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CORRELATION OF UNCONFINED COMPRESSIVE STRENGTH WITH INDEX PROPERTIES OF SOILS FOUND IN DIASPORA, BAHIRDAR

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SCHOOL OF RESEARCH AND POSTGRADUATE STUDIES

FACULTY OF CIVIL AND WATER RESOURCE ENGINEERING

CORRELATION OF UNCONFINED COMPRESSIVE STRENGTH WITH INDEX PROPERTIES OF SOILS FOUND IN DIASPORA, BAHIRDAR

By

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CORRELATION OF UNCONFINED COMPRESSIVE STRENGTH WITH INDEX PROPERTIES OF SOILS FOUND IN DIASPORA, BAHIRDAR

BY BIRHAN-MESKEL HADDIS

A thesis submitted to the school of Research and Graduate Studies of Bahir Dar Institute of Technology, School of Civil and Water Resource Engineering in Partial Fulfillment of the requirements for the Degree

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Master of Science in Civil Engineering (Geotechnical Engineering)

Main Advisor: Samuel Tadesse (Dr. -Ing)

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Bahir Dar, Ethiopia

JUNE 12, 2020

DECLARATION

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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To my father and mother

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LIST OF ABBREVATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
CPI	Cone Penetration Index
DCPI	Dynamic Cone Penetration Index
ERA	Ethiopia Road Authority
Gs	Specific Gravity
LI	Liquidity Index
LL/W_{LL}	Liquid Limit
MDD	Maximum Dry Density
MLRA	Multiple Linear Regression Analysis
NMC	Natural Moisture Content
PI	Plasticity Index
PL/W_{PL}	Plastic Limit
PF	Percentage Fines
R	Correlation Coefficient
SPSS	Statistical Package for the Social Science
SLRA	Simple Linear Regression Analysis
TP	Test Point
UCS	Unconfined Compressive Strength
USCS	Unified Soil Classification System

ABSTRACT

Correlations are important to estimate engineering properties of soils particularly for project where there is a financial limitation, lack of test equipment or limited time. Although correlations are commonly used in the preliminary stage of any project, it is reasonable to assign a unique strength to soils for their respective physical properties. In this thesis, attempts have been made to obtain valid correlations between unconfined compressive strength with Atterberg limit and grain size distribution of clayey soils.

An investigation is made on the clayey soils found in Eastern part of Bahir Dar city locally named Diaspora. This paper presents SPSS prediction models which relate Atterberg limits and grain size distributions with unconfined compression strength .Twenty five test pit points were selected and the Representative disturbed and undisturbed soil samples were collected from open pits by direct excavation. Grain size analysis shows the soil is silty clay and according to USCS classification the soil sample falls in CH (Inorganic clay), MH (Inorganic silt) and in AASHTO they are in a region A-7-5 and A-7-6 (clayey). Their UCS result is from 142 to 240 kPa which indicates stiff to very stiff consistency, also they are inactive clays as the activity ratio indicates.

Comparison between the results of the developed models and the experimental data indications were within a confidence interval of 95%. To evaluate the effect of each parameters verification of the model was performed and discussed. According to the performed analysis, Liqudity index and liquid limits were the most important variables in predicting the unconfined compressive strength. It is estimated by $\mathrm{UCS} = -3.83 * \mathrm{LL} - 136LI + 410.19$ with coefficient of determination (R^2) of 95% for clayey soils of diaspora, Bahir Dar soils.

It is recommended to carry out this correlation with a large size of data so that it will represent Bahir Dar city and its also recommended to carry out this prediction model for cites other than Bahir Dar.

Key words: UCS, Index Properties, Shear Strength, Regression Analysis, Clayey Soils.

1. INTRODUCTION

1.1. Background

Soil Mechanics tries to meet the need by a means of evaluating problems in a rational manner such soil engineering problems as: the bearing capacity of a foundation; the stability of natural slopes, embankments and excavations; the magnitude and the time-rate of settlement of a footing; the quantity of seepage through an earth dam or beneath a concrete dam or into an excavation; the force on a retaining wall. Among those engineering problems the shear strength parameters cohesion and angle of internal friction are needed for bearing capacity of a foundation, evaluation of lateral pressure of soil masses against earth retaining structures and the determination of natural slopes ,earthen embankments and cuts (Obasi & Anyaegbunam, 2005).

The unconfined compression test is a special case of a triaxial compression test in which the all-round pressure σ_3=0. The tests are carried out only on saturated samples which can stand without any lateral support. This, is, therefore, applicable to cohesive soils only. Because of the absence of any confining pressure in the unconfined compression strength test, a premature failure through a weak zone may terminate an UCS test .The test is undrained test and is based on the assumption that there is no moisture loss during the test (Murthy, 2002).

Currently many road construction projects and buildings are undergoing in the city. In light of this the output of the proposed correlation will provide road authorities, consultants, and contractor's preliminary background information on the value of UCS for a localized soil materials from soil index properties.

1.1. Statement of the Problem

Correlating engineering properties with index properties has assumed greater significance in the recent past in the field of geotechnical engineering. Since they are important to estimate engineering properties of soils particularly for projects where there is a financial limitation, lack of test equipment or limited time. Although correlations are commonly used in the preliminary stage of any project, it is reasonable to assign a unique strength to soils to their respective physical properties. In this thesis, attempts have been made to obtain valid correlations between unconfined compressive strength with Atterberg limit and grain size distribution of clayey soils found in Diaspora, Bahir Dar.

1.2. Objective

1.2.1. General objective

To develop a mathematical model between UCS values with the index properties such as atterberg limit and grain size distribution of soils of the study area.

1.2.2. Specific Objective

- To classify the soils in the study area.
- To validate the developed mathematical equations using the controlled laboratory results.

1.3. Significance of the Study

The town of Bahir Dar, having adequate land area for expansion and being an important industrial, commercial, educational and tourist center in the region will have a high potential for future development. A lot of civil engineering structures are under construction. The findings of this research will help contractors, consultants and clients to have a preliminary data on the property of soils in the study area so that it will possibly attract more investment.

1.4. Scope of the Study

The subject study is desired to conduct a localized research particularly on samples from Bahir Dar city locally named “DIASPORA”. In order to model the proposed correlation twenty five laboratory test samples are conducted in the research work. All the tests were excavated up to a depth of 1.5m and were done according to American Society for Testing Materials (ASTM) standard. The required correlation is carried out by applying a single linear regression model and multiple linear regression models with the aid of SPSS

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

1.5. Limitation of the study

The size of the statistical data is the main factor that limits the applicability of the results obtained and the other limitation would be the location of the sample collection, since the properties of a soil change not only from one place to the other but also at the place with depth and weather conditions. As a result the study is limited to the area, depth and season of the study. All laboratory samples were done using disturbed samples except UCS and natural moisture content which were undisturbed.

1.6. Thesis Outline

Chapter 1: Gives a general introduction, problem statement, objectives of the study, significance of the research, and scope of the study and outline of the thesis.

Chapter 2: This comprises a brief description about red soils and discusses previous works relevant to the present research.

Chapter 3: Discusses mainly on the methodology of the research, the location where samples were taken, what type of test methods, standards and data analysis software used.

Chapter 4: Discusses about obtained test results makes comparisons and interprets the obtained results.

Chapter 5: Shows Regression analysis using single and multiple regression analysis.

Chapter 6: Focuses on the conclusions and recommendations.

2. LITERATURE REVIEW

2.1. Soil Formation Processes

Soil mechanics grew up in northern Europe and North America, and most of its concepts regarding soil behavior developed from the study of sedimentary soils. This might be all very well if all soils were sedimentary soils(Wesley, 2009).

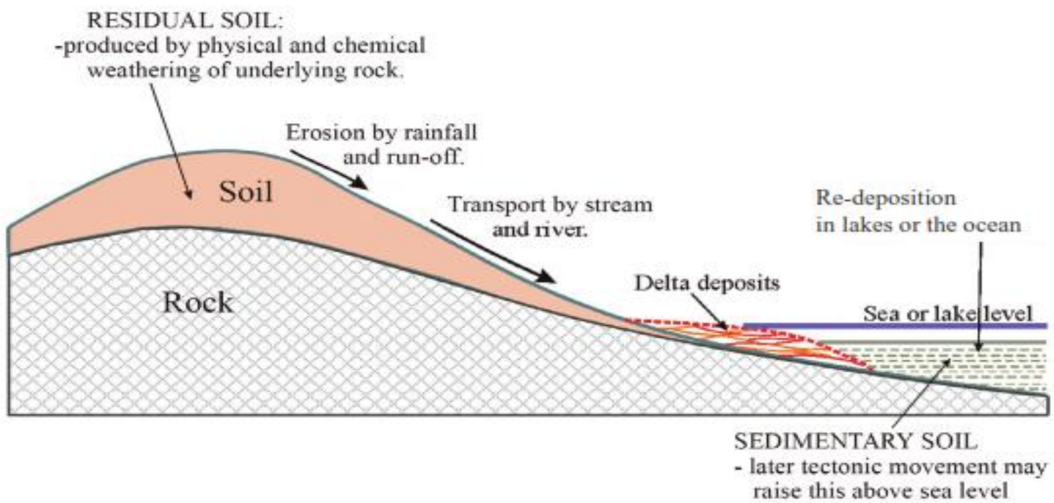


Figure 2- 1: Diagrammatic representation of soil formation processes (Wesley, 2009)

Residual soils are formed directly from the physical and chemical weathering of the parent material, normally rock of some sort. Sedimentary soils are formed by a depositional process, normally in a marine or lake environment. Figure 2.1 shows diagrammatically the physical processes that to the formation of sedimentary and residual soils. Figure 2.2 is an attempt to summarize the factors involved in the formation processes that influence the properties of the two soil types. Sedimentary soils are seen to undergo a various additional processes beyond the initial physical and chemical weathering of the parent rock. It might appear from this (Figure 2.2) diagram that the factors involved in the formation of sedimentary soils are more complex than those involved in forming (Wesley, 2009).

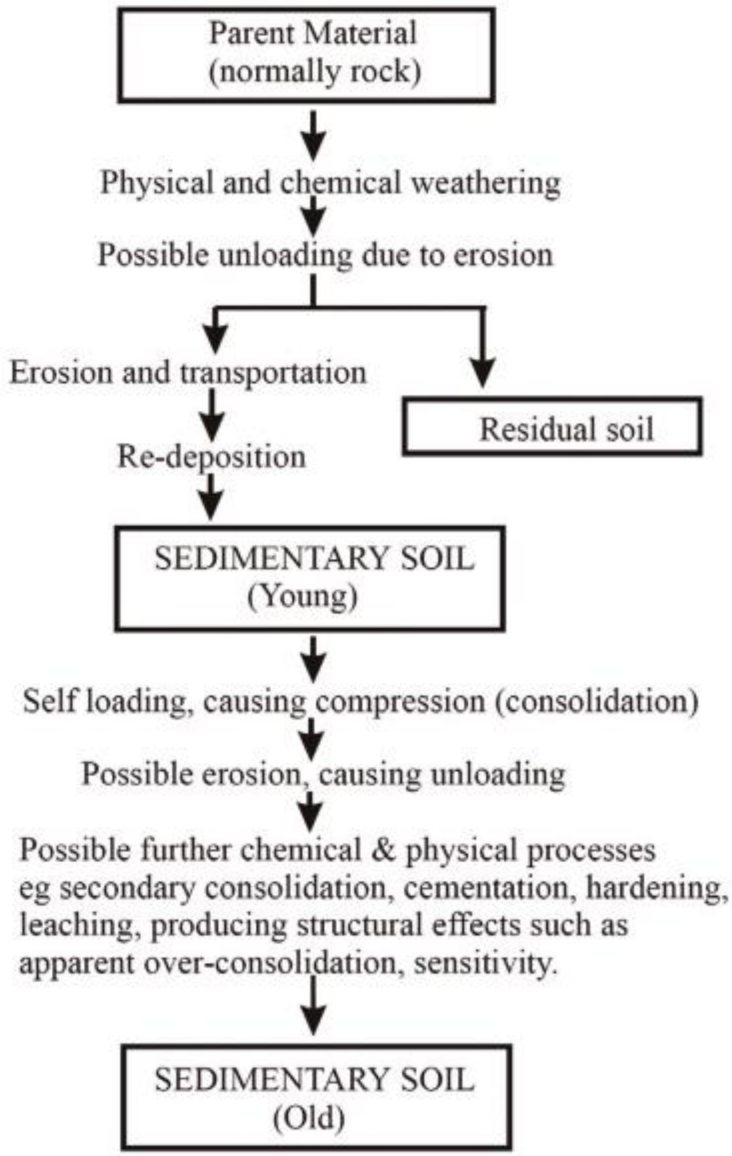


Figure 2- 2: Soil Formation Factors Influencing Soil Behavior (Wesley, 2009)

2.2 Grouping and Classification of Residual Soil

Mineralogical composition and structure, provides a basis for dividing residual soils into groups that can be expected to have fairly similar engineering properties. Soils without a strong mineralogical influence those containing low activity clays): many residual soils fall into this category. These soils are likely to be fairly coarse grained with a small clay fraction. The weathered granite soils of Hong Kong and Malaysia fall into this groups. Soils with a strong mineralogical influence, from ‘’conventional’’ clay minerals (i.e those containing high activity clays): the ‘’black cotton’’ soils or ‘’vertisols’’, also called Houston Black Clay in Texas, Tropical Black Earth of Australia, ‘’Tirs’’ of Morocco. Soils with a strong mineralogical influence, coming from special clay minerals not found in sedimentary clays: the two most important clay minerals found only in certain residual soils are Hallosite and allophone. Soils with strong mineralogical composition contain tropical red clays, volcanic ash soils and Laterites (Wesley, 2009).

***Table 2. 1:A Classification or ‘’grouping ‘’ system for residual soils* (Wesley, 2009)**

GROUPING SYSTEM		COMMON PEDOLOGICAL NAMES USED FOR GROUPS	DESCRIPTIVE INFORMATION INSITU STATE	
MAJOR DIVISION	SUBGROUP		PARENT ROCK	INFORMATION ON STRUCURE
GROUP A Soils with a strong mineralogical influence	(a)Strong macro-structure influence	Miscellaneous	Give details of type of rock from which the soil has been derived	Describe nature of structure -Stratification -Fraction, fissures, faults etc. -Presence of partially weathered rock
	(b) Strong micro structure influence	Miscellaneous		Describe nature of micro-structure and/or evidence of it: - Influence of remolding - Sensitivity - Liquidity Index
	(C) Little or no structural influence	Miscellaneous		Indicate evidence for little or no structural effect
GROUP B Soils strongly influenced by normal clay minerals	(a) Simectite (motimorilolite group)	Black cotton soils Black soils Tropical black earths Vertisols		
	(d) Other clay minerals?	?		?
GROUP C Soils strongly influenced by clay minerals essentially found only in residual soils	(a)Allophane subgroup	Volcanic ash soils Andosols or Andisol Andepits		Give basis for inclusion in this group. Describe any structural influence either macro structure or micro structure.
	(b)Hallosite subgroup	Tropical Red clays Latosols Oxisols Feralsols		As above
	(c)Sesquoxide subgroup -Gibbsite , Geotite,Hematite	Lateritic soils Laterites Feralitic soils Duricrusts		Give basis for inclusion in this group. Describe any structural effects especially cementation Effects or the sesqui-oxides

2.3 Shear strength of soils

Soil strength differs from that of other engineering materials (steel, concrete, wood,) in two important aspects one only the shear strength is of interest. The principal design situations addressed by engineers are the bearing (or load-carrying) capacity of foundations, earth pressures on retaining walls, and stability of slopes. All of these are directly dependent on the shear strength of the soil. The failure modes that govern these situations are in idealized dorm in Figure 2.4. In each case the soil tends to fail by shear movement on specific failure surfaces within the soil mass. Compressive or tensile strength is not relevant to the soil behavior in these situations. And the other is shear strength is not constant for a particular soil. Deep in the ground, soil is stronger than it is near the surface. In an embankment the lower layers are stronger than those at the top. This is because the strength is dependent on the confining pressure coming from the layers above and must be expressed in a manner that takes this into account. The soil strength may also undergo changes with time, possibly as a result of natural effects such as rainfall, or the influence of human activity on the slope (Wesley, 2010).

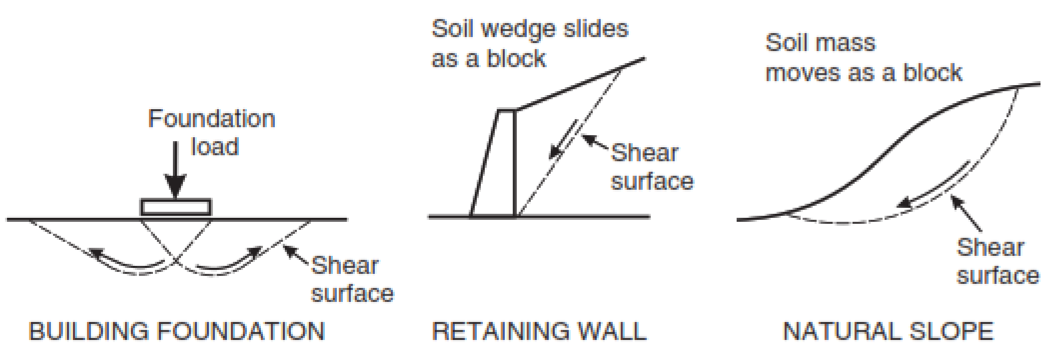


Figure 2- 3:Modes of Failure for Foundations, Retaining walls, and Soil Slopes (Wesley, 2010)

The general expression for soil shear strength, is

$$S = c' + (\sigma - u)\tan\phi' \quad 2.8$$

$$S = c' + \sigma' \tan\phi' \quad 2.9$$

Where s=shear strength or shearing resistance.

σ =total normal on shear plane

u =pore pressure on shear plane

σ' =effective normal stress on shear plane

c' =cohesion intercept in terms of effective stress

ϕ' =angle of shearing resistance (friction angle).

Principal stresses σ_1 and σ_3 or normal and shear stresses on shear plane, pore water pressure so that effective stresses can be calculated and strain should be calculated during the test of shear strength.(Wesley, 2010)

2.3.1 Direct Shear Test (Shear Box Test)

This is the earliest form of shear test and was first used by colulomb in 1776. It is illustrated conceptually in figure 2.5. The apparatus consists of a split box into which the sample is placed Porous plates are placed above or below the sample to allow water to drain into or out of the sample during the test. A hanger and weight system is then used to apply a normal (vertical) stress to the sample. A mechanical jack then applies a horizontal force to the lower half of the the box while the upper half remains stationary. The horizontal force is applied at a constant deformation rate and measurements made of both displacement and force as deformation progresses. A series of tests is done at varying normal stresses. Each test result is plotted in graphical form first as stress versus displacement and second as peak shear stress (failure value) versus normal stress. A line through these points defines the c' and ϕ' values of the material. (Wesley, 2010)

2.3.2 Triaxial Test

Triaxial tests are undoubtedly the most popular and common used today for measuring shear strength. They are preferred for theoretical reasons and because of their versatility. All types of strength tests can be carried out in the triaxial call as well as other types of tests for measuring permeability or consolidation characteristics.

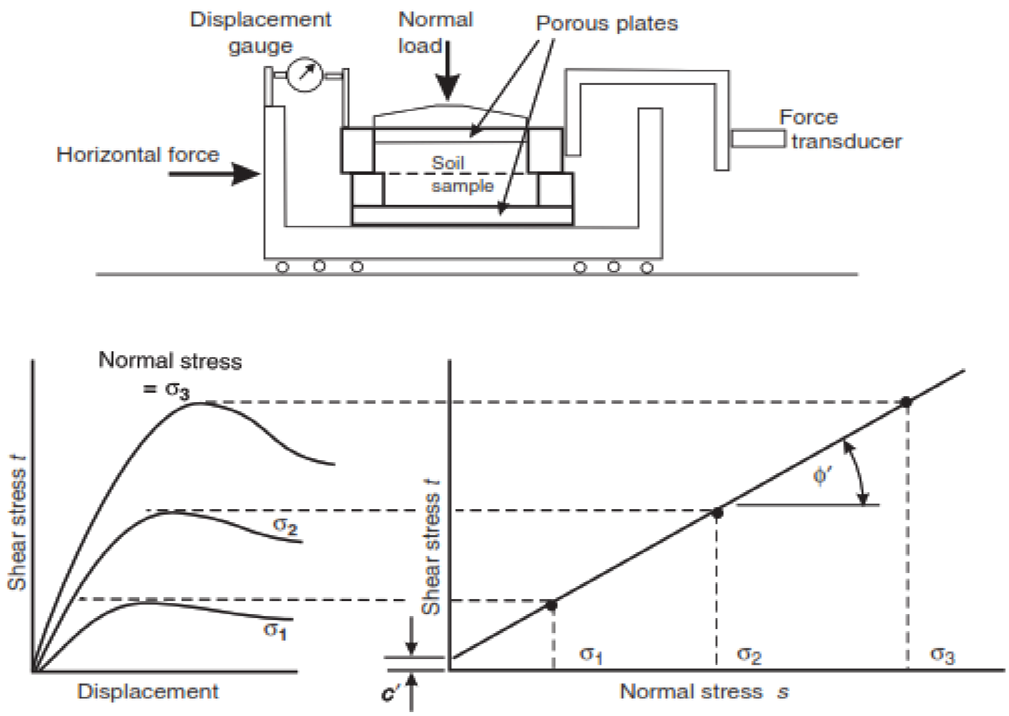


Figure 2- 4: Direct Shear (Shear Box) Test (Wesley, 2010)

Conditions during the consolidation stage and the loading stage of each test type are as follows: Undrained tests no drainage is permitted during either stage. Pore pressure is not normally measured. Consolidated Undrained Tests Drainage is permitted during the consolidation stage until the sample is fully consolidated, that is, until all pore pressure has dissipated to zero. During the loading stage no drainage is permitted, and pore pressure is normally measured. Drained Tests Full drainage is allowed during both stages. Pore pressure is therefore zero. Volume change is normally measured during loading stage. During the tests vertical deflection, vertical load and pore pressure. Volume change during the consolidation stage of both consolidated undrained tests and drained tests and during the loading stage of undrained tests (Wesley, 2010).

2.3.3 Unconfined Compression test

The unconfined compression test is a special case of the unconsolidated undrained triaxial test. In this case no confining pressure to the specimen is applied (i.e., $\sigma3=0$), for fully saturated clays, the pore water pressure in the specimen is positive and for partially saturated clays, the pore water pressure is negative (capillary pressure). Axial stress on the specimen is gradually increased until the specimen fails, so.

$$\sigma_1 = \Delta\sigma_f = q_u \qquad 2.10$$

Where, q_u is the unconfined compression strength.

Theoretically, the value of σ_f of saturated clay should be the same as that obtained from unconsolidated undrained tests using similar specimens (Das, 2008).

Table 2. 2: Relation between Unconfined Compression Strength and Consistency of Soils (Das, 2008)

Consistency	q_u (kN/m^2)
Very soft	0-24
Soft	24-48
Medium	48-96
Stiff	96-192
Very stiff	192-383
Hard	>383

Thus,

$S=C=q_u/2$

However, this seldom provides high-quality results (Das, 2008) .

If the soil is Undrained and fully saturated, no volume change can occur, which in turn means that no change in effective stress occurs. In terms of total stress, the soil behaves as though its friction angle is zero. It is important to recognize that this $\phi = 0$ case arises from two essential and important factors: 1) the soil is fully saturated. 2) The conditions are undrained. The $\phi = 0$ case is not dependent on the soil type. It is not necessary to use a triaxial cell to measure the undrained shear strength and a simple compression test on an unconfined cylindrical sample can be used (Wesley, 2010). A characteristic of true clays is the property of cohesion, sometimes referred to as no load shearing strength. Unconfined specimens of clay derive their strength and firmness from cohesion. Cohesion soils are dependent for their strength upon normal loading (Tefera 1999).

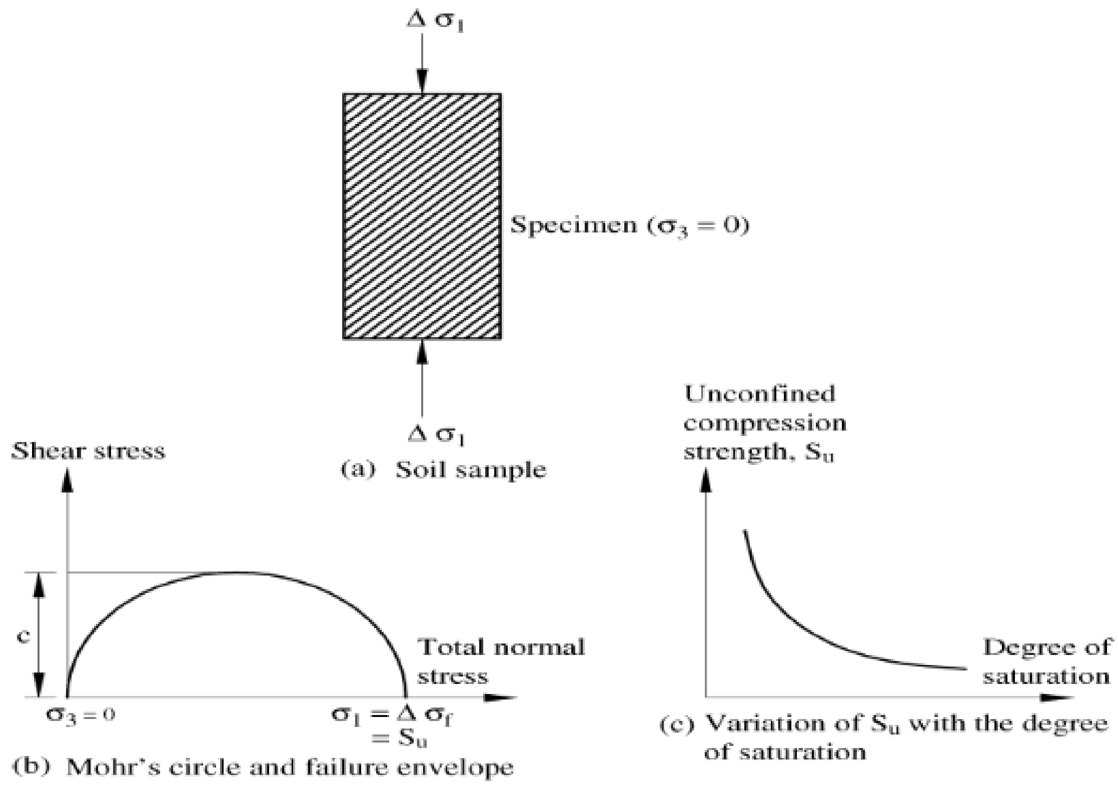


Figure 2- 5: Unconfined Compression Test (Rao, 2010)

The shearing strength of saturated cohesive clay soil in unsaturated shear test (i.e. test in which change in volume is prevented) is derived entirely from cohesion. In such a case, the shearing strength is independent of the magnitude of normal stress. However, in slow shear test, in which consolidation takes place, the shearing strength of clay increases with normal stress. It is well known that the shearing strength of cohesive clay varies with its consistency. A clay at higher liquid limit have little shearing strength, whereas the same clay at lower moisture content may have considerable shearing strength (Tefera 1999).

2.4 Application of shear strength parameters

2.4.1 Bearing capacity

Bearing Capacity is governed by a number of factors those are nature of soil and its physical and engineering properties, nature of the foundation and other details such as the size, shape, depth at which the foundation is located and rigidity of the structure, total and differential settlement that the structure can with stand without functional failure, location of ground water table relative to the level of foundation, and Initial stresses (Huat, Ali, Omar, & Singh, 2006).

Historically, a number of investigations have undertaken studies relating to foundation bearing capacity. The original theoretical concepts for analyzing conditions considered applicable to foundation performance using the theory of plasticity are credited to Prandtl (1920) and Reissner (1924). Prandtl studied the effect of a long, narrow metal tool bearing against the surface of a smooth metal mass that possessed cohesion and internal friction but no weight. The results of prandtl's work were extended by Reissner to include the condition where the bearing area is located below the surface of the resisting material and a surcharge weight acts on a plane that is level with the bearing area. Terzaghi (1943) applied the developments of Prandtl and Reissner to soil foundation problems, extending the theory to consider rough foundation surfaces bearing on materials that possess weight. Terzaghi developed general bearing capacity equations for a strip footing that combined the effects in order to simplify the calculations necessary for foundation design. His Through the ensuing years, the ultimate bearing capacity for shallow and deep foundations has continued to be studied in the quest for a refined definition of foundation-soil behavior and a generalized bearing capacity equation which agrees well with failure conditions occurring in model and large scale foundations (Meyerhof (1951), Hanson (1970), Vesic (1975) and De Beer (1970)(Huat et al., 2006).

2.4.1.1 Meyerhof's bearing capacity theory

Meyerhof's (1951) considered the effects of shearing resistance within the soil above foundation level, the shape and roughness of foundation, and derived a general bearing capacity equation. His expression for the shape, depth and inclination factors, and the bearing capacity factors are shown in Table (2.3) and. According to Meyerhof,

For vertical load: $q_{ult} = cN_C \; S_c \, d_c \; + \frac{1}{2} B_\Upsilon N_\Upsilon S_\Upsilon d_\Upsilon + qN_q S_q$ 2.1

For inclined load: $q_{ult} = cN_C \; S_c \, d_c \, i_c + \frac{1}{2} B_\Upsilon N_\Upsilon S_\Upsilon d_\Upsilon i_\Upsilon + qN_q S_q \, d_q i_q$ 2.2

Where, C= cohesion

N_c, N_Y, N_q =bearing capacity factors, q = Vertical footing pressure

B= original width of footing

S_c, S_Y, S_q = Shape factor

d_c, d_Y, d_q =depth factor

i_c i_q, i_Y =inclination factor

Table 2. 3:Meyerhof's Bearing Capacity Factors *(Huat et al., 2006)*

For ϕ	Shape	Depth	Inclination
Any	$s_c= 1+0.2k_p\frac{B}{L}$	$d_c= 1+0.2\sqrt{k_p}\frac{D}{B}$	$i_c=i_q= (1-\frac{\alpha}{90^\circ})^2$
For ϕ=0	$s_q= s_Y=1.0$	$d_q=d_Y=1.0$	$i_Y=1$
For ϕ ≥ 10°	$s_q= s_Y=0$	$d_q =d_Y=1+0.1\sqrt{k_p}\frac{D}{B}$	$i_Y=(1-\frac{\alpha}{90^\circ})^2$

Where $$N_q = exp^{\Pi\tan\phi}tan^2\left(\frac{\Pi}{4}\right)+\frac{\phi}{2} \quad 2.3$$

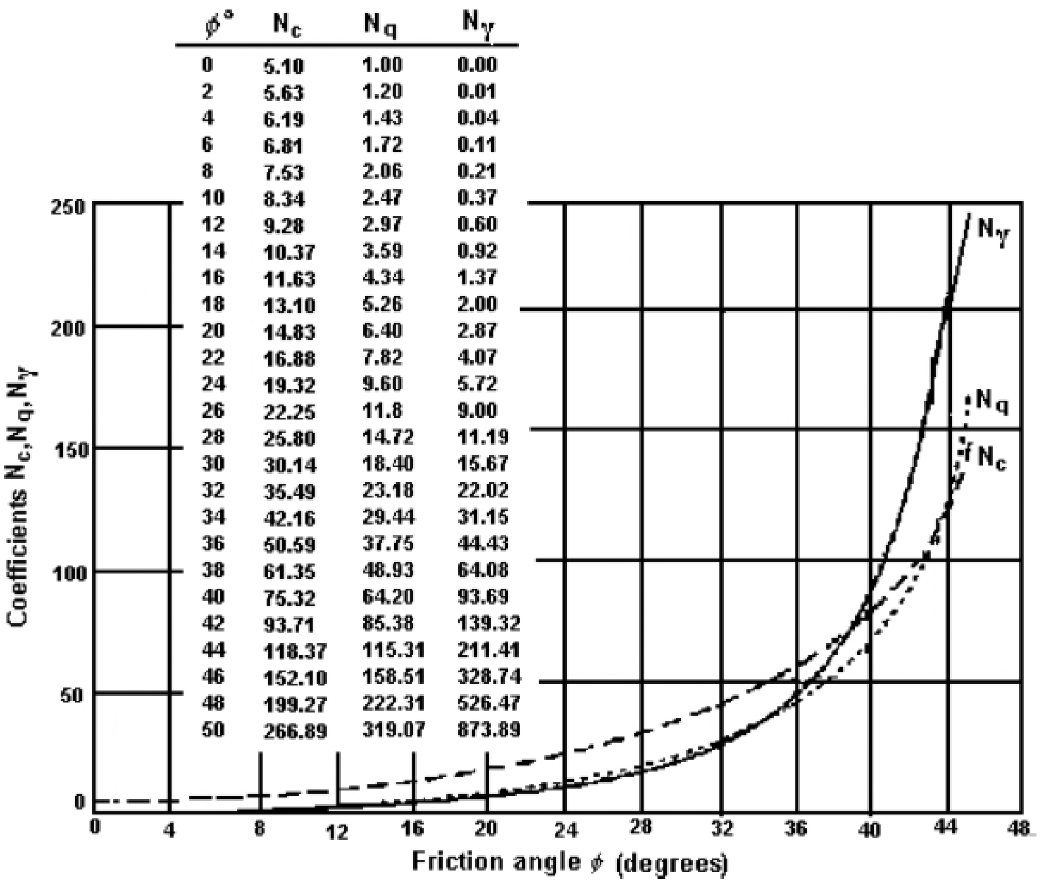
$$N_c = \left({}^{N}\!/_{q} - 1\right)cot\phi \quad 2.4$$

$$N_q = \left(N_q - 1\right)\tan(1.4\phi) \quad 2.5$$

For footing subjected to eccentric loading, Meyerhof suggested the following correction:

$$B' = B - 2C \quad 2.6$$

Where B' reduced width of footing to account for effect of load with eccentricity, e: B=original width of footing and e= eccentricity measured from the symmetrical axis of the Footing. Vertical footing pressure, can be calculated as follows:



$\phi°$	N_c	N_q	N_γ
0	5.10	1.00	0.00
2	5.63	1.20	0.01
4	6.19	1.43	0.04
6	6.81	1.72	0.11
8	7.53	2.06	0.21
10	8.34	2.47	0.37
12	9.28	2.97	0.60
14	10.37	3.59	0.92
16	11.63	4.34	1.37
18	13.10	5.26	2.00
20	14.83	6.40	2.87
22	16.88	7.82	4.07
24	19.32	9.60	5.72
26	22.25	11.8	9.00
28	25.80	14.72	11.19
30	30.14	18.40	15.67
32	35.49	23.18	22.02
34	42.16	29.44	31.15
36	50.59	37.75	44.43
38	61.35	48.93	64.08
40	75.32	64.20	93.69
42	93.71	85.38	139.32
44	118.37	115.31	211.41
46	152.10	158.51	328.74
48	199.27	222.31	526.47
50	266.89	319.07	873.89

Figure 2- 6: Meyerhof Bearing Capacity Factors (Huat et al., 2006)

$$q = \frac{p}{(B' * L)} \qquad 2.7$$

Where= vertical pressure: p= vertical load and L= length of footing (Huat et al., 2006).

2.5 Index properties

In geotechnical engineering, more than in any other field of civil engineering, success depends on practical experience. The design of ordinary soil supporting or soil supported structures is necessarily based on simple empirical rules, but these rules can be used safely only by the engineer who has a background of experience. Large projects involving unusual features may call for extensive application of scientific methods to design, but the program for the required investigations cannot be laid out wisely, nor can the results be interpreted intelligently. Unless the engineer in charge of design possesses a large amount of

experience. Since personal experience is necessarily somewhat limited, the engineer is compelled to rely at least to some extent on the records of the experiences of others. If these records contain adequate descriptions of the soil conditions, they constitute a storehouse of valuable information. Otherwise, they may be misleading. Consequently one of the foremost aims in attempts to reduce the hazards in dealing with soils has been to find simple methods for discriminating among the different kinds of soil in a given category. The properties on which the distinctions are based are known as Index properties, and the tests required to determine the index properties are classification tests. The nature of any soil can be altered by appropriate manipulation. Vibrations, for example, can transform a loose sand into a dense one. Hence, the behavior of a soil in the field depends not only on the significant properties of the individual constituents of the soil mass, but also on those properties that are due to the arrangement of the particles within the mass. Accordingly, it is convenient to divide index properties into two classes: soil grain properties and soil aggregate properties. The principal soil grain properties are the size and shape of the grains and, in clay soils, the mineralogical character of the smallest grains.
Most significant aggregate property of cohesion less soils is the relative density, whereas that of cohesive soils is the consistency.(Terzaghi, Peck, & Mesri, 1996)

2.5.1 Atterberg limit

The Swedish scientist, Atterberg, developed a method of describing quantitatively the effect of varying water content on the consistency of fine-grained soils. He established the four states of soil consistency which are called the liquid, the plastic, the semi-solid, and the solid states. He also proposed a series of tests for determining the boundaries known as Atterberg limits between the physical states of soil. Each boundary or limit is defined by the water content that produces a specified consistency (Evett, Liu, & B., 2009).

The liquid state is produced when a fine-grained soil mixed with a large quantity of water. In such state, the soil behaves like a liquid. That is, it flows freely like a liquid and has no resistance to deformation. If, however, its water content is gradually reduced, it will begin to show to a very small strength and this is defined by moisture content of the soil at the point and is designated by WL. At a moisture content lower than its liquid limit, the soil is in a plastic state. If the sample is subjected to a further decrease in moisture content, it will eventually lose its plasticity. The moisture content at which the sample when it is rolled into a thread, starts to crumble rather than distort is called its plastic limit and is designated by W_P. After the plastic limit, the soil displays the properties of semi- solid. With a further decrease in moisture content, the soil sample will finally reach a point where it can no longer change in volume. At this point, the soil is said to have reached its shrinkage limit designated by W_S (Authority, 2013).

Most soils are suitable for embankment construction and the use of the majority of available materials should be encouraged. Some soils are, however, generally unsuitable a) material with more than 5% weight of organic materials, b) Materials with a swell of more than 3% (e.g. black cotton soils), c) Clays with a plasticity index over 45 or a liquid limit over 90 (Authority, 2013).

2.5.2 Grain size analysis

Grain size analysis, which is among the oldest of soil tests, is widely used in engineering classifications of soils. Grain-size analysis is also utilized in part of the specifications of soil for airfields, roads, earth dams, and other part of the specifications of soil for airfields, roads, earth dams, and other soil embankment construction. Additionally, frost susceptibility of soils can be fairly accurately predicted from the results of grain-size analysis. The standard grain - size analysis test determines the relative proportions of different grain sizes as they are distributed among certain size ranges. The results of grain size analysis are usually presented in the form of grain size distribution curve, known as gradation curve, on a semi logarithmic plot. The ordinate of this curve represents the percentage finer than any given diameter D, while the abscissa represents the size, D (usually expressed in mm) in a logarithmic scale. The shape and slope of gradation curve indicate the type of gradation. A steep or broken slope indicated poor gradation for most engineering purposes. A gentle or even slope indicated good gradation. A soil is said to be well graded if all particles are represented fairly well while a soil is poorly graded and if there is a deficiency or excess of certain sizes. The sizes of soil particles and their distribution throughout the soil mass are important factors which influence soil properties and performance (Tefera 1999).

Table 2. 4:Description of Phases of Soil Water System (Das, 2008)

	Phases of Soil water system				
	Solid state	**Semi solid state**	**Plastic state**	**Liquid state**	**Suspension**
Moisture content			water content decreasing		
Atterberg limit	Shrinkage Limit	Plastic Limit	Plasticity Index	Liquid Limit	
Shrinkage limit	Volume constant	Volume Decreasing			
Shear strength	Shear strength increasing			Very little to none	
Liqudity Index	LI <0	LI =0	0<LI<1	LI=1	LI>1

2.6 Properties of Fine Grained Soils

Properties of fine grained soils exhibit considerable changes with change of water content. Dry clay may be suitable as a foundation for heavy loads as long as it remains dry, but may turn into swamp when wet .Many of the fine grained soils shrink on drying and expand on wetting, which may adversely affect structures founded on them. The properties of fine grained soils may vary considerably between their condition in the ground and their state after being disturbed. Even if moisture content does not change (Terzaghi et al., 1996).

2.6.1 Silts

Silt is a fine-grained soil with little or no plasticity. The least plastic varieties generally consist of more or less equi-dimensional grains of quartz and are sometimes called rock flour; whereas the most plastic types contain an appreciable percentage of flake –shaped particles and are referred to as plastic silt. Because of its smooth texture, silt is often mistaken for clay, but it may be readily distinguished from clay without laboratory testing. If shaken in the palm of the hand, as part of saturated inorganic silt expels enough water to make its surface appear glossy. If the pat is bent between the fingers, its surface again becomes dull. This procedure is known as the shaking test. After the pat has dried, it is brittle and dust can be detached by rubbing it with the finger (Terzaghi et al., 1996).

2.6.2 Clay Minerals

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

The minerals of clays are formed by chemical weathering of rock forming minerals such as feldspar and micas. The clay minerals include illite, kaolinite, montmorillonite, Hallosite and Vermiculite; however, the first three are major ones. Most clay minerals of interest to the geotechnical engineers are made up of two basic units, the octahedral and the tetrahedral sheets. The octahedral unit consists of two layers of oxygen or hydroxyls with aluminum atoms embedded in between, the aluminum may be replaced by magnesium or iron. The tetrahedron sheet consists of a central silica cation surrounded by four oxygen anions, one at each corner of the tetrahedron (Bowles, 1979).

On the basis of their crystalline arrangement, clay minerals are divided into three general groups namely kaolinite, illite and montmorillonite. It is found that kaolinite shows little swelling whereas montmorillonite clay minerals are highly expansive and create major engineering problems (Muluneh, 2012).

The main groups of crystalline materials that make up clays are the minerals Kaolinite, illite, and montmorillonite. Kaolinite has a structure that consists of one silica sheet and one alumina sheet bonded together into a layer about 0.72 nm thick and stacked repeatedly. The layers are held together by hydrogen bonds. Tightly stacked layers result from numerous hydrogen bonds. Kaolinite is common in clays in humid tropical regions. Illite consists of repeated layers of one alumina sheet sand-witched by two silicate sheets. The layers each of thickness 0.96mm, are held together by potassium ions. Montmorillonite has a structure similar to illite, but the layers are held together by weak van der waals forces. Montmorillonite belongs to the smectite clay family. It is an aluminum smectite with a small amount of Al^{+3} replaced by Mg^{2+}. This causes a charge inequity that is balanced by exchangeable cations Na^{+} or ca^{2+} and oriented water. Additional water can easily enter the bond and separate the layers in montmorillonite, causing swelling. If the predominant exchangeable cation is Ca^{2+} (calcium smectite), there are two water layers, while if it is Na^{+} (sodium smectite), there is usually only one water layer. Sodium smectite can absorb enough water to cause particles to separate. Calcium smectites do not usually absorb enough water to cause particle separation because of their divalent cations. Montmorillonite is often called a swelling or expansive clay(Terzaghi et al., 1996).

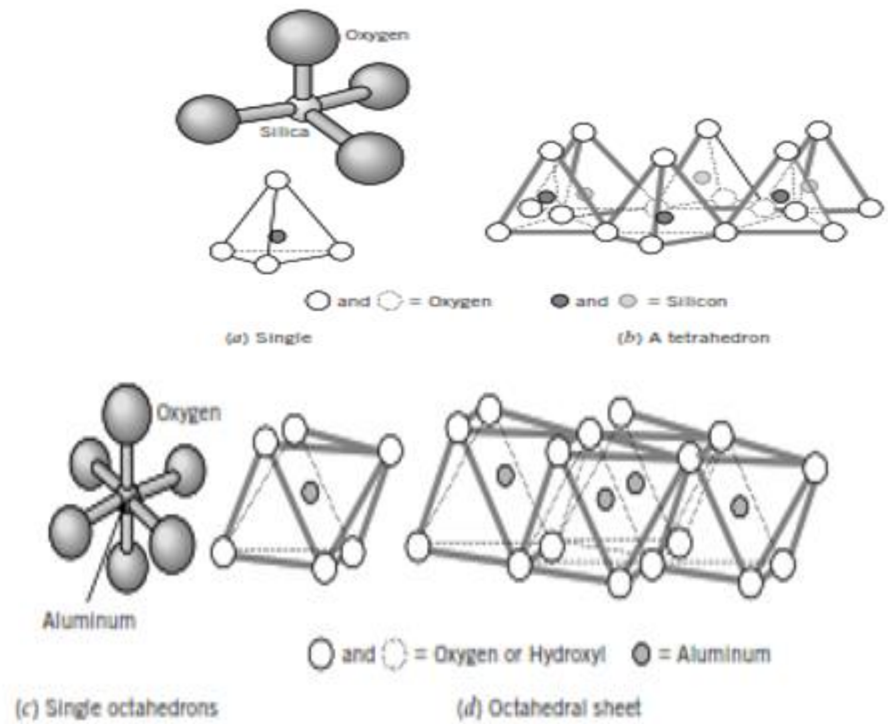


Figure 2. 7: A, Silica Tetrahedrons, B, Silica Sheets, Single Aluminum Octahedrons, Aluminum Sheets (Muni 2000)

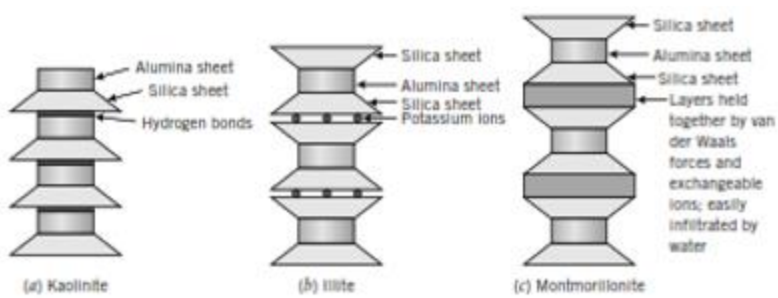


Figure 2- 7:Structure of Kaolinite, illite, montmorillonite ***(Muni 2000)***

2.7 Soil classification

2.7.1 Unified soil classification system

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

2.7.2AASHTO classification system

In embankments –materials in the A-1, A-2-4, A-2-5, or A-3 groups shall be used when available and shall be compacted to the depth specified to not less than 95 percent the maximum density. If material of this character is not available and materials from A-2-6, A-2-7, A-4, A-6, or A-7 groups must be used, special attention should be given to the design and construction of the embankment. Materials from these groups shall be compacted to not less than 95 percent of the maximum density and within two percentage points of the optimum moisture content. (Officials, 2000).

In subgrades- Materials classified in the A-1, A-2-4, A-2-5, or A-3, groups shall be used when available and shall be compacted to the depth specified to not less than 95 percent of the maximum density. Materials in the A-2-6, A-2-7, A-4, A-5, A-6, or A-7 groups may be used if compacted to the depth specified to not less than 95 percent of the maximum density and within two percentage points of the optimum moisture content per T 99 (Officials, 2000).

2.8 Relationships of UCS with Index Properties

2.8.1 Plastic limit and Shear strength

Schofield and Worth (1968) contended that the ‘crumbling’ of soil in the plastic limit test implies a tensile failure, similar to that observed in split – cylinder tests on concrete. While this may well explain the eventual failure of the soil thread, examination of the method shows that cannot be a test of soil strength, tensile or otherwise. In any material strength test, some stress must be controlled or measured. This may occur either using a load cell, as in a split-cylinder concrete strength test, or using dead weight, as in the fall cone test for liquid limit. In the plastic limit test no stresses are controlled directly; enough vertical stress is applied using the hand to cause the soil thread to yield and elongate, but this stress is never measured. The paper has shown the plastic limit as defined by Atterberg (1911) is a measure of soil brittleness, and does not correspond to a fixed soil strength. And a quantity termed the plastic strength limit, PL_{100}, is suggested for correlations with strength properties, but not for analysis of the water content at which the soil becomes brittle (Haigh, Vardanega, & Bolton, 2013).

2.8.2 Liquid limit and Shear strength

Atterberg (1911a, 1911b) proposed a method for measuring the liquid limit of soils based on the stability of a groove in a clay bed when the soil container was struck on the hand. This method was standardized by Casagrandea (1932) into the percussion technique which he subsequently criticized for its cumbersome nature Casagrandea (1958). The method essentially relies on the inducement of as slope failure as the cup is ''tapped'' the water content when the 'canel' fails after 25 blows is the liquid limit. It was recognized by worth (1979) and wood (1999) that the Casagrandea percussion test for liquid limit is determined by slope stability and liquid limit should therefore correspond to a fixed ratio of strength to density. Haigh (2012) performed a Newmarkian sliding block analysis of the test to show that this ratio is approximately $1m^2/s^2$. As soil density decreases with increasing water content, a soil with a high W_L will exhibit a lower strength at liquid limit than those soils with lower liquid limits. Regressions are constructed by plotting liquidity index against the logarithm of undrained shear strength for the entire dataset. The resulting regression equation is (Vardanega & Haigh, 2014).

$$I_L = 1.15 - 0.283In(C_u) \qquad 2.11$$

Table 2. 5:Activity (Plasticity Index / % clay-sized particles) of common soil minerals *(Uehara & Gillman, 1981)*

Mineral	Activity
Quartz	0.0
Mica (muscovite)	0.18
Kaolinite	0.33 - 0.46
Illite	0.90
Ca-montmorillonite	1.5
Na-montmorillonite	7.2

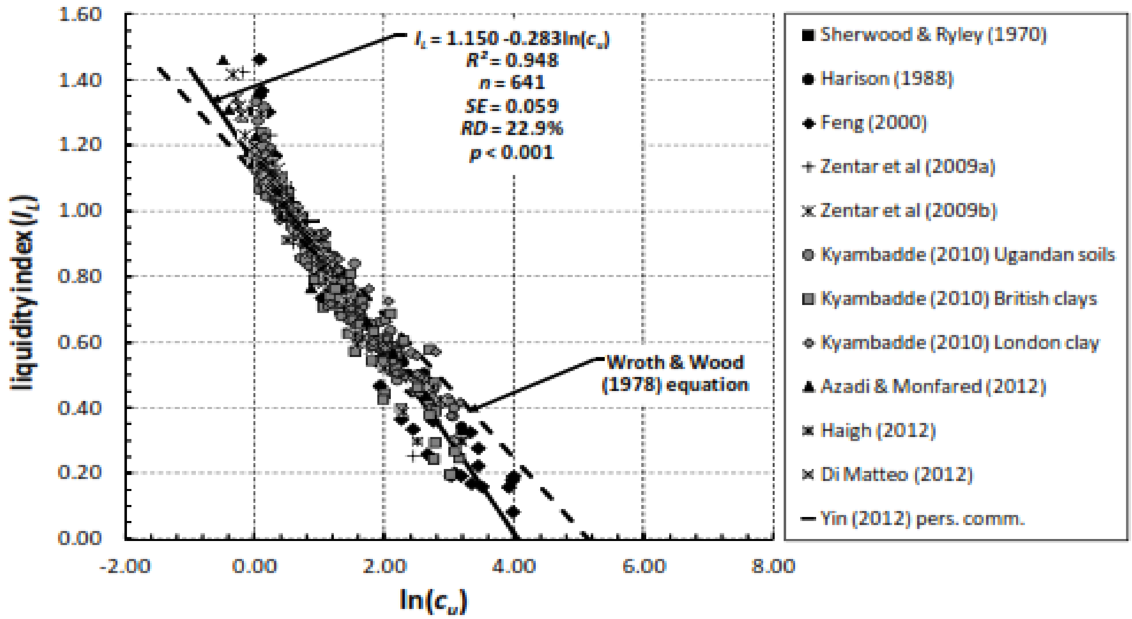


Figure 2- 8:Liquidity index plotted against undrained shear strength (Vardanega & Haigh, 2014)

2.8.3 Clay Activity and Shear Strength

Skempton (1953) showed that the contribution of cohesion to shear strength increases with clay activity. In kaolinitic samples with activity of about 0.4, 80% or more of the shear strength is a ttributable to internal friction. (Uehara & Gillman, 1981).

The origin and mineralogical composition of Ethiopian Red clay soils have been studied by different researchers. The Ethiopian red clay soils are principally residual and derived from the weathering of volcanic rocks. The parent rock for black and red clays in Ethiopia is mainly olivine basalt. Basalt and trachyte. Ethiopian red clay soils have developed where rain fall is plentiful and drainage is good, and contain Kaolinite and Hallosite as the principal clay minerals, but Montmorillonite is also frequently present in significant amounts. The red color of the Ethiopian soils indicates the presence of iron. The following (table 2.6) show the ranges in the properties of Ethiopian soils. (Morin & Parry, 1971).

Table 2. 6:Ranges in properties of Ethiopia soils (Morin & Parry, 1971).

	Black clays	Red clays	Other clays	Lacustrine soils
Parent rock	Olivine, basalt, trachyte	Olivine, basalt, basalt, trachyte	Olivine basalt basalt,trachyte,ignimbrite,etc	
Rain fall, mm/year	228.6-1346.2	1219.2-2336.8	10.16-1219.2	<203.2-1041.4
Temperature °F	54-68	57-68	62-82	66-80
Drainage	Poor to good	Fair to good	Poor-good	Poor
Principal clay minerals	Montmorillonite, Kaolinite and Hallosite	Kaolinite, hallosite,montmorillonite	Montmorillonite, Kaolinite	Montmorillonite
PH value	7.2-8.4	5.1-6.8	6.3-9.1	8-9.1
Principal cations	Calcium, magnesium, potassium	Calcium,magnesium,potassium	Calcium	Calcium
Cation exchange capacity,m.e/100g	42-95	30-77	22-90	61(one test)
Clay (2µ),%	13-75	34-76	5-51	3-41
Liquid Limit,%	37-88	44-66	NP-57	NP-70
Plasticity index,%	11-48	14-30	NP-35	NP-35
Shrinkage limit,%	7-28	10-30	11-19	15-20
Specific gravity	2.62-2.94	2.61-2.9	2.61-2.9	2.61-2.92
Organic content, %	2-7+	1-4+	2-7+	4+
Compaction test: Maximum Density ,kg/cu.m	1106.27-101	1619.32-1186.32	1170.4-1667.42	1218.5-1142.96
Optimum moisture,%	40-17	38-29	28-21	30-27
California bearing ratio(CBR) test values	2-8	6-9	-	-
Unconfined compressive strength, kpa	96.76-267.28	146.57-250.99	61.79-159.02	64.66-192.56
Expansive pressure, kpa	11.5-95.8	21.1-95.8	5.75-143.7	19.16-114.96

Alemayehu Deriba (2017), from Addis Ababa university (Ethiopia) studied the relationship between Dynamic Cone Penetration Index (DCPI) and Unconfined Compressive Strength (UCS).The research consisted of field, laboratory testing and analysis of the results for thirty samples from fourteen test pits of Alem Gena town soils (Dirriba, 2017).

Table 2. 7:Single Correlation Equations and R2 of Category (Dirriba, 2017)

Dependable Item	Variable Item	Equation	R^2
	DCPI	UCS=-58.59*ln[DCPI]+308.04	0.831
UCS	NMC	UCS=-2.45(NMC)+229.83	0.729
	Gs	UCS=-424.98(Gs)+1318.5	0.749
	LI	UCS=-76.48(LI)+151.56	0.725

From this research Unconfined Compression strength (UCS) is highly influenced by DCPI NMC, Gs and Liquidity Index (LI) (Dirriba, 2017).

Addis kebede (2016) **,** The research were undertaken in order to study the reliability of using standard penetration test (SPT) and index properties (IL,ILM,PI and PL) in predicting some properties, (such as shear strength parameter's) (qu and Cu) of silty clay and sandy silt using the selected 112 borehole data. For the investigation the sample data were taken from Addis Abeba housing Development program at Bole Arebasa condominium Building (Kebede, 2016).

Among the single linear regression analysis the correlation between SPT and, IL, ILM, PI of silty clay soil has resulted the following relationship (Kebede, 2016).

$C_u = 5.931N-12.81$ $R^2=0.8819$ n=20 2.12

$C_u = 60.143I_L^2 - 77.589I_L + 40.971$ $R^2=0.8604$ n=20 2.13

$N=0.003PI^2 - 0.6696PI+30.088$ $R^2=0.8431$ n=20 2.14

Gediyon Andualem (2015), From Addis Abeba University introduced the use of Dynamic Cone Penetration (DCP) with the place of unconfined shear strength. Seventeen test pits were excavated and thirty three disturbed and undisturbed samples were taken at a depth of 1m to 3m. It has been found out that parameters like unconfined compression strength and liquidity index have influence on the dynamic cone penetration index (DCPI) (Andualem, 2015).

Multiple Regression for (red clay soils of Debre Markos)

The developed equation for multiple regression of UCS (kpa) with DCPI (mm/blow) and LI for red clay soils, with N=20 and adjusted R^2 =81.6% is

$$UCS=-96.408\ln(DCPI)-552.123*(LI)+480.035 \quad 2.15$$

Table 2. 8: Single Correlations for red clay soils

Equation	R^2	Sample size
UCS=-209.51 ln(DCPI)+800.5	0.8019	20
UCS=-970.23(LI)+204.69	0.8144	20
DCPI=81.415(LI)+20.197	0.7776	20

Those correlations were used to develop bearing capacity equation based on the bearing capacity theory. Bearing capacity equation for initial loading condition will be:

q_{ult}=-538.625*ln (DCPI)+2058.086+ϒ*D, for red clayey soils 2.16

Table 2. 9: Summery of relationships of done in Ethiopia

R/ships	Name of author			
	Deriba (2017)	Kebede (2016)	Andualem (2015)	Mengistu (2017)
UCS and DCPI	-58.59*ln(**DCPI**)+308.04	-----	-209.51 ln(DCPI)+800.5	----
UCS and LI	-76.48**IL**+151.56	$60.143I_L^2-77.589I_L$ +40.971	-970.23IL+204.69	200.971-1.97IL
UCS and SPT	-----	5.931**N-**12.81	----	-----
UCS and NMC	-2.45(**NMC**)+229.83	-----	----	-----
No of samples	13	112	20	12

3 MATERIALS AND METHODS

To achieve the objective of the research an experimental testing program were prepared on twenty five soil samples collected from Eastern part of Bahir Dar city (Diaspora) soils. Based on this program unconfined compressive strength and index tests such as Specific gravity, sieve analysis, and atterberg limit tests are conducted for twenty five samples after transporting to the laboratory.

Table 3. 1: Test program

Laboratory tests	Undrained shear strength	Liquid limit	Plastic limit	Moisture content	Specific gravity	Grain size analysis
Amount of sample	-	300g	300g	Homogenous clay and silt-30g, Medium grained soils 300g	10g	2000g
Testing Procedure	ASTM-D2166	ASTM D4318-00	ASTM D4318-00	ASTM D - 2216	ASTM D 854-83	ASTM D422-07
Type of Test	Unconfined compressive strength	Casagrandea	-	Oven method	Density Bottle	Wet Sieve and, Hydrometer analysis
Methods of sampling	Undisturbed	Disturbed	Disturbed	Undisturbed	Disturbed	Disturbed
Sieve size	-	0.425mm	0.425mm	-	2mm	0.075µmm
Depth of sampling	1.5m	1.5m	1.5m	1.5m	1.5m	1.5m

3.2 Description of the Study Area

3.2.1 Project location and Description

The project is situated in Bahir Dar city of Amhara region, located at the southern part of Lake Tana at an Latitude of 11^{0} 35’ E and Longitude of 37^{o}23’ E ,565 km North of Addis Ababa, source of Blue Nile. The town has a potential for expansion in all directions except to the side of Lake Tana (construction, 2007).

Figure 3- 1 : Figure showing where the site is located from Ethiopia Map (Gugssa, 2018)

Bahir Dar lies on 1797m above sea level and the climate is classified as warm and temperate. The topography of the town is mainly flat with some small hills on its East and West sides. The summers here have a good deal of rainfall, while the winters have very little. In Bahir Dar, the average annual temperature is 19.6°c/67.2°F.The rainfall here is around 1419 mm /55.9 inch per year (organization, 2013).

Figure 3- 2: Average Monthly rainy days over the year (organization, 2013)

Legend

Mean RF: Mean Rainfall in mm

Mean Max: Mean Maximum Temperature in ⁰C

Mean Min: Mean Minimum Temperature in ⁰C

Extreme Maximum: Extreme Maximum Temperature in ⁰C

Extreme Minimum: Extreme Minimum Temperature in ⁰C

Wet1: Small Rainy Season

Wet2: Main Rainy Season

Dry*: Transition period between the two rainy seasons

Dry: Dry season

3.3 Sample Collection

A total of twenty five test pit points were selected and excavated using local labor from each test pits at 1.5m depth and the numbers of test pits were limited because of the constraint in budget and time. The samples were taken at the end of April and at the beginning of May months. Both disturbed and undisturbed soil samples were taken to the laboratory as per the procedure stated in table 3.1 .The location of the research area were tracked using hand GPS and laboratory tests were conducted in the geotechnical and high way laboratories of Bahir Dar institute of technology . After the test results were obtained comparison of test results were made besides characterization of soil be made based on the interpretation of results.

Figure 3- 3: Location of sample points

Table 3. 2: The Location of Sample points

Sample location code	Easting	Northing	Elevation
TP-01	328708	1283870	1756
TP-02	328578	1283735	1804
TP-03	328721	1283720	1827
TP-04	329475	1283498	1858
TP-05	329657	1283401	1863
TP-06	330021	1283445	1875
TP-07	330102	1283614	1881
TP-08	329929	1283805	1881
TP-09	329660	1283465	1872
TP-10	331820	1283647	1899
TP-11	329740	1284191	1878
TP-12	329645	1284138	1874
TP-13	329432	1284162	1870
TP-14	329204	1284164	1864
TP-15	329191	1284075	1863
TP-16	328961	1284248	1853
TP-17	328844	1284311	1843
TP-18	328837	1284302	1845
TP-19	328742	1284365	1839
TP-20	328519	1284445	1830
TP-21	322851	1284439	1829
TP-22	328525	1284729	1832
TP-23	328524	1284738	1832
TP-24	328520	1284728	1832
TP-25	328515	1284727	1828

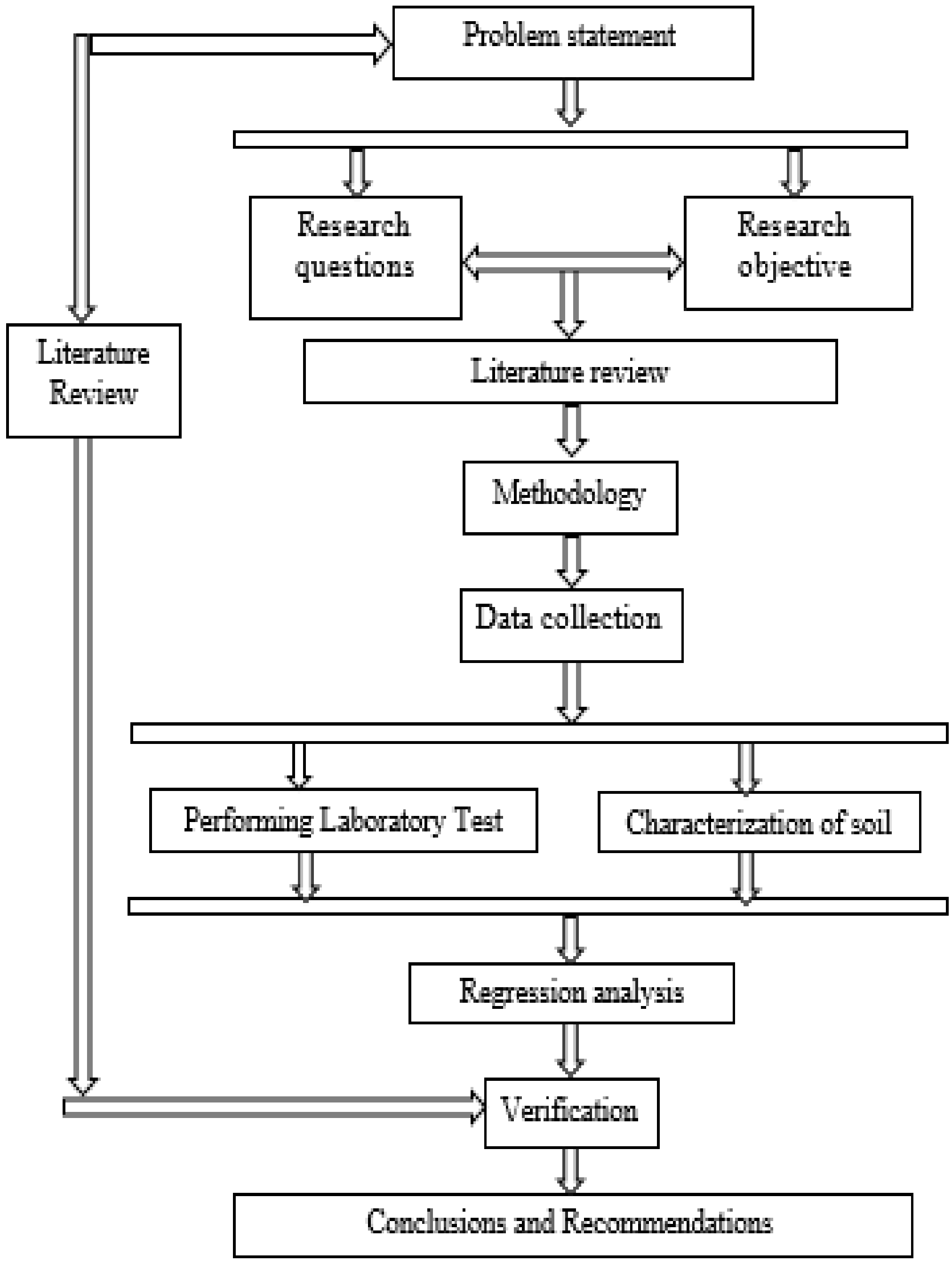


Figure 3- 4: Illustrates Summarized Methodology Flow Chart of the Research

4 DISCUSSION INTERPRETATION AND TEST RESULTS

4.2 Laboratory Test Results

Based on the samples retrieved from the sites, Laboratory tests on the twenty five samples were conducted in the geotechnical Laboratory of Bahir Dar Institute of Technology. The primary purpose of this section is to review all the test results obtained in this research, compare them with previous results done not to repeat the correlations already established. Finally to classify the soils in the study area whether they are suitable as a construction material or not.

Atteberg Limits, Natural Moisure Content (NMC), Percent Passing sieve No.200 Unconfined Compression Strength (UCS) and Specific Gravity (Gs) test results are summerized and Compiled (Table 4.2) ,inorder to analyze the intended correlations. Detail test data and results are tabulated in Appendix.

Table 4. 1: Table Showing the Test Result

No	Test pit location	Percent Passing Sieve No 200 (%)	NMC (%)	Gs	LL (%)	PL (%)	PI (%)	AASHTO	USCS	UCS(kPa)
1	TP-01	97.69	35.42	2.73	67	37	30	A-7-5	MH	142.3
2	TP-02	97.65	33.91	2.78	64	32	32	A-7-6	CH	167.5
3	TP-03	98.98	30.04	2.76	55.9	25	30.9	A-7-5	MH	221.3
4	TP-04	99.00	29.94	2.78	55	24	31	A-7-5	MH	239.2
5	TP-05	99.27	32.39	2.80	62	29	33	A-7-5	CH	195.9
6	TP-06	99.00	31.26	2.78	57	26	31	A-7-5	MH	208.0
7	TP-07	97.84	31.59	2.77	59	28	31	A-7-6	CH	204.3
8	TP-08	97.75	32.45	2.72	63	31	32	A-7-5	MH	185.0
9	TP-09	98.55	33.28	2.78	64	33	31	A-7-5	MH	165.9
10	TP-10	99.35	30.82	2.75	62	29	33	A-7-6	CH	189.7
11	TP-11	99.27	33.25	2.78	63	30	33	A-7-6	CH	187.7
12	TP-12	99.52	32.29	2.73	61	28	33	A-7-6	CH	197.0
13	TP-13	99.19	30.98	2.79	57	25	32	A-7-6	CH	208.0
14	TP-14	98.93	31.50	2.77	59	28	31	A-7-6	CH	202.1
15	TP-15	97.96	32.54	2.70	63	32	31	A-7-5	MH	174.1
16	TP-16	98.57	32.39	2.71	57	26	31	A-7-6	CH	204.4
17	TP-17	98.24	35.20	2.71	67	36	31	A-7-5	MH	149.0
18	TP-18	99.23	32.23	2.77	60	28	32	A-7-6	CH	197.6

19	TP-19	97.22	30.50	2.73	56	25	31	A-7-6	CH	211.6
20	TP-20	97.70	30.35	2.73	56	25	31	A-7-6	CH	217.7
21	TP-21	97.09	34.59	2.79	66	35	31	A-7-6	CH	154.7
22	TP-22	98.55	34.09	2.74	65	33	32	A-7-6	CH	157.4
23	TP-23	98.55	30.00	2.72	55	24	31	A-7-6	CH	208.0
24	TP-24	97.75	28.77	2.76	54	24	30	A-7-6	CH	227.5
25	TP-25	99.04	28.54	2.75	50	19.2	30.8	A-7-6	CH	245.0

*Tp- Testing point,*NMC-Natural Moisture content, *LL-Liquid limit, *PL-Plastic limit, *PI-Plasticity index, *UCS-*Unconfined Compressive Strength, *USCS-Unified soil Classification system.

4.3 Comparison of Test Results with Other Researchers

The comparison of red soil data between the current study and previously done researches is presented in (Table 4.3). The values were compared in order to identify the classification of the red soil with respect to lateritic soil from different areas. The comparison is made on the bases of various Laboratory test results for clay soil in the country.

According the results as shown in table 4.3 the ranges of values are close to the results obtained by (Fasil, 2003) on red clays of Bahir Dar and Samuel (1989) on Addis Abeba.

Table 4. 2: Comparison of Test Results with Previous Studies

Previous Research						
	Morin & parry(1971)	(Zelalem, 2005)	(Wakuma,2007)	(Samuel,1989)	(Abegna,2003)	Current Research
Soil Type	Red Clay	Lateritic	Lateritic	Red Clay	Red Clay	clayey
Location	Ethiopia	Nejo-Mendi	Asossa	Addis Ababa	Bahir Dar	Bahir Dar
Clay Content	34-76	2-20.6	2.5-60	53-68	74 -82	68-86
Activity	-	0.97-0.98	0.62-1.02	-	0.56	0.46-0.37
Liquid Limit (%)	44-46	48-67	41-72	57-76	61 -68	50-67
Plastic Index (%)	14-30	17-27	20-48	33-47	24 -31	30-33
Shrinkage Limit (%)	10 - 30	7.1-15.7	-	14-20	09-12	-
Free swell (%)	-	20-40	11.0-45.0	30-40	-	-
Specific Gravity	2.61-2.9	2.78-3.03	2.19-2.94	-	2.75 -2.83	2.71-2.80
UCS(kPa)	-	165-553	-	-	148 -220	142.3 - 239.2
Plasticity Chart	-	MH	CH,SC,MH,CL,& SM	CH	-	CH-MH

4.4 Classification and Identification of Soils

Soil classification systems worldwide capture great physical insight and enable geotechnical engineers to anticipate the properties and behavior of soils by grouping them into similar response categories based on their index properties. Unlike steel and concrete ,soils occur in a large variety as a result soils which have similar behavior must be grouped together to form a known group. As there is a wide varieties of soils covering the earth, it is desirable to systemize or classify the soils into broad groups of similar behavior (santamarina, park, & j.carlos, 2017).

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

Grain size analysis was done in an effort to determine the percentage of different grain sizes contained within the soil from various parts of the study area. From Hydrometer and sieve analysis results of twety five samples shows 68-86% clay, 13-31% silt, and 0.33-2.21% sand.

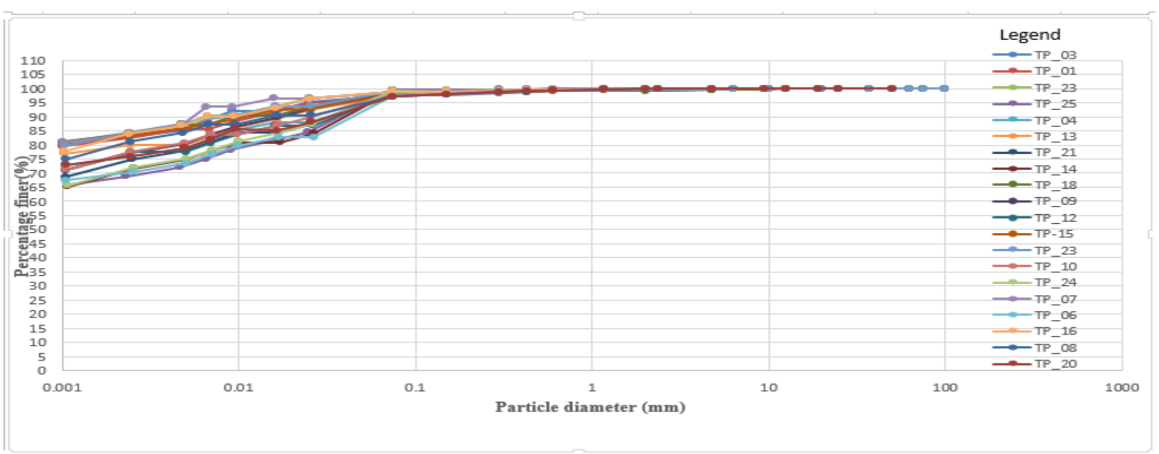


Figure 4- 1: Figure Showing Typical Grain size Distribution

4.4.1 USCS classification system

For proper classification according to this system, some or all of the following information must be known: Percent of gravel –the fraction passing the 76.2-mm sieve and retained on the No. 4 sieve (4.75-mm opening). Percent of sand-that is, the fraction passing the No.4 sieve (4.75-mmopening) and retained on the No. 200 sieve (0.075-mm opening). Percent of silt and clay – that is, the fraction finer than the No. 200 sieve (0.075-mm opening). Uniformly coefficient (C_u) and the coeffiecnt of gradation (C_c) (Leeper, 1956). The basis for USCS (Unified soil Classification system) is Liquid Limit and plasticity Index of a soil. According to this classification scheme soil samples from the study area falls in CH and MH region, this shows that the soil is more of Inorganic clay with lesser amount of Inorganic silt soil.

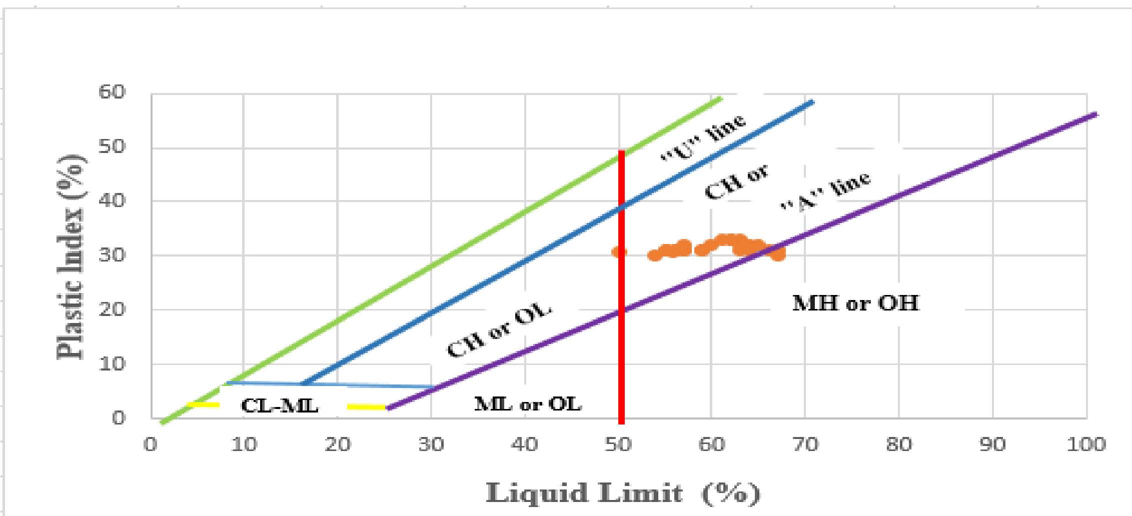


Figure 4- 2: Unified Soil Classification System in the study area

4.4.2 Identification of inorganic fine grained soils

The soils Described as fat clay, CH, are identified as high to very high dry strength, no dilatancy, and high toughness and plasticity. The plot of plasticity index versus liquid limit falls above ''A" line. Hence the soils described as elastic silt, MH, (Table 4.3) are identified as low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity. The plot of plasticity index versus liquid limit falls below ''A" line. These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. As it is shown in Table (4.4).

Table 4. 3:Identification of Inorganic Fine-Grained soils from Manual Tests (Evett et al., 2009)

Soil Symbol	Dry strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be informed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None to slow	High

Table 4. 4: ***Swelling Potential and plasticity Index Ranges (Chen & Hue, 1998)***

Swell potential	Plasticity Index,%
Low	0-15
Medium	10-35
High	20-55
Very High	35>

Plasticity Index parameter can be used as a primary indicator of the swelling characteristics of a soil as it is shown in Table 4.5. The PI value between 30-33% indicates the soil has a medium swell potential which is the case in the current study. Such clays belong to the CH and MH groups of the unified classification system.

4.4.3 AASHTO classification system

According to AASHTO Soil classification system the soil samples fall in the region of A-7-5 and A-7-6 as shown in figure. Which indicates the soils are clayey soils are usual types of significant constituent materials and their rating as a subgrade are from fair to poor and they have got moderate PI in relation to LL which may b*e* elastic as Well as subject to considerable volume change capacity between wet and dry states.

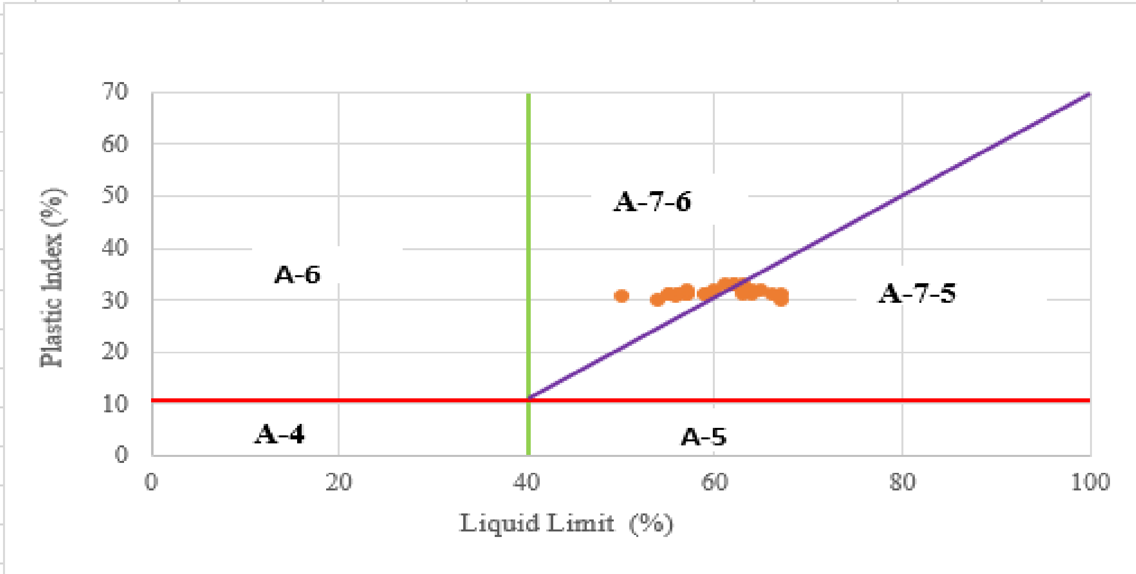


Figure 4- 3: AASHTO Classification System in the Study Area

The equivalence between AASHTO and USCS shows based on results of Liquid limit and Plasticity index on Unified soil classification system (organic silt and clay, lean clay, fat clay) lies for clayey soils on AASHTO ,so the usual consistent materials for the study area is clayey soil, As it is indicated in the table 4.6 .

Table 4. 5:Equivalence between AASHTO and USCS *(K.R.Arora, 2004)*

AASHTO system	*USCS (most probable)*
A-1-a	GW,GP
A-1-b	SW,SM,GM,SP
A-2-4	GM,SM
A-2-5	GM,SM
A-2-6	GC,SC
A-2-7	GM,GC,SM,SC
A-3	SP
A-4	ML,OL,MH,OH
A-5	MH,OH,ML,OH
A-6	CL
A-7-5	OH,MH,CL,OL
A-7-6	CH,CL,OH

4.4.4 Activity

Activity (A) of a soil is the ratio of the plasticity index and the percentage of clay fraction (Minus 2µ size). Thus

$$A = \frac{I_P}{F} \qquad 4.0$$

Where I_p= plasticty index(%), F= clay fraction (%).

The amount of water is a soil mass depends upon the type of clay mineral present. Activity is a measure of water-holding capacity of clayey soils.The changes in the volume of clayey soil during swelling or shrinkage depend upon the activity.

The soils containing the clay mineral montmorillonite have very high activity (A>4). The soil containing the mineral Kaolinite are least active (A<1), whereas the soils containing the mineral illite are moderately active (A=1 to 2). Depending upon activity, the soils are classified into three types (Table 4.6).For a soil of specific origin, the activity is constant. The plasticity index increases as the amount of clay fraction increases (Million, 2009).

Table 4. 6:Activity of Clay Minerals Table (Million, 2009)

Activity	Soil type
A<0.75	Inactive
A=0.75 to 1.25	Normal
A>1.25	Active

Mineralogical analysis shows the soils in the study area contain the clay mineral kaolinite dominantly in the range from 10.3 to 24.7%.(Abagena, 2003). From summary of result value distingush the range of activity values lies between 0.46 to 0.37 with an average of Activity value 0.42 which lies in the group of inactive clay, A<0.75. Figure 4.4 shows for twenty five collected data of Activity of soils from the study area fall in a group of Kaolinite.and as shows Activity values are normally less than 0.5 for kaolinitic clays. soils with clay activites less than 0.5 are treated as low-expansion material .(Million, 2009).

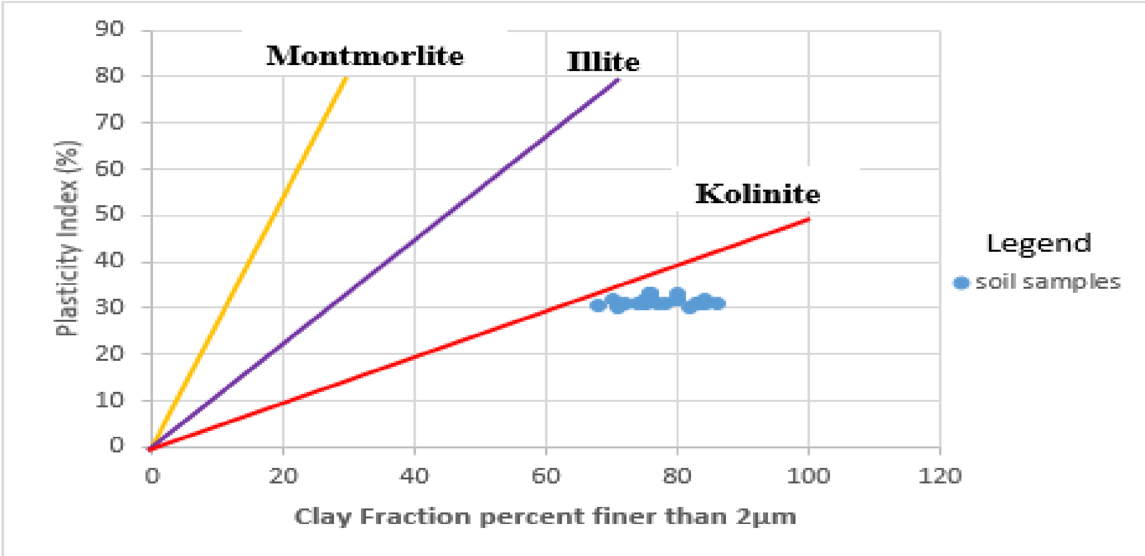


Figure 4- 4: Activity Chart

4.5 Mechanical Property Results and Discussion

The unconfined compressive strength tests of collected results from the study area ranges from 142 to 240 kPa which indicate a stiff to very stiff consistancy. The relationship between unconfined compressive strength and consistancy of soil has a relation, the average value of UCS result 191 kPa fall in a range of stiff consistancy.

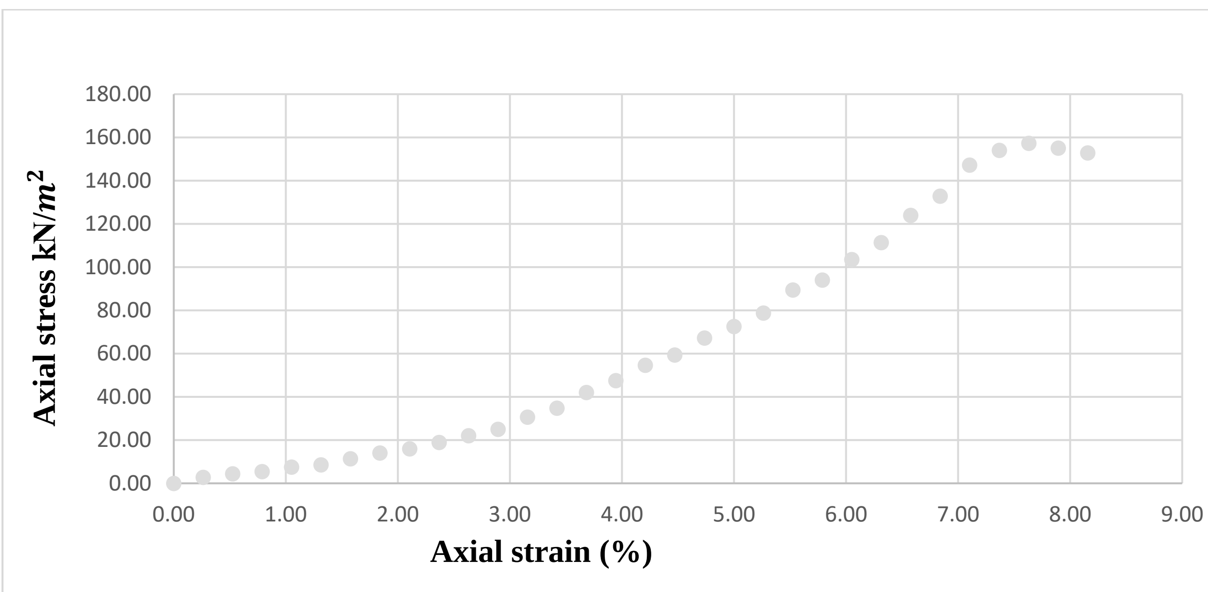


Figure 4- 5: Typical Unconfined Compressive Strength Graph for Test Point

Table 4. 7:Relation between Unconfined Compression Strength and Consistency of Soils *(Evett et al., 2009)*

Consistency	q_u (kN/m^2)
Very soft	0-24
Soft	24-48
Medium	48-96
Stiff	96-192
Very stiff	192-383

5 REGRESSION ANALYSIS AND CORRELATIONS

Different models are used for the correlation and those models with a higher coefficient of determination (R^2) are accepted as significant relationships. Single and multiple correlation are carried out.

Correlation coefficient or coefficent of regression (R): Are the measures of how well the least-square regression line (best fit line) fits the sample data. Value of R=1 or -1 (R^2=1) shows that there is a perfect linear correlation and also perfect linear regression. On the other hand R=0 or approaches to zero shows no valid relationship can be obtained between the variables.

5.2 Scatter Plot and Best- Fit Curve using Single Linear Analysis

The study takes Unconfined Compressive Strength as the dependent variable whereas the liquid limit, plastic limit,plasticity index,and grain size (pp200) are independent variables.The correlation is done for the two soil categories separately. For the categorized group an individual combined single correlation data is plotted in the best fit paper.

5.2.1 UCS versus Percentage passing sieve No.200

The best fitting trend line for relationship between UCS (kPa)and % passing sieve No.200 (%) is UCS=12.71*pp_{200}-1061.43, as the srength of this correaltion is 14.1% or has R^2=0.14.

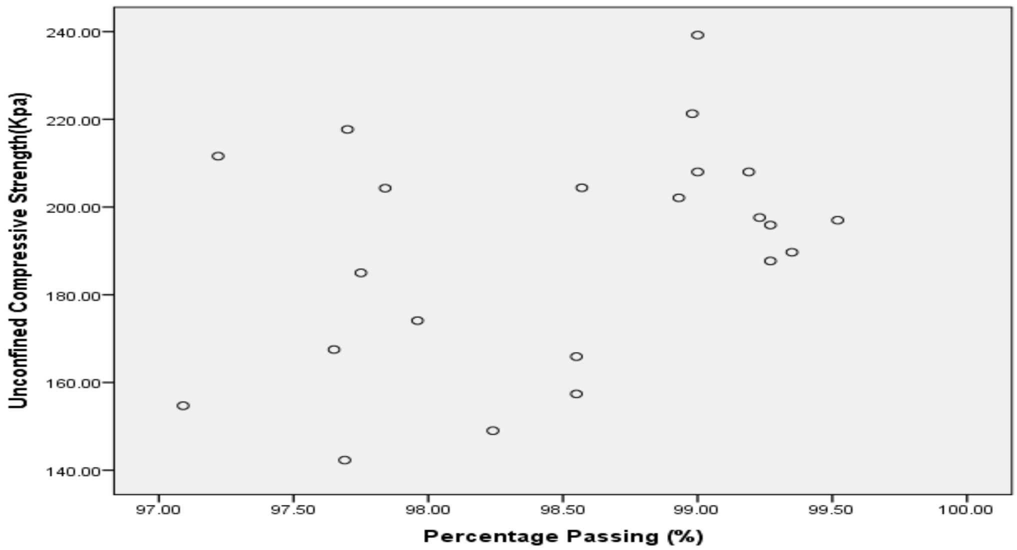


Figure 5- 1: Scatter Diagram of UCS versus Percentage Passing Sieve No.200ve No.200

5.2.2 UCS versus Liquid Limit

The best fitting trend line for relationship between UCS (kPa) and LL (%) is UCS =574.879-6.324*LL.The strength of this correaltion is only 92.1% or has R^2=0.92. It is deemed reliable enough to be used as a predictor for the estimation of the UCS.

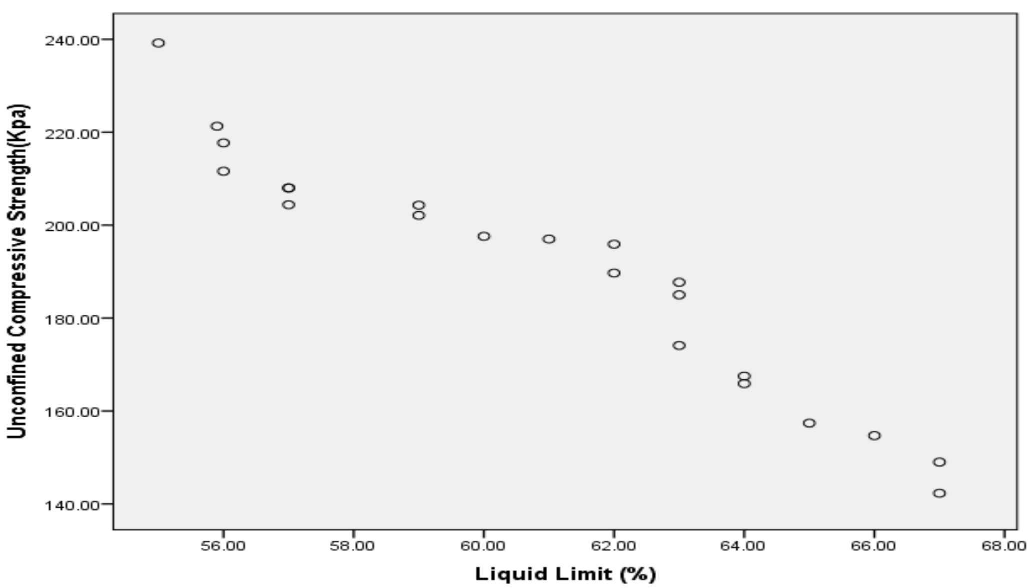


Figure 5- 2: Scatter Diagram of UCS versus Liquid Limit

5.2.3 UCS versus Plasticity Index

The relationship between the UCS (kPa) and the plasticity index (%) for the tested samples is shown in fiqure 5.3. The best fitting trend line for this relationship is UCS= 1.956*PI+128.339, the strength of this equation in predicting an outcome from the plastic Index is around 0.4% or has R^2 =0.04.

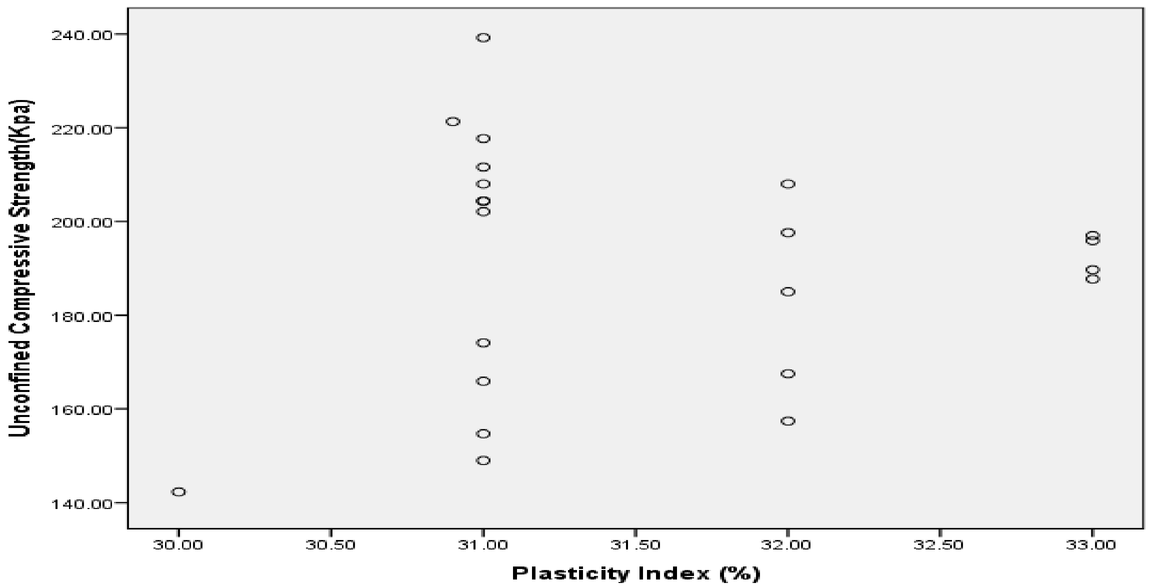


Figure 5- 3: Scatter Diagram of UCS versus Plasticity Index

5.2.4 UCS Versus Liquidity Index

The relationship between the UCS (kPa) and the liqudity index (%) for the tested samples is shown in fiqure 5.4. The best fitting trend line for this relationship is UCS= -324.78*LI+159.22, the strength of this equation in predicting an outcome from the plastic Index is around 90.% or has R^2 =0.90.

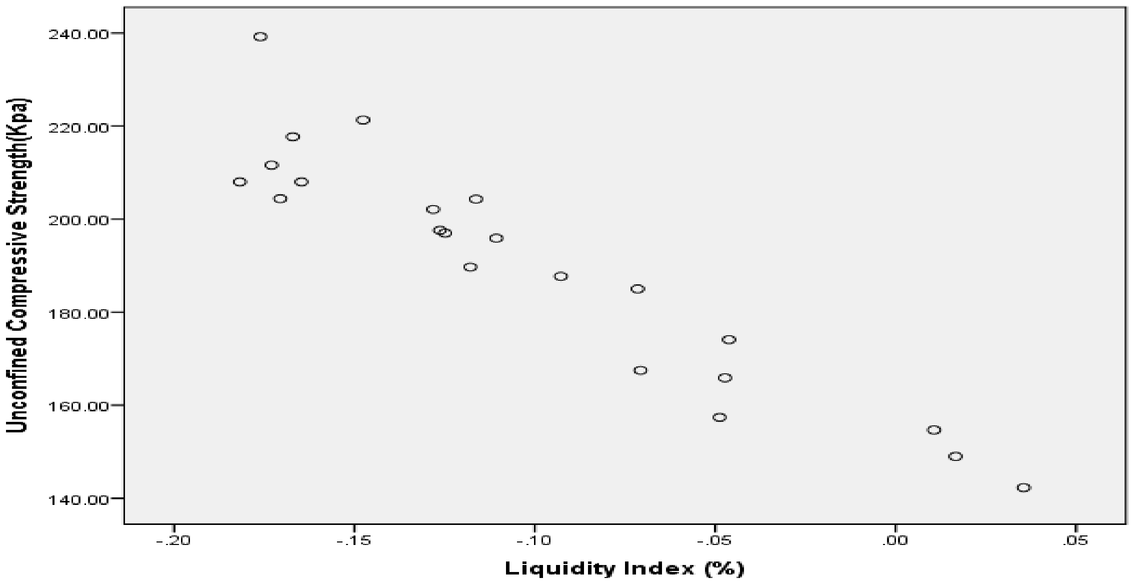


Figure 5- 4: Scatter Diagram of UCS versus Liquidity Index

5.3 Scatter Plot and Best- Fit Curve using Multiple Linear Analysis

Multiple Correlations is a technique that allows additional factors to enter the analysis separately so that the effect of each can be estimated using one model equations. It is valuable for quantifying the impact of various simultaneous influences upon a single dependent variable. Furthermore, because of omitted variables bias with single regression, multiple regression is often essential even the investigator is only interested in the effects of one of the independent variables.

The study takes Unconfined Compressive Strength as the dependent variable whereas the liquid limit, plastic limit,plasticity index,and grain size (pp200) are independent variables.

5.3.1 UCS versus Percentage passing sieve NO.200 and Liquid limit

The best fitting trend line for relationship between UCS and % passing sieve No.200 (%) is UCS=-6.08*LL +4.75 pp_{200} -92.25, as the srength of this correaltion is R^2=0.93 and R=93.9% for pp_{200} (%) and LL(%).

5.3.2 UCS versus liquidity index and liquid limit

The best fitting trend line for relationship between UCS,Liqudity index and Liquid Limit is UCS=-3.83*LL -136.18LI+410.19, as the srength of this correaltion is R^2=0.95 and R=95% for LI (%) and LL .

5.3.3 UCS versus Liquidity index and Percent passing No 200

The best fitting trend line for relationship between UCS and PL is UCS=-328.629*LI—1.01PP_{200}-257.39.The strength of this equation in predictiing an outcome from the plastic limit is or has R^2 =0.90 and R=90.4% for pecentage passing no 200 and Liqudity index .

5.3.4 UCS versus Plasticity index and Percent passing No 200

The best fitting trend line for relationship between UCS and PL is UCS=-6.36*PI+16.83PP200-1266.96. The strength of this equation in predictiing an outcome from the plastic limit is or has R^2 =0.17 and R^2=17.2% for pecentage passing no 200 and Plasticity index respectivly.

Table 5. 1: Summary of Newly Developed Possible Multiple empirical equation

Equations	N	R^2	Significant level	equation
UCS= -6.08*LL +4.75 pp_{200} -92.25	22	0.93	Insignificant	Equation 5
UCS=-3.83*LL -136.18LI+410.192	22	0.95	significant	Equation 6
UCS= -328.62*LI-1.01PP_{200}+257.39	22	0.90	Insignificant	Equation 7
UCS= 6.36*PI+16.83PP_{200}-1266.96	22	0.17	Insignificant	Equation 8

*All parameters are in percent except UCS (kPa)

Table 5. 2: Summary of Newly Developed Possible single Empirical Equations

Equations	N	R^2	Significant level	equation
UCS= UCS=12.71*pp_{200}-1061.43	22	0.14	Insignificant	Equation 1
UCS=-324.78*LI+159.22	22	0.90	significant	Equation 2
UCS= 574.879-6.324*LL	22	0.92	significant	Equation 3
UCS= 1.956*PI+128.339	22	0.04	Insignificant	Equation 4

*All parameters are in percent except UCS (kPa)

5.4 Verification the Developed Equations

The validation of the developed correlation is conducted by using the control sample in order to select the best equation, the UCS value is calculated for both soil data and control sample a soil data using best newly developed equations. The results are shown in the following tables.

Table 5. 3: Predicting UCS Values Using Newly Developed Equations

Test pit ID	Experimental UCS value (kpa)	Predicted UCS value (%)		
		Equation 3	Equation 2	Equation 6
TP-23	208	227.07	220.41	225.41
TP-24	227.5	233.401	225.16	225.16
TP-25	245	258.697	259.54	259.54

Table 5. 4: Checking Accuracy of Newly Developed Formulas

Test pit Id	Experimental UCS value (%)	Variation of UCS experimental value (%)		
		Equation 2	Equation 3	Equation 6
TP-23	208	6.97	8.37	6.2
TP-24	227.5	2.59	1.02	2.7
TP-25	245	5.59	5.93	4.7

6 CONCLUSIONS AND RECOMMENDATIONS

6.2 Conclusions

The research is conducted to find a localized correlation between UCS value and soil index properties within the scope of the study. Using the obtained twenty two results a single and multiple linear regressions is analyzed and a relationship developed that UCS value in terms of pp200, LL and LI. The suitability of the developed correlation is evaluated by utilizing a separate control sample test results. From the results of the study the following conclusions are drawn.

From the results of linear and multiple regression analysis, a better correlation of multiple regression than the single regressions is obtained as given below: With R^2=0.90
0.92, 0.95 respectively.

$$\mathrm{UCS} = -324.8 * \mathrm{LI} + 159.229 \quad \mathrm{R}^2 = 0.90 \tag{6.1}$$

$$\mathrm{UCS} = -574.879 * \mathrm{LL} - 6.324 \quad \mathrm{R}^2 = 0.92 \tag{6.2}$$

$$\mathrm{UCS} = -3.83 * \mathrm{LL} - 136LI + 410.19 \quad \mathrm{R}^2 = 0.95 \tag{6.3}$$

After analyzing the data it has been found out that parameters like Liquidity index, Liquid Limit have influence on Unconfined Compressive Strength. Unconfined Compressive Strength can be estimated by $\mathrm{UCS} = -3.83 * \mathrm{LL} - 136LI + 410.19 \quad \mathrm{R}^2 = 0.95$,in which Liquid limit and Liquidity index are in percent and UCS is in kPa, the coefficient of determination (R^2) of 95.0% for clayey soils of Diaspora, Bahir Dar.

6.3 Recommendation

The exposure in trying to conduct the research made it to review previous recommended topics in similar areas which makes the current research the extension of Fasil Abagena (2003), Investigation into some of the engineering properties of Red clay soils in Bahir Dar. During the work progress the research enlighten areas where further efforts might be added in the future.

1. It is recommended to carry out this correlation with a large number of samples including all areas that were not covered in the current research because of financial and time constraint.
2. It's advisable to conduct the research with triaxial test since it can work for all types of soils.
3. It is also recommended to carry out such a study in other parts of Ethiopia where there is mass construction in specific areas.

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APPENDICES

Appendix A: Natural moisture content test results

A1 Natural moisture content test result of TP 01 at D=1.5m

Container No	572	574
Mass of container ,g	35.5	36.5
Mass of container + wet soil ,g	137.5	137.5
Mass of container +dry soil ,g	111.1	110.8
Mass of water ,g	26.4	26.7
Mass of dry soil ,g	75.6	74.3
Water content ,%	34.92063	35.9354
Average water content , %	35.42802	

A2 Natural moisture content test result of TP 02 at D=1.5m

Container No	830	932
Mass of container ,g	37	36.5
Mass of container + wet soil ,g	136.8	126.7
Mass of container +dry soil ,g	110	105.3
Mass of water ,g	26.8	21.4
Mass of dry soil ,g	73	68.8
Water content ,%	36.71233	31.10465
Average water content , %	33.90849	

A3 Natural moisture content test result of TP 03 at D=1.5m

Container No	27	A1
Mass of container ,g	37.5	36.5
Mass of container + wet soil ,g	147.9	137.5
Mass of container +dry soil ,g	122.6	110.8
Mass of water ,g	25.3	26.7
Mass of dry soil ,g	85.1	74.3
Water content ,%	29.72973	30.36342
Average water content , %	30.04658	

A4 Natural moisture content test result of TP 04 at D=1.5m

Container No	572	666
Mass of container ,g	35.5	36.5
Mass of container + wet soil ,g	136.5	137.5
Mass of container +dry soil ,g	113	110.8
Mass of water ,g	23.5	26.7
Mass of dry soil ,g	77.5	74.3
Water content ,%	30.32258	29.55975
Average water content , %	29.94116	

A5 Natural moisture content test result of TP 05 at D=1.5m

Container No	A3	N
Mass of container ,g	37.5	37
Mass of container + wet soil ,g	139.8	145.7
Mass of container +dry soil ,g	113.5	120.5
Mass of water ,g	26.3	25.2
Mass of dry soil ,g	76	83.5
Water content ,%	34.60526	30.17964
Average water content , %	32.39245	

A6 Natural moisture content test result of TP 06 at D=1.5m

Container No	90	H-25
Mass of container ,g	36.5	31.5
Mass of container + wet soil ,g	131.9	120.9
Mass of container +dry soil ,g	110.4	98.5
Mass of water ,g	21.5	22.4
Mass of dry soil ,g	73.9	67
Water content ,%	29.09337	33.43284
Average water content , %	31.2631	

A7 Natural moisture content test result of TP 07 at D=1.5m

Container No	9	B
Mass of container ,g	38	37
Mass of container + wet soil ,g	147.7	153.4
Mass of container +dry soil ,g	121.7	115.8
Mass of water ,g	26	37.6
Mass of dry soil ,g	83.7	70.6
Water content ,%	32.12	35.533
Average water content , %	31.59	

A8 Natural moisture content test result of TP 08 at D=1.5m

Container No	821	572
Mass of container ,g	37.5	35.5
Mass of container + wet soil ,g	141.5	136.6
Mass of container +dry soil ,g	117.1	110.8
Mass of water ,g	24.4	25.8
Mass of dry soil ,g	79.6	75.3
Water content ,%	30.65327	34.26295
Average water content , %	32.45811	

A9 Natural moisture content test result of TP 09 at D=1.5m

Container No	575	566
Mass of container ,g	36.5	36.5
Mass of container + wet soil ,g	141.9	137.5
Mass of container +dry soil ,g	116.9	110.8
Mass of water ,g	25	26.7
Mass of dry soil ,g	80.4	74.3
Water content ,%	31.09453	35.48387
Average water content , %	33.2892	

A10 Natural moisture content test result of TP 10 at D=1.5m

Container No	574	938
Mass of container ,g	36.5	36.5
Mass of container + wet soil ,g	137.9	140.5
Mass of container +dry soil ,g	114	116
Mass of water ,g	23.9	24.5
Mass of dry soil ,g	77.5	79.5
Water content ,%	30.8387	30.8176
Average water content , %	30.8282	

A11 Natural moisture content test result of TP 11 at D=1.5m

Container No	988	939
Mass of container ,g	36.5	36
Mass of container + wet soil ,g	140.5	139.6
Mass of container +dry soil ,g	113.8	114.5
Mass of water ,g	26.7	25.1
Mass of dry soil ,g	77.3	78.5
Water content ,%	34.54075	31.9442
Average water content , %	33.25764	

A12 Natural moisture content test result of TP 12 at D=1.5m

Container No	948	503
Mass of container ,g	36.5	34.5
Mass of container + wet soil ,g	147.71	135.4
Mass of container +dry soil ,g	121.2	110.2
Mass of water ,g	26.51	25.2
Mass of dry soil ,g	84.7	75.7
Water content ,%	31.2987	33.2893
Average water content , %	32.294	

A13 Natural moisture content test result of TP 13 at D=1.5m-11

Container No	985	90
Mass of container ,g	36.0	36.5
Mass of container + wet soil ,g	160.8	139.3
Mass of container +dry soil ,g	131.5	114.8
Mass of water ,g	29.3	24.5
Mass of dry soil ,g	95.5	78.3
Water content ,%	30.68063	31.28991
Average water content , %	30.98527	

A14 Natural moisture content test result of TP 14 at D=1.5m

Container No	577	999
Mass of container ,g	37.0	37.0
Mass of container + wet soil ,g	126.4	135.6
Mass of container +dry soil ,g	105.8	111.1
Mass of water ,g	20.6	24.5
Mass of dry soil ,g	68.8	74.1
Water content ,%	29.94186	33.06343
Average water content , %	31.50264	

A15 Natural moisture content test result of TP 15 at D=1.5m

Container No	666	21
Mass of container ,g	37.5	37.5
Mass of container + wet soil ,g	127.5	157
Mass of container +dry soil ,g	104.3	129.17
Mass of water ,g	23.2	24.4
Mass of dry soil ,g	66.8	91.67
Water content ,%	34.7305	30.3589
Average water content , %	32.54	

A16 Natural moisture content test result of TP 16 at D=1.5m

Container No	503	572
Mass of container ,g	34.5	35.5
Mass of container + wet soil ,g	139.5	139.6
Mass of container +dry soil ,g	115.2	112.8
Mass of water ,g	24.5	26.8
Mass of dry soil ,g	80.7	77.3
Water content ,%	30.11152	34.67012
Average water content , %	32.39082	

A17 Natural moisture content test result of TP 17 at D=1.5m

Container No	45	938
Mass of container ,g	36.0	36.5
Mass of container + wet soil ,g	128.1	131.5
Mass of container +dry soil ,g	103.80	107.1
Mass of water ,g	24.3	24.4
Mass of dry soil ,g	67.8	70.6
Water content ,%	35.84071	34.84071
Average water content , %	35.20081	

A18 Natural moisture content test result of TP 18 at D=1.5m

Container No	992	948
Mass of container ,g	35.5	36.5
Mass of container + wet soil ,g	155.5	139.5
Mass of container +dry soil ,g	127.8	113.1
Mass of water ,g	27.2	26.4
Mass of dry soil ,g	92.3	76.6
Water content ,%	30.0108	34.4648
Average water content , %	32.23	

A19 Natural moisture content test result of TP 19 at D=1.5m

Container No	N-N	570
Mass of container ,g	38.2	36.5
Mass of container + wet soil ,g	144.7	131.5
Mass of container +dry soil ,g	118.7	125.6
Mass of water ,g	26	5.9
Mass of dry soil ,g	80.5	89.1
Water content ,%	32.29814	28.71737
Average water content , %	30.50775	

A20 Natural moisture content test result of TP 20 at D=1.5m

Container No	984	B
Mass of container ,g	36.5	37
Mass of container + wet soil ,g	141.2	138.6
Mass of container +dry soil ,g	117.6	114.2
Mass of water ,g	23.6	24.4
Mass of dry soil ,g	81.1	77.2
Water content ,%	29.09988	31.60622
Average water content , %	30.35305	

A21 Natural moisture content test result of TP 21 at D=1.5m

Container No	938	992
Mass of container ,g	36.5	35.5
Mass of container + wet soil ,g	146.5	124.1
Mass of container +dry soil ,g	116.7	102.6
Mass of water ,g	29.8	21.5
Mass of dry soil ,g	80.2	67.1
Water content ,%	37.15711	32.04176
Average water content , %	34.59942	

A22 Natural moisture content test result of TP 22 at D=1.5m

Container No	930	43
Mass of container ,g	35.5	39
Mass of container + wet soil ,g	137.5	143
Mass of container +dry soil ,g	111.1	117.4
Mass of water ,g	26.4	25.6
Mass of dry soil ,g	75.6	78.4
Water content ,%	35.53299	32.65306
Average water content , %	34.09393	

A23 Natural moisture content test result of TP 23 at D=1.5m

Container No	996	931
Mass of container ,g	36.1	36.5
Mass of container + wet soil ,g	140.8	150.8
Mass of container +dry soil ,g	116.3	124.7
Mass of water ,g	24.5	26.1
Mass of dry soil ,g	80.2	88.2
Water content ,%	30.54863	29.45824
Average water content , %	30.0034	

A24 Natural moisture content test result of TP 24 at D=1.5m

Container No	B1	28
Mass of container ,g	38.5	37.31
Mass of container + wet soil ,g	151.1	152.11
Mass of container +dry soil ,g	125.7	126.7
Mass of water ,g	25.4	25.4
Mass of dry soil ,g	87.2	89.39
Water content ,%	29.12844	28.426
Average water content , %	28.77722	

A25 Natural moisture content test result of TP 25 at D=1.5m

Container No	A	939
Mass of container ,g	36.5	36.5
Mass of container + wet soil ,g	133.9	138.5
Mass of container +dry soil ,g	112.4	115.6
Mass of water ,g	21.5	22.9
Mass of dry soil ,g	75.9	79.1
Water content ,%	28.32675	28.76884
Average water content , %	28.54779	

Appendix B: Specific gravity test results

B-1 Specific gravity test result of TP-01 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer, soil and water in (gm), (wb)	158.9	172.6
Mass of pycnometer and water in (gm),	165.24	178.96
$T^o c$	27	27
Relative density of water at $20^o c$	0.99823	0.99823
Relative density of water at $27^o c$	0.99645	0.99645
Correction factor (K)	0.99822	0.99822
Gs at $T^o c$	2.73	2.75
Gs at $20^o c$	2.73	2.74
Average Gs at $20^o c$	2.73	

B-2 Specific gravity test result of TP-02 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	171.9	172.6
Mass of pycnometer and water in (gm),	178.3	178.96
$T^o c$	27	27
Relative density of water at $20^o c$	0.99823	0.99823
Relative density of water at $27^o c$	0.99645	0.99645
Correction factor (K)	0.99822	0.99822
Gs at $T^o c$	2.78	2.77
Gs at $20^o c$	2.77	2.79
Average Gs at $20^o c$	2.78	

B-3 Specific gravity test result of TP-03 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	165.5	166.7
Mass of pycnometer and water in (gm),	171.86	173.11
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.75	2.79
Gs at 20^{o}c	2.74	2.78
Average Gs at 20^{o}c	2.76	

B-4 Specific gravity test result of TP-04 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	158.1	173
Mass of pycnometer and water in (gm),	164.52	179.41
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.79	2.79
Gs at 20^{o}c	2.79	2.78
Average Gs at 20^{o}c	2.79	

B-5 Specific gravity test result of TP-05 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	160.9	157.4
Mass of pycnometer and water in (gm),	167.31	163.87
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.79	2.83
Gs at 20^{o}c	2.78	2.83
Average Gs at 20^{o}c	2.80	

B-6 Specific gravity test result of TP-06 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	172.1	171.9
Mass of pycnometer and water in (gm),	178.5	178.31
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.78	2.79
Gs at 20^{o}c	2.77	2.78
Average Gs at 20^{o}c	2.78	

B-7 Specific gravity test result of TP-07 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	173.6	172.6
Mass of pycnometer and water in (gm),	179.98	178.96
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.76	2.78
Gs at 20^{o}c	2.76	2.77
Average Gs at 20^{o}c	2.77	

B-8 Specific gravity test result of TP-08 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	166.7	165.6
Mass of pycnometer and water in (gm),	173	171.96
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.70	2.75
Gs at 20^{o}c	2.70	2.74
Average Gs at 20^{o}c	2.72	

B-9 Specific gravity test result of TP-09 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	159.5	159.8
Mass of pycnometer and water in (gm),	165.89	166.24
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.77	2.81
Gs at 20^{o}c	2.77	2.80
Average Gs at 20^{o}c	2.78	

B-10 Specific gravity test result of TP-10 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	172	159.8
Mass of pycnometer and water in (gm),	178.4	166.24
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.78	2.73
Gs at 20^{o}c	2.77	2.73
Average Gs at 20^{o}c	2.75	

B-11 Specific gravity test result of TP-11 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	172.6	172.6
Mass of pycnometer and water in (gm),	179	178.96
T°c	27	27
Relative density of water at 20°c	0.99645	0.99645
Relative density of water at 27°c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T°c	2.78	2.79
Gs at 20°c	2.77	2.78
Average Gs at 20°c	2.78	

B-12 Specific gravity test result of TP-11 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	158.9	172.6
Mass of pycnometer and water in (gm),	165.24	178.96
T°c	27	27
Relative density of water at 20°c	0.99645	0.99645
Relative density of water at 27°c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T°c	2.73	2.75
Gs at 20°c	2.73	2.74
Average Gs at 20°c	2.73	

B-13 Specific gravity test result of TP-12 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	171.6	170
Mass of pycnometer and water in (gm),	178	176.45
T^oc	27	27
Relative density of water at 20^oc	0.99645	0.99645
Relative density of water at 27^oc	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^oc	2.78	2.82
Gs at 20^oc	2.77	2.81
Average Gs at 20^oc	2.79	

B-14 Specific gravity test result of TP-13 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	173.1	158.1
Mass of pycnometer and water in (gm),	179.5	164.5
T^oc	27	27
Relative density of water at 20^oc	0.99645	0.99645
Relative density of water at 27^oc	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^oc	2.78	2.78
Gs at 20^oc	2.77	2.77
Average Gs at 20^oc	2.77	

B-15 Specific gravity test result of TP-14 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	164.3	164.8
Mass of pycnometer and water in (gm),	170.6	171.1
T°c	27	27
Relative density of water at 20°c	0.99645	0.99645
Relative density of water at 27°c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T°c	2.70	2.70
Gs at 20°c	2.70	2.70
Average Gs at 20°c	2.70	

B-16 Specific gravity test result of TP-15 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	159.4	157.6
Mass of pycnometer and water in (gm),	165.7	163.94
T°c	27	27
Relative density of water at 20°c	0.99645	0.99645
Relative density of water at 27°c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T°c	2.70	2.73
Gs at 20°c	2.70	2.73
Average Gs at 20°c	2.71	

B-17 Specific gravity test result of TP-16 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	170.9	159.4
Mass of pycnometer and water in (gm),	177.23	165.69
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.72	2.70
Gs at 20^{o}c	2.72	2.69
Average Gs at 20^{o}c	2.71	

B-18 Specific gravity test result of TP-17 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	170.5	158.7
Mass of pycnometer and water in (gm),	176.88	165.1
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.76	2.78
Gs at 20^{o}c	2.76	2.77
Average Gs at 20^{o}c	2.77	

B-19 Specific gravity test result of TP-18 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	158.9	172.6
Mass of pycnometer and water in (gm),	165.24	178.96
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.73	2.75
Gs at 20^{o}c	2.73	2.74
Average Gs at 20^{o}c	2.73	

B-20 Specific gravity test result of TP-19 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	158.9	172.6
Mass of pycnometer and water in (gm),	165.24	178.96
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.73	2.75
Gs at 20^{o}c	2.73	2.74
Average Gs at 20^{o}c	2.71	

B-21 Specific gravity test result of TP-19 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	172.6	178.96
Mass of pycnometer and water in (gm),	158.75	165.24
T^oc	27	27
Relative density of water at 20^oc	0.99823	0.99823
Relative density of water at 27^oc	0.99645	0.99645
Correction factor (K)	0.99822	0.99822
Gs at T^oc	2.85	2.75
Gs at 20^oc	2.84	2.74
Average Gs at 20^oc	2.79	

B-22 Specific gravity test result of TP-19 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	177.8	180.0
Mass of pycnometer and water in (gm),	171.6	173.5
T^oc	27	27
Relative density of water at 20^oc	0.99645	0.99645
Relative density of water at 27^oc	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^oc	2.63	2.86
Gs at 20^oc	2.63	2.85
Average Gs at 20^oc	2.74	

B-23 Specific gravity test result of TP-19 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	171.86	173.11
Mass of pycnometer and water in (gm),	165.6	166.7
T^oc	27	27
Relative density of water at 20^oc	0.99645	0.99645
Relative density of water at 27^oc	0.99645	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^oc	2.67	2.79
Gs at 20^oc	2.67	2.78
Average Gs at 20^oc	2.72	

B-24 Specific gravity test result of TP-19 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	164.52	179.51
Mass of pycnometer and water in (gm),	158.4	172.9
T^oc	27	27
Relative density of water at 20^oc	0.99645	0.99645
Relative density of water at 27^oc	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^oc	2.58	2.95
Gs at 20^oc	2.57	2.94
Average Gs at 20^oc	2.76	

B-25 Specific gravity test result of TP-19 at D=1.5m

Density bottle number	10	16
Mass of oven dry sample in (gm),(wo)	10	10
Mass of pycnometer,soil and water in (gm), (wb)	164.52	179.41
Mass of pycnometer and water in (gm),	158.2	173.0
T^{o}c	27	27
Relative density of water at 20^{o}c	0.99645	0.99645
Relative density of water at 27^{o}c	0.99823	0.99823
Correction factor (K)	0.99822	0.99822
Gs at T^{o}c	2.72	2.79
Gs at 20^{o}c	2.71	2.78
Average Gs at 20^{o}c	2.75	

Appendix C: Liquid Limit and Plastic Limit test results

C1 Liquid limit and plastic limit test result of TP 23 at D=1.5 m

			Liquid limit		plastic limit
Container No	ZA	20	985	A-7	M1
Mass of container, g	36.20	36.10	36.20	37.50	37.00
Mass of container + Wet soil, g	61.50	61.50	60.50	51.24	50.09
Mass of container + Dry soil, g	53.00	51.80	51.70	48.00	46.11
Mass of water, g	9.70	8.80	12.10	3.24	3.98
Mass of dry soil, g	15.60	15.60	14.10	10.50	9.11
Water content, %	62.18	56.41	85.82	30.86	43.69
No of blows	29	27	18		
Liquid Limit, %	67				
Plastic Limit, %	37				
PI, %	30				

		Liquid Limit		Plastic Limit	
Trial No	1	2	3	1	2
Container No	988	939	B1	ZZ1	A3
Mass of container, g	36.50	38.20	36.50	36.30	35.80
Mass of container + Wet soil, g	61.60	65.70	67.40	53.87	53.78
Mass of container + Dry soil, g	52.00	54.80	55.30	49.46	49.57
Mass of water, g	9.60	10.90	12.10	4.41	4.21
Mass of dry soil, g	15.50	16.60	18.80	13.16	13.77
Water content, %	61.94	65.66	64.36	33.51	30.57

No of blows	30	24	15
Liquid Limit, %	64		
Plastic Limit, %	32		
PI, %	32		

C3 Liquid limit and plastic limit test result of TP 24 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	AZ	9	930	A3	H
Mass of container, g	35.90	36.10	36.10	36.00	36.00
Mass of container + Wet soil, g	61.40	61.60	62.00	58.20	58.60
Mass of container + Dry soil, g	53.40	53.20	52.40	53.80	53.90
Mass of water, g	8.00	8.40	9.60	4.40	4.70
Mass of dry soil, g	17.50	17.10	16.30	17.80	17.90
Water content, %	45.71	49.12	58.90	24.72	26.26
No of blows	34	28	24		
Liquid Limit, %	55.9				
Plastic Limit, %	25				
PI, %	30.9				

C4 Liquid limit and plastic limit test result of TP 01 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	988	575	53	984	574
Mass of container, g	36.00	35.50	36.70	37.20	36.00

Mass of container + Wet soil, g	58.20	59.50	63.20	48.10	47.70
Mass of container + Dry soil, g	50.80	51.20	53.70	46.10	45.30
Mass of water, g	7.40	8.30	9.50	2.00	2.40
Mass of dry soil, g	14.80	15.70	17.00	8.90	9.30
Water content, %	50.00	52.87	55.88	22.47	25.81
No of blows	35	30	24		
Liquid Limit, %	55				
Plastic Limit, %	24				
PI, %	31				

C5 Liquid limit and plastic limit test result of TP 22 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	27	B-52	B-13	573	53
Mass of container, g	36.00	36.50	36.50	36.50	35.90
Mass of container + Wet soil, g	50.24	53.13	51.56	64.60	63.30
Mass of container + Dry soil, g	44.94	46.72	45.47	58.30	57.10
Mass of water, g	5.30	6.41	6.09	6.30	6.20
Mass of dry soil, g	8.94	10.22	8.97	21.80	21.20
Water content, %	59.28	62.72	67.89	28.90	29.25
No of blows	30	24	17		
Liquid Limit, %	62				
Plastic Limit, %	29				
PI, %	33				

C6 Liquid limit and plastic limit test result of TP 08 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2

Container No	988	575	53	984	574
Mass of container, g	36.00	37.70	37.90	36.40	36.00
Mass of container + Wet soil, g	64.70	67.10	65.70	54.00	52.50
Mass of container + Dry soil, g	54.70	56.50	55.40	50.30	49.10
Mass of water, g	10.00	10.60	10.30	3.70	3.40
Mass of dry soil, g	18.70	18.80	17.50	13.90	13.10
Water content, %	53.48	56.38	58.86	26.62	25.95
No of blows	35	29	20		
Liquid Limit, %	57				
Plastic Limit, %	26				
PI, %	31				

C7 Liquid limit and plastic limit test result of TP 07 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	930	575	936	Z	ZA
Mass of container, g	37.20	37.60	36.70	36.30	36.10
Mass of container + Wet soil, g	64.40	68.70	68.60	51.96	49.90
Mass of container + Dry soil, g	54.70	57.40	55.90	48.30	47.10
Mass of water, g	9.70	11.30	12.70	3.66	2.80
Mass of dry soil, g	17.50	19.80	19.20	12.00	11.00
Water content, %	55.43	57.07	66.15	30.50	25.45
No of blows	32	27	17		
Liquid Limit, %	59%				
Plastic Limit, %	28%				
PI, %	31%				

C8 Liquid limit and plastic limit test result of TP 11 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	5	53	939	574	B-85
Mass of container, g	36.70	37.30	36.50	36.40	36.00
Mass of container + Wet soil, g	57.94	62.25	59.22	55.20	54.80
Mass of container + Dry soil, g	50.13	52.84	50.36	50.80	50.40
Mass of water, g	7.81	9.41	8.86	4.40	4.40
Mass of dry soil, g	13.43	15.54	13.86	14.40	14.40
Water content, %	58.15	60.55	63.92	30.56	30.56
No of blows	35	29	23	------	-----
Liquid Limit, %	63				
Plastic Limit, %	31				
PI, %	32				

C9 Liquid limit and plastic limit test result of TP 03 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	AZ	9	930	A3	H
Mass of container, g	35.90	37.50	38.20	37.40	38.00
Mass of container + Wet soil, g	62.80	63.00	65.20	56.22	55.310
Mass of container + Dry soil, g	51.90	53.70	55.00	51.50	51.10
Mass of water, g	10.90	9.30	10.20	4.72	4.21
Mass of dry soil, g	16.00	16.20	16.80	14.10	13.10
Water content, %	68.13	57.41	60.71	33.48	31.14

No of blows	28	22	15
Liquid Limit, %	64		
Plastic Limit, %	33		
PI, %	31		

C10 Liquid limit and plastic limit test result of TP 17 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	M3	H3	9	939	502
Mass of container, g	36.50	36.00	37.20	37.20	36.00
Mass of container + Wet soil, g	59.45	57.72	59.61	48.70	47.40
Mass of container + Dry soil, g	50.87	49.49	50.86	46.10	44.80
Mass of water, g	8.58	8.23	8.75	2.60	2.60
Mass of dry soil, g	14.37	13.49	13.66	8.90	8.80
Water content, %	59.71	61.01	64.06	29.21	29.55
No of blows	32	28	20		
Liquid Limit, %	62				
Plastic Limit, %	29				
PI, %	33				

C11 Liquid limit and plastic limit test result of TP 10 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	570	574	984	939	996

Mass of container, g	37.00	37.00	36.30	36.60	37.40
Mass of container + Wet soil, g	59.00	59.10	58.33	57.40	58.60
Mass of container + Dry soil, g	51.50	50.80	49.23	52.60	53.60
Mass of water, g	7.500	8.300	9.100	4.800	5.000
Mass of dry soil, g	14.50	13.80	13.20	16.00	16.20
Water content, %	51.72	60.14	68.94	30.00	30.86
No of blows	30	24	17		
Liquid Limit, %	63				
Plastic Limit, %	30				
PI, %	33				

C12 Liquid limit and plastic limit test result of TP 13 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	ZA	20	985	A-7	M1
Mass of container, g	36.50	36.50	36.00	37.00	36.00
Mass of container + Wet soil, g	55.03	52.36	62.91	41.84	39.90
Mass of container + Dry soil, g	48.14	46.32	52.30	40.84	39.00
Mass of water, g	6.89	6.04	10.61	1.00	0.90
Mass of dry soil, g	11.64	9.82	16.30	3.84	3.00
Water content, %	59.19	61.51	65.09	26.04	30.00
No of blows	30	23	17		
Liquid Limit, %	61				
Plastic Limit, %	28				
PI, %	33				

C13 Liquid limit and plastic limit test result of TP 23 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	MZ	A-135	931	N-N	B
Mass of container, g	36.20	38.20	36.80	37.40	37.40
Mass of container + Wet soil, g	62.90	64.20	62.00	52.75	51.20
Mass of container + Dry soil, g	53.30	54.70	52.60	49.65	48.40
Mass of water, g	9.60	9.50	9.40	3.10	2.80
Mass of dry soil, g	17.10	16.50	15.80	12.25	11.00
Water content, %	56.14	57.58	59.49	25.31	25.45
No of blows	29	23	18		
Liquid Limit, %	57				
Plastic Limit, %	25				
PI, %	32				

C14 Liquid limit and plastic limit test result of TP 12 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	29	931	566	988	578
Mass of container, g	37.60	36.10	36.20	35.70	37.10
Mass of container + Wet soil, g	62.40	62.50	63.30	52.70	53.30
Mass of container + Dry soil, g	53.40	52.80	53.20	48.90	49.80
Mass of water, g	9.00	9.70	10.10	3.80	3.50
Mass of dry soil, g	15.80	16.70	17.00	13.20	12.70
Water content, %	56.96	54.08	59.41	28.79	27.50
No of blows	35	28	25		
Liquid Limit, %	59				
Plastic Limit, %	28				
PI, %	31				

C15 Liquid limit and plastic limit test result of TP 09 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	985	984	570	821	578
Mass of container, g	36.00	36.50	36.10	37.60	37.10
Mass of container + Wet soil, g	58.00	58.60	58.40	58.40	55.90
Mass of container + Dry soil, g	50.50	50.30	49.30	53.30	51.40
Mass of water, g	7.50	8.30	9.10	5.10	4.50
Mass of dry soil, g	14.50	13.80	13.20	15.70	14.30
Water content, %	51.72	60.14	68.94	32.48	31.47
No of blows	35	28	20		
Liquid Limit, %	63				
Plastic Limit, %	32				
PI, %	31				

C16 Liquid limit and plastic limit test result of TP 04 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	502	N-N	ZZ1	821	578
Mass of container, g	36.20	38.20	36.80	35.80	36.20
Mass of container + Wet soil, g	62.90	64.20	62.00	58.30	58.80
Mass of container + Dry soil, g	53.30	54.70	52.60	53.60	54.10
Mass of water, g	9.60	9.50	9.40	4.70	4.70
Mass of dry soil, g	17.10	16.50	15.80	17.80	17.90
Water content, %	56.14	57.58	59.49	26.40	26.26

No of blows	29	23	18
Liquid Limit, %	57		
Plastic Limit, %	26		
PI, %	31		

C17 Liquid limit and plastic limit test result of TP 14 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	573	821	90	B-52	574
Mass of container, g	36.20	36.10	36.20	37.40	37.00
Mass of container + Wet soil, g	61.50	60.50	62.40	50.49	50.00
Mass of container + Dry soil, g	51.80	51.70	50.30	46.96	47.11
Mass of water, g	9.70	8.80	12.10	3.53	3.35
Mass of dry soil, g	15.60	15.60	14.10	9.56	9.61
Water content, %	62.18	56.41	85.85	36.92	34.86
No of blows	30	27	18		
Liquid Limit, %	67				
Plastic Limit, %	36				
PI, %	31				

C18 Liquid limit and plastic limit test result of TP 16 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	502	N-N	ZZ1	T1	A3

Mass of container, g	38.10	36.50	36.00	36.00	35.50
Mass of container + Wet soil, g	59.40	60.60	62.10	43.21	41.23
Mass of container + Dry soil, g	53.00	51.10	52.00	41.63	39.95
Mass of water, g	6.40	9.50	10.10	1.58	1.28
Mass of dry soil, g	14.90	14.60	16.00	5.63	4.45
Water content, %	42.95	65.07	63.13	28.06	28.76
No of blows	35	29	20		
Liquid Limit, %	60				
Plastic Limit, %	28				
PI, %	32				

C19 Liquid limit and plastic limit test result of TP 21 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	936	931	966	935	574
Mass of container, g	35.80	37.10	37.50	37.20	36.00
Mass of container + Wet soil, g	59.40	61.20	61.90	49.50	49.00
Mass of container + Dry soil, g	51.10	52.60	53.00	47.00	46.50
Mass of water, g	8.30	8.60	8.90	2.50	2.50
Mass of dry soil, g	15.30	15.50	15.50	9.80	10.50
Water content, %	54.25	55.48	57.42	25.51	23.81
No of blows	34	30	19		
Liquid Limit, %	56				
Plastic Limit, %	25				
PI, %	31				

C20 Liquid limit and plastic limit test result of TP 01 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	3	1.5
Container No	992	20	985	M3	821

Mass of container, g	30.20	36.10	36.00	36.00	37.20
Mass of container + Wet soil, g	53.10	61.50	64.30	48.50	51.00
Mass of container + Dry soil, g	45.40	52.50	54.00	49.00	48.20
Mass of water, g	7.70	9.00	10.30	2.50	2.80
Mass of dry soil, g	15.20	16.40	18.00	10.00	11.00
Water content, %	50.66	57.88	57.22	25.00	25.45
No of blows	34	28	22		
Liquid Limit, %	56				
Plastic Limit, %	25				
PI, %	31				

C21 Liquid limit and plastic limit test result of TP 03 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	B-85	999	934	930	502
Mass of container, g	36.00	35.80	35.60	36.90	36.90
Mass of container + Wet soil, g	60.80	60.30	61.00	54.19	56.88
Mass of container + Dry soil, g	51.50	50.60	50.90	49.75	51.64
Mass of water, g	9.30	9.70	10.10	4.44	5.24
Mass of dry soil, g	15.50	14.80	15.30	12.85	14.74
Water content, %	60.00	65.54	66.01	34.55	35.55
No of blows	34	29	23		
Liquid Limit, %	66				
Plastic Limit, %	35				
PI, %	31				

C23 Liquid limit and plastic limit test result of TP 05 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	988	G-3	ZZ1	575	B-13

Mass of container, g	36.50	36.50	37.10	38.20	31.30
Mass of container + Wet soil, g	58.70	60.50	63.60	52.40	45.00
Mass of container + Dry soil, g	51.30	52.20	54.10	49.70	42.30
Mass of water, g	7.40	8.30	9.50	2.70	2.70
Mass of dry soil, g	14.80	15.70	17.00	11.50	11.00
Water content, %	50.00	52.87	55.88	23.48	24.55
No of blows	35	30	24		
Liquid Limit, %	55				
Plastic Limit, %	24				
PI, %	31				

C24 Liquid limit and plastic limit test result of TP 06 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	948	936	570	90	H-25
Mass of container, g	37.50	37.30	36.00	36.40	36.00
Mass of container + Wet soil, g	60.70	61.70	60.40	50.31	48.44
Mass of container + Dry soil, g	52.90	53.30	51.60	47.64	46.07
Mass of water, g	7.80	8.40	8.80	2.67	2.37
Mass of dry soil, g	15.40	16.00	15.60	11.24	10.07
Water content, %	50.65	52.50	56.41	23.75	23.54
No of blows	35	30	20		
Liquid Limit, %	54				
Plastic Limit, %	24				
PI, %	30				

C25 Liquid limit and plastic limit test result of TP 02 at D=1.5 m

	Liquid Limit			Plastic Limit	
Trial No	1	2	3	1	2
Container No	923	934	507	B1	H-25
Mass of container, g	36.20	36.10	36.20	36.00	36.00
Mass of container + Wet soil, g	55.50	57.79	59.10	48.60	48.20

Mass of container + Dry soil, g	49.20	50.51	51.05	46.60	46.20
Mass of water, g	6.30	7.28	8.05	2.00	2.00
Mass of dry soil, g	13.00	14.41	14.85	10.60	10.20
Water content, %	48.46	50.52	54.21	18.87	19.61
No of blows	29	25	16		
Liquid Limit, %	50%				
Plastic Limit, %	19.2%				
PI, %	30.8%				

Appendix D Grain size analysis result

D1 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	334.6	339.2	0.0	0.0	0	100.0
No 8	2	318.5	319.4	0.5	0.05	0.05	99.95
No 10	1.18	280.6	283.1	1.2	0.12	0.17	99.83
No 16	0.6	276.1	279.7	3.6	0.36	0.53	99.47
No 30	0.475	380.1	382.1	2.0	0.20	0.73	99.27
No 50	0.3	261.6	264.8	3.1	0.31	1.04	98.96
No 100	0.15	266.5	274.7	8.2	0.82	1.26	98.14
No 200	0.075	263.2	271.1	4.5	0.45	1.71	97.69
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.032	0.001	1.031	7.8	0.02496	97.54	97.54
5	1.031	0.001	1.030	8.1	0.01609	94.40	94.40
15	1.031	0.001	1.030	8.1	0.00929	94.40	94.40
30	1.030	0.001	1.029	8.4	0.00669	91.25	91.25
60	1.029	0.001	1.028	8.6	0.00479	88.10	88.10
250	1.028	0.001	1.027	8.9	0.00238	84.96	84.96
1440	1.027	0.001	1.026	9.2	0.00101	81.81	81.81

D2 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	453.5	453.5	0.00	0.00	0.0	100.0
No 8	2	373.5	374.0	1.00	0.10	0.10	99.9

No 10	1.18	280.5	282.0	2.00	0.20	0.30	99.70
No 16	0.6	276.1	276.7	3.00	0.30	0.60	99.40
No 30	0.425	378.0	379.3	7.50	0.75	1.35	99.65
No 50	0.3	317.5	320.7	4.00	0.40	1.75	99.25
No 100	0.15	313.5	314.9	5.50	0.55	2.30	99.70
No 200	0.075	373.5	373.6	0.50	0.05	1.0	99.65
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.032	0.001	1.031	7.8	0.02496	97.54	95.25
5	1.031	0.001	1.030	8.1	0.01609	94.40	92.18
15	1.031	0.001	1.030	8.1	0.00929	94.40	92.18
30	1.030	0.001	1.029	8.4	0.00669	91.25	89.10
60	1.029	0.001	1.028	8.6	0.00479	88.10	86.03
250	1.028	0.001	1.027	8.9	0.00238	84.96	82.96
1440	1.027	0.001	1.026	9.2	0.00101	81.81	79.89

D3 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 8	2.36	334.6	334.6	0.0	0.0	0.0	100.0
No 10	2	318.5	319.4	0.8	0.08	0.08	99.92
No 16	1.18	280.6	283.1	0.3	0.03	0.11	99.89
No 30	0.6	276.1	279.7	1.5	0.15	0.26	99.74
	0.425	380.1	382.1	0.9	0.09	0.35	99.65
No 50	0.3	261.6	264.8	2.4	0.24	0.59	99.41
No 100	0.15	266.5	269.0	2.6	0.26	0.85	99.15
No 200	0.075	263.2	271.1	1.7	0.17	1.02	98.98
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer (%)	Percentage finer for combined analysis (%)
2	1.032	0.001	1.031	7.8	0.02496	98.47	97.47
5	1.032	0.001	1.031	7.8	0.01579	98.47	97.47
15	1.031	0.001	1.030	8.1	0.00929	95.29	94.33
30	1.031	0.001	1.030	8.1	0.00657	95.29	94.33
60	1.029	0.001	1.028	8.6	0.00479	88.94	88.04
250	1.028	0.001	1.027	8.9	0.00238	85.76	84.89
1440	1.027	0.001	1.026	9.2	0.00101	82.59	81.75

D4 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	453.5	453.5	0.00	0.00	0.00	100.0
No 8	2	373.5	374.5	0.90	0.09	0.09	99.91
No 10	1.18	280.2	282.9	1.50	0.15	0.24	99.76
No 16	0.6	377.5	381.4	0.60	0.06	0.30	99.70
No 30	0.425	377.5	381.7	2.30	0.23	0.53	99.47
No 50	0.3	317.0	318.3	3.20	0.32	0.85	99.15
No 100	0.15	312.0	313.2	1.40	0.14	0.99	99.01
No 200	0.075	373.0	373.1	0.1	0.01	1.00	99.00
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.032	0.001	1.031	7.8	0.02496	97.03	95.73
5	1.031	0.001	1.030	8.1	0.01609	93.90	92.64
15	1.030	0.001	1.029	8.4	0.00946	90.77	89.55
30	1.030	0.001	1.029	8.4	0.00669	90.77	89.55
60	1.029	0.001	1.028	8.6	0.00479	87.64	86.46
250	1.028	0.001	1.027	8.9	0.00238	84.51	83.38
1440	1.026	0.001	1.025	9.4	0.00102	78.25	77.20

D5 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	334.6	334.6	0.00	0.00	0.0	100.0
No 8	2	318.5	319.4	0.50	0.05	0.05	99.95
No 10	1.18	280.6	283.1	0.50	0.05	0.10	99.90
No 16	0.6	276.1	277.4	1.40	0.14	0.24	99.76
No 30	0.425	380.1	382.1	2.00	0.20	0.44	99.56
No 50	0.3	261.6	264.8	1.00	0.10	0.54	99.46
No 100	0.15	266.5	268.2	1.00	0.10	0.64	99.36
No 200	0.075	263.3	269.3	0.9	0.09	0.73	99.27
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.029	0.001	1.028	8.6	0.02621	88.75	88.10
5	1.028	0.001	1.027	8.9	0.01686	85.58	84.95
15	1.028	0.001	1.027	8.9	0.00974	85.58	84.95
30	1.027	0.001	1.026	9.2	0.00700	82.41	81.81

60	1.026	0.001	1.025	9.4	0.00500	79.24	78.66
250	1.025	0.001	1.024	9.7	0.00249	76.07	75.51
1440	1.023	0.001	1.022	10.2	0.00106	69.73	69.22

D6 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.1	0.00	0.0	0.0	100
No 8	2	374.0	374.9	0.30	0.03	0.03	99.97
No 10	1.18	280.6	281.1	0.40	0.04	0.07	99.93
No 16	0.6	276.1	277.2	3.60	0.36	0.43	99.57
No 30	0.425	377.8	379.1	2.70	0.27	0.70	99.30
No 50	0.3	317.5	318.1	1.20	0.12	0.82	99.18
No 100	0.15	312.4	314.2	1.60	0.16	0.98	99.02
No 200	0.075	373.2	374.7	0.20	0.02	1.00	99.00
Time (min)	**Actual reading**	**Composite correction**	**Corrected reading**	**Effective depth(cm)**	**Grain size(mm)**	**Percentage finer**	**Percentage finer for combined analysis**
2	1.03	0.001	0.031	7.8	0.02496	97.54	96.57
5	1.029	0.001	0.030	8.1	0.01609	94.40	93.45
15	1.028	0.001	0.029	8.4	0.00946	91.25	90.34
30	1.027	0.001	0.029	8.4	0.00669	91.25	90.34
60	1.026	0.001	0.028	8.6	0.00479	88.10	87.22
250	1.025	0.001	0.027	8.9	0.00238	84.96	84.11
1440	1.024	0.001	0.026	9.2	0.00101	81.81	80.99

D7 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	453.5	453.5	0.00	0.00	0.00	100.0
No 8	2	373.5	373.7	1.54	0.15	0.15	99.85
No 10	1.18	280.0	280.1	2.60	0.26	0.41	99.59
No 16	0.6	280.0	381.7	3.60	0.36	0.77	99.23
No 30	0.425	378.0	380.3	2.50	0.25	1.02	98.98
No 50	0.3	317.5	318.7	5.10	0.51	1.53	98.47
No 100	0.15	313.5	314.4	2.20	0.22	1.75	98.25
No 200	0.075	373.5	373.7	4.10	0.41	2.16	97.84

Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.031	0.001	1.030	8.1	0.02544	94.71	92.66
5	1.031	0.001	1.030	8.1	0.01609	94.40	92.35
15	1.030	0.001	1.029	8.4	0.00946	91.25	89.27
30	1.030	0.001	1.029	8.4	0.00669	91.25	89.27
60	1.029	0.001	1.028	8.6	0.00479	88.10	86.20
250	1.028	0.001	1.027	8.9	0.00238	84.96	83.12
1440	1.027	0.001	1.026	9.2	0.00101	81.81	80.04

D8 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	334.6	334.6	0.0	0.00	0.0	100.0
No 8	2	318.5	318.5	0.9	0.09	0.09	99.91
No 10	1.18	280.6	280.6	2.5	0.25	0.34	99.66
No 16	0.6	276.1	276.1	3.6	0.36	0.70	99.30
No 30	0.425	380.1	380.1	2.0	0.20	0.90	99.10
No 50	0.3	261.6	261.6	3.2	0.32	1.22	98.78
No 100	0.15	266.5	266.5	2.5	0.25	1.47	98.53
No 200	0.075	263.2	263.2	7.8	0.78	2.25	97.75
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.028	0.001	1.030	8.9	0.02666	84.68	82.78
5	1.028	0.001	1.029	8.9	0.01686	84.68	82.78
15	1.027	0.001	1.028	9.2	0.00990	81.55	79.81
30	1.026	0.001	1.027	9.4	0.00708	78.41	76.64
60	1.025	0.001	1.026	9.7	0.00508	75.27	73.58
250	1.024	0.001	1.026	10.0	0.00253	72.14	70.51
1440	1.023	0.001	1.025	10.2	0.00106	69.00	67.45

D9 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.2	0.0	0.0	0.0	100.0
No 8	2	374.0	374.2	1.2	0.12	0.12	99.88

No 10	1.18	280.6	280.9	1.5	0.15	0.27	99.73
No 16	0.6	271.6	272.2	2.1	0.21	0.48	99.52
No 30	0.425	377.8	378.9	3.3	0.33	0.81	99.19
No 50	0.3	317.5	318.8	1.9	0.19	1.00	99.00
No 100	0.15	312.4	315.3	3.6	0.36	1.36	98.64
No 200	0.075	373.2	373.9	0.9	0.09	1.45	98.55
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.031	0.001	1.030	8.1	0.02544	94.40	93.03
5	1.030	0.001	1.029	8.4	0.01638	91.25	89.93
15	1.029	0.001	1.028	8.6	0.00957	88.10	86.82
30	1.029	0.001	1.028	8.6	0.00677	88.10	86.82
60	1.028	0.001	1.027	8.9	0.00487	84.96	83.72
250	1.027	0.001	1.026	9.2	0.00242	81.81	80.62
1440	1.025	0.001	1.024	9.7	0.00104	75.52	74.42

D10 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.1	0.0	0.0	0.00	100.0
No 8	2	374.0	374.3	0.3	0.03	0.03	99.98
No 10	1.18	280.6	281.0	0.4	0.04	0.07	99.97
No 16	0.6	276.1	279.7	3.6	0.4	0.47	99.80
No 30	0.425	377.8	380.5	2.7	0.3	0.77	99.58
No 50	0.3	317.5	318.7	1.2	0.1	0.87	99.46
No 100	0.15	312.4	314.0	1.6	0.2	1.07	99.37
No 200	0.075	373.2	373.4	0.2	0.02	1.09	99.35
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.029	0.001	1.028	8.6	0.02621	87.46	86.89
5	1.028	0.001	1.027	8.9	0.01686	84.34	83.79
15	1.027	0.001	1.026	9.2	0.00990	81.21	80.68
30	1.026	0.001	1.025	9.4	0.00708	78.09	77.58
60	1.025	0.001	1.024	9.7	0.00508	74.97	74.48
250	1.024	0.001	1.023	10	0.00253	71.84	71.37
1440	1.022	0.001	1.021	10.5	0.00108	65.60	65.17

D11 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.1	0.0	0.0	0.0	100.0
No 8	2	374.0	374.2	0.9	0.09	0.09	99.91
No 10	1.18	280.6	281.0	2.5	0.25	0.34	99.66
No 16	0.6	276.1	276.9	1.3	0.13	0.47	99.53
No 30	0.425	377.8	378.7	2.0	0.20	0.67	99.33
No 50	0.3	317.5	318.3	3.2	0.32	0.99	99.01
No 100	0.15	312.4	313.8	1.7	0.17	0.16	98.84
No 200	0.075	373.2	373.4	6.0	0.60	0.76	98.24
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.031	0.001	1.030	8.1	0.02544	93.17	92.06
5	1.030	0.001	1.029	8.4	0.01638	90.58	88.99
15	1.029	0.001	1.028	8.6	0.00688	87.46	85.92
30	1.028	0.001	1.027	8.9	0.00495	84.34	82.85
60	1.027	0.001	1.026	9.2	0.00245	81.21	79.78
250	1.026	0.001	1.025	9.4	0.00245	78.09	76.72
1440	1.024	0.001	1.023	10	0.00105	71.84	70.58

D12 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retaine d soil	Mass of Retained soil	Percentag e Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.1	0.0	0.0	0.0	100.0
No 8	2	374.0	374.2	0.2	0.02	0.02	99.98
No 10	1.18	280.6	282.1	0.3	0.03	0.05	99.95
No 16	0.6	271.6	273.7	0.6	0.06	0.11	99.89
No 30	0.425	377.8	381.1	1.1	0.11	0.22	99.78
No 50	0.3	317.5	319.4	1.3	0.13	0.35	99.65
No 100	0.15	312.4	316.6	2.9	0.29	0.64	99.36
No 200	0.075	373.2	374.1	0.7	0.07	0.71	99.29
Time (min)	Actual reading	Composite correction	Correct ed reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.031	0.001	1.030	8.1	0.02544	94.40	93.73
5	1.031	0.001	1.030	8.1	0.01609	94.40	93.73

15	1.030	0.001	1.029	8.4	0.00946	91.25	90.60
30	1.030	0.001	1.029	8.4	0.00669	89.68	89.04
60	1.029	0.001	1.028	8.9	0.00478	88.10	87.48
250	1.028	0.001	1.027	9.2	0.00242	84.96	84.35
1440	1.027	0.001	1.026	9.4	0.00102	80.24	79.67

D13 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentag e Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.1	0.00	0.00	0.00	100.00
No 8	2	374.0	374.4	0.90	0.09	0.09	99.91
No 10	1.18	280.6	381.3	0.50	0.05	0.14	99.86
No 16	0.6	276.1	276.9	1.10	0.11	0.25	99.75
No 30	0.425	377.8	380.2	1.30	0.13	0.38	99.62
No 50	0.3	317.5	319.2	0.60	0.06	0.44	99.56
No 100	0.15	312.4	316.3	1.80	0.18	0.62	99.38
No 200	0.075	373.2	374.0	1.50	0.15	0.77	99.23
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.030	0.001	1.029	8.9	0.02590	91.25	90.55
5	1.029	0.001	1.028	9.2	0.01658	88.10	87.42
15	1.028	0.001	1.027	9.2	0.00974	84.96	84.30
30	1.027	0.001	1.026	9.4	0.00700	81.81	81.81
60	1.026	0.001	1.025	9.7	0.00500	78.66	78.93
250	1.025	0.001	1.024	10.0	0.00249	75.52	74.93
1440	1.024	0.001	1.023	10.5	0.00105	72.37	71.81

D14 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.2	0.0	0.0	0.0	100.0
No 8	2	374.0	374.2	1.2	0.12	0.12	99.88
No 10	1.18	280.6	280.9	1.5	0.15	0.27	99.73
No 16	0.6	271.6	272.2	2.1	0.21	0.48	99.52
No 30	0.425	377.8	378.9	3.3	0.33	0.81	99.19
No 50	0.3	317.5	318.8	1.9	0.19	1.00	99.00
No 100	0.15	312.4	315.3	3.6	0.36	1.36	98.64

No 200	0.075	373.2	373.9	0.9	0.09	1.45	98.55
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.031	0.001	1.030	8.1	0.02544	94.40	93.03
5	1.030	0.001	1.029	8.4	0.01638	91.25	89.93
15	1.029	0.001	1.028	8.6	0.00957	88.10	86.82
30	1.029	0.001	1.028	8.6	0.00677	88.10	86.82
60	1.028	0.001	1.027	8.9	0.00487	84.96	83.72
250	1.027	0.001	1.026	9.2	0.00242	81.81	80.62
1440	1.025	0.001	1.024	9.7	0.00104	75.52	74.42

D15 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentag e Retained	Cumulative Percentage Retained	Percentage finer
No 8	2.36	334.6	339.2	0	0.0	0.0	100.0
No 10	2	318.5	319.4	0.9	0.09	0.09	99.91
No 16	1.18	280.6	282.9	2.3	0.23	0.32	99.68
No 30	0.6	276.1	279.3	3.2	0.32	0.64	99.36
No	0.425	380.1	382.2	2.1	0.21	0.85	99.15
No 50	0.3	261.6	264.8	3.2	0.32	1.17	98.83
No 100	0.15	266.5	276.0	9.5	0.95	2.12	97.88
No 200	0.075	263.2	270.9	7.6	0.76	2.89	97.12
Time (min)	Actual Hyd. reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.030	0.001	1.029	8.4	0.02590	93.15	90.47
5	1.030	0.001	1.029	8.4	0.01638	93.15	90.47
15	1.029	0.001	1.028	8.6	0.00957	89.94	87.35
30	1.029	0.001	1.028	8.6	0.00677	89.94	87.35
60	1.028	0.001	1.027	8.9	0.00487	86.73	84.35
250	1.027	0.001	1.026	9.2	0.00242	83.52	81.11
1440	1.025	0.001	1.024	9.7	0.00104	77.09	74.87

D16 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	334.6	334.6	0.00	0.00	0.00	100.0
No 8	2	318.5	318.7	1.01	0.10	0.10	99.90
No 10	1.18	280.6	281.6	2.65	0.27	0.37	99.63

No 16	0.6	276.1	278.8	3.89	0.39	0.76	99.25
No 30	0.425	380.1	384.0	4.20	0.42	1.18	98.83
No 50	0.3	261.6	265.8	1.30	0.13	2.31	98.70
No 100	0.15	266.5	267.8	1.20	0.12	2.43	98.58
No 200	0.075	2633	264.5	0.10	0.01	2.44	98.57
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.030	0.001	1.029	8.4	0.02590	90.40	89.10
5	1.029	0.001	1.028	8.6	0.01658	87.28	86.02
15	1.028	0.001	1.027	8.9	0.00974	84.17	82.95
30	1.028	0.001	1.027	8.9	0.00688	84.17	82.95
60	1.027	0.001	1.026	9.2	0.00495	81.05	79.88
250	1.026	0.001	1.025	9.4	0.00245	77.93	76.81
1440	1.024	0.001	1.023	10.0	0.00105	71.70	70.66

D17 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	453.5	453.5	0.0	0.0	0.0	100
No 8	2	373.5	375.5	1.54	0.2	0.2	99.8
No 10	1.18	280.5	283.1	2.6	0.3	0.5	99.6
No 16	0.6	276.1	279.7	3.6	0.4	0.9	99.2
No 30	0.425	378.0	380.5	2.5	0.3	1.2	99.0
No 50	0.3	317.5	322.6	5.1	0.5	1.7	98.5
No 100	0.15	313.5	315.7	2.2	0.2	1.9	98.2
No 200	0.075	373.5	377.6	4.1	0.4	2.3	97.8
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.032	0.001	1.031	7.8	0.02496	97.54	96.83
5	1.032	0.001	1.031	7.8	0.01579	97.54	96.83
15	1.031	0.001	1.030	8.1	0.00929	94.40	93.71
30	1.030	0.001	1.029	8.4	0.00669	91.25	90.58
60	1.030	0.001	1.029	8.4	0.00473	91.25	90.58
250	1.028	0.001	1.027	8.9	0.00238	84.96	84.34
1440	1.027	0.001	1.026	9.2	0.00101	81.81	81.21

D18 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.1	0.00	0.00	0.00	100.00
No 8	2	374.0	374.4	0.90	0.09	0.09	99.91
No 10	1.18	280.6	381.3	0.50	0.05	0.14	99.86
No 16	0.6	276.1	276.9	1.10	0.11	0.25	99.75
No 30	0.425	377.8	380.2	1.30	0.13	0.38	99.62
No 50	0.3	317.5	319.2	0.60	0.06	0.44	99.56
No 100	0.15	312.4	316.3	1.80	0.18	0.62	99.38
No 200	0.075	373.2	374.0	1.50	0.15	0.77	99.23
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.030	0.001	1.029	8.9	0.02590	91.25	90.55
5	1.029	0.001	1.028	9.2	0.01658	88.10	87.42
15	1.028	0.001	1.027	9.2	0.00974	84.96	84.30
30	1.027	0.001	1.026	9.4	0.00700	81.81	81.81
60	1.026	0.001	1.025	9.7	0.00500	78.66	78.93
250	1.025	0.001	1.024	10.0	0.00249	75.52	74.93
1440	1.024	0.001	1.023	10.5	0.00105	72.37	71.81

D19 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	453.5	453.5	0.00	0.00	0.00	100.0
No 8	2	373.5	374.0	0.50	0.05	0.05	99.95
No 10	1.18	280.5	281.5	2.50	0.25	0.30	99.70
No 16	0.6	276.1	277.0	3.60	0.36	0.66	99.34
No 30	0.425	378.0	381.5	2.00	0.20	0.86	99.14
No 50	0.3	317.5	320.0	3.20	0.32	1.18	98.82
No 100	0.15	313.5	318.0	8.20	0.82	2.00	98.00
No 200	0.075	373.5	374.0	7.80	0.78	2.78	97.22
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.030	0.001	1.029	8.4	0.02590	91.25	88.71

5	1.029	0.001	1.028	8.6	0.01658	88.10	85.65
15	1.029	0.001	1.028	8.6	0.00957	88.10	85.65
30	1.028	0.001	1.027	8.9	0.00688	84.96	82.59
60	1.027	0.001	1.026	9.2	0.00495	81.81	79.54
250	1.026	0.001	1.025	9.4	0.00245	78.66	76.48
1440	1.025	0.001	1.024	9.7	0.00104	75.52	73.42

D20 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	453.5	453.5	0.0	0.0	0.0	100.0
No 8	2	373.5	374.0	0.9	0.1	0.1	99.90
No 10	1.18	280.5	282.0	1.5	0.2	0.3	99.80
No 16	0.6	276.1	276.7	0.6	0.1	0.4	99.70
No 30	0.425	378.0	379.3	2.3	0.2	0.6	99.50
No 50	0.3	317.5	320.7	3.2	0.3	0.9	99.20
No 100	0.15	313.5	314.9	1.4	0.1	1.0	99.00
No 200	0.075	373.5	373.6	0.1	0.01	1.01	99.00
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.029	0.001	1.028	8.6	0.02621	87.46	86.21
5	1.029	0.001	1.028	8.6	0.01658	87.46	86.21
15	1.028	0.001	1.027	8.9	0.00974	84.34	83.13
30	1.027	0.001	1.026	9.2	0.00700	81.21	80.05
60	1.026	0.001	1.025	9.4	0.00500	78.09	76.97
250	1.026	0.001	1.025	9.4	0.00245	78.09	76.97
1440	1.024	0.001	1.023	10	0.00105	71.84	70.81

D21 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	453.5	453.5	0.00	0.0	0.0	100.00
No 8	2	373.5	374.0	0.90	0.1	0.1	100.91
No 10	1.18	280.5	281.0	2.50	0.1	0.2	99.66

No 16	0.6	378.0	379.4	3.60	0.1	0.3	99.30
No 30	0.425	370.0	380.0	2.00	0.2	0.5	99.10
No 50	0.3	317.5	318.5	3.20	0.1	0.6	99.78
No 100	0.15	313.5	314.5	9.10	0.1	0.7	99.87
No 200	0.075	373.5	374.4	7.80	0.1	0.8	99.09
Time (mm)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.032	0.001	1.031	7.8	0.02496	97.54	94.70
5	1.031	0.001	1.030	8.1	0.01609	94.40	91.65
15	1.030	0.001	1.029	8.4	0.00946	91.25	88.59
30	1.029	0.001	1.028	8.6	0.00677	88.10	85.54
60	1.029	0.001	1.028	8.6	0.00479	88.10	85.54
250	1.028	0.001	1.027	8.9	0.00238	84.96	82.48
1440	1.027	0.001	1.026	9.2	0.00101	81.81	79.43

D22 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.1	0.00	0.00	0.0	100.0
No 8	2	374.0	374.2	0.21	0.02	0.02	99.98
No 10	1.18	280.6	281.0	1.01	0.10	0.12	99.88
No 16	0.6	276.1	276.6	2.65	0.27	0.39	99.61
No 30	0.425	377.8	379.0	3.89	0.39	0.78	99.22
No 50	0.3	317.5	319.0	4.20	0.42	0.10	98.80
No 100	0.15	312.4	315.1	1.30	0.13	0.23	98.67
No 200	0.075	373.2	374.0	1.20	0.12	0.35	98.55
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.030	0.001	1.029	8.4	0.02590	90.40	89.10
5	1.029	0.001	1.028	8.6	0.01658	87.28	86.02
15	1.028	0.001	1.027	8.9	0.00974	84.17	82.95
30	1.028	0.001	1.027	8.9	0.00688	84.17	82.95
60	1.027	0.001	1.026	9.2	0.00495	81.05	79.88
250	1.026	0.001	1.025	9.4	0.00245	77.93	76.81
1440	1.024	0.001	1.023	10.0	0.00105	71.70	70.66

D23 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	454.1	454.1	0.0	0.0	0.0	100.0
No 8	2	374.0	374.2	0.9	0.09	0.09	99.91
No 10	1.18	280.6	281.0	2.5	0.25	0.34	99.66
No 16	0.6	276.1	276.9	1.3	0.13	0.47	99.53
No 30	0.425	377.8	378.7	2.0	0.20	0.67	99.33
No 50	0.3	317.5	318.3	3.2	0.32	0.99	99.01
No 100	0.15	312.4	313.8	1.7	0.17	0.16	98.84
No 200	0.075	373.2	373.4	6.0	0.60	0.76	98.24
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.031	0.001	1.030	8.1	0.02544	93.17	92.06
5	1.030	0.001	1.029	8.4	0.01638	90.58	88.99
15	1.029	0.001	1.028	8.6	0.00688	87.46	85.92
30	1.028	0.001	1.027	8.9	0.00495	84.34	82.85
60	1.027	0.001	1.026	9.2	0.00245	81.21	79.78
250	1.026	0.001	1.025	9.4	0.00245	78.09	76.72
1440	1.024	0.001	1.023	10	0.00105	71.84	70.58

D24 Grain size analysis result of TP 25 at D=1.5m

Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	334.6	339.2	0.00	0.00	0.0	100.0
No 8	2	318.5	319.4	0.20	0.02	0.02	99.98
No 10	1.18	280.6	283.1	0.40	0.04	0.06	99.94
No 16	0.6	276.1	279.7	0.50	0.05	0.11	99.89
No 30	0.425	380.1	382.1	1.20	0.12	0.23	99.77
No 50	0.3	261.6	264.8	1.50	0.15	0.38	99.62
No 100	0.15	266.5	276.6	2.70	0.27	0.65	99.35
No 200	0.075	263.3	271.1	0.80	0.08	0.73	99.27
Time (min)	Actual reading	Composite correction	Corrected reading	Effective depth(cm)	Grain size(mm)	Percentage finer	Percentage finer for combined analysis
2	1.029	0.001	1.028	8.6	0.02621	89.33	88.68
5	1.028	0.001	1.027	8.9	0.01686	86.14	85.51
15	1.027	0.001	1.026	9.2	0.00990	82.95	82.35
30	1.026	0.001	1.025	9.4	0.00708	79.76	79.18
60	1.025	0.001	1.024	9.7	0.00508	76.57	76.01

250	1.024	0.001	1.023	10.0	0.00253	73.38	72.85
1440	1.023	0.001	1.022	10.2	0.00106	70.19	69.68

D25 Grain size analysis result of TP 25 at D=1.5m

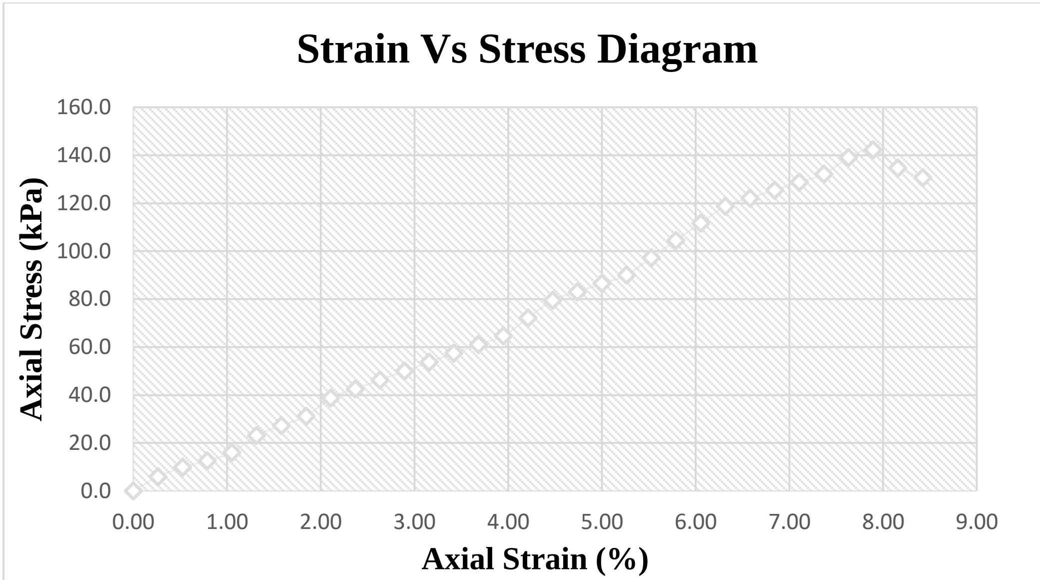
Sieve No	Sieve opening in mm	Mass of sieve (g)	Mass of sieve + Retained soil	Mass of Retained soil	Percentage Retained	Cumulative Percentage Retained	Percentage finer
No 4	2.36	453.5	453.5	0.0	0.0	0.0	100.0
No 8	2	373.5	374.5	0.2	0.02	0.02	99.98
No 10	1.18	280.5	282.5	0.4	0.04	0.04	99.94
No 16	0.6	378.0	381.0	0.5	0.05	0.09	99.89
No 30	0.425	378.0	385.5	1.2	0.12	0.21	99.77
No 50	0.3	317.5	321.5	1.5	0.15	0.36	99.62
No 100	0.15	313.5	319.0	2.7	0.27	0.63	99.35
No 200	0.075	373.5	374.0	0.8	0.08	0.71	99.27
Time (min)	**Actual reading**	**Composite correction**	**Corrected reading**	**Effective depth(cm)**	**Grain size(mm)**	**Percentage finer**	**Percentage finer for combined analysis**
2	1.029	0.001	1.028	8.6	0.02621	89.33	88.68
5	1.028	0.001	1.027	8.9	0.01686	86.14	85.51
15	1.027	0.001	1.026	9.2	0.00990	82.95	82.35
30	1.026	0.001	1.025	9.4	0.00708	79.76	79.18
60	1.025	0.001	1.024	9.7	0.00508	76.57	76.01
250	1.024	0.001	1.023	10.0	0.00253	73.38	72.85
1440	1.023	0.001	1.022	10.2	0.00106	70.19	69.68

Appendix E: Unconfined Compressive Strength test results

E01 Unconfined compression test result of TP 01 at D=1.5m

Test pit Depth, m	1.5	Ring calibration Factor, kN/div	0.04493
Length of sample, mm	76	Diameter of sample, mm	38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.15	0.0067	1137.1	5.9
0.4	0.53	0.25	0.0112	1140.1	9.9
0.6	0.79	0.32	0.0144	1143.1	12.6
0.8	1.05	0.41	0.0184	1146.2	16.1
1	1.32	0.59	0.0265	1149.2	23.1
1.2	1.58	0.7	0.0315	1152.3	27.3
1.4	1.84	0.8	0.0359	1155.4	31.1
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.1	0.0494	1161.6	42.5
2	2.63	1.2	0.0539	1164.8	46.3
2.2	2.89	1.3	0.0584	1167.9	50.0
2.4	3.16	1.4	0.0629	1171.1	53.7
2.6	3.42	1.5	0.0674	1174.3	57.4
2.8	3.68	1.6	0.0719	1177.5	61.1
3	3.95	1.7	0.0764	1180.7	64.7
3.2	4.21	1.9	0.0854	1184.0	72.1
3.4	4.47	2.1	0.0944	1187.2	79.5
3.6	4.74	2.2	0.0988	1190.5	83.0
3.8	5.00	2.3	0.1033	1193.8	86.6
4	5.26	2.4	0.1078	1197.1	90.1
4.2	5.53	2.6	0.1168	1200.5	97.3
4.4	5.79	2.8	0.1258	1203.8	104.5
4.6	6.05	3	0.1348	1207.2	111.7
4.8	6.32	3.2	0.1438	1210.6	118.8
5	6.58	3.3	0.1483	1214.0	122.1
5.2	6.84	3.4	0.1528	1217.4	125.5
5.4	7.11	3.5	0.1573	1220.9	128.8
5.6	7.37	3.6	0.1617	1224.3	132.1
5.8	7.63	3.8	0.1707	1227.8	139.1
6	7.89	3.9	0.1752	1231.3	142.3
6.2	8.16	3.7	0.1662	1234.9	134.6
6.4	8.42	3.6	0.1617	1238.4	130.6

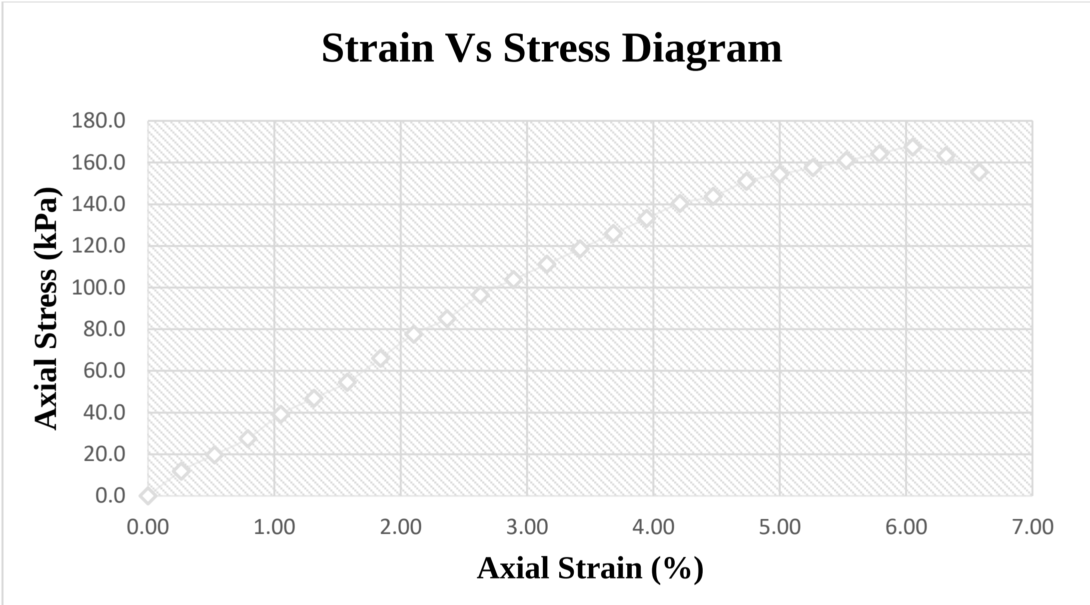


Unconfined compressive strength q_u, (Kpa) =142.3 kPa

E02 Unconfined compression test result of TP 02 at D=1.5m

Test pit Depth, m	1.5	Ring calibration Factor, kN/div	0.04493
Length of sample, mm	76	Diameter of sample, mm	38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.3	0.0135	1137.1	11.9
0.4	0.53	0.5	0.0225	1140.1	19.7
0.6	0.79	0.7	0.0315	1143.1	27.5
0.8	1.05	1	0.0449	1146.2	39.2
1	1.32	1.2	0.0539	1149.2	46.9
1.2	1.58	1.4	0.0629	1152.3	54.6
1.4	1.84	1.7	0.0764	1155.4	66.1
1.6	2.11	2	0.0899	1158.5	77.6
1.8	2.37	2.2	0.0988	1161.6	85.1
2	2.63	2.5	0.1123	1164.8	96.4
2.2	2.89	2.7	0.1213	1167.9	103.9
2.4	3.16	2.9	0.1303	1171.1	111.3
2.6	3.42	3.1	0.1393	1174.3	118.6
2.8	3.68	3.3	0.1483	1177.5	125.9
3	3.95	3.5	0.1573	1180.7	133.2
3.2	4.21	3.7	0.1662	1184.0	140.4
3.4	4.47	3.8	0.1707	1187.2	143.8
3.6	4.74	4	0.1797	1190.5	151.0
3.8	5.00	4.1	0.1842	1193.8	154.3
4	5.26	4.2	0.1887	1197.1	157.6
4.2	5.53	4.3	0.1932	1200.5	160.9
4.4	5.79	4.4	0.1977	1203.8	164.2
4.6	6.05	4.5	0.2022	1207.2	167.5
4.8	6.32	4.4	0.1977	1210.6	163.3
5	6.58	4.2	0.1887	1214.0	155.4

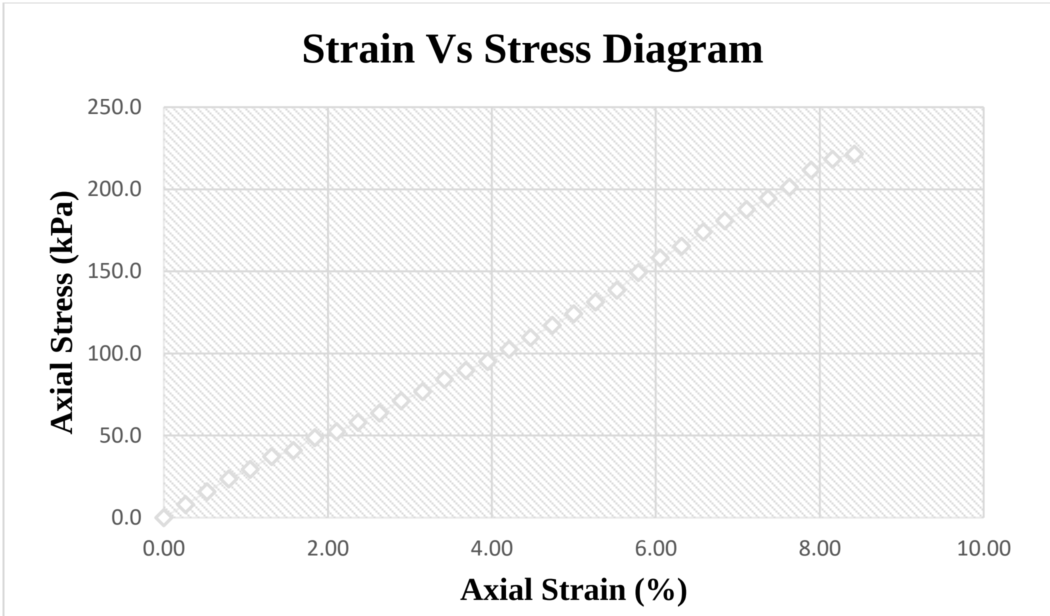


Unconfined compressive strength q_u, (Kpa) = 167.5 kPa

E03 Unconfined compression test result of TP 03 at D=1.5m

Test pit Depth, m	1.5	Ring calibration Factor, kN/div	0.04493
Length of sample, mm	76	Diameter of sample, mm	38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0.00	0.0000	1134.1	0.0
0.2	0.26	0.20	0.0090	1137.1	7.9
0.4	0.53	0.40	0.0180	1140.1	15.8
0.6	0.79	0.60	0.0270	1143.1	23.6
0.8	1.05	0.75	0.0337	1146.2	29.4
1	1.32	0.95	0.0427	1149.2	37.1
1.2	1.58	1.05	0.0472	1152.3	40.9
1.4	1.84	1.25	0.0562	1155.4	48.6
1.6	2.11	1.35	0.0607	1158.5	52.4
1.8	2.37	1.5	0.0674	1161.6	58.0
2	2.63	1.65	0.0741	1164.8	63.6
2.2	2.89	1.85	0.0831	1167.9	71.2
2.4	3.16	2.00	0.0899	1171.1	76.7
2.6	3.42	2.20	0.0988	1174.3	84.2
2.8	3.68	2.35	0.1056	1177.5	89.7
3	3.95	2.50	0.1123	1180.7	95.1
3.2	4.21	2.70	0.1213	1184.0	102.5
3.4	4.47	2.90	0.1303	1187.2	109.7
3.6	4.74	3.10	0.1393	1190.5	117.0
3.8	5.00	3.30	0.1483	1193.8	124.2
4	5.26	3.50	0.1573	1197.1	131.4
4.2	5.53	3.70	0.1662	1200.5	138.5
4.4	5.79	4.00	0.1797	1203.8	149.3
4.6	6.05	4.25	0.1910	1207.2	158.2
4.8	6.32	4.45	0.1999	1210.6	165.2
5	6.58	4.70	0.2112	1214.0	173.9
5.2	6.84	4.90	0.2202	1217.4	180.8
5.4	7.11	5.10	0.2291	1220.9	187.7
5.6	7.37	5.30	0.2381	1224.3	194.5
5.8	7.63	5.50	0.2471	1227.8	201.3
6	7.89	5.80	0.2606	1231.3	211.6
6.2	8.16	6.00	0.2696	1234.9	218.3
6.4	8.42	6.10	0.2741	1238.4	221.3

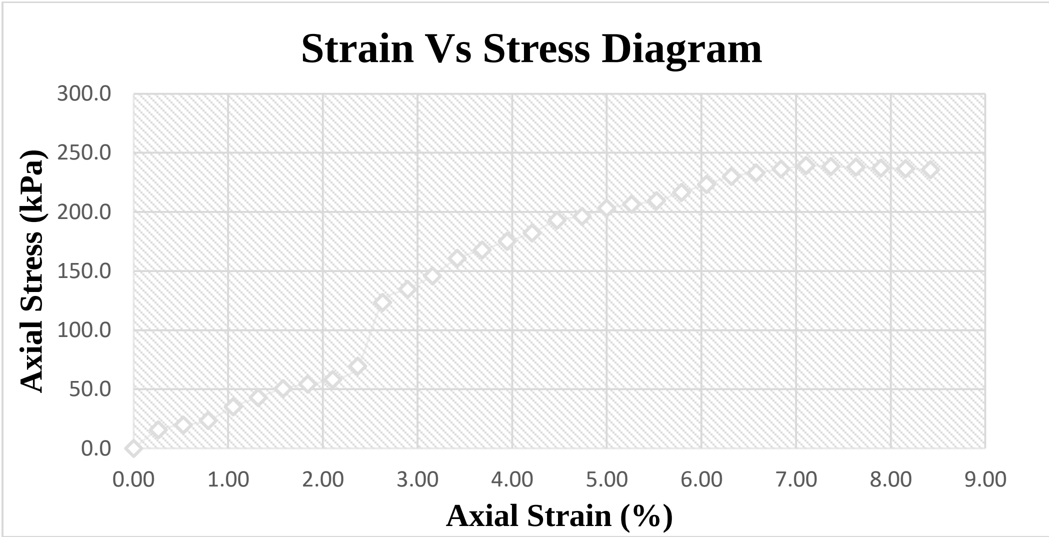


Unconfined compressive strength q_u, (Kpa) = 221.3 kpa

E04 Unconfined compression test result of TP 04 at D=1.5m

Test pit Depth, m	1.5	Ring calibration Factor, kN/div	0.04493
Length of sample, mm	76	Diameter of sample, mm	38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.4	0.0180	1137.1	15.8
0.4	0.53	0.5	0.0225	1140.1	19.7
0.6	0.79	0.6	0.0270	1143.1	23.6
0.8	1.05	0.9	0.0404	1146.2	35.3
1	1.32	1.1	0.0494	1149.2	43.0
1.2	1.58	1.3	0.0584	1152.3	50.7
1.4	1.84	1.4	0.0629	1155.4	54.4
1.6	2.11	1.5	0.0674	1158.5	58.2
1.8	2.37	1.8	0.0809	1161.6	69.6
2	2.63	3.2	0.1438	1164.8	123.4
2.2	2.89	3.5	0.1573	1167.9	134.6
2.4	3.16	3.8	0.1707	1171.1	145.8
2.6	3.42	4.2	0.1887	1174.3	160.7
2.8	3.68	4.4	0.1977	1177.5	167.9
3	3.95	4.6	0.2067	1180.7	175.0
3.2	4.21	4.8	0.2157	1184.0	182.2
3.4	4.47	5.1	0.2291	1187.2	193.0
3.6	4.74	5.2	0.2336	1190.5	196.2
3.8	5.00	5.4	0.2426	1193.8	203.2
4	5.26	5.5	0.2471	1197.1	206.4
4.2	5.53	5.6	0.2516	1200.5	209.6
4.4	5.79	5.8	0.2606	1203.8	216.5
4.6	6.05	6	0.2696	1207.2	223.3
4.8	6.32	6.2	0.2786	1210.6	230.1
5	6.58	6.3	0.2831	1214.0	233.2
5.2	6.84	6.4	0.2876	1217.4	236.2
5.4	7.11	6.5	0.2920	1220.9	239.2
5.6	7.37	6.5	0.2920	1224.3	238.5
5.8	7.63	6.5	0.2920	1227.8	237.9



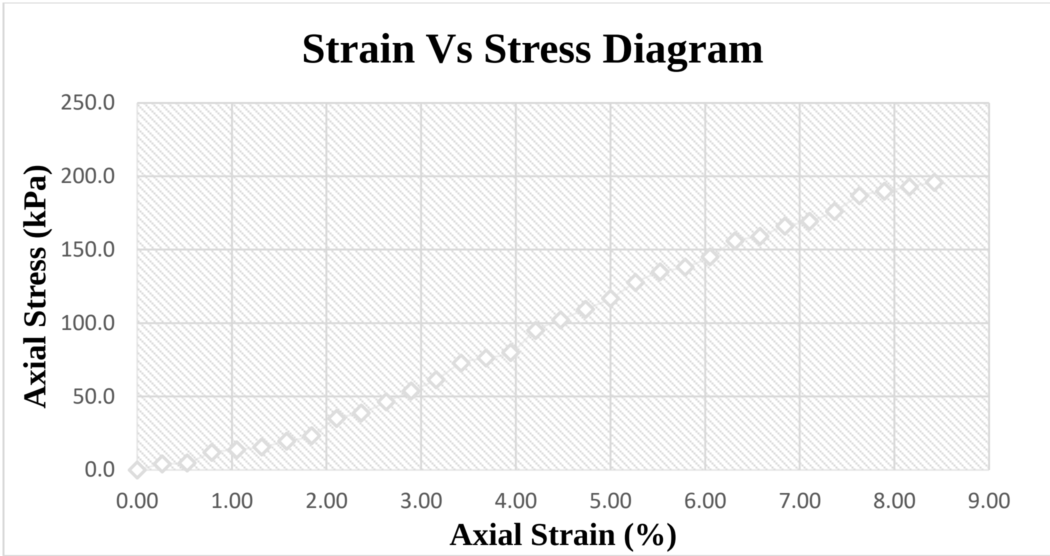
Unconfined compressive strength q_u, (Kpa) = 239.2 kPa

E05 Unconfined compression test result of TP 05 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.12	0.0054	1140.1	4.7
0.6	0.79	0.3	0.0135	1143.1	11.8
0.8	1.05	0.35	0.0157	1146.2	13.7
1	1.32	0.4	0.0180	1149.2	15.6
1.2	1.58	0.5	0.0225	1152.3	19.5
1.4	1.84	0.6	0.0270	1155.4	23.3
1.6	2.11	0.9	0.0404	1158.5	34.9
1.8	2.37	1	0.0449	1161.6	38.7
2	2.63	1.2	0.0539	1164.8	46.3
2.2	2.89	1.4	0.0629	1167.9	53.9
2.4	3.16	1.6	0.0719	1171.1	61.4
2.6	3.42	1.9	0.0854	1174.3	72.7
2.8	3.68	2	0.0899	1177.5	76.3
3	3.95	2.1	0.0944	1180.7	79.9
3.2	4.21	2.5	0.1123	1184.0	94.9
3.4	4.47	2.7	0.1213	1187.2	102.2
3.6	4.74	2.9	0.1303	1190.5	109.4
3.8	5.00	3.1	0.1393	1193.8	116.7
4	5.26	3.4	0.1528	1197.1	127.6
4.2	5.53	3.6	0.1617	1200.5	134.7
4.4	5.79	3.7	0.1662	1203.8	138.1
4.6	6.05	3.9	0.1752	1207.2	145.2
4.8	6.32	4.2	0.1887	1210.6	155.9
5	6.58	4.3	0.1932	1214.0	159.1
5.2	6.84	4.5	0.2022	1217.4	166.1
5.4	7.11	4.6	0.2067	1220.9	169.3
5.6	7.37	4.8	0.2157	1224.3	176.1
5.8	7.63	5.1	0.2291	1227.8	186.6
6	7.89	5.2	0.2336	1231.3	189.7
6.2	8.16	5.3	0.2381	1234.9	192.8
6.4	8.42	5.4	0.2426	1238.4	195.9

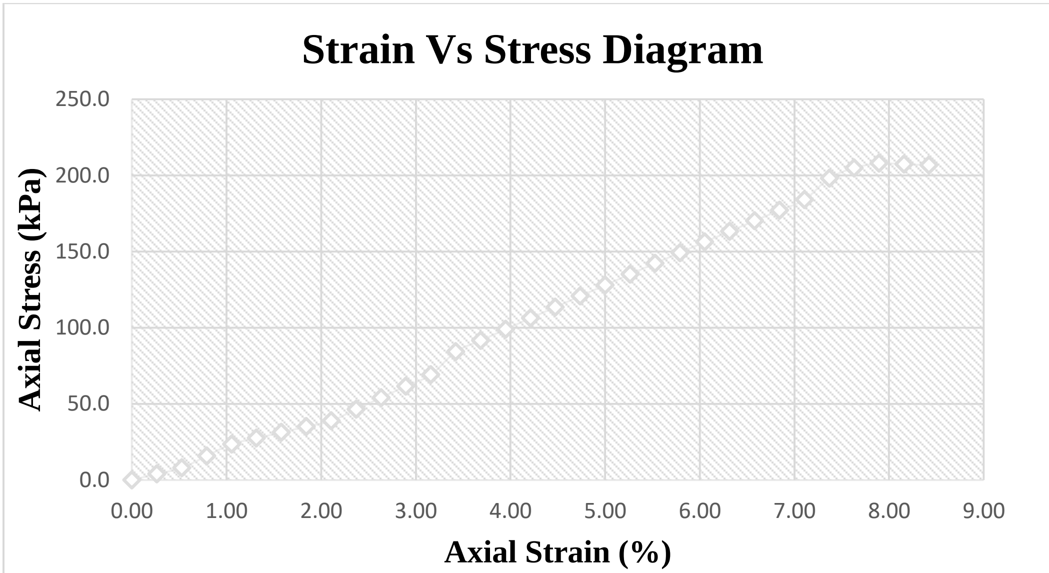


Unconfined compressive strength q_u, (Kpa) =195.9 kPa

E06 Unconfined compression test result of TP 06 at D=1.5m

Test pit Depth, m	1.5	Ring calibration Factor, kN/div	0.04493
Length of sample, mm	76	Diameter of sample, mm	38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.2	0.0090	1140.1	7.9
0.6	0.79	0.4	0.0180	1143.1	15.7
0.8	1.05	0.6	0.0270	1146.2	23.5
1	1.32	0.7	0.0315	1149.2	27.4
1.2	1.58	0.8	0.0359	1152.3	31.2
1.4	1.84	0.9	0.0404	1155.4	35.0
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.2	0.0539	1161.6	46.4
2	2.63	1.4	0.0629	1164.8	54.0
2.2	2.89	1.6	0.0719	1167.9	61.6
2.4	3.16	1.8	0.0809	1171.1	69.1
2.6	3.42	2.2	0.0988	1174.3	84.2
2.8	3.68	2.4	0.1078	1177.5	91.6
3	3.95	2.6	0.1168	1180.7	98.9
3.2	4.21	2.8	0.1258	1184.0	106.3
3.4	4.47	3	0.1348	1187.2	113.5
3.6	4.74	3.2	0.1438	1190.5	120.8
3.8	5.00	3.4	0.1528	1193.8	128.0
4	5.26	3.6	0.1617	1197.1	135.1
4.2	5.53	3.8	0.1707	1200.5	142.2
4.4	5.79	4	0.1797	1203.8	149.3
4.6	6.05	4.2	0.1887	1207.2	156.3
4.8	6.32	4.4	0.1977	1210.6	163.3
5	6.58	4.6	0.2067	1214.0	170.2
5.2	6.84	4.8	0.2157	1217.4	177.1
5.4	7.11	5	0.2247	1220.9	184.0
5.6	7.37	5.4	0.2426	1224.3	198.2
5.8	7.63	5.6	0.2516	1227.8	204.9
6	7.89	5.7	0.2561	1231.3	208.0
6.2	8.16	5.7	0.2561	1234.9	207.4
6.4	8.42	5.7	0.2561	1238.4	206.8



Unconfined compressive strength q_u, (Kpa) = 208 kPa

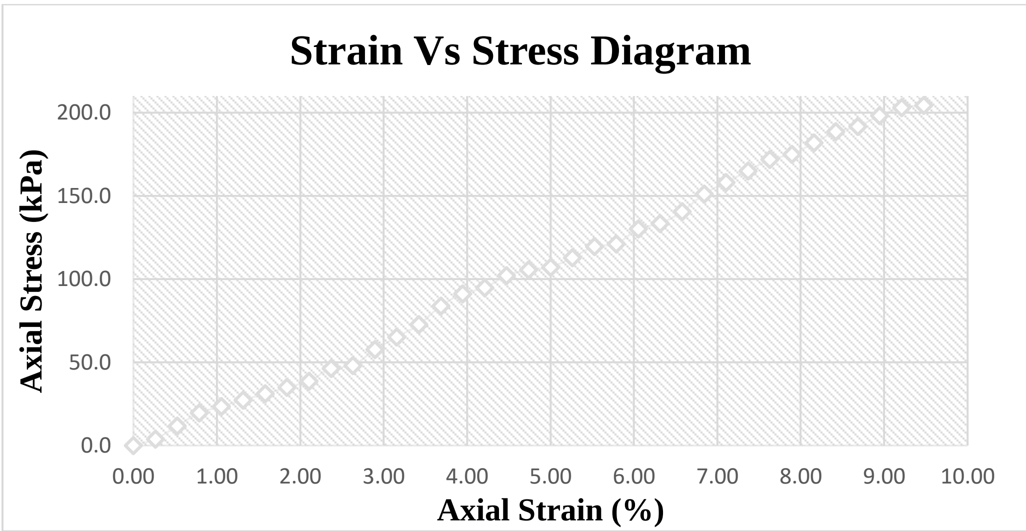
E07 Unconfined compression test result of TP 07 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain, e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.3	0.0135	1140.1	11.8
0.6	0.79	0.5	0.0225	1143.1	19.7
0.8	1.05	0.6	0.0270	1146.2	23.5
1	1.32	0.7	0.0315	1149.2	27.4
1.2	1.58	0.8	0.0359	1152.3	31.2
1.4	1.84	0.9	0.0404	1155.4	35.0
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.2	0.0539	1161.6	46.4
2	2.63	1.25	0.0562	1164.8	48.2
2.2	2.89	1.5	0.0674	1167.9	57.7
2.4	3.16	1.7	0.0764	1171.1	65.2
2.6	3.42	1.9	0.0854	1174.3	72.7
2.8	3.68	2.2	0.0988	1177.5	83.9
3	3.95	2.4	0.1078	1180.7	91.3
3.2	4.21	2.5	0.1123	1184.0	94.9
3.4	4.47	2.7	0.1213	1187.2	102.2
3.6	4.74	2.8	0.1258	1190.5	105.7
3.8	5.00	2.85	0.1281	1193.8	107.3
4	5.26	3.01	0.1352	1197.1	113.0
4.2	5.53	3.2	0.1438	1200.5	119.8
4.4	5.79	3.25	0.1460	1203.8	121.3
4.6	6.05	3.5	0.1573	1207.2	130.3
4.8	6.32	3.6	0.1617	1210.6	133.6
5	6.58	3.8	0.1707	1214.0	140.6
5.2	6.84	4.1	0.1842	1217.4	151.3
5.4	7.11	4.3	0.1932	1220.9	158.2
5.6	7.37	4.5	0.2022	1224.3	165.1
5.8	7.63	4.7	0.2112	1227.8	172.0
6	7.89	4.8	0.2157	1231.3	175.1
6.2	8.16	5	0.2247	1234.9	181.9

6.4	8.42	5.2	0.2336	1238.4	188.7
6.6	8.68	5.3	0.2381	1242.0	191.7
6.8	8.95	5.5	0.2471	1245.6	198.4
7	9.21	5.65	0.2539	1249.2	203.2
7.2	9.47	5.7	0.2561	1252.8	204.4



Unconfined compressive strength q_u =204.4 kPa

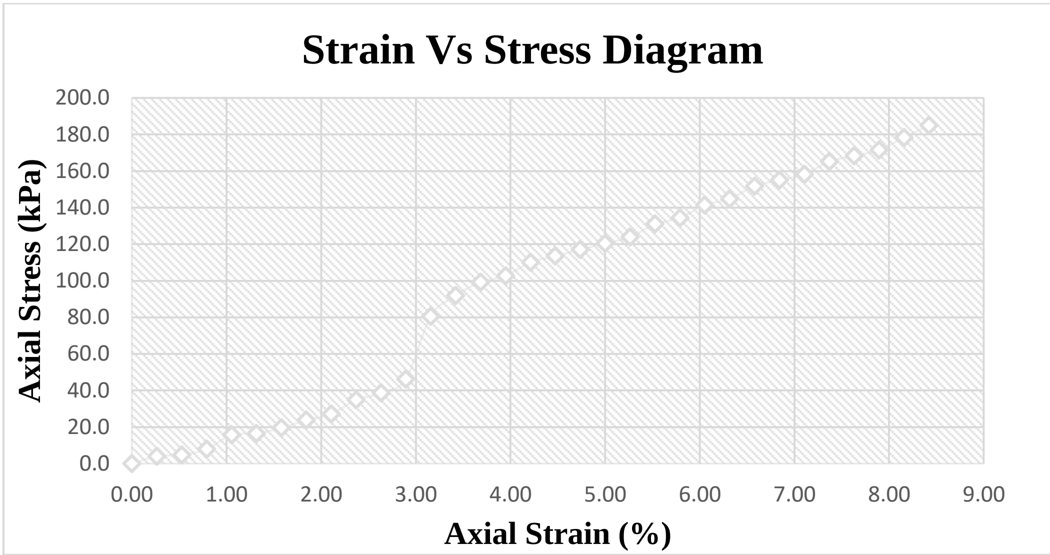
E08 Unconfined compression test result of TP 08 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.12	0.0054	1140.1	4.7
0.6	0.79	0.2	0.0090	1143.1	7.9
0.8	1.05	0.4	0.0180	1146.2	15.7
1	1.32	0.42	0.0189	1149.2	16.4
1.2	1.58	0.5	0.0225	1152.3	19.5
1.4	1.84	0.61	0.0274	1155.4	23.7
1.6	2.11	0.7	0.0315	1158.5	27.1
1.8	2.37	0.9	0.0404	1161.6	34.8
2	2.63	1	0.0449	1164.8	38.6
2.2	2.89	1.2	0.0539	1167.9	46.2
2.4	3.16	2.1	0.0944	1171.1	80.6
2.6	3.42	2.4	0.1078	1174.3	91.8
2.8	3.68	2.6	0.1168	1177.5	99.2
3	3.95	2.7	0.1213	1180.7	102.7
3.2	4.21	2.9	0.1303	1184.0	110.1
3.4	4.47	3	0.1348	1187.2	113.5
3.6	4.74	3.1	0.1393	1190.5	117.0
3.8	5.00	3.2	0.1438	1193.8	120.4
4	5.26	3.3	0.1483	1197.1	123.9
4.2	5.53	3.5	0.1573	1200.5	131.0
4.4	5.79	3.6	0.1617	1203.8	134.4
4.6	6.05	3.8	0.1707	1207.2	141.4
4.8	6.32	3.9	0.1752	1210.6	144.7
5	6.58	4.1	0.1842	1214.0	151.7
5.2	6.84	4.2	0.1887	1217.4	155.0
5.4	7.11	4.3	0.1932	1220.9	158.2
5.6	7.37	4.5	0.2022	1224.3	165.1
5.8	7.63	4.6	0.2067	1227.8	168.3

6	7.89	4.7	0.2112	1231.3	171.5
6.2	8.16	4.9	0.2202	1234.9	178.3
6.4	8.42	5.1	0.2291	1238.4	185.0



Unconfined compressive strength q_u =185 kPa

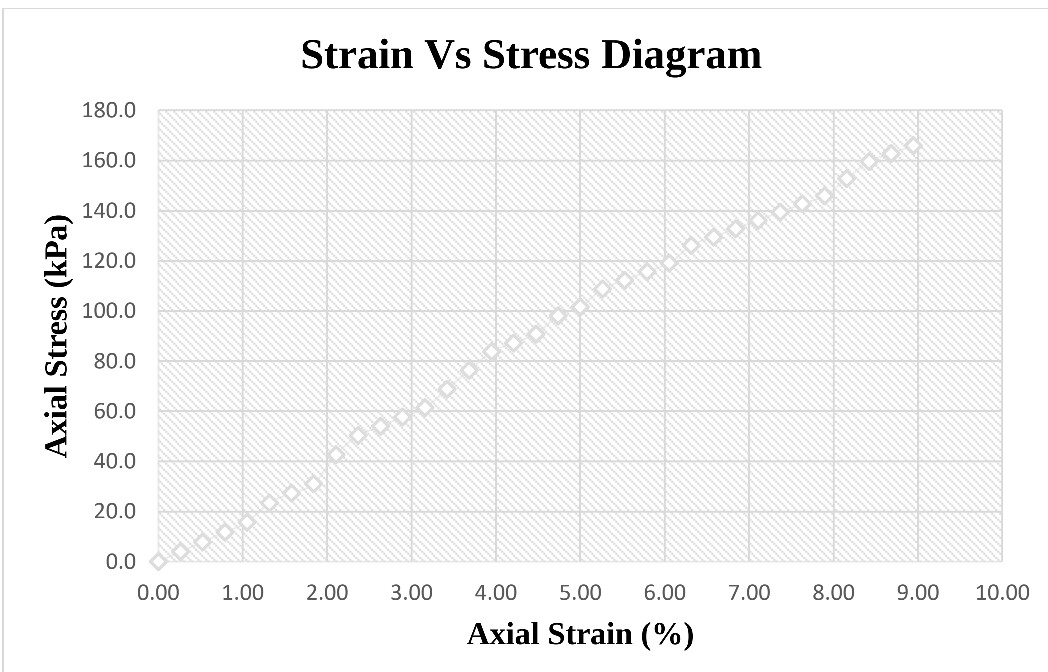
E09 Unconfined compression test result of TP 09 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	**Axial Strain,e [%]**	**Proving Ring Reading, [div]**	**Applied Load,P [kN]**	**Corrected Area, A [mm^2]**	**Axial Stress,s [kN/m^2]**
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.2	0.0090	1140.1	7.9
0.6	0.79	0.3	0.0135	1143.1	11.8
0.8	1.05	0.4	0.0180	1146.2	15.7
1	1.32	0.6	0.0270	1149.2	23.5
1.2	1.58	0.7	0.0315	1152.3	27.3
1.4	1.84	0.8	0.0359	1155.4	31.1
1.6	2.11	1.1	0.0494	1158.5	42.7
1.8	2.37	1.3	0.0584	1161.6	50.3
2	2.63	1.4	0.0629	1164.8	54.0
2.2	2.89	1.5	0.0674	1167.9	57.7
2.4	3.16	1.6	0.0719	1171.1	61.4
2.6	3.42	1.8	0.0809	1174.3	68.9
2.8	3.68	2	0.0899	1177.5	76.3
3	3.95	2.2	0.0988	1180.7	83.7
3.2	4.21	2.3	0.1033	1184.0	87.3
3.4	4.47	2.4	0.1078	1187.2	90.8
3.6	4.74	2.6	0.1168	1190.5	98.1
3.8	5.00	2.7	0.1213	1193.8	101.6
4	5.26	2.9	0.1303	1197.1	108.8
4.2	5.53	3	0.1348	1200.5	112.3
4.4	5.79	3.1	0.1393	1203.8	115.7
4.6	6.05	3.2	0.1438	1207.2	119.1

4.8	6.32	3.4	0.1528	1210.6	126.2
5	6.58	3.5	0.1573	1214.0	129.5
5.2	6.84	3.6	0.1617	1217.4	132.9
5.4	7.11	3.7	0.1662	1220.9	136.2
5.6	7.37	3.8	0.1707	1224.3	139.5
5.8	7.63	3.9	0.1752	1227.8	142.7
6	7.89	4	0.1797	1231.3	146.0
6.2	8.16	4.2	0.1887	1234.9	152.8
6.4	8.42	4.4	0.1977	1238.4	159.6
6.6	8.68	4.5	0.2022	1242.0	162.8
6.8	8.95	4.6	0.2067	1245.6	165.9



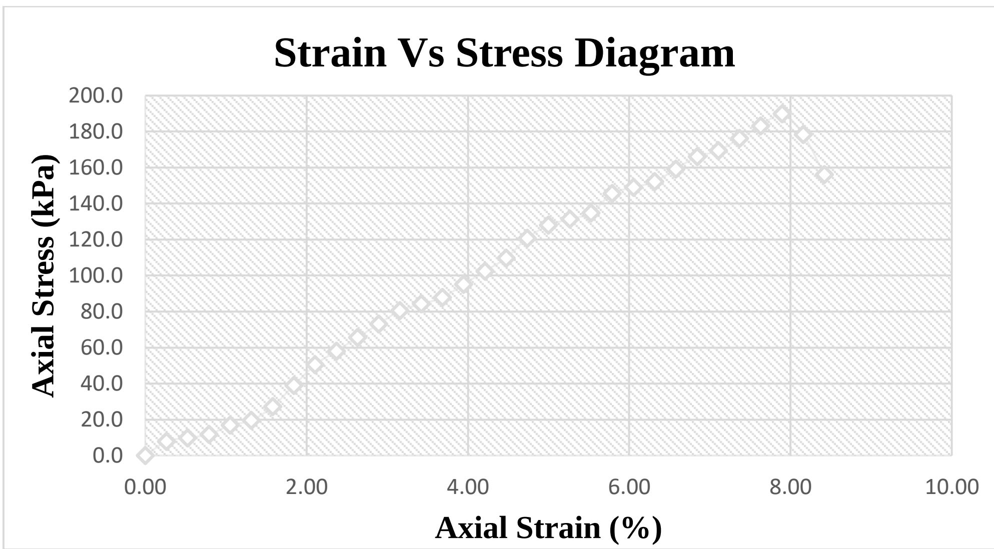
Unconfined compressive strength q_u, (Kpa) = 165.9 kPa

E10 Unconfined compression test result of TP 10 at D=1.5m

Test pit Depth, m	1.5	Ring calibration Factor, kN/div	0.04493
Length of sample, mm	76	Diameter of sample, mm	38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.2	0.0090	1137.1	7.9
0.4	0.53	0.25	0.0112	1140.1	9.9
0.6	0.79	0.3	0.0135	1143.1	11.8
0.8	1.05	0.43	0.0193	1146.2	16.9
1	1.32	0.5	0.0225	1149.2	19.5
1.2	1.58	0.7	0.0315	1152.3	27.3
1.4	1.84	1	0.0449	1155.4	38.9
1.6	2.11	1.3	0.0584	1158.5	50.4
1.8	2.37	1.5	0.0674	1161.6	58.0
2	2.63	1.7	0.0764	1164.8	65.6
2.2	2.89	1.9	0.0854	1167.9	73.1
2.4	3.16	2.1	0.0944	1171.1	80.6
2.6	3.42	2.2	0.0988	1174.3	84.2
2.8	3.68	2.3	0.1033	1177.5	87.8
3	3.95	2.5	0.1123	1180.7	95.1
3.2	4.21	2.7	0.1213	1184.0	102.5
3.4	4.47	2.9	0.1303	1187.2	109.7
3.6	4.74	3.2	0.1438	1190.5	120.8
3.8	5.00	3.4	0.1528	1193.8	128.0
4	5.26	3.5	0.1573	1197.1	131.4
4.2	5.53	3.6	0.1617	1200.5	134.7
4.4	5.79	3.9	0.1752	1203.8	145.6
4.6	6.05	4	0.1797	1207.2	148.9

4.8	6.32	4.1	0.1842	1210.6	152.2
5	6.58	4.3	0.1932	1214.0	159.1
5.2	6.84	4.5	0.2022	1217.4	166.1
5.4	7.11	4.6	0.2067	1220.9	169.3
5.6	7.37	4.8	0.2157	1224.3	176.1
5.8	7.63	5	0.2247	1227.8	183.0
6	7.89	5.2	0.2336	1231.3	189.7
6.2	8.16	4.9	0.2202	1234.9	178.3
6.4	8.42	4.3	0.1932	1238.4	156.0

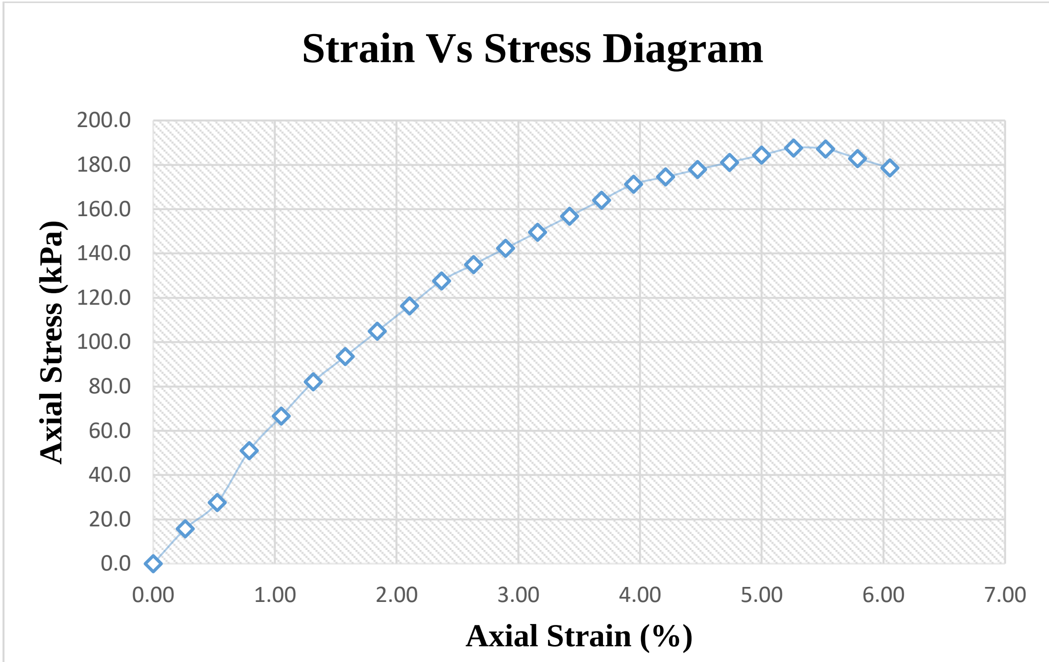


Unconfined compressive strength q_u=189.7 kPa

E11 Unconfined compression test result of TP 11 at D=1.5m

Test pit Depth, m	1.5	Ring calibration Factor, kN/div	0.04493
Length of sample, mm	76	Diameter of sample, mm	38

Specimen Deformation, ΔL [mm]	Axial Strain, e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress, s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.4	0.0180	1137.1	15.8
0.4	0.53	0.7	0.0315	1140.1	27.6
0.6	0.79	1.3	0.0584	1143.1	51.1
0.8	1.05	1.7	0.0764	1146.2	66.6
1	1.32	2.1	0.0944	1149.2	82.1
1.2	1.58	2.4	0.1078	1152.3	93.6
1.4	1.84	2.7	0.1213	1155.4	105.0
1.6	2.11	3	0.1348	1158.5	116.3
1.8	2.37	3.3	0.1483	1161.6	127.6
2	2.63	3.5	0.1573	1164.8	135.0
2.2	2.89	3.7	0.1662	1167.9	142.3
2.4	3.16	3.9	0.1752	1171.1	149.6
2.6	3.42	4.1	0.1842	1174.3	156.9
2.8	3.68	4.3	0.1932	1177.5	164.1
3	3.95	4.5	0.2022	1180.7	171.2
3.2	4.21	4.6	0.2067	1184.0	174.6
3.4	4.47	4.7	0.2112	1187.2	177.9
3.6	4.74	4.8	0.2157	1190.5	181.2
3.8	5.00	4.9	0.2202	1193.8	184.4
4	5.26	5	0.2247	1197.1	187.7
4.2	5.53	5	0.2247	1200.5	187.1
4.4	5.79	4.9	0.2202	1203.8	182.9
4.6	6.05	4.8	0.2157	1207.2	178.7



Unconfined compressive strength q_u, (Kpa) = 187.7 kPa

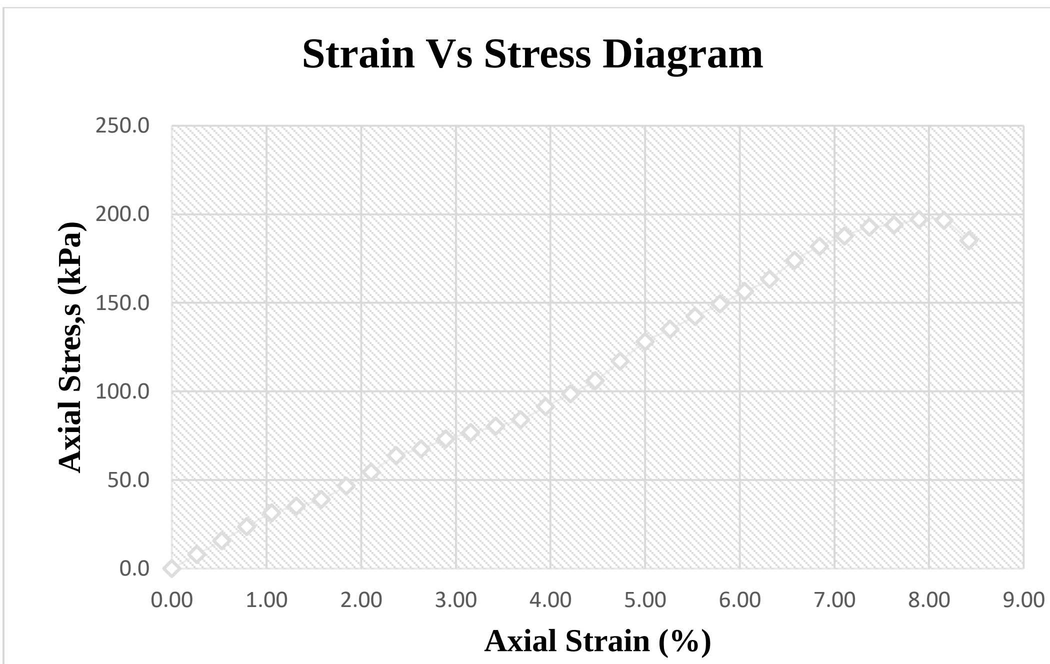
E12 Unconfined compression test result of TP 08 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area,A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.2	0.0090	1137.1	7.9
0.4	0.53	0.4	0.0180	1140.1	15.8
0.6	0.79	0.6	0.0270	1143.1	23.6
0.8	1.05	0.8	0.0359	1146.2	31.4
1	1.32	0.9	0.0404	1149.2	35.2
1.2	1.58	1	0.0449	1152.3	39.0
1.4	1.84	1.2	0.0539	1155.4	46.7
1.6	2.11	1.4	0.0629	1158.5	54.3
1.8	2.37	1.65	0.0741	1161.6	63.8
2	2.63	1.75	0.0786	1164.8	67.5
2.2	2.89	1.9	0.0854	1167.9	73.1
2.4	3.16	2	0.0899	1171.1	76.7
2.6	3.42	2.1	0.0944	1174.3	80.3
2.8	3.68	2.2	0.0988	1177.5	83.9
3	3.95	2.4	0.1078	1180.7	91.3
3.2	4.21	2.6	0.1168	1184.0	98.7
3.4	4.47	2.8	0.1258	1187.2	106.0
3.6	4.74	3.1	0.1393	1190.5	117.0
3.8	5.00	3.4	0.1528	1193.8	128.0
4	5.26	3.6	0.1617	1197.1	135.1
4.2	5.53	3.8	0.1707	1200.5	142.2
4.4	5.79	4	0.1797	1203.8	149.3

4.6	6.05	4.2	0.1887	1207.2	156.3
4.8	6.32	4.4	0.1977	1210.6	163.3
5	6.58	4.7	0.2112	1214.0	173.9
5.2	6.84	4.93	0.2215	1217.4	181.9
5.4	7.11	5.1	0.2291	1220.9	187.7
5.6	7.37	5.25	0.2359	1224.3	192.7
5.8	7.63	5.3	0.2381	1227.8	193.9
6	7.89	5.4	0.2426	1231.3	197.0
6.2	8.16	5.4	0.2426	1234.9	196.5
6.4	8.42	5.1	0.2291	1238.4	185.0



Unconfined compressive strength q_u, = 197.0 kPa

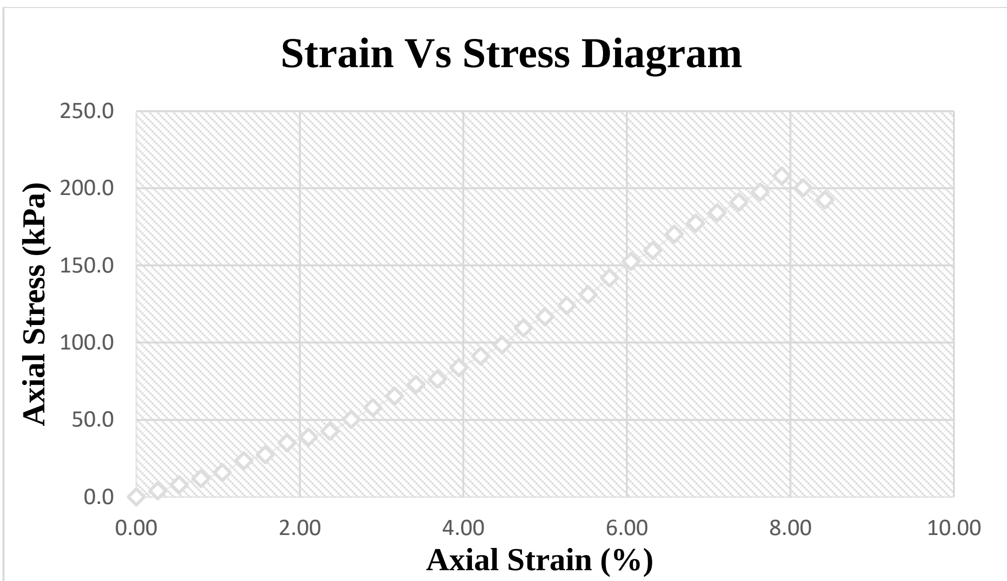
E13 Unconfined compression test result of TP 13 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL[mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0.0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.2	0.0090	1140.1	7.9
0.6	0.79	0.3	0.0135	1143.1	11.8
0.8	1.05	0.4	0.0180	1146.2	15.7
1	1.32	0.6	0.0270	1149.2	23.5
1.2	1.58	0.7	0.0315	1152.3	27.3
1.4	1.84	0.9	0.0404	1155.4	35.0
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.1	0.0494	1161.6	42.5
2	2.63	1.3	0.0584	1164.8	50.1
2.2	2.89	1.5	0.0674	1167.9	57.7
2.4	3.16	1.7	0.0764	1171.1	65.2
2.6	3.42	1.9	0.0854	1174.3	72.7
2.8	3.68	2	0.0899	1177.5	76.3
3	3.95	2.2	0.0988	1180.7	83.7
3.2	4.21	2.4	0.1078	1184.0	91.1
3.4	4.47	2.6	0.1168	1187.2	98.4
3.6	4.74	2.9	0.1303	1190.5	109.4
3.8	5.00	3.1	0.1393	1193.8	116.7
4	5.26	3.3	0.1483	1197.1	123.9
4.2	5.53	3.5	0.1573	1200.5	131.0
4.4	5.79	3.8	0.1707	1203.8	141.8

4.6	6.05	4.1	0.1842	1207.2	152.6
4.8	6.32	4.3	0.1932	1210.6	159.6
5	6.58	4.6	0.2067	1214.0	170.2
5.2	6.84	4.8	0.2157	1217.4	177.1
5.4	7.11	5	0.2247	1220.9	184.0
5.6	7.37	5.2	0.2336	1224.3	190.8
5.8	7.63	5.4	0.2426	1227.8	197.6
6	7.89	5.7	0.2561	1231.3	208.0
6.2	8.16	5.5	0.2471	1234.9	200.1
6.4	8.42	5.3	0.2381	1238.4	192.3



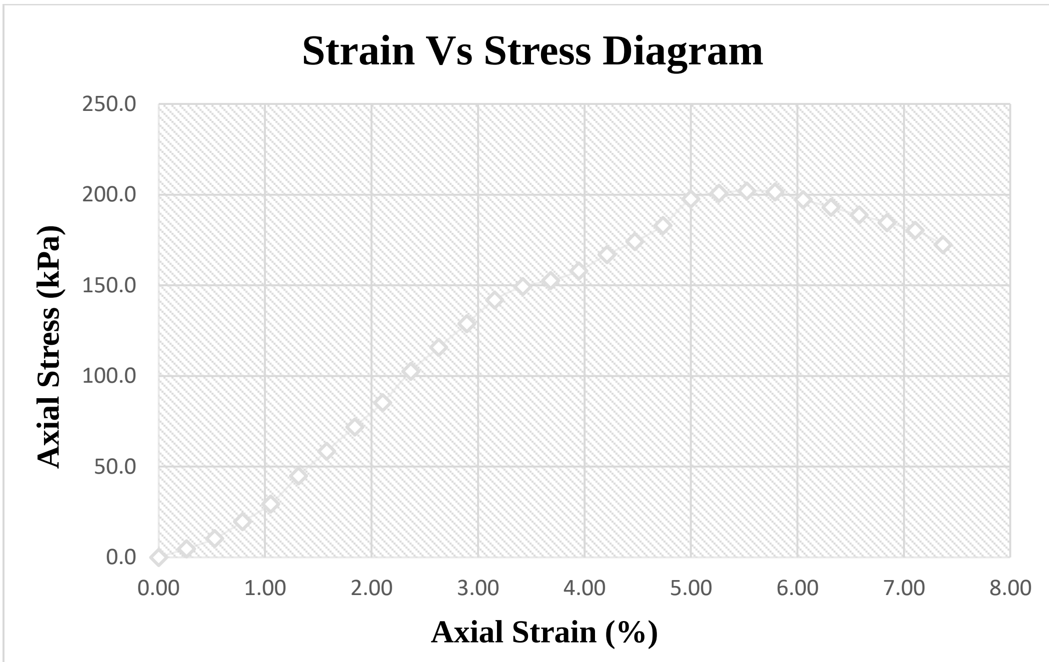
Unconfined compressive strength q_u =208 kPa

E14 Unconfined compression test result of TP 14 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493
Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.12	0.0054	1137.1	4.7
0.4	0.53	0.26	0.0117	1140.1	10.2
0.6	0.79	0.5	0.0225	1143.1	19.7
0.8	1.05	0.75	0.0337	1146.2	29.4
1	1.32	1.15	0.0517	1149.2	45.0
1.2	1.58	1.5	0.0674	1152.3	58.5
1.4	1.84	1.85	0.0831	1155.4	71.9
1.6	2.11	2.2	0.0988	1158.5	85.3
1.8	2.37	2.65	0.1191	1161.6	102.5
2	2.63	3	0.1348	1164.8	115.7
2.2	2.89	3.35	0.1505	1167.9	128.9
2.4	3.16	3.7	0.1662	1171.1	142.0
2.6	3.42	3.9	0.1752	1174.3	149.2
2.8	3.68	4	0.1797	1177.5	152.6
3	3.95	4.15	0.1865	1180.7	157.9
3.2	4.21	4.4	0.1977	1184.0	167.0
3.4	4.47	4.6	0.2067	1187.2	174.1
3.6	4.74	4.85	0.2179	1190.5	183.0
3.8	5.00	5.25	0.2359	1193.8	197.6
4	5.26	5.35	0.2404	1197.1	200.8
4.2	5.53	5.4	0.2426	1200.5	202.1
4.4	5.79	5.4	0.2426	1203.8	201.5
4.6	6.05	5.3	0.2381	1207.2	197.3

4.8	6.32	5.2	0.2336	1210.6	193.0
5	6.58	5.1	0.2291	1214.0	188.8
5.2	6.84	5	0.2247	1217.4	184.5
5.4	7.11	4.9	0.2202	1220.9	180.3
5.6	7.37	4.7	0.2112	1224.3	172.5



Unconfined compressive strength q_u= 202.1 kPa

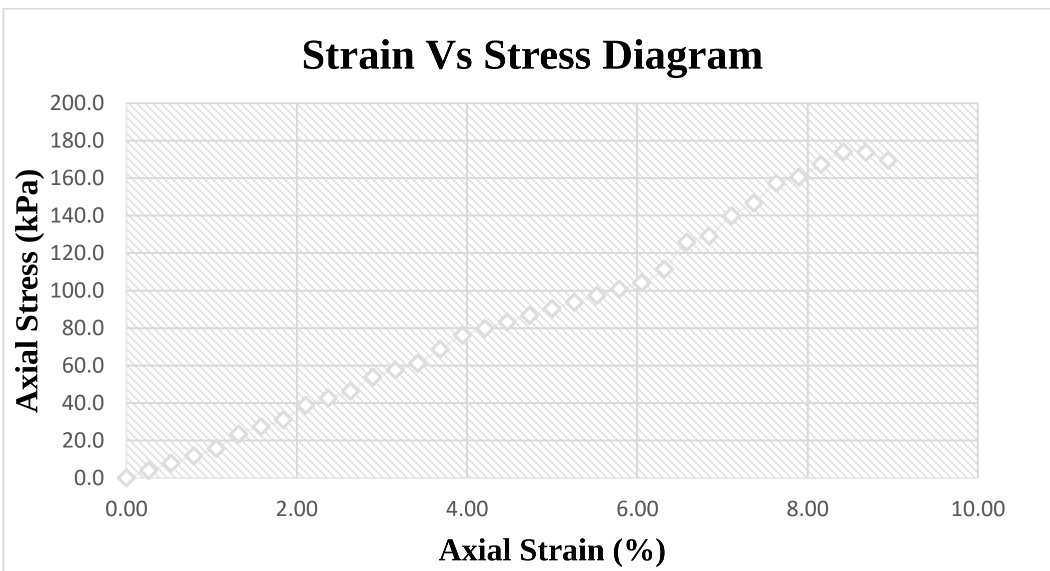
E15 Unconfined compression test result of TP 15 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.2	0.0090	1140.1	7.9
0.6	0.79	0.3	0.0135	1143.1	11.8
0.8	1.05	0.4	0.0180	1146.2	15.7
1	1.32	0.6	0.0270	1149.2	23.5
1.2	1.58	0.7	0.0315	1152.3	27.3
1.4	1.84	0.8	0.0359	1155.4	31.1
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.1	0.0494	1161.6	42.5
2	2.63	1.2	0.0539	1164.8	46.3
2.2	2.89	1.4	0.0629	1167.9	53.9
2.4	3.16	1.5	0.0674	1171.1	57.5
2.6	3.42	1.6	0.0719	1174.3	61.2
2.8	3.68	1.8	0.0809	1177.5	68.7
3	3.95	2	0.0899	1180.7	76.1
3.2	4.21	2.1	0.0944	1184.0	79.7
3.4	4.47	2.2	0.0988	1187.2	83.3
3.6	4.74	2.3	0.1033	1190.5	86.8
3.8	5.00	2.4	0.1078	1193.8	90.3
4	5.26	2.5	0.1123	1197.1	93.8
4.2	5.53	2.6	0.1168	1200.5	97.3
4.4	5.79	2.7	0.1213	1203.8	100.8
4.6	6.05	2.8	0.1258	1207.2	104.2

4.8	6.32	3	0.1348	1210.6	111.3
5	6.58	3.4	0.1528	1214.0	125.8
5.2	6.84	3.5	0.1573	1217.4	129.2
5.4	7.11	3.8	0.1707	1220.9	139.8
5.6	7.37	4	0.1797	1224.3	146.8
5.8	7.63	4.3	0.1932	1227.8	157.4
6	7.89	4.4	0.1977	1231.3	160.6
6.2	8.16	4.6	0.2067	1234.9	167.4
6.4	8.42	4.8	0.2157	1238.4	174.1
6.6	8.68	4.8	0.2157	1242.0	173.6
6.8	8.95	4.7	0.2112	1245.6	169.5



Unconfined compressive strength q_u, (kPa) = 174.1 kpa

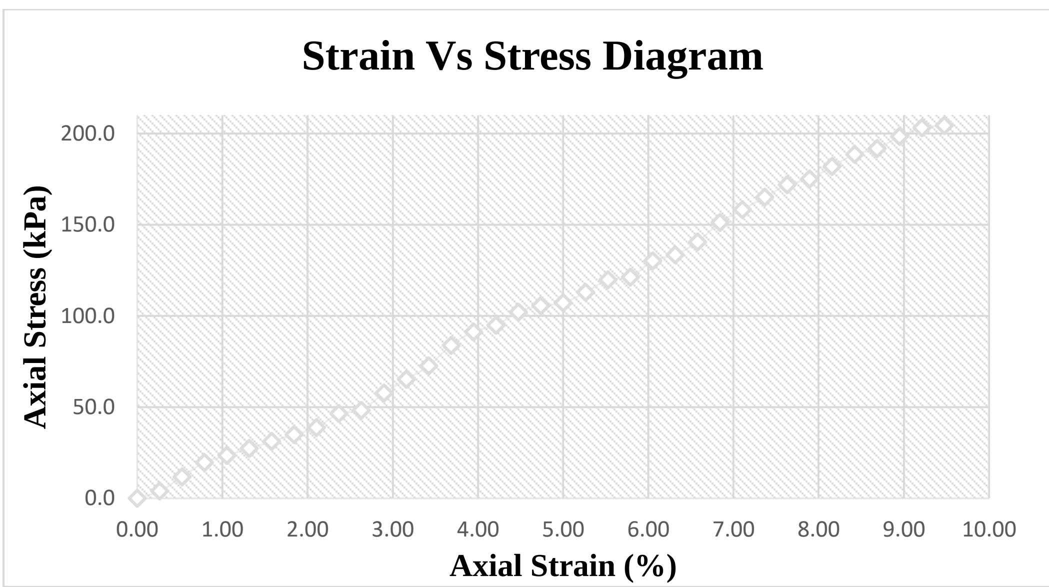
E16 Unconfined compression test result of TP 16 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, kN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0.0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.3	0.0135	1140.1	11.8
0.6	0.79	0.5	0.0225	1143.1	19.7
0.8	1.05	0.6	0.0270	1146.2	23.5
1.0	1.32	0.7	0.0315	1149.2	27.4
1.2	1.58	0.8	0.0359	1152.3	31.2
1.4	1.84	0.9	0.0404	1155.4	35.0
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.2	0.0539	1161.6	46.4
2.0	2.63	1.25	0.0562	1164.8	48.2
2.2	2.89	1.5	0.0674	1167.9	57.7
2.4	3.16	1.7	0.0764	1171.1	65.2
2.6	3.42	1.9	0.0854	1174.3	72.7
2.8	3.68	2.2	0.0988	1177.5	83.9
3.0	3.95	2.4	0.1078	1180.7	91.3
3.2	4.21	2.5	0.1123	1184.0	94.9
3.4	4.47	2.7	0.1213	1187.2	102.2
3.6	4.74	2.8	0.1258	1190.5	105.7
3.8	5.00	2.85	0.1281	1193.8	107.3
4.0	5.26	3.01	0.1352	1197.1	113.0
4.2	5.53	3.2	0.1438	1200.5	119.8
4.4	5.79	3.25	0.1460	1203.8	121.3
4.6	6.05	3.5	0.1573	1207.2	130.3

4.8	6.32	3.6	0.1617	1210.6	133.6
5.0	6.58	3.8	0.1707	1214.0	140.6
5.2	6.84	4.1	0.1842	1217.4	151.3
5.4	7.11	4.3	0.1932	1220.9	158.2
5.6	7.37	4.5	0.2022	1224.3	165.1
5.8	7.63	4.7	0.2112	1227.8	172.0
6.0	7.89	4.8	0.2157	1231.3	175.1
6.2	8.16	5	0.2247	1234.9	181.9
6.4	8.42	5.2	0.2336	1238.4	188.7
6.6	8.68	5.3	0.2381	1242.0	191.7
6.8	8.95	5.5	0.2471	1245.6	198.4
7.0	9.21	5.65	0.2539	1249.2	203.2
7.2	9.47	5.7	0.2561	1252.8	204.4



Unconfined compressive strength q_u =204.4 kPa

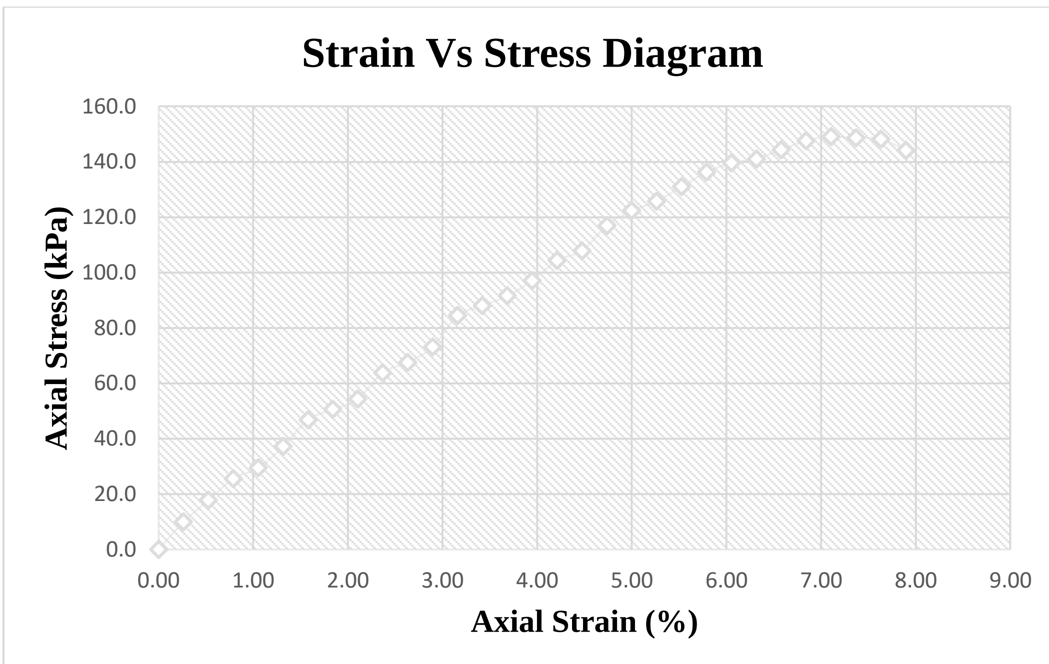
E17 Unconfined compression test result of TP 17 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, KN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	**Axial Strain,e [%]**	**Proving Ring Reading, [div]**	**Applied Load,P [kN]**	**Corrected Area, A [mm^2]**	**Axial Stress,s [kN/m^2]**
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.25	0.0112	1137.1	9.9
0.4	0.53	0.45	0.0202	1140.1	17.7
0.6	0.79	0.65	0.0292	1143.1	25.5
0.8	1.05	0.75	0.0337	1146.2	29.4
1	1.32	0.95	0.0427	1149.2	37.1
1.2	1.58	1.2	0.0539	1152.3	46.8
1.4	1.84	1.3	0.0584	1155.4	50.6
1.6	2.11	1.4	0.0629	1158.5	54.3
1.8	2.37	1.65	0.0741	1161.6	63.8
2	2.63	1.75	0.0786	1164.8	67.5
2.2	2.89	1.9	0.0854	1167.9	73.1
2.4	3.16	2.2	0.0988	1171.1	84.4
2.6	3.42	2.3	0.1033	1174.3	88.0
2.8	3.68	2.4	0.1078	1177.5	91.6
3	3.95	2.55	0.1146	1180.7	97.0
3.2	4.21	2.75	0.1236	1184.0	104.4
3.4	4.47	2.85	0.1281	1187.2	107.9
3.6	4.74	3.1	0.1393	1190.5	117.0
3.8	5.00	3.25	0.1460	1193.8	122.3
4	5.26	3.35	0.1505	1197.1	125.7
4.2	5.53	3.5	0.1573	1200.5	131.0
4.4	5.79	3.65	0.1640	1203.8	136.2
4.6	6.05	3.75	0.1685	1207.2	139.6

4.8	6.32	3.8	0.1707	1210.6	141.0
5	6.58	3.9	0.1752	1214.0	144.3
5.2	6.84	4	0.1797	1217.4	147.6
5.4	7.11	4.05	0.1820	1220.9	149.0
5.6	7.37	4.05	0.1820	1224.3	148.6
5.8	7.63	4.05	0.1820	1227.8	148.2
6	7.89	3.95	0.1775	1231.3	144.1



Unconfined compressive strength q_u, (Kpa) =149 kpa

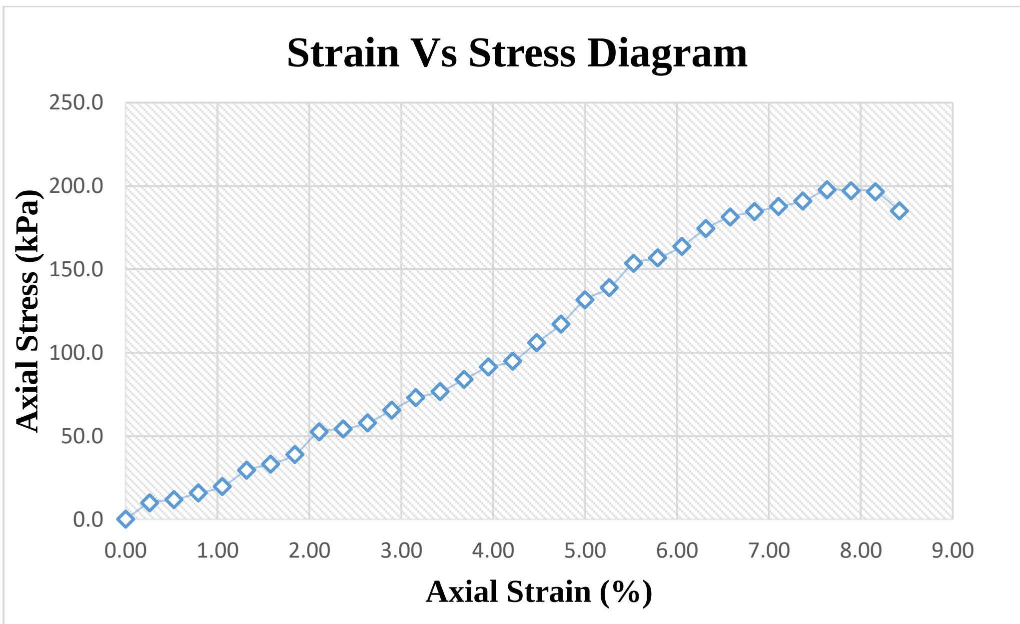
E18 Unconfined compression test result of TP 18 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, KN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.25	0.0112	1137.1	9.9
0.4	0.53	0.3	0.0135	1140.1	11.8
0.6	0.79	0.4	0.0180	1143.1	15.7
0.8	1.05	0.5	0.0225	1146.2	19.6
1	1.32	0.75	0.0337	1149.2	29.3
1.2	1.58	0.85	0.0382	1152.3	33.1
1.4	1.84	1	0.0449	1155.4	38.9
1.6	2.11	1.35	0.0607	1158.5	52.4
1.8	2.37	1.4	0.0629	1161.6	54.1
2	2.63	1.5	0.0674	1164.8	57.9
2.2	2.89	1.7	0.0764	1167.9	65.4
2.4	3.16	1.9	0.0854	1171.1	72.9
2.6	3.42	2	0.0899	1174.3	76.5
2.8	3.68	2.2	0.0988	1177.5	83.9
3	3.95	2.4	0.1078	1180.7	91.3
3.2	4.21	2.5	0.1123	1184.0	94.9
3.4	4.47	2.8	0.1258	1187.2	106.0
3.6	4.74	3.1	0.1393	1190.5	117.0
3.8	5.00	3.5	0.1573	1193.8	131.7
4	5.26	3.7	0.1662	1197.1	138.9
4.2	5.53	4.1	0.1842	1200.5	153.5
4.4	5.79	4.2	0.1887	1203.8	156.8
4.6	6.05	4.4	0.1977	1207.2	163.8

4.8	6.32	4.7	0.2112	1210.6	174.4
5	6.58	4.9	0.2202	1214.0	181.4
5.2	6.84	5	0.2247	1217.4	184.5
5.4	7.11	5.1	0.2291	1220.9	187.7
5.6	7.37	5.2	0.2336	1224.3	190.8
5.8	7.63	5.4	0.2426	1227.8	197.6
6	7.89	5.4	0.2426	1231.3	197.0
6.2	8.16	5.4	0.2426	1234.9	196.5
6.4	8.42	5.1	0.2291	1238.4	185.0



Unconfined compressive strength q_u, (Kpa) =197.6 kPa

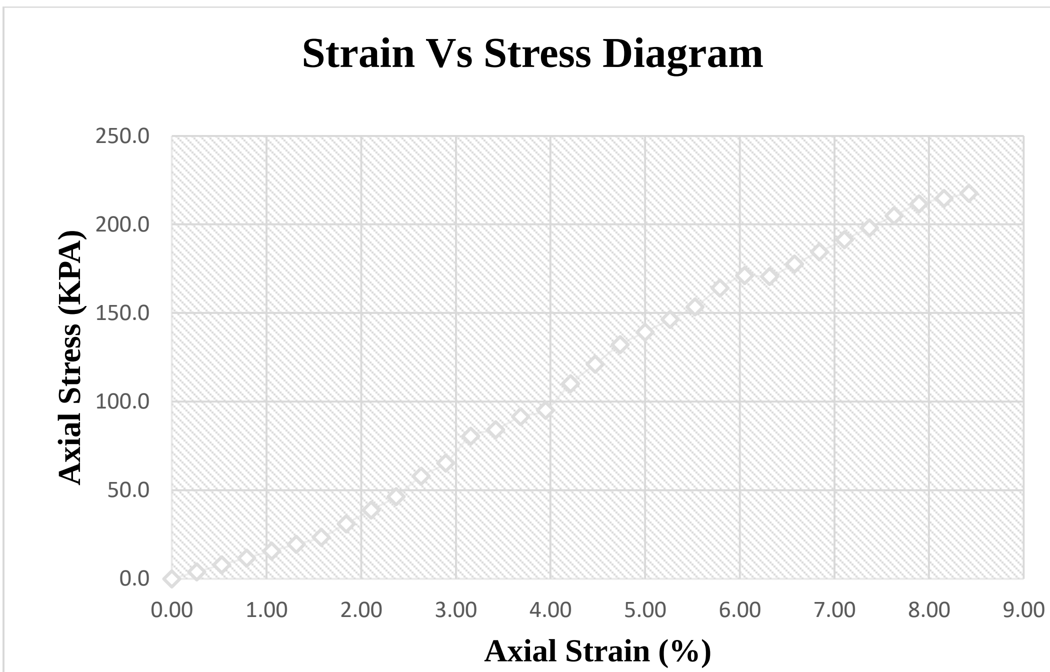
E19 Unconfined compression test result of TP 19 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, KN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	**Axial Strain,e [%]**	**Proving Ring Reading, [div]**	**Applied Load,P [kN]**	**Corrected Area, A [mm^2]**	**Axial Stress,s [kN/m^2]**
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.2	0.0090	1140.1	7.9
0.6	0.79	0.3	0.0135	1143.1	11.8
0.8	1.05	0.4	0.0180	1146.2	15.7
1	1.32	0.6	0.0270	1149.2	23.5
1.2	1.58	0.8	0.0359	1152.3	31.2
1.4	1.84	0.9	0.0404	1155.4	35.0
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.1	0.0494	1161.6	42.5
2	2.63	1.2	0.0539	1164.8	46.3
2.2	2.89	1.4	0.0629	1167.9	53.9
2.4	3.16	1.6	0.0719	1171.1	61.4
2.6	3.42	1.8	0.0809	1174.3	68.9
2.8	3.68	2	0.0899	1177.5	76.3
3	3.95	2.2	0.0988	1180.7	83.7
3.2	4.21	2.4	0.1078	1184.0	91.1
3.4	4.47	2.6	0.1168	1187.2	98.4
3.6	4.74	2.8	0.1258	1190.5	105.7
3.8	5.00	3.1	0.1393	1193.8	116.7
4	5.26	3.4	0.1528	1197.1	127.6
4.2	5.53	3.6	0.1617	1200.5	134.7
4.4	5.79	3.8	0.1707	1203.8	141.8

4.6	6.05	4.1	0.1842	1207.2	152.6
4.8	6.32	4.2	0.1887	1210.6	155.9
5	6.58	4.6	0.2067	1214.0	170.2
5.2	6.84	4.8	0.2157	1217.4	177.1
5.4	7.11	5	0.2247	1220.9	184.0
5.6	7.37	5.2	0.2336	1224.3	190.8
5.8	7.63	5.4	0.2426	1227.8	197.6
6	7.89	5.8	0.2606	1231.3	211.6
6.2	8.16	5.6	0.2516	1234.9	203.8
6.4	8.42	5.4	0.2426	1238.4	195.9



Unconfined compressive strength q_u, (Kpa) =211.6 kpa

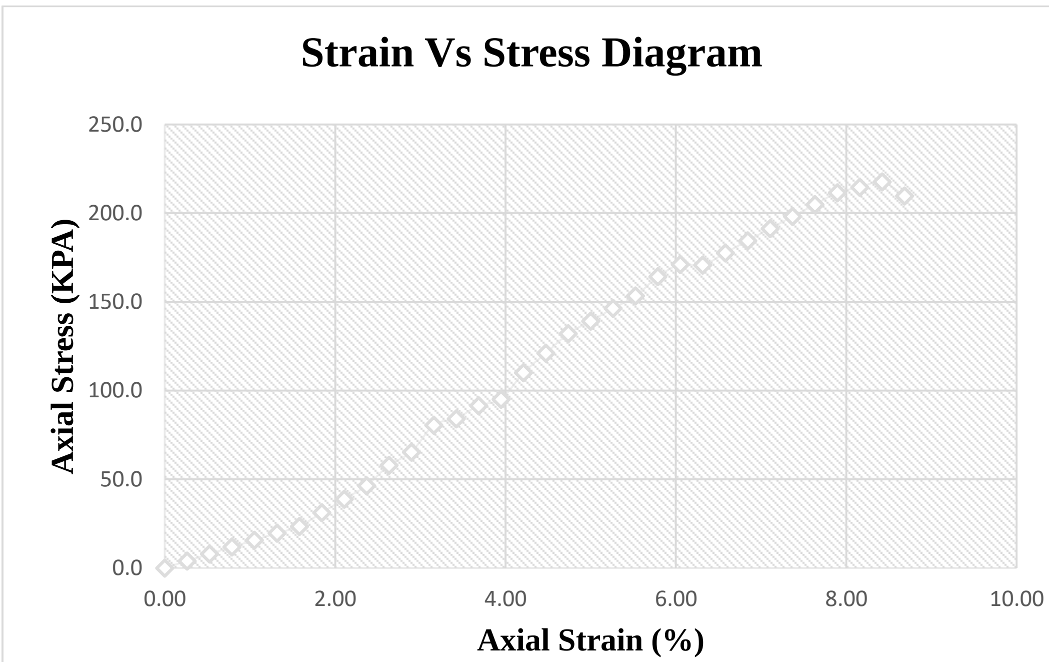
E20 Unconfined compression test result of TP 10 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, KN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	**Axial Strain,e [%]**	**Proving Ring Reading, [div]**	**Applied Load,P [kN]**	**Corrected Area, A [mm^2]**	**Axial Stress,s [kN/m^2]**
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.2	0.0090	1140.1	7.9
0.6	0.79	0.3	0.0135	1143.1	11.8
0.8	1.05	0.4	0.0180	1146.2	15.7
1	1.32	0.5	0.0225	1149.2	19.5
1.2	1.58	0.6	0.0270	1152.3	23.4
1.4	1.84	0.8	0.0359	1155.4	31.1
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.2	0.0539	1161.6	46.4
2	2.63	1.5	0.0674	1164.8	57.9
2.2	2.89	1.7	0.0764	1167.9	65.4
2.4	3.16	2.1	0.0944	1171.1	80.6
2.6	3.42	2.2	0.0988	1174.3	84.2
2.8	3.68	2.4	0.1078	1177.5	91.6
3	3.95	2.5	0.1123	1180.7	95.1
3.2	4.21	2.9	0.1303	1184.0	110.1
3.4	4.47	3.2	0.1438	1187.2	121.1
3.6	4.74	3.5	0.1573	1190.5	132.1
3.8	5.00	3.7	0.1662	1193.8	139.3
4	5.26	3.9	0.1752	1197.1	146.4
4.2	5.53	4.1	0.1842	1200.5	153.5
4.4	5.79	4.4	0.1977	1203.8	164.2
4.6	6.05	4.6	0.2067	1207.2	171.2

4.8	6.32	4.6	0.2067	1210.6	170.7
5	6.58	4.8	0.2157	1214.0	177.7
5.2	6.84	5	0.2247	1217.4	184.5
5.4	7.11	5.2	0.2336	1220.9	191.4
5.6	7.37	5.4	0.2426	1224.3	198.2
5.8	7.63	5.6	0.2516	1227.8	204.9
6	7.89	5.8	0.2606	1231.3	211.6
6.2	8.16	5.9	0.2651	1234.9	214.7
6.4	8.42	6	0.2696	1238.4	217.7
6.6	8.68	5.8	0.2606	1242.0	209.8



Unconfined compressive strength q_u, (Kpa) =217.7 kPa

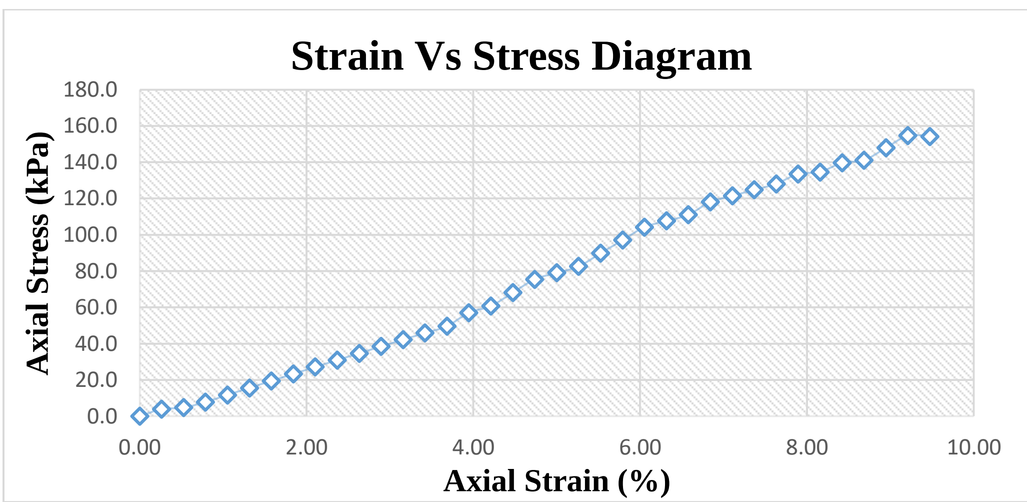
E21 Unconfined compression test result of TP 13 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, KN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	**Axial Strain,e [%]**	**Proving Ring Reading, [div]**	**Applied Load,P [kN]**	**Corrected Area, A [mm^2]**	**Axial Stress,s [kN/m^2]**
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.12	0.0054	1140.1	4.7
0.6	0.79	0.2	0.0090	1143.1	7.9
0.8	1.05	0.3	0.0135	1146.2	11.8
1	1.32	0.4	0.0180	1149.2	15.6
1.2	1.58	0.5	0.0225	1152.3	19.5
1.4	1.84	0.6	0.0270	1155.4	23.3
1.6	2.11	0.7	0.0315	1158.5	27.1
1.8	2.37	0.8	0.0359	1161.6	30.9
2	2.63	0.9	0.0404	1164.8	34.7
2.2	2.89	1	0.0449	1167.9	38.5
2.4	3.16	1.1	0.0494	1171.1	42.2
2.6	3.42	1.2	0.0539	1174.3	45.9
2.8	3.68	1.3	0.0584	1177.5	49.6
3	3.95	1.5	0.0674	1180.7	57.1
3.2	4.21	1.6	0.0719	1184.0	60.7
3.4	4.47	1.8	0.0809	1187.2	68.1
3.6	4.74	2	0.0899	1190.5	75.5
3.8	5.00	2.1	0.0944	1193.8	79.0
4	5.26	2.2	0.0988	1197.1	82.6
4.2	5.53	2.4	0.1078	1200.5	89.8
4.4	5.79	2.6	0.1168	1203.8	97.0

4.6	6.05	2.8	0.1258	1207.2	104.2
4.8	6.32	2.9	0.1303	1210.6	107.6
5	6.58	3	0.1348	1214.0	111.0
5.2	6.84	3.2	0.1438	1217.4	118.1
5.4	7.11	3.3	0.1483	1220.9	121.4
5.6	7.37	3.4	0.1528	1224.3	124.8
5.8	7.63	3.5	0.1573	1227.8	128.1
6	7.89	3.66	0.1644	1231.3	133.6
6.2	8.16	3.7	0.1662	1234.9	134.6
6.4	8.42	3.85	0.1730	1238.4	139.7
6.6	8.68	3.9	0.1752	1242.0	141.1
6.8	8.95	4.1	0.1842	1245.6	147.9
7	9.21	4.3	0.1932	1249.2	154.7
7.2	9.47	4.3	0.1932	1252.8	154.2



Unconfined compressive strength q_u, (Kpa) =154.7 kpa

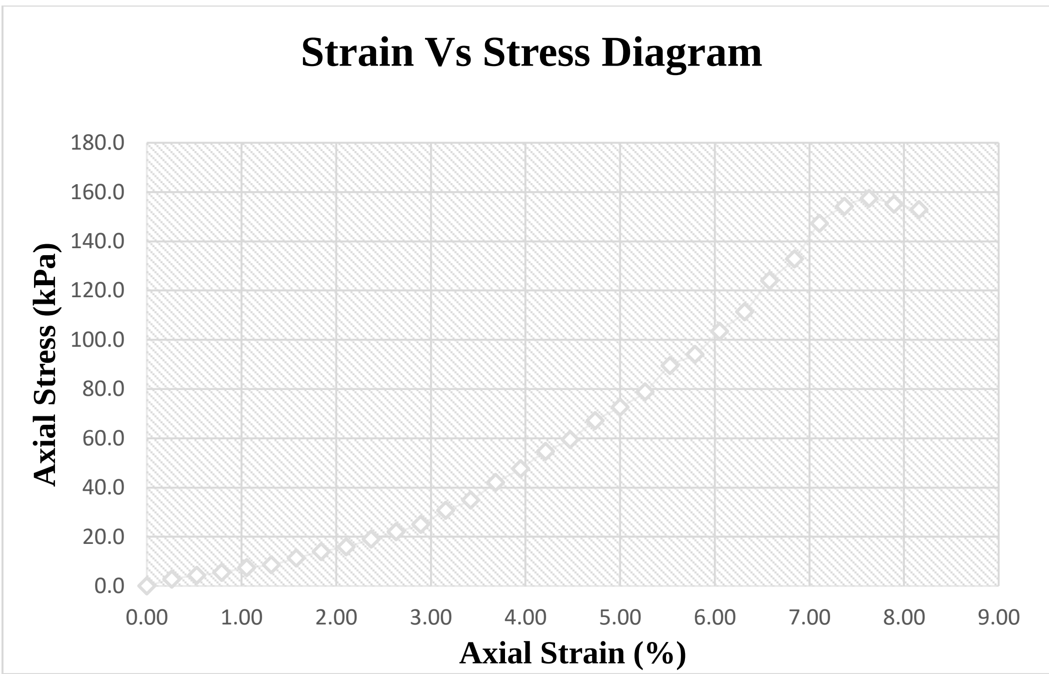
E22 Unconfined compression test result of TP 22 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, KN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	**Axial Strain,e [%]**	**Proving Ring Reading, [div]**	**Applied Load,P [kN]**	**Corrected Area, A [mm^2]**	**Axial Stress,s [kN/m^2]**
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.07	0.0031	1137.1	2.8
0.4	0.53	0.11	0.0049	1140.1	4.3
0.6	0.79	0.14	0.0063	1143.1	5.5
0.8	1.05	0.19	0.0085	1146.2	7.4
1	1.32	0.22	0.0099	1149.2	8.6
1.2	1.58	0.29	0.0130	1152.3	11.3
1.4	1.84	0.36	0.0162	1155.4	14.0
1.6	2.11	0.41	0.0184	1158.5	15.9
1.8	2.37	0.49	0.0220	1161.6	19.0
2	2.63	0.57	0.0256	1164.8	22.0
2.2	2.89	0.65	0.0292	1167.9	25.0
2.4	3.16	0.8	0.0359	1171.1	30.7
2.6	3.42	0.91	0.0409	1174.3	34.8
2.8	3.68	1.1	0.0494	1177.5	42.0
3	3.95	1.25	0.0562	1180.7	47.6
3.2	4.21	1.44	0.0647	1184.0	54.6
3.4	4.47	1.57	0.0705	1187.2	59.4
3.6	4.74	1.78	0.0800	1190.5	67.2
3.8	5.00	1.93	0.0867	1193.8	72.6
4	5.26	2.1	0.0944	1197.1	78.8
4.2	5.53	2.39	0.1074	1200.5	89.5
4.4	5.79	2.52	0.1132	1203.8	94.1

4.6	6.05	2.78	0.1249	1207.2	103.5
4.8	6.32	3	0.1348	1210.6	111.3
5	6.58	3.35	0.1505	1214.0	124.0
5.2	6.84	3.6	0.1617	1217.4	132.9
5.4	7.11	4	0.1797	1220.9	147.2
5.6	7.37	4.2	0.1887	1224.3	154.1
5.8	7.63	4.3	0.1932	1227.8	157.4
6	7.89	4.25	0.1910	1231.3	155.1
6.2	8.16	4.2	0.1887	1234.9	152.8



Unconfined compressive strength q_u, (Kpa) =157.4 kpa

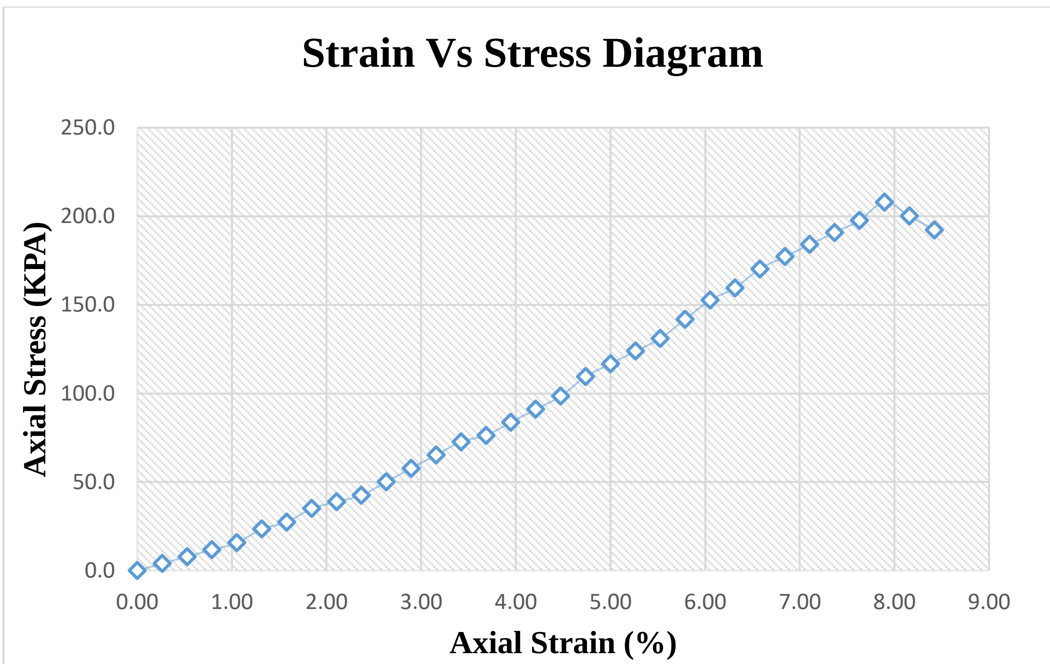
E23 Unconfined compression test result of TP 23 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, KN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	**Axial Strain, e [%]**	**Proving Ring Reading, [div]**	**Applied Load,P [kN]**	**Corrected Area, A [mm^2]**	**Axial Stress,s [kN/m^2]**
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.2	0.0090	1140.1	7.9
0.6	0.79	0.3	0.0135	1143.1	11.8
0.8	1.05	0.4	0.0180	1146.2	15.7
1	1.32	0.6	0.0270	1149.2	23.5
1.2	1.58	0.7	0.0315	1152.3	27.3
1.4	1.84	0.9	0.0404	1155.4	35.0
1.6	2.11	1	0.0449	1158.5	38.8
1.8	2.37	1.1	0.0494	1161.6	42.5
2	2.63	1.3	0.0584	1164.8	50.1
2.2	2.89	1.5	0.0674	1167.9	57.7
2.4	3.16	1.7	0.0764	1171.1	65.2
2.6	3.42	1.9	0.0854	1174.3	72.7
2.8	3.68	2	0.0899	1177.5	76.3
3	3.95	2.2	0.0988	1180.7	83.7
3.2	4.21	2.4	0.1078	1184.0	91.1
3.4	4.47	2.6	0.1168	1187.2	98.4
3.6	4.74	2.9	0.1303	1190.5	109.4
3.8	5.00	3.1	0.1393	1193.8	116.7
4	5.26	3.3	0.1483	1197.1	123.9
4.2	5.53	3.5	0.1573	1200.5	131.0
4.4	5.79	3.8	0.1707	1203.8	141.8
4.6	6.05	4.1	0.1842	1207.2	152.6

4.8	6.32	4.3	0.1932	1210.6	159.6
5	6.58	4.6	0.2067	1214.0	170.2
5.2	6.84	4.8	0.2157	1217.4	177.1
5.4	7.11	5	0.2247	1220.9	184.0
5.6	7.37	5.2	0.2336	1224.3	190.8
5.8	7.63	5.4	0.2426	1227.8	197.6
6	7.89	5.7	0.2561	1231.3	208.0
6.2	8.16	5.5	0.2471	1234.9	200.1
6.4	8.42	5.3	0.2381	1238.4	192.3



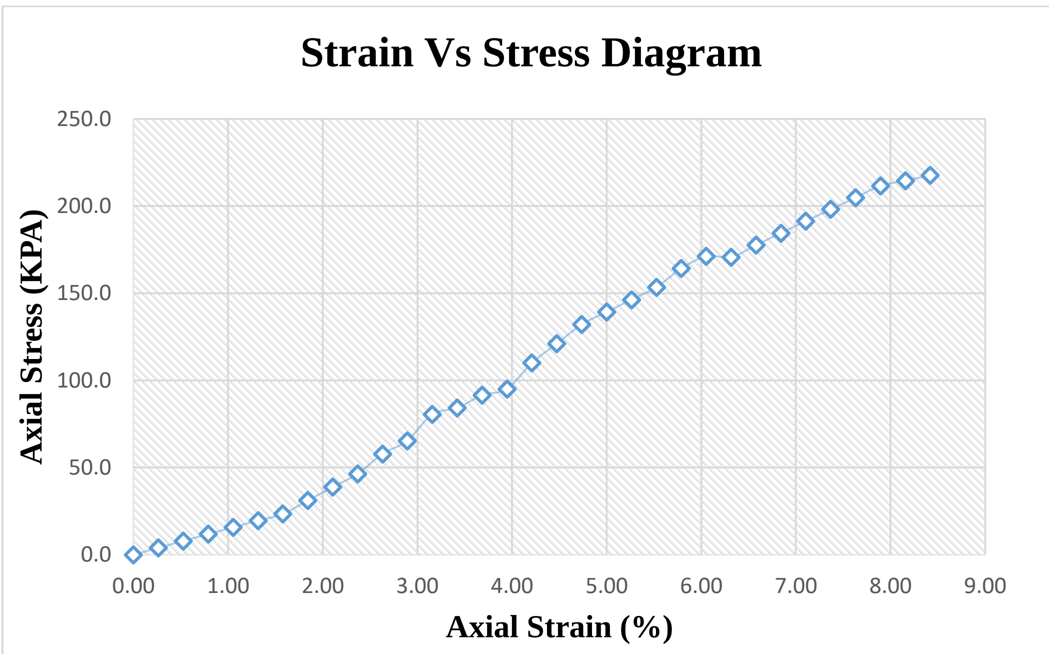
Unconfined compressive strength q_u, (Kpa) =208 kpa

E24 Unconfined compression test result of TP 24 at D=1.5m

Test pit Depth, m	1.5	Ring calibration Factor, KN/div	0.04493
Length of sample, mm	76	Diameter of sample, mm	38

Specimen Deformation, ΔL [mm]	**Axial Strain,e [%]**	**Proving Ring Reading, [div]**	**Applied Load,P [kN]**	**Corrected Area, A [mm^2]**	**Axial Stress,s [kN/m^2]**
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.1	0.0045	1137.1	4.0
0.4	0.53	0.2	0.0090	1140.1	7.9
0.6	0.79	0.4	0.0180	1143.1	15.7
0.8	1.05	0.6	0.0270	1146.2	23.5
1	1.32	0.8	0.0359	1149.2	31.3
1.2	1.58	1.2	0.0539	1152.3	46.8
1.4	1.84	1.4	0.0629	1155.4	54.4
1.6	2.11	1.6	0.0719	1158.5	62.1
1.8	2.37	1.8	0.0809	1161.6	69.6
2	2.63	2.2	0.0988	1164.8	84.9
2.2	2.89	2.4	0.1078	1167.9	92.3
2.4	3.16	2.6	0.1168	1171.1	99.8
2.6	3.42	2.8	0.1258	1174.3	107.1
2.8	3.68	3	0.1348	1177.5	114.5
3	3.95	3.2	0.1438	1180.7	121.8
3.2	4.21	3.4	0.1528	1184.0	129.0
3.4	4.47	3.6	0.1617	1187.2	136.2
3.6	4.74	3.8	0.1707	1190.5	143.4
3.8	5.00	4	0.1797	1193.8	150.5
4	5.26	4.2	0.1887	1197.1	157.6
4.2	5.53	4.4	0.1977	1200.5	164.7
4.4	5.79	4.6	0.2067	1203.8	171.7

4.6	6.05	4.8	0.2157	1207.2	178.7
4.8	6.32	5.2	0.2336	1210.6	193.0
5	6.58	5.4	0.2426	1214.0	199.9
5.2	6.84	5.6	0.2516	1217.4	206.7
5.4	7.11	5.8	0.2606	1220.9	213.5
5.6	7.37	6.2	0.2786	1224.3	227.5
5.8	7.63	6.2	0.2786	1227.8	226.9
6	7.89	6.2	0.2786	1231.3	226.2
6.2	8.16	6.2	0.2786	1234.9	225.6
6.4	8.42	6	0.2696	1238.4	217.7



Unconfined compressive strength q_u, (Kpa) =227.5 kPa

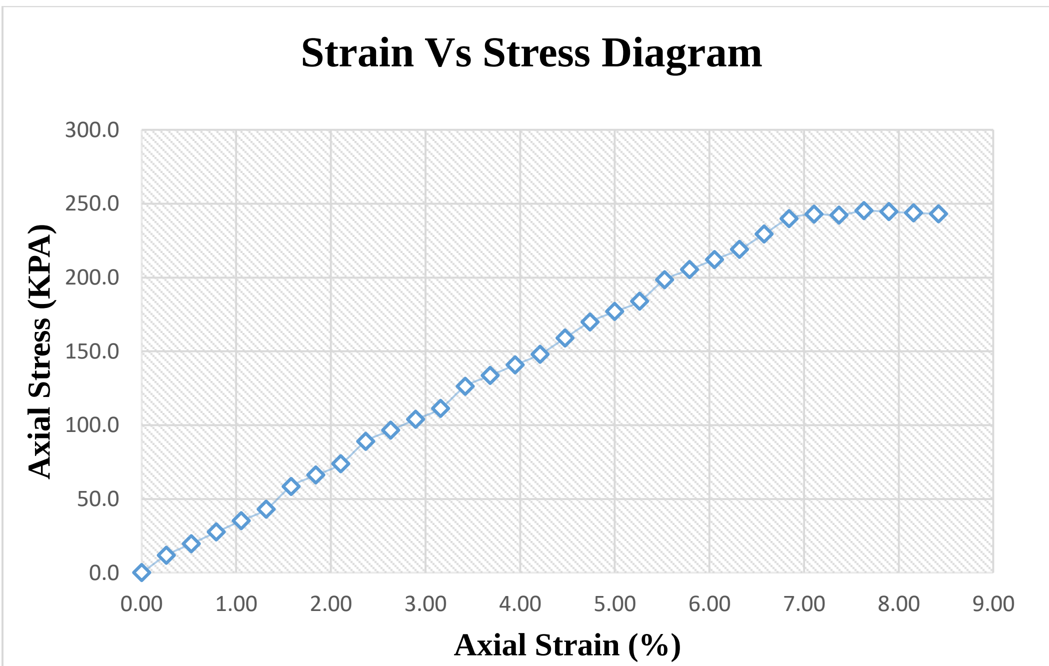
E25 Unconfined compression test result of TP 25 at D=1.5m

Test pit Depth, m 1.5 Ring calibration Factor, KN/div 0.04493

Length of sample, mm 76 Diameter of sample, mm 38

Specimen Deformation, ΔL [mm]	Axial Strain,e [%]	Proving Ring Reading, [div]	Applied Load,P [kN]	Corrected Area, A [mm^2]	Axial Stress,s [kN/m^2]
0	0.00	0	0.0000	1134.1	0.0
0.2	0.26	0.3	0.0135	1137.1	11.9
0.4	0.53	0.5	0.0225	1140.1	19.7
0.6	0.79	0.7	0.0315	1143.1	27.5
0.8	1.05	0.9	0.0404	1146.2	35.3
1	1.32	1.1	0.0494	1149.2	43.0
1.2	1.58	1.5	0.0674	1152.3	58.5
1.4	1.84	1.7	0.0764	1155.4	66.1
1.6	2.11	1.9	0.0854	1158.5	73.7
1.8	2.37	2.3	0.1033	1161.6	89.0
2	2.63	2.5	0.1123	1164.8	96.4
2.2	2.89	2.7	0.1213	1167.9	103.9
2.4	3.16	2.9	0.1303	1171.1	111.3
2.6	3.42	3.3	0.1483	1174.3	126.3
2.8	3.68	3.5	0.1573	1177.5	133.6
3	3.95	3.7	0.1662	1180.7	140.8
3.2	4.21	3.9	0.1752	1184.0	148.0
3.4	4.47	4.2	0.1887	1187.2	158.9
3.6	4.74	4.5	0.2022	1190.5	169.8
3.8	5.00	4.7	0.2112	1193.8	176.9
4	5.26	4.9	0.2202	1197.1	183.9
4.2	5.53	5.3	0.2381	1200.5	198.4
4.4	5.79	5.5	0.2471	1203.8	205.3

4.6	6.05	5.7	0.2561	1207.2	212.1
4.8	6.32	5.9	0.2651	1210.6	219.0
5	6.58	6.2	0.2786	1214.0	229.5
5.2	6.84	6.5	0.2920	1217.4	239.9
5.4	7.11	6.6	0.2965	1220.9	242.9
5.6	7.37	6.6	0.2965	1224.3	242.2
5.8	7.63	6.7	0.3010	1227.8	245.2
6	7.89	6.7	0.3010	1231.3	244.5
6.2	8.16	6.7	0.3010	1234.9	243.8
6.4	8.42	6.7	0.3010	1238.4	243.1



Unconfined compressive strength q_u, (Kpa) =245.2 kPa

Photos taken while performing tests