ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

A STUDY ON THE EFFECT OF REMOLDING ON THE MECHANICAL BEHAVIOR OF ADDIS ABABA RED CLAY SOIL

A thesis submitted to the school of graduate studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of

Master of Science in Civil Engineering

By

Merihun Lukas

Advisor:

Dr. Hadush Seged

April 2010

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

A thesis submitted to the school of graduate studies of
Addis Ababa University in partial fulfillment of the requirements for
the Degree of
Master of Science in Civil Engineering

By

Merihun Lukas

Approved by Board of Examiners

1.	______________	______________	______________
	Advisor	Signature	Date
2.	______________	______________	______________
	External Examiner	Signature	Date
3.	______________	______________	______________
	Internal Examiner	Signature	Date
4.	______________	______________	______________
	Chairman	Signature	Date

Dedicated to

Our

Baby

Acknowledgement

My first thank goes to almighty God who has given me good teachers, friends and family who are the part taker of this thesis research and who also gave me courage, health and support throughout my study and to carry out this research work.

I am very grateful for my research advisor Dr. Hadush Seged Who has encouraged, directed, and given me academic advisory throughout the research work with good heart and patient.

Maichew Technical College, my sponsor, also deserves thank for its financial support until the completion of the study.

Dr. Azad Koliji, Stanford University, who has sent me academic materials for reference and encouraged me; Leidulf and Solveig, Norway, who has sent me materials helpful for the research work; Addis Ababa University for its fund; all my good friends and relatives for direct and indirect support in my study and research work deserve great thank from deepest of my heart.

Last but not least, Helen Tekeste, my wife, who is always with me, supporting and encouraging deserves respect and thank for her help, without it I could not be fruitful.

List of Symbols

A	Area
A_o	Initial area
$\mathring{A}$	Angstrom units
B	Skempton's pore pressure parameter
C	Total Cohesion of soil in kpa
C'	Effective cohesion of soil in kpa
C_c	Compression Index
C_v	Coefficient of consolidation
D	Diameter
d_{90}	Compression dial reading at 90% consolidation
d_o	Compression dial reading at zero time in consolidation
E	Young's modulus
e	Void ratio
e_o	Initial void ratio
G_s	Specific gravity of soil specimen
$\hat{H}$	Average specimen height
H	Height of specimen
H_s	Height of solid
K_0	Coefficient of lateral earth pressure at rest
M_v	Modulus of compressibility
P_c	Pre consolidation pressure

t_{90}	Time at 90% consolidation
U_w	Pore water pressure
V_o	Original Volume of the specimen
w_o	Initial moisture content
w_f	Final moisture content
ε	strain
ν	Poisson's ratio
ϕ	Angle of internal friction
ϕ'	Angle of internal friction/effective
η	Shear stress ratio
σ_c	Confining stress
σ_1, σ_1'	Total and effective major principal stress
σ_3, σ_3'	Total and effective minor principal stress
$\Delta\sigma_a$	Deviator stress
τ	Shear stress

List of Abbreviations

Auto-triax	Automatic triaxial testing machine
ATD	Automatic Triaxial Data logger
AVC	Automatic Volume Change
BP	Back pressure
CP	Cell pressure
LL	Liquid Limit
PP	Pore pressure
PI	Plasticity Index
PL	Plastic Limit
CU	Consolidated Undrained test
CD	Consolidated Drained test
UU	Unconsolidated Undrained test
OC	Over consolidated
NC	Normally consolidated
OCR	Over consolidation ratio
OMC	Optimum moisture content
MDD	Maximum dry density
RTC	Real Time Control

List of Figures

List of Tables

Abstract

This research work tries to see the effect of soil remolding on the mechanical behavior of red clay of Addis Ababa. It is tried to identify the effect of remolding by conducting a series of laboratory tests such as triaxial compression and consolidation tests on the undisturbed and remolded soil samples. The soil was remolded by compacting at OMC. It was also done basic tests to see the engineering properties of the soils.

The one dimensional consolidation tests were done on samples of diameters of 50mm and 70mm and height of 18mm with the effective consolidation stresses of 50 kpa to 1600 kpa. A total of eight one-dimensional consolidation tests were run, out of which four were undisturbed and four were remolded samples. The deformation and hydro-mechanical /permeability while loading/ behavior were examined using the one dimensional consolidation test.

The triaxial tests were done on samples of 38mm and height of twice the diameter. Two triaxial testing machines were employed on the testing program. Soil samples collected from Kolfe areas were conducted on the newly acquired Automatic triaxial testing machines and samples collected from Addisu Gebeya area were tested on the semi automatic triaxial compression machine procured two years ago. The type of triaxial test employed was Consolidated undrained/CU/ with pore pressure measurement and with the effective consolidation pressure of 150 kpa, 250 kpa and 350 kpa. A total of twenty-four triaxial CU tests were run out of which twelve were undisturbed and twelve were remolded. The results of triaxial tests were used to examine the stress-strain and strength behavior.

The results show that remolding reduces the peak deviator stress, effective cohesion and permeability and increases amount of compression and time required for consolidation.

1. INTRODUCTION

1.1 General

When civil engineering structures rest on the ground, they induce stress on the underlying soil and the stress will be distributed in the soil mass. Depending on the engineering property, the response of the soil to the applied stress is different. As long as the applied stress does not exceed the load carrying capacity, the soil resists the applied load. It is also common to the applied stress to produce some deformation on the soil.

Once the applied stress is beyond the strength of the soil, it undergoes excessive deformation immediately or after long time, and/or fail or collapses. Depending on different factors the manner how the soil collapses or fails is also different.

The behavior how the soil responds for the applied mechanical load can be taken as the mechanical behavior of the soil. The mechanical behavior of soils is different for different types of soils and affected by several conditions. The volume change, deformation, strength and hydraulic conductivity of fine grained soils are very important for engineering problems (Mitchel, J. K., 1976).

If the soil contains large amount of clay minerals, it has the properties of high plasticity, high shrinkage and swell, low permeability, high compressibility. Clay mineral attracts water to its surface and results in plasticity. If the soil contains non clay mineral which has low affinity for water, the plasticity is lower.

The behavior of fine grained soil is very dependant on loading or geological history and the soil structure. Structure of the soil refers to soil fabric, which expresses the geometric arrangement of soil mineral grains, and the inter-particle forces. The first one affects mostly the volume change and water retention behavior and the second one mostly affects the strength and deformation elements of the soil (Koliji A., 2008).

Strength and deformation behavior of saturated clay is influenced by: drainage conditions, disturbance (change in effective stress and loss of cementation), over consolidation ratio and creep effects.

For characterization of engineering behavior of soils it is common practice to use undisturbed and remolded soil samples. Remolding the soil disrupts the soil fabric progressively and the water retention and mechanical behavior may be altered and make it different from that of undisturbed soil of the same mineralogy.

Natural soils show various structures, characterized by structural units, such as aggregates, porous block, fissures, earth worm holes and root channels. They differ from reconstituted soils, namely the soil with the same mineralogy from which the structures are removed by remolding in a number of important aspects (Koliji A., 2008).

To identify the effect of remolding on the mechanical behavior, it is customary to compare the strength, deformation and hydraulic conductivity with undisturbed soil of similar mineralogy.

Strength and deformation properties can be studied in the Laboratory with different approaches such as: isotropic compression, confined compression (oedometer), tri-axial compression and direct shear tests. The hydraulic conductivity behavior of soil can be obtained directly from permeability test or from oedometer test results (Lambe, T.W., and Whitman, R.V., 1979).

For this research soil samples of disturbed and undisturbed conditions have been collected from Kolfe and Addisu Gebeya that are known areas of Addis Ababa having red clay soils (Tadesse, S., 1989 and Abzo, H., 1992). Tests for remolded and undisturbed samples have been conducted with different loading conditions and the responses of the clay soils under different loading conditions have been examined.

1.2 Objective of the Study

The main objective of this thesis research is to study the behavior of Addis Ababa red clay soil under different intensity of mechanical loading when the soil is kept in its field condition of moisture content, density, and structures (undisturbed) and when the soil is remolded or disturbed from its natural conditions of moisture, density and structures by involving theoretical and experimental studies. In general, it is intended to see and examine the effect of remolding on the mechanical behavior of Addis Ababa Red clay soil.

It is also aimed at to put in use the newly acquired automatic tri-axial apparatus (Auto-triax) and to benefit from the special feature of the machine.

1.3 Methodology

In the current thesis research work as a method to perform the intended research work, review of the literatures has been done for revising the accepted theories and practices in the topic areas at hand. As part of methodology to perform the research, sample collection and series of laboratory tests to reveal different natures and behavior have been exhaustively carried out. Based on the theories and laboratory tests performed, the results obtained have been analyzed and discussed thoroughly. Finally, the findings and results of the research have been reported.

1.4 Scope of the study

The current research work focuses on Northern and Western Addis Ababa where red clay soil is found. Addisu Gebeya from Northern and Kolfe from Western Addis Ababa (Tadesse, S., 1989 and Abzo, H., 1992). Two test pits were opened at each site to a depth of 2.5m and disturbed and undisturbed samples are collected.

Deformation, permeability, strength and stress-strain behavior of the red clay soil were studied in the laboratory under remolded and undisturbed condition with different state of mechanical loading.

1.5 Limitation of the study

It was initially intended to collect samples from three areas of Addis Ababa where red clay is found. Due to electric power problem at the national level the time for the lab work was limited and shortage of financial support restricted the domain of the study areas in to only two areas of Addis Ababa. It would have been worth to open additional test pits and collect samples from additional areas where red clay is found.

1.6 Organization of the thesis

The thesis has a total of six chapters. Chapter one deals with the general behavior of soils as the back ground. It also includes the objective of the thesis work, scope and limitations of the thesis, as well as organization of the thesis. Chapter two is totally devoted to literature review, to summarize the nature of soil formation and behavior of soils under loading and different situations. Chapter three shows the existing and conventional theories, practices and approaches to study mechanical behavior of soil in the laboratory. Chapter four summarizes all laboratory tests conducted and their results. The results and findings are discussed in chapter five. Chapter six contains conclusion and indicates points for further researches. Appendix-A introduces the newly acquired tri-axial compression machine called Auto-triax. The hard wares and soft wares to perform effective stress compression testing are introduced in this chapter. Procedures and guide lines to use the machine are also discussed in this section. The detail information and results for laboratory test are attached in the appendix-B. The reference section, which lists down the books and academic materials that have been reviewed, is dedicated for citation to acknowledge the materials and authors.

2. Literature Review

2.1 Red clay soil

2.1.1 General

Clay refers for soil particles finer than 2 microns (0.002mm) and 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 primarily caused the deformation.

Clay soil may contain clay minerals as well as non clay minerals. The non clay minerals that found in clay are quartz, feldspar or mica of clay size. Clay minerals are mostly in the form of sheets; their thickness is relatively smaller than width and length of the sheets, their surface area is so larger than their volume. As the result the behavior of clay is governed by the surface forces (Terzaghi, K. and Peck, R.B., 1967).

Soil behavior is attributed to the properties of clay minerals that 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.

2.1.2 Clay Minerals

Clay minerals are small group of minerals that constitute clay soils together with other minerals. Most of clay minerals are formed from two basic units known as octahedral and silica sheets. The octahedral units consist of aluminum, magnesium or iron embedded between two layers of oxygen or hydroxyl layers. The silica sheet consist tetrahedron of four oxygen atoms and one silicon atom in between.

Most of the clay minerals are the product of chemical weathering of rock forming minerals like feldspar and mica. The clay minerals include Illite, Kaolinite, Montmorillonite, Halloysite and Vermiculite; however, the first three are the major ones.

2.1.2.1 Illite

Illite is made up of octahedral sheet bonding with two silica sheets: one at the top and another at the bottom. The illite layers are bonded by potassium ions. Illite particles range from 50Å to 500Å in thickness and have specific surface area of about $80m^2/g$.

2.1.2.2 Kaolinite

Kaolinite is composed of a single tetrahedron sheet and single aluminum octahedral sheet combined in a unit so as the tips of the silica tetrahedron and one of the layers of the octahedral sheet form a common layer. The association of a silica tetrahedral sheet with aluminum octahedral sheet forms one layer of kaolinite. The thickness of kaolinite layer is about 7Å. The kaolinite mineral is formed by stacking the layers of 7Å thick one above the other with the base of silica sheet bonding the hydroxyls of the octahedral sheet by hydrogen bond. Since the hydrogen bonds are relatively strong, therefore, the mineral is stable and water can not enter between the sheets to expand the unit cells.

2.1.2.3 Montmorillonite

Montmorillonite has similar structure to illite. The structure has one octahedral sheet sandwiched between two silica sheets and bonded with weak Vander walls forces. Large amount of water is attracted in to the space between the layers and causing the layers to expand significantly. Montmorillonite particles have the lateral dimension of 1000Å to 5000Å and thickness of 10 Å to 50 Å, and its specific area is about $800m^2/g$.

2.1.3 Origin and Mineral Composition of Ethiopian Red Clay soils

According to the study of Morin and Parry (1971), the Ethiopian red clay soils have formed as residual from basaltic volcanic rocks in places with plenty of rainfall and good drainage. The principal clay minerals that constitute the Ethiopian red clay are kaolinite and halloysite. Montmorillonite is also found in the Ethiopian red clay as accessory or less amount than as in Ethiopian black clay.

The Ethiopian red clay is found to be acidic, which is similar to that of other tropical soils. The cation exchange capacity is from 30 to 77 milli-equivalents per 100g. The Ethiopian red clay soils do not show wide range index properties as other tropical soils. They have also generally lower clay contents, liquid limits and plasticity indices (Morin, W.J., and Parry, W.T., 1971).

The shrinkage limit of the red clay varies from 10% to 30%. Morin and Parry (1971) have also indicated that the volume change tendency of the Ethiopian red clay soil is also significant at the lower moisture content. However, red clay soils are less expansive than the Ethiopian black clay soils because of high amount of kaolinite and halloysite relative to montmorillonite.

The unconfined compressive strength of the red clay soil varies from 147 to 251kpa and has even more strength. The Ethiopian red clay soils have similar densities, however, lower dry density than other tropical soils when compacted according to AASHTO standard. The red clay soil show less plasticity but some are near to the dividing line between low plasticity and high plasticity groups (Morin, W.J., and Parry, W.T., 1971). The summery of the properties of Ethiopian red clay soil is shown below.

Table: 2.1 Properties of Ethiopian red clay soils (Morin and Parry 1971).

Properties	**Values/Results**
Parent Rock	Olivine basalt, Basalt, Trachyte,
Rain fall, cm/yr	122-234
Temperature, ^{o}F	57-68
Drainage	Fair – good
Principal Clay minerals	Kaolinite, Hallysite, Montmorillonite
PH Value	5.1-6.8
Principal Cations	Calcium, magnesium, potassium
Cation Exchange capacity, m.e./100g	30-77
Clay (2µ), %	34-76
Liquid Limit, %	44-66
Plasticity Index, %	14-30
Shrinkage Limit, %	10-30
Specific gravity	2.61-2.91
Organic Content, %	1-4
Compaction Test:	
Max Density g/cc	1.185-1.698
Optimum Moisture Content, %	38-29
CBR Test Value	6-9
Unconfined Compressive Strength, kpa.	147-251
Expansion Pressure, kPa	21-958

2.2 Mechanical Behavior of Soils

2.2.1 Volume Change Behavior

Swelling and shrinkage behavior of clay soils are directly related to plastic properties of clay. The observed actual amount of swell or shrinkage as a result of wetting and drying depends not only on the mineralogy but also particle arrangement, initial water content and confining pressure.

The consequence of volume change such as settlement due to compression and heave due to expansion makes this property very useful in engineering problems. Moreover, changes in volume have a tendency to lead to change in strength and deformation behavior which in tern can affect stability of the soil.

Among different factors: pressure, temperature, and chemical environment, affecting volume changes of the soil, the effect of pressure has been most important.

More importantly, physical interactions like bending, sliding, rolling and crushing of soil particles have a tendency to control resistance to volume change behavior of the soil.

Since chemical precipitates may act as cementing agents between soil particles and hence surface force and water adsorption properties are likely to be influenced, chemical and organic environment has also a tendency to control the resistance to volume change behavior of soil.

Changing the mineral detail of a soil will also change the volume change behavior of the soil. Small differences in certain characteristics of expansive minerals can have also a major effect on the swelling of a soil. Soil fabric and structure are also responsible for volume change behavior of a particular soil. Compacted, expansive soils with flocculated structures are likely to be more expansive than with dispersed structures. At the pressure less than pre-consolidation pressure, a soil with flocculated structure is less compressible than the same soil with a dispersed structure. The reverse is true for pressure greater than pre-consolidation pressure.

Depending on stress history, a soil may be more compressible or expansive. A soil which is over consolidated has less tendency to compression than a soil which is normally consolidated but the reverse will take place for expansion at the same void ratio (Mitchell, J.K., 1976).

If the soil contains non expansive clay minerals, the pore water chemistry has relatively little effect on the compression behavior of the soil after the initial fabric has formed and the structure has stabilized under a moderate effective pressure.

The stress path followed during loading or unloading has a great effect on the compression or swelling behavior of the soil. Unloading a soil from some specific point to another point in one step may give considerably different behavior than if the unloading is done in stages. Similarly, differences in load increment magnitude and duration influence the equilibrium pressure–void ratio relationships for clays (Mitchell, J.K., 1976).

2.2.2 Strength and Deformation Behavior

Frictional resistance between soil particles in contact has basic responsibility for strength of the soil. The effective stress for a given type of soil determines the magnitude of frictional resistance. The effective stress is controlled by the applied stress, physical and chemical forces of interaction and the volume change tendency of the soil.

The most important factors affecting the strength of saturated clay are drainage conditions, disturbance (manifested by a change in effective stress and loss of cementation), over consolidation ratio and creep effects whereas the strength of cohesion less soil depend mostly on relative density, effective minor principal stress and test type. The peak strength of clay may considerably be greater than the strength after very large strain or shear displacement.

In the absence of chemical cementation between soil particles the strength of sand and normally consolidated clay depends directly on effective stress. The peak value of effective angle of internal friction for clays decreases with increasing plasticity index.

Increase in plasticity results in decreases with the residual friction angle. The residual strength is the shear strength along a well-defined failure surface at large displacement. It is independent of stress history and original structure. For a given set of testing conditions it depends only on effective stress.

When clays are over consolidated, they may exhibit higher strength than that of normally consolidated clays. The strength envelop of the two types of clays at the same effective stress depends up on type of clay, drainage conditions during shearing and amount of over consolidation.

While heavily over consolidated (OCR = 6 to 8) clays have greater volume after drained shear failure or higher effective stress after undrained shear failure; normally consolidated (OCR=1) and moderately over consolidated clays (OCR up to about 4) have small volume after drained shear failure or lower effective stress after undrained shear failure than at the start of deformation (Mitchell, J. K., 1976).

2.2.2.1 Stress – Strain Behavior

The stress-strain behaviors of soils are different for different types and condition of soils. Soils like some quick clay, cemented soils, heavily over consolidated clays and dense sands have brittle nature. But Remolded and insensitive clays, and loose sands have ductile nature (Mitchell, J. K., 1976).

Increasing in pre shear consolidation pressure increases the modules of deformation as well as strength of clay soils. An increase in confining pressure has also similar effect for cohesion less soils.

The pore water pressure of saturated clay increases while shearing, if drainage is not allowed. The amount of pore water pressure increment is dependant on interaction between fabric and stress state and the ease with which shear deformation can develop overall changes or transfer of normal stress from soil structure to the pore water pressure (Mitchell, J. K., 1976).

For constant value of total minor principal stress the magnitude of the pore pressure developed in undrained loading may depend more on the strain than on the stress (Mitchell, J. K., 1976).

2.3 Hydro-mechanical behavior /Permeability

Soil mass consists of solid particles of various sizes with interconnected void spaces. The continuous void spaces in a soil permit water to flow from a point of high energy to a point of low energy. The property of a soil that allows the seepage of fluids through its interconnected void spaces is termed as permeability.

2.3.1 Factors Affecting Permeability of soil

Permeability of a soil is dependant on many factors including size of soil grain, properties of pore fluid, void ratio, shape and arrangement of pores and degree of saturation.

Permeability appears to be proportional to the square of an effective grain size. This proportionality is due to the fact that the pore size is related to particle size. The viscosity of water, which is dependant on the temperature, also affects the permeability of the soil. An increase in degree of saturation and/or void ratio causes an increase in permeability.

2.3.2 Determining Permeability of soil

Soil permeability can be measured in the laboratory or in the field. In the laboratory, methods used to determine the permeability are: falling or variable head test, constant head test, and direct or indirect measurement during oedometer test. Since relatively large permeability is required to obtain good precision with the constant head test, its application is limited to pervious soils. The falling head test is used for fine graind soils. The determination of permeability from oedometer test is normally done on soils with low permeability soils.

2.4 Soil Remolding

Soil as construction and foundation material can be used in its natural or undisturbed state or remolded state to meet the specific requirement such as to obtain satisfactory engineering properties like shear strength, compressibility, or permeability.

When the soil is remolded, the fabric of soil is progressively disrupted and the behavior of the soil is altered. Depending on the size and strength of the soil particle, particle arrangement may alter the water retention and mechanical behavior of the soil and make it different from that of undisturbed soil of the same mineralogy.

Natural soils show various structures, characterized by structural units, such as porous block, fissures, earth worm holes and root channels. They differ from remolded soils, namely the soil with the same mineralogy from which the structures are removed by compacting, in a number of important aspects.

The mechanical behavior of natural soils is predominantly influenced by inter-particle bonding. These materials are often referred to as natural structured soils/undisturbed soils.

To identify the extra features in the mechanical behavior of natural soils arising from soil structure, it is widely accepted to compare it with remolded soil of the same mineralogy as a reference state.

As indicated in BS 1377-1, in the laboratory soil remolding can be done by compacting the soil in to a mold at specified moisture content by applying specified compacting effort and also by compacting the soil in to the mold at specified moisture content, to achieve specified dry density.

The two types of commonly practiced laboratory compaction tests are Standard Compaction test and Modified Compaction test. Generally it is accepted that use of standard compaction test to simulate the field compaction for routine foundation and embankment design. Whenever needed to simulate heavy compacting effort in the field, the modified compaction test shall be used in the laboratory.

3. LABORATORY TESTS TO DETERMINE MECHANICAL BEHAVIOR OF SOILS

3.1 General

It would be possible to determine the elastic constants E (Young's modulus) and ν (Poisson's ration) from a simple test, if the soil were isotropic and linearly elastic. Generally, such a simple approach is not possible with soils. Therefore, it becomes important to conduct different types of tests that are designed to study stress-strain behavior during specific type of loading. The most common types of tests used to study stress-strain behavior of soil are described in Fig 3.1.

3.2 One dimensional consolidation /Oedometer Test

In this test, stress is applied to the soil specimen along the vertical axis, while strain in the lateral direction is restricted. Hence the volumetric strain is equal to axial strain.

Shear stress and shear strain as well as compressive stress and volume changes occur in the test, but since the soil is prevented from failing in shear, compression is the dominant source of strain. Since the stress condition in this test is approximately similar to the actual site condition and the test is simple, the test is popular.

The major challenge that can be considered as experimental difficulty with the oedometer test is side friction in which shear force develops along the cylindrical surface of the specimen as vertical strain occurs. The presence of side friction distributes the one dimensional state of strain and prevents some of the axial force reaching the bottom portion of the specimen. To minimize the effect of the side friction forces, the thickness to diameter ratio of the specimen is kept as small as practical (Lambe, T.W., and Whitman, R.V., 1979).

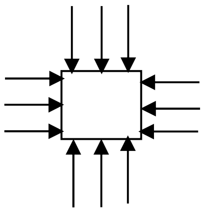
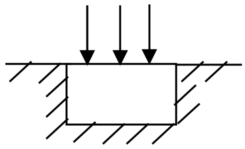
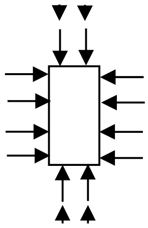
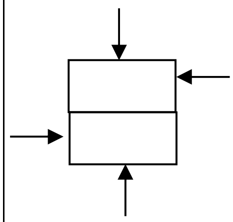
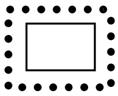
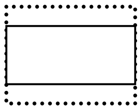
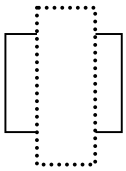
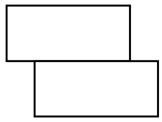
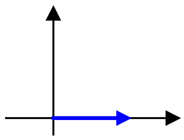
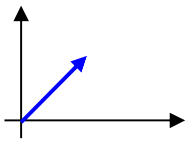
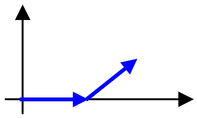
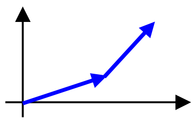
Test	Isotropic compression	Confined compression (Oedometer)	Triaxial Compression	Direct shear
Basic Condition				
Type of deformation	Volumetric deformation 	Volumetric and some distortion 	Distortion and volumetric 	Primarily distortion but some volumetric 
Stress path				
Uses	For study of purely volumetric strain	For approximating certain field condition	Most common test for studying stress-strain and strength properties	Simple test for measuring strength

Fig 3.1 Common types of stress strain tests (Lambe, T.W., and Whitman, R.V., 1979).

3.3 Triaxial Test

The triaxial test is the most common test used to determine the stress-strain behavior of soil. A cylindrical specimen of soil is first subjected to a confining pressure σ_c with equal stresses in all surfaces of the specimen. Then the axial stress is increased, $\Delta\sigma_a$, until the specimen fails. Since there is no shearing stress on the sides of cylindrical specimen, the axial stress $\sigma_c+\Delta\sigma_a$ and confining stress σ_c are the major and minor principal stresses, σ_1 and σ_3 , respectively. The increment of axial stress, $\Delta\sigma_a=\sigma_1 - \sigma_3$, is the deviator stress.

The triaxial test is used to determine the mechanical properties of many materials, such as concrete. Usually there is no confining pressure for a test on concrete, although a confining pressure may be employed in some very special tests. However, a confining pressure is usually essential when testing soil (Lambe, T.W., and Whitman, R.V., 1979).

3.3.1 Size of specimen

The soil cylinder is commonly about 38 mm in diameter and from 75 to 100 mm in length. Specimens about 75 mm in diameter and from 150 to 200 mm long are also encountered frequently. Much large specimens are used in the testing of soils containing gravel. Generally the length of triaxial specimens is about twice of the diameter.

3.3.2 Confining Pressure

The pressure vessel is usually composed of a transparent cylinder/cell with metal end pieces. Either gas or liquid under pressure is used to apply the confining pressure, although the use of liquid, usually de-aired water is preferable.

The soil is encased by a flexible membrane or jacket and two end caps, thus the confining fluid does not penetrate in to the pore spaces.

3.3.3 Axial Loading

In standard triaxial test, the soil is failed by increasing the axial stress while holding the confining pressure constant. Axial force is applied to the loading piston either by means of dead weights, controlled stress test, or by geared or hydraulic loading press, controlled strain test.

3.3.4 Control of pressure in pore spaces

If a dry soil specimen is completely sealed, and if the volume of the soil changes during loading, there must be some change in the volume and pressure of the air occupying the pores of the soil. A drainage system, consisting of a porous stone plus a passage to out side of the pressure vessel, is usually provided so that air can move into or out of the soil and there by prevent the pressure change. The drainage provision will prove to be of great importance during tests on soils containing water.

3.3.5 Measurement of volume Changes

It is not easy to make accurate measurement of the changes in the volume of dry soil, either as the confining pressure or the additional axial stress is applied. When a soil is saturated with water, change in volume during a triaxial test can be determined by measuring the volume of water that flows into or out of the specimen.

4. LABORATORY TEST RESULTS

4.1 General

Soil samples were collected from known areas, Kolfe and Addisu Gebeya, where red clay soils are found. Two test pits were opened at each site and disturbed and undisturbed samples were taken. The moisture content was determined immediately after sampling and transporting it to laboratory by warping with plastic bag to avoid moisture loss. Undisturbed samples were kept under tube sampler sealed with wax and wrapped with plastic bag and moist clothes. Disturbed samples were air dried to constant moisture and sieved with different sieve sizes after pulverizing depending on the requirement of specific test procedures.

Laboratory tests were conducted on disturbed and undisturbed soil samples according to the need. Tests such as Atterberg limits, particle size analysis, specific gravity, free swell and compaction were conducted on disturbed samples. Other tests like triaxial compression and consolidation tests were conducted on both undisturbed and remolded soil samples.

Disturbed soil samples were air dried and oven dried at 105 degree centigrade according to the need for the type of specific requirement of the test procedure. Soil remolding for the specified testes were done at OMC with standard compacting effort.

4.2 Moisture content

The moisture content of the soil which is defined as the ratio between mass of water to mass of soil solid was determine immediately after the sample was taken from the site. The samples were kept in plastic bag to prevent moisture loss during transportation from site to laboratory.

The method employed for determining the moisture content was oven drying method. The measured amount of wet soil was put in an oven of

105 degree centigrade and kept for 24 hours and examined for weight loss. The result of moisture content determination is as follows.

Table 4.1 Moisture content at depth of 2.5m during sample collection

No	Pit Description	Moisture content, %
1	Kolfe pit 1	22
2	Kolfe pit 2	27
3	Addisu Gebeya pit 1	27
4	Addisu Gebeya pit 2	28

4.3 Density Determination

The bulk mass density of the soil was determined by the core cutter method. Tube samplers for collecting undisturbed samples were used as means for cutting core of soil sample. The mass of soil in side the tube sampler was divided to the internal volume of tube sampler for obtaining the bulk density of the soil. The values of determined bulk density are as follows.

Table 4.2 Bulk Density of soil at depth of 2.5m

No	Pit Description	Bulk Density, g/cc
1	Kolfe pit 1	1.92
2	Kolfe pit 2	1.87
3	Addisu Gebeya pit 1	1.90
4	Addisu Gebeya pit 2	1.90

4.4 Specific Gravity Determination

Specific gravity which is the measure of heaviness of the soil particles were determined by the method of small pychnometer method using a soil sample passing 2mm sieve and oven dried at 105 degree centigrade. The specific gravities of four test pits are determine and stated below.

Table 4.3 Specific gravity of soils at depth of 2.5m

No	Pit Description	Specific gravity
1	Kolfe pit 1	2.72
2	Kolfe pit 2	2.73
3	Addisu Gebeya pit 1	2.71
4	Addisu Gebeya pit 2	2.71

4.5 Atterberg limits

Soil samples passing 425 micro meter sieve were used for Atterberg limits determination. Casagrand's apparatus was used for the determination of liquid limit. For the determination of plastic limit a soil sample was rolled in to 3mm thread until it begins to crumble. Shrinkage limit was determined by mercury method. The shrinkage dish filled with soil paste without entrapping air was oven dried and the volume of oven dried soil pat was determined from the volume of shrinkage dish and mass of displaced mercury. The results of Atterber limits and plasticity index are indicated below.

Table 4.4 Atterberg Limits

No	Pit Description	Liquid limit, %	Plastic limit, %	Shrinkage limit, %	Plasticity index, PI, %
1	Kolfe pit 1	61	27	12	34
2	Kolfe pit 2	71	33	17	38
3	Addisu Gebeya pit 1	63	28	17	35
4	Addisu Gebeya pit 2	72	33	20	39

4.6 Free Swell

Swelling tendency was also determined from the samples passing 425 micrometer sieve and oven dried. The 10ml of soil sample was put in water for 24 hours and swelling was examined as percentage of volume change to the original volume. The results obtained are as follows.

Table 4.5 Free Swell

No	Pit Description	Free swell, %	Swelling tendency
1	Kolfe pit 1	10	Low
2	Kolfe pit 2	20	Low
3	Addisu Gebeya pit 1	32.5	Moderate
4	Addisu Gebeya pit 2	33	Moderate

4.7 Particle Size Analysis/Hydrometer test

An oven dried sample passing 75 micrometer sieve was used for particle size analysis. Sodium hexametaphospate was used as dispersing agent and mechanical stirrer was also used. An average laboratory temperature was 20 degree centigrade. H151 ASTM standard hydrometer was employed. The test was conducted According to ASTM D422 and the results obtained are plotted blow.

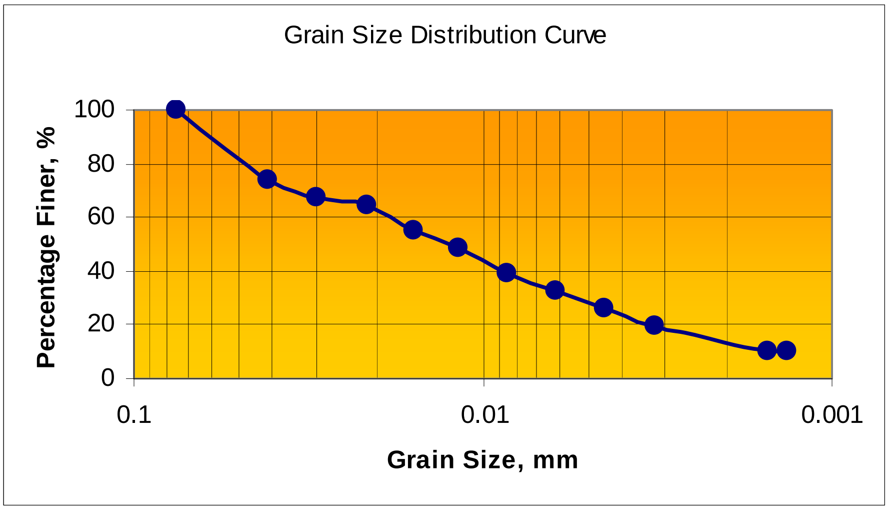


Fig 4.1 Particle Size distribution for Kolfe pit 1.

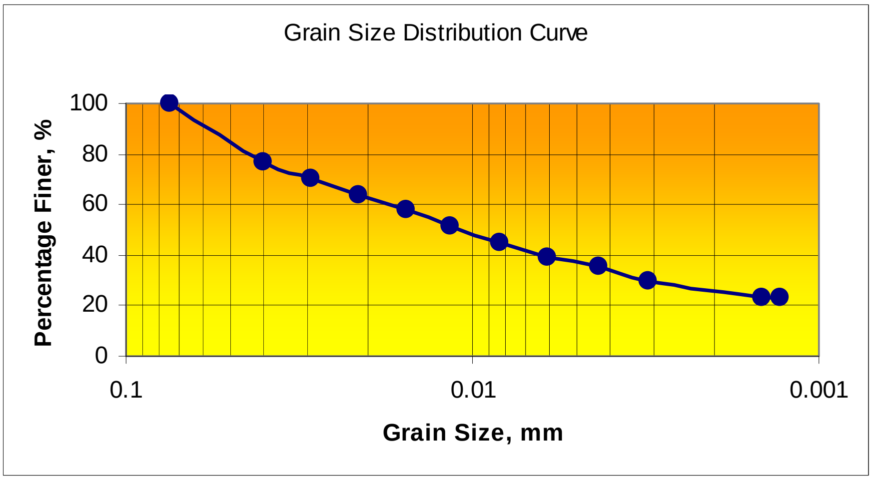


Fig 4.2 Particle Size distribution for Kolfe pit 2.

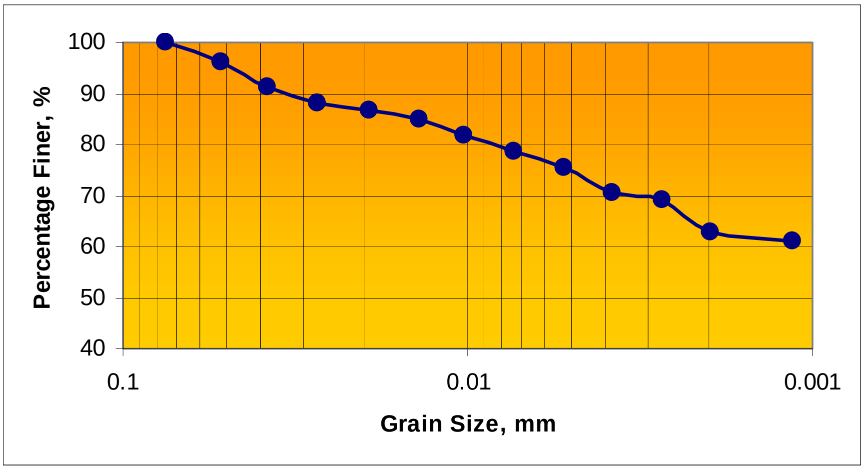


Fig 4.3 Particle Size distribution for Addisu Gebeya pit 1.

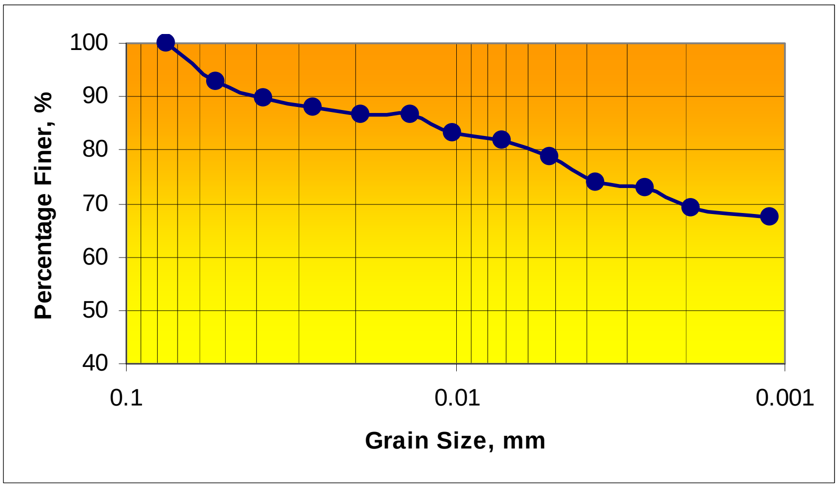


Fig 4.4 Particle Size distribution for Addisu Gebeya pit 2.

4.8 Standard compaction

Standard proctor compaction test which simulates light compacting effort was used to obtain the moisture-dry density relationship of the specific soil samples. It is done in a 4 inches diameter mold with a 2 Kg rammer falling from 305 mm height. The soil was compacted with different moisture content in three layers each suffering 25 blows. After obtaining the density and moisture of the each compacted soil sample, the following relationships for dry density and moisture content are obtained.

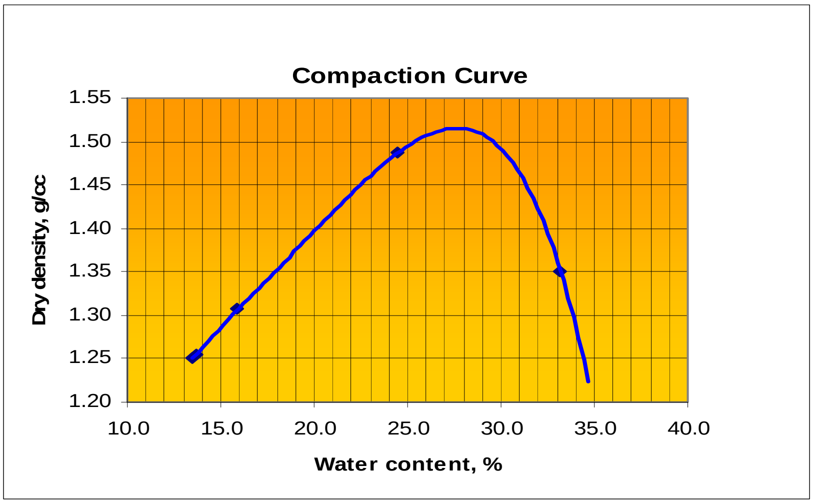


Fig 4.5 Standard compaction curve for Kolfe pit 1.

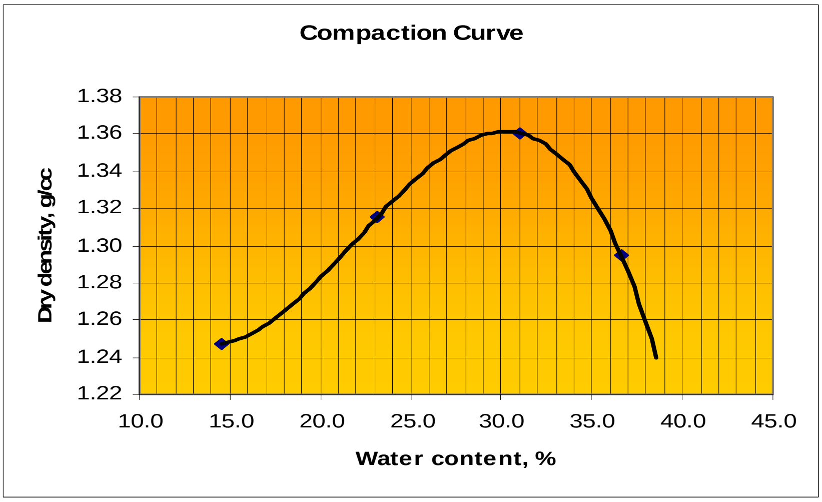


Fig 4.6 Standard compaction curve for Kolfe pit 2.

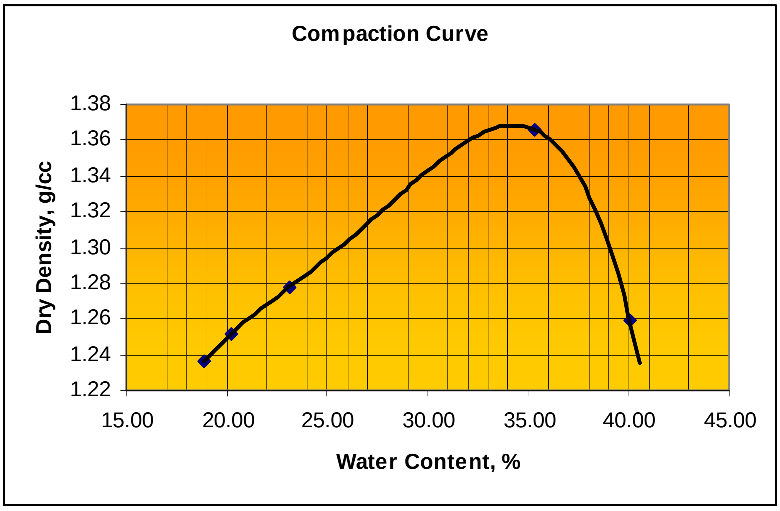


Fig 4.7 Standard compaction curve for Addisu Gebeya 1

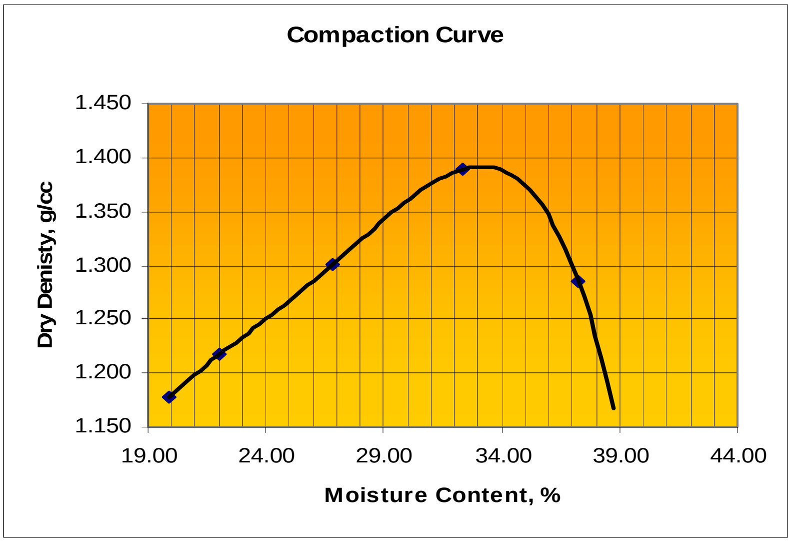


Fig 4.8 Standard compaction curve for Addisu Gebeya 2

Table 4.6 OMC and MDD

No	Pit Description	OMC, %	MDD, g/cc	Wet density, g/cc
1	Kolfe pit 1	28	1.53	1.95
2	Kolfe pit 2	32	1.36	1.78
3	Addisu Gebeya pit 1	34	1.37	1.83
4	Addisu Gebeya pit 2	34	1.39	1.86

4.9 One dimensional Consolidation Test

The one dimensional consolidation test was carried out to study the stress-strain and compressibility of the soil at hand under different conditions using the apparatus called Oedometer. Tests were carried on undisturbed and remolded samples. Diameters of 50mm and 70 mm soil samples having height of 18 mm were loaded from 50 kpa to 1600 kPa by doubling the loading. For each loading starting from 50 kpa to 1600 kPa the compression was recorded from the dial gage at intervals of: 0.1, 0.25, 0.5, 1, 2, 4, … 1440mins for twenty-four hours. Unloading was also done by steps to examine the unloading behavior. A total of eight consolidation tests were run on samples of four undisturbed and four remolded and different results were obtained.

From this test coefficient of consolidation (Cv), void ratio (e), coefficient of compression (av), compression index (Cc), modulus of elasticity (E), volume compressibility (mv), amount of compression and pre-consolidation pressure were obtained.

Among the two methods, root time method proposed by Taylor and log time method proposed by Casadrande and Fadum (Budhu, M., 2007) that can be used to calculate Cv, the root time method was employed for this test.

Pre-consolidation pressure was also determined from void ratio versus log pressure curve by simplified method and Casagrande's method discussed in Buduh (2007).

From pre-consolidation pressure obtained from the above method and effective overburden pressure, the over consolidation ratio (OCR) was also calculated. Other parameters were also determined. The results of these parameters are summarized below and detailed calculations are shown in the appendix-B.

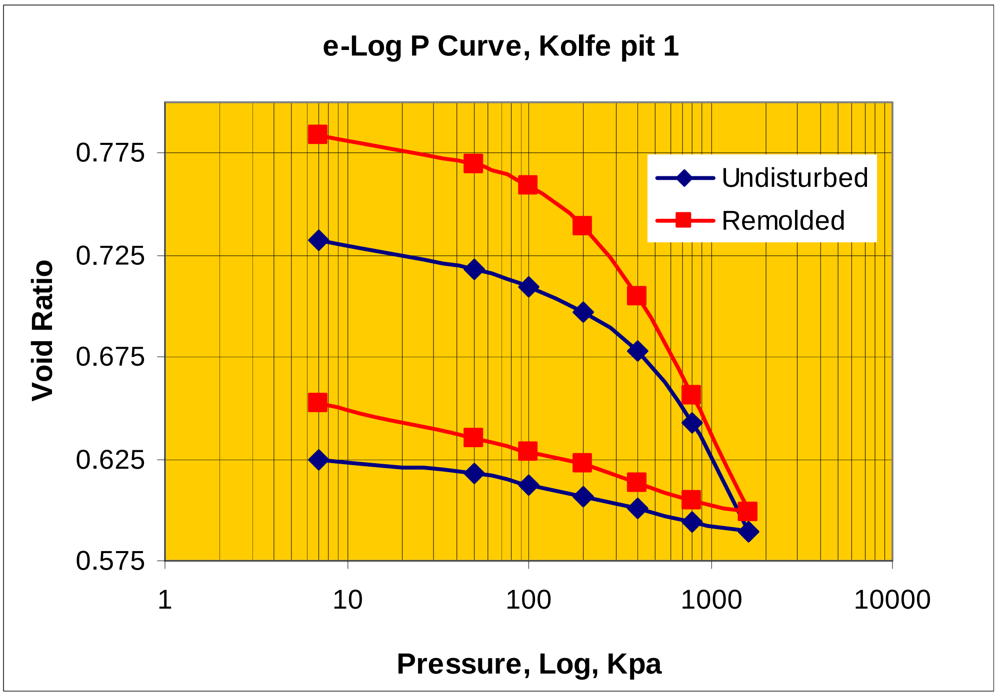


Fig: 4.9 e-Log p Curve for Kolfe Pit 1.

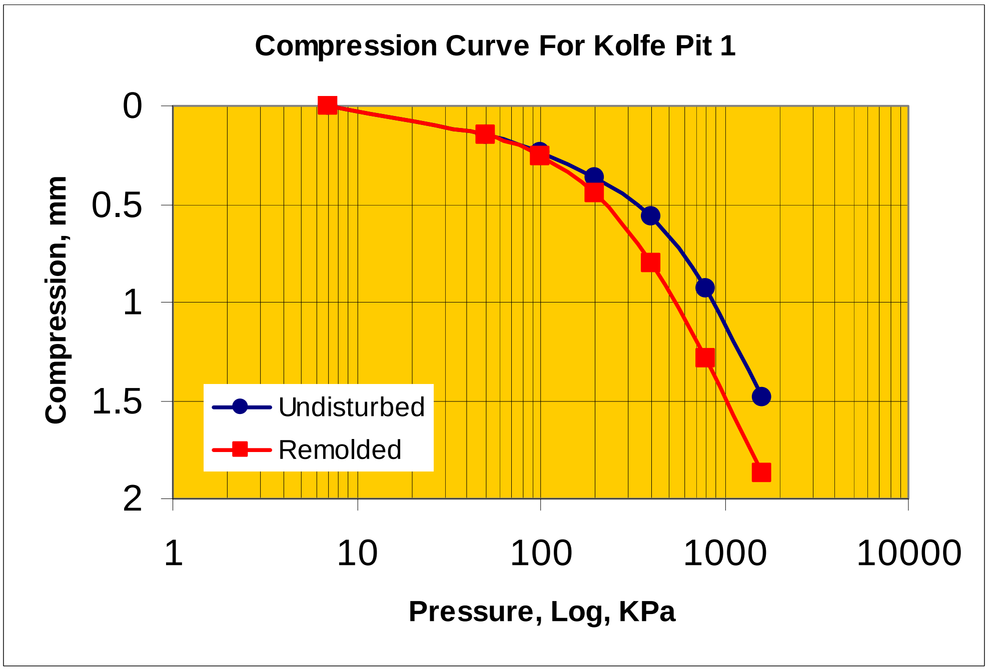


Fig: 4.10 Compression Curve for Kolfe Pit 1.

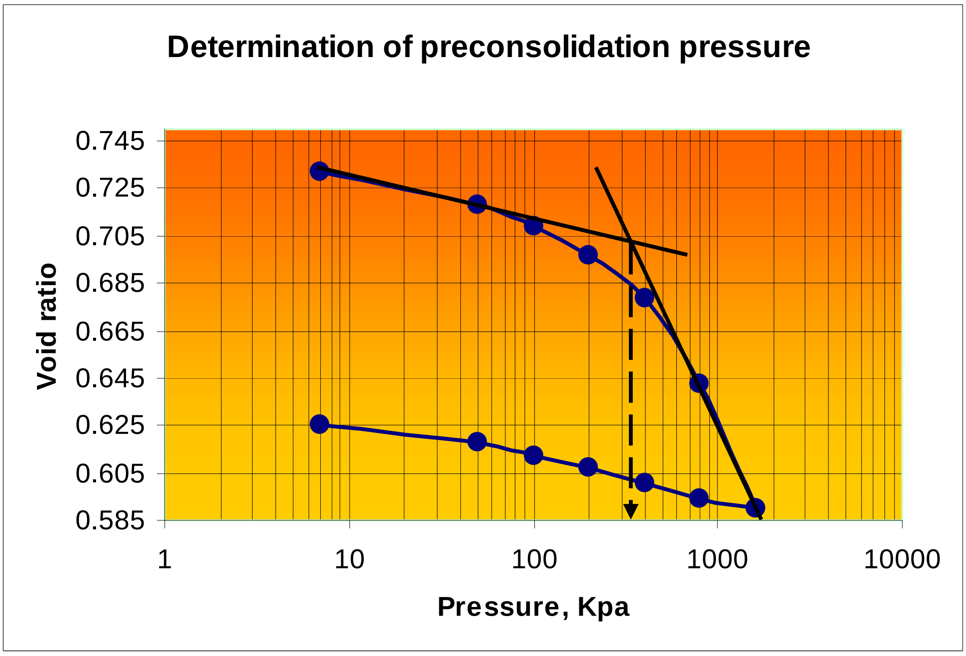


Fig: 4.11 Simplified method of determination of PC, Kolfe Pit1 /Undist.

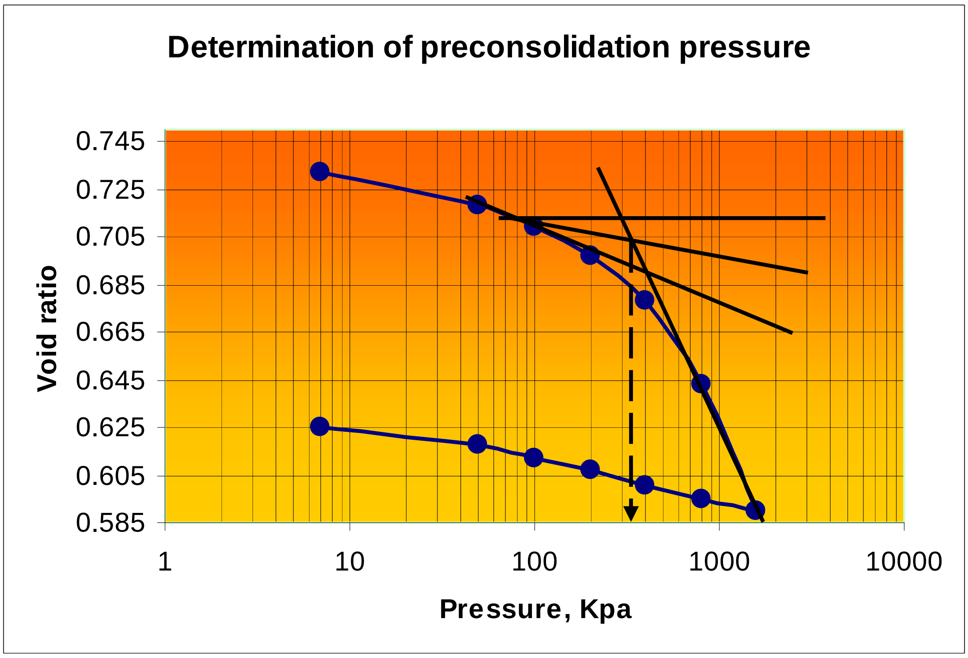


Fig: 4.12 Casagrande's method of determination of PC, Kolfe Pit1 /Undist.

Table: 4.7 Consolidation Parameters of Undisturbed Sample of Kolfe pit1.

Loading, Kpa	Cumulative Change in height of sample at the end of loading, mm	Void ratio	Cv, m2/yr	Mv, m2/MN	Ec, MN/m2
50	0.145	0.718	67.30	0.182	5.488
100	0.242	0.709	57.70	0.108	9.251
200	0.368	0.697	51.11	0.071	14.038
400	0.561	0.678	44.91	0.055	18.300
800	0.929	0.643	30.04	0.053	18.940
1600	1.481	0.590	25.05	0.040	24.741
Cc	0.147	Pc, kPa	340	OCR	7.2

Table: 4.8 Consolidation Parameters of Remolded Sample of Kolfe pit1.

Loading, P1, Kpa	Cumulative Change in height of sample at the end of loading, mm	Void ratio	Cv, m2/yr	Mv, m2/MN	Ec, MN/m2
50	0.149	0.769	37.15	0.1925	5.1946
100	0.255	0.759	30.31	0.1188	8.4203
200	0.450	0.739	27.01	0.1099	9.1000
400	0.802	0.704	23.11	0.1003	9.9716
800	1.292	0.656	20.72	0.0712	14.0392
1600	1.868	0.599	13.01	0.0431	23.2056
Cc	0.175	Pc, kPa	220		

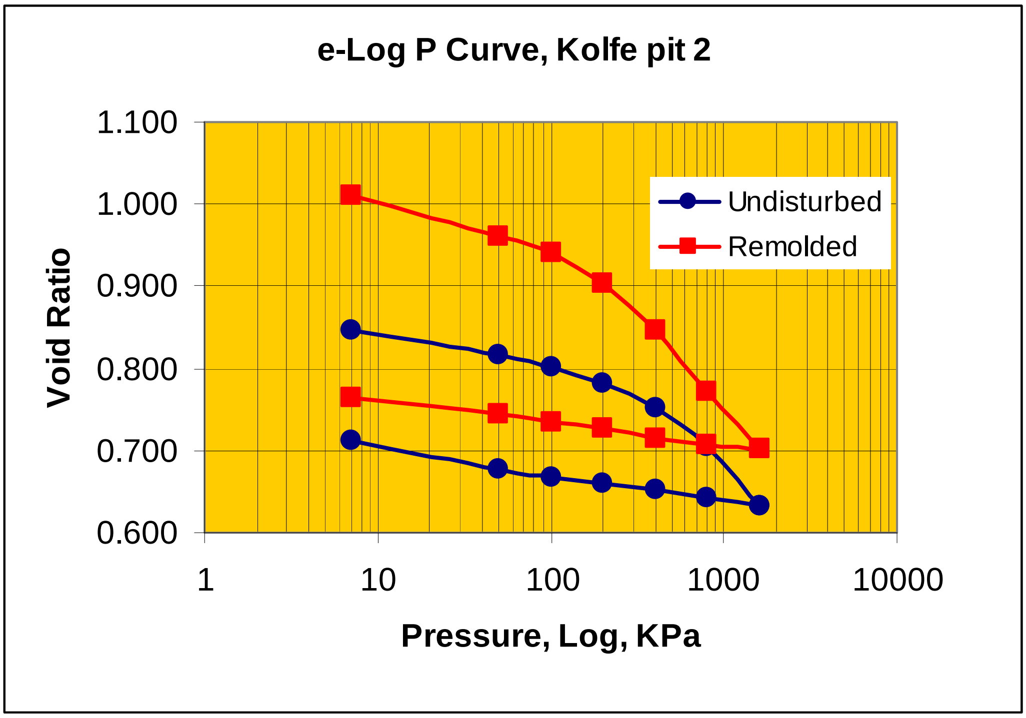


Fig: 4.13 e-Logs P Curve for Kolfe Pit 2.

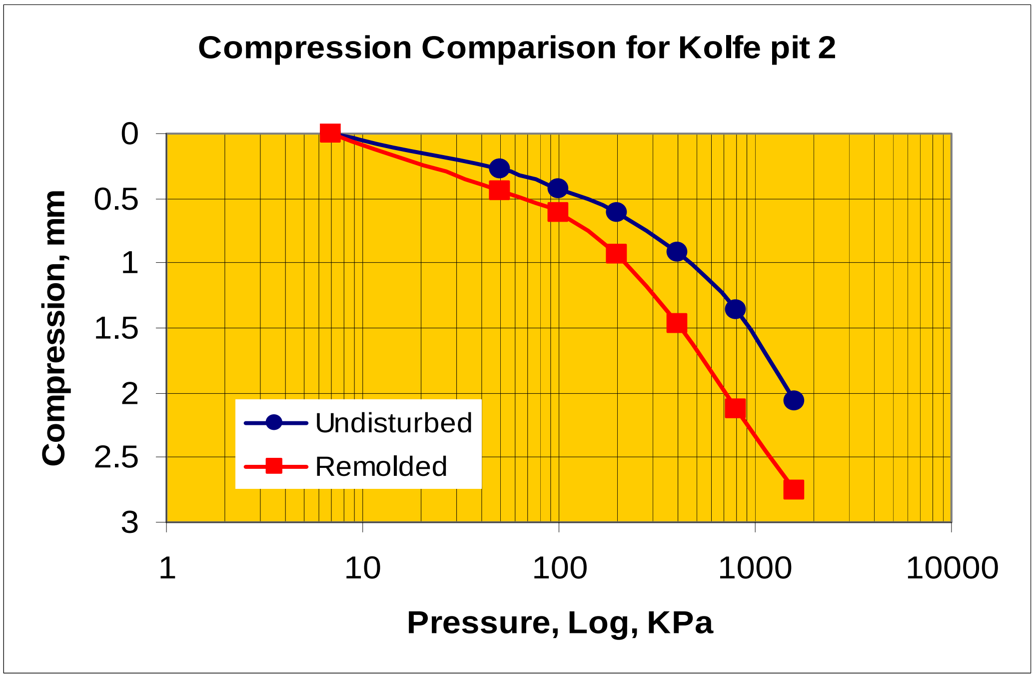


Fig: 4.14 Compression Curve for Kolfe Pit 2.

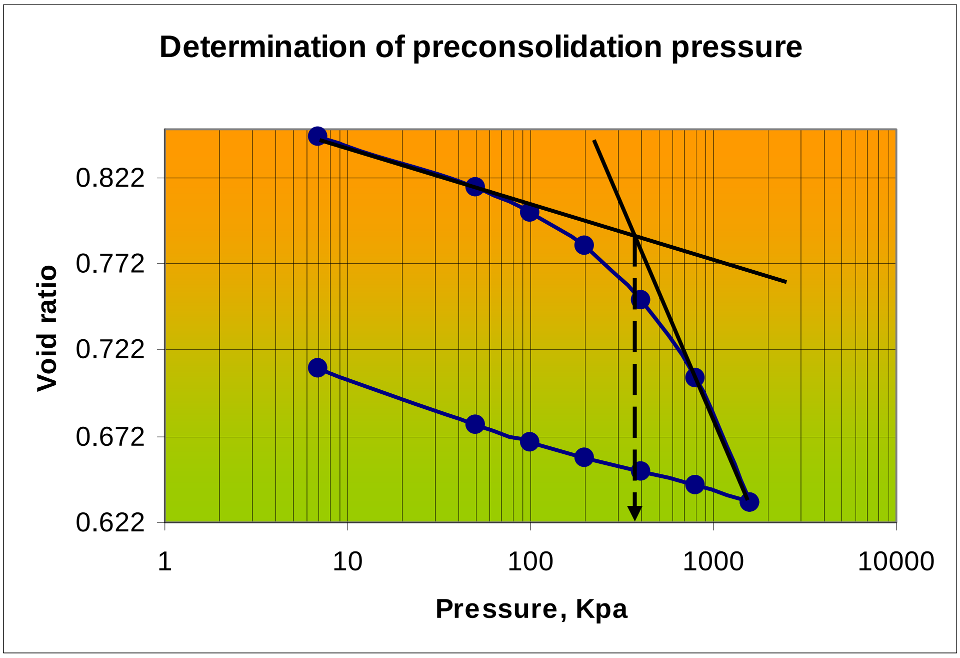


Fig: 4.15 Simplified method of determination of PC, Kolfe Pit2 /Undist.

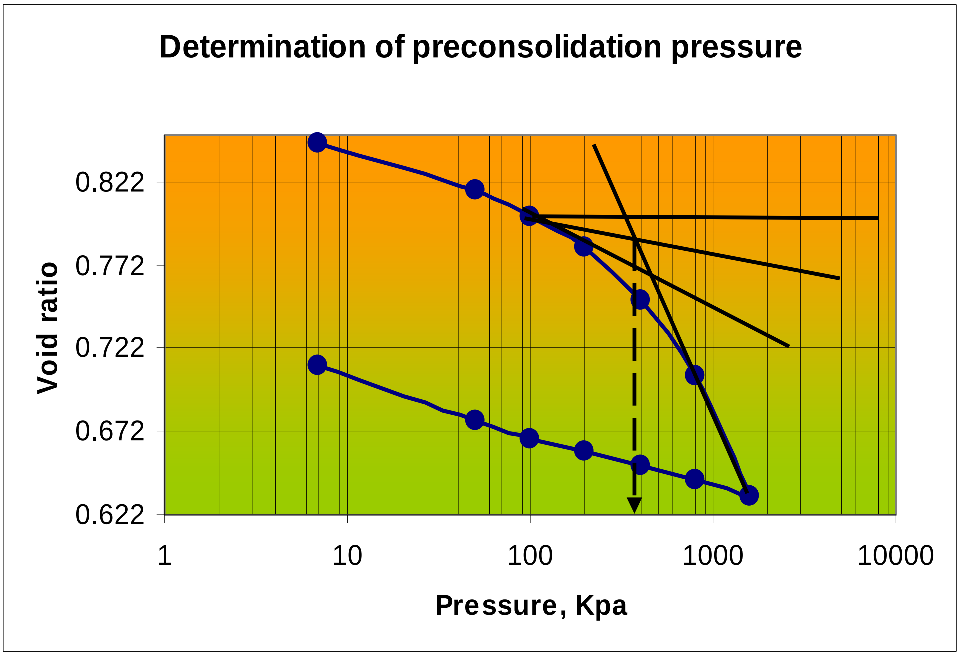


Fig: 4.16 Casagrande's method of determination of PC, Kolfe Pit2 /Undist.

Table: 4.9 Consolidation Parameters of Undisturbed Sample of Kolfe pit2.

Loading, Kpa	Cumulative Change in height of sample at the end of loading, mm	Void ratio	Cv, m2/yr	Mv, m2/MN	Ec, MN/m2
50	0.282	0.816	64.37	0.3643	2.7447
100	0.432	0.801	57.59	0.1693	5.9060
200	0.615	0.782	51.37	0.1042	9.6000
400	0.918	0.751	42.26	0.0871	11.4752
800	1.365	0.705	35.45	0.0654	15.2859
1600	2.065	0.634	26.76	0.0526	19.0114
Cc	0.195	Pc, kPa	380	OCR	8.2

Table: 4.10 Consolidation Parameters of Remolded Sample of Kolfe pit 2.

Loading, P1, Kpa	Cumulative Change in height of sample at the end of loading, mm	Void ratio	Cv, m2/yr	Mv, m2/MN	Ec, MN/m2
50	0.440	0.960	35.81	0.5685	1.7591
100	0.615	0.941	29.47	0.1993	5.0171
200	0.940	0.904	24.39	0.1869	5.3492
400	1.465	0.846	19.82	0.1539	6.4990
800	2.120	0.773	16.95	0.0990	10.0977
1600	2.760	0.701	13.78	0.0504	19.8500
Cc	0.240	Pc, kPa	180		

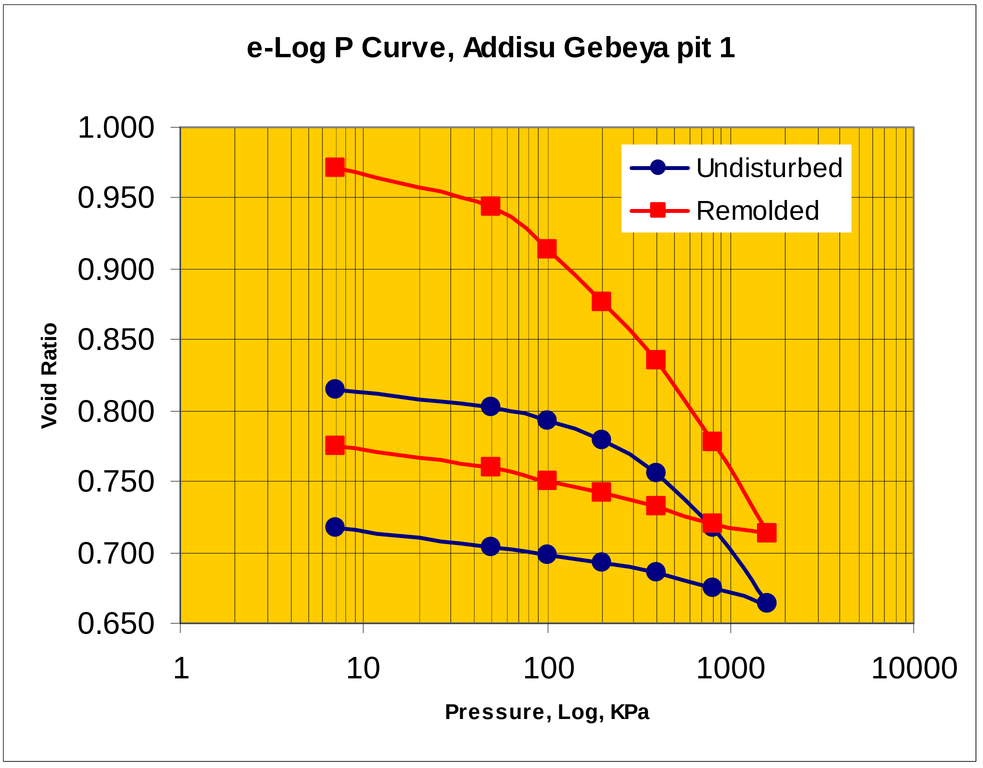


Fig: 4.17 Compression Curve for Addisu Gebeya pit 1.

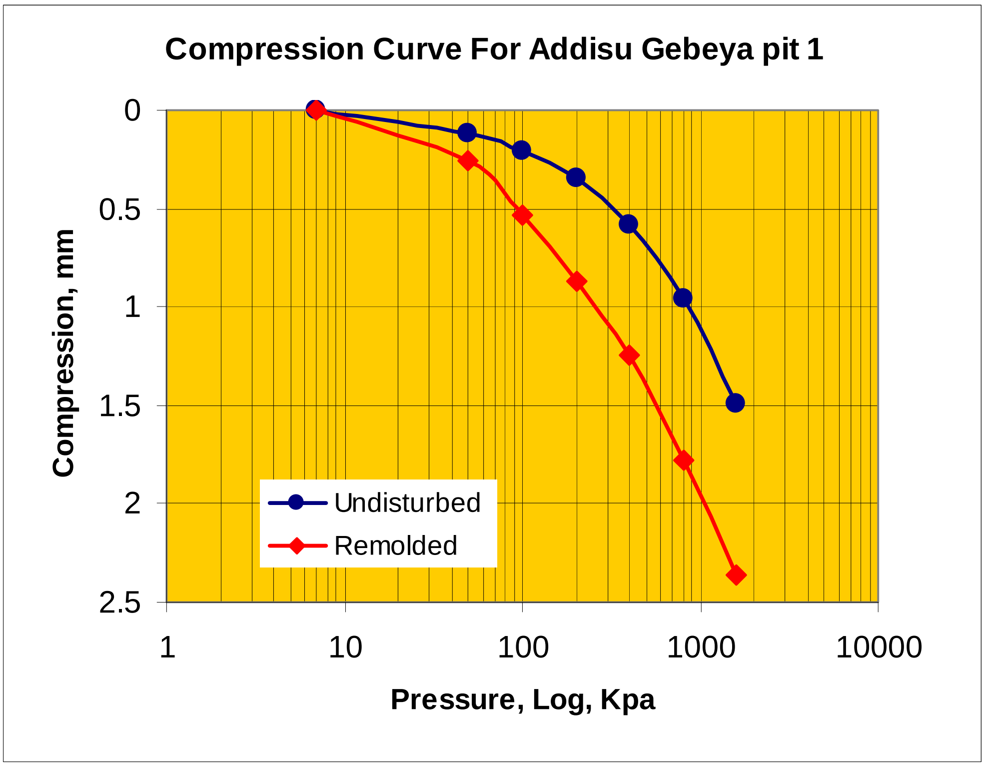


Fig: 4.18 Compression Curve for Addisu Gebeya pit 1.

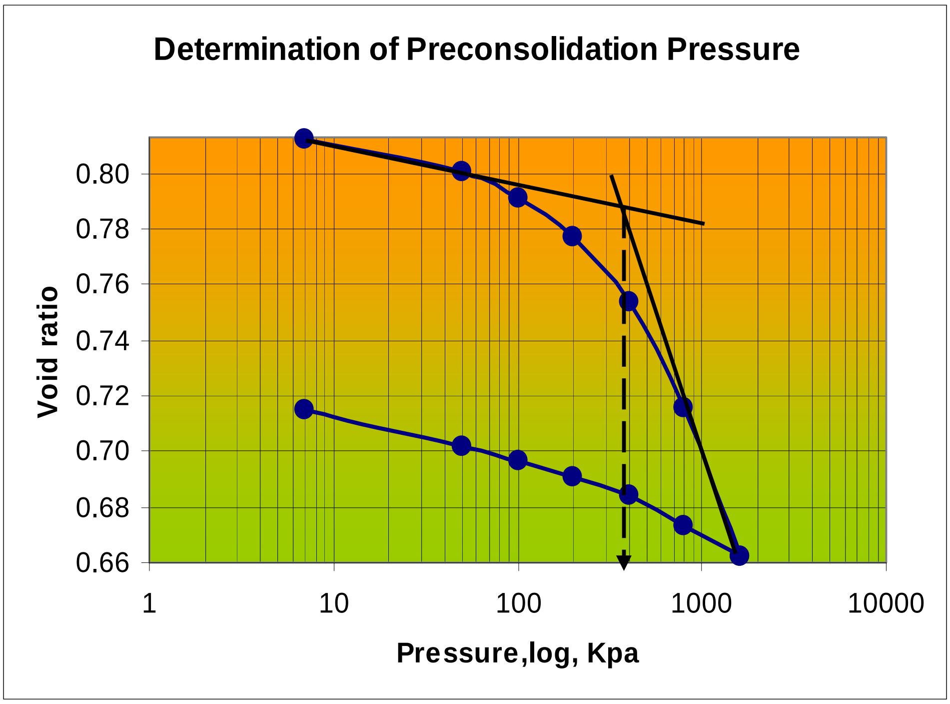


Fig: 4.19 Simplified method of determination of PC, Addisu G. pit1/Undist.

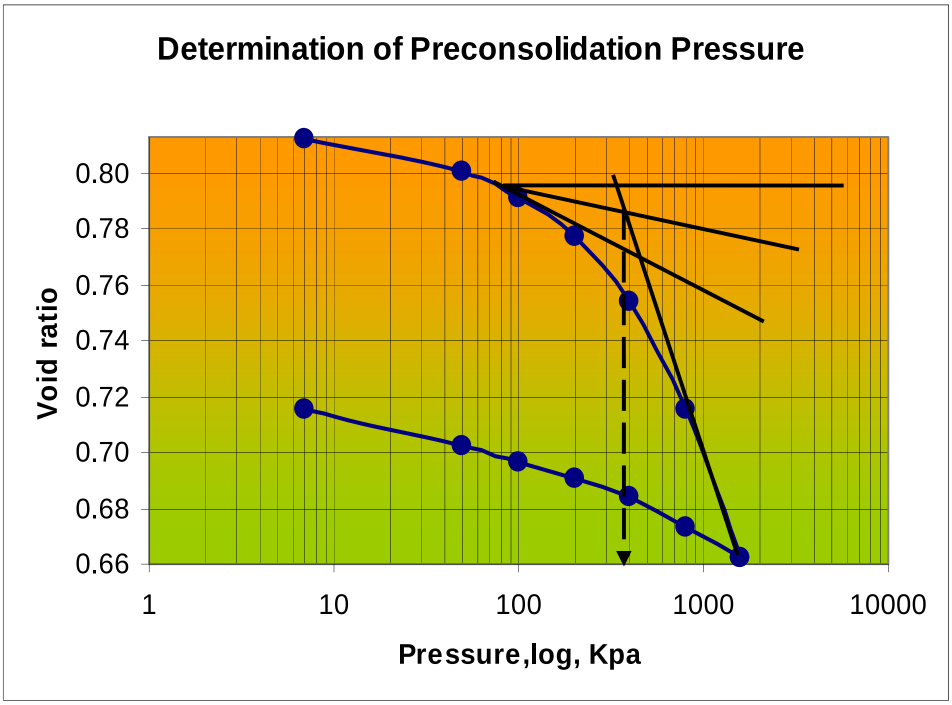


Fig: 4.20 Casagrande's method of determination of PC, Addisu G. pit1/Undist.

Table: 4.11 Consolidation Parameters of Undi. Sample of Addisu G. pit 1.

Loading, Kpa	Cumulative Change in height of sample at the end of loading, mm	Void ratio	Cv, m2/yr	Mv, m2/MN	Ec, MN/m2
50	0.118	0.803	71.46	0.1525	6.559
100	0.210	0.793	64.20	0.1029	9.718
200	0.350	0.779	49.09	0.0787	12.707
400	0.582	0.756	38.78	0.0658	15.202
800	0.962	0.718	29.42	0.0544	18.368
1600	1.490	0.664	25.19	0.0388	25.791
Cc	0.152	Pc, kPa	380	OCR	8.2

Table: 4.12 Consolidation Parameters of Remo. Sample of Addisu G. pit 1.

Loading, P1, Kpa	Cumulative Change in height of sample at the end of loading, mm	Void ratio	Cv, m2/yr	Mv, m2/MN	Ec, MN/m2
50	0.252	0.944	28.60	0.3256	3.0714
100	0.533	0.913	19.66	0.3167	3.1580
200	0.868	0.876	17.76	0.1918	5.2140
400	1.243	0.835	16.43	0.1094	9.1371
800	1.774	0.777	13.72	0.0792	12.6230
1600	2.364	0.713	5.75	0.0455	22.0014
Cc	0.204	Pc, kPa	140		

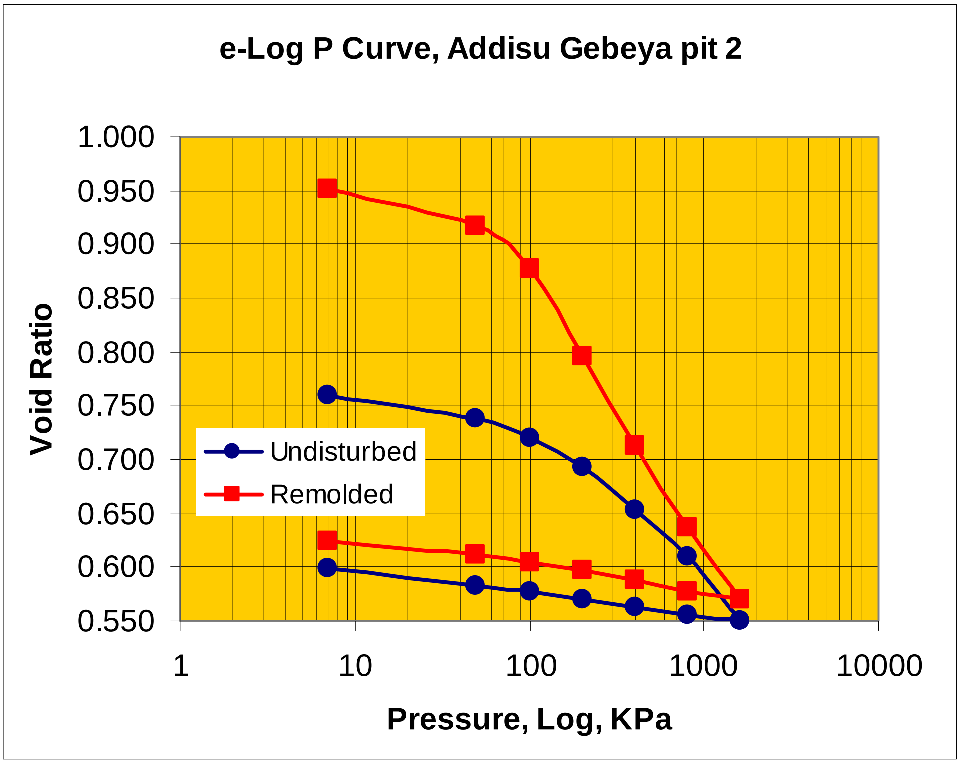


Fig: 4.21 e-Log P Curve for Addisu Gebeya pit 2.

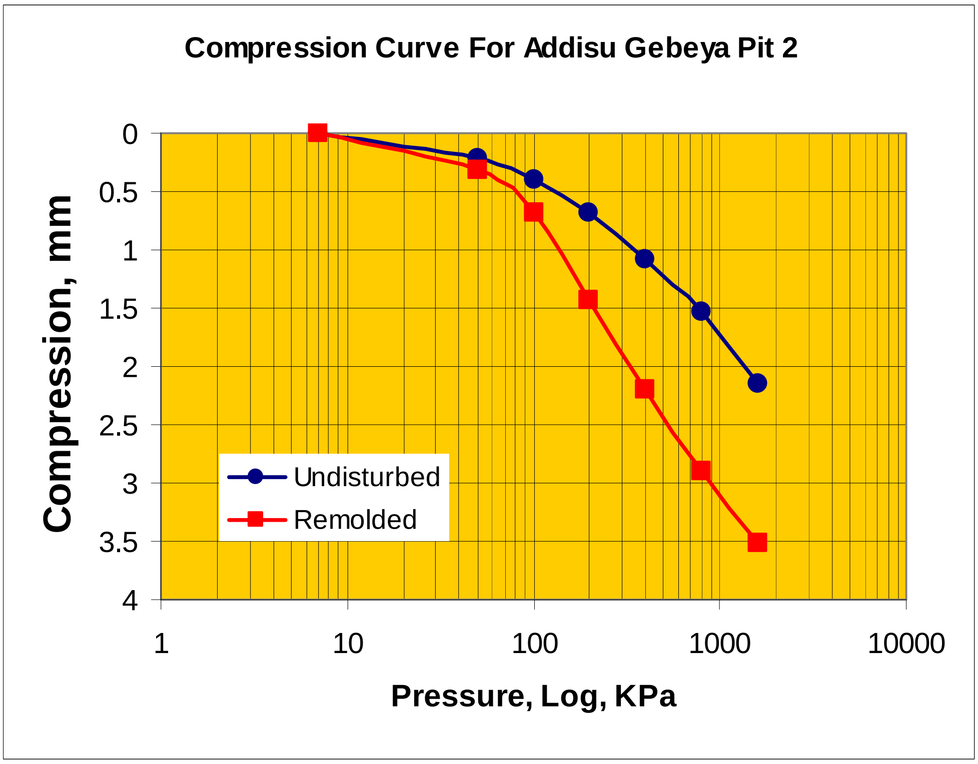


Fig: 4.22 Compression Curve for Addisu Gebeya pit 2.

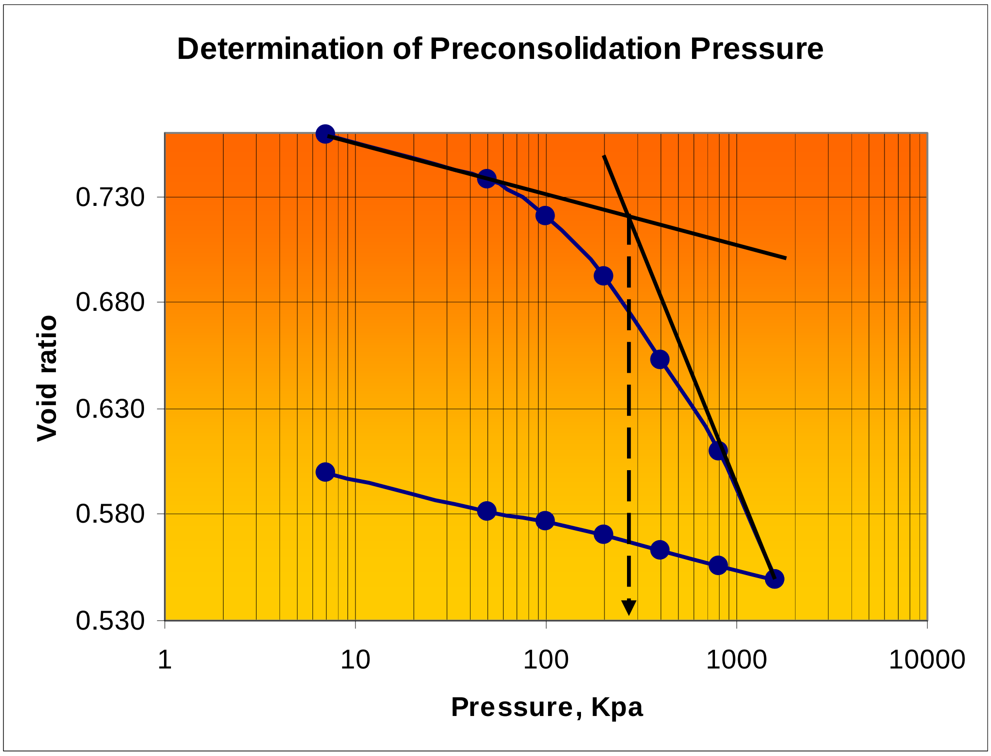


Fig: 4.23 Simplified method of determination of PC, Addisu G. pit2/Undist.

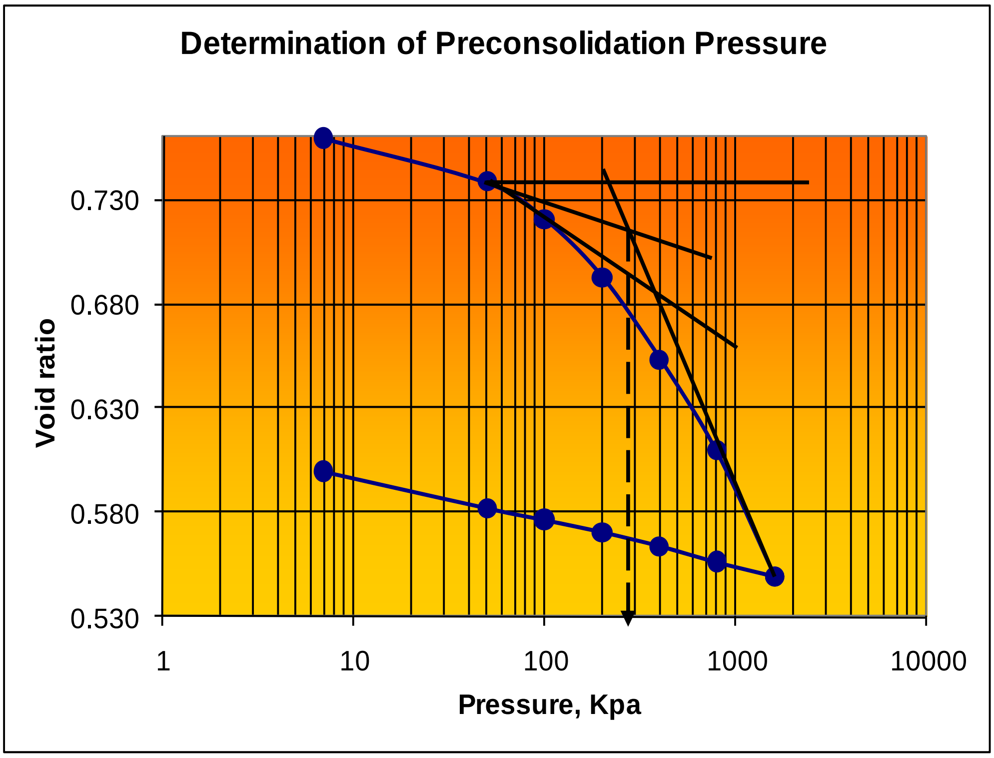


Fig: 4.24 Casagrande's method of determination of PC, Addisu G. pit2/Undist.

Table: 4.13 Consolidation Parameters of Undi. Sample of Addisu G. pit 2.

Loading, Kpa	Cumulative Change in height of sample at the end of loading, mm	Void ratio	Cv, m2/yr	Mv, m2/MN	Ec, MN/m2
50	0	0.738	60.23	0.2778	3.600
100	0.215	0.721	54.30	0.2035	4.913
200	0.396	0.693	43.39	0.1625	6.155
400	0.682	0.653	35.34	0.1172	8.531
800	1.088	0.609	27.60	0.0659	15.168
1600	1.534	0.549	23.95	0.0468	21.384
Cc	0.172	Pc, kPa	280	OCR	6.0

Table: 4.14 Consolidation Parameters of Remo. Sample of Addisu G. pit 2.

Loading, Kpa	Cumulative Change in height of sample at the end of loading, mm	Void ratio	Cv, m2/yr	Mv, m2/MN	Ec, MN/m2
50	0.314	0.917	29.95	0.4057	2.465
100	0.682	0.877	22.67	0.4161	2.403
200	1.432	0.796	15.70	0.4331	2.3091
400	2.203	0.712	12.98	0.2327	4.2978
800	2.899	0.637	11.27	0.1101	9.0787
1600	3.512	0.570	8.38	0.0507	19.708
Cc	0.236	Pc, kPa	100		

4.10 Triaxial compression Test

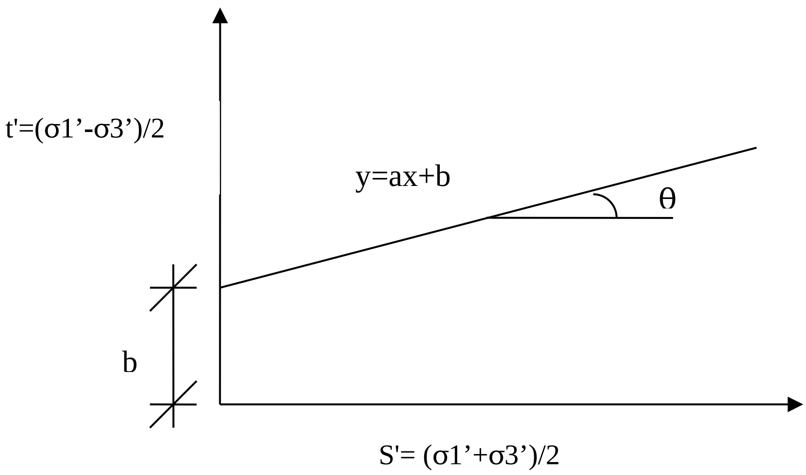
Triaxial compression test was conducted to study the stress-strain and strength behavior of the soil, on undisturbed and remolded, specimens of diameter 38mm and height is twice the diameter. Two triaxial machines, Automatic triaxial and semi automatic trixial were employed.

Among three types of triaxial compression testing named unconsolidated undrained (UU), consolidated undrained (CU) and consolidated drained (CD) tests; CU test with pore pressure measurement was employed for the advantage of time and obtaining both total stress and effective stress parameters. Under this test three main stages called saturation, consolidation and compression/shearing were performed.

Saturation was done according to BS 1137 part 8 clause 5.3, saturation by increment of cell pressure and back pressure. Pore pressure parameter B was checked at each cell pressure increment as controlling mechanism for saturation and for the B value of 0.95 and more; it was considered as the soil was saturated. 50 kPa of cell pressure increment and 10 kPa of back pressure difference from cell pressure were used for saturation. It was seen that the soil was saturated for the back pressure of 190 kPa to 390 kPa.

Consolidation stage was performed for the selected effective consolidation pressures of 150 kPa, 250 kPa and 350 kPa to bring the soil at three different effective stresses. 350 kPa is higher than PC of Kolfe pit 1 and Addisu Gebeya pit 2 and lower than PC of Kolfe pit 2 and Addisu Gebeya pit 1. It is worth noting that applying more than 350 kPa was practically difficult because of compressor and pressure gage problem in our lab. Consolidation stages were continued until 95% or more excess pore pressure dissipates and volume change was almost ceased. It is worth noting here that indicating information like time for 100% consolidation obtained from consolidation stage was used in compression stages for calculating and adjusting the machine speed as rate of axial displacement. Shearing or compression was done as final stage by calculated axial displacement rate and continued until about 20% of axial strain and one of the failure criterion stated in BS 1137, part 8 clause 1.2.8 (maximum deviator stress, maximum effective principal stress ratio and shearing under constant pore pressure) was clearly observed.

As stated in BS 1377, the modified failure envelop method was employed to determine the effective shear strength parameters. This method was employed to use the advantage of convenience and to eliminate the difficulty of obtaining tangent line for three points on three circles of Mohr's failure diagram (Arora, K.r., 1997).



$\Phi' = \sin^{-1}(\tan\theta)$
$C' = b/(\cos \Phi')$

Fig: 4.25 Modified failure envelop

Mohr-Coulomb failure criterion:

$(\sigma1'-\sigma3')/2 = (\sigma1'+\sigma3')/2 * \sin \Phi' + C' \cos \Phi'$ ➔ y=ax+b

$a = \tan\theta = \sin \Phi'$, $b = C' \cos \Phi'$

Some of the results obtained are shown below and detail test data and results are attached in the appendix.

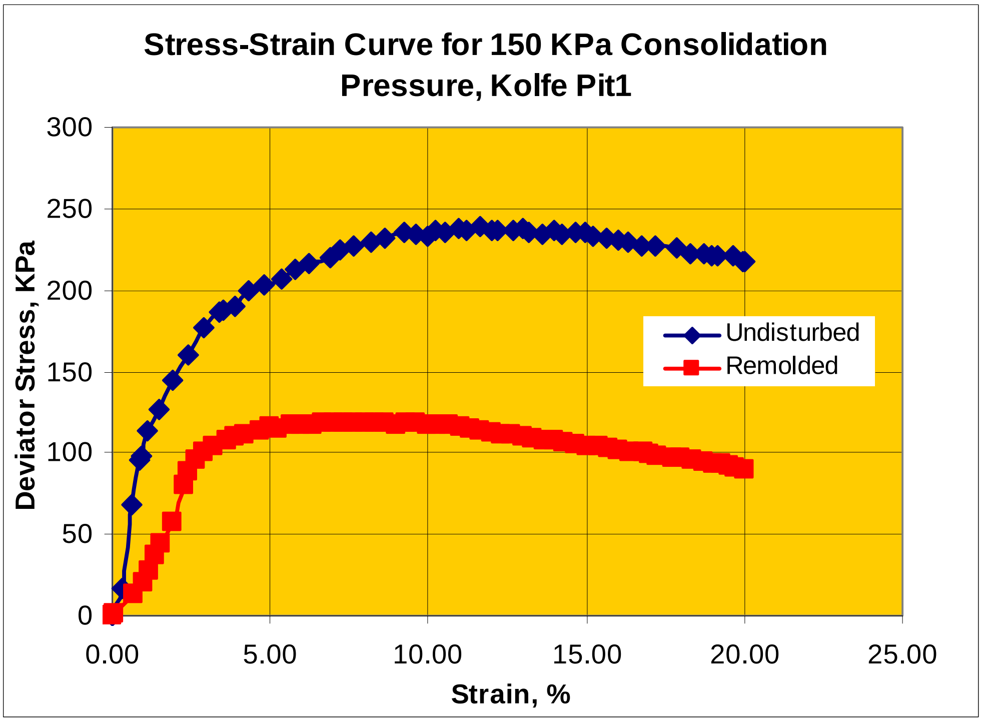


Fig: 4.26 Stress-Strain Curves for 150 kPa Consolidation Pressure, Kolfe Pit 1

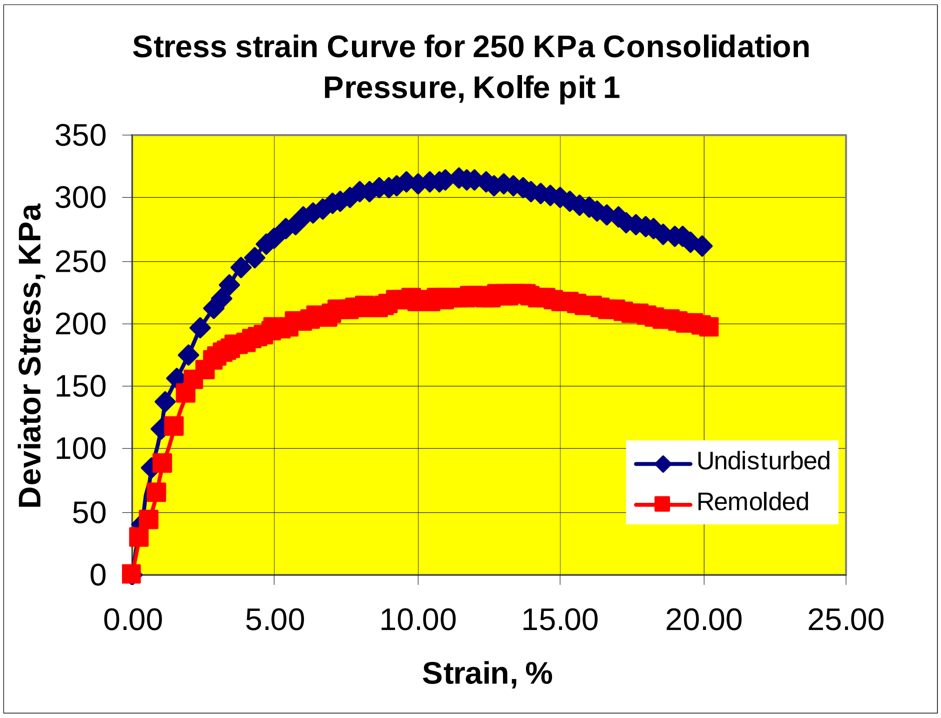


Fig: 4.27 Stress-Strain Curves for 250 kPa Consolidation Pressure, Kolfe Pit 1

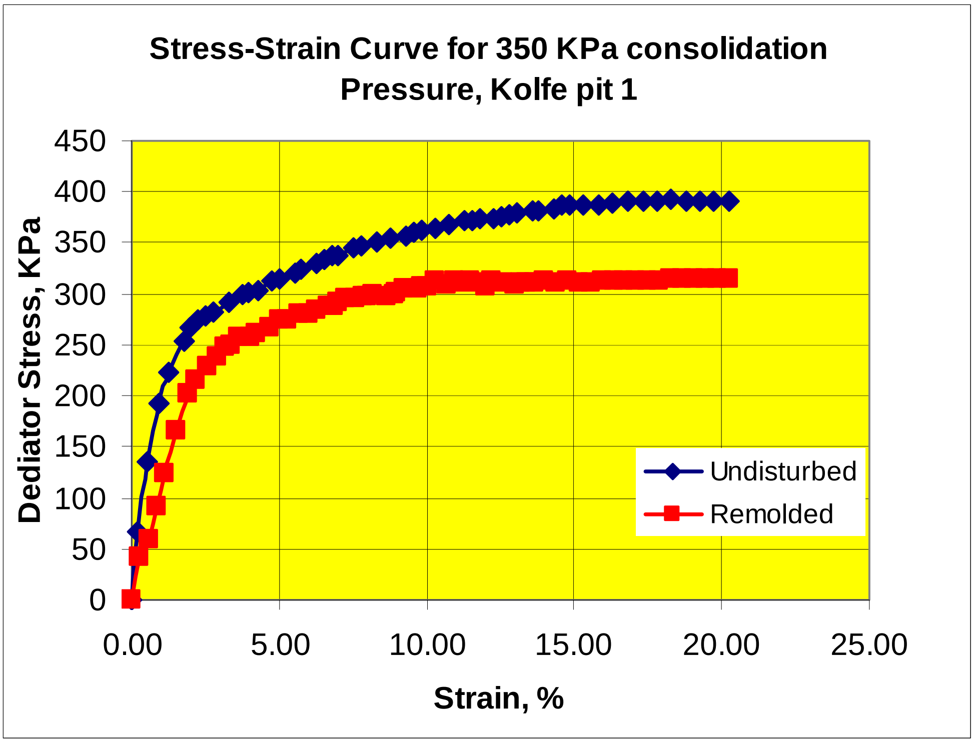


Fig: 4.28 Stress-Strain Curves for 350 kPa Consolidation Pressure, Kolfe Pit 1

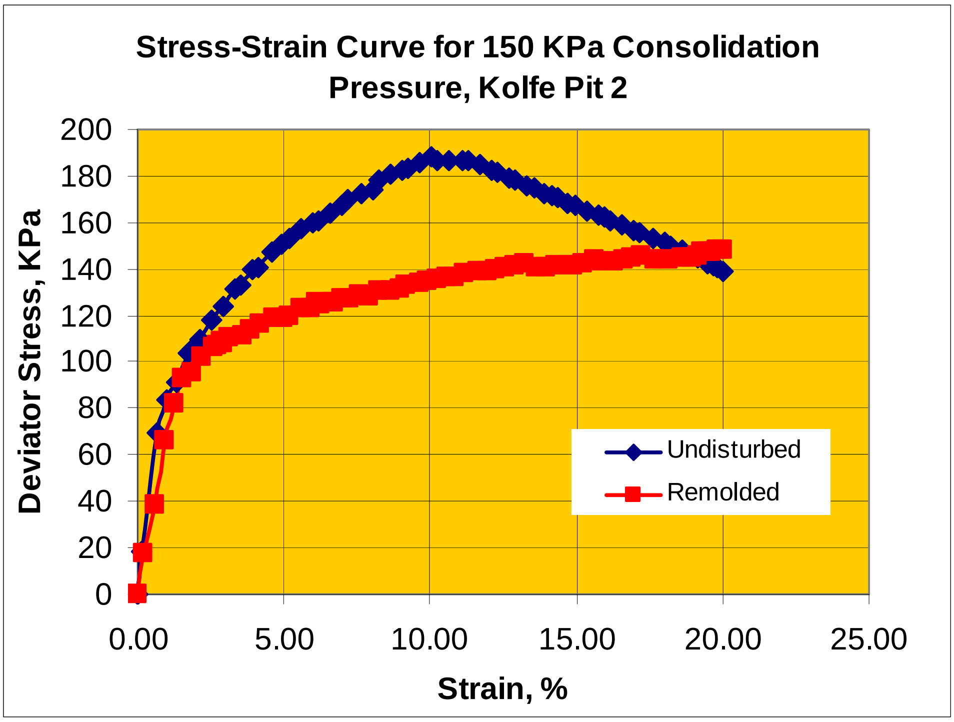


Fig: 4.29 Stress-Strain Curves for 150 kPa Consolidation Pressure, Kolfe Pit 2

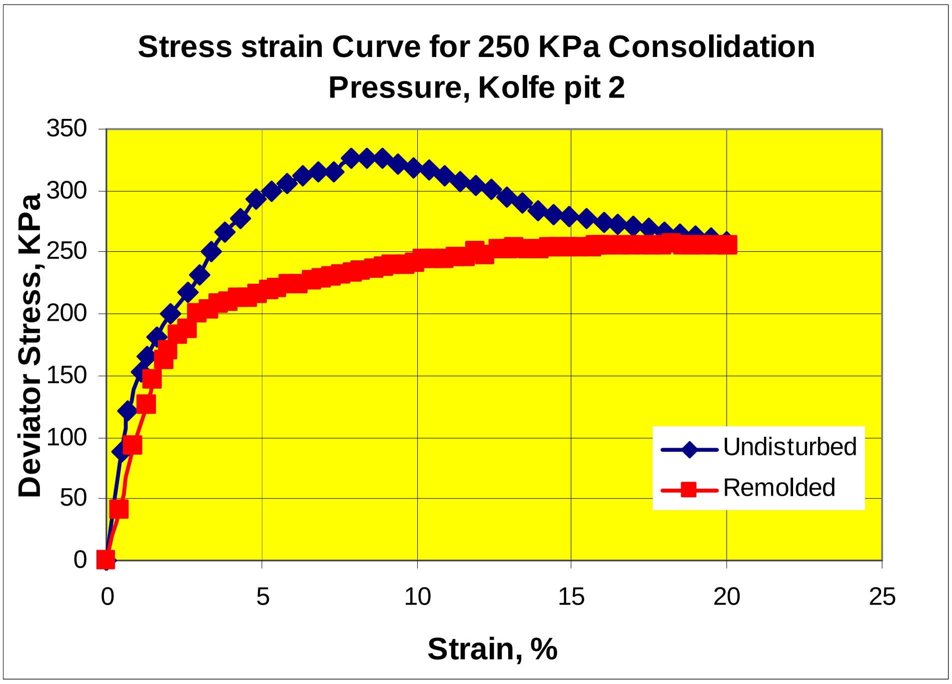


Fig: 4.30 Stress-Strain Curves for 250 kPa Consolidation Pressure, Kolfe Pit 2

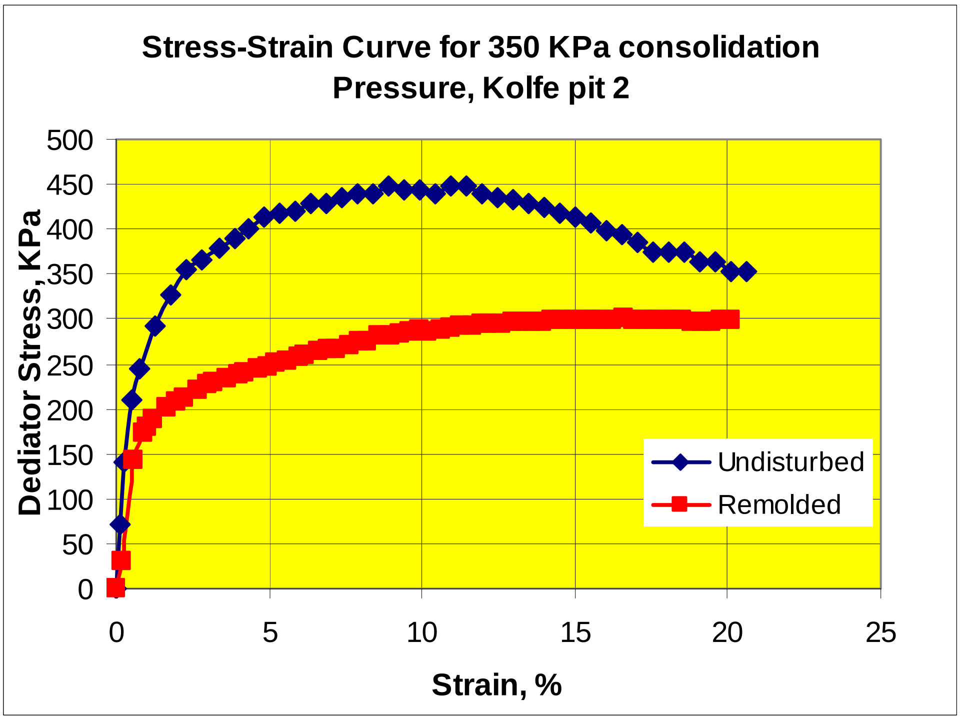
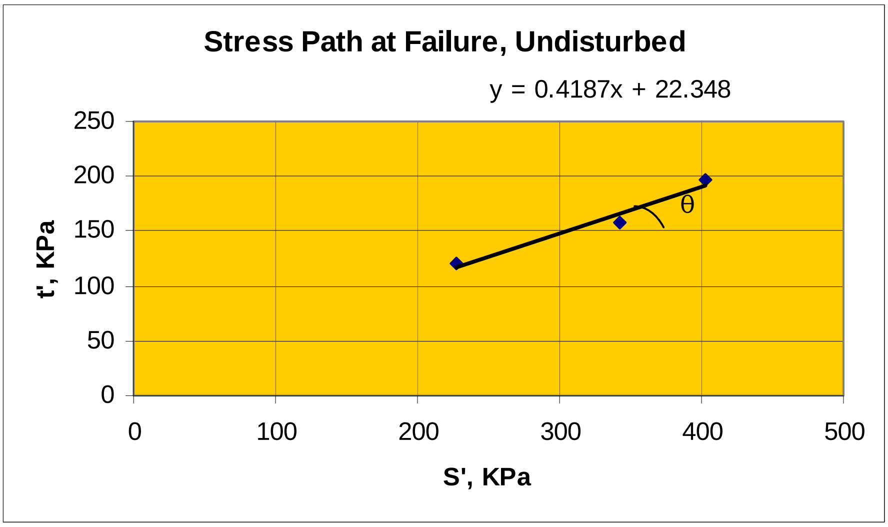


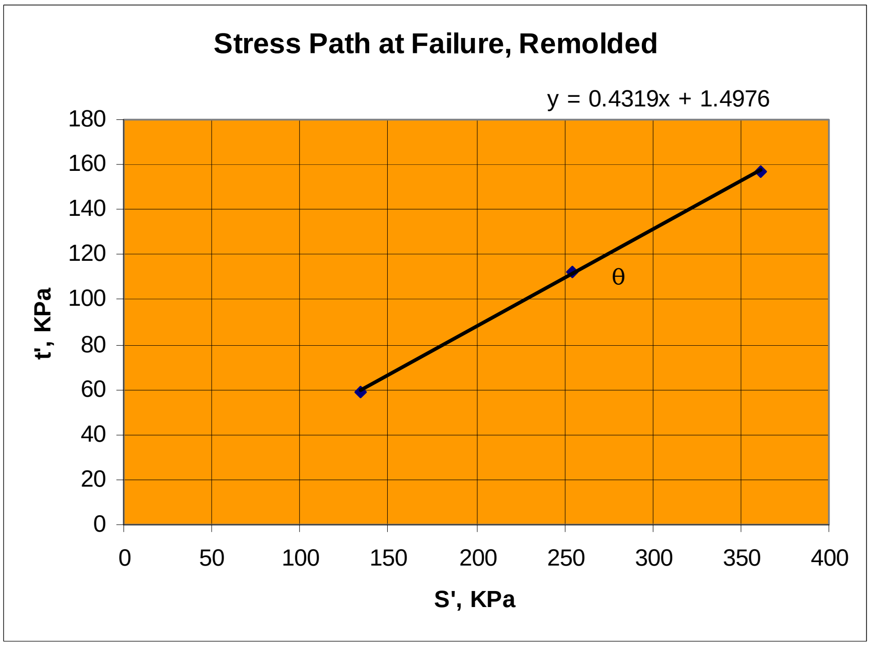
Fig: 4.31 Stress-Strain Curves for 350 kPa Consolidation Pressure, Kolfe Pit 2.

Table: 4.15 Conditions at failure, Kolfe pit 1

Effective Consolidation Pressure	**Pore Pressure at Failure, KPa**		**Deviator Stress at Failure, Δσa, Kpa**		**Effective Angle of internal Friction, Φ'**		**Effective Cohesion, C', Kpa**	
Kolfe 1	Und.	Remo.	Und.	Remo.	Und.	Remo.	Und.	Remo.
150 kPa	43	65	239	119	***16.7***	***30.6***	***23.4***	***1.7***
250 kPa	65	108	315	223				
350 kPa	142	146	392	315				



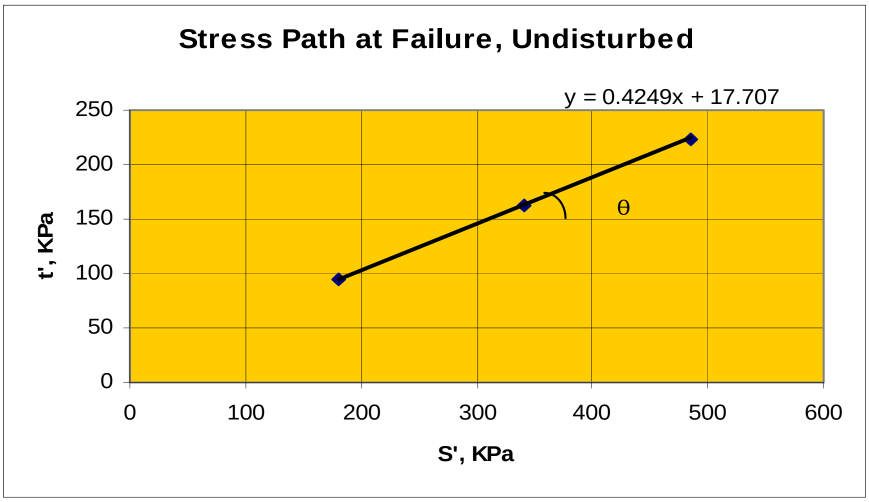
θ	16	t'o	22.3



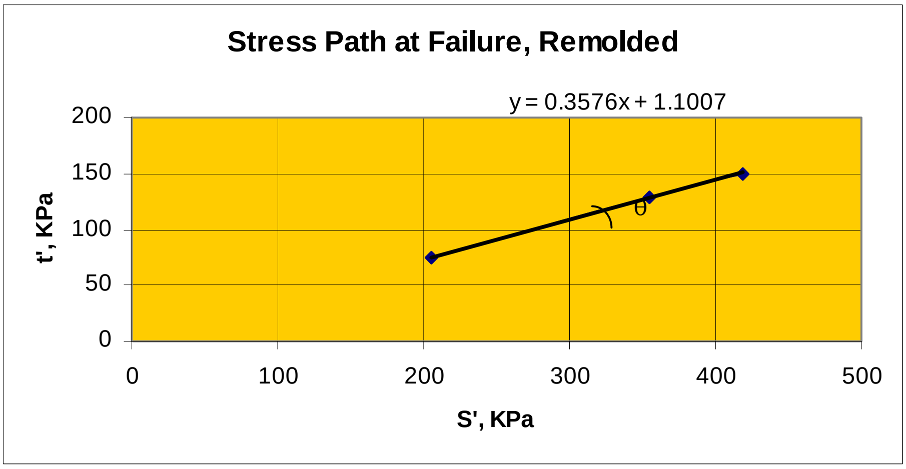
θ	27	t'0	1.5

Table: 4.16 Conditions at failure, Kolfe pit 2

Effective Consolidation Pressure	**Pore Pressure at Failure, KPa**		**Deviator Stress at Failure,Δσa, Kpa**		**Effective Angle of internal Friction, Φ'**		**Effective Cohesion, C', Kpa**	
Kolfe 2	Und.	Remo.	Und.	Remo.	Und.	Remo.	Und.	Remo.
150 kPa	64	19	188	148	***23***	***14.4***	***19.2***	***1.1***
250 kPa	72	25	326	257				
350 kPa	87	81	447	300				



θ	21	t'0	17.7



θ	14	t'0	1.1

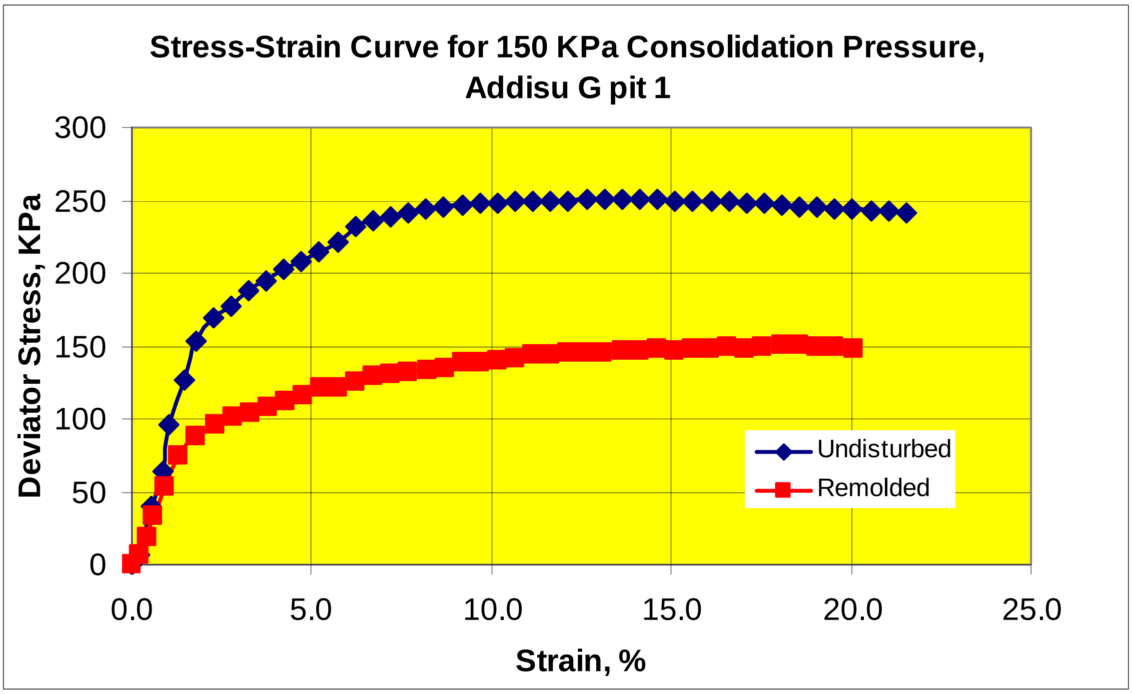


Fig: 4.32 Stress-Strain Curves for 150 kPa Consolidation Pressure, Addisu G Pit 1

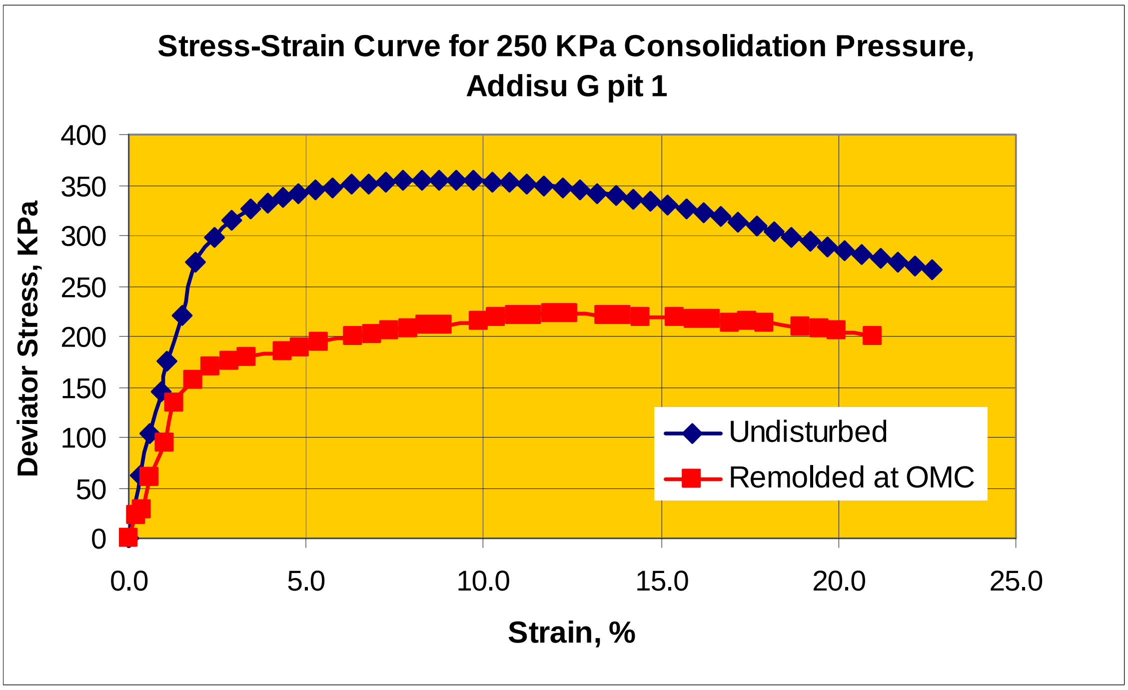


Fig: 4.33 Stress-Strain Curves for 250 kPa Consolidation Pressure, Addisu G Pit 1

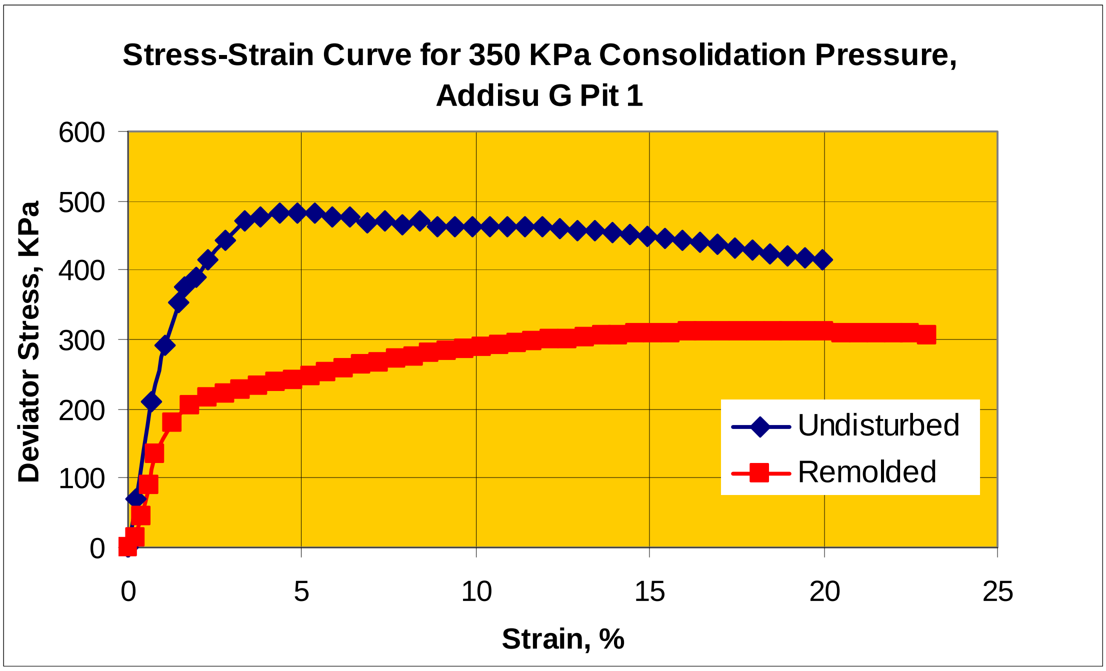


Fig: 4.34 Stress-Strain Curves for 350 kPa Consolidation Pressure, Addisu G Pit 1

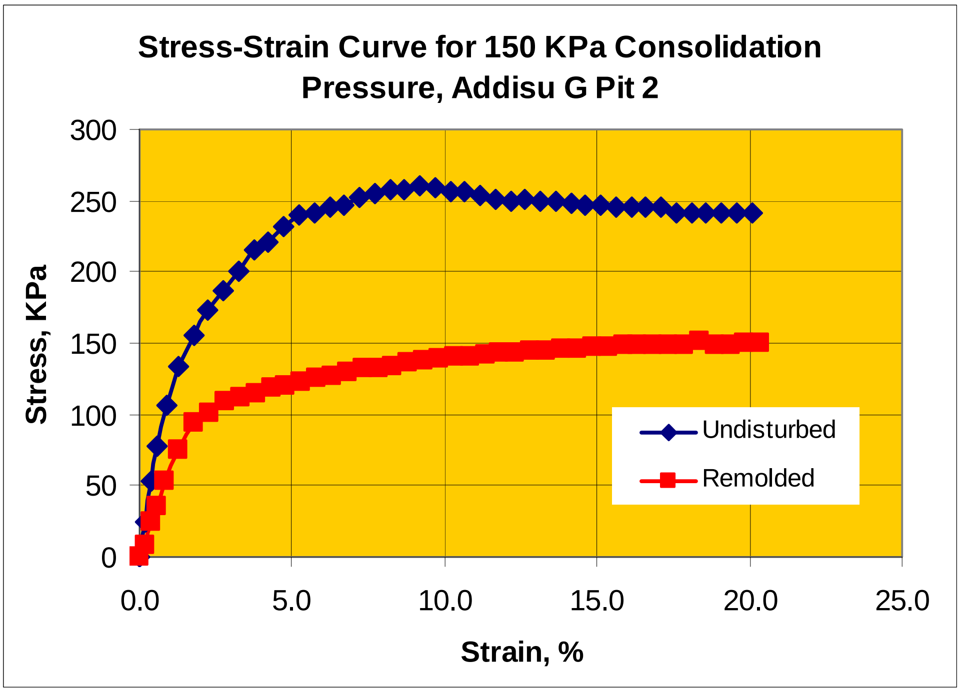


Fig: 4.35 Stress-Strain Curves for 250 kPa Consolidation Pressure, Addisu G Pit 2

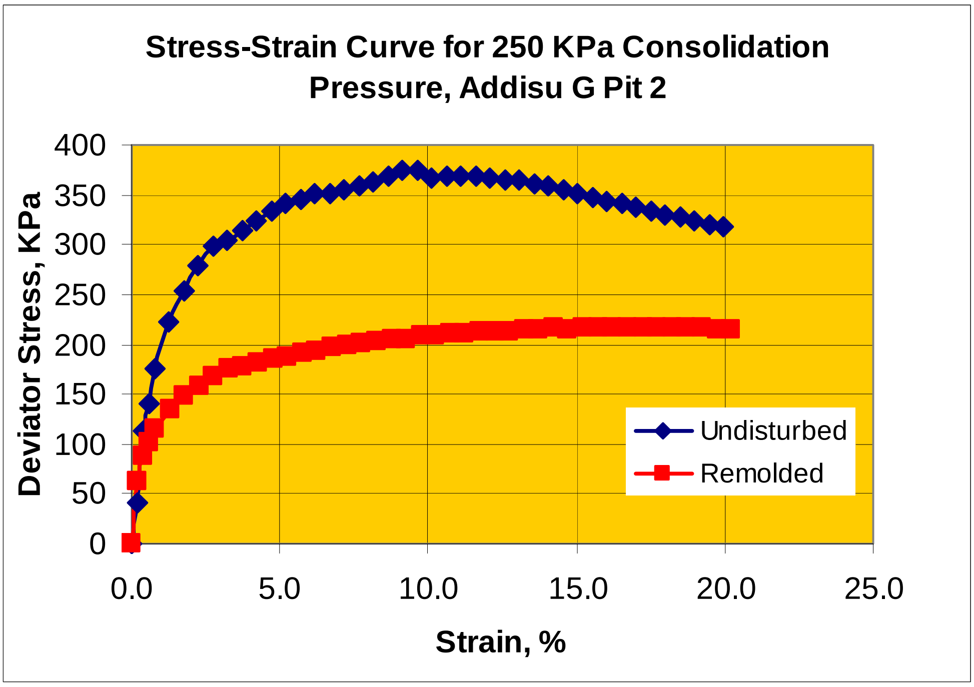


Fig: 4.36 Stress-Strain Curves for 250 kPa Consolidation Pressure, Addisu G Pit 2

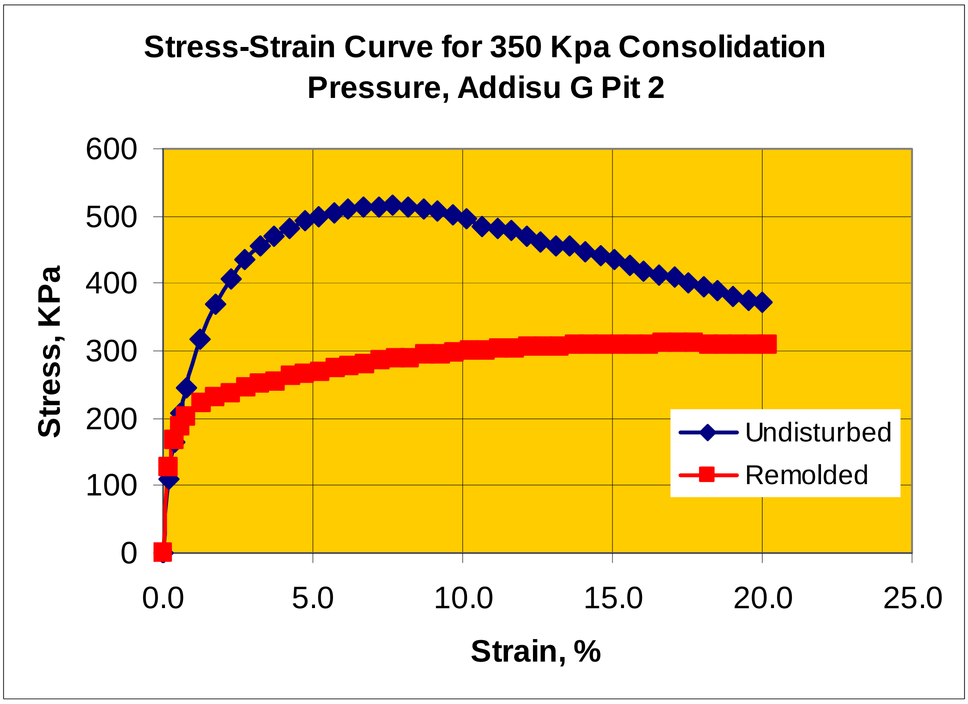
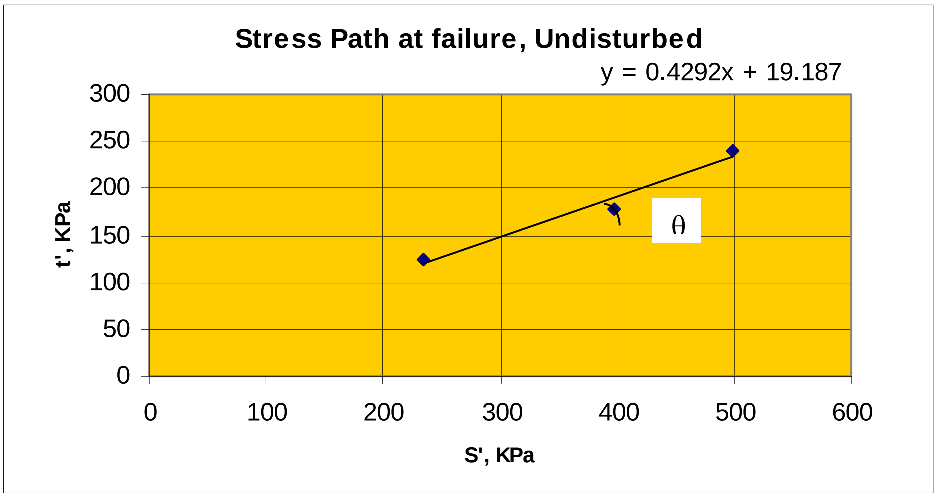


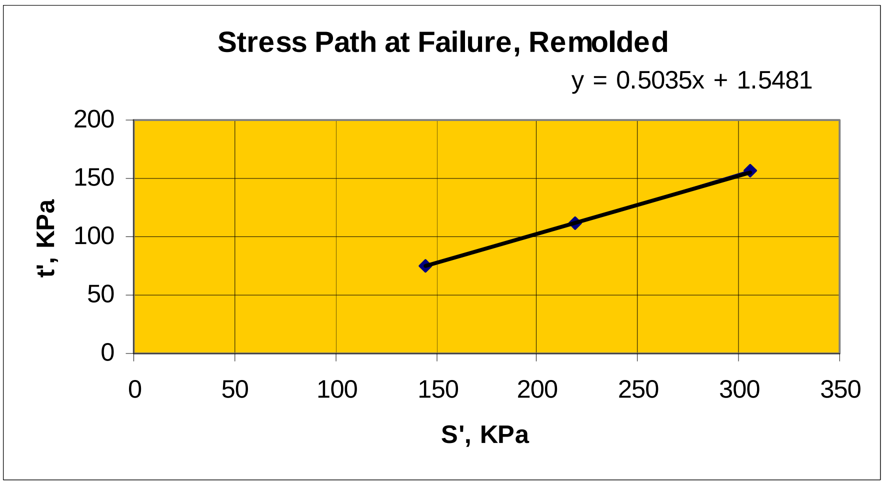
Fig: 4.37 Stress-Strain Curves for 350 kPa Consolidation Pressure, Addisu G Pit 2

Table: 4.17 Conditions at failure, Addisu Gebeya pit 1

Effective Consolidation Pressure	**Pore Pressure at Failure, KPa**		**Deviator Stress at Failure,Δσa, Kpa**		**Effective Angle of internal Friction, Φ'**		**Effective Cohesion, C', Kpa**	
Addisu G Pit 1	Und.	Remo.	Und.	Remo.	Und.	Remo.	Und.	Remo.
150 kPa	40	80	251	150	***15.5***	***15.5***	***20***	***1.7***
250 kPa	29	142	335	223				
350 kPa	93	199	482	312				



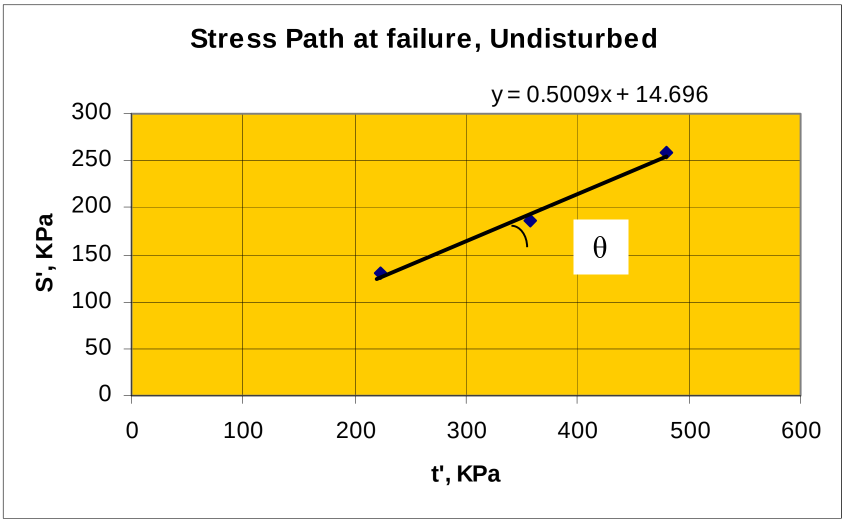
θ	15	t'o	19.2



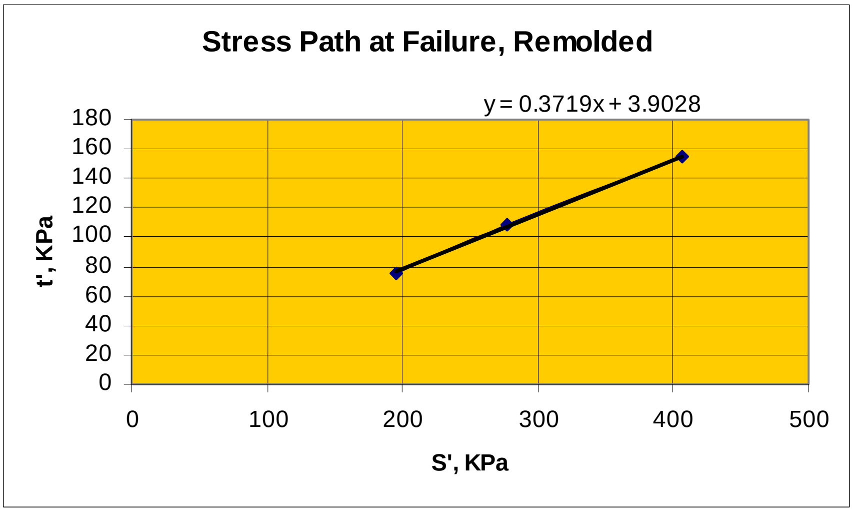
θ	15	t'o	1.6

Table: 4.18 Conditions at failure, Addisu Gebeya pit 2

Effective Consolidation Pressure	**Pore Pressure at Failure, KPa**		**Deviator Stress at Failure,Δσa, kPa**		**Effective Angle of internal Friction, Φ'**		**Effective Cohesion, C', kPa**	
Addisu G Pit 2	Und.	Remo.	Und.	Remo.	Und.	Remo.	Und.	Remo.
150 kPa	56	31	260	152	***21.3***	***19***	***15.3***	***4.1***
250 kPa	80	80	374	217				
350 kPa	128	98	515	311				



θ	27	t'o	14.7



θ	18	t'o	3.9

4.11 Permeability Test

Since the permeability behavior while loading is of interest, the permeability was measured indirectly from consolidation test. The soil at hand is fine grained soil with expected low permeability, the determination of permeability from falling head permeability test requires relatively longer time. Therefore, the permeability coefficient was calculated from oedometer test also saves time. The product of coefficient of consolidation with modulus of compressibility and unit weight of water gives the coefficient of permeability. Kz=Cv*(Mv*γw). The results obtained for different conditions are stated below.

Table: 4.19 Coefficient Permeability at different loadings (K, m/yr), Kolfe

	Undisturbed		Remolded	
Loading, kPa	Kolfe Pit 1	Kolfe Pit 2	Kolfe Pit 1	Kolfe Pit 2
50	0.120	0.230	0.070	0.200
100	0.061	0.096	0.035	0.058
200	0.036	0.052	0.029	0.045
400	0.024	0.036	0.023	0.030
800	0.016	0.023	0.014	0.016
1600	0.010	0.014	0.006	0.007

Table: 4.20 Coefficient Permeability at different loadings (K, m/yr), Addisu Gebeya.

	Undisturbed		Remolded	
Loading, kPa	Addisu Gebeya Pit 1	Addisu Gebeya Pit 2	Addisu Gebeya Pit 1	Addisu Gebeya Pit 2
50	0.107	0.126	0.091	0.119
100	0.065	0.108	0.061	0.093
200	0.038	0.069	0.033	0.067
400	0.025	0.041	0.018	0.030
800	0.016	0.018	0.011	0.012
1600	0.010	0.011	0.003	0.004

5. DISCUSSION OF TEST RESULTS

5.1 One dimensional consolidation test

5.1.1 Undisturbed Samples

The Oedometer test run on four undisturbed samples at loading intensities varying from 50 kPa to 1600 kPa revealed that the amount of total deformation at the end of final loading is similar for Kolfe pit 1 and Addisu Gebeya pit 1 as well as for Kolfe pit 2 and Addisu Gebeya pit 2 for consolidation period of twenty-four hours. Since for loadings higher than PC the soil behavior will change and results in larger magnitude of deformation, it was also recognized larger amount of deformation for steps of higher loadings, especially for loadings beyond PC.

The reading taken from the dial gage micrometer of one dimensional consolidation apparatus and plotted against the respective loading also illustrates that the coefficient of consolidation, Cv, varies on the early stages of loadings but more or less comes to comparable state for the later stages of higher loadings, in which the ability of soil for compression decreases or takes longer time and void ratio decreases to minimum value, for all four test pits.

It was noticed that the calculated void ratios for undisturbed soil samples for each steps of loadings are comparable for both initial and final steps of loadings for Kolfe pit 2 and Addisu Gebeya pit 1 as well as for Kolfe pit 1 and Addisu Gebeya pit2. Generally void ratios for all of samples were reduced to lower value since increasing intencity of loadings at each steps of loading brought soil grains more closely to each other. The modulus of volume compressibility, Mv, was found to be more variable at early stages of loadings. But, at the end of loadings the modulus of compressibility behavior was found as approaching one another. The calculated amounts of compression index, Cc, were similar for Kolfe pit 1 and Addisu Gebeya pit 1 while it was differenet for other pits.

The preconsolidation stresses and OCRs for samples collected from Kolfe pit 2 and Addisu Gebeya pit 1 were similar while different for other pits, however all of the for samples collected show that all are heavily over consolidated soils in their natural states.

5.1.2 Remolded samples

The dial gage reading recorded at the end of final loadings on the remolded samples show that all of the samples undergo large deformations since remolding alters geometrical arrargement and removes cementation between soil particles. The amount of deformation differs from soil to soil, however the difference between Kolfe pit 2 and Addisu Gebeya pit 1 is not much exaggerated as others. Larger amount of deformations for steps of loadings beyond PC have been seen, as loadings higher than PC change the soil behavior and results in larger magnitude of deformation as expected.

The values of coefficient of consolidation, Cv, are more or less comparable for Kolfe pit 1 and 2 as well as for Addisu Gebeya pit 1 and 2 both at the initial and final steps of loading. But the Cv values deacreased for increased intencity of loadings since soil compression takes longer time and void ratio decreases to minimum values while increasing loadings to large magintude.

The calculated void ratio for the remolded samples decreased from large values to low values while loading intensity increases bringing soil grains more closly. The amount of void ratio for Kolfe pit 2 and Addisu Gebeya 1 are found to be comparable both at initial and final stages of loadings, however the final void ratio is similar for Kolfe 1 and Addisu Gebeya pit 2. The modulus of volume compressibility, Mv, was found to be similar at the end of loadings for Kolfe pit 1 and Addisu Gebeya pit 1 as well as Kolfe 2 and Addisu Gebeya 2 at the final stages of loadings. However, the modulus of compressibility behavior was found as more variable at the initial stages of mechanical loading.

The calculated amounts of coefficient of compression, Cc, were similar for Kolfe pit 2 and Addisu Gebeya pit 2. The preconsolidation pressure that indicates the compacting effort/energy for remolded samples of all pits found to be variable and lower than that of undisturbed samples.

The amounts of total deformation of remolded samples were higher than the deformation recorded in undisturbed samples because of the larger initial void ratio of remolded samples. Large magnitudes of volume compressibility and compression index were also observed in remolded samples because of relatively higher void ratio of remolded samples. The higher initial void ratios of remolded samples were due to low preloading stress/ compactive effort of remolded samples comaring with relatively larger PC of undisturbed samples. The values of Cv for remolded samples were lower than the values of undisturbed samples because of low permeability of remolded samples.

5.2 Triaxial compression test

When strictly following the BS 1377, recommendation of failure criterion, there was considerable difference between the deviator stress at the maximum effective stress ratio and maximum deviator stress to consider it as failure stress. Therefore, by reviewing the previous works (Tadesse, S., 1989 and Abzo, H., 1992) in these areas and to consider this additional stress, the current research also considers maximum deviator stress or deviator stress at 20% strain as failure stress. For example, for kolfe pit 1 the deviator stress at maximum effective stress ratio is 187 kPa where as the maximum deviator stress is 239 kPa, for 150 kPa effective consolidation pressure. The detail data is attached in the appendix-B for all of four test pits.

The General trend of stress-Strain curve of undisturbed samples for the research at hand is more or less comparable with the results obtained by the work of Tarekegn (2009) for the same places.

The effective shear strength parameters for undisturbed samples obtained in the current research are not also very different from those obtained by the work of Tadesse (1989).

5.2.1 Undisturbed samples

The deviator stresses recorded during the compression stage of triaxial compression for all of undisturbed samples are much higher than their respective effective consolidation pressure. The effective shear strength parameters obtained are considerable as soil structure (geometrical arrangement and grain contact) still there in the natural state favoring for good strength.

5.2.2 Remolded samples

The failure stresses for the remolded samples during compression is equal to 150 kPa for 150 kPa of effective consolidation pressure, which is less than the PC obtained, except for Kolfe pit 1. For the effective consolidation pressures of 250 kPa and 350 kPa, which are greater than PC for remolded samples, the obtained deviator stress is clearly lower than the stated effective confining stresses except for Kolfe pit 2 of 250 kPa effective confining pressure. The effective cohesions of all remolded soil samples were very small. Effecetive angles of internal friction of all samples were variable.

Comparing the stress-strain behavior, the failure stress of remolded samples were lower than the failure stress of undisturbed samples because of the preshearing stress for remolded samples were lower than that of the PC, which soil expeoerienced previously, of undisturbed samples.

The effective cohesions of remolded samples were considerably lower than that of undisturbed samples as cementation between particles were affected during pulverization of sample preparation and compaction of soil remolding. Variable behaviors of effective angleof internal friction were recognized for both disturbed and undisturbed samples due to variable physical properties such as moisture content and amount of silt of samples.

5.3 Permeability test

5.3.1 Undisturbed samples

The amount of coefficient of permeability for undisturbed samples as calculated from one dimensional consolidations test is variable in the early stage of loading and converges to some specific lower value at later and larger amount of loadings. The permeability behavior of undisturbed samples when recognized in saturation stages of triaxial compression test, it requires fewer days to achieve B value grater than or equal to 0.95. This is might be because of favorable soil grain arrangements since the sample is in its natural state.

5.3.2 Remolded samples

The permeability of remolded samples as determined from consolidation test shows that the values are variable and more or less lower in the early loading stages and decreases considerably to the specific values as loading to higher intensity and remolding alters the geometrical arrangements of soil grains that favor in permeability. When the permeability behavior was recognized in the consolidation stages of triaxial compression, the dissipation of excess pore water pressure and stabilization of volume change was required longer time.

The coefficients of permeability of remolded samples were lower than that of undisturbed samples while the remolded samples have relativel larger void ratios than that of the undisturbed ones. This might be because of less favorable arrangements of soil grain in the remoled state due to rearrangement of soil grains has not yet been taken place due to short time during consolidation.

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From the laboratory tests were run, the response of remolded and undisturbed samples at different conditions of mechanical loading, the following conclusions can be drawn about the effect remolding that is manifested by alteration of moisture content, densiry, soil grain arrangement and cohesion between soil particles.

When the heavily overconsolidated Addis Ababa red clays collected from Kolfe and Addisu Gebeya remolded at OMC and tested under:

- oedometer undergo large deformation, 1.87mm to 3.51mm, because of remolding resulted in larger initial void ratios, 0.769 to 0.917, than undisturbed samples due to low preloading stresses/ compacting effort, 100kPa to 220kPa, that the soil has ever exprienced,
- oedometer shown smaller coefficient of consolidation, 37.15m^2/yr to 8.38m^2/yr, and result in reduced permeability, 0.119m/yr to 0.003m/yr. This might be because of short time for the soil grains of remolded samples to be arranged in the favorable condition,
- triaxial compression result in low deviator stresses in general, because of low preshearing stresses that the remolded samples had ever experienced.
- triaxial compression result in considerably reduced effective cohesion, 1.1kPa to 4.1kPa, due to remoldinging resulted in reduced cementation between soil grains and variable effective angle of internal friction, 14.4^0 to 30.6^0, due to variable physical properties like moisture content and amount of silt contents.

6.2 Recommendations for further research

The author recommends that further researches can be conducted with increased number of samples from same areas and additional areas that are not included in this research of Addis Ababa where red clay soil found can be included. This research topic can also be further employed by using cyclic triaxial and unsaturated triaxial compression machines.

The consolidation and permeability behavior of the remolded soil can further be cheked considering creep effects.

APPENDIX-A

AUTOMATIC TRIAXIAL TESTING MACHINE

A.1 General

As the first user of the Auto-triax, it is worth indicating the general and specific features as well as benefits of the machine since it gives better insight of the machine for the other users.

The Auto-triax enables full automatic or half automatic control of all test stages required to perform effective stress tests from start to finish. In half automatic control when one stage, say saturation, is completed the user must confirm the system to continue consolidation stage and when consolidation is completed, the user must operate on the triaxial machine before starting compression. In fully automatic control, before starting a new test the user sets up the different information of each of the test stages and once the test has been started it stops only after compression is completed.

Since the system controls the valves, the Auto-triax eliminates operator/human error that may happen while opening and closing valves at different test stages. The system also gives different plots such as pressure (cell, back, and pore) versus time, volume change versus time, deviator stress versus time, B parameter versus cell pressure, e.t.c while the test is running. The system also records different data like load, displacement, pore pressure at a predefined data logging rate and calculates and applies corrections. The Auto-triax is also with the ability to generate test report of each stage with predefined report formats or with user defined formats in Microsoft Excel worksheet.

1. Triaxial Compression frame
2. Submersible load cell
3. Triaxial cell
4. Displacement transducer
5. Mounting bracket
6. Pressure transducer block
7. Pressure transducer
8. RTC box
9. Volume change unit
10. Servo flow
11. Air-water cylinder
12. Automatic triaxial Data log
13. Lantronix server Device
14. Level one Ethernet switch
16. Solenoid valve

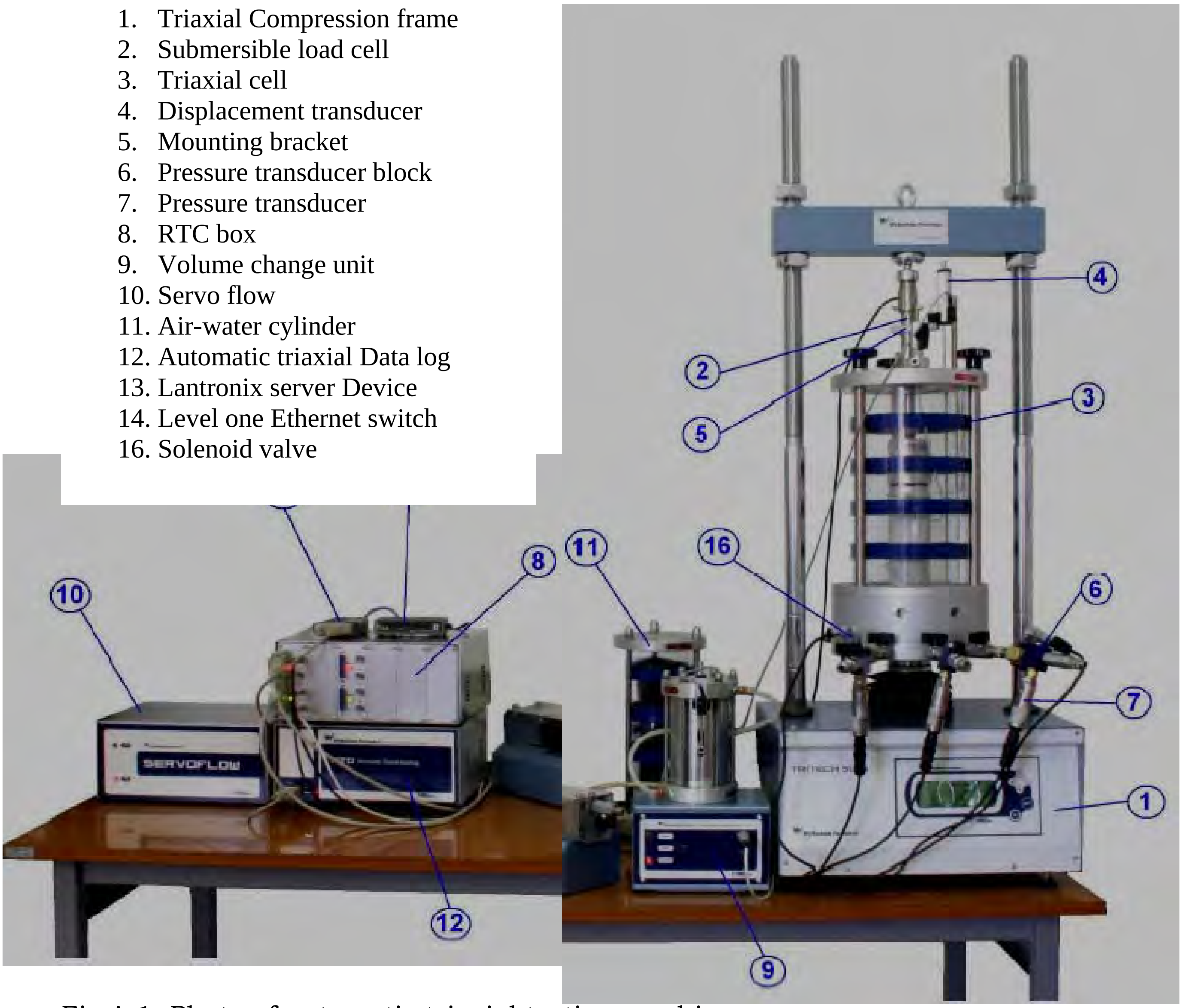


Fig A.1: Photo of automatic triaxial testing machine

The Auto-triax system comprises different components like computer, Triaxial frame, Real Time Control (RTC) box which is the brain of Auto-triax that allows control of the system, Automatic Triaxial Data logger (ATD) which provides automatic data acquisition of the transducer values; Servo flow pressure controller which regulates the supply of pressure in direct proportion to a signal received from the RTC box; Automatic Volume Change (AVC) device which measures the volume of water that enters or exits from the sample, Solenoid valves which allow pressure lines to be automatically opened and closed as the command comes from the software; pressure transducers which read the amount of pressure supplied or developed; network switch which facilitates communication between software and hardware and air-water cylinders which help as a mechanism to change air pressure to water pressure. The Auto-traix works with two soft wares (RTC management software and effective stress test soft) through which the user communicates with the triaxial system.

A.2 How to start the Auto-triax system

As a first task to use the system turn on all the components such as computer, ATD, RTC box and the triaxial frame. After turning on all the components, run the Real-Time Control Management software first and then effective stress test software by clicking the icons on the desktop.

A.3 Working with the software

A.3.1 RTC management software

The Real Time Control (RTC) Management software works with the Real Time Control (RTC) box. It manages communication connections to other system components and controls pressures, valves, compression frames and volume change devices. The RTC Management software receives commands from the operator or the automatic test software (e.g. increase a pressure, close a pressure line, change the automatic volume change device flow direction) and applies them to the triaxial system, using a closed loop control system. The RTC Management software also manages the transducer calibrations and the setup of up to three triaxial systems. Therefore RTC management software requires setting connection to ATD and system using buttons on the panel. It also requires setting type of machine to be used and type of test to be performed. It displays channels for transducer calibration, calibration details and status of connection.

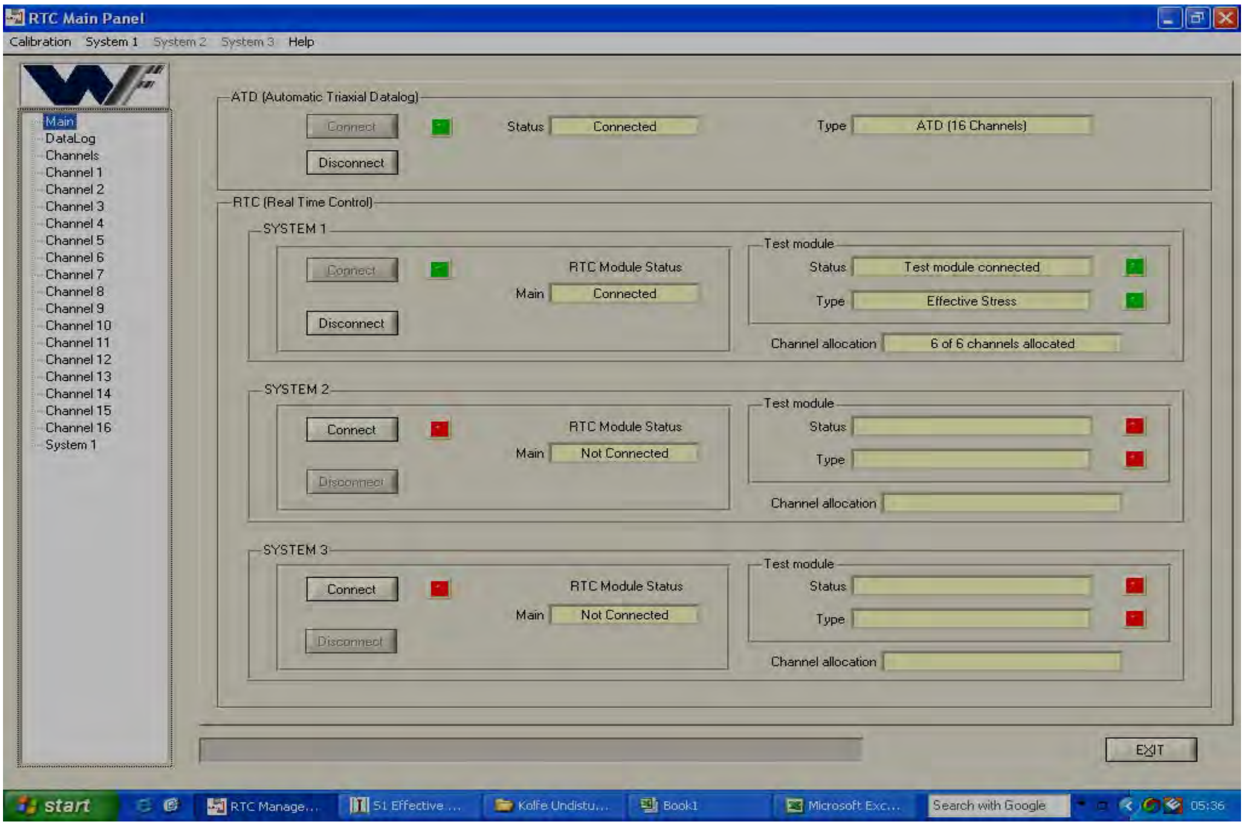


Fig: A.2 RTC management software window

4.3.2 Effective stress software

The Effective Stress Test Module software is used together with the Real-Time Control Management software to allow the user full or half automatic control of an effective stress triaxial test. From the start to the end of the test the software has total control of the triaxial frame, the cell and back pressures, the pressure line valves, and the volume change device.

The software displays live transducer readings, graphical test data and calculated specimen dimensions throughout the test. Current or historic test data can be easily reviewed and transferred into a spreadsheet template to create test reports.

Therefore, the software requires connection with RTC system and information for test and specimen set up such as test standard, drainage condition, use of side drain or not, membrane thickness, specimen size, moisture content, type and method of sample preparation, and other details required for complete test such as cell pressure increment, back pressure differential, effective consolidation pressure, drainage condition, rate of axial displacement during shearing, failure criteria, and application of correction.

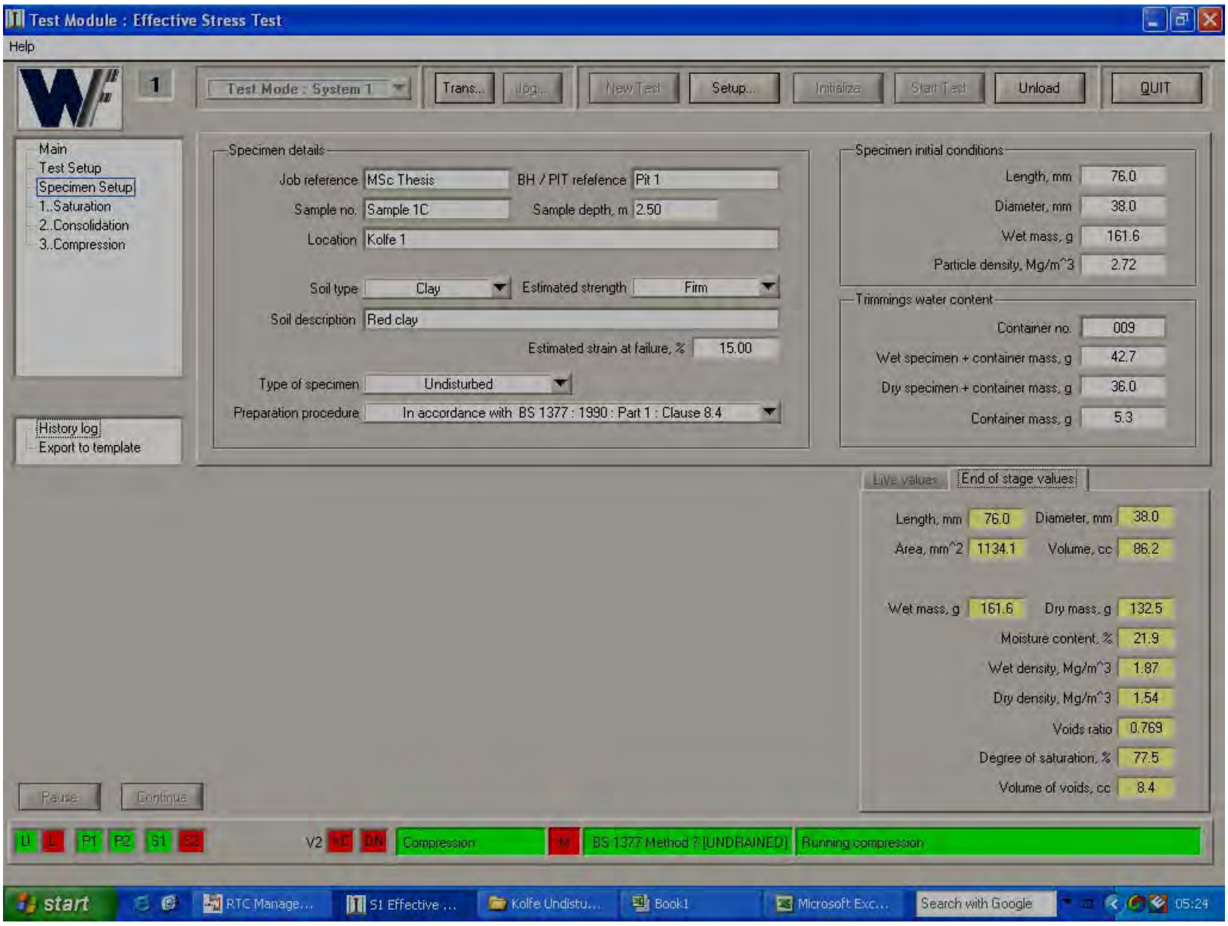


Fig: A.3 Effective stress test software window

A.4 Performing triaxial test

Preparing and setting the test specimen on Auto-triax is similar with that of standard triaxial apparatus except in Auto-triax new test is performed after it has given the file name and location where all test information are going to be saved.

Saturation stage can be continued with full or half automatic control of the software once after all information required for this stage has been entered in the effective stress test software in the saturation panel. The software in this stage allows the user to select which method of saturation (cell and back pressure increment or cell pressure increment). The software is also with the option to select automatic or manual saturation. If automatic saturation option is selected, the software requires the amount of cell pressure in increment, back pressure differential, time to wait for constant value of B parameter. If auto saturation option is not selected, the user enters the value for cell pressure increment and back pressure differential at each step of cell pressure or back pressure increment or increments. The software or the user decides the value for B Parameter (greater than 0.95) to end saturation stage.

Automatic consolidation or manual consolidation stage continues once saturation stage is completed. To perform auto saturation stage the effective stress test software requires effective consolidation pressure and percent of termination dissipation or degree of consolidation. In this option consolidation starts and ends automatically based on the given information. To perform manual consolidation the software only requires the target cell pressure and back pressure that is needed to achieve the required effective consolidation pressure. The user must end the consolidation stage when the required of amount degree of consolidation is achieved when the manual consolidation is being performed.

As the final stage of the test, compression/shearing stage can be performed automatically or manually. In this stage the software requires whether drained or undrained shearing is going to be performed. Failure criterion, termination strain, correction to be applied or not, data logging rate are also required. If auto compression stage was selected, the system starts and ends automatically the shearing stage based on the given information. To perform manual compression, the user is responsible to start and end this test stage.

Performing full automatic triaxial test requires every and detail information at the beginning of the test and the test can only be stopped after shearing stages. This full automatic option of the test will not enable the user to correct any mistake or to change test parameters and hence is not recommended unless the user is very familiar with the system. Manual or half automatic triaxial test has an advantage to correct or amend the test information during the whole test for some parameters or between stages.

After performing fully automatic or half automatic triaxial test, the effective stress test software enables the user to generate and save a report of each test stages with the initial given information and the final obtained results. The report can be generated on the excel template provided with the software or the user can generate his/her own template.

For the current test half automatic control was used to use the advantage of changing inputs and amending any mistakes that may probably happen.

APPENDIX-B

Complete Laboratory Tests

Moisture Content Determination

Moisture content test for Kolfe Pit #1

Location: ***Kolfe area***			Job ref.	***Thesis research***
			Pit no.	***#1***
Soil Description: ***Red brown clay***			Sample no.	***#1***
			Depth	***2.5m***
Test method: Oven dried, BS 1377-2: 1990: 3.2			Date	***06/09/2001E.C***
Specimen ref.	#1	#2		
Container no.	38	29		
Mass of wet soil + container (m_2) g	42.72	85.92		
Mass of dry soil + container (m_3) g	35.99	71.44		
Mass of container (m_1) g	5.3	5.19		
Mass of moisture (m_2- m_3)g	6.73	14.48		
Mass of dry soil (m_3- m_1)g	30.69	66.25		
Moisture content = $(m_2-m_3)/(m_3- m_1)*100$, %	21.9	21.9		
Average	**22**			

Moisture content test for Kolfe Pit #2

Location: ***Kolfe area***			Job ref.	***Thesis research***
			Pit no.	***#2***
Soil Description: ***Red brown clay***			Sample no.	***#1***
			Depth	***2.5m***
Test method: Oven dried, BS 1377-2: 1990: 3.2			Date	***06/09/2001E.C***
Specimen ref.	#1	#2		
Container no.	66	74		
Mass of wet soil + container (m_2) g	40.74	94.6		
Mass of dry soil + container (m_3) g	33.32	75.63		
Mass of container (m_1) g	5.25	5.22		
Mass of moisture (m_2- m_3)g	7.42	18.97		
Mass of dry soil (m_3- m_1)g	28.07	70.41		
Moisture content = $(m_2-m_3)/(m_3- m_1)*100$ %	26	27		
Average	27			

Moisture content test for Addisu Gebeya Pit #1

Location: ***Addisu Gebeya***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Oven dried, BS 1377-2: 1990: 3.2		Date	***15/10/2001E.C***

Specimen ref.	#1	#2		
Container no.	38	29		
Mass of wet soil + container (m_2) g	44.76	37.19		
Mass of dry soil + container (m_3) g	38.52	32.61		
Mass of container (m_1) g	15.68	15.74		
Mass of moisture (m_2- m_3)g	6.24	4.58		
Mass of dry soil (m_3- m_1)g	22.84	16.87		
Moisture content = (m_2-m_3)/(m_3- m_1)*100 %	27.3	27.1		
Average	***27***			

Moisture content test for Addisu Gebeya Pit #2

Location: ***Addisu Gebeya***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Oven dried, BS 1377-2: 1990: 3.2		Date	***15/10/2001E.C***

Specimen ref.	#1	#2		
Container no.	66	74		
Mass of wet soil + container (m_2) g	43.01	41.43		
Mass of dry soil + container (m_3) g	37.01	35.82		
Mass of container (m_1) g	15.87	15.79		
Mass of moisture (m_2- m_3)g	6	5.61		
Mass of dry soil (m_3- m_1)g	21.14	20.03		
Moisture content = (m_2-m_3)/(m_3- m_1)*100 %	28.4	28.0		
Average	***28***			

Density Determination

Field Density test for Kolfe pit #1

Location: ***Kolfe area***	Job ref.	***Thesis research***		
	Pit no.	***#1***		
Soil Description: ***Red brown clay***	Sample no.	***#1***		
	Depth	***2.5m***		
Test method: Core Cutter, BS 1377-9: 2.4	Date	***06/09/2001E.C***		
Mass of soil + Sampler (m_2) g	2450			
Mass of Sampler (m_1) g	768			
Mass of Soil (m_2- m_1)g	1682			
Height of Sampler, (H)cm	11.2			
Diameter of Sampler, (D) cm	10			
Volume of Sampler/soil, ($V=\pi*D^2/4*H$)cm^3	879.6			
Density, ρ, g/cc	1.91			

Field Density test for Kolfe pit #2

Location: ***Kolfe area***	Job ref.	***Thesis research***		
	Pit no.	***#2***		
Soil Description: ***Red brown clay***	Sample no.	***#1***		
	Depth	***2.5m***		
Test method: Core Cutter, BS 1377-9: 2.4	Date	***06/09/2001E.C***		
Mass of soil + Sampler (m_2) g	2561			
Mass of Sampler (m_1) g	810			
Mass of Soil (m_2- m_1)g	1751			
Height of Sampler, (H)cm	12			
Diameter of Sampler, (D) cm	10			
Volume of Sampler/soil, ($V=\pi*D^2/4*H$)cm^3	942.5			
Density, ρ, g/cc	1.86			

Field Density test for Addisu Gebeya pit #1

Location: ***Addisu Gebeya***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Core Cutter, BS 1377-9: 2.4		Date	***15/10/2001E.C***

Mass of soil + Sampler (m_2) g	2417			
Mass of Sampler (m_1) g	610			
Mass of Soil (m_2- m_1)g	1807			
Height of Sampler, (H)cm	11.2			
Diameter of Sampler, (D) cm	10.4			
Volume of Sampler/soil, ($V=\pi*D^2/4*H$)cm^3	951.4			
Density, ρ, g/cc	1.90			

Field Density test for Addisu Gebeya pit #2

Location: ***Addisu Gebeya***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Core Cutter, BS 1377-9: 2.4		Date	***15/10/2001E.C***

Mass of soil + Sampler (m_2) g	2510			
Mass of Sampler (m_1) g	574			
Mass of Soil (m_2- m_1)g	1396			
Height of Sampler, (H)cm	12			
Diameter of Sampler, (D) cm	10.4			
Volume of Sampler/soil, ($V=\pi*D^2/4*H$)cm^3	1019.4			
Density, ρ, g/cc	1.90			

Specific Gravity Determination

Specific gravity test for Kolfe pit #1

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Small pyknometer BS 1377-2:1990:8.3		Date	***11/09/2001E.C***

Specimen ref.	#1	#2	
Pyknometer number	P20	P41	
Mass of bottle + soil + water ($m3$) g	150.02	155.68	
Mass of bottle + soil ($m2$) g	53.54	59.76	
Mass of bottle full of water ($m4$) g	144.79	149.44	
Mass of bottle ($m1$) g	45.29	49.89	
Mass of soil ($m2 - m1$) g	8.26	9.87	
Mass of water in full bottle ($m4 - m1$) g	99.50	99.55	
Mass of water used ($m3 - m2$) g	96.47	95.92	
Volume of soil particles ($m4 - m1$) – ($m3 - m2$) mL	3.03	3.63	
Specific Gravity ($m2 - m1$)/(($m4 - m1$) – ($m3 - m2$))	2.726	2.720	
Average	2.72		

Specific gravity test for Kolfe pit #2

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Small pyknometer BS 1377-2:1990:8.3		Date	***11/09/2001E.C***

Specimen ref.	#1	#2	
Pyknometer number	P8	P10	
Mass of bottle + soil + water ($m3$) g	162.81	158.78	
Mass of bottle + soil ($m2$) g	58.65	53.82	
Mass of bottle full of water ($m4$) g	157.09	153.62	
Mass of bottle ($m1$) g	49.64	45.65	
Mass of soil ($m2 - m1$) g	9.01	8.17	
Mass of water in full bottle ($m4 - m1$) g	107.44	107.97	
Mass of water used ($m3 - m2$) g	104.16	104.96	
Volume of soil particles ($m4 - m1$) – ($m3 - m2$) mL	3.28	3.01	
Specific Gravity ($m2 - m1$)/(($m4 - m1$) – ($m3 - m2$))	2.743	2.714	
Average	2.73		

Specific gravity test for Addisu Gebeya pit #1

Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Small pyknometer BS 1377-2:1990:8.3		Date	***21/10/2001E.C***

Specimen ref.	#1	#2	
Pyknometer number	P13	P2	
Mass of bottle + soil + water ($m3$) g	156.33	155.37	
Mass of bottle + soil ($m2$) g	61.21	59.22	
Mass of bottle full of water ($m4$) g	148.68	149.53	
Mass of bottle ($m1$) g	49.10	49.96	
Mass of soil ($m2 - m1$) g	12.11	9.26	
Mass of water in full bottle ($m4 - m1$) g	99.58	99.57	
Mass of water used ($m3 - m2$) g	95.13	96.14	
Volume of soil particles ($m4 - m1$) – ($m3 - m2$) mL	4.45	3.43	
Specific Gravity ($m2 - m1$)/(($m4 - m1$) – ($m3 - m2$))	2.721	2.702	
Average	2.71		

Specific gravity test for Addisu Gebeya pit #2

Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Small pyknometer BS 1377-2:1990:8.3		Date	***21/10/2001E.C***

Specimen ref.	#1	#2	
Pyknometer number	P14	P52	
Mass of bottle + soil + water ($m3$) g	153.13	153.34	
Mass of bottle + soil ($m2$) g	56.42	56.31	
Mass of bottle full of water ($m4$) g	148.08	149.1	
Mass of bottle ($m1$) g	48.42	49.58	
Mass of soil ($m2 - m1$) g	7.99	6.72	
Mass of water in full bottle ($m4 - m1$) g	99.66	99.51	
Mass of water used ($m3 - m2$) g	96.71	97.03	
Volume of soil particles ($m4 - m1$) – ($m3 - m2$) mL	2.95	2.48	
Specific Gravity ($m2 - m1$)/(($m4 - m1$) – ($m3 - m2$))	2.710	2.708	
Average	2.71		

Atterberg limits Determination

Liquid Limit test for Kolfe pit #1

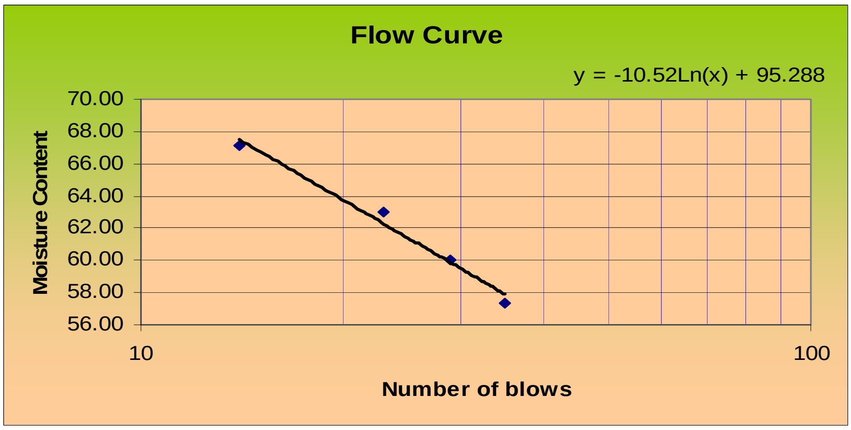
Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Small pyknometer BS 1377-2:1990:8.3		Date	***11/09/2001E.C***

Plastic Limit test

Test no.	#1	#2		
Container no.	H4	C29		
Mass of wet soil + container (m_2) g	18.77	17.46		
Mass of dry soil + container (m_3) g	18.15	16.73		
Mass of container (m_1) g	15.77	14.04		
Mass of moisture (m_2- m_3)g	0.62	0.73		
Mass of dry soil (m_3- m_1)g	2.38	2.69		
Moisture content = (m_2-m_3)/(m_3- m_1)*100, %	26.05	27.14		
Average, %	***27***			

Liquid Limit test

Test no.	#1	#2	#3	#4
Number of blows	14	23	29	35
Container no.	A19	C31	80	71
Mass of wet soil + container (m_2) g	38.62	36.14	36.47	39.16
Mass of dry soil + container (m_3) g	29.36	27.58	28.68	30.56
Mass of container (m_1) g	15.57	14	15.71	15.56
Mass of moisture (m_2- m_3)g	9.26	8.56	7.79	8.6
Mass of dry soil (m_3- m_1)g	13.79	13.58	12.97	15
Moisture content(m_2-m_3)/(m_3- m_1)*100, %	67.15	63.03	60.06	57.33



LL=-10.52*LN(25)+95.288=61	PL=27	PI=LL-PL=34	

Liquid Limit test for Kolfe pit #2

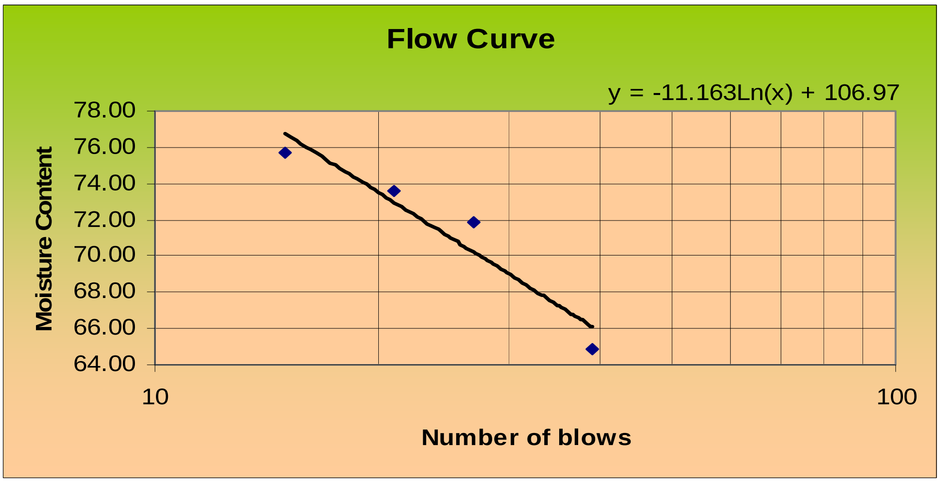
Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Small pyknometer BS 1377-2:1990:8.3		Date	***11/09/2001E.C***

Plastic Limit test

Test no.	#1	#2		
Container no.	76	D34		
Mass of wet soil + container (m_2) g	19.64	19.21		
Mass of dry soil + container (m_3) g	18.62	18.26		
Mass of container (m_1) g	15.55	15.35		
Mass of moisture (m_2- m_3)g	1.02	0.95		
Mass of dry soil (m_3- m_1)g	3.07	2.91		
Moisture content = (m_2-m_3)/(m_3- m_1)*100, %	33.22	32.65		
Average, %	***33***			

Liquid Limit test

Test no.	#1	#2	#3	#4
Number of blows	15	21	27	39
Container no.	24	98	C15	C18
Mass of wet soil + container (m_2) g	35.31	38.6	36.95	32.66
Mass of dry soil + container (m_3) g	26.83	28.83	27.31	25.14
Mass of container (m_1) g	15.63	15.55	13.9	13.54
Mass of moisture (m_2- m_3)g	8.48	9.77	9.64	7.52
Mass of dry soil (m_3- m_1)g	11.2	13.28	13.41	11.6
Moisture content(m_2-m_3)/(m_3- m_1)*100, %	75.71	73.57	71.89	64.83



LL=-11.163*LN(25)+106.97=71	PL=33	PI=LL-PL=38	

Liquid Limit test for Addisu Gebeya pit #1

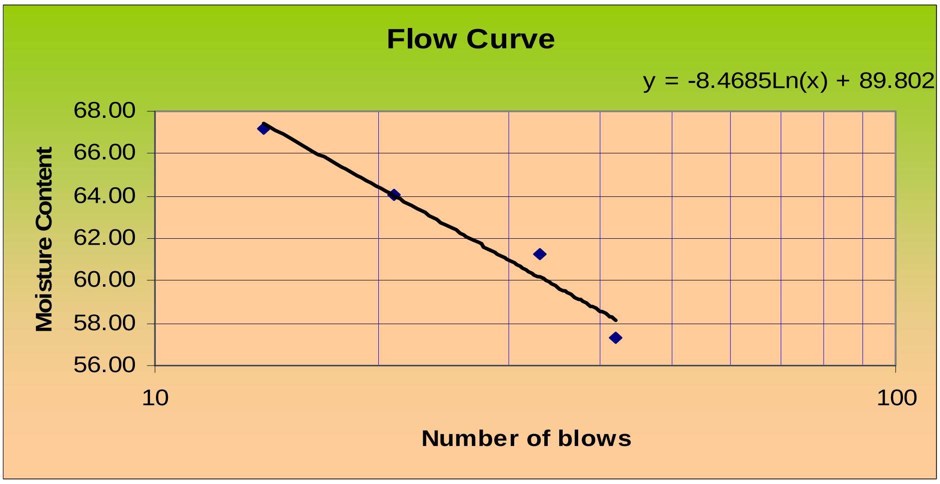
Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Small pyknometer BS 1377-2:1990:8.3		Date	***21/10/2001E.C***

Plastic Limit test

Test no.	#1	#2		
Container no.	A19	B1		
Mass of wet soil + container (m_2) g	17.88	17.27		
Mass of dry soil + container (m_3) g	17.38	16.83		
Mass of container (m_1) g	15.58	15.32		
Mass of moisture (m_2- m_3)g	0.5	0.44		
Mass of dry soil (m_3- m_1)g	1.8	1.51		
Moisture content = (m_2-m_3)/(m_3- m_1)*100, %	27.78	29.14		
Average, %	***28***			

Liquid Limit test

Test no.	#1	#2	#3	#4
Number of blows	14	21	33	42
Container no.	D22	69	H4	34
Mass of wet soil + container (m_2) g	30.72	29.49	27.98	27.51
Mass of dry soil + container (m_3) g	24.7	24.09	23.34	23.18
Mass of container (m_1) g	15.74	15.66	15.77	15.62
Mass of moisture (m_2- m_3)g	6.02	5.4	4.64	4.33
Mass of dry soil (m_3- m_1)g	8.96	8.43	7.57	7.56
Moisture content(m_2-m_3)/(m_3- m_1)*100, %	67.19	64.06	61.29	57.28



LL =-8.4685*LN(25)+89.802=63	PL=28	PI=LL-PL=35	

Liquid Limit test for Addisu Gebeya pit #2

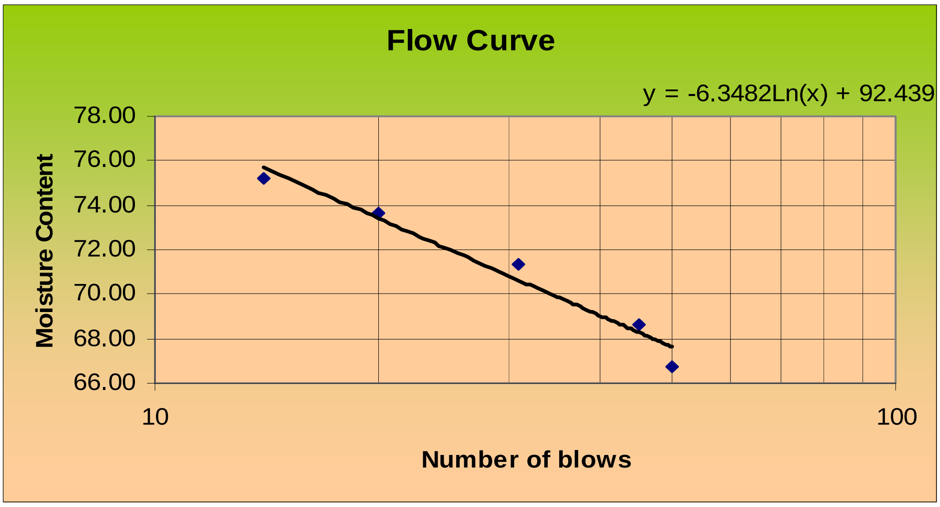
Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Small pyknometer BS 1377-2:1990:8.3		Date	***21/10/2001E.C***

Plastic Limit test

Test no.	#1	#2		
Container no.	100	48		
Mass of wet soil + container (m_2) g	18.02	17.67		
Mass of dry soil + container (m_3) g	17.4	17.17		
Mass of container (m_1) g	15.45	15.67		
Mass of moisture (m_2- m_3)g	0.62	0.5		
Mass of dry soil (m_3- m_1)g	1.95	1.5		
Moisture content = (m_2-m_3)/(m_3- m_1)*100, %	31.79	33.33		
Average, %	***33***			

Liquid Limit test

Test no.	#1	#2	#3	#4
Number of blows	14	20	31	45
Container no.	D361	C29	71	GHI
Mass of wet soil + container (m_2) g	26.1	19.91	22.26	22.7
Mass of dry soil + container (m_3) g	21.58	17.42	19.47	19.81
Mass of container (m_1) g	15.57	14.04	15.56	15.6
Mass of moisture (m_2- m_3)g	4.52	2.49	2.79	2.89
Mass of dry soil (m_3- m_1)g	6.01	3.38	3.91	4.21
Moisture content(m_2-m_3)/(m_3- m_1)*100, %	75.21	73.67	71.36	68.65



LL =-6.3482*LN(25)+92.439=72	PL=33	PI=LL-PL=39	

Determination of Shrinkage Limit

Shrinkage limit test for Kolfe pit #1

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Volumetric shrinkage, BS 1377-2:1990:6.4		Date	***11/09/2001E.C***

Shrinkage dish no.	3A	M18
Mass of wet soil + coated shrinkage dish (m3) g	96.44	96.97
Mass of dry soil + coated Shrinkage dish (m4) g	68.62	67.89
Mass of coated shrinkage dish (m2)g	24.66	24.07
Mass of wet soil (m1 = m3 – m2) g	71.78	72.9
Mass of dry soil (md = m4 – m2)g	43.96	43.82
Mass of water, g	27.82	29.08
Moisture content %	63.28	66.36
Mass of Mercury in shrinkage dish (full) + Mercury dish, g	880	861
Mass of displaced Mercury + Mercury dish, g	560	553
Mass of Mercury dish,g	246	246
Volume of mercury in shrinkage dish (vol. of wet soil)Vo, cc	46.79	45.39
Vol. of mercury displaced by dry soil (vol. of oven dried soil)Vf, cc	23.17	22.66
Shrinkage limit, Ws= Wo - (Vo-Vf)/Ws*1*100 ,%	10	14
Average Shrinkage limit, %	12	

Shrinkage limit test for Kolfe pit #2

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Volumetric shrinkage, BS 1377-2:1990:6.4		Date	***11/09/2001E.C***

Shrinkage dish no.	2A	M3
Mass of wet soil + coated shrinkage dish (m3) g	94.68	95.64
Mass of dry soil + coated Shrinkage dish (m4) g	64.11	64.31
Mass of coated shrinkage dish (m2)g	23.56	24.69
Mass of wet soil (m1 = m3 – m2) g	71.12	70.95
Mass of dry soil (md = m4 – m2)g	40.55	39.62
Mass of water, g	30.57	31.33
Moisture content %	75.39	79.08
Mass of Mercury in shrinkage dish (full) + Mercury dish, g	866	880
Mass of displaced Mercury + Mercury dish, g	543	556
Mass of Mercury dish,g	246	246
Volume of mercury in shrinkage dish (vol. of wet soil)Vo, cc	45.82	46.86
Vol. of mercury displaced by dry soil (vol. of oven dried soil)Vf, cc	21.92	22.88
Shrinkage limit, Ws= Wo - (Vo-Vf)/Ws*1*100 ,%	16	19
Average Shrinkage limit, %	17	

Shrinkage limit test for Addisu Gebeya pit #1

Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Volumetric shrinkage, BS 1377-2:1990:6.4		Date	***21/10/2001E.C***

Shrinkage dish no.	3A	M18
Mass of wet soil + coated shrinkage dish (m3) g	99.45	97.73
Mass of dry soil + coated Shrinkage dish (m4) g	69.55	68.33
Mass of coated shrinkage dish (m2)g	24.64	24.09
Mass of wet soil (m1 = m3 – m2) g	74.81	73.64
Mass of dry soil (md = m4 – m2)g	44.91	44.24
Mass of water, g	29.9	29.4
Moisture content %	66.58	66.46
Mass of Mercury in shrinkage dish (full) + Mercury dish, g	824	800
Mass of displaced Mercury + Mercury dish, g	516	514
Mass of Mercury dish,g	186	186
Volume of mercury in shrinkage dish (vol. of wet soil)Vo, cc	47.08	45.31
Vol. of mercury displaced by dry soil (vol. of oven dried soil)Vf, cc	24.35	24.21
Shrinkage limit, Ws= Wo - (Vo-Vf)/Ws*1*100 ,%	15.96	18.75
Average Shrinkage limit, %	17	

Shrinkage limit test for Addisu Gebeya pit #2

Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Volumetric shrinkage, BS 1377-2:1990:6.4		Date	***21/10/2001E.C***

Shrinkage dish no.	2A	M3
Mass of wet soil + coated shrinkage dish (m3) g	95.38	99.48
Mass of dry soil + coated Shrinkage dish (m4) g	64.54	67.5
Mass of coated shrinkage dish (m2)g	23.6	24.7
Mass of wet soil (m1 = m3 – m2) g	71.78	74.78
Mass of dry soil (md = m4 – m2)g	40.94	42.8
Mass of water, g	30.84	31.98
Moisture content %	75.33	74.72
Mass of Mercury in shrinkage dish (full) + Mercury dish, g	806	820
Mass of displaced Mercury + Mercury dish, g	494	508
Mass of Mercury dish,g	182	182
Volume of mercury in shrinkage dish (vol. of wet soil)Vo, cc	46.12	47.15
Vol. of mercury displaced by dry soil (vol. of oven dried soil)Vf, cc	23.03	24.06
Shrinkage limit, Ws= Wo - (Vo-Vf)/Ws*1*100 ,%	18.92	20.76
Average Shrinkage limit, %	20	

Free Swell Capacity Determination

Free swell test for Kolfe pit #1

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: BS 1377-2:1990:6.4		Date	***11/09/2001E.C***
Test no.	1	2	
Initial Volume, ml	10.0	10.0	
Final Volume, ml	10.8	11.2	
Free Swell, %	8.0	12.0	
Average %	***10***		

Free swell test for Kolfe pit #2

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: BS 1377-2:1990:6.4		Date	***11/09/2001E.C***
Test no.	1	2	
Initial Volume, ml	10.0	10.0	
Final Volume, ml	12.0	12.0	
Free Swell, %	20.0	20.0	
Average %	***20***		

Free swell test for Addisu Gebeya pit #1

Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: BS 1377-2:1990:6.4		Date	***11/09/2001E.C***
Test no.	1	2	
Initial Volume, ml	10.0	10.0	
Final Volume, ml	13.5	13.0	
Free Swell, %	35.0	30.0	
Average %	***33***		

Free swell test for Addisu Gebeya pit #1

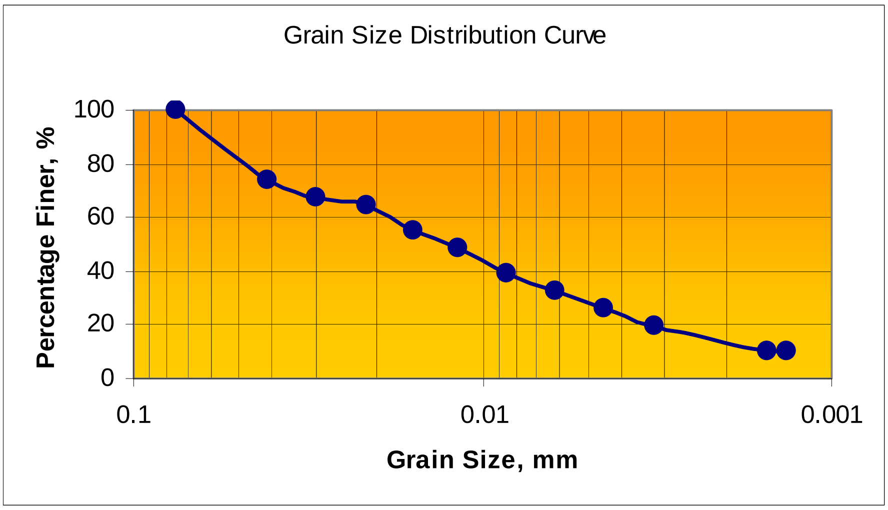
Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: BS 1377-2:1990:6.4		Date	***11/09/2001E.C***
Test no.	1	2	
Initial Volume, ml	10.00	10.00	
Final Volume, ml	13.40	13.20	
Free Swell, %	34.00	32.00	
Average %	***33***		

Particle Size Analysis

Hydrometer test for Kolfe pit #1

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Hydrometer, ASTM D 422-63		Date	***25/09/2001E.C***
		Specific Gravity	**2.72**
Lab Temperature: 20 degree centigrade		Composite correction	**-0.0027**
		K Value	**0.01336**

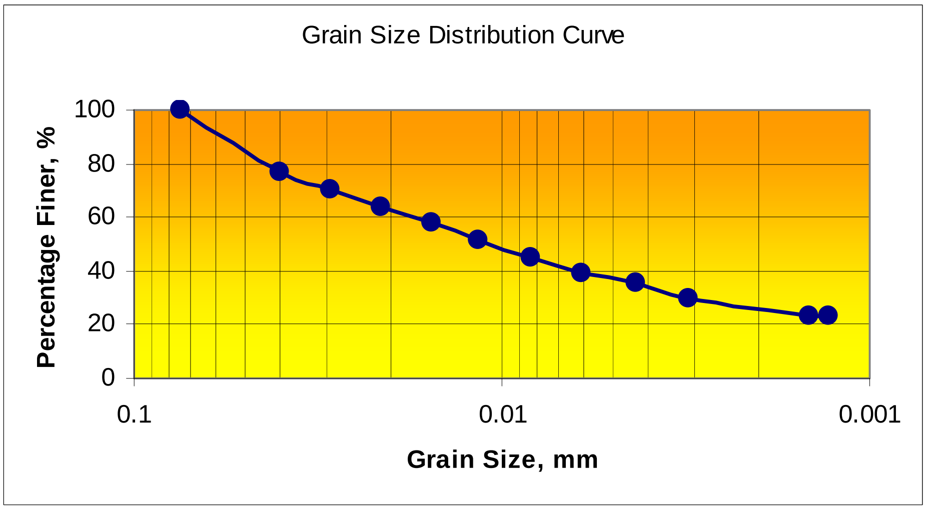
Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)
1	1.0260	-0.0027	1.0233	9.42	0.01336	0.0410	73.69
2	1.0240	-0.0027	1.0213	9.95	0.01336	0.0298	67.37
4	1.0230	-0.0027	1.0203	10.22	0.01336	0.0214	64.20
8	1.0200	-0.0027	1.0173	11.01	0.01336	0.0157	54.72
15	1.0180	-0.0027	1.0153	11.54	0.01336	0.0117	48.39
30	1.0150	-0.0027	1.0123	12.33	0.01336	0.0086	38.90
60	1.0130	-0.0027	1.0103	12.86	0.01336	0.0062	32.58
120	1.0110	-0.0027	1.0083	13.39	0.01336	0.0045	26.25
240	1.0090	-0.0027	1.0063	13.92	0.01336	0.0032	19.93
1140	1.0060	-0.0027	1.0033	14.71	0.01336	0.0015	10.44
1440	1.0060	-0.0027	1.0033	14.71	0.01336	0.0014	10.44



Hydrometer test for Kolfe pit #2

Location: ***Kolfe area***	Job ref.	***Thesis research***
	Pit no.	***#2***
Soil Description: ***Red brown clay***	Sample no.	***#1***
	Depth	***2.5m***
Test method: Hydrometer, ASTM D 422-63	Date	***25/09/2001E.C***
	Specific Gravity	**2.73**
Lab Temperature: 20 degree centigrade	Composite correction	**-0.0027**
	K Value	**0.01333**

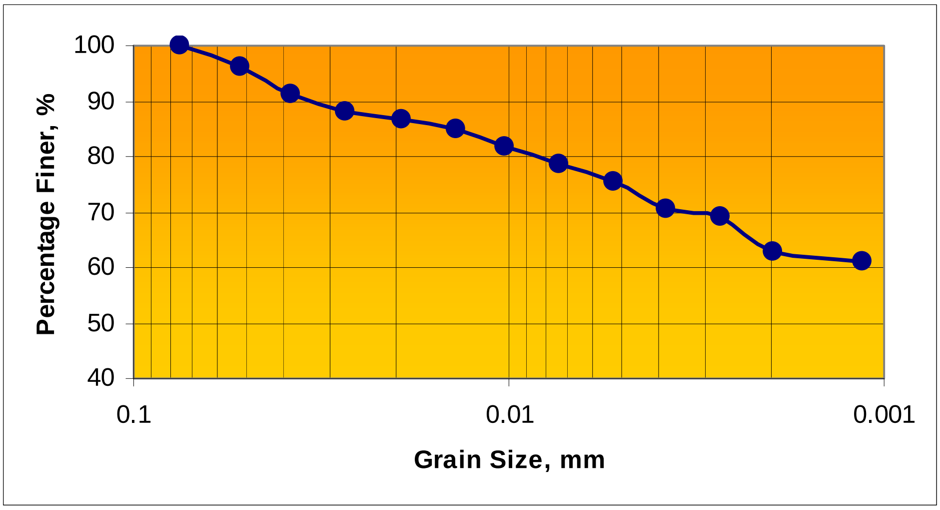
Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)
1	1.0270	-0.0027	1.0243	9.16	0.01333	0.0403	76.69
2	1.0250	-0.0027	1.0223	9.69	0.01333	0.0293	70.38
4	1.0230	-0.0027	1.0203	10.22	0.01333	0.0213	64.07
8	1.0210	-0.0027	1.0183	10.75	0.01333	0.0154	57.76
15	1.0190	-0.0027	1.0163	11.27	0.01333	0.0116	51.44
30	1.0170	-0.0027	1.0143	11.80	0.01333	0.0084	45.13
60	1.0150	-0.0027	1.0123	12.33	0.01333	0.0060	38.82
120	1.0140	-0.0027	1.0113	12.60	0.01333	0.0043	35.66
240	1.0120	-0.0027	1.0093	13.13	0.01333	0.0031	29.35
1150	1.0100	-0.0027	1.0073	13.65	0.01333	0.0015	23.04
1440	1.0100	-0.0027	1.0073	13.65	0.01333	0.0013	23.04



Hydrometer test for Addisu Gebeya pit #1

Location: ***Addisu Gebeya area***	Job ref.	***Thesis research***
	Pit no.	***#1***
Soil Description: ***Red brown clay***	Sample no.	***#1***
	Depth	***2.5m***
Test method: Hydrometer, ASTM D 422-63	Date	***25/10/2001E.C***
	Specific Gravity	**2.71**
Lab Temperature: 20 degree centigrade	Composite correction	**-0.0027**
	K Value	**0.01340**

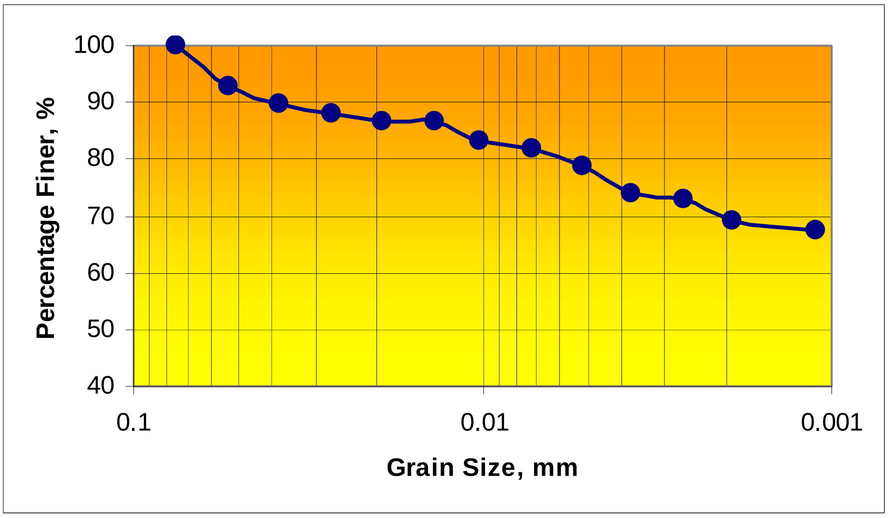
Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficien t K	Grain Size (mm)	Perc. Finer (%)
0.5	1.0330	-0.0027	1.0303	7.57	0.01340	0.0522	96.04
1	1.0315	-0.0027	1.0288	7.97	0.01340	0.0378	91.28
2	1.0305	-0.0027	1.0278	8.23	0.01340	0.0272	88.11
4	1.0300	-0.0027	1.0273	8.36	0.01340	0.0194	86.53
8	1.0295	-0.0027	1.0268	8.50	0.01340	0.0138	84.95
15	1.0285	-0.0027	1.0258	8.76	0.01340	0.0102	81.78
30	1.0275	-0.0027	1.0248	9.03	0.01340	0.0074	78.61
60	1.0265	-0.0027	1.0238	9.29	0.01340	0.0053	75.44
120	1.0250	-0.0027	1.0223	9.69	0.01340	0.0038	70.68
240	1.0245	-0.0027	1.0218	9.82	0.01340	0.0027	69.10
480	1.0225	-0.0027	1.0198	10.35	0.01340	0.0020	62.76
1440	1.0220	-0.0027	1.0193	10.48	0.01340	0.0011	61.17



Hydrometer test for Addisu Gebeya pit #2

Location: ***Addisu Gebeya area***	Job ref.	***Thesis research***
	Pit no.	***#2***
Soil Description: ***Red brown clay***	Sample no.	***#1***
	Depth	***2.5m***
Test method: Hydrometer, ASTM D 422-63	Date	***25/10/2001E.C***
	Specific Gravity	**2.71**
Lab Temperature: 20 degree centigrade	Composite correction	**-0.0027**
	K Value	**0.01340**

Elapsed Time (min)	Actual Hydrometer Reading	Composite Correction	Corrected Hydrometer Reading	Effective Depth (cm)	Coefficient K	Grain Size (mm)	Perc. Finer (%)
0.5	1.0320	-0.0027	1.0293	7.84	0.01340	0.0531	92.87
1	1.0310	-0.0027	1.0283	8.10	0.01340	0.0381	89.70
2	1.0305	-0.0027	1.0278	8.23	0.01340	0.0272	88.11
4	1.0300	-0.0027	1.0273	8.36	0.01340	0.0194	86.53
8	1.0300	-0.0027	1.0273	8.36	0.01340	0.0137	86.53
15	1.0290	-0.0027	1.0263	8.63	0.01340	0.0102	83.36
30	1.0285	-0.0027	1.0258	8.76	0.01340	0.0072	81.78
60	1.0275	-0.0027	1.0248	9.03	0.01340	0.0052	78.61
120	1.0260	-0.0027	1.0233	9.42	0.01340	0.0038	73.85
240	1.0258	-0.0027	1.0231	9.49	0.01340	0.0027	73.06
480	1.0245	-0.0027	1.0218	9.82	0.01340	0.0019	69.10
1440	1.0240	-0.0027	1.0213	9.95	0.01340	0.0011	67.51

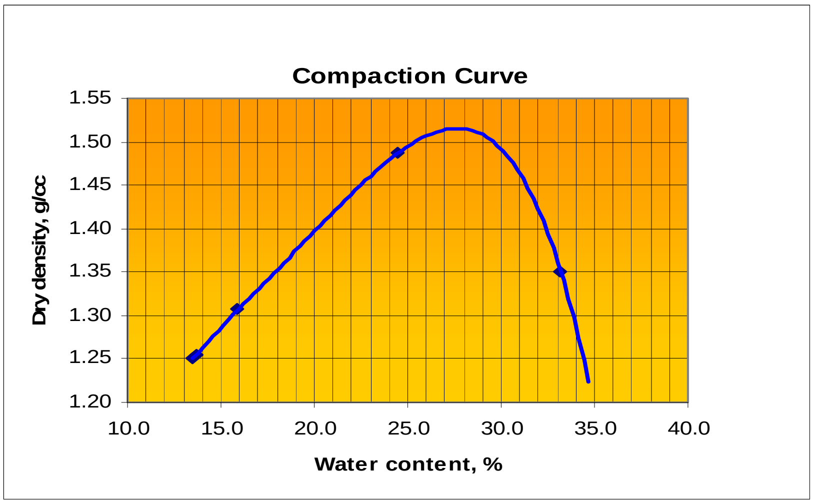


Compaction Test

Standard compaction test for Kolfe pit #1

Location: ***Kolfe area***			Job ref.	***Thesis research***	
			Pit no.	***#1***	
Soil Description: ***Red brown clay***			Sample no.	***#1***	
			Depth	***2.5m***	
Test method: Standard Compaction, ASTM D 698-91			Date	***15/10/2001E.C***	
Blows/layer	**25**	**No. of layers**	**3**	**Wt of hammer, Kg**	**2.5**
Mold dia, cm	**10.16**	**Mold Ht, cm**	**12**	**Vol, CC**	**972.88**

Water Content Determination					
Determination No	1	2	3	4	5
Container No	30	cmc4	34	8	31
Mass of Container, M_1 ,g	5.3	5.2	5.26	5.31	5.3
Mass of Container + Wet Soil, M_2 ,g	140	188	154.5	158	238
Mass of Container + Dry Soil, M_3 ,g	124	166	134	128	180
Mass of Water, M_2-M_3 ,g	16	22	20.5	30	58
Mass of Dry Soil, M_3-M_1 ,g	118.7	160.8	128.4	122.9	174.7
Moisture Content, $w=(M_2-M_3)/(M_3-M_1)*100$, %	13.5	13.7	15.9	24.5	33.2
Density Determination					
Water content. Wo, %	13.5	13.7	15.9	24.5	33.2
Wt of soil + mold, g	7042	7050	7136	7462	7412
Wt of mold, g	5662	5662	5662	5662	5662
Wt of soil in mold, g	1380	1388	1474	1800	1750
Wet density, g/cc	1.42	1.43	1.52	1.85	1.80
Dry density, g/cc	1.25	1.25	1.31	1.49	1.35



Optimum moisture Content	**28%**	***Maximum Dry Density***	**1.53 g/cc**

Standard compaction test for Kolfe pit #2

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Standard Compaction, ASTM D 698-91		Date	***15/10/2001E.C***

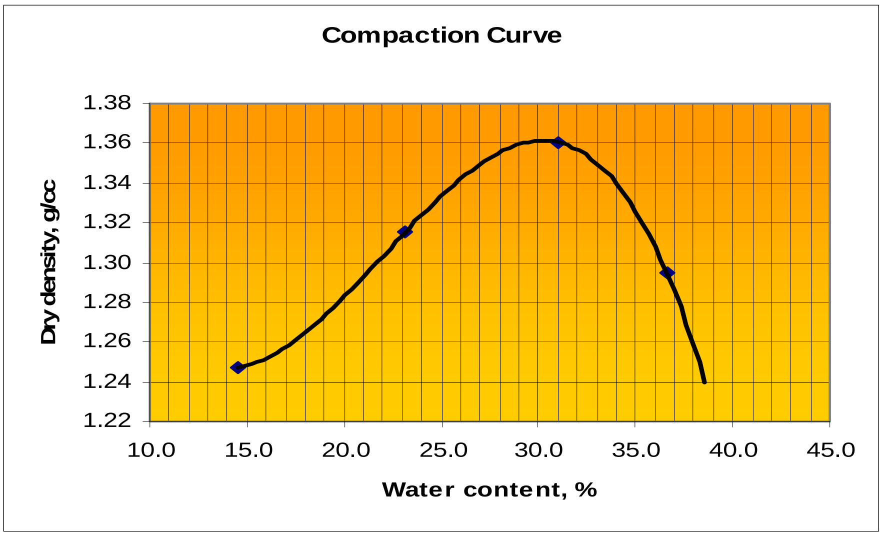
Blows/layer	**25**	**No. of layers**	**3**	**Wt of hammer, Kg**	**2.5**
Mold dia, cm	**10.16**	**Mold Ht, cm**	**12**	**Vol, CC**	**972.88**

Water Content Determination

Determination No	1	2	3	4	5
Container No	28	43	25	26	
Mass of Container, M_1 ,g	5.32	5.15	186	248	
Mass of Container + Wet Soil, M_2 ,g	194	186	524	625	
Mass of Container + Dry Soil, M_3 ,g	170	152	444	524	
Mass of Water, M_2-M_3 ,g	24	34	80	101	
Mass of Dry Soil, M_3-M_1 ,g	164.68	146.85	258	276	
Moisture Content, $w=(M_2-M_3)/(M_3-M_1)*100$, %	14.6	23.2	31.0	36.6	

Density Determination

Water content. Wo, %	14.6	23.2	31.0	36.6	
Wt of soil + mold, g	7052	7238	7396	7383	
Wt of mold, g	5662	5662	5662	5662	
Wt of soil in mold, g	1390	1576	1734	1721	
Wet density, g/cc	1.429	1.620	1.782	1.769	
Dry density, g/cc	1.25	1.32	1.36	1.30	

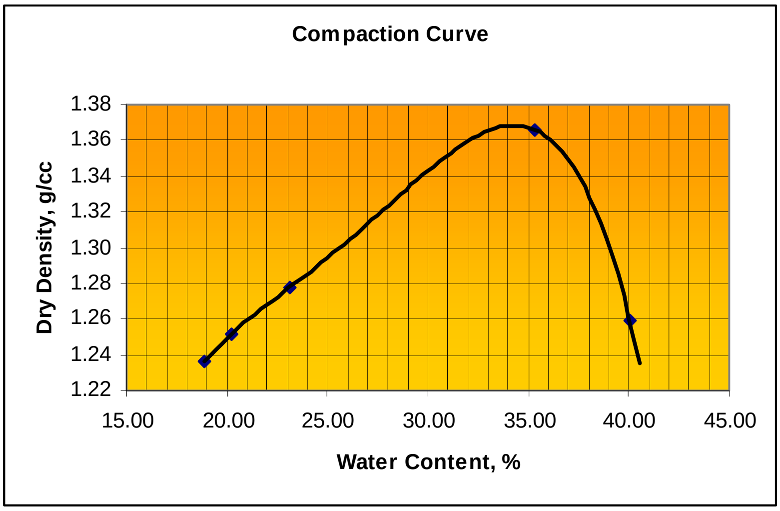


Optimum moisture Content	**31%**	***Maximum Dry Density***	**1.36 g/cc**

Standard compaction test for Addisu Gebeya pit #1

Location: ***Kolfe area***				Job ref.	***Thesis research***		
				Pit no.	***#1***		
Soil Description: ***Red brown clay***				Sample no.	***#1***		
				Depth	***2.5m***		
Test method: Standard Compaction, ASTM D 698-91				Date	***15/11/2001E.C***		
Blows/layer	**25**	**No. of layers**	**3**	**Wt of hammer, Kg**	**2.5**		
Mold dia, cm	**10.16**	**Mold Ht, cm**	**12**	**Vol, CC**	**972.88**		

Water Content Determination					
Determination No	1	2	3	4	5
Container No	36	4	B2	31	B3
Mass of Container, M_1 ,g	5.22	5.21	5.28	5.3	5.29
Mass of Container + Wet Soil, M_2 ,g	310.5	237	210.5	220	236
Mass of Container + Dry Soil, M_3 ,g	262	198	172	164	170
Mass of Water, M_2-M_3 ,g	48.5	39	38.5	56	66
Mass of Dry Soil, M_3-M_1 ,g	256.78	192.79	166.72	158.7	164.71
Moisture Content, $w=(M_2-M_3)/(M_3-M_1)*100$, %	18.89	20.23	23.09	35.29	40.07
Density Determination					
Water content. Wo, %	18.89	20.23	23.09	35.29	40.07
Wt of soil + mold, g	7092	7126	7192	7460	7378
Wt of mold, g	5662	5662	5662	5662	5662
Wt of soil in mold, g	1430	1464	1530	1798	1716
Wet density, g/cc	1.470	1.505	1.573	1.848	1.764
Dry density, g/cc	1.24	1.25	1.28	1.37	1.26



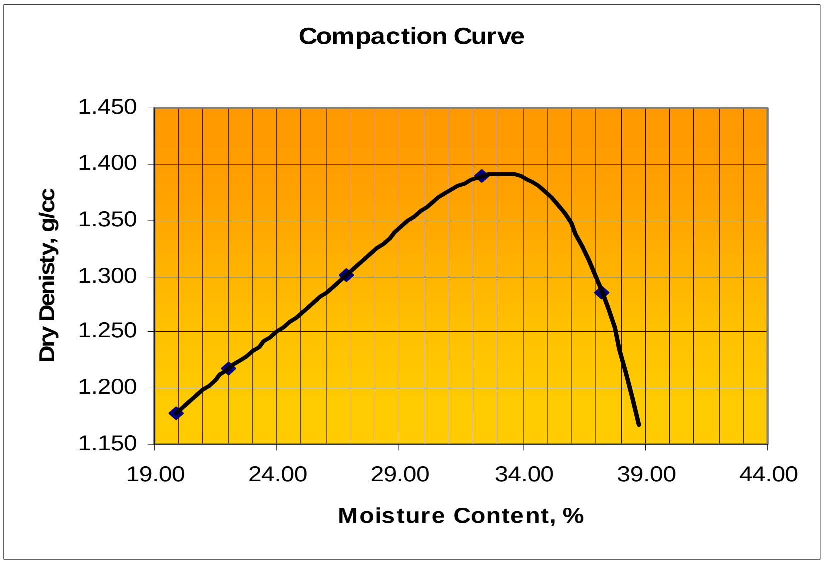
Optimum moisture Content	**35%**	***Maximum Dry Density***	**1.37 g/cc**

Standard compaction test for Addisu Gebeya pit #2

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: Standard Compaction, ASTM D 698-91		Date	***15/11/2001E.C***

Blows/layer	**25**	**No. of layers**	**3**	**Wt of hammer, Kg**	**2.5**
Mold dia, cm	**10.16**	**Mold Ht, cm**	**12**	**Vol, CC**	**972.88**

Water Content Determination					
Determination No	1	2	3	4	5
Container No	66	88	8	34	30
Mass of Container, M_1 ,g	5.28	5.15	5.31	5.26	5.66
Mass of Container + Wet Soil, M_2 ,g	240	232	204	210	212
Mass of Container + Dry Soil, M_3 ,g	201	191	162	160	156
Mass of Water, M_2-M_3 ,g	39	41	42	50	56
Mass of Dry Soil, M_3-M_1 ,g	195.72	185.85	156.69	154.74	150.34
Moisture Content, $w=(M_2-M_3)/(M_3-M_1)*100$, %	19.93	22.06	26.80	32.31	37.25
Density Determination					
Water content. Wo, %	19.93	22.06	26.80	32.31	37.25
Wt of soil + mold, g	7036	7108	7266	7450	7378
Wt of mold, g	5662	5662	5662	5662	5662
Wt of soil in mold, g	1374	1446	1604	1788	1716
Wet density, g/cc	1.412	1.486	1.649	1.838	1.764
Dry density, g/cc	1.178	1.218	1.300	1.389	1.285



Optimum moisture Content	**35%**	***Maximum Dry Density***	**1.37 g/cc**

Consolidation Test

One dimensional consolidation test for Kolfe pit #1/ Undisturbed

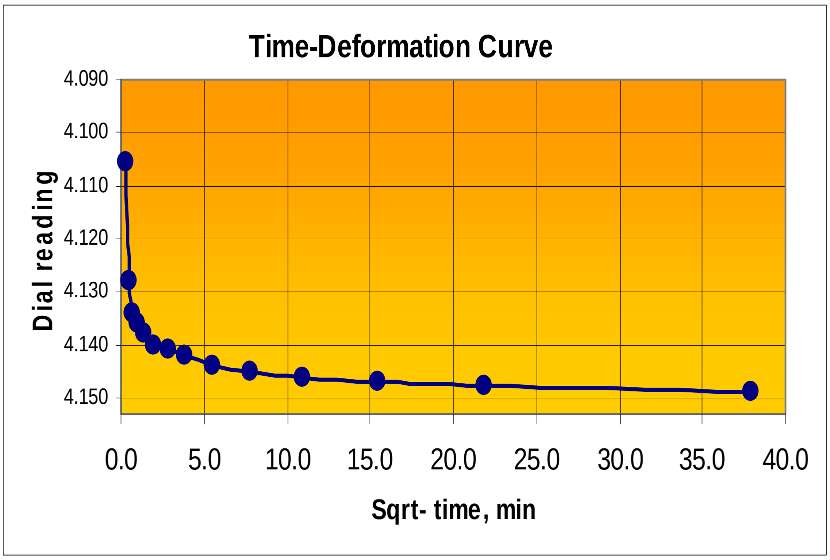
Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: One dimensional oedometer, BS 1377-5:3		Specific gravity	***2.72***
Sample Type	***Undisturbed***	Initial Ht. of specimen, mm	***18***
Height of ring, mm	***20***	Initial mass of specimen, g	***67.78***
Diameter of ring, mm	***50***	Initial bulk density, g/cc	***1.92***
Ini. Moisture content, %	***22***	Initial dry density, g/cc	***1.57***
Final moisture content, %	***27***		

Deformation Versus Time Reading for Different Loadings

Load increment: ***7 KPa – 50 KPa***

Initial height, Ho, mm	***17.996***		
Final height, Hf, mm	***17.86***		
Deformation, mm	***0.145***		

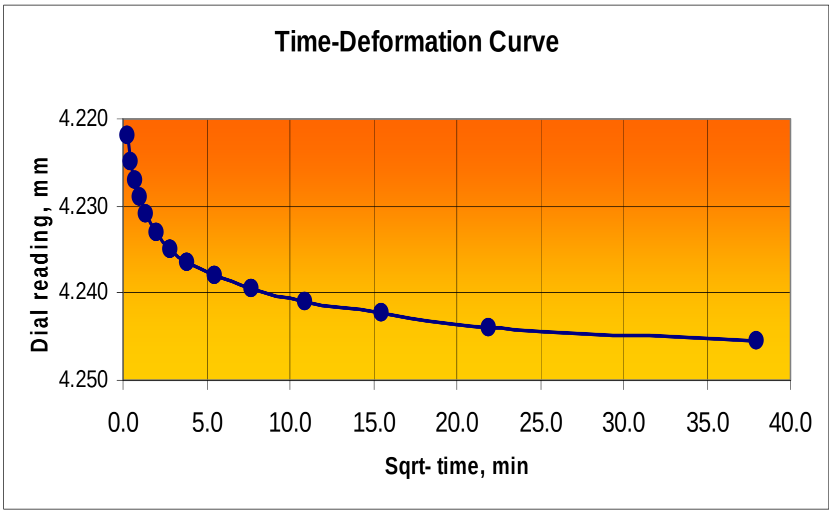
Elapsed Time (min)	Def. Dial Reading (mm)
0	4.002
0.1	4.106
0.25	4.128
0.5	4.134
1	4.136
2	4.138
4	4.140
8	4.141
15	4.142
30	4.144
60	4.145
120	4.146
240	4.147
480	4.148
1440	4.149



do, mm	***4.055***	Average ht, Ĥ, mm	***17.93***	t90, min	***0.53***
d90,mm	***4.132***	Cv, m^2/yr	***67.30***	Cv = $(0.111*\hat{H}^2)/t90$	

Load increment: ***50 KPa – 100 KPa***

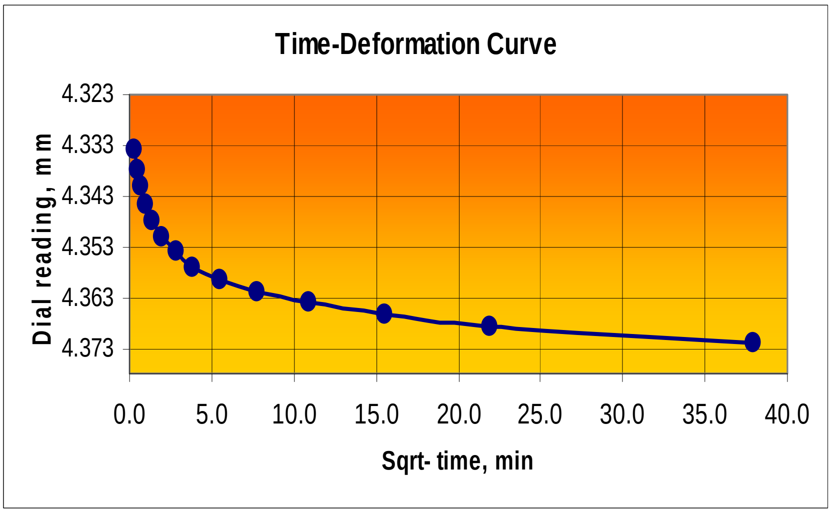
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.86***
		Final height, Hf, mm	***17.76***
		Deformation, mm	***0.096***
0	4.152		
0.1	4.222		
0.25	4.225		
0.5	4.227		
1	4.229		
2	4.231		
4	4.233		
8	4.235		
15	4.237		
30	4.238		
60	4.240		
120	4.241		
240	4.242		
480	4.244		
1440	4.246		



do, mm	***4.217***	Ĥ, Havg, mm	***17.81***	t90, min	***0.61***
d90,mm	***4.228***	Cv, m²/yr	***57.70***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***100 KPa – 200 KPa***

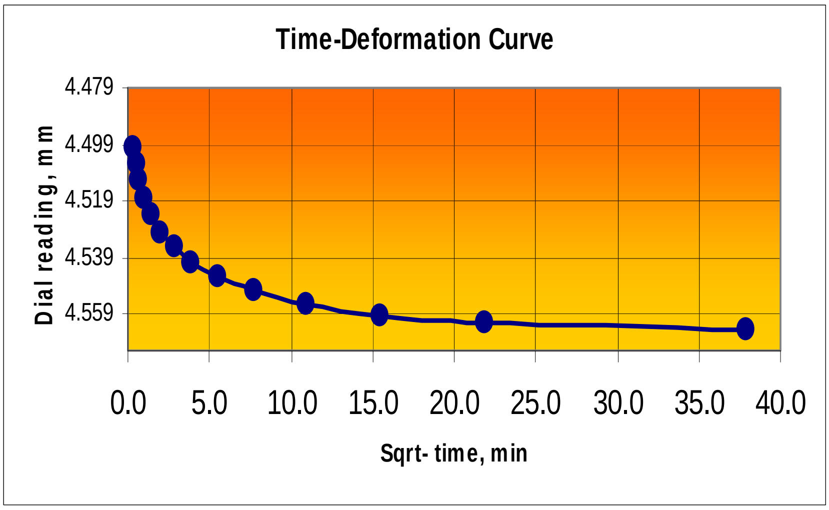
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.76***
		Final height, Hf, mm	***17.63***
		Deformation, mm	***0.123***
0	4.249		
0.1	4.334		
0.25	4.338		
0.5	4.341		
1	4.344		
2	4.348		
4	4.351		
8	4.354		
15	4.357		
30	4.359		
60	4.362		
120	4.364		
240	4.366		
480	4.369		
1440	4.372		



do, mm	***4.327***	Havg.mm	***17.70***	t90, min	***0.88***
d90,mm	***4.342***	Cv, m²/yr	***51.11***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***200 KPa – 400 KPa***

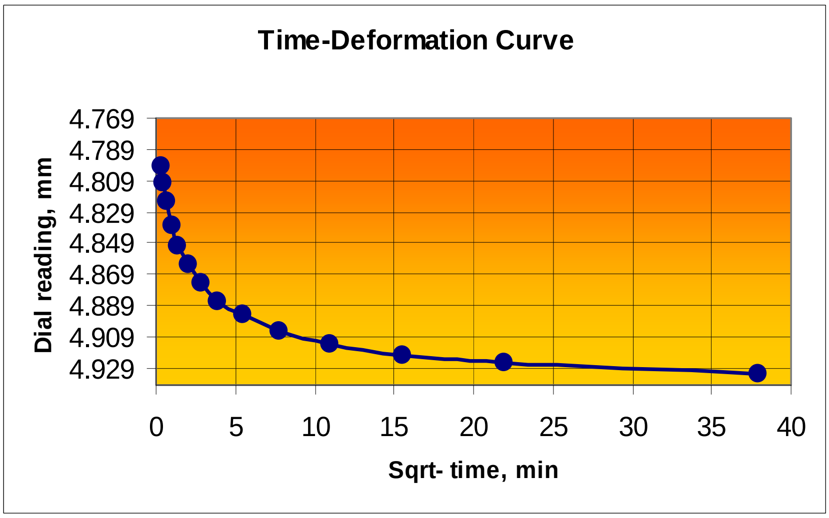
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.63***
		Final height, Hf, mm	***17.44***
		Deformation, mm	***0.190***
0	4.375		
0.1	4.500		
0.25	4.506		
0.5	4.512		
1	4.518		
2	4.524		
4	4.530		
8	4.535		
15	4.541		
30	4.546		
60	4.551		
120	4.555		
240	4.560		
480	4.562		
1440	4.565		



do, mm	***4.492***	Ĥ,Havg.mm	***17.54***	t90, min	***0.76***
d90,mm	***4.52***	Cv, m^2/yr	***44.91***	Cv = (0.111*Ĥ²)/t90	

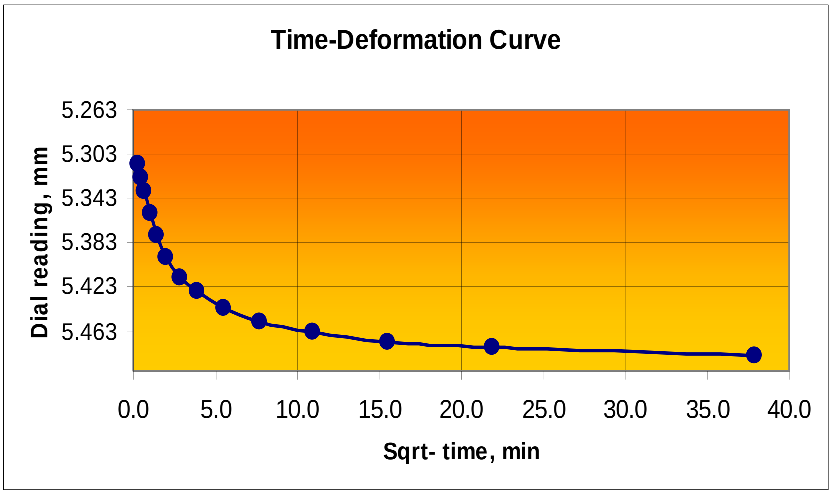
Load increment: ***400 KPa – 800 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.44***
		Final height, Hf, mm	***17.07***
		Deformation, mm	***0.362***
0	4.571		
0.1	4.800		
0.25	4.810		
0.5	4.822		
1	4.838		
2	4.851		
4	4.863		
8	4.875		
15	4.886		
30	4.895		
60	4.905		
120	4.914		
240	4.922		
480	4.929		
1440	4.939		



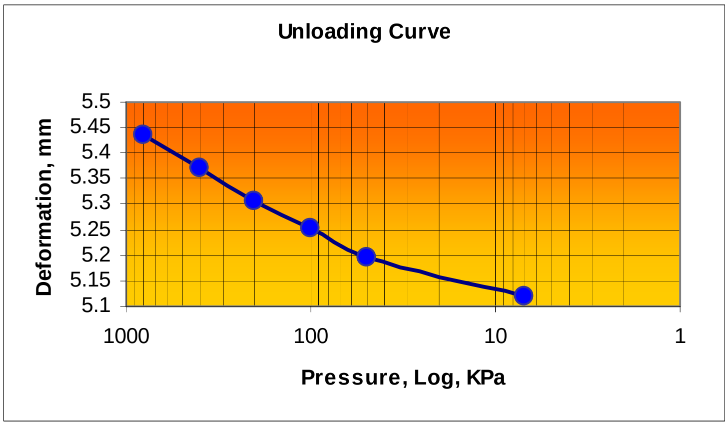
do, mm	***4.783***	Ĥ, Havg, mm	***17.26***	t90, min	***1.1***
d90,mm	***4.85***	Cv, m^2/yr	***30.04***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***800 KPa – 1600 KPa***					
Elapsed Time (min)	Def. Dial Reading (mm)	Initial height, Ho, mm	***17.07***		
		Final height, Hf, mm	***16.52***		
		Deformation, mm	***0.55***		
0	4.939				
0.1	5.311				
0.25	5.324				
0.5	5.337				
1	5.357				
2	5.377				
4	5.396				
8	5.415				
15	5.427				
30	5.442				
60	5.454				
120	5.464				
240	5.473				
480	5.478				
1440	5.485				
do, mm	***5.293***	Ĥ,Havg.mm	***16.80***	t90, min	***1.25***
d90,mm	***5.383***	Cv, m²/yr	***25.05***	Cv = (0.111*Ĥ²)/t90	



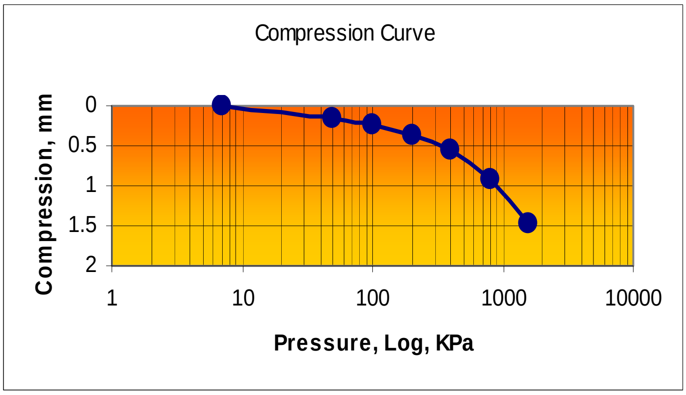
Unloading

Pressure Decrement, KPa	Def. Dial Reading (mm)
1600 -800	5.436
800-400	5.370
400-200	5.307
200-100	5.252
100-50	5.195
50-7	5.120



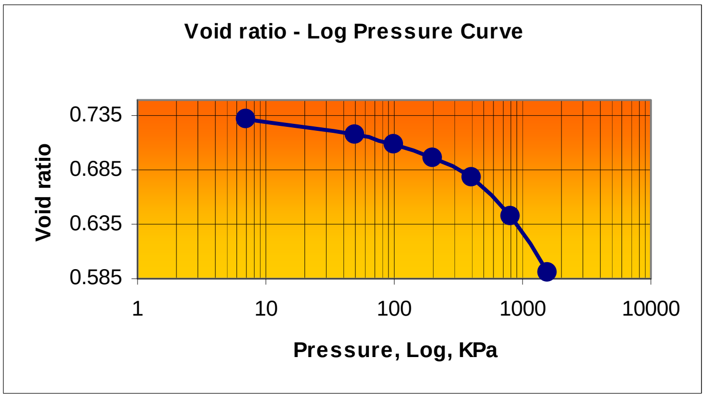
Compression at the end of each loading

Loading, KPa	Deformation ,mm	Ht of Specimen, mm
7	0.004	17.996
50	0.145	17.855
100	0.242	17.759
200	0.368	17.632
400	0.561	17.439
800	0.929	17.071
1600	1.481	16.519



Void ratio at the end of each loading & Coefficient of compression

Loading, KPa	Void ratio, e
7	0.732
50	0.718
100	0.709
200	0.697
400	0.678
800	0.643
1600	0.590
e=(H-Hs)/Hs	Hs=Ho/(1+eo)
av	**7.38E-05**



Cc	***0.147***	$Cc= (e_A-e_B)/\log(\sigma_{ZB}-\sigma_{ZA})$		e_A	***0.678***
e_B	***0.590***	σ_{ZA}, Kpa	***400***	σ_{ZB}, Kpa	***1600***

Calculation of Modulus of Elasticity & Volume Compressibility

Loading, P1, Kpa	Loading , P2, Kpa	H1, Ht at start of Compression , mm	H2, Ht at end of Compression , mm	M_v, Modulus of Volume Compressibility, m^2/MN	Modulus of Elasticity, E, MN/m^2
7	0	18	17.996	-	-
50	7	17.996	17.86	0.182	5.488
100	50	17.86	17.76	0.108	9.251
200	100	17.76	17.63	0.071	14.038
400	200	17.63	17.44	0.055	18.300
800	400	17.44	17.07	0.053	18.940
1600	800	17.07	16.52	0.040	24.741

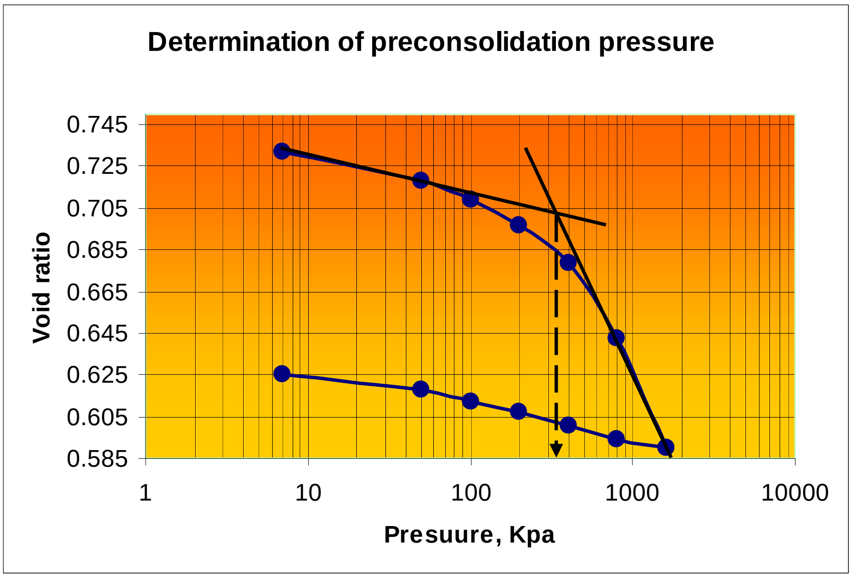
$m_v =((H1-H2)/H1)*(1000/(P2-P1))$

$E=1/mv$

Determination of Pre-consolidation pressure, Pc and over consolidation ratio, OCR

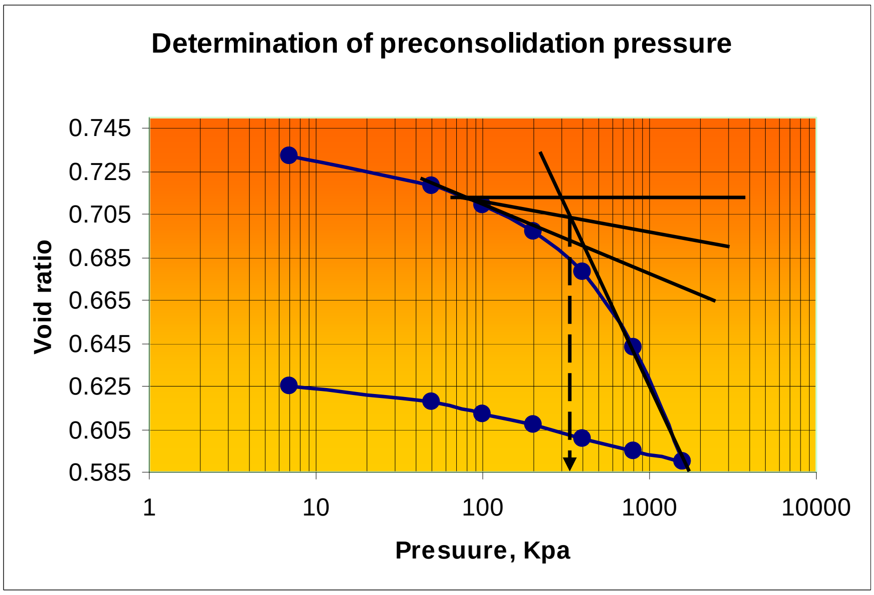
Simplified Method

Loading, KPa	Void ratio, e
7	0.732
50	0.718
100	0.709
200	0.697
400	0.678
800	0.643
1600	0.590
1600	0.590
800	0.594
400	0.601
200	0.607
100	0.612
50	0.618
7	0.625



Casagrande's Method

Load, Kpa	Void ratio
7	0.732
50	0.718
100	0.709
200	0.697
400	0.678
800	0.643
1600	0.590
1600	0.590
800	0.594
400	0.601
200	0.607
100	0.612
50	0.618
7	0.625



Pc, KPa	***320***	Po=Unit weight*Depth, KPa	**47.1**
OCR=Pc/Po	***6.8***	**Heavily Over consolidated**	

One dimensional consolidation test for Kolfe pit #2/ Undisturbed

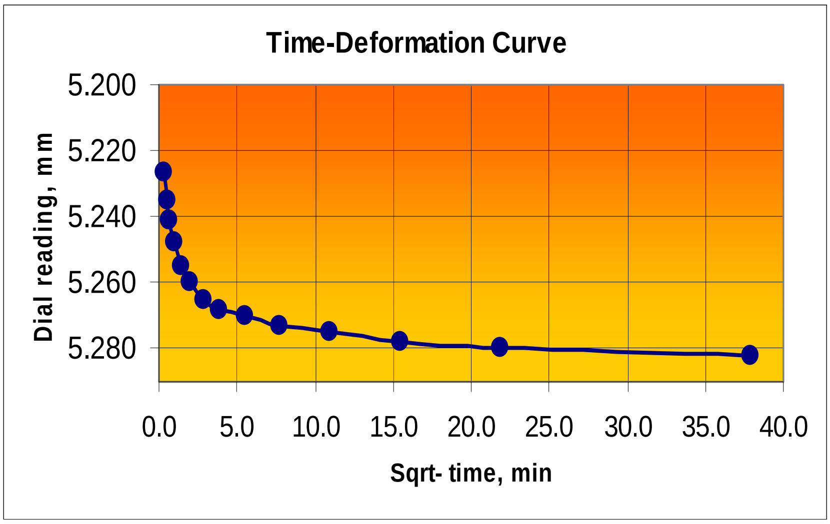
Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: One dimensional oedometer, BS 1377-5:3		Specific gravity	***2.73***
Sample Type	***Undisturbed***	Initial Ht. of specimen, mm	***18***
Height of ring, mm	***20***	Initial mass of specimen, g	***130.16***
Diameter of ring, mm	***70***	Initial bulk density, g/cc	***1.88***
Ini. Moisture content, %	***27***	Initial dry density, g/cc	***1.48***
Final moisture content, %	***30***		

Deformation Versus Time Reading for Different Loadings

Load increment: ***7 KPa – 50 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)
0	5.000
0.1	5.227
0.25	5.235
0.5	5.241
1	5.248
2	5.255
4	5.260
8	5.265
15	5.268
30	5.270
60	5.273
120	5.275
240	5.278
480	5.280
1440	5.282

Initial height, Ho, mm	***18***
Final height, Hf, mm	***17.72***
Deformation, mm	***0.282***

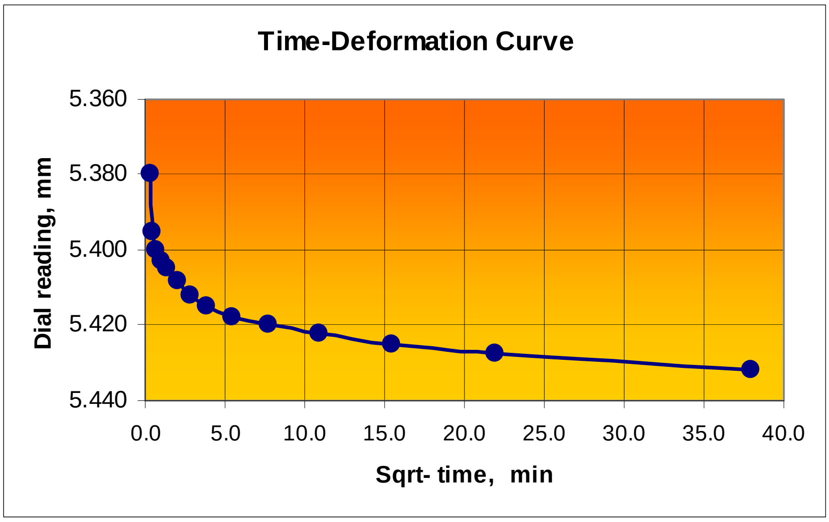


do, mm	***5.29***	Average ht, Ĥ, mm	***17.86***	t90, min	***0.55***
d90,mm	***5.34***	Cv, m²/yr	***64.37***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***50 KPa – 100 KPa***

Initial height, Ho, mm	***17.72***
Final height, Hf, mm	***17.57***
Deformation, mm	***0.150***

Elapsed Time (min)	Def. Dial Reading (mm)
0	5.282
0.1	5.380
0.25	5.395
0.5	5.400
1	5.403
2	5.405
4	5.408
8	5.412
15	5.415
30	5.418
60	5.420
120	5.422
240	5.425
480	5.427
1440	5.432

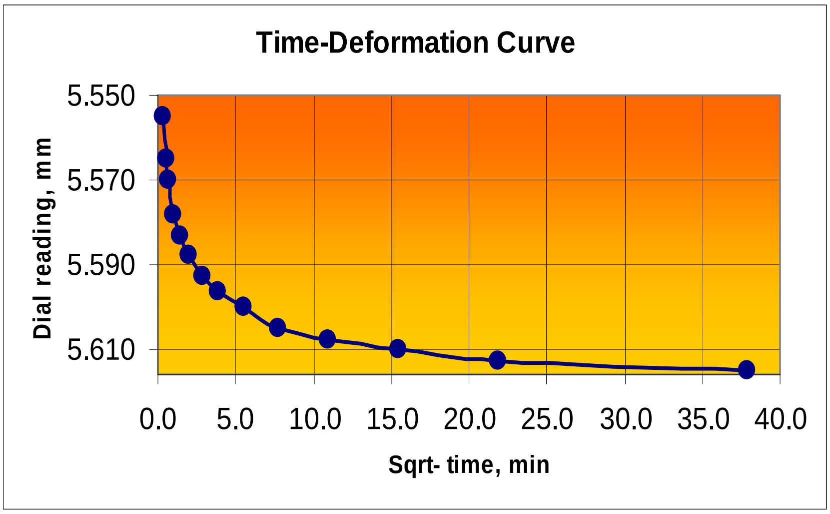


do, mm	***5.584***	Ĥ, H_{avg}, mm	***17.64***	t90, min	***0.6***
d90,mm	***5.623***	Cv, m^2/yr	***57.59***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***100 KPa – 200 KPa***

Initial height, Ho, mm	***17.57***
Final height, Hf, mm	***17.39***
Deformation, mm	***0.183***

Elapsed Time (min)	Def. Dial Reading (mm)
0	5.432
0.1	5.555
0.25	5.565
0.5	5.570
1	5.578
2	5.583
4	5.588
8	5.593
15	5.597
30	5.600
60	5.605
120	5.608
240	5.610
480	5.613
1440	5.615

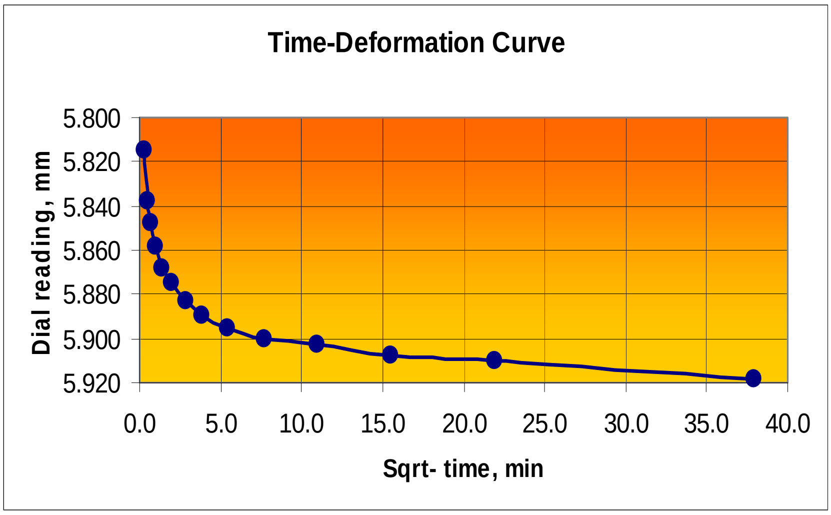


do, mm	***5.9***	H_{avg}.mm	***17.48***	t90, min	***0.66***
d90,mm	***5.956***	Cv, m^2/yr	***51.37***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***200 KPa – 400 KPa***

Initial height, Ho, mm	***17.39***
Final height, Hf, mm	***17.08***
Deformation, mm	***0.303***

Elapsed Time (min)	Def. Dial Reading (mm)
0	5.615
0.1	5.815
0.25	5.838
0.5	5.848
1	5.858
2	5.868
4	5.875
8	5.883
15	5.890
30	5.895
60	5.900
120	5.903
240	5.908
480	5.910
1440	5.918

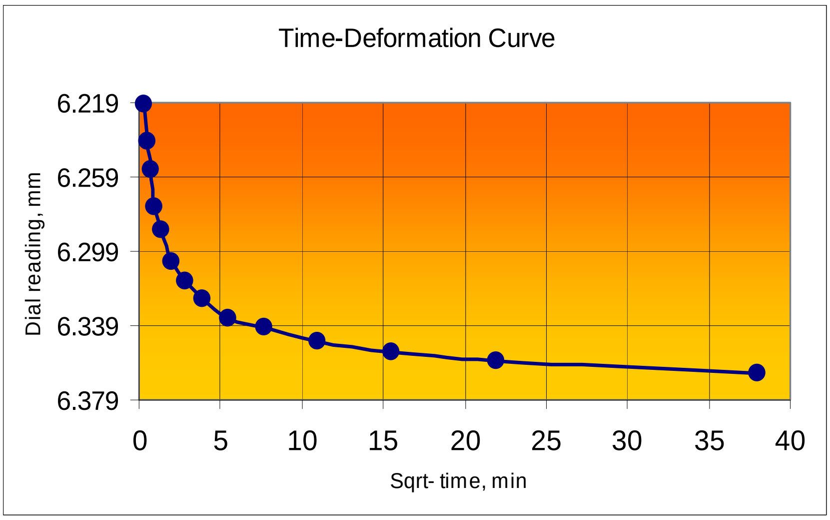


do, mm	***6.3***	Ĥ,Havg.mm	***17.23***	t90, min	***0.78***
d90,mm	***6.364***	Cv, m^2/yr	***42.26***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***400 KPa – 800 KPa***

Initial height, Ho, mm	***16.58***
Final height, Hf, mm	***16.03***
Deformation, mm	***0.545***

Elapsed Time (min)	Def. Dial Reading (mm)
0	5.918
0.1	6.220
0.25	6.240
0.5	6.255
1	6.275
2	6.288
4	6.305
8	6.315
15	6.325
30	6.335
60	6.340
120	6.348
240	6.353
480	6.358
1440	6.365

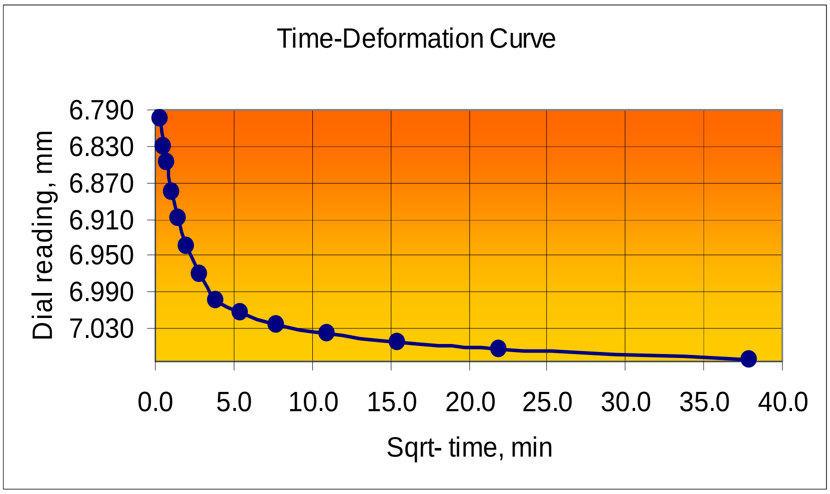


do, mm	***6.772***	Ĥ, Havg, mm	***16.86***	t90, min	***0.89***
d90,mm	***6.862***	Cv, m^2/yr	***35.45***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***800 KPa – 1600 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)
0	6.365
0.1	6.800
0.25	6.830
0.5	6.848
1	6.880
2	6.908
4	6.940
8	6.970
15	6.998
30	7.013
60	7.025
120	7.035
240	7.045
480	7.053
1440	7.065

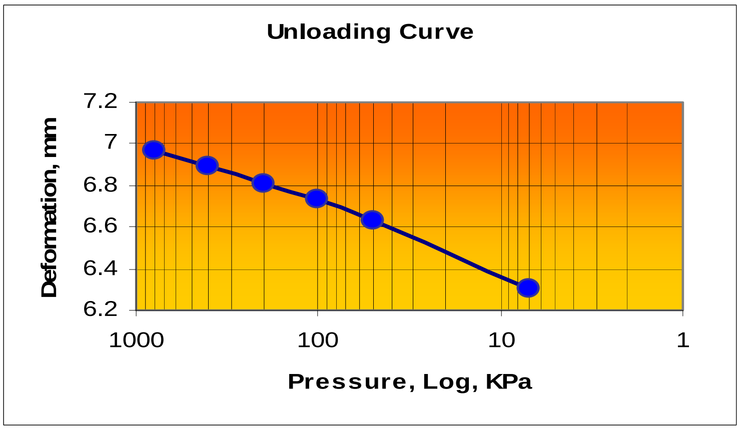
Initial height, Ho, mm	***16.64***
Final height, Hf, mm	***15.94***
Deformation, mm	***0.70***



do, mm	***7.28***	Ĥ,Havg.mm	***16.29***	t90, min	***1.1***
d90,mm	***7.41***	Cv, m²/yr	***26.76***	Cv = (0.111*Ĥ²)/t90	

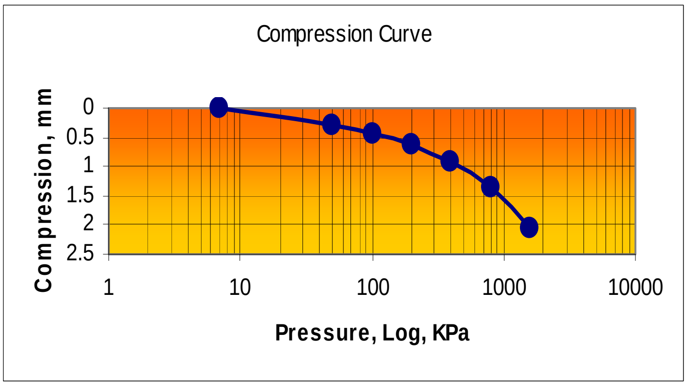
Unloading

Pressure Decrement, KPa	Def. Dial Reading (mm)
1600 -800	6.970
800-400	6.890
400-200	6.810
200-100	6.730
100-50	6.630
50-7	6.305



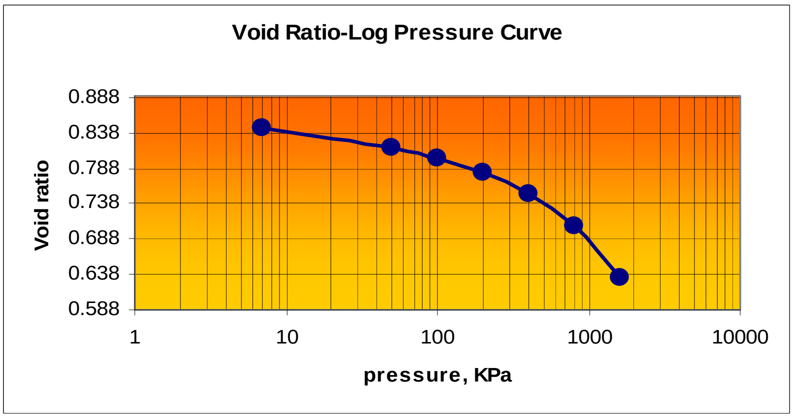
Compression at the end of each loading

Loading, KPa	Deformation ,mm	Ht of Specimen, mm
7	0	18.000
50	0.282	17.718
100	0.432	17.568
200	0.615	17.385
400	0.918	17.082
800	1.365	16.635
1600	2.065	15.935



Void ratio at the end of each loading & Coefficient of compression

Loading, KPa	Void ratio, e
7	0.845
50	0.805
100	0.777
200	0.742
400	0.700
800	0.643
1600	0.590
e=(H-Hs)/Hs	Hs=Ho/(1+eo)
av	***9.80E-05***



Cc	***0.196***	Cc= $(e_A-e_B)/\log(\sigma_{ZB}-\sigma_{ZA})$		e_A	***0.751***
e_B	***0.634***	σ_{ZA}, Kpa	***400***	σ_{ZB}, Kpa	***1600***

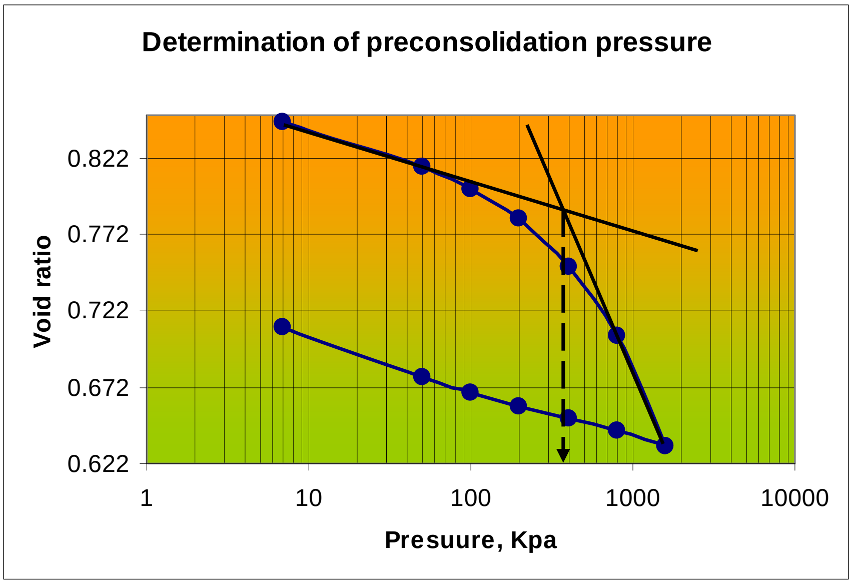
Calculation of Modulus of Elasticity & Volume Compressibility

Loading, P1, Kpa	Loading , P2, Kpa	H1, Ht at start of Compression , mm	H2, Ht at end of Compression , mm	M_v, Modulus of Volume Compressibility, m^2/MN	Modulus of Elasticity, E, MN/m^2
7	0	18	18		
50	7	18	17.72	0.3643	2.7447
100	50	17.72	17.57	0.1693	5.9060
200	100	17.57	17.39	0.1042	9.6000
400	200	17.39	17.08	0.0871	11.4752
800	400	17.08	16.64	0.0654	15.2859
1600	800	16.64	15.94	0.0526	19.0114
$m_v = ((H1-H2)/H1)*(1000/(P2-P1))$			E=1/mv		

Determination of Pre-consolidation pressure, Pc and over consolidation ratio, OCR

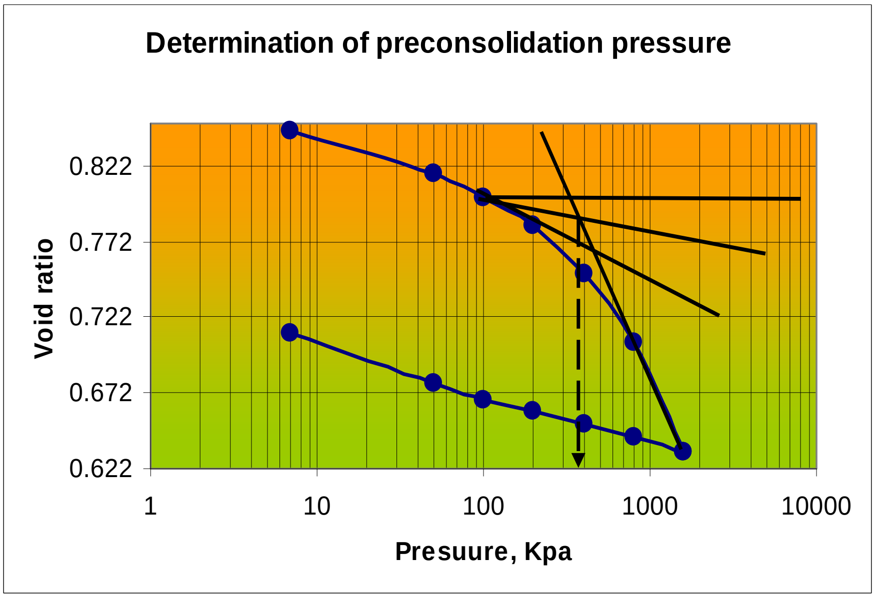
Simplified Method

Loading, KPa	Void ratio, e
7	0.845
50	0.816
100	0.801
200	0.782
400	0.751
800	0.705
1600	0.634
1600	0.634
800	0.643
400	0.651
200	0.660
100	0.668
50	0.678
7	0.711



Casagrande's Method

Load, Kpa	Void ratio
7	0.845
50	0.816
100	0.801
200	0.782
400	0.751
800	0.705
1600	0.634
1600	0.634
800	0.643
400	0.651
200	0.660
100	0.668
50	0.678
7	0.711



Pc, KPa	***380***	Po=Unit weight*Depth, KPa	***46.1***
OCR=Pc/Po	***8.2***	**Heavily Over consolidated**	

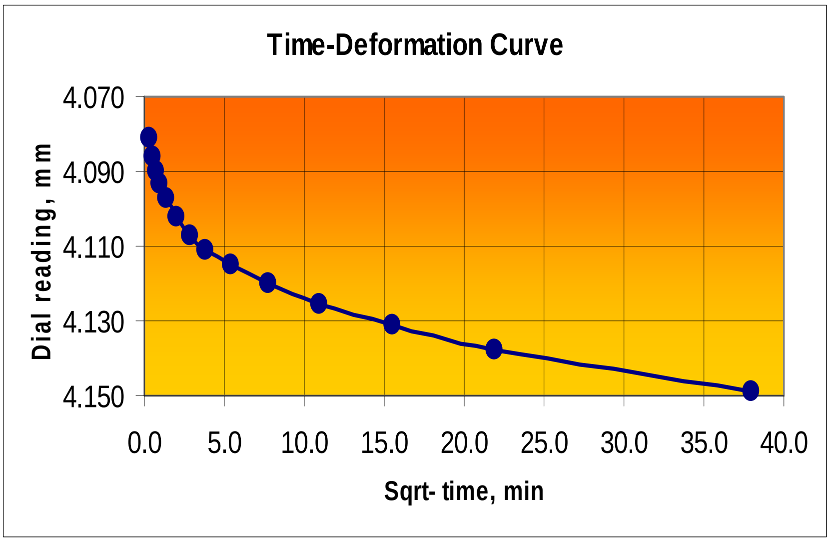
One dimensional consolidation test for Kolfe pit #1/ Remolded

Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: One dimensional oedometer, BS 1377-5:3		Specific gravity	***2.72***
Sample Type	***Remolded at OMC***	Initial Ht. of specimen, mm	***18***
Height of ring, mm	***20***	Initial mass of specimen, g	***68.98***
Diameter of ring, mm	***50***	Initial bulk density, g/cc	***1.95***
Ini. Moisture content, %	***28***	Initial dry density, g/cc	***1.52***
Final moisture content, %	***29***		

Deformation Versus Time Reading for Different Loadings

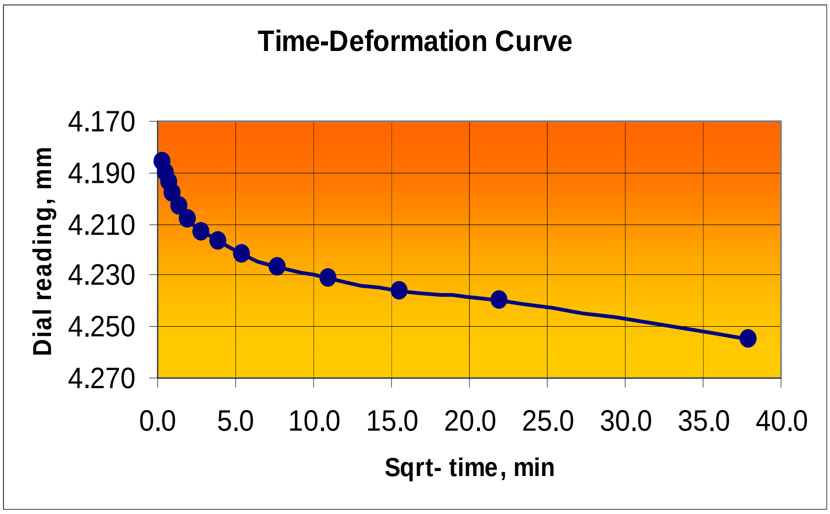
Load increment: ***7 KPa – 50 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***18***
		Final height, Hf, mm	***17.85***
		Deformation, mm	***0.149***
0	4.000		
0.1	4.081		
0.25	4.086		
0.5	4.090		
1	4.093		
2	4.098		
4	4.102		
8	4.107		
15	4.111		
30	4.115		
60	4.120		
120	4.125		
240	4.131		
480	4.138		
1440	4.149		

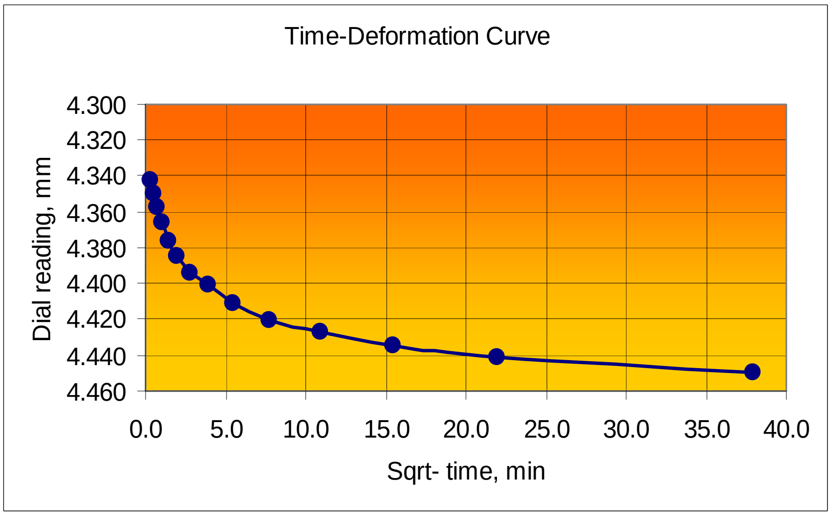


do, mm	***4.073***	Average ht, Ĥ, mm	***17.93***	t90, min	***0.96***
d90,mm	***4.091***	Cv, m²/yr	***37.15***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***50 KPa – 100 KPa***			
Elapsed Time (min)	Def. Dial Reading (mm)	Initial height, Ho, mm	***17.85***
		Final height, Hf, mm	***17.75***
		Deformation, mm	***0.106***
0	4.149		
0.1	4.186		
0.25	4.190		
0.5	4.194		
1	4.198		
2	4.203		
4	4.208		
8	4.213		
15	4.217		
30	4.222		
60	4.227		
120	4.231		
240	4.236		
480	4.240		
1440	4.255		
do, mm	***4.18***	Ĥ, Havg, mm ***17.80***	t90, min ***1.14***
d90,mm	***4.12***	Cv, m²/yr ***30.31***	Cv = (0.111*Ĥ²)/t90

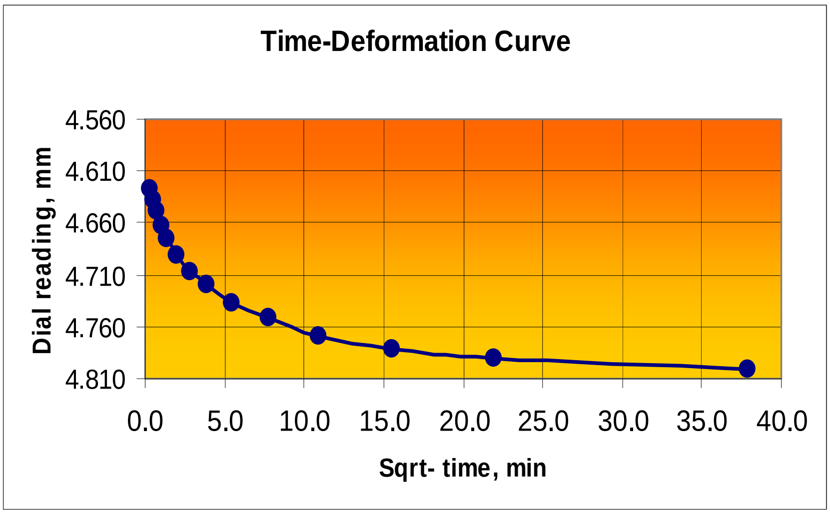


Load increment: ***100 KPa – 200 KPa***		Date	***15/12/01 E.C.***
Elapsed Time (min)	Def. Dial Reading (mm)	Initial height, Ho, mm	***17.75***
		Final height, Hf, mm	***17.55***
		Deformation, mm	***0.20***
0	4.250		
0.1	4.342		
0.25	4.350		
0.5	4.357		
1	4.366		
2	4.376		
4	4.385		
8	4.394		
15	4.401		
30	4.411		
60	4.420		
120	4.427		
240	4.435		
480	4.441		
1440	4.450		
do, mm	***4.33***	Havg.mm ***17.65***	t90, min ***1.28***
d90,mm	***4.373***	Cv, m²/yr ***27.01***	Cv = (0.111*Ĥ²)/t90



Load increment: ***200 KPa – 400 KPa***

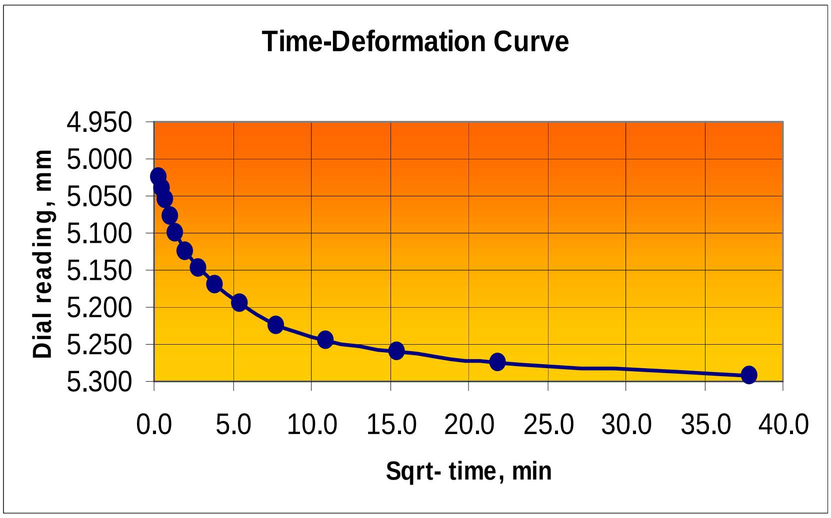
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.55***
		Final height, Hf, mm	***17.20***
		Deformation, mm	***0.352***
0	4.450		
0.1	4.627		
0.25	4.638		
0.5	4.648		
1	4.662		
2	4.676		
4	4.691		
8	4.708		
15	4.720		
30	4.737		
60	4.752		
120	4.769		
240	4.782		
480	4.790		
1440	4.802		



do, mm	***4.61***	Ĥ,Havg.mm	***17.37***	t90, min	***1.45***
d90,mm	***4.676***	Cv, m^2/yr	***23.11***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***400 KPa – 800 KPa***

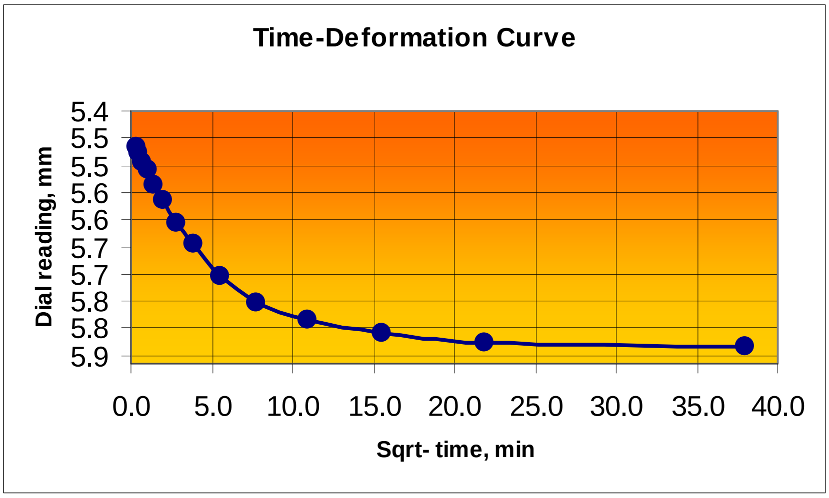
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.20***
		Final height, Hf, mm	***16.71***
		Deformation, mm	***0.49***
0	4.802		
0.1	5.025		
0.25	5.040		
0.5	5.056		
1	5.078		
2	5.100		
4	5.125		
8	5.148		
15	5.169		
30	5.195		
60	5.224		
120	5.244		
240	5.260		
480	5.276		
1440	5.292		



do, mm	***5.00***	Ĥ, Havg, mm	***16.95***	t90, min	***1.54***
d90,mm	***5.108***	Cv, m^2/yr	***20.72***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***800 KPa – 1600 KPa***

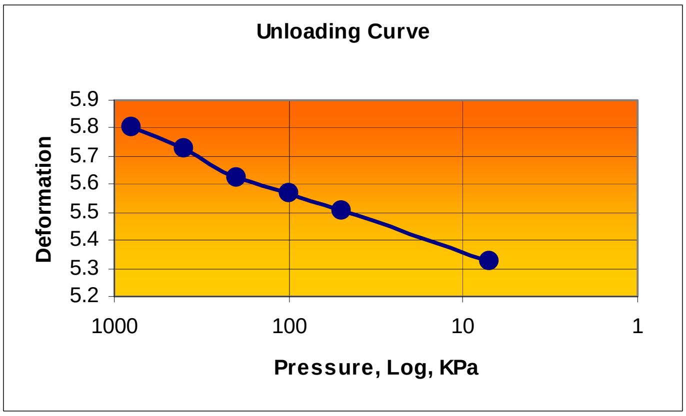
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***16.71***
		Final height, Hf, mm	***16.13***
		Deformation, mm	***0.58***
0	5.292		
0.1	5.500		
0.25	5.513		
0.5	5.528		
1	5.545		
2	5.571		
4	5.601		
8	5.642		
15	5.681		
30	5.740		
60	5.787		
120	5.819		
240	5.845		
480	5.861		
1440	5.868		



do, mm	***5.48***	Ĥ,Havg.mm	***16.42***	t90, min	***2.3***
d90,mm	***5.635***	Cv, m²/yr	***13.01***	Cv = (0.111*Ĥ²)/t90	

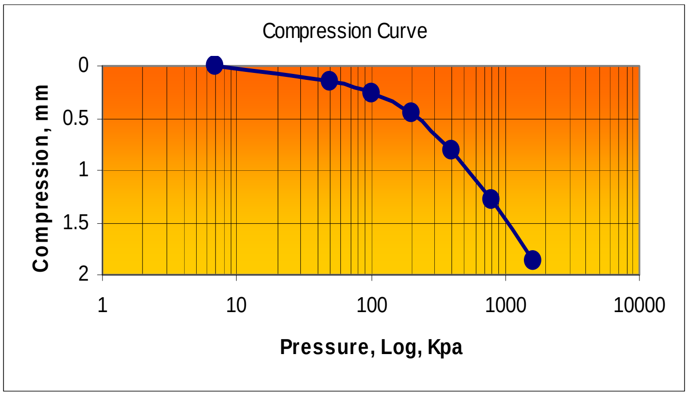
Unloading

Pressure Decrement, KPa	Def. Dial Reading (mm)
1600 -800	5.806
800-400	5.724
400-200	5.624
200-100	5.570
100-50	5.505
50-7	5.324



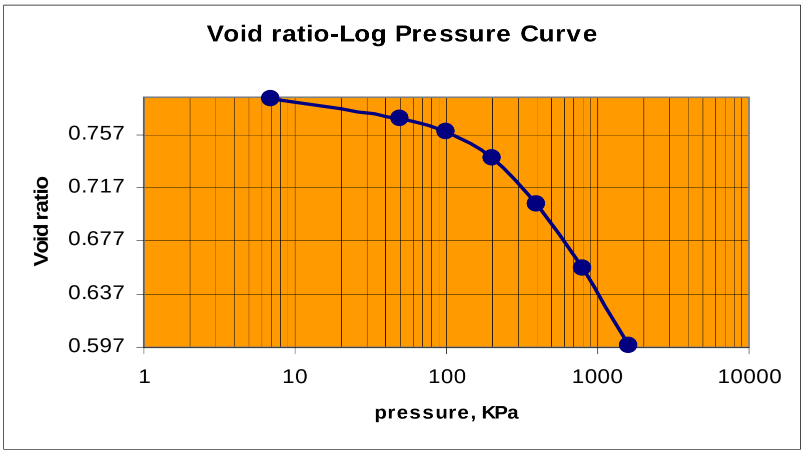
Compression at the end of each loading

Loading, KPa	Deformation ,mm	Ht of Specimen, mm
7	0	18.000
50	0.149	17.851
100	0.250	17.750
200	0.450	17.550
400	0.802	17.198
800	1.292	16.708
1600	1.868	16.132



Void ratio at the end of each loading & Coefficient of compression

Loading, KPa	Void ratio, e
7	0.784
50	0.769
100	0.759
200	0.739
400	0.704
800	0.656
1600	0.599
e=(H-Hs)/Hs	Hs=Ho/(1+eo)
av	***8.80E-05***



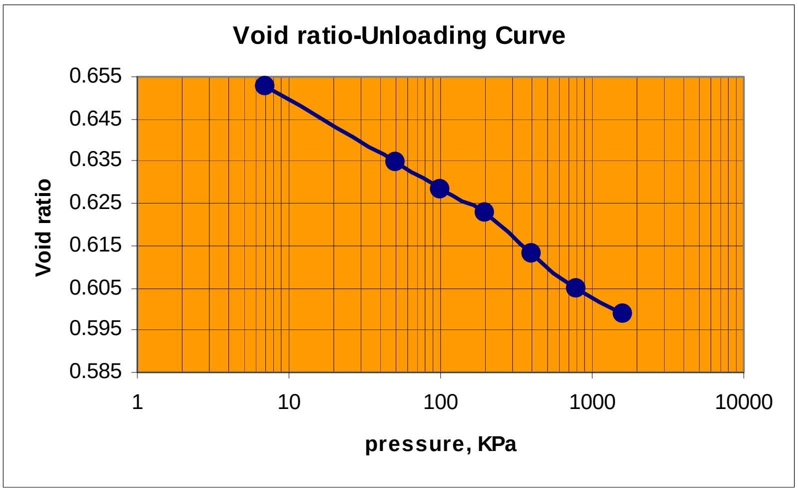
Cc	***0.175***	$Cc = (e_A - e_B)/\log(\sigma_{ZB} - \sigma_{ZA})$	e_A	***0.704***
e_B	***0.599***	σ_{ZA}, Kpa ***400***	σ_{ZB}, Kpa	***1600***

Calculation of Modulus of Elasticity & Volume Compressibility

Loading, P1, Kpa	Loading , P2, Kpa	H1, Ht at start of Compression , mm	H2, Ht at end of Compression , mm	M_v, Modulus of Volume Compressibility, m^2/MN	Modulus of Elasticity, E, MN/m^2
7	0	18	18	-	-
50	7	18	17.85	0.1925	5.1946
100	50	17.85	17.75	0.1188	8.4203
200	100	17.75	17.55	0.1099	9.1000
400	200	17.55	17.20	0.1003	9.9716
800	400	17.20	16.71	0.0712	14.0392
1600	800	16.71	16.13	0.0431	23.2056
$m_v = ((H1-H2)/H1)*(1000/(P2-P1))$			E=1/mv		

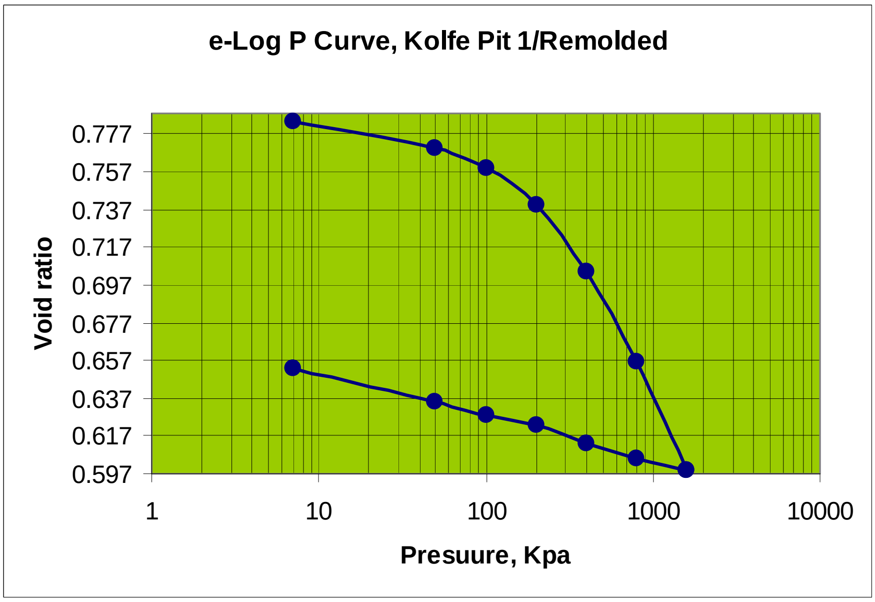
Void ratio at the end of each step of unloading

Loading, KPa	Void ratio, e
1600	0.599
800	0.605
400	0.613
200	0.623
100	0.628
50	0.635
7	0.653



e-Log P Curve

Load, Kpa	Void ratio
7	0.784
50	0.770
100	0.759
200	0.739
400	0.704
800	0.656
1600	0.599
1600	0.599
800	0.605
400	0.613
200	0.623
100	0.628
50	0.635
7	0.653



One dimensional consolidation test for Kolfe pit #2/ Remolded

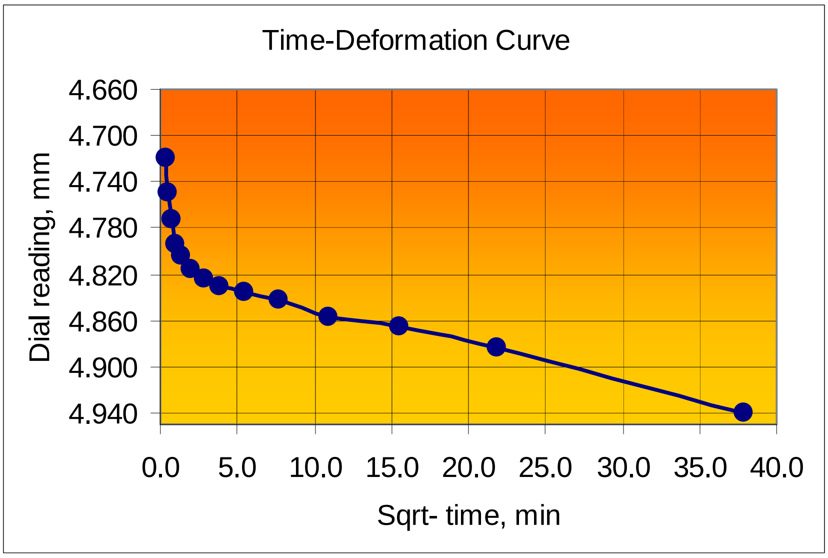
Location: ***Kolfe area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: One dimensional oedometer, BS 1377-5:3		Specific gravity	***2.73***
Sample Type	***Remolded at OMC***	Initial Ht. of specimen, mm	***18***
Height of ring, mm	***20***	Initial mass of specimen, g	***123.30***
Diameter of ring, mm	***70***	Initial bulk density, g/cc	***1.78***
Ini. Moisture content, %	***31***	Initial dry density, g/cc	***1.36***
Final moisture content, %	***30***		

Deformation Versus Time Reading for Different Loadings

Load increment: ***7 KPa – 50 KPa***

		Initial height, Ho, mm	***18***
		Final height, Hf, mm	***17.56***
		Deformation, mm	***0.440***

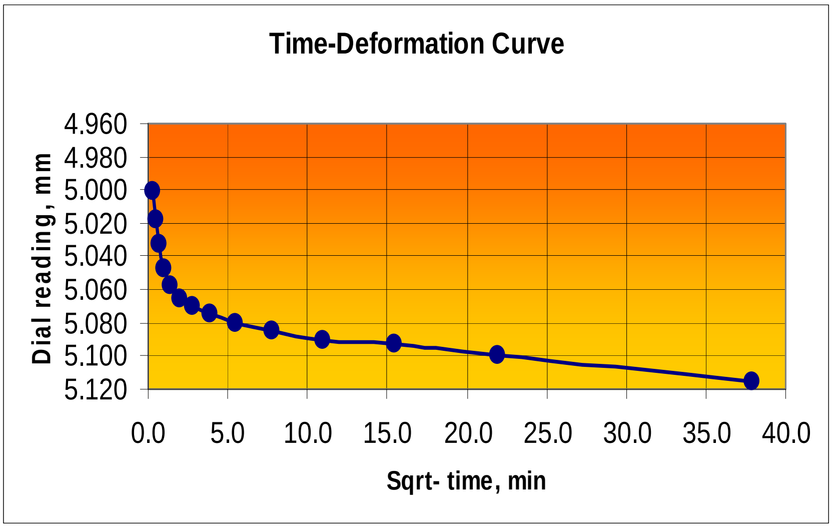
Elapsed Time (min)	Def. Dial Reading (mm)
0	4.500
0.1	4.720
0.25	4.750
0.5	4.773
1	4.795
2	4.805
4	4.815
8	4.824
15	4.830
30	4.835
60	4.842
120	4.857
240	4.865
480	4.884
1440	4.940



do, mm	***4.665***	Average ht, Ĥ, mm	***17.78***	t90, min	***0.98***
d90,mm	***4.782***	Cv, m²/yr	***35.81***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***50 KPa – 100 KPa***

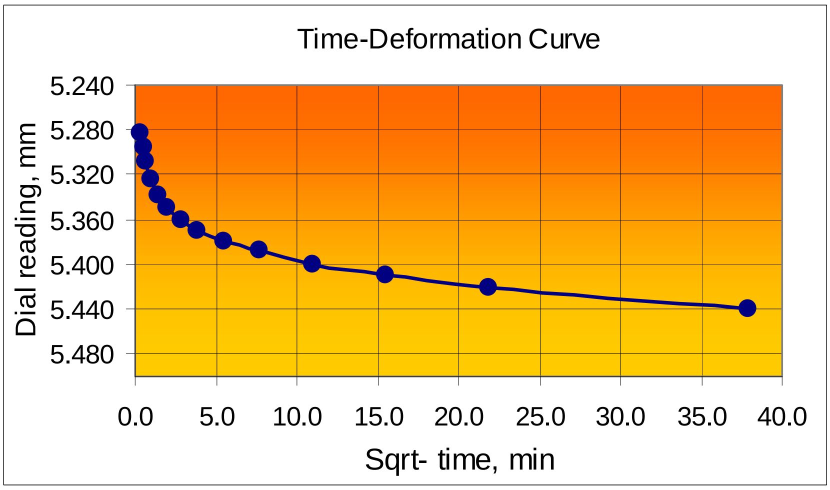
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.56***
		Final height, Hf, mm	***17.39***
		Deformation, mm	***0.240***
0	4.875		
0.1	5.001		
0.25	5.018		
0.5	5.033		
1	5.047		
2	5.057		
4	5.065		
8	5.070		
15	5.075		
30	5.080		
60	5.085		
120	5.090		
240	5.093		
480	5.100		
1440	5.115		



do, mm	***4.97***	Ĥ, Havg, mm	***17.66***	t90, min	***1.15***
d90,mm	***5.042***	Cv, m^2/yr	***29.47***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***100 KPa – 200 KPa***

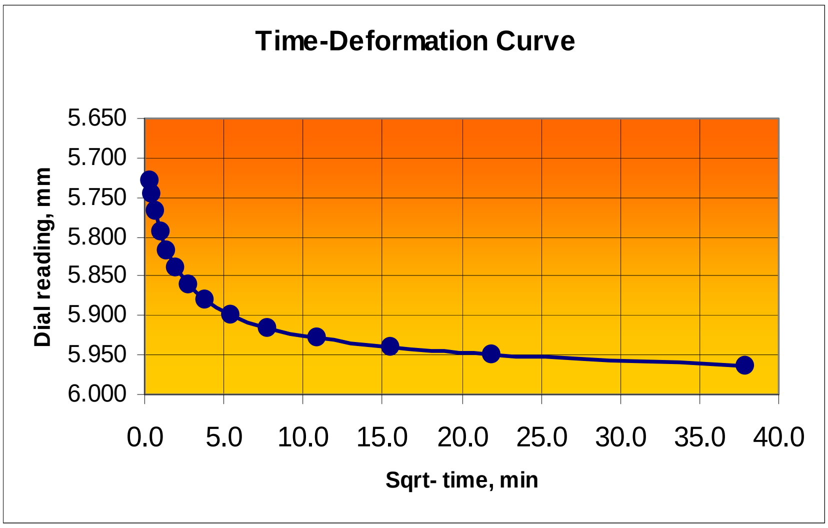
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.93***
		Final height, Hf, mm	***17.06***
		Deformation, mm	***0.325***
0	5.115		
0.1	5.282		
0.25	5.295		
0.5	5.308		
1	5.323		
2	5.338		
4	5.350		
8	5.360		
15	5.370		
30	5.380		
60	5.388		
120	5.400		
240	5.410		
480	5.420		
1440	5.440		



do, mm	***5.26***	Havg.mm	***17.22***	t90, min	***1.35***
d90,mm	***5.33***	Cv, m^2/yr	***24.39***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***200 KPa – 400 KPa***

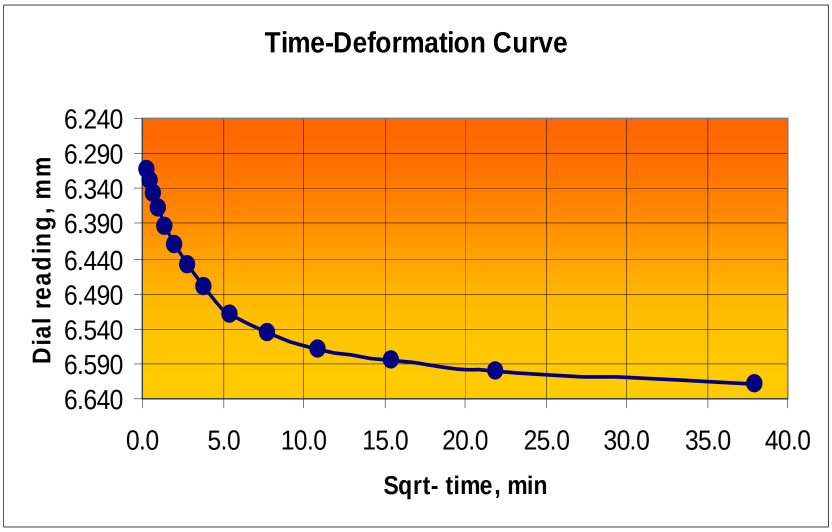
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.06***
		Final height, Hf, mm	***16.54***
		Deformation, mm	***0.525***
0	5.440		
0.1	5.730		
0.25	5.747		
0.5	5.767		
1	5.795		
2	5.818		
4	5.840		
8	5.860		
15	5.880		
30	5.900		
60	5.915		
120	5.928		
240	5.940		
480	5.950		
1440	5.965		



do, mm	***5.70***	Ĥ,Havg.mm	***16.80***	t90, min	***1.58***
d90,mm	***5.82***	Cv, m²/yr	***19.82***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***400 KPa – 800 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***16.54***
		Final height, Hf, mm	***15.88***
		Deformation, mm	***0.655***
0	5.965		
0.1	6.312		
0.25	6.330		
0.5	6.347		
1	6.368		
2	6.395		
4	6.420		
8	6.450		
15	6.480		
30	6.521		
60	6.545		
120	6.570		
240	6.585		
480	6.600		
1440	6.620		

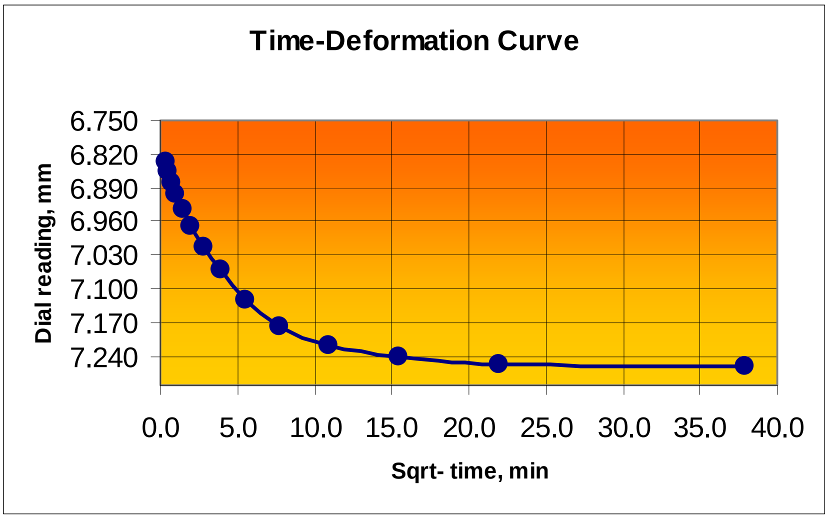


do, mm	***6.283***	Ĥ, Havg, mm	***16.21***	t90, min	***1.72***
d90,mm	***6.398***	Cv, m²/yr	***16.95***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***800 KPa – 1600 KPa***

Initial height, Ho, mm	***15.88***
Final height, Hf, mm	***15.24***
Deformation, mm	***0.64***

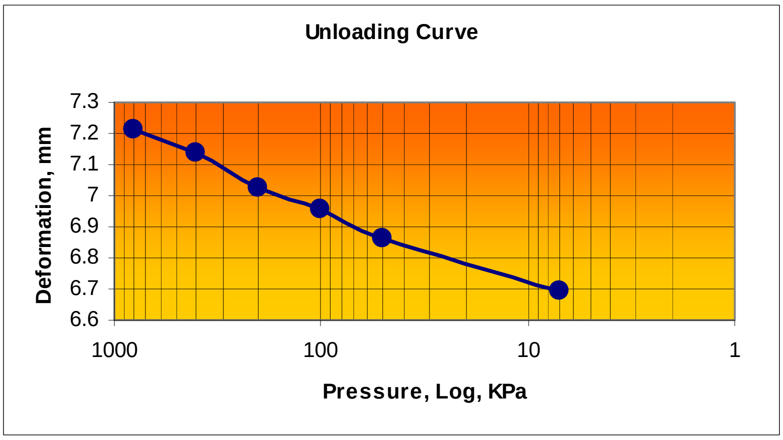
Elapsed Time (min)	Def. Dial Reading (mm)
0	6.620
0.1	6.838
0.25	6.855
0.5	6.878
1	6.905
2	6.936
4	6.970
8	7.015
15	7.060
30	7.125
60	7.180
120	7.218
240	7.240
480	7.255
1440	7.260



do, mm	***6.81***	Ĥ,Havg.mm	***15.56***	t90, min	***1.95***
d90,mm	***6.96***	Cv, m²/yr	***13.78***	Cv = (0.111*Ĥ²)/t90	

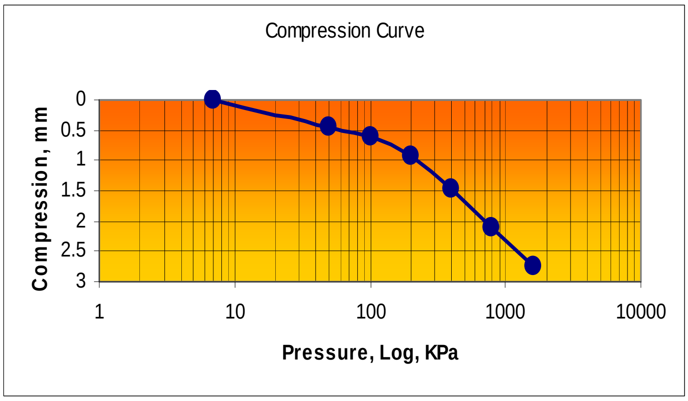
Unloading

Pressure Decrement, KPa	Def. Dial Reading (mm)
1600 -800	7.215
800-400	7.135
400-200	7.025
200-100	6.955
100-50	6.865
50-7	6.695



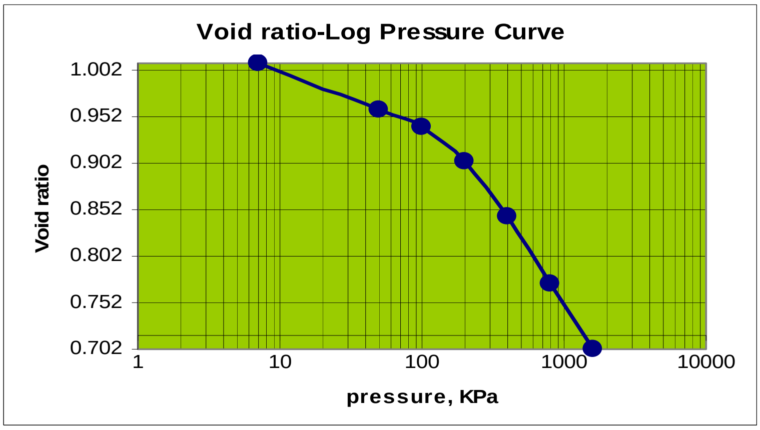
Compression at the end of each loading

Loading, KPa	Deformation ,mm	Ht of Specimen, mm
7	0	18.000
50	0.440	17.560
100	0.615	17.385
200	0.940	17.060
400	1.465	16.535
800	2.120	15.880
1600	2.760	15.240



Void ratio at the end of each loading & Coefficient of compression

Loading, KPa	Void ratio, e
7	1.009
50	0.960
100	0.941
200	0.904
400	0.846
800	0.773
1600	0.701
e=(H-Hs)/Hs	Hs=Ho/(1+eo)
av	***1.20E-04***



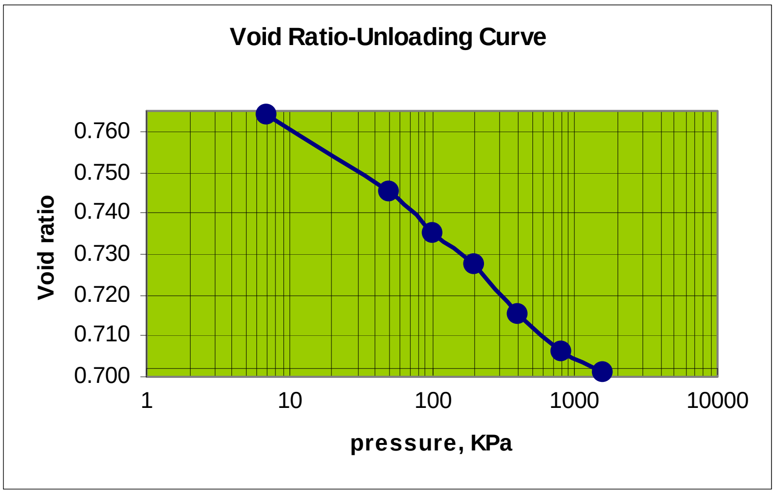
Cc	***0.240***	Cc= $(e_A-e_B)/\log(\sigma_{ZB}-\sigma_{ZA})$		e_A	***0.846***
e_B	***0.701***	σ_{ZA}, Kpa	***400***	σ_{ZB}, Kpa	***1600***

Calculation of Modulus of Elasticity & Volume Compressibility

Loading, P1, Kpa	Loading , P2, Kpa	H1, Ht at start of Compression , mm	H2, Ht at end of Compression , mm	M_v, Modulus of Volume Compressibility, m^2/MN	Modulus of Elasticity, E, MN/m^2
7	0	18	18	-	-
50	7	18	17.56	0.5685	1.7591
100	50	17.56	17.39	0.1993	5.0171
200	100	17.39	17.06	0.1869	5.3492
400	200	17.06	16.54	0.1539	6.4990
800	400	16.54	15.88	0.0990	10.0977
1600	800	15.88	15.24	0.0504	19.8500
m_v =((H1-H2)/H1)*(1000/(P2-P1))			E=1/mv		

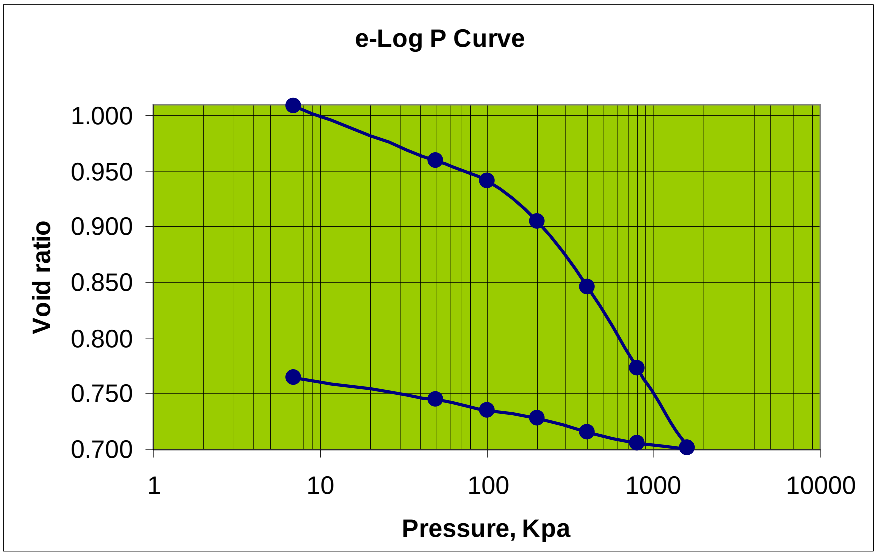
Void ratio at the end of each step of unloading

Loading, KPa	Void ratio, e
1600	0.701
800	0.706
400	0.715
200	0.727
100	0.735
50	0.745
7	0.764



e-Log Curve

Load, Kpa	Void ratio
7	1.009
50	0.984
100	0.959
200	0.922
400	0.863
800	0.789
1600	0.718
1600	0.718
800	0.723
400	0.732
200	0.744
100	0.752
50	0.762
7	0.781



One dimensional consolidation test for Addisu G pit #1/undisturbed

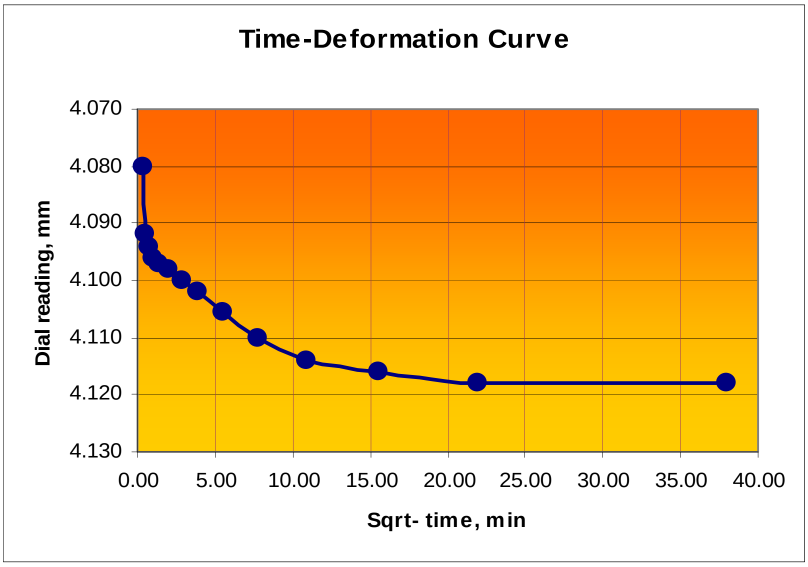
Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: One dimensional oedometer, BS 1377-5:3		Specific gravity	***2.71***
Sample Type	***Undisturbed***	Initial Ht. of specimen, mm	***18***
Height of ring, mm	**20**	Initial mass of specimen, g	**67.04**
Diameter of ring, mm	**50**	Initial bulk density, g/cc	**1.90**
Ini. Moisture content, %	**27**	Initial dry density, g/cc	**1.49**
Final moisture content, %	**33**		

Deformation Versus Time Reading for Different Loadings

Load increment: ***7 KPa – 50 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)
0	4.000
0.1	4.080
0.25	4.092
0.5	4.094
1	4.096
2	4.098
4	4.099
8	4.100
15	4.102
30	4.104
60	4.107
120	4.110
240	4.113
480	4.116
1440	4.118

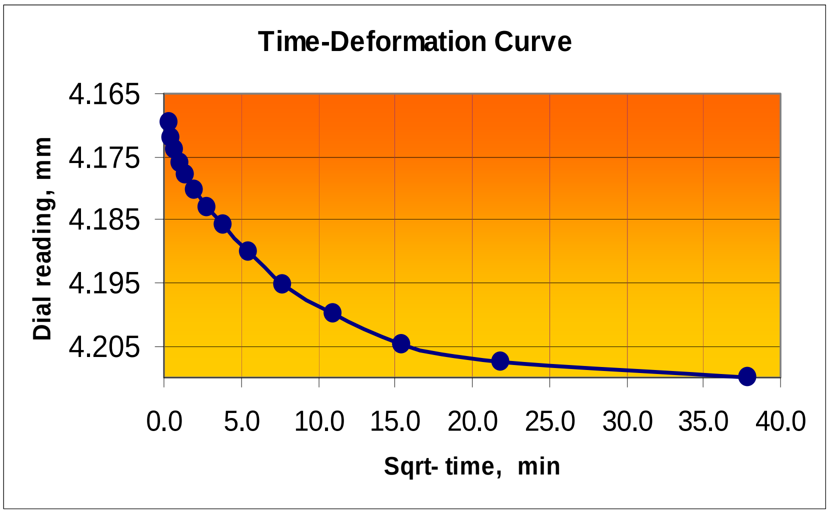
Initial height, Ho, mm	***18***
Final height, Hf, mm	***17.88***
Deformation, mm	***0.118***



do, mm	***4.065***	Average ht, Ĥ, mm	***17.94***	t90, min	***0.5***
d90,mm	***4.094***	Cv, m²/yr	***71.46***	Cv = (0.111*Ĥ²)/t90	

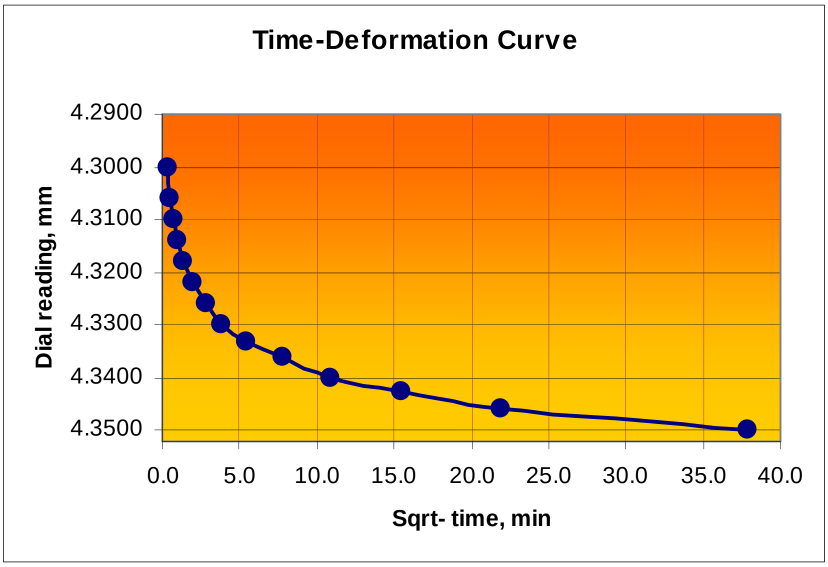
Load increment: ***50 KPa – 100 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)			
		Initial height, Ho, mm	***17.88***	
		Final height, Hf, mm	***17.79***	
		Deformation, mm	***0.092***	
0	4.118			
0.1	4.170			
0.25	4.172			
0.5	4.174			
1	4.176			
2	4.178			
4	4.180			
8	4.183			
15	4.186			
30	4.190			
60	4.195			
120	4.200			
240	4.205			
480	4.207			
1440	4.210			
do, mm	***4.162***	Ĥ, Havg, mm	***17.84***	t90, min ***.55***
d90,mm	***4.174***	Cv, m²/yr	***64.20***	Cv = (0.111*Ĥ²)/t90



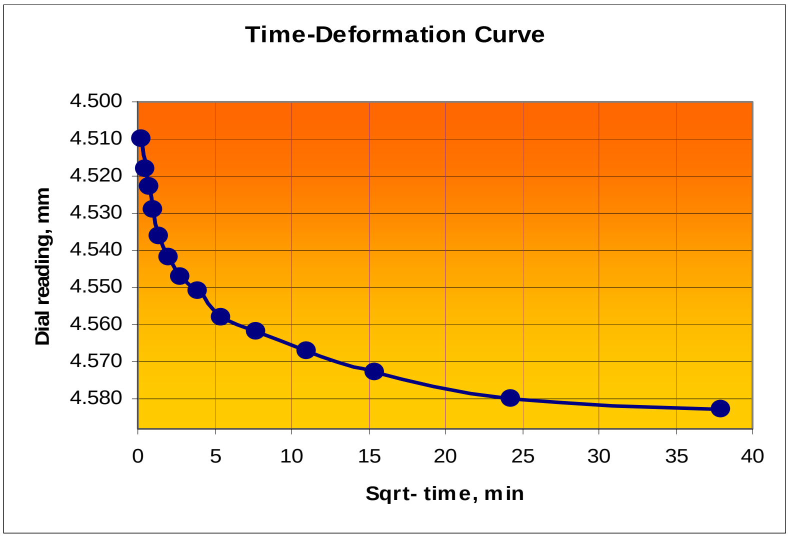
Load increment: ***100 KPa – 200 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)			
		Initial height, Ho, mm	***17.79***	
		Final height, Hf, mm	***17.65***	
		Deformation, mm	***0.140***	
0	4.200			
0.1	4.302			
0.25	4.306			
0.5	4.310			
1	4.314			
2	4.318			
4	4.322			
8	4.326			
15	4.330			
30	4.333			
60	4.336			
120	4.340			
240	4.343			
480	4.346			
1440	4.350			
do, mm	***4.29***	Havg.mm	***17.72***	t90, min ***0.71***
d90,mm	***4.314***	Cv, m²/yr	***49.09***	Cv = (0.111*Ĥ²)/t90



Load increment: ***200 KPa – 400 KPa***

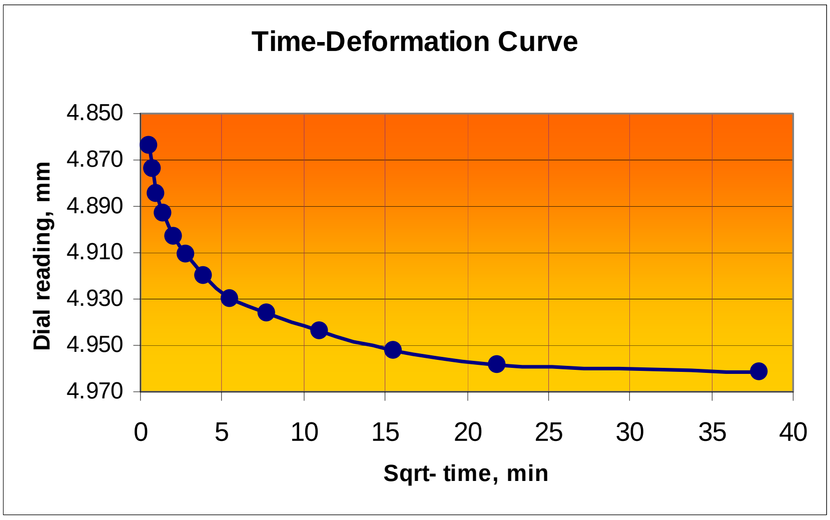
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.65***
		Final height, Hf, mm	***17.42***
		Deformation, mm	***0.232***
0	4.350		
0.1	4.510		
0.25	4.518		
0.5	4.523		
1	4.529		
2	4.536		
4	4.542		
8	4.547		
15	4.551		
30	4.558		
60	4.562		
120	4.567		
240	4.573		
480	4.580		
1440	4.583		



do, mm	***4.507***	Ĥ,Havg.mm	***17.53***	t90, min	***0.88***
d90,mm	***4.54***	Cv, m^2/yr	***38.78***	Cv = (0.111*Ĥ²)/t90	

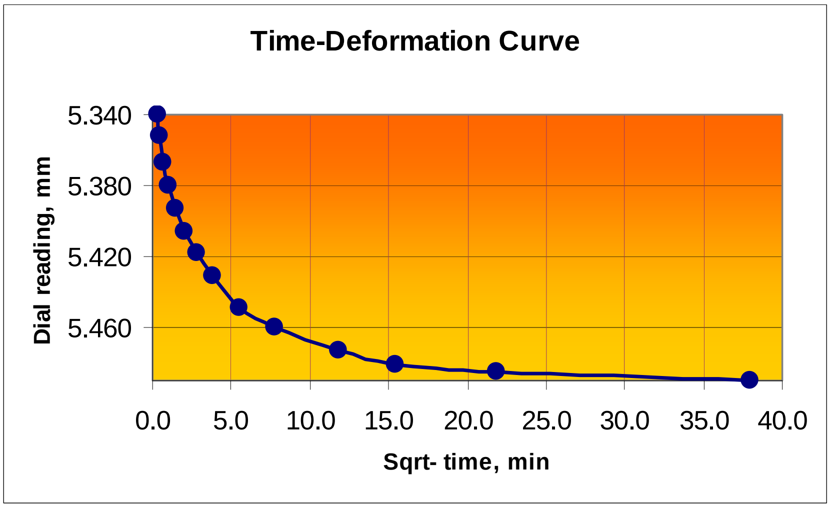
Load increment: ***400 KPa – 800 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.42***
		Final height, Hf, mm	***17.04***
		Deformation, mm	***0.380***
0	4.582		
0.1	4.850		
0.25	4.864		
0.5	4.874		
1	4.885		
2	4.893		
4	4.903		
8	4.911		
15	4.920		
30	4.930		
60	4.936		
120	4.944		
240	4.952		
480	4.959		
1440	4.962		



do, mm	***4.841***	ĤHavg.mm	***17.23***	t90, min	***1.12***
d90,mm	***4.882***	Cv, m^2/yr	***29.42***	Cv = (0.111*Ĥ²)/t90	

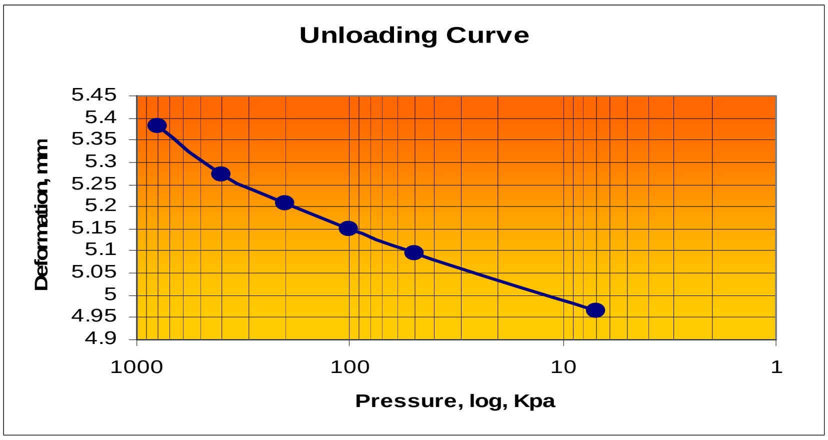
Load increment: ***800 KPa – 1600 KPa***			
Elapsed Time (min)	Def. Dial Reading (mm)	Initial height, Ho, mm	***17.03***
		Final height, Hf, mm	***16.51***
		Deformation, mm	***0.52***
0	4.962		
0.1	5.340		
0.25	5.352		
0.5	5.367		
1	5.380		
2	5.393		
4	5.406		
8	5.418		
15	5.431		
30	5.449		
60	5.460		
120	5.473		
240	5.481		
480	5.485		
1440	5.490		



do, mm	***4.841***	Ĥ,Havg.mm	***16.77***	t90, min	***1.24***
d90,mm	***4.882***	Cv, m²/yr	***25.19***	Cv = (0.111*Ĥ²)/t90	

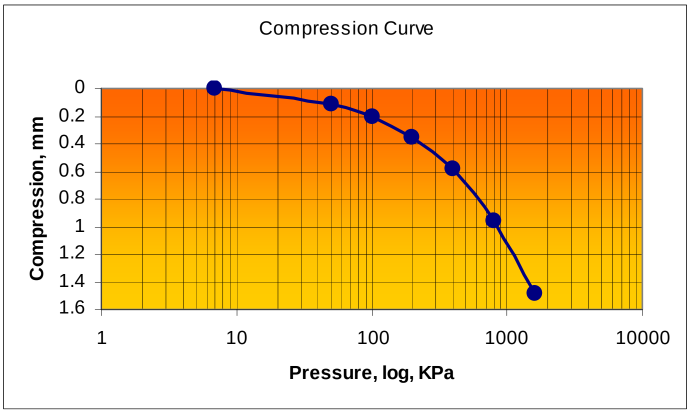
Unloading

Pressure Decrement, KPa	Def. Dial Reading (mm)
1600 -800	5.382
800-400	5.273
400-200	5.207
200-100	5.151
100-50	5.096
50-7	4.966



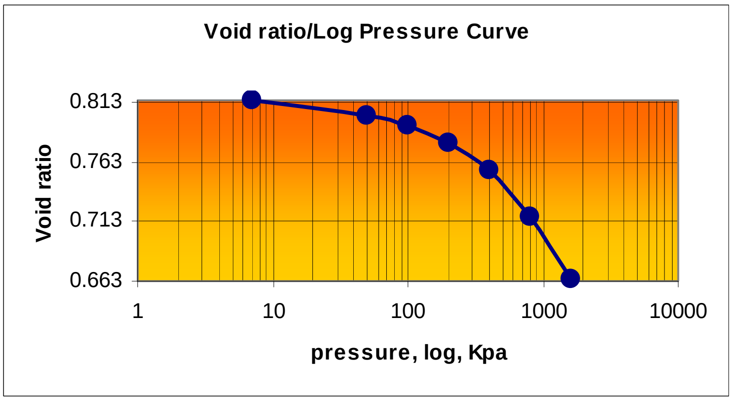
Compression at the end of each loading

Loading, KPa	Deformation ,mm	Ht of Specimen, mm
7	0	18.000
50	0.118	17.882
100	0.210	17.790
200	0.350	17.650
400	0.582	17.418
800	0.962	17.039
1600	1.490	16.510



Void ratio at the end of each loading & Coefficient of compression

Loading, KPa	Void ratio, e
7	0.814
50	0.803
100	0.793
200	0.779
400	0.756
800	0.718
1600	0.664
e=(H-Hs)/Hs	Hs=Ho/(1+eo)
av	***7.63E-05***



Cc	***0.152***	Cc= $(e_A-e_B)/\log(\sigma_{ZB}-\sigma_{ZA})$		e_A	***0.756***
e_B	***0.664***	σ_{ZA}, Kpa	***400***	σ_{ZB}, Kpa	***1600***

Calculation of Modulus of Elasticity & Volume Compressibility

Loading, P1, Kpa	Loading , P2, Kpa	H1, Ht at start of Compression , mm	H2, Ht at end of Compression , mm	M_v, Modulus of Volume Compressibility, m^2/MN	Modulus of Elasticity, E, MN/ m^2
50	7	18	17.88	0.1525	6.559
100	50	17.88	17.79	0.1029	9.718
200	100	17.79	17.65	0.0787	12.707
400	200	17.65	17.42	0.0658	15.202
800	400	17.42	17.04	0.0544	18.368
1600	800	17.04	16.51	0.0388	25.791

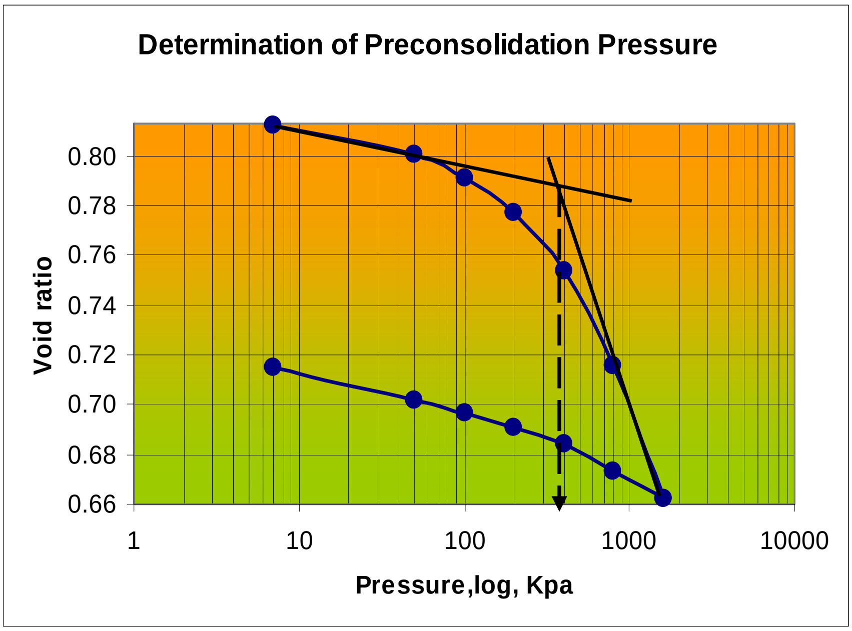
$m_v = ((H1-H2)/H1)*(1000/(P2-P1))$

$E=1/mv$

Determination of Pre-consolidation pressure, Pc and over consolidation ratio, OCR

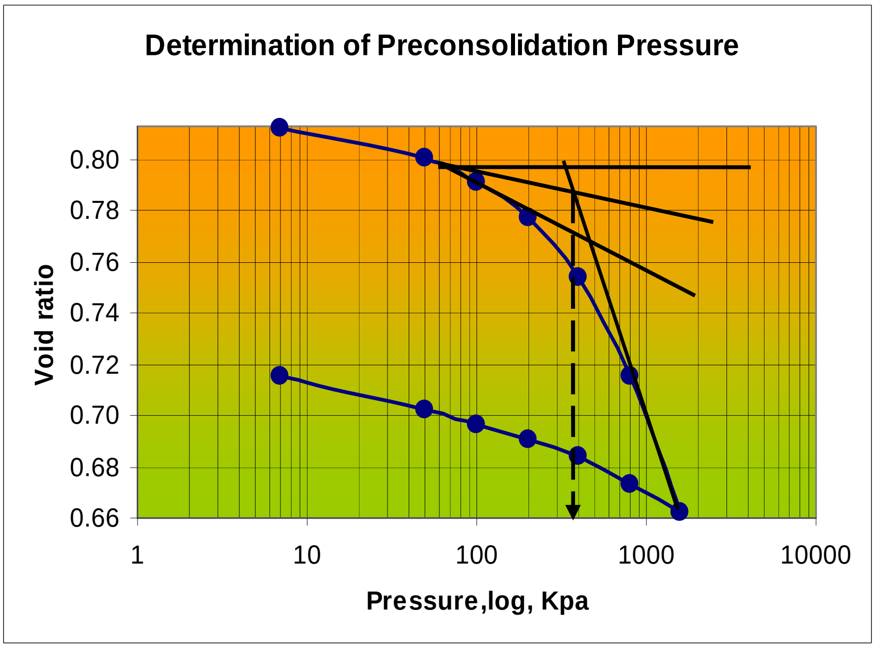
Simplified Method

Loading, KPa	Void ratio, e
7	0.814
50	0.803
100	0.793
200	0.779
400	0.756
800	0.718
1600	0.664
1600	0.664
800	0.675
400	0.686
200	0.693
100	0.698
50	0.704
7	0.717



Casagrande's Method

Load, Kpa	Void ratio
7	0.814
50	0.803
100	0.793
200	0.779
400	0.756
800	0.718
1600	0.664
1600	0.664
800	0.675
400	0.686
200	0.693
100	0.698
50	0.704
7	0.717



Pc, KPa	***380***	Po=Unit weight*Depth, KPa	***47.5***
OCR=Pc/Po	***8.0***	**Heavily Over consolidated**	

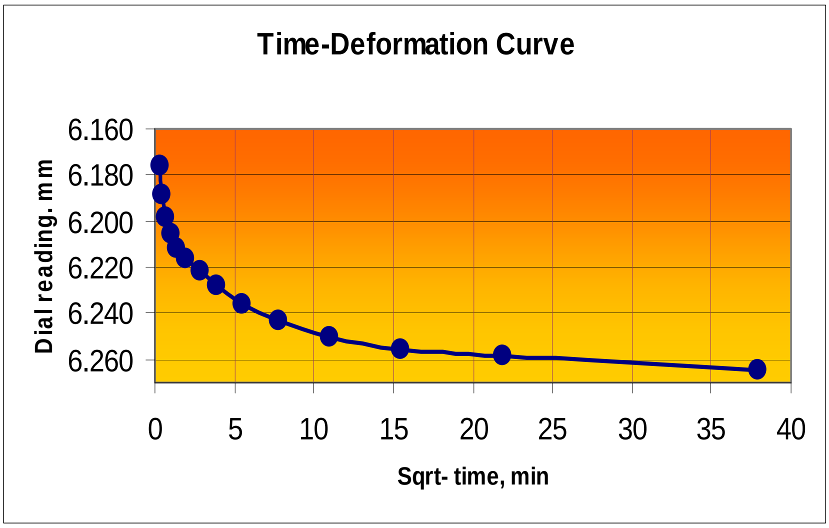
One dimensional consolidation test for Addisu G pit #2/undisturbed

Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: One dimensional oedometer, BS 1377-5:3		Specific gravity	***2.71***
Sample Type	***Undisturbed***	Initial Ht. of specimen, mm	***18***
Height of ring, mm	**20**	Initial mass of specimen, g	**67.51**
Diameter of ring, mm	**50**	Initial bulk density, g/cc	**1.90**
Ini. Moisture content, %	**28**	Initial dry density, g/cc	**1.49**
Final moisture content, %	**33**		

Deformation Versus Time Reading for Different Loadings

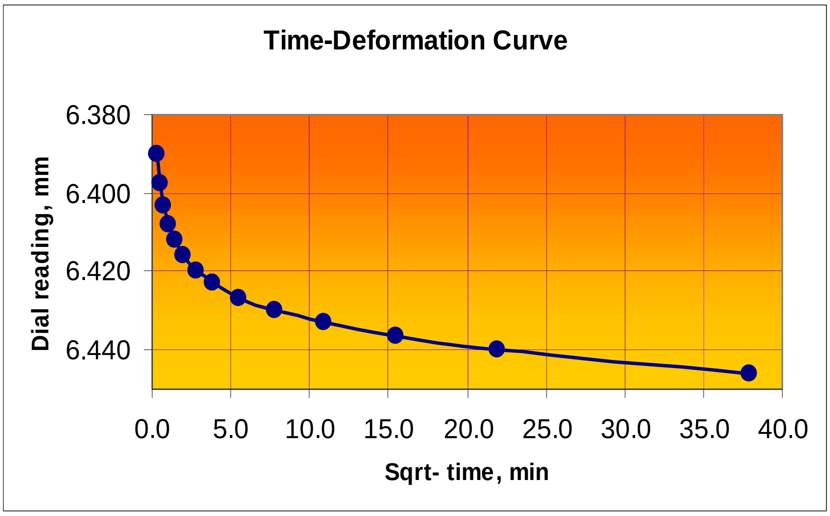
Load increment: ***7 KPa – 50 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***18***
		Final height, Hf, mm	***17.79***
		Deformation, mm	***0.215***
0	6.050		
0.1	6.176		
0.25	6.189		
0.5	6.199		
1	6.206		
2	6.212		
4	6.216		
8	6.222		
15	6.228		
30	6.236		
60	6.244		
120	6.250		
240	6.256		
480	6.258		
1440	6.265		

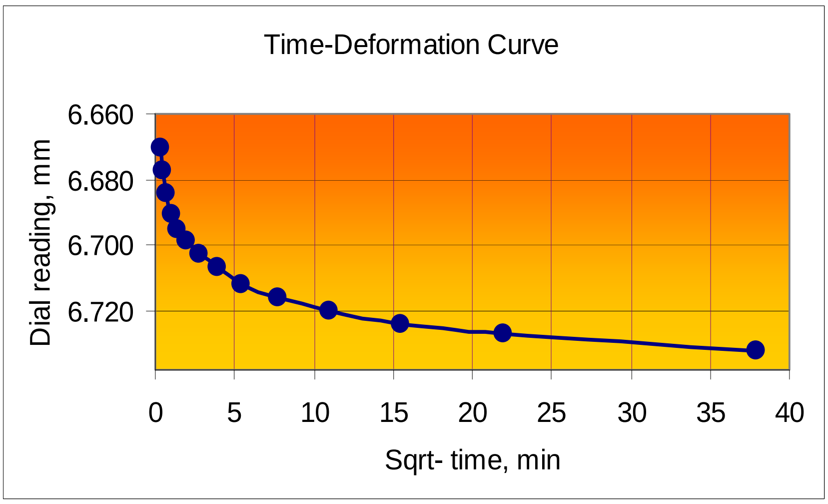


do, mm	***6.197***	Average ht, Ĥ, mm	***17.89***	t90, min	***0.59***
d90,mm	***6.207***	Cv, m^2/yr	***60.23***	Cv = $(0.111*Ĥ^2)/t90$	

Load increment: ***50 KPa – 100 KPa***					
Elapsed Time (min)	Def. Dial Reading (mm)	Initial height, Ho, mm	***17.79***		
		Final height, Hf, mm	***17.60***		
		Deformation, mm	***0.181***		
0	6.265				
0.1	6.390				
0.25	6.397				
0.5	6.403				
1	6.408				
2	6.412				
4	6.416				
8	6.420				
15	6.423				
30	6.427				
60	6.430				
120	6.433				
240	6.437				
480	6.440				
1440	6.446				
do, mm	***6.381***	Ĥ, Havg, mm	***17.69***	t90, min	***0.64***
d90,mm	***6.406***	Cv, m²/yr	***54.30***	Cv = (0.111*Ĥ²)/t90	

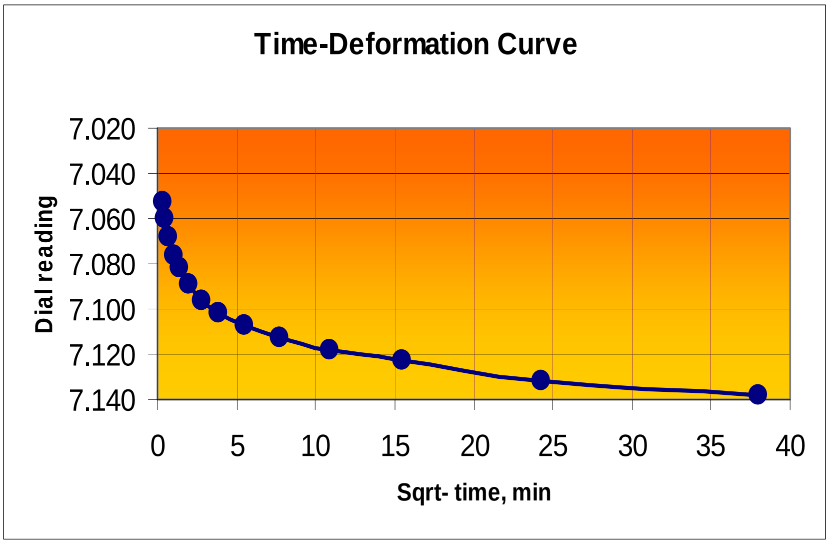


Load increment: ***100 KPa – 200 KPa***					
Elapsed Time (min)	Def. Dial Reading (mm)	Initial height, Ho, mm	***17.60***		
		Final height, Hf, mm	***17.32***		
		Deformation, mm	***0.286***		
0	6.446				
0.1	6.670				
0.25	6.677				
0.5	6.684				
1	6.690				
2	6.696				
4	6.699				
8	6.703				
15	6.707				
30	6.712				
60	6.716				
120	6.720				
240	6.724				
480	6.727				
1440	6.732				
do, mm	***6.63***	Havg.mm	***17.46***	t90, min	***0.78***
d90,mm	***6.678***	Cv, m²/yr	***43.39***	Cv = (0.111*Ĥ²)/t90	



Load increment: ***200 KPa – 400 KPa***

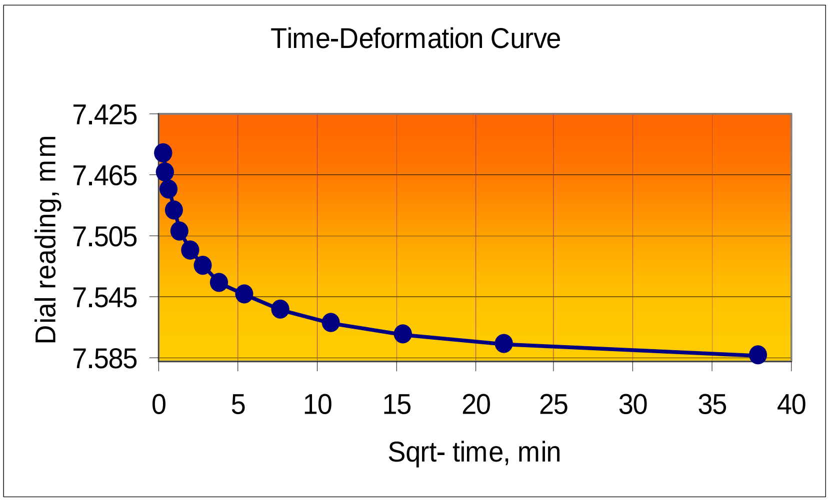
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.22***
		Final height, Hf, mm	***16.91***
		Deformation, mm	***0.406***
0	6.732		
0.1	7.053		
0.25	7.060		
0.5	7.068		
1	7.076		
2	7.082		
4	7.089		
8	7.096		
15	7.102		
30	7.107		
60	7.113		
120	7.118		
240	7.123		
480	7.131		
1440	7.138		



do, mm	***7.041***	Ĥ,Havg.mm	***17.12***	t90, min	***0.92***
d90,mm	***7.077***	Cv, m²/yr	***35.32***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***400 KPa – 800 KPa***

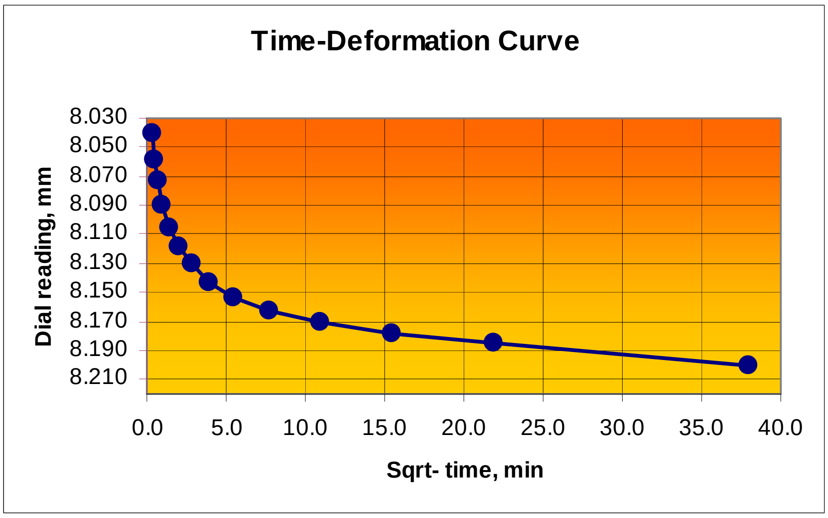
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***16.91***
		Final height, Hf, mm	***16.47***
		Deformation, mm	***0.446***
0	7.138		
0.1	7.451		
0.25	7.464		
0.5	7.475		
1	7.489		
2	7.503		
4	7.515		
8	7.525		
15	7.536		
30	7.545		
60	7.554		
120	7.563		
240	7.570		
480	7.577		
1440	7.584		



do, mm	***7.428***	Ĥ, Havg, mm	***16.69***	t90, min	***1.12***
d90,mm	***7.549***	Cv, m²/yr	***27.60***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***800 KPa – 1600 KPa***

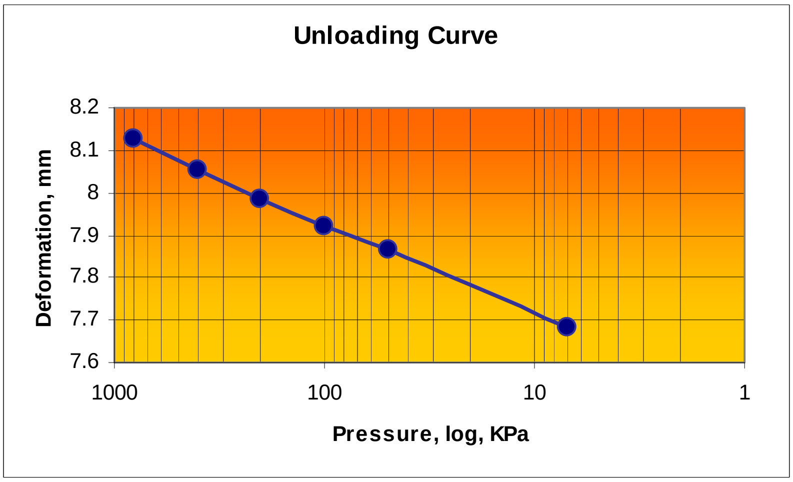
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***16.47***
		Final height, Hf, mm	***15.85***
		Deformation, mm	***0.62***
0	7.584		
0.1	8.044		
0.25	8.058		
0.5	8.072		
1	8.088		
2	8.104		
4	8.119		
8	8.133		
15	8.143		
30	8.153		
60	8.163		
120	8.171		
240	8.179		
480	8.185		
1440	8.200		



do, mm	***8.02***	Ĥ,Havg.mm	***16.16***	t90, min	***1.21***
d90,mm	***8.1***	Cv, m²/yr	***23.95***	Cv = (0.111*Ĥ²)/t90	

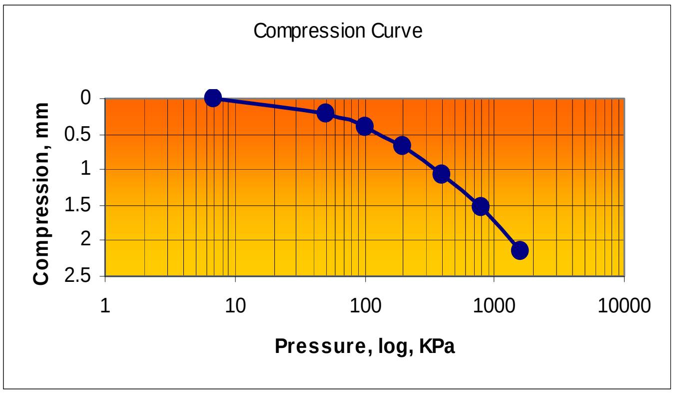
Unloading

Pressure Decrement, KPa	Def. Dial Reading (mm)
1600 -800	8.129
800-400	8.054
400-200	7.984
200-100	7.920
100-50	7.866
50-7	7.684



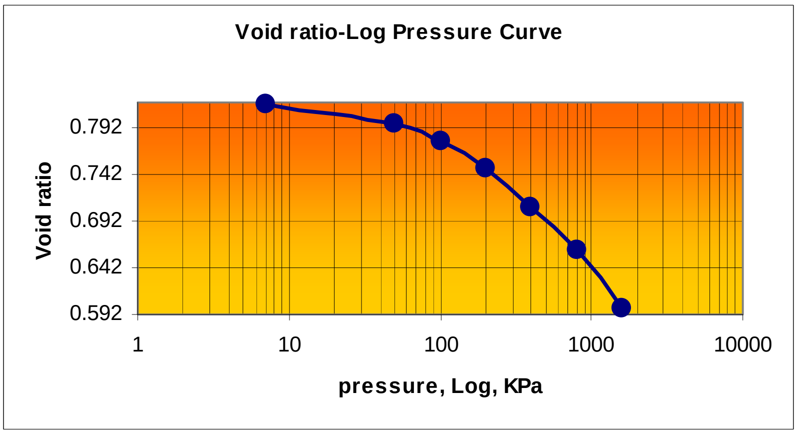
Compression at the end of each loading

Loading, KPa	Deformation ,mm	Ht of Specimen, mm
7	0	18.000
50	0.215	17.785
100	0.396	17.604
200	0.682	17.318
400	1.088	16.912
800	1.534	16.466
1600	2.150	15.850



Void ratio at the end of each loading & Coefficient of compression

Loading, KPa	Void ratio, e
7	0.816
50	0.794
100	0.776
200	0.747
400	0.706
800	0.661
1600	0.599
e=(H-Hs)/Hs	Hs=Ho/(1+eo)
av	***8.93E-05***



Cc	***0.178***	Cc= $(e_A-e_B)/\log(\sigma_{ZB}-\sigma_{ZA})$		e_A	***0.706***
e_B	***0.599***	σ_{ZA}, Kpa	***400***	σ_{ZB}, Kpa	***1600***

Calculation of Modulus of Elasticity & Volume Compressibility

Loading, P1, Kpa	Loading , P2, Kpa	H1, Ht at start of Compression , mm	H2, Ht at end of Compression , mm	M_v, Modulus of Volume Compressibility, m^2/MN	Modulus of Elasticity, E, MN/m^2
50	7	18	17.79	0.2778	3.600
100	50	17.79	17.60	0.2035	4.913
200	100	17.60	17.32	0.1625	6.155
400	200	17.32	16.91	0.1172	8.531
800	400	16.91	16.47	0.0659	15.168
1600	800	16.47	15.85	0.0468	21.384

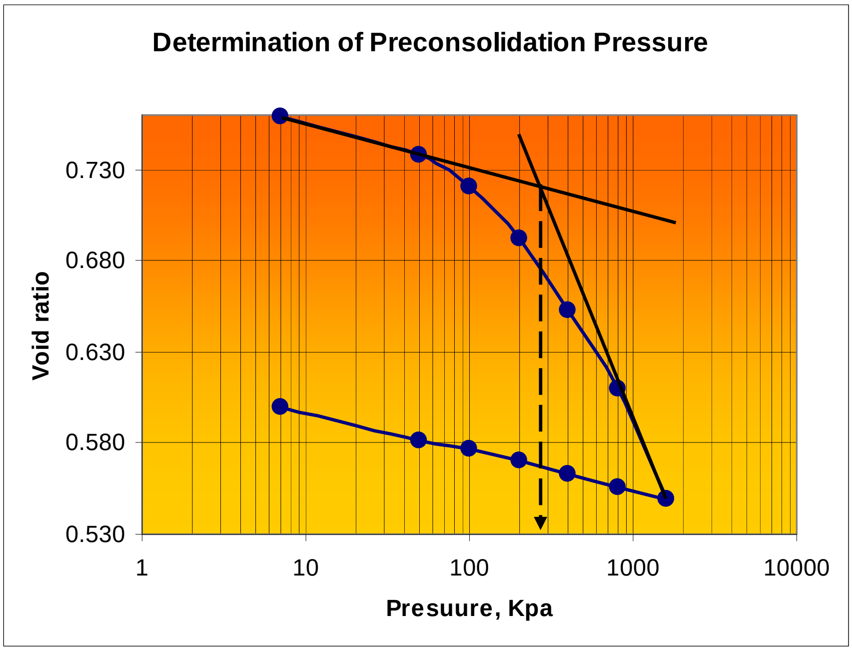
$m_v = ((H1-H2)/H1)*(1000/(P2-P1))$

$E=1/mv$

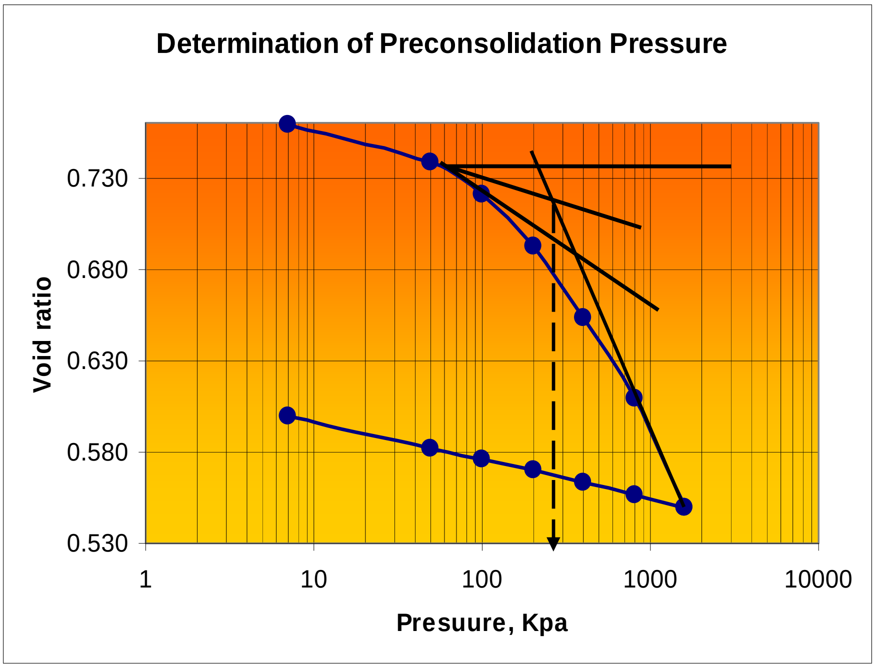
Determination of Pre-consolidation pressure, Pc and over consolidation ratio, OCR

Simplified Method

Loading, KPa	Void ratio, e
7	0.759
50	0.738
100	0.721
200	0.693
400	0.653
800	0.609
1600	0.549
1600	0.549
800	0.556
400	0.563
200	0.570
100	0.576
50	0.582
7	0.600



Load, Kpa	Void ratio
7	0.759
50	0.738
100	0.721
200	0.693
400	0.653
800	0.609
1600	0.549
1600	0.549
800	0.556
400	0.563
200	0.570
100	0.576
50	0.582
7	0.600



Pc, KPa	***280***	Po=Unit weight*Depth, KPa	**46.66**
OCR=Pc/Po	***6.0***	**Heavily Over consolidated**	

One dimensional consolidation test for Addisu G pit #1/Remolded

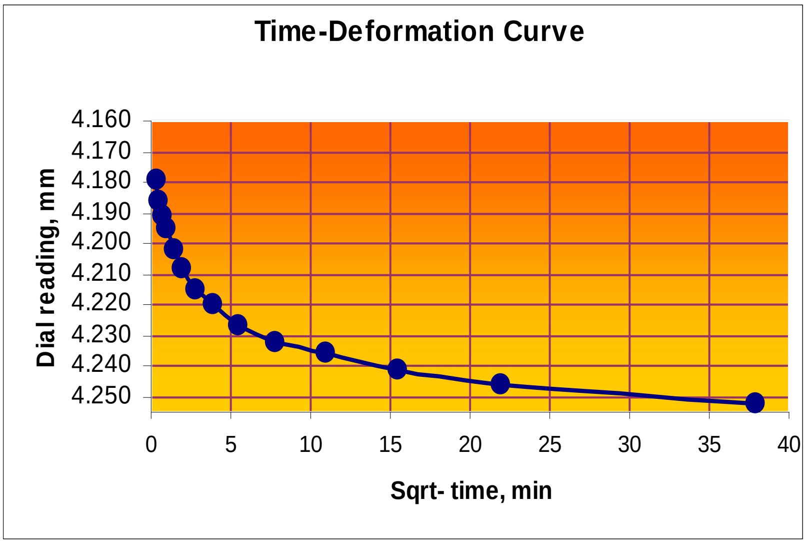
Location: ***Addisu Gebeya area***		Job ref.	***Thesis research***
		Pit no.	***#1***
Soil Description: ***Red brown clay***		Sample no.	***#1***
		Depth	***2.5m***
Test method: One dimensional oedometer, BS 1377-5:3		Specific gravity	***2.71***
Sample Type	***Remolded at OMC***	Initial Ht. of specimen, mm	***18***
Height of ring, mm	***20***	Initial mass of specimen, g	***65.10***
Diameter of ring, mm	***50***	Initial bulk density, g/cc	***1.84***
Ini. Moisture content, %	***34***	Initial dry density, g/cc	***1.37***
Final moisture content, %	***32***		

Deformation Versus Time Reading for Different Loadings

Load increment: ***7 KPa – 50 KPa***

Initial height, Ho, mm	***18.00***
Final height, Hf, mm	***17.75***
Deformation, mm	***0.252***

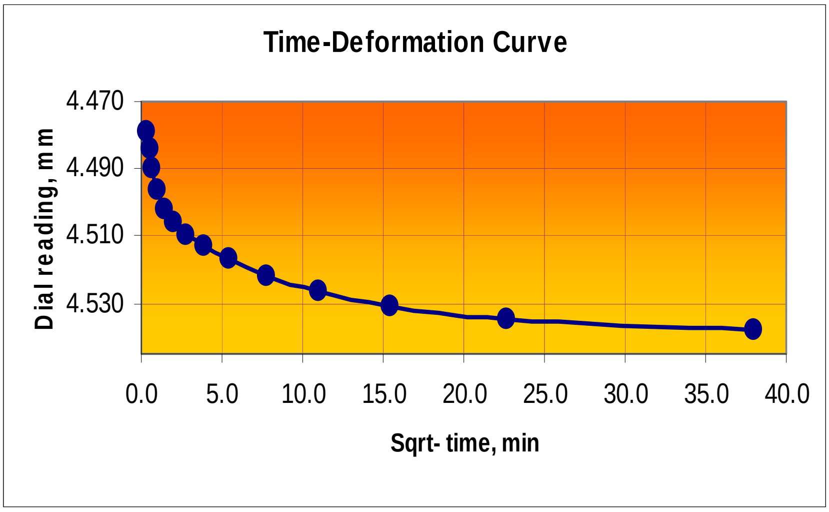
Elapsed Time (min)	Def. Dial Reading (mm)
0	4.000
0.1	4.181
0.25	4.186
0.5	4.191
1	4.197
2	4.202
4	4.208
8	4.215
15	4.220
30	4.227
60	4.232
120	4.236
240	4.241
480	4.246
1440	4.252



do, mm	***4.17***	Average ht, Ĥ, mm	***17.87***	t90, min	***1.24***
d90,mm	***4.19***	Cv, m²/yr	***28.60***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***50 KPa – 100 KPa***

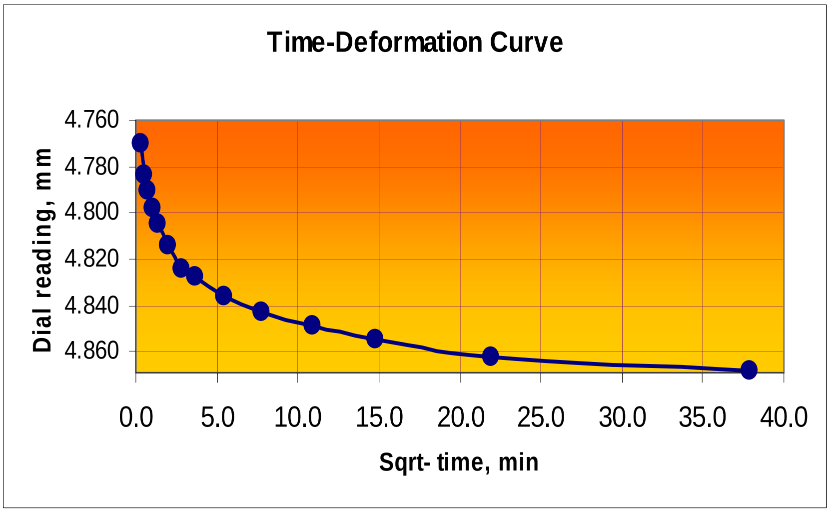
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.75***
		Final height, Hf, mm	***17.47***
		Deformation, mm	***0.281***
0	4.252		
0.1	4.479		
0.25	4.484		
0.5	4.490		
1	4.497		
2	4.502		
4	4.506		
8	4.510		
15	4.513		
30	4.517		
60	4.522		
120	4.526		
240	4.531		
480	4.535		
1440	4.533		



do, mm	***4.443***	Ĥ, Havg, mm	***17.61***	t90, min	***1.75***
d90,mm	***4.493***	Cv, m²/yr	***19.66***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***100 KPa – 200 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***17.47***
		Final height, Hf, mm	***17.13***
		Deformation, mm	***0.33***
0	4.538		
0.1	4.770		
0.25	4.784		
0.5	4.790		
1	4.798		
2	4.805		
4	4.814		
8	4.824		
15	4.828		
30	4.836		
60	4.843		
120	4.849		
240	4.855		
480	4.862		
1440	4.868		

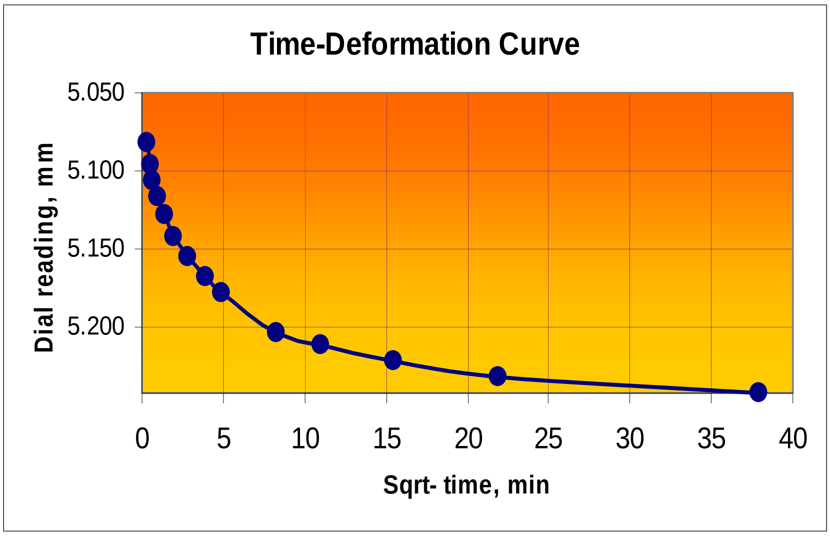


do, mm	***4.762***	Havg.mm	***17.30***	t90, min	***1.87***
d90,mm	***4.795***	Cv, m²/yr	***17.76***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***200 KPa – 400 KPa***

Initial height, Ho, mm	***17.13***
Final height, Hf, mm	***16.76***
Deformation, mm	***0.375***

Elapsed Time (min)	Def. Dial Reading (mm)
0	4.868
0.1	5.091
0.25	5.098
0.5	5.106
1	5.117
2	5.129
4	5.142
8	5.155
15	5.169
30	5.179
60	5.204
120	5.212
240	5.223
480	5.233
1440	5.243

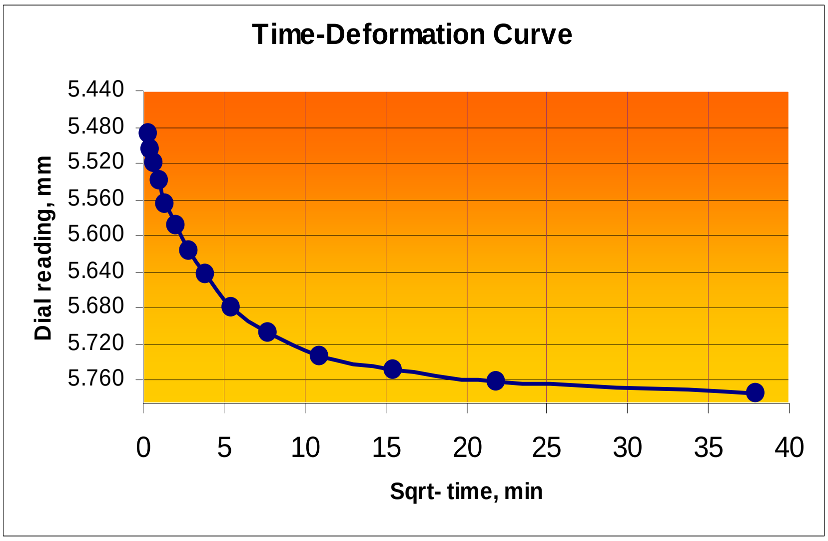


do, mm	***5.069***	Ĥ,Havg.mm	***16.94***	t90, min	***1.94***
d90,mm	***5.12***	Cv, m²/yr	***16.47***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***400 KPa – 800 KPa***

Initial height, Ho, mm	***16.76***
Final height, Hf, mm	***16.23***
Deformation, mm	***0.531***

Elapsed Time (min)	Def. Dial Reading (mm)
0	5.243
0.1	5.488
0.25	5.505
0.5	5.520
1	5.540
2	5.564
4	5.589
8	5.617
15	5.643
30	5.679
60	5.708
120	5.733
240	5.749
480	5.762
1440	5.774

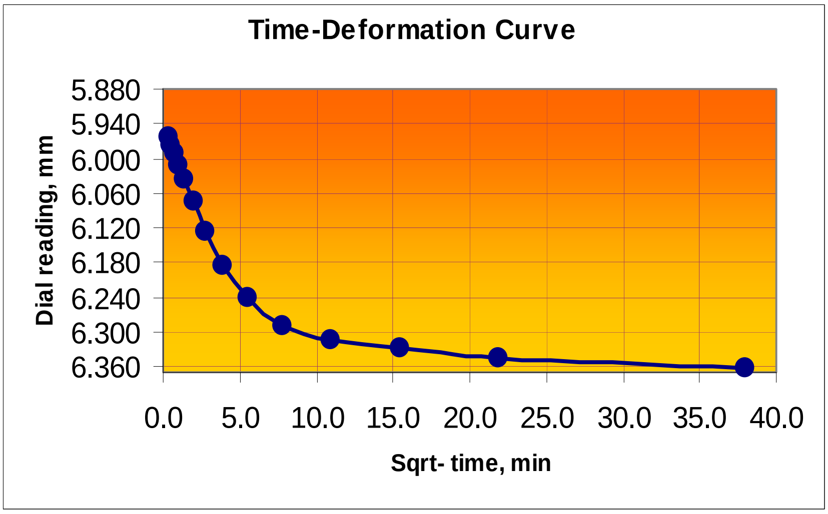


do, mm	***5.464***	Ĥ, Havg, mm	***16.49***	t90, min	***2.2***
d90,mm	***5.562***	Cv, m²/yr	***13.72***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***800 KPa – 1600 KPa***

Initial height, Ho, mm	***16.23***
Final height, Hf, mm	***15.64***
Deformation, mm	***0.59***

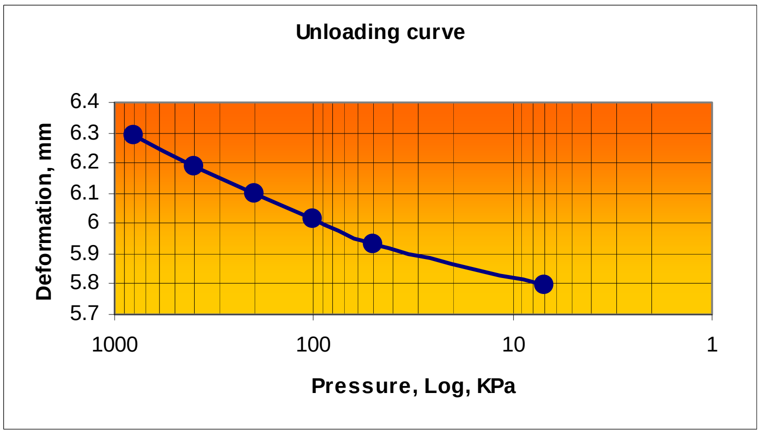
Elapsed Time (min)	Def. Dial Reading (mm)
0	5.774
0.1	5.964
0.25	5.977
0.5	5.992
1	6.012
2	6.038
4	6.075
8	6.125
15	6.185
30	6.241
60	6.290
120	6.315
240	6.330
480	6.347
1440	6.364



do, mm	***5.943***	Ĥ,Havg.mm	***15.93***	t90, min	***4.9***
d90,mm	***6.227***	Cv, m^2/yr	***5.75***	Cv = (0.111*$Ĥ^2$)/t90	

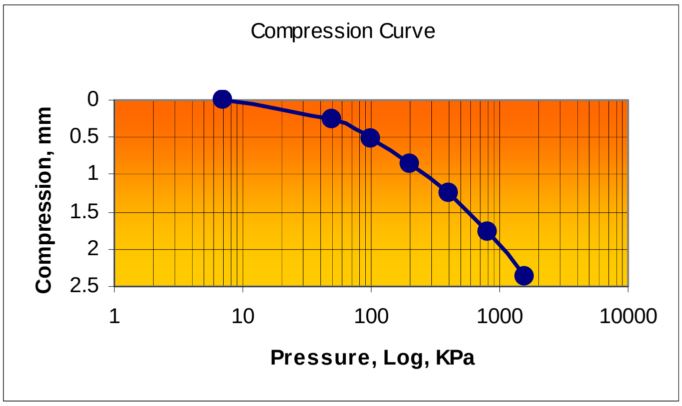
Unloading

Pressure Decrement, KPa	Def. Dial Reading (mm)
1600 -800	6.291
800-400	6.189
400-200	6.096
200-100	6.017
100-50	5.930
50-7	5.794



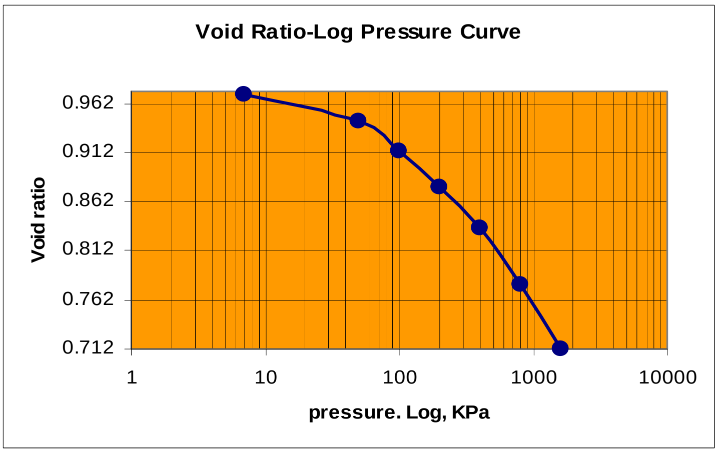
Compression at the end of each loading

Loading, KPa	Deformation ,mm	Ht of Specimen, mm
7	0	18.000
50	0.252	17.748
100	0.533	17.467
200	0.868	17.132
400	1.243	16.757
800	1.774	16.226
1600	2.364	15.636



Void ratio at the end of each loading & Coefficient of compression

Loading, KPa	Void ratio, e
7	0.971
50	0.944
100	0.913
200	0.876
400	0.835
800	0.777
1600	0.713
e=(H-Hs)/Hs	Hs=Ho/(1+eo)
av	***1.02E-04***



Cc	***0.204***	Cc= $(e_A - e_B)/\log(\sigma_{ZB} - \sigma_{ZA})$		e_A	***0.835***
e_B	***0.713***	σ_{ZA}, Kpa	***400***	σ_{ZB}, Kpa	***1600***

Calculation of Modulus of Elasticity & Volume Compressibility

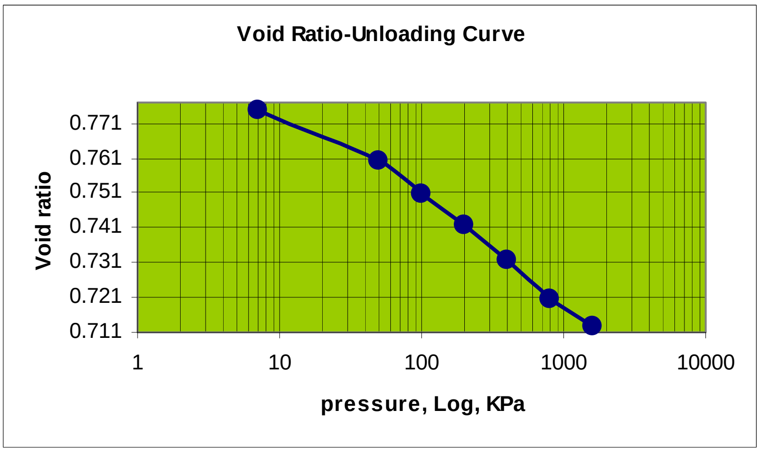
Loading, P1, Kpa	Loading , P2, Kpa	H1, Ht at start of Compression , mm	H2, Ht at end of Compression , mm	M_v, Modulus of Volume Compressibility, m^2/MN	Modulus of Elasticity, E, MN/m^2
50	7	18	17.75	0.3256	3.0714
100	50	17.75	17.47	0.3167	3.1580
200	100	17.47	17.13	0.1918	5.2140
400	200	17.13	16.76	0.1094	9.1371
800	400	16.76	16.23	0.0792	12.6230
1600	800	16.23	15.64	0.0455	22.0014

$m_v = ((H1-H2)/H1)*(1000/(P2-P1))$

$E = 1/mv$

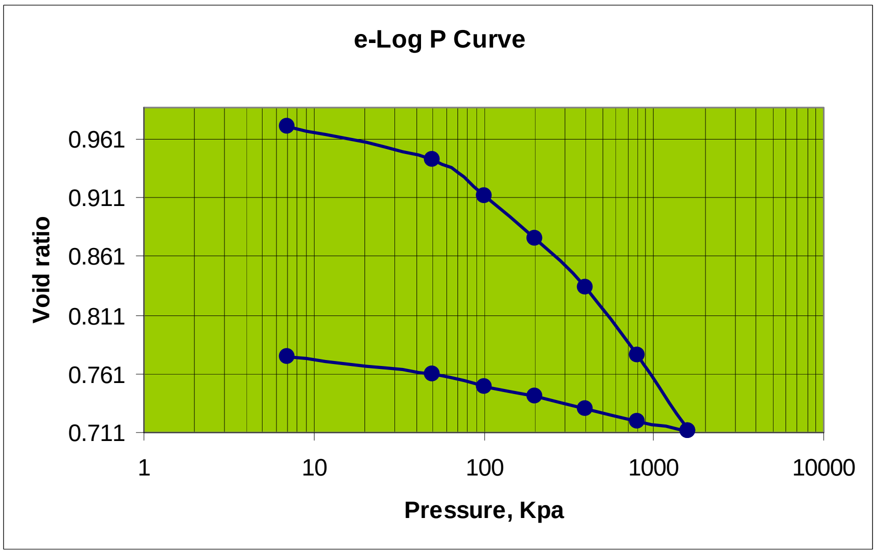
Void ratio at the end of each step of unloading

Loading, KPa	Void ratio, e
1600	0.713
800	0.721
400	0.732
200	0.742
100	0.751
50	0.760
7	0.775



e-Log P Curve

Load, Kpa	Void ratio
7	0.971
50	0.944
100	0.913
200	0.876
400	0.835
800	0.777
1600	0.713
1600	0.713
800	0.721
400	0.732
200	0.742
100	0.751
50	0.760
7	0.775



One dimensional consolidation test for Addisu G. pit #2/ Remolded

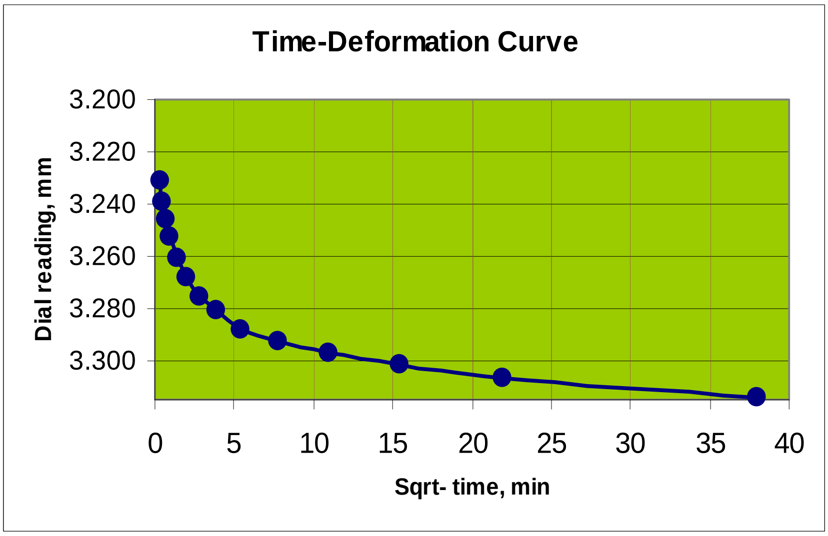
Location:	***Addisu Gebeya***	Job ref.	***Thesis research***
		Pit no.	***#2***
Soil Description:	***Red brown clay***	Sample no.	***#1***
		Depth	***2.5m***
Test method: One dimensional oedometer, BS 1377-5:3		Specific gravity	***2.71***
Sample Type	***Remolded at OMC***	Initial Ht. of specimen, mm	***18***
Height of ring, mm	***20***	Initial mass of specimen, g	***65.79***
Diameter of ring, mm	***50***	Initial bulk density, g/cc	***1.86***
Ini. Moisture content, %	***34***	Initial dry density, g/cc	***1.39***
Final moisture content, %	***30***		

Deformation Versus Time Reading for Different Loadings

Load increment: ***7 KPa – 50 KPa***

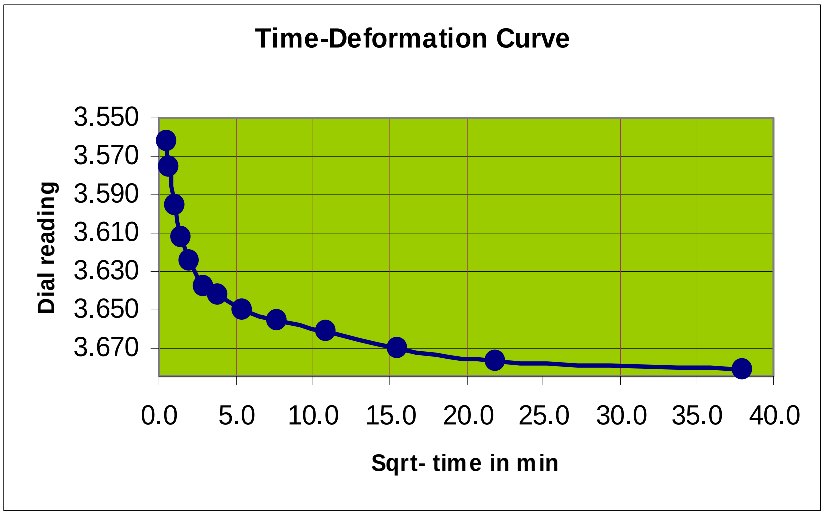
Elapsed Time (min)	Def. Dial Reading (mm)
0	3.000
0.1	3.231
0.25	3.239
0.5	3.246
1	3.253
2	3.261
4	3.268
8	3.276
15	3.281
30	3.288
60	3.293
120	3.297
240	3.302
480	3.307
1440	3.314

Initial height, Ho, mm	***18***
Final height, Hf, mm	***17.69***
Deformation, mm	***0.314***

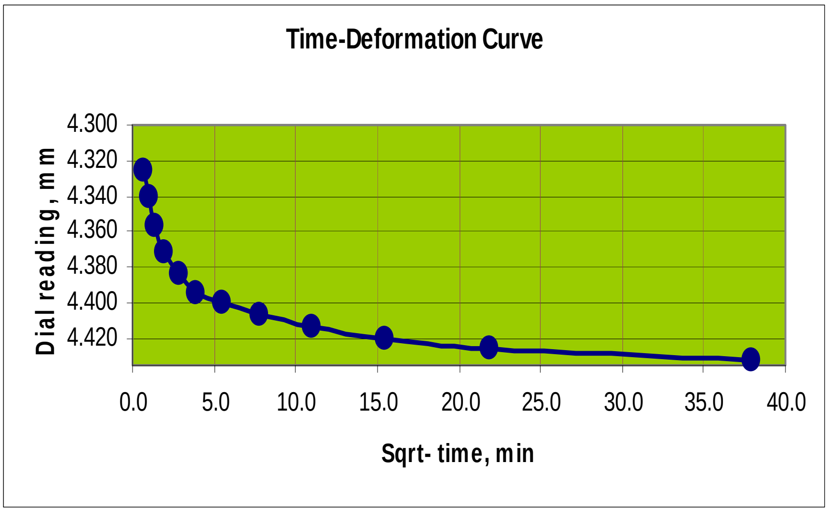


do, mm	***3.094***	Average ht, Ĥ, mm	***17.84***	t90, min	***1.18***
d90,mm	***3.125***	Cv, m²/yr	***29.35***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***50 KPa – 100 KPa***					
Elapsed Time (min)	Def. Dial Reading (mm)	Initial height, Ho, mm	***17.69***		
		Final height, Hf, mm	***17.32***		
		Deformation, mm	***0.496***		
0	3.186				
0.1	3.530				
0.25	3.562				
0.5	3.576				
1	3.596				
2	3.612				
4	3.625				
8	3.638				
15	3.643				
30	3.650				
60	3.656				
120	3.662				
240	3.670				
480	3.677				
1440	3.682				
do, mm	***3.528***	Ĥ, Havg, mm	***17.50***	t90, min	***1.5***
d90,mm	***3.612***	Cv, m^2/yr	***22.67***	Cv = $(0.111*Ĥ^2)/t90$	

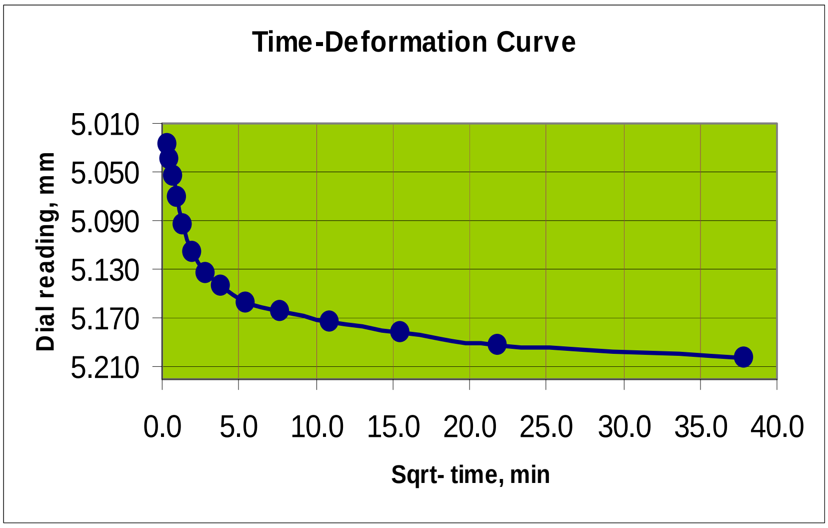


Load increment: ***100 KPa – 200 KPa***			Date	***15/12/01 E.C.***	
Elapsed Time (min)	Def. Dial Reading (mm)	Initial height, Ho, mm	***17.32***		
		Final height, Hf, mm	***16.57***		
		Deformation, mm	***0.75***		
0	3.682				
0.1	4.250				
0.25	4.280				
0.5	4.326				
1	4.340				
2	4.357				
4	4.372				
8	4.384				
15	4.394				
30	4.400				
60	4.406				
120	4.414				
240	4.420				
480	4.425				
1440	4.432				
do, mm	***5.26***	Havg.mm	***16.94***	t90, min	***2.03***
d90,mm	***5.33***	Cv, m^2/yr	***15.70***	Cv = $(0.111*Ĥ^2)/t90$	



Load increment: ***200 KPa – 400 KPa***

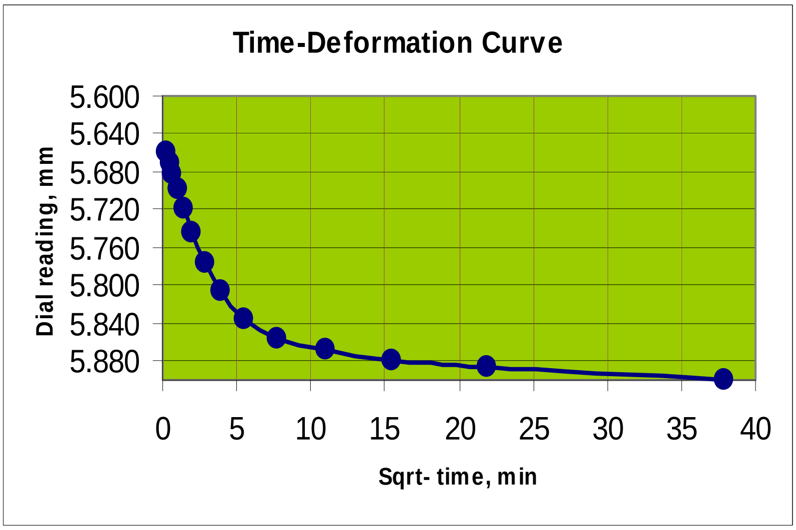
Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***16.57***
		Final height, Hf, mm	***15.80***
		Deformation, mm	***0.771***
0	4.432		
0.1	5.028		
0.25	5.040		
0.5	5.053		
1	5.071		
2	5.093		
4	5.115		
8	5.133		
15	5.144		
30	5.158		
60	5.165		
120	5.174		
240	5.182		
480	5.192		
1440	5.203		



do, mm	***5.01***	Ĥ,Havg.mm	***16.18***	t90, min	***2.24***
d90,mm	***5.115***	Cv, m²/yr	***12.98***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***400 KPa – 800 KPa***

Elapsed Time (min)	Def. Dial Reading (mm)		
		Initial height, Ho, mm	***15.80***
		Final height, Hf, mm	***15.10***
		Deformation, mm	***0.696***
0	5.203		
0.1	5.659		
0.25	5.672		
0.5	5.682		
1	5.698		
2	5.718		
4	5.744		
8	5.777		
15	5.807		
30	5.835		
60	5.856		
120	5.867		
240	5.879		
480	5.887		
1440	5.899		

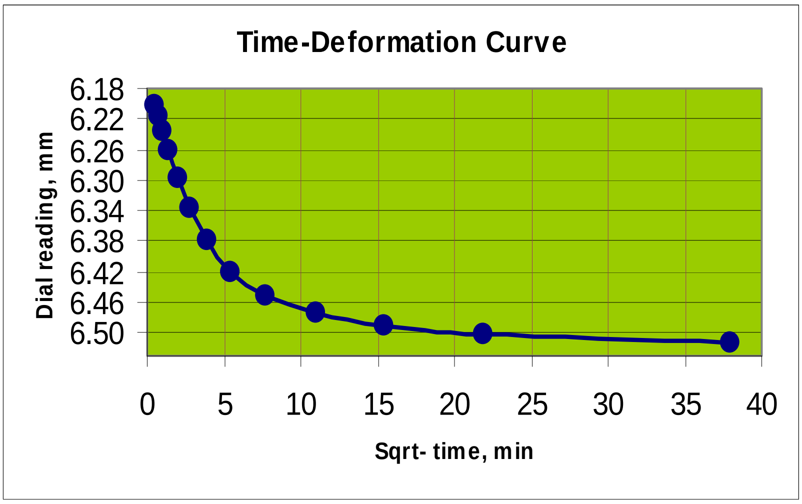


do, mm	***5.64***	Ĥ, Havg, mm	***15.45***	t90, min	***2.35***
d90,mm	***5.755***	Cv, m²/yr	***11.27***	Cv = (0.111*Ĥ²)/t90	

Load increment: ***800 KPa – 1600 KPa***

Initial height, Ho, mm	***15.10***
Final height, Hf, mm	***14.49***
Deformation, mm	***0.61***

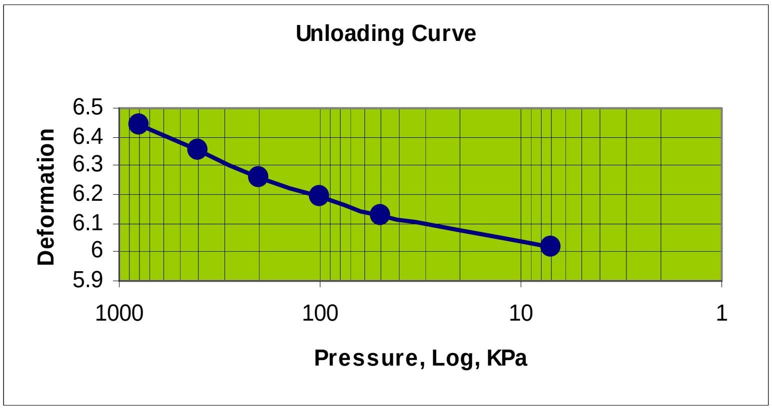
Elapsed Time (min)	Def. Dial Reading (mm)
0	5.899
0.1	6.190
0.25	6.202
0.5	6.216
1	6.236
2	6.262
4	6.298
8	6.337
15	6.378
30	6.422
60	6.452
120	6.475
240	6.490
480	6.502
1440	6.512



do, mm	***6.168***	Ĥ,Havg.mm	***14.79***	t90, min	***2.9***
d90,mm	***6.341***	Cv, m²/yr	***8.38***	Cv = (0.111*Ĥ²)/t90	

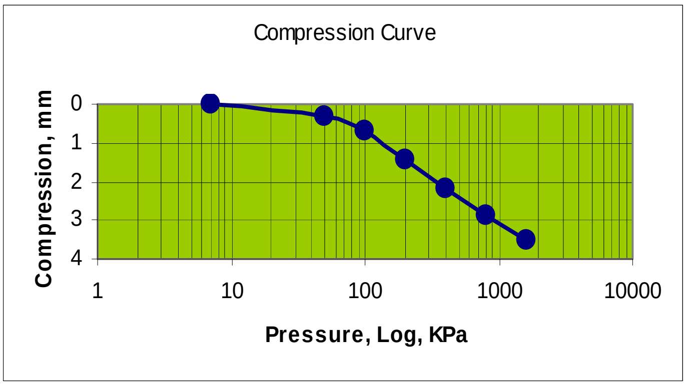
Unloading

Pressure Decrement, KPa	Def. Dial Reading (mm)
1600 -800	6.443
800-400	6.352
400-200	6.262
200-100	6.190
100-50	6.126
50-7	6.016



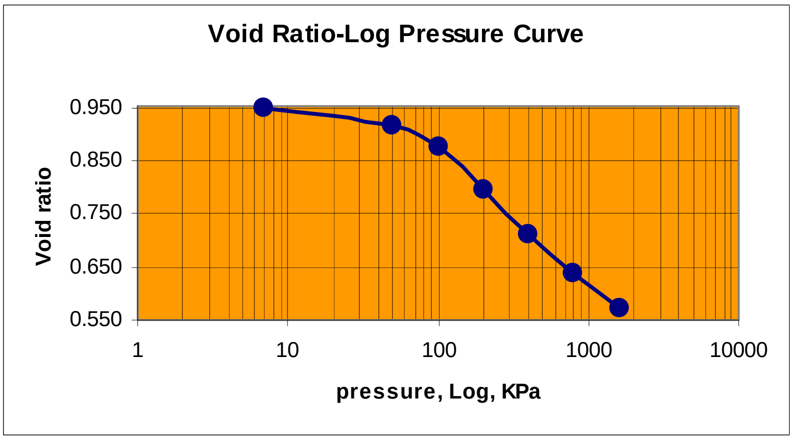
Compression at the end of each loading

Loading, KPa	Deformation ,mm	Ht of Specimen, mm
7	0	18.000
50	0.314	17.686
100	0.682	17.318
200	1.432	16.568
400	2.203	15.797
800	2.899	15.101
1600	3.512	14.488



Void ratio at the end of each loading & Coefficient of compression

Loading, KPa	Void ratio, e
7	0.951
50	0.917
100	0.877
200	0.796
400	0.712
800	0.637
1600	0.570
e=(H-Hs)/Hs	Hs=Ho/(1+eo)
av	***1.18E-04***



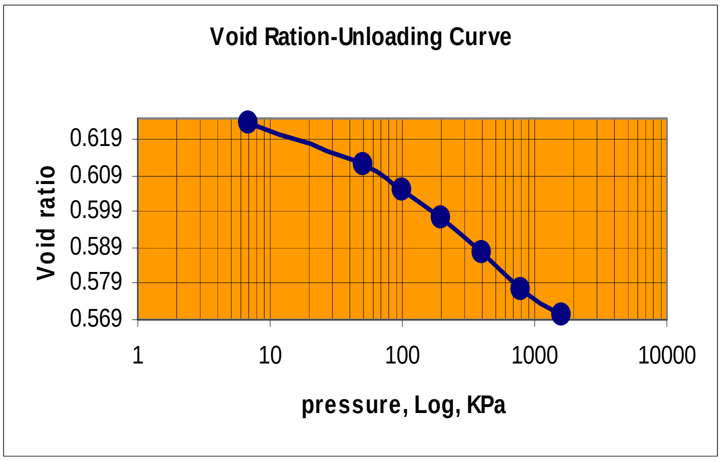
Cc	***0.236***	$C_c = (e_A - e_B)/\log(\sigma_{ZB} - \sigma_{ZA})$		e_A	***0.712***
e_B	***0.570***	σ_{ZA}, Kpa	***400***	σ_{ZB}, Kpa	***1600***

Calculation of Modulus of Elasticity & Volume Compressibility

Loading, P1, Kpa	Loading , P2, Kpa	H1, Ht at start of Compression , mm	H2, Ht at end of Compression , mm	M_v, Modulus of Volume Compressibility, m^2/MN	Modulus of Elasticity, E, MN/m^2
50	7	18	17.69	0.4057	2.465
100	50	17.69	17.32	0.4161	2.403
200	100	17.32	16.57	0.4331	2.3091
400	200	16.57	15.80	0.2327	4.2978
800	400	15.80	15.10	0.1101	9.0787
1600	800	15.10	14.49	0.0507	19.708
$m_v = ((H1-H2)/H1)*(1000/(P2-P1))$		E=1/mv			

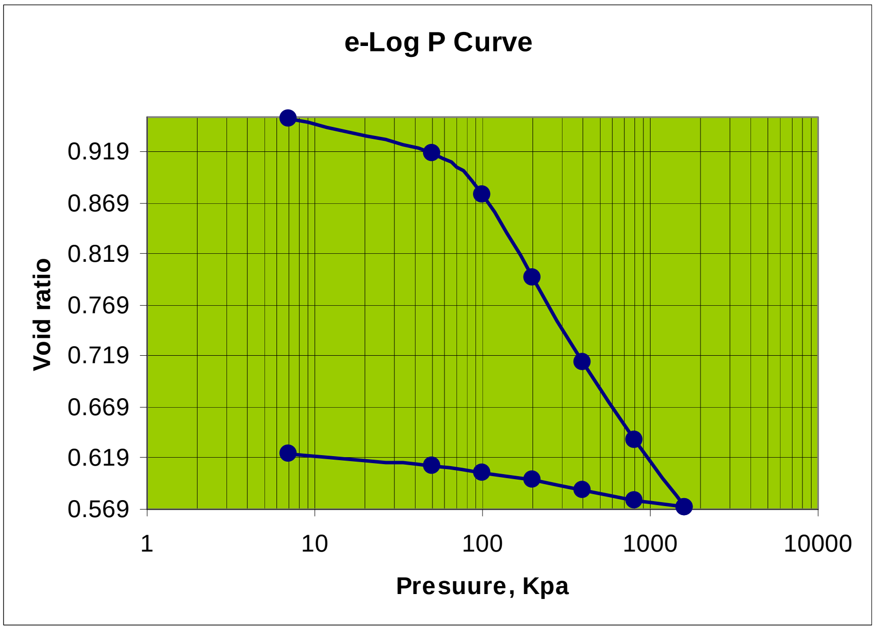
Void ratio at the end of each step of unloading

Loading, KPa	Void ratio, e
1600	0.570
800	0.578
400	0.588
200	0.597
100	0.605
50	0.612
7	0.624



e-Log Curve

Load, Kpa	Void ratio
7	0.951
50	0.917
100	0.877
200	0.796
400	0.712
800	0.637
1600	0.570
1600	0.570
800	0.578
400	0.588
200	0.597
100	0.605
50	0.612
7	0.624

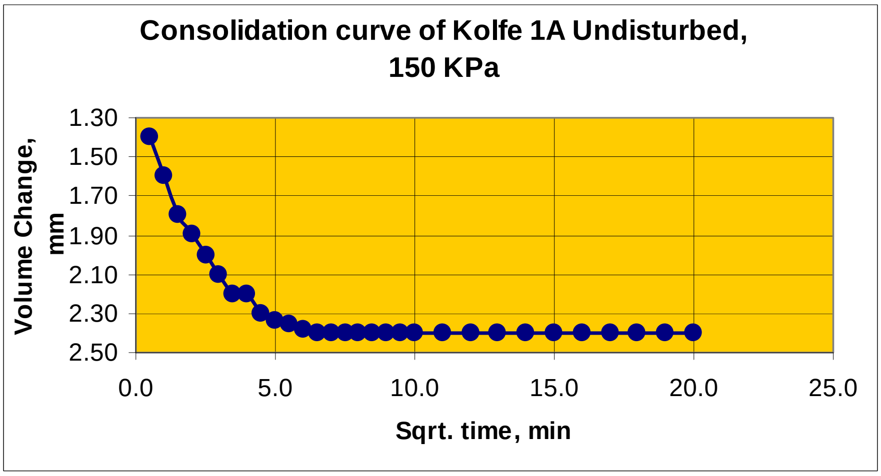


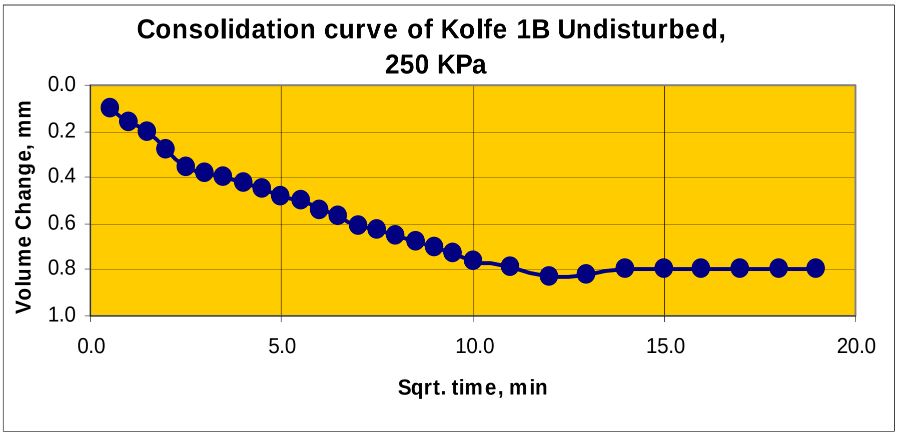
Triaxial compression test result for Kolfe pit #1/Undisturbed

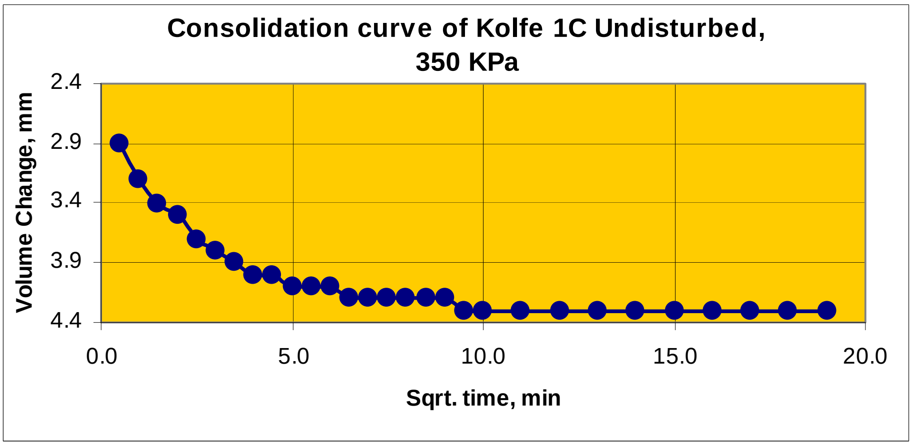
Consolidation Stage Result Kolfe pit 1		
Location: ***Kolfe***	Job ref.	***Thesis research***
Soil Description: Red brown clay	Pit no.	***#1***
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8	Sample no.	***#1***
	Depth	***2.5m***

Undisturbed Sample

Effective Consolidation Pressure 150 Kpa			**Effective Consolidation Pressure 250 Kpa**			**Effective Consolidation Pressure 350 Kpa**		
Initial Condition	CP, Kpa	***450***	**Initial Condition**	CP, Kpa	***550***	**Initial Condition**	CP, Kpa	***750***
	BP, Kpa	**300**		BP, Kpa	***300***		BP, Kpa	**400**
	PP, Kpa	***441***		PP, Kpa	***460***		PP, Kpa	***738***
Final Condition	PP, Kpa	***307***	**Final Condition**	PP, Kpa	**301**	**Final Condition**	PP, Kpa	**413**
	ΔVolume, ml	***2.3***		ΔVolume, ml	***0.8***		ΔVolume, ml	***4.3***
	% Consolidation	**95**		% Consolidation	**95**		% Consolidation	**96**
Sqrt. Time	**ΔVolume, ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume, ml**	**PP, Kpa**	**Sqrt. Time**	**Δ vol, ml**	**PP, Kpa**
0.0	0.00	441	0.0	0.0	457	0.0	0.0	738
0.5	1.40	340	0.5	0.1	405	0.5	2.9	645
1.0	1.60	324	1.0	0.2	401	1.0	3.2	636
2.0	1.90	311	2.0	0.3	401	2.0	3.5	602
3.0	2.10	308	3.0	0.4	398	3.0	3.8	572
4.0	2.20	306	4.0	0.4	397	4.0	4.0	536
5.0	2.34	306	5.0	0.5	394	5.0	4.1	508
6.0	2.38	306	6.0	0.5	391	6.0	4.1	480
7.0	2.40	306	7.0	0.6	383	7.0	4.2	457
8.0	2.40	307	8.0	0.7	376	8.0	4.2	440
9.0	2.40	308	9.0	0.7	371	9.0	4.2	427
10.0	2.40	306	10.0	0.8	362	10.0	4.3	417
15.0	2.40	307	15.0	0.8	335	15.0	4.3	413
16.0	2.40	308	16.0	0.8	330	16.0	4.3	413
17.0	2.40	310	17.0	0.8	328	17.0	4.3	413
18.0	2.40	307	18.0	0.8	324	18.0	4.3	413
19.0	2.40	308	19.0	0.8	323	19.0	4.3	413
20.0	2.40	309	20.0	0.8	320	20.0	4.3	413
21.0	2.40	309	21.0	0.8	319	21.0	4.3	413
22.0	2.40	308	22.0	0.8	318	22.0	4.3	413
23.0	2.40	308	23.0	0.8	317	23.0	4.3	413
24.0	2.30	308	24.0	0.8	317	24.0	4.3	413
25.0	2.30	309	25.0	0.8	316	25.0	4.3	413
26.0	2.30	309	26.0	0.8	316	26.0	4.3	413
27.0	2.30	310	27.0	0.8	316	27.0	4.3	413
28.0	2.30	310	28.0	0.8	316	28.0	4.3	413
29.0	2.30	309	29.0	0.8	317	29.0	4.3	413
30.0	2.30	309	30.0	0.8	315	30.0	4.3	413
31.0	2.30	310	31.0	0.7	313	31.0	4.3	413
32.0	2.30	308	32.0	0.7	311	32.0	4.3	413
33.0	2.30	309	33.0	0.7	309	33.0	4.3	413


Consolidation curve of Kolfe 1A Undisturbed, 150 KPa
Volume Change, mm
1.30
1.50
1.70
1.90
2.10
2.30
2.50
0.0
5.0
10.0
15.0
20.0
25.0
Sqrt. time, min

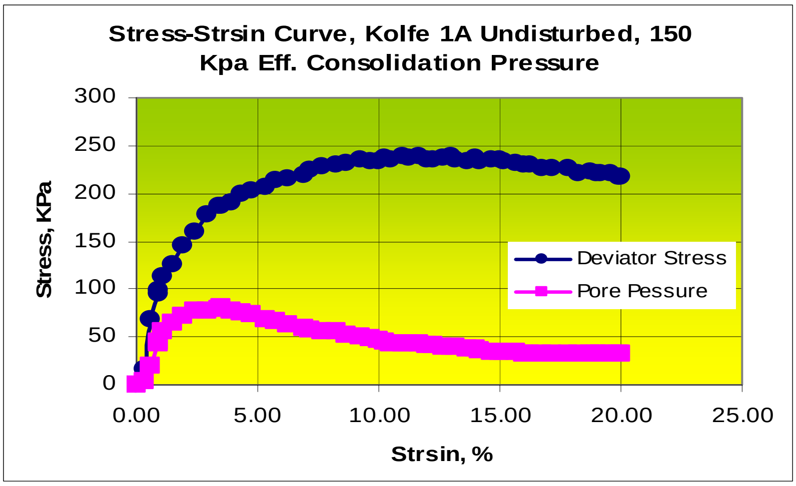

Consolidation curve of Kolfe 1B Undisturbed, 250 KPa
Volume Change, mm
0.0
0.2
0.4
0.6
0.8
1.0
0.0
5.0
10.0
15.0
20.0
Sqrt. time, min

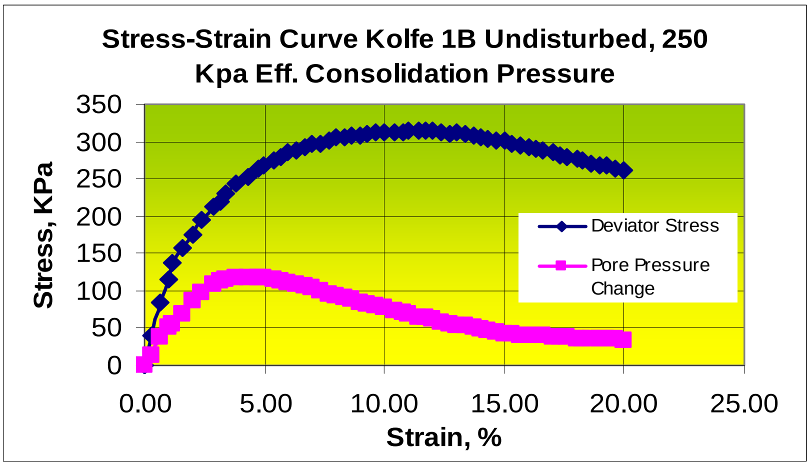

Consolidation curve of Kolfe 1C Undisturbed, 350 KPa
Volume Change, mm
2.4
2.9
3.4
3.9
4.4
0.0
5.0
10.0
15.0
20.0
Sqrt. time, min

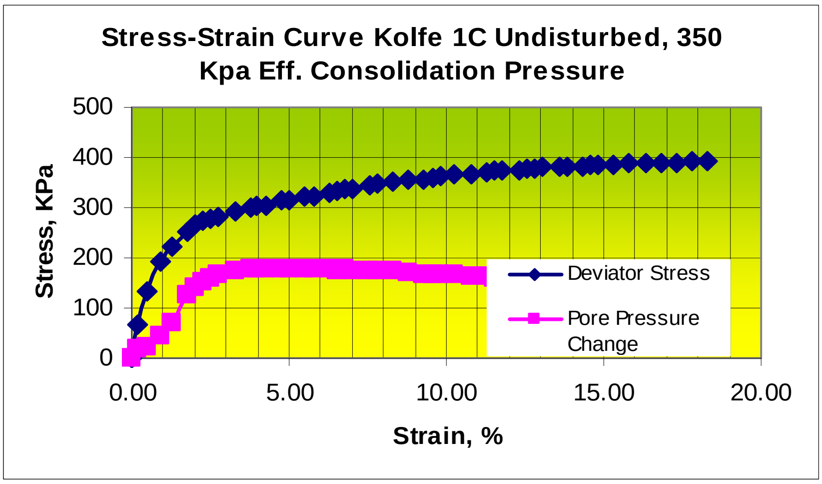
Compression stage Result for 150 KPa Effective Consolidation Pressure								
Location:	***Kolfe***			Job ref.	***Thesis research***			
Soil Description:	Red brown clay			Pit no.	***#1***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#1A***			
				Depth	***2.5m***			
CP, Kpa	***150***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
11.64	**239**	**354**	**43**	**346**	**107**	**227**	**120**	**3.23**
Test result								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.00	0	311	0	150	150	150	0	1.00
0.32	17	315	4	163	146	154	8	1.12
0.60	68	331	20	198	130	164	34	1.52
1.12	113	366	55	208	95	152	57	2.19
1.49	126	375	64	212	86	149	63	2.47
1.91	145	383	72	223	78	150	72	2.86
2.40	161	388	77	234	73	153	80	3.20
3.90	190	389	78	262	72	167	95	3.65
4.31	200	386	75	275	75	175	100	3.67
6.88	220	371	60	310	90	200	110	3.44
7.20	225	369	58	317	92	204	112	3.44
8.64	232	363	52	330	98	214	116	3.37
9.22	235	362	51	334	99	217	118	3.38
10.99	238	355	44	344	106	225	119	3.25
11.64	239	354	43	346	107	227	120	3.23
12.99	238	351	40	348	110	229	119	3.16
13.99	237	348	37	350	113	232	119	3.10
14.20	234	347	36	348	114	231	117	3.05
14.63	235	346	35	350	115	233	118	3.05
14.99	235	346	35	350	115	233	118	3.05
15.20	233	346	35	348	115	232	117	3.03
15.64	231	345	34	347	116	232	116	2.99
15.99	230	344	33	347	117	232	115	2.97
16.29	229	344	33	346	117	232	115	2.96
16.74	227	344	33	344	117	230	113	2.94
17.16	227	344	33	344	117	230	113	2.94
17.83	226	343	32	344	118	231	113	2.91
18.29	222	344	33	339	117	228	111	2.90
18.74	223	343	32	341	118	229	111	2.89
18.99	221	344	33	338	117	227	110	2.89
19.17	221	344	33	338	117	227	110	2.89
19.62	221	344	33	338	117	227	110	2.89
19.95	217	344	33	334	117	225	108	2.85
19.99	217	344	33	334	117	225	108	2.85

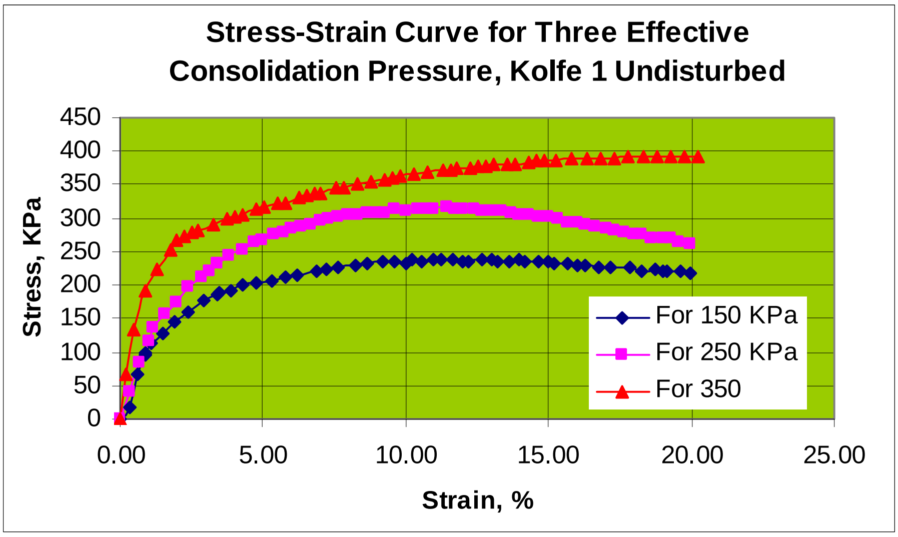
Compression Stage Result for 250 KPa Effective Consolidation Pressure								
Location: ***Kolfe***					Job ref.	***Thesis research***		
Soil Description: Red brown clay					Pit no.	***#1***		
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8					Sample no.	***#1B***		
					Depth	***2.5m***		
CP, Kpa	***250***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
11.42	**315**	**394**	**65**	**500**	**185**	**342**	**158**	**2.71**
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.00	0	329	0	250	250	250	0	1.00
0.32	40	343	14	276	236	256	20	1.17
0.67	85	366	37	298	213	256	43	1.40
1.00	116	379	50	316	200	258	58	1.58
1.18	137	385	56	331	194	262	69	1.71
1.59	156	398	69	337	181	259	78	1.87
1.98	175	415	86	339	164	252	87	2.06
2.39	196	427	98	348	152	250	98	2.29
2.87	213	437	108	354	142	248	106	2.50
3.16	220	441	112	357	138	247	110	2.59
3.41	231	444	115	366	135	250	115	2.72
3.79	245	447	118	376	132	254	122	2.86
4.30	253	447	118	385	132	258	126	2.92
4.72	263	447	118	394	132	263	131	3.00
4.99	267	446	117	400	133	266	134	3.02
5.37	275	444	115	410	135	272	137	3.04
5.70	278	442	113	415	137	276	139	3.03
5.99	285	440	111	424	139	281	142	3.05
6.35	288	438	109	429	141	285	144	3.05
6.68	292	435	106	436	144	290	146	3.03
7.00	296	432	103	443	147	295	148	3.02
8.31	305	421	92	463	158	311	153	2.93
9.62	312	409	81	482	169	325	156	2.84
10.00	311	405	77	485	173	329	156	2.80
11.42	315	394	65	500	185	342	158	2.71
11.73	314	393	64	500	186	343	157	2.69
12.99	311	383	54	507	196	352	156	2.59
13.35	310	381	52	508	198	353	155	2.57
15.00	301	372	43	508	207	358	150	2.45
16.63	287	370	41	496	209	353	144	2.37
17.00	285	366	37	498	213	356	142	2.34
18.59	271	364	36	485	214	350	136	2.27
19.00	269	363	35	484	215	350	134	2.25
19.99	261	362	34	478	216	347	131	2.21

Compression Stage Result for 350 KPa Effective Consolidation Pressure								
Location: ***Kolfe***				Job ref.	***Thesis research***			
Soil Description: Red brown clay				Pit no.	***#1***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#1C***			
				Depth	***2.5m***			
CP, Kpa	***350***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
20.23	**392**	**563**	**142**	**599**	**208**	**403**	**196**	**2.89**
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.00	0	421	0	350	350	350	0	1.00
0.19	67	438	17	400	333	367	34	1.20
0.51	135	445	24	461	326	393	67	1.41
0.91	192	465	44	498	306	402	96	1.63
1.28	224	493	72	502	278	390	112	1.81
1.75	253	547	126	477	224	350	127	2.13
1.99	266	563	142	474	208	341	133	2.28
2.25	274	574	153	471	197	334	137	2.39
2.49	278	582	161	467	189	328	139	2.47
2.74	283	587	166	466	184	325	141	2.54
3.27	291	594	173	468	177	322	146	2.65
3.76	299	598	177	472	173	322	149	2.73
3.99	302	599	178	474	172	323	151	2.76
4.27	304	599	178	476	172	324	152	2.77
4.78	313	600	179	484	171	328	157	2.83
5.02	315	600	179	486	171	329	158	2.84
5.51	321	599	178	493	172	333	161	2.87
5.77	323	598	177	496	173	335	162	2.87
6.28	330	597	176	504	174	339	165	2.90
6.52	333	596	175	508	175	341	167	2.91
7.80	347	594	173	523	177	350	173	2.96
8.30	351	593	172	529	178	353	176	2.98
9.80	363	587	166	547	184	365	182	2.98
10.27	365	587	166	549	184	367	182	2.98
12.29	375	579	158	567	192	379	187	2.95
13.81	381	576	155	576	195	386	191	2.95
14.31	383	573	152	581	198	389	191	2.93
15.82	388	569	148	590	202	396	194	2.92
16.32	389	568	147	592	203	397	195	2.92
18.30	392	564	143	599	207	403	196	2.90
19.74	392	563	142	599	208	403	196	2.89
20.23	392	563	142	599	208	403	196	2.89


Stress-Strsin Curve, Kolfe 1A Undisturbed, 150 Kpa Eff. Consolidation Pressure
Stress, KPa
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strsin, %
Deviator Stress
Pore Pessure

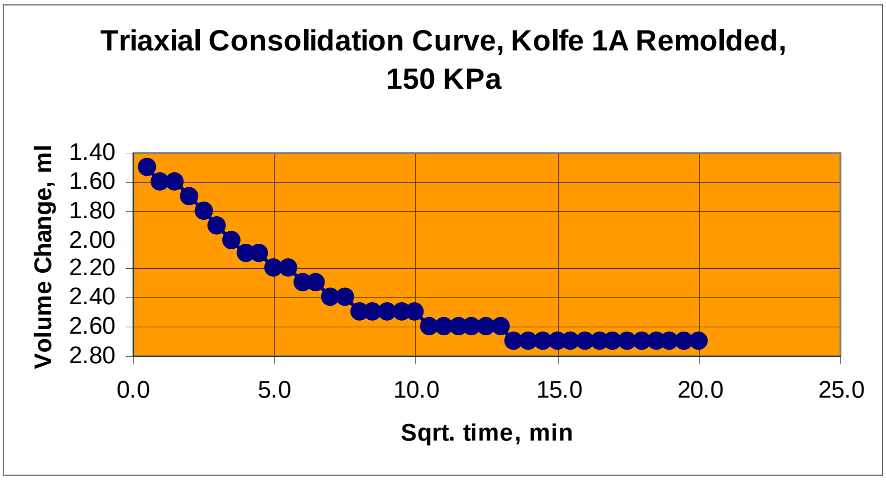

Stress-Strain Curve Kolfe 1B Undisturbed, 250 Kpa Eff. Consolidation Pressure
Stress, KPa
350
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
Deviator Stress
Pore Pressure Change

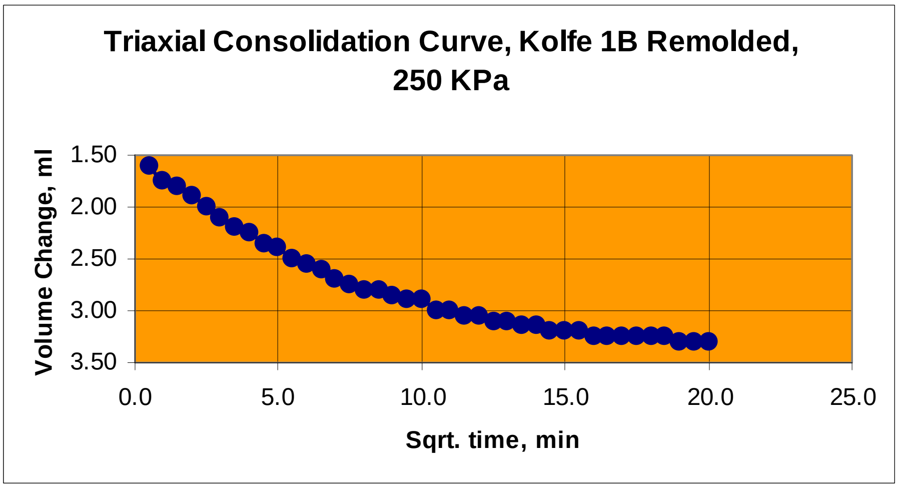

Stress-Strain Curve Kolfe 1C Undisturbed, 350 Kpa Eff. Consolidation Pressure
Stress, KPa
500
400
300
200
100
0
0.00
5.00
10.00
15.00
20.00
Strain, %
Deviator Stress
Pore Pressure Change

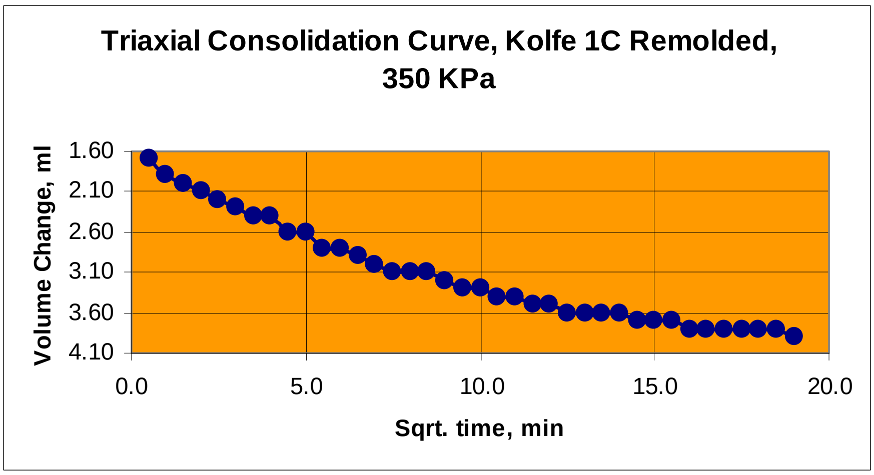

Stress-Strain Curve for Three Effective Consolidation Pressure, Kolfe 1 Undisturbed
Stress, KPa
450
400
350
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
For 150 KPa
For 250 KPa
For 350

Triaxial compression test result for Kolfe pit #1/Remolded

Consolidation Stage Result for Kolfe pit 1 Remolded at OMC								
Location: ***Kolfe***			Job ref.	***Thesis research***				
Soil Description: Red brown clay			Pit no.	***#1***				
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8			Sample no.	***#1A***				
			Depth	***2.5m***				
Remolded Sample								
Effective Consolidation Pressure 150 Kpa			**Effective Consolidation Pressure 250 Kpa**			**Effective Consolidation Pressure 350 Kpa**		
Initial Condition	CP, Kpa	***500***	**Initial Condition**	CP, Kpa	***550***	**Initial Condition**	CP, Kpa	***685***
	BP, Kpa	**350**		BP, Kpa	***300***		BP, Kpa	**335**
	PP, Kpa	***484***		PP, Kpa	***537***		PP, Kpa	***658***
Final Condition	PP, Kpa	**353**	**Final Condition**	PP, Kpa	**308**	**Final Condition**	PP, Kpa	**348**
	ΔVolume,ml	***2.7***		ΔVolume,ml	***3.4***		ΔVolume,ml	***4.1***
	% Cosolidation	**97.7**		% Cosolidation	**96.7**		% Cosolidation	**96.1**
Sqrt. Time	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**
0.0	0.00	484	0.0	0.00	537	0.0	0.00	658
0.5	1.50	353	0.5	1.60	537	0.5	1.70	452
1.0	1.60	352	1.0	1.75	537	1.0	1.90	463
2.0	1.70	352	2.0	1.90	536	2.0	2.10	447
3.0	1.90	352	3.0	2.10	534	3.0	2.30	443
4.0	2.10	351	4.0	2.25	530	4.0	2.40	453
5.0	2.20	351	5.0	2.40	526	5.0	2.60	450
6.0	2.30	351	6.0	2.55	521	6.0	2.80	425
7.0	2.40	353	7.0	2.70	512	7.0	3.00	417
8.0	2.50	352	8.0	2.80	507	8.0	3.10	415
9.0	2.50	352	9.0	2.85	498	9.0	3.20	408
10.0	2.50	352	10.0	2.90	488	10.0	3.30	404
11.0	2.60	351	11.0	3.00	477	11.0	3.40	405
12.0	2.60	352	12.0	3.05	465	12.0	3.50	400
13.0	2.60	351	13.0	3.10	453	13.0	3.60	399
14.0	2.70	351	14.0	3.15	442	14.0	3.60	401
15.0	2.70	353	15.0	3.20	436	15.0	3.70	406
16.0	2.70	353	16.0	3.25	428	16.0	3.80	414
17.0	2.70	352	17.0	3.25	420	17.0	3.80	412
18.0	2.70	352	18.0	3.25	412	18.0	3.80	402
19.0	2.70	351	19.0	3.30	404	19.0	3.90	399
20.0	2.70	353	20.0	3.30	396	20.0	3.90	398
21.0	2.70	353	21.0	3.35	388	21.0	4.00	398
22.0	2.70	352	22.0	3.35	380	22.0	4.00	397
23.0	2.70	351	23.0	3.35	372	23.0	4.00	396
24.0	2.70	353	24.0	3.35	364	24.0	4.00	396
25.0	2.60	355	25.0	3.30	356	25.0	4.00	395
26.0	2.70	354	26.0	3.35	348	26.0	4.00	394
27.0	2.70	354	27.0	3.40	340	27.0	4.10	392
28.0	2.80	352	28.0	3.45	332	28.0	4.10	390
29.0	2.80	353	29.0	3.45	324	29.0	4.10	388
30.0	2.70	355	30.0	3.40	316	30.0	4.10	385


Triaxial Consolidation Curve, Kolfe 1A Remolded, 150 KPa
Volume Change, ml
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
0.0
5.0
10.0
15.0
20.0
25.0
Sqrt. time, min


Triaxial Consolidation Curve, Kolfe 1B Remolded, 250 KPa
Volume Change, ml
1.50
2.00
2.50
3.00
3.50
0.0
5.0
10.0
15.0
20.0
25.0
Sqrt. time, min


Triaxial Consolidation Curve, Kolfe 1C Remolded, 350 KPa
Volume Change, ml
1.60
2.10
2.60
3.10
3.60
4.10
0.0
5.0
10.0
15.0
20.0
Sqrt. time, min

Compression Stage result for 150 KPa Effective Consolidation Pressure, Remolded								
Location: ***Kolfe***			Job ref.	***Thesis research***				
Soil Description: Red brown clay			Pit no.	***#1***				
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8			Sample no.	***#1A***				
			Depth	***2.5m***				
CP, Kpa	***150***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', Kpa	σ1'/σ3'
6.64	**119**	**418**	**65**	**204**	**85**	**144**	**59**	**2.40**
Test results								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', Kpa	σ1'/σ3'
0.00	0	353	0	150	150	150	0	1.00
0.09	1	353	0	151	150	151	1	1.01
0.67	13	354	1	162	149	156	7	1.09
1.00	20	357	4	166	146	156	10	1.14
1.51	44	362	9	185	141	163	22	1.31
1.89	57	366	13	194	137	166	29	1.42
2.64	95	382	29	216	121	169	48	1.79
2.88	100	384	31	219	119	169	50	1.84
3.22	104	389	36	218	114	166	52	1.91
4.99	116	407	54	212	96	154	58	2.20
5.21	115	408	55	210	95	153	58	2.21
6.33	118	416	63	205	87	146	59	2.35
6.64	119	418	65	204	85	144	59	2.40
6.99	119	420	67	202	83	142	59	2.43
7.33	119	422	69	200	81	140	59	2.47
7.66	118	423	70	198	80	139	59	2.48
7.99	118	424	71	197	79	138	59	2.50
8.30	119	425	72	197	78	137	59	2.52
9.63	118	427	74	194	76	135	59	2.55
10.63	117	424	71	196	79	137	58	2.48
11.99	113	420	67	196	83	139	56	2.36
12.30	112	419	66	196	84	140	56	2.33
13.00	110	417	64	196	86	141	55	2.28
13.99	107	414	61	196	89	143	54	2.20
14.63	105	412	59	196	91	144	53	2.16
15.00	104	411	58	196	92	144	52	2.13
16.99	99	405	52	197	98	148	50	2.01
17.26	98	404	51	197	99	148	49	1.99
18.71	94	400	47	198	103	150	47	1.92
19.70	91	396	43	198	107	152	45	1.85
20.00	90	395	42	198	108	153	45	1.83

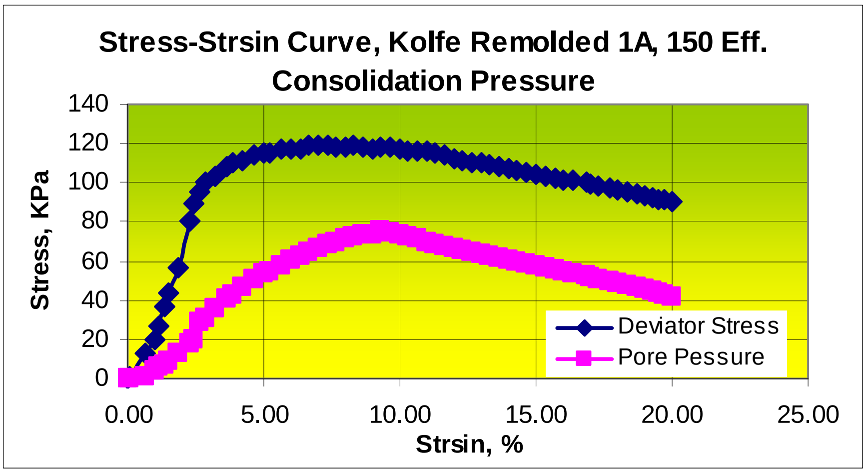
Compression Stage Result for 250 Eff. Consolidation Pressure, Remolded								
Location: ***Kolef***				Job ref.	***Thesis research***			
Soil Description: Red brown clay				Pit no.	***#1***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#1B***			
				Depth	***2.5m***			
CP, Kpa	***250***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', Kpa	σ1'/σ3'
12.84	**223**	**406**	**108**	**366**	**142**	**254**	**112**	**2.57**
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', Kpa	σ1'/σ3'
0.00	0	298	0	250	250	250	0	1.00
0.29	30	305	7	273	243	258	15	1.12
0.87	65	314	15	300	235	267	32	1.28
1.10	89	326	27	311	223	267	44	1.40
2.21	154	361	62	342	188	265	77	1.82
3.18	176	380	82	345	168	257	88	2.05
3.34	179	381	82	346	168	257	89	2.06
4.22	187	385	86	351	164	257	94	2.14
5.49	197	390	92	355	158	257	99	2.25
6.88	205	398	99	356	151	253	102	2.36
7.00	208	398	99	358	151	255	104	2.38
8.20	213	403	104	359	146	253	107	2.46
9.45	218	407	108	360	142	251	109	2.54
9.70	218	407	109	359	141	250	109	2.54
9.83	219	408	110	360	140	250	110	2.56
10.00	216	408	110	357	140	249	108	2.54
10.29	218	409	110	357	140	249	109	2.56
10.49	217	409	110	357	140	248	109	2.55
10.71	221	409	111	360	139	249	110	2.59
10.95	218	409	111	357	139	248	109	2.57
11.00	220	409	111	359	139	249	110	2.58
11.83	221	409	111	360	139	250	111	2.59
12.84	223	406	108	366	142	254	112	2.57
13.07	223	405	106	367	144	255	111	2.55
14.26	221	400	101	369	149	259	110	2.48
15.07	218	398	99	368	151	259	109	2.44
16.15	213	395	97	367	153	260	107	2.39
17.23	209	392	94	365	156	261	104	2.34
18.04	206	390	92	364	158	261	103	2.30
19.12	201	388	89	362	161	262	101	2.25
20.20	197	385	86	361	164	262	99	2.20

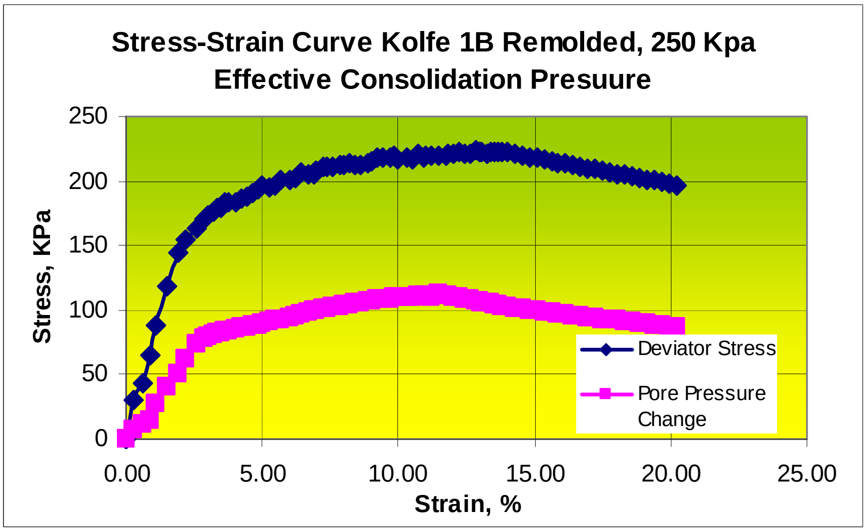
Compression Stage Result for 350 KPa Effective Consolidation Pressure, Remolded			
Location: ***Kolfe***		Job ref.	***Thesis research***
Soil Description: Red brown clay		Pit no.	***#1***
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8		Sample no.	***#1***
		Depth	***2.5m***
CP, Kpa	***350***		

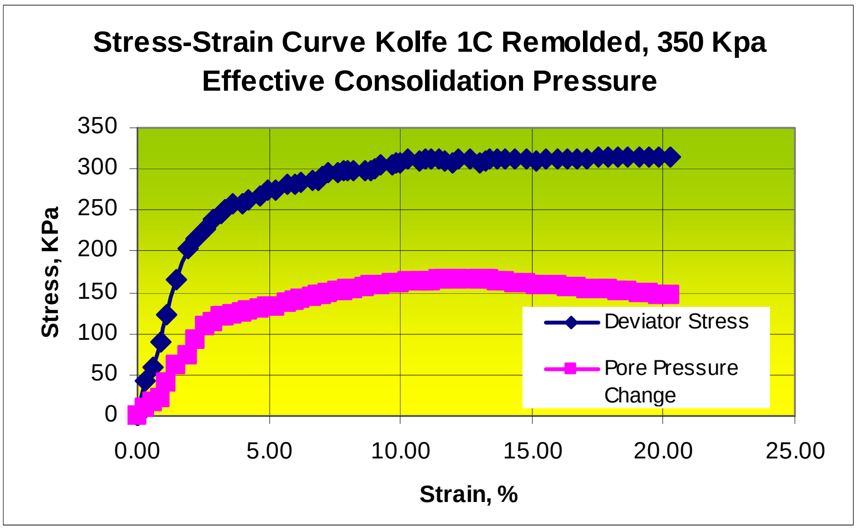
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', Kpa	σ1'/σ3'
20.23	**315**	**508**	**146**	**518**	**204**	**361**	**157**	**2.55**

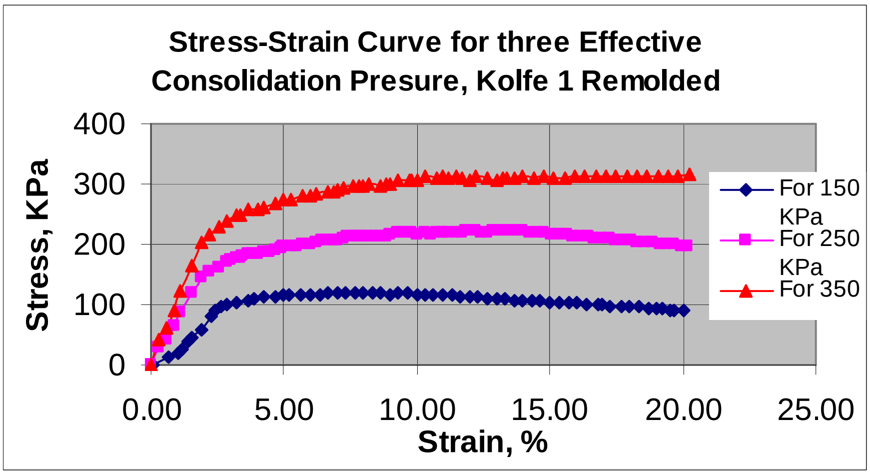
Test results

Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', Kpa	σ1'/σ3'
0.00	0	362	0	350	350	350	0	1.00
0.29	42	372	10	382	340	361	21	1.12
0.60	60	379	17	393	333	363	30	1.18
1.10	124	402	40	434	310	372	62	1.40
1.51	165	422	61	454	289	372	83	1.57
1.90	202	435	74	479	276	377	101	1.73
2.21	216	454	92	474	258	366	108	1.84
2.59	228	470	108	470	242	356	114	1.94
3.34	250	483	121	479	229	354	125	2.09
3.64	257	485	123	484	227	355	129	2.13
4.00	258	488	126	482	224	353	129	2.15
4.22	262	489	127	485	223	354	131	2.18
4.66	267	491	129	488	221	354	134	2.21
4.99	275	493	131	494	219	356	138	2.26
5.26	274	495	133	491	217	354	137	2.26
6.88	287	508	146	491	204	347	144	2.41
7.00	291	508	146	495	204	349	146	2.43
8.88	299	520	159	490	191	341	150	2.56
9.00	301	520	159	492	191	342	151	2.57
10.95	312	525	164	498	186	342	156	2.67
11.16	311	525	164	497	186	342	156	2.67
12.99	308	528	167	491	183	337	154	2.68
13.22	310	527	166	494	184	339	155	2.68
14.38	311	523	162	499	188	344	156	2.65
15.94	313	519	158	505	192	349	156	2.63
16.33	313	518	157	506	193	350	157	2.62
17.89	314	514	153	511	197	354	157	2.59
18.28	314	513	152	512	198	355	157	2.58
19.45	314	510	149	516	201	359	157	2.56
20.23	315	508	146	518	204	361	157	2.55


Stress-Strsin Curve, Kolfe Remolded 1A, 150 Eff. Consolidation Pressure
Stress, KPa
140
120
100
80
60
40
20
0
0.00
5.00
10.00
15.00
20.00
25.00
Strsin, %
Deviator Stress
Pore Pessure

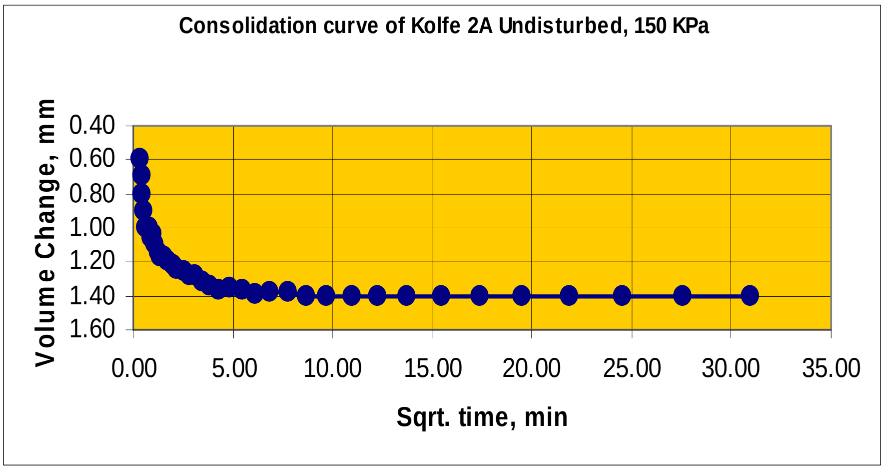

Stress-Strain Curve Kolfe 1B Remolded, 250 Kpa Effective Consolidation Presuure
Stress, KPa
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
Deviator Stress
Pore Pressure Change

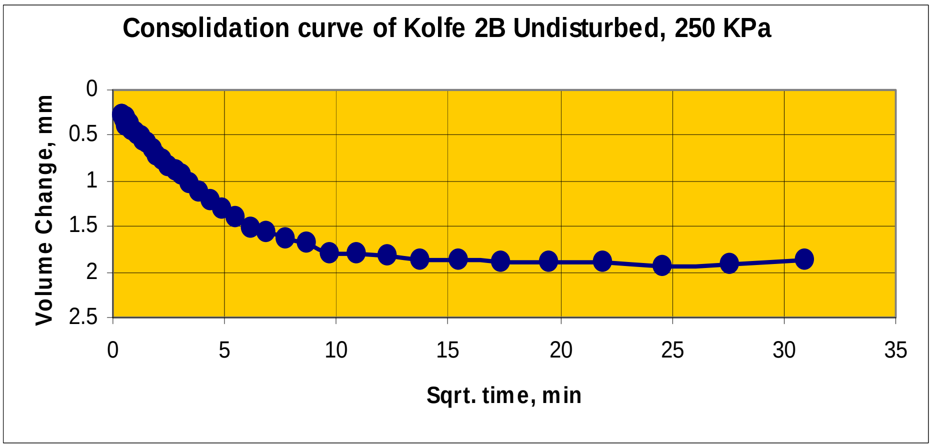

Stress-Strain Curve Kolfe 1C Remolded, 350 Kpa Effective Consolidation Pressure
Stress, KPa
350
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
Deviator Stress
Pore Pressure Change

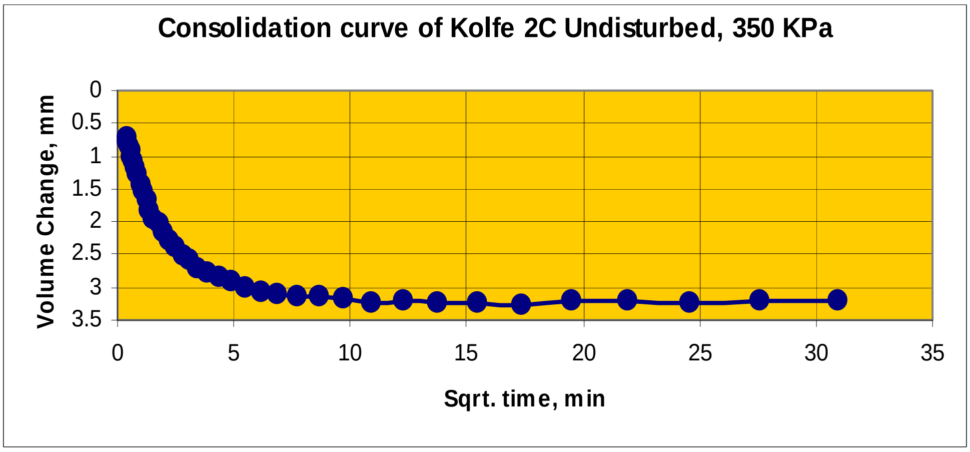

Stress-Strain Curve for three Effective Consolidation Presure, Kolfe 1 Remolded
Stress, KPa
400
300
200
100
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
For 150 KPa
For 250 KPa
For 350

Triaxial compression test result for Kolfe pit #2/ Undisturbed

Consolidation Stage Result								
Location: ***Kolfe***				Job ref.	***Thesis research***			
Soil Description: Red brown clay				Pit no.	***#2***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#1***			
				Depth	***2.5m***			
Undisturbed Sample								
Effective Consolidation Pressure 150 Kpa			**Effective Consolidation Pressure 250 Kpa**			**Effective Consolidation Pressure 350 Kpa**		
Initial Condition	CP, Kpa	***450***	**Initial Condition**	CP, Kpa	***650***	**Initial Condition**	CP, Kpa	***600***
	BP, Kpa	**300**		BP, Kpa	***400***		BP, Kpa	**250**
	PP, Kpa	***450***		PP, Kpa	***532***		PP, Kpa	***572***
Final Condition	PP, Kpa	**305**	**Final Condition**	PP, Kpa	**405**	**Final Condition**	PP, Kpa	**250.4**
	ΔVolume,ml	***1.4***		ΔVolume,ml	***1.9***		ΔVolume,ml	***3.2***
	% Consolidation	**97**		% Consolidation	**98**		% Consolidation	**99.9**
Sqrt. Time	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**
0.00	0.00	450	0	0	531.9	0	0	572.0
0.39	0.60	450	0.39	0.29	531.1	0.39	0.71	569.1
0.71	1.00	369	0.71	0.36	527.2	0.71	1.07	550.9
0.80	1.00	358	0.8	0.37	526.0	0.8	1.19	543.1
0.89	1.06	349	0.89	0.45	523.9	0.89	1.27	532.4
1.00	1.03	342	1	0.47	521.7	1	1.43	519.0
1.13	1.10	336	1.13	0.5	519.0	1.13	1.54	500.9
1.26	1.15	333	1.26	0.52	515.8	1.26	1.66	479.4
1.41	1.17	329	1.41	0.55	512.1	1.41	1.82	454.3
1.59	1.17	326	1.59	0.58	507.8	1.59	1.95	429.2
1.78	1.20	324	1.78	0.65	502.5	1.78	2.03	404.5
2.00	1.22	322	2	0.73	496.2	2	2.16	381.5
2.24	1.25	320	2.24	0.77	489.6	2.24	2.28	361.4
2.52	1.26	318	2.52	0.85	481.6	2.52	2.39	343.5
2.83	1.28	317	2.83	0.89	472.5	2.83	2.52	328.6
3.07	1.28	317	3.07	0.93	465.0	3.07	2.58	318.9
3.45	1.32	317	3.45	1.02	453.2	3.45	2.7	306.1
3.87	1.35	315	3.87	1.11	439.3	3.87	2.79	294.3
4.35	1.36	315	4.35	1.22	424.3	4.35	2.85	283.8
4.88	1.36	315	4.88	1.31	407.7	4.88	2.91	274.5
5.48	1.37	315	5.48	1.4	390.6	5.48	3.01	268.1
6.15	1.39	314	6.15	1.51	373.5	6.15	3.06	262.7
6.90	1.38	313	6.9	1.56	358.0	6.9	3.12	259.0
7.75	1.38	313	7.75	1.64	343.0	7.75	3.14	256.3
8.72	1.40	313	8.72	1.69	330.7	8.72	3.15	254.7
9.75	1.40	313	9.75	1.79	322.1	9.75	3.16	253.6
10.95	1.40	313	10.95	1.79	315.7	10.95	3.23	252.8
12.29	1.40	313	12.29	1.82	311.4	12.29	3.22	252.0
13.78	1.40	313	13.78	1.88	309.3	13.78	3.25	251.5
15.49	1.40	313	15.49	1.87	307.1	15.49	3.23	251.0
17.38	1.40	313	17.38	1.9	306.1	17.38	3.27	251.0
19.52	1.40	313	19.52	1.89	305.0	19.52	3.22	250.4
21.91	1.40	313	21.91	1.9	304.5	21.91	3.22	250.4
24.60	1.40	313	24.6	1.93	303.9	24.6	3.23	249.9
27.60	1.40	313	27.6	1.92	303.6	27.6	3.21	249.9
30.98	1.40	313	30.98	1.88	303.9	30.98	3.19	249.4


Consolidation curve of Kolfe 2A Undisturbed, 150 KPa
Volume Change, mm
0.40
0.60
0.80
1.00
1.20
1.40
1.60
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Sqrt. time, min

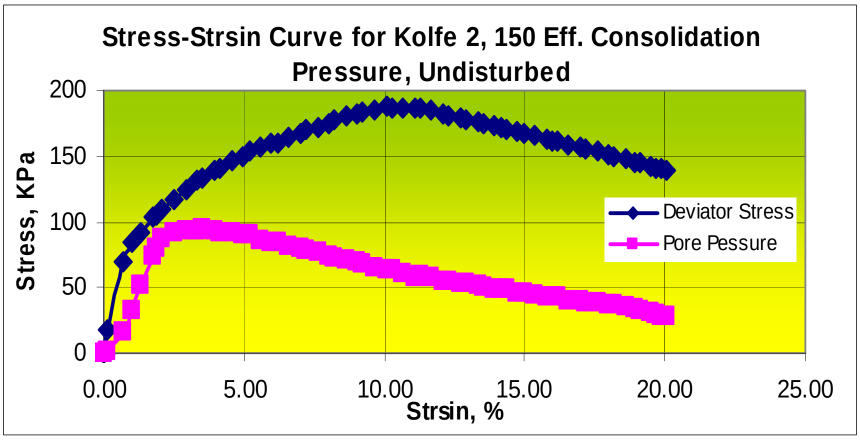

Consolidation curve of Kolfe 2B Undisturbed, 250 KPa
Volume Change, mm
0
0.5
1
1.5
2
2.5
0
5
10
15
20
25
30
35
Sqrt. time, min

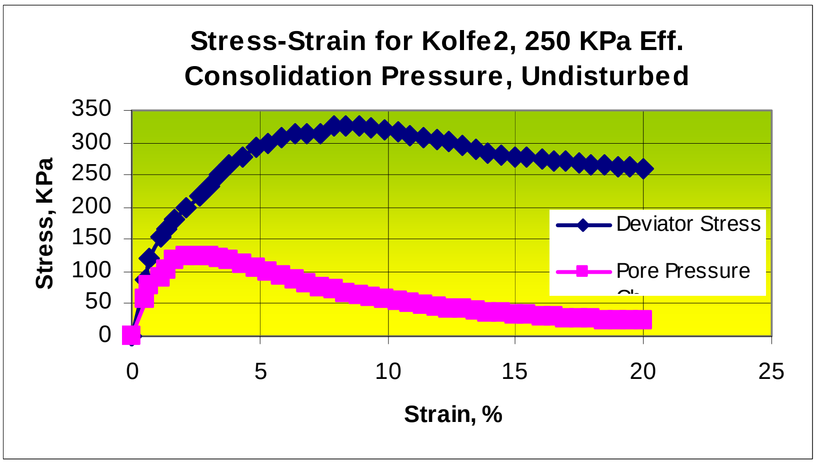

Consolidation curve of Kolfe 2C Undisturbed, 350 KPa
Volume Change, mm
0
0.5
1
1.5
2
2.5
3
3.5
0
5
10
15
20
25
30
35
Sqrt. time, min

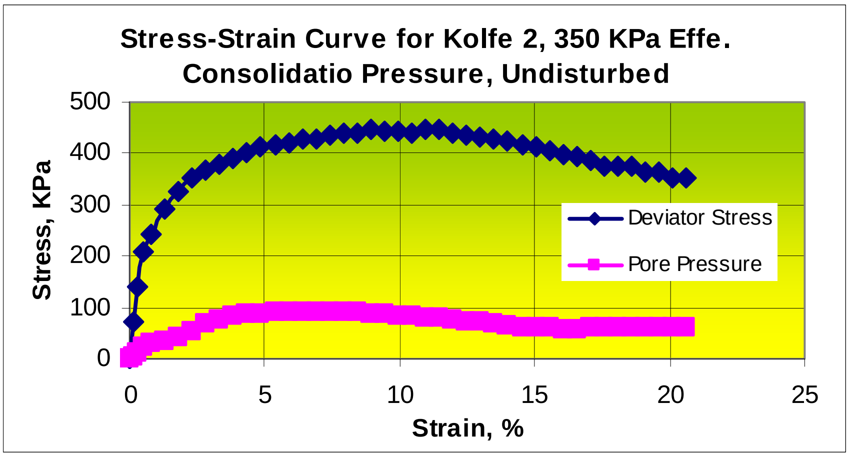
Compression Stage Result for 150 KPa Eff. Consolidation Pressure								
Location:	***Kolfe***			Job ref.	***Thesis research***			
Soil Description:	Red brown clay			Pit no.	***#2***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#2A***			
				Depth	***2.5m***			
CP, Kpa	***150***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
10.06	**188**	**371**	**64**	**274**	**86**	**180**	**94**	**3.19**
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.00	0	306	0	150	150	150	0	1.00
0.13	18	308	2	166	148	157	9	1.12
0.68	69	322	16	204	134	169	35	1.52
1.00	84	339	33	201	117	159	42	1.71
1.31	91	358	51	190	99	144	46	1.93
2.10	109	394	88	171	62	117	55	2.76
3.94	140	399	93	197	57	127	70	3.45
4.14	140	398	92	199	58	128	70	3.42
5.96	160	391	85	225	65	145	80	3.46
6.17	161	391	85	226	65	145	80	3.47
7.62	172	383	77	245	73	159	86	3.36
8.03	174	380	74	250	76	163	87	3.29
8.23	179	379	73	255	77	166	89	3.32
8.63	181	377	71	260	79	169	90	3.29
9.03	182	375	69	263	81	172	91	3.25
9.23	184	374	68	265	82	174	92	3.24
9.65	186	371	65	271	85	178	93	3.19
10.06	188	371	64	274	86	180	94	3.19
11.07	187	365	58	279	92	185	93	3.04
12.70	179	360	53	276	97	186	90	2.85
12.91	178	360	53	275	97	186	89	2.84
13.32	176	358	51	275	99	187	88	2.78
13.53	175	357	50	275	100	187	87	2.76
13.91	173	356	49	273	101	187	86	2.72
14.14	172	356	49	272	101	186	86	2.71
14.33	171	355	48	272	102	187	85	2.68
14.72	168	353	46	272	104	188	84	2.63
15.33	165	351	44	271	106	188	83	2.57
16.98	157	346	40	267	110	189	78	2.42
17.17	156	345	39	267	111	189	78	2.40
18.95	146	340	34	262	116	189	73	2.25
19.13	145	339	33	262	117	190	72	2.23
20.02	139	334	28	262	122	192	70	2.14

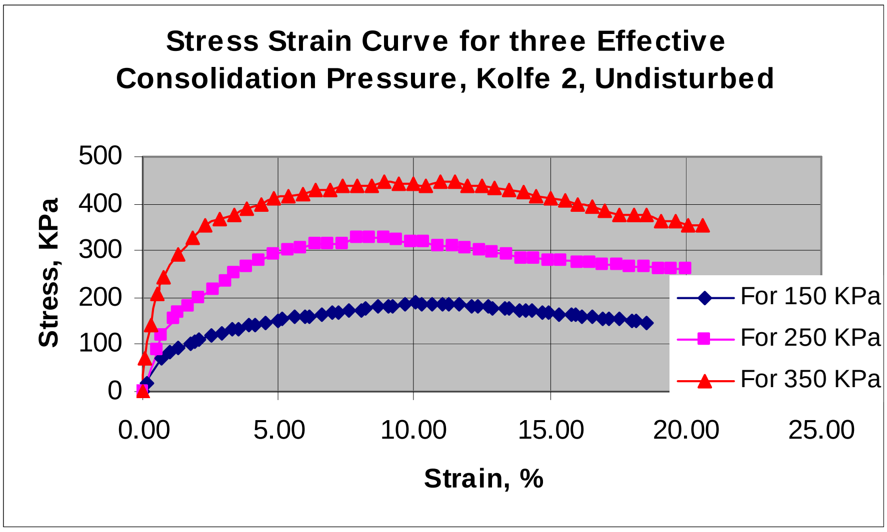
Compression Stage Result for 250 KPa Eff. Consolidation Pressure								
Location: **Kolfe**				Job ref.	**Thesis research**			
Soil Description: Red brown clay				Pit no.	**#2**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	**#2B**			
				Depth	**2.5m**			
CP, Kpa	**250**							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', KPa	σ1'/σ3'
7.87	**326**	**479**	**72**	**504**	**178**	**341**	**163**	**2.82**
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', KPa	σ1'/σ3'
0	0	408	0	250	250	250	0	1.00
0.5	88	465	57	281	193	237	44	1.46
0.67	121	486	78	293	172	232	61	1.70
1.13	153	500	92	311	158	235	77	1.97
1.33	166	510	102	314	148	231	83	2.12
1.66	182	525	117	315	133	224	91	2.37
2.09	200	531	123	327	127	227	100	2.57
2.63	218	533	125	344	125	235	109	2.74
3.82	267	525	117	400	133	266	133	3.00
4.33	277	520	112	415	138	276	139	3.01
4.84	293	514	106	437	144	290	147	3.04
5.34	299	507	100	450	150	300	150	2.99
5.85	306	501	93	463	157	310	153	2.95
6.35	312	495	87	476	163	319	156	2.92
6.86	315	489	81	484	169	327	158	2.86
7.36	315	484	76	489	174	332	158	2.81
7.87	326	479	72	504	178	341	163	2.82
8.37	326	475	67	508	183	346	163	2.78
8.88	326	471	63	513	187	350	163	2.74
9.38	322	468	60	513	190	351	161	2.69
9.89	319	464	56	513	194	353	159	2.64
10.39	317	461	53	514	197	355	158	2.61
11.91	305	454	46	509	204	356	152	2.49
12.41	302	451	43	508	207	358	151	2.46
13.43	290	447	39	501	211	356	145	2.37
14.94	279	441	33	496	217	356	140	2.29
15.45	277	440	32	495	218	356	139	2.27
16.96	271	436	28	493	222	358	136	2.22
17.47	269	435	27	492	223	358	135	2.21
18.99	263	433	25	488	225	357	132	2.17
19.49	261	432	24	487	226	356	131	2.16
20.00	259	432	24	485	226	355	130	2.15

Compression Stage Result for 350 Eff. Consolidation Pressure								
Location: ***Kolfe***				Job ref.	***Thesis research***			
Soil Description: Red brown clay				Pit no.	***#2***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#2C***			
				Depth	***2.5m***			
CP, Kpa	***350***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', ,kpa	σ1'/σ3'
8.93	**447**	**492**	**87**	**710**	**263**	**486**	**224**	**2.7**
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', ,kpa	σ1'/σ3'
0	0	405	0	350	350	350	0	1.00
0.11	71	410	5	416	345	381	36	1.21
0.28	141	415	10	481	340	411	71	1.42
0.51	210	426	21	539	329	434	105	1.64
0.79	244	434	29	565	321	443	122	1.76
1.3	291	439	34	607	316	462	146	1.92
1.81	326	447	42	634	308	471	163	2.06
2.32	354	459	54	650	296	473	177	2.19
2.83	366	472	67	649	283	466	183	2.29
3.34	378	481	76	652	274	463	189	2.38
3.85	390	488	83	658	268	463	195	2.46
4.35	400	491	86	664	264	464	200	2.52
4.86	413	494	89	674	261	468	207	2.58
5.37	417	497	92	675	258	467	209	2.61
5.88	420	498	93	677	257	467	210	2.63
6.39	428	498	93	685	257	471	214	2.66
6.89	428	498	93	685	257	471	214	2.66
7.4	436	497	92	694	258	476	218	2.69
8.93	447	492	87	710	263	486	224	2.70
9.43	443	492	87	706	263	485	222	2.68
10.96	447	485	80	717	270	493	224	2.66
11.47	447	483	78	719	272	496	224	2.64
12.99	432	475	70	712	280	496	216	2.54
13.5	428	473	68	711	283	497	214	2.52
14.01	425	470	65	710	285	498	213	2.49
15.53	406	465	60	697	291	494	203	2.40
16.04	398	464	59	689	291	490	199	2.37
17.57	375	465	60	665	290	478	188	2.29
18.07	375	465	60	665	290	478	188	2.29
19.09	364	465	60	654	290	472	182	2.26
20.11	352	465	60	643	291	467	176	2.21


Stress-Strsin Curve for Kolfe 2, 150 Eff. Consolidation Pressure, Undisturbed
Stress, KPa
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strsin, %
Deviator Stress
Pore Pessure

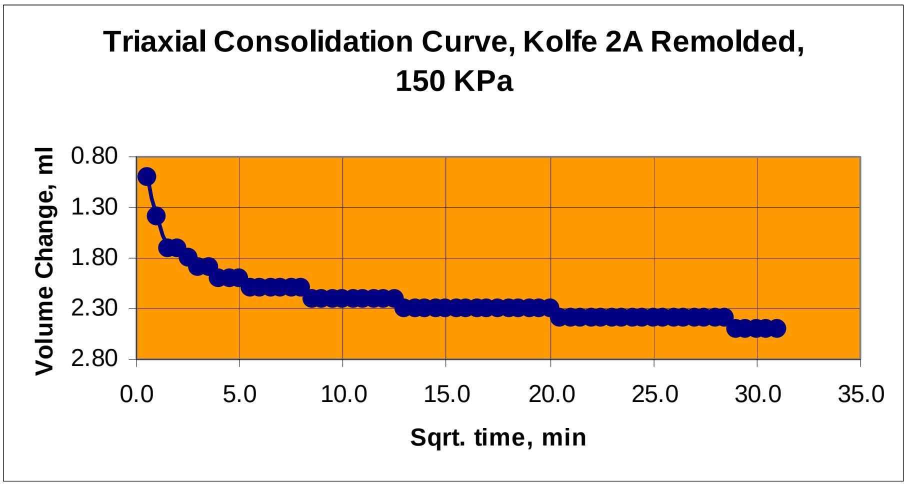

Stress-Strain for Kolfe2, 250 KPa Eff. Consolidation Pressure, Undisturbed
Stress, KPa
350
300
250
200
150
100
50
0
0
5
10
15
20
25
Strain, %
Deviator Stress
Pore Pressure

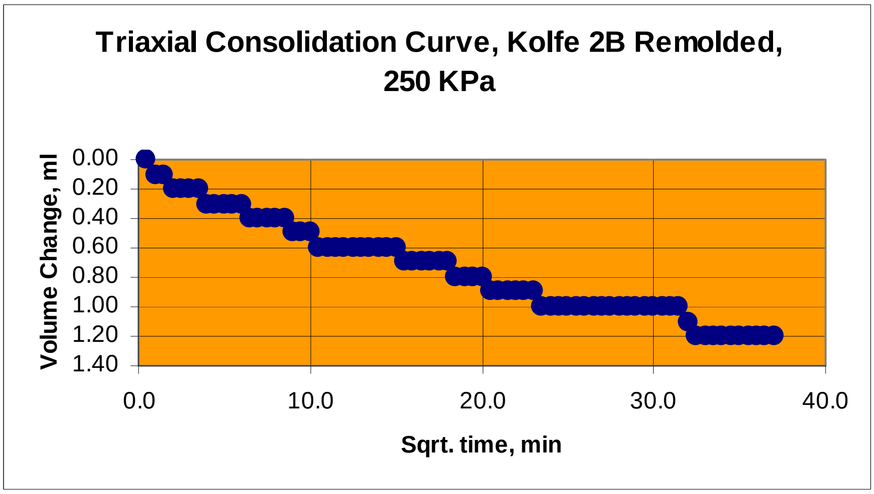

Stress-Strain Curve for Kolfe 2, 350 KPa Effe. Consolidatio Pressure, Undisturbed
Stress, KPa
500
400
300
200
100
0
0
5
10
15
20
25
Strain, %
Deviator Stress
Pore Pressure

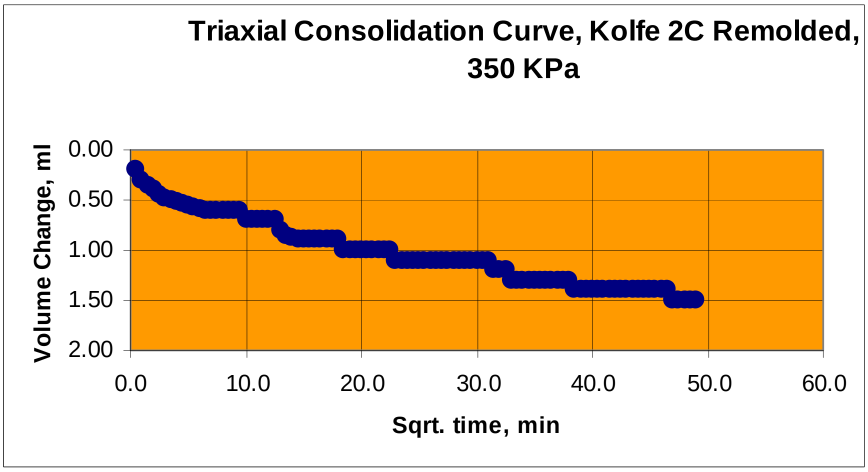

Stress Strain Curve for three Effective Consolidation Pressure, Kolfe 2, Undisturbed
Stress, KPa
500
400
300
200
100
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
For 150 KPa
For 250 KPa
For 350 KPa

Triaxial compression test result for Kolfe pit #2/ Remolded

Consolidation Stage Result for Kolfe Pit 2 Undisturbed								
Location: ***Kolfe***				Job ref.	***Thesis research***			
Soil Description: Red brown clay				Pit no.	***#2***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#1***			
				Depth	***2.5m***			
Remolded Sample								
Effective Consolidation Pressure 150 Kpa			**Effective Consolidation Pressure 250 Kpa**			**Effective Consolidation Pressure 350 Kpa**		
Initial Condition	CP, Kpa	***550***	**Initial Condition**	CP, Kpa	***550***	**Initial Condition**	CP, Kpa	***650***
	BP, Kpa	**400**		BP, Kpa	***300***		BP, Kpa	**300**
	PP, Kpa	***557***		PP, Kpa	***537***		PP, Kpa	***632***
Final Condition	PP, Kpa	**405**	**Final Condition**	PP, Kpa	**309**	**Final Condition**	PP, Kpa	**302**
	ΔVolume,ml	***2.5***		ΔVolume,ml	***96***		ΔVolume,ml	***1.5***
	% Consolidation	**97**		% Consolidation			% Consolidation	**99**
Sqrt. Time	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**
0.0	0.00	557	0.0	0.00	537.0	0.0	0.00	632
0.5	1.00	555	0.5	0.00	537.0	0.5	0.20	632
2.5	1.80	512	2.5	0.20	535.0	2.5	0.45	632
5.0	2.00	485	5.0	0.30	526.0	5.0	0.56	630
10.0	2.20	449	10.0	0.50	488.0	10.0	0.70	615
11.0	2.20	443	11.0	0.60	477.0	11.0	0.70	611
12.0	2.20	436	12.0	0.60	466.0	12.0	0.70	609
12.5	2.20	434	12.5	0.60	461.0	12.5	0.70	605
13.0	2.30	431	13.0	0.60	455.0	13.0	0.80	602
14.0	2.30	426	14.0	0.60	445.0	14.0	0.87	597
15.0	2.30	423	15.0	0.60	436.0	15.0	0.90	593
16.0	2.30	420	16.0	0.70	428.0	16.0	0.90	587
17.0	2.30	418	17.0	0.70	420.0	17.0	0.90	579
18.0	2.30	415	18.0	0.70	411.0	18.0	0.90	572
19.0	2.30	414	19.0	0.80	405.0	19.0	1.00	563
20.0	2.30	412	20.0	0.80	398.0	20.0	1.00	554
21.0	2.40	410	21.0	0.9	390.0	21.0	1	546
22.0	2.40	409	22.0	0.9	383.0	22.0	1	534
23.0	2.40	408	23.0	0.9	376.0	23.0	1.1	524
24.0	2.40	405	24.0	1	368.0	24.0	1.1	513
25.0	2.40	404	25.0	1	361.0	25.0	1.1	503
26.0	2.40	404	26.0	1	356.0	26.0	1.1	491
27.0	2.40	403	27.0	1	351.0	27.0	1.1	479
28.0	2.40	404	28.0	1	346.0	28.0	1.1	469
29.0	2.50	403	29.0	1	341.0	29.0	1.1	459
30.0	2.50	402	30.0	1	335.0	30.0	1.1	449
31.0	2.50	402	31.0	1	330.0	31.0	1.1	440
32.0	2.5	402	32.0	1.1	326.0	32.0	1.2	433
33.0	2.5	402	33.0	1.2	323.0	33.0	1.3	426
34.0	2.5	402	34.0	1.2	320.0	34.0	1.3	419
35.0	2.5	402	35.0	1.2	316.0	35.0	1.3	413
35.5	2.5	403	35.5	1.2	316.0	35.5	1.3	412
36.5	2.5	403	36.5	1.2	314.0	36.5	1.3	407
37.0	2.5	405	37.0	1.2	310.0	37.0	1.3	407
						38.5	1.4	399
						47.0	1.5	346
						48.0	1.5	342
						49.0	1.5	339


Triaxial Consolidation Curve, Kolfe 2A Remolded, 150 KPa
Volume Change, ml
0.80
1.30
1.80
2.30
2.80
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Sqrt. time, min

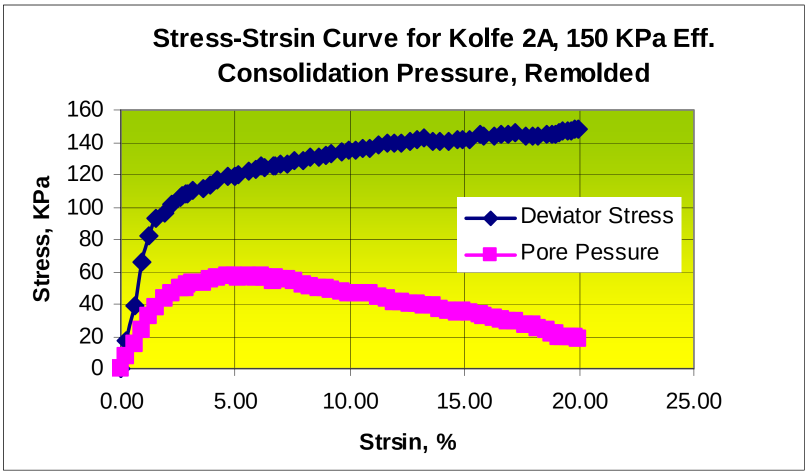

Triaxial Consolidation Curve, Kolfe 2B Remolded, 250 KPa
Volume Change, ml
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
0.0
10.0
20.0
30.0
40.0
Sqrt. time, min

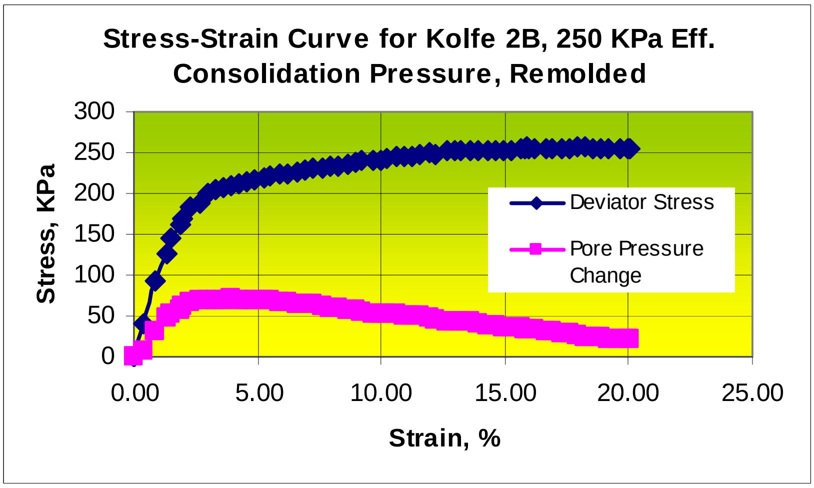

Triaxial Consolidation Curve, Kolfe 2C Remolded, 350 KPa
Volume Change, ml
0.00
0.50
1.00
1.50
2.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Sqrt. time, min

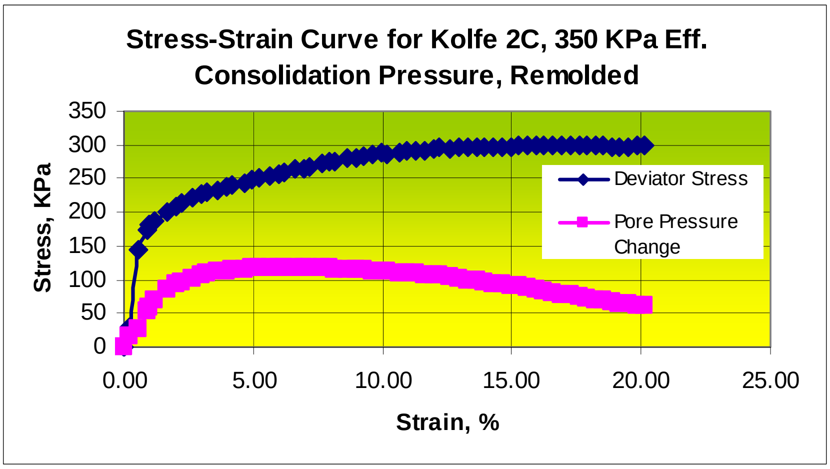
Compression Stage Result for 150 Kpa, Remolded								
Location: **Kolfe**				Job ref.	**Thesis research**			
Soil Description: Red brown clay				Pit no.	**#2**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	**#2A**			
				Depth	**2.5m**			
CP, Kpa	**150**							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
19.81	**148**	**429**	**19.00**	**279**	**131**	**205**	**74**	**2.13**
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.00	0	410	0	150	150	150	0	1.00
0.20	18	418	8	160	142	151	9	1.13
0.62	39	425	15	174	135	154	19	1.29
1.55	93	448	38	205	112	159	46	1.83
1.89	96	453	43	203	107	155	48	1.90
2.19	102	457	47	205	103	154	51	1.99
3.57	111	463	53	208	97	152	56	2.15
3.88	114	465	55	208	95	151	57	2.20
4.21	117	466	56	210	94	152	58	2.24
5.90	123	466	56	217	94	155	62	2.31
6.11	125	467	57	218	93	156	63	2.35
7.93	128	462	52	227	98	163	64	2.31
8.25	131	461	51	230	99	165	65	2.31
9.94	135	457	47	238	103	171	67	2.31
10.26	135	457	47	239	103	171	68	2.31
10.58	136	457	47	239	103	171	68	2.32
10.87	136	456	46	240	104	172	68	2.31
11.20	138	454	44	244	106	175	69	2.30
11.63	139	453	43	246	107	176	70	2.30
12.58	141	450	40	251	110	180	70	2.29
12.89	141	450	40	251	110	180	71	2.29
13.22	142	449	39	253	111	182	71	2.29
13.63	141	448	38	252	112	182	70	2.26
13.95	140	447	37	254	113	183	70	2.24
14.27	141	446	36	255	114	185	71	2.23
15.86	143	442	32	261	118	190	72	2.21
16.29	143	441	31	262	119	191	72	2.21
17.98	144	437	27	267	123	195	72	2.17
18.18	144	435	25	269	125	197	72	2.16
19.64	147	429	19	278	131	205	74	2.12
19.98	148	428	18	280	132	206	74	2.12

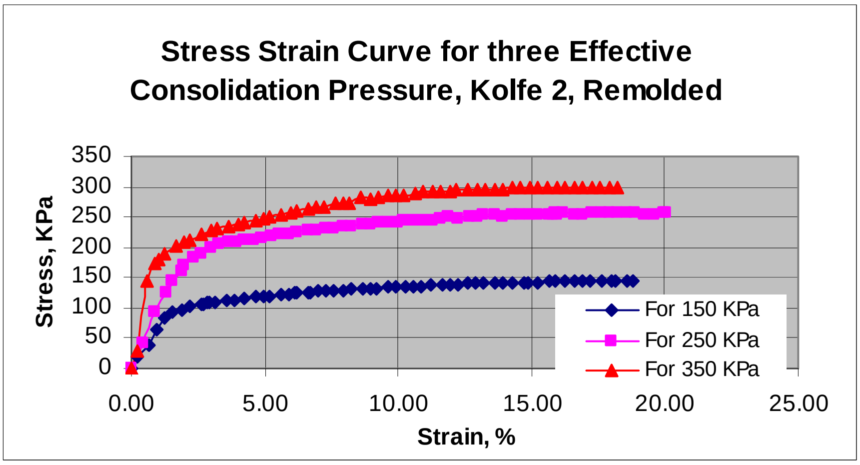
Compression Stage Result for 250 KPa Eff. Consolidation Pressure, Remolded								
Location: ***Kolfe***				Job ref.	***Thesis research***			
Soil Description: Red brown clay				Pit no.	**#2**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#2B***			
				Depth	***2.5m***			
CP, Kpa	***250***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', KPa	σ1'/σ3'
18.24	**257**	**339**	**2.22**	**807**	**468**	**211**		
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', Kpa	t', KPa	σ1'/σ3'
0.00	0	287	0	250	250	250	0	1.00
0.41	40	295	8	282	242	262	20	1.17
0.90	93	317	30	313	220	267	47	1.42
1.30	126	334	47	329	203	266	63	1.62
1.50	146	340	53	343	197	270	73	1.74
1.90	162	345	58	354	192	273	81	1.84
2.00	170	350	63	357	187	272	85	1.91
2.31	183	353	66	367	184	275	92	2.00
2.64	188	356	69	369	181	275	94	2.04
2.96	200	356	69	381	181	281	100	2.11
3.29	204	356	69	385	181	283	102	2.12
3.61	207	356	69	388	181	284	104	2.15
3.94	210	358	71	389	179	284	105	2.17
4.24	212	357	70	392	180	286	106	2.18
5.87	223	353	66	407	184	295	112	2.22
6.19	224	353	66	408	184	296	112	2.21
8.24	234	347	60	425	190	308	117	2.23
9.97	241	340	53	438	197	318	121	2.22
10.19	244	340	53	441	197	319	122	2.23
12.21	248	333	46	452	204	328	124	2.21
13.95	252	328	40	461	210	335	126	2.20
14.28	253	326	39	464	211	338	127	2.20
15.98	255	321	34	471	216	343	128	2.18
16.21	256	320	33	473	217	345	128	2.18
17.93	256	313	26	480	224	352	128	2.14
18.24	257	312	25	482	225	354	129	2.14
19.22	255	309	22	483	228	355	128	2.12
20.08	256	308	21	485	229	357	128	2.12

Compression Stage Result for 350 KPa Eff. Consolidation Pressure, Remolded								
Location: ***Kolfe***				Job ref.	***Thesis research***			
Soil Description: Red brown clay				Pit no.	***#2***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no	***#2C***			
				Depth	***2.5m***			
CP, Kpa	***350***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
16.60	**300**	**371**	**81**	**569**	**269**	**419**	**150**	**2.12**
Test results								
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.00	0	290	0	350	350	350	0	1.00
0.21	30	306	17	363	333	348	15	1.09
0.90	173	343	53	470	297	383	87	1.58
1.20	188	359	69	469	281	375	94	1.67
1.99	208	382	92	466	258	362	104	1.81
2.21	212	386	96	466	254	360	106	1.84
3.19	230	398	109	471	241	356	115	1.95
4.21	241	404	115	476	235	356	121	2.02
5.97	257	407	118	489	232	361	128	2.10
6.19	259	408	118	491	232	361	129	2.12
7.95	274	407	118	507	232	370	156	2.18
8.18	274	406	116	508	234	371	137	2.17
9.94	287	402	112	525	238	381	144	2.21
10.18	286	402	112	524	238	381	143	2.21
11.95	293	396	106	538	244	391	147	2.20
12.18	295	396	106	540	244	392	148	2.21
12.61	295	393	104	541	246	394	148	2.20
12.96	296	390	101	545	249	397	148	2.19
13.95	295	385	95	550	255	402	148	2.16
14.27	298	384	95	553	255	404	149	2.17
15.26	299	379	90	559	260	410	149	2.15
16.25	298	373	83	565	267	416	149	2.12
16.60	300	371	81	569	269	419	150	2.12
17.91	298	361	71	577	279	428	149	2.07
18.86	297	357	67	580	283	432	149	2.05
19.18	297	355	65	582	285	433	149	2.04
20.13	298	351	61	587	289	438	149	2.03


Stress-Strsin Curve for Kolfe 2A, 150 KPa Eff. Consolidation Pressure, Remolded
Stress, KPa
160
140
120
100
80
60
40
20
0
0.00
5.00
10.00
15.00
20.00
25.00
Strsin, %
Deviator Stress
Pore Pessure


Stress-Strain Curve for Kolfe 2B, 250 KPa Eff. Consolidation Pressure, Remolded
Stress, KPa
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
Deviator Stress
Pore Pressure Change


Stress-Strain Curve for Kolfe 2C, 350 KPa Eff. Consolidation Pressure, Remolded
Stress, KPa
350
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
Deviator Stress
Pore Pressure Change


Stress Strain Curve for three Effective Consolidation Pressure, Kolfe 2, Remolded
Stress, KPa
350
300
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
For 150 KPa
For 250 KPa
For 350 KPa

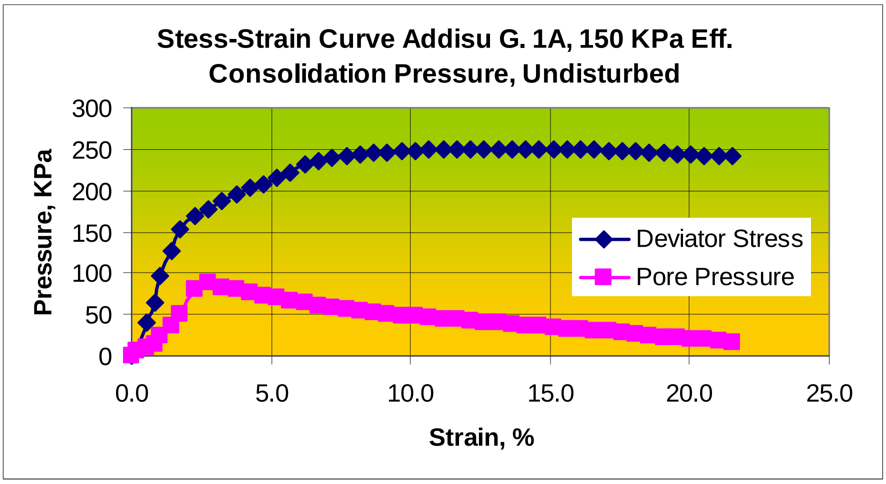
Triaxial compression test result for Addisu G. pit #1/ Undisturbed

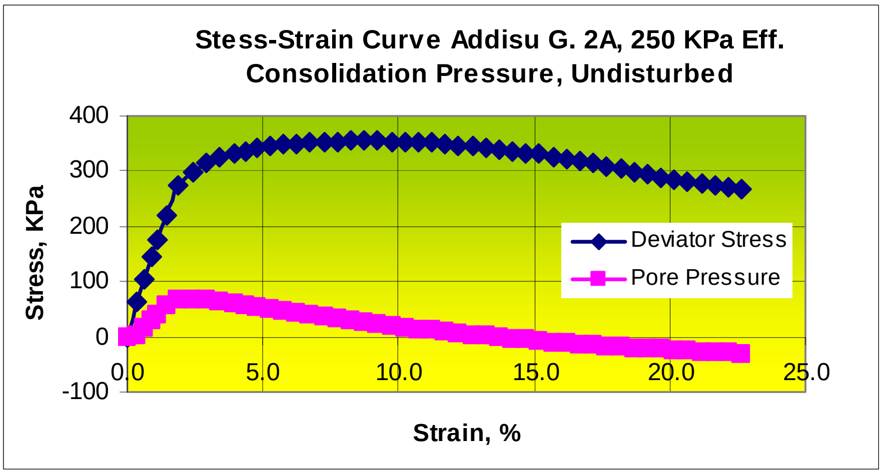
Consolidation Stage Results								
Location: ***Addisu Gebeya***				Job ref.	***Thesis research***			
Soil Description: Red brown clay				Pit no.	***#1***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#1***			
				Depth	***2.5m***			
Undisturbed Sample								
Effective Consolidation Pressure 150 Kpa			**Effective Consolidation Pressure 250 Kpa**			**Effective Consolidation Pressure 350 Kpa**		
Initial Condition	CP, Kpa	***600***	**Initial Condition**	CP, Kpa	***550***	**Initial Condition**	CP, Kpa	***650***
	BP, Kpa	**450**		BP, Kpa	***300***		BP, Kpa	**300**
	PP, Kpa	***591***		PP, Kpa	***534***		PP, Kpa	***631***
Final Condition	PP, Kpa	**456**	**Final Condition**	PP, Kpa	**303**	**Final Condition**	PP, Kpa	**300.2**
	ΔVolume,ml	***1.63***		ΔVolume,ml	***2.9***		ΔVolume,ml	***3.05***
	% Consolidation	**96**		% Consolidation	**98.7**		% Consolidation	**99.9**
Sqrt. Time	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**
0.0	0.00	591	0.0	0.00	534	0.0	0.00	631
0.4	1.02	458	0.4	1.39	304	0.4	1.42	302
0.5	1.09	458	0.5	1.47	304	0.5	1.54	302
0.6	1.21	458	0.6	1.64	304	0.6	1.84	302
0.7	1.26	458	0.7	1.72	304	0.7	1.95	302
0.8	1.27	458	0.8	1.83	304	0.8	1.98	302
0.9	1.35	458	0.9	1.85	304	0.9	2.13	301
1.0	1.38	458	1.0	1.93	304	1.0	2.17	301
1.1	1.41	458	1.1	2.05	304	1.1	2.24	301
1.3	1.44	458	1.3	2.06	304	1.3	2.37	301
1.6	1.44	458	1.6	2.26	304	1.6	2.50	301
2.0	1.53	458	2.0	2.41	304	2.0	2.58	301
2.8	1.52	458	2.8	2.59	304	2.8	2.72	301
3.1	1.53	458	3.1	2.65	304	3.1	2.81	301
4.4	1.56	458	4.4	2.77	304	4.4	2.85	301
4.9	1.57	458	4.9	2.84	304	4.9	2.87	301
5.5	1.59	458	5.5	2.89	304	5.5	2.94	301
6.2	1.57	458	6.2	2.92	304	6.2	2.92	301
7.8	1.61	458	7.8	2.92	304	7.8	2.99	301
8.7	1.61	458	8.7	2.92	304	8.7	2.99	301
9.8	1.63	457	9.8	2.92	304	9.8	3.03	301
11.0	1.62	457	11.0	2.94	304	11.0	3.03	301
12.3	1.64	457	12.3	2.98	304	12.3	3.04	301
13.8	1.64	457	13.8	2.99	304	13.8	3.05	301
15.5	1.66	457	15.5	2.97	304	15.5	3.05	301
17.4	1.65	456	17.4	3.01	304	17.4	3.07	301
19.5	1.66	456	19.5	3.01	303	19.5	3.03	301
21.9	1.65	456	21.9	2.99	303	21.9	3.01	300
24.6	1.66	456	24.6	3.02	303	24.6	3.05	300
27.6	1.65	456	27.6	2.98	303	27.6	3.05	300
31.0	1.63	456	31.0	2.92	303	31.0	3.05	300

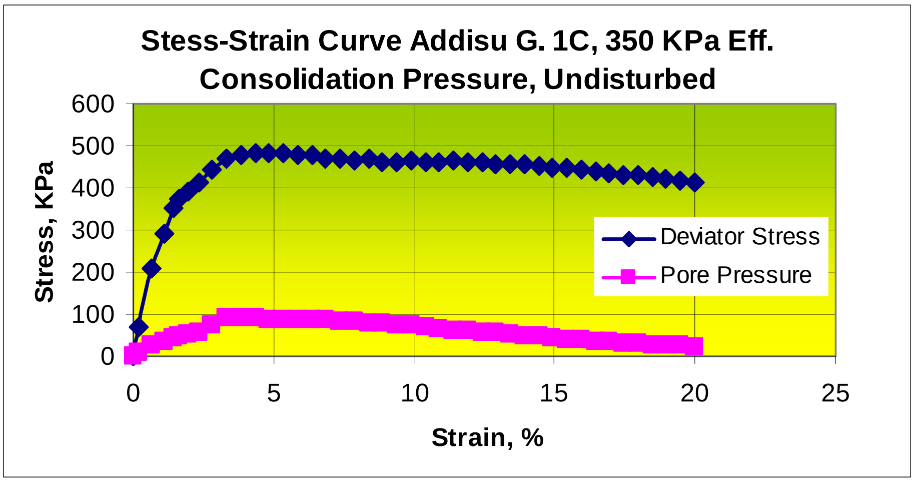
Compression Stage Result for 150 KPa Eff. Consolidation Pressure, Undisturbed								
Location: **Addisu Gebeya**					Job ref.	**Thesis research**		
Soil Description: Red brown clay					Pit no.	**#1**		
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8					Sample no.	**#1**		
					Depth	**2.5m**		
CP, Kpa	**150**							
Failure Condition								
Strain, %	Δσa, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
12.64	251	505	40	360	110	235	125	3.28
Test result								
Strain, %	Δσa, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	465	0	150	150	150	0	1.00
0.6	40	475	10	180	140	160	20	1.29
1.0	96	490	25	221	125	173	48	1.77
1.4	127	502	37	240	113	176	63	2.12
1.8	153	515	50	253	100	177	77	2.53
2.3	170	545	80	240	70	155	85	3.43
3.2	188	548	83	255	67	161	94	3.81
3.7	195	545	80	265	70	168	98	3.77
4.7	208	538	73	285	77	181	104	3.72
5.2	215	535	70	295	80	187	108	3.69
6.2	232	529	64	319	86	202	116	3.70
6.7	236	526	61	325	89	207	118	3.64
7.2	239	524	59	330	91	210	119	3.63
7.7	241	522	57	334	93	214	120	3.58
8.2	243	520	55	338	95	217	122	3.57
8.7	245	518	53	342	97	219	123	3.53
9.2	247	516	51	346	99	222	123	3.49
9.7	248	514	49	349	101	225	124	3.45
10.2	248	513	48	350	102	226	124	3.43
10.7	249	512	47	353	103	228	125	3.41
11.2	249	510	45	354	105	230	125	3.38
11.7	250	508	43	356	107	232	125	3.34
12.1	250	507	42	358	108	233	125	3.31
12.6	251	505	40	360	110	235	125	3.28
13.1	251	505	40	361	110	236	125	3.27
13.6	250	504	39	362	111	237	125	3.25
14.1	250	502	37	363	113	238	125	3.22
15.1	250	499	35	365	116	240	125	3.16
16.1	250	497	32	367	118	243	125	3.12
17.1	248	494	30	368	121	244	124	3.06
18.1	247	491	26	371	124	247	123	3.00
19.1	245	488	23	372	127	250	123	2.93
20.0	244	486	21	373	129	251	122	2.89

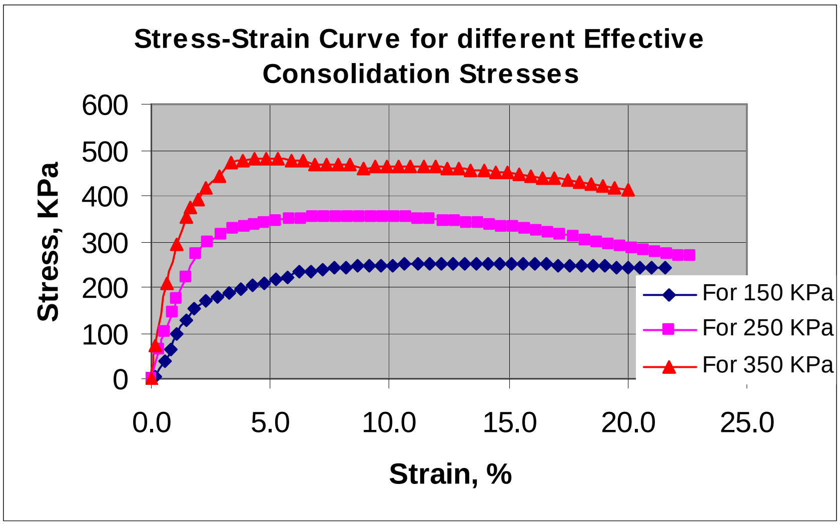
Compression Stage Result for 250 KPa Eff. Consolidation Pressure, Undisturbed								
Location: **Addisu Gebeya**				Job ref.	**Thesis research**			
Soil Description: Red brown clay				Pit no.	**#1**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	**#1**			
				Depth	**2.5m**			
CP, Kpa	**250**							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
8.24	**355**	**339**	**29**	**575**	**221**	**398**	**177**	**2.61**
Test results								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	310	0	250	250	250	0	1.00
0.3	63	312	2	311	248	279	32	1.25
0.9	146	338	28	368	222	295	73	1.66
1.1	176	348	38	388	212	300	88	1.83
1.5	220	368	58	412	192	302	110	2.14
1.9	273	376	66	457	184	320	137	2.49
2.4	299	377	67	482	183	332	150	2.64
2.9	315	376	66	499	184	342	158	2.71
3.4	326	373	63	513	187	350	163	2.75
3.9	332	370	60	522	190	356	166	2.74
4.3	337	366	56	531	194	362	169	2.74
4.8	341	363	53	538	197	368	171	2.73
5.3	346	359	49	547	201	374	173	2.72
5.8	348	356	46	552	204	378	174	2.70
6.3	350	352	42	558	208	383	175	2.68
6.8	352	349	39	563	211	387	176	2.67
7.3	353	345	35	567	215	391	176	2.64
7.7	354	342	32	572	218	395	177	2.63
8.2	355	339	29	575	221	398	177	2.61
8.7	355	336	26	578	224	401	177	2.58
9.7	354	330	20	584	230	407	177	2.54
10.7	352	324	14	588	236	412	176	2.49
11.2	351	321	11	590	239	414	176	2.47
11.7	349	318	8	590	242	416	174	2.44
12.2	347	316	6	591	244	418	173	2.42
12.7	344	313	3	591	247	419	172	2.40
13.2	342	311	1	591	249	420	171	2.37
14.2	336	306	-4	590	254	422	168	2.33
15.2	330	302	-8	589	258	423	165	2.28
16.2	322	298	-12	584	262	423	161	2.23
17.2	314	295	-15	579	265	422	157	2.18
18.2	304	291	-19	573	269	421	152	2.13
19.2	294	288	-22	566	272	419	147	2.08
20.2	285	285	-25	560	275	417	143	2.04

Compression Stage Result for 350 KPa Eff. Consolidation Pressure, Undisturbed								
Location: ***Addisu Gebeya***					Job ref.	***Thesis research***		
Soil Description: Red brown clay					Pit no.	***#1***		
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8					Sample no.	***#1***		
					Depth	***2.5m***		
CP, Kpa	***350***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
4.37	**482**	**398**	**93.40**	**739**	**257**	**498**	**241**	**2.88**
Test result								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0	0	305	0	350	350	350	0	1.00
0.2	71	315	10	411	340	375	35	1.21
0.66	210	333	28	532	322	427	105	1.65
1.08	292	340	35	607	315	461	146	1.93
1.43	353	350	45	658	305	482	177	2.16
1.62	375	355	50	675	300	488	188	2.25
1.93	390	358	53	687	297	492	195	2.31
2.32	415	363	58	707	292	499	208	2.42
2.82	442	379	74	718	276	497	221	2.60
3.33	471	395	90	731	260	495	236	2.81
3.83	478	395	90	738	260	499	239	2.84
4.37	482	398	93	739	257	498	241	2.88
4.84	482	393	88	744	262	503	241	2.84
5.35	482	391	86	746	264	505	241	2.83
5.85	478	394	89	739	261	500	239	2.83
6.35	478	393	88	740	262	501	239	2.82
6.86	469	392	87	732	263	498	235	2.78
7.36	470	390	85	735	265	500	235	2.77
7.87	466	387	82	734	268	501	233	2.74
8.37	470	384	79	741	271	506	235	2.74
8.88	462	382	77	734	273	503	231	2.69
9.38	463	380	75	737	275	506	231	2.68
9.88	463	377	72	741	278	510	232	2.67
10.39	463	374	69	744	281	512	231	2.65
11.91	462	364	59	753	291	522	231	2.59
12.41	460	362	57	752	293	523	230	2.57
14.93	449	348	43	756	307	531	225	2.47
15.94	443	344	39	754	311	533	221	2.42
16.95	436	339	34	752	316	534	218	2.38
17.96	429	335	30	749	320	534	214	2.34
18.97	422	331	26	745	324	535	211	2.30
19.98	414	328	23	740	327	533	207	2.27

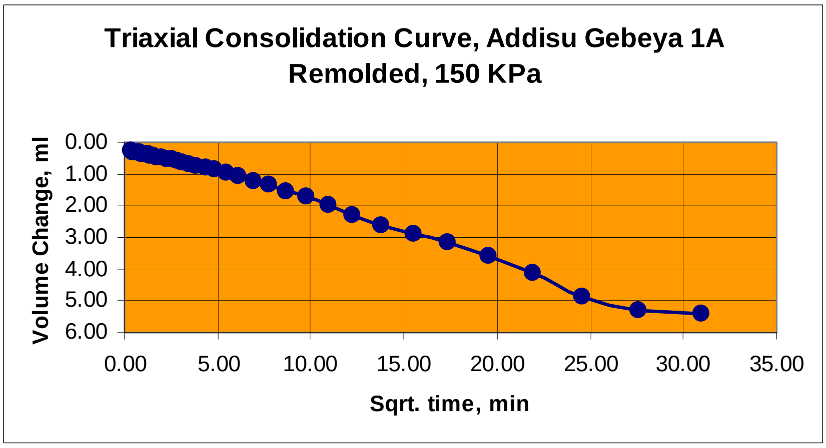

Stess-Strain Curve Addisu G. 1A, 150 KPa Eff. Consolidation Pressure, Undisturbed
Pressure, KPa
300
250
200
150
100
50
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
Deviator Stress
Pore Pressure

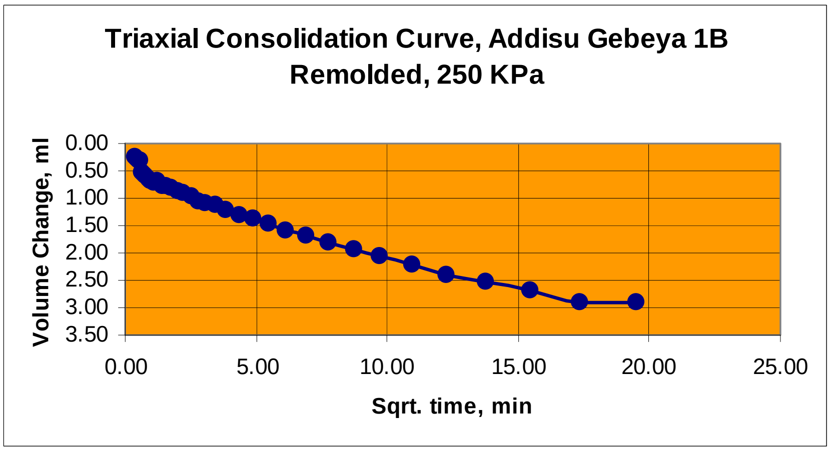

Stess-Strain Curve Addisu G. 2A, 250 KPa Eff. Consolidation Pressure, Undisturbed
Stress, KPa
400
300
200
100
0
-100
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
Deviator Stress
Pore Pressure

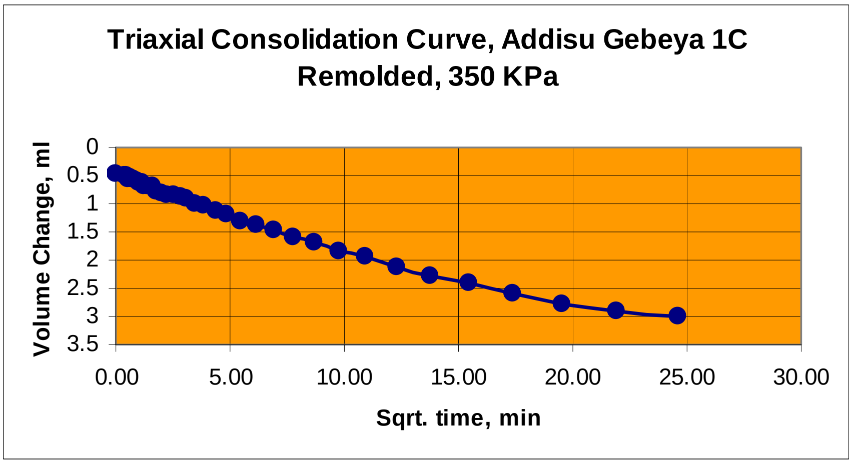

Stess-Strain Curve Addisu G. 1C, 350 KPa Eff. Consolidation Pressure, Undisturbed
Stress, KPa
600
500
400
300
200
100
0
0
5
10
15
20
25
Strain, %
Deviator Stress
Pore Pressure


Stress-Strain Curve for different Effective Consolidation Stresses
Stress, KPa
600
500
400
300
200
100
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
For 150 KPa
For 250 KPa
For 350 KPa

Consolidation Stage Results, Addisu Gebeya Pit 1, Remolded								
Location: **Addisu Gebeya**				Job ref.	**Thesis research**			
Soil Description: Red brown clay				Pit no.	**#1**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	**#1**			
				Depth	**2.5m**			
Remolded Sample								
Effective Consolidation Pressure 150 Kpa			**Effective Consolidation Pressure 250 Kpa**			**Effective Consolidation Pressure 350 Kpa**		
Initial Condi tion	CP, Kpa	**540**	**Initial Condi tion**	CP, Kpa	**695**	**Initial Condi tion**	CP, Kpa	**600**
	BP, Kpa	**390**		BP, Kpa	**445**		BP, Kpa	**250**
	PP, Kpa	**522**		PP, Kpa	**681**		PP, Kpa	**578**
Final Condi tion	PP, Kpa	**393**	**Final Condi tion**	PP, Kpa	**453**	**Final Condi tion**	PP, Kpa	**250.3**
	ΔVolume, ml	**5.4**		ΔVolume, ml	**2.9**		ΔVolume, ml	**2.99**
	% Consolidation	**98**		% Consolidation	**97**		% Consolidati on	**99.9**
Sqrt. Time	**ΔVolume, ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume, ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume, ml**	**PP, Kpa**
0.00	0.00	522	0.00	0.00	681	0	0	576
0.39	0.29	392	0.39	0.26	681	0.39	0.47	249
0.50	0.30	392	0.50	0.32	681	0.5	0.51	249
0.56	0.32	392	0.56	0.31	681	0.56	0.54	249
0.63	0.33	392	0.63	0.54	453	0.63	0.57	249
0.71	0.34	392	0.71	0.56	453	0.71	0.54	249
0.80	0.34	392	0.80	0.60	453	0.8	0.55	249
0.89	0.35	392	0.89	0.65	453	0.89	0.56	249
1.00	0.38	392	1.00	0.68	453	1	0.58	249
1.13	0.39	392	1.13	0.71	453	1.13	0.63	249
1.26	0.40	392	1.26	0.70	453	1.26	0.62	249
1.41	0.43	392	1.41	0.78	453	1.41	0.69	249
1.78	0.47	392	1.78	0.81	453	1.78	0.7	249
2.00	0.50	392	2.00	0.86	453	2	0.77	249
2.24	0.52	392	2.24	0.91	453	2.24	0.81	249
2.52	0.56	392	2.52	0.96	453	2.52	0.85	249
2.83	0.59	392	2.83	1.06	453	2.83	0.83	249
3.07	0.62	392	3.07	1.08	453	3.07	0.89	249
3.87	0.73	392	3.87	1.22	453	3.87	0.99	249
4.35	0.80	392	4.35	1.30	453	4.35	1.04	249
4.88	0.87	392	4.88	1.39	453	4.88	1.11	249
5.48	0.96	393	5.48	1.47	453	5.48	1.2	249
6.15	1.07	392	6.15	1.60	453	6.15	1.31	249
6.90	1.23	392	6.90	1.70	453	6.9	1.37	249
8.72	1.54	393	8.72	1.95	453	8.72	1.59	249
9.75	1.74	393	9.75	2.06	453	9.75	1.7	250
10.95	1.99	393	10.95	2.21	453	10.95	1.84	250
12.29	2.29	393	12.29	2.41	453	12.29	1.93	250
13.78	2.65	393	13.78	2.52	453	13.78	2.12	250
15.49	2.87	393	15.49	2.69	453	15.49	2.28	250
17.38	3.14	393	17.38	2.90	453	17.38	2.41	250
19.52	3.57	393	19.52	2.91		19.52	2.58	250
21.91	4.11	393				21.91	2.79	250
24.60	4.85	393				24.6	2.9	250
27.60	5.30	393				27.6	2.99	250
30.98	5.40	393						


Triaxial Consolidation Curve, Addisu Gebeya 1A
Remolded, 150 KPa
Volume Change, ml
0.00
1.00
2.00
3.00
4.00
5.00
6.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Sqrt. time, min

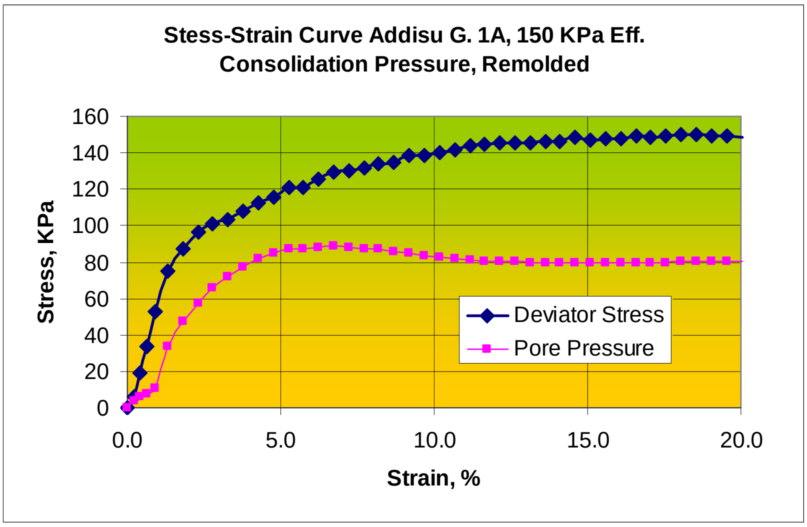

Triaxial Consolidation Curve, Addisu Gebeya 1B
Remolded, 250 KPa
Volume Change, ml
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
0.00
5.00
10.00
15.00
20.00
25.00
Sqrt. time, min

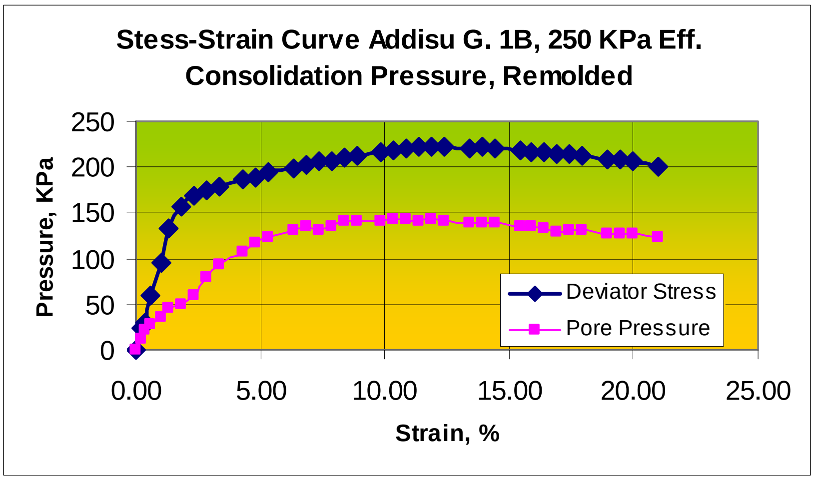

Triaxial Consolidation Curve, Addisu Gebeya 1C
Remolded, 350 KPa
Volume Change, ml
0
0.5
1
1.5
2
2.5
3
3.5
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Sqrt. time, min

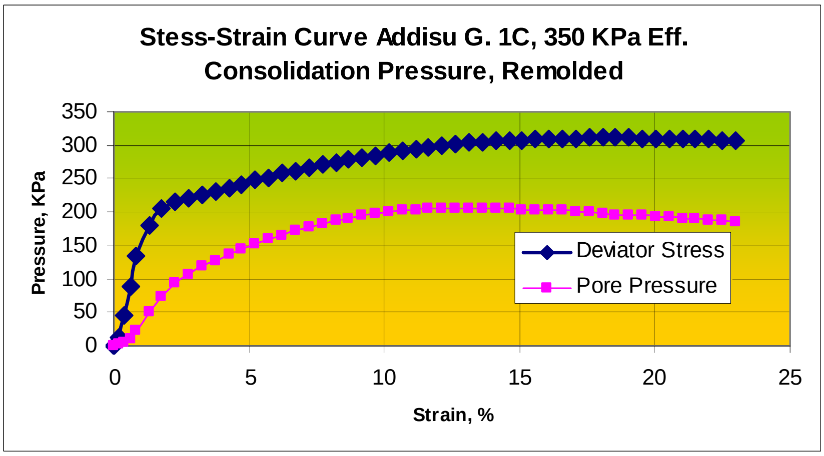
Compression Stage result for 150 KPa Eff. Consolidation Pressure								
Location: **Addisu Gebeya**				Job ref.	**Thesis research**			
Soil Description: Red brown clay				Pit no.	**#1**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	**#1**			
				Depth	**2.5m**			
CP, Kpa	**150**							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	Stress ratio	σ1, Kpa	σ1', Kpa	σ3', Kpa		
18.06	**150**	**490**	**80**	**220**	**70**	**145**	**75**	**3.15**
Test results								
Strain, %	Δσa, Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	410	0	150	150	150	0	1.00
0.2	6	414	4	152	146	149	3	1.04
0.4	19	416	6	163	144	153	10	1.13
0.6	34	418	8	176	142	159	17	1.24
0.9	53	421	10	193	140	166	27	1.38
1.3	75	444	34	191	116	154	38	1.65
1.8	88	458	48	190	102	146	44	1.85
2.3	97	468	58	189	92	141	48	2.05
2.8	101	476	66	185	84	135	51	2.20
3.3	103	482	72	181	78	129	52	2.33
3.8	108	488	77	180	73	127	54	2.49
4.3	112	492	82	180	68	124	56	2.66
4.8	116	495	85	181	65	123	58	2.78
5.3	121	497	87	184	63	124	61	2.92
5.7	121	498	87	184	63	123	61	2.94
6.2	126	499	88	187	62	125	63	3.04
6.7	129	499	88	191	62	126	65	3.10
7.2	130	498	88	192	62	127	65	3.10
7.7	131	498	87	194	63	128	66	3.10
8.2	134	497	87	197	63	130	67	3.12
8.7	135	496	86	199	64	132	67	3.10
9.2	138	495	85	204	65	134	69	3.12
10.7	142	492	82	210	68	139	71	3.07
11.2	144	491	81	213	69	141	72	3.09
12.6	145	490	80	215	70	143	73	3.08
13.1	146	490	80	216	70	143	73	3.07
14.6	148	490	80	218	70	144	74	3.11
15.1	147	490	80	218	70	144	74	3.09
16.1	148	490	80	218	70	144	74	3.10
17.1	148	490	80	218	70	144	74	3.12
18.1	150	490	80	220	70	145	75	3.15
19.1	149	490	80	219	70	144	75	3.14
20.1	149	491	81	218	69	144	74	3.14

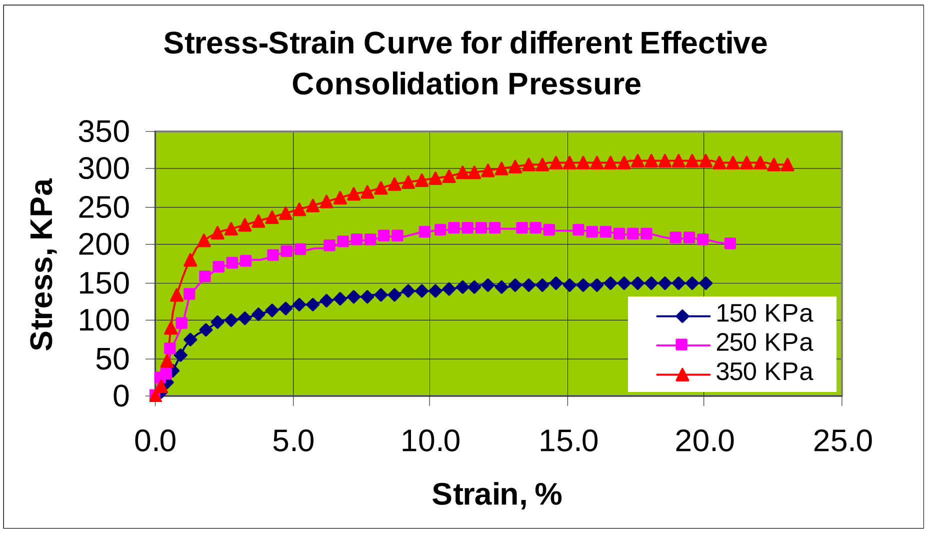
Compression Stage result for 250 KPa Eff. Consolidation Pressure								
Location: ***Addisu Gebeya***					Job ref.	***Thesis research***		
Soil Description: Red brown clay					Pit no.	***#1***		
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8					Sample no.	***#1***		
					Depth	***2.5m***		
CP, Kpa	***250***							
Failure Condition								
Strain, %	Δσa.Kpa	ΔPP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
11.89	**223**	**453**	**142**	**330**	**108**	**219**	**111**	**3.07**
Test results								
Strain , %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.00	0	311	0	250	250	250	0	1.00
0.20	23	322	11	262	239	250	11	1.10
0.40	29	332	21	258	229	243	15	1.13
0.60	61	339	28	282	222	252	30	1.27
1.00	95	348	37	308	213	261	47	1.44
1.31	133	356	45	338	205	272	67	1.65
1.81	157	361	50	357	200	278	79	1.79
2.31	169	371	60	359	190	274	85	1.89
2.82	175	391	80	345	170	258	87	2.03
3.32	178	404	93	336	157	247	89	2.13
4.33	186	419	108	328	142	235	93	2.31
4.83	189	428	117	322	133	228	95	2.43
5.34	193	434	123	321	127	224	97	2.52
6.35	199	441	130	319	120	220	100	2.66
6.85	202	445	134	318	116	217	101	2.75
7.35	206	443	132	324	118	221	103	2.74
7.86	207	447	136	321	114	218	104	2.81
8.36	211	451	140	320	110	215	105	2.92
8.86	212	453	142	320	108	214	106	2.95
9.87	216	453	142	324	108	216	108	2.99
10.38	219	454	143	326	107	217	110	3.05
10.88	221	453	142	328	108	218	110	3.05
11.38	222	451	140	331	110	221	111	3.02
11.89	223	453	142	330	108	219	111	3.07
12.39	222	453	142	331	108	220	111	3.05
13.91	221	450	139	333	111	222	111	2.99
14.41	220	449	138	332	112	222	110	2.96
15.42	219	446	135	334	115	224	109	2.90
16.93	214	440	129	334	121	228	107	2.77
17.44	214	443	132	333	118	226	107	2.81
17.94	213	442	131	332	119	226	106	2.78
19.96	206	437	126	329	124	226	103	2.67

Compression Stage result for 350 KPa Eff. Consolidation Pressure								
Location: **Addisu Gebeya**					Job ref.	**Thesis research**		
Soil Description: Red brown clay					Pit no.	**#1**		
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8					Sample no.	**#1**		
					Depth	**2.5m**		
CP, Kpa	**350**							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
17.56	**312**	**504**	**199**	**462**	**151**	**306**	**156**	**3.07**
Strain , %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0	0	305	0	350	350	350	0	1.00
0.2	14	307	2	362	348	355	7	1.04
0.4	46	309	4	392	346	369	23	1.13
0.6	89	314	9	430	341	386	45	1.26
0.8	134	328	23	461	327	394	67	1.41
1.29	180	356	51	479	299	389	90	1.60
1.79	206	380	75	481	275	378	103	1.75
2.28	215	398	93	472	257	365	108	1.84
2.77	221	412	107	464	243	353	110	1.91
3.26	226	423	118	458	232	345	113	1.97
3.76	232	432	127	454	223	338	116	2.04
4.25	237	442	137	450	213	332	118	2.11
4.74	242	450	145	447	205	326	121	2.18
5.24	247	457	152	445	198	321	124	2.25
5.73	252	464	159	443	191	317	126	2.32
6.23	258	471	166	442	184	313	129	2.40
6.72	262	477	172	441	178	309	131	2.47
7.21	267	482	177	440	173	306	134	2.55
7.7	271	487	182	439	168	303	136	2.62
8.2	275	492	187	438	163	300	137	2.69
8.69	279	496	191	438	159	298	140	2.76
9.18	282	500	195	437	155	296	141	2.82
9.68	285	503	198	437	152	295	143	2.88
10.17	289	505	200	439	150	294	145	2.93
10.66	292	507	202	440	148	294	146	2.97
11.65	297	510	205	442	145	293	148	3.04
12.14	300	511	206	444	144	294	150	3.08
13.62	306	511	206	449	144	297	153	3.12
14.11	306	511	206	450	144	297	153	3.12
15.59	309	509	204	456	146	301	155	3.11
16.09	310	508	203	457	147	302	155	3.11
17.56	312	504	199	462	151	306	156	3.07
18.06	311	503	198	463	152	308	156	3.05
19.54	311	499	194	466	156	311	155	3.00
20.03	311	498	193	468	157	312	155	2.98


Stess-Strain Curve Addisu G. 1A, 150 KPa Eff.
Consolidation Pressure, Remolded
Stress, KPa
160
140
120
100
80
60
40
20
0
0.0
5.0
10.0
15.0
20.0
Strain, %
Deviator Stress
Pore Pressure


Stess-Strain Curve Addisu G. 1B, 250 KPa Eff.
Consolidation Pressure, Remolded
Pressure, KPa
250
200
150
100
50
0
0.00
5.00
10.00
15.00
20.00
25.00
Strain, %
Deviator Stress
Pore Pressure


Stess-Strain Curve Addisu G. 1C, 350 KPa Eff.
Consolidation Pressure, Remolded
Pressure, KPa
350
300
250
200
150
100
50
0
0
5
10
15
20
25
Strain, %
Deviator Stress
Pore Pressure

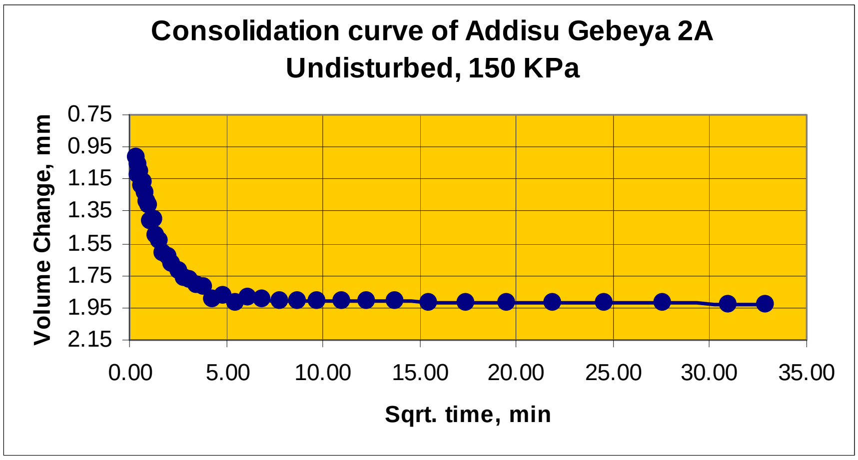

Stress-Strain Curve for different Effective Consolidation Pressure
Stress, KPa
350
300
250
200
150
100
50
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
150 KPa
250 KPa
350 KPa

Triaxial compression test result for Addisu Gebeya pit#2/Undisturbed

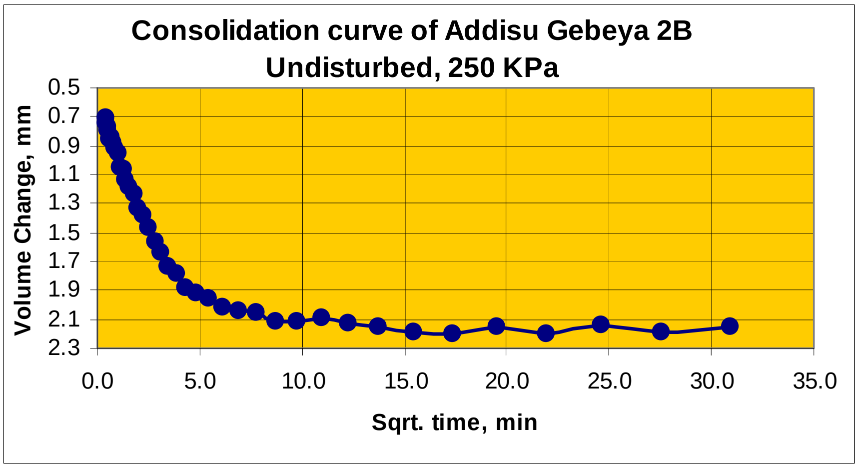
Consolidation Stage Result Addisu Gebeya Pit 2, Undisturbed		
Location: ***Addisu Gebeya***	Job ref.	***Thesis research***
Soil Description: Red brown clay	Pit no.	***#2***
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8	Sample no.	***#1***
	Depth	***2.5m***

Undisturbed Sample

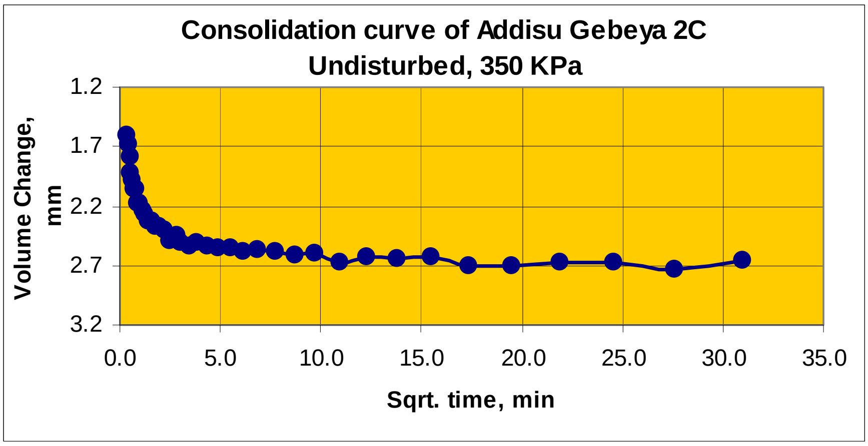
Effective Consolidation Pressure 150 Kpa			**Effective Consolidation Pressure 250 Kpa**			**Effective Consolidation Pressure 350 Kpa**		
Initial Condition	CP, Kpa	***450***	**Initial Condition**	CP, Kpa	***550***	**Initial Condition**	CP, Kpa	***600***
	BP, Kpa	**300**		BP, Kpa	***300***		BP, Kpa	**250**
	PP, Kpa	***436***		PP, Kpa	***528***		PP, Kpa	***584***
Final Condition	PP, Kpa	**302.3**	**Final Condition**	PP, Kpa	**301**	**Final Condition**	PP, Kpa	**250.4**
	ΔVolume,ml	***1.93***		ΔVolume,ml	***2.2***		ΔVolume,ml	***2.7***
	% Consolidation	**98**		% Consolidation	**99**		% Consolidation	**99**
Sqrt. Time	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**
0.0	0.00	436	0.0	0.0	528	0.0	0.0	584
0.4	1.02	303	0.4	0.7	302	0.4	1.6	254
0.5	1.13	303	0.5	0.8	302	0.5	1.8	254
0.6	1.10	303	0.6	0.8	302	0.6	1.9	254
0.7	1.17	303	0.7	0.8	302	0.7	2.1	254
0.8	1.24	303	0.8	0.9	302	0.8	2.1	252
0.9	1.29	302	0.9	0.9	302	0.9	2.2	252
1.0	1.31	302	1.0	1.0	302	1.0	2.2	252
1.1	1.41	302	1.1	1.1	302	1.1	2.2	252
1.3	1.40	303	1.3	1.1	302	1.3	2.3	252
1.4	1.50	303	1.4	1.1	302	1.4	2.3	252
1.6	1.53	303	1.6	1.2	302	1.6	2.3	252
1.8	1.61	303	1.8	1.2	302	1.8	2.4	252
2.0	1.63	302	2.0	1.3	302	2.0	2.4	252
2.2	1.68	302	2.2	1.4	302	2.2	2.4	252
2.5	1.72	303	2.5	1.5	302	2.5	2.5	252
2.8	1.76	302	2.8	1.6	302	2.8	2.5	252
3.1	1.77	302	3.1	1.6	302	3.1	2.5	252
3.5	1.81	302	3.5	1.7	302	3.5	2.5	252
3.9	1.82	302	3.9	1.8	302	3.9	2.5	252
4.4	1.90	302	4.4	1.9	302	4.4	2.5	252
5.5	1.92	302	5.5	2.0	302	5.5	2.6	252
6.9	1.90	302	6.9	2.0	302	6.9	2.6	251
7.8	1.90	302	7.8	2.1	302	7.8	2.6	251
8.7	1.90	302	8.7	2.1	302	8.7	2.6	251
9.8	1.91	302	9.8	2.1	302	9.8	2.6	251
11.0	1.91	302	11.0	2.1	302	11.0	2.7	251
12.3	1.91	302	12.3	2.1	302	12.3	2.6	251
13.8	1.91	302	13.8	2.2	302	13.8	2.7	251
15.5	1.91	302	15.5	2.2	302	15.5	2.6	251
17.4	1.92	302	17.4	2.2	301	17.4	2.7	251
19.5	1.92	302	19.5	2.2	301	19.5	2.7	251
21.9	1.92	302	21.9	2.2	301	21.9	2.7	251
24.6	1.92	302	24.6	2.1	301	24.6	2.7	251
27.6	1.92	302	27.6	2.2	301	27.6	2.7	250
31.0	1.93	302	31.0	2.2	301	31.0	2.7	250



Consolidation curve of Addisu Gebeya 2A
Undisturbed, 150 KPa
Volume Change, mm
0.75
0.95
1.15
1.35
1.55
1.75
1.95
2.15
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Sqrt. time, min



Consolidation curve of Addisu Gebeya 2B
Undisturbed, 250 KPa
Volume Change, mm
0.5
0.7
0.9
1.1
1.3
1.5
1.7
1.9
2.1
2.3
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Sqrt. time, min

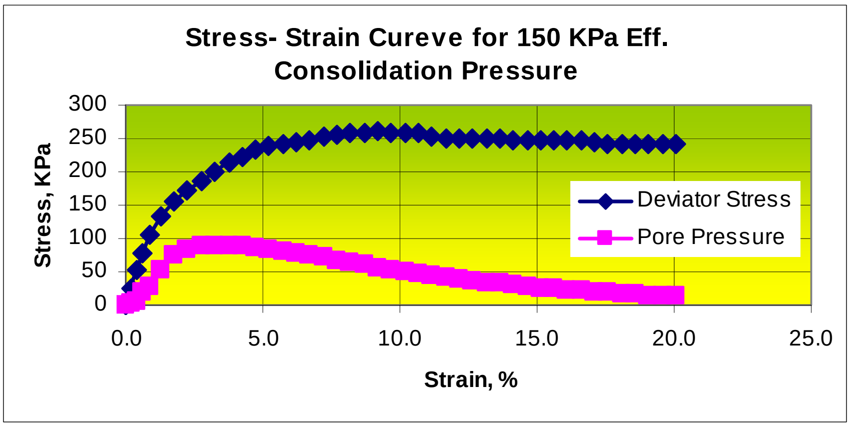


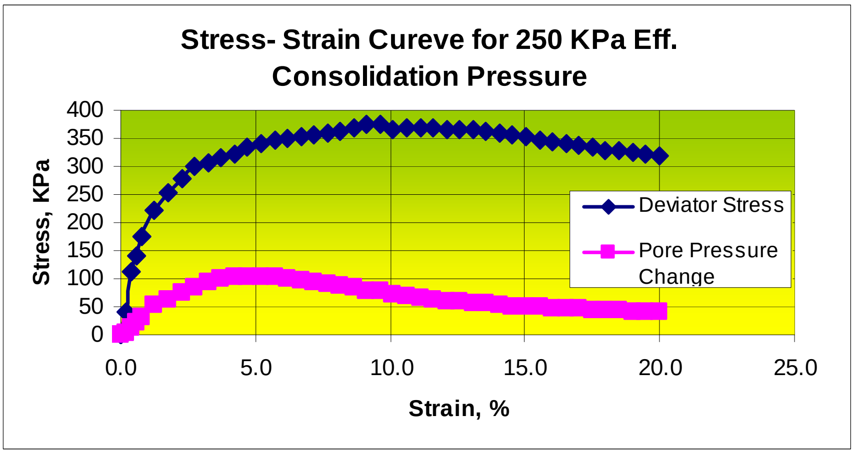
Consolidation curve of Addisu Gebeya 2C
Undisturbed, 350 KPa
Volume Change, mm
1.2
1.7
2.2
2.7
3.2
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Sqrt. time, min

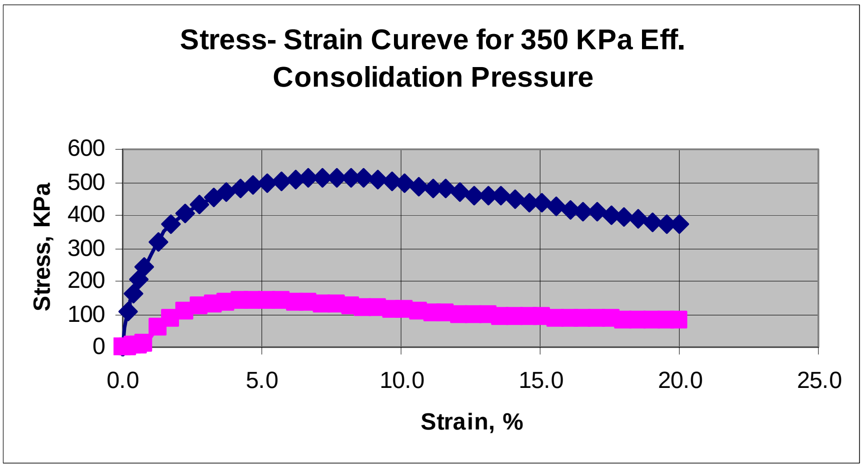
Compression Stage Result for 150 Eff. Consolidation Pressure, Undisturbed								
Location: **Addisu Gebeya**				Job ref.	**Thesis research**			
Soil Description: Red brown clay				Pit no.	**#2**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	**#2A**			
				Depth	**2.5m**			
CP, Kpa	**150**							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
9.2	**260**	**378**	**4.59**	**710**	**332**	**72**		
Test results								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	321	0	150	150	150	0	1.00
0.2	25	324	2	173	148	160	13	1.17
0.6	78	341	20	208	130	169	39	1.60
0.9	106	350	29	227	121	174	53	1.88
1.3	133	375	54	229	96	163	67	2.38
1.8	156	396	74	232	76	154	78	3.06
2.3	173	405	84	239	66	153	87	3.60
2.8	187	410	88	249	62	155	94	4.03
3.3	200	411	90	260	60	160	100	4.33
3.8	215	411	90	275	60	168	108	4.58
4.2	221	410	89	282	61	172	111	4.62
4.7	232	408	87	295	63	179	116	4.66
5.2	240	406	84	306	66	186	120	4.66
5.7	241	402	81	310	69	189	121	4.50
6.2	245	399	78	317	72	195	123	4.39
6.7	247	396	74	323	76	199	124	4.27
7.2	252	392	71	331	79	205	126	4.19
7.7	255	388	67	338	83	210	128	4.08
8.2	258	385	64	344	86	215	129	3.99
8.7	258	381	60	348	90	219	129	3.87
9.2	260	378	56	354	94	224	130	3.78
9.7	259	374	53	356	97	227	130	3.66
10.2	257	371	49	358	101	229	129	3.55
10.7	257	368	47	360	103	231	129	3.50
11.2	254	366	44	360	106	233	127	3.41
12.7	251	358	37	364	113	239	126	3.21
13.6	250	353	32	368	118	243	125	3.12
14.1	248	351	30	368	120	244	124	3.06
15.6	246	346	24	372	126	249	123	2.96
16.1	246	344	23	373	127	250	123	2.93
17.6	242	340	19	373	131	252	121	2.84
18.1	241	338	17	374	133	253	121	2.81
19.6	242	335	14	378	136	257	121	2.78
20.1	241	334	13	378	137	258	121	2.76

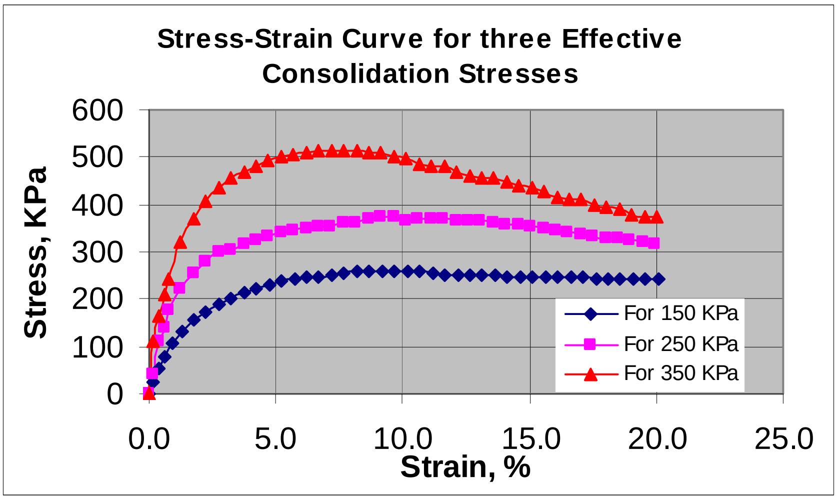
Compression Stage Result for 250 Eff. Consolidation Pressure								
Location:	***Addisu Gebeya***			Job ref.	***Thesis research***			
Soil Description:	Red brown clay			Pit no.	***#2***			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	***#2B***			
				Depth	***2.5m***			
CP, Kpa	***250***							
Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
9.14	**374**	**404**	**80**	**544**	**170**	**357**	**187**	**3.19**
Test result								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	324	0	250	250	250	0	1.00
0.2	40	328	3	287	247	267	20	1.16
0.4	113	337	13	350	237	294	56	1.47
0.6	141	345	21	370	229	300	71	1.62
0.8	176	357	33	393	217	305	88	1.81
1.3	223	378	54	420	196	308	112	2.14
1.8	254	389	64	440	186	313	127	2.37
2.3	278	399	75	454	175	315	139	2.59
2.7	299	409	85	464	165	315	150	2.81
3.2	305	418	94	461	156	309	153	2.95
3.7	315	424	99	466	151	308	158	3.09
4.2	323	427	102	471	148	309	162	3.19
4.7	333	428	103	480	147	313	167	3.27
5.2	342	428	103	489	147	318	171	3.33
6.7	352	422	97	505	153	329	176	3.31
7.2	355	419	94	511	156	333	178	3.28
8.7	369	408	83	536	167	351	185	3.22
9.1	374	404	80	544	170	357	187	3.19
9.6	374	401	77	547	173	360	187	3.15
10.1	367	398	73	544	177	360	183	3.07
10.6	369	394	70	549	180	365	184	3.04
11.1	368	391	66	552	184	368	184	3.00
12.6	365	383	58	557	192	374	183	2.90
13.1	364	381	56	558	194	376	182	2.88
14.6	356	376	51	555	199	377	178	2.79
16.0	344	372	48	547	202	374	172	2.70
17.5	333	369	45	538	205	372	167	2.62
18.0	329	368	44	535	206	371	165	2.60
19.5	321	366	41	529	209	369	160	2.54
20.0	318	365	41	527	209	368	159	2.52

Compression Stage Result for 350 Eff. Consolidation Pressure								
Location: **Addisu Gebeya**				Job ref.	**Thesis research**			
Soil Description: Red brown clay				Pit no.	**#2**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	**#2C**			
				Depth	**2.5m**			
CP, Kpa	**350**							
Failure Condition								
Strain , %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
7.68	**515**	**393**	**128**	**737**	**222**	**479**	**258**	**3.32**
Test results								
Strain , %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	265	0	350	350	350	0	1.00
0.2	109	267	2	458	348	403	55	1.31
0.4	163	270	5	508	345	427	82	1.47
0.6	208	273	8	550	342	446	104	1.61
0.8	244	277	12	582	338	460	122	1.72
1.3	319	322	57	612	293	452	159	2.09
1.8	370	352	87	633	263	448	185	2.41
2.3	407	373	109	649	241	445	204	2.69
2.7	435	387	122	662	228	445	217	2.91
3.2	455	396	131	674	219	446	227	3.08
3.7	470	401	136	684	214	449	235	3.20
4.2	483	404	139	694	211	452	241	3.29
4.7	493	405	140	702	210	456	246	3.35
5.2	500	405	140	710	210	460	250	3.38
5.7	505	403	139	717	211	464	253	3.39
6.2	509	402	137	722	213	468	255	3.39
6.7	513	399	134	728	216	472	256	3.38
7.2	514	396	131	733	219	476	257	3.35
7.7	515	393	128	737	222	479	258	3.32
8.2	515	390	125	740	225	482	257	3.29
9.7	502	380	115	738	235	486	251	3.13
10.2	495	376	111	734	239	486	248	3.08
11.6	480	367	102	728	248	488	240	2.94
12.1	469	364	99	720	251	485	235	2.87
12.6	462	362	97	715	253	484	231	2.83
13.1	457	360	96	711	254	483	229	2.80
14.6	440	356	91	699	259	479	220	2.70
15.6	427	353	88	689	262	475	214	2.63
16.1	417	352	87	680	263	471	209	2.59
17.6	400	350	85	665	265	465	200	2.51
18.0	394	349	84	660	266	463	197	2.48
19.5	374	346	81	643	269	456	187	2.39
20.0	372	346	81	641	269	455	186	2.38


Stress- Strain Cureve for 150 KPa Eff. Consolidation Pressure
Stress, KPa
300
250
200
150
100
50
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
Deviator Stress
Pore Pressure


Stress- Strain Cureve for 250 KPa Eff. Consolidation Pressure
Stress, KPa
400
350
300
250
200
150
100
50
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
Deviator Stress
Pore Pressure Change

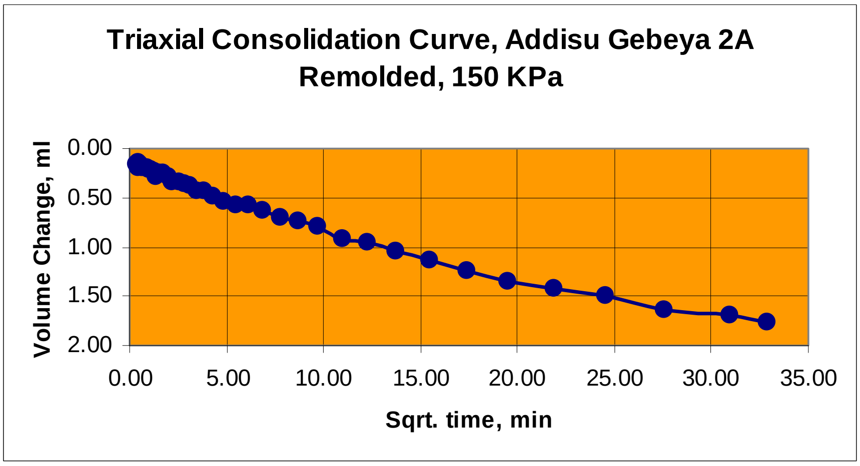

Stress- Strain Cureve for 350 KPa Eff. Consolidation Pressure
Stress, KPa
600
500
400
300
200
100
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %

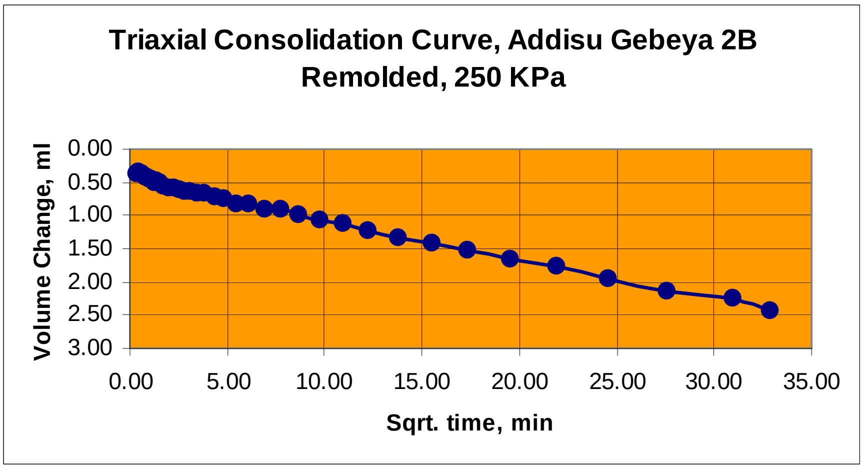


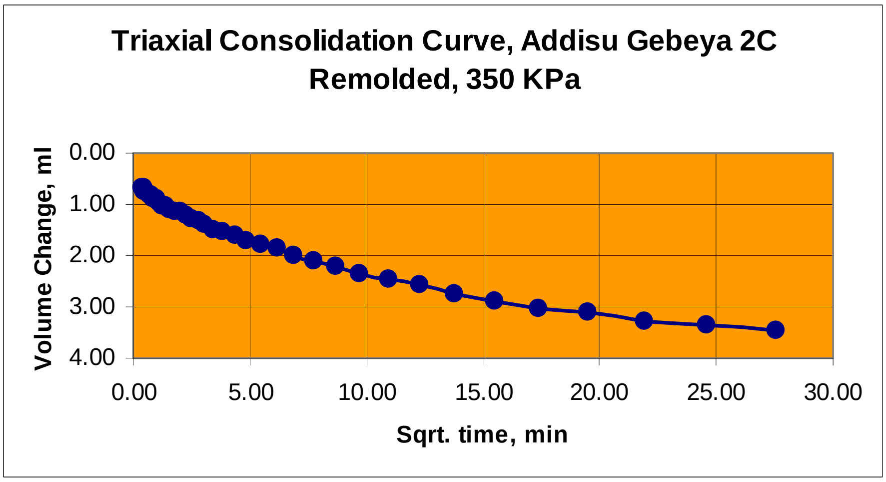
Stress-Strain Curve for three Effective Consolidation Stresses
Stress, KPa
600
500
400
300
200
100
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
For 150 KPa
For 250 KPa
For 350 KPa

Triaxial compression test result for Addisu Gebeya pit #2/Remolded

Consolidation Stage Result, Addisu Gebeya Pit 2, Remolded								
Location: ***Addisu Gebeya***					Job ref.	***Thesis research***		
Soil Description: Red brown clay					Pit no.	***#2***		
Test method: CU with measurement of					Sample no.	***#1***		
pore water pressure, BS 1377: Clause 8					Depth	***2.5m***		
Remolded Sample								
Effective Consolidation Pressure 150 Kpa			**Effective Consolidation Pressure 250 Kpa**			**Effective Consolidation Pressure 350 Kpa**		
Initial Condition	CP, Kpa	***560***	**Initial Condition**	CP, Kpa	***550***	**Initial Condition**	CP, Kpa	***600***
	BP, Kpa	**410**		BP, Kpa	***300***		BP, Kpa	**250**
	PP, Kpa	***544***		PP, Kpa	***536***		PP, Kpa	***573***
Final Condition	PP, Kpa	**410.2**	**Final Condition**	PP, Kpa	**303**	**Final Condition**	PP, Kpa	**300.2**
	ΔVolume,ml	***1.76***		ΔVolume,ml	***2.4***		ΔVolume,ml	***3.5***
	% Consolidation	**99.9**		% Consolidation	**98.5**		% Consolidation	**99.9**
Sqrt. Time	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**	**Sqrt. Time**	**ΔVolume,ml**	**PP, Kpa**
0.00	0.00	544	0.00	0.00	536	0.00	0.00	573
0.39	0.17	542	0.39	0.38	304	0.39	0.68	573
0.45	0.14	542	0.45	0.37	304	0.45	0.67	573
0.50	0.19	542	0.50	0.36	304	0.50	0.75	572
0.56	0.16	542	0.56	0.37	304	0.56	0.75	570
0.63	0.19	542	0.63	0.38	304	0.63	0.78	565
0.71	0.19	542	0.71	0.41	304	0.71	0.81	560
0.80	0.20	542	0.80	0.42	304	0.80	0.83	555
0.89	0.20	542	0.89	0.42	304	0.89	0.88	548
1.00	0.22	541	1.00	0.46	304	1.00	0.91	541
1.41	0.28	540	1.41	0.49	304	1.41	1.03	520
1.78	0.26	539	1.78	0.55	304	1.78	1.15	506
2.00	0.29	539	2.00	0.58	304	2.00	1.16	499
2.52	0.35	537	2.52	0.61	304	2.52	1.30	485
2.83	0.36	535	2.83	0.63	304	2.83	1.33	478
3.45	0.44	532	3.45	0.67	304	3.45	1.51	464
4.35	0.48	528	4.35	0.71	304	4.35	1.62	446
5.48	0.57	523	5.48	0.82	304	5.48	1.77	428
6.15	0.57	519	6.15	0.83	304	6.15	1.86	419
7.75	0.70	513	7.75	0.92	304	7.75	2.11	395
8.72	0.74	508	8.72	1.00	304	8.72	2.22	380
9.75	0.79	505	9.75	1.08	304	9.75	2.36	365
10.95	0.91	501	10.95	1.12	304	10.95	2.47	350
12.29	0.96	497	12.29	1.23	304	12.29	2.57	335
13.78	1.04	492	13.78	1.33	304	13.78	2.74	320
15.49	1.13	488	15.49	1.42	304	15.49	2.89	315
17.38	1.24	483	17.38	1.54	304	17.38	3.02	310
19.52	1.35	476	19.52	1.65	304	19.52	3.12	305
21.91	1.43	469	21.91	1.77	304	21.91	3.27	285
24.60	1.49	462	24.60	1.95	304	24.60	3.36	265
27.60	1.64	454	27.60	2.13	303	27.60	3.45	250
30.98	1.70	447	30.98	2.38	303	30.98	3.46	250


Triaxial Consolidation Curve, Addisu Gebeya 2A Remolded, 150 KPa
Volume Change, ml
0.00
0.50
1.00
1.50
2.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Sqrt. time, min


Triaxial Consolidation Curve, Addisu Gebeya 2B Remolded, 250 KPa
Volume Change, ml
0.00
0.50
1.00
1.50
2.00
2.50
3.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Sqrt. time, min


Triaxial Consolidation Curve, Addisu Gebeya 2C Remolded, 350 KPa
Volume Change, ml
0.00
1.00
2.00
3.00
4.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Sqrt. time, min

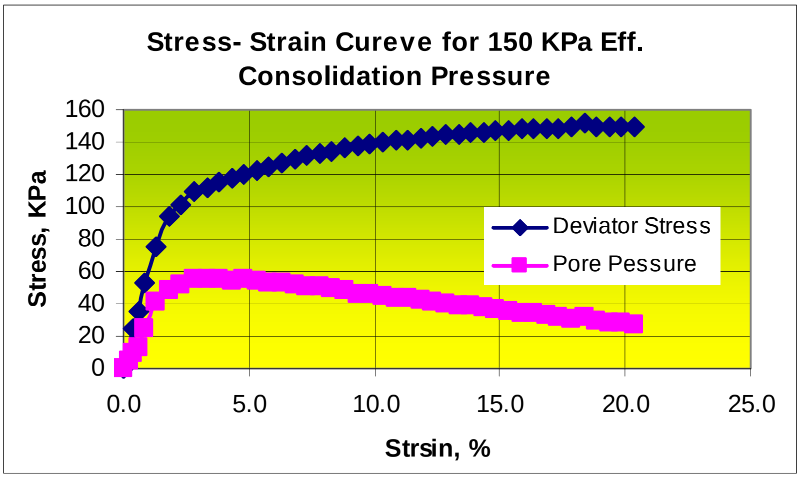
Compression Stage Result for 150 Eff. Consolidation Pressure								
Location: ***Addisu Gebeya***					Job ref.	***Thesis research***		
Soil Description: Red brown clay					Pit no.	**#2**		
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8					Sample no.	***#2A***		
					Depth	***2.5m***		
CP, Kpa	***150***							
Failure Condition								
Strain , %	Δσa.Kpa	PP, Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa
18.36	**152**	**505**	**31**	**271**	**119**	**195**	**76**	**2.28**
Test results								
Strain , %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	474	0	150	150	150	0	1.00
0.2	9	478	4	154	146	150	4	1.06
0.4	25	483	9	166	141	153	12	1.18
0.6	36	487	13	172	137	154	18	1.26
0.8	53	499	25	178	125	151	26	1.42
1.3	75	515	41	184	109	146	37	1.69
1.8	94	522	48	195	102	148	47	1.92
2.3	102	526	52	199	98	149	51	2.04
2.8	109	529	55	204	95	150	54	2.14
3.3	112	529	55	207	95	151	56	2.18
3.8	115	529	55	210	95	152	58	2.22
4.3	118	528	54	214	96	155	59	2.24
4.8	120	529	55	215	95	155	60	2.26
5.3	122	528	54	218	96	157	61	2.27
5.8	125	527	53	222	97	160	63	2.29
6.3	127	526	53	224	97	161	63	2.30
6.8	129	525	52	227	98	163	65	2.31
7.3	132	524	51	231	99	165	66	2.33
7.8	133	524	50	233	100	166	66	2.33
8.3	134	523	49	235	101	168	67	2.33
8.8	136	522	48	238	102	170	68	2.34
9.3	137	520	46	241	104	172	69	2.33
9.8	138	520	46	242	104	173	69	2.34
10.3	140	519	45	245	105	175	70	2.33
11.3	142	517	43	249	107	178	71	2.33
12.8	145	514	40	255	110	182	73	2.33
13.3	145	513	39	256	111	183	73	2.31
14.9	147	511	37	260	113	187	73	2.30
15.4	148	509	36	262	114	188	74	2.29
16.4	148	508	34	264	116	190	74	2.28
17.9	149	505	31	268	119	194	75	2.25
18.4	152	505	31	271	119	195	76	2.28
19.9	150	501	28	272	122	197	75	2.23
20.4	149	500	27	273	123	198	75	2.21

Compression Stage Result for 250 Eff. Consolidation Pressure								
Location: **Addisu Gebeya**				Job ref.	**Thesis research**			
Soil Description: Red brown clay				Pit no.	**#2**			
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8				Sample no.	**#2B**			
				Depth	**2.5m**			
CP, Kpa	**250**							
Failure Condition								
Strain , %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
16.72	**217**	**472**	**80**	**387**	**170**	**278**	**108**	**2.27**
Test results								
Strain , %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	392	0	250	250	250	0	1.00
0.2	62	436	44	268	206	237	31	1.30
0.4	87	454	61	276	189	232	44	1.46
0.6	102	463	71	281	179	230	51	1.57
0.8	115	469	77	288	173	231	58	1.66
1.3	134	476	84	300	166	233	67	1.81
1.8	149	481	89	310	161	236	75	1.93
2.3	158	485	93	315	157	236	79	2.01
2.8	167	489	97	320	153	237	84	2.09
3.3	175	491	99	326	151	238	87	2.16
3.8	178	493	101	326	149	237	89	2.20
4.3	182	495	103	329	147	238	91	2.24
4.8	185	496	104	332	146	239	93	2.27
5.3	188	496	104	334	146	240	94	2.29
5.8	191	496	104	337	146	242	96	2.31
6.3	194	495	103	341	147	244	97	2.32
6.8	196	495	102	344	148	246	98	2.33
7.3	199	494	102	347	148	248	100	2.34
8.3	202	492	100	353	150	251	101	2.35
9.8	208	487	95	363	155	259	104	2.35
10.3	209	486	94	365	156	260	104	2.34
11.7	212	483	91	372	159	266	106	2.33
12.2	213	481	89	374	161	267	106	2.32
13.7	215	478	86	379	164	272	108	2.31
14.2	216	477	85	382	165	273	108	2.31
15.2	216	474	82	384	168	276	108	2.29
16.7	217	472	80	387	170	278	108	2.27
17.2	217	470	78	389	172	280	109	2.26
17.7	217	469	77	390	173	282	109	2.25
18.2	216	468	75	390	175	282	108	2.24
19.7	215	464	72	393	178	286	108	2.21
20.2	215	463	71	394	179	286	108	2.20

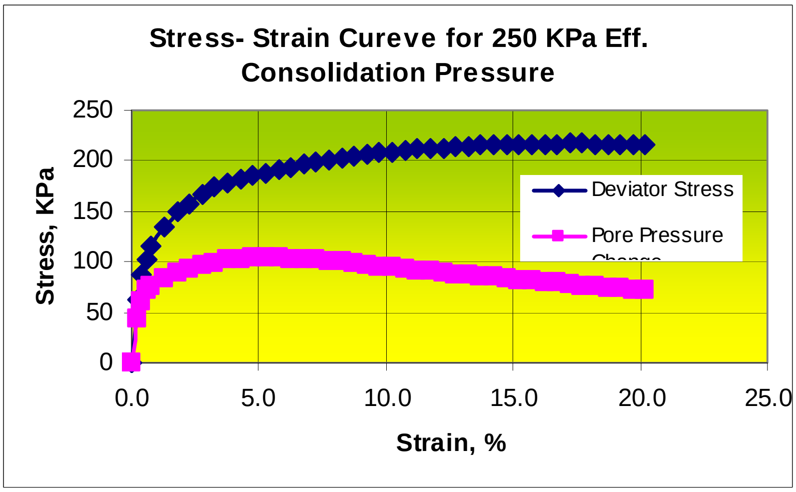
Compression Stage Result for 350 Eff. Consolidation Pressure			
Location:	**Addisu Gebeya**	Job ref.	**Thesis research**
Soil Description:	Red brown clay	Pit no.	**#2**
Test method: CU with measurement of pore water pressure, BS 1377: Clause 8		Sample no.	**#2C**
		Depth	**2.5m**
CP, Kpa	**350**		

Failure Condition								
Strain, %	Δσa.Kpa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
17.23	**311**	**487**	**98**	**563**	**252**	**407**	**155**	**2.23**

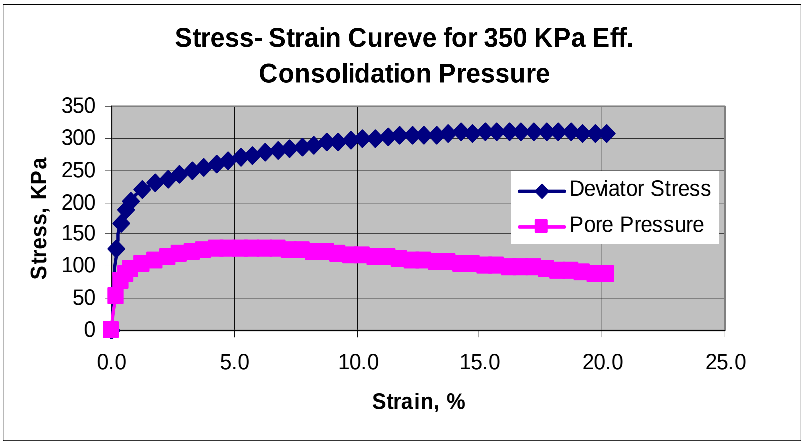
Strain, %	Dev. Stress, KPa	PP, Kpa	ΔPP, Kpa	σ1', Kpa	σ3', Kpa	s', KPa	t', KPa	σ1'/σ3'
0.0	0	386	0	350	350	350	0	1.00
0.2	128	440	54	424	296	360	64	1.43
0.4	167	462	76	442	274	358	84	1.61
0.6	189	474	88	451	262	357	94	1.72
0.8	202	480	94	458	256	357	101	1.79
1.3	221	490	104	467	246	357	111	1.90
1.8	231	495	110	472	240	356	116	1.96
2.3	237	501	115	472	235	354	119	2.01
2.8	244	505	119	475	231	353	122	2.05
3.3	250	508	122	478	228	353	125	2.10
3.8	254	511	125	479	225	352	127	2.13
4.3	261	513	127	484	223	354	131	2.17
4.8	265	513	128	488	222	355	133	2.19
5.3	269	514	128	491	222	356	135	2.21
5.8	273	513	128	496	222	359	137	2.23
6.3	277	513	127	501	223	362	139	2.24
6.8	281	512	126	505	224	364	141	2.26
7.3	285	512	126	509	224	367	142	2.27
7.8	287	510	124	513	226	369	144	2.27
8.3	290	509	123	517	227	372	145	2.28
8.8	293	507	121	522	229	375	147	2.28
9.3	294	505	119	525	231	378	147	2.28
10.8	300	501	115	535	235	385	150	2.28
11.3	303	499	113	540	237	388	151	2.28
12.7	305	494	108	548	242	395	153	2.26
13.2	306	492	106	550	244	397	153	2.26
14.7	308	489	103	555	247	401	154	2.25
15.2	309	487	101	558	249	404	155	2.24
16.7	310	483	97	563	253	408	155	2.23
17.2	311	482	98	563	252	407	155	2.23
17.7	311	480	94	566	256	411	155	2.22
18.2	309	479	93	566	257	412	155	2.20
19.7	308	474	88	570	262	416	154	2.18
20.2	308	474	88	571	262	416	154	2.18



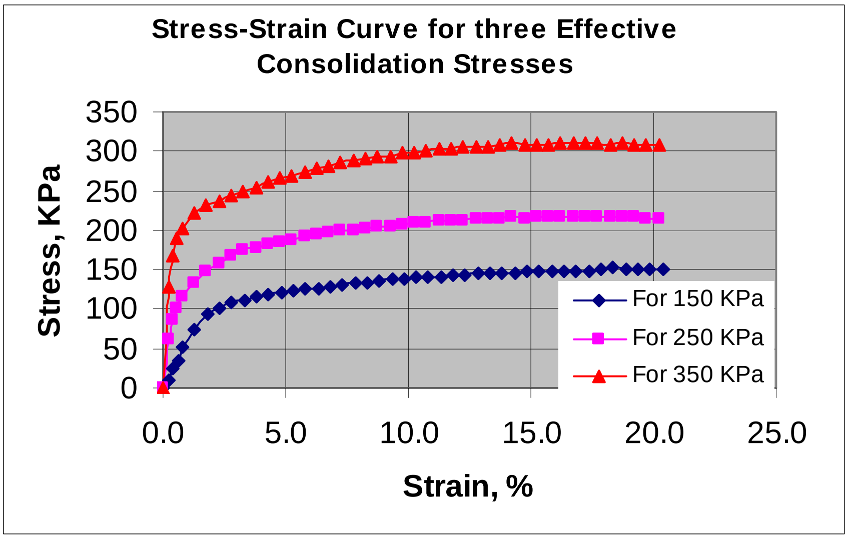
Stress- Strain Cureve for 150 KPa Eff. Consolidation Pressure
Stress, KPa
160
140
120
100
80
60
40
20
0
0.0
5.0
10.0
15.0
20.0
25.0
Strsin, %
Deviator Stress
Pore Pessure



Stress- Strain Cureve for 250 KPa Eff. Consolidation Pressure
Stress, KPa
250
200
150
100
50
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
Deviator Stress
Pore Pressure



Stress- Strain Cureve for 350 KPa Eff. Consolidation Pressure
Stress, KPa
350
300
250
200
150
100
50
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
Deviator Stress
Pore Pressure


Stress-Strain Curve for three Effective Consolidation Stresses
Stress, KPa
350
300
250
200
150
100
50
0
0.0
5.0
10.0
15.0
20.0
25.0
Strain, %
For 150 KPa
For 250 KPa
For 350 KPa

References

1. Terzaghi, K. and Peck, R.B. , Soil mechanics in Engineering Practice**,** John Willey & Sons, New York, 1967.
2. Lambe, T.W., and Whitman, R.V., Soil Mechanics, John Willey & Sons, New York, 1979.
3. Koliji A., Mechanical Behavior of unsaturated aggregated soil, PHD Dissertation Work, Switzerland, 2008.
4. Budhu, M., Soil Mechanics and Foundations, John Willey & Sons, Arizona, 2007.
5. Mitchell, J. K., Fundamentals of soil behavior, John Willey & Sons, California – Berkley , 1976.
6. Samuel, T., Investigation in to some of engineering properties of Addis Ababa red clay soil, MSc Thesis, Addis Ababa University, 1989.
7. Hailermariam, A., Investigation in to shear strength characteristics of red clay soils, MSc Thesis, Addis Ababa University, 1992.
8. BS1377, Methods of test for soil for engineering purpose, British Standard, UK, 1990.
9. ASTM Vol. 0408, Standard test methods for soil and rock, American Standard for Testing and Materials, USA, 1998.
10. Morin, W.J., and Parry, W.T., Geotechnical Properties of Ethiopian Volcanic Soils, Geotechnique Vol. 21, No 3, 223-232, 1971.
11. Das, B.M, Advanced Soil Mechanics, Taylor and Francs, New York, 2008.
12. Lambe, T.W., Soil Testing for Engineers, John Wiley and sons, USA, 1962.
13. Arora, K.r., Soil Mechanics and Foundation Engineering, Standard publishers and distributors, Delhi, 1997.
14. Semma, T., A study on the stress-strain behavior of undisturbed Addis Ababa Red clay soil using constitutive models and FEM, MSc Thesis, Addis Ababa University, 2009.

DECLARATION

I, the undersigned, declare that this thesis is my original work performed under the supervision of my research advisor Dr. Hadush Seged and has not been presented as a thesis for a degree in any other university. All sources of materials used for this thesis have also been duly acknowledged.

Name: Merihun Lukas

Signature ____________

Place Faculty of Technology,
Addis Ababa University,
Addis Ababa.

Date April, 2010