Jimma University

Jimma Institute of Technology

School of Graduate Studies

Faculty of Civil and Environmental Engineering

Geotechnical Engineering Chair

Developing correlation between undrained shear strength and index properties of cohesive soils found in Waliso Town

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

By

Iftiyom Kebebe Negasa

August, 2021

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Main Advisor: Dr. -Ing. Fekadu Fufa (PhD)

Co-Advisor: Mr. Habte Tamirat (MSc.)

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Declaration

I, the undersigned, declare that this thesis entitled: "Developing correlation between undrained shear strength and index properties of cohesive soils found in Waliso Town" is my original work, and has not been presented by any other person for an award of a degree in any University. All sources of material used for this thesis have to be duly acknowledged.

Candidate:

Iftiyom Kebebe

__________________ _______________

Signature Date

APPROVAL SHEET

As Master research Advisors, we hereby certify that we have read and evaluated this MSc research prepared under our guidance, by Iftiyom Kebebe entitled: "Developing correlation between undrained shear strength and index properties of cohesive soils found in Waliso Town". We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

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As a member of the Board of Examiners of the MSc Thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Iftiyom Kebebe and examined the candidate. We recommended that the thesis could be accepted as fulfilling the thesis requirement for the degree of Master of Science in Geotechnical Engineering.

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Chair Person Signature Date

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Abstract

In developing countries including Ethiopia, infrastructures are currently constructing in fast rate. Accurate determination of the soil shear strength parameters is a major concern in the design of these different geotechnical structures. However, experimental determination of the strength parameters is extensive, cumbersome and costly. And also, the laboratory equipment's and field instruments are not available in all areas to get these parameters. In order to cope with such problems, developing correlation is a crucial one to get shear strength parameters.

Therefore, this study was conducted to develop correlation between undrained shear strength and Index properties of cohesive soils found in Waliso Town. Index properties and undrained shear strength behavior of these soils was studied by conducting laboratory tests.

For this study, undisturbed and disturbed soil samples from twenty test pits at 3m depths were taken. And also, ten secondary data was used. Totally, thirty soil samples were used. For test procedures American Society for Testing & Material (ASTM) standards was used. For analysis and developing correlation Microsoft Excel (MS-Excel) and Computer program aided Software (SPSS 20) were used. Combining selected variables, single linear regression and multiple linear regression models were developed for the prediction of undrained shear strength parameter.

The study shows that undrained shear strength parameter (Cu) was significantly correlated with plastic limit(PL), liquid limit(LL),bulk density(γb), dry density(γd) and natural moisture content (NMC) whereas it was not significantly correlated with plasticity index (PI), specific gravity(Gs) and liquidity index (LI) of study area soil.

From the study, the best Model is obtained from multiple linear regression (MLR) analysis and given by: $Cu = 90.939*\gamma d - 0.804*LL - 1.311*PL + 37.044$; *coefficient of determination* (R^2) = 0.843, *Adj.* R^2 = 0.825 *and P value* =0.00 < 0.05. *Using the developed model, undrained shear strength parameter can be computed as well as it is expected to have wide application in the construction to minimize the cost, effort, and time for laboratory tests of undrained shear strength of the study area.*

Key words: *Correlation, Index Properties, undrained shear strength, Regression*

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List of Abbreviations

AASHTO	American Association of State of Highway & Transportation Officials
ASTM	American Society for Testing & Material
C	Cohesion
Cu	Undrained shear strength
LI	Liquidity index
LL	Liquid Limit
PI	Plasticity Index
PL	Plastic Limit
q_u	Unconfined Compression strength
SL	Shrinkage Limit
SPSS	Statistical Package for Social Science
TSA	Total Stress Analysis
UC	Unconfined Compression
UCS	Unconfined Compression strength
UU	Unconsolidated Undrained
USCS	Unified soil classification system
w	Moisture content
ϕ	friction angle
σ_1	Major principal stress
σ_3	Minor principal stress

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

In the field of civil engineering, nearly all projects are built on or into the ground. Thus, during the planning, design and constructions of these projects' engineers must give great attention. For all structures geotechnical engineers must study the properties of soils and identify the soil types. Shear strength of soil is an important part of geotechnical engineering because of the role it plays in the evaluation of bearing capacity of foundations for residential and commercial facilities, the evaluation of stability of the slope for highway embankments, earth dams, artificial canals, excavations and the design of earth retaining structures like retaining walls, sheet piles and coffer dams. Problematic soils such as expansive soils have a lot of impacts on these structures.

Expansive soils are clayey minerals which exhibit significant volume change when subjected to moisture variations. Expansive soils swell if its moisture content increases and shrinks when its moisture content decreases. Ethiopia is one of the countries in Africa in which expansive soils have been reported [1].

In developing countries including Ethiopia, infrastructures are currently constructing in fast rate. For these conditions, studying geotechnical engineering properties of soil are fundamental for design purposes. As we know Ethiopia is one of the poorest countries in the world. Due to this laboratory equipment and field instruments can't be available in all areas of the country. For this reason, getting engineering properties of soils are difficult. Waliso is one of the developing towns in which a few soil tests were done before. In other way, infrastructure constructions are undertaking quickly in this town. Conducting all soil tests for these structures are essential to get all properties. But, According to Jain Rajeev et al [2] Under variable constituent composition, determination of these parameters in the laboratory becomes laborious and time-consuming task. So, it is necessary to find simpler and faster methods of obtaining these engineering properties.

Developing correlation in geotechnical engineering has been used in order to correlate different engineering properties of soils. This indicates that the importance of developing correlation for prediction in geotechnical practice is much crucial. Geotechnical activities are either made of soil or resting on natural soil, involving large quantities of soil. Consequently, it is often necessary for the geotechnical engineer to quickly characterize the soil. And also, determine their engineering properties to assess the suitability of the soil for any engineering practices. One of most important engineering properties of soil is its ability to resist sliding along internal surfaces. The stability of structures built on soil depends on the shearing resistance [2].

According to Zumrawi et al [3] it is quite important that an engineer has to ensure that:

- ✓ The structure is safe against shear failure in the soil that supports it.
- ✓ Does not undergo excessive settlement.

Shear strength of soil is characterized by cohesion (c) and friction angle (ϕ). The two parameters mentioned primarily, define the soil maximum ability to resist shear stress under defined load [4]. These Soil properties such as cohesion and angle of internal friction of soil are necessary for [5]:

- ➢ Estimating the load bearing capacity of the soil.
- ➢ The stability of geotechnical structures.
- ➢ In analyzing stress and strain characteristics of soils.

Undrained shear strength is a very important parameter in engineering. Undrained shear strength is a parameter to the bearing capacity of soil that could stand on it. Some laboratory tests needed to obtain these parameters are expensive and time-consuming. While other soil properties like index properties can be performed quicker and cheaper.

The undrained shear strength is used to [5]:

- ✓ Estimate the short-term bearing capacity of fine-grained soils for foundations.
- ✓ Estimate the short-term stability of slopes.
- ✓ Compare the shear strength of soils from a site.
- ✓ Establish soil strength variability quickly and cost-effectively.
- ✓ Determine the stress-strain characteristics under fast (undrained) loading conditions

In this study, undrained shear strength was obtained by correlating with index properties of cohesive soils. This minimize effort, cost and time for any geotechnical practice in analyzing and designing conditions of study area.

1.2. Statement of the problem

The difficulty lies in the evaluation of the shear strength, and more complex situations occur when the soil state is unsaturated. Some soils exhibit a relatively higher strength at the time of construction; however, their strength generally decreases with time. According to this guy a lot of infrastructures fails in Canada due to shear strength failure of the soils. [6].

According to [1] most parts of Ethiopia is covered by expansive soils which is problematic soils causes infrastructures failures. This problematic soils leads shear strength failure of soils which causes infrastructures failure in our country. So that, these needs detail geotechnical investigation of the sub-surface condition of the soils which gives paramount importance for safe and economical design and construction activities to determine the geotechnical problems. Experimental determination of strength parameters used for design purposes are difficult to carry out and expensive in cost. And also, there is limitation of equipment's to determine strength parameters. To solve this problem developing correlation is an important method to predict engineering properties of soils.

The geotechnical properties of soils on which a superstructure is to be constructed must be well understood in order to avoid superstructure and foundation failures. One of the most important engineering properties of soil is its ability to resist sliding along internal surfaces within a mass. The stability of structures built on soil depends upon the shearing resistance offered by the soil along probable surfaces of slippage. [7].

Accurate determination of the soil shear strength parameters is a major concern in the design of different geotechnical structures. The key parameters can be determined either in the field or in the laboratory. However, experimental determination of the strength parameters is extensive, cumbersome and costly. Further, it is not always possible to conduct the tests on every new situation. In order to cope with such problems, numerical solutions have been developed to estimate shear strength parameters [8].

1.3 Research questions

The result of this study is addressed by the following questions:

1. What is the undrained shear strength and index properties of cohesive soils found in Waliso town?
2. What is the appropriate empirical correlation between undrained shear strength and index properties of cohesive soils found in study area?
3. Is the develop correlation between undrained shear strength and index properties valid when compared to others?

1.4 Objectives of the Study

1.4.1 General Objective of the study

The general objective of the study is to develop correlation between undrained shear strength and index properties of cohesive soils found in Waliso town.

1.4.2 Specific Objective of the study

The specific objectives of the study are:

- To determine the undrained shear strength and index properties of cohesive soils found in Waliso town.
- To develop an appropriate empirical correlation between undrained shear strength and index properties of cohesive soils found in study area.
- To examine the validity of the developed correlations between undrained shear strength and index properties by comparing with others.

1.5 Scope and Limitation of the Study

This research work was done on cohesive soil found in Waliso town and focused on developing correlation between undrained shear strength and index properties of cohesive soil found in this study area.

In order to address the aforementioned objectives, different test pits were dig out in the town. The samples were collected from few test pits at limited depth in the town. From each test pit for undrained shear strength and Index property tests both undisturbed and disturbed samples were taken. Index properties and undrained shear strength behavior of these soils were studied and different laboratory tests were conducted according to ASTM soil testing standard procedures. Then correlation was developed between undrained shear strength and index properties of cohesive soils found in Waliso town.

Based on the trends of the scatter plot of test results the correlation was analyzed using a linear regression model. The proposed correlation was carried out by applying a single linear regression model and multiple linear regression models with the aid of Microsoft Excel and SPSS Software. The scope of the developed correlation, discussions and result obtained are limited to the test procedures followed, the range and quantity of sample used, apparatus used, sampling areas and methods of analysis used in the subject study.

Therefore, the findings should be considered as indicative rather than definitive for the whole study area.

1.6 Significance of the Study

These correlations are very important to estimate engineering property of soils, especially for preliminary investigation of projects.

The result of this study helps to minimize effort, cost and time for future laboratory tests of soils. The outcomes also useful for obtaining undrained shear strength and index properties of study area. In addition, it can be used for consultants, contractors and municipality of the study area. They can use for analyze and design of all structures simply without consuming of time and cost. And also, it can be used as references for the next researchers.

1.7 Organization of the Thesis

The thesis is structured into five main chapters, along with appendix incorporated at the end of the thesis. The introduction chapter highlights the background, statement of the problem, the objectives, Research question, Scope & Limitation and Significance of the Study. Chapter two deals with the review of different books and published literature related to the study issue. Chapter three stated materials and methods used for the study. This chapter also shows location and topography of the study area. In Chapter four, results of laboratory, statistical modeling, and discussion of results were presented. Under Chapter five, the conclusion and recommendation were presented. Lastly, details of the laboratory test results and regression analysis were presented under the appendix section.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

Soils are natural resources. They are necessary for our existence. They provide food, shelter, construction materials, and gems. They protect the environment and provide support for our buildings [5]. This shows that the soils have their own strengths which can withstand external actions. Strength of soils varies from soil to soil, place to place and condition to condition.

Soil strength is the resistance to mass deformation [9]. According to this guy, mass deformation developed from a combination of particle rolling, sliding, and crushing. This is reduced by any pore pressure that exists or develops during particle movement.

The shear strength is measured in terms of two soil parameters, cohesion and angle of internal friction [9]. Cohesion(c) is inter-particle attraction of a soil. Angle of internal friction (ϕ) is the resistance to inter particle slip a soil.

2.2 Shear Strength of Soils

Shear strength may be defined as the resistance to shearing stresses and consequent tendency for shear deformation. Shear strength of soils is an important parameter for in many foundation engineering problems. Like in bearing capacity of shallow foundations and piles, lateral earth pressure on retaining walls. And also, the stability of the slopes of dams and embankments [10].

Basically, a soil derives its shearing strength from Resistance due to the interlocking of particles. Frictional resistance between individual soil grain due to sliding or rolling friction and Cohesion between soil particles. Granular soils of sands may derive their strength from the first two sources. While cohesive soils may derive their shear strength from the second and third source. Highly plastic clays, however, may exhibit the third source alone for their shearing strength [9].

Shear strength of soil is used to describe the magnitude of shear stress that the soil resists. Shear resistance of soil is depending on friction and interlocking of particles, and possibly bonding [11].

2.2.1 Shear Strength of Cohesive Soil

A characteristic of true clay is the property of cohesion, sometimes referred to as no load shear strength. Unconfined specimens of clay soil derive strength and firmness from cohesion. The shear strength of saturated cohesive soil in undrained shear test is derived entirely from cohesion. It is well known that the shear strength of cohesive clay varies with its consistency. Clay which is at liquid limit has very little shear strength. Whereas, the same clay at lower moisture content may have considerable shear strength [12].

2.3 Undrained shear strength

The undrained shear strengths are the sole strength parameter of an undrained soil [13]. According to these guys the undrained shear strength is dependent of the shearing stresses.

The most critical foundation design scenario presented by saturated, slow-draining soils such as clays and silts. This involve undrained conditions prevailing immediately after the foundation is constructed. Therefore, the undrained shear strength is typically used to design foundations on clay or silt soils [14].

Undrained shear strength is used to estimate short-term bearing capacity of fine-grained soils for foundations. And also estimate the short-term stability of slopes. Short-term condition in fine-grained soils need a total stress analysis (TSA). And also, the shear strength parameter is the undrained shear strength (S_u) [5].

2.3.1 Predicting Undrained Shear Strength

We can use the consistency of clay soil to identify its physical property. One may predict undrained shear strength of clay soils in the field simply by using one's finger. Table 2.1 shows general relationship of consistency and Unconfined Compression Strength (UCS) of clays [9].

Table 2.1: General Relationship of Consistency and UCS of Clays [9].

Consistency	qu(KN/m^2)	Remark
Very Soft	0-25	Squishes between finger when squeezed
Soft	25-50	Very easily deformed by squeezing
Medium Stiff (firm)	50-100	Thumb makes impression to deform
Stiff	100-200	Hard to deform by hand squeezing
Very Stiff	200-400	Very hard to deform by hand
Hard	>400	Nearly impossible to deform by hand

2.4. Test methods of Undrained Shear Strength

The test Shear Strength of Soil is an undrained test. This is based on the assumption that there is no moisture loss during the test [15].

2.4.1. Laboratory methods

Laboratory tests are used to determine any required geotechnical properties of soils. Therefore, learning to perform laboratory tests of soils plays an important role in the Geotechnical engineering profession [16]. There are different laboratory test methods of undrained shear strength.

i) Unconfined Compression (UC) Test

Unconfined compression test provides a quick and simple means to measure the unconfined compressive strength (qu). And also measure undrained shear strength (su) of cylindrical specimens of cohesive soil. With respect to shear strength, cohesive soil can fail under conditions of rapid loading. This happen where excess pore pressures do not have time to dissipate. Under these conditions, the state of stress in an element of soil can be illustrated. This is in terms of a Mohr circle, with minor and major total principal stresses [17].

An unconfined compression test can be used to determine the cu values based on the measured qu. since this test can be visualized as an undrained Triaxial test with no confining pressure (hence unconsolidated) [5].

The unconfined compression test is a special type of unconsolidated-undrained test. This is commonly used for clay specimens. In this test, the confining pressure σ_3 is 0. An axial load is rapidly applied to the specimen to cause failure. At failure, the total minor principal stress is zero and the total major principal stress is σ_1. Because of the undrained shear strength is independent of the confining pressure, we have [15].

$$\tau_f = \frac{\sigma_1}{2} = \frac{qu}{2} = cu \quad \text{...} \ 2.1$$

Where q_u is the unconfined compression strength.

Cu is the undrained shear strength.

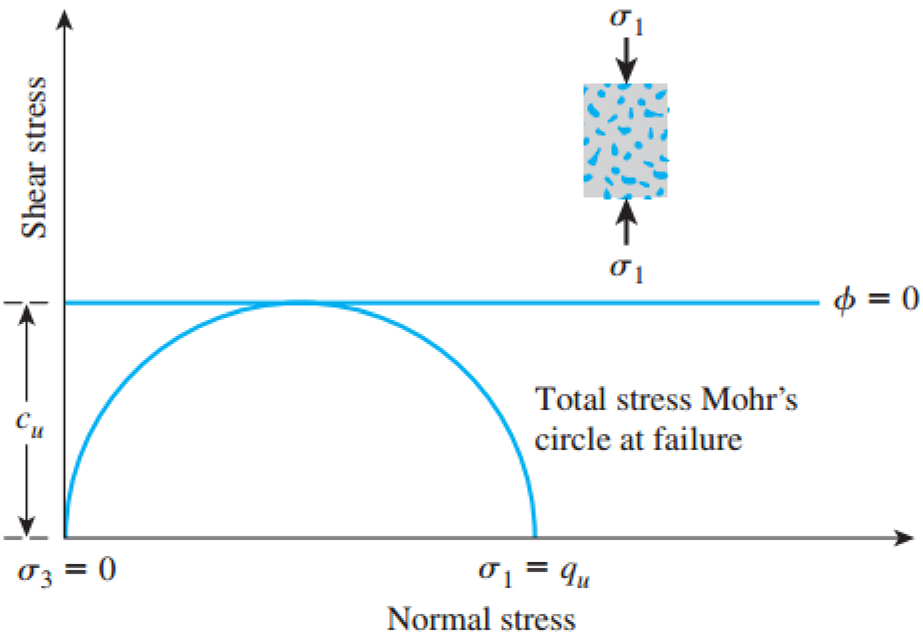


Figure 2-1: Unconfined compression test [15].

The unconfined compression test is a special case of a triaxial compression test. The tests are carried out only on saturated samples which can stand without any lateral support. The test, is, therefore, applicable to cohesive soils only [15].

In this test the sample is a cylinder with a diameter d and a height h. a height equal to about 2 times the diameter. The ratio h/d is about 2 to ensure that the oblique shear plane that typically develops. During failure it can propagate through the entire sample without intersecting the top or bottom platen. The sample remains unconfined during the test; therefore, the minor principal stress σ_3 is zero. A vertical load is applied to the sample. This is done by pushing upon the bottom platen at a constant rate of displacement. While holding the top platen in a fixed position [18].

The vertical total stress σ is calculated by dividing vertical load by cross-sectional area of sample. Unconfined compression test gives both undrained shear strength and modulus of deformation for fine-grained soils. Axial stress on the specimen is gradually increased until the specimen fails. The sample fails either by shearing on an inclined plane or by bulging. Vertical stress at any stage of loading is obtained by dividing total vertical load by cross-sectional area. The cross-sectional area of the sample increases with the increase in compression [15].

The cross-sectional area A at any stage of loading of the sample may be computed. This is based on the basic assumption that the total volume of the sample remains the same.

That is

$$Aoho = Ah \quad \text{……} \quad 2.2$$

Where Ao, ho is equal to initial cross-sectional area and height of sample respectively.

And also, A, h is equal to cross-sectional area and height respectively at any stage of loading.

If Δh is the compression of the sample, the strain ε

$$\varepsilon = \frac{\Delta h}{h} \quad \text{……} \quad 2.3$$

Since Δh = ho-h or h = ho-Δh, we may write Aoho= A (ho- Δh) Therefore,

$$A = \frac{Aoho}{\mathrm{ho}-\Delta \mathrm{h}} = \frac{\mathrm{Ao}}{1-\frac{\Delta \mathrm{h}}{\mathrm{ho}}} = \frac{Ao}{1-\varepsilon} \quad \text{……} \quad 2.4$$

The average vertical stress at any stage of loading may be written as:

$$\sigma_1 = \frac{P}{A} = \frac{P(1-\varepsilon)}{\mathrm{A}} \quad \text{……} \quad 2.5$$

Where P is the vertical load at the strain ε. using the relationship given by Eq. (2.5) stress strain curves may be plotted. The peak value is taken as the unconfined compressive strength q_u, [11].

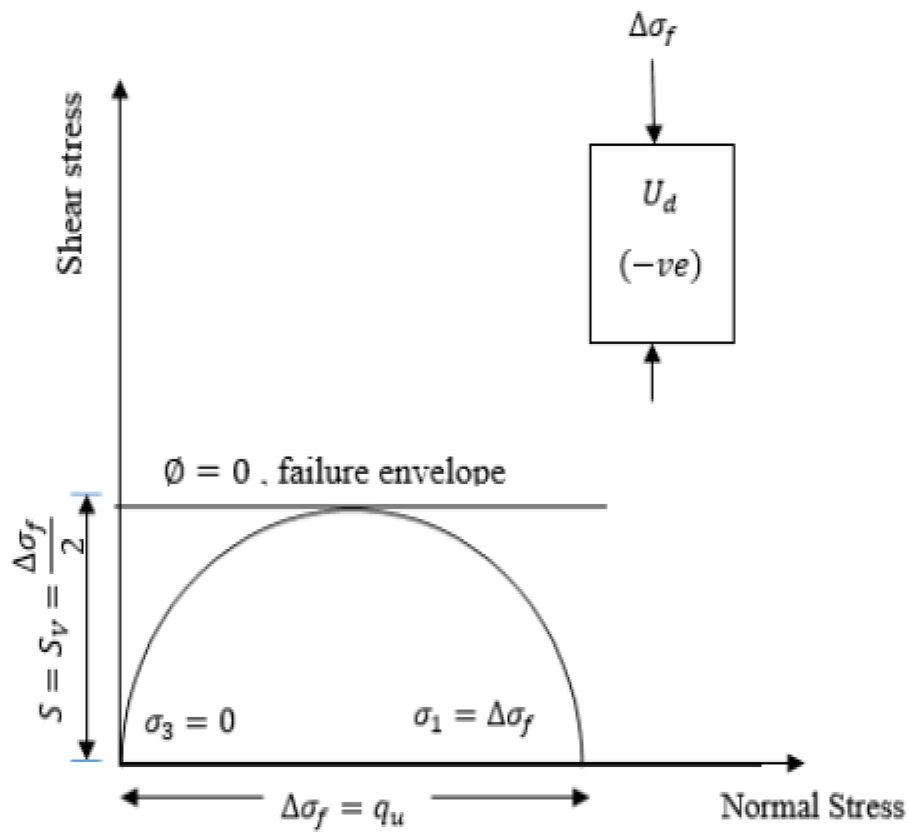


Figure 2-2: Mohr -Circle on Undrained Condition [15].

The unconfined compression test (UC) is a special case of the unconsolidated-undrained (UU) triaxial compression test [15]. According to [15]. The only difference between the UC test and UU test is that:

- ✓ A total confining pressure under which no drainage was permitted was applied in the UU test.
- ✓ Absence of any confining pressure in the UC test.
- ✓ A premature failure through a weak zone may terminate an unconfined compression test.

ii) Unconsolidated-Undrained (UU) Triaxial Compression Test

In this, no drainage is permitted during application of lateral loads to soil sample during shearing operation. Since no pore water can escape, pore water pressure is set up, which may be measured [19]. The Unconsolidated Undrained (UU) Triaxial strength test provides a means to measure the undrained shear strength (su). This su is su of over-consolidated cylindrical specimens of cohesive soil. This information is utilized to estimate bearing capacity of structures when placed on deposits of cohesive soil [17].

2.4.2. In situ Methods

Vane shear tests

From experience, it has been found that vane test can be used as a reliable in-situ test. For determining the shear strength of soft-sensitive clays it can be used.

It has been determined that vane gives results similar to unconfined compression tests on undisturbed samples [20].

The vane should be regarded as a method to be used under the following conditions:

1. The clay is normally consolidated and sensitive.
2. Only the undrained shear strength is required.

2.5 Index Properties

Index properties are basic for distinguishing soils. Index properties may be divided into two mains categories. Namely, soil grain properties and soil aggregate properties. The soil grain properties are properties of individual grains as expressed by size, shape, and mineralogical characteristics. The soil aggregate properties are the properties of the soil mass as a whole. The most significant aggregate property of cohesion less soils is the relative density. Whereas, that of cohesive soils is the consistency [12].

The various properties of soils, which would be considered as index properties, are [5]:

1. The size and shape of particles.
2. The relative density or consistency of soil.

Index properties are like moisture content, liquid limit, bulk density and particle size distribution. These are easier and quicker to determine [21].

Index tests are the most basic types of laboratory tests performed on soil samples. Index tests include the water content (also known as moisture content), specific gravity tests, and unit weight determinations. And also, particle size distributions and Atterberg limits, which are used to classify the soil [22]. Let us see index properties one by one.

2.5.1 Moisture content

Moisture content is ratio of weight of water in given soil mass to weight of solid particles [23]. Natural water content used to express the consistency of clay soil in its natural state. Consistency is a term used to indicate the degree of firmness of cohesive soils. The moisture content test was carried out in laboratory as per the processes of ASTM D 2216.

2.5.2 Specific gravity

It is ratio of mass in air of given volume of soil to mass in air of an equal volume of distilled water at stated temperature [24]. The Specific gravity test was carried out in laboratory as per the procedures of ASTM D 854-58.

2.5.3 Grain Size Determination

Soil consists mostly different sized soil particles as a major constituent ingredient. The determination of the fractions of the particles will help [24]:

- ✓ To identify the soil type.
- ✓ to estimate many other engineering properties such as strength and permeability and
- ✓ To identify whether the soil is suitable for construction projects.

Two methods are mostly used to determine grain size distribution are Sieve analysis and Hydrometer analysis. Sieve analysis are used for a coarse-grained portion of the soil (size coarser than 0.075mm). Hydrometer analysis are also used for fine grained portions (size finer than 0.075mm). ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils carried out.

2.5.4 Atterberg Limit

The Swedish soil scientist Albert Atterberg originally defined seven “limits of consistency” to classify fine-grained soils. But in current engineering practice only two of limits, the liquid and plastic limits, are commonly used [25]. A third limit, called the shrinkage limit, is used occasionally.

The volume change and flow behaviour of a fine-grained soil both depend upon its moisture content. At a high level of moisture, the soil has the properties of a liquid. While at a low moisture content, it takes on the properties of a solid. At moisture contents between these two states, the soil passes from plastic state to semi-solid state. This happen when the moisture content decreases. The physical condition of the soil-water mixture is denoted as its consistency.

The boundaries of these states, expressed in terms of moisture content, are termed the Atterberg limits [26]. Wide varieties of soil engineering properties have been correlated to the liquid and plastic limits. These Atterberg limits are used to classify a fine-grained soil according to the USCS or AASHTO system. The Atterberg limits are based on the moisture content of the soil [24]. Atterberg Limits were carried out in accordance of test procedures of ASTM D 4318 Standard Test Method. Liquid Limit (LL), Plastic Limit (PL) and shrinkage limit (SL) of Soils are defined as follow according to [26]:

Liquid Limit: is the moisture content above which the soil-water mixture passes to a liquid state.

At this stage, the mixture behaves like a viscous fluid and flows under its own weight. Below this moisture content, the mixture is in a plastic state. Any change in moisture content on either side of the LL produces a change in the volume of soil.

Plastic Limit: is the moisture content above which the soil-water mixture passes to a plastic state. At this stage, the mixture is deformed to any shape under minor pressure. Below this moisture content, the mixture is in a semi-solid state. Any change in moisture content at either side of PL produces a change in volume of soil.

Shrinkage Limit: is the moisture content above which the mixture of soil and water passes to a semi-solid state. Using limit, the following indices are defined and used in the classification and description of fine grained-soils:

Plasticity Index $PI = LL - PL$ …………………………………………………...2.6

Liquidity Index $LI = \frac{w-PL}{PI}$ ……………………………………………………… 2.7

Where W = moisture content in the field

Atterberg limits are used extensively in the classification of fine-grained soils.

Table 2.2: Description of the Strength of Fine-Grained Soils Based on Liquidity Index [5].

Values of LI	Description of soil strength
LI < 0	Semisolid state—high strength, brittle, (sudden) fracture is expected
0 < LI < 1	Plastic state—intermediate strength, soil deforms like a plastic material
LI > 1	Liquid state—low strength, soil deforms like a viscous fluid

Table 2.3: Typical Atterberg Limits for Soils [5].

Soil type	LL (%)	PL (%)	PI (%)
Sand	Non plastic		
Silt	30-40	20-25	10-15
Clay	40-150	25-50	15-100
Minerals			
Kaolinite	50-60	30-40	10-25
Illite	95-120	50-60	50-70
Montmorillonite	290-710	50-100	200-660

2.5.5 Bulk and dry density

Bulk density is ratio of weight of soil to total volume of soil, including water and air. Whereas, dry density is the ratio of the dry solids to the total volume [27].

2.6. Classification of the Soils

The behaviour of a soil mass under load depends upon many factors. These factors are properties of various constituents present in the mass, the density, the degree of saturation. Environmental conditions are another factor since the behaviour of soils varies with conditions. Soils are grouped based on certain definite principles and rated according to their performance and the properties. A given soil can be understood to a certain extent, based on some simple tests.

Many systems are in use that is based on grain size distribution and limits of soil. Systems that are quite popular amongst engineers are AASHTO Soil Classification System and Unified Soil Classification System.

American Association of State Highway and Transportation Official classification system is useful for classifying soils for highways [28].

The Unified Soil Classification System (USCS) is now almost universally accepted. USCS has been adopted by the American Society for Testing and Materials (ASTM). The USCS was published in 1953. It has since been adopted by ASTM as the standard classification of soils for engineering purposes. Success of USCS is indicated by its routine use worldwide and its acceptance for international geotechnical communication [24].

USCS is the most popular system for use in all types of engineering problems involving soils and shall be used when precise soil classification is required [28].

2.6.1 AASHTO Soil Classification System

The AASHTO soil classification system is used to determine the suitability of soils. This is for earth works, embankments, and road bed materials. According to AASHTO, granular soils are soils in which 35% or less are finer than the No. 200 sieve. And Silt-clay soils are soils in which more than 35% are finer than the No. 200 sieve [5].

Table 2.4: Soil Types, Average Grain Size, and Description According to AASHTO [5].

Gravel	75 mm to 2 mm (No. 10 sieve)
Sand	2 mm (No. 10 sieve) to 0.075 mm (No. 200 sieve
Silt & Clay	<0.075 mm (No. 200 sieve) Silty: PI <10% Clayey: PI <11 %

The AASHTO system classifies soils into seven major groups, A-1 through A-7. The first three groups, A-1 through A-3. These are granular (coarse-grained) soils. While the last four groups, A-4 through A-7. These are silt-clay (fine-grained) soils.

Silt and clay soils are located within the plasticity chart, as shown in Figure 2.3.

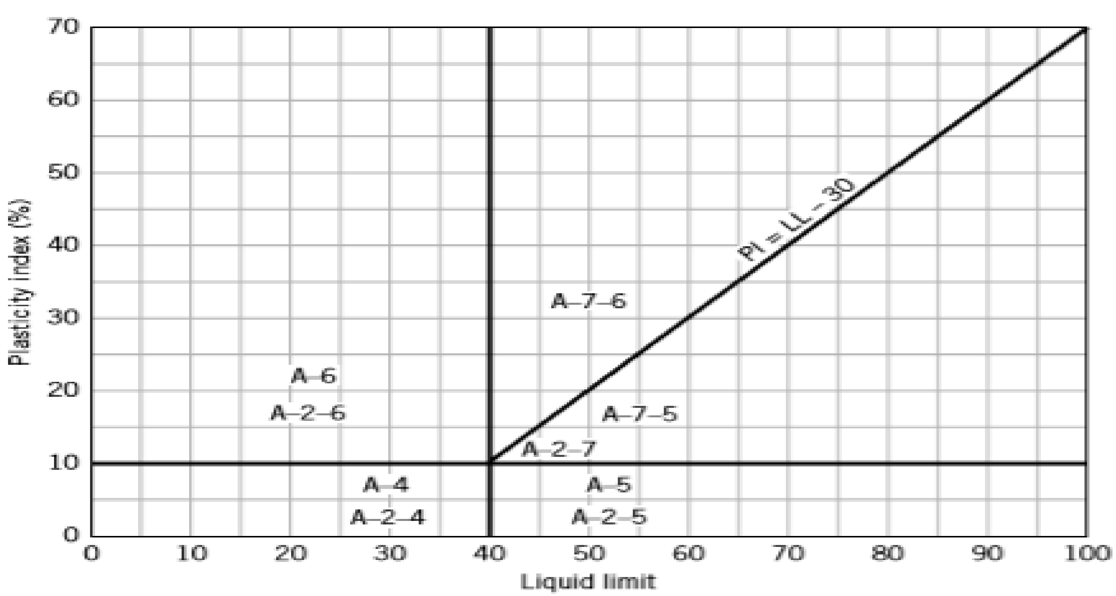


Figure 2-3: AASHTO classification of silt and clay within the plasticity chart [5].

2.6.2 Unified Soil Classification System (USCS)

USCS was originally developed for use in airfield construction but was later modified for general use. The USCS is neither too elaborate nor too simplistic. The USCS uses symbols for the particle size groups. These symbols and their representations are G-gravel, S-sand, M-silt, and C-clay. These are combined with other symbols expressing gradation characteristics. W- For well graded and P- for poorly graded and plasticity characteristics, H- for high and L- for low. And also, a symbol O - indicating the presence of organic material. A typical classification of CL means a clay soil with low plasticity. While SP means a poorly graded sand [5].

Table 2.5: The USCS symbols to represent the soil types and the index properties [9].

Symbol	Soil type	Symbol	Index property
G	Gravel	W	Well-graded(for grain size distribution)
S	Sand	P	Poorly-graded (for grain size distribution)
M	Silt	L	Low to medium Plasticity
C	Clay	H	Highly Plasticity
O	Organic silts & Clays		
Pt	Highly organic soil and Peat		

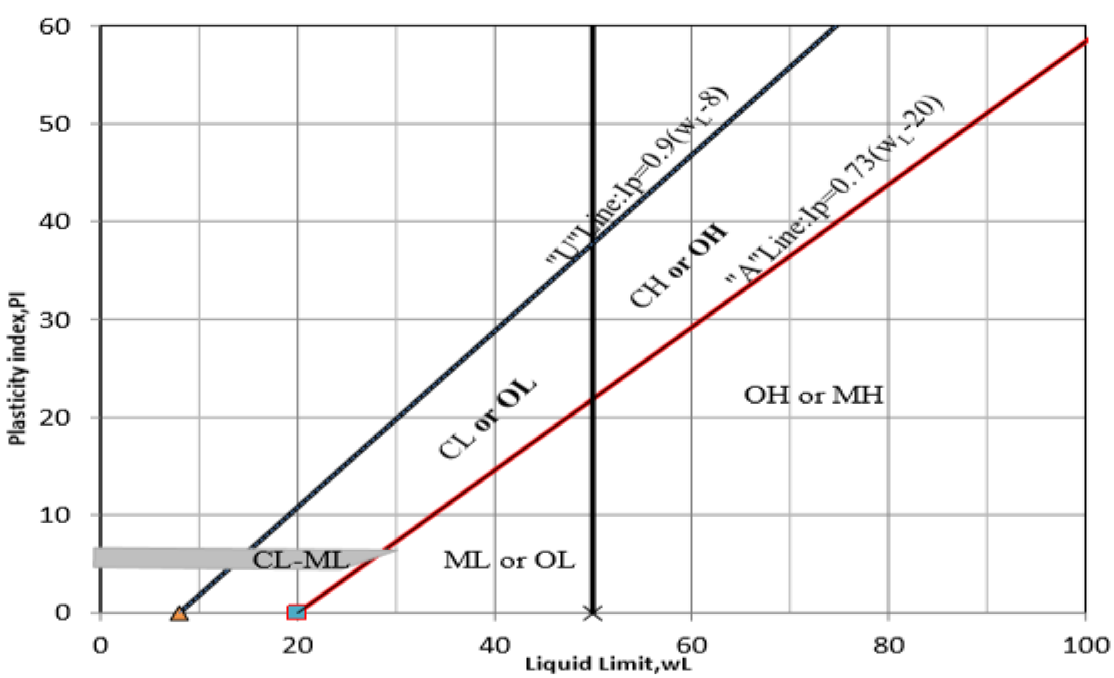


Figure 2-4: Plasticity chart for group symbols of fine-grained soils [9].

2.6.3 American Society for Testing and Materials (ASTM) Classification System

The American Society for Testing and Materials classification system (ASTM-CS) is nearly identical to the USCS. ASTM-CS uses the same symbols as USCS but provides a better scheme for mixed soils. i.e. soils consisting of mixtures of, for example, sand, gravel, and clay. Soils are classified by group symbols and group names. For example, we can have a soil with a group symbol, SW-SM. and also a group name, which describes the soil, as “well-graded sand with silt”. This is if the gravel content is less than 15% [5].

2. 7 Correlations of Undrained Shear Strength (Cu) with Index Properties of soils

Correlations are very important to estimate engineering properties of soils, especially for preliminary investigation of projects. Correlations also used for projects where there is financial limitation, lack of test equipment and limited time. Several investigators attempted to develop correlations for prediction of undrained shear strength. They look in terms of either compositional factors or environmental factors or combination of both. Many relationships have been established from which undrained shear strength can be estimated based on index test.

2. 7.1 Undrained Shear Strength of Cohesive Soils with Moisture content

The variation of shear strength of soil between consistencies limits corresponding fitting equation helps in estimating strength [29].

According to these guys this strength is strength at any corresponding water content. They developed correlations of undrained shear strength with consistency limits as follows:

For red soils, $Su = 378.11 exp^{-0.106w}$ …………………………………………… 2.8

For black soil, $Su = 559.89\ exp^{-0.079w}$ ……………………………………………2.9

The proposed model between water content and undrained shear strength, of the soft clay soil by Rahem et al. [30].

$$Su = -6.0 \times ln(w\%) + 15 \quad \text{…… 2.10}$$

2.7.2 Undrained Shear Strength with Atterberg limits Relationship

The measured values for liquid and plastic limits of soils have been widely used as index parameters. They are utilized to compute plasticity index, which can be empirically correlated against many soil properties.

Undrained Shear Strength from Liquid Limit and Plastic Limit by using multiple regression was modelled by Jacob [31].

$$\mathrm{Cu} = 41.805 - 0.165\mathrm{LL} - 0.325\mathrm{PL} \quad \text{…… 2.11}$$

Regression technique was constructed by plotting liquidity index against logarithm of Cu for the entire data set. The resulting regression equation was developed by Vardanega et al. [32]:

$$Cu = exp^{35\,(1-IL)}\ kPa \quad \ldots\ldots 2.12$$

A simple regression analysis revealed that the undrained shear strength (in kPa) obtained. And it could be related to the liquidity index as modelled by Kayabali et al. [33]:

$$Su = 84 \cdot 8\ (0.02044^{LI}) \quad \ldots\ldots 2.13$$

The relationship between undrained shear strength and liquidity index developed by Mengistu [34].

$$\mathrm{Cu} = 114.396 - 1.135\mathrm{LI} \quad \ldots\ldots 2.14$$

The other model developed between undrained shear strength and other parameters by Yohannes [35]

$$Su = 291.541 + 1.949w - 2.687LL + 0.431PI - 178.302LI - 2.405OMC \ldots 2.15$$

CHAPTER THREE
MATERIALS AND METHODS

3.1 Description of the study area

Waliso is one of a town in Oromiya national regional state located in south west Oromiya and gots its name from the middle son of Liban which is one of major clans of Oromo. Waliso town is a zonal town of South west Showa and ruled by its own Mayor.Waliso town have four Ganda (Kebele). Those are: Ganda Ayetu, Ganda Ejersa, Ganda Burqa Guddina and Ganda Hora.

The geographical location of Waliso town is approximately between $8^0$31'30" N – $8^0$33'30" N latitude and $37^0$57'30" E – $37^0$59'30" E longitude. It is located at a distance of 114 km in the south west direction from Finfinne. Waliso is located on Jimma to Finfinne road at about 232 km from Jimma. The altitude of Waliso is approximately about 1900m to 2000m above mean sea level.

Table 3.1: Test Pit Location of Study Area

Test pit number	Location of Test Pit	Northing	Easting
TP1	Ejersa, Garasu Dhuki High School	8.52823	37.96435
TP2	Ejersa, Waliso Health Center	8.53911	37.97149
TP3	Ayetu, inside Compound of kebele	8.53992	37.97554
TP4	Ayetu, around Stadium	8.53774	37.97675
TP5	Hora, Waliso Liban primary School	8.53698	37.97526
TP6	Hora, Waliso water Supply	8.53421	37.97739
TP7	Hora, Waliso KG School	8.53491	37.97506
TP8	Burqa, Guddina Inside Compound of kebele	8.53697	37.97167
TP9	Burqa Guddina, Burqa Guddina Primary School	8.52892	37.97049
TP10	Burqa Guddina,Waliso General Hospital	8.52030	37.96937
TP11	Burqa Guddina,Waliso Health Center number 2	8.52396	37.97213
TP12	Ayetu, Ayetu Primary School	8.54398	37.98241
TP13	Ayetu, Adventist primary School	8.54956	37.98586
TP14	Ayetu, Waliso Secondary school	8.55238	37.9891
TP15	Ejersa, inside Compound of kebele	8.54338	37.9735
TP16	Ejersa, Guddina Waliso Primary School	8.54866	37.9728
TP17	Ganda Ejersa Land office	8.54532	37.97592
TP18	Ejersa, Teachers association office	8.54828	37.97676
TP19	Ejersa Around University	8.55113	37.98125
TP20	Ayetu, Adventist KG School	8.55008	37.98245

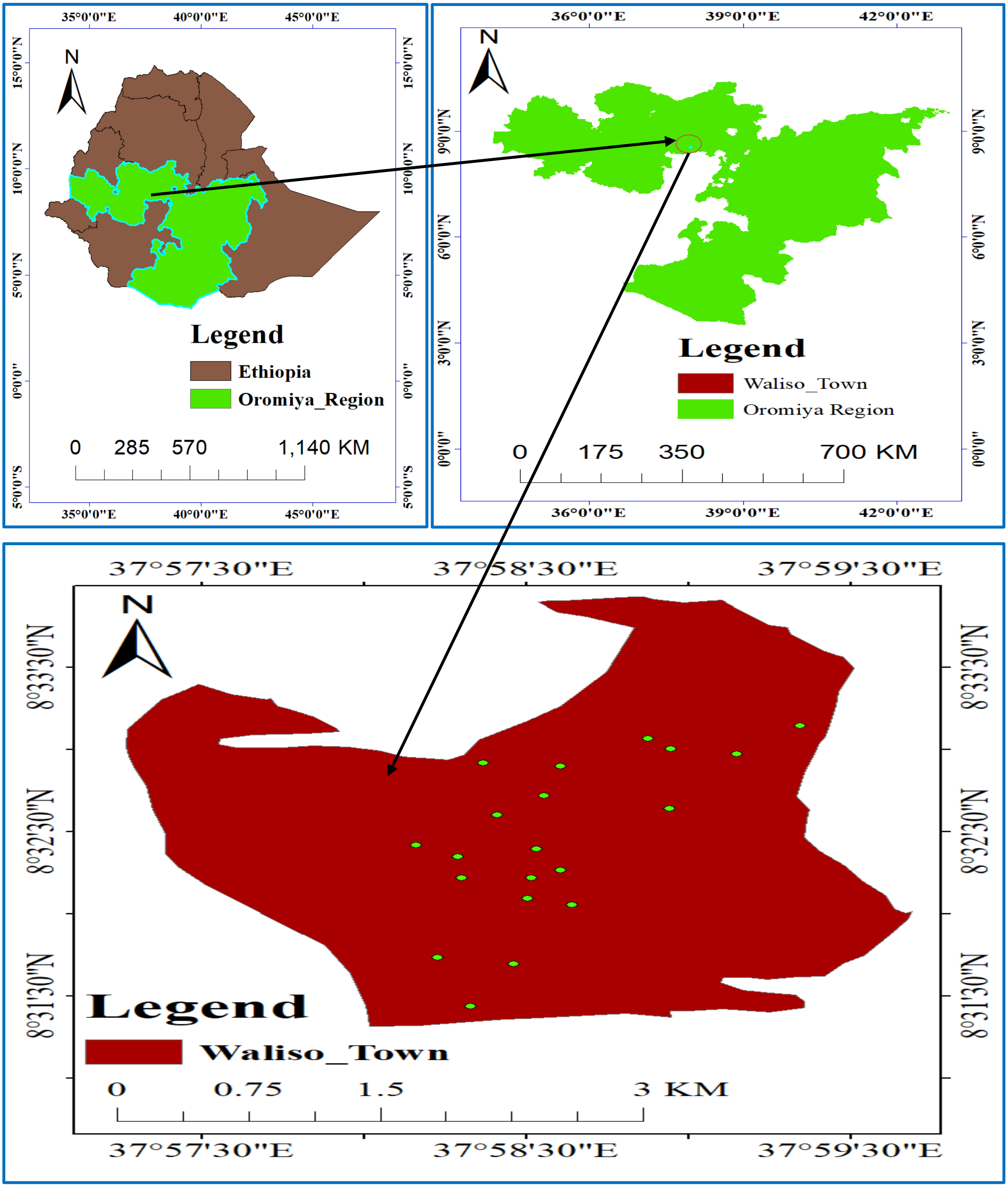


Figure 3-1: Geographical location of Waliso Town

3.2 Study design

A study design is the process that guides researchers on how to collect, analyse and interpret observations. Therefore, the objective of the research was achieved in accordance with the methodology outlined below.

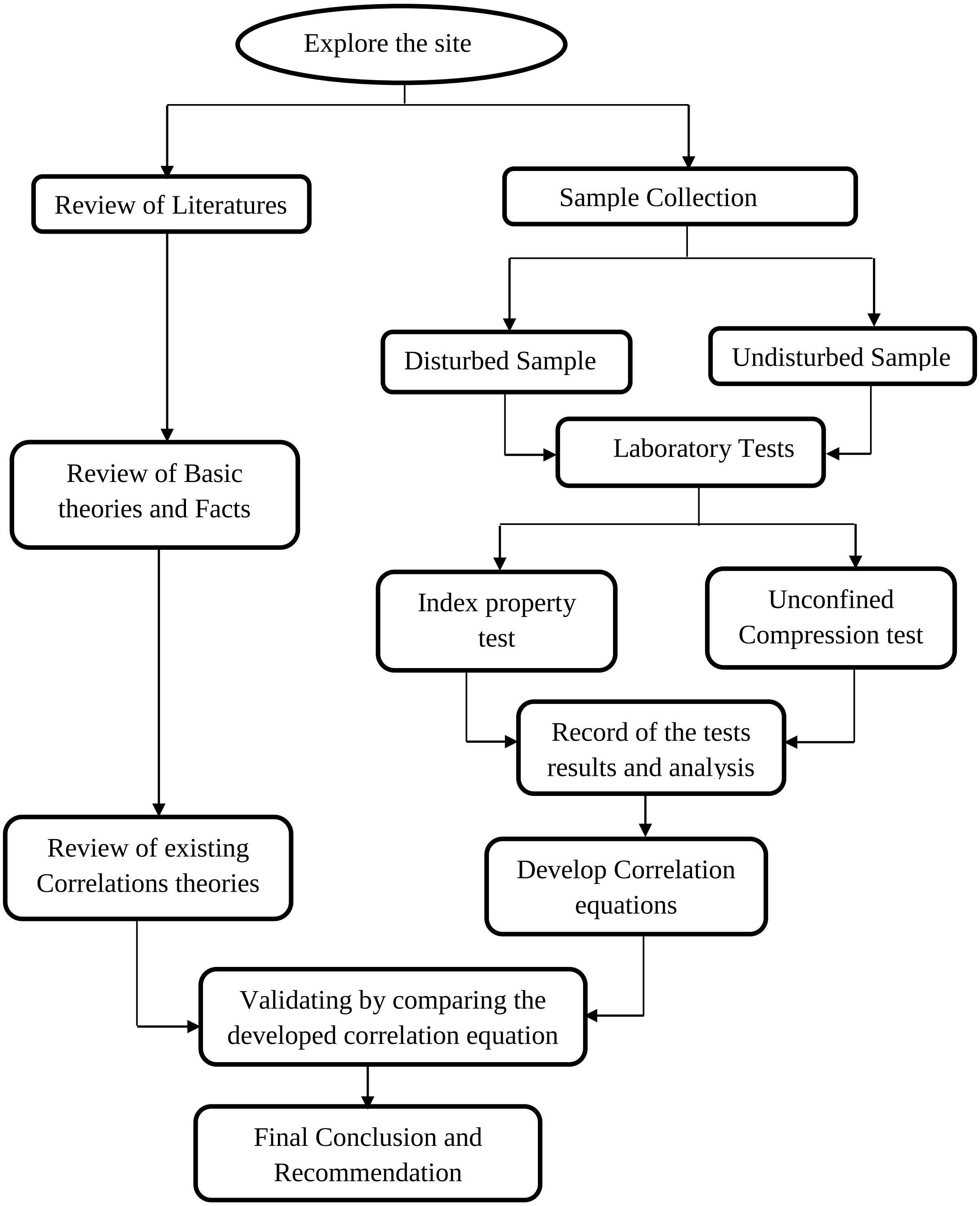


Figure 3-2: Study Design flow chart

3.3 Study Population

At an early stage in the planning of any investigation, decisions must made concerning the study population. That is, concerning the population of individual units investigated. According to this Research thesis, the study population that was concerned the study of Engineering properties of the sub-surface soils that was collected from 20 (Twenty) test pits around study area.

The population is too large to consider during data collection process from all test pits. Instead, the samples selected individually from each test pits; that the sample was representative of the population. That means, each samples taken from each test pits (Population) for data collection and analysis.

3.4 Sample size and sampling procedures

The size of soil collected should specified in sample collection procedure according to ASTM Standard Test Manual. For my study twenty test pits were excavated by local labor which was primary data. The samples were collected from each test pits at required depth. Disturbed and undisturbed soil samples were collected from test pits. Both samples used to determine index properties, soil classification, Unconfined Compression Strength (UCS), etc. Shelby Tube sampling techniques used to extract undisturbed soil as per ASTM D1587-94 specification. Plastic bag was used for sampling and transporting disturbed soil samples according to ASTM D 4220-95. This is due to its very minimum degree of disturbance and keeps the moisture of the sample.

The sample collection procedure and all laboratory tests conducted according to ASTM Standard Test Manual.

3.5 Sampling and Data collection process

3.5.1 Sampling

The study of the total population is not possible and it is also impracticable. The research work cannot be undertaken without use of sampling. Sampling is indispensable technique of the research. Purposive Sampling technique was used in this study.

Sampling is mainly concerned with ensuring that a sample is representative of the population. It will be large enough to provide sufficient material to achieve the desired detection limit.

3.5.2 Data Collection Process

The collection of data refers to a plan for gathering data and information from different sources.

Data collection process consists of gathering relevant information from Waliso Town Municipality and collection of soil samples. A set of procedure was followed ASTM Standard Manuals. This is used to get the desired data and information from the field work. And also, to process and analyse the facts in a logical and scientific manner. In collection of data both disturbed and undisturbed samples were taken.

3.6 Sources of Data

For this Research thesis primary data which was obtained from laboratory tests and secondary data were used. Samples were taken from test pits at desired depth through disturbed and undisturbed sampling methods. For comparison also, secondary data was used.

3.7 Laboratory Test

Laboratory tests that were conducted: Natural moisture content, Specific gravity, Bulk and Dry Density, Sieve and Hydrometer analysis, Atterberg limit and unconfined compression test. This was used for calculating index properties, undrained shear strength of soils and other characteristics of soils. All laboratory tests were conducted according to ASTM laboratory test manuals.

3.8 Statistical Data Analysis for Correlation and Regression

Many problems in engineering and the sciences involve a study or analysis of the relationship between two or more variables. In statistical terms, a correlation is a mathematical measure of the strength of association between two quantitative variables. A closely related cousin of correlation analysis is regression analysis. The collection of statistical tools that are used to model and explore relationships between variables are related in a non-deterministic manner is called regression analysis. Because problems of this type occur so frequently in many branches of engineering and science, regression analysis is one of the most widely used statistical tools [36].

3.8.1 Data distribution Analysis of the Model

3.8.1.1 Choice of Sample Size

Technically, the size of the sample depends upon the precision the researcher desires in estimating the population parameter at a particular confidence level. There is no single rule that can use to determine sample size. A larger sample is much more likely to be representative of the population. Furthermore, with a large sample the data are likely to be more accurate and precise. It was pointed out in that the larger the sample, the smaller the standard error.

In general, the standard error of a sample mean is inversely proportional to the square root of sample size (n) [37].

When conducting research investigation on quantitative data, the sample size calculated by the following formula:

$$N = \frac{{t_\alpha}^2 * S^2}{\varepsilon^2}$$

Where; N = the desired sample size,

S = the standard deviation of observations,

ε = the permissible in the estimate of mean and tα is the value of at 5% level of significance

3.8.1.2 Normality Test

To supplement the graphical assessment of normality, you can formally test for normality. For example, the Kolmogorov-Smirnov and ShapiroWilk test reported in the SPSS Explore procedure used to test the hypothesis that the distribution is normal. (SPSS recommends these tests only when your sample size is less than 50). The hypotheses used in testing data normality are as follows [38];

H0: the distribution of the data is normal.

Ha: the distribution of the data is not normal.

If a test does not reject normality, this suggests that a parametric procedure that assumes normality, (e.g., a t-test) safely used. However, we emphasize again that it is always a good idea to examine data graphically in addition to the formal tests for normality.

To further examine the data (and perhaps understand the reasons for the discrepancy), you can visualize the distribution of the data using graphical displays such as a histogram, boxplot, stem-and-leaf diagram, and normal Q-Q plot. A brief explanation of how to interpret each of these plots in the context of normality:

- Histogram: When a histogram's shape approximates a bell curve, it suggests that the data may have come from a normal population.
- Q-Q Plot: A quantile-quantile (q-q) plot is a graph used to display the degree to which quantizes of a reference (known) distribution differ from the sample quantizes of the data. When the data fit the reference distribution, then the points will lie in a tight random scatter around the reference line.

3.9 Considerations for Statistical Analysis

There are various statistical techniques for analysing data. To choose an appropriate technique of statistical analysis in the challenging task to a research worker.

The major types of tests employed for analysing data to interpret the test results are:

- Parametric statistics or tests, and
- Non-parametric statistics or tests.

A researcher has to select either of these approaches for analysing his own research data depending on the criteria for choosing an appropriate statistical approach. [39]

3.9.1 Parametric Tests

The parametric tests are the tests of the most powerful type and used if their basic assumptions will based upon the nature of the population values and the ways of sample selection.

- The observations are independent. The selection of one case is in no way dependent upon the selection of any other case,
- The population values are normally distributed or, if not, the nature of their distribution known.
- The population values have equal variances or the ratio of their variances known.
- The variables measured are expressed in interval or ratio scales. Nominal or ordinal do not qualify.

3.9.1.1 Standard Error of the Mean or SEMn

The means of randomly selected samples, which are normally distributed, have their own standard deviation known as the standard deviation or standard error of the mean. The standard error of mean of a sample computed from the following formula:

SEMn or σM = $\frac{S}{\sqrt{N}}$ Where, SEMn = Standard error of mean

S = Standard deviation of sample scores

N = Size of the sample

The value of the true mean of an infinite population not known, for it cannot calculated. However, a particular mean calculated from a randomly selected sample related to the population mean in the following way.

68 % of sample means will lie within a range of ± 1 SEMn of the population mean.

95 % of sample means will lie within ± 1.96 SEMn of the population mean.

99 % of sample means will lie within ± 2.58 SEMn of the population mean.

3.9.1.2 Level of Significance

The rejection or acceptance of a null hypothesis depends upon level of significance as a criterion. Rejecting the null hypothesis at the 5 percent level indicates that a difference in means as large as that found between the experimental and control group means would not likely have resulted from sampling error in more than 5 out of 100 experiment. This suggests 95 percent likelihood or probability that the difference was due to the experimental variable.

The Sigma values that must exceed the values in the following table for Rejection of Hypothesis are:

Table 3.2: Sigma value that must be exceeded for Rejection of Hypothesis

Test	Level of 0.05	Significance 0.01
One tailed test	1.64	2.33
Two tailed	1.96	2.58
Probability	0.95	0.99

3.9.1.3 The Significance of R

To test the significance of a coefficient of correlation we may establish the null hypothesis that r = 0 and that any value of r, other than 0, is the possible result of sampling error. We assume that the sample r is one of a number of random samples. To use the z value and the probability table the r converted into z value by the formula, $Z = r\sqrt{N-1}$; if z value exceeds the table value, the hypothesis rejected and if not then the hypothesis is accepted.

3.9.1.4 The t- Test

The t- Test is a simple experiment that designed to establish cause effect relationships. It is used to determine whether the difference between means of two groups or conditions is due to the independent variable, or if the difference is simply due to chance.

Thus, this procedure establishes the probability of the outcome of an experiment, and in doing so enables the researcher to reject or retain the null hypothesis. When small samples, fewer than 30 observations in number, are involved, the t-test used to determine the statistical significance. To compute t-value for the significance of the difference between two means, when N is fewer than 30, the formula is:

$$t = \frac{(M_1 - M_2)}{\sqrt{\frac{(N_1-1)S_1^2+(N_2-1)S_2^2}{N_1+N_2-2}}\sqrt{\frac{1}{N_1}+\frac{1}{N_2}}}$$

3.9.1.5 Analysis of Variance (F) ANOVA Test

The analysis of variance is a convenient way to determine whether the means of more than two random samples are too different to attribute to sampling error. The question raised by the analysis of variance is whether the sample means differ from their own sample means (with in group variance).

If the variation of sample means from the grand mean is greater enough than the variance of the individual values from their sample means, the samples are different enough to reject a null hypothesis or sampling error explanation. If the among groups variance is not substantially greater than the within group variance, the samples are not significantly different and probably behave as random samples from the same population.

$$F = \frac{Variance\ among\ groups}{Variance\ within\ groups}$$

The significance of the 'f 'ratio found in 'f 'tables which indicate the values necessary to reject the null hypothesis at the 0.05 or the 0.01 levels.

3.9.2 Non-Parametric Tests

Non-parametric, or distribution free tests are used when the nature of the population distribution is not known or when the data are expressed as nominal or ordinal measures. The variables in non-parametric tests usually presented in rank order or discrete values.

3.9.2.1 Chi-Square Test (χ2)

The Chi-square test applies only to discrete data (discrete variables are those expressed in frequency counts). The test would provide a method of testing the difference between actual Preferences and choices based upon a probability assumption.

The Chi-square formula: $\chi 2 = \sum[\frac{(fo-fe)^2}{fe}]$

Where, χ2 = Chi-square

fo = frequency of observed sampling error

fe = frequency of Expected sampling error

3.9.2.2 The Sign Test

The sign test sometimes used to evaluate the effect of a type of treatment in a before-after experiment. The sign test uses the principles of the standard error of a dichotomous variable; deriving a Z-score by the formula:

$$Z = \frac{O - NP}{\sqrt{NP(1-\rho)}}$$

Where, O = +ve changes

N = + and –ve changes

P = 0.5 (equal probability of a gain or loss)

If Z value exceeds the table value, the null hypothesis rejected and if not exceeded then the null hypothesis is accepted.

3.10 Correlation and Regression Analysis

Regression analysis is an important technique in engineering and science to model and study relationships between two or more variables. The method of regression analysis used to develop the line or curve, which provides the best fit through a set of data points. The best-fit model will be in the form of linear, parabolic or logarithmic trend.

Best fitting a regression model requires several assumptions [36].

- The method of least squares used in order to choose the best fitting line for a set of data.
- The confidence level of an estimate will gives some idea about the accuracy of an estimate. A variable with a confidence level (CL) ≥ 95% is the best to choose.

3.10.1 Simple Linear Regression

The case of simple linear regression considers a single regressor variable or predictor variable X and a dependent or response variable Y. Suppose that the true relationship between Y and X is a straight line and that the observation Y at each level of X is a random variable. Therefore, the fitted or estimated regression line is $Y = \beta 0 + \beta 1X$, where the intercept β0 and the slope β1 are unknown regression coefficients. Note that each pair of observations satisfies the relationship: $Yi = \beta 0 + \beta 1xi + ei$, Where $ei = Yi - Y$ is called the residual. The residual describes the error in the fit of the model to the i^{th} observation Yi. The residuals used to provide information about the adequacy of the fitted model.

3.10.2 Multiple Linear Regression Model

Many applications of regression analysis involve situations that have more than one regressor or predictor variable. A regression model that contains more than one regressor variable called a multiple regression model. A multiple regression model described by the following relationship: $Y = \beta 0 + \beta 1x1 + \beta 2x2 + ... + \beta kxk + \epsilon$; Where, Y= Dependent variable or response, xi (i = 1, 2 … k) = independent variables or predictors, and βj (j = 0, 1…k) = Regression coefficients

3.10.2.1 R-squared (R2) and Adjusted R-square (Adj. R2)

The coefficient of multiple determinations R^2 used as a global statistic to assess the fit of the model. Computationally:

$$R^2 = \frac{SS_R}{SS_T} = 1 - \frac{SS_E}{SS_T}$$

Where, SSR = Regression or model sum of squares

SST = Total sum of square

SSE = Error or residual Sum of squares

Many regression users prefer to use an adjusted R^2statistic, which is:

$$R_{adj}2 = 1 - \frac{\frac{SS_E}{n-p}}{\frac{SS_T}{n-1}}$$

Where, SS_E / (n − p) = Error or residual Sum of squares
SS_T/ (n − 1) = Constant

3.10.2.2 Multicollinearity

Multiple regression expects to find the dependencies between the response variable Y and the regressor xi. In situations in which these dependencies are strong, we say that Multicollinearity exists. Multicollinearity can have serious effects on the estimates of the regression coefficients and on the general applicability of the estimated model.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Laboratory Test Results

In this study, laboratory tests were performed to determine the index properties and undrained shear strength of study area soils. The following laboratory result shows the primary data of the soil conducted on the study area.

4.1.1 Natural moisture content

Moisture contents of the soil samples were determined in the laboratory according to ASTM D2216.A set of samples were dried to a constant weight using oven dry at temperature of 105ºC.

Table 4.1: Natural moisture content

Test Pit	Location of Test Pit	Natural moisture Content w (%)
TP1	Ejersa, Garasu Dhuki High School	41.79
TP2	Ejersa, Waliso Health Center	41.15
TP3	Ayetu, inside Compound of kebele	37.91
TP4	Ayetu, around Stadium	40.86
TP5	Hora, Waliso Liban primary School	40.12
TP6	Hora, Waliso water Supply	39.05
TP7	Hora, Waliso KG School	38.85
TP8	Burqa, Guddina Inside Compound of kebele	40.07
TP9	Burqa Guddina, Burqa Guddina Primary School	40.50
TP10	Burqa Guddina,Waliso General Hospital	38.12
TP11	Burqa Guddina,Waliso Health Center number 2	37.86
TP12	Ayetu, Ayetu Primary School	40.56
TP13	Ayetu, Adventist primary School	39.52
TP14	Ayetu, Waliso Secondary school	38.94
TP15	Ejersa, inside Compound of kebele	37.54
TP16	Ejersa, Guddina Waliso Primary School	40.04
TP17	Ganda Ejersa Land office	39.75
TP18	Ejersa, Teachers association office	38.67
TP19	Ejersa Around University	36.23
TP20	Ayetu, Adventist KG School	38.54

From table 4.1, the natural moisture content of soils of the study area ranges from 36.23% to 41.79%. This shows that the soil of study area is fine grained soil according to B.M.Das [16].

4.1.2 Specific Gravity

Specific gravity is defined as the ratio of the mass of a unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The test was accompanied, according to ASTM D854-58, Standard Test for Gravity of Soil Solids by density bottle, procedure.

Table 4.2: Specific Gravity

Test pit	Location of Test Pit	Specific Gravity(Gs)
1	Ejersa, Garasu Dhuki High School	2.73
2	Ejersa, Waliso Health Center	2.71
3	Ayetu, inside Compound of kebele	2.70
4	Ayetu, around Stadium	2.69
5	Hora, Waliso Liban primary School	2.71
6	Hora, Waliso water Supply	2.71
7	Hora, Waliso KG School	2.68
8	Burqa, Guddina Inside Compound of kebele	2.70
9	Burqa Guddina, Burqa Guddina Primary School	2.71
10	Burqa Guddina,Waliso General Hospital	2.72
11	Burqa Guddina,Waliso Health Center number 2	2.70
12	Ayetu, Ayetu Primary School	2.70
13	Ayetu, Adventist primary School	2.71
14	Ayetu, Waliso Secondary school	2.70
15	Ejersa, inside Compound of kebele	2.68
16	Ejersa, Guddina Waliso Primary School	2.71
17	Ganda Ejersa Land office	2.70
18	Ejersa, Teachers association office	2.73
19	Ejersa Around University	2.72
20	Ayetu, Adventist KG School	2.70

From Table 4.2, the average specific gravity of the study area ranges from 2.68 to 2.73. This indicates that the Soil of study area is clay and silty clay according to B.M.Das [16].

4.1.3 Bulk and Dry Density

The density of soil was determined according to ASTM D 2937 (a standard test for a density of soil in place by the drive cylinder method). This method is achieved to determine the in-place density of undisturbed soil found by pushing or drilling a thin-walled cylinder. The bulk density is the ratio of a mass of moist soil to the volume of the soil sample, and the dry density is the ratio of the mass of the dry soil to the volume of the soil sample.

Table 4.3: Bulk Density & Dry Density

Test Pit	Location of Test Pit	Bulk density(γb)(g/m^3)	Dry density(γd) (g/m^3)
TP1	Ejersa, Garasu Dhuki High School	1.75	1.27
TP2	Ejersa, Waliso Health Center	1.78	1.35
TP3	Ayetu, inside Compound of kebele	1.91	1.45
TP4	Ayetu, around Stadium	1.87	1.43
TP5	Hora, Waliso Liban primary School	1.78	1.30
TP6	Hora, Waliso water Supply	1.79	1.29
TP7	Hora, Waliso KG School	1.95	1.47
TP8	Burqa, Guddina Inside Compound of kebele	1.87	1.43
TP9	Burqa Guddina, Burqa Guddina Primary School	1.82	1.32
TP10	Burqa Guddina,Waliso General Hospital	1.78	1.29
TP11	Burqa Guddina,Waliso Health Center number 2	1.92	1.46
TP12	Ayetu, Ayetu Primary School	1.94	1.45
TP13	Ayetu, Adventist primary School	1.76	1.32
TP14	Ayetu, Waliso Secondary school	1.79	1.40
TP15	Ejersa, inside Compound of kebele	1.95	1.47
TP16	Ejersa, Guddina Waliso Primary School	1.78	1.42
TP17	Ganda Ejersa Land office	1.80	1.30
TP18	Ejersa, Teachers association office	1.82	1.41
TP19	Ejersa Around University	1.92	1.46
TP20	Ayetu, Adventist KG School	1.85	1.41

From Table 4.3, the bulk density and dry density of the sites range from 1.75 to 1.95 g/cm^3 and 1.27 to 1.47 g/cm^3 respectively. This shows that the soil of the study area is fine grained soil.

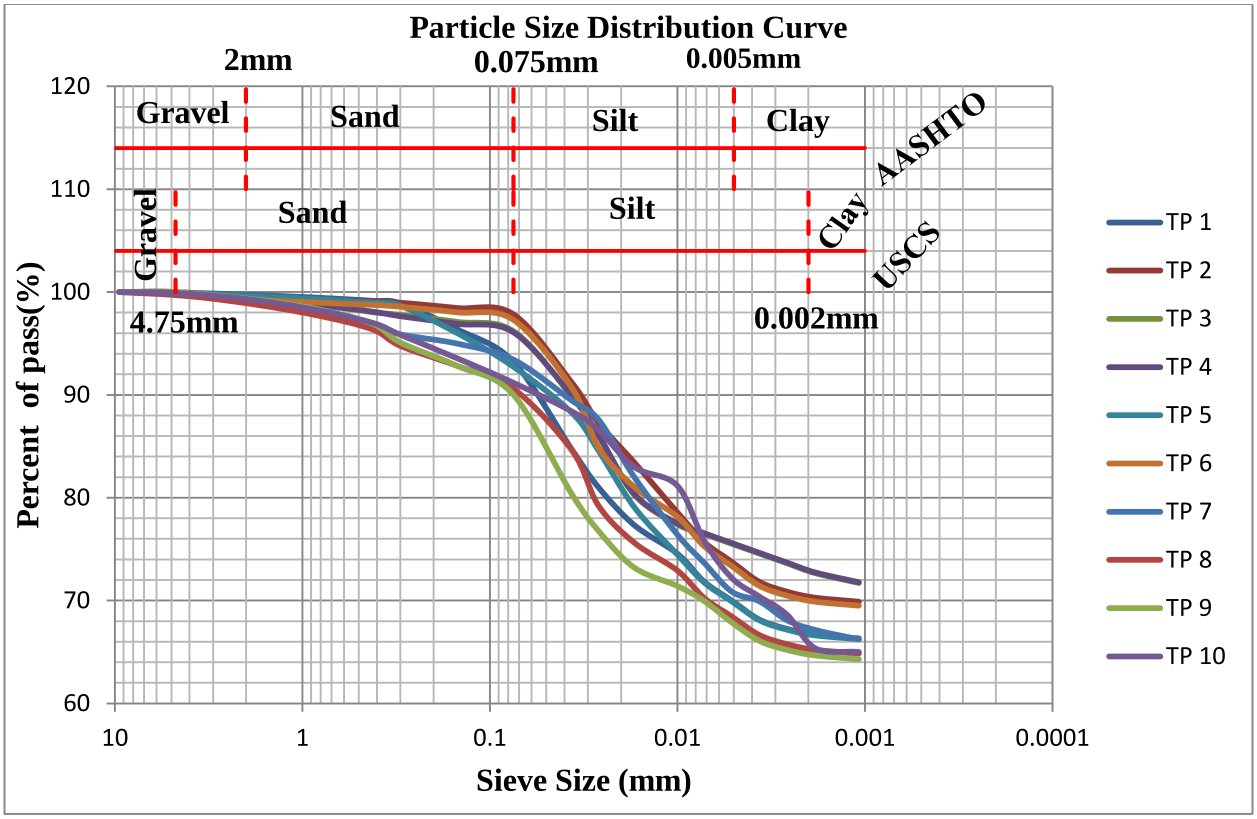
4.1.4 Grain Size Analysis

This test was performed according to ASTM D 422 to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis was done to determine the distribution of the coarser, larger -sized particles, and the hydrometer analysis method was used to determine the distribution of the finer particles, respectively. For this study both wet sieve analysis and hydrometer analysis was done.

Table 4.4: Grain Size Distributions.

Test pits	% of passing 0.075mm	Grain size distribution According to AASHTO classification				Grain size distribution According to USCS classification			
		% Gravel	% Sand	% silt	% clay	% Gravel	% Sand	% silt	% clay
TP1	93.22	0.25	6.53	23.23	69.99	0.04	6.74	26.53	66.69
TP2	97.84	0.46	1.70	27.56	70.28	0.00	2.16	24.08	73.76
TP3	96.20	0.86	2.95	23.53	72.66	0.00	3.80	23.53	72.66
TP4	96.09	0.73	3.18	23.36	72.73	0.12	3.79	23.36	72.73
TP5	92.74	0.34	6.92	26.13	66.61	0.08	7.18	26.13	66.61
TP6	97.30	0.68	2.02	23.95	73.35	0.12	2.58	27.41	69.89
TP7	93.43	0.90	5.67	22.57	70.86	0.30	6.27	26.29	67.14
TP8	90.61	1.08	8.31	22.17	68.44	0.27	9.12	25.40	65.21
TP9	90.02	0.62	9.36	22.16	67.86	0.04	9.94	25.36	64.66
TP10	91.18	0.67	8.15	18.99	72.19	0.09	8.73	25.82	65.36
TP11	97.30	0.68	2.02	23.80	73.50	0.12	2.58	27.27	70.03
TP12	96.62	0.35	3.03	23.64	72.98	0.05	3.33	27.08	69.54
TP13	93.49	0.32	6.19	23.01	70.48	0.00	6.51	26.34	67.15
TP14	91.08	0.67	8.25	22.28	68.80	0.24	8.68	25.53	65.55
TP15	93.78	0.33	5.89	22.66	71.12	0.05	6.17	26.01	67.77
TP16	93.24	0.21	6.55	22.95	70.29	0.00	6.76	26.27	66.97
TP17	98.33	0.01	1.66	21.13	77.20	0.00	1.67	24.06	74.28
TP18	97.82	0.11	2.06	21.49	76.33	0.00	2.18	24.38	73.45
TP19	97.59	0.17	2.24	22.25	75.34	0.02	2.39	25.13	72.46
TP20	97.68	0.40	1.92	23.90	73.78	0.04	2.28	27.38	70.30

As presented on Table 4.4, the percentage of finer than sieve #200 (0.075mm) is more than 90%. This indicates that the soil of study area is classified as fine grained soils.



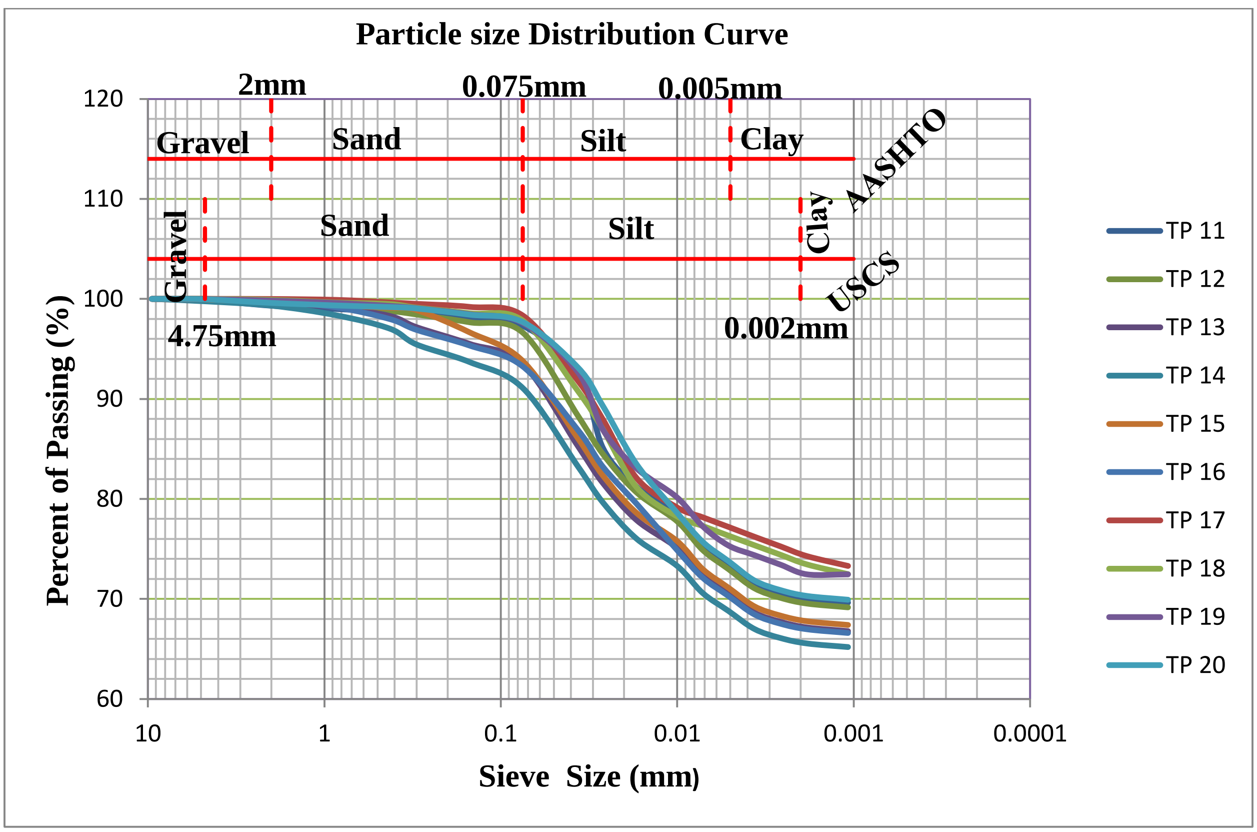


Figure 4-1: Particle Size distributions Curve

4.1.5 Atterberg Limit's Test

This test was executed as per ASTM D4318 for Liquid Limit, Plastic Limit and Plasticity Index of soils. The air-dried samples were arranged by drying the specimen in the air. The portions of the samples passing the No. 40 (0.425mm) sieve were used for the preparation of the sample for this test. In this research, Casagrande method was used to carry out Atterberg limit.

Table 4.5: Liquid limit, Plastic Limit, plasticity index and liquidity index

Test Pit	Location of Test Pit	LL	PL	PI	LI
TP1	Ejersa, Garasu Dhuki High School	75.20	40.89	34.31	0.0262
TP2	Ejersa, Waliso Health Center	72.80	39.23	33.57	0.0572
TP3	Ayetu, inside Compound of kebele	60.26	30.69	29.57	0.2442
TP4	Ayetu, around Stadium	70.50	39.32	31.18	0.0.494
TP5	Hora, Waliso Liban primary School	75.20	40.93	34.27	-0.0236
TP6	Hora, Waliso water Supply	72.40	37.50	34.90	0.0444
TP7	Hora, Waliso KG School	60.00	26.73	33.27	0.3643
TP8	Burqa, Guddina Inside Compound of kebele	73.52	39.97	33.55	0.0030
TP9	Burqa Guddina, Burqa Guddina Primary School	72.00	40.51	31.49	-0.0003
TP10	Burqa Guddina,Waliso General Hospital	63.60	40.45	23.15	-0.1006
TP11	Burqa Guddina,Waliso Health Center number 2	59.00	28.45	30.55	0.3080
TP12	Ayetu, Ayetu Primary School	69.70	32.62	37.08	0.2141
TP13	Ayetu, Adventist primary School	70.00	38.46	31.54	0.3360
TP14	Ayetu, Waliso Secondary school	59.10	38.10	21.00	0.0400
TP15	Ejersa, inside Compound of kebele	58.40	26.70	31.70	0.3420
TP16	Ejersa, Guddina Waliso Primary School	67.45	32.42	35.03	0.2175
TP17	Ganda Ejersa Land office	73.60	36.22	37.38	0.9440
TP18	Ejersa, Teachers association office	57.20	29.32	27.88	0.3354
TP19	Ejersa Around University	61.95	27.38	34.57	0.2560
TP20	Ayetu, Adventist KG School	65.50	32.42	33.08	0.1850

From Table 4.5, it was manifested that liquid limit ranges from 57.20% to 75.20 %, the plastic limit ranges from 26.7% to 40.93%, plastic index from 21% to 37.38% and Liquidity index ranges from -0.006 to 0.9440. This shows that the soil is fine grained (silt and clay) soil according to M.Budhu [5].

4.1.6 Soil Classification

There are different systems for soil classification based on the grain size distribution and Atterberg limits of soil. In this study, American Association State of Highway and Transportation Officials (AASHTO) and the Unified Soil Classification System (USCS) was used to classify the study area soil.

4.1.6.1 AASHTO Soil Classification

According to AASHTO Soil Classification System, the soil of study area ranges between A-7-5 and A-7-6. This implies that the soils of the study area are fine grained soils which are highly clayey soils.

Table 4.6: AASHTO Soil Classification

TEST PITS	Liquid Limit (LL), %	Plastic Limit (PL), %	Plastic Index (PI), %	Equation of line: PI=LL-30	Percentage of passing No. 200 sieve, %	AASHTO Classification
TP1	75.20	40.89	34.31	45.20	93.22	A-7-5
TP2	72.80	39.23	33.57	42.80	97.84	A-7-5
TP3	60.26	30.69	29.57	30.26	90.20	A-7-5
TP4	70.50	39.32	31.18	40.50	96.09	A-7-5
TP5	75.20	40.93	34.27	45.20	92.74	A-7-5
TP6	72.40	37.50	34.90	42.40	97.30	A-7-5
TP7	60.00	26.73	33.27	30.00	93.43	A-7-6
TP8	73.52	39.97	33.55	43.52	90.61	A-7-5
TP9	72.00	40.51	31.49	42.00	90.02	A-7-5
TP10	63.60	40.45	23.15	33.60	91.18	A-7-5
TP11	59.00	28.45	30.55	29.00	97.30	A-7-6
TP12	69.70	32.62	37.08	39.70	96.62	A-7-5
TP13	70.00	38.46	31.54	40.00	93.49	A-7-5
TP14	59.10	38.10	21.00	29.10	91.08	A-7-5
TP15	58.40	26.70	31.70	28.40	93.78	A-7-6
TP16	67.45	32.42	35.03	37.45	93.24	A-7-5
TP17	73.60	36.22	37.38	43.60	98.33	A-7-5
TP18	57.20	29.32	27.88	27.20	97.82	A-7-6
TP19	61.95	27.38	34.57	31.95	97.59	A-7-6
TP20	65.50	32.42	33.08	35.50	97.68	A-7-5

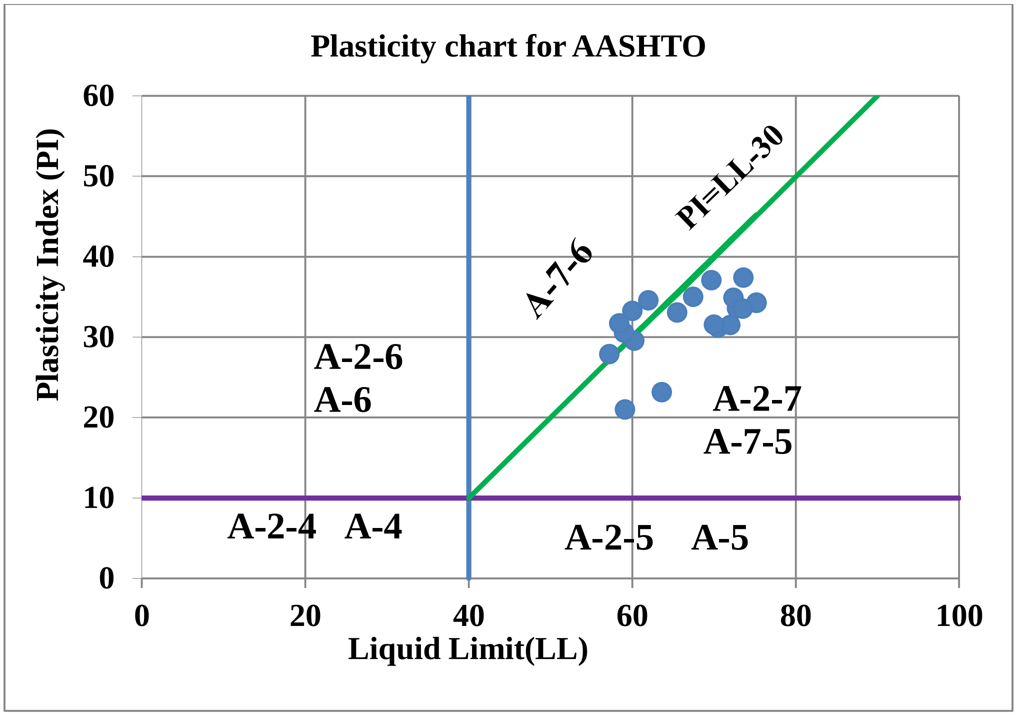


Figure 4-2: Plasticity chart for AASHTO

4.1.6.2 Unified Soil Classification System (USCS)

According to USCS, the Soil of study area ranges between CH (Clay soil with High plasticity) and MH (Silt soil of High plasticity). This implies that the soils of the study area are fine grained soils which are highly plastic.

Table 4.7: Unified Soil Classification Systems

TEST PITS	Liquid Limit (LL), %	Plastic Limit (PL), %	Plastic Index (PI), %	Equation of A-line: PI = 0.73*(LL-20)	Equation of U-line: PI = 0.9*(LL-8)	Percentage of passing No. 200 sieve, %	Unified Soil Classification System (USCS)
TP1	75.20	40.89	34.31	40.30	60.48	93.22	MH
TP2	72.80	39.23	33.57	38.54	58.32	97.84	MH
TP3	60.26	30.69	29.57	29.39	47.03	90.20	CH
TP4	70.50	39.32	31.18	36.87	56.25	96.09	MH
TP5	75.20	40.93	34.27	40.30	60.48	92.74	MH
TP6	72.40	37.50	34.90	38.25	57.96	97.30	MH
TP7	60.00	26.73	33.27	29.20	46.80	93.43	CH
TP8	73.52	39.97	33.55	39.07	58.97	90.61	MH
TP9	72.00	40.51	31.49	37.96	57.60	90.02	MH
TP10	63.60	40.45	23.15	31.83	50.04	91.18	MH
TP11	59.00	28.45	30.55	28.47	45.90	97.30	CH

TP12	69.70	32.62	37.08	36.28	55.53	96.62	CH
TP13	70.00	38.46	31.54	36.50	55.80	93.49	MH
TP14	59.10	38.10	21.00	28.54	45.99	91.08	MH
TP15	58.40	26.70	31.70	28.03	45.36	93.78	CH
TP16	67.45	32.42	35.03	34.64	53.51	93.24	CH
TP17	73.60	36.22	37.38	39.13	59.04	98.33	MH
TP18	57.20	29.32	27.88	27.16	44.28	97.82	CH
TP19	61.95	27.38	34.57	30.62	48.56	97.59	CH
TP20	65.50	32.42	33.08	33.22	51.75	97.68	MH

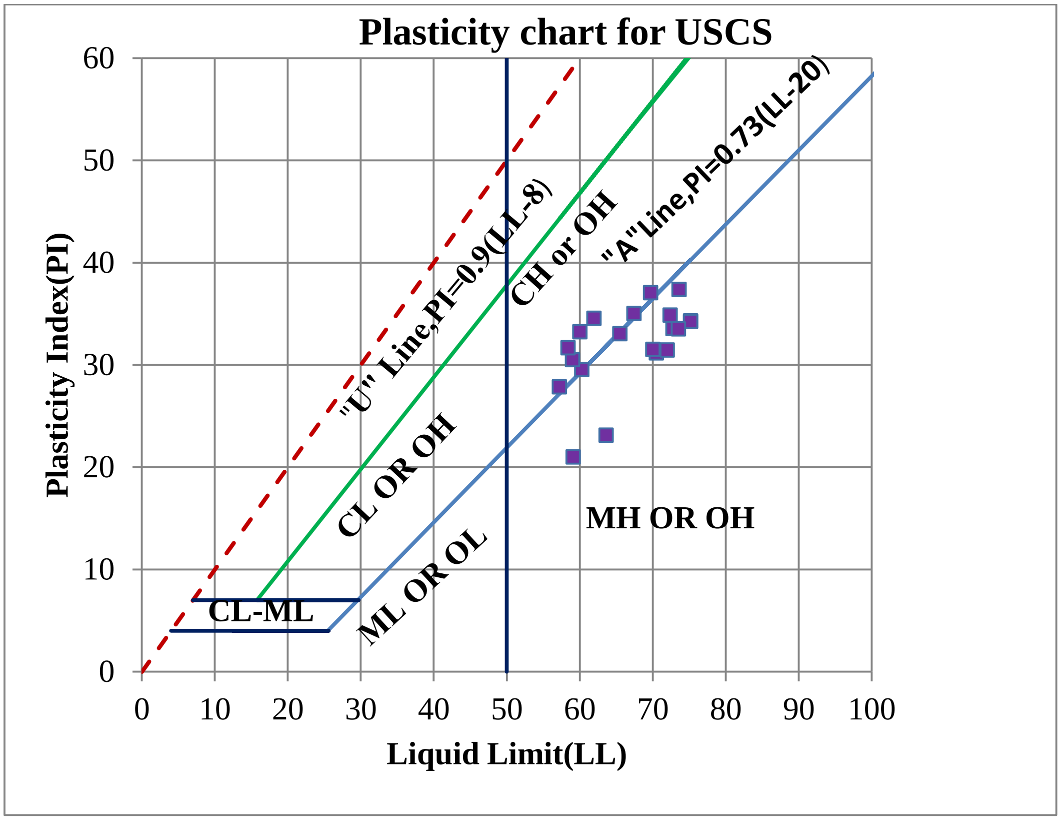


Figure 4-3: Plasticity Chart for USCS

4.1.7 Undrained shear Strength (Cu)

For determination of undrained shear strength, ASTM D 2166 was used to conduct the test on undisturbed samples collected by Shelby tube sampler.

Table 4.8: Undrained Shear Strength (Cu)

Test Pit	Location of Test Pit	Height(mm)	Diameter(mm)	Undrained shear Strength (Cu kN/m^2)
TP1	Ejersa, Garasu Dhuki High School	75	37.5	35.16
TP2	Ejersa, Waliso Health Center	77	37.5	49.02
TP3	Ayetu, inside Compound of kebele	80	37.5	76.71
TP4	Ayetu, around Stadium	80.5	37.5	54.86
TP5	Hora, Waliso Liban primary School	75	37.5	40.29
TP6	Hora, Waliso water Supply	79	37.5	52.63
TP7	Hora, Waliso KG School	80	37.5	80.69
TP8	Burqa, Guddina Inside Compound of kebele	80.5	37.5	56.33
TP9	Burqa Guddina, Burqa Guddina Primary School	79	37.5	43.94
TP10	Burqa Guddina,Waliso General Hospital	79	37.5	55.37
TP11	Burqa Guddina,Waliso Health Center number 2	80.5	37.5	81.66
TP12	Ayetu, Ayetu Primary School	80.5	37.5	55.49
TP13	Ayetu, Adventist primary School	80	37.5	45.27
TP14	Ayetu, Waliso Secondary school	80.5	37.5	59.02
TP15	Ejersa, inside Compound of kebele	81.5	37.5	83.74
TP16	Ejersa, Guddina Waliso Primary School	80.5	37.5	55.64
TP17	Ganda Ejersa Land office	80.5	37.5	48.18
TP18	Ejersa, Teachers association office	79	37.5	61.14
TP19	Ejersa Around University	81.5	37.5	80.06
TP20	Ayetu, Adventist KG School	81	37.5	72.11

Undrained shear strength is half of the ultimate shear stress of a soil, which is obtained from shear stress versus shear strain curve at quantified failure criteria condition. From Table 4.8, undrained shear strength of soils of study area varies from 35.16 to 83.74 kN/m^2. This shows that Consistency of Soil of study area is ranges from medium to stiff according to J.E Bowles [9]

4.2 Results of Correlation and Regression Analysis

4.2.1 Choice of Sample size

Technically, the size of the sample depends upon the precision the researcher desires in estimating the population parameter at a particular confidence level. A larger sample is much more likely to be representative of the population. Furthermore, with a large sample the data are likely to be more accurate and precise. It was pointed out in that the larger the sample, the smaller the standard error. In case of my study I used thirty number of samples.

4.2.1.1 Discussion on Sample Size

It would often suggested that one should include at least 30 subjects in a sample since this number permits the use of large sample statistics. Statistically speaking, a sample n= 30 is considered large, since with this n, the t-distribution and the normal curve are practically the same for hypothesis testing purposes. In experimental research, one should select a sample that will permit at least 30 in each group.

4.2.2 Statistical Data distribution result

Table 4.9: Results of Descriptive Statistics of Data Distribution

Statistics										
		NMC	GS	γb	γd	LL	PL	PI	LI	Cu
N	Valid	30	30	30	30	30	30	30	30	30
	Missing	0	0	0	0	0	0	0	0	0
Mean		36.7623	2.7017	1.8430	1.3937	66.7360	34.2637	32.4723	.131223	65.2103
Std. Error of Mean		.85623	.00470	.01524	.01280	1.48285	1.01236	.83260	.0417152	3.75486
Median		38.5200	2.7000	1.8350	1.4100	66.4750	32.6600	33.1750	.042200	57.6750
Mode		25.50[a]	2.70	1.78	1.32[a]	56.10[a]	32.42	21.00[a]	-.1186[a]	95.00[a]
Std. Deviation		4.68977	.02574	.08347	.07010	8.12192	5.54491	4.56032	.2284836	20.56621
Variance		21.994	.001	.007	.005	65.966	30.746	20.796	.052	422.969
Skewness		-1.373	-.354	.009	-.355	.382	.022	-.313	1.690	.470
Std. Error of Skewness		.427	.427	.427	.427	.427	.427	.427	.427	.427
Kurtosis		.635	.169	-1.410	-1.406	-.694	-1.706	1.046	4.160	-.895
Std. Error of Kurtosis		.833	.833	.833	.833	.833	.833	.833	.833	.833
Range		16.29	.10	.26	.22	29.80	15.70	22.30	1.0626	69.84
Minimum		25.50	2.65	1.71	1.27	55.90	26.70	21.00	-.1186	35.16
Maximum		41.79	2.75	1.97	1.49	85.70	42.40	43.30	.9440	105.00
Sum		1102.87	81.05	55.29	41.81	2002.08	1027.91	974.17	3.9367	1956.31
Percentiles	25	36.0225	2.6875	1.7800	1.3200	59.0750	28.4875	29.6675	-.022475	48.8100
	50	38.5200	2.7000	1.8350	1.4100	66.4750	32.6600	33.1750	.042200	57.6750
	75	40.0475	2.7200	1.9225	1.4600	72.9800	40.0900	34.9325	.269000	80.9325

4.2.2.1 Discussion on Statistical data output

From the above table, the result of Skewness over its standard error as well as kurtosis over its standard error is between-2 and +2. This shows each dependent and independent variables are normally distributed.

4.2.3 Normality Test Result

Table 4.10: Test of Normality for each variable

Tests of Normality						
Variables	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
NMC	.233	30	.071	.789	30	.062
GS	.174	30	.121	.948	30	.148
γb	.156	30	.062	.922	30	.060
γd	.156	30	.061	.900	30	.059
LL	.134	30	.177	.943	30	.111
PL	.155	30	.062	.875	30	.071
PI	.088	30	.200*	.976	30	.716
LI	.194	30	.056	.844	30	.051
Cu	.167	30	.052	.936	30	.071

4.2.3.1 Discussion on Normality Test output

From the above table, the normality test result fulfil the basic assumption of normality test. The value of Skewness and kurtosis over its standard error is between the ranges of -1.96 to +1.96, this implies that the data is normally distributed.

The kolmogrov-smirnov[a] and shapiro-wilk test shows, the significance levels (α) greater than 0.05, this shows the sample data are not significantly different than a normal population or we accept the null hypothesis.

Ho: The sample data are not significantly different than a normal population.

Ha: The sample data are significantly different than a normal population

So that the shapiro-wilk and kolmogrov-smirnova test results fulfil assumption for normally distributed data. In general, the test results fulfil the basic requirement of normal probability distribution data. So that we use parametric statistical test for evaluation of the hypothesis test. The independent t-test is used for parametric statistical test. The reason for selecting independent t-test is based on the data is continuous that fulfil normality test and it compares the means of two independent variables.

4.2.4 Correlation Analysis Result

4.2.4.1 Pearson correlation coefficient, R

The Pearson correlation coefficient (r) is used specifically to describe relationships when the variables to be correlated are continuous (measured on at least an interval scale).

Table 4.11: Result of Pearson correlation coefficient in Correlation matrix.

Correlations										
		NMC	GS	γb	γd	LL	PL	PI	LI	CU
NMC	Pearson Correlation	1	.397	-.495	-.527	.556	.586	.278	.366	-.814
	Sig. (2-tailed)		.030	.005	.003	.001	.001	.137	.047	.000
	N	30	30	30	30	30	30	30	30	30
GS	Pearson Correlation	.397	1	-.439	-.472	.407	.370	.275	-.032	-.518
	Sig. (2-tailed)	.030		.015	.009	.026	.044	.142	.866	.003
	N	30	30	30	30	30	30	30	30	30
γb	Pearson Correlation	-.495	-.439	1	.864	-.773	-.813	-.387	.186	.834
	Sig. (2-tailed)	.005	.015		.000	.000	.000	.034	.325	.000
	N	30	30	30	30	30	30	30	30	30
γd	Pearson Correlation	-.527	-.472	.864	1	-.756	-.835	-.332	.102	.845
	Sig. (2-tailed)	.003	.009	.000		.000	.000	.073	.592	.000
	N	30	30	30	30	30	30	30	30	30
LL	Pearson Correlation	.556	.407	-.773	-.756	1	.843	.756	-.113	-.850
	Sig. (2-tailed)	.001	.026	.000	.000		.000	.000	.550	.000
	N	30	30	30	30	30	30	30	30	30
PL	Pearson Correlation	.586	.370	-.813	-.835	.843	1	.285	-.228	-.880
	Sig. (2-tailed)	.001	.044	.000	.000	.000		.127	.225	.000
	N	30	30	30	30	30	30	30	30	30
PI	Pearson Correlation	.278	.275	-.387	-.332	.756	.285	1	.076	-.444
	Sig. (2-tailed)	.137	.142	.034	.073	.000	.127		.691	.014
	N	30	30	30	30	30	30	30	30	30
LI	Pearson Correlation	.366*	-.032	.186	.102	-.113	-.228	.076	1	-.050
	Sig. (2-tailed)	.047	.866	.325	.592	.550	.225	.691		.792
	N	30	30	30	30	30	30	30	30	30
CU	Pearson Correlation	-.814	-.518	.834	.845	-.850	-.880	-.444	-.050	1
	Sig. (2-tailed)	.000	.003	.000	.000	.000	.000	.014	.792	
	N	30	30	30	30	30	30	30	30	30

The possible values of the correlation coefficient range from -1 to +1 and the closer the number is to an absolute value of 1, the greater the degree of relatedness. The Pearson correlation coefficient can be tested for statistical significance (using the conventional probability criterion of .05).

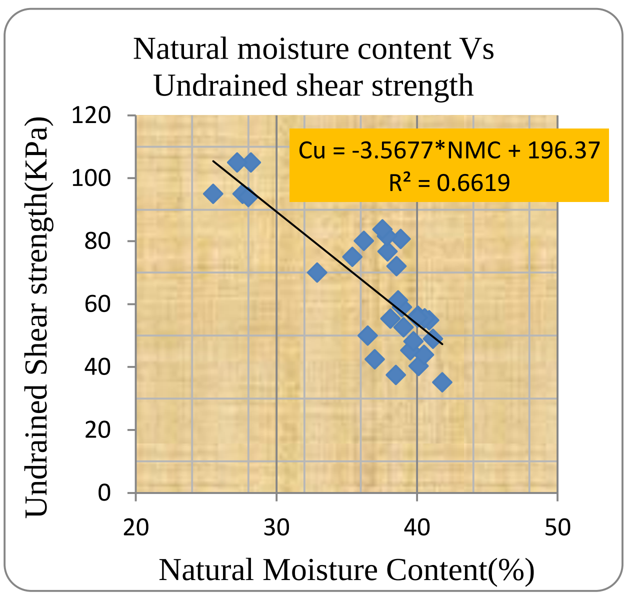
4.3 Formulation of New Empirical Equations

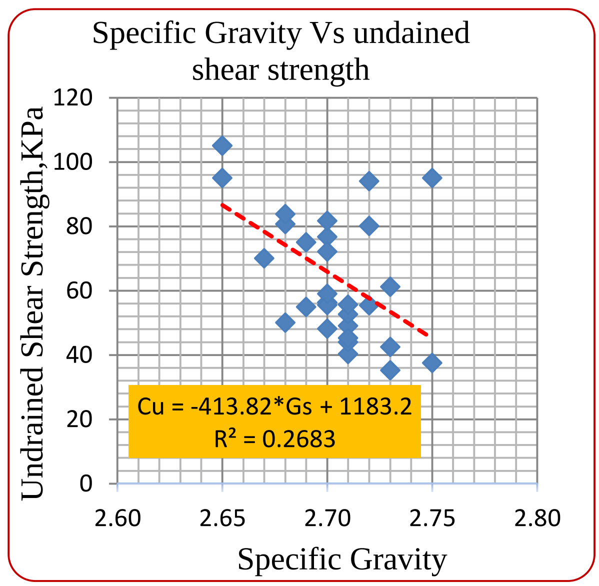
4.3.1 Using Simple Linear Regression Analysis

The relationship of two or more variables expressed in mathematical form by determining an equation connecting the two variables. Generally in this work, the value of Undrained Shear strength (Cu) was considered as the dependent variable whereas Natural moisture content (NMC), Liquid limit (LL), Plastic limit (PL), Plastic Index (PI), Liquidity Index (LI), Specific gravity (Gs), Bulk Density (γb) and Dry Density (γd) were the independent (Predictor) variables.

4.3.1.1 Scatter Plot for Simple Linear Regression

The Microsoft excel spread sheet is found to be the most powerful and manageable tool for scatter plot analysis and determination of correlation between two variables. However, when determination of the relationships between more than two variables are required (the dependent variable requires two or more independent variables) regression analysis is used and the SPSS software is found to be the most powerful and descriptive tool.





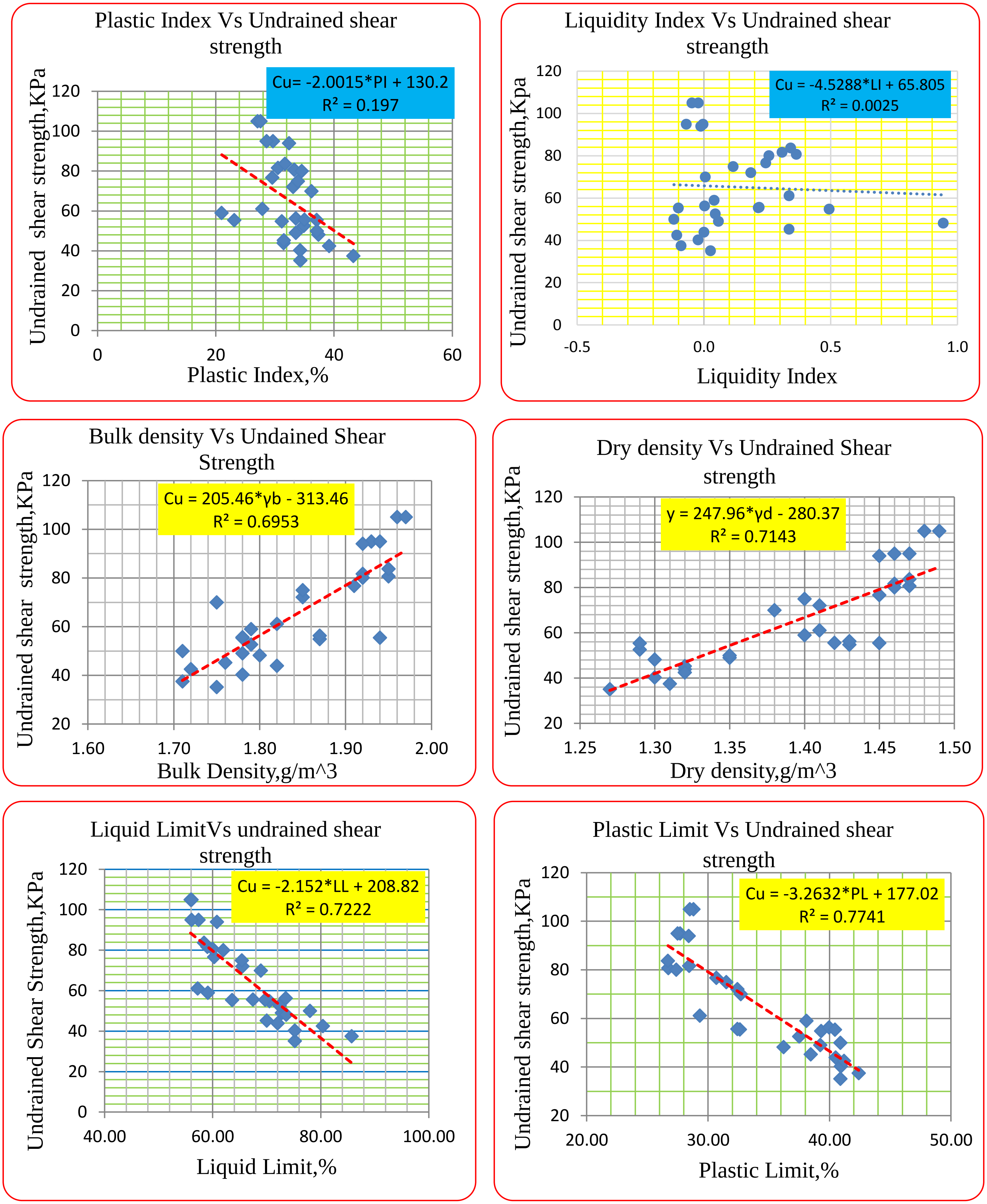


Figure 4-4: Scatter Plots of Dependent Variable Vs Independent Variables

4.3.1.2 Formula developed from Simple Linear Regression outputs

1. Cu = -3.2632*PL+177.02; R^2 = 0.7741
2. Cu = -2.152*LL+208.82; R^2 = 0.7222
3. Cu = 247.96*γd-280.37; R^2 = 0.7143
4. Cu = 205.46*γb -313.46; R^2 = 0.6953

4.3.1.3 Discussion on Single Linear Regression

After carefully analysing the data on the scatter plot and different models, Cu is highly influenced by PL, LL, γd and γb by achieving a coefficient of determination value (R^2 of 0.7741, 0.7222, 0.7143 and 0.6953 respectively. This category also shows that correlation of Cu has strong relation with PL, LL, γd and γb that gave good correlation result.

4.3.2 Using Multiple Linear Regression Analysis

A number of techniques used to judge the adequacy of a regression model. Some of which are confidence level (CL), R-squared value (R^2), and adjusted R-square (Adj.R^2). The regression coefficients then calculated using SPSS 20 software for each sample parameters to develop best empirical equations and their validation carried out using control test results.

Table 4.12: Input Data for SPSS 20 computer program

TP	NMC	GS	γb	γd	LL	PL	PI	LI	Cu
1	41.79	2.73	1.75	1.27	75.20	40.89	34.31	0.0262	35.16
2	41.15	2.71	1.78	1.35	72.80	39.23	33.57	0.0572	49.02
3	37.91	2.70	1.91	1.45	60.26	30.69	29.57	0.2442	76.71
4	40.86	2.69	1.87	1.43	70.50	39.32	31.18	0.4940	54.86
5	40.12	2.71	1.78	1.30	75.20	40.93	34.27	-0.0236	40.29
6	39.05	2.71	1.79	1.29	72.40	37.50	34.90	0.0444	52.63
7	38.85	2.68	1.95	1.47	60.00	26.73	33.27	0.3643	80.69
8	40.07	2.70	1.87	1.43	73.52	39.97	33.55	0.0030	56.33
9	40.50	2.71	1.82	1.32	72.00	40.51	31.49	-0.0003	43.94
10	38.12	2.72	1.78	1.29	63.60	40.45	23.15	-0.1006	55.37
11	37.86	2.70	1.92	1.46	59.00	28.45	30.55	0.3080	81.66
12	40.56	2.70	1.94	1.45	69.70	32.62	37.08	0.2141	55.49
13	39.52	2.71	1.76	1.32	70.00	38.46	31.54	0.3360	45.27
14	38.94	2.70	1.79	1.40	59.10	38.10	21.00	0.0400	59.02
15	37.54	2.68	1.95	1.47	58.40	26.70	31.70	0.3420	83.74
16	40.04	2.71	1.78	1.42	67.45	32.42	35.03	0.2175	55.64
17	39.75	2.70	1.80	1.30	73.60	36.22	37.38	0.9440	48.18
18	38.67	2.73	1.82	1.41	57.20	29.32	27.88	0.3354	61.14
19	36.23	2.72	1.92	1.46	61.95	27.38	34.57	0.2560	80.06
20	38.54	2.70	1.85	1.41	65.50	32.42	33.08	0.1850	72.11

21	28.2	2.65	1.96	1.48	55.9	28.8	27.1	-0.0221	105
22	36.5	2.68	1.71	1.35	78	40.9	37.1	-0.1186	50
23	27.6	2.75	1.93	1.46	57.4	27.7	29.7	-0.0034	95
24	28	2.72	1.92	1.45	60.8	28.4	32.4	-0.0123	94
25	27.2	2.65	1.97	1.49	56.1	28.5	27.6	-0.0471	105
26	35.4	2.69	1.85	1.40	65.4	31.5	33.9	0.1150	75
27	38.5	2.75	1.71	1.31	85.7	42.4	43.3	-0.0901	37.5
28	37	2.73	1.72	1.32	80.4	41.2	39.2	-0.1071	42.5
29	25.5	2.65	1.94	1.47	56.1	27.5	28.6	-0.0699	95
30	32.9	2.67	1.75	1.38	68.9	32.7	36.2	0.0055	70

4.3.2.1 New Formula developed from Multiple Linear Regression output

To select the best fit model the following points are taken in to consideration

- The value of R^2 for the regression analysis should have relatively higher value and approaches to one.
- The slopes of the line for the measured versus Predicted Undrained shear strength graph should have relatively higher value and approaches to one.
- The equation should give approximately the same undrained shear strength value compared with the measured one for the control test samples.
- Equations that have parameters which could be easily determined in soil mechanics laboratories.

From Multi Linear regression output the following equations gave a better estimation of Calculated Undrained shear strength than many other models developed.

MODEL 1: $Cu = 138.748*\gamma d - 1.246*LL - 44.989$

$R^2 = 0.818$, Adj. $R^2 = 0.804$ and $P < 0.05$

MODEL 2: $Cu = - 3.041*PL – 0.947*PI + 200.159$

$R^2 = 0.815$, Adj.$R^2 = 0.801$ and $P < 0.05$

MODEL 3: $Cu = - 2.251*NMC – 59.22* Gs + 134.842*\gamma b + 59.427$

$R^2 = 0.912$, Adj. $R^2 = 0.902$ and $P < 0.05$

MODEL 4: $Cu = 0.781*LL – 2.501*PL – 21.550*LI +205.894$

$R^2 = 0.868$, Adj.$R^2 = 0.852$ and $P < 0.05$

MODEL 5: $Cu = 90.939*\gamma d – 0.804*LL – 1.311*PL + 37.044$

$R^2 = 0.843$, Adj. $R^2 = 0.825$ and $P < 0.05$

MODEL 6: $Cu = -2.113*NMC - 38.828*Gs + 80.839*\gamma b + 83.471*\gamma d - 17.536$

$R^2 = 0.931$, Adj. $R^2 = 0.920$ and $P < 0.05$

MODEL 7: $Cu = -94.392*Gs + 47.908*\gamma b + 88.165*\gamma d - 1.074*LL + 180.746$

$R^2 = 0.838$, Adj.$R^2 = 0.812$ and $P < 0.05$

MODEL 8: $Cu = -113.629*Gs + 33.951*\gamma b + 46.948*\gamma d - 0.650*LL - 1.354*PL + 333.974$

$R^2 = 0.863$, Adj.$R^2 = 0.835$ and $P < 0.05$

4.3.2.2 Discussion on Multiple Linear Regression

The results of the Regression output of the above models shows that the relationship developed is relatively reasonable because ($P < 0.05$), this shows there is significance relationship between the correlated variables, and the value of R^2 and Adj.R^2 from the multiple linear regression analysis is improved than the R^2value of the single linear regression analysis.

Among Models developed from Multiple Linear Regression, **MODEL 5:** $Cu = 90.939*\gamma d - 0.804*LL - 1.311*PL + 37.044$ describes the relation better than the others. This is because that, the soil under investigation found to be sensitive to dry density, Liquid Limit and Plastic Limit. And also, it has good regression analysis with coefficient of determination (R^2) of 0.843.The equation developed has parameters that easily determined in soil mechanics laboratories. Thus, one may use these suggested equations for the estimation of the undrained shear strength of the study area.

4.4 Checking Adequacy of Developed model using SPSS output

4.4.1 Interpreting Descriptive Statistics

The output described in this section is produced using the options in the Regression as the table 4.13. This table tells us the mean and standard deviation of each variable in a data set, so that the average number of undrained shear strength is 65.2103. This table isn’t necessary for interpreting the regression model, but it is a useful summary of the data.

In addition to the descriptive statistics, selecting this option produces a correlation matrix too. The correlation matrix is extremely useful for getting a rough idea of the relationships between predictors and the outcome, and for a preliminary look for multicollinearity.

Table 4.13: Descriptive Statistics of the Developed model

Descriptive Statistics			
	Mean	Std. Deviation	N
Cu	65.2103	20.56621	30
γd	1.3937	.07010	30
LL	66.7360	8.12192	30
PL	34.2637	5.54491	30

Table 4.14: Correlation Matrix of developed model

Correlations					
		Cu	γd	LL	PL
Pearson Correlation	Cu	1.000	.845	-.850	-.880
	γd	.845	1.000	-.756	-.835
	LL	-.850	-.756	1.000	.843
	PL	-.880	-.835	.843	1.000
Sig. (1-tailed)	Cu	.	.000	.000	.000
	γd	.000	.	.000	.000
	LL	.000	.000	.	.000
	PL	.000	.000	.000	.
N	Cu	30	30	30	30
	γd	30	30	30	30
	LL	30	30	30	30
	PL	30	30	30	30

4.4.2 Regression Model Summary

This section of output describes the overall model, whether the model is successful in predicting Undrained shear strength. This option is selected by default in SPSS because it provides us with some very important information about the model on the values of R, R^2 and the adjusted R^2.

Table 4.15: Model summary of developed Regression model

Model Summary[b]										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.918[a]	.843	.825	8.61294	.843	46.450	3	26	.000	1.028
a. Predictors: (Constant), PL, γd, LL										
b. Dependent Variable: Cu										

From the Table 4.15, model, the R^2 value is 0.843 or 84.3 % which means that the predictors accounts 84.3 % of variation in undrained shear strength. The adjusted R^2gives us some idea of how well the model generalizes and ideally the same or very close to the value of R^2 (Example, the difference is 0.843 - 0.825 = 0.018 (1.8%). This means that if the model derived from the population rather than a sample which account approximately 1.8 % variance in the outcome.

The change statistics tell us whether the change in R^2 is significant. The significance of R^2 can actually be tested using an F-ratio. As such, the change in the amount of variance that can be explained gives F-ratio which is significant ($p <.05$).

Finally, Durbin–Watson statistic is found in the last column of the table in SPSS Output. This statistic informs us about whether the assumption of independent errors is tenable.

4.4.3 Analysis of Variance (ANOVA)

This section output shows whether the model is significantly better at predicting the outcome than using the mean as a best guess. Specifically, the F-ratio represents the ratio of the improvement in prediction that results from fitting the model, relative to the inaccuracy that still exists in the model.

Table 4.16 ANOVA of the developed model

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10337.350	3	3445.783	46.450	.000[b]
	Residual	1928.753	26	74.183		
	Total	12266.103	29			
a. Dependent Variable: CU						
b. Predictors: (Constant), PL, γd, LL						

If the improvement due to fitting the regression model is much greater than the inaccuracy within the model then the value of F will be greater than 1 and SPSS calculates the exact probability of obtaining the value of F by chance. For the model the value of F is 46.450, which is highly significant ($p <.05$). From the ANOVA test results the model significantly improved our ability to predict the outcome variable.

4.4.4 Regression Model parameters

So far several summary statistics tells us whether or not the model has improved our ability to predict the outcome variable. The next part of the output is concerned with the parameters of the model. In multiple regression model there are several unknown quantities (the b-values), which tells the relationship between Undrained shear strength and each predictors. Therefore the t-test associated with b-value is significant, if the value in the column labelled Sig.is < .05 that indicates the predictor have a significant contribution to the model. The smaller the value of Sig. (and the larger the value of t), the greater the contribution of that predictor.

Table 4.17: Coefficients of Regression model parameters for developed model

Model 1	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	37.044	76.717		.483	.000	-120.650	194.739
γd	90.939	42.111	.310	2.159	.040	4.378	177.500
LL	-.804	.372	-.317	-2.162	.040	-1.568	-.040
PL	-1.311	.647	-.353	-2.026	.043	-2.641	.019

Correlations			Collinearity Statistics	
Zero-order	Partial	Part	Tolerance	VIF
.845	.390	.168	.294	3.406
-.850	-.390	-.168	.280	3.566
-.880	-.369	-.158	.240	5.033

a. Dependent Variable: Cu

4.5.5 Multicollinearity Diagnostics

Multicollinearity exists when there is a strong correlation between two or more predictors in a regression model. SPSS produces various collinearity diagnostics, one of which is the variance inflation factor (VIF). The VIF indicates whether a predictor has a strong linear relationship with the other predictor(s). Specifically, it provides the VIF and tolerance statistics (with tolerance being 1/VIF). There are a few guidelines applied here: [40].

- If the largest VIF is greater than 10 then there is cause for concern
- If the average VIF is substantially greater than 1 then the regression may be biased
- Tolerance below 0.1 indicates a serious problem.
- Tolerance below 0.2 indicates a potential problem.

For this model, the VIF values are all well below 10 and the tolerance statistics all well above 0.2; therefore there is no collinearity within a data.

4.6 Comparisons of Previously Developed Models with Values of Study Area

The appropriateness of existing models mostly the Mengistu and Jacob along with the developed model was examined using additional test results stated above from the focused study area.

Cu = 41.805-0.165LL-0.325PL...Jacob [31].

Cu=114.396-1.135LI …….Mengistu [34].

Table 4.18: Comparison of the developed Model with Existing Model

Test Pit No	Measured Cu, kPa	Current Model		Jacob, Kiran		Mengistu, Jara	
		Predicted Cu, kPa	Variation in %	Predicted Cu, kPa	Variation in %	Predicted Cu, kPa	Variation in %
TP1	35.16	38.469	9.411	16.108	54.187	114.366	225.274
TP2	49.02	49.850	1.693	17.043	65.232	114.331	133.234
TP3	76.71	80.222	4.578	21.888	71.467	114.119	48.767
TP4	54.86	58.856	7.284	17.394	68.295	113.835	107.501
TP5	40.29	41.145	2.121	16.095	60.053	114.423	183.998
TP6	52.63	46.983	10.729	17.672	66.423	114.346	117.263
TP7	80.69	87.441	8.367	23.218	71.226	113.983	41.260
TP8	56.33	55.576	1.339	16.684	70.382	114.393	103.076
TP9	43.94	46.087	4.886	16.759	61.859	114.396	160.347
TP10	55.37	50.191	9.354	18.165	67.194	114.510	106.809
TP11	81.66	85.081	4.189	22.824	72.050	114.046	39.660
TP12	55.49	70.102	26.333	19.703	64.493	114.153	105.718
TP13	45.27	50.382	11.293	17.756	60.779	114.015	151.855
TP14	59.02	66.893	13.340	19.671	66.671	114.351	93.749
TP15	83.74	88.767	6.003	23.492	71.947	114.008	36.145
TP16	55.64	69.445	24.811	20.139	63.804	114.149	105.157
TP17	48.18	48.606	0.884	17.890	62.869	113.325	135.211
TP18	61.14	80.841	32.222	22.838	62.646	114.015	86.482
TP19	80.06	84.112	5.061	22.685	71.665	114.105	42.525
TP20	72.11	70.103	2.783	20.461	71.625	114.186	58.350
TP21	105	88.933	15.302	23.222	77.884	114.421	8.972
TP22	50	43.480	13.041	15.643	68.715	114.531	129.061
TP23	95	87.351	8.052	23.332	75.441	114.400	20.421
TP24	94	82.790	11.926	22.543	76.018	114.410	21.713
TP25	105	90.075	14.214	23.286	77.823	114.449	8.999
TP26	75	70.481	6.026	20.777	72.298	114.265	52.354
TP27	37.5	31.685	15.507	13.885	62.975	114.498	-205.329
TP28	42.5	38.429	9.580	15.149	64.355	114.518	169.453
TP29	95	89.567	5.718	23.611	75.146	114.475	20.500
TP30	70	64.275	8.179	19.809	71.701	114.390	63.414

As presented in Table 4.18, from the current Model predicted Cu values are a little bit varied from the measured (actual) Cu value. Also on a Table 4.18, the value which was predicted by existing models were varied from measured value. This may be happened due to the difference in test procedures and the unique properties of the geological material where models were developed. In addition, it is key to note that the test results obtained from the subject study area are may not well matched by the above existing models.

4.7 Validation of the Developed Formula

Among the other Models developed the following equation gives best fit model after the interpretation of SPSS out. The selected model gives adequate regression analysis by fulfilling the required statistical considerations. And also, the developed formula gives almost the same undrained shear strength values of the study area when compared with actual values.

Cu = 90.939*γd – 0.804*LL – 1.311*PL + 37.044

Table 4.19: Predicted Undrained shear strength values using newly developed equations

Test Pit No	Calculated Cu in KPa (A)	Predicted Cu, in KPa (B)	Variation $= \frac{\lvert(A-B)\rvert}{A} * 100$
TP1	35.16	38.469	9.411
TP2	49.02	49.850	1.693
TP3	76.71	80.222	4.578
TP4	54.86	58.856	7.284
TP5	40.29	41.145	2.121
TP6	52.63	46.983	10.729
TP7	80.69	87.441	8.367
TP8	56.33	55.576	1.339
TP9	43.94	46.087	4.886
TP10	55.37	50.191	9.354
TP11	81.66	85.081	4.189
TP12	55.49	70.102	26.333
TP13	45.27	50.382	11.293
TP14	59.02	66.893	13.340
TP15	83.74	88.767	6.003
TP16	55.64	69.445	24.811
TP17	48.18	48.606	0.884
TP18	61.14	80.841	32.222
TP19	80.06	84.112	5.061
TP20	72.11	70.103	2.783
TP21	105	88.933	15.302
TP22	50	43.480	13.041
TP23	95	87.351	8.052
TP24	94	82.790	11.926
TP25	105	90.075	14.214

TP26	75	70.481	6.026
TP27	37.5	31.685	15.507
TP28	42.5	38.429	9.580
TP29	95	89.567	5.718
TP30	70	64.275	8.179
Average Variation			9.807

4.7.1 Cross Validation for control test

In this section it was tried to validate the developed equations by using eight control tests.

The data that is used as a control test is conducted on different parts of Waliso soil sample.

Table 4.20: Sample Data for Control test

Location of Test Pits	NMC	Gs	γb	γd	LL	PL	PI	LI	CU
Ejersa, Garasu Dhuki High School	41.79	2.73	1.75	1.27	75.20	40.89	34.31	0.0262	35.16
Ejersa, Waliso Health Center	41.15	2.71	1.78	1.35	72.80	39.23	33.57	0.0572	49.02
Ayetu, inside Compound of kebele	37.91	2.70	1.91	1.45	60.26	30.69	29.57	0.2442	76.71
Ayetu, around Stadium	40.86	2.69	1.87	1.43	70.50	39.32	31.18	0.4940	54.86
Hora, Waliso Liban primary School	40.12	2.71	1.78	1.30	75.20	40.93	34.27	-0.0236	40.29
Hora, Waliso water Supply	39.05	2.71	1.79	1.29	72.40	37.50	34.90	0.0444	52.63
Burqa Guddina Inside Compound	40.07	2.70	1.87	1.43	73.52	39.97	33.55	0.0030	56.33
BG.Burqa Guddina Primary School	40.50	2.71	1.82	1.32	72.00	40.51	31.49	-0.0003	43.94

Table 4.21: Prediction of Undrained shear strength and Validation of the newly developed equations by Control test Samples

Location of Test Pits	Calculated Cu in KPa (A)	Predicted Cu, in KPa (B)	Variation $= \frac{\lvert(A-B)\rvert}{A} * 100$
Ejersa, Garasu Dhuki High School	35.16	38.469	9.411
Ejersa, Waliso Health Center	49.02	49.850	1.693
Ayetu, inside Compound of it	76.71	80.222	4.578
Ayetu, around Stadium	54.86	58.856	7.284
Hora, Waliso Liban primary School	40.29	41.145	2.121
Hora, Waliso water Supply	52.63	46.983	10.729
Burqa Guddina Inside Compound	56.33	55.576	1.339
BG.Burqa Guddina Primary School	43.94	46.087	4.886
Average Variation			5.255

4.7.2 Discussion on the Validation of Developed Formula

The predicted undrained shear strength values using newly developed equations shows the variation of the actual value with the predicted value of the model is 9.807%. This indicates there is a small variation exit between the actual value and the predicted value and the model developed can be used for estimation of undrained shear strength of the study area.

After Checking Validation of the newly developed equations by Control test Samples, the equations give approximately the same undrained shear strength value compared with the measured one for the control test samples with accuracy range of 5.255%. This indicates that there is a very good prediction of the values.

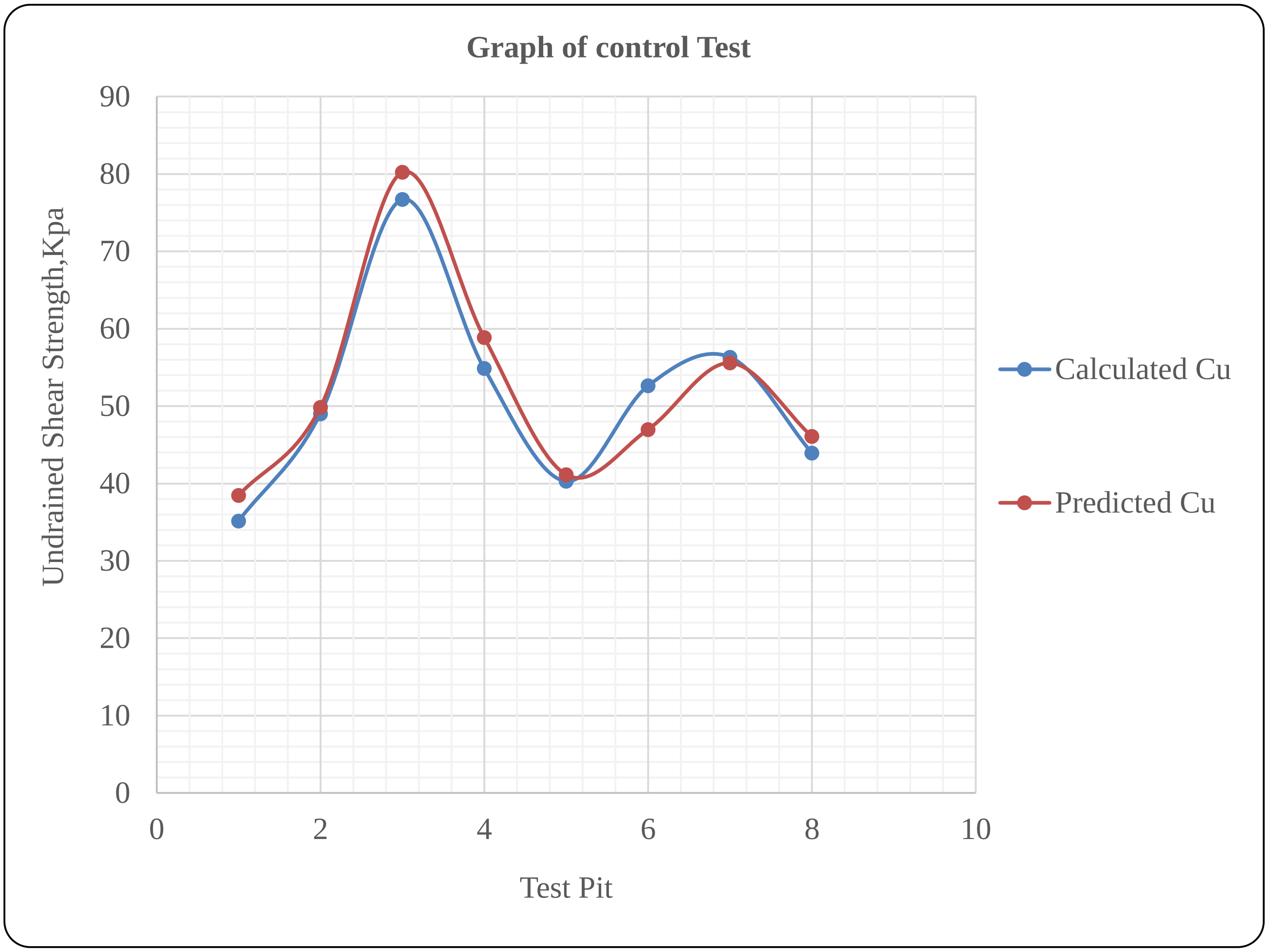


Figure 4-5: Graph of Control test for Validation

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

The research was conducted to study correlation between Undrained shear strength and Index properties of soils found in Waliso town. The necessary laboratory tests were done on samples collected from different places of Waliso town. Using the obtained test results, a single and multiple linear regressions were analysed.

Different models were developed for the prediction of Cu value from Gs, NMC, γbulk, γdry, LL, PL, and PI & LI.

The following conclusions may be drawn from this study.

- From the Single Linear Regression Analysis, the Plastic limit (PL) has good correlation with Undrained shear strength among other single index parameters.
- From multiple linear regression (MLR) analysis, a best Model from all with better coefficient of determination, good significance level and less Std. error was obtained as given below:

  $Cu = 90.939*\gamma d - 0.804*LL - 1.311*PL + 37.044$; $R^2 = 0.843$, Adj. $R^2 = 0.825$,

  $P = 0.00 < 0.05$, Tolerance = 0.294> 0.2 & VIF=5.033< 10.
- Undrained shear strength parameter were significantly correlated with plastic limit, liquid limit, bulk density, dry density, natural moisture content where as it was no significantly correlated with plasticity index, specific gravity and liquidity index of this study area soil.
- Comparison of the measured and predicted undrained shear strength values of all the studied data indicates that there is a good approach between the calculated and Predicted Undrained shear strength values.

5.2 RECOMMENDATIONS

The following points are some of the recommendations given:

- The accuracy of newly developed equations may be further modified by increasing other additional soil samples and by decreasing expected errors during sampling and testing time.
- Further detailed laboratory analysis should be carried out by adding test pit depth of soil samples from different locations of the town.
- From the Comparison made one can see that the newly developed equations are acceptable. But applicability of the result will be limited to the study area. Therefore the results should only be applied to the study area.
- Finally, Waliso is one of the fast growing towns in Oromiya in which further detailed Engineering soil investigation is essential.

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APPENDIX -A: Laboratory Test Results

NATURAL MOISTURE CONTENTS

NATURAL MOISTURE CONTENT										
		Test Pit 1			Test Pit 2			Test Pit 3		
Trial		1	2	3	1	2	3	1	2	3
Can Code		10G	6F	1A	29	P10	K4	P2	T5	P3
Wt of Can	gram	17.6	17.5	17.8	17.4	17.4	17.9	17.5	17.8	17.3
Wt of Can + Wet Soil	gram	76.6	75	84.6	76.3	81.8	83.9	83.2	85.7	88.8
Wt of Can + Dry Soil	gram	59.2	57.9	65.1	59.2	63	64.6	65.3	67.2	68.8
Moisture Content	%	41.83	42.33	41.23	40.91	41.23	41.33	37.45	37.45	38.83
Avg.Moisture Content	%	41.79			41.15			37.91		

NATURAL MOISTURE CONTENT										
		Test Pit 4			Test Pit 5			Test Pit 6		
Trial		1	2	3	1	2	3	1	2	3
Can Code		T1	G3	T2	6F	10G	1A	29	P10	K4
Wt of Can	gram	17.5	17.2	17.6	17.5	17.6	17.8	17.9	17.4	17.5
Wt of Can + Wet Soil	gram	91.4	82.2	85	75.5	75.2	83.9	75.3	80.8	82.9
Wt of Can + Dry Soil	gram	69.3	63.7	65.7	59.2	58.3	65.1	59.2	63.1	64.4
Moisture Content	%	42.66	39.78	40.12	39.09	41.52	39.75	38.98	38.73	39.45
Avg.Moisture Content	%	40.86			40.12			39.05		

NATURAL MOISTURE CONTENT										
		Test Pit 7			Test Pit 8			Test Pit 9		
Trial		1	2	3	1	2	3	1	2	3
Can Code		P2	T5	P3	T1	G3	T2	1A	6F	10G
Wt of Can	gram	17.5	17.8	17.3	17.5	17.2	17.6	17.8	17.5	17.6
Wt of Can + Wet Soil	gram	82.2	85.1	87.9	90.4	81.2	85.1	76.5	75.1	82.9
Wt of Can + Dry Soil	gram	64.3	66.1	68.1	69.3	63.2	65.7	59.2	58.5	64.5
Moisture Content	%	38.25	39.34	38.98	40.73	39.13	40.33	41.79	40.49	39.23
Avg.Moisture Content	%	38.85			40.07			40.50		

NATURAL MOISTURE CONTENT										
		Test Pit 10			Test Pit 11			Test Pit 12		
Trial		1	2	3	1	2	3	1	2	3
Can Code		N10	P12	K4	P2	T5	P3	T1	G3	T2
Wt of Can	gram	17.4	17.4	17.5	17.5	17.8	17.3	17.5	17.2	17.6
Wt of Can + Wet Soil	gram	76.3	81.9	83.9	83.1	86.2	87.2	89.4	82.6	86.1
Wt of Can + Dry Soil	gram	60.2	64.1	65.4	65.3	67.1	68.1	68.6	64.2	65.9
Moisture Content	%	37.62	38.12	38.62	37.24	38.74	37.60	40.70	39.15	41.82
Avg.Moisture Content	%	38.12			37.86			40.56		

NATURAL MOISTURE CONTENT										
		Test Pit 13			Test Pit 14			Test Pit 15		
Trial		1	2	3	1	2	3	1	2	3
Can Code		B2	D8	L10	N10	P12	K4	P2	T5	P3
Wt of Can	gram	17.5	17.8	17.6	17.4	17.6	17.5	17.5	17.8	17.3
Wt of Can + Wet Soil	gram	77.8	76.1	80.2	79.4	82.6	83.9	84.9	86.9	89.2
Wt of Can + Dry Soil	gram	60.6	59.4	62.8	62.1	64.1	65.5	66.8	68.1	69.2
Moisture Content	%	39.91	40.14	38.50	38.70	39.78	38.33	36.71	37.38	38.54
Avg.Moisture Content	%	39.52			38.94			37.54		

NATURAL MOISTURE CONTENT										
		Test Pit 16			Test Pit 17			Test Pit 18		
Trial		1	2	3	1	2	3	1	2	3
Can Code		T1	G3	T2	B2	D8	L10	N10	P12	K4
Wt of Can	gram	17.5	17.2	17.6	17.5	17.8	17.6	17.4	17.6	17.5
Wt of Can + Wet Soil	gram	88.2	83.9	85.8	79.4	77.1	84.1	78.4	81.6	82.9
Wt of Can + Dry Soil	gram	67.8	65.1	66.2	62.1	60.2	64.9	61.5	63.8	64.5
Moisture Content	%	40.56	39.25	40.33	38.79	39.86	40.59	38.32	38.53	39.15
Avg.Moisture Content	%	40.04			39.75			38.67		

NATURAL MOISTURE CONTENT							
		Test Pit 19			Test Pit 20		
Trial		1	2	3	1	2	3
Can Code		P2	T5	P3	T1	G3	T2
Wt of Can	gram	17.5	17.8	17.3	17.5	17.2	17.6
Wt of Can + Wet Soil	gram	82.9	84.1	85.6	84.1	82.6	85.8
Wt of Can + Dry Soil	gram	65.7	66.5	67.2	65.6	64.5	66.7
Moisture Content	%	35.68	36.14	36.87	38.46	38.27	38.90
Avg. Moisture Content	%	36.23			38.54		

Specific Gravity

Specific Gravity										
			Test pit 1			Test pit 2			Test pit 3	
Initial Temp.Ti	21°C		Final Temp.TX		23°C	Ti =21°C	TX=23°C		Ti =21°C	TX=23°C
Trial no.			1	2	3	1	2	3	1	2	3
Pycnometer(P).Code			3H	B	A7	8	2	11	3	9	D
Mass of P.(MP)		gram	24.9	26.6	26.9	26.4	25.3	22.5	27	27.1	25.9
MP +Water (MPW) at Ti		gram	120.5	122.1	121.7	123.1	117.5	118.4	121.3	121.3	120.6
MP + dry soil (MPS)		gram	49.9	51.6	51.9	51.4	50.3	47.5	52	52.1	50.9
Mass of dry soil (MS)		gram	25	25	25	25	25	25	25	25	25
MP + Soil + Water (MPSW)		gram	136.4	137.9	137.5	138.9	133.3	134.1	137.1	137	136.3
Correction factor (K) for TX			0.9993	0.9993	0.9993	0.9993	0.9993	0.9993	0.9993	0.9993	0.9993
Gs at TX			2.75	2.72	2.72	2.72	2.72	2.69	2.72	2.69	2.69
Gs at 20°C			2.75	2.72	2.72	2.72	2.72	2.69	2.72	2.69	2.69
Avg.Gs at 20°C			2.73			2.71			2.70		

Specific Gravity										
			Test pit 4			Test pit 5			Test pit 6	
Initial Temp.Ti	21°C		Final Temp.TX		24°C	Ti =21°C	TX=23°C		Ti =21°C	TX=23°C
Trial no.			1	2	3	1	2	3	1	2	3
Pycnometer(P).Code			18	13	H	3H	B	A7	8	2	11
Mass of P.(MP)		gram	27	25.4	26.7	24.9	26.6	26.9	25.4	25.3	23.5
MP +Water (MPW) at Ti		gram	122.2	123.5	122.8	120.6	121.5	121.5	122.1	117.3	119.8
MP + dry soil (MPS)		gram	52	50.4	51.7	49.9	51.6	51.9	51.4	50.3	47.5
Mass of dry soil (MS)		gram	25	25	25	25	25	25	25	25	25
MP + Soil + Water (MPSW)		gram	137.8	139.2	138.6	136.4	137.2	137.3	137.8	133.1	135.6
Correction factor (K) for TX			0.9991	0.9991	0.9991	0.9993	0.9993	0.9993	0.9993	0.9993	0.9993
Gs at TX			2.66	2.69	2.72	2.72	2.69	2.72	2.69	2.72	2.72
Gs at 20°C			2.66	2.69	2.71	2.72	2.69	2.72	2.69	2.72	2.72
Avg.Gs at 20°C			2.69			2.71			2.71		

Specific Gravity										
			Test pit 7			Test pit 8			Test pit 9	
Initial Temp.Ti	21°C		Final Temp.TX		23°C	Ti =21°C	TX=24°C		Ti =21°C	TX=23°C
Trial no.			1	2	3	1	2	3	1	2	3
Pycnometer(P).Code			3	9	D	18	13	H	3H	B	A7
Mass of P.(MP)		gram	27.1	27.1	25.9	27.1	25.4	26.7	25.1	26.6	26.9
MP +Water (MPW) at Ti		gram	121.4	121.5	120.9	122.2	123.5	122.8	120.8	121.5	121.5
MP + dry soil (MPS)		gram	52.1	52.1	50.9	52	50.4	51.7	49.9	51.6	51.9
Mass of dry soil (MS)		gram	25	25	25	25	25	25	25	25	25
MP + Soil + Water (MPSW)		gram	137.1	137.2	136.5	137.9	139.2	138.6	136.6	137.2	137.3
Correction factor (K) for TX			0.9993	0.9993	0.9993	0.9991	0.9991	0.9991	0.9993	0.9993	0.9993
Gs at TX			2.69	2.69	2.66	2.69	2.69	2.72	2.72	2.69	2.72
Gs at 20°C			2.69	2.69	2.66	2.69	2.69	2.71	2.72	2.69	2.72
Avg.Gs at 20°C			2.68			2.70			2.71		

Specific Gravity											
			Test pit 13			Test pit 14			Test pit 15		
Initial Temp.Ti	21°C	Final Temp.TX			23°C	Ti =21°C	TX=23°C		Ti =21°C	TX=23°C	
Trial no.			1	2	3	1	2	3	1	2	3
Pycnometer(P).Code			3H	B	A7	8	2	11	3	9	D
Mass of P.(MP)		gram	26.1	26.6	26.9	25.5	25.3	23.5	27.1	27.1	25.9
MP +Water (MPW) at Ti		gram	121.6	121.4	121.4	122.1	118.5	119.7	121.6	121.5	121.2
MP + dry soil (MPS)		gram	49.9	51.6	51.9	51.4	50.3	47.5	52.1	52.1	50.9
Mass of dry soil (MS)		gram	25	25	25	25	25	25	25	25	25
MP + Soil + Water (MPSW)		gram	137.4	137.1	137.2	137.9	134.2	135.4	137.2	137.2	136.9
Correction factor (K) for TX			0.9993	0.9993	0.9993	0.9993	0.9993	0.9993	0.9993	0.9993	0.9993
Gs at TX			2.72	2.69	2.72	2.72	2.69	2.69	2.66	2.69	2.69
Gs at 20°C			2.72	2.69	2.72	2.72	2.69	2.69	2.66	2.69	2.69
Avg.Gs at 20°C			2.71			2.70			2.68		

Specific Gravity											
			Test pit 16			Test pit 17			Test pit 18		
Initial Temp.Ti	21°C	Final Temp.TX			24°C	Ti =21°C	TX=23°C		Ti =21°C	TX=23°C	
Trial no.			1	2	3	1	2	3	1	2	3
Pycnometer(P).Code			18	13	H	3H	B	A7	8	2	11
Mass of P.(MP)		gram	27.1	25.4	26.7	25.1	26.6	26.9	26.4	25.3	22.5
MP +Water (MPW) at Ti		gram	122.1	123.5	122.8	120.9	122.1	121.7	123	117.4	118.1
MP + dry soil (MPS)		gram	52	50.4	51.7	49.9	51.6	51.9	51.4	50.3	47.5
Mass of dry soil (MS)		gram	25	25	25	25	25	25	25	25	25
MP + Soil + Water (MPSW)		gram	137.9	139.2	138.6	136.6	137.8	137.5	138.8	133.2	134
Correction factor (K) for TX			0.9991	0.9991	0.9991	0.9993	0.9993	0.9993	0.9993	0.9993	0.9993
Gs at TX			2.72	2.69	2.72	2.69	2.69	2.72	2.72	2.72	2.75
Gs at 20°C			2.71	2.69	2.71	2.69	2.69	2.72	2.72	2.72	2.75
Avg.Gs at 20°C			2.71			2.70			2.73		

Specific Gravity								
			Test pit 19			Test pit 20		
Initial Temp. Ti	21°C	Final Temp. TX			23°C	Ti =21°C	TX=24°C	
Trial no.			1	2	3	1	2	3
Pycnometer(P).Code			3	9	D	18	13	H
Mass of P.(MP)		gram	27	27.1	25.9	27	25.4	26.7
MP +Water (MPW) at Ti		gram	121.3	121.5	120.3	122.1	123.5	122.8
MP + dry soil (MPS)		gram	52	52.1	50.9	52	50.4	51.7
Mass of dry soil (MS)		gram	25	25	25	25	25	25
MP + Soil + Water (MPSW)		gram	137.1	137.2	136.2	137.8	139.2	138.6
Correction factor (K) for TX			0.9993	0.9993	0.9993	0.9991	0.9991	0.9991
Gs at TX			2.72	2.69	2.75	2.69	2.69	2.72
Gs at 20°C			2.72	2.69	2.75	2.69	2.69	2.71
Avg. Gs at 20°C			2.72			2.70		

Bulk Density & Dry Density

Test Type:	Bulk and dry density								
Test pit	1			2			3		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
Mass of can (MC)	17.10	17.1	17.10	37.70	33.2	35.45	17.60	17.3	17.45
MC+ Wet soil (MCWS)	162.60	171.5	167.05	102.50	105.5	104.00	96.70	98.4	97.55
MC + Dry Soil (MCDS)	122.50	130.5	126.50	86.30	88.5	87.40	77.50	78.8	78.15
Mass of Dry soil (MDS)	105.40	113.4	109.40	48.60	55.3	51.95	59.90	61.5	60.70
Mass of Water (MW)	40.10	41	40.55	16.20	17	16.60	19.20	19.6	19.40
Water content (w)	38.05	36.16	37.10	33.33	30.74	32.04	32.05	31.87	31.96
Total weight(gm)	146.00	141.2	143.60	158.50	144	151.25	168.20	169.30	168.75
Height(cm)	7.50	7.40	7.45	8.00	7.4	7.70	8.00	8.00	8.00
Volume(cm^3)	82.79	81.69	82.24	88.31	81.69	85.00	88.31	88.31	88.31
wet unit wt (KN/m^3)	17.30	16.96	17.13	17.61	17.29	17.45	18.68	18.81	18.75
Dry unit wt (KN/m^3)	12.53	12.45	12.49	13.20	13.23	13.22	14.15	14.26	14.21
Dry Density (Kg/m^3)	1.28	1.27	1.27	1.35	1.35	1.35	1.44	1.45	1.45
Bulk density (Kg/m^3)	1.76	1.73	1.75	1.79	1.76	1.78	1.90	1.92	1.91

Test Type:	Bulk and dry density								
Test pit	4			5			6		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
Mass of can (MC)	17.40	17.5	17.45	17.10	17.1	17.10	37.70	36.2	36.95
MC+ Wet soil (MCWS)	88.60	100.7	94.65	162.60	172.5	167.55	102.50	105.5	104.00
MC + Dry Soil (MCDS)	72.70	79.9	76.30	122.50	131.5	127.00	84.30	85.9	85.10
Mass of Dry soil (MDS)	55.30	62.4	58.85	105.40	114.40	109.90	46.60	49.7	48.15
Mass of Water (MW)	15.90	20.8	18.35	40.10	41.00	40.55	18.20	19.60	18.90
Water content (w)	28.75	33.33	31.04	38.05	35.84	36.94	39.06	39.44	39.25
Total weight(gm)	164.70	168.20	166.45	146.00	148.2	147.10	158.50	154.4	156.45
Height(cm)	8.00	8.10	8.05	7.50	7.50	7.50	8.00	7.8	7.90
Volume(cm^3)	88.31	89.42	88.86	82.79	82.79	82.79	88.31	86.10	87.21
wet unit wt (KN/m^3)	18.30	18.45	18.37	17.30	17.56	17.43	17.61	17.59	17.60
Dry unit wt (KN/m^3)	14.21	13.84	14.02	12.53	12.93	12.73	12.66	12.62	12.64
Dry Density (Kg/m^3)	1.45	1.41	1.43	1.28	1.32	1.30	1.29	1.29	1.29
Bulk density (Kg/m^3)	1.86	1.88	1.87	1.76	1.79	1.78	1.79	1.79	1.79

Test Type:	Bulk and dry density								
Test pit	7			8			9		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
Mass of can (MC)	17.60	17.4	17.50	17.40	17.5	17.45	17.20	17.3	17.25
MC+ Wet soil (MCWS)	96.80	98.6	97.70	88.60	100.7	94.65	162.60	172.5	167.55
MC + Dry Soil (MCDS)	77.50	78.8	78.15	71.70	80.9	76.30	122.50	130.5	126.50
Mass of Dry soil (MDS)	59.90	61.4	60.65	54.30	63.4	58.85	105.30	113.20	109.25
Mass of Water (MW)	19.30	19.8	19.55	16.90	19.8	18.35	40.10	42.00	41.05
Water content (w)	32.22	32.25	32.23	31.12	31.23	31.18	38.08	37.10	37.59
Total weight(gm)	171.60	172.20	171.90	164.70	168.20	166.45	159.20	157.3	158.25
Height(cm)	8.00	8.00	8.00	8.00	8.10	8.05	7.80	8.00	7.90
Volume(cm^3)	88.31	88.31	88.31	88.31	89.42	88.86	86.10	88.31	87.21
wet unit wt (KN/m^3)	19.06	19.13	19.10	18.30	18.45	18.37	18.14	17.47	17.81
Dry unit wt (KN/m^3)	14.42	14.46	14.44	13.95	14.06	14.01	13.14	12.74	12.94
Dry Density (Kg/m^3)	1.47	1.47	1.47	1.42	1.43	1.43	1.34	1.30	1.32
Bulk density (Kg/m^3)	1.94	1.95	1.95	1.86	1.88	1.87	1.85	1.78	1.82

Test Type:	Bulk and dry density								
Test pit	10			11			12		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
Mass of can (MC)	37.70	36.2	36.95	17.40	17.60	17.50	17.40	17.50	17.45
MC+ Wet soil (MCWS)	102.50	105.5	104.00	96.80	98.60	97.70	89.60	101.70	95.65
MC + Dry Soil (MCDS)	84.30	86.5	85.40	77.90	78.80	78.35	71.70	79.9	75.80
Mass of Dry soil (MDS)	46.60	50.3	48.45	60.50	61.20	60.85	54.30	62.4	58.35
Mass of Water (MW)	18.20	19.00	18.60	18.90	19.80	19.35	17.90	21.8	19.85
Water content (w)	39.06	37.77	38.41	31.24	32.35	31.80	32.97	34.94	33.95
Total weight(gm)	158.50	152.4	155.45	170.60	171.20	170.90	169.70	175.20	172.45
Height(cm)	8.00	7.8	7.90	8.00	8.10	8.05	8.00	8.10	8.05
Volume(cm^3)	88.31	86.10	87.21	88.31	89.42	88.86	88.31	89.42	88.86
wet unit wt (KN/m^3)	17.61	17.36	17.48	18.95	18.78	18.87	18.85	19.22	19.04
Dry unit wt (KN/m^3)	12.66	12.60	12.63	14.44	14.19	14.32	14.18	14.24	14.21
Dry Density (Kg/m^3)	1.29	1.28	1.29	1.47	1.45	1.46	1.45	1.45	1.45
Bulk density (Kg/m^3)	1.79	1.77	1.78	1.93	1.91	1.92	1.92	1.96	1.94

Test Type:	Bulk and dry density								
Test pit	13			14			15		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
Mass of can (MC)	17.30	17.4	17.35	17.40	17.6	17.50	17.40	17.60	17.50
MC+ Wet soil (MCWS)	162.60	172.5	167.55	102.50	105.5	104.00	96.80	98.60	97.70
MC + Dry Soil (MCDS)	127.50	132.5	130.00	84.10	86.2	85.15	76.90	78.80	77.85
Mass of Dry soil (MDS)	110.20	115.10	112.65	66.70	68.6	67.65	59.50	61.20	60.35
Mass of Water (MW)	35.10	40.00	37.55	18.40	19.30	18.85	19.90	19.80	19.85
Water content (w)	31.85	34.75	33.30	27.59	28.13	27.86	33.45	32.35	32.90
Total weight(gm)	154.20	156.5	155.35	158.50	160.4	159.45	176.60	174.20	175.40
Height(cm)	8.00	8.00	8.00	8.00	8.1	8.05	8.20	8.10	8.15
Volume(cm^3)	88.31	88.31	88.31	88.31	89.42	88.86	90.52	89.42	89.97
wet unit wt (KN/m^3)	17.13	17.38	17.26	17.61	17.60	17.60	19.14	19.11	19.13
Dry unit wt (KN/m^3)	12.99	12.90	12.95	13.80	13.73	13.77	14.34	14.44	14.39
Dry Density (Kg/m^3)	1.32	1.32	1.32	1.41	1.40	1.40	1.46	1.47	1.47
Bulk density (Kg/m^3)	1.75	1.77	1.76	1.79	1.79	1.79	1.95	1.95	1.95

Test Type:	Bulk and dry density								
Test pit	16			17			18		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
Mass of can (MC)	17.40	17.60	17.50	17.50	17.4	17.45	17.40	17.3	17.35
MC+ Wet soil (MCWS)	92.60	101.70	97.15	168.60	172.5	170.55	99.50	102.5	101.00
MC + Dry Soil (MCDS)	77.70	83.9	80.80	126.50	130.5	128.50	81.30	83.25	82.28
Mass of Dry soil (MDS)	60.30	66.3	63.30	109.00	113.10	111.05	63.90	65.95	64.93
Mass of Water (MW)	14.90	17.8	16.35	42.10	42.00	42.05	18.20	19.25	18.73
Water content (w)	24.71	26.85	25.78	38.62	37.14	37.88	28.48	29.19	28.84
Total weight(gm)	156.70	160.20	158.45	161.20	158.5	159.85	156.50	160.4	158.45
Height(cm)	8.00	8.10	8.05	8.10	8.00	8.05	7.80	8.00	7.90
Volume(cm^3)	88.31	89.42	88.86	89.42	88.31	88.86	86.10	88.31	87.21
wet unit wt (KN/m^3)	17.41	17.58	17.49	17.69	17.61	17.65	17.83	17.82	17.82
Dry unit wt (KN/m^3)	13.96	13.86	13.91	12.76	12.84	12.80	13.88	13.79	13.83
Dry Density (Kg/m^3)	1.42	1.41	1.42	1.30	1.31	1.30	1.41	1.41	1.41
Bulk density (Kg/m^3)	1.77	1.79	1.78	1.80	1.79	1.80	1.82	1.82	1.82

Test Type:	Bulk and dry density					
Test pit	19			20		
Trial	1	2	Avg.	1	2	Avg.
Mass of can (MC)	17.40	17.50	17.45	17.30	17.40	17.35
MC+ Wet soil (MCWS)	95.80	97.60	96.70	90.60	102.70	96.65
MC + Dry Soil (MCDS)	76.90	78.20	77.55	72.70	82.9	77.80
Mass of Dry soil (MDS)	59.50	60.70	60.10	55.40	65.5	60.45
Mass of Water (MW)	18.90	19.40	19.15	17.90	19.8	18.85
Water content (w)	31.76	31.96	31.86	32.31	30.23	31.27
Total weight(gm)	172.10	174.10	173.10	163.70	167.20	165.45
Height(cm)	8.10	8.20	8.15	8.00	8.20	8.10
Volume(cm^3)	89.42	90.52	89.97	88.31	90.52	89.42
wet unit wt (KN/m^3)	18.88	18.87	18.87	18.18	18.12	18.15
Dry unit wt (KN/m^3)	14.33	14.30	14.31	13.74	13.91	13.83
Dry Density (Kg/m^3)	1.46	1.46	1.46	1.40	1.42	1.41
Bulk density (Kg/m^3)	1.92	1.92	1.92	1.85	1.85	1.85

Combined Grain Size Distribution Tables and Curves from sieve & hydrometer analysis

PARTICLE SIZE DISTRIBUTION OF TEST PIT 1

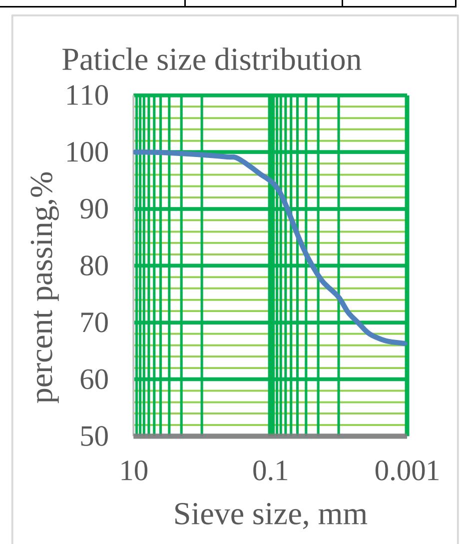
Sieve Analysis

Sample preparation : Oven-dried sample				
Method of sieving: Wet sieving				
Mass dry soil	1000	gm	gm	
mass pass 0.075	932.18	gm	gm	
percentage of pass 0.075 mm	93.22	%	%	
Total mass	1000		gm	
Sieve Size	Mass R, gm	% of Retain	% Cum. R	% of Pass
9.5	0.00	0	0	100
4.75	0.40	0.04	0.04	99.96
2	2.10	0.21	0.25	99.75
0.85	2.90	0.29	0.54	99.46
0.425	3.10	0.31	0.85	99.15
0.300	2.50	0.25	1.1	98.9
0.150	25.12	2.51	3.61	96.39
0.075	31.70	3.17	6.78	93.22
Pan	932.18	93.22	100.00	0.00

Combined Sieve and Hydrometer Analysis

particle size	percent pass
9.5	100
4.75	99.96
2	99.75
0.85	99.46
0.4250	99.15
0.300	98.9
0.150	96.388
0.075	93.22
0.0376	84.66
0.0270	80.99
0.0174	77.33
0.0102	74.57
0.0073	71.82
0.0052	69.99
0.0037	68.15
0.0026	67.24
0.0019	66.69
0.0011	66.32

% of soil particle size	AASHTO	USCS
% of gravel	0.25	0.04
% of Sand	6.53	6.74
% of Silt	23.23	26.53
% of Clay	69.99	66.69



Hydrometer analysis

Total oven Dry mass 50

Specific Gravity 2.73

Time (min.)	A. Hydr Reading	Temp.	Comp.corr.	Corr.Hydr reading	Corr. factor (a)	Effe. Depth of Hydromet	Values of K	Diameter of soil Particle (mm)	% finer,P	Adjusted Percent of finer
1	50	21	-3.85	46.15	0.984	8.2	0.013166	0.0376	90.82	84.66
2	48	21	-3.85	44.15	0.984	8.4	0.013166	0.0270	86.89	80.99
5	46	21	-3.85	42.15	0.984	8.8	0.013166	0.0174	82.95	77.33
15	44.5	21	-3.85	40.65	0.984	9.0	0.013166	0.0102	80.00	74.57
30	43	21	-3.85	39.15	0.984	9.2	0.013166	0.0073	77.05	71.82
60	42	21	-3.85	38.15	0.984	9.4	0.013166	0.0052	75.08	69.99
120	41	22	-3.85	37.15	0.984	9.6	0.013012	0.0037	73.11	68.15
240	40.5	22	-3.85	36.65	0.984	9.7	0.013012	0.0026	72.13	67.24
480	40.2	21	-3.85	36.35	0.984	9.7	0.013166	0.0019	71.54	66.69
1440	40	21	-3.85	36.15	0.984	9.7	0.013166	0.0011	71.14	66.32

Test Pit 2

PARTICLE SIZE DISTRIBUTION

Sieve analysis

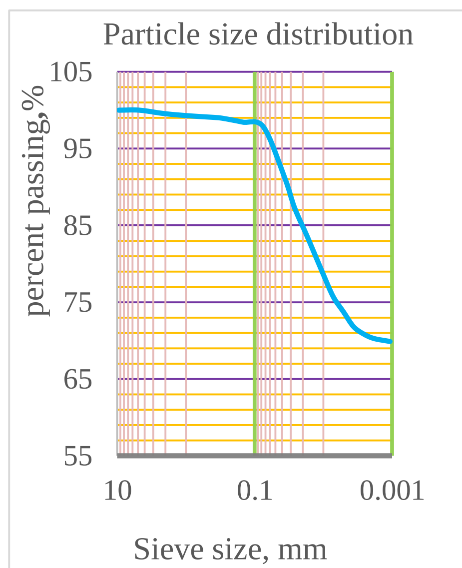
Sample preparation : Oven-dried sample		
Method of sieving: Wet sieving		
Mass dry soil	1000	gm
mass pass 0.075	978	gm
percentage of pass 0.075 mm	97.84	%

Sieve Size,	Mas of R, gm	% R	% Cum. R	% Pass
9.5	0	0	0	100
4.75	0.000	0	0	100
2	4.600	0.46	0.46	99.54
0.85	2.900	0.29	0.75	99.25
0.425	1.700	0.17	0.92	99.08
0.300	1.200	0.12	1.04	98.96
0.150	5.100	0.51	1.55	98.45
0.075	6.100	0.61	2.16	97.84
Pass	978.400	97.84	100	0

Combined sieve and Hydrometer Analysis

particle size	percent pass
9.5	100
4.75	100
2	99.54
0.85	99.25
0.4250	99.08
0.300	98.96
0.150	98.45
0.075	97.84
0.036	91.16
0.026	87.29
0.017	83.42
0.010	78.59
0.007	75.69
0.005	73.76
0.004	71.82
0.003	70.86
0.002	70.28
0.001	69.89

% of soil particle size	AASHTO	USCS
% of gravel	0.46	0.00
% of Sand	1.70	2.16
% of Silt	27.56	24.08
% of Clay	70.28	73.76



Hydrometer analysis

Total oven Dry mass 50

Specific Gravity 2.71

Time (min.)	A. Hydro. Reading	Temp.	Composite Correction	Corrected Hydrometer Reading	Correction factor (a)	Eff. Depth Of Hydro. (L)	Values of K	Diameter of soil Particle (mm)	% finer,P	Adjusted % of finer
1	51	21	-3.85	47.15	0.988	8.0	0.013242	0.037	93.17	91.16
2	49	21	-3.85	45.15	0.988	8.3	0.013242	0.027	89.22	87.29
5	47	21	-3.85	43.15	0.988	8.6	0.013242	0.017	85.26	83.42
15	44.5	21	-3.85	40.65	0.988	9.0	0.013242	0.010	80.32	78.59
30	43	21	-3.85	39.15	0.988	9.3	0.013242	0.007	77.36	75.69
60	42	21	-3.85	38.15	0.988	9.5	0.013242	0.005	75.38	73.76
120	41	22	-3.85	37.15	0.988	9.6	0.013084	0.004	73.41	71.82
240	40.5	22	-3.85	36.65	0.988	9.7	0.013084	0.003	72.42	70.86
480	40.2	21	-3.85	36.35	0.988	9.7	0.013242	0.002	71.83	70.28
1440	40	21	-3.85	36.15	0.988	9.8	0.013242	0.001	71.43	69.89

Test Pit 3

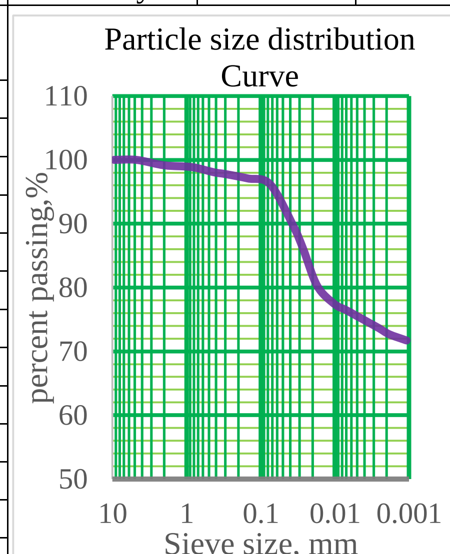
TEST METHOD: ASTM D 422		
Sample preparation: Oven-dried sample		
Method of sieving:Wet sieving		
Mass dry soil (before wash)	1000	gm
mass pass 0.075 mm	961.95	gm
%ge of pass 0.075 mm	9.62	%

Sieve Size	Wt. R	% R	% Cum. Retained	% Pass
9.5	0	0	0	100
4.75	0.05	0.005	0.005	99.995
2	8.50	0.85	0.855	99.145
0.85	2.80	0.28	1.135	98.865
0.425	8.20	0.82	1.955	98.045
0.300	2.70	0.27	2.225	97.775
0.150	6.80	0.68	2.905	97.095
0.075	9.00	0.9	3.805	96.20
Pass	961.95	96.195	100	0

Combined sieve and Hydrometer Analysis

particle size	percent pass
9.5	100.00
4.75	100.00
2	99.15
0.85	98.87
0.4250	98.05
0.300	97.78
0.150	97.10
0.075	96.20
0.037	89.80
0.027	86.00
0.017	80.28
0.010	77.42
0.007	76.47
0.005	75.52
0.004	74.57
0.003	73.62
0.002	72.66
0.001	71.71

% of soil particle size	AASHTO	USCS
% of gravel	0.86	0.00
% of Sand	2.95	3.80
% of Silt	23.53	23.53
% of Clay	72.66	72.66



Hydrometer Analysis

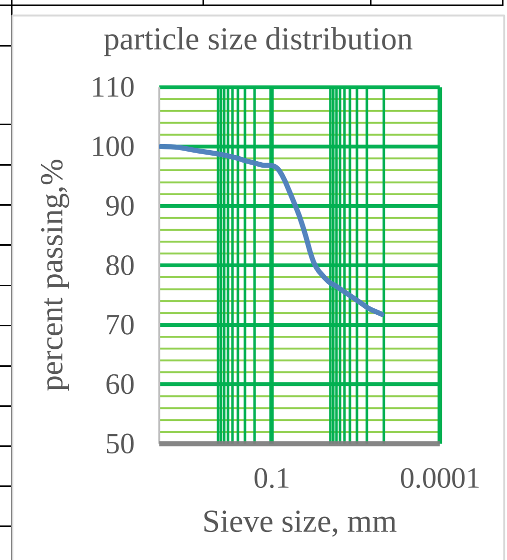
Total oven Dry mass 50

Specific Gravity 2.70

Time (minutes)	Hydrometer Reading	Temp.	Composite correction	Corrected Hydro. Reading.	Correction factor(a)	Effe. Depth of Hydro. (L)	Values of K	Diameter of soil Particle (mm)	% finer,P	Adjusted Percent finer
1	51	22	-3.85	47.15	0.990	7.9	0.01312	0.037	93.36	89.80
2	49	22	-3.85	45.15	0.990	8.3	0.01312	0.027	89.40	86.00
5	46	22	-3.85	42.15	0.990	8.8	0.01312	0.017	83.46	80.28
15	44.5	22	-3.85	40.65	0.990	9.0	0.01312	0.010	80.49	77.42
30	44	23	-3.85	40.15	0.990	9.1	0.01282	0.007	79.50	76.47
60	43.5	23	-3.85	39.65	0.990	9.2	0.01282	0.005	78.51	75.52
120	43	23	-3.85	39.15	0.990	9.2	0.01282	0.004	77.52	74.57
240	42.5	23	-3.85	38.65	0.990	9.3	0.01282	0.003	76.53	73.62
480	42	22	-3.85	38.15	0.990	9.4	0.01312	0.002	75.54	72.66
1440	41.5	21	-3.85	37.65	0.990	9.5	0.01328	0.001	74.55	71.71

Test Pit 4

PARTICLE SIZE DISTRIBUTION									
Sieve Analysis					Combined sieve and hydrometer analysis				
Sample preparation : Oven-dried sample					particle size	percent pass	% of soil particle size	AASHTO	USCS
Method of sieving: Wet Sieving					9.5	100	% of gravel	0.73	0.12
Mass dry soil (before wash)			1000	gm	4.75	99.88	% of Sand	3.18	3.79
mass pass 0.075 mm			960.9	gm	2	99.27	% of Silt	23.36	23.36
% of pass 0.075 mm			9.609	%	0.85	98.72	% of Clay	72.73	72.73
Total mass			1000	gm	0.425	98.1			
Sieve Size	Wt. R	% R	% Cum. Retained	% P	0.300	97.65			
9.5	0	0	0	100	0.150	96.91			
4.75	1.20	0.12	0.12	99.88	0.075	96.09			
2	6.10	0.61	0.73	99.27	0.037	89.89			
0.85	5.50	0.55	1.28	98.72	0.027	86.08			
0.425	6.20	0.62	1.9	98.1	0.017	80.36			
0.300	4.50	0.45	2.35	97.65	0.010	77.50			
0.150	7.40	0.74	3.09	96.91	0.007	76.54			
0.075	8.20	0.82	3.91	96.09	0.005	75.59			
Pass	960.90	96.09	100	0	0.004	74.64			
					0.003	73.68			
					0.002	72.73			
					0.001	71.78			



Hydrometer Analysis

Total oven dry mass 50

Specific Gravity 2.69

Time (min)	A/Hydr. Rdg	Temp.	Comp. Corr.	Corr. Hydr. Rfg	Corr. factor(a)	Effe. Depth of Hydr.(L)	Values of K	D (mm)	% finer,P	Adj. % of finer
1	51	22	-3.85	47.15	0.992	8.0	0.01316	0.037	93.55	89.89
2	49	22	-3.85	45.15	0.992	8.3	0.01316	0.027	89.58	86.08
5	46	22	-3.85	42.15	0.992	8.8	0.01316	0.017	83.63	80.36
15	44.5	22	-3.85	40.65	0.992	9.0	0.01316	0.010	80.65	77.50
30	44	23	-3.85	40.15	0.992	9.1	0.01301	0.007	79.66	76.54
60	43.5	23	-3.85	39.65	0.992	9.2	0.01301	0.005	78.67	75.59
120	43	23	-3.85	39.15	0.992	9.2	0.01301	0.004	77.67	74.64
240	42.5	23	-3.85	38.65	0.992	9.3	0.01301	0.003	76.68	73.68
480	42	23	-3.85	38.15	0.992	9.4	0.01301	0.002	75.69	72.73
1440	41.5	21	-3.85	37.65	0.992	9.5	0.01332	0.001	74.70	71.78

Test pit 5

PARTICLE SIZE DISTRIBUTION

Sieve Analysis

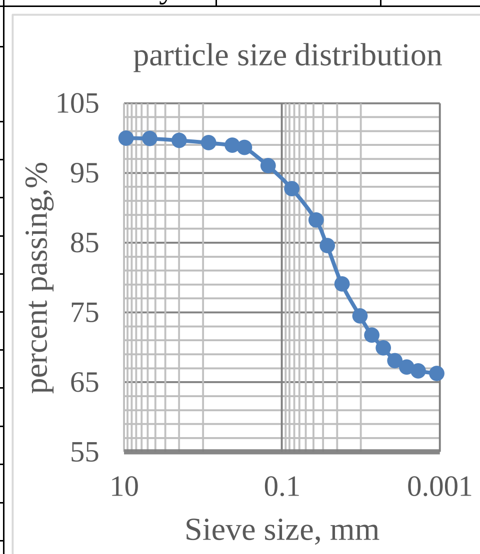
Sample preparation : Oven-dried sample		
Method of sieving: Wet Sieving		
Mass dry soil	1000	gm
Mass pass 0.075 mm,	927.40	gm
percentage of pass 0.075	92.74	%
Total mass	1000	gm

Sieve Size,mm	Wt. R	% R	% Cum. Retained	% P
9.5	0	0	0	100
4.75	0.800	0.08	0.08	99.92
2.00	2.600	0.26	0.34	99.66
0.85	3.400	0.34	0.68	99.32
0.425	3.600	0.36	1.04	98.96
0.300	2.900	0.29	1.33	98.67
0.150	26.500	2.65	3.98	96.02
0.075	32.800	3.28	7.26	92.74
Pass	927.40	92.74	100	0

Combined sieve & Hydrometer analysis

particle size	percent pass
9.5	100
4.75	99.92
2	99.66
0.85	99.32
0.4250	98.96
0.300	98.67
0.150	96.02
0.075	92.74
0.0370	88.24
0.0267	84.57
0.0174	79.07
0.0103	74.49
0.0073	71.74
0.0052	69.91
0.0037	68.08
0.0026	67.16
0.0019	66.61
0.0011	66.25

% of soil particle size	AASHTO	USCS
% of gravel	0.34	0.08
% of Sand	6.92	7.18
% of Silt	26.13	26.13
% of Clay	66.61	66.61



Hydrometer Analysis

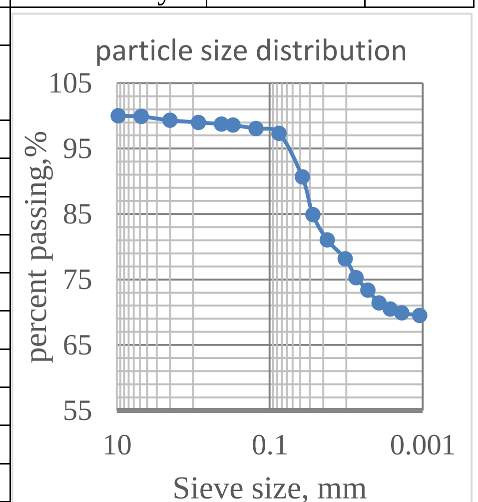
Total oven Dry mass 50

Specific Gravity 2.71

Time (min.)	A/Hydr Rdg	Temp.	Comp Corr	corr. hydr Rdg	CorR.factor (a)	Eff.Depth of Hyd.(L)	Values of K	D (mm)	% finer,P	Adj. % of finer
1	52	21	-3.85	48.15	0.988	7.8	0.01324	0.0370	95.14	88.24
2	50	21	-3.85	46.15	0.988	8.2	0.01324	0.0267	91.19	84.57
5	47	21	-3.85	43.15	0.988	8.6	0.01324	0.0174	85.26	79.07
15	44.5	21	-3.85	40.65	0.988	9.0	0.01324	0.0103	80.32	74.49
30	43	22	-3.85	39.15	0.988	9.3	0.01308	0.0073	77.36	71.74
60	42	22	-3.85	38.15	0.988	9.5	0.01308	0.0052	75.38	69.91
120	41	22	-3.85	37.15	0.988	9.6	0.01308	0.0037	73.41	68.08
240	40.5	22	-3.85	36.65	0.988	9.7	0.01308	0.0026	72.42	67.16
480	40.2	21	-3.85	36.35	0.988	9.7	0.01324	0.0019	71.83	66.61
1440	40	21	-3.85	36.15	0.988	9.8	0.01324	0.0011	71.43	66.25

Test pit 6

PARTICLE SIZE DISTRIBUTION									
Sieve Analysis					Combined sieve & Hydrometer analysis				
Sample preparation : Oven-dried sample					particle size	percent pass	% of soil particle size	AASHTO	USCS
Method of sieving: Wet Sieving					9.5	100	% of gravel	0.68	0.12
Mass dry soil (before wash)			1000	gm	4.75	99.88	% of Sand	2.02	2.58
mass pass 0.075 mm			973.0	gm	2	99.32	% of Silt	23.95	27.41
percentage of pass 0.075 mm			97.30	%	0.85	98.98	% of Clay	73.35	69.89
Total mass		1000		gm	0.4250	98.75			
Sieve Size,mm	Wt. of Retained	% Retained	% Cum. Retained	% Pass	0.300	98.57			
9.5	0.000	0	0	100	0.150	98.03			
4.75	1.200	0.12	0.12	99.88	0.075	97.3			
2	5.600	0.56	0.68	99.32	0.037	90.65			
0.85	3.400	0.34	1.02	98.98	0.027	84.88			
0.425	2.300	0.23	1.25	98.75	0.018	81.04			
0.300	1.800	0.18	1.43	98.57	0.010	78.16			
0.150	5.400	0.54	1.97	98.03	0.007	75.27			
0.075	7.300	0.73	2.70	97.30	0.005	73.35			
Pan	973.00	97.3	100	0	0.004	71.43			
					0.003	70.47			
					0.002	69.89			
					0.001	69.50			



Hydrometer Analysis

Total oven Dry mass 50

Specific Gravity 2.71

Time min	A/Hydr. Rdg, Ra	Temp.	Compo. Correction	Corr. Hydr. Rdg	Corr. factor(a)	Effe. Depth (L)	Value of K	D (mm)	% finer,P	Adj. % of finer
1	51	21	-3.85	47.15	0.988	8.0	0.01324	0.037	93.17	90.65
2	48	21	-3.85	44.15	0.988	8.5	0.01324	0.027	87.24	84.88
5	46	21	-3.85	42.15	0.988	8.8	0.01324	0.018	83.29	81.04
15	44.5	21	-3.85	40.65	0.988	9.0	0.01324	0.010	80.32	78.16
30	43	21	-3.85	39.15	0.988	9.3	0.01324	0.007	77.36	75.27
60	42	22	-3.85	38.15	0.988	9.5	0.01308	0.005	75.38	73.35
120	41	22	-3.85	37.15	0.988	9.6	0.01308	0.004	73.41	71.43
240	40.5	22	-3.85	36.65	0.988	9.7	0.01308	0.003	72.42	70.47
480	40.2	22	-3.85	36.35	0.988	9.7	0.01308	0.002	71.83	69.89
1440	40	21	-3.85	36.15	0.988	9.8	0.01324	0.001	71.43	69.50

Test pit 7

PARTICLE SIZE DISTRIBUTION

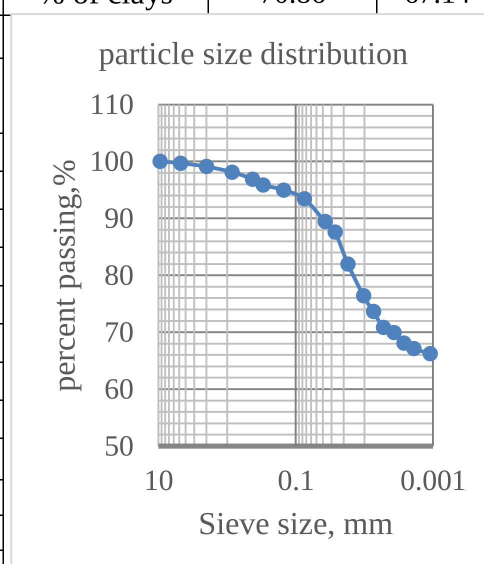
Sieve Analysis

Sample preparation : Oven-dried sample		
Method of sieving: Wet sieving		
Mass dry soil	1000	gm
Mass pass 0.075 mm	934.3	gm
percent of pass 0.075	93.43	%
Total mass	1000	gm

Sieve Size	Mass of Ret.,	% Ret.	% Cum. Ret.	% Passing
9.5	0	0	0	100
4.75	3	0.3	0.3	99.7
2	6	0.6	0.9	99.1
0.85	9.6	0.96	1.86	98.14
0.425	12.4	1.24	3.1	96.9
0.300	10.2	1.02	4.12	95.88
0.150	8.9	0.89	5.01	94.99
0.075	15.6	1.56	6.57	93.43
Pass	934.30	93.43	100	0

Combined sieve & Hydrometer analysis

particle size	percent pass	% of soil particle size	AASHTO	USCS
9.5	100	% of gravel	0.90	0.30
4.75	99.7	% of Sand	5.67	6.27
2	99.1	% of Silt	22.57	26.29
0.85	98.14	% of clays	70.86	67.14
0.4250	96.9			
0.300	95.88			
0.150	94.99			
0.075	93.43			
0.0374	89.43			
0.0267	87.58			
0.0174	82.00			
0.0103	76.43			
0.0074	73.65			
0.0053	70.86			
0.0037	69.93			
0.0027	68.07			
0.0019	67.14			
0.0011	66.22			



Hydrometer Analysis

Total oven Dry mass 50

Specific Gravity 2.68

Time (min.)	Actual Hydro. Reading	Temp.	Composite correction	Corrected Hydro. Reading	Correction factor(a)	Effe. Depth of Hydro(L)	Values of K	Diameter of soil Particle (mm)	% finer,P	Adj. of finer
1	52	21	-3.85	48.15	0.994	7.8	0.01336	0.0374	95.72	89.43
2	51	21	-3.85	47.15	0.994	8.0	0.01336	0.0267	93.73	87.58
5	48	21	-3.85	44.15	0.994	8.5	0.01336	0.0174	87.77	82.00
15	45	21	-3.85	41.15	0.994	9.0	0.01336	0.0103	81.81	76.43
30	43.5	21	-3.85	39.65	0.994	9.2	0.01336	0.0074	78.82	73.65
60	42	21	-3.85	38.15	0.994	9.5	0.01336	0.0053	75.84	70.86
120	41.5	22	-3.85	37.65	0.994	9.5	0.01320	0.0037	74.85	69.93
240	40.5	22	-3.85	36.65	0.994	9.7	0.01320	0.0027	72.86	68.07
480	40	21	-3.85	36.15	0.994	9.8	0.01336	0.0019	71.87	67.14
1440	39.5	21	-3.85	35.65	0.994	9.9	0.01336	0.0011	70.87	66.22

Test pit 8

PARTICLE SIZE DISTRIBUTION

Sieve Analysis

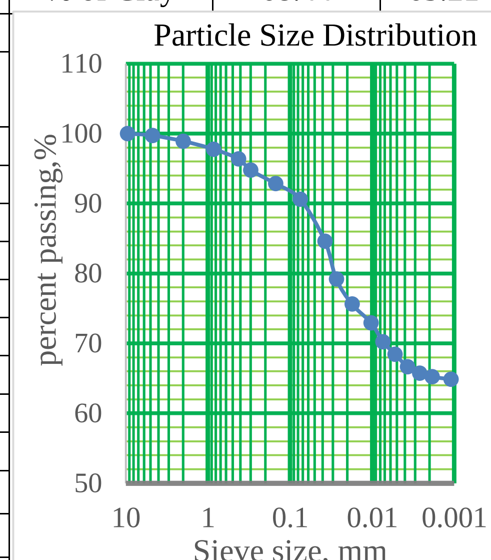
Sample preparation : Oven-dried sample		
Method of sieving: Wet Sieving		
Mass dry soil	1000	gm
Mass pass 0.075 mm	906	gm
%age of pass 0.075	90.61	%
Total mass,	1000	gm

Sieve Size	Wt. of Ret.	% of Ret.	% Cum. Ret.	% of Passing
9.5	0	0	0	100
4.75	2.7	0.27	0.27	99.73
2	8.1	0.81	1.08	98.92
0.85	11.6	1.16	2.24	97.76
0.425	13.8	1.38	3.62	96.38
0.300	16.2	1.62	5.24	94.76
0.150	19.3	1.93	7.17	92.83
0.075	22.2	2.22	9.39	90.61
Pass	906.10	90.61	100	0

Combined sieve & Hydrometer analysis

particle size	% of pass
9.5	100
4.75	99.73
2	98.92
0.85	97.76
0.425	96.38
0.300	94.76
0.150	92.83
0.075	90.61
0.038	84.59
0.027	79.21
0.018	75.62
0.010	72.93
0.007	70.24
0.005	68.44
0.004	66.65
0.003	65.75
0.002	65.21
0.001	64.86

% of soil particle size	AASHTO	USCS
% of gravel	1.08	0.27
% of Sand	8.31	9.12
% of Silt	22.17	25.40
% of Clay	68.44	65.21



Hydrometer Analysis

Total oven Dry mass 50

Specific Gravity 2.70

Time (min.)	Hydro. Reading	Temp.	Comp. correc.	CorrectHydro. reading	Corr. factor (a)	Effe. Depth of Hyd. (L)	Values of K	D (mm)	% finer,P	Adjusted % of finer
1	51	21	-3.85	47.15	0.99	8.0	0.01328	0.038	93.36	84.59
2	48	21	-3.85	44.15	0.99	8.5	0.01328	0.027	87.42	79.21
5	46	21	-3.85	42.15	0.99	8.8	0.01328	0.018	83.46	75.62
15	44.5	21	-3.85	40.65	0.99	9.0	0.01328	0.010	80.49	72.93
30	43	21	-3.85	39.15	0.99	9.3	0.01328	0.007	77.52	70.24
60	42	21	-3.85	38.15	0.99	9.5	0.01328	0.005	75.54	68.44
120	41	22	-3.85	37.15	0.99	9.6	0.01312	0.004	73.56	66.65
240	40.5	22	-3.85	36.65	0.99	9.7	0.01312	0.003	72.57	65.75
480	40.2	22	-3.85	36.35	0.99	9.7	0.01312	0.002	71.97	65.21
1440	40	21	-3.85	36.15	0.99	9.8	0.00000	0.000	71.58	64.86

Test pit 9

PARTICLE SIZE DISTRIBUTION

Sieve Analysis

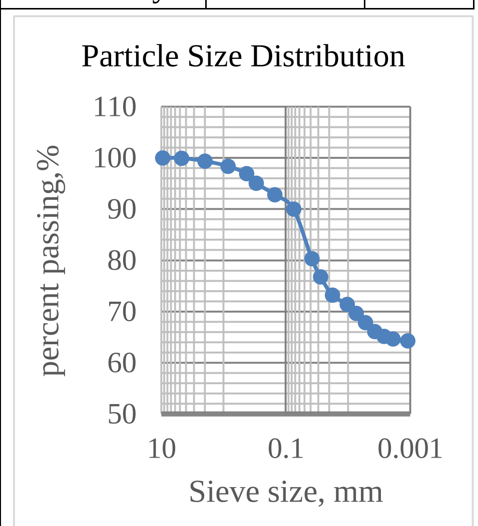
Sample preparation : Oven-dried sample		
Method of sieving: Wet sieving		
Mass dry soil (before wash)	1000	gm
Mass pass 0.075 mm	900	gm
%age of pass 0.075 mm	90.02	%
Total mass	1000	gm

Sieve Size	Wt. of Retained	% of Retained	% Cum. Retained	% of Pass
9.5	0	0	0	100
4.75	0.4	0.04	0.04	99.96
2	5.8	0.58	0.62	99.38
0.85	10.1	1.01	1.63	98.37
0.425	14.3	1.43	3.06	96.94
0.300	18.5	1.85	4.91	95.09
0.150	22.6	2.26	7.17	92.83
0.075	28.1	2.81	9.98	90.02
Pan	900.20	90.02	100	0

Combined sieve & Hydrometer analysis

particle size	percent pass
9.5	100
4.75	99.96
2	99.38
0.85	98.37
0.4250	96.94
0.300	95.09
0.150	92.83
0.075	90.02
0.0382	80.31
0.0275	76.76
0.0177	73.20
0.0103	71.42
0.0074	69.64
0.0053	67.86
0.0037	66.08
0.0026	65.19
0.0019	64.66
0.0011	64.30

% of soil particle size	AASHTO	USCS
% of gravel	0.62	0.04
% of Sand	9.36	9.94
% of Silt	22.16	25.36
% of Clay	67.86	64.66



Hydrometer Analysis

Total oven Dry mass 50

Specific Gravity 2.71

Time (min.)	A.Hydr Readin	Temp.	Comp. Corr.	Corr.Hy rdg	Corr.fa ctor.(a)	Effe. Depth	Values of K	D (mm)	% finer,P	Adjusted Percent of finer
1	49	21	-3.85	45.15	0.988	8.3	0.01324	0.0382	89.22	80.31
2	47	21	-3.85	43.15	0.988	8.6	0.01324	0.0275	85.26	76.76
5	45	21	-3.85	41.15	0.988	9.0	0.01324	0.0177	81.31	73.20
15	44	21	-3.85	40.15	0.988	9.1	0.01324	0.0103	79.34	71.42
30	43	21	-3.85	39.15	0.988	9.3	0.01324	0.0074	77.36	69.64
60	42	21	-3.85	38.15	0.988	9.5	0.01324	0.0053	75.38	67.86
120	41	22	-3.85	37.15	0.988	9.6	0.01308	0.0037	73.41	66.08
240	40.5	22	-3.85	36.65	0.988	9.7	0.01308	0.0026	72.42	65.19
480	40.2	21	-3.85	36.35	0.988	9.7	0.01324	0.0019	71.83	64.66
1440	40	21	-3.85	36.15	0.988	9.8	0.01324	0.0011	71.43	64.30

Test Pit 10

PARTICLE SIZE DISTRIBUTION

Sieve Analysis

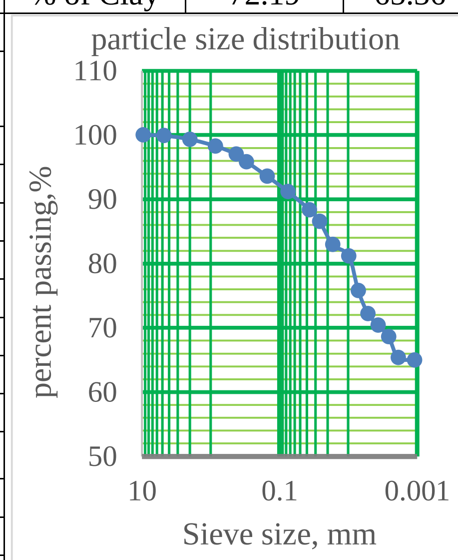
Sample preparation : Oven-dried sample		
Method of sieving: Wet Sieving		
Mass dry soil (before wash)	1000	gm
mass pass 0.075 mm	911.8	gm
%ge of pass 0.075 mm	91.18	%
Total mass	1000	grm

Sieve Size,mm	Wt. of Ret.	% of Ret.	% Cum. Ret.	% of Pass
9.5	0	0	0	100
4.75	0.9	0.09	0.09	99.91
2	5.8	0.58	0.67	99.33
0.85	10.5	1.05	1.72	98.28
0.425	12.6	1.26	2.98	97.02
0.300	11.8	1.18	4.16	95.84
0.150	22.7	2.27	6.43	93.57
0.075	23.9	2.39	8.82	91.18
Pan	911.80	91.18	100	0

Combined sieve & Hydrometer analysis

particle size	percent pass
9.5	100
4.75	99.91
2	99.33
0.85	98.28
0.4250	97.02
0.300	95.84
0.150	93.57
0.075	91.18
0.0365	88.38
0.0261	86.58
0.0169	82.98
0.0098	81.18
0.0072	75.79
0.0052	72.19
0.0037	70.39
0.0026	68.60
0.0019	65.36
0.0011	65.00

% of soil particle size	AASHTO	USCS
% of gravel	0.67	0.09
% of Sand	8.15	8.73
% of Silt	18.99	25.82
% of Clay	72.19	65.36



Hydrometer Analysis

Total oven Dry mass 50

Specific Gravity 2.72

Time (minutes)	Actual Hydro. Reading	Temp.	Compo. Correctio	Corrected Hyd.rdg.	Corr. factor (a)	Effe. Depth (L)	Values of K	Diameter of soil Particle (mm)	% finer,P	Adjusted Percent of finer
1	53	21	-3.85	49.15	0.986	7.7	0.013204	0.0365	96.92	88.38
2	52	21	-3.85	48.15	0.986	7.8	0.013204	0.0261	94.95	86.58
5	50	21	-3.85	46.15	0.986	8.2	0.013204	0.0169	91.01	82.98
15	49	21	-3.85	45.15	0.986	8.3	0.013204	0.0098	89.04	81.18
30	46	21	-3.85	42.15	0.986	8.8	0.013204	0.0072	83.12	75.79
60	44	21	-3.85	40.15	0.986	9.1	0.013204	0.0052	79.18	72.19
120	43	21	-3.85	39.15	0.986	9.3	0.013204	0.0037	77.20	70.39
240	42	22	-3.85	38.15	0.986	9.5	0.013048	0.0026	75.23	68.60
480	40.2	21	-3.85	36.35	0.986	9.7	0.013204	0.0019	71.68	65.36
1440	40	21	-3.85	36.15	0.986	9.8	0.013204	0.0011	71.29	65.00

Test Pit 11

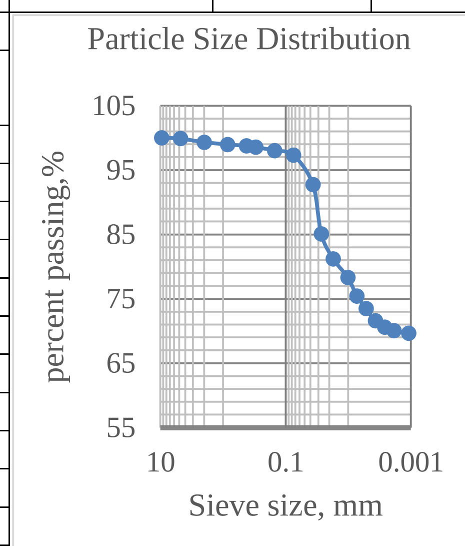
TEST METHOD: ASTM D 422		
Sample preparation : Oven-dried sample		
Method of sieving: Wet sieving		
Mass dry soil	1000	gm
mass pass 0.075	973	gm
% of pass 0.075	97.30	%
Total mass	1000	gm

Sieve Size	Mass of Ret.	% of R	% Cum. R	% of Pass
9.5	0	0	0	100
4.75	1.20	0.12	0.12	99.88
2	5.60	0.56	0.68	99.32
0.85	3.40	0.34	1.02	98.98
0.425	2.30	0.23	1.25	98.75
0.300	1.80	0.18	1.43	98.57
0.150	5.40	0.54	1.97	98.03
0.075	7.30	0.73	2.70	97.30
Pan	973.00	97.30	100	0.00

Combined Sieve and Hydrometer Analysis

particle size	% pass
9.5	100
4.75	99.88
2	99.32
0.85	98.98
0.4250	98.75
0.300	98.57
0.150	98.03
0.075	97.3
0.037	92.76
0.027	85.06
0.017	81.20
0.010	78.31
0.007	75.42
0.005	73.50
0.004	71.57
0.003	70.61
0.002	70.03
0.001	69.64

% of soil particle size	AASHTO	USCS
% of gravel	0.68	0.12
% of Sand	2.02	2.58
% of Silt	23.80	27.27
% of Clay	73.50	70.03



Hydrometer Analysis
Total oven dry mass 50
Specific Gravity 2.70

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydro meter Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	52	22	-3.85	48.15	0.99	7.8	0.01312	0.037	95.34	92.76
2	48	22	-3.85	44.15	0.99	8.4	0.01312	0.027	87.42	85.06
5	46	22	-3.85	42.15	0.99	8.8	0.01312	0.017	83.46	81.20
15	44.5	22	-3.85	40.65	0.99	9.0	0.01312	0.010	80.49	78.31
30	43	22	-3.85	39.15	0.99	9.2	0.01312	0.007	77.52	75.42
60	42	22	-3.85	38.15	0.99	9.4	0.01312	0.005	75.54	73.50
120	41	22	-3.85	37.15	0.99	9.6	0.01312	0.004	73.56	71.57
240	40.5	22	-3.85	36.65	0.99	9.7	0.01312	0.003	72.57	70.61
480	40.2	22	-3.85	36.35	0.99	9.7	0.01312	0.002	71.97	70.03
1440	40	21	-3.85	36.15	0.99	9.7	0.01328	0.001	71.58	69.64

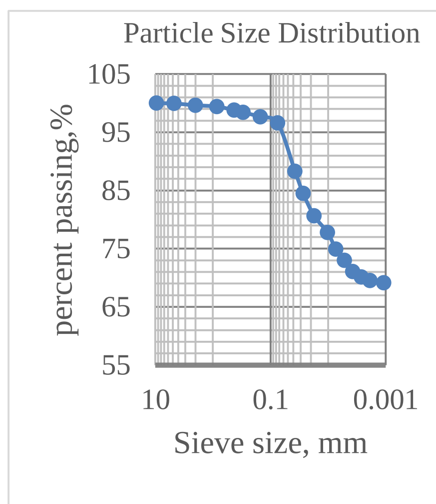
Test Pit 12

TEST METHOD: ASTM D 422				
Sample preparation : Oven-dried sample				
Method of sieving: Wet sieving				
Mass dry soil		1000	gm	
Mass pass 0.075 mm		966.20	gm	
percentage of pass 0.075		96.62	%	
Total mass	1000		gm	
Sieve Size	Mass of Ret.	% Retained	% Cum. Retained	% of Pass
9.5	0	0	0	100
4.75	0.50	0.05	0.05	99.95
2	3.00	0.30	0.35	99.65
0.85	2.30	0.23	0.58	99.42
0.425	6.10	0.61	1.19	98.81
0.300	3.70	0.37	1.56	98.44
0.150	7.80	0.78	2.34	97.66
0.075	10.40	1.04	3.38	96.62
Pan	966.20	96.62	100	0

Combined sieve and Hydrometer Analysis

particle size	percent pass
9.5	100
4.75	99.95
2	99.65
0.85	99.42
0.4250	98.81
0.300	98.44
0.150	97.66
0.075	96.62
0.037	88.29
0.027	84.46
0.017	80.64
0.010	77.77
0.007	74.90
0.005	72.98
0.004	71.07
0.003	70.11
0.002	69.54
0.001	69.16

% of soil particle size	AASHTO	USCS
% of gravel	0.35	0.05
% of Sand	3.03	3.33
% of Silt	23.64	27.08
% of Clay	72.98	69.54

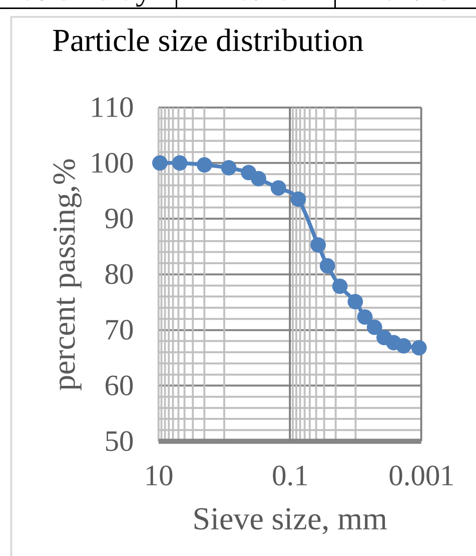


Hydrometer Analysis
Total oven dry mass 50
Specific Gravity 2.70

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydrometer Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	52	22	-3.85	48.15	0.99	7.8	0.01312	0.037	95.34	92.76
2	48	22	-3.85	44.15	0.99	8.4	0.01312	0.027	87.42	85.06
5	46	22	-3.85	42.15	0.99	8.8	0.01312	0.017	83.46	81.20
15	44.5	22	-3.85	40.65	0.99	9.0	0.01312	0.010	80.49	78.31
30	43	22	-3.85	39.15	0.99	9.2	0.01312	0.007	77.52	75.42
60	42	22	-3.85	38.15	0.99	9.4	0.01312	0.005	75.54	73.50
120	41	22	-3.85	37.15	0.99	9.6	0.01312	0.004	73.56	71.57
240	40.5	22	-3.85	36.65	0.99	9.7	0.01312	0.003	72.57	70.61
480	40.2	22	-3.85	36.35	0.99	9.7	0.01312	0.002	71.97	70.03
1440	40	21	-3.85	36.15	0.99	9.7	0.01328	0.001	71.58	69.64

Test Pit 13

TEST METHOD: ASTM D 422					Combined sieve and Hydrometer Analysis				
Sample preparation : Oven-dried sample									
Method of sieving: Wet sieving					particle size	percent pass	% of soil part.size	AASHTO	USCS
Mass dry soil			1000	gm	9.5	100	% of gravel	0.32	0.00
mass pass 0.075 mm			934.9	gm	4.75	100	% of Sand	6.19	6.51
percentage of pass 0.075 mm			93.49	%	2	99.68	% of Silt	23.01	26.34
Total mass		1000		gm	0.85	99.13	% of Clay	70.48	67.15
Sieve Size	Mass of Ret,	% Ret.	% Cum. Retained	% of Pass	0.4250	98.29			
9.5	0	0	0	100	0.300	97.17			
4.75	0	0	0	100	0.150	95.5			
2	3.2	0.32	0.32	99.68	0.075	93.49			
0.85	5.5	0.55	0.87	99.13	0.0372	85.26			
0.425	8.4	0.84	1.71	98.29	0.0269	81.56			
0.300	11.2	1.12	2.83	97.17	0.0173	77.87			
0.150	16.7	1.67	4.5	95.5	0.0101	75.10			
0.075	20.1	2.01	6.51	93.49	0.0073	72.32			
Pan	934.90	93.49	100	0	0.0052	70.48			
					0.0037	68.63			
					0.0026	67.71			
					0.0019	67.15			
					0.0011	66.78			



Hydrometer Analysis
Total oven dry mass 50
Specific Gravity 2.71

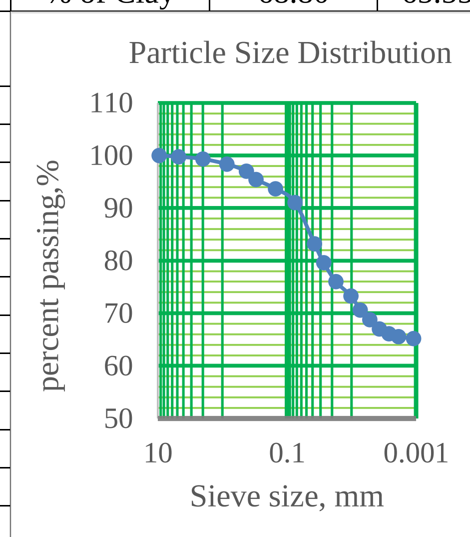
Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydro meter Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	50	22	-3.85	46.15	0.988	8.1	0.013084	0.037	91.19	85.26
2	48	22	-3.85	44.15	0.988	8.4	0.013084	0.027	87.24	81.56
5	46	22	-3.85	42.15	0.988	8.8	0.013084	0.017	83.29	77.87
15	44.5	22	-3.85	40.65	0.988	9.0	0.013084	0.010	80.32	75.10
30	43	22	-3.85	39.15	0.988	9.2	0.013084	0.007	77.36	72.32
60	42	22	-3.85	38.15	0.988	9.4	0.013084	0.005	75.38	70.48
120	41	22	-3.85	37.15	0.988	9.6	0.013084	0.004	73.41	68.63
240	40.5	22	-3.85	36.65	0.988	9.7	0.013084	0.003	72.42	67.71
480	40.2	22	-3.85	36.35	0.988	9.7	0.013084	0.002	71.83	67.15
1440	40	21	-3.85	36.15	0.988	9.7	0.013242	0.001	71.43	66.78

Test pit 14

TEST METHOD: ASTM D 422		
Sample preparation : Oven-dried sample		
Method of sieving: Wet sieving		
Mass dry soil	1000	gm
mass pass 0.075 mm	911	gm
percentage of pass 0.075 mm	91.08	%
Total mass	1000	gm

Sieve Size	Mass of Ret,	% Ret.	% Cum. Ret.	% of Pass
9.5	0	0	0	100
4.75	2.4	0.24	0.24	99.76
2	4.3	0.43	0.67	99.33
0.85	9.8	0.98	1.65	98.35
0.425	13.3	1.33	2.98	97.02
0.300	15.8	1.58	4.56	95.44
0.150	17.6	1.76	6.32	93.68
0.075	26	2.6	8.92	91.08
Pan	910.8	91.08	100	0

Combined sieve and Hydrometer Analysis				
particle size	percent pass	% of soil part.size	AASHTO	USCS
9.5	100	% of gravel	0.67	0.24
4.75	99.76	% of Sand	8.25	8.68
2	99.33	% of Silt	22.28	25.53
0.85	98.35	% of Clay	68.80	65.55
0.4250	97.02			
0.300	95.44			
0.150	93.68			
0.075	91.08			
0.037	83.23			
0.027	79.62			
0.017	76.01			
0.010	73.31			
0.007	70.60			
0.005	68.80			
0.004	67.00			
0.003	66.09			
0.002	65.55			
0.001	65.19			



Hydrometer Analysis

Total oven dry mass 50

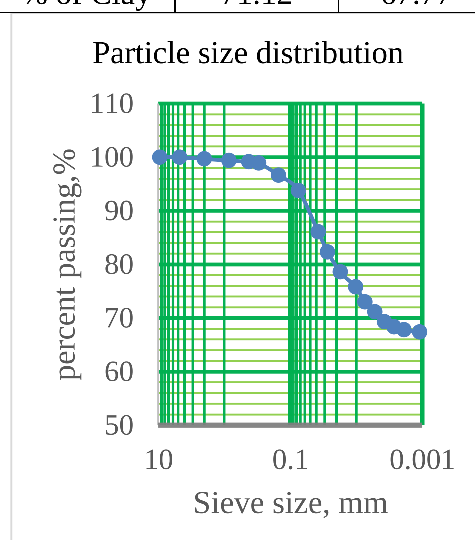
Specific Gravity 2.70

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydro meter Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	50	22	-3.85	46.15	0.990	8.2	0.01312	0.037	91.38	83.23
2	48	22	-3.85	44.15	0.990	8.5	0.01312	0.027	87.42	79.62
5	46	22	-3.85	42.15	0.990	8.8	0.01312	0.017	83.46	76.01
15	44.5	22	-3.85	40.65	0.990	9.0	0.01312	0.010	80.49	73.31
30	43	22	-3.85	39.15	0.990	9.3	0.01312	0.007	77.52	70.60
60	42	22	-3.85	38.15	0.990	9.5	0.01312	0.005	75.54	68.80
120	41	22	-3.85	37.15	0.990	9.6	0.01312	0.004	73.56	67.00
240	40.5	22	-3.85	36.65	0.990	9.7	0.01312	0.003	72.57	66.09
480	40.2	22	-3.85	36.35	0.990	9.7	0.01312	0.002	71.97	65.55
1440	40	21	-3.85	36.15	0.990	9.8	0.01328	0.001	71.58	65.19

Test pit 15

TEST METHOD: ASTM D 422			Combined sieve and Hydrometer Analysis				
Sample preparation : Oven-dried sample							
Method of sieving: Wet sieving			particle size	percent pass	% of soil part.size	AASHTO	USCS
Mass dry soil	1000	gm	9.5	100	% of gravel	0.33	0.05
mass pass 0.075 mm	937.80	gm	4.75	99.95	% of Sand	5.89	6.17
percentage of pass 0.075 mm	93.78	%	2	99.67	% of Silt	22.66	26.01
Total mass	1000	gm	0.85	99.35	% of Clay	71.12	67.77

Sieve Size	Mass of Ret,	% Ret.	% Cum. Ret.	% of Pass	particle size	percent pass
					0.4250	99.11
9.5	0	0	0	100	0.300	98.88
4.75	0.5	0.05	0.05	99.95	0.150	96.65
2	2.8	0.28	0.33	99.67	0.075	93.78
0.85	3.2	0.32	0.65	99.35	0.0377	86.04
0.425	2.4	0.24	0.89	99.11	0.0271	82.31
0.300	2.3	0.23	1.12	98.88	0.0175	78.58
0.150	22.3	2.23	3.35	96.65	0.0102	75.79
0.075	28.7	2.87	6.22	93.78	0.0073	72.99
Pan	937.8	93.78	100	0	0.0052	71.12
					0.0037	69.26
					0.003	68.33
					0.0019	67.77
					0.0011	67.40



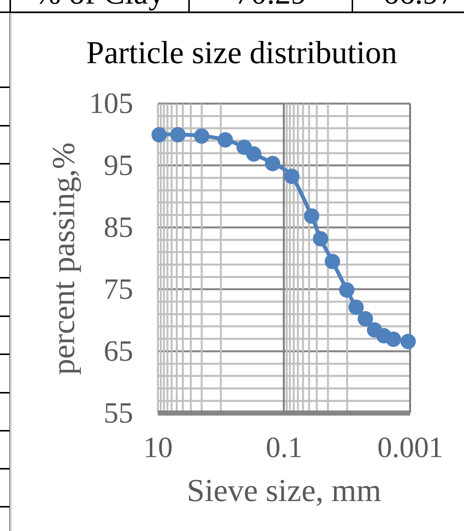
Hydrometer Analysis
Total oven dry mass 50
Specific Gravity 2.68

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydro meter Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	50	22	-3.85	46.15	0.994	8.2	0.01320	0.0377	91.75	86.04
2	48	22	-3.85	44.15	0.994	8.4	0.01320	0.0271	87.77	82.31
5	46	22	-3.85	42.15	0.994	8.8	0.01320	0.0175	83.79	78.58
15	44.5	22	-3.85	40.65	0.994	9.0	0.01320	0.0102	80.81	75.79
30	43	22	-3.85	39.15	0.994	9.2	0.01320	0.0073	77.83	72.99
60	42	22	-3.85	38.15	0.994	9.4	0.01320	0.0052	75.84	71.12
120	41	22	-3.85	37.15	0.994	9.6	0.01320	0.0037	73.85	69.26
240	40.5	22	-3.85	36.65	0.994	9.7	0.01320	0.0026	72.86	68.33
480	40.2	22	-3.85	36.35	0.994	9.7	0.01320	0.0019	72.26	67.77
1440	40	22	-3.85	36.15	0.994	9.7	0.01320	0.0011	71.87	67.40

Test pit 16

TEST METHOD: ASTM D 422			Combined sieve and Hydrometer Analysis				
Sample preparation : Oven-dried sample							
Method of sieving: Wet sieving			particle size	percent pass	% of soil part.size	AASHTO	USCS
Mass dry soil	1000	gm	9.5	100	% of gravel	0.21	0.00
mass pass 0.075 mm	937.80	gm	4.75	100	% of Sand	6.55	6.76
percentage of pass 0.075 mm	93.78	%	2	99.79	% of Silt	22.95	26.27
Total mass	1000	gm	0.85	99.14	% of Clay	70.29	66.97

Sieve Size	Mass of Ret,	% Ret.	% Cum. Ret.	% of Pass		
					0.425	97.98
9.5	0	0	0	100	0.300	96.9
4.75	0	0	0	100	0.150	95.33
2	2.1	0.21	0.21	99.79	0.075	93.24
0.85	6.5	0.65	0.86	99.14	0.036	86.87
0.425	11.6	1.16	2.02	97.98	0.026	83.19
0.300	10.8	1.08	3.1	96.9	0.017	79.50
0.150	15.7	1.57	4.67	95.33	0.010	74.89
0.075	20.9	2.09	6.76	93.24	0.007	72.13
Pass	932.4	93.24	100	0	0.005	70.29
					0.004	68.45
					0.003	0.003
					0.002	66.97
					0.001	66.60



Hydrometer Analysis

Total oven dry mass 50

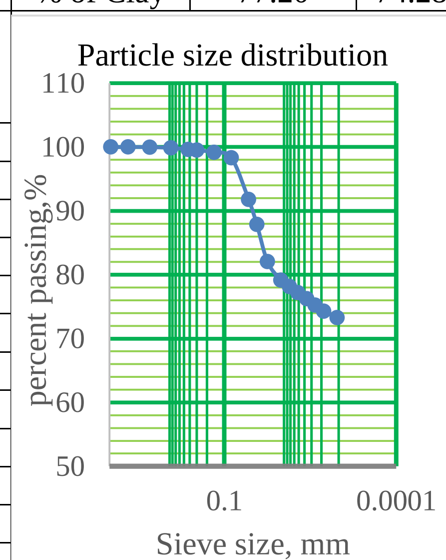
Specific Gravity 2.71

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydro meter Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	51	21	-3.85	47.15	0.988	8.0	0.013242	0.037	93.17	86.87
2	49	21	-3.85	45.15	0.988	8.3	0.013242	0.027	89.22	83.19
5	47	21	-3.85	43.15	0.988	8.6	0.013242	0.017	85.26	79.50
15	44.5	21	-3.85	40.65	0.988	9.0	0.013242	0.010	80.32	74.89
30	43	21	-3.85	39.15	0.988	9.3	0.013242	0.007	77.36	72.13
60	42	21	-3.85	38.15	0.988	9.5	0.013242	0.005	75.38	70.29
120	41	21	-3.85	37.15	0.988	9.6	0.013242	0.004	73.41	68.45
240	40.5	21	-3.85	36.65	0.988	9.7	0.013242	0.003	72.42	67.52
480	40.2	21	-3.85	36.35	0.988	9.7	0.013242	0.002	71.83	66.97
1440	40	20	-3.85	36.15	0.988	9.8	0.013402	0.001	71.43	66.60

Test Pit 17

TEST METHOD: ASTM D 422			Combined sieve and Hydrometer Analysis				
Sample preparation : Oven-dried sample							
Method of sieving: Wet sieving			particle size	percent pass	% of soil part.size	AASHTO	USCS
Mass dry soil	1000	gm	9.5	100	% of gravel	0.01	0.00
mass pass 0.075 mm	983.33	gm	4.75	100	% of Sand	1.66	1.67
percentage of pass 0.075	98.33	%	2	99.994	% of Silt	21.13	24.06
Total mass	1000	gm	0.85	99.864	% of Clay	77.20	74.28

Sieve Size	Mass of Ret,	% Ret.	% Cum. Ret.	% of Pass		
					0.4250	99.644
9.5	0.000	0	0	100	0.300	99.504
4.75	0.000	0	0	100	0.150	99.184
2	0.060	0.006	0.006	99.994	0.075	98.333
0.85	1.300	0.13	0.136	99.864	0.038	91.80
0.425	2.200	0.22	0.356	99.644	0.027	87.91
0.300	1.400	0.14	0.496	99.504	0.018	82.07
0.150	3.200	0.32	0.816	99.184	0.010	79.15
0.075	8.510	0.851	1.667	98.333	0.007	78.17
Pass	983.33	98.333	100	0	0.005	77.20
					0.004	76.22
					0.003	75.25
					0.002	74.28
					0.001	73.30



Hydrometer Analysis

Total oven dry mass 50

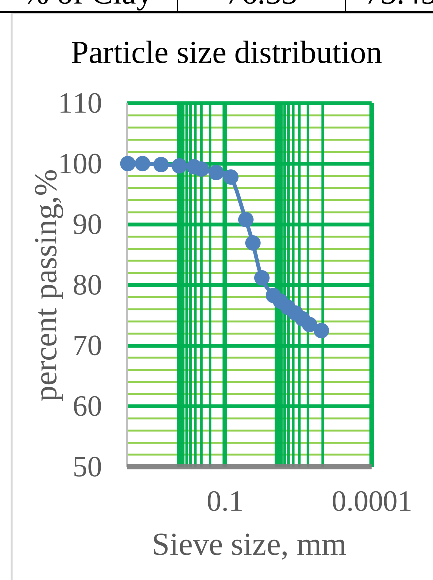
Specific Gravity 2.70

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydrometer Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	51	21	-3.85	47.15	0.990	8.0	0.01328	0.038	93.36	91.80
2	49	21	-3.85	45.15	0.990	8.3	0.01328	0.027	89.40	87.91
5	46	21	-3.85	42.15	0.990	8.8	0.01328	0.018	83.46	82.07
15	44.5	21	-3.85	40.65	0.990	9.0	0.01328	0.010	80.49	79.15
30	44	21	-3.85	40.15	0.990	9.1	0.01328	0.007	79.50	78.17
60	43.5	21	-3.85	39.65	0.990	9.2	0.01328	0.005	78.51	77.20
120	43	22	-3.85	39.15	0.990	9.2	0.01312	0.004	77.52	76.22
240	42.5	22	-3.85	38.65	0.990	9.3	0.01312	0.003	76.53	75.25
480	42	22	-3.85	38.15	0.990	9.4	0.01312	0.002	75.54	74.28
1440	41.5	21	-3.85	37.65	0.990	9.5	0.01328	0.001	74.55	73.30

Test Pit 18

TEST METHOD: ASTM D 422			Combined sieve and Hydrometer Analysis				
Sample preparation : Oven-dried sample							
Method of sieving: Wet sieving			particle size	percent pass	% of soil part.size	AASHTO	USCS
Mass dry soil	1000	gm	9.5	100	% of gravel	0.11	0.00
mass pass 0.075 mm	978.2	gm	4.75	100	% of Sand	2.06	2.18
percentage of pass 0.075	97.82	%	2	99.888	% of Silt	21.49	24.38
Total mass	1000		gm	0.85	99.628	% of Clay	76.33	73.45

Sieve Size	Mass of Ret,	% Ret.	% Cum. Ret.	% of Pass		
					0.4250	99.484
9.5	0.000	0	0	100	0.300	99.124
4.75	0.000	0	0	100	0.150	98.564
2	1.120	0.112	0.112	99.888	0.075	97.824
0.85	2.600	0.26	0.372	99.628	0.037	90.77
0.425	1.440	0.144	0.516	99.484	0.027	86.92
0.300	3.600	0.36	0.876	99.124	0.017	81.15
0.150	5.600	0.56	1.436	98.564	0.010	78.26
0.075	7.400	0.74	2.176	97.824	0.007	77.30
Pass	978.24	97.824	100	0	0.005	76.33
					0.004	75.37
					0.003	74.41
					0.002	73.45
					0.001	72.48



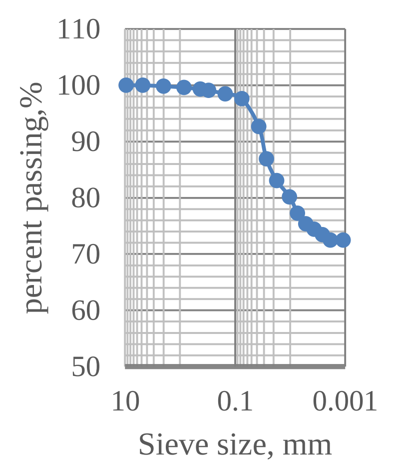
Hydrometer Analysis
Total oven dry mass 50
Specific Gravity 2.73

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydro meter Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	51	21	-3.85	47.15	0.984	8.0	0.013166	0.037	92.79	90.77
2	49	21	-3.85	45.15	0.984	8.3	0.013166	0.027	88.86	86.92
5	46	21	-3.85	42.15	0.984	8.8	0.013166	0.017	82.95	81.15
15	44.5	21	-3.85	40.65	0.984	9.0	0.013166	0.010	80.00	78.26
30	44	21	-3.85	40.15	0.984	9.1	0.013166	0.007	79.02	77.30
60	43.5	21	-3.85	39.65	0.984	9.2	0.013166	0.005	78.03	76.33
120	43	22	-3.85	39.15	0.984	9.2	0.013012	0.004	77.05	75.37
240	42.5	22	-3.85	38.65	0.984	9.3	0.013012	0.003	76.06	74.41
480	42	21	-3.85	38.15	0.984	9.4	0.013166	0.002	75.08	73.45
1440	41.5	21	-3.85	37.65	0.984	9.5	0.013166	0.001	74.10	72.48

Test pit 19

TEST METHOD: ASTM D 422					Combined sieve and Hydrometer Analysis				
Sample preparation : Oven-dried sample									
Method of sieving: Wet sieving					particle size	percent pass	% of soil part.size	AASHTO	USCS
Mass dry soil		1000	gm		9.5	100	% of gravel	0.17	0.02
mass pass 0.075 mm		975.90	gm		4.75	99.98	% of Sand	2.24	2.39
percentage of pass 0.075		97.59	%		2	99.83	% of Silt	22.25	25.13
Total mass		1000		gm	0.85	99.59	% of Clay	75.34	72.46
Sieve Size	Mass of Ret,	% Ret.	% Cum. Ret.	% of Pass	0.4250	99.30			
9.5	0	0	0	100	0.300	99.07			
4.75	0.200	0.02	0.02	99.98	0.150	98.46			
2	1.500	0.15	0.17	99.83	0.075	97.56			
0.85	2.400	0.24	0.41	99.59	0.037	92.66			
0.425	2.900	0.29	0.7	99.3	0.027	86.89			
0.300	2.300	0.23	0.93	99.07	0.017	83.04			
0.150	6.100	0.61	1.54	98.46	0.010	80.15			
0.075	8.700	0.87	2.41	97.59	0.007	77.27			
Pass	975.90	97.59	100	0	0.005	75.34			
					0.004	74.38			
					0.003	73.42			
					0.002	72.46			
					0.001	72.46			

Particle size distribution

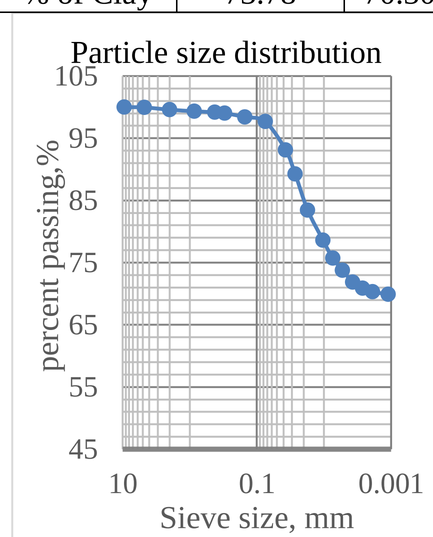


Hydrometer Analysis
Total oven dry mass 50
Specific Gravity 2.72

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydro meter Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	52	21	-3.85	48.15	0.986	7.8	0.013204	0.037	94.95	92.66
2	49	21	-3.85	45.15	0.986	8.3	0.013204	0.027	89.04	86.89
5	47	21	-3.85	43.15	0.986	8.6	0.013204	0.017	85.09	83.04
15	45.5	21	-3.85	41.65	0.986	8.9	0.013204	0.010	82.13	80.15
30	44	21	-3.85	40.15	0.986	9.1	0.013204	0.007	79.18	77.27
60	43	21	-3.85	39.15	0.986	9.3	0.013204	0.005	77.20	75.34
120	42.5	22	-3.85	38.65	0.986	9.4	0.013048	0.004	76.22	74.38
240	42	22	-3.85	38.15	0.986	9.5	0.013048	0.003	75.23	73.42
480	41.5	22	-3.85	37.65	0.986	9.5	0.013048	0.002	74.25	72.46
1440	41.5	21	-3.85	37.65	0.986	9.5	0.013204	0.001	74.25	72.46

Test Pit 20

TEST METHOD: ASTM D 422					Combined sieve and Hydrometer Analysis				
Sample preparation : Oven-dried sample									
Method of sieving: Wet sieving					particle size	percent pass	% of soil part.size	AASHTO	USCS
Mass dry soil			1000	gm	9.5	100	% of gravel	0.40	0.04
mass pass 0.075 mm			976.80	gm	4.75	99.96	% of Sand	1.92	2.28
percentage of pass 0.075			97.68	%	2	99.6	% of Silt	23.90	27.38
Total mass		1000		gm	0.85	99.34	% of Clay	73.78	70.30
Sieve Size	Mass of Ret,	% Ret.	% Cum. Ret.	% of Pass	0.4250	99.30			
9.5	0.000	0	0	100	0.300	99.18			
4.75	0.400	0.04	0.04	99.96	0.150	98.42			
2	3.600	0.36	0.4	99.6	0.075	97.68			
0.85	2.600	0.26	0.66	99.34	0.037	93.13			
0.425	1.600	0.16	0.82	99.18	0.027	89.26			
0.300	1.400	0.14	0.96	99.04	0.017	83.45			
0.150	6.200	0.62	1.58	98.42	0.010	78.62			
0.075	7.400	0.74	2.32	97.68	0.007	75.72			
Pass	976.80	97.68	100	0	0.005	73.78			
					0.004	71.85			
					0.003	0.003			
					0.002	70.30			
					0.001	69.92			

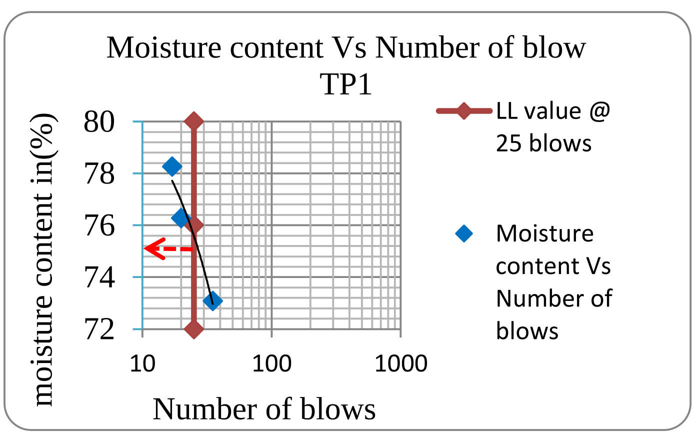


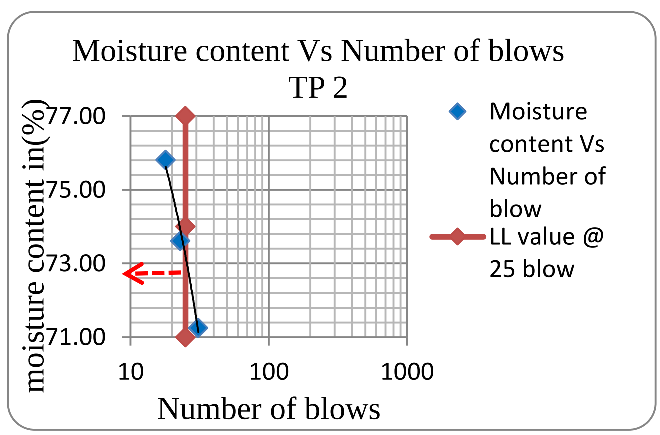
Hydrometer Analysis
Total oven dry mass 50
Specific Gravity 2.70

Time (min.)	Hydrometer Reading	Temp.	Composite correction	Corr.hydrometer Reading	Correction factor (a)	Effe. Depth of Hydr(L)	Values of K	Dia soil Part(mm)	% finer,P	Adjusted Percent of finer
1	52	21	-3.85	48.15	0.990	7.8	0.01328	0.037	95.34	93.13
2	50	21	-3.85	46.15	0.990	8.2	0.01328	0.027	91.38	89.26
5	47	21	-3.85	43.15	0.990	8.6	0.01328	0.017	85.44	83.45
15	44.5	21	-3.85	40.65	0.990	9.0	0.01328	0.010	80.49	78.62
30	43	21	-3.85	39.15	0.990	9.3	0.01328	0.007	77.52	75.72
60	42	21	-3.85	38.15	0.990	9.5	0.01328	0.005	75.54	73.78
120	41	22	-3.85	37.15	0.990	9.6	0.01312	0.004	73.56	71.85
240	40.5	22	-3.85	36.65	0.990	9.7	0.01312	0.003	72.57	70.88
480	40.2	21	-3.85	36.35	0.990	9.7	0.01328	0.002	71.97	70.30
1440	40	21	-3.85	36.15	0.990	9.8	0.01328	0.001	71.58	69.92

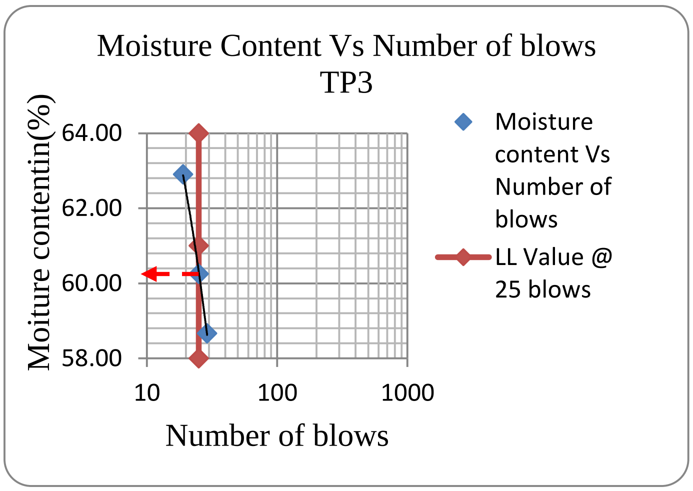
Liquid limit and plastic limit

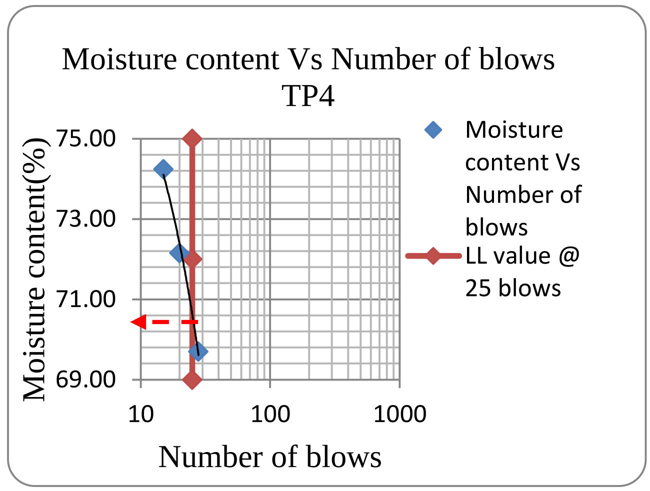
ATTERBERG LIMITS TEST										
	Units	Test Pit 1					Test Pit 2				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	35	20	17			31	23	18		
Can Code		G	G53	NB	A17	B11	ML	IK	NH	G14	I12
Mass of Can (Mc)	gram	17.6	17.9	17.9	21.9	16.9	17.4	17.4	17.4	20.1	23.3
Mc + wet Soil	gram	26.6	28.3	30.2	28.4	22.8	31.1	29.9	28.3	22.8	26.3
Mc + Dry Soil	gram	22.8	23.8	24.8	26.5	21.1	25.4	24.6	23.6	22	25.5
Mass of Dry soil	gram	5.2	5.9	6.9	4.6	4.2	8	7.2	6.2	1.9	2.2
Mass of Water	gram	3.80	4.50	5.40	1.9	1.70	5.70	5.30	4.70	0.8	0.80
Water Content	%	73.08	76.27	78.26	41.30	40.48	71.25	73.61	75.81	42.11	36.36
Liquid Limit (LL)	%	75.20					72.80				
Plastic Limit (PL)	%	40.89					39.23				
Plastic Index (PI)	%	34.31					33.57				



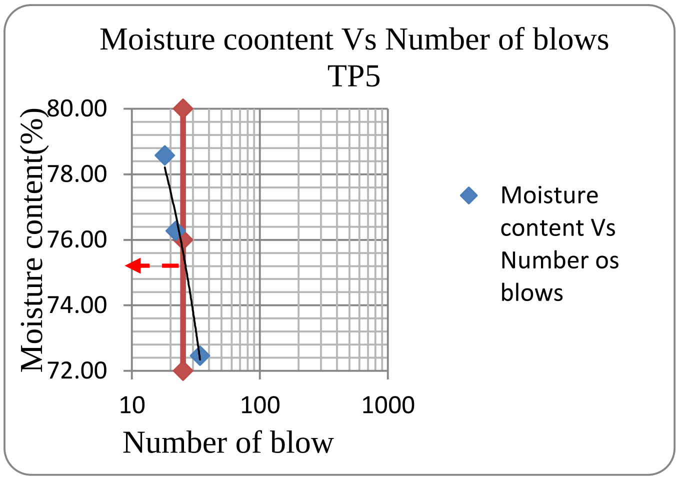


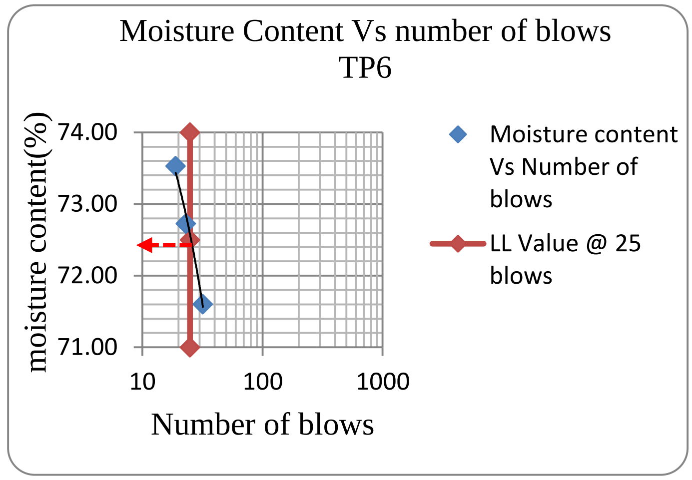
ATTERBERG LIMITS TEST										
	Units	Test Pit 3					Test Pit 4				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	29	25	19			28	20	15		
Can Code		P2	T2D	K4	A17	B11	P62	G3C3	A13	Y7	G8
Mass of Can (Mc)	gram	17.6	17.7	17.7	21.9	16.9	35.6	37.4	36.6	19.5	18.7
Mc + wet Soil	gram	29.5	30.2	27.8	28.3	23.7	46.8	51	48.1	25.6	24.3
Mc + Dry Soil	gram	25.1	25.5	23.9	26.8	22.1	42.2	45.3	43.2	23.9	22.7
Mass of Dry soil	gram	7.5	7.8	6.2	4.9	5.2	6.6	7.9	6.6	4.4	4
Mass of Water	gram	4.40	4.70	3.90	1.5	1.60	4.60	5.70	4.90	1.7	1.60
Water Content	%	58.67	60.26	62.90	30.61	30.77	69.70	72.15	74.24	38.64	40.00
Liquid Limit (LL)	%	60.26					70.50				
Plastic Limit (PL)	%	30.69					39.32				
Plastic Index (PI)	%	29.57					31.18				



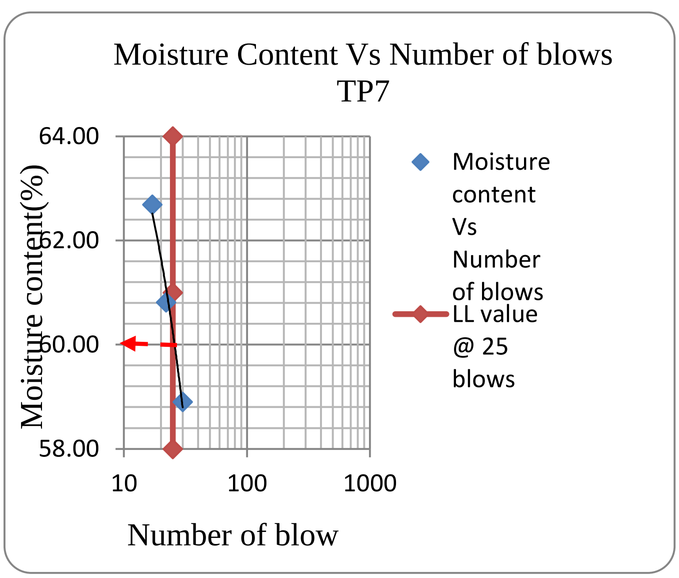


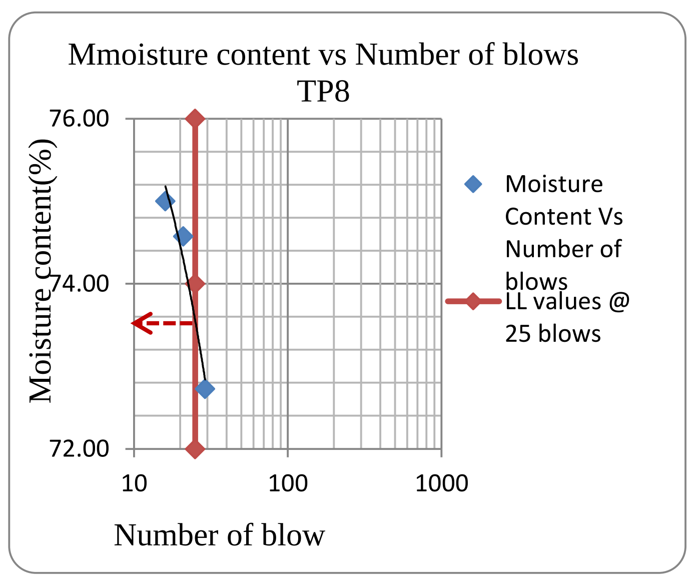
ATTERBERG LIMITS TEST										
	Units	Test Pit 5					Test Pit 6				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	34	32	23	19			32	23	19	
Can Code		M2	G2	G3	B1	G4	I2	G2	G3	B1	G4
Mass of Can (Mc)	gram	17.4	17.3	17.4	17.4	22.2	23.4	17.3	17.4	17.4	22.2
Mc + wet Soil	gram	29.3	31.2	30.7	29.2	25.5	26.7	31.2	30.7	29.2	25.5
Mc + Dry Soil	gram	24.3	25.4	25.1	24.2	24.6	25.8	25.4	25.1	24.2	24.6
Mass of Dry soil	gram	6.9	8.1	7.7	6.8	2.4	2.4	8.1	7.7	6.8	2.4
Mass of Water	gram	5.00	5.80	5.60	5.00	0.9	0.90	5.80	5.60	5.00	0.9
Water Content	%	72.46	71.60	72.73	73.53	37.50	37.50	71.60	72.73	73.53	37.50
Liquid Limit (LL)	%	75.20					72.40				
Plastic Limit (PL)	%	40.93					37.50				
Plastic Index (PI)	%	34.27					34.90				



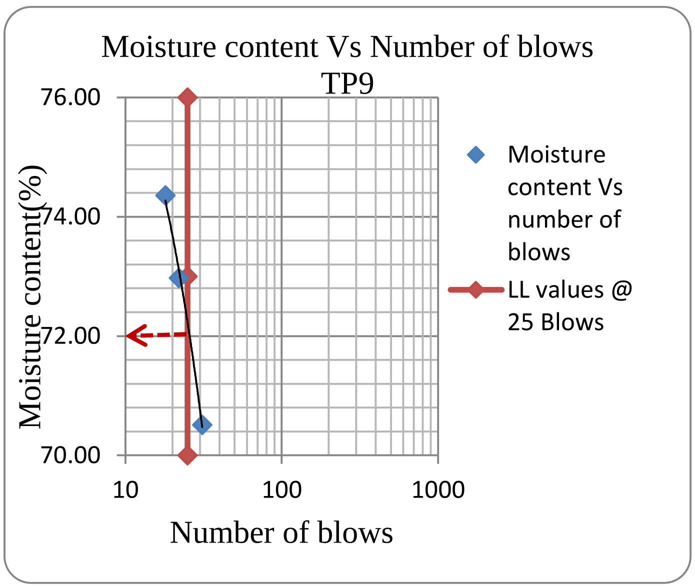


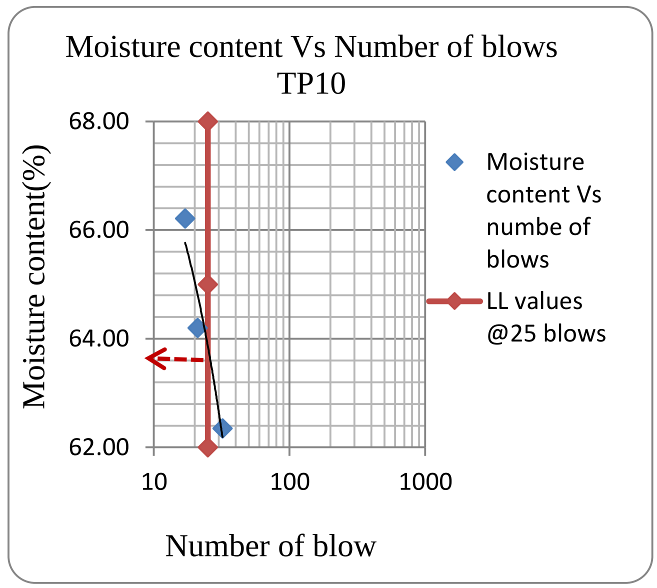
ATTERBERG LIMITS TEST											
	Units	Test Pit 7					Test Pit 8				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	30	22	17			29	21	16		
Can Code		D2	T3	K4	A7	B5	P2	C3	A1	I7	G8
Mass of Can (Mc)	gram	17.5	17.4	17.4	17.9	16.7	36.5	37.3	36.4	19.6	18.9
Mc + wet Soil	gram	29.1	29.3	28.3	24.2	23.2	47.9	47.6	48.3	24.8	23.5
Mc + Dry Soil	gram	24.8	24.8	24.1	22.9	21.8	43.1	43.2	43.2	23.3	22.2
Mass of Dry soil	gram	7.3	7.4	6.7	5	5.1	6.6	5.9	6.8	3.7	3.3
Mass of Water	gram	4.30	4.50	4.20	1.3	1.40	4.80	4.40	5.10	1.5	1.30
Water Content	%	58.90	60.81	62.69	26.00	27.45	72.73	74.58	75.00	40.54	39.39
Liquid Limit (LL)	%	60.00					73.52				
Plastic Limit (PL)	%	26.73					39.97				
Plastic Index (PI)	%	33.27					33.55				



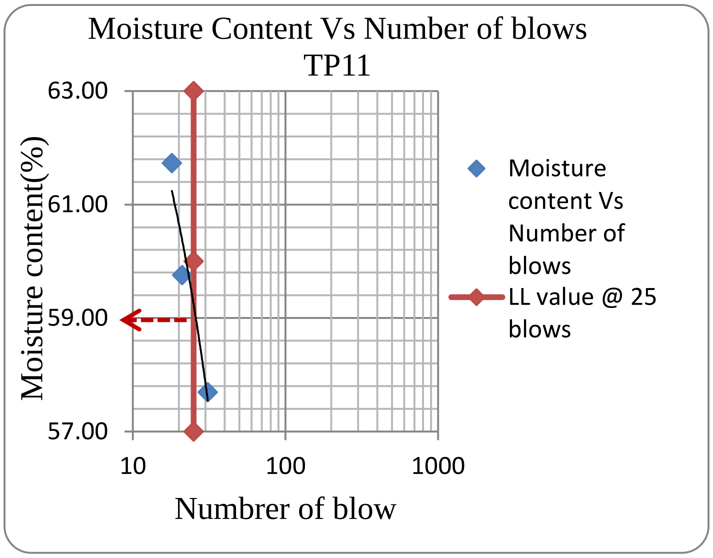


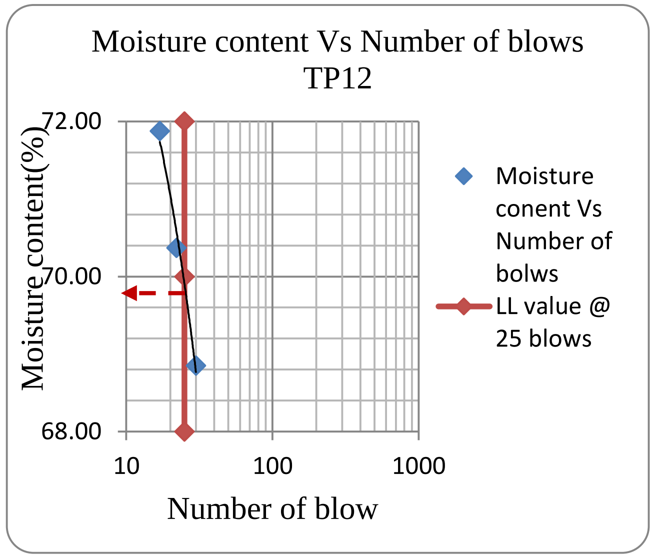
ATTERBERG LIMITS TEST											
	Units	Test Pit 9					Test Pit 10				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	1	2	3	1	2	1	2	3	1
Number of Blows	N	31	32	21	17			32	21	17	
Can Code		G2	G2	G3	B1	G4	I2	G2	G3	B1	G4
Mass of Can (Mc)	gram	17.4	17.3	17.4	17.4	22.2	23.2	17.3	17.4	17.4	22.2
Mc + wet Soil	gram	30.7	31.1	30.7	29.7	25.3	26.7	31.1	30.7	29.7	25.3
Mc + Dry Soil	gram	25.2	25.8	25.5	24.8	24.4	25.7	25.8	25.5	24.8	24.4
Mass of Dry soil	gram	7.8	8.5	8.1	7.4	2.2	2.5	8.5	8.1	7.4	2.2
Mass of Water	gram	5.50	5.30	5.20	4.90	0.9	1.00	5.30	5.20	4.90	0.9
Water Content	%	70.51	62.35	64.20	66.22	40.91	40.00	62.35	64.20	66.22	40.91
Liquid Limit (LL)	%	72.00					63.60				
Plastic Limit (PL)	%	40.51					40.45				
Plastic Index (PI)	%	31.49					23.15				



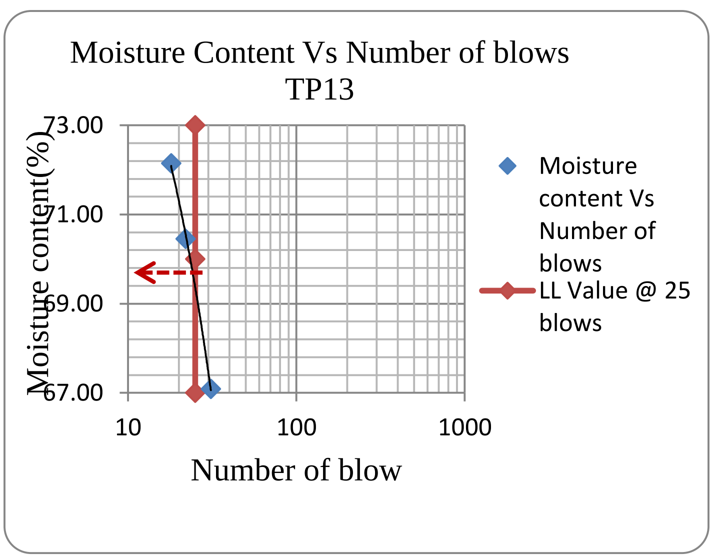


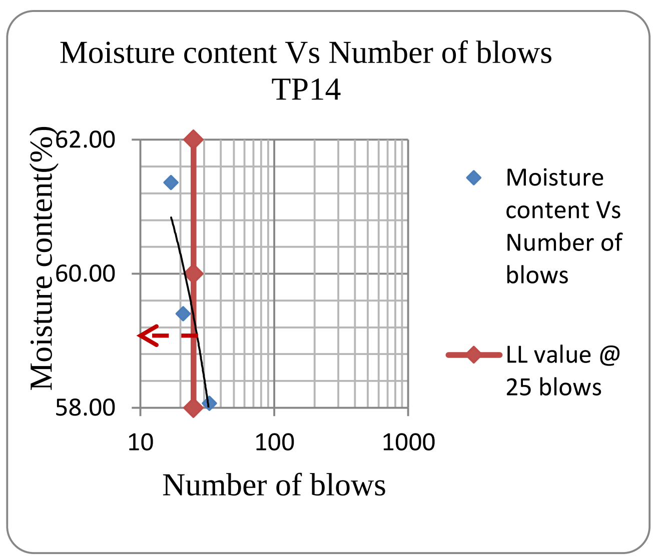
ATTERBERG LIMITS TEST											
	Units	Test Pit 11					Test Pit 12				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	31	21	18			30	22	17		
Can Code		D2	T3	K4	A7	B5	L2	D3	BK1	A7	G8
Mass of Can (Mc)	gram	17.4	17.4	17.4	17.9	16.8	35.6	37.4	36.5	19.5	18.7
Mc + wet Soil	gram	29.7	30.5	30.5	24.9	23.8	45.9	46.6	47.5	25.7	24.7
Mc + Dry Soil	gram	25.2	25.6	25.5	23.3	22.3	41.7	42.8	42.9	24.2	23.2
Mass of Dry soil	gram	7.8	8.2	8.1	5.4	5.5	6.1	5.4	6.4	4.7	4.5
Mass of Water	gram	4.50	4.90	5.00	1.6	1.50	4.20	3.80	4.60	1.5	1.50
Water Content	%	57.69	59.76	61.73	29.63	27.27	68.85	70.37	71.88	31.91	33.33
Liquid Limit (LL)	%	59.00					69.70				
Plastic Limit (PL)	%	28.45					32.62				
Plastic Index (PI)	%	30.55					37.08				



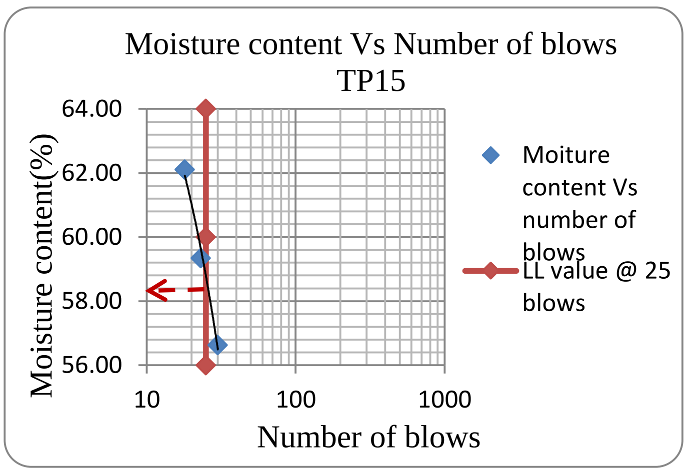


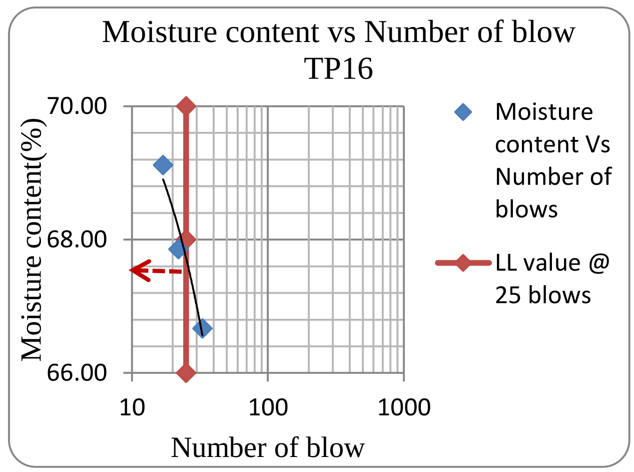
ATTERBERG LIMITS TEST										
	Units	Test Pit 13					Test Pit 14				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	31	22	18			33	21	17		
Can Code		G2	M5	N3	A7	B1	G2	G3	B1	G4	I2
Mass of Can (Mc)	gram	17.3	17.4	17.3	18.8	17.9	17.4	17.4	17.4	22.3	23.4
Mc + wet Soil	gram	30.5	32.4	30.9	26.7	26.2	32.1	33.5	31.6	26.6	27.8
Mc + Dry Soil	gram	25.2	26.2	25.2	24.5	23.9	26.7	27.5	26.2	25.4	26.6
Mass of Dry soil	gram	7.9	8.8	7.9	5.7	6	9.3	10.1	8.8	3.1	3.2
Mass of Water	gram	5.30	6.20	5.70	2.2	2.30	5.40	6.00	5.40	1.2	1.20
Water Content	%	67.09	70.45	72.15	38.60	38.33	58.06	59.41	61.36	38.71	37.50
Liquid Limit (LL)	%	70.00					59.10				
Plastic Limit (PL)	%	38.46					38.10				
Plastic Index (PI)	%	31.54					21.00				



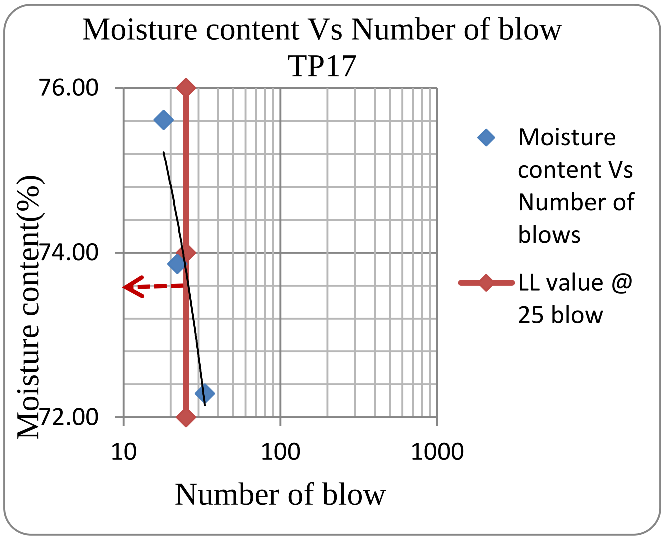


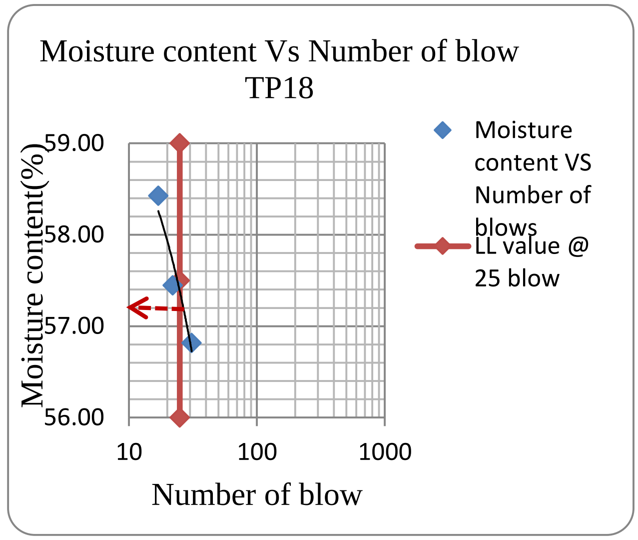
ATTERBERG LIMITS TEST										
	Units	Test Pit 15					Test Pit 16				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	30	23	18			33	22	17		
Can Code		D2	T3	K4	A7	B5	L2	D3	BK1	A7	G8
Mass of Can (Mc)	gram	17.4	17.4	17.4	18.9	17.8	35.4	37.2	36.3	18.5	17.9
Mc + wet Soil	gram	30.4	31.9	32.8	26.1	23.9	44.4	46.6	47.8	25.9	24.8
Mc + Dry Soil	gram	25.7	26.5	26.9	24.6	22.6	40.8	42.8	43.1	24.1	23.1
Mass of Dry soil	gram	8.3	9.1	9.5	5.7	4.8	5.4	5.6	6.8	5.6	5.2
Mass of Water	gram	4.70	5.40	5.90	1.5	1.30	3.60	3.80	4.70	1.8	1.70
Water Content	%	56.63	59.34	62.11	26.32	27.08	66.67	67.86	69.12	32.14	32.69
Liquid Limit (LL)	%	58.40					67.45				
Plastic Limit (PL)	%	26.70					32.42				
Plastic Index (PI)	%	31.70					35.03				



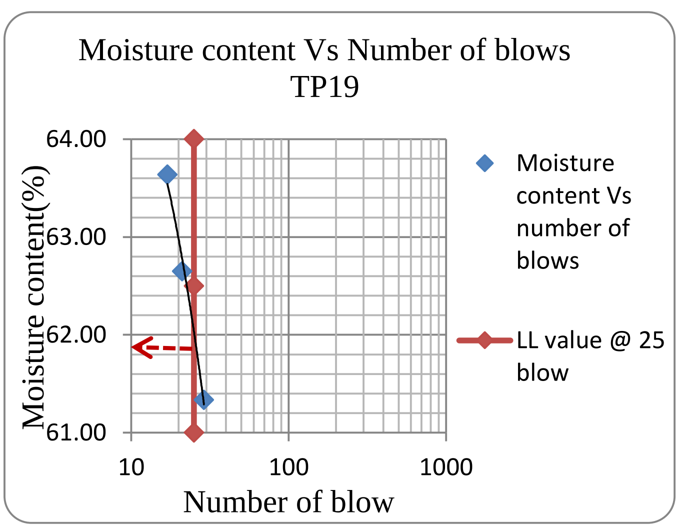


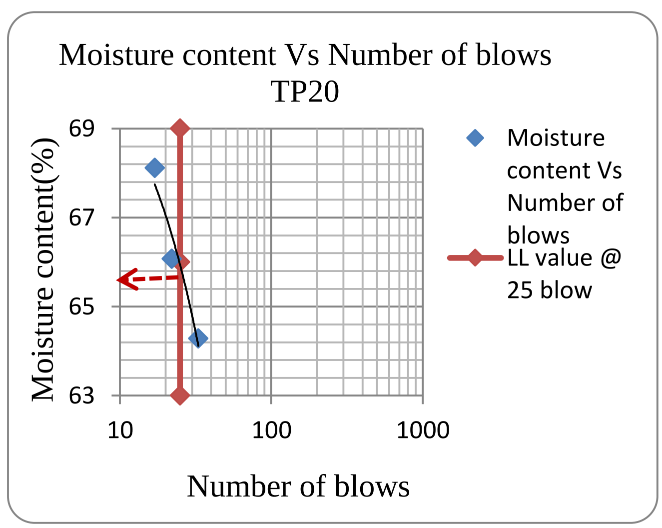
ATTERBERG LIMITS TEST										
	Units	Test Pit 17					Test Pit 18				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	33	22	18			31	22	17		
Can Code		H2	M5	N3	A7	B1	G2	G3	B1	G4	I2
Mass of Can (Mc)	gram	17.3	17.4	17.4	18.1	17.6	17.3	17.4	17.3	18.2	17.8
Mc + wet Soil	gram	31.6	32.7	31.8	26.8	26.2	31.1	32.2	31.4	26.6	26.6
Mc + Dry Soil	gram	25.6	26.2	25.6	24.5	23.9	26.1	26.8	26.2	24.7	24.6
Mass of Dry soil	gram	8.3	8.8	8.2	6.4	6.3	8.8	9.4	8.9	6.5	6.8
Mass of Water	gram	6.00	6.50	6.20	2.3	2.30	5.00	5.40	5.20	1.9	2.00
Water Content	%	72.29	73.86	75.61	35.94	36.51	56.82	57.45	58.43	29.23	29.41
Liquid Limit (LL)	%	73.60					57.20				
Plastic Limit (PL)	%	36.22					29.32				
Plastic Index (PI)	%	37.38					27.88				



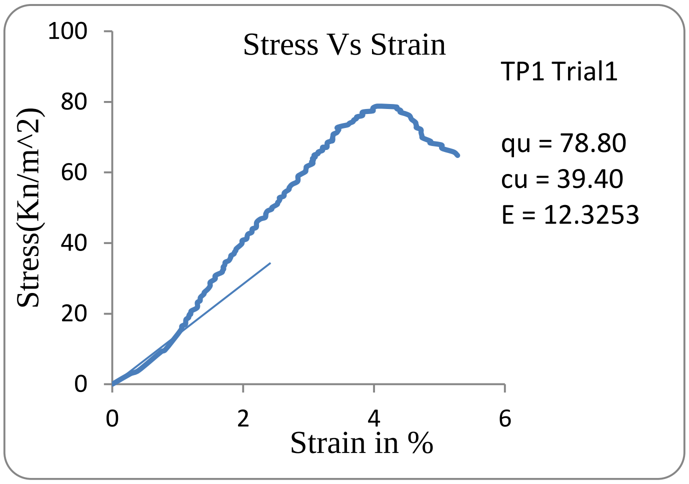


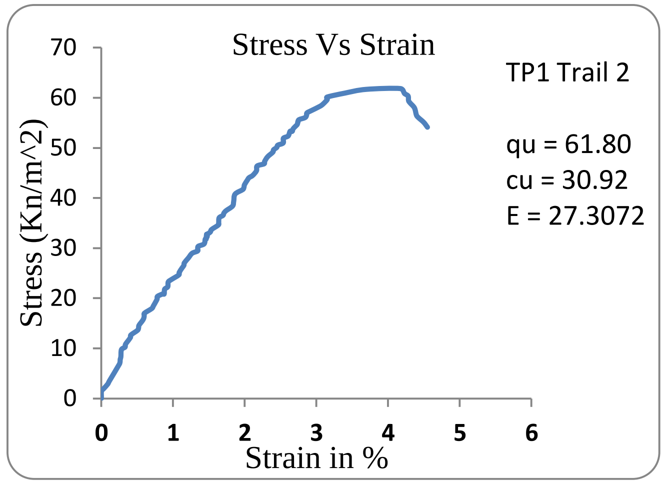
ATTERBERG LIMITS TEST											
	Units	Test Pit 19					Test Pit 20				
Test		Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Trial number		1	2	3	1	2	1	2	3	1	2
Number of Blows	N	29	21	17			33	22	17		
Can Code		D2	T3	K4	A7	B5	L2	D3	BK1	A7	G8
Mass of Can (Mc)	gram	17.3	17.4	17.5	18.9	17.8	35.3	37.1	36.2	18.5	17.9
Mc + wet Soil	gram	29.4	30.9	31.9	26.9	24.7	44.5	46.4	47.8	25.9	24.8
Mc + Dry Soil	gram	24.8	25.7	26.3	25.2	23.2	40.9	42.7	43.1	24.1	23.1
Mass of Dry soil	gram	7.5	8.3	8.8	6.3	5.4	5.6	5.6	6.9	5.6	5.2
Mass of Water	gram	4.60	5.20	5.60	1.7	1.50	3.60	3.70	4.70	1.8	1.70
Water Content	%	61.33	62.65	63.64	26.98	27.78	64.29	66.07	68.12	32.14	32.69
Liquid Limit (LL)	%	61.95					65.50				
Plastic Limit (PL)	%	27.38					32.42				
Plastic Index (PI)	%	34.57					33.08				

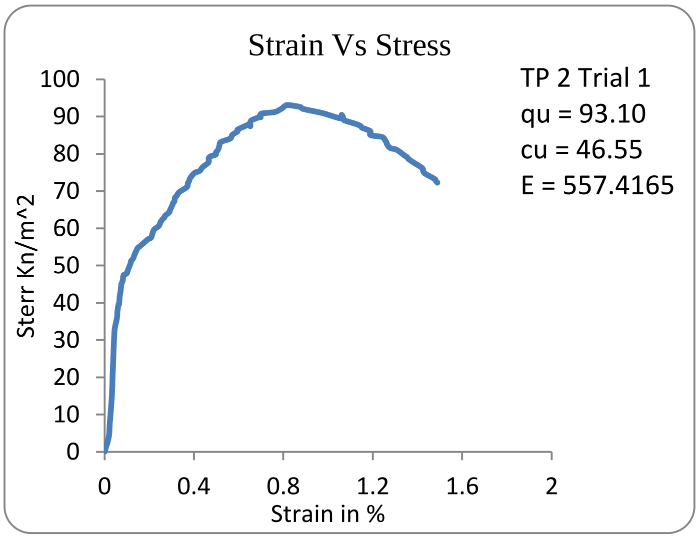


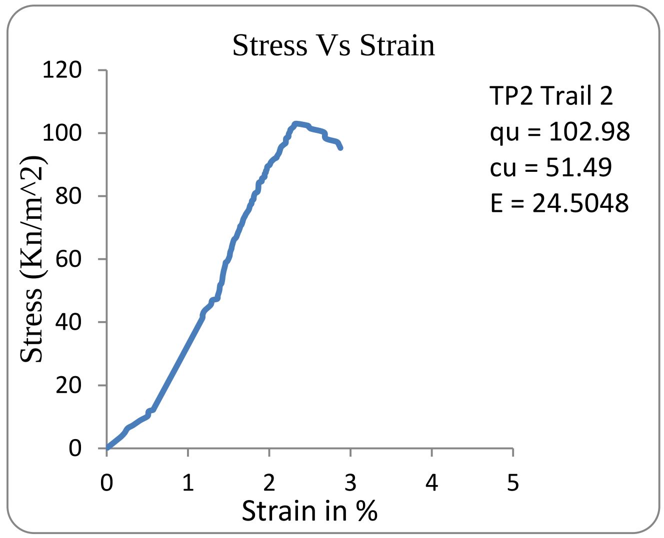


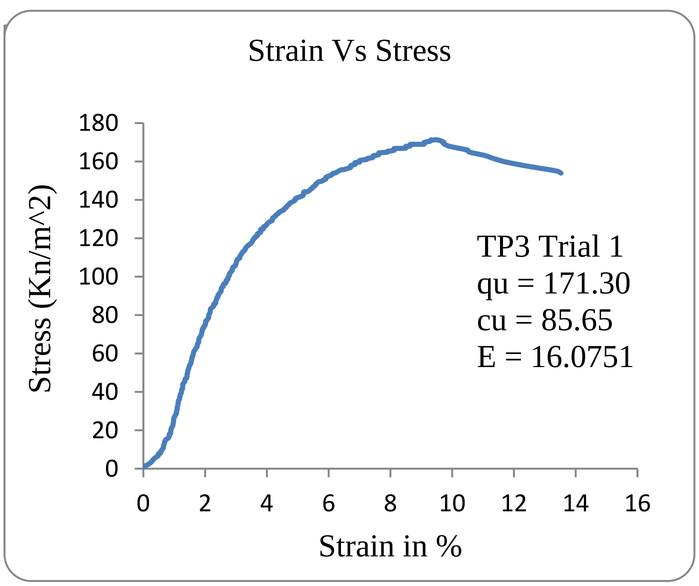
Unconfined Compressive Strength & Undrained Shear Strength

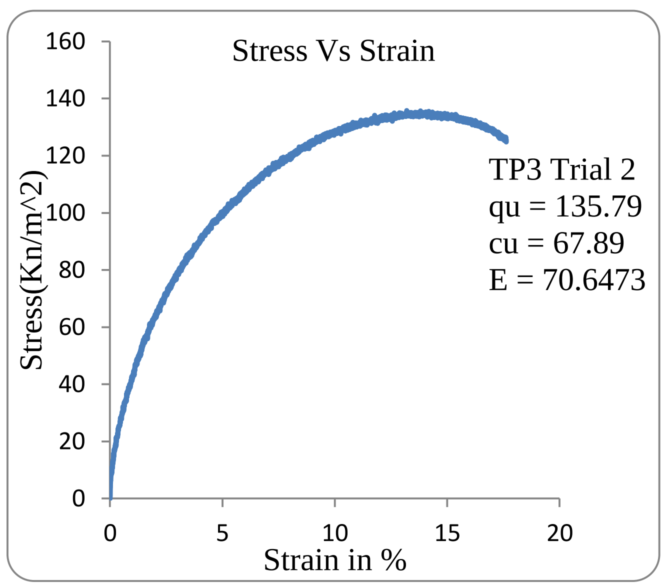


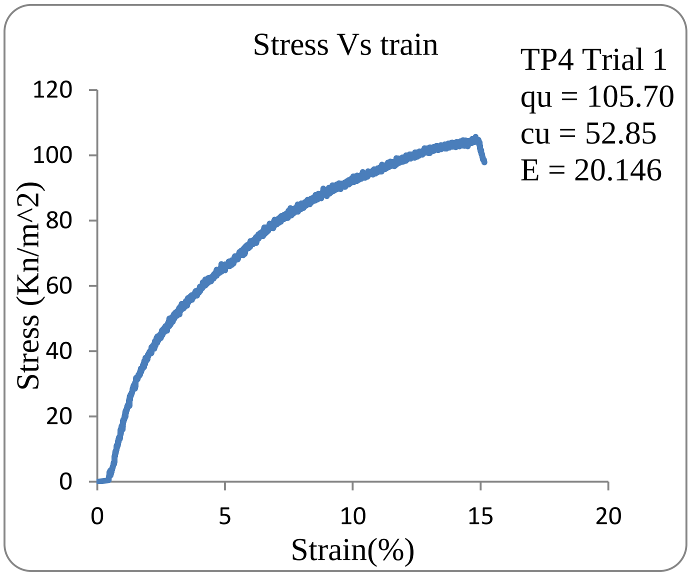


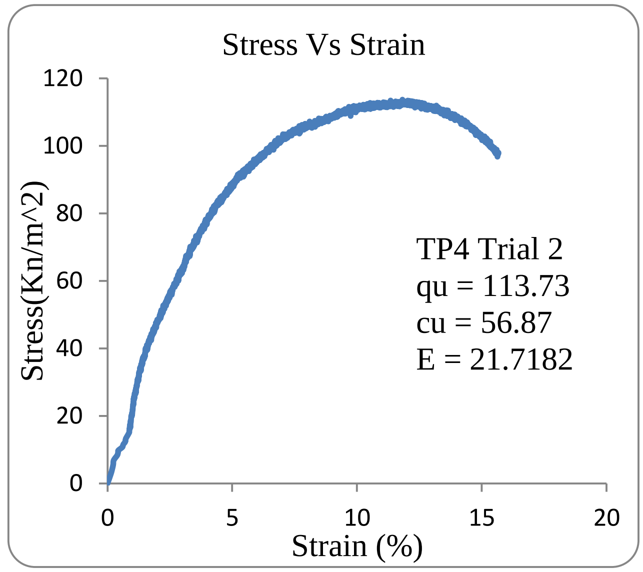


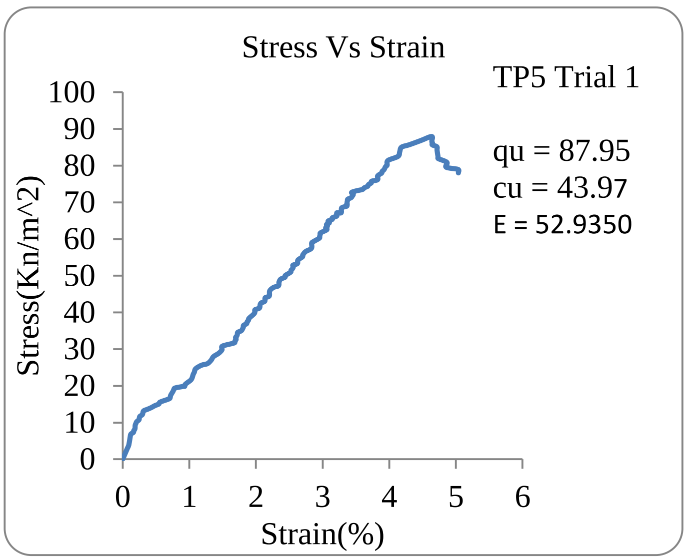


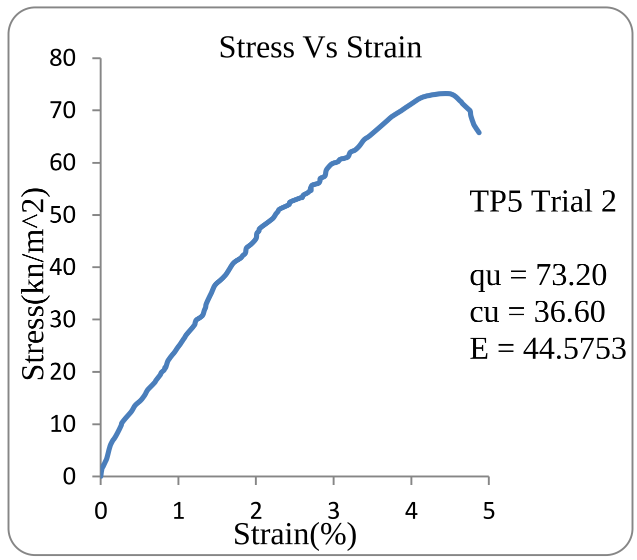


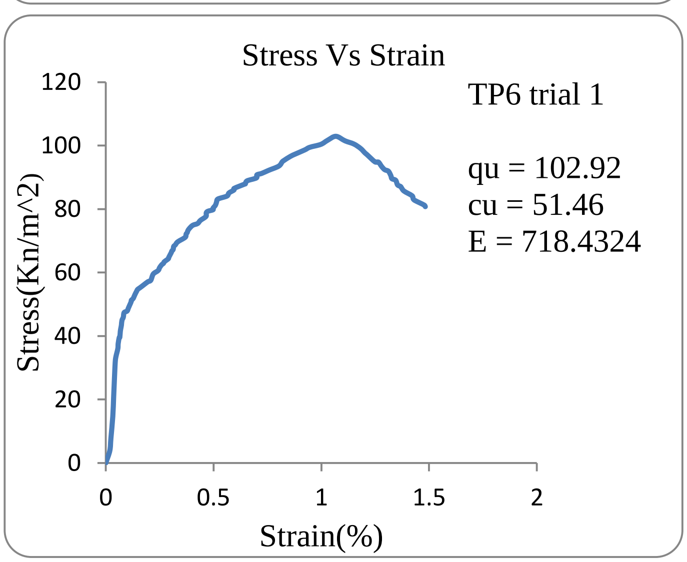


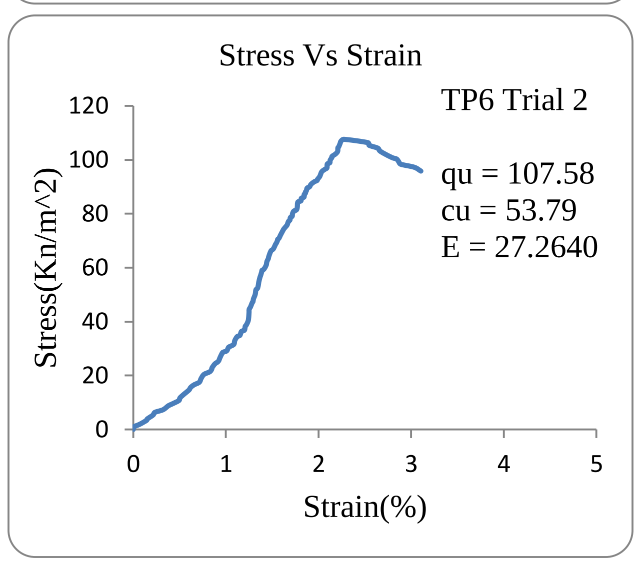

Stress Vs train
TP4 Trial 1
qu = 105.70
cu = 52.85
E = 20.146
Stress (Kn/m^2)
Strain(%)
120
100
80
60
40
20
0
0
5
10
15
20

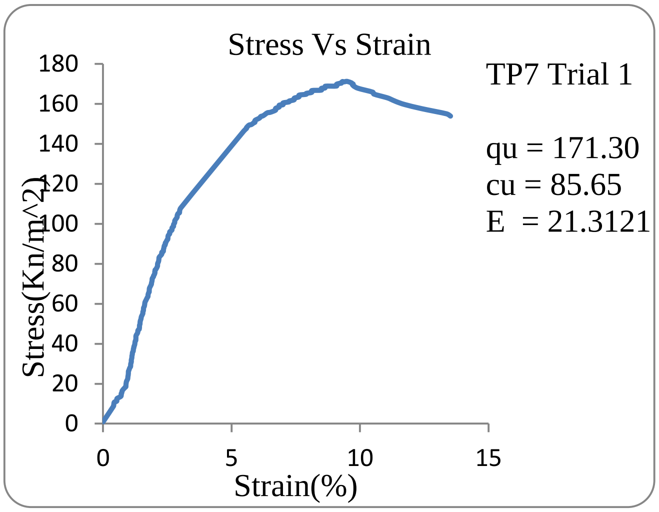

Stress Vs Strain
TP4 Trial 2
qu = 113.73
cu = 56.87
E = 21.7182
Stress(Kn/m^2)
Strain (%)
120
100
80
60
40
20
0
0
5
10
15
20

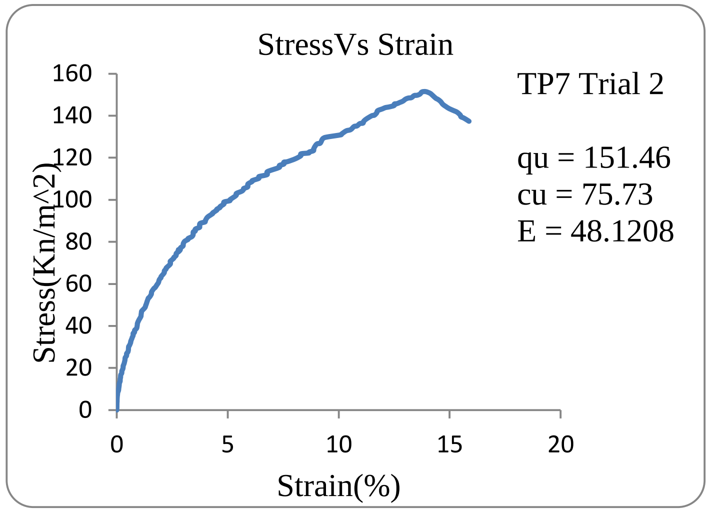

Stress Vs Strain
TP5 Trial 1
qu = 87.95
cu = 43.97
E = 52.9350
Stress(Kn/m^2)
Strain(%)
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6

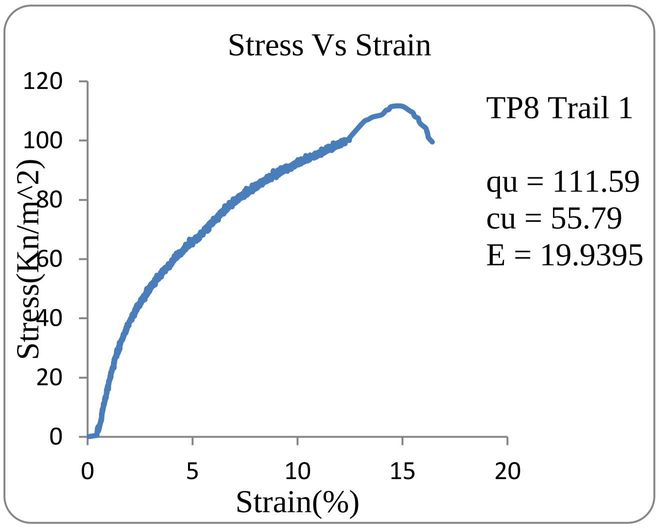

Stress Vs Strain
TP5 Trial 2
qu = 73.20
cu = 36.60
E = 44.5753
Stress(kn/m^2)
Strain(%)
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5

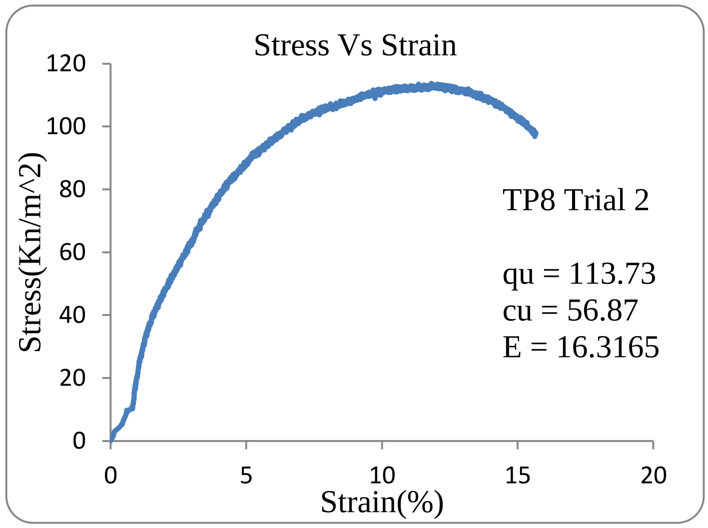

Stress Vs Strain
TP6 trial 1
qu = 102.92
cu = 51.46
E = 718.4324
Stress(Kn/m^2)
Strain(%)
120
100
80
60
40
20
0
0
0.5
1
1.5
2

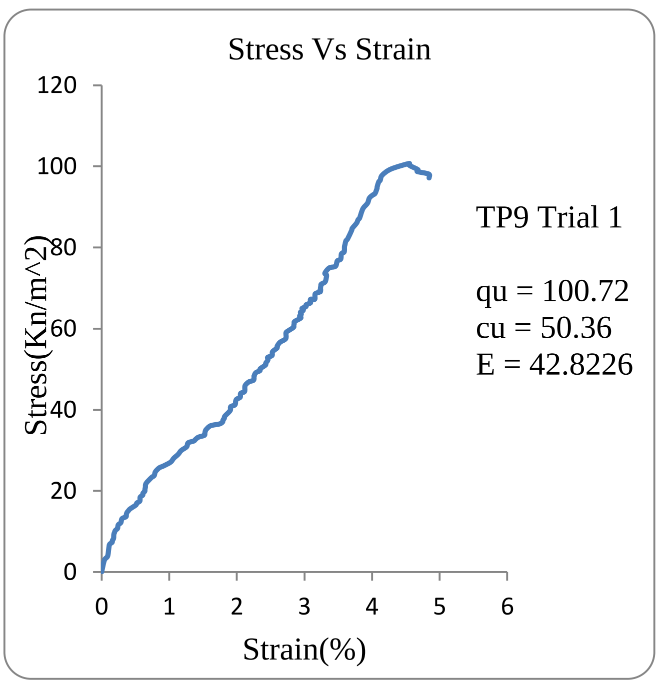

Stress Vs Strain
TP6 Trial 2
qu = 107.58
cu = 53.79
E = 27.2640
Stress(Kn/m^2)
Strain(%)
120
100
80
60
40
20
0
0
1
2
3
4
5

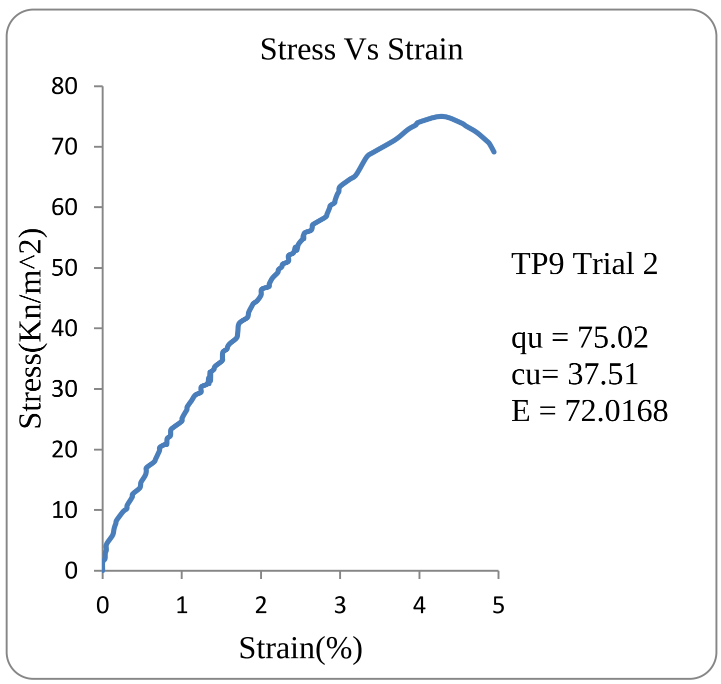

Stress Vs Strain
TP7 Trial 1
qu = 171.30
cu = 85.65
E = 21.3121
Stress(Kn/m^2)
Strain(%)

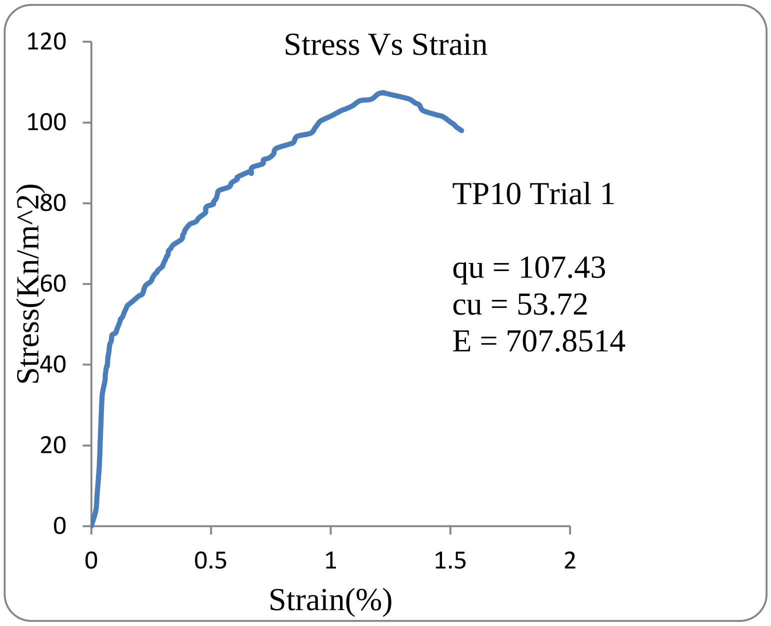

StressVs Strain
TP7 Trial 2
qu = 151.46
cu = 75.73
E = 48.1208
Stress(Kn/m^2)
Strain(%)

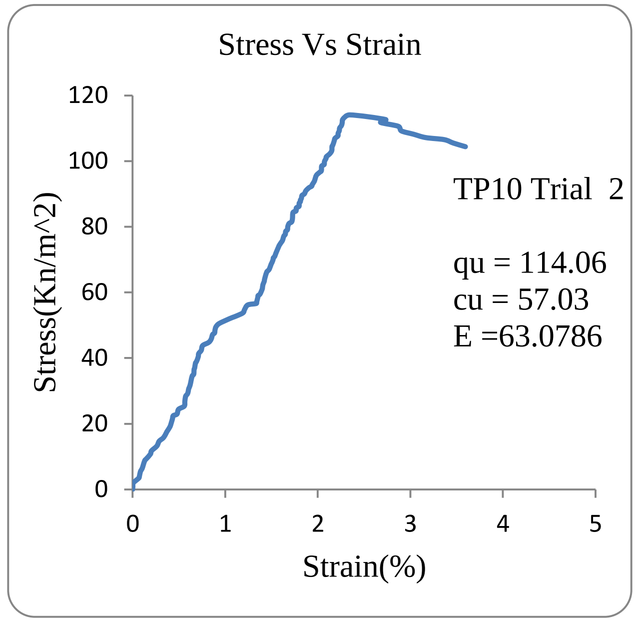

Stress Vs Strain
TP8 Trail 1
qu = 111.59
cu = 55.79
E = 19.9395
Stress(Kn/m^2)
Strain(%)


Stress Vs Strain
TP8 Trial 2
qu = 113.73
cu = 56.87
E = 16.3165
Stress(Kn/m^2)
Strain(%)


Stress Vs Strain
TP9 Trial 1
qu = 100.72
cu = 50.36
E = 42.8226
Stress(Kn/m^2)
Strain(%)


Stress Vs Strain
TP9 Trial 2
qu = 75.02
cu= 37.51
E = 72.0168
Stress(Kn/m^2)
Strain(%)





Unconfined Compressive Strength & Undrained Shear Strength in Tabular Form

Test Type:	Unconfined compression Test(ASTM D-2216)								
Test Pit	1			2			3		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
qu (Kn/m^2	78.80	61.84	70.32	93	103	98.04	171.30	135.79	153.55
Cu(Kn/m^2)	39.4	30.92	35.16	46.55	51.49	49.02	85.65	67.895	76.77
Young's M.(E)	12.3253	27.3072	19.8163	557.4165	24.5048	290.961	16.075	70.6473	86.7223

Test Type:	Unconfined compression Test(ASTM D-2216)								
Test Pit	4			5			6		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
qu (Kn/m^2	105.70	113.73	109.72	87.95	73.20	80.58	102.92	107.58	105.25
Cu(Kn/m^2)	52.85	56.865	54.86	43.975	36.6	40.29	51.46	53.79	52.63
Young's M.(E)	20.146	21.7182	20.9321	52.9350	44.5753	48.7551	718.4324	27.2640	372.8482

Test Type:	Unconfined compression Test(ASTM D-2216)								
Test Pit	7			8			9		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
qu (Kn/m^2	171.30	151.46	161.38	111.59	113.73	112.66	87.95	73.20	80.58
Cu(Kn/m^2)	85.65	75.73	80.69	55.795	56.865	56.33	43.975	36.6	40.29
Young's M.(E)	21.3121	48.1208	34.7165	19.9395	16.3165	18.128	100.8226	72.0168	86.4197

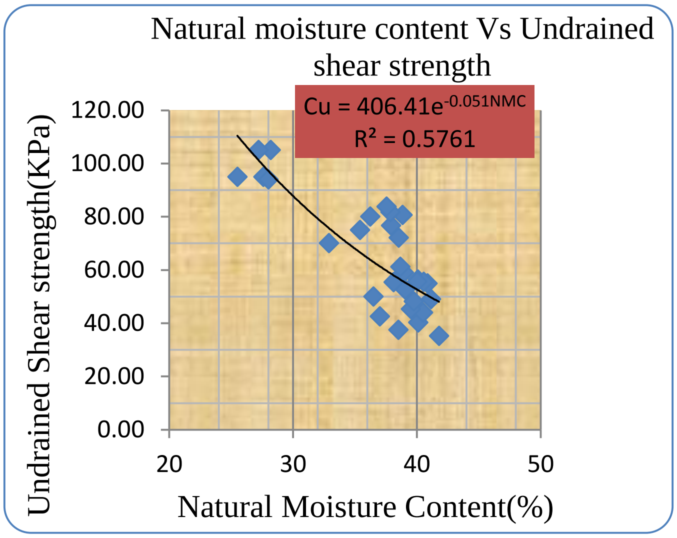
Test Type:	Unconfined compression Test(ASTM D-2216)								
Test Pit	10			11			12		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
qu (Kn/m^2	102.92	107.58	105.25	174.89	151.76	163.33	111.59	110.34	110.97
Cu(Kn/m^2)	51.46	53.79	52.63	87.445	75.88	81.66	55.795	55.17	55.48
Young's M.(E)	707.8514	63.0786	385.465	20.5558	65.0767	42.8162	17.8614	26.2036	21.9486

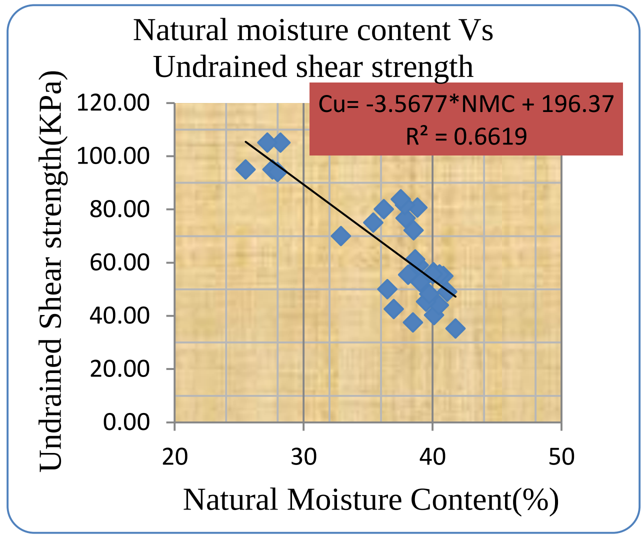
Test Type:	Unconfined compression Test(ASTM D-2216)								
Test Pit	13			14			15		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
qu (Kn/m^2	100.84	80.22	90.53	113.12	122.96	118.04	178.19	156.77	167.48
Cu(Kn/m^2)	50.42	40.11	45.27	56.56	61.48	59.02	89.095	78.385	83.74
Young's M.(E)	278.749	21.3556	150.0523	607.17	18.1408	312.6554	21.074	96.011	58.5426

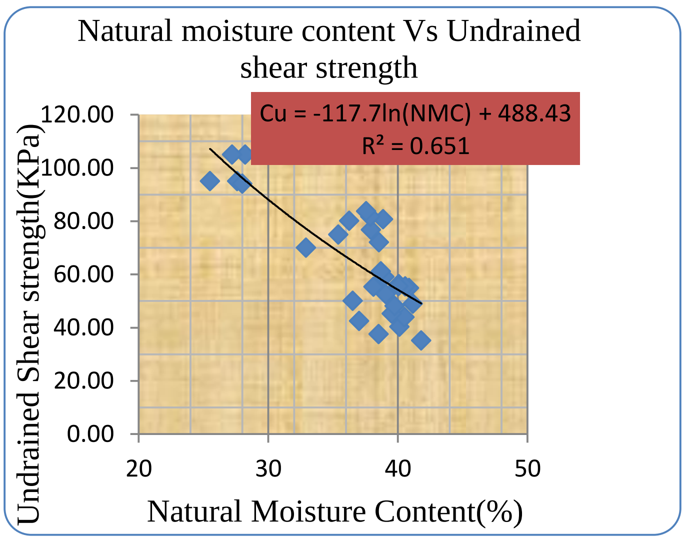
Test Type:	Unconfined compression Test(ASTM D-2216)								
Test Pit	16			17			18		
Trial	1	2	Avg.	1	2	Avg.	1	2	Avg.
qu (Kn/m^2	110.23	112.30	111.27	101.76	90.96	96.36	121.64	122.91	122.28
Cu(Kn/m^2)	55.115	56.15	55.63	50.88	45.48	48.18	60.82	61.455	61.14
Young's M.(E)	122.6981	205.926	164.3093	36.6593	352.2702	194.4648	584.2343	17.9127	301.0735

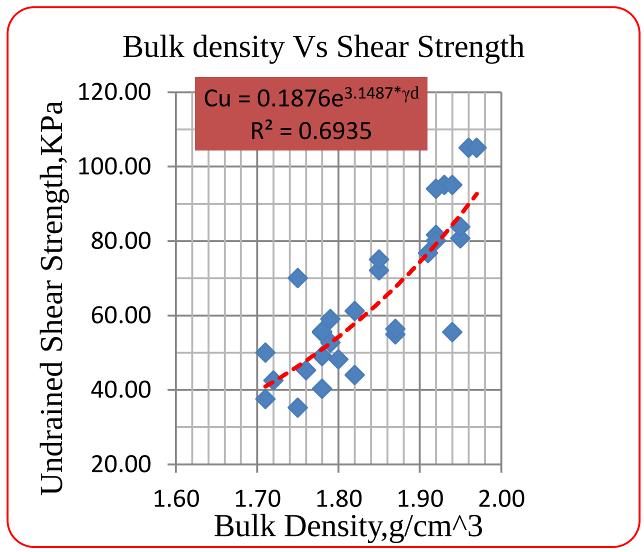
Test Type:	Unconfined compression Test(ASTM D-2216)					
Test Pit	19			20		
Trial	1	2	Avg.	1	2	Avg.
qu (Kn/m^2	177.93	142.32	160.13	110.24	178.19	144.22
Cu(Kn/m^2)	88.97	71.16	80.06	55.12	89.095	72.11
Young's M.(E)	14.0138	108.3616	61.1877	25.4842	35.321	30.4026

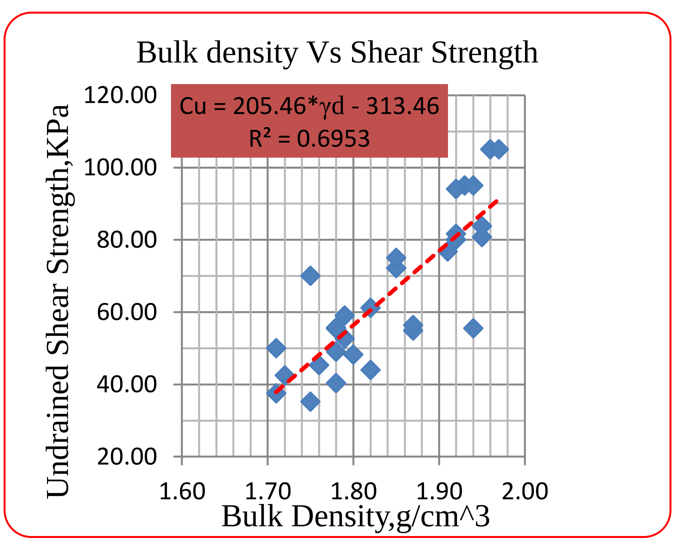
SCATOR PLOT

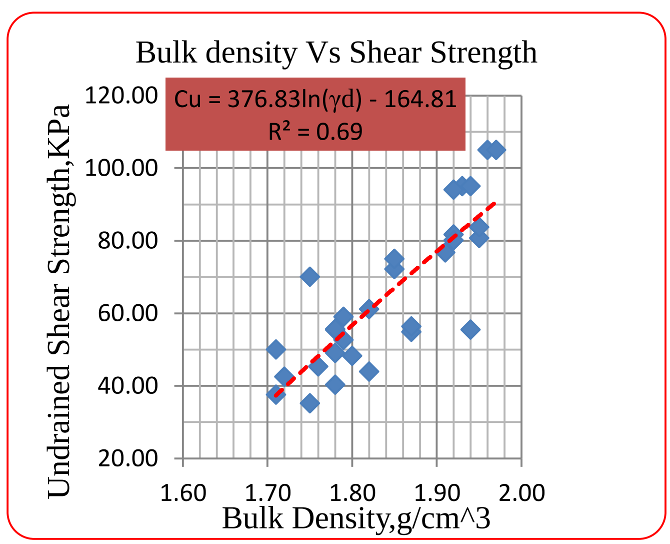

Natural moisture content Vs Undrained shear strength
Cu = 406.41e^-0.051NMC
R² = 0.5761
Undrained Shear strength(KPa)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
20
30
40
50
Natural Moisture Content(%)


Natural moisture content Vs Undrained shear strength
Cu= -3.5677*NMC + 196.37
R² = 0.6619
Undrained Shear strength(KPa)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
20
30
40
50
Natural Moisture Content(%)


Natural moisture content Vs Undrained shear strength
Cu = -117.7ln(NMC) + 488.43
R² = 0.651
Undrained Shear strength(KPa)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
20
30
40
50
Natural Moisture Content(%)

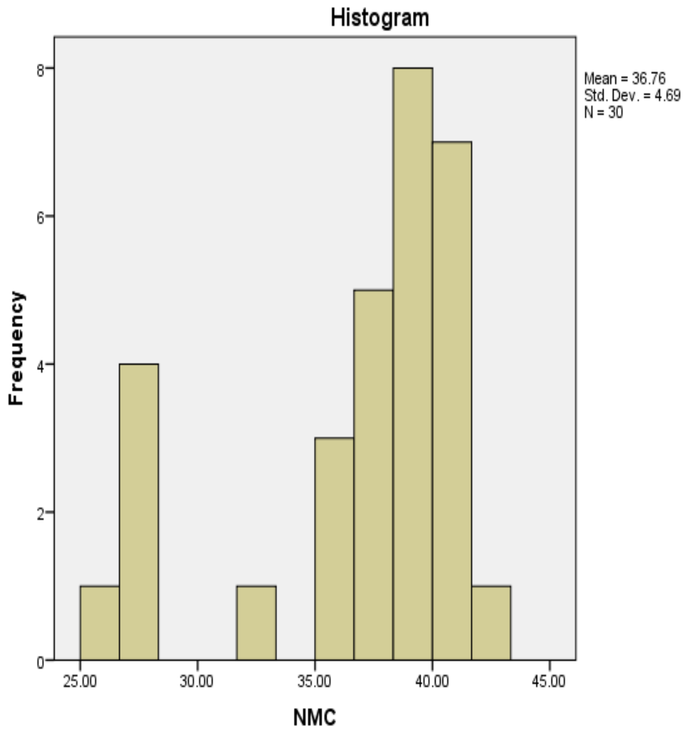

Bulk density Vs Shear Strength
Cu = 0.1876e^3.1487*γd
R² = 0.6935
Undrained Shear Strength,KPa
120.00
100.00
80.00
60.00
40.00
20.00
1.60
1.70
1.80
1.90
2.00
Bulk Density,g/cm^3

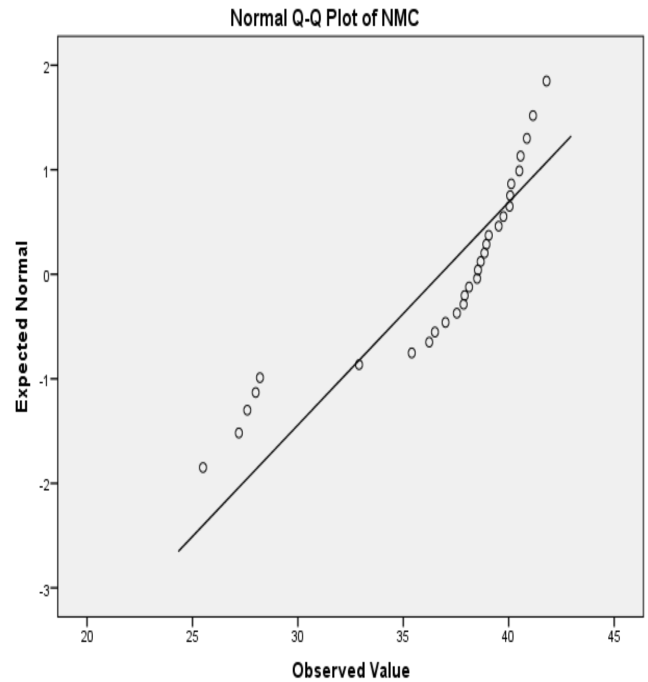

Bulk density Vs Shear Strength
Cu = 205.46*γd - 313.46
R² = 0.6953
Undrained Shear Strength,KPa
120.00
100.00
80.00
60.00
40.00
20.00
1.60
1.70
1.80
1.90
2.00
Bulk Density,g/cm^3

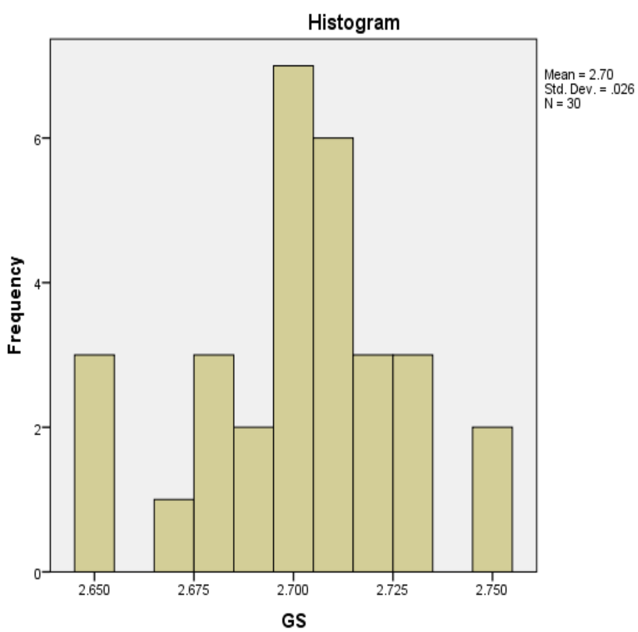

Bulk density Vs Shear Strength
Cu = 376.83ln(γd) - 164.81
R² = 0.69
Undrained Shear Strength,KPa
120.00
100.00
80.00
60.00
40.00
20.00
1.60
1.70
1.80
1.90
2.00
Bulk Density,g/cm^3

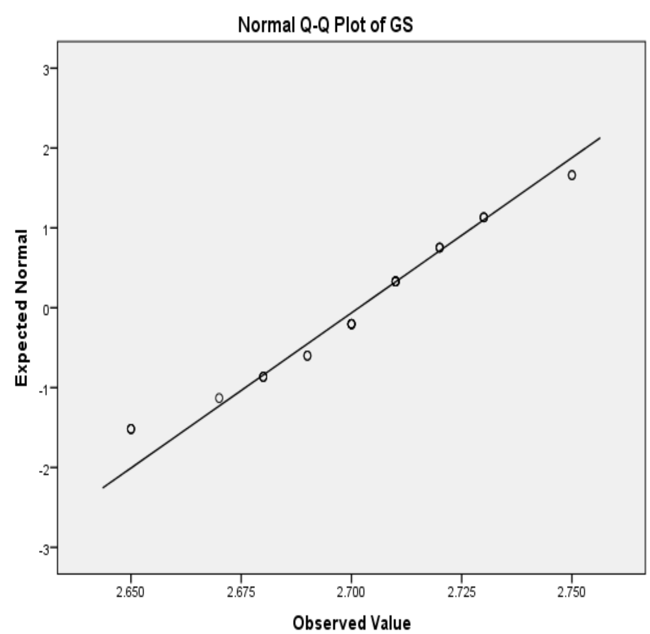
APPENDIX –B: SPSS Regression analysis output

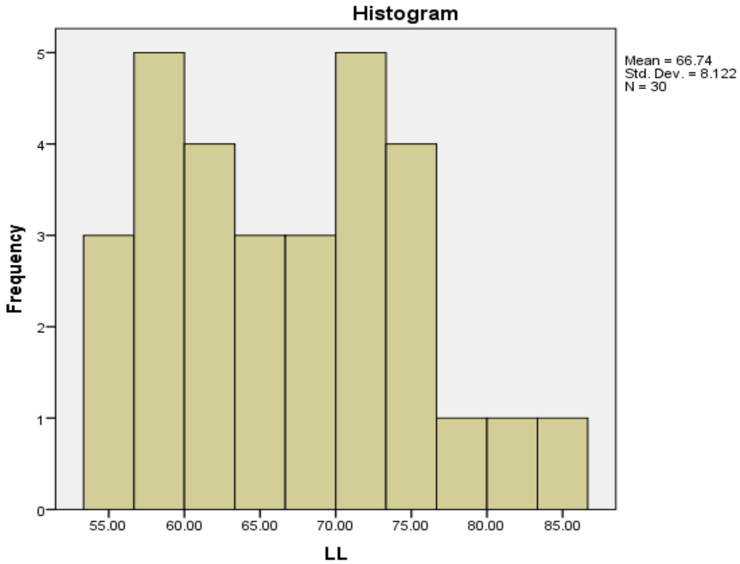
Graph of Normality test for each Variables

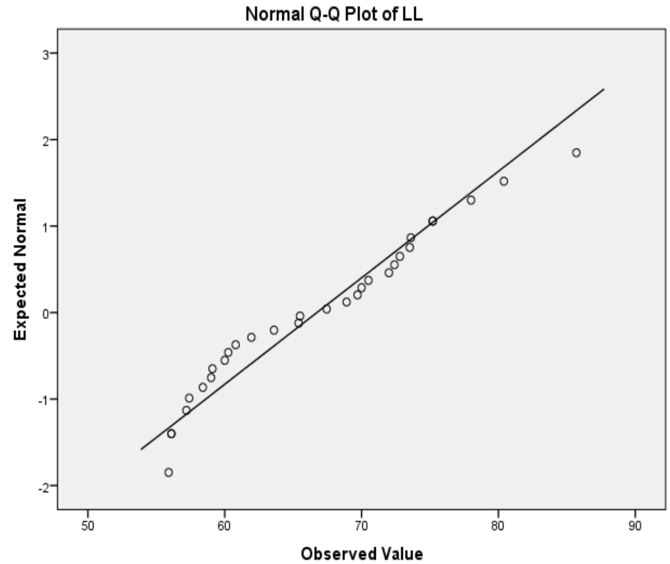


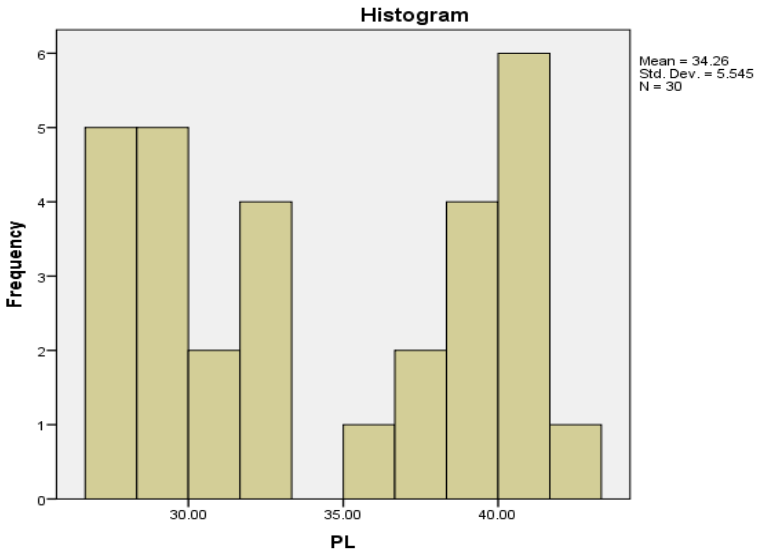


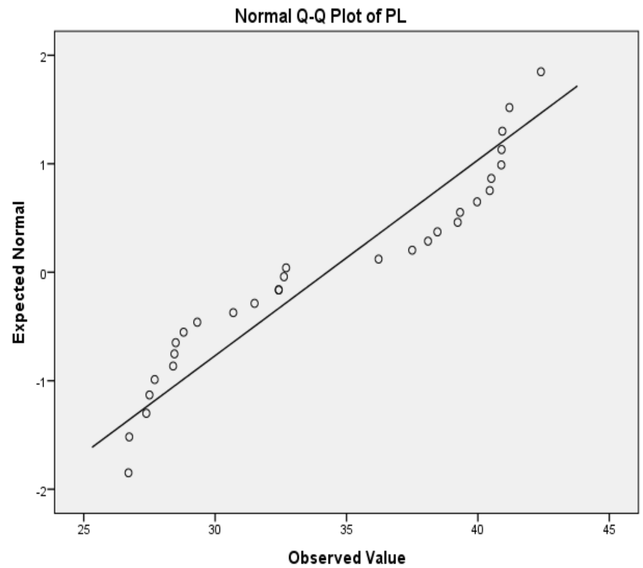


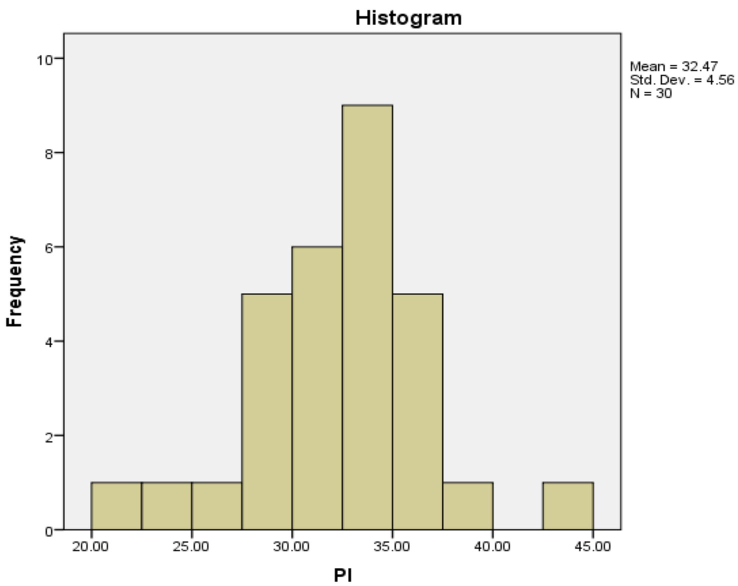


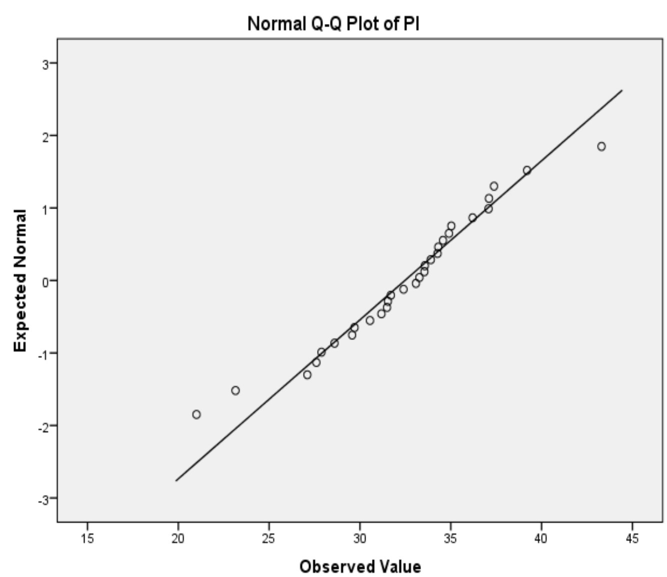

Histogram
Mean = 66.74
Std. Dev. = 8.122
N = 30
Frequency
LL


Normal Q-Q Plot of LL
Expected Normal
Observed Value


Histogram
Mean = 34.26
Std. Dev. = 5.545
N = 30
Frequency
PL


Normal Q-Q Plot of PL
Expected Normal
Observed Value


Histogram
Mean = 32.47
Std. Dev. = 4.56
N = 30
Frequency
PI


Normal Q-Q Plot of PI
Expected Normal
Observed Value

SPSS Output of Correlation Analysis

Descriptive Statistics													
	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
NMC	30	16.29	25.50	41.79	1102.87	36.7623	.85623	4.68977	21.994	-1.373	.427	.635	.833
GS	30	.10	2.65	2.75	81.05	2.7017	.00470	.02574	.001	-.354	.427	.169	.833
γb	30	.26	1.71	1.97	55.29	1.8430	.01524	.08347	.007	.009	.427	-1.410	.833
γd	30	.22	1.27	1.49	41.81	1.3937	.01280	.07010	.005	-.355	.427	-1.406	.833
LL	30	29.80	55.90	85.70	2002.08	66.7360	1.48285	8.12192	65.966	.382	.427	-.694	.833
PL	30	15.70	26.70	42.40	1027.91	34.2637	1.01236	5.54491	30.746	.022	.427	-1.706	.833
PI	30	22.30	21.00	43.30	974.17	32.4723	.83260	4.56032	20.796	-.313	.427	1.046	.833
LI	30	1.0626	-.1186	.9440	3.9367	.131223	.0417152	.2284836	.052	1.690	.427	4.160	.833
CU	30	69.84	35.16	105.00	1956.31	65.2103	3.75486	20.56621	422.969	.470	.427	-.895	.833
Valid N	30												

Correlations										
		NMC	Gs	γb	γd	LL	PL	PI	LI	CU
NMC	Pearson Correlation	1	.397	-.495	-.527	.556	.586	.278	.366	-.814
	Sig. (2-tailed)		.030	.005	.003	.001	.001	.137	.047	.000
	N	30	30	30	30	30	30	30	30	30
Gs	Pearson Correlation	.397	1	-.439	-.472	.407	.370	.275	-.032	-.518
	Sig. (2-tailed)	.030		.015	.009	.026	.044	.142	.866	.003
	N	30	30	30	30	30	30	30	30	30
γb	Pearson Correlation	-.495	-.439	1	.864	-.773	-.813	-.387	.186	.834
	Sig. (2-tailed)	.005	.015		.000	.000	.000	.034	.325	.000
	N	30	30	30	30	30	30	30	30	30
γd	Pearson Correlation	-.527	-.472	.864	1	-.756	-.835	-.332	.102	.845
	Sig. (2-tailed)	.003	.009	.000		.000	.000	.073	.592	.000

	N	30	30	30	30	30	30	30	30	30
LL	Pearson Correlation	.556	.407	-.773	-.756	1	.843	.756	-.113	-.850
	Sig. (2-tailed)	.001	.026	.000	.000		.000	.000	.550	.000
	N	30	30	30	30	30	30	30	30	30
PL	Pearson Correlation	.586	.370	-.813	-.835	.843	1	.285	-.228	-.880
	Sig. (2-tailed)	.001	.044	.000	.000	.000		.127	.225	.000
	N	30	30	30	30	30	30	30	30	30
PI	Pearson Correlation	.278	.275	-.387	-.332	.756	.285	1	.076	-.444
	Sig. (2-tailed)	.137	.142	.034	.073	.000	.127		.691	.014
	N	30	30	30	30	30	30	30	30	30
LI	Pearson Correlation	.366*	-.032	.186	.102	-.113	-.228	.076	1	-.050
	Sig. (2-tailed)	.047	.866	.325	.592	.550	.225	.691		.792
	N	30	30	30	30	30	30	30	30	30
CU	Pearson Correlation	-.814	-.518	.834	.845	-.850	-.880	-.444	-.050	1
	Sig. (2-tailed)	.000	.003	.000	.000	.000	.000	.014	.792	
	N	30	30	30	30	30	30	30	30	30

MODEL 1: REGRESSION ANALYSIS OUTPUT

Descriptive Statistics

	Mean	Std. Deviation	N
CU	65.2103	20.56621	30
Dd	1.3937	.07010	30
LL	66.7360	8.12192	30

Correlations

		CU	Dd	LL
Pearson Correlation	CU	1.000	.845	-.850
	Dd	.845	1.000	-.756
	LL	-.850	-.756	1.000
Sig. (1-tailed)	CU	.	.000	.000
	Dd	.000	.	.000
	LL	.000	.000	.

N	CU	30	30	30
	Dd	30	30	30
	LL	30	30	30

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	LL, Dd[b]	.	Enter

a. Dependent Variable: CU

b. All requested variables entered.

Model Summary[b]										
Model	R	R Square	Adj. R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.904[a]	.818	.804	9.09462	.818	60.649	2	27	.000	1.114

a. Predictors: (Constant), LL, Dd

b. Dependent Variable: CU

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10032.874	2	5016.437	60.649	.000[b]
	Residual	2233.228	27	82.712		
	Total	12266.103	29			

a. Dependent Variable: CU

b. Predictors: (Constant), LL, Dd

Coefficients[a]													
Model 1		Unstandardized Coefficients		Standardize Coeff.	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
	(Constant)	-44.989	68.805		-.654	.519	-186.165	96.188					
	Dd	138.748	36.829	.473	3.767	.001	63.182	214.314	.845	.587	.309	.428	2.337
	LL	-1.246	.318	-.492	-3.921	.001	-1.898	-.594	-.850	-.602	-.322	.428	2.337

a. Dependent Variable: CU

Coefficient Correlations[a]				
Model			LL	Dd
1	Correlations	LL	1.000	.756
		Dd	.756	1.000
	Covariances	LL	.101	8.854
		Dd	8.854	1356.354

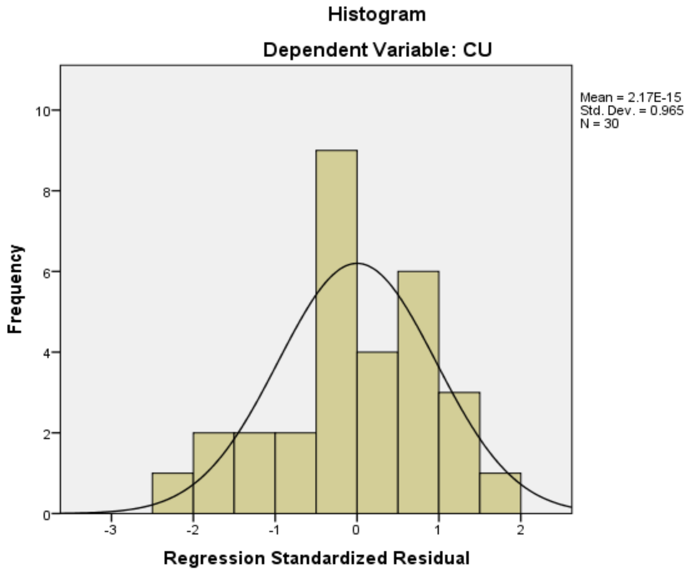
a. Dependent Variable: CU

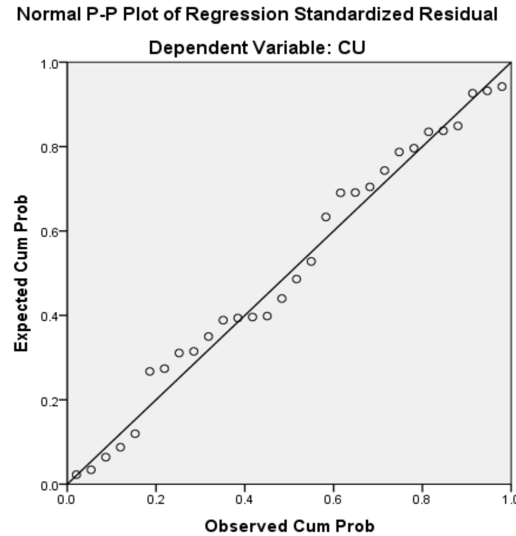
Collinearity Diagnostics[a]						
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	Dd	LL
1	1	2.986	1.000	.00	.00	.00
	2	.014	14.787	.00	.03	.28
	3	.000	90.896	1.00	.97	.72

a. Dependent Variable: CU

Residuals Statistics[a]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	29.9680	91.8314	65.2103	18.60003	30
Std. Predicted Value	-1.895	1.431	.000	1.000	30
Standard Error of Predicted Value	1.686	4.908	2.783	.738	30
Adjusted Predicted Value	27.4876	90.2974	65.2048	18.78227	30
Residual	-18.22074	14.30679	.00000	8.77541	30
Std. Residual	-2.003	1.573	.000	.965	30
Stud. Residual	-2.130	1.657	.000	1.016	30
Deleted Residual	-20.59864	15.87356	.00550	9.74883	30
Stud. Deleted Residual	-2.292	1.716	-.007	1.046	30
Mahal. Distance	.030	7.477	1.933	1.649	30
Cook's Distance	.000	.197	.037	.050	30
Centered Leverage Value	.001	.258	.067	.057	30

a. Dependent Variable: CU





MODEL 2: REGRESSION ANALYSIS OUTPUT

Descriptive Statistics			
	Mean	Std. Deviation	N
CU	65.2103	20.56621	30
PL	34.2637	5.54491	30
PI	32.4723	4.56032	30

Correlations				
		CU	PL	PI
Pearson Correlation	CU	1.000	-.880	-.444
	PL	-.880	1.000	.285
	PI	-.444	.285	1.000
Sig. (1-tailed)	CU	.	.000	.007
	PL	.000	.	.063
	PI	.007	.063	.
N	CU	30	30	30
	PL	30	30	30
	PI	30	30	30

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
2	PI, PL[b]	.	Enter

a. Dependent Variable: CU

b. All requested variables entered.

Model Summary[b]										
Model	R	R Square	Adj. R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2	.903[a]	.815	.801	9.17867	.815	59.298	2	27	.000	.950

a. Predictors: (Constant), PI, PL

b. Dependent Variable: CU

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	9991.408	2	4995.704	59.298	.000[b]
	Residual	2274.695	27	84.248		
	Total	12266.103	29			

a. Dependent Variable: CU

b. Predictors: (Constant), PI, PL

Coefficients[a]													
Model		Unstandardized Coefficients		Standardized Coeff.	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
2	(Constant)	200.159	14.301		13.996	.000	170.815	229.503					
	PL	-3.041	.321	-.820	-9.483	.000	-3.699	-2.383	-.880	-.877	-.786	.919	1.089
	PI	-.947	.390	-.210	-2.428	.022	-1.747	-.147	-.444	-.423	-.201	.919	1.089

a. Dependent Variable: CU

Coefficient Correlations[a]				
Model			PI	PL
2	Correlations	PI	1.000	-.285
		PL	-.285	1.000
	Covariances	PI	.152	-.036
		PL	-.036	.103

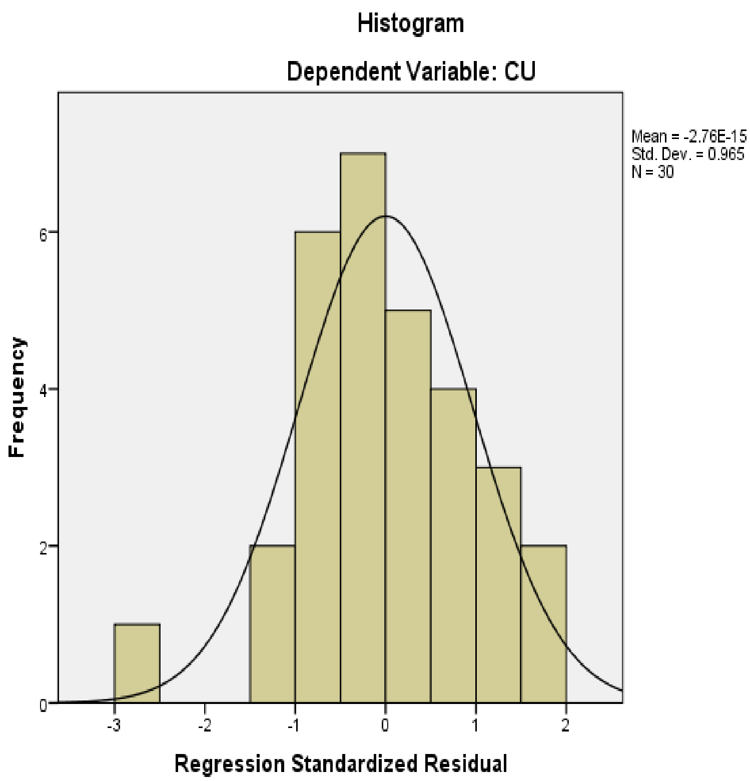
a. Dependent Variable: CU

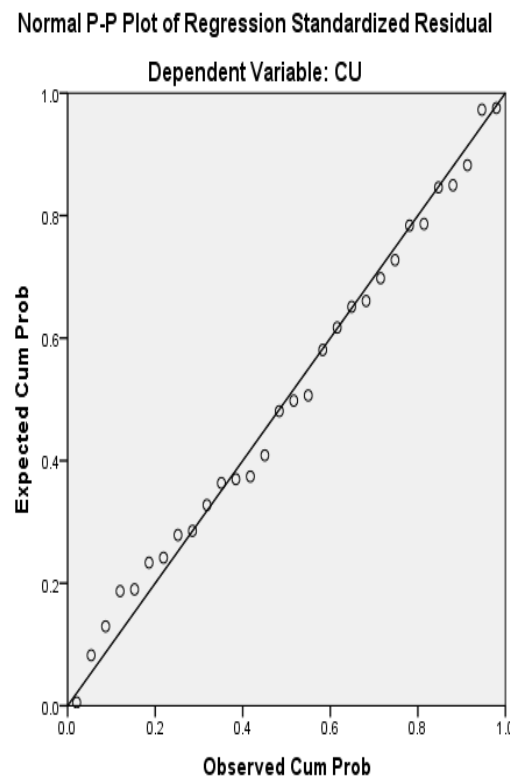
Collinearity Diagnostics[a]						
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	PL	PI
2	1	2.975	1.000	.00	.00	.00
	2	.016	13.623	.04	.88	.36
	3	.009	18.285	.96	.12	.64

a. Dependent Variable: CU

Residuals Statistics[a]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	30.2137	89.4462	65.2103	18.56155	30
Std. Predicted Value	-1.885	1.306	.000	1.000	30
Standard Error of Predicted Value	1.815	5.242	2.794	.799	30
Adjusted Predicted Value	27.7698	89.5173	65.1878	18.72099	30
Residual	-23.45321	18.08680	.00000	8.85651	30
Std. Residual	-2.555	1.971	.000	.965	30
Stud. Residual	-2.667	2.074	.001	1.013	30
Deleted Residual	-25.54851	20.03007	.02258	9.78006	30
Stud. Deleted Residual	-3.049	2.219	-.002	1.069	30
Mahal. Distance	.167	8.491	1.933	1.960	30
Cook's Distance	.000	.212	.035	.052	30
Centered Leverage Value	.006	.293	.067	.068	30

a. Dependent Variable: CU





MODEL 3: REGRESSION ANALYSIS OUTPUT

Descriptive Statistics			
	Mean	Std. Deviation	N
Cu	65.2103	20.56621	30
NMC	36.7623	4.68977	30
Gs	2.7017	.02574	30
γb	1.8430	.08347	30

Correlations					
		Cu	NMC	Gs	γb
Pearson Correlation	Cu	1.000	-.814	-.518	.834
	NMC	-.814	1.000	.397	-.495
	Gs	-.518	.397	1.000	-.439
	γb	.834	-.495	-.439	1.000
Sig. (1-tailed)	Cu	.	.000	.002	.000
	NMC	.000	.	.015	.003
	Gs	.002	.015	.	.008
	γb	.000	.003	.008	.
N	Cu	30	30	30	30
	NMC	30	30	30	30
	Gs	30	30	30	30
	γb	30	30	30	30

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
3	Bd, GS, NMC[b]	.	Enter

a. Dependent Variable: CU

b. All requested variables entered.

Model Summary[b]										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
3	.955[a]	.912	.902	6.43459	.912	90.085	3	26	.000	1.980

a. Predictors: (Constant), Bd, GS, NMC

b. Dependent Variable: CU

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
3	Regression	11189.601	3	3729.867	90.085	.000[b]
	Residual	1076.502	26	41.404		
	Total	12266.103	29			

a. Dependent Variable: Cu

b. Predictors: (Constant), γb, Gs, NMC

Coefficient Correlations[a]

Model			γb	Gs	NMC
3	Correlations	γb	1.000	.304	.389
		Gs	.304	1.000	-.230
		NMC	.389	-.230	1.000
	Covariances	γb	299.138	279.171	2.028
		Gs	279.171	2817.682	-3.677
		NMC	2.028	-3.677	.091

a. Dependent Variable: CU

Collinearity Diagnostics[a]

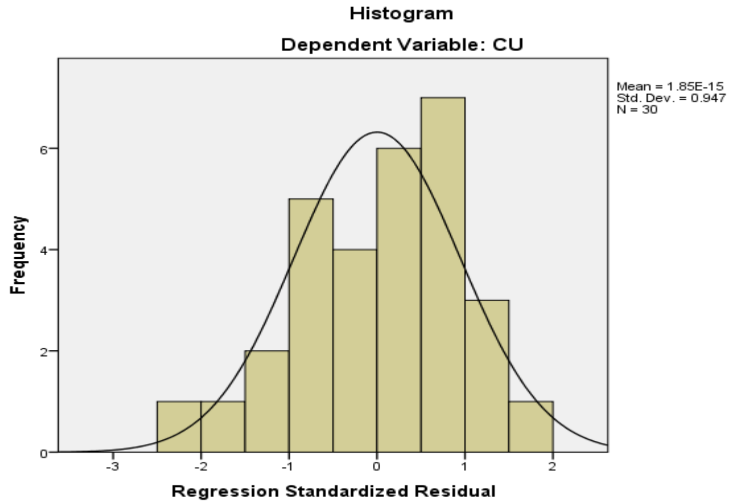
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	NMC	GS	γb
3	1	3.986	1.000	.00	.00	.00	.00
	2	.013	17.202	.00	.59	.00	.02
	3	.001	65.639	.01	.39	.02	.80
	4	3.126E-005	357.056	.99	.02	.98	.18

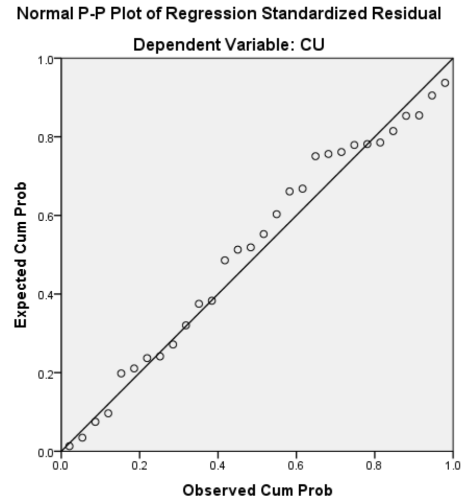
a. Dependent Variable: CU

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	39.6768	106.9160	65.2103	19.64302	30
Std. Predicted Value	-1.300	2.123	.000	1.000	30
Standard Error of Predicted Value	1.321	4.497	2.218	.789	30
Adjusted Predicted Value	40.1745	111.3175	65.3392	19.90873	30
Residual	-14.35159	9.85792	.00000	6.09268	30
Std. Residual	-2.230	1.532	.000	.947	30
Stud. Residual	-2.445	1.566	-.009	1.018	30
Deleted Residual	-17.25265	10.29433	-.12888	7.07875	30
Stud. Deleted Residual	-2.733	1.613	-.024	1.060	30
Mahal. Distance	.256	13.196	2.900	2.910	30
Cook's Distance	.000	.455	.042	.096	30
Centered Leverage Value	.009	.455	.100	.100	30

a. Dependent Variable: CU





MODEL 4: REGRESSION ANALYSIS OUTPUT

Descriptive Statistics

	Mean	Std. Deviation	N
CU	65.2103	20.56621	30
LL	66.7360	8.12192	30
PL	34.2637	5.54491	30
LI	.131223	.2284836	30

Correlations

		Cu	LL	PL	LI
Pearson Correlation	CU	1.000	-.850	-.880	-.050
	LL	-.850	1.000	.843	-.113
	PL	-.880	.843	1.000	-.228
	LI	-.050	-.113	-.228	1.000
Sig. (1-tailed)	CU	.	.000	.000	.396
	LL	.000	.	.000	.275
	PL	.000	.000	.	.112
	LI	.396	.275	.112	.
N	CU	30	30	30	30
	LL	30	30	30	30
	PL	30	30	30	30
	LI	30	30	30	30

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
4	LI, LL, PL[b]	.	Enter

a. Dependent Variable: CU
b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
4	.931[a]	.868	.852	7.90205	.868	56.813	3	26	.000	2.010

a. Predictors: (Constant), LI, LL, PL
b. Dependent Variable: Cu

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
4	Regression	10642.600	3	3547.533	56.813	.000[b]
	Residual	1623.503	26	62.442		
	Total	12266.103	29			

a. Dependent Variable: Cu
b. Predictors: (Constant), LI, LL, PL

Coefficients[a]

Model		Unstandardized Coefficients		Standard. Coeffi.	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
4	(Constant)	205.894	12.440		16.551	.000	180.324	231.464					
	LL	-.781	.340	-.309	-2.301	.030	-1.480	-.083	-.850	-.411	-.164	.283	3.533
	PL	-2.501	.508	-.674	-4.927	.000	-3.545	-1.458	-.880	-.695	-.352	.272	3.680
	LI	-21.550	6.673	-.239	-3.229	.003	-35.267	-7.833	-.050	-.535	-.230	.926	1.080

a. Dependent Variable: CU

Coefficient Correlations[a]

Model			LI	LL	PL
4	Correlations	LI	1.000	-.151	.248
		LL	-.151	1.000	-.845
		PL	.248	-.845	1.000
	Covariances	LI	44.531	-.342	.841
		LL	-.342	.115	-.146
		PL	.841	-.146	.258

a. Dependent Variable: Cu

Collinearity Diagnostics[a]

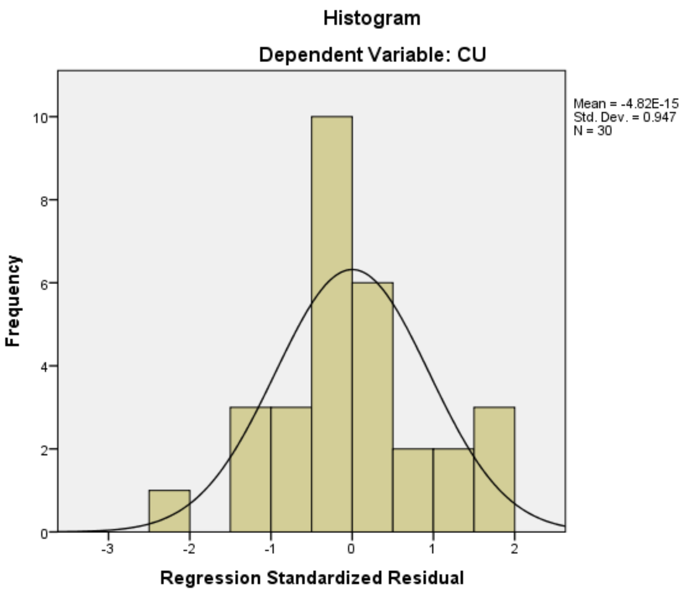
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	LL	PL	LI
4	1	3.295	1.000	.00	.00	.00	.02
	2	.691	2.184	.00	.00	.00	.88
	3	.012	16.619	.70	.01	.20	.07
	4	.003	35.825	.30	.99	.80	.03

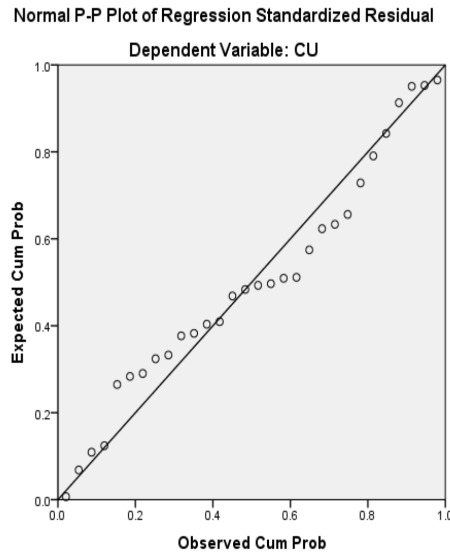
a. Dependent Variable: Cu

Residuals Statistics[a]

	Min.	Max.	Mean	Std. Deviation	N
Predicted Value	34.8088	94.7742	65.2103	19.15688	30
Std. Predicted Value	-1.587	1.543	.000	1.000	30
Standard Error of Predicted Value	1.574	5.733	2.742	.914	30
Adjusted Predicted Value	25.4993	94.7382	64.7902	19.92814	30
Residual	-19.48801	14.35135	.00000	7.48217	30
Std. Residual	-2.466	1.816	.000	.947	30
Stud. Residual	-2.609	1.975	.022	1.039	30
Deleted Residual	-21.80250	22.68070	.42014	9.20969	30
Stud. Deleted Residual	-2.977	2.101	.022	1.101	30
Mahal. Distance	.184	14.298	2.900	2.975	30
Cook's Distance	.000	1.084	.068	.200	30
Centered Leverage Value	.006	.493	.100	.103	30

a. Dependent Variable: CU





MODEL 6: REGRESSION ANALYSIS OUTPUT

Descriptive Statistics

	Mean	Std. Deviation	N
Cu	65.2103	20.56621	30
NMC	36.7623	4.68977	30
Gs	2.7017	.02574	30
γb	1.8430	.08347	30
γd	1.3937	.07010	30

Correlations

		Cu	NMC	Gs	γb	γd
Pearson Correlation	Cu	1.000	-.814	-.518	.834	.845
	NMC	-.814	1.000	.397	-.495	-.527
	Gs	-.518	.397	1.000	-.439	-.472
	γb	.834	-.495	-.439	1.000	.864
	γd	.845	-.527	-.472	.864	1.000
Sig. (1-tailed)	Cu	.	.000	.002	.000	.000
	NMC	.000	.	.015	.003	.001
	Gs	.002	.015	.	.008	.004
	γb	.000	.003	.008	.	.000
	γd	.000	.001	.004	.000	.
N	Cu	30	30	30	30	30
	NMC	30	30	30	30	30
	Gs	30	30	30	30	30
	γb	30	30	30	30	30
	γd	30	30	30	30	30

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
6	γd, Gs, NMC, γb[b]	.	Enter

a. Dependent Variable: Cu

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
6	.965[a]	.931	.920	5.81272	.931	84.509	4	25	.000	1.961

a. Predictors: (Constant), γd, Gs, NMC, γb

b. Dependent Variable: Cu

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
6	Regression	11421.410	4	2855.353	84.509	.000[b]
	Residual	844.693	25	33.788		
	Total	12266.103	29			

a. Dependent Variable: Cu

b. Predictors: (Constant), γd, Gs, NMC, γb

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coeff.	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
6	(Const.)	-17.536	143.087		-.123	.903	-312.229	277.157					
	NMC	-2.113	.277	-.482	-7.621	.000	-2.684	-1.542	-.814	-.836	-.400	.689	1.451
	Gs	-38.828	48.580	-.049	-.799	.432	-138.880	61.224	-.518	-.158	-.042	.745	1.342
	γb	80.839	25.869	.328	3.125	.004	27.562	134.116	.834	.530	.164	.250	4.001
	γd	83.471	31.868	.285	2.619	.015	17.838	149.103	.845	.464	.137	.233	4.283

a. Dependent Variable: Cu

Coefficient Correlations[a]

Model			γd	Gs	NMC	γb
6	Correlations	γd	1.000	.160	.190	-.797
		Gs	.160	1.000	-.192	.054
		NMC	.190	-.192	1.000	.079
		γb	-.797	.054	.079	1.000
	Covariances	γd	1015.539	248.096	1.677	-657.020
		Gs	248.096	2359.983	-2.591	67.308
		NMC	1.677	-2.591	.077	.570
		γb	-657.020	67.308	.570	669.183

a. Dependent Variable: Cu

Collinearity Diagnostics[a]

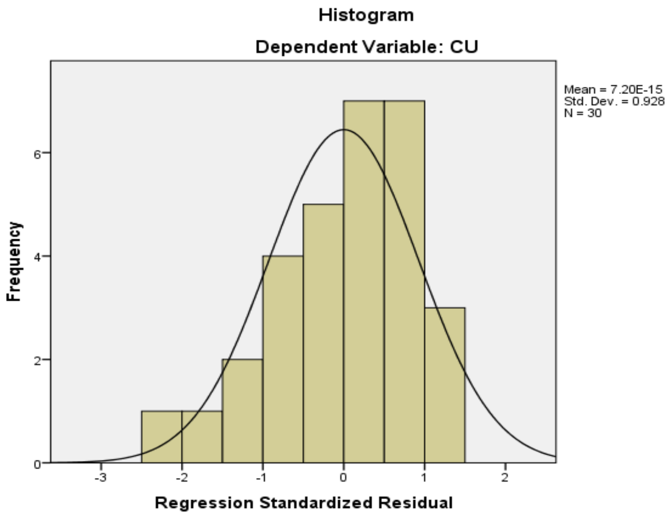
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions				
				Constant	NMC	Gs	γb	γd
6	1	4.982	1.000	.00	.00	.00	.00	.00
	2	.016	17.616	.00	.49	.00	.00	.00
	3	.001	63.303	.01	.49	.02	.05	.10
	4	.000	130.164	.00	.00	.00	.93	.86
	5	3.023E-005	405.969	.99	.01	.98	.01	.04

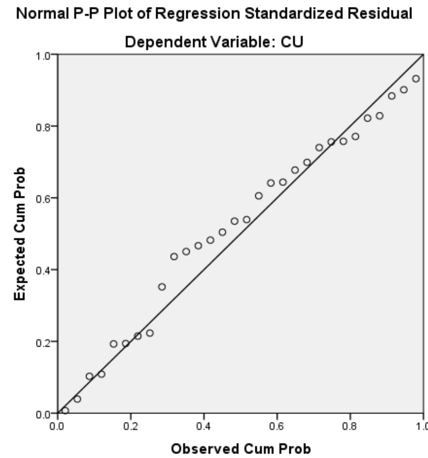
a. Dependent Variable: Cu

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	35.6474	105.7269	65.2103	19.84545	30
Std. Predicted Value	-1.490	2.042	.000	1.000	30
Standard Error of Predicted Value	1.198	4.068	2.294	.619	30
Adjusted Predicted Value	35.7467	109.4515	65.3539	20.05143	30
Residual	-14.30505	8.66150	.00000	5.39697	30
Std. Residual	-2.461	1.490	.000	.928	30
Stud. Residual	-2.698	1.528	-.011	1.013	30
Deleted Residual	-17.19689	9.10365	-.14361	6.44862	30
Stud. Deleted Residual	-3.140	1.572	-.031	1.071	30
Mahal. Distance	.265	13.235	3.867	2.670	30
Cook's Distance	.000	.362	.040	.081	30
Centered Leverage Value	.009	.456	.133	.092	30

a. Dependent Variable: CU





MODEL 7: REGRESSION ANALYSIS OUTPUT

Descriptive Statistics

	Mean	Std. Deviation	N
Cu	65.2103	20.56621	30
Gs	2.7017	.02574	30
γb	1.8430	.08347	30
γd	1.3937	.07010	30
LL	66.7360	8.12192	30

Correlations

		Cu	Gs	γb	γd	LL
Pearson Correlation	Cu	1.000	-.518	.834	.845	-.850
	Gs	-.518	1.000	-.439	-.472	.407
	γb	.834	-.439	1.000	.864	-.773
	γd	.845	-.472	.864	1.000	-.756
	LL	-.850	.407	-.773	-.756	1.000
Sig. (1-tailed)	Cu	.	.002	.000	.000	.000
	Gs	.002	.	.008	.004	.013
	γb	.000	.008	.	.000	.000
	γd	.000	.004	.000	.	.000
	LL	.000	.013	.000	.000	.
N	Cu	30	30	30	30	30
	Gs	30	30	30	30	30
	γb	30	30	30	30	30
	γd	30	30	30	30	30
	LL	30	30	30	30	30

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
`7	LL, Gs, γd, γb[b]	.	Enter

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimat	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
7	.915[a]	.838	.812	8.92090	.838	32.283	4	25	.000	.826

a. Predictors: (Constant), LL, GS, Dd, Bd

b. Dependent Variable: CU

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
7	Regression	10276.542	4	2569.136	32.283	.000[b]
	Residual	1989.561	25	`79.582		
	Total	12266.103	29			

a. Dependent Variable: CU

b. Predictors: (Constant), LL, GS, Dd, Bd

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
7	(Constant)	180.746	226.369		.798	.432	-285.470	646.962					
	Gs	-94.392	73.327	-.118	-1.287	.210	-245.411	56.627	-.518	-.249	-.104	.770	1.298
	γb	47.908	42.380	.194	1.130	.269	-39.375	135.192	.834	.221	.091	.219	4.560

	γd	88.165	49.726	.300	1.773	.088	-14.249	190.578	.845	.334	.143	.226	4.428
	LL	-1.074	.335	-.424	-3.205	.004	-1.764	-.384	-.850	-.540	-.258	.370	2.700

a. Dependent Variable: CU

Coefficient Correlations[a]

Model			LL	Gs	γd	γb
7	Correlations	LL	1.000	-.067	.260	.358
		Gs	-.067	1.000	.179	.042
		γd	.260	.179	1.000	-.655
		γb	.358	.042	-.655	1.000
	Covariances	LL	.112	-1.637	4.331	5.081
		Gs	-1.637	5376.794	654.420	129.730
		γd	4.331	654.420	2472.711	-1380.910
		γb	5.081	129.730	-1380.910	1796.070

a. Dependent Variable: CU

Collinearity Diagnostics[a]

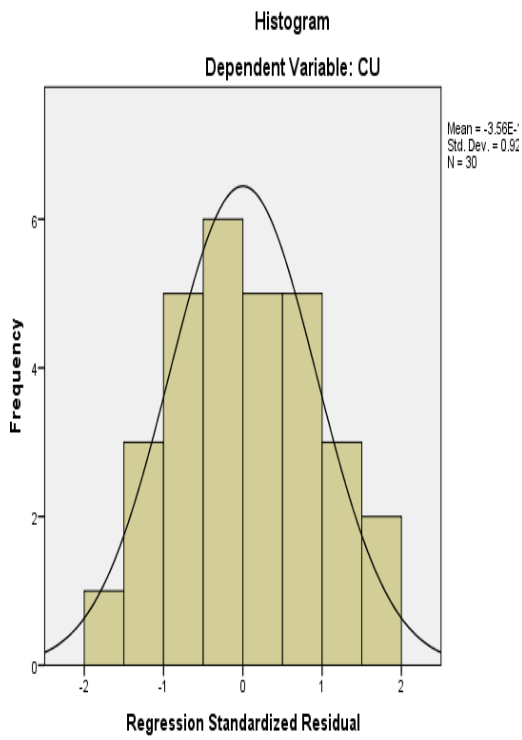
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions				
				(Constant)	GS	γb	γd	LL
7	1	4.982	1.000	.00	.00	.00	.00	.00
	2	.017	17.318	.00	.00	.00	.00	.23
	3	.001	90.582	.02	.04	.04	.27	.71
	4	.000	131.949	.00	.00	.94	.67	.05
	5	3.010E-005	406.847	.98	.96	.02	.06	.01

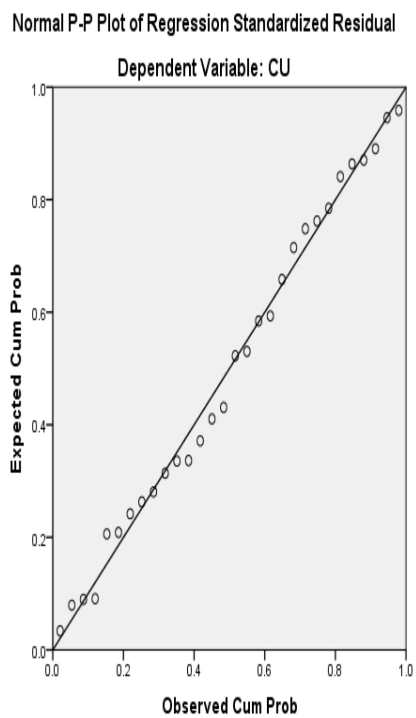
a. Dependent Variable: Cu

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	26.5291	96.0898	65.2103	18.82455	30
Std. Predicted Value	-2.055	1.640	.000	1.000	30
Standard Error of Predicted Value	1.721	5.166	3.521	.948	30
Adjusted Predicted Value	21.6135	93.9822	65.0024	19.14343	30
Residual	-16.30748	15.48831	.00000	8.28285	30
Std. Residual	-1.828	1.736	.000	.928	30
Stud. Residual	-2.070	1.967	.010	1.046	30
Deleted Residual	-20.91393	21.52540	.20797	10.56539	30
Stud. Deleted Residual	-2.228	2.097	.011	1.080	30
Mahal. Distance	.113	8.758	3.867	2.417	30
Cook's Distance	.000	.390	.060	.092	30
Centered Leverage Value	.004	.302	.133	.083	30

a. Dependent Variable: Cu





MODEL 8: REGRESSION ANALYSIS OUTPUT

Descriptive Statistics

	Mean	Std. Deviation	N
CU	65.2103	20.56621	30
GS	2.7017	.02574	30
Bd	1.8430	.08347	30
Dd	1.3937	.07010	30
LL	66.7360	8.12192	30
PL	34.2637	5.54491	30

Correlations

		Cu	Gs	γb	γd	LL	PL
Pearson Correlation	Cu	1.000	-.518	.834	.845	-.850	-.880
	Gs	-.518	1.000	-.439	-.472	.407	.370
	γb	.834	-.439	1.000	.864	-.773	-.813
	γd	.845	-.472	.864	1.000	-.756	-.835
	LL	-.850	.407	-.773	-.756	1.000	.843
	PL	-.880	.370	-.813	-.835	.843	1.000
Sig. (1-tailed)	Cu	.	.002	.000	.000	.000	.000
	Gs	.002	.	.008	.004	.013	.022
	γb	.000	.008	.	.000	.000	.000
	γd	.000	.004	.000	.	.000	.000
	LL	.000	.013	.000	.000	.	.000
	PL	.000	.022	.000	.000	.000	.
N	Cu	30	30	30	30	30	30
	Gs	30	30	30	30	30	30
	γb	30	30	30	30	30	30
	γd	30	30	30	30	30	30
	LL	30	30	30	30	30	30
	PL	30	30	30	30	30	30

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
8	PL, Gs, γb, LL, γd[b]	.	Enter

a. Dependent Variable: Cu

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
8	.929[a]	.863	.835	8.36217	.863	30.283	5	24	.000	.858

a. Predictors: (Constant), PL, Gs, γ, LL, γd

b. Dependent Variable: CU

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
8	Regression	10587.883	5	2117.577	30.283	.000[b]
	Residual	1678.220	24	69.926		
	Total	12266.103	29			

a. Dependent Variable: Cu

b. Predictors: (Constant), PL, Gs, γb, LL, γd

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coeff.	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero order	Partial	Part	Tolerance	VIF
8	(Constant)	333.974	224.273		1.489	.149	-128.903	796.852					
	GS	-113.629	69.336	-.142	-1.639	.114	-256.731	29.474	-.518	-.317	-.124	.757	1.321
	γb	33.951	40.273	.138	.843	.408	-49.168	117.070	.834	.170	.064	.213	4.686
	γd	46.948	50.539	.160	.929	.362	-57.360	151.256	.845	.186	.070	.192	5.205
	LL	-.650	.373	-.257	-1.743	.094	-1.420	.120	-.850	-.335	-.132	.263	3.806
	PL	-1.354	.642	-.365	-2.110	.045	-2.679	-.030	-.880	-.396	-.159	.190	5.253

a. Dependent Variable: CU

Coefficient Correlations[a]							
Model			PL	Gs	γb	LL	γd
8	Correlations	PL	1.000	.131	.164	-.539	.386
		Gs	.131	1.000	.062	-.126	.215
		γb	.164	.062	1.000	.209	-.533
		LL	-.539	-.126	.209	1.000	-.006
		γd	.386	.215	-.533	-.006	1.000
	Covariances	PL	.412	5.851	4.245	-.129	12.537
		GS	5.851	4807.481	174.290	-3.271	753.087
		γb	4.245	174.290	1621.885	3.135	-1084.148
		LL	-.129	-3.271	3.135	.139	-.122
		γd	12.537	753.087	-1084.148	-.122	2554.216

a. Dependent Variable: CU

Collinearity Diagnostics[a]									
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions					
				(Cons.)	Gs	γb	γd	LL	PL
8	1	5.963	1.000	.00	.00	.00	.00	.00	.00
	2	.033	13.349	.00	.00	.00	.00	.02	.06
	3	.003	46.467	.00	.00	.00	.00	.85	.60
	4	.000	113.963	.02	.06	.06	.31	.09	.27
	5	.000	144.395	.00	.00	.90	.59	.04	.00
	6	2.813E-005	460.435	.98	.94	.03	.10	.00	.07

a. Dependent Variable: CU

Residuals Statistics[a]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	27.9299	94.6343	65.2103	19.10757	30
Std. Predicted Value	-1.951	1.540	.000	1.000	30
Standard Error of Predicted Value	1.716	5.546	3.609	.995	30
Adjusted Predicted Value	23.5144	93.8037	65.0548	19.40312	30
Residual	-16.14722	14.25659	.00000	7.60721	30
Std. Residual	-1.931	1.705	.000	.910	30
Stud. Residual	-2.187	2.091	.008	1.041	30
Deleted Residual	-20.71059	21.44962	.15551	10.01732	30
Stud. Deleted Residual	-2.392	2.264	.009	1.086	30
Mahal. Distance	.255	11.788	4.833	3.001	30
Cook's Distance	.000	.368	.057	.087	30
Centered Leverage Value	.009	.406	.167	.103	30

a. Dependent Variable: CU