JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

GEOTECHNICAL ENGINEERING STREAM

INVESTIGATION ON SOME OF THE ENGINEERING PROPERTIES OF SOILS FOUND IN SOKORU TOWN

A Research submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Geotechnical Engineering)

By: TIZITA DECHASA

November, 2017

Jimma, Ethiopia

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DECLARATION

This research is my original work and has not been presented for a degree in any other university.

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This research has been submitted for examination with any approval as university supervisor.

Prof. EmerT. Quezon _____________________ _____/_____/______

Name Signature Date

Engr. Tadesse Abebe _____________________ _____/_____/______

Name Signature Date

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols	Description	SI units
A	Activity	----
A_c	Corrected Cross Sectional Area	m^2
Ao	Original Cross Sectional Area	m^2
Av	Coefficient of Compressibility	m^2/kN
AASHTO	American Association of State Highway Officials	----
ASTM	American Society for testing and Materials	----
C_c	Compression Index	----
Cc	Consistency Index	----
CH	Inorganic Clays of High Plastic	----
Cs	Swelling Index	----
Cu	Cohesion for Undrained Shear Strength	kN/m^2
Cv	Coefficient of consolidation	m^2/day
E	Void ratio	----
GI	Group Index	----
Gs	Specific Gravity	----
H	Height	m
K_v	Coefficient of Permeability	m/day
LI	Liquidity Index	%
LL/W_L	Liquid limit	%
MDD	Maximum Dry Density	kg/m^3
NMC	Natural Moisture Content	%
MH	Organic Clays of Medium to High Plasticity	----
OMC	Optimum moisture content	%
OCR	Over Consolidation Ratio	----
P	Vertical applied pressure	kN/m^2
P_c	Preconsolidation Pressure	kN/m^2
PI/I_P	Plasticity Index	%
PL/P_L	Plastic limit	%
q_u	Unconfined Compressive Strength	kN/m^2
S_L	Shrinkage Limit	%
S_u	Undrained shear strength	kN/m^2
T	Consolidation Time factor	----
t	Time	second
Uscs	Unified Soil Classification System	----
w	Water Content	%
γ_w	Unit weight of water	kN/m^3
γ_d	Dry unit weight	kN/m^3
γ_s	Solid unit weight	kN/m^3
σ'_o	Effective over burden Pressure	kN/m^2
σ'_v	Effective Vertical Pressure	kN/m
ε	Axial Strain	%
Ø	Angle of Internal Friction	---

ABSTRACT

*Proper understanding of Engineering properties of soils is utmost important in any location where all structures are to be founded. The study area of this research is located at Sokoru town, North east of Jimma as part of Jimma Zone. The objective of this study is to investigate some of the engineering properties of soils found in Sokoru town in order to understand clearly the nature of the soil and also to give information for the design, construction and environmental assessment, so that suitable foundation can be recommended for better design and construction in the town. From reconnaissance survey, it has been observed that the Town is covered by red clay soil. Representative disturbed and undisturbed samples from ten test pits were collected from different parts of the town.Laboratory tests were carried out including specific gravity, natural moisture content, Atterberg limits, unconfined compressive strength, consolidation, free swell, Gradation analysis and permeability tests. Based on the results of this study, the grain size distribution indicates all soil samples have more than 50% clay material. Therefore,clay type of soil is dominantly located in the study area. The specific gravity of the soil ranges from 2.5 to 2.73. While the Atterberg limit tests results, the soil is highly plastic clay, and the degrees of activity of most of the study area soils are inactive with maximum Activity index of 1.19. The soil has free swell between 8 % and 49% which also indicaes the soil is not expansive soi. The consistency of soils which are stiff to hard as identified based on the liquidity index value. The compaction test result shows that maximum dry density (MDD) ranges from 1.22 g/cm^3 to 1.39 g/cm^3 and the optimum moisture content (OMC) ranges from 27% to 37%. In addition, the unconfined compressive strength of the soils in the study area ranges from 154.12kN/m^2 -354.21kN/m^2 and undrained shear strength range from 77.1kN/m^2–177.12kN/m^2. Likewise, consistencies of the soils ranges from stiff to very stiff. One-dimensional consolidation tests were done, of which the result showed that the soils have compression index rangs from 0.23-0.39, swelling index ranges from 0.19-0.02. The coefficient of permeability (4.58*10^{-4} to 3.11*10^{-5} cm/sec) indicating that the soil investigated is impermeable.*

Keyword: Engineering properties ,clay

CHAPTER ONE

INTRODUCTION

1.1.Background

Sokoru is one of the woredas in the Oromia Region state of Ethiopia. The altitude of the town ranges from 1160 to 2940 meters above sea level; the highest points include Ali Shashema, Ali Derar and Kumbi. Perennial rivers include the Gilgel Gibe a tributary of the Gibe, and the Kawar; seasonal streams include the MelkaLuku. A survey of the land in this woreda shows that 36.6% is arable or cultivable, 16.8% pasture, 17.2% forest, and the remaining 29.4% is built-up or degraded. The Abelti-Gibe State Forest covers 159 square kilometers of the forested area. Teff is one important cash crop.Although coffee is another important cash crop of this woreda, less than 20 square kilometers are planted with this crop (Dechassa ,1999).

In Sokoru town, many buildings are constructed and being under construction without adequate and detailed geotechnical investigation (Wubshet,2015). In Sokoru town it is also expected that much more construction is going to be done in the future. Since jimma zone is the genetic origin of coffea Arabica it is market place in Southwest and South Ethiopia.Sokoru Town is among this.It is required to determine properly the engineering properties of soils. Since soil properties are essential for economic construction purposes.so,it is important to study soil properties in the Town.

According to many researchers idea Geotechnical investigation is an essential requirement to the design and construction of civil engineering projects. The proper design of civil engineering structures like foundation of buildings, retaining walls, high ways, etc. requires adequate knowledge of sub surface conditions at the sites of the structures. Many damages to buildings, roads and other structures founded on soils are mainly due to the lack of proper investigation of substructure condition.Investigation of the sub-surface conditions at a site is prerequisite to the economical design of the substructure elements. It is also necessary to obtain sufficient information for feasibility andeconomic 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 degradethe environment (Haile,2014).

This thesis gives better understanding about some engineering behavior of the soil in the Town. Identifying the soil characteristic is essential to construct economically different types of civil engineering structures that will serve to the people for various purpose. The results of the study will be of great importance for the ever growing building construction especially for those yet to be constructed in that area. It can be used as soil property manual as it will have a customized nature to meet the required soil information of the area with regard to the future development programs in the construction sector.

In this research to achieve the objectives, applying all the requirements procedural starting from literature review, sample collection, conducting relevant laboratory tests and analysis of results obtained from input data is done. Finally, comparison of the results with already available specification and then formulate a recommendation to who it concerns is carried out.

1.2. Objectives

1.2.1. General objective

The general objective of this research study is to investigate some of the engineering properties of soils in Sokoru Town.

1.2.2. Specific Objectives

- To determine index properties of soil in different parts of the Town.
- To determine the shear strength parameters.
- To determine the consolidation characteristic of soils locations in the study area.
- To classification of the soils based on different classification systems.

1.3. Significance of the study

The research study shall be investigating some of Engineering properties of Soils found in Sokoru Town.In this town there are many expansion projects both building and road construction, beside this there are many problems can be foreseen on the construction which are insufficient geotechnical investigations.So 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 material, environmental damage to the site and even failure of a structure.Therefore, to obtain information on type, characteristics and distributions of a soil, geotechnical investigations should be done on soil

1.4. Scope of the study

The scope of this study is limited to investigating into some of the engineering properties of soil such as index properties,shear strength parameter,compaction and consolidation characteristic. The study provide general data of the soil in the town.In this study the sample is taken from the area where the major construction activities are planned and the pit depth is limited up to 3m. Ten sampling areas were selected from the study area, which represent more than 50% of the total Area of the town.

1.5. Structure of the thesis

This thesis report 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, and scope of the thesis work and structure of the thesis are presented. Chapter two deals with a brief literature review. Chapter three deals with the description of area of (sokoru town) in which this research is done. The fourth Chapter deals with in-situ properties with sample description and the types of laboratory tests conducted and results obtained. The discussion on the laboratory results obtained from this work and comparison with previously done researches is covered in Chapter five. Chapter six is the conclusions and recommendations drawn from the research. Detailed soil profiles for each test pits, calculation of specific gravity test result, grain size and hydrometer analysis test results, atterberglimit results, compaction test results, unconfined compressive test,consolidation and permeability test results are all included in the appendix.

CHAPTER TWO

REVIEW OF RELATED LITERATURES

2.1.General

Soil is a heterogeneous material. The properties and characteristics of soils vary from place to place laterally or vertically. The tests required for determination of engineering properties are generally elaborate and time consuming. Sometimes the geotechnical engineer is interested to have some rough assessment of the engineering properties without conducting elaborate tests.This is possible if index properties are determined. The properties of soils which are not of primary interest to the geotechnical engineer but which are indicative of the engineering properties are called index properties (Arora, 2004).

In nature, Soils occur in a large variety. However, soils exhibiting similar behavior can be grouped together to form 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 (Murthy,1994).

Basic soil properties and parameters can be subdivided into physical, index, and engineeringcategories. Physical soil properties include particle size and distribution, specific gravity, and water content. Index parameters of cohesive soils include liquid limit, plastic limit, shrinkage limit, and activity. Such parameters are useful to classify cohesive soils and provide correlations with engineering soil properties. According to Punimia, et al. the index properties of soils are water content, specific gravity, particle size distribution, consistency limits, in-situ density, free- swell and density index.

Soil index properties are used extensively by engineers to discriminate between the differentkinds of soil within a broad category, e.g. clay will exhibit a wide range of engineering properties depending upon its composition. Classification tests to determine index properties will provide the engineer with valuable information when the results are compared against empirical data relative to the index properties determined (Rufaizal, 2013).

Soils are usually cohesionless, cohesive, or organic

Cohesionless soils have particles that do not tend to stick together. Mostly it is composed of sand, maybe some silt. As a result, these soils tend to shift or change in consistency under different environmental conditions. Rain and wind conditions cause water and air materials to move in and out of soils.

Cohesive soils on the other hand are characterized by very small particle sizes, such as clay or silt, where surface chemical effects predominate. They are both "sticky" and "plastic". Their shear strength equals about half its unconfined compressive strength. Therefore, cohesive soil is a better foundation than that of non-cohesive.

Organic soils are usually found in low-lying areas where the water table is near or above the ground surface. This type of soil is typically spongy, crumbly, and compressible. They are undesirable for supporting structures (Das, 2007).

The soil consists of discrete solid particles which are neither strongly bonded as in solids nor they are as free as particles of fluid. Consequently, the behaviour of soil is some what intermediate between that of a solid and a fluid. Due to this reason it engineering property investigation get crucial.

2.2. Soil Formation and Soil deposits

Soils 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.Soil is formed by the process of ‘Weathering’ of rocks that is disintegration and decomposition of rocks and minerals at or near the earth’s surface through the actions of natural or mechanical and chemical agents into smaller and smaller grains.

2.2.1. Mechanical Weathering

Mechanical weathering of rocks to smaller particles is due to the action of such agents as theexpansive forces of freezing water in fissures, due to sudden changes of temperature or due to theabrasion of rock by moving water or glaciers. Temperature changes of sufficient magnitude and frequency bring about changes in the volume of the rocks in the superficial layers of the earth's crust in terms of expansion and contraction. Such a volume change sets up tensile and shear stressesin the rock ultimately leading to the fracture of even large rocks. This type of rock weathering takesplace in a very significant manner in arid climates where free, extreme atmospheric radiation bringsabout considerable variation in temperature at sunrise and sunset. Erosion by wind and rain is a very important factor and a continuing event. Cracking forces by growing plants and roots in voids and crevasses of rock can force fragments separate apart (Das,1997).

2.2.2. Chemical Weathering

Chemical weathering (decomposition) can transform hard rock minerals into soft, easily erodiblematter. The principal types of decomposition are hydration, oxidation, carbonation, desilication andleaching. Oxygen and carbon dioxide which are always present in the air readily combine with theelements of rock in the presence of water (Murthy, 1990).

2.2.2.1. Decomposition

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

2.2.2.2. Leaching and Re-deposition

This includes laterization process; involves removal of combined silica, alkaline earth, and alkalies. There is a consequent accumulation of oxides and hydroxides of sesquioxides and the leached materials may be redeposited and accumulated elsewhere in the soil profile. Under condition of low chemical and soil-forming activity, physio-chemical weathering does not continue beyond the clay-forming stage and tends to produce end products consisting of clay minerals predominantly represented by kaolinite and occasionally by hydrated and hydrous oxide of iron and aluminum (Zelalem, 2005).

2.2.2.3.Dehydration/Desiccation

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

2.3. General Types of Soils

It has been discussed earlier that soil is formed by the process of physical and chemical weathering. The individual size of the constituent parts of even the weathered rock might range from the smallest state (colloidal) to the largest possible (boulders). This implies that all the weathered constituents of a parent rock cannot be termed soil. According to their grain size, soil particles are classified as cobbles, gravel, sand, silt and clay. Grains having diameters in the range of 4.75 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 (Morin and Perry ,1971).

2.3.1. Residual and Transported Soils

i Residual soils-are those that remain at the place of their formation as a result of chemical weathering of parent rocks and may be found on level rock surfaces where the action of elements has produced a soil with little tendency to move. Residual soils can also occur whenever the rate of breakup of the rock exceeds the rate of removal. The depth of residual soils depends primarily on climatic conditions and the time of exposure. In some areas, this depth might be considerable. In temperate zones residual soils are commonly stiff and stable. Residual soils include topsoil and laterites. Laterites are formed by chemical weathering under warm, humid tropical conditions when the rain water leaches out the soluble rock material leaving behind the insoluble hydroxide of iron and aluminum, giving them their characteristic red-brown color. An important characteristic of residual soil is that the sizes of grains are indefinite. For example, when a residual sample is sieved, the amount passing any given sieve size depends greatly on the time and energy expended in shaking, because of the partially disintegrated condition. The engineering properties of residual soils vary considerably from the top layer to thebottom layer. Residual soils have a gradual transition from a relatively fine material near the surface to large fragments of stones at greater depth. The properties of the bottom layer resemble that of the parent rock in many respects. The thickness of the residual soil formation is generally limited to a few meters

ii Transported soils-are soils that are found at locations far removed from their place of formation. The transporting agents of such soils are glaciers, wind and water. The soils are named according to the mode of transportation. *Alluvial* soils are those that have been transported by running water.The soils that have been deposited in quiet lakes are *lacustrine* soils. *Marine soils* are those deposited in sea water. The soils transported and deposited by wind are *Aeolian* soils. Those deposited primarily through the action of gravitational force, as in landslides, are *Colluvial*soils.*Glacial*soils are those deposited by glaciers. Many of these transported soils are loose and soft to a depth of several meters. Therefore, difficulties with foundations and other types of construction are generally associated with transported soilsThese soils include gravels, sands, silts and clays. As a stream or river loses its velocity it tends to some of the particles that it is carrying, dropping the larger, heavier particles first. Hence, on higher reaches of a river gravel and sand are found whilst on the lower parts silts and clays predominate. Common descriptive terms such as gravels, sands, silts, and clays are used to identify specific textures in soils. One can refer to these soil textures as soil types; that is, Sands and gravels are grouped together as coarse-grained soils. Clays and silts are fine-grained soils. To characterize fine-grained soils, one need further information on the types of minerals present and their contents. The response of fine-grained soils to loads, known as the mechanical behavior, depends on the type of predominant minerals present. are soils that are found at locations far removed from their place of formation.The transporting agencies of such soils are glaciers, wind and water. Many of these transported soils are loose and soft to a depth of several hundred feet. Therefore, difficulties with foundations and other types of construction are generally associated with transported soils (Muni Budhu,2000).

2.4. 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 0.075 mm 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 quartz. Some sands contain a fairly high percentage of mica flakes that give them the property of elasticity. 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. 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.

2.5. Soil Mineralogical Composition

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

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

Secondary minerals: formed by decomposition of primary minerals, and their subsequent weathering and re-composition into new ones (clay minerals). Humus or organic matter (decomposed organic materials). Generally the behaviors of soils are strongly dependent on the above factors.

2.5.1. Clay Minerals

Minerals are crystalline materials and make up the solids constituent of a soil. The mineral particles of fine grained soils are platy. Minerals are classified according to chemical composition and structure. Most minerals of interest to geotechnical engineers are composed of oxygen and silicon-two of the most abundant elements on earth. Silicates are a group of minerals with a structural unit called the silica tetrahedron. Silicate minerals are formed by addition of cation and interactions of tetrahedrons. Silica tetrahedrons combine to form sheets, called silicate sheets, which are thin layers of silica tetrahedrons in which three oxygen ions are shared between adjacent tetrahedrons. Silicate sheets may contain other structural units such as alumina sheets. Alumina sheets are formed by combination of alumina minerals, which consists of an aluminum ion surrounded by six oxygen or hydroxyl atoms in an octahedron (Murthy, 1990).

The term clay is applied to the fraction of grains whose equivalent diameter is less than 0.002mm. The individual grains are fragments of a single mineral i.e. a solid compound with a definite chemical composition and unique crystalline structure.

The minerals of clays are formed by the weathering of rocks. Most clay minerals of interest to 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 as shown in Figure 2.1. 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 (Taylor,1990).

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

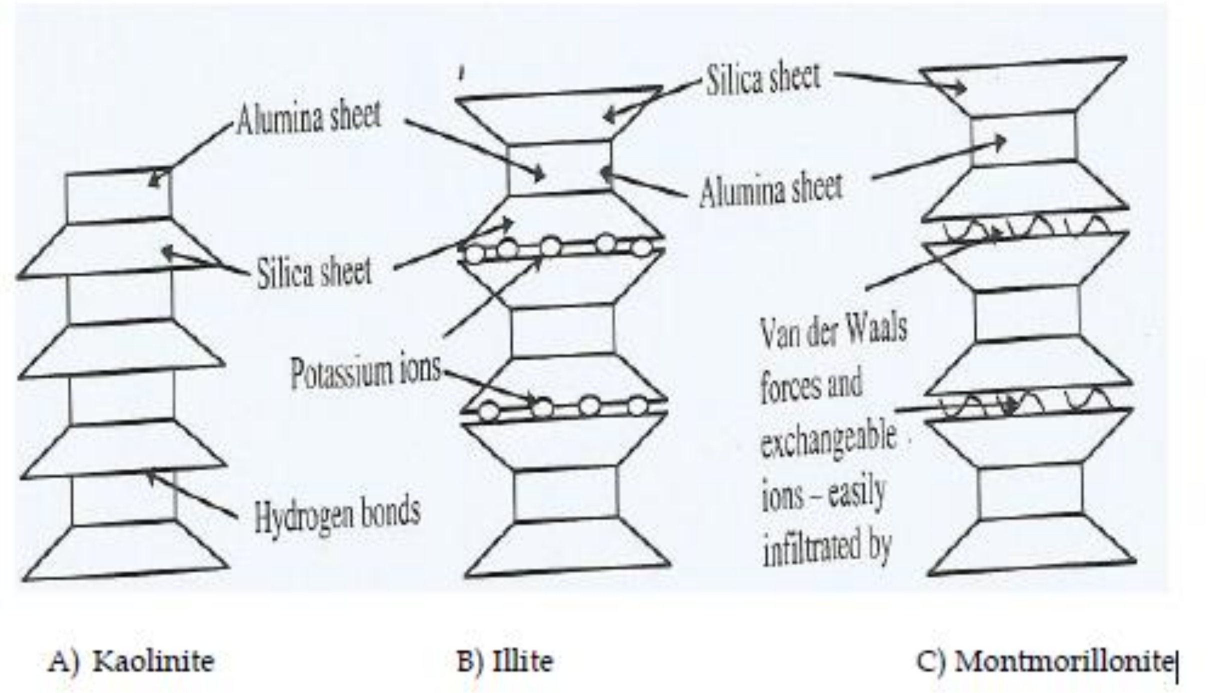

Figure 2.1. structure of kaolinite,illite and montmorillonite

2.5.1.1. Kaolinite

Kaolinites are very stable with strong structure and absorb little water. They have low swelling and shrinkage responses to water content variation.This is the most dominant part of residual clay deposits and is made up from large stacks of alternating single tetrahedral sheets of silicate and octahedral sheets of aluminumbonded together into a layer about 0.72nm thick and stacked repeatedly. The layers are held together by hydrogen bonds The structural units join together by hydrogen bond, which develops between the oxygen of silica sheet and hydroxyls of alumina sheet. As the bond is fairly strong, the mineral is stable. Moreover, water cannot easily enter between the structural units and cause expansion (Murthy, 1990).

2.5.1.2.Illite

Illite consists of repeated layers of one alumina sheet sandwiched by two silicate sheets. The layers, each of thickness 0.96nm, are held together by potassium ions. Illite swells less than montmorillonite. However, swelling is more than in kaolinite].Illites tend to absorb more water than kaolinites and have higher swelling and shrinkage characteristics (Muni Budhu,2000).

2.5.1.3. Montmorillonite

Montmorillonite has a structure similar to illite, but the layers are held together by weak van der Waals forces and exchangeable ions. Water can easily enter the bond and separate the layers in montmorillonite, causing swelling. Montmorillonite is often called swelling or expansive clay.This mineral has a similar structure to Illite group but, in the tetrahedral sheets, some of the silicon is replaced by iron, magnesium and aluminum. Montmorillonite exhibit extremely high water absorption, swelling and shrinkage characteristics (Murthy, 1994).

2.6. Origin and Mineralogical Composition Of Ethiopian Red Clay Soils

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 more plentiful and drainage is good. They contain kaolinite, illite, montmorillonite and halloysite as the principal clay minerals. The red color of the Ethiopian soils indicates the presence of iron (Muni Budhu,2000).

2.7. Varies Researchs on Investegation of Soil

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).

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 (Bowles, 1996).

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).

Fasil (2003) described that a detailed and comprehensive geotechnical investigation is an essential requirement for the design and construction of civil engineering projects. The proper design of civil engineering structures like foundation of buildings, retaining walls, high ways, etc. requires adequate knowledge of sub surface conditions at the sites of the proposed structures. Many damages to buildings, roads and other structures founded on soils are mainly due to the lack of proper investigation of substructure condition.

Site investigations or subsurface explorations are done for obtaining the information about subsurface conditions at the site of proposed construction. Site investigations in one form or the other is generally required for every big engineering project. Information about the surface and sub-surface features is essential for the design of structures and for planning construction techniques. It consists of determining the profile of the natural soil deposits at the site, taking the soil samples and determining the engineering properties of the soils. It also includes in-situ testing of the soils (Arora et al. 2007).

The scope of soil investigation depends on the type, size and importance of the structure, the client, the engineer’s familiarity with the soils at the site and local building codes. Structures that are sensitive to settlement such as machine foundation and high-rise buildings usually requires a thorough soil investigation compared to a foundation for a house (Munu Budhu, 2000).

A site investigation in one or another is always required for any engineering or building structure. The investigation may range in scope from a simple examination of the surface soils with or without a few shallow trial pits, to a considerable depth below the surface by means of boreholes and in-situ laboratory tests on the materials encountered. The extent of the work depends on the importance and foundation arrangement of the structure, the complexity of soil conditions, and the information which may be available on the behavior of existing foundations on similar soils (Tomlison, 1980).

In the field of civil engineering, nearly all projects are built on, or into, the ground. Thus, during the planning, design, and construction of foundations, embankments, tunnel and earth-retaining structures, geotechnical engineers must study the properties of soils, such as origin, grain-size distribution, permeability, compressibility, shear strength and load-bearing capacity (Haile 2014).

Soil investigation is an essential part of the design and construction of a proposed structural system (buildings, dams, roads and highways, etc.). Soils are identified, observed, and recovered during investigation of a proposed site. Usually soil investigations are conducted only on a fraction of a proposed site because it would be prohibitively expensive to conduct an extensive investigation of a whole site. One then makes estimates and judgments based on information from a limited set of observations, and from field and laboratory test data that will have profound effects on the performance and costs of structures constructed at a site (Haile ,2014).

Jemal (2014) suggested that the safety of any civil engineering structures resting on soil foundations is extremely dependent on the detail investigation of the engineering properties of the soils. The shear strength and estimation of settlement of soils are important aspects in many foundation engineering problems such as the bearing capacity of shallow,deep foundations and bridge foundations, the stability of the slopes of dams and embankments, and lateral earth pressure onretaining walls.

Most of the soil classification systems that have been developed for engineering purposes are based on simple soil-forming processes and index properties. The main factors affecting the formations of soil are: Parent materials i.e. geology of the area, topography and drainage, climate and vegetation cover (Dagnachew ,2011).

Tadesse (2014) done investigation in to some of the engineering properties of soils found in Woldiya town. He has obtained results from laboratory tests and based on the free swell value the soils found in Woldiya town were non-expansive , marginal and expansive. The activity of the soils found within normal to active.The soils in Woldiya town are either clay soils or silty. Woldiya soil is partly active and inactive as compared to the swelling characteristic of other fine grained soil.He has classified the soil based on unified soil classification system and AASHTO classification system, and the type of soils found in Woldiya town were silty, black clay and A-4, A-7-5 respectively.

Tesfaye (2013) done on index properties, shear strength and dynamic properties of soils found in Dessie town. He has conducted laboratory tests and the free swell value found within the range of marginal to expansive. The value of liquidity index ranging from stiff to hard. He has classified the soil based on unified soil classification system and AASHTO classification system, and the type of soils found in Dessie town were silt and A-7-5 respectively.

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) 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) 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.

Mesfin (2004) 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.

Adem (2014) studied about investigation into some of the engineering properties of soils in Debre Markos Town. He obtained from the grain size analyses the dominant proportion of soil particle in the research area is clay.From his testes the soil under his investigation is inorganic clay soil. The consistency of the soil is medium and highly plastic.

From the test result are considered as low in degree of expansion.which is non expansive soils.The Specific Gravity which he obtained, is similar to the results obtained by Morin and perry study.Classifications of soils in the study area based on AASHTO Classification system and plasticity chart is classified in group A-7-5/6, according to Unified Soil Classification System,the majority of the soil sample under he's investigation is highly plastic inorganic clay and inorganic silt (MH, CH and CL).

Behaylu (2014) studied about investigation into some of the engineering properties of soils in Ambo town.He obtained from Atterberg limit test soils in Ambo town are highly plastic.Black and gray soils have higher plasticity index than reddish brown and brown soils. He identify whether the soil is organic or inorganic by conducting liquid limit test on oven drying sample.Finally he compare between oven drying and air drying samples he indicate that soils of Ambo town are inorganic. Grain size analysis shows that the predominant proportion of the soils is clay size fraction.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.

Bezza (2015) studied about investigation into some of the engineering properties of soils in Ziway town. She obtained from the grain size analyses indicate that the dominant proportion of soil particle in the research area is silty sand and silt soils. From Atterberg Limits test results the values of plastic index for silts is greater than silty sands. This reason is due to the silts soils have higher clay particle than silty sand soil, so the specific gravity of Ziway soil is low.This is may be because the soils in the study area much derived from light weighted rocks.According to Unified Soil Classification System, the soil under investigation lies below the A-line in the region of sandy silt, inorganic silt and inorganic elastic silt. That means inorganic silt with low plasticity. According to AASHTO Classification system, soils of Ziway town fall under A-2-4, A-3, and A-4. The soil under investigation have fair to good rating as sub-grade materials.

Dagnachew (2011) studied about investigation into some of the engineering properties of soils in Adama Town.He obtained from grain size analysis tests revealed that, starting from few centimeters below the ground level to the depth of investigation which is three meters, the soil in Adama town is mostly silt, and silty sand soil. Due to some organic matters in the sample the specific gravity of the few soil samples is low. Almost all the samples have free swell value of less than 50%. This shows the soil in the study area is non expansive.

Eyasu (2015) he observed that the soils in Merawi town are not expansive. No significant variations of engineering properties within the investigated depths as well as in different pits which were found in his research work.These values were within the same ranges of the red soils found in other parts of the country.The coefficient of permeability values which shows that the soil is naturally impervious clay soil that will take a long period of time to consolidate.The natural consistency of soil is soft to stiff clay soil.According to unified soil classification system the soil in the Town are classified as inorganic clay of high plasticity (CH) for all test pits. Plasticity index versus liquid limit plot falls above the "A- line".

Selamawit (2015) studied about investigation into some of the engineering properties of soils in Sebeta Town. She obtained fromresults of Atterberg limits tests soils in study area are highly plastic. Besides black and gray soils have higher plasticity index than red soils. According to AASHTO soil classification system the soils categorized on A-7 and A-6 therefore those soils have poor quality for use as subgrade. The degrees of activity of the expansive soil of the town are greater than 1.The unconfined compressive strength test result and liquidity index indicates the soil consistency of the study area ranges from stiff to very stiff.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.

Solomon (2015) studied about investigation into some of the engineering properties of soils in Debre Birhan Town.He obtained fromgrain size analysis result the soil found in Debre Birhan Town is dominantly silt and clay types. AASTHO classification system shows the soils are classified in either of A-6 or A-7 (A-7-5, A-7-6). The soil is poor to be used for sub grade material as per the AASTHO recommendation for suitability of soils as sub grade material. Free swell test results of soils under investigation shows that the soil expansiveness property ranges from low to marginal degree of expansiveness.Based on the UCS result the consistency of soils is medium to very stiff where as coefficient of permeability from consolidation test shows the soil is almost impermeable (AASHTO,1972).

Wubshet (2015) studied about investigation into some of the engineering properties of soils in Burayu Town.She obtained from Results of Atterberg limits tests show that soils of Burayu Town 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 non expansive 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 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.

Yimam (2016) studied about investigation into some of the engineering properties of soils in Kemise Town according to this study the most common types of soil found in Kemise town are clay, silt and silty sand.The free swell for clay soils indicates that the soils are non-expansive to moderate soil. The clay and silt soils have consistency of stiff to hard, while silty sand soils are hard.

Abdulfetah (2015) studied about investigation into some of the engineering properties of soils in Worabe Town. He grouped soils in Worabe Town into four types :-Expansive soils, non-expansive soils, marginal soils and sandy soils. Since expansive soils are poor and unsuitable as a construction material and as a subgrade material, proper measures should be done before construction. Thickness of Worabe expansive soils ranges from few centimeters to as much as 3m.The grain size analysis test results showed that the dominant proportion of soil particle in the research area is Highly Plastic Clay.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 in the past to a pressure in excess of the present pressure.

CHAPTER THREE

STUDY AREA AND RESEARCH METHODOLOGY

3.1. GENERAL

Sokoru is one of the woredas in the Oromia Region of Ethiopia. This woreda is named after the former *Awraja* of the same name, and covering much of the same territory as the current woreda, as well as its administrative center, Sokoru. Part of the Jimma Zone, Sokoru is bordered on the south by Omo Nada, on the west by TiroAfeta, and on the north and east by the Southern Nations, Nationalities and Peoples Region; the Gibe River defines the northern boundary. Other towns in this woreda include Deneba, Kumbi and Natri.The altitude of this woreda ranges from 1160 to 2940 meters above sea level; the highest points include Ali Shashema, Ali Derar and Kumbi. Perennial rivers include the Gilgel Gibe a tributary of the Gibe, and the Kawar; seasonal streams include the Melka Luku. A survey of the land in this woreda shows that 36.6% is arable or cultivable, 16.8% pasture, 17.2% forest, and the remaining 29.4% is built-up or degraded. The Abelti-Gibe State Forest covers 159 square kilometers of the forested area. Teff and coffee are essential cash crop of this woreda, less than 20 square kilometers are planted with this crop. The sokoru town is situated North east from Addis Ababa and North east of Jimma as part of the jimma Zone. Sokoru is located at latitude and longitude of 7°17 N, 36°15 E (Dechassa,1999).

Figure 3.1: - Map of Sokoru town and location of sample test-pits (Source :Google map 2017).

Table 3.1. Sampling location and designation of sample test pits

Test pit	Samplining Depth(m)	Pit location	Observed color
TP-1	1.5m	kentiba office	Reddish
	3m		
TP-2	1.5m	World vision	Reddish
	3m		
TP-3	1.5m	water supply office	Greyish
	3m		
TP-4	1.5m	Addisu Gebya	Black
	3m		
TP-5	1.5m	Addisu menharya	Reddish
	3m		
TP-6	1.5m	Waju	Reddish
	3m		
TP-7	1.5m	Bidru	Greyish
	3m		
TP-8	1.5m	Haro	Reddish
	3m		
TP-9	1.5m	Melke sheki	Reddish
	3m		
TP-10	1.5m	Around stadium	Greyish
	3m		

3.2. Climate

Sokoru's climate is classified as tropical.The summers are much rainier than the winters in Sokoru. The average temperature is 19.3 °C.

3.2.1. Rainfall

Rain fall data collected by National Meteorological Service Agency substation on Sokoru town located ataltitudeandlongitude 7°17 N, 36°15 E shows that the mean annual rain fall is 897.9 mm. Like other major towns in Ethiopia, Sokorutown received highest rain fall from July to August. Precipitation is the lowest in December, with an average of 17 mm. The most significant amount of precipitation occurs in July, with an average of 243 mm.

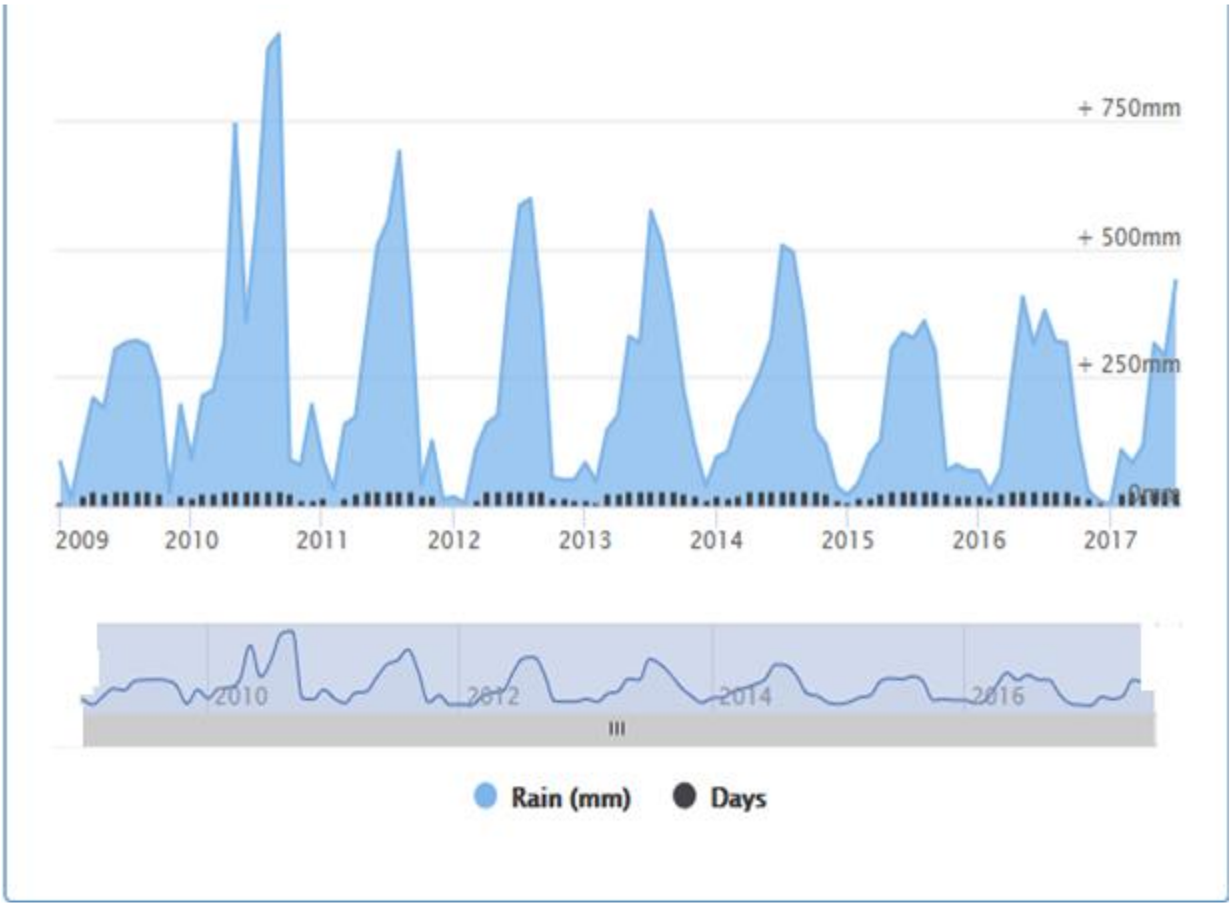

Figure 3.2.Average yearly Maximum and Minimum rain fall of Sokoru town (2009 - 2017 G.C) (Socio,2006)

3.2.2. Temperature

In a mountainous tropical country like Ethiopia altitude is by far the most important factor in controlling climate. It affects distribution of both temperature and rainfall. Generally, regions between 1500 - 2300 meters above mean sea level are categorized as 'woinadega' or sub tropical climate which have temperatures that range between 15 – 20$^{o}{}_{C}$, areas between 500 – 1500 meters above mean sea level. (i.e. 'Kola' or tropical climate) have 20 -30$^{o}{}_{C}$ and areas below 500meters above mean sea level (i.e. 'Bereha' or desert climate) have a temperature of 30^{o}C and above (Dechassa,1999).

In Ethiopia, the mean monthly temperature varies slightly throughout the year,although the difference between the minimum and maximum temperatures is high only in the dry season. According to the National Metrological Agency of Ethiopia, the highest mean maximum temperatures in the country, in the range of 40$^{o}{}_{C}$ to 45$^{o}{}_{C}$, are recorded in the Afar depression.

The other hot areas are the north-western lowlands close to the border with Sudan, which experience a mean maximum temperature of 40^{o}C in June, and the western and south-eastern lowlands with mean maximum temperatures of 35$^{o}{}_{C}$ during April. Most of the Somali, Dire Dawa and Afar regions are also hot for several months in a year. The lowest mean temperatures in the range of 5^{o}C to 15^{o}C or even lower are recorded in the morning or at night between October and January in the highland areas, with an elevation of over 2,000 m above sea level. In these areas, the midday warmth diminishes quickly by late afternoon and nights are usually cold (Socio,2006).

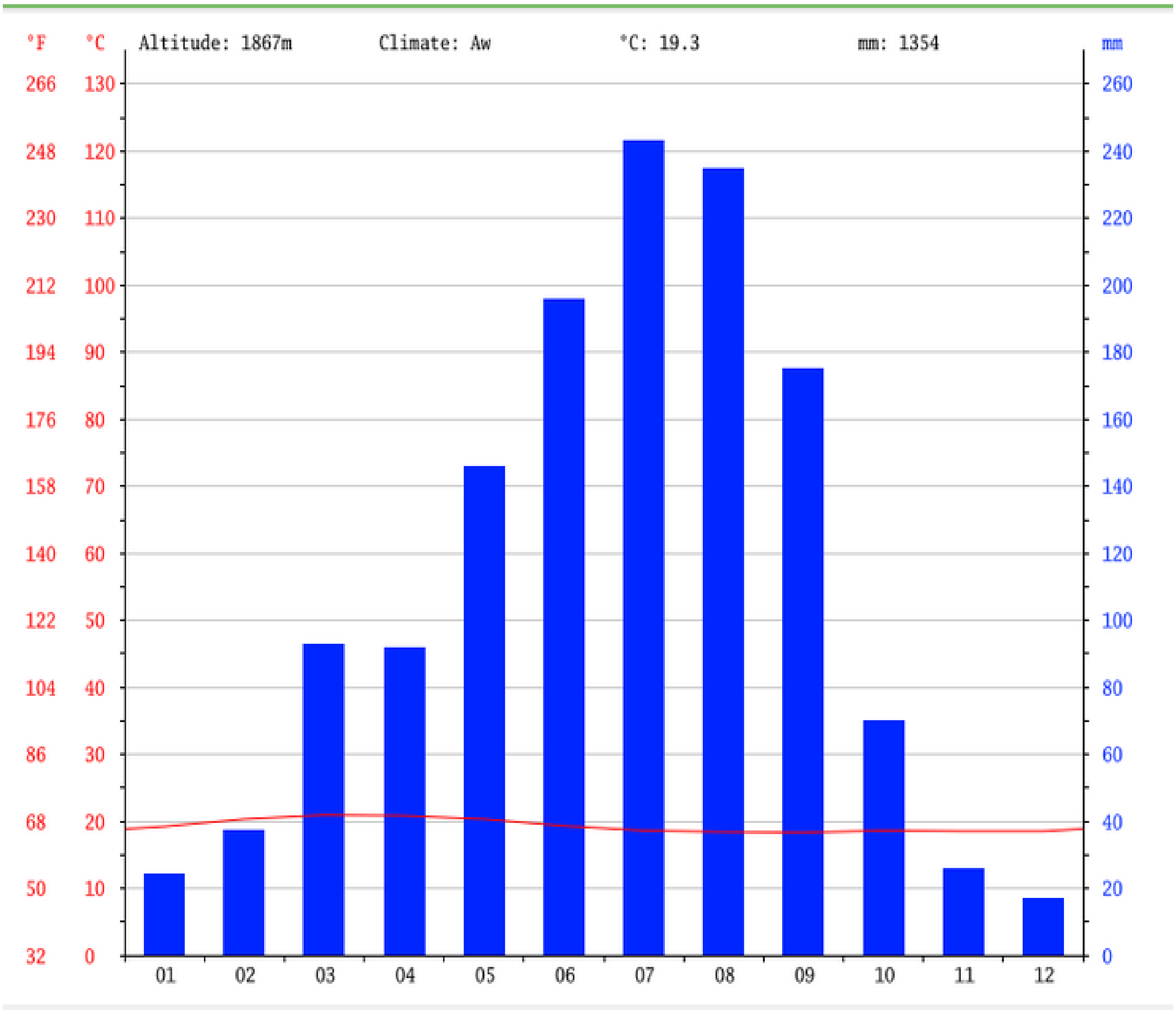

Figure 3.3. Average Monthly Maximum and Minimum temperature distribution of Sokoru Town (socio,2006)

3.3. Methodology

To investigate the engineering properties of sokoru Town, ten sampling areas were selected following to reconnaissance survey of the area,which done by visiting the entire part of the town and literature reviews of many investigators are done.Necessary information about the geology, climatic condition and topography of the site are collected and analyzed.

The location of test pits is selected so that it can well represent the soil types (visually) found in the town. Disturbed and undisturbed samples were collected in the field and transported for laboratory testing.Undisturbed samples are used for one dimensional consolidation, unconfined compression test, natural moisture content and unit weight tests. Disturbed samples are used to conduct index property tests such as specific gravity, Atterberg limit, grain size analysis, compaction and free swell. Using Microsoft Office Excel and Word, grain size distribution curve, liquid limit graph, compaction curve, consolidation and unconfined compression tests are plotted ASTM procedures are followed for all tests.

From the recovered samples the following laboratory tests were done.

- Natural moisture content
- Specific gravity test
- Atterberg limit tests
- Grain size analysis
    - ✓ Sieve analysis (wet method)
    - ✓ Hydrometer
- Free swell test
- Standard compaction test
- Unconfined Compression Test
- One-dimensional consolidation test
- Perrmability test

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

Figure 3.4.Different soil colors in Sokoru town.

3.4. IN-SITU PROPERTIES

3.4.1. Identification of soil in the study area

The soil samples for this thesis work are collected from Sokoru town. Before selecting sampling areas, visual site investigation were made. The soil has the same color in different places but the topography is varied.Accordingly, ten sampling areas were selected from various locations of the town depending on the topography.Pits were excavated to the maximum depth of three meters. Both disturbed and undisturbed soil samples were collected for this work and taken to the laboratory for testing. Each test listed on objectives was done for all samples taken except for one dimensional consolidation test is done only for three samples at a depth of three meters for TP-1, TP-2 and TP-4.

3.4.2.In-situ properties Description

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

3.4.2.1. Natural moisture content

For most soils, the water content may be an important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil. Since it was difficult to bring undisturbed samples to the laboratory, this test was done by using apparatus like moisture can, balance, core sampler and oven dry. The weight of the moisture can and the weight of can with moist soil was measured.Then the sample put it in to drying oven at a temperature of 105+5°c for 24 hours. Then after, the natural moisture content was determined.

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.

3.4.2.2. Bulk unit Weight

The bulk unit weight (also known as the total unit weight) is the natural in situ unit weight of the soil; therefore it should only be obtained from undisturbed soil specimens. The first step in the laboratory is to determine the bulk density using undisturbed sample.In situ density:-The bulk density is the ratio of mass of moist soil to the volume of the soil sample, and the dry density is the ratio of the mass of the dry soil to the volume the soil sample.The in-place density of soils is used to determine density of compacted soils used in the construction of structural fills, highway embankments, or earth dams.

3.5. Index Properties

3.5.1. General

In nature, soils occur in a large variety. However, soils exhibitsimilar 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. The tests required for the determination engineering properties are elaborate and time consuming.This is possible if index properties are determined.

3.5.2. Specific Gravity Test

The specific gravity of solid particles without void space is called the true or absolute or real specific gravity and is usually denoted by a letter Gs. In this test a known weight of oven-dried soil sample is carefully put in a pycnometer which is then half filled with distilled water. The air entrapped in the soil sample is removed by heating or by means of vacuum pump. The bottle is then topped up with distilled water up to a calibration mark and brought up to a constant temperature.

3.5.3.Grain size analysis

3.5.3.1.General

Particle size analysis is done in two stages: (i) Sieve Analysis, (ii) Hydrometer Analysis. The normal method adopted for separation of particles in a fine grained soil mass is the hydrometer analysis,here sodium hexameta phosphate is used as a dispersing agent and for the coarse grained soils the sieve analysis. Soils comprising coarser and finer sizes, both mechanical and hydrometer testing methods are performed.

In this study wet sample preparation in accordance with ASTM D 2217-85 was applied. The test method covers the quantitative determination of the distribution of particle sizes in soils.The data are presented on a semi-log plot of percent finer vs. particle diameters and combined with the data from a sieve analysis of the soil sample retained on the No.200 sieve. The principal value of the hydrometer analysis appears to be to obtain the silt and clay fraction.The combined grain size distribution curve for particles.

3.5.4. Atterberg Limlits

Atterberg limits or consistency limits are water contents at which the soil changes from one state to the other. Soil consistency is a term used to describe the degree of firmness of soil and is expressed by such terms as soft, firm or hard. It usually applies to fine grained soils whose condition is affected by changes in moisture content. Consistency limits are very important index properties of fine grained soils. As the consistency of soil changes, its engineering properties also change. Such soil properties as shearing strength and bearing capacity vary significantly with consistency. The Swedish scientist, Atterberg, established the four states of soil consistency Figure below, which are called the liquid, the plastic, the semi-solid, and the solid states.

A soil containing high water content is in a liquid state. It offers no shearing resistance and can flow like liquids. As the water content is reduced, the soil becomes stiffer and starts developing resistance to shear deformation. At some particular water content, the soil becomes plastic.

Table 3.2.States of soil consistency and Atterberg limits (Arora,2004).

States	Limit	Consistency
Liquid limit	Liquid limit	Very soft Soft
Plastic		Stiff
	Plastic limit	Very stiff
Semi-solid		
	Shrinkage limit	Extremely stiff
Solid		Hard

3.5.5. Activity of clay

Activities of soils of the study area were computed based on results obtained from hydrometer analysis (percentage of clay fraction) and Atterberg’s limit (PI). The results of activities obtained are presented in the table below.

$$\text{Activity,A} = \frac{\text{plasticity index,Ip}}{\text{percent finer than 2 micron}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.1)$$

Table 3.3. Degree of Colloidal activity (Arora,2004).

Activity	Degree of activity
<0.75	Inactive clay
0.75-1.25	Normal clay
>1.25	Active clay

Since the plastic property of soil is due to the adsorbed water that surrounds the clay particles, we can expect that the type of clay minerals and their proportional amounts in a soil will affect the liquid and plastic limits.

3.4.6. Free swell

The free swell test is one of the most commonly used simple experiments in the field of geotechnical engineering for getting an estimate of soil swelling soil potential and to identify the degree of expansiveness of the soil sample.It is the increase in volume of soil without any external constraint when subjected to submergence in water.

The free swell of the soil is determined as the ratio of the change in volume to the initial volume, expressed as a percentage.which, is defined as:

$$\text{Free Swell} = \frac{\text{Final volume - Initial volume of the soil}}{\text{Initial volume}} \times 100\% \quad \text{..................(4.2)}$$

Free swell <50%, Non expansive

Free swell between 50-100%, Marginal

Free swell >100%, expansive

Free Swell test results for oven dried samples at a temperature of 105+5 (Yimam ,2016).

3.6. Compaction Test

Compaction places soils in a dense state and hence decreases further settlement; increases shear strength and decreases permeability. Mechanical compaction is one of the most common and cost effective means of stabilizing soils. During compaction air is expelled from the void spaces. Thus compaction results in an increase in the density of the soil. In general, most engineering properties, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing the soil density. Results are used to determine appropriate methods of field compaction and to provide a standard by which to judge the acceptability of field compaction.

Two types of compaction tests routinely performed are: (1) The Standard Proctor Test, and (2) The Modified Proctor Test. In this thesis the Standard Proctor Test is used.In the Standard Proctor Test, the soil is compacted by a 24.4N hammer falling a distance of 0.305meters into a soil filled mold. The mold is filled with three equal layers of soil, and each layer is subjected to 25 drops of the hammer.

3.7. Shear strength of soil

3.7.1. General

The shear strength 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.There are three methods of laboratory shear strength test. These are direct shear test, triaxial compression test and unconfined compression test.

For soils, the Undrained Shear Strength (Su) is necessary for the determination of the bearing capacity of foundations, dams, etc. The undrained shear strength (Su) of clays is commonly determined from an Unconfined Compression Test. The Undrained Shear Strength (Su) of a cohesive soil is equal to one-half the Unconfined Compressive Strength (qu) when the soil is under the ∅= 0 condition (∅= the angle of internal friction).The most critical condition for the soil usually occurs immediately after construction, which represents undrained conditions, when the undrained shear strength is equal to the cohesion (c). This is expressed as :-

$$S_u = C = q_u \quad \text{.......(3.1)}$$

In unconfined compression test, the minor principal stress (σ_3) is zero. The major principal stress ($\sigma 1$) is the deviator stress and calculated using:-

$$\sigma_1 = \frac{P}{A} \quad \text{.......(3.2)}$$

Where:

P=Axial load

A=Corrected cross-sectional area

The corrected area can be calculated using equation

$$A = \frac{A_0}{(1-\varepsilon)} \quad \ldots \ldots \quad (3.3)$$

Where:

A_0 =initial cross-sectional area

A =cross-sectional area at any stage of loading

ε =strain, which is given by $\Delta h/h_0$

Axial stress at which the specimen fails is known as the unconfined compressive strength (qu).The stress -strain curve can be plotted between the axial stress and axial strain at different stages before failure.

The specimen of height to diameter ratio of 2 is normally used for the tests. The sample fails either by shearing on an inclined plane or by bulging. The vertical stress at any stage of loading is obtained by dividing the total vertical load by the cross-sectional area. The cross-sectional area of the sample increases with the increase in compression. The cross-sectional area A at any stage of loading of the sample may be computed on the basic assumption that the total volume of the sample remains the same.

Table 3.4. General relation between Consistency and unconfined strength of clay soil (Arora,2004).

Consistency	qu (kN/m^2)
Very soft	<25
Soft	25-50
Medium	50-100
Stiff	100-200
Very stiff	200-400
Hard	>400

3.8. Consolidation

3.8.1. General

The process whereby soil particles are packed more closely together over a period of the application of continued pressure. It is accompanied by drainage of water from the pore spaces between solid particles.The compressibility characteristics of a soil mass might be due to any or a combination of the following factors:-

1. Compression of the solid matter.
2. Compression of water and air within the voids.
3. Escape of water and air from the voids.

A consolidation test, also called an Oedometer test, is a measurement of how soils compress when saturated with water and exposed to varying amounts of load, or varying weights of the soil. Saturated conditions exist when water is added until no more can be absorbed by the soil.

A representative consolidation tests were run on samples of three undisturbed samples on different test pits. where the remaining test pits have the similar result with either of these test pits. The main purpose of one dimensional Odometer test is to get a better understanding of stress history of the soil under study.The pre-consolidation pressures for the samples have been determined by Casagrande method.

Consolidation tests were conducted by the procedure of ASTM D 2435 - Standard Test Method.It is carried out for representative samples where the remaining test pits have the 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 gaugereadingswere 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 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.

A surface load, for example due to the construction of building, results in increased stresses in the underlying soils. The increase in stress causes settlements. When the soils are fine grained and saturated, the increase in total stress is carried by the water, as excess pore pressure.

Since these soils have low hydraulic conductivity,as excess pore pressure will dissipate slowly, and the settlement will be delayed in time. The consolidation test, or odometer test, is used to determine the parameters that can be used to estimate both the magnitude and the time rate of the settlements.

The coefficient of consolidation Cv can be evaluated using laboratory tests by fitting the experimental curve with the theoretical.In my study two laboratory methods that are in common use for the determination of Cv are used. They are:

1. Casagrande logarithm of time fitting method and
2. Taylor square root of time fitting method.

From those increments of load where time-deformation readings are obtained, two alternative procedures are provided to present the data, determine the end-of-primary consolidation and compute the rate of consolidation (Murthy, 1994).

i. Logarithm-of-time-fitting method

This method has been devised by Taylor (1948). The coefficient of consolidation is the soil property that controls the time-rate or speed of consolidation under a load-increment.

In the logarithm of time fitting method, the displacement gage readings for each load increment are plotted against the times (log scale). The procedure for determining CV using logarithm of time method and a typical curve obtained. The theoretical early time settlement response in a plot of the logarithm of times versus displacement gage readings is a parabola. The straight line portion of primary and secondary consolidation to intersect at A. The ordinate of A is represented by d_{100} that is, the deformation at the end of 100% primary consolidation. Compression in excess of the above estimated 100% primary consolidation is defined as secondary compression.

The initial curved portion of the plot of deformation versus log t is approximated to be parabola on the natural scale. Times t_1 and t_2 on the curved portion such that $t_2=4t_1$, let the difference of specimen deformation during time (t_2-t_1) be equal to x. A horizontal line DE was drawn such that the vertical distance BD is equal to x. The deformation corresponding to the line DE is d_0 (that is, deformation at 0% consolidation).

The ordinate of point F on the consolidation curve represents the deformation at 50% primary consolidation, and its abscissa represents the corresponding time (t_{50}). The deformation, d50, corresponding to 50% primary consolidation is equal to the average of the deformations corresponding to the 0 and 100% deformations. Then calculation was repeated for different load increments using equation 3.4 and an average value of CV for the desired load range is determined and the results are summarized (Murthy, 1994).

$$cv=0.197\frac{H^2_{dr}}{t_{50}} \quad \text{……………………………………...(3.4)}$$

Where

H^2dr = drainage path

For specimens drained at both top and bottom, equals one–half the average height of the specimen during consolidation:

$$H_{dr} = \frac{H_{av}}{2} = \frac{H_o+H_f}{4} = \frac{H_f-d_{50}}{2} \quad \text{……………………………… (3.5)}$$

Where

H_{av}=is the average height

d_{50}= Compression of sample up to 50% consolidation.

H_0=Initial height of the specimen

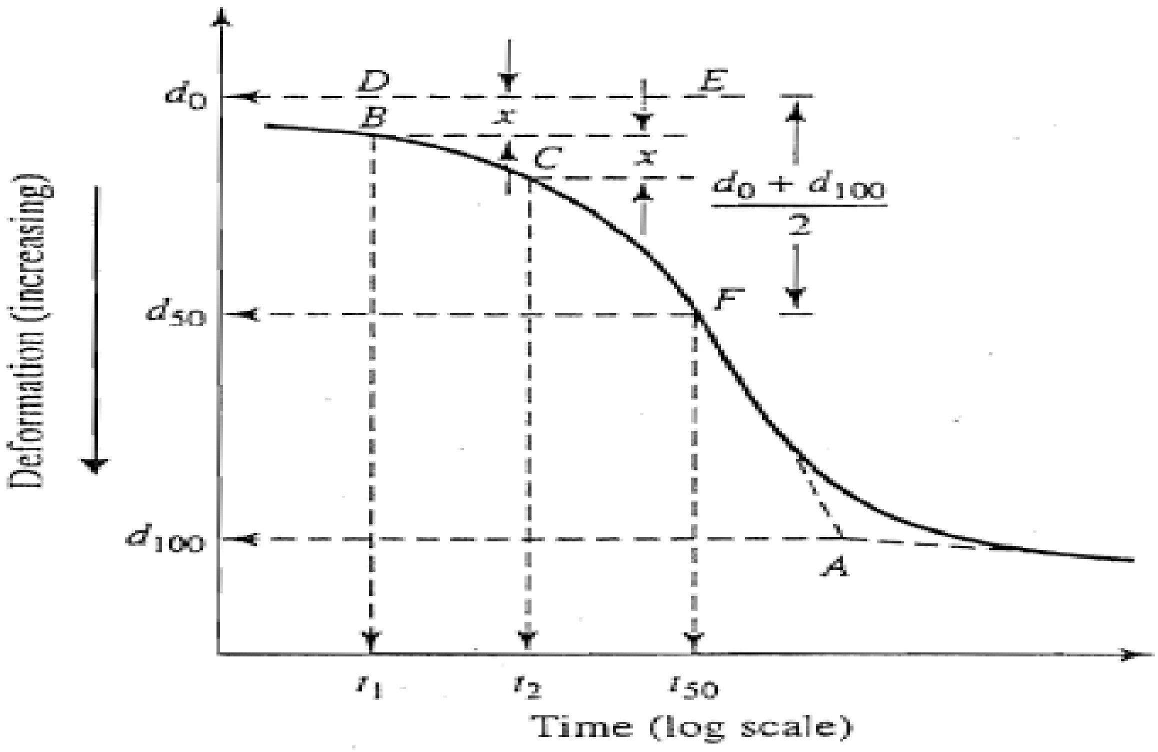

Figure 3.5.Logarithm of time fitting method for determining coefficient of consolidation(Murthy, 1994).

ii. Square-root-of-time fitting method

Square root of time fitting method was devised by Taylor, (1948). The coefficient of consolidation is the soil property that controls the time-rate or speed of consolidation under a load-increment 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 the 90 percent (R90) consolidation point. Its value may be read and is designated as t_{90}.

Usually the straight line through the early portion of the laboratory curve intersects the zero time line at a point *(do)* differing some what from the initial point (di). This intersection point is called the *corrected zero point.* If one-ninth of the vertical distance between the corrected zero point and the 90 per cent point was set off below the 90 percent point, the point obtained is called the *"100 percent primary compression point" (d100).* The compression between zero and 100 per cent point is called *"primary compression".* At the point of 90 percent consolidation, the value of T = 0.848. (Fundamentals of Geotechnical Engineering by Braja M. Das third edition)

The coefficient of consolidation cv as determined by Casagrande's semi logarithmic plot method is given by:

$$cv = 0.484\frac{H^2 dr}{T_{90}} \quad \text{……………………………………(3.10)}$$

Usually, the square root of time fitting method yields higher values of coefficient of consolidation than the logarithm of time fitting method. The same as the logarithm of time method an average value of CV for the desired load range is determined (Murthy, 1994).

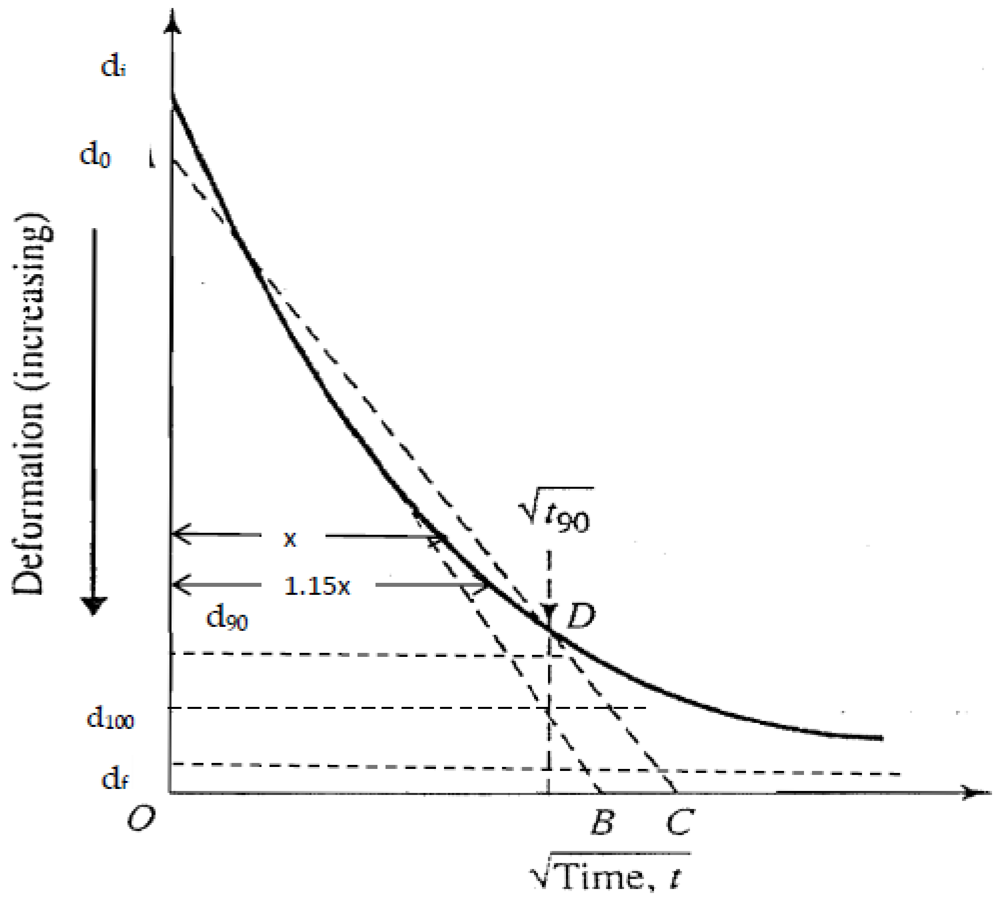

Figure 3.6.Typical curve for determining coefficient of consolidation using Square-root-of-time fitting method(Murthy, 1994).

3.8.2. Pre-consolidation pressure

Pre-consolidation pressure was determined from void ratio versus log pressure curve by the simplified method and Casagrande's method.

Soil in the field at some depth has been subjected to a certain maximum effective past pressure in its geologic history. This maximum effective past pressure may be equal to or less than the existing effective overburden pressure (P0) at the time of sampling. The reduction of effective pressure in the field may be caused by natural geologic process or human processes. During soil sampling, the existing effective overburden pressure is also released. This results in some expansion. When this specimen is subjected to a consolidation test, small amount of compression will occur when the effective pressure applied is less than the maximum effective overburden pressure in the field to which the soil has been subjected in the past.

Several methods have been proposed for determining the value of the maximum consolidation pressure. These are field method and graphical procedure based on consolidation test results. The field method is based on geological evidence. In such instances, the only remaining procedure for obtaining an approximate value of *pc* is to make an estimate based on the results of laboratory tests or on some relationships established between *pc* and other soil parameters.

There are a few graphical methods for determining the pre-consolidation pressure based on laboratory test data. No suitable criteria exist for appraising the relative merits of the various methods. The earliest and the most widely used method was the one proposed by Casagrande (1936). The method involves locating the point of maximum curvature, B, on the laboratory e-log *p* curve of an undisturbed sample. From *B,* a tangent is drawn to the curve and a horizontal line is also constructed. The angle between these two lines is then bisected. The abscissa of the point of intersection of this bisector with the upward extension of the inclined straight part corresponds to the pre- consolidation pressure Pc. Typical curve for determining pre-consolidation pressure using Casagrande method.The relative amount of pre-consolidation is usually reported as the over-consolidation ratio (OCR) (Murthy, 1994).

$$OCR = \frac{Pc}{Po} \quad \text{……………………………………..(3.6)}$$

If OCR =1, the soil is normally consolidated soil. If OCR >1 the soil is over consolidated soil. The over-consolidation ratio of soils has been observed to decrease with depth, eventually reaching a value of 1 (normally consolidated state)

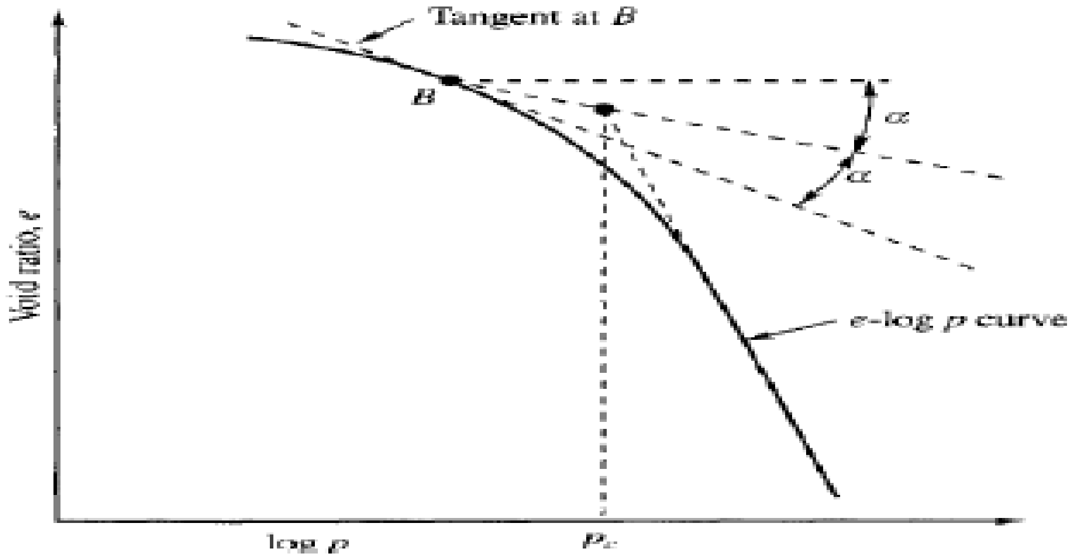

Figure 3.7. Method of determining PC by Casagrande method(Murthy, 1994).

3.8.3 Compression index (CC) and Swelling index (CS)

Compression index

The compression index (Cc) and swelling index (CS) can be determined by graphic construction from laboratory results for void ratio and pressure, which is equal to the slope of the linear portion of the void ratio versus log pressure loading curve and unloading curve respectively.

This is numerically equal to the slopes of the straight portion of the e-logp curve. Compression index is an important index used to calculate the ultimate settlement of a foundation founded on a clay layer.

$$Cc = \frac{e1-e2}{\text{log-log}} \quad \text{……………………………….(3.7)}$$

$$Cs = \frac{e1-e2}{\text{log-log}} \quad \text{………………………………..(3.8)}$$

There empirical expressions for compression index and swelling index determination is also used for approximate calculation in the absence of laboratory consolidation data. Compression index is extremely useful for determination of field settlement caused by consolidation.

3.9. Permeability

3.9.1.Coefficient of permeability

The flow of water through soils depends upon its permeability coefficient. The greater the value of the coefficient of permeability, the greater is the flow. Which means coarse sand and gravel are highly pervious and have correspondingly high permeability coefficients. Clays ,on the other hand, are relatively impervious and hence have low permeability coefficients .Others soils give a straight line relationship when results are plotted on double log scale.Consolidation pressure has a direct impact on permeability of soil, and the value of ‘k’ decreases with increasing consolidation pressure.

For this study falling head permeability test is performed.

$$K= R_t*(2.3aL)/ (A*t)*\log (h_o/h_1)\ldots\ldots\ldots\ldots\ldots\ldots(3.9)$$

Where as:-

K=coefficient of permeability in cm/sec.

a=cross sectional area of stand pipe (cm^2)

L=length of the specimen (cm)

A= cross sectional area of specimen (cm^2)

h_o=hydraulic head at the beginning of test(cm)

h_1=hydraulic head at the end of the test (cm)

t=total time for water in burette to drop from ho t h1 (sec.)

R_t=temperature correction factor for the viscosity of water

$Rt=\dot{\eta}T/\dot{\eta}20^oc$

$\dot{\eta}T$= viscosity of water at temperature t

$\dot{\eta}_{20^oc}$= viscosity of water at temperature 20^oc

Sometimes permeability can be estimated from one dimensional consolidation test. Having established coefficient of consolidation (CV), coefficient of permeability can be determined from the following relationship:-

$$K= \frac{C_v*\gamma_w*a_v}{1+eo}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.10)$$

C_v=coefficient of consolidation

a_v=coefficient of compressibility= $\Delta e/\Delta \sigma v$

e_o=initial void ratio

γ_w =unit weight of water=9.81KN/m^3

3.10. Classification of the soils

3.10.1.General

Soil classification is the arrangement of soils into different groups such that the soils in a particular group have similar behavior. They are the American Association of State Highway and Transportation officials (AASHTO) classification system and the Unified Soil Classification System(USCS) Murthy,(1994).

3.10.2. Classification of soils based on unified soil classification system (uscs)

The Unified Soil Classification System is based on the recognition of the type and predominance of the constituents considering grain-size, gradation, plasticity and compressibility.. Only sieve and Atterberg limits are necessary to completely classify a soil in this system.

3.10.2.1. 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 clays plot in the same region as inorganic silts of high compressibility but below the A-line and LL greater than 50. The equation for the U-line can be given as PI = 0.91(LL – 8).

3.10.3. AASHTO classification system

The AASHTO classification system, also called public roads administration (ERA) classification, is based on grain size distribution, liquid limit and plasticity index. This system is generally used by highway engineers for classification of sub-grade soils for the highway pavement. According to this system, soil is classified in to seven major groups, A-1 through A-7.Group A-1, A-2, A-3 are granular materials with 35% or less passing through a No.200 sieve. Soils with more than 35% passing through a No.200 sieve are classified under groups A-4, A-5, A-6 and A-7.These soils are mostly silt and clay type material.Under this classification system, a characteristic called group index (G.I) is used to describe the performance of a soil when used as a highway subgrade material.

$$GI= (F-35) [0.2+0.005(Wl-40)] +0.01(F-15) (Ip-10) \quad \ldots\ldots\ldots\ldots\ldots (3.11)$$

Where

F=percentage by mass passing American sieve no 200(size 0.075mm), expressed as a whole number

WL=liquid limit (%), expressed as a whole number

Ip=plasticity index (%), expressed as a whole number

While calculating GI from the above equation, if any term in parenthesis becomes negative, it is dropped, and not given a negative value. The maximum values of (F-35) and (F-15) are taken as 40 and that of (Wl-40) and (Ip-10) Murthy,(1994)

CHAPTER FOUR

IN-SITU PROPERTIES AND LABORATORY TEST RESULTS

4.1. IN-SITU PROPERTIES

4.1.1. Identification of soil in the study area

The soil samples for this thesis work collected from Sokoru town. Before selecting sampling areas, visual site investigation were made. The soil has the same color in different places but the topography is varied.Accordingly, ten sampling areas were selected from various locations of the town depending on the topography.Pits were excavated to the maximum depth of three meters. Both disturbed and undisturbed soil samples were collected for this work and taken to the laboratory for testing. Each test listed on objectives was done for all samples taken except for one dimensional consolidation test is done only for three samples at a depth of three meters for TP-1, TP-2 and TP-4.

4.1.2. Natural moisture content

The samples are collected at two different seasons. From table 4.1 the natural moisture content of soils of the study area ranges from 31.47%- 47.3%.

4.1.3. Bulk unit Weight

This test was done according to the Standard Reference: ASTM D 2216-98 Standard Test.The bulk density is the ratio of total mass of the soil in natural state to the total volume of the soil sample. Typical values for bulk unit weight from table 4.1 are 10.10 to 17.40 KN/m^3

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Table 4.1. Natural moisture content , Bulk Unit weight and Density of samples of Sokoru Town

Test Pit	Depth (m)	Natural moisture content (%)	Dry density (g/cm^3)	Bulk Density (g/cm^3)
TP-1	1.5m	45.83	1.03	1.50
	3m	47.30	1.11	1.64
TP-2	1.5m	42.15	1.22	1.74
	3m	42.63	1.20	1.70
TP-3	1.5m	32.90	1.25	1.66
	3m	39.43	1.24	1.71
TP-4	1.5m	31.47	1.31	1.72
	3m	38.55	1.24	1.73
TP-5	1.5m	40.18	1.00	1.40
	3m	41.34	1.03	1.45
TP-6	1.5m	47.26	1.04	1.51
	3m	47.08	1.12	1.66
TP-7	1.5m	40.16	1.23	1.75
	3m	41.17	1.21	1.72
TP-8	1.5m	31.20	1.26	1.67
	3m	38.10	1.23	1.72
TP-9	1.5m	31.55	1.30	1.71
	3m	35.60	1.27	1.76
TP-10	1.5m	38.50	1.01	1.42
	3m	39.30	1.06	1.50

4.2. Index Properties

4.2.1. Specific Gravity Test

From table 4.2 the specific gravity of the soil in the study area ranges from 2.5 to 2.73.

Table 4.2 Specific gravity of the soil of the Study Area

Test Pit	Depth (m)	Specific Gravity (GS)
TP-1	1.5m	2.59
	3m	2.53
TP-2	1.5m	2.69
	3m	2.73
TP-3	1.5m	2.61
	3m	2.62
TP-4	1.5m	2.57
	3m	2.50
TP-5	1.5m	2.62
	3m	2.73
TP-6	1.5m	2.57
	3m	2.60
TP-7	1.5m	2.66
	3m	2.71
TP-8	1.5m	2.64
	3m	2.60
TP-9	1.5m	2.53
	3m	2.54
TP-10	1.5m	2.66
	3m	2.68

4.2.2.Grain size analysis

4.2.2.1.General

The principal value of the hydrometer analysis appears to be to obtain the silt and clay fraction. 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;so it indicates soil of the study area is clay nature.The gradation curve for tests undertaken at depths 1.5m and 3m for each test pits.

Table 4.3. Grain size distribution of soils of the study area

Test pit	Depth(m)	Gravel	Sand	Silt	Clay
TP -1	1.5m	0	3.54	55.08	41.38
	3m	0	2.94	66.80	30.26
TP-2	1.5m	0	2.02	37.47	60.51
	3m	0	1.16	37.70	61.14
TP-3	1.5m	2.36	6.76	60.41	30.47
	3m	0	1.90	42.31	55.79
TP -4	1.5m	4.26	20.24	38.34	37.16
	3m	0	2.62	50.04	47.34
TP-5	1.5m	0	2.66	33.92	63.42
	3m	0	1.72	28.96	69.32
TP -6	1.5m	0	3.54	39.87	56.59
	3m	0	2.94	62.57	34.49
TP-7	1.5m	0	2.02	28.39	69.59
	3m	0	1.17	35.45	63.38
TP-8	1.5m	2.36	6.76	54.41	36.47
	3m	0	1.90	44.81	53.29
TP -9	1.5m	4.26	20.24	36.81	38.69
	3m	0	2.62	36.52	60.86
TP-10	1.5m	0	2.66	32.09	65.25
	3m	0	1.72	21.02	77.26

From the table 4.3 and Figure 4.1 and Figure 4.2,we can observe the results of grain size analysis showed that soils of Sokoru Town have clay content ranging from 30.26-77.26%, silt content from 21.02-66.8%, sand from 1.16-20.24% and gravel from 0- 4.26%.

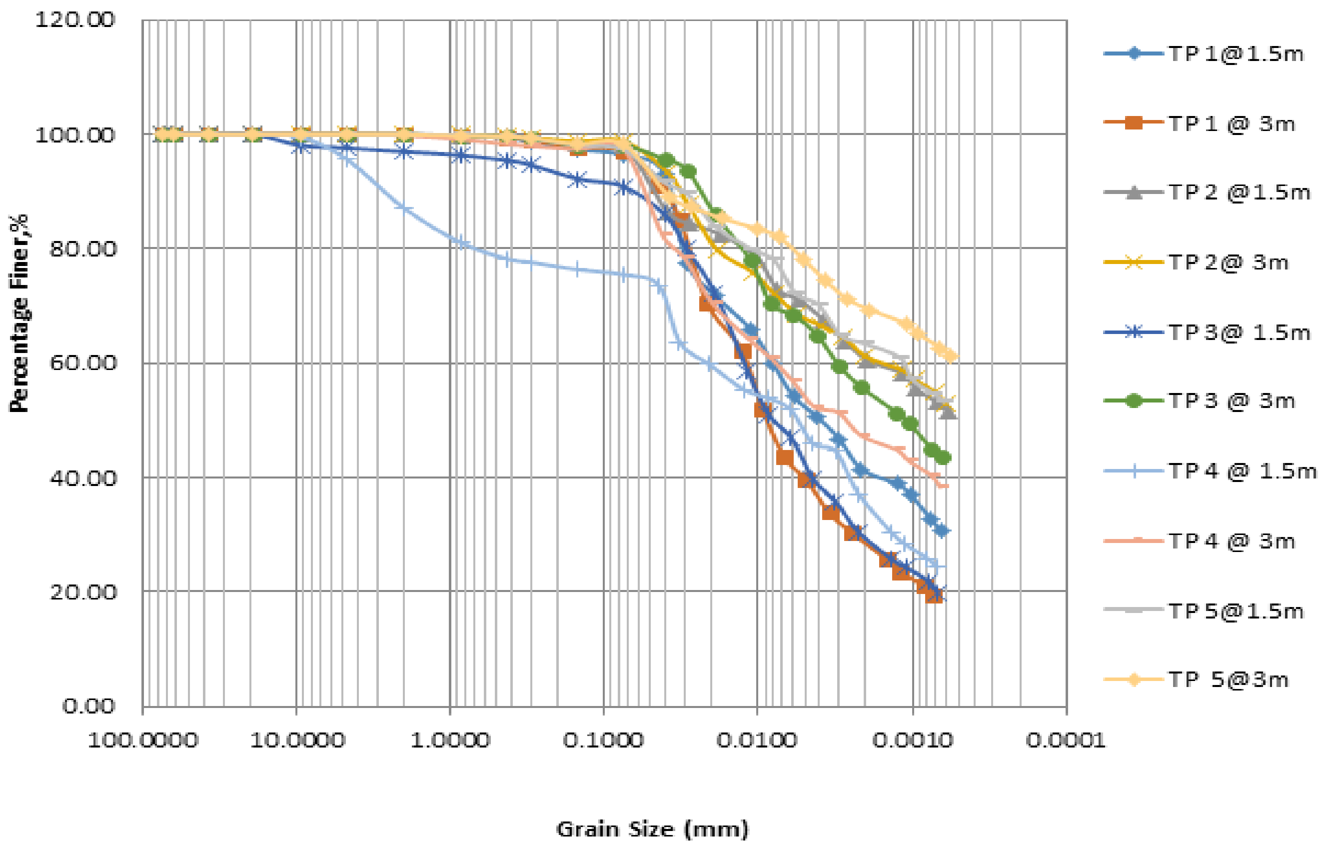

Figure 4.1 Grain size distribution curve for samples from TP-1 to TP-5

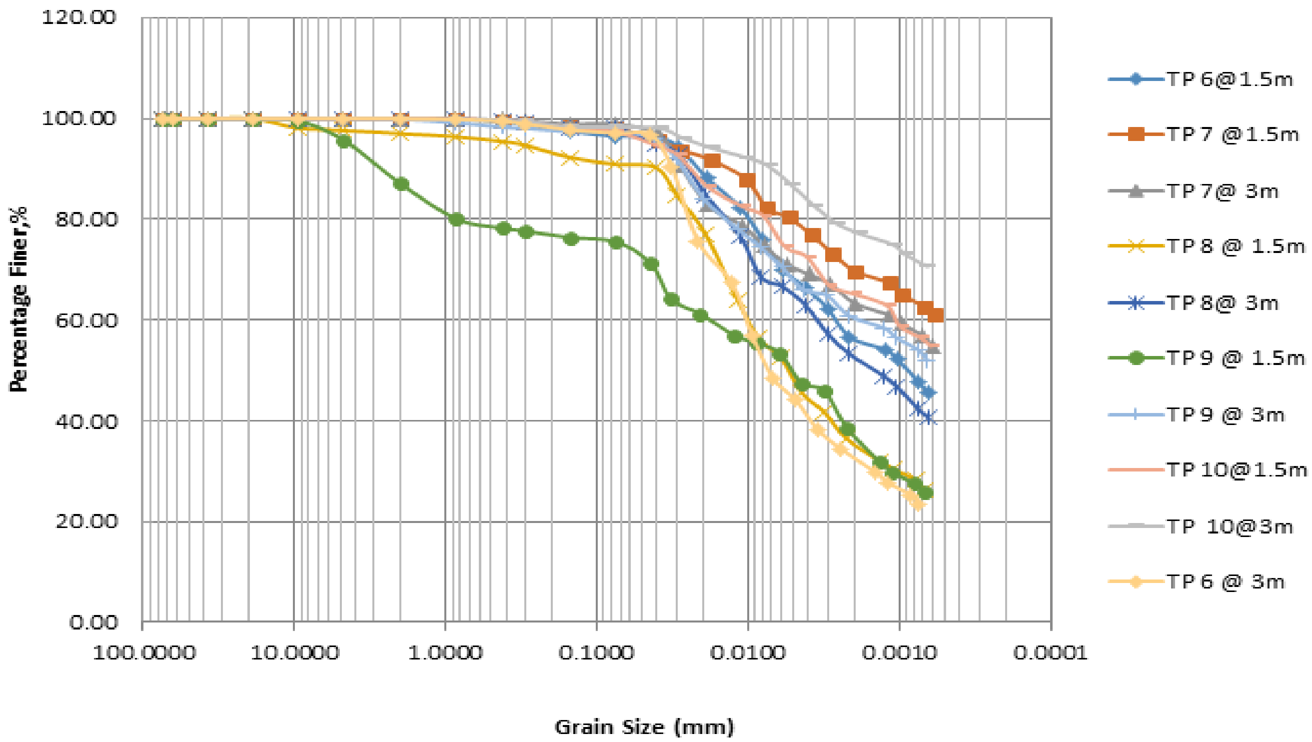

Figure 4.2 Grain size distribution curve for samples from TP-6 to TP-10

4.2.3. Atterberg Limlits.

The Atterberg Limits for soil in Sokoru town are summarized in Table 4.4 and from this we can observe that liquid limit ranges from 58.50% – 85.00 %, plastic limit ranges from 27.76% – 48.80% ,Shrinkage limit ranges from 10.71% - 17.86% and plastic index from 20.00 – 53.61%.

Table 4.4. Summery of Atterberg limits of Sokoru Town

Test pit	Depth(m)	Liquid Limit,LL (%)	Plastic Limit,PL(%)	Plasticity Index,PI (%)	Shrinkage limit(%)
TP -1	1.5m	78	43	35	12
	3m	72	48	23	15
TP-2	1.5m	67	33	34	14
	3m	71	46	25	14
TP-3	1.5m	59	33	25	11
	3m	73	39	34	14
TP -4	1.5m	78	29	49	16
	3m	85	31	54	17
TP-5	1.5m	72	42	30	14
	3m	69	49	20	13
TP -6	1.5m	70	35	35	11
	3m	72	46	26	16
TP-7	1.5m	66	46	25	14
	3m	71	44	27	12
TP-8	1.5m	59	35	23	14
	3m	73	40	33	13
TP -9	1.5m	78	28	50	16
	3m	85	32	53	18
TP-10	1.5m	72	44	28	14
	3m	74	48	26	11

4.2.4. Activity of clay

The plasticity of soil is caused by the absorbed water that surrounds the clay particles, the type of clay minerals and their proportional amounts in a soil will affect the liquid and plastic limits.

Table 4.5.Skemptons activity number of investigated soils

Test pit	Depth(m)	Gravel	Sand	Silt	Clay	LL(%)	PI(%)	Activity (A)	Degree of Activity
TP -1	1.5m	0.00	3.54	55.08	41.38	78.00	32.12	0.78	Normal
	3m	0.00	2.94	66.80	30.26	71.50	23.00	0.76	Normal
TP-2	1.5m	0.00	2.02	37.47	60.51	66.80	34.14	0.56	In active
	3m	0.00	1.16	37.70	61.14	71.20	24.89	0.41	In active
TP-3	1.5m	2.36	6.76	60.41	30.47	58.50	25.36	0.83	Normal
	3m	0.00	1.90	42.31	55.79	73.00	33.57	0.60	In active
TP -4	1.5m	4.26	20.24	38.34	37.16	78.00	49.30	1.19	In active
	3m	0.00	2.62	50.04	47.34	85.00	53.61	1.13	Normal
TP-5	1.5m	0.00	2.66	33.92	63.42	72.00	30.25	0.48	In active
	3m	0.00	1.72	28.96	69.32	68.80	20.00	0.29	In active
TP -6	1.5m	0.00	3.54	39.87	56.59	78.00	32.12	0.57	In active
	3m	0.00	2.94	62.57	34.49	71.50	23.00	0.67	In active
TP-7	1.5m	0.00	2.02	28.39	69.59	66.80	34.14	0.49	Inactive
	3m	0.00	1.16	35.45	63.38	71.20	24.89	0.39	Inactive
TP-8	1.5m	2.36	6.76	54.41	36.47	58.50	25.36	0.70	Inactive
	3m	0.00	1.90	44.81	53.29	73.00	33.57	0.63	Inactive
TP -9	1.5m	4.26	20.24	36.81	38.69	78.00	49.30	1.17	In active
	3m	0.00	2.62	36.52	60.86	85.00	53.61	0.88	Normal
TP-10	1.5m	0.00	2.66	60.86	65.25	72.00	30.25	0.46	Inactive
	3m	0.00	1.72	21.02	77.26	68.80	20.00	0.26	Inactive

From the table 4.5 the activity of the study area soil under investigation ranges from 0.26-1.19.This implies most of the study area soils fall in inactive range.

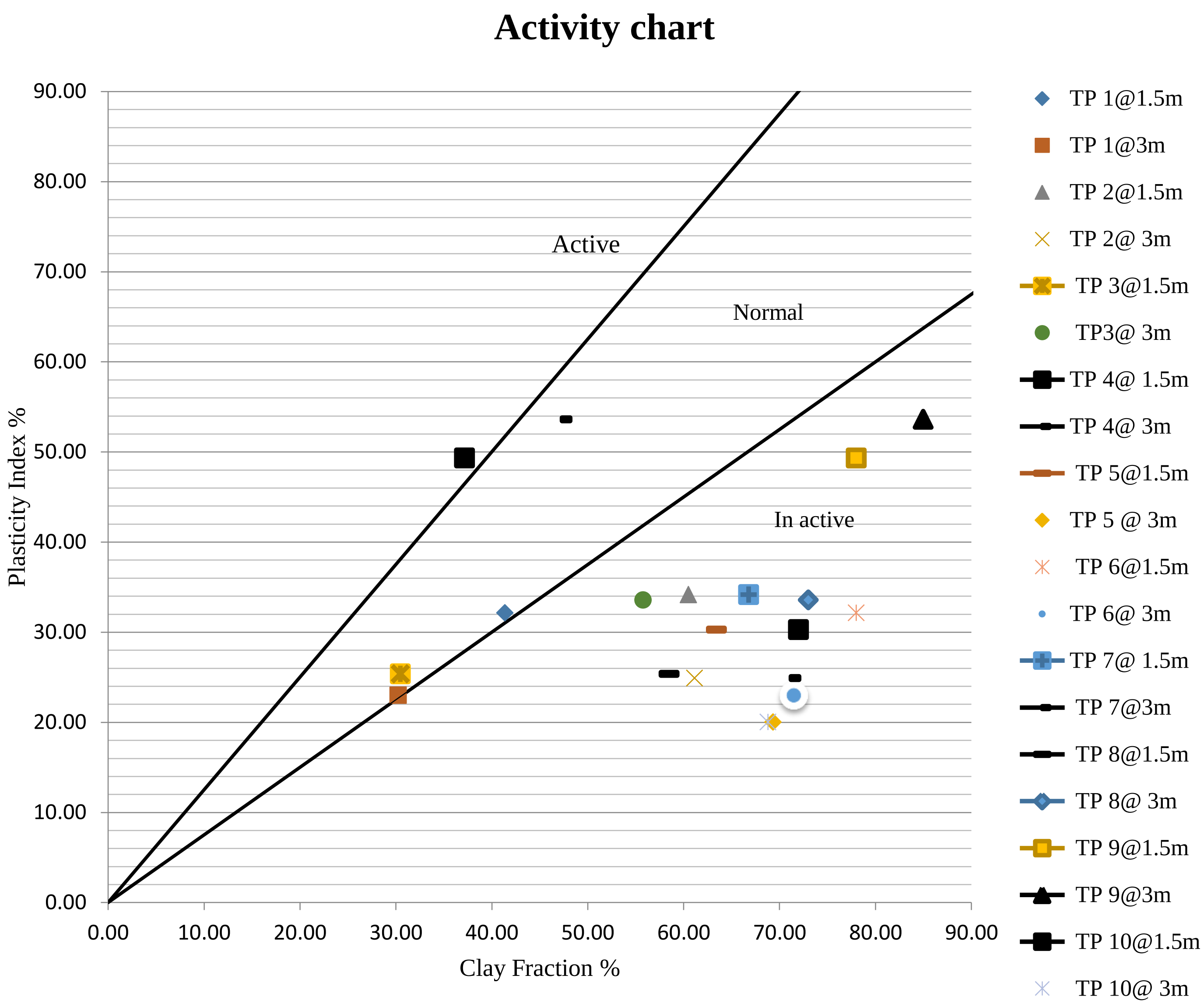

Figure 4.3. Activity chart for soils in the study area

4.2.5. Free swell

From table 4.6 one can see that the free swell of the soil under investigation ranges from 8% to 49%. Those soils having a free swell less than 50% are considered as Non expansive. All soil samples under investigation have medium swelling potential.

Table 4.6. Free swell test results in the study area

Test Pit	Depth (m)	Free Swell (%)
TP-1	1.5m	20
	3m	13
TP-2	1.5m	17
	3m	49
TP-3	1.5m	20
	3m	17
TP-4	1.5m	45
	3m	29
TP-5	1.5m	8
	3m	17
TP-6	1.5m	19
	3m	12
TP-7	1.5m	14
	3m	45
TP-8	1.5m	18
	3m	25
TP-9	1.5m	42
	3m	27
TP-10	1.5m	8
	3m	14

4.3. Compaction Test

A representative compaction tests were run on samples of five different test pits.Where the remaining test pits have the similar result with either of these test pits.The result is shown in table 4.7.

Table 4.7.summery of maximum dry density and optimum moisture content

Test Pit	Depth (m)	OMC(%)	MDD (g/cm^3)
TP-1	1.5m	37.00	1.22
	3m	35.00	1.28
TP-2	1.5m	36.50	1.28
	3m	35.00	1.29
TP-3	1.5m	31.50	1.34
	3m	30.50	1.32
TP-4	1.5m	27.07	1.39
	3m	27.00	1.31
TP-5	1.5m	36.50	1.24
	3m	37.00	1.28

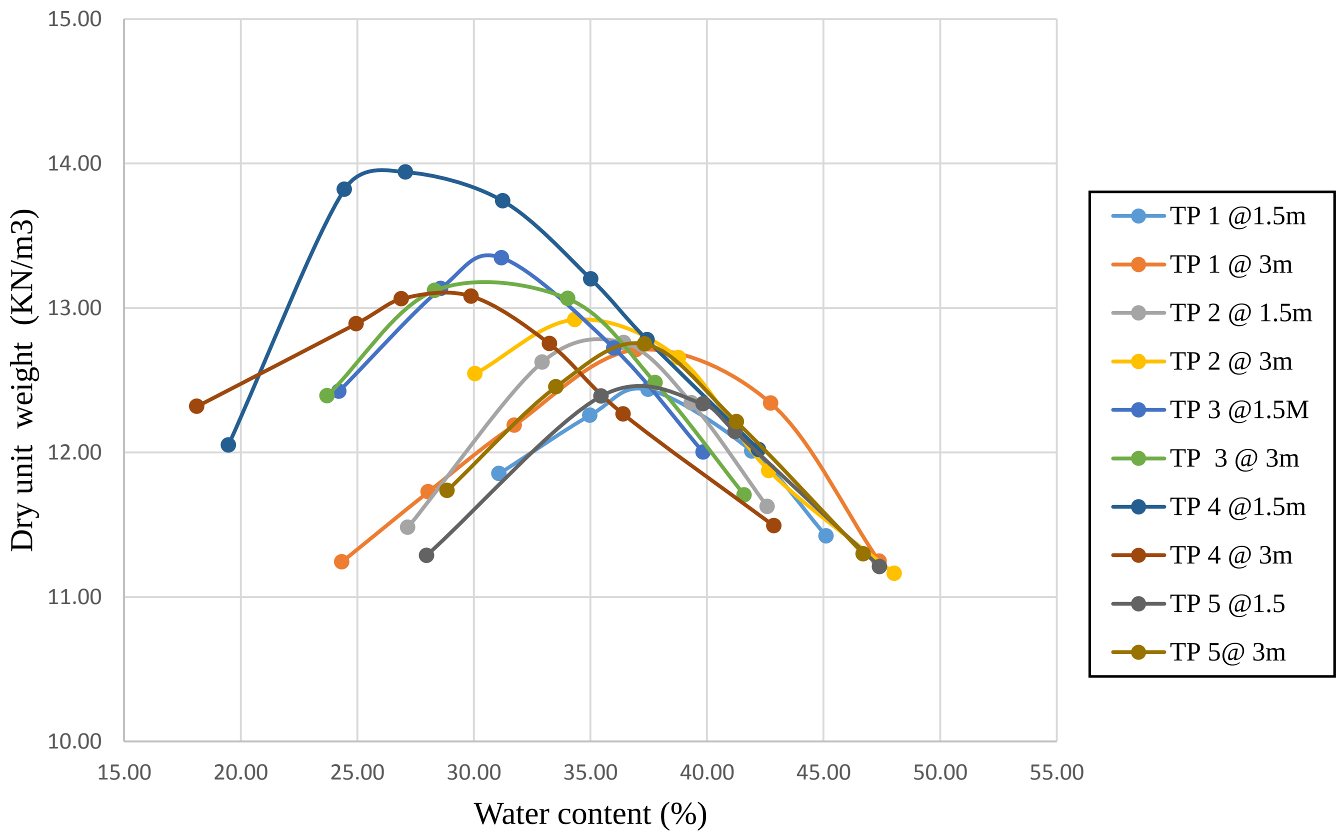

Figure 4.4. Dry Density versus Optimum Moisture Content Curve

From the test results the maximum dry density (MDD) of Sokoru ranges from 1.22 to 1.39 g/cm^3 and the optimum moisture content ranges 27% to 37%.

4.4. Shear strength of soil

4.4.2. Unconfined compression strength (ucs) test

Unconfined compressive strength of Sokoru soils is summarized on table 4.8 which ranges from 154.12–354.21 kN/m^2 and undrained shear strength range from 77.1kN/m^2–177.12kN/m^2. Likewise, consistencies of the soils ranges from stiff to very stiff.For this test the loading rate is 1.25 mm/min where as the devision factor is 8.4 N/div.

Table 4.8. Unconfined compressive strength of soils of the study area.

Test pit	sampling depth(m)	Natural moisture content (%)	Unconfined compressive strength, qu (kN/m^2)	Undrained shear strength, Su (kN/m^2)	Consistency
TP -1	1.5m	45.83	154.12	77.06	Stiff
	3m	47.30	223.50	111.75	Very stiff
TP-2	1.5m	42.15	162.50	81.25	Stiff
	3m	42.63	175.00	87.50	Stiff
TP-3	1.5m	32.90	167.60	83.80	Stiff
	3m	39.43	352.06	176.03	very Stiff
TP -4	1.5m	31.47	271.56	135.78	very Stiff
	3m	38.55	354.21	177.11	very Stiff
TP-5	1.5m	40.18	309.68	154.84	very Stiff
	3m	41.34	389.14	194.57	very Stiff

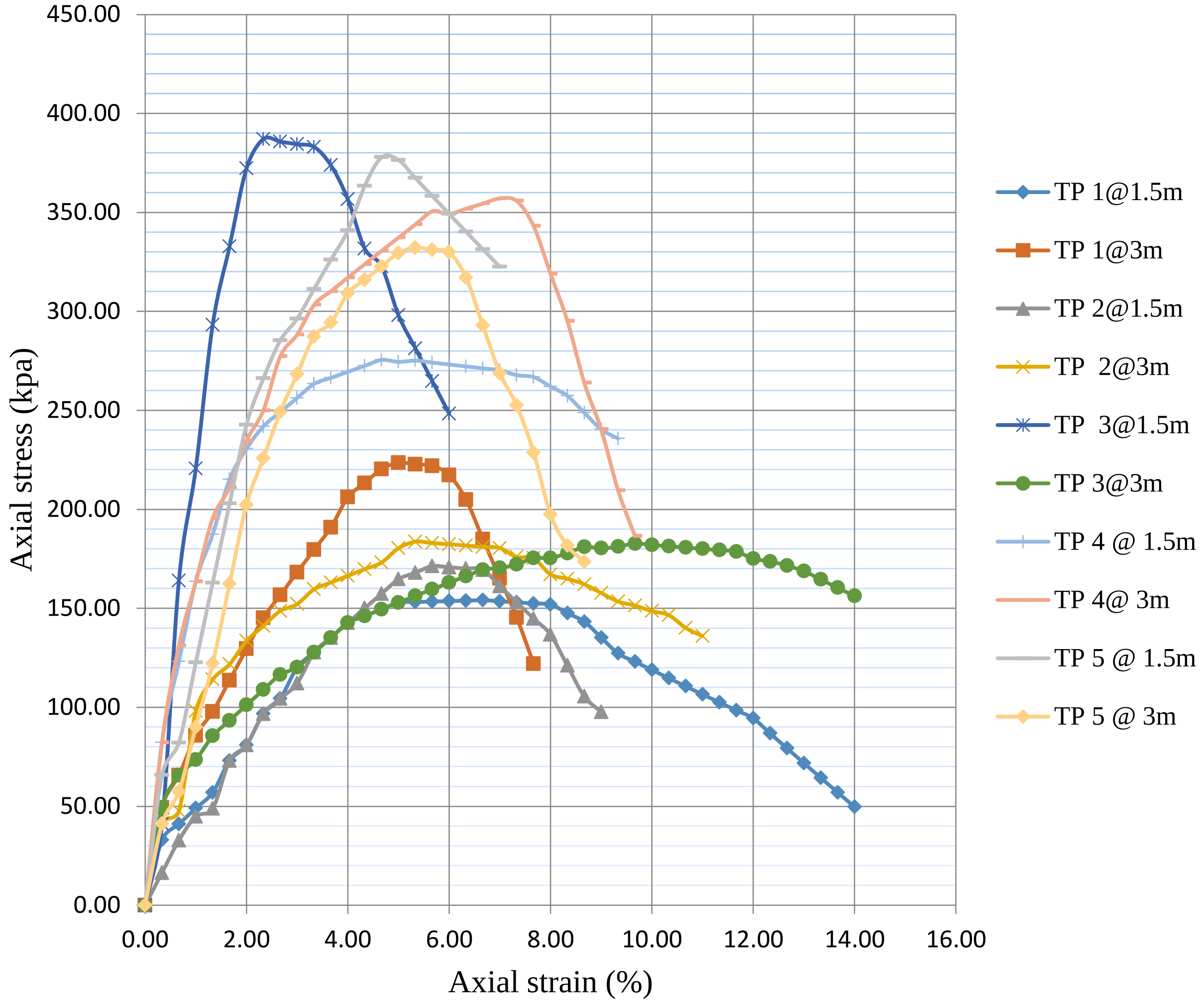

Figure 4.5 Axial stress Vs. Axial Strain of the study area

4.5. Consolidation

4.5.1. Pre-consolidation pressure

Preconsolidation stress is the maximum vertical effective stress that 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 (Teferraet al., 1999). Pre-consolidation pressure was determined from void ratio versus log pressure curve by the simplified method and Casagrande's method.

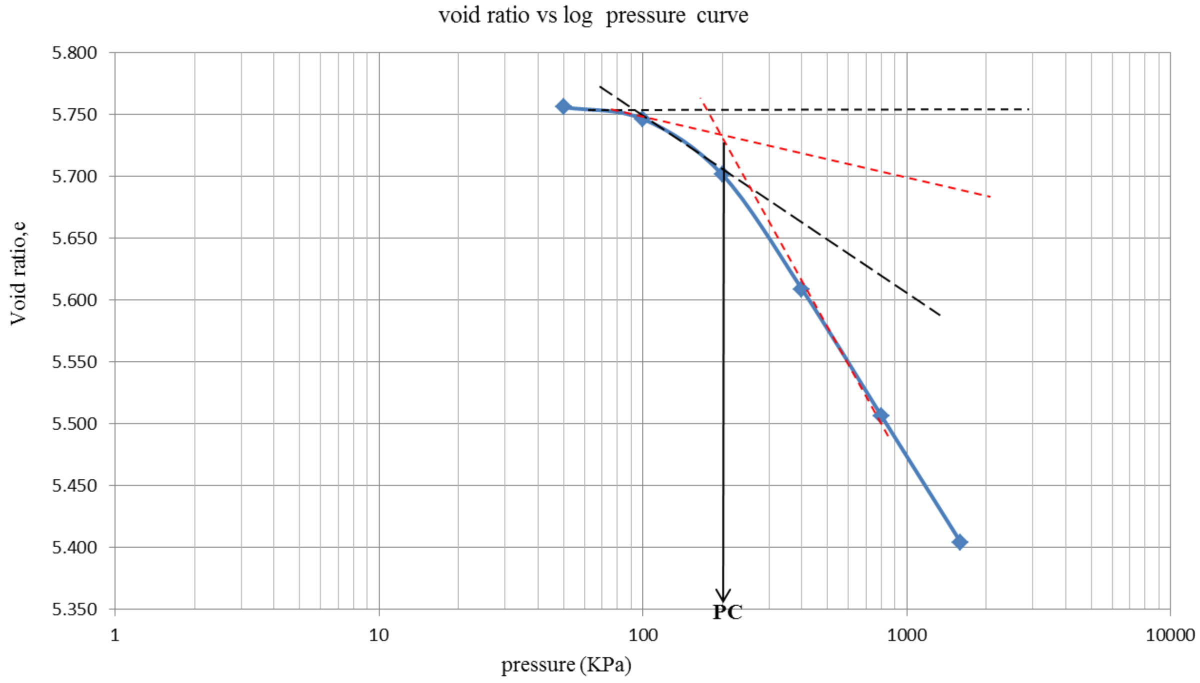

Figure 4.6.Typical void ratio Vs pressure curve used to determine Pc for TP-4

4.5.2.Compression index (CC) and Swelling index (CS)

Compression index

The compression index (Cc) and swelling index (CS) can be determined by graphic construction from laboratory results for void ratio and pressure, which is equal to the slope of the linear portion of the void ratio versus log pressure loading curve and unloading curve respectively.

There graphical expressions for compression index and swelling index determination is used in this study which is indicated on table 4.9.

Table 4.9. Summary of consolidation test results

Test pit	Depth(m)	Total unit weight(kN/m^3)	Pressure (kPa)	Void ratio (e)	Compression index (CC)	Swelling index (CS)	Over burden pressure (kpa	Pre-consolidation pressure (kpa)	Over consolidation ratio (OCR
TP-1	3	16.09	50	1.09	0.23	0.02	48.27	150.00	3.11
			100	1.06					
			200	1.01					
			400	0.94					
			800	0.87					
			1600	0.8					
			800	0.83					
			400	0.84					
			200	0.84					
			100	0.85					
			50	0.86					
TP-2	3	11.77	50	1.44	0.39	0.19	35.32	175.00	8.49
			100	1.43					
			200	1.39					
			400	1.29					
			800	1.18					
			1600	1.03					
			800	1.11					
			400	1.15					
			200	1.15					
			100	1.16					
			50	1.16					
TP-4	3	12.16	50	5.76	0.33	0.13	36.49	225.00	6.17
			100	5.75					
			200	5.7					
			400	5.61					
			800	5.51					
			1600	5.4					
			800	5.44					
			400	5.49					
			200	5.53					
			100	5.57					
			50	5.6					

4.5.3. Coefficient of consolidation

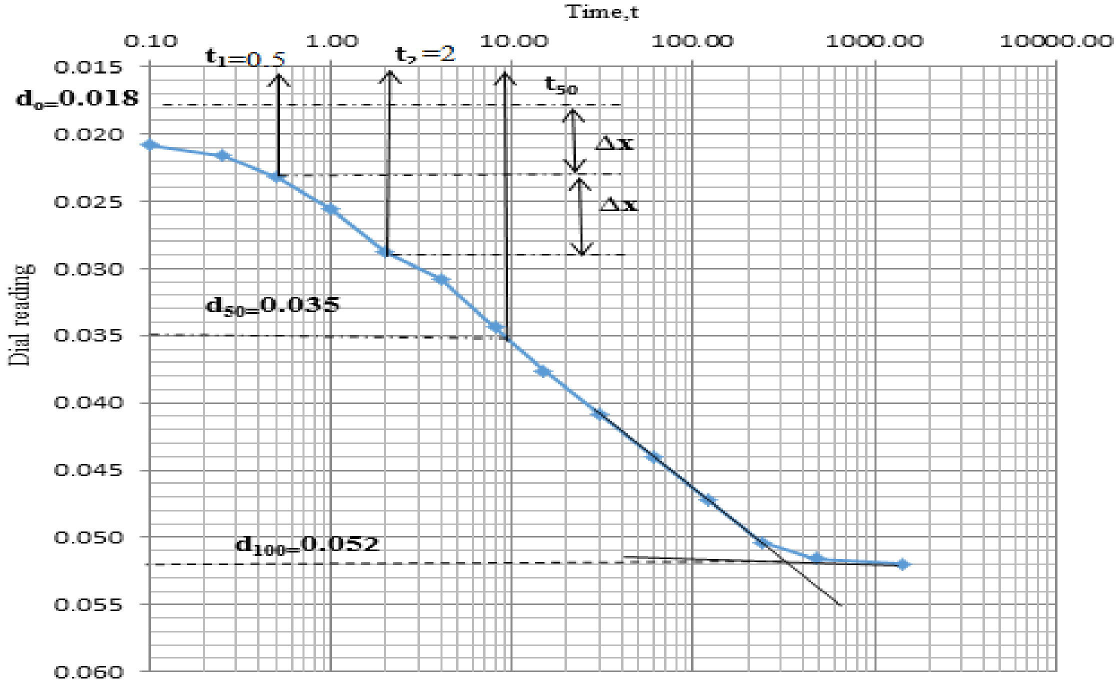

Figure 4.6. Typical curve for determining coefficient of consolidation using Logarithm of time fitting method

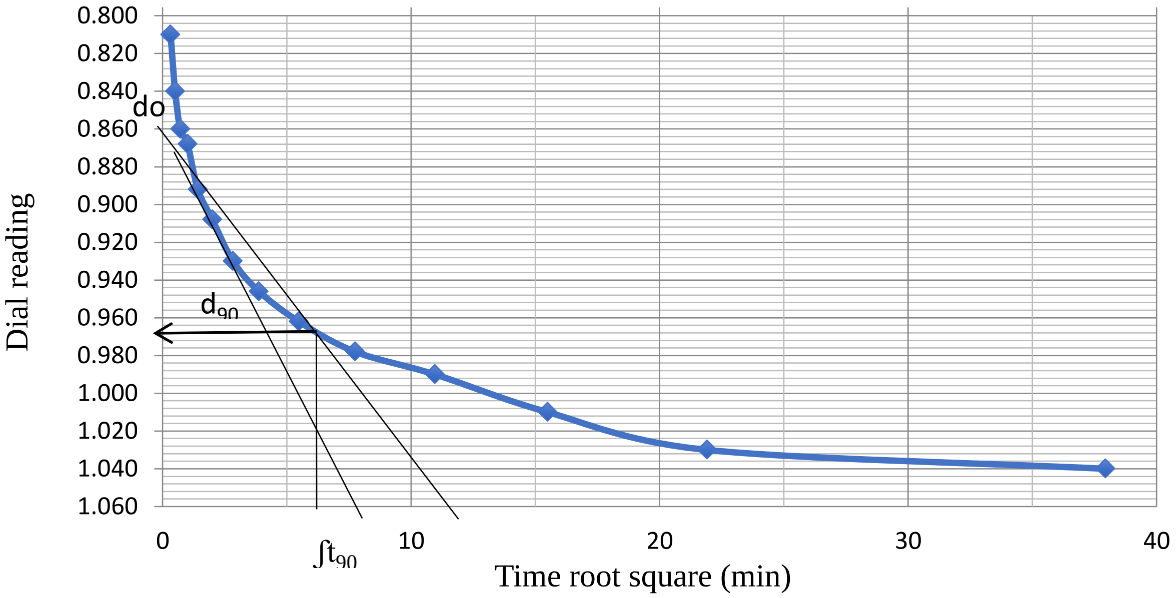

Figure 4.7. Typical curve for determining coefficient of consolidation using Square-root-of-time fitting method

A representative consolidation tests were run on samples of three undisturbed samples on different test pits. where the remaining test pits have the similar result with either of these test pits.

4.6. Permeability

The flow of water through soils depends upon its permeability coefficient I use falling head permeability test since this test is appropriate for fine grained soil. Since my soil is fine grain soil I prefer this test. A representative permeability tests were run on samples of three disturbed samples on three different test pits,where the remaining test pits have the similar result with either of these test pits.Coefficient of permeability for Tp-1 is 4.58*10^-4,for TP-2 is 3.05*10^-4,for Tp-4 is 3.11*10^-5.

The values of coefficient of permeability for the tested soils using falling head test lie between $4.58*10^{-4}$and $3.11*10^{-5}$cm/sec, which indicates that the soils are practically impervious.Whereas estimating from one dimensional consolidation test $1*10^{\wedge-8}$ to $9.1*10^{\wedge-8}$ cm/s.In void ratio versus log coefficient of permeability graph all soil samples taken from study area have nearly straight line relationship figure 4.8.

Table 4.10 Summary of coefficient of consolidation, coefficient of compressibility and coefficient of permeability

Test pit	Depth(m)	Pressure (kPa)	Void ratio (e)	Coefficient of consolidation (Cv) ∫t method 10-3(cm^2/min)	Coefficient of consolidation (Cv) log t method 10-3(cm^2/min)	Coefficient of Compressibility, av ($10^{-5}cm^2$/KN	Coefficient of permeability (k) 10^{-8}(cm/s)
TP-1	3	50	1.09	2.21	79.79	3.3	3.4
		100	1.06	3.26E-01	3.32E+00	2.33	3.6
		200	1.01	1.38E-02	9.91E+00	2.5	1.7
		400	0.94	1.54E+00	2.19E+00	1.75	1.4
		800	0.87	1.39E+00	2.44E+00	0.95	6.9
		1600	0.8	5.18E+01	7.77E-01	0.42	1.2
		800	0.83	1.06E+02	6.08E-01	0.17	9.7
		400	0.84	1.05E+01	1.30E+00	0.11	6.2
		200	0.84	8.26E+01	6.49E-01	0.18	7.9
		100	0.85	2.40E+01	9.74E-01	0.32	4.1
		50	0.86	3.68E+02	3.90E-01	0.69	1.3
TP-2	3	50	1.09	6.30E-02	5.69E+00	2.8	8.3
		100	1.06	4.05E-02	6.64E+00	0.71	1.4
		200	1.01	5.65E-03	1.32E+01	1.8	5.0
		400	0.94	1.40E-01	4.91E+00	1.99	1.4
		800	0.87	1.49E-03	2.43E+01	1.21	9.5
		1600	0.8	4.95E-01	3.87E+00	0.85	2.3
		800	0.83	2.40E+02	4.84E-01	0.46	5.9
		400	0.84	3.21E-03	1.94E+01	0.5	8.6
		200	0.84	8.56E-05	6.48E+01	0.14	6.4
		100	0.85	1.05E+01	1.30E+00	0.26	1.4
		50	0.86	6.60E+02	3.25E-01	0.52	1.8
TP-4	3	50	1.09	1.65E-01	4.00E+00	0.13	1.0
		100	1.06	9.79E-01	2.22E+00	0.28	1.3
		200	1.01	1.84E-01	3.98E+00	0.67	6.0
		400	0.94	4.86E+01	6.60E-01	0.69	1.7
		800	0.87	1.44E+02	4.91E-01	0.39	2.9
		1600	0.8	1.51E+03	2.44E-01	0.2	1.6
		800	0.83	2.04E+02	4.86E-01	0.07	7.7
		400	0.84	9.41E+03	1.30E-01	0.17	8.5
		200	0.84	1.45E+04	1.09E-01	0.31	2.4
		100	0.85	9.04E+03	1.23E-01	0.67	3.2
		50	0.86	2.16E+04	8.96E-02	0.8	9.1

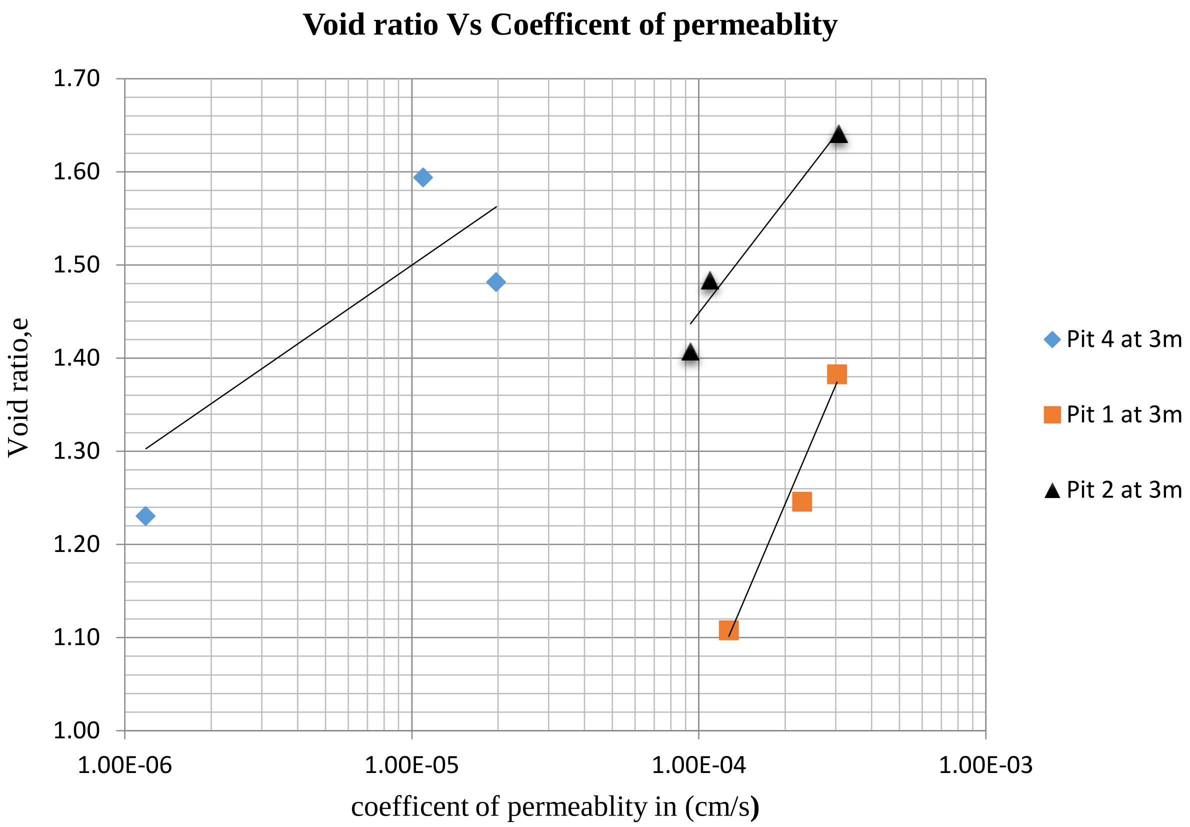

Figure 4.8 Void ratio Vs Log Coefficient of Permeability

From a plot of void ratio versus coefficient of permeability one obtains a straight line relationship for some cohesive soils.It must be noted that each plot in above is for a given soil. The permeability of soil at a given void ratio may not have any relationship with that of another soil at the same void ratio. Paradoxically, the soil with the largest void ratio (i.e. clay) is the list pervious. This is because the individual void passages in clay are extremely small through which water cannot flow easily From the above figure, we can notice that the permeability of a soil is directly proportional to that of void ratio.Which shows the coefficient of permeability increase as the void ratio increases.

CHAPTER FIVE

DISCUSSIONS OF THE LABORATORY TEST RESULTS

5.1. Classification of the soils

5.1.1.General

Soil classification is the arrangement of soils into different groups such that the soils in a particular group have similar behavior. They are the American Association of State Highway and Transportation officials (AASHTO) classification system and the Unified Soil Classification System(USCS) .

5.1.2. Classification of soils based on unified soil classification system (uscs)

The Unified Soil Classification System is based on the recognition of the type and predominance of the constituents considering grain-size, gradation, plasticity and compressibility.. Only sieve and Atterberg limits are necessary to completely classify a soil in this system.

5.1.2.1. 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.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. Inorganic clay values lie above the A-line, and values for inorganic silts lie below the A-line..

Table 5.1 Classifications of soils based on USC Classification system

Test pit	Depth(m)	Percent amount of particle size				LL(%)	PI(%)	Classification according to UCS
		Gravel	Sand	Silt	Clay			
TP -1	1.5m	0	3.54	55.08	41.38	78.00	32.12	MH
	3m	0	2.94	66.8	30.26	71.50	23.00	MH
TP-2	1.5m	0	2.02	37.47	60.51	66.80	34.14	CH
	3m	0	1.16	37.7	61.14	71.20	24.89	CH
TP-3	1.5m	2.36	6.76	60.41	30.47	58.50	25.36	MH
	3m	0	1.9	42.31	55.79	73.00	33.57	CH
TP -4	1.5m	4.26	20.24	38.34	37.16	78.00	49.30	MH
	3m	0	2.62	50.04	47.34	85.00	53.61	MH
TP-5	1.5m	0	2.66	33.92	63.42	72.00	30.25	CH
	3m	0	1.72	28.96	69.32	68.80	20.00	CH
TP -6	1.5m	0	3.54	39.87	56.59	70.00	34.64	CH
	3m	0	2.94	62.57	34.49	71.50	25.52	MH
TP-7	1.5m	0	2.02	28.39	69.59	66.35	24.89	CH
	3m	0	1.16	35.46	63.38	71.20	27.10	CH
TP-8	1.5m	2.36	6.76	54.41	36.47	58.85	23.02	MH
	3m	0	1.9	44.81	53.29	73.00	33.04	CH
TP -9	1.5m	4.26	20.24	36.81	38.69	78.00	50.24	CH
	3m	0	2.62	36.52	60.86	85.00	53.40	CH
TP-10	1.5m	0	2.66	36.22	61.12	72.00	28.10	CH
	3m	0	1.72	21.02	77.26	74.30	26.45	CH

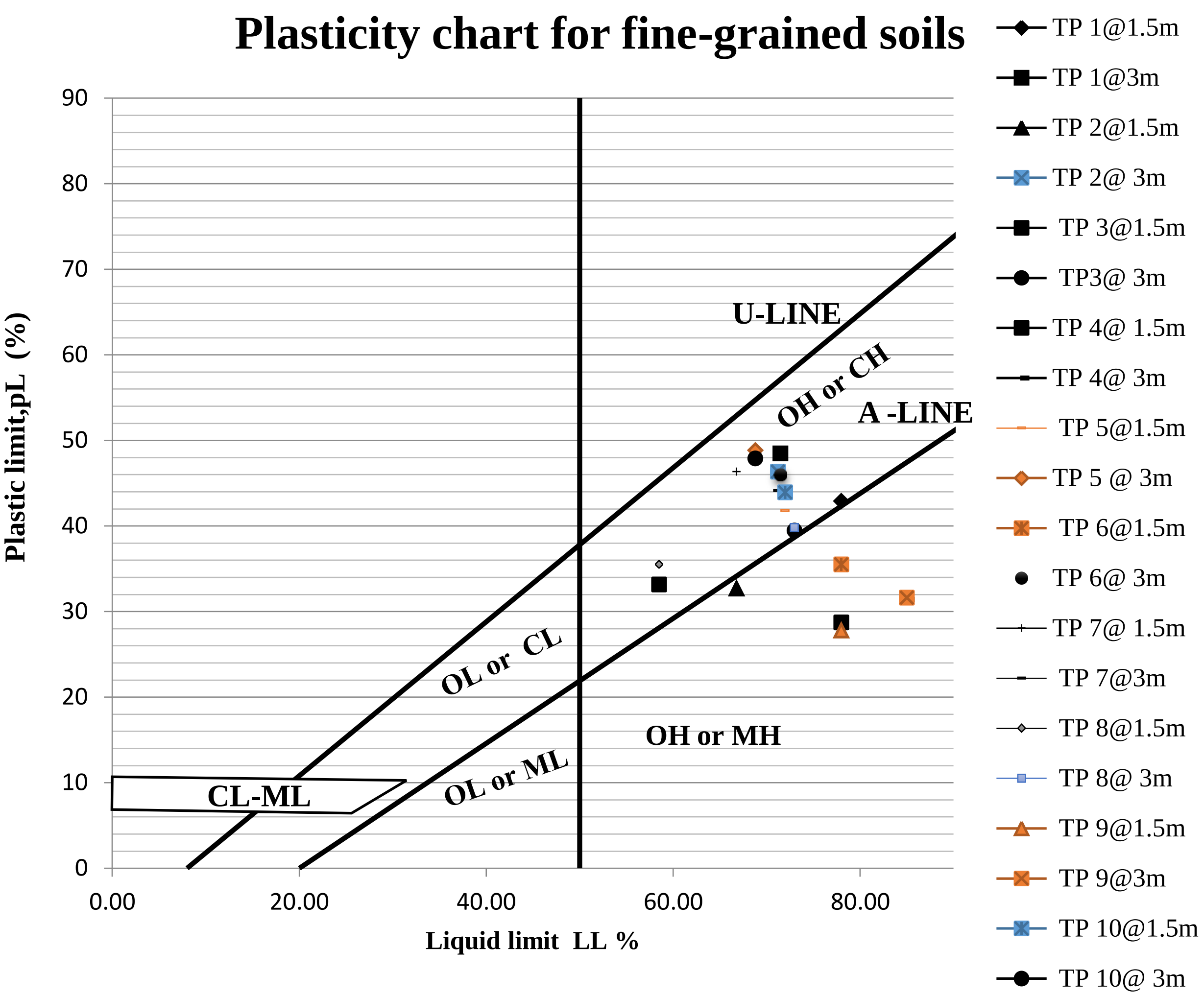

Figure 5.1. plasticity chart for the study area according to unified soil classification system

According to unified soil classification system as shown in table below the soils of the study area fall under CH region, which shows that the soils are inorganic clays of high plasticity and the soils fall under MH region, which are inorganic silts of high plasticity. According grain size analysis result red colored soils have high clay fraction thus it is better to classify the soil as clay rather than silt.

5.1.3. AASHTO classification system

The AASHTO classification system, also called public roads administration (ERA) classification, is based on grain size distribution, liquid limit and plasticity index. This system is generally used by highway engineers for classification of sub-grade soils for the highway pavement.Since the percentage of particles passing No. 200 sieve for all soil sample is greater than 35%, soils of the study area are fine grained soil.

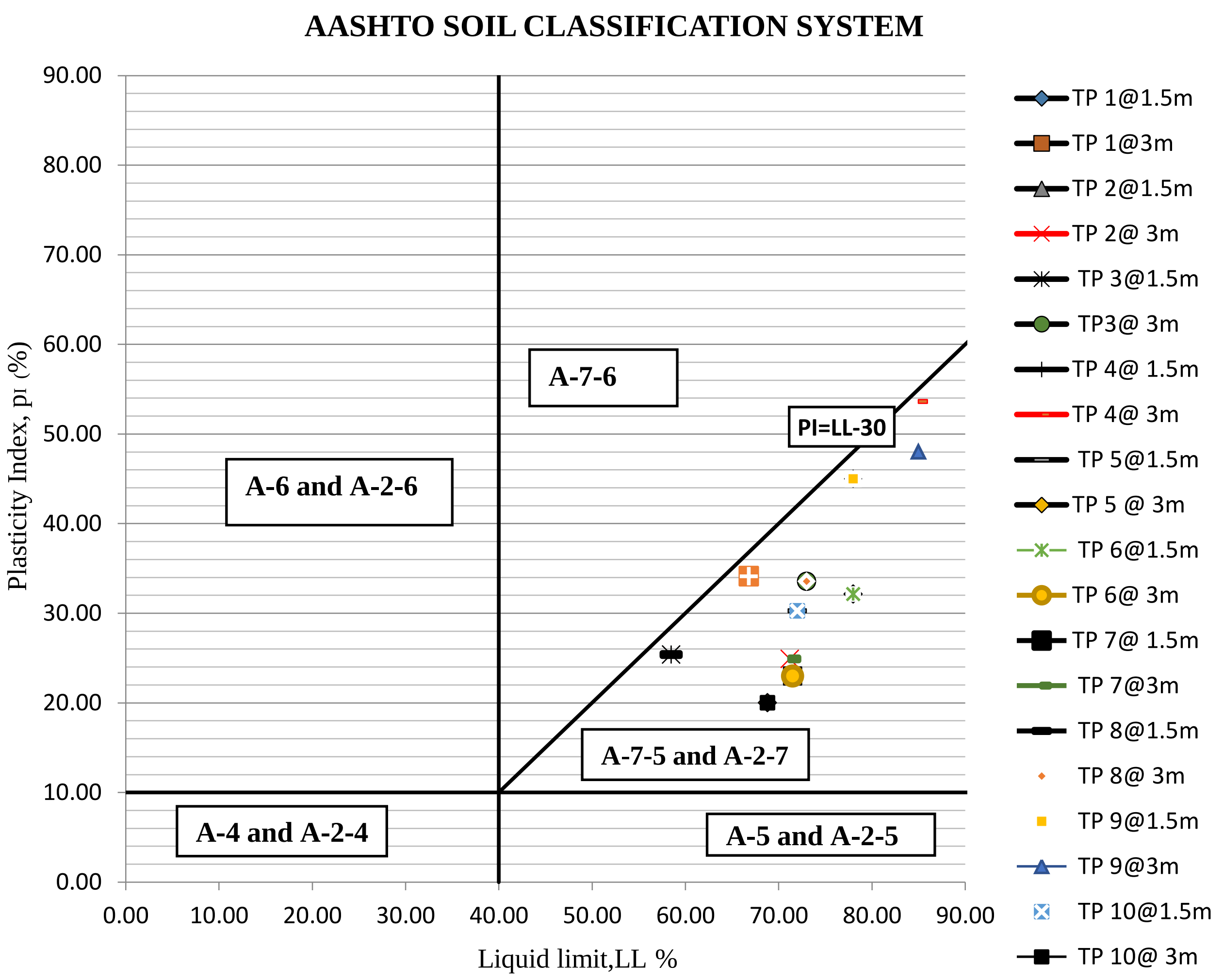

Figure 5.2. Chart for use in AASHTO soil classification system

Table 5.2. Classifications of soils based on AASHTO Classification system

Test pit	No.10	No.40	N0.200	LL(%)	PI(%)	GI	Group classification	Usual types of significant constituent materials	General rating as sub-grade	Classification according to AASHTO
TP -1	99.98	99.38	96.46	78	32	42	A-7-5	Clayey soils	Fair	A-7-5(42)
	99.96	99.40	97.06	72	23	33	A-7-5	Clayey soils	Fair	A-7-5(33)
TP- 2	100.00	99.62	97.98	67	34	41	A-7-5	Clayey soils	Fair	A-7-5(41)
	99.98	99.70	98.84	71	25	35	A-7-5	Clayey soils	Fair	A-7-5(35)
TP-3	97.00	95.44	90.88	59	25	28	A-7-5	Clayey soils	Fair	A-7-5(28)
	99.94	99.58	98.10	73	34	43	A-7-5	Clayey soils	Fair	A-7-5(43)
TP -4	87.10	78.24	75.50	78	49	40	A-7-5	Clayey soils	Fair	A-7-5(40)
	99.84	98.30	97.38	85	54	62	A-7-5	Clayey soils	Fair	A-7-5(62)
TP-5	100.00	99.60	97.34	72	30	39	A-7-5	Clayey soils	Fair	A-7-5(39)
	99.96	99.66	98.28	69	20	30	A-7-5	Clayey soils	Fair	A-7-5(30)
TP -6	99.98	99.38	96.46	70	35	42	A-7-5	Clayey soils	Fair	A-7-5(42)
	99.96	97.06	97.06	72	26	35	A-7-5	Clayey soils	Fair	A-7-5(35)
TP-7	100.00	97.98	97.98	66	25	33	A-7-5	Clayey soils	Fair	A-7-5(33)
	99.98	99.70	98.84	71	27	37	A-7-5	Clayey soils	Fair	A-7-5(37)
TP-8	97.00	95.44	90.88	59	23	26	A-7-5	Clayey soils	Fair	A-7-5(26)
	99.94	99.58	98.10	73	33	42	A-7-5	Clayey soils	Fair	A-7-5(42)
TP -9	87.10	78.24	75.50	78	50	40	A-7-5	Clayey soils	Fair	A-7-5(40)
	99.84	98.30	97.38	85	53	62	A-7-5	Clayey soils	Fair	A-7-5(62)
TP-10	100.00	99.60	97.34	72	28	37	A-7-5	Clayey soils	Fair	A-7-5(37)
	99.96	99.66	98.28	74	26	37	A-7-5	Clayey soils	Fair	A-7-5(37)

From AASHTO Classification system results one can observe that all the samples collected fall under A-7-5 which are clayey soils with group index ranging from 31 to 98. The group index results indicate that generally the soils of the study area are Fair for highway subgrade material.

5.2. Discussions Of The Laboratory Test Results

The Specific Gravity lies in the range between 2.5 to 2.73, which is similar to the results obtained by Morin and a previous study by Samuel, 1989, Addiszemen, 2005. The Activity of the study area soil under investigation ranges from 0.26-1.19.This implies most of the study area soils fall in inactive range.

The result obtained from the grain size analyses the dominant proportion of soil particle in the research area is clay, which have clay content ranging from 30.26 % –77.26% ,silt faction 21.02% – 66.80 % and sand fraction 1.16% - 20.24%.

The result of Atterberg Limit of the soil samples testes the soil under investigation is clay soil. The soil in the research area has Liquid Limit ranging from 58.5% –85%, Plastic Limit ranges from 27.76% – 48.8% ,Shrinkage Limit ranges from 10.71% – 17.86% and Plastic Index from 20% – 53.61%. This means the consistency of the soil is medium and highly plastic.

From the test result one can see that the Free Swell of the soil under investigation ranges from 8% to 49%. Those soils having a Free Swell less than 50% are considered as low in degree of expansion .All soil samples under investigation are non expansive soils.

The compaction test result showed that maximum dry density (MDD) of the study area ranges from 1.22 to 1.39 g/cm^3 and the optimum moisture content (OMC) ranges from 27%to 37%.

Unconfined compressive strength tests conducted on undisturbed representative samples show that unconfined compressive strength of Sokoru soils ranges from 154.12 – 354.21 kN/m^{2}and shows plasticity chart of the study area according to Unified Soil Classification System. Accordingly soils of the study area are classified as highly plastic clay (MH,CH).

Classifications of soils in the study area based on AASHTO Classification system .From this table and chart it can be observed that soil in the study area is classified in group A-7-5. This implies the soil is Fair for subgrade material.

The compression and recompression index of the soils is calculated from the straight portions of the loading and unloading e-log p curve.This calculation shows that the compression index, Cc, ranges from 0.23-0.39 swelling index, Cs, from 0.02-019.

The coefficient of permeability of soil under investigation which is calculated from the test results of consolidation test ranges from 3.11*10^{-5} to 4.58*10^{-4} cm/sec (Table 4.13). The result shows that the soil under investigation is impermeability.

5.3. 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.Results of the current research are summarized and compared to with range of values of soils found in different part of Addis Ababa Town.

Table 5.3: Comparison of Test Results in different parts of Ethiopia

	Previous Research (Selamawit M, 2015)	Previous Research by (Adem ,2014)	Thesis by (Wubshet ,2015)	Previous Research (Hanna T. 2008)	Previous Research (Fasil A.,2003)	Previous Research (Samuel,1989)			Current
Soil type	Blackexpansive soils	Red clay	Red Clay	Lateritic	Red clay	Red clay			clay
Location	Sebeta	DebreMarkos	Burayu	Wolayita- Sodo	Bahir Dar	Addis Ababa			Sokoru
						Kolfe	Semen Gebeya	Rufael	
ClayContent (%)	33-72	50 – 72	56-74	48-70	74.4-81.8	58-70	53-68	50-70	30.3-77.3
Activity	0.35-1.25		<0.75						0.26-1.19
Liquid Limit(%)	38-97	45-68	66-72	-	60-68	61-75	57-76	56-75	58.5-85
Plasticity Index(%)	Nov-55	14-40	36-40	19-30	25 - 31	30-43	33-47	29-41	20-5-.61
Shrinkage limit(%)				22-Nov	14 - 18	15-21	14-25	14-20	10.7-17.9
Free swell (%)	40-135	30-180	40-55	28-38		15-45	15-50	30-40	Aug-49
Specific gravity (%)	2.65-2.74	2.69-2.84	2.70-2.82	2.61-2.97	2.75 – 2.83	2.66-2.73	2.70-2.77	2.66-2.74	2.5-2.73
Compaction (g/cm3)									1.2-1.39
From plasticity chart	MH, CH, CL	MH, CH, CL	CH	MH		CH	CH	CH	MH, CH

The soils of sokoru 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 sokoru could be classified as red clay soil with almost close characteristics with Kolfe, Rufael and Semen Gebeya soils.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

From the laboratory test performed,it can be observed that the soils in Sokoru Town are not expansive.No significant variations of engineering properties within the investigated depths as well as in different pits which were found in the research work.The values of specific gravity ranges from 2.50 to 2.73.These values were within the same ranges of the red soils found in other parts of the country.The moisture content of the soil found in Sokoru Town range from 31.47%-47.3%.

Grain size analysis result shows the soil under investigation is dominantly silt and clay types through which about 21.02%-66.8 is silt soil and 30.26-77.26% clay soils.Atterberg limit test shows the liquid limit of the soils is in the range of 58.5%-85%,Plastic limit falls in between 27.76%-48.8% and plasticity index lies between 20%-53.61%.

Free swell test results of soils under investigation lies in between 8% to 49%. AASTHO classification system shows the soils are classified as (A-7-5). The soil is Fair to be used for sub grade material as per the AASTHO recommendation for suitability of soils as sub grade material.

Unconfined Compressive Strength (UCS) test indicates the value of qu is in between 154.12-354.21 kN/m^{2}and the amount of cohesion lies in between 77.1 to 177.11 kN/m^2.Based on the UCS result the consistency of soils is Stiff to very Stiff.

As determined from the one-dimensional consolidation test conducted on undisturbed soil samples, compression index, Cc, ranges from 0.23-0.39, coefficient of consolidation, CV, from 1.25-17.17 (x10^{-3})cm^2/min, coefficient of permeability, k, from 4.58*10^{-4} to 3.11*10^{-5}cm/sec.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.

6.2. RECOMMENDATIONS

- In this research, samples of soil were collected only from ten test pits were excavated to the maximum depth of 3m. Ten test pits are not enough to generalize the engineering properties of soils found in Sokoru town. Therefore, it is recommended that a light weight structure is possible to construct in the study with a depth of the foundation up to 3 meters below the natural grade line. However, by increasing the number of test pits, a more detailed and accurate results can be obtained.

- To generalize the full description of the engineering properties for future the dynamic properties shall be studied in the town.

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APPENDIX- A

NATURAL MOISTURE CONTENT

TP 1

	1.5m				3m			
Trial No.	1	2	3	4	1	2	3	4
Weight of Empty container(g)	25.32	25.95	25.36	24	25.24	17.99	18.48	1.825
Weight of container + wet soil(g)	102	98.4	98.22	95	106.19	83.29	91.98	3.49
Weight of container + Oven dry soil(g)	78.24	75.68	75.28	71	80.07	62.28	68.34	2.96
Weight of water(WW) (gm)	23.76	22.72	22.94	795	26.12	21.01	23.64	0.53
Weight of Oven dry soil(WS)gm	52.92	49.73	49.92	1700	54.83	44.29	49.86	1.135
Water content (W)(%)	44.90	45.69	45.95	46.76	47.64	47.44	47.41	46.70
Average water content (W)(%)	45.83				47.30			

TP 2

	1.5m				3m		
Trial No.	1	2	3	4	1	2	3
Weight of Empty container(g)	17.74	17.06	17.96	1.23	18.11	17.68	17.388
Weight of container + wet soil(g)	81.04	84.78	100.31	4.38	71.604	78.803	67.663
Weight of container + Oven dry soil(g)	62.34	64.49	76.21	3.44	55.63	60.567	52.594
Weight of water(WW) (gm)	18.7	20.29	24.1	0.94	15.974	18.236	15.069
Weight of Oven dry soil(WS)gm	44.6	47.43	58.25	2.21	37.52	42.887	35.206
Water content (W)(%)	41.93	42.78	41.37	42.53	42.57	42.52	42.80
Average water content (W)(%)	42.15				42.63		

TP 3

	1.5m			3m		
Trial No.	1	2	3	1	2	3
Weight of Empty container(g)	17.39	17.42	17.45	17.67	17.37	18.578
Weight of container + wet soil(g)	88.59	81.29	82.49	100.07	88.06	109.58
Weight of container + Oven dry soil(g)	71.03	65.77	66.61	76.89	67.94	83.878
Weight of water(WW) (gm)	17.56	15.52	15.88	23.18	20.12	25.702
Weight of Oven dry soil(WS)gm	53.64	48.35	49.16	59.22	50.57	65.3
Water content (W)(%)	32.74	32.1	32.3	39.14	39.79	39.36
Average water content (W)(%)	32.38			39.43		

TP 4

	1.5m			3m		
Trial No.	1	2	3	1	2	3
Weight of Empty container(g)	17.4	17.99	1.8	18.81	17.67	17.56
Weight of container + wet soil(g)	85.78	89.91	3.72	87.9	88.27	88.82
Weight of container + Oven dry soil(g)	69.56	72.94	3.26	68.25	68.499	69.05
Weight of water(WW) (gm)	16.22	16.97	0.46	19.65	19.771	19.77
Weight of Oven dry soil(WS)gm	52.16	54.95	1.46	49.44	50.829	51.49
Water content (W)(%)	31.10	30.88	31.51	39.75	38.90	38.40
Average water content (W)(%)	31.16			39.01		

TP 5

	1.5m				3m		
Trial No.	1	2	3	4	1	2	3
Weight of Empty container(g)	17.91	24.47	17.61	1.81	25.147	18.67	17.59
Weight of container + wet soil(g)	87.38	117.41	89.02	4.055	98.52	101.398	81.01
Weight of container + Oven dry soil(g)	67.47	90.96	68.45	3.41	77.13	77.13	62.45
Weight of water(WW) (gm)	19.91	26.45	20.57	0.645	21.39	24.268	18.56
Weight of Oven dry soil(WS)gm	49.56	66.49	50.84	1.6	51.983	58.46	44.86
Water content (W)(%)	40.17	39.78	40.46	40.31	41.15	41.51	41.37
Average water content (W)(%)	40.18				41.34		

TP 6

	1.5m				3m		
Trial No.	1	2	3	4	1	2	3
Weight of Empty container(g)	24.82	25.99	24.06	24.1	24.34	18.1	18.08
Weight of container + wet soil(g)	100	106.6	98.22	93	106.19	83.19	91.98
Weight of container + Oven dry soil(g)	76.14	80.58	74.18	71	80.07	62.28	68.34
Weight of water(WW) (gm)	23.86	26.02	24.04	22	26.12	20.91	23.64
Weight of Oven dry soil(WS)gm	51.32	54.59	50.12	46.9	55.73	44.18	50.26
Water content (W)(%)	46.49	47.66	47.96	46.91	46.87	47.33	47.04
Average water content (W)(%)	47.26				47.08		

TP 7

	1.5m			3m		
Trial No.	1	2	3	1	2	3
Weight of Empty container(g)	17.64	17.16	17.96	17.99	17.18	17.18
Weight of container + wet soil(g)	80.14	82.78	99.31	70.60	77.95	66.50
Weight of container + Oven dry soil(g)	62.34	64.49	76.21	55.63	60.59	52.59
Weight of water(WW) (gm)	17.8	18.29	23.1	14.97	17.36	13.91
Weight of Oven dry soil(WS)gm	44.7	47.33	58.25	37.64	43.41	35.41
Water content (W)(%)	39.82	38.64	39.66	39.78	39.99	39.27
Water content (W)(%)	39.37			39.68		

TP 8

	1.5m			3m		
Trial No.	1	2	3	1	2	3
Weight of Empty container(g)	17.3	17.99	16.97	18.98	17.99	17.26
Weight of container + wet soil(g)	85.78	89.99	97.46	87.79	87.99	88.7
Weight of container + Oven dry soil(g)	69.56	72.91	78.2	69.05	69.05	69.05
Weight of water(WW) (gm)	16.22	17.08	19.26	18.74	18.94	19.65
Weight of Oven dry soil(WS)gm	52.26	54.92	61.23	50.07	51.06	51.79
Water content (W)(%)	31.04	31.1	31.46	37.43	37.09	37.94
Average water content (W)(%)	31.2			37.49		

TP 9

	1.5m				3m		
Trial No.	1	2	3	4	1	2	3
Weight of Empty container(g)	17.19	17.62	17.15	1.83	17.47	17.27	18.78
Weight of container + wet soil(g)	87.59	80.29	80.29	4.21	98.05	86.02	108.99
Weight of container + Oven dry soil(g)	71.03	65.67	65.51	3.6	76.89	67.84	85.48
Weight of water(WW) (gm)	16.56	14.62	14.78	0.61	21.16	18.18	23.51
Weight of Oven dry soil(WS)gm	53.84	48.05	48.36	1.77	59.42	50.57	66.7
Water content (W)(%)	30.76	30.43	30.56	34.46	35.61	35.95	35.25
Average water content (W)(%)	31.55				35.60		

TP 10

	1.5m			3m		
Trial No.	1	2	3	1	2	3
Weight of Empty container(g)	17.81	24.56	17.51	25.37	18.75	17.49
Weight of container + wet soil(g)	86.28	116.41	88.01	99.02	99.98	80.01
Weight of container + Oven dry soil(g)	67.32	90.86	68.35	78.1	77.12	62.45
Weight of water(WW) (gm)	18.96	25.55	19.66	20.92	22.86	17.56
Weight of Oven dry soil(WS)gm	49.51	66.3	50.84	52.73	58.37	44.96
Water content (W)(%)	38.30	38.54	38.67	39.67	39.16	39.06
Average water content (W)(%)	38.50			39.30		

APPENDIX – B

INDEX PROPERTIES TEST RESULTS

Specific Gravity

SampleNo :TP 1

	1.5m			3m		
pycnometer bottle Code	A	T	4	A	T	4
Weight of dry, clean pycnometer, wp (g)	28.06	27.66	28.71	28.06	27.66	28.71
Weight of empty pycnometer + dry soil (grams),Wps(g)	38.06	37.66	38.71	38.06	37.66	38.71
Weight of pycnometer + soil + water, Wpws (g)	85.79	85.79	84.39	85.72	85.80	84.17
Weight of pycnometer + water, wpw (g)	79.71	79.67	78.30	79.61	79.69	78.41
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	25.00	25.00
Temperature, Tx(oc)	27.00	27.00	27.00	27.00	27.00	27.00
Conversion factor , K	0.99	0.99	0.99	0.99	0.99	0.99
Specific gravity of soil (Gs)	2.57	2.61	2.58	2.59	2.59	2.38
Average specific gravity of soil (Gs)	2.59			2.53		

SampleNo :TP 2

	1.5m				3m		
pycnometer bottle Code	4	A	A	4	B	C	A
Weight of dry, clean pycnometer, wp (g)	27.62	28.02	28.02	27.62	27.51	27.75	28.26
Weight of empty pycnometer + dry soil (grams),Wps(g)	37.55	38.08	38.08	37.58	37.51	37.75	38.26
Weight of pycnometer + soil + water, Wpws (g)	84.66	85.82	85.95	84.56	84.65	84.77	86.09
Weight of pycnometer + water, wpw (g)	78.30	79.71	79.71	78.30	78.34	78.42	79.75
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	23.00	23.00	23.00
Temperature, Tx(oc)	27.00	27.00	27.00	27.00	23.00	23.00	23.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.82	2.57	2.66	2.72	2.71	2.74	2.73
Average specific gravity of soil (Gs)	2.69				2.73		

SampleNo :TP 3

	1.5m				3m		
pycnometer bottle Code	T	C	C	T	B	C	A
Weight of dry, clean pycnometer, wp (g)	28.66	27.67	27.67	28.66	27.51	27.75	28.26
Weight of empty pycnometer + dry soil (grams),Wps(g)	38.64	37.67	37.73	38.49	37.50	37.82	38.31
Weight of pycnometer + soil + water, Wpws (g)	85.83	84.76	84.55	85.71	84.52	84.65	85.95
Weight of pycnometer + water, wpw (g)	79.67	78.38	78.38	79.67	78.34	78.42	79.75
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	23.00	23.00	23.00
Temperature, Tx(oc)	25.00	25.00	27.00	27.00	23.00	23.00	23.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.62	2.75	2.61	2.62	2.61	2.62	2.61
Average specific gravity of soil (Gs)	2.61				2.62		

SampleNo :TP 4

	1.5m				3m		
pycnometer bottle Code	T	4	T	4	B	C	A
Weight of dry, clean pycnometer, wp (g)	28.66	27.63	28.66	27.62	27.51	27.75	28.26
Weight of empty pycnometer + dry soil (grams),Wps(g)	38.72	37.74	38.66	37.62	37.51	37.75	38.26
Weight of pycnometer + soil + water, Wpws (g)	85.81	84.56	85.74	84.36	84.33	84.45	85.72
Weight of pycnometer + water, wpw (g)	79.67	78.30	79.67	78.30	78.34	78.42	79.75
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	23.00	23.00	23.00
Temperature, Tx(oc)	25.00	25.00	27.00	27.00	23.00	23.00	23.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.57	2.63	2.57	2.57	2.49	2.52	2.48
Average specific gravity of soil (Gs)	2.57				2.50		

SampleNo :TP 5

	1.5m				3m		
pycnometer bottle Code	A	C	A	C	B	C	A
Weight of dry, clean pycnometer, wp (g)	28.03	27.67	28.03	27.67	27.53	27.73	28.25
Weight of empty pycnometer + dry soil (grams),Wps(g)	38.09	37.73	38.09	37.73	37.46	38.80	38.29
Weight of pycnometer + soil + water, Wpws (g)	85.85	84.67	85.88	84.58	84.64	85.41	86.14
Weight of pycnometer + water, wpw (g)	79.71	78.39	79.71	78.39	78.34	78.42	79.75
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	23.00	23.00	23.00
Temperature, Tx(oc)	25.00	25.00	27.00	27.00	23.00	23.00	23.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.57	2.66	2.62	2.63	2.74	2.72	2.75
Average specific gravity of soil (Gs)	2.62				2.74		

SampleNo :TP 6

	1.5m			3m		
pycnometer bottle Code	A	T	4	A	T	4
Weight of dry, clean pycnometer, wp (g)	28.06	27.66	28.71	28.06	27.66	28.71
Weight of empty pycnometer + dry soil (grams),Wps(g)	38.06	37.66	38.71	38.06	37.66	38.71
Weight of pycnometer + soil + water, Wpws (g)	84.89	84.69	83.39	86.22	85.41	84.18
Weight of pycnometer + water, wpw (g)	78.81	78.67	77.30	79.61	79.68	78.32
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	25.00	25.00
Temperature, Tx(oc)	27.00	27.00	27.00	27.00	27.00	27.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.58	2.54	2.58	2.98	2.36	2.44
Average specific gravity of soil (Gs)	2.57			2.60		

SampleNo :TP 7

	1.5m				3m		
pycnometer bottle Code	4	A	A	4	B	C	A
Weight of dry, clean pycnometer, wp (g)	27.62	28.02	28.02	27.62	27.51	27.75	28.26
Weight of empty pycnometer + dry soil (grams),Wps(g)	37.55	38.08	38.08	37.58	37.51	37.75	38.26
Weight of pycnometer + soil + water, Wpws (g)	85.56	84.72	84.85	84.56	85.55	85.67	86.19
Weight of pycnometer + water, wpw (g)	79.30	78.21	78.71	78.30	79.34	79.42	79.75
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	23.00	23.00	23.00
Temperature, Tx(oc)	27.00	27.00	27.00	27.00	23.00	23.00	23.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.74	2.87	2.59	2.72	2.64	2.67	2.81
Average specific gravity of soil (Gs)	2.66				2.71		

SampleNo :TP 8

	1.5m				3m		
pycnometer bottle Code	T	C	C	T	B	C	A
Weight of dry, clean pycnometer, wp (g)	28.66	27.67	27.67	28.66	27.51	27.75	28.26
Weight of empty pycnometer + dry soil (grams),Wps(g)	38.64	37.67	37.73	38.49	37.50	37.82	38.31
Weight of pycnometer + soil + water, Wpws (g)	84.83	85.76	85.55	84.70	85.42	85.57	85.85
Weight of pycnometer + water, wpw (g)	78.77	79.27	79.29	78.57	79.24	79.42	79.65
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	23.00	23.00	23.00
Temperature, Tx(oc)	25.00	25.00	27.00	27.00	23.00	23.00	23.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.55	2.85	2.68	2.69	2.61	2.57	2.61
Average specific gravity of soil (Gs)	2.64				2.60		

SampleNo :TP 9

	1.5m				3m		
pycnometer bottle Code	T	4	T	4	B	C	A
Weight of dry, clean pycnometer, wp (g)	28.66	27.63	28.66	27.62	27.51	27.75	28.26
Weight of empty pycnometer + dry soil (grams),Wps(g)	38.72	37.74	38.66	37.62	37.51	37.75	38.26
Weight of pycnometer + soil + water, Wpws (g)	84.71	85.36	84.64	85.16	84.20	85.55	84.62
Weight of pycnometer + water, wpw (g)	78.77	79.20	78.57	79.10	78.24	79.31	78.65
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	23.00	23.00	23.00
Temperature, Tx(oc)	25.00	25.00	27.00	27.00	23.00	23.00	23.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.44	2.56	2.57	2.57	2.47	2.66	2.48
Average specific gravity of soil (Gs)	2.53				2.54		

SampleNo :TP 10

	1.5m				3m		
pycnometer bottle Code	A	C	A	C	B	C	A
Weight of dry, clean pycnometer, wp (g)	28.03	27.67	28.03	27.67	27.53	27.73	28.25
Weight of empty pycnometer + dry soil (grams),Wps(g)	38.09	37.73	38.09	37.73	37.46	38.80	38.29
Weight of pycnometer + soil + water, Wpws (g)	85.85	85.57	84.78	84.68	85.62	85.31	86.04
Weight of pycnometer + water, wpw (g)	79.71	79.37	78.61	78.38	79.28	78.32	79.95
Observed temperature of water, Ti (oc)	25.00	25.00	25.00	25.00	23.00	23.00	23.00
Temperature, Tx(oc)	25.00	25.00	27.00	27.00	23.00	23.00	23.00
Conversion factor , K	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specific gravity of soil (Gs)	2.57	2.61	2.62	2.71	2.77	2.72	2.54
Average specific gravity of soil (Gs)	2.66				2.68		

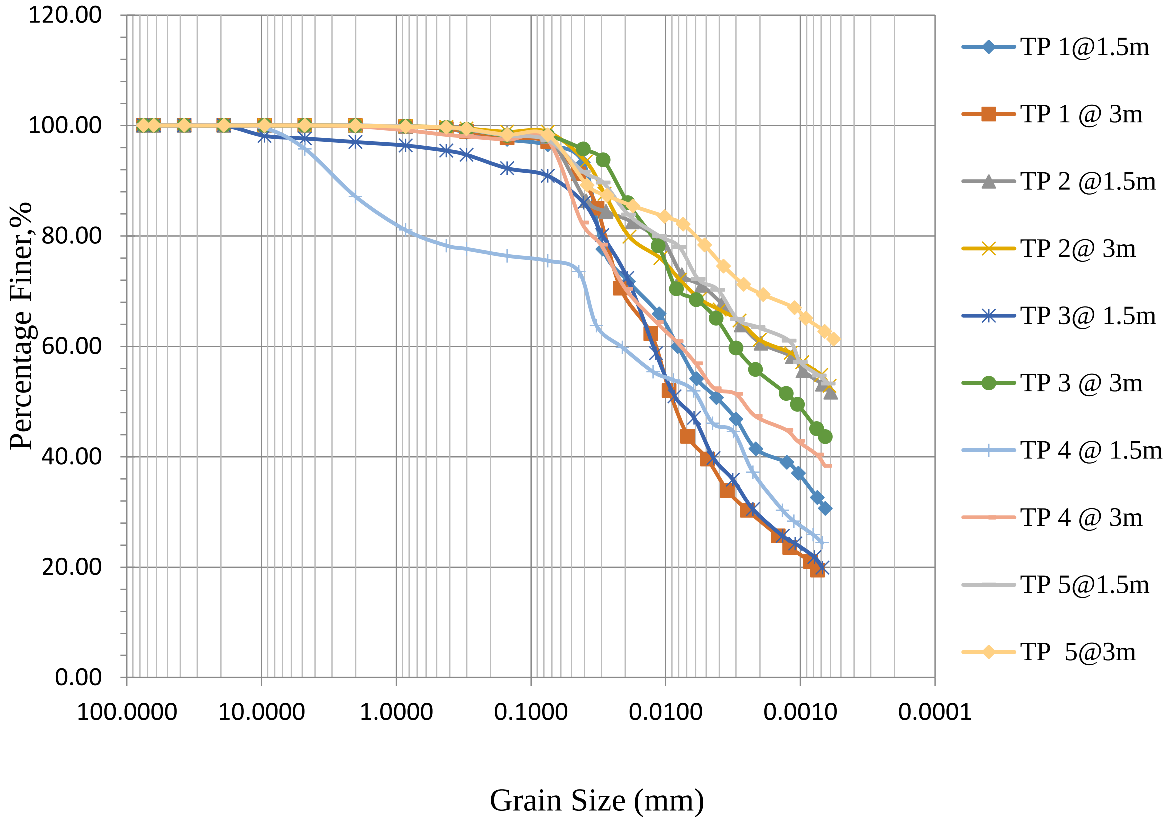
GRAIN ANALYSIS (SIEVE AND HYDROMETER ANALYSIS)

TP 1@1.5m		TP 1 @ 3m		TP 2 @1.5m		TP 2@ 3m		TP 3@ 1.5m	
Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)
75.0000	100.00	75.0000	100.00	75.000	100.00	75.0000	100.00	75.0000	100.00
63.0000	100.00	63.0000	100.00	63.000	100.00	63.0000	100.00	63.0000	100.00
37.5000	100.00	37.5000	100.00	37.500	100.00	37.5000	100.00	37.5000	100.00
19.0000	100.00	19.0000	100.00	19.000	100.00	19.0000	100.00	19.0000	100.00
9.5000	100.00	9.5000	100.00	9.500	100.00	9.5000	100.00	9.5000	98.12
4.7500	100.00	4.7500	100.00	4.750	100.00	4.7500	100.00	4.7500	97.64
2.0000	99.98	2.0000	99.96	2.000	100.00	2.0000	99.98	2.0000	97.00
0.8500	99.82	0.8500	99.80	0.850	99.86	0.8500	99.88	0.8500	96.36
0.4250	99.38	0.4250	99.40	0.425	99.62	0.4250	99.70	0.4250	95.44
0.3000	98.76	0.3000	98.94	0.300	99.30	0.3000	99.46	0.3000	94.68
0.1500	97.44	0.1500	97.74	0.150	98.54	0.1500	98.86	0.1500	92.24
0.0750	96.46	0.0750	97.06	0.075	97.98	0.0750	98.84	0.0750	90.88
0.0408	93.23	0.0443	91.18	0.039	86.32	0.0391	93.46	0.0405	85.97
0.0292	77.58	0.0322	84.98	0.028	84.41	0.0284	87.62	0.0295	80.13
0.0189	71.71	0.0216	70.53	0.018	82.50	0.0186	79.83	0.0192	72.34
0.0112	65.84	0.0128	62.27	0.010	78.67	0.0109	75.94	0.0118	58.71
0.0081	59.97	0.0094	51.94	0.008	72.94	0.0078	72.04	0.0086	50.92
0.0059	54.10	0.0068	43.68	0.005	71.02	0.0056	68.54	0.0062	47.02
0.0042	50.67	0.0049	39.55	0.004	67.68	0.0040	66.59	0.0044	39.72
0.0030	46.76	0.0035	33.87	0.003	63.86	0.0028	64.65	0.0032	35.83
0.0021	41.38	0.0025	30.26	0.002	60.51	0.0020	61.14	0.0022	30.47
0.0013	38.94	0.0015	25.61	0.001	58.12	0.0012	58.80	0.0013	25.61
0.0010	36.98	0.0012	23.54	0.001	55.57	0.0010	57.13	0.0011	24.26
0.0007	32.58	0.0008	20.96	0.001	53.12	0.0007	54.78	0.0008	21.82
0.0007	30.62	0.0007	19.41	0.001	51.65	0.0006	52.83	0.0007	19.86

TP 3 @ 3m		TP 4 @ 1.5m		TP 4 @ 3m		TP 5@1.5m		TP 5@3m	
Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)
75.0000	100.00	75.0000	100.00	75.0000	100.00	75.0000	100.00	75.0000	100.00
63.0000	100.00	63.0000	100.00	63.0000	100.00	63.0000	100.00	63.0000	100.00
37.5000	100.00	37.5000	100.00	37.5000	100.00	37.5000	100.00	37.5000	100.00
19.0000	100.00	19.0000	100.00	19.0000	100.00	19.0000	100.00	19.0000	100.00
9.5000	100.00	9.5000	99.54	9.5000	100.00	9.5000	100.00	9.5000	100.00
4.7500	100.00	4.7500	95.74	4.7500	100.00	4.7500	100.00	4.7500	100.00
2.0000	99.94	2.0000	87.10	2.0000	99.84	2.0000	100.00	2.0000	99.96
0.8500	99.82	0.8500	81.04	0.8500	99.12	0.8500	99.88	0.8500	99.76
0.4250	99.58	0.4250	78.24	0.4250	98.30	0.4250	99.60	0.4250	99.66
0.3000	99.26	0.3000	77.64	0.3000	98.02	0.3000	99.28	0.3000	99.38
0.1500	98.14	0.1500	76.38	0.1500	97.44	0.1500	98.16	0.1500	98.34
0.0750	98.10	0.0750	75.50	0.0750	97.38	0.0750	97.34	0.0750	98.28
0.0409	95.70	0.0441	73.53	0.0420	82.38	0.0409	91.59	0.0383	89.18
0.0291	93.76	0.0326	63.70	0.0302	78.37	0.0291	89.65	0.0272	87.29
0.0191	85.97	0.0209	59.77	0.0198	70.37	0.0189	83.82	0.0174	85.40
0.0114	78.18	0.0124	55.35	0.0117	64.36	0.0111	79.94	0.0102	83.51
0.0083	70.39	0.0087	53.87	0.0083	60.86	0.0079	77.99	0.0074	82.09
0.0059	68.44	0.0062	51.91	0.0060	56.85	0.0057	72.17	0.0051	78.30
0.0042	65.04	0.0045	46.01	0.0044	52.35	0.0041	70.22	0.0037	74.52
0.0030	59.68	0.0031	44.53	0.0030	51.35	0.0029	64.88	0.0026	71.21
0.0022	55.79	0.0022	37.16	0.0022	47.34	0.0021	63.42	0.0019	69.32
0.0013	51.40	0.0014	30.28	0.0013	44.84	0.0012	61.00	0.0011	66.96
0.0010	49.46	0.0011	28.31	0.0010	42.84	0.0010	57.11	0.0009	65.06
0.0008	45.08	0.0008	25.86	0.0008	40.34	0.0007	54.68	0.0007	62.70
0.0007	43.62	0.0007	24.38	0.0007	38.34	0.0006	53.23	0.0006	61.28

TP 6@1.5m		TP 6 @ 3m		TP 7 @1.5m		TP 7@ 3m		TP 8 @ 1.5m	
Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)
75.0000	100.00	75.0000	100.00	75.0000	100.00	75.0000	100.00	75.0000	100.00
63.0000	100.00	63.0000	100.00	63.0000	100.00	63.0000	100.00	63.0000	100.00
37.5000	100.00	37.5000	100.00	37.5000	100.00	37.5000	100.00	37.5000	100.00
19.0000	100.00	19.0000	100.00	19.0000	100.00	19.0000	100.00	19.0000	100.00
9.5000	90.50	9.5000	90.50	9.5000	100.00	9.5000	100.00	9.5000	98.12
4.7500	95.25	4.7500	95.25	4.7500	100.00	4.7500	100.00	4.7500	97.64
2.0000	98.00	2.0000	98.00	2.0000	100.00	2.0000	99.98	2.0000	97.00
0.8500	99.15	0.8500	99.15	0.8500	99.86	0.8500	99.88	0.8500	96.36
0.4250	99.58	0.4250	99.58	0.4250	99.62	0.4250	99.70	0.4250	95.44
0.3000	99.70	0.3000	99.70	0.3000	99.30	0.3000	99.46	0.3000	94.68
0.1500	99.85	0.1500	99.85	0.1500	98.54	0.1500	98.86	0.1500	92.24
0.0750	99.93	0.0750	99.93	0.0750	97.98	0.0750	98.84	0.0750	90.88
0.0408	96.35	0.0443	96.75	0.0388	95.59	0.0391	96.89	0.0405	90.24
0.0292	94.32	0.0322	90.44	0.0276	93.68	0.0284	90.84	0.0295	84.60
0.0189	88.23	0.0216	75.72	0.0177	91.77	0.0186	82.76	0.0192	77.08
0.0112	82.15	0.0128	67.30	0.0104	87.94	0.0109	78.73	0.0118	63.92
0.0081	76.06	0.0094	56.79	0.0075	82.21	0.0078	74.69	0.0086	56.40
0.0059	69.98	0.0068	48.37	0.0054	80.30	0.0056	71.06	0.0062	52.64
0.0042	66.33	0.0049	44.17	0.0038	76.86	0.0040	69.04	0.0044	45.49
0.0030	62.27	0.0035	38.28	0.0027	73.03	0.0028	67.02	0.0032	41.73
0.0021	56.59	0.0025	34.49	0.0020	69.59	0.0020	63.38	0.0022	36.47
0.0013	54.16	0.0015	29.87	0.0011	67.30	0.0012	60.96	0.0013	31.96
0.0010	52.13	0.0012	27.76	0.0010	64.96	0.0010	59.23	0.0011	30.45
0.0007	47.67	0.0008	25.24	0.0007	62.61	0.0007	56.79	0.0008	28.20
0.0007	45.64	0.0007	23.56	0.0006	61.04	0.0006	54.77	0.0007	26.32

TP 8@ 3m		TP 9 @ 1.5m		TP 9 @ 3m		TP 10@1.5m		TP 10@3m	
Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)	Sieve Size opening (mm)	Percentage finer particle(%)
75.0000	100.00	75.0000	100.00	75.0000	100.00	75.0000	100.00	75.0000	100.00
63.0000	100.00	63.0000	100.00	63.0000	100.00	63.0000	100.00	63.0000	100.00
37.5000	100.00	37.5000	100.00	37.5000	100.00	37.5000	100.00	37.5000	100.00
19.0000	100.00	19.0000	100.00	19.0000	100.00	19.0000	100.00	19.0000	100.00
9.5000	100.00	9.5000	99.54	9.5000	100.00	9.5000	100.00	9.5000	100.00
4.7500	100.00	4.7500	95.74	4.7500	100.00	4.7500	100.00	4.7500	100.00
2.0000	99.94	2.0000	87.10	2.0000	99.84	2.0000	100.00	2.0000	99.96
0.8500	99.82	0.8500	81.04	0.8500	99.12	0.8500	99.88	0.8500	99.76
0.4250	99.58	0.4250	78.24	0.4250	98.30	0.4250	99.60	0.4250	99.66
0.3000	99.26	0.3000	77.64	0.3000	98.02	0.3000	99.28	0.3000	99.38
0.1500	98.14	0.1500	76.38	0.1500	97.44	0.1500	98.16	0.1500	98.34
0.0750	98.10	0.0750	75.50	0.0750	97.38	0.0750	97.34	0.0750	98.28
0.0409	94.87	0.0441	75.11	0.0420	96.09	0.0409	94.65	0.0383	98.04
0.0291	92.86	0.0326	65.28	0.0302	92.09	0.0291	92.64	0.0272	96.08
0.0191	84.78	0.0209	61.34	0.0198	84.08	0.0189	86.60	0.0174	94.12
0.0114	76.71	0.0124	57.02	0.0117	78.07	0.0111	82.57	0.0102	92.16
0.0083	68.63	0.0087	55.45	0.0083	74.47	0.0079	80.55	0.0074	90.59
0.0059	66.61	0.0062	53.48	0.0060	70.47	0.0057	74.51	0.0051	86.67
0.0042	62.98	0.0045	47.58	0.0044	66.06	0.0041	72.50	0.0037	82.75
0.0030	57.33	0.0031	46.01	0.0030	64.86	0.0029	66.86	0.0026	79.22
0.0022	53.29	0.0022	38.73	0.0022	60.86	0.0021	65.25	0.0019	77.26
0.0013	48.85	0.0014	31.85	0.0013	58.45	0.0012	62.83	0.0011	74.90
0.0010	46.83	0.0011	29.89	0.0010	56.45	0.0010	58.80	0.0009	72.94
0.0008	42.39	0.0008	27.53	0.0008	54.05	0.0007	56.39	0.0007	70.59
0.0007	40.78	0.0007	25.95	0.001	52.05	0.0006	54.78	0.0006	69.02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Percentage Finer,%
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1.0000
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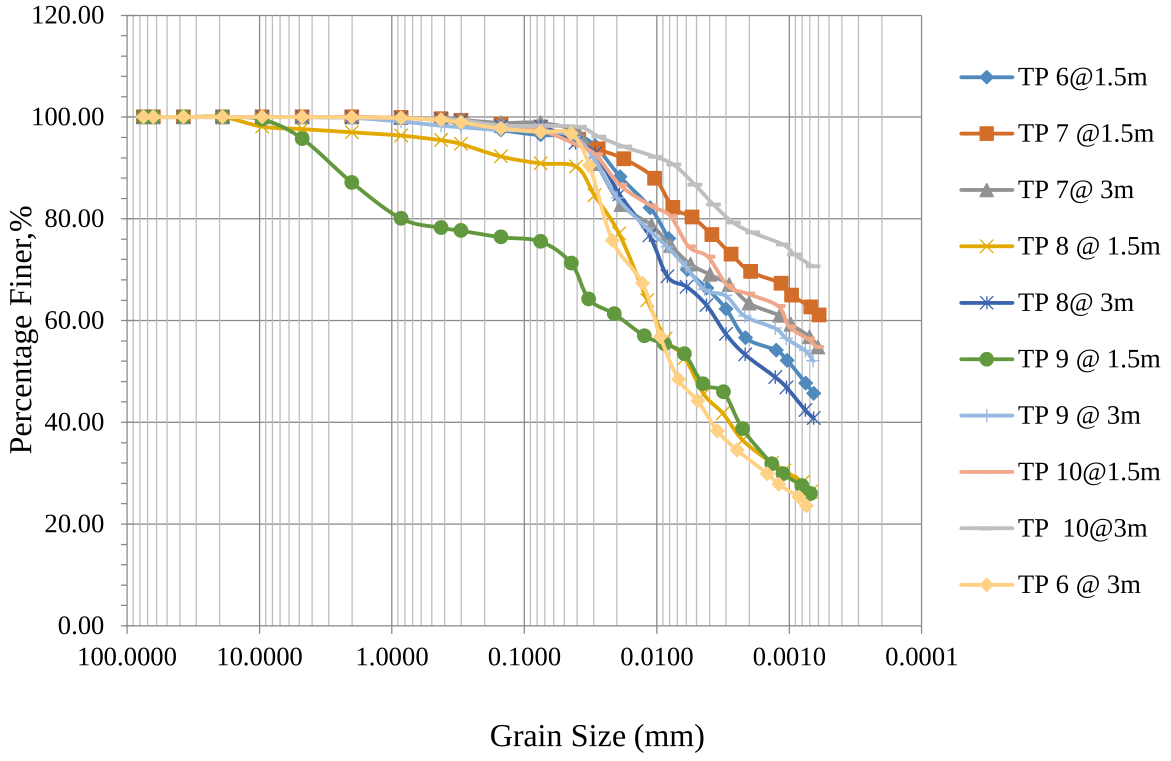
0.0100
0.0010
0.0001
Grain Size (mm)
TP 1@1.5m
TP 1 @ 3m
TP 2 @1.5m
TP 2@ 3m
TP 3@ 1.5m
TP 3 @ 3m
TP 4 @ 1.5m
TP 4 @ 3m
TP 5@1.5m
TP 5@3m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Percentage Finer,%
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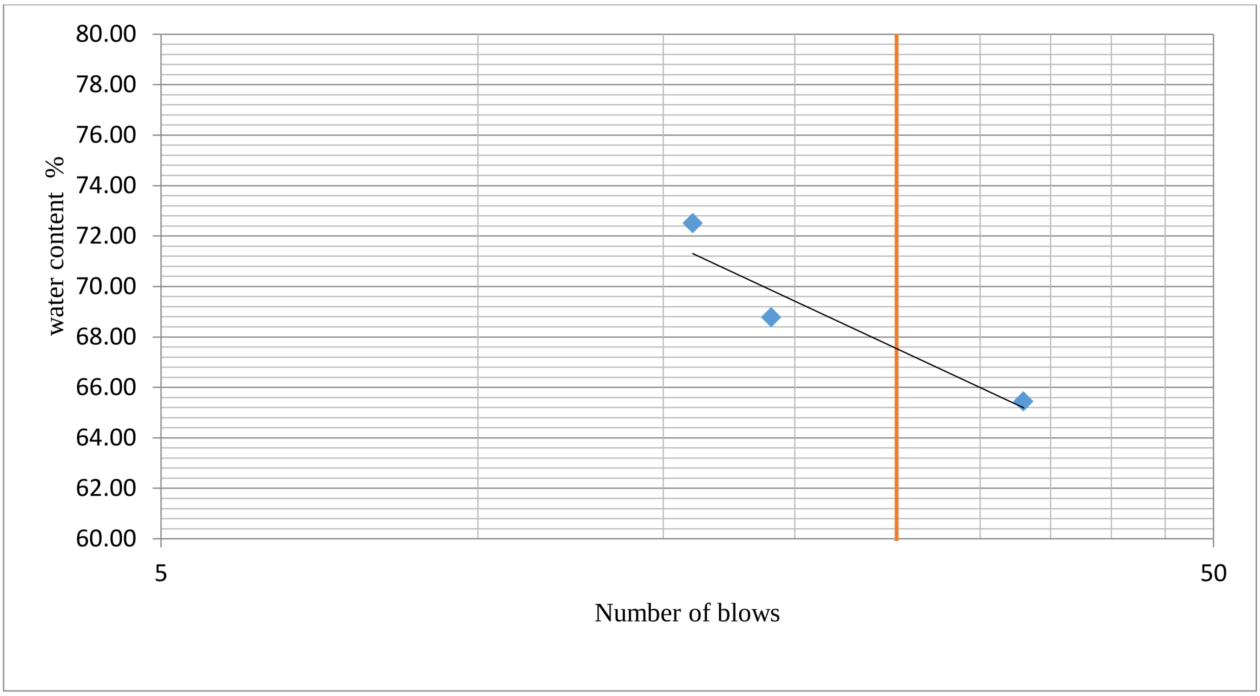
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Grain Size (mm)
TP 6@1.5m
TP 7 @1.5m
TP 7@ 3m
TP 8 @ 1.5m
TP 8@ 3m
TP 9 @ 1.5m
TP 9 @ 3m
TP 10@1.5m
TP 10@3m
TP 6 @ 3m

ATTERBERG LIMITS

TP 1 @ 1.5m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	33	27	20	16			
Mass of container + Wet soil, g	39.27	40.5	35.35	39.72	16.097	13.39	13.82
Mass of container + Dry soil, g	29.87	30.59	27.63	29.64	13.112	10.95	11.49
Mass of can, g	17.32	17.89	18.04	17.61	6.159	5.59	6.05
Mass of water, g	9.4	9.91	7.72	10.08	2.985	2.44	2.33
Mass of dry soil, g	12.55	12.7	9.59	12.03	6.953	5.36	5.44
Water content, %	74.90	78.03	80.50	83.79	42.93	45.52	42.83

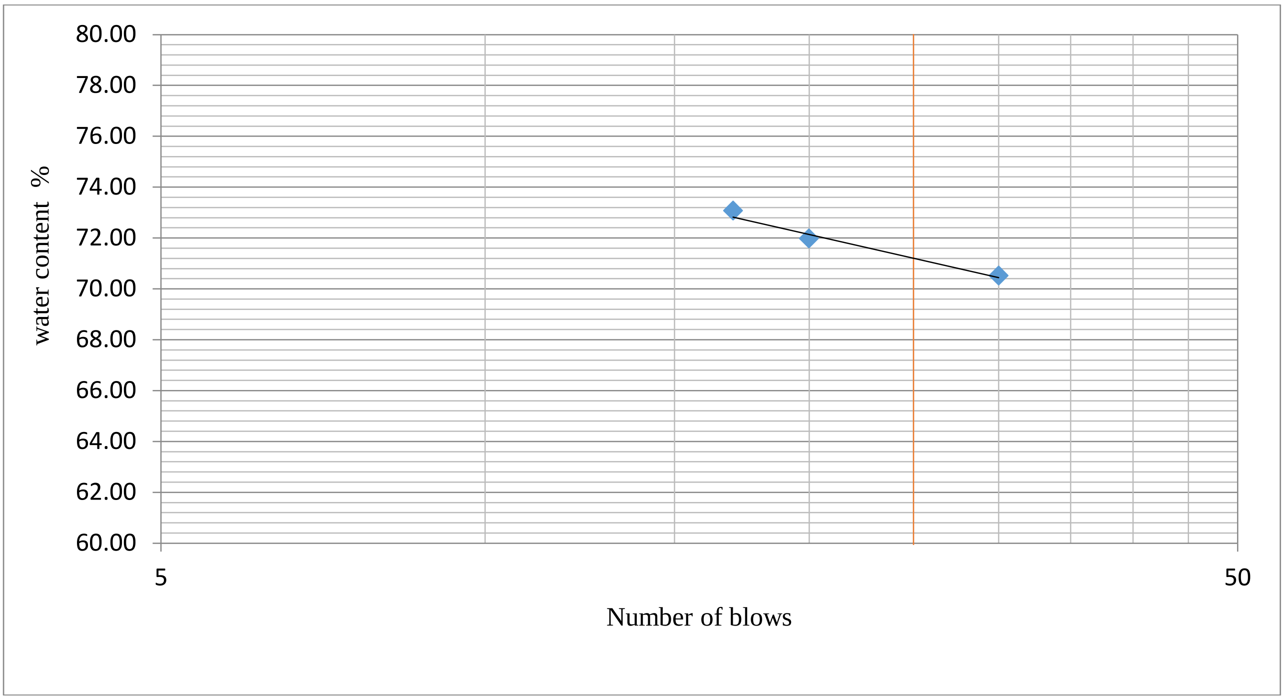
Liquid Limit = 78 plastic limit = 42.88 plastic index = 35.12



TP 1@3m

	Liquid Limit			plastic limit		
Trial No	1	2	3	1	2	3
Number of drops	30	20	17			
Mass of container + Wet soil, g	41.35	41.01	41.16	12.97	16.159	12.206
Mass of container + Dry soil, g	31.52	31.33	31.45	10.82	12.55	10.28
Mass of can, g	17.58	17.88	18.16	6.26	5.82	6.41
Mass of water, g	9.83	9.68	9.71	2.15	3.609	1.926
Mass of dry soil, g	13.94	13.45	13.29	4.56	6.73	3.87
Water content, %	70.52	71.97	73.06	47.15	53.63	49.77

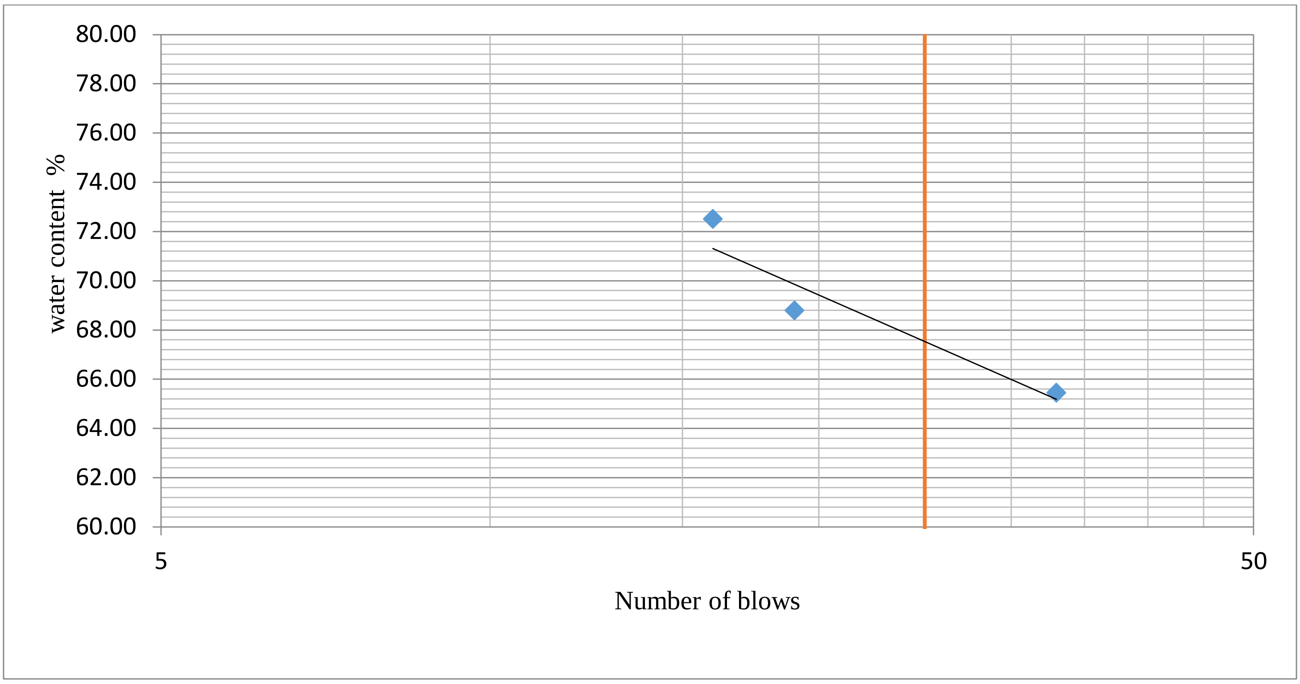
Liquid Limit = 71.50 plastic limit = 48.46 plastic index = 23.04



TP 2 @ 1.5m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	33	23	19	16			
Mass of container + Wet soil, g	38.49	40.19	37.52	37.81	13.68	15.98	13.73
Mass of container + Dry soil, g	30.22	31.21	29.37	29.32	11.86	13.48	11.87
Mass of can, g	17.583	17.39	17.52	17.61	6.29	5.84	6.16
Mass of water, g	8.27	8.98	8.15	8.49	1.82	2.5	1.86
Mass of dry soil, g	12.637	13.82	11.85	11.71	5.57	7.64	5.71
Water content, %	65.44	64.98	68.78	72.50	32.68	32.72	32.57

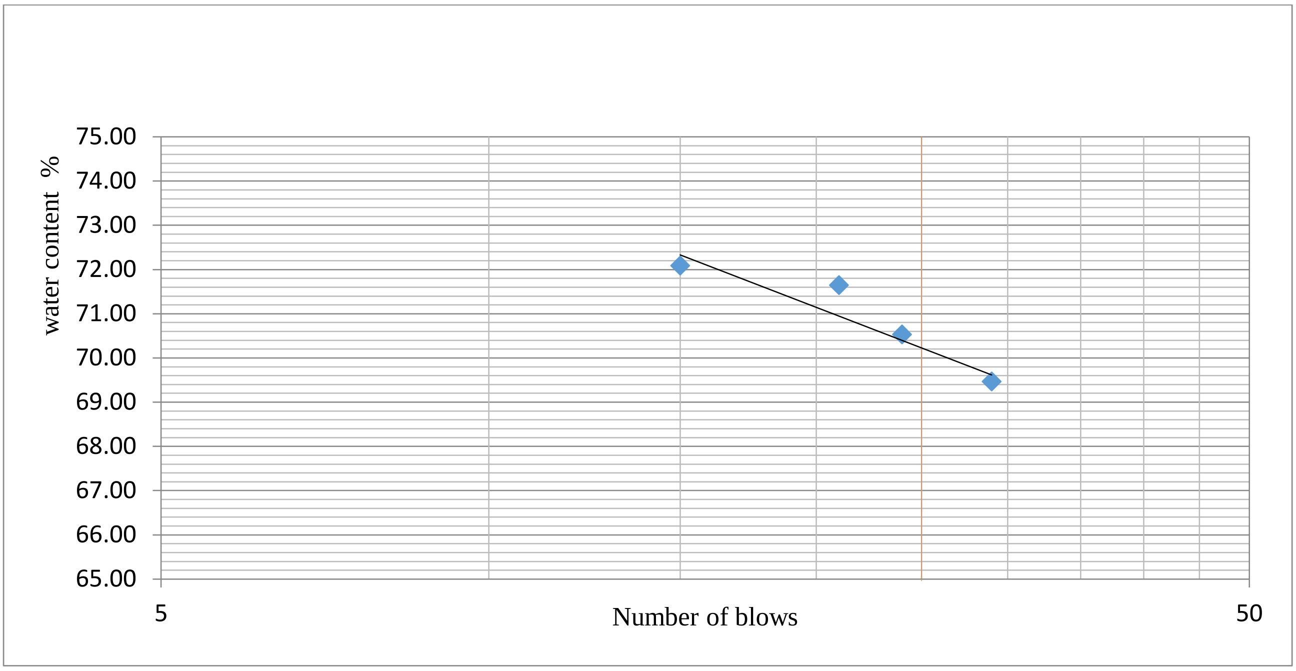
Liquid Limit = 66.8 plastic limit = 32.66 plastic index = 34.14



TP 2 @ 3m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	29	24	21	15			
Mass of container + Wet soil, g	38	40.9	38.87	43.44	13.26	14.84	14.07
Mass of container + Dry soil, g	30.04	31.57	30.18	32.57	11.04	11.88	11.74
Mass of can, g	18.58	18.34	18.05	17.49	6.32	5.41	6.69
Mass of water, g	7.96	9.33	8.69	10.87	2.22	2.96	2.33
Mass of dry soil, g	11.46	13.23	12.13	15.08	4.72	6.47	5.05
Water content, %	69.46	70.52	71.64	72.08	47.03	45.75	46.14

Liquid Limit = 71.2 plastic limit= 46.31 plastic index = 24.89



TP 3 @ 1.5m

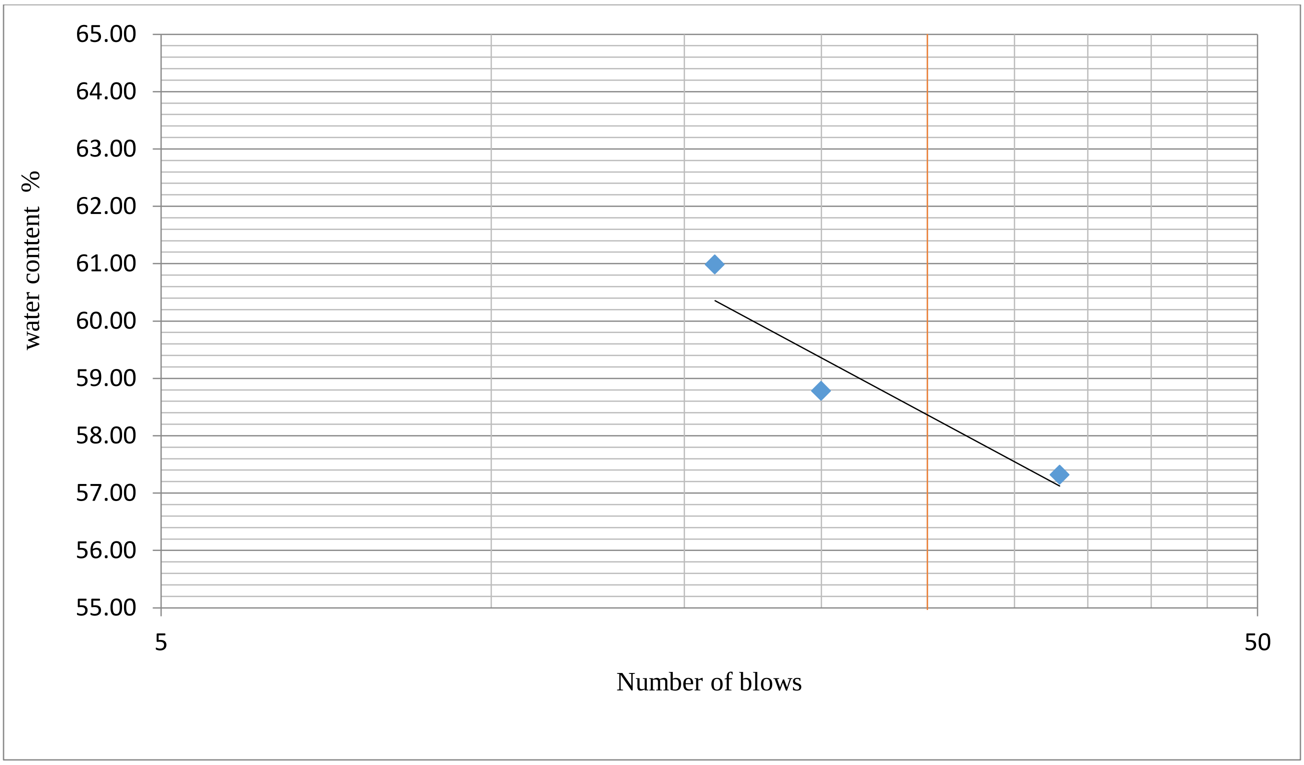
	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	33	27	20	16			
Mass of container + Wet soil, g	43.21	40.21	40.15	38.96	11.58	11.83	13.37
Mass of container + Dry soil, g	34.36	31.78	31.78	30.88	10.24	10.24	11.45
Mass of can, g	18.92	17.39	17.54	17.63	6.19	5.43	5.68
Mass of water, g	8.85	8.43	8.37	8.08	1.34	1.59	1.92
Mass of dry soil, g	15.44	14.39	14.24	13.25	4.05	4.81	5.77
Water content, %	57.32	58.58	58.78	60.98	33.09	33.06	33.28

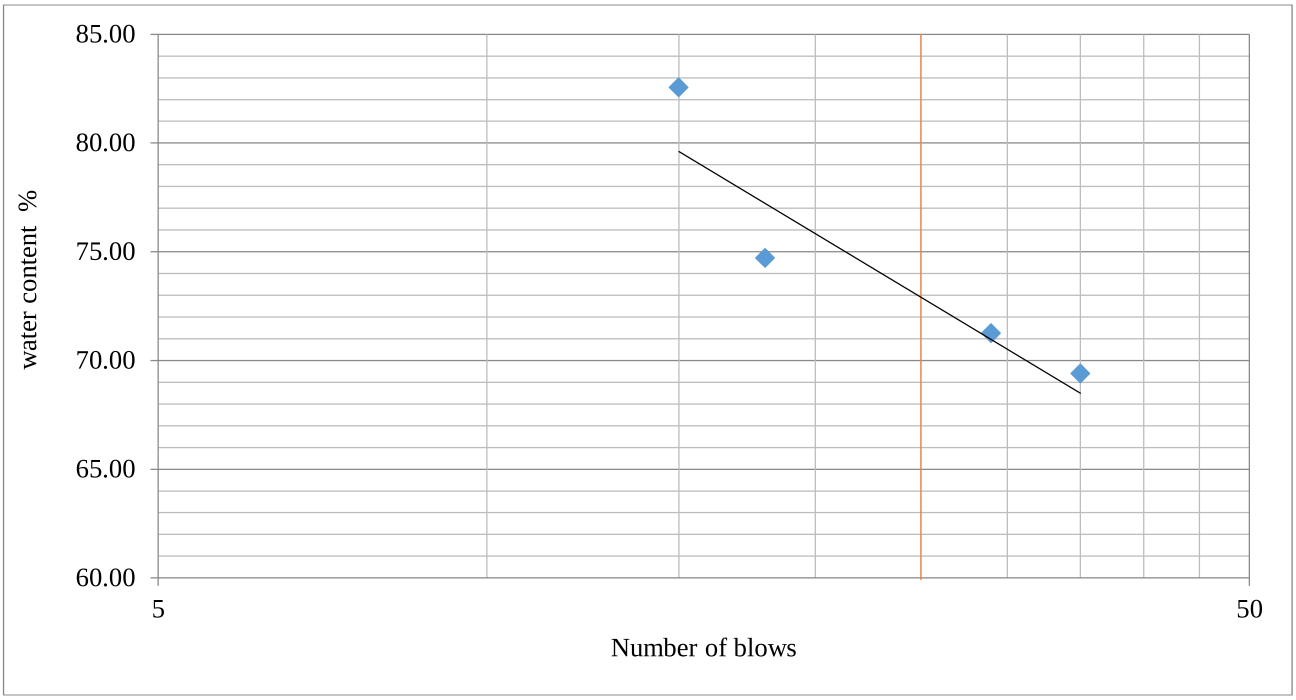
liquid Limit = 58.5 plastic limit = 33.14 plastic index = 25.36

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	35	29	18.00	15			
Mass of container + Wet soil, g	35.58	38.8	43.20	38.59	12.36	13.66	15.09
Mass of container + Dry soil, g	28.37	29.88	31.98	29.23	10.32	11.51	12.44
Mass of can, g	17.98	17.36	16.96	17.89	5.27	5.95	5.55
Mass of water, g	7.21	8.92	11.22	9.36	2.04	2.15	2.65
Mass of dry soil, g	10.39	12.52	15.02	11.34	5.05	5.56	6.89
Water content, %	69.39	71.25	74.70	82.54	40.40	38.67	38.46

TP 3@ 3m

liquid Limit = 73 plastic limit = 39.43 plastic index = 33.57

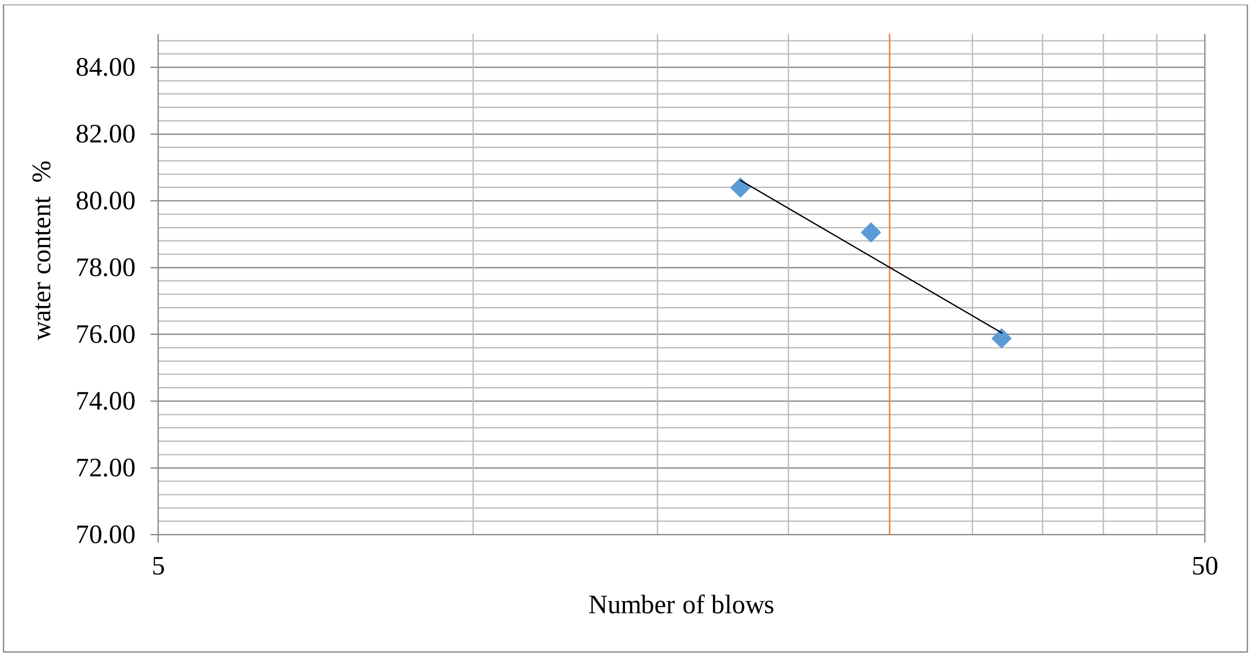



85.00
80.00
75.00
70.00
65.00
60.00
water content %
5
50
Number of blows

TP 4@1.5m

liquid Limit = 78 plastic limit = 28.70 plastic index = 49.30

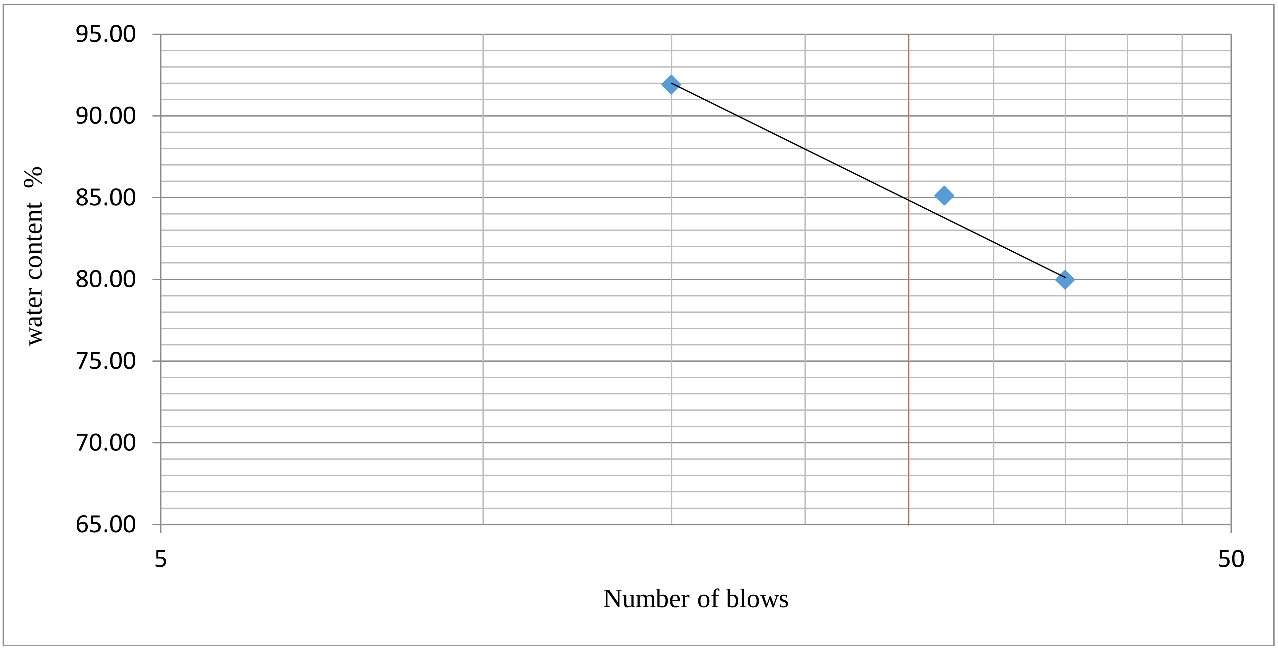
	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	35	32	24	18			
Mass of container + Wet soil, g	45.19	38.62	34.18	39.07	17.374	16.72	14.71
Mass of container + Dry soil, g	34.32	29.72	27.05	29.89	14.91	14.59	12.78
Mass of can, g	17.97	17.99	18.03	18.47	6.28	5.51	6.09
Mass of water, g	10.87	8.9	7.13	9.18	2.464	2.13	1.93
Mass of dry soil, g	16.35	11.73	9.02	11.42	8.63	9.08	6.69
Water content, %	66.48	75.87	79.05	80.39	28.55	23.46	28.85



TP 4@ 3m

	Liquid Limit			plastic limit		
Trial No	1	2	3	1	2	3
Number of drops	35	27	15			
Mass of container + Wet soil, g	42.76	45.01	40.12	16.43	14.78	13.2
Mass of container + Dry soil, g	31.59	32.43	29.91	14	12.76	11.63
Mass of can, g	17.62	17.65	18.8	6.39	6.35	6.54
Mass of water, g	11.17	12.58	10.21	2.43	2.02	1.57
Mass of dry soil, g	13.97	14.78	11.11	7.61	6.41	5.09
Water content, %	79.96	85.12	91.90	31.93	31.51	30.84

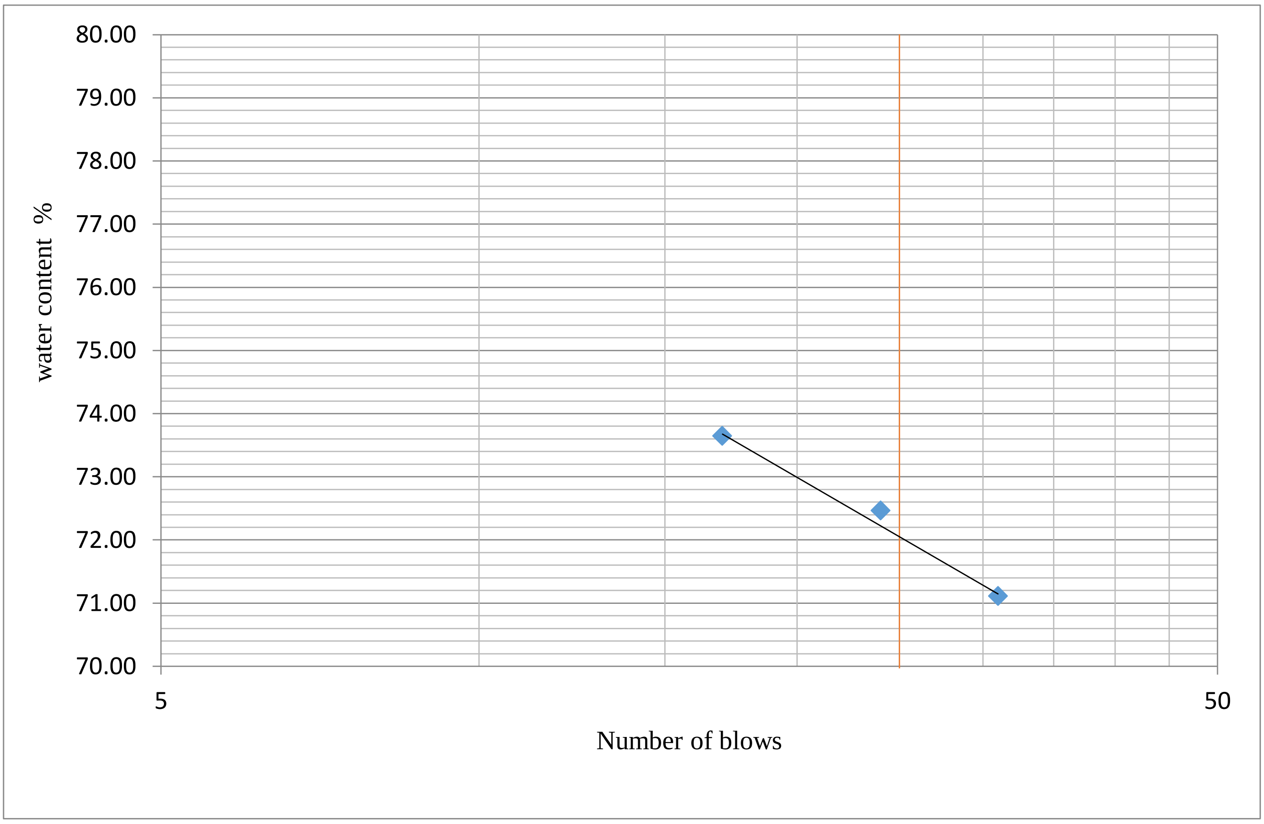
liquid Limit = 85 plastic limit = 31.39 plastic index = 53.61



TP 5 @ 1.5m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	31	24	17	15			
Mass of container + Wet soil, g	38.02	38.08	38.36	36.96	12.86	13.07	12.69
Mass of container + Dry soil, g	29.6	29.5	29.92	28.47	11.03	10.85	10.74
Mass of can, g	17.76	17.66	18.46	18.39	6.28	5.51	6.09
Mass of water, g	8.42	8.58	8.44	8.49	1.83	2.22	1.95
Mass of dry soil, g	11.84	11.84	11.46	10.08	4.75	5.34	4.65
Water content, %	71.11	72.47	73.65	84.23	38.53	41.57	41.94

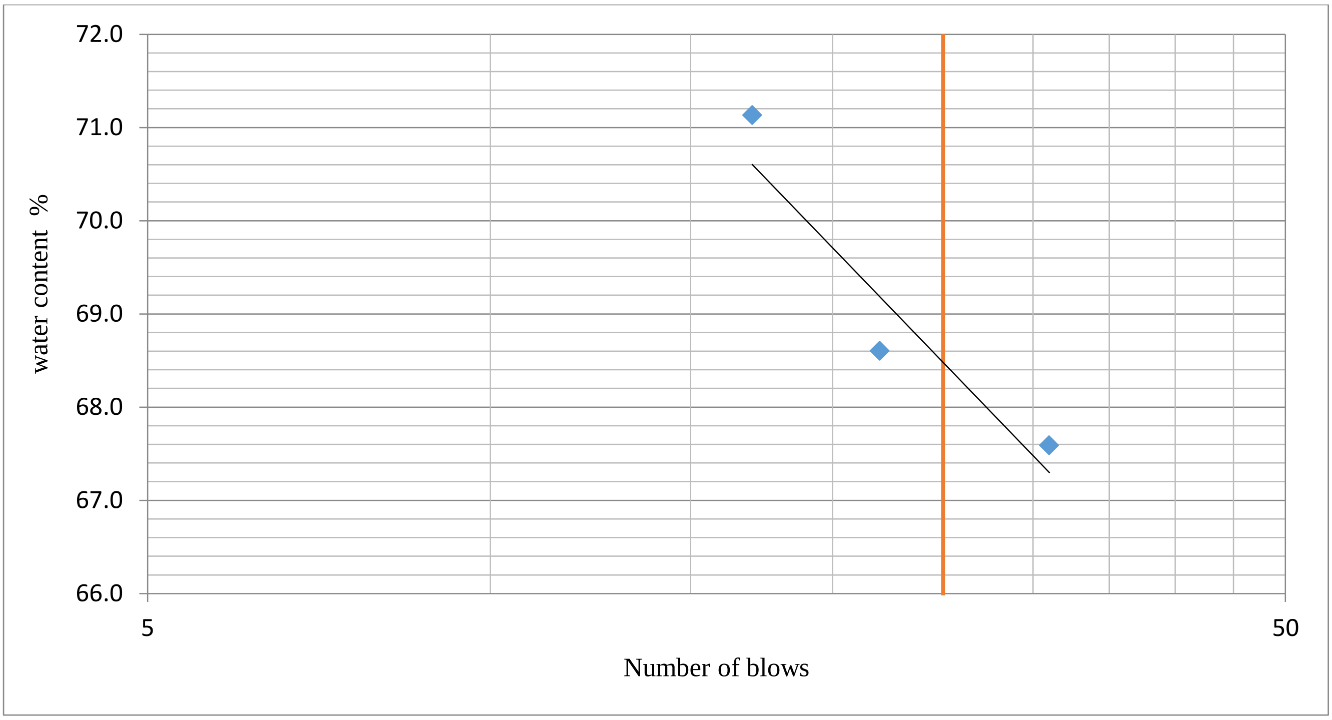
Liquid Limit = 72 plastic limit = 41.75 plastic index = 30.25



TP 5 @ 3m

	Liquid Limit			plastic limit		
Trial No	1	2	3	1	2	3
Number of drops	31	22	17			
Mass of container + Wet soil, g	34.85	30.96	31.1	13.57	12.98	11.93
Mass of container + Dry soil, g	23.13	20.8	20.85	11.29	10.77	9.94
Mass of can, g	5.79	5.99	6.44	6.56	6.33	5.83
Mass of water, g	11.72	10.16	10.25	2.28	2.21	1.99
Mass of dry soil, g	17.34	14.81	14.41	4.73	4.44	4.11
Water content, %	67.6	68.6	71.1	48.20	49.77	48.42

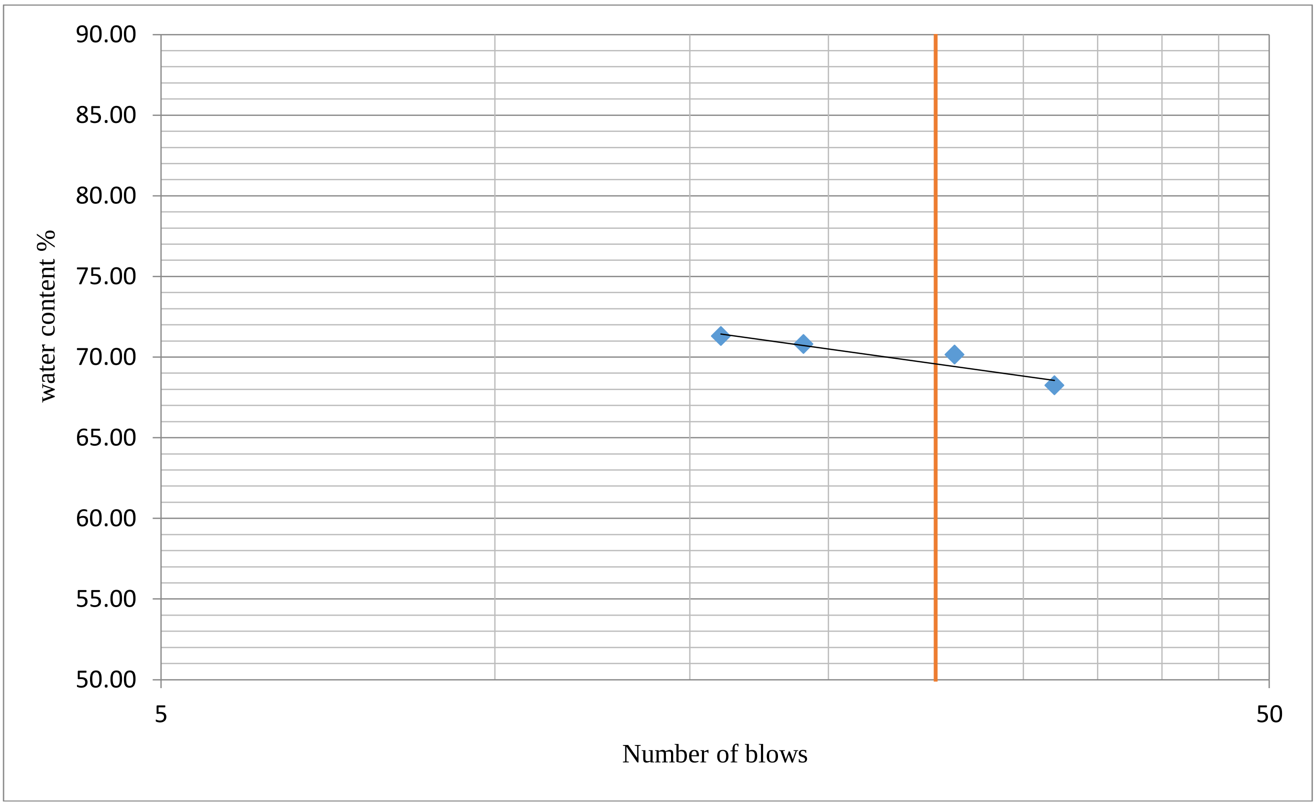
Liquid Limit= 68.8 plastic limit = 48.80 plastic index = 20.00



TP 6 @ 1.5m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	32	26	19	16			
Mass of container + Wet soil, g	35.27	39.5	34.25	34.62	16.97	14.29	14.89
Mass of container + Dry soil, g	27.87	30.59	27.53	27.54	14.12	11.99	12.59
Mass of can, g	17.32	17.89	18.04	17.61	6.159	5.59	6.05
Mass of water, g	7.4	8.91	6.72	7.08	2.85	2.3	2.3
Mass of dry soil, g	10.55	12.7	9.49	9.93	7.961	6.4	6.54
Water content, %	70.14	70.16	70.81	71.30	35.80	35.94	35.17

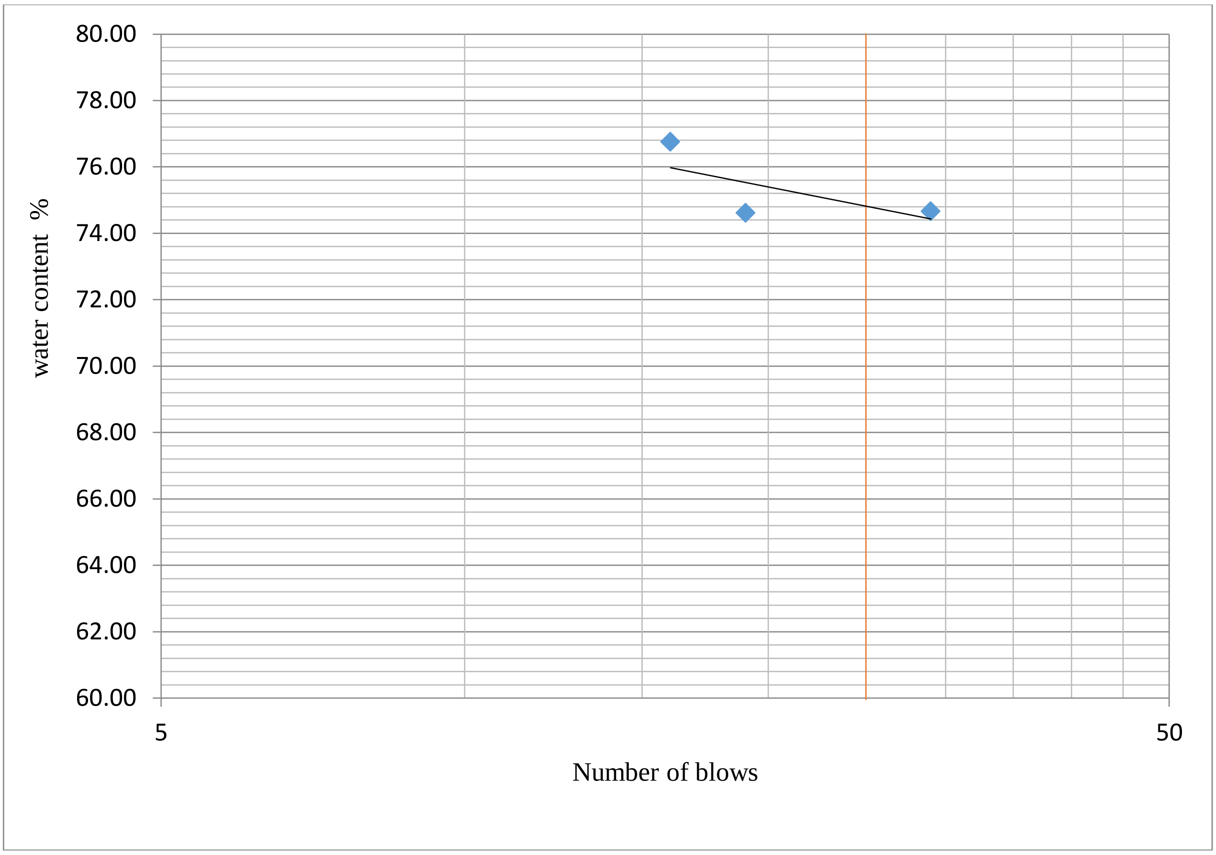
Liquid Limit = 70 plastic limit = 35.48 plastic index = 34.64



TP 6 @ 3m

	Liquid Limit			plastic limit		
Trial No	1	2	3	1	2	3
Number of drops	29	19	16			
Mass of container + Wet soil, g	43.5	39.06	41.65	12.47	15.59	12.36
Mass of container + Dry soil, g	32.42	30.01	31.45	10.52	12.55	10.48
Mass of can, g	17.58	17.88	18.16	6.26	5.82	6.41
Mass of water, g	11.08	9.05	10.2	1.95	3.04	1.88
Mass of dry soil, g	14.84	12.13	13.29	4.26	6.73	4.07
Water content, %	74.66	74.61	76.75	45.77	45.17	46.19

Liquid Limit = 71.5plastic limit = 45.98 plastic index = 25.52



TP 7 @ 1.5m

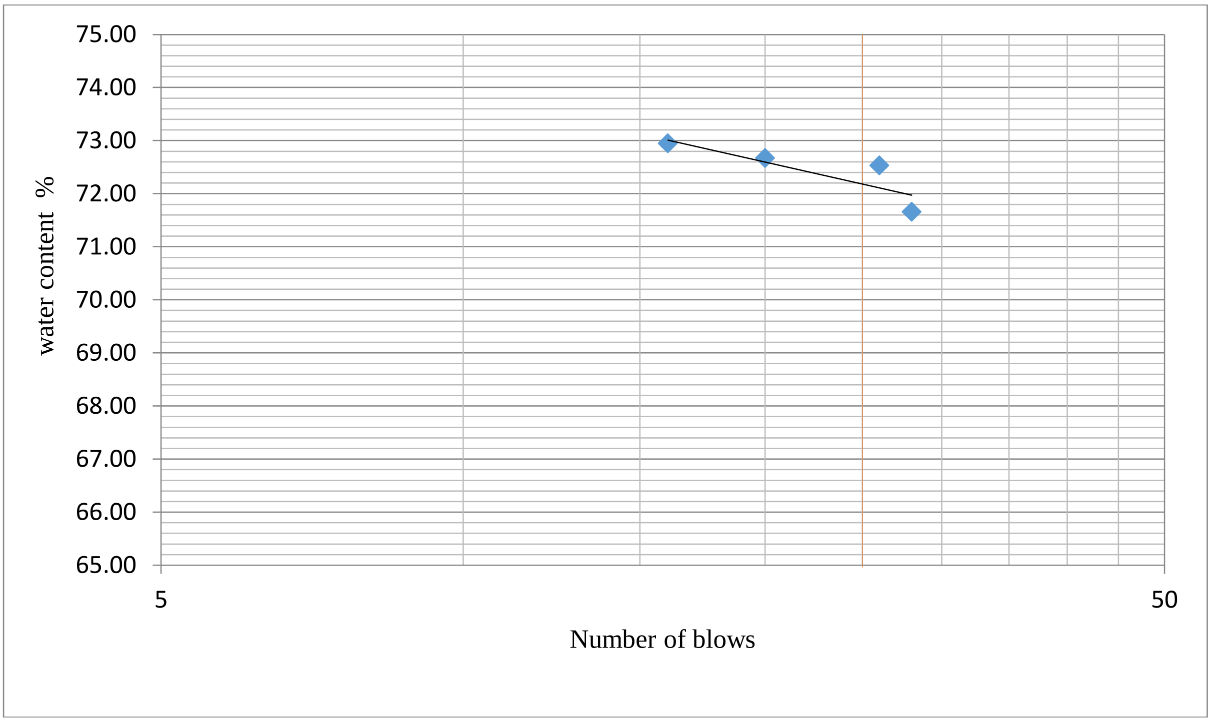
	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	31	22	20	16			
Mass of container + Wet soil, g	38.49	40.01	37.42	37.71	13.88	17.18	14.99
Mass of container + Dry soil, g	30.22	31.01	29.47	29.62	11.86	14.09	12.57
Mass of can, g	17.583	17.39	17.52	17.61	6.29	5.84	6.16
Mass of water, g	8.27	9	7.95	8.09	2.02	3.09	2.42
Mass of dry soil, g	12.637	13.62	11.95	12.01	5.57	8.25	6.41
Water content, %	65.44	66.08	66.53	67.36	36.27	37.45	37.75

Liquid Limit = 66.35plastic limit = 46..31plastic index =24.89

TP 7 @ 3m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	28	26	20	16			
Mass of container + Wet soil, g	38.2	40.01	38.77	40.82	13.16	14.44	14.01
Mass of container + Dry soil, g	30.01	30.9	30.05	30.98	11.04	11.7	11.78
Mass of can, g	18.58	18.34	18.05	17.49	6.32	5.41	6.69
Mass of water, g	8.19	9.11	8.72	9.84	2.12	2.74	2.23
Mass of dry soil, g	11.43	12.56	12	13.49	4.72	6.29	5.09
Water content, %	71.65	72.53	72.67	72.94	44.92	43.56	43.81

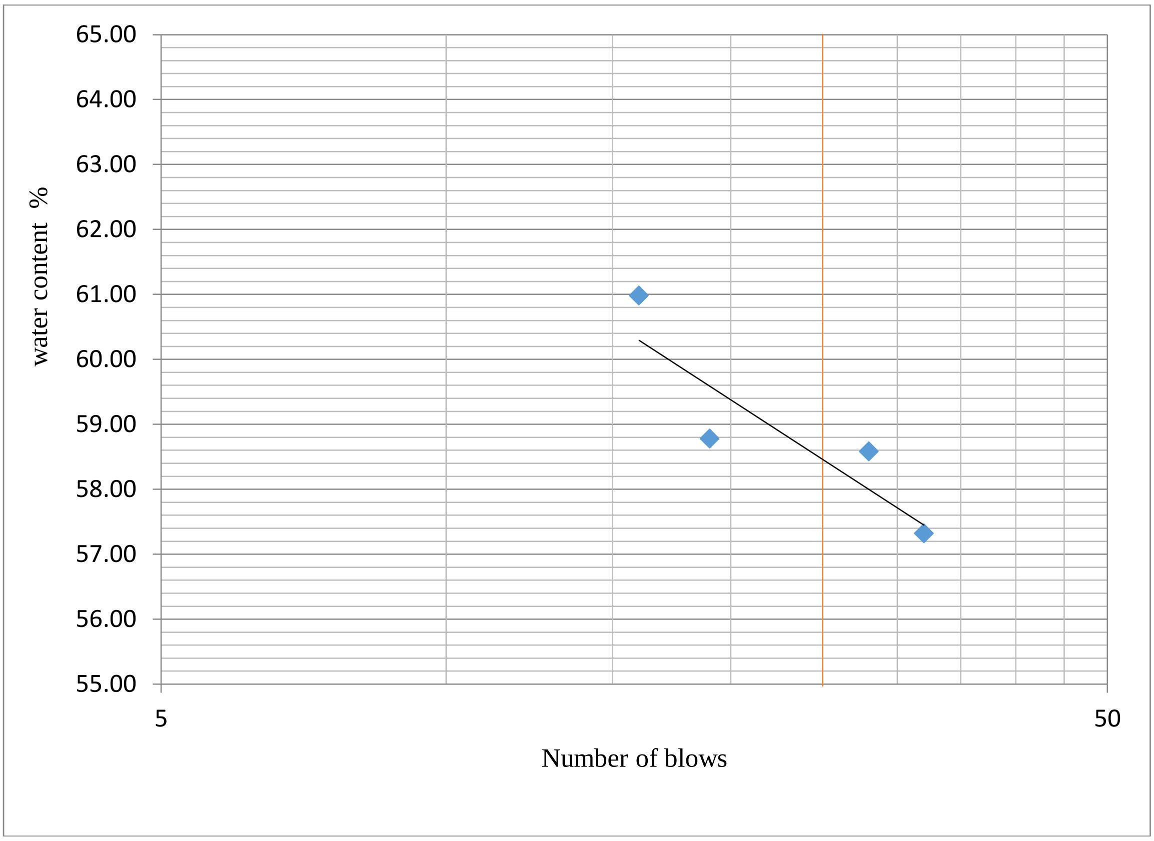
Liquid Limit = 71.2 plastic limit = 44.10 plastic index =27.10



TP 8 @ 1.5m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	32	28	19	16			
Mass of container + Wet soil, g	43.61	40.11	40.01	38.95	11.68	11.83	13.47
Mass of container + Dry soil, g	34.46	31.68	31.68	31.08	10.24	10.14	11.45
Mass of can, g	18.92	17.39	17.54	17.63	6.19	5.43	5.68
Mass of water, g	9.15	8.43	8.33	7.87	1.44	1.69	2.02
Mass of dry soil, g	15.54	14.29	14.14	13.45	4.05	4.71	5.77
Water content, %	58.88	58.99	58.91	58.51	35.56	35.88	35.01

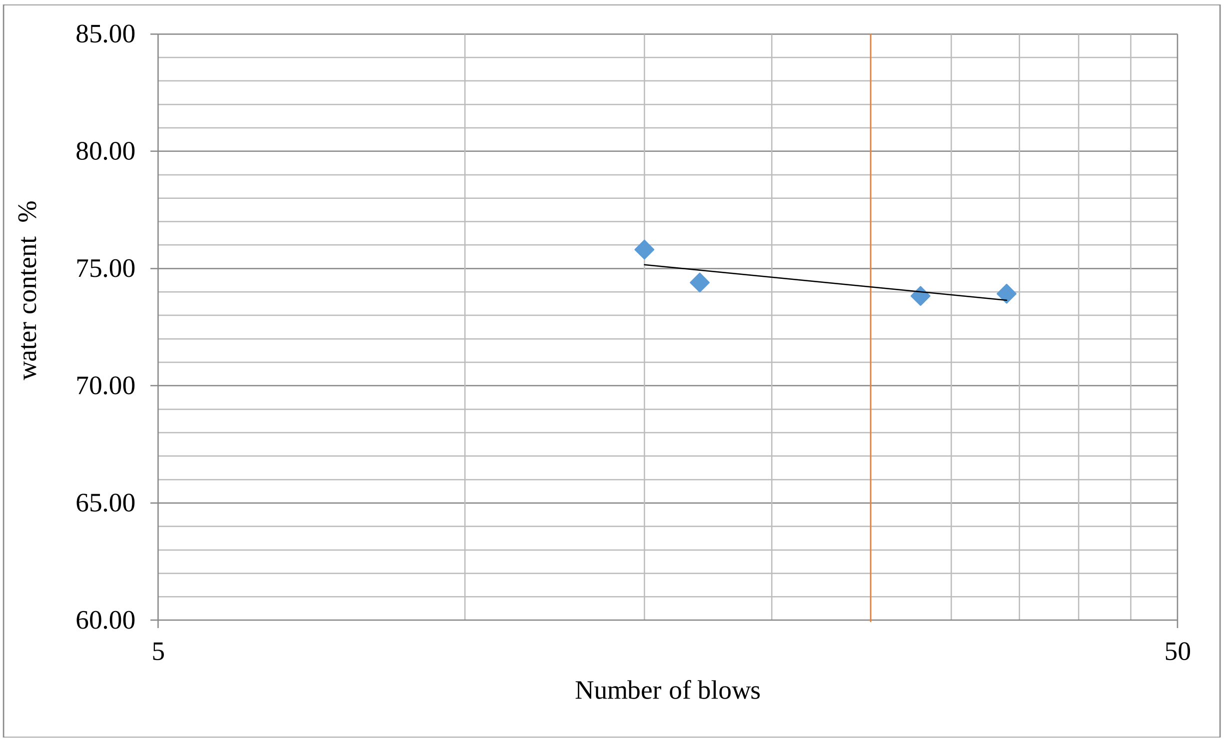
Liquid Limit = 58.5 plastic limit = 35.48 plastic index =23.02



TP 8 @ 3m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	34	28	17.00	15			
Mass of container + Wet soil, g	35.58	38.6	41.20	37.79	12.46	13.6	15.19
Mass of container + Dry soil, g	28.1	29.58	30.86	29.21	10.42	11.51	12.44
Mass of can, g	17.98	17.36	16.96	17.89	5.27	5.95	5.55
Mass of water, g	7.48	9.02	10.34	8.58	2.04	2.09	2.75
Mass of dry soil, g	10.12	12.22	13.90	11.32	5.15	5.56	6.89
Water content, %	73.91	73.81	74.39	75.80	39.61	37.59	39.91

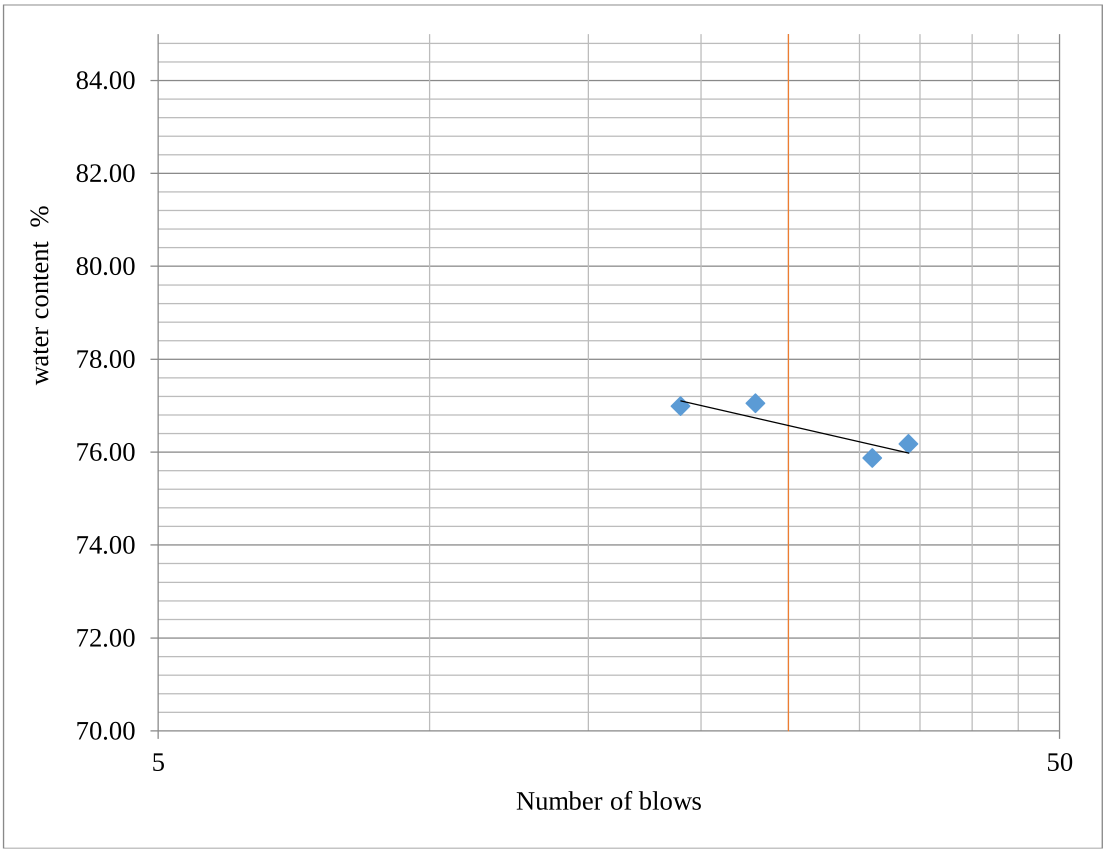
Liquid Limit = 73 plastic limit = 39.76 plastic index =33.24



TP 9 @ 1.5m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	34	31	23	19			
Mass of container + Wet soil, g	44.59	38.62	34	38.7	17.34	17.32	14.61
Mass of container + Dry soil, g	33.08	29.72	27.05	29.9	14.91	14.59	12.78
Mass of can, g	17.97	17.99	18.03	18.47	6.28	5.51	6.09
Mass of water, g	11.51	8.9	6.95	8.8	2.43	2.73	1.83
Mass of dry soil, g	15.11	11.73	9.02	11.43	8.63	9.08	6.69
Water content, %	76.17	75.87	77.05	76.99	28.16	30.07	27.35

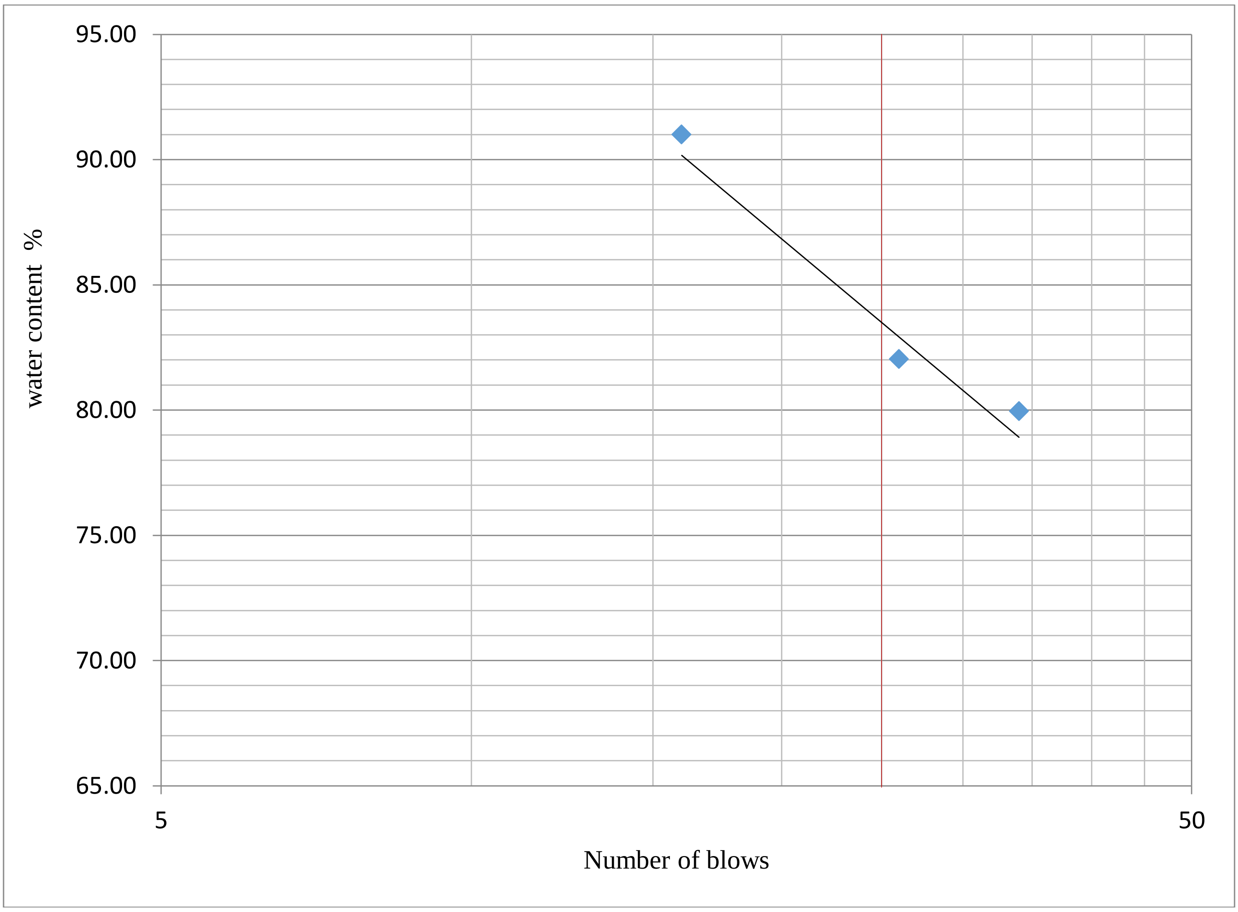
Liquid Limit = 78.00 plastic limit = 27.76 plastic index =50.24



TP 9 @ 3m

	Liquid Limit			plastic limit		
Trial No	1	2	3	1	2	3
Number of drops	34	26	16			
Mass of container + Wet soil, g	42.76	44.01	40.02	16.33	14.68	13.2
Mass of container + Dry soil, g	31.59	32.13	29.91	13.9	12.66	11.63
Mass of can, g	17.62	17.65	18.8	6.39	6.35	6.54
Mass of water, g	11.17	11.88	10.11	2.43	2.02	1.57
Mass of dry soil, g	13.97	14.48	11.11	7.51	6.31	5.09
Water content, %	79.96	82.04	91.00	32.36	32.01	30.84

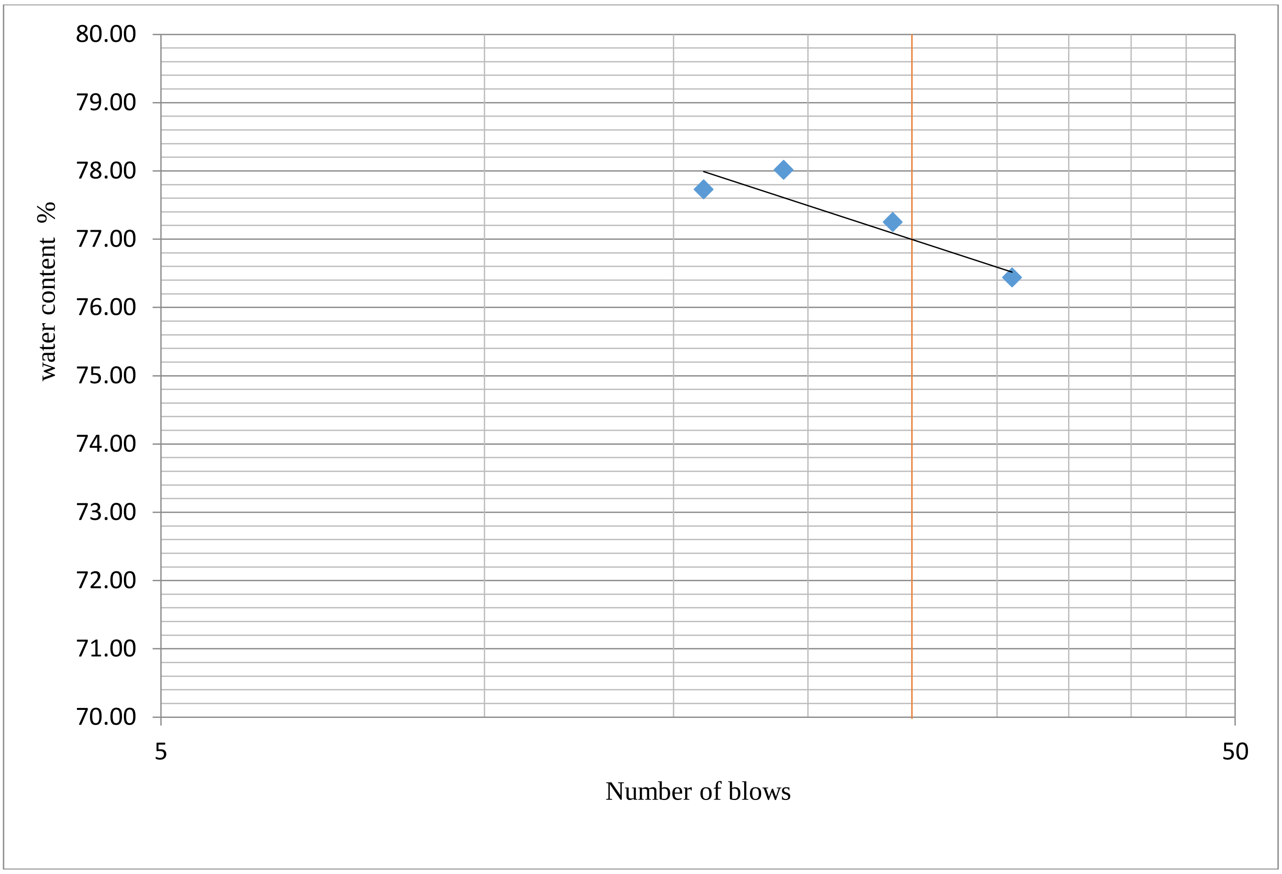
Liquid Limit = 85 plastic limit = 31.60 plastic index =53.40



TP 10@ 1.5m

	Liquid Limit				plastic limit		
Trial No	1	2	3	4	1	2	3
Number of drops	31	24	19	16			
Mass of container + Wet soil, g	38.05	38.38	38.86	36.66	13.26	13.37	13.19
Mass of container + Dry soil, g	29.26	29.35	29.92	28.67	11.13	11.01	10.99
Mass of can, g	17.76	17.66	18.46	18.39	6.28	5.51	6.09
Mass of water, g	8.79	9.03	8.94	7.99	2.13	2.36	2.2
Mass of dry soil, g	11.5	11.69	11.46	10.28	4.85	5.5	4.9
Water content, %	76.43	77.25	78.01	77.72	43.92	42.91	44.90

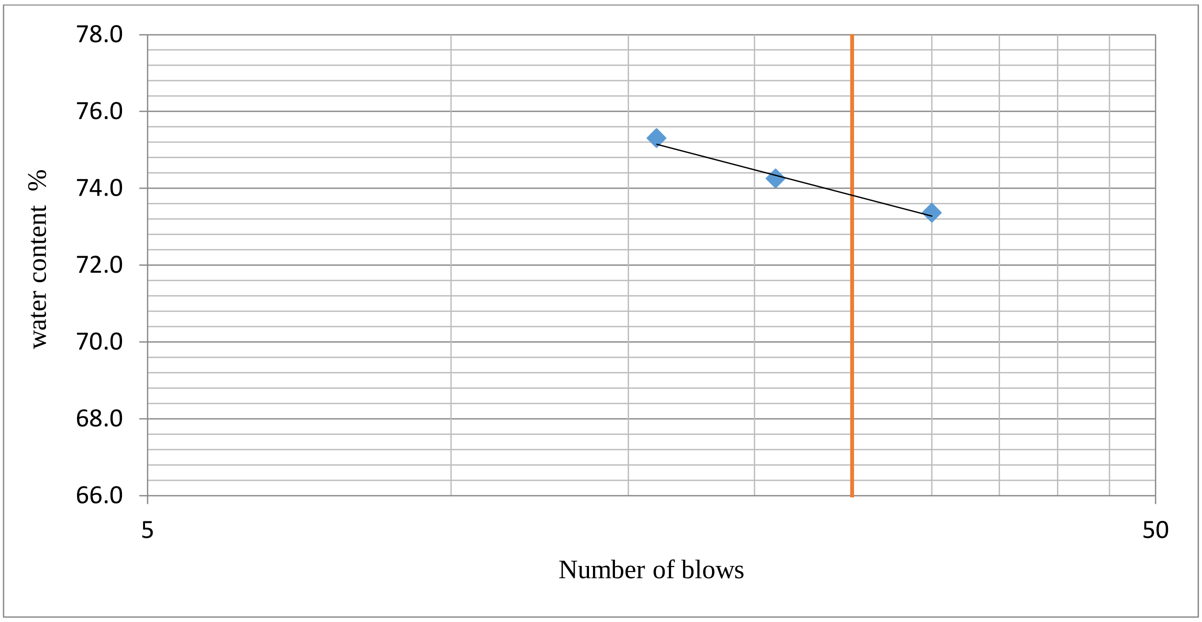
Liquid Limit = 72 plastic limit = 43.9 plastic index =28.10



TP 10@ 3m

	Liquid Limit			plastic limit		
Trial No	1	2	3	1	2	3
Number of drops	30	21	16			
Mass of container + Wet soil, g	35.85	30.89	31.7	12.07	12.58	11.93
Mass of container + Dry soil, g	23.13	20.28	20.85	10.29	10.57	9.94
Mass of can, g	5.79	5.99	6.44	6.56	6.33	5.83
Mass of water, g	12.72	10.61	10.85	1.78	2.01	1.99
Mass of dry soil, g	17.34	14.29	14.41	3.73	4.24	4.11
Water content, %	73.4	74.2	75.3	47.72	47.41	48.42

Liquid Limit = 74.3 plastic limit = 47.85 plastic index =26.45

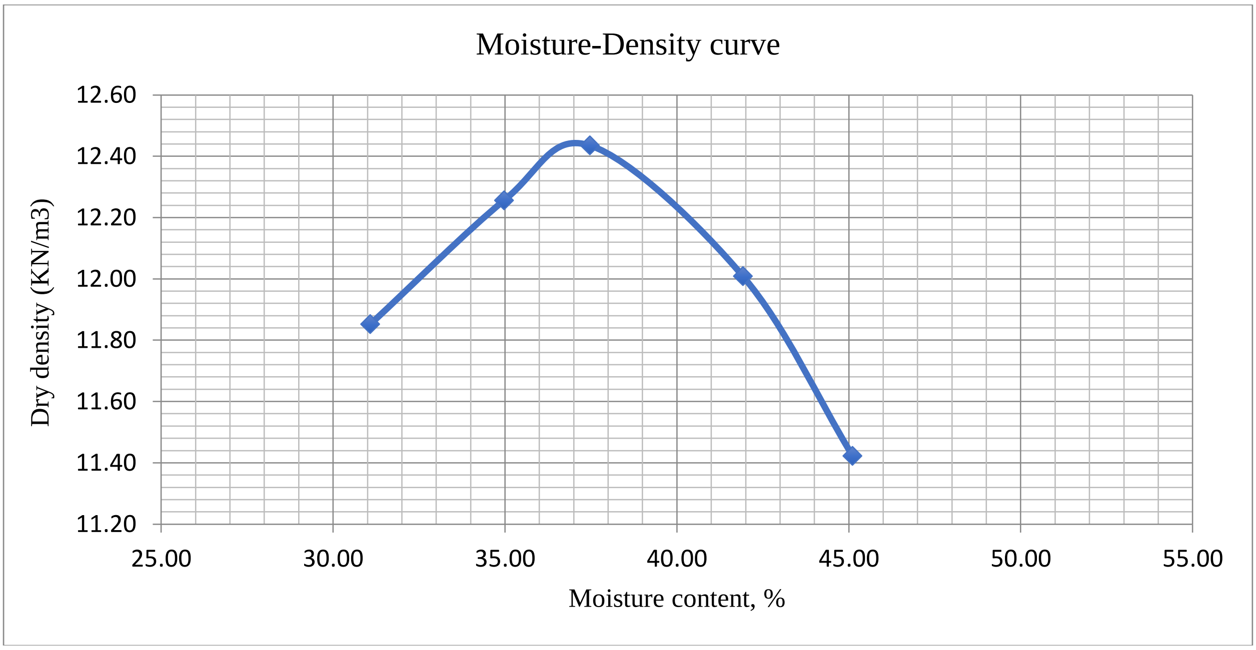


APPENDIX - C

COMPACTION TEST RESULTS

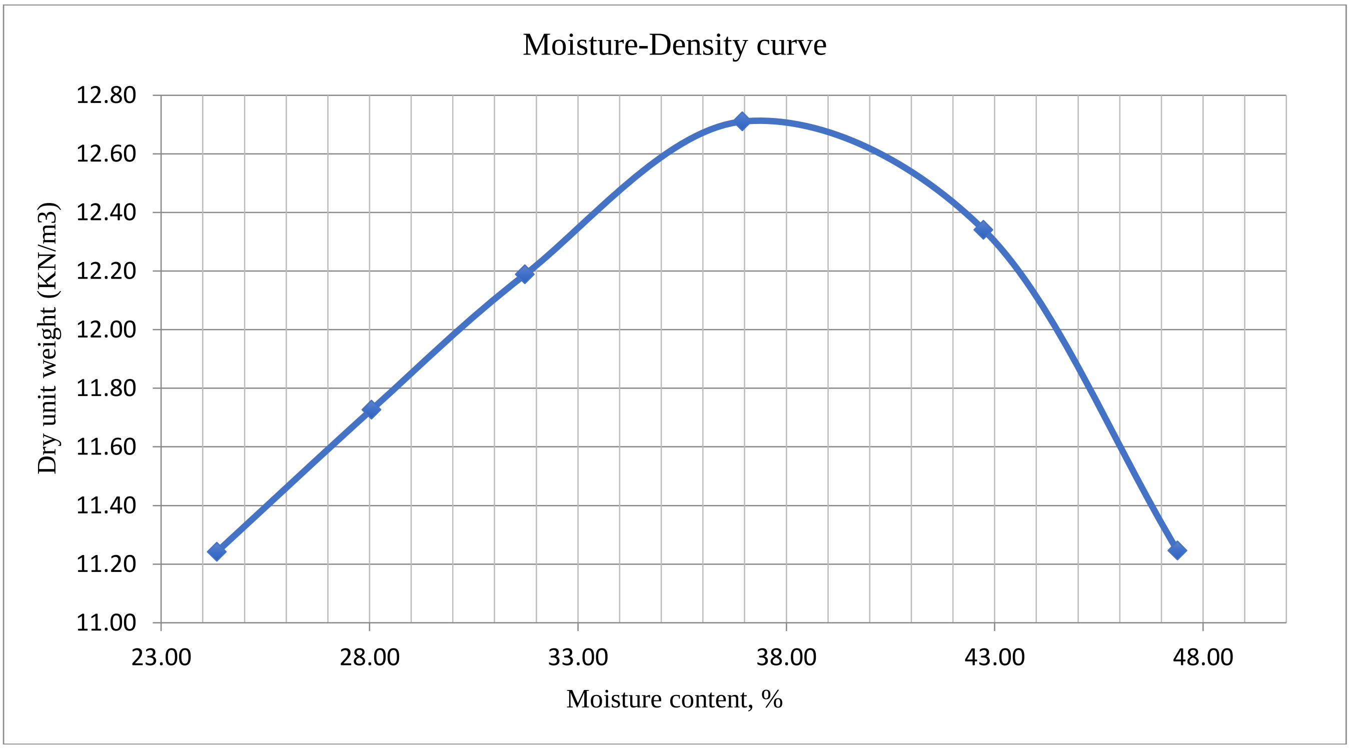
TP 1 @1.5m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4500	1495	1.58	96.17	77.42	18.75	17.04	60.38	31.05	31.08	11.85
				115.6	92.289	23.311	17.36	74.929	31.11		
2	4630	1625	1.72	94.82	74.87	19.95	17.83	57.04	34.98	37.78	12.26
				101.69	77.34	24.35	17.35	59.99	40.59		
3	4650	1645	1.74	97.396	75.56	21.836	17.38	58.18	37.53	37.48	12.43
				93.73	73.01	20.72	17.64	55.37	37.42		
4	4645	1640	1.74	88.52	67.81	20.71	18.77	49.04	42.23	41.92	12.01
				68.12	53.39	14.73	17.99	35.4	41.61		
5	4580	1575	1.67	84.68	62.87	21.81	17.58	45.29	48.16	48.38	11.03
				89.61	66.04	23.57	17.55	48.49	48.61		



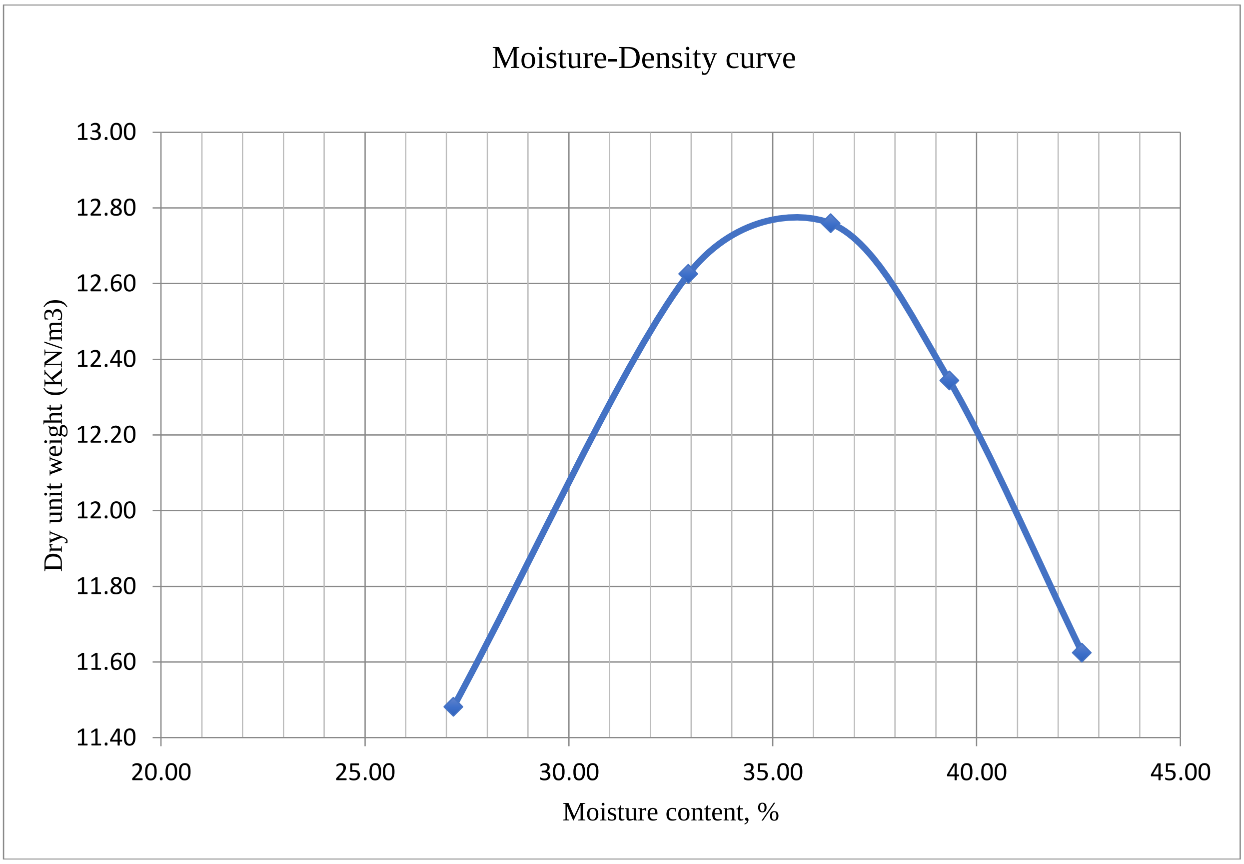
TP 1 @ 3m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4350	1345	1.42	97.48	81.87	15.61	17.46	64.41	24.24	24.34	11.24
				110.87	92.59	18.28	17.78	74.81	24.44		
2	4430	1425	1.51	86.68	71.89	14.79	19.53	52.36	28.25	28.05	11.56
				89.49	73.64	15.85	16.73	56.91	27.85		
3	4530	1525	1.62	90.55	73.95	16.6	18.29	55.66	29.82	31.73	12.03
				105.23	83.33	21.9	18.23	65.1	33.64		
4	4680	1675	1.77	105.79	84	21.79	25.36	58.64	37.16	36.95	12.71
				112.32	88.9	23.42	25.16	63.74	36.74		
5	4690	1685	1.78	89.07	69.67	19.4	17.66	52.01	37.30	37.49	12.74
				92.74	72.16	20.58	17.55	54.61	37.69		
6	4600	1595	1.69	107.24	78.49	28.75	17.82	60.67	47.39	47.39	11.25
				115.19	84.09	31.1	18.46	65.63	47.39		



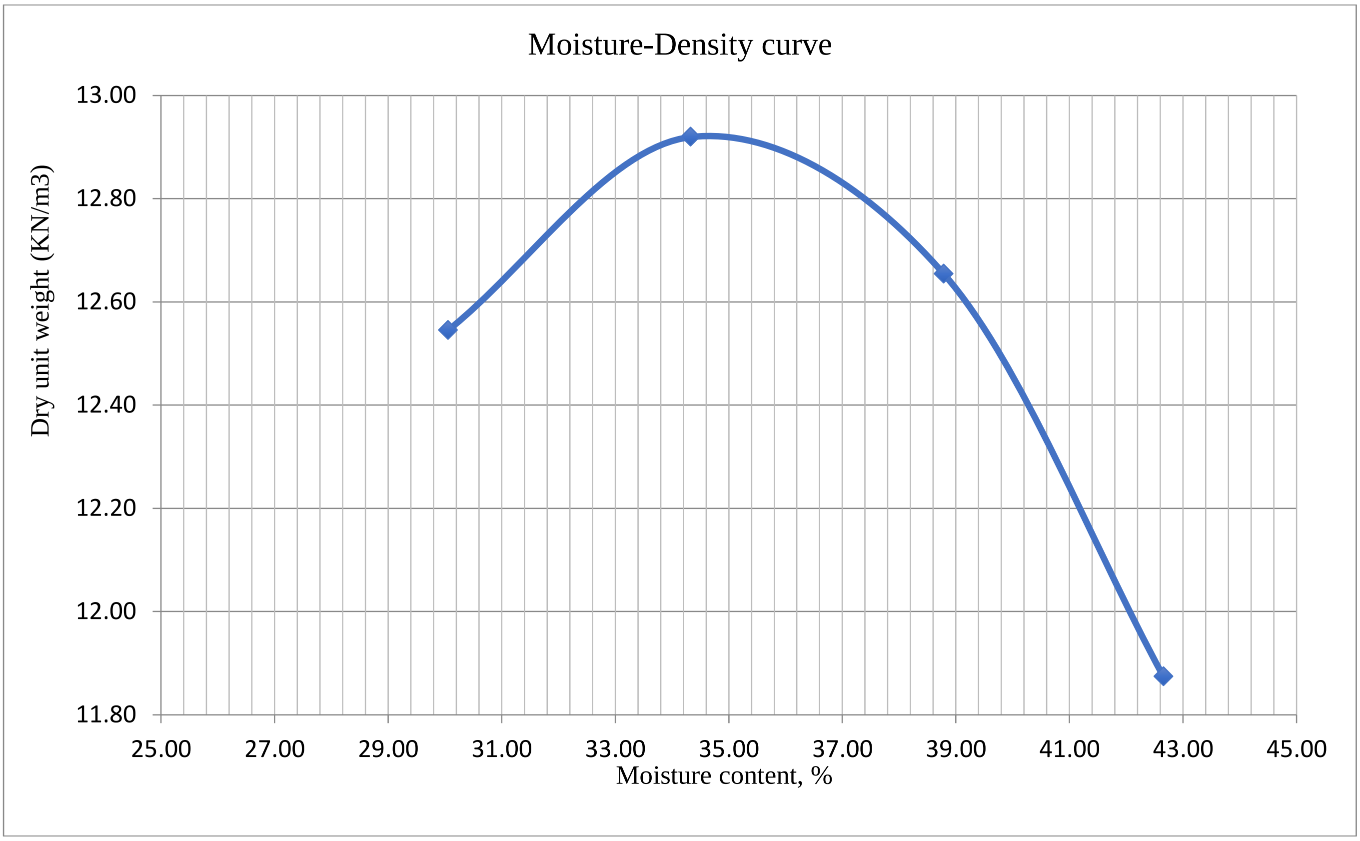
TP 2 @ 1.5m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4410	1405	1.49	82.77	68.89	13.88	17.85	51.04	27.19	27.17	11.48
				73.91	61.92	11.99	17.75	44.17	27.15		
2	4620	1615	1.71	81.5	65.64	15.86	16.93	48.71	32.56	32.93	12.63
				92.16	73.85	18.31	18.88	54.97	33.31		
3	4680	1675	1.77	86.12	67.78	18.34	17.55	50.23	36.51	36.43	12.76
				95.21	74.56	20.65	17.74	56.82	36.34		
4	4660	1655	1.75	110.15	83.92	26.23	17.49	66.43	39.49	39.33	12.34
				107.53	82.45	25.08	18.44	64.01	39.18		
5	4600	1595	1.69	116.53	86.79	29.74	17.53	69.26	42.94	42.59	11.62
				86.44	65.9	20.54	17.27	48.63	42.24		



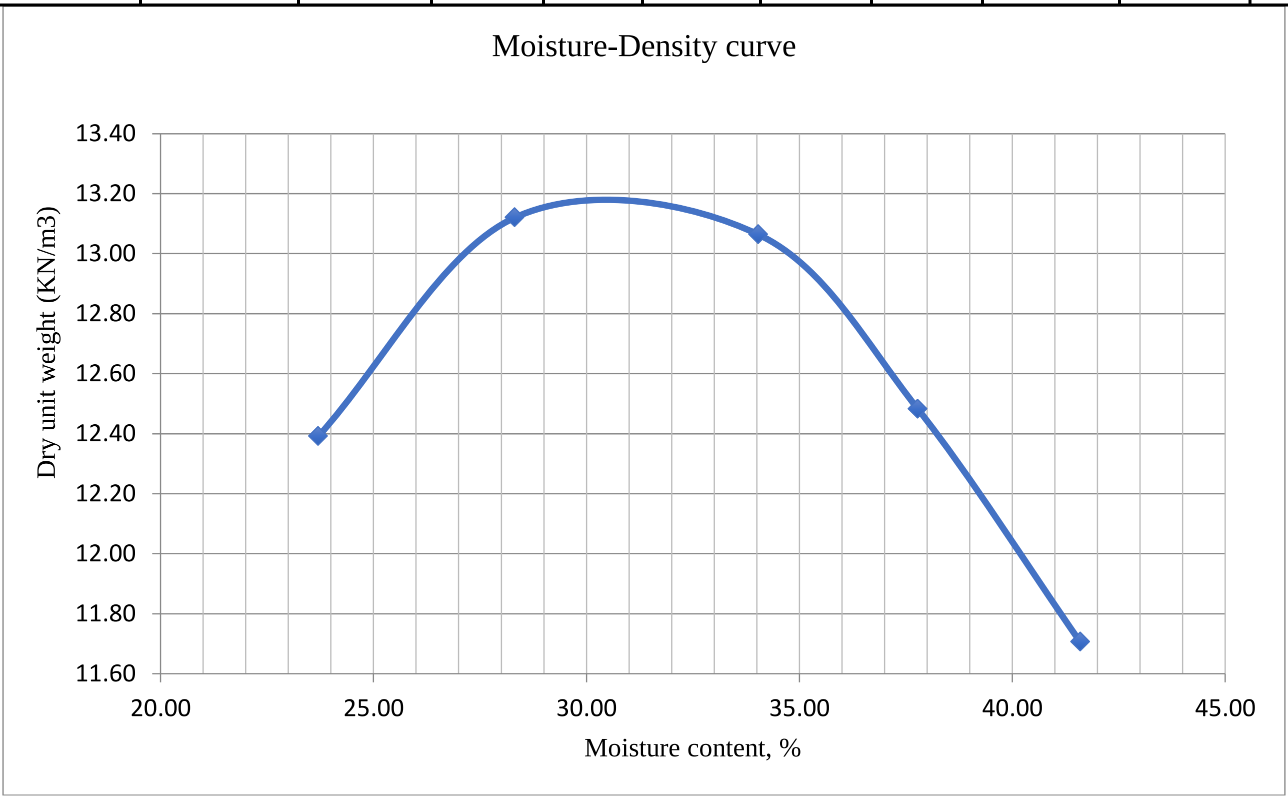
TP 2 @ 3m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water, g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4570	1570	1.66	111.598	89.99	21.608	17.19	72.8	29.68	30.06	12.54
				83.149	67.94	15.209	17.96	49.98	30.43		
2	4670	1670	1.77	118.93	93.03	25.9	17.98	75.05	34.51	34.33	12.92
				81.95	65.54	16.41	17.49	48.05	34.15		
3	4690	1690	1.79	103.403	79.46	23.943	17.66	61.8	38.74	38.79	12.65
				116.36	88.71	27.65	17.5	71.21	38.83		
4	4630	1630	1.73	86.46	66.1	20.36	18.15	47.95	42.46	42.66	11.87
				97.98	73.99	23.99	18.01	55.98	42.85		
5	4590	1590	1.68	96.299	70.8	25.499	17.65	53.15	47.98	48.03	11.16
				92.665	68.23	24.435	17.42	50.81	48.09		


Moisture-Density curve
Dry unit weight (KN/m3)
13.00
12.80
12.60
12.40
12.20
12.00
11.80
25.00
27.00
29.00
31.00
33.00
35.00
37.00
39.00
41.00
43.00
45.00
Moisture content, %

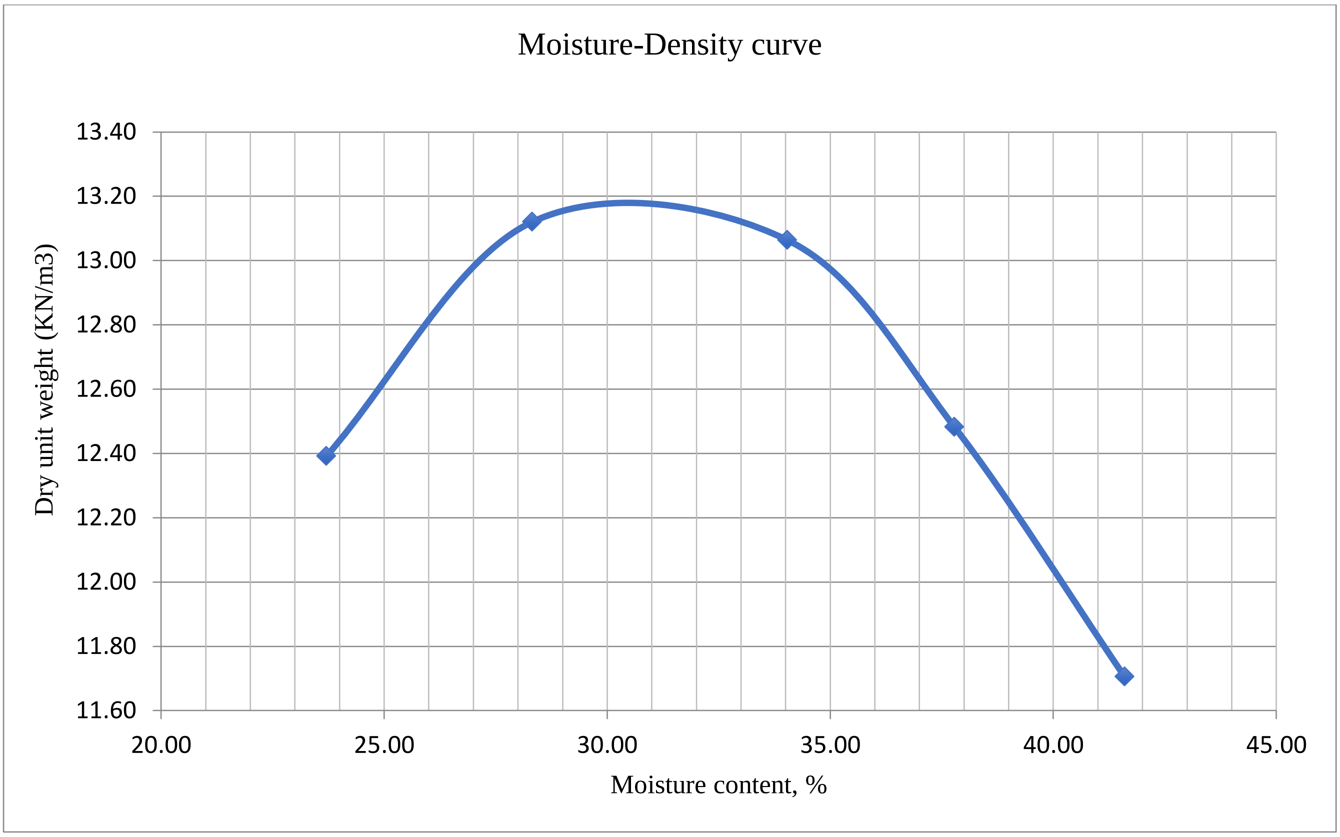
TP 3 @1.5m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4490	1485	1.57	96.34	81.04	15.3	17.39	63.65	24.04	24.22	12.42
				99.87	83.75	16.12	17.68	66.07	24.40		
2	4600	1595	1.69	78.19	63.89	14.3	17.61	46.28	30.90	28.58	12.89
				80.05	66.93	13.12	16.968	49.962	26.26		
3	4690	1685	1.78	97.82	78.83	18.99	17.33	61.5	30.88	31.19	13.35
				106.92	85.64	21.28	18.1	67.54	31.51		
4	4670	1665	1.76	107.62	85.64	21.98	24.46	61.18	35.93	36.01	12.72
				101.52	79.48	22.04	18.42	61.06	36.10		
5	4620	1615	1.71	101.88	77.88	24	17.85	60.03	39.98	39.84	12.00
				117.67	89.22	28.45	17.54	71.68	39.69		



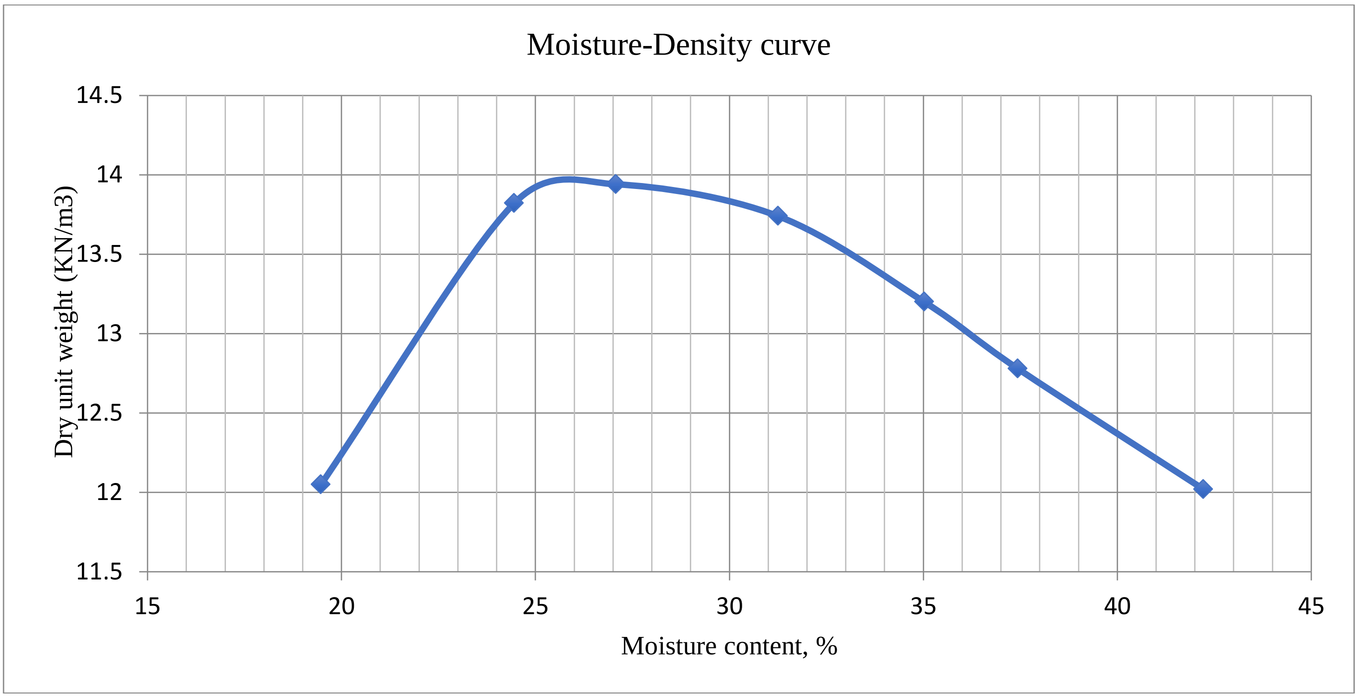
TP 3 @ 3m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4475	1475	1.56	98	82.57	15.43	17.32	65.25	23.65	23.70	12.39
				89.4	75.62	13.78	17.62	58	23.76		
2	4620	1620	1.72	113.15	92.23	20.92	17.52	74.71	28.00	28.32	13.12
				74.45	61.71	12.74	17.21	44.5	28.63		
3	4685	1685	1.78	103.36	81.38	21.98	17.76	63.62	34.55	34.04	13.06
				98.88	78.56	20.32	17.95	60.61	33.53		
4	4655	1655	1.75	103.53	80.53	23	18	62.53	36.78	37.78	12.48
				104.3	79.92	24.38	17.06	62.86	38.78		
5	4595	1595	1.69	91.78	70.04	21.74	17.63	52.41	41.48	41.60	11.71
				112.78	84.99	27.79	18.37	66.62	41.71		



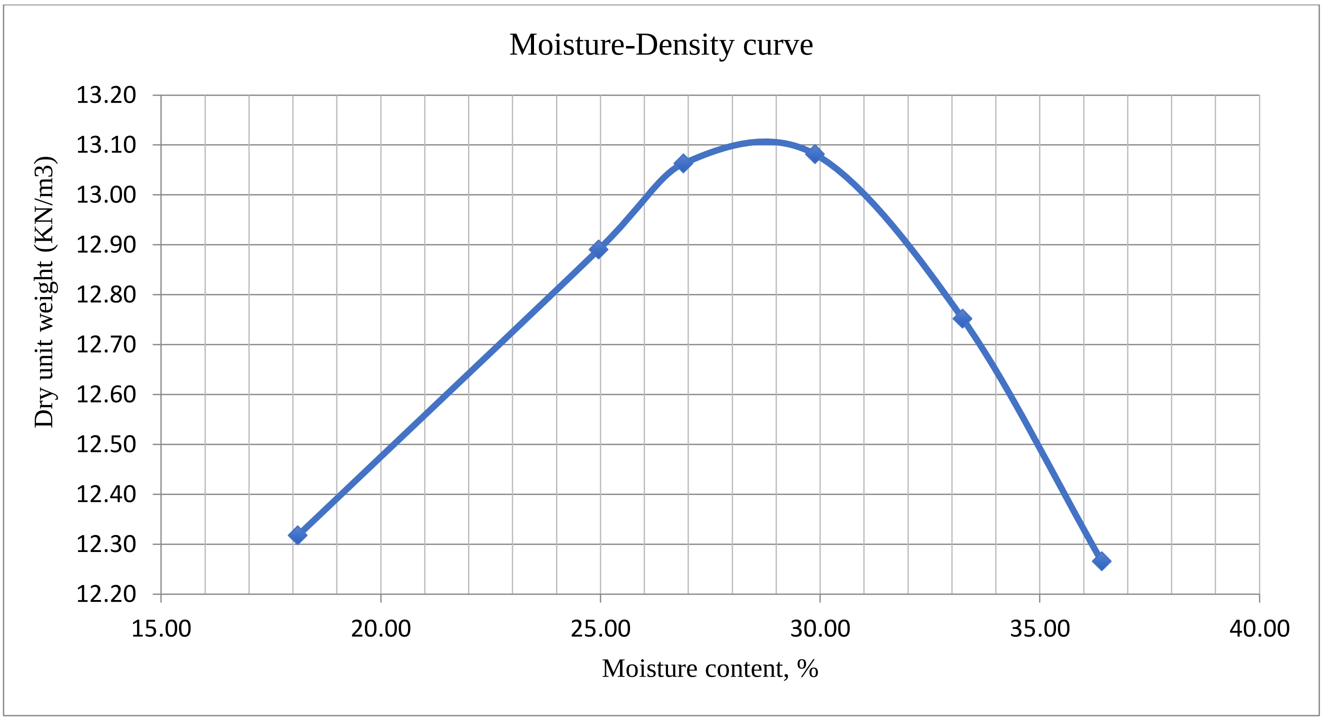
TP 4 @1.5m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4390	1385	1.47	91.41	79.25	12.16	18.43	60.82	19.99	19.47	12.05
				85.05	74.29	10.76	17.52	56.77	18.95		
2	4660	1655	1.75	97.75	81.77	15.98	18.03	63.74	25.07	24.45	13.82
				76.55	65.15	11.4	17.3	47.85	23.82		
3	4710	1705	1.81	87.41	72.69	14.72	17.66	55.03	26.75	27.07	13.94
				89.48	73.89	15.59	16.97	56.92	27.39		
4	4740	1735	1.84	108.86	86.97	21.89	17.62	69.35	31.56	31.25	13.74
				98.08	79.22	18.86	18.27	60.95	30.94		
5	4720	1715	1.82	73.73	59.46	14.27	17.67	41.79	34.15	35.02	13.20
				106.07	83.19	22.88	19.43	63.76	35.88		
6	4695	1690	1.79	102.57	79.54	23.03	18.23	61.31	37.56	37.43	12.78
				83.66	65.75	17.91	17.74	48.01	37.30		
7	4650	1645	1.74	110.26	82.77	27.49	17.82	64.95	42.32	42.22	12.02
				93.95	71.29	22.66	17.49	53.8	42.12		



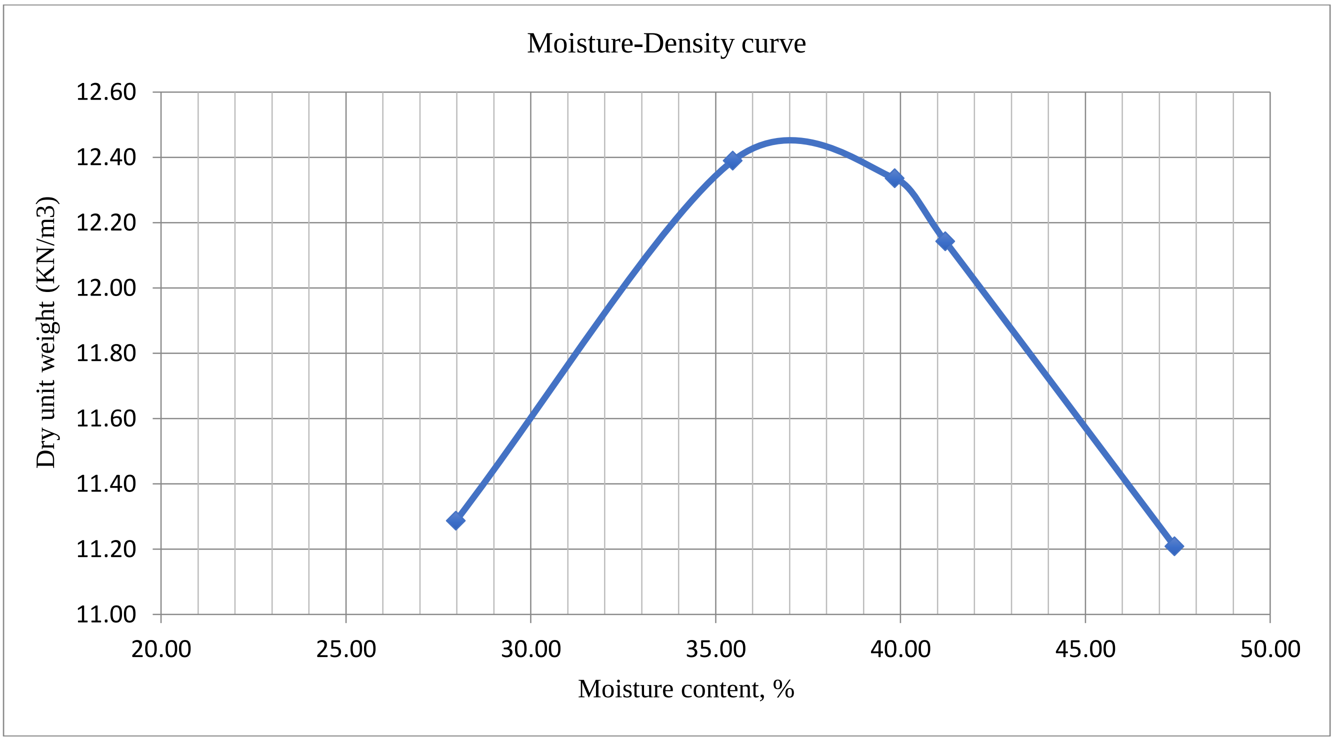
TP 4 @ 3m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4375	1375	1.46	116.36	100.9	15.46	17.24	83.66	18.48	18.11	12.10
				102.47	89.69	12.78	17.69	72	17.75		
2	4550	1550	1.64	90.99	76.46	14.53	17.59	58.87	24.68	24.96	12.89
				88.11	73.85	14.26	17.34	56.51	25.23		
3	4595	1595	1.69	96.17	79.37	16.8	18.1	61.27	27.42	26.89	13.06
				89.25	74.38	14.87	17.96	56.42	26.36		
4	4635	1635	1.73	103.89	84.03	19.86	17.82	66.21	30.00	29.89	13.08
				90.54	73.84	16.7	17.76	56.08	29.78		
5	4635	1635	1.73	95	75.61	19.39	16.96	58.65	33.06	33.24	12.75
				83.39	66.84	16.55	17.33	49.51	33.43		
6	4610	1610	1.71	113.19	87.76	25.43	17.34	70.42	36.11	36.41	12.27
				107.12	82.98	24.14	17.22	65.76	36.71		
7	4580	1580	1.67	92.91	70.36	22.55	17.64	52.72	42.77	42.87	11.49
				81.75	62.45	19.3	17.54	44.91	42.97		



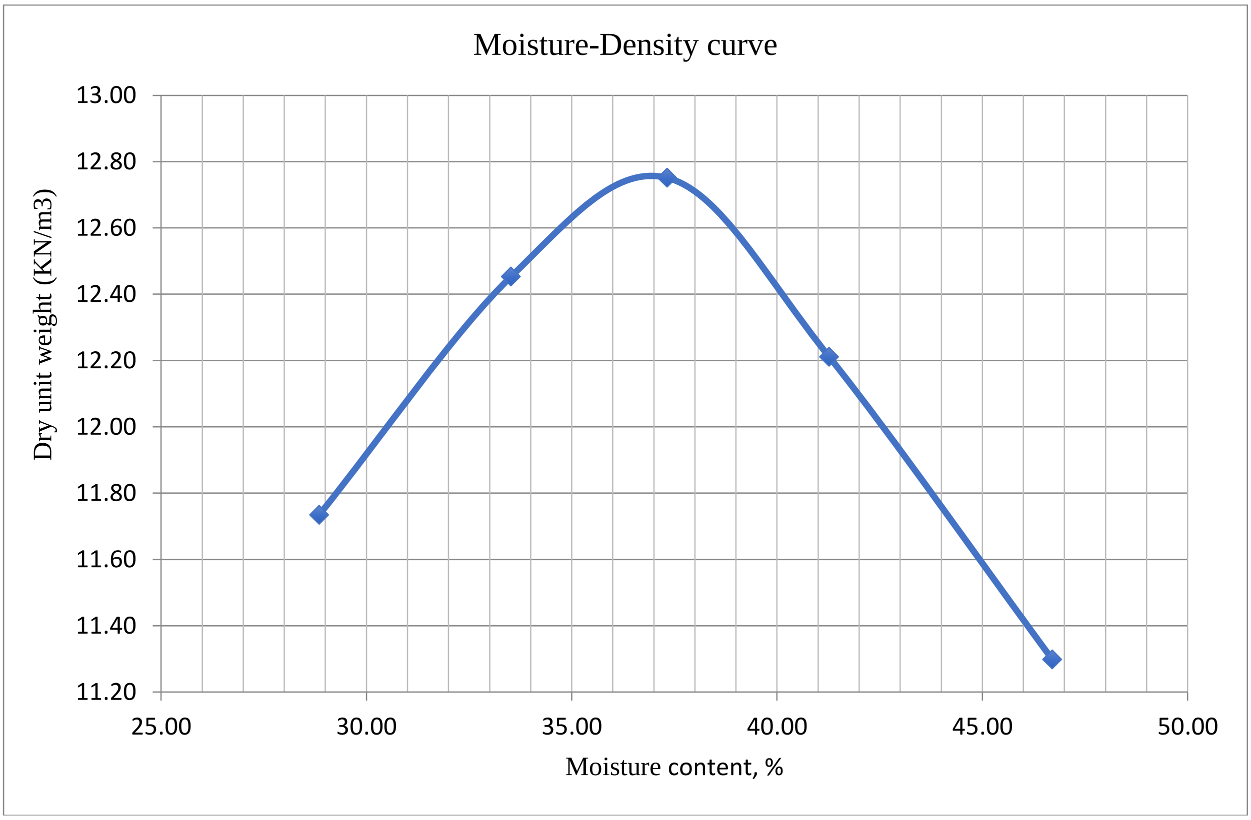
TP 5 @1.5m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4395	1390	1.47	96.31	79.15	17.16	17.34	61.81	27.76	27.98	11.29
				98.02	80.27	17.75	17.3	62.97	28.19		
2	4620	1615	1.71	96.24	75.84	20.4	17.94	57.9	35.23	35.46	12.39
				90.26	71.18	19.08	17.72	53.46	35.69		
3	4665	1660	1.76	103.94	79.72	24.22	19.95	59.77	40.52	39.84	12.34
				102.73	78.61	24.12	17.02	61.59	39.16		
4	4655	1650	1.75	116.63	87.8	28.83	18.145	69.655	41.39	41.21	12.14
				109.35	82.81	26.54	18.128	64.682	41.03		
5	4595	1590	1.68	96.04	70.81	25.23	17.64	53.17	47.45	47.41	11.21
				101.73	74.99	26.74	18.54	56.45	47.37		



TP5@ 3m

Trial No.	Mass of compacted soil + mold, g	Mass of compacted soil, g	Wet unit weight (KN/m^3)	Mass of wet soil + can, g	Mass of dry soil + can, g	Mass of water,g	Mass of can, g	Mass of dry soil,g	Moisture content, %	Avarege water contant %	Dry unit weight (KN/m^3)
1	4455	1455	1.54	93.23	76.26	16.97	17.33	58.93	28.80	28.85	11.73
				96.89	79.09	17.8	17.508	61.582	28.90		
2	4600	1600	1.69	83.88	67.19	16.69	17.3	49.89	33.45	33.52	12.45
				90.707	72.29	18.417	17.456	54.834	33.59		
3	4695	1695	1.80	100.67	78.186	22.484	17.61	60.576	37.12	37.33	12.83
				105.89	81.78	24.11	17.55	64.23	37.54		
4	4660	1660	1.76	89.05	68.2	20.85	17.68	50.52	41.27	41.27	12.21
				108.86	82.33	26.53	18.05	64.28	41.27		
5	4595	1595	1.69	115.96	84.66	31.3	17.62	67.04	46.69	46.71	11.30
				108.186	79.26	28.926	17.35	61.91	46.72		



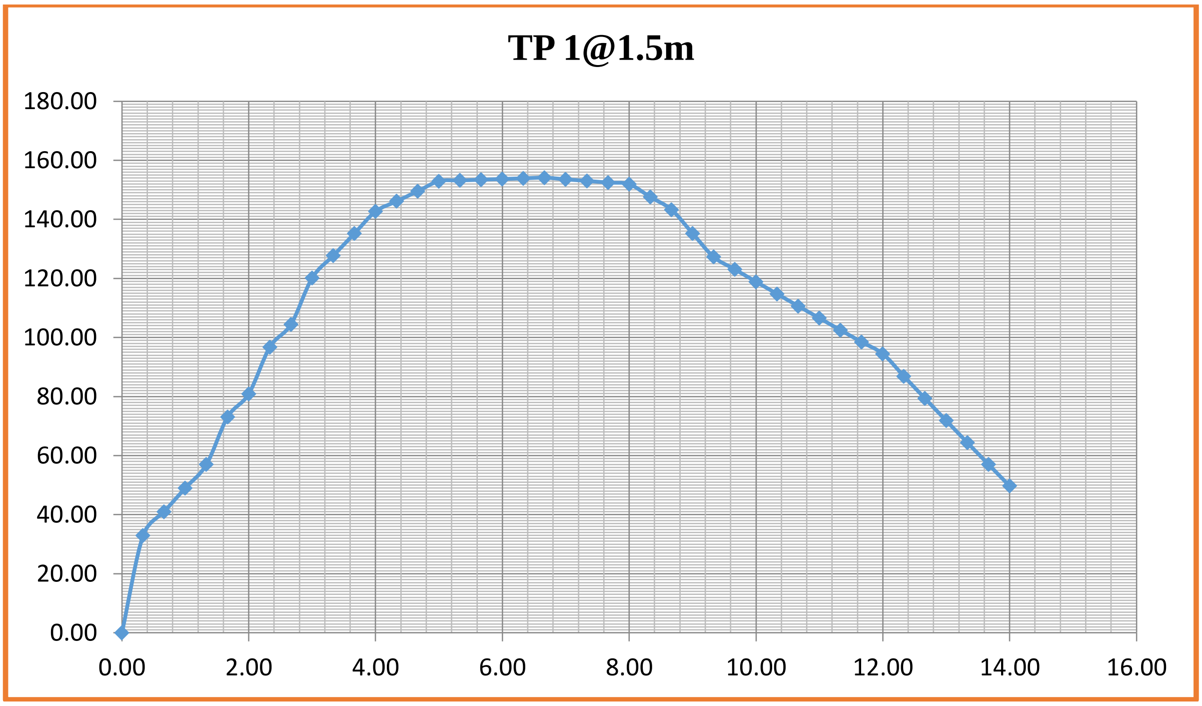
APPENDIX – D

UNCONFINED COMPRESSION STRENGTH TEST RESULTS

TP 1@1.5m

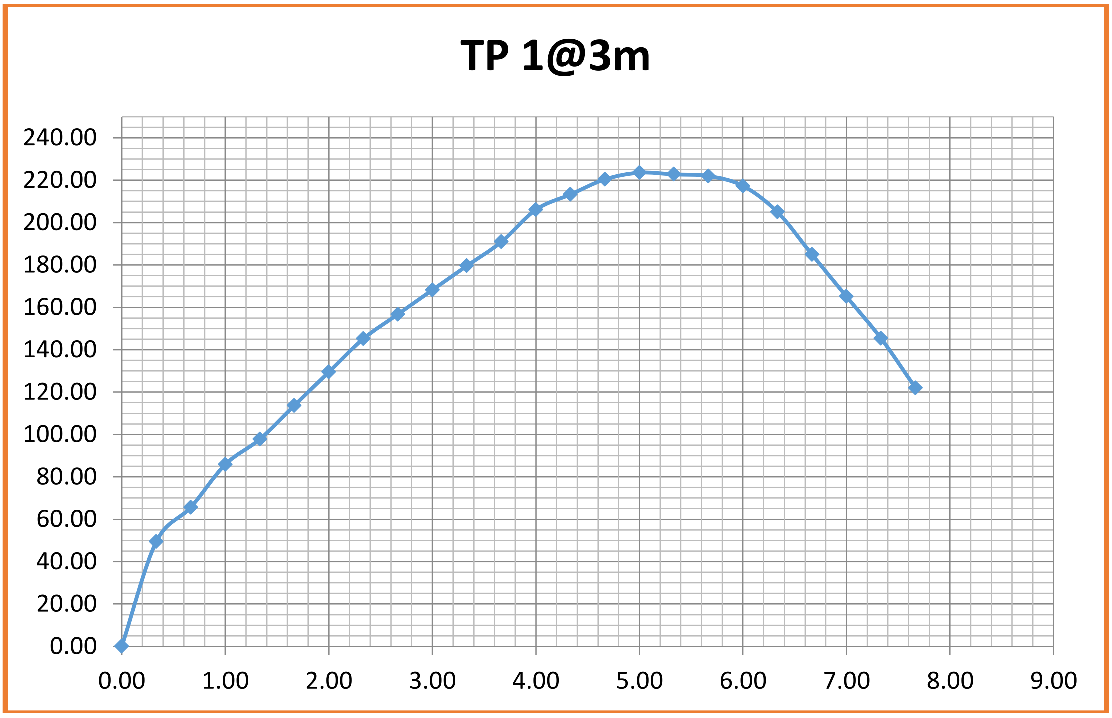
Deformation Dial Reading	Load Dial Reading	Sample Deformation ∆L (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	4.0	0.20	0.00	0.33	10.21	33.60	32.92
40	5.0	0.40	0.01	0.67	10.24	42.00	41.01
60	6.0	0.60	0.01	1.00	10.28	50.40	49.04
80	7.0	0.80	0.01	1.33	10.31	58.80	57.03
100	9.0	1.00	0.02	1.67	10.35	75.60	73.07
120	10.0	1.20	0.02	2.00	10.38	84.00	80.92
140	12.0	1.40	0.02	2.33	10.42	100.80	96.77
160	13.0	1.60	0.03	2.67	10.45	109.20	104.47
180	15.0	1.80	0.03	3.00	10.49	126.00	120.13
200	16.0	2.00	0.03	3.33	10.52	134.40	127.70
220	17.0	2.20	0.04	3.67	10.56	142.80	135.22
240	18.0	2.40	0.04	4.00	10.60	151.20	142.68
260	18.5	2.60	0.04	4.33	10.63	155.40	146.13
280	19.0	2.80	0.05	4.67	10.67	159.60	149.56
300	19.5	3.00	0.05	5.00	10.71	163.80	152.95
320	19.6	3.20	0.05	5.33	10.75	164.64	153.20
340	19.7	3.40	0.06	5.67	10.78	165.48	153.44
360	19.8	3.60	0.06	6.00	10.82	166.32	153.67
380	19.9	3.80	0.06	6.33	10.86	167.16	153.90
400	20.0	4.00	0.07	6.67	10.90	168.00	154.12
420	**20.0**	4.20	0.07	7.00	10.94	168.00	153.57
440	20.0	4.40	0.07	7.33	10.98	168.00	153.02
460	20.0	4.60	0.08	7.67	11.02	168.00	152.47
480	20.0	4.80	0.08	8.00	11.06	168.00	151.92
500	19.5	5.00	0.08	8.33	11.10	163.80	147.59

520	19.0	5.20	0.09	8.67	11.14	159.60	143.28
540	18.0	5.40	0.09	9.00	11.18	151.20	135.24
560	17.0	5.60	0.09	9.33	11.22	142.80	127.26
580	16.5	5.80	0.10	9.67	11.26	138.60	123.07
600	16.0	6.00	0.10	10.00	11.30	134.40	118.90
620	15.5	6.20	0.10	10.33	11.35	130.20	114.75
640	15.0	6.40	0.11	10.67	11.39	126.00	110.64
660	14.5	6.60	0.11	11.00	11.43	121.80	106.55
680	14.0	6.80	0.11	11.33	11.47	117.60	102.49
700	13.5	7.00	0.12	11.67	11.52	113.40	98.46
720	13.0	7.20	0.12	12.00	11.56	109.20	94.46
740	12.0	7.40	0.12	12.33	11.60	100.80	86.86
760	11.0	7.60	0.13	12.67	11.65	92.40	79.32
780	10.0	7.80	0.13	13.00	11.69	84.00	71.83
800	9.0	8.00	0.13	13.33	11.74	75.60	64.40
820	8.0	8.20	0.14	13.67	11.78	67.20	57.03
840	7.0	8.40	0.14	14.00	11.83	58.80	49.71



TP 1@3m

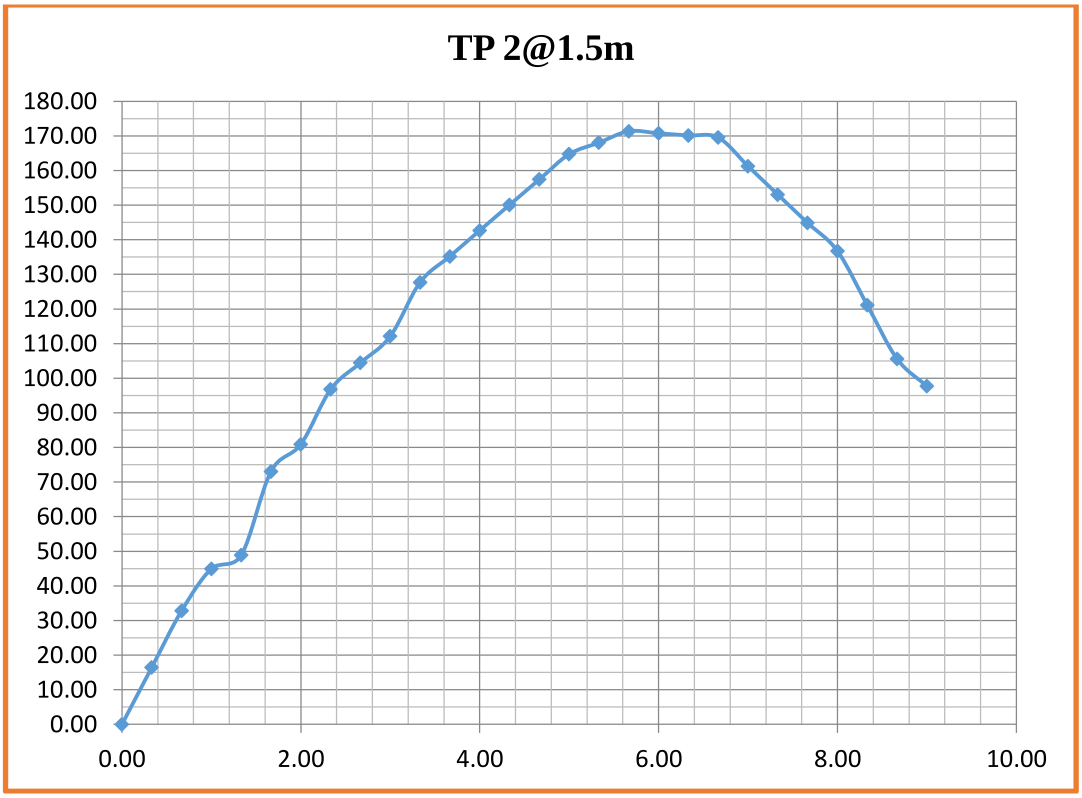
Deformation Dial Reading	Load Dial Reading	Sample Deformation ΔL (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	6.0	0.20	0.00	0.33	10.21	50.40	49.37
40	8.0	0.40	0.01	0.67	10.24	67.20	65.61
60	10.5	0.60	0.01	1.00	10.28	88.20	85.83
80	12.0	0.80	0.01	1.33	10.31	100.80	97.76
100	14.0	1.00	0.02	1.67	10.35	117.60	113.67
120	16.0	1.20	0.02	2.00	10.38	134.40	129.46
140	18.0	1.40	0.02	2.33	10.42	151.20	145.15
160	19.5	1.60	0.03	2.67	10.45	163.80	156.71
180	21.0	1.80	0.03	3.00	10.49	176.40	168.19
200	22.5	2.00	0.03	3.33	10.52	189.00	179.58
220	24.0	2.20	0.04	3.67	10.56	201.60	190.89
240	26.0	2.40	0.04	4.00	10.60	218.40	206.09
260	27.0	2.60	0.04	4.33	10.63	226.80	213.27
280	28.0	2.80	0.05	4.67	10.67	235.20	220.40
300	28.5	3.00	0.05	5.00	10.71	239.40	223.55
320	28.5	3.20	0.05	5.33	10.75	239.40	222.76
340	28.5	3.40	0.06	5.67	10.78	239.40	221.98
360	28.0	3.60	0.06	6.00	10.82	235.20	217.32
380	26.5	3.80	0.06	6.33	10.86	222.60	204.94
400	24.0	4.00	0.07	6.67	10.90	201.60	184.95
420	21.5	4.20	0.07	7.00	10.94	180.60	165.09
440	19.0	4.40	0.07	7.33	10.98	159.60	145.37
460	16.0	4.60	0.08	7.67	11.02	134.40	121.98



TP 2@1.5m

Deformation Dial Reading	Load Dial Reading	Sample Deformation ΔL (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	2.0	0.20	0.00	0.33	10.21	16.80	16.46
40	4.0	0.40	0.01	0.67	10.24	33.60	32.81
60	5.5	0.60	0.01	1.00	10.28	46.20	44.96
80	6.0	0.80	0.01	1.33	10.31	50.40	48.88
100	9.0	1.00	0.02	1.67	10.35	75.60	73.07
120	10.0	1.20	0.02	2.00	10.38	84.00	80.92
140	12.0	1.40	0.02	2.33	10.42	100.80	96.77
160	13.0	1.60	0.03	2.67	10.45	109.20	104.47
180	14.0	1.80	0.03	3.00	10.49	117.60	112.13
200	16.0	2.00	0.03	3.33	10.52	134.40	127.70
220	17.0	2.20	0.04	3.67	10.56	142.80	135.22
240	18.0	2.40	0.04	4.00	10.60	151.20	142.68
260	19.0	2.60	0.04	4.33	10.63	159.60	150.08

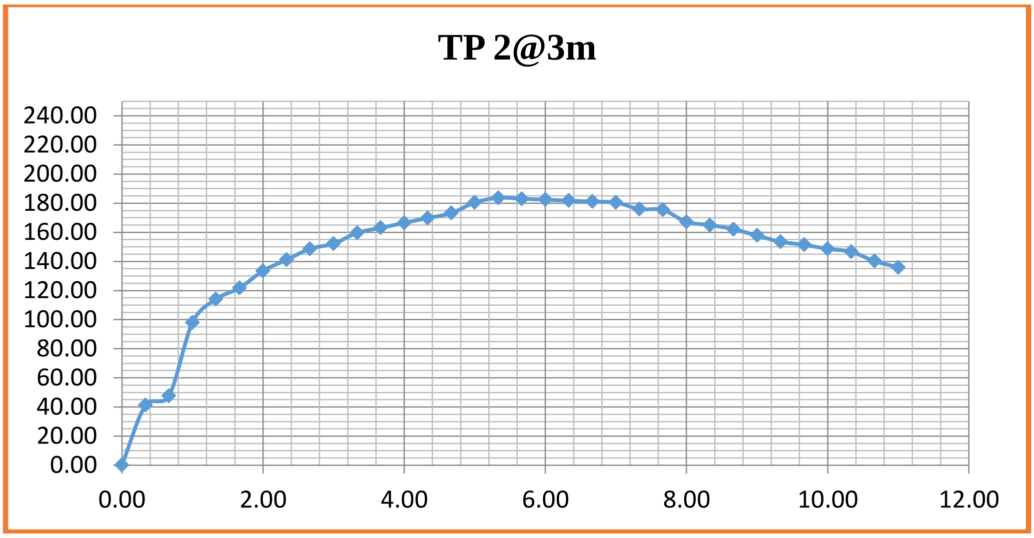
280	20.0	2.80	0.05	4.67	10.67	168.00	157.43
300	21.0	3.00	0.05	5.00	10.71	176.40	164.72
320	21.5	3.20	0.05	5.33	10.75	180.60	168.05
340	22.0	3.40	0.06	5.67	10.78	184.80	171.35
360	22.0	3.60	0.06	6.00	10.82	184.80	170.75
380	22.0	3.80	0.06	6.33	10.86	184.80	170.14
400	22.0	4.00	0.07	6.67	10.90	184.80	169.54
420	21.0	4.20	0.07	7.00	10.94	176.40	161.25
440	20.0	4.40	0.07	7.33	10.98	168.00	153.02
460	19.0	4.60	0.08	7.67	11.02	159.60	144.85
480	18.0	4.80	0.08	8.00	11.06	151.20	136.73
500	16.0	5.00	0.08	8.33	11.10	134.40	121.10
520	14.0	5.20	0.09	8.67	11.14	117.60	105.58
540	13.0	5.40	0.09	9.00	11.18	109.20	97.68



TP 2@3m

Deformation Dial Reading	Load Dial Reading	Sample Deformation ∆L (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	5.0	0.20	0.00	0.33	10.21	42.00	41.15
40	5.8	0.40	0.01	0.67	10.24	48.72	47.57
60	12.0	0.60	0.01	1.00	10.28	100.80	98.09
80	14.0	0.80	0.01	1.33	10.31	117.60	114.05
100	15.0	1.00	0.02	1.67	10.35	126.00	121.79
120	16.5	1.20	0.02	2.00	10.38	138.60	133.51
140	17.5	1.40	0.02	2.33	10.42	147.00	141.12
160	18.5	1.60	0.03	2.67	10.45	155.40	148.68
180	19.0	1.80	0.03	3.00	10.49	159.60	152.17
200	20.0	2.00	0.03	3.33	10.52	168.00	159.63
220	20.5	2.20	0.04	3.67	10.56	172.20	163.06
240	21.0	2.40	0.04	4.00	10.60	176.40	166.45
260	21.5	2.60	0.04	4.33	10.63	180.60	169.83
280	22.0	2.80	0.05	4.67	10.67	184.80	173.17
300	23.0	3.00	0.05	5.00	10.71	193.20	180.41
320	23.5	3.20	0.05	5.33	10.75	197.40	183.68
340	23.5	3.40	0.06	5.67	10.78	197.40	183.04
360	23.5	3.60	0.06	6.00	10.82	197.40	182.39
380	23.5	3.80	0.06	6.33	10.86	197.40	181.74
400	23.5	4.00	0.07	6.67	10.90	197.40	181.10
420	23.5	4.20	0.07	7.00	10.94	197.40	180.45
440	23.0	4.40	0.07	7.33	10.98	193.20	175.98
460	23.0	4.60	0.08	7.67	11.02	193.20	175.34
480	22.0	4.80	0.08	8.00	11.06	184.80	167.11
500	21.8	5.00	0.08	8.33	11.10	183.12	165.00
520	21.5	5.20	0.09	8.67	11.14	180.60	162.13
540	21.0	5.40	0.09	9.00	11.18	176.40	157.78
560	20.5	5.60	0.09	9.33	11.22	172.20	153.46
580	20.3	5.80	0.10	9.67	11.26	170.52	151.41
600	20.0	6.00	0.10	10.00	11.30	168.00	148.62

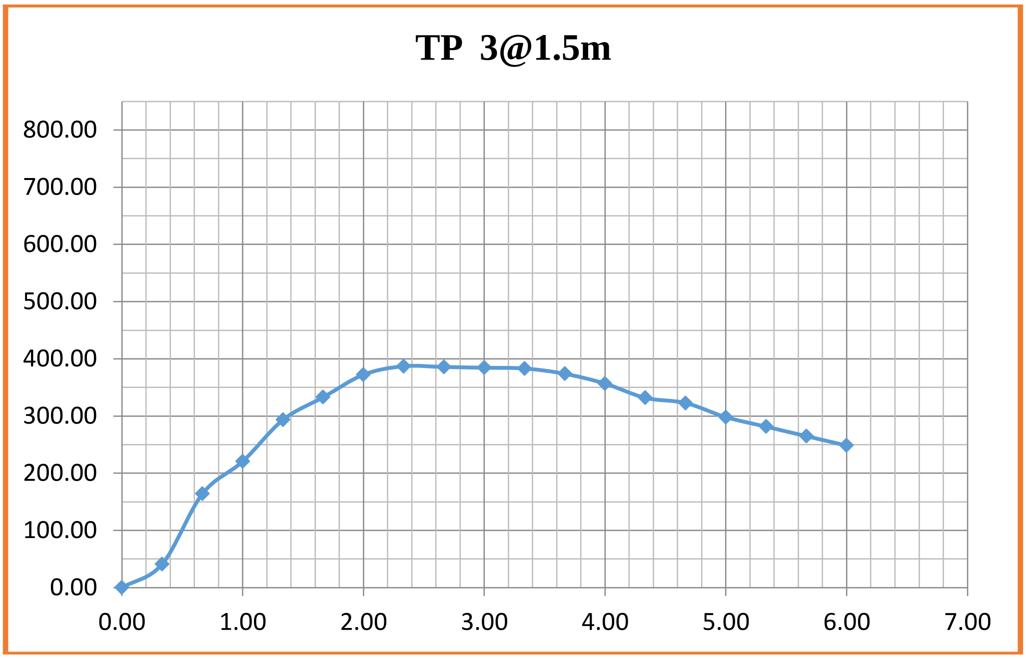
620	19.8	6.20	0.10	10.33	11.35	166.32	146.59
640	19.0	6.40	0.11	10.67	11.39	159.60	140.14
660	18.5	6.60	0.11	11.00	11.43	155.40	135.95



TP 3@1.5m

Deformation Dial Reading	Load Dial Reading	Sample Deformation ∆L (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	5.0	0.20	0.00	0.33	10.21	42.00	41.15
40	20.0	0.40	0.01	0.67	10.24	168.00	164.03
60	27.0	0.60	0.01	1.00	10.28	226.80	220.70
80	36.0	0.80	0.01	1.33	10.31	302.40	293.28
100	41.0	1.00	0.02	1.67	10.35	344.40	332.88
120	46.0	1.20	0.02	2.00	10.38	386.40	372.21
140	48.0	1.40	0.02	2.33	10.42	403.20	387.07
160	48.0	1.60	0.03	2.67	10.45	403.20	385.75
180	48.0	1.80	0.03	3.00	10.49	403.20	384.43
200	48.0	2.00	0.03	3.33	10.52	403.20	383.11
220	47.0	2.20	0.04	3.67	10.56	394.80	373.83
240	45.0	2.40	0.04	4.00	10.60	378.00	356.69
260	42.0	2.60	0.04	4.33	10.63	352.80	331.75
280	41.0	2.80	0.05	4.67	10.67	344.40	322.73

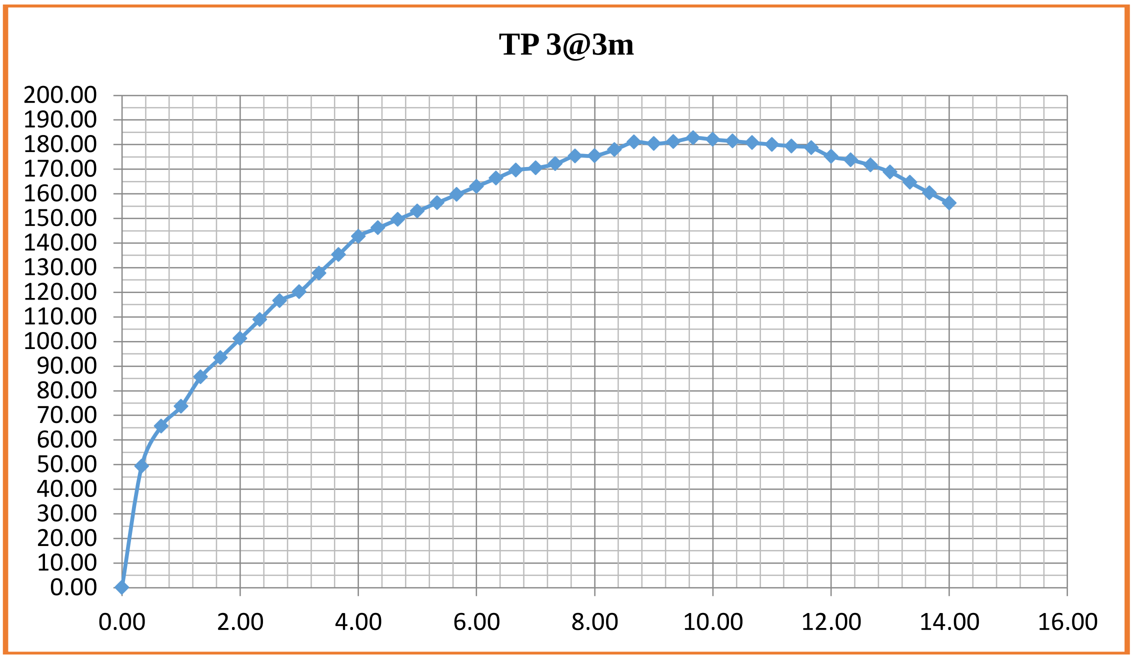
300	38.0	3.00	0.05	5.00	10.71	319.20	298.07
320	36.0	3.20	0.05	5.33	10.75	302.40	281.39
340	34.0	3.40	0.06	5.67	10.78	285.60	264.82
360	32.0	3.60	0.06	6.00	10.82	268.80	248.36



TP 3@3m

Deformation Dial Reading	Load Dial Reading	Sample Deformation ∆L (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	6.0	0.20	0.00	0.33	10.21	50.40	49.37
40	8.0	0.40	0.01	0.67	10.24	67.20	65.61
60	9.0	0.60	0.01	1.00	10.28	75.60	73.57
80	10.5	0.80	0.01	1.33	10.31	88.20	85.54
100	11.5	1.00	0.02	1.67	10.35	96.60	93.37
120	12.5	1.20	0.02	2.00	10.38	105.00	101.14
140	13.5	1.40	0.02	2.33	10.42	113.40	108.86
160	14.5	1.60	0.03	2.67	10.45	121.80	116.53
180	15.0	1.80	0.03	3.00	10.49	126.00	120.13
200	16.0	2.00	0.03	3.33	10.52	134.40	127.70

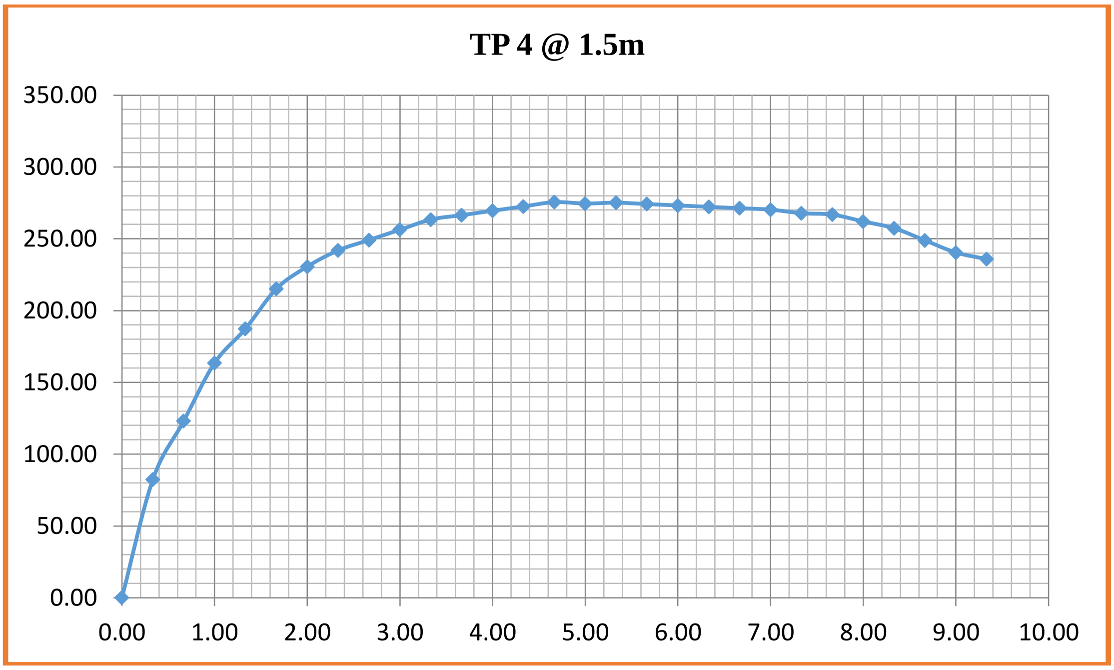
220	17.0	2.20	0.04	3.67	10.56	142.80	135.22
240	18.0	2.40	0.04	4.00	10.60	151.20	142.68
260	18.5	2.60	0.04	4.33	10.63	155.40	146.13
280	19.0	2.80	0.05	4.67	10.67	159.60	149.56
300	19.5	3.00	0.05	5.00	10.71	163.80	152.95
320	20.0	3.20	0.05	5.33	10.75	168.00	156.33
340	20.5	3.40	0.06	5.67	10.78	172.20	159.67
360	21.0	3.60	0.06	6.00	10.82	176.40	162.99
380	21.5	3.80	0.06	6.33	10.86	180.60	166.28
400	22.0	4.00	0.07	6.67	10.90	184.80	169.54
420	22.2	4.20	0.07	7.00	10.94	186.48	170.47
440	22.5	4.40	0.07	7.33	10.98	189.00	172.15
460	23.0	4.60	0.08	7.67	11.02	193.20	175.34
480	23.1	4.80	0.08	8.00	11.06	194.04	175.47
500	23.5	5.00	0.08	8.33	11.10	197.40	177.86
520	24.0	5.20	0.09	8.67	11.14	201.60	180.99
540	24.0	5.40	0.09	9.00	11.18	201.60	180.33
560	24.2	5.60	0.09	9.33	11.22	203.28	181.16
580	24.5	5.80	0.10	9.67	11.26	205.80	182.73
600	24.5	6.00	0.10	10.00	11.30	205.80	182.06
620	24.5	6.20	0.10	10.33	11.35	205.80	181.39
640	24.5	6.40	0.11	10.67	11.39	205.80	180.71
660	24.5	6.60	0.11	11.00	11.43	205.80	180.04
680	24.5	6.80	0.11	11.33	11.47	205.80	179.36
700	24.5	7.00	0.12	11.67	11.52	205.80	178.69
720	24.1	7.20	0.12	12.00	11.56	202.44	175.11
740	24.0	7.40	0.12	12.33	11.60	201.60	173.72
760	23.8	7.60	0.13	12.67	11.65	199.92	171.62
780	23.5	7.80	0.13	13.00	11.69	197.40	168.81
800	23.0	8.00	0.13	13.33	11.74	193.20	164.58
820	22.5	8.20	0.14	13.67	11.78	189.00	160.39
840	22.0	8.40	0.14	14.00	11.83	184.80	156.22



TP 4 @ 1.5m

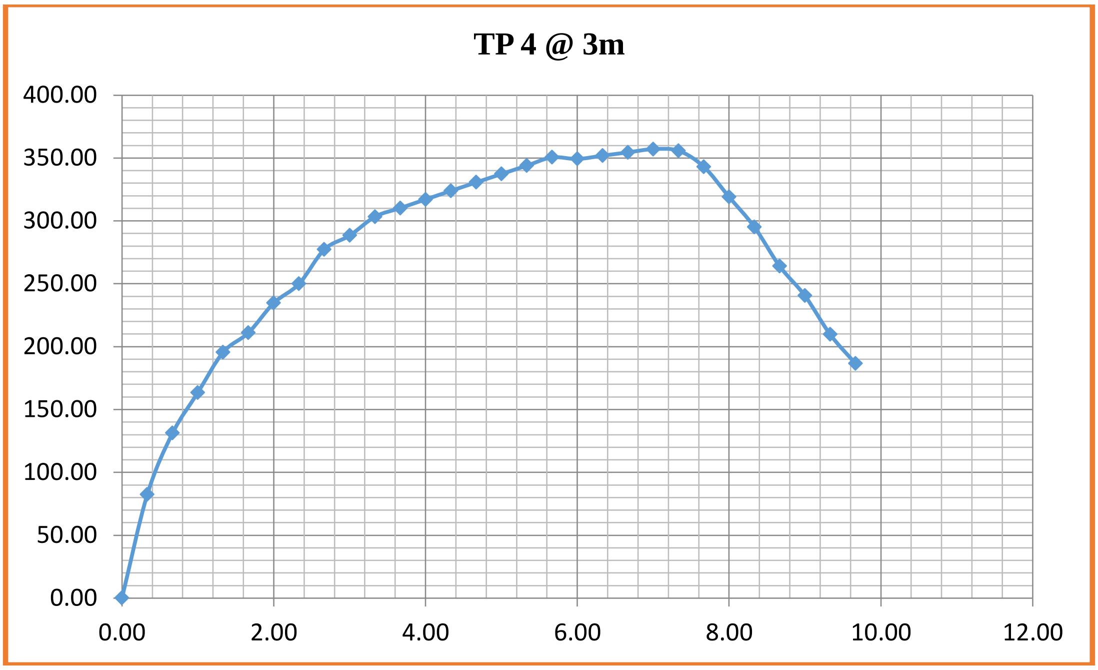
Deformation Dial Reading	Load Dial Reading	Sample Deformation ∆L (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	10.0	0.20	0.00	0.33	10.21	84.00	82.29
40	15.0	0.40	0.01	0.67	10.24	126.00	123.02
60	20.0	0.60	0.01	1.00	10.28	168.00	163.48
80	23.0	0.80	0.01	1.33	10.31	193.20	187.37
100	26.5	1.00	0.02	1.67	10.35	222.60	215.15
120	28.5	1.20	0.02	2.00	10.38	239.40	230.61
140	30.0	1.40	0.02	2.33	10.42	252.00	241.92
160	31.0	1.60	0.03	2.67	10.45	260.40	249.13
180	32.0	1.80	0.03	3.00	10.49	268.80	256.29
200	33.0	2.00	0.03	3.33	10.52	277.20	263.39
220	33.5	2.20	0.04	3.67	10.56	281.40	266.46
240	34.0	2.40	0.04	4.00	10.60	285.60	269.50
260	34.5	2.60	0.04	4.33	10.63	289.80	272.51
280	35.0	2.80	0.05	4.67	10.67	294.00	275.50
300	35.0	3.00	0.05	5.00	10.71	294.00	274.53

320	35.2	3.20	0.05	5.33	10.75	295.68	275.13
340	35.2	3.40	0.06	5.67	10.78	295.68	274.17
360	35.2	3.60	0.06	6.00	10.82	295.68	273.20
380	35.2	3.80	0.06	6.33	10.86	295.68	272.23
400	35.2	4.00	0.07	6.67	10.90	295.68	271.26
420	35.2	4.20	0.07	7.00	10.94	295.68	270.29
440	35.0	4.40	0.07	7.33	10.98	294.00	267.79
460	35.0	4.60	0.08	7.67	11.02	294.00	266.83
480	34.5	4.80	0.08	8.00	11.06	289.80	262.07
500	34.0	5.00	0.08	8.33	11.10	285.60	257.33
520	33.0	5.20	0.09	8.67	11.14	277.20	248.86
540	32.0	5.40	0.09	9.00	11.18	268.80	240.43
560	31.5	5.60	0.09	9.33	11.22	264.60	235.81



TP 4 @ 3m

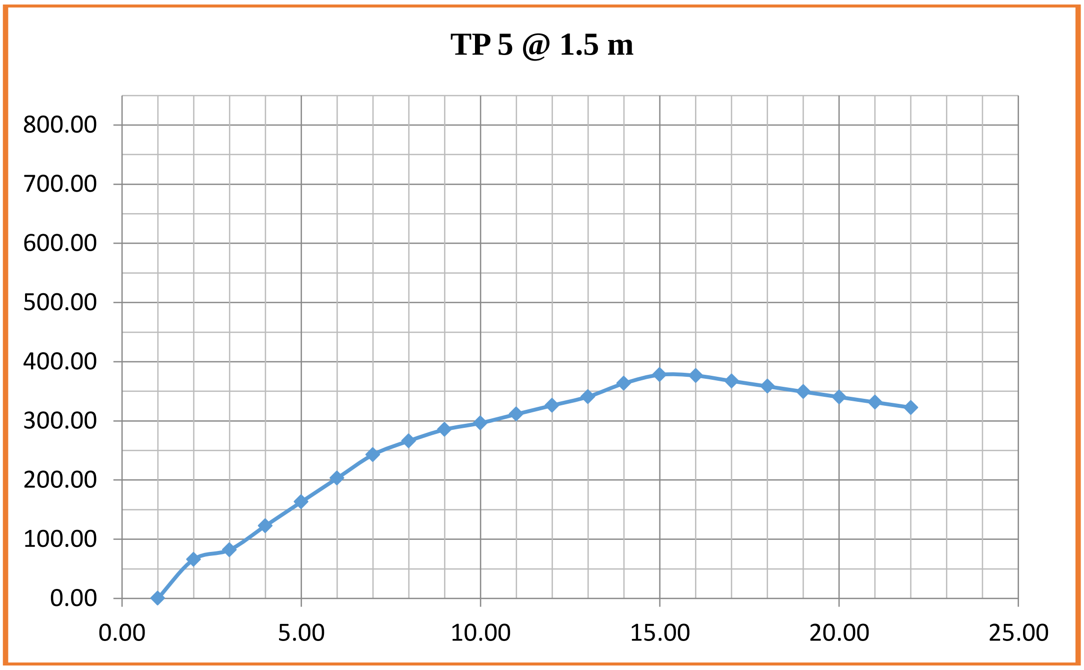
Deformation Dial Reading	Load Dial Reading	Sample Deformation ∆L (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	10.0	0.20	0.00	0.33	10.21	84.00	82.29
40	16.0	0.40	0.01	0.67	10.24	134.40	131.23
60	20.0	0.60	0.01	1.00	10.28	168.00	163.48
80	24.0	0.80	0.01	1.33	10.31	201.60	195.52
100	26.0	1.00	0.02	1.67	10.35	218.40	211.10
120	29.0	1.20	0.02	2.00	10.38	243.60	234.65
140	31.0	1.40	0.02	2.33	10.42	260.40	249.98
160	34.5	1.60	0.03	2.67	10.45	289.80	277.26
180	36.0	1.80	0.03	3.00	10.49	302.40	288.32
200	38.0	2.00	0.03	3.33	10.52	319.20	303.29
220	39.0	2.20	0.04	3.67	10.56	327.60	310.20
240	40.0	2.40	0.04	4.00	10.60	336.00	317.06
260	41.0	2.60	0.04	4.33	10.63	344.40	323.85
280	42.0	2.80	0.05	4.67	10.67	352.80	330.60
300	43.0	3.00	0.05	5.00	10.71	361.20	337.28
320	44.0	3.20	0.05	5.33	10.75	369.60	343.92
340	45.0	3.40	0.06	5.67	10.78	378.00	350.50
360	45.0	3.60	0.06	6.00	10.82	378.00	349.26
380	45.5	3.80	0.06	6.33	10.86	382.20	351.89
400	46.0	4.00	0.07	6.67	10.90	386.40	354.49
420	46.5	4.20	0.07	7.00	10.94	390.60	357.06
440	46.5	4.40	0.07	7.33	10.98	390.60	355.78
460	45.0	4.60	0.08	7.67	11.02	378.00	343.06
480	42.0	4.80	0.08	8.00	11.06	352.80	319.04
500	39.0	5.00	0.08	8.33	11.10	327.60	295.18
520	35.0	5.20	0.09	8.67	11.14	294.00	263.94
540	32.0	5.40	0.09	9.00	11.18	268.80	240.43
560	28.0	5.60	0.09	9.33	11.22	235.20	209.61
580	25.0	5.80	0.10	9.67	11.26	210.00	186.46



TP 5 @ 1.5 m

Deformation Dial Reading	Load Dial Reading	Sample Deformation ∆L (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	8.0	0.20	0.00	0.33	10.21	67.20	65.83
40	10.0	0.40	0.01	0.67	10.24	84.00	82.02
60	15.0	0.60	0.01	1.00	10.28	126.00	122.61
80	20.0	0.80	0.01	1.33	10.31	168.00	162.93
100	25.0	1.00	0.02	1.67	10.35	210.00	202.98
120	30.0	1.20	0.02	2.00	10.38	252.00	242.75
140	33.0	1.40	0.02	2.33	10.42	277.20	266.11
160	35.5	1.60	0.03	2.67	10.45	298.20	285.30
180	37.0	1.80	0.03	3.00	10.49	310.80	296.33
200	39.0	2.00	0.03	3.33	10.52	327.60	311.28
220	41.0	2.20	0.04	3.67	10.56	344.40	326.11
240	43.0	2.40	0.04	4.00	10.60	361.20	340.84
260	46.0	2.60	0.04	4.33	10.63	386.40	363.35
280	48.0	2.80	0.05	4.67	10.67	403.20	377.82
300	48.0	3.00	0.05	5.00	10.71	403.20	376.50

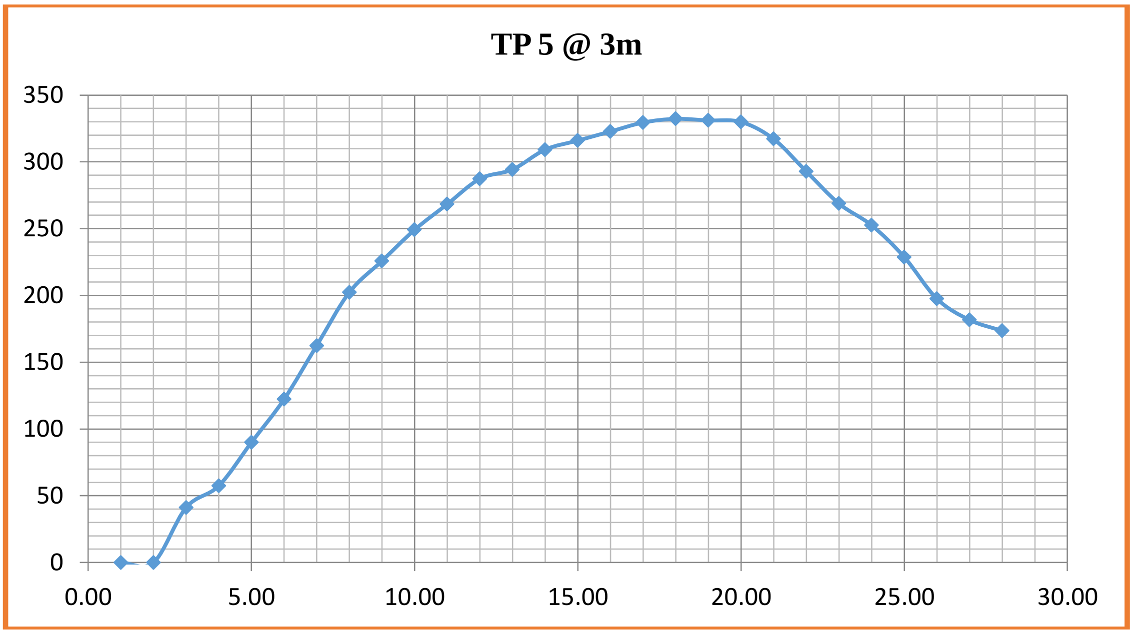
320	47.0	3.20	0.05	5.33	10.75	394.80	367.37
340	46.0	3.40	0.06	5.67	10.78	386.40	358.28
360	45.0	3.60	0.06	6.00	10.82	378.00	349.26
380	44.0	3.80	0.06	6.33	10.86	369.60	340.28
400	43.0	4.00	0.07	6.67	10.90	361.20	331.37
420	42.0	4.20	0.07	7.00	10.94	352.80	322.51



TP 5 @ 3m

Deformation Dial Reading	Load Dial Reading	Sample Deformation ∆L (mm)	Strain	Siren In %	Corrected Area	Load In (N)	Stress (Kpa)
0	0.0	0.00	0.00	0.00	10.17	0.00	0.00
20	5.0	0.20	0.00	0.33	10.21	42.00	41.15
40	7.0	0.40	0.01	0.67	10.24	58.80	57.41
60	11.0	0.60	0.01	1.00	10.28	92.40	89.92
80	15.0	0.80	0.01	1.33	10.31	126.00	122.20
100	20.0	1.00	0.02	1.67	10.35	168.00	162.38
120	25.0	1.20	0.02	2.00	10.38	210.00	202.29
140	28.0	1.40	0.02	2.33	10.42	235.20	225.79

160	31.0	1.60	0.03	2.67	10.45	260.40	249.13
180	33.5	1.80	0.03	3.00	10.49	281.40	268.30
200	36.0	2.00	0.03	3.33	10.52	302.40	287.33
220	37.0	2.20	0.04	3.67	10.56	310.80	294.30
240	39.0	2.40	0.04	4.00	10.60	327.60	309.13
260	40.0	2.60	0.04	4.33	10.63	336.00	315.96
280	41.0	2.80	0.05	4.67	10.67	344.40	322.73
300	42.0	3.00	0.05	5.00	10.71	352.80	329.44
320	42.5	3.20	0.05	5.33	10.75	357.00	332.19
340	42.5	3.40	0.06	5.67	10.78	357.00	331.02
360	42.5	3.60	0.06	6.00	10.82	357.00	329.85
380	41.0	3.80	0.06	6.33	10.86	344.40	317.08
400	38.0	4.00	0.07	6.67	10.90	319.20	292.84
420	35.0	4.20	0.07	7.00	10.94	294.00	268.75
440	33.0	4.40	0.07	7.33	10.98	277.20	252.49
460	30.0	4.60	0.08	7.67	11.02	252.00	228.71
480	26.0	4.80	0.08	8.00	11.06	218.40	197.50
500	24.0	5.00	0.08	8.33	11.10	201.60	181.65
520	23.0	5.20	0.09	8.67	11.14	193.20	173.44



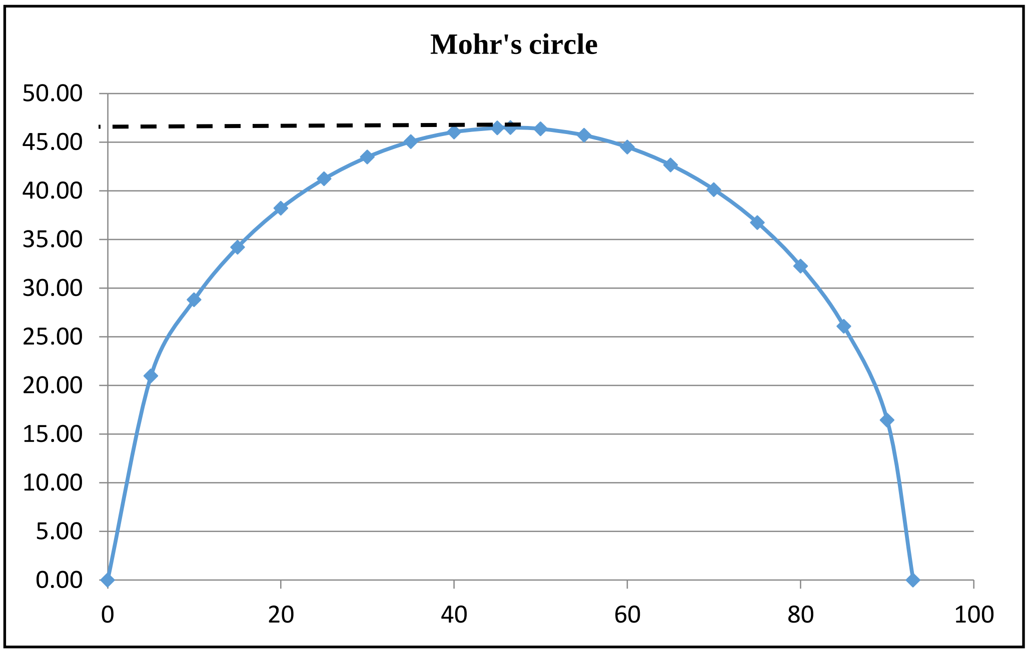
σ	τ
0	0.00
5	20.98
10	28.81
15	34.21
20	38.21
25	41.23
30	43.47
35	45.06
40	46.04
45	46.48
47	46.50
50	46.37
55	45.72
60	44.50
65	42.66
70	40.12
75	36.74
80	32.25
85	26.08
90	16.43
93	0.00

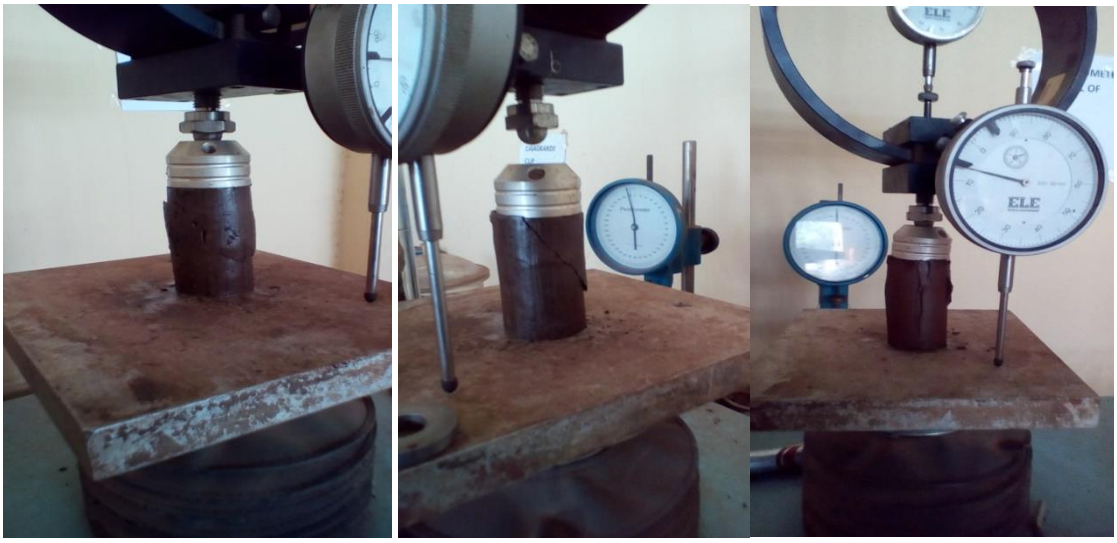
And the undrained shear strength (S_u) of the specimen can be determined by plotting Mohr‟s Circle, which is the radius of the circle:

su=qu/2

Mohr‟s circle is drawn using equation:$(\sigma\text{-}qu/2)^2\text{-}\tau 2{=}(qu/2)^2$

Where σ =axial stress
τ=su=cu=undrainedshearstength
qu=unconfined compressive strength





Some pictures on unconfined compressive test

APPENDIX – E

CONSOLIDATION TEST RESULTS

E.1. Test procedure

One-dimensional consolidation of a soil is determined by means of the apparatus known as consolidometer (sometimes referred to as Oedometer). The test was performed by placing a cylindrical specimen of undisturbed soil sample in a consolidation cell. With regard to specimen dimensions, ASTM D2435-96 specified that 1) the minimum height and diameter was 0.5 in. and 2.00 in., respectively, 2) the height exceed 10 times the maximum particle size, and 3) the diameter: height ratios exceed 2.5.

An undisturbed specimen is recovered using Shelby tube sampling and carefully trimmed of the soil to remove the outer, more disturbed portion of the soil, and to cut a soil specimen that fits into a consolidation ring. Using this approach, a consolidation ring with a slanting edge was slowly and gently pushed onto the undisturbed soil specimen with a diameter larger than the diameter of the ring. As the ring was incrementally slid down onto the soil specimen, excess soil was carefully trimmed away from the sides of the specimen so that the trimmed soil specimen fits closely into the consolidation ring.

The soil-filled consolidation ring is then placed in the consolidation cell. The soil specimen was sandwiched between two porous stones. The bottom stone was fixed to the consolidation cell, while the top stone was fixed to the loading cap used to transfer load to the soil specimen. The porous stones act as freely draining materials so that drainage in the soil specimen was two-way and the drainage distance was half the height of the specimen. The consolidation cell was filled with water and placed in the load frame.

When the consolidation cell is first placed in the load frame, a seating load of 7kpa was applied until the soil saturated fully. Once the seating load was applied, the deformation indicator was set to zero. Loads were applied in steps such a way that the successive load intensity, p, was twice the preceding one. The load intensities used were 50, 100, 200, 400, 800 and 1600 kpa. Each load was being allowed to stand until compression has practically ceased (for 24 hours). The dial readings were taken at elapsed time of 0, ¼, ½, 1, 2, 4, 8, 15, 30, 60, 120, 240, 480, and 1440 minutes from the time the new increment of load was put on the sample. This procedure was followed for all the samples.

Determination of height of solids,Hs , in the soil specimen:

$$Hs = \frac{Ms}{A*Gs*rw}$$

1. Determination of initial height of voids, Hv

$$Hv=H-Hs$$

2. Determination of the initial void ratio, eo, of the specimen

$$eo = \frac{vv}{vs} = \frac{Hv*a}{Hs} *a= \frac{Hv}{Hs}$$

3. For the first incremental loading (total load/unit area of specimen), which causes deformation h1, change in void ratio e_1 :

$$\Delta e_1 = \frac{H_1}{Hs}$$

$\Delta H_{1\,=}$ is obtained from the initial and the final dial readings for the loading. At this time, the effective pressure on the specimen is $\sigma= \sigma_1= \sigma_1$

4. The new void ratio, , after consolidation caused by the pressure increment

$$e_1=e_o-\Delta e_1$$

For the next loading, σ (*note*: σ equals the cumulative load per unit area of specimen), which causes additional deformation H_2, the void ratio e_2 at the end of consolidation can be calculated as:

$$e_2=e_1-\frac{H_2}{Hs}$$

Note that, at this time, the effective pressure on the specimen is $\sigma=\sigma_2=\sigma_2$ Proceeding in similar manner, one can obtain the void ratios at the end of the consolidation for all load increments are presented on table E-3 using load dial readings and final specimen height summarized on table E-1and E-2 for loading unloading respectively.

The effective pressures (σ=σ) and the corresponding void ratios (*e*) at the end of consolidation are plotted on semi logarithmic graph as shown on figure E-1 below.

Table E-1 summery of void ratios at the end of each incremental loading and unloading

Pressure (KPa)	Do	Deformation dial reading at 50% consolidation	Deformation on Dial reading Representing 100% Primary Consolidation	Time for 50% consolidation	Thickness of specimen at 50% consolidation	Half-thickness of specimen at 50% consolidation	Initial deformation reading	Change in Thickness of Specimen ,ΔH	Change in Void Ratio [$\Delta e=\Delta H/H_s$]	Void Ratio [$e=e_0-\Delta e$]	Coefficient of consolidation (Cv) log t method $10^{-3}(cm^2/min)$
50	0.212	0.265	0.318	0.25	19.735	9.9	0.02	0.298	0.032	1.088	2.21
100	0.400	0.474	0.548	6	19.526	9.8	0.02	0.528	0.056	1.064	3.32
200	0.760	0.898	1.035	2	19.103	9.6	0.02	1.015	0.107	1.013	9.91
400	1.388	1.544	1.7	9	18.456	9.2	0.02	1.68	0.178	0.942	2.19
800	2.168	2.284	2.4	8	17.716	8.9	0.02	2.38	0.252	0.868	2.44
1600	2.749	2.875	3	25	17.126	8.6	0.02	2.98	0.315	0.805	7.77
800	2.823	2.793	2.762	32	17.208	8.6	0.02	2.742	0.290	0.830	6.08
400	2.703	2.694	2.684	15	17.307	8.7	0.02	2.664	0.282	0.838	1.30
200	2.657	2.640	2.622	30	17.361	8.7	0.02	2.602	0.275	0.845	6.49
100	2.606	2.586	2.566	20	17.414	8.7	0.02	2.546	0.269	0.851	9.74
50	2.545	2.526	2.506	50	17.475	8.7	0.02	2.486	0.263	0.857	3.90

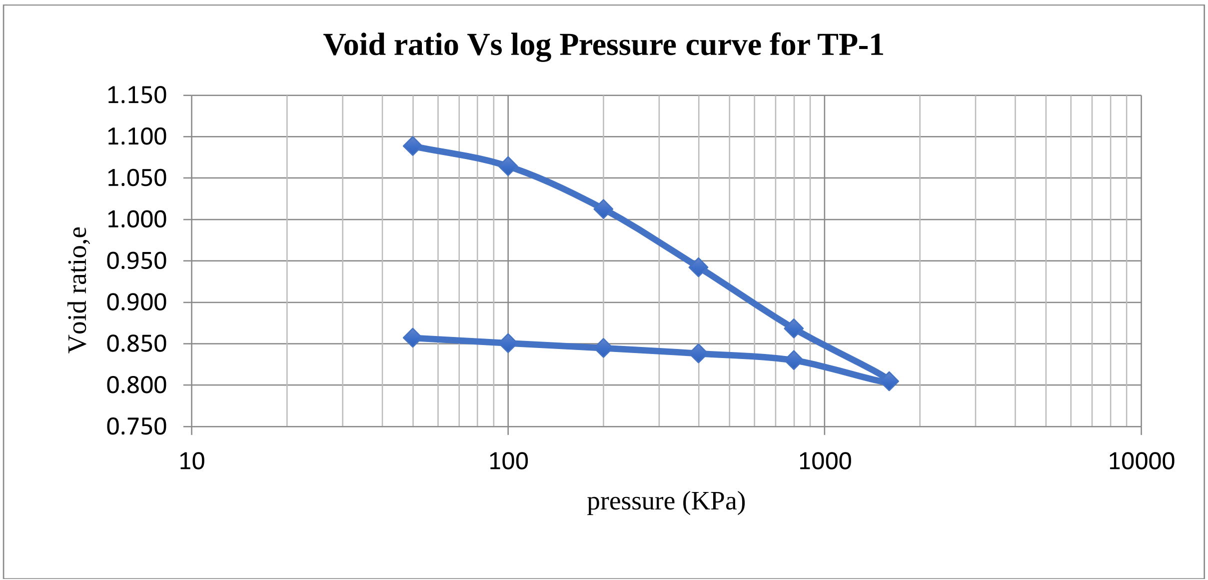


Fig E-1 Effective pressure versus void ratios for each load increment on semi-log scale

Table E-2 summery of void ratios at the end of each incremental loading and unloading

Pressure (KPa)	Do	Deformation dial reading at 50% consolidation	Deformation Dial reading Representing 100% Primary Consolidation	Time for 50% consolidation	Thickness of specimen at 50% consolidation	Half-thickness of specimen at 50% conso.	Initial deformation reading	Change in Thickness of Specimen, ΔH	Change in Void Ratio [$\Delta e=\Delta H/H_s$]	Void Ratio [$e=e_0-\Delta e$]	Coefficient of consolidation (Cv) log t method 10-3(cm2/min)
50	0.366	0.385	0.404	3.5	19.615	9.808	0.144	0.26	0.032	1.439	5.69
100	0.424	0.449	0.474	3	19.551	9.776	0.144	0.33	0.041	1.430	6.64
200	0.785	0.807	0.829	1.5	19.193	9.597	0.144	0.685	0.085	1.386	1.32
400	1.680	1.640	1.600	4	18.360	9.180	0.144	1.456	0.180	1.291	4.91
800	2.502	2.501	2.500	0.8	17.499	8.750	0.144	2.356	0.291	1.180	2.43
1600	3.038	3.369	3.700	5	16.631	8.316	0.144	3.556	0.439	1.032	3.87
800	3.343	3.222	3.100	40	16.779	8.389	0.144	2.956	0.365	1.106	4.84
400	2.791	2.777	2.762	1	17.224	8.612	0.144	2.618	0.323	1.148	1.94
200	2.774	2.745	2.715	0.3	17.256	8.628	0.144	2.571	0.317	1.154	6.48
100	2.695	2.682	2.669	15	17.318	8.659	0.144	2.525	0.312	1.159	1.30
50	2.651	2.637	2.624	60	17.363	8.681	0.144	2.4795	0.306	1.165	3.25

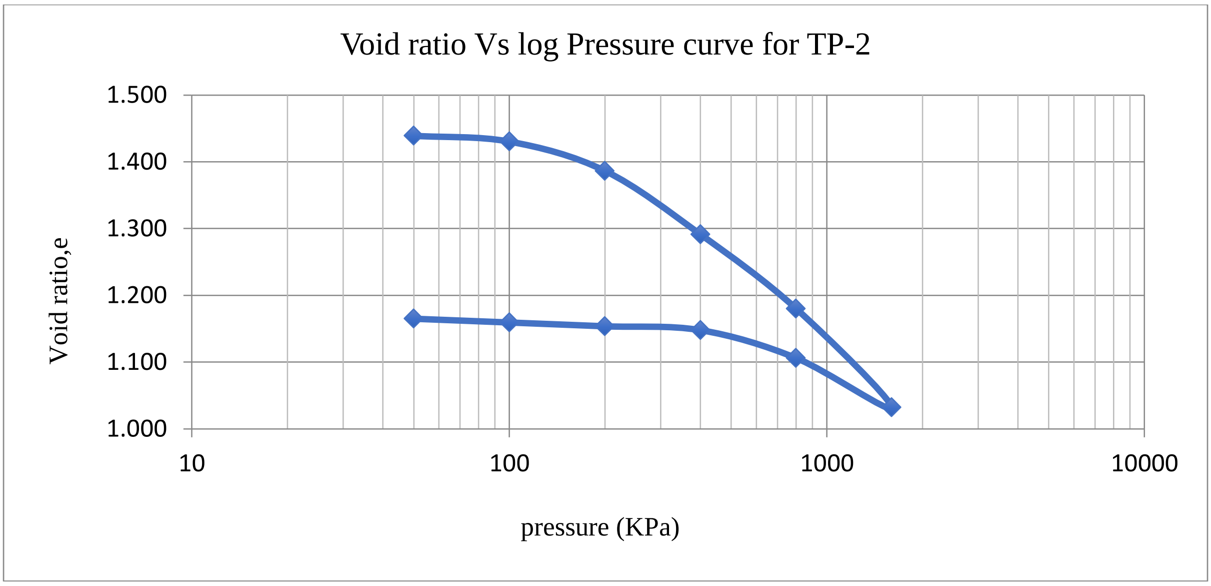


Fig E-2 Effective pressure versus void ratios for each load increment on semi-log scale

Table E-3 summery of void ratios at the end of each incremental loading and unloading

Pressure (KPa)	Do	Deformation dial reading at 50% consolidation	Deformation Dial reading Representing 100% Primary Consolidation	Time for 50% consolidation	Thickness of specimen at 50% consolidation	Half-thickness of specimen at 50% conso.	Initial deformation reading	Change in Thickness of Specimen,ΔH	Change in Void Ratio [$\Delta e=\Delta H/H_s$]	Void Ratio [$e=e_0-\Delta e$]	Coefficient of consolidation (Cv) log t method $10^{-3}(cm^2/min)$
50	0.018	0.035	0.052	5	19.965	9.983	0.02	0.032	0.004	5.756	4.00
100	0.044	0.087	0.129	9	19.914	9.957	0.02	0.109	0.014	5.746	2.22
200	0.286	0.388	0.490	5	19.612	9.806	0.02	0.47	0.059	5.701	3.98
400	0.840	1.035	1.230	30	18.965	9.483	0.02	1.21	0.151	5.609	6.60
800	1.420	1.735	2.050	40	18.265	9.133	0.02	2.03	0.253	5.507	4.91
1600	2.196	2.533	2.870	80	17.467	8.734	0.02	2.85	0.356	5.404	2.44
800	2.942	2.756	2.570	40	17.244	8.622	0.02	2.55	0.318	5.442	4.86
400	2.518	2.369	2.220	150	17.631	8.816	0.02	2.2	0.275	5.485	1.30
200	2.162	2.031	1.900	180	17.969	8.985	0.02	1.88	0.235	5.525	1.09
100	1.788	1.669	1.550	160	18.331	9.166	0.02	1.53	0.191	5.569	1.23
50	1.494	1.417	1.340	220	18.583	9.292	0.02	1.32	0.165	5.595	8.96

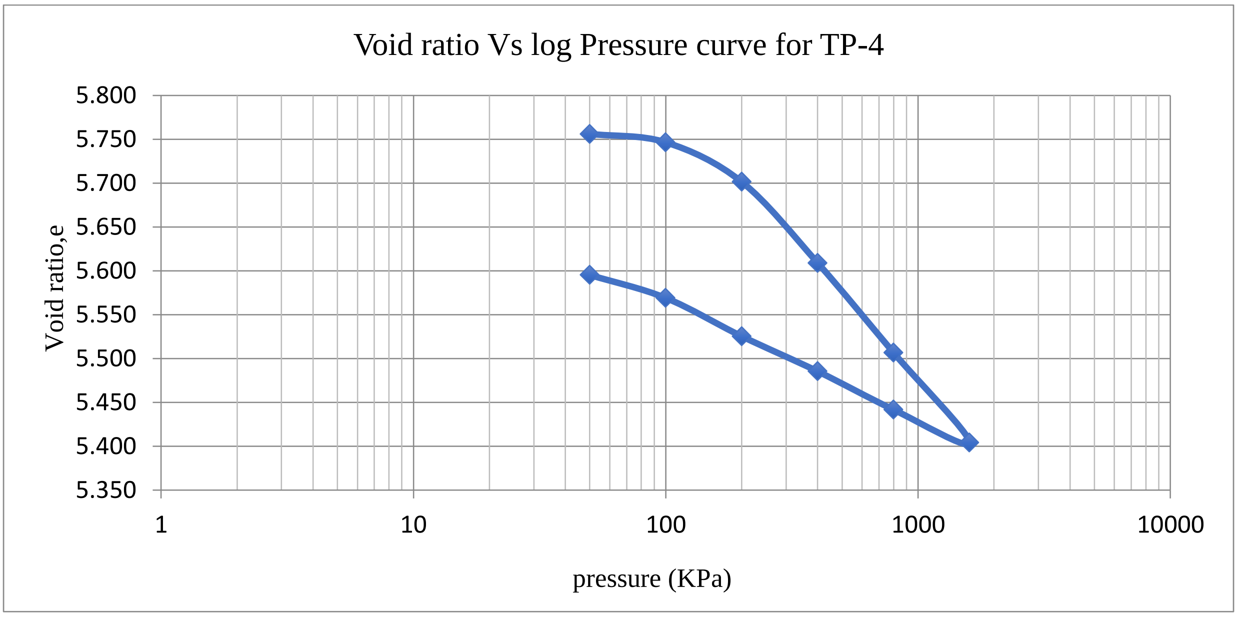


Fig E-3 Effective pressure versus void ratios for each load increment on semi-log scale

E.1.3.Coefficient of consolidation cv

i. Logarithm of time fitting method

<u>For 50kpa</u>

Using the procedure presented previously in this document sample graphical procedure for the given loading is presented below:

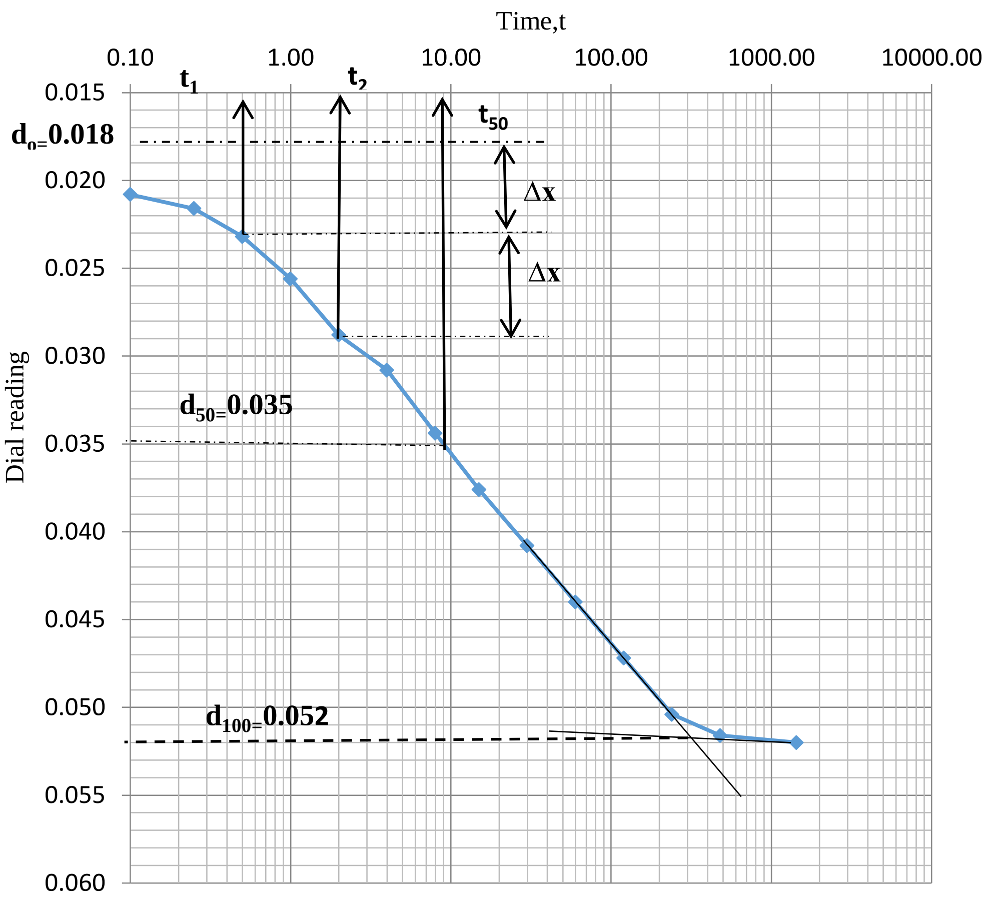


Fig C-2 Typical curve for determining Cv using log-time method

$$d_{50} = \frac{d_{100} + d_0}{2}$$

From the figure we can read t_{50}

$$H_{dr} = \frac{Hav}{2} = \frac{h_o + h_f}{4} = \frac{h_o - d_{50}}{2}$$

Where Hdr=drainage path

Ho=Initial height of the specimen=2cm

d_{50}=Compression of sample up to 50% consolidation.

$$Cv=0.197*\frac{H_{dr}^2}{t}$$

In similar manner cvfor each incremental loading can be determined using consolidation data given and the results are summarized in table C-5 below:

Table E-3 summery of void ratios at the end of each incremental loading and unloading

Pressure (KPa)	Do	Deformation dial reading at 50% consolidation	Deformation Dial reading Representing 100% Primary Consolidation	Time for 50% consolidation	Thickness of specimen at 50% consolidation	Half-thickness of specimen at 50% consolidation	Initial deformation reading	Change in Thickness of Specimen,ΔH	Change in Void Ratio [Δe=ΔH/H_s]	Void Ratio [e=e_0-Δe]	Coefficient of consolidation (Cv) log t method 10^{-3}(cm^2/min)
50	0.212	0.265	0.318	0.25	19.735	9.9	0.02	0.298	0.032	1.088	2.21
100	0.400	0.474	0.548	6	19.526	9.8	0.02	0.528	0.056	1.064	3.32
200	0.760	0.898	1.035	2	19.103	9.6	0.02	1.015	0.107	1.013	9.91
400	1.388	1.544	1.7	9	18.456	9.2	0.02	1.68	0.178	0.942	2.19
800	2.168	2.284	2.4	8	17.716	8.9	0.02	2.38	0.252	0.868	2.44
1600	2.749	2.875	3	25	17.126	8.6	0.02	2.98	0.315	0.805	7.77
800	2.823	2.793	2.762	32	17.208	8.6	0.02	2.742	0.290	0.830	6.08
400	2.703	2.694	2.684	15	17.307	8.7	0.02	2.664	0.282	0.838	1.30
200	2.657	2.640	2.622	30	17.361	8.7	0.02	2.602	0.275	0.845	6.49
100	2.606	2.586	2.566	20	17.414	8.7	0.02	2.546	0.269	0.851	9.74
50	2.545	2.526	2.506	50	17.475	8.7	0.02	2.486	0.263	0.857	3.90

ii. Square root of time fitting method

$$cv=0.848\frac{Hdr^2}{t_{90}}$$

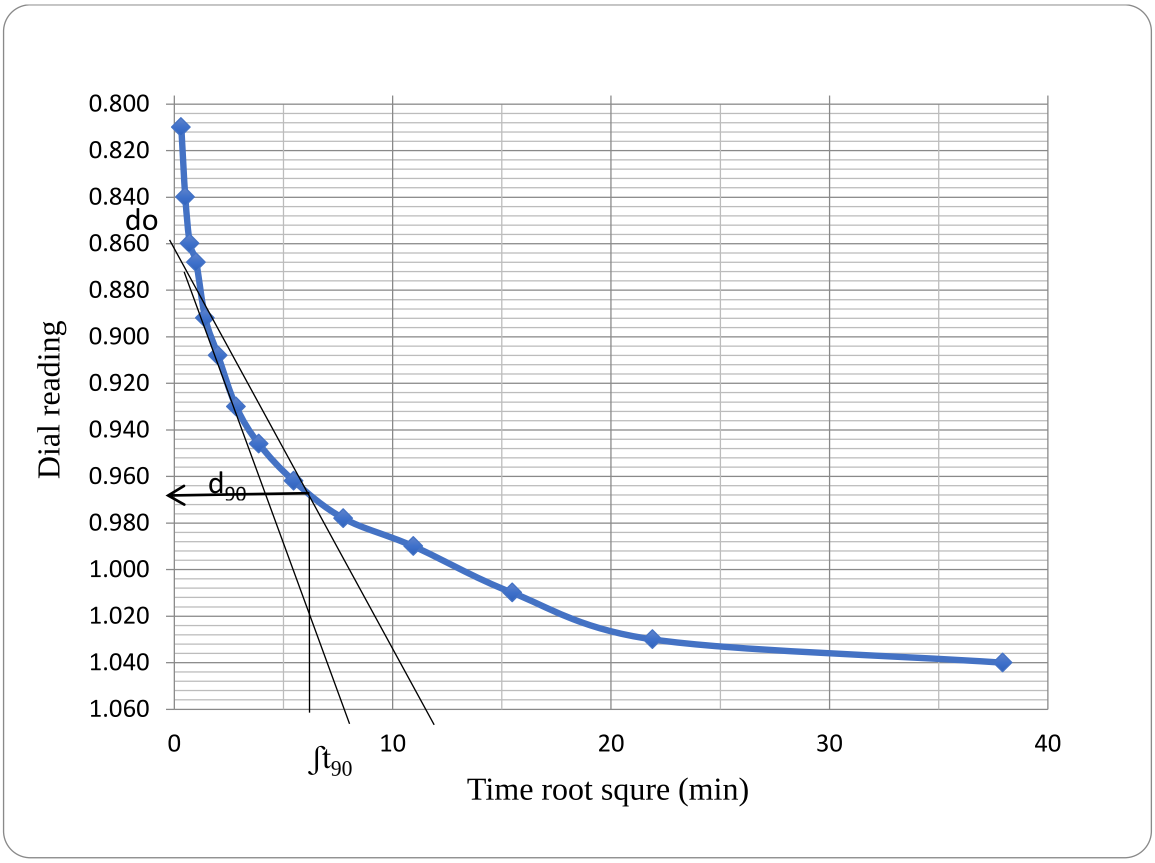


Fig C-3 typical curve for determination of using square root of time method

From the above figure we get do,d90,t90,d50

$$d_{100}=d_o+1.11(d_{90}-d_o)$$

$$Hdr=\frac{Hav}{2}$$

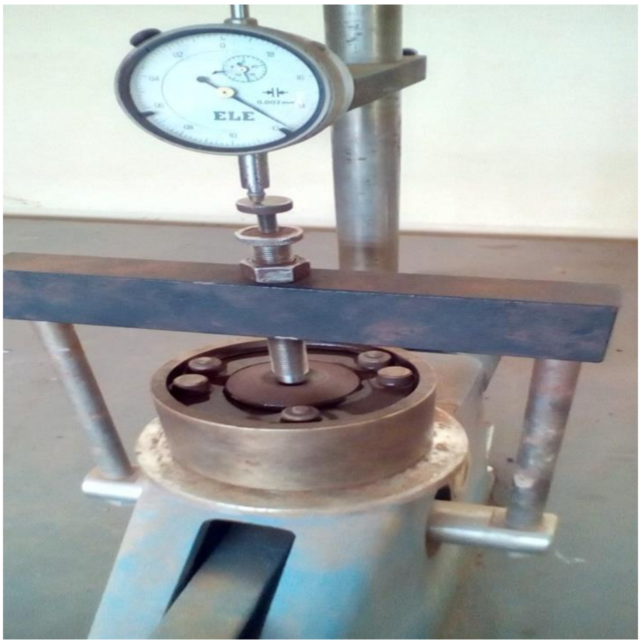
$$cv=0.848*\frac{Hdr^2}{t}$$

For the desired loading range Cv can be determined by taking the average value.

In similar manner one can determine Cv using square root of time method for each incremental loading for all samples is summarized below.

Table E-1 Dial gauge reading and final specimen height for each incrementalloading

Pressure (KPa)	do	d_{90}	d_{100}	d_{50}	90%	t_{90}(min)	Hdr(cm)	Cv*10^-3 cm^2/min	Coefficient of consolidation Cv (m^2/year)
50	0.26	0.278	0.28	0.27	1.8	3.2	9.865	6.3	0.25
100	0.42	0.472	0.478	0.449	3	9	9.776	4.05	0.09
200	0.86	0.968	0.98	0.92	6.2	38.4	9.54	5.65	0.02
400	1.45	1.62	1.639	1.544	4.5	20.3	9.228	1.4	0.04
800	2.23	2.56	2.597	2.413	5.5	30.3	8.793	1.49	0.02
1600	2.75	2.79	2.794	2.772	4	16	8.614	4.95	0.04
800	2.82	2.78	2.776	2.798	9.75	95.1	8.601	2.4	0.01
400	2.7	2.69	2.689	2.694	5.5	30.3	8.653	3.21	0.02
200	2.65	2.64	2.639	2.644	4	16	8.678	8.56	0.04
100	2.59	2.58	2.579	2.584	4	16	8.708	1.05	0.04
50	2.54	2.57	2.573	2.557	1.5	2.3	8.722	6.6	0.29



APPENDIX – F

PERMEABILITY TEST RESULT

Pit 1 at 3m depth for 10 No. of compaction

Specimen Data		Falling head data sheet			
Specimen Mass (g)	1150	Trial	01	02	03
Specimen Height, L (cm)	11.6	Head, h_o (cm)	83.2	82.3	81.5
Specimen diameter, D (cm)	10.2	Head,h_1 (cm)	61.5	58.8	59
Bulk density, g (g/cm^2)	1.21	Time, t (s)	28	29	30
Water Content, w	22.62	Temperature, T (^oc)	21	20	20
Dry density,g_{dry}(g/cm^2)	**1.00**	Volume, (ml)	50	52	51
Aeragecolected volume (cm3)	51	Height deroped(cm)	21.7	23.5	22.5
Aerage of height deroped (cm)	22.57	Permeability at T^oc, K_T	2.98E-04	3.20E-04	2.98E-04
Initial void ratio, e	**1.38**	R_t for T	0.9761	1.0000	1.0000
Cross-sectional area of stand pipe, a (cm^2)	2.26	Permeability at 20^oC, K_{20}	2.91E-04	3.20E-04	2.98E-04
Cross-sectional area of soil specimen, A (cm^2)	81.67	**Average K_{20} (cm/s)**	**3.03E-04**		

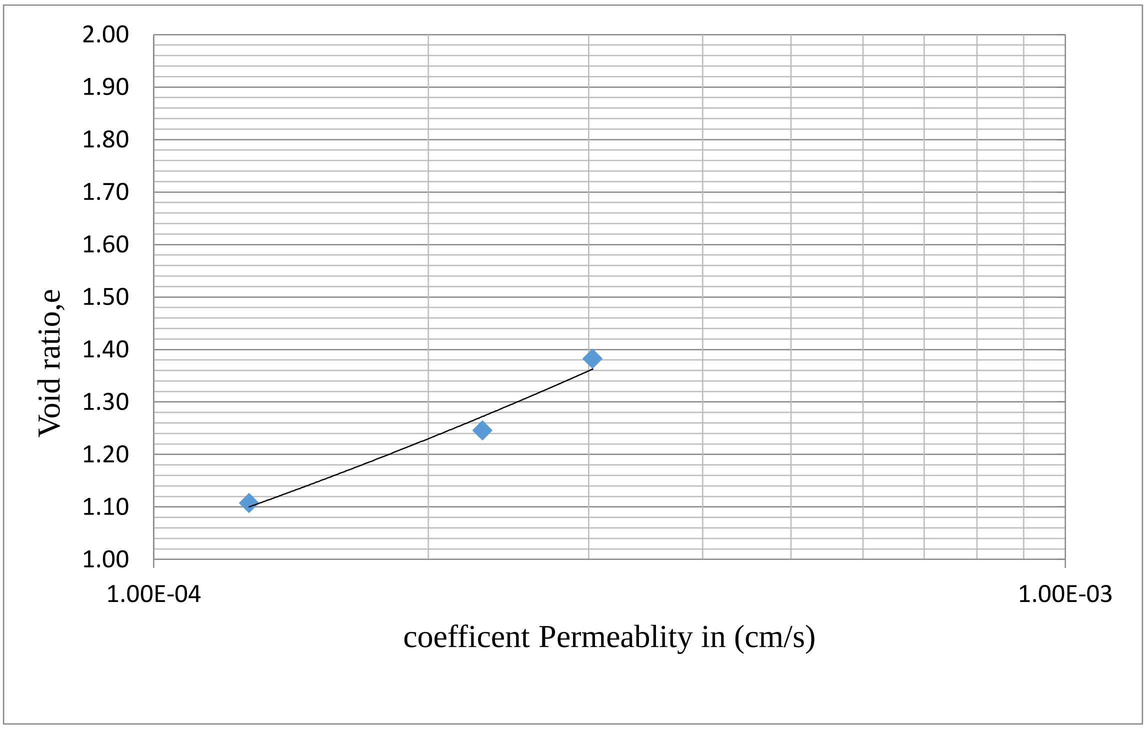
Pit 1 at 3m depth for 20 No. of compaction

Specimen Data		Falling head data sheet			
Specimen Mass (g)	1220	Trial	01	02	03
Specimen Height, L (cm)	11.6	Head, h_o (cm)	92.7	90	88.5
Specimen diameter, D (cm)	10.2	Head,h_1 (cm)	69.4	68.8	67.1
Bulk density, g (g/cm^2)	1.29	Time, t (s)	34	33	35
Water Content, w	29.74	Temperature, T (^oc)	20	20	20
Dry density,g_{dry}(g/cm^2)	**1.06**	Volume, (ml)	51	50	50
Aeragecolected volume (cm3)	50.33	Height deroped (cm)	23.3	21.2	21.4
Aerage of height deroped (cm)	21.97	Permeability at T^oc, K_T	2.39E-04	2.28E-04	2.22E-04
Initial void ratio, e	**1.25**	R_t for T	1.0000	1.0000	1.0000
Cross-sectional area of stand pipe, a (cm^2)	2.29	Permeability at 20^oC, K_{20}	2.39E-04	2.28E-04	2.22E-04
Cross-sectional area of soil specimen, A (cm^2)	81.67	**Average K_{20} (cm/s)**	**2.29E-04**		

Pit 1 at 3m depth for 30 No. of compaction

Specimen Data		
Specimen Mass	(g)	1300
Specimen Height, L	(cm)	11.6
Specimen diameter, D	(cm)	10.2
Bulk density, g	(g/cm^2)	1.37
Water Content, w		29.74
Dry density,g_{dry}(g/cm^2)		**1.13**
Aeragecolected volume	(cm3)	51.00
Aerage of height deroped	(cm)	21.33
Initial void ratio, e		**1.11**
Cross-sectional area of stand pipe, a (cm^2)		2.39
Cross-sectional area of soil specimen, A (cm^2)		81.67

Falling head data sheet				
Trial		01	02	03
Head, h_o	(cm)	94.3	89.5	89.2
Head,h_1	(cm)	73.3	68	67.7
Time, t	(s)	60	60	60
Temperature, T	(^{o}c)	21	21	21
Volume,	(ml)	53	50	50
Height deroped	(cm)	21	21.5	21.5
Permeability at T^{o}c, K_T		1.23E-04	1.34E-04	1.34E-04
R_t for T		0.9761	0.9761	0.9761
Permeability at 20^{o}C, K_{20}		1.20E-04	1.31E-04	1.31E-04
Average K_{20}	**(cm/s)**	**1.27E-04**		



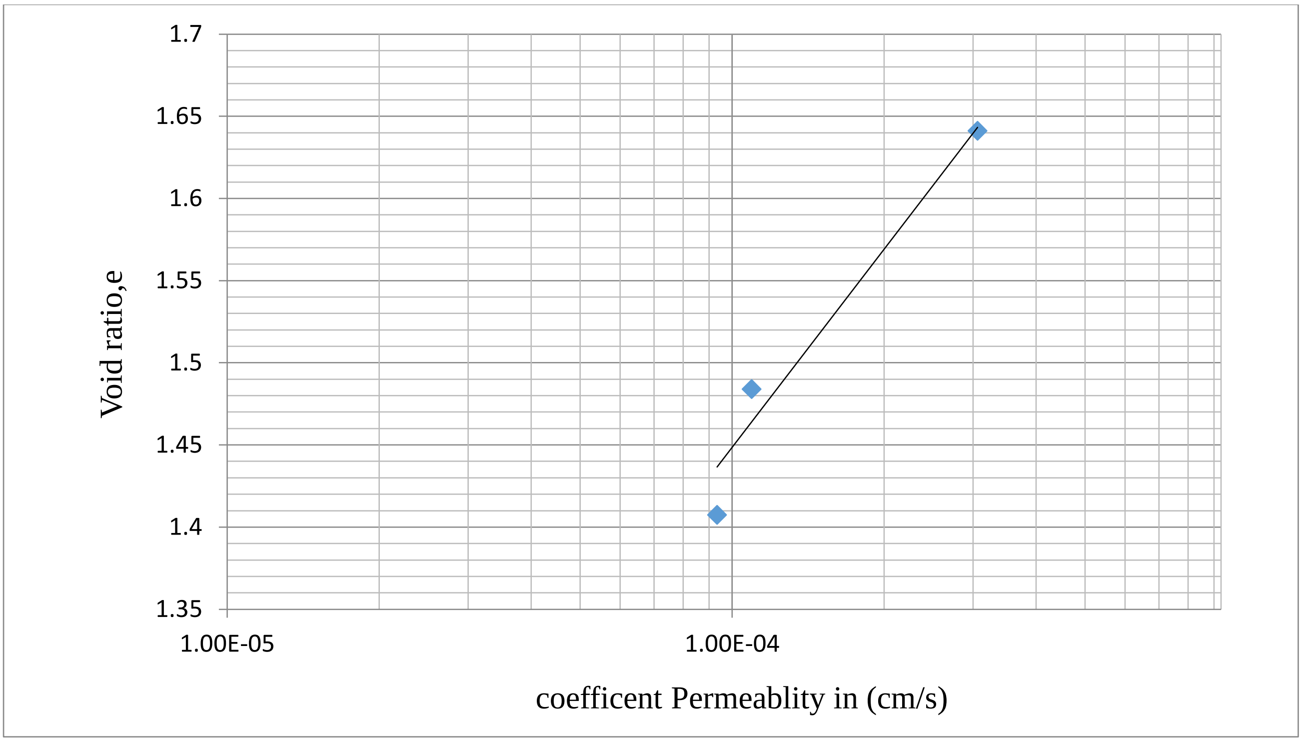
Pit 2 at 3m depth for 10 No. of compaction

Specimen Data			Falling head data sheet			
Specimen Mass (g)	1185		Trial	01	02	03
Specimen Height, L (cm)	11.6		Head, h_o (cm)	86	90.8	90.1
Specimen diameter, D (cm)	10.2		Head, h_1 (cm)	62.9	70	69.7
Bulk density, g (g/cm^2)	1.25		Time, t (s)	30	24	23
Water Content, w	31.35		Temperature, T (^oc)	21	21	21
Dry density, g_{dry} (g/cm^2)	**1.03**		Volume, (ml)	50	50	50
Aeragecolected volume (cm3)	50		Height deroped (cm)	23.1	20.8	20.4
Aerage of height deroped (cm)	21.43		Permeability at T^oc, K_T	2.97E-04	3.09E-04	3.18E-04
Initial void ratio, e	**1.64**		R_t for T	0.9761	0.9761	0.9761
Cross-sectional area of stand pipe, a (cm^2)	2.33		Permeability at 20^oC, K_{20}	2.90E-04	3.02E-04	3.11E-04
Cross-sectional area of soil specimen, A (cm^2)	81.67		**Average K_{20} (cm/s)**	**3.06E-04**		

Pit 2 at 3m depth for 20 No. of compaction

Specimen Data			Falling head data sheet			
Specimen Mass (g)	1260		Trial	01	02	03
Specimen Height, L (cm)	11.6		Head, h_o (cm)	80.3	84.3	83
Specimen diameter, D (cm)	10.2		Head, h_1 (cm)	57.6	63.3	62.3
Bulk density, g (g/cm^2)	1.33		Time, t (s)	75	74	76
Water Content, w	30.30		Temperature, T (^oc)	22	22	22
Dry density, g_{dry} (g/cm^2)	**1.10**		Volume, (ml)	50	50	50
Aeragecolected volume (cm3)	50		Height deroped (cm)	22.7	21	20.7
Aerage of height deroped (cm)	21.47		Permeability at T^oc, K_T	1.26E-04	1.10E-04	1.08E-04
Initial void ratio, e	**1.48**		R_t for T	0.9531	0.9531	0.9531
Cross-sectional area of stand pipe, a (cm^2)	2.33		Permeability at 20^oC, K_{20}	1.20E-04	1.05E-04	1.02E-04
Cross-sectional area of soil specimen, A (cm^2)	81.67		**Average K_{20} (cm/s)**	**1.09E-04**		

Pit 2 at 3m depth for 30 No. of compaction						
Specimen Data		**Falling head data sheet**				
Specimen Mass (g)	1300	Trial	01	02	03	
Specimen Height, L (cm)	11.6	Head, h_o (cm)	88.4	90.8	89.7	
Specimen diameter, D (cm)	10.2	Head,h_1 (cm)	67.4	70.1	69.7	
Bulk density, g (g/cm^2)	1.37	Time, t (s)	76	78	78	
Water Content, w	28.77	Temperature, T (^{o}c)	23	23	23	
Dry density,g$_{dry}$(g/cm^2)	**1.13**	Volume, (ml)	50	50	50	
Aeragecolected volume (cm^3)	50	Height deroped (cm)	21	20.7	20	
Aerage of height deroped (cm)	20.57	Permeability at T^{o}c, K_T	1.06E-04	9.86E-05	9.62E-05	
Initial void ratio, e	**1.41**	R_t for T	0.9311	0.9311	0.9311	
Cross-sectional area of stand pipe, a (cm^2)	2.43	Permeability at 20^{o}C, K_{20}	9.88E-05	9.18E-05	8.95E-05	
Cross-sectional area of soil specimen, A (cm^2)	81.67	**Average K_{20} (cm/s)**	**9.34E-05**			



Pit 4 at 3m depth for 10 No.of compaction				
Specimen Data		**Falling head data sheet**		
Specimen Mass (g)	1105	Trial	01	02
Specimen Height, L (cm)	11.6	Head, h_o (cm)	81	88.5
Specimen diameter, D (cm)	10.2	Head,h_1 (cm)	70.2	76.7
Bulk density, g (g/cm^2)	1.17	Time, t (s)	400	399
Water Content, w	28.51	Temperature, T (^oc)	23	22
Dry density,g_{dry} (g/cm2)	**0.96**	Volume, (ml)	30	30
Aeragecolected volume (cm3)	30	Height deroped (cm)	10.8	11.8
Aerage of height deroped (cm)	11.30	Permeability at T^oc, K_T	1.16E-05	1.16E-05
Initial void ratio, e	**1.59**	R_t for T	0.9311	0.9531
Cross-sectional area of stand pipe, a (cm^2)	2.65	Permeability at 20^oC, K_{20}	1.08E-05	1.11E-05
Cross-sectional area of soil specimen, A (cm^2)	81.67	**Average K_{20} (cm/s)**	**1.10E-05**	

Pit 4 at 3m depth for 20 No. of compaction				
Specimen Data		**Falling head data sheet**		
Specimen Mass (g)	1155	Trial	01	02
Specimen Height, L (cm)	11.6	Head, h_o (cm)	85	89.7
Specimen diameter, D (cm)	10.2	Head,h_1 (cm)	75.5	79.5
Bulk density, g (g/cm^2)	1.22	Time, t (s)	185	180
Water Content, w	37.73	Temperature, T (^oc)	23	23
Dry density,g_{dry}(g/cm^2)	**1.01**	Volume, (ml)	25	27
Aeragecolected volume (cm3)	26	Height deroped (cm)	9.5	10.2
Aerage of height deroped (cm)	9.85	Permeability at T^oc, K_T	2.07E-05	2.17E-05
Initial void ratio, e	**1.48**	R_t for T	0.9311	0.9311
Cross-sectional area of stand pipe, a (cm^2)	2.64	Permeability at 20^oC, K_{20}	1.93E-05	2.02E-05
Cross-sectional area of soil specimen, A (cm^2)	81.67	**Average K_{20} (cm/s)**	**1.97E-05**	

Pit 4 at 3m depth for 30 No. of compaction						
Specimen Data				**Falling head data sheet**		
Specimen Mass	(g)	1285		Trial	01	02
Specimen Height, L	(cm)	11.6		Head, h_o (cm)	86	87
Specimen diameter, D	(cm)	10.2		Head,h_1 (cm)	75	76.7
Bulk density, g	(g/cm^2)	1.36		Time, t (s)	600	600
Water Content, w		37.02		Temperature, T (°c)	23	22
Dry density,g$_{dry}$(g/cm^2)		**1.12**		Volume, (ml)	5	5
Aeragecolected volume	(cm3)	5		Height deroped (cm)	11	10.3
Aerage of height deroped	(cm)	10.65		Permeability at T°c, K_T	1.31E-06	1.21E-06
Initial void ratio, e		**1.23**		R_t for T	0.9311	0.9531
Cross-sectional area of stand pipe, a	(cm^2)	0.47		Permeability at 20°C, K_{20}	1.22E-06	1.15E-06
Cross-sectional area of soil specimen, A (cm^2)		81.67		**Average K_{20} (cm/s)**	**1.18E-06**