ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAiT)

SCHOOL OF GRAGUATE STUDIES

DEPARTMENT OF CIVIL AND ENVIROMENTAL ENGINEERING

CORRELETION BETWEEN UNDRAINED SHEAR STRENGTH, SWELLING PRESSURE AND STANDARD PENETRATION TEST WITH LIQUIDITY INDEX

A Project Paper Submitted to School of Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Engineer in Civil Engineering under Geotechnical Engineering.

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June, 2017

Addis Ababa, Ethiopia

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Approved By Board of Examiners

Dr.Ing. Asrat Worku		
Advisor	Signature	Date
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Chair person	Signature	Date

DECLARATION

I, the undersigned, declare that this project titled “ Correlation b/n Undrained Shear Strength, Swelling Pressure and Standard Penetration Test With Liquidity Index ” is my original work performed under the supervision of my project advisor Dr.-Ing Asrat Worku and has not been presented as a thesis for a degree in any other university. All sources of the materials used for this project have been duly acknowledged /referred.

Name: - Dereje Megersa

Signature:-

Place: - Addis Ababa institute of Technology (AAiT), Addis Ababa

Date: - June, 2017

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LIST OF SYMBOLS AND ABBREVIATIONS

UCS	Unconfined Compression Strength
USCS	Unified Soil Classification System
CU	Undrained Shear Strength
SPT	Standard Penetration Test
P_S	Swelling Pressure
FS	Free Swell
LL	Liquid Limit
IL	Liquidity Index
PL	Plastic Limit
NMC	Natural Moisture Content
PI	Plasticity Index
CH	Inorganic clays of high plasticity
MH	Inorganic silts of high plasticity
CL	Inorganic clays of low plasticity
ML	Inorganic silts of low plasticity
m	Meter
kPa	kilo Pascal
σ	Normal Stress on Shear Plane
ϕ	Angle of internal friction
C	Cohesion
ω	Moisture Content
ω_L	Moisture Content at Liquid Limit
ω_P	Moisture Content at Plastic Limit
N	Number of sample
R^2	Correlation Coefficient

ABSTRACT

Geotechnical investigation is an essential requirement to the design and construction of civil engineering projects the behavior of soil properties is very challenging and unique nature. Geotechnical engineers usually attempts to develop empirical equations specific to a certain region and soil type, but the soil behavior uncertainties involved in this process. The reasons for this result can easily be related to quality of the in situ, borehole sampling and laboratory tests. In addition, there is also a more important reason that affects the obtained results which is the heterogeneous nature of the soil.

Determining of undrained shear strength and Swelling Pressure parameters in laboratory are really tedious and time consuming. Therefore, a correlation between undrained shear strength, Swelling Pressure and SPT with Liquidity Index are useful for restraint of testing number and costs. This study the data are obtained from results of field and laboratory tests that have been carried out for Addis Ababa Housing project at koyefeche Condominium building site.

As a result of the studies the correlation are established the Undrained shear strength can be estimated by $Cu = 33.65e^{-0.78IL}$ with coefficient of determination (R^2) of 51.2 %, Swelling Pressure can be estimated by $Ps = 19.53\ IL^2 - 20.27\ IL + 30.73$ with coefficient of determination (R^2) of 70.4 % and the better and more reliable correlation found SPT number Silt with high plasticity **(**MH) and Silt with low plasticity (ML) Soil. Finally, the output of this study can serve as a basis for detail investigation to carry out further correlation study by using carefully performed and well controlled borehole sampling and laboratory testing.

Keywords: - Undrained Shear Strength, Swelling Pressure, SPT number (*N*) and Liquidity Index (IL).

1. INTRODUCTION

1.1. GENERAL

Geotechnical investigation is an essential requirement to the design and construction of civil engineering projects. The proper design of civil engineering structures like foundation of buildings, retaining walls, high ways, etc. requires adequate knowledge of sub surface conditions at the sites of the structures. Many damages to buildings, roads and other structures founded on soils are mainly due to the lack of proper investigation of substructure condition.

The soil behavior is very challenging because it is such a unique material that shows different properties even with in short distance. Due to continuous interaction with soil throughout the history, many methods have been developed to comprehend its behavior. However, it still comprises many unknowns so, many people have been researching and analyzing this material continuously to understand and speak the same language with it. The key tools to predict the behavior of soils can be described as geotechnical parameters which allow the engineers to define the engineering properties of soils have been determined by sampling from boreholes laboratory and field tests. From this empirical correlations have been established in order to estimate the geotechnical design parameters of soil.

The measured values for the liquid limits, plastic limits, and plasticity index of soils are widely used as index parameters. They are used to compute the Liquid index, which can be empirically correlated against many soil properties in geotechnical design.

Correlations are very important to estimate engineering properties of soils, especially for preliminary investigation of projects. Correlations may also be used for projects where there is financial limitation, lack of test equipment and limited time.

1.2. IMPORTANCE

Due to the unavailability of equipment and also financial and time limitations in a project, in many cases various types of relationships (correlation) are important to estimate the geotechnical parameters using the values that are extracted from the in-situ and laboratory testing. These important design parameters are undrained shear strength, Swelling Pressure and standard penetration test (SPT) with natural moisture content and Atterberg limits.

Undrained shear strength, Swelling Pressure and standard penetration test are very important parameters in engineering. They are very important to determine the bearing capacity of soil. Some of the laboratory tests used to obtain these values are expensive and time consuming, while soil properties like natural moisture content and Atterberg limits can be performed faster and cheaper.

1.3. OBJECTIVE

1.3.1 General objective

The general objective of this study is to obtain the relationship between undrained shear strength, swelling pressure and SPT number (N) with index properties of soils found in koyefeche condominium site.

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1.3.2 Specific objective

The specific objective of this study is to establish the relationship between undrained shear strength, Swelling Pressure and SPT number with liquidity Index.

1.4. SCOPE OF THE PROJECT

This project has been intended to address the correlation between undrained shear strength, Swelling Pressure and standard penetration test (SPT) with the index properties of soil found in the Koyefeche area. The data used for analysis are based on undisturbed and disturbed samples from available site investigation reports. Disturbed samples were used for Index property tests and undisturbed samples for undrained shear strength, swelling pressure determination and in situ tests for standard penetration number. The output of this study is expected to serve as a basis for further studies and to provide a preliminary estimate of the undrained shear strength, swelling pressure and SPT blow counts (N).

1.5. METHODOLOGY

In order to achieve the objectives, the following methods were used:-

The data are obtained from results of field and laboratory tests collected from Addis Ababa Housing Construction Project office and Literature sources including reference books written in geotechnical areas, journals and research papers.

Statistical regression analyses of available data were carried out and correlations were developed and also analyzed to fit the test results. Under the discussions of the obtained results the suitability of the developed correlations were discussed. Finally, based on the results obtained conclusions and recommendations were made.

1.6. LIMITATION OF THE PROJECT

The area covered in this study is the main factor that limits the applicability of the results obtained. Since the correlation results are highly material dependent, the applicability will also be limited to the areas of the study. Therefore, the results should only be applied to these areas.

1.7. ORGANIZATION OF THE PROIECT

This project work is organized into six Chapters; the first chapter presents a general description, importance, objectives, scope of the study, methodology and limitation of the project. The second Chapter presents the brief literature review which discusses the undrained shear strength, Swelling Pressure, standard penetration test and Atterberg limit. The third Chapter discusses the data collection and preparation, the fourth Chapter Analysis and result, the fifth Chapter discussion on the results, Under Chapter six, Conclusions and recommendations were presented.

2. LITERATURE REVIEW

2.1 UNDRAINED SHEAR STRENGTH OF CLAY SOILS

2.1.1 General

It is usually assumed that the shear strength of soils is governed by the Mohr-Coulomb failure criterion:

$$s = c + \sigma \tan\phi \quad \text{……(2.1)}$$

Where s is the shear stress at failure along any plane

σ is the normal stress on that plane and

C and ϕ are the shear strength parameters; cohesion and angle of shearing resistance.

A complication arises when the normal stresses within a soil are carried partly by the soil skeleton itself and partly by water within the soil voids. Considering only the stresses with in the soil skeleton, equation 2.1 is modified to equation 2.2

$$s = c' + (\sigma - \upsilon)\tan\phi \quad \text{……(2.2)}$$

Or

$$s = c' + \sigma' \tan\phi \quad \text{……(2.3)}$$

Where:

$\sigma' = (\sigma' - u)$, the effective normal stress (on the soil skeleton) and u is pore water pressure developed

c' and ϕ' are the shear strength parameters related to effective stresses.

For most saturated clays, tested under quick undrained conditions, the angle of shearing resistance is zero. This means that the shear strength of the clay is a fixed value and is equal to the 'apparent cohesion' (i.e., the response of pore water pressure to imposed loads). For drained conditions, or in terms of effective stresses, it is found that the shear strength of soils is principally a frictional phenomenon. This does not appear to be the case for over consolidated clays which have a built-in pre-stress or for partially saturated clays, in which the particles are drawn together by surface tension effects, giving them some cohesion.

The choice between total and effective stress analysis depends on the application. In case of foundation design, because it imposes both shear stresses and compressive stresses (confining pressures) on the underlying soil; the shear stresses must be carried by the soil skeleton but the compressive stresses are initially carried largely by the resulting increase in pore water pressures. This leaves the effective stresses little changed, which implies that the foundation loading is not accompanied by any increase in shear strength. As the excess pore pressures dissipate, the soil consolidates, and effective stresses increase, leading to an increase in shear strength. Thus, for foundations, it is the short term condition, the immediate response of the soil, which is most critical. This is the justification for the use of quick undrained shear strength tests rather than effective stress analysis for foundation design. Effective stress analysis must be used where long-term stability is important. [8]

2.2. PREDICTING UNDRAINED SHEAR STRENGTH OF CLAY

2.2.1 From Simple Hand Tests

There are many ways to predict the undrained shear strength of clay soils where the normal laboratory becomes difficult to perform or when cross checking is required. One way is to mould a piece of clay between the fingers and applying the observations indicated in Table 2-1.

Table 2-1 Estimating the Shear Strength and SPT N-Value form consistency [8]

Description	**qu(kPa)**	**SPT N-Value**	**Remark**
Very Soft	<25	0-2	Squishes between finger when squeezed
Soft	25-50	3.-5	Very easily deformed by squeezing
Medium Stiff (firm)	50-100	6.-9	*Thumb makes impression easily*
Stiff	100-200	10.-16	Hard to deform by hand squeezing
Very Stiff	200-400	17-30	Very hard to deform by hand
Hard	>400	>30	Nearly impossible to deform by hand

2.2.2 From Simple Classification Tests

The other way of predicting undrained shear strength is by using simple laboratory tests like Atterberg limits. It is known that the liquid and plastic limits are moisture contents at which soil has specific values of undrained shear strength. It therefore follows that, for a remoulded soil, the shear strength depends on the value of the natural moisture content in relation to the liquid and plastic limit values. This can be conveniently expressed by using the concept of liquidity index.

The undrained strength of clays has been widely related to the liquidity index I_L, defined by equation .**[5]**

$$\mathbf{I_L = \frac{W-Wp}{WL-Wp}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(2.4)}$$

Houston & Mitchell (1969) proposed the limits on the remoulded strength of clay shown in Figure 2.1 based on data extracted from the literature. Latterly, several authors have proposed relationships between strength and liquidity index, while not explicitly recognizing the band of strengths which exists in the data. Schofield & Wroth (1968) upon examination of vane shear test data from Skempton & Northey (1952) made the observation that ‘from these data it appears that the liquid limit and plastic limit do correspond approximately to fixed strengths which are in the proposed ratio of 1:100’ Based on this observation, Wroth & Wood, (1978) proposed equation : **[5]**

$$\mathbf{C_u = 170e^{-4.6\,IL} = 1.7\times 10^{\,2\,(1 - IL)}\ \ kpa} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(2.5)}$$

This equation implies that the undrained shear strength of soil should be 1.7 kPa at the liquid limit and 170 kPa at the plastic limit.

An alternative correlation (equation 2-6) was proposed by Leroueil et al. (1983)

$$\mathbf{C_u = \frac{1}{(IL-0.21)}2 \qquad kpa \quad 0.5 < IL < 2.5} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(2.6)}$$

Whilst this equation fits the collected data presented in Leroueil et al (1983) well between liquidity indices of 0.5 and 2.5, it should obviously not be extrapolated below these values, as it predicts infinite strength at a liquidity index of 0.21. Locat & Demers (1988) suggested equation (2-7) for computing strengths at high liquidity indices. This equation was said to be valid for the range $1.5 < I_L < 6.0$.

$$\mathbf{C_u = \left(\frac{1.167}{I_L}\right)^{2.44} \quad kpa \quad 1.5 < I_L < 6.0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.7)}$$

For comparative purposes, Equations (2-5), (2-6), (2-7) are plotted on Figure 2-1 for the ranges in which they were reported to be valid in the original publications. O'Kelly (2013) also recently reviewed some of the many proposed empirical relationships linking water content and undrained shear strength.

Equation (2.5) was re-written by Wood (1990) in the form shown as equation (2.8)

$$\mathbf{C_u = C_L\, 35^{\,(1 - I_L)} \qquad (where,\ C_L = 1.7\ kpa)\ 0.2 < I_L < 1.1 \ldots\ldots\ldots\ldots\ldots\ldots (2.8)}$$

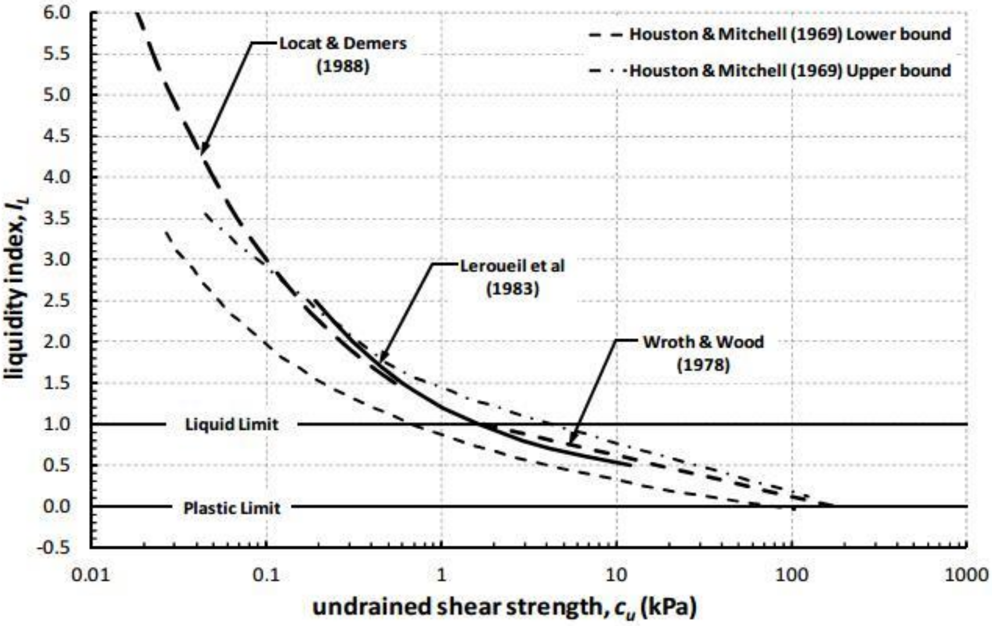

Figure 2-1 Curves Undrained Shear strength vs Liquidity index by different researchers as cited by [5]

2.3. LABORATORY TESTING METHODS FOR DETERMINIG SWELLING PRESSURE

2.3.1 Swelling Pressure

Swelling Pressure is the amount of pressure a soil exerts upon swelling or the pressure required recompressing the fully swollen sample back to its initial volume. Most of the structural damages occur when the swelling pressure is greater than the foundation pressure, assessing the swelling pressure is an important task in dealing with expansive soil. The available techniques for quantitative measurement swelling pressure of expansive soils can be categorized into three groups. Namely, odometer tests, soil suction tests and empirical methodology. [1]

2.3.2. Odometer Tests

Among these techniques the odometer tests are capable of simulating some of the factors which affect the swelling characteristics of expansive soils. It should be noted, however, that the odometer tests have limitation. The odometer tests consider moisture as well as volume change in one dimension only. In the in-situ, the above changes take place in three directions. For simplicity, however, the odometer testing techniques have become popular and are extensively used. The different types of techniques under these methods are [1]:-

2.3.2.1 Constant Volume Method

The specimen in the constant volume method is allowed to absorb water without any increase in volume by increasing the applied pressure as the test proceeds until the sample reaches equilibrium. The more load is added to keep the volume of the sample constant while the sample absorbs water. The swelling pressure can be determined by plotting the applied pressure against change in volume. This method does not represent the in-situ condition where the applied load, after the structure is in service, does not change with time. When the swelling process occurs, a constant pressure acts rather than different pressure which increase with time to a counter act the swelling process. Information such as the amount of heave which could be expected under application of a certain load or load which could be applied to limit the heave within tolerable limit cannot be furnished by this method. The method needs uninterrupted monitoring for a long period.

2.3.2.2 Swell-Consolidation Method (Free Swell Method)

In this method an undisturbed sample is allowed to absorb water under a load of 1psi (7kpa) and is put aside to fully expand and reach equilibrium. Then it is consolidated by increasing the applied pressure in intervals following the conventional consolidation test procedure. The load increment is continued until the sample reaches its initial volume (zero volume change). The load correspond to zero volume change is taken as swelling pressure. Fig. 2-2 shows the stress –strain relationship for this test. [1]

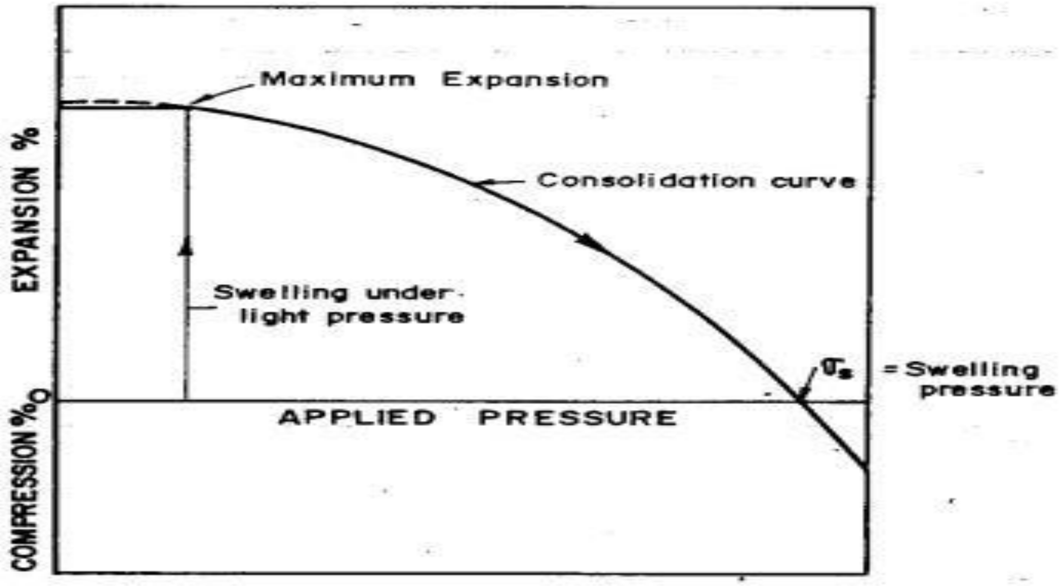

Figure 2.2 Determination of swelling pressure by swelling consolidation method. [1]

This method is quite popular and many investigators have used this method to establish a relationship between swell and applied pressure and to evaluate swelling pressure. The most serious drawback of this method is that it does not represent the normal sequence of load-submersion. In the field the soils is first subjected to the structural load and then swell later following exposure to moisture but not vice versa.

2.3.2.3 Different Pressure Method

In this method several identical samples (three or more) are loaded with different loads close to expected swelling pressure. The samples are set aside to consolidate in dry state. When equilibrium is reached, then they are subjected in water and the subsequent swell is recorded. The samples are again left until they reach equilibrium and the swelling practically ceases. The pressure corresponding to zero volume change is taken as the swelling pressure.

2.3.2.4 Double-Odometer Method

This method was proposed by Jennings and Knight and has been used by many investigators to study the swell-pressure relationship of an expansive soil. This method is based on subjecting two identical samples to consolidation test. The first sample is consolidated at its natural moisture content while the second sample is first-allowed to absorb water and swell under light load followed by consolidation. For the two samples the applied pressures are plotted against vertical strain (or Void ratio) on the same diagram. The pressure corresponding to the intersection point of the two curves is taken as the swelling pressure.

This method usually gives a relatively high swelling pressure. This is due to the fact that the pressure taken as the swelling pressure is not that required to bring the sample to its initial volume, but to its volume after being compressed in the dry state to a pressure equal to the swelling pressure. [1]

Table 2.2 Comparison of various methods of determining swelling pressure

Name of the Method	**Merits and Demerits**	
	Merits	**Demerits**
Constant volume Swell Pressure Method	a) Experimental Procedure versatile and results fairly accurate.	a) Experimental procedure does not simulate field condition as the weight of the structure inservice does not change with time
	b) Standardized Equipment is readily available in the market.	b) This procedure necessitates un interrupted presence of the personnel throughout the experiment.
	c) Rational estimation of Load which could be applied such that the heave developed is tolerable.	c) Experiment consumes relatively longer time
Different Pressures Test	a) Soil Sample in consolidometer is subjected to uniform pressure all through its thickness	a) Sample in consolidometer is laterally confined and suffers good amount of side friction.
	b) Suitable to big projects	b) Requires a large number of similar soil samples.
Double Odometer method	a) Swelling pressure of higher order is produced	a) It does not require normal sequence of loading-submersion of soil sample.
Swell Consolidation method	a) Most favorable to pre-consolidated clays	a) The pressure required to compress the pre-wetted sample is higher than other methods.

2.3.3 Factors Influencing Swelling and Shrinking of a Soil

The factors influencing the shrink swell potential of a soil can be considered in three different groups [10].

I. Soil characteristic that influence the basic nature of the internal force field. These includes:-
   - Clay mineralogy (Kaolinite, Montmorillonite and Elite)
   - Plasticity
   - Dry density
   - Soil suction
   - Soil water chemistry
   - Soil structures and fabrics

II. The environment factor that influence the changes that may occur in the internal force system. These include.
   - Initial moisture condition
   - Moisture variation
   - Climate (Ground water, Drainage and manmade water source, Vegetation, Permeability, Temperature)

III. State of stress, which include
   - Stress history
   - Surcharge load
   - Soil profile

2.4. STANDARD PENETRATION TEST (SPT)

Standard Penetration Test (SPT) is most widely used method for determining the shear strength properties of soil. Around 1902 Colonel Charles in Boston began making exploratory boring using 1-inch diameter drive samplers. From that time wash boring with cuttings is used. During the late 1920s and early 1930s, the procedure was standardized by Mohr (1940). Mohr developed a slightly larger diameter split-spoon drive sampler. The value recorded for the first round of advance is usually discarded because of fall in and contamination of borehole. The second pair of numbers are then combined and reported as a single value for the last 304.8 mm, this value is reported as the SPT blow count value, commonly termed “N”. [6]

Advantage of this test is simplicity, the availability of a wide variety of correlations for its data and the sample is obtained with each test. Another advantage of this simple and economical test is the significant body of research that has been done to correlate empirically the SPT N values with geotechnical design parameters. Thus the N value Saves money by reducing laboratory testing. Unfortunately, the SPT test is anything but standard.

2.4.1 Purpose of Standard Penetration Test

The main purpose of the test is to determine the shear strength of soil and the main reason for its widespread use is that it is simple and inexpensive. The soil strength parameters which can inferred approximate, but may give a useful guide in ground conditions where it may not be possible to obtain borehole samples of adequate quality like gravels, sand, silts, clay containing sand or gravel and weak rock. If the samples are found to be unacceptably disturbed, it may be necessary to use a different method form ensuring strength like the plate load test. The SPT is used as the primary soil descriptor in a geotechnical engineering analysis and design. In most practices, SPT is used in conjunction with other laboratory and field testing procedures and serves as an indicator of the soil profile. The SPT has been correlated with the soil's capacity to resist ground failure or excessive settlement once a new building is put on. Therefore, the N-values obtained on a specific site are very important criteria for engineers to evaluate the stability and the possible settlement of new building to be constructed. [6]

The Standard Penetration Tests aims to determine the SPT-N value, which gives an indication of the soil stiffness and can be empirically related to many engineering properties.

2.4.2 Equipment and Test Procedure

In 1958 the test method was standardized by ASTM D1586 as follows:

- A standard sampler with dimensions shown in Figure 2.3 is driven into the soil by the energy delivered from a 63.5 kg. Weight hammers having a free fall of 760 mm
- For every 150 mm. penetration of the sampler from the bottom of borehole, number of blow counts are recorded until a total distance of 450 mm. is penetrated.

- Number of blow counts required for the penetration of last 300 mm. is added and it is referred as SPT N value. The number of blow counts recorded during the first 150 mm. is ignored in order to prevent the adverse effects of disturbances during boring process on the test results.
- Procedure is repeated after the drilling to the depth of the next test. (Conventionally test is performed at every 1.0 to 1.5 meters intervals.)

Test is usually stopped on the following conditions:

- 50 or more blows are required for a 150 mm. penetration.
- 100 blows are obtained to drive the required 300 mm.
- 10 successive blows produce no advance.

Precautions

- The drill rods should be of standard specification and should not be in bent condition.
- The split spoon sampler must be in good condition and the cutting shoe must be free from wear and tear.
- The drop hammer must be of the right weight and the fall should be free, frictionless and vertical.
- The height of fall must be exactly 750 mm. Any change from this will seriously affect the N value.
- The bottom of the borehole must be properly cleaned before the test is carried out. If this is not done, the test gets carried out in the loose, disturbed soil and not in the undisturbed soil.
- When a casing is used in borehole, it should be ensured that the casing is driven just short of the level at which the SPT is to be carried out. Otherwise, the test gets carried out in a soil plug enclosed at the bottom of the casing.
- In spite of all these imperfections, SPT is still extensively used because the test is simple and relatively economical.
- it is the only test that provides representative soil samples both for visual inspection in the field and for natural moisture content and classification tests in the laboratory

2.4.3 Correction of SPT N value

The SPT N-values/300mm should be adjusted for different factors before employing them for computing the allowable bearing pressure .The SPT N-values are converted to N_{70} standard energy ratio value (Bowles 1988) using [2]:

$$N'_{70} = C_N \times N \times n_1 \times n_2 \times n_3 \times n_4$$

N'_{70} = adjusted N

CN = adjustment for overburden pressure $(p''o/p'o)^{1/2}$

p'o = overburden pressure

p"o= reference overburden pressure (95.76kPa or 1.0kg/cm^2)

n_1= Er/Erb (where Er is average energy ratio that depends on the drill system and Erb is the standard energy ratio).

n_2 = Rod length correction;

Rod length > 10 m = 1, Rod length 6-10 m = 0.95

Rod length 4-6 m = 0.85, Rod length 0-4 m = 0.75

n_3 = sampler correction (1.00 in this case)

n_4 = borehole diameter correction (1.00 in this case)

2.5. INDEX PROPERTIES

The tests required for determination of engineering properties are generally elaborated and time consuming. Sometimes the geotechnical engineers are interested to have some rough assessment of the engineering properties without conducting elaborate tests. This is possible if index properties are determined. The properties of soils which are not of primary interest to the geotechnical engineer but which are indicative of the engineering properties are called index properties [3].

The behavior of soils should thus be understood by conducting tests on physical attributes of the soil particle and soil aggregate constituents. The physical properties of soils which serve mainly for identification and classification purpose are commonly known as index properties which can be determined by simple laboratory tests. Index property tests are Atterberg limits.

2.5.1 Atterberg Limits

Atterberg Limits tests are used to confirm visual descriptions. They are performed on fine-grained soils (clays, silts) to determine the amount of water necessary to achieve a range of behavioral states. Atterberg limits tests should be performed on each representative soil, and additional tests are advisable to confirm grouping of apparently similar soils and where project complexity justifies additional testing. These test results have been correlated with other soil properties. The liquid limit (LL), plastic limit (PL) and shrinkage limit (SL) are Atterberg limits.

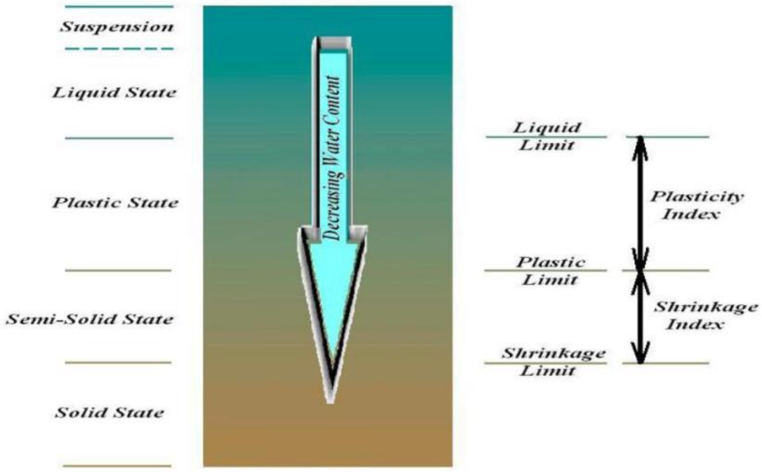

Figure 2.3 Atterberge limits and indices

2.5. 2. Liquidity Index (IL)

Liquidity Index (IL): 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: - $\mathbf{I_L = \frac{W-Wp}{WL-Wp}}$**………………… (2.9)**

The value of Liquidity Index (LI) varies according to the consistency of soils as follows: [4]

LI	Description of soil strength
LI < 0	Semisolid state -High strength but brittle , i.e. sudden fracture is expected
0 < LI < 1	Plastic state - Intermediate strength
LI > 1	Liquid state - Low strength

3. DATA COLLECTION AND PREPARATION

3.1.GENERAL

This project depends on the available test data conducted for Construction of G+4 and G+7 Condominium buildings for koyefeche project III site. The geotechnical investigations comprises of core drilling, in-situ tests, monitoring of ground water, collection of representative samples, and subsequent laboratory tests on representative samples to determine the engineering properties of the sub-surface materials. The field investigation was conducted from December 14, 2013 to July 08, 2014. [12]

3.1.1. Location

The Project site is found in the Eastern part of Addis Ababa in the locality known as KoyeFeche, Akaki Kaliti Sub-City about 7-km East of Tirunesh Beijing Hospital. The project site is characterized by undulating topography with an average elevation of 2197m above sea level. [12]

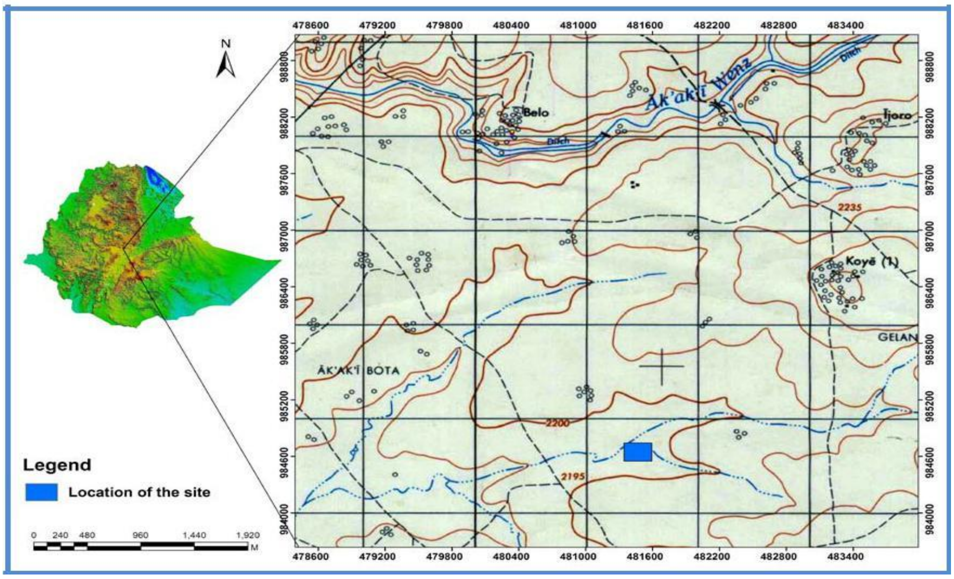

Figure 3-1: Location map of the condominium site [12]

3.1.2. Data Collection and Preparation

Main data for this project are primarily based on secondary data collected from Addis Ababa Housing Construction Project office. The results of field and laboratory tests data further filtered the required tests, parameters and depth.

The data were also classified using USCS by the soil type for the Analysis. According to Unified Soil Classification System, the data can be grouped as follows:

1- Silt with High Plasticity (MH)

2-Silt with Low Plasticity (ML)

3 -Clay with High Plasticity (CH)

4-Clay with Low Plasticity (CL)

Using the Unified Soil Classification System (USCS), the samples of the study area are further classified by using the Plasticity Chart in Figure 3.2.

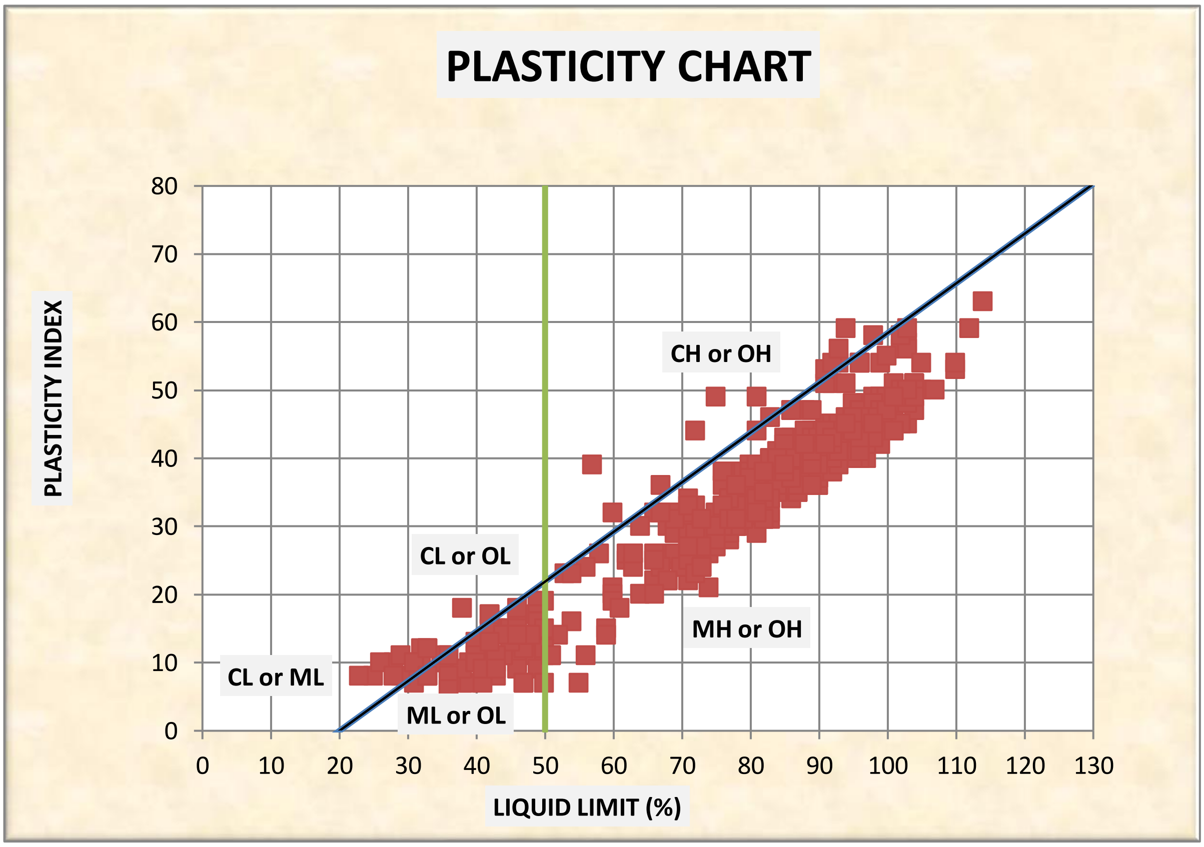

Figure 3.2 Plasticity chart according to Unified Soil Classification System (USCS)

4.ANALYSIS AND RESULT

4.1.DATA ANALYSIS METHODS

Generally in these analysis procedures the value of undrained shear strength, Swelling Pressure (ps) and standard penetration numbers (SPT) was considered as dependent variables where as the liquid index (LI), liquid limit (LL), plastic limit (PL), plasticity index (PI), natural moisture content (ω), and Free swell values were the independent variables.

4.1.1.Scatter Plot

In carrying out the statistical analysis, MS excel spreadsheet is used to determine the scatter plot, correlation and regression. The MS excel spread sheet is found to be the most powerful and manageable tool for scatter plot analysis and determination of correlation between two variables the best fit curve for each correlation is selected one with the higher value of R^2

The parameters considered as component of analysis included undrained shear strength, Swelling Pressure (ps), standard penetration numbers (SPT), natural water content, liquidity index, plasticity index, liquid limit and Plastic limit.

All the data obtained are used to study relation of undrained shear strength, Swelling Pressure (ps) and SPT with the Atterberg limits (PI, LL, and PL), liquidity index and natural moisture content.

The summary of laboratory and Field data used for analysis are provided in Appendix A.

4.2. REGRESSION ANALYSIS

Regression analysis is a statistical technique for modeling and investigating the relationship between two or more variables. Many problems in engineering and science involve exploring and making use of the relationships between two or more variables. Regression analysis may take the form linear, parabolic, logarithmic etc depending on the trend that may exist between the dependent and independent variables.

Regression analysis divided into either single regression or multiple regression analysis pertinent to the number of variables involved in the system. A regression model that pertinent to the number of variables involved in the system. A regression model that contains one independent variable or regressor is termed as single regression model.

A variable whose value is predicted is called dependent variable or response. A variable(s) used to predict the value of dependent variable is termed independent or regressor variable (s).

A convenient way of measuring how well the regression model performs as a predictor of the dependent variable is to compute the reduction in the sum of squares of deviations that can be attributed to regressor variables and this quantity termed the coefficient of determination, R^2, The value of R^2 is always between 0 and 1, because R is between -1 and+1, where by a negative value of R indicates inversely relationship and positive value implies direct relationship.

4.2.1.Single Regression Analysis

In developing correlations, the first step is a scatter diagram is generated by applying the Excel Spreadsheet, in order to study the relationships developed between Cu, Ps and SPT with IL, NMC, PI, PL and LL. Consequently, the scatter plots are presented from Figure 4-1 up to Figure 4-48:

4.2.1.1. Correlation of Undrained Shear Strength

Correlation between Undrained Shear Strength Vs Liquidity Index

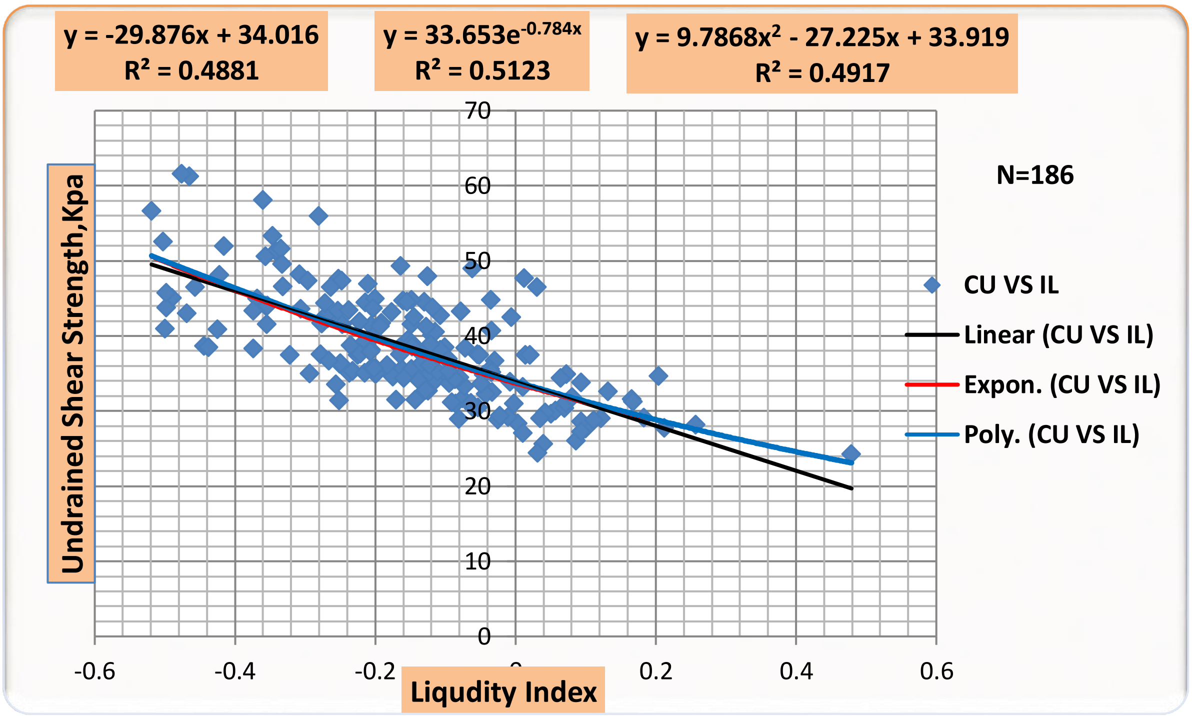

Figure 4-1 Scatter plot and best fit curves for C_U vs I_L (MH Soil depth 2.5m-3.1m)

Correlation between Liquidity Index Vs Undrained Shear Strength

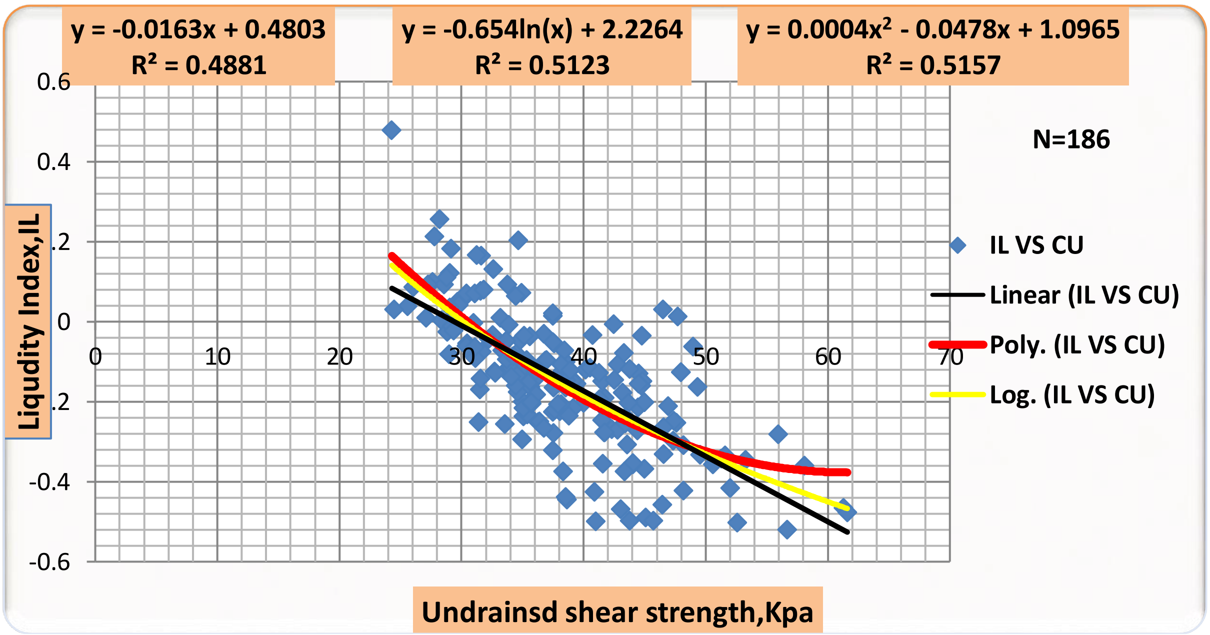

Figure 4-2 Scatter plot and best fit curves for I_L vs C_U (MH Soil depth 2.5m-3.1m)

Correlation between Undrained Shear Strength Vs Natural Moisture Content

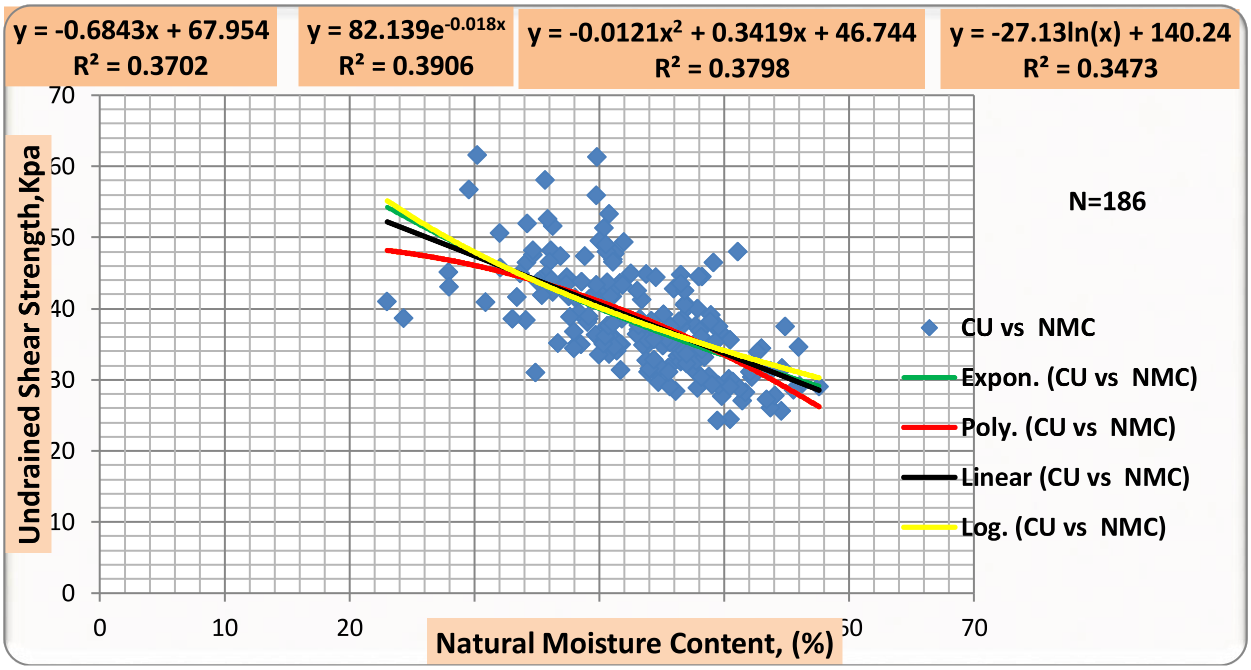

Figure 4-3 Scatter plot and best fit curves for C_U vs ω (MH Soil depth 2.5m-3.1m)

Correlation between Undrained Shear Strength Vs Plasticity Index

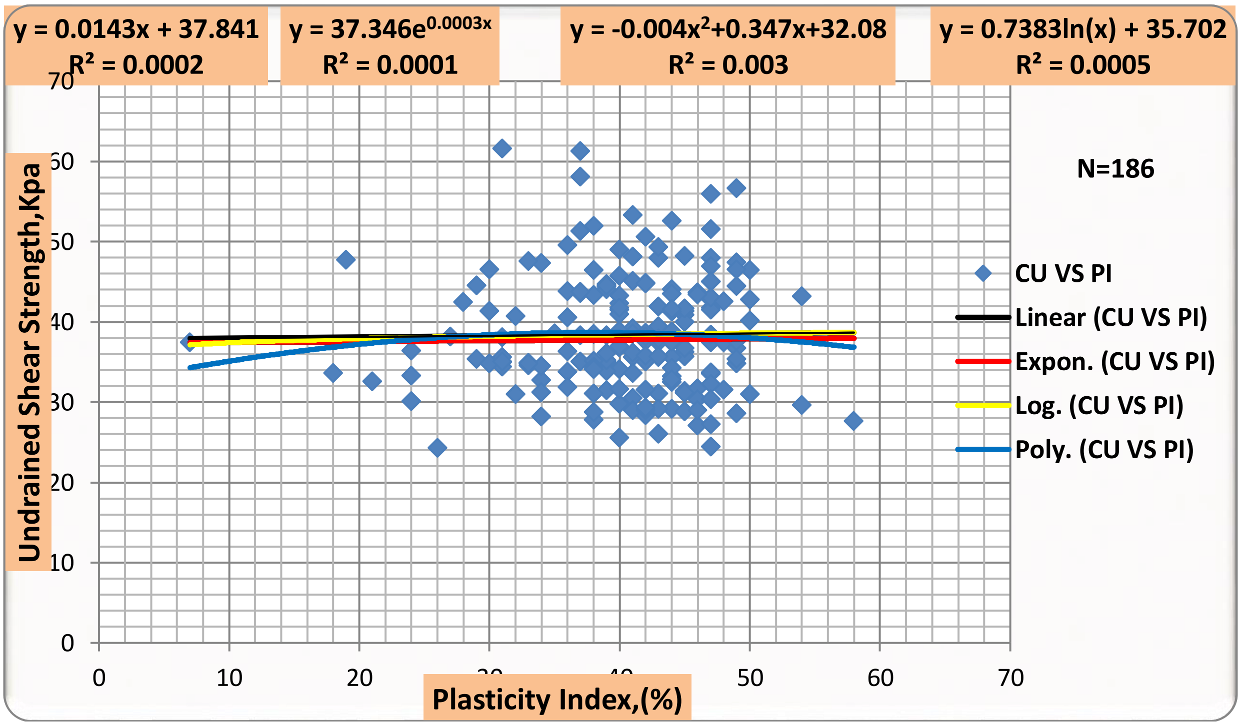

Figure 4-4 Scatter plot and best fit curves for C_U vs PI (MH Soil depth 2.5m-3.1m)

Correlation between Undrained Shear Strength Vs Plastic Limit

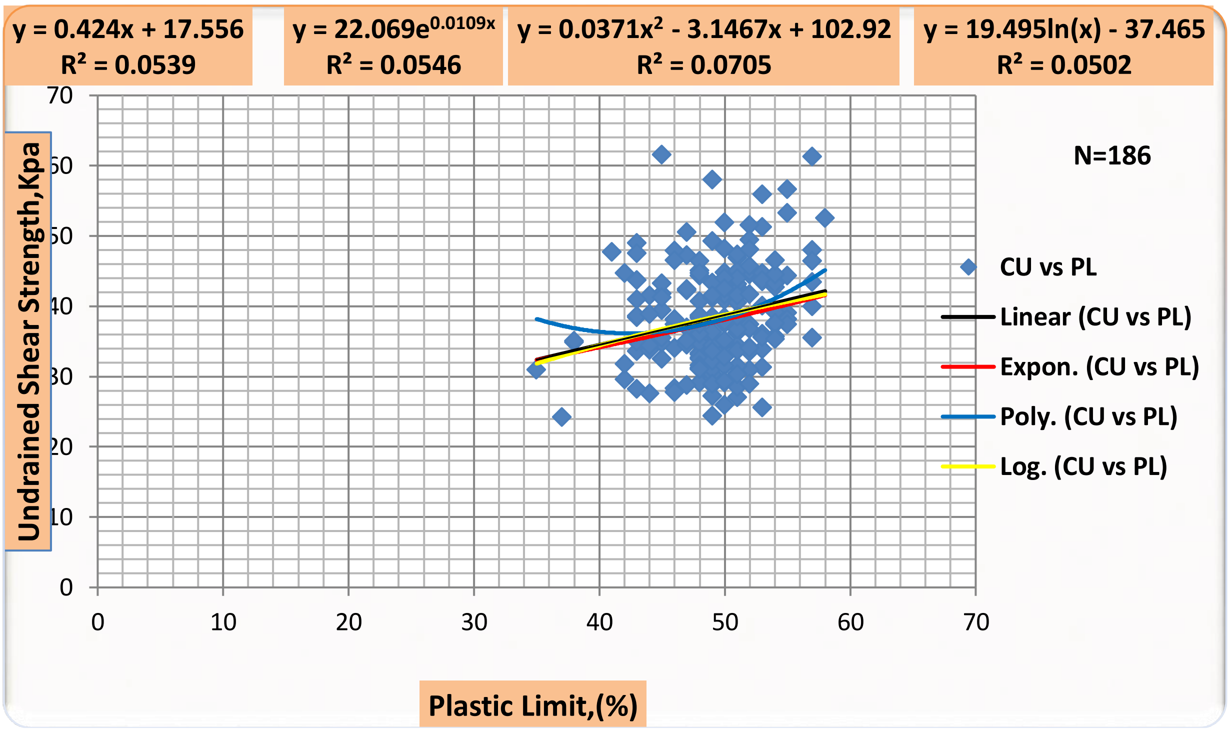

Figure 4-5 Scatter plot and best fit curves for C_U vs PL (MH Soil depth 2.5m-3.1m)

Correlation between Undrained Shear Strength Vs Liquid Limit

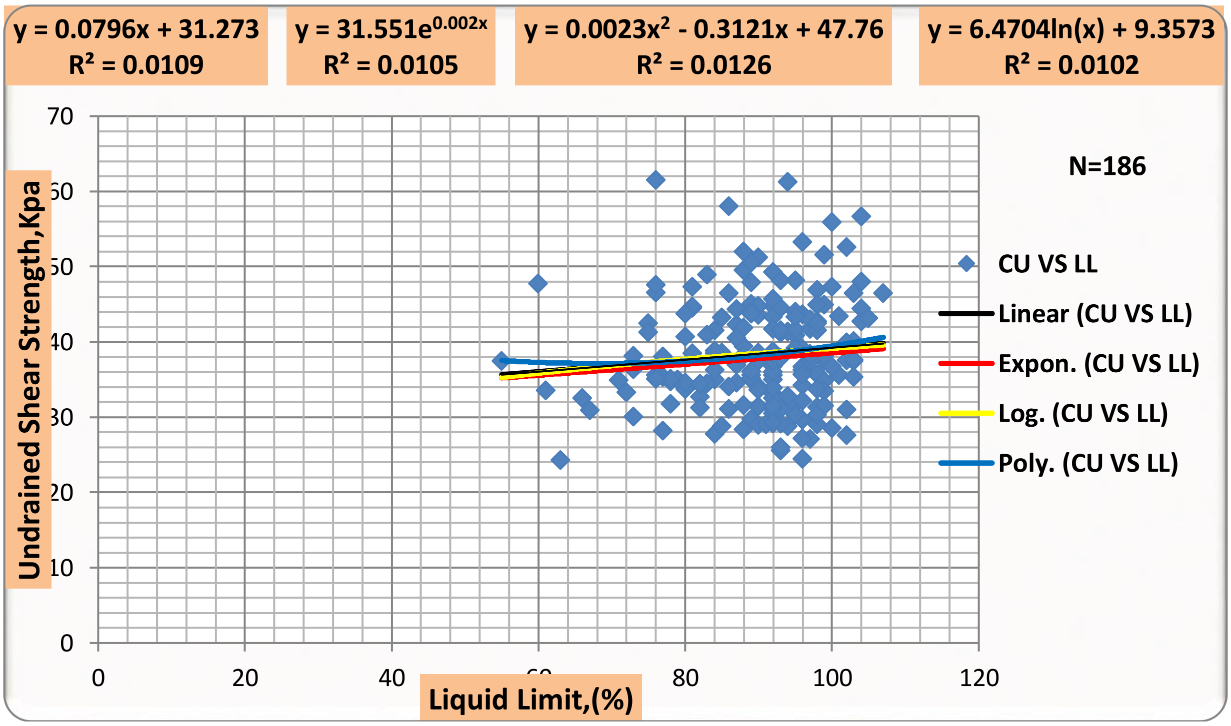

Figure 4-6 Scatter plot and best fit curves for C_U vs LL (MH Soil depth 2.5m-3.1m)

4.2.1.2 Correlation of Swelling Pressure (Ps)

Correlation Between Swelling Pressure (Ps) Vs Liquidity Index

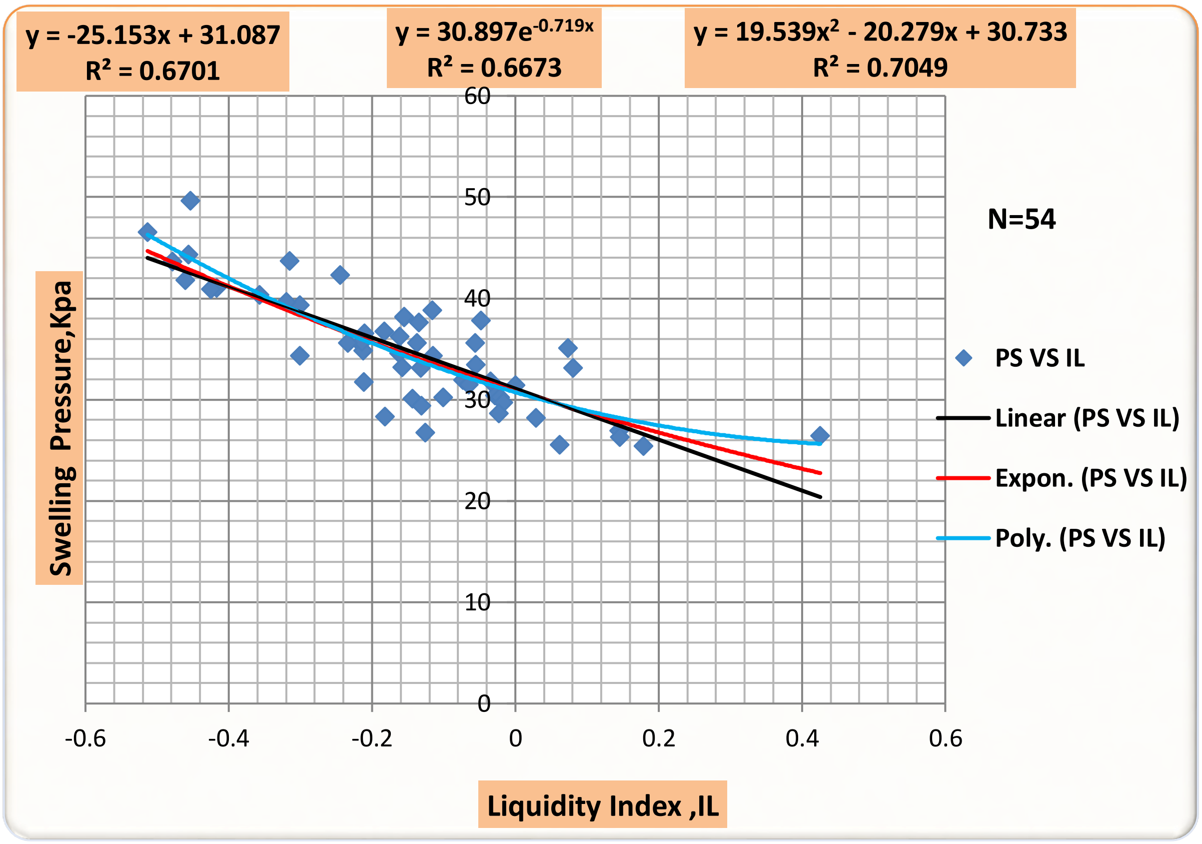

Figure 4-7 Scatter plot and best fit curves for Ps vs I_L (MH Soil depth 2.5m-3.0m)

Correlation between Swelling Pressure (Ps) Vs Natural Moisture Content

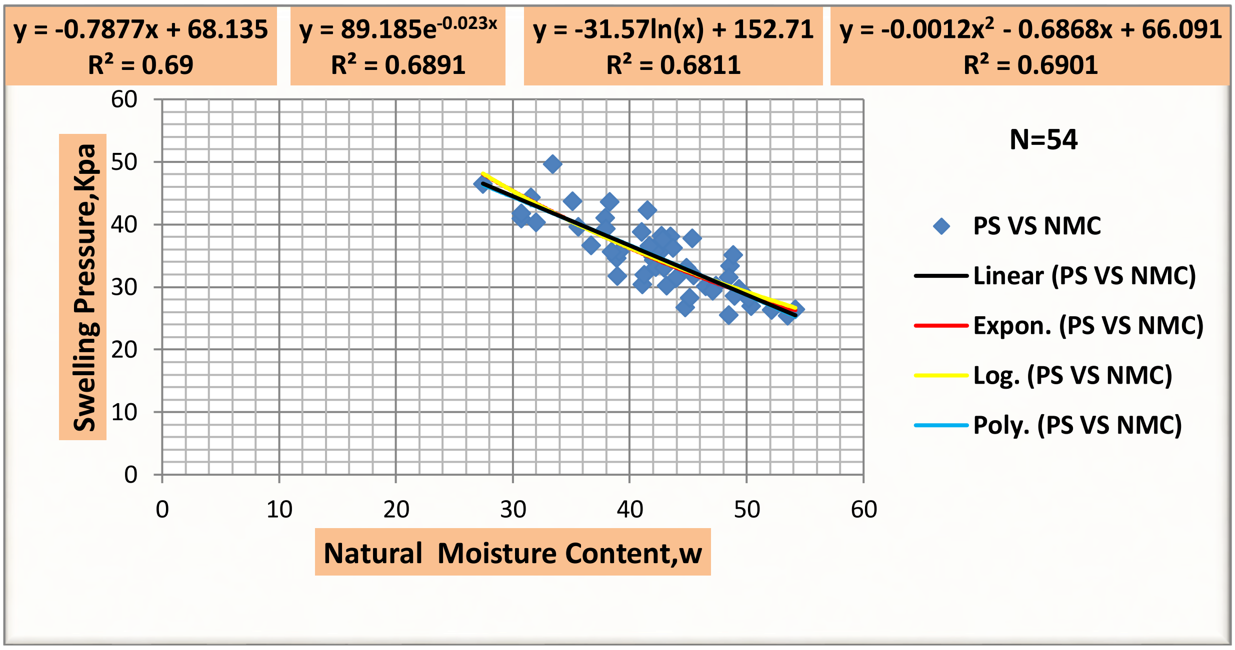

Figure 4-8 Scatter plot and best fit curves for Ps vs ω (MH Soil depth 2.5m-3.0m)

Correlation between Swelling Pressure (Ps) Vs Plastic Index (PI)

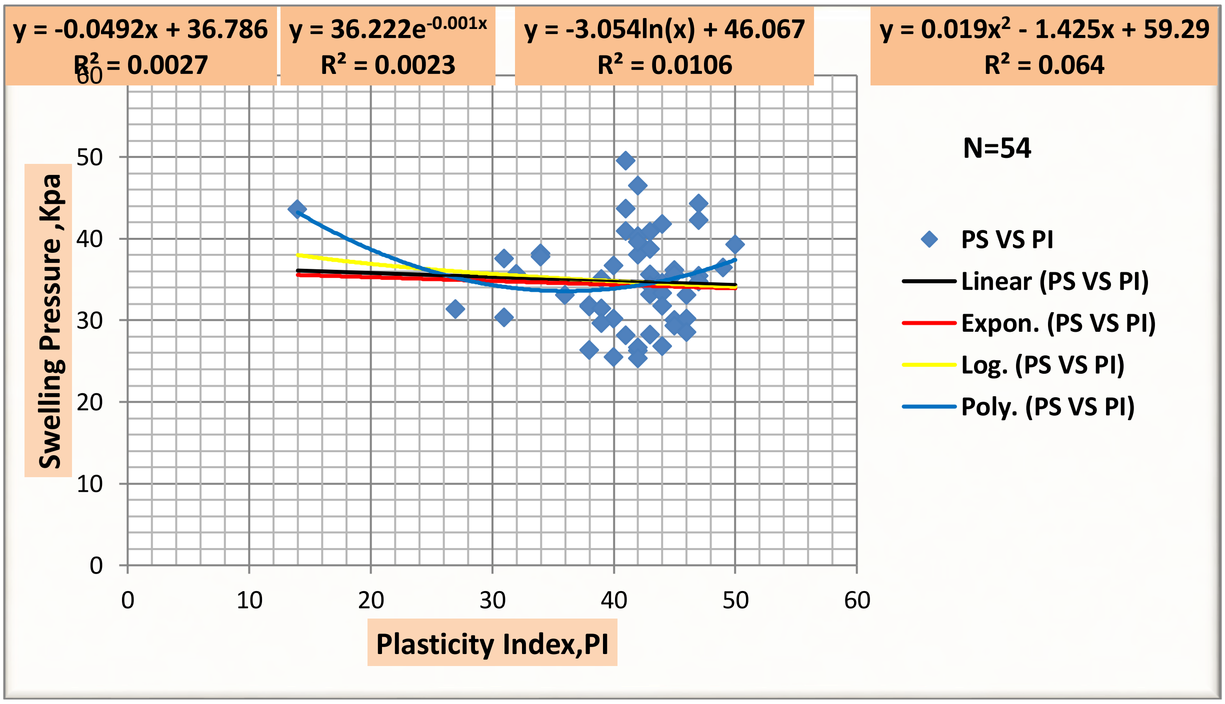

Figure 4-9 Scatter plot and best fit curves for Ps vs PI (MH Soil depth 2.5m-3.0m)

Correlation between Swelling Pressure (Ps) Vs Plastic Limit (PL)

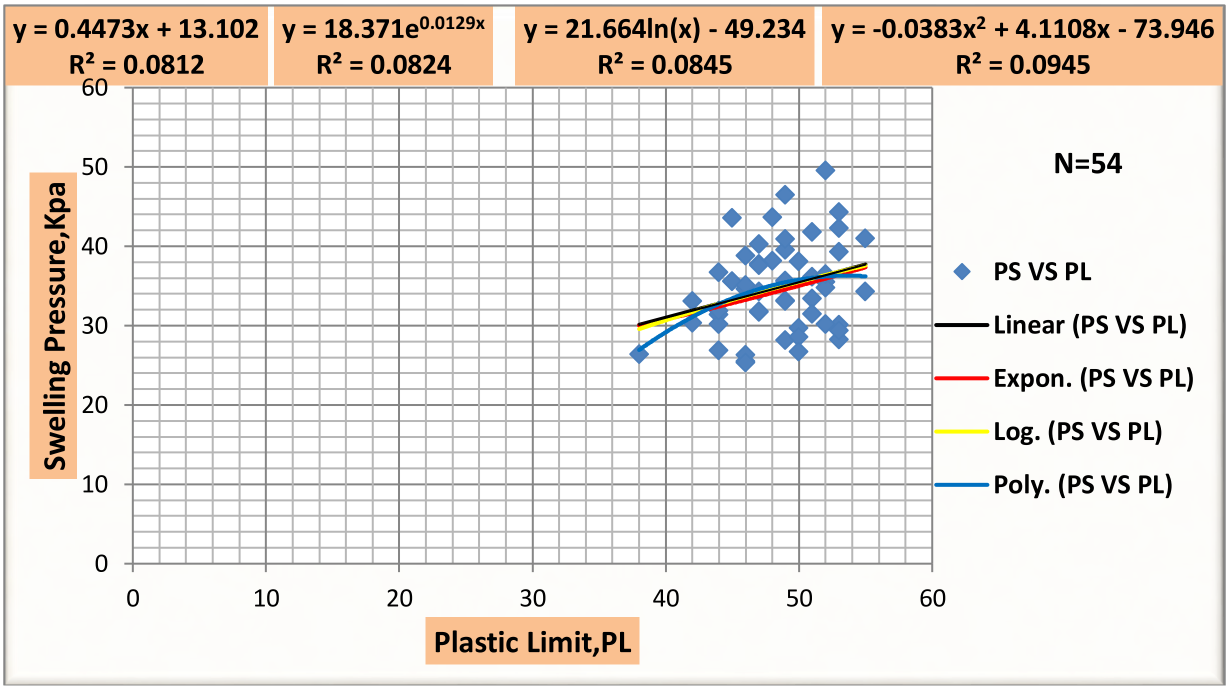

Figure 4-10 Scatter plot and best fit curves for Ps vs PL (MH Soil depth 2.5m-3.0m)

Correlation between Swelling Pressure (Ps) Vs Liquid Limit (LL)

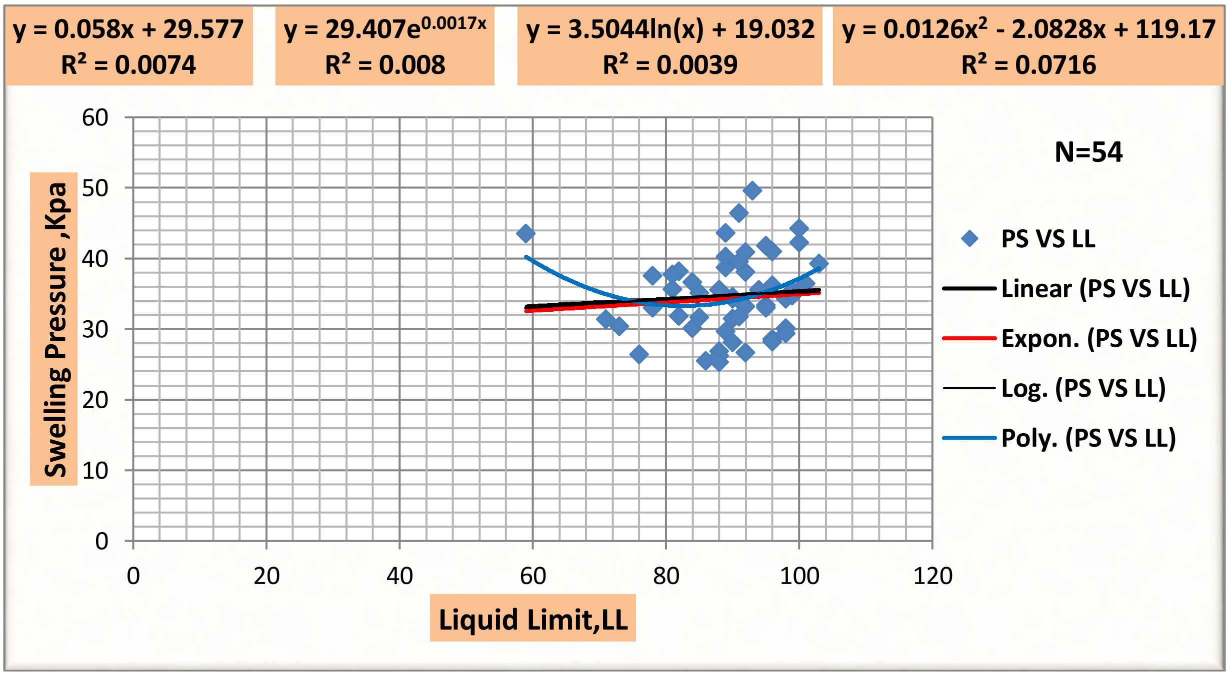

Figure 4-11 Scatter plot and best fit curves for Ps vs LL (MH Soil depth 2.5m-3.0m)

Correlation between Swelling Pressure (Ps) Vs Free Swell

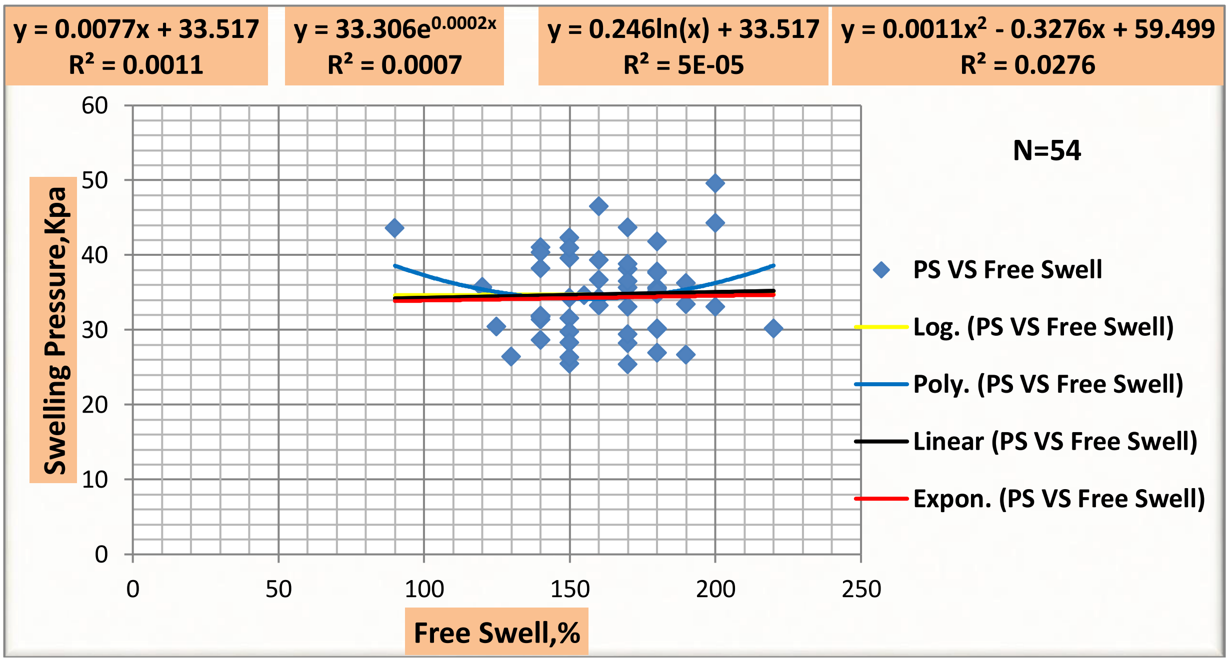

Figure 4-12 Scatter plot and best fit curves for Ps vs free swell (MH Soil depth 2.5m-3.0m)

Correlation between Liquidity Index Vs Swelling Pressure (Ps)

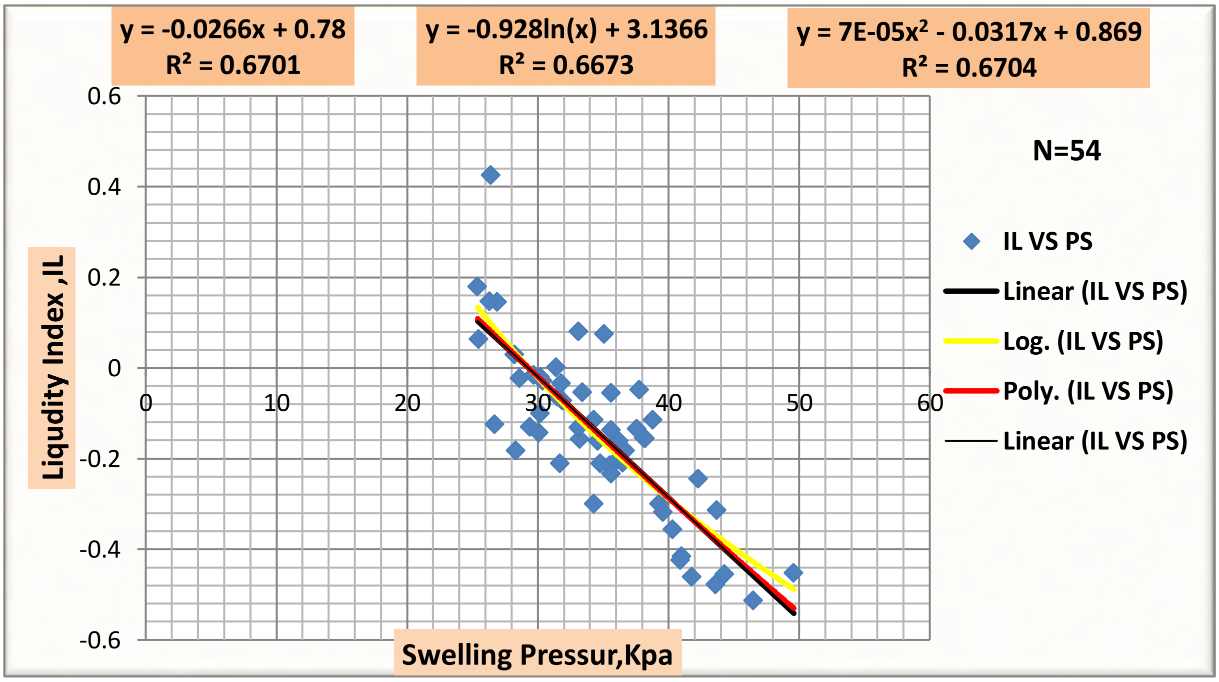

Figure 4-13 Scatter plot and best fit curves for IL vs Ps (MH Soil depth 2.5m-3.0m)

4.2.1.3 Correlation of Standard penetration numbers (SPT)

Correlation between Standard Penetration Number Vs Liquidity Index

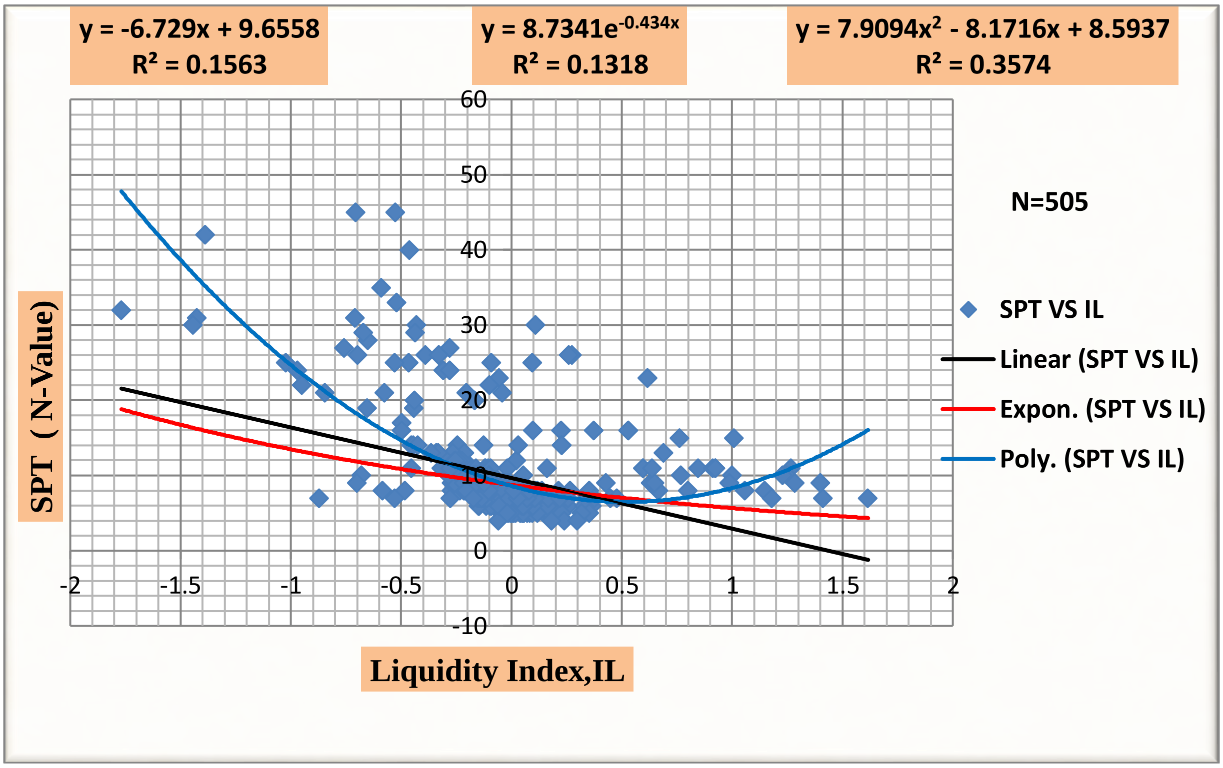

Figure 4-14 Scatter plot and best fit curves for SPT vs IL (MH and ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

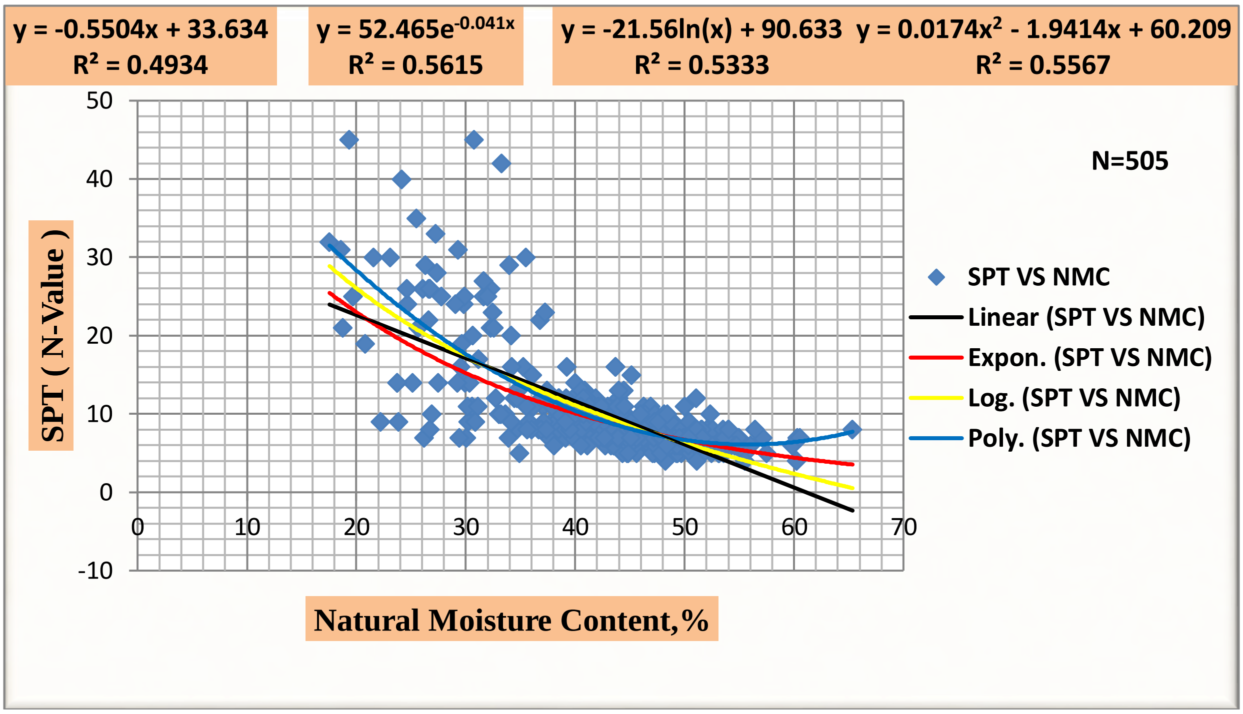

Figure 4-15 Scatter plot and best fit curves for SPT vs NMC (MH and ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration Number Vs Plasticity Index

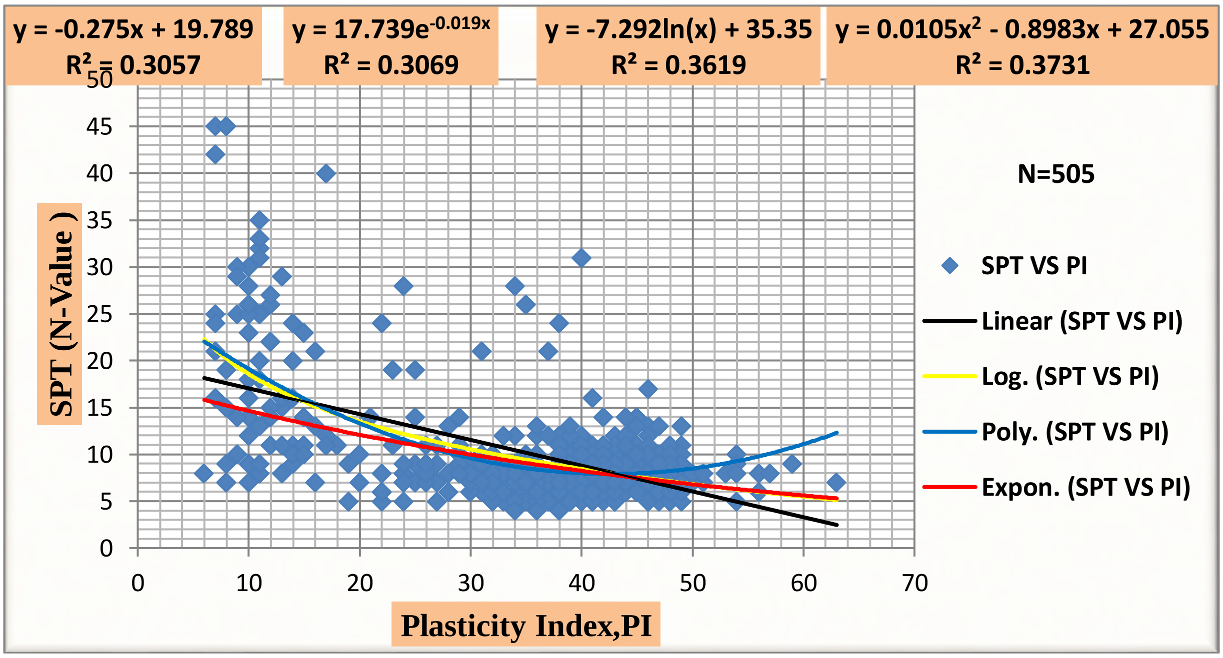

Figure 4-16 Scatter plot and best fit curves for SPT vs PI (MH and ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration NumberVs Plastic Limit

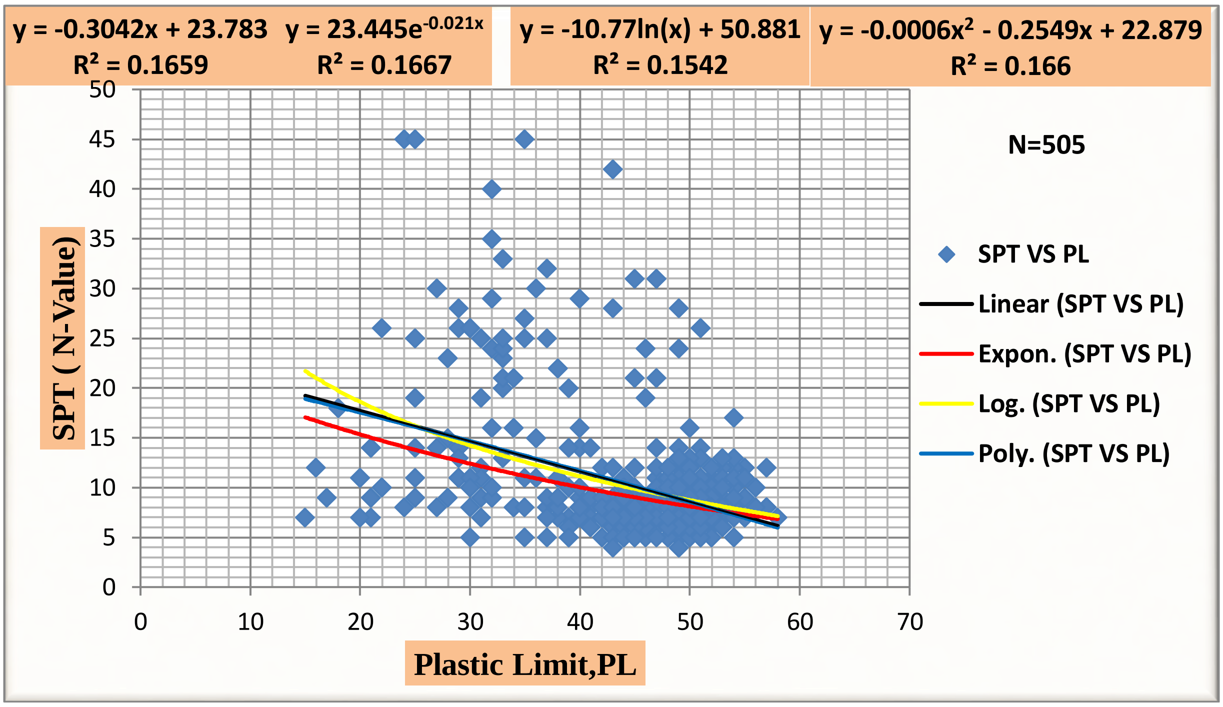

Figure 4-17 Scatter plot and best fit curves for SPT vs PL (MH and ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration NumberVs Liquid Limit

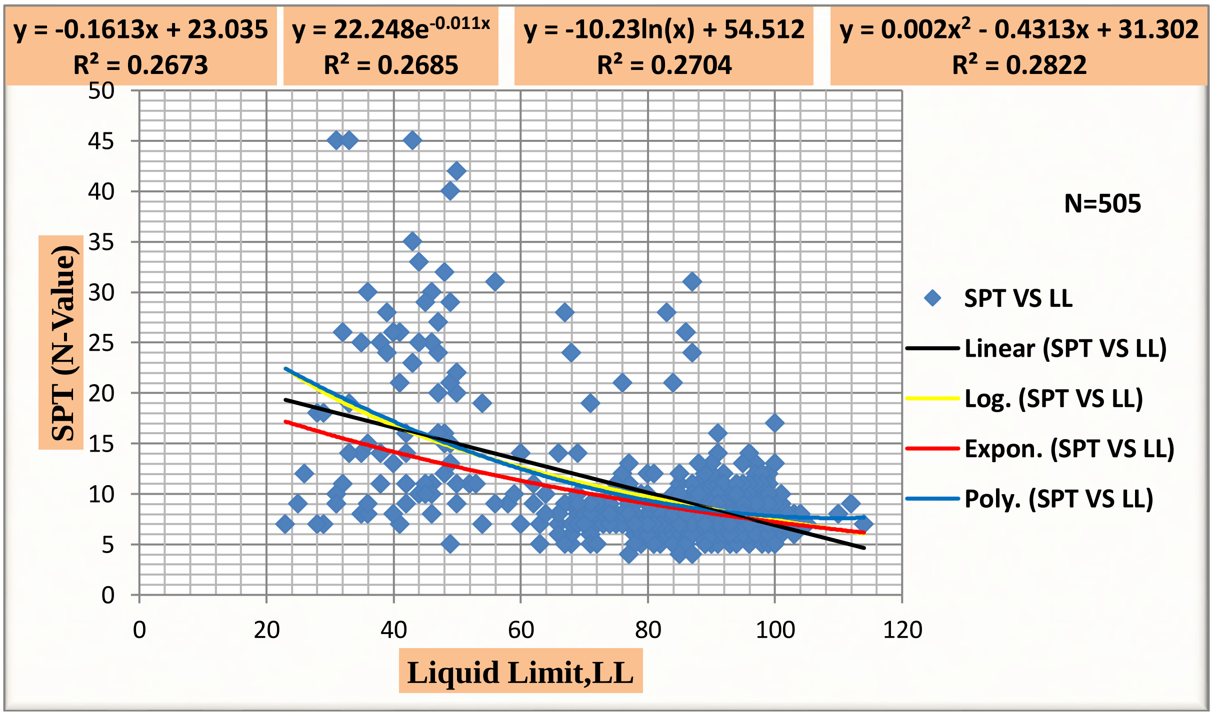

Figure 4-18 Scatter plot and best fit curves for SPT vs LL (MH and ML Soil at the depth of 1.50m-9.60m)

- **Silt with high plasticity Soil (MH)**

Correlation between Standard Penetration Number Vs Liquidity Index

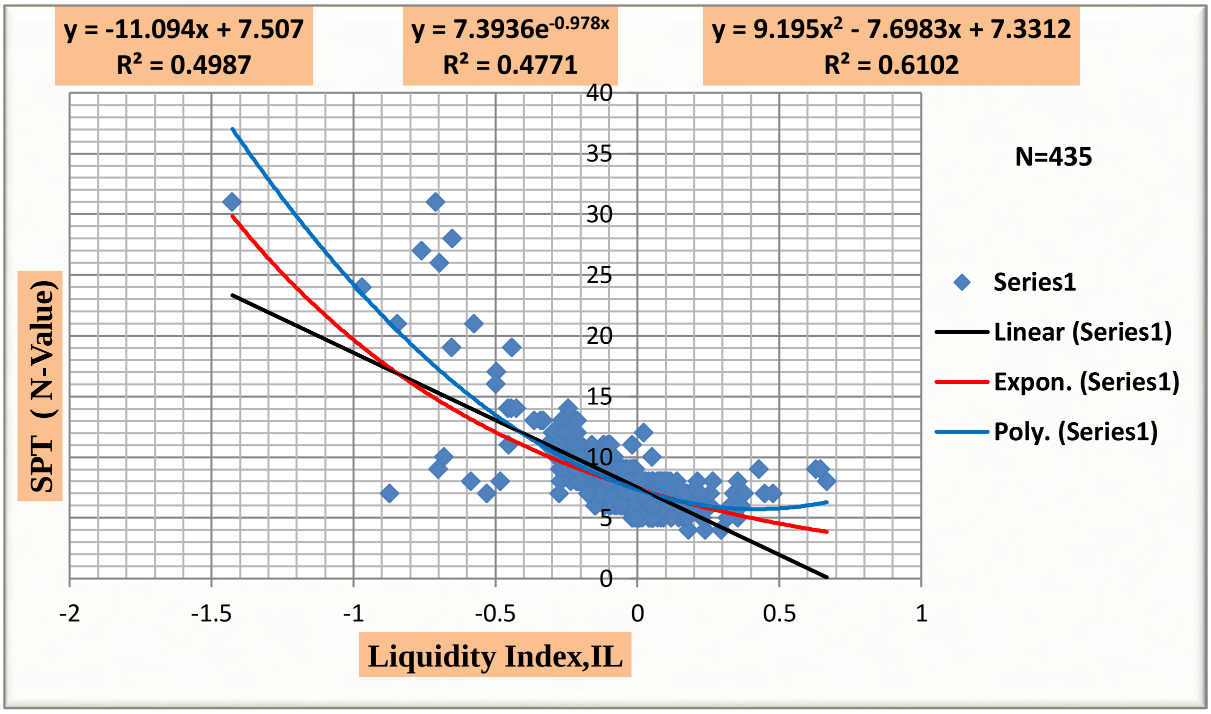

Figure 4-19 Scatter plot and best fit curves for SPT vs IL (MH Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

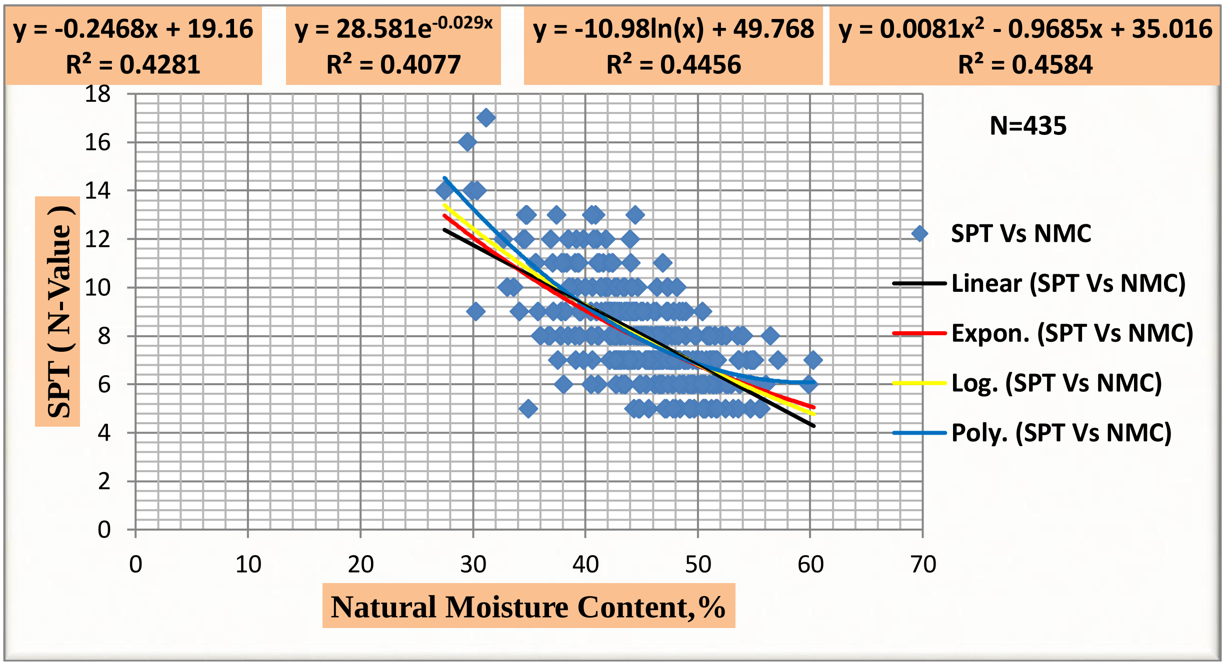

Figure 4-20 Scatter plot and best fit curves for SPT vs NMC (MH Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration NumberVs Plastic Limit

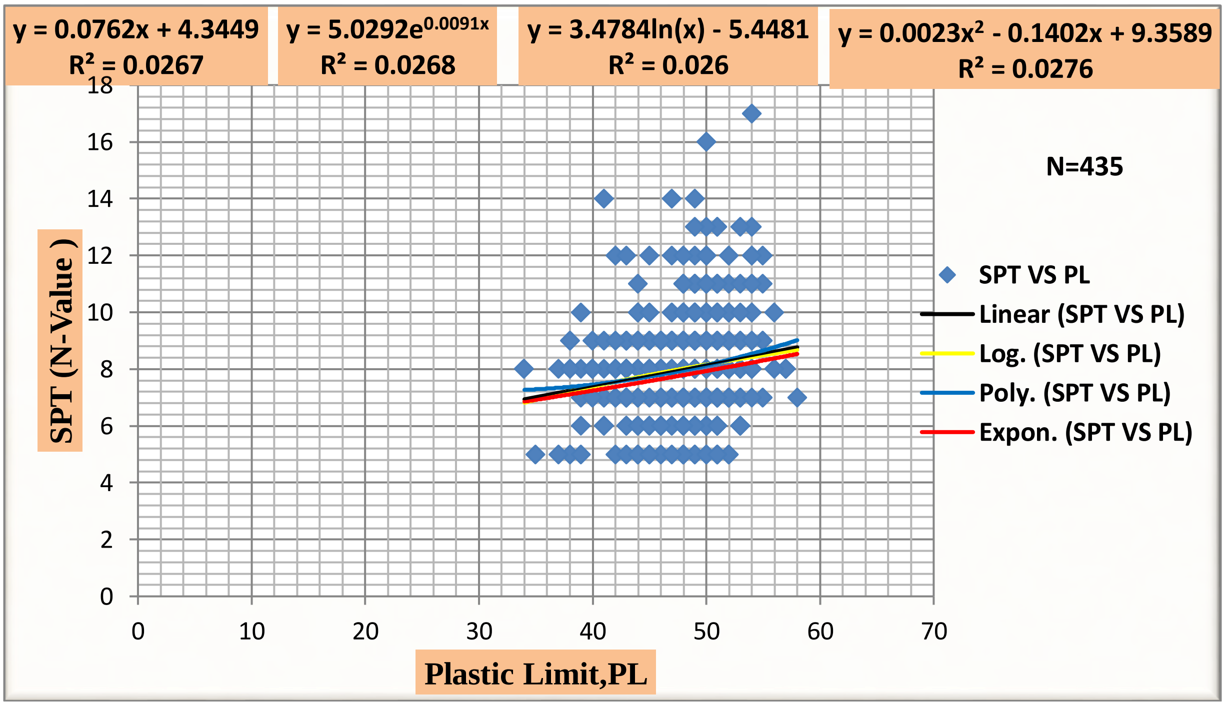

Figure 4-21 Scatter plot and best fit curves for SPT vs PL (MH Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration Number Vs Plasticity Index

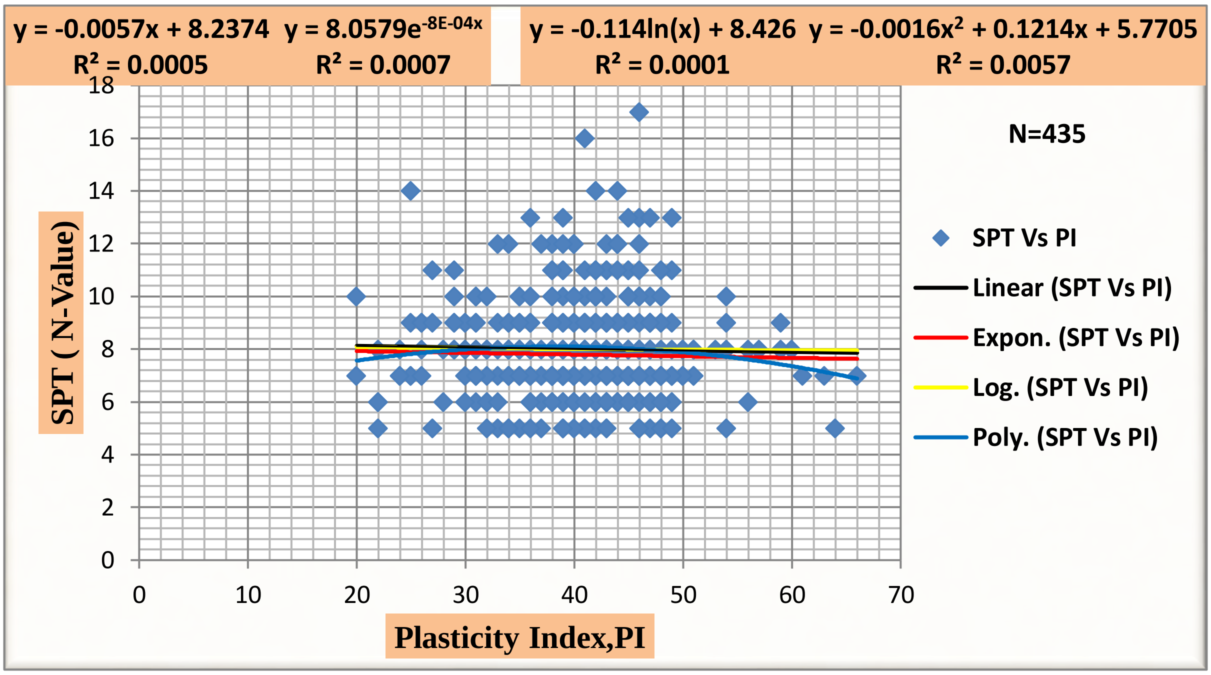

Figure 4-22 Scatter plot and best fit curves for SPT vs PI (MH Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration NumberVs Liquid Limit

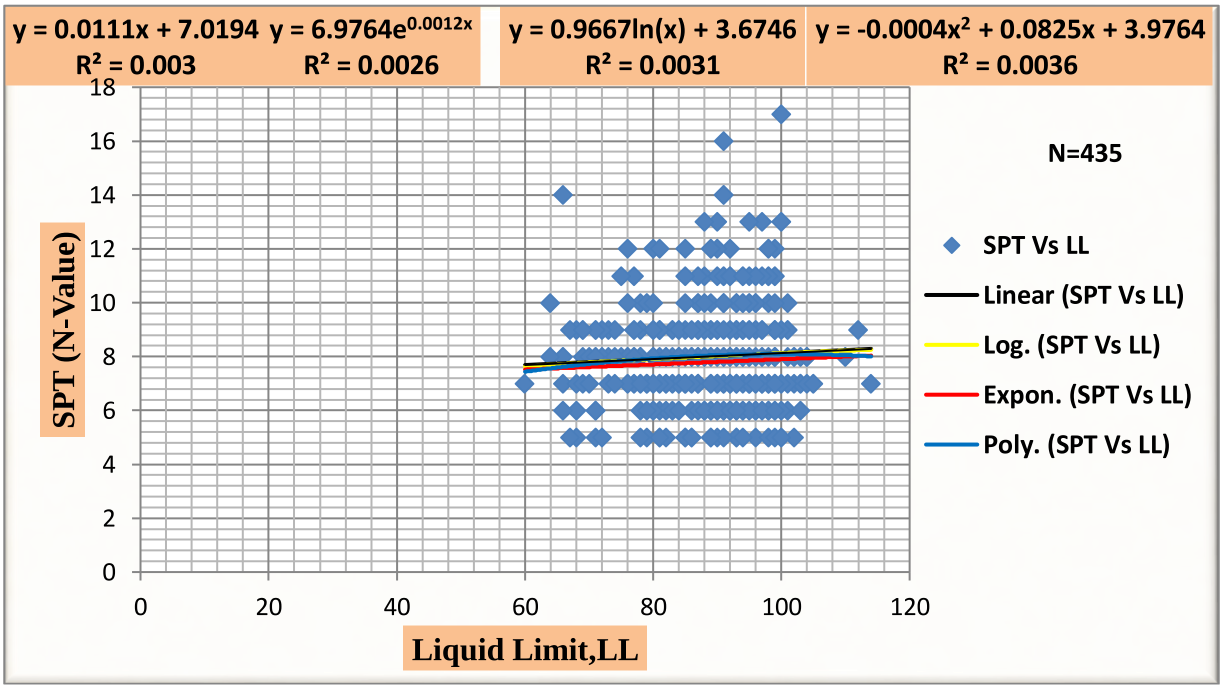

Figure 4-23 Scatter plot and best fit curves for SPT vs LL (MH Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration Number Vs Liquidity Index

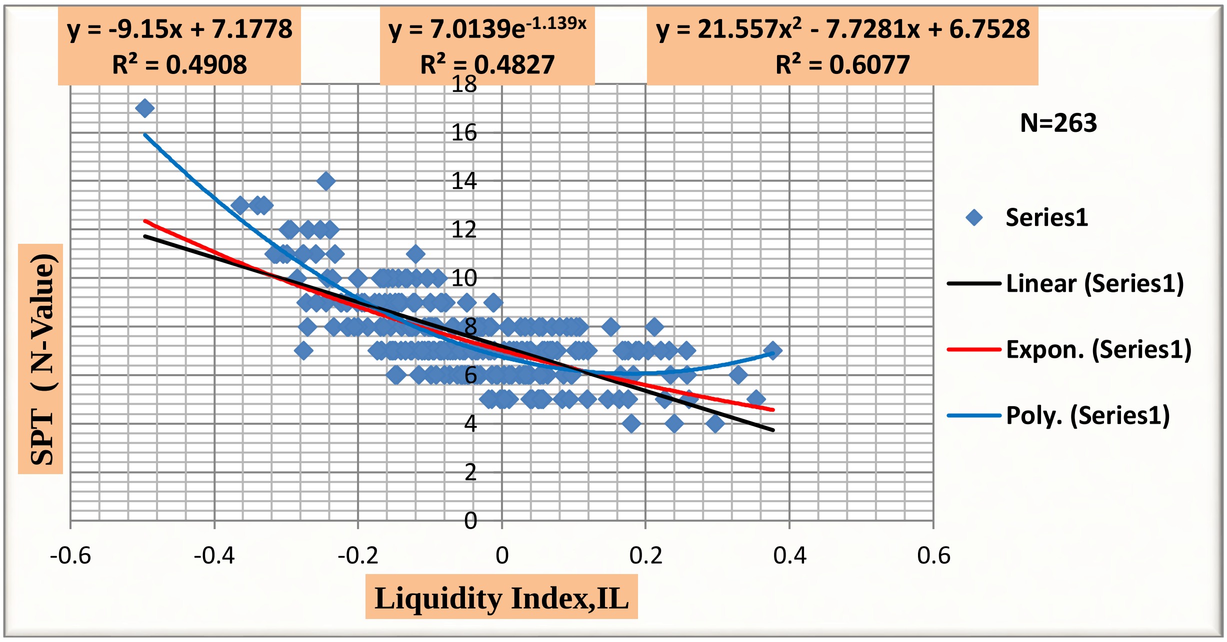

Figure 4-24 Scatter plot and best fit curves for SPT vs IL (MH Soil at the depth of 1.50m-5.10m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

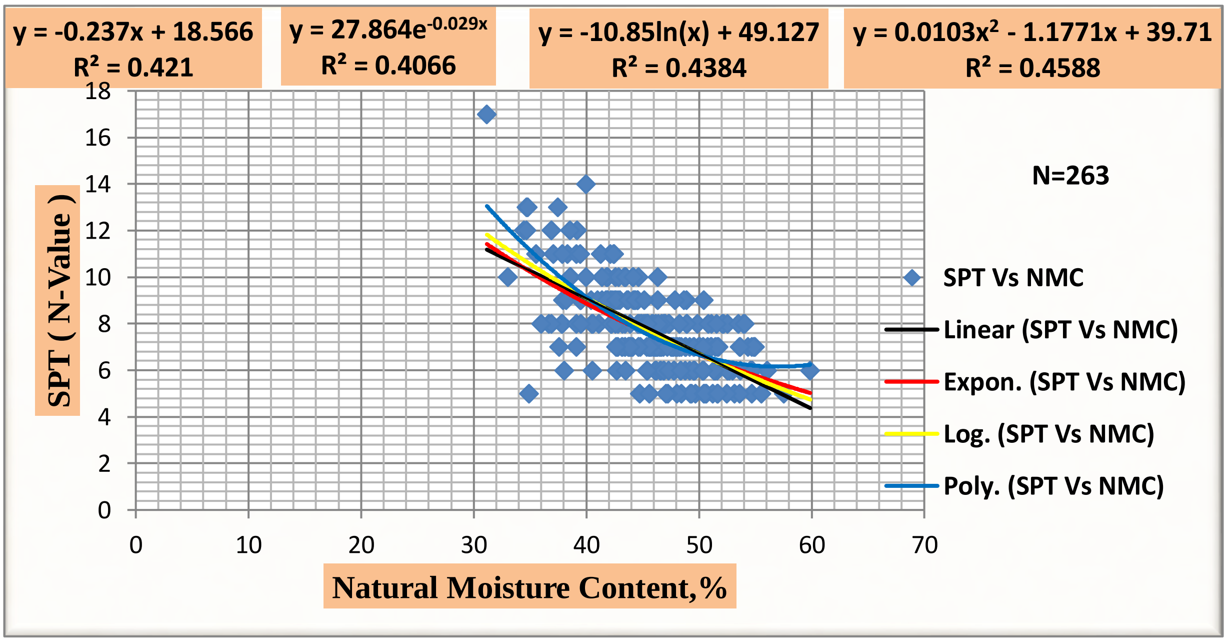

Figure 4-25 Scatter plot and best fit curves for SPT vs NMC (MH Soil at the depth of 1.50m-5.10m)

Correlation between Standard Penetration Number Vs Liquidity Index

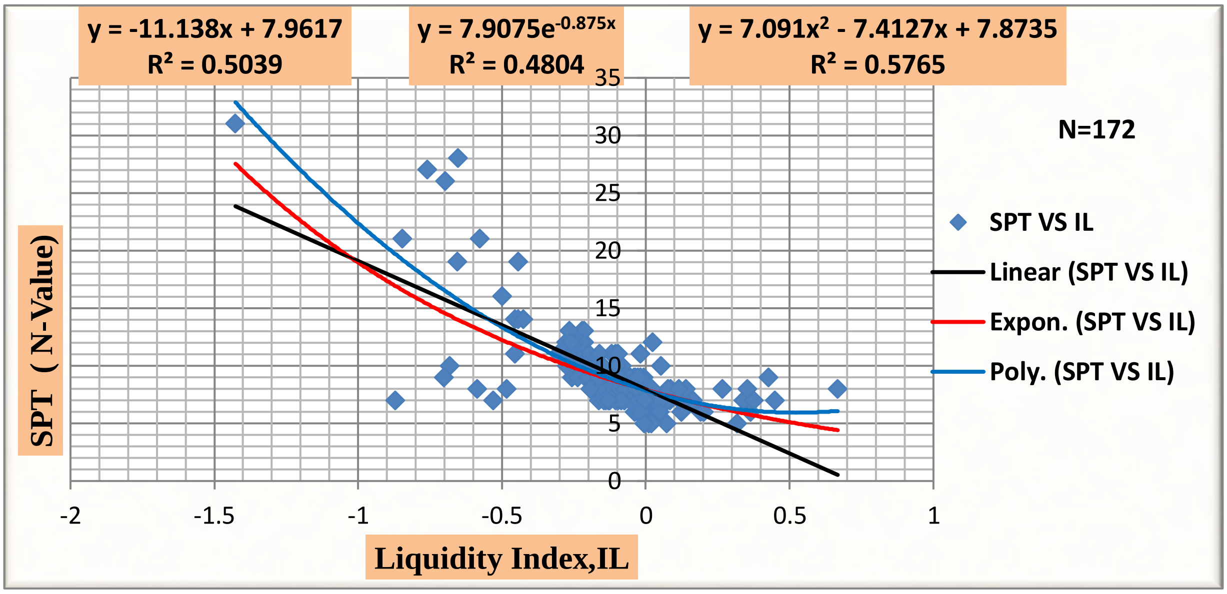

Figure 4-26 Scatter plot and best fit curves for SPT vs IL (MH soil at the depth of 6.00m-9.60m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

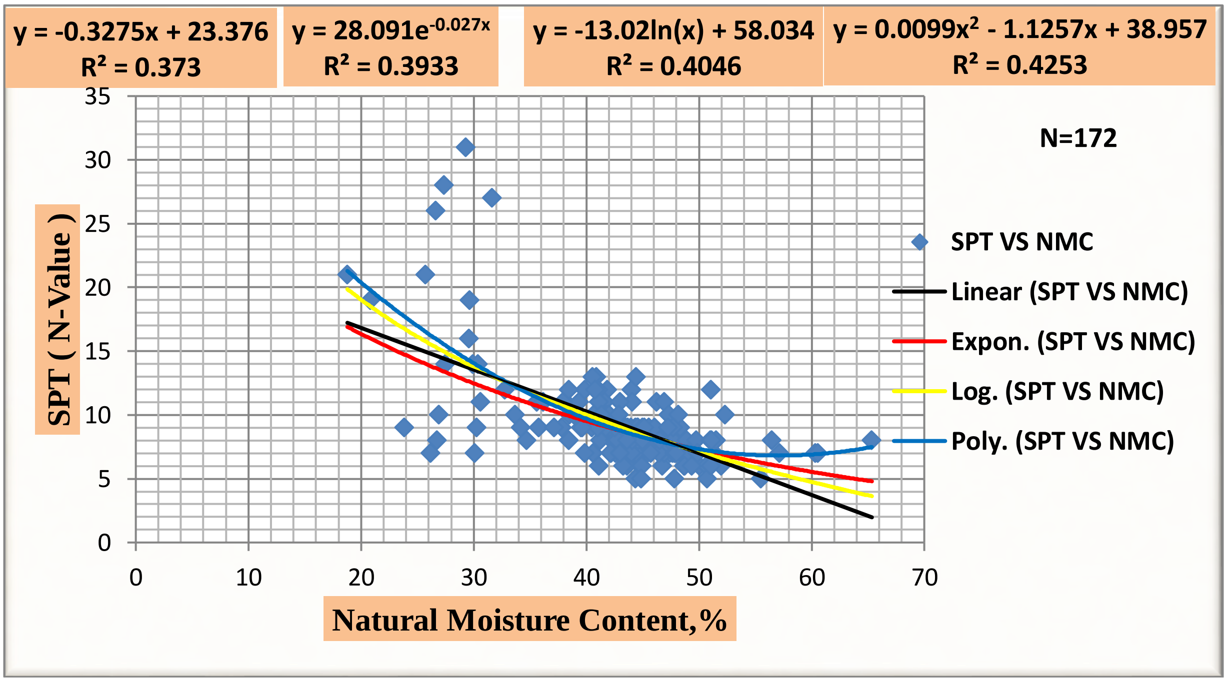

Figure 4-27 Scatter plot and best fit curves for SPT vs NMC (MH soil at the depth of 6.00m-9.60m)

Correlation between Standard Penetration Number Vs Liquidity Index

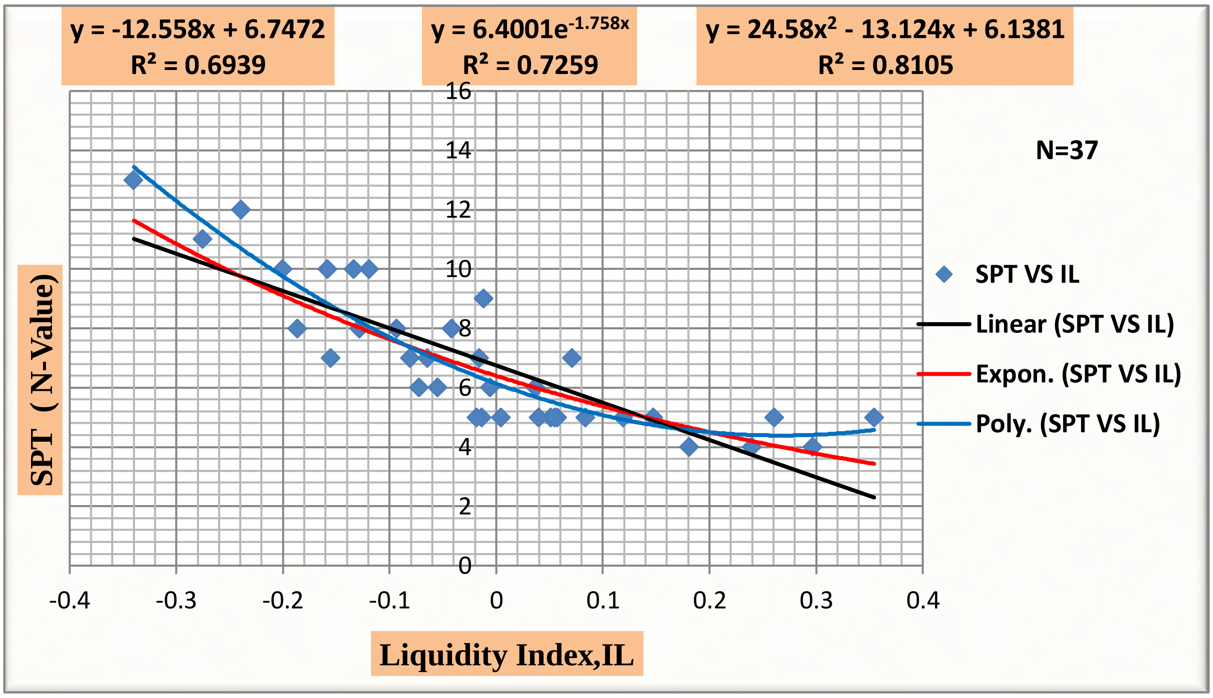

Figure 4-28 Scatter plot and best fit curves for SPT vs IL (MH soil at the depth of 1.50m-2.10m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

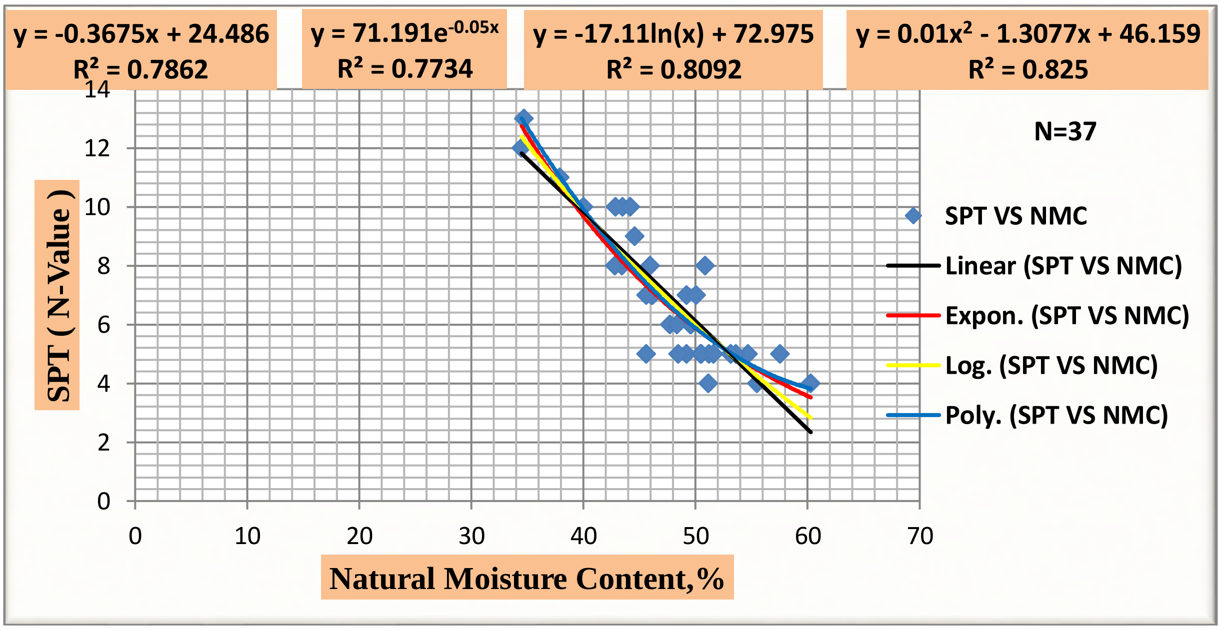

Figure 4-29 Scatter plot and best fit curves for SPT vs NMC (MH soil at the depth of 1.50m-2.10m)

Correlation between Standard Penetration Number Vs Liquidity Index

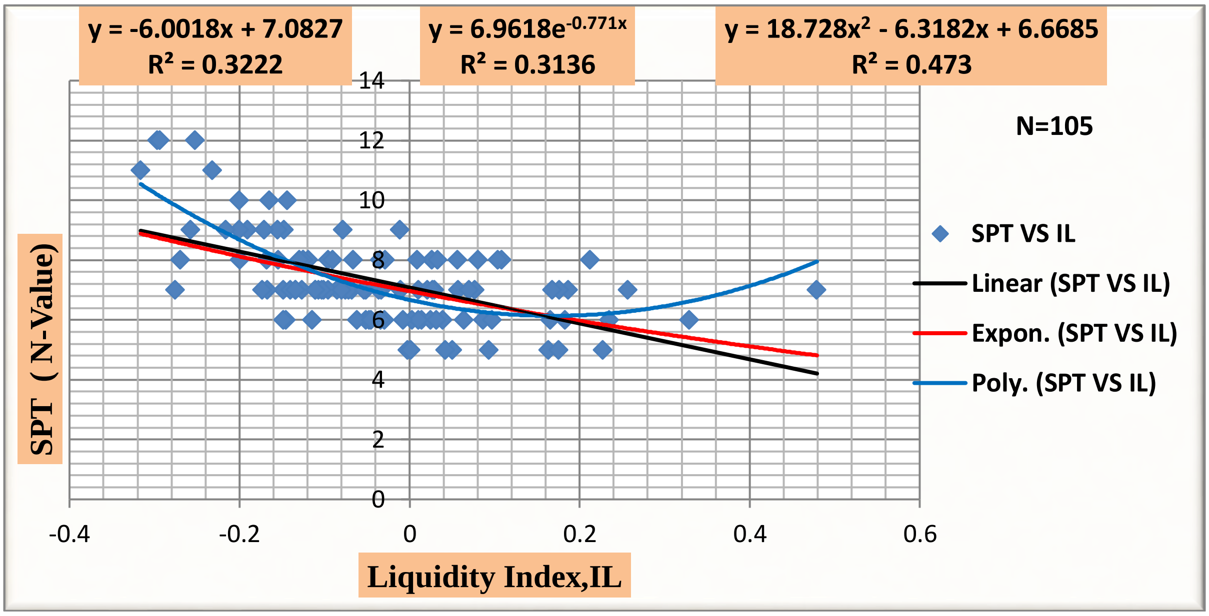

Figure 4-30 Scatter plot and best fit curves for SPT vs IL (MH soil at the depth of 3.60m-4.50m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

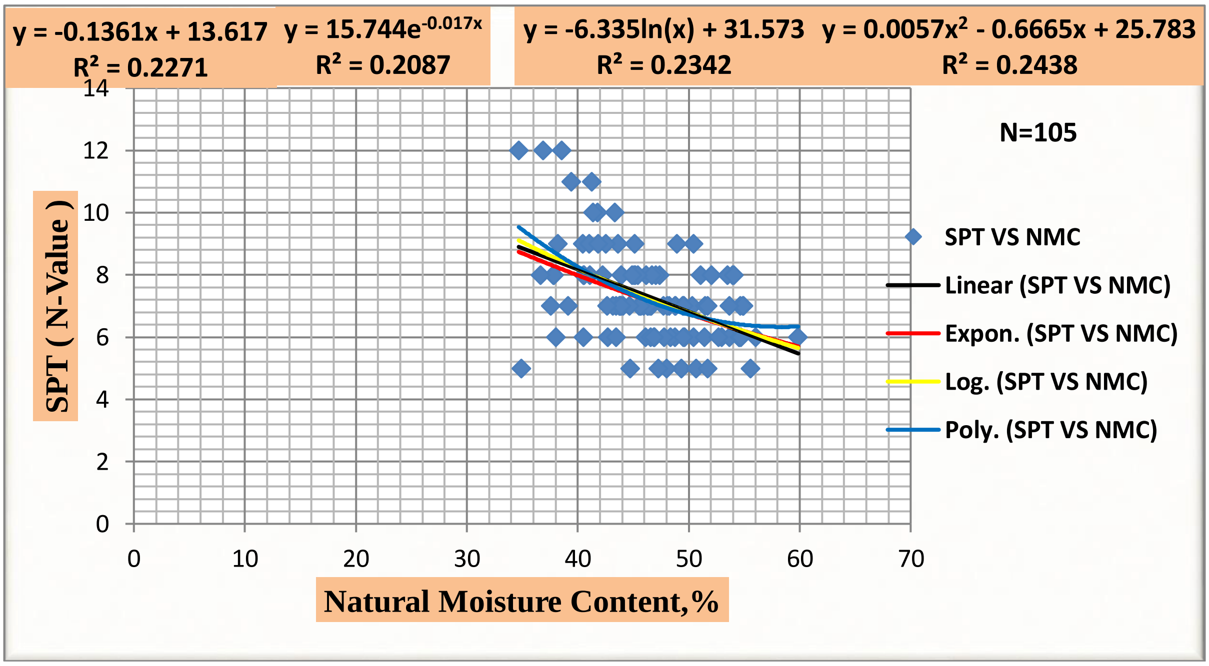

Figure 4-31 Scatter plot and best fit curves for SPT vs NMC (MH soil at the depth of 3.60m-4.50m)

Correlation between Standard Penetration Number Vs Liquidity Index

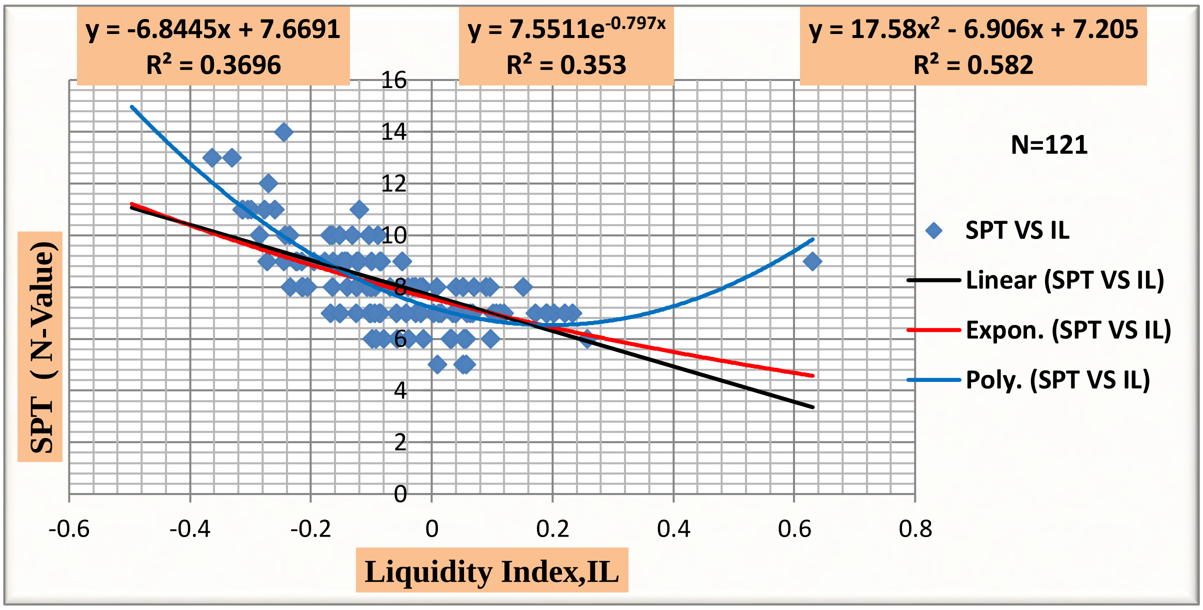

Figure 4-32 Scatter plot and best fit curves for SPT vs IL (MH soil at the depth of 4.50m-5.10m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

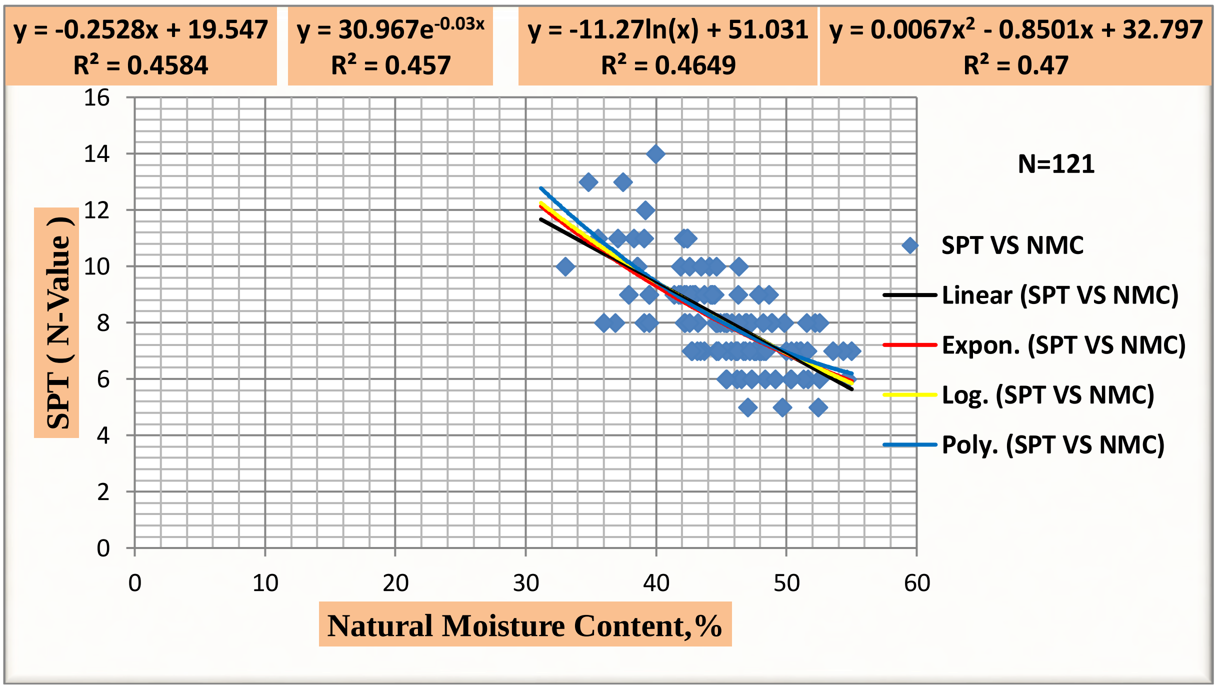

Figure 4-33 Scatter plot and best fit curves for SPT vs NMC (MH soil at the depth of 4.50m-5.10m)

- **Silt with Low Plasticity Soil (ML)**

Correlation between Standard Penetration Number Vs Liquidity Index

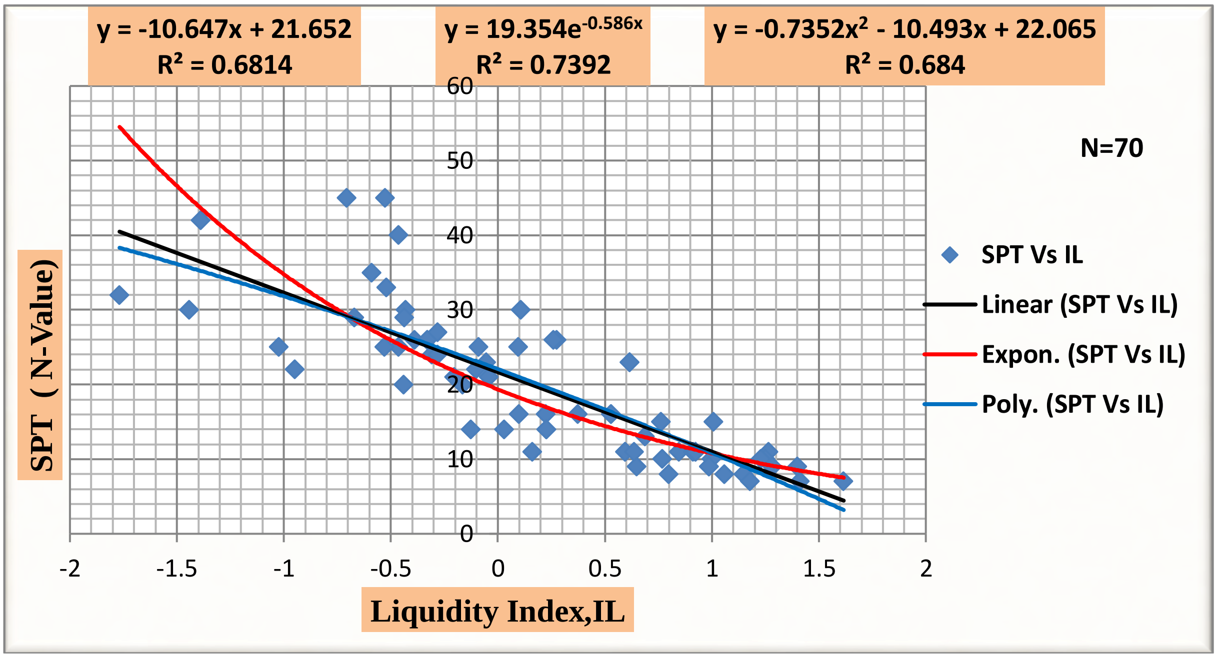

Figure 4-34 Scatter plot and best fit curves for SPT vs IL (ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

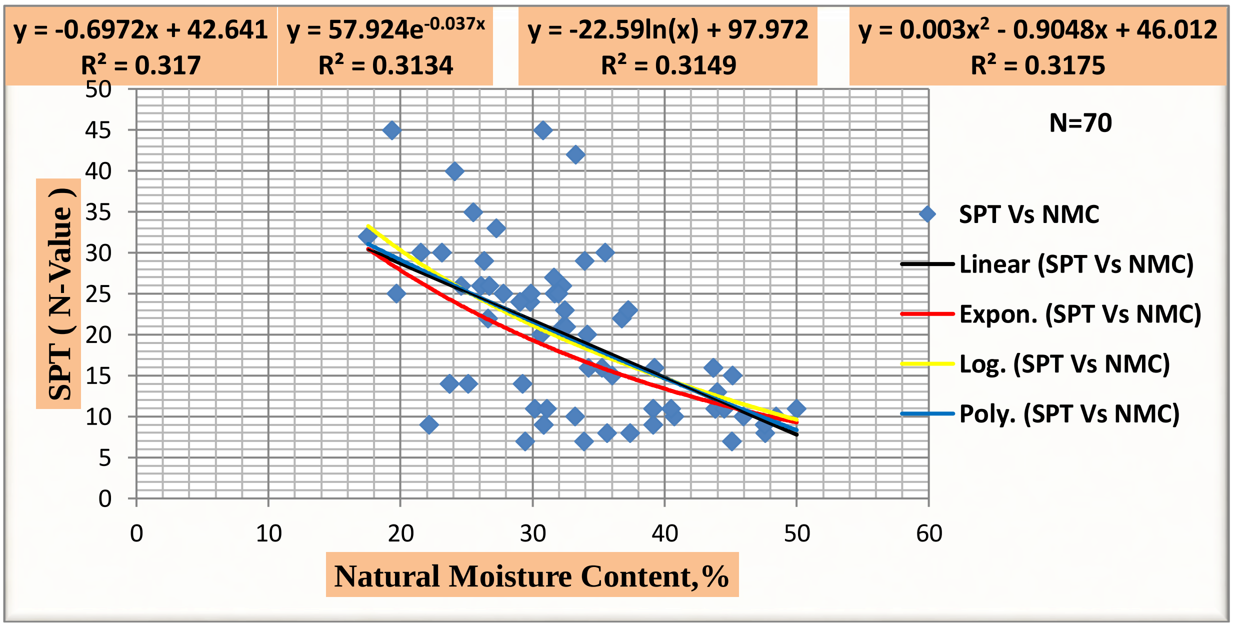

Figure 4-35 Scatter plot and best fit curves for SPT vs NMC (ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration Number Vs Plasticity Index

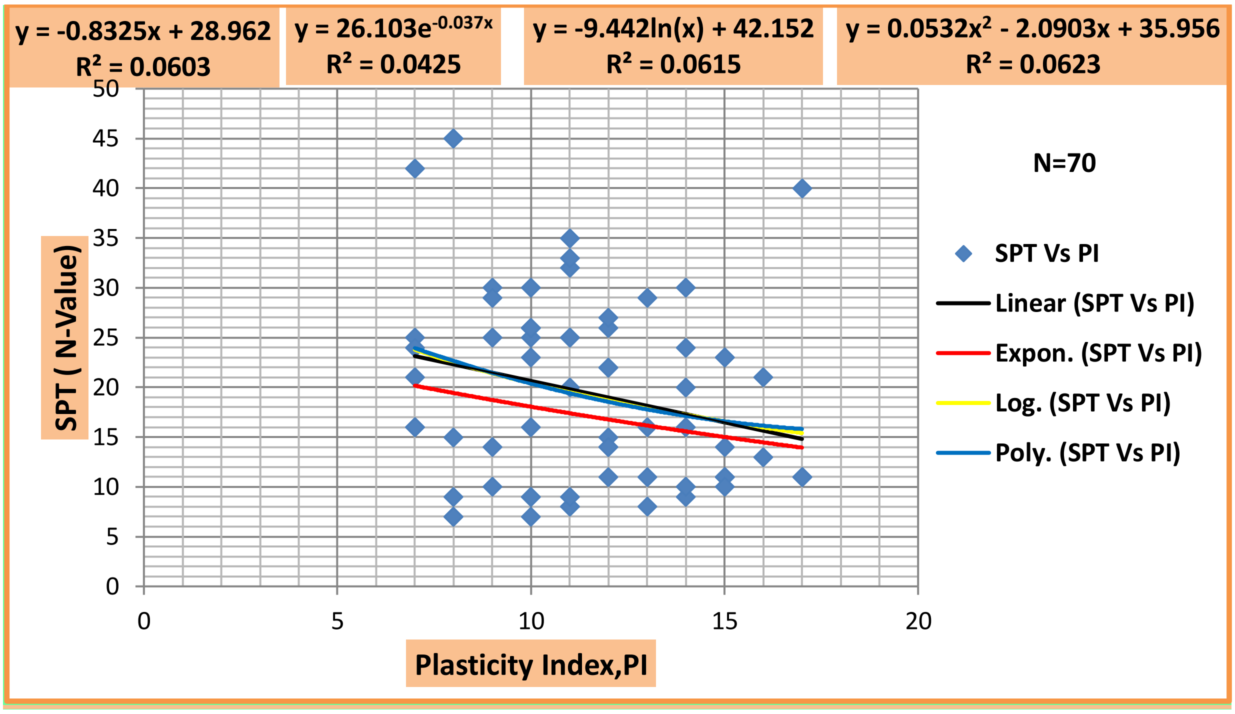

Figure 4-36 Scatter plot and best fit curves for SPT vs PI (ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration NumberVs Plastic Limit

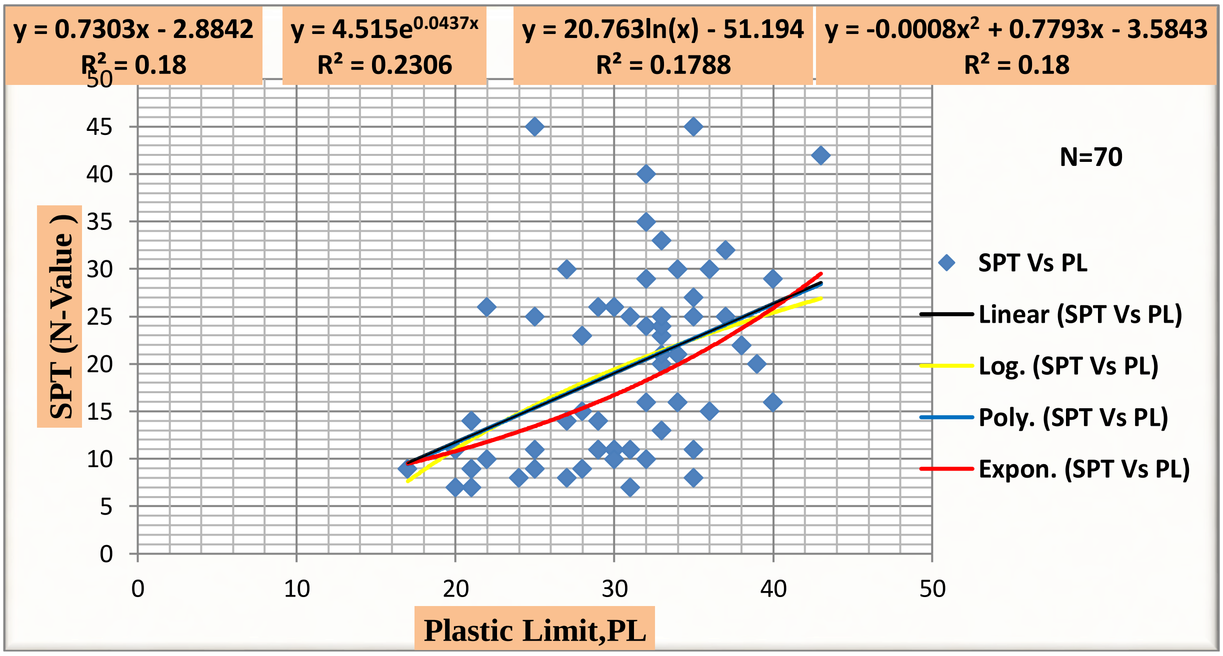

Figure 4-37 Scatter plot and best fit curves for SPT vs PL (ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration NumberVs Liquid Limit

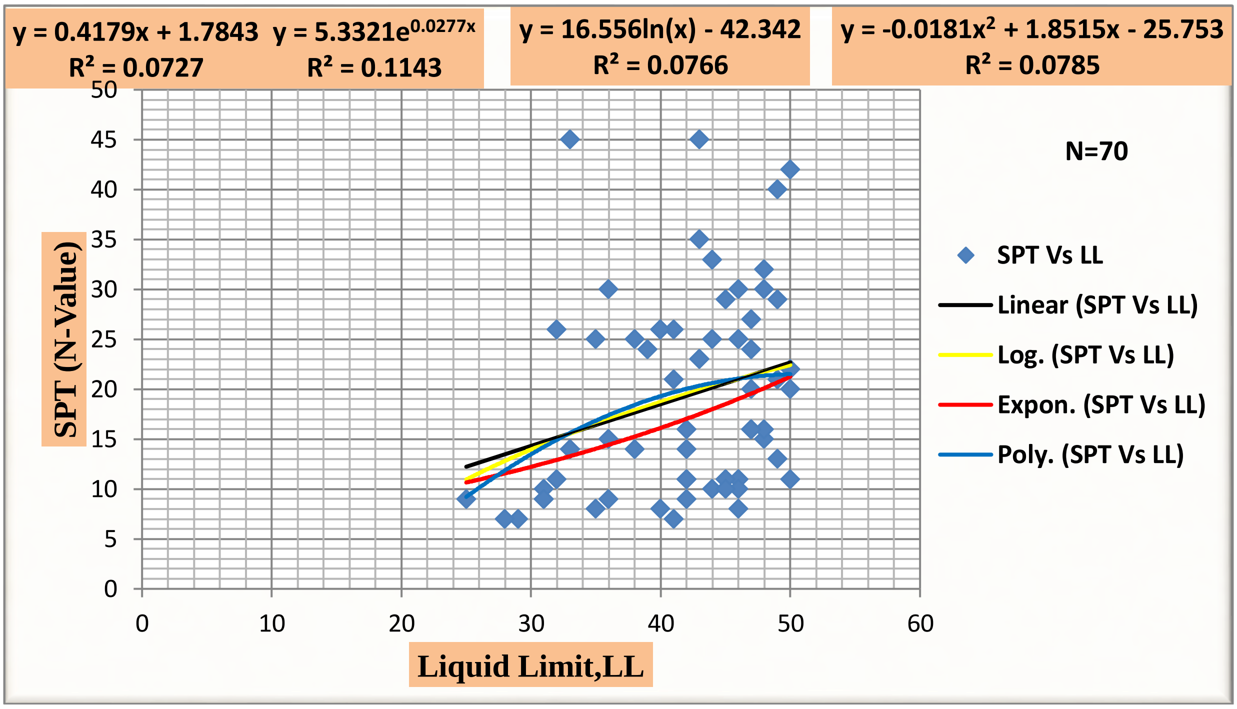

Figure 4-38 Scatter plot and best fit curves for SPT vs LL (ML Soil at the depth of 1.50m-9.60m)

Correlation between Standard Penetration Number Vs Liquidity Index

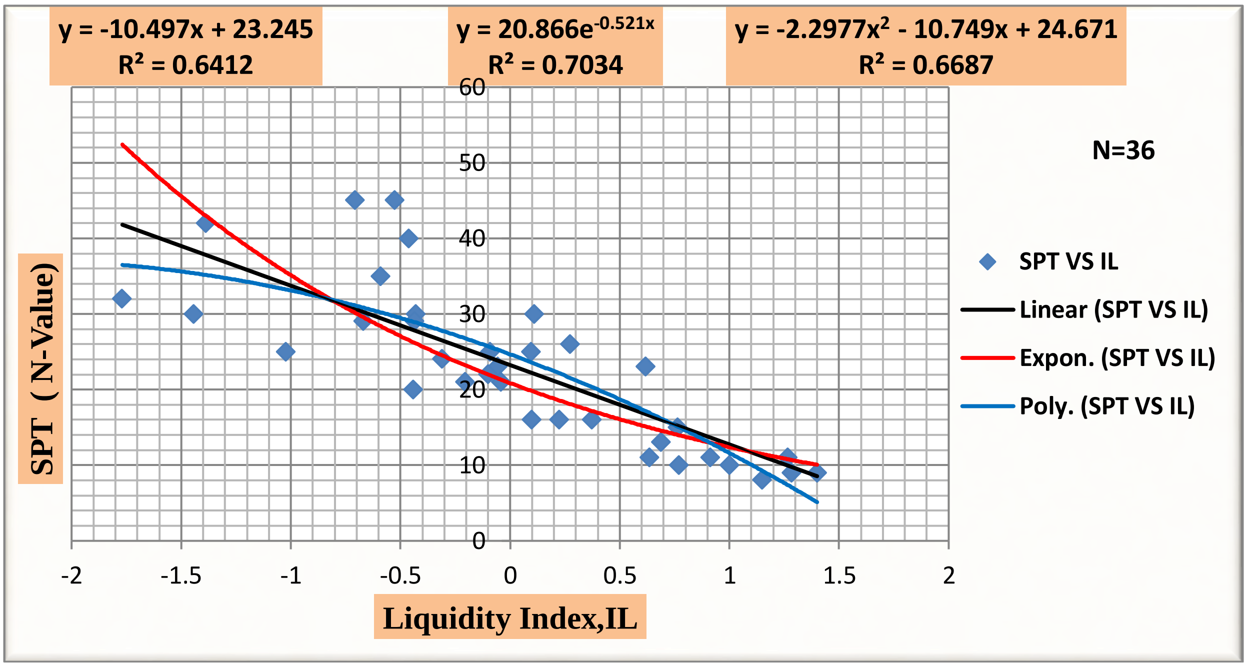

Figure 4-39 Scatter plot and best fit curves for SPT vs IL (ML Soil at the depth of 1.50m-5.10m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

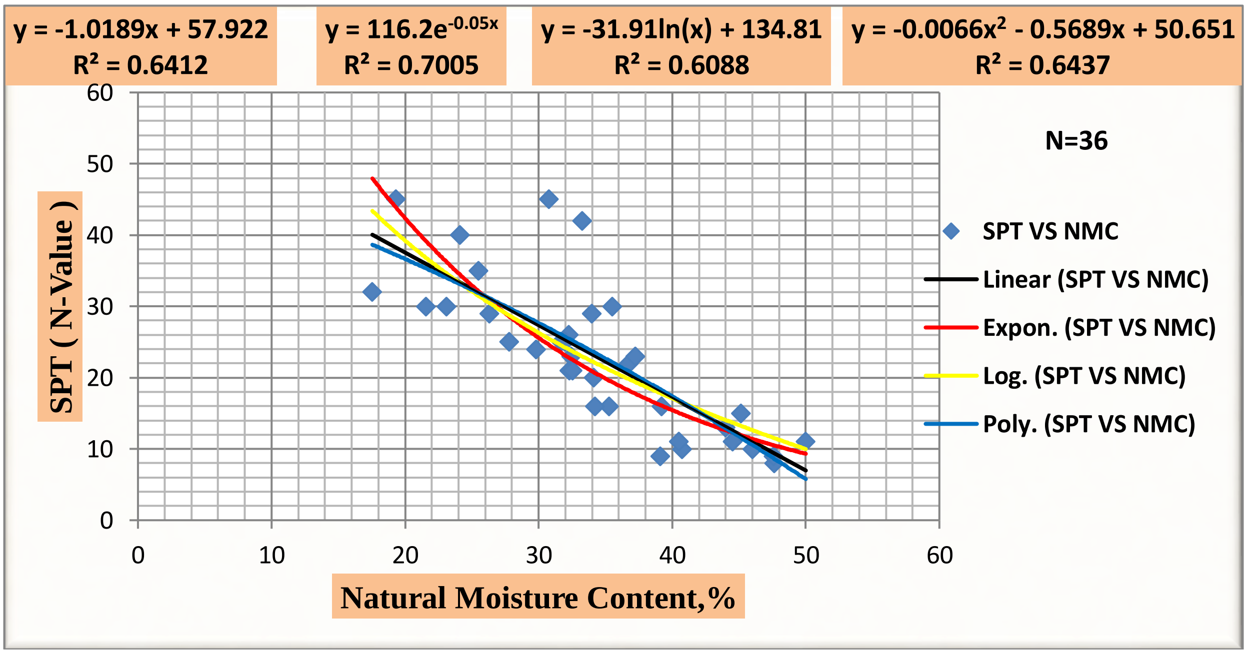

Figure 4-40 Scatter plot and best fit curves for SPT vs NMC (ML Soil at the depth of 1.50m-5.10)

Correlation between Standard Penetration Number Vs Liquidity Index

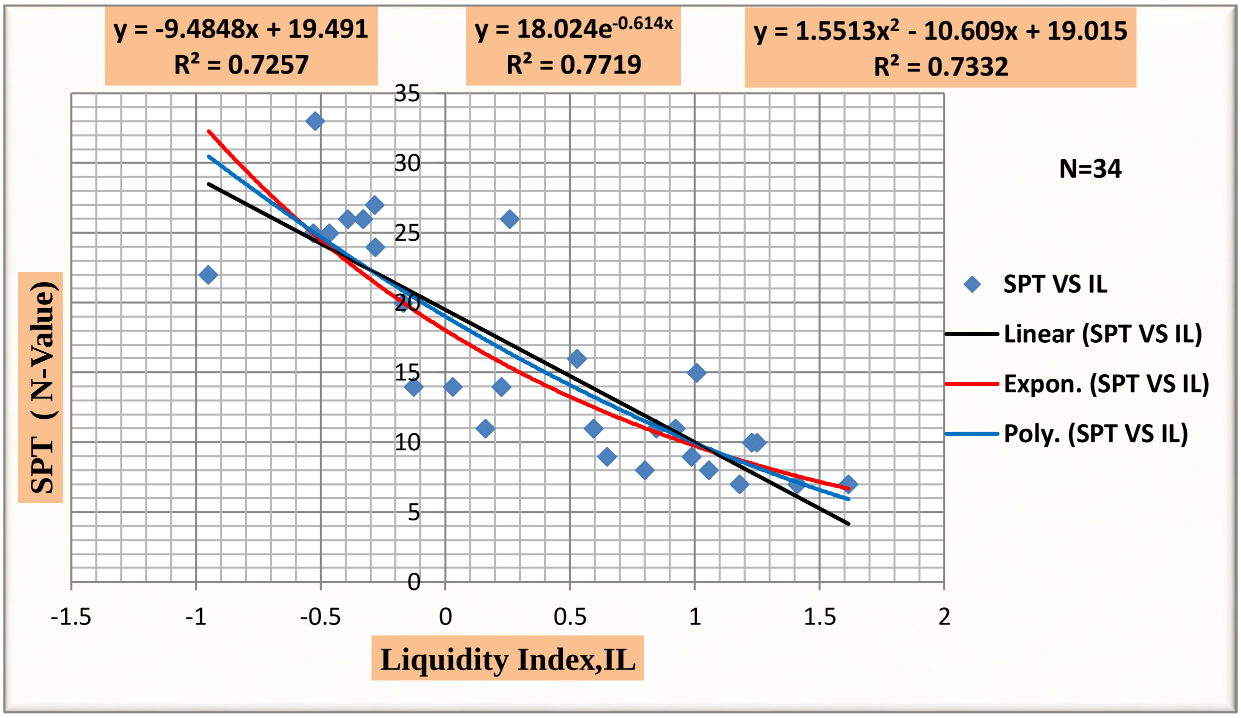

Figure 4-41 Scatter plot and best fit curves for SPT vs IL (ML Soil at the depth of 6.00m-9.60m)

Correlation Between Standard Penetration Number Vs Natural Moisture Content

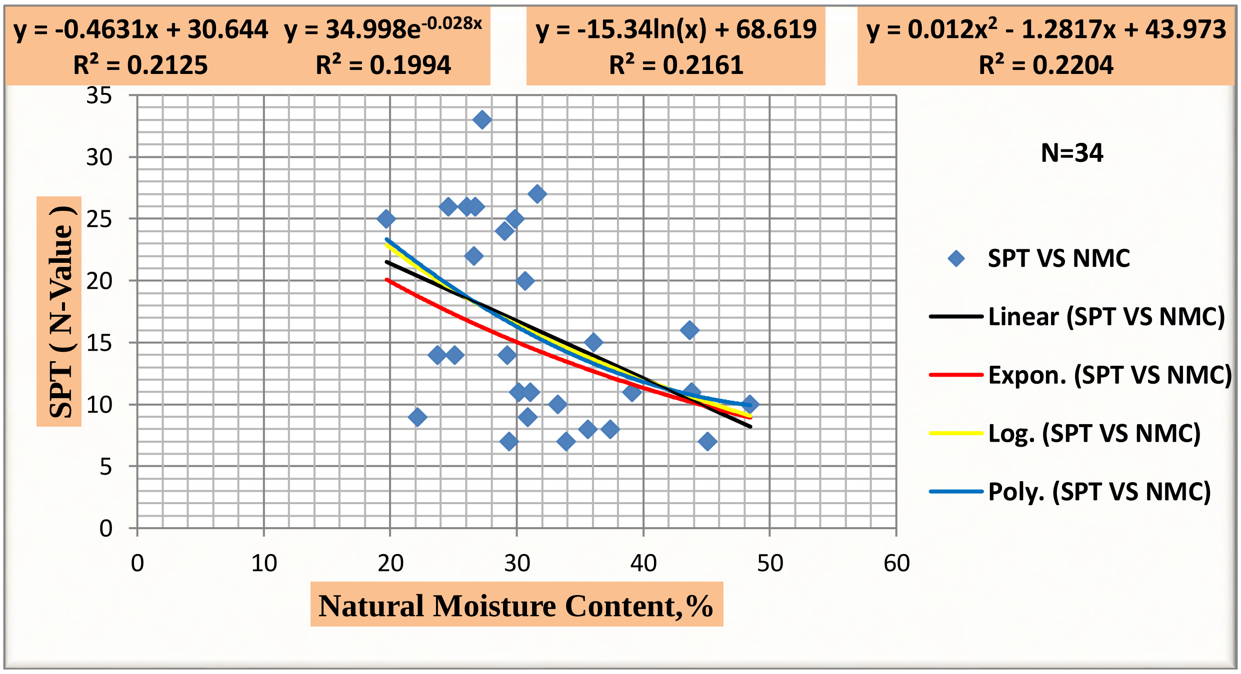

Figure 4-42 Scatter plot and best fit curves for SPT vs NMC (ML Soil at the depth of 6.00m-9.60m)

Correlation between Standard Penetration Number Vs Liquidity Index

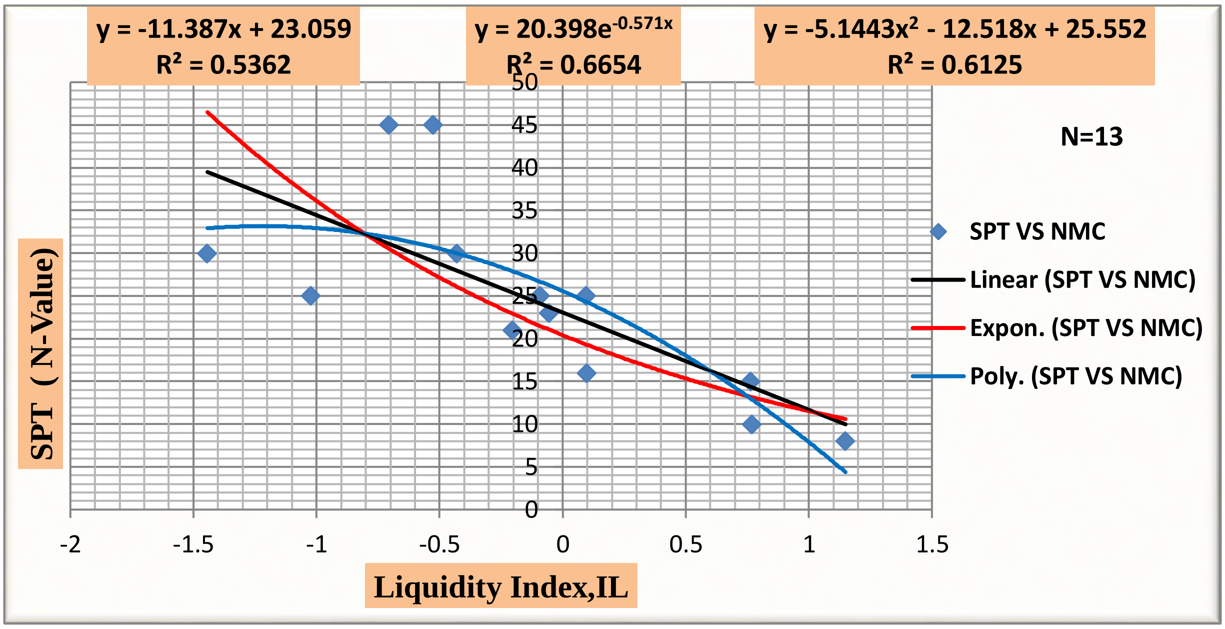

Figure 4-43 Scatter plot and best fit curves for SPT vs IL (ML Soil at the depth of 1.50m-2.10m)

Correlation between Standard Penetration Number Vs Natural Moisture Content

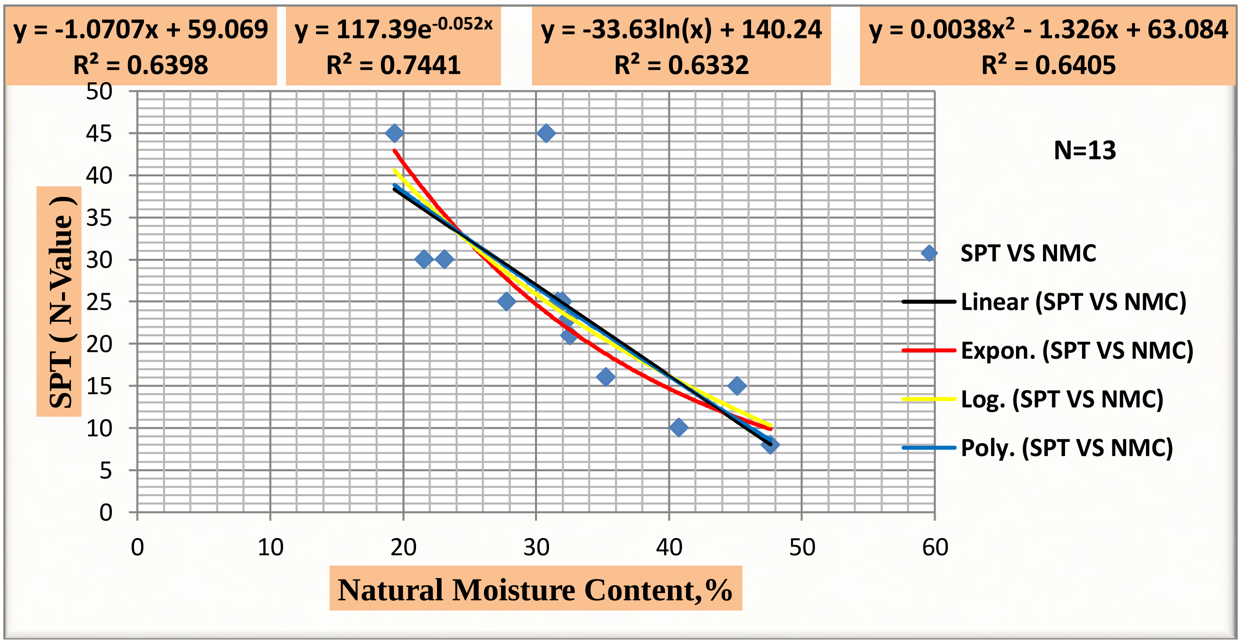

Figure 4-44 Scatter plot and best fit curves for SPT vs NMC (ML Soil at the depth of 1.50m-2.10m)

Correlation between Standard Penetration Number Vs Liquidity Index

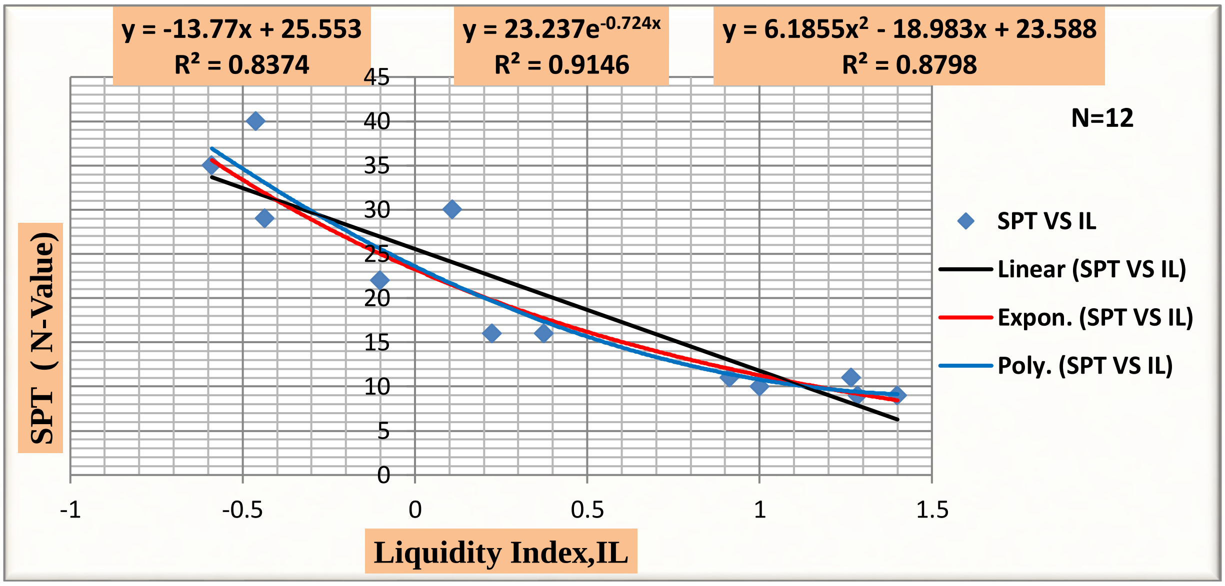

Figure 4-45 Scatter plot and best fit curves for SPT vs IL (ML Soil at the depth of 3.00m-3.60m)

Correlation Between Standard Penetration Number Vs Natural Moisture Content

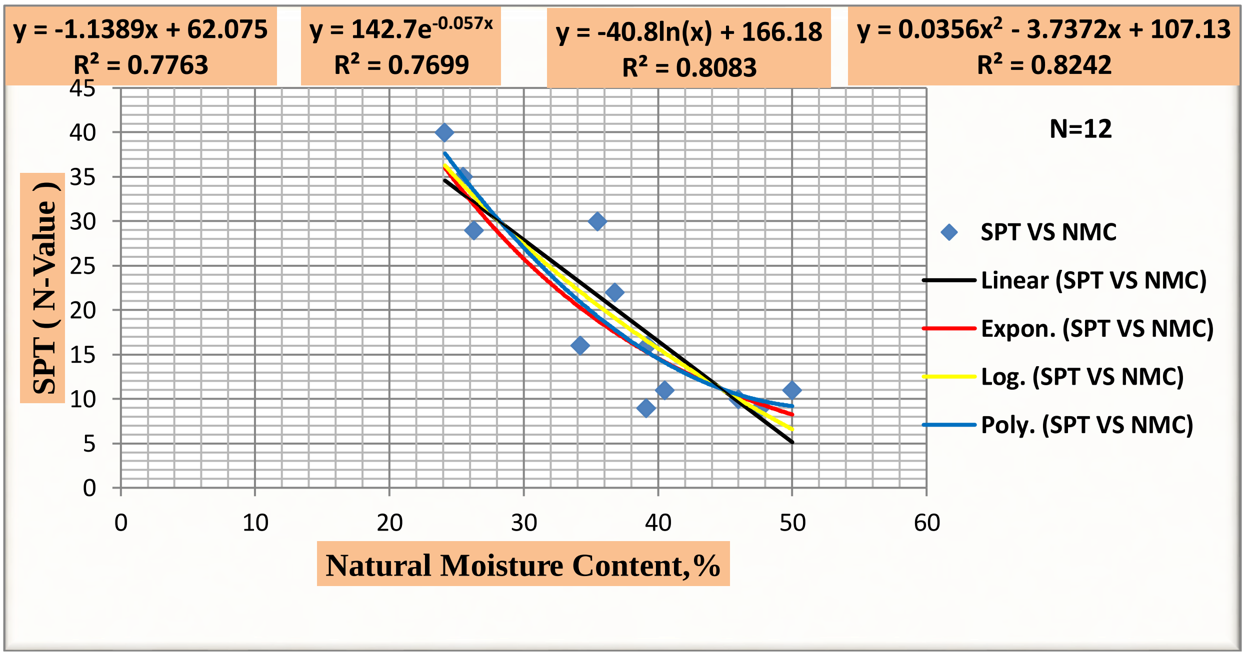

Figure 4-46 Scatter plot and best fit curves for SPT vs NMC (ML Soil at the depth of 3.00m-3.60m)

Correlation between Standard Penetration Number Vs Liquidity Index

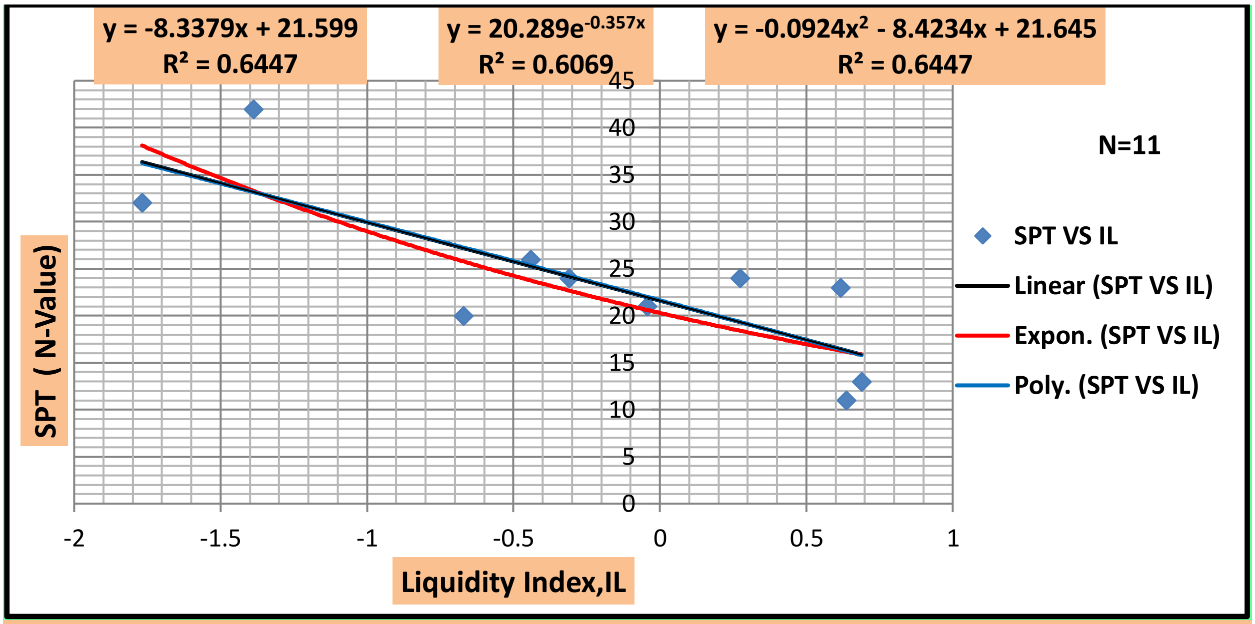

Figure 4-47 Scatter plot and best fit curves for SPT vs IL (ML Soil at the depth of 4.50m-5.10)

Correlation between Standard Penetration Number Vs Natural Moisture Content

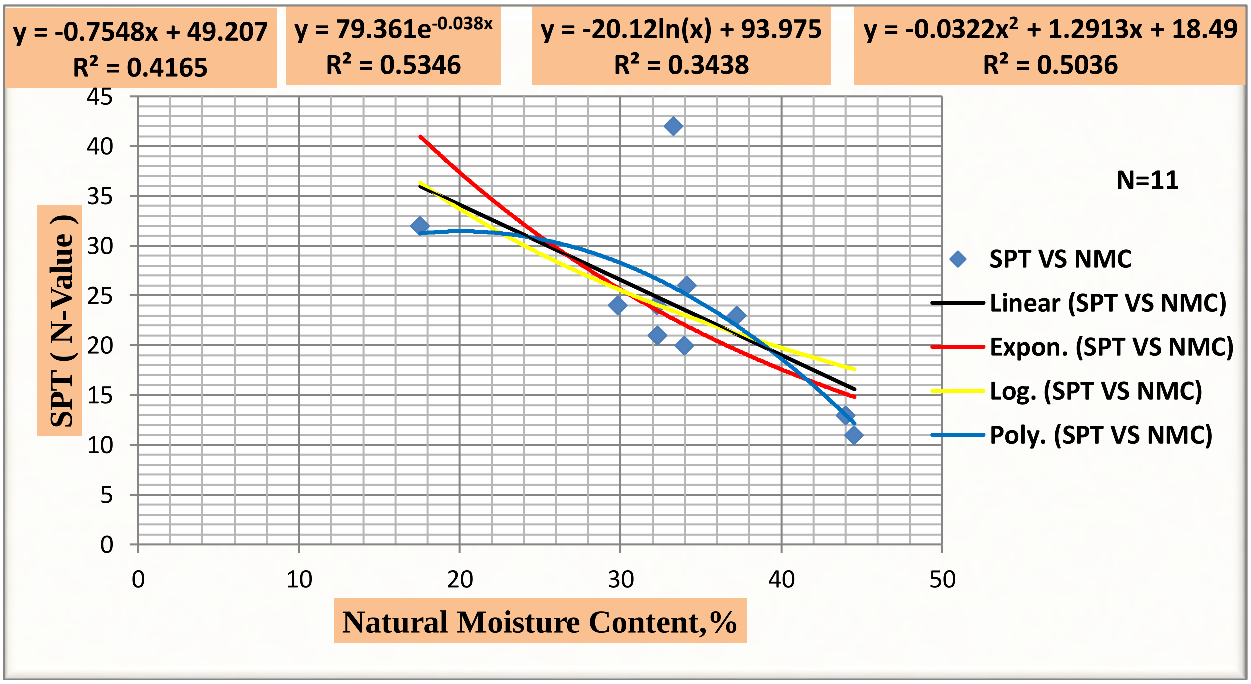

Figure 4-48 Scatter plot and best fit curves for SPT vs NMC (ML Soil at the depth of 4.50m-5.10)

4.2.2. Multiple Linear Regression Analysis

A regression model that contains more than one predictor variable is called multiple regression models. The multiple regression equations take the form $y=b_1x_1+b_2x_2+----+c$, the b's are the regression coefficients, representing the amount of the dependent variable changes when the independent changes 1unit. c is constant, where the regression line intercepts the y axis, representing the amount the dependent y will be when all the independent variables are 0.

During analyzing the multiple linear regressions, after going through a number of alternative Combinations of predictors the following results are presented here under.

4.2.2.1 Correlation of Undrained Shear Strength

The resulting regression analysis after correlating Cu with PI, NMC and LL are expressed by the following multiple linear equations with its corresponding correlation coefficients:

$Cu= 40.175 - 0.9*PI - 0.753*LL+0.763*NMC$, with $R^2=0.504$ Adj. R= 0.50, N = 186

The details of the statistical out-put of multiple linear equations indicates that the relationship developed between Cu with PI, NMC and LL is significant ($\alpha<0.05$). Besides, the R^2 value of the multiple linear regression analysis is improved than the R^2 value of the individual parameters, i.e. PI, NMC and LL. For further reference, the details of Cu single regression analysis have shown in Table 4-1 and multiple regression analysis in Appendix A-2.

4.2.2.2 Correlation of Swelling Pressure

The resulting regression analysis after correlating Ps with PL, NMC, IL and LL are expressed by the following multiple linear equations with its corresponding correlation coefficients:

$Ps= 57.55 - 0.75*NMC - 0.175*LL+0.512*PL$, with $R^2=0.73$ Adj. R= 0.713, N = 54

$Ps= 55.70 - 0.065*LL - 0.406*NMC-14.37*IL$, with $R^2=0.73$ Adj. R= 0.720, N = 54

The details of the statistical out-put of multiple linear equations indicates that the relationship developed between Ps with PL, NMC, IL and LL are significant ($\alpha<0.05$). Besides, the R^2value of the multiple regression analysis are improved than the R^2 value of the individual parameters, i.e. PL, NMC, IL and LL. For further reference, the details of Ps single regression analysis have shown in Table 4-2 and multiple regression analysis in Appendix A- 2.

4.2.2.3 Correlation of Standard penetration numbers (SPT)

The resulting regression analysis after correlating SPT with PL, NMC, IL,PI and LL are expressed by the following multiple linear equations with its corresponding correlation coefficients:

Silt with high plasticity Soil (MH)

$SPT = 21.20 - 0.365*NMC+0.035*LL$, with $R^2=0.803$ Adj. $R= 0.792$, $N = 37$

$SPT = 12.64 +0.97*PI -14.22*IL$, with $R^2=0.88$ Adj. $R= 0.85$, $N = 12$

Silt with low plasticity Soil (ML)

$SPT = 15.82 -1.09*NMC +0.057*LL-0.59*PL$, with $R^2=0.90$ Adj. $R= 0.86$, $N = 12$

$SPT = 20.38 - 1.37*IL - 0.33*NMC+0.026*LL$, with $R^2=0.804$ Adj. $R= 0.79$, $N = 36$

$SPT = 17.10 - 0.870*NMC-0.059*LL +0.94*PL$, with $R^2=0.64$ Adj. $R= 0.623$, $N = 70$

$SPT = 17.625 - 0.861*NMC+ 0.10*PL$, with $R^2=0.64$ Adj. $R= 0.630$, $N = 70$

The details of the statistical out-put of multiple linear equations indicates that the relationship developed between SPT with PL, NMC, IL, PI and LL are significant ($\alpha<0.05$). Besides, the R^2value of the multiple regression analysis are better than all the above stated models. Furthermore, the details of SPT single regression analysis have shown in Table 4-3 to 4-15 and multiple regression analysis in Appendix A- 2.

4.3. SUMMARY OF CORRELATIONS

After analyzing the data trends on the scatter plot from Figure 4-1 up to Figure 4-48 and applying different models, correlations were developed for Undrained Shear Strength, Swelling Pressure and Standard penetration numbers(SPT). The summery of the correlations achieved from the regression analysis are presented in Table 4-1 up to Table 4-15.

4.3.1 Summary of Correlations for Undrained Shear Strength

Table 4-1 Summary of Undrained shear strength correlation

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
C_U Vs I_L	186	Linear	$Cu = -29.87I_L + 34.01$	0.488
		Exponential	$Cu = 33.65e^{-0.78IL}$	0.512
		Polynomial	$Cu = 9.786\ I_L^2 -27.22I_L + 33.91$	0.491
I_L Vs CU	186	Linear	$I_L = -0.016C_U + 0.480$	0.488
		Logarithmic	$I_L = -0.65 \ln(C_U) +2.226$	0.512
		Polynomial	$I_L = 0.000C_U^2 - 0.047\ C_U +1.096$	0.515
C_U Vs ω	186	Linear	$Cu = -0.684\ \omega + 67.95$	0.370
		Exponential	$Cu = 82.13e^{-0.01\ \omega}$	0.390
		Logarithmic	$C_U = -27.1 \ln(\omega) +140.2$	0.347
		Polynomial	$Cu = -0.012\omega^2 + 0.341\omega + 46.74$	0.379
C_U Vs PI	186	Linear	$Cu = 0.014PI + 37.84$	0.000
		Exponential	$Cu = 37.34e^{0.000PI}$	0.000
		Logarithmic	$C_U = 0.738\ln(PI) +35.7$	0.000
		Polynomial	$Cu =-0.004PI^2 +0.347PI + 32.08$	0.003
C_U Vs PL	186	Linear	$Cu = 0.424PL + 17.55$	0.053
		Exponential	$Cu = 22.06\ e^{0.010PL}$	0.054
		Logarithmic	$C_U\ 19.49 \ln(PL)-37.46$	0.050
		Polynomial	$Cu\ \ 0.037PL^2 -3.146PL + 102.9$	0.070
C_U Vs LL	186	Linear	$Cu = 0.079LL + 31.27$	0.010
		Exponential	$Cu = 31.55\ e^{0.002\ LL}$	0.010
		Logarithmic	$C_U = 6.470 \ln(LL) +9.357$	0.010
		Polynomial	$Cu = 0.002\ LL^2-0.312\ LL + 47.76$	0.012

4.3.2 Summary of Correlations for Swelling Pressure

Table 4-2 Summary of Swelling Pressure correlation

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
Ps Vs I_L	54	Linear	$Ps = -25.15I_L + 31.08$	0.670
		Exponential	$Ps = 30.89e^{-0.71IL}$	0.667
		Polynomial	$Ps = 19.53\ IL2-20.27\ I_L + 30.73$	0.704
I_L Vs Ps	54	Linear	$I_L = -0.026Ps + 0.78$	0.670
		Logarithmic	$I_L = -0.92 \ln(Ps) + 3.136$	0.667
		Polynomial	$I_L = 7E\text{-}05Ps^2 -0.031\ Ps + 0.869$	0.670
Ps Vs ω	54	Linear	$Ps = -0.787\ \omega + 68.13$	0.690
		Exponential	$Ps = 89.18e^{-0.02\ \omega}$	0.689
		Logarithmic	$Ps = -31.5 \ln(\omega) + 152.7$	0.681
		Polynomial	$Ps =- 0.001\omega^2 -0.686\omega + 66.09$	0.690
Ps Vs PI	54	Linear	$Ps = -0.049PI + 36.78$	0.002
		Exponential	$Ps = 36.22e^{-0.00}$	0.002
		Logarithmic	$Ps = -3.05 \ln(PI) + 46.06$	0.010
		Polynomial	$Ps = 0.019PI^2 -1.425PI + 59.29$	0.064
Ps Vs PL	54	Linear	$Ps = 0.447\ PL + 13.1$	0.081
		Exponential	$Ps = 18.37\ e^{0.012PL}$	0.082
		Logarithmic	$Ps = 21.66 \ln(PL) -49.23$	0.084
		Polynomial	$Ps= -0.038PL^2 + 4.11PL -73.94$	0.094
Ps Vs LL	54	Linear	$Ps= 0.058\ LL +29.57$	0.007
		Exponential	$Ps = 29.40\ e^{0.001\ LL}$	0.008
		Logarithmic	$Ps = 3.504 \ln(LL) +19.13$	0.003
		Polynomial	$Ps = 0.012LL^2-2.082LL + 119.1$	0.071
Ps Vs Free Swell	54	Linear	$Ps= 0.007\ x + 33.51$	0.001
		Exponential	$Ps = 33.30\ e^{0.000x}$	0.000
		Logarithmic	$Ps = 0.246 \ln(x) + 33.51$	5E-05
		Polynomial	$Ps = 0.001\ x^2-0.327x + 59.49$	0.027

4.3.3 Summary of Correlations for Standard penetration numbers (SPT)

Table 4-3 Summary of SPT correlation for MH and ML Soil (at depth 1.5m-9.6m)

Correlation	No. Of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	505	Linear	$SPT = -6.729 I_L + 9.655$	0.156
		Exponential	$SPT = 8.734 e^{-0.43IL}$	0.131
		Polynomial	$SPT = 7.909\, I_L^2 - 8.171 I_L + 8.593$	0.357
SPT Vs ω	505	Linear	$SPT = -0.550\, \omega + 33.63$	0.493
		Exponential	$SPT = 52.46 e^{-0.04\, \omega}$	0.561
		Logarithmic	$SPT = -21.5 \ln(\omega) + 90.63$	0.533
		Polynomial	$SPT = 0.017\omega^2 - 1.941\omega + 60.2$	0.556
SPT Vs PI	505	Linear	$SPT = -0.275PI + 19.78$	0.305
		Exponential	$SPT = 17.73 e^{-0.01\, PI}$	0.306
		Logarithmic	$SPT = -7.29 \ln(PI) + 35.35$	0.361
		Polynomial	$SPT = 0.010PI^2 - 0.898PI + 27.05$	0.373
SPT Vs PL	505	Linear	$SPT = -0.304PL + 23.78$	0.165
		Exponential	$SPT = 23.44\, e^{0.02PL}$	0.166
		Logarithmic	$SPT = -10.7 \ln(PL) + 50.88$	0.154
		Polynomial	$SPT = -0.00PL^2 - 0.254PL + 22.87$	0.166
SPT Vs LL	505	Linear	$SPT = -0.161LL + 23.03$	0.267
		Exponential	$SPT = 22.24\, e^{-0.01LL}$	0.268
		Logarithmic	$SPT = -10.2 \ln(LL) + 54.51$	0.270
		Polynomial	$SPT = 0.002LL^2 - 0.431\, LL + 31.30$	0.282

Table 4-4 Summary of SPT correlation for MH Soil (at depth 1.50m-9.60m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	435	Linear	$SPT = -11.09 I_L + 7.505$	0.498
		Exponential	$SPT = 7.393 e^{-0.97\, IL}$	0.477
		Polynomial	$SPT = 9.195\, I_L^2 - 7.698 I_L + 7.331$	0.610
SPT Vs ω	435	Linear	$SPT = -0.246\, \omega + 19.16$	0.428
		Exponential	$SPT = 28.58 e^{-0.02\, \omega}$	0.407
		Logarithmic	$SPT = -10.91 \ln(\omega) + 49.76$	0.445
		Polynomial	$SPT = 0.008 \omega^2 - 0.968 \omega + 35.01$	0.458
SPT Vs PI	435	Linear	$SPT = -0.005 PI + 8.237$	0.000
		Exponential	$SPT = 8.057 e^{-8E-0\, PI}$	0.000
		Logarithmic	$SPT = -0.11 \ln(PI) + 8.426$	0.000
		Polynomial	$SPT = 0.001 PI^2 + 0.121 PI + 5.770$	0.005
SPT Vs PL	435	Linear	$SPT = 0.076 PL + 4.344$	0.026
		Exponential	$SPT = 5.029 e^{0.009 PL}$	0.026
		Logarithmic	$SPT = 3.478 \ln(PL) - 5.448$	0.026
		Polynomial	$SPT = 0.002 PL^2 - 0.140 PL + 9.358$	0.027
SPT Vs LL	435	Linear	$SPT = 0.011 LL + 7.019$	0.003
		Exponential	$SPT = 6.976\, e^{0.001 LL}$	0.002
		Logarithmic	$SPT = 0.966 \ln(LL) + 3.674$	0.003
		Polynomial	$SPT = -0.00\, LL^2 + 0.082\, LL + 3.976$	0.003

Table 4-5 Summary of SPT correlation for MH Soil (at depth 1.50 m-5.10 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	263	Linear	$SPT = -9.15 I_L + 7.177$	0.490
		Exponential	$SPT = 7.013\, e^{-1.13\, IL}$	0.482
		Polynomial	$SPT = 21.55\, I_L^2 - 7.728 I_L + 6.752$	0.607
SPT Vs ω	263	Linear	$SPT = -0.237\, \omega + 18.56$	0.421
		Exponential	$SPT = 27.86\, e^{-0.02 \omega}$	0.406
		Logarithmic	$SPT = -10.8 \ln(\omega) + 49.12$	0.438
		Polynomial	$SPT = 0.010 \omega^2 - 1.177 \omega + 39.71$	0.458

Table 4-6 Summary of SPT correlation for MH Soil (at depth 6.0 m-9.60 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	172	Linear	$SPT = -11.13I_L + 7.961$	0.503
		Exponential	$SPT = 7.907\ e^{-0.87\ IL}$	0.480
		Polynomial	$SPT = 7.091\ I_L^2 – 7.412I_L + 7.873$	0.576
SPT Vs ω	172	Linear	$SPT = -0.327\ \omega + 23.37$	0.373
		Exponential	$SPT = 28.09\ e^{-0.02\ \omega}$	0.393
		Logarithmic	$SPT = -13.0\ \ln(\omega) +58.03$	0.404
		Polynomial	$SPT = 0.009\omega^2 – 1.125\omega + 38.95$	0.425

Table 4-7 Summary of SPT correlation for MH Soil (at depth 1.50 m-2.10 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	37	Linear	$SPT = -12.55I_L + 6.747$	0.693
		Exponential	$SPT = 6.4\ e^{-1.75\ IL}$	0.725
		Polynomial	$SPT = 24.58\ I_L^2 – 13.12I_L + 6.138$	0.810
SPT Vs ω	37	Linear	$SPT = -0.367\ \omega + 24.48$	0.786
		Exponential	$SPT = 71.19\ e^{-0.05\ \omega}$	0.773
		Logarithmic	$SPT = -22.8\ \ln(\omega) +95.24$	0.809
		Polynomial	$SPT = 0.001\omega^2 – 1.307\omega + 46.15$	0.825

Table 4-8 Summary of SPT correlation for MH Soil (at depth 3.0 m-3.60 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	105	Linear	$SPT = -6.001I_L + 7.082$	0.322
		Exponential	$SPT = 6.961\ e^{-0.77\ IL}$	0.313
		Polynomial	$SPT = 18.72I_L^2 – 6.318I_L + 6.668$	0.473
SPT Vs ω	105	Linear	$SPT = -0.136\ \omega + 13.61$	0.227
		Exponential	$SPT = 15.74\ e^{-0.01\ \omega}$	0.208
		Logarithmic	$SPT = -6.33\ \ln(\omega) +31.57$	0.234
		Polynomial	$SPT = 0.005\omega^2 – 0.666\omega + 25.78$	0.243

Table 4-9 Summary of SPT correlation for MH Soil (at depth 4.5 m-5.1 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	121	Linear	$SPT = -6.844 I_L + 7.669$	0.369
		Exponential	$SPT = 7.511e^{-0.79\, IL}$	0.353
		Polynomial	$SPT = 17.58\, I_L^2 - 6.906 I_L + 7.205$	0.582
SPT Vs ω	121	Linear	$SPT = -0.252\omega + 19.54$	0.458
		Exponential	$SPT = 30.96\, e^{-0.03\, \omega}$	0.457
		Logarithmic	$SPT = -11.2 \ln(\omega) + 51.03$	0.464
		Polynomial	$SPT = 0.006\omega^2 - 0.850\omega + 32.79$	0.470

Table 4-10 Summary of SPT correlation for ML Soil (at depth 1.50m-9.60m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	70	Linear	$SPT = -10.64 I_L + 21.65$	0.681
		Exponential	$SPT = 19.35e^{-0.58\, IL}$	0.739
		Polynomial	$SPT = -0.735\, I_L^2 - 10.49 I_L + 22.06$	0.684
SPT Vs ω	70	Linear	$SPT = -0.697\, \omega + 42.64$	0.317
		Exponential	$SPT = 57.92e^{-0.03\, \omega}$	0.313
		Logarithmic	$SPT = -22.5 \ln(\omega) + 97.97$	0.314
		Polynomial	$SPT = 0.003\omega^2 - 0.904\omega + 46.01$	0.317
SPT Vs PI	70	Linear	$SPT = -0.832PI + 28.96$	0.060
		Exponential	$SPT = 26.10\, e^{-0.03\, PI}$	0.042
		Logarithmic	$SPT = -9.44 \ln(PI) + 42.15$	0.061
		Polynomial	$SPT = 0.053PI^2 - 2.090PI + 35.95$	0.062
SPT Vs PL	70	Linear	$SPT = 0.730PL - 2.884$	0.180
		Exponential	$SPT = 4.515e^{0.043PL}$	0.230
		Logarithmic	$SPT = 20.76 \ln(PL) - 51.19$	0.178
		Polynomial	$SPT = -0.00PL^2 + 0.779PL - 3.584$	0.180
SPT Vs LL	70	Linear	$SPT = 0.417LL + 1.784$	0.072
		Exponential	$SPT = 5.332\, e^{0.027\, LL}$	0.114
		Logarithmic	$SPT = 16.55 \ln(LL) - 42.34$	0.076
		Polynomial	$SPT = -0.018\, LL^2 + 1.851\, LL - 25.75$	0.078

Table 4-11 Summary of SPT correlation for ML Soil (at depth 1.50 m-5.10 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	36	Linear	$SPT = -10.49 I_L + 23.24$	0.641
		Exponential	$SPT = 20.86\, e^{-0.52\, IL}$	0.703
		Polynomial	$SPT = -2.297\, I_L^2 - 10.74 I_L + 24.67$	0.668
SPT Vs ω	36	Linear	$SPT = -1.018\, \omega + 57.92$	0.641
		Exponential	$SPT = 116.2\, e^{-0.05\, \omega}$	0.700
		Logarithmic	$SPT = -31.9 \ln(\omega) + 134.8$	0.608
		Polynomial	$SPT = -0.006\omega^2 - 0.568\omega + 50.65$	0.643

Table 4-12 Summary of SPT correlation for ML Soil (at depth 6.0 m-9.6 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	34	Linear	$SPT = -9.484 I_L + 19.49$	0.725
		Exponential	$SPT = 18.02 e^{-0.61\, IL}$	0.771
		Polynomial	$SPT = 1.551\, I_L^2 - 10.60 I_L + 19.01$	0.733
SPT Vs ω	34	Linear	$SPT = -0.463\, \omega + 30.64$	0.212
		Exponential	$SPT = 34.99\, e^{-0.02\, \omega}$	0.199
		Logarithmic	$SPT = -15.3 \ln(\omega) + 68.61$	0.216
		Polynomial	$SPT = 0.012\omega^2 - 1.281\omega + 43.97$	0.220

Table 4-13 Summary of SPT correlation for ML Soil (at depth 1.50 m-2.10 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	13	Linear	$SPT = -11.38\, I_L + 23.05$	0.536
		Exponential	$SPT = 20.39 e^{-0.57\, IL}$	0.665
		Polynomial	$SPT = -5.144\, I_L^2 - 12.51 I_L + 25.55$	0.612
SPT Vs ω	13	Linear	$SPT = -1.070\, \omega + 59.06$	0.639
		Exponential	$SPT = 117.3\, e^{-0.05\, \omega}$	0.744
		Logarithmic	$SPT = -33.6 \ln(\omega) + 140.2$	0.633
		Polynomial	$SPT = 0.003\omega^2 - 1.326\omega + 63.08$	0.640

Table 4-14 Summary of SPT correlation for ML Soil (at the depth 3.0 m-3.60 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	12	Linear	$SPT = -13.77 I_L + 25.55$	0.837
		Exponential	$SPT = 23.23 e^{-0.72\, IL}$	0.914
		Polynomial	$SPT = 6.185\, I_L^2 - 18.98 I_L + 23.58$	0.879
SPT Vs ω	12	Linear	$SPT = -1.238\, \omega + 62.07$	0.776
		Exponential	$SPT = 142.7\, e^{-0.05\, \omega}$	0.769
		Logarithmic	$SPT = -40.8 \ln(\omega) + 166.1$	0.808
		Polynomial	$SPT = -0.035\omega^2 - 3.737\omega + 107.1$	0.824

Table 4-15 Summary of SPT correlation for ML Soil (at depth 4.50 m-5.10 m)

Correlation	No. of Data	Type of Regression	Regression Equation	Coefficient of Regression R^2
SPT Vs I_L	11	Linear	$SPT = -8.337 I_L + 21.59$	0.644
		Exponential	$SPT = 20.28 e^{-0.35\, IL}$	0.606
		Polynomial	$SPT = -0.092\, I_L^2 - 8.423 I_L + 21.64$	0.644
SPT Vs ω	11	Linear	$SPT = -0.754\, \omega + 49.20$	0.416
		Exponential	$SPT = 79.36\, e^{-0.03\, \omega}$	0.534
		Logarithmic	$SPT = -30.1 \ln(\omega) + 93.97$	0.343
		Polynomial	$SPT = -0.032\omega^2 + 1.291\omega + 18.49$	0.503

5. Discussion

In the following sections, the Correlation results obtained from the analysis presented and discussed. Considering the correlation coefficient (R^2), the best fitting between the results has been plotted. The purpose of use of this statistical method is to give us a statistic known as the correlation coefficient which is a summary value of a large coefficient of regression representing the degree of linear association between two measured variables. R^2 is a statistic that will give some information about the goodness of fit of a relationship. In regression, the R^2 coefficient of determination is a statistical measure of how well the regression line approximates the real data points (Taylor, 1990). According to the values of R^2, the relationship between any two parameters can be classified as (R^2<0.30) are considered to have no correlation, (R^2 of 0.30 to 0.499) are considered to be a mild relationship, (R^2 of 0.50 to 0.699) are considered to be a moderate relationship and (R^2 of 0.70 to 1.0) are considered to be a strong relationship.

5.1. Undrained Shear Strength Correlation

The undrained shear strength with liquidity index of this study shows that some points scattered from the trend line, the best fitting trend line for this relationship is $Cu = 33.65e^{-0.78IL}$.

The strength of this equation in predicting around 51.20 % or $R^2 = 0.512$. This means the relationships between undrained shear strength and liquidity index are considered to a moderate relationships. This leads to conclude that the undrained shear strength can be predicted from liquidity index with significant errors. Furthermore (Ref. Fig 4-1 and Table 4-1)

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From figure 4-3 Show that the relationships between the undrained shear strength with natural moisture content, the best fitting trend line for this relationship is $Cu = 82.13e^{-0.01\,\omega}$ the strength of this equation in predicting an outcome from the natural moisture content is around 39 % or $R^2 = 0.390$. This shows a small correlation coefficient can be an indication of a mild relationship between undrained shear strength and natural moisture content .

Figures 4-4, 4-5 and 4-6 are shows the relationships between undrained shear strength with plastic index, plastic limit and liquid limit, The best fitting trend line for this relationship are $Cu = -0.004PI^2 + 0.347PI + 32.08$, $Cu = 0.037PL^2 - 3.146PL + 102.9$ and $Cu = 0.002\,LL^2 - 0.312\,LL + 47.76$ respectively.
The strength of this equation predicting an out come from the plastic index, plastic limit and liquid limit are widely scattered from the trend line and with small coefficient of regression $R^2 = 0.003$, 0.070 and 0.012, this shows they have no relationship. (Ref. Table 4-1)

The undrained shear strength of this study shows inaccuracy results, which is carried out using secondary data, it is very difficult to identify the exact reason for the incidence of such deviation from the anticipated one, the reasons for this results the samples could be easily disturbed due to handling, transportation and testing .

5.2 Swelling Pressure Correlation

The relationship between the swelling pressure and liquidity index is shown in Figure 4-7, the results shows a general trend of decreasing swelling pressure with increment of liquidity index.

The best fitting trend line for this relationship is $Ps = 19.53\,IL^2 - 20.27\,IL + 30.73$, the strength of this equation in predicting an outcome from the liquidity index is around 70.4 % or $R^2 = 0.704$. This means the relationships between swelling pressure and liquidity index are considered to a strong relationship. This leads to conclude that swelling pressure has significantly influenced by liquidity index. (Ref. Table 4-2)

Natural moisture content is one of the factors, which influence the swelling characteristic of expansive soils. the best fitting trend line for this relationship is $Ps = - 0.001\omega^2 - 0.686\omega + 66.09$ the strength of this equation in predicting an outcome from the natural moisture content is around 69 % or $R^2 = 0.690$, The results show a general trend of decreasing swelling pressure with increasing of natural moisture content. (Ref. Fig 4-8)

This means the relationships between swelling pressure and natural moisture content are considered to a moderate relationship. Also, in Figures 4-9, 4-10, 4-11 and 4-12 respectively shows the relationships between swelling pressures with plastic index, plastic limit, liquid limit and free swell are widely scattered points from the trend line. This shows that a correlation coefficient (R^2 = 0.064, 0.094, 0.071 and 0.027) respectively, can be an indication of no relationship between swelling pressure with plastic index, plastic limit, liquid limit and free swell in the study area.

5.3. Standard penetration numbers Correlation

5.3.1 Silt with high plasticity (MH Soil)

Figures 4-28 and 4-29 are shown the relationships between corrected SPT number (N) with liquidity index and natural moisture content the best fitting trend line for this relationship are $SPT = 24.58\ I_L^2 – 13.12\ I_L + 6.138$ and $SPT = 0.01\omega^2 – 1.307\omega + 46.15$. The strength of this equation in predicting an outcome from the liquidity index and natural moisture content are around $R^2 = 0.810$ and R2 = 0.825 these relationships are considered to a strong relationships. This leads to conclude that SPT number (N) predicted from liquidity index and natural moisture content without significant errors.

Most of the Figures show the relationships between corrected SPT number (N) and Atterberg limits PI, PL and LL respectively. From these Figures, It can be noticed that the Atterberg limits have no effect on SPT number (N). Also, considering the values of correlation coefficient (R^2<0.30), these relationships are considered to have no correlations. (Ref. Tables 4-3, 4-4 and 4-10)

5.3.2 Silt with low plasticity (ML Soil)

From Figures 4-34, 4-39, 4-41 and 4-45 are shown the relationships between corrected SPT number (N) with liquidity index the best fitting trend line for this relationship are $SPT = 19.35\ e^{-0.58\ IL}$, $SPT = 20.86\ e^{-0.52\ IL}$, $SPT = 18.02\ e^{-0.61\ IL}$ and $SPT = 23.23e^{-0.72\ IL}$ respectively, The strength of this equation in predicting an outcome from the liquidity index are around $R^2 = 0.739$, 0.703, 0.771 and 0.914. The relationships between Standard penetration numbers with liquidity index are considered to strong relationships.

Figures 4-40, 4-44 and 4-46 are shown the relationships between corrected SPT number (N) with natural moisture content the best fitting trend line for this relationship are $SPT = 116.2\ e^{-0.05\ \omega}$, $SPT = 117.3\ e^{-0.05\ \omega}$ and $SPT = 0.035\omega^2 - 3.737\omega + 107.1$.
The strength of this equation in predicting an outcome from the liquidity index and natural moisture content is around $R^2 = 0.70$, 0.744 and 0.824 respectively. The relationships between Standard penetrations numbers with natural moisture content are considered to strong relationships. (Ref, Table 4-11 to 4-14)

5.4. Comparison with Existing correlation

5.4.1 Comparison for correlation of CU vs IL

To evaluate the capabilities of present proposed correlations, predicted undrained shear strength with liquidity index values and compared with previous studies developed by Vardanega and Haigh, (2014), Wroth and Wood (1978), Addis Kebede and Amanuel Aberra were selected for comparison.

.

According to Wroth & Wood

$C_u = 170e^{-4.6IL} = 1.7\times 10^{2\,(1 - IL)}$ kpa …………………………………….…………..…. (5.1)

According P.J. Vardanega & S.K. Haigh

$C_u = C_L\, 35^{\,(1 - I_L)}$ (where, $C_L = 1.7$ kpa) $0.2 < I_L < 1.1$ ……………..…..….. (5.2)

According to Addis Kebede

$Cu = 38.103e^{-1.81I_L}$ kpa …………………………………………………..…. (5.3)

According to Amanuel Aberra

$Cu = 41.91^{-2.75I_L}$ kpa……………………..…………..……………...…..(5.4)

According to this study

$Cu = 33.65e^{-0.78IL}$ kpa…………………………………………….…………....(5.5)

Using the above equations the undrained shear strengths of the study area is compared with the previous studies as shown in Figure 5.1.

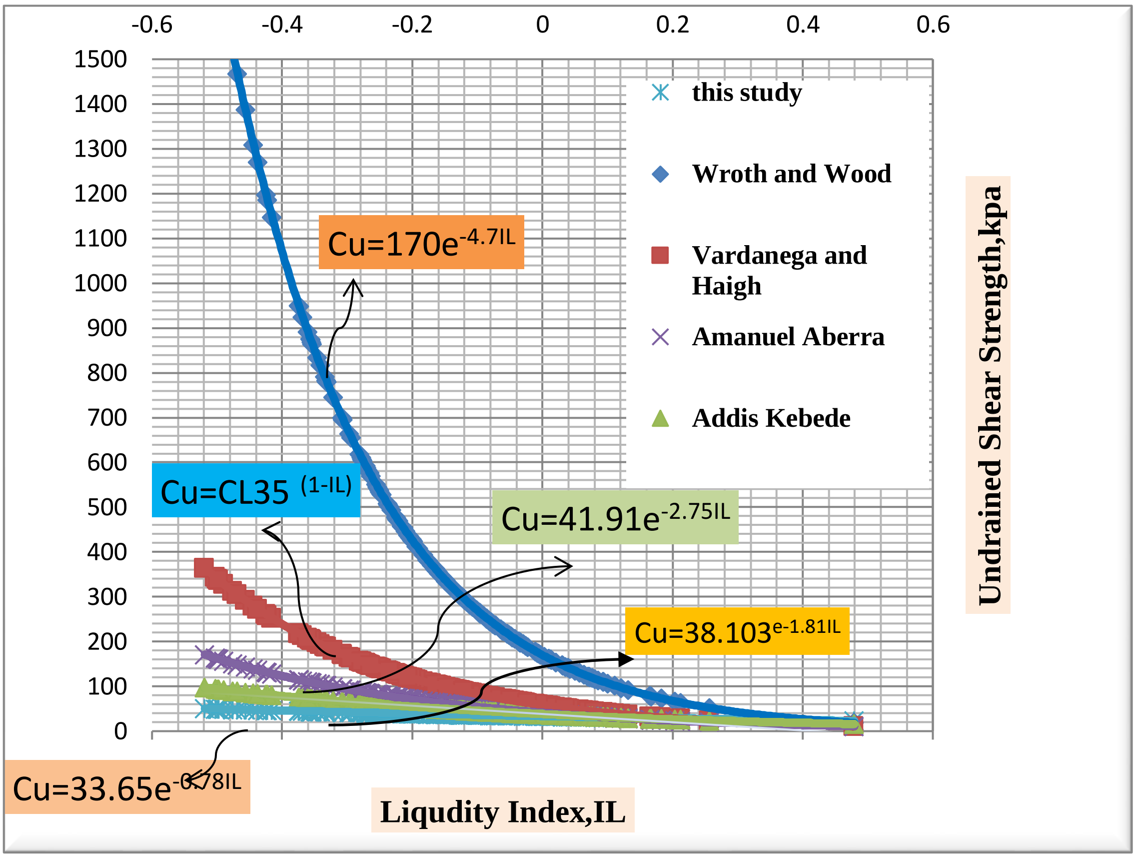

Figure 5.1: Comparison of new and previous Relationship between undrained shear strength with liquidity index

Comparison of predicted undrained shear strength with liquidity index in the study, present correlations have relatively some difference relationship is observed comparing to the previous relationship. These differences could have been caused by soil physical as well as mechanical properties of each locality. Therefore, for different locality, it is recommended the specific relationship regarding that particular area to be used.

5.4.2 Comparison for correlation of SPT vs IL

To evaluate the capabilities of present proposed correlations, predicted Standard penetration numbers with liquidity index values and compared with local previous studies developed by Addis Kebede and Amanuel Aberra were selected for comparison.

Comparison of predicted Standard penetration numbers with liquidity index in this study, compared with local previous studies have relatively similar types of linear relations are found. Figure 5.2

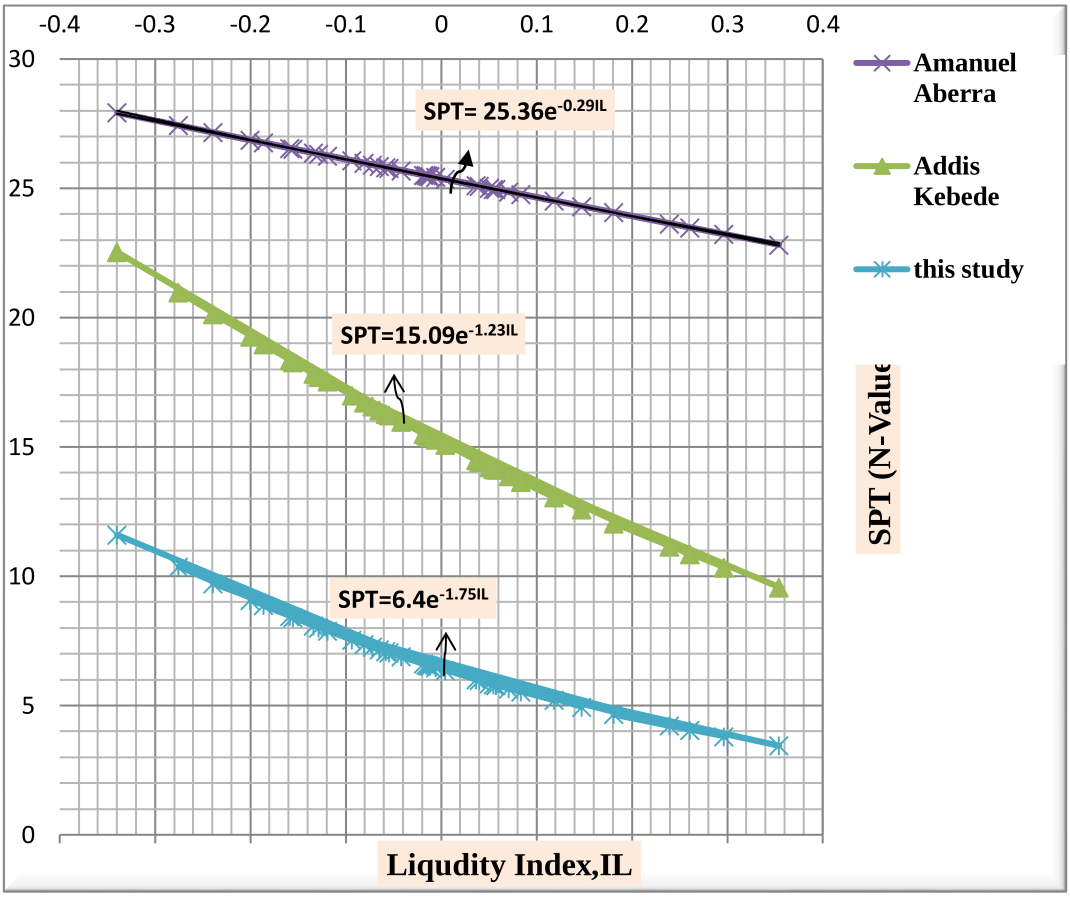

Figure 5.2: Comparison of new and previous Relationship between SPT (N-Value) with liquidity index

6. CONCLUSION AND RECOMMENDATION

6.1. CONCLUSION

The major findings and observations are stated in this section. This study was conducted to find an appropriate correlation between Cu, Ps and SPT number (N) with liquidity index. The following results are concluded based on the results on the discussion presented in this study:

- According to the single regression analysis the correlation between undrained shear strength and liquidity index has resulted the following relationship:

  $Cu = 33.65e^{-0.78IL}$ R^2 value 0.512 N=186

- According to the single regression analysis the correlation between swelling pressure and liquidity index has resulted the following relationship:

  $Ps = 19.53\ IL^2 - 20.27\ IL + 30.73$ R^2 value 0.704 N=54

- According to the single regression analysis the correlation between SPT number and liquidity index has resulted the following relationship:

Silt with high plasticity Soil (MH soil)

$SPT = 9.195\ I_L^2 - 7.698 I_L + 7.331$ R^2 value 0.610 N=435

$SPT = 21.55\ I_L^2 - 7.728 I_L + 6.752$ R^2 value 0.607 N=263

$SPT = 24.58\ I_L^2 - 13.12\ I_L + 6.138$ R^2 value 0.810 N=37

Silt with low plasticity Soil (ML soil)

$SPT = 19.35\ e^{-0.528IL}$ R^2 value 0.739 N=70

$SPT = 20.86\ e^{-0.52\ IL}$ R^2 value 0.703 N=36

$SPT = 18.02\ e^{-0.61\ IL}$ R^2 value 0.771 N=34

$SPT = 23.23e^{-0.72\ IL}$ R^2 value 0.914 N=12

- The standard penetration test (SPT) is considered reliable predicted from liquidity index.

- The Atterberg limits PI, PL, and LL do not affect the undrained shear strength, swelling pressure and SPT number in this study.

6.2. RECOMMENDATION

The Project trying to conduct has revealed areas where further efforts may be proved in the future, Following are some of the recommendations in relation to the study:-

- It is recommended to get the generalized correlation, tests should be done in more sites with different soil conditions, so that generalized and reliable relations would be developed.
- The accuracy of newly developed equations for undrained shear strength may be further modified or improved by taking many soil samples and decreasing expected errors during sampling and testing time.
- The extent of applicability of the developed correlations for local soil need further work.

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APPENDIX- A-1: REGRESSION ANALYSIS LABORATORY AND FIELD DATA

Laboratory data used for undrained shear strength correlation

Sr. No	BH-ID	Depth, m	NMC	Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index (IL)	UCS Kpa	CU Kpa
				LL	PL	PI					
1	BH - 49	2.50 -3.00	39.16	81	43	38	MH	160	-0.10105	77.06	38.53
2	BH - 33	2.50 -3.00	40.37	90	53	37	MH	160	-0.34135	102.6	51.3
3	BH - 34	2.50 -3.00	41.24	60	41	19	MH	70	0.012632	95.5	47.75
4	BH - 61	2.50 -3.00	40.78	61	43	18	MH	60	-0.12333	67.24	33.62
5	BH - 75	2.50 -3.10	39.73	96	51	45	MH	200	-0.25044	72.6	36.3
6	BH - 78	2.50 -3.10	41.71	98	53	45	MH	200	-0.25089	62.8	31.4
7	BH - 79	2.50 -3.10	44.03	98	53	45	MH	180	-0.19933	71.4	35.7
8	BH - 80	2.50 -3.10	36.28	99	52	47	MH	200	-0.33447	103.2	51.6
9	BH - 81	2.50 -3.10	36.28	87	47	40	MH	200	-0.268	84.7	42.35
10	BH - 82	2.50 -3.10	40.41	71	38	33	MH	150	0.07303	69.9	34.95
11	BH - 84	2.50 -3.10	55.96	87	48	39	MH	160	0.204103	69.3	34.65
12	BH - 85	2.50 -3.10	41.42	86	46	40	MH	150	-0.1145	68.22	34.11
13	BH - 92	2.50 -3.10	39.81	94	57	37	MH	160	-0.46459	122.6	61.3
14	BH - 86	2.50 -3.10	41.36	89	48	41	MH	140	-0.16195	71.3	35.65
15	BH - 87	2.50 -3.10	48.24	81	52	29	MH	170	-0.12966	89.1	44.55
16	BH - 88	2.50 -3.10	41.67	90	53	37	MH	200	-0.30622	87.2	43.6
17	BH - 97	2.50 -3.10	38.38	88	45	43	MH	180	-0.15395	78.9	39.45
18	BH - 98	2.50 -3.10	47.73	92	50	42	MH	170	-0.05405	75.2	37.6
19	BH - 99	2.50 -3.10	47.36	80	44	36	MH	160	0.093333	67.6	33.8
20	BH 100	2.50 -3.10	40.45	92	49	43	MH	170	-0.19884	71.2	35.6
21	BH -107	2.50 - 3.10	30.9	95	50	45	MH	130	-0.42444	81.8	40.9
22	BH-108	2.50 - 3.00	48.94	96	55	41	MH	140	-0.1478	78.3	39.15
23	BH-109	2.50 - 3.00	46.14	88	46	42	MH	140	0.003333	56.8	28.4
24	BH-110	2.50 - 3.00	49.67	96	51	45	MH	160	-0.02956	73.5	36.75
25	BH-115	2.50 - 3.10	40.82	96	55	41	MH	140	-0.34585	106.6	53.3
26	BH-127	2.50 - 3.10	39.8	100	53	47	MH	150	-0.28085	111.9	55.95
27	BH-128	2.50 - 3.00	51.11	104	57	47	MH	160	-0.12532	96.02	48.01
28	BH-103	2.50 - 3.10	39.73	94	49	45	MH	120	-0.206	82.8	41.4
29	BH-111	2.50 - 3.10	34.22	88	50	38	MH	130	-0.41526	104	52
30	BH-117	2.50 - 3.10	43.77	92	50	42	MH	170	-0.14833	89.7	44.85
31	BH-118	2.50 - 3.10	40.65	102	54	48	MH	140	-0.27813	75.1	37.55
32	BH-119	2.50 - 3.10	47.76	102	52	50	MH	140	-0.0848	62.02	31.01
33	BH-121	2.50 - 3.10	46.62	90	46	44	MH	155	0.014091	75	37.5
34	BH-122	2.50 - 3.10	47.04	103	53	50	MH	160	-0.1192	80.3	40.15
35	BH-123	2.50 - 3.10	46.92	80	48	32	MH	150	-0.03375	81.5	40.75
36	BH-124	2.50 - 3.10	49.59	99	52	47	MH	95	-0.05128	75	37.5
37	BH-125	2.50 - 3.10	35.43	88	45	43	MH	120	-0.22256	83.8	41.9
38	BH - 177	2.50-3.00	27.94	89	48	41	MH	200	-0.48927	90.2	45.1
39	BH - 184	2.50-3.10	41.79	79	48	31	MH	140	-0.20032	70.04	35.02
40	BH - 185	2.50-3.00	44.54	104	55	49	MH	185	-0.21347	88.9	44.45
41	BH - 210	2.50-3.10	41.12	98	51	47	MH	190	-0.21021	93.9	46.95
42	BH - 211	2.50-3.10	40.51	104	54	50	MH	175	-0.2698	85.6	42.8
43	BH - 170	2.50-3.10	45.96	98	51	47	MH	190	-0.10723	85.6	42.8
44	BH - 173	2.50-3.10	47.88	102	57	45	MH	190	-0.20267	80	40
45	BH - 156	2.50-3.00	52.99	82	51	31	MH	220	0.064194	68.9	34.45
46	BH - 158	2.50-3.00	54.58	93	53	40	MH	170	0.0395	51.2	25.6
47	BH - 159	2.50-3.00	36.15	95	50	45	MH	170	-0.30778	96.4	48.2
48	BH - 162	2.50-3.00	44.74	96	42	54	MH	180	0.050741	59.34	29.67
49	BH - 147	2.50-3.10	49.82	102	44	58	MH	180	0.100345	55.3	27.65
50	BH - 134	2.50-3.10	37.59	95	50	45	MH	160	-0.27578	83.4	41.7
51	BH - 137	2.50-3.00	56.06	92	48	44	MH	180	0.183182	58.3	29.15
52	BH - 138	2.50-3.00	38.23	84	47	37	MH	160	-0.23703	70.16	35.08
53	BH - 139	2.50-3.00	50.47	96	49	47	MH	160	0.031277	48.98	24.49
54	BH - 141	2.50-3.00	34.18	107	57	50	MH	200	-0.4564	92.98	46.49
55	BH - 222	2.50-3.00	45.55	95	49	46	MH	170	-0.075	63.4	31.7
56	BH - 225	2.50-3.00	41.04	97	50	47	MH	200	-0.19064	83.5	41.75
57	BH - 230	2.50-3.00	39.06	77	46	31	MH	150	-0.22387	76.2	38.1
58	BH - 233	2.50-3.10	46.27	72	48	24	MH	120	-0.07208	66.7	33.35
59	BH - 235	2.50-3.10	42.57	99	52	47	MH	170	-0.20064	90	45
60	BH - 212	2.50-3.00	41.28	77	48	29	MH	180	-0.23172	70.8	35.4
61	BH - 213	2.50-3.00	36.92	81	47	34	MH	180	-0.29647	94.7	47.35
62	BH - 217	2.50-3.00	34.93	67	35	32	MH	130	-0.00219	62	31
63	BH - 236	2.50-3.00	44.2	88	49	39	MH	180	-0.12308	76.6	38.3
64	BH - 237	2.50-3.00	38.56	89	50	39	MH	180	-0.29333	70	35
65	BH - 251	2.50-3.10	43.81	99	50	49	MH	180	-0.12633	69.7	34.85

Sr. No	BH-ID	Depth, m	NMC	Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index (IL)	UCS Kpa	CU Kpa
				LL	PL	PI					
66	BH - 253	2.50-3.00	50.48	101	57	44	MH	200	-0.14818	71.2	35.6
67	BH - 255	2.50-3.10	40.04	88	52	36	MH	180	-0.33222	99.1	49.55
68	BH - 256	2.50-3.10	49.17	86	48	38	MH	160	0.030789	93	46.5
69	BH - 257	2.50-3.00	43.77	82	48	34	MH	140	-0.12441	65.5	32.75
70	BH - 258	2.50-3.00	39.99	99	52	47	MH	180	-0.25553	67.1	33.55
71	BH - 259	2.50-3.00	50.37	73	49	24	MH	110	0.057083	60.2	30.1
72	BH - 260	2.50-3.00	46.64	97	50	47	MH	180	-0.07149	76.9	38.45
73	BH - 261	2.50-3.00	46.87	87	51	36	MH	170	-0.11472	81.1	40.55
74	BH - 239	2.50-3.00	41.65	92	50	42	MH	170	-0.19881	70.1	35.05
75	BH - 240	2.50-3.00	41.23	80	47	33	MH	140	-0.17485	69.2	34.6
76	BH - 243	2.50-3.10	37.41	87	48	39	MH	190	-0.27154	88.8	44.4
77	BH - 245	2.50-3.10	40.61	89	46	43	MH	170	-0.12535	96	48
78	BH - 246	2.50-3.10	40.54	83	43	40	MH	200	-0.0615	98.01	49.005
79	BH - 248	2.50-3.10	41.47	105	51	54	MH	200	-0.17648	86.4	43.2
80	BH - 249	2.50-3.10	40.65	96	50	46	MH	170	-0.20326	87.4	43.7
81	BH - 271	2.50-3.00	41.88	85	45	40	MH	180	-0.078	86.6	43.3
82	BH - 275	2.50-3.00	44.38	90	51	39	MH	170	-0.16974	63	31.5
83	BH -277	2.50-3.00	48.88	99	55	44	MH	170	-0.13909	76.4	38.2
84	BH - 279	2.50-3.00	43.25	84	49	35	MH	150	-0.16429	77.1	38.55
85	BH - 266	2.50-3.00	48.09	92	52	40	MH	180	-0.09775	73.7	36.85
86	BH - 267	2.50-3.00	47.78	66	45	21	MH	110	0.132381	65.2	32.6
87	BH - 268	2.50-3.00	50.69	89	49	40	MH	170	0.04225	59.6	29.8
88	BH - 269	2.50-3.00	46.53	90	48	42	MH	160	-0.035	89.6	44.8
89	BH - 272	2.50-3.00	48.46	92	48	44	MH	170	0.010455	66.4	33.2
90	BH - 286	2.50-3.10	45.12	78	48	30	MH	160	-0.096	69.6	34.8
91	BH - 298	2.50-3.00	38.07	84	44	40	MH	180	-0.14825	83.1	41.55
92	BH - 300	2.50-3.00	49.46	63	37	26	MH	140	0.479231	48.6	24.3
93	BH - 301	2.50-3.00	51.47	97	51	46	MH	170	0.010217	54.2	27.1
94	BH - 302	2.50-3.10	48.8	92	51	41	MH	150	-0.05366	61	30.5
95	BH - 305	2.50-3.10	46.55	92	48	44	MH	190	-0.03295	65.1	32.55
96	BH - 308	2.50-3.00	34.16	85	48	37	MH	170	-0.37405	76.7	38.35
97	BH - 288	2.50-3.10	47.86	94	49	45	MH	170	-0.02533	57.7	28.85
98	BH - 292	2.50-3.10	43.18	84	48	36	MH	140	-0.13389	72.7	36.35
99	BH - 296	2.50-3.10	52.23	95	49	46	MH	190	0.070217	60.8	30.4
100	BH - 306	2.50-3.00	46.28	83	49	34	MH	150	-0.08	69	34.5
101	BH - 307	2.50-3.10	43.15	87	47	40	MH	170	-0.09625	74	37
102	BH - 315	2.50-3.10	54.69	99	51	48	MH	160	0.076875	63.1	31.55
103	BH - 317	2.50-3.10	53.71	93	50	43	MH	170	0.086279	52.1	26.05
104	BH - 320	2.50-3.00	43.5	78	45	33	MH	160	-0.04545	69.7	34.85
105	BH - 322	2.50-3.00	55.59	100	51	49	MH	200	0.093673	57.2	28.6
106	BH - 323	2.50-3.00	39.41	98	51	47	MH	170	-0.2466	83.1	41.55
107	BH - 324	2.50-3.10	52.71	92	53	39	MH	180	-0.00744	67.8	33.9
108	BH - 325	2.50-3.10	54.9	97	54	43	MH	160	0.02093	75	37.5
109	BH - 310	2.50-3.10	51.73	77	43	34	MH	190	0.256765	56.48	28.24
110	BH - 311	2.50-3.10	54.62	88	48	40	MH	130	0.1655	63.3	31.65
111	BH - 318	2.50-3.00	53.7	82	48	34	MH	190	0.167647	62.55	31.275
112	BH - 330	2.50-3.00	41.83	90	48	42	MH	170	-0.1469	77.2	38.6
113	BH - 331	2.50-3.00	45.69	89	50	39	MH	130	-0.11051	70.5	35.25
114	BH - 332	2.50-3.10	43.93	93	48	45	MH	80	-0.09044	62.3	31.15
115	BH - 333	2.50-3.00	54.08	84	46	38	MH	190	0.212632	55.6	27.8
116	BH - 337	2.50-3.10	53.39	96	49	47	MH	160	0.093404	54.5	27.25
117	BH - 339	2.50-3.10	52.08	92	49	43	MH	160	0.071628	62.2	31.1
118	BH - 388	2.50-3.10	36.06	76	46	30	MH	140	-0.33133	93.15	46.575
119	BH - 390	2.50-3.10	45.15	95	54	41	MH	170	-0.21585	78.4	39.2
120	BH - 393	2.50-3.10	43.89	76	45	31	MH	150	-0.03581	71.2	35.6
121	BH - 394	2.50-3.10	30.25	76	45	31	MH	150	-0.47581	123.2	61.6
122	BH- 414	2.50-3.00	40.33	78	47	31	MH	180	-0.21516	70.2	35.1
123	BH -422	2.50-3.00	35.76	81	42	39	MH	180	-0.16	89.5	44.75
124	BH -423	2.50-3.00	36.69	76	38	38	MH	130	-0.03447	70.31	35.155
125	BH -410	2.50-3.00	23.03	83	43	40	MH	220	-0.49925	82	41
126	BH -412	2.50-3.00	24.36	85	43	42	MH	200	-0.44381	77.3	38.65
127	BH -419	2.50-3.00	34.68	76	43	33	MH	190	-0.25212	95.2	47.6

Sr. No	BH-ID	Depth, m	NMC	Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index (IL)	UCS Kpa	CU Kpa
				LL	PL	PI					
128	BH - 440	2.50-3.00	49.56	93	50	43	MH	150	-0.01023	58.4	29.2
129	BH - 443	2.50-3.00	44.9	78	42	36	MH	170	0.080556	63.7	31.85
130	BH - 444	2.50-3.00	43.02	73	49	24	MH	120	-0.24917	72.8	36.4
131	BH - 448	2.50-3.10	40.51	89	48	41	MH	150	-0.18268	72.3	36.15
132	BH - 453	2.50-3.00	46.85	75	47	28	MH	130	-0.00536	85	42.5
133	BH -465	2.50-3.10	32.03	89	47	42	MH	140	-0.35643	101.2	50.6
134	BH -475	2.50-3.10	33.7	98	51	47	MH	190	-0.36809	90	45
135	BH -458	2.50-3.00	39.21	75	45	30	MH	160	-0.193	82.7	41.35
136	BH -461	2.50-3.00	35.33	95	51	44	MH	190	-0.35614	88.1	44.05
137	BH -462	2.50-3.10	27.97	97	50	47	MH	200	-0.46872	86.1	43.05
138	BH - 502	2.50-3.10	48.2	92	53	39	MH	170	-0.12308	72.2	36.1
139	BH - 505	2.50-3.00	35.89	102	58	44	MH	150	-0.5025	105.2	52.6
140	BH - 506	2.50-3.10	38.88	100	51	49	MH	190	-0.24735	94.8	47.4
141	BH -509	2.50-3.10	46.38	97	55	42	MH	200	-0.20524	76.4	38.2
142	BH -510	2.50-3.00	37.35	95	49	46	MH	210	-0.25326	86.8	43.4
143	BH -511	2.50-3.00	36.21	89	50	39	MH	200	-0.35359	88.1	44.05
144	BH - 516	2.50-3.00	40.74	92	48	44	MH	190	-0.165	75.1	37.55
145	BH - 527	2.50-3.00	37.96	82	44	38	MH	190	-0.15895	68.9	34.45
146	BH - 528	2.50-3.00	46.55	98	51	47	MH	210	-0.09468	67.5	33.75
147	BH - 529	2.50-3.00	48.23	96	52	44	MH	170	-0.08568	68.5	34.25
148	BH - 535	2.50-3.00	43.42	93	49	44	MH	220	-0.12682	82.5	41.25
149	BH - 538	2.50-3.00	43.1	73	46	27	MH	100	-0.10741	76.4	38.2
150	BH - 547	2.50-3.00	45.4	96	54	42	MH	160	-0.20476	71.5	35.75
151	BH - 549	2.50-3.00	46.79	90	52	38	MH	160	-0.13711	68.2	34.1
152	BH - 550	2.50-3.00	35.09	89	53	36	MH	140	-0.4975	87.6	43.8
153	BH - 552	2.50-3.00	44.37	96	53	43	MH	150	-0.2007	71.4	35.7
154	BH - 553	2.50-3.10	44.2	103	55	48	MH	180	-0.225	75	37.5
155	BH - 554	2.50-3.10	37.98	100	51	49	MH	170	-0.26571	73.5	36.75
156	BH - 558	2.50-3.10	39.8	92	54	38	MH	150	-0.37368	86.7	43.35
157	BH - 539	2.50-3.00	43.17	103	54	49	MH	170	-0.22102	75.3	37.65
158	BH - 541	2.50-3.00	40.93	92	52	40	MH	150	-0.27675	83.5	41.75
159	BH - 542	2.50-3.00	47.98	93	54	39	MH	140	-0.15436	89.1	44.55
160	BH - 543	2.50-3.10	45.75	55	48	7	MH	120	-0.32143	75	37.5
161	BH - 544	2.50-3.00	46.53	101	57	44	MH	200	-0.23795	86.99	43.495
162	BH -559	2.50-3.00	47.01	96	49	47	MH	170	-0.04234	64.5	32.25
163	BH -561	2.50-3.00	44.02	92	50	42	MH	180	-0.14238	63.1	31.55
164	BH - 562	2.50-3.00	57.6	98	52	46	MH	200	0.121739	58.1	29.05
165	BH - 575	2.50-3.00	51.24	85	47	38	MH	160	0.111579	57.6	28.8
166	BH - 576	2.50-3.00	41.11	103	54	49	MH	180	-0.26306	93.1	46.55
167	BH - 577	2.50-3.00	49.32	103	54	49	MH	170	-0.09551	70.7	35.35
168	BH - 578	2.50-3.00	44.38	94	50	44	MH	170	-0.12773	65.6	32.8
169	BH - 579	2.50-3.00	45.68	90	49	41	MH	150	-0.08098	58	29
170	BH - 580	2.50-3.00	48.18	98	51	47	MH	200	-0.06	60.8	30.4
171	BH - 581	2.50-3.00	50.48	91	49	42	MH	160	0.035238	58.1	29.05
172	BH - 582	2.50-3.00	45.59	86	48	38	MH	150	-0.06342	62.2	31.1
173	BH - 565	2.50-3.10	32.09	92	52	40	MH	170	-0.49775	91.5	45.75
174	BH - 566	2.50-3.10	29.57	104	55	49	MH	200	-0.51898	113.4	56.7
175	BH- 567	2.50-3.10	33.4	93	49	44	MH	160	-0.35455	83.19	41.595
176	BH - 568	2.50-3.10	38.62	80	43	37	MH	130	-0.11838	87.57	43.785
177	BH - 570	2.50-3.10	35.67	86	49	37	MH	140	-0.36027	116.2	58.1
178	BH - 571	2.50-3.00	47.02	90	49	41	MH	170	-0.04829	67.3	33.65
179	BH - 572	2.50-3.00	41.98	92	49	43	MH	150	-0.16326	98.7	49.35
180	BH - 574	2.50-3.00	49.06	92	50	42	MH	180	-0.02238	58.7	29.35
181	BH - 488	2.50-3.00	34.68	93	52	41	MH	200	-0.42244	96.36	48.18
182	BH - 489	2.50-3.00	33.07	92	51	41	MH	180	-0.43732	77.1	38.55
183	BH - 490	2.50-3.00	43.05	98	50	48	MH	200	-0.14479	85.1	42.55
184	BH - 476	2.50-3.00	37.66	92	48	44	MH	180	-0.235	77.6	38.8
185	BH - 481	2.50-3.00	39.16	84	44	40	MH	140	-0.121	77.8	38.9
186	BH - 483	2.50-3.00	41.13	93	50	43	MH	180	-0.20628	75.8	37.9

Laboratory data used for swelling pressure correlation

Sr. No	BH-ID	Depth, m	NMC	Atterberg Limit (AASHTOT89&90)			USCS	Free Swell	Liquidity Index IL	Swelling Pressure Kpa
				LL	PL	PI				
1	BH - 97	2.50-3.10	42.62	88	45	43	MH	180	-0.05535	35.6
2	BH - 79	2.50-3.10	46.54	98	53	45	MH	180	-0.14356	30.1
3	BH - 85	2.50-3.10	48.5	86	46	40	MH	150	0.0625	25.5
4	BH - 106	2.50-3.10	42.1	98	55	43	MH	160	-0.3	34.3
5	BH - 115	2.50-3.10	37.92	96	55	41	MH	140	-0.41659	41
6	BH - 117	2.50-3.80	43.5	92	50	42	MH	170	-0.15476	38.1
7	BH - 121	2.50-3.90	38.88	90	46	44	MH	155	-0.16182	34.6
8	BH - 122	2.50-3.10	37.97	103	53	50	MH	160	-0.3006	39.3
9	BH - 125	2.50-3.10	39.1	88	45	43	MH	120	-0.13721	35.6
10	BH - 127	2.45-3.00	41.51	100	53	47	MH	150	-0.24447	42.3
11	BH - 187	2.50-3.10	41.12	73	42	31	MH	125	-0.02839	30.4
12	BH - 208	2.50-3.00	36.7	84	44	40	MH	160	-0.1825	36.7
13	BH - 224	2.50-3.10	42.72	82	48	34	MH	140	-0.15529	38.2
14	BH - 228	2.50-3.10	44.01	71	44	27	MH	140	0.00037	31.4
15	BH - 236	2.50-3.00	50.4	88	44	44	MH	180	0.145455	26.9
16	BH - 213	2.50-3.00	45.37	81	47	34	MH	180	-0.04794	37.8
17	BH - 245	2.50-3.10	41.03	89	46	43	MH	170	-0.11558	38.8
18	BH - 252	2.50-3.10	42.06	90	47	43	MH	150	-0.11488	34.3
19	BH - 258	2.50-3.00	41.87	99	52	47	MH	180	-0.21553	35.5
20	BH - 294	2.50-3.00	42.05	99	52	47	MH	180	-0.2117	34.8
21	BH - 298	2.50-3.00	43.18	84	44	40	MH	180	-0.0205	30.2
22	BH - 304	2.50-3.00	52.14	88	46	42	MH	150	0.14619	26.3
23	BH - 314	2.50-3.00	43.75	96	51	45	MH	190	-0.16111	36.2
24	BH - 339	2.50-3.10	42.22	92	49	43	MH	160	-0.15767	33.2
25	BH - 414	2.50-3.00	42.83	78	47	31	MH	180	-0.13452	37.6
26	BH - 418	2.50-3.00	41.25	82	44	38	MH	140	-0.07237	31.9
27	BH - 423	2.50-3.00	54.17	76	38	38	MH	130	0.425526	26.4
28	BH - 434	2.50-3.10	50.18	90	49	41	MH	170	0.02878	28.2
29	BH - 447	2.50-3.10	38.97	85	47	38	MH	140	-0.21132	31.7
30	BH - 443	2.50-3.00	44.9	78	42	36	MH	170	0.080556	33.1
31	BH - 461	2.50-3.00	48.6	95	51	44	MH	190	-0.05455	33.4
32	BH - 465	2.50-3.10	32.03	89	47	42	MH	140	-0.35643	40.3
33	BH - 469	2.50-3.00	48.49	90	51	39	MH	150	-0.06436	31.5
34	BH - 472	2.50-3.00	49.36	89	50	39	MH	150	-0.01641	29.7
35	BH - 488	2.50-3.10	33.42	93	52	41	MH	200	-0.45317	49.6
36	BH - 491	3.00-3.60	42.17	81	49	32	MH	120	-0.21344	35.7
37	BH - 478	2.50-3.00	47.39	98	52	46	MH	220	-0.10022	30.2
38	BH - 482	2.50-3.00	35.11	89	48	41	MH	170	-0.31439	43.7
39	BH - 497	2.50-3.10	48.97	96	50	46	MH	140	-0.02239	28.6
40	BH - 511	2.50-3.00	48.89	85	46	39	MH	180	0.074103	35.1
41	BH - 533	2.50-3.00	44.74	92	50	42	MH	190	-0.12524	26.7
42	BH - 517	2.50-3.00	35.6	91	49	42	MH	150	-0.31905	39.6
43	BH - 536	2.50-3.10	45.48	91	47	44	MH	140	-0.03455	31.8
44	BH - 540	2.50-3.10	53.53	88	46	42	MH	170	0.179286	25.4
45	BH - 545	2.50-3.00	42.94	95	49	46	MH	200	-0.13174	33.1
46	BH - 552	2.50-3.00	45.17	96	53	43	MH	150	-0.18209	28.3
47	BH - 557	2.50-3.10	38.3	59	45	14	MH	90	-0.47857	43.6
48	BH - 563	2.50-3.00	31.59	100	53	47	MH	200	-0.45553	44.3
49	BH - 572	2.50-3.00	30.75	92	49	43	MH	150	-0.42442	40.9
50	BH - 560	2.50-3.00	30.74	95	51	44	MH	180	-0.46045	41.8
51	BH - 581	2.50-3.00	27.44	91	49	42	MH	160	-0.51333	46.5
52	BH - 583	2.50-3.00	38.49	94	49	45	MH	170	-0.23356	35.6
53	BH - 586	2.50-3.00	47.11	98	53	45	MH	170	-0.13089	29.4
54	BH - 590	2.50-3.10	41.72	101	52	49	MH	170	-0.2098	36.5

Laboratory and Field data used for SPT correlation

Sr. No	BH-ID	Depth (m)	NMC	Gs	Wet Sieve Analysis (AASHTO T27)			Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index LI	SPT N-values 300mm	Adjusted SPT N-values
					2.mm	0.425mm	0.075mm	LL	PL	PI					
1	BH-49	3.00-3.60	39.16	2.59	99.6	98.6	93.4	81	43	38	MH	160	-0.10105	7	7
2	BH-61	1.50-2.10	49.24	2.63	97.4	94.2	91	68	46	22	MH	90	0.14727	5	5
3	BH-62	1.50-2.10	43.52	2.61	100	99.9	98.9	95	49	46	MH	150	-0.11913	10	10
4	BH-106	6.00-6.60	44	2.6	99.9	99.6	98.8	99	55	44	MH	150	-0.25	13	12
5	BH-107	6.00-6.60	39.86	2.57	99.8	99.4	98.7	92	49	43	MH	140	-0.21256	13	12
6	BH-107	7.40-8.00	42.17	2.59	99.8	99	98.3	93	51	42	MH	160	-0.21024	11	9
7	BH-108	3.00-3.60	48.94	2.58	99.9	99.5	98.9	96	55	41	MH	140	-0.1478	9	9
8	BH-108	6.00-6.60	51.08	2.6	99.6	98.6	97.8	96	50	46	MH	140	0.02348	13	12
9	BH-108	7.40-8.00	39.51	2.6	99.7	99.4	98.8	81	43	38	MH	170	-0.09184	11	9
10	BH-109	3.00-3.60	46.14	2.58	100	99.8	99.3	88	46	42	MH	140	0.00333	6	6
11	BH-109	6.00-6.60	40.91	2.57	99.8	99.6	99.2	97	51	46	MH	100	-0.21935	14	13
12	BH-110	3.00-3.60	49.67	2.58	99.7	99.4	98.9	96	51	45	MH	160	-0.02956	6	6
13	BH-110	5.90-6.50	41.86	2.58	99.9	99.7	99.1	98	54	44	MH	120	-0.27591	13	12
14	BH-111	1.40-2.00	18.61	2.56	99.4	98.6	97.9	87	47	40	MH	140	-0.70975	47	31
15	BH-112	4.50-5.10	40.01	2.58	99.8	99	98.4	96	51	45	MH	140	-0.24422	14	14
16	BH-112	6.00-6.60	29.93	2.6	99.7	98.9	98	91	49	42	MH	170	-0.45405	15	14
17	BH-112	7.50-8.10	41.28	2.61	99.5	98.5	97.7	88	49	39	MH	180	-0.19795	14	11
18	BH-113	6.00-6.60	35.63	2.55	99.3	98.4	97.5	99	50	49	MH	160	-0.29327	12	11
19	BH-114	7.40-8.00	40.58	2.56	99.9	99.5	98.6	100	51	49	MH	150	-0.21265	16	13
20	BH-115	6.00-6.60	46.25	2.57	99.9	99.8	99.5	90	47	43	MH	140	-0.01744	12	11
21	BH-115	9.00-9.60	50.05	2.59	98.8	98.5	97.9	80	43	37	MH	130	0.19054	8	6
22	BH-127	4.40-5.00	41.92	2.56	99.9	99.7	99.2	91	49	42	MH	130	-0.16857	10	10
23	BH-127	7.40-8.00	45.45	2.57	99.9	98.7	97.6	97	49	48	MH	135	-0.07396	9	7
24	BH-127	8.90-9.50	44.35	2.61	99.2	98.8	98.4	95	51	44	MH	150	-0.15114	10	8
25	BH-128	3.00-3.60	51.11	2.57	99.8	99.3	98.7	104	57	47	MH	160	-0.12532	8	8
26	BH-128	9.00-9.60	41.82	2.56	99.8	99.5	99	73	44	29	MH	120	-0.07517	11	9
27	BH-129	3.00-3.60	47.38	2.56	90.5	88.7	87.7	87	45	42	MH	160	0.05667	8	8
28	BH-129	6.00-6.60	32.75	2.56	99.6	99.4	98.8	80	42	38	MH	130	-0.24342	13	12
29	BH-129	9.00-9.60	27.47	2.6	100	99.9	99.6	91	47	44	MH	120	-0.44386	18	14
30	BH-130	3.00-3.60	48.81	2.57	99.8	99.4	99	94	51	43	MH	130	-0.05093	6	6
31	BH-103	5.90-6.50	52.34	2.6	99.6	98.9	98.3	94	50	44	MH	180	0.05318	11	10
32	BH-104	6.00-6.60	30.61	2.57	98.7	97.1	96.3	70	39	31	MH	120	-0.27065	12	11
33	BH-103	7.50-8.10	40.52	2.59	99.7	99.5	99	77	43	34	MH	110	-0.07294	11	9
34	BH-104	4.50-5.10	37.09	2.56	99.7	99.3	98.9	87	49	38	MH	150	-0.31342	11	11
35	BH-104	7.50-8.10	41.62	2.59	99.6	99.1	98.7	94	52	42	MH	140	-0.24714	13	11
36	BH-104	9.00-9.60	26.63	2.62	99.4	98.7	97.5	86	51	35	MH	130	-0.69629	40	26
37	BH-105	1.40-2.00	46.18	2.57	99.7	98.9	97.2	97	53	44	MH	150	-0.155	7	7
38	BH-105	4.50-5.10	38.35	2.59	99.6	98.9	97.9	95	50	45	MH	160	-0.25889	12	11
39	BH-105	5.90-6.50	41.06	2.63	99	98.2	97.5	90	50	40	MH	160	-0.2235	13	12
40	BH-105	8.90-9.50	42.24	2.56	99.5	98.8	97.3	85	46	39	MH	140	-0.09641	10	8
41	BH-111	6.10-6.70	47.33	2.59	99.6	98.7	97.8	96	51	45	MH	160	-0.08156	11	10
42	BH-111	7.40-8.00	44.57	2.57	99.4	98.5	97.1	94	50	44	MH	110	-0.12341	11	9
43	BH-116	3.10-3.70	40.47	2.61	99.2	98.5	97.8	89	47	42	MH	130	-0.15548	9	9
44	BH-117	3.10-3.70	43.77	2.58	99.5	99.3	98.8	92	50	42	MH	170	-0.14833	7	7
45	BH-117	6.20-6.80	34.68	2.61	99.6	98.7	97.8	91	53	38	MH	150	-0.48211	9	8
46	BH-117	7.60-8.20	44.08	2.59	99.5	98.4	97.3	91	49	42	MH	160	-0.11714	13	11
47	BH-118	4.40-5.00	41.92	2.57	99.6	98.8	98	99	52	47	MH	170	-0.21447	9	9
48	BH-118	6.10-6.70	44.69	2.56	99.6	99.1	98.4	90	46	44	MH	140	-0.02977	8	7
49	BH-118	7.60-8.20	41.43	2.58	99.7	99.1	98	94	51	43	MH	160	-0.22256	12	10
50	BH-119	3.10-3.70	47.76	2.58	98.9	98.4	97.1	102	52	50	MH	140	-0.0848	7	7
51	BH-119	4.40-5.00	42.86	2.56	100	99.9	99.7	99	52	47	MH	165	-0.19447	9	9
52	BH-119	6.00-6.60	46.97	2.59	100	100	99.9	99	50	49	MH	150	-0.06184	9	8
53	BH-119	7.40-8.00	55.49	2.6	99.3	98	96.2	100	52	48	MH	135	0.07271	6	5
54	BH-120	4.85-5.45	39.11	2.58	99.9	99.5	98.8	85	44	41	MH	150	-0.11927	11	11
55	BH-121	3.10-3.70	46.62	2.61	100	99.7	98.9	90	46	44	MH	155	0.01409	6	6
56	BH-122	3.10-3.70	47.04	2.61	99.8	99.6	99.2	103	53	50	MH	160	-0.1192	8	8
57	BH-122	4.40-5.00	39.22	2.58	100	99.7	99.4	90	50	40	MH	145	-0.2695	12	12
58	BH-122	5.90-6.50	36.21	2.57	99.9	99.5	99.1	90	53	37	MH	155	-0.45378	12	11
59	BH-122	7.40-8.00	49.57	2.59	99.7	99.5	99.2	95	50	45	MH	130	-0.00956	8	7
60	BH-123	1.50-2.10	49.21	2.59	96.2	95	94.5	91	46	45	MH	160	0.07133	7	7
61	BH-123	3.10-3.70	46.92	2.62	99.9	99.5	98.6	80	48	32	MH	150	-0.03375	6	6
62	BH-123	4.50-5.10	37.92	2.57	99.9	99.7	99.4	93	48	45	MH	160	-0.224	9	9
63	BH-123	6.00-6.60	41.78	2.56	99.9	99.5	99.1	98	50	48	MH	170	-0.17125	11	10
64	BH-124	1.50-2.10	49.54	2.6	100	99.8	99.6	101	53	48	MH	160	-0.07208	6	6
65	BH-124	3.10-3.70	49.59	2.62	100	99.7	99.2	99	52	47	MH	95	-0.05128	7	7
66	BH-124	4.40-5.00	43.02	2.57	100	99.7	99.3	93	50	43	MH	140	-0.16233	9	9
67	BH-124	5.90-6.50	46.93	2.57	100	99.8	99.5	90	51	39	MH	160	-0.10436	12	11
68	BH-124	7.40-8.00	44.83	2.59	100	99.7	99.4	90	46	44	MH	120	-0.02659	7	6
69	BH-125	1.50-2.10	53.15	2.59	77.2	75.3	74.6	93	51	42	MH	150	0.05119	5	5
70	BH-125	4.50-5.10	46.37	2.58	99.9	99.4	97.6	91	50	41	MH	135	-0.08854	10	10
71	BH-126	1.50-2.10	46.06	2.62	99.8	99.2	98.5	99	50	49	MH	160	-0.08041	7	7
72	BH-126	6.00-6.60	43.02	2.58	99.8	99.5	98.8	89	47	42	MH	140	-0.09476	12	11
73	BH-126	7.50-8.10	50.67	2.55	100	99.9	99.5	88	49	39	MH	130	0.04282	7	6

Sr. No	BH-ID	Depth (m)	NMC	Gs	Wet Sieve Analysis (AASHTO T27)			Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index LI	SPT N-values 300mm	Adjusted SPT N-values
					2.mm	0.425mm	0.075mm	LL	PL	PI					
74	BH-126	9.00-9.60	46.31	2.57	100	99.8	99.4	87	46	41	MH	150	0.00756	10	8
75	BH-188	4.50-5.10	47.97	2.59	91.5	91.1	90.8	103	53	50	MH	200	-0.1006	8	7
76	BH-189	3.00-3.60	48.28	2.6	93.7	89.8	87.9	103	55	48	MH	190	-0.14	7	7
77	BH-189	4.50-5.10	48.67	2.63	96.3	94.4	93.6	92	52	40	MH	150	-0.08325	10	9
78	BH-190	4.50-5.10	31.17	2.58	97.2	96.3	96.1	100	54	46	MH	185	-0.4963	19	17
79	BH-190	7.50-8.10	25.7	2.62	98.8	98.2	97.4	84	47	37	MH	160	-0.57568	27	21
80	BH-177	7.50-8.10	41.1	2.58	99.4	98.7	98.2	91	48	43	MH	150	-0.16047	16	11
81	BH-184	3.10-3.70	41.79	2.6	95	91.2	90	79	48	31	MH	140	-0.20032	10	10
82	BH-184	9.00-9.60	47.37	2.6	99.8	99.7	99.2	96	49	47	MH	180	-0.03468	14	9
83	BH-185	7.50-8.10	40.62	2.57	96.5	96.1	95.4	79	44	35	MH	140	-0.09657	10	7
84	BH-186	4.50-5.10	45.41	2.62	99.2	98.6	98.1	89	46	43	MH	175	-0.01372	7	6
85	BH-186	6.00-6.60	43.61	2.64	96.5	95	94.6	81	45	36	MH	150	-0.03861	8	6
86	BH-186	9.00-9.60	60.31	2.59	99.9	99.7	99.6	86	47	39	MH	160	0.34128	10	7
87	BH-187	3.10-3.70	41.12	2.62	85.2	78.6	76.8	73	42	31	MH	125	-0.02839	8	8
88	BH-208	3.00-3.60	37.82	2.61	93.2	92	91.6	84	44	40	MH	160	-0.1545	8	8
89	BH-209	1.60-2.20	50.09	2.61	99.8	99.6	99.4	98	53	45	MH	175	-0.06467	7	7
90	BH-209	3.10-3.70	43.38	2.62	99.5	99	98.7	96	50	46	MH	180	-0.14391	10	10
91	BH-209	7.50-8.10	45.87	2.58	98.9	97.4	96.8	86	47	39	MH	134	-0.02897	12	8
92	BH-211	3.10-3.70	40.51	2.63	100	99.8	99.6	104	54	50	MH	175	-0.2698	8	8
93	BH-211	4.50-5.10	46.33	2.62	99.9	99.7	99.4	101	53	48	MH	180	-0.13896	10	9
94	BH-211	6.00-6.60	38.15	2.6	99.1	88.3	61	99	51	48	MH	165	-0.26771	14	11
95	BH-211	9.00-9.60	39.35	2.63	99.7	99.2	85.1	98	53	45	MH	170	-0.30333	16	11
96	BH-167	3.10-3.70	54.96	2.6	95.4	94.9	94	103	58	45	MH	160	-0.06756	7	7
97	BH-167	4.50-5.10	52.21	2.61	91.5	90.7	90.2	92	50	42	MH	150	0.05262	8	8
98	BH-169	3.10-3.70	52.08	2.6	92.1	90.7	89.9	102	46	56	MH	210	0.10857	8	8
99	BH-169	4.50-5.10	45.49	2.61	98.8	97.7	96.7	87	49	38	MH	150	-0.09237	8	8
100	BH-169	9.00-9.60	44.4	2.59	99.3	98.4	97.3	92	41	51	MH	160	0.06667	10	7
101	BH-170	3.10-3.70	45.96	2.56	98.7	98	97.3	98	51	47	MH	190	-0.10723	7	7
102	BH171	4.50-5.10	42.22	2.61	83.7	82.5	81.5	87	51	36	MH	160	-0.24389	10	9
103	BH172	4.50-5.10	46.13	2.6	65.3	94.1	91	98	53	45	MH	170	-0.15267	7	7
104	BH-172	9.00-9.60	46.29	2.59	98.9	98.1	97.3	103	46	57	MH	210	0.00509	11	8
105	BH-173	4.50-5.10	55.02	2.61	97.6	97.5	97.2	114	51	63	MH	220	0.06381	8	7
106	BH-173	9.00-9.60	51.35	2.59	98.2	96.6	95.7	98	51	47	MH	200	0.00745	11	7
107	BH-174	4.50-5.10	44.6	2.6	98.3	97.6	95.7	91	40	51	MH	190	0.0902	8	8
108	BH-156	3.00-3.60	52.99	2.6	84.7	83.2	81.6	82	51	31	MH	220	0.06419	6	6
109	BH-156	4.50-5.10	51.15	2.61	95.8	95.1	93.8	92	51	41	MH	210	0.00366	8	7
110	BH-156	9.00-9.60	42.9	2.59	98.1	97.6	96.3	84	44	40	MH	170	-0.0275	10	7
111	BH-157	9.00-9.60	47.67	2.57	98.9	98	97	104	53	51	MH	170	-0.10451	10	7
112	BH-158	3.00-3.60	54.58	2.59	99.5	98.8	97.9	93	53	40	MH	170	0.0395	6	6
113	BH-158	9.00-9.60	48.01	2.56	99	98.1	97.6	110	57	53	MH	160	-0.16962	11	8
114	BH-159	9.00-9.60	51.52	2.61	99.3	98.4	97.8	99	57	42	MH	180	-0.13048	11	8
115	BH-160	3.00-3.60	48.09	2.56	99.3	98.3	97.2	79	41	38	MH	180	0.18658	7	7
116	BH-160	4.50-5.10	49.71	2.6	95.1	94.2	93.6	81	48	33	MH	160	0.05182	6	5
117	BH-160	9.00-9.60	48.76	2.59	95.8	95.1	94.5	82	46	36	MH	190	0.07667	11	7
118	BH-161	3.00-3.60	48.38	2.61	70.6	67.1	66	103	47	56	MH	160	0.02464	6	6
119	BH-161	4.50-5.10	46.23	2.59	93.1	91.4	90.8	98	49	49	MH	210	-0.05653	7	6
120	BH-161	9.00-9.60	48.39	2.58	99.7	99.2	98.3	95	47	48	MH	170	0.02896	11	7
121	BH-162	3.00-3.60	44.74	2.59	96.6	96	95.3	96	42	54	MH	180	0.05074	5	5
122	BH-162	4.50-5.10	44.54	2.57	97.9	97.6	97.3	112	53	59	MH	150	-0.14339	10	9
123	BH-162	9.00-9.60	48.31	2.6	94.4	89.1	86.9	69	37	32	MH	170	0.35344	12	8
124	BH-163	4.50-5.10	44.77	2.56	96.7	96	94.7	86	52	34	MH	190	-0.21265	8	8
125	BH-163	9.00-9.60	47.97	2.6	89.2	88.9	88.1	93	48	45	MH	220	-0.00067	9	7
126	BH-164	3.10-3.70	37.87	2.6	89.3	86.8	85.6	88	41	47	MH	190	-0.0666	10	8
127	BH-164	6.00-6.60	44.57	2.59	98.9	98.3	97.3	92	52	40	MH	150	-0.18575	10	8
128	BH-164	7.50-8.10	41.23	2.58	99.2	97.8	95.9	86	43	43	MH	180	-0.04116	13	8
129	BH-165	1.50-2.10	43.47	2.6	95.8	94.6	93.2	101	50	51	MH	250	-0.12804	8	8
130	BH-165	4.50-5.10	45.83	2.57	99.1	98.6	98.2	95	49	46	MH	200	-0.06891	10	8
131	BH-165	9.00-9.60	33.66	2.6	99.9	99.4	98.4	93	39	54	MH	160	-0.09889	16	10
132	BH-166	3.10-3.70	53.98	2.58	99.9	99.6	98.9	90	53	37	MH	150	0.02649	8	8
133	BH-166	4.50-5.10	52.57	2.56	99.5	98.9	98	102	57	45	MH	180	-0.09844	9	8
134	BH-143	9.00-9.60	40.77	2.57	96.3	95.5	94.6	98	52	46	MH	180	-0.24413	15	12
135	BH-144	9.00-9.60	43.81	2.6	84.7	83.7	83.2	95	51	44	MH	190	-0.16341	9	7
136	BH-145	1.50-2.10	53.61	2.63	95.4	95.1	94.7	93	50	43	MH	180	0.08395	5	5
137	BH-145	4.50-5.10	49.89	2.58	99.9	99.7	98.9	71	49	22	MH	130	0.04045	8	8
138	BH-145	6.00-6.60	43.96	2.61	97.5	97	96.5	89	51	38	MH	150	-0.18526	10	9
139	BH-145	9.00-9.60	41.96	2.62	99	98.7	98.1	93	52	41	MH	190	-0.24488	13	10
140	BH-146	4.50-5.10	50.78	2.58	99.8	99.7	99.3	105	55	50	MH	160	-0.0844	7	7
141	BH-146	6.00-6.60	43.18	2.6	97	96	95.4	87	48	39	MH	190	-0.12359	8	7
142	BH-147	4.50-5.10	44.14	2.59	97	95.8	94.3	93	51	42	MH	140	-0.16333	10	10
143	BH-147	9.00-9.60	40.66	2.61	96.2	95	93.6	78	47	31	MH	150	-0.20452	13	10
144	BH-148	6.00-6.60	42.54	2.63	95.2	93.9	92.9	81	43	38	MH	160	-0.01211	9	8
145	BH-150	6.00-6.60	29.57	2.59	96.5	95.7	95.1	91	50	41	MH	150	-0.49829	17	16
146	BH-131	3.00-3.60	43.47	2.59	98.7	98.4	97.9	89	48	41	MH	150	-0.11049	7	7
147	BH-131	4.50-5.10	39.5	2.61	98.66	98.3	97	84	49	35	MH	160	-0.27143	9	9
148	BH-131	7.50-8.10	43.19	2.59	97.5	97.3	96.7	88	47	41	MH	170	-0.09293	11	9

Sr. No	BH-ID	Depth (m)	NMC	Gs	Wet Sieve Analysis (AASHTO T27)			Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index LI	SPT N-values 300mm	Adjusted SPT N-values
					2.mm	0.425mm	0.075mm	LL	PL	PI					
149	BH-133	3.10-3.70	45.7	2.64	99.6	98.9	98	95	50	45	MH	160	-0.09556	7	7
150	BH-133	7.50-8.10	43.28	2.59	84.8	83.5	82.3	71	43	28	MH	140	0.01	7	6
151	BH-134	1.50-2.10	48.45	2.6	81.4	79.6	78.8	90	49	41	MH	180	-0.01341	5	5
152	BH-134	3.10-3.70	37.59	2.61	99.6	99.2	98.6	95	50	45	MH	160	-0.27578	7	7
153	BH-134	4.50-5.10	41.43	2.58	99.6	98.9	98.2	94	51	43	MH	150	-0.22256	9	9
154	BH-135	9.00-9.60	38.52	2.57	99.8	99.6	98.7	79	44	35	MH	140	-0.15657	13	10
155	BH-136	4.50-5.10	41.77	2.6	99.5	98.8	98.2	90	49	41	MH	130	-0.17634	9	9
156	BH-136	6.00-6.60	43.69	2.58	92.6	90.9	90	83	47	36	MH	150	-0.09194	10	9
157	BH-136	9.00-9.60	30.26	2.59	92.1	91.4	90.3	78	40	38	MH	190	-0.25632	11	9
158	BH-137	3.00-3.60	56.06	2.61	94	93.6	92.5	92	48	44	MH	180	0.18318	6	6
159	BH-137	4.50-5.10	47.68	2.59	99.4	98.4	96	82	43	39	MH	140	0.12	7	7
160	BH-137	7.50-8.10	42.19	2.61	98.7	97.8	95.7	85	47	38	MH	180	-0.12658	8	7
161	BH-138	4.50-5.10	42.47	2.62	100	99.9	99.2	92	54	38	MH	160	-0.30342	11	11
162	BH-138	7.50-8.10	46.72	2.6	99.5	98.6	97.6	84	49	35	MH	180	-0.06514	10	8
163	BH-139	3.00-3.60	50.47	2.61	91.8	91.4	91.3	96	49	47	MH	160	0.03128	6	6
164	BH-139	7.50-8.10	51.97	2.58	98	97.5	96.4	71	41	30	MH	40	0.36567	7	6
165	BH-140	3.00-3.60	49.38	2.6	95.6	94.2	92.6	82	43	39	MH	180	0.16359	5	5
166	BH-140	4.50-5.10	46.86	2.58	91.7	90.9	90.4	90	48	42	MH	160	-0.02714	8	8
167	BH-141	7.50-8.10	45.62	2.58	97.6	96.8	95.7	83	48	35	MH	180	-0.068	10	8
168	BH-142	1.50-2.10	34.71	2.64	99.5	98.8	98.2	95	50	45	MH	130	-0.33978	4	13
169	BH-142	3.00-3.60	42.74	2.59	90.5	89.2	88.4	92	49	43	MH	160	-0.14558	6	6
170	BH-142	4.50-5.10	42.24	2.58	99.6	98.9	98.2	99	53	46	MH	190	-0.23391	8	8
171	BH-151	4.50-5.10	42.15	2.62	99.7	99.5	98.8	98	55	43	MH	190	-0.29884	11	11
172	BH-151	7.50-8.10	44.44	2.6	98.6	98.2	97.8	90	54	36	MH	140	-0.26556	16	13
173	BH-152	3.10-3.70	53.54	2.63	99.6	98.9	98.1	99	52	47	MH	190	0.03277	8	8
174	BH-153	4.50-5.10	35.56	2.58	99.5	98.9	98.3	92	49	43	MH	160	-0.31256	11	11
175	BH-153	6.00-6.60	37.92	2.6	94.3	94.2	93.9	97	51	46	MH	190	-0.28435	12	11
176	BH-220	3.00-3.60	59.87	2.63	99.9	99.6	99.1	92	50	42	MH	150	0.235	6	6
177	BH-220	7.50-8.10	39.85	2.59	100	99.8	99.2	79	41	38	MH	150	-0.03026	8	7
178	BH-221	3.00-3.60	48.87	2.63	99.8	99.2	97	81	42	39	MH	160	0.17615	7	7
179	BH-221	9.00-9.60	42.58	2.61	99.8	99.7	99.4	87	48	39	MH	150	-0.13897	9	7
180	BH-222	3.00-3.60	45.55	2.61	99.8	99.4	98.7	95	49	46	MH	170	-0.075	7	7
181	BH-223	3.00-3.60	47.82	2.58	99.9	99.6	98.9	96	50	46	MH	200	-0.04739	6	6
182	BH-223	6.00-6.60	44.36	2.58	99.9	99.3	97.2	79	44	35	MH	130	0.01029	6	5
183	BH-223	9.00-9.60	37.83	2.61	76	62.9	42.2	68	38	30	MH	170	-0.00567	12	9
184	BH-224	3.10-3.70	42.28	2.6	99.8	99.3	98.6	82	48	34	MH	140	-0.16824	8	8
185	BH-224	4.50-5.10	47.55	2.64	99.8	99.3	98.7	91	51	40	MH	190	-0.08625	9	7
186	BH-225	3.00-3.60	41.04	2.58	99.7	99.3	98.8	97	50	47	MH	200	-0.19064	10	9
187	BH-226	7.50-8.10	47.41	2.6	99.9	99.8	99.6	98	50	48	MH	170	-0.05396	8	7
188	BH-227	3.00-3.60	46.36	2.6	99.5	98.8	97.5	96	51	45	MH	200	-0.10311	7	7
189	BH-227	6.00-6.60	43.16	2.57	99.9	99.3	97.2	98	52	46	MH	190	-0.19217	7	8
190	BH-228	4.50-5.10	45.78	2.59	99.7	99.1	98.6	66	41	25	MH	160	0.1912	9	7
191	BH-229	1.50-2.10	47.75	2.6	95.7	95.2	93.9	92	48	44	MH	180	-0.00568	6	6
192	BH-229	3.10-3.70	43.64	2.57	99.9	99.6	98.3	101	52	49	MH	200	-0.17061	9	9
193	BH-229	4.50-5.10	42.19	2.58	97.8	97.6	97.3	95	49	46	MH	160	-0.14804	11	9
194	BH-229	7.50-8.10	41.81	2.61	99.9	99.8	99.6	89	49	40	MH	190	-0.17975	13	9
195	BH-230	7.50-8.10	38.89	2.59	99.9	99.7	99.1	64	44	20	MH	180	-0.2555	12	10
196	BH-231	4.50-5.10	51.67	2.57	99.7	99.3	98.8	68	46	22	MH	150	0.25773	7	6
197	BH-231	6.00-6.60	45.41	2.59	99	98.1	96.7	104	54	50	MH	200	-0.1718	9	8
198	BH-231	9.00-9.60	42.89	2.62	96.2	92.3	88.4	87	52	35	MH	190	-0.26029	14	10
199	BH-232	7.50-8.10	46.73	2.59	99.9	99.4	97.5	66	44	22	MH	160	0.12409	9	6
200	BH-233	3.10-3.70	46.27	2.61	99.5	99.2	98.7	72	48	24	MH	120	-0.07208	8	8
201	BH-234	7.50-8.10	44.03	2.58	92	87.1	83.1	54	38	16	MH	120	0.37688	9	7
202	BH-235	3.10-3.70	42.57	2.57	99.9	99.8	99.5	99	52	47	MH	170	-0.20064	9	9
203	BH-235	4.50-5.10	44.66	2.6	100	99.9	99.4	91	49	42	MH	200	-0.10333	12	10
204	BH-212	3.00-3.60	41.28	2.61	99.9	99.8	98.8	77	48	29	MH	180	-0.23172	11	11
205	BH-212	4.50-5.10	42.62	2.62	99.92	99.8	99.4	101	54	47	MH	200	-0.24213	12	10
206	BH-213	3.00-3.60	36.92	2.64	99.7	99.6	99.1	81	47	34	MH	180	-0.29647	12	12
207	BH-213	7.50-8.10	42.04	2.58	98.3	95.1	92.5	76	47	29	MH	160	-0.17103	13	10
208	BH-214	3.00-3.60	43.81	2.6	99.9	99.7	99	87	50	37	MH	150	-0.1673	7	7
209	BH-214	4.50-5.10	42.2	2.58	99.9	99.5	98.8	92	51	41	MH	170	-0.21463	8	8
210	BH-214	7.50-8.10	44.39	2.62	99.9	99.8	99.5	100	55	45	MH	190	-0.23578	11	9
211	BH-215	4.50-5.10	48.4	2.63	99.9	99.5	98.9	100	53	47	MH	210	-0.09787	6	6
212	BH-216	7.50-8.10	46.95	2.58	98.6	97.7	97	78	44	34	MH	140	0.08676	9	8
213	BH-217	3.00-3.60	34.93	2.61	99.9	99.7	99.1	67	35	32	MH	130	-0.00219	5	5
214	BH-218	1.50-2.10	42.88	2.64	96.9	96.5	95.7	95	50	45	MH	150	-0.15822	15	10
215	BH-218	4.50-5.10	51.08	2.63	97.6	97	96.3	87	52	35	MH	160	-0.02629	7	7
216	BH-218	7.50-8.10	44.06	2.61	99.4	98.4	95.9	94	51	43	MH	180	-0.1614	10	8
217	BH-219	4.50-5.10	44.66	2.59	99.8	99.5	98.9	75	43	32	MH	150	0.05187	8	8
218	BH-219	6.00-6.60	60.54	2.64	99.3	98.7	97.4	82	43	39	MH	180	0.44974	8	7
219	BH-236	1.50-2.10	45.64	2.6	99.4	99.2	98.4	85	44	41	MH	200	0.04	5	5
220	BH-236	4.50-5.10	44.2	2.57	99.9	99.6	98.5	88	49	39	MH	180	-0.12308	12	9
221	BH-237	3.00-3.60	38.56	2.57	99.1	98.6	98	89	50	39	MH	180	-0.29333	13	12
222	BH-237	4.50-5.10	38.62	2.58	99.5	97.1	93.6	87	45	42	MH	160	-0.1519	13	10
223	BH-237	6.00-6.60	35.81	2.61	90.9	86.7	84.1	67	41	26	MH	120	-0.19962	12	9

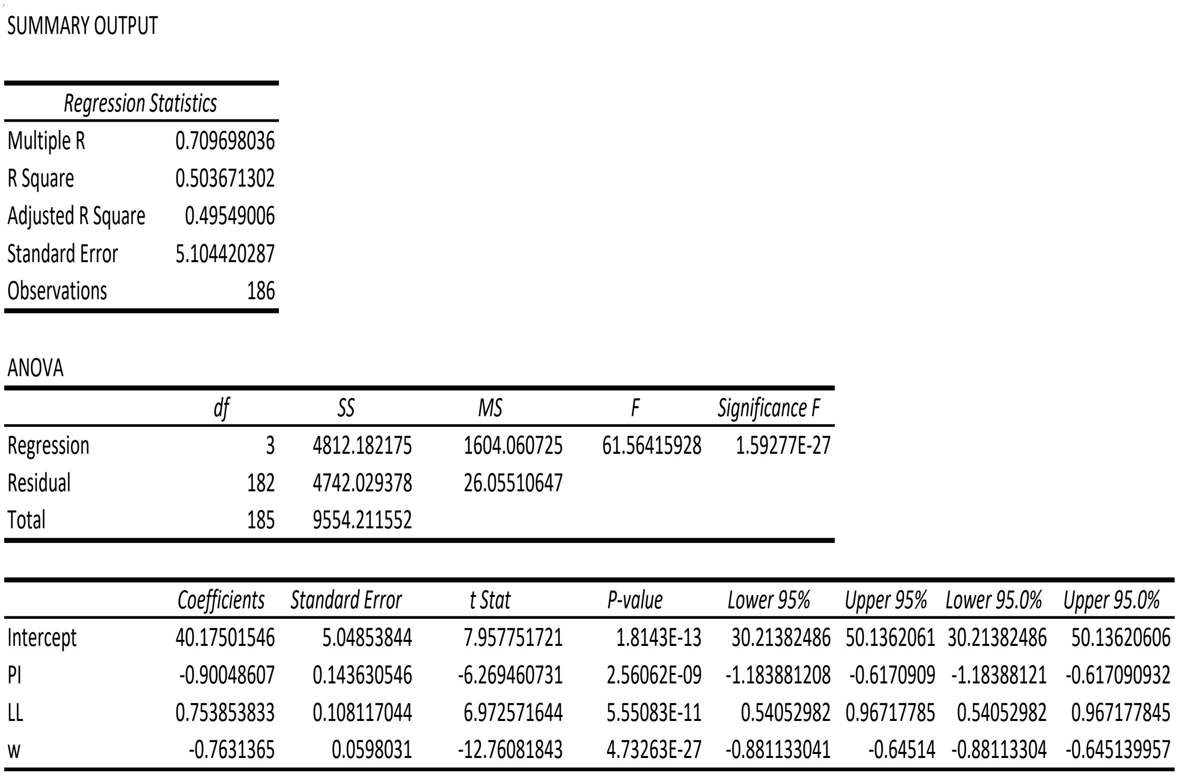
Sr. No	BH-ID	Depth (m)	NMC	Gs	Wet Sieve Analysis (AASHTO T27)			Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index LI	SPT N-values 300mm	Adjusted SPT N-values
					2.mm	0.425mm	0.075mm	LL	PL	PI					
224	BH-250	9.00-9.60	41.15	2.58	98.5	98.1	97.5	80	41	39	MH	150	0.00385	8	6
225	BH-251	3.10-3.70	43.81	2.61	97.8	97.4	97	99	50	49	MH	180	-0.12633	7	7
226	BH-251	4.50-5.10	43.72	2.58	99.5	99.1	98.4	90	48	42	MH	140	-0.1019	7	7
227	BH-252	4.50-5.10	47.7	2.63	99.1	98.7	98.2	98	52	46	MH	180	-0.09348	7	7
228	BH-252	7.50-8.10	42.09	2.6	99.4	98.9	98.1	88	46	42	MH	130	-0.0931	12	9
229	BH-253	1.50-2.10	49.59	2.6	99.2	98.8	98.3	91	48	43	MH	170	0.03698	6	6
230	BH-253	4.50-5.10	46.96	2.61	98.3	97.8	97.1	91	51	40	MH	150	-0.101	8	8
231	BH-253	6.00-6.60	48.36	2.59	99.7	99.4	98.8	87	49	38	MH	160	-0.01684	10	9
232	BH-254	4.50-5.10	48.08	2.58	99.9	99.7	98.8	68	43	25	MH	120	0.2032	7	7
233	BH-254	7.50-8.10	45.16	2.58	99.8	99.4	98.6	84	49	35	MH	170	-0.10971	10	8
234	BH-255	4.50-5.10	47.89	2.62	99.3	98.3	97.4	94	50	44	MH	190	-0.04795	9	9
235	BH-256	4.50-5.10	49.17	2.61	99.9	99.5	97.7	86	48	38	MH	160	0.03079	7	6
236	BH-256	6.00-6.60	47.71	2.62	99.9	99.5	98.3	96	50	46	MH	190	-0.04978	10	8
237	BH-257	4.50-5.10	45.38	2.62	99.3	98.8	98.2	87	50	37	MH	170	-0.12486	7	7
238	BH-257	7.50-8.10	44.51	2.64	99.8	99.3	98.6	80	47	33	MH	130	-0.07545	11	9
239	BH-258	4.50-5.10	46.59	2.59	99.8	99.3	98.7	93	50	43	MH	120	-0.0793	6	6
240	BH-259	3.00-3.60	50.37	2.62	98.1	97.7	96.5	73	49	24	MH	110	0.05708	7	7
241	BH-259	7.50-8.10	43.1	2.62	97.3	96.7	96.1	80	49	31	MH	120	-0.19032	10	8
242	BH-260	3.00-3.60	46.64	2.6	99.7	99.1	97.6	97	50	47	MH	180	-0.07149	5	7
243	BH-260	4.50-5.10	46.71	2.58	91.7	90.6	90	84	44	40	MH	130	0.06775	8	7
244	BH-261	3.00-3.60	46.87	2.6	99.5	98.8	98	87	51	36	MH	170	-0.11472	6	6
245	BH-261	4.50-5.10	46.87	2.63	95.4	93.8	92.3	85	42	43	MH	150	0.11326	7	7
246	BH-261	7.50-8.10	39.34	2.58	96.3	95.2	94.1	89	50	39	MH	180	-0.27333	12	10
247	BH-238	3.00-3.60	48.06	2.59	92.6	91.8	91.1	85	48	37	MH	140	0.00162	5	5
248	BH-239	4.50-5.10	47.57	2.62	99.9	99.5	98.3	90	46	44	MH	150	0.03568	7	7
249	BH-240	4.50-5.10	48.3	2.62	99.8	99.8	99	85	46	39	MH	130	0.05897	7	7
250	BH-240	6.00-6.60	65.35	2.62	100	99.8	98.2	76	44	32	MH	110	0.66719	9	8
251	BH-241	4.50-5.10	52.47	2.61	100	99.8	99.3	98	52	46	MH	170	0.01022	5	5
252	BH-241	6.00-6.60	46.94	2.6	99.8	99.2	98	76	43	33	MH	140	0.11939	8	7
253	BH-241	9.00-9.60	45.56	2.58	100	99.6	98.5	83	47	36	MH	150	-0.04	12	9
254	BH-242	3.00-3.60	47.26	2.6	97.9	97	96.2	86	39	47	MH	130	0.17574	5	5
255	BH-244	1.50-2.10	34.48	2.64	99.8	99.3	97.1	89	45	44	MH	180	-0.23909	12	12
256	BH-244	3.10-3.70	38.24	2.6	94	93.2	92.8	81	47	34	MH	170	-0.25765	9	9
257	BH-244	7.50-8.10	42.88	2.6	99.9	99.6	98.3	99	51	48	MH	190	-0.16917	12	10
258	BH-245	1.50-2.10	44.59	2.62	99.6	99.4	98.6	81	45	36	MH	140	-0.01139	9	9
259	BH-245	3.10-3.70	40.61	2.6	98.5	98	97.5	89	46	43	MH	170	-0.12535	8	8
260	BH-246	3.10-3.70	40.54	2.63	99.3	98.9	98.3	83	43	40	MH	200	-0.0615	6	6
261	BH-246	4.50-5.10	42.82	2.58	99.5	99.2	98.6	93	50	43	MH	170	-0.16698	7	7
262	BH-246	6.00-6.60	42.77	2.62	99.4	98.8	97.8	76	40	36	MH	180	0.07694	8	8
263	BH-246	9.00-9.60	57.13	2.59	98.8	98.5	98	83	52	31	MH	190	0.16548	8	7
264	BH-248	4.50-5.10	42.38	2.59	98.1	97.8	96.7	99	45	54	MH	170	-0.04852	9	9
265	BH-248	7.50-8.10	46.45	2.61	99.6	99	97.4	69	43	26	MH	150	0.13269	8	7
266	BH-249	6.00-6.60	45.72	2.58	96.3	95.7	94.6	93	49	44	MH	180	-0.07455	8	7
267	BH-270	4.50-5.10	44.3	2.64	99.6	98.9	97.7	74	48	26	MH	130	-0.14231	11	9
268	BH-271	3.10-3.70	41.88	2.63	99.4	99.2	98.9	85	45	40	MH	180	-0.078	9	9
269	BH-275	4.50-5.10	44.67	2.6	93.3	92.5	90.7	85	44	41	MH	160	0.01634	9	7
270	BH-277	1.50-2.10	48.29	2.62	99.9	99.7	99.5	98	51	47	MH	190	-0.05766	4	
271	BH-278	1.50-2.10	50.47	2.63	99.5	99.1	98.7	91	48	43	MH	180	0.05744	5	5
272	BH-279	4.50-5.10	43.25	2.61	99.9	99.6	98.6	84	49	35	MH	150	-0.16429	9	8
273	BH-281	1.50-2.10	42.83	2.6	99.8	99.5	99.1	80	46	34	MH	170	-0.09324	8	8
274	BH-263	1.50-2.10	45.94	2.59	99.8	99.7	99.4	110	56	54	MH	200	-0.1863	8	8
275	BH-263	4.50-5.10	42.98	2.63	99.2	98.2	94	50	31	19	MH	90	0.63053	12	9
276	BH-264	3.00-3.60	39.46	2.62	99.3	98.9	98.6	75	48	27	MH	140	-0.3163	14	11
277	BH-265	4.50-5.10	42.41	2.58	99.9	99.8	99.3	96	54	42	MH	150	-0.27595	13	11
278	BH-267	6.00-6.60	49.9	2.61	99.9	99.4	98.6	91	52	39	MH	160	-0.05385	8	7
279	BH-268	3.00-3.60	50.69	2.62	99.9	99.5	98.9	89	49	40	MH	170	0.04225	5	5
280	BH-268	4.50-5.10	47.08	2.61	99.7	99.5	99	81	45	36	MH	180	0.05778	6	5
281	BH-268	7.50-8.10	38.47	2.6	99.5	99.2	98.1	85	48	37	MH	160	-0.25757	15	12
282	BH-269	4.50-5.10	47.35	2.62	99.9	99.5	98.5	91	51	40	MH	140	-0.09125	6	6
283	BH-272	4.50-5.10	44.95	2.59	99.2	98.4	94.7	80	46	34	MH	160	-0.03088	11	8
284	BH-286	1.50-2.10	50.86	2.62	99.2	99	98.7	104	53	51	MH	200	-0.04196	8	8
285	BH-286	3.10-3.70	45.12	2.64	98.8	98.2	97.3	78	48	30	MH	160	-0.096	8	8
286	BH-287	6.00-6.60	48.94	2.6	99	97.9	95.9	94	50	44	MH	170	-0.02409	9	7
287	BH-298	3.00-3.60	38.07	2.6	95.8	94.3	93.1	84	44	40	MH	180	-0.14825	6	6
288	BH-298	4.50-5.10	48.91	2.59	99.9	99.6	98.3	92	50	42	MH	150	-0.02595	9	8
289	BH-299	3.00-3.60	49.53	2.6	99.9	99.6	98.9	71	39	32	MH	140	0.32906	6	6
290	BH-299	4.50-5.10	50.35	2.58	99.9	99.6	98.3	89	49	40	MH	160	0.03375	7	6
291	BH-299	6.00-6.60	48.93	2.62	99.9	99.6	98.6	94	49	45	MH	180	-0.00156	12	8
292	BH-300	3.00-3.60	49.46	2.6	99.6	99.1	98.4	63	37	26	MH	140	0.47923	7	7
293	BH-300	4.50-5.10	43.43	2.61	99.7	99.3	98.4	60	40	20	MH	110	0.1715	8	7
294	BH-300	7.50-8.10	45.02	2.59	99.3	98.5	97.6	93	49	44	MH	150	-0.09045	12	8
295	BH-301	3.00-3.60	51.47	2.58	99.8	99.3	98.7	97	51	46	MH	170	0.01022	7	7
296	BH-301	4.50-5.10	51.6	2.6	99.4	98.8	98.2	102	54	48	MH	200	-0.05	8	8
297	BH-301	6.00-6.60	47.34	2.6	99.8	99.4	98.7	91	53	38	MH	160	-0.14895	10	10
298	BH-301	9.00-9.60	48.15	2.59	99.8	99.5	99	96	56	40	MH	170	-0.19625	14	10

Sr. No	BH-ID	Depth (m)	NMC	Gs	Wet Sieve Analysis (AASHTO T27)			Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index LI	SPT N-values 300mm	Adjusted SPT N-values
					2.mm	0.425mm	0.075mm	LL	PL	PI					
299	BH-302	1.50-2.10	51.22	2.64	98.8	96.4	92.9	99	51	48	MH	160	0.00458	5	5
300	BH-302	3.10-3.70	48.8	2.61	89.2	84.2	77.5	92	51	41	MH	150	-0.05366	7	7
301	BH-302	4.50-5.10	46.99	2.58	99.8	99.4	98.9	88	52	36	MH	140	-0.13917	8	8
302	BH-303	3.10-3.70	46.21	2.62	99.6	99	98.5	70	46	24	MH	120	0.00875	8	8
303	BH-303	4.50-5.10	46.21	2.6	99.7	99.3	98.4	91	47	44	MH	140	-0.01795	7	7
304	BH-303	9.00-9.60	42.52	2.6	99.9	98.9	96.9	69	43	26	MH	120	-0.01846	12	9
305	BH-304	4.50-5.10	43.21	2.62	99.8	99.4	98.6	95	50	45	MH	180	-0.15089	7	7
306	BH-304	7.50-8.10	49.74	2.6	99.6	99.2	98.4	82	49	33	MH	160	0.02242	11	8
307	BH-305	3.00-3.60	46.55	2.6	99.6	99.5	98.8	92	48	44	MH	190	-0.03295	7	7
308	BH-309	3.10-3.70	41.4	2.62	99.4	99.2	98.4	95	49	46	MH	190	-0.16522	10	10
309	BH-309	4.50-5.10	47.31	2.59	99.9	99.8	99.2	99	53	46	MH	200	-0.1237	9	8
310	BH-309	6.00-6.60	42.16	2.58	99.2	98.8	98.2	96	49	47	MH	180	-0.14553	9	7
311	BH-288	9.00-9.60	46.5	2.59	99.9	99.5	99.2	97	50	47	MH	190	-0.07447	12	8
312	BH-289	1.50-2.10	57.53	2.63	91	89.6	88.9	84	43	41	MH	160	0.35439	5	5
313	BH-289	3.10-3.70	46.7	2.59	99.6	99.3	98.6	93	52	41	MH	170	-0.12927	8	8
314	BH-289	4.50-5.10	46.3	2.58	99.8	99.8	96.3	101	52	49	MH	200	-0.11633	8	7
315	BH-289	7.50-8.10	49.11	2.61	99.8	99.8	99.6	89	49	40	MH	150	0.00275	10	7
316	BH-290	7.50-8.10	38.47	2.6	99.8	99.6	99.2	66	34	32	MH	160	0.13969	12	8
317	BH-292	3.10-3.70	43.18	2.63	99.9	99.8	99.2	84	48	36	MH	140	-0.13389	7	7
318	BH-292	4.50-5.10	48.27	2.6	99.9	99.6	98.2	94	50	44	MH	180	-0.03932	9	8
319	BH-292	6.00-6.60	47.7	2.62	92.1	91.2	90.1	62	37	25	MH	130	0.428	12	9
320	BH-293	3.10-3.70	45.42	2.6	100	99.8	98.6	97	54	43	MH	150	-0.19953	8	8
321	BH-294	4.50-5.10	45.43	2.6	96.6	93.8	92.4	89	47	42	MH	150	-0.03738	6	6
322	BH-295	4.50-5.10	43.51	2.6	99.7	97.8	96.5	91	49	42	MH	160	-0.13071	11	10
323	BH-297	4.50-5.10	33.05	2.62	99.9	99.7	98.7	87	45	42	MH	190	-0.28452	11	10
324	BH-306	3.00-3.60	46.28	2.6	99.7	99	98.3	83	49	34	MH	150	-0.08	7	7
325	BH-306	4.50-5.10	42.62	2.59	99.5	99	98.4	91	48	43	MH	170	-0.12512	9	8
326	BH-307	4.50-5.10	37.47	2.59	99.2	98.5	97.8	100	53	47	MH	180	-0.33043	14	13
327	BH-314	3.00-3.60	51.46	2.58	97.1	96.4	95.8	96	51	45	MH	190	0.01022	6	6
328	BH-314	4.50-5.10	53.62	2.62	91.5	90.3	89.6	92	52	40	MH	160	0.0405	7	7
329	BH-315	3.10-3.70	54.69	2.59	99.9	99.5	97.7	99	51	48	MH	160	0.07688	5	7
330	BH-315	4.50-5.10	45.4	2.64	99.7	99.1	98	93	50	43	MH	150	-0.10698	8	8
331	BH-315	7.50-8.10	43.5	2.6	98.6	98	95.6	90	46	44	MH	190	-0.05682	11	9
332	BH-316	3.00-3.60	50.45	2.59	99.8	99.5	97.8	99	51	48	MH	170	-0.01146	10	9
333	BH-316	4.50-5.10	42.67	2.58	99.8	99	96	92	48	44	MH	150	-0.12114	11	9
334	BH-316	9.00-9.60	41.76	2.6	98.3	97.6	96.3	72	46	26	MH	120	-0.16308	14	9
335	BH-317	3.10-3.70	53.71	2.64	98.7	98.3	97.7	93	50	43	MH	170	0.08628	6	6
336	BH-317	4.50-5.10	43.75	2.6	98.6	98	96.5	91	48	43	MH	180	-0.09884	10	9
337	BH-317	7.50-8.10	51.02	2.61	97.5	96.8	95.2	89	46	43	MH	160	0.11674	12	8
338	BH-320	3.00-3.60	43.5	2.63	99.8	99.4	98.8	78	45	33	MH	160	-0.04545	6	6
339	BH-320	4.50-5.10	46.28	2.62	100	99.8	99	77	45	32	MH	120	0.04	7	7
340	BH-320	9.00-9.60	44.98	2.58	99.7	99.5	98.3	87	48	39	MH	150	-0.07744	12	9
341	BH-321	7.50-8.10	50.74	2.58	99.9	99.7	99.2	89	50	39	MH	150	0.01897	6	5
342	BH-322	3.00-3.60	55.59	2.6	99.9	99.5	97.9	100	51	49	MH	200	0.09367	5	5
343	BH-322	4.50-5.10	50	2.58	99.9	99.6	98.8	85	46	39	MH	180	0.10256	7	7
344	BH-322	6.00-6.60	47.9	2.6	99.7	99.1	98.1	100	52	48	MH	190	-0.08542	8	7
345	BH-322	9.00-9.60	46.1	2.58	99.5	99.2	98.8	84	49	35	MH	140	-0.08286	12	9
346	BH-323	4.50-5.10	44.35	2.59	99.4	99.1	98.2	97	50	47	MH	160	-0.12021	9	9
347	BH-323	7.50-8.10	51.13	2.6	99.9	99.5	98.3	91	52	39	MH	140	-0.02231	10	8
348	BH-324	3.10-3.70	52.71	2.59	99.9	99.6	99.1	92	53	39	MH	180	-0.00744	6	6
349	BH-324	4.50-5.10	47.23	2.6	99.9	99.5	98.9	78	40	38	MH	120	0.19026	7	7
350	BH-324	6.00-6.60	47.83	2.58	93.9	93.1	92.7	71	37	34	MH	230	0.31853	5	5
351	BH-325	3.10-3.70	54.9	2.59	100	99.8	98.6	97	54	43	MH	160	0.02093	7	7
352	BH-326	4.50-5.10	48.44	2.58	99.9	99.4	97.6	86	48	38	MH	170	0.01158	7	7
353	BH-326	6.00-6.60	47.85	2.6	99.8	99.5	98.1	84	46	38	MH	120	0.04868	8	7
354	BH-326	9.00-9.60	56.48	2.58	99.7	99.6	98.4	77	49	28	MH	100	0.26714	10	8
355	BH-327	1.50-2.10	50.54	2.62	89.4	87.2	85.8	94	48	46	MH	150	0.05522	5	5
356	BH-327	4.50-5.10	54.69	2.6	99.9	99.5	97.7	98	50	48	MH	170	0.09771	6	6
357	BH-327	7.50-8.10	48.68	2.58	99.8	99.4	98.6	79	41	38	MH	130	0.20211	7	6
358	BH-327	9.00-9.60	44.93	2.61	99.8	99.4	98.5	88	46	42	MH	160	-0.02548	8	6
359	BH-310	1.50-2.10	51.64	2.61	99.9	99.6	98.8	86	47	39	MH	210	0.11897	5	5
360	BH-310	3.10-3.70	51.73	2.59	99.9	99.8	99.1	77	43	34	MH	190	0.25676	7	7
361	BH-311	3.10-3.70	54.62	2.62	99.9	99.5	98.8	88	48	40	MH	130	0.1655	6	6
362	BH-311	4.50-5.10	47.33	2.61	99.8	99.1	96.2	98	50	48	MH	180	-0.05563	5	
363	BH-311	6.00-6.60	48.75	2.6	99.9	99.6	98.3	94	49	45	MH	160	-0.00556	7	6
364	BH-311	9.00-9.60	49.34	2.61	72.8	69.6	68.4	95	50	45	MH	190	-0.01467	7	6
365	BH-312	3.10-3.70	54.74	2.6	88.8	83.8	82.6	99	50	49	MH	170	0.09673	6	6
366	BH-312	4.50-5.10	52.55	2.59	99.5	98.9	97.8	97	50	47	MH	200	0.05426	6	6
367	BH-312	7.50-8.10	43.03	2.58	98.3	97.9	95.8	95	49	46	MH	190	-0.12978	8	7
368	BH-313	3.10-3.70	51.72	2.62	99.6	99.3	98.9	78	44	34	MH	130	0.22706	5	5
369	BH-313	4.50-5.10	51.36	2.58	99.1	98.4	97.6	90	49	41	MH	160	0.05756	6	6
370	BH-313	6.00-6.60	51.07	2.6	99.7	99.5	98.8	92	49	43	MH	180	0.04814	7	6
371	BH-313	9.00-9.60	47.99	2.59	97.6	96.6	95.2	93	48	45	MH	190	-0.00022	10	7
372	BH-318	3.00-3.60	53.7	2.63	99.9	99.8	99.3	82	48	34	MH	190	0.16765	7	7
373	BH-318	4.50-5.10	51.63	2.6	99.9	99.7	98.8	90	47	43	MH	150	0.10767	8	7

Sr. No	BH-ID	Depth (m)	NMC	Gs	Wet Sieve Analysis (AASHTO T27)			Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index LI	SPT N-values 300mm	Adjusted SPT N-values
					2.mm	0.425mm	0.075mm	LL	PL	PI					
374	BH-318	6.00-6.60	49.89	2.59	99.2	98.7	96.5	96	50	46	MH	170	-0.00239	9	7
375	BH-318	9.00-9.60	40.99	2.59	97.4	96.5	95.3	81	43	38	MH	160	-0.05289	13	9
376	BH-319	4.50-5.10	46.4	2.63	99.8	99.5	98.5	88	47	41	MH	190	-0.01463	9	8
377	BH-330	7.50-8.10	37.17	2.59	100	99.9	99.3	86	44	42	MH	160	-0.16262	12	9
378	BH-331	3.00-3.60	45.69	2.62	99.9	99.6	99.1	89	50	39	MH	130	-0.11051	7	7
379	BH-331	4.50-5.10	44.8	2.59	99.9	99.7	99.4	85	47	38	MH	150	-0.05789	7	7
380	BH-331	6.00-6.60	47.27	2.62	99.8	99.5	98.9	80	50	30	MH	130	-0.091	11	9
381	BH-332	3.10-3.70	43.93	2.64	99.9	99.7	99.3	93	48	45	MH	80	-0.09044	9	8
382	BH-332	4.50-5.10	34.83	2.61	99.9	99.7	99.1	88	49	39	MH	120	-0.36333	16	13
383	BH-332	7.50-8.10	41.37	2.59	99.8	99.4	98.5	80	48	32	MH	140	-0.20719	15	10
384	BH-333	3.00-3.60	54.08	2.59	99.7	99.1	98.5	84	46	38	MH	190	0.21263	9	8
385	BH-333	4.50-5.10	39.53	2.6	99.8	99.7	99.3	71	42	29	MH	90	-0.08517	11	9
386	BH-333	9.00-9.60	18.78	2.58	99.1	98.6	97.6	76	45	31	MH	140	-0.84581	34	21
387	BH-334	3.10-3.70	44.12	2.62	99.9	99.6	99.2	81	43	38	MH	170	0.02947	8	7
388	BH-334	7.50-8.10	44.86	2.58	99.6	99.1	98.3	72	45	27	MH	120	-0.00519	7	5
389	BH-334	9.00-9.60	27.36	2.63	99.5	98.7	97.3	67	43	24	MH	100	-0.65167	50	28
390	BH-335	4.50-5.10	38.59	2.59	99.9	99.5	98.7	88	48	40	MH	160	-0.23525	11	10
391	BH-338	7.50-8.10	45.14	2.6	99.7	99.6	98.5	77	46	31	MH	120	-0.02774	13	9
392	BH-339	4.50-5.10	50.39	2.61	99.8	99.4	98.4	93	48	45	MH	180	0.05311	7	6
393	BH-388	4.50-5.10	39.13	2.62	99.9	99.6	99	71	42	29	MH	120	-0.09897	9	8
394	BH-388	9.00-9.60	39.64	2.63	99.9	99.4	97.1	71	44	27	MH	120	-0.16148	12	9
395	BH-389	7.50-8.10	43.63	2.6	99.7	99.6	99.4	86	45	41	MH	150	-0.03341	11	8
396	BH-390	1.70-2.30	45.62	2.63	98.9	98	97	70	46	24	MH	120	-0.01583	7	7
397	BH-390	3.10-3.70	45.15	2.62	96.1	93.9	92.6	95	54	41	MH	170	-0.21585	9	9
398	BH-387	1.50-2.10	37.89	2.63	100	99.5	98.6	94	50	44	MH	170	-0.27523	11	11
399	BH-391	1.50-2.10	44.19	2.6	98.2	96.5	95.3	85	49	36	MH	140	-0.13361	10	10
400	BH-391	6.00-6.60	29.65	2.63	99.3	98.9	98	71	46	25	MH	100	-0.654	24	19
401	BH-414	6.00-6.60	26.92	2.61	100	98.8	95.3	79	48	31	MH	160	-0.68	12	10
402	BH-410	6.00-6.60	26.2	2.61	98.8	97.7	97.5	92	49	43	MH	160	-0.53023	9	7
403	BH-412	6.00-6.60	26.76	2.6	99.7	99	98.3	87	49	38	MH	170	-0.58526	11	8
404	BH-416	6.00-6.60	23.87	2.61	99.1	97.8	97.3	80	47	33	MH	120	-0.70091	12	9
405	BH-440	6.00-6.60	30.09	2.58	100	99.6	96.9	75	51	24	MH	90	-0.87125	9	7
406	BH-446	7.50-8.10	34.18	2.63	99.6	99.1	98.4	69	38	31	MH	120	-0.12323	12	9
407	BH-393	4.50-5.10	39.52	2.6	99.9	99.2	97.9	66	40	26	MH	130	-0.01846	9	8
408	BH-414	4.50-5.10	42.75	2.6	93.8	88.2	79	74	44	30	MH	140	-0.04167	7	7
409	BH-422	9.00-9.60	30.38	2.6	98.1	96.6	92.7	66	41	25	MH	140	-0.4248	22	14
410	BH-423	3.00-3.60	36.69	2.6	99.4	98.9	98	76	38	38	MH	130	-0.03447	9	8
411	BH-423	4.50-5.10	36.91	2.62	95.8	89.5	84.9	64	34	30	MH	180	0.097	10	8
412	BH-407	3.00-3.60	43.85	2.62	99.8	98.7	97.2	79	48	31	MH	170	-0.13387	7	7
413	BH-419	3.00-3.60	34.68	2.6	98.2	97.9	97.4	76	43	33	MH	190	-0.25212	12	12
414	BH-440	3.00-3.60	49.56	2.6	100	99.8	99.3	93	50	43	MH	150	-0.01023	7	7
415	BH-440	4.50-5.10	50.4	2.62	99.7	99.4	97.8	80	42	38	MH	100	0.22105	8	7
416	BH-441	1.50-2.10	48.38	2.64	100	99.6	99.1	99	51	48	MH	170	-0.05458	6	6
417	BH-441	3.00-3.60	44.67	2.61	99.7	98.7	96.8	80	42	38	MH	150	0.07026	7	7
418	BH-441	4.50-5.10	45.39	2.62	99.8	99	97.2	77	43	34	MH	130	0.07029	9	8
419	BH-443	3.00-3.60	44.9	2.63	99.8	98.1	94.5	78	42	36	MH	170	0.08056	8	8
420	BH-443	4.50-5.10	48.76	2.61	92.8	82.4	72.5	58	32	26	MH	110	0.64462	10	9
421	BH-444	4.50-5.10	36.04	2.59	100	99.1	93.7	77	43	34	MH	170	-0.20471	9	8
422	BH-445	3.00-3.60	43.94	2.62	99.1	92.5	87.7	78	43	35	MH	150	0.02686	7	7
423	BH-445	4.50-5.10	45.27	2.63	100	99.6	97.5	74	45	29	MH	160	0.00931	9	8
424	BH-446	3.00-3.60	42.68	2.62	99.9	99.2	98.1	99	51	48	MH	190	-0.17333	7	7
425	BH-446	4.50-5.10	45.43	2.6	99.4	97.5	95.6	95	50	45	MH	150	-0.10156	9	8
426	BH-446	7.50-8.10	34.18	2.63	99.6	99.1	98.4	69	38	31	MH	120	-0.12323	12	9
427	BH-448	1.70-2.30	40	2.63	97.5	96.1	94.4	94	49	45	MH	170	-0.2	10	10
428	BH-451	4.50-5.10	24.69	2.62	96	88.4	80.4	68	46	22	MH	170	-0.96864	27	24
429	BH-439	7.50-8.10	20.83	2.63	72.3	52.6	42	54	31	23	MH	70	-0.44217	27	19
430	BH-451	9.00-9.60	29.31	2.61	59.5	37.3	28.9	56	45	11	MH	20	-1.42636	50	31
431	BH-459	9.00-9.60	31.65	2.59	81.4	61.6	45.9	51	40	11	MH	50	-0.75909	50	27
432	BH-110	1.50-2.10	53.16	2.63	99.9	99.6	99	100	54	46	MH	150	-0.01826	5	5
433	BH-128	1.50-2.10	51.15	2.59	99.5	98.8	97.4	77	43	34	MH	170	0.23971	4	4
434	BH-118	1.50-2.10	55.51	2.61	99.6	98.7	98.1	85	49	36	MH	150	0.18083	4	4
435	BH-158	1.50-2.10	60.28	2.61	99.9	99.4	98.7	87	49	38	MH	200	0.29684	4	4
436	BH-7	1.50-2.10	35.27	2.58	37.9	0	22.9	47	34	13	ML	40	0.09769	16	16
437	BH-7	3.00-3.60	24.14	2.57	83.1	63.8	47.1	49	32	17	ML	60	-0.46235	50	40
438	BH-8	1.50-2.10	21.57	2.58	53.7	40.1	31.1	46	36	10	ML	20	-1.443	50	30
439	BH-9	1.50-2.10	40.77	2.56	58.4	48.3	38.8	44	30	14	ML	30	0.76929	10	10
440	BH-10	1.50-2.00	30.8	2.58	56	45.4	27.8	43	35	8	ML	40	-0.525	50	45
441	BH-12	1.50-2.10	45.16	2.57	45	34.9	25.7	48	36	12	ML	60	0.76333	15	15
442	BH-12	2.90-3.60	35.53	2.58	52.3	43.2	32.4	48	34	14	ML	40	0.10929	50	30
443	BH-14	1.50-2.10	23.13	2.58	38.3	28.1	19.8	36	27	9	ML	40	-0.43	50	30
444	BH-15	1.50-2.00	19.35	2.58	58.9	44.5	31.3	33	25	8	ML	30	-0.70625	50	45
445	BH-18	4.50-4.95	37.26	2.58	85	60.9	48.7	43	28	15	ML	50	0.61733	19	23
446	BH-5	3.00-3.60	34.24	2.56	25.7	21.5	17	42	32	10	ML	40	0.224	16	16
447	BH-5	4.40-5.00	17.55	2.56	76.5	54.8	42.8	48	37	11	ML	40	-1.76818	50	32

Sr. No	BH-ID	Depth (m)	NMC	Gs	Wet Sieve Analysis (AASHTO T27)			Atterberg Limit (AASHTOT89&90)			USCS	Free Swell (%)	Liqudity Index LI	SPT N-values 300mm	Adjusted SPT N-values
					2.mm	0.425mm	0.075mm	LL	PL	PI					
448	BH-37	6.00-6.60	30.68	2.56	67.4	58.4	47.4	47	33	14	ML	60	-0.16571	24	20
449	BH-38	4.40-5.00	32.29	2.6	66.6	60.7	48.8	41	29	12	ML	200	0.27417	50	26
450	BH-42	4.50-5.10	34.16	2.56	64.5	33.5	18.8	50	39	11	ML	40	-0.44	50	20
451	BH-44	1.00-1.60	31.67	2.62	65	41.7	28.6	38	31	7	ML	20	0.09571	50	25
452	BH-45	3.00-3.60	39.24	2.6	65.8	55.4	45.1	48	34	14	ML	30	0.37429	18	16
453	BH-45	4.50-5.10	33.97	2.57	45.5	42.2	39	49	40	9	ML	40	-0.67	50	29
454	BH-46	1.50-2.10	32.45	2.57	77.1	57.2	46.5	43	33	10	ML	30	-0.055	25	23
455	BH-47	4.10-4.70	29.84	2.57	76.3	52.6	34.8	39	32	7	ML	10	-0.30857	50	24
456	BH-49	7.50-8.10	45.11	2.58	85.5	62.6	49.8	41	31	10	ML	30	1.411	9	7
457	BH-50	4.50-5.10	33.29	2.61	39.3	35	27.8	50	43	7	ML	130	-1.38714	50	42
458	BH-25	2.80-3.15	25.52	2.57	72.31	61.6	49.9	43	32	11	ML	40	-0.58909	50	35
459	BH-53	1.50-2.10	47.64	2.58	77.1	69.3	50.8	46	35	11	ML	40	1.14909	8	8
460	BH-54	3.00-3.60	36.79	2.57	35.7	27	21.9	50	38	12	ML	30	-0.10083	22	22
461	BH-55	4.50-5.10	44.02	2.56	51.2	41.5	32.1	49	33	16	ML	30	0.68875	13	13
462	BH-58	3.00-3.60	50	2.6	77.1	66.6	56	46	31	15	ML	60	1.26667	11	11
463	BH-61	4.50-5.10	32.32	2.57	80.1	62.7	47.1	49	33	16	ML	40	-0.0425	35	21
464	BH-61	6.00-6.60	26.62	2.56	75.3	55.7	44.6	50	38	12	ML	30	-0.94833	38	22
465	BH-61	7.50-8.10	29.89	2.58	52.3	43.5	36.7	46	35	11	ML	30	-0.46455	32	25
466	BH-62	6.00-6.60	31.63	2.57	52.9	46.6	33.9	47	35	12	ML	60	-0.28083	48	27
467	BH-62	9.00-9.60	29.08	2.58	70.9	60.1	46.6	47	33	14	ML	80	-0.28	50	24
468	BH-63	1.50-2.10	27.8	2.59	61.5	45.7	33.6	46	37	9	ML	20	-1.02222	50	25
469	BH-64	1.50-2.10	32	2.57	70.8	55.3	41.5	44	33	11	ML	30	-0.09091	22	25
470	BH-288	9.00-9.6	30.17	2.61	72.6	60.4	51	32	20	12	ML	50	0.8475	18	11
471	BH-292	9.00-9.60	19.71	2.58	82.6	61.8	46.7	35	25	10	ML	30	-0.529	50	25
472	BH-293	9.00-9.60	29.27	2.59	88.3	67.1	50.3	38	29	9	ML	40	0.03	22	14
473	BH-295	9.00-9.60	33.25	2.58	51.9	36.7	22.8	31	22	9	ML	10	1.25	11	10
474	BH-386	9.00-9.60	26.1	2.61	50	18.9	11.7	40	30	10	ML	5	-0.39	50	26
475	BH-391	7.00-7.60	27.27	2.62	71.3	43.5	34.3	44	33	11	ML	40	-0.52091	50	33
476	BH-392	9.00-9.60	24.6	2.63	55.8	36.1	29.1	32	22	10	ML	5	0.26	50	26
477	BH-416	9.00-9.60	37.4	2.58	63.2	55.7	46.3	40	27	13	ML	50	0.8	12	8
478	BH-453	9.00-9.60	26.72	2.61	49.1	21.2	17	40	30	10	ML	-	-0.328	13	26
479	BH-437	9.00-9.60	31.11	2.6	82.9	64	51.2	42	29	13	ML	20	0.16231	16	11
480	BH-18	4.50-4.95	37.26	2.58	85	60.9	48.7	43	28	15	ML	50	0.61733	19	23
481	BH-40	3.00-3.60	26.33	2.6	75.9	69.9	59.7	45	32	13	ML	90	-0.43615	50	29
482	BH-42	1.50-2.10	32.57	2.59	88.8	80	72.6	41	34	7	ML	50	-0.20429	21	21
483	BH-60	3.10-3.70	40.53	2.57	86.6	83.6	79.5	42	25	17	ML	100	0.91353	11	11
484	BH-297	8.10-10.50	39.13	2.62	94.8	92.4	90.3	46	29	17	ML	80	0.59588	18	11
485	BH-306	9.00-9.60	43.71	2.6	100	99.6	98.9	47	40	7	ML	20	0.53	23	16
486	BH-307	7.50-8.10	43.86	2.62	98.5	97	96	45	30	15	ML	80	0.924	16	11
487	BH-287	3.10-3.70	47.6	2.58	96.5	89.9	83.6	42	28	14	ML	60	1.4	9	9
488	BH-308	7.50-8.10	22.2	2.58	92.7	84.4	73.1	25	17	8	ML	40	0.65	13	9
489	BH-296	9.00-9.60	33.93	2.61	88.8	77.3	57.6	29	21	8	ML	50	1.61625	10	7
490	BH-297	9.00-9.60	39.13	2.62	94.8	92.4	90.3	46	29	17	ML	80	0.59588	18	11
491	BH-306	9.00-9.60	43.71	2.6	100	99.6	98.9	47	40	7	ML	20	0.53	23	16
492	BH-307	7.50-8.10	43.86	2.62	98.5	97	96	45	30	15	ML	80	0.924	16	11
493	BH-386	3.10-3.70	46.01	2.6	97	94.7	96	46	32	14	ML	80	1.00071	10	10
494	BH-386	4.50-5.10	44.55	2.58	98.7	97.3	96	50	35	15	ML	90	0.63667	12	11
495	BH-386	9.00-9.60	36.07	2.58	80.8	70.8	96	36	28	8	ML	-	1.00875	22	15
496	BH-423	7.50-8.10	35.64	2.62	93.1	87.5	96	35	24	11	ML	20	1.05818	12	8
497	BH-417	7.50-8.10	25.13	2.6	89	74.9	96	42	27	15	ML	40	-0.12467	22	14
498	BH-445	9.00-9.60	29.44	2.6	81.1	68.5	96	28	20	8	ML	10	1.18	10	7
499	BH-448	7.50-8.10	30.88	2.6	89	80.1	96	31	21	10	ML	10	0.988	12	9
500	BH-455	9.00-9.60	23.73	2.59	81.2	68.7	96	33	21	12	ML	40	0.2275	20	14
501	BH-448	9.00-9.60	30.88	2.6	89	80.1	60.4	31	21	10	ML	10	0.988	12	9
502	BH-451	3.10-3.70	39.13	2.6	96.5	92	79.7	36	25	11	ML	-	1.28455	9	9
503	BH-453	9.00-9.60	26.72	2.61	49.1	21.2	17	40	30	10	ML	-	-0.328	13	26
504	BH-437	9.00-9.60	48.46	2.62	99.6	98.9	97	45	30	15	ML	80	1.23067	14	10
505	BH-455	9.00-9.60	23.73	2.59	81.2	68.7	59.6	33	21	12	ML	40	0.2275	20	14

APPENDIX- A-2: MULTIPL REGRESSION ANALYSIS SUMMARY OUTPUT



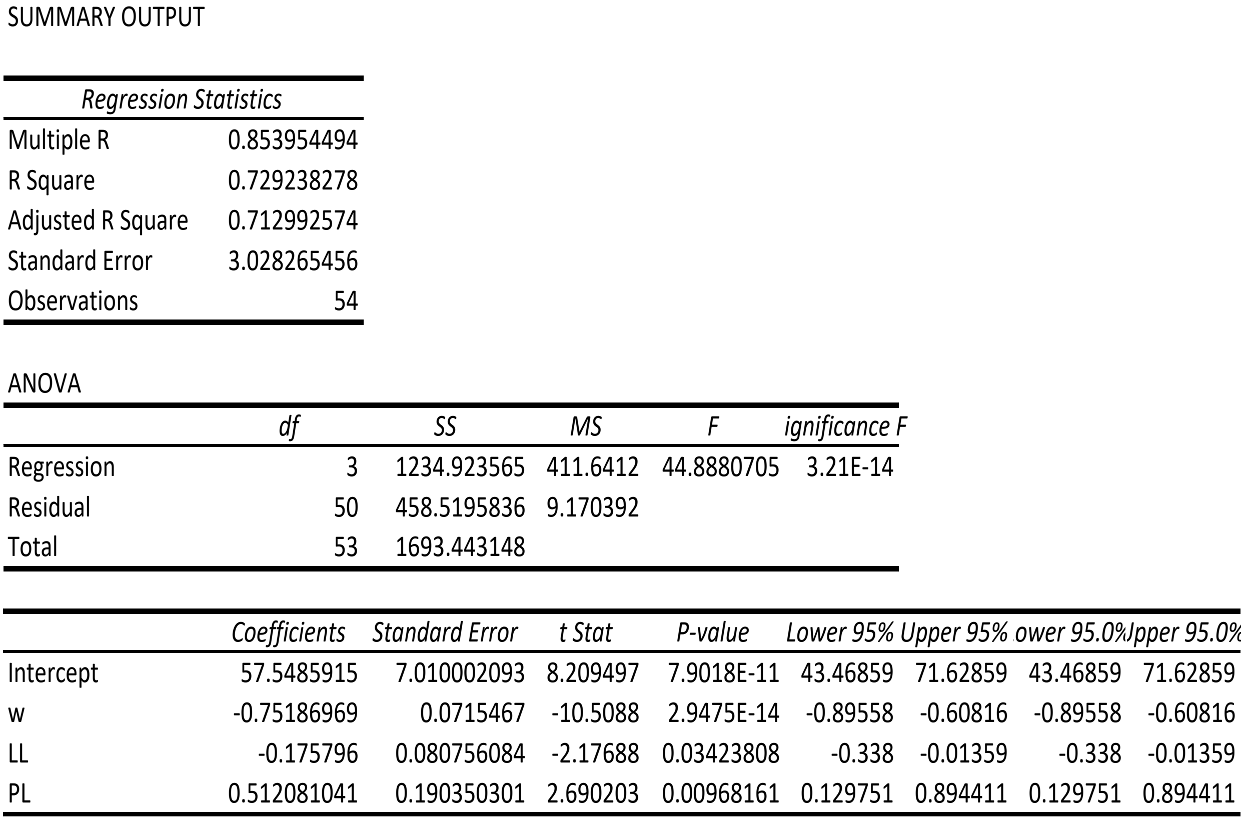
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.709698036
R Square	0.503671302
Adjusted R Square	0.49549006
Standard Error	5.104420287
Observations	186

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	4812.182175	1604.060725	61.56415928	1.59277E-27
Residual	182	4742.029378	26.05510647		
Total	185	9554.211552			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	40.17501546	5.04853844	7.957751721	1.8143E-13	30.21382486	50.1362061	30.21382486	50.13620606
PI	-0.90048607	0.143630546	-6.269460731	2.56062E-09	-1.183881208	-0.6170909	-1.18388121	-0.617090932
LL	0.753853833	0.108117044	6.972571644	5.55083E-11	0.54052982	0.96717785	0.54052982	0.967177845
w	-0.7631365	0.0598031	-12.76081843	4.73263E-27	-0.881133041	-0.64514	-0.88113304	-0.645139957



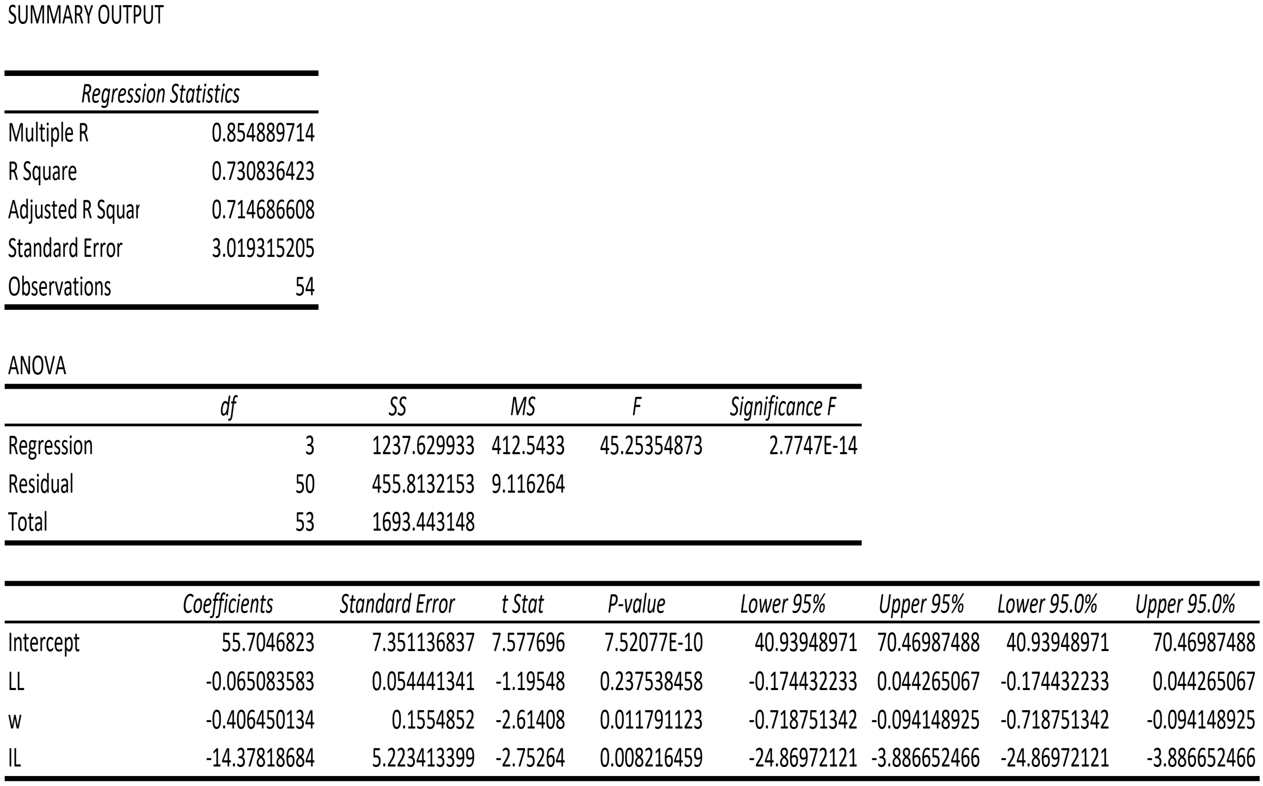
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.853954494
R Square	0.729238278
Adjusted R Square	0.712992574
Standard Error	3.028265456
Observations	54

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	3	1234.923565	411.6412	44.8880705	3.21E-14
Residual	50	458.5195836	9.170392		
Total	53	1693.443148			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Jpper 95.0%*
Intercept	57.5485915	7.010002093	8.209497	7.9018E-11	43.46859	71.62859	43.46859	71.62859
w	-0.75186969	0.0715467	-10.5088	2.9475E-14	-0.89558	-0.60816	-0.89558	-0.60816
LL	-0.175796	0.080756084	-2.17688	0.03423808	-0.338	-0.01359	-0.338	-0.01359
PL	0.512081041	0.190350301	2.690203	0.00968161	0.129751	0.894411	0.129751	0.894411



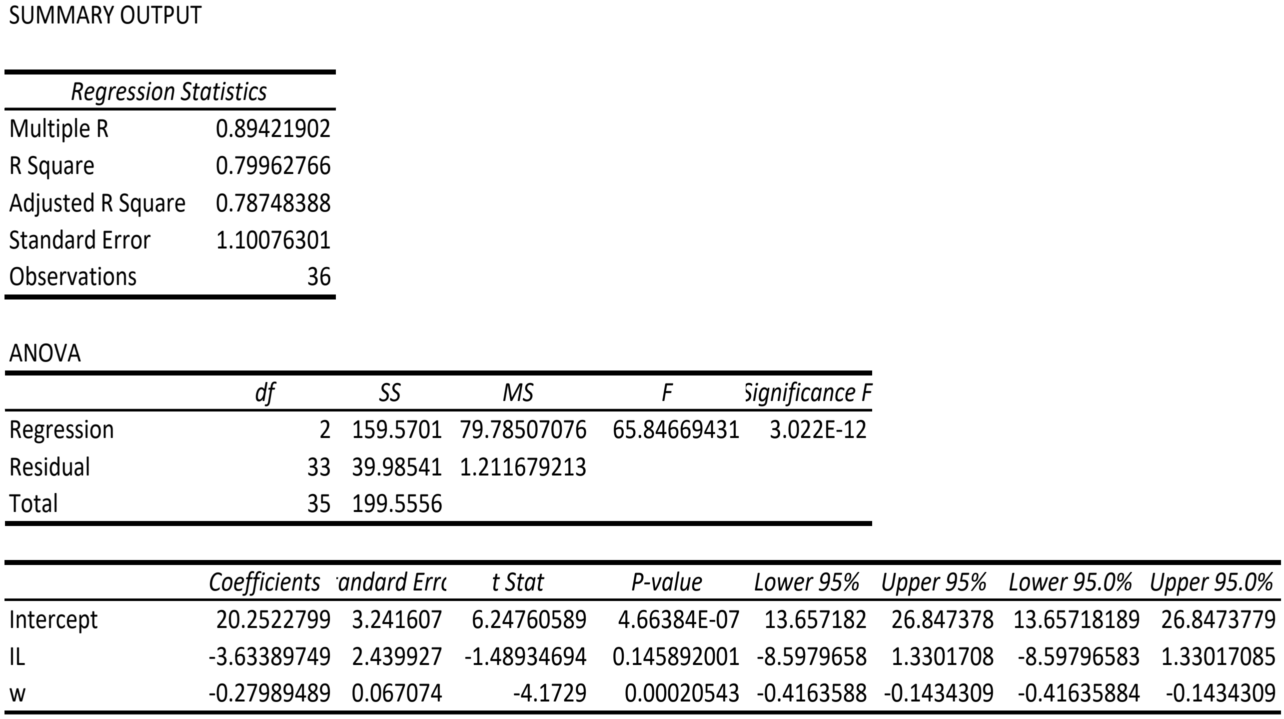
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.854889714
R Square	0.730836423
Adjusted R Squar	0.714686608
Standard Error	3.019315205
Observations	54

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1237.629933	412.5433	45.25354873	2.7747E-14
Residual	50	455.8132153	9.116264		
Total	53	1693.443148			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	55.7046823	7.351136837	7.577696	7.52077E-10	40.93948971	70.46987488	40.93948971	70.46987488
LL	-0.065083583	0.054441341	-1.19548	0.237538458	-0.174432233	0.044265067	-0.174432233	0.044265067
w	-0.406450134	0.1554852	-2.61408	0.011791123	-0.718751342	-0.094148925	-0.718751342	-0.094148925
IL	-14.37818684	5.223413399	-2.75264	0.008216459	-24.86972121	-3.886652466	-24.86972121	-3.886652466



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.89421902
R Square	0.79962766
Adjusted R Square	0.78748388
Standard Error	1.10076301
Observations	36

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	159.5701	79.78507076	65.84669431	3.022E-12
Residual	33	39.98541	1.211679213		
Total	35	199.5556			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	20.2522799	3.241607	6.24760589	4.66384E-07	13.657182	26.847378	13.65718189	26.8473779
IL	-3.63389749	2.439927	-1.48934694	0.145892001	-8.5979658	1.3301708	-8.59796583	1.33017085
w	-0.27989489	0.067074	-4.1729	0.00020543	-0.4163588	-0.1434309	-0.41635884	-0.1434309

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.89702
R Square	0.804645
Adjusted R Square	0.78633
Standard Error	1.103746
Observations	36

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	3	160.5714	53.52378	43.93475	1.88E-11
Residual	32	38.9842	1.218256		
Total	35	199.5556			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	20.38301	3.25359	6.264775	5.05E-07	13.75566	27.01035	13.75566	27.01035
IL	-1.37321	3.493444	-0.39308	0.696865	-8.48913	5.7427	-8.48913	5.7427
w	-0.33306	0.089235	-3.73242	0.000738	-0.51483	-0.1513	-0.51483	-0.1513
LL	0.026669	0.029418	0.906554	0.371419	-0.03325	0.086592	-0.03325	0.086592

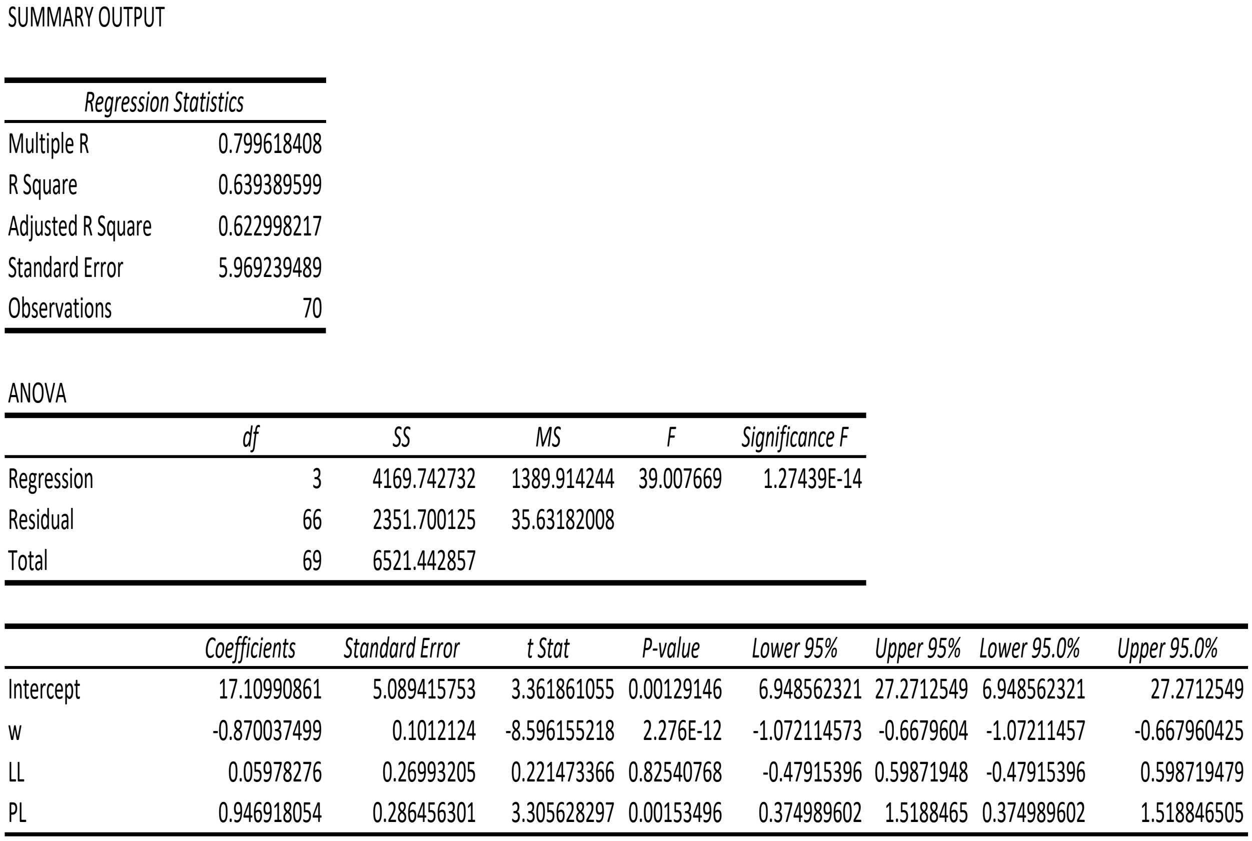
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.79945081
R Square	0.6391216
Adjusted R Square	0.62834911
Standard Error	5.92672657
Observations	70

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	4167.994975	2083.997487	59.32905195	1.48E-15
Residual	67	2353.447882	35.12608779		
Total	69	6521.442857			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	17.6251279	4.494389152	3.921584737	0.00020955	8.65429	26.59596609	8.654289712	26.59596609
PL	1.00337465	0.12974534	7.733415682	7.27849E-11	0.744402	1.262347427	0.744401868	1.262347427
w	-0.8617318	0.093338692	-9.232310585	1.47105E-13	-1.04804	-0.675426985	-1.048036597	-0.675426985



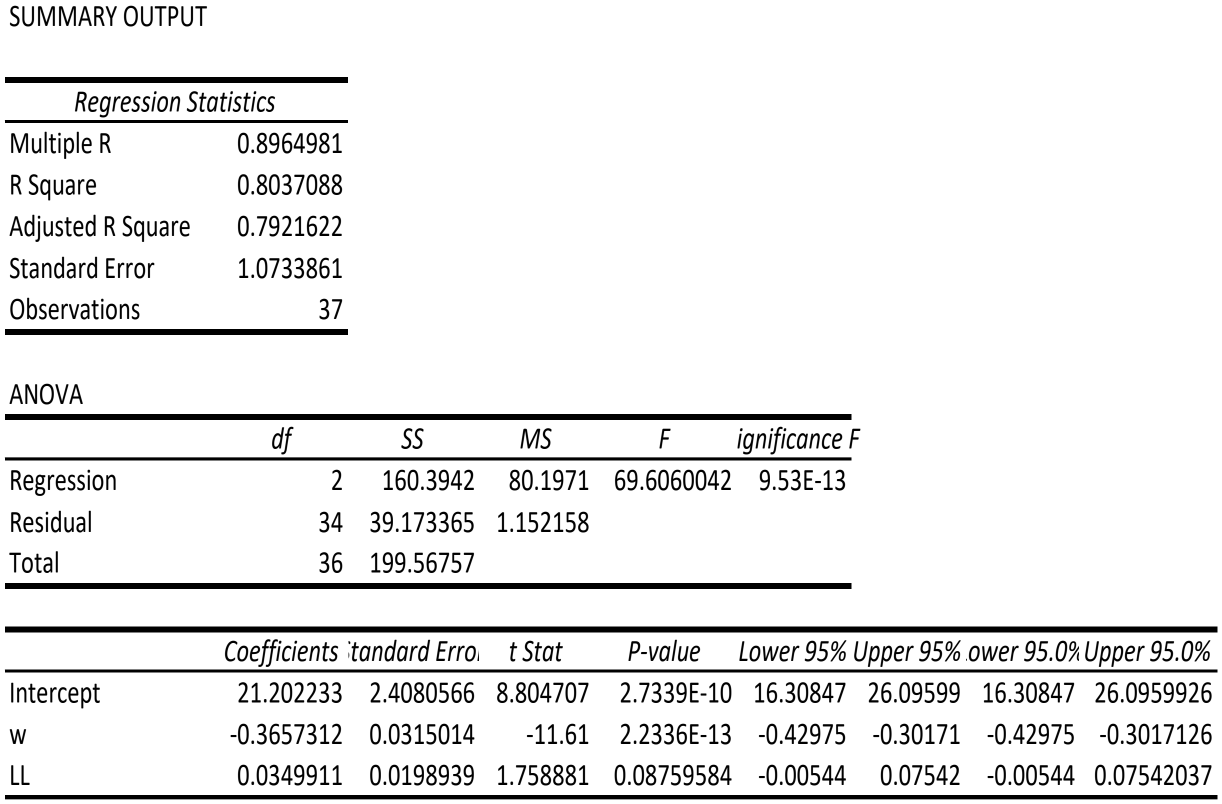
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.799618408
R Square	0.639389599
Adjusted R Square	0.622998217
Standard Error	5.969239489
Observations	70

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	4169.742732	1389.914244	39.007669	1.27439E-14
Residual	66	2351.700125	35.63182008		
Total	69	6521.442857			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	17.10990861	5.089415753	3.361861055	0.00129146	6.948562321	27.2712549	6.948562321	27.2712549
w	-0.870037499	0.1012124	-8.596155218	2.276E-12	-1.072114573	-0.6679604	-1.07211457	-0.667960425
LL	0.05978276	0.26993205	0.221473366	0.82540768	-0.47915396	0.59871948	-0.47915396	0.598719479
PL	0.946918054	0.286456301	3.305628297	0.00153496	0.374989602	1.5188465	0.374989602	1.518846505



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.8964981
R Square	0.8037088
Adjusted R Square	0.7921622
Standard Error	1.0733861
Observations	37

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	160.3942	80.1971	69.6060042	9.53E-13
Residual	34	39.173365	1.152158		
Total	36	199.56757			

	Coefficients	*tandard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	21.202233	2.4080566	8.804707	2.7339E-10	16.30847	26.09599	16.30847	26.0959926
w	-0.3657312	0.0315014	-11.61	2.2336E-13	-0.42975	-0.30171	-0.42975	-0.3017126
LL	0.0349911	0.0198939	1.758881	0.08759584	-0.00544	0.07542	-0.00544	0.07542037

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.935419568
R Square	0.875009768
Adjusted R Square	0.847234161
Standard Error	4.323002927
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1177.471478	588.73574	31.50281343	8.629E-05
Residual	9	168.1951887	18.688354		
Total	11	1345.666667			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	12.64211365	7.981743252	1.5838788	0.147681621	-5.413844	30.698071	-5.413844	30.69807
PI	0.970271791	0.589867267	1.6448985	0.134400879	-0.3641007	2.3046443	-0.364101	2.304644
IL	-14.22169236	1.79440226	-7.925588	2.38488E-05	-18.280912	-10.162472	-18.28091	-10.1625

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.947767
R Square	0.898263
Adjusted R Squar	0.860111
Standard Error	4.136792
Observations	12

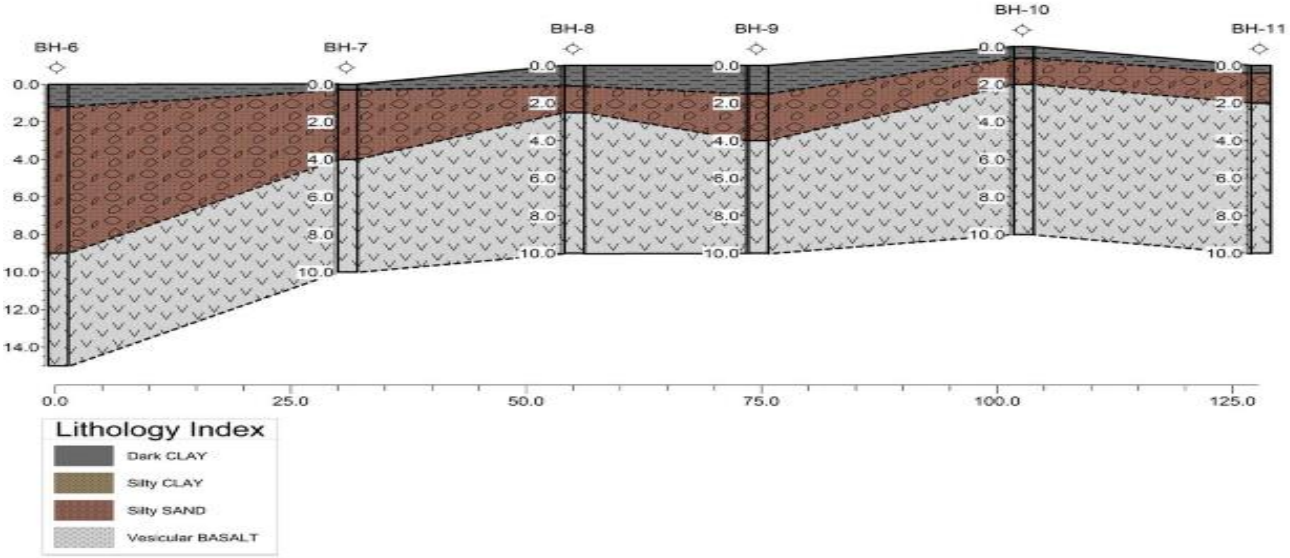
ANOVA

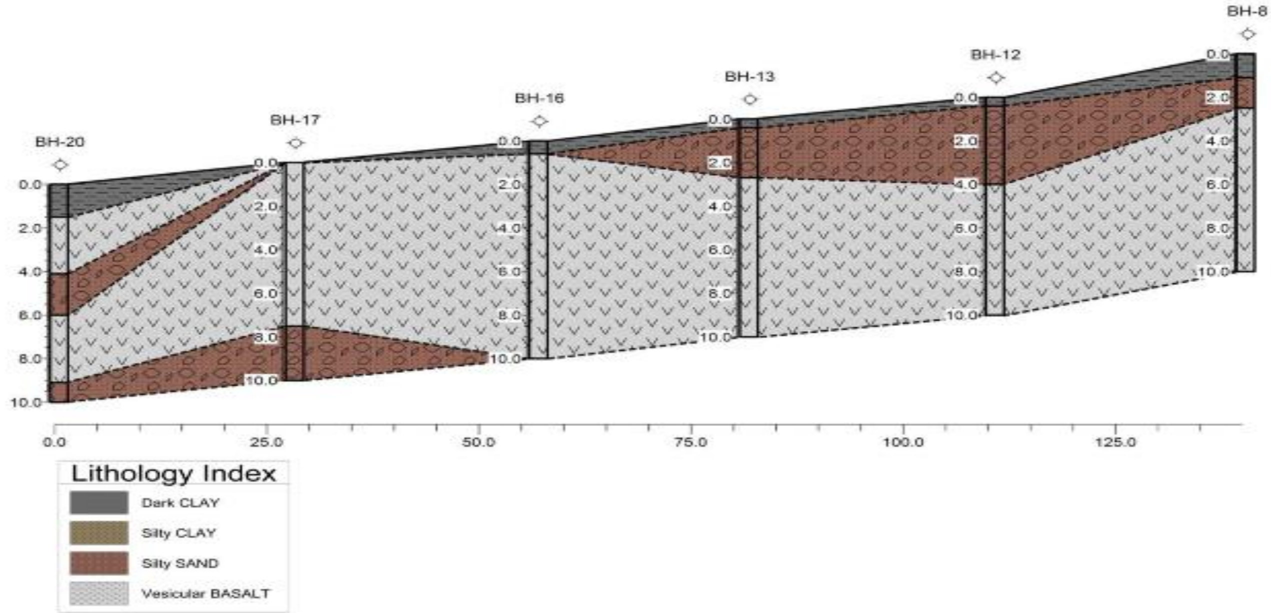
	df	*SS*	*MS*	*F*	*ignificance F*
Regression	3	1208.76231	402.9208	23.544657	0.000253
Residual	8	136.904359	17.11304		
Total	11	1345.66667			

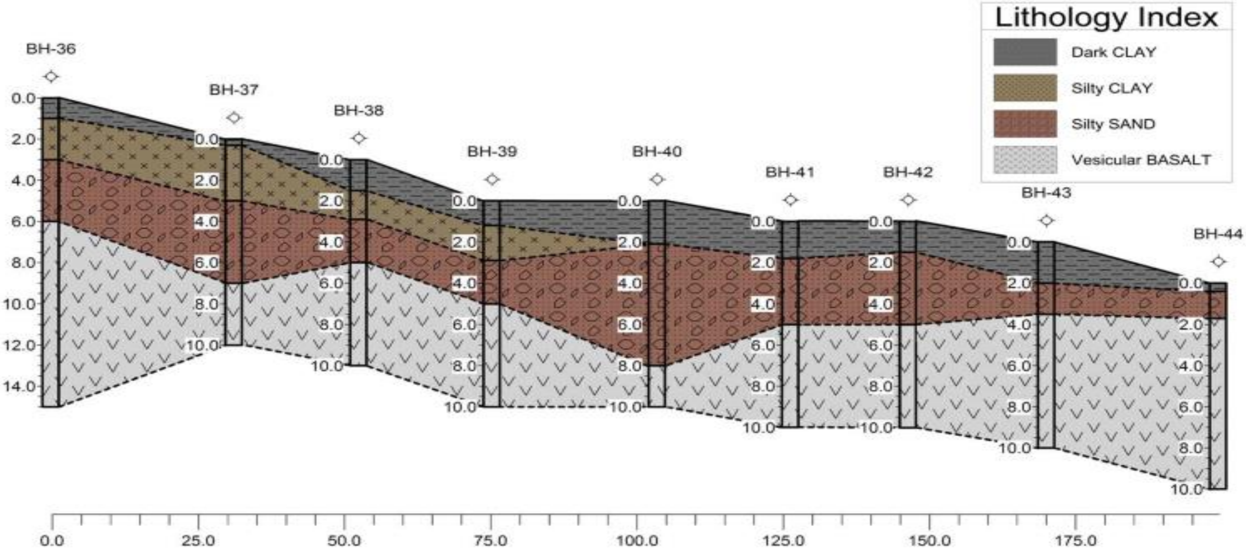
	Coefficients	*Standard Erroi*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Jpper 95.0%*
Intercept	15.8192	16.1209109	0.981285	0.3551929	-21.3557	52.99409	-21.3557	52.99409
w	-1.09086	0.15252418	-7.15207	9.689E-05	-1.44259	-0.73914	-1.44259	-0.73914
LL	1.244729	0.57280336	2.173048	0.0615256	-0.07616	2.565616	-0.07616	2.565616
PL	-0.35933	0.62467709	-0.57523	0.5809495	-1.79984	1.081175	-1.79984	1.081175

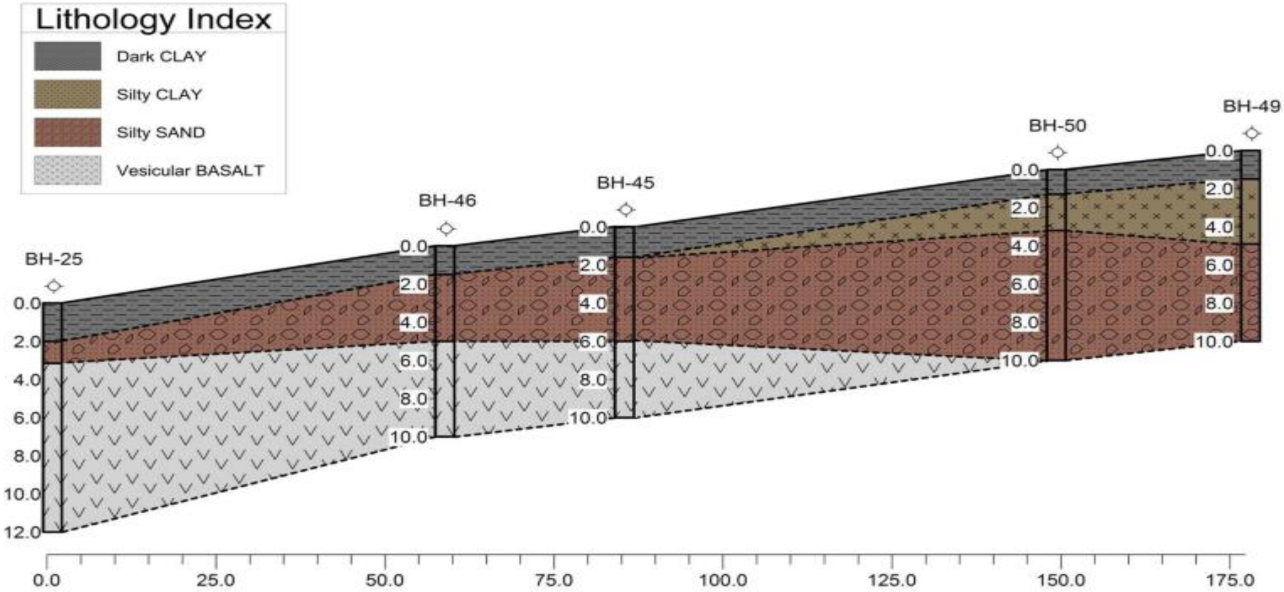
APPENDIX -B: SOIL CROSS SECTION PROFILE

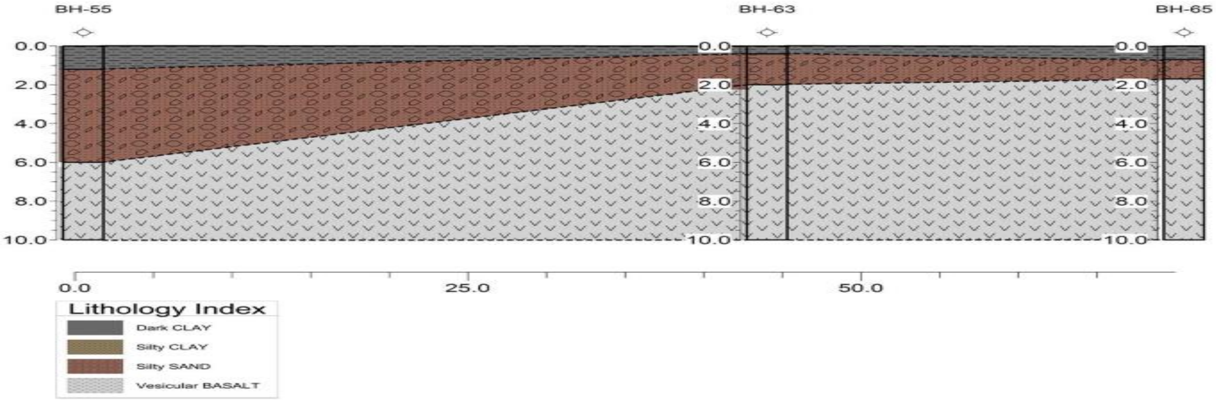
Some of soil cross section profiles are attached

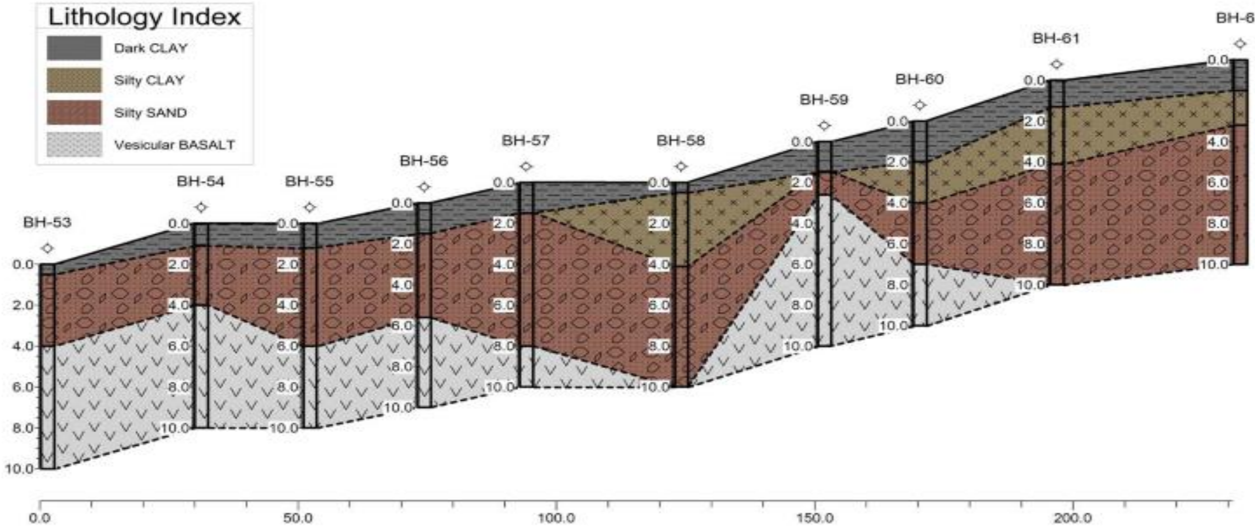


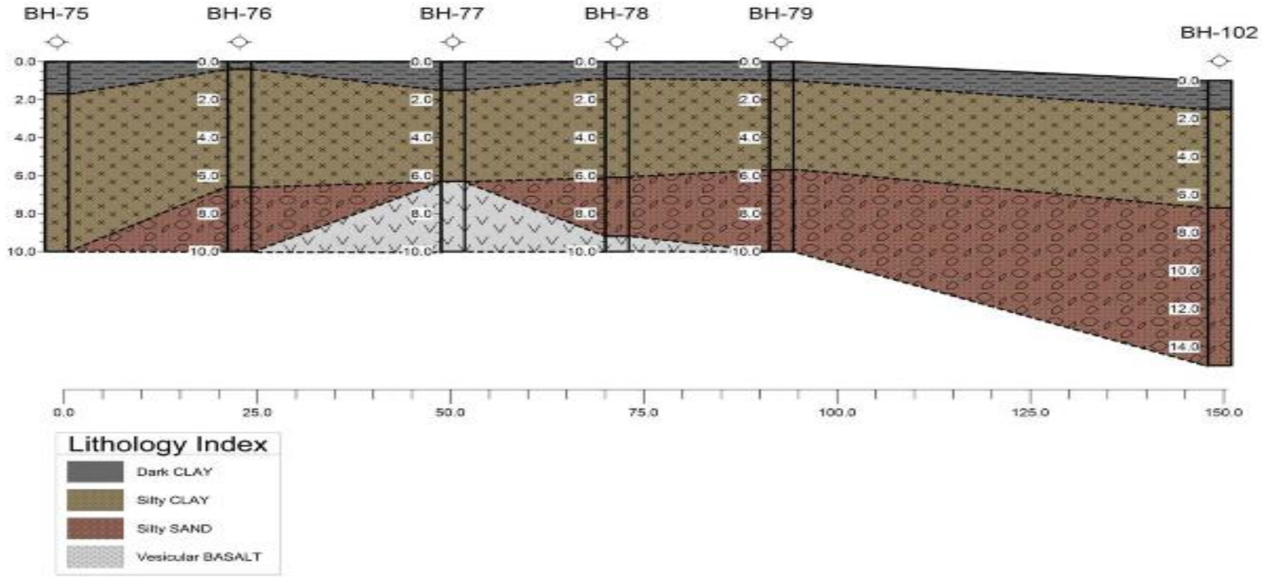


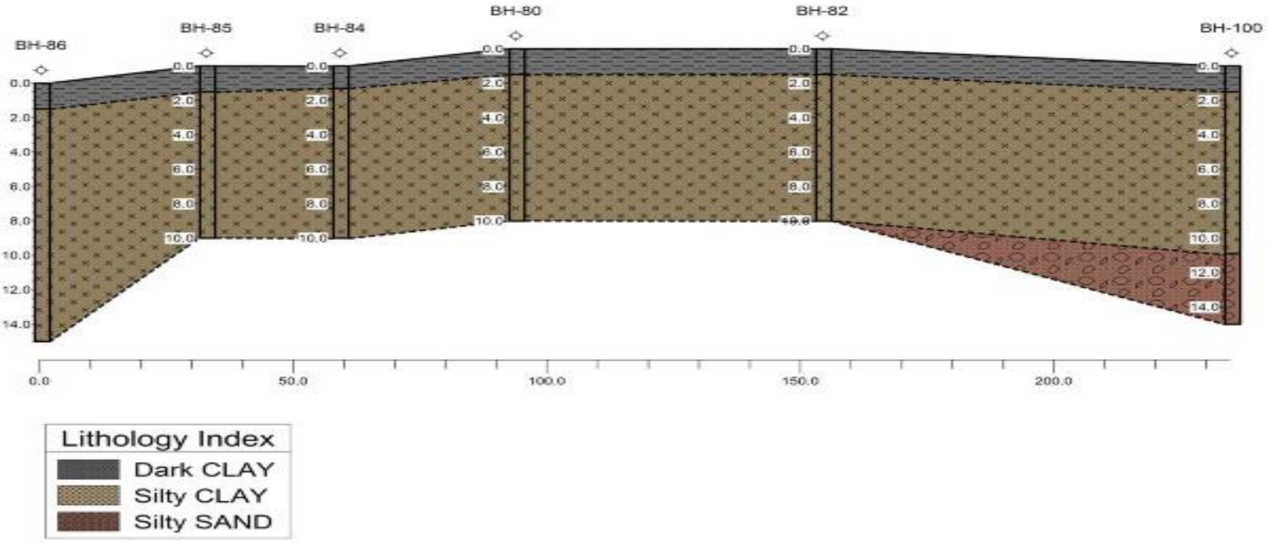


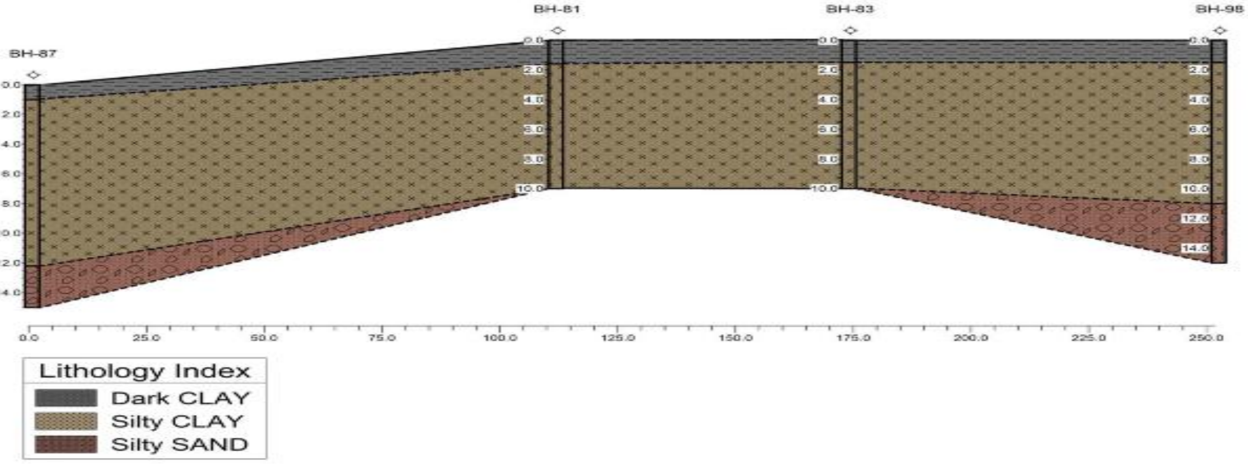

Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT
BH-25
BH-46
BH-45
BH-50
BH-49
0.0
2.0
4.0
6.0
8.0
10.0
12.0
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0

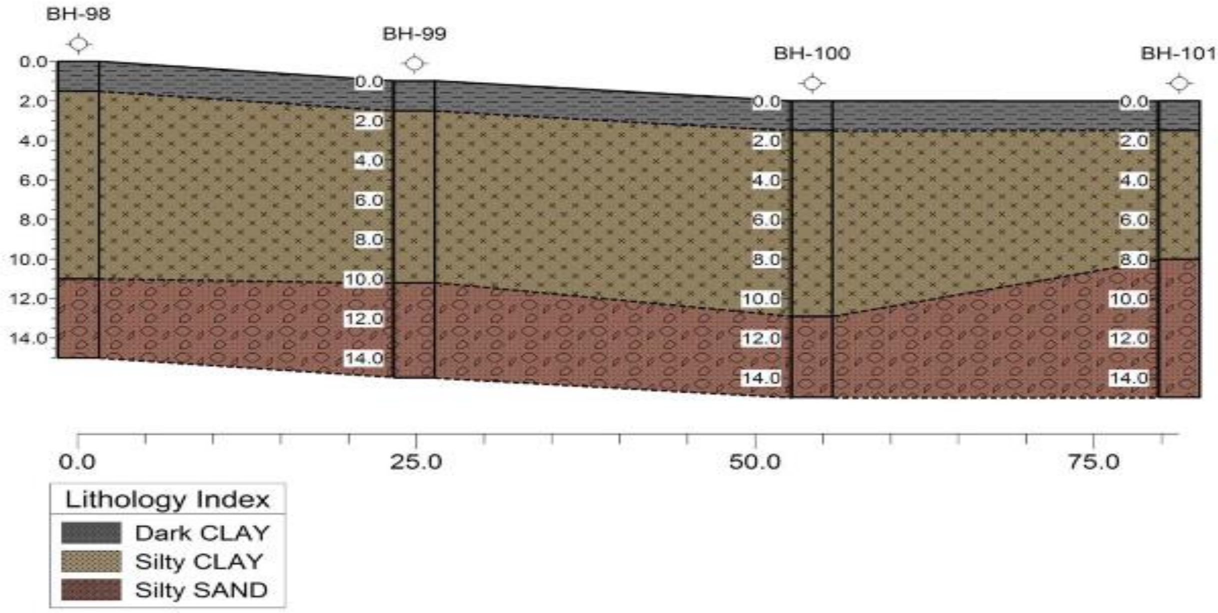

BH-55
BH-63
BH-65
0.0
2.0
4.0
6.0
8.0
10.0
0.0
25.0
50.0
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT

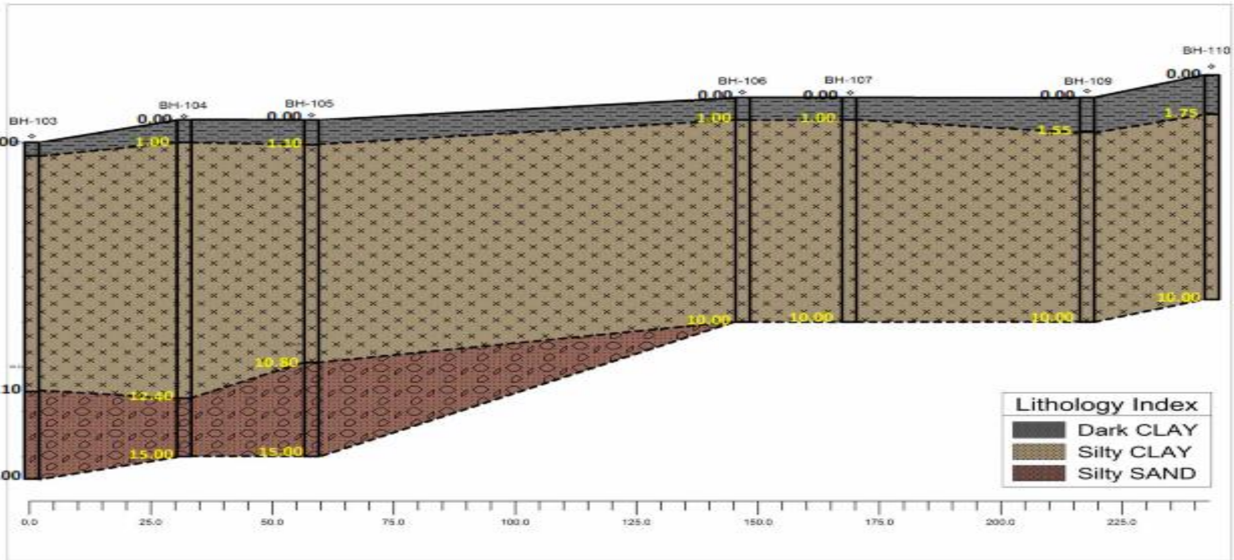

Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT
BH-53
BH-54
BH-55
BH-56
BH-57
BH-58
BH-59
BH-60
BH-61
BH-62
0.0
2.0
4.0
6.0
8.0
10.0
0.0
50.0
100.0
150.0
200.0

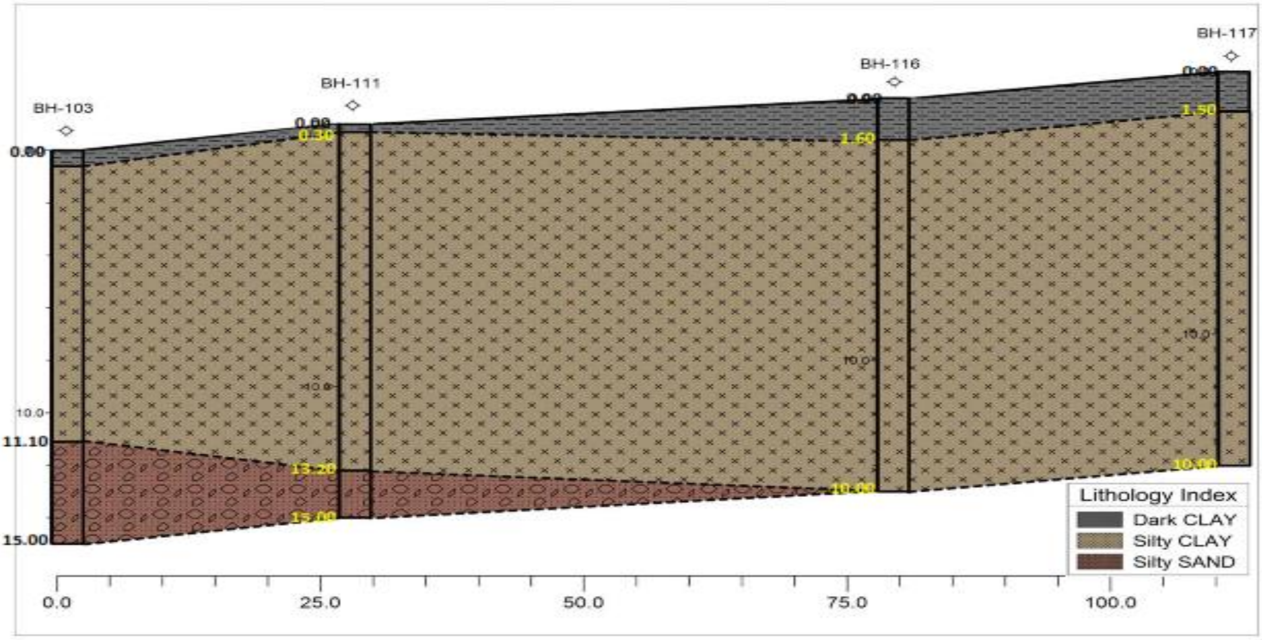

BH-75
BH-76
BH-77
BH-78
BH-79
BH-102
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
0.0
25.0
50.0
75.0
100.0
125.0
150.0
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT


BH-86
BH-85
BH-84
BH-80
BH-82
BH-100
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
0.0
50.0
100.0
150.0
200.0
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND


BH-87
BH-81
BH-83
BH-98
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
250.0
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND


BH-98
BH-99
BH-100
BH-101
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
0.0
25.0
50.0
75.0
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND


BH-103
BH-104
BH-105
BH-106
BH-107
BH-109
BH-110
0.00
1.00
1.10
1.00
1.00
1.55
1.75
10.00
10.00
10.00
10.00
10.80
11.10
12.40
15.00
15.00
15.00
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0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BH-117
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Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
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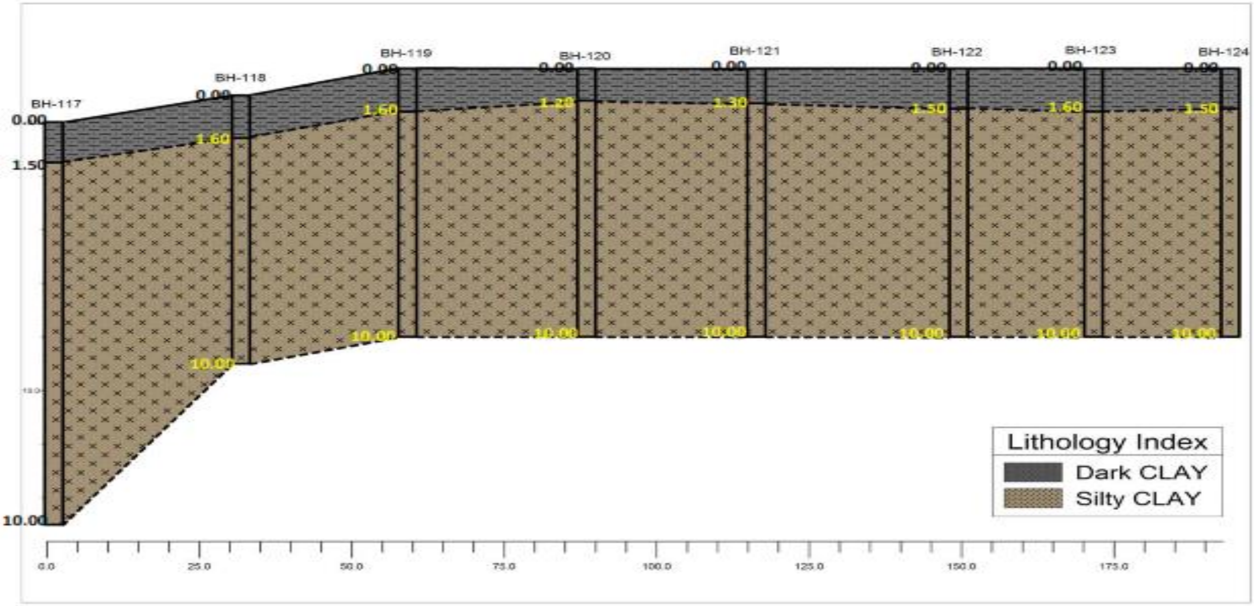
100.0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BH-122
BH-123
BH-124
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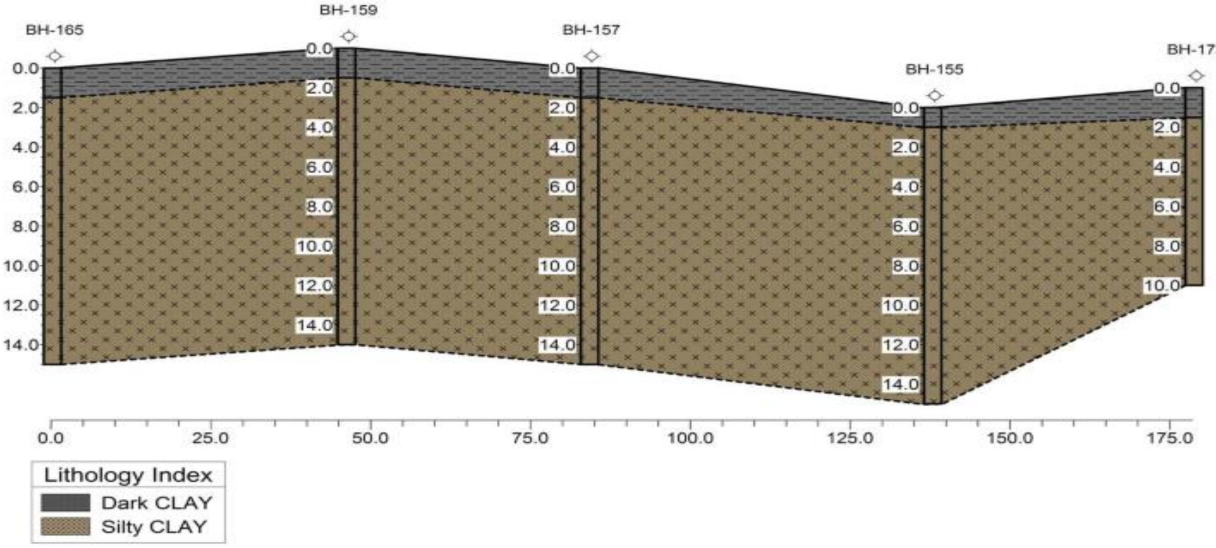
175.0
Lithology Index
Dark CLAY
Silty CLAY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BH-157
BH-155
BH-173
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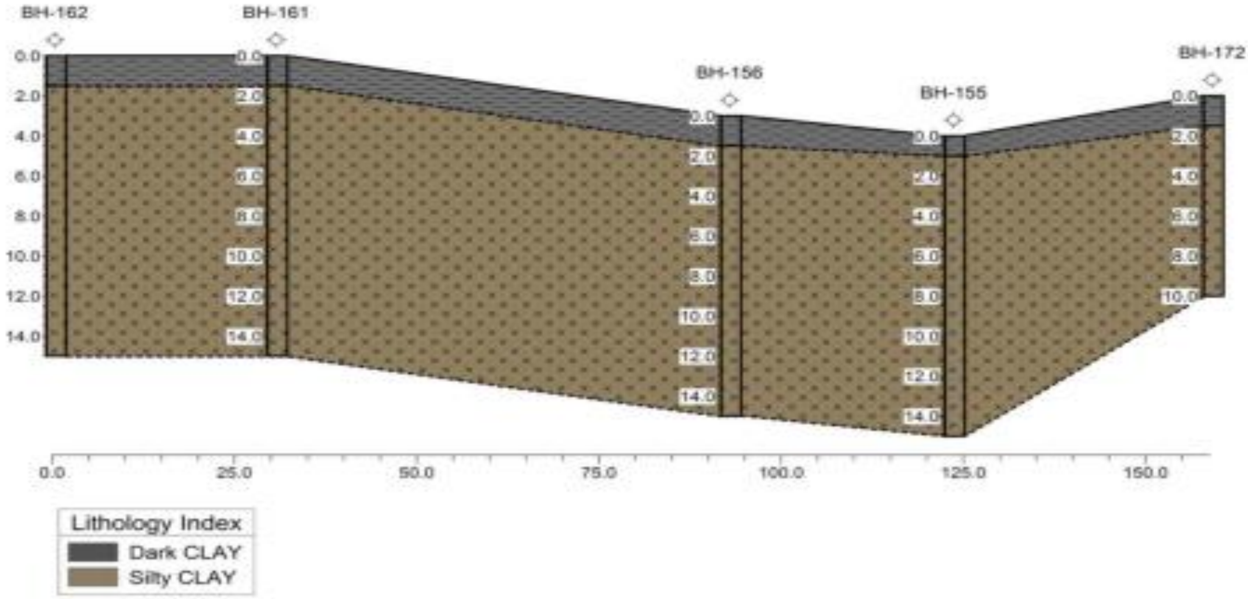
Lithology Index
Dark CLAY
Silty CLAY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BH-156
BH-155
BH-172
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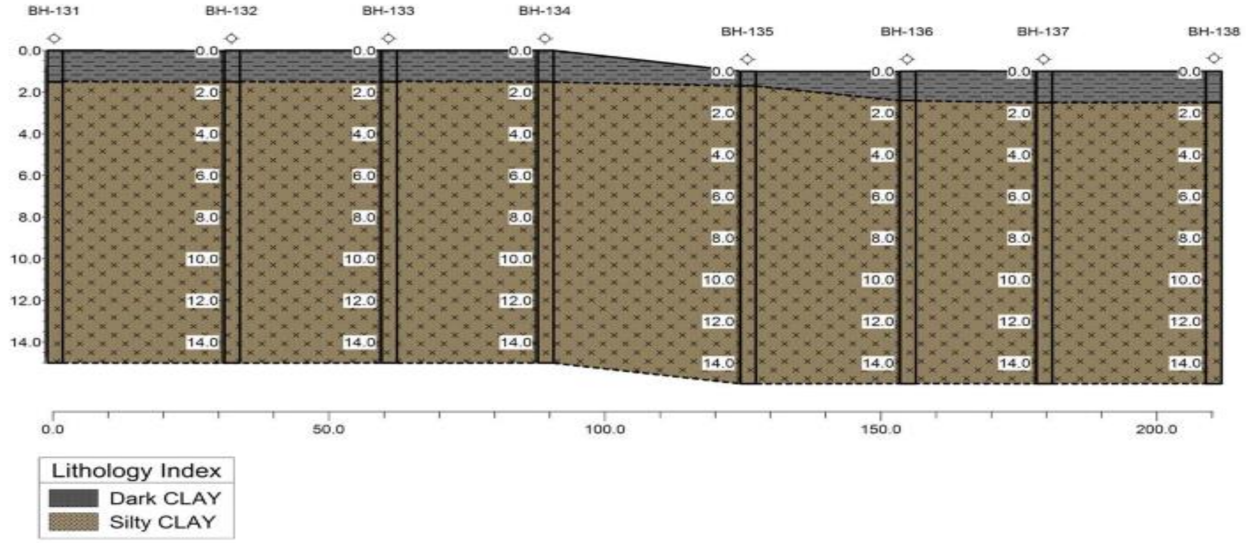
150.0
Lithology Index
Dark CLAY
Silty CLAY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BH-134
BH-135
BH-136
BH-137
BH-138
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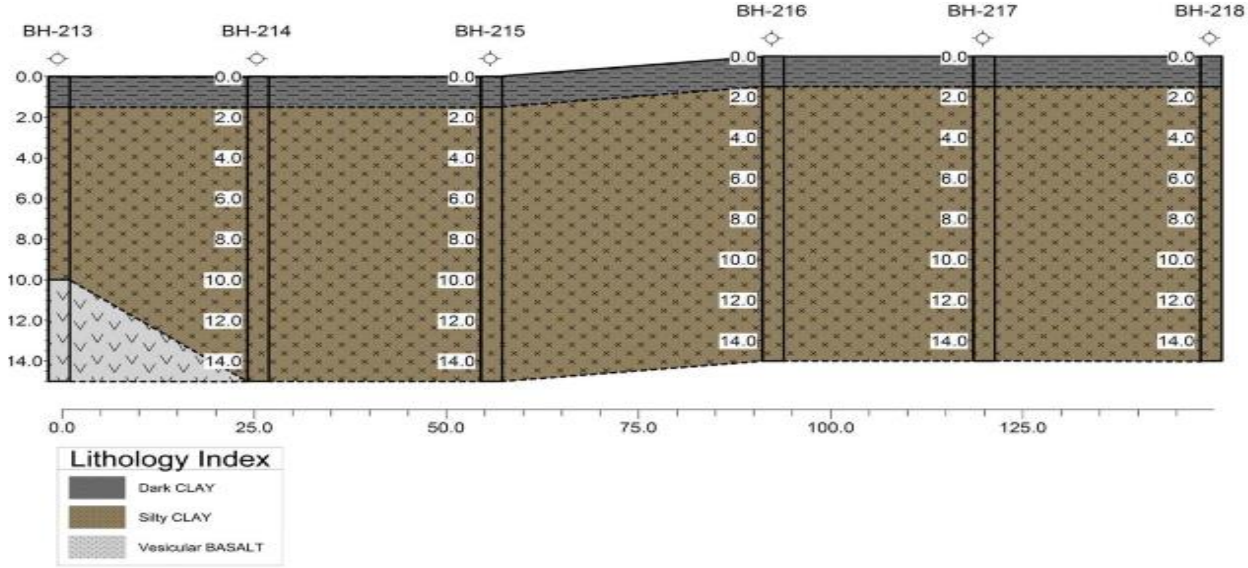
Lithology Index
Dark CLAY
Silty CLAY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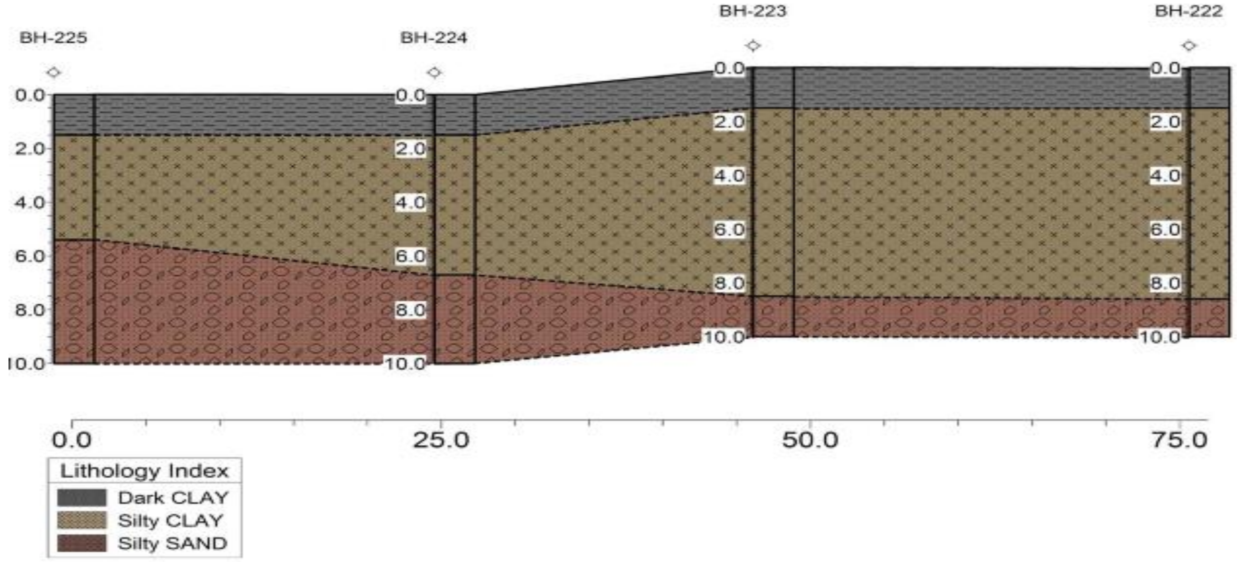
125.0
Lithology Index
Dark CLAY
Silty CLAY
Vesicular BASALT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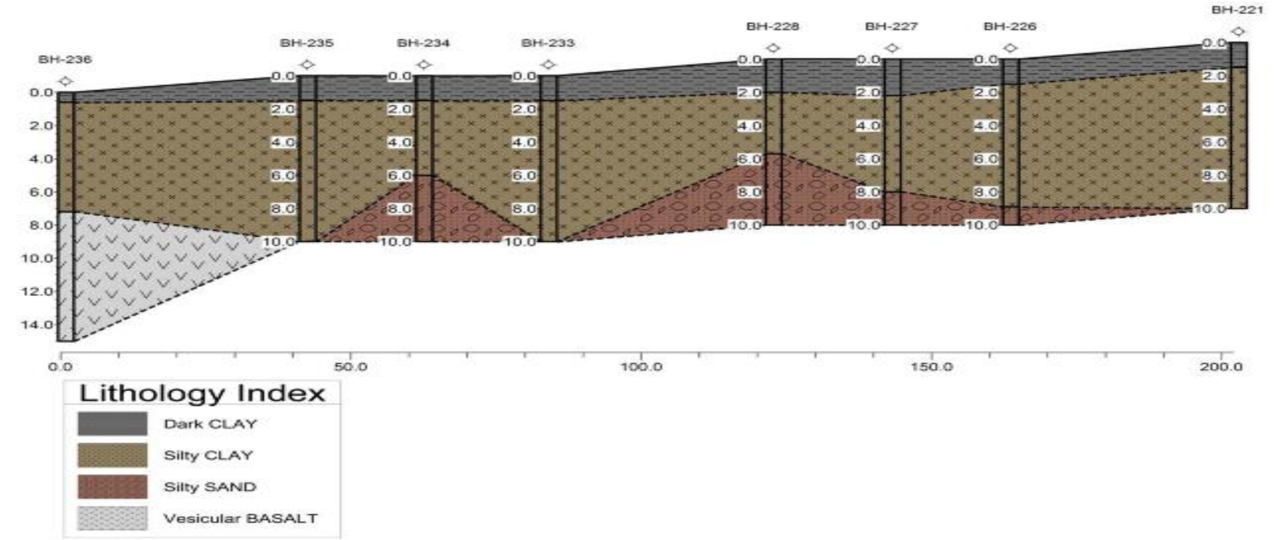
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND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BH-221
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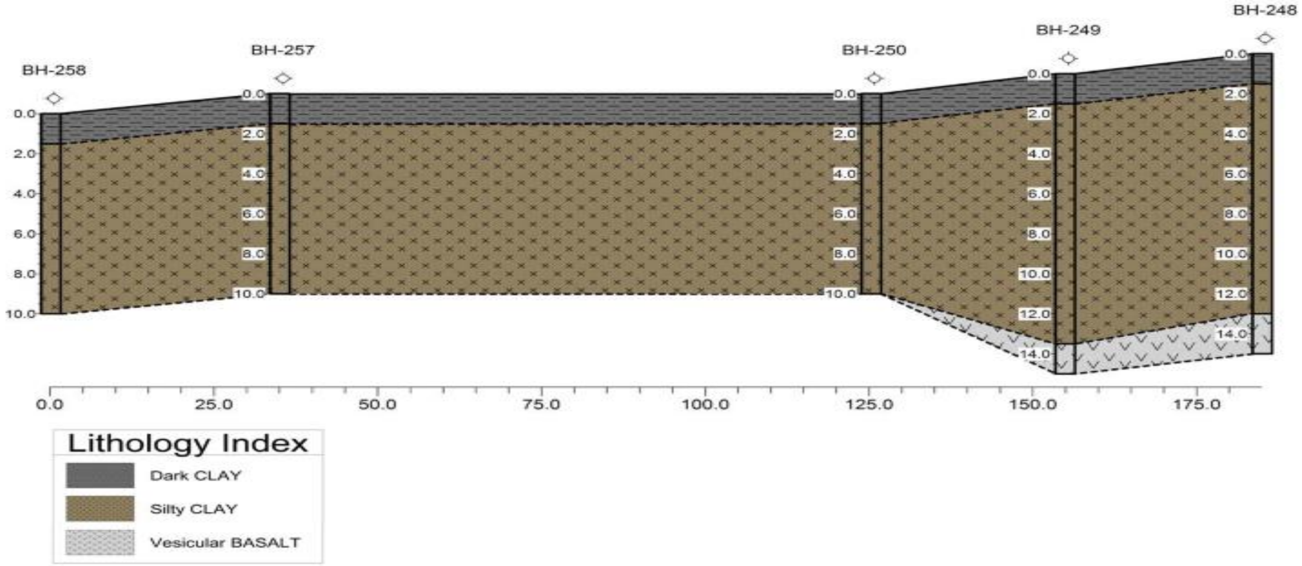
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT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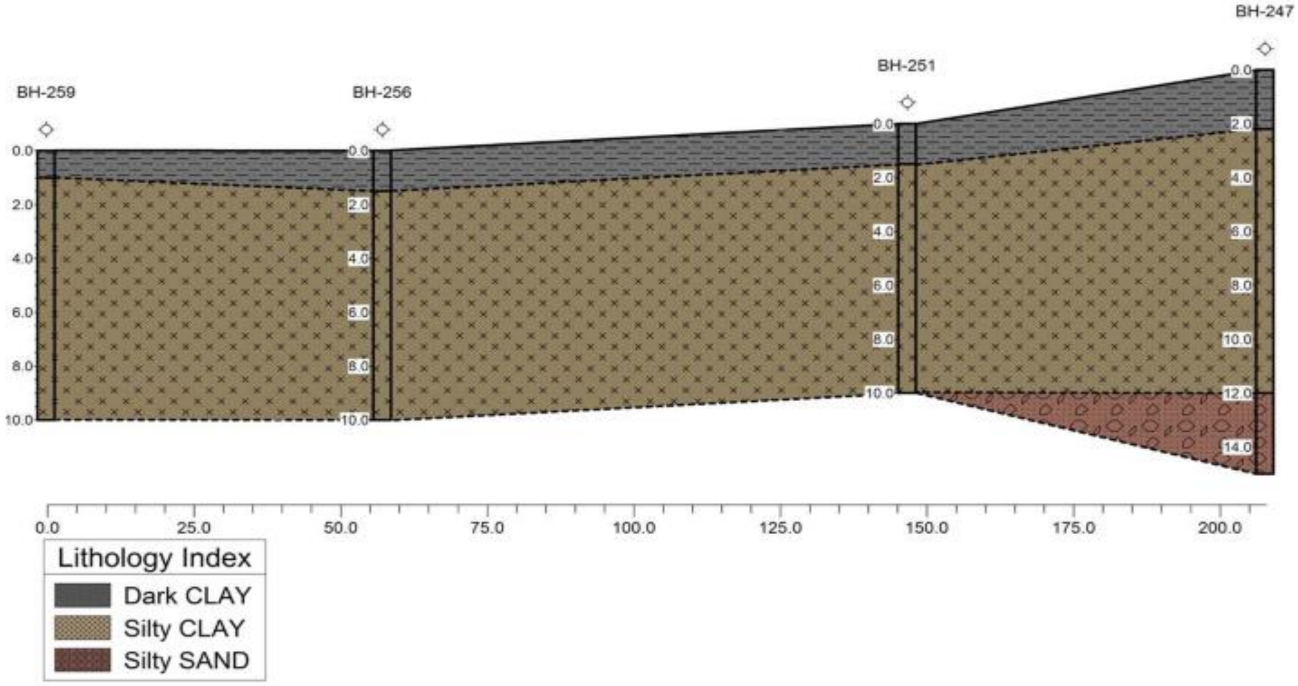
Lithology Index
Dark CLAY
Silty CLAY
Vesicular BASALT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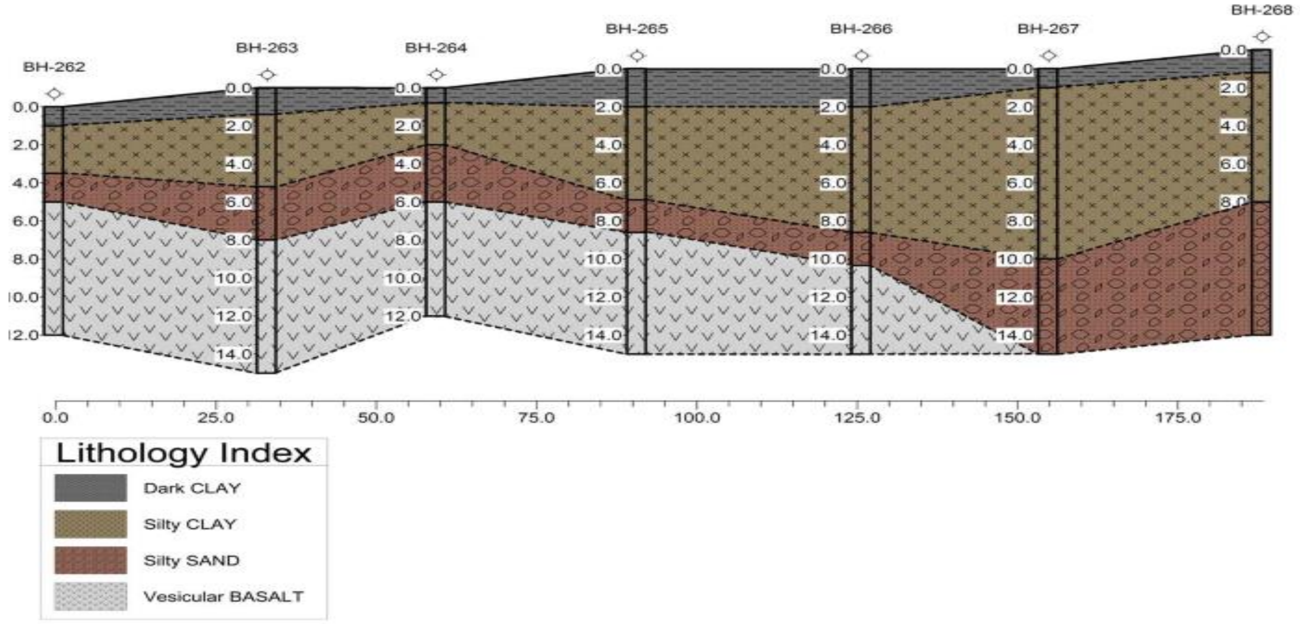
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND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BH-264
BH-265
BH-266
BH-267
BH-268
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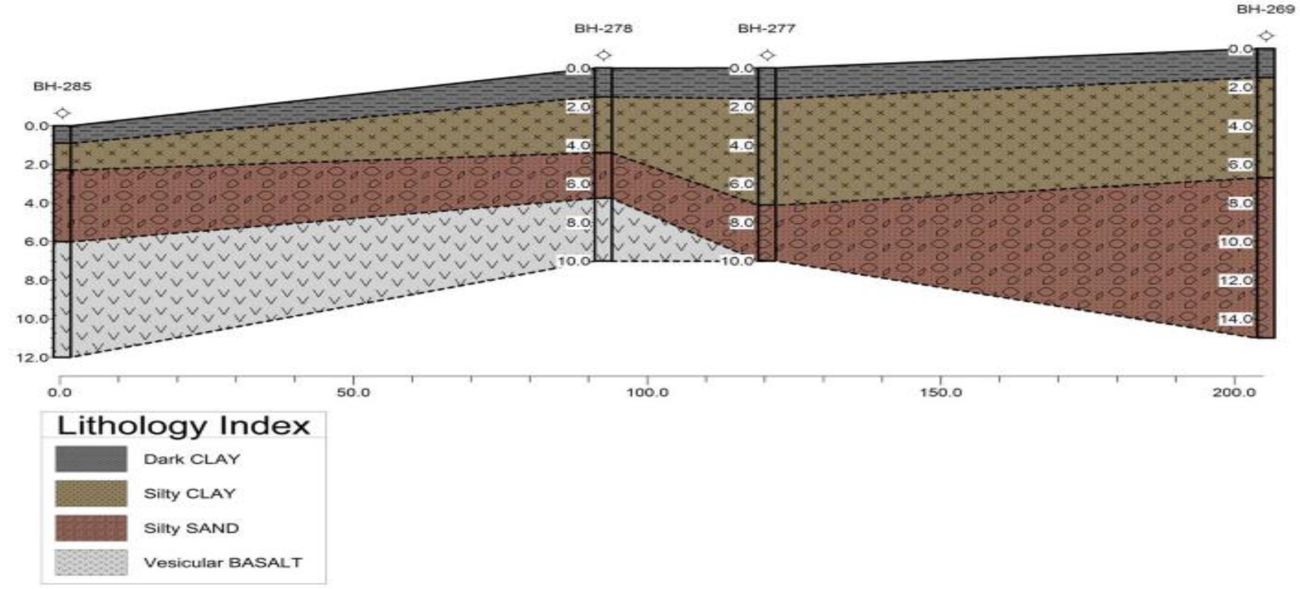
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT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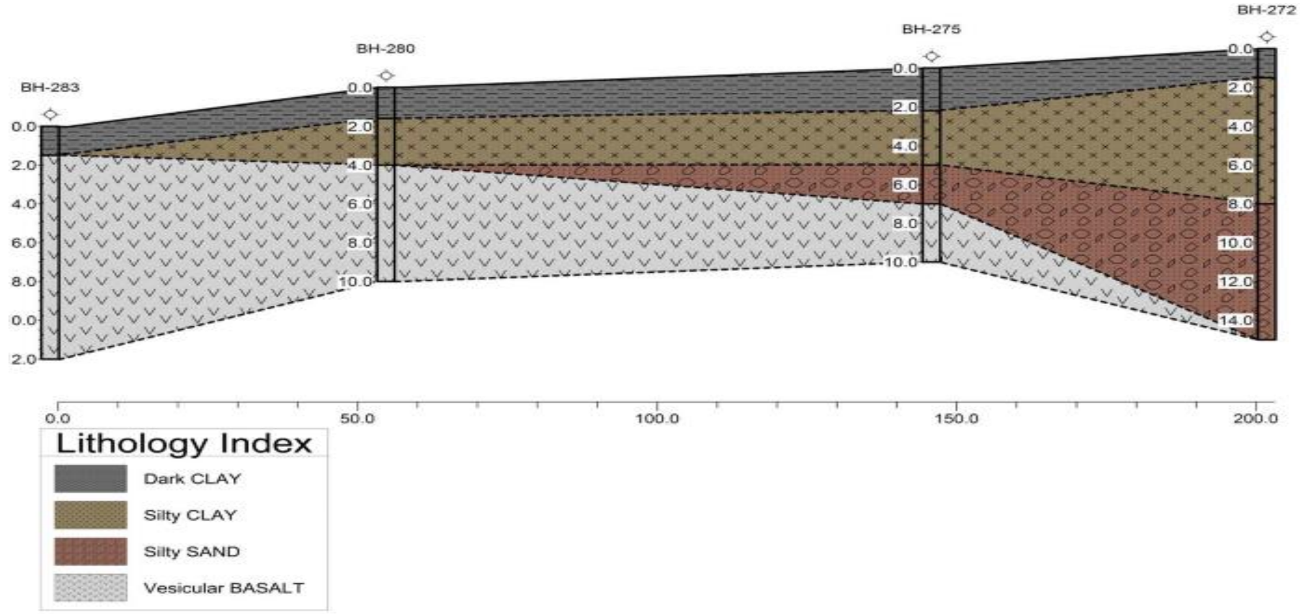
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT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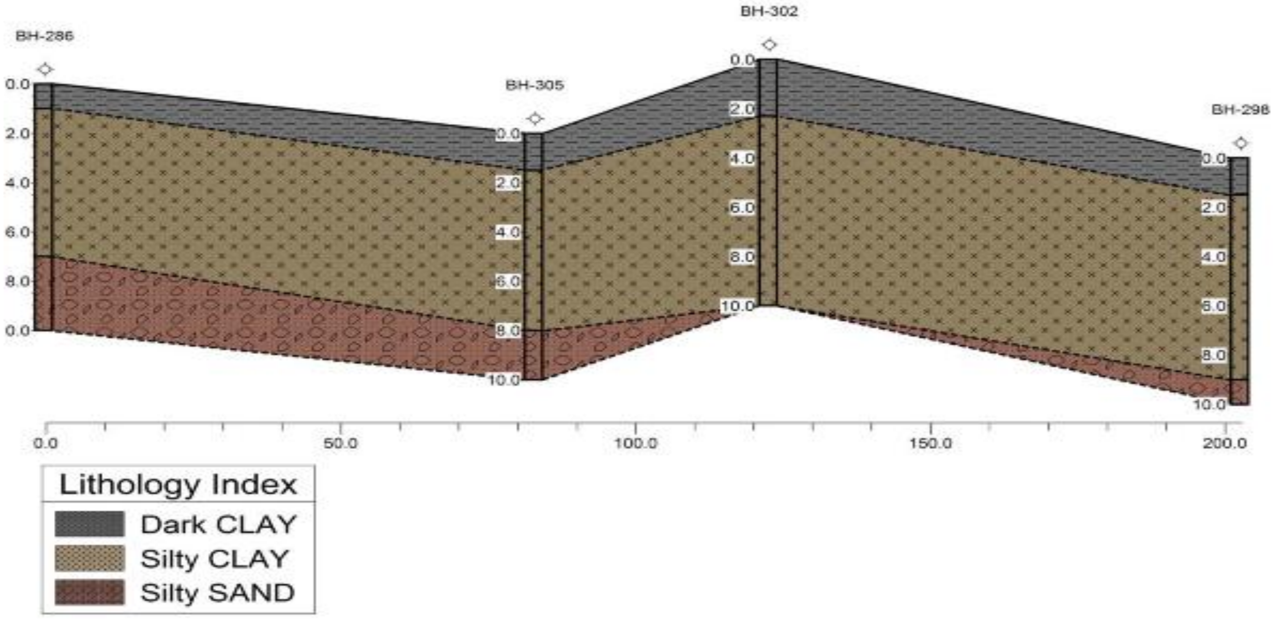
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT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BH-302
BH-298
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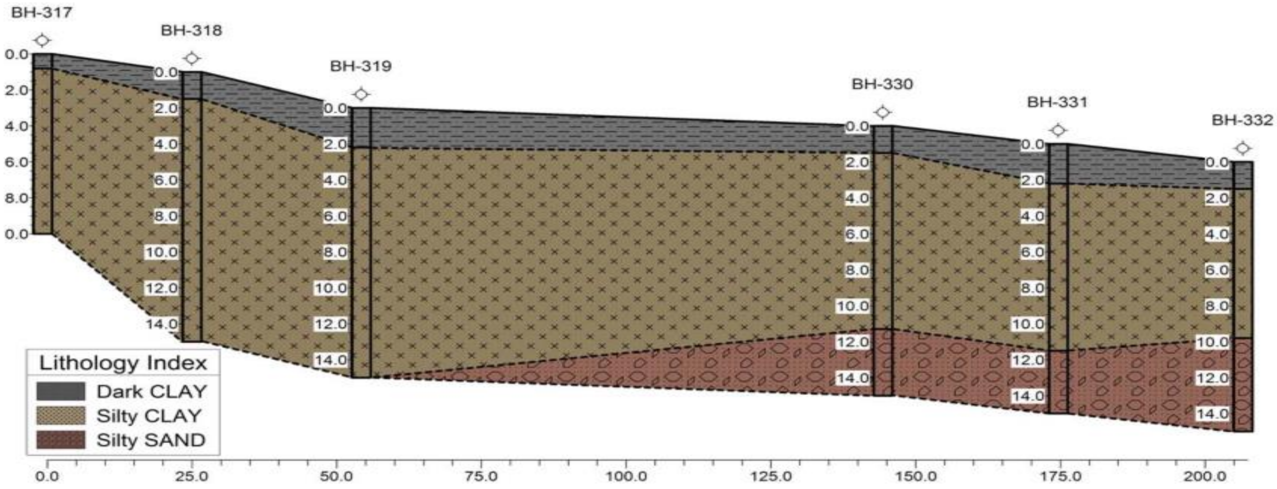
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND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BH-319
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BH-332
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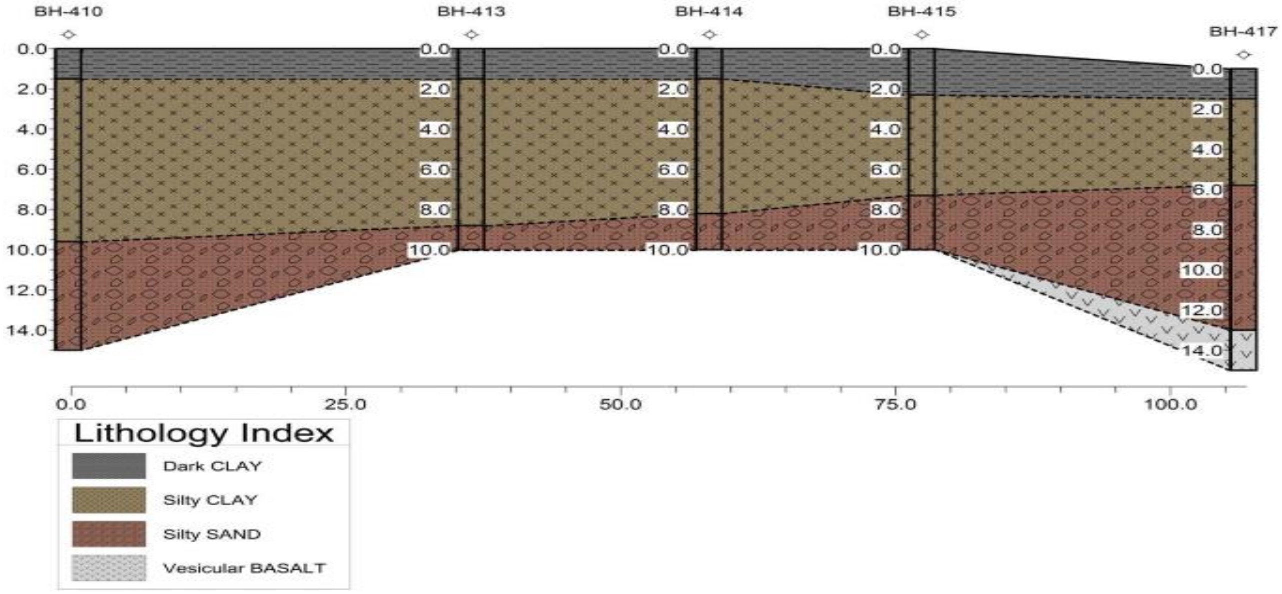
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND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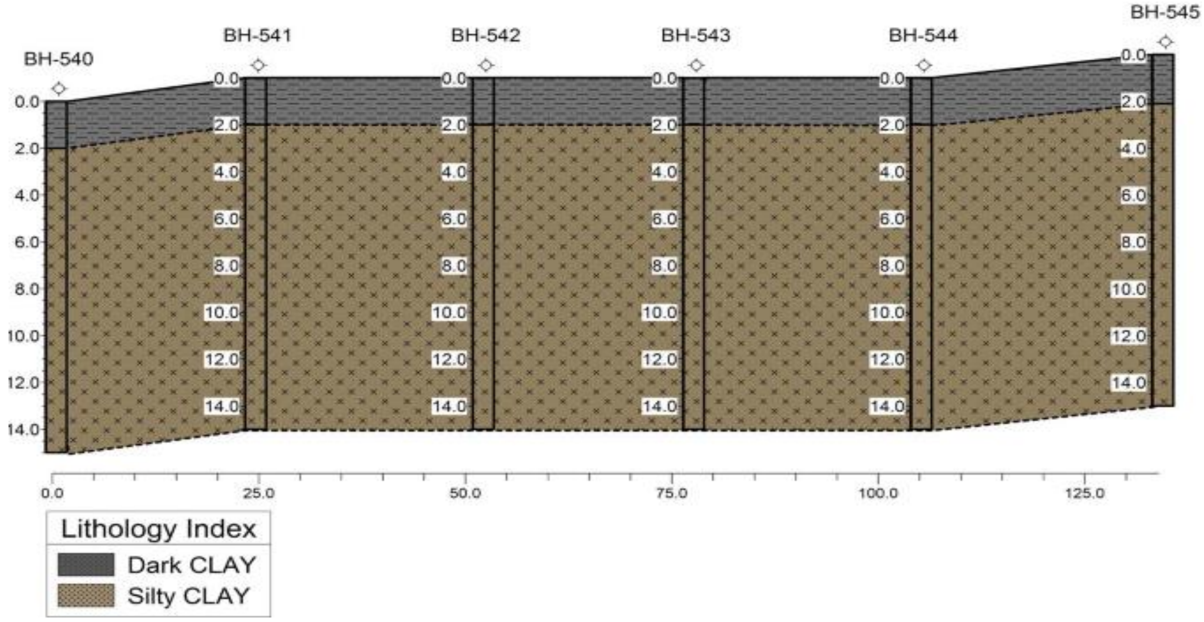
Lithology Index
Dark CLAY
Silty CLAY
Silty SAND
Vesicular BASALT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BH-545
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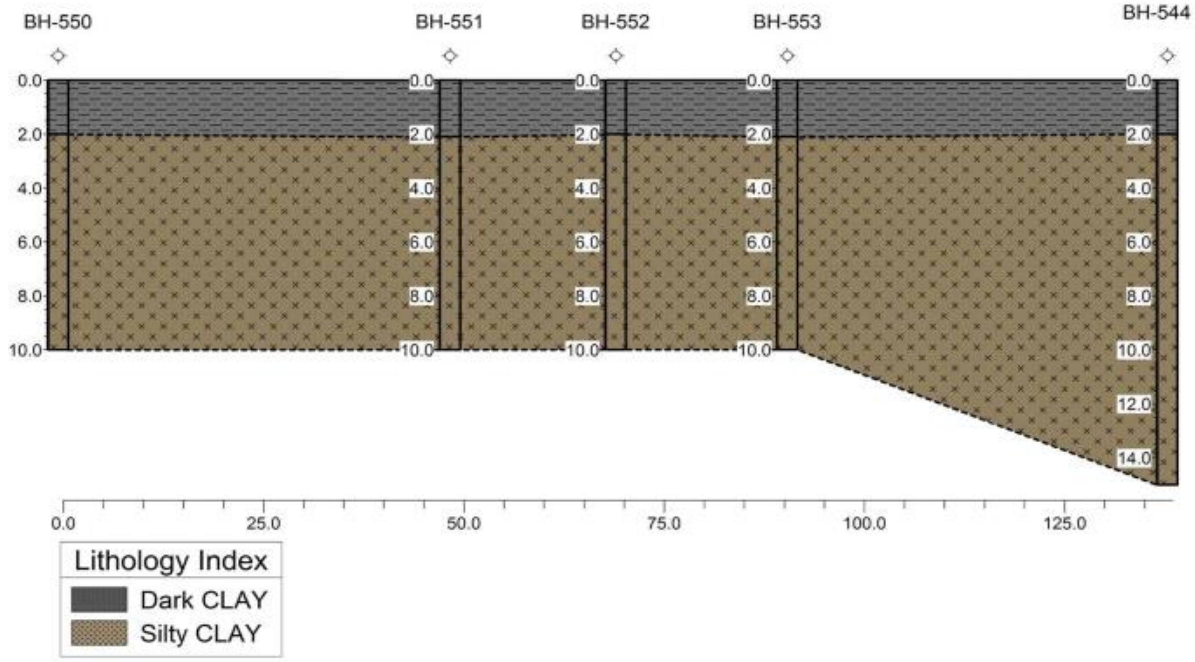
Lithology Index
Dark CLAY
Silty CLAY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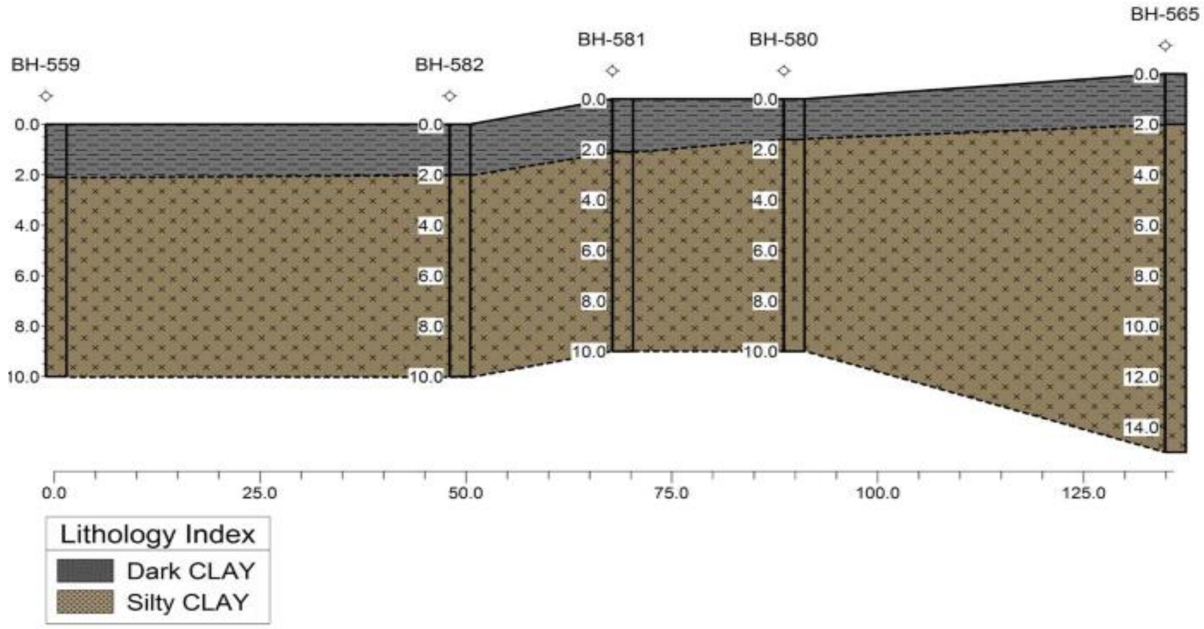
Lithology Index
Dark CLAY
Silty CLAY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75.0
100.0
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Lithology Index
Dark CLAY
Silty CLAY