JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
(HIGHWAY ENGINEERING STREAM)

DEVELOPING CORRELATIONS BETWEEN DYNAMIC CONE PENETROMETER AND CBR FOR SUBGRADE SOILS IN ADDIS ABABA

BY – SALEM HABEKIRSTOS BEYENE

A MASTERS THESIS SUBMITTED TO JIMMA UNIVERSITY SCHOOL OF GRADUATE STUDIES AS A PARTIAL FULFILLMENT FOR THE REQUIREMENTS OF THE DEGREE OF MASTERS OF SCIENCE IN CIVIL ENGINEERING (HIGHWAY ENGINEERING)

DECEMBER/2016

JIMMA, ETHIOPIA

JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

(HIGHWAY ENGINEERING STREAM)

DEVELOPING CORRELATIONS BETWEEN DYNAMIC CONE PENETROMETER AND CBR FOR SUBGRADE SOILS IN ADDIS ABABA

A MASTERS THESIS SUBMITTED TO JIMMA UNIVERSITY SCHOOL OF GRADUATE STUDIES AS A PARTIAL FULFILLMENT FOR THE REQUIREMENTS OF THE DEGREE OF MASTERS OF SCIENCE IN CIVIL ENGINEERING (HIGHWAY ENGINEERING)

MAIN ADVISOR – DR.-ING. ESAYAS ALEMAYEHU (PhD)

CO. ADVISOR – JEMAL JIBRIL (MSc)

BY – SALEM HABEKIRSTOS BEYENE

DECEMBER/2016

JIMMA, ETHIOPIA

JIMMA UNIVERSITY

POST GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

MSc. Thesis on:

DEVELOPING CORRELATION BETWEEN DYNAMIC CONE PENETROMETER AND CBR FOR SUBGRADE SOILS IN ADDIS ABABA

BY

SALEM HABEKIRSTOS BEYENE

Approved by board of examiners:

Chairman	Signature	Date
…………………………..	………………………	………………………….
Advisor	Signature	Date
…………………………..	………………………….	………………………….
Co- advisor	Signature	Date
…………………………..	………………………….	………………………….
Internal Examiner	Signature	Date
…………………………..	………………………….	………………………….
External Examiner	Signature	Date
…………………………..	………………………….	………………………….

Acknowledgement

First I would like to thank the almighty God for everything that he did for me.

Next I would like to express my deepest gratitude to my advisor Dr. Esayas Alemayehu (Phd) and Mr. Jemal Jibril (MSc) for their professional and genuine guidance.

My special thanks go to my beloved family and friends for their support and encouragement during the whole study.

Last but not least, I would like to thank ERA and Jimma University for giving me this special opportunity to pursue MSc. And finally I would like to thank Addis Ababa City Road Authority and Gondwana Engineering Plc.'s staffs especially Ato. Zerihun Nuru for providing me laboratory services.

ABSTRACT

California Bearing Ratio test is used to value the suitability of the sub grade and the materials used in sub base and base course. This test can be done in the laboratory as well as in the field. Dynamic cone penetrometer is an instrument used to evaluate insitu strength of pavement base, sub base and sub grade materials.

But CBR testing is relatively an expensive, time consuming test and has low repeatability. Moreover, it is very difficult to mould the sample at desired insitu density in the laboratory. Therefore, to overcome these problems, the other method (Dynamic Cone Penetrometer) is used in this study. This device is cheap, portable and less time taking.

A study was carried out to find the correlation between Cone Penetrometer (DCP) with CBR values that best suit subgrade soils. Accordingly, several laboratory tests and field tests in Addis Ababa has been conducted on 10 test pits with three layers. From the tests, the Atterberg limits (PI, LL, and PL), In situ density, classification (sieve analysis), California bearing ratio, insitu Moisture Content, and Dynamic cone penetration results are acquired. Based on this laboratory and field test results analyses were carried out using SPSS software.

After seeing the scatter diagram it is observed that DCPI is highly influenced by natural moisture content and in situ density. It is also found out a good relationship does exist between DCP and CBR.

In order to find out an expression that best suits the value of CBR from DCP and other parameters different techniques are used. The accepted one is the expression developed by using two stage residual inclusion estimation using as variable. From the analysis result gives the following equations with coefficient of determination of R^2*=0.827*

Keywords: DCP, CBR, Correlation

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AACRA	Addis Ababa City Road Authority
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BS	British standards
CBR	California Bearing Ratio
CPT	Cone penetration test
DCP	Dynamic cone penetrometer
DCPI	Dynamic cone penetration index
Ft	Feet
FWD	Falling weight deflectometer
KN	Kilo newton
LI	Liquidity Index
LL	Liquid Limit
MDD	Maximum Dry Density
mm	Millimetre
MnDOT	Minnesota department of transportation
NMC	Natural Moisture Content
OMC	Optimum Moisture Content
PI	Plasticity Index
PL	Plasticity Limit
R^2	Coefficient of determination
SPSS	Statistical Package for Social Science Software
TRRL	Transport road research laboratory
USCS	Unified Soil Classification System

CHAPTER 1
INTRODUCTION

1.1 Background

DCP, also known as the Scala penetrometer, was developed in 1956 in South Africa as an in situ pavement evaluation technique for evaluating pavement layer strength (Scala, 1956.) Since then, this device has been extensively used in South Africa, the United Kingdom, the United States, Australia, and many other countries, because of its Portability, simplicity, cost effectiveness, and the ability to provide rapid measurement of In situ strength of pavement layers and subgrades. The DCP has also been proven to be Useful during pavement design and quality control program (Farshad, 2003).

The DCP has been intended to alleviate many of the deficiencies of systems that are manually pushed into soil or paving materials. The device is relatively simple in design and operation, and operator variability is reduced and thus correlations with strength parameters are more accurate.

California bearing ratio is empirical test developed in 1928-29 and is widely applied in design of flexible payment over the world. This test was introduced during 2nd world war in USA and now it is being used as standard method of design in other parts of world. But due to its imperialness (Brown, 1996 It is in essence a simple penetration test developed to evaluate the strength of road sub grades (soil below the pavement) and makes no attempt to determine any of the standard soil properties such as density. It is merely a value and it is integral to the process of road design. It is however, by far the most commonly used in Pavement Design. The CBR test should be used with soil at the calculated equilibrium moisture content. Almost all design charts for the road foundations are based on the CBR value of the sub grade materials. (B.S, 1990) it is recently being discouraged in some advanced countries because CBR test procedure is costly and a lot of time is required to perform this test. This test also required a large amount of soil sample for the laboratory test (Farshad, 2003).

In the construction industry of our country (Ethiopia), particularly in road construction, if especially the terrain type is classified as escarpment, a high volume of excavation (sometimes it requires an excavation as deep as 10m from the original ground level) is needed for the construction of the road project. Hence the foundation investigation carried out at the design stage will be barely used .This will lead to the need for another subgrade investigation at the final road level. So, most geotechnical engineers find out that a high amount of money is invested through these stages .this is due to the use of dynamic cone penetration is limited to few design offices and the absence of developed design charts or formula which correlate DCP and CBR test results for subgrade soils.

Thus, due to the relatively fast and easy use of DCP test the development of correlations between CBR and DCP test for sub grade materials will reduce cost and time required for design and construction. Besides, since the currently available correlations were not developed based on the test made on local soil, it may either underestimate or overestimate the soil strength. In either case, it may have a negative impact on the economy of the country in general and on the construction industry in particular.

1.2 Statement of the Problem

California Bearing Ratio test is most widely used for analysis and design of pavement layers. Virtually, all design charts for the road foundations are based on the CBR value of the sub grade materials. However, California Bearing Ratio test is expensive, relatively slow to conduct and generally not favored by Highway Engineers.

There is much interest in finding quick, cheap test methods to carry out the required design and analysis efficiently with short time.

DCP, being light and portable offers an attractive means of determining in situ soil strength at a comparative speed and ease of operation and its higher repeatability from

CBR, various correlations have been developed by different researchers from samples of their locality. Hence, adopting those developed correlations without adjustment for locally available subgrade soils leads misinterpretation of the local soil behavior.

1.3 Research questions

The research questions that this study will attempt to clarify during the study period are:

1. What are the expected result of DCP test?
2. What are the expected CBR value?
3. What will be the correlation between DCP and CBR of Addis Ababa?
4. What will be the result of this study compared to previously done researches?

1.4 Objectives

1.4.1 General Objective

- To make a correlation between Dynamic Cone Penetrometer test and California Bearing Ratio test to be adopted for subgrade material in Addis Ababa.

1.4.2 Specific Objective

- To assess the properties of soils using DCP results of the soil.
- To determine the CBR values of the soil.
- To establish correlation between DCP and CBR.
- To compare the correlation with previously done researches.

1.5 Significance of the study

Currently, most geotechnical, material and highway engineers use DCP to find CBR by using the equation provided by TRL manual and adapted by ERA which is for all types of soil. This may either underestimate or overestimate the soil strength. In either case, it may have a negative impact on the economy of our country in general and in particular on the construction industry.

Therefore, correlations developed between DCP and CBR for locally used sub grade materials to enable the Geotechnical Engineer and/ or road designers to use the empirical curves developed for CBR to determine the thickness of pavement and its component layers and to verify the adequacy of the existing pavement layer easily and promptly is desired (Farshad, 2003).

1.6 Scope of the Study

The Field and Laboratory tests that are done in this thesis are Soaked CBR value, DCP test, sieve analysis, compaction test, Atterberg limits, insitu density and in situ moisture content determination tests. The study area was targeted only on random selection of A-7-5 soils in Addis Ababa. And also only 10 test pits was excavated at 1m, 1.5m and 2m.

As in most researches that attempt to correlate different engineering parameters, the size of statistical data is the main factor that limits the applicability of the results obtained. The other limitation would be the number of test pits.

1.7 Thesis Organization

The thesis is organized and presented under five chapters. The first chapter highlights introduction of the subject study. Chapter two deals with review of published literatures and journals. In chapter three, discussions on sample collection, methods and test results were made. In chapter four, correlation and regression analyses between the CBR and DCP test results were conducted and under chapter five, the conclusion and recommendation were presented. At the end, details of the regression, field and laboratory test results enclosed under appendix section.

CHAPTER 2

LITERATURE REVIEW

2.1. General

Pavement structure design is based on three factors: loading (projected traffic), paving material properties (strength, aging, environmental effects, etc.), and subgrade support. But many uncertainties exist in pavement design. Even after a road is opened to traffic, the engineer cannot verify the accuracy of the traffic projection until the project has been through its design life (Wu and Sargand, 2007).

During the design stage, the engineer selects a subgrade support value based on a few samples taken from the project site and some engineering assumptions. The engineer controls paving material properties through quality assurance/quality control (QA/QC) programs during construction. Most states use density of the in-place subgrade and unbound base for construction quality control. However, density is not a load-bearing indicator. Also, in most cases, thickness of the unbound base layer is not monitored closely (Wu and Sargand, 2007).

Experience shows that it is very costly to repair a failed pavement caused by poor base or subgrade quality. Therefore it is very important and beneficial to verify and improve, if needed, the quality of the base and subgrade prior to paving operations and to provide engineers an opportunity to re-evaluate and modify pavement structure design during paving operations (Wu and Sargand, 2007).

Pavement performance depends greatly upon the quality and uniformity of materials incorporated into the pavement structure. Careful monitoring of material quality and the dimensions of pavement layers during construction improves overall compliance with specifications as well as in-service performance of the pavement (Wu and Sargand, 2007).

To give useful information, it necessary to investigate the current pavement condition using some form of destructive or non-destructive testing. The usual method of destructive testing is to dig test pits at suitable intervals along the road. These are very useful as pavement thicknesses can be measured and sample can be easily taken for laboratory testing. However, test pits are expensive to dig and reinstate and are rarely dug at intervals of less than 2-3 kilometres. As a result, the quality control/ quality assurance procedures of construction should be based on a criterion that closely correlates to the performance parameters used in the design (Wu and Sargand, 2007).

2.2 Dynamic Cone Penetration

2.2.1 Historical Development of DCP

The first Dynamic Cone Penetrometer (DCP), which is similar the one available now, known as Scala Penetrometer was developed by Scala (1956) in Australia. It was used for determination of in-situ CBR of cohesive subgrade soils. The Scala Penetrometer consists of about 9 kg hammer which drops from 510 mm height through a vertical guide rod. The hammer impact energy is ultimately applied on to a cone (having apex angle 30^o) fitted at bottom end of the guide rod (Kumar,Ajmi and Valkati,2015).

Later, a similar tool like DCP was developed by van Vuuren (1969). It consists of a 10 kg hammer which drops freely from 460 mm height. The impulse force is applied on to a cone having 30^o. He has developed a relationship between the DCP test results and CBR values of subgrade soil (Kumar,Ajmi and Valkati,2015).

For rapid evaluation of flexible pavements a DCP was used by the Transvaal Roads Department of South Africa in 1973 (Kleyn 1975). The DCP consisted of 8 kg hammer which drops from height of 574 mm. The cone's apex angles considered were 30^o and 60^o and a comparative study was carried out between the DCP test results (Kleyn et al 1982). Another report (Kleyn and Savage, 1982) reveals that, several investigations were made on subgrade tested with DCP using 8 kg hammer dropped from height of 574 mm and with the cone's apex angle as 60^o (Kumar,Ajmi and Valkati,2015)

2.2.2 Description of the Device

The DCP tests were conducted according to the procedure laid down in ASTM-D6951-3 (2003). The apparatus consists of 16mm diameter steel rod in which a tempered steel cone with a 20 mm base diameter and a 60 degree point angle is attached. The DCP is driven into the soil by a 8kg hammer with a free fall of 575mm. The hammer correction factor is unity for 8kg hammer. Figure1 shows the dimensions of the dynamic cone penetrometer.

The DCP index or reading is defined as the penetration depth (D) in mm for a single drop of hammer. The cone is driven in to the ground up to the desired depth and average DCP index is calculated for a single blow. Depth of penetration considered in the study was 800mm because the stresses induced due to the wheel load becomes negligible beyond this depth. (Gill, Jha and Choudhary, 2010).

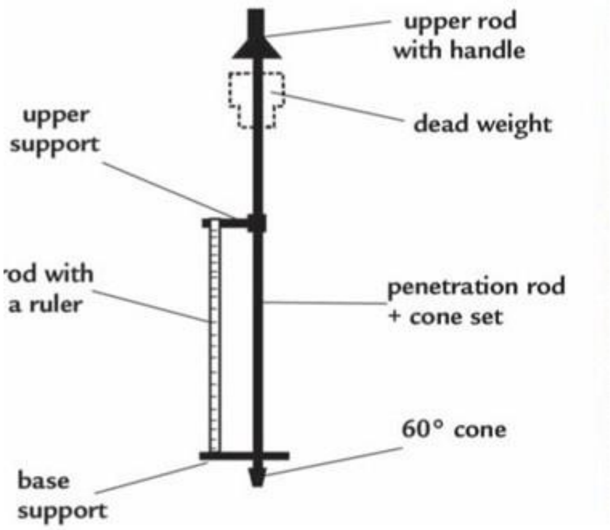


Fig. 2.1: Dynamic Cone Penetrometer

2.2.3. Test Procedure

To begin with the testing procedure, initial reading on the DCP scale should be noted while holding the rod vertical and the cone in contact with surface of compacted soil to be tested. While one person holds the DCP handle, another person should lift the hammer to the predetermined height (i.e. 575 mm) and allow it to drop freely on to the anvil. Cumulative penetration values of the cone should be noted for each blow. Generally, the DCP testing should be stopped when the cone penetration is not more than 1 mm per blow since the cone may encounter a rock, gravel larger than 20 mm size or hard strata. After the DCP test is over, the cone-rod should be extracted out and the soil sample may be collected for conducting other tests in laboratory.

An extension rod of additional length of 1000 mm may be used in place of the standard penetrating rod where it is necessary to test the deep soil (Livneh and Livneh, 1994).

A study was conducted by Livneh (1991) for determining the change in rate of penetration due to change in the cone apex angle from 30^o to 60^o and suggested the following relationship to convert DCP index value (in mm/blow) interms of the other. Ayers,Thompson and Uzarski suggested the following:-

$$DCP\ 30^0 = 0.006 + 1.092\ DCP\ 60^0 \ldots\ldots \text{(Equation 2.1)}.$$

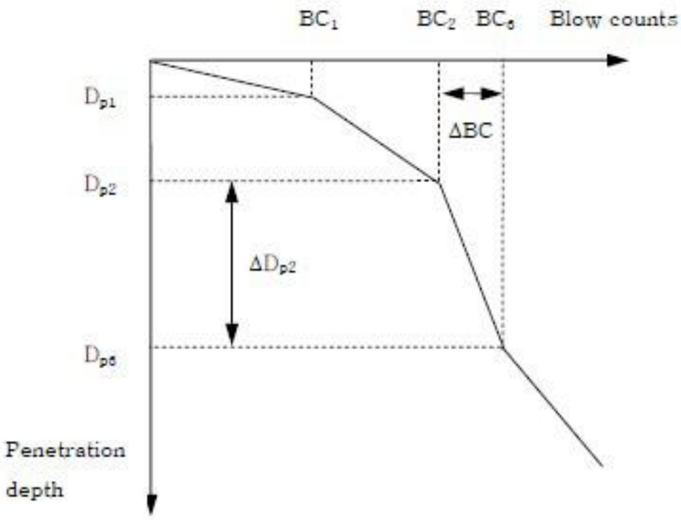
The DCP test can also be conducted in a laboratory on remolded material compacted in a steel mould which significantly eliminates the effect of confinement and such test can also be carried out as a prototype model (Ayers et al, 1989 cited by Kumar, Ajmi and Valkati, 2015). Figure 2.2 shows the penetration result from the first drop of the hammer. Hammer blows are repeated and the penetration depth is measured for each hammer drop. This process is continued until a desired penetration depth is reached. DCPT results consist of number of blow counts versus penetration depth. Since the recorded blow counts are cumulative values, results of DCPT in general are given as incremental values defined as follows,

$$PI = \frac{\Delta Dp}{\Delta BC} \text{ --------------------------------(Equation 2.2)}$$

Where PI = DCP penetration index in units of length divided by blow count;

ΔDp = Penetration depth; BC = blow counts corresponding to penetration depth ΔDp.

The DCP results, when plotted, describes the number of blows to reach a certain depth affording an instantaneous visual illustration of in-situ material strength (Fig 2.2). The slope of the curve at any point expressed in terms of mm/blow is called the dynamic cone penetration index (DCPI) which represents the resistance offered by the material; the lower the DCPI the stiffer the material, and vice versa (Farshad , 2003). As a result, values of the penetration index (PI) represent DCPT characteristics at certain depths.



(a)

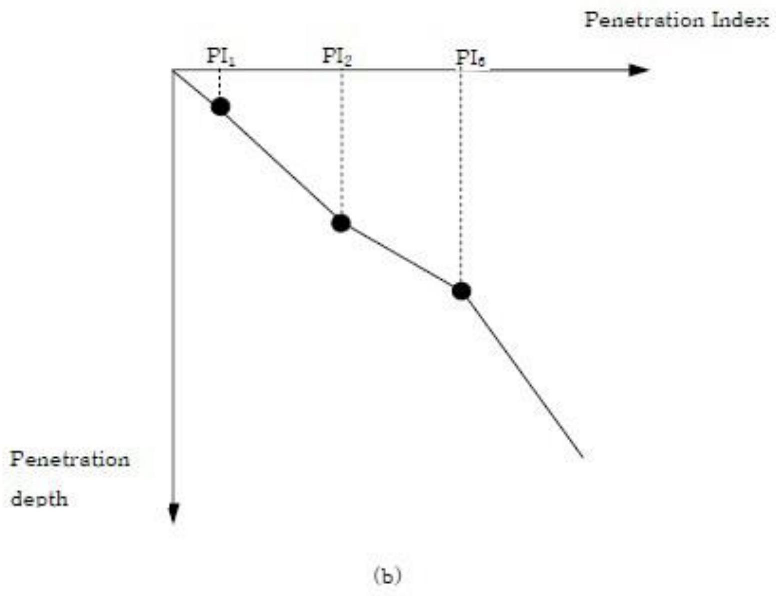


Figure 2.2: Typical DCP test results (a) Penetration depth vs. blow counts (b) Penetration index vs. penetration depth

The DCP cannot penetrate some strong surface and base materials such as hot mix asphalt or cement treated bases. These layers must be removed before the test can begin and their strength assessed using different criteria. Thus, if the cone does not penetrate 25 millimeters after 10 blows with the 8kg hammer (20 blows with the 5.05 kg hammer), the test should be stopped. If this firm material is a stabilized soil or high-strength aggregate base layer, it should be cored or drilled with an auger to allow access of the DCP cone to underlying layers. The DCP test can then proceed through the access hole after the depth of the material layer has been recorded.

The material layer is assigned a CBR value of 100+. However, if a core or auger drill is not available, the 8kg DCP hammer can normally be used to drive the lower rod and cone through the firm material. If the cone penetration was stopped by a large rock or other object, the DCP should be extracted and another attempt made within a few meter of the initial test. The DCP is generally not suitable for soils having significant amounts of aggregate greater than a 2-inch-sieve size. Besides, if repeated DCP tests are conducted longitudinally, a longitudinal picture of the selected section can also be developed which allows delineation of the area into homogeneous sections (Done and Piouslin, 2004).

2.2.4 Application of DCP

- **Cohesive and Selected Backfill Materials**

Historically, the compaction levels of pavement sub grade and base layers have been determined by means of in-place density testing such as sand replacement and nuclear gauge methods. In an effort to determine whether there is a reasonable correlation between the DCPI and in-place compaction density of cohesive and select backfill materials, some testing has been performed on these materials to determine if such a correlation exits. Most results of DCP testing have indicated too much variability in DCP results to practically apply a correlation (Burnham, 1997 cited by Farshad, 2003). Siekmeier et al. (1999), as part of the Minnesota Department of Transportation study, investigated the correlation between DCP results and compaction of soils consisting of mixture of clayey and silty sand fills. They first correlated DCPI to the CBR. CBR was then related to the modulus using published relationships. They examined the relations between the modulus and percent compaction. It was concluded that a good correlation did not exist between the DCP results and percent compaction, partly because a typical range of soil mixtures at the site was not truly uniform (Farshad, 2003).

- **Granular Base Layer Compaction**

The Minnesota Department of Transportation suggests this application to reduce testing time and effort while providing more consistent quality control of base layer compaction (Burnham, 1977). Using this procedure, immediately after the compaction of each layer of granular base material, DCP tests are conducted to insure that the DCPI is less than 19 mm per blow. The DCPI limiting value is valid for all freshly compacted base materials.

The DCPI dramatically decreases as the density of the material increase and under traffic loading. Using this method, the DCP testing will only indicate those adequately compacted base layers that pass. Test failure, however, must be confirmed by other methods such as the nuclear gauge or the sand cone density method. Based on general agreement between the DCPI and percent compaction, the Minnesota Department of Transportation has revised the limiting penetration rate to the following (Siekmeier et al., 1998):

a) 15 mm/blow in the upper 75 mm;
b) 10 mm/blow at depths between 75 and 150 mm; and
c) 5 mm/blow at depths below 150 mm.

They concluded that the penetration rate is a function of moisture content, set-up time, and construction traffic, and that accurate and repeatable tests depend on seating the cone tip properly and beginning the test consistently. They recommended the following:

a) The test is performed consistently and not more than one day after compaction while the base material is still damp;
b) The construction traffic be distributed uniformly by requiring haul trucks to vary their path; and
c) At least two dynamic cone Penetrometer tests be conducted at selected sites within each 800 cubic meters of constructed base course.

They proposed a Penetration Index Method (Trial MnDOT Specifications 2211.3C4) which described a step-by-step procedure for determining the pass and fail tests (Siekmeier, et al. 1998). Siekmeier et al. (1999), as part of the Minnesota Department of Transportation study, studied the correlation between DCP results and compaction of soils consisting of sand and gravel mixture with less than 10-percent fine. They first correlated DCPI to the CBR. CBR was then correlated to the modulus using published relationships. They examined the relations between the modulus and percent compaction. It was concluded a good correlation existed between the DCP results and percent compaction (Farshad, 2003).

- **Granular Materials around Utilities**

Many transportation agencies use granular soils as backfill and embedment materials in the installation of underground utility structures, including the thermoplastic pipe used in gravity flow applications. The granular backfill relies on proper compaction to achieve adequate strength and stiffness and to ensure satisfactory pipe performance.

The commonly used standard proctor test for granular materials cannot be used because it does not provide a well-defined moisture-density relationship. In addition, this approach requires density measurements on each lift of the compacted fill for the entire length of the pipe. Recent studies indicate that DCP blow count profiles provide a basis for comparison between compaction equipment, level of compaction energy, and materials. But, it should be noted that these data alone do not reveal what level of compaction must be achieved with each type of backfill material in order to achieve the specific performance criteria. The results have also indicated that the DCPI values are very sensitive to the depth of measurements (Jayawickrama, et al., 2000; cited by Farshad, 2003).

- **Backfill Compaction of Pavement Drain Trenches**

The Minnesota Department of Transportation has indicated that the DCP testing is reliable and effective in improving the compaction of these trenches. Using this procedure, immediately after installation of the pavement edge drainpipe and fine filter granular backfill material, DCP testing is conducted to insure that the DCPI is less than 75 mm per blow. In this approach, each 150 mm of compacted backfill material is tested for compliance (Burnham, 1997 cited by Farshad, 2003).

2.2.5 Application of DCP for Performance Evaluation of Pavement Layers

Performance evaluation of pavement layers is needed on a regular basis in order to categorize the implementation of rehabilitation measures (e.g., Kleyn, et al., 1982). The Minnesota Department of Transportation, based on the analysis of Mn/Road DCP testing, has recommended the following limiting values for DCPI during a rehabilitation study (Burnham, 1997 cited by Farshad, 2003).

a) Silty/Clayey material: DCPI less than 25 mm/blow;
b) Select granular material: DCPI less than 7 mm/blow; and
c) Mn/Road Class 3 special gradation requirements: DCPI less than 5 mm/blow

The above values are based on the assumption that adequate confinement exists near the testing surface. In the event that higher values than the above mentioned limiting values are encountered, additional testing methods are needed. It should be noted that the above values are independent of the moisture content. Moisture content can cause large variability in DCP test results. Nevertheless, a limiting value was recognized. (Gabr et al., 2000 cited by Farshad, 2003). Proposed a model by which the DCP data are utilized to evaluate the pavement distress state. They proposed a model to predict the distress level of pavement layers using penetration resistance of the sub grade and aggregate base course layers based on coupled contribution of the sub grade and the aggregate base course materials. They provided a step-by-step procedure, based on the correlation of the DCPI with CBR, by which the DCP data can be used to evaluate the pavement distress state for categorizing the need for rehabilitation measures. Although their pavement stress model was specific in this study regarding the type of the aggregate base course (ABC) material tested, the framework of the procedure can be used at other sites (Farshad,2003).

2.2.6 Application of DCP to Obtain Layer Thickness

DCP can also be used effectively to determine the soil layer thickness from the changing slope of the depth versus the profile of the accumulated blows. Livneh (1987) showed that the layer thickness obtained from DCP tests correspond reasonably well to the thickness obtained from the test pits. It was concluded that the DCP test is a reliable alternative for project evaluation (Farshad, 2003).

2.2.7 Complementing falling weight deflectometer (FWD) during Back calculation

It has been shown that the DCP is very useful when the moduli back calculated from FWD data are in question, such as when the asphalt concrete is less than 76 mm or when shallow bedrock is present (e.g., Little et al., 1995). These two situations often cause a misinterpretation of FWD data. The DCP can be readily applied in these two situations to increase the accuracy of the stiffness measurement. In addition, it is not possible to conduct a FWD test directly on weak sub grade or base layers because of the large deflections that can exceed the equipment's calibration limit (Farshad, 2003).

2.2.8 Factors Affecting DCP Results

There are some factors that affect the applicability of the equipment and reliability of the test results obtained from the dynamic cone penetrometer. Several investigators have studied the influence of several factors on the Dynamic Cone Penetration Index (DCPI) and they have implied that the following are the factors affecting the outcome of the DCP results.

a) Material Effects: Klein and Savageas cited by Amini (Amini, 2003), indicated that moisture content, gradation, density, and plasticity were important material properties influencing the DCPI. Hassan (Hassan, 1996). Performed a study on the effects of several variables on the DCPI. He concluded that for fine-grained soils, moisture content, soil classification and dry density affect the DCPI. For coarse-grained soils, coefficient of uniformity and confining pressures were important variables.

b) Vertical Confinement Effect: Livneh, et al. (Livneh, 1995) performed a comprehensive study of the vertical confinement effect on dynamic cone penetrometer strength values in pavement and sub grade evaluations. The results have shown that there is no vertical confinement effect by upper cohesive layers on the DCP values of lower cohesive sub grade layers. In addition, their findings have indicated that no vertical confinement effect exists by the upper granular layer on the DCP values of the cohesive sub grade beneath them. Any difference between confined and unconfined values in the case of granular materials is due to the friction developed in the DCP rod by tilted penetration or by a collapse of the granular material on the rod surface during penetration.

c) Side Friction Effect: Because the DCP device is not completely vertical while penetrating through the soil, the penetration resistance would be apparently higher due to side friction. This apparent higher resistance may also be caused when penetrating in a collapsible granular material. This effect is usually small in cohesive soils compared to collapsible granular material (Carter and Bentley, 1991).

2.3 California Bearing Ratios (CBR)

2.3.1. General

The California Bearing Ratio test was developed by the California State Highways Department in the 1930's. It is in essence a simple penetration test developed to evaluate the strength of road sub grades (soil below the pavement) and makes no attempt to determine any of the standard soil properties such as density. It is merely a value and it is integral to the process of road design. It is however by far the most commonly used in Pavement Design. The CBR test should be used with soil at the calculated equilibrium moisture content. Almost all design charts for the road foundations are based on the CBR value of the sub grade materials. It is also used as a means of classifying the suitability of a soil for use as sub grade or base course material in highway construction.

During World War II, the US corps of engineers adopted the test for use in airfield construction (Bowles, 1984).The CBR test (ASTM terms the test simply as a bearing ratio test) measures the shearing resistance of a soil under controlled moisture and density conditions. The test yields the bearing ratio number, but from previous statement, it is evident that this number is not a constant for a given soil but applies only for the tested state of the soil. The CBR number is obtained as the ratio of the unit load (in KN/m^2) required effecting a certain depth of penetration of the penetration piston (with an area of $19.4cm^2$) in to a compacted specimen of soil at some water content and density to the standard unit load required to obtain the same depth of penetration on a standard sample of crushed stone. It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. In equation form

$$CBR\ (\%) = \frac{\text{Test Unit Load}}{\text{Standard Unit Load}} * 100 \quad \text{………………………} \quad \text{(Equation 2.3)}$$

From the above equation, it can be seen that the CBR number is a percentage of the standard unit Load. In practice, the percentage symbol is dropped and the ratio is simply a number, such as 3, 45, and 60. Values of standard unit loads to use in equation 2.3 are listed in Table 2.1 below.

Table 2.1 Values of standard unit loads

Penetration(mm)	Standard unit load (MPa)
2.5	6.9
5.0	10.3
7.5	13.0
10.5	16.0
12.7	18.0

The CBR values are usually calculated for penetration of 2.54 mm and 5.04 mm. Generally the CBR value at 2.54 mm will be greater that at 5.04 mm and in such a case/the former shall be taken as CBR for design purpose. If CBR for 5.04 mm exceeds that for 2.54 mm, the test should be repeated. If identical results follow, the CBR corresponding to 5.04 mm penetration should be taken for design (Bowles, 1984).

The CBR value for a given soil will depend upon its density, molding moisture content, and moisture content after soaking. Since the product of laboratory compaction should closely represent the results of field compaction, the first two of these variables must be carefully controlled during the preparation of laboratory samples for testing. Unless it can be ascertained that the soil being tested will not accumulate moisture and be affected by it in the field after construction, the CBR tests should be performed on soaked samples (David & John, 2005) In addition, the result of a CBR test also depends on the resistance to the penetration of the piston. Therefore, the CBR indirectly estimates the shear strength of the material being tested (Rodriguez et al. 1988 cited by Munir, 2003) relative ratings of supporting strengths as a function of CBR values are given in Table 2.2

Table 2.2 Ratings of supporting strengths

CBR (%)	Material	Rating
> 80	Sub base	Excellent
50 to 80	Sub base	Very good
30 to 50	Sub base	Good
20 to 30	Sub grade	Very good
10 to 20	Sub grade	Fair-good
5 to 10	Sub grade	Poor-fair
< 5	Sub grade	Very poor

Generally, clays have a CBR value of 6 or less. Silty and sandy soils are next, with CBR values of 6 to 8. The best soils for road-building purposes are the sands and gravels whose CBR values normally exceed 10.

The equipment for determining CBR value is a piston having an area of three square inches. The piston is moved in vertical direction on a soil sample with a speed of 0.05 inch/ minute. A Proving ring with dial gauge is attached to the piston to measure the load at certain penetration. The CBR value is the comparison between applied piston loads on a soil sample and the standard loads, which value is expressed in percentage (ASTM D- 1883, AASTHO T-193).

Basically, the CBR value describes the strength soil compared to the standard material. Indirectly, it also describes the relative density of the soil. Several correlations between CBR values and the results of other field measurements exist such as to results of Dynamic Cone Penetrometer (DCP) test (Van Vuuren, 1969), (Klimochko, 1991), (Smith and Pratt, 1983). This has been used in practice (Nugroho, Yusa and Ningsih, 2012).

2.3.2 Description of the Device

Equipment required for field tests are a setfield CBR tools and a CBR mould. The CBR mould was used to obtain undisturbed sample for determination of physical and mechanical properties of the soil in laboratory and CBR mould uses to determine CBR value after soaked in the Laboratory for 4 (four) days. Along mould containing specimen soaked, swelling of the specimen should be noted to know swelling potential of the soil from different location. Figure 2 shows the layout of CBR test in the Laboratory (soaked) ((Nugroho,Yusa and Ningsih, 2012).

Figure 2.3: CBR testing apparatus

2.3.3 Test Procedure

The California Bearing Ratio (CBR) test may be performed either in the laboratory, typically with a recompacted sample, or in the field. The field and Laboratory CBR tests have been carried out nearly in all projects in accordance with ASSHTO T193, BS1377:1990, ASTM D 4429 and ASTM D1883-73 respectively.

2.3.3.1 Insitu CBR Test

Field in-place tests are used to determine the relative strength of soils, sub-base and some base materials in the condition at which they exist at the time of testing. Field in-place CBR tests are used for the design of flexible pavement components and for other applications in which CBR is the desired strength parameter. If field CBR is to be used directly for evaluation or design without consideration for variation due to change in water content, the test should be conducted under one of the conditions stated in ASTM D 4429-93 (ASTM,2000).

In the field study, once a set of field CBR tools are setup for carrying out the penetration test, the cylindrical plunger is allowed to penetrate the soil at a given rate. The force required to cause the plunger to penetrate the in-situ soil with respect to the penetration depth would be recorded by means of a calibrated proving ring. Later, the results of the in-situ soil shall be compared with the relationship between force and penetration to that of a standard load of a crushed stone base material.

In order to get a reliable result care measures shall be taken for any construction test activities, such as grading or compacting carried out subsequent to the field in-situ test which will probably invalidate the results of the test. It should be further noted that during in-situ testing the removal of larger-sized particles which may adversely affects the test result is not possible (Peter, 2006). Therefore, the in-situ test is likely to encounter such problems in coarser types of in-situ material, whereas the laboratory CBR test is limited to particles passing 3/4 inch (19 mm) sieve size (ASTM, 2000).

2.3.3.2 Laboratory CBR Test

Laboratory CBR test is carried out as per the procedure outlined in AASHTO T 193-63 or ASTM D 1883-73. This test method provides the determination of the CBR of a material at optimum water content or a range of water content from a specified compaction test and a specified dry unit weight. The dry unit weight is usually given as a percentage of maximum dry density from the compaction tests of either standard proctor test (ASTM D 698) or modified proctor test (ASTM D 1557).

The Laboratory CBR test procedure is based on the principle of a plunger of standard area advancing into a remolded sample at a specified rate of penetration. Prior to the penetration test the soil sample is remolded in laboratory at a desired moisture content and density. The remolded sample may be soaked for 96 hour with a surcharge load not less than 4.52 kg/10 lb that is a representative of the pavement weight in the field. Swell readings are taken during this period at arbitrary selected times. It is worth nothing that the soaking requirement depends on the climate of the study area and on the specifications requirement to be applied in the design (ASTM, 2000).

At the end of the soaking period the penetration test is carried out at a rate of 1.27mm/min and the force or load required to cause the penetration will be recorded with respect to the standard penetration depths at each 0.5mm penetration, including the load value at 2.54 mm and 5.08 mm until the total penetration is 12.7mm. The penetration resistance load is then plotted against the penetration depth and correction is made for the load-penetration curve.

Using the corrected value taken from the load-penetration curve for 2.54 mm and 5.08 mm penetration, the bearing ratio is calculated by dividing the corrected load by the corresponding standard load, multiplied by 100. Its value ranges from 0 (worst) to 100 (best). If the bearing ratio of 2.54 mm is greater than that of 5.08 mm, the bearing ratio that should be reported for the soil is normally the one at 2.54 mm penetration. When the ratio at 5.08 mm penetration is greater, the test is entirely repeated on a fresh specimen. If the repeated result of 5.08 mm is again greater, the design bearing ratio will be that of 5.08 mm or else, if the bearing ratio of 2.54 mm is greater the design bearing ratio will be that of 2.54 mm penetration (ASTM, 2000).

In the laboratory test, if the soil sample is remolded using one density and one moisture content, the design CBR value will be the one that satisfies the above bearing ratio criteria. Whereas in the case of a range of densities are used in the test, after getting the bearing ratio for each sample, density versus CBR curve is plotted and the design CBR value of the soil will be the one corresponding to the desired dry density from the Density-CBR plot. The later approach is more practiced in different specifications and also the current research has followed this testing procedure.

The CBR values is then determined by reading from the curve the load that causes a penetration of 2.54 mm and 5.08 mm and dividing these values by the standard load 6.9 MPa and 10.3 MPa respectively required producing the same penetration in the standard crushed stone as the two values are then compared, generally the CBR value at 2.54 mm will be greater that at 5.08 mm and in such a case the former shall be taken as CBR for design purpose If CBR for 5.08mm exceeds that for 2.54mm, the test should be repeated. If identical results follow, the CBR corresponding to 5.08 mm penetration should be taken for design (Worku, 2010).

2.3.4 Application of CBR Value

Numerous pavement design charts are published in which one enters a chart with the CBR (Structural Number) together with design traffic class and reads directly the thickness of sub base, base-course, and/or flexible pavement thickness based on expected wheel loads .Sometimes the CBR is converted to a sub grade modulus (also using charts) before entering the paving design charts using the formula (Worku, 2010). The main application of California Bearing Ratio (CBR) is to evaluate the stiffness modulus and shear strength of sub grade. Generally, the sub grade soil cannot bear the construction and commercial traffic without any distress, therefore; a layer of rigid or flexible pavement is required to be laid on top of the sub grade to carry the traffic load.

The determination of the thickness of the pavement layer is governed by the strength of sub grade, thus the information on the stiffness modulus and shear strength of sub grade are required before any pavement design is carried out. These parameters are necessary to determine the thickness of the overlying pavement in order to achieve optimum and economic design. The stiffness modulus and shear strength of sub grade are controlled by soil type, particularly plasticity, degree of remolding, density and effective stress (The Highway Agency, 1994). The effective stress is dependent on the stress from the overlying soil layers, the stress history and the suction. In turn, suction is dependent on the moisture content history, the soil type and the depth of the water table.

Due to the number of factors that make the measurement of stiffness modulus and shear strength of sub grade complicated, it is necessary to adopt a more simplified test method that can be used as an index test. This is where CBR test come into frame in measurement of sub grade strength. The CBR test is a simple strength test that compares the bearing capacity of a material with that of a well graded standard crushed stone base material. This means that the standard crushed stone material should have a CBR value of 100%. The resistance of the crushed stone under standardized conditions is well established. Therefore, the purpose of a CBR test is to determine the relative resistance of the sub grade material under the same conditions.

If the CBR value of sub grade is high, it means that the sub grade is strong. Accordingly, the design of pavement thickness can be reduced in conjunction with the stronger sub grade. Thus, it will give a considerable cost saving in term of construction besides an optimum design. However, if the CBR value of sub grade indicates that the sub grade is weak i.e. low reading of CBR reading, the thickness of pavement shall be increased in order to spread the traffic load over a greater area of the weak sub grade. This is important to prevent the weak sub grade material to deform excessively and causing the road pavement fail (Kin, 2006).

Alternatively, the easiest method to overcome this weak sub grade before the construction of pavement is by replacing the soil with adequately compacted soil in layers. Otherwise, the sub grade can be stabilized by lime, cement, or the use of a geotextile to produce a stable platform for construction equipment and traffic load in long term. It should also be noted that the change in pavement thickness needed to carry a given traffic load is not directly proportional to the change in CBR value of the sub grade soil. For example, a one-unit change in CBR from 5 to 4 requires a greater increase in pavement thickness than does a one-unit change in CBR from 10 to 9 (Kin, 2006).

The CBR test is used exclusively in conjunction with pavement design methods and the method of sample preparation and testing must relate to the assumptions made in the design method as well as the assumed site conditions. For instance, the design may assume that soaked CBR values are always used, regardless of actual site conditions (Carter and Bentley, 1991 cited by Kin, 2006).

2.4 CBR Correlation with DCP

Several correlations have been reported between the DCP and CBR. Livneh (Livneh, 1989) compared 21 correlations that were published in the world technical literature. However, many researchers have already pointed out the importance local soil characteristics on the obtained correlation between DCP and CBR. It was reported that differences in geographic areas throughout the world lead to changes in the empirical values obtained (Livneh, 1989 Cited by Zumrawi, 2014). Several relationships are available to convert values of DCP to CBR. Such varieties of relationships do exist since large strain penetration takes place during testing of compacted soil by both the tests. A few salient details of different investigations made for development of the relationships are given below.

- Development of Scala Penetrometer (1956) for estimation of in-situ CBR of cohesive soils has led to development of the present version of DCP.
- Scala (1956) and Kleyn (1975) initially identified straight line relationship between the DCPand CBR values plotted on log-log chart.
- Laboratory CBR values were used for development of the US Corps of Engineer's relationship (Webster et al 1992). Many DCP to CBR relationships developed by different researchers around the globe were considered in this study and they were found to be in close agreement with the relationship developed by Webster et al (1992). Therefore, this relationship has been widely used by several researchers (Livneh 1995; Siekmeier et al 2000 and Chen et al 2001).
- Ese et al (1994), extensively evaluated 23 granular base courses in Norway and correlated laboratory CBR and DCP θo values. They reported that, (i) difference in confining pressure in CBR mould and prevailing in-situ condition was accounted in development of the relationship and (ii) suggested that, a critical stability value of 2.6 mm/blow may be taken for gravel base.
- Nazzal (2003), conducted many laboratory CBR and field DCP tests on compacted granular materials, clay and soils stabilized. During the laboratory CBR testing, the moisture content and density were maintained similar to in-situ condition. He reported that, by using the equation (No.15), the estimated CBR values were well matching with the values obtained by equation (No. 10) (Webster et al 1992), when the DCP60o value

is greater than 20 mm/blow.A summary of some of these correlations with corresponding authors is presented in table form

Table 2.3: Relationships between DCP and CBR Values (Srinivasa, 2009).

Reference/Developed/Source	Equation
Kleyn and Van Heerden 1983	Log10CBR=2.632-1.28 Log10(60^0 DCP)
Smith and Pratt 1983 (Developed for ARRB)	Log10CBR=2.555-1.145 Log10(60^0 DCP)
McElvaney et al 1985	Log10CBR=2.81-1.32 Log10(60^0 DCP)
Livneh and Ishai 1987	Log10 CBRF =2.2-0.71 (Log10(30^0 DCP))1.5
Harison (1989)	For 60^0 DCP ≥ 10 mm/blow: Log10CBR=2.56-1.16 Log10(o 60 DCP)
	Or For o 60 DCP < 10 mm/blow: Log10CBR=2.54-1.12 Log10(60^0 DCP)
TRL, Road Note 8 1990	Log10CBR=2.48-1.057 Log10(60^0 DCP)
Livneh, 1991	Log10CBR=2.2-0.71[Log10(1.1× 60^0 DCP)]1.5
Webster et al, 1992; The Relationship developed for the US Corps of Engineers	Overall correlative relationship: Log10 CBR =2.465-1.12 Log10(60^0 DCP)

Table 2.3: Contd.

Ese et al 1994	Log10 CBR =2.438-1.065 Log10(60^0 DCP)
Webster et al 1994	For CH soil: Log10 CBR =2.542-1.0 Log10(60^0 DCP)
	For CL soil having CBR<10%: Log10 CBR =3.538-2.0 Log10(60^0 DCP)
Livneh et al 1995	Log10 CBRF =2.14-0.69 (Log10(60^0 DCP))1.5
Nazzal (2003)	CBR = 1.04 + 2559.44/(-7.35+ 60^0 DCP 1.84) c
Coonse (1999) at North Carolina State University (Cited in Roy 2007)	Log10 CBRf =2.53-1.14 Log10(60^0 DCP)

DCP 30^0 and DCP 60^0 are the penetration values in mm/blow where the cone apex angles are 30^0 and 60^0 respectively; CBR is the California Bearing Ratio (%); CBRF indicates field CBR; and CBRf indicates the field CBR value of cohesive residual soil.

Although good correlations have been obtained, all studies have found that the results are material and moisture dependent, and that equations should be used with care and only with a full understanding of the material properties of the soils on which the equation was developed and the soil being tested (Bowles, 1984).

It should also be remembered that strengths predicted from DCP penetration are determined at the in-situ moisture content and density of the sub grade soils at the time of testing, which must be taken into consideration when relating these values back to those determined in a laboratory (David and John, 2005).

In addition Yitagesu Desalegne has done his MSc thesis on developing correlation between DCP and CBR on sub grade material on JIMMA-MIZAN road in 2012. (Desalegne, 2012) His finding is:-correlation equation

Log (CBR) = 2.954 – 1.496log (DCPI) with $R^2 = 0.943$……………….. (Equation 2.4)

He concludes that, the results of the statistical analysis show that good correlation does exist between the dynamic cone penetration indexes (DCPI) and unsoaked California Bearing Ratio (CBR) values. However, care should have to be made while using the formula as the CBR values obtained from the correlation indicates the in situ CBR value at the time of testing rather than the CBR values at the worst condition (Soaked CBR). Nevertheless, it can be used directly at any time for the delineation of the area into homogeneous sections.

CHAPTER 3
STUDY AREA AND METHODS

3.1 Study Area

In order to have sufficient and reliable data for the target analysis, laboratory tests conducted on soil samples obtained from different localities of Addis Ababa city on the basis of soil type which is A-7-5 based on AACRA map. Addis Ababa is the capital city of Ethiopia with population no of 2,112,737. It is situated at c.8, 000 ft (2,440 m) on a well-watered plateau surrounded by hills and mountains. It is a grassland biome located at the foot of mount "Entoto" and forms part of the watershed for "Awash" river. It has sub-tropical highland climate with temperature differences up to 10^0C. Daily maximum temperatures don't usually exceed 23^0C during dry seasons. The location of collected soil samples site is shown with the aid of map in Figure 3.1:

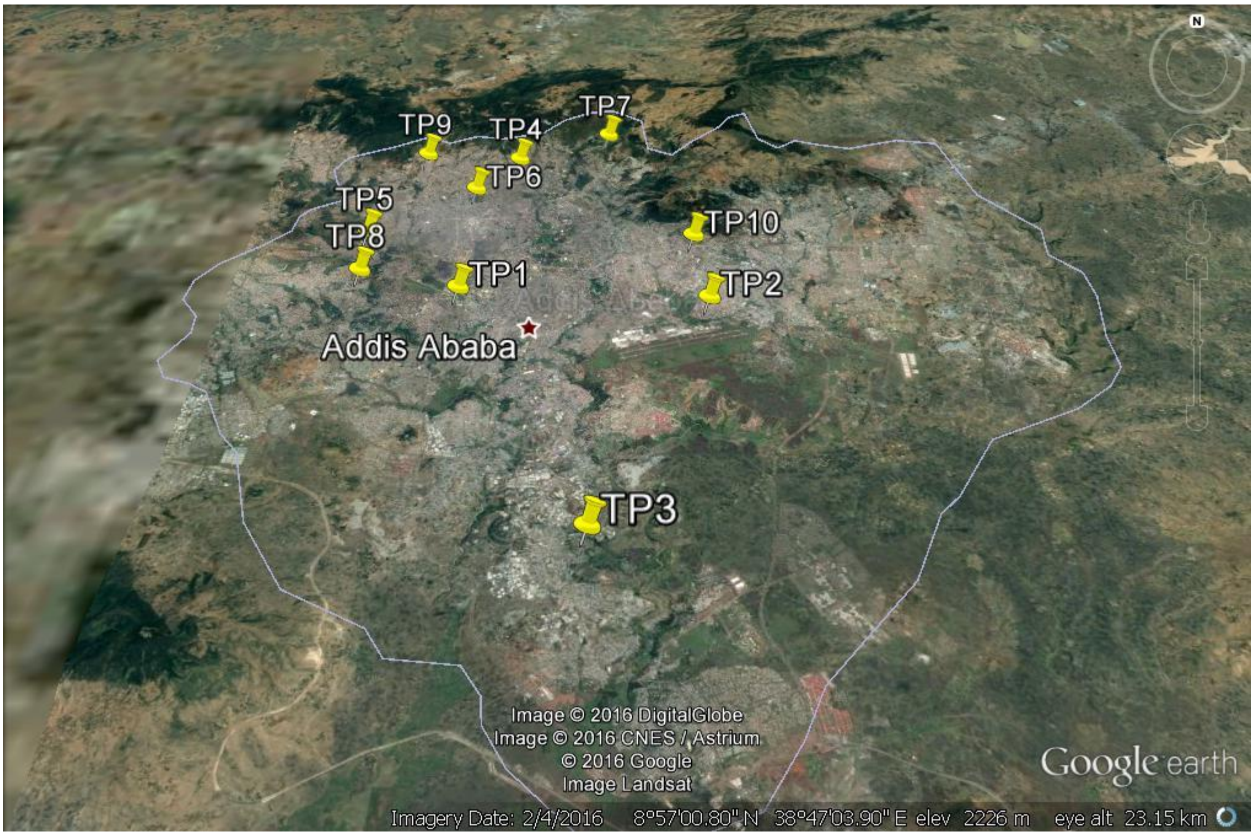


Figure 3.1 Location of test pits

Table 3.1 Sample description

S.N	Designation	Sampling area	sampling depth(m)	color
1	TP 1	lideta	1	light brown clay soil
2	TP 1	lideta	1.5	dark brown clay soil
3	TP 1	lideta	2	light brown clay soil
4	TP2	bole	1	black soil
5	TP2	bole	1.5	black soil
6	TP2	bole	2	black soil
7	TP3	kaliti	1	silty clay soil
8	TP3	kaliti	1.5	silty clay soil
9	TP3	kaliti	2	silty clay soil
10	TP4	adissu gebeya	1	light brown clay soil
11	TP4	adissu gebeya	1.5	dark brown clay soil
12	TP4	adissu gebeya	2	dark brown clay soil
13	TP5	kolfe	1	dark clay soil
14	TP5	kolfe	1.5	dark clay soil
15	TP5	kolfe	2	light clay soil
16	TP6	adiss ketema	1	black soil
17	TP6	adiss ketema	1.5	black soil
18	TP6	adiss ketema	2	black soil
19	TP7	entoto	1	red fine grained soil
20	TP7	entoto	1.5	red fine grained soil
21	TP7	entoto	2	light red fine grained soil
22	TP8	weyra sefer	1	red clay soil
23	TP8	weyra sefer	1.5	red clay soil
24	TP8	weyra sefer	2	red clay soil
25	TP9	winget	1	light brown clay soil
26	TP9	winget	1.5	light brown clay soil
27	TP9	winget	2	dark brown clay soil
28	TP10	megenagna	1	light brown clay soil
29	TP10	megenagna	1.5	dark brown clay soil
30	TP10	megenagna	2	dark brown silty clay soil

3.2. Study design

An experimental study was used during the study period and the data was analyzed and interpreted using both descriptive and analytical methods of approach.

3.3. Study Population

The population for this study is A-7-5 soil types found in Adiss Abeba.

3.4. Sample size and sampling procedures

A total of thirty disturbed and undisturbed samples were gathered with three layers which is 1m, 1.5m and 2m.The samples location were taken according to Addis Abeba soil classification map.

3.4.1 Field and Laboratory Test Methods

- **Field Tests and sampling methods**

  Soil Sampling- Representative disturbed soil samples were collected using Polythene bag from the different layers of test pits, individually, for classification tests (refer to ASTM D 4220). Undisturbed samples were collected for in situ density, bulk density and in situ moisture content tests (refer to ASTM D1587).

Figure 3.2: Sampling in TP 1

Dynamic Cone Penetration test- Overseas Road Note 8, a User Manual for a Program to Analyse Dynamic Cone Penetration Data, TRRL, 1992[17]/ASTM D 6951-03. Upper rod with handle, upper support, 8 kg dead weight, penetration rod with cone set (60^0 or 30^0), rod with ruler and base support are the components of DCP.

Figure 3.3 DCP apparatus

- **Laboratory test methods**

Based on the samples retrieved from the sites, laboratory tests on the thirty samples were conducted in the geotechnical and highway laboratories of Gondwana engineering PLC. Accordingly, the following different kinds of tests have been performed.

Moisture Content (ASTM D 2216)

Change in moisture content is the most influential parameter that affects the property of soils. Moisture content is defined as the ratio expressed as a percentage of mass of water to mass of soil solids. The moisture content test is carried out in laboratory as per the procedures of AASHTO T 265 or ASTM D 2216 and in field according to AASHTO T 217.

Specific Gravity (ASTM D 854)

The specific gravity of selected samples was measured in accordance with ASTM D 854-98(Standard Test Method for Specific Gravity of Soils).

Atterberg Limits (ASTM D 4318/ AASHTO 89-90/BS for soil of low plasticity)

Based on their mode of formation and mineralogical composition different soils respond differently for the same moisture content. Albert Atterberg. The three Atterberg limits which are liquid limit, plastic limit and shrinkage limits are the boundary between each of the two consecutive states of the soil-water phases. Their test is performed only on that portion of a soil which passes the 425mm (No. 40) sieve (Mittal and Shukla, 2000).

***Liquid Limit*:**

The liquid limit (LL) is the water content, expressed in percent, at which the soil changes from a liquid state to a plastic state. The liquid limit of a soil highly depends upon the clay mineral present. The conventional liquid limit test is carried out in accordance of test procedures of AASHTO T 89 or ASTM D 4318. A soil containing high water content is in the liquid state and it offers no shearing resistance.

***Plastic Limit*:**

The plastic limit (PL) is the water content, expressed in percentage, below which the soil stops behaving as a plastic material. The conventional plastic limit test is carried out as per the procedure of AASHTO T 90 or ASTM D 4318. The soil in the plastic state can be remolded into different shapes. When the water content is reduced the plasticity of the soil decreases changing into semisolid state and it cracks when remolded.

Grain size Analysis Test (ASTM D 422-63)

Grain size analysis is a process in which the proportion of material of each grain size present in a given soil is determined. In this particular study, the wet sieving method is used in the laboratory to determine the fine content of the soil samples. The test was performed according to the procedure described by ASTM D1140-97, Standard Test Method for Amount of Material in the Soils Finer than the No. 200 (0.075mm) Sieve.

Soil Classification

Soils exhibiting similar behavior can be grouped together to form a particular group under different standardized classification systems. A classification scheme provides a method of identifying soils in a particular group that would likely exhibit similar characteristics. There are different classification devises such as USCS and AASHTO classification systems, which are used to specify a certain soil type that is best suitable for a specific application. This particular research was done by AASHTO classification.

Modified Proctor test (ASTM 1557 or AASHTO T 180)

Compaction of a soil improves the engineering properties, i.e. it increases the shear strength of the soil and hence, the bearing capacity. It increases the stiffness and thus, reduces future settlement, void ratio and permeability. At lower water content than the optimum the soil is rather stiff and has a lot of void spaces and hence, the dry density is low. On the other hand, at water content more than the optimum the additional water reduces the dry density as it occupies the space that might have been occupied by solid particles (Arora, 2004).

The laboratory standard proctor and modified proctor tests are performed as per (AASHTO T 99 or ASTM D 698) and (AASHTO T 180 or ASTM D 1557) respectively. The corresponding water content at which the maximum dry density occurs is termed as the optimum moisture content (ASTM, 2000).

Liquid Limit: The liquid limit (LL) is the water content, expressed in percent, at which the soil changes from a liquid state to a plastic state and principally it is defined as the water content at which the soil pat cut using standard groove closes for about a distance of 13cm (1/2 in.) at 25 blows of the liquid limit machine (Casagrande Apparatus). The liquid limit of a soil highly depends upon the clay mineral present. The conventional liquid limit test is carried out in accordance of test procedures of AASHTO T 89 or ASTM D 4318. A soil containing high water content is in the liquid state and it offers no shearing resistance.

Plastic Limit: The plastic limit (PL) is the water content, expressed in percentage, below which the soil stops behaving as a plastic material and it begin to crumble when rolled into a thread of soil of 3.0mm diameter. The conventional plastic limit test is carried out as per the procedure of AASHTO T 90 or ASTM D 4318. The soil in the plastic state can be remolded into different shapes. When the water content is reduced the plasticity of the soil decreases changing into semisolid state and it cracks when remolded..

Three-point CBR Test (AASHTO T 193)

Details of three point CBR test has been described in the previous chapter thoroughly. Three point CBR tests were done as specified by AASHTO T-193.

Figure 3.4: CBR soaking

In order to have satisfactory data for utilizing the correlations, the above laboratory test and field test equipment's were calibrated. It is conducted by the researcher on thirty samples collected from different localities of Addis Ababa, so as to get records of test results of soil classification, Atterberg limits (LL, PL, and PI), optimum moisture content, California bearing ratio, insitu moisture content, insitu density and Dynamic cone penetration. Then, discussions on sample collection and summary of laboratory test results were presented.

3.5. Study variables

Dependent variables: - the dependent variables for the study was the correlation between CBR and DCP.

Independent variables: - the independent variables was DCP, CBR, moisture content (NMC, OMC) and density (Insitu density, MDD).

3.6. Data collection process

The data used for this research was collected from:-

Primary data - the representative samples was collected field and laboratory tests for CBR, DCP, sieve analysis, atterburg limit, compaction, moisture content(NMC,OMC) and density (insitu density, MDD) was conducted.

Secondary data - was collected from AACRA, different journals, previous thesis, books, websites, literature …..

3.7. Data processing and analysis

The data processing started by reading the previous findings. Then the disturbed and undisturbed samples was collected from the boreholes and laboratory tests was carried out and the observed results was recorded. Once the researcher collected all the necessary data, then the data was analyzed by using Excel. From the recorded data CBR and DCPI was determined. Finally regression analysis was done to correlate CBR and DCP using SPSS statistics software. For laboratory works or testing procedures AASHTO and ASTM manual was used.

3.8. Ethical considerations

The data was collected based on the willingness of the authorities (i.e.kebele). Before the collection of the data the purpose of the data collection was clearly described to the peoples who live around the sampling area by the researcher. The data was kept confidential and it is used only for the research purpose.

CHAPTER-4

RESULTS AND REGRESSION ANALYSIS

4.1 Field and Laboratory test Results

In order to analyze the intended correlation, the test results were compiled and summarized. The tables below illustrate results of laboratory and field tests.

Table 4.1 Natural moisture content and specific gravity

Designation	sampling depth(m)	Specific gravity	NMC (%)
TP 1	1	2.77	39.62
TP 1	1.5	2.8	37.12
TP 1	2	2.78	35.68
TP2	1	2.61	50.2
TP2	1.5	2.62	46.74
TP2	2	2.66	48.250
TP3	1	2.61	45.9
TP3	1.5	2.66	46.1
TP3	2	2.64	48.06
TP4	1	2.77	38.142
TP4	1.5	2.76	38
TP4	2	2.82	40
TP5	1	2.78	34.9
TP5	1.5	2.63	43.65
TP5	2	2.7	37.42
TP6	1	2.83	45
TP6	1.5	2.82	38
TP6	2	2.84	42.3
TP7	1	2.7	40.36
TP7	1.5	2.79	40.74
TP7	2	2.83	31.78
TP8	1	2.66	47.31
TP8	1.5	2.74	42.89
TP8	2	2.84	42.56
TP9	1	2.78	37.95
TP9	1.5	2.81	36.54
TP9	2	2.8	35.42
TP10	1	2.74	35
TP10	1.5	2.6	34.98
TP10	2	2.623	35.9

Table 4.2 Grain size, atterburg limits and classification of soil samples

Designation	sampling depth(m)	% Passing sieve			Atterburg limit			AASHTO (Soil Classification)
		2mm	0.425mm	0.750mm	LL (%)	PL (%)	PI (%)	
TP 1	1	99.1	94.4	84	57	31.15	26	A-7-5
TP 1	1.5	97.8	91.5	83.4	54	32	22	A-7-5
TP 1	2	98.2	90.8	79.2	55.3	29.8	25	A-7-5
TP2	1	90.6	88.8	86.9	73.1	34	40	A-7-5
TP2	1.5	97.1	96.9	96.6	77.3	41	37	A-7-5
TP2	2	96.8	96.6	96.3	66.1	33	33	A-7-5
TP3	1	99.6	99.2	96	87.7	37	51	A-7-5
TP3	1.5	94.8	94.3	93.3	71.3	27	44	A-7-5
TP3	2	99.7	99.4	96.7	92.7	43	50	A-7-5
TP4	1	97	89	78	69.8	41.03	29	A-7-5
TP4	1.5	99.2	95.6	87.5	70.9	31.28	40	A-7-5
TP4	2	98.4	94.4	84.7	66	20.27	45	A-7-5
TP5	1	99.5	93.2	87.8	62.4	38.7	24	A-7-5
TP5	1.5	99.1	92.9	79.5	60	35.09	25	A-7-5
TP5	2	97.9	92.6	80	59.9	34.04	26	A-7-5
TP6	1	96.4	92.3	87.6	63	46.32	17	A-7-5
TP6	1.5	95.8	92.6	88.9	60.9	42.08	19	A-7-5
TP6	2	97.8	94.4	90.2	63.8	43.53	20	A-7-5
TP7	1	98.6	96.5	93.3	63.5	23.26	40	A-7-5
TP7	1.5	98.8	97.4	96.8	63.7	31.11	33	A-7-5
TP7	2	97.8	88.7	78.9	48.9	11.58	37	A-7-5
TP8	1	98.8	95.1	87.8	73.3	51.38	22	A-7-5
TP8	1.5	98.6	94.9	84.1	70	42.57	27	A-7-5
TP8	2	98.4	96.3	93.2	66	36.69	29	A-7-5
TP9	1	95.8	86.3	72.4	62.3	33.55	29	A-7-5
TP9	1.5	92.4	90.5	88.7	61.2	34.2	27	A-7-5
TP9	2	93.8	92.2	90.1	63.2	34	30	A-7-5
TP10	1	96	88	72.4	49.7	30.77	19	A-7-5
TP10	1.5	96.6	91	80.2	80.5	47.19	33	A-7-5
TP10	2	97.1	87.5	75.1	83.6	37.36	46	A-7-5

Table 4.3 compaction, CBR and DCPI data

Designation	sampling depth(m)	bulk density (gm/cm3)	OMC (%)	MDD (gm/cc)	DCPI (mm/blow)	lab CBR (%)
TP 1	1	1.71	25.9	1.49	31	3.9
TP 1	1.5	1.94	24.2	1.5	27.21	5.3
TP 1	2	1.81	23.3	1.52	29	5.1
TP2	1	1.42	25	1.43	35.2	1.879
TP2	1.5	1.57	26	1.437	32	1.985
TP2	2	1.49	27	1.315	33.5	1.25
TP3	1	1.5	32	1.368	33.2	2.48
TP3	1.5	1.69	30	1.33	31.8	2.17
TP3	2	1.57	31	1.315	33	1.43
TP4	1	1.89	21.5	1.49	28.2	4.3
TP4	1.5	1.74	20.2	1.52	31	3.4
TP4	2	1.82	19.09	1.57	32	3.2
TP5	1	1.71	24.3	1.55	29	2.62
TP5	1.5	1.79	30.2	1.48	31.8	2.8
TP5	2	1.82	22.9	1.5	29.9	3.7
TP6	1	1.62	39.76	1.44	31.6	2.36
TP6	1.5	1.87	32.575	1.45	27.8	4.85
TP6	2	1.74	32	1.568	31.2	5.03
TP7	1	1.9	24	1.58	30.5	3.82
TP7	1.5	1.89	26	1.53	29.58	3.8
TP7	2	1.86	24.6	1.58	26.7	3.7
TP8	1	1.57	29	1.52	31.9	2.22
TP8	1.5	1.79	29	1.48	32	3.5
TP8	2	1.82	31	1.34	30.4	3.59
TP9	1	1.93	29.2	1.53	29	5.4
TP9	1.5	1.95	27.89	1.53	28.5	6.1
TP9	2	1.96	26	1.665	28.1	6.2
TP10	1	1.97	23.3	1.55	26	6.2
TP10	1.5	1.85	23.5	1.09	27.21	6.4
TP10	2	1.959	34	1.28	28	6.2

4.2 Discussion of Test Results

In accordance to the AASHTO classification system the soils are classified as A-7-5. From the conventional Atterberg limit tests, a liquid limit value ranging from 54 up to 92.7, plasticity limit value of 20 up to 48 and a plasticity index value of 17 up to 50 were obtained. From the modified proctor test, after plotting moisture-density curve, a range of maximum dry density along with the optimum moisture content were obtained. Similarly, the CBR test was carried out and after the penetration test were carried out a CBR value ranging fr om 1.25 up to 6.2 is obtained at 95% MDD of modified AASHTO proctor density which is very low. On the other hand the DCPI result ranges from 27.8- 32.6. In general the result shows that for CBR less than 6.2 the DCPI result was above 27 mm/blow. Most of the samples are clayey soils with high moisture due to season of sampling resulting in the values of test results described above.

4.3 Regression analysis

4.3.1 Introduction

A convenient way of measuring how well the regression model performs as a predictor of the dependent variable is to compute the reduction in the sum of squares of deviations that can be attributed to regressor variables and this quantity termed the coefficient of determination, R^2. The value of R^2 is always between 0 and 1, because R is between -1 and +1, whereby a negative value of R indicates inversely relationship and positive value implies direct relationship. Many problems in engineering require that we decide whether to accept or reject a statement about some correlations. A number of techniques can be used to judge the adequacy of a regression model some of which are standard error (α), R-squared value (R^2), R-adjusted and the t-test (Douglas and George, 2003).

In this research work, an attempt is made to apply single linear regression model and multiple linear regression models to characterize the strength of subgrade soil from soil index parameters using a statistical approach. The general representation of a probabilistic single and multiple linear regression models are presented in the following forms:

$$Y = \beta 0 + \beta 1\, x + \varepsilon \text{……………………….. (Equation 4.1)}$$

$$Y = \alpha 0 + \alpha 1 x1 + \alpha 2 x2 \ldots + \alpha n xn + \varepsilon \text{………………… (Equation 4.2)}$$

Where, the slope ($\beta 1$) and intercept ($\beta 0$) of the single linear regression model are called regression coefficients. Similarly, coefficients $\alpha 0$, $\alpha 1$, $\alpha 2$ and αn are termed multiple regression coefficients. The appropriate way to generalize this to a probabilistic linear model is to assume that the actual value of Y is determined by the mean value function (the linear model) plus the random error term, ε (Douglas and George, 2003). The basic assumption to estimate the regression coefficients of the single and multiple regression models is based on the least square method.

4.3.2 Scatter Plot

In the subject study, the California Bearing Ratio is taken as the dependent variable whereas DCP is independent variables. Prior to carrying out the regression analysis using the thirty laboratory and field test results, a scatter diagram is generated by applying the Excel Spreadsheet, in order to study the relationships developed In the figures below (Figure 4-1 to 4-9) the scatter plot of CBR and DCPI with maximum dry density, bulk density, NMC, PI and OMC are presented.

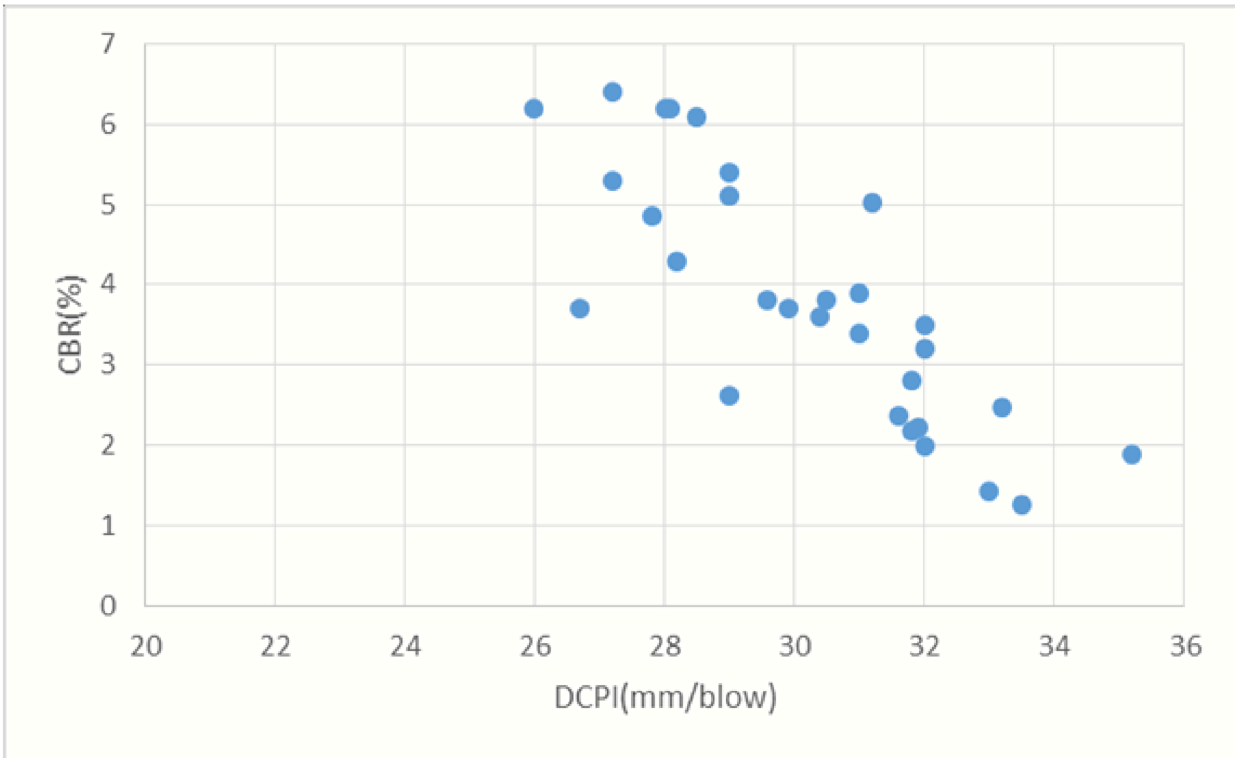


Figure 4.1: Scatter plot for DCPI and CBR

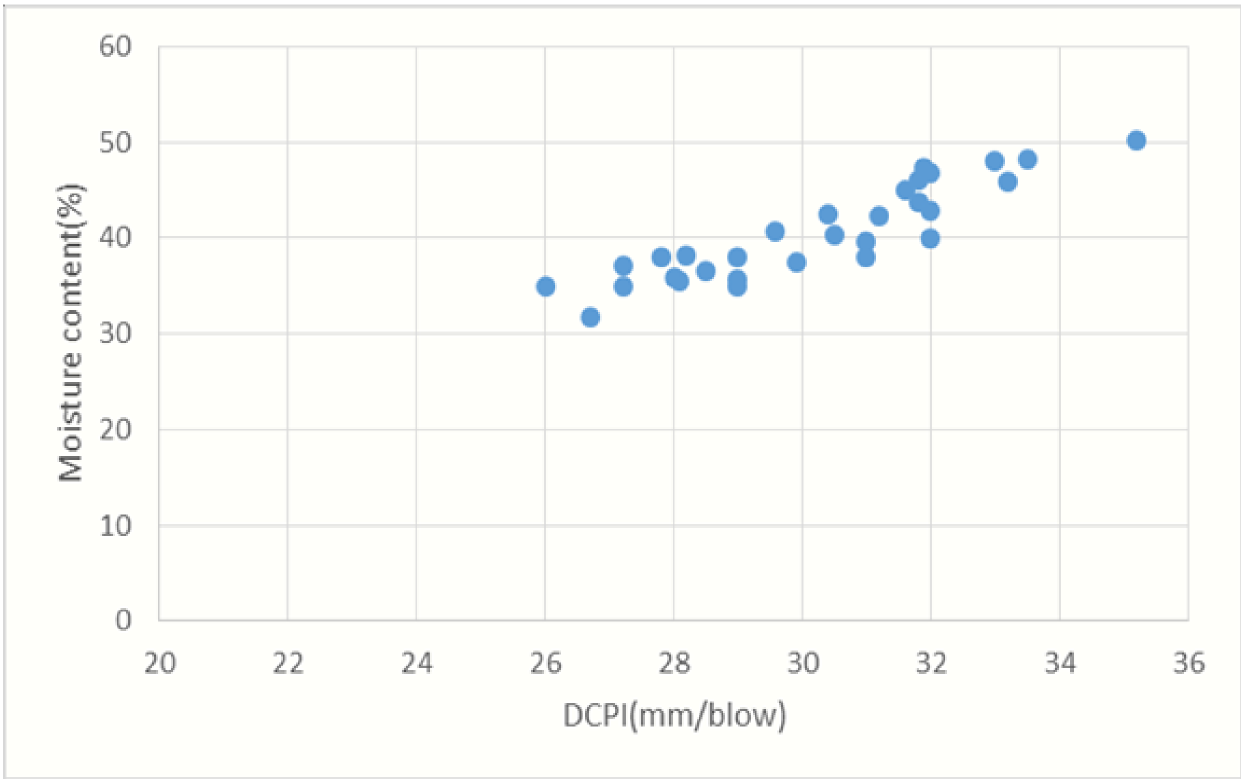


Figure 4.2: Scatter plot for DCPI and Natural moisture content

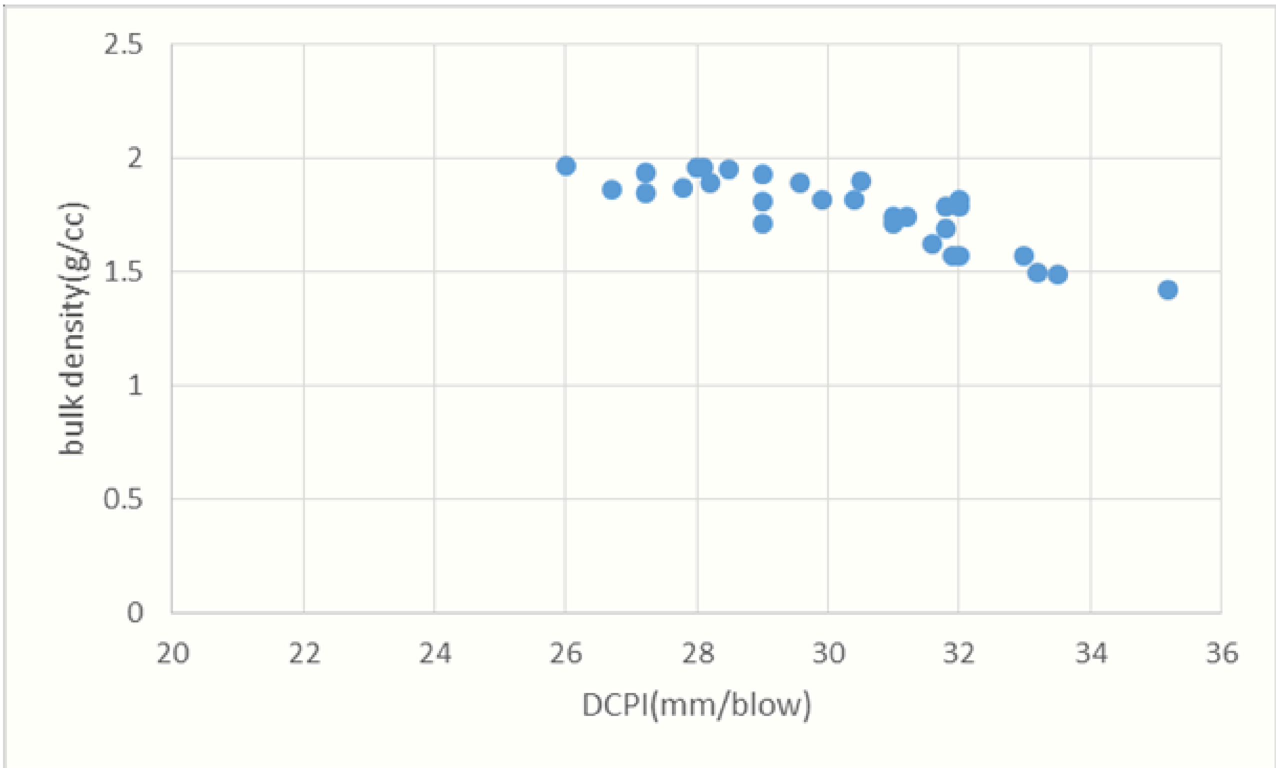


Figure 4.3: Scatter plot for DCPI and bulk density

The above scatter diagrams provide a visual method of displaying a relationship between variables as plotted in a two dimensional coordinate system. When we see the trend of the scatter plot for DCPI and CBR it shows a relatively fair, negative correlation (means when CBR increases DCPI decreases) and also a linear association between them. The other scatter plot that shows linear association, good and positive correlation is DCPI with NMC.The last one also shows good negative correlation and linear association is between DCPI and bulk density. The above scatter plot shows a linear response and hence, a linear regression model expresses the association between the subject parameters.

For single regression models Excel spreadsheet was used in this research. The summary of developed equations are presented in table 4.4

Table 4.4: Summary of correlation equations

Equations	R^2
CBR= -0.5576(DCPI)+20.674	0.6648
DCPI= -12.3(γ bulk)+52.001	0.7199
DCPI= 0.4168(NMC)+13.307	0.8159

4.4 Multiple Regression

4.4.1 Ordinary least square method

Various alternative combinations of predictors were examined using SPSS. Then the ones' with better influence on the dependent variable, CBR was taken for analysis. The result of the analysis gave equation 4.3 with adjusted R^2=0.815

CBR=20.674- 0.558(DCPI) …………… (Equation 4.3)

4.4.2 Two stage least square method

There are two stages in this method, as the name suggests. The first regression estimates an ordinary least square prediction of the explanatory term by regressing it on instrumental variables. The second completes the overall process by using previously estimated explanatory term and substituting it by the predicted or residual value from step one. The coefficient of interests are estimated using ordinary least square method (Landau and Everitt, 2004).

- **Two stage predictor substitution**

The previous equation developed by ordinary least square method only gives attention to values which have direct influence on the dependent variable, which is CBR value. The intention of this method is to give values such as Natural moisture content and Bulk density, which have no direct influence on CBR, but have influence on DCPI. This method combines the effect of NMC and Bulk density by using them to predict a DCPI value different form the field determined one. Then use it to estimate a CBR in combination with any other variable suitable enough to give a fair correlation. The result of the analysis gave equation 4.5 with coefficient of determination R^2=0.799

Predicted DCPI=-1.129* γ bulk +0.405 NMC+15.97 ………….......... (Equation 4.4)

CBR=21.447-0.58 (predicted DCPI)……………... (Equation 4.5)

- **Two stage residual inclusion estimation**

This method is almost similar to the one mentioned above. The only additional matter here is that in the previous one field determined DCPI did not have any use in the equation developed. In order to combine the effects of field determined DCPI and predicted DCPI, a two stage residual inclusion estimation was conducted. The objective of this thesis was to find a value of CBR from DCPI, which calls for the use of field DCPI in the equation. This method works similarly to that of the predictor substitution method. But, the variable is not replaced by a predictor, instead it is included as an additional variable with DCPI. The result of the analysis after two stages of regression gave equation 4.7 with R^2=0.827. This shows better relation than other estimates.

Predicted DCPI=-1.129* γ bulk +0.405 NMC+15.97 R^2=0.825... (Equation 4.6)

CBR=21.744 -0.241*PDCPI-0.351*DCPI…….. (Equation 4.7)

4.5 Discussion of Regression Analysis

After seeing the scatter diagrams and finding the equation. It can be seen that there is a reasonable indication that Dynamic Cone penetrometer is highly influenced by natural moisture content and insitu density. Their coefficients of determination are 0.8159 and 0.7199 respectively.

Since the purpose of this thesis is to find the value of CBR from DCPI and other known soil parameters, a multiple regression was carried out by taking DCPI as independent and CBR as a dependent by ordinary least square method. The result has reviled that CBR has a good correlation with the aforementioned parameters by achieving coefficient of determination of 0.815.

In the ordinary least square method, since the effect of natural moisture content and bulk density is not significant on CBR, both parameters were overlooked during the development of equation 4.3. However since both parameters have a huge impact on DCPI a two stage regression, with predictor substituted, was carried out. The result shows that CBR has a fair correlation with the predicted DCPI, natural moisture content and bulk density by achieving coefficient of determination of 0.799. A two stage least square residual inclusion estimation was carried out and the result reviled that CBR has a good relation with DCPI, Bulk density and natural moisture content by achieving a coefficient of determination of 0.827 with 30 samples**.**as the coefficient of determination shows the better equation is the last one done by a two stage least square residual inclusion estimation this method also include the actual penetration index and the predicted penetration index.

4.6 Comparisons between Actual CBR and CBR by developed equations

There are many equations developed around the world correlating CBR with DCP values. But most of the correlations were made using insitu or unsoaked CBR values. This research correlates laboratory determined four days soaked CBR with DCP. Comparison between actual laboratories determined CBR and CBR estimated with the developed equations and some other developed equations are shown in the table below.

Table 4.5 Comparisons among Laboratory Measured and Developed values

Actual CBR	EstimatedCBR(%)	Yitagesu D.	Webster	Kleyn and van Heerden	variation to actual CBR			
					NEW	Yitagesu D.	Webster	leyn and van Heerd
3.9	3.61	5.28	3.83	5.51	-7.37	35.47	7.91	35.52
5.3	5.25	6.42	4.19	5.83	-0.96	21.16	12.04	17.83
5.1	4.73	5.84	4.13	5.78	-7.33	14.47	19.53	12.87
1.879	1.03	4.37	3.37	5.07	-45.36	132.51	48.25	139.06
1.985	2.53	5.04	3.39	5.10	27.37	153.83	69.80	155.65
1.25	1.83	4.70	3.21	4.92	46.62	276.38	146.04	282.85
2.48	2.17	4.77	3.48	5.18	-12.50	92.28	26.26	95.21
2.17	2.69	5.09	3.41	5.12	24.13	134.37	57.28	135.74
1.43	2.05	4.81	3.25	4.96	43.25	236.49	121.63	241.17
4.3	4.79	6.09	3.91	5.58	11.36	41.57	0.93	38.74
3.4	3.78	5.28	3.69	5.37	11.14	55.40	5.63	55.45
3.2	3.25	5.04	3.64	5.33	1.69	57.45	5.33	58.58
2.62	4.78	5.84	3.50	5.20	82.26	122.82	56.64	119.70
2.8	2.96	5.09	3.55	5.24	5.71	81.64	21.90	82.70
3.7	4.24	5.58	3.76	5.44	14.68	50.73	4.34	49.60
2.36	2.85	5.13	3.46	5.16	20.86	117.55	46.46	118.52
4.85	4.94	6.22	4.05	5.71	1.80	28.22	7.92	25.28
5.03	3.29	5.23	4.13	5.78	-34.62	4.03	29.51	4.21
3.82	3.77	5.41	3.78	5.47	-1.38	41.72	2.87	41.26
3.8	4.05	5.67	3.78	5.47	6.59	49.14	3.81	47.69
3.7	5.93	6.61	3.76	5.44	60.21	78.54	30.85	72.93
2.22	2.51	5.06	3.39	5.10	12.96	128.02	52.78	129.51
3.5	2.96	5.04	3.71	5.40	-15.31	43.96	3.70	44.99
3.59	3.57	5.44	3.73	5.42	-0.67	51.54	4.03	50.95
5.4	4.54	5.84	4.22	5.86	-15.98	8.11	24.00	6.59
6.1	4.86	5.99	4.43	6.05	-20.40	-1.77	30.34	3.51
6.2	5.11	6.12	4.47	6.08	-17.61	-1.29	29.50	3.34
6.2	5.89	6.87	4.47	6.08	-5.01	10.87	17.65	6.77
6.4	5.43	6.42	4.53	6.13	-15.10	0.34	27.16	2.42
6.2	5.10	6.15	4.47	6.08	-17.80	-0.77	28.99	2.89
AVG(%)					19.60	69.08	31.44	69.38

Where;

Newly developed - CBR=21.744 - 0.241*PDCPI-0.351*DCPI

Yitagesu Desalegne - log (CBR) = 2.954 – 1.496log (DCPI)

Webster - Log CBR=3.538-2.0 Log DCPI

Kleyn and van Heerden - Log CBR=2.632-1.28 Log DCPI

The comparison shows an average of 19.6% variation of computed values to actual laboratory determined values by use of residual inclusion estimation method of correlation. Relationships given by other scholars before the conduction of this research are also examined for comparison with the new estimates. Variation calculations show relative results of good correlation by this research rather than use of the equations developed before. Variation results show 31.44% for Webster's estimates, Yitagesu's 69.08% (unsoaked CBR) estimates and 69.38% for kleyn's estimates. Webster's formula is closer to the equation developed in this research in terms of accuracy to the results obtained in the laboratory.

CHAPTER 5

CONCLUSTION AND RECOMMENDATIONS

5.1 Conclusions

The main aim of the research was to find a correlation between CBR value and DCP within the scope of the study since DCP is cheap, portable and very easy to operate and it is easy to conduct as many test as possible in a single spot to achieve a better result. Accordingly, the required laboratory and field tests were conducted on samples retrieved from different selected sites in Addis Ababa. Using the obtained thirty test results a linear multiple regressions were analysed and a relationship was developed that predict CBR value in terms of DCP.

In the research the laboratory result of CBR ranges from 1.25 up to 6.2 which is very low. On the other hand the DCPI result ranges from 27.8 up to 32.6. In general the result shows that for CBR less than 6.2 the DCPI result was above 27 mm/blow.so we can see that for soils which have low CBR value the Dynamic cone penetration index gets higher.

In the research the result of single regression shows that the correlation developed between DCPI ,NMC and Bulk density shows good relation with a determination coefficients (R^2) of 0.8159 and 0.7199 respectively. And it also shows there is a good relation between DCPI and CBR using two stage least square residual inclusion estimation method of analysis with coefficient of determination (R^2) of 0.827 . The equations developed are shown below.

$$\text{Predicted DCPI}=-1.129^{*}\,\gamma\,\text{bulk} + 0.405\,\text{NMC}+15.97 \quad \text{(Equation 5.1)}$$

$$\text{CBR}=22.175 - 0.241^{*}\text{PDCPI} - 0.351^{*}\text{DCPI} \quad \text{(Equation 5.2)}$$

In the research comparison has also been made between the actual CBR values and the newly developed equation, Yitagesu’s, Webster and Kleyn and van Heerden equations. The results of comparison showed that the actual CBR values determined in the laboratory exhibits lower variation when compared with the CBR values obtained from DCP– CBR relation proposed in this research than the others. But relatively Webster’s formula is closer to the equation developed in this research in terms of accuracy to the results obtained in the laboratory.

Finally the results of the statistical analysis show that good correlation does exist between the dynamic cone penetration (DCP) and California Bearing Ratio (CBR) values. Therefore DCP values can be used to estimate CBR in addition with bulk density and Natural moisture content of the soil type which is A-7-5 for preliminary stage.

5.2 Recommendation

- It is recommended to use the developed equation for estimating CBR value for A-7-5 soil types hence CBR can be replaced by DCP for preliminary stage rather than using TRL formula which is used by ERA for all types of soil.

- It is recommended to collect more data in order to make a better correlation between CBR and DCP and also to have more accurate correlation in order to use the developed equation for final stage.

- And it is recommended that various soil types should be studied so that charts or formulas can be produced for different types of soil.

REFERENCES

Amini, F., (2003). "Potential applications of dynamic and static cone penetrometers in Mn/DOT pavement design and construction, Final Report," Jackson State University.

ASTM-D 4429-93., (2000). "Insitu CBR testing aanual book of ASTM standards. Volume 04.08," west Conshohocken. Pennsylvania.

ASTM-D 6951-3., (2003). "Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications,"

Ayers, M. E., Thompson M. R., and Uzarski D. R., (1989). "Rapid Shear Strength Evaluation of In-Situ Granular Materials," Transportation Research Record No. 1227,

Bowles, J.E., (1984). "Engineering Properties of Soils and Their Measurement," McGraw-Hill, second edition, Singapore.TRB, Washington, D.C.

Choudhary, A.K., Jha, J.N. & Gill, K.S., (2010). "Utilization CBR estimation using Dynamic Cone Penetrometer," Geotechnical Special Publication, ASCE.

David, J., & John, H., (2005). "Relationship between DCP, Stiffness, Shear Strength, and R-value," Technical memorandum prepared for: California Department of Transportation (Caltrans) Division of Research and Innovation Office of Roadway Research. Technical Memorandum TM-UCB-PRC-2005-12, Pavement Research Center University of California.Berkeley & University of California, Davis.

Desalegne Y., (2012). "Developing correlations between DCP and CBR for locally used subgrade," Ethiopia.

Done and Piouslin, S., (2004). "Measurement of Road Pavement Strength by Dynamic Cone Penetrometer," Unpublished Project Report PR INT/278/04 ProjectRecord No R8157.

Douglas, C.M., and George, C.R., (2003). "Applied Statistics and Probability for Engineers," Third Edition John Wiley & Sons Inc. USA.

Farshad, A., (2003). "Potential Applications of Dynamic and Static Cone Penetrometer in Mndot Pavement Design and Construction, final report," Mississippi Department of Transportation and the U.S. Department of Transportation Federal Highway Administration, Jackson State University, Mississippi.

Hassan, A., (1996). "The Effect of Material Parameters on Dynamic Cone Penetrometer Results for Fine-grained Soils and Granular Materials," Oklahoma State University. Oklahoma.

Kin, M.W., (2006). “California Bearing Ratio Correlation with Soil Index Properties,” Faculty of Civil Engineering, University of Technology. Malaysia.

Kleyn E. G. (1975). “The Use of the Dynamic Cone Penetrometer (DCP),” Report No. 2/74, Transvaal Roads Department, Pretoria, South Africa.

Kleyn, E. G., Maree, J. F. and Savage, P. F. (1982). “The Application of a Portable Pavement Dynamic Cone Penetrometer to Determine In-Situ Bearing Properties of Road Pavement Layers and Subgrades in South Africa,” The European Symposium on Penetration Testing, Amsterdam, Netherland.

Kumar, R.S., Ajmi, A.S., & Valkati B., (2015). “Comparative study of subgrade soil strength estimation models developed based on CBR, DCP & FWD test results,” IARJSET, Vol.2, issue 8.

Livneh, M. and Livneh, N. A., (1994). “Subgrade Strength Evaluation with the Extended Dynamic Cone Penetrometer,” Congress Int., Association of Engineering Geology, Vol. 1, Lisbon.

Livneh, M., (1991). “Verification of CBR and Elastic Modulus Values Derived from Local DCP Tests,” Proc., 9th Asian Regional Conference on Soil Mechanics & Foundation Engineering, Vol. 1Bangkok.

Livneh, M., Ishai, I. and Livneh, N. (1995). “Effect of Vertical Confinement on Dynamic Cone Penetrometer Strength Values in Pavement and Subgrade Evaluation,” Transportation Research Record 1473.

Munir, D. N., (2003). “Field Evaluation of Insitu Test Technology for QC/QA during Construction of Pavement Layers and Embankments,” Department of Civil and Environmental Engineering, Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College.

Nugroho, S.A., Yusa, M., and Ningsih, S.R., (2012). “Correlation between Index Properties and California Bearing Ratio Test of Pekanbaru with and without soaked,” IJCE.

Peter, M.S., (2006). “U.S. Army engineer and Development Center. A generalized approach to soil strength prediction with machine learning methods,” ERDC/CRREL Technical report 06-15. Engineer Research and Development center. Hanover. NH.USA.

Worku, Z., (2010). “Prediction of CBR values from index Property tests,” Addis Ababa University. Ethiopia.

Wu, S., and Sargand, S., (2007). “Use of Dynamic cone penetrometer in subgrade and base acceptance.” Ohio university, USA

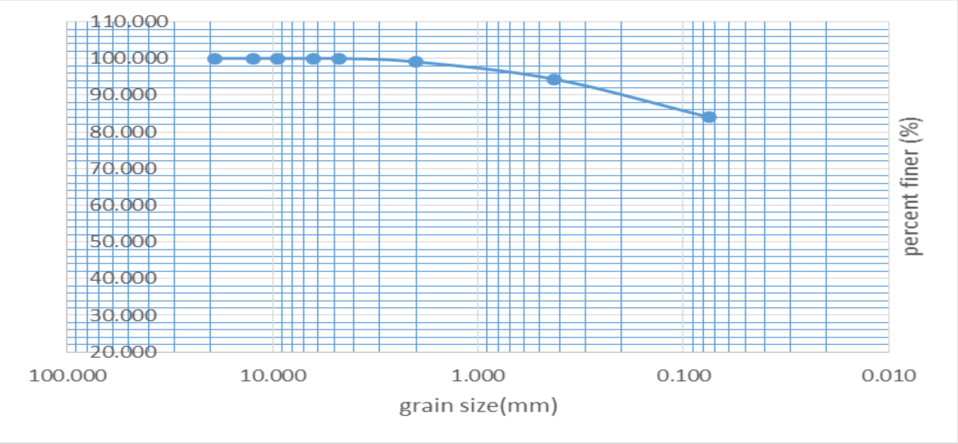
Zumrawi, M.M.E., (2014). “Prediction of In-situ CBR of subgrade Cohesive soils from Dynamic Cone Penetrometer and soil properties,” IACSIT.Vol 6.No.5.

APPENDICES

APPENDIX A: SIVE ANALYSIS RESULTS

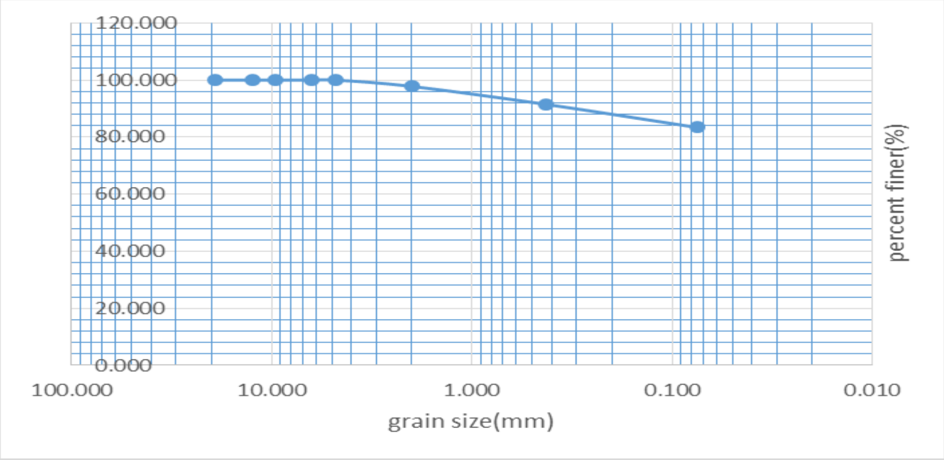
TP 1: Location of Sample: Lideta 1m

ASTM, Sieve Opening(mm)	CUMMULATIVE mass retained	WT. RETAINED	% retained	% passing
19.000		0.000	0.000	100.000
12.500	0.000	0.000	0.000	100.000
9.500	0.000	0.000	0.000	100.000
6.300	0.000	0.000	0.000	100.000
4.750	0.000	0.000	0.000	100.000
2.000	7.000	7.000	0.900	99.100
0.425	29.000	22.000	2.700	94.400
0.075	124.000	102.000	12.400	84.000
total		131.000	16.000	
total mass before wet sieve =	825.0			



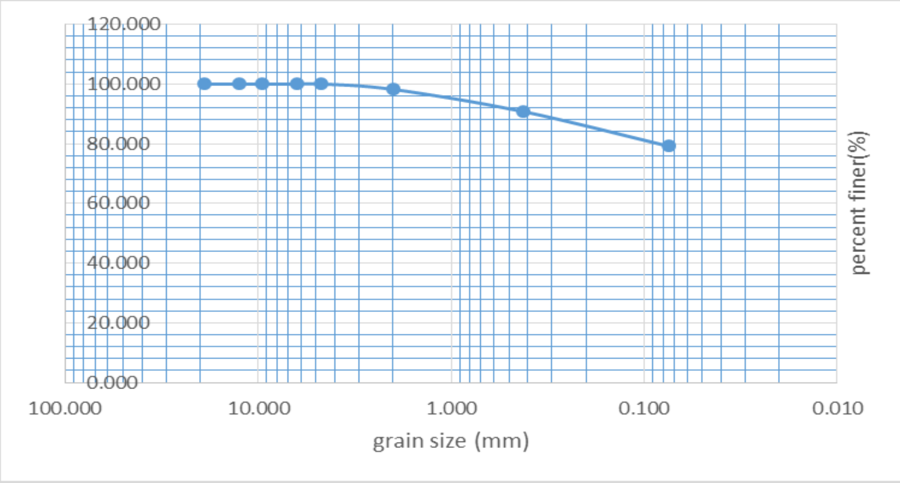
TP 1.: Location of Sample: Lideta 1.5m

ASTM, Sieve Opening(mm)	CUMMULATIVE mass retained	WT. RETAINED	% retained	% passing
19.000		0.000	0.000	100.000
12.500	0.000	0.000	0.000	100.000
9.500	0.000	0.000	0.000	100.000
6.300	0.000	0.000	0.000	100.000
4.750	0.000	0.000	0.000	100.000
2.000	18.000	18.000	2.200	97.800
0.425	70.000	52.000	6.300	91.500
0.075	118.000	66.000	8.100	83.400
total		136.000	16.600	
total mass before wet sieve =	818.0			



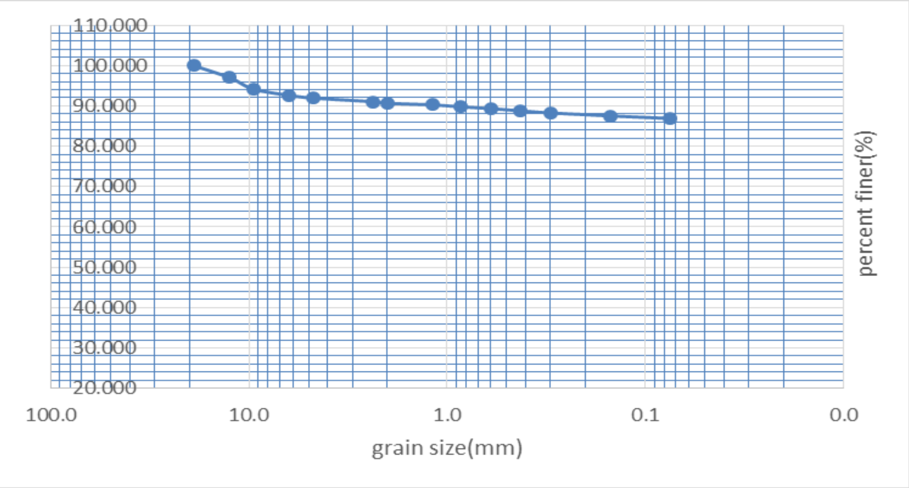
TP 1: Location of Sample: Lideta 2m

ASTM, Sieve Opening(mm)	CUMMULATIVE mass retained	WT. RETAINED	% retained	% passing
19.000		0.000	0.000	100.000
12.500	0.000	0.000	0.000	100.000
9.500	0.000	0.000	0.000	100.000
6.300	0.000	0.000	0.000	100.000
4.750	0.000	0.000	0.000	100.000
2.000	15.000	15.000	1.800	98.200
0.425	75.000	60.000	7.400	90.800
0.075	154.000	94.000	11.600	79.200
total		169.000	20.800	
otal mass before wet sieve :	845.0			



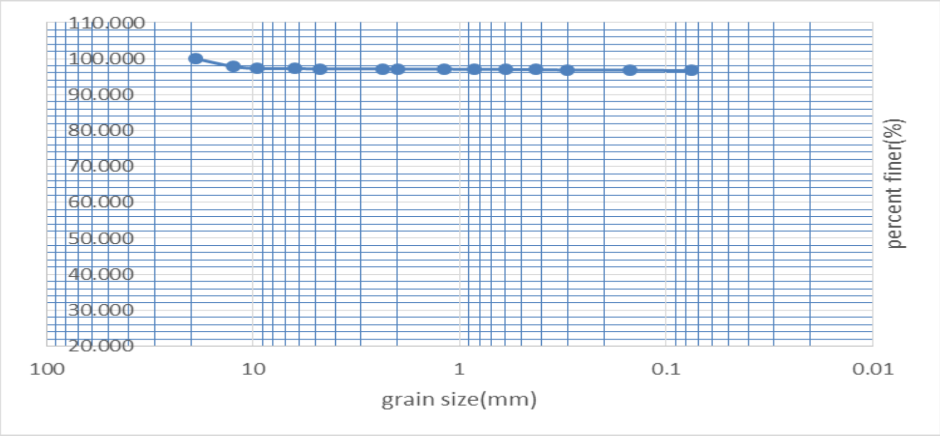
TP 2: Location of Sample: Bole 1m

TM, Sieve Opening(m	CUMMULATIVE mass retained	cummulative % retained	cummulaive % pass
19.0	0.0	0.00	100.000
12.5	22.4	3.00	97.005
9.5	43.6	5.83	94.170
6.3	55.0	7.35	92.646
4.8	60.2	8.05	91.951
2.4	66.9	8.95	91.055
2.0	69.9	9.35	90.654
1.2	72.9	9.75	90.253
0.9	76.4	10.22	89.785
0.6	79.7	10.66	89.343
0.4	83.9	11.22	88.782
0.3	87.7	11.73	88.274
0.2	93.2	12.46	87.538
0.1	98.0	13.10	86.897
total mass before we	747.9		



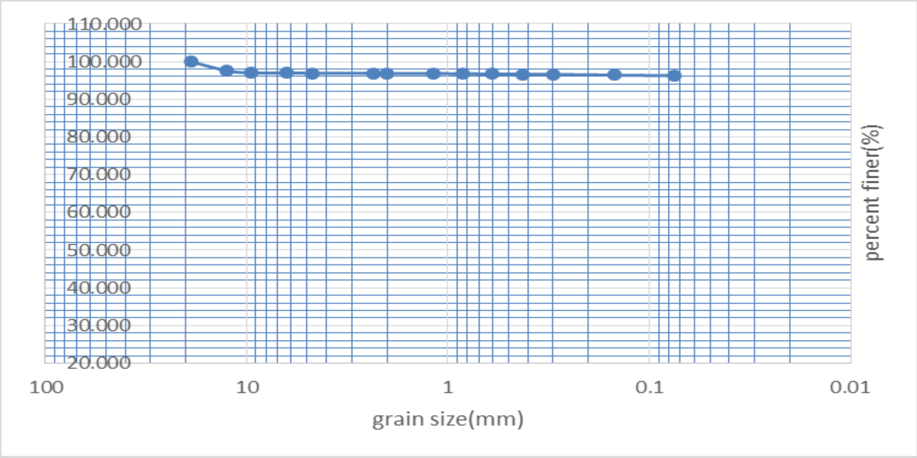
TP 2: Location of Sample: Bole 1.5m

ASTM, Sieve Opening(mm)	CUMMULATIVE mass retained	cummulative % retained	cummulaive % pass
19	0	0.00	100.000
12.5	15.9	2.14	97.859
9.5	20.3	2.73	97.266
6.3	20.6	2.77	97.226
4.75	20.8	2.80	97.199
2.36	21	2.83	97.172
2	21.41	2.88	97.116
1.18	21.62	2.91	97.088
0.85	21.9	2.95	97.051
0.6	22.21	2.99	97.009
0.425	22.5	3.03	96.970
0.3	23.4	3.15	96.848
0.15	23.6	3.18	96.822
0.075	24.7	3.33	96.673
total			
total mass before wet sieve	742.5		



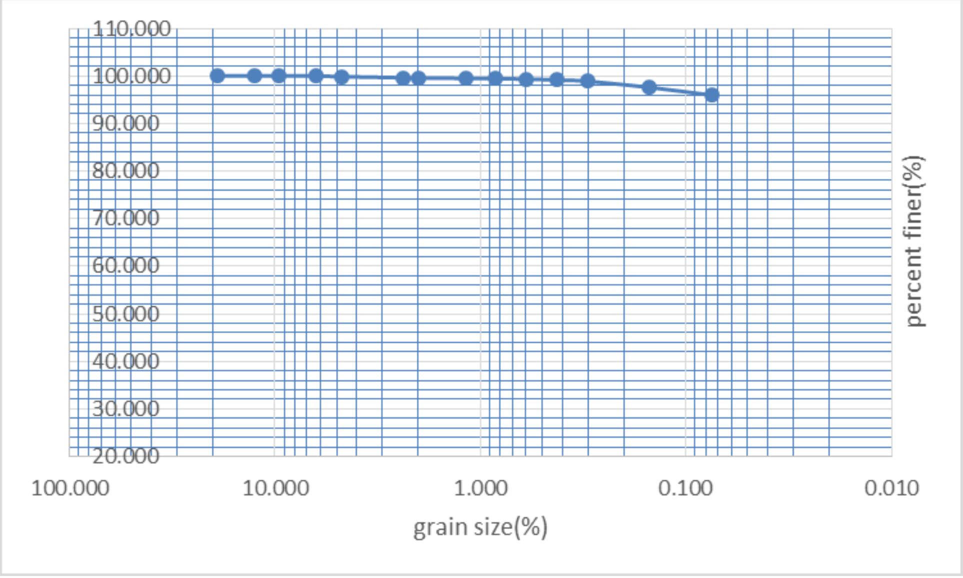
TP 2: Location of Sample: Bole 2m

ASTM, Sieve Opening(mm)	CUMMULATIVE mass retained	cummulative % retained	cummulaive % pass
19	0	0.00	100.000
12.5	17.9	2.43	97.573
9.5	22.1	3.00	97.004
6.3	22.5	3.05	96.950
4.75	22.6	3.06	96.936
2.36	23	3.12	96.882
2	23.15	3.14	96.861
1.18	23.3	3.16	96.841
0.85	23.7	3.21	96.787
0.6	24.1	3.27	96.733
0.425	24.6	3.34	96.665
0.3	25.1	3.40	96.597
0.15	26.3	3.57	96.434
0.075	27.6	3.74	96.258
total			
total mass before wet sieve	737.6		



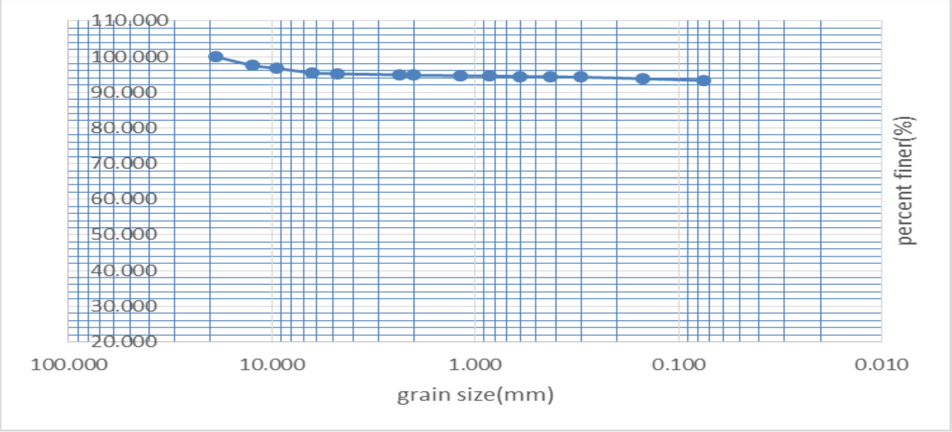
TP 3: Location of Sample: Kaliti 1m

ASTM, Sieve Opening(mm)	Cummulative mass retained	Cummulative % retained	cummulaive % pass
19.000	0	0.00	100.000
12.500	0	0.00	100.000
9.500	0	0.00	100.000
6.300	0	0.00	100.000
4.750	0.9	0.13	99.875
2.360	2.8	0.39	99.611
2.000	3.2	0.44	99.556
1.180	3.6	0.50	99.500
0.850	4	0.56	99.444
0.600	4.7	0.65	99.347
0.425	6	0.83	99.167
0.300	8.1	1.13	98.875
0.150	17.4	2.42	97.583
0.075	29	4.03	95.972
total mass before wet sieve (g) =	720		



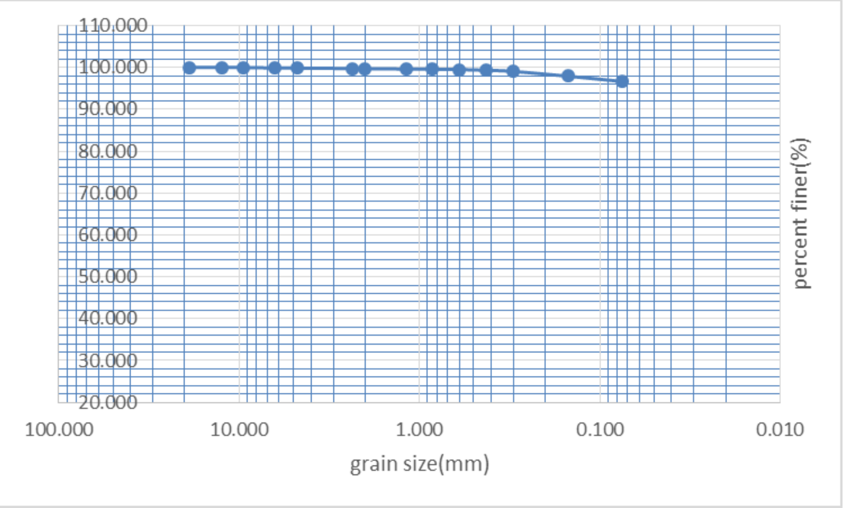
TP 3: Location of Sample: Kaliti 1.5m

ASTM, Sieve Opening(mm)	CUMMULATIVE mass retained	cummulative % retained	cummulaive % pass
19.000	0.0	0.00	100.000
12.500	19.5	2.42	97.583
9.500	26.4	3.27	96.728
6.300	36.6	4.54	95.464
4.750	38.7	4.80	95.203
2.360	41.2	5.11	94.893
2.000	42.1	5.22	94.782
1.180	43.0	5.33	94.670
0.850	43.8	5.43	94.571
0.600	44.6	5.53	94.472
0.425	45.5	5.64	94.360
0.300	46.4	5.75	94.249
0.150	49.9	6.18	93.815
0.075	53.9	6.68	93.319
total mass before wet sieve(g) =	806.8		



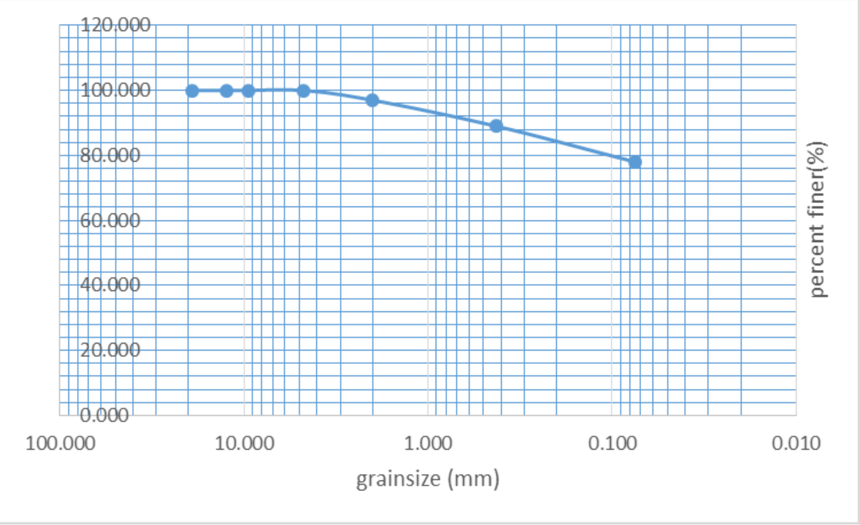
TP 3: Location of Sample: Kaliti 2m

ASTM, Sieve Opening(mm)	Cummulative mass retained	Cummulative % retained	cummulaive % pass
19.000	0	0.00	100.000
12.500	0	0.00	100.000
9.500	0	0.00	100.000
6.300	0.8	0.10	99.898
4.750	0.9	0.11	99.885
2.360	1.9	0.24	99.758
2.000	2.3	0.29	99.707
1.180	2.7	0.34	99.656
0.850	3.1	0.40	99.605
0.600	3.8	0.48	99.515
0.425	5.1	0.65	99.350
0.300	7.3	0.93	99.069
0.150	16.2	2.07	97.934
0.075	26	3.32	96.685
total mass before wet sieve (g) = 784.2			



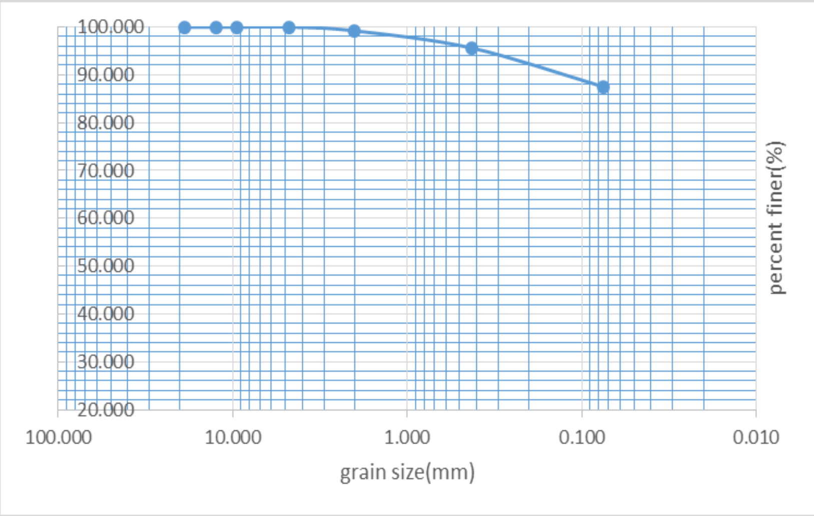
TP;4 Location of Sample:Addisu Gebeya 1m

ASTM, Sieve Opening(mm)	CUMMULATIVE mass retained	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	0.000	100.000
12.500	0.000	0.000	0.000	100.000
9.500	0.000	0.000	0.000	100.000
4.750	0.000	0.000	0.000	100.000
2.000	25.000	25.000	3.000	97.000
0.425	93.000	68.000	8.000	89.000
0.075	161.000	93.000	11.000	78.000
total		186.000		
total mass before wet sieve =	844.0			



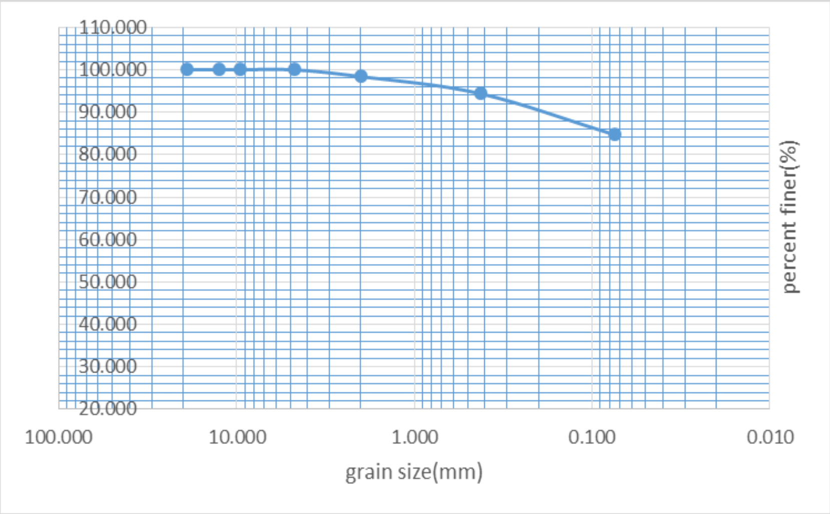
TP;4 Location of Sample:Addisu Gebeya 1.5m

ASTM, Sieve Opening(mm)	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
4.750	0.000	0.000	100.000
2.000	7.000	0.800	99.200
0.425	31.000	3.600	95.600
0.075	70.000	8.100	87.500
total	108.000		
total mass before wet sieve	865		



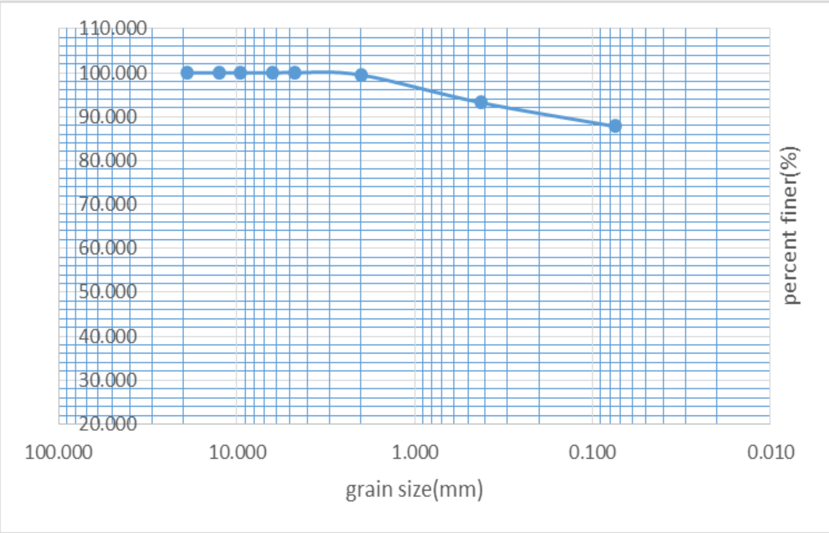
TP; 4 Location of Sample:Addisu Gebeya 2m

STM, Sieve Opening(m	T. RETAINI	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
4.750	0.000	0.000	100.000
2.000	15.000	1.400	98.400
0.425	78.000	5.600	94.400
0.075	103.000	15.300	84.700
total	196.000		
total mass before wet	823		



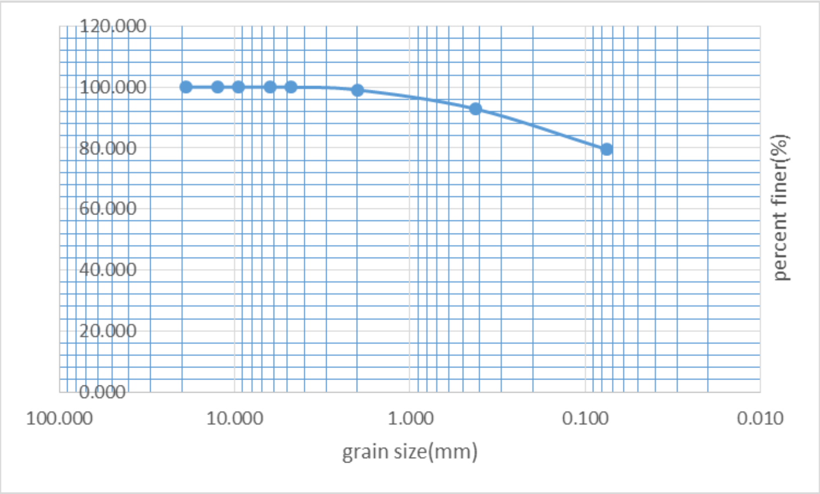
TP;5 Location of Sample:Kolfe 1m

ASTM, Sieve Opening(mm)	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
6.300	0.000	0.000	100.000
4.750	0.000	0.000	100.000
2.000	10.000	0.500	99.500
0.425	61.000	5.800	93.200
0.075	130.000	17.200	87.800
total	201.000	23.500	
92.0			
total mass before wet sieve =	962		



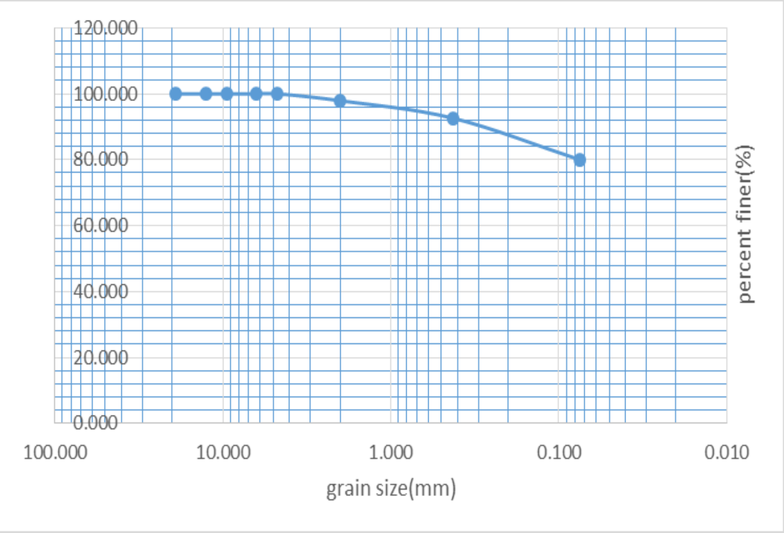
TP;5 Location of Sample:Kolfe 1.5m

ASTM, Sieve Opening(mm)	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
6.300	0.000	0.000	100.000
4.750	0.000	0.000	100.000
2.000	8.000	0.900	99.100
0.425	59.000	6.200	92.900
0.075	128.000	13.400	79.500
total	195.000	20.500	
92.0			
total mass before wet sieve	954		



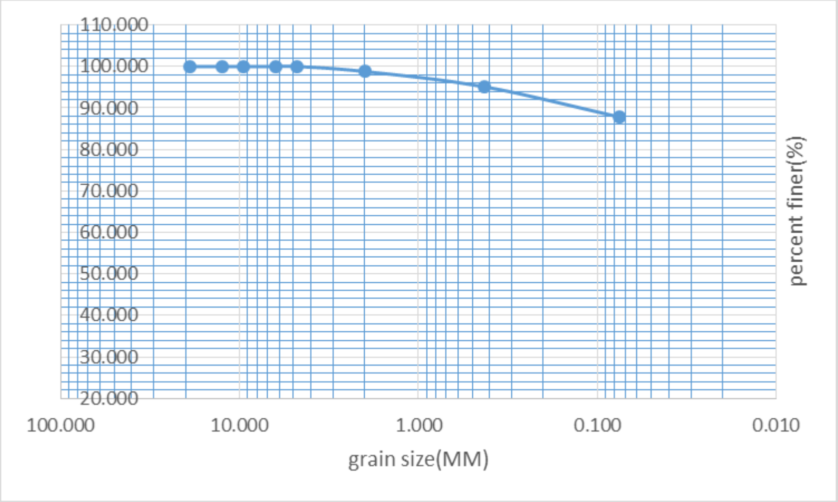
TP;5 Location of Sample:Kolfe 2m

ieve Open	CUMMULATIVE mass retained	WT. RETAINED	% retained	% passing
19.000		0.000	0.000	100.000
12.500	0.000	0.000	0.000	100.000
9.500	0.000	0.000	0.000	100.000
6.300	0.000	0.000	0.000	100.000
4.750	0.000	0.000	0.000	100.000
2.000	19.000	19.000	2.100	97.900
0.425	66.000	47.000	5.300	92.600
0.075	160.000	113.000	12.600	80.000
total		179.000	20.000	
	total mass before wet sieve =	894		



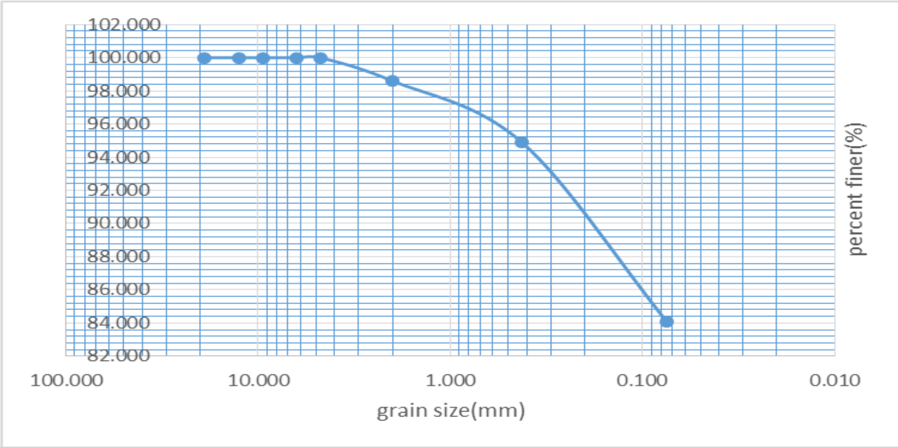
TP;9Location of Sample: Winget 1m

ASTM, Sieve Opening(mm)	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
6.300	0.000	0.000	100.000
4.750	0.000	0.000	100.000
2.000	16.000	1.200	98.800
0.425	50.000	3.900	95.100
0.075	98.000	7.300	87.800
total	164.000	12.400	
total mass before wet sieve =	1345		



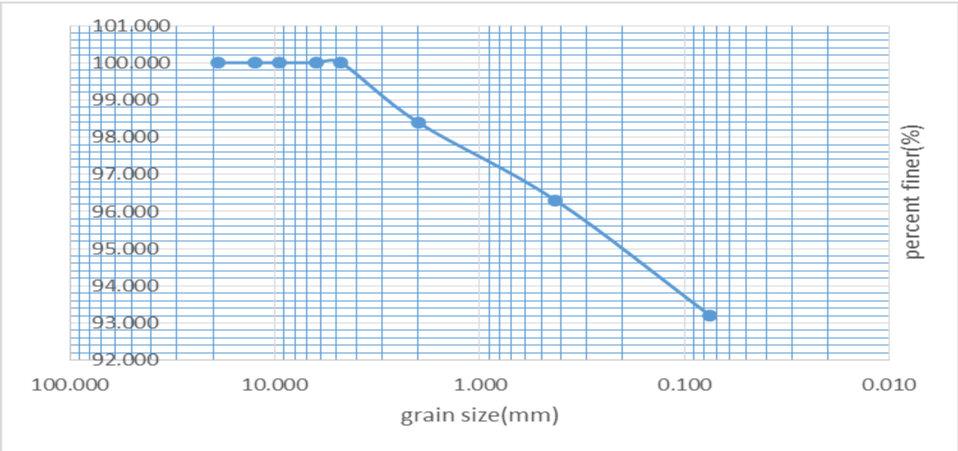
TP;9 Location of Sample: Winget 1.5m

ASTM, Sieve Opening(mm)	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
6.300	0.000	0.000	100.000
4.750	0.000	0.000	100.000
2.000	15.000	1.400	98.600
0.425	42.000	3.800	94.900
0.075	119.000	10.700	84.100
total	176.000	15.900	
total mass before wet sieve =	1107		



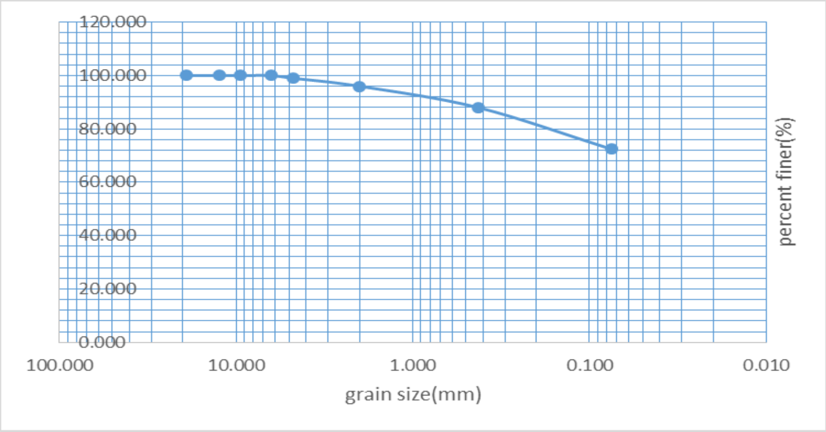
TP;9 Location of Sample: Winget 2m

ieve Open	T. RETAINI	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
6.300	0.000	0.000	100.000
4.750	0.000	0.000	100.000
2.000	17.000	1.600	98.400
0.425	68.000	3.700	96.300
0.075	158.000	6.800	93.200
total	243.000	12.100	
		total mass before wet siev	1240



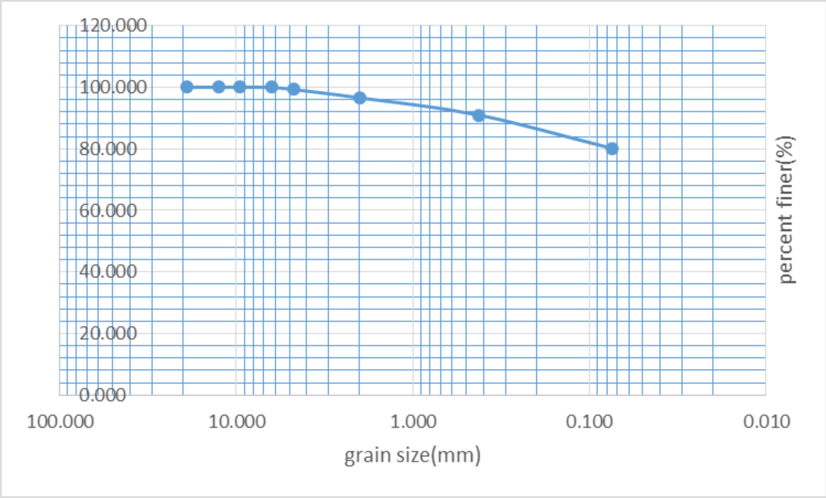
TP;10 Location of Sample: Megenagna 1m

ASTM, Sieve Opening(mm)	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
6.300	0.000	0.000	100.000
4.750	11.000	1.200	99.000
2.000	22.000	2.600	96.000
0.425	71.000	8.000	88.000
0.075	140.000	15.800	72.400
total	244.000	27.600	
total mass before wet sieve =	884		



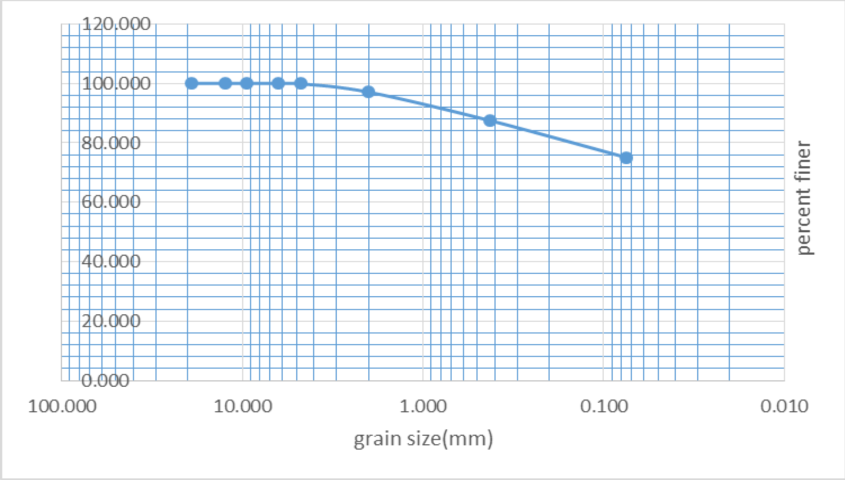
TP;10 Location of Sample: Megenagna 1.5m

ASTM, Sieve Opening(mm)	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
6.300	0.000	0.000	100.000
4.750	5.000	0.700	99.300
2.000	20.000	2.700	96.600
0.425	42.000	5.600	91.000
0.075	81.000	10.900	80.200
total	148.000	19.900	
total mass before wet sieve =	746		



TP;10 Location of Sample: Megenagna 2m

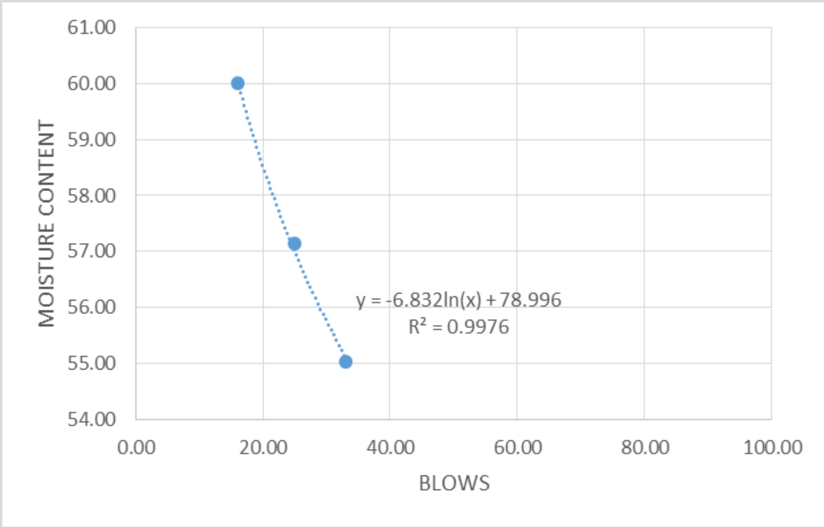
ieve Open	WT. RETAINED	% retained	% passing
19.000	0.000	0.000	100.000
12.500	0.000	0.000	100.000
9.500	0.000	0.000	100.000
6.300	0.000	0.000	100.000
4.750	1.000	0.100	99.900
2.000	22.000	2.800	97.100
0.425	75.000	9.600	87.500
0.075	96.000	12.300	75.100
total	194.000	24.800	
	total mass before wet sieve =	780	



APPENDIX B: ATTERBERG LIMIT RESULTS

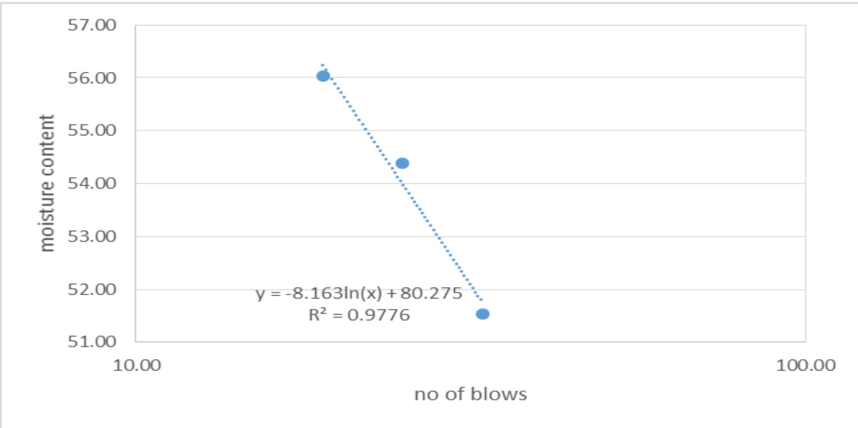
TP 1: Location of Sample: Lideta 1m

DESCRIPTION	LIQUID LIM	Colum	Colum	DESCRIPTIO	PLASTIC LIMI	Colum
trial no.	1	2	3	trial no.	1	2
can no.	G3	Z1	R4	can no.	D2	J2
mass of can,g	11.60	11.50	11.50	mass of can,g	11.59	11.58
mass of can+wet soil,g	47.10	50.00	51.50	mass of can+wet soil,g	13.89	13.87
mass of can+dry soil,g	34.50	36.00	36.50	mass of can+dry soil,g	13.35	13.32
mass of water,g	12.60	14.000	15.00	mass of water,g	0.54	0.55
mass of dry soil,g	22.90	24.50	25.00	mass of dry soil,g	1.76	1.74
water content,%	**55.02**	**57.14**	**60.00**	water content,%	30.68	31.61
No. of blows	**33.00**	**25.00**	**16.00**	**PL(avg)=**	**31.15**	
LL(@ 25 no of blow)=	**57.00**					
PI=	**26**					



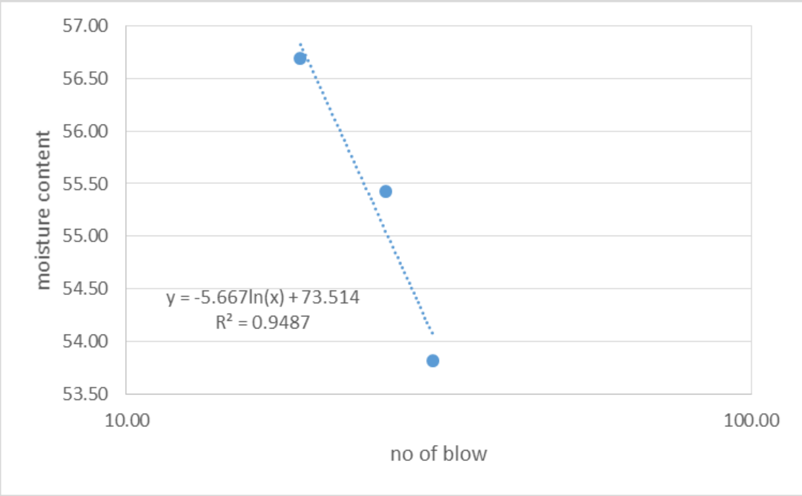
TP 1.: Location of Sample: Lideta 1.5m

LIDETA 1.5						
DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIO	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	A7	C5	J2	can no.	F1	R1
mass of can,g	11.40	11.40	11.50	mass of can,g	11.59	11.60
mass of can+wet soil,g	55.80	57.10	58.00	mass of can+wet soil,g	13.81	13.81
mass of can+dry soil,g	40.70	41.00	41.30	mass of can+dry soil,g	13.28	13.27
mass of water,g	15.10	16.10	16.70	mass of water,g	0.53	0.54
mass of dry soil,g	29.30	29.60	29.80	mass of dry soil,g	1.69	1.67
water content,%	51.54	54.39	56.04	water content,%	32.60	31.40
No. of blows	33.00	25.00	19.00	PL(avg)=	32.00	
LL(@ 25 no of blow)=	54.00					
PI=	22					



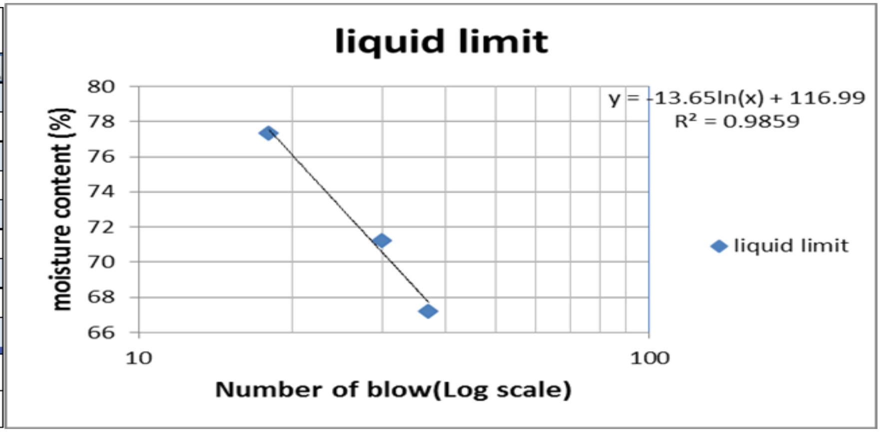
TP 1.: Location of Sample: Lideta 2m

LIDETA 2M						
DESCRIPTION	LIQUID LIMIT	Column1	Colum	DESCRIPTIC	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	A1	A4	S3	can no.	D7	D8
mass of can,g	11.40	11.30	11.50	mass of can,g	11.59	11.58
mass of can+wet soil,g	47.70	50.00	51.30	mass of can+wet soil,g	13.79	13.78
mass of can+dry soil,g	35.00	36.20	36.90	mass of can+dry soil,g	13.29	13.27
mass of water,g	12.70	13.80	14.40	mass of water,g	0.50	0.51
mass of dry soil,g	23.60	24.90	25.40	mass of dry soil,g	1.70	1.69
water content,%	53.81	55.42	56.69	water content,%	29.41	30.18
No. of blows	31.00	26.00	19.00	PL(avg)=	29.80	
LL(@ 25 no of blow)=	55.27					
PI=	25					



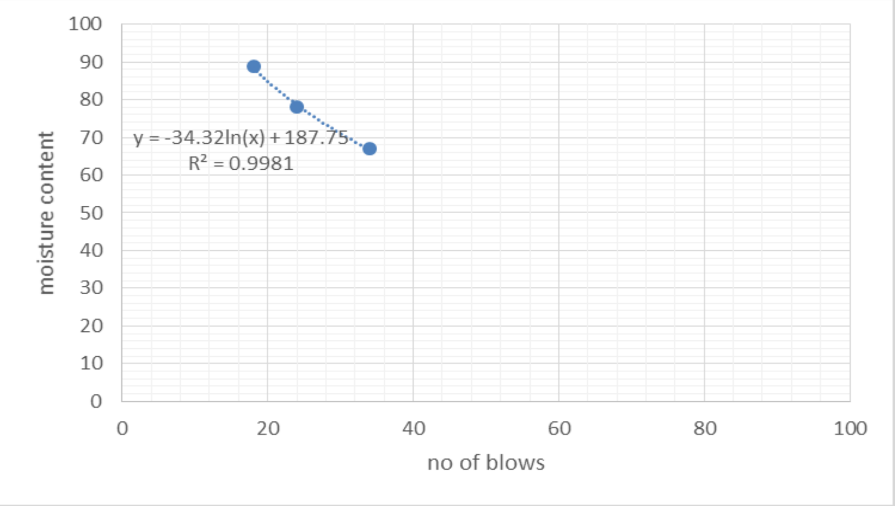
TP2; Location of Sample: Bole 1m

BOLE 1 METER						
DESCRIPTION	LIQUID LIM	Column	Column	DESCRIPTIC	PLASTIC LIM	Column
trial no.	1	2	3	trial no.	1	2
can no.	Y5	G5	O6	can no.	Z5	R1
mass of can,g	15	15	15	mass of can,g	16	15
mass of can+wet soil,g	33	38	34	mass of can+wet soil,g	17.950	17.380
mass of can+dry soil,g	25	28	26	mass of can+dry soil,g	17.50	16.80
mass of water,g	8	9	8	mass of water,g	0.45	1
mass of dry soil,g	10	13	12	mass of dry soil,g	1	2
water content,%	77	71	67	water content,%	33	34
No. of blows	18	30	37	PL(avg)=	34	
LL(@ 25 no of blow)=	73.05					
PI=	40					



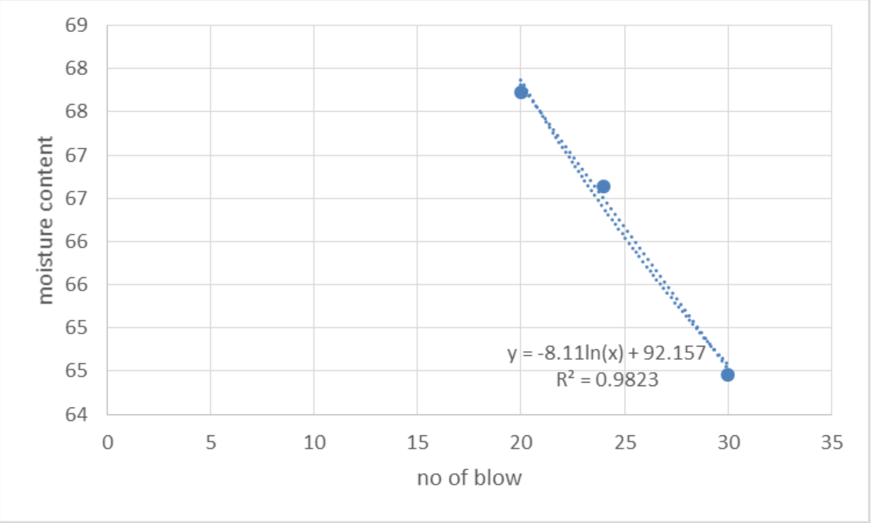
TP2; Location of Sample: Bole 1.5m

BOLE 1.5 METER						
DESCRIPTION	LIQUID LIM	Column	Column	DESCRIPTIO	PLASTIC LIM	Column
trial no.	1	2	3	trial no.	1	2
can no.	J4	S1	S7	can no.	A2	R7
mass of can,g	15	15	15	mass of can,g	15.00	15
mass of can+wet soil,g	34	36	37	mass of can+wet soil,g	18.00	17.63
mass of can+dry soil,g	25	27	28	mass of can+dry soil,g	17.10	16.90
mass of water,g	9	9	9	mass of water,g	0.90	1
mass of dry soil,g	10	12	13	mass of dry soil,g	2	2
water content,%	89	78	67	water content,%	43	38
No. of blows	18	24	34	PL(avg)=	41	
LL(@ 25 no of blow)=	77.3					
PI=	37					



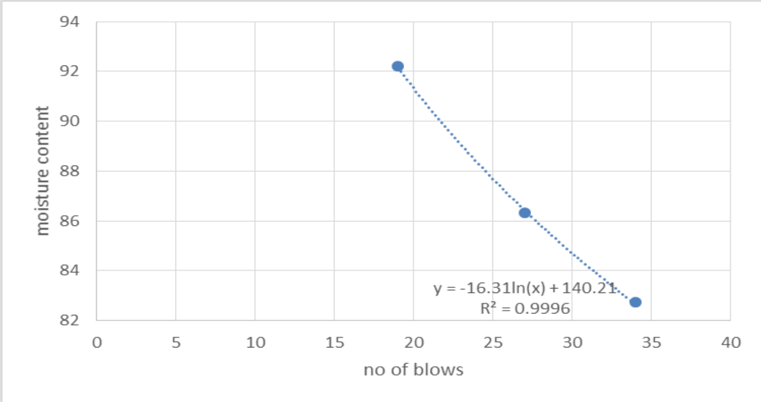
TP2; Location of Sample: Bole 2m

BOLE 2 METER						
DESCRIPTION	LIQUID LIMI	Column	Column	DESCRIPTION	PLASTIC LIMI	Column
TRIAL NO	1	2	3	TRIAL NO	1	2
CAN NO.	J1	O9	G7	CAN NO.	P3	W2
MASS OF CAN,g	15	15	16	MASS OF CAN,g	16	15
MASS OF can+wet soil,g	35	34	34	MASS OF can+wet soil,g	19	17
mass of can+dry soil,g	27	27	27	mass of can+dry soil,g	18	17
mass of water,g	8	8	7	mass of water,g	1	1
mass of dry soil,g	12	12	11	mass of dry soil,g	2	2
water content,%	68	67	64	water content,%	33	33
No. of blows	20	24	30	PL(avg)	33	
LL(@ 25 no of blow)=	66.05					
PI=	33					



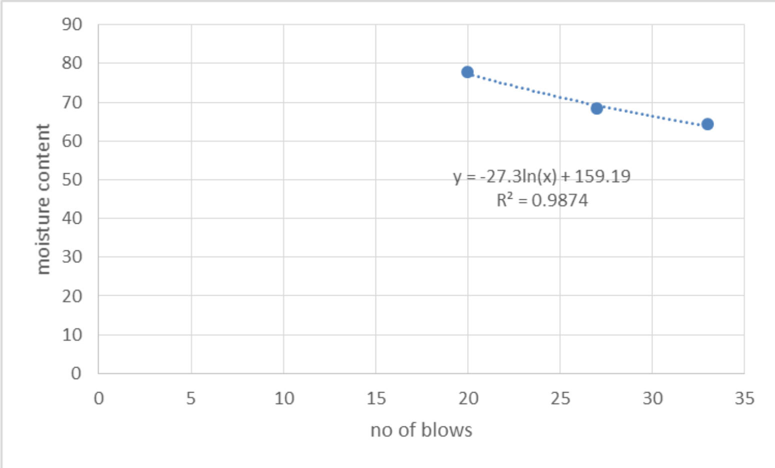
TP3; Location of Sample: Kaliti 1m

DESCRIPTION	LIQUID LIMIT	Column	Column	DESCRIPTION	PLASTIC LIMIT	Column
trial no.	1	2	3	trial no.	1	2
can no.	Z4	C2	M1	can no.	L6	O7
mass of can,g	17	15	15	mass of can,g	14	20
mass of can+wet soil,g	36	32	31	mass of can+wet soil,g	21	28
mass of can+dry soil,g	27	24	24	mass of can+dry soil,g	20	25
mass of water,g	9	8	7	mass of water,g	2	2
mass of dry soil,g	10	9	9	mass of dry soil,g	5	6
water content,%	92	86	83	water content,%	35	39
No. of blows	19	27	34	PL(avg)=		37
LL(@ 25 no of blow)=	87.71					
PI=	51					



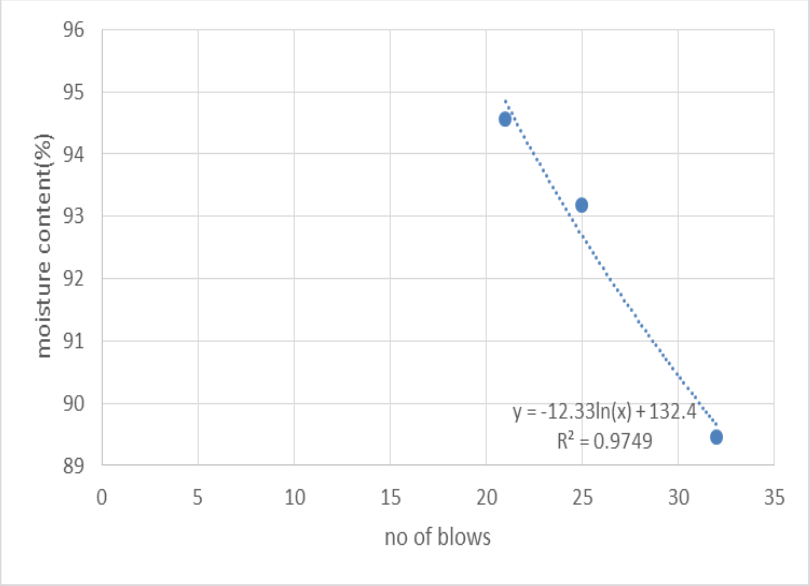
TP3; Location of Sample: Kaliti 1.5m

DESCRIPTION	LIQUID LIMIT	Column	Column	DESCRIPTION	PLASTIC LIMIT	Column
trial no.	1	2	3	trial no.	1	2
can no.	A5	J2	A2	can no.	S3	O5
mass of can,g	15	15	15	mass of can,g	15	15
mass of can+wet soil,g	38	37	31	mass of can+wet soil,g	18.80	18.70
mass of can+dry soil,g	29	28	24	mass of can+dry soil,g	18.10	17.80
mass of water,g	9	9	7	mass of water,g	0.70	0.90
mass of dry soil,g	14	13	9	mass of dry soil.g	3.10	2.80
water content,%	64	68	78	water content,%	22.58	32.14
No.of blows	33	27	20	PL(avg)=		27
LL(@ 25 no of blow)=	71.31					
PI=	44					



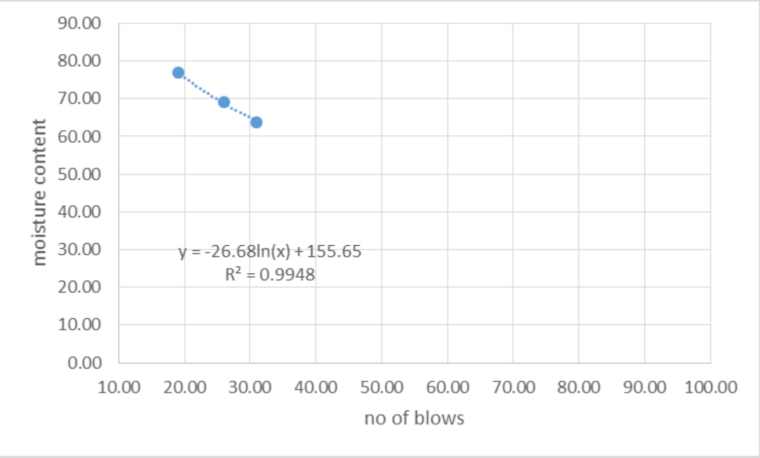
TP3; Location of Sample: Kaliti 2m

DESCRIPTION	LIQUID LIM	Colum	Colum	DESCRIPTION	PLASTIC LIMIT	Colu
trial no.	1	2	3	trial no.	1	2
can no.	A7	B2	B7	can no.	H2	F6
mass of can,g	17	15	16	mass of can,g	16	16
mass of can+wet soil,g	39	37	33	mass of can+wet soil,g	19	18
mass of can+dry soil,g	28	26	25	mass of can+dry soil,g	18	18
mass of water,g	11	11	8	mass of water,g	1	1
mass of dry soil,g	11	11	9	mass of dry soil,g	2	2
water content,%	**95**	**93**	**89**	water content,%	43	43
No. of blows	**21**	**25**	**32**	**PL(avg)=**	**43**	
LL(@ 25 no of blow)=	92.7					
PI=	50					



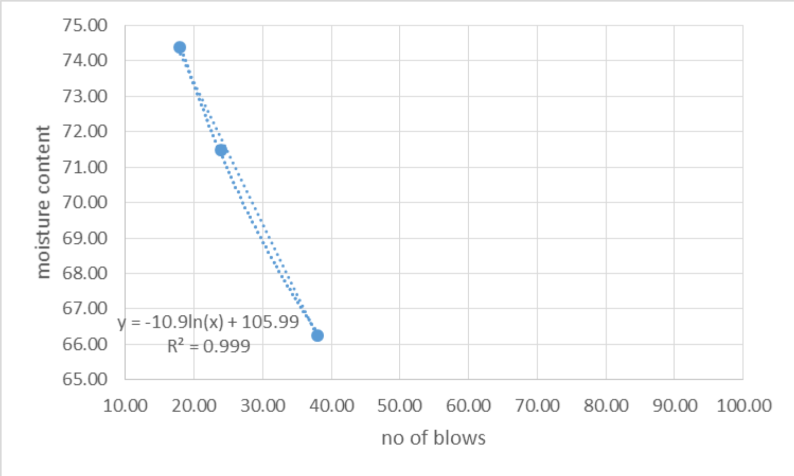
TP4; Location of Sample: Adissu gebeya 1m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIO	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	G2	A7	A2	can no.	Z5	R1
mass of can,g	15.10	15.30	15.80	mass of can,g	15.50	16.10
mass of can+wet soil,g	57.73	58.80	57.70	mass of can+wet soil,g	29.58	30.33
mass of can+dry soil,g	39.20	41.00	41.40	mass of can+dry soil,g	26.30	26.80
mass of water,g	18.53	17.80	16.30	mass of water,g	4.33	4.49
mass of dry soil,g	24.10	25.70	25.60	mass of dry soil,g	10.80	10.70
water content,%	**76.89**	**69.26**	**63.67**	water content,%	40.09	41.96
No. of blows	**19.00**	**26.00**	**31.00**	**PL(avg)=**	**41.03**	
LL(@ 25 no of blow)=	**69.77**					
PI=	**29**					



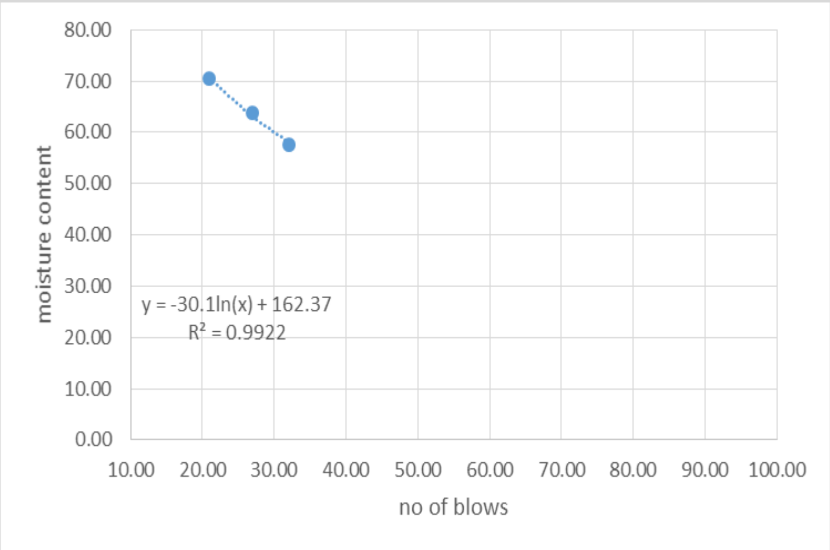
TP4; Location of Sample: Adissu gebeya 1.5m

DESCRIPTION	LIQUID LIM	Colum	Colum	DESCRIPTIO	PLASTIC LIMI	Colum
trial no.	1	2	3	trial no.	1	2
can no.	G2	A7	A2	can no.	Z5	R1
mass of can,g	15.30	15.10	16.10	mass of can,g	15.50	15.80
mass of can+wet	56.70	57.80	56.73	mass of can+wet soil,g	29.58	30.33
mass of can+dry	40.20	40.00	39.40	mass of can+dry soil,g	26.30	26.80
mass of water,g	16.50	17.80	17.33	mass of water,g	3.33	3.49
mass of dry soil,	24.90	24.90	23.30	mass of dry soil,g	10.80	11.00
water content,%	**66.27**	**71.49**	**74.38**	water content,%	30.83	31.73
No. of blows	**38.00**	**24.00**	**18.00**	**PL(avg)=**	**31.28**	
25 no of blow)=	**70.90**					
PI=	**40**					



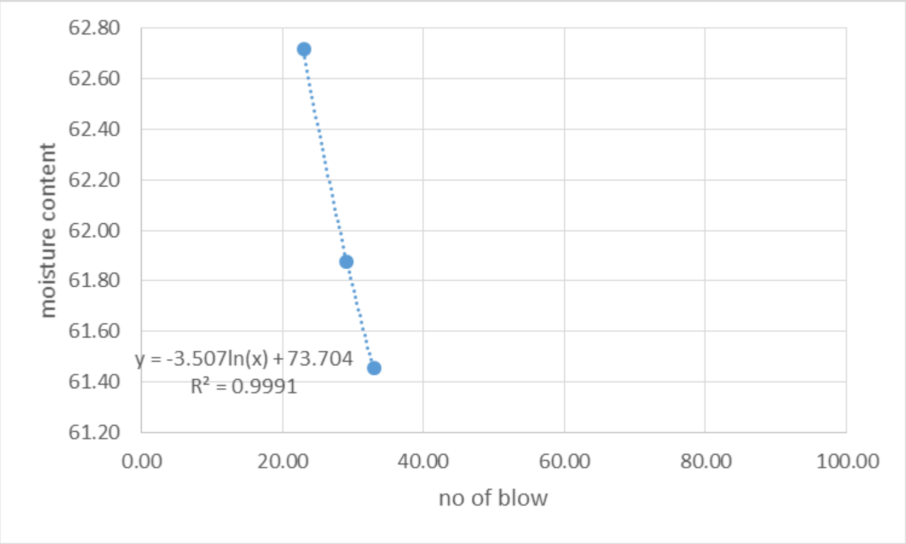
TP4; Location of Sample: Adissu gebeya 2m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIO	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	G1	A3	A5	can no.	F2	Z2
mass of can,g	15.10	15.30	15.50	mass of can,g	15.80	16.10
mass of can+wet soil,g	59.93	61.00	59.80	mass of can+wet soil,g	30.33	31.58
mass of can+dry soil,g	41.40	43.20	43.60	mass of can+dry soil,g	28.23	28.93
mass of water,g	18.53	17.80	16.20	mass of water,g	2.53	2.59
mass of dry soil,g	26.30	27.90	28.10	mass of dry soil,g	12.43	12.83
water content,%	**70.46**	**63.80**	**57.65**	water content,%	20.35	20.19
No. of blows	**21.00**	**27.00**	**32.00**	**PL(avg)=**	**20.27**	
LL(@ 25 no of blow)=	**66**					
PI=	**45**					



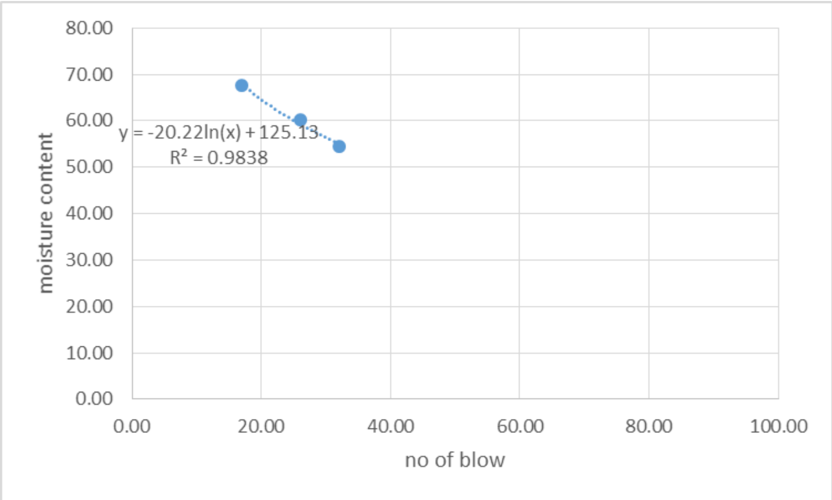
TP5; Location of Sample: Kolfe 1m

DESCRIPTION	LIQUID LIMI	Colum	Colum	DESCRIPTIC	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	A7	B4	G8	can no.	S3	F1
mass of can,g	15.65	13.86	15.65	mass of can,g	15.67	11.69
mass of can+wet soil,g	46.01	43.91	45.71	mass of can+wet soil,g	19.83	15.15
mass of can+dry soil,g	34.46	32.42	34.12	mass of can+dry soil,g	18.67	14.48
mass of water,g	11.56	11.49	11.59	mass of water,g	1.16	1.07
mass of dry soil,g	18.81	18.57	18.48	mass of dry soil,g	2.99	2.79
water content,%	61.46	61.87	62.72	water content,%	38.87	38.53
No. of blows	33.00	29.00	23.00	PL(avg)=	38.70	
LL(@ 25 no of blow)=	62.42					
PI=	24					



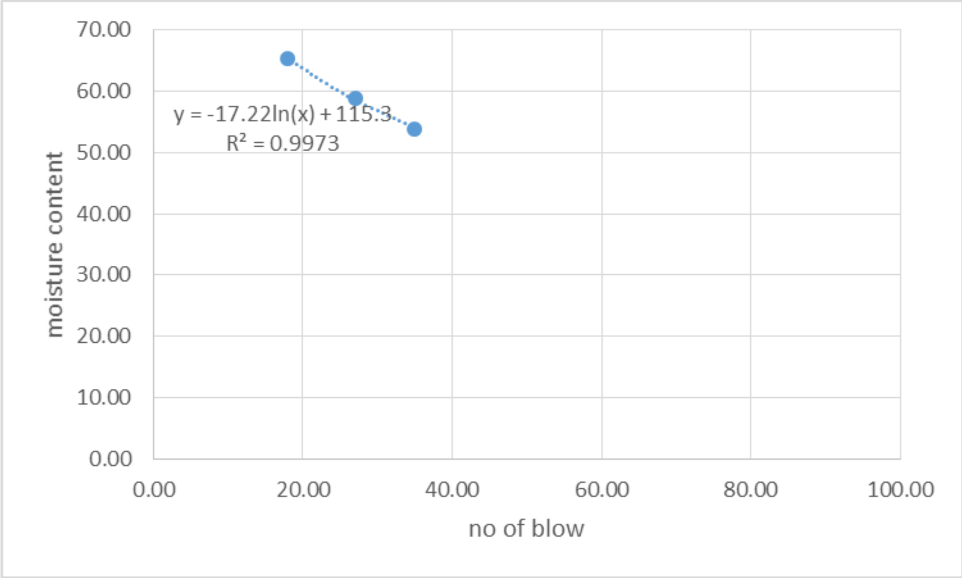
TP5; Location of Sample: Kolfe 1.5m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIC	ASTIC L	Colum
trial no.	1	2	3	trial no.	1	2
can no.	D3	A2	C3	can no.	D5	S1
mass of can,g	20.80	21.40	21.10	mass of can,g	20.80	20.90
mass of can+wet soil,g	53.30	57.20	52.80	mass of can+wet soil,g	31.60	31.20
mass of can+dry soil,g	40.10	44.74	41.63	mass of can+dry soil,g	28.80	28.50
mass of water,g	13.10	12.46	11.17	mass of water,g	2.80	2.68
mass of dry soil,g	19.40	20.70	20.53	mass of dry soil,g	8.00	7.62
water content,%	67.53	60.19	54.41	water content,%	35.00	35.17
No. of blows	17.00	26.00	32.00	PL(avg)=	35.09	
LL(@ 25 no of blow)=	60.04					
PI=	25					



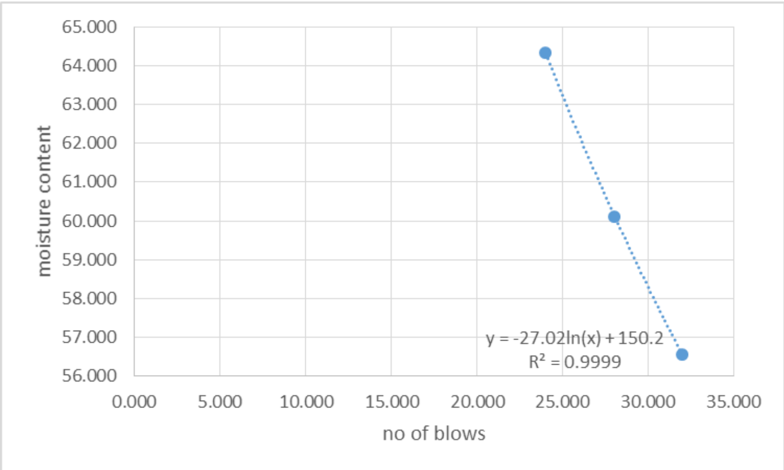
TP5; Location of Sample: Kolfe 2m

DESCRIPTION	LIQUID LIMIT	Column1	Colum	DESCRIPTIO	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	D12	A4	C9	can no.	A12	G5
mass of can,g	16.50	16.70	16.70	mass of can,g	20.70	20.90
mass of can+wet soil,g	54.10	51.50	51.50	mass of can+wet soil,g	34.00	33.70
mass of can+dry soil,g	41.00	38.60	37.70	mass of can+dry soil,g	30.70	30.40
mass of water,g	13.20	12.90	13.80	mass of water,g	3.36	3.27
mass of dry soil,g	24.50	21.90	21.10	mass of dry soil,g	9.96	9.52
water content,%	53.88	58.90	65.40	water content,%	33.73	34.35
No. of blows	35.00	27.00	18.00	PL(avg)=	34.04	
LL(@ 25 no of blow)=	59.87					
PI=	26					



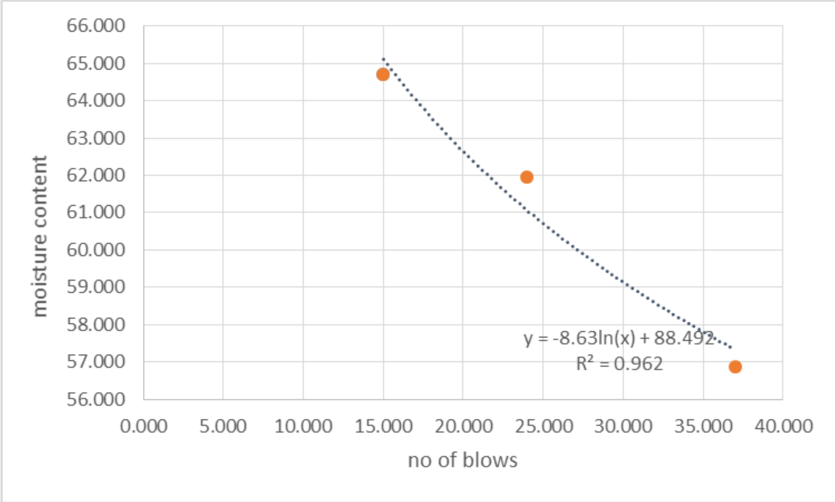
T6; Location of Sample: Addis Ketema 1m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIO	PLASTIC LIM	Colum
trial no.	1	2	3	trial no.	1	2
can no.	j3	a5	c2	can no.	e8	f6
mass of can,g	15.630	15.670	15.550	mass of can,g	15.630	15.760
mass of can+wet soil,g	45.300	42.410	47.580	mass of can+wet soil,g	18.980	19.300
mass of can+dry soil,g	34.580	32.370	35.040	mass of can+dry soil,g	18.000	18.100
mass of water,g	10.720	10.040	12.540	mass of water,g	0.980	1.200
mass of dry soil,g	18.950	16.700	19.490	mass of dry soil,g	2.370	2.340
water content,%	56.570	60.120	64.341	water content,%	41.350	51.282
No. of blows	32.000	28.000	24.000	PL(avg)=	46.316	
LL(@ 25 no of blow)=	63					
PI=	17					



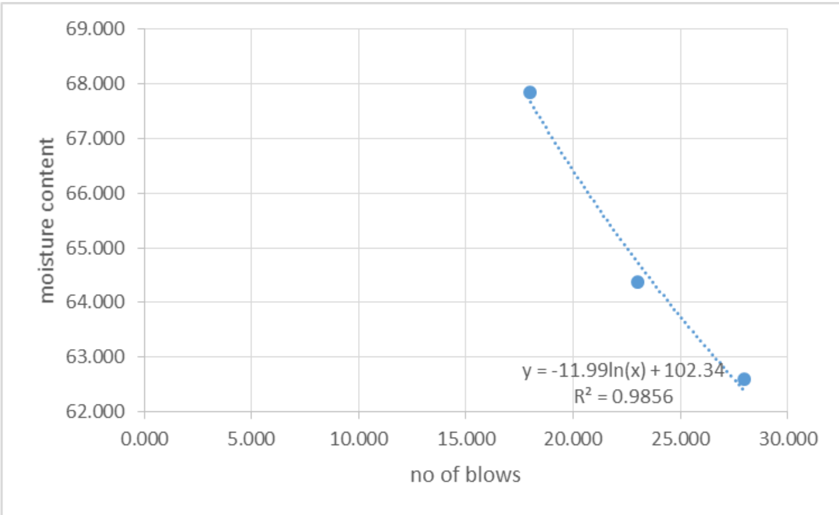
T6; Location of Sample: Addis Ketema 1.5m

DESCRIPTION	LIQUID LIMIT	Column1	Column2	DESCRIPTIO	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	D20	d4	b1	can no.	s2	h1
mass of can,g	15.670	15.570	15.630	mass of can,g	15.980	15.960
mass of can+wet	47.110	42.180	40.650	mass of can+wet soil,g	20.250	22.360
mass of can+dry	34.760	32.000	31.580	mass of can+dry soil,g	18.900	20.600
mass of water,g	12.350	10.180	9.070	mass of water,g	1.350	1.760
mass of dry soil,	19.090	16.430	15.950	mass of dry soil,g	2.920	4.640
water content,%	64.694	61.960	56.865	water content,%	46.233	37.931
No. of blows	15.000	24.000	37.000	PL(avg)=	42.082	
25 no of blow)=	60.85					
PI=	19					



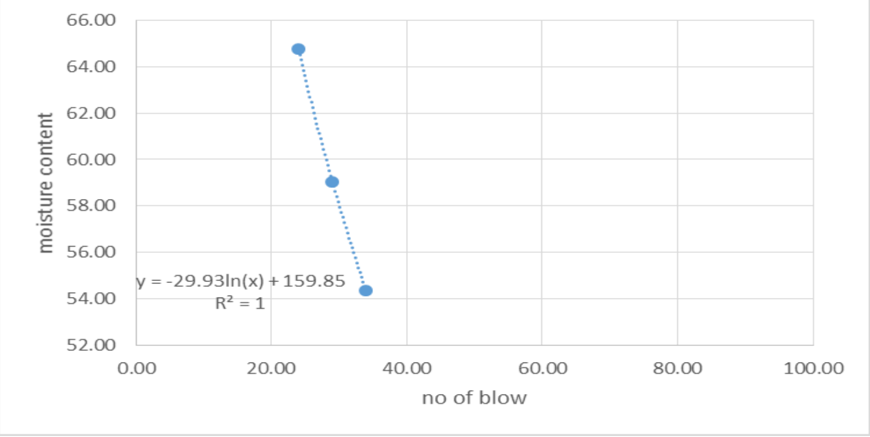
TP 6; Location of Sample: Addis Ketema 2m

DESCRIPTION	LIQUID LIMIT	Column	Colum	DESCRIPTIC	PLASTIC LIN	Colum
trial no.	1	2	3	trial no.	1	2
can no.	c18	e1	e3	can no.	b12	d5
mass of can,g	15.630	15.830	15.550	mass of can,g	13.620	15.860
mass of can+wet soil,g	44.310	41.110	46.450	an+wet soil,g	17.580	20.340
mass of can+dry soil,g	33.270	31.210	33.960	an+dry soil,g	16.380	18.980
mass of water,g	11.040	9.900	12.490	ass of water,g	1.200	1.360
mass of dry soil,g	17.640	15.380	18.410	s of dry soil,g	2.760	3.120
water content,%	62.585	64.369	67.844	ter content,%	43.478	43.590
No. of blows	28.000	23.000	18.000	PL(avg)=	43.534	
LL(@ 25 no of blow)=	63.75					
PI=	20					



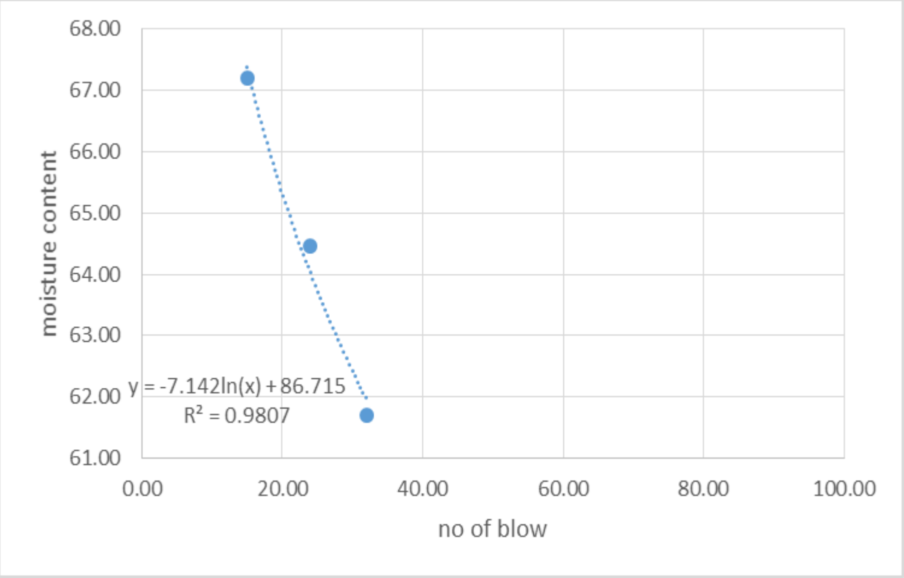
TP 7; Location of Sample: Entoto 1m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIC	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	c1	g1	b4	can no.	d12	f8
mass of can,g	15.30	15.50	15.37	mass of can,g	15.60	15.72
mass of can+wet soil,g	47.81	51.05	44.77	mass of can+wet soil,g	27.95	26.82
mass of can+dry soil,g	35.74	37.97	34.42	mass of can+dry soil,g	25.57	24.77
mass of water,g	12.07	13.08	10.35	mass of water, g	2.38	2.05
mass of dry soil,g	20.44	20.20	19.05	mass of dry soil,g	9.97	9.05
water content,%	59.05	64.75	54.33	water content,%	23.87	22.65
No. of blows	29.00	24.00	34.00	PL(avg)=	23.26	
LL(@ 25 no of blow)=	63.51					
PI=	40					



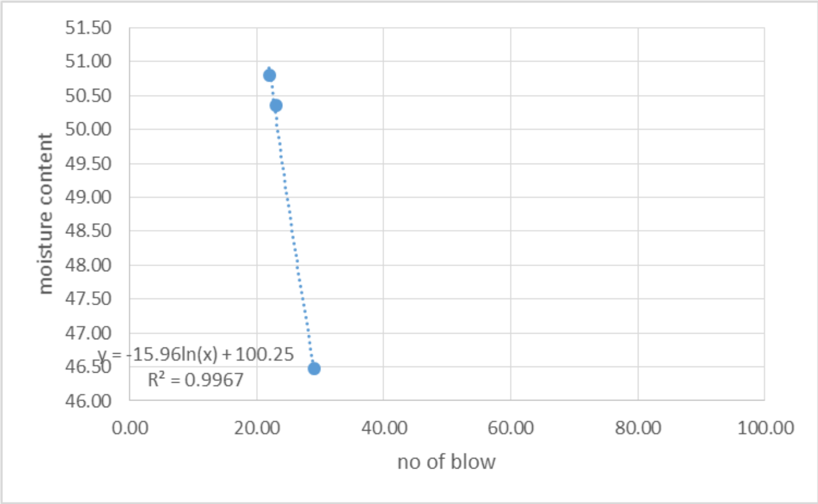
TP 7; Location of Sample: Entoto 1.5m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIC	PLASTIC LIMI	Colum
trial no.	1	2	3	trial no.	1	2
can no.	A9	A5	C2	can no.	Z5	R1
mass of can,g	15.70	15.70	15.57	mass of can,g	15.63	15.82
mass of can+wet soil,g	45.58	48.82	42.54	mass of can+wet soil,g	25.72	24.59
mass of can+dry soil,g	33.57	35.80	32.25	mass of can+dry soil,g	23.40	22.60
mass of water,g	12.01	13.02	10.29	mass of water,g	2.32	1.99
mass of dry soil,g	17.87	20.20	16.68	mass of dry soil,g	7.77	6.78
water content,%	67.21	64.46	61.69	water content,%	30.86	31.35
No. of blows	15.00	24.00	32.00	PL(avg)=	31.11	
LL(@ 25 no of blow)=	63.73					
PI=	33					



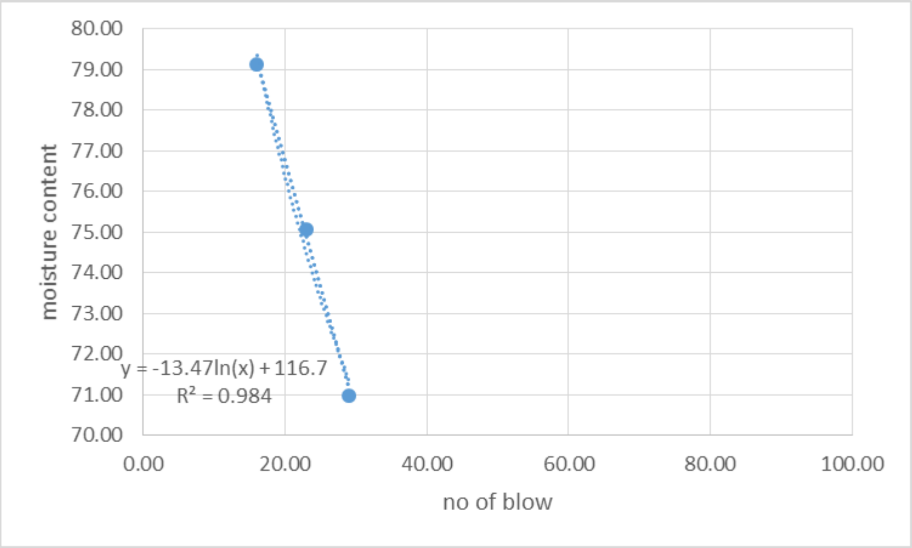
TP 7; Location of Sample: Entoto 2m

DESCRIPTION	LIQUID LIMIT	Colum	Column2	DESCRIPTIO	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	A4	A3	C5	can no.	h5	d1
mass of can,g	15.67	15.70	16.00	mass of can,g	15.30	15.45
mass of can+wet soil,g	49.01	52.25	45.97	mass of can+wet soil,g	29.15	28.02
mass of can+dry soil,g	37.78	40.01	36.46	mass of can+dry soil,g	27.61	26.81
mass of water,g	11.23	12.24	9.51	mass of water, g	1.54	1.21
mass of dry soil,g	22.11	24.31	20.46	mass of dry soil,g	12.31	11.36
water content,%	50.79	50.35	46.48	water content,%	12.51	10.65
No. of blows	22.00	23.00	29.00	PL(avg)=	11.58	
LL(@ 25 no of blow)=	48.88					
PI=	37					



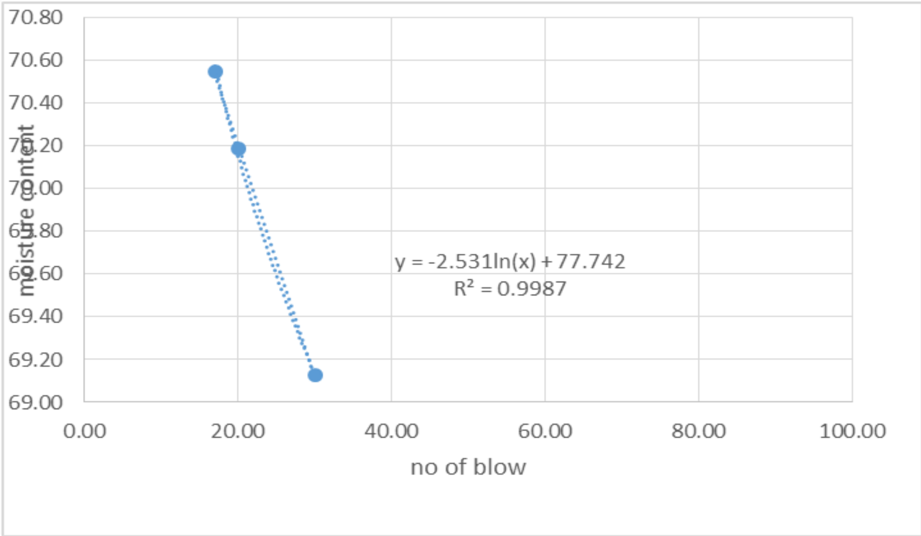
TP 8; Location of Sample: Weyra Sefer 1m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIO	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	f3	h2	c1	can no.	H1	F2
mass of can,g	15.08	15.70	15.63	mass of can,g	15.50	15.50
mass of can+wet soil,g	42.30	39.50	31.30	mass of can+wet soil,g	19.93	20.47
mass of can+dry soil,g	31.00	28.70	20.50	mass of can+dry soil,g	18.61	18.60
mass of water, g	11.30	10.80	10.80	mass of water,g	1.32	1.87
mass of dry soil,g	15.92	14.39	13.65	mass of dry soil,g	3.11	3.10
water content,%	70.98	75.05	79.12	water content,%	42.44	60.32
No. of blows	29.00	23.00	16.00	PL(avg)=	51.38	
LL(@ 25 no of blow)=	73.34					
PI=	22					



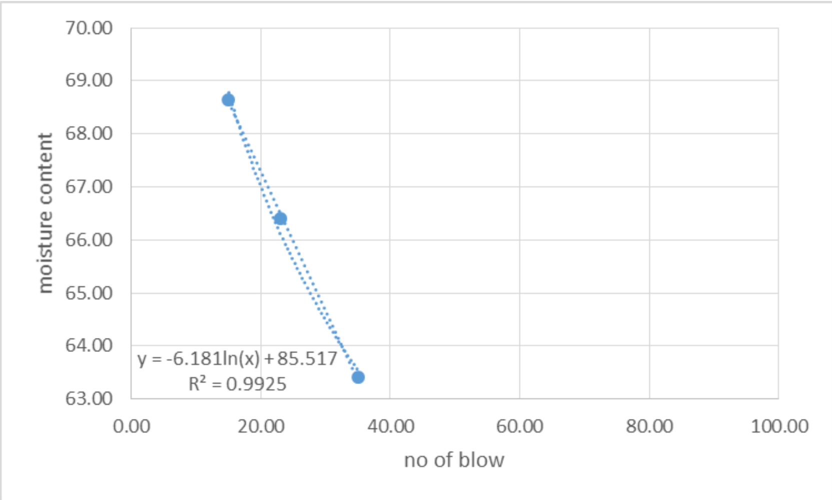
TP 8; Location of Sample: Weyra Sefer 1.5m

DESCRIPTION	LIQUID LIM	Colum	Colum	DESCRIPTIC	ASTIC I	Colum
trial no.	1	2	3	trial no.	1	2
can no.	A3	D7	C2	can no.	Z2	G1
mass of can,g	15.18	15.51	15.72	mass of can,g	15.56	15.67
mass of can+wet soil,g	41.09	40.00	36.05	mass of can+wet soil,g	21.80	22.46
mass of can+dry soil,g	30.50	29.90	27.64	mass of can+dry soil,g	19.93	20.44
mass of water,g	10.59	10.10	8.41	mass of water, g	1.87	2.02
mass of dry soil,g	15.32	14.39	11.92	mass of dry soil,g	4.37	4.77
water content,%	69.13	70.19	70.55	water content,%	42.79	42.35
No. of blows	30.00	20.00	17.00	PL(avg)=	42.57	
LL(@ 25 no of blow)=	70.00					
PI=	27					



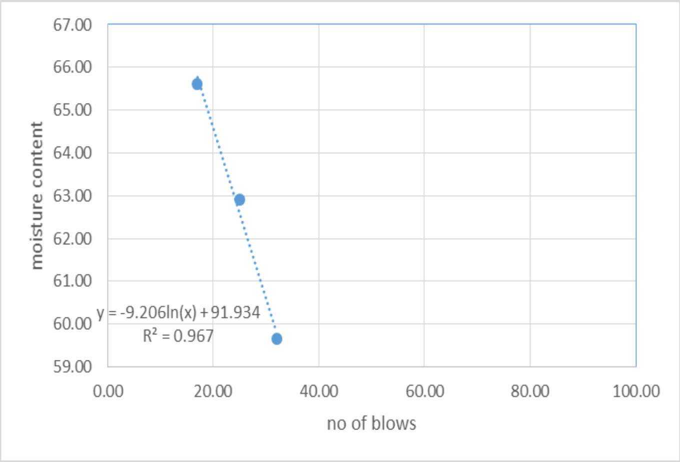
TP 8; Location of Sample: Weyra Sefer 2m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIC	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	A1	D5	D3	can no.	D5	A1
mass of can,g	13.89	15.67	15.67	mass of can,g	15.50	15.50
mass of can+wet soil,g	43.42	42.56	30.54	mass of can+wet soil,g	25.00	25.00
mass of can+dry soil,g	31.40	31.83	24.77	mass of can+dry soil,g	22.45	22.45
mass of water,g	12.02	10.73	5.77	mass of water,g	2.55	2.55
mass of dry soil,g	17.51	16.16	9.10	mass of dry soil,g	6.95	6.95
water content,%	68.65	66.40	63.41	water content,%	36.69	36.69
No. of blows	15.00	23.00	35.00	PL(avg)=	36.69	
LL(@ 25 no of blow)=	66.00					
PI=	29					



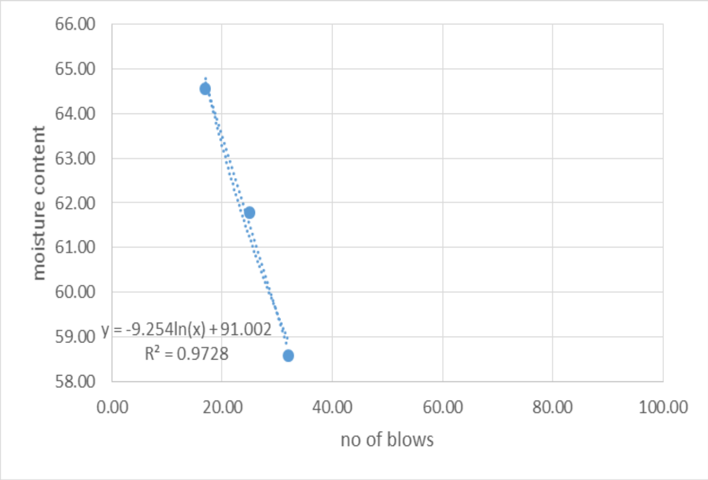
TP 9; Location of Sample: Winget 1m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIC	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	A3	A6	C7	can no.	C3	G
mass of can,g	16.60	16.50	16.70	mass of can,g	21.08	20.49
mass of can+wet soil,g	43.90	45.50	48.00	mass of can+wet soil,g	28.30	28.24
mass of can+dry soil,g	33.70	34.20	35.60	mass of can+dry soil,g	26.49	26.29
mass of water,g	10.20	11.20	12.40	mass of water,g	1.80	2.00
mass of dry soil,g	17.10	17.80	18.90	mass of dry soil,g	5.40	5.80
water content,%	**59.65**	**62.92**	**65.61**	water content,%	33.50	33.60
No. of blows	**32.00**	**25.00**	**17.00**	PL(avg)=	**33.55**	
LL(@ 25 no of blow)=	**62.30**					
PI=	**29**					



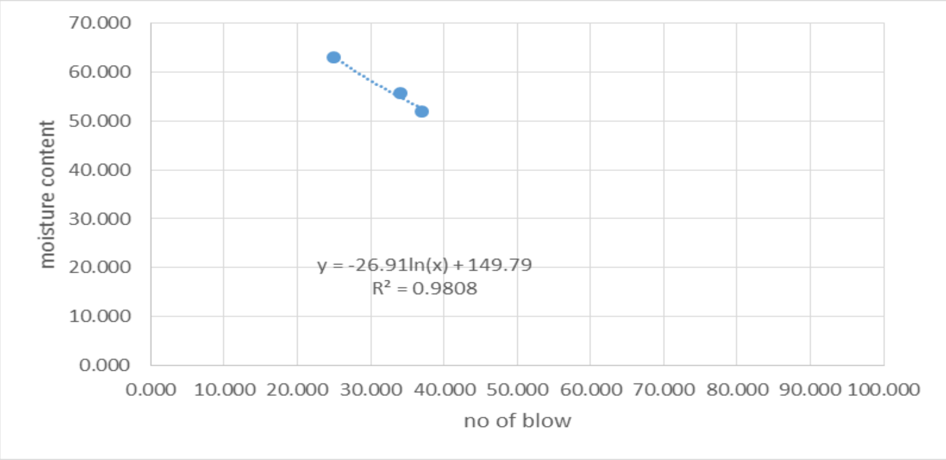
TP 9; Location of Sample: Winget 1.5m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIC	PLASTIC LIMIT	Colum
trial no.	1	2	3	trial no.	1	2
can no.	c2	a2	g3	can no.	d2	d3
mass of can,g	16.50	16.60	16.70	mass of can,g	20.91	21.69
mass of can+wet soil,g	47.90	47.50	50.60	mass of can+wet soil,g	26.81	21.69
mass of can+dry soil,g	36.30	35.70	37.30	mass of can+dry soil,g	25.30	20.39
mass of water,g	11.60	11.80	13.30	mass of water,g	1.50	1.30
mass of dry soil,g	19.80	19.10	20.60	mass of dry soil,g	4.40	3.80
water content,%	**58.59**	**61.78**	**64.56**	water content,%	34.40	34.00
No. of blows	**32.00**	**25.00**	**17.00**	PL(avg)=	**34.20**	
LL(@ 25 no of blow)=	**61.21**					
PI=	**27**					



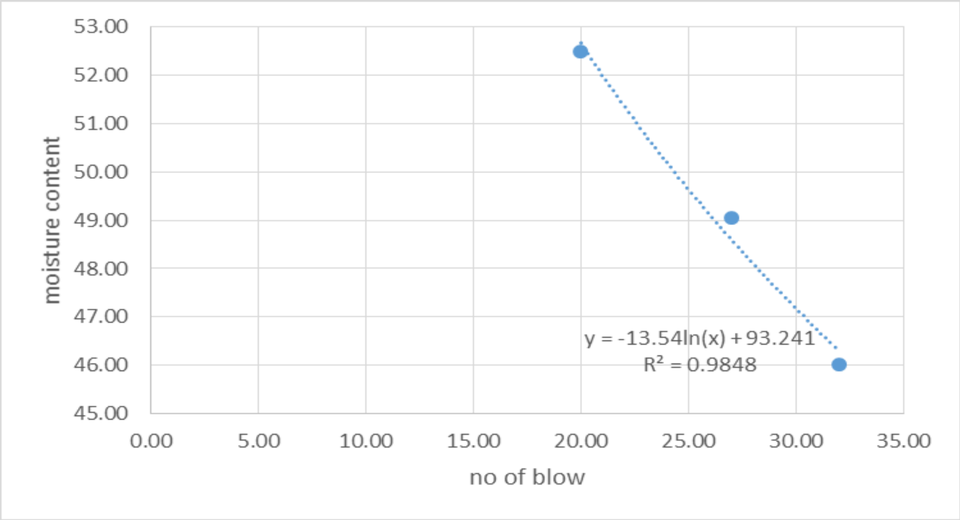
TP 9; Location of Sample: Winget 2m

DESCRIPTION	QUID L	Colum	Colum	RIPTIC	ASTIC I	Colum
trial no.	1	2	3	trial no.	1	2
can no.	a24	h10	d6	can no.	z3	c9
mass of can,g	14.870	15.480	14.560	of can,g	16	15
mass of can+wet soil,g	48.500	49.000	51.300	vet soil,g	17.950	17.380
mass of can+dry soil,g	37.000	37.000	37.100	dry soil,g	17.50	16.80
mass of water,g	11.500	12.000	14.200	f water,g	0.45	1
mass of dry soil,g	22.130	21.520	22.540	dry soil,g	1	2
water content,%	51.966	55.762	62.999	ontent,%	33	34
No. of blows	37.000	34.000	25.000	PL(avg)=	34	
LL(@ 25 no of blow)=	63.17					
PI=	30					



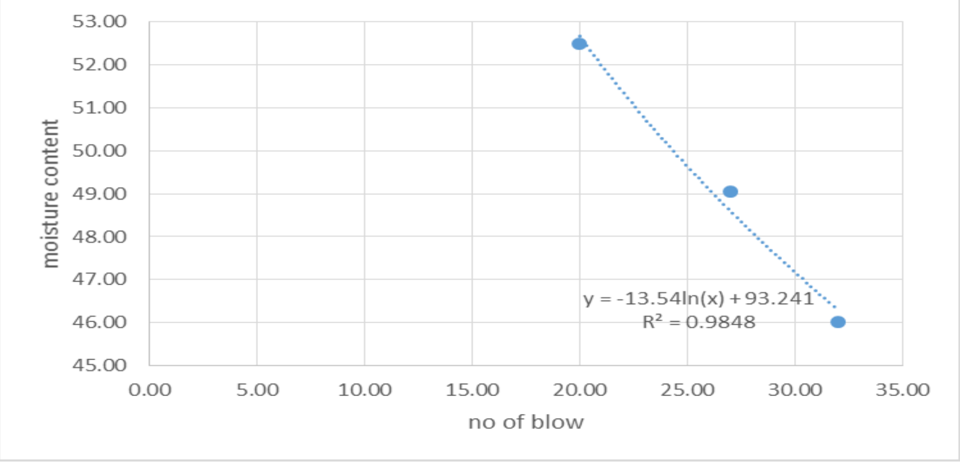
TP 10; Location of Sample: Megenagna 1m

DESCRIPTION	QUID L	Colum	Colum	DESCRIPTIC	ASTIC I	Colum
trial no.	1	2	3	trial no.	1	2
can no.	F2	C1	A7	can no.	Z5	R1
mass of can,g	11.40	11.60	11.20	mass of can,g	11.30	11.30
mass of can+wet soil	49.80	51.10	53.90	mass of can+wet soil,g	13.00	13.00
mass of can+dry soil,	37.70	38.00	39.20	mass of can+dry soil,g	12.60	12.60
mass of water,g	12.10	13.00	14.70	mass of water,g	0.40	0.40
mass of dry soil,g	26.30	26.50	28.00	mass of dry soil,g	1.30	1.30
water content,%	46.01	49.06	52.50	water content,%	30.77	30.77
No. of blows	32.00	27.00	20.00	PL(avg)=	30.77	
LL(@ 25 no of blow)=	49.66					
PI=	19					



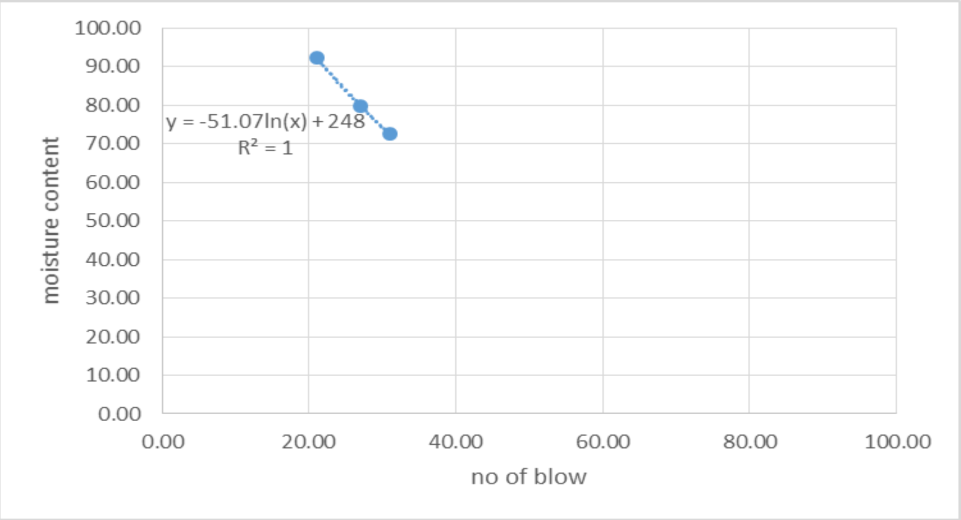
TP 10; Location of Sample: Megenagna 1.5m

DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIC	LASTIC LI	Colum
trial no.	1	2	3	trial no.	1	2
can no.	c4	c7	s4	can no.	z5	b3
mass of can,g	15.31	15.57	15.78	mass of can,g	15.45	15.32
mass of can+wet soil,g	60.93	62.20	63.90	mass of can+wet soil,g	21.40	20.97
mass of can+dry soil,g	40.30	39.50	42.40	mass of can+dry soil,g	19.42	19.23
mass of water,g	20.63	22.70	21.50	mass of water,g	1.98	1.74
mass of dry soil,g	24.99	27.70	26.62	mass of dry soil,g	3.97	3.91
water content,%	**82.55**	**81.95**	**80.77**	**water content,%**	**49.87**	**44.50**
No. of blows	**19.00**	**21.00**	**24.00**	**PL(avg)=**	**47.19**	
LL(@ 25 no of blow)=	**80.50**					
PI=	**33**					



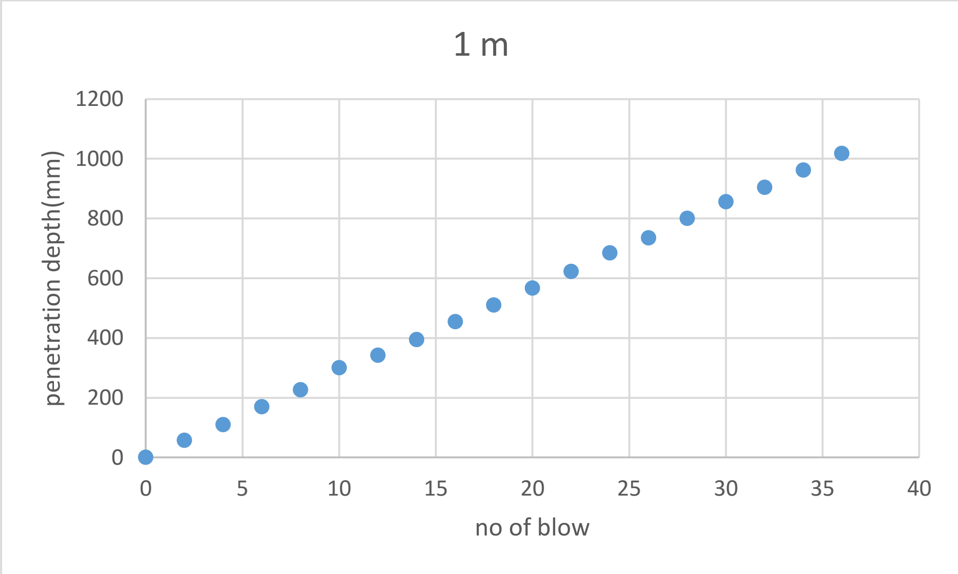
TP 10; Location of Sample: Megenagna 2m

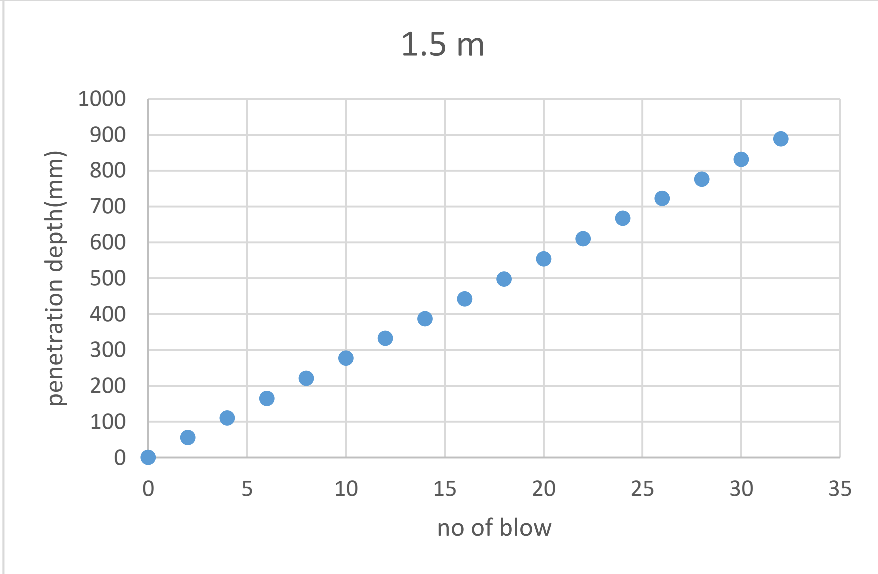
DESCRIPTION	LIQUID LIMIT	Colum	Colum	DESCRIPTIC	PLASTIC LIMI	Colum
trial no.	1	2	3	trial no.	1	2
can no.	J2	R2	F1	can no.	A2	R1
mass of can,g	15.70	15.54	15.54	mass of can,g	15.66	15.74
mass of can+wet soil,g	44.63	45.30	45.62	mass of can+wet soil,g	30.52	28.25
mass of can+dry soil,g	30.73	32.10	32.97	mass of can+dry soil,g	26.46	24.81
mass of water,g	13.90	13.20	12.65	mass of water,g	4.06	3.44
mass of dry soil,g	15.03	16.56	17.43	mass of dry soil,g	10.80	9.07
water content,%	**92.48**	**79.71**	**72.58**	water content,%	**37.59**	**37.93**
No. of blows	**21.00**	**27.00**	**31.00**	**PL(avg)=**	**37.76**	
LL(@ 25 no of blow)=	**83.61**					
PI=	**46**					

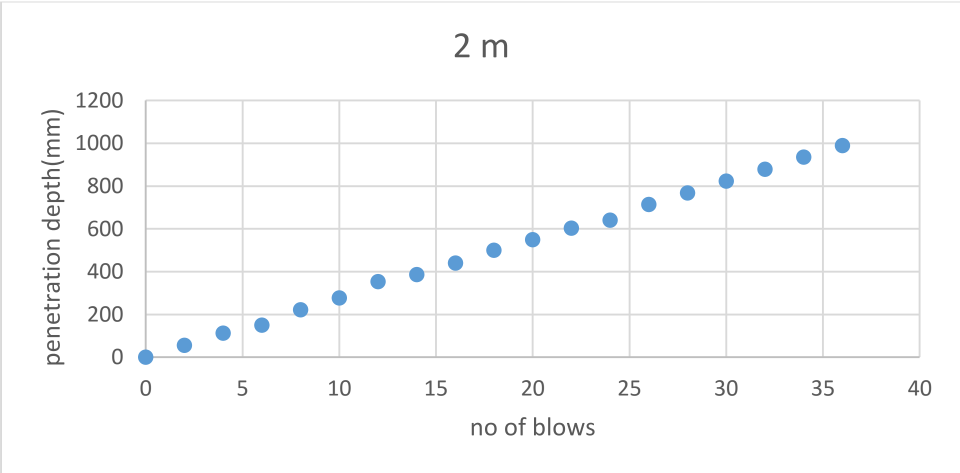


APPENDIX C: RESULTS OF DCP TESTS

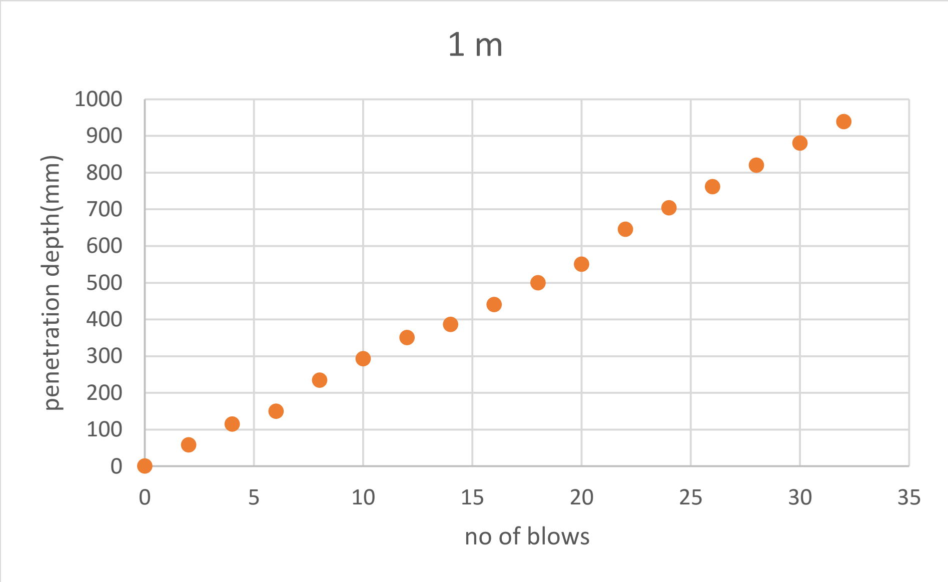
TP 9:-WINGET

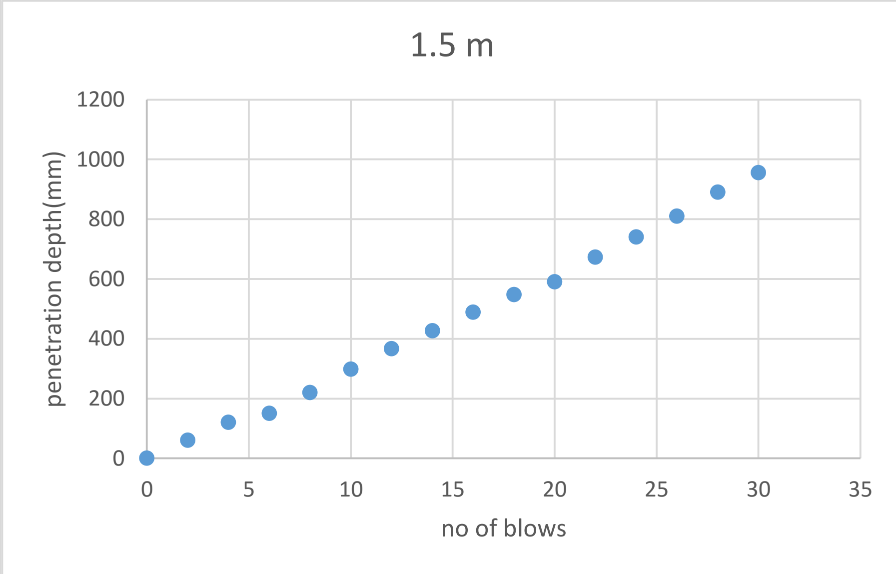


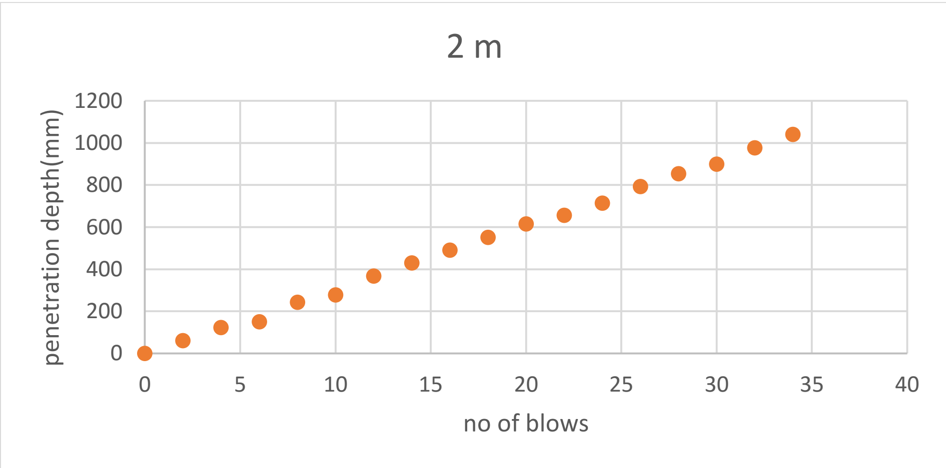




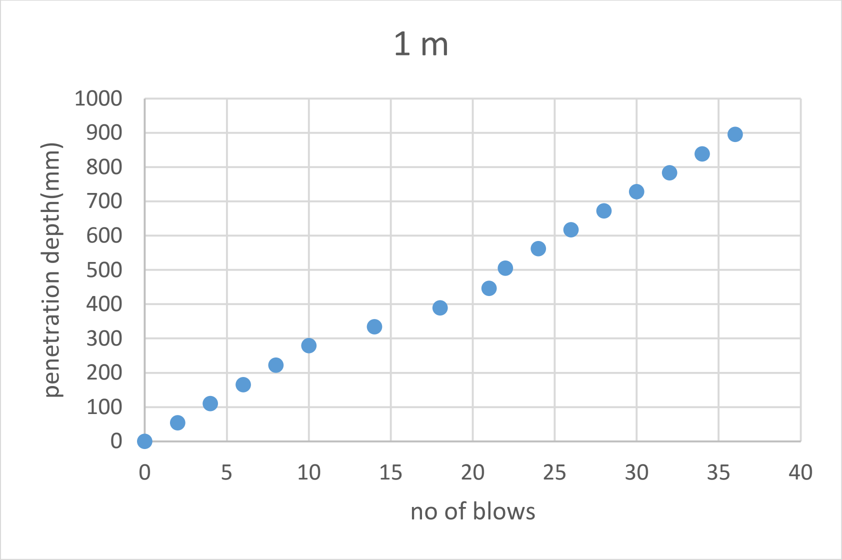
TP:-4ADISSU GEBEYA

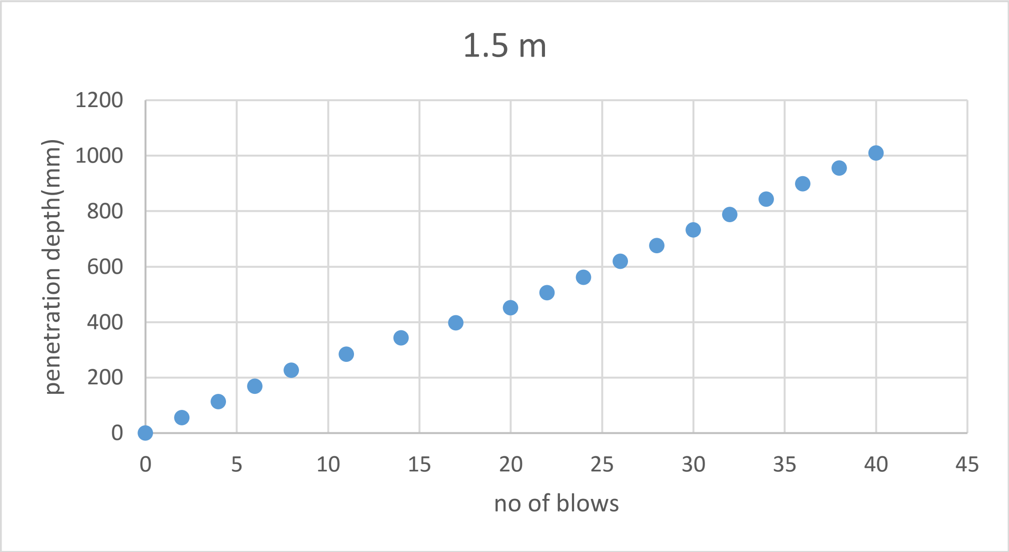


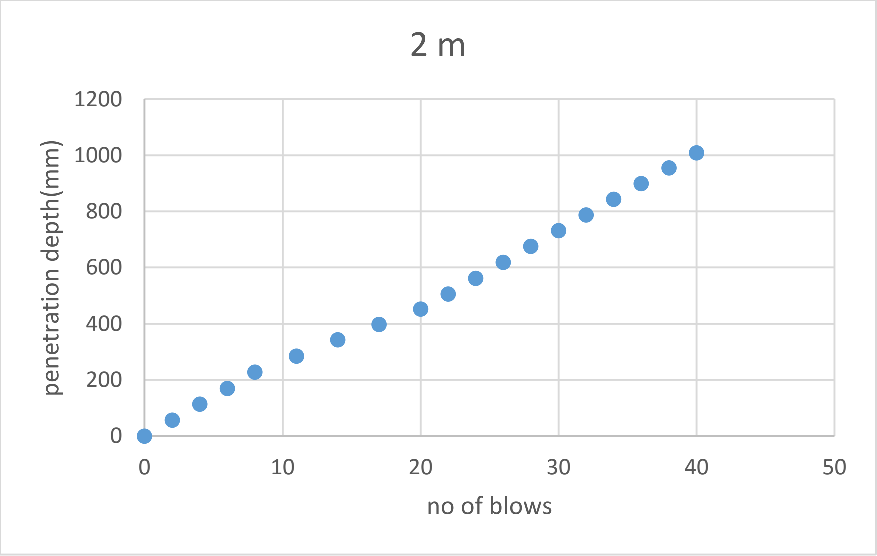




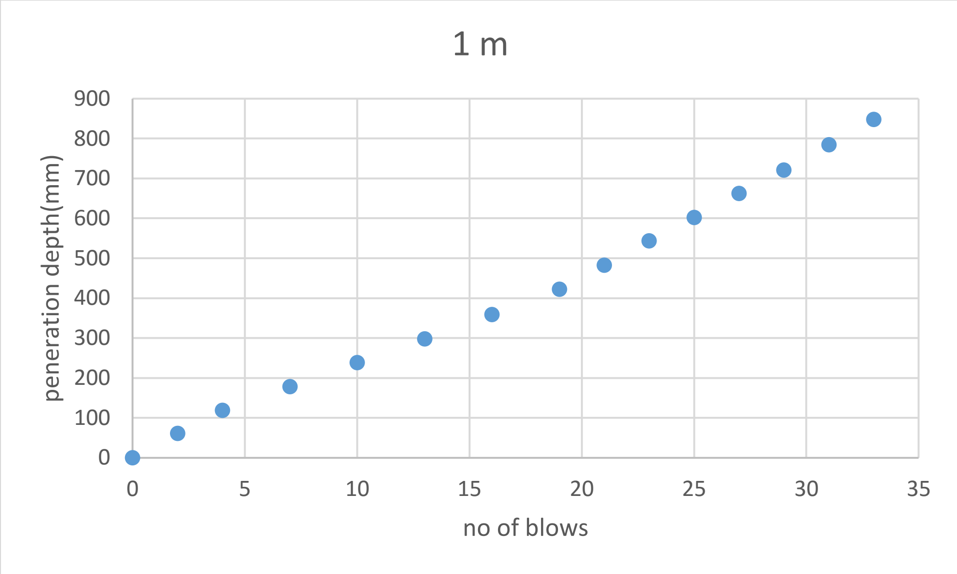
TP: 10 MEGENAGNA

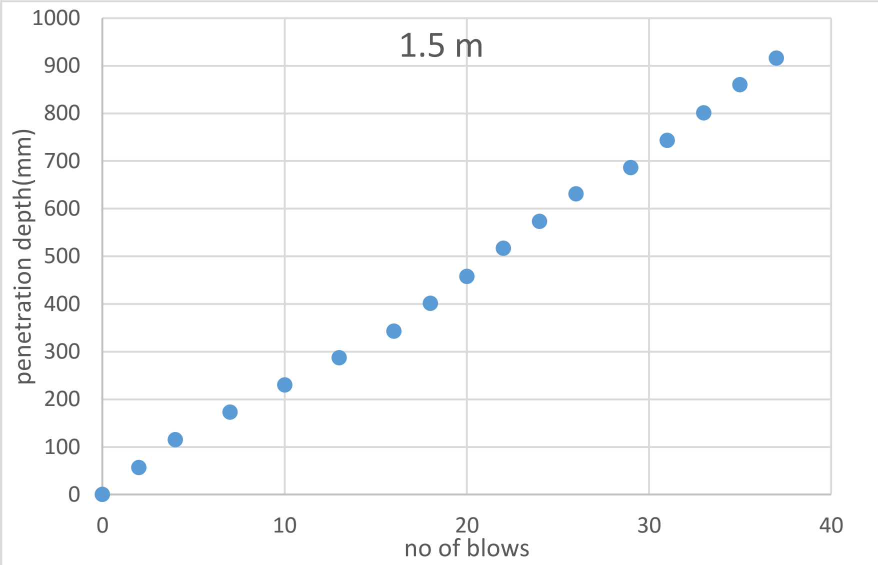


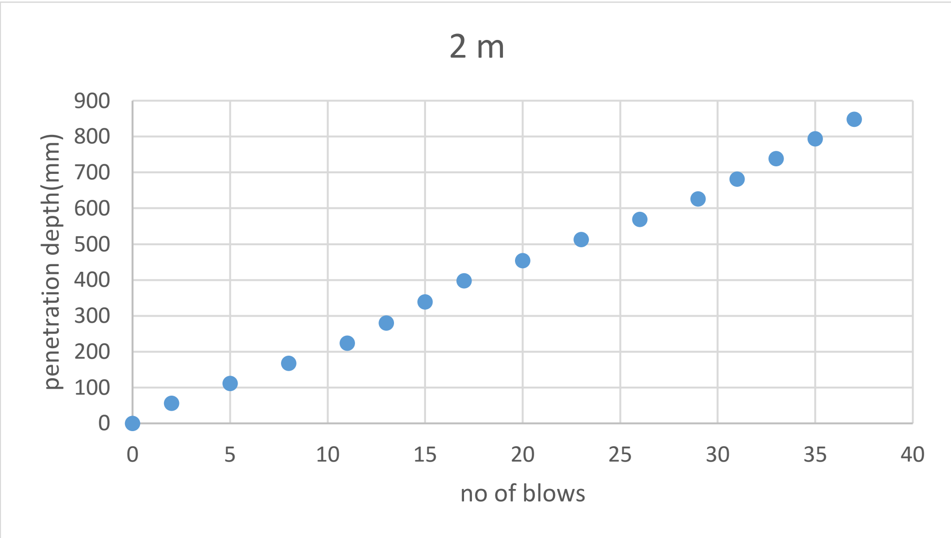




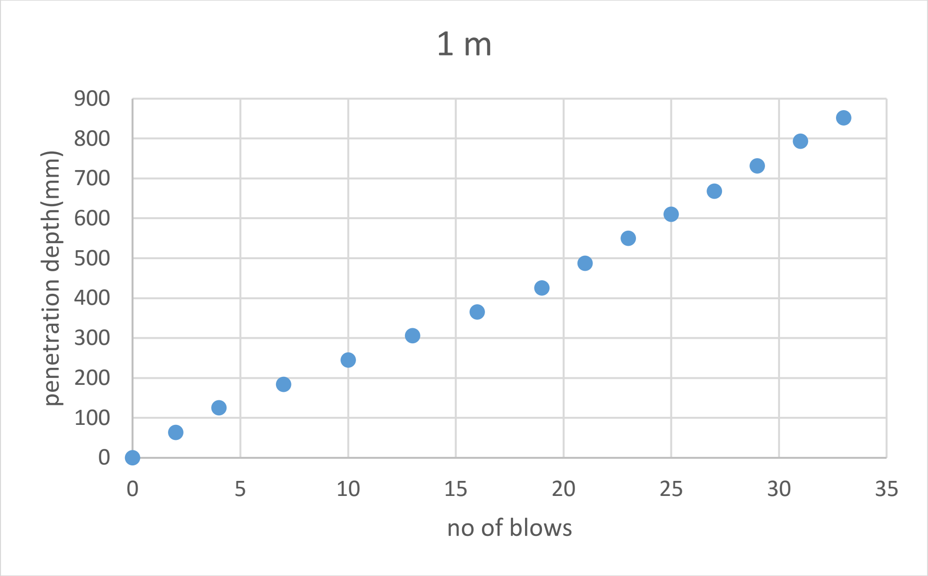
TP 1:- LIDETA

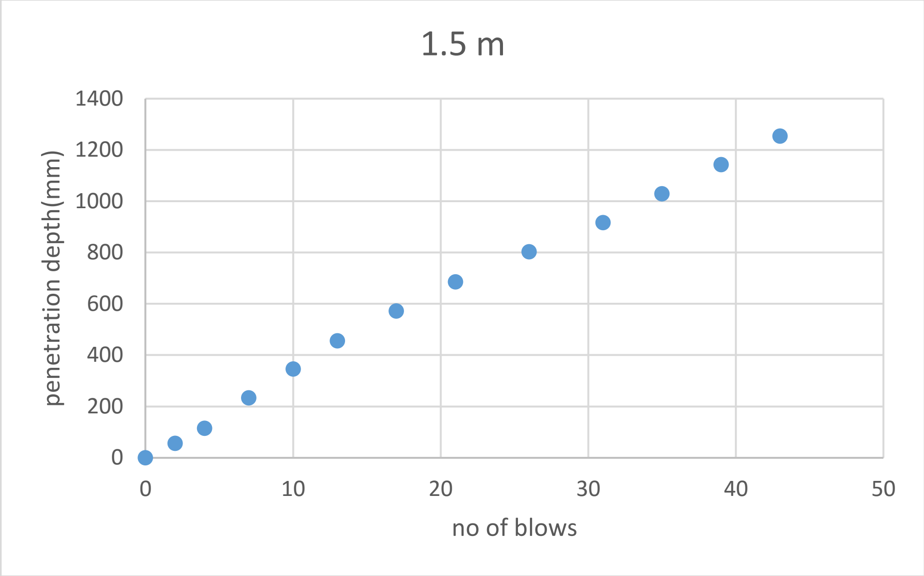

1 m
peneration depth(mm)
no of blows
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30
35

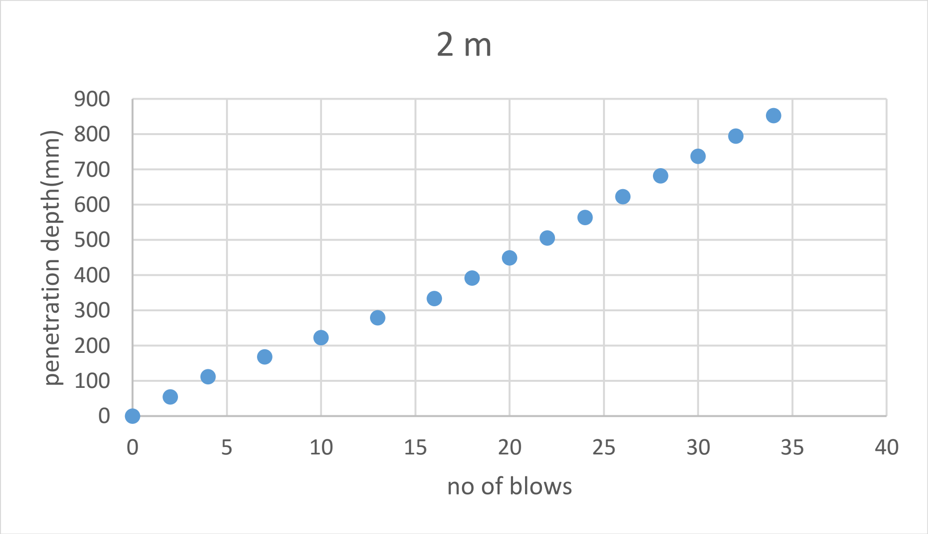

1.5 m
penetration depth(mm)
no of blows
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40


2 m
penetration depth(mm)
no of blows
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30
35
40

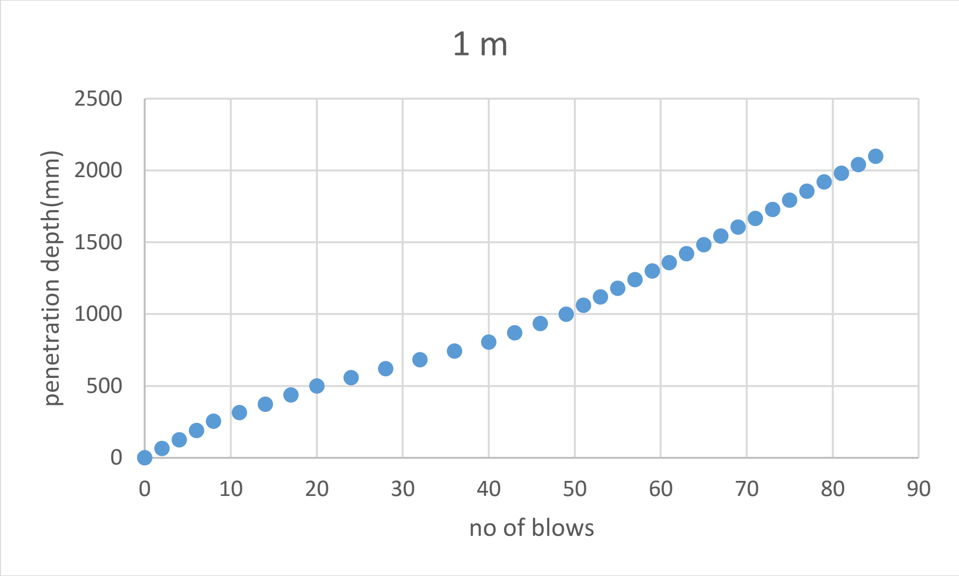
TP 5:-KOLFE

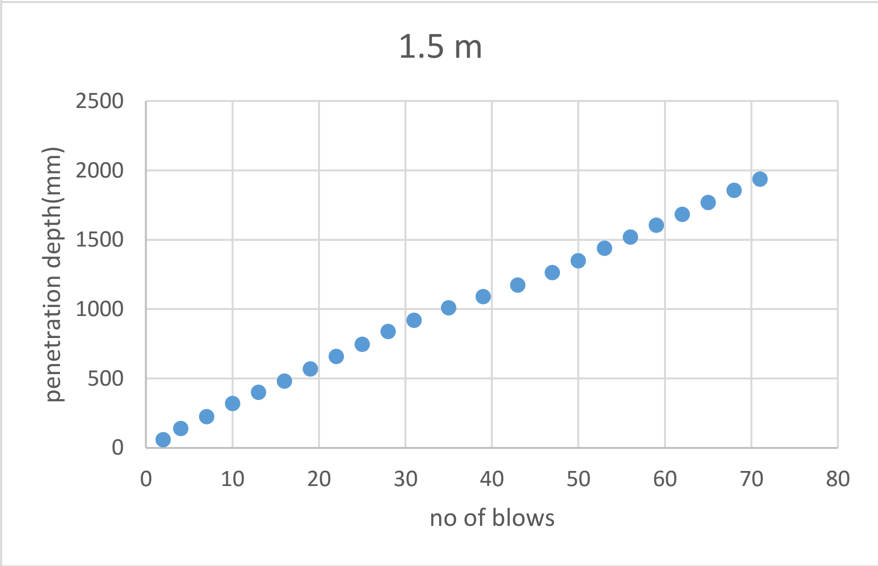

1 m
penetration depth(mm)
no of blows
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30
35

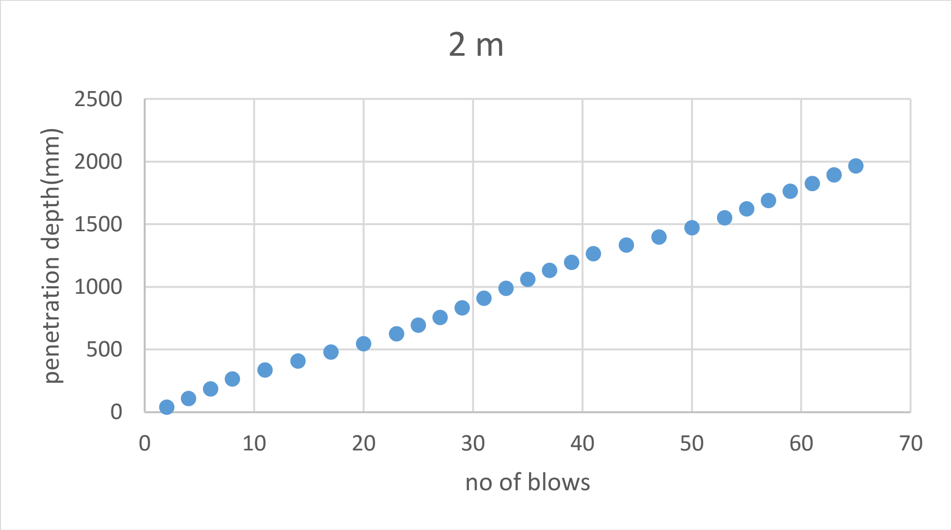

1.5 m
penetration depth(mm)
no of blows
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50


2 m
penetration depth(mm)
no of blows
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30
35
40

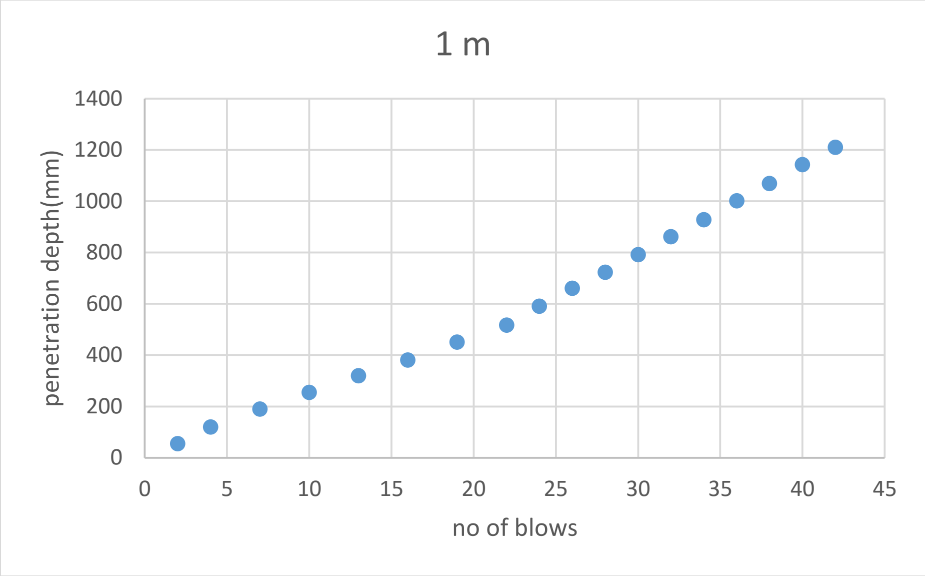
TP 6:-ADDIS KETEMA

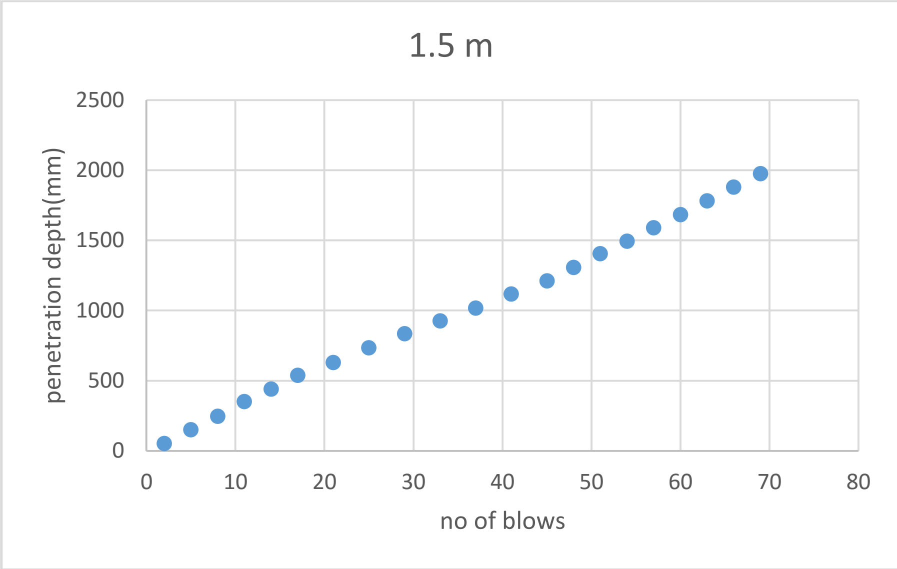


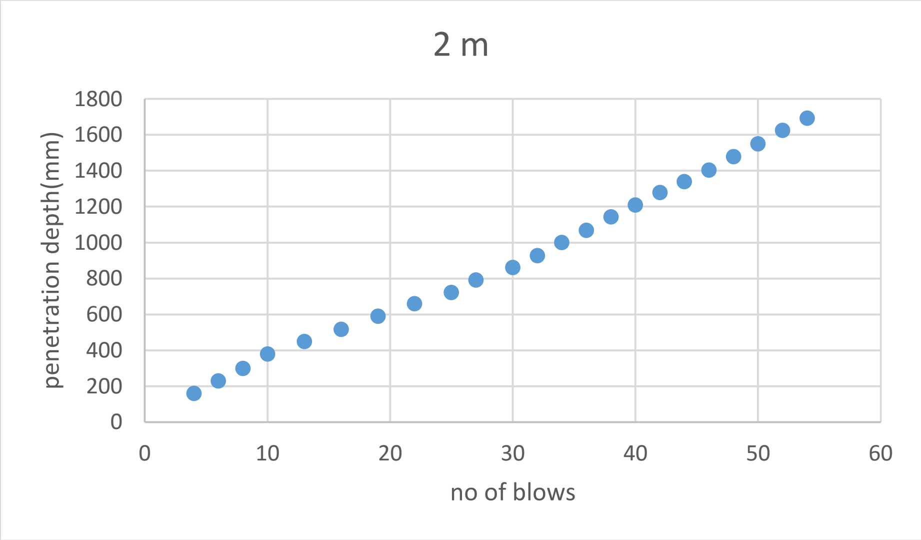




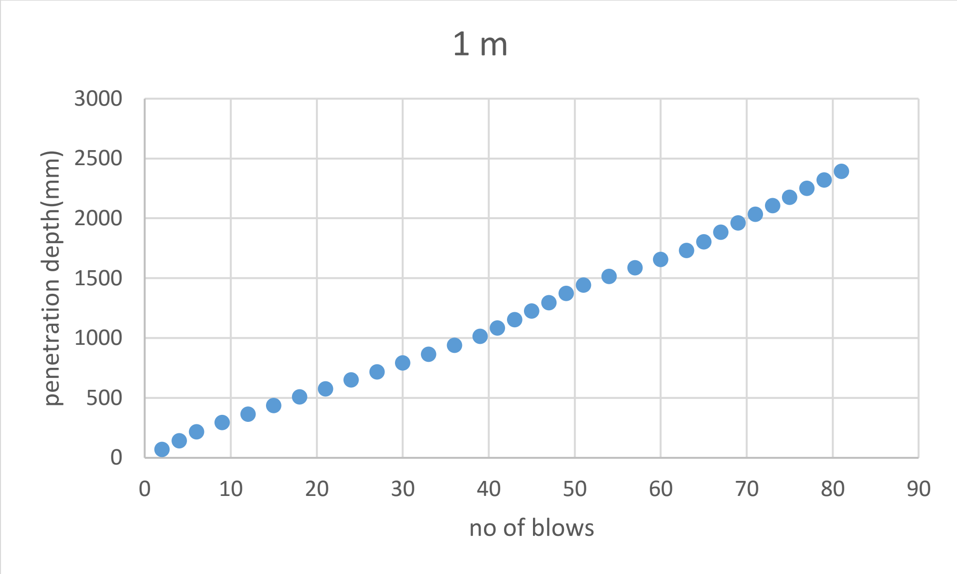
TP 8:-WEYRA SEFER

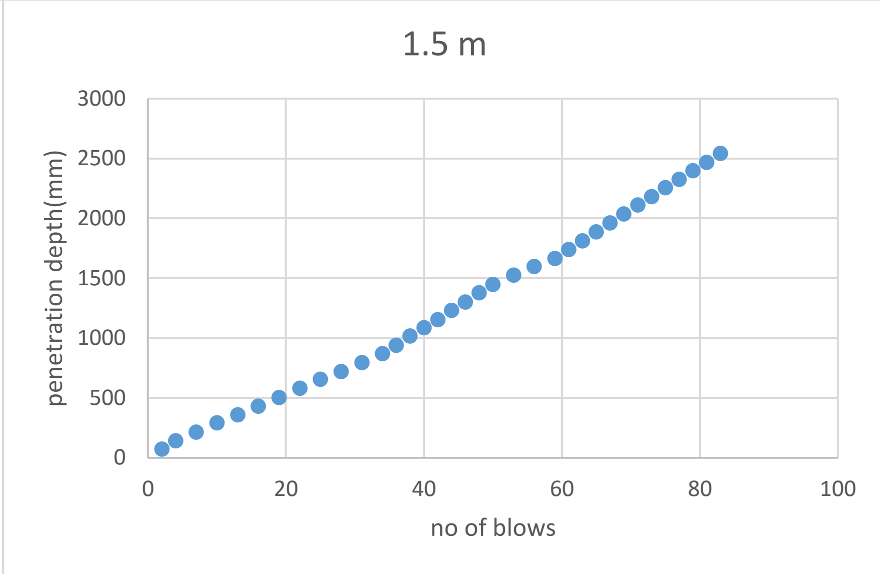


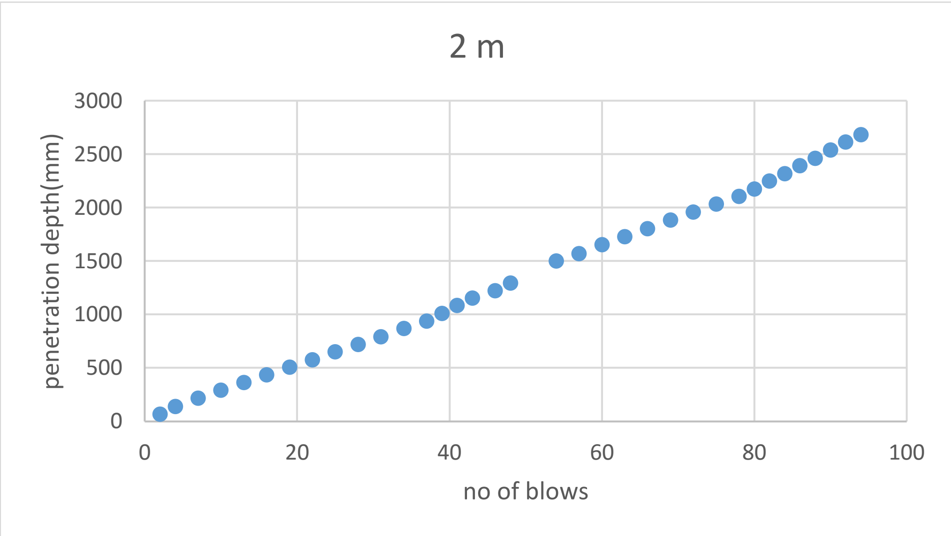




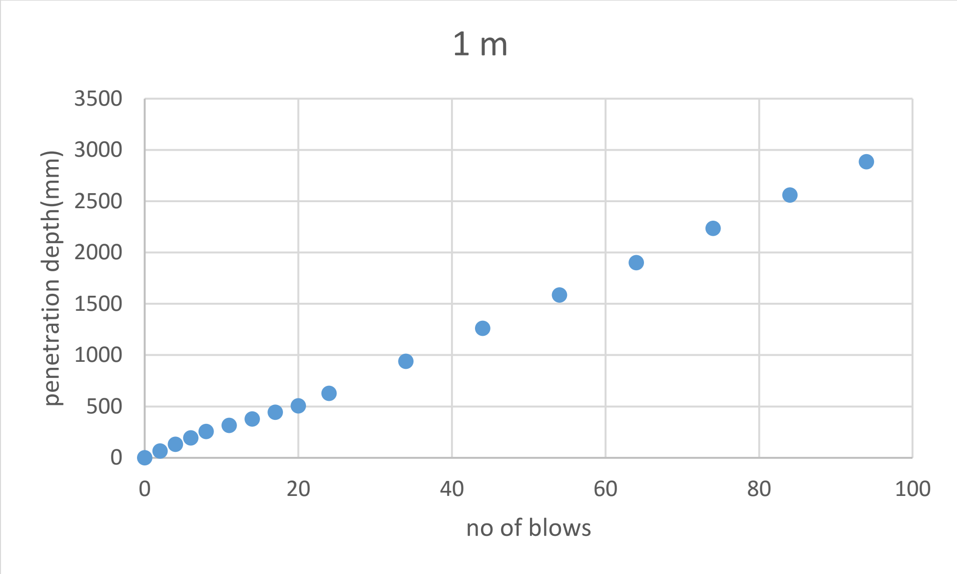
TP 7:-ENTOTO

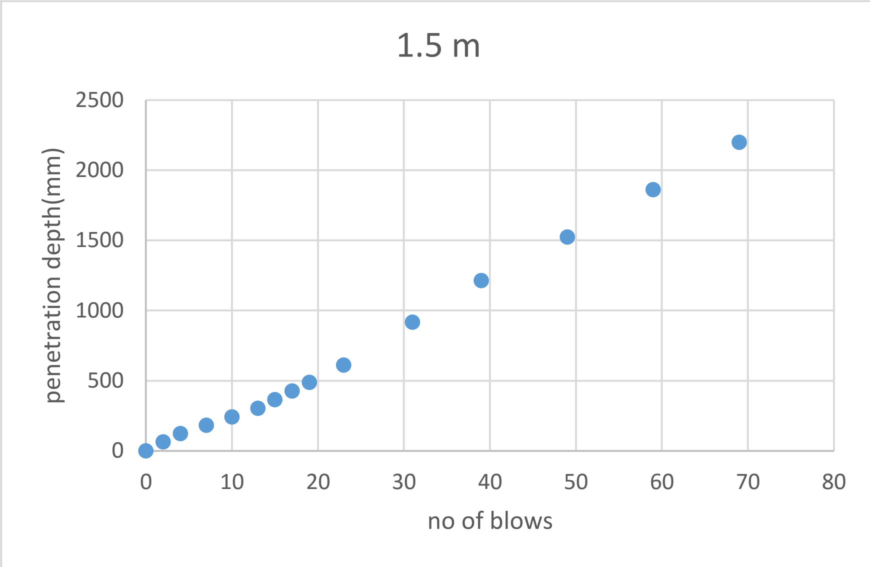

1 m
3000
2500
2000
1500
1000
500
0
penetration depth(mm)
0
10
20
30
40
50
60
70
80
90
no of blows

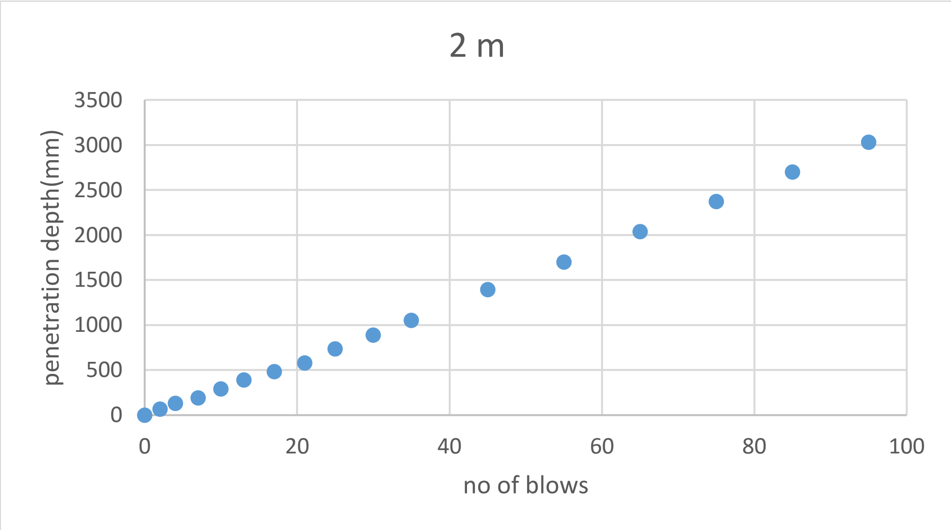

1.5 m
3000
2500
2000
1500
1000
500
0
penetration depth(mm)
0
20
40
60
80
100
no of blows


2 m
3000
2500
2000
1500
1000
500
0
penetration depth(mm)
0
20
40
60
80
100
no of blows

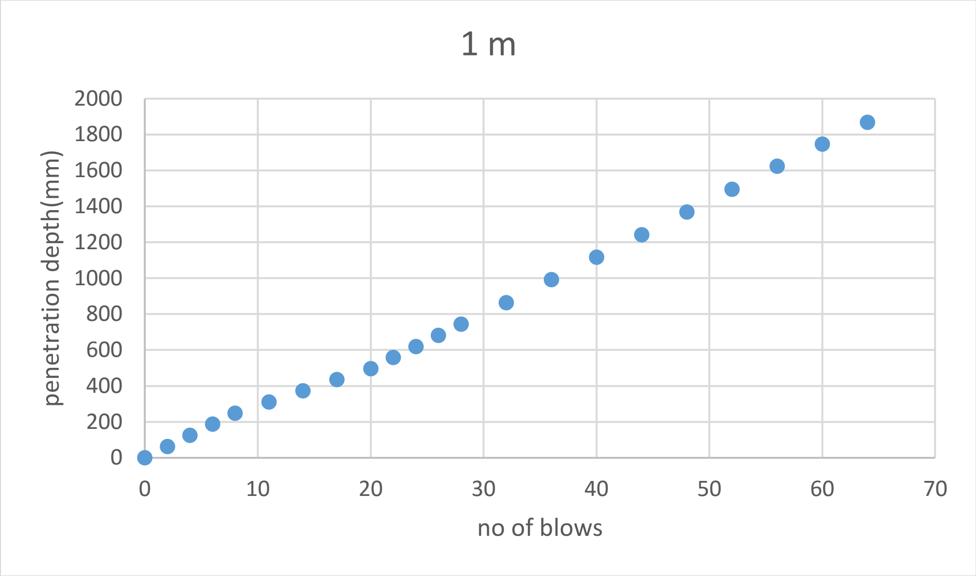
TP 2:- BOLE

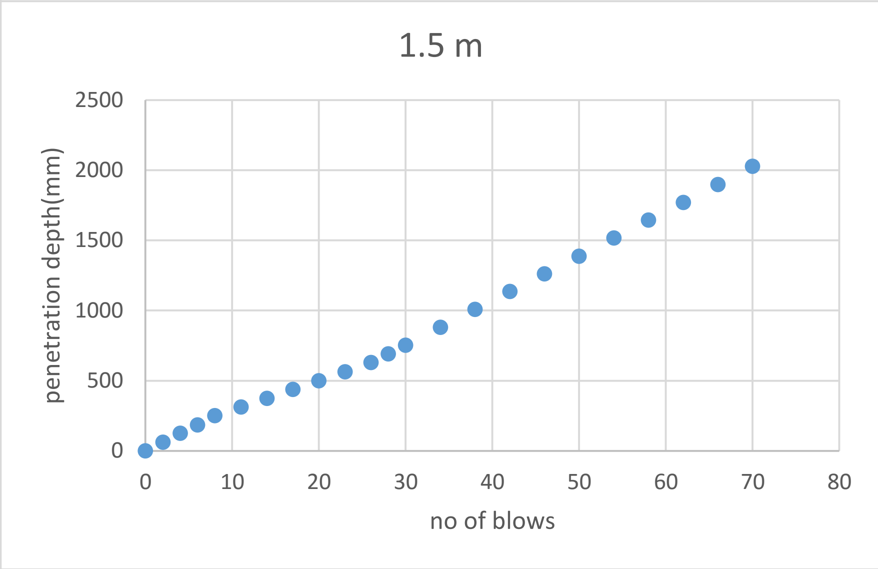

1 m
penetration depth(mm)
no of blows
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100

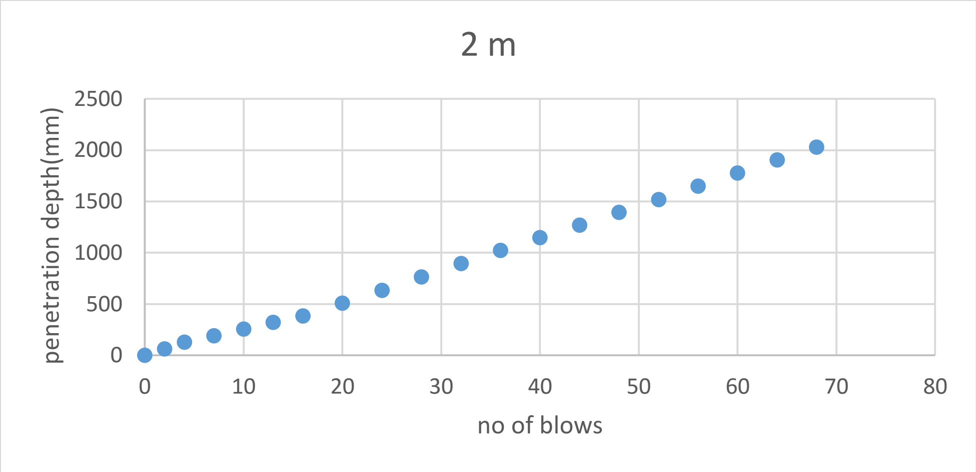

1.5 m
penetration depth(mm)
no of blows
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80


2 m
penetration depth(mm)
no of blows
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100

TP 3:-KALITI


1 m
penetration depth(mm)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
no of blows

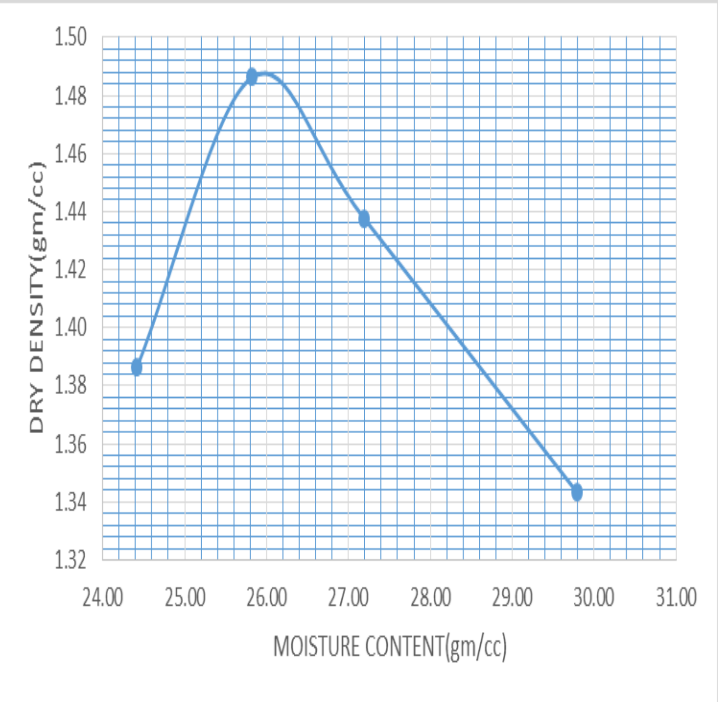

1.5 m
penetration depth(mm)
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
no of blows


2 m
penetration depth(mm)
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
no of blows

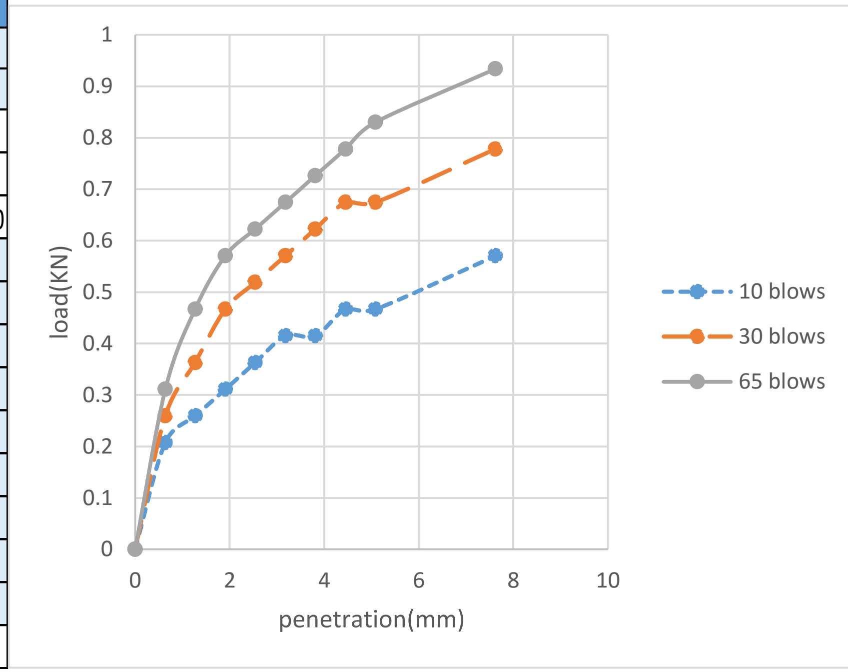
APPENDIX D: MODIFIED PROCTER TEST RESULTS AND CBR VALUE

TP 1: Location of Sample: Lideta 1m

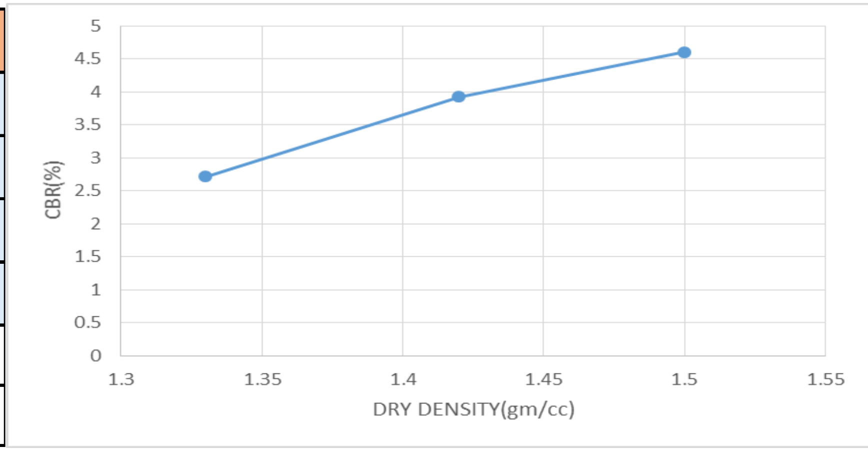
DESCRIPTION	STURE CONTENT DETERMIN	Colum	Colum	Colum
Trial no.	**1**	**2**	**3**	**4**
Can no.	C1	B2	G2	A9
Mass of can,g	47.00	43.09	46.16	41.37
Mass of can+wet soil,g	224.95	221.32	170.87	163.65
Mass of can+dry soil,g	190.03	184.74	144.21	135.58
Mass of water,g	34.92	36.58	26.66	28.07
Mass of dry soil,g	143.03	141.65	98.05	94.21
Water content,%	**24.41**	**25.82**	**27.19**	**29.80**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	5442.00	5442.00	5442.00	5442.00
Mass of mold + compacted soil	9105.00	9414.00	9326.00	9145.00
Mass of compacted soil	3663.00	3972.00	3884.00	3703.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.72	1.87	1.83	1.74
Dry density	**1.39**	**1.49**	**1.44**	**1.34**
MMD	1.49			
OMC	25.9			



Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.33	1.42	1.5			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	4	0.208	5.000	0.259	6.000	0.311
1.27	5	0.259	7	0.363	9	0.467
1.91	6	0.311	9	0.467	11	0.571
2.54	7	0.363	10	0.519	12	0.623
3.18	8	0.415	11	0.571	13	0.674
3.81	8	0.415	12	0.623	14	0.726
4.45	9	0.467	13	0.674	15	0.778
5.08	9	0.467	13	0.674	16	0.830
7.62	11	0.571	15	0.778	18	0.934
before soaking 3 sampls were remolded with omc 25.9%						

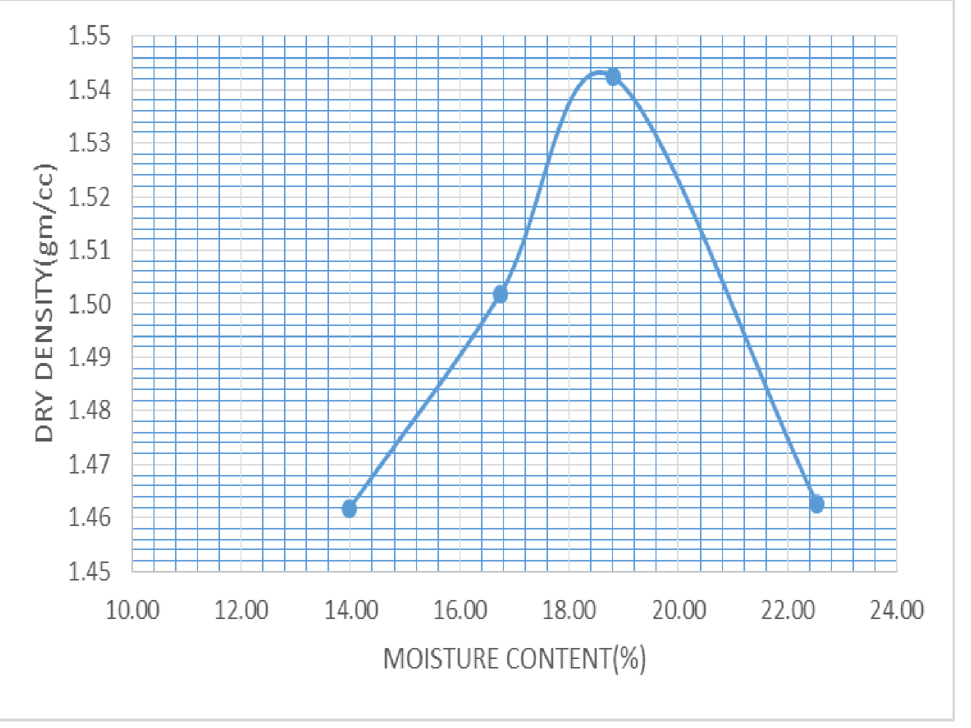


DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.33	10	13.24	20	0.36	0.47	2.719033233	2.35
1.42	30	13.24	20	0.52	0.69	3.927492447	3.45
1.5	65	13.24	20	0.61	0.82	4.607250755	4.1
MDD at 95%	1.47						
cbr at 95%	3.9						

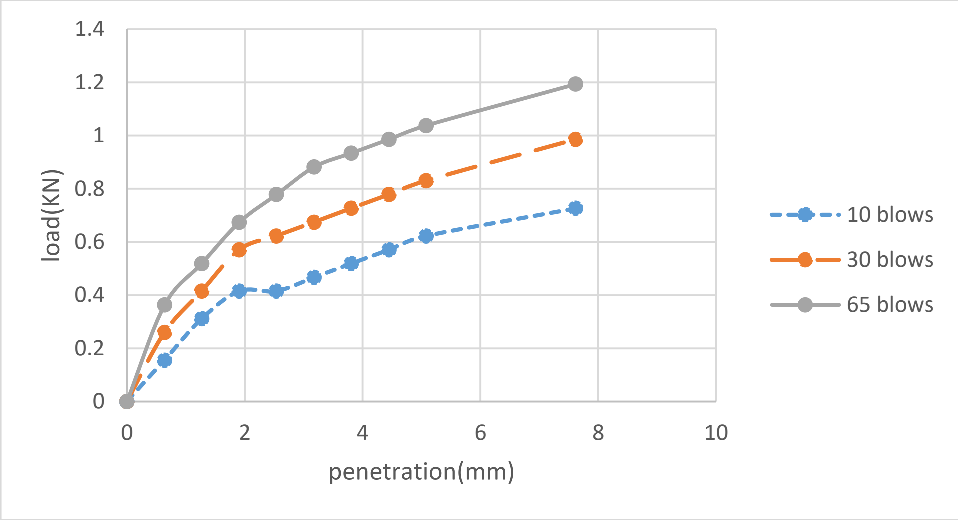


TP 1: Location of Sample: Lideta 1.5m

lideta 1.5				
DESCRIPTION	OISTURE CONTENT DETERMINAT	Colum	Colum	Colum
Trial no.	**1**	**2**	**3**	**4**
Can no.	C5	b9	b5	c2
Mass of can,g	45.59	46.18	46.24	44.35
Mass of can+wet soil,g	226.00	235.00	208.00	226.00
Mass of can+dry soil,g	204.00	208.00	183.00	193.00
Mass of water,g	22.15	27.09	25.71	33.50
Mass of dry soil,g	158.41	161.82	136.76	148.65
Water content,%	**13.98**	**16.74**	**18.80**	**22.54**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	5442.00	5442.00	5442.00	5442.00
Mass of mold + compacte	8981.00	9166.00	9334.00	9249.00
Mass of compacted soil	3539.00	3724.00	3892.00	3807.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.67	1.75	1.83	1.79
Dry density	**1.46**	**1.50**	**1.54**	**1.46**
MMD	1.5			
OMC	24.2			

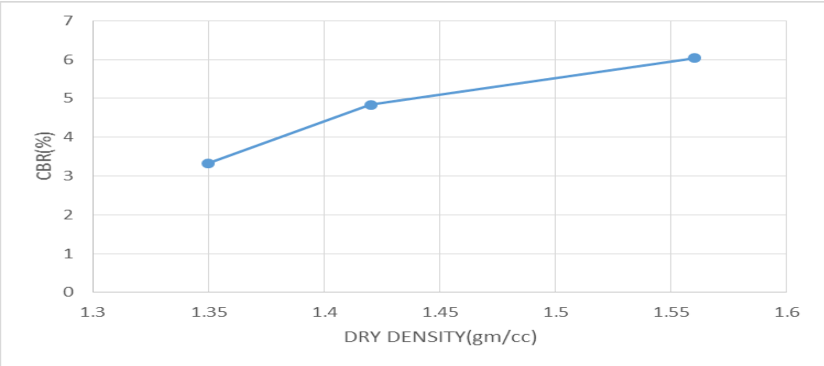


lideta 1.5m							
Density	5 layer						
No. of blows/layer	10	30	65				
Dry density (g/cm3)	1.35	1.42	1.56				
Penetration data 10 blow			30 blow		65 blow		
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.0	
0	0	0	0	0	0	0	
0.64	3	0.156	5.000	0.259	7.000	0.363	
1.27	6	0.311	8	0.415	10	0.519	
1.91	8	0.415	11	0.571	13	0.674	
2.54	8	0.415	12	0.623	15	0.778	
3.18	9	0.467	13	0.674	17	0.882	
3.81	10	0.519	14	0.726	18	0.934	
4.45	11	0.571	15	0.778	19	0.986	
5.08	12	0.623	16	0.830	20	1.038	
7.62	14	0.726	19	0.986	23	1.193	



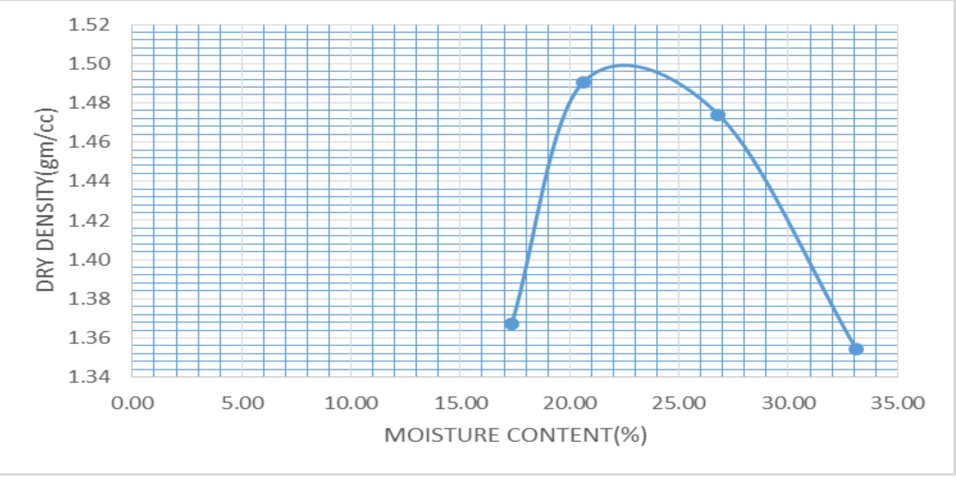
Before soaking 3 sampls were remolded with omc 19.7%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.35	10	13.24	20	0.44	0.62	3.3232628	3.1
1.42	30	13.24	20	0.64	0.83	4.8338369	4.15
1.56	65	13.24	20	0.8	1.04	6.0422961	5.2

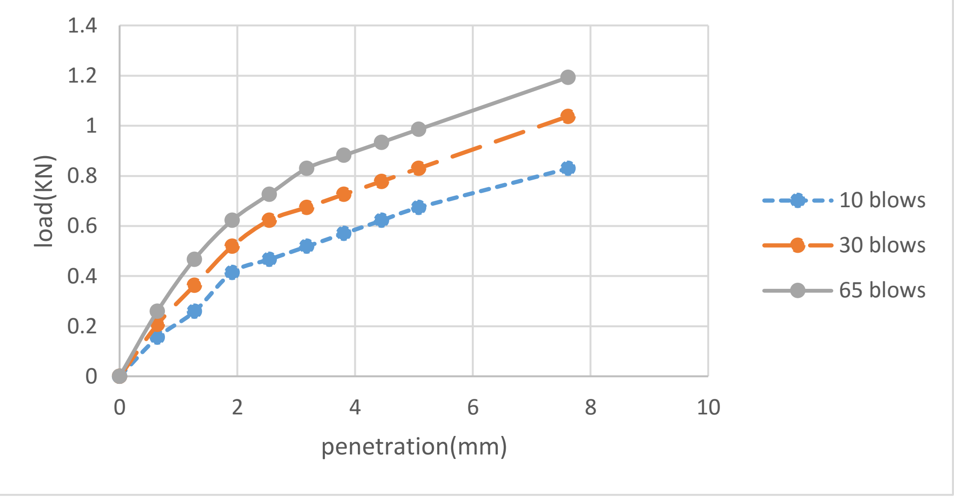


TP 1.: Location of Sample: Lideta 2m

	LIDETA 2M			
DESCRIPTION	MOISTURE CONTENT DETERMINATION	Colum	Colum	Colum
Trial no.	1	2	3	4
Can no.	C5	B4	G7	A3
Mass of can,g	41.28	41.59	44.41	40.65
Mass of can+wet soil,g	212.29	241.21	186.18	172.47
Mass of can+dry soil,g	187.00	207.08	156.21	139.68
Mass of water,g	25.29	34.13	29.97	32.79
Mass of dry soil,g	145.72	165.49	111.80	99.03
Water content,%	**17.36**	**20.62**	**26.81**	**33.11**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	5442.00	5442.00	5442.00	5442.00
Mass of mold + compac	8850.00	9261.00	9412.00	9271.00
Mass of compacted soil	3408.00	3819.00	3970.00	3829.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.60	1.80	1.87	1.80
Dry density	**1.37**	**1.49**	**1.47**	**1.35**
MDD	1.52			
OMC	23.30%			

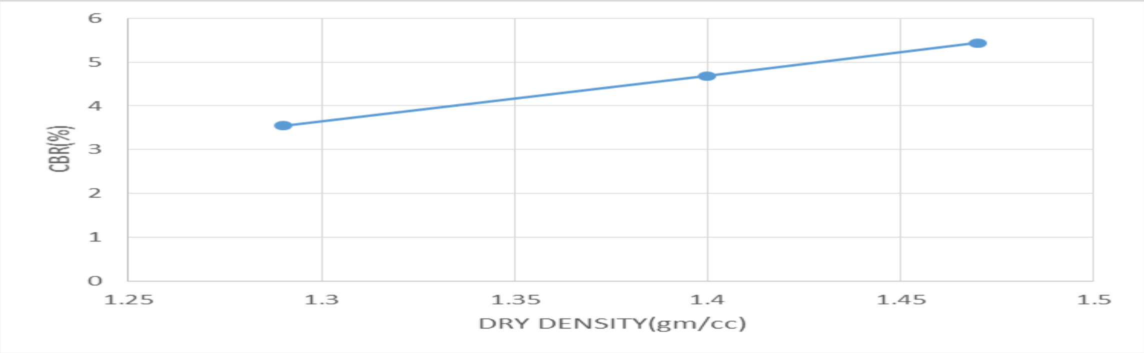


lideta 2m						
Density	**5 layer**					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.29	1.4	1.47			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	**Dial**	**Load**	**Dial**	**Load RF(.05188)**
0	0	0	0	0	0	0
0.64	3	0.156	4.000	0.208	5.000	0.259
1.27	5	0.259	7	0.363	9	0.467
1.91	8	0.415	10	0.519	12	0.623
2.54	9	0.467	12	0.623	14	0.726
3.18	10	0.519	13	0.674	16	0.830
3.81	11	0.571	14	0.726	17	0.882
4.45	12	0.623	15	0.778	18	0.934
5.08	13	0.674	16	0.830	19	0.986
7.62	16	0.830	20	1.038	23	1.193



before soaking 3 sampls were remolded with omc 18%

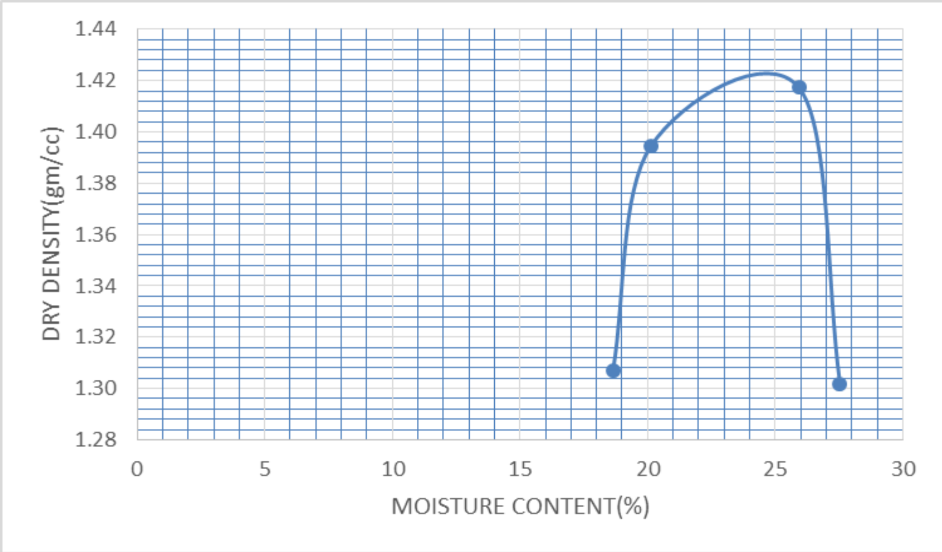
DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.29	10	13.24	20	0.47	0.67	3.549848943	3.35
1.4	30	13.24	20	0.62	0.85	4.682779456	4.25
1.47	65	13.24	20	0.72	1.01	5.438066465	5.05



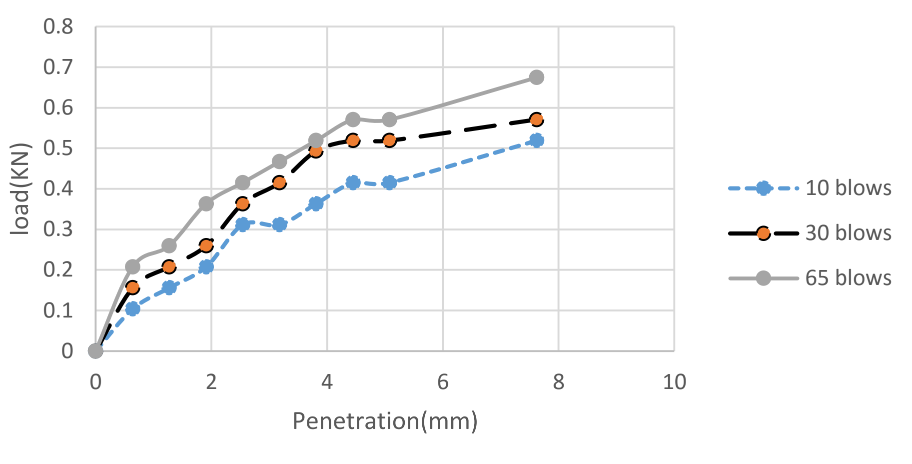
TP 2.: Location of Sample: Bole 1m

Bole 1M

DESCRIPTION	MOISTURE CONTENT DETERMINATION	Column	Column	Column
Trial no.	1	2	3	4
Can no.	a6	h3	d5	s2
Mass of can,g	14.890	15.20	15.40	14.870
Mass of can+wet soil,g	283.50	245.600	368.250	297.400
Mass of can+dry soil,g	241.300	207.00	295.600	236.400
Mass of water,g	42.200	38.600	72.650	61.000
Mass of dry soil,g	226.410	191.800	280.20	221.530
Water content,%	19	20	26	28
DESCRIPTION	DRY DENSITY DETERMINATION			
Trial No.	1	2	3	4
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	4374	4594	4698	4580
Mass of compacted soil	1470	1588	1692	1574
Volume of mold	948	948	948	948
Bulk density	1.55	1.68	1.78	1.66
Dry density	1.31	1.39	1.42	1.30

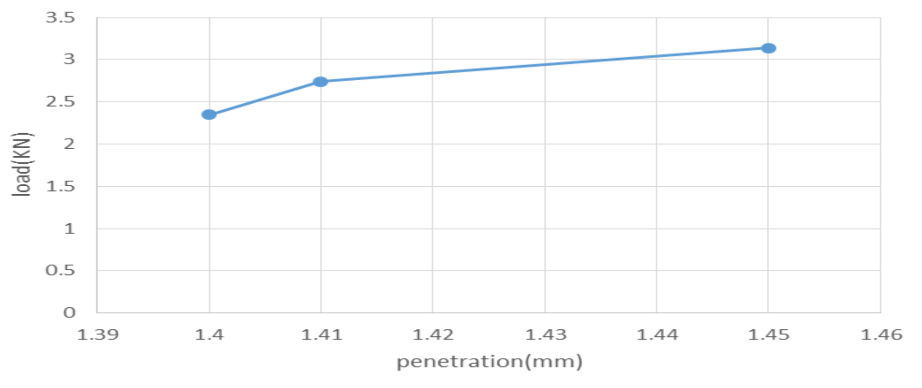


Density	5 layer					
No. of blo	10	30	65			
Dry densit	1.4	1.41	1.45			
Penetration data			30 blow		65 blow	
Penetratio	Dial	Load	Dial	Load	Dial	Load
0	0	0	0	0	0	0
0.64	2	0.104	3.000	0.156	4.000	0.208
1.27	3	0.156	4	0.208	5	0.259
1.91	4	0.208	5	0.259	7	0.363
2.54	6	0.311	7	0.363	8	0.415
3.18	6	0.311	8	0.415	9	0.467
3.81	7	0.363	9.5	0.493	10	0.519
4.45	8	0.415	10	0.519	11	0.571
5.08	8	0.415	10	0.519	11	0.571
7.62	10	0.519	11	0.571	13	0.674



before soaking 3 sampls were remolded with omc 25%

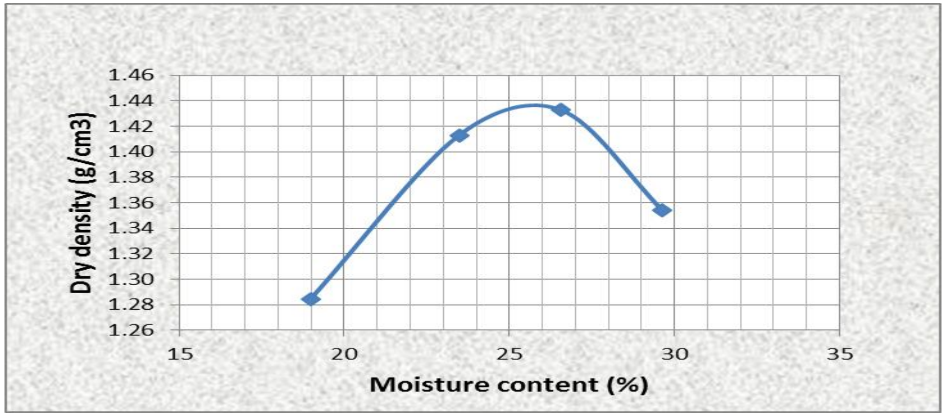
DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.4	10	13.24	20	0.311	0.415	2.3489426	2.075
1.41	30	13.24	20	0.363	0.519	2.7416918	2.595
1.45	65	13.24	20	0.415	0.571	3.1344411	2.855
mdd at 95%		1.3585					
cbr at 95%		1.879					



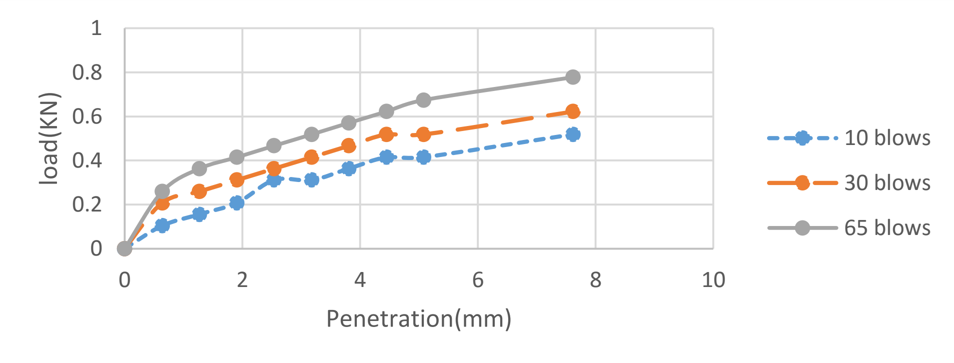
TP 2: Location of Sample: Bole 1.5m

Bole 1.5M

DESCRIPTION	MOISTURE CONTENT DETERMINATION	Column	Column	Column
Trial no.	1	2	3	4
Can no.	B4	F7	H4	H3
Mass of can,g	15	15	15	15
Mass of can+wet soil,g	279	235	341	289
Mass of can+dry soil,g	237	193	273	226
Mass of water,g	42	42	69	63
Mass of dry soil,g	222	178	258	211
Water content,%	19	23	27	30
DESCRIPTION	DRY DENSITY DETERMINATION			
Trial No.	1	2	3	4
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	4455	4660	4725	4670
Mass of compacted soil	1449	1654	1719	1664
Volume of mold	948	948	948	948
Bulk density	1.53	1.74	1.81	1.76
Dry density	1.28	1.41	1.43	1.35

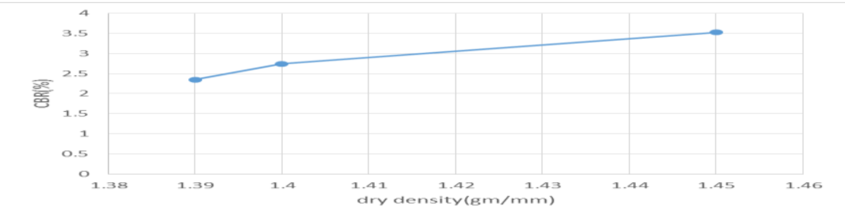


Density	5 layer					
No. of blo	10	30	65			
Dry densit	1.39	1.4	1.45			
Penetration data			30 blow		65 blow	
Penetratio	Dial	Load	Dial	Load	Dial	Load
0	0	0	0	0	0	0
0.64	2	0.104	4.000	0.208	5.000	0.259
1.27	3	0.156	5	0.259	7	0.363
1.91	4	0.208	6	0.311	8	0.415
2.54	6	0.311	7	0.363	9	0.467
3.18	6	0.311	8	0.415	10	0.519
3.81	7	0.363	9	0.467	11	0.571
4.45	8	0.415	10	0.519	12	0.623
5.08	8	0.415	10	0.519	13	0.674
7.62	10	0.519	12	0.623	15	0.778



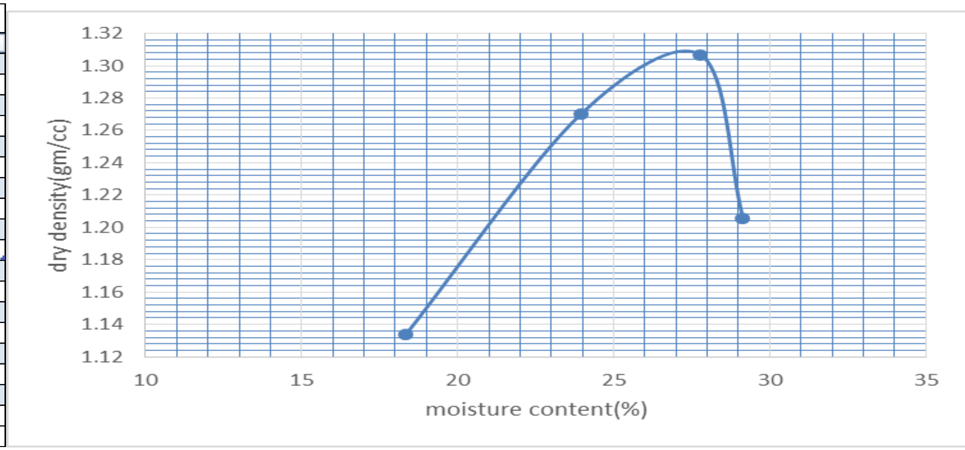
before soaking 3 sampls were remolded with omc 26%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.39	10	13.24	20	0.311	0.415	2.3489426	2.075
1.4	30	13.24	20	0.363	0.519	2.7416918	2.595
1.45	65	13.24	20	0.467	0.674	3.5271903	3.37
mdd at 95%		1.365					
cbr at 95%		1.985					

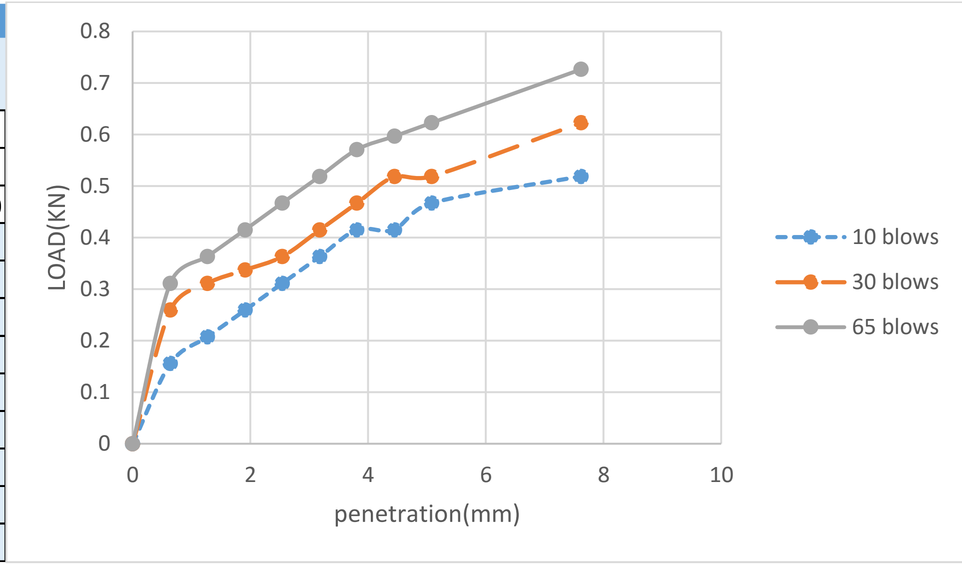


TP 2.: Location of Sample: Bole 2m

Bole 2M				
DESCRIPTION	MOISTURE CONTENT DETERMINATION	Column	Column	Column
Trial no.	1	2	3	4
Can no.	b3	f2	g1	a4
Mass of can,g	15.000	15.60	14.90	14.870
Mass of can+wet soil,g	268.60	231.000	346.000	279.000
Mass of can+dry soil,g	229.300	189.40	274.000	219.400
Mass of water,g	39.300	41.600	72.000	59.600
Mass of dry soil,g	214.300	173.800	259.10	204.530
Water content,%	18	24	28	29
DESCRIPTION	DRY DENSITY DETERMINATION			
Trial No.	1	2	3	4
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	4278	4498	4589	4482
Mass of compacted soil	1272	1492	1583	1476
Volume of mold	948	948	948	948
Bulk density	1.34	1.57	1.67	1.56
Dry density	1.13	1.27	1.31	1.21
omc	27			
mdd	1.315			

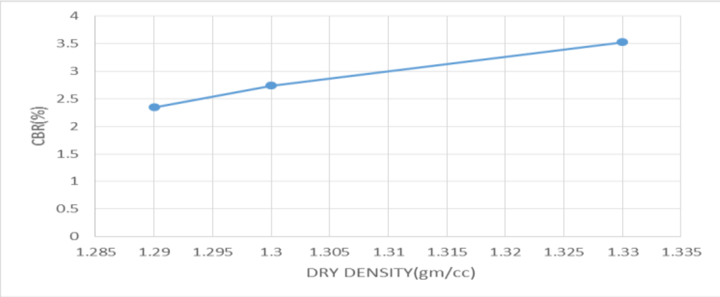


Density	5 layer					
No. of blo	10	30	65			
Dry densit	1.29	1.3	1.33			
Penetration data			30 blow		65 blow	
Penetratio	Dial	Load	Dial	Load	Dial	Load
0	0	0	0	0	0	0
0.64	3	0.156	5.000	0.259	6.000	0.311
1.27	4	0.208	6	0.311	7	0.363
1.91	5	0.259	6.5	0.337	8	0.415
2.54	6	0.311	7	0.363	9	0.467
3.18	7	0.363	8	0.415	10	0.519
3.81	8	0.415	9	0.467	11	0.571
4.45	8	0.415	10	0.519	11.5	0.597
5.08	9	0.467	10	0.519	12	0.623
7.62	10	0.519	12	0.623	14	0.726



before soaking 3 sampls were remolded with omc 27%

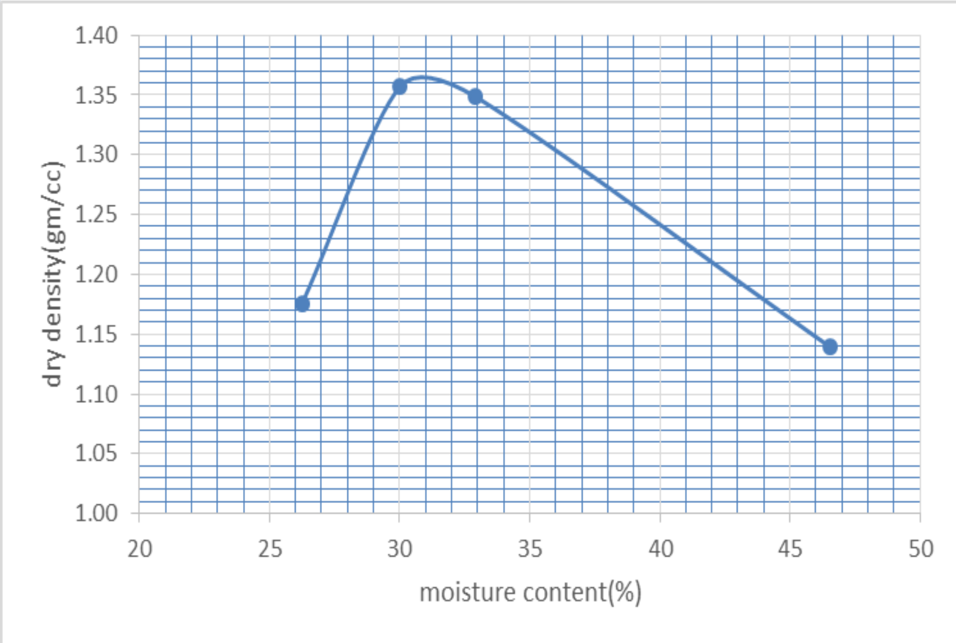
DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.29	10	13.24	20	0.311	0.467	2.3489426	2.335
1.3	30	13.24	20	0.363	0.519	2.7416918	2.595
1.33	65	13.24	20	0.467	0.623	3.5271903	3.115
mdd at 95%		1.249					
cbr at 95%		1.25					



TP 3: Location of Sample: Kaliti 1m

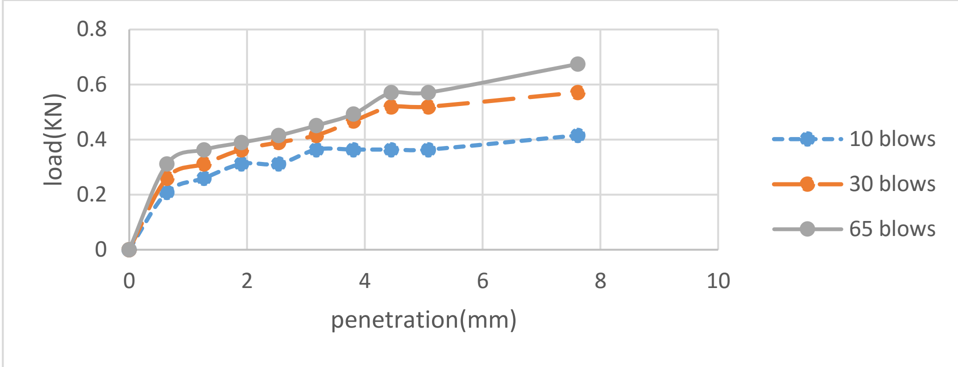
DESCRIPTION	Column1	Colum	Colum	Colum
Trial no.	**1**	**2**	**3**	**4**
Can no.	d12	r3	p4	j2
Mass of can,g	37.80	35.800	31.500	33.80
Mass of can+wet soil,g	235	201.450	226	284
Mass of can+dry soil,g	194	163	178	205
Mass of water,g	41	38	48	80
Mass of dry soil,g	156	127	147	171
Water content,%	**26**	**30**	**33**	**47**

DESCRIPTION	Column1	Colum	Colum	Colum
Trial No.	1	2	3	4
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	4407	4672	4698	4582
Mass of compacted soil	1401	1666	1692	1576
Volume of mold	944	944	944	944
Bulk density	1.48	1.76	1.79	1.67
Dry density	**1.18**	**1.36**	**1.35**	**1.14**
omc	32			
mdd	1.368			

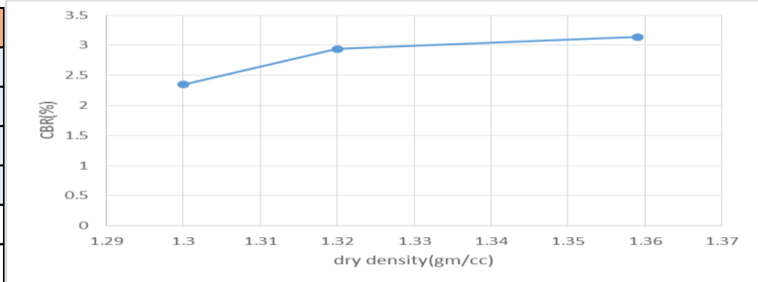


Density	5 layer					
No. of blo	10	30	65			
Dry densit	1.3	1.32	1.359			
Penetration data			30 blow		65 blow	
Penetratio	Dial	Load	Dial	Load	Dial	Load
0	0	0	0	0	0	0
0.64	4	0.208	5.000	0.259	6.000	0.311
1.27	5	0.259	6	0.311	7	0.363
1.91	6	0.311	7	0.363	7.5	0.389
2.54	6	0.311	7.5	0.389	8	0.415
3.18	7	0.363	8	0.415	8.7	0.451
3.81	7	0.363	9	0.467	9.5	0.493
4.45	7	0.363	10	0.519	11	0.571
5.08	7	0.363	10	0.519	11	0.571
7.62	8	0.415	11	0.571	13	0.674

before soaking 3 sampls were remolded with omc 32%



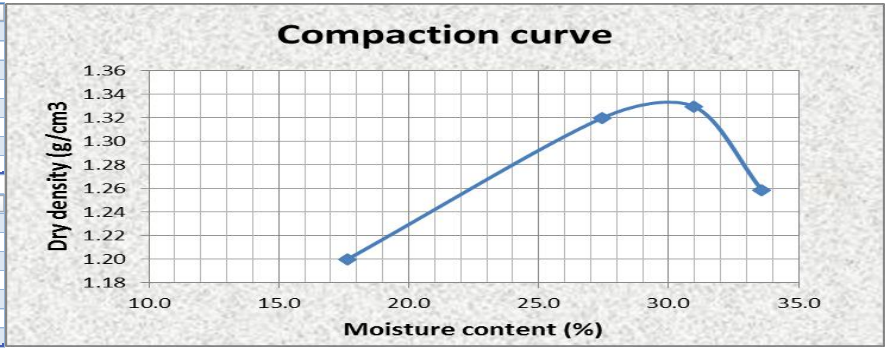
DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.3	10	13.24	20	0.311	0.363	2.3489426	1.815
1.32	30	13.24	20	0.389	0.519	2.9380665	2.595
1.359	65	13.24	20	0.415	0.571	3.1344411	2.855
mdd at 95%		1.299					
cbr at 95%		2.48					



TP 3.: Location of Sample: Kaliti 1.5m

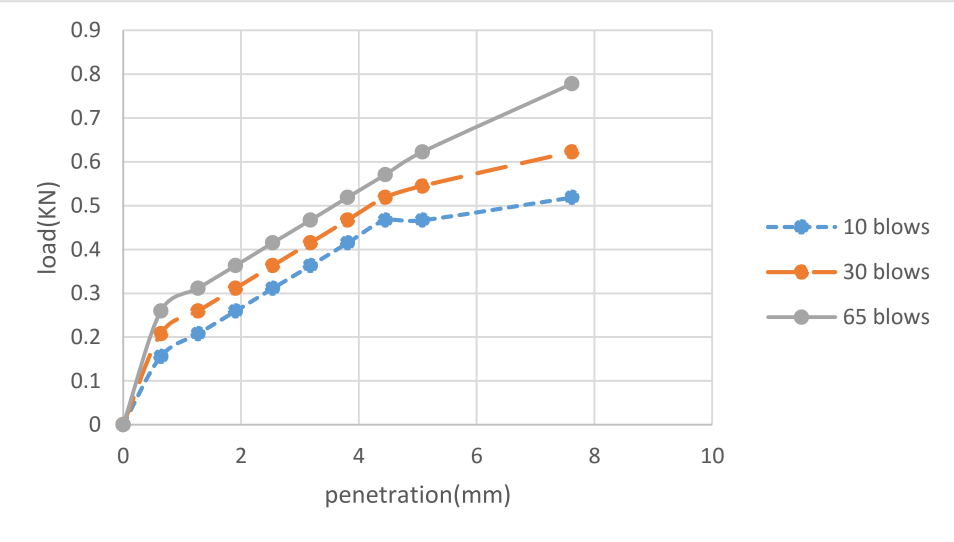
DESCRIPTION	Column1	Colum	Colum	Colum
Trial no.	2	3	4	5
Can no.	L2	B5	K9	
Mass of can,g	52.4	39.0	44.3	42.1
Mass of can+wet soil,g	177.1	107.1	142.4	152.7
Mass of can+dry soil,g	158.4	92.4	119.2	124.9
Mass of water,g	18.7	14.7	23.2	27.8
Mass of dry soil,g	106.0	53.4	75.0	82.8
Water content,%	17.6	27.4	31.0	33.6

DESCRIPTION	Column1	Colum	Colum	Colum
Trial No.	2	3	4	5
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	4380	4515	4650	4595
Mass of compacted soil	1374	1509	1644	1589
Volume of mold	944	944	944	945
Bulk density	1.46	1.60	1.74	1.68
Dry density	1.20	1.32	1.33	1.26



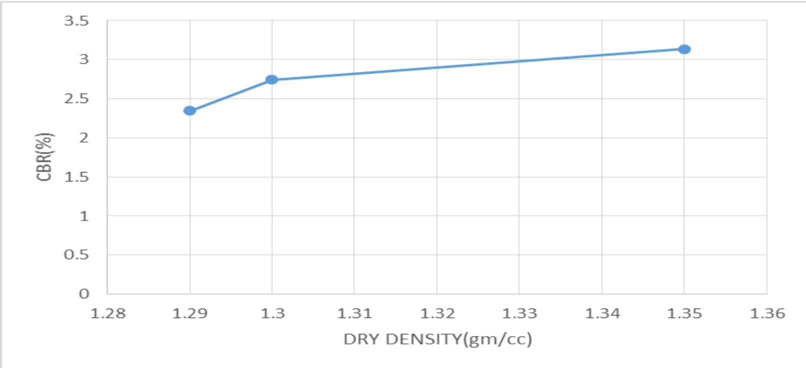
OMC	**30**
MDD	**1.33**

Density	5 layer						
No. of blo	10	30	65				
Dry densit	1.29	1.3	1.35				
Penetration data			30 blow		65 blow		
Penetratio	Dial	Load	Dial	Load	Dial	Load	
0	0	0	0	0	0	0	
0.64	3	0.156	4.000	0.208	5.000	0.259	
1.27	4	0.208	5	0.259	6	0.311	
1.91	5	0.259	6	0.311	7	0.363	
2.54	6	0.311	7	0.363	8	0.415	
3.18	7	0.363	8	0.415	9	0.467	
3.81	8	0.415	9	0.467	10	0.519	
4.45	9	0.467	10	0.519	11	0.571	
5.08	9	0.467	10.5	0.545	12	0.623	
7.62	10	0.519	12	0.623	15	0.778	



before soaking 3 sampls were remolded with omc 30%

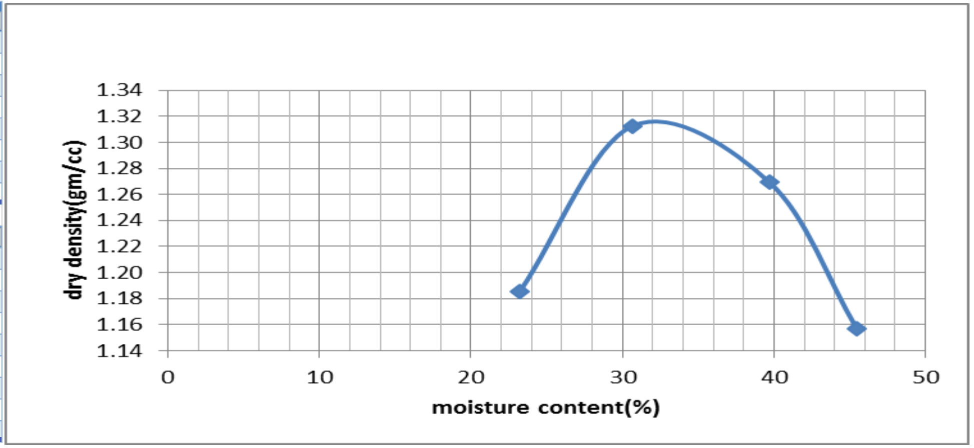
DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.29	10	13.24	20	0.311	0.467	2.3489426	2.335
1.3	30	13.24	20	0.363	0.545	2.7416918	2.725
1.35	65	13.24	20	0.415	0.623	3.1344411	3.115
mdd at 95%		1.263					
cbr at 95%		2.17					



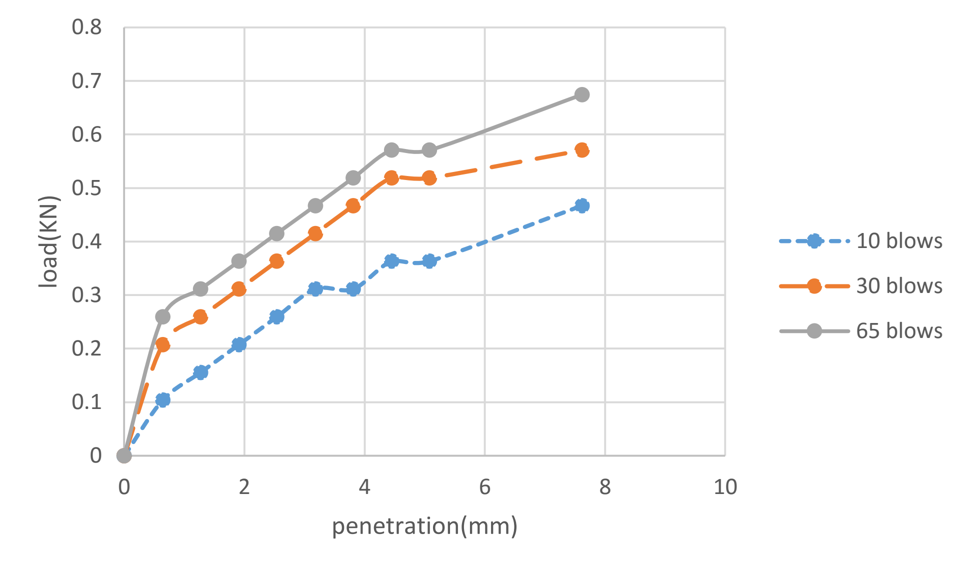
TP 3.: Location of Sample: Kaliti 2m

DESCRIPTION	Column1	Colum	Colum	Colum
Trial no.	1	2	3	4
Can no.	A3	S2	F5	K4
Mass of can,g	43	37	32	34
Mass of can+wet soil,g	221	191	218	279
Mass of can+dry soil,g	187	155	166	203
Mass of water,g	33	36	53	76
Mass of dry soil,g	144	118	133	168
Water content,%	23	31	40	45

DESCRIPTION	Column1	Colum	Colum	Colum
Trial No.	1	2	3	4
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	4385	4625	4680	4595
Mass of compacted soil	1379	1619	1674	1589
Volume of mold	944	944	944	944
Bulk density	1.46	1.72	1.77	1.68
Dry density	1.19	1.31	1.27	1.16
OMC	31			
MDD	1.315			

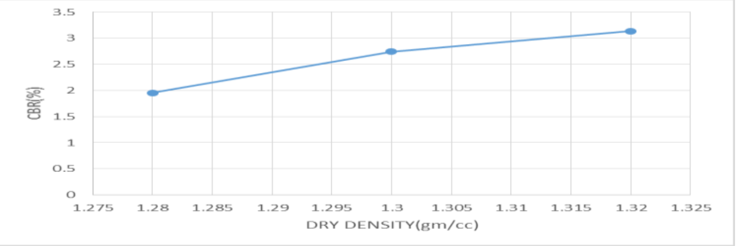


Density	5 layer					
No. of blo	10	30	65			
Dry densit	1.28	1.3	1.32			
Penetration data			30 blow		65 blow	
Penetratio	Dial	Load	Dial	Load	Dial	Load
0	0	0	0	0	0	0
0.64	2	0.104	4.000	0.208	5.000	0.259
1.27	3	0.156	5	0.259	6	0.311
1.91	4	0.208	6	0.311	7	0.363
2.54	5	0.259	7	0.363	8	0.415
3.18	6	0.311	8	0.415	9	0.467
3.81	6	0.311	9	0.467	10	0.519
4.45	7	0.363	10	0.519	11	0.571
5.08	7	0.363	10	0.519	11	0.571
7.62	9	0.467	11	0.571	13	0.674



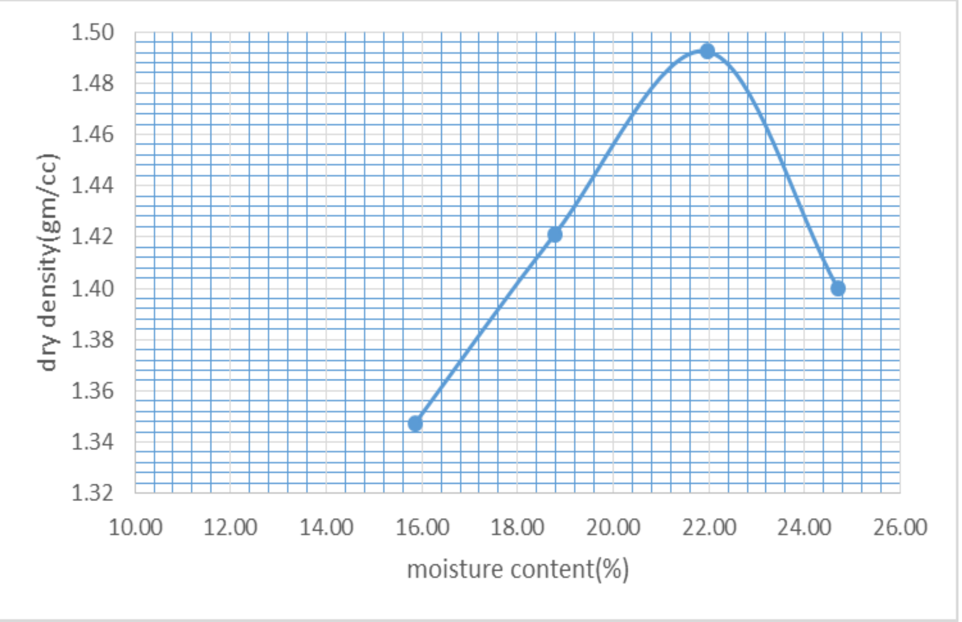
before soaking 3 sampls were remolded with omc 31%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.28	10	13.24	20	0.259	0.363	1.9561934	1.815
1.3	30	13.24	20	0.363	0.519	2.7416918	2.595
1.32	65	13.24	20	0.415	0.571	3.1344411	2.855
mdd at 95%		1.263					
cbr at 95%		1.43					

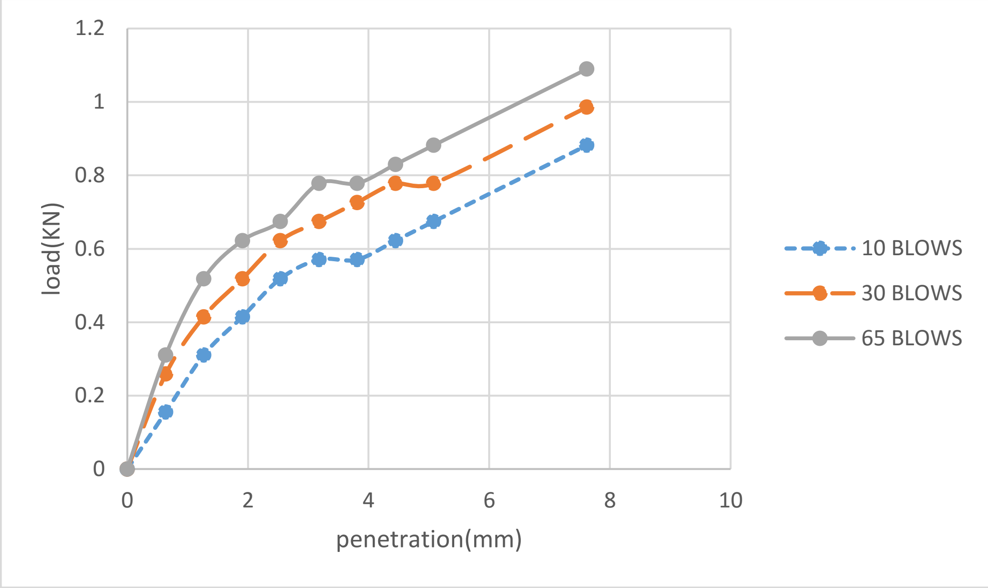


TP 4: Location of Sample: Adissu Gebeya 1m

DESCRIPTION	TURE CONTENT DETERMI	Colum	Colum	Colum
Trial no.	1	2	3	4
Can no.	C1	D3	B5	F3
Mass of can,g	57.00	59.00	58.00	59.00
Mass of can+wet soil,g	364.00	369.00	369.00	362.00
Mass of can+dry soil,g	322.00	320.00	313.00	302.00
Mass of water,g	42.00	49.00	56.00	60.00
Mass of dry soil,g	265.00	261.00	255.00	243.00
Water content,%	**15.85**	**18.77**	**21.96**	**24.69**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	1	2	3	4
Mass of mold	5433.00	5433.00	5433.00	5433.00
Mass of mold + compacte	8748.00	9018.00	9299.00	9141.00
Mass of compacted soil	3315.00	3585.00	3866.00	3708.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.56	1.69	1.82	1.75
Dry density	**1.35**	**1.42**	**1.49**	**1.40**
MDD = 1.49g/cm3				
OMC = 21.5%				

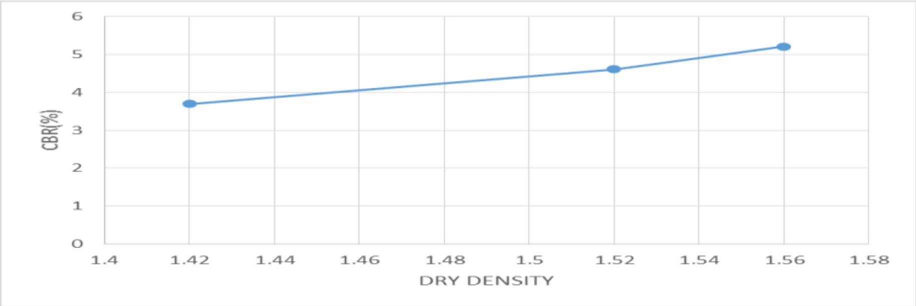


Density	5 layer						
No. of blows/layer	10	30	65				
Dry density (g/cm3)	1.42	1.52	1.56				
Penetration data 10 blow			30 blow		65 blow		
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)	
0	0	0	0	0	0	0	
0.64	3	0.156	5.000	0.259	6.000	0.311	
1.27	6	0.311	8	0.415	10	0.519	
1.91	8	0.415	10	0.519	12	0.623	
2.54	10	0.519	12	0.623	13	0.674	
3.18	11	0.571	13	0.674	15	0.778	
3.81	11	0.571	14	0.726	15	0.778	
4.45	12	0.623	15	0.778	16	0.830	
5.08	13	0.674	15	0.778	17	0.882	
7.62	17	0.882	19	0.986	21	1.089	



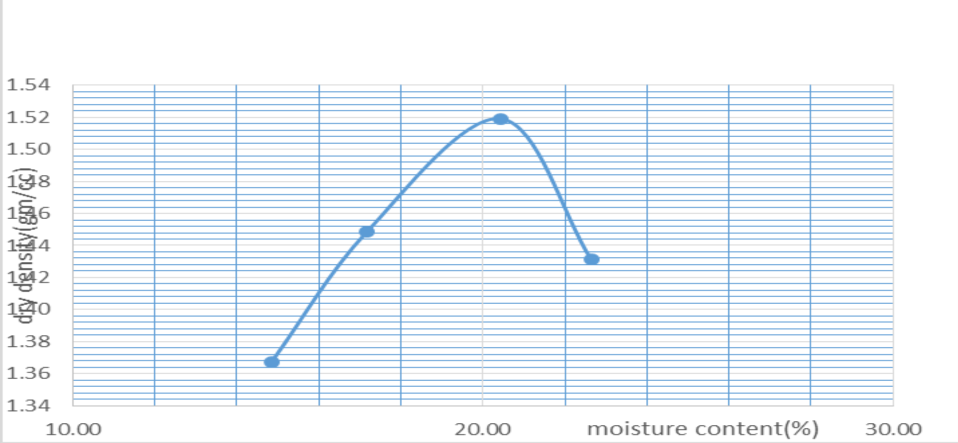
before soaking 3 sampls were remolded with omc 19.0%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.42	10	13.24	20	0.49	0.68	3.700906344	3.4
1.52	30	13.24	20	0.61	0.79	4.607250755	3.95
1.56	65	13.24	20	0.69	0.88	5.211480363	4.4
MDD at 95%	1.49						
cbr at 95%	4.3						

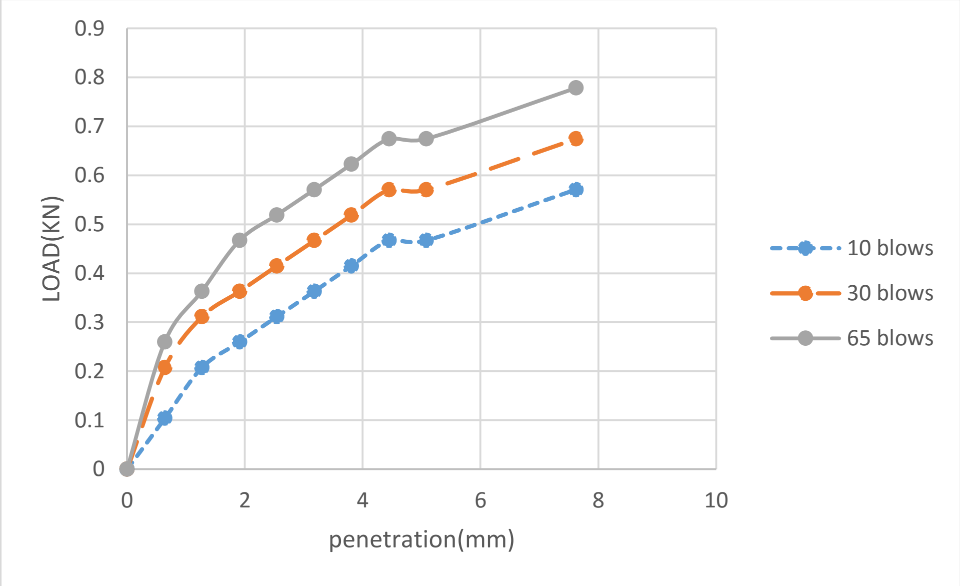


TP 4.: Location of Sample: Adissu Gebeya 1.5m

DESCRIPTION	MOISTURE CONTENT DETERMINATION	Colum	Colum	Colum
Trial no.	1	2	3	4
Can no.	D8	F7	B2	F11
Mass of can,g	59.00	58.00	59.00	57.00
Mass of can+wet soil,g	384.00	389.00	389.00	382.00
Mass of can+dry soil,g	342.00	340.50	333.00	322.00
Mass of water,g	42.00	48.50	56.00	60.00
Mass of dry soil,g	283.00	282.50	274.00	265.00
Water content,%	**14.84**	**17.17**	**20.44**	**22.64**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	1	2	3	4
Mass of mold	5433.00	5433.00	5433.00	5433.00
Mass of mold + compacte	8768.00	9038.00	9319.00	9161.00
Mass of compacted soil	3335.00	3605.00	3886.00	3728.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.57	1.70	1.83	1.76
Dry density	**1.37**	**1.45**	**1.52**	**1.43**
MDD = 1.52 g/cm3				
OMC = 20.2 %				

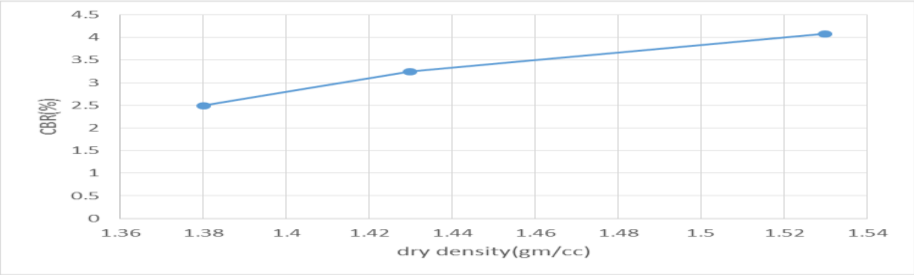


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.38	1.43	1.53			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	2	0.104	4.000	0.208	5.000	0.259
1.27	4	0.208	6	0.311	7	0.363
1.91	5	0.259	7	0.363	9	0.467
2.54	6	0.311	8	0.415	10	0.519
3.18	7	0.363	9	0.467	11	0.571
3.81	8	0.415	10	0.519	12	0.623
4.45	9	0.467	11	0.571	13	0.674
5.08	9	0.467	11	0.571	13	0.674
7.62	11	0.571	13	0.674	15	0.778



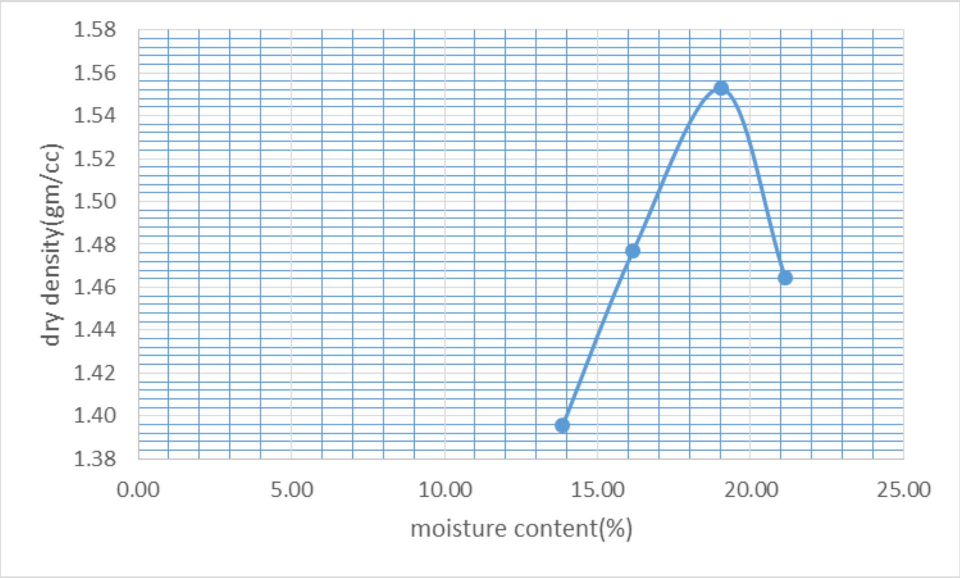
before soaking 3 sampls were remolded with omc 20.20%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.38	10	13.24	20	0.33	0.48	2.49244713	2.4
1.43	30	13.24	20	0.43	0.58	3.247734139	2.9
1.53	65	13.24	20	0.54	0.68	4.078549849	3.4
MDD at 95%	1.52						
cbr at 95%	3.4						

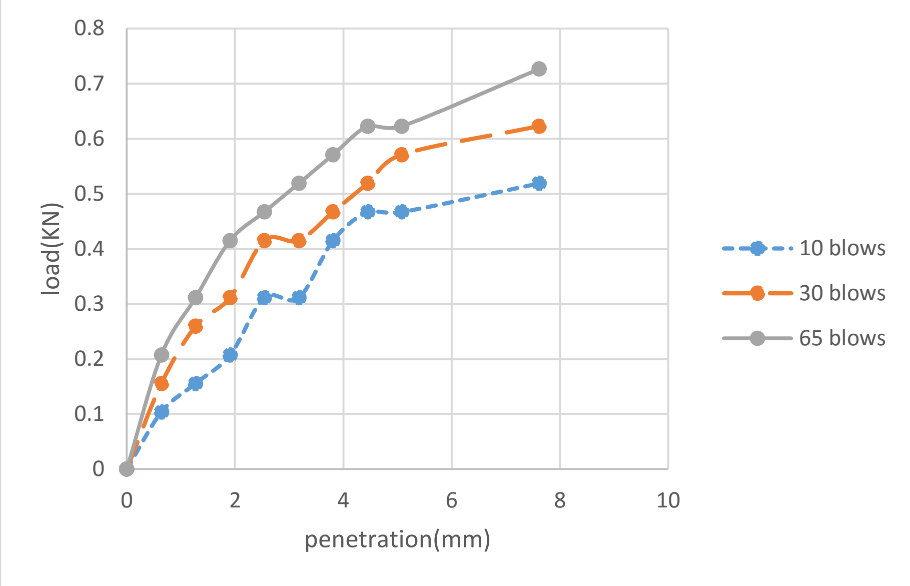


TP 4.: Location of Sample: Adissu Gebeya 2m

DESCRIPTION	URE CONTENT DETERM	Colum	Colum	Colum
Trial no.	1	2	3	4
Can no.	C5	D4	B6	F4
Mass of can,g	59.00	57.00	59.00	58.00
Mass of can+wet soil,g	404.00	409.00	409.00	402.00
Mass of can+dry soil,g	362.00	360.00	353.00	342.00
Mass of water,g	42.00	49.00	56.00	60.00
Mass of dry soil,g	303.00	303.00	294.00	284.00
Water content,%	**13.86**	**16.17**	**19.05**	**21.13**
DESCRIPTION	**RY DENSITY DETERMINATION**			
Trial No.	1	2	3	4
Mass of mold	5433.00	5433.00	5433.00	5433.00
Mass of mold + compacted	8808.00	9078.00	9359.00	9201.00
Mass of compacted soil	3375.00	3645.00	3926.00	3768.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.59	1.72	1.85	1.77
Dry density	**1.40**	**1.48**	**1.55**	**1.46**
MDD = 1.57g/cm3				
OMC = 19.09%				

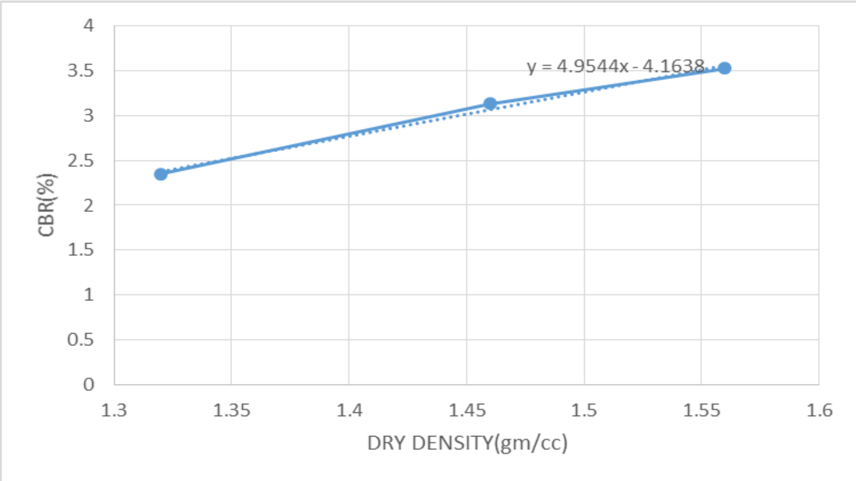


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.32	1.46	1.56			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	2	0.104	3.000	0.156	4.000	0.208
1.27	3	0.156	5	0.259	6	0.311
1.91	4	0.208	6	0.311	8	0.415
2.54	6	0.311	8	0.415	9	0.467
3.18	6	0.311	8	0.415	10	0.519
3.81	8	0.415	9	0.467	11	0.571
4.45	9	0.467	10	0.519	12	0.623
5.08	9	0.467	11	0.571	12	0.623
7.62	10	0.519	12	0.623	14	0.726



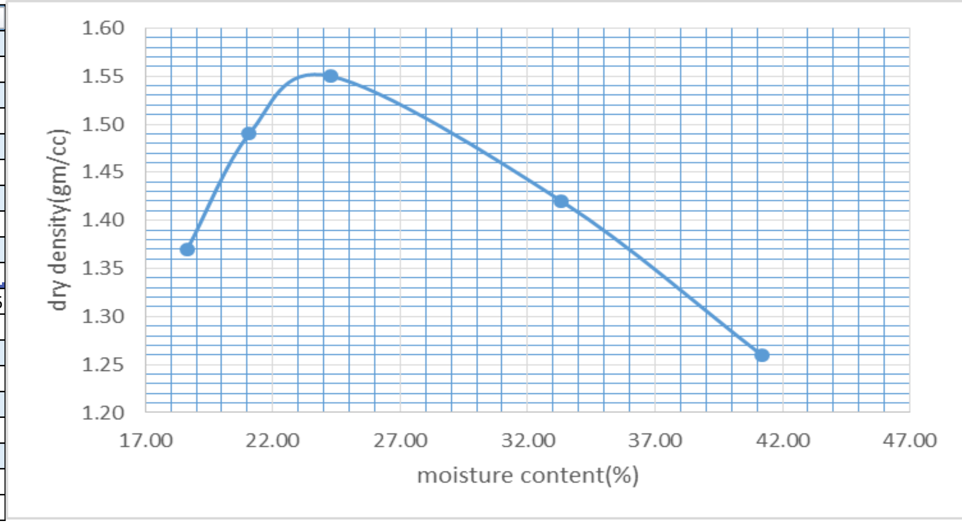
before soaking 3 sampls were remolded with omc 20.20%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.32	10	13.24	20	0.311	0.467	2.348942598	2.335
1.46	30	13.24	20	0.415	0.571	3.134441088	2.855
1.56	65	13.24	20	0.467	0.623	3.527190332	3.115
MDD at 95%	1.49						
cbr at 95%	3.2						

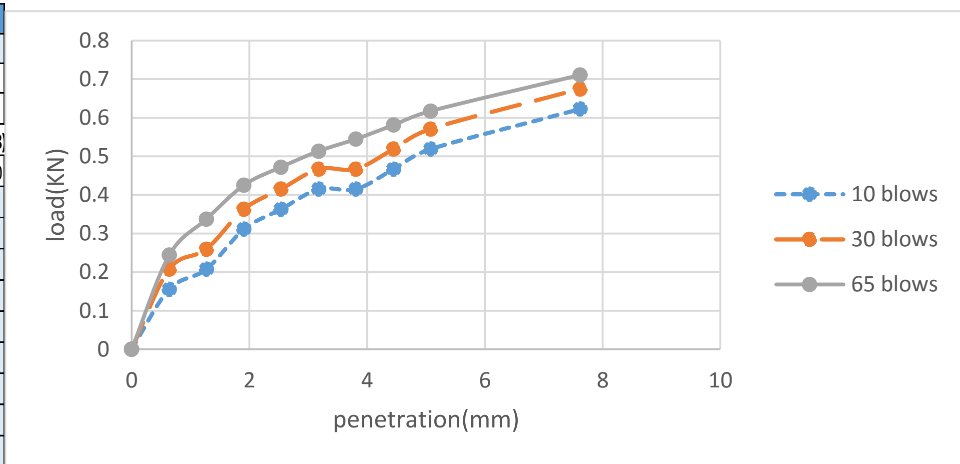


TP 5: Location of Sample: Kolfe 1m

DESCRIPTION	ISTURE CONTENT DETERMINA	Column1	Colum	Colum	Colum
Trial no.	1	2	3	4	5
Can no.	F1	D2	J2	C4	B2
Mass of can,g	5	5	5	5	5
Mass of can+wet soil,g	215	206	220	205	245
Mass of can+dry soil,g	182	171	178	155	175
Mass of water,g	33	35	42	50	70
Mass of dry soil,g	177	166	173	150	170
Water content,%	**18.64**	**21.08**	**24.28**	**33.33**	**41.18**
DESCRIPTION	**DRY DENSITY DETERMINATION**				
Trial No.	**1**	**2**	**3**	**4**	5
Mass of mold	5630	5630	5630	5630	5630
Mass of mold + compacted soil	7169	7323	7450	7418	7312
Mass of compacted soil	1539	1593	1820	1788	1682
Volume of mold	944	944	944	944	944
Bulk density	1.63	1.69	1.93	1.89	1.78
Dry density	**1.37**	**1.49**	**1.55**	**1.42**	**1.26**
MDD (g/cc)	1.55				
OMC (%)	24.3				

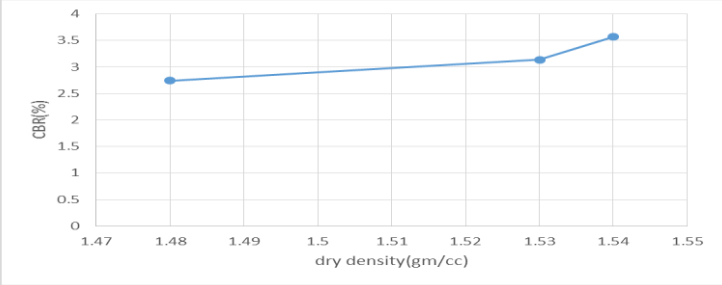


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.48	1.53	1.54			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	3	0.156	4.000	0.208	4.700	0.244
1.27	4	0.208	5	0.259	6.5	0.337
1.91	6	0.311	7	0.363	8.2	0.425
2.54	7	0.363	8	0.415	9.1	0.472
3.18	8	0.415	9	0.467	9.9	0.514
3.81	8	0.415	9	0.467	10.5	0.545
4.45	9	0.467	10	0.519	11.2	0.581
5.08	10	0.519	11	0.571	11.9	0.617
7.62	12	0.623	13	0.674	13.7	0.711



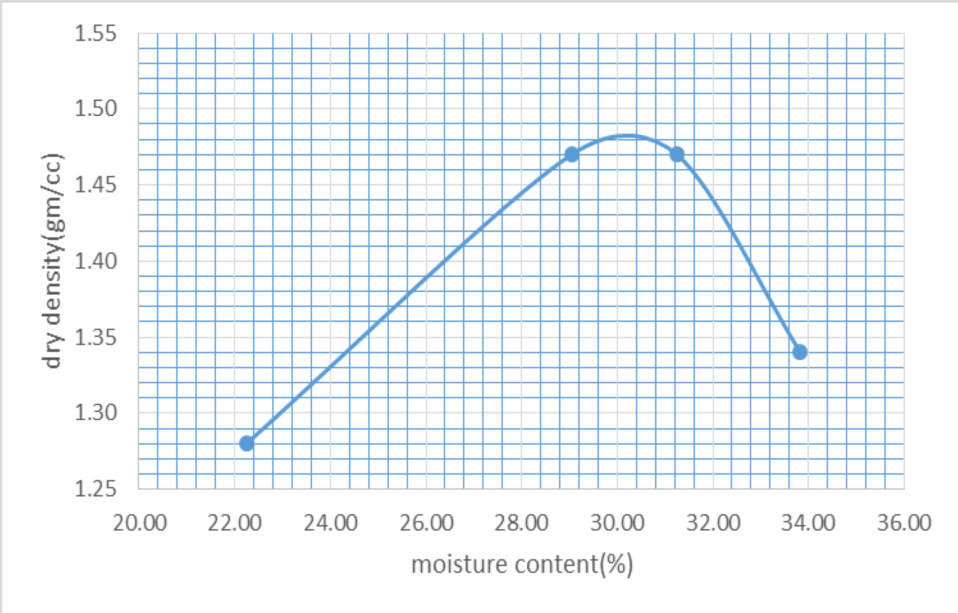
before soaking 3 sampls were remolded with omc 29%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.48	10	13.24	20	0.363	0.519	2.741691843	2.595
1.53	30	13.24	20	0.415	0.571	3.134441088	2.855
1.54	65	13.24	20	0.472	0.617	3.564954683	3.085
MDD at 95%	1.47						
cbr at 95%	2.62						

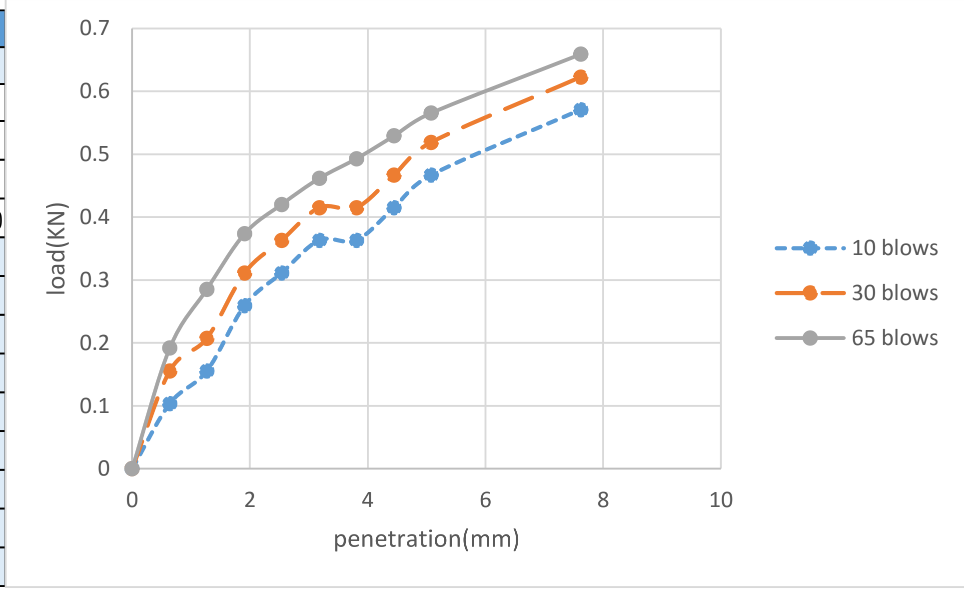


TP 5: Location of Sample: Kolfe 1.5m

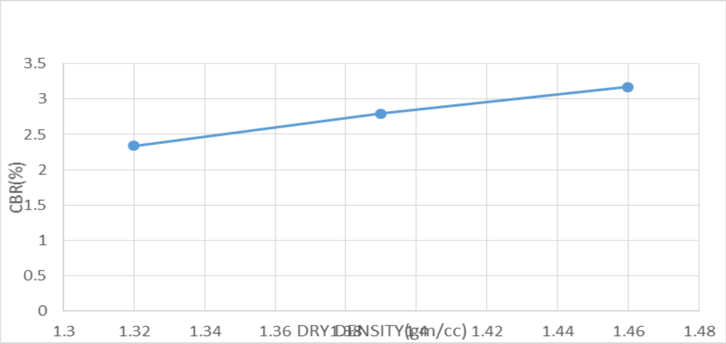
DESCRIPTION	ISTURE CONTENT DETERMINA	Colum	Colum	Colum
Trial no.	**1**	**2**	**3**	**4**
Can no.	J2	A5	S2	G2
Mass of can,g	64	59	68	63
Mass of can+wet soil,g	364	386	415	378
Mass of can+dry soil,g	309	312	332	298
Mass of water,g	55	74	83	80
Mass of dry soil,g	245	253	264	235
Water content,%	**22.24**	**29.04**	**31.25**	**33.83**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	5433	5433	5433	5433
Mass of mold + compac	8745	9532	9465	9240
Mass of compacted soi	3312	4100	4032	3807
Volume of mold	2124	2124	2124	2124
Bulk density	1.56	1.93	1.90	1.79
Dry density	**1.28**	**1.47**	**1.47**	**1.34**
MDD (g/cc)	1.48			
OMC (%)	30.2			



Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.32	1.39	1.46			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	2	0.104	3.000	0.156	3.700	0.192
1.27	3	0.156	4	0.208	5.5	0.285
1.91	5	0.259	6	0.311	7.2	0.374
2.54	6	0.311	7	0.363	8.1	0.420
3.18	7	0.363	8	0.415	8.9	0.462
3.81	7	0.363	8	0.415	9.5	0.493
4.45	8	0.415	9	0.467	10.2	0.529
5.08	9	0.467	10	0.519	10.9	0.565
7.62	11	0.571	12	0.623	12.7	0.659

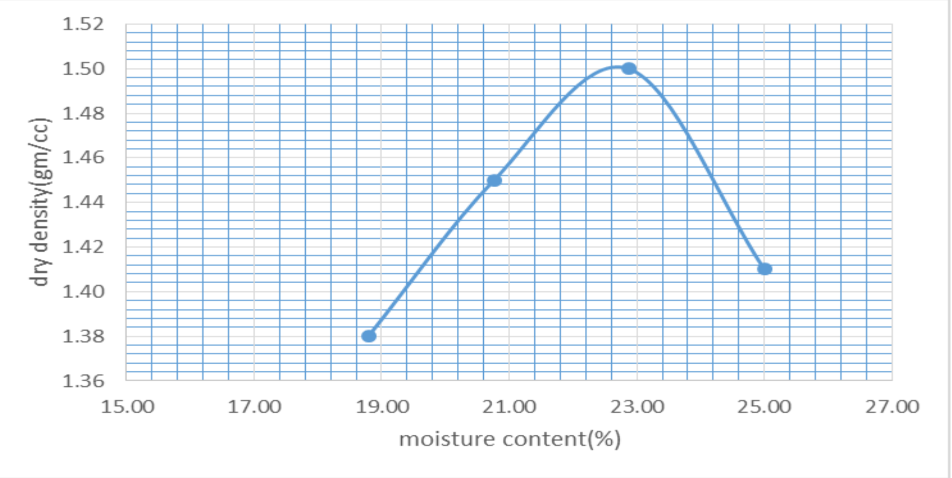


DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.32	10	13.24	20	0.31	0.46	2.341389728	2.3
1.39	30	13.24	20	0.37	0.51	2.794561934	2.55
1.46	65	13.24	20	0.42	0.56	3.172205438	2.8
MDD at 95%	1.44						
cbr at 95%	2.8						

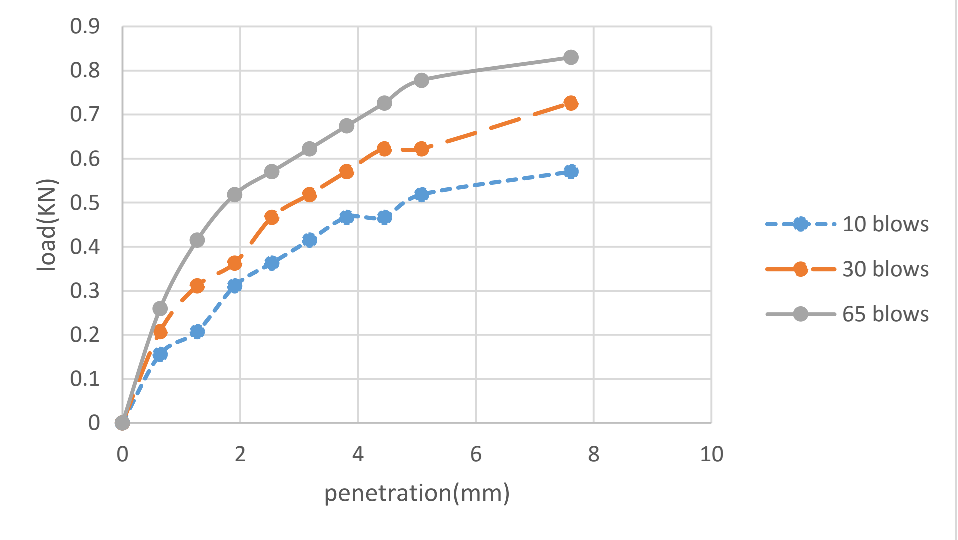


TP 5: Location of Sample: Kolfe 2m

DESCRIPTION	MOISTURE CONTENT DETERMINA	Colum	Colum	Colum
Trial no.	1	2	3	4
Can no.	C10	C2	C8	C1
Mass of can,g	68	71	65	69
Mass of can+wet soil,g	403	420	425	424
Mass of can+dry soil,g	350	360	358	353
Mass of water,g	53	60	67	71
Mass of dry soil,g	282	289	293	284
Water content,%	**18.79**	**20.76**	**22.87**	**25.00**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	5433	5433	5433	5433
Mass of mold + compac	8907	9159	9346	9188
Mass of compacted soil	3474	3726	3913	3755
Volume of mold	2124	2124	2124	2124
Bulk density	1.64	1.75	1.84	1.77
Dry density	**1.38**	**1.45**	**1.50**	**1.41**
MDD (g/cc)	1.5			
OMC (%)	22.9			

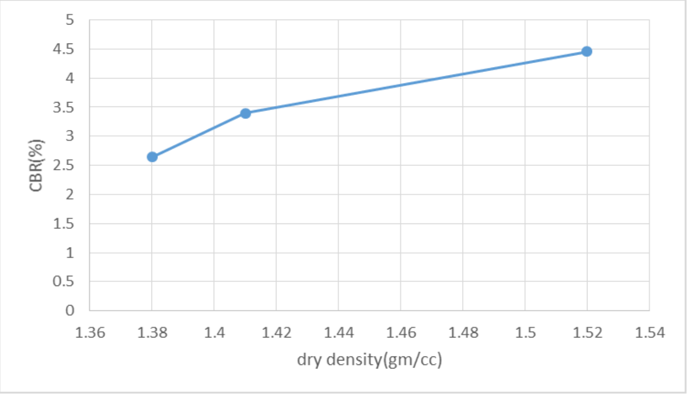


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.38	1.41	1.52			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	3	0.156	4.000	0.208	5.000	0.259
1.27	4	0.208	6	0.311	8	0.415
1.91	6	0.311	7	0.363	10	0.519
2.54	7	0.363	9	0.467	11	0.571
3.18	8	0.415	10	0.519	12	0.623
3.81	9	0.467	11	0.571	13	0.674
4.45	9	0.467	12	0.623	14	0.726
5.08	10	0.519	12	0.623	15	0.778
7.62	11	0.571	14	0.726	16	0.830



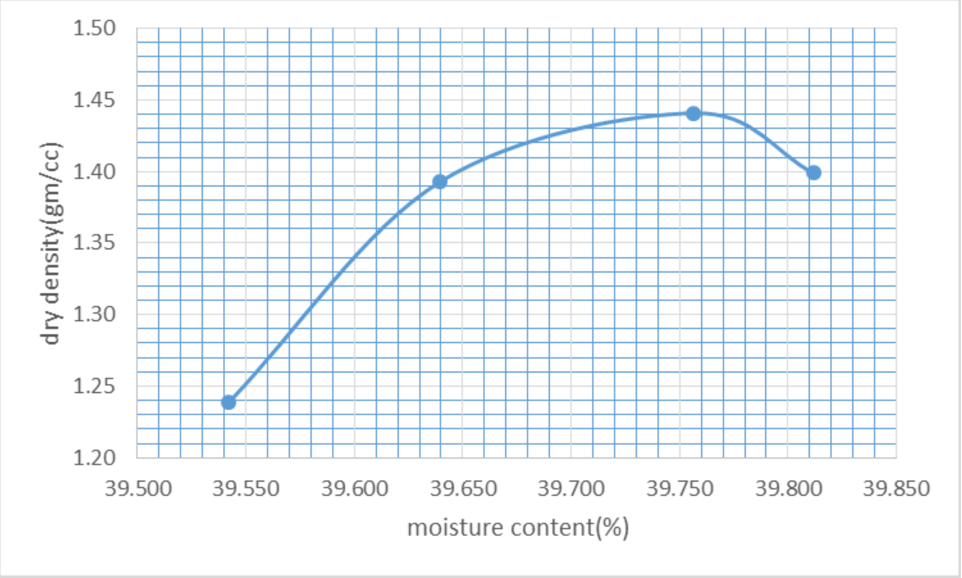
before soaking 3 sampls were remolded with omc 22.9%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.38	10	13.24	20	0.35	0.52	2.643504532	2.6
1.41	30	13.24	20	0.45	0.64	3.398791541	3.2
1.52	65	13.24	20	0.59	0.76	4.456193353	3.8
MDD at 95%	1.43						
cbr at 95%	3.7						

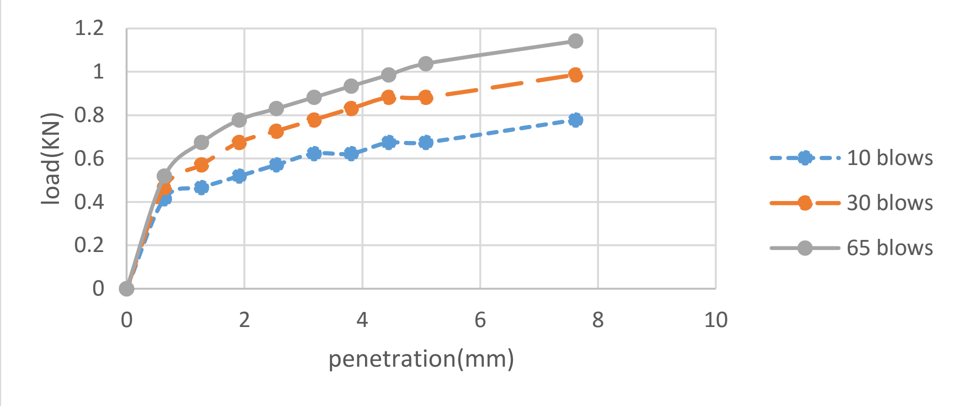


TP 6: Location of Sample: Addiss Ketema 1m

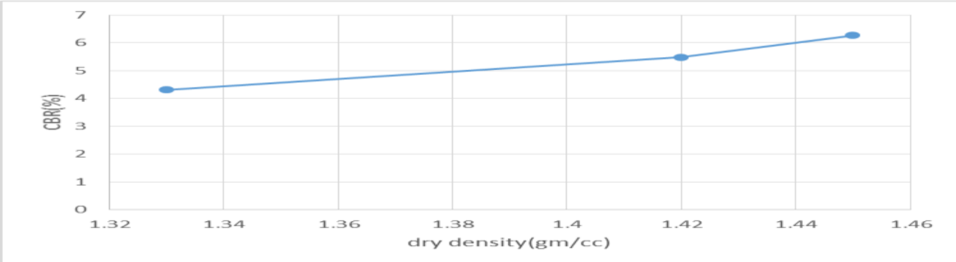
DESCRIPTION	ISTURE CONTENT DETERMIN/	Colum	Colum	Colum
Trial no.	1	2	3	4
Can no.	a32	r6	t8	k12
Mass of can,g	13.890	15.700	15.890	15.690
Mass of can+wet soil,g	31.570	31.200	35.400	33.530
Mass of can+dry soil,g	26.560	26.800	29.850	28.450
Mass of water,g	5.010	4.400	5.550	5.080
Mass of dry soil,g	12.670	11.100	13.960	12.760
Water content,%	**39.542**	**39.640**	**39.756**	**39.812**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	1	2	3	4
Mass of mold	3006	3006	3006	3006
Mass of mold + compact	4645	4850	4915	4860
Mass of compacted soil	1639	1844	1909	1854
Volume of mold	948	948	948	948
Bulk density	1.73	1.95	2.01	1.96
Dry density	**1.24**	**1.39**	**1.44**	**1.40**



Density	5 layer					
No. of blo	10	30	65			
Penetration data 10 blow			30 blow		65 blow	
Penetratio	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	8	0.415	9.000	0.467	10.000	0.519
1.27	9	0.467	11	0.571	13	0.674
1.91	10	0.519	13	0.674	15	0.778
2.54	11	0.571	14	0.726	16	0.830
3.18	12	0.623	15	0.778	17	0.882
3.81	12	0.623	16	0.830	18	0.934
4.45	13	0.674	17	0.882	19	0.986
5.08	13	0.674	17	0.882	20	1.038
7.62	15	0.778	19	0.986	22	1.141

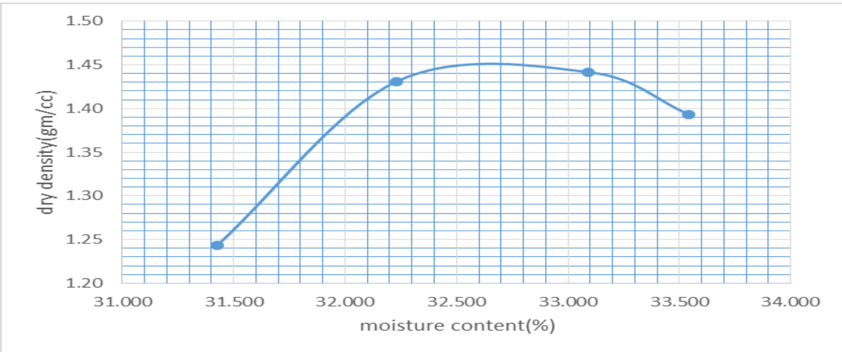


DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.33	10	13.24	20	0.571	0.674	4.312688822	3.37
1.42	30	13.24	20	0.726	0.882	5.483383686	4.41
1.45	65	13.24	20	0.83	1.038	6.268882175	5.19
MDD at 95	1.368						
cbr at 95%	4.85						

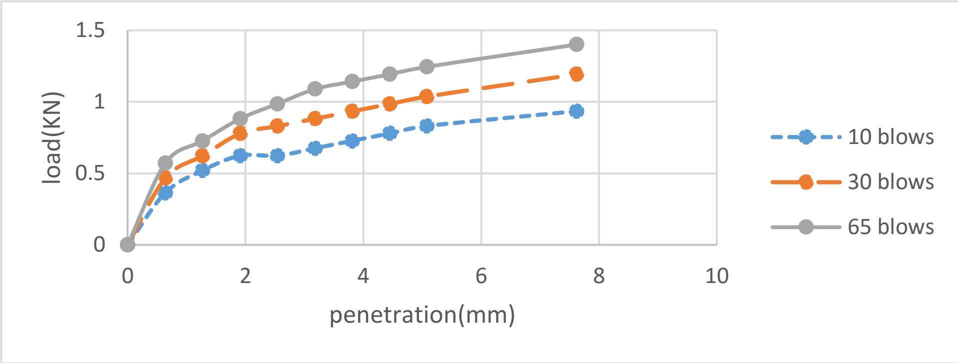


TP 6: Location of Sample: Addiss Ketema 1.5m

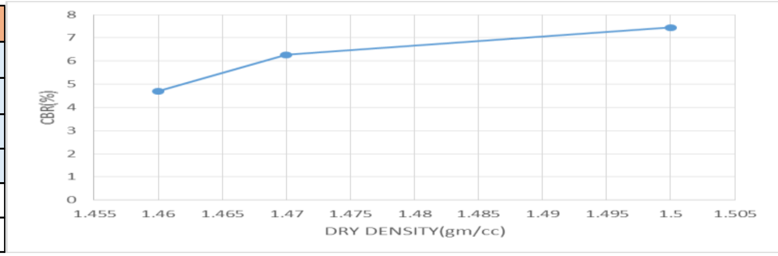
DESCRIPTION	OISTURE CONTENT DETERMINAT	Colum	Colum	Colum
Trial no.	1	2	3	4
Can no.	h2	a23	h4	g4
Mass of can,g	15.290	15.480	15.560	15.660
Mass of can+wet soil,g	36.870	34.680	41.300	32.780
Mass of can+dry soil,g	31.710	30.000	34.900	28.480
Mass of water,g	5.160	4.680	6.400	4.300
Mass of dry soil,g	16.420	14.520	19.340	12.820
Water content,%	**31.425**	**32.231**	**33.092**	**33.541**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	4555	4800	4825	4770
Mass of compacted soil	1549	1794	1819	1764
Volume of mold	948	948	948	948
Bulk density	1.63	1.89	1.92	1.86
Dry density	**1.26**	**1.48**	**1.40**	**1.27**



Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.46	1.47	1.5			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	7	0.363	9.000	0.467	11.000	0.571
1.27	10	0.519	12	0.623	14	0.726
1.91	12	0.623	15	0.778	17	0.882
2.54	12	0.623	16	0.830	19	0.986
3.18	13	0.674	17	0.882	21	1.089
3.81	14	0.726	18	0.934	22	1.141
4.45	15	0.778	19	0.986	23	1.193
5.08	16	0.830	20	1.038	24	1.245
7.62	18	0.934	23	1.193	27	1.401

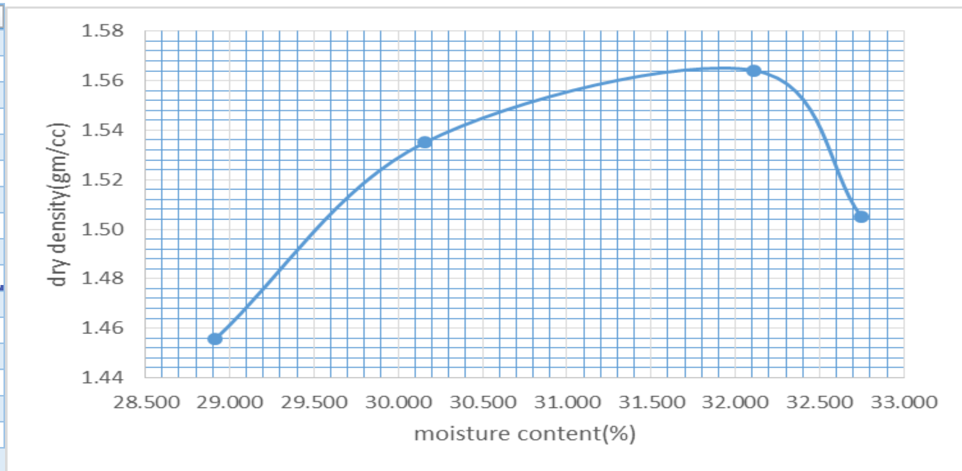


DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.46	10	13.24	20	0.623	0.83	4.705438066	4.15
1.47	30	13.24	20	0.83	1.038	6.268882175	5.19
1.5	65	13.24	20	0.986	1.245	7.447129909	6.225
MDD at 95%	1.41						
cbr at 95%	2.36						

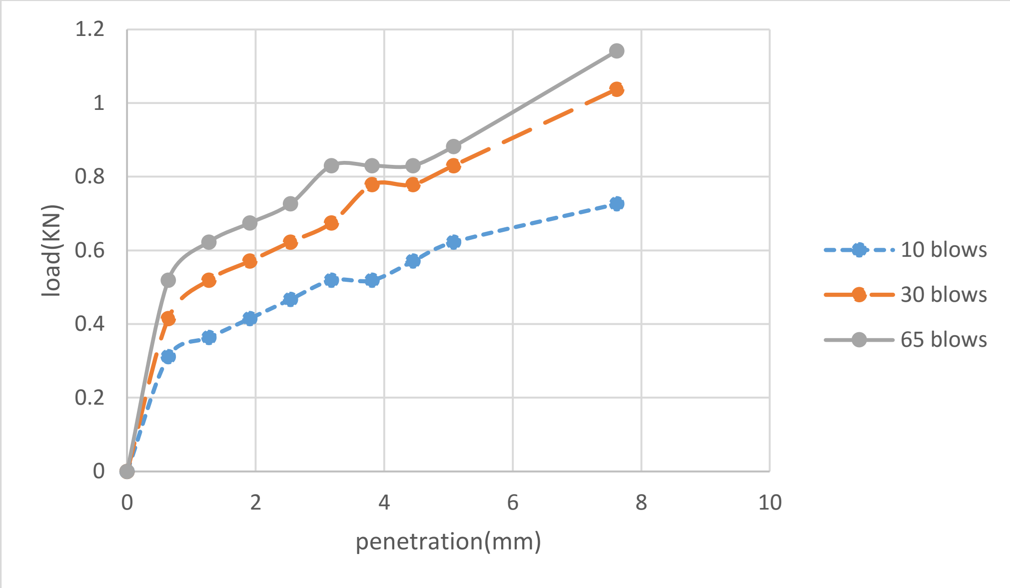


TP 6: Location of Sample: Addiss Ketema 2m

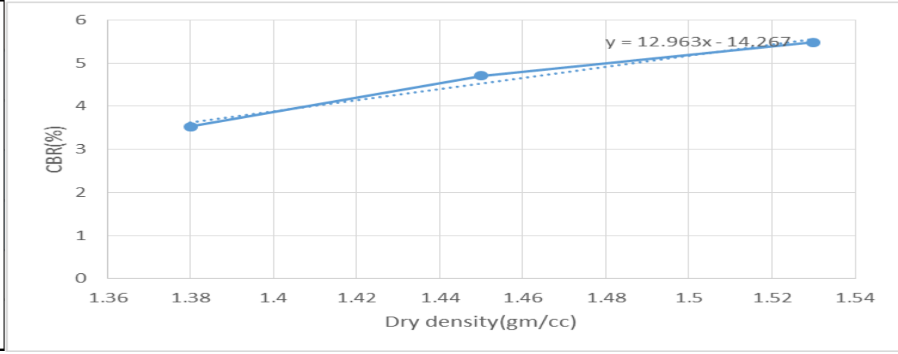
DESCRIPTION	CONTENT DE	Colum	Colum	Colum
Trial no.	**1**	**2**	**3**	**4**
Can no.	a6	j6	h3	k1
Mass of can,g	14.230	15.650	15.780	15.960
Mass of can+wet soil,g	34.560	33.156	39.850	32.540
Mass of can+dry soil,g	30.000	29.100	34.000	28.450
Mass of water,g	4.560	4.056	5.850	4.090
Mass of dry soil,g	15.770	13.450	18.220	12.490
Water content,%	**28.916**	**30.156**	**32.108**	**32.746**
DESCRIPTION	**NSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	4785	4900	4965	4900
Mass of compacted soil	1779	1894	1959	1894
Volume of mold	948	948	948	948
Bulk density	1.88	2.00	2.07	2.00
Dry density	**1.46**	**1.53**	**1.56**	**1.51**



Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.52	1.54	1.55			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	6	0.311	8.000	0.415	10.000	0.519
1.27	7	0.363	10	0.519	12	0.623
1.91	8	0.415	11	0.571	13	0.674
2.54	9	0.467	12	0.623	14	0.726
3.18	10	0.519	13	0.674	16	0.830
3.81	10	0.519	15	0.778	16	0.830
4.45	11	0.571	15	0.778	16	0.830
5.08	12	0.623	16	0.830	17	0.882
7.62	14	0.726	20	1.038	22	1.141

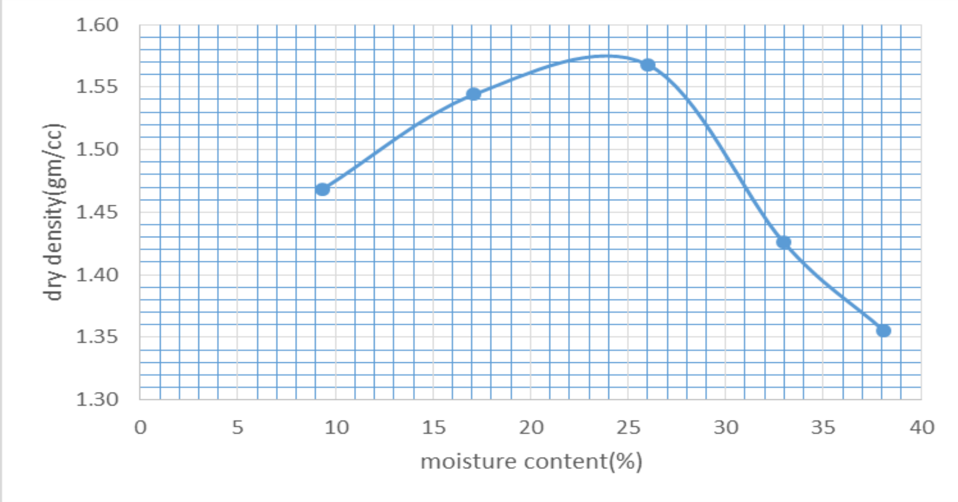


DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.38	10	13.24	20	0.467	0.623	3.527190332	3.115
1.45	30	13.24	20	0.623	0.83	4.705438066	4.15
1.53	65	13.24	20	0.726	0.882	5.483383686	4.41
MDD at 95%	1.489						
cbr at 95%	5.03						

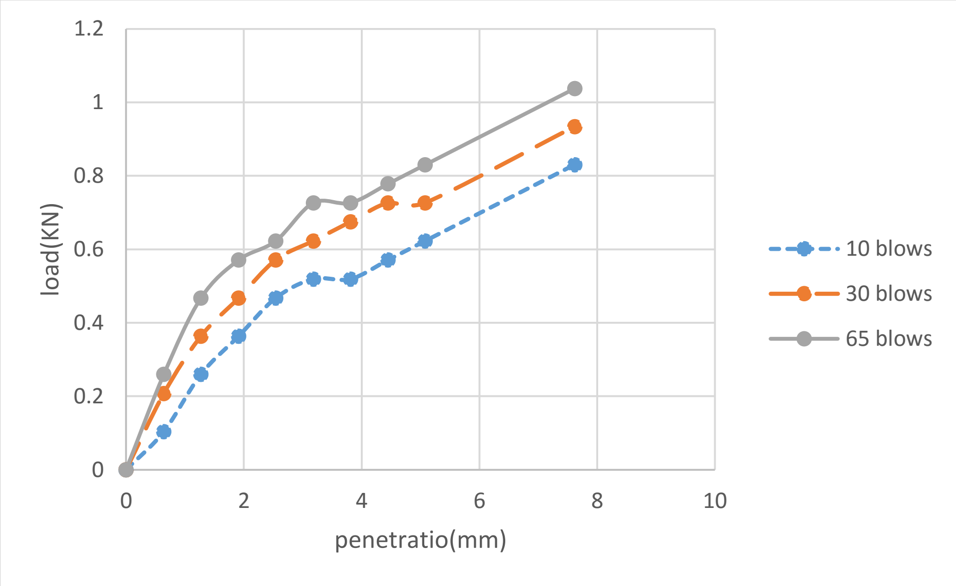


TP 7: Location of Sample: Entoto 1m

DESCRIPTION	OISTURE CONTENT DETERMINAT	Colum	Colum	Colum	Column
Trial no.	1	2	3	4	5
Can no.	b3	g7	j2	r9	s8
Mass of can,g	5	5	5	5	5
Mass of can+wet soil,g	181	183	165	243	208
Mass of can+dry soil,g	166	157	132	184	152
Mass of water,g	15	26	33	59	56
Mass of dry soil,g	161	152	127	179	147
water content,%	**9**	**17**	**26**	**33**	**38**
DESCRIPTION	**DRY DENSITY DETERMINATION**				
Trial No.	1	2	3	4	5
Mass of mold	5630	5630	5630	5630	5630
Mass of mold + compacted	7145	7337	7495	7420	7397
Mass of compacted soil	1515	1707	1865	1790	1767
Volume of mold	944	944	944	944	944
Bulk density	1.60	1.81	1.98	1.90	1.87
Dry density	**1.47**	**1.54**	**1.57**	**1.43**	**1.36**
MDD (g/cc)	1.58				
OMC (%)	24				

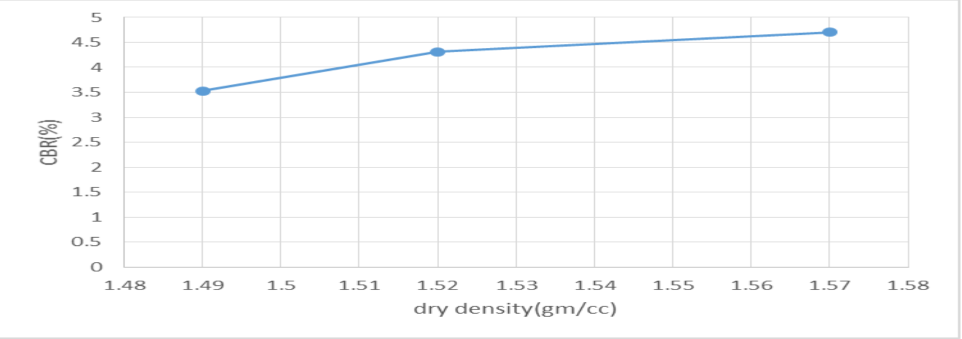


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.49	1.52	1.57			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	2	0.104	4.000	0.208	5.000	0.259
1.27	5	0.259	7	0.363	9	0.467
1.91	7	0.363	9	0.467	11	0.571
2.54	9	0.467	11	0.571	12	0.623
3.18	10	0.519	12	0.623	14	0.726
3.81	10	0.519	13	0.674	14	0.726
4.45	11	0.571	14	0.726	15	0.778
5.08	12	0.623	14	0.726	16	0.830
7.62	16	0.830	18	0.934	20	1.038



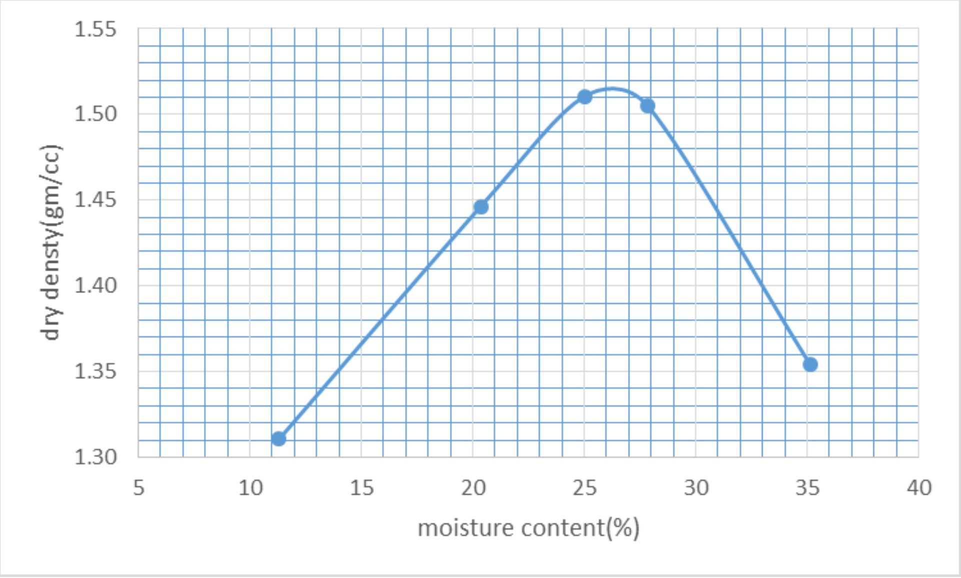
before soaking 3 sampls were remolded with omc 24.0%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.49	10	13.24	20	0.467	0.623	3.527190332	3.115
1.52	30	13.24	20	0.571	0.726	4.312688822	3.63
1.57	65	13.24	20	0.623	0.83	4.705438066	4.15
MDD at 95%	1.5						
cbr at 95%	3.822						

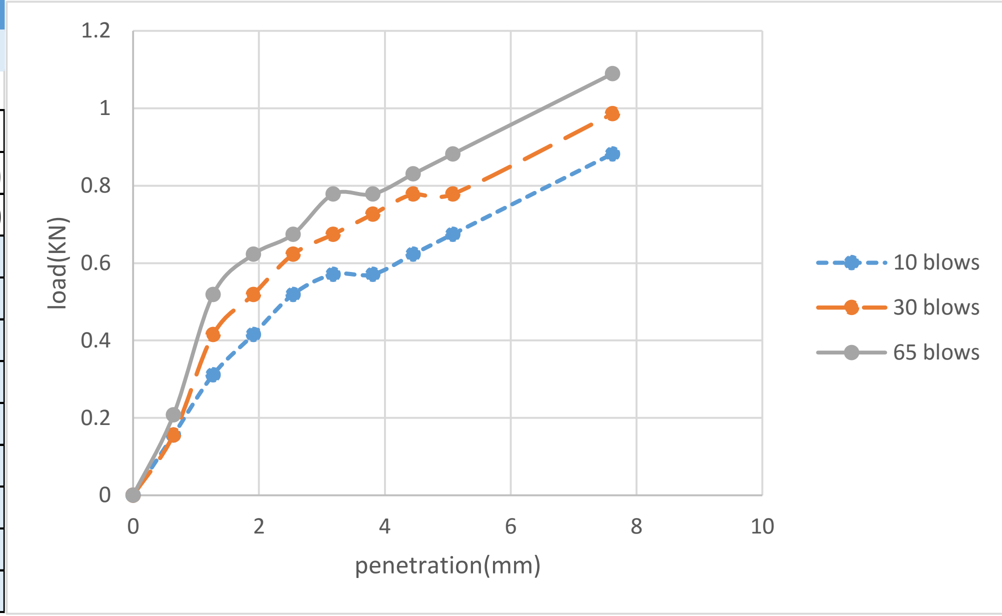


TP 7: Location of Sample: Entoto 1.5m

DESCRIPTION	MOISTURE CONTENT DETERMINATION	Colum	Colum	Colum	Column
Trial no.	1	2	3	4	5
Can no.	C5	F7	H4	G2	A1
Mass of can,g	5	5	5	5	5
Mass of can+wet soil,g	192	212	235	207	232
Mass of can+dry soil,g	173	177	189	163	173
Mass of water,g	19	35	46	44	59
Mass of dry soil,g	168	172	184	158	168
Water content,%	**11**	**20**	**25**	**28**	**35**
DESCRIPTION	**DRY DENSITY DETERMINATION**				
Trial No.	**1**	**2**	**3**	**4**	**5**
Mass of mold	3006	3006	3006	3006	3006
Mass of mold + compacted soil	7014	7281	7421	7455	7362
Mass of compacted soil	1383	1650	1790	1824	1731
Volume of mold	948	948	948	948	948
Bulk density	1.46	1.74	1.89	1.92	1.83
Dry density	**1.31**	**1.45**	**1.51**	**1.50**	**1.35**
MDD (g/cc)	1.53				
OMC (%)	26				

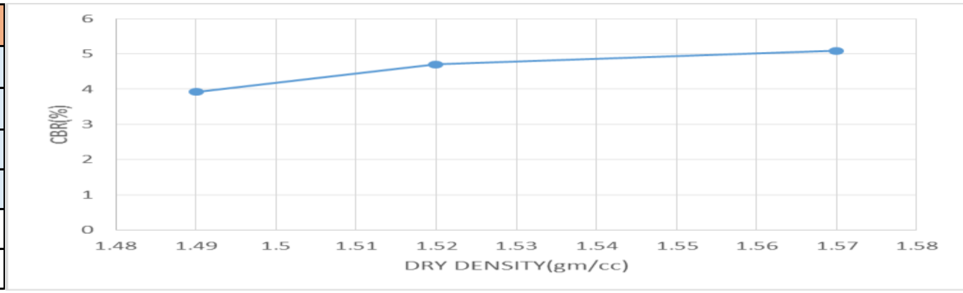


Density	5 layer						
No. of blows/layer	10	30	65				
Dry density (g/cm3)	1.48	1.5	1.51				
Penetration data 10 blow			30 blow		65 blow		
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)	
0	0	0	0	0	0	0	
0.64	3	0.156	3.000	0.156	4.000	0.208	
1.27	6	0.311	8	0.415	10	0.519	
1.91	8	0.415	10	0.519	12	0.623	
2.54	10	0.519	12	0.623	13	0.674	
3.18	11	0.571	13	0.674	15	0.778	
3.81	11	0.571	14	0.726	15	0.778	
4.45	12	0.623	15	0.778	16	0.830	
5.08	13	0.674	15	0.778	17	0.882	
7.62	17	0.882	19	0.986	21	1.089	



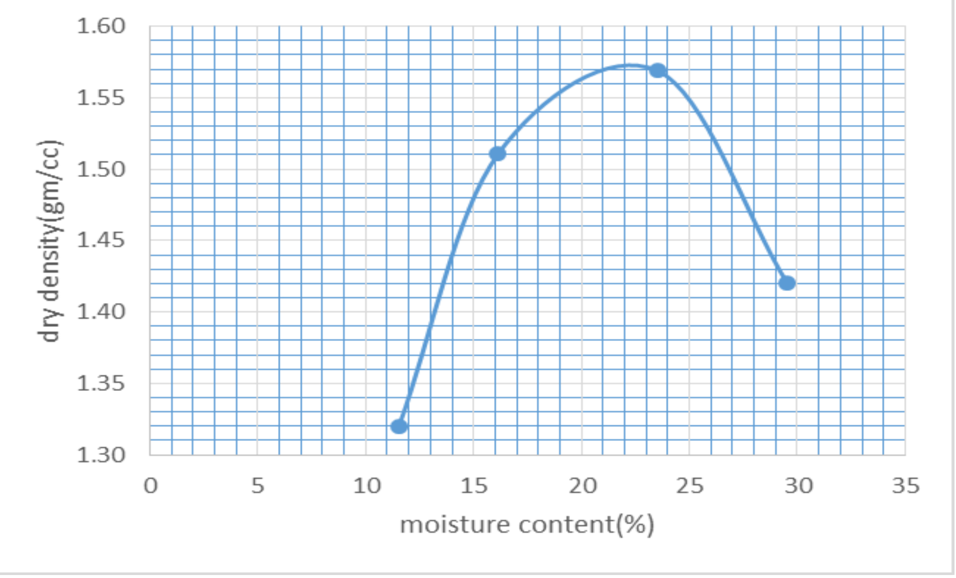
before soaking 3 sampls were remolded with omc 26.0%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.49	10	13.24	20	0.519	0.674	3.919939577	3.37
1.52	30	13.24	20	0.623	0.778	4.705438066	3.89
1.57	65	13.24	20	0.674	0.882	5.090634441	4.41
MDD at 95%	1.45						
cbr at 95%	3.8						

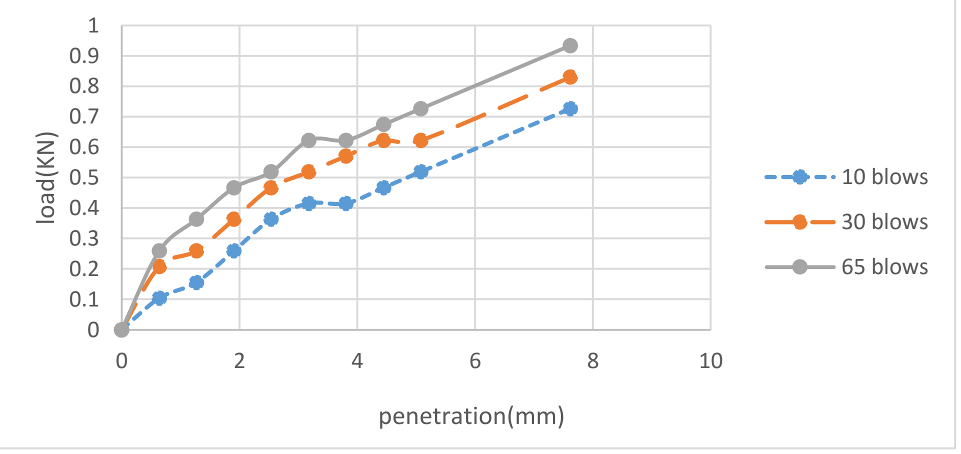


TP 7: Location of Sample: Entoto 2m

DESCRIPTION	E CONTENT DETE	Colum	Colum	Column
Trial no.	1	2	4	5
Can no.	b9	h4	j2	s6
Mass of can,g	5	5	5	5
Mass of can+wet soil,g	237	257	252	277
Mass of can+dry soil,g	213	222	205	215
Mass of water,g	24	35	47	62
Mass of dry soil,g	208	217	200	210
water content,%	**12**	**16**	**24**	**30**
DESCRIPTION	**DENSITY DETERMINATION**			
Trial No.	1	2	4	5
Mass of mold	3006	3006	3006	3006
Mass of mold + compacted soil	7064	7331	7505	7412
Mass of compacted soil	1396	1663	1837	1744
Volume of mold	948	948	948	948
Bulk density	1.47	1.75	1.94	1.84
Dry density	**1.32**	**1.51**	**1.57**	**1.42**
MDD (g/cc)	1.58			
OMC (%)	24.6			

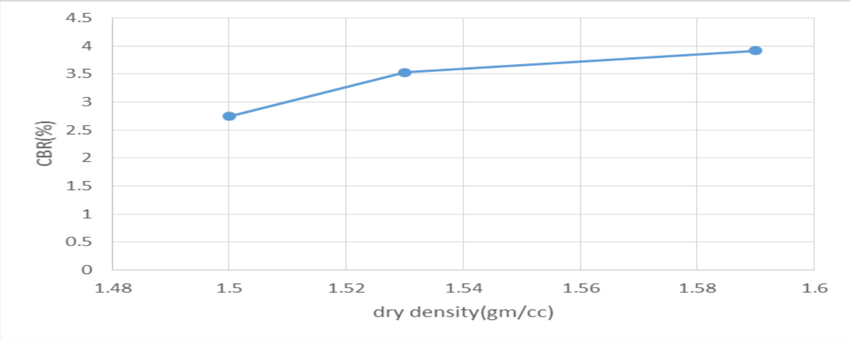


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.5	1.53	1.59			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	2	0.104	4.000	0.208	5.000	0.259
1.27	3	0.156	5	0.259	7	0.363
1.91	5	0.259	7	0.363	9	0.467
2.54	7	0.363	9	0.467	10	0.519
3.18	8	0.415	10	0.519	12	0.623
3.81	8	0.415	11	0.571	12	0.623
4.45	9	0.467	12	0.623	13	0.674
5.08	10	0.519	12	0.623	14	0.726
7.62	14	0.726	16	0.830	18	0.934



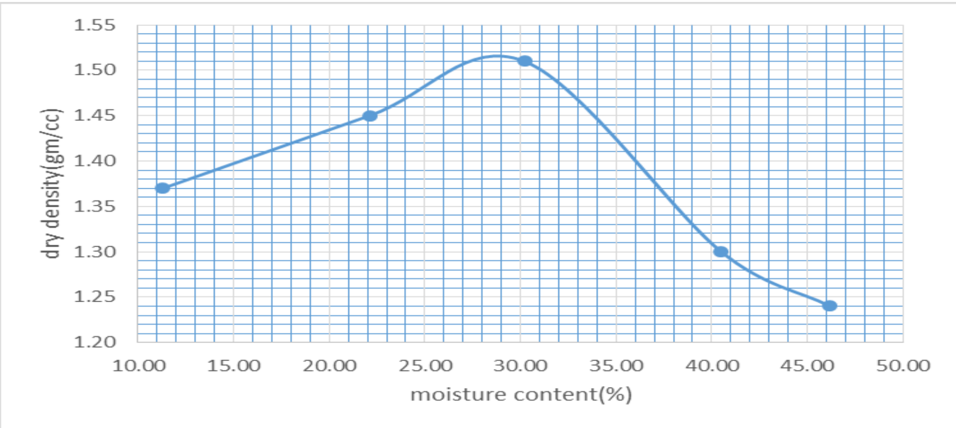
before soaking 3 sampls were remolded with omc 24.6%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.5	10	13.24	20	0.363	0.519	2.741691843	2.595
1.53	30	13.24	20	0.467	0.623	3.527190332	3.115
1.59	65	13.24	20	0.519	0.726	3.919939577	3.63
MDD at 95%	1.5						
cbr at 95%	3.799						

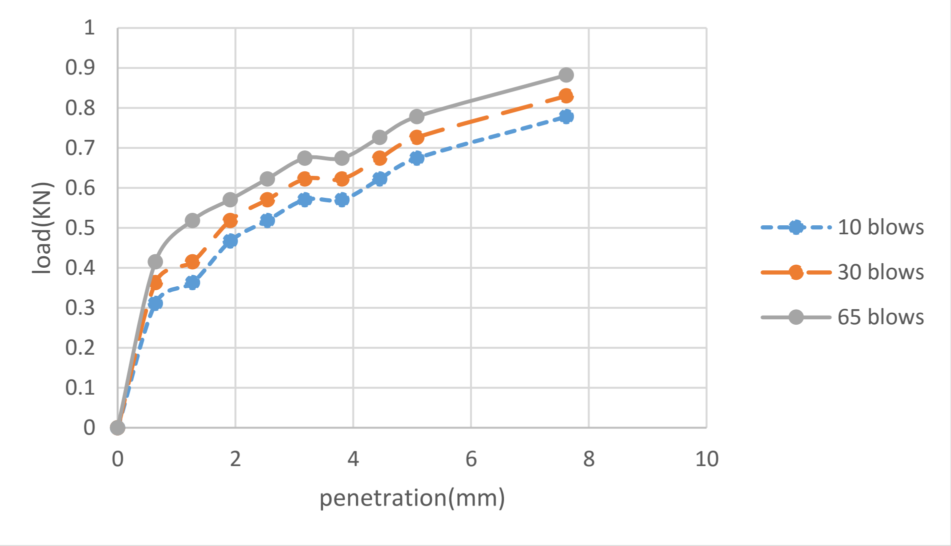


TP 8: Location of Sample: Weyra sefer 1m

DESCRIPTI	MOISTURE CONTENT DETERMINATIO	Colum	Colum	Colum	Column
Trial no.	1	2	3	4	5
Can no.	J2	C7	D5	B2	A5
Mass of can,g	5	5	5	5	5
Mass of can+	172	154	186	182	198
Mass of can+	155	127	144	131	137
Mass of wate	17	27	42	51	61
Mass of dry s	150	122	139	126	132
Water conten	**11.30**	**22.10**	**30.20**	**40.50**	46.20
DESCRIPTION	**DRY DENSITY DETERMINATION**				
Trial No.	**1**	**2**	**3**	**4**	**5**
Mass of mold	5630	5630	5630	5630	5630
Mass of mold	7070	7304	7484	7353	7338
Mass of comp	1440	1674	1854	1723	1708
Volume of mo	944	944	944	944	944
Bulk density	1.53	1.58	1.75	1.83	1.81
Dry density	**1.37**	**1.45**	**1.51**	**1.30**	**1.24**
MDD (g/cc)	1.52				
OMC (%)	29				

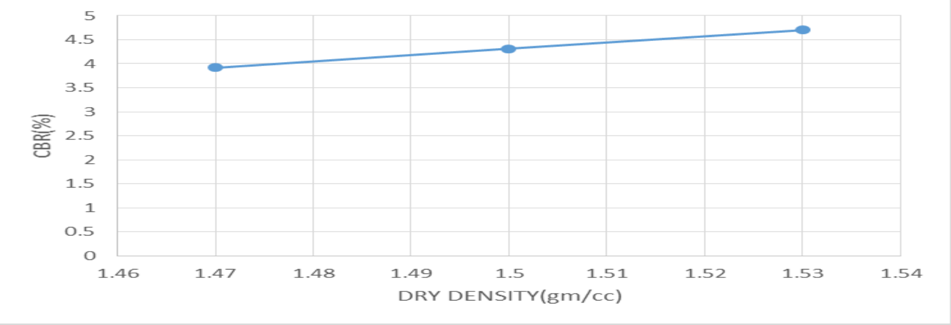


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.47	1.5	1.53			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	6	0.311	7.000	0.363	8.000	0.415
1.27	7	0.363	8	0.415	10	0.519
1.91	9	0.467	10	0.519	11	0.571
2.54	10	0.519	11	0.571	12	0.623
3.18	11	0.571	12	0.623	13	0.674
3.81	11	0.571	12	0.623	13	0.674
4.45	12	0.623	13	0.674	14	0.726
5.08	13	0.674	14	0.726	15	0.778
7.62	15	0.778	16	0.830	17	0.882



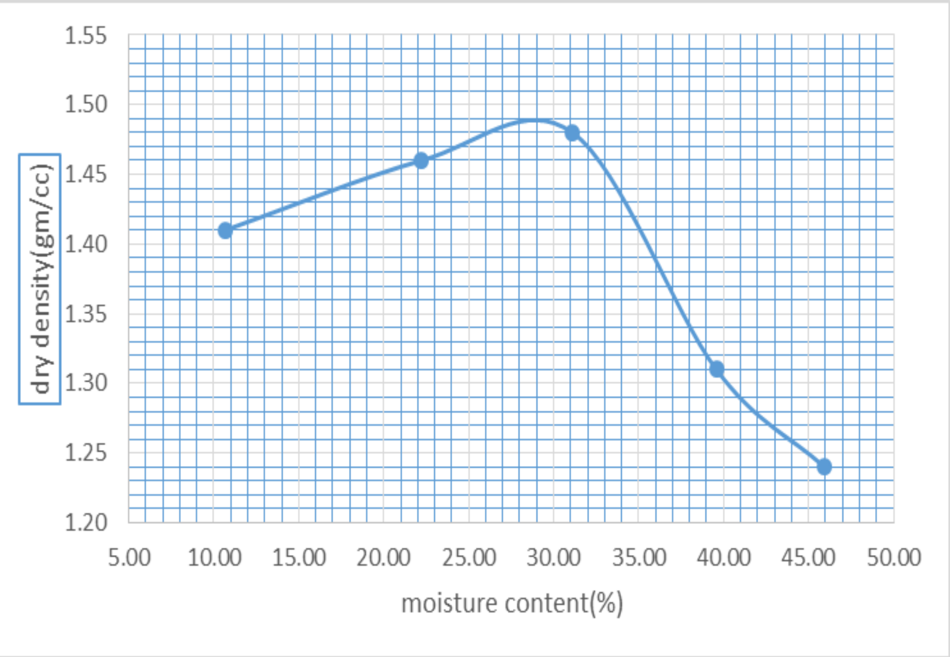
before soaking 3 sampls were remolded with omc 29%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.47	10	13.24	20	0.519	0.674	3.919939577	3.37
1.5	30	13.24	20	0.571	0.726	4.312688822	3.63
1.53	65	13.24	20	0.623	0.778	4.705438066	3.89
MDD at 95%	1.44						
cbr at 95%	3.58						

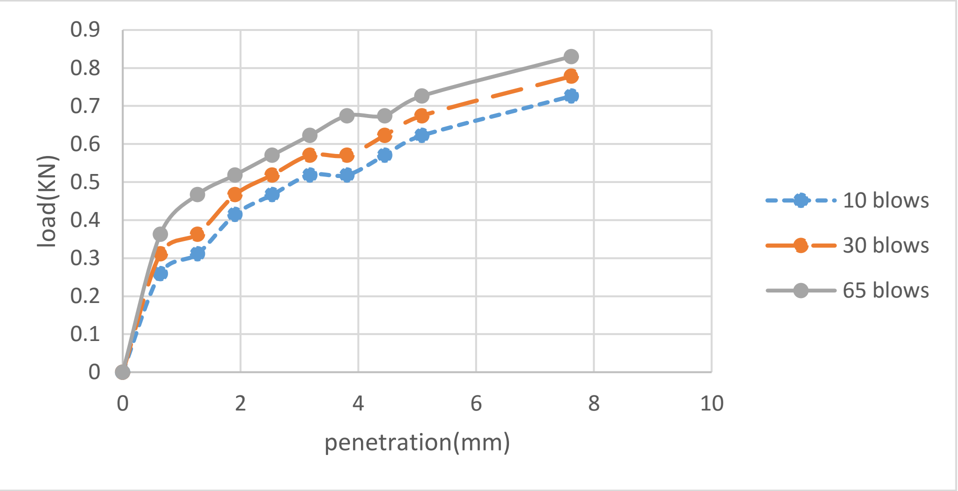


TP 8: Location of Sample: Weyra sefer 1.5m

DESCRIPTION	MOISTURE CONTENT DETERMINATIC	Colum	Colum	Colum	Column
Trial no.	1	2	3	4	5
Can no.	C5	J7	S3	H4	A1
Mass of can,g	5	5	5	5	5
Mass of can+wet soi	192	203	182	199	221
Mass of can+dry soi	174	167	140	144	153
Mass of water,g	18	36	42	55	69
Mass of dry soil,g	169	162	135	139	149
Water content,%	**10.65**	**22.22**	**31.11**	**39.57**	45.95
DESCRIPTION	**DRY DENSITY DETERMINATION**				
Trial No.	**1**	**2**	**3**	**4**	**5**
Mass of mold	5630	5630	5630	5630	5630
Mass of mold + com	7104	7320	7466	7350	7340
Mass of compacted	1474	1690	1836	1720	1710
Volume of mold	944	944	944	944	944
Bulk density	1.56	1.58	1.75	1.82	1.81
Dry density	**1.41**	**1.46**	**1.48**	**1.31**	**1.24**
MDD (g/cc)	1.48				
OMC (%)	29				

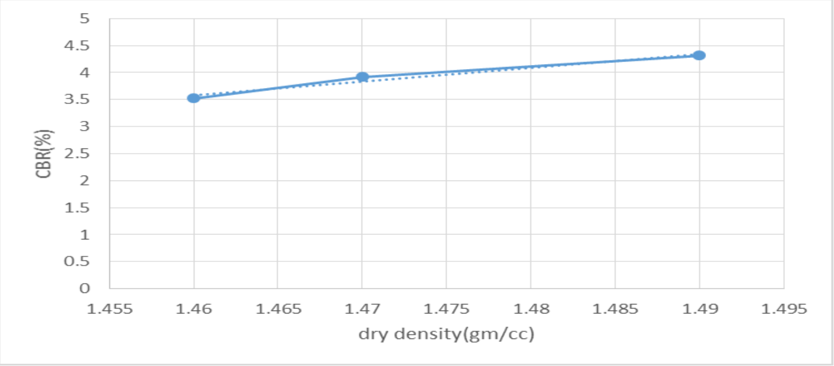


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.46	1.47	1.49			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	5	0.259	6.000	0.311	7.000	0.363
1.27	6	0.311	7	0.363	9	0.467
1.91	8	0.415	9	0.467	10	0.519
2.54	9	0.467	10	0.519	11	0.571
3.18	10	0.519	11	0.571	12	0.623
3.81	10	0.519	11	0.571	13	0.674
4.45	11	0.571	12	0.623	13	0.674
5.08	12	0.623	13	0.674	14	0.726
7.62	14	0.726	15	0.778	16	0.830



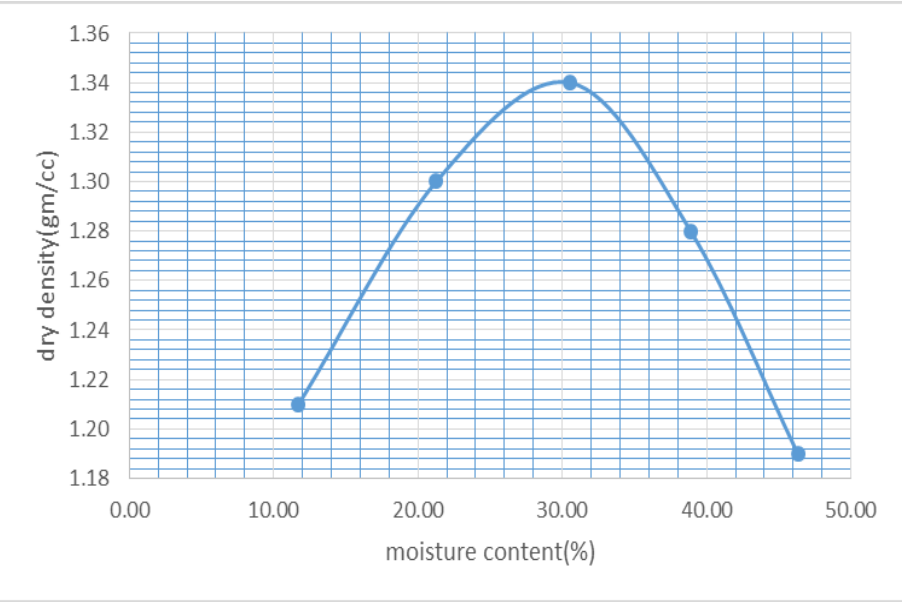
before soaking 3 sampls were remolded with omc 29%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.46	10	13.24	20	0.467	0.623	3.527190332	3.115
1.47	30	13.24	20	0.519	0.674	3.919939577	3.37
1.49	65	13.24	20	0.571	0.726	4.312688822	3.63
MDD at 95%	1.41						
cbr at 95%	2.22						

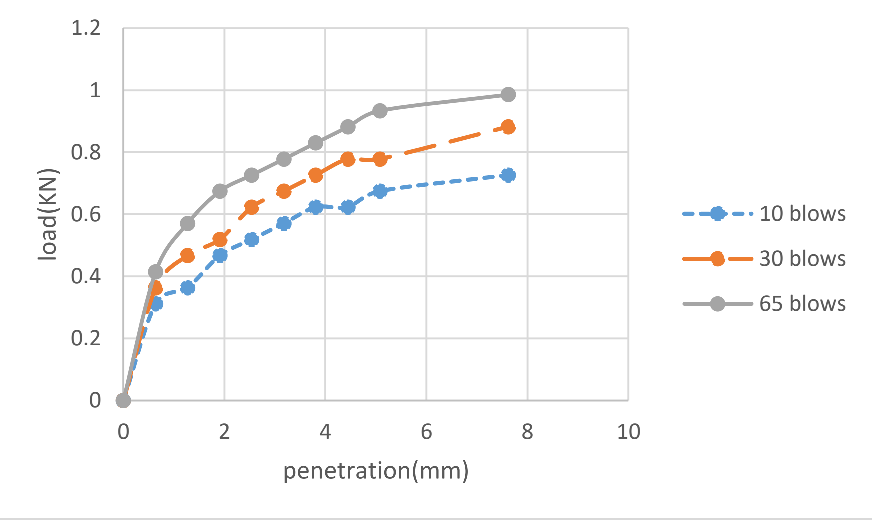


TP 8: Location of Sample: Weyra sefer 2m

DESCRIPTION	ISTURE CONTENT DETERMINA	Colum	Colum	Colum	Column
Trial no.	**1**	**2**	**3**	**4**	5
Can no.	c1	f3	h1	G2	s6
Mass of can,g	5	5	5	5	5
Mass of can+wet soil,g	186	216	176	205	223
Mass of can+dry soil,g	167	179	136	149	154
Mass of water,g	19	37	40	56	69
Mass of dry soil,g	162	174	131	144	149
Water content,%	**11.73**	**21.26**	**30.53**	**38.89**	46.31
DESCRIPTION	**DRY DENSITY DETERMINATION**				
Trial No.	**1**	**2**	**3**	**4**	**5**
Mass of mold	3006	3006	3006	3006	3006
Mass of mold + compacted soil	6910	7122	7284	7315	7280
Mass of compacted soil	1280	1492	1654	1685	1650
Volume of mold	948	948	948	948	948
Bulk density	1.35	1.58	1.75	1.78	1.74
Dry density	**1.21**	**1.30**	**1.34**	**1.28**	**1.19**
MDD (g/cc)	1.34				
OMC (%)	31				

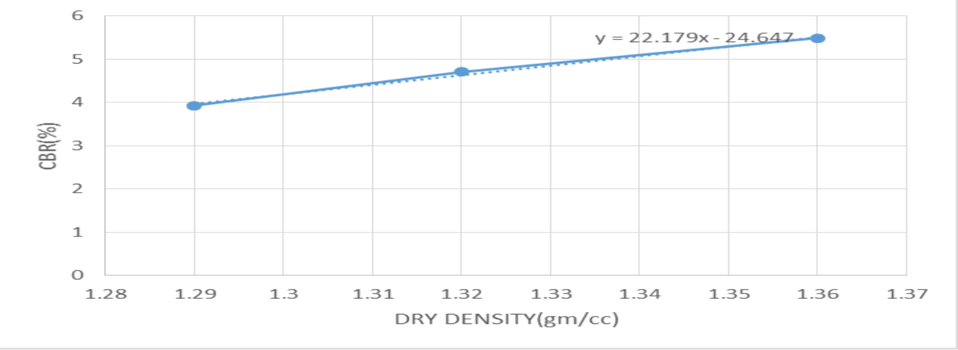


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.29	1.32	1.36			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.05188)
0	0	0	0	0	0	0
0.64	6	0.311	7.000	0.363	8.000	0.415
1.27	7	0.363	9	0.467	11	0.571
1.91	9	0.467	10	0.519	13	0.674
2.54	10	0.519	12	0.623	14	0.726
3.18	11	0.571	13	0.674	15	0.778
3.81	12	0.623	14	0.726	16	0.830
4.45	12	0.623	15	0.778	17	0.882
5.08	13	0.674	15	0.778	18	0.934
7.62	14	0.726	17	0.882	19	0.986



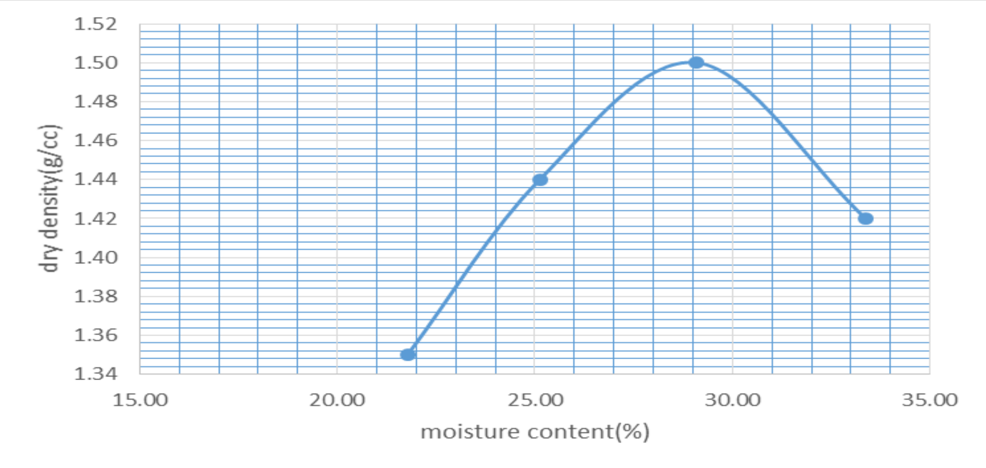
before soaking 3 sampls were remolded with omc 31%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.29	10	13.24	20	0.519	0.674	3.919939577	3.37
1.32	30	13.24	20	0.623	0.778	4.705438066	3.89
1.36	65	13.24	20	0.726	0.934	5.483383686	4.67
MDD at 95%	1.27						
cbr at 95%	3.59						

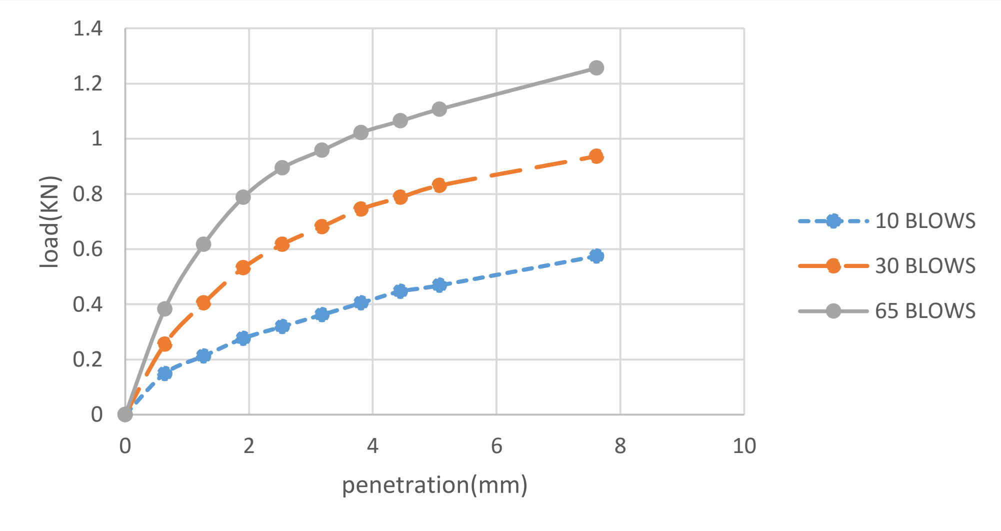


TP 9: Location of Sample: Winget 1m

DESCRIPTION	STURE CONTENT DETERMINAT	Column1	Column2	Column3
Trial no.	1	2	3	4
Can no.	A6	B4	B7	A2
Mass of can,g	30.84	30.50	31.31	30.17
Mass of can+wet soil,g	180.14	140.97	121.68	121.98
Mass of can+dry soil,g	153.77	118.79	101.31	99.01
Mass of water,g	26.77	22.18	20.37	22.97
Mass of dry soil,g	122.93	88.29	70.00	68.84
Water content,%	**21.78**	**25.12**	**29.10**	**33.37**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	1	2	3	4
Mass of mold	4982.00	4982.00	4982.00	4982.00
Mass of mold + compacted soil	8474.00	8814.00	9107.00	8999.00
Mass of compacted soil	3492.00	3832.00	4125.00	4017.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.64	1.80	1.94	1.89
Dry density	**1.35**	**1.44**	**1.50**	**1.42**
MDD (g/cc)	1.53			
OMC (%)	29.2			

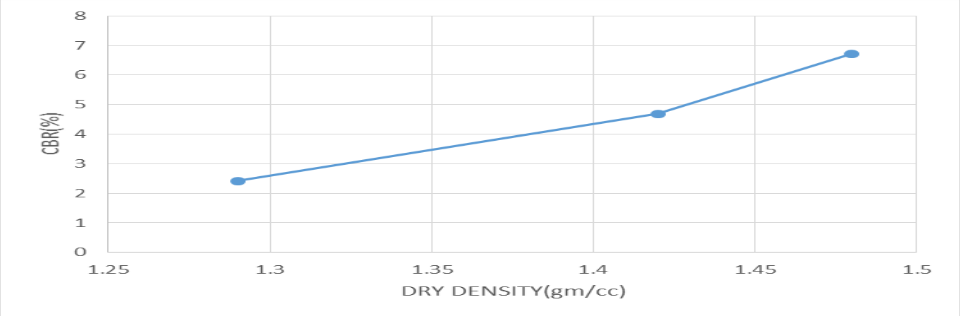


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.3	1.4	1.5			
Penetration data 10 blow		30 blow		65 blow		
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.02129)
0	0	0	0	0	0	0
0.64	7	0.149	12.000	0.255	18.000	0.383
1.27	10	0.213	19	0.405	29	0.617
1.91	13	0.277	25	0.532	37	0.788
2.54	15	0.319	29	0.617	42	0.894
3.18	17	0.362	32	0.681	45	0.958
3.81	19	0.405	35	0.745	48	1.022
4.45	21	0.447	37	0.788	50	1.065
5.08	22	0.468	39	0.830	52	1.107
7.62	27	0.575	44	0.937	59	1.256



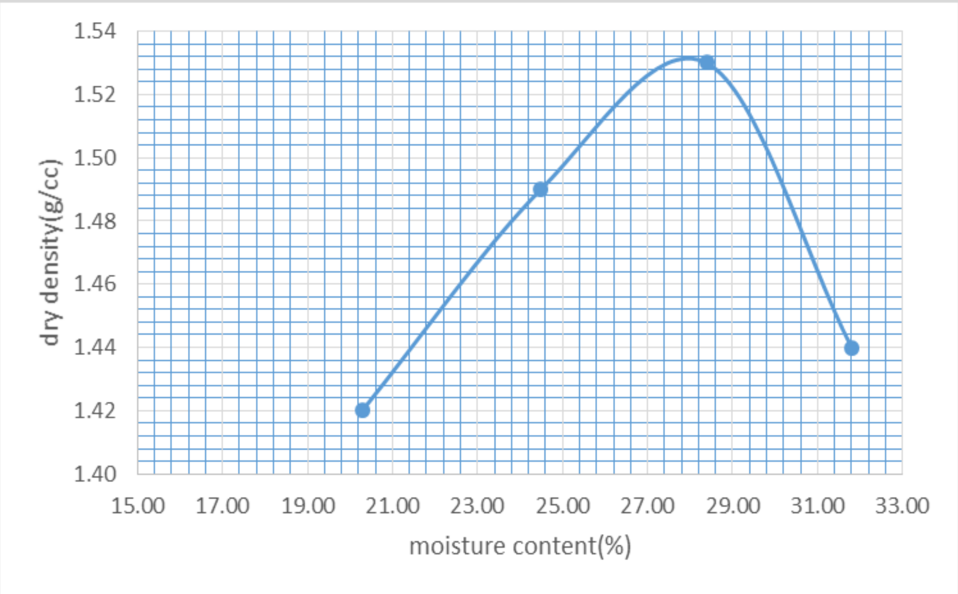
before soaking 3 sampls were remolded with omc 29.20%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.29	10	13.24	20	0.32	0.47	2.416918429	2.35
1.42	30	13.24	20	0.62	0.83	4.682779456	4.15
1.48	65	13.24	20	0.89	1.1	6.722054381	5.5
MDD at 95%	1.45						
cbr at 95%	6.1						

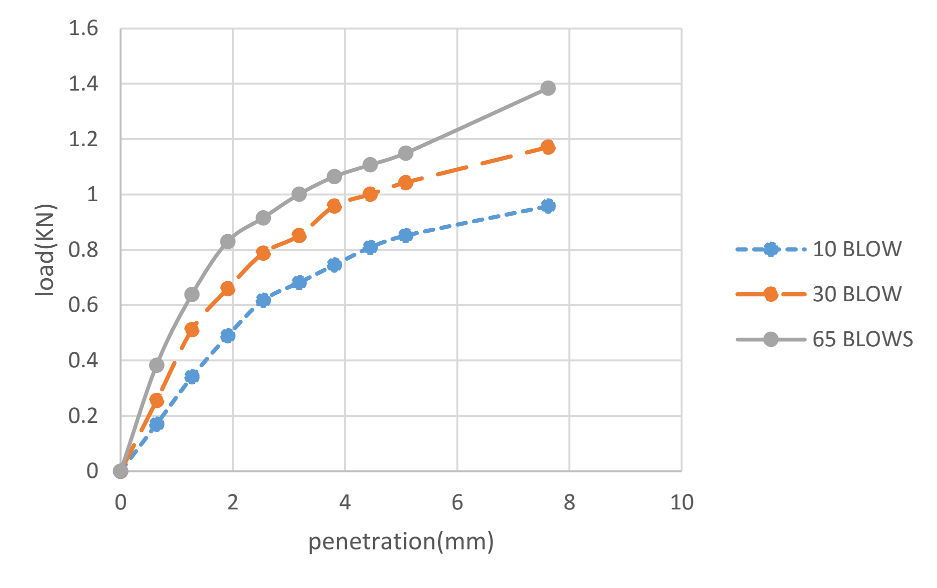


TP 9: Location of Sample: Winget 1.5m

Trial no.	1	2	3	4
Can no.	C2	B3	B1	A5
Mass of can,g	20.37	20.99	19.92	20.27
Mass of can+wet soil,g	121.95	103.19	122.36	111.92
Mass of can+dry soil,g	104.82	87.02	99.71	90.29
Mass of water,g	17.13	16.17	22.65	21.63
Mass of dry soil,g	84.45	66.03	79.79	68.02
Water content,%	**20.28**	**24.49**	**28.39**	**31.80**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	1	2	3	4
Mass of mold	4982.00	4982.00	4982.00	4982.00
Mass of mold + compacted so	8621.00	8923.00	9146.00	9017.00
Mass of compacted soil	3639.00	3941.00	4164.00	4035.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.71	1.86	1.96	1.90
Dry density	**1.42**	**1.49**	**1.53**	**1.44**
MDD (g/cc)	1.53			
OMC (%)	27.89			

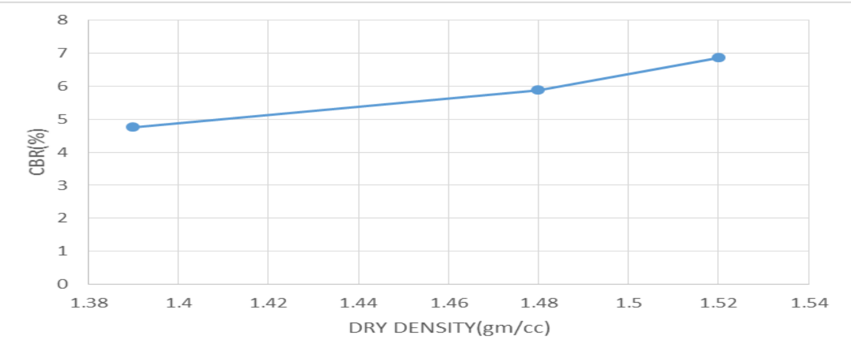


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.39	1.48	1.52			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load RF(.02129)
0	0	0	0	0	0	0
0.64	8	0.170	12.000	0.255	18.000	0.383
1.27	16	0.341	24	0.511	30	0.639
1.91	23	0.490	31	0.660	39	0.830
2.54	29	0.617	37	0.788	43	0.915
3.18	32	0.681	40	0.852	47	1.001
3.81	35	0.745	45	0.958	50	1.065
4.45	38	0.809	47	1.001	52	1.107
5.08	40	0.852	49	1.043	54	1.150
7.62	45	0.958	55	1.171	65	1.384



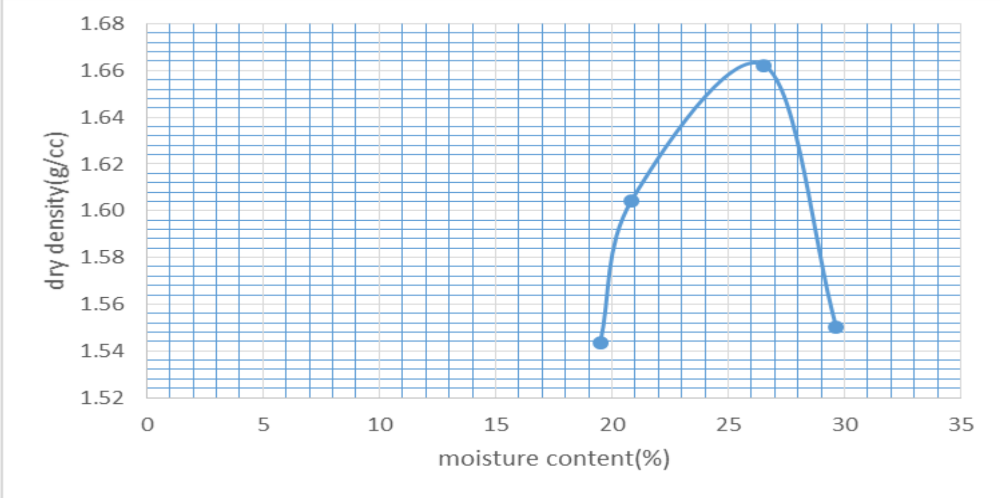
before soaking 3 sampls were remolded with omc 27.80%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.39	10	13.24	20	0.63	0.86	4.758308157	4.3
1.48	30	13.24	20	0.78	1.03	5.891238671	5.15
1.52	65	13.24	20	0.91	1.35	6.873111782	6.75
MDD at 95%	1.45						
cbr at 95%	5.4						

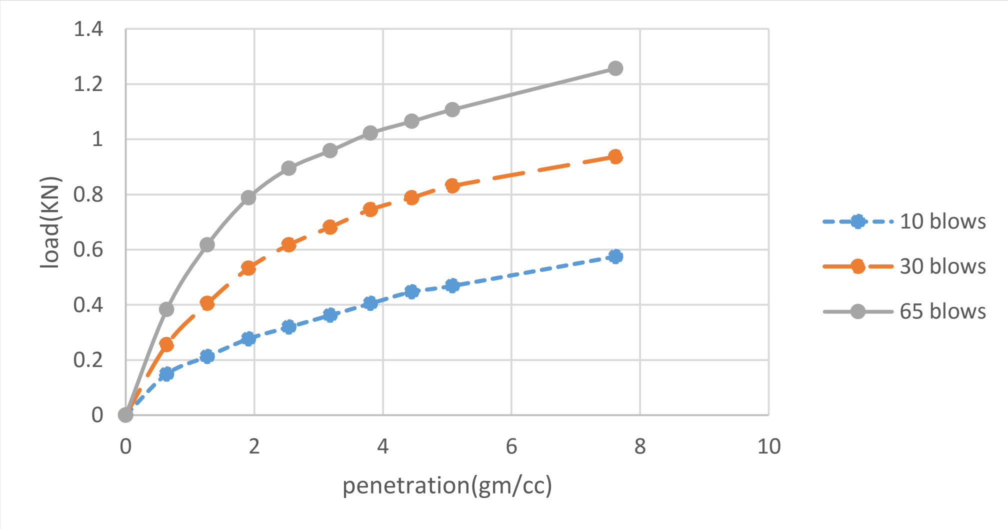


TP 9: Location of Sample: Winget 2m

DESCRIPTION	CONTENT DETE	Colum	Colum	Colum
Trial no.	**1**	**2**	**3**	**4**
Can no.	B4	F7	H4	H3
Mass of can,g	15	15	15	15
Mass of can+wet soil,	260	230	341	289
Mass of can+dry soil,	220	193	273	226
Mass of water,g	40	37	69	63
Mass of dry soil,g	205	178	258	211
Water content,%	**19**	**21**	**27**	**30**
DESCRIPTION	**DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	4982	4982	4982	4982
Mass of mold + comp	8900	9100	9450	9250
Mass of compacted s	3918	4118	4468	4268
Volume of mold	2124	2124	2124	2124
Bulk density	1.84	1.94	2.10	2.01
Dry density	**1.54**	**1.60**	**1.66**	**1.55**
mdd	1.665			
omc	26			

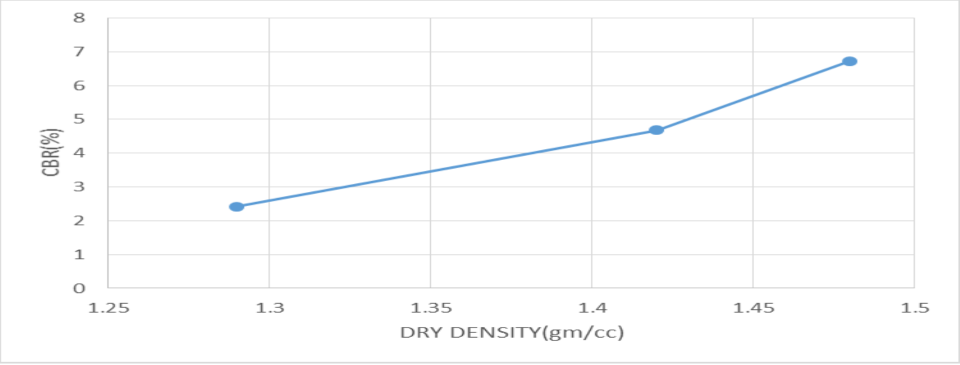


Density	**5 layer**						
No. of blows/layer	10	30	65				
Penetration data 10 blow			30 blow		65 blow		
Penetration (mm)	Dial	Load	**Dial**	**Load**	**Dial**	**Load RF(.02129)**	
0	0	0	0	0	0	0	
0.64	7	0.149	12.000	0.255	18.000	0.383	
1.27	10	0.213	19	0.405	29	0.617	
1.91	13	0.277	25	0.532	37	0.788	
2.54	15	0.319	29	0.617	42	0.894	
3.18	17	0.362	32	0.681	45	0.958	
3.81	19	0.405	35	0.745	48	1.022	
4.45	21	0.447	37	0.788	50	1.065	
5.08	22	0.468	39	0.830	52	1.107	
7.62	27	0.575	44	0.937	59	1.256	



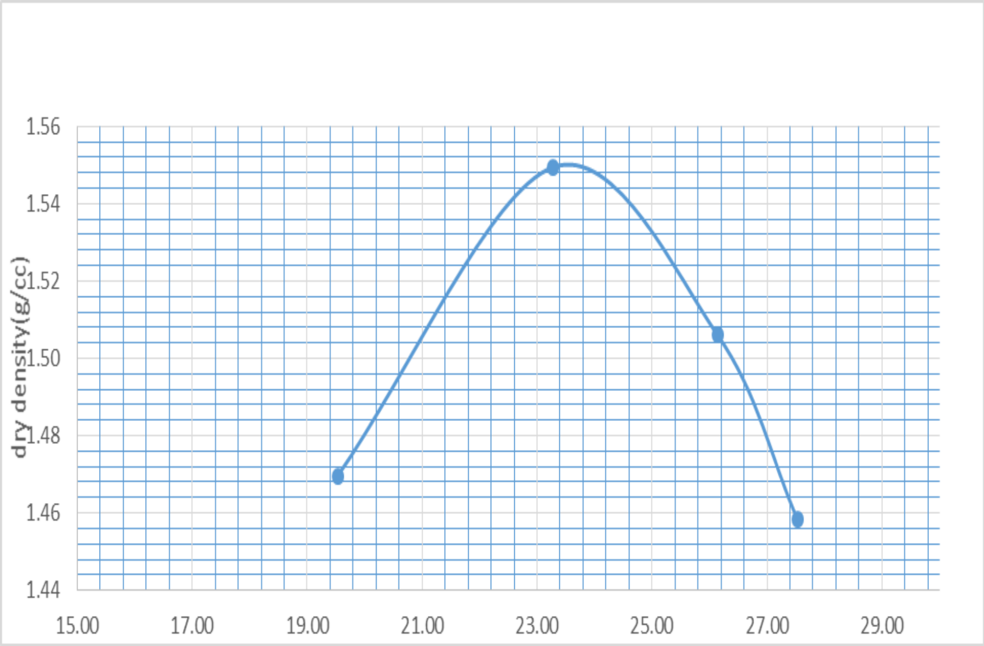
before soaking 3 sampls were remolded with omc 29.20%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.29	10	13.24	20	0.32	0.47	2.416918429	2.35
1.42	30	13.24	20	0.62	0.83	4.682779456	4.15
1.48	65	13.24	20	0.89	1.1	6.722054381	5.5
MDD at 95%	1.44						
cbr at 95%	6.2						

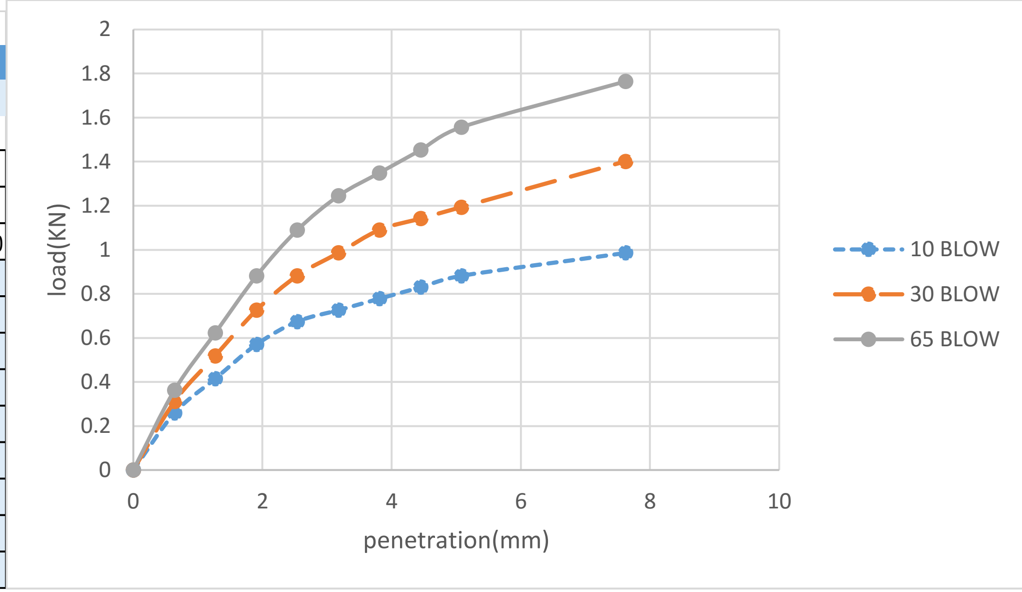


TP 10: Location of Sample: Megenagna 1m

DESCRIPTION	MOISTURE CONTENT DETERMINATION	Colum	Colum	Colum
Trial no.	**1**	**2**	**3**	**4**
Can no.	A2	D5	G7	F1
Mass of can,g	42.81	41.46	46.97	44.31
Mass of can+wet soil,g	182.73	225.30	222.27	214.08
Mass of can+dry soil,g	159.87	190.59	185.94	177.43
Mass of water,g	22.86	34.71	36.33	36.65
Mass of dry soil,g	117.06	149.13	138.97	133.12
Water content,%	**19.53**	**23.27**	**26.14**	**27.53**
DESCRIPTION	**DRY DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	5433.00	5433.00	5433.00	5433.00
Mass of mold + compact	9164.00	9490.00	9468.00	9383.00
Mass of compacted soil	3731.00	4057.00	4035.00	3950.00
Volume of mold	2124.00	2124.00	2124.00	2124.00
Bulk density	1.76	1.91	1.90	1.86
Dry density	**1.47**	**1.55**	**1.51**	**1.46**
MDD (g/cc)	1.55			
OMC (%)	23.3			

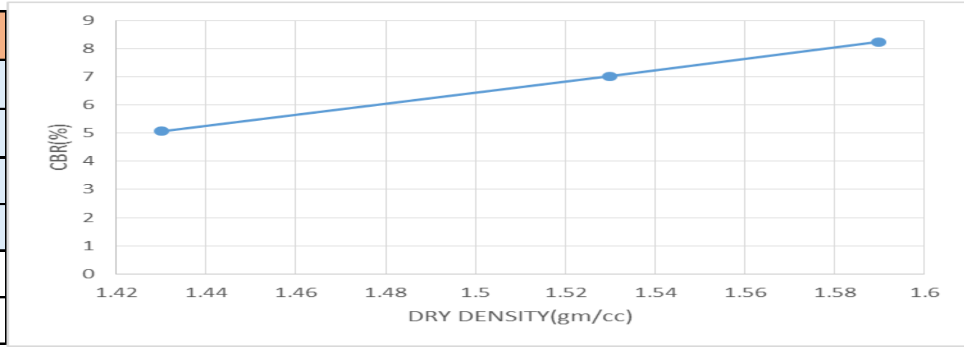


Megenagna 1m						
Density	**5 layer**					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.43	1.53	1.59			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	**Dial**	**Load**	**Dial**	**Load**
0	0	0	0	0	0	0
0.64	5	0.259	6.000	0.311	7.000	0.363
1.27	8	0.415	10	0.519	12	0.623
1.91	11	0.571	14	0.726	17	0.882
2.54	13	0.674	17	0.882	21	1.089
3.18	14	0.726	19	0.986	24	1.245
3.81	15	0.778	21	1.089	26	1.349
4.45	16	0.830	22	1.141	28	1.453
5.08	17	0.882	23	1.193	30	1.556
7.62	19	0.986	27	1.401	34	1.764



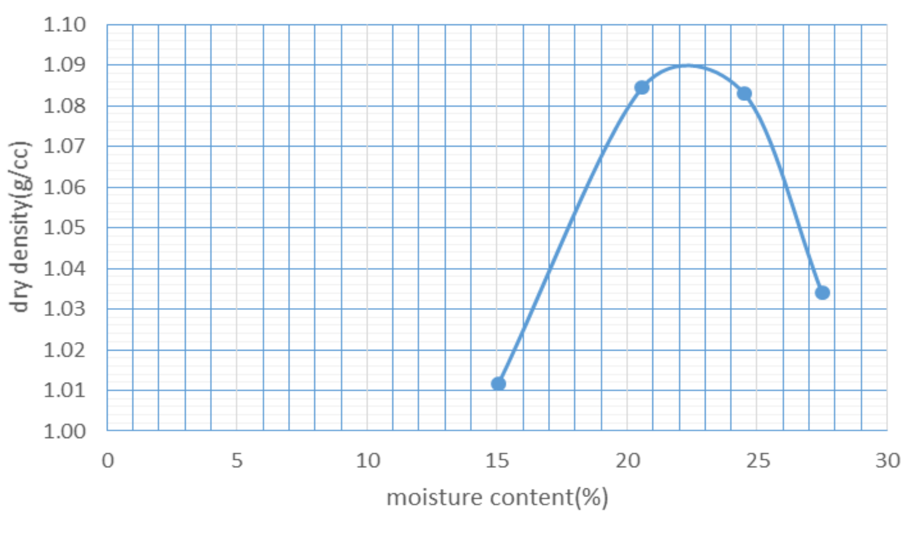
before soaking 3 sampls were remolded with omc 23.30%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.43	10	13.24	20	0.67	0.88	5.060423	4.4
1.53	30	13.24	20	0.93	1.19	7.0241692	5.95
1.59	65	13.24	20	1.09	1.56	8.2326284	7.8
MDD at 95%	1.47						
cbr at 95%	6						

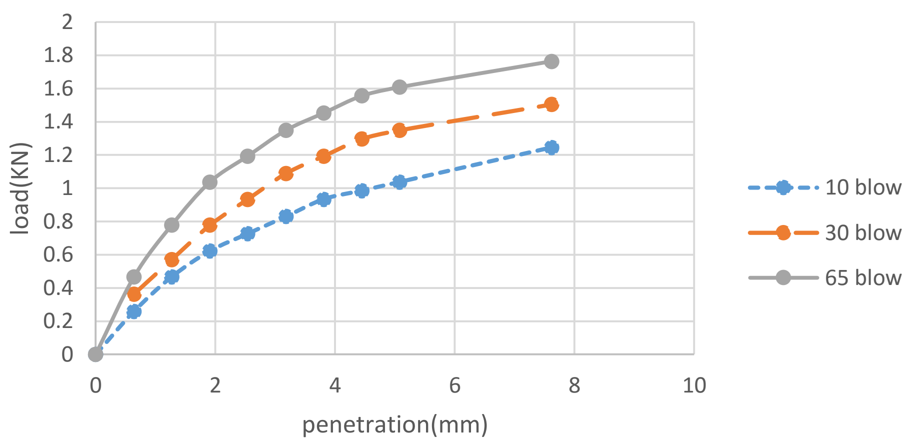


TP 10: Location of Sample: Megenagna 1.5m

DESCRIPTION	RE CONTENT DETER	Colum	Colum	Colum
Trial no.	**1**	**2**	**3**	**4**
Can no.	B4	F7	H4	H3
Mass of can,g	5	5	5	5
Mass of can+wet soil,g	242	251	249	260
Mass of can+dry soil,g	211	209	201	205
Mass of water,g	31	42	48	55
Mass of dry soil,g	206	204	196	200
Water content,%	**15**	**21**	**24**	**28**
DESCRIPTION	**Y DENSITY DETERMINATION**			
Trial No.	**1**	**2**	**3**	**4**
Mass of mold	5631	5631	5631	5631
Mass of mold + compacted	8103	8409	8495	8431
Mass of compacted soil	2472	2778	2864	2800
Volume of mold	2124	2124	2124	2124
Bulk density	1.16	1.31	1.35	1.32
Dry density	**1.01**	**1.08**	**1.08**	**1.03**
MDD (g/cc)	1.09			
OMC (%)	23.5			

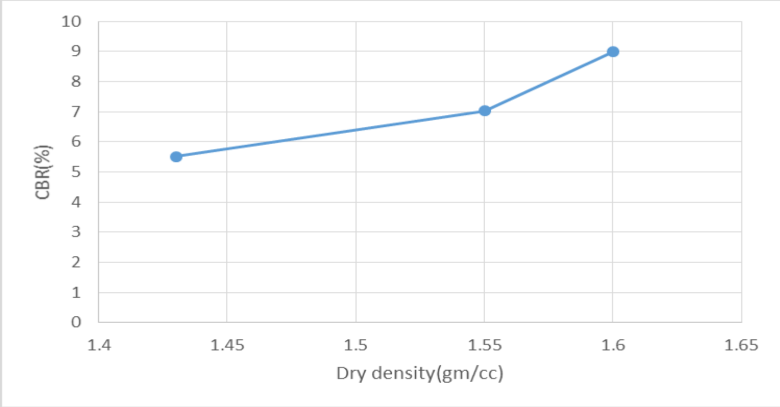


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.43	1.55	1.6			
Penetration data			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load
0	0	0	0		0	0
0.64	5	0.259	7.000	0.363	9.000	0.467
1.27	9	0.467	11	0.571	15	0.778
1.91	12	0.623	15	0.778	20	1.038
2.54	14	0.726	18	0.934	23	1.193
3.18	16	0.830	21	1.089	26	1.349
3.81	18	0.934	23	1.193	28	1.453
4.45	19	0.986	25	1.297	30	1.556
5.08	20	1.038	26	1.349	31	1.608
7.62	24	1.245	29	1.505	34	1.764



before soaking 3 sampls were remolded with omc 20.40%

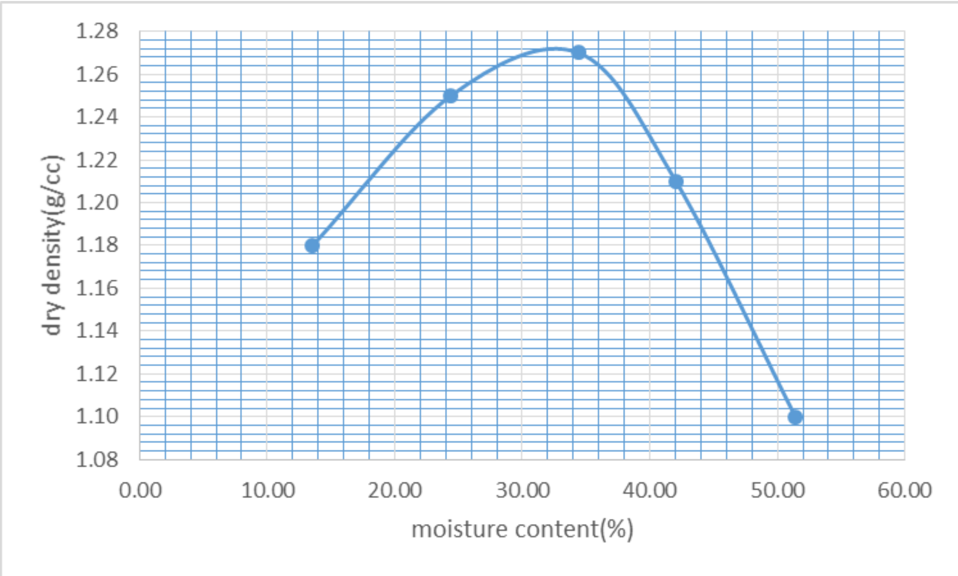
DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.43	10	13.24	20	0.73	1.04	5.5135952	5.2
1.55	30	13.24	20	0.93	1.35	7.0241692	6.75
1.6	65	13.24	20	1.19	1.61	8.9879154	8.05



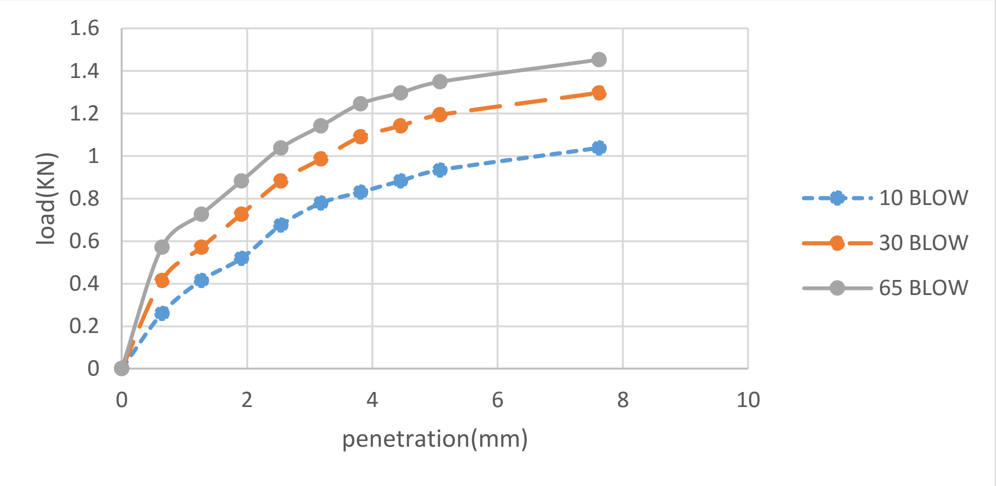
Density -cbr 95%		6.4
mdd	1.46	

TP 10: Location of Sample: Megenagna 2m

DESCRIPTION	ISTURE CONTENT DETERMINA	Column	Column2	Colum	Colum
Trial no.	1	2	3	4	5
Can no.	C2	G2	G7	A5	F8
Mass of can,g	5.00	5.00	5.00	5.00	5.00
Mass of can+wet soil,g	231.00	163.00	216.00	201.00	220.00
Mass of can+dry soil,g	204.00	132.00	162.00	143.00	147.00
Mass of water,g	27.00	31.00	54.00	58.00	73.00
Mass of dry soil,g	199.00	127.00	157.00	138.00	142.00
Water content,%	**13.57**	**24.41**	**34.39**	**42.03**	**51.41**
DESCRIPTION	**DRY DENSITY DETERMINATION**				
Trial No.	1	2	3	4	5
Mass of mold	5631.00	5631.00	5631.00	5631.00	5631.00
Mass of mold + compacte	6905.00	7102.00	7246.00	7253.00	7210.00
Mass of compacted soil	1274.00	1471.00	1615.00	1622.00	1573.00
Volume of mold	2124.00	2124.00	2124.00	2124.00	2124.00
Bulk density	1.35	1.55	1.71	1.72	1.66
Dry density	**1.18**	**1.25**	**1.27**	**1.21**	**1.10**
MDD (g/cc)	1.28				
OMC (%)	34				

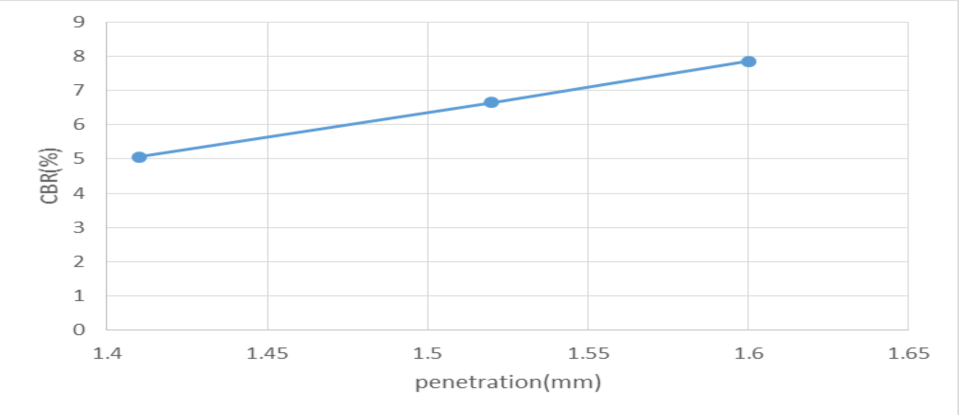


Density	5 layer					
No. of blows/layer	10	30	65			
Dry density (g/cm3)	1.41	1.52	1.6			
Penetration data 10 blow			30 blow		65 blow	
Penetration (mm)	Dial	Load	Dial	Load	Dial	Load
0	0	0	0		0	0
0.64	5	0.259	8.000	0.415	11.000	0.571
1.27	8	0.415	11	0.571	14	0.726
1.91	10	0.519	14	0.726	17	0.882
2.54	13	0.674	17	0.882	20	1.038
3.18	15	0.778	19	0.986	22	1.141
3.81	16	0.830	21	1.089	24	1.245
4.45	17	0.882	22	1.141	25	1.297
5.08	18	0.934	23	1.193	26	1.349
7.62	20	1.038	25	1.297	28	1.453



before soaking 3 sampls were remolded with omc 20.60%

DD(g/cm3)	no of blows	Standard Load		Load		CBR%	
		2.54mm	5.08mm	2.54mm	5.08mm	2.54mm	5.08mm
1.41	10	13.24	20	0.67	0.93	5.060423	4.65
1.52	30	13.24	20	0.88	1.19	6.6465257	5.95
1.6	65	13.24	20	1.04	1.35	7.8549849	6.75
MDD at 95%	1.49						
cbr at 95%	6.2						



APPENDEX E SPSS outputs

Multiple regression

Ordinary least square method

Determination of CBR using DCPI

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.815[a]	.665	.653	.9143038

a. Predictors: (Constant), DCPI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	46.413	1	46.413	55.521	.000[b]
	Residual	23.407	28	.836		
	Total	69.819	29			

a. Dependent Variable: Actual CBR

b. Predictors: (Constant), DCPI

Coefficients[a]

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.

		B	Std. Error	Beta		
1	(Constant)	20.674	2.267		9.120	.000
	DCPI	-.558	.075	-.815	-7.451	.000

a. Dependent Variable: Actual CBR

Two stage predictor substitution
Predicted DCPI

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.908[a]	.825	.812	1.002

a. Predictors: (Constant), bulk density(gm/cm3), NMC(%)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	127.691	2	63.846	63.589	.000[b]
	Residual	27.109	27	1.004		
	Total	154.800	29			

a. Dependent Variable: DCPI(MM/BLOW)

b. Predictors: (Constant), bulk density(gm/cm3), NMC(%)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	15.970	3.235		4.937	.000
	NMC(%)	.405	.043	.858	9.433	.000
	bulk density(gm/cm3)	-1.129	1.040	-.099	-1.085	.287

a. Dependent Variable: DCPI(MM/BLOW)

Determination of CBR using PDCPI

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.799[a]	.639	.626	.9492054

a. Predictors: (Constant), PDCPI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	44.592	1	44.592	49.492	.000[b]
	Residual	25.228	28	.901		
	Total	69.819	29			

a. Dependent Variable: Actual CBR

b. Predictors: (Constant), PDCPI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	21.447	2.510		8.544	.000
	PDCPI	-.580	.082	-.799	-7.035	.000

a. Dependent Variable: Actual CBR

Two stage residual inclusion estimation

Determination of CBR using PDCPI and DCPI

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.827[a]	.684	.660	.9046609

a. Predictors: (Constant), PDCPI, DCPI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	47.722	2	23.861	29.155	.000[b]
	Residual	22.097	27	.818		
	Total	69.819	29			

a. Dependent Variable: Actual CBR

b. Predictors: (Constant), PDCPI, DCPI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	21.744	2.397		9.071	.000
	DCPI	-.351	.179	-.513	-1.956	.061
	PDCPI	-.241	.190	-.332	-1.265	.217

a. Dependent Variable: Actual CBR

APPENDEX F

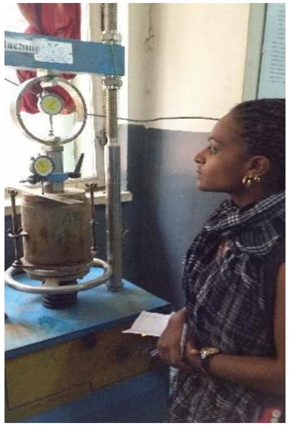
Photos taken at the sites and laboratory

TP1 – Lideta

DCP at TP4- Addisu Gebeya

Specific gravity test in Laboratory

CBR testing in Laboratory



Air drying of samples