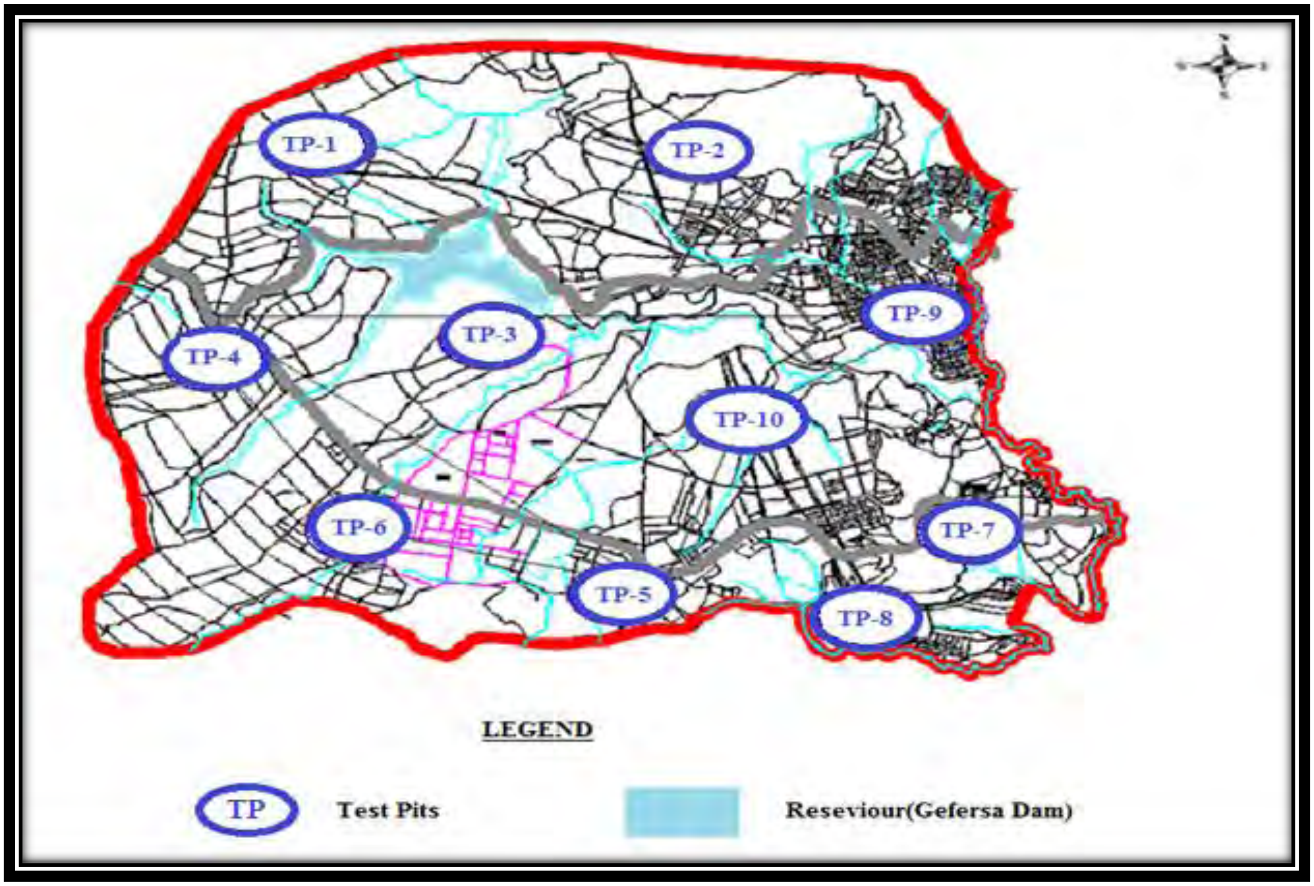


Figure 4.1: Location of sampling areas shown on map of Burayu town

4.2. Laboratory Test Results

4.2.1. Index properties

4.2.1.1. General

In nature, Soils occur in a large variety. However, soils exhibiting similar behavior can be grouped together to from a particular group. Engineers are continually searching for simplified tests that will increase their knowledge of soils beyond that which can be gained from visual examination without having to resort to the expense, detail, and precision required with engineering properties tests. These simplified tests provide indirect information about the engineering properties of soils and are, therefore, called index tests. Simple tests which are required to determine the index properties are classification tests. The soil are classified and identified based on index properties. Some of the index properties of soil are; Natural moisture content, Specific gravity, consistence limits, Grain size analysis, free swelling of the soil.

4.2.1.2. Natural Moisture Content

The water content of a soil is an important parameter that controls its behavior. It is quantitative measure of the wetness of a soil mass. The water content of a soil can be determined to a high degree of precision, as it involves only mass which can be determined more accurately than volumes (Arora, K.R.). For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil (ASTM, 2004,).

The characteristics of a soil, especially a fine-grained soil, change to a marked degree with a variation of its water content (B.M.Das). The natural moisture contents of the soil under investigation were determined following ASTM D2216-98. Natural moisture content of soils of the study area ranges from 30.8 %- 33.7%.

Table 4.2: Natural Moisture Content of the soil under investigation

Test Pit	Depth	NMC (%)
TP-1	1.5m	32.4
	3.0m	31.9
TP-2	1.5m	32.7
	3.0m	33.6
TP-3	1.5m	32.9
	3.0m	31.1
TP-4	1.5m	32.4
	3.0m	31.5
TP-5	1.5m	30.8
	3.0m	31.9
TP-6	2.0m	33.2
TP-7	2.0m	32.9
TP-8	2.0m	33.2
TP-9	1.5m	32.9
	3.0m	33.7
TP-10	1.5m	31.8
	3.0m	32.9

4.2.1.3. Specific Gravity

Specific gravity of soil is the ratio of weight of a given volume of soil particles in air at a stated temperature to the weight of an equal volume of distilled water at a stated temperature. The specific gravity of a soil is often used in relating a weight of soil to its volume. The specific gravity of soil is used in calculating phase relationships of soils (that is the relative volumes of solids to water and air in a given volume of soil) (Krishna R., 2002).

ASTM D 854-00 Standard Test for Specific Gravity of soil solids by Water Pycnometer is used for determination of the specific gravity of soil. The test result of specific gravity of the study area is given in the following Table 4.3.

Table 4.3: Specific gravity of soil in the study area

Test Pit	Depth	Specific Gravity (G_S)
TP-1	1.5m	2.79
	3.0m	2.74
TP-2	1.5m	2.81
	3.0m	2.78
TP-3	1.5m	2.82
	3.0m	2.76
TP-4	1.5m	2.70
	3.0m	2.74
TP-5	1.5m	2.73
	3.0m	2.74
TP-6	2.0m	2.74
TP-7	2.0m	2.73
TP-8	2.0m	2.76
TP-9	1.5m	2.76
	3.0m	2.81
TP-10	1.5m	2.79
	3.0m	2.78

The specific gravity of soil varies from 2.70 - 2.82%. The values showed a variation with in a limited range at different depths and different location.

4.2.1.4. Grain-size Distribution

Grain size analysis provides the grain size distribution required in classifying the soil. Grain size Analysis test is used to determine the percentage of different grain sizes contained within a soil.

The test method covers the quantitative determination of the distribution of particle sizes in soils. The grain size distribution of coarse-grained soil is generally determined by means of sieve analysis, whereas for a fine grained soil, the grain size distribution can be obtained by means of by a sedimentation process, using a hydrometer analysis (ASTM, 2004).

ASTM D 422-63 Standard Test Method for Particle-Size Analysis of Soils is used in the test analysis. The summary of the sieve and hydrometer analysis is shown in the following table and Figure below.

Test Pit	Depth	Percent Amount Of Particle Size			
		Gravel	Sand	Silt	Clay
TP-1	1.5m	0.8	16.7	18.7	63.7
	3.0m	0	14.2	21.6	64.2
TP-2	1.5m	0.01	8.2	23.3	68.5
	3.0m	0	7.9	19.9	72.2
TP-3	1.5m	0.7	13.3	28.3	57.7
	3.0m	0	8.3	19.4	72.3
TP-4	1.5m	0.4	14.6	29.3	55.7
	3.0m	0	5.2	22.8	72.0
TP-5	1.5m	0	2.8	34.1	63.1
	3.0m	1.8	5.3	30.1	62.9
TP-6	2.0m	0.3	5.6	27.7	66.4
TP-7	2.0m	0.1	4.7	31.5	63.7
TP-8	2.0m	0.3	7.5	22.8	69.4
TP-9	1.5m	0	2.8	24.7	72.5
	3.0m	0	3.6	23.6	72.8
TP-10	1.5m	0.1	3.7	25	71.3
	3.0m	0	6.7	19.5	73.8

Table 4.4: Summary of Grain Size analysis result

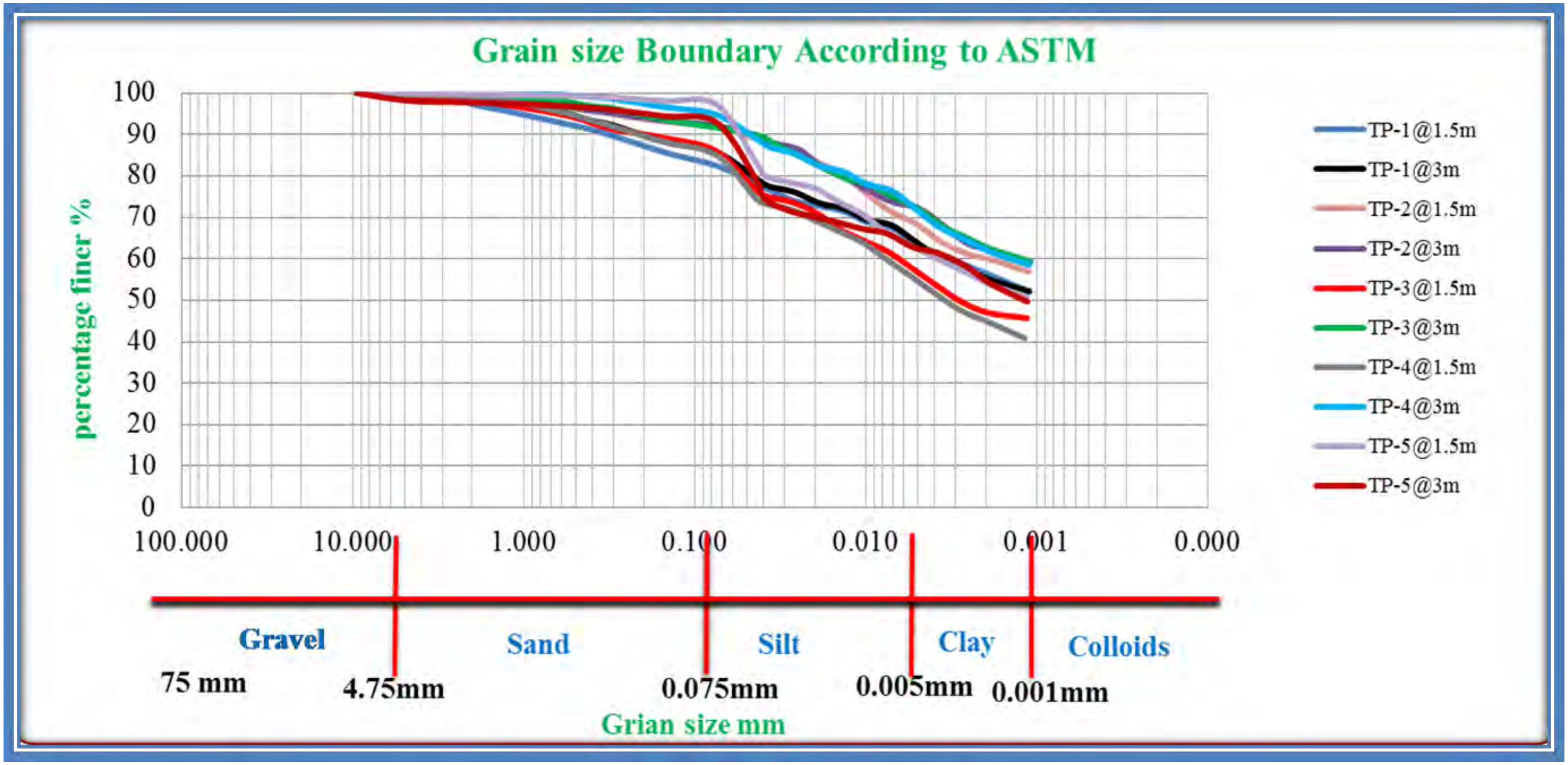


Figure 4.2: Grain size distribution curve for TP-1 to TP-5

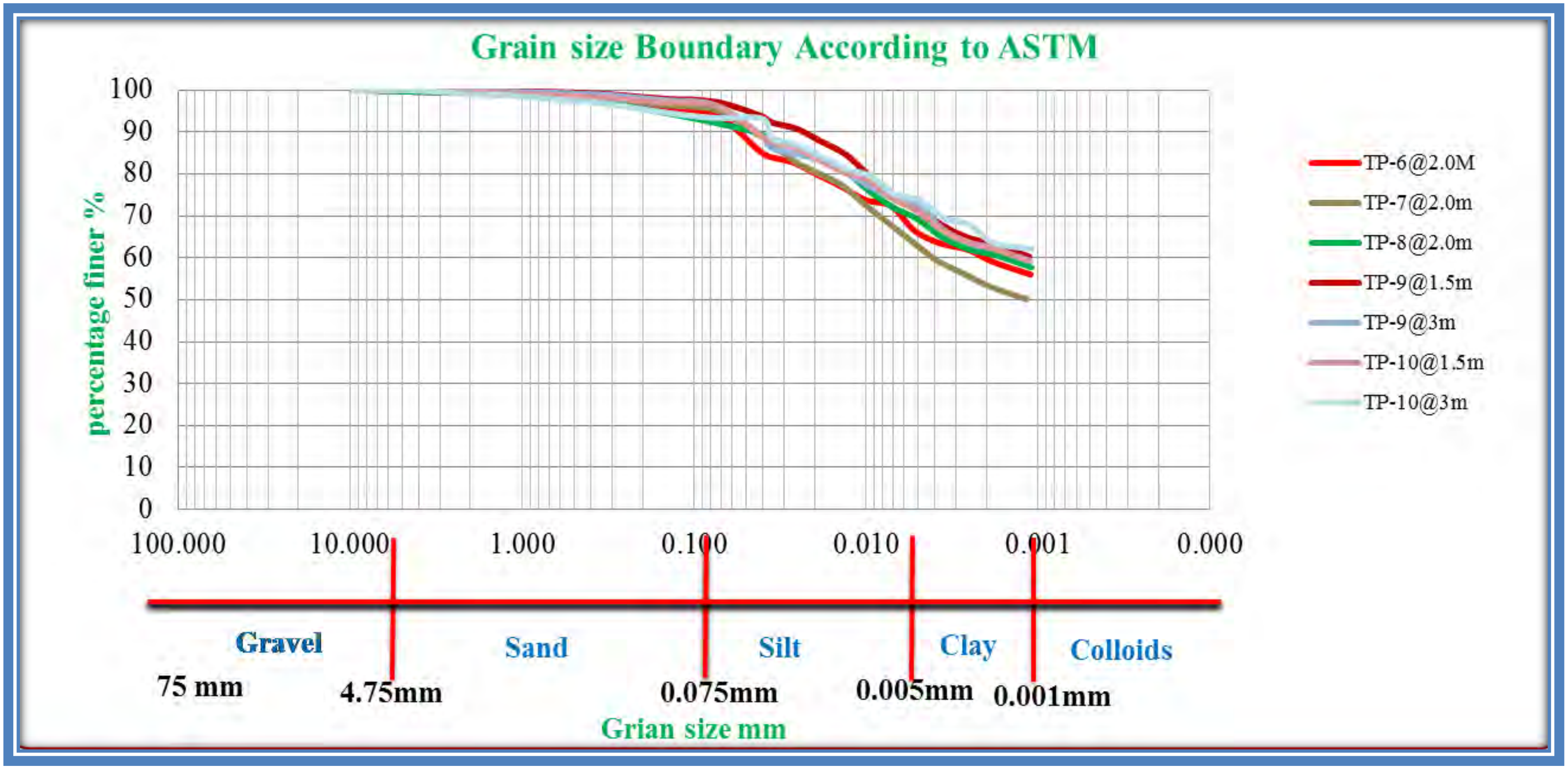


Figure 4.3: Grain size distribution curve for TP-6 to TP-10

From the table and graph above we can observe the following results;

- The results of grain size analysis showed that soils of Burayu town have clay content ranging from 55.7-73.8%, silt content from 18.7-34.1%, sand from 2.8-16.7% and gravel from 0-1.8%.
- For all test pits, the percentage of soil passing sieve no.200 is more than 90%.This means the constitute of the soil is mainly fine grained soils.The hydrometer analysis shows the gradual falling of particles; it indicates soil of the study area is clay nature.

4.2.1.5. Atterberg Limits

Atterberg Limits are defined as water contents at certain limiting or critical stages in soil behavior. They are used in classification of fine grained soils, and they are useful because they correlate with the engineering properties and engineering behavior of fine-grained soils (Robert D.H., et al., 1981).

It was done based on the Standard Reference: ASTM D 4318-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 sample of soil passing sieve No 40(0.425mm) is used to determine the Atterberg Limits.

The Atterberg Limits for soil in Burayu town are summarized in Table 4.5 below and from this we can see that liquid limit ranges from 66.1 – 72.1%, plastic limit ranges from 30.6 – 34.1 % and plastic index from 35.5 – 39.8%.

Table 4.5: Atterberg Limit Result Summary for air dried soil samples

Test Pit	Depth	Liquid Limit	Plastic Limit	Plasticity Index
TP-1	1.5m	68.9	32.4	36.5
	3.0m	71.3	34.0	37.3
TP-2	1.5m	71.9	32.4	39.5
	3.0m	69.1	32.7	36.4
TP-3	1.5m	70.8	33.0	37.8
	3.0m	71.5	33.3	38.2
TP-4	1.5m	69.3	32.4	36.9
	3.0m	73.4	34.1	39.3
TP-5	1.5m	71.0	33.1	37.9
	3.0m	66.1	30.6	35.5
TP-6	2.0m	68.8	31.0	37.8
TP-7	2.0m	72.1	32.7	39.4
TP-8	2.0m	72.1	32.3	39.8
TP-9	1.5m	68.8	31.8	37.0
	3.0m	70.3	32.1	38.2
TP-10	1.5m	70.7	32.7	38.0
	3.0m	69.5	31.8	37.7

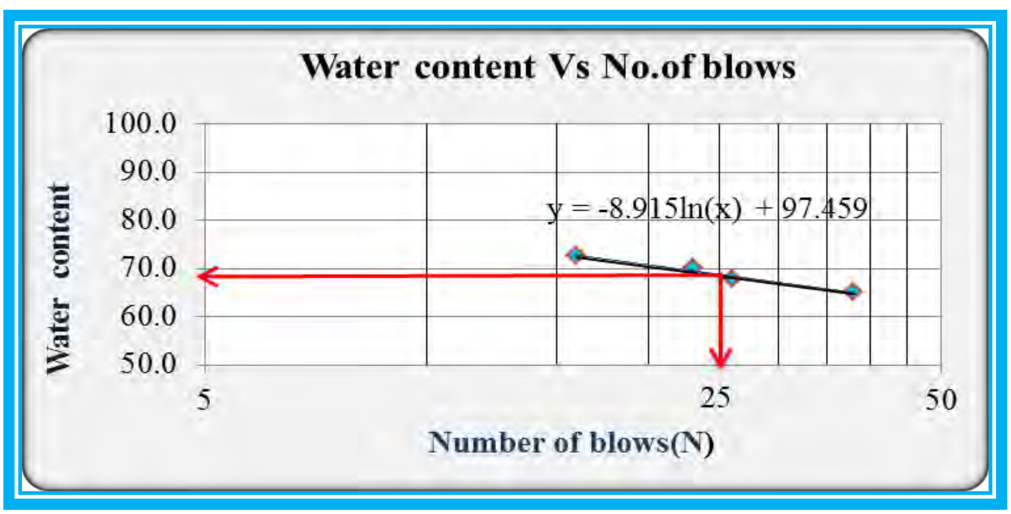


Figure 4.4: Typical liquid limit determinations for TP-9 @1.5 m

4.2.1.6. Free-Swell

Both the amount of swelling and the magnitude of swelling pressure are known to be dependent on the clay minerals, the soil mineralogy and structure, fabric and several physic-chemical aspects of the soil. Among clay minerals Montimorillonite influences the magnitude of swelling maximally than Illites and Kaolinites (Das, B.M).

To study the swelling property of the soils, the simplest test conducted is free swell test. The test is conducted by adding 10ml of dry soil passing No.40 sieve into 100ml graduate cylinder filled with distilled (tap) water. After 24 hours, final volume of the suspension being read. The free swell of the soil is then determined as a ratio of the change in volume to the initial volume. The free swell of soils of the study area ranges from 45-55%.This shows that the degree of swell of the soils is non-swelling.

$$Free\ swell = \frac{final\ volume - initial\ volume}{initial\ volume} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

Table 4.6: Free swell test results

Test Pit	Depth	Free Swell (%)	Test Condition
TP-1	1.5m	47.5	Oven Dry
	3.0m	52.5	“
TP-2	1.5m	50	“
	3.0m	52.5	“
TP-3	1.5m	40	“
	3.0m	52.5	“
TP-4	1.5m	45	“
	3.0m	48	“
TP-5	1.5m	53	“
	3.0m	55	“
TP-6	2.0m	42.5	“
TP-7	2.0m	53	“
TP-8	2.0m	45	“
TP-9	1.5m	50	“
	3.0m	55	“
TP-10	1.5m	52.5	“
	3.0m	47.5	“

4.2.2. Classification of the Soils

Soil classification is the arrangement of soils into different groups such that the soils in a particular group have similar behavior. It is the sort of labeling of soils with different labels. As there is a wide varieties of soils covering the earth, it is desirable to systemize or classify the soils into broad groups of similar behavior (Arora, K.R.).

Although, there are many soil classification systems are present in the world, Currently, two more elaborate classification systems are commonly used by soils engineers. Both systems take into consideration the particle-size distribution and Atterberg limits. They are the American Association of State Highway and Transportation Officials (AASHTO) classification system and the Unified Soil Classification System. The soils under investigation have been classified according to UCSC and AASHTO.

4.2.2.2. Unified Soil Classification System

The system is most popular for use in all types of engineering problems involving soils. This system classifies soils into two broad categories:

- Coarse-grained soils that are gravelly and sandy in nature with less than 50% passing through the No.200 sieve. The group symbols start with a prefix of G or S. G stands for gravel or gravelly soil, and S for sand or sandy soil.
- Fine-grained soils are with 50% or more passing through the No.200 sieve. The group symbols start with prefixes of M, which stands for inorganic silt, C for inorganic clay, or O for organic silts and clays. The symbol Pt is used for peat, muck, and other highly organic soils (Das, B.M., 1997).

Classification of the study area soil using USCS classification system is given below.

Table 4.7: Classification of soil based on USCS

Test Pit	Depth	percent Amount Of particle size				LL (%)	PI (%)	classification according to USCS
		Gravel	Sand	Silt	Clay			
TP-1	1.5m	0.8	16.7	18.7	63.7	68.9	36.5	CH
	3.0m	0	14.2	21.6	64.2	71.3	37.3	CH
TP-2	1.5m	0	8.2	23.3	68.5	71.9	39.5	CH
	3.0m	0	7.9	19.9	72.2	69.1	36.4	CH
TP-3	1.5m	0.7	13.3	28.3	57.7	70.8	37.8	CH
	3.0m	0	8.31	19.4	72.3	71.5	38.2	CH
TP-4	1.5m	0.4	14.6	29.3	55.7	69.3	36.9	CH
	3.0m	0	5.2	22.8	72	73.4	39.3	CH
TP-5	1.5m	0	2.8	34.1	63.1	71.0	37.9	CH
	3.0m	1.8	5.3	30.1	62.9	66.1	35.5	CH
TP-6	2.0m	0.3	5.57	27.7	66.4	68.8	37.8	CH
TP-7	2.0m	0.1	4.7	31.5	63.7	72.1	39.4	CH
TP-8	2.0m	0.3	7.5	22.8	69.4	72.1	39.8	CH
TP-9	1.5m	0	2.79	24.7	72.5	68.8	37.0	CH
	3.0m	0	3.6	23.6	72.8	70.3	38.2	CH
TP-10	1.5m	0.1	3.7	25	71.3	70.7	38.0	CH
	3.0m	0	6.7	19.5	73.8	69.5	37.7	CH

4.2.2.3. Plasticity Chart

The information provided in the plasticity chart is of great value and is the basis for the classification of fine-grained soils in the Unified Soil Classification System. Plasticity index, numerical difference between liquid limit and plastic limit, represents the range in water content through which a soil is in plastic state. A high numerical value of plasticity index is an indication of the presence of high percentage of clay in the soil sample. This implies that the plasticity values increase with the responding increase in clay content. The important feature of this chart is the empirical A-line that is given by the equation PI = 0.73(LL - 20). An A-line separates the inorganic clays from the inorganic silts. Inorganic clay values lie above the A-line, and values for inorganic silts lie below the A-line. Organic silts plot in the same region below the A-line and with LL ranging from 30 to 50 as the inorganic silts of medium compressibility. Organic clays plot in the same region as inorganic silts of high compressibility but below the A-line and LL greater than 50. A line called the U-line lies above the A-line. The U-line is approximately the upper limit of the relationship of the plasticity index to the liquid limit for any currently known soil. The equation for the U-line can be given as PI = 0.91(LL - 8) (Das, B.M., 1997). As could be seen in plasticity chart, all test pits of the study area fall in the inorganic clay range.

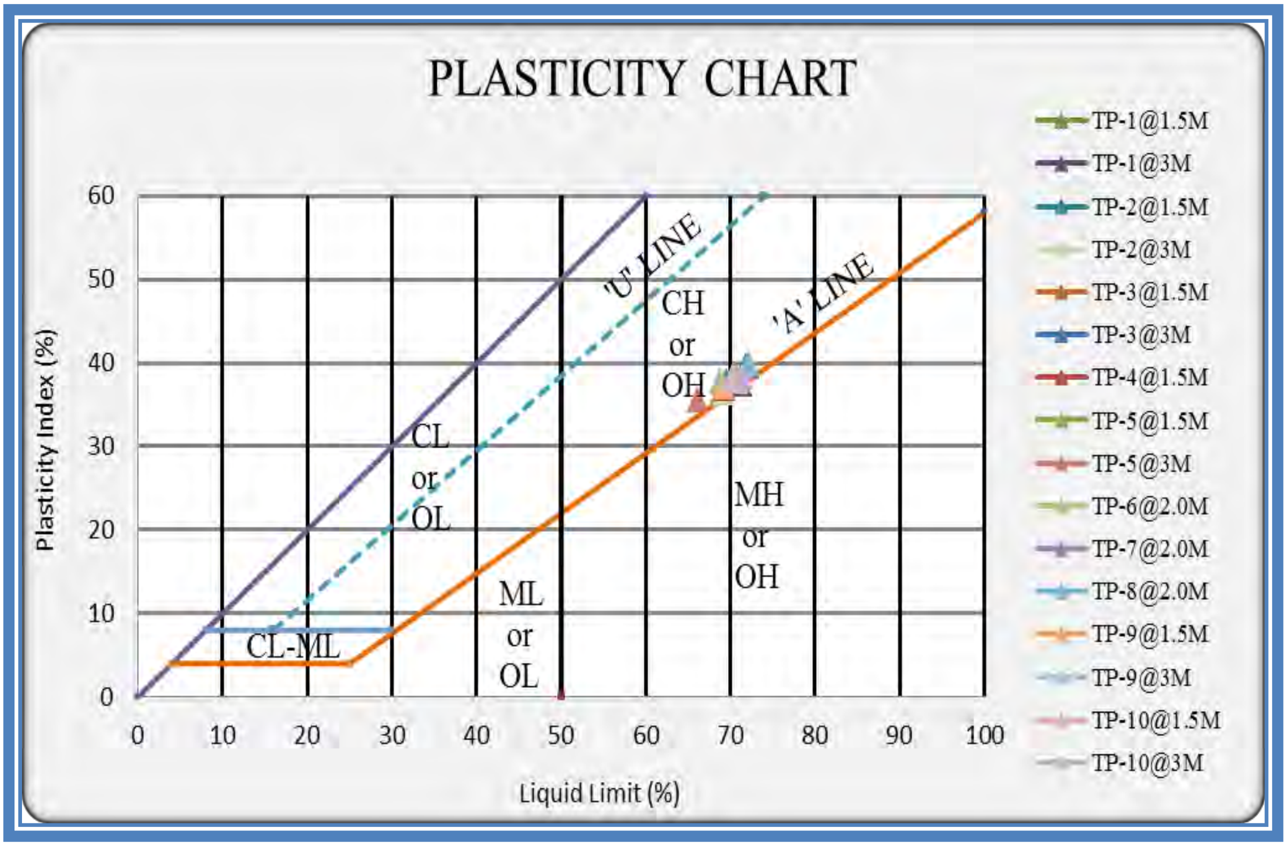


Figure 4.5: plasticity chart according to USCS system of classification

4.2.2.4. AASHTO Classification System

According to this system, soil is classified into seven major groups: A-1 through A-7. Soils classified under groups A-1, A-2, and A-3 are granular materials of which 35% or less of the particles pass through the No.200 sieve. Soils of which more than 35% pass through the No.200 sieve are classified under groups A-4, A-5, A-6, and A-7. These soils are mostly silt and clay type materials (Das, B.M., 1997).Classification of the study area soil using AASHTO classification system is given below.

Table 4.8: Classification of soil based on AASHTO

Test Pit	Depth	percent Amount Of particle size				LL (%)	PI (%)	Classification according to AASHTO	Usual types of significant constituent materials
		Gravel	Sand	Silt	Clay				
TP-1	1.5m	0.8	16.7	18.7	63.7	68.9	36.5	A-7-5	Clayey soil
	3.0m	0	14.2	21.6	64.2	71.3	37.3	A-7-5	Clayey soil
TP-2	1.5m	0	8.2	23.3	68.5	71.9	39.5	A-7-5	Clayey soil
	3.0m	0	7.9	19.9	72.2	69.1	36.4	A-7-5	Clayey soil
TP-3	1.5m	0.7	13.3	28.3	57.7	70.8	37.8	A-7-5	Clayey soil
	3.0m	0	8.3	19.4	72.3	71.5	38.2	A-7-5	Clayey soil
TP-4	1.5m	0.4	14.6	29.3	55.7	69.3	36.9	A-7-5	Clayey soil
	3.0m	0	5.2	22.8	72.0	73.4	39.3	A-7-5	Clayey soil
TP-5	1.5m	0	2.8	34.1	63.1	71.0	37.9	A-7-5	Clayey soil
	3.0m	1.8	5.3	41.7	51.2	66.1	35.5	A-7-5	Clayey soil
TP-6	2.0m	0.33	5.57	27.72	66.3	68.8	37.8	A-7-5	Clayey soil
TP-7	2.0m	0.1	4.7	31.5	63.7	72.1	39.4	A-7-5	Clayey soil
TP-8	2.0m	0.34	7.5	22.8	69.4	72.1	39.8	A-7-5	Clayey soil
TP-9	1.5m	0	2.79	24.7	72.5	68.8	37.0	A-7-5	Clayey soil
	3.0m	0	3.6	23.6	72.8	70.3	38.2	A-7-5	Clayey soil
TP-10	1.5m	0.1	3.7	25.0	71.3	70.7	38.0	A-7-5	Clayey soil
	3.0m	0	6.7	19.5	73.8	69.5	37.7	A-7-5	Clayey soil

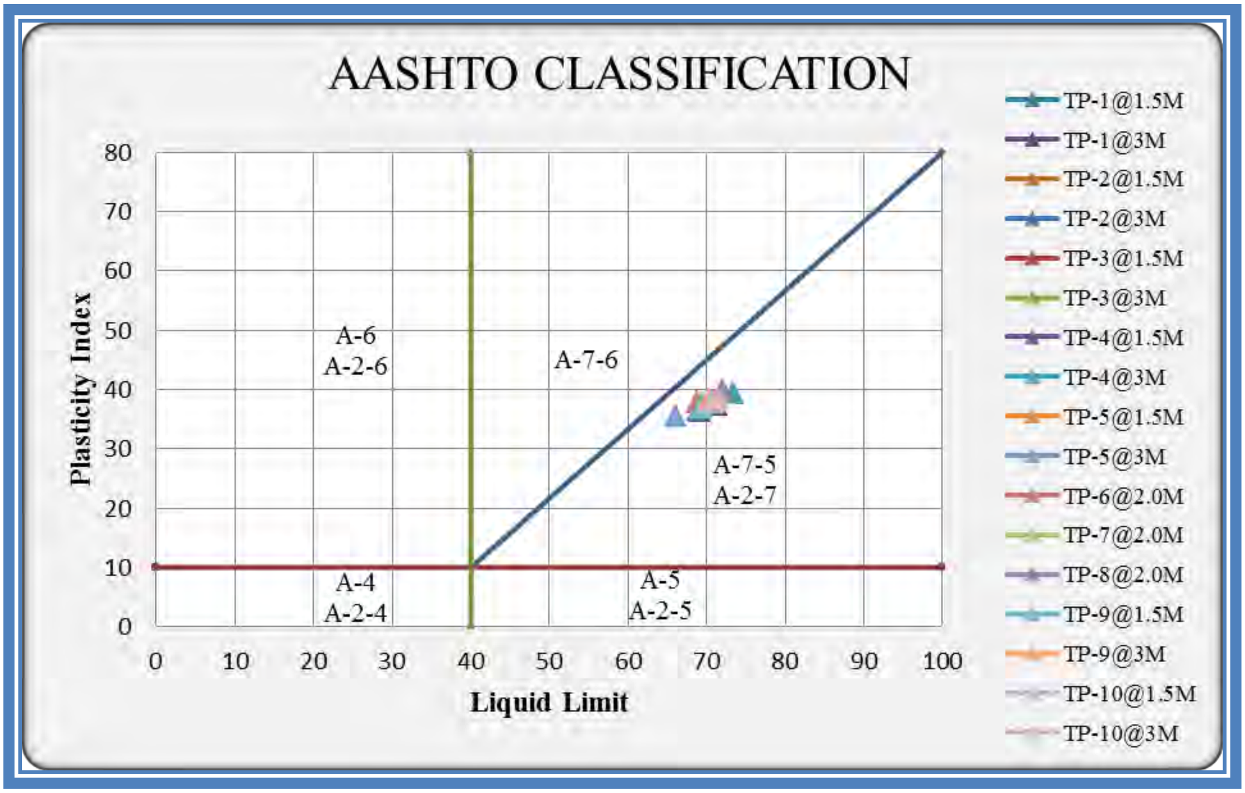


Figure 4.6: Plasticity chart according to AASHTO system of classification

4.2.2.5. Liquidity Index

The liquidity index of a soil indicates the nearness of its water content to its liquid limit. When the soil is at its liquid limit, its liquidity index is 100% and it behaves as a liquid. When soil is at the plastic limit, its liquidity index is zero. A negative value of the liquidity index indicates water content smaller than the plastic limit. The soil is then in hard (desiccated) state. The liquidity index is also called Water-Plasticity ratio (Arora, K.R.).

Liquidity index is given by

$$I_L = \frac{w(\%) - Pl}{PI} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

Where: - I_L= Liquidity index, W (%) = water content, P_L= plasticity limit and P_I= plasticity index

When $I_L < 0$: soil is in semi-plastic solid state or solid state, $I_L = 0$: soil is very stiff state,

$0 < I_L < 1$: soil is in plastic state and $I_L > 1$: soil is in liquid state.

The liquidity index values for the soils under investigation are calculated and summarized below.

Table 4.9: Liquidity index of the study area

Test Pit	Depth	NMC (%)	Plastic Limit	Plasticity Index	Liquidity Index	Remark
TP-1	1.5m	32.4	32.4	36.5	0.00	very stiff state
	3.0m	31.9	34.0	37.3	-0.06	solid state
TP-2	1.5m	32.7	32.4	39.5	0.01	plastic state
	3.0m	33.6	32.7	36.4	0.02	plastic state
TP-3	1.5m	32.9	33.0	37.8	0.00	plastic state
	3.0m	31.1	33.3	38.2	-0.06	solid state
TP-4	1.5m	32.4	32.4	36.9	0.00	very stiff state
	3.0m	31.5	34.1	39.3	-0.07	solid state
TP-5	1.5m	30.8	33.1	37.9	-0.06	solid state
	3.0m	31.9	30.6	35.5	0.04	plastic state
TP-6	2.0m	33.2	31.0	38.7	0.06	plastic state
TP-7	2.0m	32.9	32.7	39.4	0.01	plastic state
TP-8	2.0m	33.2	32.3	39.8	0.02	plastic state
TP-9	1.5m	32.9	31.8	37.0	0.03	plastic state
	3.0m	33.7	32.1	38.2	0.04	plastic state
TP-10	1.5m	31.8	32.7	38.0	-0.02	solid state
	3.0m	32.9	31.8	37.7	0.03	plastic state

As can be seen from the table the natural consistency of most of study area soils can be said to be in plastic state.

4.2.2.6. Activity

Skempton's colloidal activity is determined as the ratio of the plasticity index of the clay content to fines. He observed that, for a given soil, the plasticity index is directly proportional to the percent of clay-size fraction (i.e., percent by weight finer than 0.002 mm in size). Activity designated by "A" is defined as:

$$Ac = PI/C \quad \text{.. (4.3)}$$

Where C is the percent of clay - size fraction by weight finer than 0.002 mm in size. Activity has been used as an index property to determine the swelling potential of clays (Das, B.M., 1997).

Colloidal activity values for the soils under investigation are calculated and summarized below.

Table 4.10: Activity of the soil in the study area

Test Pit	Depth	PI	Clay fraction %	A=PI/C	Remark
TP-1	1.5m	36.5	55.62	0.66	Inactive
	3.0m	37.3	55.72	0.67	Inactive
TP-2	1.5m	39.5	59.25	0.67	Inactive
	3.0m	36.4	62.80	0.58	Inactive
TP-3	1.5m	37.8	47.03	0.80	Normal
	3.0m	38.2	62.22	0.61	Inactive
TP-4	1.5m	36.9	44.92	0.82	Normal
	3.0m	39.3	61.57	0.64	Inactive
TP-5	1.5m	37.9	53.91	0.70	Inactive
	3.0m	35.5	54.09	0.66	Inactive
TP-6	2.0m	37.8	58.99	0.64	Inactive
TP-7	2.0m	39.4	53.15	0.74	Inactive
TP-8	2.0m	39.8	60.63	0.66	Inactive
TP-9	1.5m	37.0	63.35	0.58	Inactive
	3.0m	38.2	62.29	0.61	Inactive
TP-10	1.5m	38.0	62.31	0.61	Inactive
	3.0m	37.7	63.60	0.59	Inactive

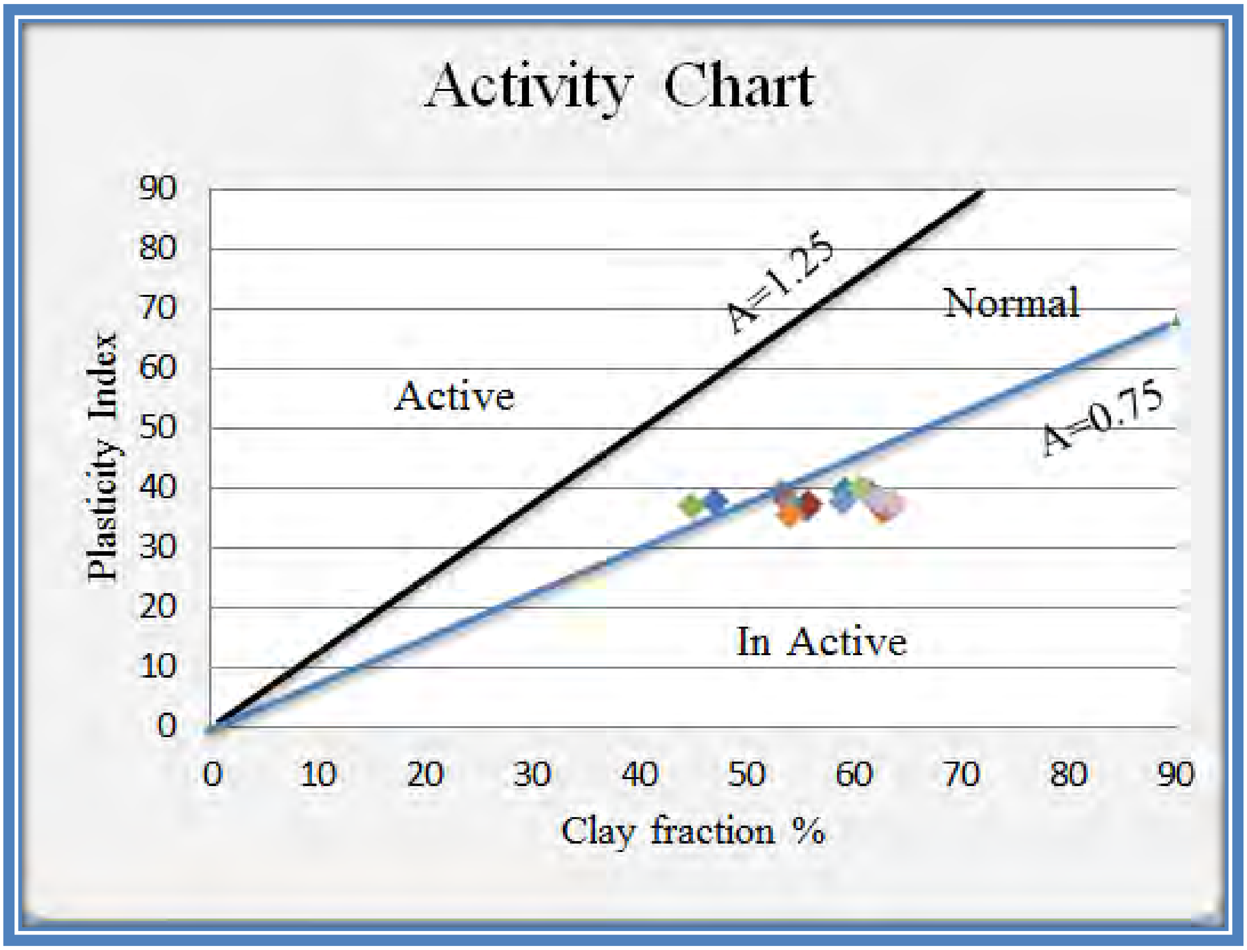


Figure 4.7: Activity chart of soils of the study area

From the above table and figure the most of study area soil lie in inactive range. This implies that soils collected from field are non-swelling soils.

4.2.3. Compaction Test

Compaction is a process of packing the soil particles by reducing the air voids in the soil through mechanical means. Soils have to be compacted to a dense state to improve their engineering properties like shear strength and therefore bearing capacity, stiffness and reduce settlement, compressibility and permeability.

A particular amount of water, which causes maximum lubrication, without becoming excess to cause hindrance is called optimum moisture content (OMC) and at this stage the soil would be compacted at a density called maximum dry density (MDD) (James, 1976).

Laboratory standard proctor compaction test was used according to ASTM D698 to determine the maximum dry density and optimum moisture content of soil under investigation. The values of maximum dry density and optimum moisture contents for selected soil samples have been summarized in table 4.11 and figure 4.8 below.

Table 4.11: Summary of Standard Compaction Test Result for selected soil sample

Test Pit	Depth (m)	OMC (%)	MDD (g/cm3)
TP-1	3.0m	30.4	1.33
TP-2	3.0m	30.5	1.31
TP-3	3.0m	33.8	1.38
TP-5	3.0m	35.0	1.37
TP-7	2.0m	32.1	1.32
TP-9	3.0m	31.9	1.35

From the test result showed above the maximum dry density (MDD) of Burayu ranges from 1.31 to 1.38 g/cm^3 and the optimum moisture content ranges 30.4 to 35.0 %.

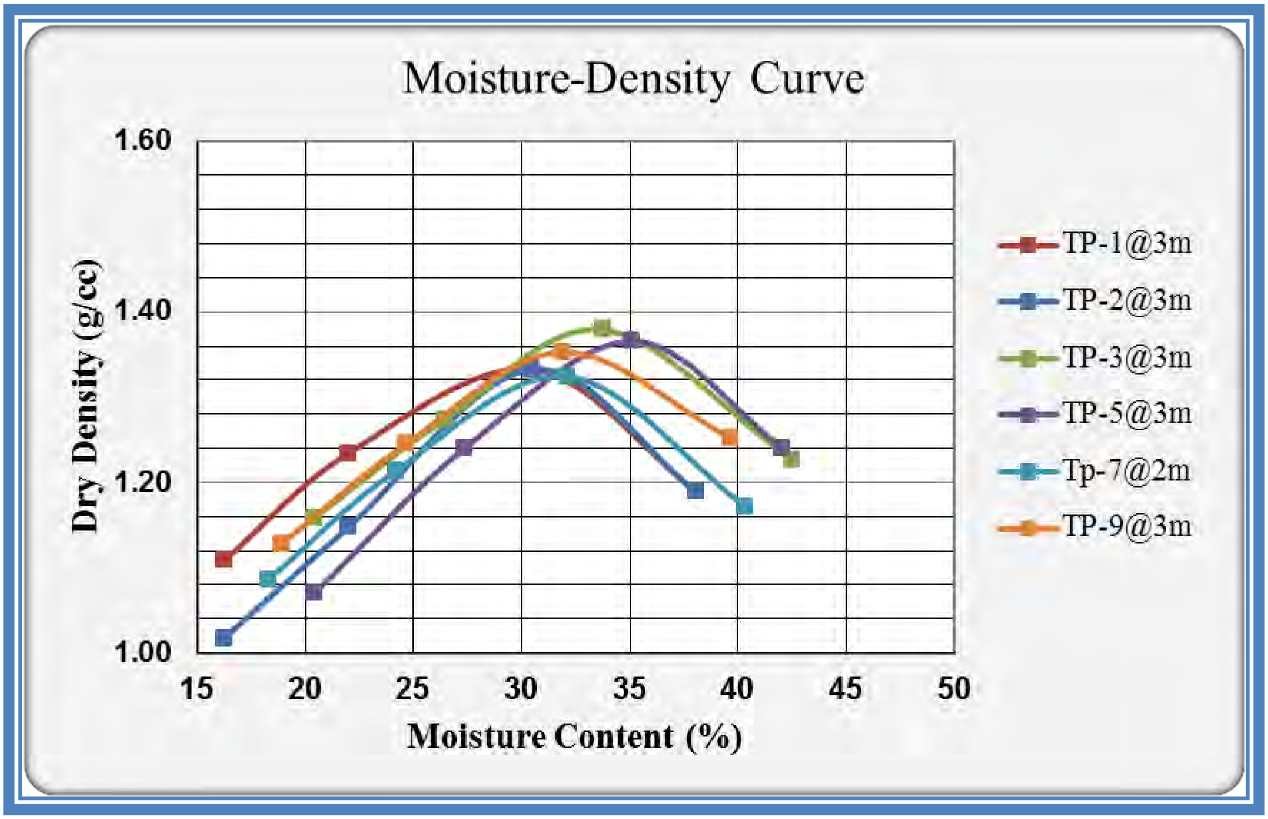


Figure 4.8: Dry Density versus Optimum Moisture Content Curve

4.2.4. Shear Strength of Soil

4.2.4.1. General

The shear strength of a soil is its maximum resistance to shear stresses just before the failure. It is the principal engineering property which controls the stability of a soil mass under loads. It governs the bearing capacity of soils , the stability of slopes in soils , the earth pressure against retaining structure and many other problem. All the problem of soils engineering are related in one way or the other with the shear strength of the soil (Arora, K.R.).

The most common laboratory methods employed to obtain shear strength parameters are direct shear test, triaxial compression test and unconfined compression test. For this thesis UCS test are conducted.

4.2.4.2. Unconfined Compression Strength (UCS) Test

Unconfined compression test is a one of the simplest and quickest test used for the determination of shear strength of cohesive soils (Murthy, 1990).

The consistency of clay soils and other cohesive soils is usually described as soft, medium, stiff or hard. The most direct quantitative measure of consistency is the load per unit area at which unconfined cylindrical samples of the soil fails in compression test. This quantity is known as the unconfined compressive strength of the soil (Terzaghi, K., 1996).

Unconfined Compressive Strength of soils of the study area is summarized below in table 4.12 and figure 4.9.

Table 4.12: Unconfined Compressive Strength of soils of the study area

Test Pit	Depth (m)	Water content (%)	UCS (kN/m^2)	Liquidity Index (L_I)	Consistency*
TP-3	3.0m	31.1	465.18	-0.06	Hard
TP-4	3.0m	31.4	372.82	-0.07	Hard
TP-5	3.0m	31.9	328.88	0.04	Hard
TP-9	3.0m	33.7	306.68	0.04	Hard

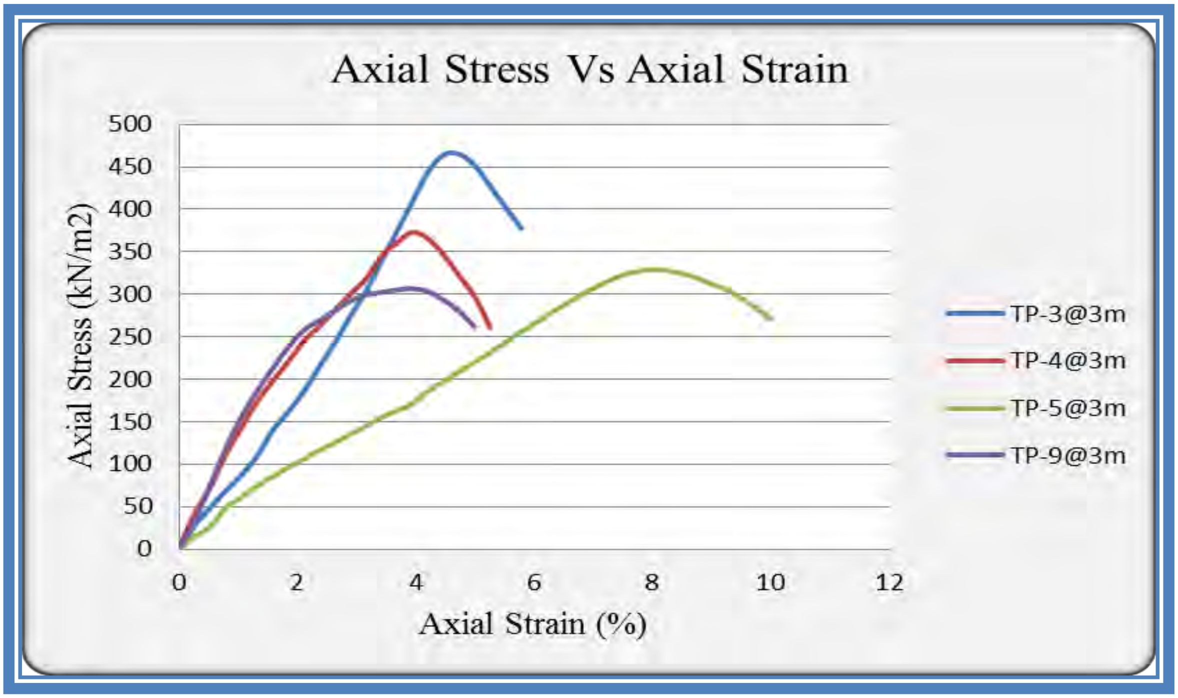


Figure 4.9: Axial stress Vs. Axial Strain of the study area

Compressive strength of soils of the study area ranges from 306.68kN/m^2 – 465.18kN/m ^{2}, which fall in the range of hard state. The remaining test pits have similar soil texture with either of these test pits.

4.2.5. One-dimensional Consolidation Test

Consolidation test also called Oedometer test, is a measurement of how soils compress when saturated with water and exposed to varying amounts of load.

Consolidation tests were carried out for representative samples where the remaining test pits have similar result with either of these test pits. After carefully trimming the soil sample at its top and bottom, it was placed inside the metal ring with porous stones at its top and bottom. A sitting load of 7kPa was applied. The loads were applied through the lever arm and the dial gauge readings were taken at a time interval of 0.1,0.25,0.5,1,2,4,8,15,30,60,120,240,480,1440 minutes. The loads were doubled every 24hrs starting from 50kPa to 1600kPa.

Preconsolidation stress is the maximum vertical effective stress that a soil was subjected to in the past and swelling pressure is defined as the vertical pressures require preventing the volume change of laterally confined sample when it is allowed to take in water (Teferra, et al., 1999).

Preconsolidation pressures and Swelling pressure of soils of the study area were done for representative samples by using graphical method from void ratio Vs log p curve as shown in Fig 4.10 & 4.11 and table 4.13 below.

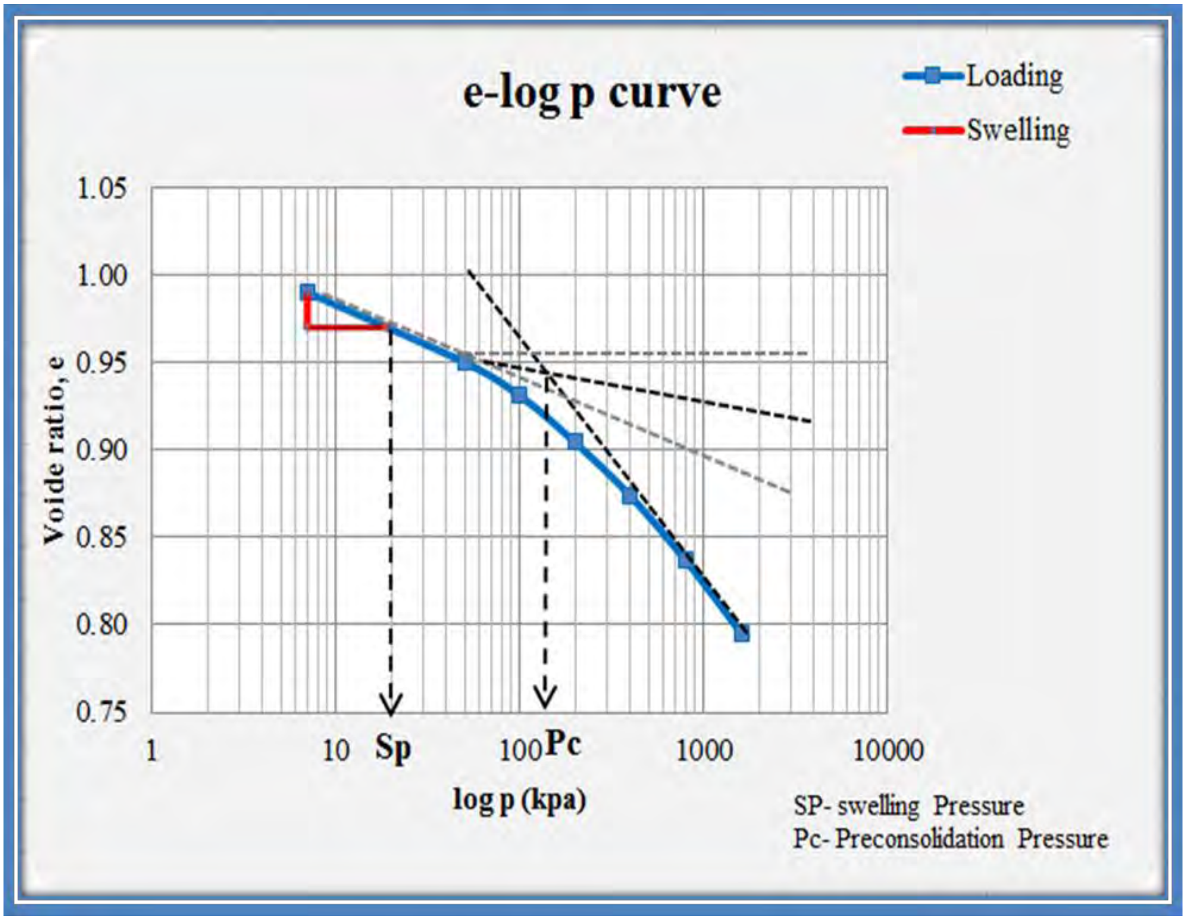


Figure 4.10: Void ratio Vs log p curve of sample taken from Gefersa Guji area.

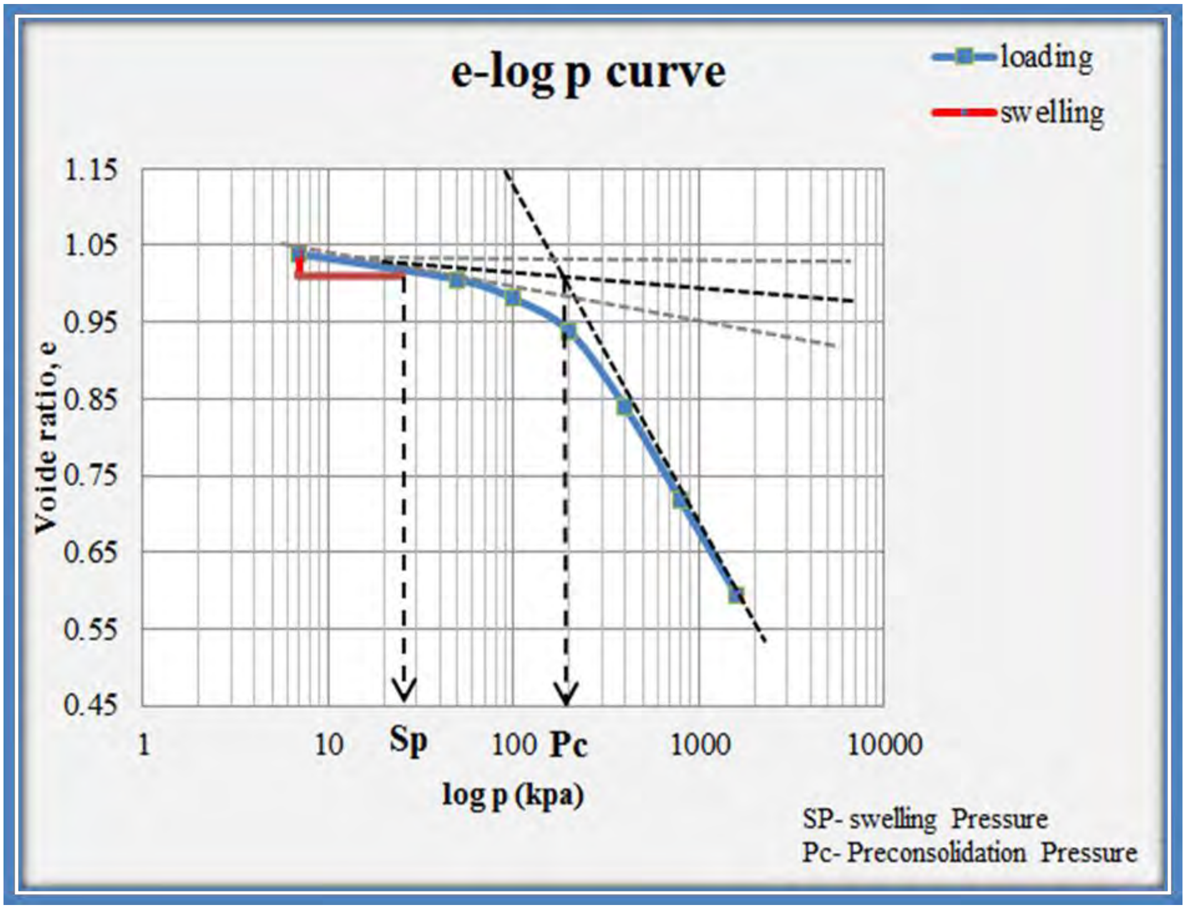


Figure 4.11: Void ratio Vs log p curve of sample taken from Melka Gefersa area.

Table 4.13: Preconsolidation and swelling pressure test results of soils of Burayu town

Test pit	Depth (m)	Total unit weight (kN/m^3)	Overburden pressure, Po (Kpa)	Compression index (Cc)	Preconsolidation Pressure, Pc (Kpa)	Swelling Pressure (KPa)	Over consolidation ratio
TP-3	3	19.8	59.4	0.099	150	20	2.53
TP-7	2	18.4	36.8	0.133	200	25	5.44

4.2.5.4. Coefficient of consolidation (Cv)

The Coefficient of Consolidation is a parameter used to describe the rate at which saturated clay or other soil undergoes consolidation when subjected to an increase in pressure.

The coefficient of consolidation Cv can be evaluated by means of laboratory tests by fitting the experimental curve with the theoretical. There are two laboratory methods that are in common use for the determination of Cv. They are: Casagrande logarithm of time fitting method and Taylor square root of time fitting method.

In Casagrande logarithm of time fitting method, the interval between 0 and 100% consolidation is divided in to equal intervals of percent consolidation. Since it has been found that the laboratory and theoretical curves have better correspondence at the central portion, the value of Cv is computed by taking the time t and time factor T at 50% consolidation (Murthy, 1990).

$$C_v = 0.197 \frac{{H_{dr}}^2}{t_{50}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.4)$$

Where: - ${H_{dr}}^2$ = drainage path

Square root of time fitting method was devised by Taylor. The fitting method consists of first drawing the straight line which best fits the early portion of the laboratory curve. Next a straight line is drawn which at all points has abscissa 1.15 times as great as those of the first line. The intersection of this line and the laboratory curve is taken as 90% consolidation point. Its value may be read and is designated as t_{90}.

$$C_v = 0.484 \frac{{H_{dr}}^2}{t_{90}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.5)$$

Consolidation coefficients of soils of the study area are summarized below in table 4.14.

Table 4.14: Consolidation coefficients of soils of the study area

Location	Test Pit No.	Depth(m)	Pressure (kPa)	Void ratio (e)	Coefficient of Consolidation Cv ($10^{-3}cm^2/sec$)
Gefersa Guji	TP-3	3	50	0.95	2.20
			100	0.93	1.90
			200	0.90	1.69
			400	0.87	1.57
			800	0.84	1.25
			1600	0.80	1.05
Melka Gefersa	TP-7	2	50	1.01	2.49
			100	0.98	2.15
			200	0.94	1.72
			400	0.84	1.35
			800	0.72	1.03
			1600	0.59	0.84

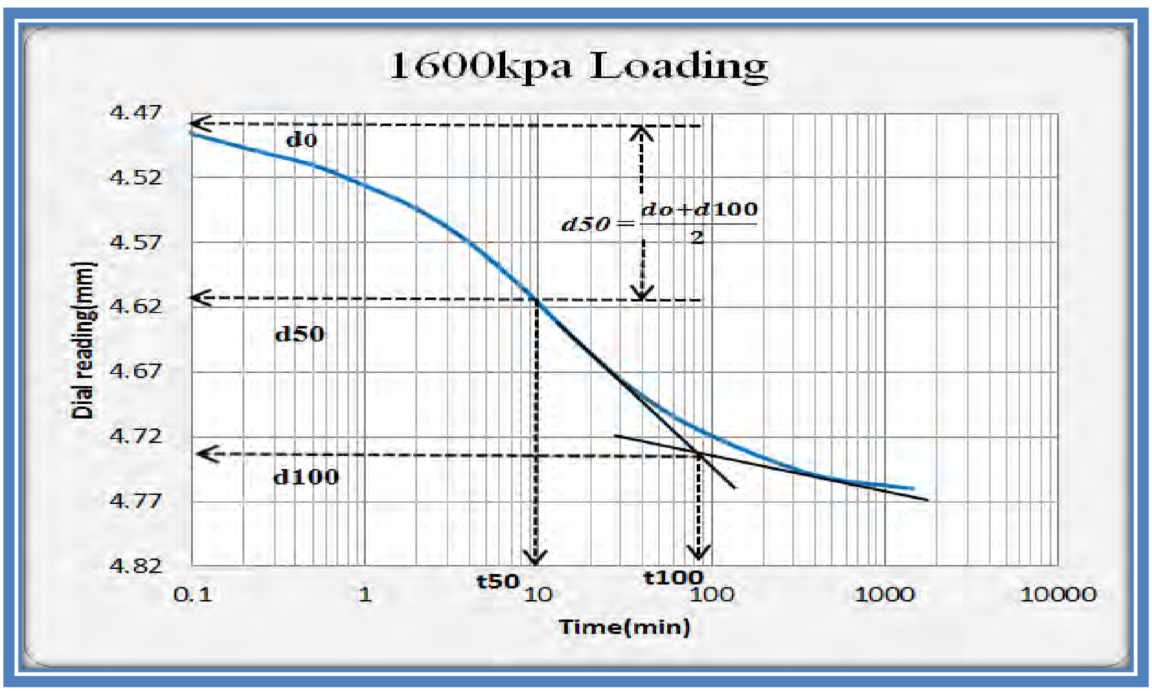


Figure 4.12: Typical curve (Logarithm of time curve fitting method) of TP-3@3m

4.2.5.5. Coefficient of Permeability

The coefficient of permeability can be measured using field tests, or tests conducted in the laboratory. Permeability is sometimes also estimated from one dimensional consolidation test. The coefficient of permeability can be obtained from the following relationship (Teferra, et al., 1999).

$$k = \frac{cv * av * \gamma w}{1 + e} \dots\dots\dots\dots\dots\dots\dots . (4.6)$$

Where: c_v - coefficient of consolidation, a_v- coefficient of compressibility, ɣw- unit weight of water and e - void ratio.

Using the above equation, the coefficient of permeability as the function of void ratio was calculated from the consolidation test results and shown in Table 4.15. It is noted that coefficient of compressibility (a_v) is the ratio of change in void ratio to change in pressure, was obtained from Fig 4.13. As shown in Table 4.15, the range of values of coefficient of permeability lies between $0.41* 10^{-8}$ - $6.94* 10^{-8}$ cm/sec, which indicates that the soils are practically impervious or have low permeability. In general, void ratio versus log coefficient of permeability is close to a straight line for nearly all soils (Krishna R., 2002). As shown in Fig 4.14, for all the soil samples void ratio versus log coefficient of permeability is close to a straight line.

Table 4.15: Relationship between Void ratio and coefficient of permeability

Depth(m)	Pressure (kPa)	Void ratio (e)	Coefficient of Consolidation, Cv ($10^{-3}cm^2/sec$)	Coefficient of Compressibility, a_v ($10^{-5}cm^2/KN$)	Coefficient of permeability, k ($10^{-8}cm/sec$)
3	50	0.95	2.20	36	4.06
	100	0.93	1.90	28	2.76
	200	0.90	1.69	16	1.42
	400	0.87	1.57	14	1.18
	800	0.84	1.25	10	0.68
	1600	0.80	1.05	7	0.41
2	50	1.01	2.49	56	6.94
	100	0.98	2.15	39	4.23
	200	0.94	1.72	43	3.81
	400	0.84	1.35	31	2.27
	800	0.72	1.03	20	1.20
	1600	0.59	0.84	17.5	0.92

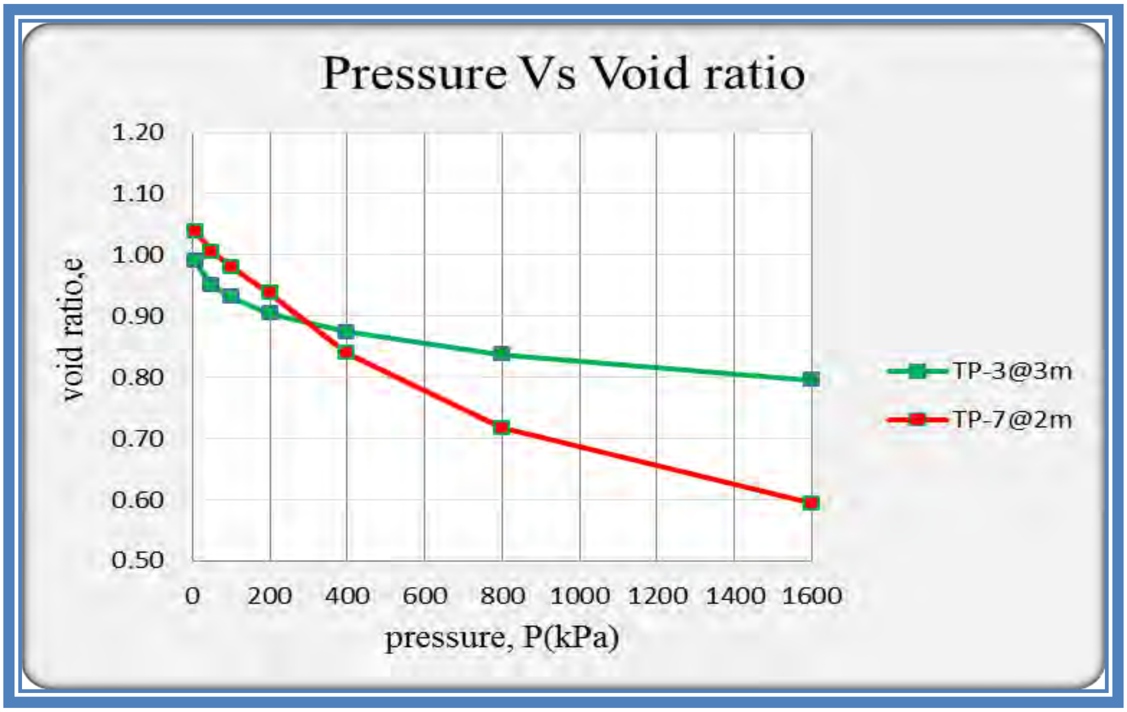


Figure 4.13 Plot of vertical effective stress Vs void ratio on linear scale

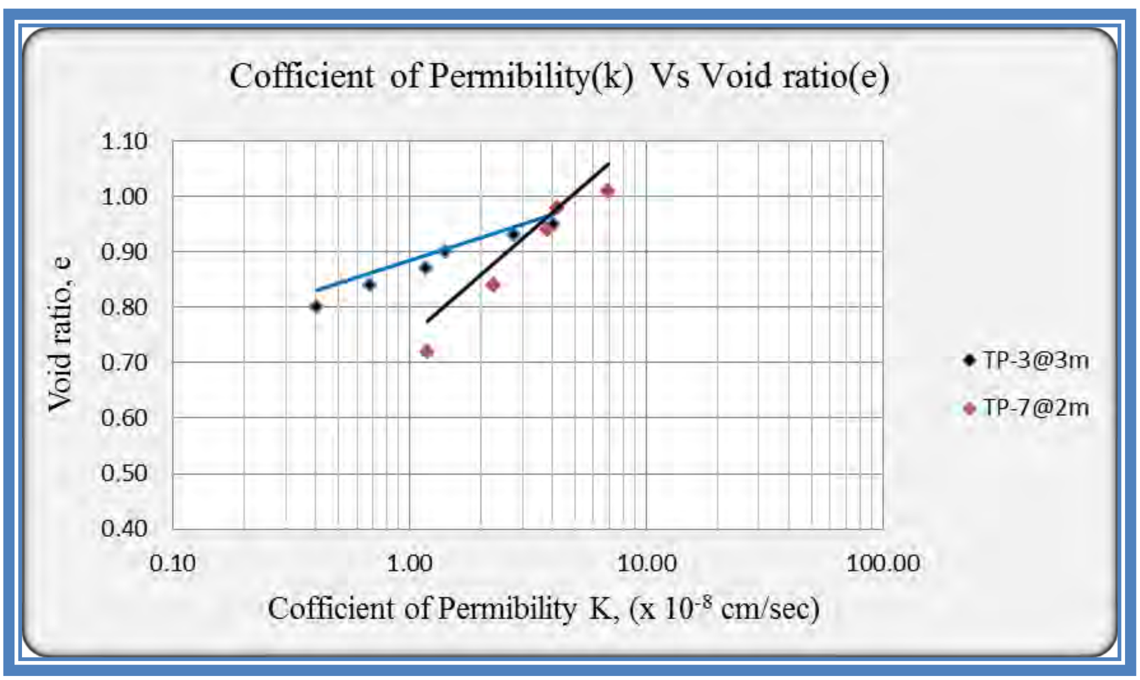


Figure: 4.14 Void ratios Vs Log Coefficient of Permeability

CHAPTER 5

5. DISCUSSION AND COMPARISON OF TEST RESULTS AND SOIL MAP OF BURAYU TOWN

5.1. Discussion of the laboratory test results

The soil samples were collected from Burayu town. As the town is situated at the southwestern foot of Entoto Ridge, most of the existing built up areas of the town lies on rugged terrain (land profile with steep slopes, deep streams or river valleys with steep gradients, deep river/stream banks, gullies and ridges) with limited flat lands. This topographic setting plays important role for the formation of soils in the town.

The results of grain size analysis conducted on disturbed soil samples were indicated in Fig 4.2, 4.3 and summarized in Table 4.4.The results indicate that the predominant proportion of soil particles in the study area is clay, which have clay content ranging from 55.7-73.8%, silt content ranging from 18.7-34.1%, sand content ranging from 2.8-16.7% and gravel content ranging from 0-1.8%.

The results of specific gravity test indicate that the specific gravity of soils of the study area ranges from 2.7-2.82%, which is in the range of typical specific gravity values of inorganic soils.

Test results of Atterberg's limits indicate that soils of the study are have Liquid limit ranging from 66.1-72.1%, plastic limit ranges from 30.6 – 34.1 % and plastic index from 35.5 – 39.8%.

The free swell of soils of the study area ranges from 40-55%.This shows that the degree of expansiveness of the soils is non-expansive.

Table 4.6 and Fig 4.4 show classification of soils of the study area according to USCS. Accordingly soils of the study area are classified as highly plastic clay (CH).

Table 4.7 and Fig 4.5 indicate classifications of soils of the study area according to AASHTO soil classification system. Accordingly soils of the study area are grouped in A-7-5, which means clay soil with poor quality as a subgrade material.

The Activity of the study area soil under investigation ranges from 0.58-0.82.This implies most of the study area soils fall in inactive range.

The Compaction test result showed that maximum dry density (MDD) of the study area ranges from 1.31 to 1.38 g/cm^3 and the optimum moisture content (OMC) ranges from 30.5 to 35.0%.

Unconfined compressive strength tests conducted on undisturbed representative samples show that unconfined compressive strength of Burayu soils ranges from 306.68 – 465.18kN/m^2.

Consolidation tests were carried out for representative samples where the remaining test pits have similar result with either of these test pits. The test results show that TP-3 has Preconsolidation pressure of 150kPa and swelling pressure 20kPa, whereas TP-7 has preconsolidation pressure of 200kPa and swelling pressure 25kPa.

5.2. Comparison of test results with previously done researches

For the soil under investigation Index property tests were studied and comparisons were made with known Addis Ababa red clay soils as we discussed in the literature (Samuel.Tadesse, 1989). Results of the current research are summarized and compared to with range of values of soils found in different Addis Ababa town. A comparison of the study area soil with other parts of the country is given in the table below.

Table 5.1: Comparison of Test Results in different parts of Addis Ababa town

Description	**Previous Research (Samuel.T,1989)**	**Previous Research (Samuel.T,1989)**	**Previous Research (Samuel.T,1989)**	**Current Research**
Soil Type	Red clay	Red Clay	Red Clay	Red Clay
Location	Kolfe	Rufael	Semen Gebeya	Burayu
Clay Content	58-70	50-70	53-68	56-74
Activity	<0.75	<0.75	<0.75	<0.75
Liquid Limit	61-75	56 -75	57-76	66-72
Plastic Limit	28-33	27-34	24-31	31-34
Plastic Index	30-43	29-41	33-47	36-40
Specific	2.66-2.73	2.66-2.74	2.70-2.77	2.70-2.82
Soil	CH	CH	CH	CH
Free Swell	15-45	30-40	15-50	40-55

As shown in the table above the soils of Burayu town when compared with the previously tested soils of Kolfe, Rufael and Semen Gebeya show considerable similarities with Clay content, activity and classification. More similarity is observed with respect to the index tests and physical properties. Moreover, the test result shows that the value of plasticity is high as these soils due to the mode of formation, i.e., they are formed at warm temperate climatic conditions. Generally, the soil of Burayu could be classified as red clay soil with almost close characteristics with Kolfe, Rufael and Semen Gebeya soils. However, Burayu soil has high value of specific gravity.

5.3. Soil map of Burayu town

5.3.1. General

Soil map is a map i.e. a geographical representation showing diversity of soil types and/or soil properties (soil pH, textures, organic matter, depths of horizons etc.) in the area of interest. For this thesis soil map of Burayu town was prepared based on information collected from GPS data, field visual observation of different areas and laboratory tests results.

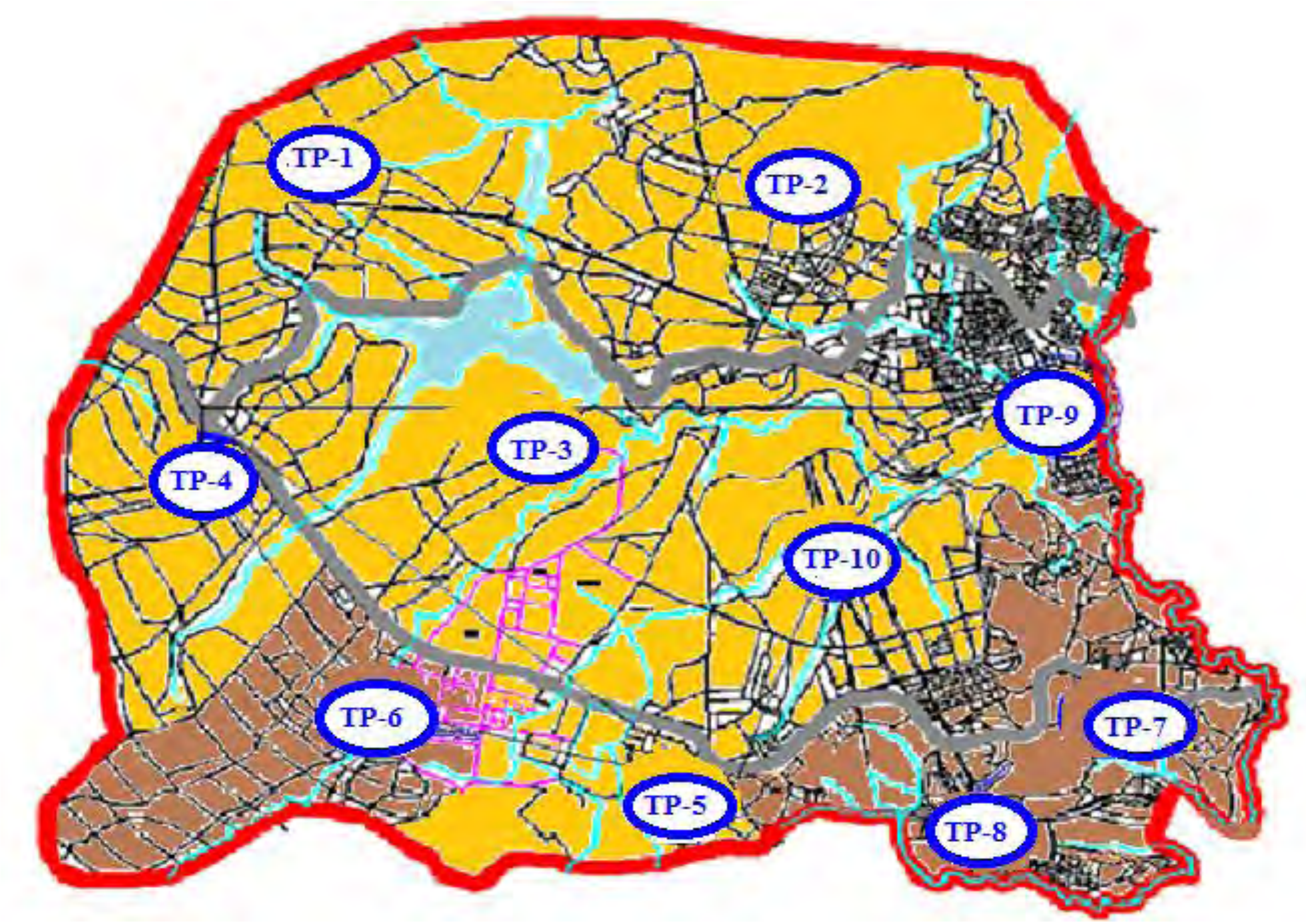
5.3.2. Soil map of the study area

Visual observation made during reconnaissance survey for test pit location shows that almost all parts of Burayu town are covered with reddish brown clay soil. Test pits are excavated to a maximum depth of 3m where in some areas boulder are encounter so it makes the excavation difficult. The vertical soil profiles i.e. bore hole log in details are presented in Appendix-A for the ten test pits. Index tests conducted in soil laboratory of AAiT indicate that one main type of soils is available in Burayu town.

(1) Highly plastic clay soils (CH): These are mainly reddish clay soils with no degree of expansive in nature. Test results shows that almost all parts of Burayu town are covered with highly plastic clay soil.

❖ Blocks and Boulders: At many localities like Gefersa Nono and Melka Gefersa are covered with massive blocks and boulders which are buried under the reddish brown soil. As compared to the basalt unit the ignimbrites are thick and characterized by columnar joints as observed in the quarry face. Both of these rock units are widely used as construction materials.

Oromia Urban Plan Institute has given structural map of the Burayu town and soil map of the town has been done on this structural map as shown below.



LEGEND

CH @ 1.5m & 3.0m with Activity A= max 0.82(Normal)

CH@ 2m - Top layer with Activity A =max 0.74 (Inactive)
Rock - bottom layer

Reseviour

Figure 5.1: Soil Map of Burayu town

CHAPTER 6

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusion

From the results of the investigation we can conclude that:

- Since pit excavation method of exploration is used, the outcomes would be applicable only for light structures which under lie their foundation up to depth of 3m.
- Results of Atterberg limits tests show that soils of Burayu town have liquid limit ranging from 66.1-72.1%, plastic limit 30.6-36.1% and PI ranging from 32.7-39.8%. This indicates that soils of the study area are highly plastic.
- The grain size distribution indicates all soil samples have clay material more than 50%. Therefore clay type of soil is dominantly located in the study area.
- The free swell test result indicates that soils of the study area are nonexpansive which means degree of swell of the soils is non-swelling.
- The degrees of activity of most of the study area soils are Inactive with maximum Activity index of 0.74.
- USCS soil classification system indicates one main type of soils, which is: CH, high plastic clay soils whereas AASHTO soil classification system shows that soils of the study area are grouped in A-7-5, this indicate that they have poor quality and unsuitable for using as a sub grade material.
- The Compaction test result showed that maximum dry density (MDD) of the study area ranges from 1.31 to 1.38 g/cm3 and the optimum moisture content (OMC) ranges 30.5 to 35.0%.
- The unconfined compressive strength test result and liquidity index indicates the soil consistency of the study area fall in hard state.
- Finally the consolidation test result shows that the soil exists naturally in a condition of over-consolidated, which has O.C.R >1, therefore the soil had been subjected to a pressure in excess of the present pressure.

6.2. Recommendations

- The numbers of test pits taken are not enough to generalize the engineering properties of soils found in Burayu town. However, by increasing the number of test pits, more detail results can be obtained.

- Correlations that relate index proprieties with shear strength parameters were not done due to insufficient data. Further studies can shade light on this aspect of the problem.

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APPENDIX – A

BORE HOLE-LOG

Test pit: 01 (TP-1) Sampled Date:23/08/2007

Location: At Gefersa Burayu

Coordinate, x: 0457922 Elevation(m): 2524

y:1004419

Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	_	Fill	_
-1.5	+-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell tests
-3.0	+-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+- +-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity, Free swell, compaction, Consolidation and UCS tests

Test pit: 02 (TP-2)			Sampled Date:24/08/2007
Location: At Burayu Keta			
Coordinate, x: 0462512 y: 1004200		Elevation(m): 2547	
Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	_	Fill	_
-1.5	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell tests
-3.0	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity, Free swell, compaction, Consolidation and UCS tests

Test pit: 03 (TP-3) Sampled Date:26/08/2007

Location: At Gefersa Guji

Coordinate, x: 0460044 Elevation(m): 2615

y: 1001363

Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	_	Fill	_
-1.5	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell tests
-3.0	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity, Free swell, compaction, Consolidation and UCS tests

<table>
<tr><td colspan="4">Test pit: 04(TP-4) Sampled Date:28/05/2007
Location: At Gefersa Guji
Coordinate, x: 0456788 Elevation(m): 2627
y: 1000991</td></tr>
<tr><td>Depth (m)</td><td>Test pit Log</td><td>Visual Description</td><td>Type Of Test Done</td></tr>
<tr><td>-0.3</td><td>_</td><td>Fill</td><td>_</td></tr>
<tr><td>-1.5</td><td>+-+-+-+-+-+-+-+-
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+-+-+-+-+-+-+-+-</td><td>Reddish Brown Clay</td><td>Grain size analysis, Atterberg limit, Specific gravity and Free swell tests</td></tr>
<tr><td>-3.0</td><td>+-+-+-+-+-+-+-+-
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+-+-+-+-+-+-+-+-</td><td>Reddish Brown Clay</td><td>Grain size analysis, Atterberg limit, Specific gravity, Free swell, compaction, Consolidation and UCS tests</td></tr>
</table>

Test pit: 05 (TP-5) Location: At Gefersa Nono Coordinate, x: 0461502 Elevation(m): 2647 y: 0997341			Sampled Date:27/05/2007
Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	_	Fill	_
-1.5	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell tests
-3.0	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity, Free swell, compaction, Consolidation and UCS tests

Test pit: 06 (TP-6) Sampled Date:26/06/2007

Location: At Gefersa Nono

Coordinate, x: 0458443 Elevation(m): 2637

y: 0998377

Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	_	Fill	_
-2.0	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell
Unknown	/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0	Boulder Material	……………..

Test pit: 07(TP-7) Location: At Melka Gefersa Coordinate, x: 0465636 Elevation(m): 2536 y: 0998303			Sampled Date:29/05/2007
Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	_	Fill	_
-2.0	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell, Compaction tests
Unknown	/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0	Boulder Material	……………..

Test pit: 08(TP-8) Sampled Date:27/06/2007

Location: At Melka Gefersa

Coordinate, x: 0464349 Elevation(m): 2500

y: 0997057

Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	–	Fill	–
-2.0	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell
Unknown	/0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0 /0/0/0/0/0/0/0/0/0	Boulder Material	………………

Test pit: 09(TP-9) Sampled Date:21/05/2007

Location: At Leku keta

Coordinate, x: 0465229 Elevation(m): 2595

y: 1001703

Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	_	Fill	_
-1.5	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell tests
-3.0	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity, Free swell, compaction, Consolidation and UCS tests

Test pit: 10(TP-10)			Sampled Date:21/08/2007
Location: At Leku keta			
Coordinate, x: 0462950 y: 1000055		Elevation(m): 2619	
Depth (m)	Test pit Log	Visual Description	Type Of Test Done
-0.3	_	Fill	_
-1.5	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity and Free swell tests
-3.0	+-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+- +-+-+-+-+-+-+-	Reddish Brown Clay	Grain size analysis, Atterberg limit, Specific gravity, Free swell, compaction, Consolidation and UCS tests

APPENDIX – B

INDEX PROPERTIES TEST RESULTS

(A) Grain size analysis

Test pit 1(TP-1)

At 1.5m depth

Sieve Analysis (weight of dry soil= 204.2g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1264.7	1.7	0.83	0.83	99.17
No.8	2.360	989.8	999.3	9.5	0.79	1.62	98.38
No.10	2.000	955.8	968.7	12.9	1.08	2.70	97.30
No.16	1.180	894.4	917.2	22.8	1.90	4.60	95.40
No.30	0.600	830.8	862.4	31.6	2.63	7.23	92.77
No.40	0.425	786.2	802.4	16.2	1.35	8.58	91.42
No.50	0.300	750.1	771.3	21.2	1.77	10.35	89.65
No.100	0.150	777.9	825.8	47.9	3.99	14.34	85.66
No.200	0.075	763.4	801.7	38.3	3.19	17.53	82.47
Pan	-	734.8	736.9	2.1	0.18	17.71	82.29

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03250	0.00236	1.03014	7.703100	21.4	0.01322	0.042354754	93.93	77.47
1	1.03200	0.00236	1.02964	7.835360	21.4	0.01322	0.036993848	92.37	76.18
2	1.03100	0.00236	1.02864	8.099880	21.2	0.01325	0.026660888	89.26	73.61
4	1.03050	0.00236	1.02814	8.232140	21.3	0.01323	0.018982433	87.70	72.33
8	1.03000	0.00236	1.02764	8.364400	21.1	0.01326	0.013562724	86.14	71.04
15	1.02900	0.00236	1.02664	8.628920	21.9	0.01314	0.009963128	83.02	68.47
30	1.02850	0.00236	1.02614	8.761180	21.5	0.01320	0.007133368	81.47	67.18
60	1.02700	0.00236	1.02464	9.157960	21.6	0.01318	0.005150756	76.79	63.33
120	1.02600	0.00236	1.02364	9.422480	21.6	0.01331	0.003729667	73.67	60.76
240	1.02500	0.00236	1.02264	9.687000	21.6	0.01318	0.002648721	70.56	58.19
480	1.02400	0.00236	1.02164	9.951520	23.5	0.01290	0.001856716	67.44	55.62
1440	1.02250	0.00236	1.02014	10.348300	21.9	0.01314	0.001113567	62.77	51.76

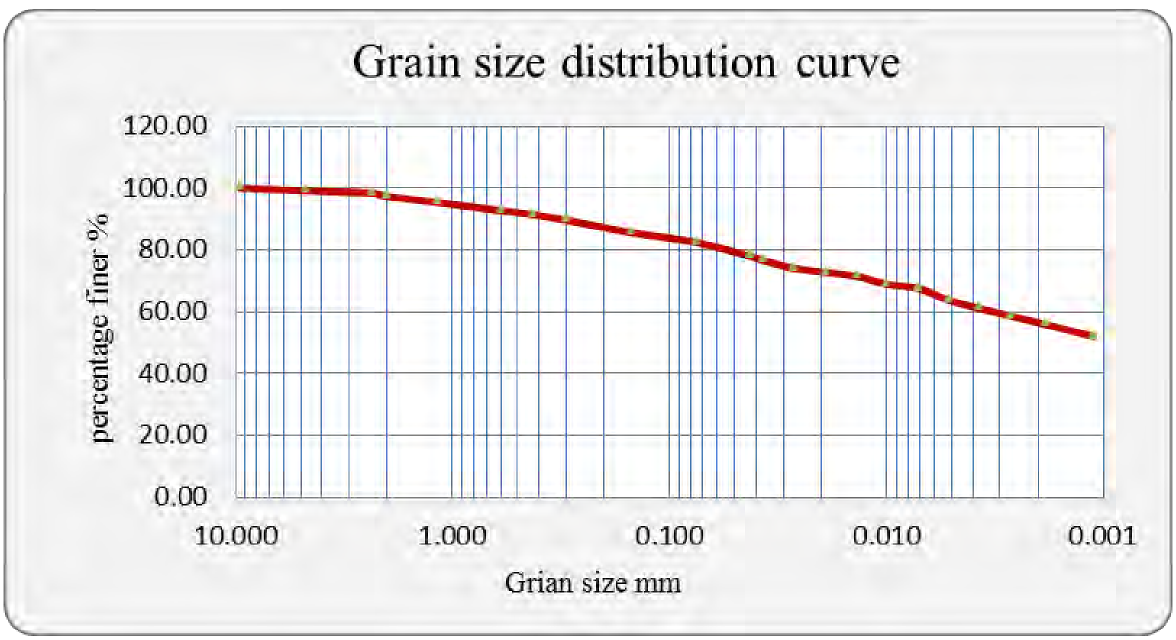

Figure: Grain size distribution curve for TP-1@1.5m

At 3m depth

Sieve Analysis (weight of dry soil= 172.5g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1263.0	0.0	0.00	0.00	100.00
No.8	2.360	989.8	999.3	9.5	0.79	0.79	99.21
No.10	2.000	955.8	967.1	11.3	0.94	1.73	98.27
No.16	1.180	894.4	909.4	15.0	1.25	2.98	97.02
No.30	0.600	830.8	849.2	18.4	1.53	4.52	95.48
No.40	0.425	786.2	809.8	23.6	1.97	6.48	93.52
No.50	0.300	750.1	765.8	15.7	1.31	7.79	92.21
No.100	0.150	777.9	826.1	48.2	4.02	11.81	88.19
No.200	0.075	763.4	792.4	29.0	2.42	14.23	85.78
Pan	-	734.8	736.6	1.8	0.15	14.38	85.63

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03200	0.00236	1.02964	7.835360	21.7	0.01299	0.041970177	93.28	80.01
1	1.03150	0.00236	1.02914	7.967620	21.7	0.01299	0.036652724	91.71	78.67
2	1.03100	0.00236	1.02864	8.099880	21.4	0.01303	0.026222175	90.13	77.32
4	1.03000	0.00236	1.02764	8.364400	21.5	0.01302	0.018820518	86.99	74.62
8	1.02950	0.00236	1.02714	8.496660	21.5	0.01302	0.013412919	85.41	73.27
15	1.02850	0.00236	1.02614	8.761180	21.4	0.01303	0.009958183	82.26	70.57
30	1.02800	0.00236	1.02564	8.893440	21.1	0.01308	0.00711895	80.69	69.22
60	1.02650	0.00236	1.02414	9.290220	21.1	0.01308	0.005144925	75.97	65.17
120	1.02500	0.00236	1.02264	9.687000	21.6	0.01300	0.003693579	71.25	61.12
240	1.02400	0.00236	1.02164	9.951520	22.6	0.01285	0.002616629	68.10	58.42
480	1.02300	0.00236	1.02064	10.216040	23.6	0.01270	0.001852782	64.96	55.72
1440	1.02200	0.00236	1.01964	10.480560	21.1	0.01308	0.001115457	61.81	53.02

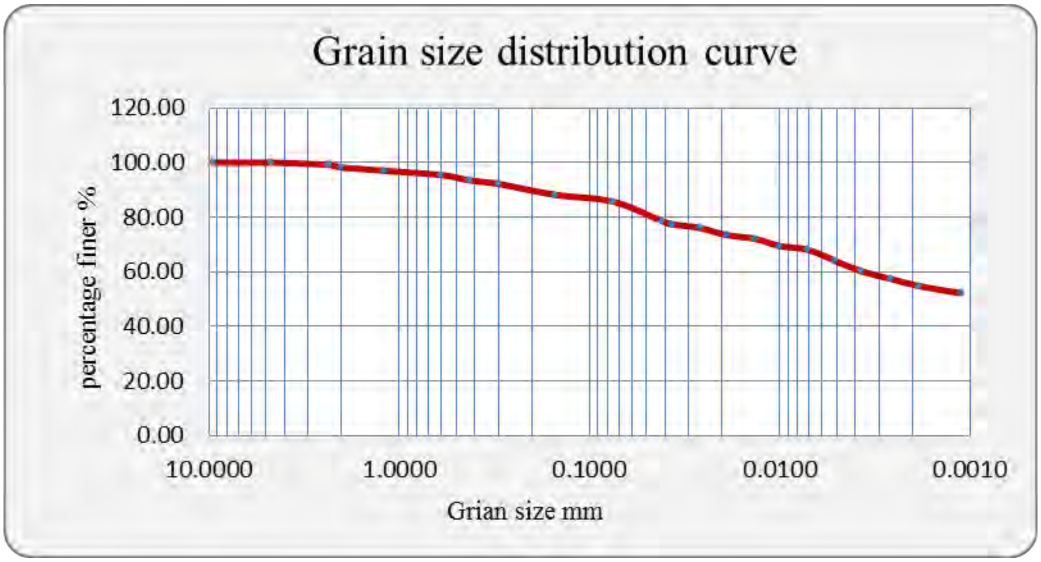

Figure: Grain size distribution curve for TP-1@3.0m

Test pit 2(TP-2)

At 1.5m depth

Sieve Analysis (weight of dry soil= 99.1g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1263.1	0.1	0.01	0.01	99.99
No.8	2.360	989.8	998.8	9.0	0.75	0.76	99.24
No.10	2.000	955.8	966.3	10.5	0.88	1.63	98.37
No.16	1.180	894.4	895.6	1.2	0.10	1.73	98.27
No.30	0.600	830.8	843.8	13.0	1.08	2.82	97.18
No.40	0.425	786.2	789.0	2.8	0.23	3.05	96.95
No.50	0.300	750.1	773.9	23.8	1.98	5.03	94.97
No.100	0.150	777.9	799.9	22.0	1.83	6.87	93.13
No.200	0.075	763.4	779.5	16.1	1.34	8.21	91.79
Pan	-	734.8	735.4	0.6	0.05	8.26	91.74

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03300	0.00222	1.03078	7.570840	22.5	0.01287	0.04087	95.60	87.76
1	1.03250	0.00222	1.03028	7.703100	22.5	0.01287	0.03571	94.05	86.33
2	1.03200	0.00222	1.02978	7.835360	22.5	0.01287	0.02546	92.50	84.90
4	1.03100	0.00222	1.02878	8.099880	22.5	0.01287	0.01831	89.39	82.05
8	1.03000	0.00222	1.02778	8.364400	22.1	0.01293	0.01322	86.28	79.20
15	1.02850	0.00222	1.02628	8.761180	21.9	0.01296	0.00990	81.63	74.93
30	1.02700	0.00222	1.02478	9.157960	22.1	0.01293	0.00714	76.97	70.65
60	1.02600	0.00222	1.02378	9.422480	22.5	0.01287	0.00510	73.86	67.80
120	1.02450	0.00222	1.02228	9.819260	22.8	0.01282	0.00367	69.20	63.52
240	1.02350	0.00222	1.02128	10.083780	23.9	0.01266	0.00259	66.10	60.67
480	1.02300	0.00222	1.02078	10.216040	22.9	0.01281	0.00187	64.54	59.25
1440	1.02200	0.00222	1.01978	10.480560	20.3	0.01320	0.00113	61.44	56.39

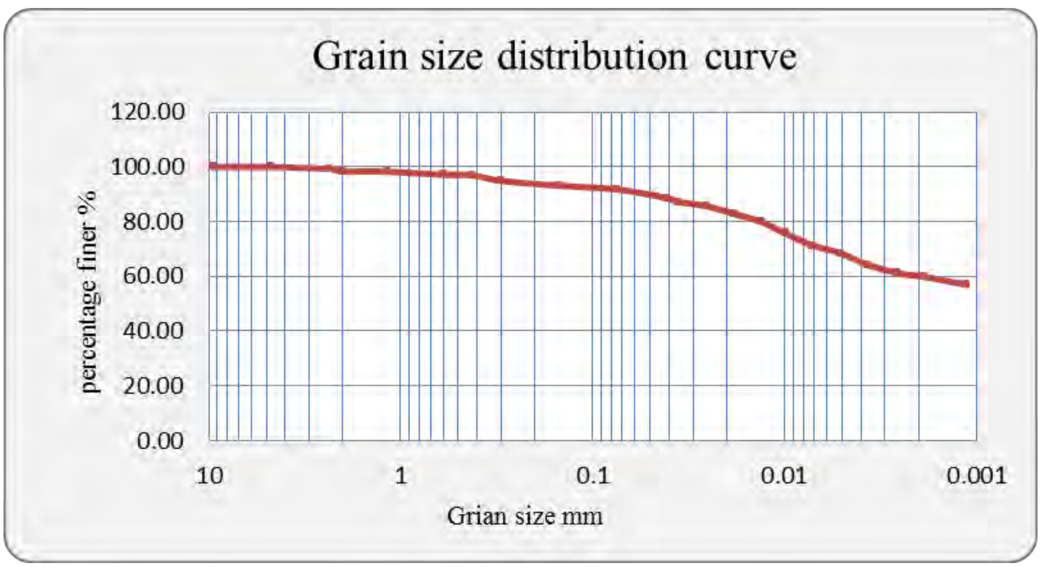

Figure: Grain size distribution curve for TP-2@1.5m

At 3m depth

Sieve Analysis (weight of dry soil= 95.6g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.000	0.000	100.00
2"	50.000	1199.0	1199.0	0.0	0.000	0.000	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.000	0.000	100.00
1"	25.000	1217.0	1217.0	0.0	0.000	0.000	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.000	0.000	100.00
1/2"	12.500	459.2	459.2	0.0	0.000	0.000	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.000	0.000	100.00
No.4	4.750	1262.8	1262.8	0.0	0.000	0.000	100.00
No.8	2.360	989.8	998.7	8.9	0.742	0.742	99.26
No.10	2.000	955.8	966.7	10.9	0.908	1.650	98.35
No.16	1.180	894.4	898.3	3.9	0.325	1.975	98.03
No.30	0.600	830.8	844.4	13.6	1.133	3.108	96.89
No.40	0.425	786.2	798.9	12.7	1.058	4.167	95.83
No.50	0.300	750.1	759.1	9.0	0.750	4.917	95.08
No.100	0.150	777.6	798.4	20.8	1.733	6.650	93.35
No.200	0.075	763.4	777.9	14.5	1.208	7.858	92.14
Pan	-	734.8	736.1	1.3	0.108	7.967	92.03

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03350	0.0022	1.03130	7.438580	22.7	0.01266	0.039854424	97.86	90.17
1	1.03300	0.0022	1.03080	7.570840	22.7	0.01266	0.034820434	96.29	88.73
2	1.03250	0.0022	1.03030	7.703100	22.4	0.01270	0.024924215	94.73	87.29
4	1.03100	0.0022	1.02880	8.099880	22.5	0.01269	0.018050938	90.04	82.96
8	1.03000	0.0022	1.02780	8.364400	22.7	0.01266	0.012940008	86.92	80.08
15	1.02900	0.0022	1.02680	8.628920	22.2	0.01273	0.009655194	83.79	77.20
30	1.02800	0.0022	1.02580	8.893440	22.4	0.01270	0.006914774	80.66	74.32
60	1.02750	0.0022	1.02530	9.025700	22.7	0.01266	0.004908253	79.10	72.88
120	1.02600	0.0022	1.02380	9.422480	23.6	0.01252	0.003508297	74.41	68.56
240	1.02450	0.0022	1.02230	9.819260	23.2	0.01258	0.00254457	69.72	64.24
480	1.02400	0.0022	1.02180	9.951520	22.2	0.01273	0.001832958	68.16	62.80
1440	1.02300	0.0022	1.02080	10.216040	20.2	0.01304	0.001098174	65.03	59.92

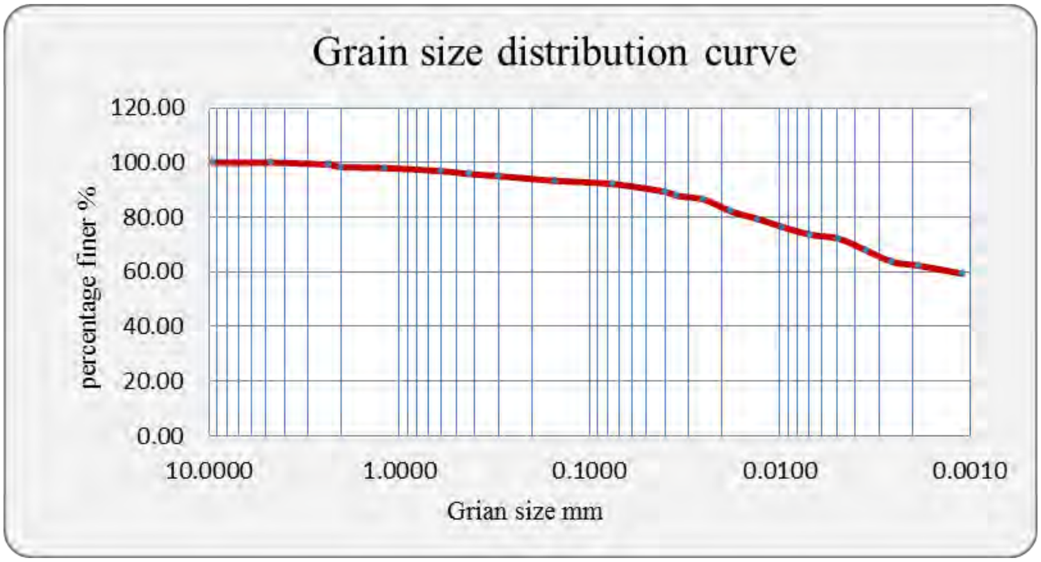

Figure: Grain size distribution curve for TP-2@3.0m

Test pit 3(TP-3)

At 1.5m depth

Sieve Analysis (weight of dry soil= 162.7g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1264.2	1.2	0.74	0.74	99.26
No.8	2.360	989.8	999.3	9.5	0.79	1.53	98.47
No.10	2.000	955.8	958.9	3.1	0.26	1.79	98.21
No.16	1.180	894.4	909.2	14.8	1.23	3.02	96.98
No.30	0.600	830.8	856.4	25.6	2.13	5.15	94.85
No.40	0.425	786.2	806.4	20.2	1.68	6.84	93.16
No.50	0.300	750.1	773.3	23.2	1.93	8.77	91.23
No.100	0.150	777.9	802.8	24.9	2.08	10.85	89.15
No.200	0.075	763.4	801.7	38.3	3.19	14.04	85.96
Pan	-	734.8	736.7	1.9	0.16	14.20	85.80

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03100	0.00236	1.02864	8.099880	21.4	0.01322	0.043431886	88.83	76.36
1	1.03050	0.00236	1.02814	8.232140	21.4	0.01322	0.037918959	87.28	75.02
2	1.03000	0.00236	1.02764	8.364400	21.2	0.01325	0.027092727	85.73	73.69
4	1.02900	0.00236	1.02664	8.628920	21.3	0.01323	0.019434515	82.62	71.02
8	1.02750	0.00236	1.02514	9.025700	21.1	0.01326	0.014088669	77.97	67.02
15	1.02650	0.00236	1.02414	9.290220	21.9	0.01314	0.010337857	74.87	64.36
30	1.02550	0.00236	1.02314	9.554740	21.5	0.01320	0.007449425	71.77	61.69
60	1.02400	0.00236	1.02164	9.951520	21.6	0.01318	0.005369283	67.12	57.69
120	1.02250	0.00236	1.02014	10.348300	21.6	0.01331	0.003908606	62.46	53.69
240	1.02100	0.00236	1.01864	10.745080	21.6	0.01318	0.002789629	57.81	49.69
480	1.02000	0.00236	1.01764	11.009600	23.5	0.01290	0.001952929	54.71	47.03
1440	1.01950	0.00236	1.01714	11.141860	21.9	0.01314	0.001155476	53.16	45.70

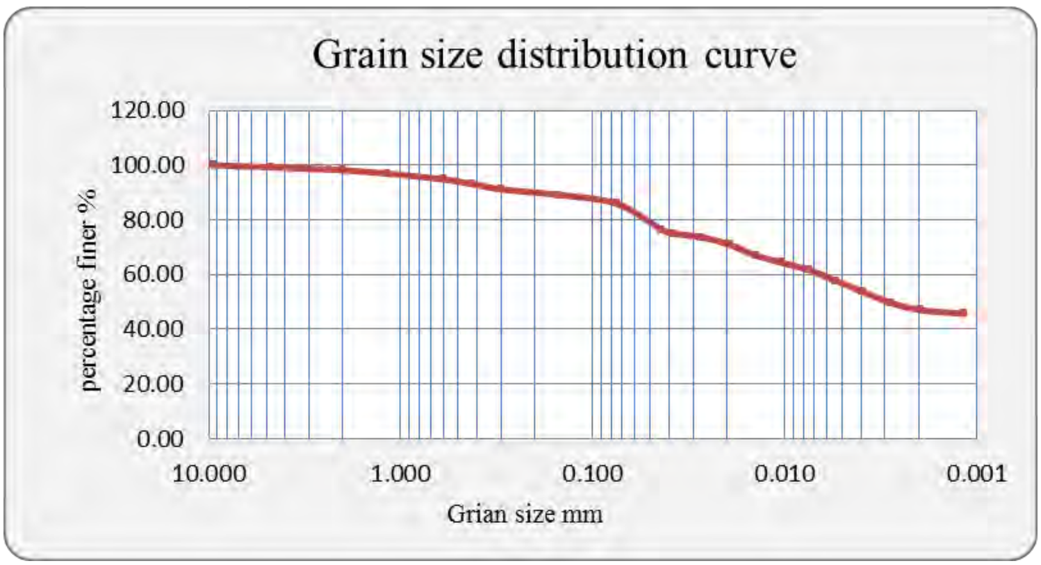

Figure: Grain size distribution curve for TP-3@1.5m

At 3m depth

<u>Sieve Analysis</u> (weight of dry soil= 100.1g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1263.0	0.0	0.00	0.00	100.00
No.8	2.360	989.8	991.3	1.5	0.13	0.13	99.88
No.10	2.000	955.8	959.1	3.3	0.28	0.40	99.60
No.16	1.180	894.4	899.4	5.0	0.42	0.82	99.18
No.30	0.600	830.8	844.2	13.4	1.12	1.93	98.07
No.40	0.425	786.2	799.8	13.6	1.13	3.07	96.93
No.50	0.300	750.1	757.8	7.7	0.64	3.71	96.29
No.100	0.150	777.9	811.1	33.2	2.77	6.48	93.53
No.200	0.075	763.4	785.4	22.0	1.83	8.31	91.69
Pan	-	734.8	735.2	0.4	0.03	8.34	91.66

<u>Hydrometer analysis</u>

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03350	0.00236	1.03114	7.438580	21.7	0.01299	0.040893694	97.66	89.54
1	1.03300	0.00236	1.03064	7.570840	21.7	0.01299	0.035728435	96.09	88.10
2	1.03200	0.00236	1.02964	7.835360	21.4	0.01303	0.025790449	92.95	85.23
4	1.03100	0.00236	1.02864	8.099880	21.5	0.01302	0.018520532	89.82	82.35
8	1.03000	0.00236	1.02764	8.364400	21.5	0.01302	0.013308116	86.68	79.48
15	1.02950	0.00236	1.02714	8.496660	21.4	0.01303	0.0098067	85.11	78.04
30	1.02850	0.00236	1.02614	8.761180	21.1	0.01308	0.007065817	81.98	75.16
60	1.02750	0.00236	1.02514	9.025700	21.1	0.01308	0.005071151	78.84	72.29
120	1.02600	0.00236	1.02364	9.422480	21.6	0.01300	0.0036428	74.14	67.98
240	1.02500	0.00236	1.02264	9.687000	22.6	0.01285	0.002581619	71.00	65.10
480	1.02400	0.00236	1.02164	9.951520	23.6	0.01270	0.001828638	67.86	62.22
1440	1.02300	0.00236	1.02064	10.216040	21.1	0.01308	0.00110129	64.73	59.35

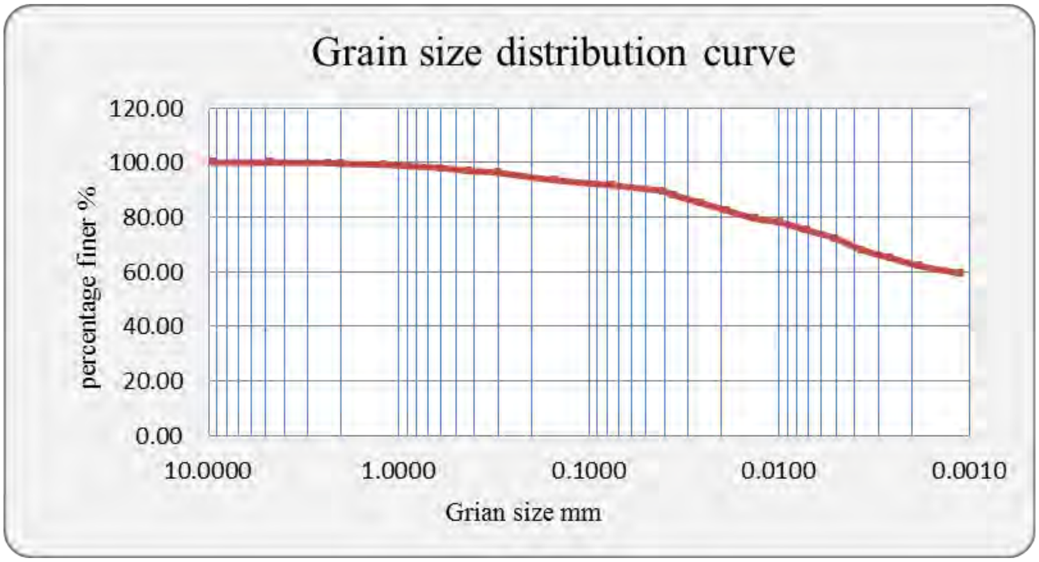

Figure: Grain size distribution curve for TP-3@3.0m

Test pit 4(TP-4)

At 1.5m depth

Sieve Analysis (weight of dry soil= 178.0g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1263.7	0.7	0.39	0.39	99.61
No.8	2.360	989.8	993.3	3.5	0.29	0.68	99.32
No.10	2.000	955.8	958.7	2.9	0.24	0.93	99.07
No.16	1.180	894.4	907.2	12.8	1.07	1.99	98.01
No.30	0.600	830.8	862.4	31.6	2.63	4.63	95.37
No.40	0.425	786.2	806.4	20.2	1.68	6.31	93.69
No.50	0.300	750.1	771.3	21.2	1.77	8.08	91.92
No.100	0.150	777.9	822.8	44.9	3.74	11.82	88.18
No.200	0.075	763.4	801.7	38.3	3.19	15.01	84.99
Pan	-	734.8	736.7	1.9	0.16	15.17	84.83

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03000	0.00236	1.02764	8.364400	21.4	0.01322	0.044135372	87.78	74.61
1	1.02950	0.00236	1.02714	8.496660	21.4	0.01322	0.038523359	86.20	73.26
2	1.02900	0.00236	1.02664	8.628920	21.2	0.01325	0.027517789	84.61	71.91
4	1.02800	0.00236	1.02564	8.893440	21.3	0.01323	0.01973015	81.43	69.21
8	1.02700	0.00236	1.02464	9.157960	21.1	0.01326	0.014191519	78.26	66.51
15	1.02600	0.00236	1.02364	9.422480	21.9	0.01314	0.010411184	75.08	63.81
30	1.02450	0.00236	1.02214	9.819260	21.5	0.01320	0.007551838	70.32	59.76
60	1.02300	0.00236	1.02064	10.216040	21.6	0.01318	0.005440175	65.55	55.71
120	1.02150	0.00236	1.01914	10.612820	21.6	0.01331	0.003958246	60.79	51.66
240	1.02000	0.00236	1.01764	11.009600	21.6	0.01318	0.002823757	56.02	47.61
480	1.01900	0.00236	1.01664	11.274120	23.5	0.01290	0.001976251	52.85	44.92
1440	1.01750	0.00236	1.01514	11.670900	21.9	0.01314	0.00118259	48.08	40.87

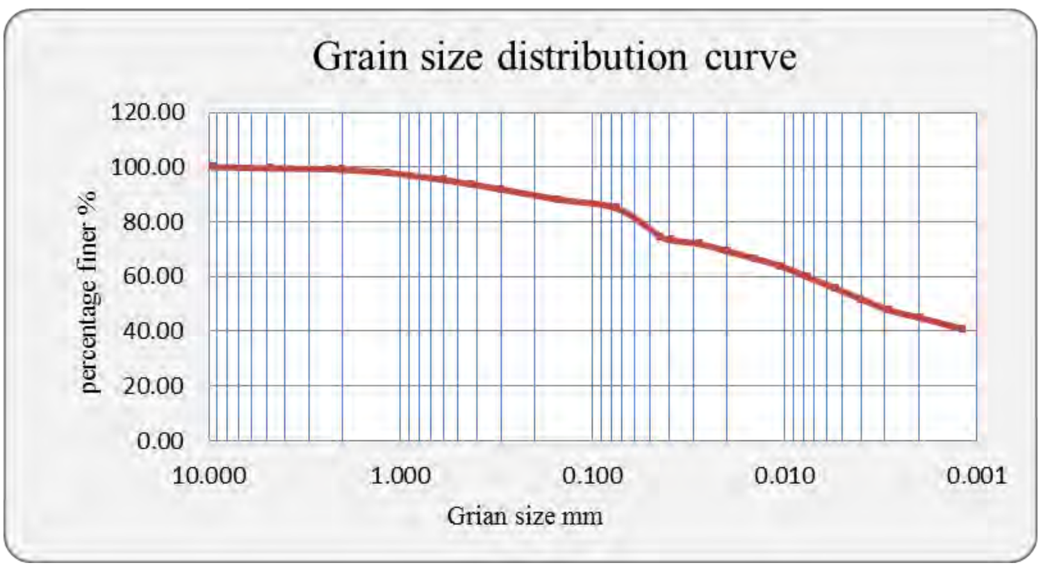

Figure: Grain size distribution curve for TP-4@1.5m

At 3m depth

Sieve Analysis (weight of dry soil= 63.1g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1263.0	0.0	0.00	0.00	100.00
No.8	2.360	989.8	990.3	0.5	0.04	0.04	99.96
No.10	2.000	955.8	956.1	0.3	0.03	0.07	99.93
No.16	1.180	894.4	895.4	1.0	0.08	0.15	99.85
No.30	0.600	830.8	834.2	3.4	0.28	0.43	99.57
No.40	0.425	786.2	790.8	4.6	0.38	0.82	99.18
No.50	0.300	750.1	757.8	7.7	0.64	1.46	98.54
No.100	0.150	777.9	801.1	23.2	1.93	3.39	96.61
No.200	0.075	763.4	785.4	22.0	1.83	5.23	94.78
Pan	-	734.8	735.2	0.4	0.03	5.26	94.74

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03200	0.00236	1.02964	7.835360	21.7	0.01299	0.041970177	93.29	88.42
1	1.03150	0.00236	1.02914	7.967620	21.7	0.01299	0.036652724	91.71	86.92
2	1.03100	0.00236	1.02864	8.099880	21.4	0.01303	0.026222175	90.14	85.43
4	1.03000	0.00236	1.02764	8.364400	21.5	0.01302	0.018820518	86.99	82.45
8	1.02950	0.00236	1.02714	8.496660	21.5	0.01302	0.013412919	85.42	80.96
15	1.02850	0.00236	1.02614	8.761180	21.4	0.01303	0.009958183	82.27	77.98
30	1.02800	0.00236	1.02564	8.893440	21.1	0.01308	0.00711895	80.70	76.48
60	1.02650	0.00236	1.02414	9.290220	21.1	0.01308	0.005144925	75.98	72.01
120	1.02500	0.00236	1.02264	9.687000	21.6	0.01300	0.003693579	71.25	67.54
240	1.02400	0.00236	1.02164	9.951520	22.6	0.01285	0.002616629	68.11	64.55
480	1.02300	0.00236	1.02064	10.216040	23.6	0.01270	0.001852782	64.96	61.57
1440	1.02200	0.00236	1.01964	10.480560	21.1	0.01308	0.001115457	61.81	58.59

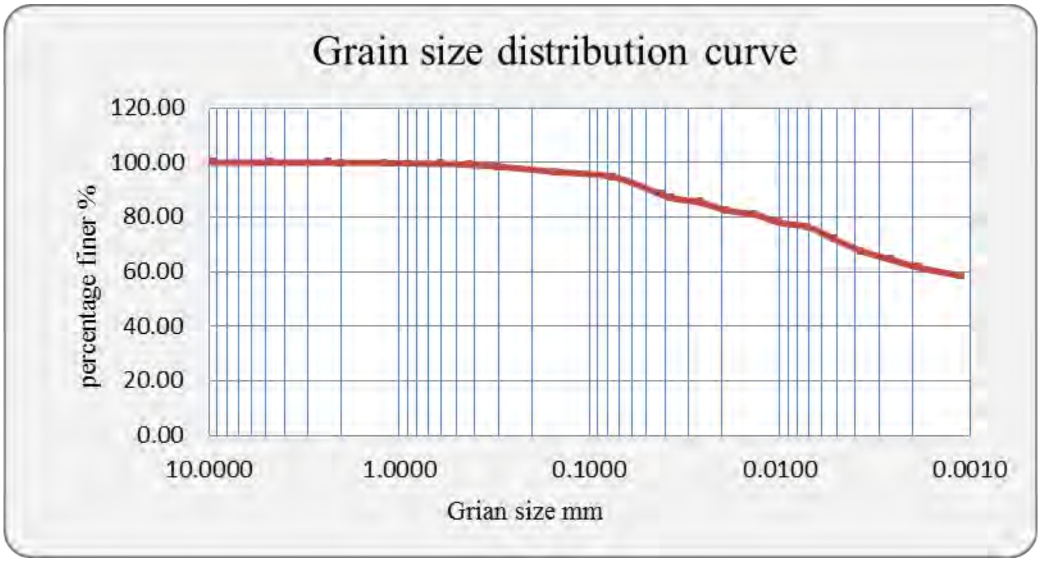

Figure: Grain size distribution curve for TP-4@3.0m

<u>Test pit 5(TP-5)</u>

At 1.5m depth

<u>Sieve Analysis</u> (weight of dry soil= 34.3g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.5	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.5	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.5	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.75	1263.0	1263.0	0.0	0.00	0.00	100.00
No.8	2.36	989.9	992.0	2.1	0.18	0.18	99.83
No.10	2	956.0	957.0	1.0	0.08	0.26	99.74
No.16	1.18	894.5	896.3	1.8	0.15	0.41	99.59
No.30	0.6	831.1	833.6	2.5	0.21	0.62	99.38
No.40	0.425	786.1	788.3	2.2	0.18	0.80	99.20
No.50	0.3	750.1	753.3	3.2	0.27	1.07	98.93
No.100	0.15	777.9	788.0	10.1	0.84	1.91	98.09
No.200	0.075	763.3	773.6	10.3	0.86	2.77	97.23
Pan	-	734.8	735.9	1.1	0.09	2.86	97.14

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.02950	0.00244	1.02706	8.496660	21.6	0.01300	0.043755922	85.43	83.07
1	1.02850	0.00244	1.02606	8.761180	20.9	0.01311	0.03879283	82.28	80.00
2	1.02800	0.00244	1.02556	8.893440	19.8	0.01328	0.028012299	80.70	78.46
4	1.02750	0.00244	1.02506	9.025700	20.9	0.01311	0.019687049	79.12	76.93
8	1.02640	0.00244	1.02396	9.316672	20.4	0.01319	0.01422979	75.65	73.55
15	1.02550	0.00244	1.02306	9.554740	20.4	0.01319	0.010523904	72.81	70.79
30	1.02400	0.00244	1.02156	9.951520	20.7	0.01314	0.007566819	68.07	66.18
60	1.02300	0.00244	1.02056	10.216040	20.6	0.01315	0.005427796	64.91	63.11
120	1.02200	0.00244	1.01956	10.480560	21.5	0.01302	0.003846323	61.76	60.04
240	1.02100	0.00244	1.01856	10.745080	23.2	0.01267	0.00268087	58.60	56.98
480	1.02000	0.00244	1.01756	11.009600	24.1	0.01251	0.001893864	55.44	53.91
1440	1.01900	0.00244	1.01656	11.274120	21.3	0.01305	0.001154261	52.28	50.84

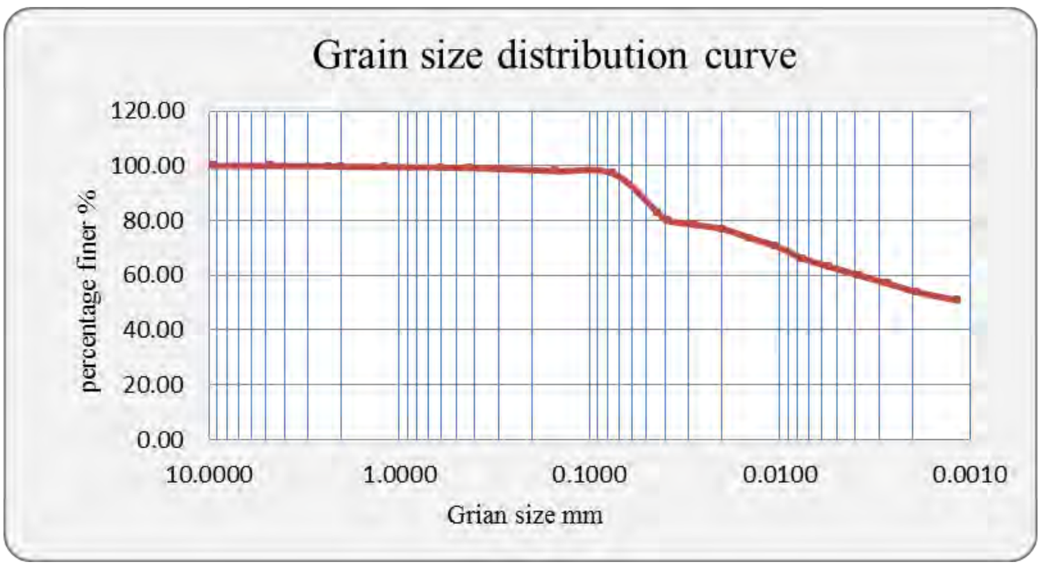

Figure: Grain size distribution curve for TP-5@1.5m

At 3m depth

Sieve Analysis (weight of dry soil= 65.5g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1264.2	1.2	1.83	1.83	98.17
No.8	2.360	989.9	994.2	4.3	0.36	2.19	97.81
No.10	2.000	956.0	957.1	1.1	0.09	2.28	97.72
No.16	1.180	894.5	898.0	3.5	0.29	2.57	97.43
No.30	0.600	831.1	837.2	6.1	0.51	3.08	96.92
No.40	0.425	786.1	790.8	4.7	0.39	3.47	96.53
No.50	0.300	750.1	756.8	6.7	0.56	4.03	95.97
No.100	0.150	777.9	796.7	18.8	1.57	5.60	94.40
No.200	0.075	763.3	781.2	17.9	1.49	7.09	92.91
Pan	-	734.8	736.0	1.2	0.10	7.19	92.81

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.02950	0.0025	1.02700	8.496660	21.6	0.01300	0.043755922	84.97	78.95
1	1.02800	0.0025	1.02550	8.893440	20.2	0.01322	0.039418549	80.25	74.56
2	1.02700	0.0025	1.02450	9.157960	19.8	0.01328	0.028425836	77.10	71.64
4	1.02650	0.0025	1.02400	9.290220	20.1	0.01323	0.020168525	75.53	70.18
8	1.02600	0.0025	1.02350	9.422480	20.3	0.01320	0.014327729	73.96	68.71
15	1.02550	0.0025	1.02300	9.554740	20.1	0.01323	0.010562213	72.38	67.25
30	1.02510	0.0025	1.02260	9.660548	20.4	0.01319	0.007482614	71.12	66.08
60	1.02400	0.0025	1.02150	9.951520	20.5	0.01317	0.005363581	67.66	62.87
120	1.02350	0.0025	1.02100	10.083780	21.2	0.01306	0.003785857	66.09	61.40
240	1.02250	0.0025	1.02000	10.348300	22.5	0.01287	0.002671398	62.94	58.48
480	1.02100	0.0025	1.01850	10.745080	24.3	0.01260	0.00188444	58.22	54.09
1440	1.01950	0.0025	1.01700	11.141860	21.4	0.01303	0.001146151	53.50	49.71

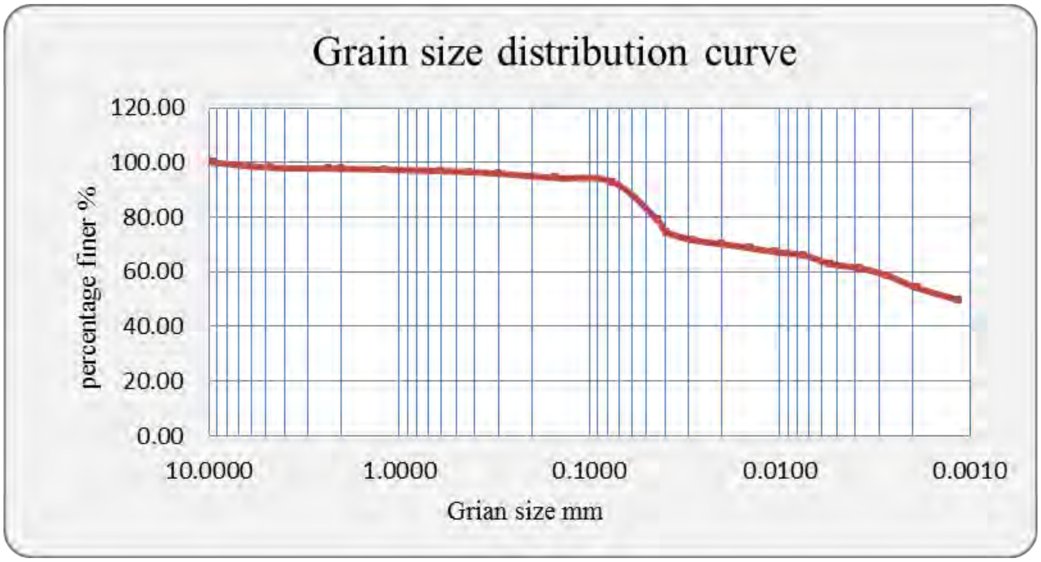

Figure: Grain size distribution curve for TP-5@3.0m

Test pit 6(TP-6)

At 2.0m depth

Sieve Analysis (weight of dry soil= 72.5g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1266.9	3.9	0.33	0.33	99.68
No.8	2.360	989.8	994.2	4.4	0.37	0.69	99.31
No.10	2.000	955.8	957.8	2.0	0.17	0.86	99.14
No.16	1.180	894.4	898.6	4.2	0.35	1.21	98.79
No.30	0.600	830.8	838.9	8.1	0.68	1.88	98.12
No.40	0.425	786.2	793.2	7.0	0.58	2.47	97.53
No.50	0.300	750.1	758.7	8.6	0.72	3.18	96.82
No.100	0.150	777.9	795.2	17.3	1.44	4.63	95.38
No.200	0.075	763.4	778.6	15.2	1.27	5.89	94.11
Pan	-	734.8	736.6	1.8	0.15	6.04	93.96

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03100	0.00208	1.02892	8.099880	22.7	0.01284	0.04218	91.00	85.64
1	1.03050	0.00208	1.02842	8.232140	22.7	0.01284	0.03683	89.42	84.16
2	1.03000	0.00208	1.02792	8.364400	22.3	0.01290	0.02637	87.85	82.68
4	1.02900	0.00208	1.02692	8.628920	22.2	0.01291	0.01896	84.70	79.71
8	1.02800	0.00208	1.02592	8.893440	22.2	0.01291	0.01361	81.56	76.75
15	1.02700	0.00208	1.02492	9.157960	22.1	0.01293	0.01010	78.41	73.79
30	1.02650	0.00208	1.02442	9.290220	22.4	0.01288	0.00717	76.84	72.31
60	1.02450	0.00208	1.02242	9.819260	22.4	0.01288	0.00521	70.55	66.39
120	1.02350	0.00208	1.02142	10.083780	23.1	0.01278	0.00370	67.40	63.43
240	1.02300	0.00208	1.02092	10.216040	25.4	0.01243	0.00257	65.83	61.95
480	1.02200	0.00208	1.01992	10.480560	26.2	0.01232	0.00182	62.68	58.99
1440	1.02100	0.00208	1.01892	10.745080	23	0.01279	0.00110	59.53	56.03

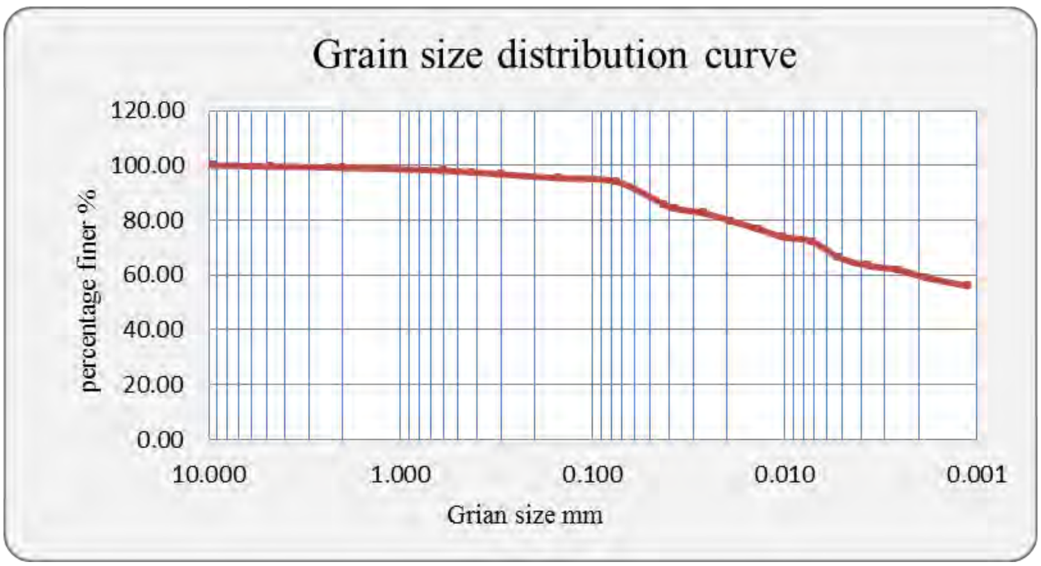

Figure: Grain size distribution curve for TP-6@2.0m

Test pit 7(TP-7)

At 2.0m depth

Sieve Analysis (weight of dry soil= 58.4g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1263.6	0.6	0.05	0.05	99.95
No.8	2.360	989.8	995.0	5.2	0.43	0.48	99.52
No.10	2.000	955.8	957.5	1.7	0.14	0.63	99.38
No.16	1.180	894.4	897.8	3.4	0.28	0.91	99.09
No.30	0.600	830.8	836.5	5.7	0.48	1.38	98.62
No.40	0.425	786.2	790.4	4.2	0.35	1.73	98.27
No.50	0.300	750.1	755.8	5.7	0.47	2.21	97.79
No.100	0.150	777.9	794.6	16.7	1.39	3.60	96.40
No.200	0.075	763.4	777.3	13.9	1.16	4.76	95.24
Pan	-	734.8	736.1	1.3	0.11	4.87	95.13

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03200	0.00232	1.02968	7.835360	21.5	0.01302	0.042067143	93.69	89.23
1	1.03150	0.00232	1.02918	7.967620	21.5	0.01302	0.036737405	92.11	87.72
2	1.03000	0.00232	1.02768	8.364400	21.7	0.01299	0.026554881	87.37	83.21
4	1.02900	0.00232	1.02668	8.628920	21.7	0.01299	0.019071734	84.22	80.21
8	1.02800	0.00232	1.02568	8.893440	21.7	0.01299	0.013690895	81.06	77.20
15	1.02650	0.00232	1.02418	9.290220	21.8	0.01297	0.010207217	76.33	72.69
30	1.02500	0.00232	1.02268	9.687000	21.7	0.01299	0.007378634	71.59	68.18
60	1.02350	0.00232	1.02118	10.083780	21.7	0.01299	0.005323264	66.86	63.67
120	1.02200	0.00232	1.01968	10.480560	22.2	0.01291	0.003815293	62.12	59.16
240	1.02100	0.00232	1.01868	10.745080	23.6	0.01270	0.002687218	58.96	56.16
480	1.02000	0.00232	1.01768	11.009600	23.9	0.01266	0.001916582	55.81	53.15
1440	1.01900	0.00232	1.01668	11.274120	20.3	0.01320	0.001168153	52.65	50.14

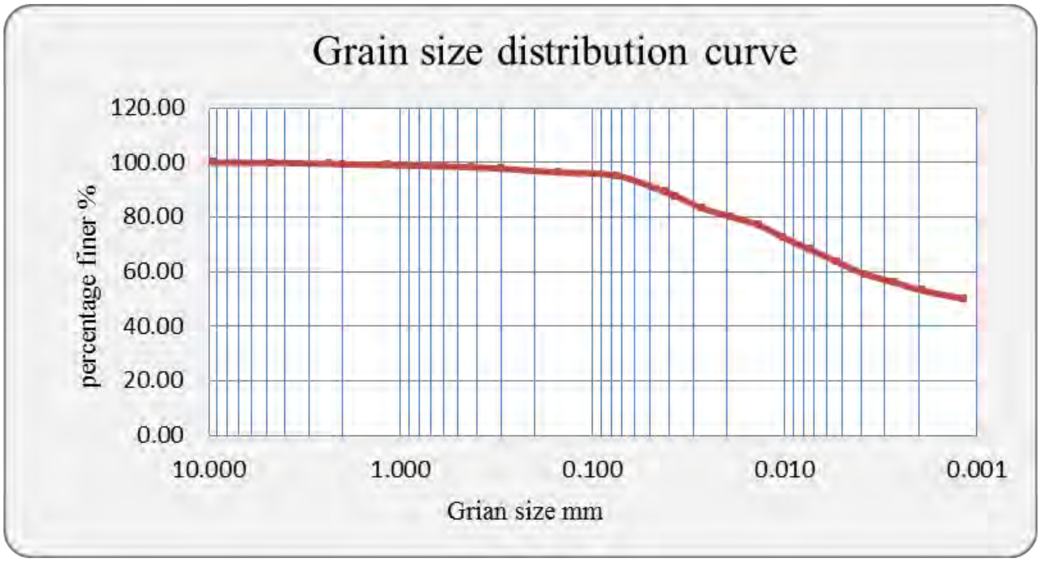

Figure: Grain size distribution curve for TP-7@2.0m

Test pit 8(TP-8)

At 2.0m depth

Sieve Analysis (weight of dry soil= 96.1g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1267.1	4.1	0.34	0.34	99.66
No.8	2.360	989.8	993.3	3.5	0.29	0.63	99.37
No.10	2.000	955.8	957.9	2.1	0.18	0.81	99.19
No.16	1.180	894.4	898.7	4.3	0.36	1.17	98.83
No.30	0.600	830.8	840.9	10.1	0.84	2.01	97.99
No.40	0.425	786.2	793.2	7.0	0.58	2.59	97.41
No.50	0.300	750.1	758.7	8.6	0.72	3.31	96.69
No.100	0.150	777.9	802.9	25.0	2.08	5.39	94.61
No.200	0.075	763.4	792.7	29.3	2.44	7.83	92.17
Pan	-	734.8	736.9	2.1	0.18	8.01	91.99

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03300	0.00216	1.03084	7.570840	21.8	0.01321	0.04197	97.36	89.73
1	1.03250	0.00216	1.03034	7.703100	21.8	0.01321	0.03666	95.78	88.27
2	1.03200	0.00216	1.02984	7.835360	21.8	0.01321	0.02615	94.20	86.82
4	1.03100	0.00216	1.02884	8.099880	21.8	0.01321	0.01880	91.04	83.91
8	1.03000	0.00216	1.02784	8.364400	21.9	0.01323	0.01352	87.88	81.00
15	1.02850	0.00216	1.02634	8.761180	21.9	0.01323	0.01011	83.15	76.64
30	1.02700	0.00216	1.02484	9.157960	22.0	0.01294	0.00715	78.41	72.27
60	1.02600	0.00216	1.02384	9.422480	22.5	0.01287	0.00510	75.26	69.36
120	1.02450	0.00216	1.02234	9.819260	23.2	0.01276	0.00365	70.52	65.00
240	1.02350	0.00216	1.02134	10.083780	25.3	0.01245	0.00255	67.37	62.09
480	1.02300	0.00216	1.02084	10.216040	26.1	0.01220	0.00178	65.79	60.63
1440	1.02200	0.00216	1.01984	10.480560	22.8	0.01282	0.00109	62.63	57.72

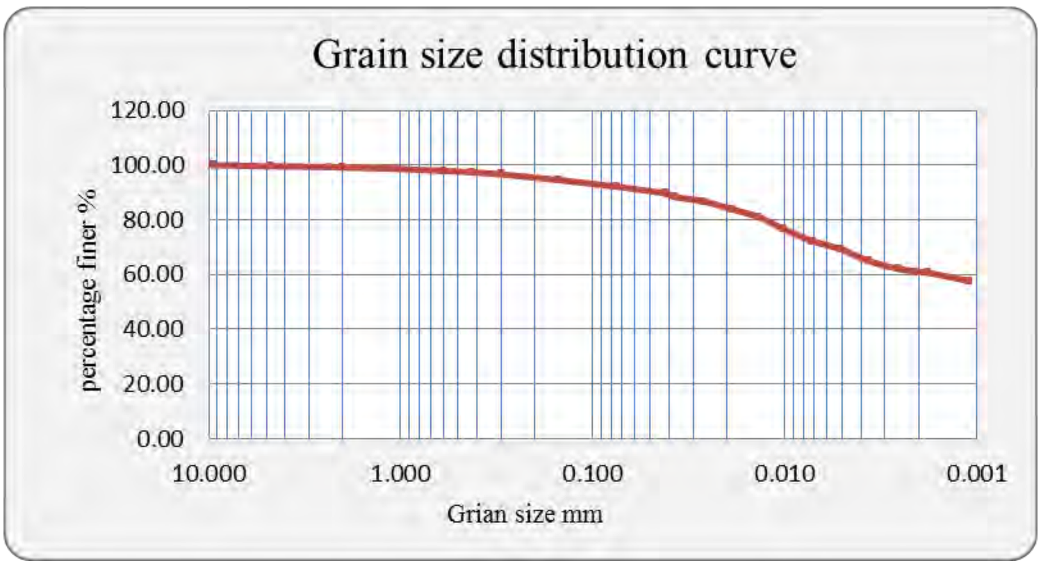

Figure: Grain size distribution curve for TP-8@2.0m

Test pit 9(TP-9)

At 1.5m depth

Sieve Analysis (weight of dry soil= 34.1g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1263.1	0.1	0.01	0.01	99.99
No.8	2.360	989.8	990.8	1.0	0.08	0.09	99.91
No.10	2.000	955.8	956.3	0.5	0.04	0.13	99.87
No.16	1.180	894.4	895.6	1.2	0.10	0.23	99.77
No.30	0.600	830.8	833.8	3.0	0.25	0.48	99.52
No.40	0.425	786.2	789.0	2.8	0.23	0.72	99.28
No.50	0.300	750.1	753.9	3.8	0.32	1.03	98.97
No.100	0.150	777.9	789.9	12.0	1.00	2.03	97.97
No.200	0.075	763.4	772.5	9.1	0.76	2.79	97.21
Pan	-	734.8	735.4	0.6	0.05	2.84	97.16

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03300	0.00222	1.03078	7.570840	22.5	0.01287	0.04087	96.53	93.83
1	1.03250	0.00222	1.03028	7.703100	22.5	0.01287	0.03571	94.96	92.31
2	1.03200	0.00222	1.02978	7.835360	22.5	0.01287	0.02546	93.39	90.79
4	1.03100	0.00222	1.02878	8.099880	22.5	0.01287	0.01831	90.26	87.74
8	1.03000	0.00222	1.02778	8.364400	22.1	0.01293	0.01322	87.12	84.69
15	1.02850	0.00222	1.02628	8.761180	21.9	0.01296	0.00990	82.42	80.12
30	1.02700	0.00222	1.02478	9.157960	22.1	0.01293	0.00714	77.71	75.54
60	1.02600	0.00222	1.02378	9.422480	22.5	0.01287	0.00510	74.58	72.49
120	1.02450	0.00222	1.02228	9.819260	22.8	0.01282	0.00367	69.87	67.92
240	1.02350	0.00222	1.02128	10.083780	23.9	0.01266	0.00259	66.74	64.87
480	1.02300	0.00222	1.02078	10.216040	22.9	0.01281	0.00187	65.17	63.35
1440	1.02200	0.00222	1.01978	10.480560	20.3	0.01320	0.00113	62.03	60.30

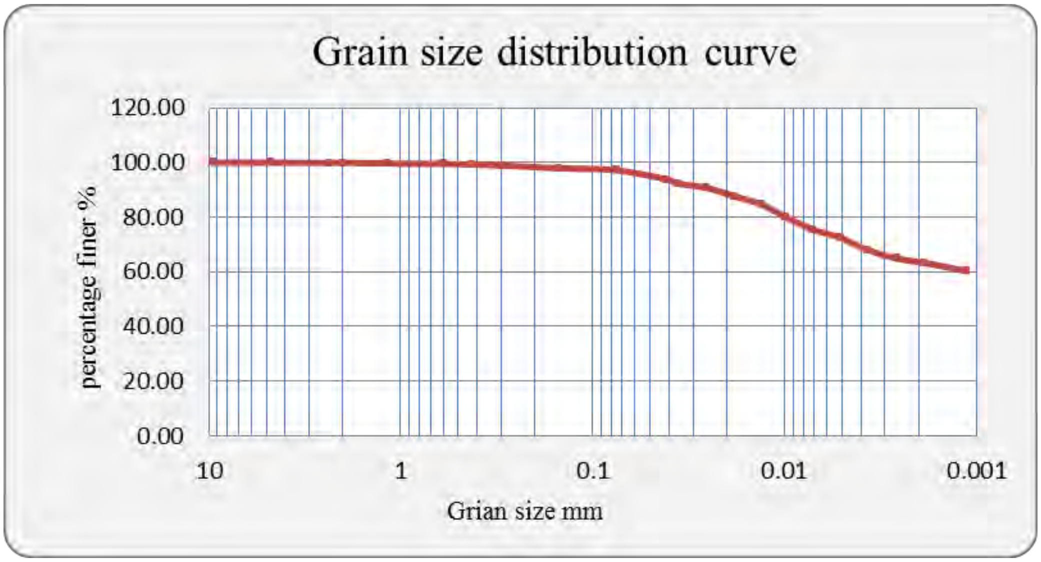

Figure: Grain size distribution curve for TP-9@1.5m

At 3m depth

Sieve Analysis (weight of dry soil= 44.6g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.000	0.000	100.00
2"	50.000	1199.0	1199.0	0.0	0.000	0.000	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.000	0.000	100.00
1"	25.000	1217.0	1217.0	0.0	0.000	0.000	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.000	0.000	100.00
1/2"	12.500	459.2	459.2	0.0	0.000	0.000	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.000	0.000	100.00
No.4	4.750	1262.8	1262.8	0.0	0.000	0.000	100.00
No.8	2.360	989.8	991.7	1.9	0.158	0.158	99.84
No.10	2.000	955.8	956.7	0.9	0.075	0.233	99.77
No.16	1.180	894.4	896.3	1.9	0.158	0.392	99.61
No.30	0.600	830.8	834.4	3.6	0.300	0.692	99.31
No.40	0.425	786.2	788.9	2.7	0.225	0.917	99.08
No.50	0.300	750.1	754.1	4.0	0.333	1.250	98.75
No.100	0.150	777.6	791.4	13.8	1.150	2.400	97.60
No.200	0.075	763.4	777.9	14.5	1.208	3.608	96.39
Pan	-	734.8	736.1	1.3	0.108	3.717	96.28

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03200	0.0022	1.02980	7.835360	22.7	0.01266	0.040903549	92.59	89.25
1	1.03100	0.0022	1.02880	8.099880	22.7	0.01266	0.036016495	89.48	86.25
2	1.03050	0.0022	1.02830	8.232140	22.4	0.01270	0.025765887	87.93	84.75
4	1.03000	0.0022	1.02780	8.364400	22.5	0.01269	0.018343317	86.37	83.26
8	1.02900	0.0022	1.02680	8.628920	22.7	0.01266	0.013143026	83.27	80.26
15	1.02800	0.0022	1.02580	8.893440	22.2	0.01273	0.009802067	80.16	77.27
30	1.02700	0.0022	1.02480	9.157960	22.4	0.01270	0.007016854	77.05	74.27
60	1.02650	0.0022	1.02430	9.290220	22.7	0.01266	0.004979658	75.50	72.77
120	1.02450	0.0022	1.02230	9.819260	23.6	0.01252	0.003581402	69.29	66.78
240	1.02350	0.0022	1.02130	10.083780	23.2	0.01258	0.002578616	66.18	63.79
480	1.02300	0.0022	1.02080	10.216040	22.2	0.01273	0.001857159	64.63	62.29
1440	1.02200	0.0022	1.01980	10.480560	20.2	0.01304	0.0011123	61.52	59.30

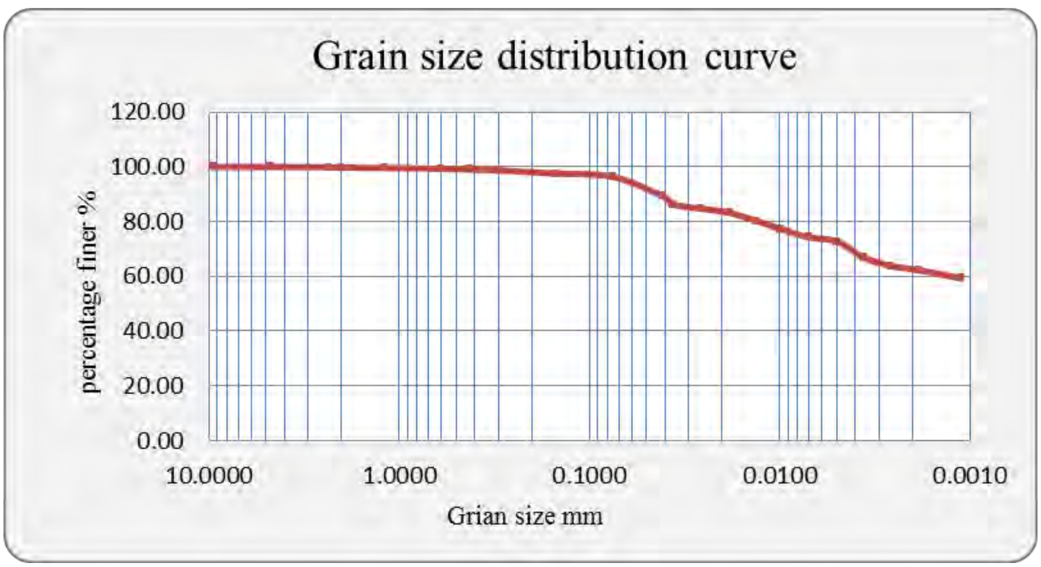

Figure: Grain size distribution curve for TP-9@3.0m

Test pit 10(TP-10)

At 1.5m depth

Sieve Analysis (weight of dry soil= 45.6g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.00	0.00	100.00
2"	50.000	1199.0	1199.0	0.0	0.00	0.00	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.00	0.00	100.00
1"	25.000	1217.0	1217.0	0.0	0.00	0.00	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.00	0.00	100.00
1/2"	12.500	459.2	459.2	0.0	0.00	0.00	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.00	0.00	100.00
No.4	4.750	1263.0	1263.6	0.6	0.05	0.05	99.95
No.8	2.360	989.8	992.8	3.0	0.25	0.30	99.70
No.10	2.000	955.8	958.3	2.5	0.21	0.51	99.49
No.16	1.180	894.4	897.6	3.2	0.27	0.77	99.23
No.30	0.600	830.8	836.8	6.0	0.50	1.28	98.73
No.40	0.425	786.2	790.0	3.8	0.32	1.59	98.41
No.50	0.300	750.1	753.9	3.8	0.32	1.91	98.09
No.100	0.150	777.9	790.9	13.0	1.08	2.99	97.01
No.200	0.075	763.4	772.5	9.1	0.76	3.75	96.25
Pan	-	734.8	735.4	0.6	0.05	3.80	96.20

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03200	0.00222	1.02978	7.835360	22.5	0.01287	0.04158	92.77	89.29
1	1.03150	0.00222	1.02928	7.967620	22.5	0.01287	0.03631	91.21	87.79
2	1.03100	0.00222	1.02878	8.099880	22.5	0.01287	0.02589	89.66	86.29
4	1.03000	0.00222	1.02778	8.364400	22.5	0.01287	0.01860	86.54	83.30
8	1.02900	0.00222	1.02678	8.628920	22.1	0.01293	0.01342	83.43	80.30
15	1.02850	0.00222	1.02628	8.761180	21.9	0.01296	0.00990	81.87	78.80
30	1.02700	0.00222	1.02478	9.157960	22.1	0.01293	0.00714	77.19	74.30
60	1.02600	0.00222	1.02378	9.422480	22.5	0.01287	0.00510	74.08	71.30
120	1.02450	0.00222	1.02228	9.819260	22.8	0.01282	0.00367	69.41	66.80
240	1.02350	0.00222	1.02128	10.083780	23.9	0.01266	0.00259	66.29	63.81
480	1.02300	0.00222	1.02078	10.216040	22.9	0.01281	0.00187	64.73	62.31
1440	1.02200	0.00222	1.01978	10.480560	20.3	0.01320	0.00113	61.62	59.31

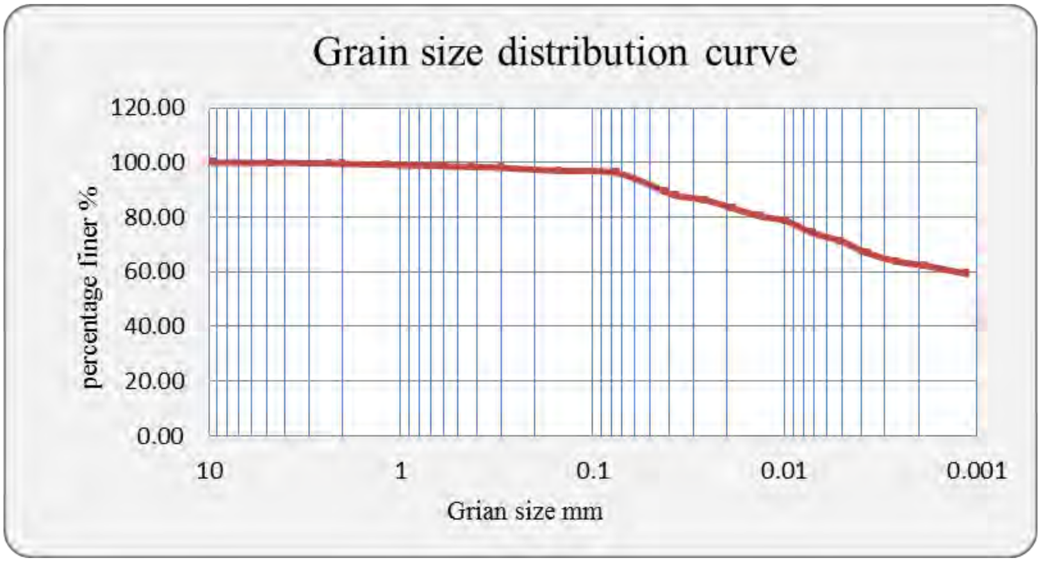

Figure: Grain size distribution curve for TP-10@1.5m

At 3m depth

Sieve Analysis (weight of dry soil= 81.6g out of total weight of sample = 1200g)

Sieve No	Sieve opening,mm	Mass of sieve, gm	Mass of seive + retained, gm	Mass of retained, gm	Percentage retained,%	Comm. percentage retained,%	Percentage finer,%
3"	75.000	1057.0	1057.0	0.0	0.000	0.000	100.00
2"	50.000	1199.0	1199.0	0.0	0.000	0.000	100.00
1.5"	37.500	1084.0	1084.0	0.0	0.000	0.000	100.00
1"	25.000	1217.0	1217.0	0.0	0.000	0.000	100.00
3/4"	19.000	1178.5	1178.5	0.0	0.000	0.000	100.00
1/2"	12.500	459.2	459.2	0.0	0.000	0.000	100.00
3.8"	9.500	1165.0	1165.0	0.0	0.000	0.000	100.00
No.4	4.750	1262.8	1262.8	0.0	0.000	0.000	100.00
No.8	2.360	989.8	998.7	8.9	0.742	0.742	99.26
No.10	2.000	955.8	959.7	3.9	0.325	1.067	98.93
No.16	1.180	894.4	896.3	1.9	0.158	1.225	98.78
No.30	0.600	830.8	844.4	13.6	1.133	2.358	97.64
No.40	0.425	786.2	790.9	4.7	0.392	2.750	97.25
No.50	0.300	750.1	759.1	9.0	0.750	3.500	96.50
No.100	0.150	777.6	799.4	21.8	1.817	5.317	94.68
No.200	0.075	763.4	779.9	16.5	1.375	6.692	93.31
Pan	-	734.8	736.1	1.3	0.108	6.800	93.20

Hydrometer analysis

Elapse time(T),min	Actual Hydrometer reading(RA)	Composition correction	Corrected Hydrometer reading(RC)	Effective depth(L),cm	Test tempreture	Coefficient(K)	Grain size(D),mm	Percentage finer(P),%	Combined Percentage finer,%
0.75	1.03300	0.0022	1.03080	7.570840	22.7	0.01266	0.040207174	96.29	89.85
1	1.03250	0.0022	1.03030	7.703100	22.7	0.01266	0.035123268	94.73	88.39
2	1.03200	0.0022	1.02980	7.835360	22.4	0.01270	0.025137275	93.17	86.94
4	1.03100	0.0022	1.02880	8.099880	22.5	0.01269	0.018050938	90.04	84.02
8	1.03000	0.0022	1.02780	8.364400	22.7	0.01266	0.012940008	86.92	81.10
15	1.02950	0.0022	1.02730	8.496660	22.2	0.01273	0.009580913	85.35	79.64
30	1.02800	0.0022	1.02580	8.893440	22.4	0.01270	0.006914774	80.66	75.27
60	1.02750	0.0022	1.02530	9.025700	22.7	0.01266	0.004908253	79.10	73.81
120	1.02600	0.0022	1.02380	9.422480	23.6	0.01252	0.003508297	74.41	69.43
240	1.02550	0.0022	1.02330	9.554740	23.2	0.01258	0.002510062	72.85	67.97
480	1.02400	0.0022	1.02180	9.951520	22.2	0.01273	0.001832958	68.16	63.60
1440	1.02350	0.0022	1.02130	10.083780	20.2	0.01304	0.001091042	66.59	62.14

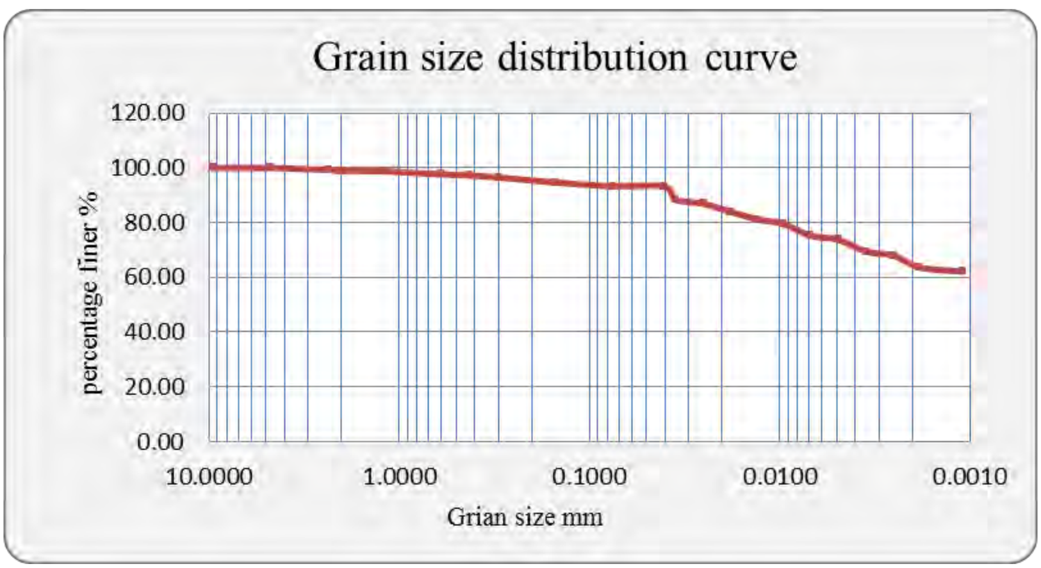

Figure: Grain size distribution curve for TP-10@3.0m

(B) Atterberg Limits

 # Test pit 1 (TP-1)

At 1.5m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	I5	C5	T4	K3	A3	D5
Mass of container,gm	15.4	15.4	15.6	15.6	15.3	15.9
Mass of container +wet soil,gm	33.1	36.9	32.5	33.7	22.7	22.8
Mass of container +dry soil,gm	26.1	28.1	25.5	26.1	20.9	21.1
Mass of water, gm	7.0	8.8	7.0	7.6	1.8	1.7
Mass of dry soil, gm	10.7	12.7	9.9	10.5	5.6	5.2
Water content(ω), %	65.4	69.3	70.7	72.4	32.14	32.69
No of blows	32	26	23	16	32.42	

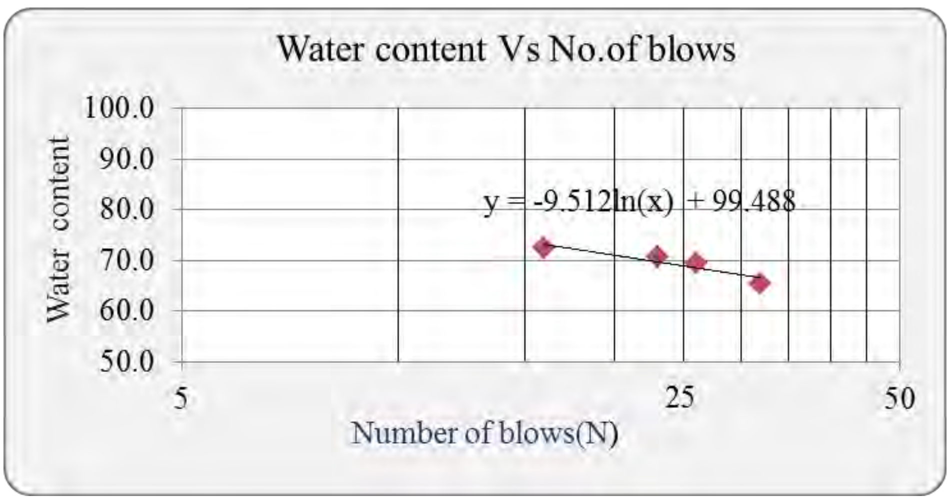

Figure: Liquid Limit determination for TP-1@1.5m

At 3m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	J3	C5	B7	D2	Z3	D2
Mass of container,gm	15.1	15.3	15.7	15.5	15.6	15.6
Mass of container +wet soil,gm	36.0	36.1	36.3	34.3	22.1	22.1
Mass of container +dry soil,gm	27.5	27.5	27.7	26.3	20.4	20.5
Mass of water, gm	8.5	8.6	8.6	8.0	1.7	1.6
Mass of dry soil, gm	12.4	12.2	12.0	10.8	4.8	4.9
Water content(ω), %	68.5	70.5	71.7	74.1	35.42	32.65
No of blows	38	28	23	17	34.03	

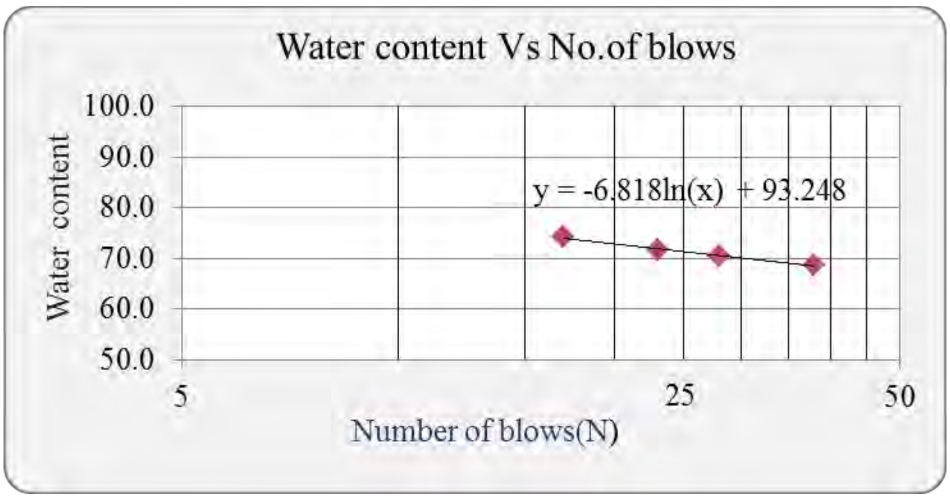

Figure: Liquid Limit determination for TP-1@3.0m

 # Test pit 2 (TP-2)

At 1.5m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A4	C5	G6	D2	T3	E5
Mass of container,gm	15.7	15.9	15.7	15.9	15.2	15.5
Mass of container +wet soil,gm	36.7	36.4	36.3	39.3	22.3	22.3
Mass of container +dry soil,gm	28.1	27.9	27.6	29.3	20.6	20.6
Mass of water, gm	8.6	8.5	8.7	10.0	1.7	1.7
Mass of dry soil, gm	12.4	12.0	11.9	13.4	5.4	5.1
Water content(ω), %	69.4	70.8	73.1	74.6	31.48	33.33
No of blows	38	26	23	16	32.41	

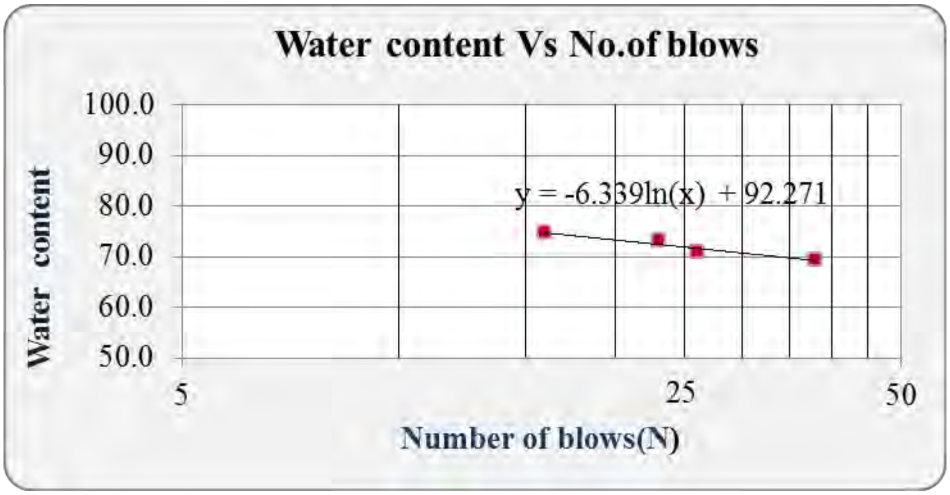

Figure: Liquid Limit determination for TP-2@1.5m

At 3m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A1	E2	U4	D6	T3	D2
Mass of container,gm	15.3	15.8	15.4	15.5	15.6	15.8
Mass of container +wet soil,gm	35.2	32.8	36.3	34.9	22.5	22.3
Mass of container +dry soil,gm	27.2	25.9	27.7	26.8	20.8	20.7
Mass of water, gm	8.0	6.9	8.6	8.1	1.7	1.6
Mass of dry soil, gm	11.9	10.1	12.3	11.3	5.2	4.9
Water content(ω), %	67.2	68.3	69.9	71.7	32.69	32.65
No of blows	33	27	23	17	32.67	

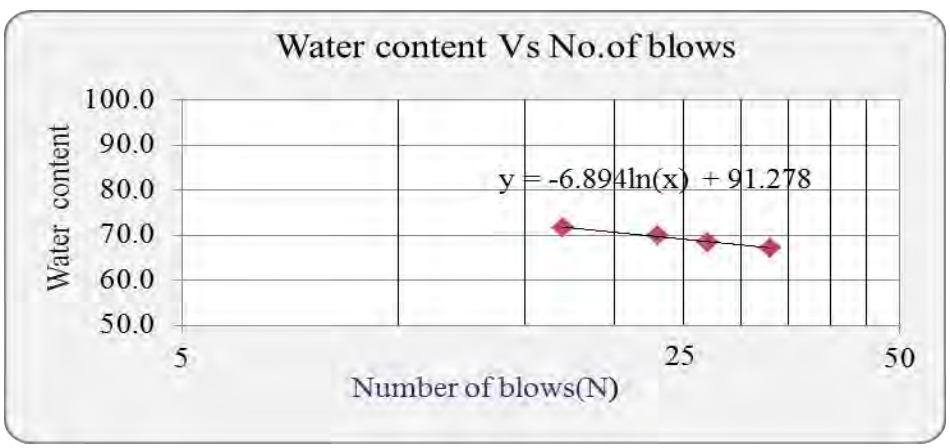

Figure: Liquid Limit determination for TP-2@3.0m

Test pit 3 (TP-3)

At 1.5m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	I5	C5	T4	K3	A3	D5
Mass of container,gm	15.9	15.6	15.7	15.7	15.6	15.8
Mass of container +wet soil,gm	33.2	36.9	32.5	33.7	22.7	22.8
Mass of container +dry soil,gm	26.1	28.1	25.5	26.1	20.9	21.1
Mass of water, gm	7.1	8.8	7.0	7.6	1.8	1.7
Mass of dry soil, gm	10.2	12.5	9.8	10.4	5.3	5.3
Water content(ω), %	69.6	70.4	71.4	73.1	33.96	32.08
No of blows	32	26	23	16	33.02	

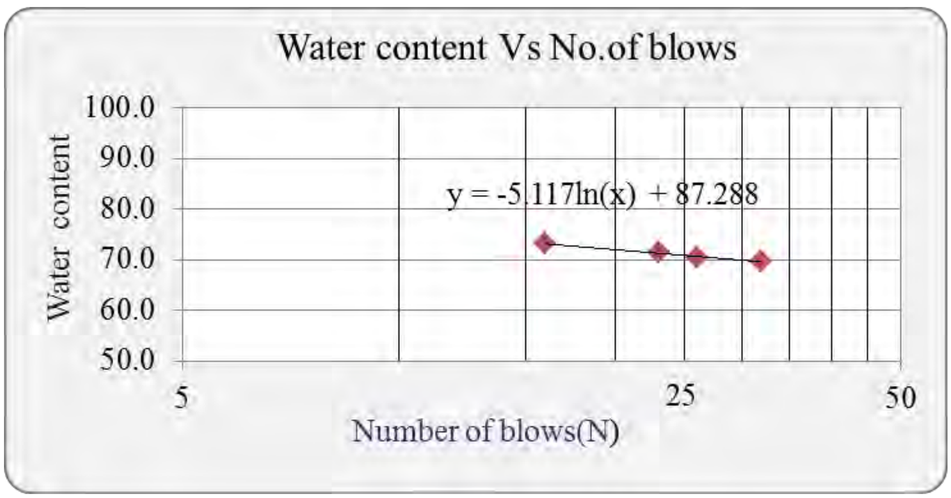

Figure: Liquid Limit determination for TP-3@1.5m

At 3m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	J3	C5	B4	D2	T3	D2
Mass of container,gm	15.2	15.4	15.2	15.1	15.4	15.6
Mass of container +wet soil,gm	36.0	36.3	34.3	36.2	22.1	22.1
Mass of container +dry soil,gm	27.5	27.7	26.3	27.2	20.4	20.5
Mass of water, gm	8.5	8.6	8.0	9.0	1.7	1.6
Mass of dry soil, gm	12.3	12.3	11.1	12.1	5	4.9
Water content(ω), %	69.1	69.9	72.1	74.4	34.00	32.65
No of blows	38	28	23	17	33.33	

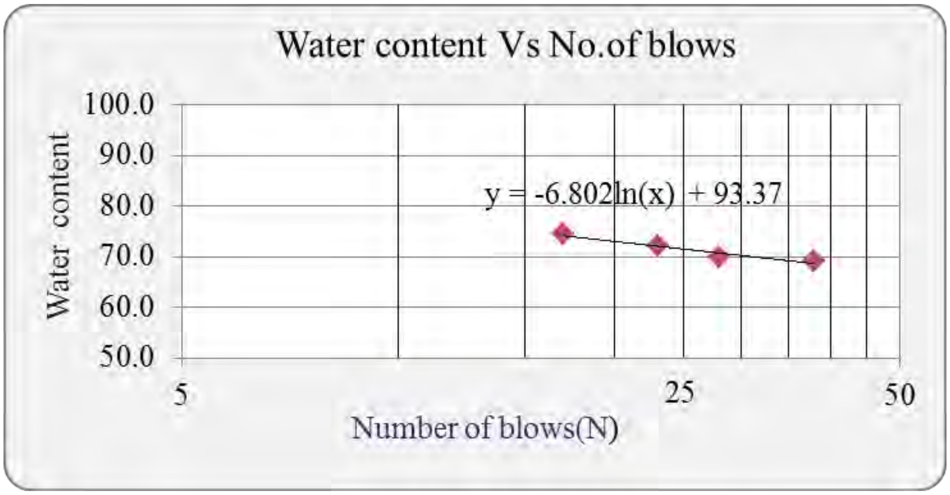

Figure: Liquid Limit determination for TP-3@3.0m

 # Test pit 4 (TP-4)

At 1.5m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	I5	C5	T4	K3	A3	D5
Mass of container,gm	15.6	15.4	15.6	15.6	15.5	15.7
Mass of container +wet soil,gm	33.1	36.9	32.5	33.7	22.7	22.8
Mass of container +dry soil,gm	26.1	28.1	25.5	26.1	20.9	21.1
Mass of water, gm	7.0	8.8	7.0	7.6	1.8	1.7
Mass of dry soil, gm	10.5	12.7	9.9	10.5	5.4	5.4
Water content(ω), %	66.7	69.3	70.7	72.4	33.33	31.48
No of blows	32	26	23	16	32.41	

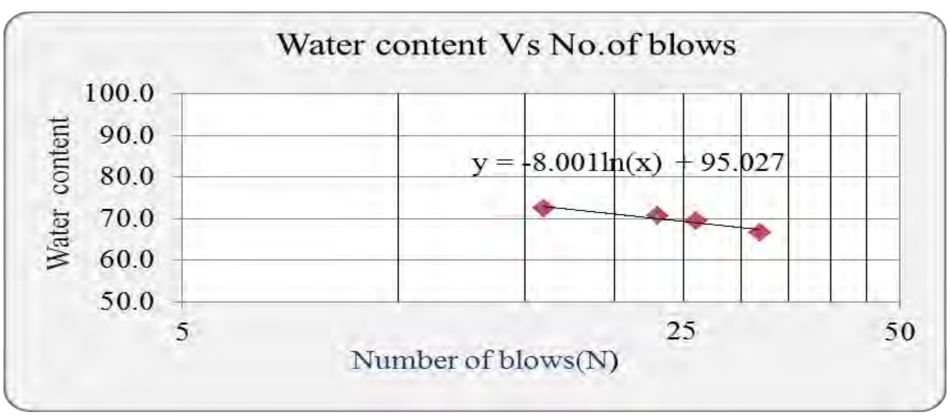

Figure: Liquid Limit determination for TP-4@1.5m

At 3.0m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	J3	C5	B4	D2	T3	D2
Mass of container,gm	15.3	15.7	15.5	15.5	15.6	15.6
Mass of container +wet soil,gm	36.0	36.3	34.3	36.3	22.1	22.1
Mass of container +dry soil,gm	27.5	27.7	26.3	27.2	20.4	20.5
Mass of water, gm	8.5	8.6	8.0	9.1	1.7	1.6
Mass of dry soil, gm	12.2	12.0	10.8	11.7	4.8	4.9
Water content(ω), %	69.7	71.7	74.1	77.8	35.42	32.65
No of blows	38	28	23	17	34.03	

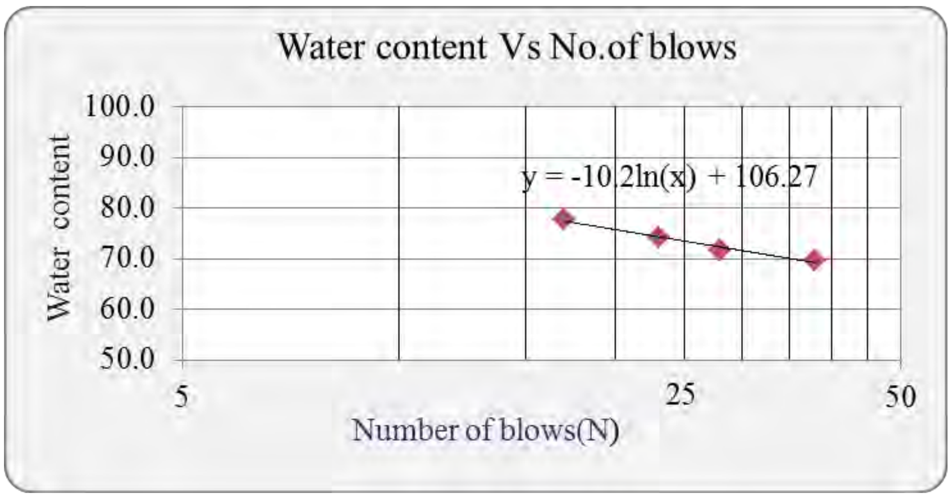

Figure: Liquid Limit determination for TP-4@3.0m

 # Test pit 5 (TP-5)

At 1.5m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A14	A28	C30	D21	A3	D5
Mass of container,gm	15.7	15.4	15.6	15.4	15.3	15.2
Mass of container +wet soil,gm	37.0	36.2	36.2	36.1	22.7	22.3
Mass of container +dry soil,gm	28.3	27.6	27.6	27.3	20.9	20.5
Mass of water, gm	8.7	8.6	8.6	8.8	1.8	1.8
Mass of dry soil, gm	12.6	12.2	12.0	11.9	5.6	5.3
Water content(ω), %	69.0	70.5	71.7	73.9	32.14	33.96
No of blows	37	26	21	16	33.05	

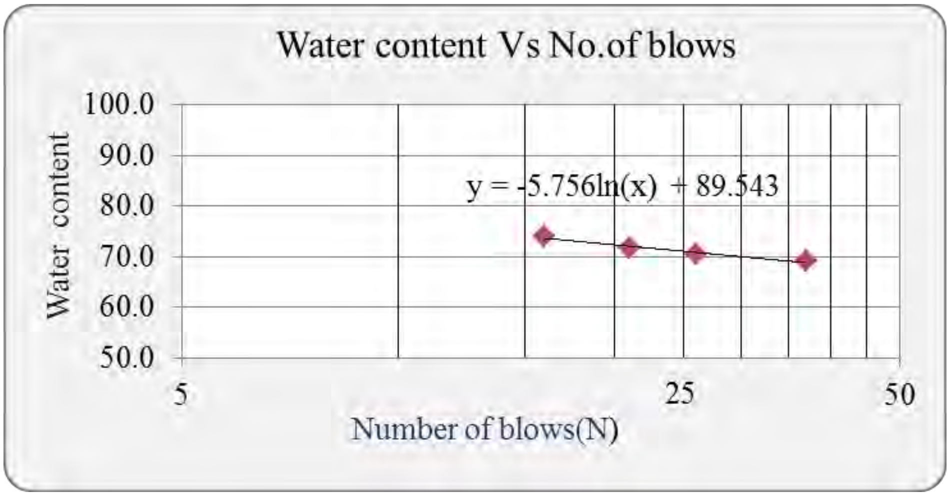

Figure: Liquid Limit determination for TP-5@1.5m

At 3.0m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	D8	C5	E9	J9	T3	D2
Mass of container,gm	15.5	15.4	15.7	15.5	15.2	15.9
Mass of container +wet soil,gm	33.5	35.7	35.0	35.1	22.6	22.6
Mass of container +dry soil,gm	26.6	27.7	27.1	26.9	20.9	21
Mass of water, gm	6.9	8.0	7.9	8.2	1.7	1.6
Mass of dry soil, gm	11.1	12.3	11.4	11.4	5.7	5.1
Water content(ω), %	62.2	65.0	69.3	71.9	29.82	31.37
No of blows	32	26	22	16	30.60	

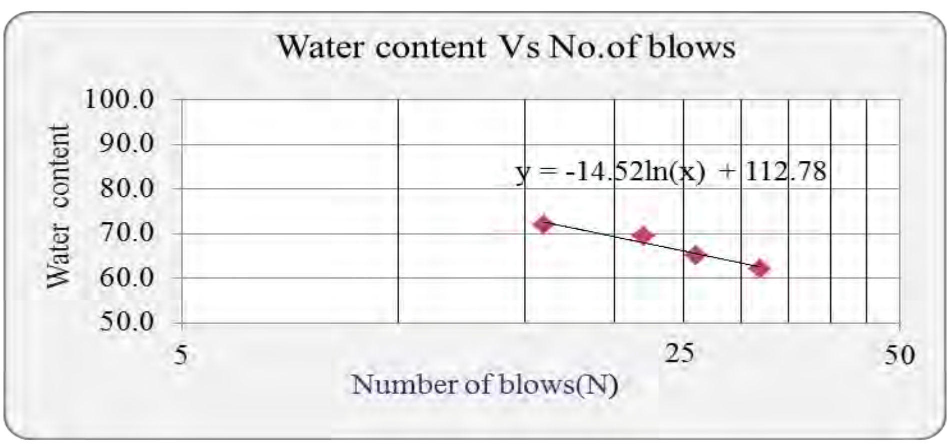

Figure: Liquid Limit determination for TP-5@3.0m

 # Test pit 6 (TP-6)

At 2.0m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A4	C5	G6	D2	T3	E5
Mass of container,gm	15.9	15.8	15.6	15.8	15.4	15.3
Mass of container +wet soil,gm	37.5	33.7	35.7	34.0	22.1	21.7
Mass of container +dry soil,gm	28.9	26.4	27.4	26.3	20.5	20.2
Mass of water, gm	8.6	7.3	8.3	7.7	1.6	1.5
Mass of dry soil, gm	13.0	10.6	11.8	10.5	5.1	4.9
Water content(ω), %	66.2	68.9	70.3	73.3	31.37	30.61
No of blows	32	26	21	16	30.99	

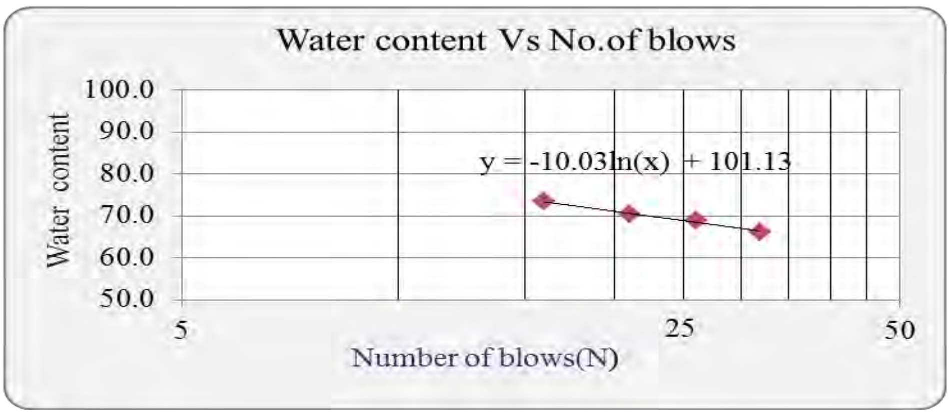

Figure: Liquid Limit determination for TP-6@2.0m

 # Test pit 7 (TP-7)

At 2.0m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A1	C5	C7	H6	T3	D5
Mass of container,gm	15.9	15.6	15.8	15.6	15.3	15.6
Mass of container +wet soil,gm	31.8	33.6	37.6	32.6	22.2	22.1
Mass of container +dry soil,gm	25.3	26.1	28.4	25.2	20.5	20.5
Mass of water, gm	6.5	7.5	9.2	7.4	1.7	1.6
Mass of dry soil, gm	9.4	10.5	12.6	9.6	5.2	4.9
Water content(ω), %	69.1	71.4	73.0	77.1	32.69	32.65
No of blows	34	27	23	14	32.67	

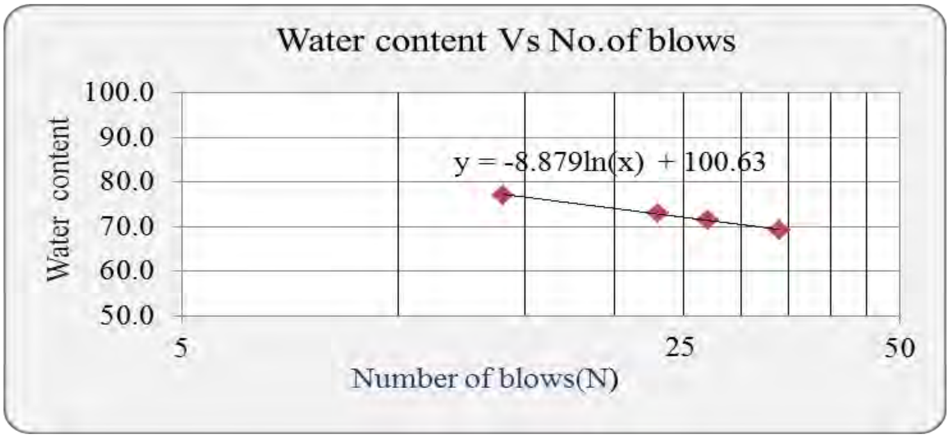

Figure: Liquid Limit determination for TP-7@2.0m

 # Test pit 8 (TP-8)

At 2.0m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	H24	C5	G6	D2	T3	E5
Mass of container,gm	15.7	15.7	14.0	15.6	15.2	15.3
Mass of container +wet soil,gm	38.6	35.5	33.1	33.5	21.8	21.8
Mass of container +dry soil,gm	29.2	27.3	25.0	25.7	20.2	20.2
Mass of water, gm	9.4	8.2	8.1	7.8	1.6	1.6
Mass of dry soil, gm	13.5	11.6	11.0	10.1	5	4.9
Water content(ω), %	69.6	70.7	73.6	77.2	32.00	32.65
No of blows	31	26	24	16	32.33	

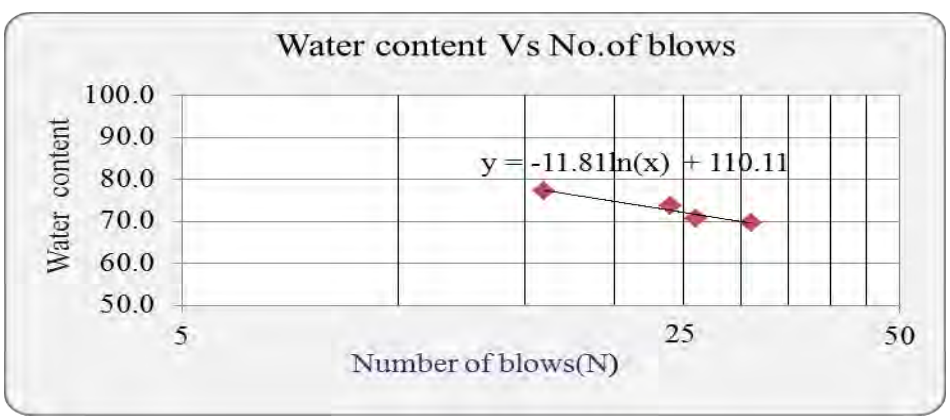

Figure: Liquid Limit determination for TP-8@2.0m

 # Test pit 9 (TP-9)

At 1.5m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A4	C5	G6	D2	T3	E5
Mass of container,gm	15.5	15.8	15.5	15.8	15.2	15.3
Mass of container +wet soil,gm	36.3	36.1	36.1	39.1	22.3	22.3
Mass of container +dry soil,gm	28.1	27.9	27.6	29.3	20.6	20.6
Mass of water, gm	8.2	8.2	8.5	9.8	1.7	1.7
Mass of dry soil, gm	12.6	12.1	12.1	13.5	5.4	5.3
Water content(ω), %	65.1	67.8	70.2	72.6	31.48	32.08
No of blows	38	26	23	16	31.78	

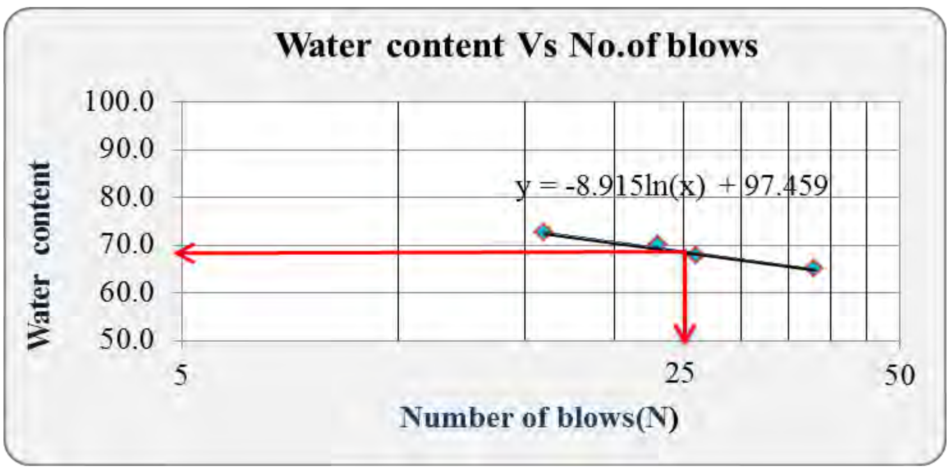

Figure: liquid limit determinations for TP-9 @1.5m

At 3.0m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A1	C2	U4	D6	T3	D2
Mass of container,gm	15.7	15.8	15.6	15.7	15.6	15.6
Mass of container +wet soil,gm	35.2	32.8	36.3	34.9	22.5	22.3
Mass of container +dry soil,gm	27.2	25.9	27.7	26.8	20.8	20.7
Mass of water, gm	8.0	6.9	8.6	8.1	1.7	1.6
Mass of dry soil, gm	11.5	10.1	12.1	11.1	5.2	5.1
Water content(ω), %	69.6	68.3	71.1	73.0	32.69	31.37
No of blows	33	27	23	17	32.03	

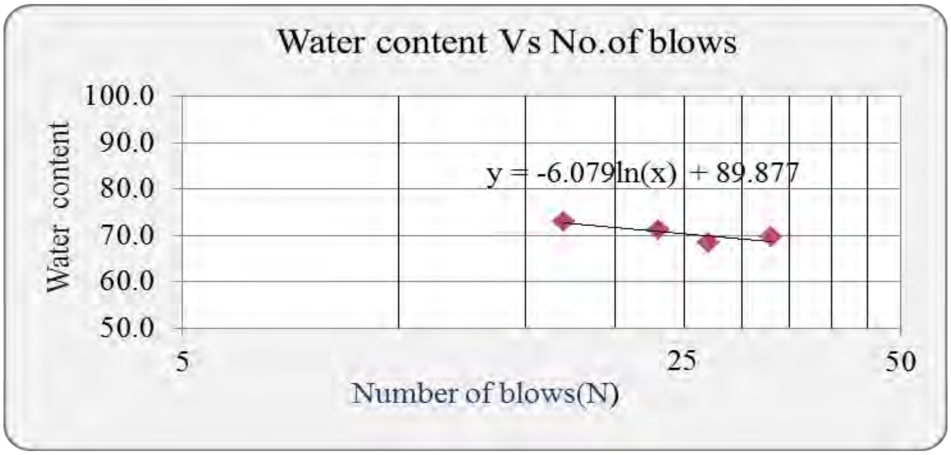

Figure: Liquid Limit determinations for TP-9 @3.0m

 # Test pit 10 (TP-10)

At 1.5m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A4	C5	G6	D2	T3	E5
Mass of container,gm	15.5	15.8	15.5	15.9	15.2	15.3
Mass of container +wet soil,gm	36.6	36.3	36.3	39.1	22.4	22.3
Mass of container +dry soil,gm	28.1	27.9	27.6	29.3	20.6	20.6
Mass of water, gm	8.5	8.4	8.7	9.8	1.8	1.7
Mass of dry soil, gm	12.6	12.1	12.1	13.4	5.4	5.3
Water content(ω), %	67.5	69.4	71.9	73.1	33.33	32.08
No of blows	38	28	24	17	32.70	

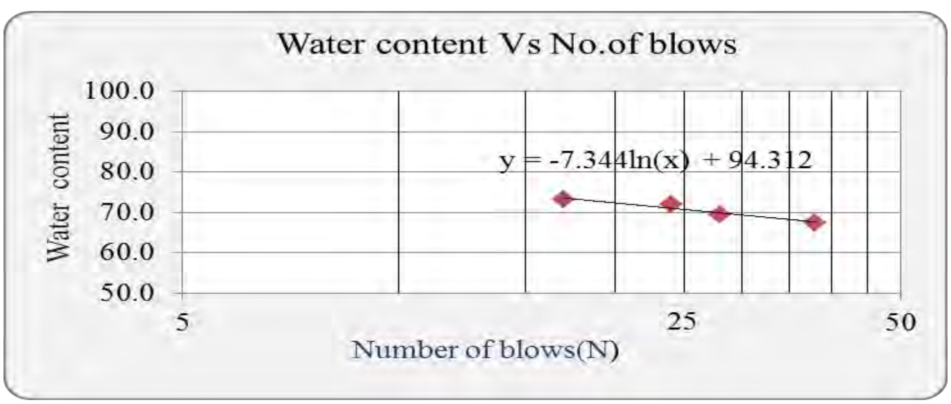

Figure : Liquid Limit determinations for TP-10@1.5m

At 3m depth

	Liquid Limit				Plastic Limit	
Trail No	1	2	3	4	1	2
Container No	A1	C2	U4	D6	T3	D2
Mass of container,gm	15.3	15.8	15.4	15.5	15.5	15.6
Mass of container +wet soil,gm	35.2	32.8	36.3	34.9	22.5	22.4
Mass of container +dry soil,gm	27.2	25.9	27.7	26.8	20.8	20.7
Mass of water, gm	8.0	6.9	8.6	8.1	1.7	1.7
Mass of dry soil, gm	11.9	10.1	12.3	11.3	5.3	5.1
Water content(ω), %	67.2	68.3	69.9	71.7	32.08	33.33
No of blows	36	29	24	18	32.70	

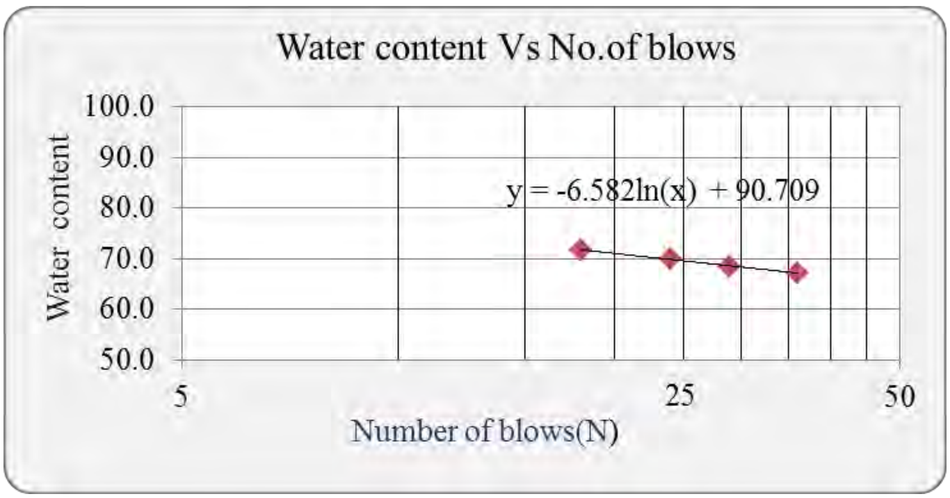

Figure: Liquid Limit determinations for TP-10@3.0m

APPENDIX - C

COMPACTION TEST RESULTS

 # Test pit 1 (TP-1)

At 3.0m depth

Trial Number	1	2	3	4
Mold weight +sample (gm)	4356.6	4560.9	4781.5	4689.8
Mold weight (gm)	3140	3140	3140	3140
Sample weight (gm)	1216.6	1420.9	1641.5	1549.8
Mold volume (Cm3)	944	944	944	944
Bulk density(g/cm3)	1.29	1.51	1.74	1.64
Moisture Content (%)				
Wet weight +can	43.2	42.7	54.9	46.6
Dry weight + can	39.3	37.8	45.7	38.0
weight of can	15.3	15.5	15.5	15.4
weight of moisture	3.9	4.9	9.2	8.6
Weight of dry soil	24.0	22.3	30.2	22.6
Moisture content (%)	16.3	22.0	30.5	38.1
Dry density (g/cm3)	1.11	1.23	1.33	1.19

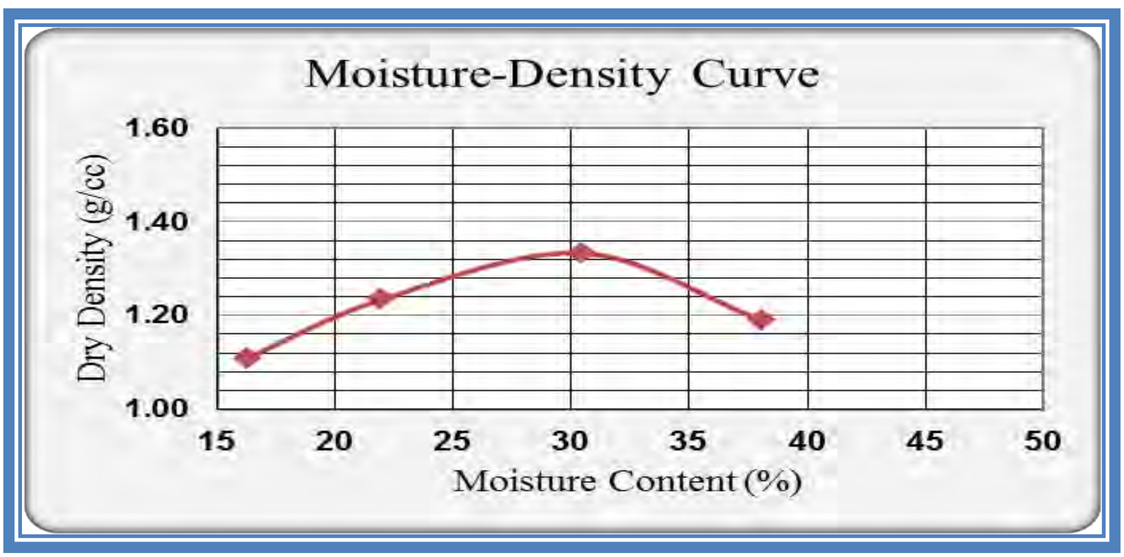

Figure: Dry Density versus Optimum Moisture Content for TP-1@3m

 # Test pit 2 (TP-2)

At 3.0m depth

Trial Number	1	2	3	4
Mold weight +sample (gm)	4256.6	4460.9	4781.5	4689.8
Mold weight (gm)	3140	3140	3140	3140
Sample weight (gm)	1116.6	1320.9	1641.5	1549.8
Mold volume (Cm3)	944	944	944	944
Bulk density(g/cm3)	1.18	1.40	1.74	1.64
Moisture Content (%)				
Wet weight +can	43.2	42.7	54.9	46.6
Dry weight + can	39.3	37.8	45.7	38.0
weight of can	15.3	15.5	15.5	15.4
weight of moisture	3.9	4.9	9.2	8.6
Weight of dry soil	24.0	22.3	30.2	22.6
Moisture content (%)	16.3	22.0	30.5	38.1
Dry density (g/cm3)	1.02	1.15	1.33	1.19

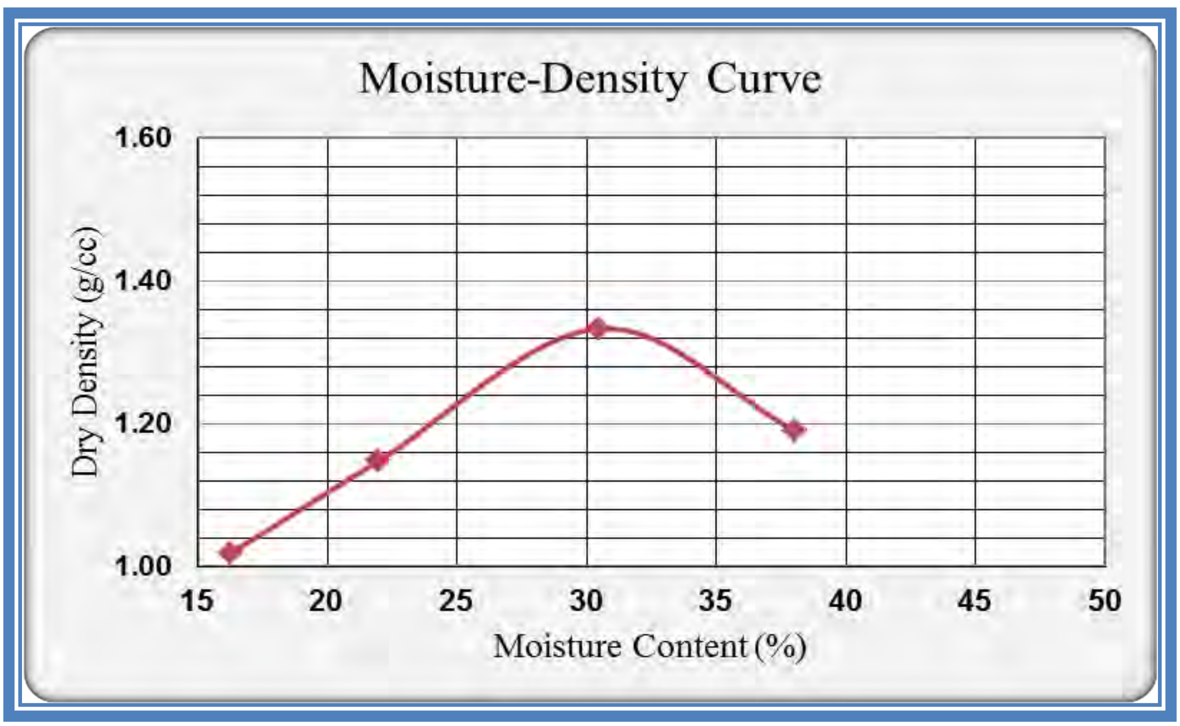

Figure: Dry Density versus Optimum Moisture Content for TP-2@3m

 # Test pit 3 (TP-3)

At 3.0m depth

Trial Number	1	2	3	4
Mold weight +sample (gm)	4456.6	4660.9	4881.5	4789.8
Mold weight (gm)	3140	3140	3140	3140
Sample weight (gm)	1316.6	1520.9	1741.5	1649.8
Mold volume (Cm3)	944	944	944	944
Bulk density(g/cm3)	1.39	1.61	1.84	1.75
Moisture Content (%)				
Wet weight +can	44.2	43.7	55.9	47.6
Dry weight + can	39.3	37.8	45.7	38.0
weight of can	15.3	15.5	15.5	15.4
weight of moisture	4.9	5.9	10.2	9.6
Weight of dry soil	24.0	22.3	30.2	22.6
Moisture content (%)	20.4	26.5	33.8	42.5
Dry density (g/cm3)	1.16	1.27	1.38	1.23

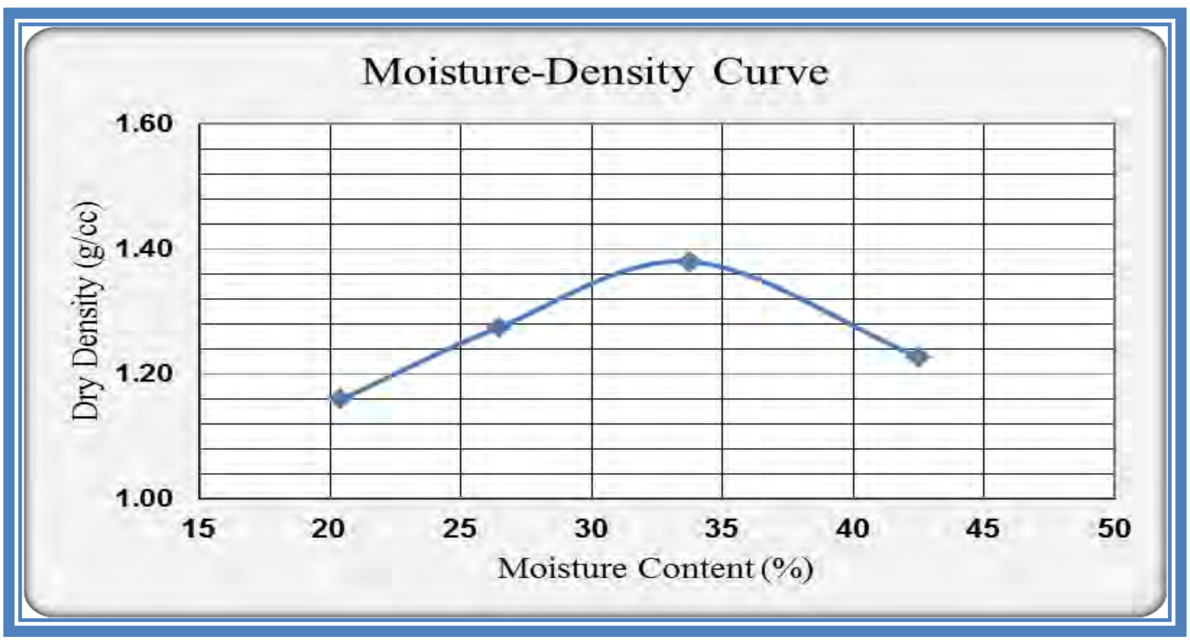

Figure: Dry Density versus Optimum Moisture Content for TP-3@3m

 # Test pit 5 (TP-5)

At 3.0m depth

Trial Number	1	2	3	4
Mold weight +sample (gm)	4356.6	4630.9	4881.5	4803.8
Mold weight (gm)	3140	3140	3140	3140
Sample weight (gm)	1216.6	1490.9	1741.5	1663.8
Mold volume (Cm3)	944	944	944	944
Bulk density(g/cm3)	1.29	1.58	1.84	1.76
Moisture Content (%)				
Wet weight +can	44.2	43.9	56.3	47.5
Dry weight + can	39.3	37.8	45.7	38.0
weight of can	15.3	15.5	15.5	15.4
weight of moisture	4.9	6.1	10.6	9.5
Weight of dry soil	24.0	22.3	30.2	22.6
Moisture content (%)	20.4	27.4	35.1	42.0
Dry density (g/cm3)	1.07	1.24	1.37	1.24

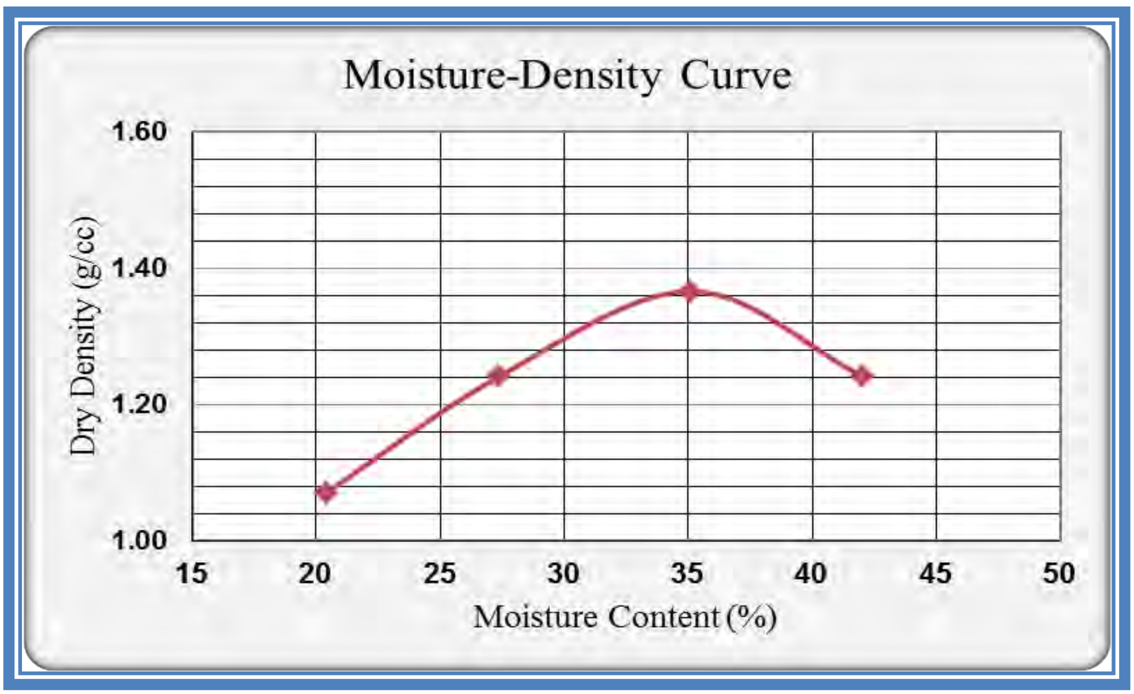

Figure: Dry Density versus Optimum Moisture Content for TP-5@3m

 # Test pit 7 (TP-7)

At 2.0m depth

Trial Number	1	2	3	4
Mold weight +sample (gm)	4356.9	4561.1	4781.8	4690.1
Mold weight (gm)	3140	3140	3140	3140
Sample weight (gm)	1216.9	1421.1	1641.8	1550.1
Mold volume (Cm3)	944	944	944	944
Bulk density(g/cm3)	1.29	1.51	1.74	1.64
Moisture Content (%)				
Wet weight +can	43.7	43.2	55.4	47.1
Dry weight + can	39.3	37.8	45.7	38.0
weight of can	15.3	15.5	15.5	15.4
weight of moisture	4.4	5.4	9.7	9.1
Weight of dry soil	24.0	22.3	30.2	22.6
Moisture content (%)	18.3	24.2	32.1	40.3
Dry density (g/cm3)	1.09	1.21	1.32	1.17

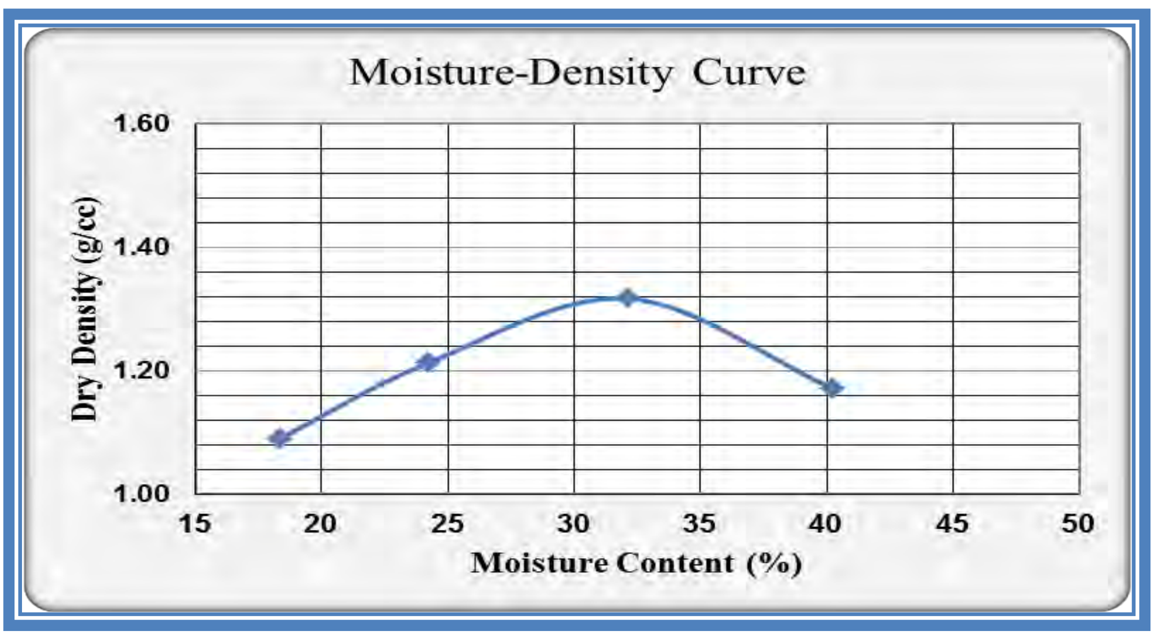

Figure: Dry Density versus Optimum Moisture Content for TP-7@2m

 # Test pit 9 (TP-9)

At 3.0m depth

Trial Number	1	2	3	4
Mold weight +sample (gm)	4405.4	4603.8	4824.2	4790.5
Mold weight (gm)	3140	3140	3140	3140
Sample weight (gm)	1265.4	1463.8	1684.2	1650.5
Mold volume (Cm3)	944	944	944	944
Bulk density(g/cm3)	1.34	1.55	1.78	1.75
Moisture Content (%)				
Wet weight +can	43.3	40.1	43.3	47.1
Dry weight + can	38.9	35.3	36.7	38.1
weight of can	15.6	15.8	16.0	15.4
weight of moisture	4.4	4.8	6.6	9.0
Weight of dry soil	23.3	19.5	20.7	22.7
Moisture content (%)	18.9	24.6	31.9	39.6
Dry density (g/cm3)	1.13	1.24	1.35	1.25

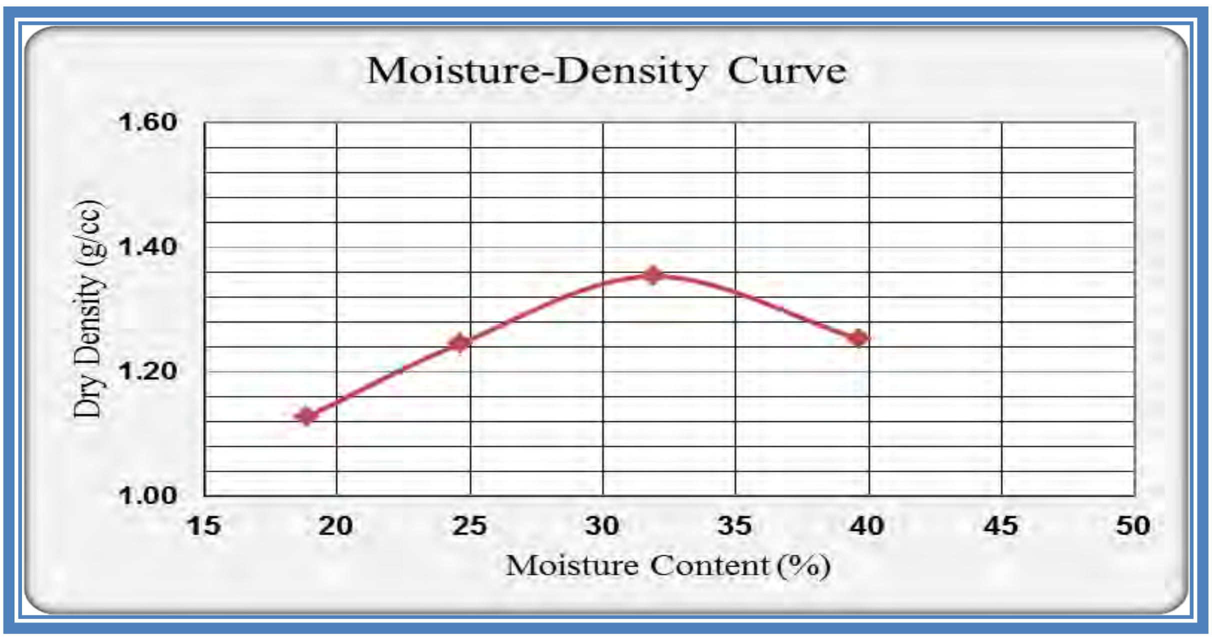

Figure: Dry Density versus Optimum Moisture Content for TP-9@3m

APPENDIX – D

UNCONFINED COMPRESSION STRENGTH TEST RESULTS

 # Test pit 3 (TP-3)

At 3.0m depth

Deformation Dial Reading (division)	Sample Deformation (mm)	Strain (e) (ΔL/Lo)	% Strain	Corrected Area Ac=Ao/(1-ε)	Proving Ring Reading (division)	Load (KN)	Stress (Kpa)
0	0.0	0.00000	0.00000	0.00113	0	0.00000	0.00
20	0.2	0.00263	0.26316	0.00114	22	0.03124	27.47
40	0.4	0.00526	0.52632	0.00114	39	0.05538	48.57
60	0.6	0.00789	0.78947	0.00114	55	0.07810	68.32
80	0.8	0.01053	1.05263	0.00115	70	0.09940	86.72
100	1.0	0.01316	1.31579	0.00115	88	0.12496	108.73
120	1.2	0.01579	1.57895	0.00115	113	0.16046	139.25
140	1.4	0.01842	1.84211	0.00116	131	0.18602	161.00
160	1.6	0.02105	2.10526	0.00116	151	0.21442	185.08
180	1.8	0.02368	2.36842	0.00116	175	0.24850	213.92
200	2.0	0.02632	2.63158	0.00116	199	0.28258	242.61
220	2.2	0.02895	2.89474	0.00117	225	0.31950	273.56
240	2.4	0.03158	3.15789	0.00117	250	0.35500	303.13
260	2.6	0.03421	3.42105	0.00117	280	0.39760	338.59
280	2.8	0.03684	3.68421	0.00118	310	0.44020	373.84
300	3.0	0.03947	3.94737	0.00118	340	0.48280	408.90
320	3.2	0.04211	4.21053	0.00118	370	0.52540	443.76
340	3.4	0.04474	4.47368	0.00119	388	0.55096	464.07
360	3.6	0.04737	4.73684	0.00119	390	0.5538	465.18
380	3.8	0.05000	5.00000	0.00119	380	0.5396	452.00
400	4.0	0.05263	5.26316	0.00120	360	0.5112	427.02
420	4.2	0.05526	5.52632	0.00120	340	0.4828	402.18
440	4.4	0.05789	5.78947	0.00120	320	0.4544	377.47

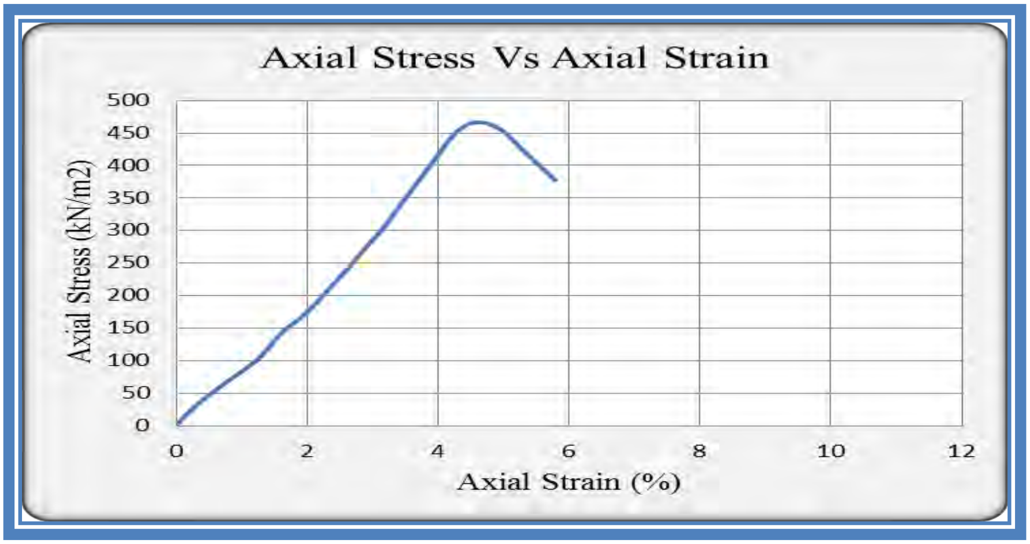

Figure: Axial stress Vs. Axial Strain of TP-3@3m

 # Test pit 4 (TP-4)

At 3.0m depth

Deformation Dial Reading (division)	Sample Deformation (mm)	Strain (e) (ΔL/Lo)	% Strain	Corrected Area Ac=Ao/(1-ε)	Proving Ring Reading (division)	Load (KN)	Stress (Kpa)
0	0.0	0.00000	0.00000	0.00113	0	0.00000	0.00
20	0.2	0.00263	0.26316	0.00114	33	0.04686	41.21
40	0.4	0.00526	0.52632	0.00114	58	0.08236	72.24
60	0.6	0.00789	0.78947	0.00114	89	0.12638	110.56
80	0.8	0.01053	1.05263	0.00115	115	0.16330	142.47
100	1.0	0.01316	1.31579	0.00115	140	0.19880	172.98
120	1.2	0.01579	1.57895	0.00115	160	0.22720	197.17
140	1.4	0.01842	1.84211	0.00116	179	0.25418	219.99
160	1.6	0.02105	2.10526	0.00116	199	0.28258	243.92
180	1.8	0.02368	2.36842	0.00116	214	0.30388	261.60
200	2.0	0.02632	2.63158	0.00116	230	0.32660	280.40
220	2.2	0.02895	2.89474	0.00117	247	0.35074	300.31
240	2.4	0.03158	3.15789	0.00117	262	0.37204	317.69
260	2.6	0.03421	3.42105	0.00117	285	0.40470	344.63
280	2.8	0.03684	3.68421	0.00118	299	0.42458	360.58
300	3.0	0.03947	3.94737	0.00118	310	0.44020	372.82
320	3.2	0.04211	4.21053	0.00118	305	0.43310	365.80
340	3.4	0.04474	4.47368	0.00119	290	0.4118	346.86
360	3.6	0.04737	4.73684	0.00119	270	0.3834	322.05
380	3.8	0.05000	5.00000	0.00119	250	0.355	297.37
400	4.0	0.05263	5.26316	0.00120	220	0.3124	260.96

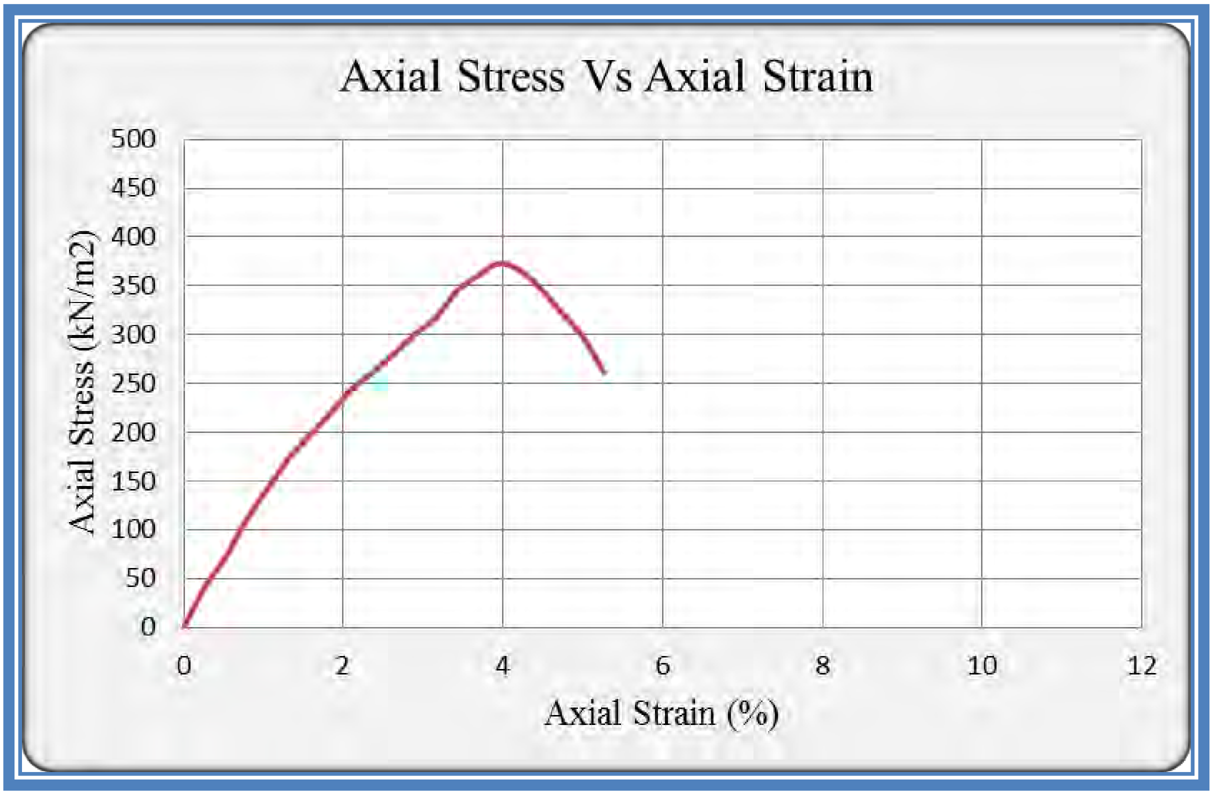

Figure: Axial stress Vs. Axial Strain of TP-4@3m

 # Test pit 5 (TP-5)

At 3.0m depth

Deformation Dial Reading (division)	Sample Deformation (mm)	Strain (e) (ΔL/Lo)	% Strain	Corrected Area Ac=Ao/(1-ε)	Proving Ring Reading (division)	Load (KN)	Stress (Kpa)
0	0.0	0.00000	0.00000	0.00113	0	0.00000	0.00
20	0.2	0.00263	0.26316	0.00114	12	0.01704	14.99
40	0.4	0.00526	0.52632	0.00114	21	0.02982	26.16
60	0.6	0.00789	0.78947	0.00114	39	0.05538	48.45
80	0.8	0.01053	1.05263	0.00115	49	0.06958	60.71
100	1.0	0.01316	1.31579	0.00115	60	0.08520	74.14
120	1.2	0.01579	1.57895	0.00115	69	0.09798	85.03
140	1.4	0.01842	1.84211	0.00116	78	0.11076	95.86
160	1.6	0.02105	2.10526	0.00116	86	0.12212	105.41
180	1.8	0.02368	2.36842	0.00116	95	0.13490	116.13
200	2.0	0.02632	2.63158	0.00116	103	0.14626	125.57
220	2.2	0.02895	2.89474	0.00117	111	0.15762	134.96
240	2.4	0.03158	3.15789	0.00117	119	0.16898	144.29
260	2.6	0.03421	3.42105	0.00117	128	0.18176	154.78
280	2.8	0.03684	3.68421	0.00118	135	0.19170	162.80
300	3.0	0.03947	3.94737	0.00118	142	0.20164	170.78
320	3.2	0.04211	4.21053	0.00118	155	0.22010	185.90
340	3.4	0.04474	4.47368	0.00119	165	0.23430	197.35
360	3.6	0.04737	4.73684	0.00119	175	0.24850	208.73
380	3.8	0.05000	5.00000	0.00119	185	0.26270	220.05
400	4.0	0.05263	5.26316	0.00120	195	0.27690	231.30
420	4.2	0.05526	5.52632	0.00120	206	0.29252	243.67
440	4.4	0.05789	5.78947	0.00120	217	0.30814	255.97
460	4.6	0.06053	6.05263	0.00121	227	0.32234	267.02
480	4.8	0.06316	6.31579	0.00121	238	0.33796	279.17
500	5.0	0.06579	6.57895	0.00121	248	0.35216	290.09
520	5.2	0.06842	6.84211	0.00122	258	0.36636	300.93
540	5.4	0.07105	7.10526	0.00122	267	0.37914	310.55
560	5.6	0.07368	7.36842	0.00122	275	0.39050	318.95
580	5.8	0.07632	7.63158	0.00123	281	0.39902	324.98
600	6.0	0.07895	7.89474	0.00123	285	0.40470	328.67
620	6.2	0.08158	8.15789	0.00123	286	0.40612	328.88
640	6.4	0.08421	8.42105	0.00124	284	0.40328	325.65
660	6.6	0.08684	8.68421	0.00124	281	0.39902	321.28
680	6.8	0.08947	8.94737	0.00125	275	0.39050	313.51
700	7.0	0.09211	9.21053	0.00125	270	0.38340	306.92
720	7.2	0.09474	9.47368	0.00125	262	0.37204	296.97
740	7.4	0.09737	9.73684	0.00126	252	0.35784	284.80
760	7.6	0.10000	10.00000	0.00126	240	0.34080	270.45

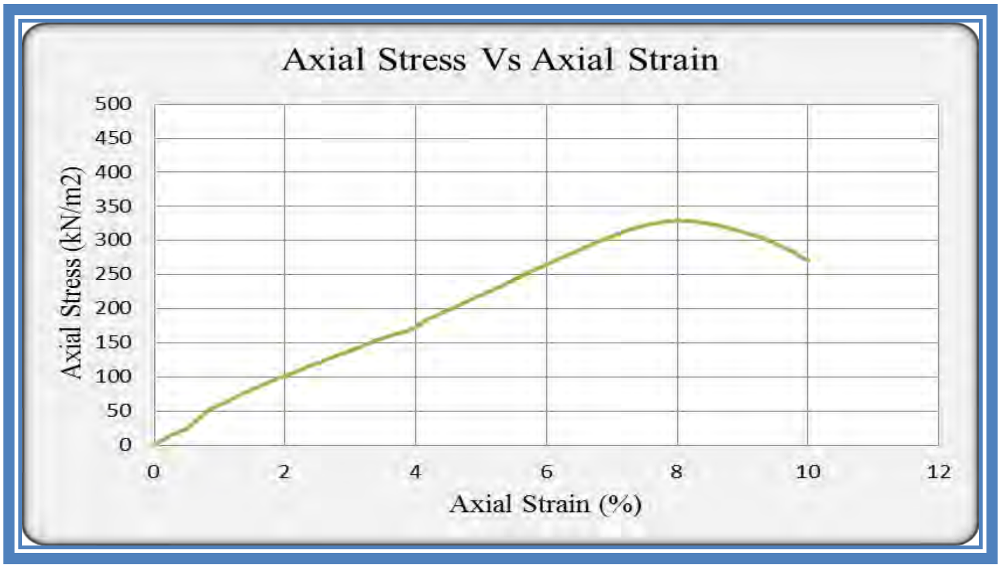

Figure: Axial stress Vs. Axial Strain of TP-5@3m

 # Test pit 9 (TP-9)

At 3.0m depth

Deformation Dial Reading (division)	Sample Deformation (mm)	Strain (e) (ΔL/Lo)	% Strain	Corrected Area Ac=Ao/(1-ε)	Proving Ring Reading (division)	Load (KN)	Stress (Kpa)
0	0.0	0.00000	0.00000	0.00113	0	0.00000	0.00
20	0.2	0.00263	0.26316	0.00114	26	0.03692	32.47
40	0.4	0.00526	0.52632	0.00114	60	0.08520	74.73
60	0.6	0.00789	0.78947	0.00114	95	0.13490	118.01
80	0.8	0.01053	1.05263	0.00115	125	0.17750	154.86
100	1.0	0.01316	1.31579	0.00115	150	0.21300	185.34
120	1.2	0.01579	1.57895	0.00115	172	0.24424	211.96
140	1.4	0.01842	1.84211	0.00116	193	0.27406	237.20
160	1.6	0.02105	2.10526	0.00116	210	0.29820	257.40
180	1.8	0.02368	2.36842	0.00116	220	0.31240	268.93
200	2.0	0.02632	2.63158	0.00116	230	0.32660	280.40
220	2.2	0.02895	2.89474	0.00117	240	0.34080	291.80
240	2.4	0.03158	3.15789	0.00117	247	0.35074	299.50
260	2.6	0.03421	3.42105	0.00117	250	0.35500	302.31
280	2.8	0.03684	3.68421	0.00118	253	0.35926	305.10
300	3.0	0.03947	3.94737	0.00118	255	0.36210	306.68
320	3.2	0.04211	4.21053	0.00118	253	0.35926	303.44
340	3.4	0.04474	4.47368	0.00119	245	0.3479	293.04
360	3.6	0.04737	4.73684	0.00119	235	0.3337	280.30
380	3.8	0.05000	5.00000	0.00119	220	0.3124	261.68

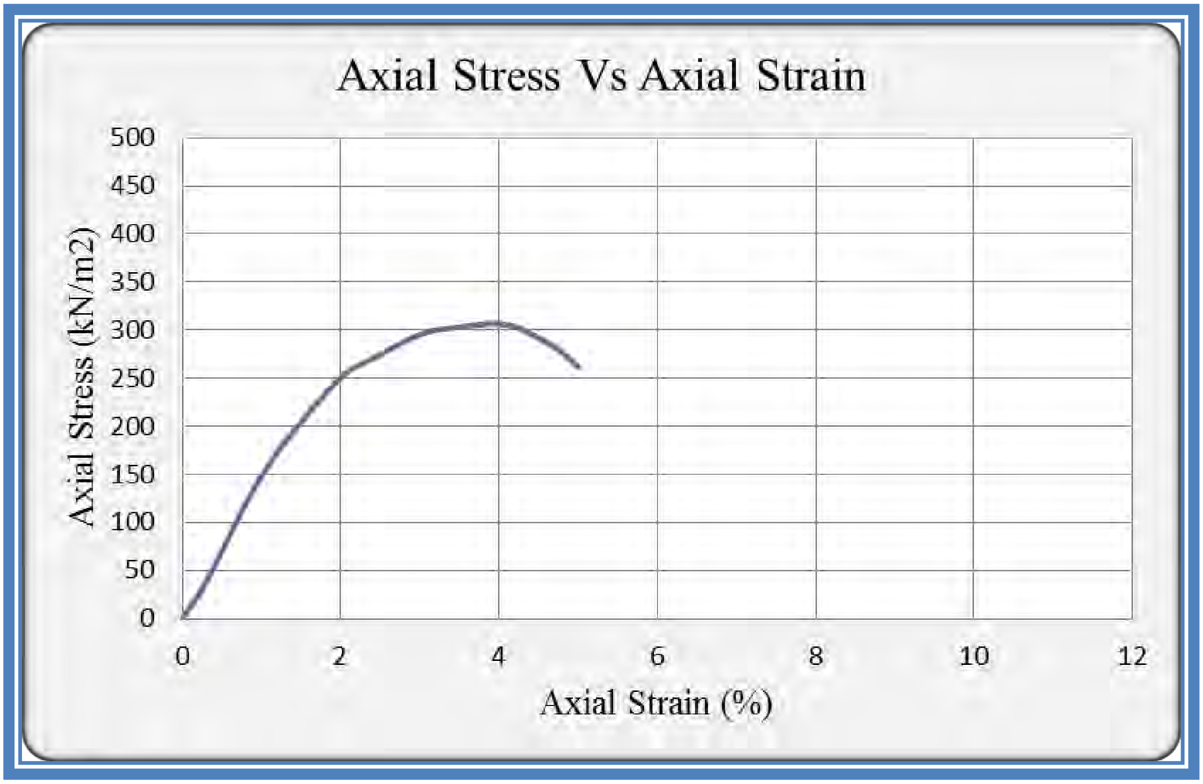

Figure: Axial stress Vs. Axial Strain of TP-9@3m

APPENDIX – E

CONSOLIDATION TEST RESULTS

❖ Dial guage reading for each incremental loading of TP-3@3m

Square root of time	time(min)	50kpa Dial reading(mm)	100kpa Dial reading(mm)	200kpa Dial reading(mm)	400kpa Dial reading(mm)	800kpa Dial reading(mm)	1600kpa Dial reading(mm)
0.000	0	3.018	3.244	3.410	3.654	3.966	4.340
0.316	0.1	3.150	3.314	3.530	3.810	4.136	4.486
0.500	0.25	3.164	3.322	3.538	3.824	4.148	4.500
0.707	0.5	3.174	3.328	3.546	3.834	4.158	4.510
1.000	1	3.182	3.334	3.554	3.846	4.170	4.526
1.414	2	3.190	3.342	3.566	3.858	4.186	4.544
2.000	4	3.198	3.350	3.578	3.872	4.204	4.570
2.828	8	3.206	3.362	3.590	3.890	4.226	4.604
3.873	15	3.212	3.370	3.600	3.904	4.250	4.640
5.477	30	3.218	3.378	3.614	3.920	4.278	4.676
7.746	60	3.224	3.388	3.626	3.932	4.298	4.704
10.954	120	3.230	3.392	3.634	3.942	4.312	4.724
15.492	240	3.234	3.398	3.642	3.952	4.318	4.740
21.909	480	3.238	3.404	3.648	3.958	4.330	4.752
37.947	1440	3.244	3.410	3.654	3.966	4.340	4.760

❖ Applied pressure Vs void ratio summary table of TP-3@3m

Pressure, kPa	ΔH(mm)	Cumulative. ΔH (mm)	H_f	$H_v=H_f-H_s$	$e_f=Hv/Hs$	$\Delta e=\Delta H/H_s$	$e=e_o-\Delta e$
7	-0.406	-0.406	20.406	10.26	1.01	-0.04	0.99
50	0.266	0.266	19.734	9.587	0.94	0.02	0.95
100	0.166	0.432	19.568	9.421	0.93	0.04	0.93
200	0.244	0.676	19.324	9.177	0.90	0.07	0.90
400	0.312	0.988	19.012	8.865	0.87	0.10	0.87
800	0.374	1.362	18.638	8.491	0.84	0.13	0.84
1600	0.420	1.782	18.218	8.071	0.80	0.18	0.80

❖ Determination of preconsolidation pressure from e-logp curve according to Casagrande method for TP-3@3m

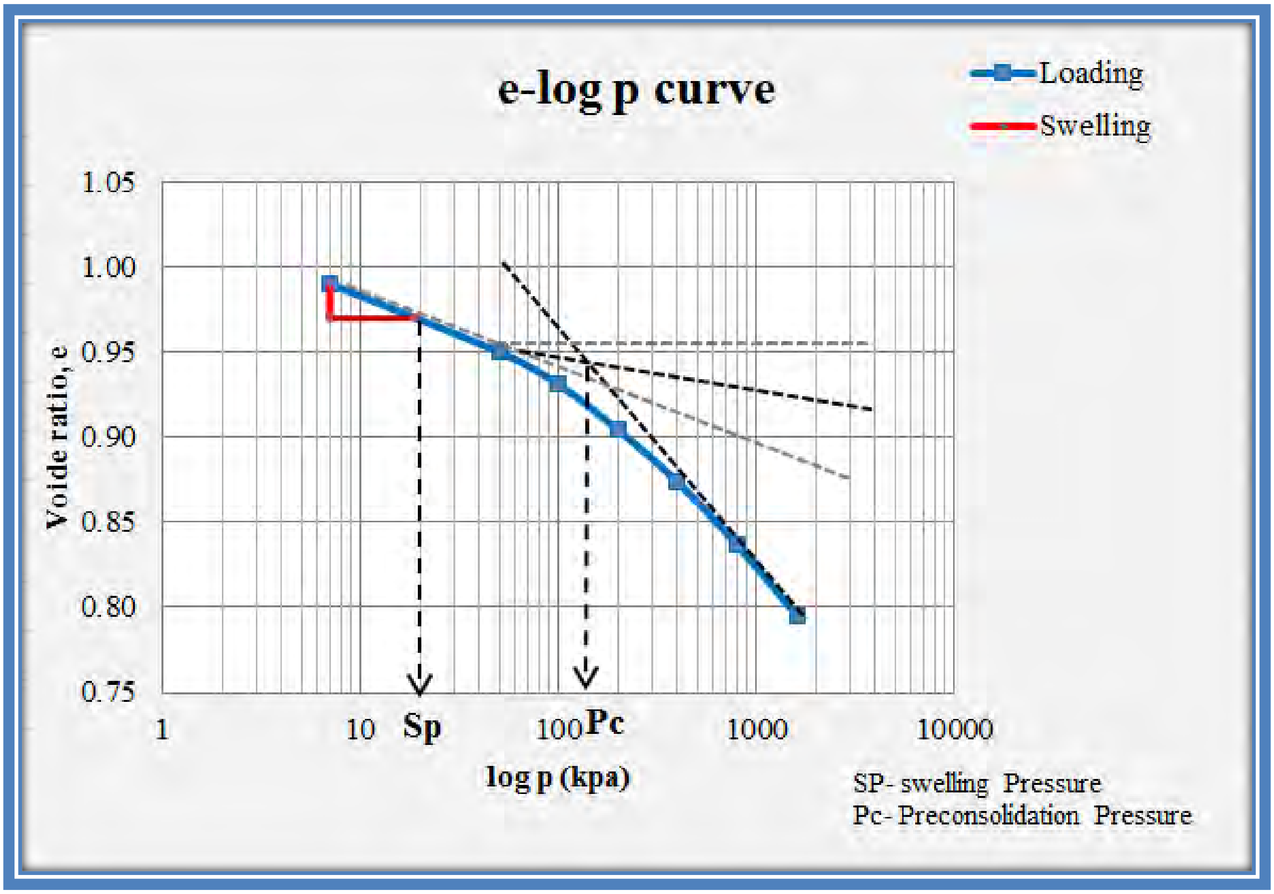

Figure: Void ratio Vs log p curve for TP-3@3m

❖ Dial guage reading for each incremental loading of TP-7@2m

Square root of time	time(min)	50kpa Dial reading(mm)	100kpa Dial reading(mm)	200kpa Dial reading(mm)	400kpa Dial reading(mm)	800kpa Dial reading(mm)	1600kpa Dial reading(mm)
0.000	0	7.312	7.376	7.614	7.84	9.02	10.236
0.316	0.1	7.321	7.535	7.698	7.978	9.356	10.356
0.500	0.25	7.322	7.538	7.71	7.998	9.37	10.37
0.707	0.5	7.324	7.542	7.72	7.998	9.384	10.384
1.000	1	7.326	7.548	7.728	8.012	9.448	10.448
1.414	2	7.331	7.554	7.74	8.081	9.504	10.504
2.000	4	7.336	7.56	7.752	8.192	9.63	10.63
2.828	8	7.342	7.57	7.764	8.291	9.756	10.756
3.873	15	7.348	7.578	7.776	8.422	9.888	10.898
5.477	30	7.358	7.588	7.786	8.616	9.986	10.986
7.746	60	7.362	7.597	7.798	8.841	10.068	11.068
10.954	120	7.364	7.603	7.812	8.96	10.166	11.166
15.492	240	7.366	7.609	7.822	8.999	10.218	11.318
21.909	480	7.366	7.612	7.838	9.001	10.232	11.432
37.947	1440	7.367	7.614	7.84	9.02	10.236	11.456

❖ Applied pressure Vs void ratio summary table of TP-7@2m

Pressure, kPa	ΔH(mm)	Cumulative. ΔH (mm)	H_f	$H_v = H_f - H_s$	$e_f = Hv/Hs$	$\Delta e = \Delta H/H_s$	$e = e_o - \Delta e$
7	-0.288	-0.288	20.288	10.34	1.03	0.028	1.04
50	0.055	0.055	19.945	9.995	1.00	0.004	1.01
100	0.238	0.293	19.707	9.757	0.98	0.029	0.98
200	0.226	0.519	19.481	9.531	0.95	0.052	0.94
400	1.180	1.699	18.301	8.351	0.83	0.170	0.84
800	1.216	2.915	17.085	7.135	0.71	0.292	0.72
1600	1.22	4.135	15.865	5.915	0.59	0.415	0.59

❖ Determination of preconsolidation pressure from e-logp curve according to Casagrande method for TP-7@2m.

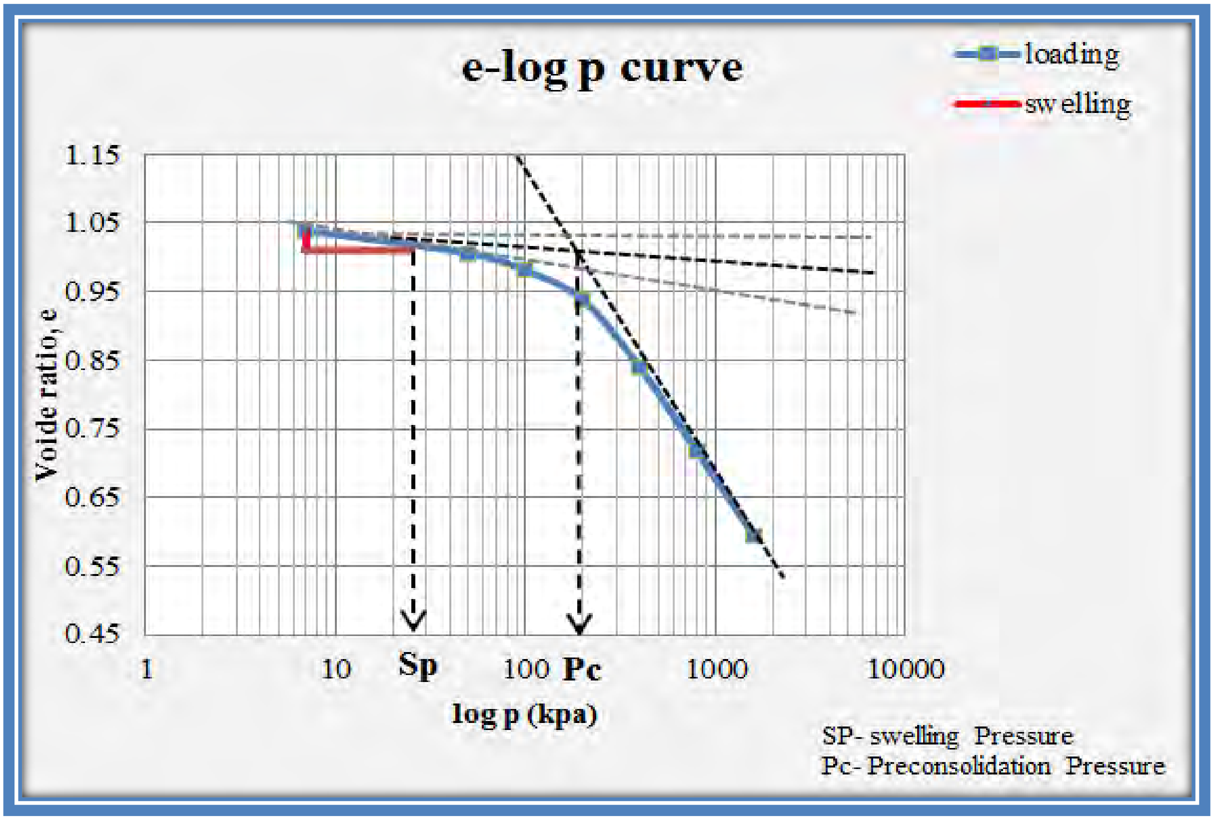

Figure: Void ratio Vs log p curve for TP-7@2m

❖ Pressure Vs Void ratio for TP-3@3m and TP-7@2m

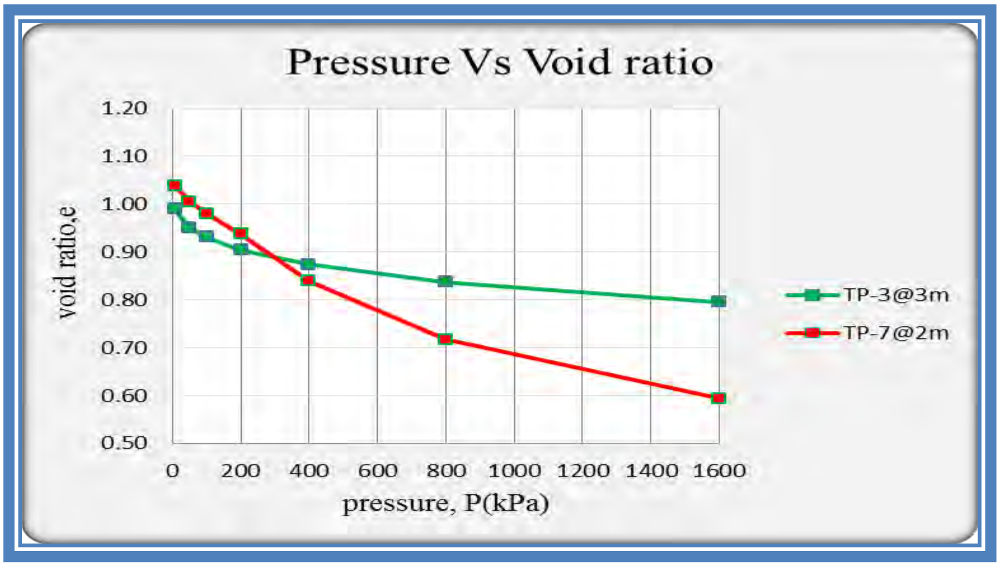

Figure: Pressure Vs Void ratio for TP-3@3m and TP-7@2m

❖ Pressure Vs Coefficient of consolidation for TP-3@3m and TP-7@2m

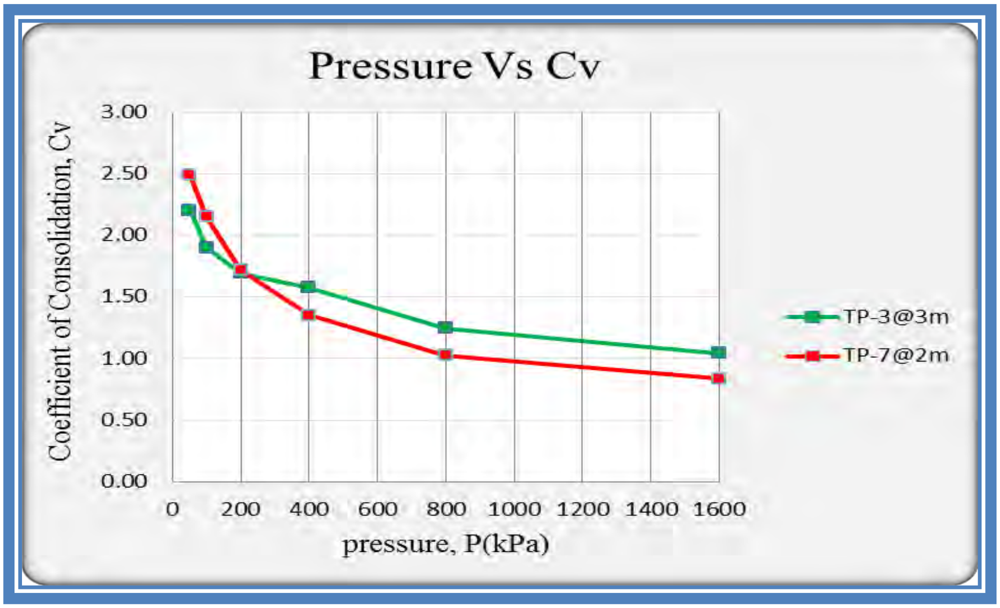

Figure: Pressure Vs Cv for TP-3@3m and TP-7@2m