JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

GEOTECHNICAL ENGINEERING STREAM

CORRELATION BETWEEN UNCONFINED COMPRESSIVE STRENGTH AND INDEX PROPERTIES OF SOILS: A CASE STUDY IN SARBO TOWN, JIMMA ZONE.

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

BY: - YASIN SHIFA

April, 2022

Jimma, Ethiopia

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BY: - YASIN SHIFA

Advisor: - Damtew Tsige (PhD)

Co-Advisor: - Shelema Amena (MSc.)

April, 2022

Jimma, Ethiopia

APPROVAL SHEET

I, the undersigned and certify that the thesis entitled: **"CORRELATION BETWEEN UNCONFINED COMPRESSIVE STRENGTH AND INDEX PROPERTIES OF SOILS: A CASE STUDY IN SARBO TOWN, JIMMA ZONE"** is the work of Yasin Shifa and has been accepted and submitted for examination with my approval as university advisor in partial fulfillment of the requirements for Degree of Master of Science in Geotechnical Engineering.

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DECLARATION

I, the under signed, declare that this research entitle "**CORRELATION BETWEEN UNCONFINED COMPRESSIVE STRENGTH AND INDEX PROPERTIES OF SOILS: A CASE STUDY IN SARBO TOWN, JIMMA ZONE**" is my original work and has not been presented by any other person on an award of degree in this or other university and all the source used for this thesis have been dully acknowledged.

Candidate: Yasin Shifa ______________________ ______________________

Name Signature Date

As masters research advisors, we hear by certify that we have read and evaluated this MSc research prepared under our guidance, by **Yasin Shifa "CORRELATION BETWEEN UNCONFINED COMPRESSIVE STRENGTH AND INDEX PROPERTIES OF SOILS: A CASE STUDY IN SARBO TOWN, JIMMA ZONE".**

We recommended that it can be summited as fulfilling the MSc research requirement.

Damtew Tsige (PhD) ______________________ ______________________

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ABSTRACT

Correlations are important to estimate the engineering properties of soils, particularly for projects where there is a financial limitation, a lack of test equipment, or limited time. Although correlations are commonly used in the preliminary stage of any project, it is reasonable to assign a unique strength to soils for their respective physical properties. Therefore, this study aims to establish a correlation between unconfined compressive strength and index properties of soils. In this work, undisturbed and disturbed soil samples were collected from fourteen test pits at 1.0 m and 2.0 m depths and from four test pits at a depth of 1.5m for a total of thirty-two sample specimens using purposive sampling techniques. For the test procedures, American Society for Testing and Material (ASTM) standards and Indian Standard Methods of Test for Soils (IS) were used. To develop the correlational models for this study, Statistical Package for Social Science (SPSS-25), Microsoft Excel-2016, and Origin-Pro 8.5 softwares were used. The objective of this study is modelling of Unconfined compressive strength with index properties in the study area. Based on both single and multiple linear regression analysis a unique correlation is obtained by combining Unconfined compressive strength (UCS) with soil index properties for the study area. From the laboratory test results, the soil type of study area was fine-grained with high plasticity silty soil (MH) and clayey soil (A-7-5) according to the soil classification systems of USCS and AASHTO respectively with medium-stiff to stiff unconfined compressive strength consistency. Accordingly, the best Model is obtained from single linear regression (SLR) analysis and given by $CS = 385.334 - 3.697 * LL$*with* R^2*=0.871, p-value =0.000 < 0.05nfor fine grained cohesive soils of the study area.*

Key words*: Soil classification, Correlation, Unconfined compression test, Index Properties, Regression Analysis*

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
Ac	Activity of Clay
FS	Free Swell Index
Gs	Specific Gravity
JIT	Jimma Institute of Technology
IS	Indian Standard
LI	Liquidity Index
LL	Liquid Limit
m	Meter
MLRA	Multiple Linear Regression Analysis
NMC	Natural Moisture Content
N	Number of samples
PI	Plasticity Index
PL	Plastic Limit
PFP	Percentage Fines Particle
R	Correlation Coefficient
R^2	Coefficient of determination/Determinant factor
SPSS	Statistical Package for the Social Science
SLRA	Simple Linear Regression Analysis
Su/Cu	Undrained shear strength
TP	Test Point
UC	Unconfined Compression
UCS	Unconfined Compressive Strength

USCS	Unified Soil Classification System
UU	Unconsolidated Undrained
USCS	Unified soil classification system
VIF	Variance inflation factors
α/p-value	Significance level
ρ_d	Dry density
ρ_b	Bulk density
ω	Moisture Content

CHAPTER ONE

1. INTRODUCTION

1.1. Background

It is necessary to determine the in-situ engineering properties of soil for the safety and stability of the structure that is built on it. One of the major tasks as a Geotechnical Engineer is to establish empirical relationship for the soil tests based on the soil condition using sufficient number of tests. However, obtaining the engineering properties of these tests doesn't require the same amount of money, time and energy. That is why correlation is necessary. Investigating index properties are much easier than investigating other engineering properties. Therefore, by obtaining the index property of soils that involves simpler and quicker method of testing, the engineering properties can be predicted satisfactorily from empirical correlations (Mengistu, 2017).

The shear strength of a soil is its maximum resistance to shear stresses just before the failure. For fine grained soils the shear strength generally can be categorized into drained and undrained condition based on the pore water pressure dissipation. In situ soil condition is recorded in undrained condition. The undrained shear strength (Cu) of fine-grained soils is one of the key geotechnical parameters. The undrained shear strength can be determined in the laboratory by unconfined compression strength or triaxial test (Das & Sobhan, 2018).

According to many researchers' idea soil strength is an essential requirement to the design and construction of civil engineering projects. The proper design of civil engineering structures like foundation of buildings, retaining walls, high ways, etc. requires adequate knowledge of sub surface conditions at the sites of the structures. Many damages to buildings, roads and other structures founded on soils are mainly due to the lack of proper investigation of substructure condition. Investigation of the sub-surface conditions at a site is prerequisite to the economical design of the substructure elements. It is also necessary to obtain sufficient information for feasibility and economic studies of the proposed project. Public building officials may require soil data together with the recommendations of the geotechnical consultant prior to issuing a building permit, particularly if there is a chance that the project will endanger the public health or safety or degrade the environment (HAILE, 2014).

Undrained shear strength is a very important parameter in engineering. Undrained shear strength is a parameter to the bearing capacity of soil that could bear on it. Some laboratory tests needed to obtain these values are expensive and time consuming, while soil properties like moisture content and Atterberge limits can be performed faster and cheaper (Khalid et al., 2015).

The results relation of the study will be of great importance for the ever-growing building construction especially for those yet to be constructed in that area. It can be used as soil property manual as it will have a customized nature to meet the required soil information of the area with regard to the future development programs in the construction sector and if correlation development is needs. In Serbo town it is also expected that much more construction is going to be done in the future. Since Jimma zone is the genetic origin of coffee Arabica it is market place in Southwest and South Ethiopia. Serbo town is found in Jimma zone. It is required to determine properly the engineering properties of soils. Since soil properties are essential for economic construction purposes. So, it is important to study soil properties in the Town.

In this research to achieve the objectives, applying all the requirements procedural starting from literature review, sample collection, conducting relevant laboratory tests and analysis of results obtained from input data is done.

1.2. Statement of the Problem

Correlations are important to estimate Engineering properties of soil particularly where there is a financial limitation, lack of equipment, limited time and also correlations are used commonly to get preliminary background information of the soil. Many attempts have been made to get the best mathematical relationship between undrained shear strength and liquidity index for different kinds of soil in different countries (Vardanega & Haigh, 2014).

The unconfined compressive strength of soil is a load per unit area at which an unconfined cylindrical specimen of soil will fail in the simple compression test. This test requires time, precision and expertise. UCS test gives the parameters of shear strength of the soil that is useful for computing Safe Bearing Capacity of soil as well as strength of soil (Yilmaz et al., 2019).

To quickly characterize the strength parameters there is need to identify the quickest methods to determine these parameters. One very famous method to quickly characterize such parameters is to develop models correlating them with quickly characterized parameters such as index properties of soils (Khalid et al., 2015). Such prediction models are very rare for unconfined compressive strength of soils. For the quick prediction of unconfined compression strength of soils there is need of development of prediction models. This study is an attempt towards this direction in the study area of Jimma Zone Serbo Town.

1.3. Objective

1.3.1. General Objective

The general objective of this study is to develop mathematical model between the index properties of soils with unconfined compressive strength of the study area.

1.3.2. Specific Objectives

1. To determine the unconfined compressive strength, index properties, and classification of the study areas' soil.
2. To develop appropriate empirical correlations between the unconfined compressive strength and index properties.
3. To compare with models developed for other soils.

1.4. Significance of the Study

In Serbo town, there are many civil engineering projects such as building and road construction. Besides, this there are many problems can be for seen on the construction which are insufficient geotechnical investigations. So insufficient geotechnical investigations faulty interpretation of results or failure to portray results in a clearly understandable manner may contribute to in appropriate designs; delays in construction schedules, costly construction modifications, and use of substandard material, environmental damage to the site and even failure of a structure.

1.5. Scope and Limitation of the Study

The scope of this study is limited to investigating into some of the correlation of soil between index properties and Unconfined Compressive Strength. In order to model the proposed correlation Thirty-Two laboratory test samples are conducted in the research work. All the tests were excavated up to a depth of 2m and were done according to American Society for Testing Materials (ASTM) standard. The required correlation is carried out by applying a single linear regression model and multiple linear regression models with the aid of SPSS Software.

Furthermore, the scope of the developed correlation is limited to the test procedures followed in the subject research work.

1.6. Thesis Outline

This thesis is organized into five chapter.

Chapter one: - Gives general introduction, problem statement, objective of the study, significance of the research, and scope and limitation of study and outline of the thesis.

Chapter two: - Deals with review of published literature related to the study issue, and what type of test methods.

Chapter three: - Discusses mainly on the methodology of the research, the location where sample were taken, period of study, sample collation method and data processing analysis.

Chapter four: - Discusses about obtained test results makes comparisons and interprets the obtained result and shows regression analysis using single and multiple regression analysis. Chapter five: - Focuses on the conclusion and recommendation of the thesis.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. General

Empirical correlations are widely used in geotechnical engineering practice as a tool to estimate the engineering properties of soils. Useful correlations exist between the index properties obtained from simple routine testing and the strength and deformations properties of cohesive soils among others. For practical purposes the results of routine index tests and correlations can be used as a first approximation of the soil parameters for use in preliminary design of geotechnical structures, and later as a mean to validate the results of laboratory tests. Results from several index tests obtained for a given site can be used to assess the variation in the properties of the soil mass (Balasubramanian, 2017).

The term clay is commonly used to refer to a material composed of a mass of small mineral particles which, in association with certain quantities of water, exhibits the property of plasticity. The behavior of clay soils depends to a large extent on the nature and characteristics of the minerals present. The most significant properties of clay depend upon the type of mineral. Clay minerals are essentially crystalline in nature. The crystalline minerals whose surface activity is high are clay minerals. These clay minerals impart cohesion and plasticity. Clays have less deformation to resistance when they are wet and become hard when they are dry. Clays are virtually impervious and difficult to compact when they are wet. Large expansion and contraction with changes in water content are characteristics of clays. Clay soils swell when wetted and shrink when they dry out. They are also defined as particles smaller than 0.002mm (Das & Sobhan, 2018).

The behavior of a soil mass depends upon the behavior of the discrete particles composing the mass and the pattern of particle arrangement. It needs to be well recognized that the presence of clay minerals in a soil aggregate has a great influence on the engineering properties of the soil as a whole. When moisture is present, the engineering behavior of a soil will change greatly as the percentage of clay mineral content increases. The behavior of the soil mass is profoundly influenced by the amount of water present.

Consistency is a term used to indicate the degree of firmness of cohesive soils. The consistency of natural cohesive soil deposits is expressed qualitatively by such terms as very soft, soft, stiff, very stiff, hard. The physical properties of clays greatly differ at different water contents. A soil which is very soft at a higher percentage of water content becomes very hard with a decrease in water content. However, it has been found that at the same water content, two samples of clay of different origins may possess different consistency. Clay may be relatively soft while the other may be hard. Further, a decrease in water content may have little effect on one sample of clay but may transform the other sample from a liquid to a very firm condition.

2.2. Index Property Tests of Soils

In geotechnical engineering, more than in any other field of civil engineering, success depends on practical experience. The design of ordinary soil supporting or soil supported structures is necessarily based on simple empirical rules, but these rules can be used safely only by the engineer who has a background of experience. Large projects involving unusual features may call for extensive application of scientific methods to design, but the program for the required investigations cannot be laid out wisely, nor can the results be interpreted intelligently. Unless the engineer in charge of design possesses a large amount of experience. Since personal experience is necessarily somewhat limited, the engineer is compelled to rely at least to some extent on the records of the experiences of others. If these records contain adequate descriptions of the soil conditions, they constitute a storehouse of valuable information. Otherwise, they may be misleading. Consequently, one of the foremost aims in attempts to reduce the hazards in dealing with soils has been to find simple methods for discriminating among the different kinds of soil in a given category. The properties on which the distinctions are based are known as Index properties, and the tests required to determine the index properties are classification tests. The nature of any soil can be altered by appropriate manipulation. Vibrations, for example, can transform a loose sand into a dense one. Hence, the behavior of a soil in the field depends not only on the significant properties of the individual constituents of the soil mass, but also on those properties that are due to the arrangement of the particles within the mass. Accordingly, it is convenient to divide index properties into two classes: soil grain properties and soil aggregate properties. The principal soil grain properties are the size and shape of the grains and, in clay soils, the mineralogical character of the smallest grains. Most significant aggregate property of cohesion less soils is the relative density, whereas that of cohesive soils is the consistency (Terzaghi et al., 1996)

2.2.1. Natural Moisture Content

The moisture content of soil (also referred to as water content) is an indication of the amount of water present in soil. By definition, moisture content is the ratio of the mass of water to the mass of solids in the sample expressed as a percentage.

$$\omega = \frac{Mw}{Ms} * 100\% \quad (2.1)$$

Where, ω = moisture content of soil, in %

Mw = mass of water in soil sample

Ms = mass of solids in soil sample

The water content of soil in the field is usually between 3 and 70% but value greater than 100% are sometimes found in soft soil below the ground water table, which simply means that more than 50% of the total mass is that of water (Das & Sobhan, 2018).

The water content is one of the most significant index properties used in establishing a correlation between soil behavior and its properties. Moreover, it is used in expressing the phase relationships of air, water, and solids in a given volume of material. In fine-grained (cohesive) soils, the consistency of a given soil type depends on its water content (ASTM, 1999).

The higher moisture content reflects a higher clay percentage, as clay particles interact with water differently than the larger particle sizes and retain more water than the larger particles under similar conditions.

Therefore, where the moisture content decreases at depth, it is generally an indication that the soil has less clay and more of the coarse soil fraction. Table 2-1 shows that typical values of water content in a saturated state for different types of soil (Das, 2002).

Table 2-1 Range of water content of soil

Soil	Natural Water Content in a Saturated State %
Loose uniform sand	25-30
Dense uniform sand	12-16
Loose angular - grained silty sand	25
Dense angular - grained silty sand	15
Stiff clay	20
Soft clay	30-50
Soft organic clay	80-130
Glacial till	10

2.2.2. Specific Gravity

In general, the term specific gravity is defined as the ratio of the mass of a given volume of a material to the mass of an equal volume of water. In effect, it tells us how much the material is heavier than (or lighter) than water. The particular specific gravity of a soil actually denotes the specific gravity of the solid matter of the soil and refers, therefore, to the ratio of the mass of solid matter of a given soil sample to the mass of an equal volume (i.e. equal to the volume of the solid matter) of water. Alternatively, specific gravity of soil may be defined as the ratio of the unit mass of solids (mass of solids divided by volume of solids) in the soil to the unit mass of water. The specific gravity of most natural soil falls in the general range of 2.60 - 2.80; the smaller the values are for coarse-grained soil (Das & Sobhan, 2018).

2.2.3. Grain Size Analysis

A soil consists of particles of various shapes, sizes and quantity. Grain-size (particle size) analysis is a method of separation of soils in to different fractions based on particle size. It expresses quantitatively the proportions, by mass, of varies sizes of particles present in a soil. It is shown graphically on a particle size distribution curve. The grain-size distribution of coarse-grained soils (size > 0.075 mm) is determined directly by a sieve analysis, while that of fine-grained soils (size < 0.075 mm) is determined indirectly by hydrometer analysis. The grain-size distribution of mixed soils is determined by combined sieve and hydrometer analysis (Das & Sobhan, 2018).

Soil consists mostly of different sized soil particles as a major constituent ingredient. The determination of the fractions of the particles will help to identify the soil type as well as to estimate many other engineering properties such as strength and permeability and also to identify whether the soil is suitable for construction projects such as highways, dams or as backfill or for filter design (Jibril, 2017).

Percentage of clay, silt and sand can be determined by physical analysis for brick making. This are usually done through wet sieve analysis method in well-established laboratories. Good brick making soil possesses the following physical properties sand, silt and clay percentage as shown on Table 2-2 (Vardanega & Haigh, 2014).

Table 2-2 Percent composition of soil (Vardanega & Haigh, 2014)

Soil Composition	Percentage
Sand	20 - 45%
Silt	25-45%
Clay	20-35%

Percent composition of soil determined by mechanical analysis (i.e., sieve) and hydrometer analysis by different classification method as shown in Table 2-3.

Table 2-3 Soil classification based on grain size range in mm (Vardanega & Haigh, 2014)

Soil Type	USCS Symbol	USCS	AASHTO	USDA	MIT
Gravel	G	76.2 to 4.75	76.2 to 2	>2	> 2
Sand	S	4.75 to 0.0.75	2 to 0.075	2 to 0.05	2 to 0.06 .
Silt	M	Fines < 0.075	0.075 to 0.002	0 .05 to 0.002	0.06 to 0.002
Clay	C	< 0.002	< 0.002	< 0.002	<0.002

2.2.4. Properties of Fine-Grained Soils

Properties of fine-grained soils exhibit considerable changes with change of water content. Dry clay may be suitable as a foundation for heavy loads as long as it remains dry, but may turn into swamp when wet. Many of the fine-grained soils shrink on drying and expand on wetting, which may adversely affect structures founded on them. The properties of fine-grained soils may vary considerably between their condition in the ground and their state after being disturbed. Even if moisture content does not change (K.R. Arora, 2004)

A. Silts

Silt is a fine-grained soil with little or no plasticity. The least plastic varieties generally consist of more or less equidimensional grains of quartz and are sometimes called rock flour; whereas the most plastic types contain an appreciable percentage of flake –shaped particles and are referred to as plastic silt. Because of its smooth texture, silt is often mistaken for clay, but it may be readily distinguished from clay without laboratory testing. If shaken in the palm of the hand, as part of saturated inorganic silt expels enough water to make its surface appear glossy. If the pat is bent between the fingers, its surface again becomes dull. This procedure is known as the shaking test. After the pat has dried, it is brittle and dust can be detached by rubbing it with the finger (K.R. Arora, 2004).

B. Clay Minerals

Clay refers for soil particles finer than 0.002mm or 0.005mm depending on which classification system used. It has the property of plasticity when mixed with some amount of water. Plasticity refers for the behavior of material that deforms in shape and keeps its deformation even after the removal of the pressure that caused the deformation. Clay soil may contain clay minerals as well as non-clay minerals. The non-clay minerals that are found in clay are quartz, feldspar or mica. Clay minerals are mostly in the form of sheets; their thickness is relatively smaller than the width and length of the sheets, their surface area is larger than their volume. Consequently, the behavior of clay is governed by the surface forces Soil behavior is attributed to the properties of clay minerals that are found in the specific soil. Therefore, it is vital to know the behavior of clay minerals for understanding the engineering behavior of fine grained soils (Muluneh, 2012).

2.2.5. Atterberge Limit Test

A fine-gained soil can exist in any of several states; which state depends on the amount of water in the soil system. When water is added to a dry soil, each particle is covered with a film of adsorbed water.

If the addition of water is continued, the thickness of the water film on a particle increases. Increasing the thickness of the water films permits the particles to slide past one another more easily. The behavior of the soil, therefore, is related to the amount of water in the system. Approximately sixty years ago, A. Atterberge defined the boundaries of four states in terms of "limits" as follows (Kalinski, 2011).

These test methods are used as an integral part of several engineering classification systems to characterize the fine-grained fractions of soils (ASTM D 2487 and D 3282) and to specify the fine-grained fraction of construction materials (ASTM D 1241). The liquid limit, plastic limit, and plasticity index of soils used extensively, either individually or together, with other soil properties to correlate with engineering behavior such as compressibility, hydraulic conductivity (permeability), compatibility, shrink-swell, and shear strength parameters of soil.

A. Liquid Limit

The water content at which the soil has such small shear strength that it flows to close a groove of standard width when jarred in a specified manner. The liquid limit is defined as the moisture content at which soil begins to behave as a liquid material and begins to flow on the application of a very small shearing force. When a soil becomes a viscous fluid, the soil will begin to flow under its own weight and very small amount of energy input. The liquid limit is primarily use by civil and geotechnical engineers as a physical property of a soil. The Liquid limit is the water content corresponding to the arbitrary limit between the liquid and plastic state of soil. The liquid limit is determined in the laboratory with the help of the standard liquid limit apparatus designed by Casagrande. After getting the entire values plot a graph between number of blows and respective water content, from that we get the value of liquid limit.

As explained, the liquid limit is the dividing line between the liquid and plastic states. It is quantified for the given soil as specific water content; from a physical stand point, it is the water content at which the shear strength of the soil becomes so small that the soil flows to close standard groove cut in a sample of soil when it is jarred in a standard manner. The liquid limit is identified in the laboratory as that water content at which the groove cut into the soil pat in standard liquid limit device requires 25 blows (drops) from a height of 1cm to close along a distance of 13 mm (Casagrande method).

B. Plastic Limit

Plastic Limit Test: Plastic limit is the water content corresponding to the arbitrary limit between the plastic and semi- solid states of the soil. To determine the plastic limit, the soil specimen should be passing 425-micron sieve. The soil mixed thoroughly with distilled water until the soil mass becomes plastic enough to be easily mounded with fingers. The soil was rolled between the fingers until a diameter 3 mm is reached. These are kept for the water content determination.

C. Plastic Index

Plasticity index (PI) is the range of water content over which the soil behaves plastically. From the Atterberg limit values, it is possible to determine plasticity index using the formula: Plasticity index, PI = LL – PL.

Table 2-4 Plasticity Index (Kalinski, 2011)

Plasticity Index	Plasticity
0	Non plastic
<7	Low plastic
7-17	Medium
> 17	High plastic

D. Liquidity Index

The Atterberg limits are found for remolded soil samples. These limits as such do not indicate the consistency of undisturbed soils. The index that is used to indicate the consistency of undisturbed soils is called as the liquidity index or water plasticity ratio.

The liquidity index is expressed as

$$LI = \frac{W - W_P}{PI} \qquad (2.2)$$

Where, LI is liquidity index, W is natural moisture content, Wp is plastic limit, and PI is the soil specimen's plastic index. The value of LI varies according to the consistency of soils as shown below.

Table 2-5 The consistency of the soil (Kalinski, 2011)

Consistency	Liquidity Index
Semi solid or solid state	Negative
Very stiff state (W=WP)	0
Very soft state (W=WL)	1
Liquid state (when disturbed)	>1

2.2.6. Linear Shrinkage

The linear shrinkage value is a way of quantifying the amount of shrinkage likely to be experienced by clayey material. Such a value is all relevant to the converse condition of expansion due to wetting. Shrinkage due to drying is significant in clays, but less so in silts and sands. If the drying process is prolonged after the plastic limit has been reached, the soil will continue to decrease in volume, which is also relevant to the converse condition of expansion due to wetting (Bureau of Indian Standards, 1992).

2.2.7. Free Swell Index

Free swell or differential free swell, also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water. The potentiality of damage to structure due to swelling of expansive clay need be identified by an investigation of those soil likely to possess undesirable expensive characteristics. This testing is provided to reflect the potential of the soil to swell under different simulated conditions (Bureau of Indian Standards, 1977). For the given soil the free swell index in percent can be calculated as follow:

$$Free\ Swell\ Index = \frac{Final\ volume - Initial\ volume}{Initial\ volume} * 100 \tag{2.3}$$

2.3. Soil Classification

2.3.1. Unified Soil Classification System

The most used soil classification system among engineers is Unified Soil Classification System (ASTM, 2017). It was originally developed by Casagrandea (1948) for use in the airfield construction works undertaken by the Army Corps of Engineers during World War II. In corporation with the U.S Bureau of Reclamation, the Waterways Experiment Station (WES) revised this system in 1952 to make it applicable to dams, foundations, and other constructions (WES 1960). An important difference is that, unlike the USDA and AASHTO systems, USCS incorporates organic soils as well as gravels Stain, Garacia-Gaines, & Franken, 2015 as mentioned by (HADDIS, 2020).

2.5.2 AASHTO Classification System

In embankments –materials in the A-1, A-2-4, A-2-5, or A-3 groups shall be used when available and shall be compacted to the depth specified to not less than 95 percent the maximum density. If material of this character is not available and materials from A-2-6, A-2-7, A-4, A-6, or A-7 groups must be used, special attention should be given to the design and construction of the embankment. Materials from these groups shall be compacted to not less than 95 percent of the maximum density and within two percentage points of the optimum moisture content. (AASHTO, 2008).

In subgrades- Materials classified in the A-1, A-2-4, A-2-5, or A-3, groups shall be used when available and shall be compacted to the depth specified to not less than 95 percent of the maximum density. Materials in the A-2-6, A-2-7, A-4, A-5, A-6, or A-7 groups may be used if compacted to the depth specified to not less than 95 percent of the maximum density and within two percentage points of the optimum moisture content per AASHTO T 99.

2.4. Undrain Shear Strength

The shear strength of fine-grained soils generally can be divided into two parts as drained and undrained shear strengths depending on whether the pore water pressure dissipates or not. In situ shear strength of soils is recorded almost in undrained condition. The undrained shear strength (Su) of fine-grained soils that can be measured in situ and in laboratory is one of the key geotechnical parameters. Undrained shear strength of the soil depends upon the prevailing in situ conditions, which can vary with time, the rate of loading, and many other factors. The remolded undrained shear strength (Sur) is of importance in many geotechnical applications including pile design and submarine soil investigations for offshore structures. Undrained shear strength decreases with the increase in water content. Additionally, the undrained shear strength of a clayey soil also depends on the dominant clay mineral present. The undrained shear strength of Kaolinitic soils is a result of the net attractive forces and the mode of particle arrangement as governed by the inter particle forces, whereas that of montmorillonite soils can be attributed to the viscous shear resistance of the double-layer water.

The undrained shear strength of soft clays can be determined in field or laboratory by vane shear test, while that of intact clays can be determined by unconfined compressive strength. The unconfined compression test is a special form of triaxial test in which the confining pressure is zero. The test can be conducted only on clayey soils which can stand without confinement. The test is generally performed on intact (non-fissured), saturated clay specimens. The test is conducted on undisturbed sample or remolded sample. It is convenient, simple and quick. However, the test cannot be conducted on fissured clays. In this paper the focus of the research is on soft clays for which vane shear test apparatus is easier to use. Besides, if conducted properly, results are more reliable than those obtained from unconfined compressive strength tests, which can be affected by a number of factors.

The shear strength of undisturbed clays depends on the consolidation history of the clay as well as the fabric characteristics. The ratio of natural shear strength to remolded shear which have an open structure and high moisture content. Sensitivity may be related to liquidity index, and this has indeed been found so by a number of researchers. The work of Skempton and Northey (1952) as cited by (Carter, M. and Bentley, S.P., 1991) relates mainly to clays of relatively moderate sensitivity with natural moisture contents below the liquid limit.

Atterberg limits can be employed to get bearing capacity of subsoil. By using regression analysis and central tendency parameters in statistical analysis we can obtain a correlation. There are some approaches to know bearing capacity of subsoil. Undrained shear strength shows capability or bearing capacity of soil. Relations between undrained shear strength of soil (su) and undrained cohesion (cu) in the case without confining pressure called unconfined compressive strength (qu), have been proposed by some previous research results and used as sub grade failure criteria for pavement design as depicted in Table 2-6.

Table 2-6. qu and cu relation (HADDIS, 2020)

Researcher or source	Equation
Giroud and Noiray (1981)	qu = 3.14 cu
Barenberg (1992)	qu = 3 cu
Philips (1987)	qu = 2.8 cu
Rodin (1965)	qu = 3.14 cu
Roadex III (2008)	qu = 4 cu

Soil consistency can be estimated using value of unconfined compressive strength (Terzaghi et al., 1996) as shown in Table 2-7.

Table 2-7 Soil consistency (Terzaghi et al., 1996)

Soil consistency	Ku in (kPa)
Very soft	< 24
Soft	24 – < 48
Medium	48 – < 96
Stiff	96 – < 192
Very stiff	192 – < 383
Firm	> 383

2.5. Statistical Data Analysis of 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 (Ahmed, 2015).

2.5.1. Data distribution Analysis of the Model (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 (Alan, C., E., and Wayne, A., W., 2007).

H_0: the distribution of the data is normal.

H_a: 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 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.

2.5.2. Considerations for Statistical Analysis

There are various statistical techniques for analyzing data. To choose an appropriate technique of statistical analysis in the challenging task to a research worker. The major types of tests employed for analyzing 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 analyzing his own research data depending on the criteria for choosing an appropriate statistical approach (Kumar, Y.S., 2006).

2.5.3. 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 (Elliot, T., B., and Steven, P.R. A., 2012):

- 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 give some idea about the accuracy of an estimate. A variable with a confidence level (CL) ≥ 95% is the best to choose.

A. Simple Linear Regression

The case of simple linear regression considers a single regress or 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 $Y = \beta_0 + \beta_1 X$, where the intercept β_0 and the slope β_1 are unknown regression coefficients. Note that each pair of observations satisfies the relationship: $Y_i = \beta_0 + \beta_1 x_i + e_i$, where $e_i = Y_i - Y$ 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.

B. Multiple Linear Regression Model

Many applications of regression analysis involve situations that have more than one regress or predictor variable. A regression model that contains more than one regress or variable called a multiple regression model. A multiple regression model described by the following relationship: $Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k + \epsilon$; Where, Y= Dependent variable or response, x_i (i = 1, 2 … k) = independent variables or predictors, and β_j ($_j$ = 0, 1…k) = Regression coefficients

2.6. Existing Correlations of UCS with Index Properties

Schofield and Worth (1968) contended that the 'crumbling' of soil in the plastic limit test implies a tensile failure, similar to that observed in split – cylinder tests on concrete. While this may well explain the eventual failure of the soil thread, examination of the method shows that cannot be a test of soil strength, tensile or otherwise. In any material strength test, some stress must be controlled or measured. This may occur either using a load cell, as in a split-cylinder concrete strength test, or using dead weight, as in the fall cone test for liquid limit. In the plastic limit test no stresses are controlled directly; enough vertical stress is applied using the hand to cause the soil thread to yield and elongate, but this stress is never measured. The paper has shown the plastic limit as defined by Atterberg (1911) is a measure of soil brittleness, and does not correspond to a fixed soil strength. And a quantity termed the plastic strength limit, PL100, is suggested for correlations with strength properties, but not for analysis of the water content at which the soil becomes brittle (Vardanega & Haigh, 2014).

Birhan Haddis (2020) was made a correlation between unconfined compressive strength and index properties in Bahridar city, Ethiopia. The type of soil specimens used for his study was a high plasticity silty soil (MH) for 25 number of specimens. Then he observed that unconfined compressive strength of his study area was strongly correlated with Liquid Limit and Liquidity Index with R^2 of 0.95. i.e., UCS = $-3.83 * \text{LL} - 136LI$ + 410.19 (HADDIS, 2020).

Tariku Tafari Bakala (2021) also investigated the relation of undrained shear strength (Cu) of cohesive soils with index properties in Agaro Town, Ethiopia. Accordingly, the researcher founded a relatively small Coefficient of determination/Determinant factor (R^2) of the undrained shear strength (Cu) of the study area with plastic index and plastic limits than the previous study of Birhan-Meskel Haddis (2020). The sample size used by Tariku Tafari Bakala (2021) was 30 for cohesive soil and then the developed equation was Cu=224.032-2.272*PL-2.485*PI with R^2 of 0.806 (Tafari Bakala et al., 2021).

2.7. Summary of Literature Reviews

Unconfined compression strength of fine soil can be estimated for preliminary building design from different existing correlations. However, those correlations vary from place to place according to origin, topography, environmental effects of the soil materials as mentioned earlier. The developed statistical models have a variation among them. Thus, Schofield and Worth (1968) assumes the UCS soil strength strongly correlated with plastic limit (Vardanega & Haigh, 2014), while Birhan Haddis (2020) observed the UCS was strongly correlated with liquid and liquidity index (HADDIS, 2020) and Tariku Tafari Bakala (2021) investigated that the undrained shear strength of cohesive soil made a correlation with plasticity index and plastic limits. Therefore, it is important to investigate the statistical model for Serbo towns unconfined compressive strength of its cohesive soil to get a relevant shear strength parameter.

CHAPTER THREE

3. MATERIALS AND METHODOLOGY

3.1. Study Area

The study was conducted in Jimma, Serbo town, Kersa Woreda, 345km southwest of Addis Ababa. The study area is located between latitudes 7°35'- 8° 00', and between longitudes 36°46'- 37°14'E at altitudes between 1,740-2660 m above sea level.

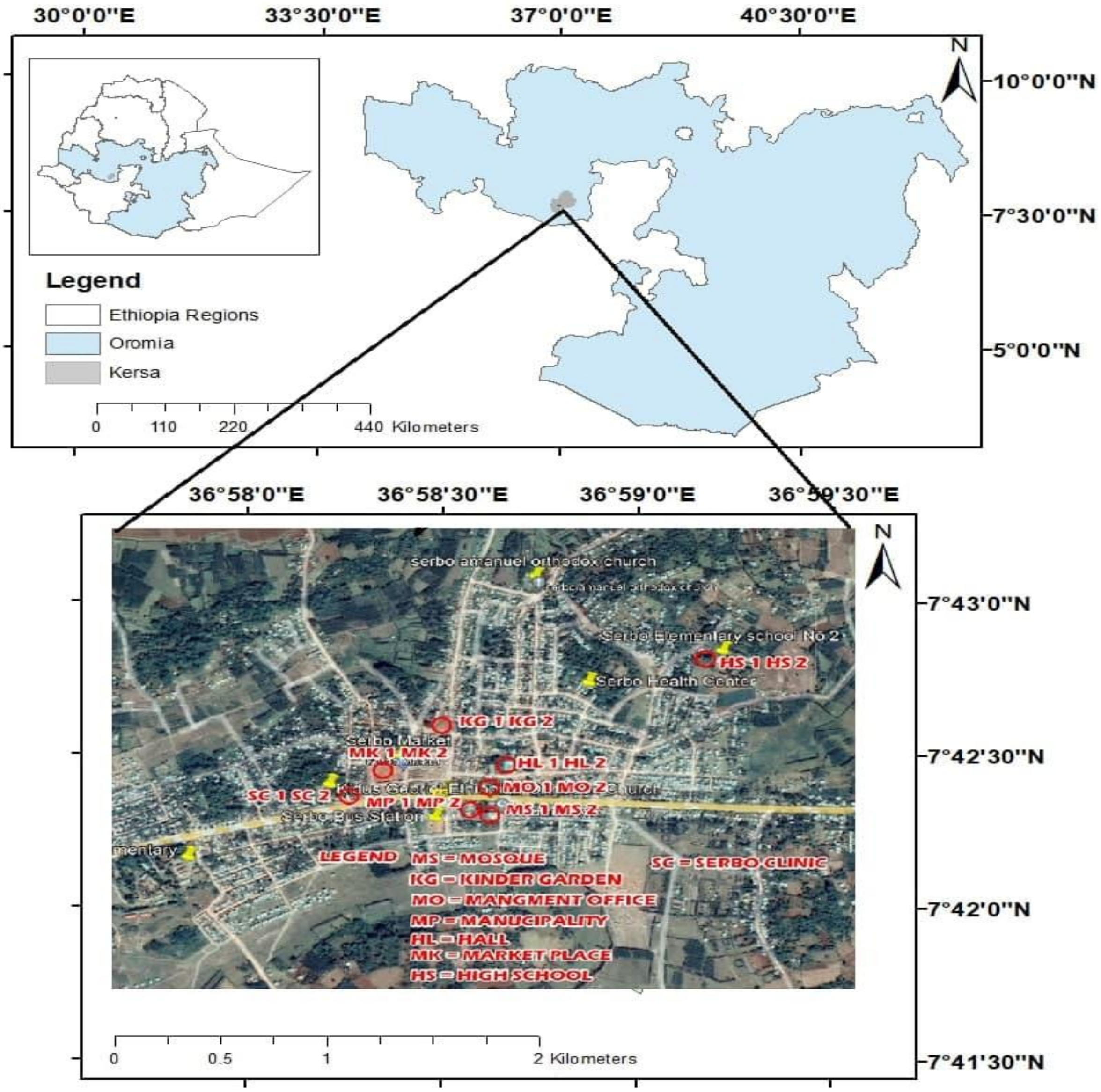

Figure 3-1 Study Area (Source Google Earth 2022)

3.2. Research Design

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

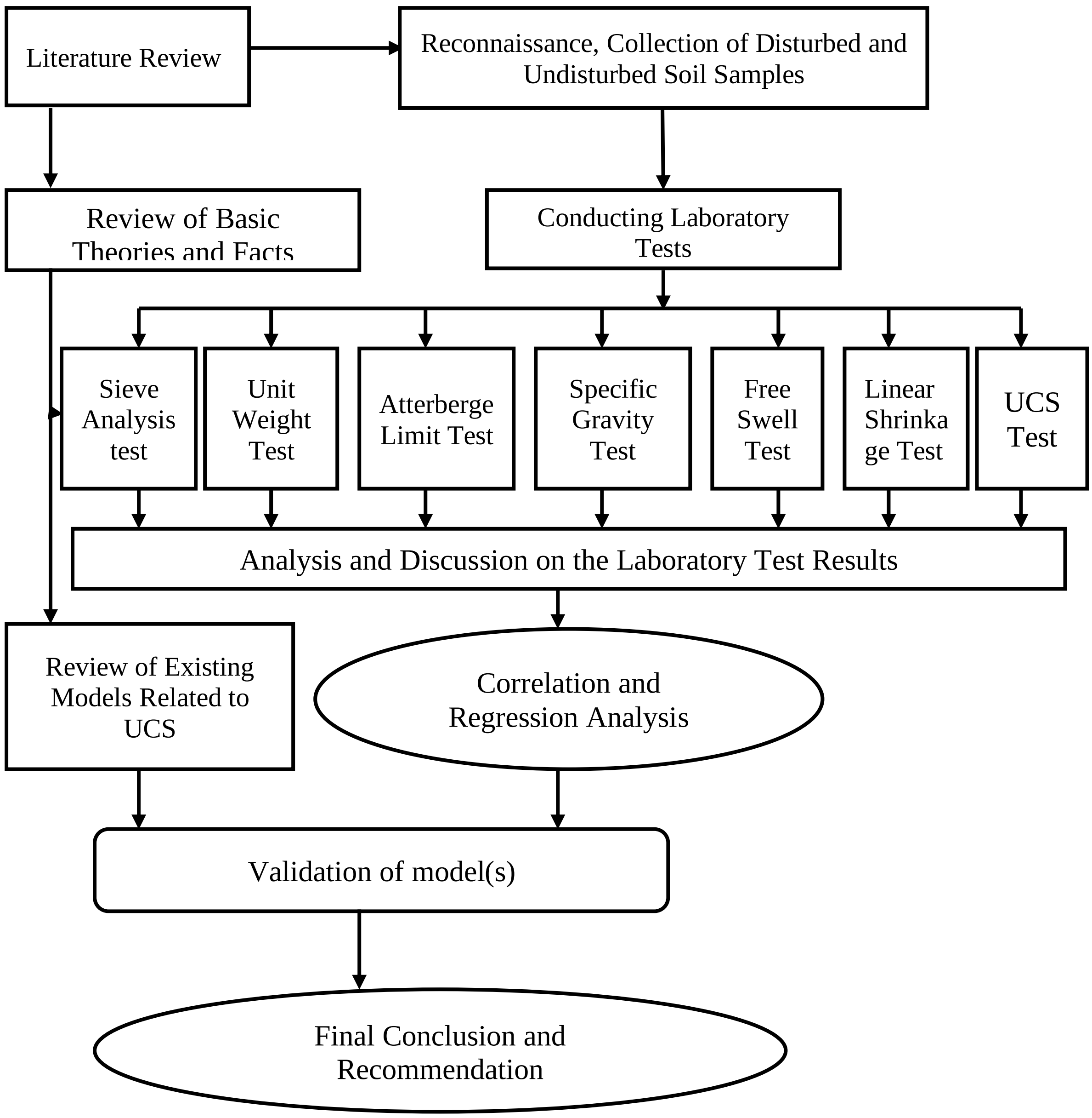

Figure 3-2 Flow chart for the overall frameworks

3.3. Study Population

The study population for this research were different types of soils in Jimma Zone, Serbo Town. The soil specimens were collected from 18 test pits to represent the different types of soils in the study area.

3.3.1. Sample Size and Selection

For this study, the soil samples were collected using a purposive sampling method which were from 18 test pits. The collected samples for this study were undisturbed and disturbed sample specimens.

3.3.2. Sampling Techniques and Procedure

The soil samples were collected from 18 test pits at a depth of 1m and 2m below ground level. The test pits were excavated manually, and the collected samples were taken to the Jimma Institute of Technology-Geotechnical Engineering soil laboratory.

3.4. Study Variables

3.4.1. Independent Variables

The independent variables which were measured and manipulated to determine its relationship to observed the phenomena were:

- # Bulk Unit Weight,
- # Natural Moisture Content,
- # Dry Unit Weight,
- # Liquid Limit,
- # Plastic Limit,
- # Plasticity Index,
- # Specific Gravity,
- # Linear Shrinkage,
- # Free Swell,
- # Percentage of Passing Fine Particle,
- # Liquidity Index, And Activity.

3.4.2. Dependent Variables

The dependent variable which was observed and measured to develop unconfined compressive strength model from index properties of soil.

3.5. Sample Collection Method and Process

Test pits were excavated using hand tools and took representative disturbed and undisturbed soil samples. The soil samples had been handled and preserved to prevent contamination by foreign material and to ensure that the in-situ soil conditions are preserved. The preserving and transporting of the samples were according to ASTM D-4220-95 (ASTM, 2000a) standard.

3.5.1. Field Survey

During the field survey, a preliminary visual survey was conducted on Serbo town's soils. To understand the general soil type of the study area, the researcher used different soil investigation papers conducted on the study area.

3.5.2. Laboratory Test Procedure

In order to classify the soils and assess the correlations between swelling pressure and index properties of soils, a series of tests conducted. To obtain the intended purpose of this research thesis the following laboratory tests was carried out in order to determine the relationship.

1. Unit weight test (ASTM D-1556)
2. Natural moisture content (ASTM D2216-98)
3. Particle size distribution (ASTM D422-98)
4. Atterberge limits (ASTM D4318-98)
5. Specific gravity of soil solid (Gs) (ASTM D854-98)
6. Linear Shrinkage Limit (IS 2720 part 20 -1977)
7. Free swell test (IS 2720 part 40 -1977)
8. Unconfined compression test (ASTM D 2166)

3.6. Data Processing and Analysis

3.6.1. Data Collection Process

The data collection represents a plan for gathering data information from the study area. A set of the procedure followed to get the desired data or information from the fieldwork according to the ASTM Standard Manual in order to process and analysis the facts in a logical and scientific manner. The investigation involved collection of relevant geologic maps and associated reports and supplementary study materials from different sources.

3.6.2. Collection Data and Analysis

Detail statistical analyses of soil index properties and unconfined compressive strength soil of the study area carried out using various data sets to determine suitable correlations for estimating unconfined compressive strength. For analysis, different data points used for development of new model. The analysis carried out by using Computer Software Program (SPSS) and Microsoft Spreadsheet (MS- Excel) to predict the correlation between unconfined compressive strength and index properties of the soils. Using laboratory test results new correlations developed and the best formula selected from developed equations and the graph of predicted value with the measured values of unconfined compressive strength plotted.

3.7. 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.

Regression analysis is concerned with how the values of Y depend on the corresponding values of X. Y, whose value is to be predicted, is known as dependent variable or response and X, which is used in predicting the value of the dependent variable, is called independent or regression variable.

3.7.1. Data Distribution Analysis of the Model

A regression model that contains more than one regression variable is called multiple Regression models whereas Regression model containing one independent variable is termed as a simple regression model as stated by (Tafari Bakala et al., 2021). Correlation analysis is a term used to denote the association or relationship between two (or more) quantitative variables. This analysis is fundamentally based on the assumption of a straight –line with the construction of a scatter plot or scatter diagram [a graphical of the data] with one variable on the X-axis and the other on the Y-axis (Adunoye, 2008). Fitting, a regression model requires several assumptions. Estimation of the model parameters require the assumption that the residuals (actual value less estimated value) corresponding to different observation are uncorrelated random variables with zero mean and constant variance. Test of hypothesis and interval estimation requires that the error be normally distributed. In addition, one assumes that the order of the model is correct; that is, if one fits a simple linear regression model, one is assuming that the phenomenon actually behaves in a linear or first-order manner. During regression analysis, a regression model with a higher value coefficient of determination (R^2), which quantifies the proportion of the variance of one variable by the other, good significance level (α), which compares estimated (predicted) and actual y values, and ranges in value from zero to one is accepted. In practice it is customary to use 5% level of significance (i.e. 95% confident that could make the right decision and be wrong with a probability of 5%) (Mengistu, 2017).The closer the R^2 to one, the better the representations (Adunoye, 2008).

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Laboratory Test Results

In this study, laboratory tests were performed to determine the index properties and unconfined compressive strength of study area's soils.

4.1.1. Natural Moisture Content

Moisture contents of the soil samples were determined in the laboratory according to ASTM D 2216(ASTM, 1999). 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	Test Pit No and Depth	Moisture Content, %	Test pit Location	Test Pit No and Depth	Moisture Content, %
Mosque	TP 1@1.5m	46.78	KG	TP-11 @ 1m	44.99
	TP 2 @1.5m	49.57		TP-11 @ 2m	38.06
	TP 3 @1.5m	48.70		TP-12 @ 1m	43.86
	TP 4 @1.5m	48.19		TP-12 @ 2m	38.13
Municipality	TP-5@1m	40.91	Serbo Market	TP-13 @ 1m	43.58
	TP-5 @2m	48.92		TP-13 @ 2m	49.20
	TP-6 @1m	38.64		TP-14 @ 1m	42.83
	TP-6 @2m	44.69		TP-14 @ 2m	46.50
City Hall	TP-7 @1m	48.33	High School	TP-15 @ 1m	48.89
	TP-7 @2m	41.41		TP-15 @ 2m	44.00
	TP-8 @1m	48.93		TP-16 @ 1m	47.40
	TP-8 @2m	47.25		TP-16 @ 2m	47.81
Old Management	TP-9 @1m	49.44	Serbo Clinic	TP-17 @ 1m	37.59
	TP-9 @2m	46.98		TP-17 @ 2m	36.19
	TP-10 @1m	46.07		TP-18 @ 1m	33.61
	TP-10 @2m	48.41		TP-18 @ 2m	36.39

From the above Table 4-1, the natural moisture content of soils of the study area ranges from 33.61 to 49.57 in percent.

4.1.2. Unit Weight

The unit weight of soil was determined according to ASTM D 1556 (ASTM, 2000c) by the Sand-Cone 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 4-2 Unit weight of the soil specimens

Test Pit No and Depth	Bulk Unit weight, (kN/m^3)	Dry Unit weight, (kN/m^3)	Test Pit No and Depth	Bulk Unit weight, (kN/m^3)	Dry Unit weight, (kN/m^3)
TP 1@1.5m	16.28	11.09	TP-11 @ 1m	16.54	11.40
TP 2 @1.5m	16.38	10.95	TP-11 @ 2m	17.24	12.49
TP 3 @1.5m	16.65	11.19	TP-12 @ 1m	17.08	11.87
TP 4 @1.5m	16.43	11.08	TP-12 @ 2m	16.98	12.29
TP-5@1m	16.74	11.88	TP-13 @ 1m	16.37	11.40
TP-5 @2m	16.42	11.02	TP-13 @ 2m	16.41	11.00
TP-6 @1m	16.59	11.96	TP-14 @ 1m	16.49	11.54
TP-6 @2m	16.08	11.11	TP-14 @ 2m	16.25	11.10
TP-7 @1m	16.71	11.26	TP-15 @ 1m	16.68	11.20
TP-7 @2m	16.63	11.76	TP-15 @ 2m	16.59	11.52
TP-8 @1m	16.02	10.76	TP-16 @ 1m	16.21	11.00
TP-8 @2m	16.40	11.14	TP-16 @ 2m	16.23	10.98
TP-9 @1m	16.70	11.18	TP-17 @ 1m	16.88	12.27
TP-9 @2m	16.78	11.42	TP-17 @ 2m	16.93	12.43
TP-10 @1m	16.94	11.60	TP-18 @ 1m	17.08	12.78
TP-10 @2m	16.39	11.05	TP-18 @ 2m	16.79	12.31

From Table 4-2 the bulk density and dry density of the sites range from 16.02 to 17.24 kN/m^3 and 10.76 to 12.78 kN/m^3 respectively.

4.1.3. Grain Size Analyses Test Result

This test was performed according to ASTM D-422 (ASTM, 1998) 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 coarse 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.

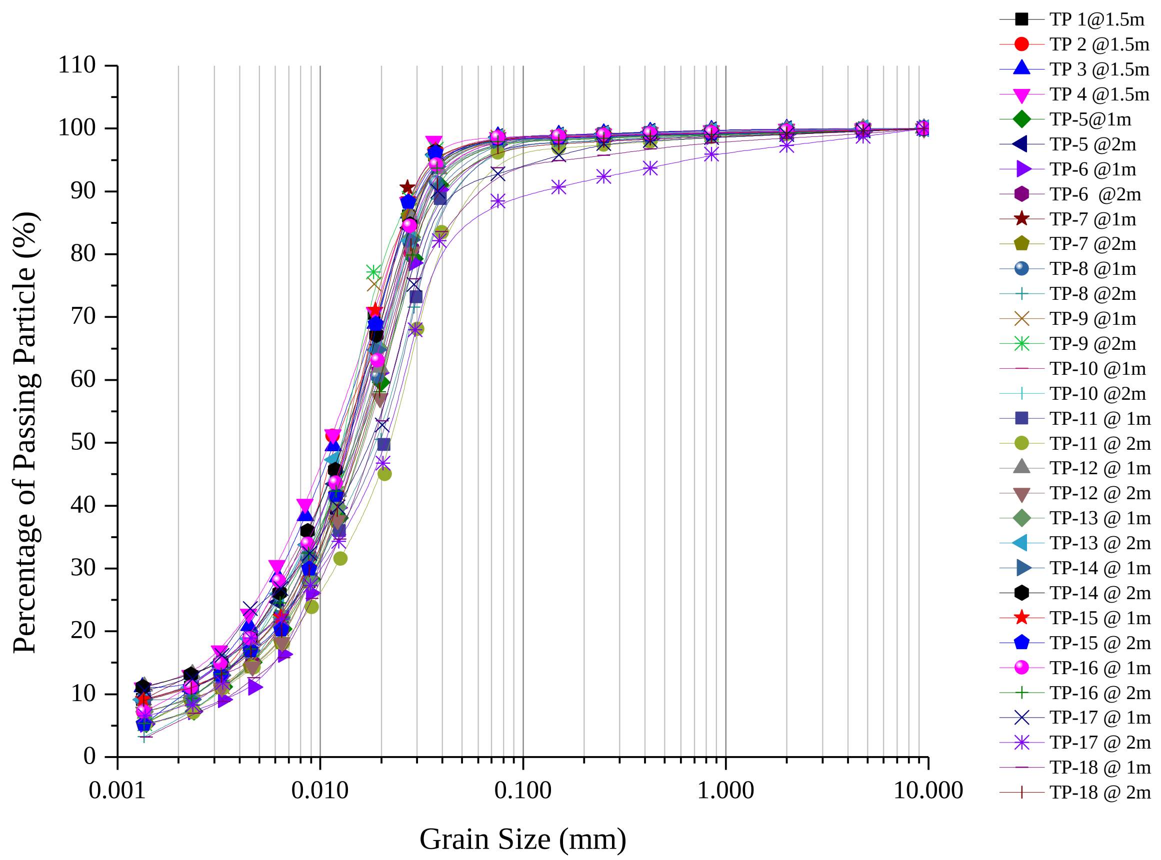

Figure 4-1 Combined grain size distribution curves

Figure 4-1 shows the percentage of finer than 0.075mm diameter particles are more than 85%. This indicates that the soil of study area is classified as fine-grained soils. Details of each test pit grain size is given under Appendix -D.

4.1.4. 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 D 854-58 (ASTM, 2018). Standard Test for Specific Gravity of Soil Solids by density bottle, procedure. Accordingly, the specific gravity of the collected soil specimen was varied from 2.62 to 2.74 as shown in the Table 4-3 below.

Table 4-3 Specific Gravity

Test Pit No and Depth	Average Specific Gravity, Gs at 20^0c	Test Pit No and Depth	Average Specific Gravity, Gs at 20^0c
TP 1@1.5m	2.72	TP-11 @ 1m	2.64
TP 2 @1.5m	2.72	TP-11 @ 2m	2.65
TP 3 @1.5m	2.73	TP-12 @ 1m	2.63
TP 4 @1.5m	2.71	TP-12 @ 2m	2.69
TP-5@1m	2.62	TP-13 @ 1m	2.67
TP-5 @2m	2.72	TP-13 @ 2m	2.72
TP-6 @1m	2.66	TP-14 @ 1m	2.70
TP-6 @2m	2.68	TP-14 @ 2m	2.69
TP-7 @1m	2.69	TP-15 @ 1m	2.69
TP-7 @2m	2.72	TP-15 @ 2m	2.70
TP-8 @1m	2.74	TP-16 @ 1m	2.70
TP-8 @2m	2.73	TP-16 @ 2m	2.70
TP-9 @1m	2.68	TP-17 @ 1m	2.64
TP-9 @2m	2.67	TP-17 @ 2m	2.65
TP-10 @1m	2.69	TP-18 @ 1m	2.63
TP-10 @2m	2.65	TP-18 @ 2m	2.69

4.1.5. Atterberg Limit's Test

This test was executed as per ASTM D-4318 (ASTM, 2000b)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.

Table 4-4 Atterberge Limit Test Result

Test Pit No and Depth	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Test Pit No and Depth	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)
TP 1@1.5m	78.7	41.6	37.1	TP-11 @ 1m	77.6	46.5	31.1
TP 2 @1.5m	88.6	47.8	40.8	TP-11 @ 2m	69.0	53.7	15.3
TP 3 @1.5m	78.2	47.2	31.0	TP-12 @ 1m	76.8	56.0	20.8
TP 4 @1.5m	85.5	50.7	34.8	TP-12 @ 2m	72.4	53.6	18.7
TP-5@1m	75.7	53.6	22.2	TP-13 @ 1m	83.1	48.9	34.2
TP-5 @2m	88.5	41.8	46.7	TP-13 @ 2m	81.8	41.5	40.3
TP-6 @1m	75.1	56.1	19.0	TP-14 @ 1m	76.5	51.4	25.1
TP-6 @2m	85.1	38.6	46.5	TP-14 @ 2m	72.5	44.6	27.9
TP-7 @1m	79.6	40.0	39.6	TP-15 @ 2m	81.4	41.7	39.7
TP-7 @2m	73.3	51.9	21.4	TP-15 @ 2m	78.1	52.0	26.1
TP-8 @1m	93.3	37.8	55.5	TP-16 @ 1m	87.3	43.0	44.3
TP-8 @2m	83.9	53.8	30.1	TP-16 @ 2m	82.7	52.9	29.8
TP-9 @1m	83.0	43.3	39.8	TP-17 @ 1m	67.5	48.9	18.6
TP-9 @2m	83.2	52.1	31.0	TP-17 @ 2m	63.3	47.3	16.0
TP-10 @1m	81.2	48.6	32.6	TP-18 @ 1m	57.3	46.1	11.2
TP-10 @2m	76.3	52.0	24.3	TP-18 @ 2m	65.3	48.4	16.9

Table 4-4 shows, the liquid limit of the soil specimens is above 50%. Hence, the consistency of the soils is classified as high plasticity soil.

4.1.6. Free Swell Index Test

Free swell index is the increase in volume of soil without any external constraint when subject to submergence in water. As IS 2720 part (40) -1977 (Bureau of Indian Standards, 1977) standard code pressure, the free swell index of the study area is described in the following Table 4-5.

Table 4-5 Free Swell Index

Test Pit No Depth	Free Swell Index, (%)	Test Pit No Depth	Free Swell Index, (%)
TP 1@1.5m	9.09	TP-11 @ 1m	8.33
TP 2 @1.5m	13.64	TP-11 @ 2m	13.04
TP 3 @1.5m	18.18	TP-12 @ 1m	13.04
TP 4 @1.5m	22.73	TP-12 @ 2m	9.09
TP-5@1m	16.67	TP-13 @ 1m	13.04
TP-5 @2m	20.83	TP-13 @ 2m	17.39
TP-6 @1m	16.67	TP-14 @ 1m	17.39
TP-6 @2m	25.00	TP-14 @ 2m	23.91
TP-7 @1m	18.18	TP-15 @ 1m	13.04
TP-7 @2m	22.73	TP-15 @ 2m	19.57
TP-8 @1m	16.67	TP-16 @ 1m	19.57
TP-8 @2m	8.33	TP-16 @ 2m	10.64
TP-9 @1m	8.33	TP-17 @ 1m	11.36
TP-9 @2m	16.67	TP-17 @ 2m	9.09
TP-10 @1m	22.73	TP-18 @ 1m	6.82
TP-10 @2m	13.04	TP-18 @ 2m	11.36

From the above Table 4-5, the free swell index of the soil specimens is between 6-25 in percent.

4.1.7. Linear Shrinkage Test

This test is used to measure the percentage decrease in dimension of a fine fraction of a soil when it is dried after having been molded in a wet condition approximately at its liquid limit (Bureau of Indian Standards, 1992). Accordingly, linear shrinkage test was made for the study area and the test result is mentioned in the table below.

Table 4-6 Linear Shrinkage Test Result

Test Pit No Depth	Linear Shrinkage, %, (%)	Test Pit No Depth	Linear Shrinkage, %, (%)
TP 1@1.5m	14.42	TP-11 @ 1m	14.74
TP 2 @1.5m	15.24	TP-11 @ 2m	14.91
TP 3 @1.5m	16.25	TP-12 @ 1m	15.31
TP 4 @1.5m	14.29	TP-12 @ 2m	15.61
TP-5@1m	12.52	TP-13 @ 1m	13.47
TP-5 @2m	15.06	TP-13 @ 2m	15.15
TP-6 @1m	14.74	TP-14 @ 1m	15.50
TP-6 @2m	14.56	TP-14 @ 2m	14.42
TP-7 @1m	15.52	TP-15 @ 1m	15.28
TP-7 @2m	14.94	TP-15 @ 2m	15.02
TP-8 @1m	15.54	TP-16 @ 1m	16.43
TP-8 @2m	16.09	TP-16 @ 2m	15.96
TP-9 @1m	15.03	TP-17 @ 1m	13.18
TP-9 @2m	15.11	TP-17 @ 2m	13.31
TP-10 @1m	17.32	TP-18 @ 1m	14.64
TP-10 @2m	15.83	TP-18 @ 2m	14.04

The linear shrinkage limit tests values of the study area vary from 12.52 to 17.32%. This shows that the value of test results greater than 8% indicates that the soil has critical degree of expansion.

4.1.8. Classification and Identification of Soils

Soil classification systems worldwide capture great physical insight and enable geotechnical engineers to anticipate the properties and behavior of soils by grouping them into similar response categories based on their index properties. Unlike steel and concrete, soils occur in a large variety as a result soil which have similar behavior must be grouped together to form a known group. As there is a wide varieties of soils covering the earth, it is desirable to systemize or classify the soils into broad groups of similar behavior (HADDIS, 2020).

Although, there are many soil classification systems are present in the world, currently, two more elaborate classification systems are commonly used by soil engineers. Both systems take into consideration the particle-size distribution and Atterberg limits. They are the American Association of state Highway and Transportation Officials (AASHTO) classification system and the Unified Soil Classification System. The soils under investigation have been classified according to UCSC and AASHTO (Zakikhani et al., 2017).

4.1.8.1. USCS Classification System

For proper classification according to this system, some or all of the following information must be known: Percent of gravel the fraction passing the 75mm sieve and retained on the No. 4 sieve (4.75mm opening). Percent of sand-that is, the fraction passing the No.4 sieve (4.75-mmopening) and retained on the No. 200 sieve (0.075-mm opening). Percent of silt and clay – that is, the fraction finer than the No. 200 sieve (0.075-mm opening). The basis for USCS (Unified soil Classification system) is Liquid Limit and plasticity Index of a soil. According to this classification scheme soil samples from the study area falls in CH and MH region, or high plasticity silty and clay soil. For most constructions this type of soil is problematic due to its low drainage, high deformations and low shear strength properties. The USCS classification of the soil specimens of the study area indicated in plasticity chart Figure 4-2 below.

From Figure 4-2, the soil specimens of the study area laid below A-Line except one test pit and all the specimens had above 50% liquid limits. Consequently, the USCS classification of the study area is high plasticity silt soil.

4.1.8.2. AASHTO Classification System

According to AASHTO Soil classification system the soil samples fall in the region of A7-5 as shown in Figure 4-3. This indicates the soils are clayey soils usual types of significant constituent materials and their rating as a subgrade are from fair to poor and they have got moderate PI in relation to LL which may be elastic as Well as subject to considerable volume change capacity between wet and dry states.

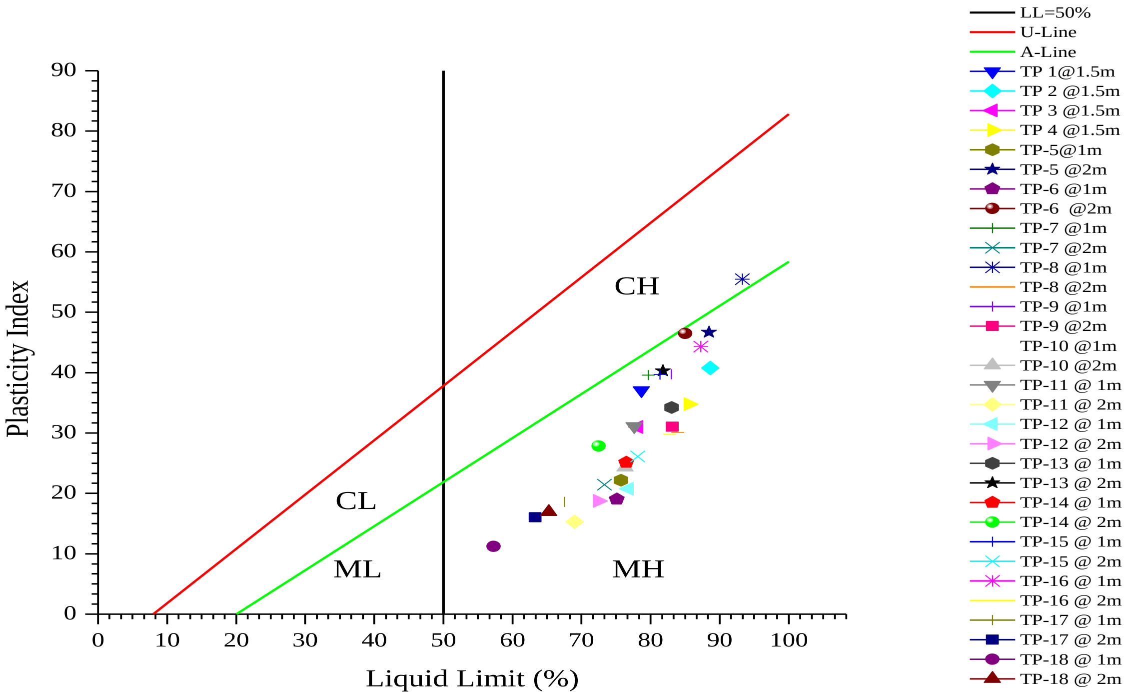

Figure 4-2 Unified Soil Classification System of the study area

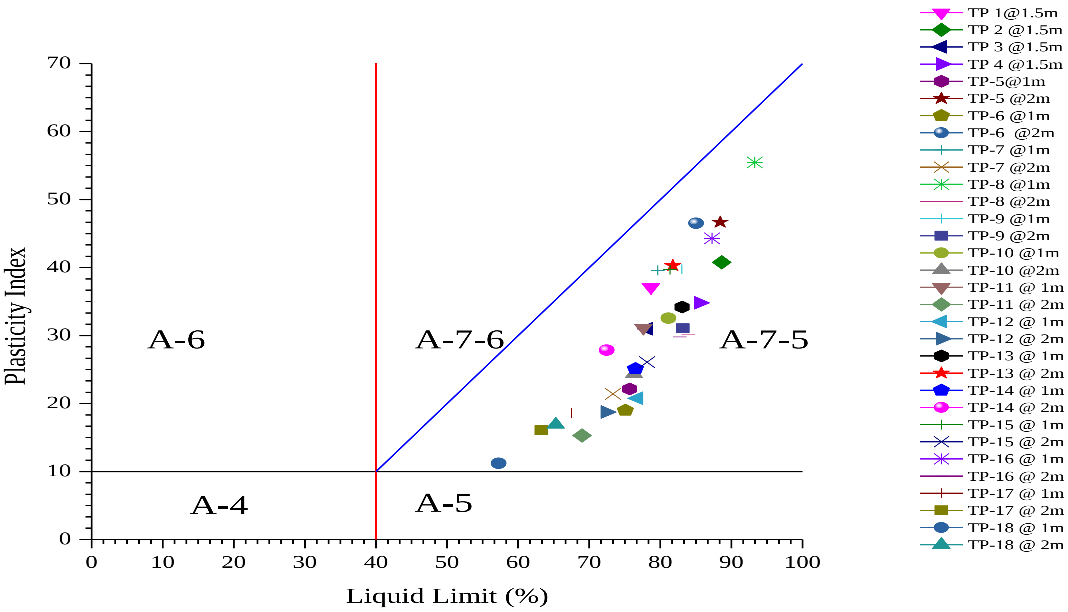

Figure 4-3 AASHTO Classification System in the Study Area

4.1.9. Activity

Figure 4.4 shows for thirty-two collected data of Activity of soils from the study area fall in a group of highly active to active as shows the Activity chart. This is the activity of the soil specimens were all above 1.25.

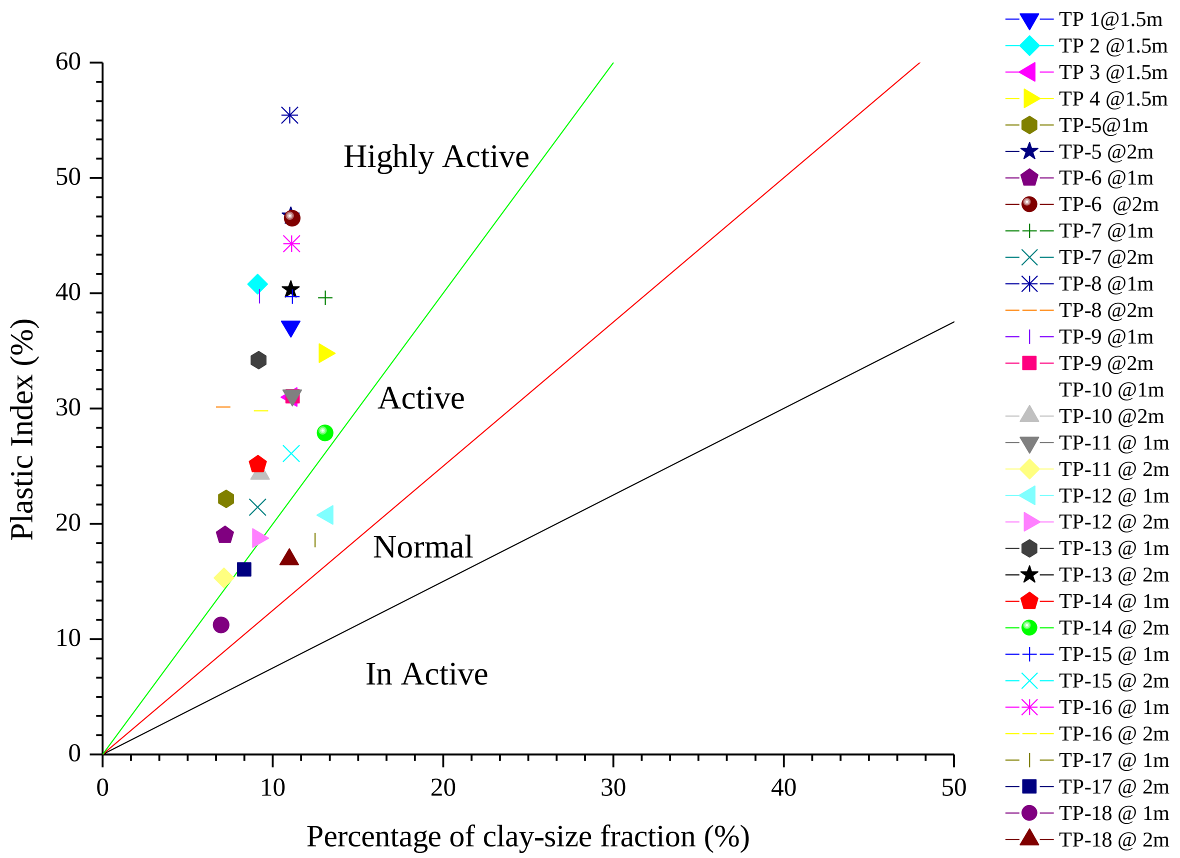

Figure 4-4 Activity Chart

4.1.10. Liquidity Index

Atterberge limits, when compared with the natural water content of the soil, give a valuable indication of the natural state of the soil in the ground. The parameter used for this purpose is the liquidity index (LI), which expresses the water content of the soil in relation to the PL and PI. For the study area the liquidity index of the collected soil specimen is summarized in Table 4-7.

Table 4-7 Liquidity Index Test Results

Test Pit No Depth	Liquidity Index	Test Pit No Depth	Liquidity Index
TP 1@1.5m	0.14	TP-11 @ 1m	-0.05
TP 2 @1.5m	0.04	TP-11 @ 2m	-1.02
TP 3 @1.5m	0.05	TP-12 @ 1m	-0.59
TP 4 @1.5m	-0.07	TP-12 @ 2m	-0.83
TP-5@1m	-0.57	TP-13 @ 1m	-0.15
TP-5 @2m	0.15	TP-13 @ 2m	0.19
TP-6 @1m	-0.92	TP-14 @ 1m	-0.34
TP-6 @2m	0.13	TP-14 @ 2m	0.07
TP-7 @1m	0.21	TP-15 @ 1m	0.18
TP-7 @2m	-0.49	TP-15 @ 2m	-0.31
TP-8 @1m	0.20	TP-16 @ 1m	0.10
TP-8 @2m	-0.22	TP-16 @ 2m	-0.17
TP-9 @1m	0.16	TP-17 @ 1m	-0.61
TP-9 @2m	-0.17	TP-17 @ 2m	-0.69
TP-10 @1m	-0.08	TP-18 @ 1m	-1.11
TP-10 @2m	-0.15	TP-18 @ 2m	-0.71

4.1.11. Unconfined Compression Test Result

The unconfined compressive strength tests of collected results from the study area ranges from 52.16 to 173.85kPa which indicate medium stiff to stiff consistency. The relationship between unconfined compressive strength and consistency of soil has a relation, the average value of UCS result 96.31 kPa fall in a range of stiff consistency.

Table 4-8 Unconfined Compressive Strength and Undrained Shear Strength Test Result

Test pit and depth	Peak UCS Value (kPa)	Cohesion, C (kPa)	Test pit and depth	Peak UCS Value (kPa)	Cohesion, C (kPa)
TP 1@1.5m	86	43	TP-11 @ 1m	84	42
TP 2 @1.5m	58	29	TP-11 @ 2m	159	80
TP 3 @1.5m	87	44	TP-12 @ 1m	107	54

TP 4 @1.5m	77	38	TP-12 @ 2m	135	68
TP-5@1m	115	58	TP-13 @ 1m	81	41
TP-5 @2m	59	29	TP-13 @ 2m	93	47
TP-6 @1m	119	60	TP-14 @ 1m	94	47
TP-6 @2m	66	33	TP-14 @ 2m	100	50
TP-7 @1m	87	44	TP-15 @ 1m	62	31
TP-7 @2m	112	56	TP-15 @ 2m	102	51
TP-8 @1m	52	26	TP-16 @ 1m	66	33
TP-8 @2m	80	40	TP-16 @ 2m	89	44
TP-9 @1m	57	29	TP-17 @ 1m	129	64
TP-9 @2m	87	43	TP-17 @ 2m	151	76
TP-10 @1m	76	38	TP-18 @ 1m	174	87
TP-10 @2m	95	48	TP-18 @ 2m	141	71

4.2. Results of Correlation and Regression Analysis

4.2.1. Statistical Data Distribution Result

Table 4-9 Results of Descriptive Statistics of Data Distribution

	N	Range	Minimum	Maximum	Mean	Mean Std. Error	Std. Deviation	Variance	Skewness	Skewness Std. Error	Kurtosis	Kurtosis Std. Error
UCS (kPa)	32	121.7	52.16	173.9	96.31	5.516	31.20	973.5	0.808	0.414	0.119	0.809
ω, %	32	15.96	33.61	49.57	44.45	0.829	4.687	21.97	-0.82	0.414	-0.57	0.809
ρ_d, (kN/m^3)	32	2.02	10.76	12.78	11.50	0.096	0.543	0.295	0.852	0.414	-0.40	0.809
LL (%)	32	36.00	57.28	93.28	78.18	1.392	7.876	62.03	-0.65	0.414	0.563	0.809
PL (%)	32	18.27	37.82	56.09	47.92	0.927	5.246	27.52	-0.31	0.414	-1.01	0.809
PI (%)	32	44.24	11.22	55.46	30.26	1.908	10.8	116.5	0.276	0.414	-0.55	0.809
G_S	32	0.12	2.62	2.74	2.69	0.006	0.033	0.001	-0.33	0.414	-0.88	0.809
FS, (%)	32	18.18	6.82	25.00	15.19	0.924	5.229	27.35	0.199	0.414	-1.04	0.809
LS, (%)	32	4.80	12.52	17.32	14.98	0.175	0.991	0.983	-0.32	0.414	0.816	0.809
PFP (%), <75μm	32	10.31	88.47	98.78	97.55	0.376	2.127	4.528	-3.20	0.414	11.08	0.809

A	32	3.55	1.49	5.04	2.975	0.169	0.955	0.912	0.281	0.414	-0.72	0.809
LI	32	1.32	-1.11	0.21	-0.24	0.070	0.397	0.158	-0.73	0.414	-0.64	0.809

From the above Table 4-9, the result of Skewness over its standard error as well as kurtosis over its standard error is between +2. The histogram and Q-Q plot of each variable shows each dependent and independent variable are normally distributed as shown in Appendix -A.

4.2.2. Normality Test Result

Table 4-10 Test of Normality for Each Variables

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
UCS (kPa)	0.138	32	0.129	0.938	32	0.064
ω, %	0.169	32	0.120	0.879	32	0.200
ρ_d, (kN/m^3)	0.179	32	0.211	0.892	32	0.104
LL (%)	0.098	32	0.200*	0.970	32	0.513
PL (%)	0.120	32	0.200*	0.949	32	0.139
PI (%)	0.088	32	0.200*	0.976	32	0.681
G_S	0.154	32	0.053	0.951	32	0.152
FS, (%)	0.128	32	0.195	0.950	32	0.140
LS, (%)	0.098	32	0.200*	0.975	32	0.649
PFP (%), <75μm	0.310	32	0.200*	0.551	32	0.214
A	0.108	32	0.200*	0.964	32	0.356
LI	0.162	32	0.132	0.898	32	0.612

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From the above table and figure, the normality test result fulfills 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-Smirnova 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 Kolmogrov-Smirnova and Shapiro-wilk test results fulfill 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, fulfill normality test and it compares the means of two independent variables.

4.2.3. Scatter Plot Strategy

In this study, Unconfined Compressive Strength was taken as the predicted variable (dependent), while the predictors (independent) variables represented by the Bulk Unit Weight, Natural Moisture Content, Dry Unit Weight, Liquid Limit, Plastic Limit, Plasticity Index, Specific Gravity, Linear Shrinkage, Free Swell, Percentage of Passing Fine Particle, Liquidity Index, And Activity. Prior to the execution of the regression analysis using the test results, a scatter plot was produced by applying the Origin Lab 8.5, in order to study the relations developed between the dependent variable and the predictor variables by visualizing to determine the model that best outfits the test results. Accordingly, the scatter plot is offered as a figure indicated successively.

From scatter plots offered on Figure 4-5, a visual method of displaying a relationship between variables as plotted in a two-dimensional coordinate system. Assessment of the scatter plots indicated that a real indication that the points lie scattered arbitrarily as a straight or looks like a straight line, mainly for the Natural Moisture Content, Dry Unit Weight, Liquid Limit, Plasticity Index, Liquidity Index, and Activity. However, the remaining independent variables such as specific gravity and bulk unit weight by some extent outliers away from the possible visual straight. Relatively, the above scatter plots are indicated a linear response and hence, a linear regression model expressed the association between the focus parameters.

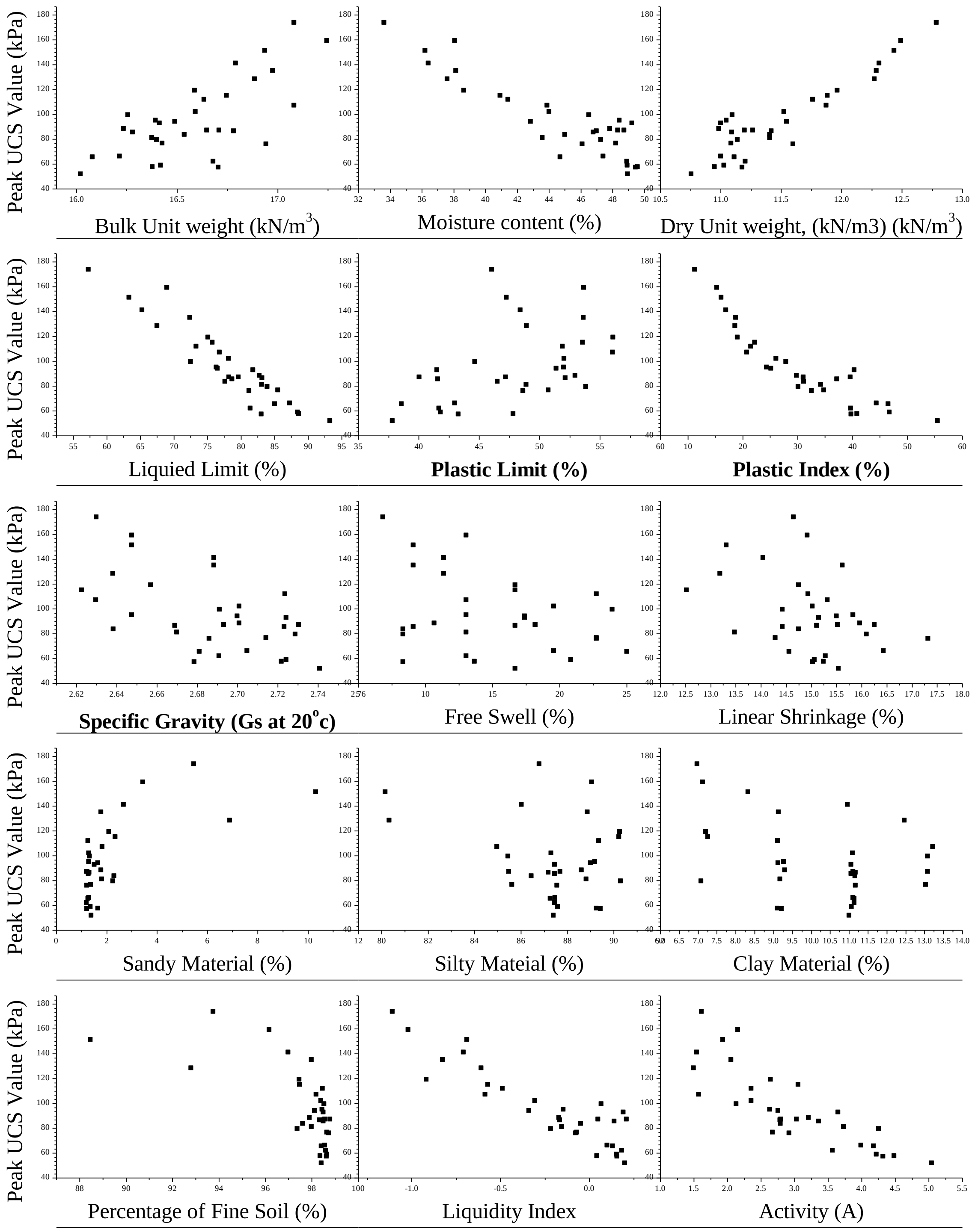

Figure 4-5 Scatter Plot Diagram of UCS with Independent Variables

4.2.4. Correlation Analysis and Result (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). 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).

Table 4-11 Significance level (α) and Pearson Correlation Coefficient (R) in correlations

		UCS (kPa)	w, %	ρd, (kN/m3)	LL	PL	PI	Gs	FS, (%)	LS %	PFP	A	LI
UCS (kPa)	R	1	-0.9[B]	0.92[B]	-0.93[b]	0.46[b]	-0.91[b]	-0.56[b]	-0.35[a]	-0.39[a]	-0.66[b]	-0.83[b]	-0.9[b]
	Sig.		0.000	0.000	0.00	0.01	0.00	0.001	0.047	0.025	0.000	0.0	0.000
	N	32	32	32	32	32	32	32	32	32	32	32	32
W, %	R	-0.9[b]	1	-0.95[b]	0.85[b]	-0.4[a]	0.82[b]	0.58[b]	0.319	0.49[b]	0.68[b]	0.71[b]	0.92[b]
	Sig.	0.000		0.000	0.000	0.023	0.000	0.000	0.075	0.004	0.000	0.00	0.000
	N	32	32	32	32	32	32	32	32	32	32	32	32
ρd, (kN/m3)	R	0.92[b]	-0.95[b]	1	-0.86[b]	0.4[b]	-0.86[b]	-0.63[b]	-0.37[a]	-0.4[a]	-0.67[b]	-0.77[b]	-0.92[b]
	Sig.	0.000	0.000		0.000	0.010	0.000	0.000	0.038	0.024	0.000	0.000	0.000
	N	32	32	32	32	32	32	32	32	32	32	32	32
LL	R	-0.93[b]	0.85[b]	-0.88[b]	1	-0.33	0.89[b]	0.58[b]	0.37[a]	0.41[a]	0.67[b]	0.86[b]	0.78[b]
	Sig.	0.000	0.000	0.000		0.068	0.000	0.000	0.035	0.021	0.000	0.000	0.000
	N	32	32	32	32	32	32	32	32	32	32	32	32
PL	R	0.46[b]	-0.40[a]	0.45[b]	-0.33	1	-0.72[b]	-0.36[a]	-0.18	-0.04	-0.11	-0.52[b]	-0.67[b]
	Sig.	0.008	0.023	0.010	0.068		0.000	0.042	0.321	0.814	0.563	0.002	0.000
	N	32	32	32	32	32	32	32	32	32	32	32	32
PI	R	-0.90[b]	0.82[b]	-0.86[b]	0.89[b]	-0.72[b]	1	0.60[b]	0.36[a]	0.32	0.54[b]	0.88[b]	0.89[b]
	Sig.	0.000	0.000	0.000	0.000	0.000		0.000	0.042	0.077	0.001	0.000	0.000
	N	32	32	32	32	32	32	32	32	32	32	32	32
GS	R	-0.56[b]	0.58[b]	-0.63[b]	0.58[b]	-0.36[a]	0.60[b]	1	0.332	0.48[b]	0.48[b]	0.56[b]	0.58[b]
	Sig.	0.001	0.000	0.000	0.000	0.042	0.000		0.063	0.006	0.005	0.001	0.000
	N	32	32	32	32	32	32	32	32	32	32	32	32
FS, (%)	R	-0.35[a]	0.319	-0.37[a]	0.37[a]	-0.18	0.36[a]	0.332	1	0.163	0.44[a]	0.152	0.36[a]
	Sig.	0.047	0.075	0.038	0.035	0.321	0.042	0.063		0.372	0.011	0.407	0.042
	N	32	32	32	32	32	32	32	32	32	32	32	32

LS, %	R	-0.39[b]	0.49[b]	-0.39[a]	0.41[a]	-0.04	0.32	0.48[b]	0.163	1	0.49[b]	0.285	0.331
	Sig.	0.025	0.004	0.024	0.021	0.814	0.077	0.006	0.372		0.004	0.114	0.064
	N	32	32	32	32	32	32	32	32	32	32	32	32
PFP	R	-0.66[b]	0.68[b]	-0.67[b]	0.67[b]	-0.11	0.54[b]	0.48[b]	0.44[a]	0.49[b]	1	0.46[b]	0.56[b]
	Sig.	0.000	0.000	0.000	0.000	0.563	0.001	0.005	0.011	0.004		0.008	0.001
	N	32	32	32	32	32	32	32	32	32	32	32	32
A	R	-0.83[b]	0.71[b]	-0.77[b]	0.86[b]	-0.52[b]	0.88[b]	0.56[b]	0.152	0.285	0.46[b]	1	0.72[b]
	Sig.	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.407	0.114	0.008		0.000
	N	32	32	32	32	32	32	32	32	32	32	32	32
LI	R	-0.90[b]	0.92[b]	-0.92[b]	0.78[b]	-0.67[b]	0.90[b]	0.58[b]	0.36[a]	0.33	0.57[b]	0.72[b]	1
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.064	0.001	0.000	
	N	32	32	32	32	32	32	32	32	32	32	32	32

b. Correlation is significant at the 0.01 level (2-tailed).
a. Correlation is significant at the 0.05 level (2-tailed).

There are two ways to interpret the degree of relationship:

- # If the Sig., or probability (p), associated with the R value 0.05 or less, then we reject Ho, and conclude that there is a statistically significant relationship between pair of variables.
- # If $p > 0.05$, then we retain Ho, and conclude that the variables are unrelated. Thus, from the table correlation matrix the p-value or Sig. (2-tailed) value is less 0.05, we can say that the correlation is not the result of chance or random sampling error. That is why we would reject Ho and conclude that the correlation is a real one, and thus, one that can be generalized from the sample to the overall population in which we are interested.

4.3. Regression Analysis and modeling between the response variable and Predictors

4.3.1. Single Linear Regression (SLRA) 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 unconfined compressive strength (UCS) was considered as the dependent variable whereas Natural moisture content (ω), Dry unit weight (γ_d), liquid limit (LL), plastic limit (PL), plasticity index (PI), specific gravity (Gs), free swell (FS), Linear shrinkage limit (LS), percentage of fine particles passing by 0.075μm (PFP), Activity of Clay (Ac), and liquidity index (LI) are the independent (Predictor) variables.

1. Model-1: Unconfined Compressive Strength (UCS) and Natural Moisture Content (ω): The resulting regression analysis after correlating UCS with ω is obtained from SPSS outputs. For instance, from coefficients table outputs of SPSS, model equation coefficients, constants and significance level of each variable was obtained as indicated on Table 4.8.

Table 4-12 Model Summary of UCS and Natural Moisture Content (ω)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.903	.816	.810	13.60536

Table 4-13 Coefficients from SPSS output for Model 1

Model		Unstandardized Coefficients		Standardized Coefficients (Beta)	t	Sig.
		B	Std. Error			
1	Constant	363.560	23.295		15.606	.000
	Moisture content, %	-6.013	.521	-.903	-11.534	.000

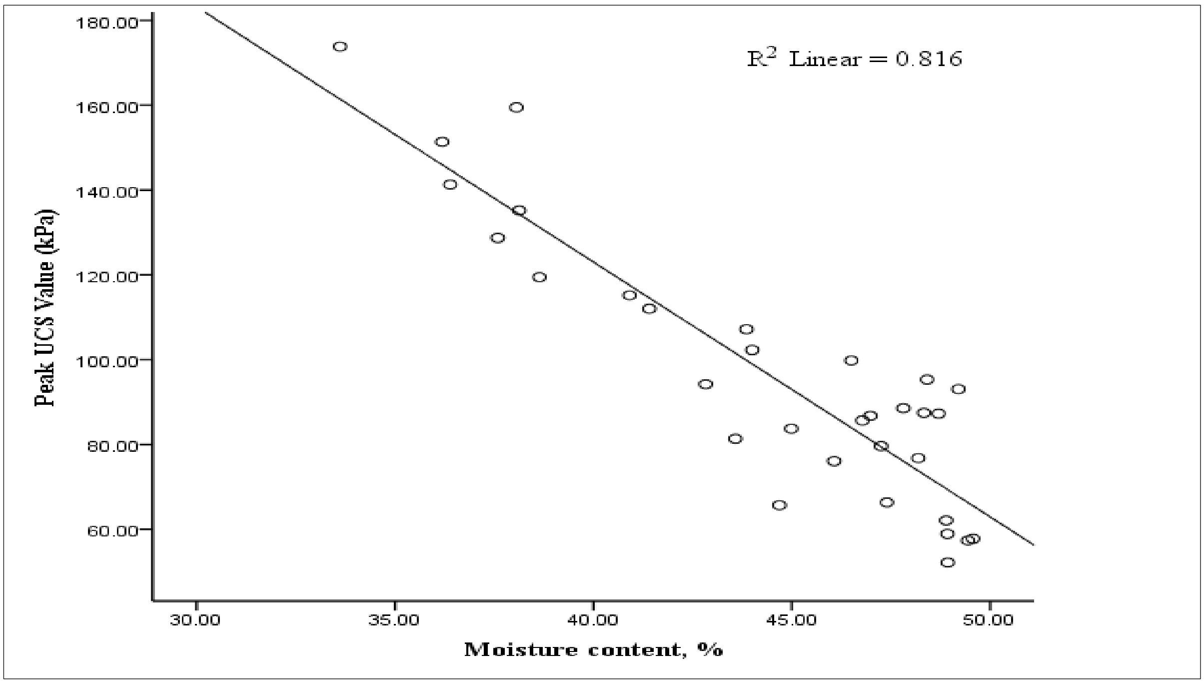

Figure 4-6 Scatter plot for model 1

From Table 4-12 and Table 4-13 as shown in Figure 4-6,

$$UCS = 363.560 - 6.013 * \omega \quad (4.1)$$

with R^2= -0. 816, p-value (α) = 0. 000 < 0.05, N = 32. The details of the statistical output showed that the relationship developed between unconfined compressive strength (UCS) and natural moisture content (ω) is significant (i.e., α < 0.05). Furthermore, the relationship between correlation variables is strong (R^2 <0.8).

2. Model-2: Unconfined Compressive Strength (UCS) and Dry unit weight (γ_d):

The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Dry unit weight (γ_d) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

$$UCS = 52.760 * \gamma_d) - 510.478 \quad (4.2)$$

with R^2=0.843 (strong correlations), p-value (α) = 0.00 < 0.05, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Dry unit weight (γ_d) is significant (α <0.05) and good correlation happened concerning the correlating variables as shown in Model-2 of Appendix-B.

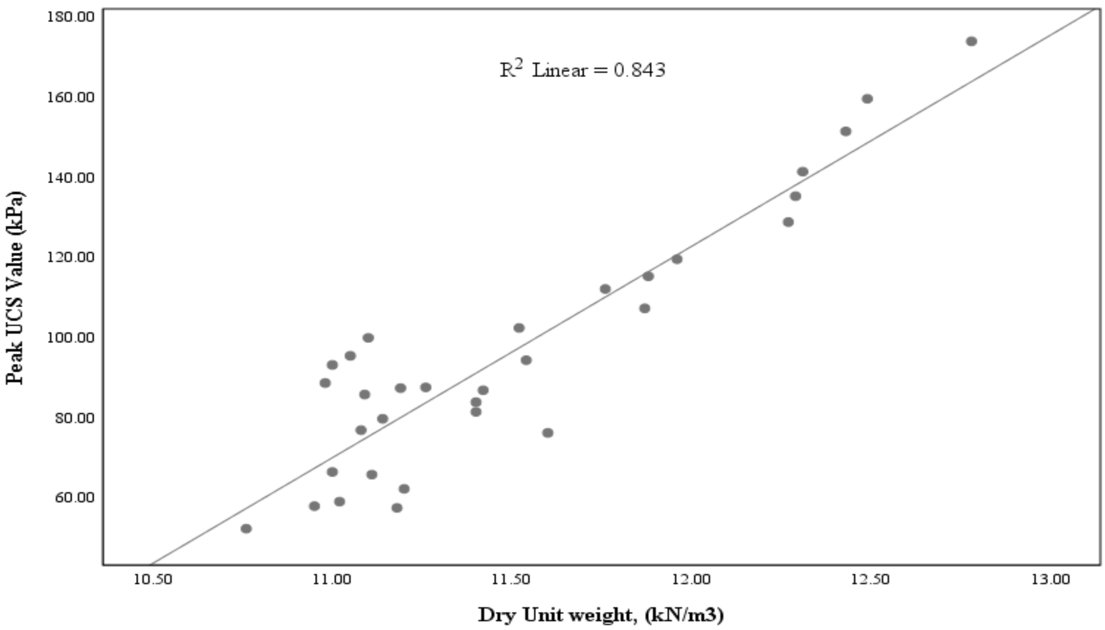

Figure 4-7 Scatter plot for model 2

3. Model-3: Unconfined Compressive Strength (UCS) and Liquid Limit (LL): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Liquid Limit (LL) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

$$UCS = 385.334 - 3.697 * LL \quad (4.3)$$

with R^2=0.871 (strong correlation), p-value (α) = 0.00 < 0.05, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Liquid Limit (LL) is significant (α <0.05) and good correlation happened concerning the correlating variables as shown in Model-3 of Appendix-B.

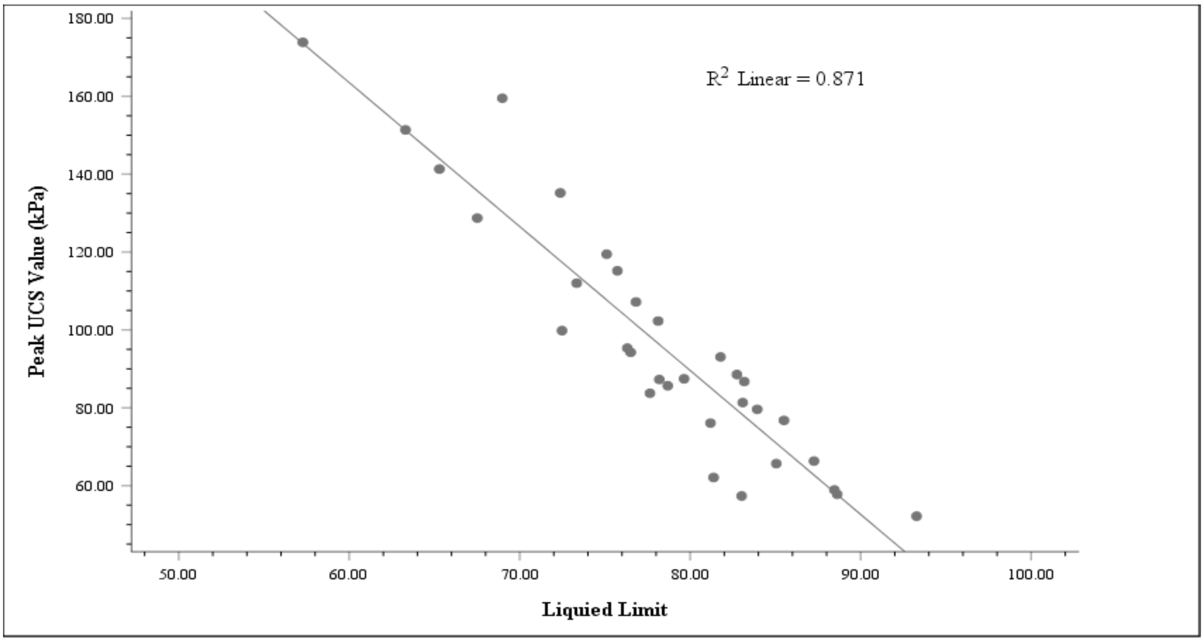

Figure 4-8 Scatter plot for Model 3

4. Model-4: Unconfined Compressive Strength (UCS) and Plastic Limit (PL): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Plastic Limit (PL) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

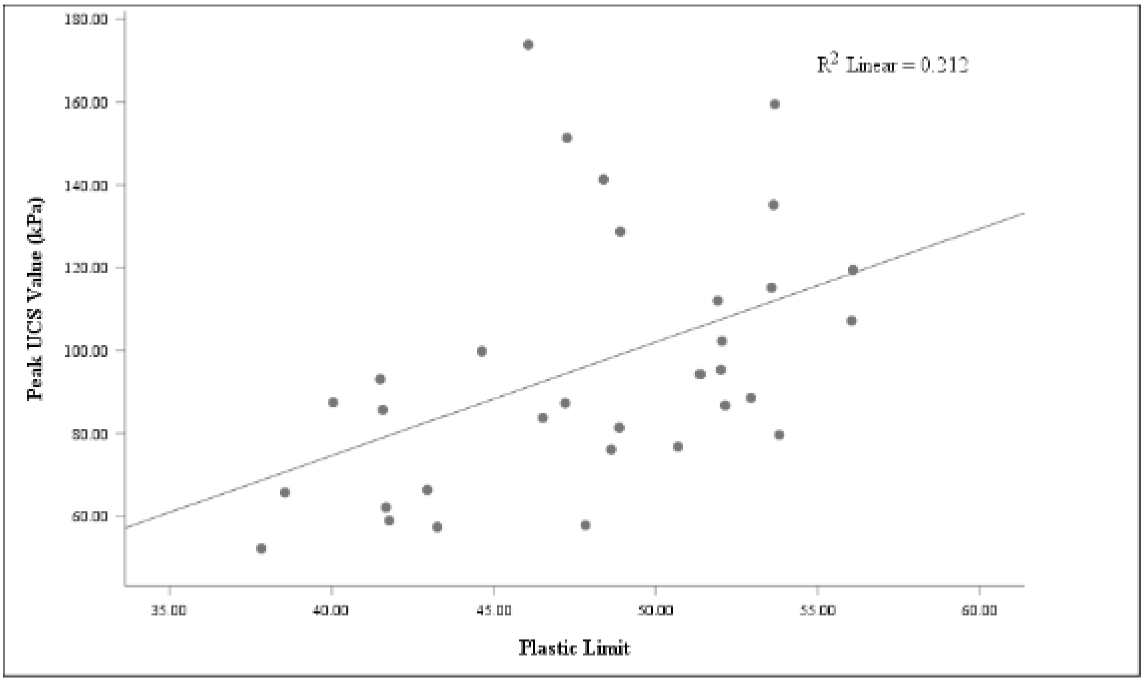

Figure 4-9 Scatter plot for Model-4

$$UCS = 2.740 * PL - 34.99 \quad (4.4)$$

with R^2=0.212 (weak correlation), p-value (α) = 0.008, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Plastic Limit (PL) is significant (α < 0.05) and weak correlation happened concerning the correlating variables as shown in Model-4 of Appendix-B.

5. Model-5: Unconfined Compressive Strength (UCS) and Plastic Index (PI): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Plastic Index (PI) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

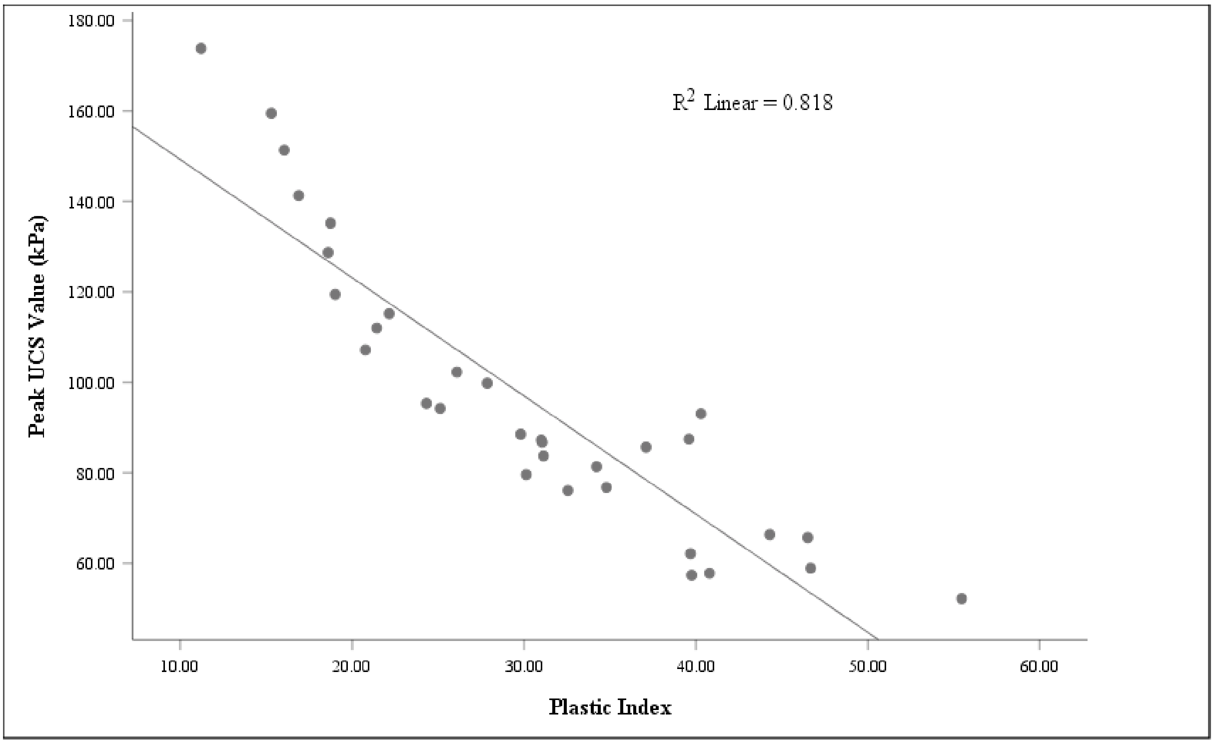

Figure 4-10 Scatter plot for Model-5

$$UCS = 175.433 - 2.615 * PI \quad (4.5)$$

with R^2=0.818 (strong correlation), p-value (α) = 0.000, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Plasticity Index (PI) is significant (α < 0.05) and strong correlation happened concerning the correlating variables as shown in Model-5 of Appendix-B.

6. Model-6: Unconfined Compressive Strength (UCS) and Specific Gravity (Gs): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and specific gravity (Gs) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

$$UCS = 1518.188 - 529.565 * G_s \quad (4.6)$$

with R2=0.316 (weak correlation), p-value (α) = 0.001, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Specific Gravity (Gs) is significant ($\alpha < 0.05$) and weak correlation happened concerning the correlating variables as shown in Model-6 of Appendix-B.

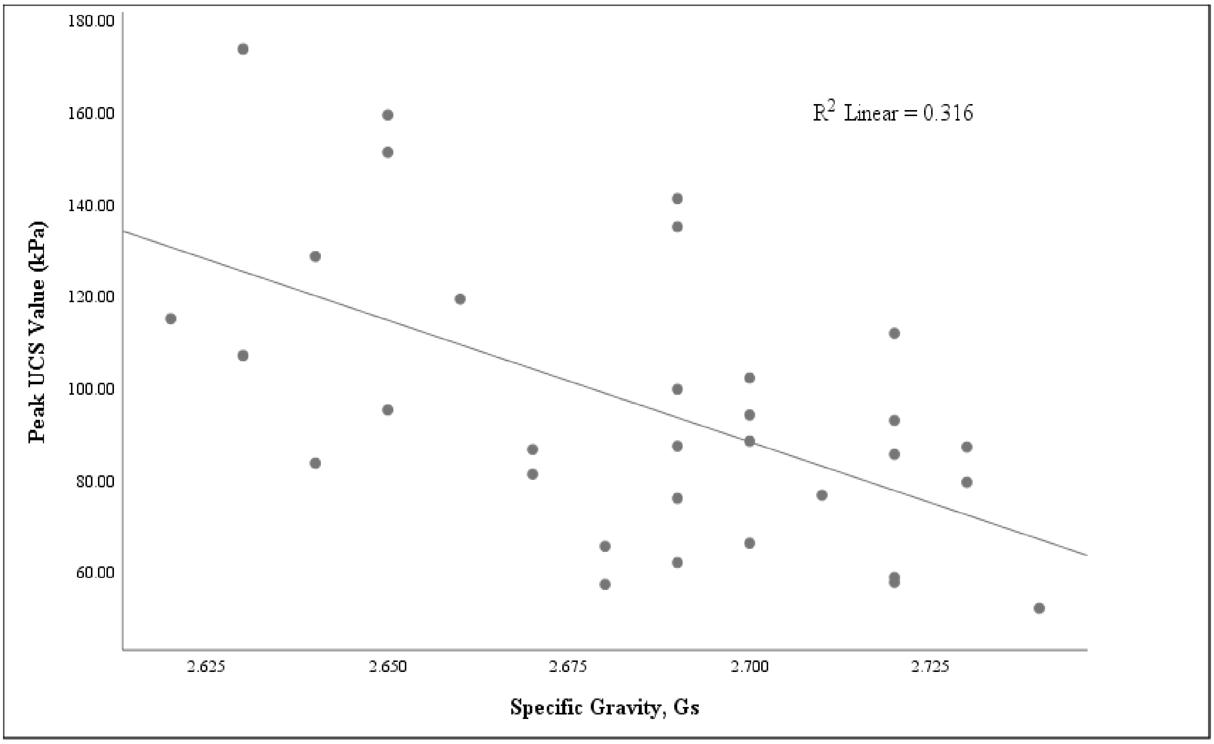

Figure 4-11 Scatter plot for Model-6

7. Model-7: Unconfined Compressive Strength (UCS) and Free Swell (FS): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Free Swell (FS) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

$$UCS = 128.420 - 2.114 * FS \quad (4.7)$$

with R2=0.126 (weak correlation), p-value (α) = 0. 0.05, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Free Swell (FS) is insignificant (α = 0.05) and weak correlation happened concerning the correlating variables as shown in Model-7 of Appendix-B.

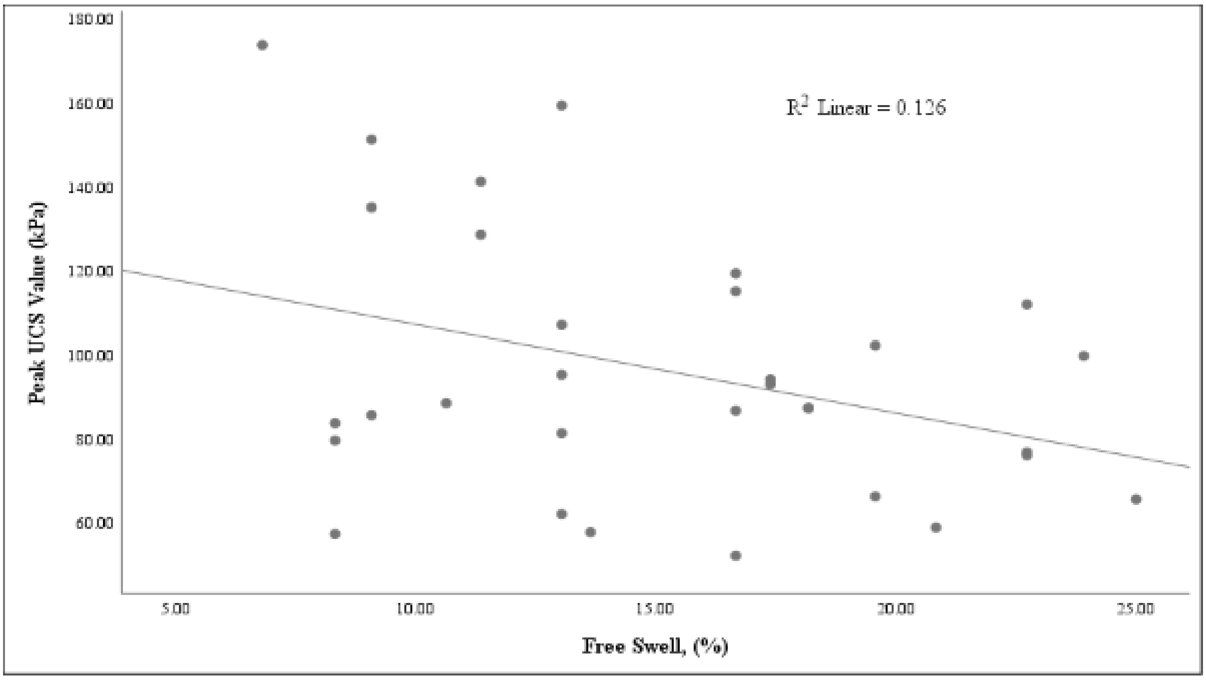

Figure 4-12 Scatter plot for Model-7

8. Model-8: Unconfined Compressive Strength (UCS) and Free Swell (FS): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Linear Shrinkage Index (LS) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

$$UCS = 282.50 - 12.428 * LS \quad (4.8)$$

with R^2=0.156 (weak correlation), p-value (α) = 0.025, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Linear Shrinkage Index (LS) is significant (α < 0.05) and weak correlation happened concerning the correlating variables as shown in Model-8 of Appendix-B.

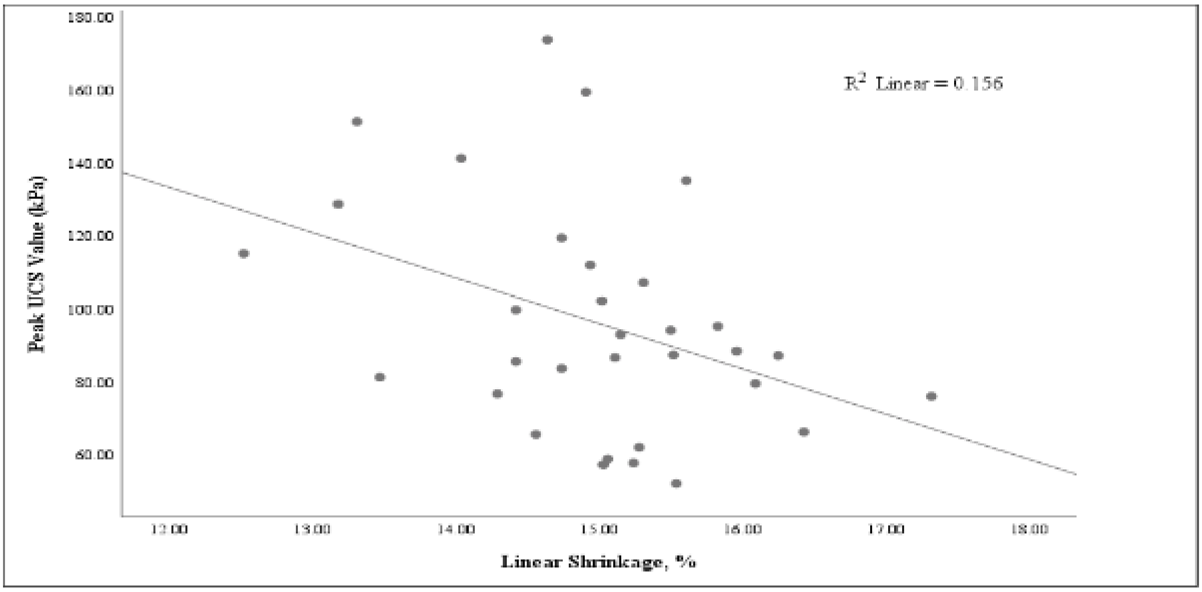

Figure 4-13 Scatter plot for Model-8

9. Model-9: Unconfined Compressive Strength (UCS) and Fine Particles Passing by 0.075µm (PFP): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Percentage of Fine Particles Passing by 0.075µm (PFP) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

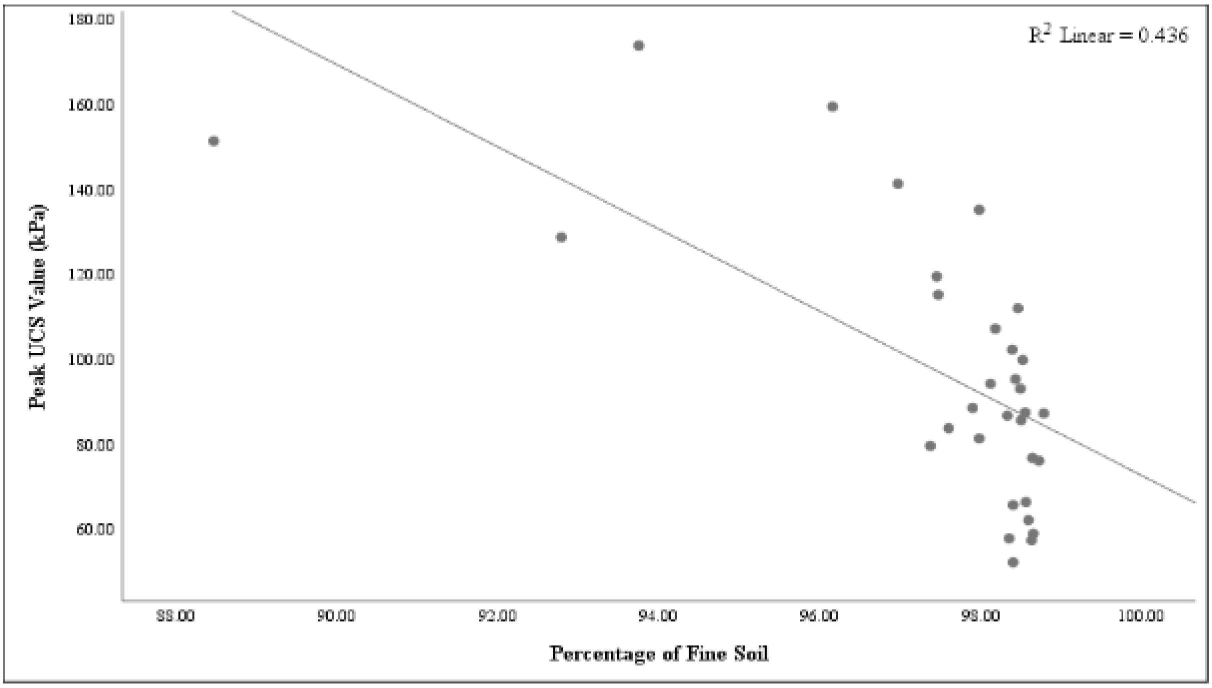

Figure 4-14 Scatter plot for Model-9

$$UCS = 1040.295 - 9.677 * PFP \quad (4.9)$$

with R^2=0.436 (Moderate correlation), p-value (α) = 0.000, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Percentage of Fine Particles Passing by 0.075µm (PFP) is significant (α < 0.05) and Moderate correlation happened concerning the correlating variables as shown in Model-9 of Appendix-B.

10. Model-10: Unconfined Compressive Strength (UCS) and Activity of Clay (Ac): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Activity of Clay (Ac) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

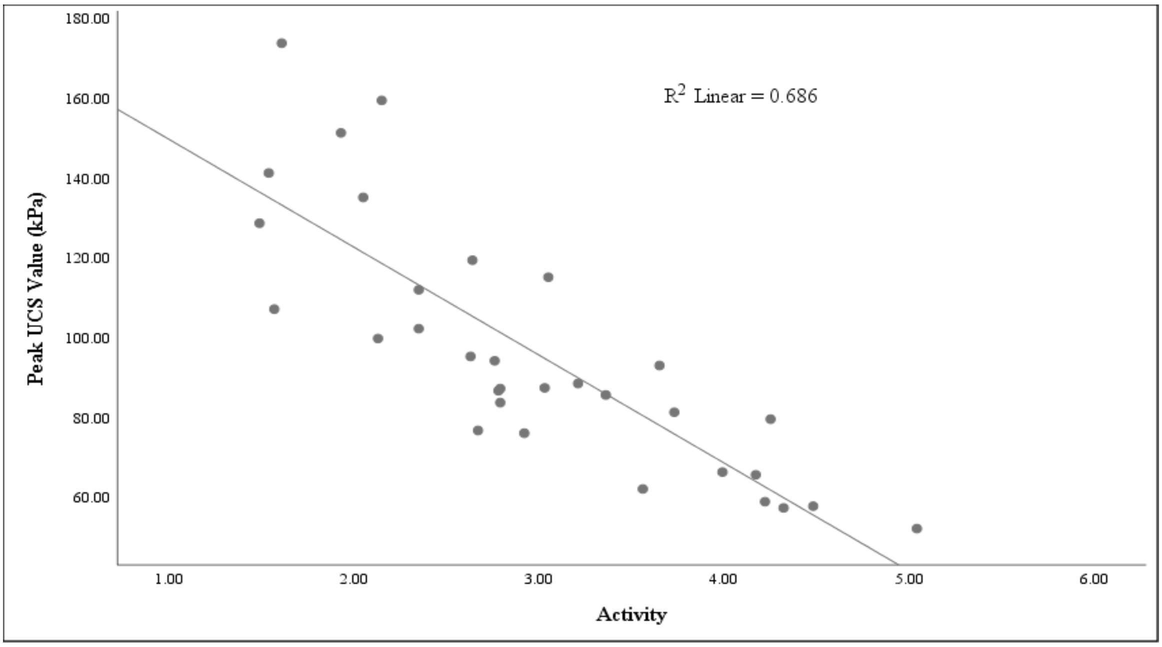

Figure 4-15 Scatter plot for Model-10

$$UCS = 176.85 - 27.07 * Ac \quad (4.10)$$

with R^2=0.686 (Moderate correlation), p-value (α) = 0.000, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Activity of Clay (Ac) is significant (α < 0.05) and Moderate correlation happened concerning the correlating variables as shown in Model-10 of Appendix-B.

11. Model-11: Unconfined Compressive Strength (UCS) and Liquidity Index (LI): The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) and Liquidity Index (LI) is expressed by the following single linear equation with its corresponding determination coefficient (R^2):

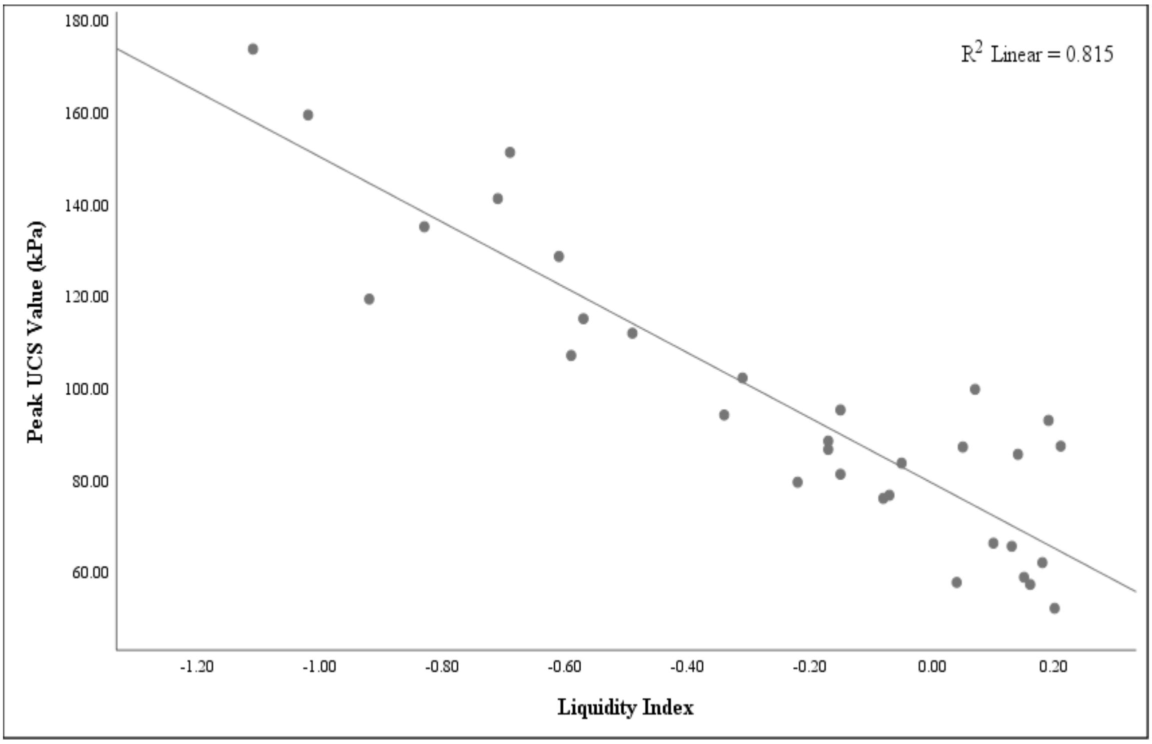

Figure 4-16 Scatter plot for Model-11

$$UCS = 79.392 - 70.941 * LI \qquad (4.11)$$

with R^2=0.815 (Strong correlation), p-value (α) = 0.000, N = 32. The details of the statistical output indicated that the relationship developed between Unconfined Compressive Strength (UCS) and Liquidity Index (LI) is significant ($\alpha < 0.05$) and strong correlation happened concerning the correlating variables as shown in Model-11 of Appendix-B.

Table 4-14 Summary of Single Linear Regression (SLR) Models

No.	Model Name	Models from Different variables	R^2	Significance level, (α)	Rank based on α and R^2
1	Model-1	$UCS = 363.560 - 6.013 * \omega$	0.816	0.000	4
2	Model-2	$UCS = 52.76 - 510.478 * \gamma_d$	0.843	0.000	2
3	Model-3	$UCS = 385.334 - 3.697 * LL$	0.871	0.000	1
4	Model-4	$UCS = 2.74 * PL - 34.99$	0.212	0.008	9
5	Model-5	$UCS = 175.433 - 2.615 * PI$	0.818	0.000	3
6	Model-6	$UCS = 1518.188 - 529.565 * Gs$	0.316	0.001	8
7	Model-7	$UCS = 128.42 - 2.144 * FS$	0.126	0.05	11
8	Model-8	$UCS = 282.5 - 12.428 * LS$	0.156	0.025	10
9	Model-9	$UCS = 1040.295 - 9.677 * PFP$	0.436	0.000	7
10	Model-10	$UCS = 176.85 - 27.07 * Ac$	0.686	0.000	6
11	Model-11	$UCS = 79.392 - 70.941LI$	0.815	0.000	5

Table 4-14 is illustrated that the developed single linear regression models based on level of the significance (α) and coefficient of determination (R^2). UCS value has strong relationship with LL, γ_d, PI, ω, & LI (i.e., from order 1 to 5). On the other hand; Ac, PFP, and Gs (i.e., orders from 6 to 8) indicated moderate relationship ($0.3 < R^2 < 0.7$). But PL, LS, and FS had weak relationship and insignificant level for FS (i.e., α>0.05) with UCS. Those predictors were also good indicators to form better multiple linear regression analysis that could provide better models for prediction of dependent variables of intensive area.

4.3.2. Multiple Linear Regression Analysis

Multiple Linear Regression analysis is tried to model the relationship between two or more illustrative variables and a predicted variable by fitting an equation to experimental data. A single index property is not a reliable means of predicting the undrained shear strength of the soil since a significant level is decrease as well as coefficient of determinant increase as various index properties are involved (varied) in the prediction of this reliant variable.

For this study, the stepwise regression analysis method of variable selection was applied. For this section, significance level and correlation coefficient of predictors on each other that was obtained from the single linear regression analysis and the scatter plot was used. For independent variables highly correlated (interdependent) to each other (i.e., correlated at .50 or .60 and above), then one might decide to combine (aggregate) them into a composite variable or eliminate one or more of the highly correlated variables (Tafari Bakala et al., 2021). Spotting multi collinearity among a set of explanatory variables might not be easy. A useful approach is the examination of the variance inflation factors (VIFs) or the tolerances of the explanatory variables. Accordingly, VIFs above 10 or tolerances below 0.1 are seen as a cause of concern (Tafari Bakala et al., 2021). Moreover, Durbin-Watson used to examine multi collinearity of predictors with no concern for the value of 1 to 3.

1. Model-1: Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Dry Unit Weight (γ_d):

   The resulting regression analysis after correlating Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Dry Unit Weight (γ_d) is expressed by the following multiple linear equations with its corresponding parameters: From Table 4-15 and Table 4-16 below, the formation equation for the above model-1 could be:

   $$UCS = 35.648 * \gamma_d - 2.083 * \omega - 221.081 \quad (4.12)$$

   R^2 =0.852, p-value = 0.000 < 0.05, Tolerance= 0.095 < 0.2 & VIF =10.565>10, Durbin-Watson= 2.969

   The details of the statistical output of Model-1 indicated that the relationship developed between Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Dry Unit Weight (γ_d) is significant (α<0.05). But the tolerance is less than 0.1 which indicates a serious problem, VIF greater than 10 and Durbin-Watson is 2.969 which is far from 2 indicates that it could be a cause for concern. Thus, there is collinearity and autocorrelation within this model.

Table 4-15 Summery model for UCS with ω and Dry Unit Weight (γ_d)

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R^2 Change	F Change	df1	df2	Sig. F Change	
1	0.923[a]	0.852	0.842	12.3925	0.852	83.753	2	29	0.000	2.969

Table 4-16 Coefficients of UCS with ω and Dry Unit Weight (γ_d) model

Model-1	Unstandardized Coefficients		Standardized Coefficients (Beta)	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error				Lower Bound	Upper Bound	Tolerance	VIF
UCS	-221.081	219.525		-1.01	0.32	-670.06	227.9		
ω, %	-2.083	1.543	-0.313	-1.35	0.19	-5.240	1.073	0.095	10.56
γ_d, (kN/m^3)	35.648	13.323	0.620	2.68	0.01	8.400	62.896	0.095	10.56

2. Model-2: Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Liquid Limit (LL):

$$UCS = 397.669 - 2.616 * \omega - 2.368 * LL \quad (4.13)$$

R^2 =0.913, p-value = 0.000 < 0.05, Tolerance= 0.271 > 0.2 & VIF = 3.693 > 10, and Durbin-Watson= 2.685 ~ 2

The details of the statistical output of Model-2 indicated that the relationship developed between Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Liquid Limit (LL) is significant (α<0.05). The tolerance is greater than 0.2 and VIF is less than the model is no collinearity within a data. The Durbin-Watson is 2.685 ~ 2 which is close to 2 indicates there is no autocorrelation detected in the sample.

Table 4-17 Summary of Multiple Linear Regression Analysis Models

Model	Models from Different variables	R^2	DW	Tolerance	VIF	Rank [a]
1	$UCS = 35.648 * \gamma_d - 2.083 * \omega - 221.081$	0.852	2.969	0.096	10.57	10
2	$UCS = 397.669 - 2.616 * \omega - 2.368 * LL$	0.913	2.685	0.271	3.693	3
3	$UCS = 286.138 - 3.285 * \omega - 1.448 * PI$	0.899	2.977	0.331	3.025	6
4	$UCS = 24.932 * \gamma_d - 2.193 * LL - 18.962$	0.915	2.795	0.235	4.259	2
5	$UCS = 33.04 * \gamma_d - 29.191 * LI - 290.646$	0.863	2.51	0.146	6.831	8
6	$UCS = 30.932 * \gamma_d - 1.281 * PI - 220.66$	0.895	2.565	0.265	3.768	5
7	$UCS = 269.218 - 2.318 * LL - 34.874 * LI$	0.947	2.763	0.385	2.599	1
8	$UCS = 318.033 - 2.435 * LL - 1.037PI$	0.898	2.052	0.221	4.742	4
9	$UCS = 130.018 - 1.408 * PI - 36.675 * LI$	0.86	2.187	0.193	5.181	7
10	$UCS = 227.992 - 3.16 * \omega - 36.763 * LI$	0.851	2.516	0.161	6.224	9
a-The rank is based on R^2, Significance (α), Durbin-Watson (DW), and Collinearity Statistics (Tolerance & VIF)						

From Table 4-17, all models are good since all models are both significant and the coefficient of determinations are strong but model 1 & 3 are negative autocorrelation and model 1, 5, 9 and 10 are have less than 0.2 tolerance which indicated that they have a potential problem based on the Collinearity Statistics.

Therefore, Model-7 (i.e., $UCS = 269.218 - 2.318 * LL - 34.874 * LI$) is the "best model" for the prediction of Unconfined Compressive Strength (UCS) of the study area based on the relative correlation coefficient (R), determinant factor (R^2) & significance level (α) of all developed models. For further information, a detail software output of each model is provided under Appendix-C of this study.

4.3.3. Discussion on Results of the Correlation

4.3.3.1. Validation of Predicted Value with actual (Measured) value of Unconfined Compressive Strength (UCS)

Considering the acceptability of the Model-7 as the best model, it can be used to approximate the Unconfined Compressive Strength of the study area.

Figure 4-17 shows the relationship between predicted and the measured value was strong based on the level of significance, Pearson correlation, and coefficient of determination.

Using Model-7 the predicted UCS value was compared with measured (i.e., tested in the laboratory from undisturbed sample) UCS value. For example, TP-5 @2m, LL= 88.46% and LI= 0.15. Then The predicted UCS value would be:

$$UCS = 269.218 - 2.318 * LL - 34.874 * LI$$

$$UCS = 269.218 - 2.318 * 88.46 - 34.874 * 0.15$$
$$= 58.84kPa$$

And the measured UCS was 58.91 kPa with variation of 0.12 %.

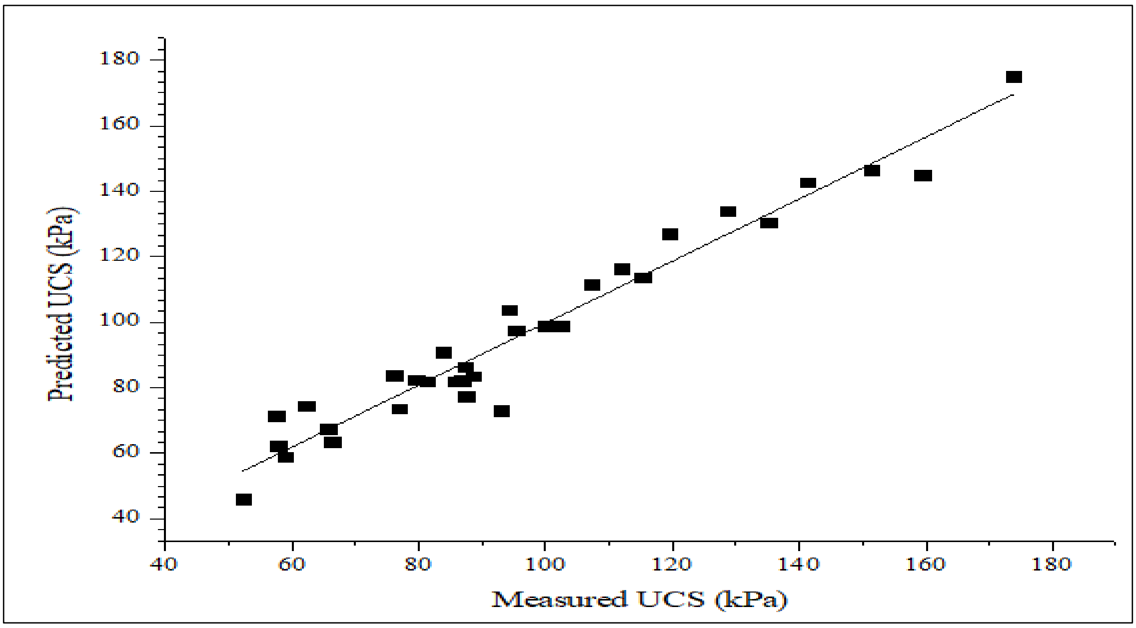

Figure 4-17 Plots of predicted and actual values of UCS for Model -7

Figure 4-17 illustrated that the predicted UCS value scatters near the straight line, through which the actual and predicted UCS value is equal, although there is little bit variation between the actual and the measured UCS.

4.3.3.2. Validation of Predicted Value with additional test results

The predicted UCS from the developed model is determined and compared to the actual UCS value from this additional test results. The validation of the developed model is led by using these test results of the study area.

Subject to the relative correlation coefficient (R), determinant factor (R^2) & significance level(α), Model-7 is chosen among the different alternative models discussed & developed above. Consequently, from Table 4-18 the relation of measured (actual) and predicted value of UCS is exhibited a little variation.

Table 4-18 Relation of the measured and predicted value of UCS

Test Pit No Depth	Test Pit Location	Liquid Limit, LL (%)	Liquidity Index (LI)	Measured Undisturbed UCS, kPa	Predicted UCS, kPa	Variation, (%)
TP 4 @1.5m	Mosque	85.50	-0.07	76.77	73.55	4.20
TP-6 @2m	Municipality	85.05	0.13	65.66	67.47	2.74
TP-7 @2m	City Hall	73.34	-0.49	112.01	116.28	3.81
TP-9 @2m	Management Building	83.17	-0.17	86.73	82.20	5.23
TP-11 @ 2m	KG	68.98	-1.02	159.49	144.88	9.16
TP-13 @ 2m	Serbo Market	81.78	0.19	93.05	72.98	21.57
TP-15 @ 2m	High School	78.12	-0.31	102.28	98.86	3.35
TP-18 @ 2m	Serbo Clinic	65.29	-0.71	141.30	142.62	0.94

4.3.3.3. Comparison of the Developed Model with Existing Models

The appropriateness of existing models mostly the (HADDIS, 2020) and (Tafari Bakala et al., 2021) along with the developed model was examined using additional test results stated above from the focused study area.

$Cu = 224.032 - 2.272 * PL - 2.485 * PI$ (Tafari Bakala et al., 2021)

$UCS = -3.83 * LL - 136LI + 410.19$ (HADDIS, 2020)

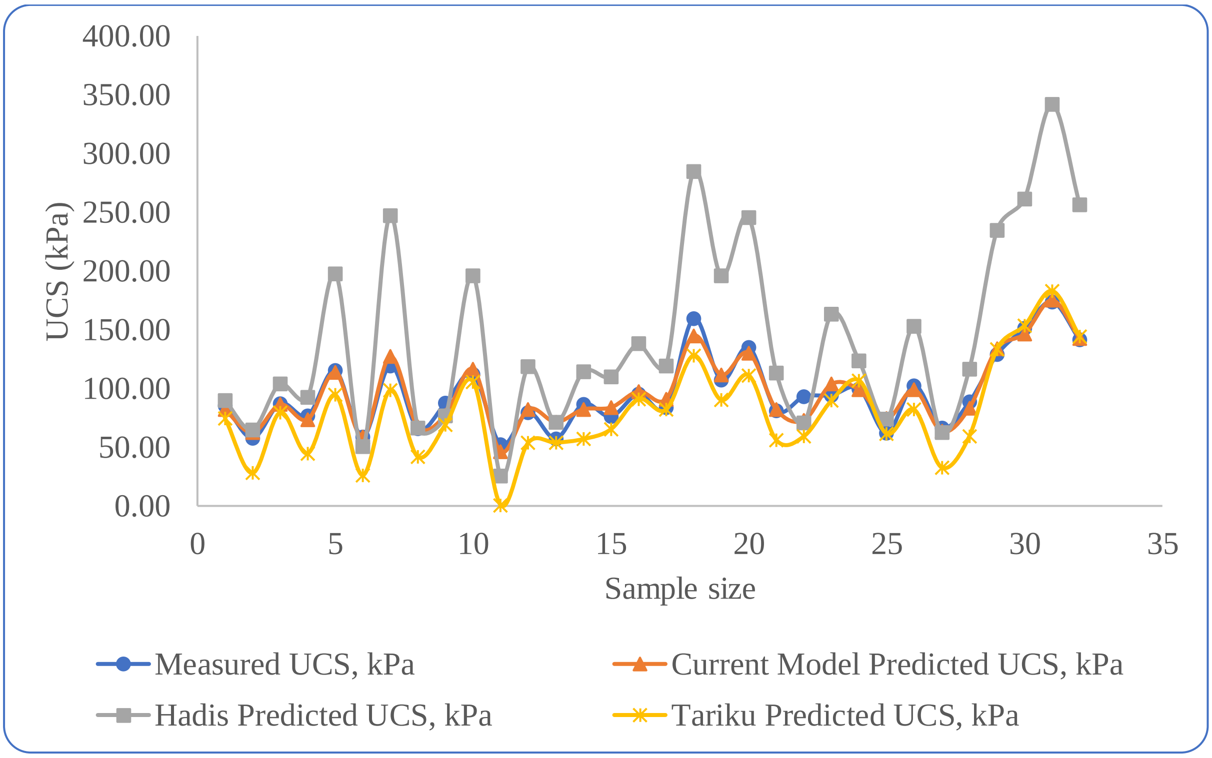

Figure 4-18 Comparison of the developed Model with Existing Model

Figure 4-18 shows, the current Model (i.e., Model-7) predicted UCS values are a little bit varied from the measured (actual) UCS value. Similarly, on a Figure 4-18 above, the value which was predicted by existing models were varied from measured value. From that figure, it is possible to see that the predicted value by the current model is found between the predicted value by the two existing models. This is 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.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusions

The research was directed to find limited statistical modeling of unconfined compressive strength from index properties of soil within the scope of the study area. The necessary laboratory tests were done on samples collected from different places of Serbo town. Using the obtained test results, a single and multiple linear regressions were analyzed.

Different models were developed for the prediction of UCS value from Bulk Unit Weight, Natural Moisture Content, Dry Unit Weight, Liquid Limit, Plastic Limit, Plasticity Index, Specific Gravity, Linear Shrinkage, Free Swell, Percentage of Passing Fine Particle, Liquidity Index, And Activity. The following conclusions may be drawn from this study.

1. From the laboratory test result, the soil type of study area was fine grained with high plasticity silty soil (MH) and clayey soil (A-7-5) according to the soil classification system of USCS and AASHTO respectively with medium-stiff to stiff unconfined compressive strength consistency.
2. The Unconfined compressive strength was significantly correlated with liquid limit, plastic limit, dry unit weight, natural moisture content, plasticity index, and liquidity index of the study area.
3. As a general, a best Model from all with better coefficient of determination ($R^2 = 0.947$), good significance level and less Std. error was obtained from multiple linear regression analysis as given below:

   $UCS = 269.218 - 2.318 * LL - 34.874 * LI$, R^2=0.947, p-value =0.000 < 0.05,
   Tolerance=0.385> 0.2 & VIF=2.599< 10, Durbin-Watson=2.763~ 2
4. The validation of the predicted statistical model was confirmed using tested results & additional test results of study area.

5.2. Recommendations

Based on studied result achieved, the following recommendations are put forward:

1. 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.
2. The developed model recommended to check its validity using other statistical software for the study area.
3. The sample specimens taken for this study was up a depth of 2m. Hence for the next study, it is recommended to take greater than this depth.

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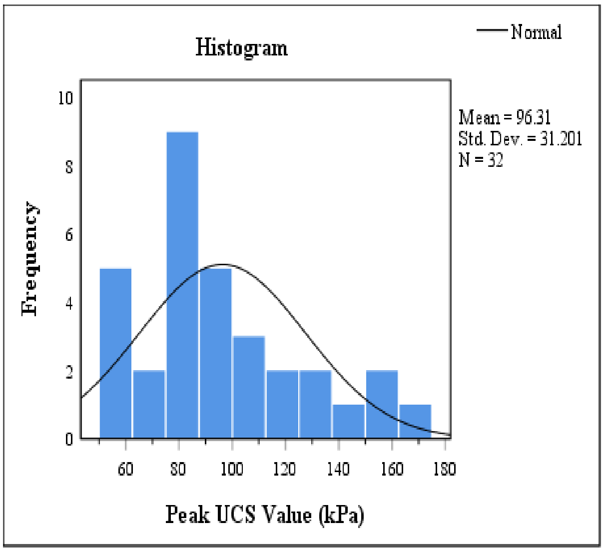
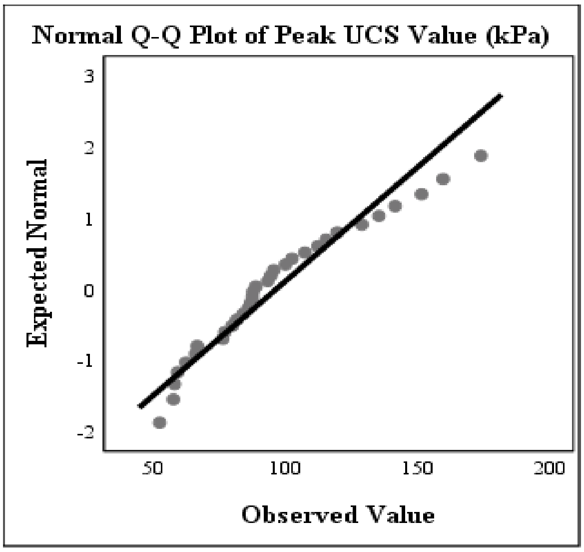
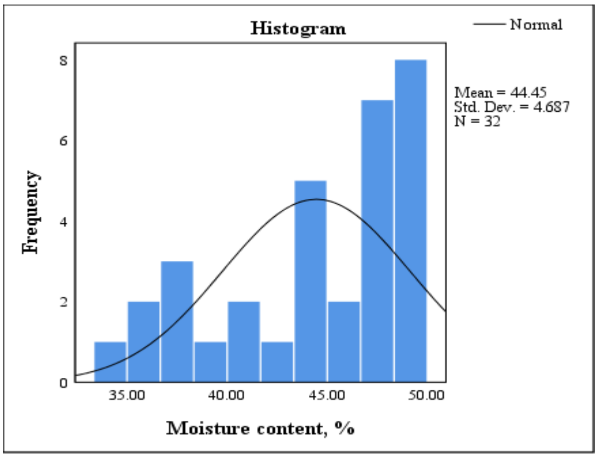
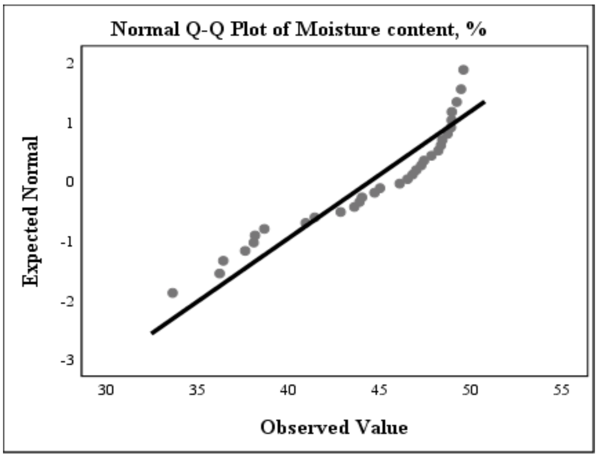
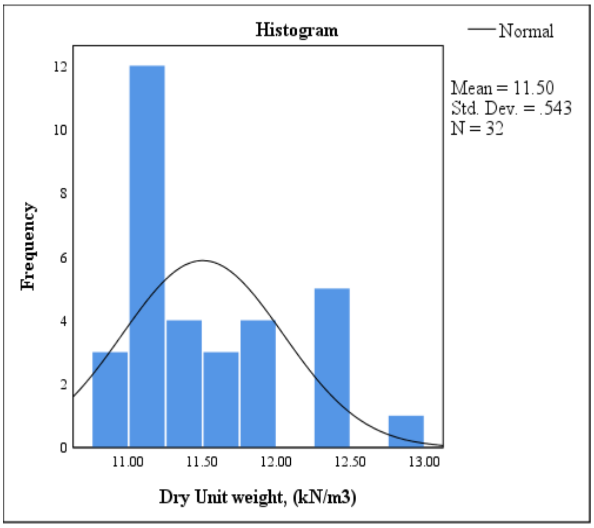
APPENDIX-A SPSS Graph of Normality Test for Each Variables

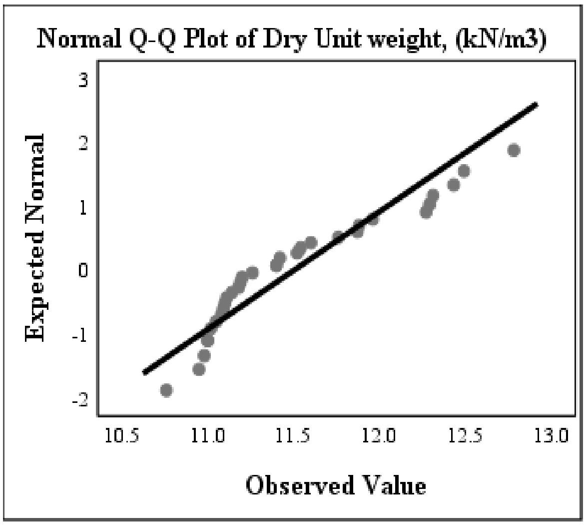


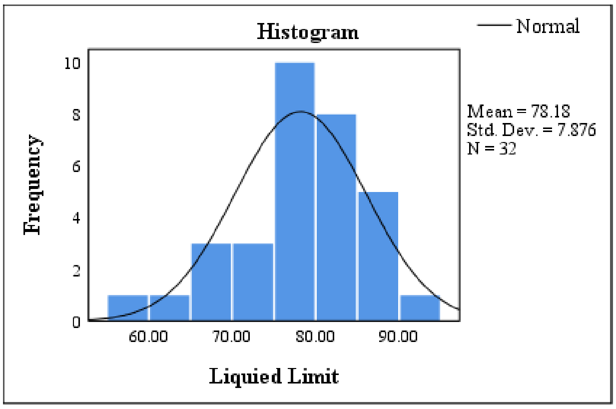


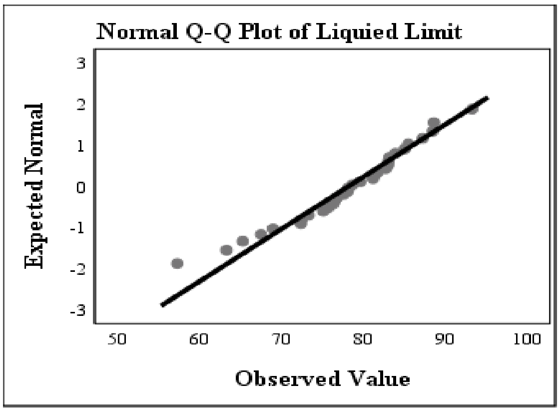


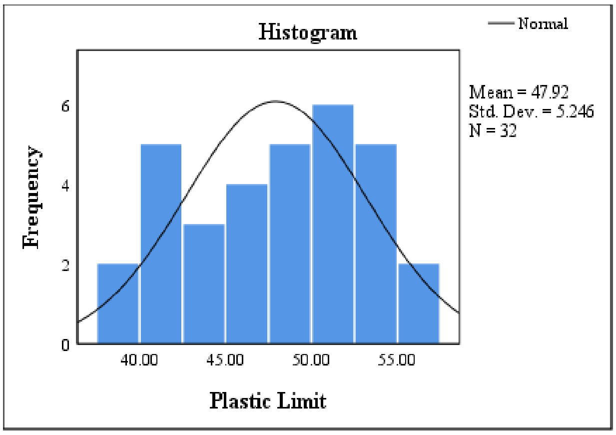


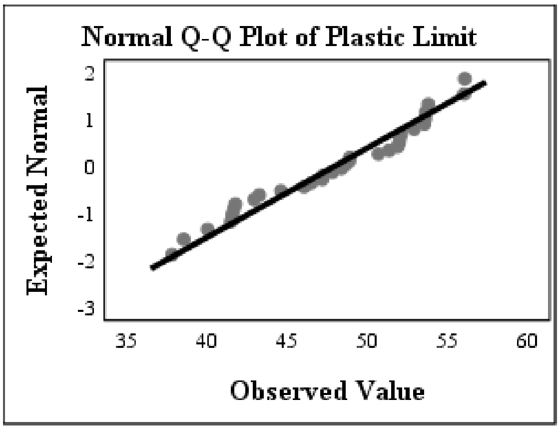


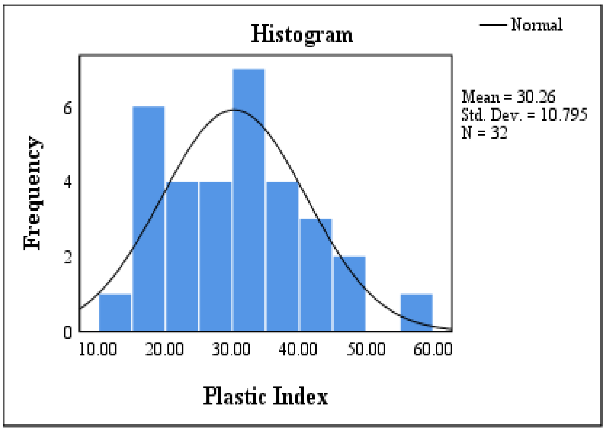


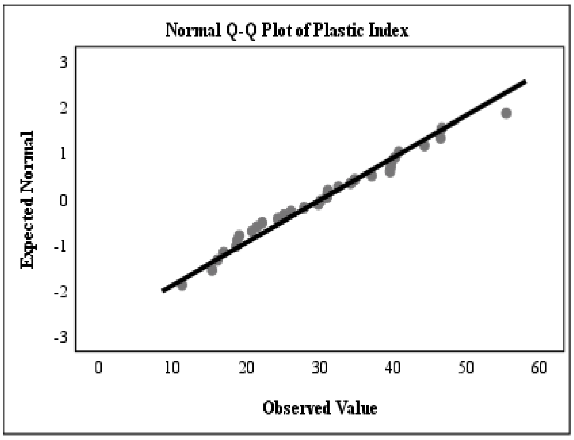

Histogram
Normal
Mean = 78.18
Std. Dev. = 7.876
N = 32
Frequency
Liquied Limit

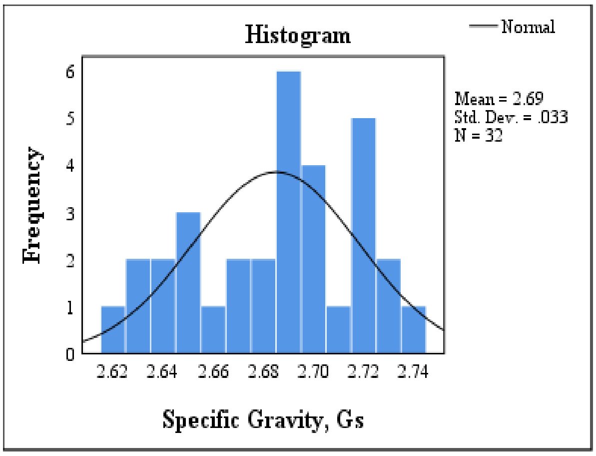

Normal Q-Q Plot of Liquied Limit
Expected Normal
Observed Value

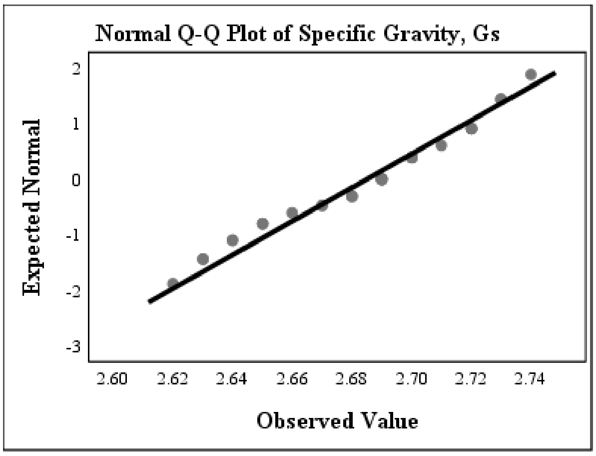

Histogram
Normal
Mean = 47.92
Std. Dev. = 5.246
N = 32
Frequency
Plastic Limit

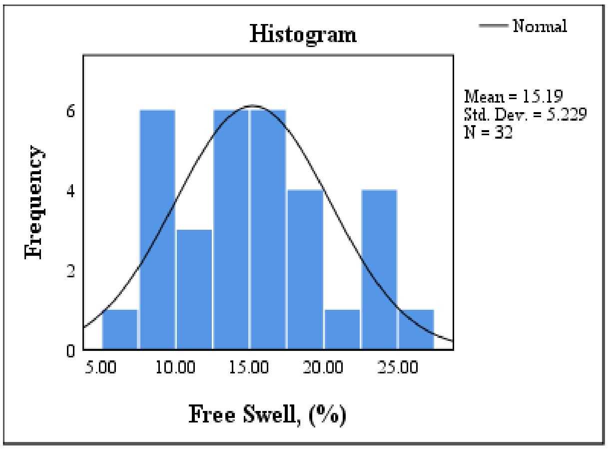

Normal Q-Q Plot of Plastic Limit
Expected Normal
Observed Value

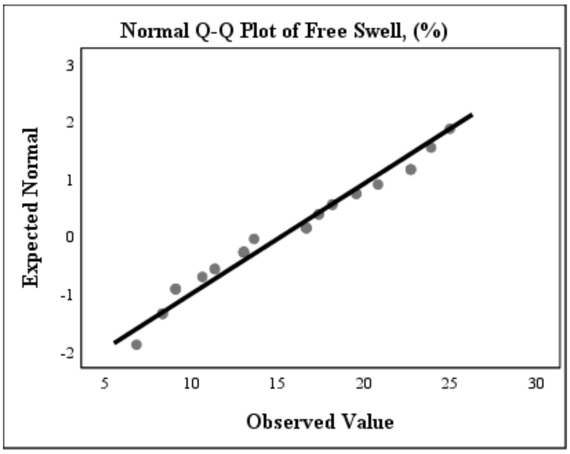

Histogram
Normal
Mean = 30.26
Std. Dev. = 10.795
N = 32
Frequency
Plastic Index

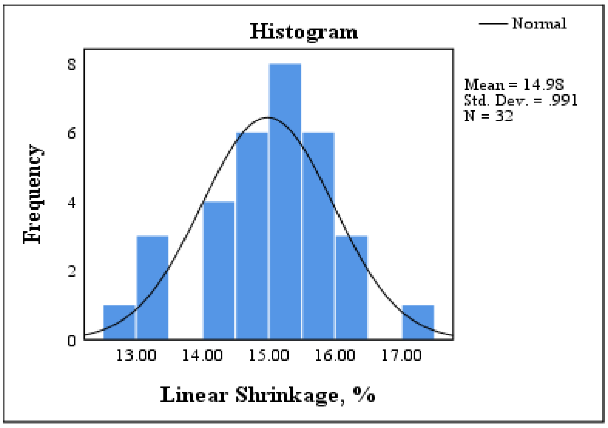

Normal Q-Q Plot of Plastic Index
Expected Normal
Observed Value

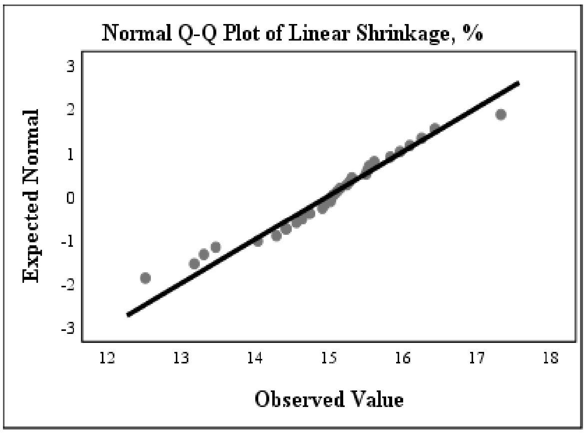

Histogram
Normal
Mean = 2.69
Std. Dev. = .033
N = 32
Frequency
Specific Gravity, Gs

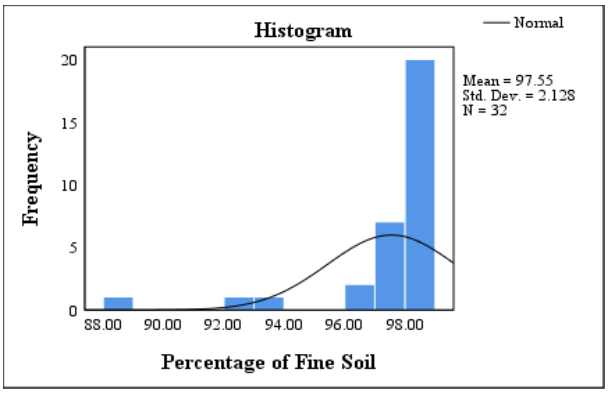

Normal Q-Q Plot of Specific Gravity, Gs
Expected Normal
Observed Value

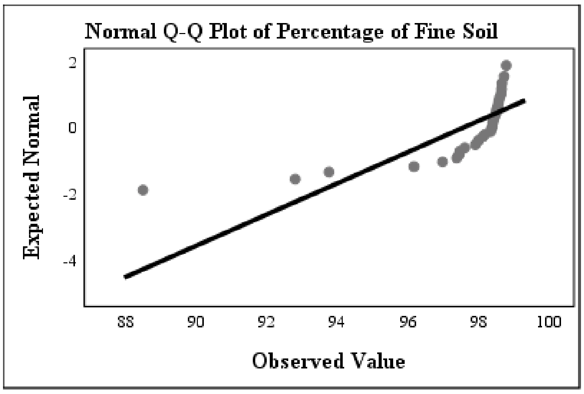

Histogram
Normal
Mean = 15.19
Std. Dev. = 5.229
N = 32
Frequency
Free Swell, (%)

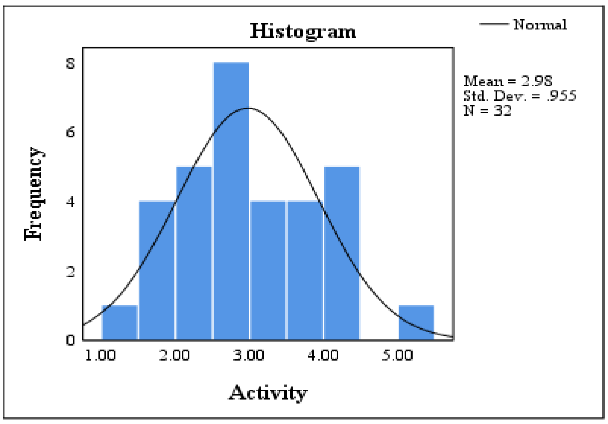

Normal Q-Q Plot of Free Swell, (%)
Expected Normal
Observed Value

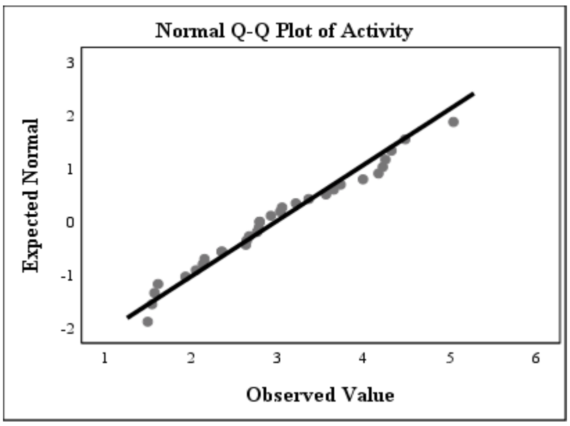

Histogram
Normal
Mean = 14.98
Std. Dev. = .991
N = 32
Frequency
Linear Shrinkage, %

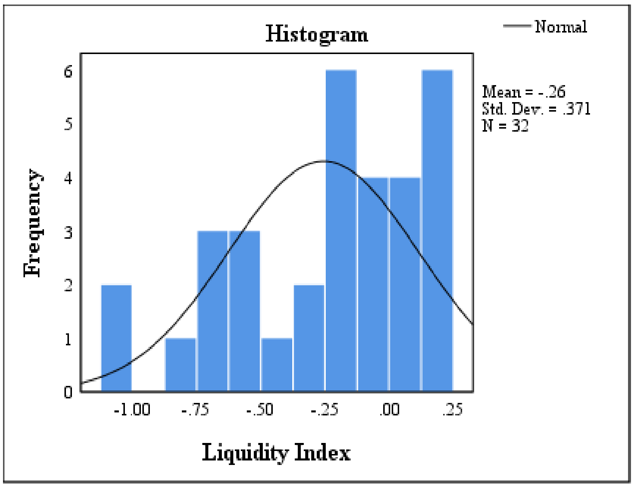

Normal Q-Q Plot of Linear Shrinkage, %
Expected Normal
Observed Value

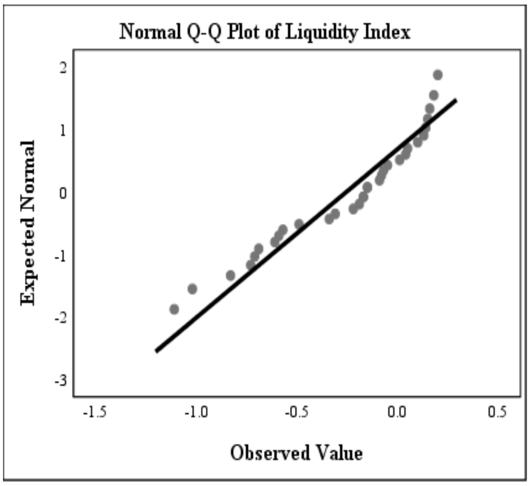

Histogram
Normal
Mean = 97.55
Std. Dev. = 2.128
N = 32
Frequency
Percentage of Fine Soil


Normal Q-Q Plot of Percentage of Fine Soil
Expected Normal
Observed Value


Histogram
Normal
Mean = 2.98
Std. Dev. = .955
N = 32
Frequency
Activity


Normal Q-Q Plot of Activity
Expected Normal
Observed Value





APPENDIX-B SPSS Regression Analysis Output for Linear Regression Analysis

1. SPSS Output for Linear Regression Analysis for Model-1 (Unconfined Compressive Strength (UCS) and Natural Moisture Content (ω))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.903[a]	.816	.810	13.60536

a. Predictors: (Constant), Moisture content, %

b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	24625.129	1	24625.129	133.033	.000[b]
1	Residual	5553.174	30	185.106		
	Total	30178.303	31			

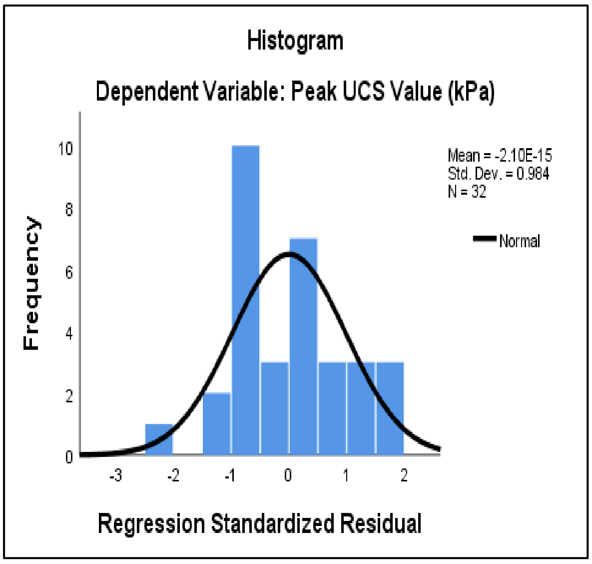
a. Dependent Variable: Peak UCS Value (kPa)

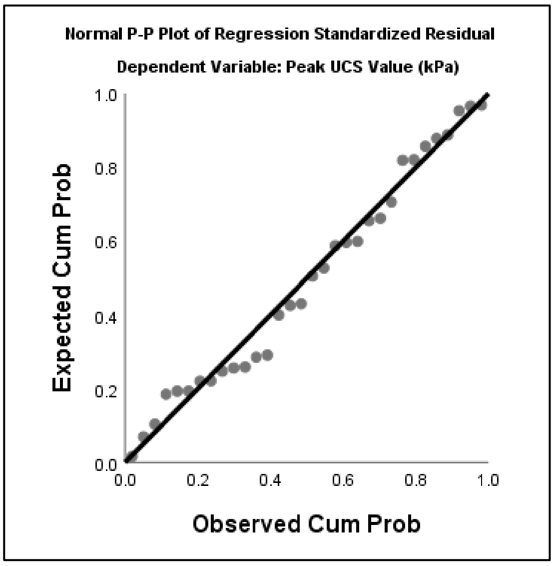
b. Predictors: (Constant), Moisture content, %

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	363.560	23.295		15.606	.000
	Moisture content, %	-6.013	.521	-.903	-11.534	.000

a. Dependent Variable: Peak UCS Value (kPa)





2. SPSS Output for Linear Regression Analysis for Model-2 (Unconfined Compressive Strength (UCS) and Dry unit weight (γd))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	0.918[a]	0.843	0.838	12.56115

a. Predictors: (Constant), Dry Unit weight, (kN/m3)

b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	25,444.831	1	25,444.831	161.265	0.000[b]
	Residual	4,733.473	30	157.782		
	Total	30,178.303	31			

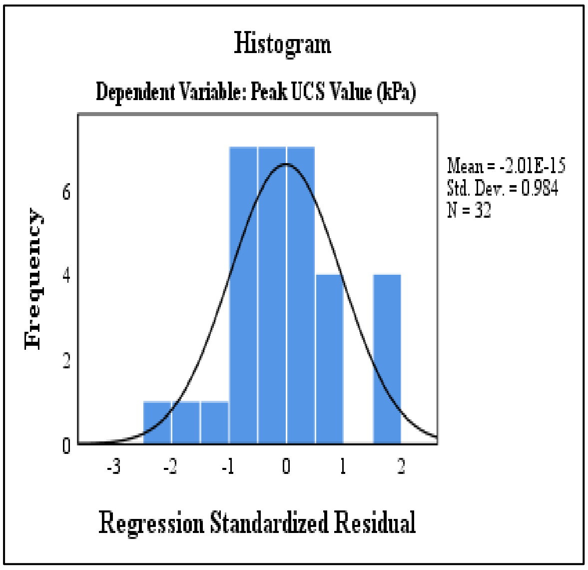
a. Dependent Variable: Peak UCS Value (kPa)

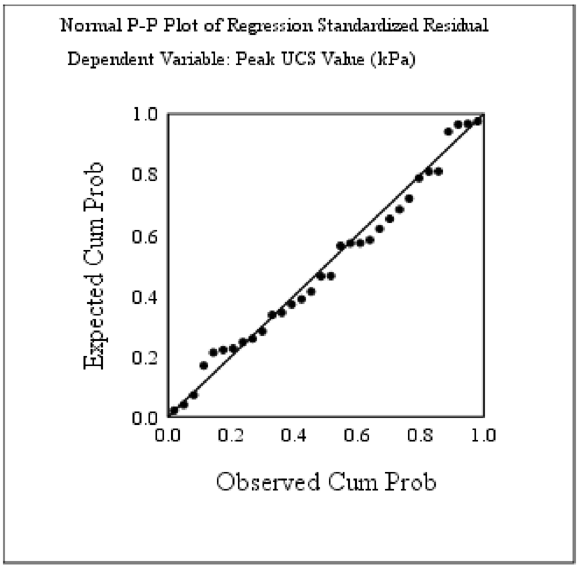
b. Predictors: (Constant), Dry Unit weight, (kN/m3)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
2	(Constant)	-510.478	47.834		-10.672	0.000
	Dry Unit weight, (kN/m3)	52.760	4.155	0.918	12.699	0.000

a. Dependent Variable: Peak UCS Value (kPa)





3. SPSS Output for Linear Regression Analysis for Model-3: (Unconfined Compressive Strength (UCS) and Liquid Limit (LL))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
3	0.933[a]	0.871	0.867	11.39510

a. Predictors: (Constant), Liquid Limit

b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
3	Regression	26,282.856	1	26,282.856	202.412	0.000[b]
	Residual	3,895.447	30	129.848		
	Total	30,178.303	31			

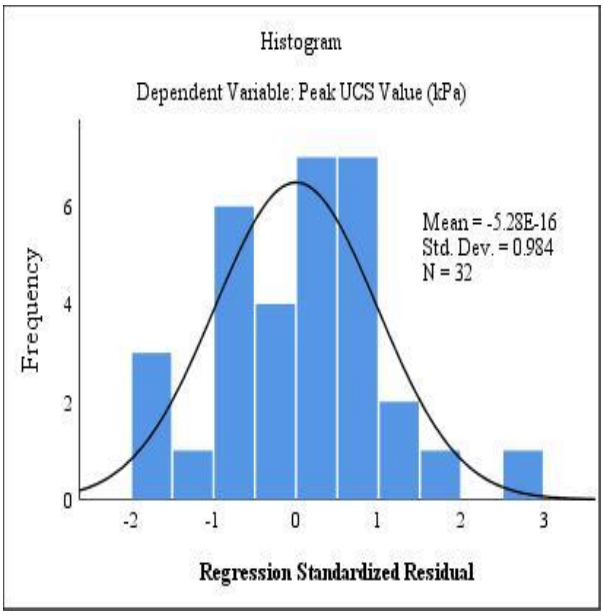
a. Dependent Variable: Peak UCS Value (kPa)

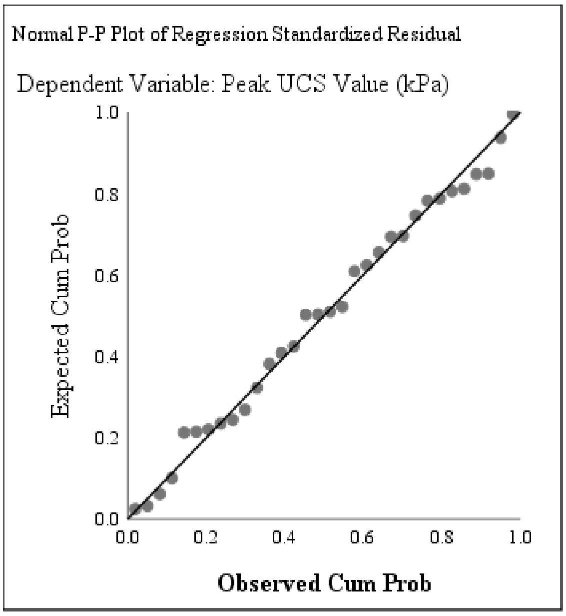
b. Predictors: (Constant), Liquied Limit

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
3	(Constant)	385.334	20.415		18.875	0.000
	Liquid Limit	-3.697	0.260	-0.933	-14.227	0.000

a. Dependent Variable: Peak UCS Value (kPa)





4. SPSS Output for Linear Regression Analysis for Model-4: (Unconfined Compressive Strength (UCS) and Plastic Limit (PL))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
4	0.461[a]	0.212	0.186	28.15047

a. Predictors: (Constant), Plastic Limit

b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
4	Regression	6,404.831	1	6,404.831	8.082	0.008[b]
	Residual	23,773.472	30	792.449		
	Total	30,178.303	31			

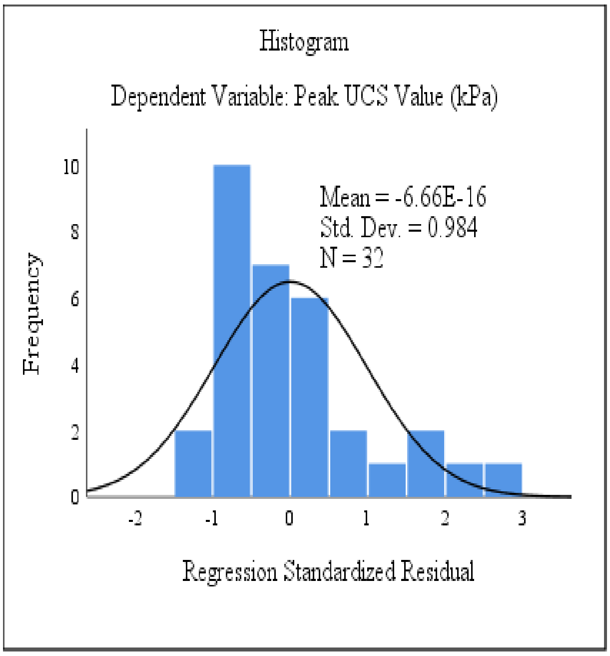
a. Dependent Variable: Peak UCS Value (kPa)

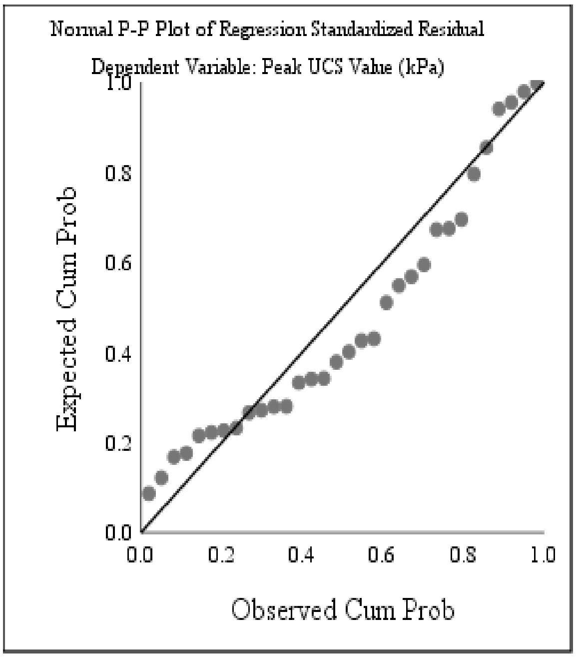
b. Predictors: (Constant), Plastic Limit

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
4	(Constant)	-34.990	46.451		-0.753	0.457
	Plastic Limit	2.740	0.964	0.461	2.843	0.008

a. Dependent Variable: Peak UCS Value (kPa)





5. SPSS Output of Linear Regression Analysis for Model-5 (Unconfined Compressive Strength (UCS) and Plastic Index (PI))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
5	0.905[a]	0.818	0.812	13.51675

a. Predictors: (Constant), Plastic Index

b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	24,697.227	1	24,697.227	135.177	0.000[b]
	Residual	5,481.077	30	182.703		
	Total	30,178.303	31			

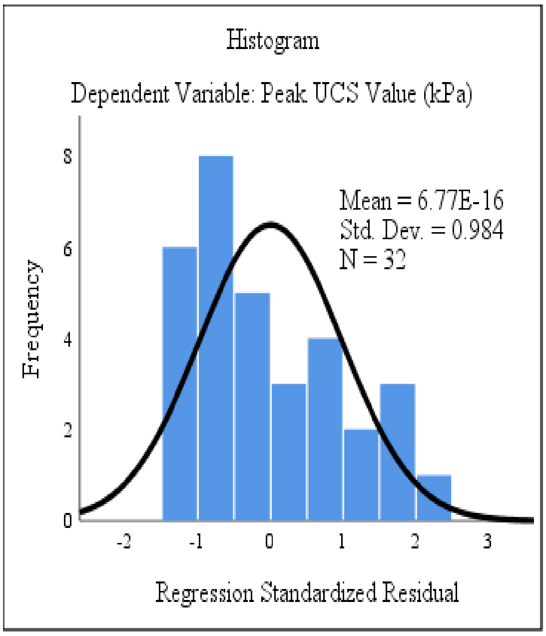
a. Dependent Variable: Peak UCS Value (kPa)

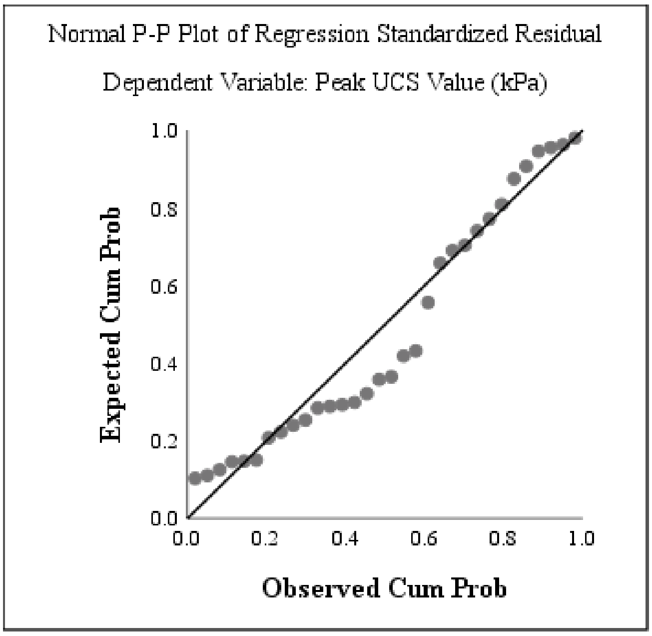
b. Predictors: (Constant), Plastic Index

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
5	(Constant)	175.433	7.213		24.322	0.000
	Plastic Index	-2.615	0.225	-0.905	-11.627	0.000

a. Dependent Variable: Peak UCS Value (kPa)





6. SPSS Output of Linear Regression Analysis for Model-6 (Unconfined Compressive Strength (UCS) and Specific Gravity (Gs))

Model Summary[b]

Model-6	R	R Square	Adjusted R Square	Std. Error of the Estimate
6	0.562[a]	0.316	0.293	26.23190

a. Predictors: (Constant), Specific Gravity, Gs at 200c
b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

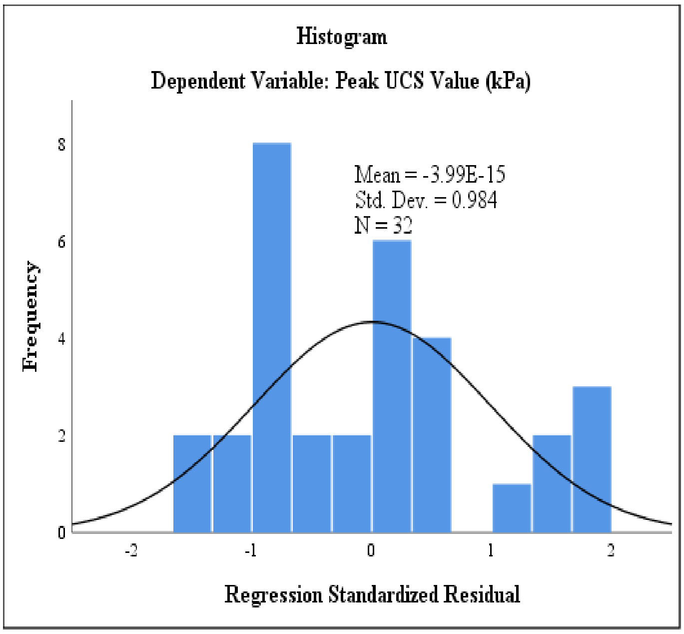
Model-6		Sum of Squares	df	Mean Square	F	Sig.
6	Regression	9,534.918	1	9,534.918	13.857	0.001[b]
	Residual	20,643.385	30	688.113		
	Total	30,178.303	31			

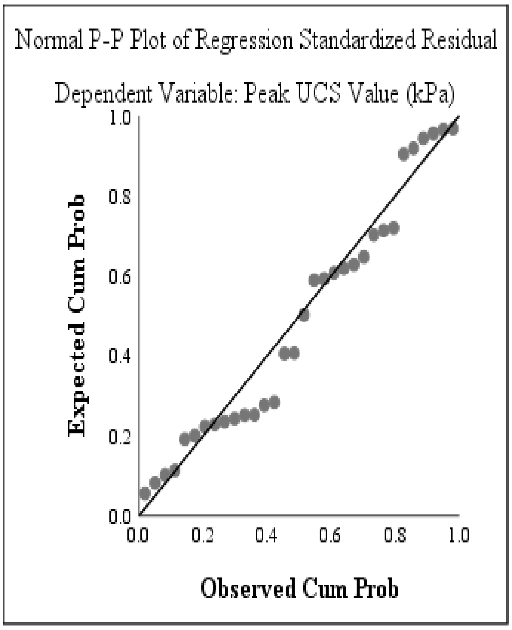
a. Dependent Variable: Peak UCS Value (kPa)
b. Predictors: (Constant), Specific Gravity, Gs at 20^0c

Coefficients[a]

Model-6		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
6	(Constant)	1518.188	382.003		3.974	0.000
	Specific Gravity, Gs at 200c	-529.565	142.262	-0.562	-3.722	0.001

a. Dependent Variable: Peak UCS Value (kPa)





7. SPSS Output of Linear Regression Analysis for Model-7 (Unconfined Compressive Strength (UCS) and Free Swell (FS))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
7	0.354[a]	0.126	0.096	29.65954	0.126	4.306	1	30	0.047

a. Predictors: (Constant), Free Swell, (%)
b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

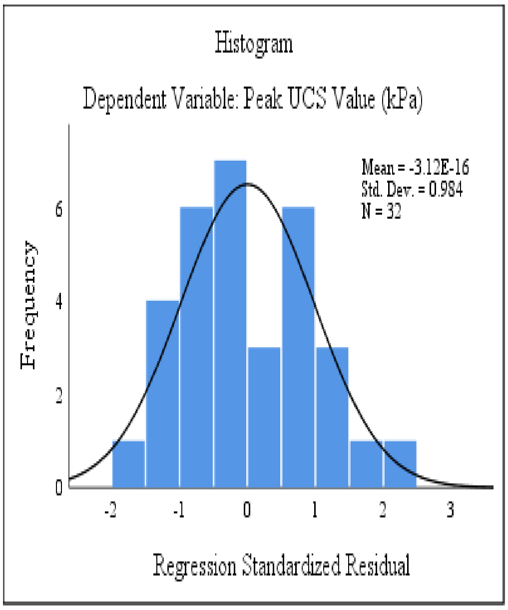
Model		Sum of Squares	df	Mean Square	F	Sig.
7	Regression	3,787.653	1	3,787.653	4.306	0.047[b]
	Residual	26,390.650	30	879.688		
	Total	30,178.303	31			

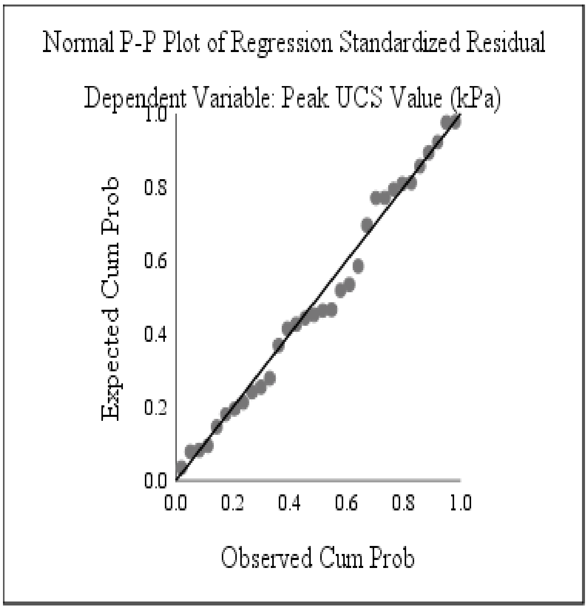
a. Dependent Variable: Peak UCS Value (kPa)
b. Predictors: (Constant), Free Swell, (%)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
7	(Constant)	128.420	16.340		7.85	0.000	95.049	161.792
	Free Swell, (%)	-2.114	1.019	-0.354	-2.07	0.047	-4.194	-0.033

a. Dependent Variable: Peak UCS Value (kPa)





8. SPSS Output of Linear Regression Analysis for Model-8 (Unconfined Compressive Strength (UCS) and Linear Shrinkage Index (LS))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R^2	F	df1	df2	Sig. F
8	0.35[a]	0.156	0.128	29.13961	0.156	5.541	1	30	0.025

a. Predictors: (Constant), Linear Shrinkage, %
b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

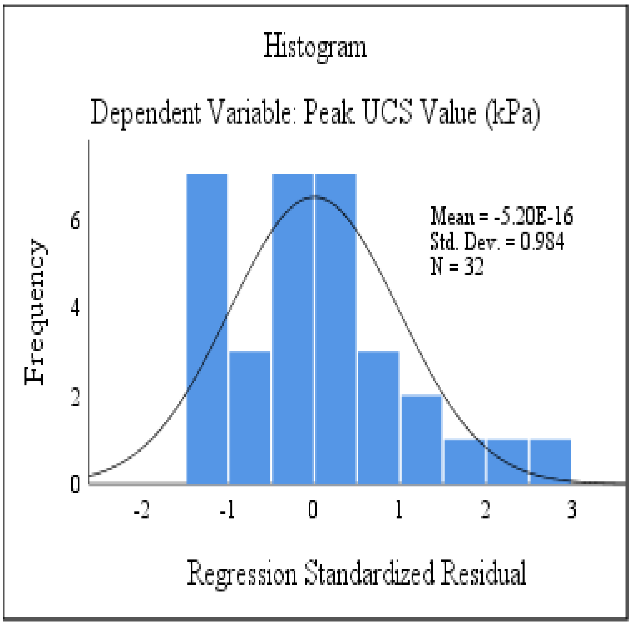
Model		Sum of Squares	df	Mean Square	F	Sig.
8	Regression	4,704.802	1	4,704.802	5.541	0.025[b]
	Residual	25,473.501	30	849.117		
	Total	30,178.303	31			

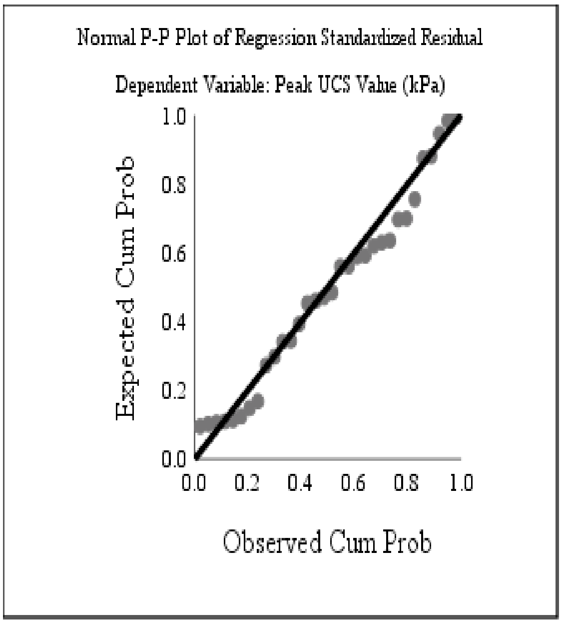
a. Dependent Variable: Peak UCS Value (kPa)
b. Predictors: (Constant), Linear Shrinkage, %

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			LB	UB
8	(Constant)	282.500	79.268		3.56	0.001	120.614	444.386
	LS, %	-12.428	5.280	-0.395	-2.3	0.025	-23.210	-1.645

a. Dependent Variable: Peak UCS Value (kPa)





9. SPSS Output of Linear Regression Analysis for Model-9 (Unconfined Compressive Strength (UCS) and Passing Percentage of Fine Particle % (PFP))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
9	0.66[a]	0.436	0.417	23.82914	0.436	23.147	1	30	0.000

a. Predictors: (Constant), Percentage of Fine Soil

b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
9	Regression	13,143.469	1	13,143.469	23.147	0.000[b]
	Residual	17,034.835	30	567.828		
	Total	30,178.303	31			

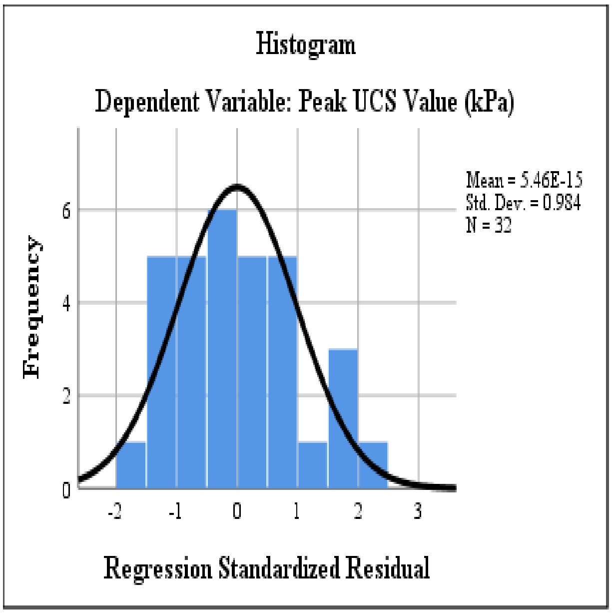
a. Dependent Variable: Peak UCS Value (kPa)

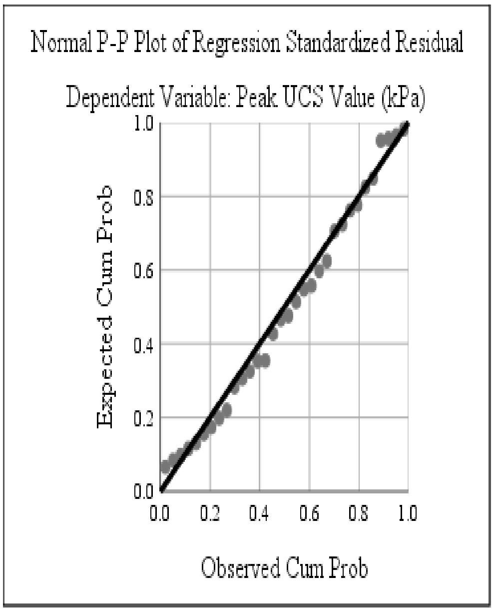
b. Predictors: (Constant), Percentage of Fine Soil

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
9	(Constant)	1040.295	196.255		5.301	0.000	639.490	1,441.100
	Percentage of Fine Soil	-9.677	2.011	-0.660	-4.811	0.000	-13.785	-5.569

a. Dependent Variable: Peak UCS Value (kPa)





10. SPSS Output of Linear Regression Analysis for Model-9 (Unconfined Compressive Strength (UCS) and Activity (Ac))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
10	0.828[a]	0.686	0.676	17.76814	0.686	65.590	1	30	0.000

a. Predictors: (Constant), Activity
b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

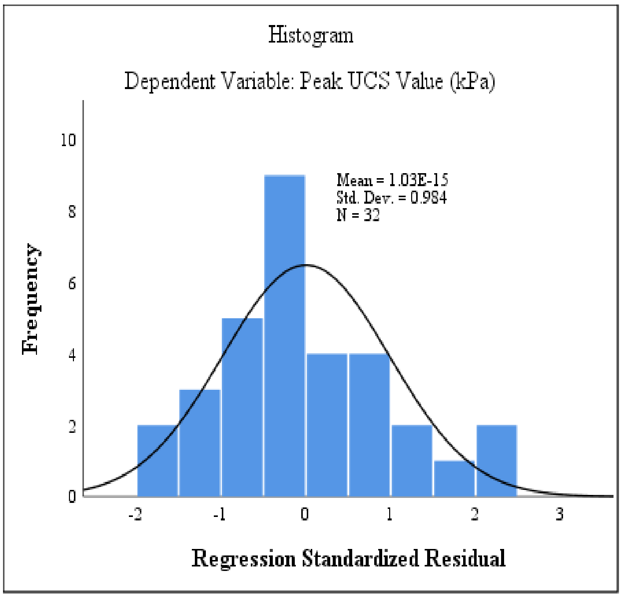
Model		Sum of Squares	df	Mean Square	F	Sig.
10	Regression	20,707.099	1	20,707.099	65.590	0.000[b]
	Residual	9,471.204	30	315.707		
	Total	30,178.303	31			

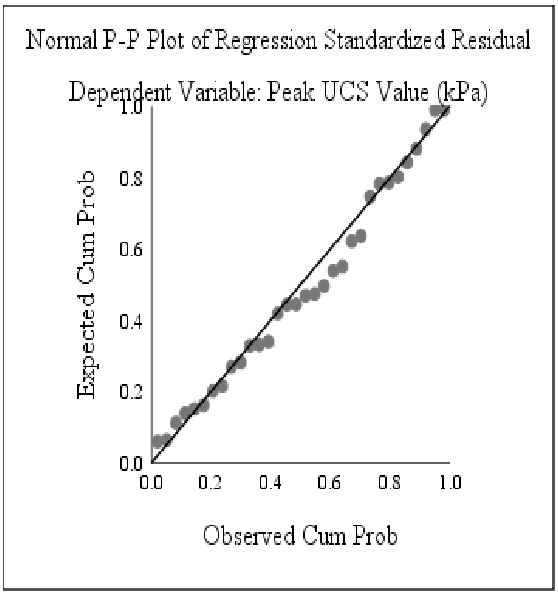
a. Dependent Variable: Peak UCS Value (kPa)
b. Predictors: (Constant), Activity

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
10	(Constant)	176.850	10.429		16.957	0.000	155.550	198.149
	Activity	-27.070	3.343	-0.828	-8.099	0.000	-33.897	-20.244

a. Dependent Variable: Peak UCS Value (kPa)





11. SPSS Output of Linear Regression Analysis for Model-9 (Unconfined Compressive Strength (UCS) and Liquidity Index (LI))

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
11	0.903[a]	0.815	0.809	13.64394	0.815	132.112	1	30	0.000

a. Predictors: (Constant), Liquidity Index
b. Dependent Variable: Peak UCS Value (kPa)

ANOVA[a]

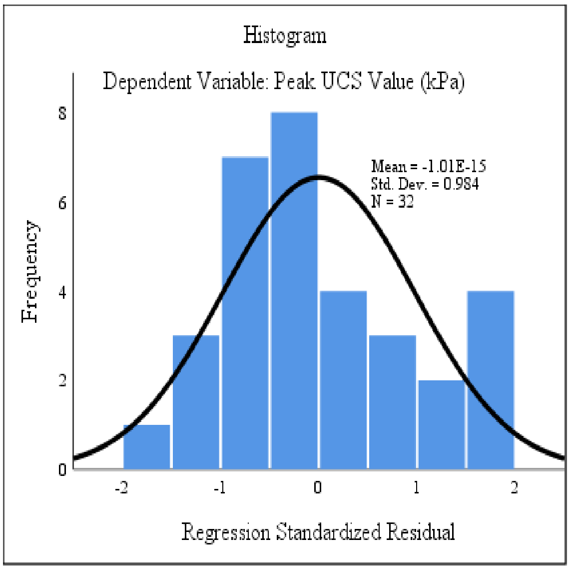
Model		Sum of Squares	df	Mean Square	F	Sig.
11	Regression	24,593.589	1	24,593.589	132.112	0.000[b]
	Residual	5,584.715	30	186.157		
	Total	30,178.303	31			

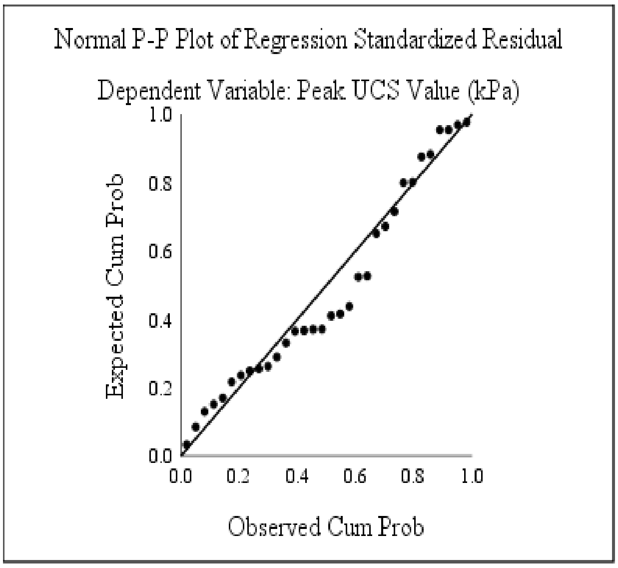
a. Dependent Variable: Peak UCS Value (kPa)
b. Predictors: (Constant), Liquidity Index

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			LB	UB
1	(Constant)	79.392	2.825		28.099	0.000	73.622	85.162
	LI	-70.941	6.172	-0.903	-11.49	0.000	-83.546	-58.336

a. Dependent Variable: Peak UCS Value (kPa)





APPENDIX-C: SPSS Regression Analysis Output for Multiple Regression

1. Model-1: Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Dry Unit Weight (γ_d)

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	0.9[a]	0.852	0.842	12.39250	0.852	83.753	2	29	0.000	2.969
a. Predictors: (Constant), Dry Unit weight, (kN/m3), Moisture content, %										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA [a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	25,724.655	2	12,862.328	83.753	0.000[b]
	Residual	4,453.648	29	153.574		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Dry Unit weight, (kN/m3), Moisture content, %						

Coefficients [a]										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-221.081	219.525		-1.007	0.322	-670.060	227.898		
	Moisture content, %	-2.083	1.543	-0.313	-1.350	0.188	-5.240	1.073	0.095	10.565

	Dry Unit weight, (kN/m3)	35.648	13.323	0.620	2.676	0.012	8.400	62.896	0.095	10.565
a. Dependent Variable: Peak UCS Value (kPa)										

2. Model-2: Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Liquid Limit (LL)

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	
2	0.9[a]	0.913	0.907	9.52962	0.913	151.655	2	29	0.000	2.685
a. Predictors: (Constant), Liquid Limit, Moisture content, %										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	27,544.710	2	13,772.355	151.655	0.000[b]
	Residual	2,633.594	29	90.814		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Liquid Limit, Moisture content, %						

Coefficients[a]										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
2	(Constant)	397.67	17.39		22.87	0.000	362.101	433.236		
	Moisture content, %	-2.616	0.702	-0.393	-3.73	0.001	-4.051	-1.181	0.271	3.693
	Liquid Limit	-2.368	0.418	-0.598	-5.67	0.000	-3.222	-1.514	0.271	3.693
a. Dependent Variable: Peak UCS Value (kPa)										

3. Model-3: Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Plastic Index (PI)

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	0.9[a]	0.899	0.892	10.2561	0.899	128.95	2	29	0.000	2.977
a. Predictors: (Constant), Plastic Index, Moisture content, %										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
3	Regression	27,127.871	2	13,563.936	128.950	0.000[b]
	Residual	3,050.432	29	105.187		

	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Plastic Index, Moisture content, %						

Coefficients[a]

Model-3		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
3	(Constant)	286.138	23.671		12.088	0.000	237.725	334.550		
	Moisture content, %	-3.285	0.683	-0.494	-4.807	0.000	-4.683	-1.888	0.331	3.025
	Plastic Index	-1.448	0.297	-0.501	-4.878	0.000	-2.054	-0.841	0.331	3.025
a. Dependent Variable: Peak UCS Value (kPa)										

4. Model-4: Unconfined Compressive Strength (UCS) with Dry Unit Weight (γ_d) and Liquid Limit (LL)

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	0.957[a]	0.915	0.909	9.39764	0.915	156.355	2	29	0.000	2.795
a. Predictors: (Constant), Liquid Limit, Dry Unit weight, (kN/m3)										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA [a]

Model		Sum of Squares	df	Mean Square	F	Sig.
4	Regression	27,617.148	2	13,808.574	156.355	0.000[b]
	Residual	2,561.155	29	88.316		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Liquid Limit, Dry Unit weight, (kN/m3)						

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
4	(Constant)	-18.96	105.36		-0.18	0.86	-234.464	196.540		
	Dry Unit weight, (kN/m3)	24.93	6.414	0.434	3.89	0.00	11.813	38.051	0.235	4.259
	Liquid Limit	-2.19	0.442	-0.554	-4.96	0.00	-3.098	-1.289	0.235	4.259
a. Dependent Variable: Peak UCS Value (kPa)										

5. Model-5: Unconfined Compressive Strength (UCS) with Dry Unit Weight (γ_d) and Liquidity Index (LI)

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	
5	0.929[a]	0.863	0.854	11.92485	0.863	91.611	2	29	0.000	2.510
a. Predictors: (Constant), Liquidity Index, Dry Unit weight, (kN/m3)										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA [a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	26,054.445	2	13,027.223	91.611	0.000[b]
	Residual	4,123.858	29	142.202		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Liquidity Index, Dry Unit weight, (kN/m3)						

Coefficients[a]										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
5	(Constant)	-290.6	115.477		-2.51	0.018	-526.8	-54.470		
	Dry Unit weight, (kN/m3)	33.040	10.308	0.575	3.205	0.003	11.957	54.123	0.146	6.831
	Liquidity Index	-29.19	14.099	-0.371	-2.07	0.047	-58.02	-0.356	0.146	6.831
a. Dependent Variable: Peak UCS Value (kPa)										

6. Model-6: Unconfined Compressive Strength (UCS) with Dry Unit Weight (γ_d) and Plastic Index (PI)

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	
6	0.946[a]	0.895	0.888	10.43867	0.895	123.97	2	29	0.000	2.565
a. Predictors: (Constant), Plastic Index, Dry Unit weight, (kN/m3)										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA [a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
6	Regression	27,018.296	2	13,509.148	123.976	0.000[b]
	Residual	3,160.007	29	108.966		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Plastic Index, Dry Unit weight, (kN/m3)						

Coefficients[a]										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
6	(Constant)	-220.67	86.004		-2.57	0.016	-396.564	-44.768		
	Dry Unit weight, (kN/m3)	30.932	6.702	0.538	4.615	0.000	17.224	44.639	0.265	3.768
	Plastic Index	-1.281	0.337	-0.443	-3.80	0.001	-1.971	-0.592	0.265	3.768

a. Dependent Variable: Peak UCS Value (kPa)

7. Model-7: Unconfined Compressive Strength (UCS) with Liquid Limit (LL) and Liquidity Index (LI)

Model Summary [b]										
					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
7	0.973[a]	0.947	0.943	7.44755	0.947	257.543	2	29	0.000	2.763
a. Predictors: (Constant), Liquidity Index, Liquid Limit										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA [a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
7	Regression	28,569.791	2	14,284.895	257.543	0.000[b]
	Residual	1,608.513	29	55.466		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Liquidity Index, Liquid Limit						

Coefficients [a]										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
7	(Constant)	269.218	22.473		11.980	0.000	223.255	315.180		
	Liquid Limit	-2.318	0.274	-0.585	-8.467	0.000	-2.878	-1.758	0.385	2.599
	Liquidity Index	-34.874	5.431	-0.444	-6.421	0.000	-45.981	-23.766	0.385	2.599
a. Dependent Variable: Peak UCS Value (kPa)										

8. Model-8: Unconfined Compressive Strength (UCS) with Liquid Limit (LL) and Plastic Index (PI)

Model Summary [b]										
					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
8	0.948[a]	0.898	0.891	10.30038	0.898	127.719	2	29	0.000	2.052
a. Predictors: (Constant), Plastic Index, Liquid Limit										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA [a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
8	Regression	27,101.467	2	13,550.733	127.719	0.000[b]
	Residual	3,076.837	29	106.098		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Plastic Index, Liquid Limit						

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std.Erro	Beta			LB	UB	T	VIF
8	(Constant)	318.03	30.456		10.44	0.0	255.744	380.323		
	LL	-2.435	0.511	-0.615	-4.76	0.0	-3.481	-1.389	0.211	4.742
	PI	-1.037	0.373	-0.359	-2.78	0.0	-1.800	-0.273	0.211	4.742
a. Dependent Variable: Peak UCS Value (kPa)										

9. Model-9: Unconfined Compressive Strength (UCS) with Plastic Index (PI) and Liquidity Index (LI)

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	
9	0.928[a]	0.860	0.851	12.05212	0.860	89.381	2	29	0.000	2.187
a. Predictors: (Constant), Liquidity Index, Plastic Index										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA [a]

Model		Sum of Squares	df	Mean Square	F	Sig.
9	Regression	25,965.951	2	12,982.975	89.381	0.000[b]
	Residual	4,212.353	29	145.254		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Liquidity Index, Plastic Index						

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
9	(Constant)	130.018	16.658		7.805	0.000	95.948	164.088		
	PI	-1.403	0.456	-0.485	-3.07	0.005	-2.336	-0.469	0.193	5.181
	LI	-36.675	12.410	-0.467	-2.95	0.006	-62.056	-11.295	0.193	5.181
a. Dependent Variable: Peak UCS Value (kPa)										

10. Model-10: Unconfined Compressive Strength (UCS) with Natural Moisture Content (ω) and Liquidity Index (LI)

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	0.923[a]	0.851	0.841	12.44566	0.851	82.916	2	29	0.000	2.516
a. Predictors: (Constant), Liquidity Index, Moisture content, %										
b. Dependent Variable: Peak UCS Value (kPa)										

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	25,686.363	2	12,843.181	82.916	0.000[b]
	Residual	4,491.941	29	154.895		
	Total	30,178.303	31			
a. Dependent Variable: Peak UCS Value (kPa)						
b. Predictors: (Constant), Liquidity Index, Moisture content, %						

Coefficients[a]										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	227.992	56.006		4.071	0.000	113.447	342.536		
	Moisture content, %	-3.160	1.190	-0.475	-2.656	0.013	-5.593	-0.727	0.161	6.224
	Liquidity Index	-36.763	14.045	-0.468	-2.618	0.014	-65.489	-8.038	0.161	6.224
a. Dependent Variable: Peak UCS Value (kPa)										

APPENDIX-D: Laboratory Test Results

1. Laboratory Test Result of Moisture Content

Test Pit Location	TP 1@1.5m		TP 2 @1.5m		TP 3 @1.5m		TP 4 @1.5m	
Test Pit Number	01		02		03		04	
Test Pit Depth, (m)	1.5		1.5		1.5		1.5	
Test Trials	01	02	01	02	01	02	01	02
Wt. of Container, (g)	40.797	37.718	37.377	34.814	35.560	26.664	39.087	36.266
Wt. of container + wet soil, (g)	147.485	140.923	141.723	150.870	136.722	121.12	144.60	145.9
Wt. of container + dry soil, (g)	113.65	107.87	107.19	112.35	103.58	90.186	110.42	110.11
Wt. of water, (g)	33.834	33.053	34.531	38.520	33.134	30.937	34.182	35.790
Wt. of dry soil, (g)	72.854	70.152	69.815	77.536	68.028	63.522	71.335	73.844
Moisture container, (%)	46.441	47.116	49.461	49.680	48.706	48.703	47.918	48.467
Ave. Moisture container, (%)	46.8		49.6		48.7		48.2	

Test Pit Location	TP-5@1m		TP-5 @2m		TP-6 @1m		TP-6 @2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Test Trials	01	02	01	02	01	02	01	02
Wt. of Container, (g)	41.39	36.57	32.59	49.69	31.45	36.08	28.78	37.17
Wt. of container + wet soil, (g)	157.32	162.25	180.12	197.84	166.59	156.78	126.56	136.02
Wt. of container + dry soil, (g)	123.76	125.66	131.49	149.34	129.07	123.01	96.29	105.56
Wt. of water, (g)	33.56	36.59	48.63	48.50	37.52	33.77	30.28	30.46
Wt. of dry soil, (g)	82.37	89.09	98.90	99.65	97.62	86.94	67.51	68.39
Moisture container, (%)	40.75	41.07	49.17	48.67	38.43	38.84	44.85	44.54
Ave. Moisture container, (%)	40.91		48.92		38.64		44.69	

Test Pit Location	TP-7 @1m		TP-7 @2m		TP-8 @1m		TP-8 @2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Test Trials	01	02	01	02	01	02	01	02
Wt. of Container, (g)	18.21	17.16	17.57	17.05	16.77	17.49	17.61	18.38
Wt. of container + wet soil, (g)	96.02	102.47	98.84	105.49	82.25	110.93	83.16	112.91
Wt. of container + dry soil, (g)	70.57	74.79	75.19	79.42	60.57	80.47	62.08	82.65

Moisture container, (%)	48.61	48.05	41.03	41.79	49.50	48.37	47.40	47.10
Ave. Moisture container, (%)	48.33		41.41		48.93		47.25	

Test Pit Location	TP-9 @1m		TP-9 @2m		TP-10 @1m		TP-10 @2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Test Trials	01	02	01	02	01	02	01	02
Wt. of Container, (g)	17.71	17.53	17.44	17.53	17.19	17.44	17.93	17.86
Wt. of container + wet soil, (g)	99.43	105.74	94.45	92.87	99.94	105.76	99.79	95.96
Wt. of container + dry soil, (g)	72.25	76.71	69.87	68.75	73.86	77.88	73.16	70.42
Wt. of water, (g)	27.17	29.03	24.58	24.12	26.08	27.88	26.63	25.54
Wt. of dry soil, (g)	54.55	59.18	52.43	51.22	56.67	60.44	55.22	52.56
Moisture container, (%)	49.81	49.06	46.87	47.10	46.03	46.12	48.22	48.59
Ave. Moisture container, (%)	49.44		46.98		46.07		48.41	

Test Pit Location	TP-11 @ 1m		TP-11 @ 2m		TP-12 @ 1m		TP-12 @ 2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Test Trials	01	02	01	02	01	02	01	02
Wt. of Container, (g)	29.68	33.63	33.14	36.49	17.48	18.40	18.02	17.41
Wt. of container + wet soil, (g)	153.78	155.66	149.82	161.40	107.06	99.02	99.24	97.27
Wt. of container + dry soil, (g)	115.36	117.70	117.92	126.69	79.77	74.43	76.80	75.25
Wt. of water, (g)	38.42	37.96	31.91	34.71	27.30	24.59	22.44	22.03
Wt. of dry soil, (g)	85.69	84.07	84.78	90.19	62.28	56.03	58.78	57.83
Moisture container, (%)	44.84	45.15	37.64	38.48	43.83	43.90	38.18	38.08
Ave. Moisture container, (%)	44.99		38.06		43.86		38.13	

Test Pit Location	TP-13 @ 1m		TP-13 @ 2m		TP-14 @ 1m		TP-14 @ 2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Test Trials	01	02	01	02	01	02	01	02
Wt. of Container, (g)	41.09	37.14	34.98	42.25	33.51	31.37	33.93	36.72
Wt. of container + wet soil, (g)	152.40	151.59	160.92	174.36	151.65	138.95	135.58	140.96
Wt. of container + dry soil, (g)	118.71	116.77	119.34	130.85	116.33	106.60	103.35	107.84
Wt. of water, (g)	33.70	34.82	41.58	43.51	35.33	32.35	32.23	33.13
Wt. of dry soil, (g)	77.61	79.62	84.36	88.60	82.82	75.23	69.42	71.12
Moisture container, (%)	43.42	43.73	49.29	49.11	42.65	43.01	46.42	46.58
Ave. Moisture container, (%)	43.58		49.20		42.83		46.50	

Test Pit Location	TP-15 @ 1m		TP-15 @ 2m		TP-16 @ 1m		TP-16 @ 2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Test Trials	01	02	01	02	01	02	01	02
Wt. of Container, (g)	17.96	17.35	17.50	17.29	16.98	17.46	17.77	18.12

Wt. of container + wet soil, (g)	97.72	104.11	96.64	99.18	91.10	108.34	91.47	104.44
Wt. of container + dry soil, (g)	71.41	75.75	72.53	74.09	67.22	79.17	67.62	76.53
Wt. of water, (g)	26.31	28.36	24.11	25.10	23.88	29.17	23.85	27.91
Wt. of dry soil, (g)	53.45	58.40	55.03	56.80	50.24	61.71	49.85	58.41
Moisture container, (%)	49.22	48.56	43.81	44.18	47.54	47.27	47.85	47.77
Ave. Moisture container, (%)	48.89		44.00		47.40		47.81	

Test Pit Location	TP-17 @ 1m		TP-17 @ 2m		TP-18 @ 1m		TP-18 @ 2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Test Trials	01	02	01	02	01	02	01	02
Wt. of Container, (g)	30.27	34.31	33.80	37.22	17.83	18.77	18.38	17.76
Wt. of container + wet soil, (g)	156.86	158.78	152.82	164.62	109.21	101.00	101.23	99.22
Wt. of container + dry soil, (g)	122.29	124.77	121.45	130.49	86.15	80.38	79.10	77.50
Wt. of water, (g)	34.57	34.01	31.37	34.14	23.06	20.62	22.13	21.71
Wt. of dry soil, (g)	92.02	90.46	87.65	93.26	68.31	61.62	60.72	59.74
Moisture container, (%)	37.57	37.60	35.78	36.60	33.75	33.47	36.44	36.35
Ave. Moisture container, (%)	37.59		36.19		33.61		36.39	

2. Laboratory Test Result of Unit Weights

Test Pit Location	TP 1@1.5m		TP 2 @1.5m		TP 3 @1.5m		TP 4 @1.5m	
Test Pit Number	01		02		03		04	
Test Pit Depth, (m)	1.5		1.5		1.5		1.5	
Trials	01	02	01	02	01	02	01	02
Specimen total weight, g	150.43	155.64	139.44	141.47	144.19	157.00	154.94	158.76
Specimen’s height, mm	80.25	80.50	72.37	75.11	75.16	80.49	81.86	82.11
Specimens Diameter, mm	38.12	38.32	38.07	38.17	38.24	37.96	38.04	38.24
Specimen’s volume, cm^3	91.59	92.84	82.38	85.95	86.32	91.09	93.03	94.30
Bulk Unit weight, (kN/m^3)	16.11	16.45	16.61	16.15	16.39	16.91	16.34	16.51
Moisture content of soil sample, %	46.78	46.78	49.57	49.57	48.70	48.70	48.19	48.19
Dry Unit weight, (kN/m^3)	10.98	11.20	11.10	10.80	11.02	11.37	11.02	11.14
Average Dry Unit weight, (kN/m^3)	11.09		10.95		11.19		11.08	

Test Pit Location	TP-5@1m		TP-5 @2m		TP-6 @1m		TP-6 @2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Trials	01	02	01	02	01	02	01	02
Specimen total weight, g	146.91	146.39	162.25	160.63	156.63	155.06	148.45	150.93
Specimen’s height, mm	75.50	74.75	81.32	80.51	81.00	80.19	80.40	80.33
Specimens Diameter, mm	38.20	38.12	39.00	38.92	38.20	38.12	38.00	38.08
Specimen’s volume, cm^3	86.53	85.31	97.14	95.78	92.83	91.52	91.18	91.49

Bulk Unit weight, (kN/m^3)	16.66	16.83	16.38	16.45	16.55	16.62	15.97	16.18
Moisture content of soil sample, %	40.91	40.91	48.92	48.92	38.64	38.64	44.69	44.69
Dry Unit weight, (kN/m^3)	11.82	11.95	11.00	11.05	11.94	11.99	11.04	11.19
Average Dry Unit weight, (kN/m^3)	11.88		11.02		11.96		11.11	

Test Pit Location	TP-7 @1m		TP-7 @2m		TP-8 @1m		TP-8 @2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Trials	01	02	01	02	01	02	01	02
Specimen total weight, g	134.49		161.46	158.54	152.63	153.06	141.21	148.29
Specimen’s height, mm	68.54		82.23	82.23	80.98	80.17	74.75	77.95
Specimens Diameter, mm	38.30		38.20	38.25	38.50	38.42	38.00	38.00
Specimen’s volume, cm^3	78.96		94.24	94.49	94.27	92.94	84.78	88.40
Bulk Unit weight, (kN/m^3)	16.71		16.81	16.46	15.88	16.16	16.34	16.46
Moisture content of soil sample, %	48.33		41.41	41.41	48.93	48.93	47.25	47.25
Dry Unit weight, (kN/m^3)	11.26		11.88	11.64	10.66	10.85	11.10	11.18
Average Dry Unit weight, (kN/m^3)	11.26		11.76		10.76		11.14	

Test Pit Location	TP-9 @1m		TP-9 @2m		TP-10 @1m		TP-10 @2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Trials	01	02	01	02	01	02	01	02
Specimen total weight, g	150.24		158.73		144.23		150.57	
Specimen’s height, mm	77.80		79.71		73.64		75.43	
Specimens Diameter, mm	38.00		38.50		38.00		39.00	
Specimen’s volume, cm^3	88.23		92.79		83.52		90.11	
Bulk Unit weight, (kN/m^3)	16.70		16.78		16.94		16.39	
Moisture content of soil sample, %	49.44		46.98		46.07		48.41	
Dry Unit weight, (kN/m^3)	11.18		11.42		11.60		11.05	
Average Dry Unit weight, (kN/m^3)	11.18		11.42		11.60		11.05	

Test Pit Location	TP-11 @ 1m		TP-11 @ 2m		TP-12 @ 1m		TP-12 @ 2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Trials	01	02	01	02	01	02	01	02
Specimen total weight, g	159.93		158.09	159.92	158.99		158.81	128.00
Specimen’s height, mm	81.50		79.30	80.22	79.67		80.20	64.92
Specimens Diameter, mm	38.50		38.00	38.00	38.20		38.10	38.16
Specimen’s volume, cm^3	94.88		89.94	90.98	91.31		91.44	74.25

Bulk Unit weight, (kN/m^3)	16.54		17.24	17.24	17.08		17.04	16.91
Moisture content of soil sample, %	44.99		38.06	38.06	43.86		38.13	38.13
Dry Unit weight, (kN/m^3)	11.40		12.49	12.49	11.87		12.33	12.24
Average Dry Unit weight, (kN/m^3)	11.40		12.49		11.87		12.29	

Test Pit Location	TP-13 @ 1m		TP-13 @ 2m		TP-14 @ 1m		TP-14 @ 2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Trials	01	02	01	02	01	02	01	02
Specimen total weight, g	148.67		150.85	151.05	150.41	150.71	151.69	154.84
Specimen’s height, mm	77.88		76.85	77.81	78.08	78.24	81.13	81.22
Specimens Diameter, mm	38.16		38.54	38.55	38.22	38.18	38.02	38.16
Specimen’s volume, cm^3	89.07		89.65	90.82	89.58	89.58	92.11	92.89
Bulk Unit weight, (kN/m^3)	16.37		16.51	16.32	16.47	16.51	16.16	16.35
Moisture content of soil sample, %	43.58		49.20	49.20	42.83	42.83	46.50	46.50
Dry Unit weight, (kN/m^3)	11.40		11.06	10.94	11.53	11.56	11.03	11.16
Average Dry Unit weight, (kN/m^3)	11.40		11.00		11.54		11.10	

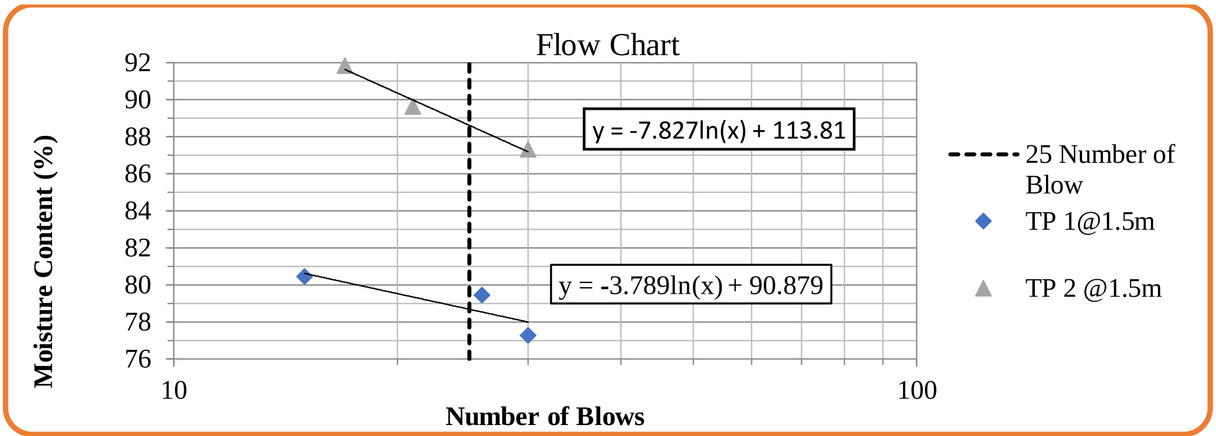
Test Pit Location	TP-15 @ 1m		TP-15 @ 2m		TP-16 @ 1m		TP-16 @ 2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Trials	01	02	01	02	01	02	01	02
Specimen total weight, g	140.70		161.85		154.63		144.83	149.61
Specimen’s height, mm	72.02		81.78		80.99		77.58	79.14
Specimens Diameter, mm	38.25		38.60		38.35		38.00	38.04
Specimen’s volume, cm^3	82.76		95.70		93.55		87.98	89.94
Bulk Unit weight, (kN/m^3)	16.68		16.59		16.21		16.15	16.32
Moisture content of soil sample, %	48.89		44.00		47.40		47.81	47.81
Dry Unit weight, (kN/m^3)	11.20		11.52		11.00		10.92	11.04
Average Dry Unit weight, (kN/m^3)	11.20		11.52		11.00		10.98	

Test Pit Location	TP-17 @ 1m		TP-17 @ 2m		TP-18 @ 1m		TP-18 @ 2m	
Test Pit Number	01		01		02		02	
Test Pit Depth, (m)	1		2		1		2	
Trials	01	02	01	02	01	02	01	02
Specimen total weight, g	156.73	155.16	152.93	153.12	155.81	154.25	157.22	126.72
Specimen’s height, mm	79.87	79.07	77.71	78.62	78.87	78.08	80.28	64.98
Specimens Diameter, mm	38.12	38.08	38.00	38.00	38.20	37.82	38.10	38.16
Specimen’s volume, cm^3	91.15	90.06	88.13	89.16	90.39	87.71	91.53	74.32
Bulk Unit weight, (kN/m^3)	16.87	16.90	17.02	16.85	16.91	17.25	16.85	16.73
Moisture content of soil sample, %	37.59	37.59	36.19	36.19	33.61	33.61	36.39	36.39
Dry Unit weight, (kN/m^3)	12.26	12.28	12.50	12.37	12.66	12.91	12.36	12.26

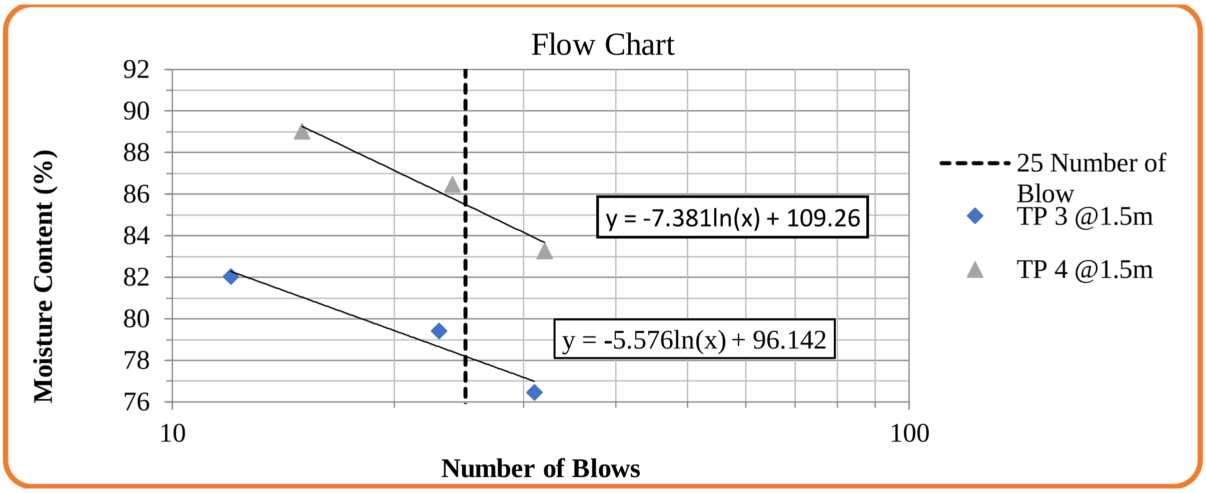
Average Dry Unit weight, (kN/m^3)	12.27	12.43	12.78	12.31

3. Laboratory Test Result of Atterberge Limits

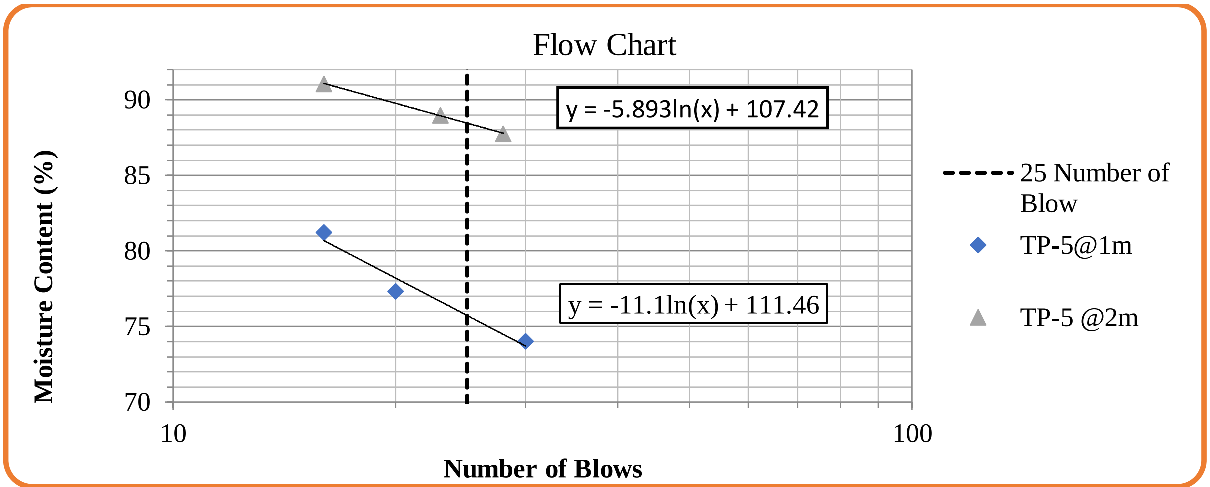
Test pit	TP 1@1.5m					TP 2 @1.5m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	30.00	26.00	15.00			30.00	21.00	17.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	18.21	18.02	17.42	5.51	5.51	17.54	18.33	17.51	5.77	6.47
Wt. of container + wet soil, (g)	34.66	29.53	29.45	16.06	16.92	31.11	30.81	29.54	15.45	15.22
Wt. of container + dry soil, (g)	27.49	24.43	24.08	12.99	13.54	24.78	24.91	23.78	12.35	12.36
Wt. of water, (g)	7.17	5.10	5.36	3.07	3.38	6.33	5.90	5.76	3.10	2.86
Wt. of dry soil, (g)	9.28	6.42	6.67	7.48	8.03	7.25	6.58	6.27	6.58	5.90
Moisture container, (%)	77.26	79.46	80.43	41.04	42.12	87.32	89.64	91.85	47.13	48.52
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	78.7		41.58	37.1		88.6		47.83	40.8	



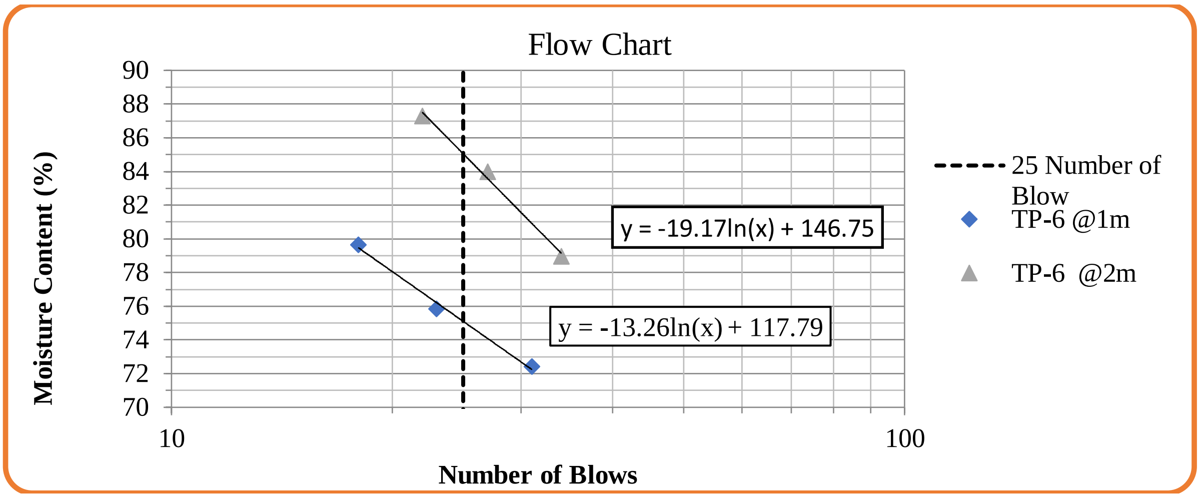
Test pit	TP 3 @1.5m					TP 4 @1.5m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	31.00	23.00	12.00			32.00	24.00	15.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.17	17.86	17.19	5.59	5.76	17.34	18.04	17.36	5.65	5.82
Wt. of container + wet soil, (g)	29.52	31.10	30.47	15.07	12.43	29.82	31.41	30.78	15.22	12.55
Wt. of container + dry soil, (g)	24.17	25.24	24.49	12.00	10.31	24.15	25.21	24.46	11.98	10.30
Wt. of water, (g)	5.35	5.86	5.99	3.07	2.11	5.67	6.20	6.32	3.24	2.25
Wt. of dry soil, (g)	7.00	7.38	7.30	6.41	4.55	6.81	7.17	7.10	6.33	4.48
Moisture container, (%)	76.47	79.43	82.04	47.95	46.45	83.26	86.47	89.01	51.18	50.22
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	78.2		47.20	31.0		85.5		50.70	34.8	



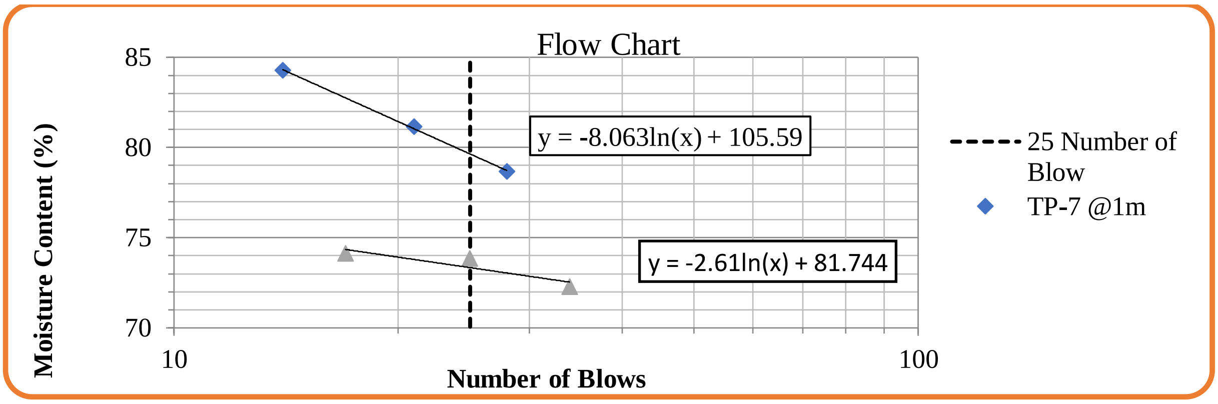
Test pit	TP-5@1m					TP-5 @2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	30.00	20.00	16.00			28.00	23.00	16.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.06	17.94	17.62	5.86	5.82	16.78	17.44	17.49	16.01	5.73
Wt. of container + wet soil, (g)	27.12	26.01	28.10	13.16	16.97	26.87	30.91	28.00	24.68	14.33
Wt. of container + dry soil, (g)	22.84	22.49	23.40	10.58	13.13	22.15	24.57	22.99	22.12	11.80
Wt. of water, (g)	4.28	3.52	4.70	2.58	3.84	4.72	6.34	5.01	2.56	2.53
Wt. of dry soil, (g)	5.78	4.55	5.78	4.73	7.30	5.38	7.12	5.50	6.11	6.07
Moisture container, (%)	74.02	77.33	81.25	54.54	52.60	87.76	88.99	91.07	41.96	41.60
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	75.7		53.57	22.2		88.5		41.78	46.7	



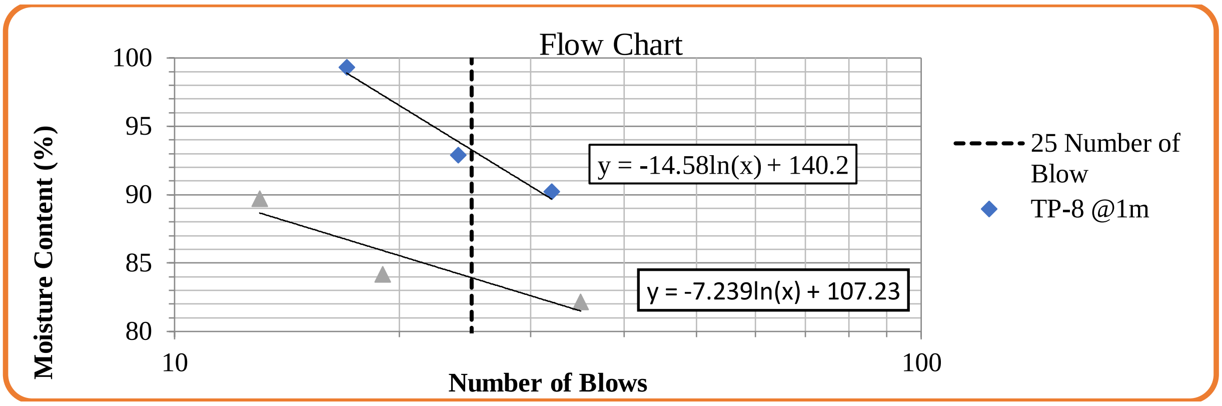
Test pit	TP-6 @1m					TP-6 @2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	31.00	23.00	18.00			34.00	27.00	22.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.71	17.44	19.90	6.73	6.16	17.53	17.58	18.39	6.47	5.75
Wt. of container + wet soil, (g)	29.72	32.34	31.15	14.31	13.80	29.94	29.90	28.95	13.07	14.41
Wt. of container + dry soil, (g)	24.67	25.91	26.16	11.53	11.11	24.46	24.27	24.03	11.24	11.99
Wt. of water, (g)	5.04	6.43	4.99	2.78	2.68	5.47	5.63	4.92	1.83	2.42
Wt. of dry soil, (g)	6.97	8.48	6.26	4.80	4.95	6.93	6.70	5.64	4.78	6.24
Moisture container, (%)	72.42	75.84	79.66	57.94	54.23	78.97	83.98	87.29	38.30	38.80
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	75.1		56.09	19.0		85.1		38.55	46.5	



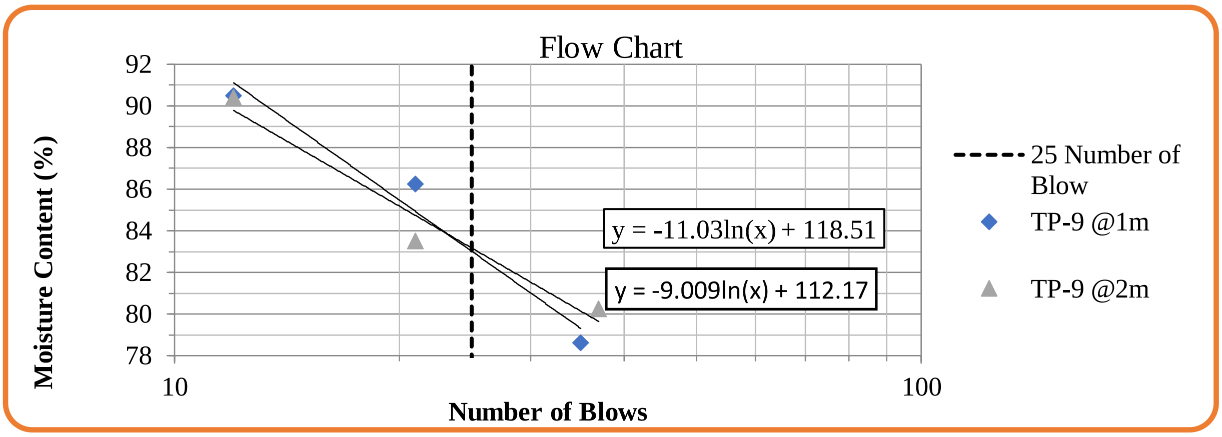
Test pit	TP-7 @1m					TP-7 @2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	28.00	21.00	14.00			34.00	25.00	17.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.17	17.86	17.20	5.59	5.76	17.05	17.93	18.40	5.85	5.73
Wt. of container + wet soil, (g)	29.28	28.72	28.36	12.33	14.73	28.80	30.24	28.88	14.17	13.38
Wt. of container + dry soil, (g)	23.95	23.86	23.26	10.40	12.17	23.87	25.01	24.42	11.33	10.76
Wt. of water, (g)	5.33	4.87	5.10	1.93	2.57	4.93	5.23	4.46	2.84	2.62
Wt. of dry soil, (g)	6.78	6.00	6.06	4.82	6.41	6.82	7.08	6.02	5.48	5.03
Moisture container, (%)	78.66	81.16	84.27	40.01	40.07	72.26	73.84	74.13	51.78	52.03
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	79.6		40.04	39.6		73.3		51.90	21.4	



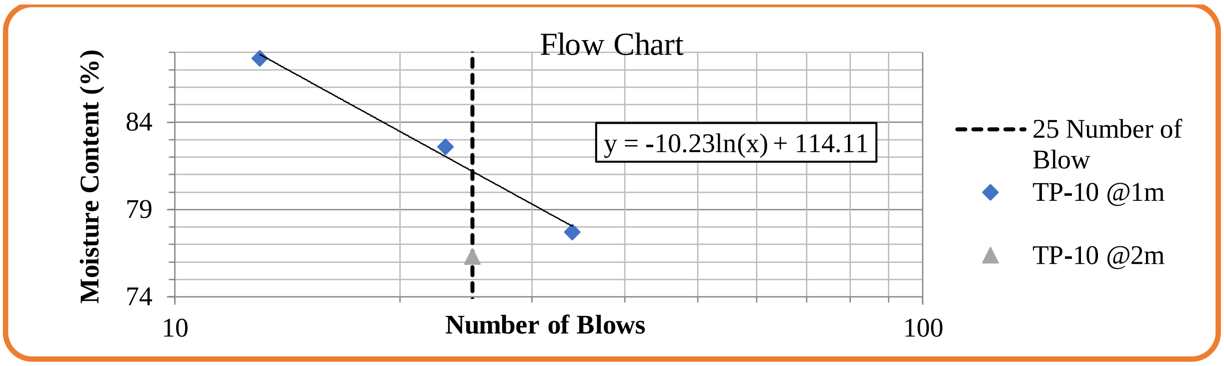
Test pit	TP-8 @1m					TP-8 @2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	32.00	24.00	17.00			35.00	19.00	13.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.44	16.78	17.49	5.78	5.51	18.02	17.42	17.71	17.02	16.07
Wt. of container + wet soil, (g)	29.84	28.90	30.07	15.36	12.43	31.44	30.66	29.52	26.74	24.81
Wt. of container + dry soil, (g)	23.96	23.06	23.80	12.73	10.53	25.39	24.61	23.93	23.33	21.76
Wt. of water, (g)	5.88	5.84	6.27	2.63	1.90	6.06	6.05	5.58	3.41	3.05
Wt. of dry soil, (g)	6.52	6.28	6.31	6.95	5.02	7.37	7.19	6.22	6.31	5.70
Moisture container, (%)	90.20	92.92	99.33	37.85	37.79	82.16	84.19	89.73	54.04	53.59
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	93.3		37.82	55.5		83.9		53.81	30.1	



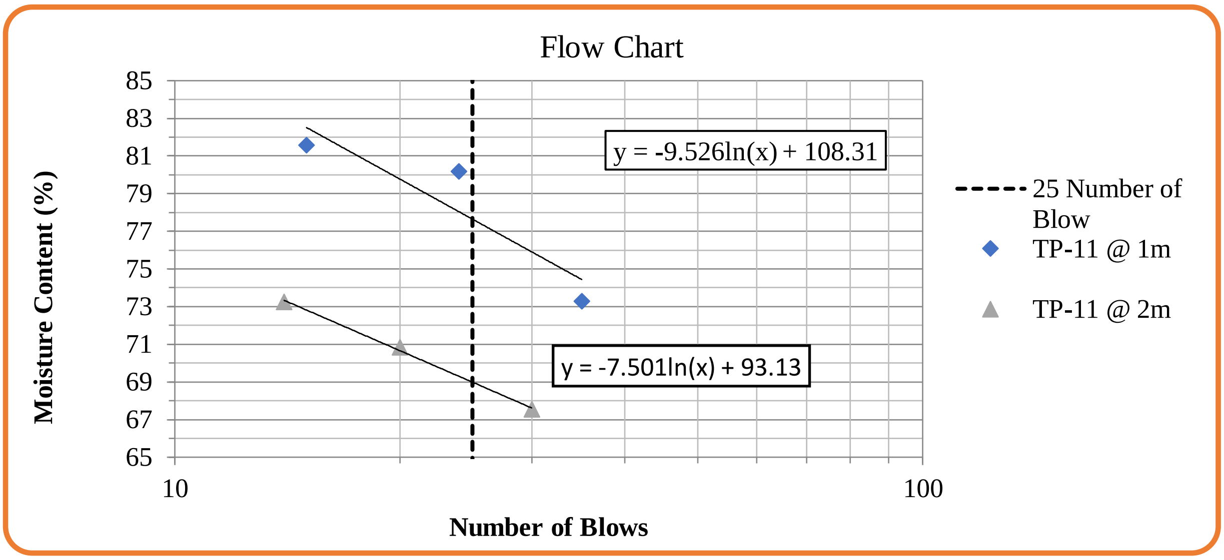
Test pit	TP-9 @1m					TP-9 @2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	35.00	21.00	12.00			37.00	21.00	12.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.62	29.69	37.38	6.73	5.83	26.69	35.60	36.50	20.22	16.30
Wt. of container + wet soil, (g)	30.37	41.68	46.63	13.51	15.40	37.48	46.99	45.87	29.82	22.72
Wt. of container + dry soil, (g)	24.76	36.13	42.24	11.48	12.49	32.68	41.81	41.42	26.53	20.52
Wt. of water, (g)	5.62	5.55	4.39	2.03	2.91	4.81	5.18	4.45	3.29	2.20
Wt. of dry soil, (g)	7.14	6.44	4.86	4.75	6.66	5.99	6.21	4.92	6.32	4.22
Moisture container, (%)	78.62	86.25	90.48	42.86	43.67	80.26	83.50	90.41	52.06	52.19
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	83.0		43.27	39.8		83.2		52.13	31.0	



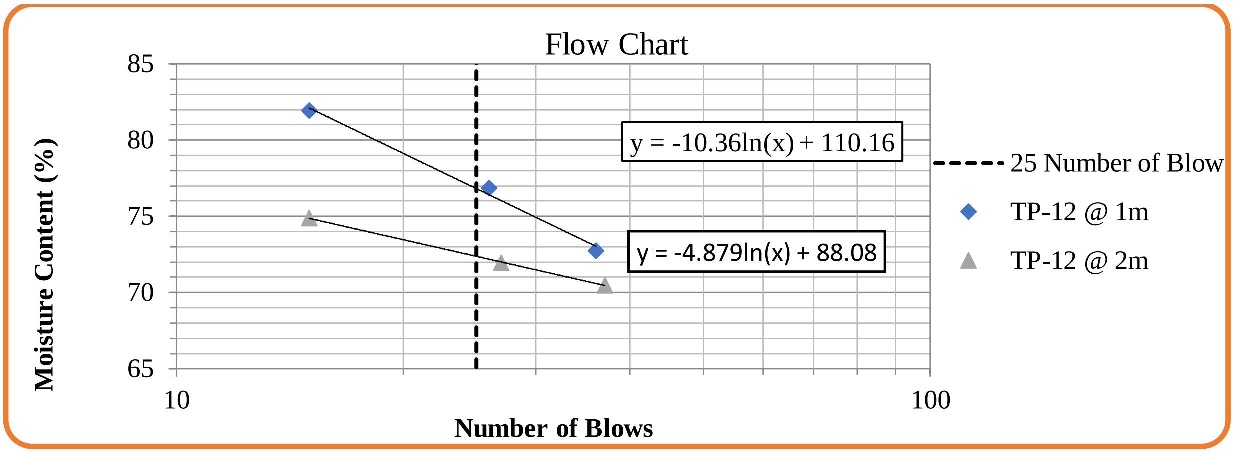
Test pit	TP-10 @1m					TP-10 @2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	34.00	23.00	13.00				25.00			
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	34.81	37.16	40.81	6.16	6.15		41.38		6.08	16.01
Wt. of container + wet soil, (g)	44.73	53.16	51.89	14.40	13.91		57.01		15.71	23.35
Wt. of container + dry soil, (g)	40.39	45.92	46.71	11.69	11.38		50.24		12.42	20.84
Wt. of water, (g)	4.34	7.24	5.17	2.70	2.53		6.76		3.29	2.52
Wt. of dry soil, (g)	5.59	8.77	5.90	5.53	5.23		8.86		6.34	4.83
Moisture container, (%)	77.71	82.59	87.65	48.87	48.39		76.31		51.91	52.08
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	81.2		48.63	32.6		76.3		52.00	24.3	



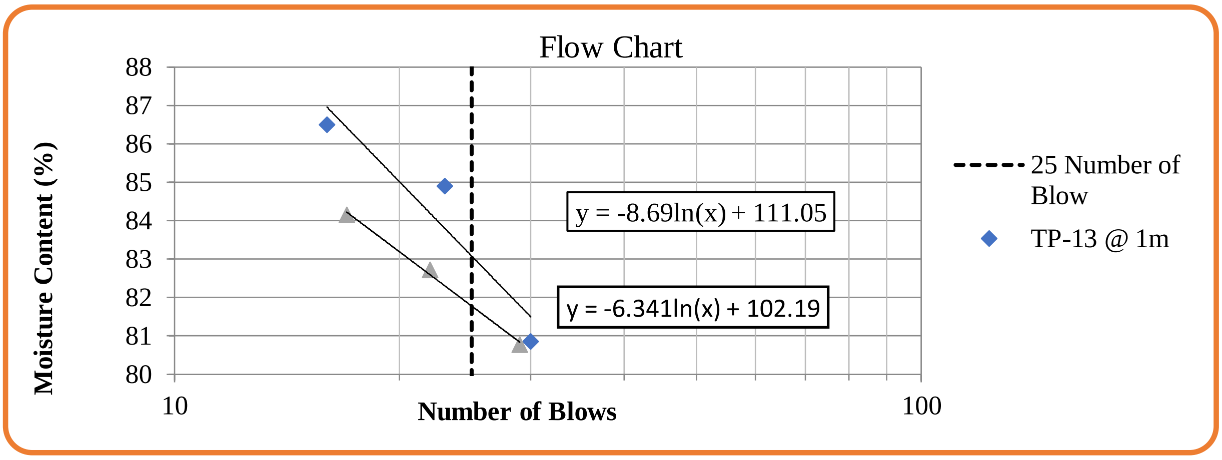
Test pit	TP-11 @ 1m					TP-11 @ 2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	35.00	24.00	15.00			30.00	20.00	14.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	36.58	21.95	19.90	17.25	18.01	36.08	37.72	28.79	6.46	5.75
Wt. of container + wet soil, (g)	47.29	31.13	29.55	26.99	25.43	52.14	49.12	39.83	18.45	18.63
Wt. of container + dry soil, (g)	42.76	27.05	25.21	23.91	23.07	45.67	44.40	35.16	14.26	14.14
Wt. of water, (g)	4.53	4.08	4.34	3.08	2.37	6.47	4.73	4.67	4.19	4.50
Wt. of dry soil, (g)	6.18	5.10	5.32	6.66	5.06	9.58	6.67	6.37	7.80	8.39
Moisture container, (%)	73.26	80.16	81.57	46.25	46.78	67.53	70.84	73.24	53.71	53.64
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	77.6		46.51	31.1		69.0		53.67	15.3	



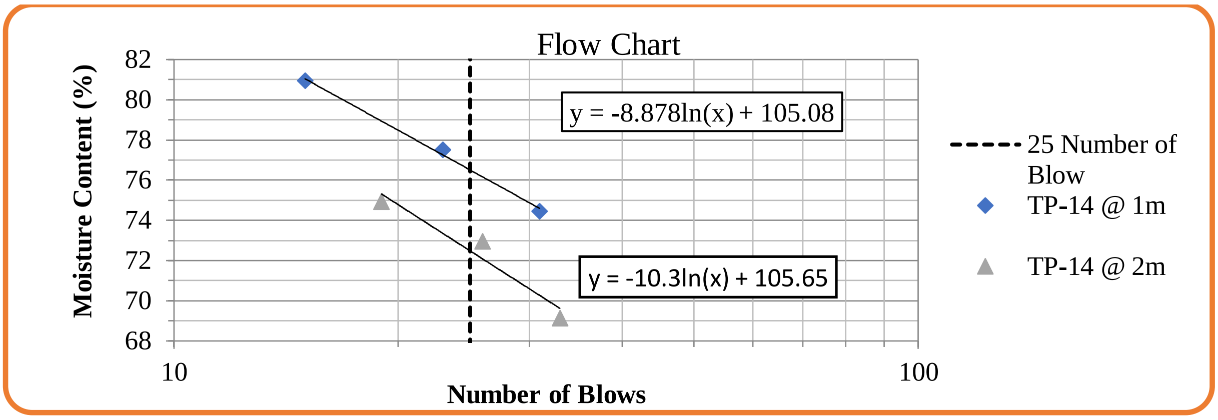
Test pit	TP-12 @ 1m					TP-12 @ 2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	36.00	26.00	15.00			37.00	27.00	15.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.49	17.53	18.38	5.59	5.76	17.93	17.04	17.57	5.72	5.86
Wt. of container + wet soil, (g)	27.28	28.30	29.45	14.03	12.70	28.24	28.07	27.27	15.51	14.93
Wt. of container + dry soil, (g)	23.15	23.62	24.47	11.02	10.19	23.97	23.46	23.12	12.09	11.76
Wt. of water, (g)	4.12	4.68	4.99	3.00	2.52	4.26	4.62	4.15	3.42	3.17
Wt. of dry soil, (g)	5.67	6.09	6.08	5.44	4.43	6.05	6.42	5.55	6.37	5.91
Moisture container, (%)	72.75	76.87	81.94	55.25	56.85	70.49	71.96	74.88	53.70	53.56
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	76.8		56.05	20.8		72.4		53.63	18.7	



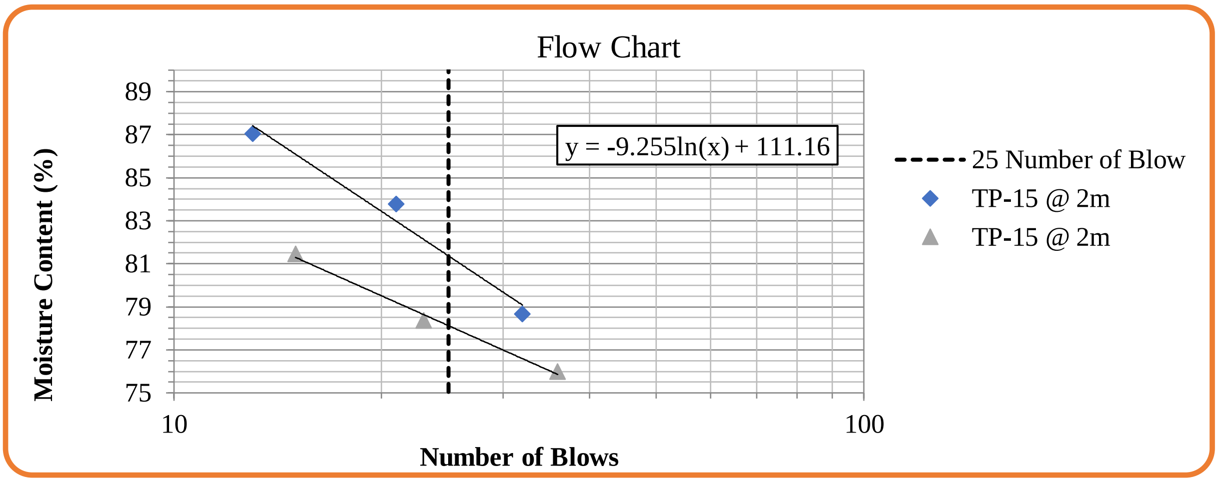
Test pit	TP-13 @ 1m					TP-13 @ 2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	30.00	23.00	16.00			29.00	22.00	17.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.64	17.98	17.52	5.69	5.67	17.16	17.89	17.50	10.89	6.10
Wt. of container + wet soil, (g)	30.89	27.77	28.77	14.61	16.94	28.99	30.86	28.77	20.06	14.78
Wt. of container + dry soil, (g)	24.96	23.27	23.55	11.69	13.23	23.70	24.99	23.62	17.40	12.20
Wt. of water, (g)	5.92	4.50	5.22	2.92	3.72	5.29	5.87	5.15	2.66	2.57
Wt. of dry soil, (g)	7.33	5.29	6.04	6.01	7.56	6.55	7.10	6.12	6.52	6.11
Moisture container, (%)	80.86	84.91	86.50	48.56	49.19	80.78	82.72	84.16	40.83	42.16
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	83.1		48.88	34.2		81.8		41.50	40.3	



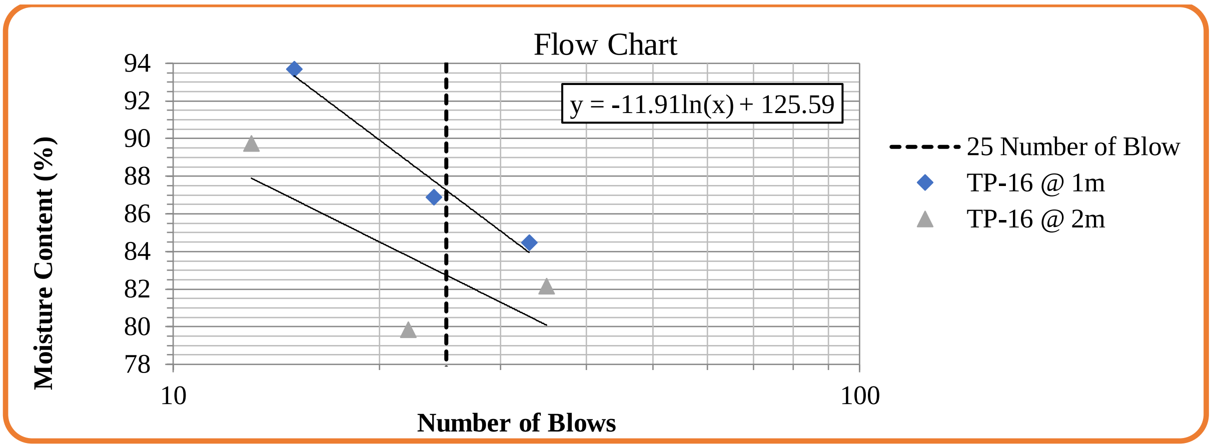
Test pit	TP-14 @ 1m					TP-14 @ 2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	31.00	23.00	15.00			33.00	26.00	19.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.44	17.65	18.55	6.16	5.96	17.44	17.81	17.87	6.06	5.79
Wt. of container + wet soil, (g)	29.62	31.72	30.81	14.69	13.11	29.88	30.65	29.87	14.15	13.48
Wt. of container + dry soil, (g)	24.42	25.58	25.33	11.76	10.71	24.79	25.24	24.73	11.61	11.15
Wt. of water, (g)	5.20	6.14	5.49	2.93	2.40	5.09	5.42	5.14	2.54	2.34
Wt. of dry soil, (g)	6.98	7.93	6.78	5.60	4.75	7.36	7.43	6.86	5.55	5.36
Moisture container, (%)	74.45	77.50	80.94	52.23	50.52	69.13	72.94	74.94	45.66	43.59
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	76.5		51.37	25.1		72.5		44.62	27.9	



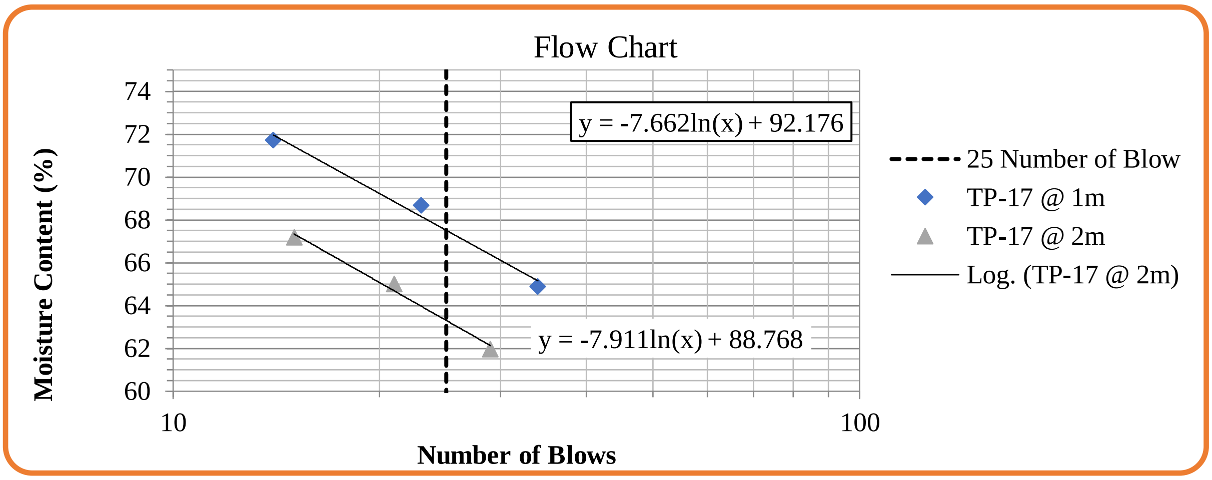
Test pit	TP-15 @ 2m					TP-15 @ 2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	32.00	21.00	13.00			36.00	23.00	15.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.39	23.77	27.29	6.16	5.80	21.87	26.77	27.45	13.04	11.02
Wt. of container + wet soil, (g)	29.83	35.20	37.50	12.92	15.07	33.14	38.61	37.37	21.99	18.05
Wt. of container + dry soil, (g)	24.35	29.99	32.75	10.94	12.33	28.27	33.41	32.92	18.93	15.64
Wt. of water, (g)	5.48	5.21	4.75	1.98	2.74	4.87	5.21	4.46	3.06	2.41
Wt. of dry soil, (g)	6.96	6.22	5.46	4.78	6.53	6.40	6.64	5.47	5.90	4.62
Moisture container, (%)	78.65	83.79	87.04	41.43	41.92	76.00	78.35	81.44	51.93	52.12
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	81.4		41.68	39.7		78.1		52.03	26.1	



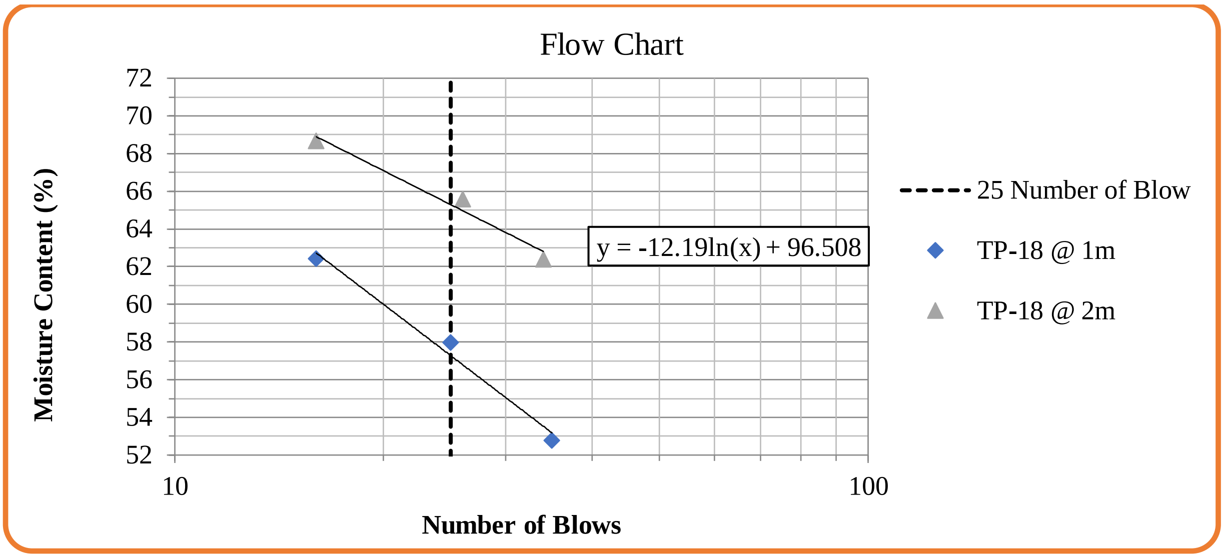
Test pit	TP-16 @ 1m					TP-16 @ 2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	33.00	24.00	15.00			35.00	22.00	13.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	26.12	26.97	29.15	5.97	5.83	18.02	29.40	17.71	11.55	16.04
Wt. of container + wet soil, (g)	37.29	41.03	40.98	14.88	13.17	31.44	43.83	29.52	21.22	24.08
Wt. of container + dry soil, (g)	32.18	34.49	35.26	12.21	10.95	25.39	37.43	23.93	17.87	21.30
Wt. of water, (g)	5.11	6.54	5.72	2.67	2.21	6.06	6.41	5.58	3.35	2.78
Wt. of dry soil, (g)	6.05	7.53	6.11	6.24	5.12	7.37	8.02	6.22	6.33	5.26
Moisture container, (%)	84.45	86.90	93.68	42.72	43.20	82.16	79.85	89.73	52.96	52.89
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	87.3		42.96	44.3		82.7		52.93	29.8	



Test pit	TP-17 @ 1m					TP-17 @ 2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	34.00	23.00	14.00			29.00	21.00	15.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.63	17.97	17.51	5.68	5.67	17.15	17.88	17.49	10.88	6.10
Wt. of container + wet soil, (g)	30.87	27.76	28.76	14.60	16.94	28.98	30.85	28.75	20.05	14.77
Wt. of container + dry soil, (g)	25.66	23.77	24.06	11.60	13.32	24.45	25.74	24.23	17.03	12.07
Wt. of water, (g)	5.21	3.98	4.70	3.00	3.61	4.53	5.11	4.53	3.03	2.70
Wt. of dry soil, (g)	8.03	5.80	6.55	5.92	7.66	7.30	7.86	6.74	6.14	5.97
Moisture container, (%)	64.87	68.66	71.73	50.65	47.18	61.97	65.00	67.19	49.30	45.21
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	67.5		48.91	18.6		63.3		47.26	16.0	



Test pit	TP-18 @ 1m					TP-18 @ 2m				
Determination	Liquid Limit			Plastic Limit		Liquid Limit			Plastic Limit	
Number of blows	35.00	25.00	16.00			34.00	26.00	16.00		
Trial No	01	2.00	03	01	02	01	2.00	03	01	02
Wt. of Container, (g)	17.43	17.64	18.54	6.16	5.96	17.43	17.80	17.87	6.06	5.78
Wt. of container + wet soil, (g)	29.61	31.70	30.80	14.68	13.10	29.86	30.64	29.85	14.14	13.47
Wt. of container + dry soil, (g)	25.40	26.54	26.09	12.01	10.83	25.09	25.55	24.97	11.46	11.01
Wt. of water, (g)	4.21	5.16	4.71	2.67	2.27	4.78	5.09	4.88	2.68	2.47
Wt. of dry soil, (g)	7.97	8.90	7.55	5.86	4.87	7.66	7.75	7.11	5.40	5.23
Moisture container, (%)	52.79	57.96	62.42	45.51	46.60	62.41	65.59	68.67	49.60	47.17
	LL (%)		**PL (%)**	**PI (%)**		**LL (%)**		**PL (%)**	**PI (%)**	
	57.3		46.06	11.2		65.3		48.39	16.9	



4. Laboratory Test Result of Specific Gravity

Test pit No	TP 1@1.5m		TP 2 @1.5m		TP 3 @1.5m		TP 4 @1.5m	
Trials	01	02	01	02	01	02	01	02
Mass of Pycnometer	30.078	30.850	30.838	32.854	30.070	30.786	29.920	30.632
Mass of Pycnometer with Dry Soil	46.382	45.399	46.894	48.243	45.973	45.389	45.743	45.162
Mass of Pycnometer with Dry Soil and Water	136.173	134.898	136.491	134.994	135.845	135.358	135.098	134.681
Mass of Pycnometer and Water	125.770	125.642	126.259	125.200	125.658	126.075	125.030	125.445
Temperature of Pycnometer with Water (T^0_{ci})	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000
Density of water at (T^0_{ci})	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
Temperature of Pycnometer with Soil and Water (T^0_{cx})	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000
Density of water at (T^0_{cx})	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
Corrected Mass of Pycnometer and Water	125.833	125.705	126.322	125.263	125.721	126.138	125.093	125.508
Correction Factor, K at 20^0_c	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
Specific Gravity, Gs at 20^0_c	2.732	2.714	2.725	2.718	2.750	2.711	2.718	2.710
Average Specific Gravity, Gs at 20^0_c	**2.72**		**2.72**		**2.73**		**2.71**	

Test pit No	TP-5@1m		TP-5 @2m		TP-6 @1m		TP-6 @2m	
Trials	01	02	01	02	01	02	01	02
Mass of Pycnometer	29.464	29.767	31.945	29.443	31.367	30.430	30.647	29.915
Mass of Pycnometer with Dry Soil	43.848	45.218	47.367	44.151	48.062	45.540	45.528	46.131
Mass of Pycnometer + Dry Soil + Water	135.575	131.818	136.549	133.026	141.536	133.998	135.212	133.452
Mass of Pycnometer and Water	126.578	122.226	126.699	123.672	131.035	124.527	125.801	123.233
Temperature of Pycnometer with Water (T^0_{ci})	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000
Density of water at (T^0_{ci})	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
Temperature of Pycnometer + Soil + Water (T^0_{cx})	23.000	23.000	23.000	23.000	23.000	23.000	23.000	23.000
Density of water at (T^0_{cx})	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
Corrected Mass of Pycnometer + Water	126.641	122.287	126.763	123.734	131.101	124.589	125.864	123.295
Correction Factor, K at 20^0_c	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
Specific Gravity, Gs at 20^0_c	2.637	2.608	2.735	2.714	2.665	2.648	2.688	2.675
Average Specific Gravity, Gs at 20^0_c	**2.62**		**2.72**		**2.66**		**2.68**	

Test pit Number	TP-7 @1m		TP-7 @2m		TP-8 @1m		TP-8 @2m	
Trials	01	02	01	02	01	02	01	02
Mass of Pycnometer	28.79	30.40	28.51	31.08	30.07	30.85	30.83	32.85
Mass of Pycnometer with Dry Soil	44.50	46.06	43.34	45.94	46.35	47.14	45.88	49.78
Mass of Pycnometer with Dry Soil and Water	134.76	136.62	134.05	134.94	136.02	135.72	135.72	135.81
Mass of Pycnometer and Water	124.80	126.72	124.59	125.48	125.77	125.64	126.26	125.20
Temperature of Pycnometer with Water (T^0_{ci})	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Density of water at (T^0_{ci})	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971
Temperature of Pycnometer with Soil and Water (T^0_{cx})	23.00	23.00	23.00	23.00	28.00	28.00	28.00	28.00
Density of water at (T^0_{cx})	0.998	0.998	0.998	0.998	0.996	0.996	0.996	0.996
Corrected Mass of Pycnometer and Water	124.86	126.78	124.66	125.55	125.67	125.54	126.16	125.10
Correction Factor, K at 20^0_c	0.999	0.999	0.999	0.999	0.998	0.998	0.998	0.998
Specific Gravity, Gs at 20^0_c	2.70	2.69	2.73	2.72	2.74	2.66	2.74	2.72
Average Specific Gravity, Gs at 20^0_c	**2.69**		**2.72**		**2.70**		**2.73**	

Test pit Number	TP-9 @1m		TP-9 @2m		TP-10 @1m		TP-10 @2m	
Trials	01	02	01	02	01	02	01	02
Mass of Pycnometer	30.07	30.78	29.46	29.76	31.94	29.44	31.36	30.43
Mass of Pycnometer with Dry Soil	45.74	47.25	44.99	45.26	47.12	45.59	47.27	47.20
Mass of Pycnometer with Dry Soil and Water	135.41	136.29	136.23	131.80	136.16	133.70	140.87	134.84
Mass of Pycnometer and Water	125.66	126.08	126.58	122.23	126.70	123.67	131.04	124.53
Temperature of Pycnometer with Water (T^0_{ci})	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Density of water at (T^0_{ci})	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971
Temperature of Pycnometer with Soil and Water (T^0_{cx})	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
Density of water at (T^0_{cx})	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996
Corrected Mass of Pycnometer and Water	125.56	125.97	126.48	122.13	126.60	123.57	130.93	124.43
Correction Factor, K at 20^0_c	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
Specific Gravity, Gs at 20^0_c	2.69	2.67	2.68	2.66	2.70	2.68	2.66	2.63
Average Specific Gravity, Gs at 20^0_c	**2.68**		**2.67**		**2.69**		**2.65**	

Test pit Number	TP-11 @ 1m		TP-11 @ 2m		TP-12 @ 1m		TP-12 @ 2m	
Trials	01	02	01	02	01	02	01	02
Mass of Pycnometer	30.64	29.91	28.78	30.40	28.50	31.07	29.00	32.32
Mass of Pycnometer with Dry Soil	44.86	45.03	44.03	45.85	44.26	45.37	49.12	45.73
Mass of Pycnometer with Dry Soil and Water	134.59	132.55	134.24	136.27	134.29	134.30	138.32	136.09
Mass of Pycnometer and Water	125.80	123.23	124.80	126.72	124.59	125.48	125.69	127.76
Temperature of Pycnometer with Water (T^0_{ci})	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Density of water at (T^0_{ci})	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971
Temperature of Pycnometer with Soil and Water (T^0_{cx})	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Density of water at (T^0_{cx})	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
Corrected Mass of Pycnometer and Water	125.73	123.17	124.73	126.65	124.53	125.42	125.62	127.69
Correction Factor, K at 20^0_c	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
Specific Gravity, Gs at 20^0_c	2.65	2.63	2.65	2.65	2.62	2.64	2.71	2.67
Average Specific Gravity, Gs at 20^0_c	**2.64**		**2.65**		**2.63**		**2.69**	

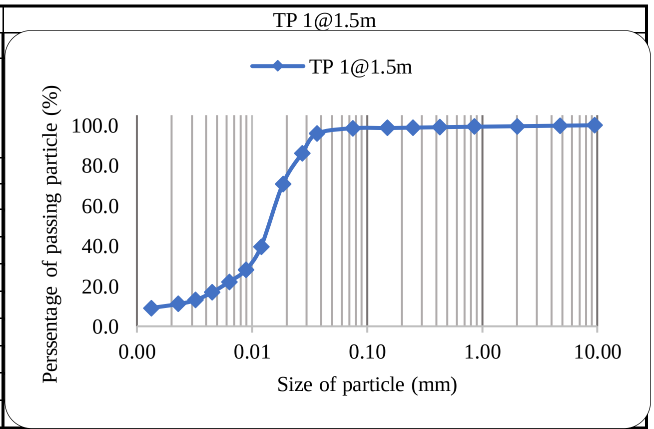
Test pit Number	TP-13 @ 1m		TP-13 @ 2m		TP-14 @ 1m		TP-14 @ 2m	
Trials	01	02	01	02	01	02	01	02
Mass of Pycnometer	29.77	30.31	31.39	31.15	30.72	30.61	30.28	30.27
Mass of Pycnometer with Dry Soil	45.12	45.31	47.13	46.20	47.02	45.47	45.64	45.65
Mass of Pycnometer with Dry Soil and Water	135.70	133.28	136.40	133.88	138.55	134.60	134.99	133.96
Mass of Pycnometer and Water	126.17	123.93	126.48	124.44	128.35	125.30	125.42	124.34
Temperature of Pycnometer with Water (T^0_{ci})	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Density of water at (T^0_{ci})	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971
Temperature of Pycnometer with Soil and Water (T^0_{cx})	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Density of water at (T^0_{cx})	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
Corrected Mass of Pycnometer and Water	126.11	123.87	126.41	124.37	128.28	125.23	125.35	124.27
Correction Factor, K at 20^0_c	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
Specific Gravity, Gs at 20^0_c	2.66	2.68	2.73	2.71	2.70	2.70	2.68	2.70
Average Specific Gravity, Gs at 20^0_c	**2.67**		**2.72**		**2.70**		**2.69**	
Test pit Number	TP-15 @ 1m		TP-15 @ 2m		TP-16 @ 1m		TP-16 @ 2m	

Trials	01	02	01	02	01	02	01	02
Mass of Pycnometer	29.43	30.59	28.98	30.42	31.00	30.14	31.10	31.64
Mass of Pycnometer with Dry Soil	45.12	46.66	44.16	45.60	46.74	46.37	46.57	48.49
Mass of Pycnometer with Dry Soil and Water	135.01	136.45	135.07	133.37	136.09	134.83	138.30	135.46
Mass of Pycnometer and Water	125.23	126.40	125.59	123.86	126.24	124.66	128.65	124.86
Temperature of Pycnometer with Water (T^0_{ci})	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Density of water at (T^0_{ci})	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971
Temperature of Pycnometer with Soil and Water (T^0_{cx})	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Density of water at (T^0_{cx})	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
Corrected Mass of Pycnometer and Water	125.16	126.33	125.52	123.79	126.17	124.59	128.58	124.80
Correction Factor, K at 20^0_c	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
Specific Gravity, Gs at 20^0_c	2.68	2.70	2.69	2.71	2.70	2.71	2.68	2.72
Average Specific Gravity, Gs at 20^0_c	**2.69**		**2.70**		**2.70**		**2.70**	

Test pit Number	TP-17 @ 1m		TP-17 @ 2m		TP-18 @ 1m		TP-18 @ 2m	
Trials	01	02	01	02	01	02	01	02
Mass of Pycnometer	30.71	29.97	28.84	30.46	28.56	31.14	29.06	32.38
Mass of Pycnometer with Dry Soil	44.95	45.12	44.12	45.94	44.35	45.46	49.22	45.83
Mass of Pycnometer with Dry Soil and Water	134.86	132.81	134.50	136.54	134.56	134.57	138.60	136.36
Mass of Pycnometer and Water	126.05	123.48	125.05	126.97	124.84	125.73	125.94	128.01
Temperature of Pycnometer with Water (T^0_{ci})	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Density of water at (T^0_{ci})	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971	0.9971
Temperature of Pycnometer with Soil and Water (T^0_{cx})	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Density of water at (T^0_{cx})	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
Corrected Mass of Pycnometer and Water	125.99	123.41	124.98	126.90	124.78	125.67	125.87	127.94
Correction Factor, K at 20^0_c	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
Specific Gravity, Gs at 20^0_c	2.65	2.63	2.65	2.65	2.62	2.64	2.71	2.67
Average Specific Gravity, Gs at 20^0_c	**2.64**		**2.65**		**2.63**		**2.69**	

5. Laboratory Test Result of Grain Size Analysis Test

Test pit Location					TP 1@1.5m
Total washed soil specimen mass, g				500	
Sieve Size	Mass of Retaining (g)	Percentage of Retaining	Cumulative Retaining	**Percentage of fine particles**	
9.50	0	0.00	0.00	**100.00**	
4.75	1.2	0.24	0.24	**99.76**	
2.00	1.23	0.25	0.49	**99.51**	
0.850	1.38	0.28	0.76	**99.24**	
0.425	1.12	0.22	0.99	**99.01**	
0.250	1.08	0.22	1.20	**98.80**	
0.150	1.01	0.20	1.40	**98.60**	
0.075	0.5	0.10	1.50	**98.50**	
Pan	492.48	98.50	100.00		
Total		500			



Time	Elapsed time t in, min	Actual Hydrometer Reading	Eff. depth, L (cm)	Temperature (c0)	K	C_T	**Par. diameter (mm)**	Value of 'a' for Gs	Corrected hydrometer reading	Percent of Fine part, (%)	**Adjusted percent fines**
10/28/2021/ 4:15:00 AM	0										
10:16:00 AM	1	50	7.9	22	0.0130	0.4	**0.037**	0.9840	49.4	97.2	**95.76**
10:17:00 AM	2	45	8.8	22	0.0130	0.4	**0.027**	0.9840	44.4	87.4	**86.06**
10:20:00 AM	5	37	10.1	22	0.0130	0.4	**0.018**	0.9840	36.4	71.6	**70.56**
10:30:00 AM	15	21	12.7	22	0.0130	0.4	**0.012**	0.9840	20.4	40.1	**39.54**

10:45:00 AM	30	15	13.7	22	0.0130	0.4	**0.009**	0.9840	14.4	28.3	**27.91**
11:15:00 AM	60	12	14.2	22	0.0130	0.4	**0.006**	0.9840	11.4	22.4	**22.10**
12:15:00 PM	120	9	14.7	23	0.0129	0.7	**0.005**	0.9840	8.7	17.1	**16.86**
2:15:00 PM	240	7	15.0	23	0.0129	0.7	**0.003**	0.9840	6.7	13.2	**12.99**
6:15:00 PM	480	6	15.2	23	0.0129	0.7	**0.002**	0.9840	5.7	11.2	**11.05**
29/10/2021 4:15 am	1440	5	15.3	23	0.0129	0.7	**0.001**	0.9840	4.7	9.2	**9.11**

For the other grain size analysis (both wet sieve analysis and hydrometer analysis) combined test result is summarized in the table below.

TP 1@1.5m		TP 2 @1.5m		TP 3 @1.5m		TP 4 @1.5m		TP-5@1m		TP-5 @2m	
Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing
9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000
4.750	99.760	4.750	100.000	4.750	100.000	4.750	100.000	4.750	99.800	4.750	100.000
2.000	99.514	2.000	99.594	2.000	99.954	2.000	99.934	2.000	99.396	2.000	99.906
0.850	99.238	0.850	99.352	0.850	99.754	0.850	99.714	0.850	98.970	0.850	99.730
0.425	99.014	0.425	99.086	0.425	99.460	0.425	99.400	0.425	98.576	0.425	99.482
0.250	98.798	0.250	98.892	0.250	99.232	0.250	99.152	0.250	98.208	0.250	99.204
0.150	98.596	0.150	98.630	0.150	99.028	0.150	98.928	0.150	97.748	0.150	98.896
0.075	98.496	0.075	98.348	0.075	98.782	0.075	98.642	0.075	97.468	0.075	98.646
0.037	95.755	0.037	95.641	0.037	96.217	0.036	98.026	0.039	91.027	0.037	95.880
0.027	86.064	0.028	80.153	0.027	86.479	0.027	88.301	0.029	79.256	0.028	84.234
0.018	70.557	0.019	64.664	0.019	68.949	0.019	70.797	0.020	59.638	0.019	64.825
0.012	39.543	0.012	51.112	0.012	49.472	0.012	51.347	0.012	38.059	0.012	43.476
0.009	27.912	0.009	31.751	0.008	38.370	0.008	40.261	0.009	28.250	0.009	33.771
0.006	22.097	0.006	25.943	0.006	28.632	0.006	30.536	0.007	20.403	0.006	24.649
0.005	16.864	0.004	18.780	0.004	20.841	0.004	22.756	0.005	15.106	0.004	18.827
0.003	12.987	0.003	12.972	0.003	14.997	0.003	16.921	0.003	11.182	0.003	14.945
0.002	11.049	0.002	9.099	0.002	11.102	0.002	13.031	0.002	7.259	0.002	11.063
0.001	9.110	0.001	7.163	0.001	11.102	0.001	11.086	0.001	5.297	0.001	9.122

TP-6 @1m		TP-6 @2m		TP-7 @1m		TP-7 @2m		TP-8 @1m		TP-8 @2m	
Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing
9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000
4.750	99.532	4.750	99.652	4.750	99.740	4.750	99.718	4.750	99.776	4.750	99.614
2.000	99.126	2.000	99.292	2.000	99.492	2.000	99.502	2.000	99.520	2.000	99.272
0.850	98.744	0.850	99.032	0.850	99.266	0.850	99.296	0.850	99.254	0.850	98.878
0.425	98.402	0.425	98.792	0.425	99.062	0.425	99.202	0.425	99.080	0.425	98.576
0.250	98.070	0.250	98.674	0.250	98.894	0.250	98.980	0.250	98.878	0.250	98.148
0.150	97.786	0.150	98.526	0.150	98.634	0.150	98.734	0.150	98.654	0.150	97.732
0.075	97.452	0.075	98.398	0.075	98.554	0.075	98.460	0.075	98.400	0.075	97.370
0.039	90.296	0.038	94.585	0.037	96.434	0.037	95.711	0.037	91.447	0.038	88.810
0.029	78.620	0.028	80.905	0.027	90.577	0.027	86.024	0.028	81.801	0.029	71.584
0.020	61.105	0.019	61.363	0.019	65.200	0.019	60.837	0.019	60.579	0.020	50.530
0.012	39.699	0.012	39.866	0.012	41.775	0.012	37.587	0.012	41.286	0.012	37.132
0.009	26.077	0.009	32.049	0.009	32.014	0.009	27.900	0.009	31.640	0.009	27.562
0.007	16.347	0.006	20.324	0.006	22.254	0.006	18.212	0.006	25.852	0.006	21.820
0.005	11.092	0.005	15.048	0.005	18.350	0.005	14.337	0.004	18.135	0.005	14.164
0.003	9.146	0.003	13.093	0.003	15.031	0.003	11.044	0.003	14.855	0.003	10.910
0.002	7.200	0.002	11.139	0.002	13.079	0.002	9.106	0.002	10.997	0.002	7.082

0.001	5.254	0.001	9.185	0.001	9.175	0.001	5.231	0.001	9.068	0.001	3.254

TP-9 @1m		TP-9 @2m		TP-10 @1m		TP-10 @2m		TP-11 @ 1m		TP-11 @ 2m	
Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing
9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000
4.750	99.830	4.750	99.630	4.750	99.924	4.750	99.724	4.750	99.890	4.750	99.590
2.000	99.602	2.000	99.348	2.000	99.700	2.000	99.480	2.000	99.694	2.000	99.114
0.850	99.356	0.850	99.084	0.850	99.478	0.850	99.258	0.850	99.522	0.850	98.642
0.425	99.112	0.425	98.880	0.425	99.234	0.425	99.014	0.425	99.370	0.425	97.910
0.250	98.944	0.250	98.572	0.250	99.042	0.250	98.818	0.250	99.202	0.250	97.462
0.150	98.680	0.150	98.368	0.150	98.914	0.150	98.630	0.150	98.598	0.150	96.898
0.075	98.630	0.075	98.328	0.075	98.720	0.075	98.432	0.075	97.596	0.075	96.156
0.038	94.863	0.037	96.734	0.037	96.753	0.038	95.339	0.039	88.857	0.040	83.512
0.028	87.023	0.027	88.902	0.028	85.002	0.028	83.520	0.030	73.200	0.030	68.118
0.018	75.263	0.018	77.152	0.019	65.416	0.020	63.822	0.021	49.713	0.021	45.027
0.012	41.943	0.012	43.863	0.012	45.830	0.012	44.124	0.012	36.013	0.013	31.558
0.009	28.224	0.009	30.156	0.009	36.038	0.009	34.275	0.009	28.184	0.009	23.861
0.006	20.384	0.006	22.323	0.006	28.203	0.006	26.396	0.006	22.312	0.007	18.088
0.005	15.092	0.005	17.036	0.005	18.998	0.005	17.137	0.005	18.985	0.005	14.239
0.003	11.172	0.003	13.120	0.003	15.081	0.003	13.198	0.003	15.071	0.003	10.968
0.002	9.212	0.002	11.162	0.002	11.164	0.002	9.258	0.002	11.156	0.002	7.120
0.001	7.252	0.001	5.287	0.001	9.205	0.001	7.288	0.001	9.199	0.001	5.195

TP-12 @ 1m		TP-12 @ 2m		TP-13 @ 1m		TP-13 @ 2m		TP-14 @ 1m		TP-14 @ 2m	
Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing
9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000
4.750	100.000	4.750	99.760	4.750	99.780	4.750	100.000	4.750	99.766	4.750	99.826
2.000	99.772	2.000	99.452	2.000	99.454	2.000	99.750	2.000	99.540	2.000	99.612
0.850	99.528	0.850	99.168	0.850	99.102	0.850	99.540	0.850	99.248	0.850	99.372
0.425	99.196	0.425	98.896	0.425	98.792	0.425	99.282	0.425	98.930	0.425	99.094
0.250	98.848	0.250	98.648	0.250	98.500	0.250	99.046	0.250	98.650	0.250	98.910
0.150	98.564	0.150	98.364	0.150	98.168	0.150	98.760	0.150	98.406	0.150	98.724
0.075	98.182	0.075	97.982	0.075	97.978	0.075	98.494	0.075	98.116	0.075	98.516
0.039	93.514	0.037	95.980	0.038	94.420	0.037	95.733	0.037	93.925	0.037	96.443
0.028	85.623	0.028	80.437	0.028	82.715	0.028	82.168	0.028	82.281	0.028	84.729
0.020	61.948	0.020	57.122	0.019	65.157	0.019	64.727	0.019	64.816	0.019	67.159
0.012	42.219	0.012	37.693	0.012	39.797	0.012	47.285	0.012	45.410	0.012	45.683
0.009	32.355	0.009	27.978	0.009	28.092	0.009	33.720	0.009	31.826	0.009	35.922
0.007	22.491	0.006	18.263	0.006	22.239	0.006	25.968	0.006	22.123	0.006	26.161
0.005	18.545	0.005	14.378	0.005	16.972	0.004	18.798	0.005	16.883	0.005	18.937
0.003	15.191	0.003	11.075	0.003	13.070	0.003	14.922	0.003	13.002	0.003	15.033
0.002	13.218	0.002	9.132	0.002	9.169	0.002	11.046	0.002	9.121	0.002	13.080
0.001	11.245	0.001	7.189	0.001	7.218	0.001	9.108	0.001	9.121	0.001	11.128

TP-15 @ 1m		TP-15 @ 2m		TP-16 @ 1m		TP-16 @ 2m	
Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing
9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000
4.750	99.784	4.750	99.674	4.750	99.850	4.750	99.668

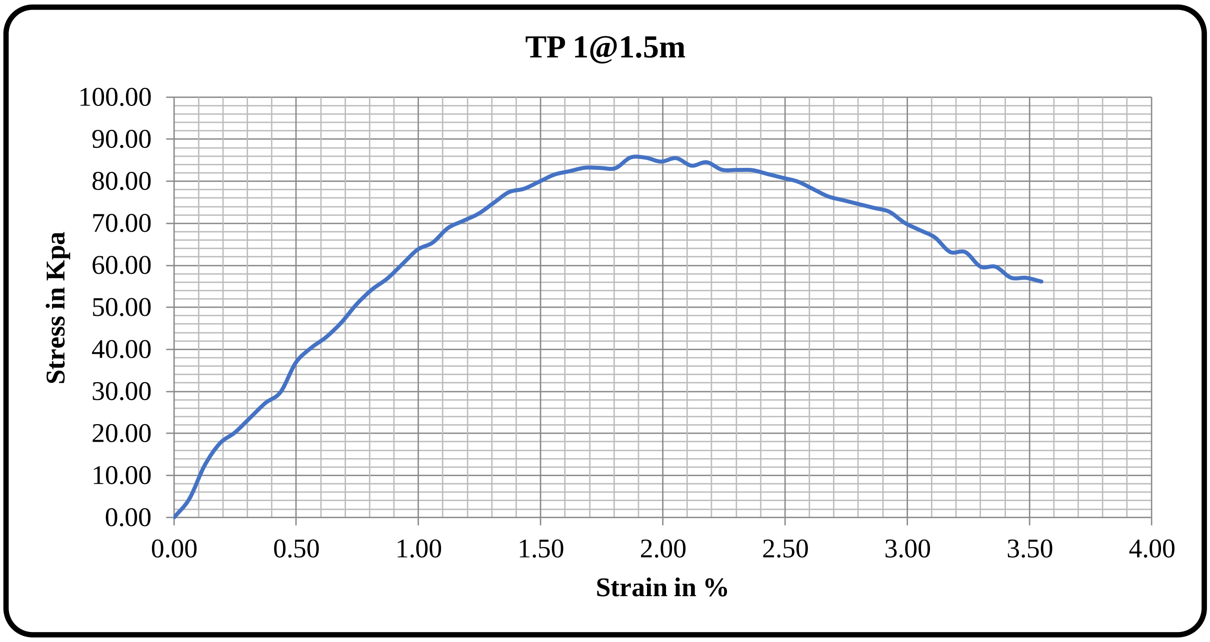
2.000	99.546	2.000	99.424	2.000	99.610	2.000	99.374
0.850	99.310	0.850	99.188	0.850	99.366	0.850	99.066
0.425	99.086	0.425	99.038	0.425	99.156	0.425	98.792
0.250	98.918	0.250	98.772	0.250	98.958	0.250	98.480
0.150	98.656	0.150	98.546	0.150	98.782	0.150	98.178
0.075	98.590	0.075	98.388	0.075	98.558	0.075	97.898
0.037	96.521	0.037	96.111	0.037	94.247	0.038	93.730
0.027	88.705	0.027	88.329	0.028	84.511	0.028	79.888
0.019	71.121	0.019	68.873	0.019	63.091	0.020	58.136
0.012	41.813	0.012	41.635	0.012	43.619	0.012	42.317
0.009	30.089	0.009	29.962	0.009	33.882	0.009	32.430
0.006	22.274	0.006	20.234	0.006	28.040	0.006	24.520
0.005	16.999	0.005	16.926	0.005	18.888	0.005	17.204
0.003	13.091	0.003	13.035	0.003	14.994	0.003	13.249
0.002	11.137	0.002	11.090	0.002	11.099	0.002	9.294
0.001	9.183	0.001	5.253	0.001	7.205	0.001	5.339

TP-17 @ 1m		TP-17 @ 2m		TP-18 @ 1m		TP-18 @ 2m	
Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing	Grain Size (mm)	Combined % passing
9.500	100.000	9.500	100.000	9.500	100.000	9.500	100.000
4.750	99.670	4.750	98.770	4.750	99.200	4.750	99.640
2.000	99.082	2.000	97.342	2.000	98.516	2.000	99.178
0.850	98.566	0.850	95.926	0.850	97.784	0.850	98.752
0.425	98.110	0.425	93.730	0.425	96.788	0.425	98.344
0.250	97.606	0.250	92.386	0.250	95.744	0.250	97.972
0.150	95.794	0.150	90.694	0.150	94.892	0.150	97.546
0.075	92.788	0.075	88.468	0.075	93.746	0.075	96.972
0.038	90.065	0.039	82.145	0.040	83.636	0.038	91.142
0.029	75.178	0.029	67.982	0.029	76.101	0.028	81.528
0.020	52.848	0.020	46.738	0.020	53.497	0.020	58.454
0.012	39.822	0.012	34.345	0.012	34.660	0.012	39.226
0.009	32.379	0.009	27.264	0.009	25.241	0.009	29.612
0.006	26.796	0.006	21.953	0.007	15.823	0.006	19.997
0.005	23.633	0.005	18.943	0.005	12.621	0.005	16.729
0.003	16.189	0.003	11.862	0.003	8.853	0.003	12.883
0.002	12.468	0.002	8.321	0.002	6.970	0.002	10.960
0.001	10.607	0.001	6.550	0.001	3.202	0.001	9.037

6. Laboratory Test Result of Unconfined Compression Test

Detaille analyzed test result of unconfined compression test for test pit 1 at 1.5m depth is shown in the blow table. But for the other 31 sample specimens is presented only the information of the specimens, peak UCS value, C value, and the stress strain curve of the specimens.

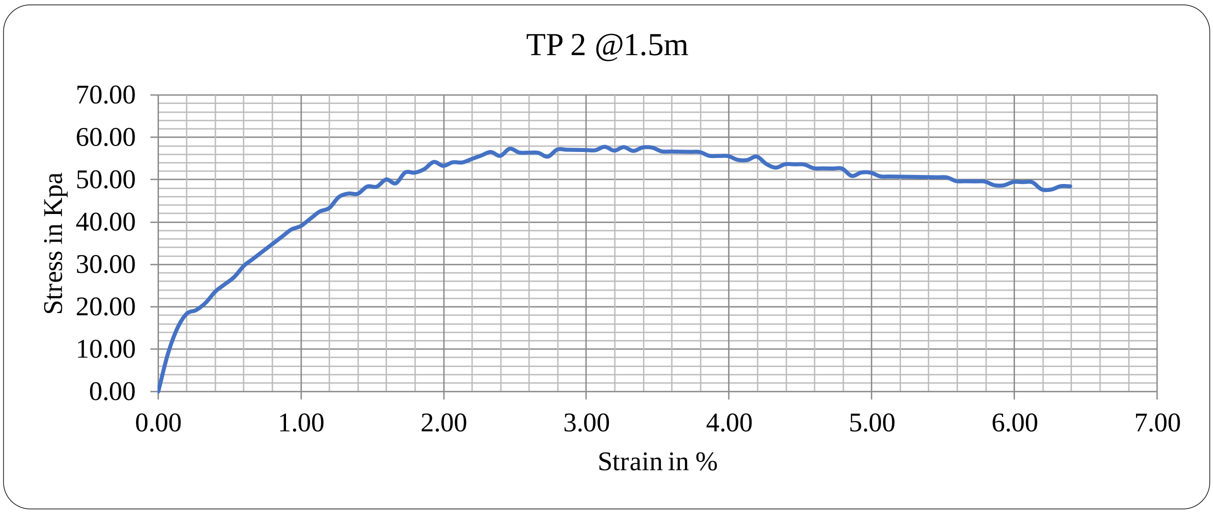
Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP 1@1.5m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
80.3	86	43



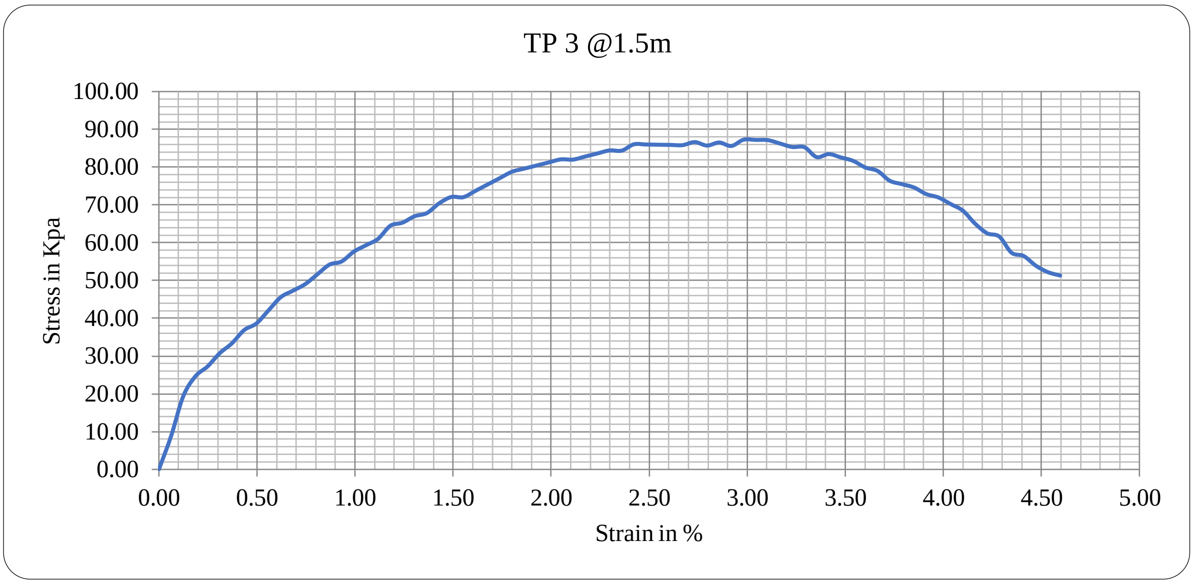
Specimens' Deformation ΔL (mm)	Resisting Reading Load (N)	Sample Height (mm)	Sample Actual Area (cm^2)	Strain	Strain in %	Corrected Area (cm^2)	Stress (kPa)
0.00	0.00	80.30	11.34	0.000	0.00	11.34	0.00
0.05	5	80.30	11.34	0.001	0.06	11.35	4.41
0.10	14	80.30	11.34	0.001	0.12	11.36	12.33
0.15	20	80.30	11.34	0.002	0.19	11.36	17.60
0.20	23	80.30	11.34	0.002	0.25	11.37	20.23
0.25	27	80.30	11.34	0.003	0.31	11.38	23.73
0.30	31	80.30	11.34	0.004	0.37	11.38	27.23
0.35	34	80.30	11.34	0.004	0.44	11.39	29.85
0.40	42	80.30	11.34	0.005	0.50	11.40	36.85
0.45	46	80.30	11.34	0.006	0.56	11.41	40.33
0.50	49	80.30	11.34	0.006	0.62	11.41	42.94
0.55	53	80.30	11.34	0.007	0.68	11.42	46.41
0.60	58	80.30	11.34	0.007	0.75	11.43	50.76

0.65	62	80.30	11.34	0.008	0.81	11.43	54.23
0.70	65	80.30	11.34	0.009	0.87	11.44	56.81
0.75	69	80.30	11.34	0.009	0.93	11.45	60.27
0.80	73	80.30	11.34	0.010	1.00	11.46	63.73
0.85	75	80.30	11.34	0.011	1.06	11.46	65.43
0.90	79	80.30	11.34	0.011	1.12	11.47	68.88
0.95	81	80.30	11.34	0.012	1.18	11.48	70.58
1.00	83	80.30	11.34	0.012	1.25	11.48	72.27
1.05	86	80.30	11.34	0.013	1.31	11.49	74.84
1.10	89	80.30	11.34	0.014	1.37	11.50	77.40
1.15	90	80.30	11.34	0.014	1.43	11.51	78.22
1.20	92	80.30	11.34	0.015	1.49	11.51	79.91
1.25	94	80.30	11.34	0.016	1.56	11.52	81.59
1.30	95	80.30	11.34	0.016	1.62	11.53	82.41
1.35	96	80.30	11.34	0.017	1.68	11.54	83.22
1.40	96	80.30	11.34	0.017	1.74	11.54	83.17
1.45	96	80.30	11.34	0.018	1.81	11.55	83.12
1.50	99	80.30	11.34	0.019	1.87	11.56	85.66
1.55	99	80.30	11.34	0.019	1.93	11.56	85.61
1.60	98	80.30	11.34	0.020	1.99	11.57	84.69
1.65	99	80.30	11.34	0.021	2.05	11.58	85.50
1.70	97	80.30	11.34	0.021	2.12	11.59	83.72
1.75	98	80.30	11.34	0.022	2.18	11.59	84.53
1.80	96	80.30	11.34	0.022	2.24	11.60	82.75
1.85	96	80.30	11.34	0.023	2.30	11.61	82.70
1.90	96	80.30	11.34	0.024	2.37	11.62	82.64
1.95	95	80.30	11.34	0.024	2.43	11.62	81.73
2.00	94	80.30	11.34	0.025	2.49	11.63	80.82
2.05	93	80.30	11.34	0.026	2.55	11.64	79.91
2.10	91	80.30	11.34	0.026	2.62	11.65	78.14
2.15	89	80.30	11.34	0.027	2.68	11.65	76.37
2.20	88	80.30	11.34	0.027	2.74	11.66	75.47
2.25	87	80.30	11.34	0.028	2.80	11.67	74.56
2.30	86	80.30	11.34	0.029	2.86	11.68	73.66
2.35	85	80.30	11.34	0.029	2.93	11.68	72.75
2.40	82	80.30	11.34	0.030	2.99	11.69	70.14
2.45	80	80.30	11.34	0.031	3.05	11.70	68.39
2.50	78	80.30	11.34	0.031	3.11	11.71	66.63
2.55	74	80.30	11.34	0.032	3.18	11.71	63.18
2.60	74	80.30	11.34	0.032	3.24	11.72	63.14
2.65	70	80.30	11.34	0.033	3.30	11.73	59.69
2.70	70	80.30	11.34	0.034	3.36	11.74	59.65
2.75	67	80.30	11.34	0.034	3.42	11.74	57.05
2.80	67	80.30	11.34	0.035	3.49	11.75	57.02
2.85	66	80.30	11.34	0.035	3.55	11.76	56.13

Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP 2 @1.5m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
75.1	58	29

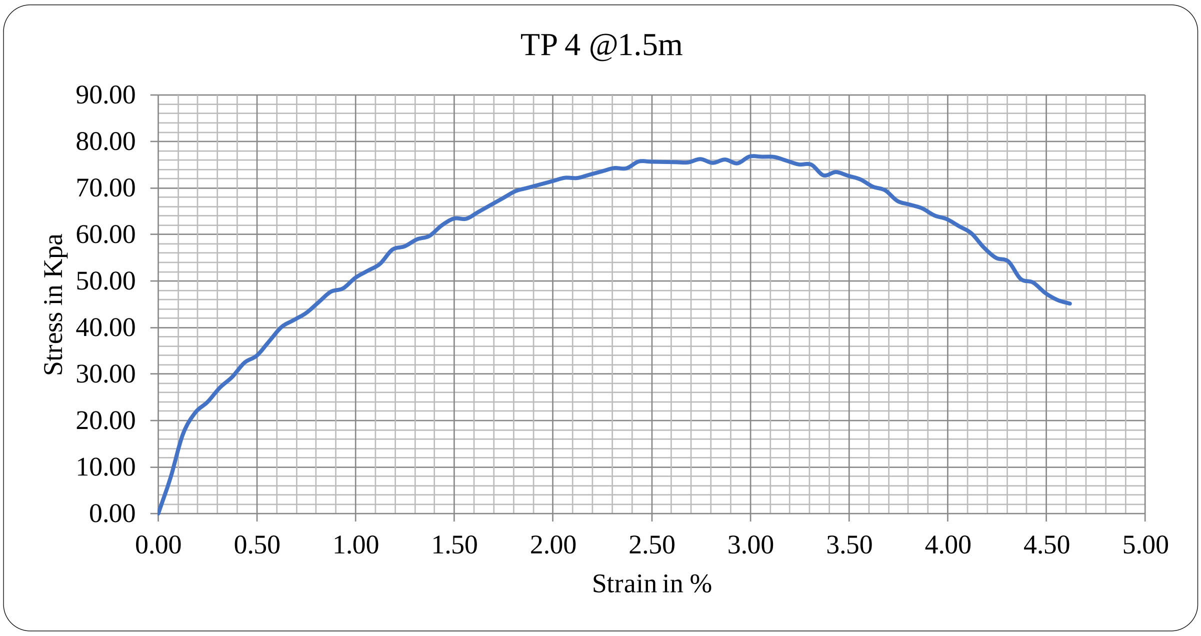


Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP 3 @1.5m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
80.50	87	44



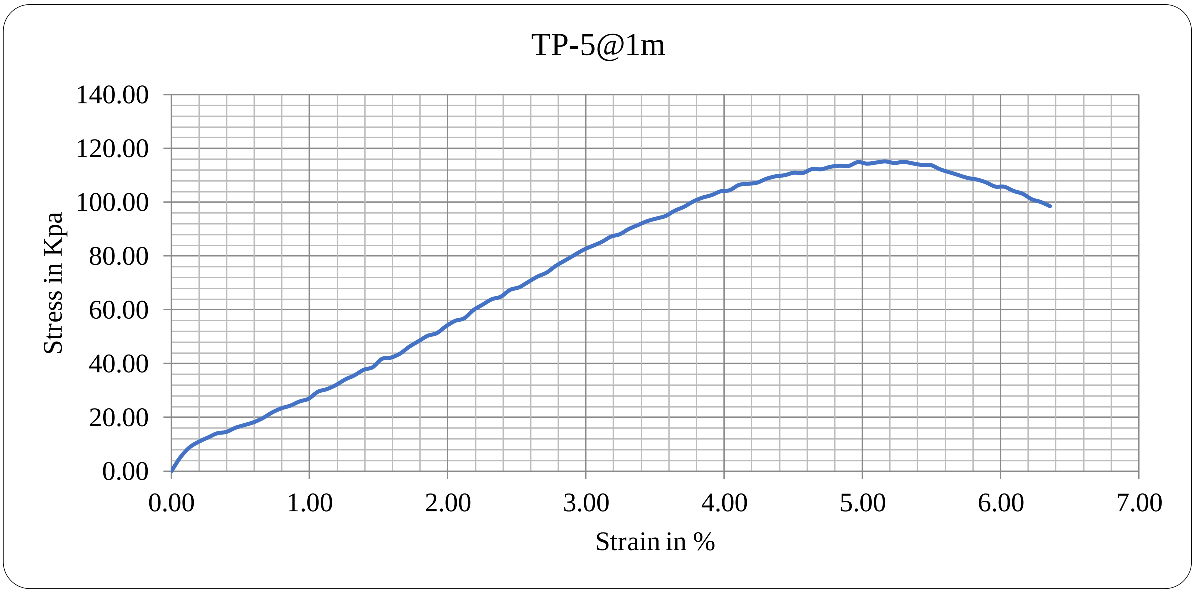
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP 4 @1.5m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
80.10	77	38



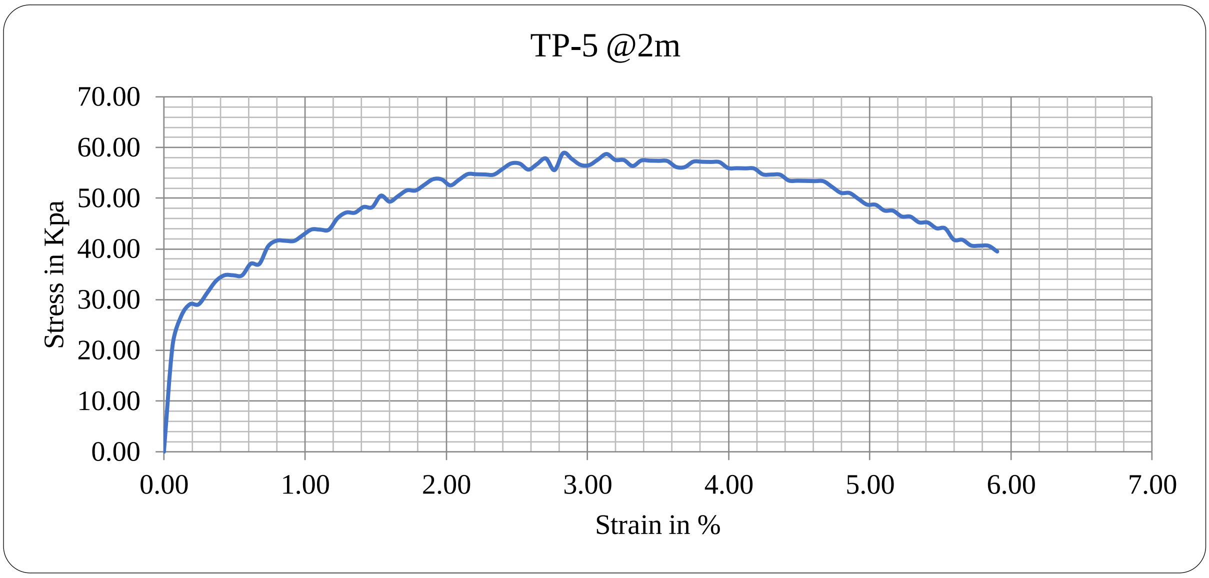
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-5@1m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
75.50	115	58



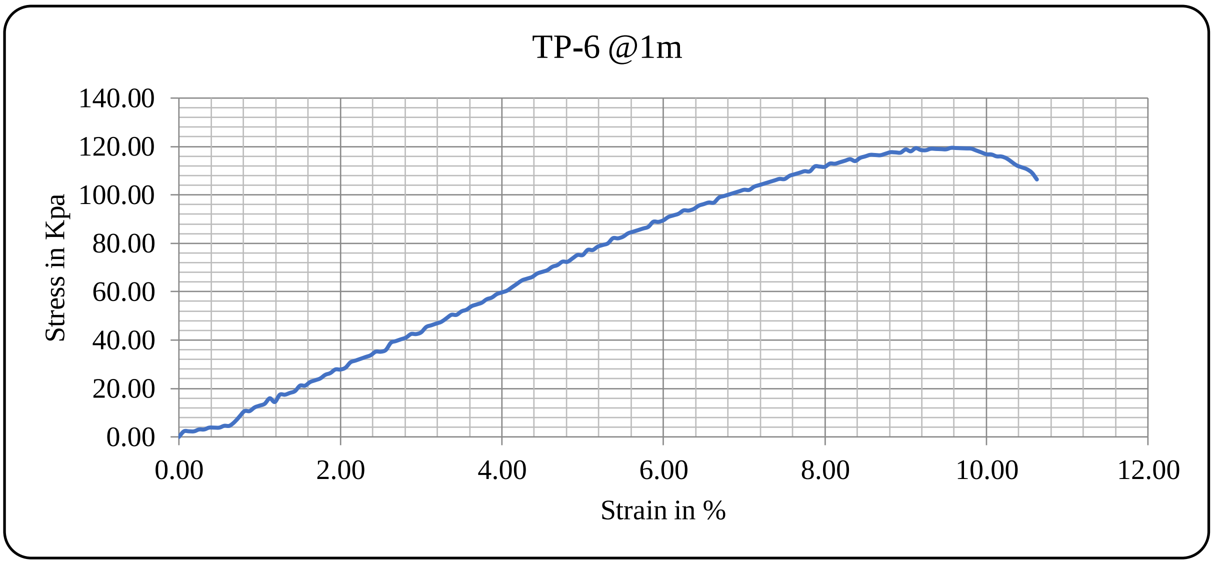
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-5 @2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
81.30	59	29

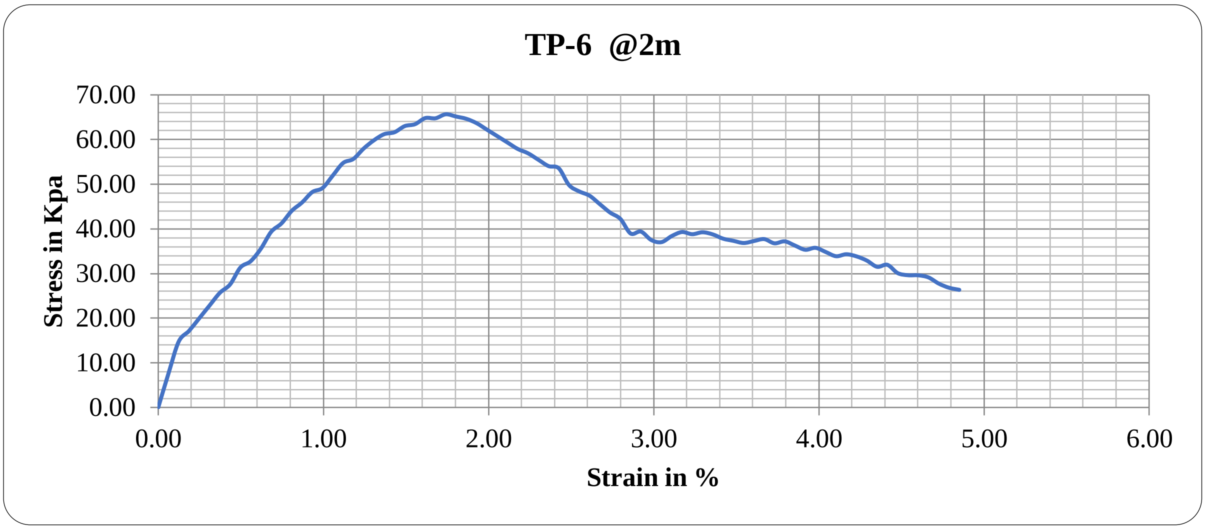


Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-6 @1m

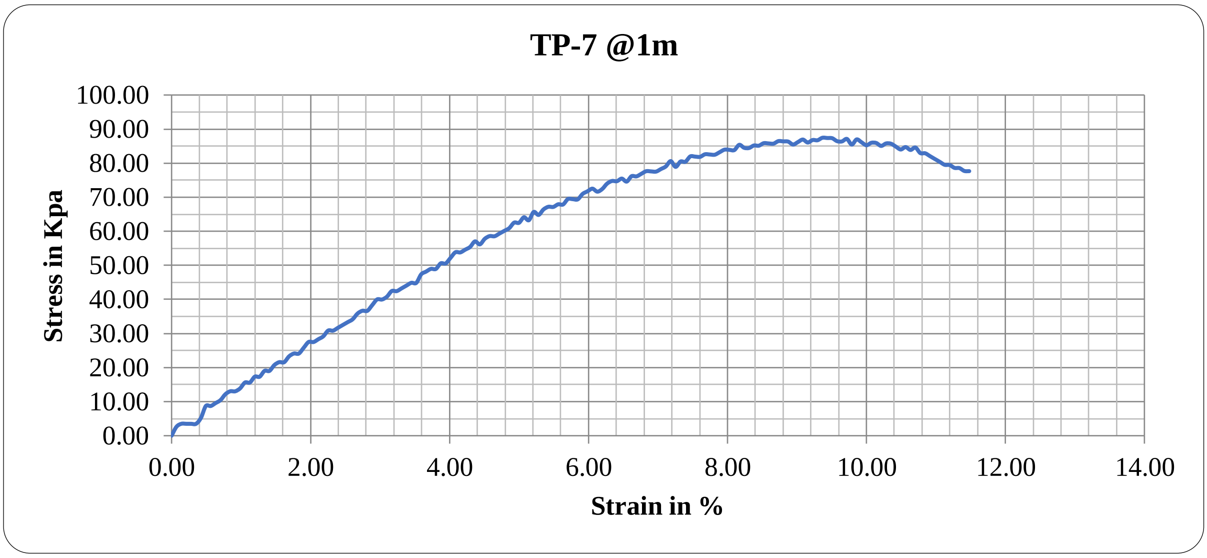
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
80.00	119	60



Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP-6 @2m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
80.40	66	33

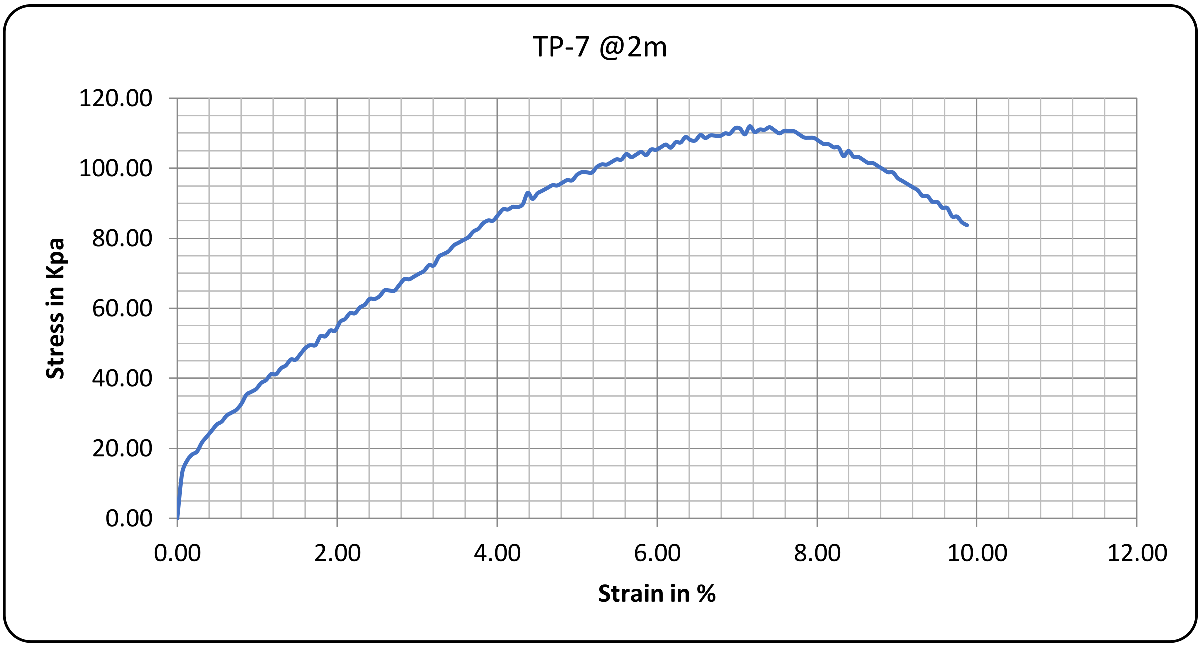


Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP-7 @1m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
71.00	87	44

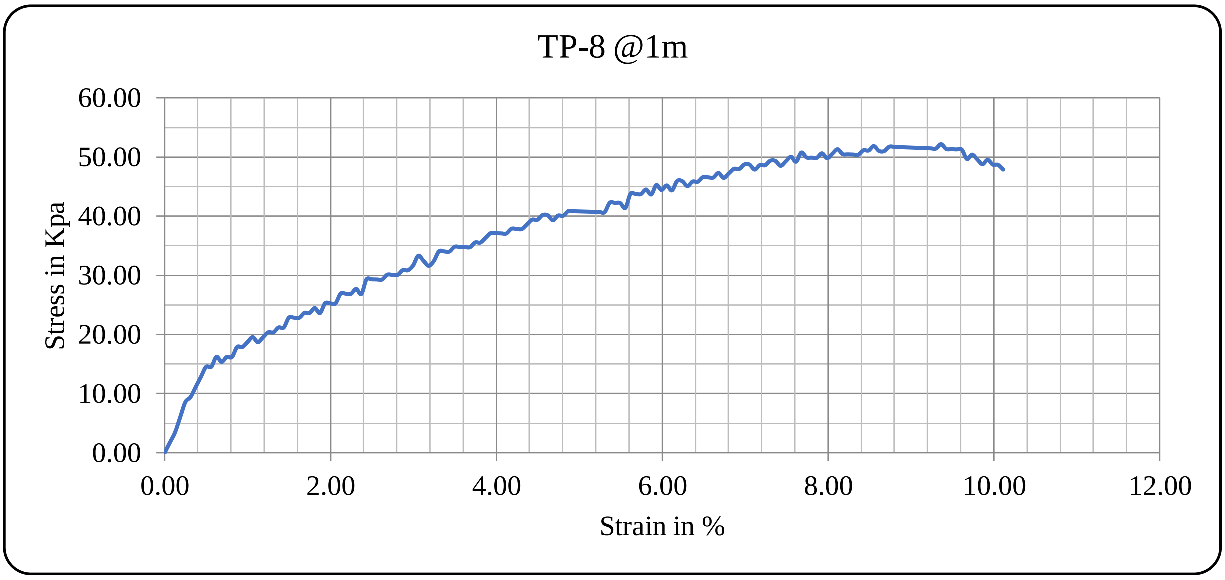


Test Type	Unconfined Compression Test (ASTM D-2166)

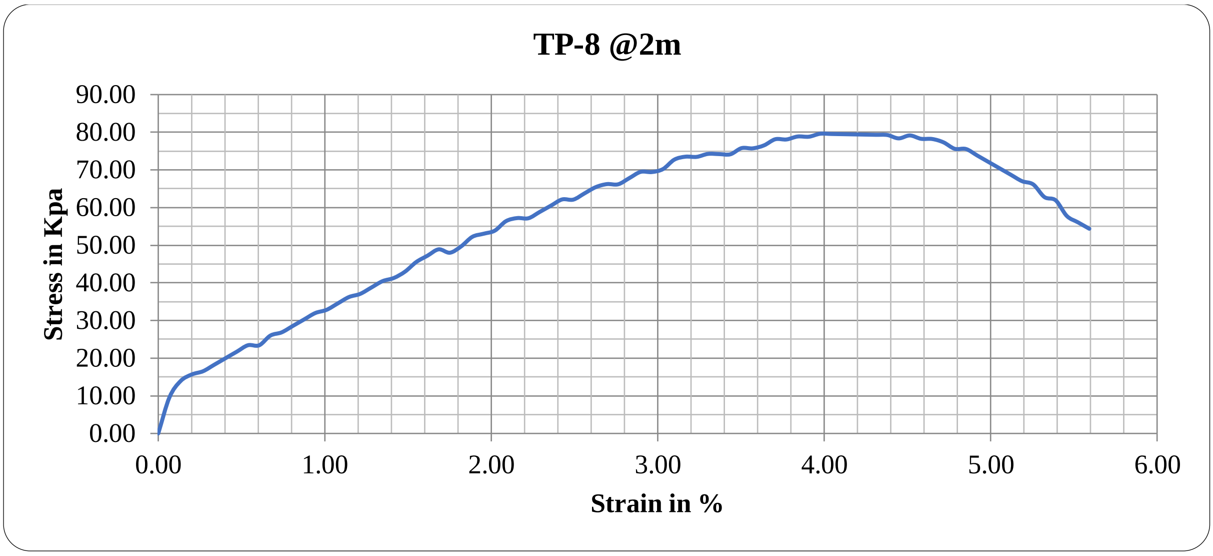
Type of Sample	Undisturbed Soil Sample		
Sample Diameter	38mm		
Test Pit Location	TP-7 @2m		
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)	
81.00	112	56	



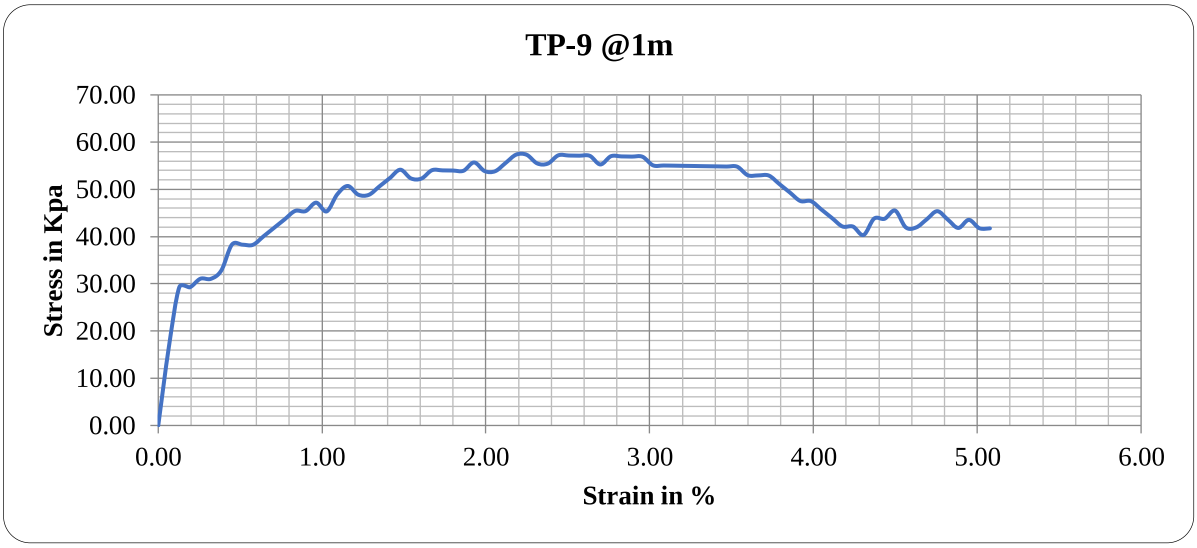
Test Type	Unconfined Compression Test (ASTM D-2166)		
Type of Sample	Undisturbed Soil Sample		
Sample Diameter	38mm		
Test Pit Location	TP-8 @1m		
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)	
80.10	52	26	



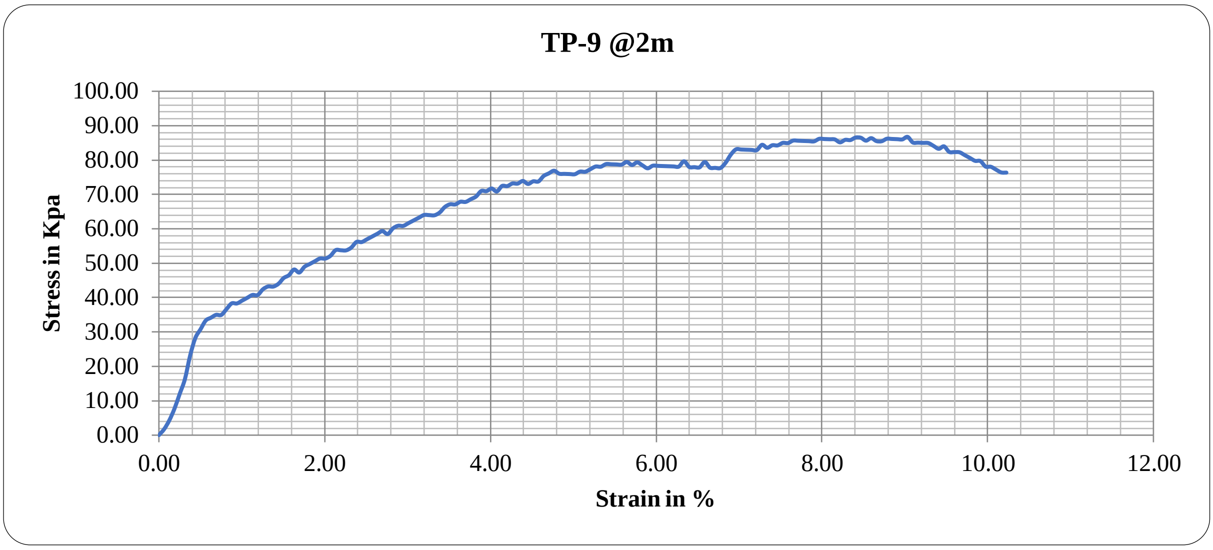
Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP-8 @2m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
74.20	80	40



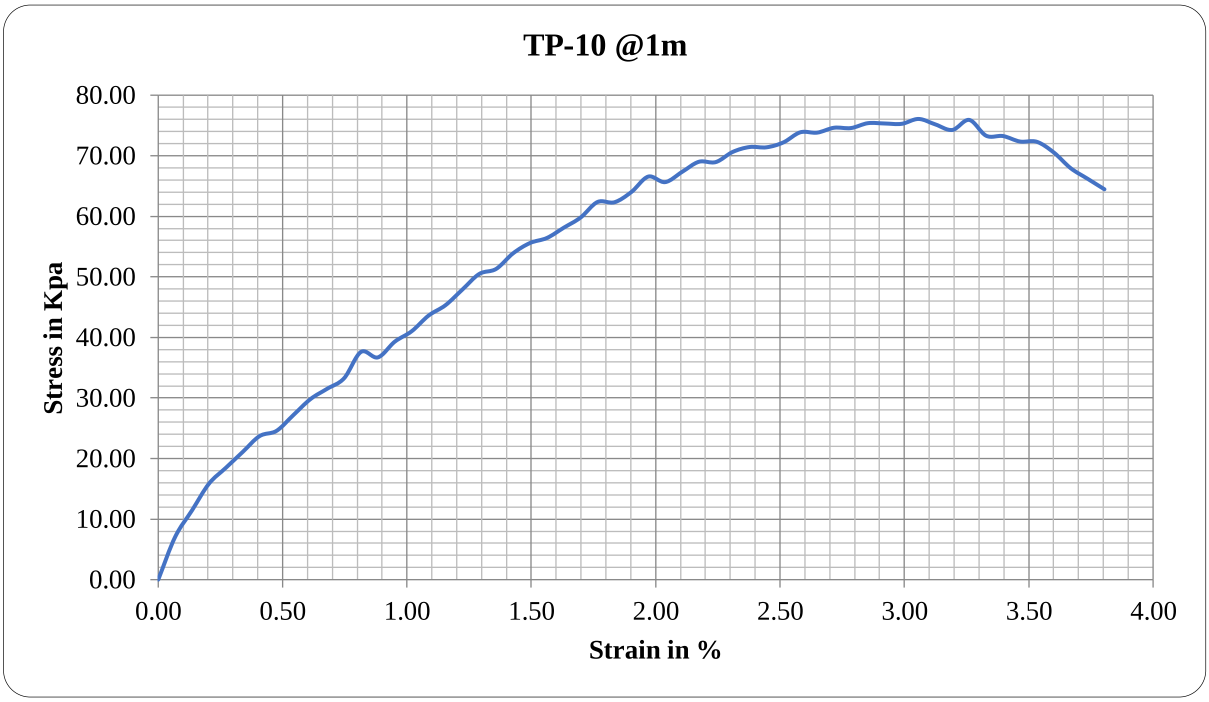
Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP-9 @1m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
77.80	57	29



Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP-9 @2m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
79.70	87	43

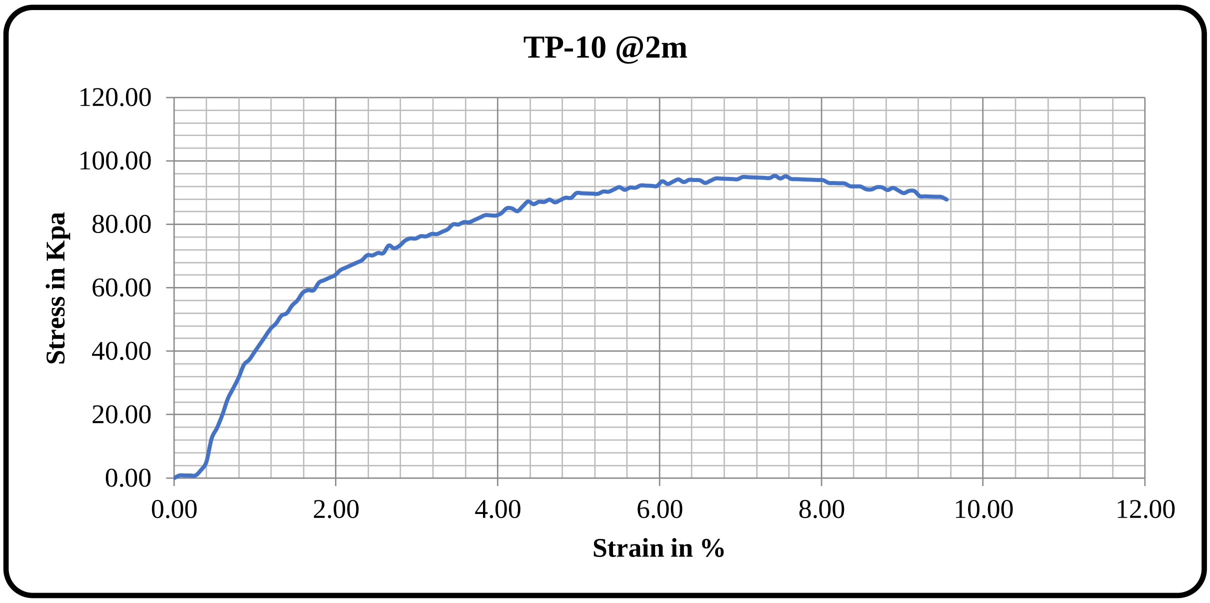


Test Type	Unconfined Compression Test (ASTM D-2166)	
Type of Sample	Undisturbed Soil Sample	
Sample Diameter	38mm	
Test Pit Location	TP-10 @1m	
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
73.60	76	38



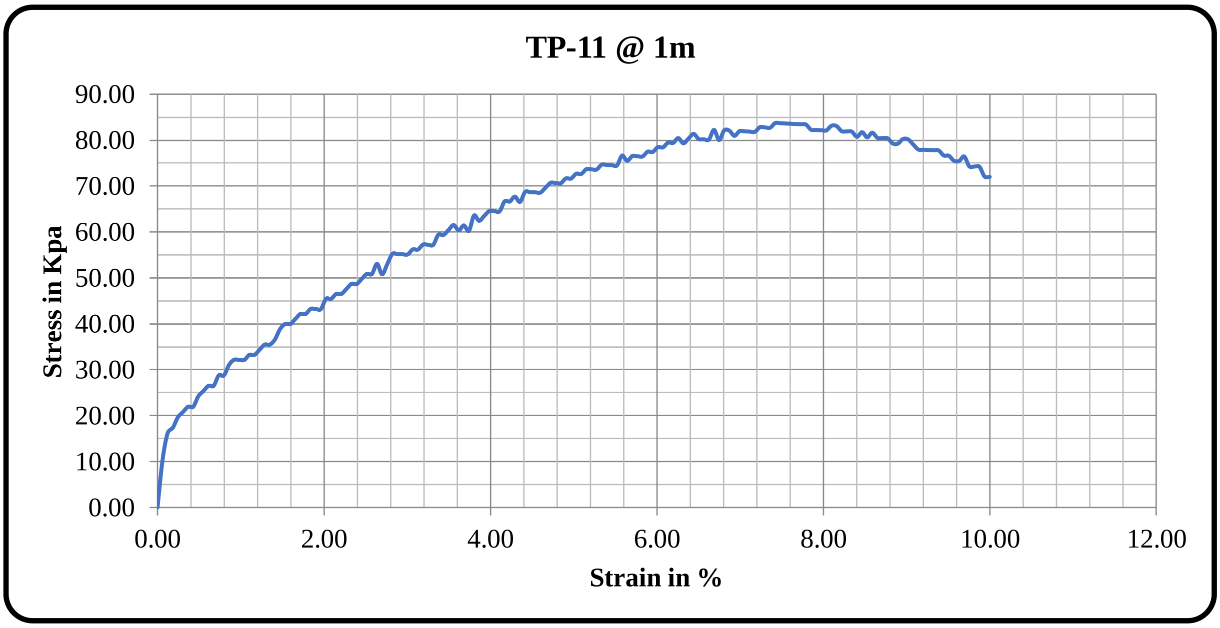
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-10 @2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
75.40	95	48

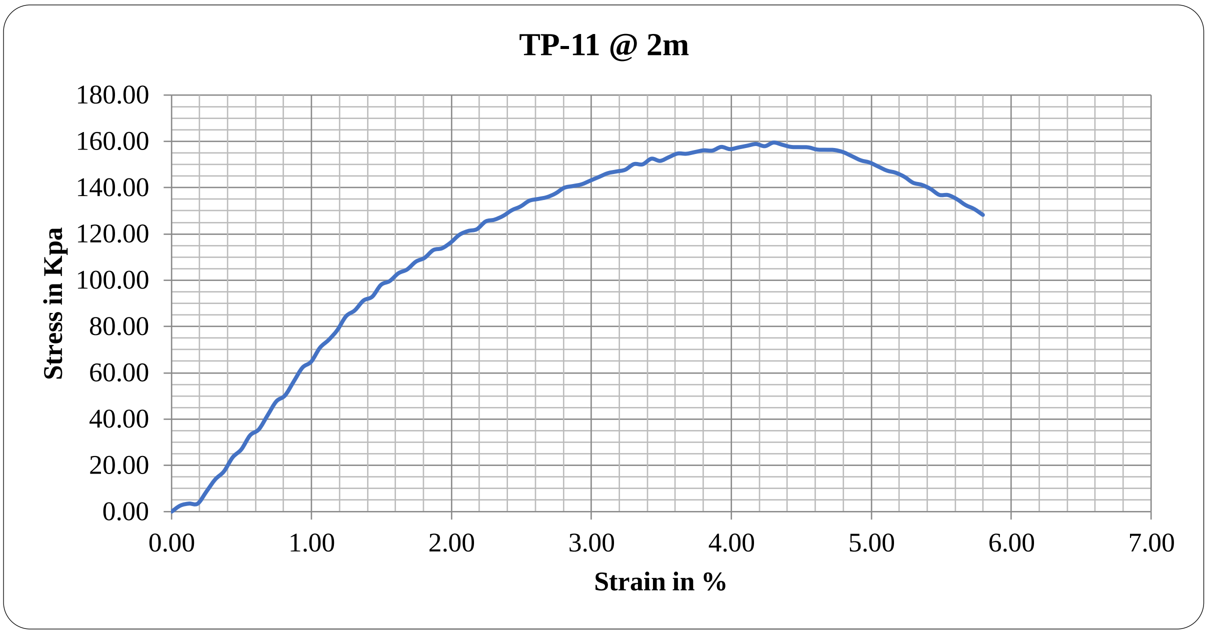


Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-11 @ 1m

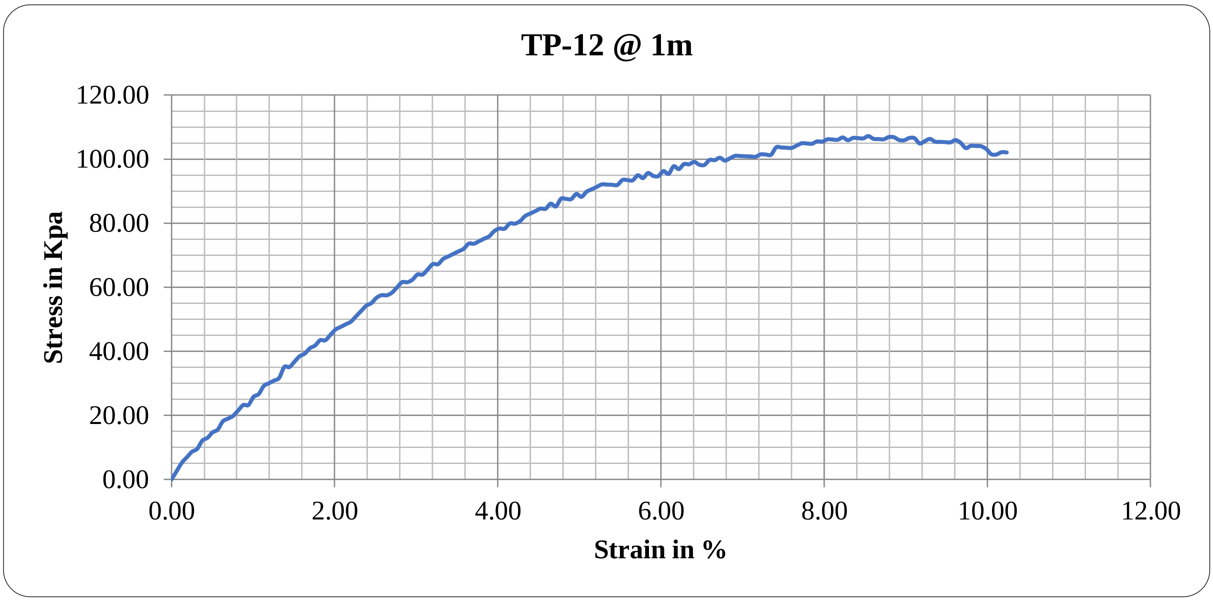
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
81.50	84	42



Test Type	Unconfined Compression Test (ASTM D-2166)		
Type of Sample	Undisturbed Soil Sample		
Sample Diameter	38mm		
Test Pit Location	TP-11 @ 2m		
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)	
80.20	159	80	

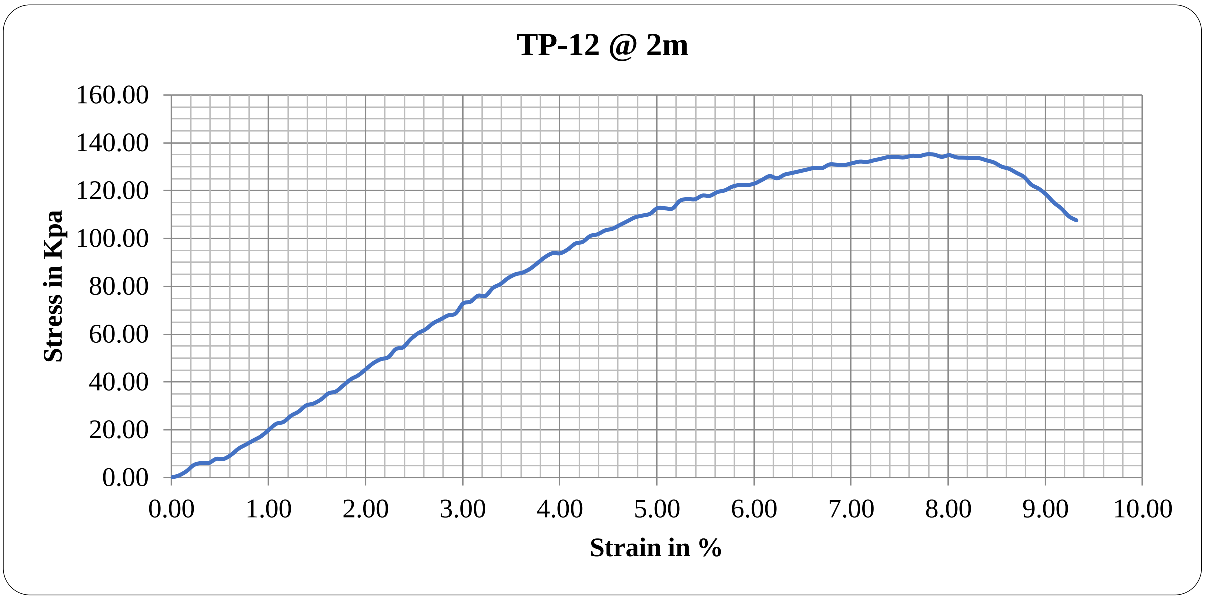


Test Type	Unconfined Compression Test (ASTM D-2166)		
Type of Sample	Undisturbed Soil Sample		
Sample Diameter	38mm		
Test Pit Location	TP-12 @ 1m		
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)	
79.60	107	54	



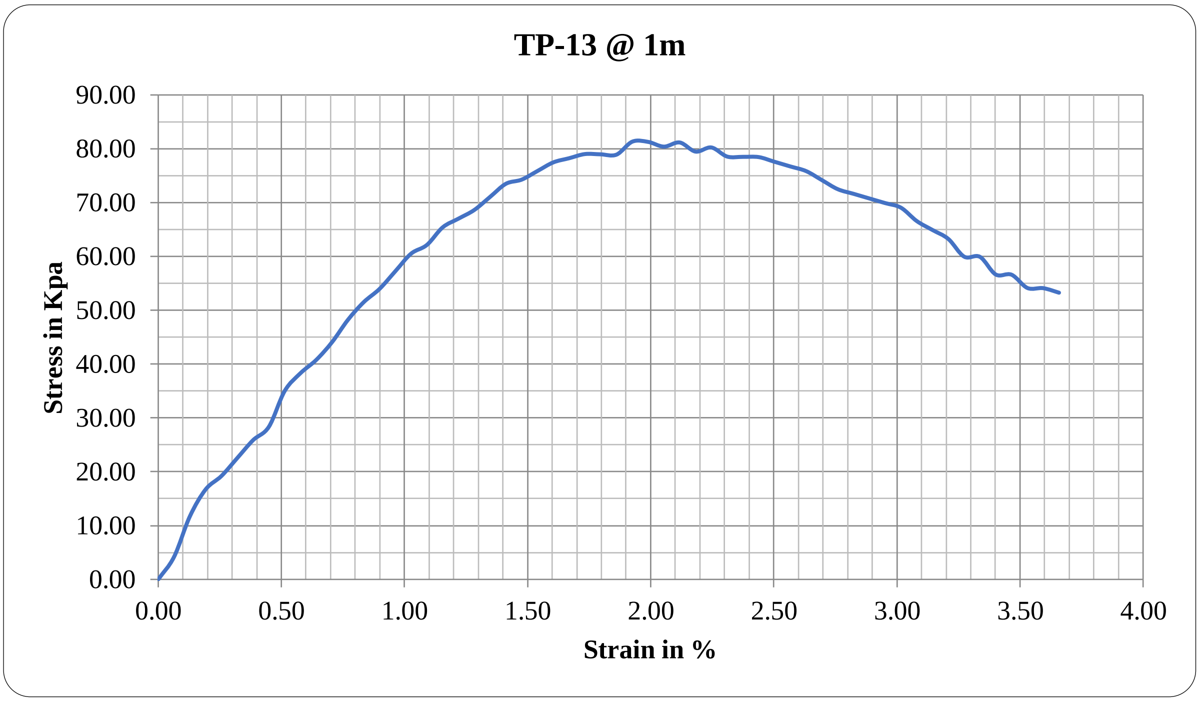
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-12 @ 2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
64.90	135	68



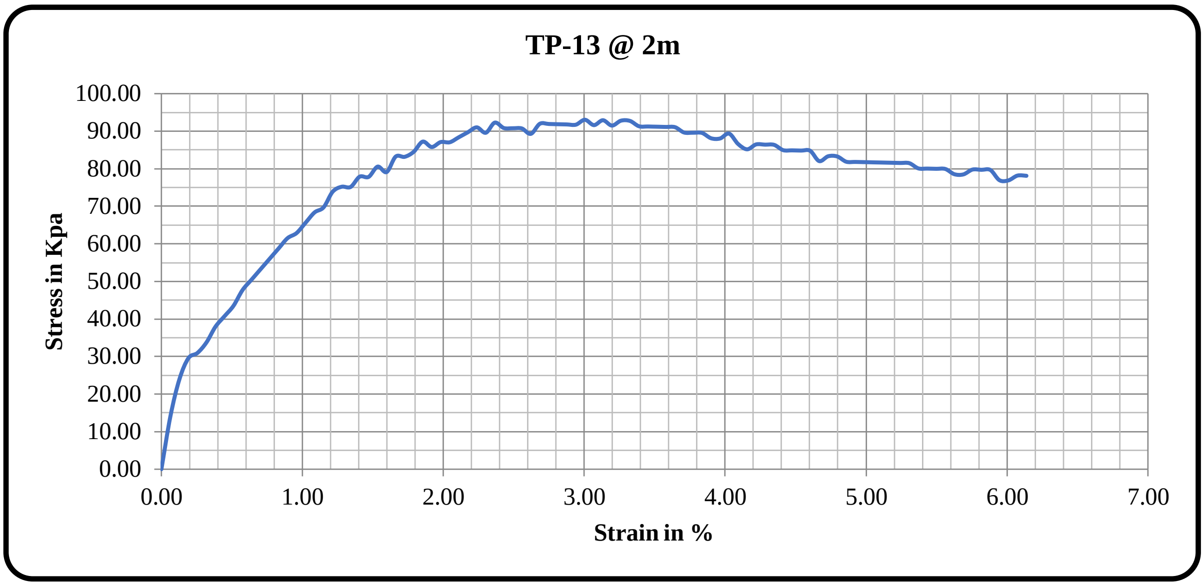
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-13 @ 1m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
77.90	81	41



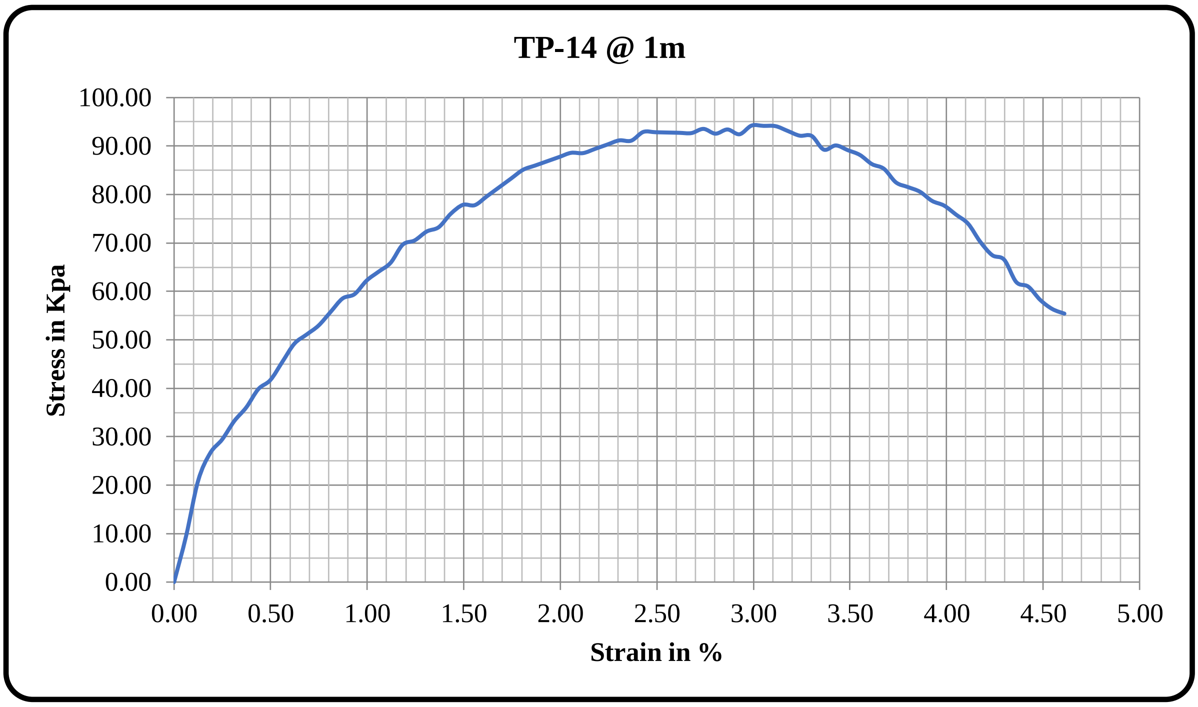
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-13 @ 2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
78.20	93	47



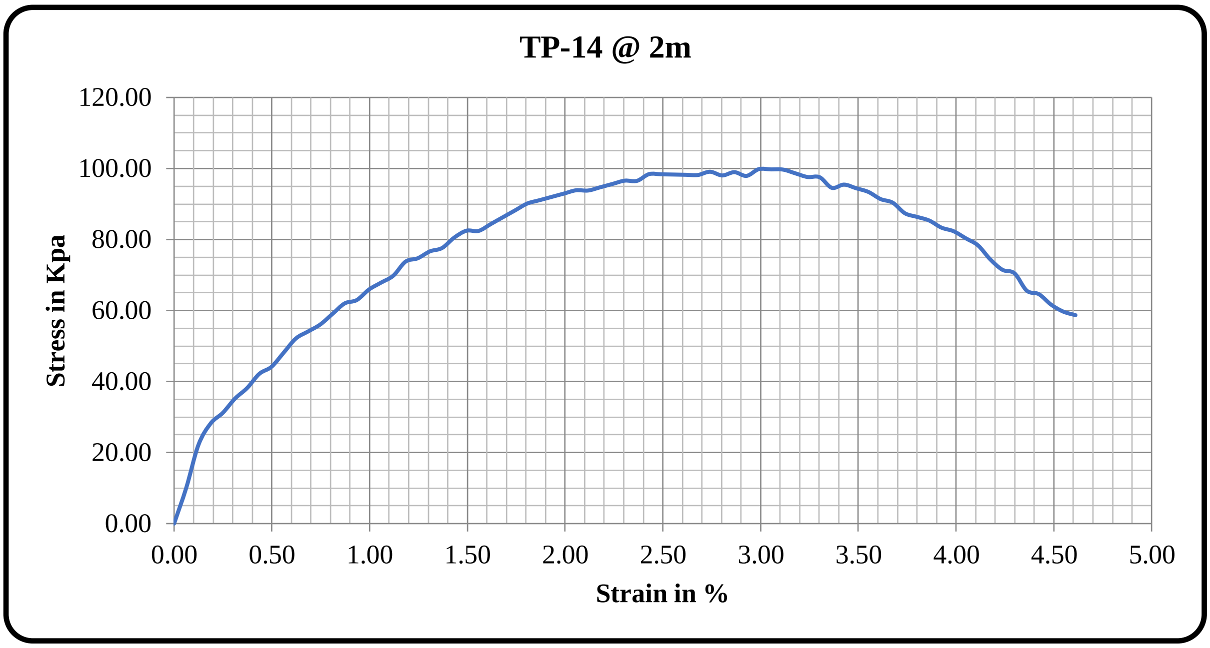
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-14 @ 1m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
80.25	94	47



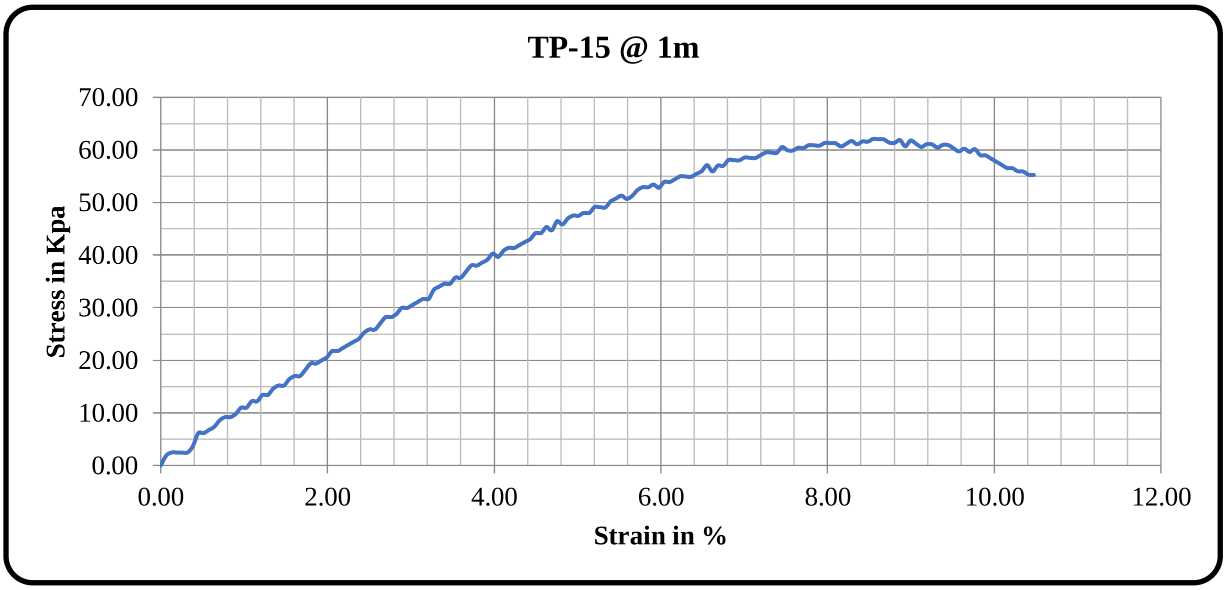
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-14 @ 2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
80.25	100	50



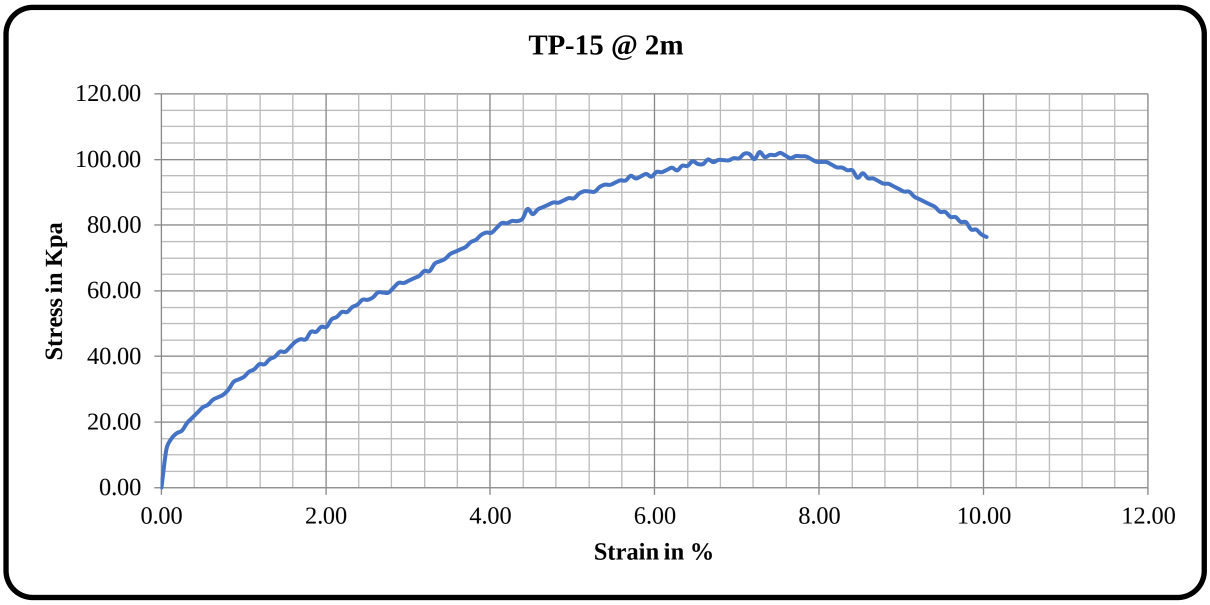
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-15 @ 1m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
77.80	62	31



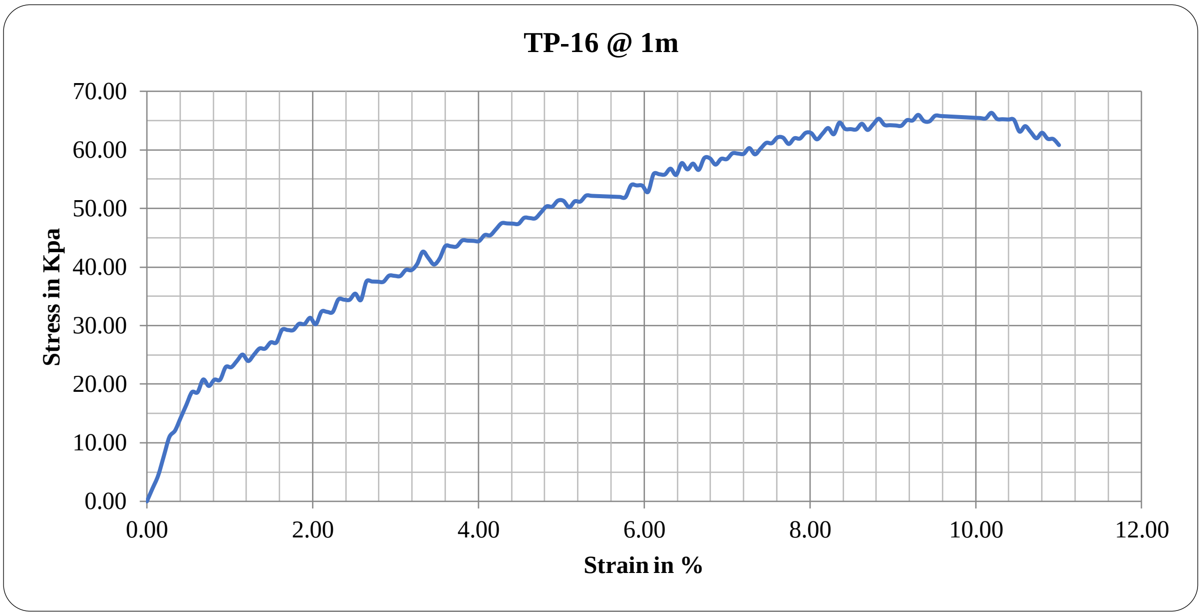
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-15 @ 2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
79.70	102	51



Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-16 @ 1m

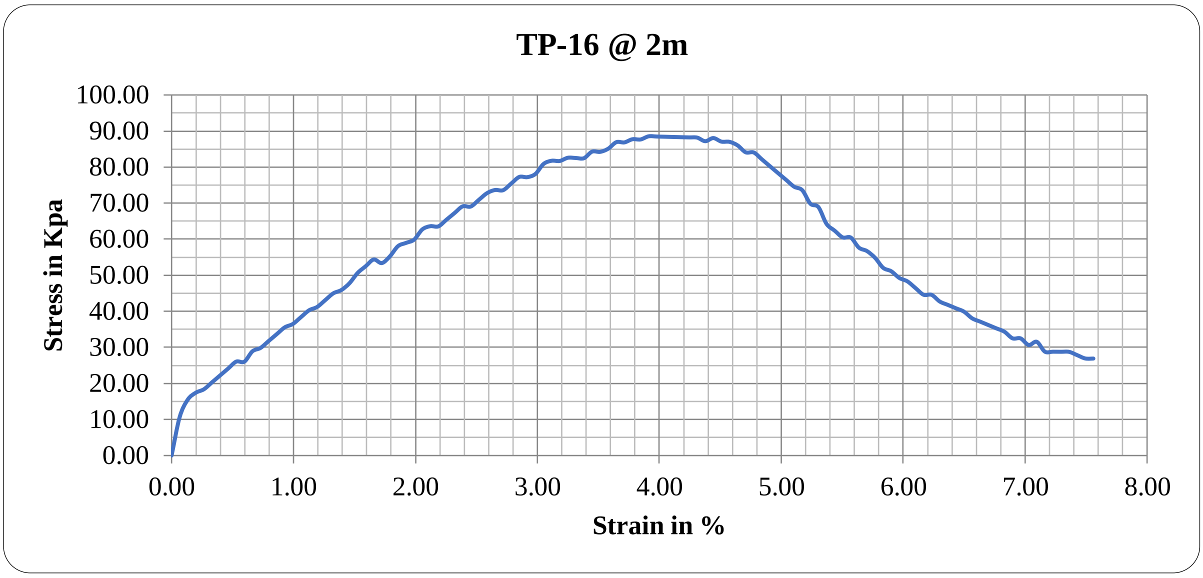
Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
73.60	66	33



Test Type	Unconfined Compression Test (ASTM D-2166)

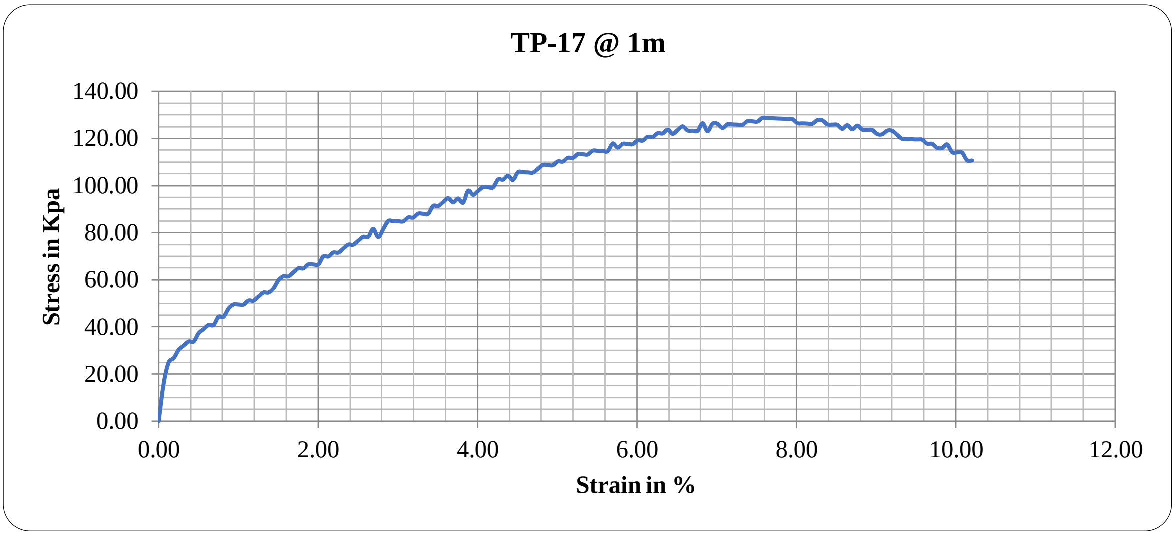
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-16 @ 2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
75.40	89	44



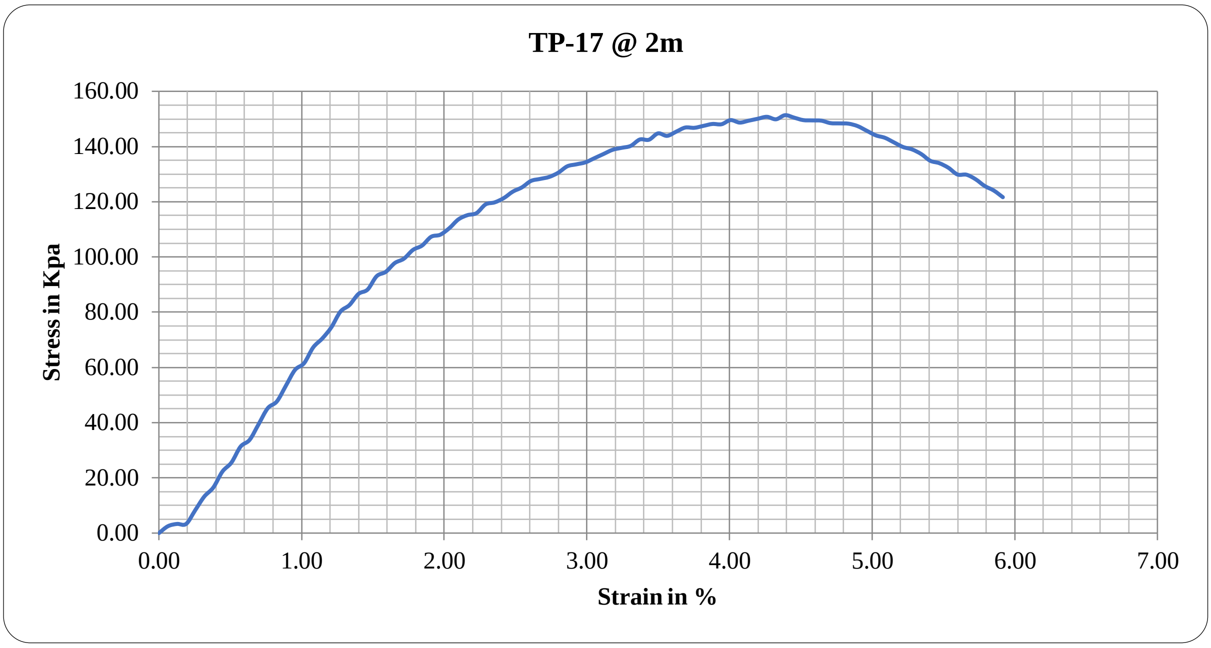
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-17 @ 1m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
79.87	129	64



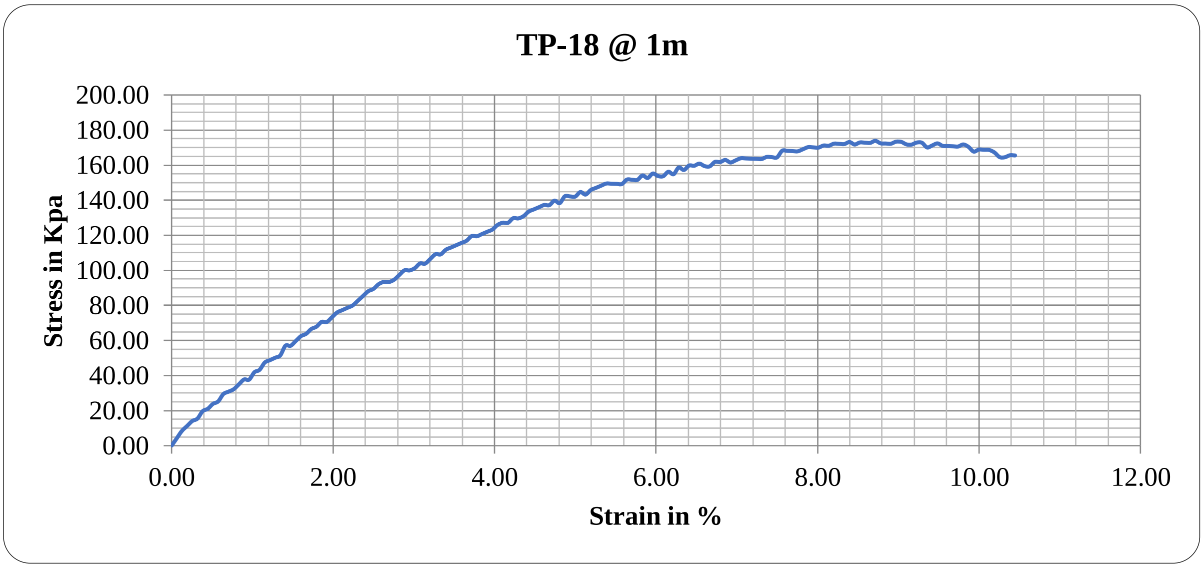
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-17 @ 2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
78.60	151	76



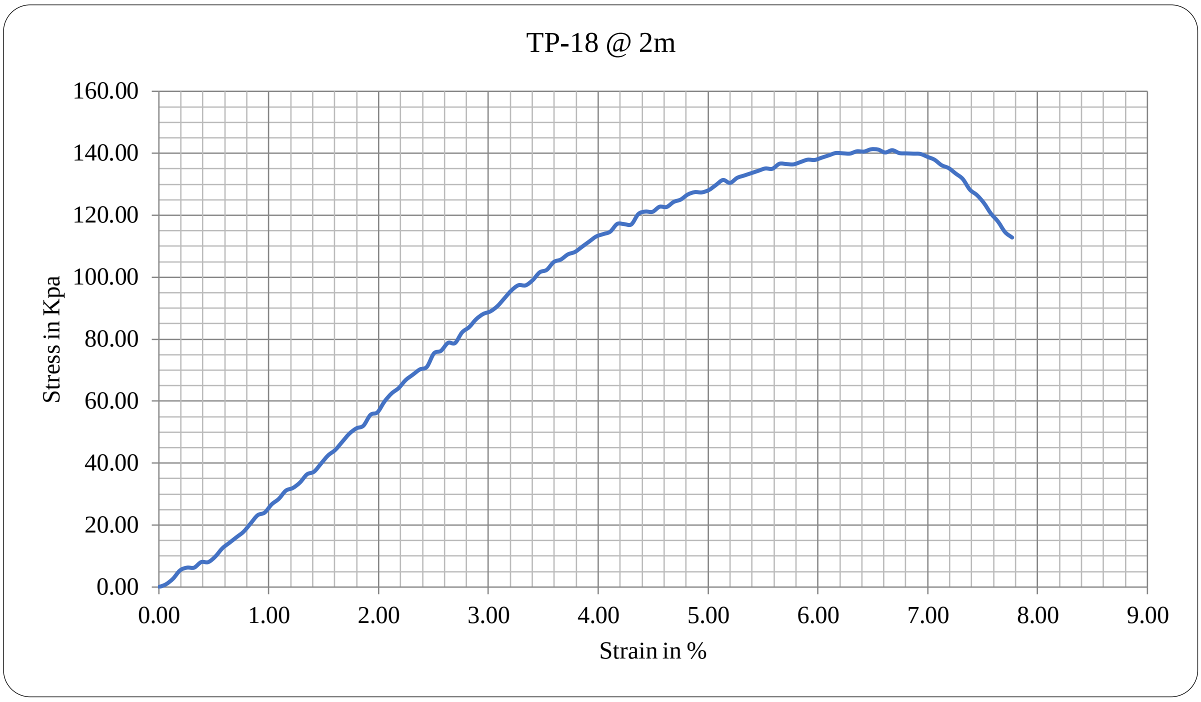
Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-18 @ 1m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
78.01	174	87



Test Type	Unconfined Compression Test (ASTM D-2166)
Type of Sample	Undisturbed Soil Sample
Sample Diameter	38mm
Test Pit Location	TP-18 @ 2m

Sample Height (mm)	Peak UCS, (kPa)	Cohesion, (kPa)
77.88	141	71



7. Laboratory Test Result of Free Swell Index

Test pit No	Initial Volume, cm^3	Final Volume, cm^3	Free Swell, (%)
TP 1@1.5m	11	12	9.09
TP 2 @1.5m	11	12.5	13.64
TP 3 @1.5m	11	13	18.18
TP 4 @1.5m	11	13.5	22.73
TP-5@1m	12	14	16.67
TP-5 @2m	12	14.5	20.83
TP-6 @1m	12	14	16.67
TP-6 @2m	12	15	25.00
TP-7 @1m	11	13	18.18
TP-7 @2m	11	13.5	22.73
TP-8 @1m	12	14	16.67
TP-8 @2m	12	13	8.33
TP-9 @1m	12	13	8.33
TP-9 @2m	12	14	16.67
TP-10 @1m	11	13.5	22.73
TP-10 @2m	11.5	13	13.04
TP-11 @ 1m	12	13	8.33
TP-11 @ 2m	11.5	13	13.04
TP-12 @ 1m	11.5	13	13.04
TP-12 @ 2m	11	12	9.09

TP-13 @ 1m	11.5	13	13.04
TP-13 @ 2m	11.5	13.5	17.39
TP-14 @ 1m	11.5	13.5	17.39
TP-14 @ 2m	11.5	14.25	23.91
TP-15 @ 1m	11.5	13	13.04
TP-15 @ 2m	11.5	13.75	19.57
TP-16 @ 1m	11.5	13.75	19.57
TP-16 @ 2m	11.75	13	10.64
TP-17 @ 1m	11	12.25	11.36
TP-17 @ 2m	11	12	9.09
TP-18 @ 1m	11	11.75	6.82
TP-18 @ 2m	11	12.25	11.36

8. Laboratory Test Result of Linear Shrinkage Index

Test pit	Initial Length, (mm)	Final Length, (mm)	Linear Shrinkage, %
TP 1@1.5m	140.00	119.81	14.42
TP 2 @1.5m	140.00	118.67	15.24
TP 3 @1.5m	140.00	117.25	16.25
TP 4 @1.5m	140.00	120.00	14.29
TP-5@1m	140.00	122.47	12.52
TP-5 @2m	140.00	118.92	15.06
TP-6 @1m	140.00	119.36	14.74
TP-6 @2m	140.00	119.62	14.56
TP-7 @1m	140.00	118.27	15.52
TP-7 @2m	140.00	119.09	14.94
TP-8 @1m	140.00	118.25	15.54
TP-8 @2m	140.00	117.47	16.09
TP-9 @1m	140.00	118.96	15.03
TP-9 @2m	140.00	118.85	15.11
TP-10 @1m	140.00	115.75	17.32
TP-10 @2m	140.00	117.84	15.83
TP-11 @ 1m	140.00	119.36	14.74
TP-11 @ 2m	140.00	119.12	14.91
TP-12 @ 1m	140.00	118.56	15.31
TP-12 @ 2m	140.00	118.14	15.61
TP-13 @ 1m	140.00	121.14	13.47
TP-13 @ 2m	140.00	118.80	15.15
TP-14 @ 1m	140.00	118.31	15.50
TP-14 @ 2m	140.00	119.81	14.42
TP-15 @ 1m	140.00	118.62	15.28
TP-15 @ 2m	140.00	118.97	15.02
TP-16 @ 1m	140.00	117.00	16.43
TP-16 @ 2m	140.00	117.66	15.96
TP-17 @ 1m	140.00	121.54	13.18
TP-17 @ 2m	140.00	121.36	13.31
TP-18 @ 1m	140.00	119.50	14.64
TP-18 @ 2m	140.00	120.35	14.04

APPENDIX-E: Photos of Test Producers

Excavations of test pits

Sampling and conducting of sand cone tests

Air drying and sample preparations

Conducting of unconfined compression test

Determination of moisture content and hydrometer test

Determination of specific gravity and Atterberge limits

Determination of Free swell index and Linear shrinkage limit