Correlation Between Consolidation Parameters and Index Properties of Remolded Fine-grained Soil

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A Thesis Submitted to Department of Civil Engineering

School of Civil Engineering and Architecture

Presented in a Partial Fulfillment of the Requirement for the Degree Master's in Geotechnical Engineering

Office of Graduate Studies

Adama Science and Technology University

September,2022

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Advisor's

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Declaration

I hereby declare that this Master Thesis entitled" Correlation Between Consolidation Parameters and Index Properties of Remolded Fine-grained Soil" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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LIST OF ABBREVIATION AND SYMBOLS

SPSS	Statistical package of social science
ASTM	American society for testing and materials
1-D	One-dimensional
AASHTO	American Association of state Highway and Transportation Official
FSI	Free swell index
USCS	Unified Soil Classification system
GPS	Geographic position system
CH	High plasticity clay
MH	High plasticity silt
MDD	Maximum dry density
OMC	Optimum moisture content
ml	milliliters
mm	millimeters
Cc	Compression index
Cs	swelling index
Cv	consolidation coefficient
Sign.	significant level
N	numbers of sample
|R|	magnitude of Pearson correlation coefficient
%	Percent
µm	micro-meters
g/cm^3	gram per cubic centimeters
p	load intensity or pressure
log	logarithm
m^2/yr	meter square per year
mm^2/min	millimeter square per minute
Min	Minimum
Max	Maximum
KN/m^2	Kilo-newton per meter square
IS	Iso standard

Is	shrinkage index
lb	pounds
Sc	consolidation settlements
σ'o	effective present vertical stress
σ'c	effective previous vertical stress
m_v	coefficient of volume compression
Cα	secondary consolidation coefficient
vd	volume in water
vk	volume in Kerosine
OCR	over consolidation ratio
LL	liquid limit
PL	plastic limit
PI	plastic index
Wn	natural moisture content
e_o	initial void ratio
R^2	Coefficient of Determination;
Gs	Specific gravity
T_v	Time factor
H_{dr}	Drainage length
T_{90}	time factor at 90% of displacement
D_{90}	90% of displacement or deformation

ABSTRACT

The engineering properties of soils are measured either in the field or the laboratory. Measurement of some of the engineering properties of soils, such as consolidation parameters, requires geotechnical equipment and expert manpower, which could be costly and time taking. To mitigate this issue, several researchers approximated these soil properties based on the easily available basic property values and in-situ test findings. This study presents correlation equations for predicting consolidation parameters from basic soil index tests. The consolidation parameters considered are compression index (Cc), swelling index (Cs), and consolidation coefficient (Cv). In order to develop the correlation equations for these consolidation characteristics from the index properties of the soil, disturbed soil samples were collected from eleven (11) tests pits in Bishoftu at depths of 1.5m & 3m. Then, the laboratory tests including Atterberg limit test, specific gravity test, compaction test, and one-dimensional consolidation test were conducted. After having all the test results, new correlations equations for the consolidation characteristics have been developed by statistical analysis using linear regression analysis methods for the prediction of Cc, Cs & Cv from liquid limit, plastic limit, plastic index, specific gravity, and initial void ratio of the fine-grained soils. According to the correlation analysis LL, PL, PI & eo yield a strong relationship with compression index and swelling index. Similarly, PI & LL have a better relationship with the consolidation coefficient.

The correlation equations of Cc, Cs &Cv from index properties were developed from single and multiple linear regression analysis, The results from the single regression analysis indicated correlations using LL and PI provided better estimates of Cc, Cs and Cv respectively. The results from the multiple regression analysis indicated that correlations using LL in combination with eo, PL in combination with PI, and PI in combination with eo provided better estimates of Cc, Cs and Cv, respectively.

Finally, comparison between the newly developed correlation equations with the existing correlation equation was made. The result of the comparison of the newly developed correlation equations with existing correlation equations indicates that the correlation equations developed from this study perform better than the existing correlations.

KEY WORDS: *consolidation parameters, regression analysis, one-dimensional consolidation, index property*

CHAPTER ONE

INTRODUCTION

1.1. Back Grounds

Engineering properties of soils are important in the analysis and design of structures resting on soils masses. The engineering properties of soils are either measured in the field or in the laboratory. Measurement of some of the engineering properties of soils, such as consolidation parameters, requires geotechnical equipment and expert manpower, which could be costly and time taking. As a result, some soil properties are approximated based on index properties of soils that can be measured easily(Vikas Kumar Jain *et al*, 2015).

In geotechnical engineering correlations and empirical relationships are used extensively. Correlations and empirical relationships can be used to forecast the value of a parameter based on the values of other, possibly more easily determined parameters provided that the appropriate correlations are employed. In general, the parameters which are more easily obtained are correlated to the parameters that are more difficult to get(Xin Kang *et al*, 2015).

There are useful correlations between engineering properties such as shear strength, compressibility, coefficient of consolidation, and index properties obtained from simple routine testing of cohesive soil. As a result, there is a worldwide trend toward developing correlation equations between the above-mentioned properties and soil index properties to accelerate the design process(YOHANNES ANOLE, 2018).

Soil compressibility characteristics should be determined for the safe and cost-effective construction of civil engineering projects. The compression index and swelling index are essential compressibility parameters to consider when calculating settlement for fine-grained soil layers. Based on Terzaghi's consolidation theory, these characteristics are measured using a laboratory Oedometer test on undisturbed or remolded samples. (Ozhan Ozkan, 2016). However, this test is time-consuming, relatively costly, and subject to human mistakes. As a result, correlations that approximate these indices to other soil parameters have been developed (Petros Xanthopoulos *et al*, 2019) .

The compressibility of remolded soils is useful in engineering structures built on fill surfaces, such as embankments in highways, railways, canals, foundation pads, and road bases

(P.K.Jain *et al*, 2016). Thus, this thesis aims to correlate consolidation parameters with basic soil properties of remolded fine-grained soil.

1.2. Problem Statement

Soil settlement is proportional to soil compressibility(V Elamathi *et al*, 2020). In the construction industry, design soil settlement is evaluated using consolidation parameters. An Oedometer test is used in the laboratory to determine these parameters. However, measuring consolidation parameters from the Oedometer test is time-consuming and costly(Ozhan Ozkan *et al*, 2016). The use of correlation equations to estimate consolidation parameters with basin index properties will assist to address this problem. This study will develop correlation equations for estimating consolidation parameters for fine-grained soils.

1.3. Significance of the Study

This study will provide correlation equations that can be used to estimate consolidation parameters from basic index properties of soils. The correlation equations can be used for a quick estimate of consolidation parameters in the absence of laboratory testing equipment and budget for conducting the test. Finally, the study gives an estimation of consolidation parameters for engineers and researchers to design structures around Bishoftu town.

1.4. General Objective

The main objective of this study is to develop correlation equations for estimating consolidation parameters of fine-grained soils from index properties.

1.3.1. Specific Objective: The specific objectives of this study is to:

- determine the index properties of disturbed fine-grained soil in the laboratory
- determine the consolidation parameters of remolded fine-grained soil in a laboratory
- develop an empirical correlation equation between consolidation parameters and index properties of fine-grained soil
- examine the performance of the proposed correlations as compared to existing equations.

1.5. Scope and Limitation of the Study

In this study, the correlation equations for predicting consolidation parameters from index soil tests are developed based on laboratory tests carried out on 18 soil samples from 11 test pits in Bishoftu town. The consolidation parameters are determined from consolidation tests conducted on remolded soil samples by compacting the soils at optimum moisture content and maximum dry density.

Concerning the statistical analysis, simple regression and multiple regression models were made and the required correlation was carried out by applying the scattering diagram method and mathematical method using SPSS-26 version software.

The secondary consolidation parameters of the soil have not been addressed in this study.

1.6. Organization of the Thesis

The thesis consists of five chapters. The first chapter is the introduction part and discusses the general overview of correlation in geotechnical engineering, objective, statement of problems, scope, limitation, and significance of the study. The second chapter is a literature review on the compressibility of soil, index properties of soil, and the previously developed correlation equation between index properties and consolidation parameters in detail. Chapter three deals with a highlight of the study area, sample collection, and laboratory test results of the study area. The fourth chapter focuses on correlation, regression analysis, and validation of the developed correlation equation in detail. The fifth chapter presented the conclusion and recommendation of the study. Finally, details of the laboratory test result and regression analyses are enclosed in the appendix section.

CHAPTER TWO

LITERATURE REVIEW

2.1. Compressibility of Soil

2.1.1. General

The expulsion of water between soil grains and the shifting of particles to a new location to attain greater density are the main causes of clay compressibility. In other words, soil compressibility is defined as the volume reduction of soil characteristics under compressive stress(Guruprasad Jadhav, 2016). According to Terzaghi (1943), A process of consolidation occurs when the water content of saturated soil decreases without being replaced by air. Consolidation is crucial in the stability analysis of an embankment, footings, or column built on clayey soils(Bhandary P. Radhika *et al*, 2017). Soil compression happens as a result of the following factors:

i. Compression of solid particles and water in the voids.

Solid particle compression is negligible. Water is almost incompressible in the range of forces involved in soil engineering, therefore compression of water in voids is similarly extremely low. As a result, the compression of solid particles and water in voids is minimal(Guruprasad Jadhav, 2016).

ii. Compression and expulsion of air in the voids.

Only partially saturated and dry soils contain air. Because air is very compressible, it compresses quickly. Furthermore, as soon as the load is applied, the air is rapidly released. However, the air in void compression and expulsion are irrelevant to saturated soil(Guruprasad Jadhav, 2016).

iii. Expulsion of water in the voids

When the soil is fully saturated, compression occurs mostly due to water expulsion from the voids. Consolidation is the compression of saturated soil under steady static pressure. It is entirely due to water expulsion from the voids. As the consolidation of soils occurs, Water escapes. The solid particles roll and slide from one location to the next, achieving tighter packing. It is worth noting that the decrease in soil volume happens not as a result of solids or water compression, but instead as a result of particles moving locations when the water leaves. (Guruprasad Jadhav, 2016).

2.2. One-Dimensional Consolidation Theory

Terzaghi proposed the theory of one-dimensional consolidation in 1925. The following are the fundamental assumptions in the formulation of a mathematical equation(K.R. ARORA, 2004):

- The soil is isotropic and homogenous.
- The soil is completely saturated.
- In the void, soil particles and water are incompressible.
- The expulsion of water from the voids causes consolidation.
- Darcy's law remains valid throughout the consolidation process.
- Soil is confined laterally, and consolidation occurs only in the axial direction. Water drainage also occurs only in the vertical direction.

Terzaghi discovered that the consolidation of a soil specimen can be quickly characterized by slopes of an $e - log\sigma$ plot, where σ is the applied effective vertical stress to the sample and e is the resulting void ratio of the sample, through the development and implementation of the consolidation test (or oedometer). On saturated specimens, the standard one-dimensional consolidation test is often conducted using an Odometer(Boo Hyun Nam *et al*, 2019). The figure below illustrates the schematic diagram for performing one consolidation test.

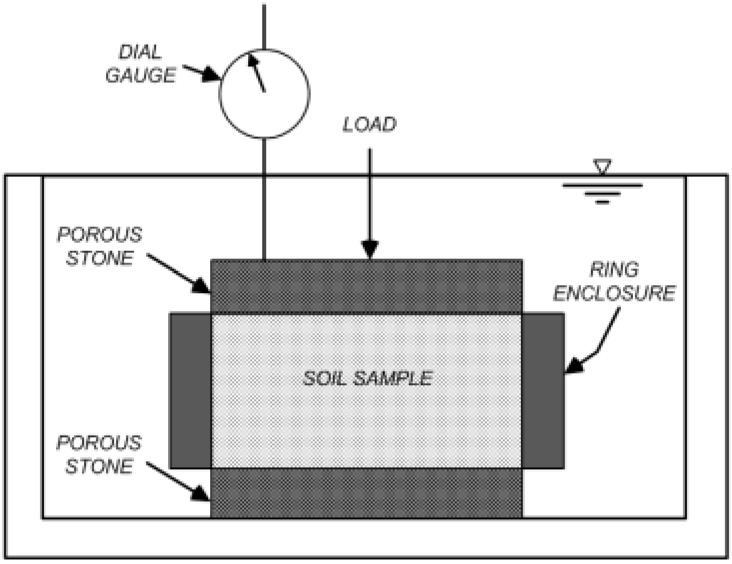


Figure 2.1 Schematic design of an oedometer(Boo Hyun Nam et al, 2019)

The compression of the soil mass results in a decrease in the volume of the mass, which causes the structure built on the mass to settle. The one-dimensional vertical compression understructure is taken into account in this regard. Saturated clay or organic soil settlement may be classified into three types: immediate (also called "initial settling," primary consolidation, and secondary compression.

i. immediate (initial) compression

When a load is applied to partially saturated soil, the volume decreases due to air expulsion and compression in the voids. The compression of solid particles causes a little reduction in volume. Initial consolidation or initial compression refers to the reduction in soil volume immediately following the application of a load. The compression of solid particles is mainly responsible for the initial consolidation of saturated soils(K.R. ARORA, 2004).

ii. primary consolidation

The pore water in the soil will initially carry the increase in vertical pressure caused by the weight of the structure built on top of saturated soft clays and organic soil. Excess pore water pressure refers to this rise in pore water pressure. As the water slowly flows out of the cohesive soil, the excess pore water pressure decreases over time. Primary consolidation refers to the flow of water from cohesive soil (which has a low permeability) when excess pore water pressures slowly dissipate. Primary consolidation requires a long time in fine-grained soils. Primary consolidation occurs more quickly in coarse-grained soils due to high permeability(K.R. ARORA, 2004).

iii. Secondary consolidation (creep)

The last component of settlement is the consequence of secondary consolidation, which occurs after essentially all of the excess pore water pressures have dissipated. Even when the extra pore water pressure created by the applied pressure has been completely dissipated and the primary consolidation is complete, the volume reduction continues at a very slow rate. Secondary consolidation refers to the extra volume reduction(K.R. ARORA, 2004).

In the case of normally consolidated (NC) clays, just the compression index (Cc) from the conventional oedometer test is required for settlement computation. When the clay is over-consolidated (OC), compression and swelling indices (Cs) are required. To calculate the level of settlement for OC clays as opposed to NC clays, Cs must be obtained(BRAJA M.DAS, 2006).

The consolidation settlement can be determined based on the consolidation ratio as follows:

For normally consolidated clay soil (OCR=1):

$$S_c = \frac{H_o}{1+e_o} C_c * log \frac{\sigma_c}{\sigma'_o} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [2.6]$$

For under consolidated clay soil (OCR<1):

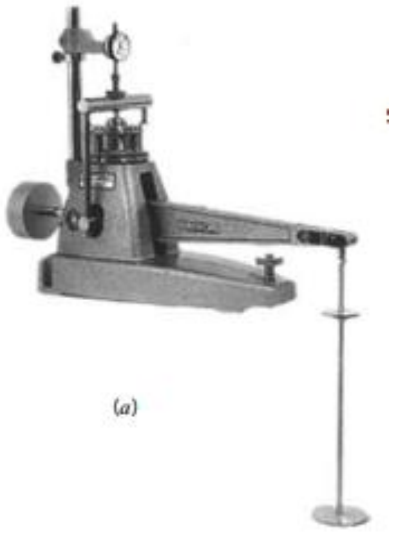
$$S_c = \frac{H_o}{1+e_o} C_s * log \frac{\sigma_c}{\sigma'_o} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [2.7]$$

For over-consolidated clay soil (OCR>1):

$$S_c = \frac{H_o}{1+e_o} \left[C_s log \frac{\sigma_c}{\sigma'_o} + C_c log \frac{\sigma_c}{\sigma'_o} \right] \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [2.8]$$

2.3. Consolidation Test

The Oedometer test, commonly known as the one-dimensional consolidation test, is used to determine consolidation parameters such as $Cc, Cs, Cr, Ca, Cv, mv,$ and σc. In a cylindrical container filled with water, a disk of soil is enclosed in a stiff metal ring and placed between two porous stones. The applied vertical stress (vertical total stress) is transmitted to the soil sample via a metal load platen positioned on top of the upper porous stone. As the soil settles under the imposed vertical force, both the metal plates and the upper porous stone can move vertically inside the ring. The platen is exposed to incremental loads, including unloading sequences, and the settlement of the soil at various fixed times under each load increment is measured by a displacement gage. Each load increment is allowed to remain on the soil until the change in settlement is negligible and the extra porewater pressure created by the current load increment has dissipated. The load increment may remain on the soil for 24 hours. Each load increment is multiplied by two. The equipment is removed at the end of the oedometer test, and the water content of the sample is calculated(MUNI BUDHU, 2011).



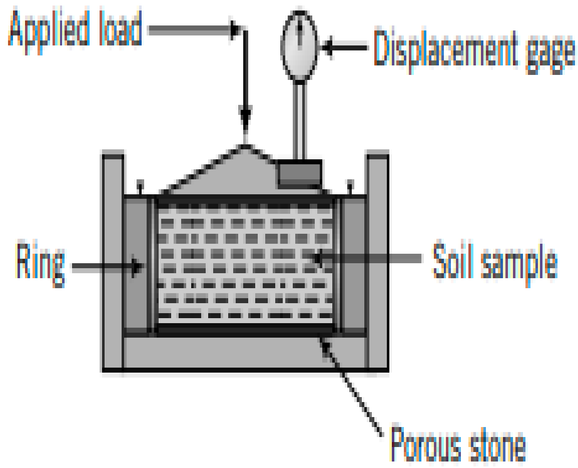


Figure 2.2 (a) A typical consolidation apparatus and (b) a floating ring cell(MUNI BUDHU, 2011).

2.3.1. Application of Consolidation Test

This test is used to measure the size and rate of volume decrease in laterally confined soil specimens under various vertical pressures. Deformation and time from various load increments are carefully recorded. The results of this test are plotted as follows:

- Curves of void ratio (e) vs effective stress (σ′) or e - log σ′
- Curves of deformation (settlement) vs time (t)

The e-log σ′ curves plot is used to determine the Pre-consolidation pressure (maximum past pressure, σ'_c), compression index (C_c) and swelling index (C_s). From the deformation versus time (t) curves consolidation coefficient (C_v) can be determined. These consolidation parameters C_c, C_s, C_v are used to determine the settlement of soil.

2.4. Consolidation Parameters

The Oedometer test determines consolidation characteristics such as compression index, swelling index, and coefficient of consolidation. The compression index (Cc) and swelling index (Cs) are used to compute primary consolidation settlement(Ayidin Alptekin *et al*, 2019). The slope of the graphs plotting void ratio vs log of stress yields these parameters. On the other hand, the coefficient of consolidation is used to estimate the time required for a certain amount of compression to happen. In consolidation theory, the prediction of the magnitude and rate of consolidation settlements is essential for the serviceability of a structure built on a compressible soil layer (Nur Izzati Ahmad Lazim *et al*, 2018).

i. Compression index

The compression index (Cc) is equal to the slope of the straight portion of the void ratio versus the log pressure plot from the e-log P curve in numerical terms(Seinn Moh dway *et al*, 2014). Its value is constant beyond the range of the recompression because the plot of e against log P is a straight line beyond this point.

$$C_c = \frac{e_2 - e_1}{log\frac{\sigma_2}{\sigma_1}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad [2.1]$$

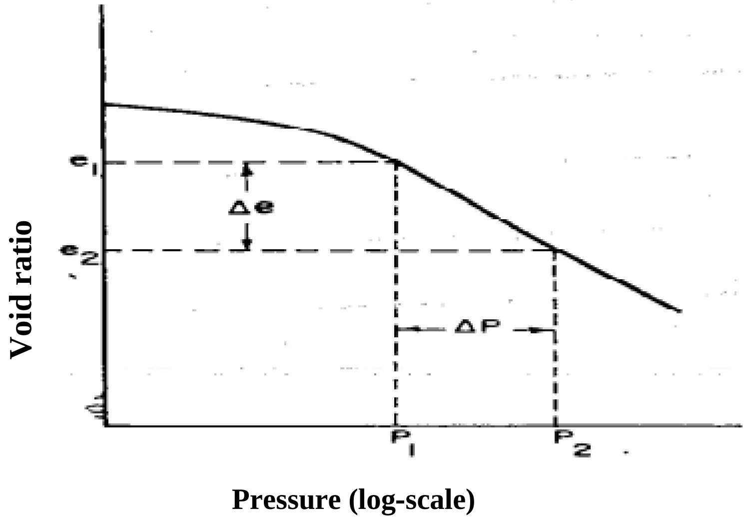


Figure 2.3 Determination of consolidation index(AKLILU FIKADU, 2015)

ii. Swelling index

Cs, or swelling index, is a crucial volume change parameter that is conventionally determined using 1-D oedometer tests. The swelling index (Cs) is equal to the slope of the $e - logp$ curve's straight-line unloading part of the void ratio versus the log pressure plot.

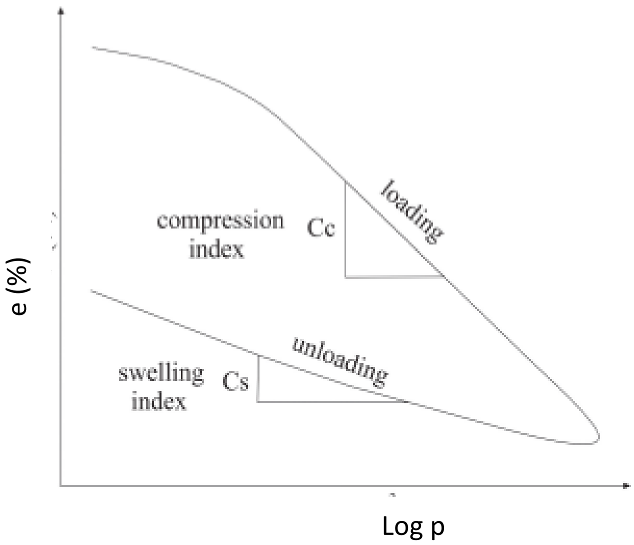


Figure 2.4 Graph of e-log P(Ayidin Alptekin *et al*, 2019)

$$C_s = \frac{e_2 - e_1}{\log\frac{\sigma_2}{\sigma_1}} \quad \cdots\cdots \quad [2.2]$$

The swell index is much less in magnitude than the compression index and can often be determined by laboratory measurements(BRAJA M.DAS, 2006).

iii. Coefficient of consolidation

The coefficient of consolidation (Cv) is essentially an indication of a soil sample's rate of consolidation and is based on the rate at which water may expel out of the compacted sample for a given load increment. A higher cv value implies a faster rate of consolidation.

In other circumstances, the settlement rate is determined by the coefficient of consolidation (C v). It is determined by a loading time interval for a known time factor for a specific sample thickness. There are two ways for calculating Cv from oedometer test data. Taylor (1942) proposed one method, called the root time method. Casagrande and Fadum (1940) proposed the other method, called the log time method. Both methods rely on a comparison of experimental and theoretical time curves.

$$C_v = \frac{Hd^2 * T_V}{t} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{[2.3]}$$

i. Square-root-of-time fitting method

A straight line is created through the points that represent the initial readings with a straight-line trend. The line is then projected back to t = 0 to yield the deformation ordinate indicating zero percent (0 %) primary consolidation. A second straight line is drawn through the zero percent (0%) ordinate, with the abscissa of this line being 1.15 times that of the first straight line through the data. The intersection of this second line with the time curve's deformation-square root is the deformation, d_{90}, and time, t_{90}, corresponding to 90 percent (90%) of primary consolidation(AKLILU FIKADU, 2015).

$$C_v = \frac{\mathrm{Hd}^2 * 0.848}{\mathrm{t}_{90}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{[2.4]}$$

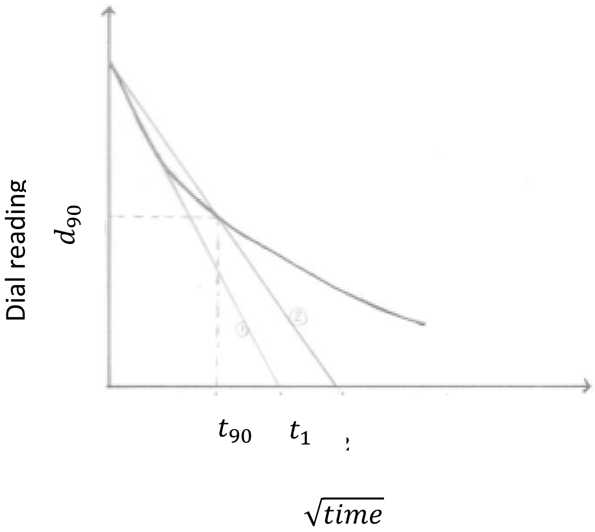


Figure 2.5 Dial reading vs square root time(ASM Fahad Hossain, 2018)

ii. Log Time Method

A straight line is formed connecting the points that indicate the final readings that have a straight-line trend and a constant slope. A second straight line is drawn that is tangent to the steepest part of the deformation-log time curve. The intersection represents the deformation, d100, and time, t100, that corresponds to 100% primary consolidation. Secondary compression is defined as compression that exceeds the estimated 100 percent primary consolidation.

The deformation indicating 0% primary consolidation is chosen by selecting any two points with a time ratio of 1 to 4. The deformation d50, which corresponds to 50% primary consolidation, is equal to the average of the deformations related to 0% and 100% primary consolidation. The time, t 50, required for 50 percent consolidation may be graphically determined from the deformation-log time curve by observing the time on the curve that corresponds to 50 percent primary consolidation(AKLILU FIKADU, 2015).

$$\mathrm{C_v} = \frac{\mathrm{Hd}^2 * 0.197}{\mathrm{t}_{50}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [2.5]$$

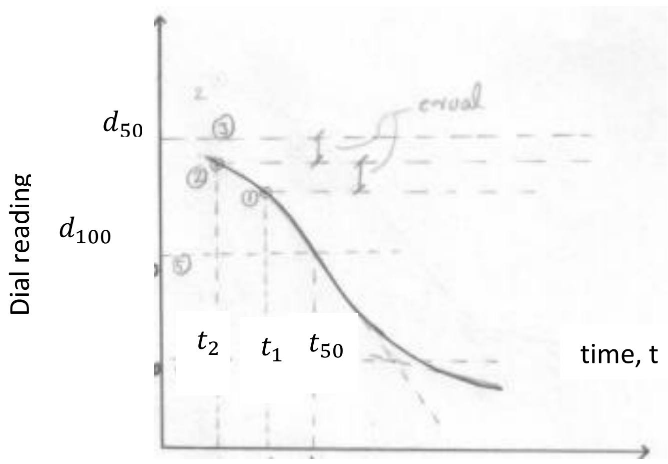


Figure 2.6 Dial reading vs time(ASM Fahad Hossain, 2018)

2.5. Soil Index Properties

Index soil properties are basic soil properties such as specific gravity, water content, particle size distribution, in-situ density, consistency limits, and relative density.

For general engineering purposes, index properties help in the identification and classification of soil. In most cases, these characteristics are determined in a laboratory. The index property of the soil may be determined using disturbed or undisturbed samples. The index properties of soil are used to provide a rough assessment of engineering properties of soil without conducting elaborate and time-consuming tests, and therefore provide correlation with engineering properties (Amit Choudhary *et al*, 2017).

i. Particle size distribution test

The proportion of each grain size present in the soil is estimated using a procedure called sieve analysis (grain-size distribution). A soil is presented in different grain sizes, such as gravel, coarser (sand), and fine (clay and silt). A sieve analysis involves shaking the soil through a stack of wire screens with openings of predetermined sizes; as a result, the side dimension of a square hole defines particle diameter for a sieve test. It should be remembered that sieve analysis does not indicate the particle shape. The particle size distributions of soil contain both coarser and fines performed by wet sieve on the No 200 (0.075mm). The soil is coarser than 0.075mm (retain on sieve No 200) done by dry sieve. The particle size passes sieve No 200 is done by hydrometer analysis. This test is carried out based on ASTM D422, Standard Test Method for particle Size Analysis for combined analysis for both hydrometer and dry sieve. The hydrometer test involves mixing a small amount of soil into a suspension and observing how the suspension settles in time. Larger particles will settle quickly, followed by smaller particles.

ii. Atterberg Limits test

Swedish soil scientist A. Atterberg recognized many phases in cohesive soils based on the amount of water in the system in early 1900. Later on, in 1920 Terzaghi and A. Casagrande (1932b), working for the U.S. Bureau of Public Roads, standardized the Atterberg limits so that they could be readily used for soil classification purposes (ASM Fahad Hossain, 2018).

The Atterberg limits are water contents at which soil behavior changes from one phase to another phase. The three Atterberg limits are: liquid limit, plastic limit, and shrinkage limits are the boundary between each of the two consecutive states of the soil-water phases. Their test is performed on the portion of soil which passes the 425µmm (No. 40) sieve. This test is conducted based on ASTM D 4318 (Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils)

Liquid limit is defined as the water content at which a standard-groove cut in the remolded soil sample by a grooving tool close to a distance of 13 mm. In other words, water content where flow curves cross 25 blows. The flow curves are straight-line plots of water content versus blows.

The plastic limit is defined as the water content at which a thread of soil just crumbles when it is carefully rolled out to a diameter of 3mm.

iii. Specific Gravity test

The specific gravity of a soil Gs is defined as the ratio of the mass in air of a given volume of soil particle to the mass in air of an equal volume of gas-free distilled water at the same temperature. The specific gravity is determined using a calibrated pycnometer, by which mass and temperature of de-aired soil sample and distilled water is measured. This method is applicable for soil samples composed of particle sizes smaller than 4.75mm. The specific gravity of soil is an important parameter for the calculation of the weight-volume relationship, including the void ratio for consolidation settlement calculations. This test is conducted according to ASTM D 854 (Standard Test for Specific Gravity of Soil Solids by Water Pycnometer)

2.6. Free Swell Index Test

This test is performed to determine the degree of the expansiveness of fine-grained soil and its dominant mineral composition. The test is carried on by taking two samples of 10gram each of oven-dried soil passing 425micro sieves into a 100ml measuring jar separately mixing thoroughly and settling for 24 hours to read a volume of soil in water and kerosene. The test is conducted based on IS: 1498 (1970) and Sridharan and Prakash 2000 procedure.

$$\text{Free swell index} = FSI = \frac{V_{d-V_k}}{V_k} * 100$$

2.7. Compaction Test

The compaction test is performed to determine the relationship between the moisture content and the dry density of soil for a specified comp-active effort. The comp-active effort is the amount of mechanical energy that is applied to the soil mass. This test is performed by two methods: standard proctor test and modified proctor test. In the Standard Proctor Test, the soil is compacted by a 5.5 lb hammer falling a distance of one foot 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. The Modified Proctor Test is identical to the Standard Proctor test except it employs, a 10 lb hammer falling a distance of 18 inches, and uses five equal layers of soil instead of three. Compaction is generally, the densification of soil by removal of air void from soil particles.

Design specifications usually state the required maximum dry density and optimum water content. The optimum water content is the water content that results at maximum dry density for a specified comp-active effort. Beyond optimum moisture content, any increase in moisture content tends to decrease dry density. This is because water takes up space that would have been occupied by solid particles. The test is conducted based on ASTM D 698 (Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort).

2.8. Existing Correlation

The consolidation characteristics of clay soils are determined in the laboratory using the oedometer test, which is particularly essential, based on Terzaghi's consolidation theory. Despite the crucial importance of this test, earlier research suggests its main drawbacks including its costliness, unwieldiness, and time-consuming aspect, in addition to its reliance on graphical approaches, which often need personal experience and a qualified workforce (Nourredine Mezouar *et al*, 2018). As a result, numerous correlations for estimating soil compressibility have been established during the last several decades, ranging from single-parameter models to multi-parameter models (Petros Xanthopoulos *et al,* 2019).

Many researchers in various regions have investigated the relationship between the compression index, swelling index, coefficient of consolidation, and index properties of the soil.

Skempton (1944) conducted a consolidation test on several clays collected from different locations and gave a model equation for the compression index of a remolded sample as $Cc = 0.007\,(LL - 10\%)$. In other cases, Terzaghi and Peck (1967) have given their model on an ordinary clay of medium to low sensitivity and presented the value of Cc corresponding to field conditions as roughly equal to 1.3 times the values of the Skempton model, which is $Cc = 0.009\,(LL - 10\%)$. Another author, Nishida (1956) also derived his theoretically linear correlation for all kinds of undisturbed clays as shown in the equation as $Cc = 0.54\,(eo - 0.35)$. Similarly, Azzouz (1976) presented his correlation equation as $Cc = 0.4\,(eo - 0.25)$. Additionally, Rendon- Herrero (1980) collected around 94 samples of America’s clay and presented his equation as $Cc = 0.3\,(eo - 0.27)$. Sirajuddin (1987) also gave a linear equation for 130 alluvial clay and silt in Bangladesh by using moisture content as $Cc = 0.0102\,(Wn - 9.15)$. The researchers, Koppula (1981) and Wroth et al (1978) proposed a correlation equation using the plasticity index for remolding clays as Cc = 1.325PI. Similarly, Sridharan and Nagaraj (2000) have given: $Cc = 0.014(PI + 3.6)$. The authors, (Nakase et al., 1988; Pandian and Nagaraj, 1990), was discovered that as the liquid limit increases, the compression index of soil increases with the increase in plasticity index. The soil compression index is determined by the plasticity of the soil. Plasticity is the property of a material that enables it to deform greatly; clay exhibits this property to a larger degree due to its high liquid limit. As a result, soil with a high liquid limit and a high plasticity index has a higher compression index.

Many researchers suggested various correlation equation of the swelling index and index properties of remolded and undisturbed sample on their investigation. Accordingly, they collected 58 data sets and developed simple and multiple regression analysis by using Microsoft office excel software(Aydın Alptekin *et al*, 2019). Some of their equations were as follows:

$Cs = 3*10^{-5}*LL^{1.6}$

$Cs = 0.0009*PL+0.0013$

$Cs = 0.0856*e -0.0226$

The other author, Vanapalli and Lu (2012), also provided that the swelling index, Cs, rises with increased plasticity, Ip, and proposed a relationship between Cs and Ip based on previously reported experimental data.

$Cs =-0.0214+(0.0013*LL)$

$Cs = (-0.033*\ln (PL)) +0.0968$

$Cs =(0.0009*PL) +0.0013$

$Cs =-0.05+(0.075*e0) +(0.015*\rho) + (0.0003*LL)$

Compared to compression index prediction, there are limited studies that have been made in the past to predict the coefficient of consolidation. Some researchers presented their observations as below.

Sridharan and Nagaraj (2004) conducted their research on the cv of remolded soils and suggested that cv values are greater for soils with less plastic than for soils with more plastic.

(Guruprasad Jadhav) was found in the determination coefficient (R^2) by utilizing the plasticity index as 0.67, and was stated that the Cv value decreases as the plasticity index increases. In his other observation, the correlation coefficient (R^2) between the liquid limit and the coefficient of consolidation (Cv) of the experimental findings obtained is 0.0179, implying that the coefficient of consolidation (Cv) value decreases as the liquid limit increases. In general, Cv reduces as the index property increases as previous authors reported. However, from their suggestion multiple regression analysis be used to best estimate the coefficient of consolidation using LL and PI as shown in the equation below with R^2 = 0.994.

$Cv = 0.451 + 0.011LL - 0.0367PI$

As evident in the table below, there are many correlations between the soil consolidation parameters and index properties.

Table 2.1 Existing correlation equation by different researchers

Equation	Reference	Applicability
Cc = 0.007*(LL-10)	Skemptom and Jone (1944)	remolded clays
Cc = 0.009* (LL-10)	Terzaghi and peck (1967)	undisturbed clays
Cc = 0.5*PI*Gs	Worth and wood (1978)	All remolded NC clays
Cc = 1.325*PI	Wroth and wood 1978	Remolded clays
Cc = 0.014* (PI +3.6)	Sridharan &Nagaraj 2000	Remolded clays
Cc = 0.0054 *(2.6w-35)	Nishida 1956	Undisturbed clays
Cc = 0.009*w+0.005*LL Cc = 0.0023*LL*Gs	Koppula 1981 Nagaraj Murthy (1986)	All clays All clays
Cs = 0.0463*Gs $[\frac{LL}{100}]$	Nagaraj Murthy (1985)	Undisturbed clays
Cs = -0.0214+0.0013LL Cs = 0.0009*PL+0.0013	Kordaeij *et al* 2015)	
Cv = $3/\ (100Is3.45$	Sridharan and Nagaraj	Remolded soils
Cv = $4X10^{-7}$-$4x10^{9}$ LL	Soibam *et al*	Soft clays
Cv=0.451 + 0.011LL – 0.0367PI	(Nur Izzati Ahmad Lazim, 2018)	Remolded cohesive soil
Cc=0.014(PI+3.6) (2000)	Sridharan and Nagaraj (2000)	All clays
Cc = Cc=0.01wn	Koppula (1981)	All clays
Cc=0.01(wn)7.549)	Herrero (1983	All clays

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study Area

The study was conducted out in the town of Bishoftu, which is located in the east Shewa zone, 47.9 kilometers southeast of Addis Ababa. The location of the study area is shown in Figure 3.1. It is located at an elevation of 1,920 meters above sea level, with mild climate conditions, generally warm and temperate. The average annual temperature is 18.7C^{o} and the average rainfall is 892mm. Its coordinates in GPS are 8°44'4.47" N and 39°0'30.726" E in DMS (Degrees Minutes Seconds)(Amanuel Adugnaw, 2021).

The major part of the Bishoftu town is covered with saturated cohesion soil (silt and clay). From various researchers tested data of the site soil, fine-grained soil covered various parts of the town (Amanuel Adugnaw, 2021).

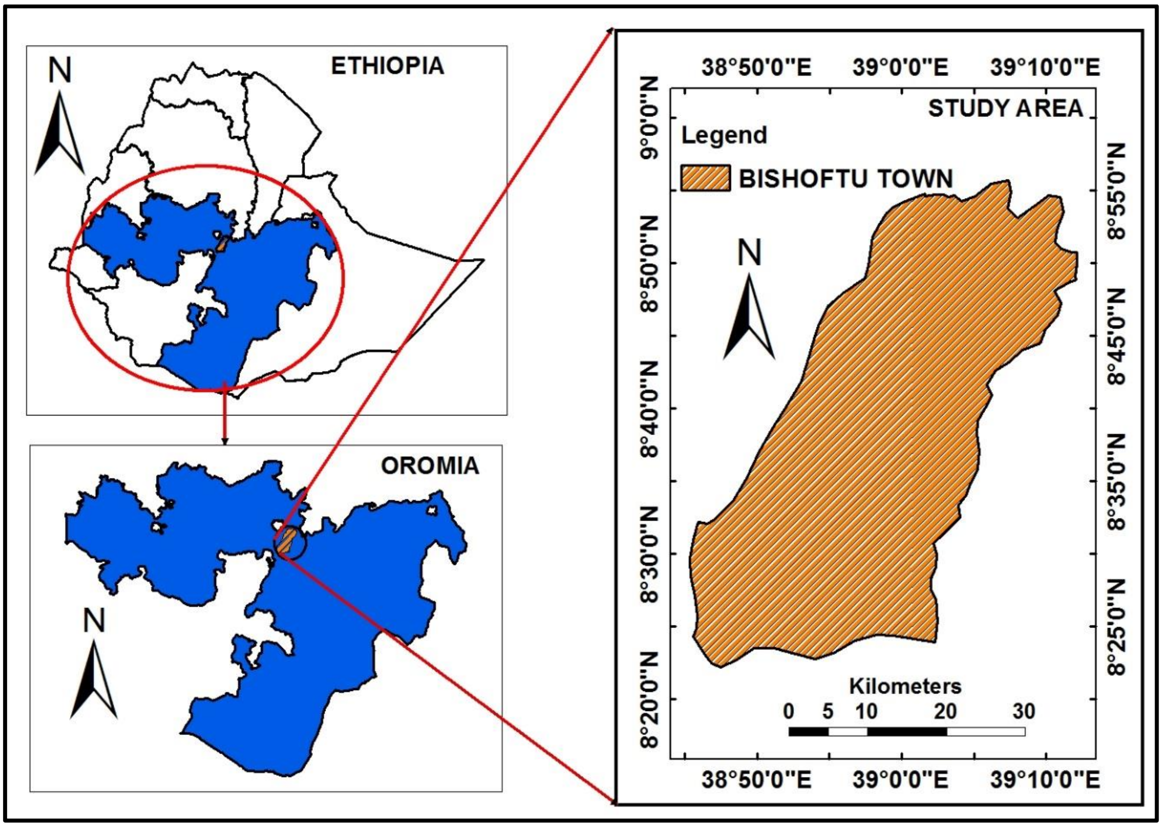


Figure 3.1 Study area

3.2. Soil Sampling and Sample Preparation

Soil samples were collected from various sites in the study area. The location of the test pits is presented in Figure 3.2 and Table 3.1. To meet the objective of the study, a disturbed sample of different properties was taken. The trial test pits were usually dug to a depth of 1.5 and 3m by giving enough digging space. Soil samples were taken at 1.5m and 3m of test pits to represent the field condition.

The practical settlement issue, including strain and seepage, was considered to take place in one direction only, this is only vertical. Hence these samples' soils were tested in one-dimensional consolidation apparatus called the oedometer test where there were no lateral strains.

Table 3.1 sample location of the study area

PIT	Location name	Northing (in degrees)	Easting (in degrees)	Altitudes (m)
PT-1	elementary school	8.763557	38.937062	1916.74
PT-2	Sunshine	8.764102	38.935155	1911.03
PT-3	Preparatory school	8.764627	38.934609	1909.33
PT-4	Real state	8.764893	38.933902	1900.73
PT-5	Inova factory	8.76532	38.934132	1899.73
PT-6	Green area	8.763093	38.935017	1917.43
PT-7	Real state	8.762451	38.935659	1916.85
PT-8	Green area	8.763178	38.936063	1915.45
PT-9	Sunshine	8.762543	38.936167	1914.95
PT-10	Preparatory school	8.763768	38.9357	1911.54
PT-11	Real state	8.763069	38.936182	1914.14

Figure 3.2 Sample location map of the study area

Soil sampling was gathered from various areas in town, with about 500 kilograms of disturbed soil. The soil sample is protected from external materials such as excessive heat and water, and the bags used to hold the soil samples are made of waterproof materials such as plastic. The name of the sampling area, depth of sampling, and color of the sample were written on the outside of the bag for identification purposes.

The sample size required for correlation is large. However, the oedometer test takes several days per test, and there will be insufficient time to use the laboratory and get accurate results.

Air drying is the first step in preparing a soil sample for the required test. The air-dry soil samples will be thoroughly pulverized using fingers and a wooden hammer before proceeding to the next step.

For particle size distribution test, representative 1000gram oven-dried samples are soaked in a wet sieve and washed on sieve No. 200. The retained samples are air-dried for sieve analysis according to ASTM D422-63 (Standard Test Method for Particle-Size Analysis of Soils) and the sedimentation (passing sieve No.200) oven-dried for hydrometer analysis according to ASTM D422- (Standard Test Method for Amount of Material in the Soils Finer than the No. 200 (0.075mm) Sieve) procedure.

For Atterberg limit tests, about 100gram and 20gram pass a 0.425mm sieve (passing no.40**)** air-dried and pulverized samples are taken, and thoroughly mix the soil with the required amount of distilled water until it appears as a smooth uniform paste prepared for liquid limit and plastic limit test respectively, according to ASTM D 4318 – (Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils).

For specific gravity tests, about 10gram passes 2mm sieve (passing No.10) oven-dried sample was taken and soaked in distilled water for 10 minutes according to ASTM D 854-00 (Standard Test for Specific Gravity of Soil Solids by Water Pycnometer).

For the compaction test, a representative 2500gram (passing No. 4) air-dried and pulverized sample was prepared according to ASTM D 698 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (600 KN/m^2).

For the One-Dimensional Consolidation test, disturbing samples of about 2500gram (passing No.4) oven-dried and pulverized are prepared for remolding at optimum moisture content through compaction. Then consolidation process is carried on similarly to undisturbed soil according to ASTM D2435 (Standard Test Method for One-Dimensional Consolidation Properties of Soils).

For the free swell index test, about 10gram passes through a 0.425mm sieve (passing sieve No.40) oven-dried sample was added to 100ml of distilled water and kerosene to settle for 24 hours.

3.3. Laboratory Testing

To reach the desired objective of this study, sequential laboratory tests were conducted on the prepared sample as the following.

Firstly, a sieve analysis and hydrometer tests were conducted to classify collected soil samples based on percent grain size and Atterberg limits.

Then, a laboratory test of index properties was performed on a disturbed sample collected from different parts of Bishoftu town. Before conducting a laboratory test the sample is oven dry or air dry and pulverized using a finger and hammer. After the sample dried desired index properties tests were conducted.

Next, a compaction test was carried out on the dried sample to get maximum dry density and optimum moisture content.

Finally, one-dimensional consolidation tests were performed on remolded samples prepared from a disturbed sample collected from various parts of the study area. In this test, vertical normal load increments were applied at regular time intervals for 24 hours. Before applying normal load, each sample was allowed to be saturated. After the saturation process was completed, the samples were subjected to a series of normal loads, while changes in thickness were recorded against time.

The accuracy of the test procedures influences the validity of the correlations. A thorough understanding of test procedures, as well as practice, is required to improve the reliability of such correlations. In this situation, an attempt was made to get accurate laboratory results by carefully adhering to the testing procedures described in ASTM standards.

3.3.1 Grain Size Distribution Test

Grain size analysis is carried on according to the ASTM D422 procedure. Based on the analysis the summary of gravel (%), sand (%), silt (%), and clay (%) of the study area is presented in Table 3.2.

Table 3.2 Grain size analysis result of Bishoftu fine-grained soil

Location	PIT	Depth (m)	Grain size analysis			
			Clay (%)	Silty (%)	Sand %	Gravel (%)
Elementary School	PT1	1.5	43	21	35	1
		3	45	19	35	0
Sunshine	PT2	1.5	45	22	32	1
		3	52	19	26	2
Preparatory School	PT3	1.5	41	15	43	0
		3	50	16	34	0
Real State	PT4	1.5	44	21	35	0
		3	48	23	25	3
Inova Factory	PT5	1.5	64	21	13	2
		3	49	24	26	1
Green Area	PT6	1.5	74	17	9	0
		3	46	21	32	0
Real State	PT7	1.5	77	13	4	3
Green Area	PT8	1.5	40	19	39	2
Sunshine	PT9	1.5	23	40	37	0
Preparatory School	PT10	1.5	35	28	34	3
		3	38	31	30	1
Real State	PT11	1.5	42	18	39	1

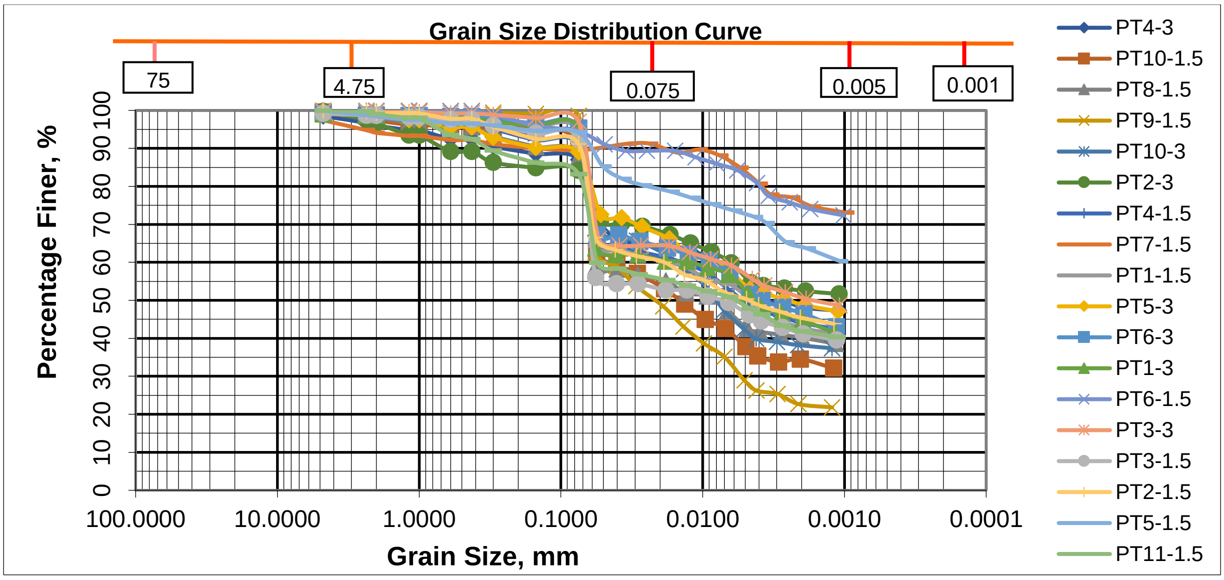


Figure 3.3 Combined sieve- hydrometers analysis curve of Bishoftu fine-grained soil

3.3.2. Atterberg Limit Test

The test is conducted according to ASTM D 4318-00 standard test method. The Atterberg limit test results are presented in Table 3.3. Atterberg Limits and Indices of the study area falls in the ranges of: - Liquid Limit (21-96) %; Plastic Limit (15-59) %; Plastic Index (6-61) %.

Activity: is measured as the ratio of a plastic index to the percent of clay fraction finer than 2μm. The activity of the study area soil ranges from active to inactive. Samples from only four pits are active, two pits are normal and 12 pits are inactive.

Table 3.3 Results of Atterberg limits test of Bishoftu fine-grained soil

Location	PIT	Depth (m)	Atterberg limit		
			Liquid limit (%)	plastic limit (%)	plastic index (in %)
Elementary School	PT-1	1.5	96	35	61
		3	94	46	48
Sunshine	PT-2	1.5	91	38	53
		3	85	36	49
Preparatory School	PT-3	1.5	71	59	12
		3	69	27	42
Real State	PT-4	1.5	66	18	48
		3	61	31	30
Inova Factory	PT-5	1.5	60	29	31
		3	58	27	31
Green Area	PT-6	1.5	50	39	11
		3	46	23	23
Real State	PT-7	1.5	45	22	23
Green Area	PT-8	1.5	41	25	16
Sunshine	PT-9	1.5	40	21	19
Preparatory School	PT-10	1.5	38	25	13
		3	25	17	8
Real State	PT11	1.5	21	15	6

Table 3.4 Activity results of fine-grained soil of study area

Finer (%)	PI (%)	A	Activity
47	61	1.30	active
33	48	1.45	active
39	53	1.36	active
21	49	2.33	active
38	12	0.32	inactive
53	42	0.79	normal
74	48	0.65	normal
62	30	0.48	inactive
43	31	0.72	inactive
43	31	0.72	inactive
42	11	0.26	inactive
48	23	0.48	inactive
39	23	0.59	inactive
48	16	0.33	inactive
72	19	0.26	inactive
40	13	0.33	inactive
42	8	0.19	inactive
40	6	0.15	inactive

3.3.3. Specific Gravity Test

This test was done in a laboratory based on the ASTM D 854-00 Standard Test Method. The laboratory test results show that the specific gravity of the study area falls in a range of 2.65-2.8 as presented in Table 3.5.

Table 3.5 Results of Specific gravity test of Bishoftu fine-grained soil

Location	Test pit	Depth (meters)	Specific Gravity
Elementary School	PT-1	1.5	2.8
		3	2.68
Sunshine	PT-2	1.5	2.75
		3	2.8
Preparatory School	PT-3	1.5	2.65
		3	2.69
Real State	PT-4	1.5	2.7
		3	2.75
Inova Factory	PT-5	1.5	2.8
		3	2.65
Green Area	PT-6	1.5	2.7
		3	2.65
Real State	PT-7	1.5	2.8
Green Area	PT-8	1.5	2.74
Sunshine	PT-9	1.5	2.7
Preparatory School	PT-10	1.5	2.8
		3	2.75
Real State	PT11	1.5	2.67

Free swell index: The soil-free swell index of the study area ranges from 0 – 72.73, thus the degree of expansion ranges from low to moderate.

$$\text{Free swell index} = FSI = \frac{V_{d} - V_{k}}{V_{k}} * 100$$

Table 3.6 Results of free swell index test of Bishoftu fine-grained soil

TEST PIT	Depth(m)	vk (In milliliters)	vd (In milliliters)	FSI %
PT-1	1.5	11	19	72.73
	3	12	20	66.67
PT-2	1.5	11	18	63.64
	3	11	17	54.55
PT-3	1.5	12.5	18.5	48.00
	3	13	18.5	42.31
PT-4	1.5	12.5	17	36.00
	3	13.5	17.5	29.63
PT-5	1.5	12	14.5	20.83
	3	10	12	20.00
PT-6	1.5	12	14	16.67
	3	12.5	14.5	16.00
PT-7	1.5	12.5	14.5	16.00
PT-8	1.5	12	13.5	12.50
PT-9	1.5	13	14.5	11.54
PT-10	1.5	14.5	16	10.34
	3	12	12	0.00
PT-11	1.5	12	12	0.00

3.3.4. Soil Classification

According to the USCS classification scheme the soil of the study area falls in CH, MH & CL regions.

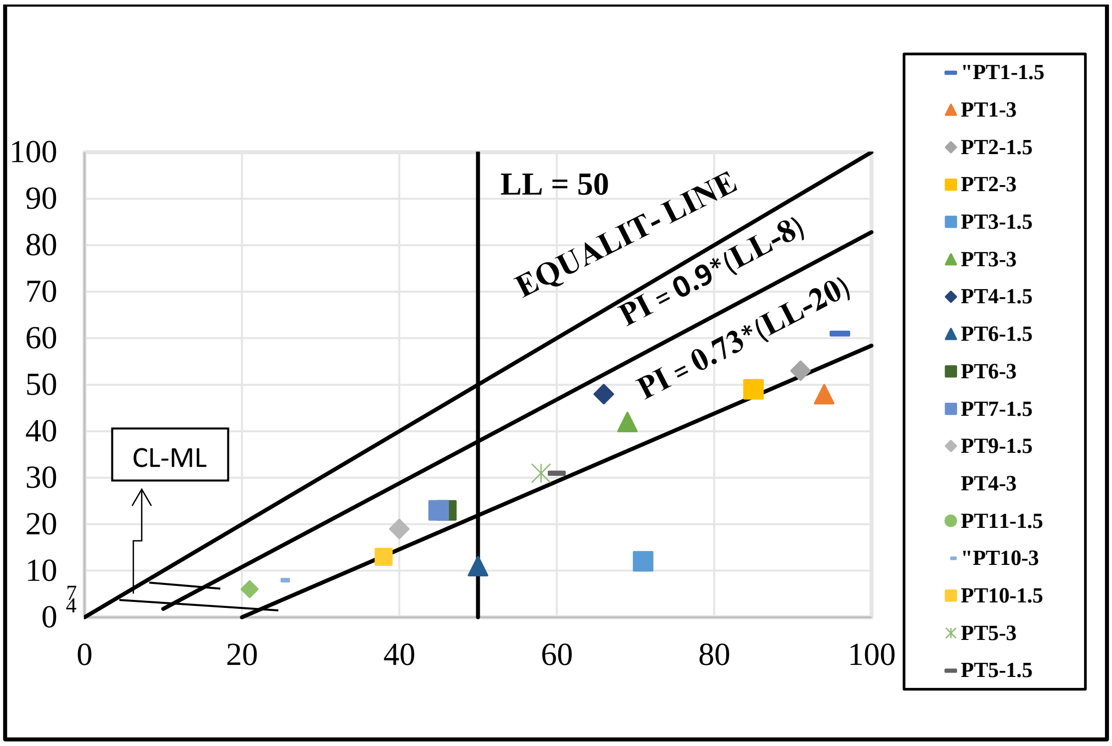


Figure 3.4 Plasticity chart of the Bishoftu fine-grained soil, according to (USCS)

According to this system, the soil of the study area falls in the region of A-7-6, A-7-5, and A-4

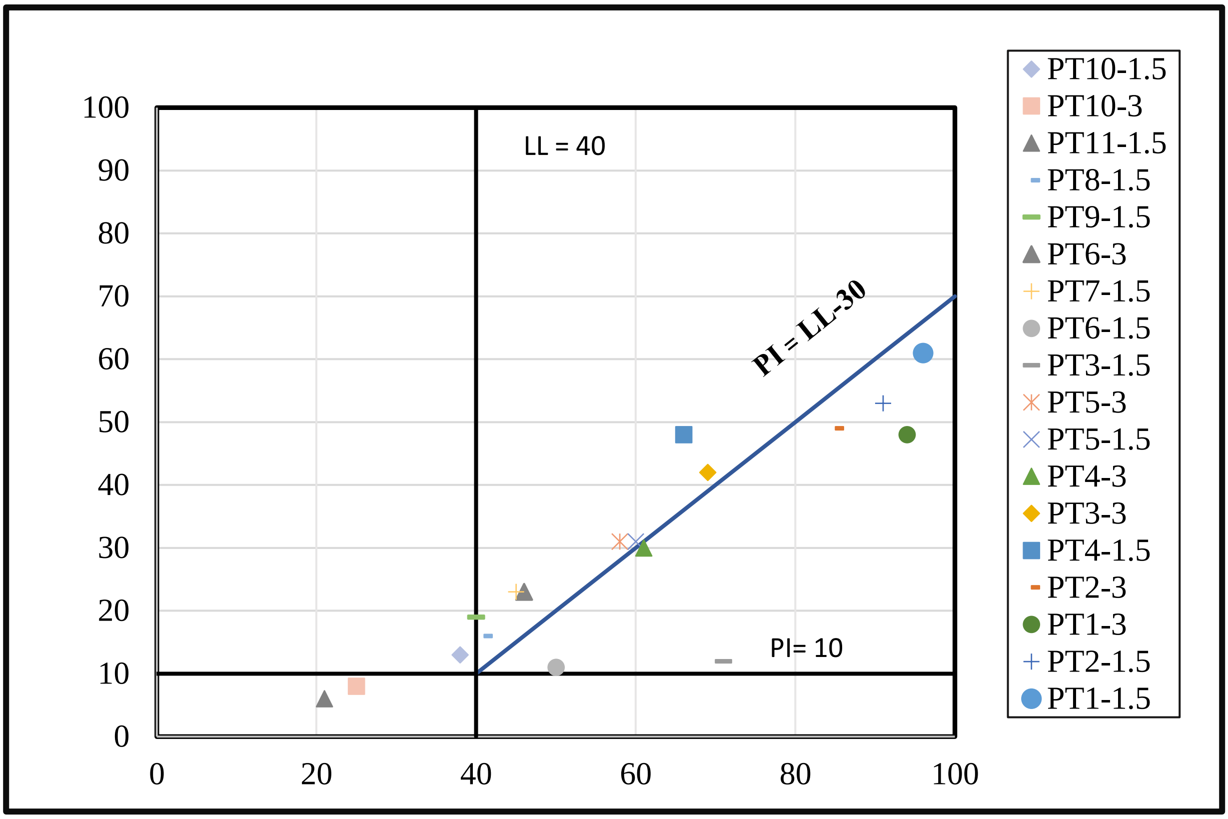


Figure 3.5 Classification of Bishoftu fine-grained soil according to the AASHTO System

3.3.5. Compaction Test

The test is conducted according to ASTM D 698 standard test methods. The results from the compaction test presented in Table 3.7. The maximum dry density of the soils from the study area ranges from (1.2-1.48) $^{g}/_{cm^3}$ and the optimum moisture content ranges from (25-39.49) %.

Table 3.7 Results of compaction test of Bishoftu fine-grained soil

Location	PIT	Depth (m)	Compaction test	
			OMC (%)	MDD (g/cm^3)
Elementary School	PT1	1.5	31.6	1.49
		3	26.5	1.56
Sunshine	PT2	1.5	31.2	1.45
		3	25	1.57
Preparatory School	PT3	1.5	25.9	1.48
		3	24.6	1.47
Real State	PT4	1.5	36.5	1.43
		3	28.3	1.26
Inova Factory	PT5	1.5	30.8	1.42
		3	28.3	1.41
Green Area	PT6	1.5	31.9	1.38
		3	32.3	1.33
Real State	PT7	1.5	26.7	1.44
Green Area	PT8	1.5	39.5	1.29
Sunshine	PT9	1.5	35.5	1.34
Preparatory School	PT10	1.5	31.9	1.36
		3	32.3	1.33
Real State	PT11	1.5	29.7	1.41

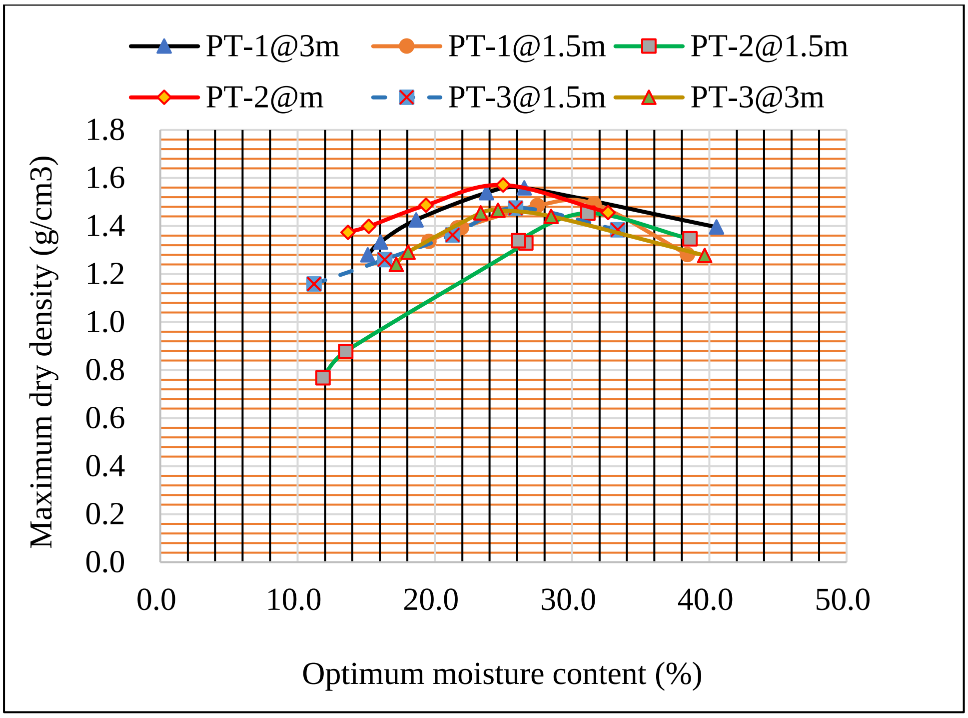


Figure 3.6 Graphs of MDD versus OMC of PT-1,2 & 3 study area fine-grained soil

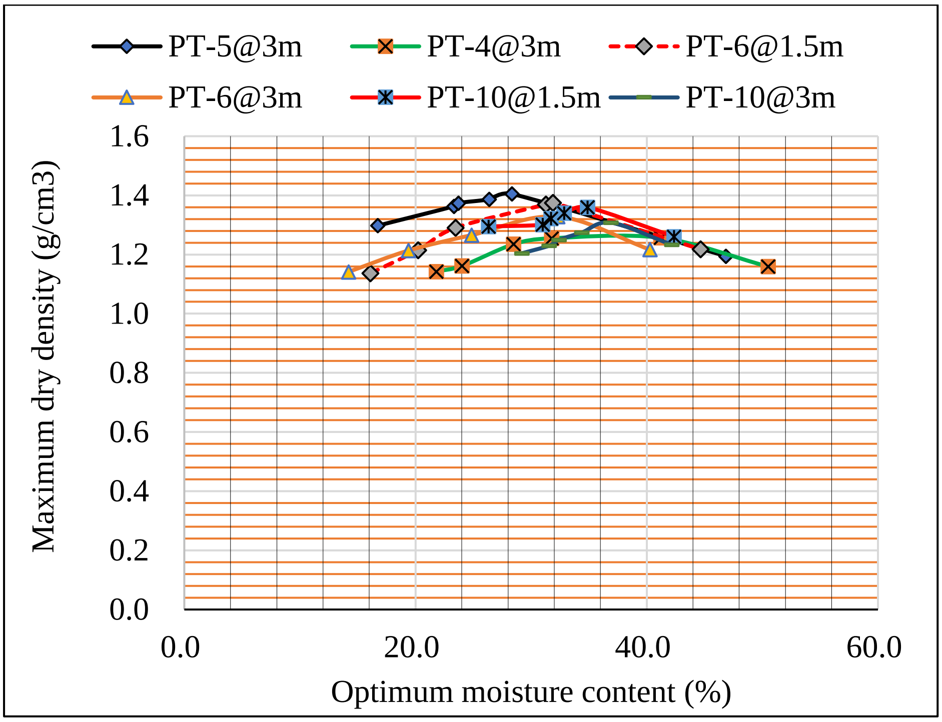


Figure 3.7 Graphs of MDD versus OMC of PT-4,5 & 10 study area fine-grained soil

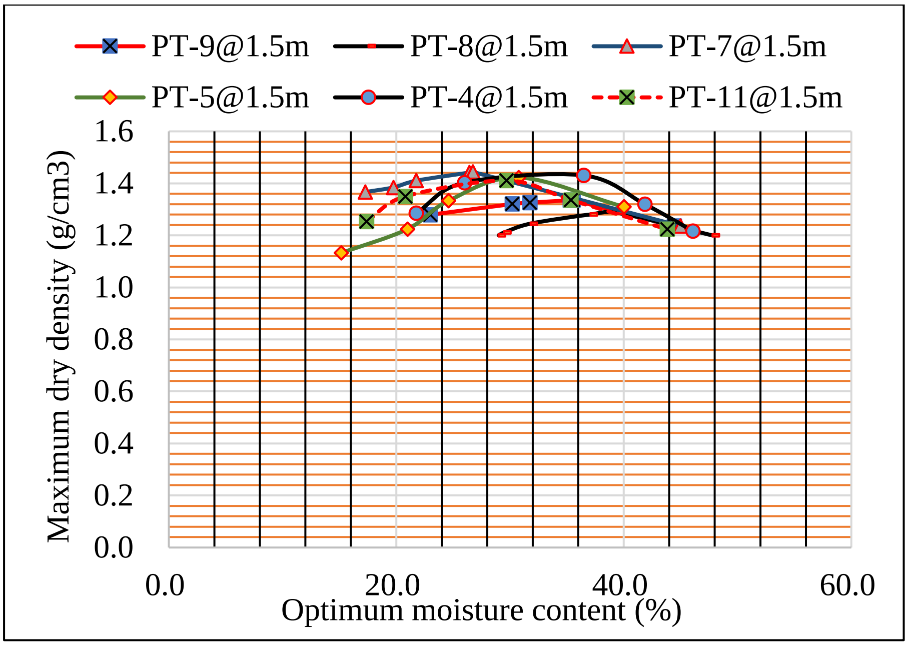


Figure 3.8 Graphs of MDD versus OMC of PT-4,5,7,8,9 &11 Bishoftu fine-grained soil

3.3.6. One-Dimensional Consolidation Test

To meet the intended objectives, a consolidation test is performed on 18 soil samples obtained from different parts of Bishoftu town where fine-grained soil is dominant. To conduct this test, the prepared sample was remolded at optimum moisture content through compaction and then a small representative sample was carefully trimmed and fitted into a rigid metal ring. In this test, ASTM D 2435-96 manual procedure methods were followed. Before loading carried on, the sample was saturated for 24 hours in an oedometers. In other words, the consolidation test apparatus is designed to permit the sample to be submerged in water during the test to make the soil weak strength. The soil sample is mounted on a porous stone bottom and a similar stone is placed on top to permit water to escape freely at the top and bottom. Before loading, the height of the sample should be accurately measured. Also, a micrometer dial is mounted in such a manner that the vertical strain in the sample can be measured as loads are applied.

The sample is loaded with five load series in which the successive load is twice the preceding one and then unloaded with two loads in which the successive load is four times the preceding one. The dial readings are taken at elapsed time of 24 hours. After the greatest load required for the test has been applied to the soil sample, the load is removed in decrements to provide data for plotting the consolidation curve. The consolidation characteristics (or parameters) of soil which are the compression index Cc, swelling index Cs, and coefficient of consolidation Cv, are determined from the test. The results of the odometer test are usually presented in the form of an e-log P graph

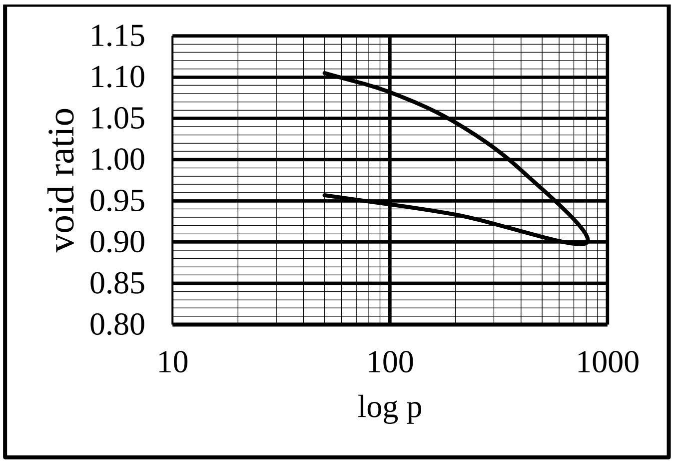


Figure 3.9 Plot of e-vs log-p for sample Real state (PT7-1.5) of Bishoftu fine-grained soil

The test covers the determination of consolidation characteristics of remolded soil specimens, such as C_C , C_s , C_v. The interval ranges of these parameters are C_c 0.102-0.606, C_s 0.01-0.345 and C_v 0.589 to 6.057in m^2/year as listed in Table 3.8.

Table 3.8 Results of one-dimensional consolidation test of Bishoftu fine-grained soil

Location	PIT	Depth (m)	consolidation parameters			
			C_V (m^2/year)	C_C	C_S	e_o
Elementary School	PT-1	1.5	0.79	0.606	0.345	2.524
		3	2.659	0.584	0.3413	2.307
Sunshine	PT-2	1.5	0.732	0.541	0.3223	0.885
		3	0.589	0.534	0.3193	1.481
Preparatory School	PT-3	1.5	0.649	0.504	0.303	1.422
		3	1.537	0.492	0.29	1.818
Real State	PT-4	1.5	0.706	0.487	0.248	1.549
		3	2.741	0.446	0.2053	1.467
Inova Factory	PT-5	1.5	1.731	0.38	0.1	1.447
		3	4.184	0.336	0.051	1.628
Green Area	PT-6	1.5	6.057	0.313	0.051	1.201
		3	3.058	0.294	0.04	1.17
Real State	PT-7	1.5	2.21	0.242	0.04	1.137
Green Area	PT-8	1.5	3.375	0.225	0.04	1.223
Sunshine	PT-9	1.5	0.968	0.221	0.033	1.06
Preparatory School	PT-10	1.5	1.747	0.214	0.0249	1.138
		3	4.447	0.132	0.01	1.082
Real state	PT-11	1.5	5.26	0.102	0.01	1.075

Table 3.9 Summary of laboratory results of Bishoftu fine-grained soil

PIT	depth	Classification		Percentage of grain size				Atterberg limits			Consolidation parameters				Compaction		Activity	Swell index	Specific gravity
		AASHTO	UCS	Clay	Silt	Sand	Gravel	LL (%)	PL (%)	PI (%)	Cv (m^2/year)	Cc	Cs	eo	MDD (g/cm^3)	OMC (%)	A	FSI (%)	Gs
PT1	1.5	A-7-5	CH	43	21	35	1	96	35	61	0.79	0.606	0.345	2.52	1.49	31.6	1.3	72.7	2.8
	3	A-7-5	MH	45	19	35	0	94	46	48	2.659	0.584	0.341	2.31	1.56	26.5	1.45	66.7	2.68
PT2	1.5	A-7-5	CH	45	22	32	1	91	38	53	0.732	0.541	0.322	0.89	1.45	31.2	1.36	63.6	2.75
	3	A-7-5	CH	52	19	26	2	85	36	49	0.589	0.534	0.319	1.48	1.57	25	2.33	54.6	2.8
PT3	1.5	A-7-5	MH	41	15	43	0	71	59	12	0.649	0.504	0.303	1.42	1.48	25.9	0.32	48	2.65
	3	A-7-6	CH	50	16	34	0	69	27	42	1.537	0.492	0.29	1.82	1.47	24.6	0.79	42.3	2.69
PT4	1.5	A-7-6	CH	44	21	35	0	66	18	48	0.706	0.487	0.248	1.55	1.43	36.5	0.65	36	2.7
	3	A-7-5	CH	48	23	25	3	61	31	30	2.741	0.446	0.205	1.47	1.26	28.3	0.48	29.6	2.75
PT5	1.5	A-7-6	CH	64	21	13	2	60	29	31	1.731	0.38	0.1	1.45	1.42	30.8	0.72	20.8	2.8
	3	A-7-6	CH	49	24	26	1	58	27	31	4.184	0.336	0.051	1.63	1.41	28.3	0.72	20	2.65
PT6	1.5	A-7-5	ML	74	17	9	0	50	39	11	6.057	0.313	0.051	1.2	1.38	31.9	0.26	16.7	2.7
	3	A-7-6	CL	46	21	32	0	46	23	23	3.058	0.294	0.04	1.17	1.33	32.3	0.48	16	2.65
PT7	1.5	A-7-6	CL	77	13	4	3	45	22	23	2.21	0.242	0.04	1.14	1.44	26.7	0.59	16	2.8
PT8	1.5	A-7-6	CL	40	19	39	2	41	25	16	3.375	0.225	0.04	1.22	1.29	39.5	0.33	12.5	2.74
PT9	1.5	A-6	CL	23	40	37	0	40	21	19	0.968	0.221	0.033	1.06	1.34	35.5	0.26	11.5	2.7
PT10	1.5	A-6	ML	35	28	34	3	38	25	13	1.747	0.214	0.025	1.14	1.36	31.9	0.33	10.3	2.8
	3	A-4	CL	38	31	30	1	25	17	8	4.447	0.132	0.01	1.08	1.33	32.3	0.19	0	2.75
PT11	1.5	A-4	CL	42	18	39	1	21	15	6	5.26	0.102	0.01	1.08	1.41	29.7	0.15	0	2.67

CHAPTER FOUR

CORRELATION BETWEEN CONSOLIDATION PARAMETERS AND INDEX PROPERTIES

4.1. General

Empirical correlations are widely used in geotechnical engineering tasks as a method for estimating soil engineering behavior(Xin Kang *et al*, 2015). Correlation is a statistical tool for estimating the strength and direction of a relationship between two variables. In other words, correlation is the degree to which two variables are related. The study of the correlation between two variables is known as simple correlation, and the analysis of the correlation between more than two variables can be partial or multiple(Mohamed Ahmed Zaid, 2015).

Regression is a statistical method that investigates, calculates, and interprets the mathematical relationship between one or more independent (predictor) variables and a dependent variable. Linear regression between a single dependent variable and a single independent variable is referred to as simple linear regression. The regression between several independent (predictor) variables and a dependent (criterion) variable is referred to as multiple regression. Independent variables are characteristics that can be directly measured, while dependent variables are characteristics whose value depends on the value of an independent variable.

The empirical correlation between consolidation parameters and soil index properties was extensively discussed in this chapter. The statistical model of soil consolidation parameters was developed by correlation and regression analysis of soil consolidation parameters and index properties. Two methods are being used to study can correlation(Sarad Chandra Kafle, 2020):

i. **Diagrammatical method:** is the study of correlation using a scatter diagram. A scatter diagram provides a dot point for a pair of data X and Y by plotting the value on the x- and y-axes, respectively. The closer and more ordered the points, the higher the correlation between variables(Sarad Chandra Kafle, 2020).

ii. **Mathematical method:** Correlation is the study of the degree of association between variables by Karl Pearson's correlation coefficient, designated by the letter "r."(Mohamed Ahmed Zaid, 2015)

4.2. Data Analysis Methods

To establish a relationship between two or more variables, valid data must be gathered from either a primary or secondary source. The data for this thesis is gathered from primary sources. Before applying the analysis method, certain key terminology is explained below.

i. **Level of significance:** The probability of making an error in rejecting a hypothesis when it is true is referred to as the degree of significance. In practice, a 5% level of significance is commonly used. This implies that we are 95% confident that we will make the right decision and have a 5% probability of being wrong(Mohamed Ahmed Zaid, 2015). The overall significance of regression equation is measured by P-Value. If the displayed P-value is less than 0.05 or 5% indicating that the multiple regression equation has good significance and is usable for prediction or it makes sense to predict(Mindaye Teshoma, 2015).

ii. **One-tailed and two-tailed Tests:** A one-tailed or one-sided test is used when a hypothesis is tested assuming that one process is better or worse than the other. The tests are called two-tailed or two-sided if the hypothesis is tested assuming that the extreme values of the statistics score on both sides of the mean in both tails of the distribution(YOHANNES ANOLE, 2018).

iii. **Standard error:** The standard error is the average measure of each sample point's deviation from the best-fit line. The best-fit curve has the smallest standard error of all curves(YOHANNES ANOLE, 2018).

iv. **Correlation coefficient(R):** The coefficient of correlation (sometimes known as the coefficient of regression) measures how well the least-square regression line (best-fit line) fits the sample data. The value ($R^2 = 1$) indicates that there is a perfect linear correlation as well as perfect linear regression. $R^2 = 0$ or approaches zero, on the other hand, indicate that no valid relationship can be obtained between the variables(YOHANNES ANOLE, 2018).

Table 4.1 Statistical Information of Dependent and Independent Variables of the study area

Typical variable	Variable name	Unit of measurement	No. of sample	Ranges		Mean	Standard Deviation
				Min.	**Max.**		
Dependent	C_c		18	0.102	0.606	0.37	0.155
	C_s		18	0.01	0.345	0.154	0.132
	C_v	m^2/year	18	0.589	6.057	2.41	1.69
Independent	LL	%	18	21.0	96.0	58.7	22.7
	PI	%	18	6	61	29.1	6
	PL	%	18	15	59	29.6	11.1
	eo	%	18	0.885	2.524	1.429	0.417
	Gs		18	2.650	2.800	2.727	0.057

Many methods can be used to obtain a relationship between two or more variables and also to check the validity of the relationships between two or more variables. In this study, however, two common methods are used: scatter plot and linear regression analysis.

4.2.1. Scatter plot and Best-Fit Curve

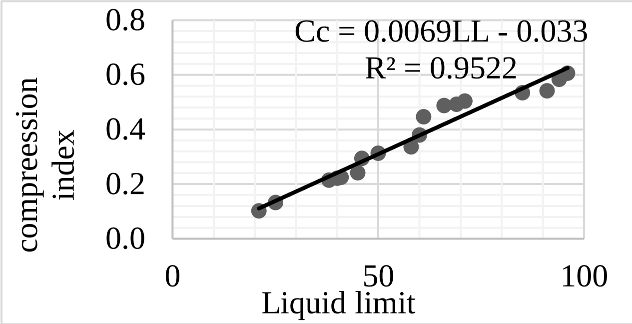
The dependent variables in this study are the compression index, coefficient of consolidation, and swelling index, whereas the independent variables are the liquid limit, plastic limit, plastic index, initial void ratio, and specific gravity. The scatter plots are used to express the degree of correlation strength of the dependent variables $Cc, Cs,$ and Cv by each independent variable of LL, PL, PI, eo, and Gs for all collected data, according to the thesis's goal. The scatter plot diagram is presented below.

4.2.1.1. Scatter plot for primary data

4.2.1.2. Scatter plots and best-fit curve for consolidation parameters and index properties

The scatter plots of the primary data are done by collecting the results of the laboratory tests of 18 soil samples. These plots are presented in Figures 4.1-4.15.as shown below

A. Relation between Cc and index properties



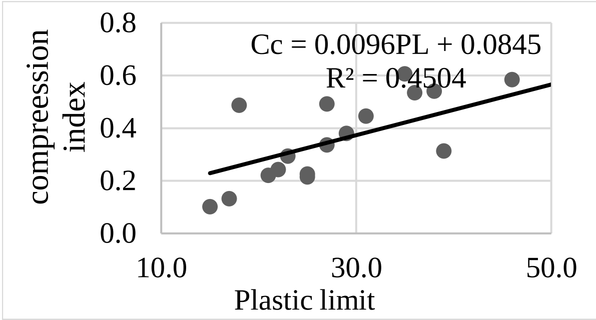


Figure 4.1(a) A. scatter plots Cc vs LL

Figure 4.2 (b) A. scatter plots Cc vs PL

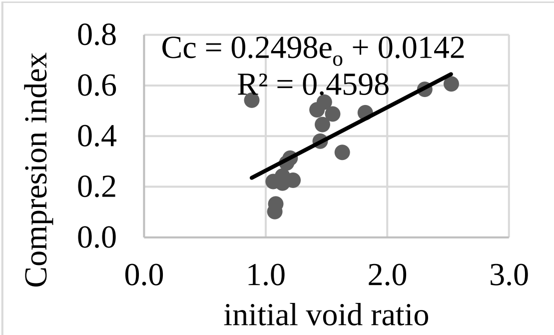


Figure 4.3 (c) A. scatter plots Cc vs eo

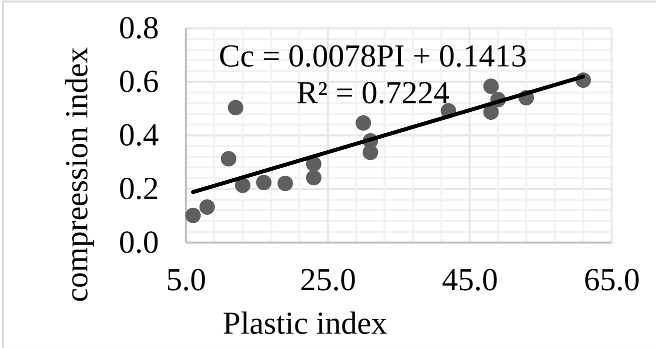


Figure 4.4 (d) A. scatter plots Cc vs PI

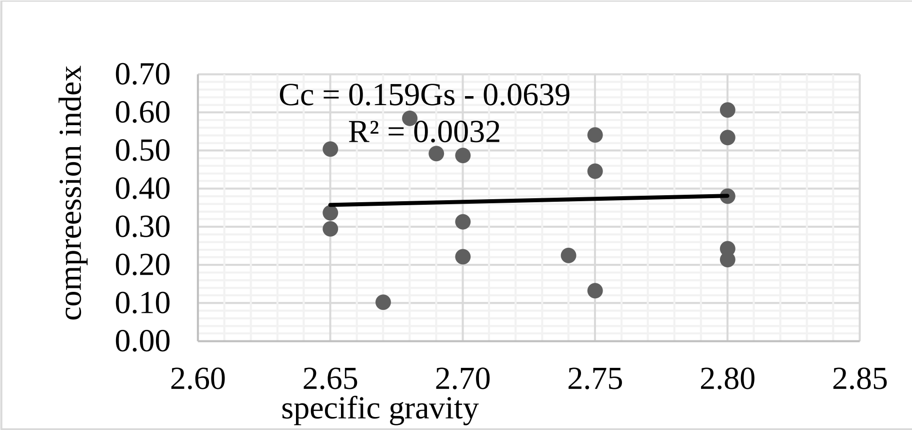


Figure 4.5 (e) A. scatter plots Cc vs Gs

The scatter diagrams shown above provide a visual representation of a relationship between variables plotted in a two-dimensional coordinate system. The diagram illustrates that the best fitting trend line relationship between the compression index and the liquid limit for all of the tested samples is Cc = 0.0069-0.033LL. The strength of this equation in predicting an outcome from the liquid limit is 95.2 % or R^2 = 0.952.

The compression index and liquid limit of the study area show that the closed scattered points to the trend line indicate that the relationship is strong. This shows that the determination of liquid limit satisfactory indicates the compressibility behavior soil of the study area.

The relationship between the compression index and the plastic limit for all of the tested samples is shown in Figure 4.2. The best fitting trend line for this relationship is $Cc = 0.0069PL + 0.0845$. The strength of this equation in predicting an outcome from the plastic limit is around 45.04 % or R^2= 0.4504.

The relationship between the plastic index and compression index of the study area illustrates that there is a tendency to increment of compression index as the plastic index increases as shown on a plotted graph. The best fitting trend line for this relationship is $Cc = 0.0078PI + 0.1403$. The strength of this equation in predicting an outcome from the plastic index is around 72.2.0 % or has an R^2 = 0.722 showing that the relationship is strong.

The best fitting trend line for the relationship between compression index and the initial void ratio is $Cc = 0.2403eo + 0.0249$. As the strength of this correlation is only 41.17 % it is deemed not reliable enough to be used as a predictor for the estimation of the compression index.

The best fitting trend line for the relationship between compression index and specific gravity is $Cc = 0.159Gs - 0.0639$. The strength of this equation in predicting an outcome from the liquid limit is 0.32 % or $R^2 = 0.0032$.

The compression index and specific gravity of the study area show that the widely scattered points from the trend line; indicate that the relationship is weak. This shows that the determination of specific gravity does not satisfactorily indicate the compressibility behavior soil of the study area. Generally, index properties namely the liquid limit, plastic limit, and plastic index are scattered close to the best-fit trend line, whereas the remaining independent variables, such as initial Void Ratio and specific gravity, deviate from the possible straight line.

B. Relation between Cv and index properties

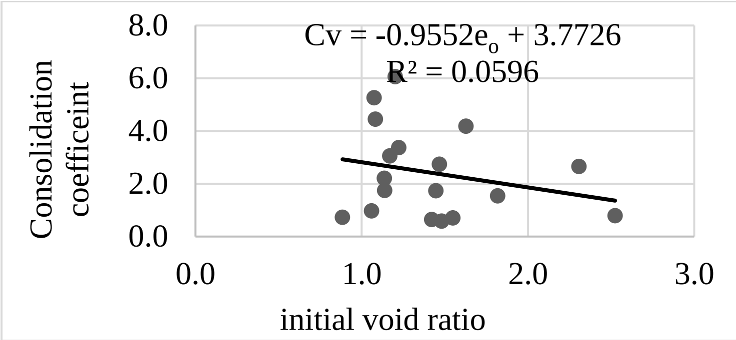


Figure 4.6 (a) B. scatter plots Cv vs eo

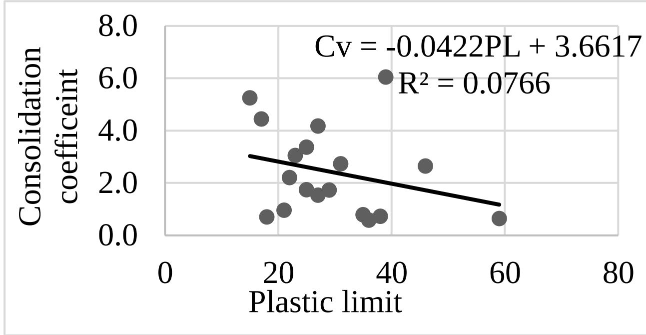


Figure 4.7 (b) B. scatter plots Cv vs PL

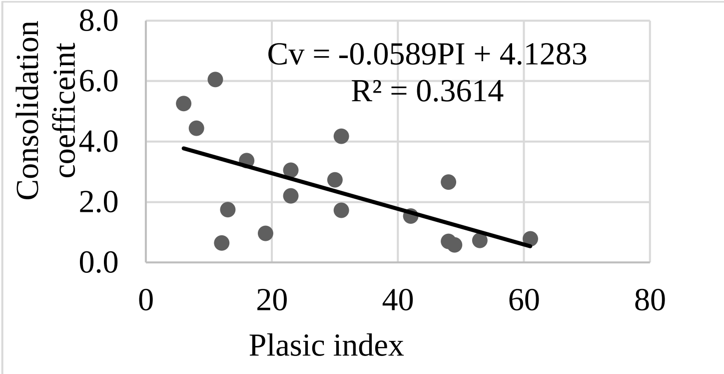


Figure 4.8 (c) B. scatter plots Cv vs PI

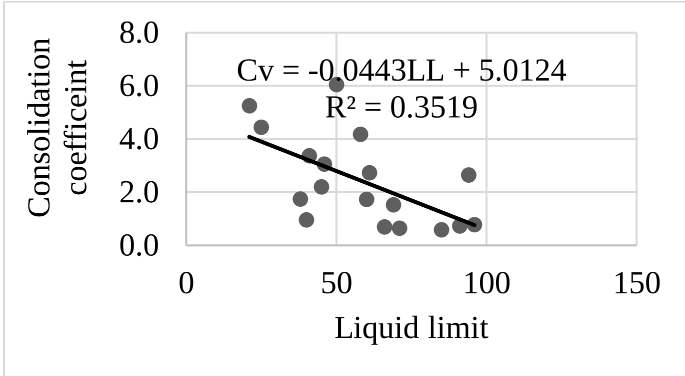


Figure 4.9 (d) B. scatter plots Cv vs LL

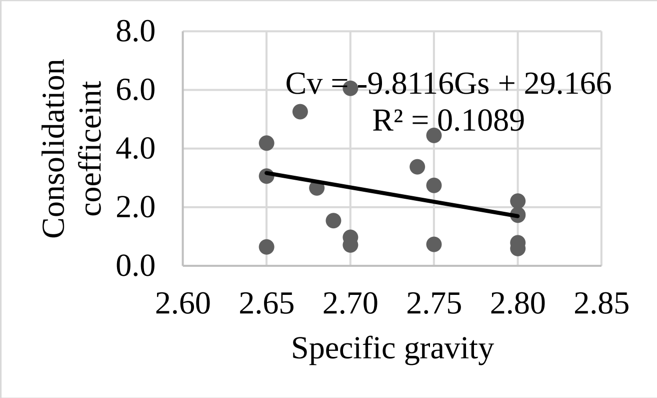
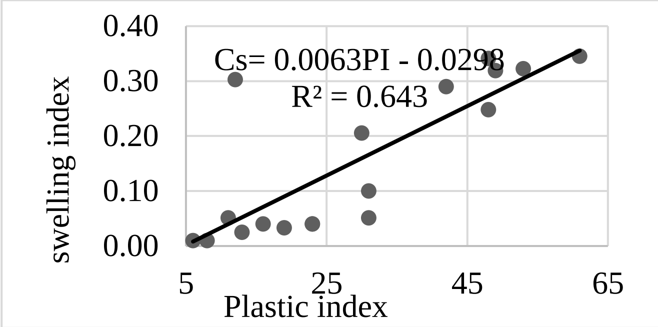


Figure 4.10 (e) B scatter plots Cv vs Gs

The coefficient of consolidation has an inverse relation with index properties of the study area; that means an increment of index properties results in decreases in the coefficient of consolidation. The graph plotted the coefficient of consolidation with LL, PL, PI, Gs, and e_o with their linear equation, R^2 shown in figures 4.6-4.10 above. The graph plotted indicates that the coefficient of consolidation and independent variables such as liquid limit and plastic index are randomly distributed around a straight line, whereas the remaining variables, initial void ratio, plastic limit, and specific gravity, are scattered and are widely scattered from the best-fit trend line.

C. Relation between Cs and index properties



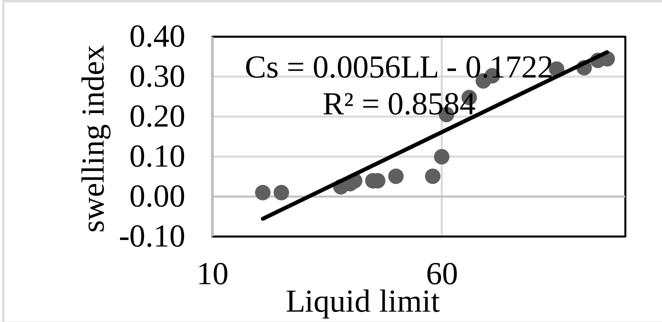


Figure 4.11 (a) C. scatter plots Cs vs PI

Figure 4.12 (b) C. scatter plots Cs vs LL

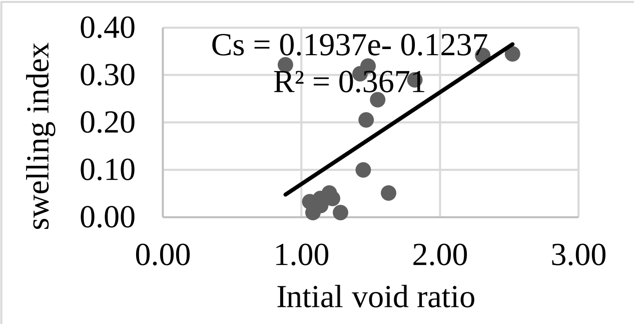


Figure 4.13 (c) C. scatter plots between Cs and eo

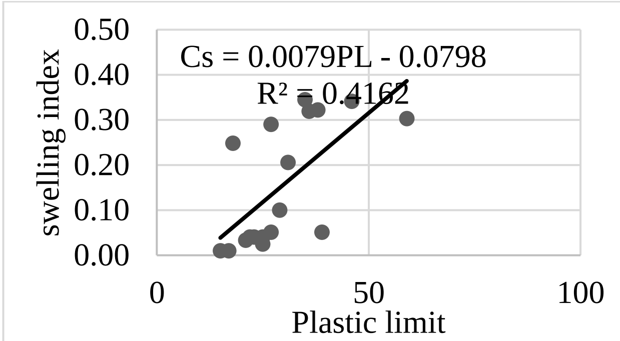


Figure 4.14 (d) C. scatter plots Cs vs PL

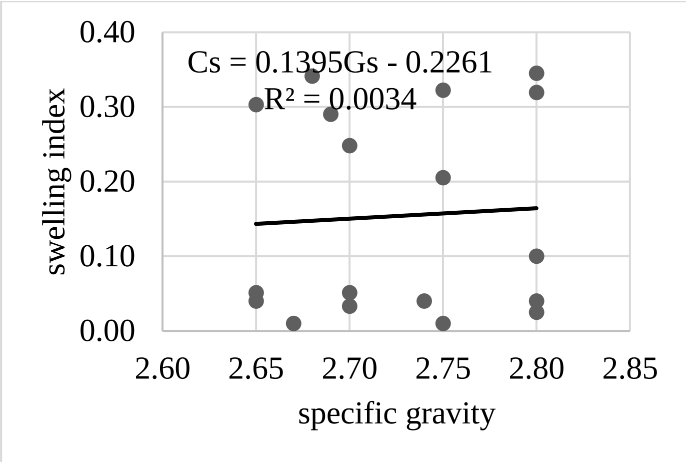


Figure 4.15 (e) C. scatter plots between Cs and Gs

The best fitting trend line of the relationship between the swelling index and the liquid limit for all of the tested samples is $Cs = 0.0056LL - 0.1722$. The strength of this equation in predicting an outcome from the liquid limit is 85.84 % or $R^2 = 0.8584$.

The swelling index and liquid limit of the study area show that the closed scattered points to the best-fit trend line; this indicates that the relationship is strong. This shows that the determination of liquid limit satisfactory indicates the swelling behavior soil of the study area. For the relationship between the plastic index and swelling index of the study area, there is a tendency to increment the swelling index as the plastic index increases as shown in Figure 4.11. The best fitting trend line for this relationship is $Cs = 0.0063PI - 0.0298$. The strength of this equation in predicting an outcome from the plastic index is around 64.3 % or has an $R^2 = 0.643$ showing that the relationship is medium.

The swelling index has a direct relation with PL, Gs, and e_o of the study area; that means an increment of these three properties results in increases in the swelling index. The graph plotted swelling index with PL, Gs, and e_o with their linear equation, R^2 shown in figures 4.11 - 4.15 above. The graph plotted indicates that the swelling index and these indices are widely scattered from the best-fit trend line, which indicates that weak relationship.

In general, liquid limit and plastic index are randomly scattered around straight lines while independent variables such as plastic limit, initial void ratio, and specific gravity are lies away from best fit straight lines.

4.2.2. Correlation and Linear Regression

4.2.2.1. Correlation

Correlation quantifies the linear relationship between two continuous variables X and Y, after the mathematician who first described it, the resulting correlation coefficient, r-value, is known as the Pearson correlation coefficient. X is the independent (explanatory) variable, while Y is the dependent (response) variable. The correlation coefficient has the significant advantage of not being dependent on the units of X and Y and may thus be used to compare any two variables regardless of their units. The correlation coefficient has a value between -1 and +1. The closer the correlation coefficient is to zero, the weaker the relationship between the variables; similarly, a correlation coefficient close to one indicates a strong relationship between the variables(YOHANNES ANOLE, 2018). Researchers recorded the interval range of Pearson correlation coefficients in different strength as, $|R| >= 0.8$ is strong correlation, $0.2 <= |R| < 0.8$ is correlation exists and $|R| < 0.2$ is weak correlation(Nourredine Mezouar, 2018).

In this thesis work, the correlation and correlation coefficient of the laboratory experimented samples are presented in the tables 4.2 below.

Table 4.2 Correlation Pearson coefficients (r) between variables for primary data

Correlations									
		Cc	Cs	Cv	LL	PL	PI	Gs	e_o
Cc	Pearson Correlation	1	.954**	-.610**	.976**	.671**	.850**	.057	.678**
	Sig. (2-tailed)		.000	.007	.000	.002	.000	.823	.002
	N	18	18	18	18	18	18	18	18
Cs	Pearson Correlation	.954**	1	-.637**	.926**	.645**	.802**	.058	.626**
	Sig. (2-tailed)	.000		.004	.000	.004	.000	.818	.005
	N	18	18	18	18	18	18	18	18
Cv	Pearson Correlation	-.610**	-.637**	1	-.593**	-.277	-.601**	-.330	-.244
	Sig. (2-tailed)	.007	.004		.009	.266	.008	.181	.329
	N	18	18	18	18	18	18	18	18
LL	Pearson Correlation	.976**	.926**	-.593**	1	.674**	.880**	.125	.666**
	Sig. (2-tailed)	.000	.000	.009		.002	.000	.621	.003
	N	18	18	18	18	18	18	18	18
PL	Pearson Correlation	.671**	.645**	-.277	.674**	1	.242	-.121	.364
	Sig. (2-tailed)	.002	.004	.266	.002		.333	.632	.138
	N	18	18	18	18	18	18	18	18
PI	Pearson Correlation	.850**	.802**	-.601**	.880**	.242	1	.242	.640**
	Sig. (2-tailed)	.000	.000	.008	.000	.333		.333	.004
	N	18	18	18	18	18	18	18	18
Gs	Pearson Correlation	.057	.058	-.330	.125	-.121	.242	1	.006
	Sig. (2-tailed)	.823	.818	.181	.621	.632	.333		.980
	N	18	18	18	18	18	18	18	18
e_o	Pearson Correlation	.678**	.626**	-.244	.666**	.364	.640**	.006	1
	Sig. (2-tailed)	.002	.005	.329	.003	.138	.004	.980	
	N	18	18	18	18	18	18	18	18
**. Correlation is significant at the 0.01 level (2-tailed).									

The above correlation results provide that, the Pearson correlation coefficient (r) ranges from 0.976 to 0.057 between dependent and independent variables. This result indicates that consolidation parameters are related to index properties to a different degree. For example, as seen in the above table the value of the Pearson correlation coefficient (r) is 0.976 between dependent variable Cc and independent variable LL. Thus, there is a strong direct relationship between Cc and LL. The value of r = -0.601 indicates there is a strong indirect (inverse) relationship between Cv and PI and for the of r = 0.057 there is a weak direct relationship between Cc and Gs.

4.2.2.2. Linear Regression Analysis

In this research work, an attempt is made to apply a single linear regression model and multiple linear regression models to characterize consolidation parameters of soil from soil index properties using a statistical approach. The general representation of a probabilistic single and multiple linear regression model is presented in the following forms:

$$y = a + bx \text{ ……………………………………………………………... (1)}$$

$$y = \beta o + \beta 1x1 + \beta 2x2 \dots\dots..\beta nxn \text{ ……………………………………. (2)}$$

Where slope (b) and y-intercept (a) are of the single linear regression model are called regression coefficients. Similarly, coefficients **β**o, **β**1, **β**2, and **β**n are termed multiple regression coefficients.

The appropriate way to generalize this to a probabilistic linear model is to assume that the actual value of Y is determined by the mean value function (the linear model).

The multiple regression equation, the value of adjusted-R^2, and the P-value are the main criteria in a linear multiple regression analysis. The determination coefficients (Adj. R^2), the overall significance (P-value), and standard error (SE) are main criteria for selection these equations(Mindaye Teshoma, 2015).

4.3. Developing Empirical Equation for Consolidation Parameters

Several functions composed of different parameters in different combinations were developed using the SPSS26 software to develop empirical equations for the prediction of the consolidation parameters of the study area (Appendix B). From among these models, the equation with the highest coefficient of determination (R^2) and most significant model was chosen, and the consolidation parameters of the study area soil were computed using this model.

4.3.1. Single Linear Regression Analysis

EQ5: regression between Cc and LL

Table 4.3 The summary model of Regression analysis between Cc and LL

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.976[a]	.952	.949	.035944
a. Predictors: (Constant), Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.412	1	.412	318.863	.000[b]
	Residual	.021	16	.001		
	Total	.433	17			
a. Dependent Variable: Compression index						
b. Predictors: (Constant), Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.033	.024		-1.370	.190
	Liquid limit	.007	.000	.976	17.857	.000
a. Dependent Variable: Compression index						

The model equation is then:

$$Cc = 0.007LL - 0.033 \quad \text{[5.1]}$$

with $R^2 = 0.952$

EQ41: regression between Cv and PI

Table 4.4 Summary model of Regression analysis between Cv and PI

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.601[a]	.361	.321	1.395436
a. Predictors: (Constant), Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	17.629	1	17.629	9.053	.008[b]
	Residual	31.156	16	1.947		
	Total	48.785	17			
a. Dependent Variable: Consolidation coefficient						
b. Predictors: (Constant), Plastic index						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.128	.658		6.273	.000
	Plastic index	-.059	.020	-.601	-3.009	.008
a. Dependent Variable: Consolidation coefficient						

The model equation is then:

$Cv = 4.128 - 0.059PI$ ………………………………………………………………… [5.2]

with $R^2 = 0.361$

EQ6: regression between Cs and LL

Table 4.5 Summary model of Regression analysis between Cs and LL

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.926[a]	.858	.849	.052829
a. Predictors: (Constant), Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.271	1	.271	96.957	.000[b]
	Residual	.045	16	.003		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.172	.035		-4.864	.000
	Liquid limit	.006	.001	.926	9.847	.000
a. Dependent Variable: Swelling index						

The model equation is then:

$Cs = -0.172 + 0.006LL$ ………………………………………………………. [5.3]

with $R^2 = 0.858$

4.3.2. Multiple Linear Regression Analysis

EQ1: Regression analysis between Cc and LL & e

Table 4.6 Summary model of Regression analysis between Cc and LL & e

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.977[a]	.954	.947	.036554
a. Predictors: (Constant), initial void ratio, Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.413	2	.206	154.386	.000[b]
	Residual	.020	15	.001		
	Total	.433	17			
a. Dependent Variable: Compression index						
b. Predictors: (Constant), initial void ratio, Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.046	.031		-1.488	.158
	Liquid limit	.007	.001	.942	12.645	.000
	initial void ratio	.019	.027	.051	.686	.503
a. Dependent Variable: Compression index						

The model equation is then,

$Cc = -0.046 + 0.007LL + 0.019eo$ …………………………………… [5.4]

With Adjusted- $R^2 = 0.947$

From this result, the model is significant and good. Since the P- value (0.000[b]) is <0.05 and Adjusted-R^2 = 0.947 implies that 94.7% of the dependent variable is explained by independent variables such as LL & e_o

EQ 52: Regression analysis between Cv and PI, e

Table 4.7 Summary model of Regression analysis between Cv and PI, eo

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.628[a]	.395	.314	1.402755
a. Predictors: (Constant), initial void ratio, Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19.269	2	9.635	4.896	.023[b]
	Residual	29.516	15	1.968		
	Total	48.785	17			
a. Dependent Variable: Consolidation coefficient						
b. Predictors: (Constant), initial void ratio, Plastic index						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.236	1.181		2.741	.015
	Plastic index	-.074	.026	-.754	-2.883	.011
	initial void ratio	.934	1.023	.239	.913	.376
a. Dependent Variable: Consolidation coefficient						

The model equation is then,

$$Cv = 3.236 + 0.934e - 0.074PI \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5.5]$$

With Adjusted- R^2 = 0.314

From this result, the model is significant and good. Since the P- value (0.023[b]) is <0.05 and Adjusted-R^2 = 0.314 implies that 31.4% of the dependent variable is explained by independent variables such as PI & e_o

EQ 28: regression analysis between Cs and PL & PI

Table 4.8 Summary model of Regression analysis between Cs and PI & PL

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.927[a]	.859	.840	.054410
a. Predictors: (Constant), Plastic limit, Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.271	2	.135	45.744	.000[b]
	Residual	.044	15	.003		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), Plastic limit, Plastic index						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.177	.040		-4.425	.000
	Plastic index	.005	.001	.686	6.868	.000
	Plastic limit	.006	.001	.479	4.798	.000
a. Dependent Variable: Swelling index						

The model equation is then,

$Cs = -0.177 + 0.005PI + 0.006PL$…………………… ………………. [5.6]

With Adjusted- R^2 = 0.84

From this result, the model is significant and good. Since the P- value (0.000^b) is <0.05 and Adjusted-R^2 = 0.84 implies that 84% of the dependent variable is explained by independent variables such as PI & PL

Table 4.9 Summary of the Developed correlations equation for Cc &Cs

Single Linear Regression Equation			
R^2	Equation		EQ.
0.46	Cc = 0.014+0.25e_o		EQ.1
0.003	Cc = -0.064+0.159Gs		EQ.2
0.722	Cc = 0.141+0.008PI		EQ.3
0.45	Cc = 0.085+0.01PL		EQ.4
0.952	Cc= -0.033+0.007LL		EQ.5
0.858	Cs = -0.172+0.006LL		EQ.6
0.416	Cs = -0.08+0.0008PL		EQ.7
0.003	Cs = -0.226+0.14Gs		EQ.8
0.391	Cs = -0.126+0.197e		EQ.9
0.643	Cs = -0.03+0.006PI		EQ.10
Multiple Regression equation			EQ.11
R	Adjusted R	Equation	EQ.12
0.958	0.945	Cc = 0.419+0.007LL-0.171Gs+0.016e_o	EQ.13
0.95	0.947	Cc = -0.046+0.007LL+0.019e_o	EQ.14
0.953	0.946	Cc = -0.037+0.007LL+0.000PL	EQ.15
0.953	0.946	Cc = -0.037+0.007PL+0.007PI	EQ.16
0.463	0.391	Cc= -0.386+0.25e_o +0.147Gs	EQ.17
0.954	0.944	Cc= -0.052+0.021e_o+0.007PL+0.006PI	EQ.18
0.680	0.612	Cc = -0.98+0.182e_o+0.321Gs+0.007PL	EQ.19
0.753	0.720	Cc= 0.061+0.007PI+0.084e	EQ.20
0.96	0.95	Cc= 0.47-0.186Gs+0.007LL	EQ.21
0.667	0.623	Cc = -0.1+0.184e+0.007PL	EQ.22
0.96	0.95	Cc = 0.435+0.007LL-0.17Gs+0.016e	EQ.23
0.862	0.819	Cs = 0.169+0.004e-0.128Gs+0.006LL	EQ.24
0.859	0.829	Cs = -0.182+0.006LL-0.001PI+0.007e	EQ.25
0.86	0.84	Cs = 0.206+0.006LL-0.14Gs	EQ.26
0.859	0.829	Cs = -0.182+0.005PI+0.006PL+0.007e	EQ.27
0.86	0.84	Cs = -0.177+0.005PI+0.006PL	EQ.28
0.394	0.314	Cs = -0.48+0.197e+0.13Gs	EQ.29
0.86	0.84	Cs = -0.176+0.005LL+0.005e	EQ.30
0.862	0.832	Cs = 0.201+0.006LL+0.002e-0.138Gs	EQ.31
0.664	0.619	Cs = -0.087+0.06e+0.005PI	EQ.32
0.862	0.832	Cs = 0.181+0.006PL+0.006PI-0.131Gs	EQ.33
0.663	0.618	Cs = 0.903-0.345Gs+0.007PI	EQ.34
0.677	0.608	Cs = 0.691+0.006PI-0.285Gs+0.05e	EQ.35

Table 4.10 Summary of the Developed correlations equations for Cv

Single Linear Regression Equation			EQ.
R	Equation		EQ.36
0.077	Cv = 3.662-0.042PL		EQ.37
0.352	Cv = 5.012-0.044LL		EQ.38
0.06	Cv = 3.772-0.955e_o		EQ.39
0.109	Cv= 29.166-9.812Gs		EQ.40
0.361	Cv= 4.128-0.059PI		EQ.41
Multiple Regression equation			
R	Adjusted R	Equation	
0.468	0.304	Cv= 19.942-5.891Gs-0.036LL-0.029PI+1.068e_o	EQ.42
0.433	0.311	Cv=3.757-0.032LL+1.223e_o -0.042PI	EQ.43
0.38	0.297	Cv= 4.661-0.021LL-0.034PI	EQ.46
0.428	0.305	Cv= 23.388-0.028LL-0.021e-6.865Gs	EQ.47
0.38	0.297	Cv= 4.661-0.056LL+0.034PL	EQ.48
0.468	0.304	Cv = 19.942-0.036PL-0.066PI-5.891Gs-1.068e	EQ.49
0.393	0.312	Cv= 4.295-0.058LL+1.059e_o	EQ.50
0.42	0.295	Cv= 16.632-4.898Gs+0.771e_o -0.067PI	EQ.51
0.395	0.314	Cv= 3.236 +0.934e_o -0.074PI	EQ.52

Using the new equations in table 4.9, the compression index, of the study area is calculated. The results of the analysis are given in (Table 4.11)

Table 4.11 Comparison of the measured value with calculated value for Cc

Measured Cc values	EQ.5	EQ.13	EQ.14	EQ.15	EQ.16	EQ.18	EQ.21	EQ.23
0.606	0.639	0.653	0.674	0.635	0.635	0.612	0.621	0.671
0.584	0.625	0.656	0.656	0.621	0.621	0.606	0.630	0.674
0.541	0.604	0.600	0.608	0.600	0.600	0.551	0.596	0.619
0.534	0.562	0.559	0.577	0.558	0.558	0.525	0.544	0.578
0.504	0.464	0.486	0.478	0.460	0.460	0.463	0.474	0.504
0.492	0.450	0.471	0.472	0.446	0.446	0.427	0.453	0.490
0.487	0.429	0.444	0.445	0.425	0.425	0.395	0.430	0.463
0.446	0.394	0.399	0.409	0.390	0.390	0.376	0.386	0.418
0.38	0.387	0.383	0.401	0.383	0.383	0.367	0.369	0.402
0.336	0.373	0.398	0.391	0.369	0.369	0.357	0.383	0.417
0.313	0.317	0.327	0.327	0.313	0.313	0.312	0.318	0.345
0.294	0.289	0.307	0.298	0.285	0.285	0.272	0.299	0.325
0.242	0.282	0.273	0.291	0.278	0.278	0.264	0.264	0.292
0.225	0.254	0.257	0.264	0.250	0.250	0.245	0.247	0.276
0.221	0.247	0.254	0.254	0.243	0.243	0.231	0.248	0.273
0.214	0.233	0.224	0.242	0.229	0.229	0.225	0.215	0.243
0.132	0.142	0.141	0.150	0.138	0.138	0.138	0.134	0.160
0.102	0.114	0.127	0.121	0.110	0.110	0.112	0.120	0.145

Using the new equations in table 4.9, the swelling index of the study area is calculated. The results of the analysis are given in (Table4.12)

Table 4.12 Comparison of the measured value with calculated value for Cs

Measured Cs values	EQ.6	EQ.10	EQ.24	EQ.25	EQ.26	EQ.27	EQ.28	EQ.30	EQ.33
0.345	0.404	0.336	0.397	0.351	0.390	0.715	0.338	0.317	0.390
0.341	0.392	0.258	0.399	0.350	0.395	0.714	0.339	0.306	0.394
0.322	0.374	0.288	0.367	0.317	0.367	0.681	0.316	0.283	0.367
0.319	0.338	0.264	0.327	0.289	0.324	0.653	0.284	0.256	0.324
0.303	0.254	0.042	0.261	0.242	0.261	0.606	0.237	0.186	0.260
0.290	0.242	0.222	0.246	0.203	0.243	0.567	0.195	0.178	0.243
0.248	0.224	0.258	0.226	0.177	0.224	0.541	0.171	0.162	0.223
0.205	0.194	0.150	0.189	0.164	0.187	0.528	0.159	0.136	0.187
0.100	0.188	0.156	0.176	0.157	0.174	0.521	0.152	0.131	0.174
0.051	0.176	0.156	0.184	0.146	0.183	0.510	0.140	0.122	0.182
0.051	0.128	0.036	0.128	0.115	0.128	0.479	0.112	0.080	0.127
0.040	0.104	0.108	0.110	0.079	0.111	0.443	0.076	0.060	0.110
0.039	0.098	0.108	0.085	0.073	0.084	0.437	0.070	0.055	0.084
0.040	0.074	0.066	0.069	0.057	0.068	0.421	0.053	0.035	0.068
0.033	0.068	0.084	0.068	0.046	0.068	0.410	0.044	0.029	0.067
0.025	0.056	0.048	0.043	0.041	0.042	0.405	0.038	0.020	0.042
0.010	-0.022	0.018	-0.029	-0.032	-0.029	0.332	-0.035	-0.046	-0.029
0.010	-0.046	0.006	-0.042	-0.054	-0.042	0.310	-0.057	-0.066	-0.043

Using the equations in table 4.10, the consolidation coefficient of the study area is calculated. The results of the analysis are given in (Table 4.13).

Table 4.13 Comparison of the measured value with calculated value for Cv

Measured Cv values	EQ.38	EQ.41	EQ.42	EQ.43	EQ.47	EQ.49	EQ.50	EQ.52
0.79	0.788	0.529	0.9178	1.21	1.425	-4.53	1.4	1.079
2.659	0.876	1.296	1.842	1.554	2.309	-3.13	1.286	1.839
0.732	1.008	1.001	-0.126	-0.299	1.943	-2.07	-0.046	0.141
0.589	1.272	1.237	0.5479	0.79	1.755	-2.66	0.933	0.993
0.649	1.888	3.420	2.9455	2.72	3.178	-0.1	1.683	3.676
1.537	1.976	1.650	2.3348	2.008	2.951	-1.59	2.218	1.826
0.706	2.108	1.296	1.9226	1.523	2.972	-1.43	2.107	1.131
2.741	2.328	2.358	2.2425	2.339	2.77	-0.92	2.311	2.386
1.731	2.372	2.299	1.9336	2.305	2.456	-1.19	2.347	2.293
4.184	2.46	2.299	3.0826	2.59	3.538	-0.43	2.655	2.463
6.057	2.812	3.479	3.2	3.164	3.427	0.624	2.667	3.544
3.058	2.988	2.771	3.2574	2.75	3.883	0.735	2.866	2.627
2.21	3.032	2.771	2.3745	2.742	2.882	-0.08	2.889	2.596
3.375	3.208	3.184	3.1668	3.269	3.404	0.538	3.212	3.194
0.968	3.252	3.007	3.1774	2.975	3.71	0.894	3.098	2.82
1.747	3.34	3.361	2.9176	3.387	3.078	0.474	3.296	3.337
4.447	3.912	3.656	3.7653	3.944	3.787	1.446	3.991	3.655
5.26	4.088	3.774	4.4311	4.148	4.448	2.129	4.215	3.796

4.4. Discussion of Correlation

4.4.1. Comparison Between Developed and Existing Correlations Equations

The validation of the developed equation is conducted by comparing known test results and predicted results using a newly developed equation and three existing correlation equations. Comparisons have been made between the newly developed and recently developed correlation equation. The detailed comparisons for soils of the same characteristics are indicated here in tables: 4.14 to 4.16.

Table 4.14 Comparison of developed and existing correlation of Cc values

Measured Cc, values	Newly Developed Cc Values for EQ.14	Variations from Measured values	Newly Developed Cc Values for EQ.5	variations from Measured values	Tirsit Demisse (2015)	Variations from measured values	Terzaghi and Peck (1967)	Variation From measured values	Solomon Desta (2012)	Variation From measured values
0.606	0.674	11.2	0.639	5.4	0.028	-95.5	0.774	27.7	0.348	-42.6
0.584	0.656	12.3	0.625	7.0	0.082	-86.0	0.756	29.5	0.336	-42.5
0.541	0.608	12.4	0.604	11.6	0.038	-93.0	0.729	34.8	0.318	-41.2
0.534	0.577	8.1	0.562	5.2	0.029	-94.5	0.675	26.4	0.282	-47.2
0.504	0.478	-5.2	0.464	-7.9	0.144	-71.4	0.549	8.9	0.198	-60.7
0.492	0.472	-4.2	0.450	-8.5	-0.015	-103.0	0.531	7.9	0.186	-62.2
0.487	0.445	-8.5	0.429	-11.9	-0.060	-112.4	0.504	3.5	0.168	-65.5
0.446	0.409	-8.3	0.394	-11.7	0.004	-99.0	0.459	2.9	0.138	-69.1
0.38	0.401	5.7	0.387	1.8	-0.006	-101.5	0.45	18.4	0.132	-65.3
0.336	0.391	16.3	0.373	11.0	-0.015	-104.5	0.432	28.6	0.12	-64.3
0.313	0.327	4.4	0.317	1.3	0.044	-86.1	0.36	15.0	0.072	-77.0
0.294	0.298	1.4	0.289	-1.7	-0.036	-112.4	0.324	10.2	0.048	-83.7
0.242	0.291	20.1	0.282	16.5	-0.042	-117.2	0.315	30.2	0.042	-82.6
0.225	0.264	17.4	0.254	12.9	-0.026	-111.7	0.279	24.0	0.018	-92.0
0.221	0.254	15.0	0.247	11.8	-0.047	-121.2	0.27	22.2	0.012	-94.6
0.214	0.242	12.9	0.233	8.9	-0.027	-112.4	0.252	17.8	0	-100.0
0.132	0.150	13.3	0.142	7.6	-0.067	-150.6	0.135	2.3	-0.078	-159.1
0.102	0.121	19.0	0.114	11.8	-0.077	-175.3	0.099	-2.9	-0.102	-200.0
Ave. Variation		8.0		4.0		-108.2		17.1		-80.5

Table 4.15 Comparison developed and existing correlation of Cs values

Measured Cs, values	Newly Developed Cs Values for EQ.6	Variation from Measured value (%)	Newly Developed Cs Values for EQ.28	Variation from Measured value (%)	Kordnaeij *et al* (2015)	Variation from Measured value (%)	Nakase et al	Variation from Measured value (%)	Aydin Alptekin (2019)	Variation from Measured value (%)
0.345	0.404	17.1	0.338	-2.0	0.103	-70.0	0.109	-68.3	0.193	-43.9
0.341	0.392	15.0	0.339	-0.6	0.101	-70.4	0.084	-75.3	0.175	-48.7
0.322	0.374	16.1	0.316	-1.9	0.097	-69.9	0.094	-70.8	0.053	-83.5
0.319	0.338	6.0	0.284	-11.0	0.089	-72.1	0.086	-73.0	0.104	-67.3
0.303	0.254	-16.2	0.237	-21.8	0.071	-76.6	0.014	-95.3	0.099	-67.3
0.29	0.242	-16.6	0.195	-32.8	0.068	-76.4	0.073	-75.0	0.133	-54.1
0.248	0.224	-9.7	0.171	-31.0	0.064	-74.0	0.084	-66.1	0.110	-55.6
0.205	0.194	-5.4	0.159	-22.4	0.058	-71.8	0.049	-76.0	0.103	-49.8
0.1	0.188	88.0	0.152	52.0	0.057	-43.4	0.051	-48.8	0.101	1.3
0.051	0.176	245.1	0.140	174.5	0.054	5.9	0.051	0.4	0.117	128.9
0.051	0.128	151.0	0.112	119.6	0.044	-14.5	0.012	-75.7	0.080	57.3
0.04	0.104	160.0	0.076	90.0	0.038	-4.0	0.036	-10.8	0.078	93.9
0.04	0.098	145.0	0.070	75.0	0.037	-7.3	0.036	-10.8	0.075	86.8
0.04	0.074	85.0	0.053	32.5	0.032	-20.3	0.022	-44.7	0.082	105.2
0.033	0.068	106.1	0.044	33.3	0.031	-7.3	0.028	-15.3	0.068	106.5
0.025	0.056	124.0	0.038	52.0	0.028	12.0	0.016	-34.8	0.075	199.3
0.01	-0.022	-320.0	-0.035	-450.0	0.011	11.0	0.007	-34.0	0.070	600.2
0.01	-0.046	-560.0	-0.057	-670.0	0.006	-41.0	0.003	-72.8	0.069	594.2
Average of variation		12.8		-34.1		-38.3		-52.6		83.5

Table 4.16 Comparison of developed and existing correlation of Cv values

Measured Cv (m/year) values	Newly Developed Cv values for EQ.52	Variation from Measured values	Newly Developed Cv values for EQ.41	Variation from Measured values	Solanki and Desai	Variation from Measured values	Nur Izzati Ahmad Lazim et al (2018)	Variation from Measured values	Asma & abbas (2011)	Variation from Measured values
0.79	1.079	36.6	0.529	-33.0	-5.0E-01	-2E+02	-0.7317	-192.6	1.446	83.1
2.659	1.839	-30.8	1.296	-51.3	-2.6E-01	-1E+02	-0.2766	-110.4	1.500	-43.6
0.732	0.141	-80.8	1.001	36.7	-3.5E-01	-1E+02	-0.4931	-167.4	1.588	117.0
0.589	0.993	68.6	1.237	110.0	-2.8E-01	-1E+02	-0.4123	-170.0	1.789	203.8
0.649	3.676	466.4	3.420	427.0	4.0E-01	-4E+01	0.7916	22.0	2.452	277.8
1.537	1.826	18.8	1.650	7.4	-1.5E-01	-1E+02	-0.3314	-121.6	2.578	67.7
0.706	1.131	60.2	1.296	83.6	-2.6E-01	-1E+02	-0.5846	-182.8	2.786	294.6
2.741	2.386	-12.9	2.358	-14.0	6.7E-02	-1E+02	0.021	-99.2	3.198	16.7
1.731	2.293	32.5	2.299	32.8	4.8E-02	-1E+02	-0.0267	-101.5	3.292	90.2
4.184	2.463	-41.1	2.299	-45.1	4.8E-02	-1E+02	-0.0487	-101.2	3.493	-16.5
6.057	3.544	-41.5	3.479	-42.6	4.1E-01	-9E+01	0.5973	-90.1	4.529	-25.2
3.058	2.627	-14.1	2.771	-9.4	1.9E-01	-9E+01	0.1129	-96.3	5.241	71.4
2.21	2.596	17.5	2.771	25.4	1.9E-01	-9E+01	0.1019	-95.4	5.446	146.4
3.375	3.194	-5.4	3.184	-5.7	3.2E-01	-9E+01	0.3148	-90.7	6.410	89.9
0.968	2.820	191.3	3.007	210.6	2.7E-01	-7E+01	0.1937	-80.0	6.693	591.4
1.747	3.337	91.0	3.361	92.4	3.8E-01	-8E+01	0.3919	-77.6	7.321	319.1
4.447	3.655	-17.8	3.656	-17.8	4.7E-01	-9E+01	0.4324	-90.3	15.234	242.6
5.26	3.796	-27.8	3.774	-28.3	5.1E-01	-9E+01	0.4618	-91.2	20.669	292.9
Variation Average		39.5		43.3		-102.7		-107.6		156.6

It can be briefly observed from the above table the newly developed relation is betters as compared to the existing equations. The existing equation and the newly developed equations of compression index have maximum average variation precent from actual values is of -108.2% and 8% respectively. This indicates that the newly developed equation is more precious as compared to the existing one. In other words, the newly developed equation variability is close to the actual compression index.

For the swelling index, the existing equation and newly developed maximum average variation percent from actual measured swelling index values is of 83.5% and -34.1% respectively. Thus, the newly developed equation is more precise than the existing one. In a similar manner for a coefficient of consolidation, the existing equation and newly developed equation has maximum average variation percent 156.6% and 43.3% respectively. From this, the newly developed equation has less variability from actual consolidation coefficient as compared to an existing one.

This variation in the developed equation by a different researcher at a different place is may occur due to the difference in test procedures and also the unique properties of the geological material where this correlation was developed.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This research was conducted to develop correlation equation between consolidation parameters and index properties of fine-grained soils available locally. Accordingly, the required laboratory tests were conducted on samples collected from different locations in Bishoftu town.

Correlation equations were developed through various single and multiple linear regression analyses, and based on the determination coefficient (R^2, adjusted-R^2), P-value or significant level and standard error of analysis, the predictive equation was selected to determine Cc, Cv, and Cs in terms of LL, PL, PI, Gs, and eo.

According to the statistical computations made, the relationship that has been made between Cc with LL and Cc with LL & e_o have highest determination coefficients of R^2 is 0.952 and Adjusted- R^2 is 0.947 respectively. The recommened correlation equations for Cc are:

$$Cc = -0.033 + 0.007LL$$

$$Cc = -0.046 + 0.007LL + 0.019eo$$

For Swelling Index, based on statistical computational analysis made, the correlation equation between Cs with LL and Cs with PI & PL have highest determination coefficients of R^2 is 0.858 and Adjusted- R^2 is 0.84 respectively. The determination coefficients of the model, R^2 is 0.858 and Adjusted-R^2 is 0.84. Thus, the developed models for these parameters is given by sigle and multiple regression equation as below:

$$Cs = -0.172 + 0.006LL$$

$$Cs = -0.177 + 0.006PL + 0.005PI$$

Similarly, from the linear regression analysis made, the correlation equation between the Cv with PI and Cv with PI & e_o are found to be better with the determination coefficients of R^2 is about 0.361 and Adjusted-R^2 is 0.314 respectively. To sum up, the correlation equation of the developed statistical models are given as below:

$$Cv = 4.128 - 0.059PI$$

$$Cv = 3.236 + 0.934eo - 0.074PI$$

The comparisons made between the newly developed equations and existing equations indicate that the correlation equations developed from this study approximate compression index, swelling index, and coefficient of consolidation values of Bishoftu fine-grained soils in a better way than existing correlation equations in the literature.

5.2. Recommendations

The exposure encountered in trying to conduct the current research has revealed areas where further efforts may be proved in the future. Following is some of the recommendations concerning the subject study.

- Further studies are required to enforce the conclusion drawn herein above and determine the extent of applicability of the newly developed empirical equations.
- The equations developed may be further improved by increasing the number of samples collected from different locations of Bishoftu town, especially from areas that cannot be covered in this paper.
- It is also recommended to carry out such a study in other parts of Ethiopia, especially in regions where fine-grained soils are abundantly found.

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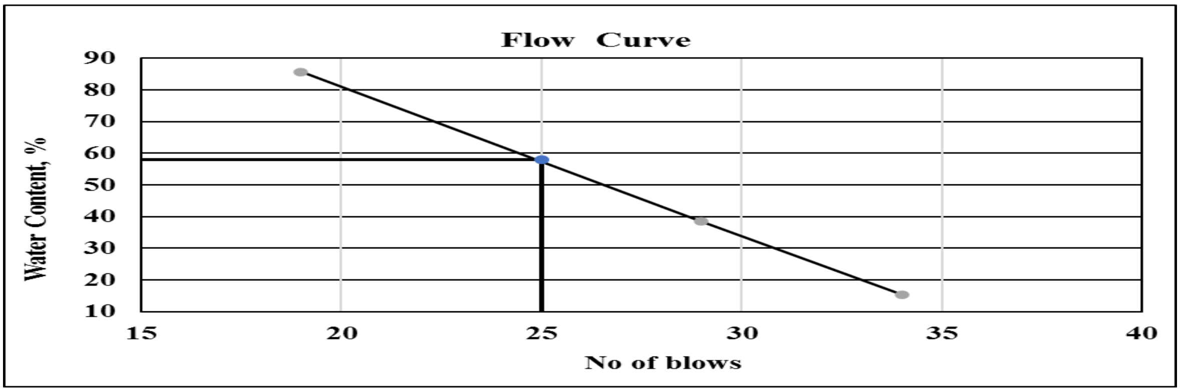
APPENDIX

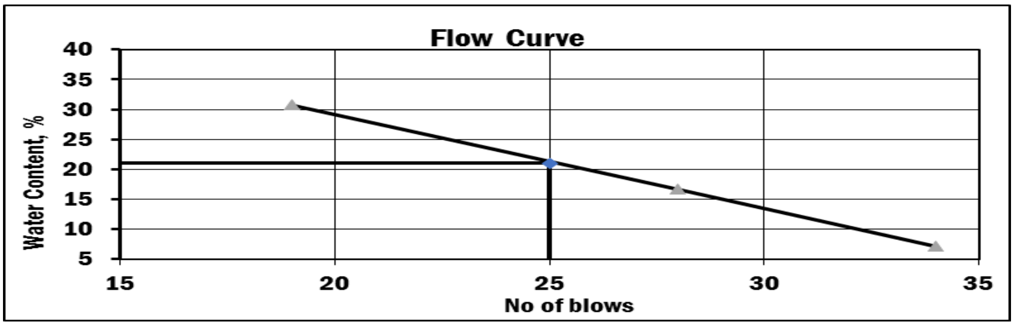
Appendix A: Details of the Laboratory Test Result

Table I-1 Laboratory test results of liquid limit and plastic limit

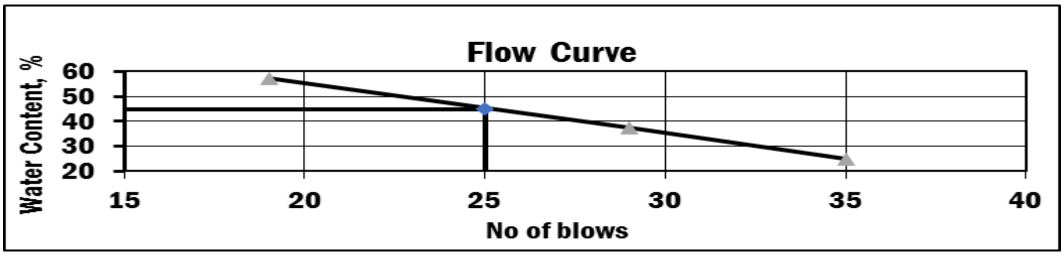
Sample No PT 1			Sample Depth, m : 1.5				
	Liquid Limit				Plastic Limit		
Trial No	1	2	3		1	2	3
Container No	A1	A2	A3		C34	71	A35
Mass of container, g	61	60	59		19.73	30.44	19.32
Mass of container + Wet soil, g	74	78	74		31.32	42.15	26.75
Mass of container + Dry soil, g	68	73	72		28.78	39.78	25.14
Mass of water, g	6.00	5.00	2.00		2.54	2.37	1.61
Mass of dry soil, g	7.00	13.00	13.00		9.05	9.34	5.82
Water content, %	85.71	38.46	15.38		28.07	25.37	27.66
No of blows	19	29	34		------	------	
Liquid Limit, % = 58		Plastic Limit, % = 27			PI, %= 31		



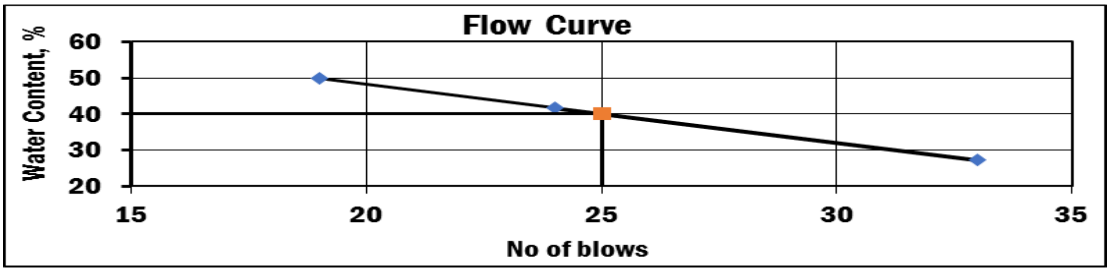
Sample No PT 1			Sample Depth, m : 3				
	Liquid Limit				Plastic Limit		
Trial No	1	2	3		1	2	3
Container No	26	A36	C31		C34	71	A35
Mass of container, g	60	61	61		19.68	19.93	19.43
Mass of container + Wet soil, g	77	75	76		28.45	34.44	24.75
Mass of container + Dry soil, g	73	73	75		27.54	33.54	23.65
Mass of water, g	4.00	2.00	1.00		0.91	0.90	1.10
Mass of dry soil, g	13.00	12.00	14.00		7.86	13.61	4.22
Water content, %	30.77	16.67	7.14		11.58	6.61	26.07
No of blows	19	28	34		------	------	
Liquid Limit, % = 21		Plastic Limit, % = 15			PI, %= 6		



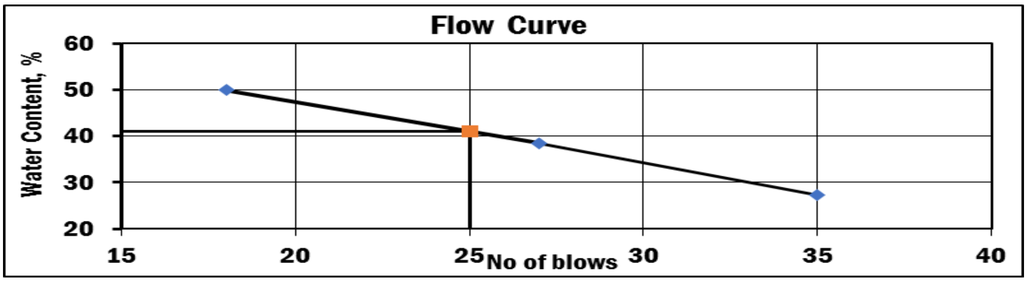
Sample No	PT 2				Sample Depth, m :	1.5			
				Liquid Limit				Plastic Limit	
Trial No		1	2	3		1	2	3
Container No		26	A36	C31		C34	71	A35
Mass of container, g		61	60	60		29.53	30.21	29.9
Mass of container + Wet soil, g		71	71	71		36.38	35.56	32.87
Mass of container + Dry soil, g		69	68	67		35.75	34.29	32.29
Mass of water, g		2.00	3.00	4.00		0.63	1.27	0.58
Mass of dry soil, g		8.00	8.00	7.00		6.22	4.08	2.39
Water content, %		25.00	37.50	57.14		10.13	31.13	24.27
No of blows		35	29	19		------	------	
Liquid Limit, % =	45	Plastic Limit, %	=	22		PI, %=	23	



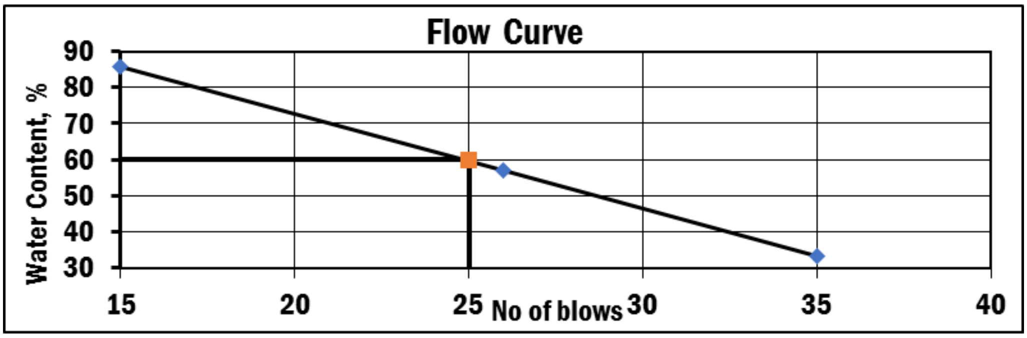
Sample No	PT 2				Sample Depth, m :	3			
				Liquid Limit				Plastic Limit	
Trial No		1	2	3		1	2	3
Container No		26	A36	C31		C34	71	A35
Mass of container, g		60	61	60		19.38	30.62	30.87
Mass of container + Wet soil, g		74	78	78		31.08	40.29	42.28
Mass of container + Dry soil, g		71	73	72		30.43	38.09	39.79
Mass of water, g		3.00	5.00	6.00		0.65	2.20	2.49
Mass of dry soil, g		11.00	12.00	12.00		11.05	7.47	8.92
Water content, %		27.27	41.67	50.00		5.88	29.45	27.91
No of blows		33	24	19		------	------	
Liquid Limit, % =	40	Plastic Limit, %	=	21		PI, %=	19	



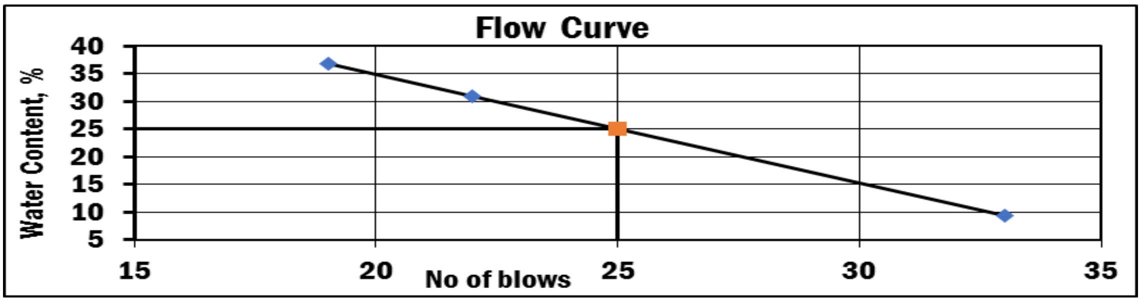
Sample No	PT 3			Sample Depth, m	: 1.5			
		Liquid Limit				Plastic Limit		
Trial No		1	2	3		1	2	3
Container No		26	A36	C31		C34	71	A35
Mass of container, g		60	61	61		30.22	19.29	19.33
Mass of container + Wet soil, g		75	79	75		36.16	25.75	23.24
Mass of container + Dry soil, g		70	74	72		35.65	24.19	22.24
Mass of water, g		5.00	5.00	3.00		0.51	1.56	1.00
Mass of dry soil, g		10.00	13.00	11.00		5.43	4.90	2.91
Water content, %		50.00	38.46	27.27		9.39	31.84	34.36
No of blows		18	27	35		------	------	
Liquid Limit, % =	41	Plastic Limit, %		=	25	PI, %=	16	



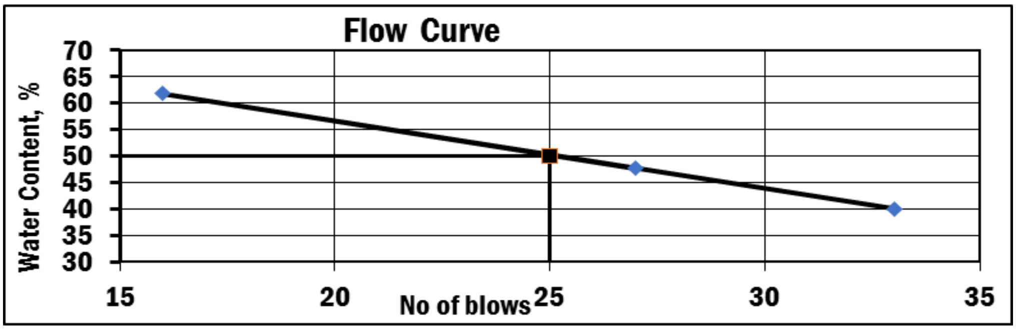
Sample No	PT 3			Sample Depth, m	: 3			
		Liquid Limit				Plastic Limit		
Trial No		1	2	3		1	2	3
Container No		26	A36	C31		C34	71	A35
Mass of container, g		95	92	96		30.99	29.53	19.7
Mass of container + Wet soil, g		107	103	109		40.11	39.07	26.81
Mass of container + Dry soil, g		104	99	103		39.01	37.46	24.36
Mass of water, g		3.00	4.00	6.00		1.10	1.61	2.45
Mass of dry soil, g		9.00	7.00	7.00		8.02	7.93	4.66
Water content, %		33.33	57.14	85.71		13.72	20.30	52.58
No of blows		35	26	15		------	------	
Liquid Limit, % =	60	Plastic Limit, %		=	29	PI, %=	31	



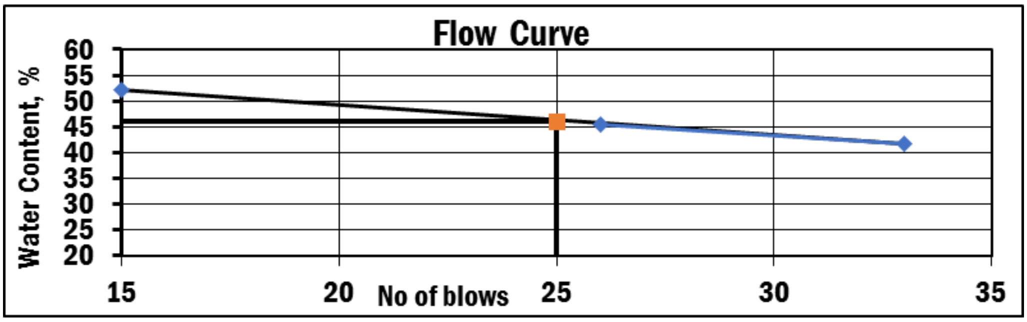
Sample No	PT 7,5			Sample Depth, m	:	1.5			
			Liquid Limit			Plastic Limit			
Trial No		1	2	3		1	2	3	
Container No		26	A36	C31		C34	71	A35	
Mass of container, g		19.58	19.6	19.52		19.42	19.29	19.33	
Mass of container + Wet soil, g		30.85	33.54	34.64		23.85	21.75	32.87	
Mass of container + Dry soil, g		29.89	30.25	30.58		23.65	21.05	31.89	
Mass of water, g		0.96	3.29	4.06		0.20	0.70	0.98	
Mass of dry soil, g		10.31	10.65	11.06		4.23	1.76	12.56	
Water content, %		9.31	30.89	36.71		4.73	39.77	7.80	
No of blows		33	22	19		------	------		
Liquid Limit, % =	25	Plastic Limit, %	=	17	PI, %=	8			



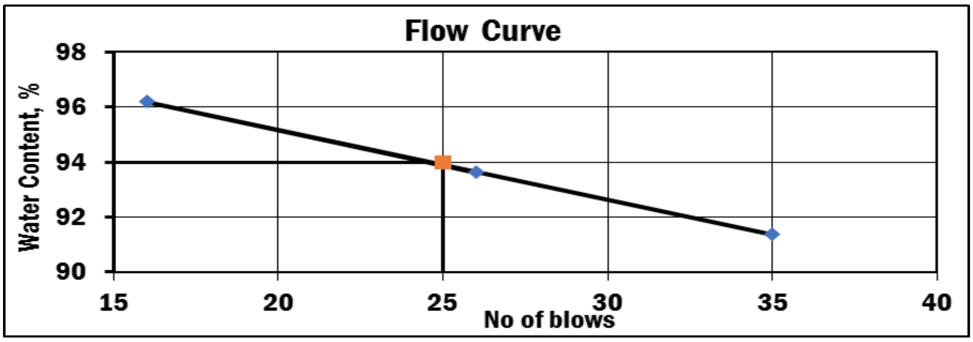
Sample No	PT 7,5			Sample Depth, m	:	3		
		Liquid Limit				Plastic Limit		
Trial No		1	2	3		1	2	3
Container No		26	A36	C31		C34	71	A35
Mass of container, g		19.61	19.63	19.43		19.65	19.62	19.36
Mass of container + Wet soil, g		29.05	30.67	30.84		24.22	22.8	31.99
Mass of container + Dry soil, g		26	26.45	27.58		22.99	21.94	28.18
Mass of water, g		3.05	4.22	3.26		1.23	0.86	3.81
Mass of dry soil, g		6.39	6.82	8.15		3.34	2.32	8.82
Water content, %		47.73	61.88	40.00		36.83	37.07	43.20
No of blows		27	16	33		------	------	



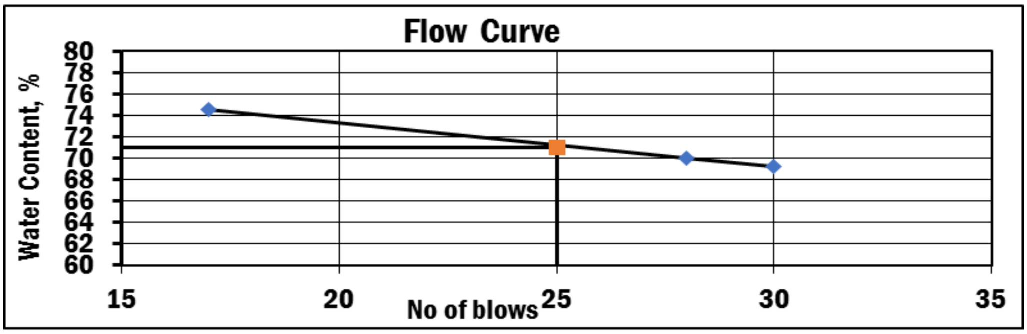
Sample No PT 8,4			Sample Depth, m : 1.5				
	Liquid Limit				Plastic Limit		
Trial No	1	2	3		1	2	3
Container No	26	A36	C31		C34	71	A35
Mass of container, g	19.63	19.61	19.45		19.54	19.65	19.62
Mass of container + Wet soil, g	31.65	33.56	35.65		25.65	23.54	33.05
Mass of container + Dry soil, g	27.53	29.45	30.58		24.52	22.85	30.26
Mass of water, g	4.12	4.11	5.07		1.13	0.69	2.79
Mass of dry soil, g	7.90	9.84	11.13		4.98	3.20	10.64
Water content, %	52.15	41.77	45.55		22.69	21.56	26.22
No of blows	15	33	26		------	------	



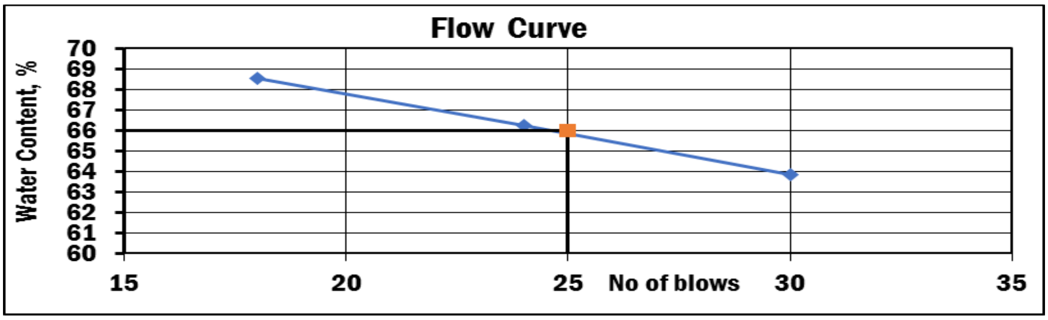
Sample No PT 4			Sample Depth, m : 3				
	Liquid Limit				Plastic Limit		
Trial No	1	2	3		1	2	3
Container No	26	A36	C31		C34	71	A35
Mass of container, g	19.52	19.74	19.62		30.69	19.44	30
Mass of container + Wet soil, g	28.64	31.57	30.93		39.05	26.08	34.33
Mass of container + Dry soil, g	24.23	25.77	25.53		36.74	24.07	32.77
Mass of water, g	4.41	5.80	5.40		2.31	2.01	1.56
Mass of dry soil, g	4.71	6.03	5.91		6.05	4.63	2.77
Water content, %	93.63	96.19	91.37		38.18	43.41	56.32
No of blows	26	16	35		------	------	
Liquid Limit, % = 94		Plastic Limit, % = 46			PI, %= 48		



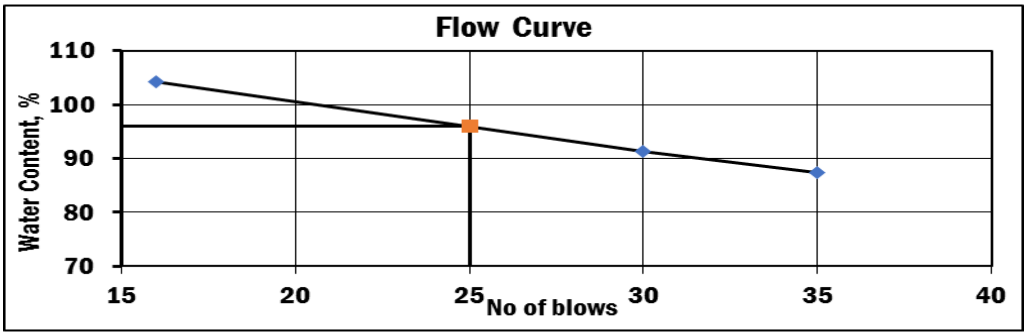
Sample No	PT 6			Sample Depth, m : 1.5				
		Liquid Limit				Plastic Limit		
Trial No		1	2	3		1	2	3
Container No		26	A36	C31		C34	71	A35
Mass of container, g		19.63	19.63	19.05		19.42	19.13	19.42
Mass of container + Wet soil, g		30.17	31.36	30.76		30.8	27.68	36.09
Mass of container + Dry soil, g		25.86	26.53	25.76		25.7	24.96	30.65
Mass of water, g		4.31	4.83	5.00		5.10	2.72	5.44
Mass of dry soil, g		6.23	6.90	6.71		6.28	5.83	11.23
Water content, %		69.18	70.00	74.52		81.21	46.66	48.44
No of blows		30	28	17		------	------	
Liquid Limit, % =	71	Plastic Limit, %	=	59		PI, %=	12	



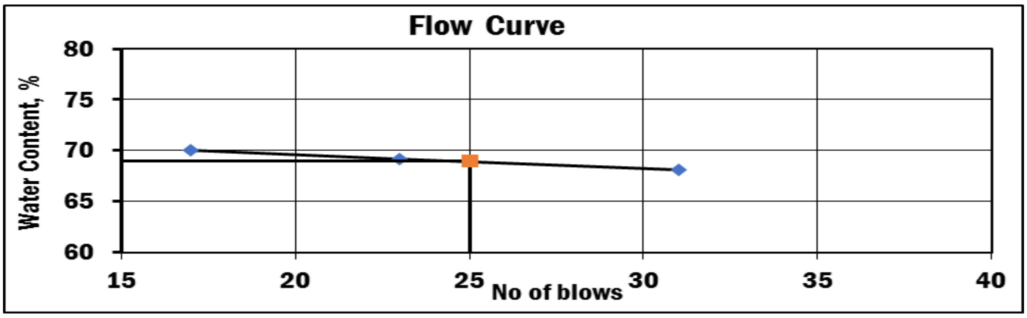
Sample No	PT 6			Sample Depth, m : 3				
		Liquid Limit				Plastic Limit		
Trial No		1	2	3		1	2	3
Container No		26	A36	C31		C34	71	A35
Mass of container, g		19.26	19.41	19.36		19.26	19.22	19.42
Mass of container + Wet soil, g		28.68	28.12	28.58		27.79	26.84	27.62
Mass of container + Dry soil, g		25.01	24.65	24.83		26.01	25.63	26.93
Mass of water, g		3.67	3.47	3.75		1.78	1.21	0.69
Mass of dry soil, g		5.75	5.24	5.47		6.75	6.41	7.51
Water content, %		63.83	66.22	68.56		26.37	18.88	9.19
No of blows		30	24	18		------	------	
Liquid Limit, % =	66	Plastic Limit, %	=	18		PI, %=	48	



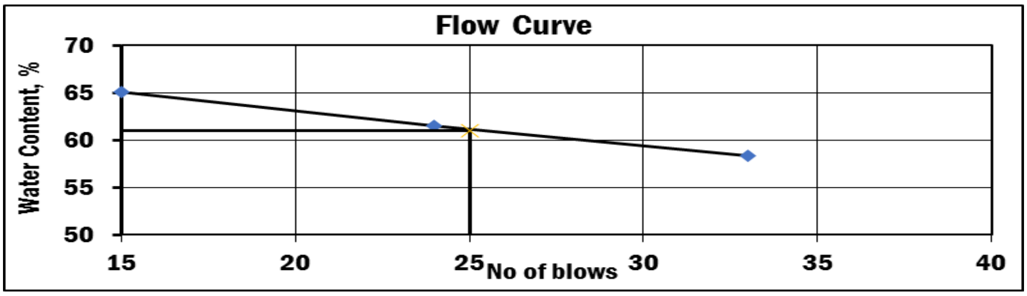
Sample No	PT	8			Sample Depth, m	: 1.5			
			Liquid Limit				Plastic Limit		
Trial No			1	2	3		1	2	3
Container No			26	A36	C31		C34	71	A35
Mass of container, g			29.68	29.51	30.44		29.67	30.11	30.30
Mass of container + Wet soil, g			44.24	39.42	44.51		40.11	39.69	40.33
Mass of container + Dry soil, g			36.81	34.69	37.95		37.35	37.12	37.88
Mass of water, g			7.43	4.73	6.56		2.76	2.57	2.45
Mass of dry soil, g			7.13	5.18	7.51		7.68	7.01	7.58
Water content, %			104.21	91.31	87.35		35.94	36.66	32.32
No of blows			16	30	35		------	------	
Liquid Limit, %	=	96	Plastic Limit, %		=	35	PI, %=	61	



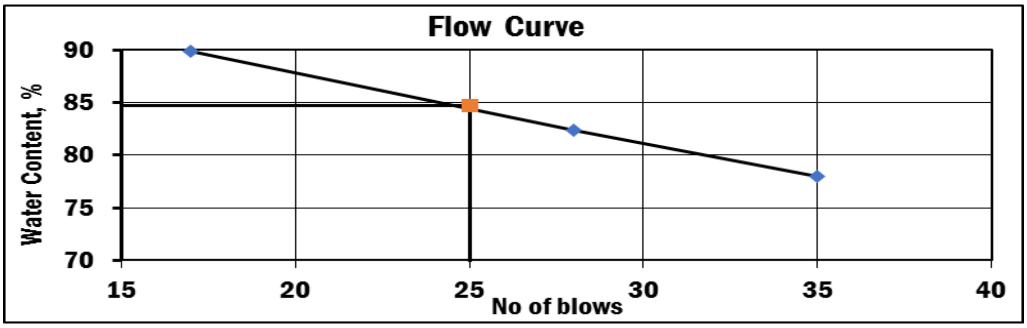
Sample No	PT	7			Sample Depth, m	: 1.5			
			Liquid Limit				Plastic Limit		
Trial No			1	2	3		1	2	3
Container No			26	A36	C31		C34	71	A35
Mass of container, g			30.28	30.63	30.52		30.52	30.63	30.28
Mass of container + Wet soil, g			39.31	42.86	40.62		42.18	44.32	43.41
Mass of container + Dry soil, g			35.59	37.86	36.53		39.73	41.44	40.53
Mass of water, g			3.72	5.00	4.09		2.45	2.88	2.88
Mass of dry soil, g			5.31	7.23	6.01		9.21	10.81	10.25
Water content, %			70.06	69.16	68.05		26.60	26.64	28.10
No of blows			17	23	31		------	------	
Liquid Limit, %	=	69	Plastic Limit, %		=	27	PI, %=	42	



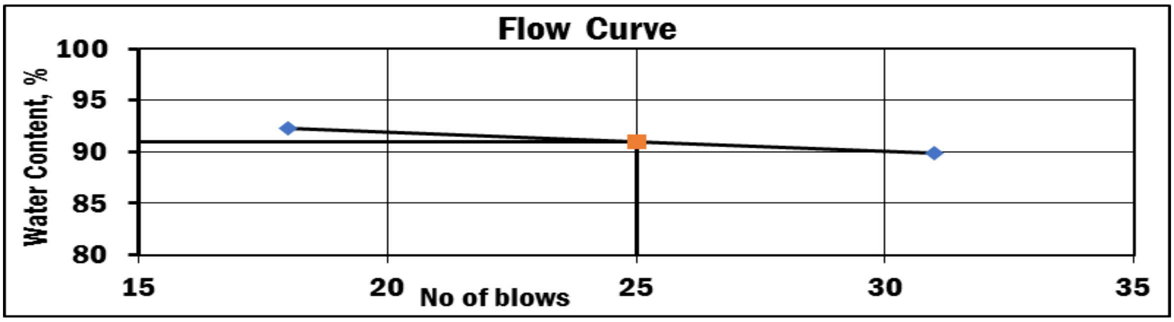
Sample No	PT	9			Sample Depth, m :		1.5		
				Liquid Limit				Plastic Limit	
Trial No			1	2	3		1	2	3
Container No			26	A36	C31		C34	71	A35
Mass of container, g			19.44	19.69	19.48		19.73	19.69	19.29
Mass of container + Wet soil, g			32.45	32.92	33.30		29.38	30.09	28.58
Mass of container + Dry soil, g			27.32	27.88	28.21		27.15	27.74	26.28
Mass of water, g			5.13	5.04	5.09		2.23	2.35	2.30
Mass of dry soil, g			7.88	8.19	8.73		7.42	8.05	6.99
Water content, %			65.10	61.54	58.30		30.05	29.19	32.90
No of blows			15	24	33		------	------	
Liquid Limit, % =		61	Plastic Limit, %		=	31	PI, %=	30	



Sample No	PT	10			Sample Depth, m :	3			
				Liquid Limit				Plastic Limit	
Trial No			1	2	3		1	2	3
Container No			26	A36	C31		C34	71	A35
Mass of container, g			19.46	19.12	19.16		29.77	30.33	29.71
Mass of container + Wet soil, g			34.78	32.69	30.78		39.55	43.40	39.73
Mass of container + Dry soil, g			27.53	26.56	25.69		37.15	40.04	36.8
Mass of water, g			7.25	6.13	5.09		2.40	3.36	2.93
Mass of dry soil, g			8.07	7.44	6.53		7.38	9.71	7.09
Water content, %			89.84	82.39	77.95		32.52	34.60	41.33
No of blows			17	28	35		------	------	
Liquid Limit, % =		85	Plastic Limit, %		=	36	PI, %=	49	



Sample No	PT	10			Sample Depth, m	: 1.5			
			Liquid Limit				Plastic Limit		
Trial No			1	2	3		1	2	3
Container No			26	A36	C31		C34	71	A35
Mass of container, g			19.47	19.43	19.16		18.51	19.48	19.34
Mass of container + Wet soil, g			30.18	29.76	30.42		28.11	26.18	27.15
Mass of container + Dry soil, g			25.04	24.84	25.09		25.54	24.23	25.09
Mass of water, g			5.14	4.92	5.33		2.57	1.95	2.06
Mass of dry soil, g			5.57	5.41	5.93		7.03	4.75	5.75
Water content, %			92.28	90.94	89.88		36.56	41.05	35.83
No of blows			18	25	31		------	------	
Liquid Limit, % =		91	Plastic Limit, %		=	38	PI, %=	53	



Sample No	PT	11			Sample Depth, m	: 1.5			
			Liquid Limit				Plastic Limit		
Trial No			1	2	3		1	2	3
Container No			26	A36	C31		C34	71	A35
Mass of container, g			60	61	61		30.22	19.29	19.33
Mass of container + Wet soil, g			76	80	76		36.16	25.75	23.24
Mass of container + Dry soil, g			71	75	73		35.65	24.19	22.24
Mass of water, g			5.00	5.00	3.00		0.51	1.56	1.00
Mass of dry soil, g			11.00	14.00	12.00		5.43	4.90	2.91
Water content, %			45.45	35.71	25.00		9.39	31.84	34.36
No of blows			19	27	35		------	------	
Liquid Limit, % =		38	Plastic Limit, %		=	25	PI, %=	13	

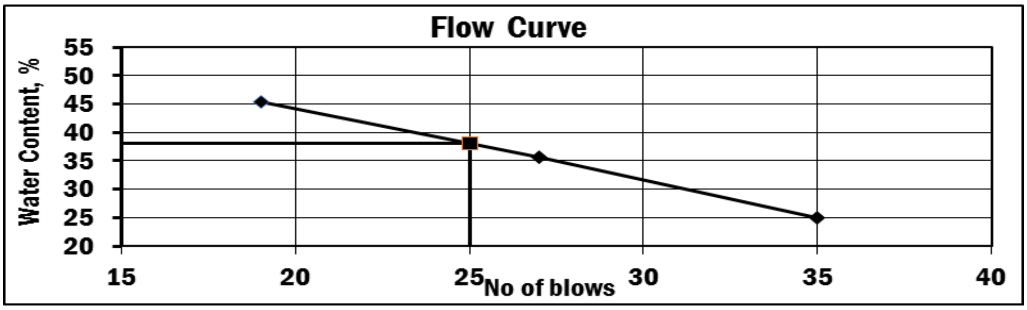


Table I-3. Laboratory test results of Specific Gravity test

PT 9@1.5m	sample -1	sample- 2
Weight of Density bottle W1 (g)	143	43
Weight of Density bottle with dry soil W2(g)	163	63
Weight of Density bottle with dry soil and water W3(g)	168	64.4
Weight of Density bottle full of water W4 (g)	155.41	51.7
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.41	7.3
Specific gravity of the soil G= (5/6)	2.7	2.74
average	2.7	

PT3@3m	Sample-1	Sample-2
Weight of Density bottle W1 (g)	153	124
Weight of Density bottle with dry soil W2(g)	172.6	144
Weight of Density bottle with dry soil and water W3(g)	175.5	147.395
Weight of Density bottle full of water W4 (g)	162.99	134.8
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.49	7.405
Specific gravity of the soil G= (5/6)	2.67	2.7
average	2.69	

PT10@3m	Sample-1	Sample-2
Weight of Density bottle W1 (g)	43	47
weight of Density bottle with dry soil W2(g)	63	67
Weight of Density bottle with dry soil and water W3(g)	59.73	70
Weight of Density bottle full of water W4 (g)	47	57.3
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.27	7.3
Specific gravity of the soil G= (5/6)	2.75	2.74
average	2.75	

PT4@1.5m	Sample-1	Sample-2
Weight of Density bottle W1 (g)	156	147
Weight of Density bottle with dry soil W2(g)	176	167
Weight of Density bottle with dry soil and water W3(g)	175	170
Weight of Density bottle full of water W4 (g)	162.41	157.41
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.41	7.41
Specific gravity of the soil G= (5/6)	2.7	2.7
average	2.7	

PT11@1.5m	Sample1	Sample2
Weight of Density bottle W1 (g)	156	47
Weight of Density bottle with dry soil W2(g)	176	67
Weight of Density bottle with dry soil and water W3(g)	175	70
Weight of Density bottle full of water W4 (g)	162.5	57.5
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.5	7.5
Specific gravity of the soil G= (5/6)	2.67	2.67
average	2.67	

PT4@3m	Sample1	Sample2
Weight of Density bottle W1 (g)	153	143
Weight of Density bottle with dry soil W2(g)	173	163
Weight of Density bottle with dry soil and water W3(g)	177	165
Weight of Density bottle full of water W4 (g)	164.273	152.273
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.273	7.273
Specific gravity of the soil G= (5/6)	2.75	2.75
average	2.75	

PT7@1.5m	Sample1	Sample2
Weight of Density bottle W1 (g)	147	143
Weight of Density bottle with dry soil W2(g)	167	163
Weight of Density bottle with dry soil and water W3(g)	174	170
Weight of Density bottle full of water W4 (g)	161.143	157.143
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.143	7.143
Specific gravity of the soil G= (5/6)	2.8	2.8
average	2.8	

PT10@1.5m	Sample1	Sample2
Weight of Density bottle W1 (g)	43	156
Weight of Density bottle with dry soil W2(g)	63	176
Weight of Density bottle with dry soil and water W3(g)	73	185
Weight of Density bottle full of water W4 (g)	60.143	172.143
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.143	7.143
Specific gravity of the soil G= (5/6)	2.8	2.8
average	2.8	

PT2@3m	Sample1	sample2
Weight of Density bottle W1 (g)	143	47
Weight of Density bottle with dry soil W2(g)	163	67
Weight of Density bottle with dry soil and water W3(g)	165	85
Weight of Density bottle full of water W4 (g)	152.143	72.143
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.143	7.143
Specific gravity of the soil G= (5/6)	2.8	2.8
average	2.8	

PT8@1.5m	Sample1	Sample2
Weight of Density bottle W1 (g)	153	156
Weight of Density bottle with dry soil W2(g)	173	176
Weight of Density bottle with dry soil and water W3(g)	256	220
Weight of Density bottle full of water W4 (g)	243.299	207.299
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.299	7.299
Specific gravity of the soil G= (5/6)	2.74	2.74
average	2.74	

PT1@1.5m	Sample1	sample2
Weight of Density bottle W1 (g)	143	47
Weight of Density bottle with dry soil W2(g)	163	67
Weight of Density bottle with dry soil and water W3(g)	165	85
Weight of Density bottle full of water W4 (g)	152.143	72.143
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.143	7.143
Specific gravity of the soil G= (5/6)	2.8	2.8
average	2.8	

PT6@1.5m	Sample1	sample2
Weight of Density bottle W1 (g)	156	153
Weight of Density bottle with dry soil W2(g)	176	173
Weight of Density bottle with dry soil and water W3(g)	195	182
Weight of Density bottle full of water W4 (g)	182.41	169.41
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.41	7.41
Specific gravity of the soil G= (5/6)	2.7	2.7
average	2.7	

PT6@3m	Sample1	sample2
Weight of Density bottle W1 (g)	143	47
Weight of Density bottle with dry soil W2(g)	163	67
Weight of Density bottle with dry soil and water W3(g)	175	87
Weight of Density bottle full of water W4 (g)	162.547	74.5472
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.5472	7.5472
Specific gravity of the soil G= (5/6)	2.65	2.65
average	2.65	

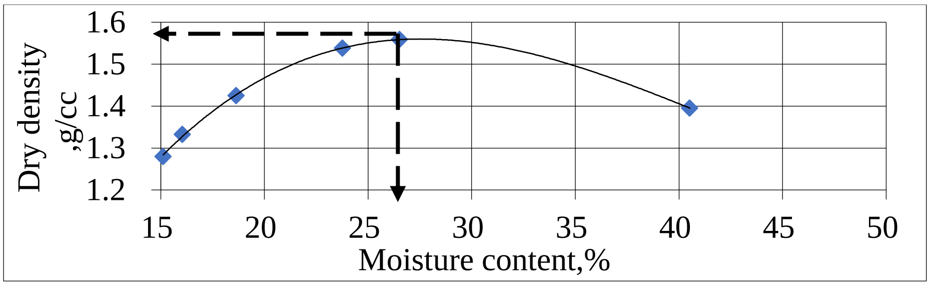
PT3@1.5m	Sample1	sample2
Weight of Density bottle W1 (g)	124	47
Weight of Density bottle with dry soil W2(g)	144	67
Weight of Density bottle with dry soil and water W3(g)	155	78
Weight of Density bottle full of water W4 (g)	142.26	65.88
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.26	7.88
Specific gravity of the soil G= (5/6)	2.75	2.54
average	2.65	

PT2@1.5m	Sample1	sample2
Weight of Density bottle W1 (g)	143	157
Weight of Density bottle with dry soil W2(g)	163	177
Weight of Density bottle with dry soil and water W3(g)	256	245
Weight of Density bottle full of water W4 (g)	243.273	232.273
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.273	7.273
Specific gravity of the soil G= (5/6)	2.75	2.75
average	2.75	

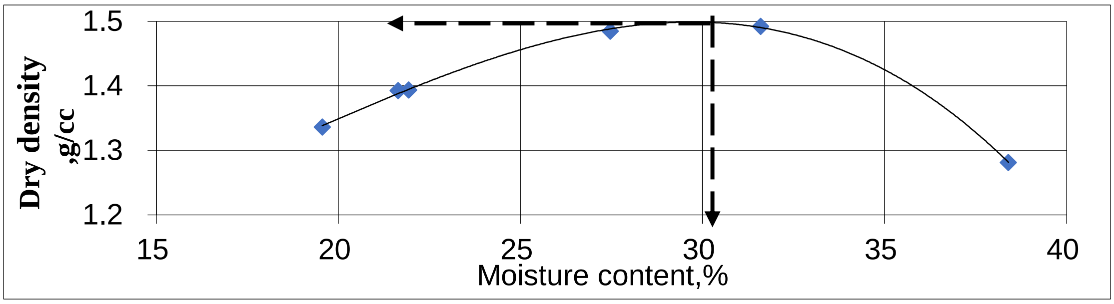
PT1@3m	Sample1	sample2
Weight of Density bottle W1 (g)	47	43
Weight of Density bottle with dry soil W2(g)	67	63
Weight of Density bottle with dry soil and water W3(g)	87	76
Weight of Density bottle full of water W4 (g)	74.463	63.463
Weight of dry soil (W2-W1) (g)	20	20
Weight of an equal volume of water(W2-W1) -(W3-W4)	7.463	7.463
Specific gravity of the soil G= (5/6)	2.68	2.68
average	2.68	

Table I-4. Laboratory test results of compaction test

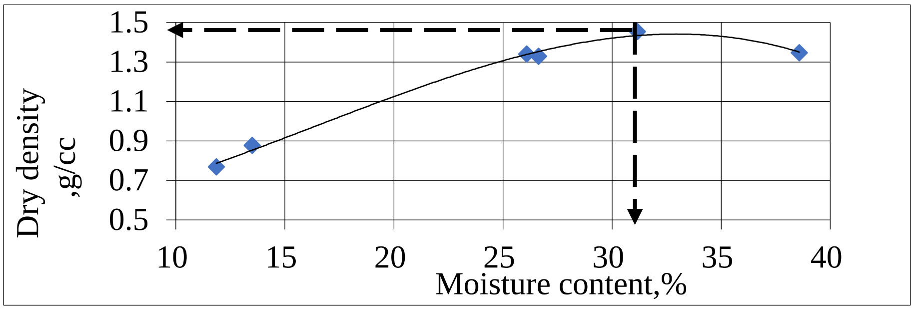
MOISTURE - DENSITY RELATION OF SOIL PT1 @3m								
A	Mold	No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil	grams	5147.0	5216.0	5352.0	5553.0	5618.0	5607.0
C	Wt. of Mold	grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil	grams	1391.0	1460.0	1596.0	1797.0	1862.0	1851.0
E	Volume of Mold	cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density	gr/cu.cm.	1.474	1.547	1.691	1.904	1.972	1.961
G	Container	No.	A23	M13	M25	M7	M27	M8
H	Wt. Cont + Wet soil	grams	66.8	68.9	68.8	66.5	50.5	99.2
I	Wt. Cont + Dry soil	grams	60.6	62.0	61.0	57.5	44.0	79.4
J	Weight of Water	grams	6.2	6.8	7.8	9.0	6.5	19.8
K	Weight of Container	grams	19.4	19.3	19.4	19.7	19.4	30.5
L	Weight of Dry Soil	grams	41.3	42.7	41.6	37.9	24.6	48.9
M	Moisture Content	%	15.1	16.0	18.6	23.8	26.5	40.5
N	Dry Density	gr/cu.cm.	1.280	1.333	1.425	1.538	1.559	1.395
Maximum Dry Density (MDD):								
MDD =	1.559	gm/cc						
Optimum Moisture Content (OMC) :								
OMC =	26.50	%						



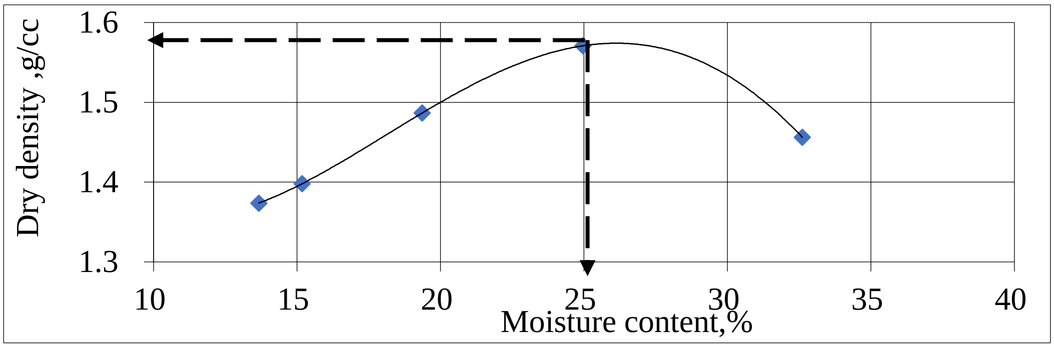
MOISTURE - DENSITY RELATION OF SOIL PT-1@1.5m									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5264.0	5355.0	5360.0	5543.0	5610.0	5430.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1508.0	1599.0	1604.0	1787.0	1854.0	1674.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.597	1.694	1.699	1.893	1.964	1.773
G	Container		No.	A23	M13	M25	M7	M27	
H	Wt. Cont + Wet soil		grams	90.6	93.2	80.8	67.6	104.0	93.8
I	Wt. Cont + Dry soil		grams	80.7	82.1	71.6	59.6	86.3	76.2
J	Weight of Water		grams	9.8	11.2	9.1	8.0	17.6	17.6
K	Weight of Container		grams	30.3	30.3	29.9	30.3	30.6	30.4
L	Weight of Dry Soil		grams	50.4	51.7	41.7	29.3	55.8	45.8
M	Moisture Content		%	19.6	21.6	21.9	27.5	31.6	38.4
N	Dry Density		gr/cu.cm.	1.336	1.393	1.394	1.485	1.492	1.281
Maximum Dry Density (MDD):									
MDD =	1.492	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	31.60	%							



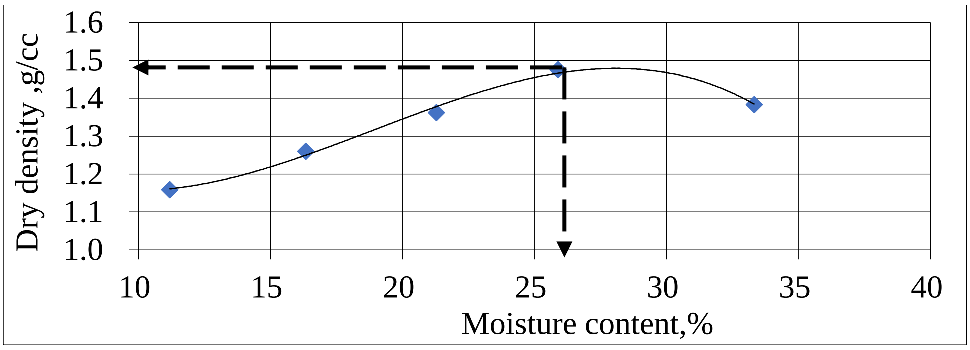
MOISTURE - DENSITY RELATION OF SOIL PT 2 @1.5m									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	4567.0	4696.0	5345.0	5350.0	5556.0	5517.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	811.0	940.0	1589.0	1594.0	1800.0	1761.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	0.859	0.996	1.683	1.689	1.907	1.865
G	Container		No.	A23	M13	M25	M7	M27	
H	Wt. Cont + Wet soil		grams	76.9	67.2	49.8	72.3	80.8	87.7
I	Wt. Cont + Dry soil		grams	70.8	61.5	43.3	61.4	66.2	68.8
J	Weight of Water		grams	6.1	5.7	6.5	11.0	14.5	18.9
K	Weight of Container		grams	19.6	19.7	19.0	19.4	19.6	19.7
L	Weight of Dry Soil		grams	51.2	41.9	24.3	42.0	46.6	49.0
M	Moisture Content		%	11.9	13.5	26.6	26.1	31.2	38.6
N	Dry Density		gr/cu.cm.	0.768	0.877	1.329	1.339	1.454	1.346
Maximum Dry Density (MDD):									
MDD =	1.454	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	31.20	%							



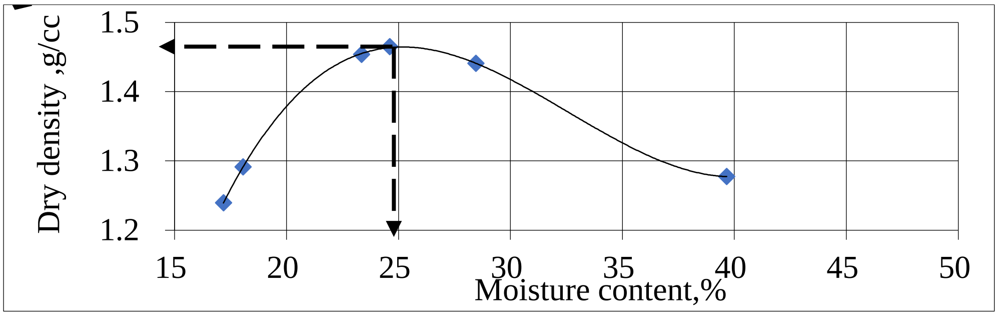
MOISTURE - DENSITY RELATION OF SOIL PT2@3m										
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5230.0	5276.0	5431.0	5609.0	5579.0	
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	
D	Wt. Wet Soil		grams	1474.0	1520.0	1675.0	1853.0	1823.0	
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	
F	Wet Density		gr/cu.cm.	1.561	1.610	1.774	1.963	1.931	
G	Container		No.	A23	M13	M25	M7	M27	
H	Wt. Cont + Wet soil		grams	89.4	73.7	66.6	79.5	135.9	
I	Wt. Cont + Dry soil		grams	82.3	67.9	60.7	69.7	109.9	
J	Weight of Water		grams	7.1	5.7	5.9	9.8	26.0	
K	Weight of Container		grams	30.1	30.1	30.3	30.4	30.0	
L	Weight of Dry Soil		grams	52.2	37.9	30.5	39.3	79.9	
M	Moisture Content		%	13.7	15.2	19.4	25.0	32.6	
N	Dry Density		gr/cu.cm.	1.374	1.398	1.487	1.571	1.456	
Maximum Dry Density (MDD):									
MDD =	1.571	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	25.00	%							



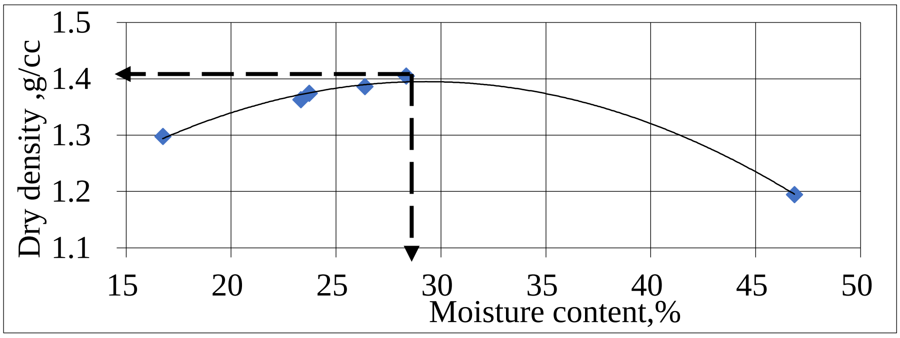
MOISTURE - DENSITY RELATION OF SOIL PT-3@1.5								
A	Mold		No.	1	2	3	4	5
B	Wt. of Mold + Wet Soil		grams	4972.0	5140.0	5316.0	5509.0	5497.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1216.0	1384.0	1560.0	1753.0	1741.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.288	1.466	1.653	1.857	1.844
G	Container		No.	A23	M13	M25	M7	M27
H	Wt. Cont + Wet soil		grams	71.6	79.3	80.8	57.3	103.7
I	Wt. Cont + Dry soil		grams	67.4	72.4	70.0	49.5	82.7
J	Weight of Water		grams	4.2	6.9	10.8	7.8	21.0
K	Weight of Container		grams	30.0	30.2	19.1	19.4	19.6
L	Weight of Dry Soil		grams	37.4	42.2	50.9	30.1	63.0
M	Moisture Content		%	11.2	16.3	21.3	25.9	33.3
N	Dry Density		gr/cu.cm.	1.159	1.260	1.363	1.475	1.383
Maximum Dry Density (MDD):								
MDD =	1.475	gm/cc						
Optimum Moisture Content (OMC) :								
OMC =	25.90	%						



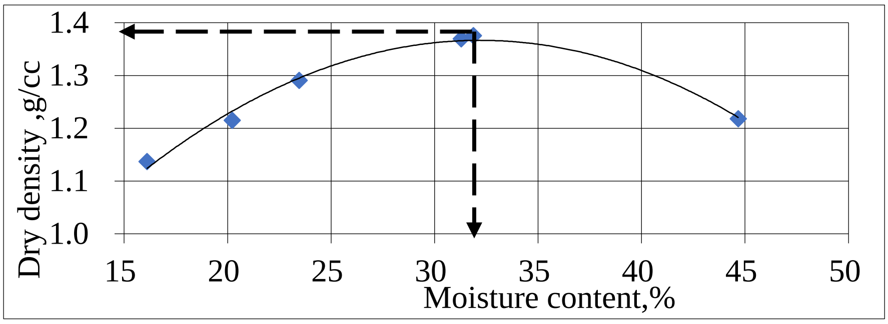
MOISTURE - DENSITY RELATION OF SOIL PT3@3m									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5127.0	5195.0	5449.0	5479.0	5503.0	5440.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1371.0	1439.0	1693.0	1723.0	1747.0	1684.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.452	1.524	1.793	1.825	1.851	1.784
G	Container		No.	A23	M13	M25	M7	M27	M28
H	Wt. Cont + Wet soil		grams	58.8	52.5	54.7	80.3	94.8	103.8
I	Wt. Cont + Dry soil		grams	53.0	47.4	48.0	69.3	80.3	83.0
J	Weight of Water		grams	5.8	5.1	6.7	11.0	14.4	20.8
K	Weight of Container		grams	19.2	19.3	19.5	24.6	29.6	30.5
L	Weight of Dry Soil		grams	33.8	28.1	28.5	44.7	50.7	52.5
M	Moisture Content		%	17.2	18.1	23.3	24.6	28.5	39.7
N	Dry Density		gr/cu.cm.	1.239	1.291	1.454	1.465	1.441	1.277
Maximum Dry Density (MDD):									
MDD =	1.465	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	24.60	%							



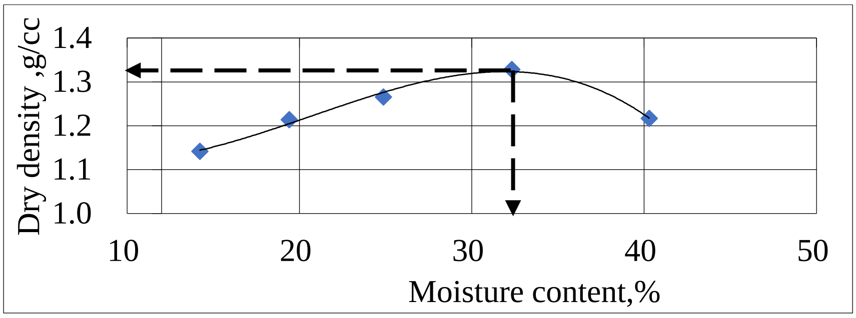
MOISTURE - DENSITY RELATION OF SOIL pt-7@1.5m								
A	Mold	No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil	grams	5186.0	5343.0	5361.0	5410.0	5458.0	5412.0
C	Wt. of Mold	grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil	grams	1430.0	1587.0	1605.0	1654.0	1702.0	1656.0
E	Volume of Mold	cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density	gr/cu.cm.	1.515	1.681	1.700	1.752	1.803	1.754
G	Container	No.	A23	M13	M25	M7	M27	m28
H	Wt. Cont + Wet soil	grams	63.4	69.5	70.4	75.1	73.5	96.9
I	Wt. Cont + Dry soil	grams	57.0	60.0	60.5	63.5	61.6	72.2
J	Weight of Water	grams	6.3	9.5	9.9	11.6	12.0	24.7
K	Weight of Container	grams	19.3	19.3	19.0	19.4	19.4	19.4
L	Weight of Dry Soil	grams	37.8	40.7	41.6	44.1	42.2	52.8
M	Moisture Content	%	16.7	23.3	23.7	26.4	28.3	46.8
N	Dry Density	gr/cu.cm.	1.298	1.363	1.374	1.386	1.405	1.195
Maximum Dry Density (MDD):								
MDD =	1.405	gm/cc						
Optimum Moisture Content (OMC) :								
OMC =	28.30	%						



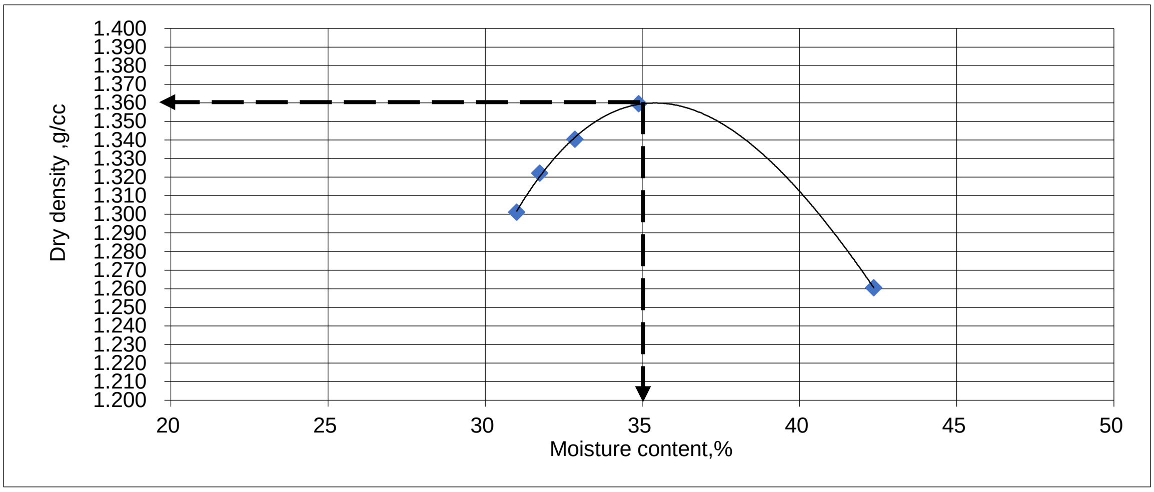
MOISTURE - DENSITY RELATION OF SOIL pt-6@1.5m									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5002.0	5135.0	5260.0	5453.0	5468.0	5419.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1246.0	1379.0	1504.0	1697.0	1712.0	1663.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.320	1.461	1.593	1.798	1.814	1.762
G	Container		No.	A23	M13	M25	M7	M27	
H	Wt. Cont + Wet soil		grams	85.2	92.9	90.6	117.9	99.3	131.9
I	Wt. Cont + Dry soil		grams	77.5	82.3	79.1	94.4	82.9	100.5
J	Weight of Water		grams	7.7	10.6	11.5	23.5	16.5	31.4
K	Weight of Container		grams	29.7	29.9	30.1	19.2	31.2	30.2
L	Weight of Dry Soil		grams	47.8	52.4	49.0	75.2	51.7	70.3
M	Moisture Content		%	16.1	20.2	23.5	31.3	31.9	44.7
N	Dry Density		gr/cu.cm.	1.137	1.215	1.290	1.369	1.375	1.218
Maximum Dry Density (MDD):									
MDD =	1.375	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	31.90	%							



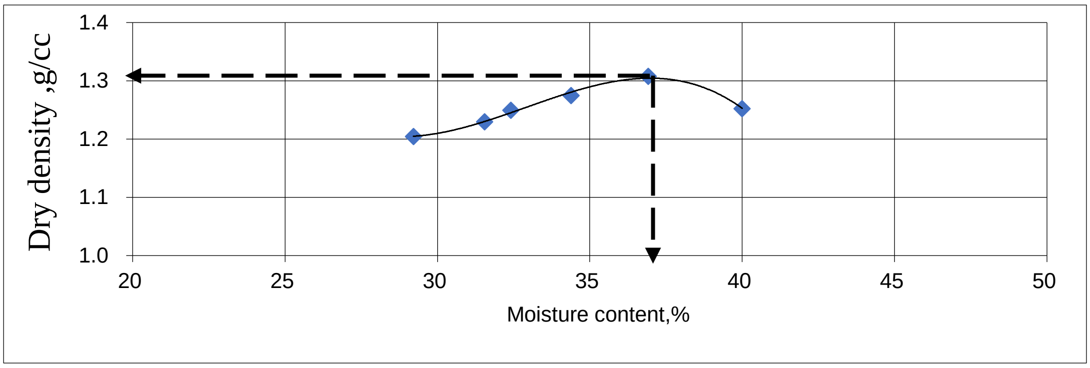
MOISTURE - DENSITY RELATION OF SOIL PT 6@3m									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	4987.0	5124.0	5248.0	5415.0	5367.0	
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	
D	Wt. Wet Soil		grams	1231.0	1368.0	1492.0	1659.0	1611.0	
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	
F	Wet Density		gr/cu.cm.	1.304	1.449	1.581	1.757	1.707	
G	Container		No.	M1	M23	M67	A16		
H	Wt. Cont + Wet soil		grams	81.4	106.8	93.2	116.6	160.4	
I	Wt. Cont + Dry soil		grams	75.0	94.3	80.7	95.5	123.0	
J	Weight of Water		grams	6.4	12.5	12.5	21.1	37.4	
K	Weight of Container		grams	30.2	29.9	30.2	30.1	30.1	
L	Weight of Dry Soil		grams	44.9	64.5	50.4	65.4	92.9	
M	Moisture Content		%	14.2	19.4	24.9	32.3	40.3	
N	Dry Density		gr/cu.cm.	1.142	1.214	1.266	1.328	1.217	
Maximum Dry Density (MDD):									
MDD =	1.328	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	32.30	%							



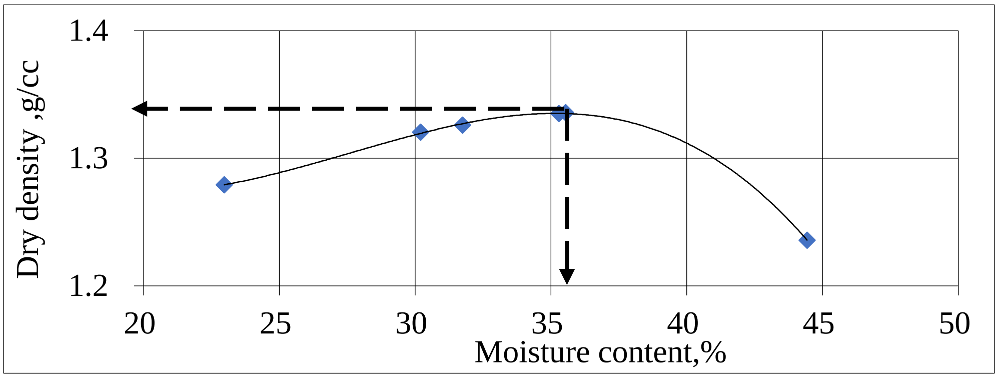
MOISTURE - DENSITY RELATION OF SOIL PT 10@1.5									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5300.0	5365.0	5400.0	5437.0	5487.0	5450.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1544.0	1609.0	1644.0	1681.0	1731.0	1694.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.636	1.704	1.742	1.781	1.834	1.794
G	Container		No.	M1	M23	M67	A16		
H	Wt. Cont + Wet soil		grams	54.8	72.7	71.1	77.1	81.9	77.5
I	Wt. Cont + Dry soil		grams	47.4	62.6	61.2	65.5	68.5	63.2
J	Weight of Water		grams	7.4	10.1	9.8	11.6	13.5	14.3
K	Weight of Container		grams	19.4	30.1	30.2	30.2	29.8	29.5
L	Weight of Dry Soil		grams	28.1	32.5	31.0	35.3	38.6	33.7
M	Moisture Content		%	26.3	31.0	31.7	32.9	34.9	42.4
N	Dry Density		gr/cu.cm.	1.295	1.301	1.322	1.340	1.359	1.261
Maximum Dry Density (MDD):									
MDD =	1.359	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	34.90	%							



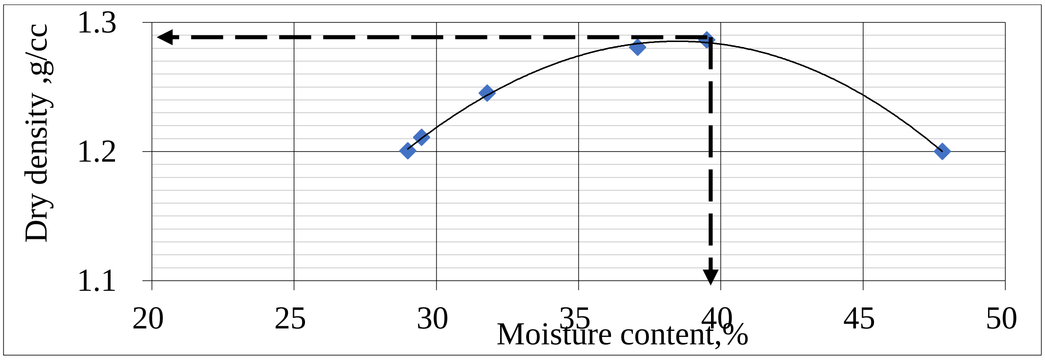
MOISTURE - DENSITY RELATION OF SOIL PT 10@3									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5225.0	5283.0	5318.0	5373.0	5446.0	5411.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1469.0	1527.0	1562.0	1617.0	1690.0	1655.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.556	1.618	1.655	1.713	1.790	1.753
G	Container		No.	M1	M23	M67	A16		
H	Wt. Cont + Wet soil		grams	63.0	68.6	67.6	65.1	68.4	69.0
I	Wt. Cont + Dry soil		grams	53.1	56.8	55.8	53.3	55.2	54.3
J	Weight of Water		grams	9.9	11.8	11.8	11.8	13.2	14.7
K	Weight of Container		grams	19.2	19.5	19.5	19.2	19.3	19.4
L	Weight of Dry Soil		grams	33.9	37.3	36.4	34.2	35.8	34.8
M	Moisture Content		%	29.2	31.5	32.4	34.4	36.9	40.0
N	Dry Density		gr/cu.cm.	1.204	1.230	1.250	1.275	1.308	1.252
Maximum Dry Density (MDD):									
MDD =	1.308	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	36.90	%							



MOISTURE - DENSITY RELATION OF SOIL PT 9@1.5									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5241.0	5379.0	5405.0	5461.0	5465.0	5441.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1485.0	1623.0	1649.0	1705.0	1709.0	1685.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.573	1.719	1.747	1.806	1.810	1.785
G	Container		No.	M1	M23	M67	A16		
H	Wt. Cont + Wet soil		grams	79.9	76.4	87.3	80.8	88.5	76.1
I	Wt. Cont + Dry soil		grams	68.6	63.2	70.9	64.7	70.3	58.7
J	Weight of Water		grams	11.3	13.2	16.4	16.1	18.2	17.4
K	Weight of Container		grams	19.5	19.4	19.3	19.1	19.2	19.4
L	Weight of Dry Soil		grams	49.1	43.8	51.6	45.6	51.1	39.2
M	Moisture Content		%	23.0	30.2	31.7	35.3	35.5	44.4
N	Dry Density		gr/cu.cm.	1.279	1.321	1.326	1.335	1.336	1.236
Maximum Dry Density (MDD):									
MDD =	1.336	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	35.50	%							



MOI+A315:J334STURE - DENSITY RELATION OF SOIL PT 8@1.5									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5218.0	5236.0	5305.0	5413.0	5450.0	5430.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1462.0	1480.0	1549.0	1657.0	1694.0	1674.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.549	1.568	1.641	1.755	1.794	1.773
G	Container		No.	M1	M23	M67	A16	M27	M28
H	Wt. Cont + Wet soil		grams	58.0	65.0	68.5	72.5	75.3	74.5
I	Wt. Cont + Dry soil		grams	49.3	54.6	56.7	58.1	59.4	56.7
J	Weight of Water		grams	8.7	10.4	11.8	14.4	15.8	17.9
K	Weight of Container		grams	19.3	19.4	19.4	19.3	19.4	19.3
L	Weight of Dry Soil		grams	30.0	35.2	37.3	38.8	40.1	37.4
M	Moisture Content		%	29.0	29.5	31.8	37.1	39.5	47.8
N	Dry Density		gr/cu.cm.	1.201	1.211	1.245	1.281	1.286	1.200
Maximum Dry Density (MDD):									
MDD =	1.286	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	39.50	%							



MOISTURE - DENSITY RELATION OF SOIL PT 7@1.5									
A	Mold		No.	1	2	3	4	5	6
B	Wt. of Mold + Wet Soil		grams	5269.0	5321.0	5377.0	5476.0	5483.0	5448.0
C	Wt. of Mold		grams	3756.0	3756.0	3756.0	3756.0	3756.0	3756.0
D	Wt. Wet Soil		grams	1513.0	1565.0	1621.0	1720.0	1727.0	1692.0
E	Volume of Mold		cu.cm.	944.0	944.0	944.0	944.0	944.0	944.0
F	Wet Density		gr/cu.cm.	1.603	1.658	1.717	1.822	1.829	1.792
G	Container		No.	M1	M23	M67	A16	M27	M28
H	Wt. Cont + Wet soil		grams	65.2	70.8	72.1	72.5	76.5	75.7
I	Wt. Cont + Dry soil		grams	58.5	62.3	62.7	61.4	64.4	58.2
J	Weight of Water		grams	6.8	8.5	9.4	11.1	12.1	17.5
K	Weight of Container		grams	19.4	19.2	19.5	19.5	19.2	19.3
L	Weight of Dry Soil		grams	39.1	43.1	43.3	42.0	45.3	38.9
M	Moisture Content		%	17.3	19.8	21.8	26.4	26.7	35.0
N	Dry Density		gr/cu.cm.	1.367	1.384	1.410	1.441	1.444	1.320
Maximum Dry Density (MDD):									
MDD =	1.444	gm/cc							
Optimum Moisture Content (OMC) :									
OMC =	26.70	%							

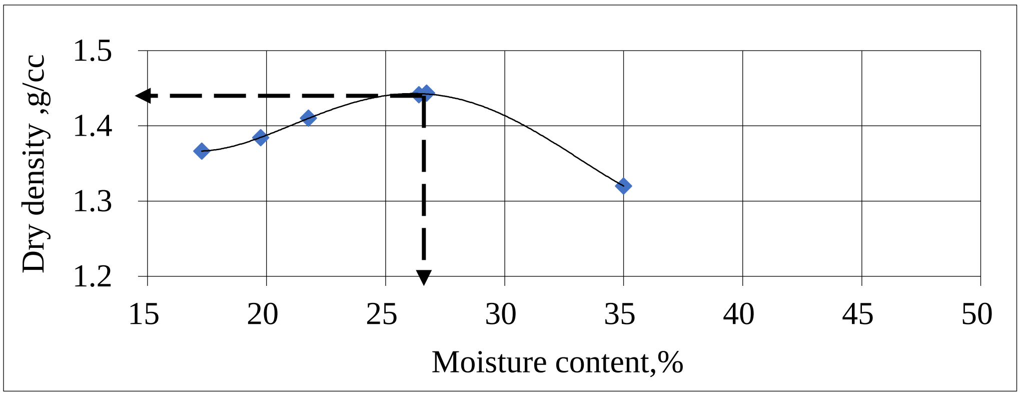
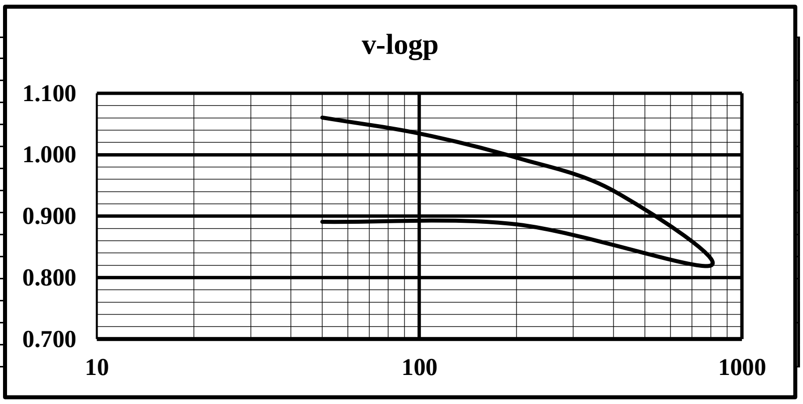


Table I-5 Laboratory test results of one- dimensional consolidation test

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
ressure(kp	50	100	200	400	800	200	50
TIME		Displacement					
0.25	0.092	0.34	0.64	1	1.842	2.4	1.879
1	0.1	0.35	0.66	1.072	1.89	2.36	1.876
2.25	0.114	0.356	0.675	1.114	1.976	2.29	1.872
4	0.128	0.365	0.69	1.15	2.02	2.23	1.868
6.25	0.143	0.3712	0.7002	1.17	2.08	2.19	1.864
9	0.1512	0.378	0.712	1.19	2.12	2.14	1.862
12.25	0.1582	0.384	0.721	1.207	2.18	2.12	1.86
16	0.1642	0.388	0.728	1.228	2.22	2.1	1.858
25	0.1732	0.396	0.741	1.256	2.28	2.081	1.854
36	0.1785	0.402	0.755	1.278	2.309	2.06	1.852
49	0.1832	0.408	0.77	1.288	2.341	2.04	1.85
64	0.1862	0.414	0.785	1.298	2.37	2.02	1.848
81	0.189	0.418	0.796	1.3087	2.408	2	1.846
100	0.1925	0.423	0.8058	1.318	2.43	1.982	1.844
121	0.195	0.428	0.812	1.326	2.454	1.96	1.843
225	0.204	0.445	0.822	1.34	2.482	1.9	1.841
400	0.206	0.456	0.828	1.35	2.5088	1.88	1.84
1440	0.209	0.458	0.835	1.354	2.522	1.878	1.838

PT. No			10	
depth	3	m	sample color	dark
volume of ring	88.36	cm^3	specific gravity	2.75
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.082
diameter of ring	75	mm	initial height of sampl	20
weight of ring	107.5		**After test**	
density of water	1	g/cm^3	weight of dry specim	116.7
height of solid	9.6053	mm	weight of water (g)	40.9
Before test			final moisture content	35.05
weight of dry sample	116.7	g		
weight of water	39.5	g		
initial moisture content	33.85	%		

pressure (Kpa)	void ratio
0	1.082
50	1.06
100	1.034
200	0.995
400	0.941
800	0.82
200	0.887
50	0.891
e1	1.06
e2	0.941
e3	0.887
e4	0.891

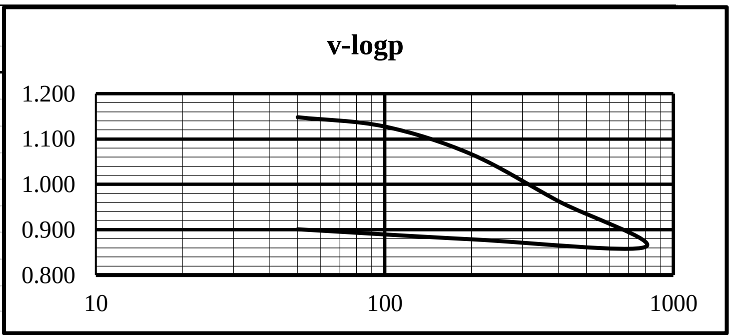


pressure (KPa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = (0.848* H^2)/t90 (m^2/year)
0	0	20	1.082		
50	0.209	19.791	1.06	36	4.783
100	0.458	19.542	1.034	51.84	3.238
200	0.835	19.165	0.995	121	1.334
400	1.354	18.646	0.941	36	4.246
800	2.522	17.478	0.82	29.16	4.605
200	1.878	18.122	0.887	16	9.023
50	1.838	18.162	0.891	37.21	3.897
					4.447

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME		Displacement					
0.25	0.152	0.3	0.678	1.51	2.452	2.84	2.69
1	0.154	0.308	0.698	1.542	2.48	2.828	2.678
2.25	0.157	0.314	0.735	1.594	2.522	2.818	2.672
4	0.16	0.321	0.768	1.624	2.565	2.808	2.668
6.25	0.164	0.328	0.789	1.65	2.6	2.8	2.665
9	0.167	0.333	0.808	1.68	2.62	2.79	2.661
12.25	0.1696	0.338	0.82	1.699	2.64	2.782	2.658
16	0.1718	0.342	0.83	1.718	2.654	2.776	2.656
25	0.175	0.348	0.848	1.754	2.684	2.764	2.653
36	0.178	0.352	0.861	1.779	2.714	2.75	2.651
49	0.181	0.355	0.874	1.798	2.73	2.74	2.649
64	0.183	0.358	0.886	1.816	2.75	2.73	2.648
81	0.185	0.361	0.896	1.828	2.76	2.72	2.647
100	0.187	0.364	0.905	1.838	2.77	2.71	2.646
121	0.189	0.367	0.912	1.848	2.78	2.7	2.645
225	0.195	0.377	0.935	1.873	2.82	2.687	2.644
400	0.199	0.386	0.946	1.895	2.84	2.686	2.643
1440	0.203	0.392	0.956	1.909	2.838	2.684	2.46

PT. No			6	
depth	3	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.65
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.17
diameter of ring	75	mm	initial height of sampl	20
weight of ring	107.8	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	107.9
height of solid	9.2162	mm	weight of water (g)	49.9
Before test			final moisture content	46.25
weight of dry sample	107.9	g		
weight of water	17.5	g		
initial moisture content	11.26	%		

pressure (Kpa)	void ratio
0	1.17
50	1.148
100	1.128
200	1.066
400	0.963
800	0.862
200	0.879
50	0.901



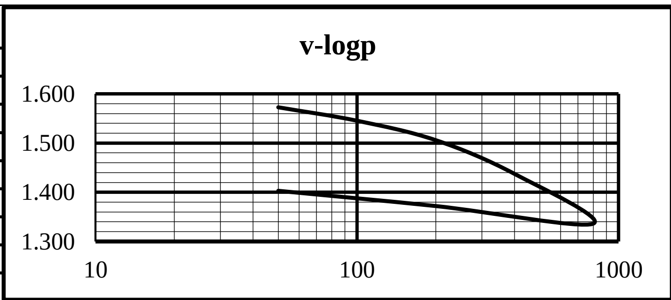
e1	1.128	p1	100	cc	0.294
e2	0.862	p2	800		
e3	0.879	p3	200	cs	0.04
e4	0.901	p4	50		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.17		
50	0.203	19.797	1.148	72.25	2.385
100	0.392	19.608	1.128	42.25	4
200	0.956	19.044	1.066	36	4.429
400	1.909	18.091	0.963	94.09	1.529
800	2.838	17.162	0.862	64	2.023
200	2.684	17.316	0.879	81	1.627
50	2.46	17.54	0.903	25	5.41
Average Cv					3.058

ONE DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME			Displacement				
0.25	0.32	0.56	0.808	1.251	1.876	2.21	1.941
1	0.336	0.566	0.812	1.252	1.888	2.2	1.9231
2.25	0.348	0.572	0.826	1.256	1.918	2.18	1.9
4	0.358	0.578	0.84	1.268	1.948	2.16	1.88
6.25	0.365	0.584	0.848	1.286	1.978	2.14	1.858
9	0.375	0.588	0.856	1.3	1.999	2.12	1.834
12.25	0.38	0.592	0.864	1.314	2.02	2.11	1.82
16	0.384	0.596	0.868	1.324	2.034	2.09	1.809
25	0.388	0.603	0.876	1.338	2.056	2.07	1.784
36	0.394	0.608	0.884	1.349	2.076	2.05	1.766
49	0.399	0.612	0.888	1.358	2.098	2.04	1.752
64	0.404	0.616	0.894	1.368	2.12	2.03	1.736
81	0.408	0.618	0.898	1.38	2.13	2.02	1.725
100	0.412	0.62	0.904	1.388	2.14	2.01	1.716
121	0.414	0.622	0.908	1.399	2.15	2	1.714
225	0.418	0.628	0.922	1.422	2.18	1.96	1.712
400	0.419	0.628	0.928	1.433	2.2	1.95	1.712
1440	0.421	0.629	0.929	1.45	2.22	1.948	1.71

PT. No		5		
depth	3	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.65
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.628
diameter of ring	75	mm	initial height of sampl	20
weight of ring	108.9		**After test**	
density of water	1	g/cm^3	weight of dry specim	89.1
height of solid	7.6104	mm	weight of water (g)	32.6
Before test			final moisture content	36.59
weight of dry sample	89.1	g		
weight of water	29.5	g		
initial moisture content	33.11	%		

pressure (Kpa)	void ratio
0	1.628
50	1.573
100	1.545
200	1.506
400	1.437
800	1.336
200	1.372
50	1.403



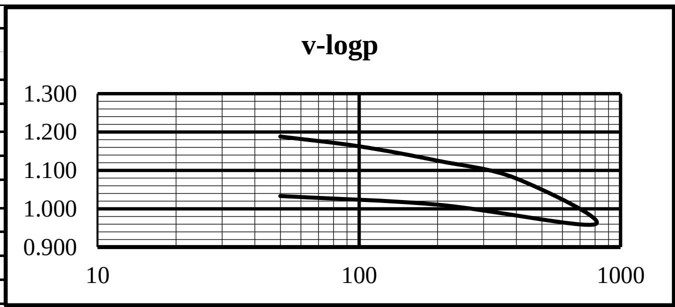
e1	1.437	p1	400	cc	0.336
e2	1.336	p2	800		
e3	1.372	p3	200	cs	0.051
e4	1.403	p4	50		

pressure (	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.628		
50	0.421	19.579	1.573	16.81	10.025
100	0.629	19.371	1.545	64	2.577
200	0.929	19.071	1.506	36	4.441
400	1.45	18.55	1.437	225	0.672
800	2.22	17.78	1.336	25	5.559
200	1.948	18.052	1.372	47.61	3.009
50	1.71	18.29	1.403	49	3.001
Average Cv				4.184	

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME			Displacement				
0.25	0.216	0.455	0.728	0.886	1.859	2.305	1.9005
1	0.218	0.457	0.731	0.888	1.889	2.28	1.88155
2.25	0.231	0.464	0.7505	0.928	1.947	2.235	1.865
4	0.243	0.4715	0.765	0.952	1.984	2.195	1.84
6.25	0.254	0.4776	0.7741	0.974	2.029	2.16	1.821
9	0.2611	0.483	0.784	0.988	2.0595	2.135	1.8035
12.25	0.2666	0.488	0.7925	1.01	2.1	2.12	1.792
16	0.2716	0.492	0.798	1.03	2.127	2.105	1.7815
25	0.2806	0.4995	0.8085	1.06	2.168	2.0805	1.763
36	0.28625	0.505	0.8195	1.08	2.1925	2.06	1.749
49	0.2911	0.51	0.8315	1.1	2.2195	2.04	1.74
64	0.2951	0.515	0.8395	1.12	2.245	2.025	1.735
81	0.2985	0.518	0.8485	1.14	2.269	2.01	1.73
100	0.30225	0.5215	0.8549	1.16	2.285	1.996	1.728
121	0.3045	0.525	0.86	1.18	2.302	1.98	1.724
225	0.311	0.5365	0.872	1.25	2.331	1.93	1.72
400	0.3125	0.542	0.878	1.28	2.3544	1.915	1.714
1440	0.315	0.5435	0.882	1.3	2.371	1.913	1.71

PT. No	8			
depth	1.5	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.74
height of ring	20	mm	method used for curv	Taylor
Cross-sectional area	44.18	cm^2	initial void ratio	1.223
diameter of ring	75	mm	initial height of sampl	20
weight of ring			**After test**	
density of water	1	g/cm^3	weight of dry specim	108.9
height of solid	9	mm	weight of water (g)	52
Before test			final moisture content	47.75
weight of dry sample	108.9	g		
weight of water	45.9	g		
initial moisture content	42.15	%		

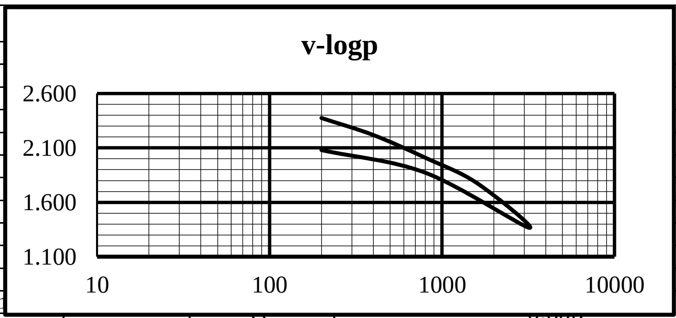
pressure (Kpa)	void ratio
0	1.223
50	1.188
100	1.163
200	1.125
400	1.079
800	0.96
200	1.011
50	1.033



e1	1.163	p1	100	cc	0.225
e2	0.96	p2	800		
e3	1.011	p3	200	cs	0.04
e4	1.033	p4	50		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.223		
50	0.315	19.685	1.188	23.04	7.393
100	0.5435	19.4565	1.163	67.24	2.475
200	0.882	19.118	1.125	118.81	1.352
400	1.3	18.7	1.079	102.01	1.507
800	2.371	17.629	0.96	36	3.795
200	1.913	18.087	1.011	47.61	3.021
50	1.71	18.29	1.033	36	4.085
Average Cv				3.375	

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	200	400	800	1600	3200	800	200
TIME		Displacement					
0.25	0.262	1.22	2.1562	3.312	4.766	4.72	3.69
1	0.278	1.252	2.186	3.338	4.78	4.7	3.68
2.25	0.288	1.282	2.232	3.364	4.84	4.65	3.654
4	0.294	1.3085	2.26	3.4	4.99	4.54	3.62
6.25	0.308	1.334	2.288	3.452	5.18	4.45	3.585
9	0.328	1.358	2.3182	3.48	5.28	4.35	3.56
12.25	0.356	1.376	2.35	3.538	5.382	4.25	3.54
16	0.384	1.392	2.368	3.581	5.452	4.15	3.52
25	0.432	1.4184	2.44	3.68	5.658	4.01	3.48
36	0.486	1.446	2.48	3.76	5.852	3.88	3.44
49	0.522	1.478	2.517	3.84	6.02	3.78	3.4
64	0.562	1.5082	2.5684	3.92	6.2156	3.75	3.35
81	0.596	1.535	2.618	4	6.326	3.74	3.33
100	0.6282	1.562	2.658	4.08	6.382	3.73	3.31
121	0.655	1.592	2.702	4.12	6.44	3.725	3.3
225	0.746	1.676	2.85	4.18	6.546	3.715	3.28
400	0.786	1.72	2.9	4.208	6.568	3.712	3.27
1440	0.848	1.736	2.92	4.25	6.5736	3.7	2.52
PT No				1			
depth			1.5	m	sample color		grey
volume of ring			88.36	cm^3	specific gravity		2.8
height of ring			20	mm	method used for curv		Taylor
cross-sectional area of ring			44.18	cm2	initial void ratio		2.524
diameter of ring			75	mm	initial height of sampl		20
weight of ring			107.5	g	**After test**		
density of water			1	g/cm^2	weight of dry specim		70.2
height of solid			5.67	mm	weight of water (g)		35
Before test					final moisture content		49.86
weight of dry sample			70.2	g			
weight of water			32	g			
initial moisture content			45.58	%			



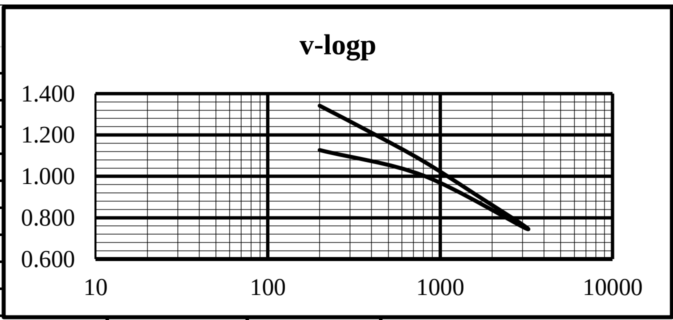
pressure (Kpa)	void ratio				
0	2.524				
200	2.375				
400	2.218				
800	2.01				
1600	1.775				
3200	1.366				
800	1.872				
200	2.08				
e1	2.375	p1	[illegible]	[illegible]	[illegible]
e2	2.01	p2	800		
e3	1.872	p3	800	cs	0.345
e4	2.08	p4	200		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	2.524		
200	0.848	19.152	2.375	201.64	0.8
400	1.736	18.264	2.218	256	0.573
800	2.92	17.08	2.01	272.25	0.471
1600	4.25	15.75	1.775	121	0.901
3200	6.5736	13.4264	1.366	121	0.655
800	3.7	16.3	1.872	62.41	1.871
200	2.52	17.48	2.08	519.84	0.258
Average Cv					0.79

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	200	400	800	1600	3200	800	200
TIME		Displacement					
0.25	0.35	1.33	2.57	3.44	4.82	4.8	3.66
1	0.375	1.356	2.586	3.468	4.86	4.75	3.62
2.25	0.415	1.428	2.596	3.556	4.98	4.68	3.56
4	0.447	1.481	2.608	3.628	5.08	4.58	3.48
6.25	0.484	1.528	2.627	3.696	5.22	4.51	3.43
9	0.52	1.558	2.649	3.774	5.328	4.43	3.34
12.25	0.556	1.589	2.671	3.838	5.382	4.34	3.26
16	0.589	1.624	2.702	3.896	5.424	4.26	3.16
25	0.656	1.682	2.752	4.012	5.488	4.18	3
36	0.722	1.732	2.788	4.126	5.555	4.08	2.92
49	0.766	1.784	2.84	4.228	5.618	4.01	2.88
64	0.798	1.818	2.88	4.329	5.6484	3.95	2.86
81	0.842	1.845	2.92	4.384	5.686	3.88	2.84
100	0.874	1.879	2.9498	4.419	5.732	3.86	2.82
121	0.894	1.906	2.982	4.442	5.758	3.85	2.81
225	0.984	1.994	3.108	4.468	5.818	3.81	2.784
400	1	2.06	3.188	4.478	5.842	3.78	2.786
1440	1.02	2.08	3.198	4.494	5.852	3.76	2.758

PT. No			4	
depth	3	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.75
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.467
diameter of ring	75	mm	initial height of sampl	20
weight of ring	107.12	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	98.48
height of solid	8.1057	mm	weight of water (g)	35
Before test			final moisture content	35.54
weight of dry sample	98.48	g		
weight of water	30	g		
initial moisture content	30.46	%		

pressure (Kpa)	void ratio
0	1.467
200	1.342
400	1.211
800	1.073
1600	0.913
3200	0.745
800	1.004
200	1.127



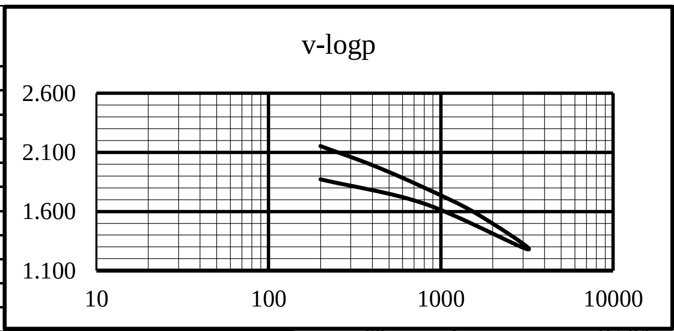
e1	1.342	p1	200	cc	0.446
e2	1.073	p2	800		
e3	1.004	p3	800	cs	0.205
e4	1.127	p4	200		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.467		
200	1.02	18.98	1.342	110.25	1.611
400	2.08	17.92	1.211	102.01	1.552
800	3.198	16.802	1.073	144	0.967
1600	4.494	15.506	0.913	118.81	0.998
3200	5.852	14.148	0.745	16.81	5.871
800	3.76	16.24	1.004	25	5.201
200	2.758	17.242	1.127	49	2.991
Average Cv					2.741

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 2435-96							
Pressure(kpa)	200	400	800	1600	3200	800	200
TIME		Displacement					
0.25	0.3135	1.22	2.3621	3.36	4.7	4.87	3.7
1	0.3265	1.304	2.386	3.403	4.82	4.802	3.665
2.25	0.3515	1.355	2.414	3.46	4.98	4.75	3.602
4	0.3705	1.39475	2.434	3.5185	5.1	4.6705	3.525
6.25	0.396	1.431	2.4575	3.574	5.2	4.5875	3.4425
9	0.424	1.458	2.4836	3.627	5.304	4.515	3.355
12.25	0.456	1.4825	2.5105	3.688	5.382	4.44	3.28
16	0.4865	1.508	2.535	3.7385	5.438	4.375	3.2
25	0.544	1.5502	2.58	3.846	5.573	4.27	3.08
36	0.598	1.589	2.618	3.943	5.7035	4.165	3
49	0.644	1.631	2.6655	4.034	5.819	4.08	2.92
64	0.68	1.6631	2.7122	4.1245	5.932	4.03	2.845
81	0.719	1.69	2.756	4.212	6.006	3.98	2.8
100	0.7511	1.7205	2.8039	4.2495	6.057	3.94	2.73
121	0.7745	1.749	2.842	4.281	6.099	3.9325	2.72
225	0.865	1.835	2.979	4.324	6.182	3.9075	2.63
400	0.893	1.89	3.044	4.343	6.205	3.896	2.608
1440	0.934	1.908	3.059	4.372	6.2128	3.875	2.63

PT. No				1
depth	3	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.68
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	2.307
diameter of ring	75	mm	initial height of sampl	20
weight of ring	80.9	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	71.6
height of solid	6.0472	mm	weight of water (g)	32
Before test			final moisture content	44.69
weight of dry sample	71.6	g		
weight of water	31	g		
initial moisture content	43.3	%		

pressure (Kpa)	void ratio				
0	2.307				
200	2.153				
400	1.992				
800	1.801				
1600	1.584				
3200	1.28				
800	1.667				
200	1.872				
e1	2.153			cc	0.584
e2	1.801	p2	800		
e3	1.667	p3	800	cs	0.341
e4	1.872	p4	200		

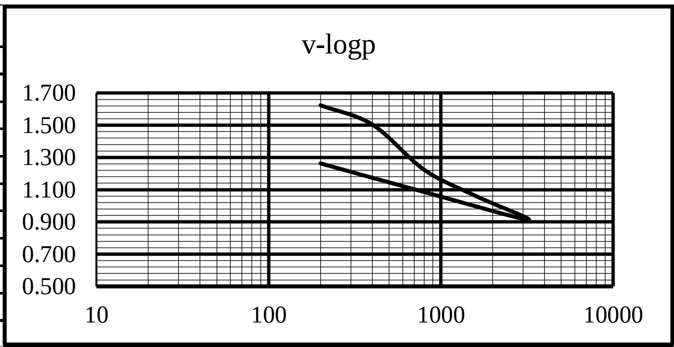


pressure (Kp	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = (0.848*H^2)/t90 (m^2/year)
0	0	20	2.307		
200	0.934	19.066	2.153	19.44	8.22
400	1.908	18.092	1.992	90.25	1.594
800	3.059	16.941	1.801	222.01	0.568
1600	4.372	15.628	1.584	100	1.074
3200	6.2128	13.7872	1.28	102.01	0.819
800	3.875	16.125	1.667	64	1.786
200	2.63	17.37	1.872	29.16	4.549
Average Cv					2.659

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	200	400	800	1600	3200	800	200
TIME			Displacement				
0.25	0.85	1.46	2.38	4.24	5.46	6.35	5.18
1	0.856	1.48	2.48	4.28	5.48	6.28	5.16
2.25	0.888	1.568	2.54	4.38	5.56	6.12	5.08
4	0.912	1.612	2.74	4.48	5.64	6.01	4.95
6.25	0.938	1.69	2.84	4.58	5.74	5.92	4.85
9	0.974	1.754	2.98	4.68	5.82	5.84	4.76
12.25	1	1.84	3.08	4.78	5.88	5.78	4.65
16	1.02	1.9	3.16	4.84	5.96	5.69	4.58
25	1.08	2	3.33	4.94	6.04	5.58	4.48
36	1.13	2.06	3.48	5.04	6.14	5.48	4.386
49	1.18	2.124	3.58	5.1	6.18	5.42	4.28
64	1.24	2.148	3.66	5.16	6.24	5.38	4.18
81	1.28	2.168	3.74	5.2	6.28	5.34	4.11
100	1.31	2.184	3.84	5.24	6.3	5.3	4.08
121	1.33	2.198	3.88	5.28	6.32	5.28	4.02
225	1.36	2.224	4.14	5.34	6.38	5.26	4.01
400	1.37	2.23	4.21	5.36	6.41	5.24	3.98
1440	1.38	2.23	4.22	5.38	6.42	5.2	3.94

PT. No			3	
depth	3	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.69
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.818
diameter of ring	75	mm	initial height of sampl	20
weight of ring	107.31		**After test**	
density of water	1	g/cm^3	weight of dry specim	84.34
height of solid	7.0967	mm	weight of water (g)	38
Before test			final moisture content	45.06
weight of dry sample	84.34	g		
weight of water	35	g		
initial moisture content	41.5	%		

pressure (Kpa)	void ratio
0	1.818
200	1.624
400	1.504
800	1.224
1600	1.06
3200	0.914
800	1.085
200	1.263



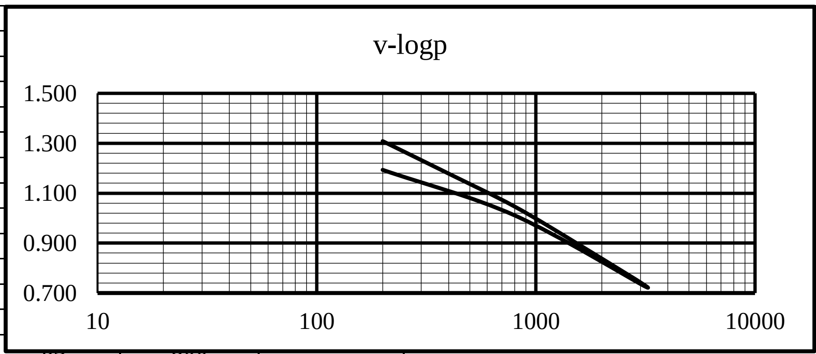
e1	1.504	p1	200	cc	0.492
e2	1.06	p2	1600		
e3	1.085	p3	800	cs	0.29
e4	1.263	p4	200		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.818		
200	1.38	18.62	1.624	125.44	1.215
400	2.23	17.77	1.504	56.25	2.468
800	4.22	15.78	1.224	100	1.095
1600	5.38	14.62	1.06	72.25	1.301
3200	6.42	13.58	0.914	42.25	1.919
800	5.2	14.8	1.085	60.84	1.583
200	3.94	16.06	1.263	96.04	1.181
Average Cv					1.537

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	200	400	800	1600	3200	800	200
TIME		Displacement					
0.25	0.2185	1.2441	2.2971	3.34	4.725	4.4	3.3
1	0.2315	1.254	2.3015	3.368	4.734	4.357	3.23
2.25	0.268	1.2901	2.327	3.4	4.752	4.27	3.14
4	0.304	1.3215	2.354	3.445	4.782	4.175	3.085
6.25	0.333	1.351	2.379	3.488	4.823	4.1	3.03
9	0.365	1.379	2.401	3.561	4.863	4.025	2.97
12.25	0.396	1.406	2.425	3.617	4.9005	3.95	2.92
16	0.45	1.433	2.45	3.658	4.933	3.885	2.85
25	0.484	1.479	2.495	3.741	5.009	3.78	2.75
36	0.53	1.519	2.542	3.831	5.1035	3.68	2.63
49	0.574	1.561	2.587	3.896	5.21	3.6	2.54
64	0.62	1.595	2.635	3.9605	5.2848	3.545	2.45
81	0.651	1.6325	2.676	4.014	5.3558	3.515	2.36
100	0.686	1.6705	2.7339	4.0656	5.457	3.485	2.3
121	0.78	1.704	2.777	4.12045	5.514	3.4675	2.24
225	0.845	1.835	2.937	4.265	5.662	3.4175	2.08
400	0.881	1.883	3.044	4.335	5.708	3.411	1.98
1440	0.941	2.014	3.103	4.397	5.7705	3.3945	1.89

PT. No				3
depth	1.5	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.65
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.422
diameter of ring	75	mm	initial height of sampl	20mm
weight of ring	107.95	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	96.665
height of solid	8.2565	mm	weight of water (g)	48
Before test			final moisture content	49.66
weight of dry sample	96.665	g		
weight of water	44.75	g		
initial moisture content	46.29	%		

pressure (Kpa)	void ratio		
0	1.422		
200	1.308		
400	1.178		
800	1.047		
1600	0.89		
3200	0.723		
800	1.011		
200	1.193		
e1	1.178		
e2	0.723		
e3	1.011		
e4	1.193	p4	200

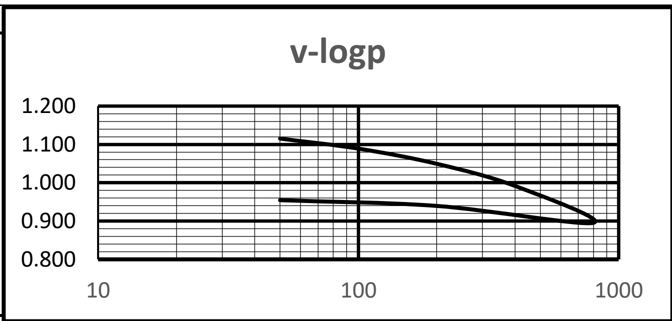


pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848 * H^2)/t90$ (m^2/year)
0	0	20	1.422		
200	0.941	19.059	1.308	324	0.493
400	2.014	17.986	1.178	324	0.439
800	3.103	16.897	1.047	400	0.314
1600	4.397	15.603	0.89	272.25	0.393
3200	5.7705	14.2295	0.723	14884	0.006
800	3.3945	16.6055	1.011	64	1.894
200	1.89	18.11	1.193	144	1.001
Average Cv					0.649

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 2435-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME		Displacement					
0.25	0.082	0.328	0.64	1.074	1.882	2.267	1.85
1	0.098	0.346	0.66	1.102	1.91	2.25	1.84
2.25	0.116	0.354	0.678	1.124	1.946	2.24	1.83
4	0.128	0.364	0.69	1.14	1.972	2.22	1.82
6.25	0.142	0.37	0.7	1.158	1.994	2.19	1.81
9	0.15	0.376	0.71	1.17	2.014	2.17	1.8
12.25	0.156	0.382	0.72	1.187	2.032	2.15	1.79
16	0.164	0.388	0.726	1.198	2.048	2.14	1.78
25	0.17	0.396	0.738	1.216	2.078	2.11	1.77
36	0.174	0.402	0.75	1.234	2.098	2.09	1.76
49	0.18	0.408	0.758	1.25	2.118	2.06	1.75
64	0.182	0.412	0.766	1.26	2.132	2.04	1.74
81	0.186	0.416	0.774	1.27	2.146	2.02	1.735
100	0.19	0.42	0.78	1.278	2.158	2	1.732
121	0.192	0.424	0.784	1.286	2.17	1.98	1.731
225	0.204	0.44	0.8	1.32	2.202	1.91	1.728
400	0.206	0.45	0.81	1.334	2.238	1.88	1.724
1440	0.216	0.462	0.832	1.374	2.272	1.86	1.72

PT. No			10	
depth	1.5	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.8
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.138
diameter of ring	75	mm	initial height of sampl	20
weight of ring	107.5	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	115.7
height of solid	9.353	mm	weight of water (g)	36.9
Before test			final moisture content	31.89
weight of dry sample	115.7	g		
weight of water	36.1	g		
initial moisture content	31.2	%		

pressure (Kpa)	void ratio
0	1.138
50	1.115
100	1.089
200	1.049
400	0.991
800	0.895
200	0.939
50	0.954

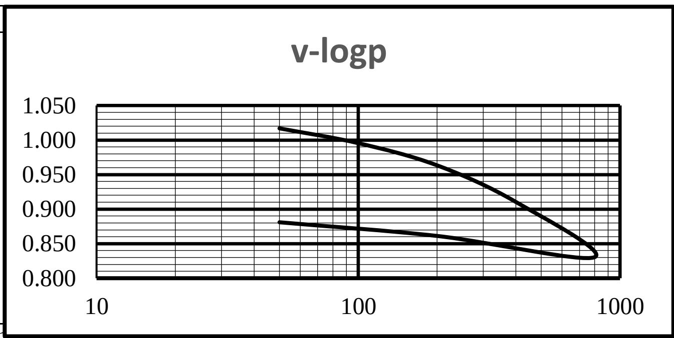


e1	1.089	p1	100	cc	0.214
e2	0.895	p2	800		
e3	0.939	p3	200	cs	0.025
e4	0.954	p4	50		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.138		
50	0.216	19.784	1.115	36.69	4.69
100	0.462	19.538	1.089	139.24	1.205
200	0.832	19.168	1.049	163.84	0.986
400	1.374	18.626	0.991	146.41	1.042
800	2.272	17.728	0.895	62.41	2.214
200	1.86	18.14	0.939	289	0.501
50	1.72	18.28	0.954	92.16	1.594
Average Cv					1.747

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 2435-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME		Displacement					
0.25	0.324	0.558	0.802	1.218	1.85	2.22	1.931
1	0.338	0.561	0.812	1.232	1.88	2.21	1.92
2.25	0.352	0.57	0.828	1.246	1.908	2.2	1.89
4	0.36	0.576	0.838	1.268	1.94	2.19	1.87
6.25	0.366	0.582	0.845	1.286	1.97	2.18	1.85
9	0.37	0.586	0.853	1.3	1.99	2.17	1.835
12.25	0.374	0.59	0.858	1.31	2.004	2.155	1.82
16	0.378	0.594	0.863	1.318	2.018	2.14	1.809
25	0.384	0.599	0.87	1.33	2.04	2.12	1.79
36	0.388	0.604	0.876	1.342	2.056	2.1	1.78
49	0.392	0.608	0.882	1.352	2.072	2.085	1.77
64	0.396	0.611	0.888	1.362	2.086	2.07	1.765
81	0.4	0.615	0.894	1.372	2.1	2.055	1.764
100	0.404	0.618	0.9	1.379	2.115	2.038	1.764
121	0.408	0.621	0.904	1.388	2.127	2.029	1.762
225	0.416	0.624	0.92	1.416	2.178	1.99	1.76
400	0.418	0.626	0.926	1.434	2.19	1.971	1.75
1440	0.42	0.628	0.94	1.454	2.23	1.932	1.74

PT. No		9			
depth	1.5	m	sample color	black	
volume of ring	88.36	cm^3	specific gravity	2.7	
height of ring	20	mm	method used for curv	Taylor	
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.06	
diameter of ring	75	mm	initial height of sampl	20	
weight of ring	107.4	g	**After test**		
density of water	1	g/cm^3	weight of dry specim	115.8	
height of solid	9.7078	mm	weight of water(g)	36	
Before test			final moisture content (%)	31.09	
weight of dry sample	115.8	g			
weight of water	33.7	g			
initial moisture content	29.1	%			



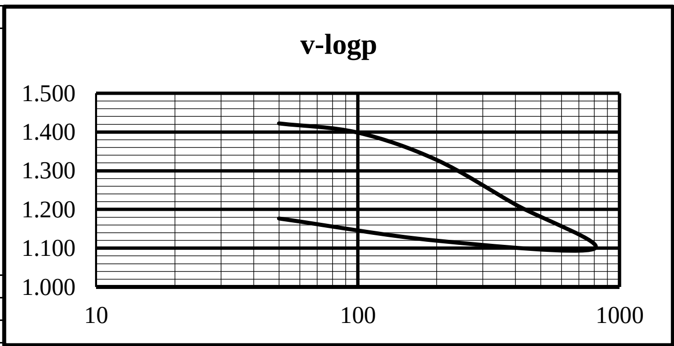
pressure (Kpa)	void ratio				
0	1.06				
50	1.017				
100	0.996				
200	0.963				
400	0.91				
800	0.83				
200	0.861				
50	0.881				
e1	0.963	p1	200	cc	0.221
e2	0.83	p2	800		
e3	0.861	p3	200	cs	0.033
e4	0.881	p4	50		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.06		
50	0.42	19.58	1.017	198.246	0.85
100	0.628	19.372	0.996	144	1.146
200	0.94	19.06	0.963	201.64	0.792
400	1.454	18.546	0.91	324	0.467
800	2.23	17.77	0.83	282.24	0.492
200	1.932	18.068	0.861	256	0.561
50	1.74	18.26	0.881	59.29	2.472
Average Cv					0.968

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 2435-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME	Displacement						
0.25	0.15	0.296	0.648	1.54	2.442	2.848	2.676
1	0.154	0.304	0.698	1.552	2.47	2.842	2.66
2.25	0.156	0.314	0.745	1.584	2.52	2.84	2.64
4	0.16	0.32	0.776	1.614	2.56	2.82	2.58
6.25	0.164	0.326	0.792	1.646	2.588	2.8	2.54
9	0.167	0.33	0.806	1.668	2.616	2.788	2.5
12.25	0.169	0.334	0.818	1.688	2.638	2.776	2.48
16	0.171	0.336	0.83	1.708	2.656	2.768	2.46
25	0.174	0.342	0.846	1.744	2.684	2.748	2.43
36	0.177	0.348	0.856	1.764	2.704	2.738	2.4
49	0.18	0.352	0.869	1.78	2.72	2.725	2.38
64	0.182	0.356	0.876	1.792	2.734	2.715	2.36
81	0.184	0.36	0.888	1.804	2.744	2.708	2.34
100	0.186	0.364	0.898	1.814	2.758	2.7	2.32
121	0.188	0.366	0.912	1.826	2.768	2.694	2.31
225	0.194	0.376	0.93	1.853	2.798	2.687	2.26
400	0.198	0.386	0.942	1.88	2.812	2.686	2.22
1440	0.204	0.398	0.974	1.914	2.848	2.678	2.21

PT. No		5		
depth	1.5	m	sample color	grey
volume of ring	88.36	cm^3	specific gravity	2.8
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.447
diameter of ring	75	mm	initial height of sampl	20
weight of ring	108.8	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	101.1
height of solid	8.1727	mm	weight of water (g)	46.7
Before test			final moisture conten	46.19
weight of dry sample	101.1	g		
weight of water	29.7	g		
initial moisture content	29.38	%		

pressure (Kpa)	void ratio		
0	1.447		
50	1.422		
100	1.398		
200	1.328		
400	1.213		
800	1.099		
200	1.119		
50	1.177		
e1	1.328	p1	
e2	1.099	p2	
e3	1.119	p3	
e4	1.177	p4	50

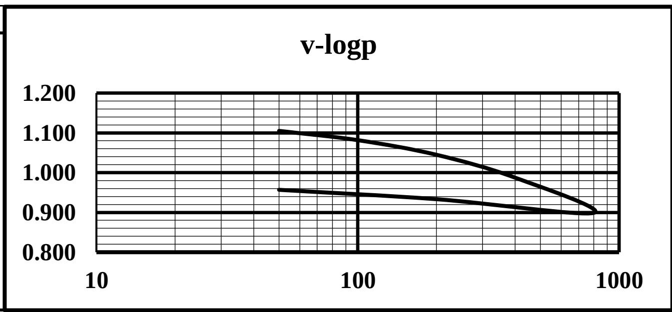


pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.447		
50	0.204	19.796	1.422	275.56	0.625
100	0.398	19.602	1.398	400	0.422
200	0.974	19.026	1.328	129.96	1.224
400	1.914	18.086	1.213	36	3.994
800	2.848	17.152	1.099	42.25	3.061
200	2.678	17.322	1.119	72.25	1.826
50	2.21	17.79	1.177	144	0.966
Average Cv					1.731

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 2435-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME		Displacement					
0.25	0.21	0.452	0.731	1.156	1.876	2.2	1.89
1	0.218	0.4535	0.736	1.167	1.895	2.19	1.889
2.25	0.233	0.462	0.753	1.185	1.927	2.15	1.88
4	0.244	0.47	0.764	1.204	1.956	2.12	1.87
6.25	0.254	0.476	0.7725	1.222	1.982	2.1	1.86
9	0.26	0.481	0.7815	1.235	2.002	2.08	1.85
12.25	0.265	0.486	0.789	1.2485	2.018	2.06	1.84
16	0.27	0.49	0.7945	1.258	2.033	2.05	1.83
25	0.277	0.4975	0.804	1.273	2.059	2.03	1.81
36	0.282	0.503	0.813	1.288	2.077	2.01	1.79
49	0.287	0.508	0.82	1.301	2.095	1.99	1.77
64	0.291	0.5115	0.827	1.311	2.109	1.98	1.76
81	0.294	0.5155	0.834	1.321	2.123	1.96	1.75
100	0.298	0.519	0.84	1.332	2.1365	1.95	1.74
121	0.3	0.52	0.844	1.342	2.1485	1.94	1.73
225	0.303	0.521	0.86	1.368	2.19	1.93	1.72
400	0.304	0.522	0.864	1.384	2.214	1.92	1.71
1440	0.304	0.522	0.866	1.404	2.231	1.91	1.69

PT. No			7	
depth	1.5	m	sample color	grey
volume of ring	88.36	cm^3	specific gravity	2.8
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.137
diameter of ring	75	mm	initial height of sampl	20
weight of ring	107.45	**g**	**After test**	
density of water	1	g/cm^3	weight of dry specim	115.75
height of solid	9.357	mm	weight of water(g)	36.45
Before test			final moisture content	31.49
weight of dry sample	115.75	g		
weight of water	34.9	g		
initial moisture content	30.15	%		

pressure (Kpa)	void ratio
0	1.137
50	1.105
100	1.082
200	1.045
400	0.987
800	0.899
200	0.933
50	0.957

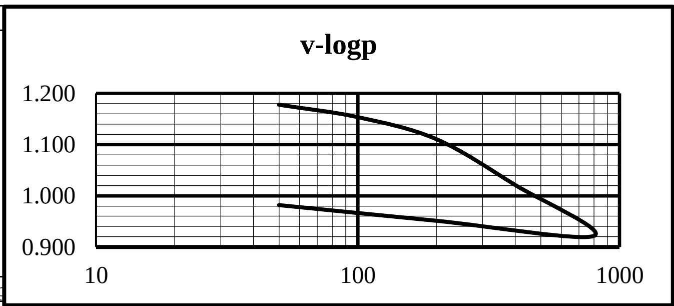


e1	1.045	p1	200	cc	0.242
e2	0.899	p2	800		
e3	0.933	p3	200	cs	0.04
e4	0.957	p4	50		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.137		
50	0.304	19.696	1.105	36	4.737
100	0.522	19.478	1.082	62.41	2.672
200	0.866	19.134	1.045	144	1.118
400	1.404	18.596	0.987	141.61	1.074
800	2.231	17.769	0.899	64	2.169
200	1.91	18.09	0.933	60.84	2.365
50	1.69	18.31	0.957	110.25	1.337
Average Cv					2.21

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME		Displacement					
0.25	0.116	0.318	0.648	1.316	2.162	2.532	2.263
1	0.126	0.324	0.66	1.327	2.19	2.526	2.257
2.25	0.136	0.334	0.678	1.354	2.233	2.524	2.244
4	0.144	0.342	0.69	1.377	2.266	2.515	2.23
6.25	0.153	0.348	0.7	1.402	2.291	2.495	2.214
9	0.1585	0.353	0.71	1.419	2.315	2.479	2.19
12.25	0.1625	0.358	0.72	1.4375	2.335	2.463	2.18
16	0.1675	0.362	0.726	1.453	2.352	2.454	2.17
25	0.172	0.369	0.738	1.48	2.381	2.429	2.15
36	0.1755	0.375	0.75	1.499	2.401	2.414	2.13
49	0.18	0.38	0.758	1.515	2.419	2.3925	2.11
64	0.182	0.384	0.766	1.526	2.433	2.3775	2.1
81	0.185	0.388	0.774	1.537	2.445	2.364	2.08
100	0.188	0.392	0.78	1.546	2.458	2.35	2.06
121	0.19	0.395	0.784	1.556	2.469	2.337	2.04
225	0.199	0.408	0.8	1.5865	2.5	2.2985	2
400	0.202	0.418	0.81	1.607	2.525	2.283	2
1440	0.21	0.43	0.822	1.635	2.535	2.269	1.99
PT. No				6			
depth			1.5	m	sample color		grey
volume of ring			88.36	cm^3	specific gravity		2.7
height of ring			20	mm	method used for curv		Taylor
cross-sectional area of ring			44.18	cm^2	initial void ratio		1.201
diameter of ring			75	mm	initial height of sampl		20
weight of ring			108.15	g	**After test**		
density of water			1	g/cm^3	weight of dry specim		108.4
height of solid			9.0874	mm	weight of water (g)		41.8
Before test					final moisture content		38.56
weight of dry sample			108.4	g			
weight of water			32.9	g			
initial moisture content			30.35	%			

pressure (Kpa)	void ratio				
0	1.201				
50	1.178				
100	1.154				
200	1.11				
400	1.021				
800	0.922				
200	0.951				
50	0.982				
e1	1.11	p			
e2	0.922	p2	800		
e3	0.951	p3	200	cs	0.051
e4	0.982	p4	50		

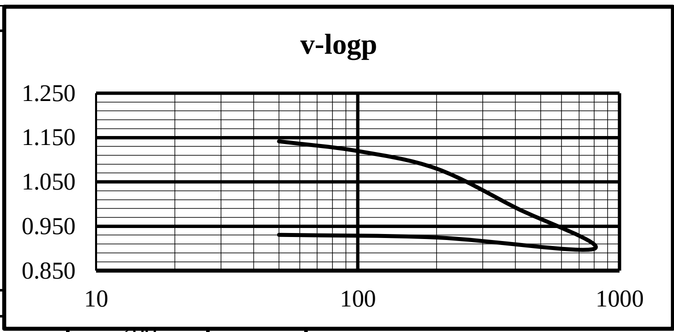


pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = (0.848*H^2)/t90 (m^2/year)	
0	0	20	1.201			
50	0.21	19.79	1.178	6.25	27.547	
100	0.43	19.57	1.154	144	1.169	
200	0.822	19.178	1.11	36	4.491	
400	1.635	18.365	1.021	36	4.119	
800	2.535	17.465	0.922	60.84	2.204	
200	2.269	17.731	0.951	100	1.382	
50	1.99	18.01	0.982	96.04	1.485	
Average Cv						6.057

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	50	100	200	400	800	200	50
TIME		Displacement					
0.25	0.237	0.426	0.655	1.388	2.146	2.534	2.3
1	0.246	0.4325	0.679	1.392	2.175	2.526	2.298
2.25	0.254	0.442	0.7115	1.415	2.214	2.52	2.2868
4	0.26	0.448	0.733	1.441	2.25	2.505	2.282
6.25	0.265	0.454	0.746	1.466	2.279	2.49	2.278
9	0.2685	0.458	0.758	1.484	2.303	2.479	2.2756
12.25	0.2715	0.462	0.769	1.499	2.321	2.4655	2.272
16	0.2745	0.465	0.778	1.513	2.337	2.454	2.27
25	0.279	0.4705	0.792	1.537	2.362	2.434	2.2676
36	0.2825	0.476	0.803	1.553	2.38	2.419	2.264
49	0.286	0.48	0.8135	1.566	2.396	2.405	2.262
64	0.289	0.4835	0.821	1.577	2.41	2.3925	2.258
81	0.292	0.4875	0.831	1.588	2.422	2.3815	2.256
100	0.295	0.491	0.839	1.5965	2.4365	2.369	2.254
121	0.298	0.494	0.848	1.607	2.4475	2.3615	2.253
225	0.305	0.5	0.865	1.6345	2.488	2.3385	2.252
400	0.308	0.506	0.876	1.657	2.501	2.3285	2.251
1440	0.312	0.513	0.878	1.684	2.539	2.305	2.25

PT. No			11	
depth	1.5	m	sample color	grey
volume of ring	88.36	cm^3	specific gravity	2.67
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.175
diameter of ring	75	mm	initial height of sampl	20
weight of ring	108.1	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	108.45
height of solid	9.1937	mm	weight of water (g)	41.35
Before test			final moisture content	38.13
weight of dry sample	108.45	g		
weight of water	31.7	g		
initial moisture content	29.23	%		

pressure (Kpa)	void ratio
0	1.175
50	1.141
100	1.12
200	1.08
400	0.992
800	0.899
200	0.925
50	0.931



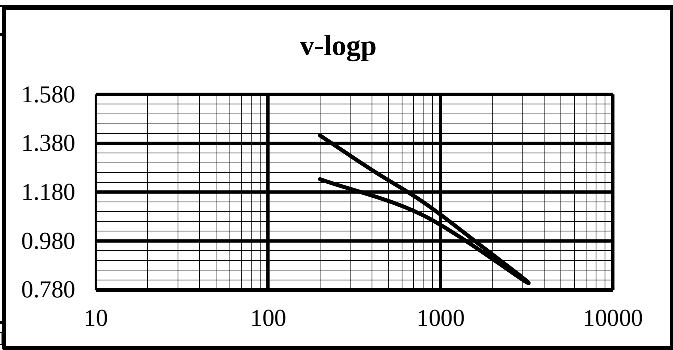
e1	1.141	p1			
e2	1.08	p2	200		
e3	0.925	p3	200	cs	0.01
e4	0.931	p4	50		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.175		
50	0.312	19.688	1.141	210.25	0.81
100	0.513	19.487	1.12	64	2.608
200	0.878	19.122	1.08	16	10.046
400	1.684	18.316	0.992	37.21	3.963
800	2.539	17.461	0.899	37.21	3.602
200	2.305	17.695	0.925	100	1.376
50	2.25	17.75	0.931	9.61	14.412
Average Cv					5.26

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	200	400	800	1600	3200	800	200
TIME			Displacement				
0.25	0.255	1.37	2.46	3.45	4.73	4.95	3.8
1	0.265	1.386	2.496	3.508	4.79	4.864	3.75
2.25	0.308	1.428	2.522	3.536	4.81	4.78	3.65
4	0.354	1.462	2.548	3.6	4.86	4.72	3.54
6.25	0.386	1.498	2.57	3.656	4.892	4.62	3.45
9	0.422	1.528	2.59	3.764	4.938	4.56	3.35
12.25	0.456	1.562	2.61	3.848	4.979	4.52	3.28
16	0.489	1.594	2.632	3.896	5.004	4.46	3.2
25	0.556	1.642	2.672	3.992	5.1	4.36	3.08
36	0.604	1.682	2.714	4.086	5.18	4.24	2.98
49	0.656	1.724	2.754	4.168	5.268	4.12	2.88
64	0.708	1.758	2.796	4.219	5.354	4.02	2.78
81	0.742	1.785	2.834	4.264	5.4256	3.92	2.65
100	0.78	1.819	2.878	4.299	5.532	3.85	2.58
121	0.814	1.856	2.912	4.3289	5.588	3.81	2.52
225	0.964	1.994	3.054	4.418	5.738	3.76	2.51
400	1.006	2.046	3.208	4.48	5.788	3.68	2.5
1440	1.074	2.182	3.228	4.484	5.805	3.65	2.48

PT. No		4		
depth	1.5	m	sample color	grey
volume of ring	88.36	cm^3	specific gravity	2.7
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.549
diameter of ring	75	mm	initial height of sampl	20mm
weight of ring	108.1	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	93.6
height of solid	7.8467	mm	weight of water(g)	45
Before test			final moisture content	48.08
weight of dry sample	93.6	g		
weight of water	41.5	g		
initial moisture content	44.34	%		

pressure (Kpa)	void ratio				
0	1.549				
200	1.412				
400	1.271				
800	1.137				
1600	0.977				
3200	0.809				
800	1.084				
200	1.233				
e1	1.271	p1		cc	0.487
e2	0.977	p2	1600		
e3	1.084	p3	800	cs	0.248
e4	1.233	p4	200		

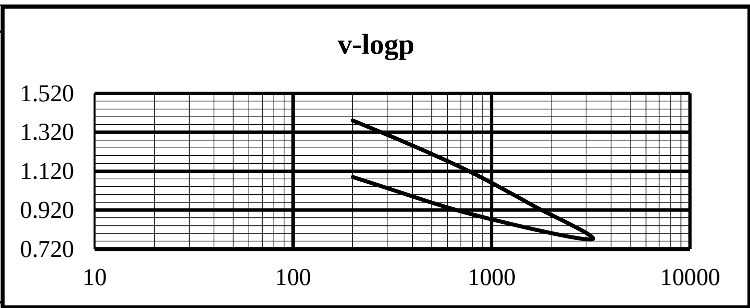


pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.549		
200	1.074	18.926	1.412	289	0.545
400	2.182	17.818	1.271	289	0.483
800	3.228	16.772	1.137	400	0.309
1600	4.484	15.516	0.977	100	1.058
3200	5.805	14.195	0.809	196	0.452
800	3.65	16.35	1.084	139.24	0.844
200	2.48	17.52	1.233	108.16	1.248
Average Cv					0.706

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	200	400	800	1600	3200	800	200
TIME		Displacement					
0.25	0.182	1.1082	2.08	3.2	4.66	5.79	4.7
1	0.198	1.122	2.107	3.228	4.678	5.75	4.66
2.25	0.228	1.1522	2.132	3.264	4.694	5.65	4.58
4	0.254	1.181	2.16	3.29	4.726	5.54	4.5
6.25	0.28	1.204	2.188	3.32	4.754	5.45	4.44
9	0.308	1.23	2.212	3.358	4.788	5.35	4.4
12.25	0.336	1.25	2.24	3.386	4.822	5.25	4.36
16	0.364	1.272	2.268	3.42	4.862	5.15	4.31
25	0.412	1.316	2.318	3.49	4.938	5.01	4.18
36	0.456	1.356	2.37	3.576	5.052	4.88	4.08
49	0.492	1.398	2.42	3.624	5.152	4.81	3.94
64	0.532	1.432	2.474	3.702	5.2156	4.77	3.84
81	0.56	1.48	2.54	3.764	5.286	4.74	3.72
100	0.592	1.522	2.5898	3.8322	5.382	4.73	3.62
121	0.626	1.552	2.642	3.912	5.44	4.725	3.54
225	0.726	1.676	2.82	4.112	5.586	4.715	3.28
400	0.756	1.72	2.88	4.19	5.628	4.712	3.22
1440	0.808	1.846	2.978	4.31	5.736	4.7	3.15

PT. No			2	
depth	3	m	sample color	black
volume of ring	88.36	cm^3	specific gravity	2.8
height of ring	20	mm	method used for curv	Taylor
cross-sectional area of ring	44.18	cm^2	initial void ratio	1.481
diameter of ring	75	mm	initial height of sampl	20
weight of ring	107.8	g	**After test**	
density of water	1	g/cm^3	weight of dry specim	99.73
height of solid	8.062	mm	weight of water(g)	50
Before test			final moisture content	50.14
weight of dry sample	99.73	g		
weight of water	48	g		
initial moisture content	48.13	%		

pressure (Kpa)	void ratio
0	1.481
200	1.381
400	1.252
800	1.111
1600	0.946
3200	0.769
800	0.898
200	1.09

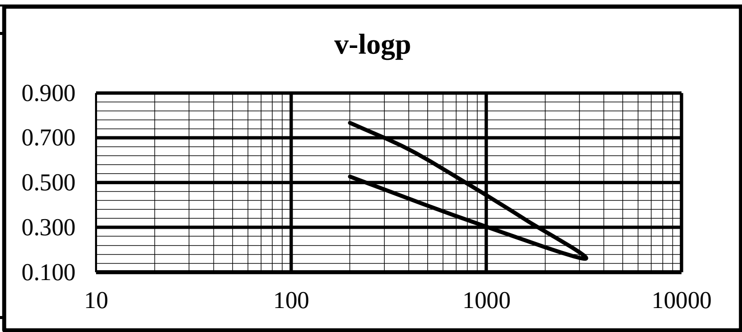


e1	1.252	p1	400	cc	0.534
e2	0.769	p2	3200		
e3	0.898	p3	800	cs	0.319
e4	1.09	p4	200		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	1.481		
200	0.808	19.192	1.381	324	0.5
400	1.846	18.154	1.252	324	0.447
800	2.978	17.022	1.111	338.56	0.376
1600	4.31	15.69	0.946	306.25	0.353
3200	5.736	14.264	0.769	262.44	0.341
800	4.7	15.3	0.898	64	1.608
200	3.15	16.85	1.09	249.64	0.5
Average Cv					0.589

ONE-DIMENSIONAL CONSOLIDATION TEST: ASTM D 3524-96							
Pressure(kpa)	200	400	800	1600	3200	800	200
TIME		Displacement					
0.25	0.291	1.659	3.063	4.485	6.28	7.179	5.65
1	0.309	1.672	3.069	4.491	6.3	7.143	5.6
2.25	0.357	1.72	3.103	4.533	6.336	7.027	5.5
4	0.405	1.762	3.139	4.593	6.376	6.9	5.42
6.25	0.444	1.801	3.172	4.651	6.431	6.8	5.32
9	0.487	1.839	3.201	4.748	6.484	6.7	5.28
12.25	0.528	1.875	3.233	4.823	6.534	6.6	5.2
16	0.569	1.911	3.267	4.877	6.577	6.513	5.12
25	0.645	1.972	3.327	4.988	6.679	6.373	5.02
36	0.707	2.025	3.389	5.108	6.805	6.24	4.88
49	0.765	2.081	3.449	5.195	6.947	6.133	4.76
64	0.827	2.127	3.513	5.281	7.046	6.06	4.68
81	0.868	2.177	3.568	5.352	7.141	6.02	4.54
100	0.915	2.227	3.645	5.421	7.276	5.98	4.48
121	0.96	2.272	3.703	5.494	7.352	5.957	4.38
225	1.127	2.447	3.916	5.687	7.549	5.89	4.2
400	1.175	2.511	4.059	5.78	7.611	5.881	4.08
1440	1.255	2.509	4.137	5.863	7.694	5.859	3.8
PT. No				2			
depth			1.5	m	sample color		grey
volume of ring			88.36	cm^3	specific gravity		2.75
height of ring			20	mm	method used for curv		Taylor
cross-sectional area of ring			44.18	cm^2	initial void ratio		0.885
diameter of ring			75	mm	initial height of sampl		20
weight of ring			143.9	g	**After test**		
density of water			1	g/cm^3	weight of dry specim		128.89
height of solid			10.6087	mm	weight of water(g)		62
Before test					final moisture content		48.1
weight of dry sample			128.89	g			
weight of water			59.7	g			
initial moisture content			46.32	%			

pressure (Kpa)	void ratio
0	0.885
200	0.767
400	0.649
800	0.495
1600	0.333
3200	0.16
800	0.333
200	0.527



e1	0.649	p1	400	cc	0.541
e2	0.16	p2	3200		
e3	0.333	p3	800	cs	0.322
e4	0.527	p4	200		

pressure (Kpa)	cumulative compression (ΔH) mm	consolidated height H = Ho - DH mm	voids ratio e= H-HS/Hs	t90 min	Cv = $(0.848*H^2)/t90$ (m^2/year)
0	0	20	0.885		
200	1.255	18.7	0.767	190.44	0.811
400	2.509	17.5	0.649	320.41	0.42
800	4.137	15.9	0.495	316.84	0.349
1600	5.863	14.1	0.333	196	0.448
3200	7.694	12.3	0.16	104.04	0.64
800	5.859	14.1	0.333	62.41	1.409
200	3.8	16.2	0.527	110.25	1.046
Average Cv					0.732

Appendix B. Linear Regression Analysis for Compression Index

Table B.1 regression analysis for equation three

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.850[a]	.722	.705	.086636
a. Predictors: (Constant), Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.313	1	.313	41.639	.000[b]
	Residual	.120	16	.008		
	Total	.433	17			
a. Dependent Variable: Compression index						
b. Predictors: (Constant), Plastic index						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.141	.041		3.458	.003
	Plastic index	.008	.001	.850	6.453	.000
a. Dependent Variable: Compression index						

Table B.2 regression analysis for equation thirteen

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	initial void ratio, Specific gravity, Liquid limit[b]	.	Enter
a. Dependent Variable: Compression index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.979[a]	.958	.948	.036220
a. Predictors: (Constant), initial void ratio, Specific gravity, Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.414	3	.138	105.260	.000[b]
	Residual	.018	14	.001		
	Total	.433	17			
a. Dependent Variable: Compression index						
b. Predictors: (Constant), initial void ratio, Specific gravity, Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.435	.426		1.020	.325
	Liquid limit	.007	.001	.956	12.776	.000
	Specific gravity	-.177	.156	-.063	-1.131	.277
	initial void ratio	.016	.027	.042	.571	.577
a. Dependent Variable: Compression index						

Table B.3 regression analysis for equation fifteen

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Liquid limit, Plastic limit[b]	.	Enter
a. Dependent Variable: Compression index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.976[a]	.953	.946	.036994
a. Predictors: (Constant), Liquid limit, Plastic limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.412	2	.206	150.560	.000[b]
	Residual	.021	15	.001		
	Total	.433	17			
a. Dependent Variable: Compression index						
b. Predictors: (Constant), Liquid limit, Plastic limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.037	.027		-1.346	.198
	Plastic limit	.000	.001	.025	.323	.751
	Liquid limit	.007	.001	.959	12.599	.000
a. Dependent Variable: Compression index						

Table B.4 regression analysis for equation sixteen

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Plastic index, Plastic limit[b]	.	Enter
a. Dependent Variable: Compression index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.976[a]	.953	.946	.036994
a. Predictors: (Constant), Plastic index, Plastic limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.412	2	.206	150.560	.000[b]
	Residual	.021	15	.001		
	Total	.433	17			
a. Dependent Variable: Compression index						
b. Predictors: (Constant), Plastic index, Plastic limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.037	.027		-1.346	.198
	Plastic limit	.007	.001	.494	8.529	.000
	Plastic index	.007	.001	.730	12.599	.000

a. Dependent Variable: Compression index

Table B.5. regression analysis for equation eighteen

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	initial void ratio, Plastic limit, Plastic index[b]	.	Enter

a. Dependent Variable: Compression index

b. All requested variables entered.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.977[a]	.954	.944	.037594

a. Predictors: (Constant), initial void ratio, Plastic limit, Plastic index

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.413	3	.138	97.367	.000[b]
	Residual	.020	14	.001		
	Total	.433	17			

a. Dependent Variable: Compression index

b. Predictors: (Constant), initial void ratio, Plastic limit, Plastic index

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.052	.035		-1.493	.158
	Plastic limit	.007	.001	.482	7.854	.000
	Plastic index	.006	.001	.697	9.369	.000
	initial void ratio	.021	.029	.056	.724	.481

a. Dependent Variable: Compression index

Table B.6. regression analysis for equation nineteen

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Specific gravity, initial void ratio, Plastic limit[b]	.	Enter

a. Dependent Variable: Compression index

b. All requested variables entered.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.825[a]	.680	.612	.099374

a. Predictors: (Constant), Specific gravity, initial void ratio, Plastic limit

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.294	3	.098	9.936	.001[b]
	Residual	.138	14	.010		
	Total	.433	17			

a. Dependent Variable: Compression index

b. Predictors: (Constant), Specific gravity, initial void ratio, Plastic limit

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.980	1.172		-.836	.417
	Plastic limit	.007	.002	.506	3.089	.008
	initial void ratio	.182	.060	.493	3.038	.009
	Specific gravity	.321	.427	.115	.753	.464

a. Dependent Variable: Compression index

Table B.7. regression analysis for equation twenty

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Plastic index, initial void ratio[b]	.	Enter
a. Dependent Variable: Compression index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.868[a]	.753	.720	.084449
a. Predictors: (Constant), Plastic index, initial void ratio				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.326	2	.163	22.831	.000[b]
	Residual	.107	15	.007		
	Total	.433	17			
a. Dependent Variable: Compression index						
b. Predictors: (Constant), Plastic index, initial void ratio						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.061	.071		.864	.401
	initial void ratio	.084	.062	.227	1.356	.195
	Plastic index	.007	.002	.705	4.215	.001
a. Dependent Variable: Compression index						

Table B.8. regression analysis for equation twenty-one

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Specific gravity, Liquid limit[b]	.	Enter
a. Dependent Variable: Compression index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.978[a]	.957	.951	.035396
a. Predictors: (Constant), Specific gravity, Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.414	2	.207	165.150	.000[b]
	Residual	.019	15	.001		
	Total	.433	17			
a. Dependent Variable: Compression index						
b. Predictors: (Constant), Specific gravity, Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.470	.412		1.142	.271
	Liquid limit	.007	.000	.984	18.143	.000
	Specific gravity	-.186	.152	-.066	-1.224	.240
a. Dependent Variable: Compression index						

Appendix C. Linear Regression Analysis for Swelling Index

Table C.1. regression analysis for equation ten

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Plastic index[b]	.	Enter
a. Dependent Variable: Swelling index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.802[a]	.643	.621	.083874
a. Predictors: (Constant), Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.203	1	.203	28.813	.000[b]
	Residual	.113	16	.007		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), Plastic index						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.030	.040		-.753	.463
	Plastic index	.006	.001	.802	5.368	.000
a. Dependent Variable: Swelling index						

Table C.2. regression analysis for equation twenty-four

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	initial void ratio, Specific gravity, Liquid limit[b]	.	Enter
a. Dependent Variable: Swelling index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.928[a]	.862	.832	.055795
a. Predictors: (Constant), initial void ratio, Specific gravity, Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.272	3	.091	29.089	.000[b]
	Residual	.044	14	.003		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), initial void ratio, Specific gravity, Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.201	.656		.306	.764
	Liquid limit	.006	.001	.929	6.880	.000
	Specific gravity	-.138	.241	-.058	-.575	.575
	initial void ratio	.002	.042	.008	.058	.955
a. Dependent Variable: Swelling index						

Table C.3. regression analysis for equation twenty-five

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Plastic index, initial void ratio, Liquid limit[b]	.	Enter
a. Dependent Variable: Swelling index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.927[a]	.859	.829	.056267
a. Predictors: (Constant), Plastic index, initial void ratio, Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.271	3	.090	28.525	.000[b]
	Residual	.044	14	.003		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), Plastic index, initial void ratio, Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.182	.052		-3.498	.004
	Liquid limit	.006	.001	.968	4.408	.001
	initial void ratio	.007	.043	.022	.162	.873
	Plastic index	-.001	.002	-.064	-.301	.767
a. Dependent Variable: Swelling index						

Table C.4. regression analysis for equation twenty-six

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Specific gravity, Liquid limit[b]	.	Enter
a. Dependent Variable: Swelling index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.928[a]	.862	.843	.053909
a. Predictors: (Constant), Specific gravity, Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.272	2	.136	46.738	.000[b]
	Residual	.044	15	.003		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), Specific gravity, Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.206	.627		.329	.747
	Liquid limit	.006	.001	.934	9.649	.000
	Specific gravity	-.140	.231	-.058	-.604	.555
a. Dependent Variable: Swelling index						

Table C.5. regression analysis for equation twenty-seven

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	initial void ratio, Plastic limit, Plastic index[b]	.	Enter
a. Dependent Variable: Swelling index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.927[a]	.859	.829	.056267
a. Predictors: (Constant), initial void ratio, Plastic limit, Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.271	3	.090	28.525	.000[b]
	Residual	.044	14	.003		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), initial void ratio, Plastic limit, Plastic index						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.182	.052		-3.498	.004
	Plastic limit	.006	.001	.474	4.408	.001
	Plastic index	.005	.001	.673	5.157	.000
	initial void ratio	.007	.043	.022	.162	.873
a. Dependent Variable: Swelling index						

Table C.6. regression analysis for equation thirty

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Liquid limit, initial void ratio[b]	.	Enter
a. Dependent Variable: Swelling index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.927[a]	.858	.840	.054535
a. Predictors: (Constant), Liquid limit, initial void ratio				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.271	2	.135	45.500	.000[b]
	Residual	.045	15	.003		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), Liquid limit, initial void ratio						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.176	.046		-3.827	.002
	initial void ratio	.005	.041	.016	.121	.905
	Liquid limit	.005	.001	.916	7.037	.000
a. Dependent Variable: Swelling index						

Table C.7. regression analysis for equation twenty-three

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Specific gravity, Plastic limit, Plastic index[b]	.	Enter
a. Dependent Variable: Swelling index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.928[a]	.862	.832	.055771
a. Predictors: (Constant), Specific gravity, Plastic limit, Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.272	3	.091	29.118	.000[b]
	Residual	.044	14	.003		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), Specific gravity, Plastic limit, Plastic index						

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.181	.681		.265	.795
	Plastic limit	.006	.001	.469	4.495	.001
	Plastic index	.006	.001	.702	6.577	.000
	Specific gravity	-.131	.249	-.055	-.526	.607
a. Dependent Variable: Swelling index						

Table C.8. regression analysis for equation thirty-four

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Plastic index, Specific gravity[b]	.	Enter
a. Dependent Variable: Swelling index			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.814[a]	.663	.618	.084213
a. Predictors: (Constant), Plastic index, Specific gravity				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.209	2	.104	14.726	.000[b]
	Residual	.106	15	.007		
	Total	.315	17			
a. Dependent Variable: Swelling index						
b. Predictors: (Constant), Plastic index, Specific gravity						

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.903	1.000		.903	.381
	Specific gravity	-.345	.369	-.144	-.934	.365
	Plastic index	.007	.001	.837	5.413	.000
a. Dependent Variable: Swelling index						

Appendix D. Linear Regression Analysis for Consolidation Coefficient

Table D.1 regression analysis for equation thirty-eight

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Liquid limit[b]	.	Enter
a. Dependent Variable: Consolidation coefficient			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.593[a]	.352	.311	1.405722
a. Predictors: (Constant), Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	17.168	1	17.168	8.688	.009[b]
	Residual	31.617	16	1.976		
	Total	48.785	17			
a. Dependent Variable: Consolidation coefficient						
b. Predictors: (Constant), Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.012	.942		5.321	.000
	Liquid limit	-.044	.015	-.593	-2.948	.009
a. Dependent Variable: Consolidation coefficient						

Table D.2. regression analysis for equation forty-two

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	initial void ratio, Specific gravity, Liquid limit, Plastic index[b]	.	Enter
a. Dependent Variable: Consolidation coefficient			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.684[a]	.468	.304	1.413537
a. Predictors: (Constant), initial void ratio, Specific gravity, Liquid limit, Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.810	4	5.702	2.854	.067[b]
	Residual	25.975	13	1.998		
	Total	48.785	17			
a. Dependent Variable: Consolidation coefficient						
b. Predictors: (Constant), initial void ratio, Specific gravity, Liquid limit, Plastic index						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	19.942	17.617		1.132	.278
	Liquid limit	-.036	.033	-.485	-1.083	.298
	Specific gravity	-5.891	6.395	-.198	-.921	.374
	Plastic index	-.029	.044	-.301	-.665	.517
	initial void ratio	1.068	1.087	.273	.982	.344
a. Dependent Variable: Consolidation coefficient						

Table D.3. regression analysis for equation forty-three

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	initial void ratio, Plastic index, Liquid limit[b]	.	Enter
a. Dependent Variable: Consolidation coefficient			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.658[a]	.433	.311	1.405880
a. Predictors: (Constant), initial void ratio, Plastic index, Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	21.114	3	7.038	3.561	.042[b]
	Residual	27.671	14	1.976		
	Total	48.785	17			
a. Dependent Variable: Consolidation coefficient						
b. Predictors: (Constant), initial void ratio, Plastic index, Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.757	1.300		2.889	.012
	Liquid limit	-.032	.033	-.426	-.966	.350
	Plastic index	-.042	.042	-.426	-.994	.337
	initial void ratio	1.223	1.068	.313	1.145	.271
a. Dependent Variable: Consolidation coefficient						

Table D.4. regression analysis for equation forty-seven

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Specific gravity, initial void ratio, Liquid limit[b]	.	Enter
a. Dependent Variable: Consolidation coefficient			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.670[a]	.449	.331	1.385117
a. Predictors: (Constant), Specific gravity, initial void ratio, Liquid limit				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	21.925	3	7.308	3.809	.035[b]
	Residual	26.860	14	1.919		
	Total	48.785	17			
a. Dependent Variable: Consolidation coefficient						
b. Predictors: (Constant), Specific gravity, initial void ratio, Liquid limit						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	23.811	16.295		1.461	.166
	Liquid limit	-.054	.020	-.721	-2.677	.018
	initial void ratio	.929	1.045	.237	.889	.389
	Specific gravity	-7.174	5.975	-.241	-1.201	.250

a. Dependent Variable: Consolidation coefficient

Table D.5. regression analysis for equation forty-nine

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Plastic index, Plastic limit, Specific gravity, initial void ratio[b]	.	Enter

a. Dependent Variable: Consolidation coefficient

b. All requested variables entered.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.684[a]	.468	.304	1.413537

a. Predictors: (Constant), Plastic index, Plastic limit, Specific gravity, initial void ratio

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.810	4	5.702	2.854	.067[b]
	Residual	25.975	13	1.998		
	Total	48.785	17			

a. Dependent Variable: Consolidation coefficient

b. Predictors: (Constant), Plastic index, Plastic limit, Specific gravity, initial void ratio

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	19.942	17.617		1.132	.278
	initial void ratio	1.068	1.087	.273	.982	.344
	Specific gravity	-5.891	6.395	-.198	-.921	.374
	Plastic limit	-.036	.033	-.238	-1.083	.298
	Plastic index	-.066	.027	-.670	-2.415	.031
a. Dependent Variable: Consolidation coefficient						

Table D.6. regression analysis for equation fifty

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Liquid limit, initial void ratio[b]	.	Enter
a. Dependent Variable: Consolidation coefficient			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.627[a]	.393	.312	1.405363
a. Predictors: (Constant), Liquid limit, initial void ratio				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19.159	2	9.580	4.850	.024[b]
	Residual	29.626	15	1.975		
	Total	48.785	17			
a. Dependent Variable: Consolidation coefficient						
b. Predictors: (Constant), Liquid limit, initial void ratio						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.295	1.182		3.634	.002
	initial void ratio	1.059	1.055	.271	1.004	.331
	Liquid limit	-.058	.020	-.773	-2.868	.012
a. Dependent Variable: Consolidation coefficient						

Table D.7. regression analysis for equation fifty-one

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	Specific gravity, initial void ratio, Plastic index[b]	.	Enter
a. Dependent Variable: Consolidation coefficient			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.648[a]	.420	.295	1.422246
a. Predictors: (Constant), Specific gravity, initial void ratio, Plastic index				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20.466	3	6.822	3.373	.049[b]
	Residual	28.319	14	2.023		
	Total	48.785	17			
a. Dependent Variable: Consolidation coefficient						
b. Predictors: (Constant), Specific gravity, initial void ratio, Plastic index						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	16.632	17.457		.953	.357
	initial void ratio	.771	1.058	.197	.729	.478
	Plastic index	-.067	.027	-.688	-2.465	.027
	Specific gravity	-4.898	6.367	-.165	-.769	.455
a. Dependent Variable: Consolidation coefficient						

Appendix E: During Conducting Laboratory Test

Wet sieve test

compaction test

Dry sieve test

liquid limit test

Hydrometers test

One-dimensional consolidation test