

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CIVIL ENGINEERING



**Correlation Of CBR, MDD And OMC With Field DCP Test For Low
Volume Road In Ethiopia**

**A Thesis Submitted to the School of Graduate Studies of Adama Science and
Technology University in Partial Fulfillment of the Requirement for the Degree of
Master of Science in Civil Engineering(Geotechnical Engineering)**

BY

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Advisor

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September, 2016

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ABSTRACT

The design of low volume road and evaluation of the existing pavement requires the value of California Bearing Ratio (CBR) as an input parameter. However this method is time consuming and demands significant effort to determine in the laboratory. On other hand, Dynamic Cone Penetrometer (DCP) is a simple, rapid, hand held and low cost device used to evaluate the strength of in situ soils. Correlating these two parameters helps the designer to determine the CBR values easily from simple field DCP test. There is lack of correlation between CBR and DCP in Ethiopia for different types of soils in different regions.

In this study, forty two disturbed soil samples were collected from Amhara, Addis Ababa City Administration, Oromia, Southern Nation and Nationalities People's and Afar Regions. The experimental program was carried out for samples collected. Field and laboratory tests were carried out. The field tests were carried out at different sites of all regions for Dynamic Cone Penetrometer (DCP) to find the DCP value. The laboratory tests were carried out for the basic geotechnical tests and California Bearing Ratio (CBR) tests to find the Optimum Moisture Content (OMC), Maximum Dry Density (MDD) and Soaked CBR values. Specific to the present study, statistical software (SPSS) was employed to investigate the significance of the individual independent variables.

The correlation between CBR and DCP, MDD and DCP, OMC and DCP have been proposed for different types of soil. Accordingly, equations such as $\ln(CBR) = -0.39\ln(DCP) + 4.828$ for GW & GP soils, $\ln(CBR) = -0.65\ln(DCP) + 5.415$ for GC soils, $\ln(CBR) = 1.692\ln(DCP) - 2.107$ for ML & SM soils, $\ln(CBR) = -1.96\ln(DCP) + 7.375$ for MH soils, $\ln(CBR) = -1.29\ln(DCP) + 4.772$ for clay soils and $\ln(CBR) = -1.22\ln(DCP) + 4.025$ for black cotton soil were developed.

The developed correlations are based on small number of sample ranging from six to ten. This resulted in moderate correlation strength. It will be improved if more sample sizes are considered.

.Finally, comparison of developed equation with existing correlation and actual laboratory test values was made. The existing correlation developed is single equation for granular and fine soils. Thus, the value of existing correlation is under predicted for granular soils and over predicted for fine soils. It is not suitable to be used in Ethiopia for prediction of CBR values of soils in general. Hence, the present study proposed new correlation equations that are suitable for prediction of CBR values for different soil types in Ethiopia.

Key words: DCP Test, CBR Test, MDD, OMC, Correlation

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LIST OF SYMBOLS

b_1, b_2, b_3	Coefficient of the non Linear Regression Equation;
C_c	Coefficient of curvature;
C_u	Coefficient of Uniformity;
D_{10}	Diameter on the cumulative size distribution curve where 10 percent of particles are fines;
D_{30}	Diameter on the cumulative size distribution curve where 30 percent of particles are fines;
D_{60}	Diameter on the cumulative size distribution curve where 60 percent of particles are fines;
R	Pearson product moment correlation coefficient;
R^2	Coefficient of Determination;
α	Standard Significant Error;
β_0, β_1	Coefficient of the Single Linear Regression Equation, and
σ	Statistical Variance.

LISTS OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials;
AFRNMS	Afar Region Near Mille Town Sample;
ARABS	Addis Abab Region Akaki Kality Alam Bank Area Sample;
ARNSS	Amhara Region North Shoa Sample;
ARZKS	Amhara Region Oromia Zone Kamise Sample;
ARRB	Australia Road Research Board;
ARWZBS	Amhara Region Wollo Zone Bati Sample;
ASTM	American Society for Testing and Materials;
CBR	California Bearing Ratio;
CH	High Plastic Clay;
CL	Low Plastic Clay;
DCP	Dynamic Cone Penetration;
DDBS	Dry Density Before Soaking;
FAO	Food and Agriculture Organization of the United Nations;
FDT	Field Density Test;
GC	Gravel Clay;
GM	Silty Gravel;
GP	Poorly Graded Gravel;
GW	Well Graded Gravel;
LL	Liquid Limit;
MCBS	Moisture Content Before Soaking;
MDD	Maximum Dry Density;

MH	High Plastic Silt;
ML	Low Plastic silt;
MnDOT	Minnesota Department of Transportation;
NMC	Natural Moisture Content;
OASS	Oromia Region West Arsi Zone Shashemenne Woreda Sample;
OESAS	Oromia Region East Shoa Zone Adami Tulu Jido Kombolcha Woreda Sample;
OH	High Plasticity Organic Soil;
OMC	Optimum Moisture Content;
ORAZCHS	Oromia Region Arsi Zone Chefa Sample;
ORESZDS	Oromia Region East Shoa Zone Dugda Sample;
ORWASLS	Oromia Region West Arsi Zone Sirba LendaSample;
PI	Plasticity Index;
PL	Plastic Limit;
PLC	Private Limited Company;
PR	Penetration Ratio;
SC	Clayey Sand;
SM	Sandy Silt;
SNNP	South Nation and National People;
SP	Poorly sorted Sand;
SPSS	Statistical Package for Social Science;
SRHZSS#31	South Region Hawasa Area Zone Shebedino Sample;
TRL	Transport Research Laboratory;
U.S	United States;

USCS	Unified Soil Classification System;
USDA	United States Department of Agriculture;
VS.	Versus, and
WC	Water Content.

CHAPTER ONE

INTRODUCTION

1.1. Background

The development of new low volume roads in short project period and enhancement of existing roads are parts of infrastructure booming in Ethiopia. In order to perform an effective and reliable pavement design, an accurate and representative material characterization technique is essential. Such a technique would be even more beneficial if it were simple, inexpensive and not time taking. Characterization of field material properties using laboratory test has a problem of difficulty of representative sample condition, cost and time taking.

DCP is the simple test device that is inexpensive, easily portable, easy to operate and understand, requires minimum maintenance and it provides continuous measurements of in situ strength of pavement section and the underlying sub grade layers without the need for digging the existing pavement as in the California Bearing Ratio (CBR) test. Thus ; it is useful to measure the in situ strength of sub grade soil, base course aggregate and chemically stabilized soils in simple way[23]. The DCP instrument was initially developed in south Africa in 1956 as in situ pavement evaluation technique for pavement layers strength. Since then , it has been extensively used in other countries[25]. In Australia, in 1956, it was used to evaluate shear strength of material in pavement [24].

The equipment consists of a steel rod with steel cone attached to one end which is driven into the pavement structures or sub grade soils using a sliding hammer. Its testing is conducted in such a way that number of blows are counted and depth of penetration is measured after each blow.

California Bearing Ratio(CBR) is a measure of resistance of material to penetration a plunger under controlled density and moisture content. It is an indirect measure of strength which represents comparison of the strength of sub-grade, sub- base and base- course material to the strength of standard crushed rock. It is the common test currently practiced in the design of pavement by assessing CBR so as to determine the thickness of pavement layers.

Laboratory CBR testing requires relatively large effort, time consuming and uneconomical. The optional method of determining CBR of the sub- grade, sub -base and base-course material could be correlating CBR with simpler test result that is Dynamic Cone Penetration (DCP) test .This test is more economical and not time consuming than laboratory CBR testing. This thesis gives general idea to obtain a correlation between DCP with CBR, OMC and MDD values for GW &GP , GC, ML & SM, MH , Expansive (black cotton clay) and all other CH & CL soils of Ethiopia separately. Thus, it is deeply focused on developing correlation equations for intended soil categories.

Currently, many low volume road construction projects are being constructed in the country. Because of this, the result of the proposed correlation equation will provide road Authorities and consultants for prediction of CBR for the encountered soil types for design and construction quality controlling with advantage of time saving and low cost without incurring additional cost for laboratory test of CBR.

1.2. Statement of the Problem

Analysis and design of road pavement layers depend on California Bearing Ratio (CBR) test value. Almost all design charts for road design based on the CBR value of the sub-grade materials. But, laboratory California Bearing Ratio (CBR) test is time taking to conduct and expensive .These problems are bottle necked for design and construction of low volume roads which are to be completed within predetermined short period and low cost. thus, it is important to find cheap and quick test method of

determining CBR value to carry out quality controlling, design and analysis of effectively with low cost and short period of time.

DCP is cheap, quick, portable and simplicity of operation equipment in determining in situ soil strength. Various correlations have been developed by different researchers. But they did it from sample of their locality. In Ethiopia, the developed correlations are for only fine grained sub-grade soils. Therefore, correlation between DCP and CBR should be developed using all categories of fine and granular soils of Ethiopia so as to enable the road designers use empirical equation developed to determine CBR so that thickness of pavement and its components layers is fixed easily.

1.3. Objective of the Study

1.3.1. General Objective

Almost all the pavement design in Ethiopia has been done using California Bearing Ratio(CBR) values predicted from DCP using correlations developed considering granular and fine soils at the same time and soils of other localities out of Ethiopia. Thus, the main objective of this thesis is to develop and check the applicability of the correlation equations between soaked CBR with DCP for all types of soil sample collected from different regions of Ethiopia. At the same time, it is intended to investigate the general relationship between laboratory MDD and OMC with field DCP for different soil categories in the country.

1.3.2. Specific Objective

- ✓ To develop and check a correlation between soaked CBR with DCP, MDD and OMC with DCP for soil samples collected from different regions of Ethiopia.
- ✓ To validate and evaluate the developed correlation equations using comparative of existing correlation being utilized in Ethiopia.

1.4. Methodology

Primary, in order to deal with the proposed objectives of the study, Literatures regarding Dynamic Cone Penetration (DCP) and California Bearing Ratio (CBR) has been studied and reviewed at the beginning stage of the study. Subsequently, previous works such as different books, technical papers, journals ,thesis and published reports of different researchers with regard to correlation of laboratory CBR, MDD and OMC with field DCP test result were assessed.

Subsequent to literature review, several laboratory tests on samples collected after field DCP tests from different regions of Ethiopia have been conducted. From laboratory tests, gradation and soil classification, Atterberge limits(LL, PL and PI) ,natural moisture content, optimum moisture content, Maximum dry density and California Bearing Ratio(CBR) results were obtained. Gradation and soil classifications, Atterberg limit, compaction and 3-points CBR tests were conducted in accordance of AASHTO T-27, AASHTO T89-T91,AASHTO T-180 method A&C and AASHTO T-193 respectively.

After detail soil classification by USCS and based on laboratory and field DCP test results, statistical regression analysis has been done to develop new correlation equations and also analyzed to fit the test results. Thus, the collected DCP data was substituted in to the existing, TRL, Overseas Road Note 8 correlation equation to find predicted CBR values. The estimated CBR values from the existing correlation were compared with the CBR values from the laboratory tests and the CBR values predicted from this thesis developed correlation equation. Furthermore, comparison results were discussed in the study to judge the application of new developed correlation in Ethiopia. Finally, Conclusions and recommendations were made.

1.5. Organization of the Study

This thesis work is organized under six chapters. The first chapter is introduction part which highlights the back ground, statement of the problem, objective of the study and methodology utilized while conducting the thesis work. Chapter two deals with review of the literature.

In chapter three discussion on Dynamic Cone penetration(DCP) test, sample collection and laboratory test results are made.

In chapter four, correlation of regression analysis were made and chapter five describes validation and evaluation of the developed correlation. Overall conclusions on the results of the thesis and recommendations for further study are described in chapter six. Finally references and appendices of details of the laboratory, field DCP test results and regression are presented

CHAPTER TWO

LITERATURE REVIEW

2.1. California Bearing Ratio (CBR)

2.1.1. General

The California bearing ratio(CBR) is defined as the ratio of the resistance to penetration of the material to the penetration resistance of standard crushed stone base materials. CBR values are commonly used for high way, airport, parking lot and other pavement design. The method was developed by California division of high way [1]. CBR is an indirect measure of soil strength based on the resistance to penetration. It is a simple strength test that compares the capacity of materials with that of well graded standard crushed stones of granular base layer . For AASHTO road test ,CBR=100 for the granular base layers and about 30% for granular sub base[1].

2.1.2. Application of California Bearing Ratio

The CBR is basic for determining the thickness of soil and aggregate layer used in design of roads and air field. It is commonly used in high way, airport, parking lot, and other pavements design based on empirical local or agency specific methods (i.e. FHWA,FAA, AASHTO).CBR also has been correlated empirical with resilient module and variable of other engineering soil properties [2] It is also used to analyze the condition of existing pavement layers. On the other hand, the value of CBR is an indication of the suitability of natural sub grade soil as a surfacing materials. During sub grade analyses, high CBR of sub grade indicates the sub grade material is strong so that the design pavement thickness is reduced, But when CBR value of sub grade is low, it shows the sub grade is weak. As a result, the thickness of

pavement shall be increased so as to spread the traffic load over a great area of the sub grade or the sub grade soil shall be subjected to stabilization such as providing capping layer.

2.1.3. Test Methods

The California Bearing Ratio (CBR) test can be conducted both in the laboratory and in the field.

2.1.3.1. CBR Test from Remolded Sample in Laboratory.

It is the determination of CBR of pavement sub grade, sub base and base course materials from laboratory compacted specimens. This method is to determine and evaluate the strength of cohesive sample having maximum particle sizes less than 19mm (3/4inch).

If most of the materials have maximum particle sizes of greater than 19mm, the gradation of the materials is modified[7].

Laboratory CBR test is carried out as per the procedure determined in AASHTO T193-63 or ASTM D1883-73. This test method provide the determination of CBR of a materials at optimum moisture contents or a range of water contents 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 compaction test of either standard proctor test (ASTM D698) or modified proctor test (ASTM D1557).[3]

This test method is used to evaluate the potential strength of sub grade, sub base and base course materials including recycled materials for use in road pavement. For application where the effect of compaction water contents on CBR is small, such as cohesion less, course grained materials, the CBR may be determined at the optimum water content of specified compaction effort. A typical laboratory CBR apparatus is shown in figure 2.1a [22].



Figure 2.1 California bearing ratio device

The laboratory CBR test procedure depends up on the principle of a plunger of standard area advancing in to the remolded sample at specified rate of penetration. Before penetration test, the soil sample is remolded in a laboratory at desired moisture contents and density. The remolded sample will be soaked for four days (96 hours) with surcharge loads not less than 4.52kg that is a representative of pavements weight in the field. Swelling Reading is taken during this stage.[Ref 1] At the end of soaking period, penetrating rate is carried out at a rate of 1.30mm/min and the force or load required to cause the penetration is recorded with respect to the standard penetration depth at each 0.5mm penetration until the total penetration is 12.7mm. The penetration on resistance load is then plotted against penetration depth and correction is made for the load penetration curve. A typical load penetration curve correction graph is presented in figure below[3]

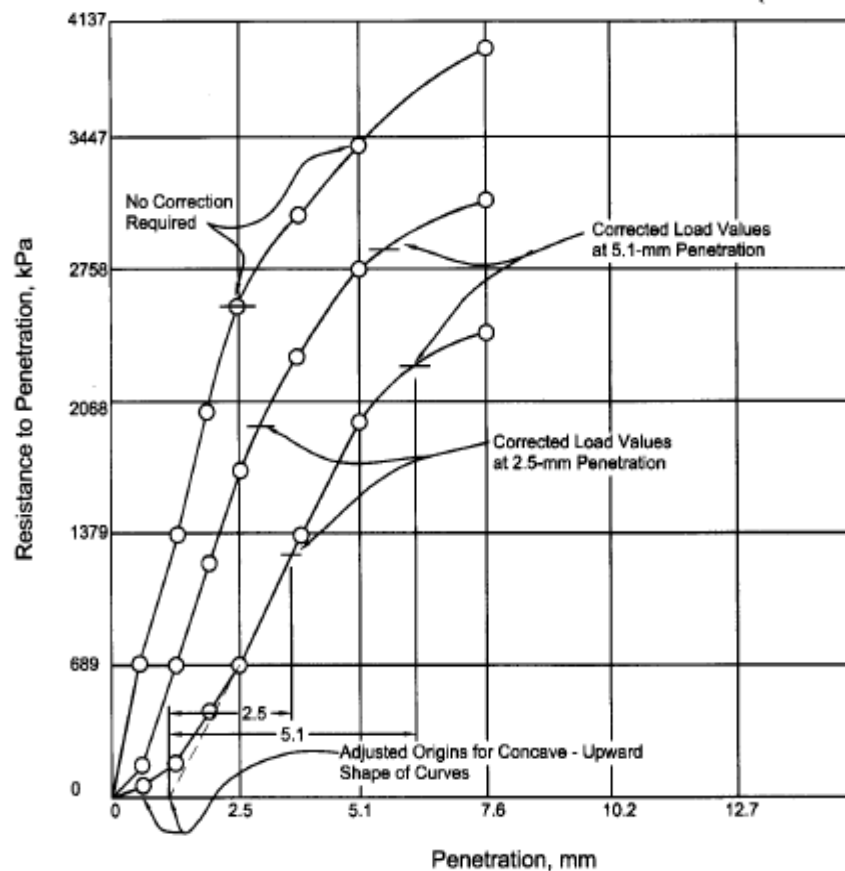


Figure 2.2 Correction of stress-strain curve

The corrected load value shall be determined for each specimen at 2.54 and 5.08mm penetration. California bearing ratio values are obtained in percent dividing the corrected load values at 2.54 and 5.08mm by the standard load of 6.9 and 10.3MPa respectively[4]. The CBR is generally selected at 2.54mm penetration. If the ratio at 5.08mm penetration is greater, the test shall be return and if a checked test gives similar results, the ratio at 5.08mm penetration shall be used[4]. Using the data obtained from the three specimens, the CBR dry density is plotted and the design CBR may be determined at the design percentage of the maximum dry density[4].

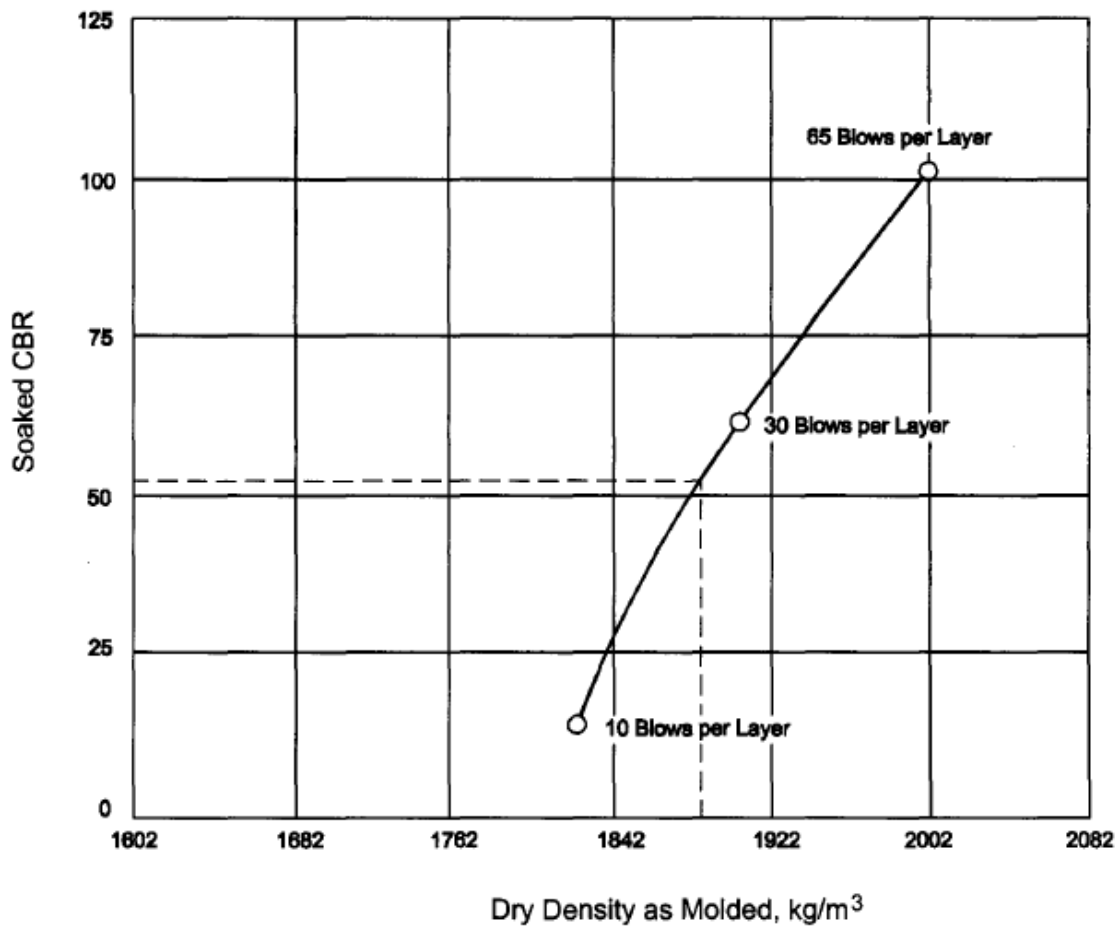


Figure 2.3 CBR-Dry Density curve

In the laboratory test, if the soil sample is remolded using one density and one moisture content, the design CBR value will be that satisfy the above bearing ratio criteria. whereas in the case of range of densities are used in the tests ,density versus CBR curve is plotted and the design CBR values of the soil will be the one that corresponds to the design dry density CBR plotted.

2.2. Index Property Tests

Naturally soil occurs in a great variety. The tests required for determination of engineering properties (permeability, compressibility and shear strength) are generally complex and time consuming . Hence, the geotechnical engineers are interested to have some irregular assessment of engineering properties

without conducting complex tests . The properties of soils w/c are not primary interest, but indicative of the engineering properties are called index properties . Simple tests to determine the index properties are known as classification tests[9].

Index properties of cohesive soils are used to characterize the physical and mechanical behaviors of soils by using moisture content, specific gravity ,particle size distribution ,Atterberg limits and moisture density relationships . Such parameters are useful to classify cohesive soils and provide correlation with engineering soil properties[10]

2.2.1. Soil Classification

There are a wide variety of soils covering earth. It is difficult to study the behavior of individual soils. It is desirable to classify the soils in to broad groups of similar behavior and study the behavior of groups. Soils having similar behavior can be grouped together to form a particular group under different standardized classification system . A soil is classified according to index properties such as particle size and plasticity characteristics[9].

There are different classification methods such as USCS and AASHTO classification system which are used to specify a certain soil type that is suitable for a specific application. These classification systems divide the soils in to two groups: cohesive or fine grained soils and cohesion less or course grained soils.

2.2.1.1. Grain Size Analysis

For particles retained on 3 '(75mm) U.S standard sieve, particles of rock that will pass a 12 cm square opening and retained on sieve 3' is cobbles particles of rock that will pass a 12 in square opening is called boulders. Soils passing a No 200 (75 μ m) U.S Standard sieve is clay and clay size particle. A clay is a fine grained soil with a placidity index equal to or greater than four[11]. Gravel is a particle of rock that pas a 3 in (75mm) and retained on 4.75mm U.S Standard sieve. Sand is a particle of rock that

will pass a No 4 (4.75mm) and retained on No- 200 (75 μ m U.S standard sieve. Silt is soil passing a No- 200 (75 μ m) U.S standard sieve and non plastic or slightly plastic[11].

For course grained materials, the grain size distribution is determine by passing soil sample either by wet or dry shaken through a series of sieve placed in decreasing opening size order and a pan at the bottom of the stock. Then the percent passing on each sieve is used for further identifying the distribution and gradation of different sizes (Ref). Particles size analysis tests are conducted according to ASTM D 422-63. In addition, the distribution of different soil particles in a given soil is determined by sedimentation process using hydrometers test for soil passing No-200 (0.075mm) sieve[11].

2.2.1.2. Moisture Content

The water content is the ratio of the mass of water to the mass of dry solid. It is the most common measure of characterizing the condition of clay, important for classification purpose, general description and describing consistence[12]. The procedure of determination of water content is measuring of the mass of moist specimen, over drying, allowing the specimen to cool. This method is described in ASTM D 2216 . Change in moisture content is the most influential parameter that affect the property of soils. In fine grained (cohesive) soils, the consistence of a given soil type depends on its water content. The moisture content test is conducted in laboratory as per the procedures of AASHTO T265or ASTM D2216. The moisture content test can be conducted in the field according to AASHTO 217.

2.2.1.3. Atterberg Limits

Atterberg limit is a water content at which the soil changes from one state to the other state. In1911, a Swedish engineer Atterberg mentioned that a fined grained soil can exist in liquid, plastic, semi-soiled and solid state[9]

At the same water content, different soils may have different consistence limit. Thus consistence limits are very important index properties of fine grained soils. The three Atterberg limits such as liquid limit, plastic limit and shrinkage limits are the boundary at which three phases such as liquid to plastic, plastic to semi-plastic and semi plastic to solid is changed respectively. The liquid limit of soil depends up on clay mineralogy present[9]

The liquid limit is determined in the laboratory by either casagrande's or by cone penetration method. About 120gm of an air drained sample passing 425 μ m(N_o-40) sieve is used to conduct the test[9].

Liquid limit; the liquid limit (LL) is a water content at which the soil changes from liquid state to plastic state. Principally LL is defined as the water content at which the soil pat cut using standard groove closes for about a distance of 13mm(1/2in) at 25 number of blows of the liquid limit machine. The conventional liquid limit test is conducted according to AASHTOT89 or ASTM D4318 test procedures.

Plastic limit; It is a water content at which the soil changes its state from plastic to semi-solid. The soil mold begins to crumble when rolled in to thread of soil of 3mm diameter. The conventional plastic limit test is carried out as per the procedure of AASHTOT 90 or ASTM D4318. The shear strength at the plastic limit is about 100 times that of the liquid limit.

Shrinkage limit; It is the water content at which the soil changes from semi-solid state to solid state. It is the smallest water content at which the soil is saturated. In other word, it the maximum water content at which a reduction of water content will not cause a decrease in the volume of the soil mass. At this point the shrinkage ceases. The test is carried out as per the procedure of AASHTOT92 or ASTM D427.

Plasticity index(PI); it is the amount of water that must be added to change a soil from its plastic limit to liquid limit. It is the numerical difference between liquid limit and plastic limit.

($PI=LL-PL$). If either plastic limit or liquid limit cannot be determined, the soil is non-plastic. When the plastic limit is greater than the liquid limit, the plasticity is considered as zero[9].

The greater the plasticity index meaning that the soil is more plastic, compressible and the greater volume change characteristic of the soil.

2.3. Dynamic Cone Penetration Test

The dynamic cone penetrometer (DCP) is defined as simple and hand held device used to measure the strength of in-situ soils[13].

Designing the early 1930, the California Bearing Ratio(CBR) was developed for the testing of materials in the laboratory for the design of pavements. But this is time taking and expensive. In addition to this, all stones greater than 19mm diameter are removed (sometimes replacement fines are added).In the field, the course materials remains and compacted under the vibrating force and materials seldom become soaked. The test results are thus incomparable with actual condition. To get rid of this incomparability, the CBR should be conducted in the field using a portable CBR testing machine which is difficult and time consuming and is seldom because of equipment requirement.

Dynamic Cone Penetration (DCP) was developed in Australia in 1956 to evaluate shear strength of material in pavements[14]. After efficiency of this equipment is noted, its development is continued in south Africa. This allowed the development of correlation and models to predict the CBR from the DCP penetration rate[14]. It was introduced in Minnesota department of transportation (MN/DOT) in 1993 and has been used since then[13].

The dynamic cone penetrometer (DCP) consists of two shafts, anvil, pointed tip cone, and handle hammer[13]

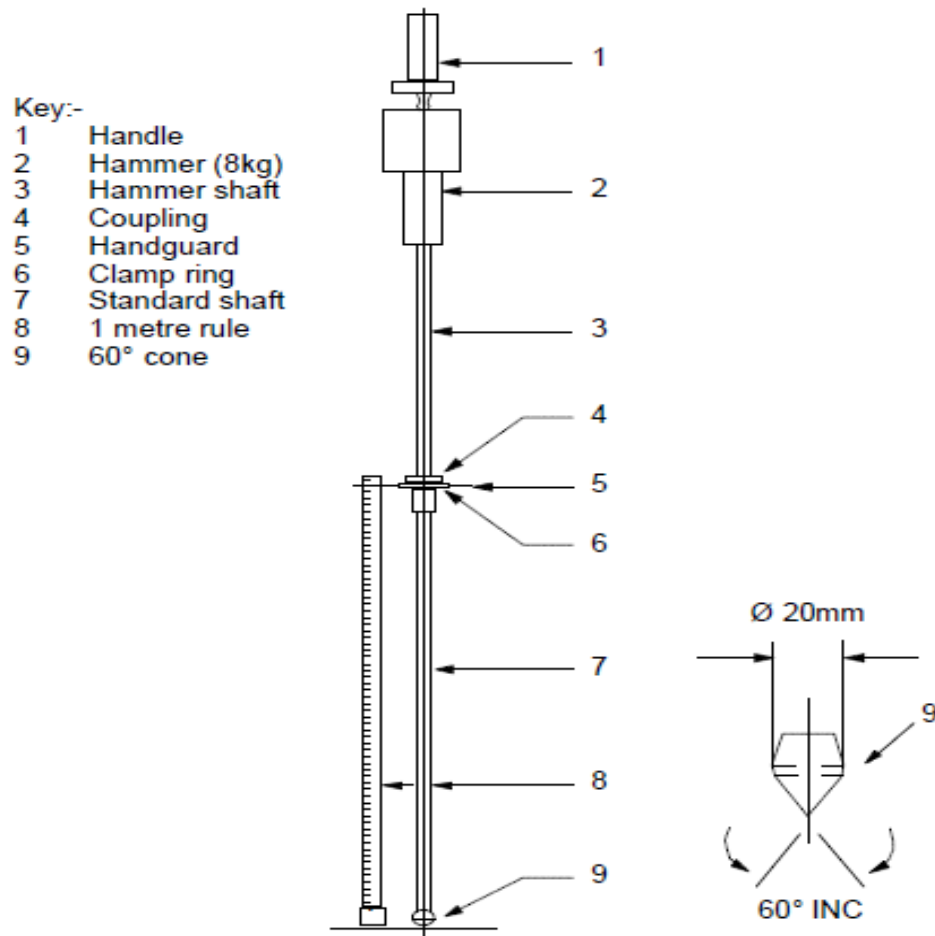


Figure 2.1 Dynamic Cone Penetrometer

Its test is carried out by raising and dropping the hammer to drive the cone on the lower shaft through the under laying pavement layers. After each hammer blow, the penetration of the cone is measured. It can drive a total of 0.75m to 1m at a test location. During the DCP test, the following aspects need to be carefully controlled.

- ◆ The apparatus must be held vertically at all times.
- ◆ The hammer must touch the base of the handle before being released.
- ◆ The hammer should be released to fall under its own mass.

- ◆ Care should be taken that the base of the measuring tape is not affected by mounding or uplift of the hard layer.
- ◆ If stone is encountered, it should be broken and the test continues normally. But if the road is bent, the test should be stopped since the road cannot move vertically. If such condition are encountered, the test should be recommended one meter away from initial test[15]

The minimum number of operators is three. Two labors and supervisor. The supervisor controls the reading and recording of the results, while the two labors are holding the apparatus vertically and operating the equipments.

2.4. Existing Correlation

2.4.1. Existing Correlation Between CBR (California Bearing Ratio) And DCP Tests

Stiffness is a function of soil moisture, density and magnitude of stress level. To ensure the long term performance of the pavement, it is essential to know stiffness of the base and subgrade during design and construction supervision. This is mostly done by mechanistic, empirically based design and rehabilitation procedures[16]. Many researchers developed relationships between CBR, OMC and MDD with dynamic cone penetration tests on the base of samples obtained from specific countries out of Ethiopia and soil types. The following are some of the empirical correlations developed by various agencies[16].

Table 2.1 Existing Correlation Between CBR And DCP Tests

S.No	Researchers	Developed Correlation Equations
1	TRL, Overseas Road Note 8 Correlation Equation	$\log(CBR) = 2.48 - 1.0571\log(DCP)$ for all soils
2	The north Carolina development of transportation developed	$\log(CBR) = 2.64 - 1.08\log(PR)$ for all soils $CBR = \left(\frac{435}{PR^{1.08}}\right), (R^2 = 0.79)$ for all soils
3	Kelyn (1975) conducted DCP tests and got correlation	$\log(CBR) = 2.62 - 1.27\log(PR)$ for all soils
4	Smith and prott(1983) suggested	$\log(CBR) = 2.56 - 1.15\log(PR)$ for all soils
5	Livach and inshia(1987)	$\log(CBR) = 2.2 - 0.71\log(PR)^{1.5}$ for all soils
6	Harison(1989) suggested the following correlation for different soils	$\log(CBR) = 2.56 - 1.16\log(PR)$ $\left(\text{For Clay Likes Soil of } PR > \frac{10mm}{Blows}\right)$ $\log(CBR) = 2.7 - 1.12\log(PR)$ (For Granular Soil of PL < 10%

S.No	Researchers	Developed Correlation Equations
7	Us army corps of engineers found the following relationships (websteretal,1992)	$\text{Log}(\text{CBR}) = 2.465 - 1.12\text{Log}(\text{PR}) \text{ or } \text{CBR} = (292/(\text{PR}^{1.12}))$ $\text{CBR} = \left(\frac{24.903}{\text{DCP}^{-1.331}} \right) (R^2 = 0.9739)$
8	During the south east Asia geotechnical conference, Livneh presented the correlation.	$\text{Log}(\text{CBR}) = 2.2 - 0.7(\text{Log}(\text{PR}))^{1.5} \text{ for all soils}$
9	Harrison (1989) of ARRB.	$\text{PRLog}(\text{CBR}) = 2.81 - 1.32\text{Log}(\text{PR}) \text{ for all soils}$
10	In 1994,Webster (Webster, Brown and Porter,1994) developed equations based on specific soil type.	$\text{CBR} = \frac{1}{(0.002871 \text{DCPI})} \text{ for high plasticity clay soil (CH)}$ $\text{CBR} = \frac{1}{(0.017019 \text{DCP})^2} \text{ for low plastic clay soils (CL)}$
11	MSc Thesis By Yitagesu Desalegn in 2012, Developing correlation between DCP and CBR for locally used sub grade materials.	$\log(\text{CBR}) = 2.954 - 1.496 \log(\text{DCPI}) \text{ with } R^2 = 0.943$

They found that the effects of soil moisture contents and dry density influences both CBR and DCP values in the same way [17].

2.4.2. Existing Correlation Between Maximum Dry Density And Dynamic Cone Penetration Tests

In addition to effects of moisture content, there is a developed correlation between DCP and density[18]. Accordingly;

Table 2.2 Existing Correlation Between MDD And DCP Tests

S.No	Researchers	Developed Correlation Equations
1	K.A.K. Karunaprema and A.G.H.J. Edirisinghe,(2003)	$MDD = 1940.75 - 1783.3 \left(\frac{1}{1+mc} \right) - 0.06 * DCP$ where mc is moisture content with $R^2 = 0.77$
2	K.A.K. Karunaprema and A.G.H.J. Edirisinghe,(2003)	$MDD = 21.908 * DCP^{-0.99}$ where $R^2 = 0.9486$ for all soils
3	K.A.K. Karunaprema and A.G.H.J. Edirisinghe,(2003)	$\frac{DD}{MDD} = 1.126 + 0.005MC - 0.156DCP^{\left(\frac{1}{MC}\right)}$ with $R^2 = 0.89$ for all soils

This indicate that if moisture Content and Dynamic Cone Penetration (DCP) values are known, it is possible to predict in calculating dry density by making use of developed correlation. Hence when moisture content and dynamic cone penetration test is known, it is possible to correlate maximum dry density and evaluate the compaction level. Therefore DCP can be used as quality control at the construction state.

2.4.3. Existing correlation between OMC and Dynamic Cone Penetration test

The DCP values increase with moisture contents .A Significance correlations exist between DCP and Moisture Contents[18].

Table 2.3 Existing Correlation Between OMC And DCP Tests

S.No	Researchers	Developed Correlation Equations
1	K.A.K. Karunaprema and A.G.H.J. Edirisinghe,(2003)	$MC = 0.5 + 6.9\log(DCP)$ with $R^2 = 0.71$ for all soils
2	K.A.K. Karunaprema and A.G.H.J. Edirisinghe,(2003)	$DCP = 0.0259 * (WC)^{1.4214}$ with $R^2 = 0.9517$ for all soils

CHAPTER-3

SAMPLE COLLECTION AND TEST RESULTS

3.1. Sample Collection

For predetermined analysis, sufficient and reliable data are required. Accordingly, field test and sample collection at the place where field test is conducted for further laboratory test was done in the five regions of Ethiopia. The regions are Oromia, Amhara, Afar, Addis Ababa and South Nation Nationality people Regions. A total of forty two distributed samples were collected after DCP test in the field at depth varying from 0.5m to 1.2m. The representative samples were selected on the bases of visual inspection of a suitable sub grade soil. On visual inspection, it is tried to include all types of soils such as gravel, sand, silt, clay and organic soil of Ethiopia. The sampling is done by converting soils classified as per FOA classification to USDA soil classification. This was done because of large scope to include all soils of Ethiopia. It was sampled to include representative soils of the country by converting FOA soil classification to USDA. The conversion is shown in as follow[20]

Table 3.1 FAO Soil Classification

	FAO	USDA
1	Acrisols	Ultisols (all suborders)
2	Andosols	Andepts
3	Arenosols	Psamments
4	Cambisols	Ochrepts, tropepts, umbrepts
5	Chernozems	Borolls
6	Ferralsols	Oxisols (all suborders)
7	Fluvisols	Fluvents
8	Gleysols	Aquents, aquepts, aquolls
9	Lixisols	Oxic Alfisols
10	Alisols	Vertisols with high activity clays
11	Greyzems	Borolls, aquolls
12	Histosols	Histosols (all suborders)
13	Kastanozems	Ustolls, borolls
14	Luvisols	Udalfs, xeralfs, ustalfs, aqualfs, boralfs
15	Nitosols	Udalfs, ustalfs, udults, ustults, xerults, humults
16	Phaeozems	Udolls, aquolls
17	Planosols	Aqualfs, xeralfs, argids, ustalfs, aquults, albolls, borolls
18	Solonchaks	Orthids, ustolls
19	Solonetz	Ustalfs, xeralfs, argids
20	Podzols	Orthods, ferrodts, humodts, aquodts
21	Podzoluvisols	Udalfs, boralfs, aqualfs
22	Leptosols	Lithosols, lithic subgroups
23	Regosols	Orthents, psamments
24	Vertisols	Udents, ustents, xerents, torrents
25	Calcisols	Calcic Aridisols
26	Gypsisols	Aridisols
27	Lithosols	
28	Anthrosols	Various orders

Based on the above soil classification, corresponding USDA soil classification is indicated in the following table[16].

Table 3.2 Soil type conversion (Baylot et al. 2013)

FAO Number	USDA Classification	USCS Classification	STP Number
1	Sand	SP, poorly sorted sand	6
2	Loamy Sand	SM, silty sand	7
3	Sandy Loam	SC, clayey sand	8
4	Silty Loam	SM, silty sand	7
5	Silt	ML, low plasticity silt	9
6	Loam	CL, low plasticity clay	10
7	Sandy Clay Loam	SC, clayey sand	8
8	Silty Clay Loam	CL, low plasticity clay	10
9	Clay Loam	CL, low plasticity clay	10
10	Sandy Clay	SC, clayey sand	8
11	Silty Clay	CL, low plasticity clay	10
12	Clay	CH, high plasticity clay	12
13	Organic	OH, high plasticity organic soil	14
14	Water	---	-999
15	Bedrock	GM, silty gravel	3
16	Other	---	-999

Considering soil distribution according to FOA classification and converting to USDA classification in regions of Ethiopia, sample collection was done to include all representative soils of the country. The FOA soil distribution is indicated in the following figure.

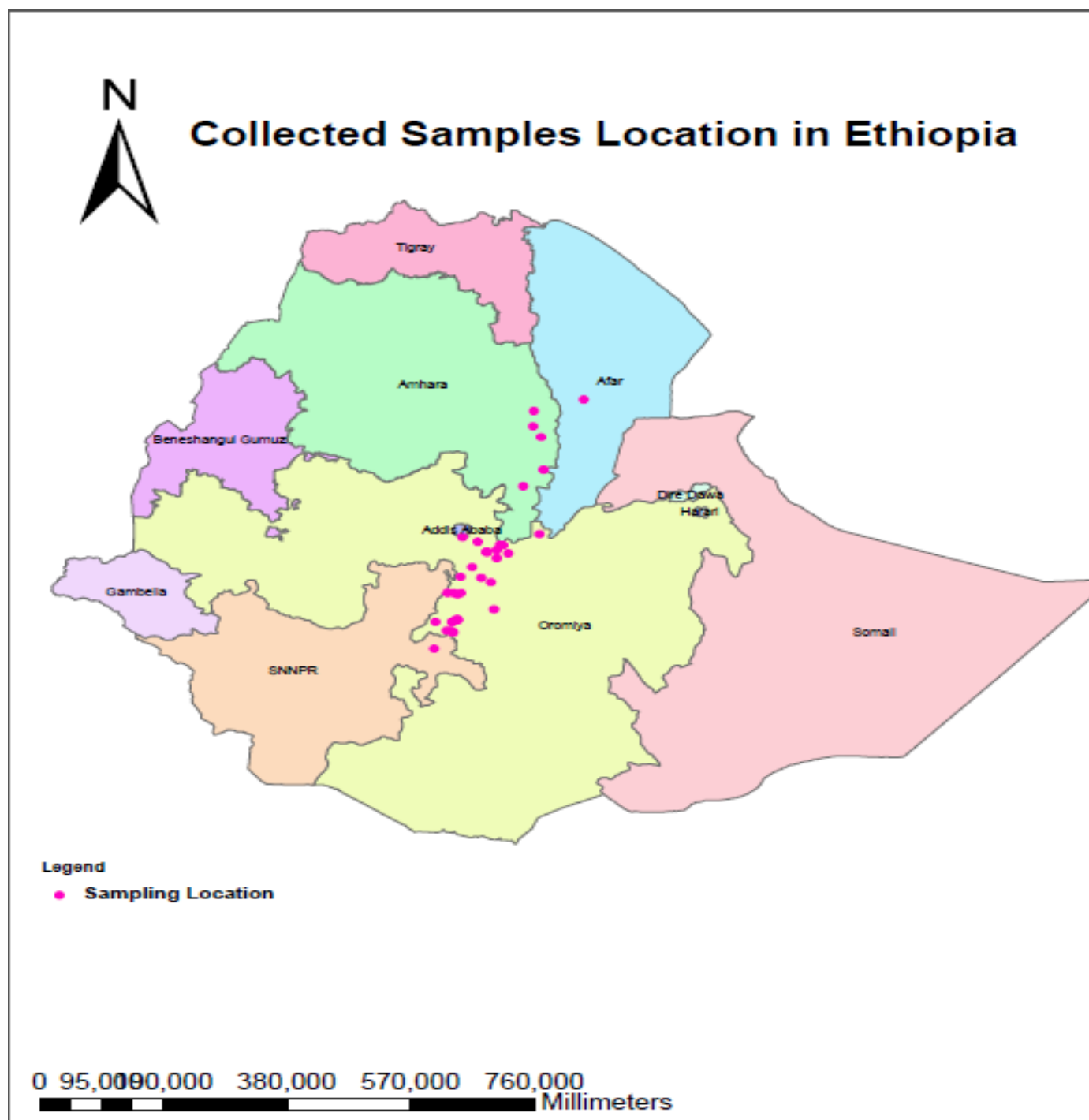


Figure 3.1 Sample Collection From Different Location Of Ethiopia

3.2. Test Results

3.2.1. Field Test Results

3.2.1.1. Discussion on Field Tests

Based on information gathered from Ethiopian soil data map and site visit, DCP(Dynamic Cone Penetration Tests) were done at place where different classes of soils exist. This test was carried on at forty two places of five regions of Ethiopia. It was done to include all soil classes (gravel, sand, silt and clay) of the country. After field test, sufficient samples were collected for further laboratory tests.

3.2.1.2. Summary of Field DCP Test Results

Field DCP tests of all the samples collected from different regions of Ethiopia were conducted in the same procedure illustrated above for each regions from which data were collected. But it is impossible to mention all the test results here. There for, some are illustrated and the remaining are included in the appendix part of the thesis. Instead of mention all the tests, the results summary are included here.

For the analysis of intended correlations, the field DCP test results are summarized hereunder in table

Blow:

Table 3.3 summary of Field DCP test for all samples

S.No	Sample Code	Location Coordinate		Penetration Index mm/Blow(DCP)
		X(m)	Y(m)	
1	OASS1	453604	795461	26.56
2	OESAS2	470090	866458	7.24
3	OESAS3	470079	866411	14.39
4	OESOS4	549660	947363	23.66
5	OESOS5	549651	947348	17.75
6	OESOS6	536753	964134	6.04
7	OESOS7	542026	963438	9.65
8	OESMS8	516122	949747	15.98

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

S.No	Sample Code	Location Coordinate		Penetration Index mm/Blow(DCP)
		X(m)	Y(m)	
9	OESMS9	516171	949985	4.73
10	OESMS10	516267	949930	4.66
11	ARNSS11	573318	1079843	5.06
12	AROZKS12	604638	1112031	23.32
13	AROZKS13	600732	1175926	9.50
14	ARWZKS14	588727	1197153	15.78
15	ARWZBS15	589706	1227710	4.56
16	AFRAWS16	650699	1244223	35.00
17	AFRNMS17	667339	1249966	35.00
18	ORESMS18	598088	985115	4.57
20	ORWASS#20	460540	794408	5.87
21	ORAZOS#21	460541	794408	18.97
22	ORAZOS#22	507399	898810	29.5
23	ORESAS#23	476063	869082	3.9
24	ORESAS#24	455215	869257	9.9
25	ORESAS#25	502042	969910	6.04
26	ORESAS#26	532332	938143	7.65
27	ORAZGS#27	522686	890497	10.87
28	ORAZCHS#28	527255	836932	13.19
29	ORWAZFS#29	463972	791727	24.5
30	ORWAZSS#30	469785	817150	10.97
31	SRHZSS#31	434071	759599	15.13
32	ORWAZSS#32	436195	812680	32.14
33	ORESBES#33	493693	920142	11.8
34	ORWASLS#34	469918	817226	9.57
35	ORWAZSLGK#35	471131	816592	9.76

S.No	Sample Code	Location Coordinate		Penetration Index mm/Blow(DCP)
		X(m)	Y(m)	
36	ORWAZSLGS#36	469644	817146	13.18
37	ORWAZANK#37	463071	812502	19.07
38	ORWAZANW#38	462404	812580	10.50
39	ORESZDS#39	475741	900676	12.26
40	ARABS#40	478446	979535	26.85
41	ORESZATS#41	464699	869206	26.32
42	ORESZASS#42	455442	869445	15.62

3.2.2. Laboratory Test Results

3.2.2.1. Discussion on Laboratory Tests

Based on the samples collected after field DCP test was conducted, laboratory tests were done on the samples turn by turn in Oromia Water Works Design and Supervision Enterprise, Federal Water Works Construction Modjo Branch and Gondwana Engineering PLC at their free time. Accordingly, the following tests have been conducted.

-  Grain size analysis
-  Liquid limit test
-  Plastic limit test
-  Modified proctor test
-  CBR test i.e. three points CBR test

Grain size analysis test has been conducted as per AASHTO T- 27. The atterberg limit tests have been conducted as per AASHTO T-89. Compaction and CBR tests have been conducted as per AASHTO T-180 Method C and AASHTO T-193 at moisture density relationship of AASHTO T-180 Method A respectively.

These conventional tests were done on the soil samples collected from different site of five regions of Ethiopia after DCP tests had been conducted. After soil grain size analysis has been done, the results indicate twenty four samples are fine grained soil and eighteen samples are course grained. After Atterberg limit tests, the results indicate that some soil samples are non plastic and the remaining are plastic. The liquid limit range is ninety to zero and the plastic limit rang is from thirty nine to zero. After grain size analysis and Atterberg limit test, the soil samples are detail classified as per AASHTO& USCS soil classification systems. Accordingly, the results indicate that all categories of soils such as GW, GP,SP, SC, SM,CL, CH, ML and MH are included.

A modified proctor test as per AASHTO T-180 method A & C was conducted. Under this samples were compacted at five layers each compaction by 25 uniform number of blows by making use of 4.54kg of hammer. From this work, moisture- density curve was plotted. After plotting the curve, a range of maximum dry density together with the optimum moisture content were read.

The CBR test was conducted on forty two samples remolded using optimum moisture content. This was done by 3-points method using 10,30 & 65 blows of modified proctor density and then soaked for four days. Then the penetration tests were carried on after four days soaking. After penetration tests were carried on, CBR values ranging from 1% for black cotton soil and 110 for well graded gravel soils encountered at 95% maximum dry density of modified proctor compaction as per AASHTO T-180 method C.

To make the results explanation easy, typical test results of all the tests for sample of OESAS#2 have been shown here under from fig 3.10 to 3.13

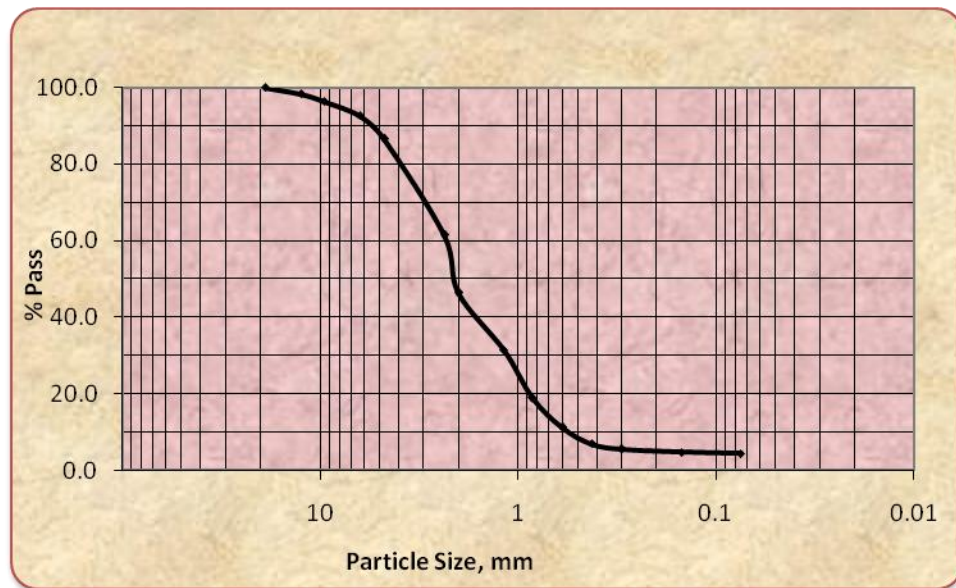


Figure 3.2 Grain Size Analysis Curve

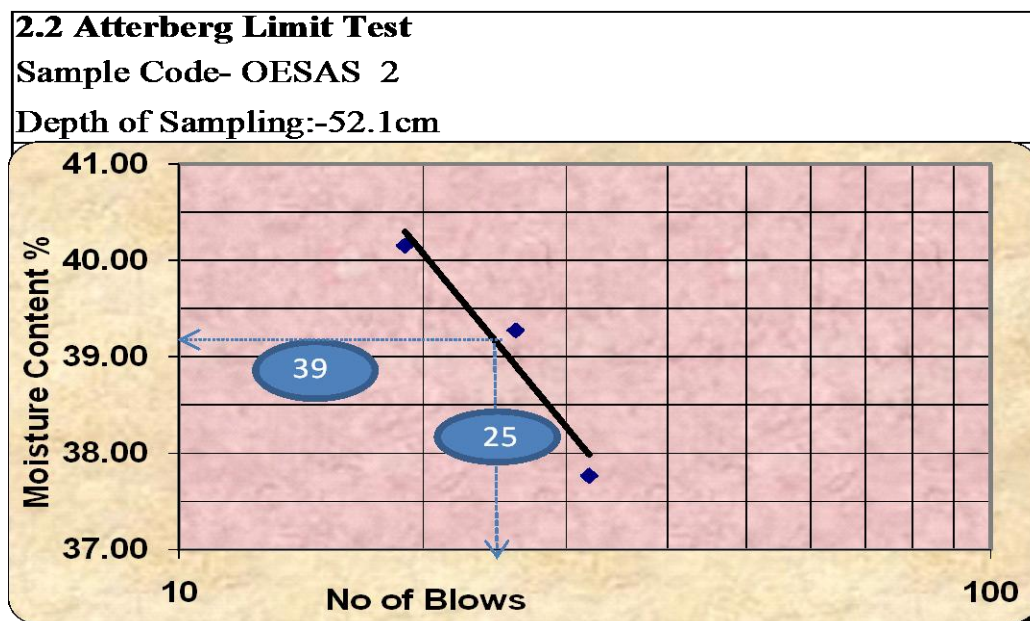


Figure 3.3 Liquid Limit Graph (Flow Curve)

1.3 Modified Proctor Test
Sample Code-OASS1
Depth of Sampling:-125cm

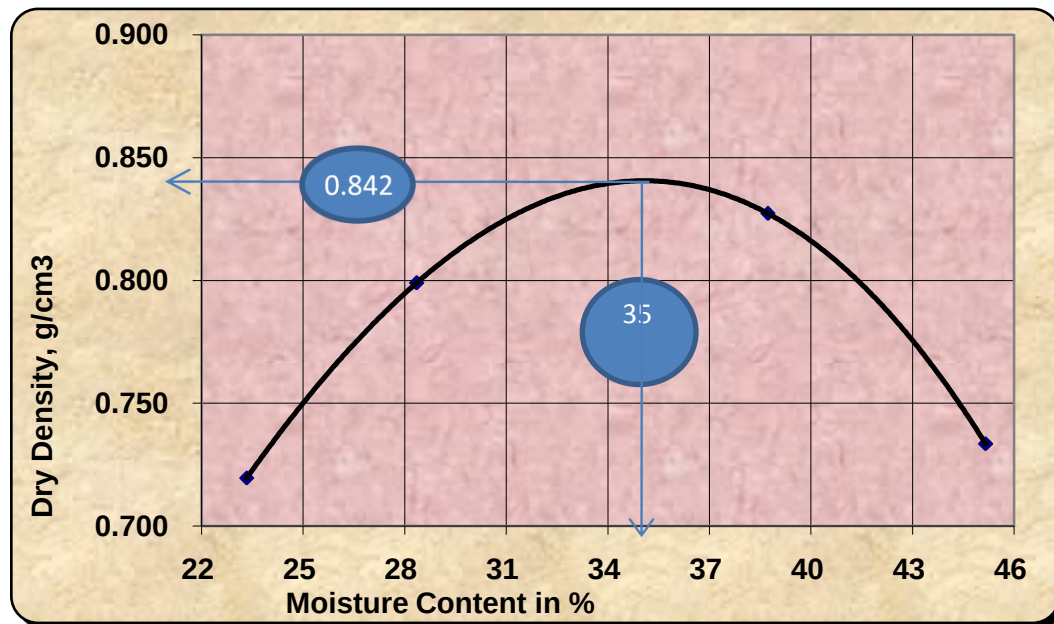


Figure 3.4 Variation Density with Moisture Content

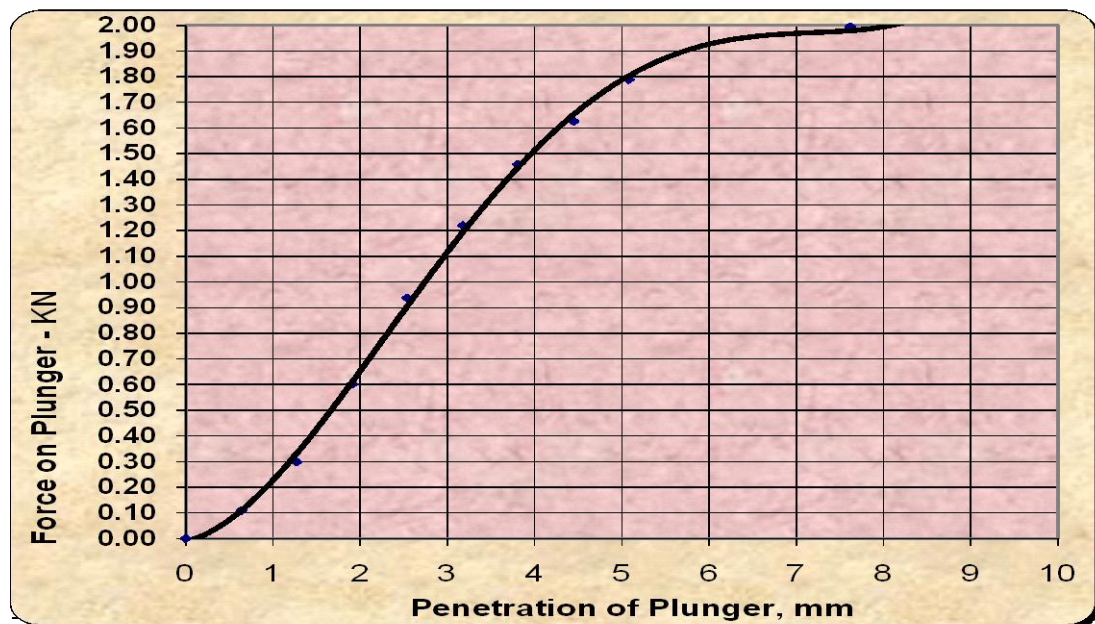


Figure 3.5 Variation of Penetration Load with Penetration Depth for 10 no of blows

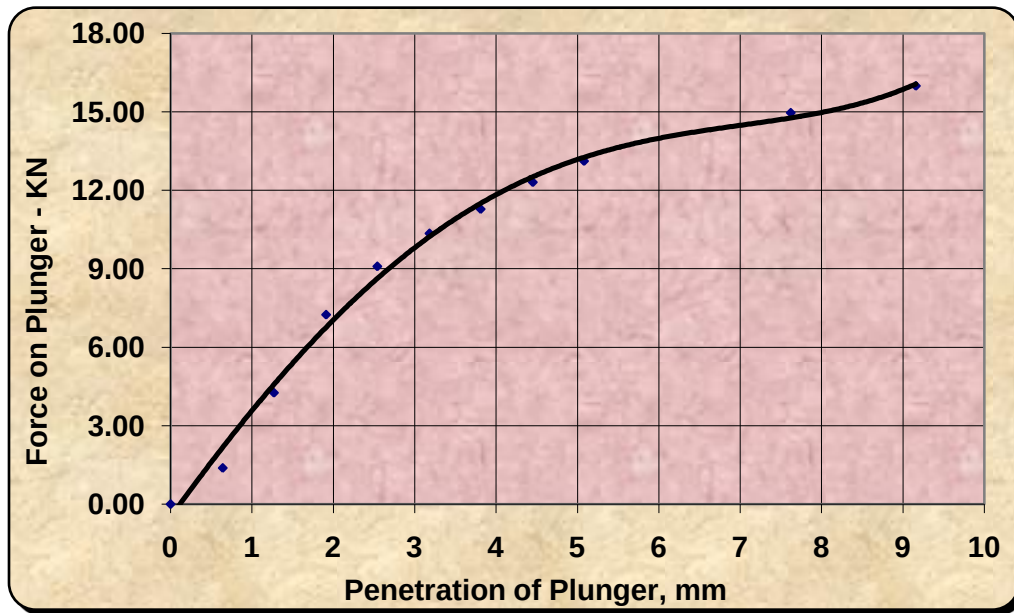


Figure 3.6 Variation of Penetration Load with Penetration Depth for 30 no of blows

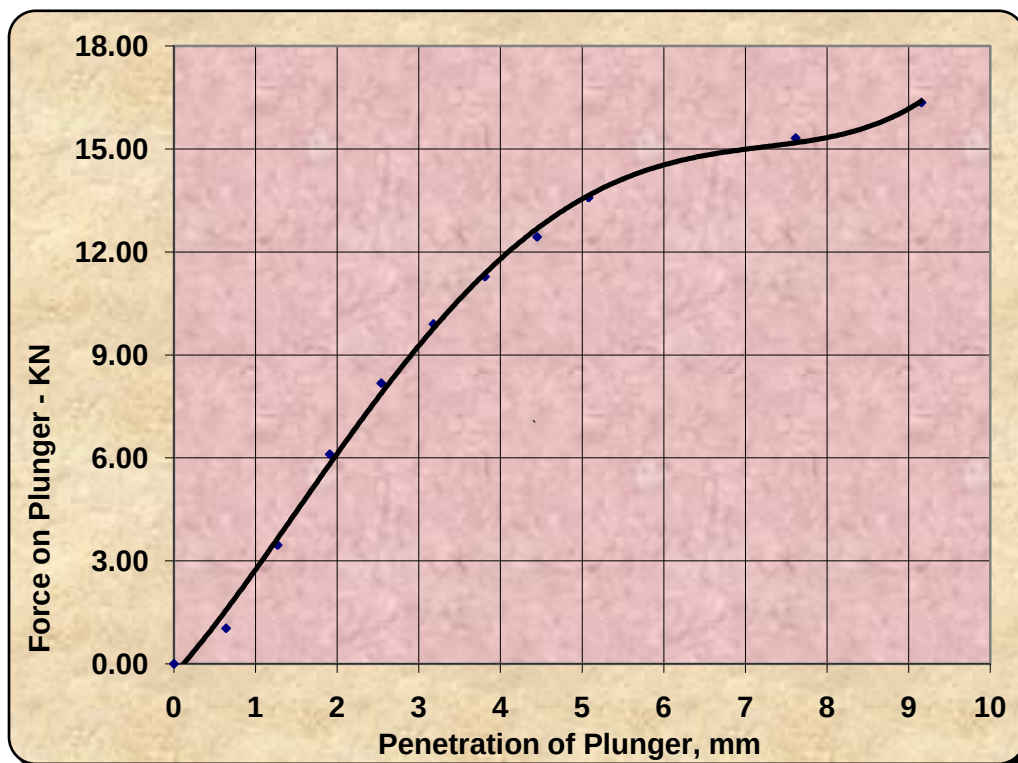


Figure 3.7 Variation of Penetration Load with Penetration Depth for 65 no of blows

1.4 California Bearing Ration Test

Sample Code-OASS1

Depth of Sampling:-125cm

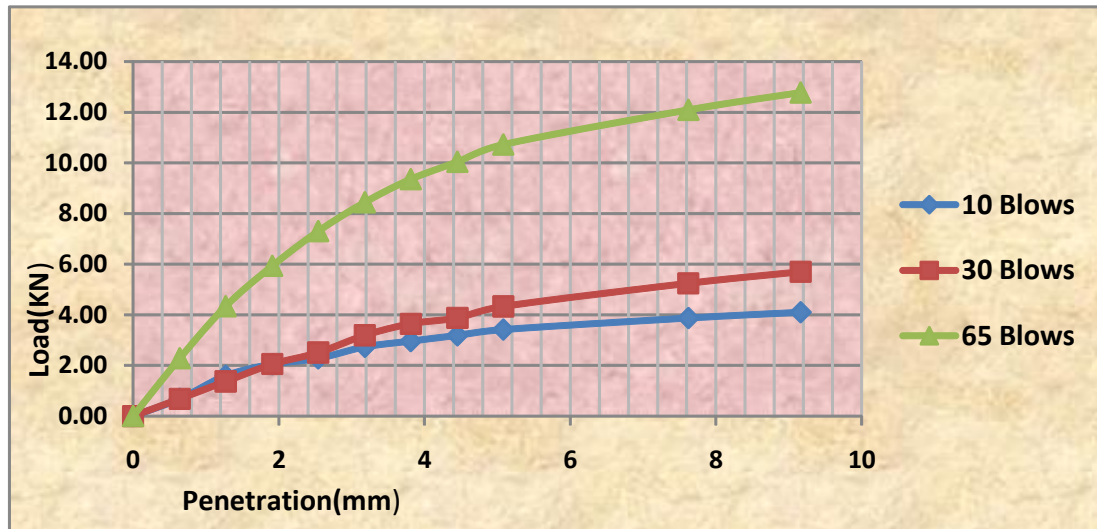


Figure 3.8 Variation of Penetration Load with Penetration Depth Graph for three blows

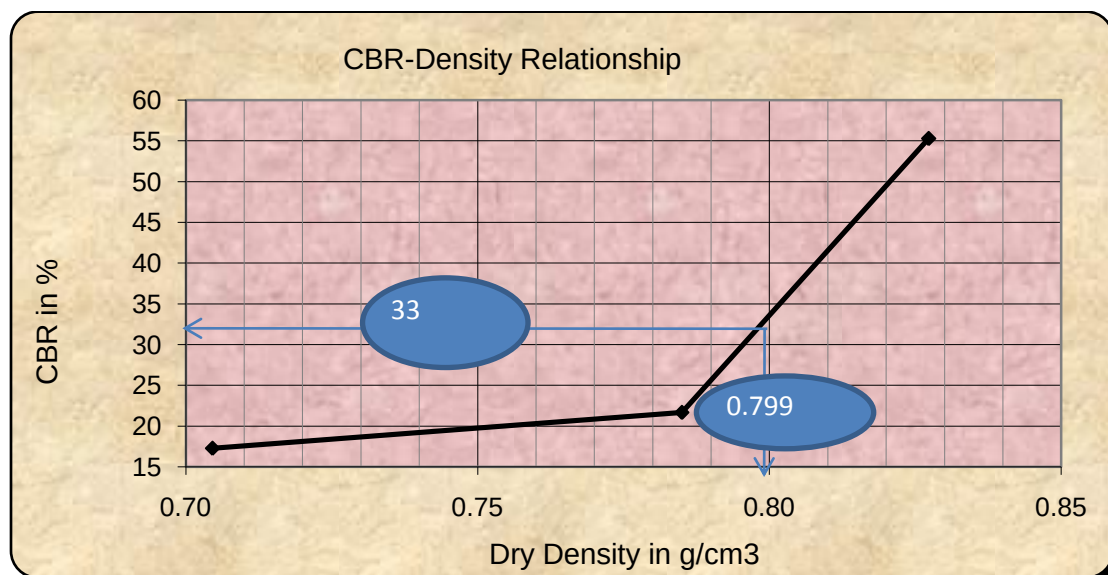


Figure 3.9 Variation of Density with CBR

For further reference, the details of all the laboratory test results of the soil samples including figures and tables have been enclosed under appendix A of this thesis.

3.2.2.2. Summary of Laboratory Test Results

Table 3.4 Summary of Laboratory Test Results for all samples

S. No	Sample Code	Location		DCP (mm)	Grain Size Analysis % passing				Atterberg limits		Soil Classification		Modified Proctor Test		CBR Test					
		X (m)	Y (m)		2.0mm	0.425 mm	0.075 mm	LL (%)	PL (%)	PI (%)	AASHTO Class	USCS Class	MDD (g/cc)	OMC (%)	No. Of Blows	Density (g/cc)	Load in (mpa) at 2.54mm	Load in (mpa) at 5.08mm	CBR (%)	CBR at 95% of MDD
1	OASS1	453604	795461	26.56	46	7	4	-	NP	-	A-1a (0)	GP	0.842	35	10	0.705	2.28	3.42	17.3	33
															30	0.785	2.51	4.33	21.7	
															65	0.827	7.3	10.72	55.3	
2	OESAS2	470090	866458	7.24	34	28	22	39	25	14	A-2-6 (0)	GC	1.59	19	10	1.36	2.99	4.03	23	68
															30	1.467	9.09	13.12	69	
															65	1.578	8.17	13.58	68	
3	OESAS3	470079	866411	14.39	14	9	3	-	NP	-	A-1a (0)	GW	1.274	14	10	1.081	3.65	5.93	30	75
															30	1.181	6.33	11.51	58	
															65	1.254	10.24	20.49	102	
4	OESOS4	549660	947363	23.66	36	6	5	-	NP	-	A-1a (0)	GW	0.932	17	10	0.808	1.38	2.53	12.7	29
															30	0.868	2.76	4.6	23	
															65	0.929	5.76	9.32	46.6	
5	OESOS5	549651	947348	17.75	27	6	4	-	NP	-	A-1a (0)	GW	0.924	27	10	0.817	1.82	3.19	16	43
															30	0.848	3.42	6.61	33.1	
															65	0.927	4.56	11.86	59.3	
6	OESOS6	536753	964134	6.04	20	16	13	42	23	19	A-2-7 (0)	GM	1.94	15	10	1.712	2.97	4.11	22.5	44
															30	1.808	5.7	8.21	43.2	
															65	1.894	5.93	9.12	45.6	
7	OESOS7	542026	963438	9.65	73	62	40	49	30	19	A-7-5 (3)	SC	1.542	27	10	1.315	2.97	4.33	22.5	60
															30	1.424	7.3	10.72	55.3	
															65	1.514	7.3	13.23	66.1	
8	OESMS8	516122	949747	15.98	41	33	26	33	21	12	A-2-6 (0)	GC	1.8	14.5	10	1.573	1.5	1.96	11.3	50
															30	1.675	5.18	8.17	40.9	
															65	1.787	9.21	14.5	72.5	
9	OESMS9	516171	949985	4.73	31	13	3	-	NP	-	A-1a (0)	GW	1.433	20	10	1.233	4.11	5.93	31.1	67
															30	1.331	5.47	10.72	53.6	
															65	1.413	12.09	18.48	92.4	
10	OESMS10	516267	949930	4.66	24	12	6	-	NP	-	A-1a (0)	GM	1.36	21	10	1.166	3.19	5.02	25.1	64
															30	1.256	6.84	9.81	51.8	
															65	1.344	10.04	16.42	82.1	
11	ARNSS11	573318	1079843	5.06	99	93	76	41	32	9	A-5 (8)	CL	1.54	22	10	1.318	0.94	1.79	9	20
															30	1.416	2.09	3.52	18	
															65	1.506	1.82	4.29	21	
12	AROKS12	604638	1112031	10.96	79	76	72	60	31	29	A-7-5 (19)	MH	1.567	27	10	1.346	0.16	0.26	1.3	2
															30	1.412	0.26	0.39	2.1	
															65	1.535	0.28	0.46	2.3	

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

S. No	Sample Code	Location		DCP (mm)	Grain Size Analysis % passing			Atterberg limits			Soil Classification		Modified Proctor Test		CBR Test					
		X (m)	Y (m)		2.0mm	0.425 mm	0.075 mm	LL (%)	PL (%)	PI (%)	AASHTO Class	USCS Class	MDD (g/cc)	OMC (%)	No. Of Blows	Density (g/cc)	Load in (mpa) at 2.5mm	Load in (mpa) at 5.08mm	CBR (%)	CBR at 95% of MDD
13	AROKS13	600732	1175926	9.5	61	48	34	35	22	13	A-2-6 (1)	SM	1.85	14.4	10	1.613	0.9	1.41	7	41
															30	1.72	3.57	6.46	32.3	
															65	1.81	5.2	10.43	52.1	
14	ARWZKS14	588727	1197153	15.78	97	95	92	73	30	43	A-7-5 (20)	CH	1.525	24	10	1.306	0.15	0.22	1.1	2
															30	1.436	0.25	0.34	1.9	
															65	1.501	0.3	0.4	2.3	
15	ARWZBS15	589706	1227710	4.56	21	11	6	26	17	9	A-2-4 (0)	GC	2.12	11	10	1.85	3.19	5.02	25	110
															30	1.929	9.12	13.91	70	
															65	2.068	16.2	27.14	136	
16	AFRAWS16	650699	1244223	35	52	49	44	48	26	22	A-7-6 (6)	SM	1.85	14	10	1.69	0.27	0.44	2	3
															30	1.768	0.28	0.5	3	
															65	1.848	0.41	0.67	3	
17	AFRNMS17	667339	1249966	35	49	48	40	25	19	6	A-4 (1)	GM	1.94	16	10	1.663	1.01	1.53	8	20
															30	1.781	2.07	3.57	18	
															65	1.984	2.99	4.95	25	
18	ORESMS18	598088	985115	4.57	23	10	5	-	NP	-	A-1a (0)	GW	2.122	6	10	1.838	5.7	10.49	52	103
															30	1.976	9.58	18.7	94	
															65	2.062	13.23	22.81	114	
20	ORWASS#20	460540	794408	18.92	97	86	58	54	32	22	A-7-5 (11)	MH	1.325	25	10	1.133	0.97	1.62	8.1	39
															30	1.201	2.3	4.95	24.7	
															65	1.301	6.56	9.44	49.7	
21	ORAZOS#21	460541	794408	8.25	96	95	82	58	33	25	A-7-5 (18)	MH	1.45	24	10	1.258	0.22	0.32	2	3
															30	1.328	0.34	0.49	3	
															65	1.448	0.48	0.63	4	
22	ORAZOS#22	507399	898810	29.5	96	88	69	44	30	14	A-7-5 (9)	ML	1.43	20	10	1.181	0.49	0.69	4	34
															30	1.309	2.3	3.11	17	
															65	1.39	5.99	8.17	45	
23	ORESAS#23	476063	869082	33.46	96	86	62	32	11	21	A-6 (10)	CL	1.44	20	10	1.238	0.31	0.5	2.5	21
															30	1.325	1.46	3.01	15	
															65	1.418	3.57	5.05	27.1	
24	ORESAS#24	455215	869257	9.9	99	93	78	39	26	13	A-6 (9)	ML	1.5	19	10	1.288	0.21	0.33	1.7	5
															30	1.395	0.51	0.73	3.9	
															65	1.519	0.82	1.27	6.3	
25	ORESAS#25	502042	969910	6.04	21	8	2	-	NP	-	A-1a (0)	GW	1.448	10	10	1.197	2.28	3.42	17.3	58
															30	1.328	5.25	8.67	43.3	
															65	1.414	7.07	13.91	69.6	

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

S. No	Sample Code	Location		DCP (mm)	Grain Size Analysis % passing			Atterberg limits			Soil Classification		Modified Proctor Test		CBR Test					
		X (m)	Y (m)		2.0mm	0.425 mm	0.075 mm	LL (%)	PL (%)	PI (%)	AASHTO Class	USCS Class	MDD (g/cc)	OMC (%)	No. Of Blows	Density (g/cc)	Load in (mpa) at 2.5mm	Load in (mpa) at 5.08mm	CBR (%)	CBR at 95% of MDD
26	ORESAS#26	532332	938143	7.65	25	10	3	-	NP	-	A-1a (0)	GW	1.454	9	10	1.238	3.19	5.25	26.2	45
															30	1.33	4.56	7.76	38.8	
															65	1.418	4.79	10.04	50.2	
27	ORAZGS#27	522686	890497	10.87	98	94	81	52	32	20		MH	1.508	22	10	1.305	0.43	0.63	3.2	18
															30	1.427	2.3	3.11	17.4	
															65	1.489	2.51	3.42	19	
28	ORAZCHS#28	527255	836932	13.19	100	100	97	58	32	26	A-7-5 (18)	MH	1.45	31	10	1.284	0.69	0.94	5.2	18
															30	1.352	2.27	2.74	17.2	
															65	1.478	2.74	3.88	20.7	
29	ORWAZFS#29	463972	791727	23.32	100	93	83	53	29	24		MH	1.505	34	10	1.27	0.25	0.54	2.7	5
															30	1.367	0.65	0.9	4.8	
															65	1.491	0.75	1.01	5.7	
30	ORWAZSS#30	469785	817150	10.97	99	92	80	79	34	45		CH	1.452	32	10	1.25	0.15	0.21	1.1	3
															30	1.357	0.3	0.42	2.3	
															65	1.44	0.55	0.75	4.2	
31	SRHZSS#31	434071	759599	15.13	99	93	85	59	31	28	A-7-5 (19)	MH	1.432	30	10	1.237	0.26	0.37	2	7
															30	1.338	0.7	0.96	5.3	
															65	1.42	1.37	1.804	10.4	
32	ORWAZSS#32	436195	812680	32.14	89	71	41	-	NP	-	A-4 (1)	SM	1.31	19	10	1.146	0.91	1.39	7	41
															30	1.209	3.5	5.23	26.5	
															65	1.291	7.38	10.49	60.5	
33	ORESBS#33	493693	920142	11.8	99	92	77	42	27	15	A-7-6 (10)	ML	1.53	28	10	1.31	0.47	0.65	4	7
															30	1.408	0.8	1.15	6	
															65	1.494	0.84	1.53	8	
34	ORWASLS#34	469918	817226	9.57	98	89	83	64	31	33	A-7-5 (20)	CH	1.482	24	10	1.299	0.23	0.3	2	5
															30	1.381	0.58	0.81	4	
															65	1.499	0.79	1.13	6	
35	ORWAZSLGK#35	471131	816592	9.76	99	89	82	67	29	38	A-7-6 (20)	CH	1.53	31	10	1.293	0.12	0.18	1	3
															30	1.406	0.35	0.46	3	
															65	1.486	0.43	0.51	3	
36	ORWAZSLGS#36	469644	817146	13.18	97	91	86	84	33	51	A-7-7 (20)	CH	1.513	26.5	10	1.328	0.14	0.19	1	2
															30	1.417	0.17	0.23	1	
															65	1.5	0.33	0.38	2	
37	ORWAZANK#37	463071	812502	19.07	100	95	90	30	20	10	A-7-8 (8)	CL	1.432	26	10	1.308	0.33	0.55	2.8	4
															30	1.374	0.46	0.8	4	
															65	1.451	0.73	1.32	6.6	

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

S. No	Sample Code	Location		DCP (mm)	Grain Size Analysis % passing			Atterberg limits			Soil Classification		Modified Proctor Test		CBR Test					
		X (m)	Y (m)		2.0mm	0.425 mm	0.075 mm	LL (%)	PL (%)	PI (%)	AASHTO Class	USCS Class	MDD (g/cc)	OMC (%)	No. Of Blows	Density (g/cc)	Load in (mpa) at 2.5mm	Load in (mpa) at 5.08m	CBR (%)	CBR at 95% of MDD
38	ORWAZANW#38	462404	812580	10.5	100	94	88	52	26	26	A-7-9 (17)	CH	1.52	24	10	1.297	0.14	0.19	1	4
															30	1.387	0.36	0.49	3	
															65	1.46	0.57	0.76	4	
39	ORESZDS#39	475741	900676	12.26	100	96	89	50	28	22	A-7-10 (15)	CH	1.41	28	10	1.251	0.42	0.59	3	5
															30	1.351	0.69	1	5	
															65	1.427	0.64	1.26	6	
40	ARABS#40	478446	979535	26.85	89	87	86	90	39	51	A-7-11 (20)	ML	1.43	28	10	1.258	0.14	0.17	1	1
															30	1.367	0.19	0.23	1	
															65	1.446	0.26	0.33	2	
41	ORESZATS#41	464699	869206	26.32	99	80	59	-	NP	-	A-7-12 (5)	ML	1.45	16	10	1.243	1.27	2.3	12	30
															30	1.339	2.53	4.37	22	
															65	1.446	5.18	8.86	44	
42	ORESZAAS#42	455442	455442	15.62	99	91	85	38	27	11	A-7-13 (8)	ML	1.463	26.5	10	1.305	0.69	1.15	6	20
															30	1.393	2.76	4.14	21	
															65	1.456	4.37	6.45	33	

CHAPTER -4

REGRESSION ANALYSIS AND CORRELATION

4.1. INTRODUCTION

Regression analysis is a statistical technique that is very useful for building and analyzing relationships between two or more variables. The modeled relationships are usually practiced to solve problems in the field of engineering and science. The modeling relationships can be done either in simple linear regression or sophisticated multiple regression. Both methods are used to develop a line or a curve that provides the best fit to observed data. The produced model could be in the form of linear, Parabolic, Exponential, polynomial or logarithmic trend.

The built model is used to predict dependent variables at a given independent observed variables. There are several assumptions in fixing a regression model. The least square methods are used to choose the best fitting line for data under considerations. In the model processing, scattered data are shown distributed on the X & Y axis to see the distribution of individual variables. In the inspection of the scattered data, no line or curve will pass exactly through all the points. The points lie scattered randomly around the line or curve. Therefore, the best fit line should be selected. This is done by least square method. In this method, estimation of the model parameters is done by the assumption that the residuals corresponding to different observations are uncorrelated random variables with zero mean and constant variance (σ^2). The variance (σ^2) of the random error (ϵ) is unknown and must be estimated from the sample data[21].

The variability of dependent variable at a particular value of repressor is dependent by the error variance(σ^2). This indicates that there is a distribution of dependent variable value at each independent variable and that the variance of this distribution is the same at each repressor

[21].The variance(σ^2) determines the variability in observations of dependent variable. This, if σ^2 is small, the observed values of dependent variable will fall close to the line, and if σ^2 is large, the observed values of dependent variable depart significantly from the line. Because σ^2 is constant, the variability in dependent variable at any values of repressor (independent variable) is the same [21]

A convenient mechanism of measuring if the regression model performs as a predictor of the dependent variable or not is to compute the minimum in the square of errors that can be attributed to independent variables. This quantity is called the coefficient of determination (R^2). It is a measure of how much or what percentage of the variation in dependent variable is described by the variation of independent variable. Its value ranges from 0 to 1.The peason's correlation coefficient returns a values of between -1 to +1. A -1 means there is a strong negative correlation and +1 means that there is a strong positive correlation.

The followings are numerical values of peason's correlation coefficient that indicate its strength of correlation[22].

+0.7 or higher.....	very strong positive relationship
+0.4 - 0.69.....	strong positive relationship
0.3 - 0.39.....	Moderate positive relationship
0.2 - 0.29.....	week positive relationships
+0.1 - 0.19.....	negligible relationship
0.....	no relationship
-0.7	very strong negative relationship
- 0.4 to - 0.69.....	strong negative relationship
-0.3 to - 0.39.....	Moderate negative relationship

- 0.2 to - 0.29.....weak negative relationships

-0.1 to - 0.19.....negligible relationship

There are different techniques in which the adequacy of a regression model can be judged. Some of them are R- squared value(R^2), R-adjusted ,standard error (@) and the t-test [21]

4.2 Regression Analysis

At the beginning of regression analysis, scatter plotting that is (XY) plotting is carried out to graphically represent the relationship between two variables. This is done to see how the variables relate to each other. It provides a visual representation of the correlation between the two variables.

In this paper, CBR, MDD and OMC are taken as dependent variables where as DCP is taken as independent variable.

Before carrying out the regression analysis and scatter plotting, the result of soil samples were classified as per USCS and soils of nearly the same behavior were grouped together. After grouping soils with nearly the same behavior, a scatter diagram was generated by making use of the Excel spreadsheets in order to visually study the relationships developed between the dependent variables and the independent variables so that the model that best fit the observed results was developed.

The purpose of correlation diagram plotting is to visually understand the relationships between dependent and independent variables. The diagram clearly shows that there is either linear line or nonlinear line on which the points lie scattered randomly around.

In this research work, single linear and non linear regression models were made to correlate laboratory test results of CBR, MDD and OMC with DCP to characterize the strength of sub

grade soils from DCP tests. The general representation of probabilistic single linear and non linear regression models are presented in the following forms:

$$Y = \beta_0 + \beta_1 X + \epsilon \quad (4.1) \quad \text{Simple linear model}$$

$$\left. \begin{array}{l} Y = b_1 + b_2 \exp(b_3 X) \\ Y = b_1 + b_2 \ln(b_3 X) \end{array} \right\} \quad (4.2) \quad \text{Some non-linear models used in this thesis}$$

Where, β_0 , β_1 and ϵ are intercept, slope and error of simple regression model respectively. Similarly; b_1 , b_2 and b_3 are coefficients of non linear regression model. The best method to generalize a probabilistic model is to assume that the actual value of dependent variable (Y) is determined by the summation of the mean value function and the random error. The basic assumption to estimate the regression coefficients of the model is based on the least square method[21].

In this research work, conducting regression model was done in three steps. Analyzing the directionality of the data by using scatter plot, estimating the model i.e fitting the appropriate line, and evaluating the validity and usefulness of the model. The first step enables to formulate the model i.e to identify that independent variable has actual influence on dependent variable. In the second step of the regression analysis of the fitting the regression line, mathematically least square estimation is used to minimize the residuals. In this step, the coefficient of determination (R^2) used as key measure to the validity of the estimated line. The final step followed is test of the significance. It is done to check whether created model and estimated coefficients can be found in the general population where the sample is drawn from. In this research work, excel spread sheet software was used to plot and analyze the data as scatter plot, add trend line of the excel was used to fit the best regression line and finally Statistical Package for Social Science

(SPSS) software was used to investigate significance of the generated models. The statistical information of the test results are presented herein under in tab

Table 4-1 Statistical Information of Dependent and Independent Variables

Variable Type	Variable Name	Unit	No. of Samples	Ranges		Mean	Standard Deviation
				Min.	Max.		
Dependent	CBR	%	41	1	110	30	28
	MDD	g/cc	41	0.842	2.122	1.503	0.264
	OMC	%	41	6	35	21.9	7.1
Independent	DCP	Mm/Blow	41	3.9	35	14.81	8.96

In order to identify the influence of one variable on the each other, the following simple linear regression for all soils categories has been analyzed. After analysis their respective correlation coefficient and level of significance together with number of samples used has been determined. Accordingly, the pearsons correlation coefficients matrix for all soil types is shown from table 4.2 to 4.6 as follows:

Table 4-2 Correlation Matrix for GW & GP soils

		DCP	CBR	MDD	OMC
DCP	Pearson Correlation	1	-.718*	-.811**	.651*
	Sig. (2-tailed)		.019	.004	.041
	N	10	10	10	10
CBR	Pearson Correlation	-.718*	1	.665*	-.536
	Sig. (2-tailed)	.019		.036	.111
	N	10	10	10	10
MDD	Pearson Correlation	-.811**	.665*	1	-.728*
	Sig. (2-tailed)	.004	.036		.017
	N	10	10	10	10
OMC	Pearson Correlation	.651*	-.536	-.728*	1
	Sig. (2-tailed)	.041	.111	.017	
	N	10	10	10	10
*. Correlation is significant at the 0.05 level (2-tailed).					
**. Correlation is significant at the 0.01 level (2-tailed).					

Table 4-3 Correlation Matrix for GC Soils

		DCP	ln(CBR)	MDD	OMC
DCP	Pearson Correlation	1	-.833*	.107	-.005
	Sig. (2-tailed)		.020	.819	.991
	N	7	7	7	7
ln(CBR)	Pearson Correlation	-.833*	1	-.025	-.037
	Sig. (2-tailed)	.020		.957	.937
	N	7	7	7	7
MDD	Pearson Correlation	.107	-.025	1	-.863*
	Sig. (2-tailed)	.819	.957		.012
	N	7	7	7	7
OMC	Pearson Correlation	-.005	-.037	-.863*	1
	Sig. (2-tailed)	.991	.937	.012	
	N	7	7	7	7
*. Correlation is significant at the 0.05 level (2-tailed).					

Table 4-4 Correlation Matrix for low plastic silt and sandy silt soils (ML&SM)

		DCP	ln(CBR)	MDD	OMC
DCP	Pearson Correlation	1	.936**	-.845*	-.566
	Sig. (2-tailed)		.006	.034	.241
	N	6	6	6	6
ln(CBR)	Pearson Correlation	.936**	1	-.794	-.395
	Sig. (2-tailed)	.006		.059	.438
	N	6	6	6	6
MDD	Pearson Correlation	-.845*	-.794	1	.465
	Sig. (2-tailed)	.034	.059		.353
	N	6	6	6	6
OMC	Pearson Correlation	-.566	-.395	.465	1
	Sig. (2-tailed)	.241	.438	.353	
	N	6	6	6	6
**. Correlation is significant at the 0.01 level (2-tailed).					
*. Correlation is significant at the 0.05 level (2-tailed).					

		DCP	ln(CBR)	MDD	OMC
DCP	Pearson Correlation	1	-.906**	.750	.480
	Sig. (2-tailed)		.005	.052	.276
	N	7	7	7	7
ln(CBR)	Pearson Correlation	-.906**	1	-.690	-.176
	Sig. (2-tailed)	.005		.087	.705
	N	7	7	7	7
MDD	Pearson Correlation	.750	-.690	1	.123
	Sig. (2-tailed)	.052	.087		.792
	N	7	7	7	7
OMC	Pearson Correlation	.480	-.176	.123	1
	Sig. (2-tailed)	.276	.705	.792	
	N	7	7	7	7
**. Correlation is significant at the 0.01 level (2-tailed).					

Table 4-5 Correlation Matrix for Black Cotton clay soils

		DCP	ln(CBR)	MDD	OMC
DCP	Pearson Correlation	1	-.936*	-.941*	.040
	Sig. (2-tailed)		.019	.017	.949
	N	5	5	5	5
ln(CBR)	Pearson Correlation	-.936*	1	.840	-.167
	Sig. (2-tailed)	.019		.075	.788
	N	5	5	5	5
MDD	Pearson Correlation	-.941*	.840	1	-.175
	Sig. (2-tailed)	.017	.075		.778
	N	5	5	5	5
OMC	Pearson Correlation	.040	-.167	-.175	1
	Sig. (2-tailed)	.949	.788	.778	
	N	5	5	5	5

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4-6 Correlation Matrix for clay soils(CL & CH)

		DCP	ln(CBR)	MDD	OMC
DCP	Pearson Correlation	1	-.796	-.520	.576
	Sig. (2-tailed)		.058	.290	.232
	N	6	6	6	6
ln(CBR)	Pearson Correlation	-.796	1	.482	-.868*
	Sig. (2-tailed)	.058		.332	.025
	N	6	6	6	6
MDD	Pearson Correlation	-.520	.482	1	-.396
	Sig. (2-tailed)	.290	.332		.437
	N	6	6	6	6
OMC	Pearson Correlation	.576	-.868*	-.396	1
	Sig. (2-tailed)	.232	.025	.437	
	N	6	6	6	6

From the above linear relationship, it is shown that the correlation between CBR and DCP for all categories of soils has moderate correlation coefficient.

The relationship between CBR and MDD indicates that as CBR values increase, MDD increase. From the above analysis, some categories of soil have strong relation and the others moderate and week relations. Accordingly, in black cotton soil, low plastic silt and sandy silt soil there are strong correlations. For well and poorly graded gravel ,highly plastic silt and other clay except black cotton soil have moderate correlations. In the above analysis table, there is no relation of CBR with MDD for gravel clay soil. This is due to the presence of more clay soils and some granular materials blended to each other. Similarly; there is a linear relationship between OMC and CBR in which strong correlation is observed in clay soil and moderate correlation in well and poorly graded gravel soil. In other remaining categories of soil, week correlation exist between CBR and OMC.

In addition to the above correlation analysis, a number of simple linear and non linear regression analysis that best fit the observed laboratory test results with DCP tests were done. Accordingly, the summary of the correlation results for different categories of soils are indicated herein under:

4.2.1. Single Linear Regression Analysis

Model A: Correlation between MDD and DCP for ML and SM Soils

The details of the statistical out- put indicates that the relationship developed between MDD and DCP for this particular soil category is significant ($\alpha < 0.05$). Its detail is indicated in **Model A of Appendix B**

The resulting regression analysis of MDD and DCP for ML and SM soils become best fit in linear regression. Accordingly, the result is expressed by the following single linear equation with the corresponding correlation coefficient:

$$\left. \begin{array}{l} \text{MDD} = -0.006 * \text{DCP} + 1.587, \text{ with} \\ R^2 = 0.714, n=6 \end{array} \right\} \quad (4.3)$$

From the value of coefficient of determination above, it is observed that moderate correlation strength exists between MDD and DCP for GW & GP soil. The developed correlation is based on only six samples. This is resulted in moderate correlation strength. It will be improved if more sample sizes are considered.

Its scatter data together with the best fitted line developed is shown in the figure below:

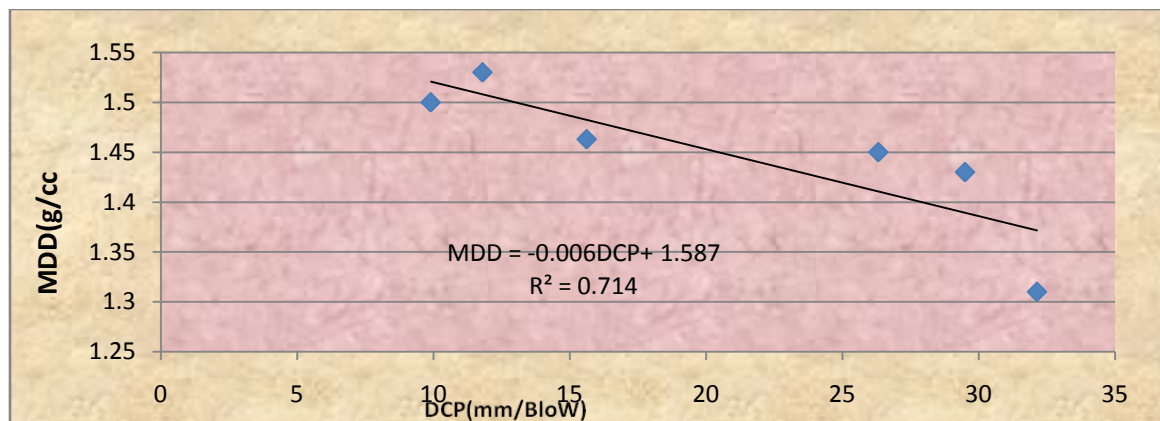


Figure 4.1 Correlation between MDD and DCP for ML and SM soils

4.2.2. Non Linear Regression Analysis

4.2.2.1. Correlation Between CBR And DCP For Different Types Of Soil.

Model 1: Correlation between CBR and DCP for well graded and poorly graded gravel soil.

After best fit line is fixed , significance test is made using SPSS soft ware and details of statistical output indicates that the relationship developed between correlating variables that are CBR and DCP for well (GW) and poorly(GP) gravel soil is significant ($\alpha < 0.05$) as indicated in **Model -1 of Appendix B**. And also moderate correlation strength exists between correlating variables of GW & GP soil. The resulting regression analysis after correlating CBR and DCP for well and poorly graded gravel soil is expressed by the following non- linear equation with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} \ln(\text{CBR}) &= -0.39 \ln(\text{DCP}) + 4.828, \text{ with} \\ R^2 &= 0.5, \quad n=10 \end{aligned} \right\} \quad (4.4)$$

And also moderate correlation strength exists between correlating variables of GW & GP soil. The developed correlation is based on only ten samples. This is resulted in moderate correlation strength. It will be improved if more sample sizes are considered.

The scatter data and the best fitted line developed is shown in the figure below:

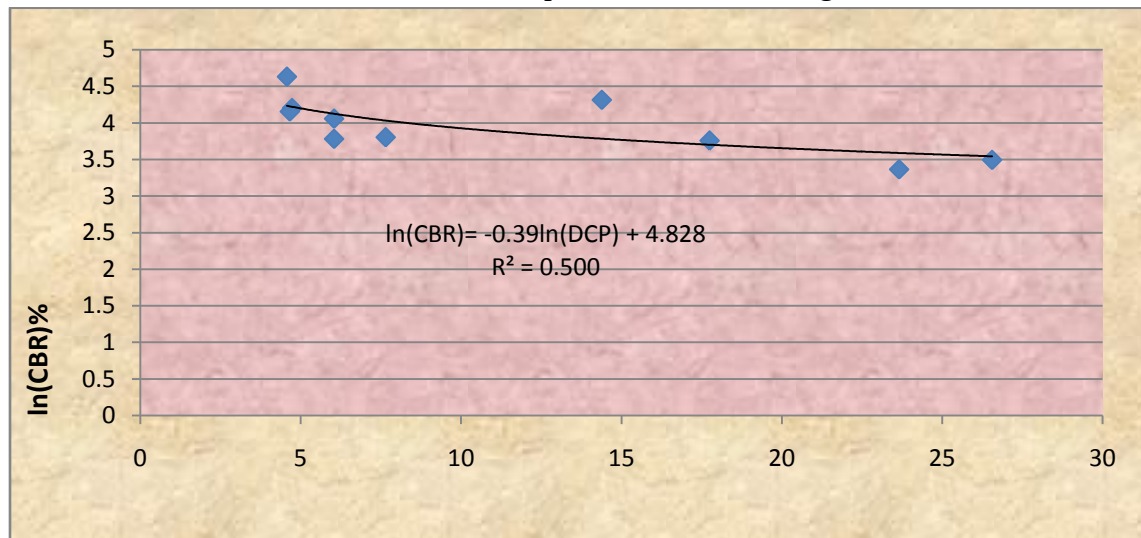


Figure 4.2 Correlation between ln(CBR) and DCP for well and poorly graded soil

Model 2: Correlation between CBR and DCP for Gravel Clay(GC) soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (CBR and DCP) for GC soil is significant ($\alpha < 0.05$) as indicated in **Model -2 of Appendix B**.

The resulting regression analysis after correlating CBR and DCP for Gravel Clay 1 soil is expressed by the following non- linear equation with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} \ln(\text{CBR}) &= -0.065 \ln(\text{DCP}) + 5.415 \text{ with} \\ R^2 &= 0.71, \quad n=7 \end{aligned} \right\} \quad (4.5)$$

And also moderate correlation strength exists between correlating variables of GC soil. The developed correlation is based on only ten samples. This is resulted in moderate correlation strength. It will be improved if more sample sizes are considered.

The scatter data and the best fitted line developed is shown in the figure below:

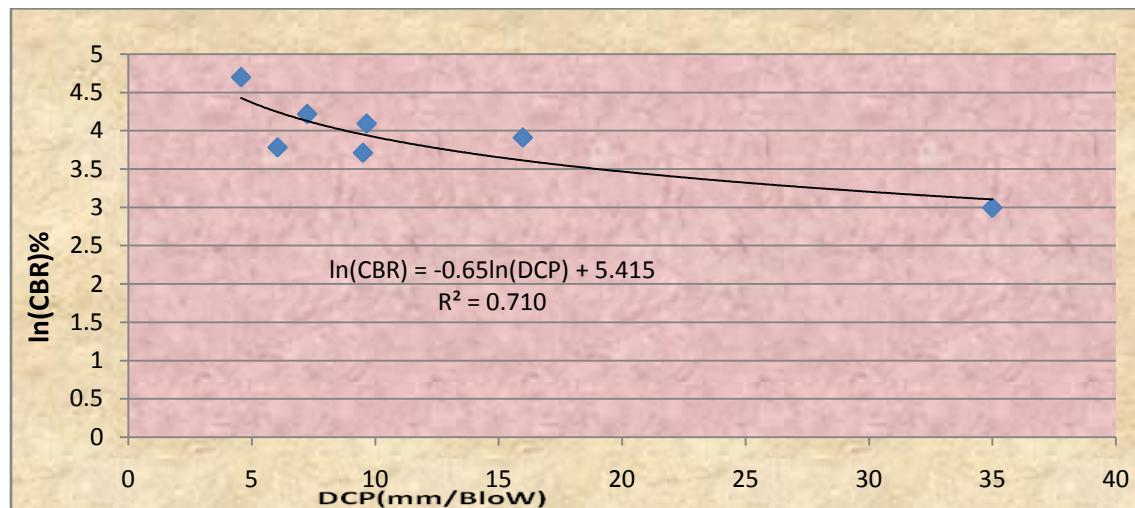


Figure 4.3 Correlation between ln(CBR) and DCP for gravel clay soil

Model 3: Correlation between CBR and DCP for Low plastic Silt (ML) and Sandy silt (SM) soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (CBR and DCP) for **Low plastic Silt (ML) and Sandy silt (SM) soil** is significant ($\alpha < 0.05$) as indicated in **Model -3 of Appendix B**.

The resulting regression analysis after correlating CBR and DCP for **Low plastic Silt (ML) and Sandy silt (SM) soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} \ln(\text{CBR}) &= 1.692 \cdot \ln(\text{DCP}) - 2.107 \text{ with} \\ R^2 &= 0.933, \quad n=6. \end{aligned} \right\} \quad (4.6)$$

And also strong correlation strength exists between correlating variables of ML & SM soil. The developed correlation is based on only six samples. This is resulted in high correlation strength. It will be improved if more sample sizes are considered.

The scatter data and the best fitted line developed is shown in the figure below:

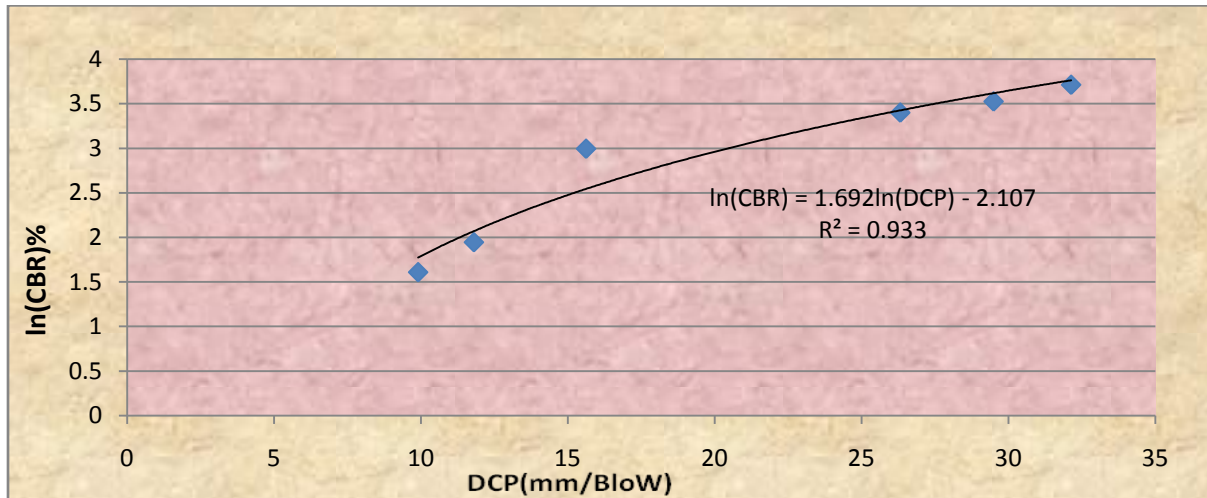


Figure 4.4 Correlation between ln(CBR) and DCP for low plastic silt and sandy silt soil

Model 4: Correlation between CBR and DCP for Highly plastic Silt(MH) soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (CBR and DCP) for **highly plastic Silt (MH) soil** is significant ($\alpha < 0.05$) as indicated in **Model -4 of Appendix B.**

The resulting regression analysis after correlating CBR and DCP for **highly plastic Silt (MH)** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} \ln(\text{CBR}) &= -1.96 \cdot \ln(\text{DCP}) + 7.375 \text{ with} \\ R^2 &= 0.825, \quad n=7 \end{aligned} \right\} \quad (4.7)$$

And also strong correlation strength exists between correlating variables of MH soil. The developed correlation is based on only seven samples. This is resulted in high correlation strength. It will be improved if more sample sizes are considered.

The scatter data and the best fitted line developed is shown in the figure below:

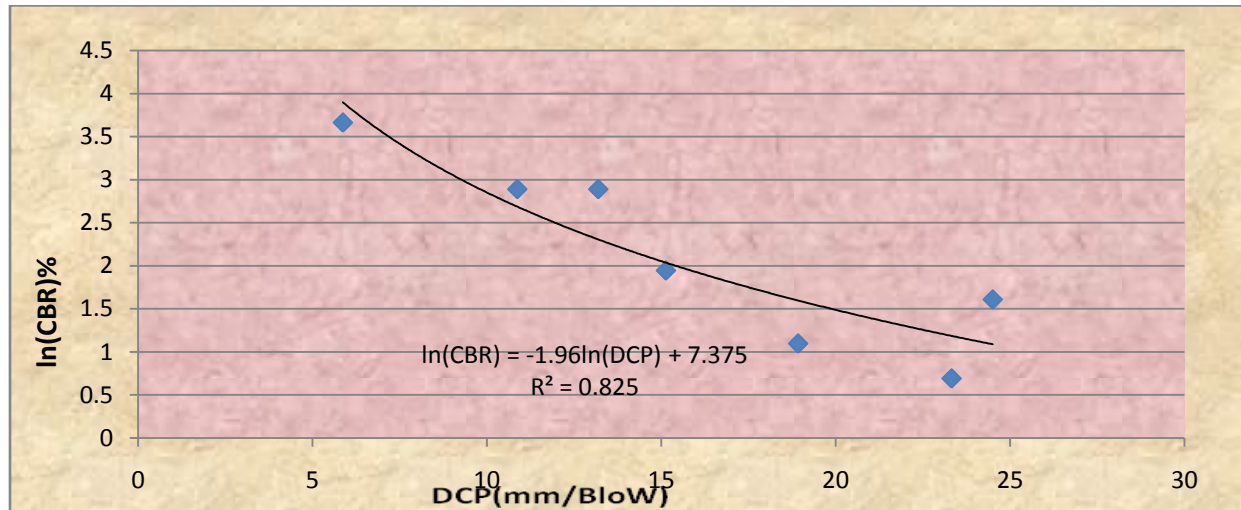


Figure 4.5 Correlation between ln(CBR) and DCP for highly plastic silt

Model 5: Correlation between CBR and DCP for Expansive (Black Cotton) Clay soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (CBR and DCP) for **expansive (Black Cotton) clay soil** is significant ($\alpha < 0.05$) as indicated in **Model -5 of Appendix B.**

The resulting regression analysis after correlating CBR and DCP for **expansive (Black Cotton) clay soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} \ln(\text{CBR}) &= -1.22 \cdot \ln(\text{DCP}) + 4.025 \text{ with} \\ R^2 &= 0.9, \quad n = 7 \end{aligned} \right\} \quad (4.8)$$

And also strong correlation strength exists between correlating variables of black cotton soil. The developed correlation is based on only seven samples. This is resulted in high correlation strength. It will be improved if more sample sizes are considered.

The scatter data and the best fitted line developed is shown in the figure below:

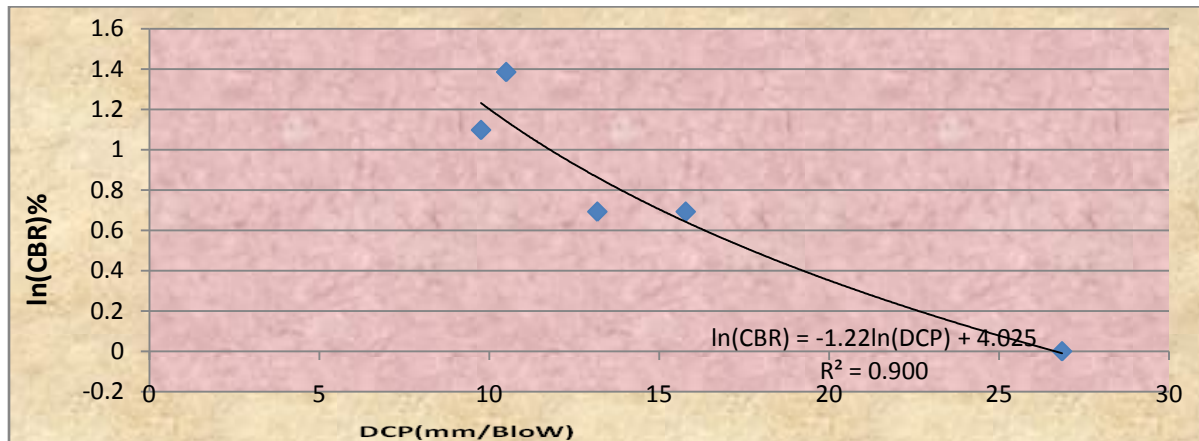


Figure 4.6 Correlation between ln(CBR) and DCP for black cotton soil

Model 6: Correlation between CBR and DCP for all clay soils except Black Cotton soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (CBR and DCP) for **expansive (Black Cotton) clay soil** is significant ($\alpha < 0.05$) as indicated in **Model -6 of Appendix B.**

The resulting regression analysis after correlating CBR and DCP **for all clay soils except Black Cotton soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} \ln(\text{CBR}) &= -1.29 \cdot \ln(\text{DCP}) + 4.772 \text{ with} \\ R^2 &= 0.808, \quad n=6 \end{aligned} \right\} \quad (4.9)$$

From the above correlation equation and its coefficient of determination value, it is observed that strong correlation exists between soaked CBR and DCP of **all clay soil**. The developed

correlation is based on only ten samples. This is resulted in moderate correlation strength. It will be improved if more sample sizes are considered.

The scatter data and the best fitted line developed is shown in the figure below:

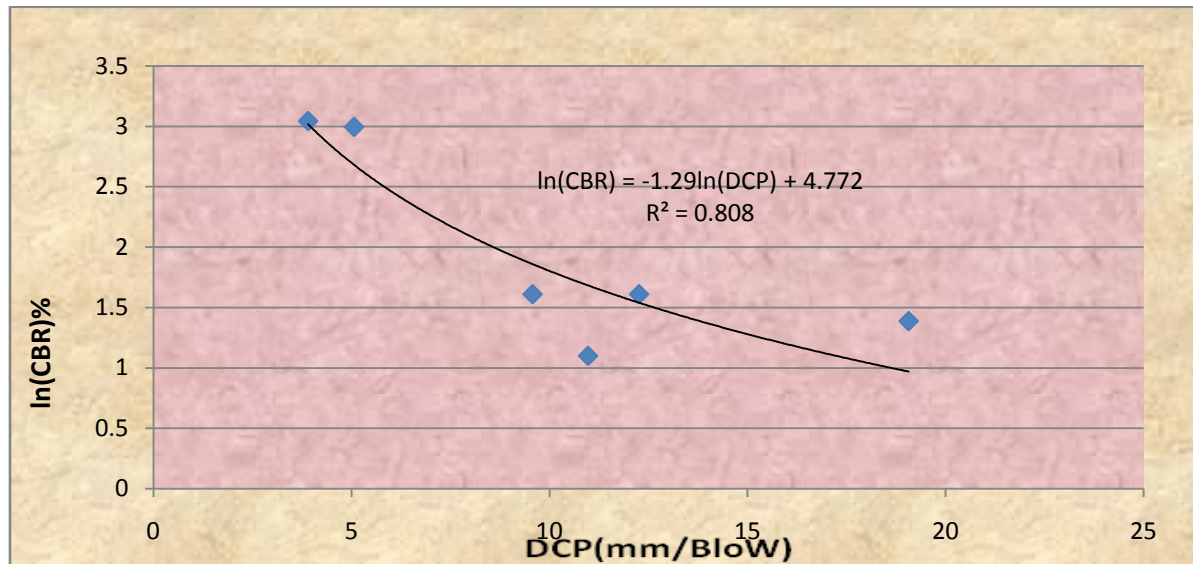


Figure 4.7 Correlation between ln(CBR) and DCP for clay soil

4.2.2.2. Correlation between MDD and DCP for different types of soil.

Model 7: Correlation Between MDD and DCP for Well(GW) and Poorly Graded(GP)

Gravel Soil

After best fit line is fixed , significance test is made using **SPSS soft ware** and details of statistical output indicates that the relationship developed between correlating variables that are MDD and DCP for well (GW) and poorly(GP) gravel soil is significant ($\alpha < 0.05$) as indicated in **Model -7 of Appendix B**.

The resulting regression analysis after correlating **MDD and DCP** for well and poorly graded gravel soil is expressed by the following non- linear equation with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} \text{MDD} &= 1.907 \exp(-0.03 \text{DCP}) \quad \text{with} \\ R^2 &= 0.764, \quad n=10 \end{aligned} \right\} \quad (4.10)$$

And also moderate correlation strength exists between correlating variables of GW & GP soil.

This is the result of small sample size used in the analysis. It could be improved by increasing sample size.

The scatter data and the best fitted line developed is shown in the figure below:

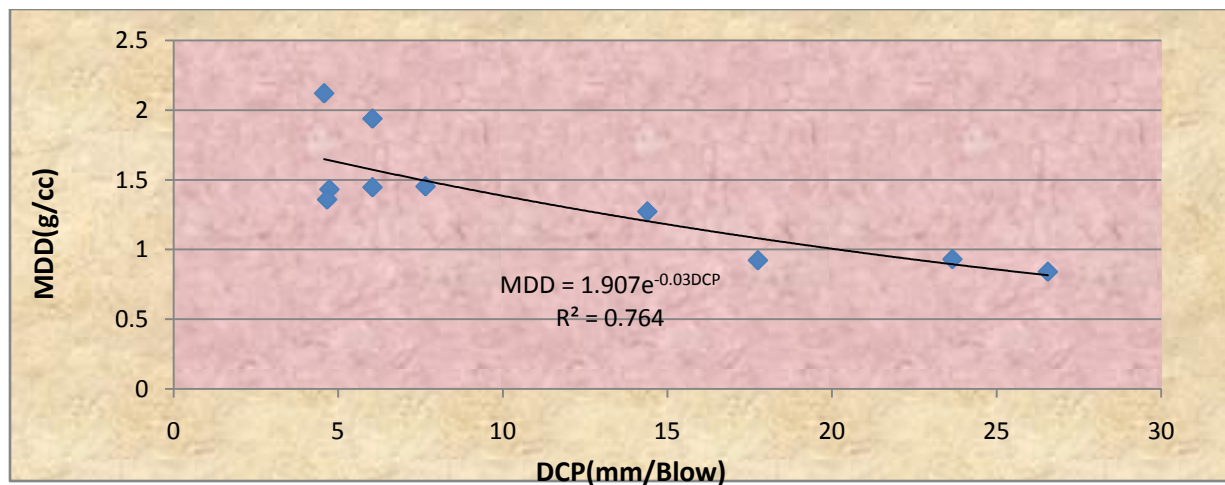


Figure 4.8 Correlation between MDD and DCP for well and poorly graded soil

Model 8: Correlation between MDD and DCP for Gravel Clay(GC) soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (MDD and DCP) for GC soil is not significant ($\alpha > 0.05$) as indicated in **Model -8 of Appendix B.**

The resulting regression analysis after correlating MDD and DCP for Gravel Clay l soil is expressed by the following non- linear equation with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} MDD &= -0.25 \ln(DCP) + 2.336 \text{ with} \\ R^2 &= 0.256, \quad n=6 \end{aligned} \right\} \quad (4.11)$$

And also it is found that weak correlation strength exists between correlating variables of GC soil. This is due to small number of samples used in the correlation development.

The scatter data and the best fitted line developed is shown in the figure below:

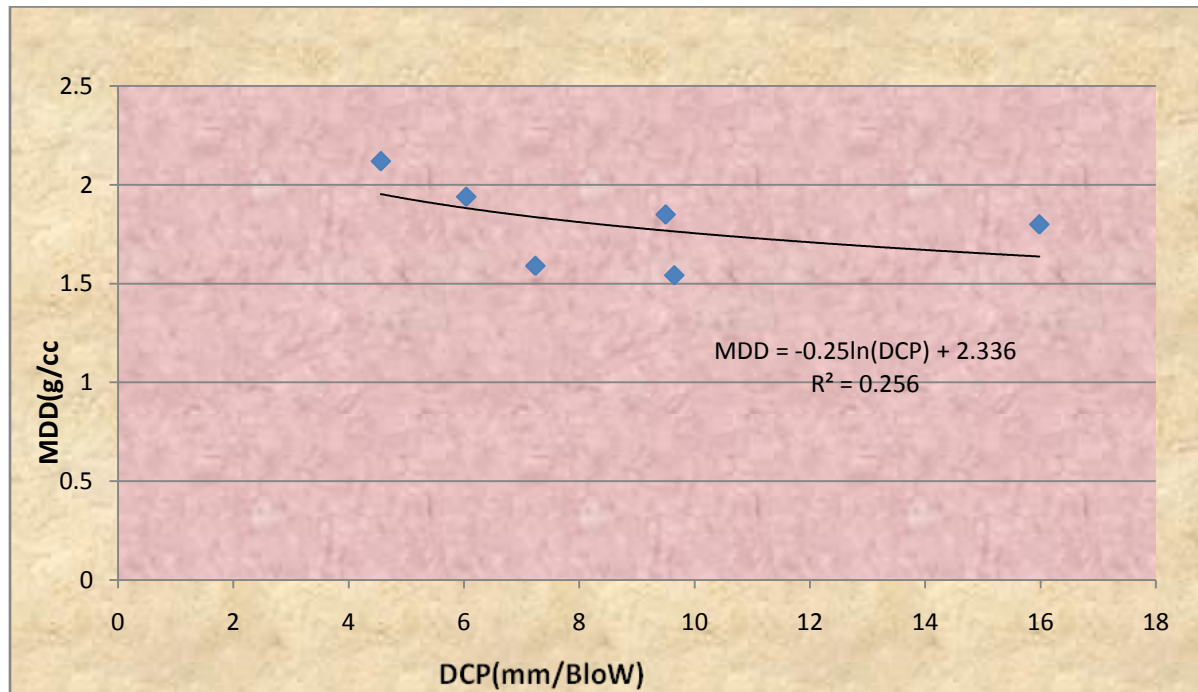


Figure 4.9 Correlation between MDD and DCP for gravel clay soil

Model 9: Correlation between MDD and DCP for Highly plastic Silt(MH) soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (MDD and DCP) for **highly plastic Silt (MH) soil** is not significant ($\alpha > 0.05$) as indicated in

Model -9 of Appendix B

The resulting regression analysis after correlating MDD and DCP for **highly plastic Silt (MH) soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} MDD &= 0.121 \cdot \ln(DCP) + 1.138 \\ R^2 &= 0.623, \quad n=7 \end{aligned} \right\} \quad (4.12)$$

. And it is observed that moderate correlation strength exists between MDD and DCP for highly plastic silt(MH) soil.If more samples are used in the analysis, the correlation will be improved more than the developed.

The scatter data and the best fitted line developed is shown in the figure below:

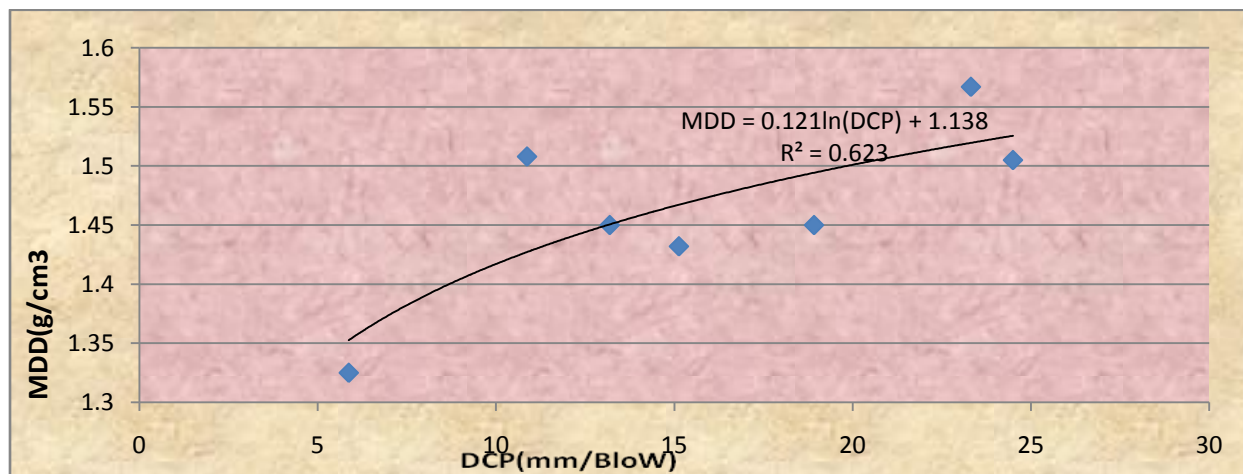


Figure 4.10 Correlation between MDD and DCP for highly plastic silt

Model 10: Correlation Maximum Dry Density (MDD) and DCP for Expansive (Black Cotton) soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (MDD and DCP) for **expansive (Black Cotton) clay soil** is significant ($\alpha < 0.05$) as indicated in **Model -10 of Appendix B**.

The resulting regression analysis after correlating MDD and DCP for **expansive (Black Cotton) clay soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} MDD &= 1.593 * \exp(-0.001 DCP) \text{ with} \\ R^2 &= 0.885, \quad n=5 \end{aligned} \right\} \quad (4.13)$$

And also it is found that strong correlation strength exists between these correlating variables of expansive soil. The developed equation is using five sample size so that the correlation will be improved using sample size more than five.

The scatter data and the best fitted line developed is shown in the figure below:

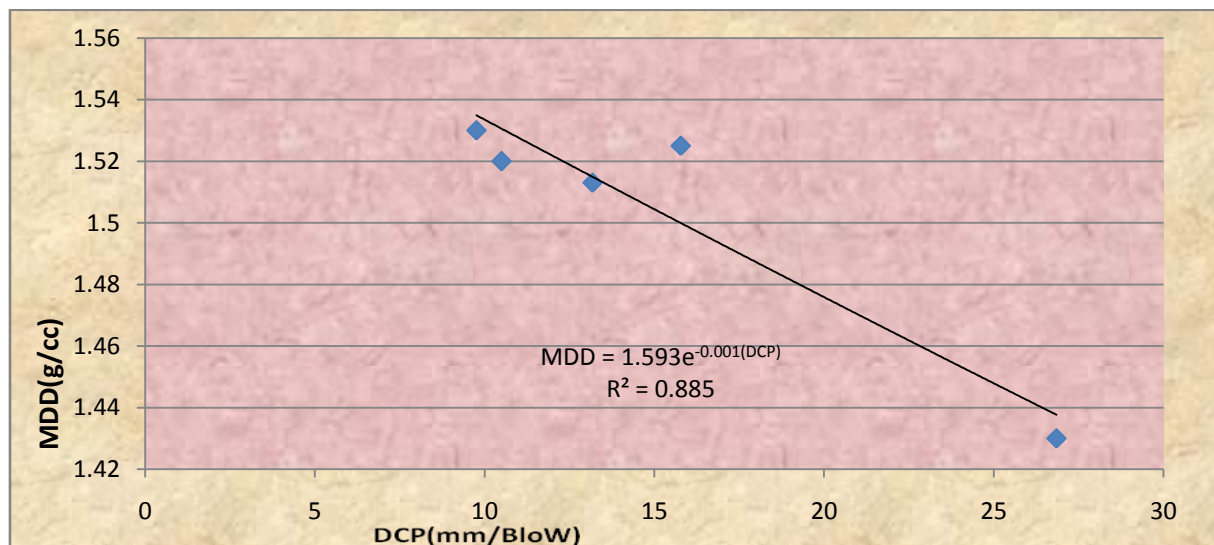


Figure 4.11 Correlation between MDD and DCP for black cotton soil

Model 11: Correlation between MDD and DCP for all clay except Black Cotton soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (MDD and DCP) for **expansive (Black Cotton) soil** is not significant ($\alpha > 0.05$) as indicated in **Model -11 of Appendix B.**

The resulting regression analysis after correlating MDD and DCP **for all clay soils except Black Cotton soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} MDD &= 1.503 * \exp(-0.001 DCP) \text{ with} \\ R^2 &= 0.270, \quad n=6 \end{aligned} \right\} \quad (4.14)$$

And also weak correlation strength exists between correlating variables of all clay except Black Cotton soil. The small sample size used leads to weak correlation equation.

The scatter data and the best fitted line developed is shown in the figure below:

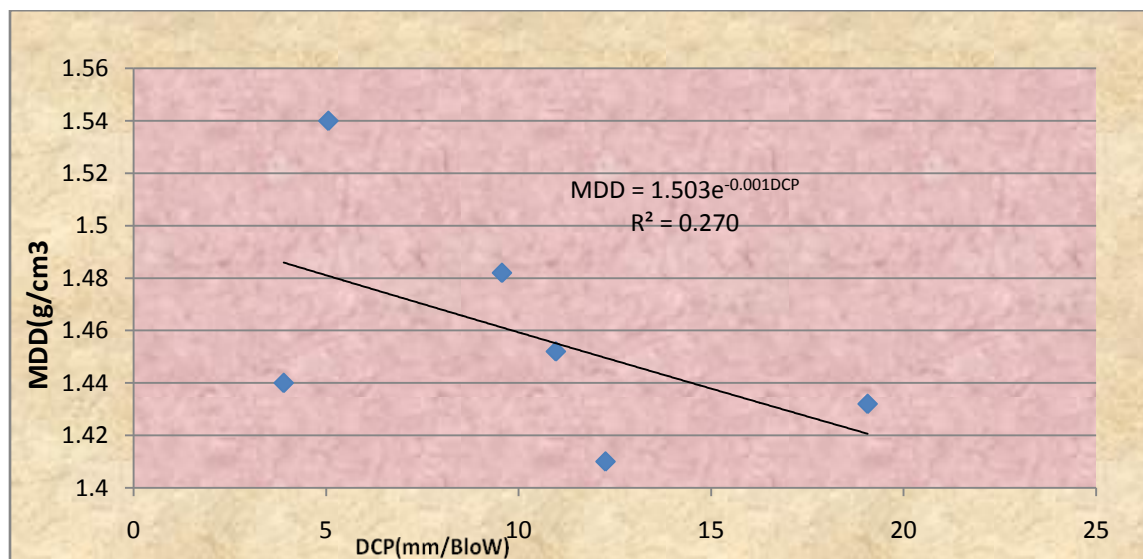


Figure 4.12 Correlation between MDD and DCP for clay soil

4.2.2.3. Correlation between OMC and DCP for different types of soil.

Model 12: Correlation Between OMC and DCP for Well(GW) and Poorly Graded(GP)

Gravel Soil

After best fit line is fixed , significance test is made using **SPSS soft ware** and details of statistical output indicates that the relationship developed between correlating variables that are

OMC and DCP for well (GW) and poorly(GP) gravel soil is significant ($\alpha < 0.05$) as indicated in **Model -12 of Appendix B**.

The resulting regression analysis after correlating **OMC and DCP** for well and poorly graded gravel soil is expressed by the following non- linear equation with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} \text{OMC} &= 9.964 \exp(0.037 \text{DCP}) \quad \text{with} \\ R^2 &= 0.356, \quad n=10 \end{aligned} \right\} \quad (4.15)$$

And also weak correlation strength exists between correlating variables of GW & GP soil because of small .

The scatter data and the best fitted line developed is shown in the figure below:

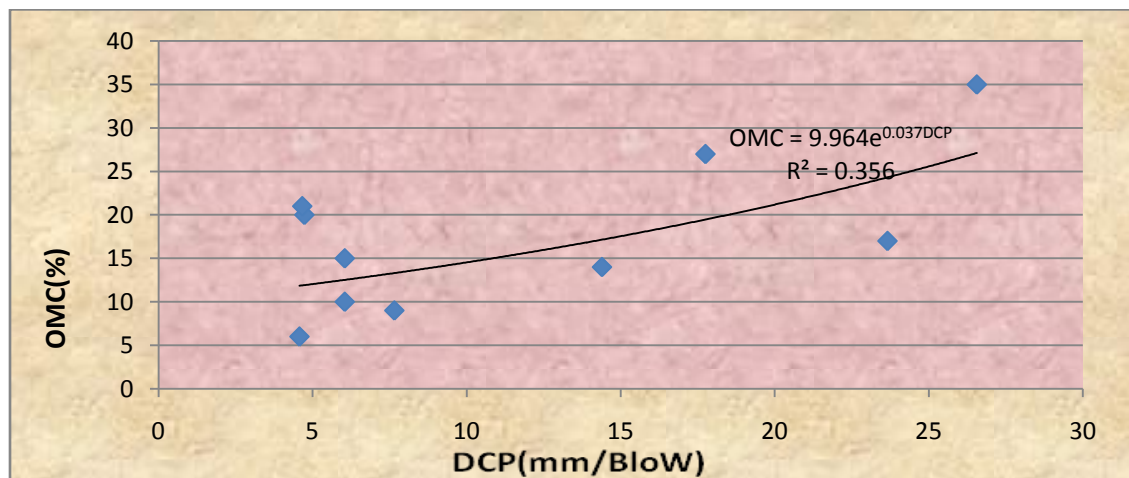


Figure 4.13 Correlation between OMC and DCP for well and poorly graded soil

Model 13: Correlation between OMC and DCP for Gravel Clay(GC) soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (OMC and DCP) for GC soil is not significant ($\alpha > 0.05$) as indicated in **Model -13 of Appendix B**.

The resulting regression analysis after correlating OMC and DCP for Gravel Clay soil is expressed by the following non- linear equation with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} OMC &= -0.879 \ln(DCP) + 14.67 \text{ with} \\ R^2 &= 0.013, \quad n=7 \end{aligned} \right\} \quad (4.16)$$

And also weak correlation strength exists between correlating variables of GC soil. This is because of small sample size used in the analysis.

The scatter data and the best fitted line developed is shown in the figure below:

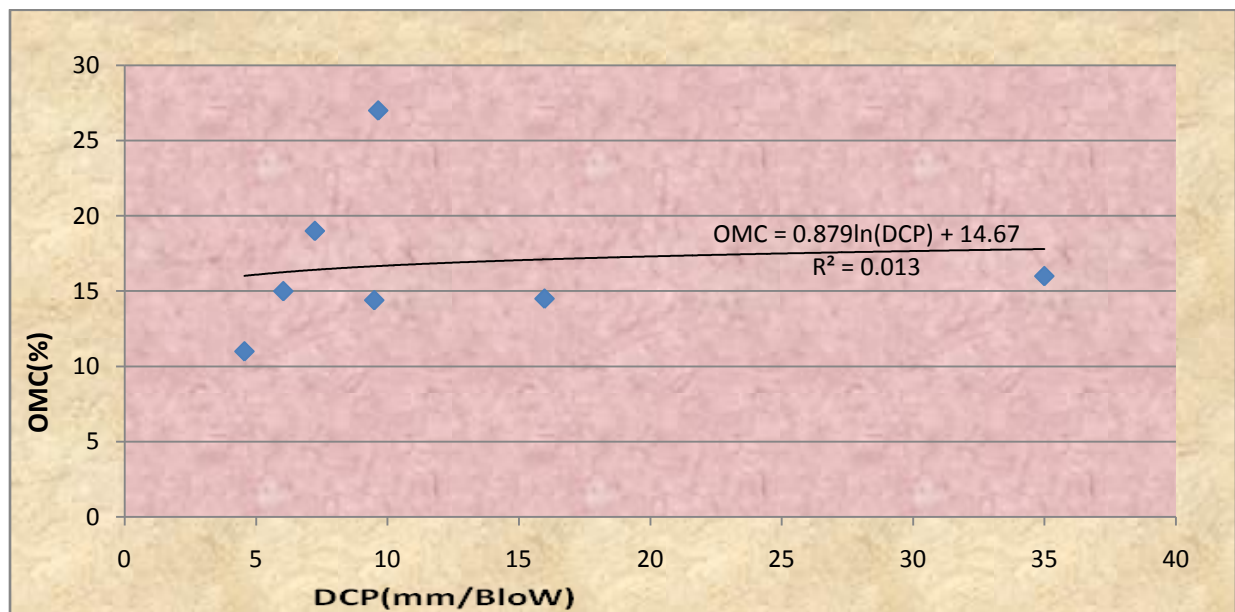


Figure 4.14 Correlation between OMC and DCP for gravel clay soil

Model 14: Correlation between OMC and DCP for Low plastic Silt(ML) and Sandy silt (SM) soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables

(OMC and DCP) for **Low plastic Silt (ML) and Sandy silt (SM) soil** is not significant ($\alpha > 0.05$) as indicated in **Model -14 of Appendix B**.

The resulting regression analysis after correlating OMC and DCP for **Low plastic Silt (ML) and Sandy silt (SM) soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} OMC &= 27.25 * \exp(-0.01 DCP) \text{ with} \\ R^2 &= 0.308, \quad n=6 \end{aligned} \right\} \quad (4.17)$$

And also weak correlation strength exists between correlating variables of ML & SM soil. This is because six samples were used in the development of equation. It can be increased by using more sample size.

The scatter data and the best fitted line developed is shown in the figure below:

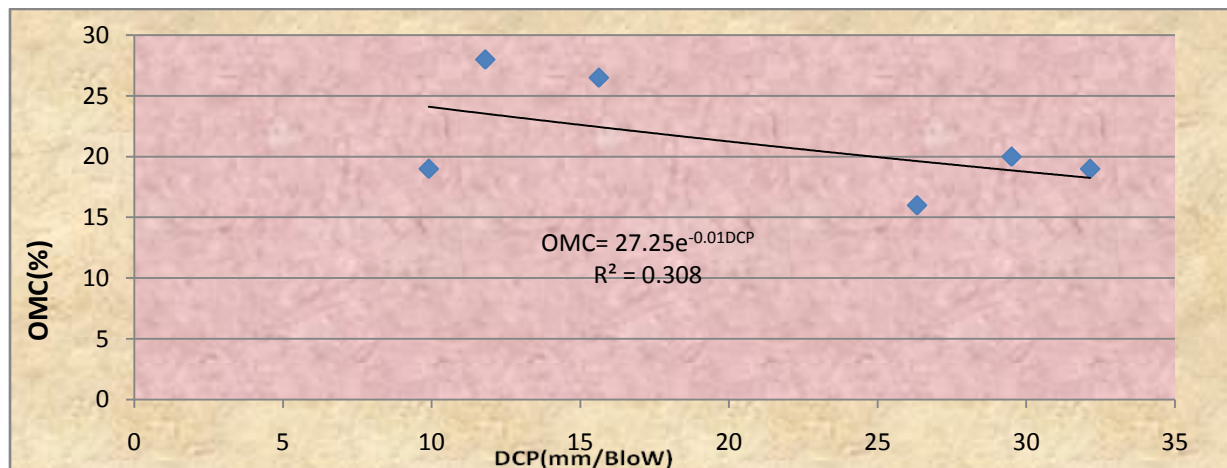


Figure 4.15 Correlation between OMC and DCP for low plastic silt and sandy silt soil

Model 15: Correlation between OMC and DCP for Highly plastic Silt(MH) soil.

After best fit non linear line is fixed, significance test is made using **SPSS** software and details of statistical output indicates that the relationship developed between correlating variables (OMC and DCP) for **highly plastic Silt(MH) soil** is not significant ($\alpha > 0.05$) as indicated in **Model -15 of Appendix B**.

The resulting regression analysis after correlating OMC and DCP for highly plastic Silt(MH) soil is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} OMC &= 22.92 * \exp(0.01 DCP) \text{ with} \\ R^2 &= 0.224, \quad n=7 \end{aligned} \right\} \quad (4.18)$$

And also weak correlation strength exists between correlating variables of MH soil. Seven samples were used in the analysis so that weak correlation strength was developed.

The scatter data and the best fitted line developed is shown in the figure below:

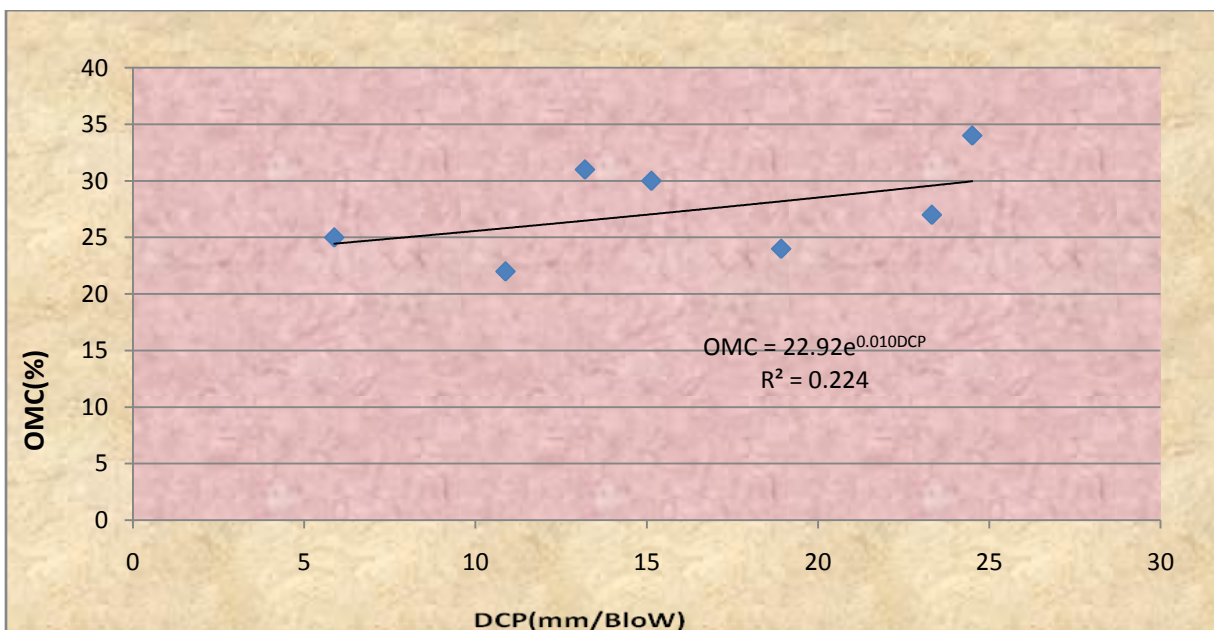


Figure 4.16 Correlation between OMC and DCP for highly plastic silt

Model 16: Correlation between OMC and DCP for Expansive (Black Cotton) Clay soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (OMC and DCP) for **expansive (Black Cotton) clay soil** is significant ($\alpha < 0.05$) as indicated in **Model -16 of Appendix B**.

The resulting regression analysis after correlating OMC and DCP for **expansive (Black Cotton) clay soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} OMC &= 26.16 * \exp(0.001 DCP) \text{ with} \\ R^2 &= 0.004, \quad n=5 \end{aligned} \right\} \quad (4.19)$$

And also weak correlation strength exists between correlating variables of expansive clay soil.

Because of small sample used in the development of equation, its correlation strength is weak.

The scatter data and the best fitted line developed is shown in the figure below:

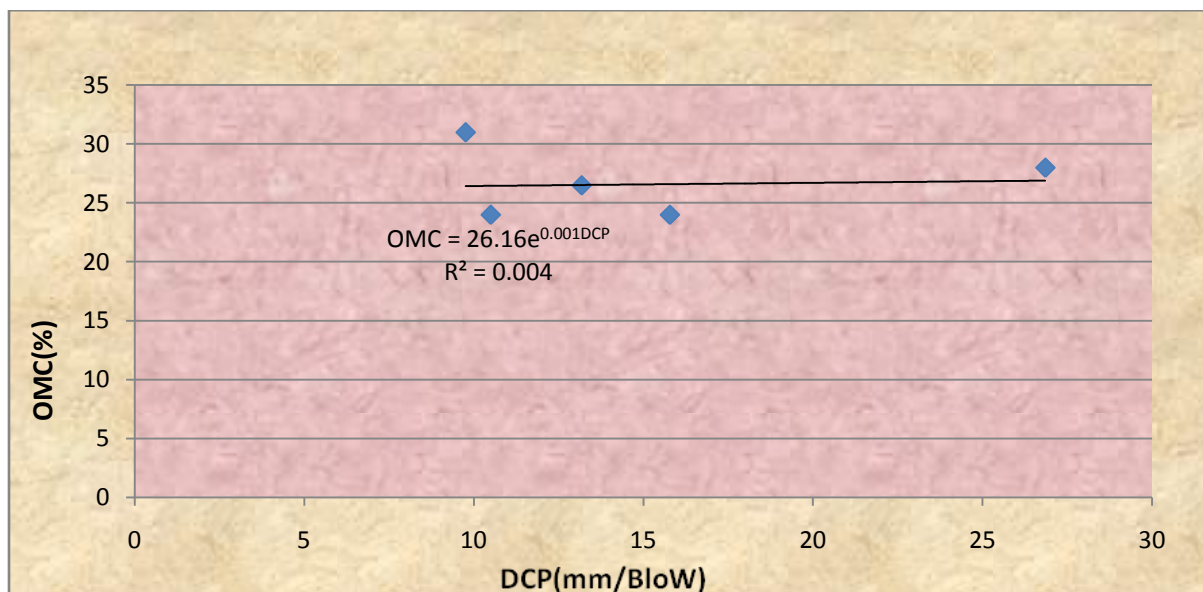


Figure 4.17 Correlation between OMC and DCP for black cotton soil

Model 17: Correlation between OMC and DCP for all clay except Black Cotton soil.

After best fit non linear line is fixed , significance test is made using **SPSS** soft ware and details of statistical output indicates that the relationship developed between correlating variables (OMC and DCP) for **expansive (Black Cotton) soil** is not significant ($\alpha > 0.05$) as indicated in **Model -17 of Appendix B.**

The resulting regression analysis after correlating OMC and DCP **for all clay soils except Black Cotton soil** is expressed by the following **non- linear equation** with its corresponding coefficient of determination (R^2) and number of samples used in the analysis:

$$\left. \begin{aligned} OMC &= 5.163 \ln(DCP) + 14.06 \text{ with} \\ R^2 &= 0.496, \quad n=6 \end{aligned} \right\} \quad (4.20)$$

And also weak correlation strength exists between correlating variables of **all clay except Black Cotton soils** because of six number of sample size used in the analysis.

The scatter data and the best fitted line developed is shown in the figure below:

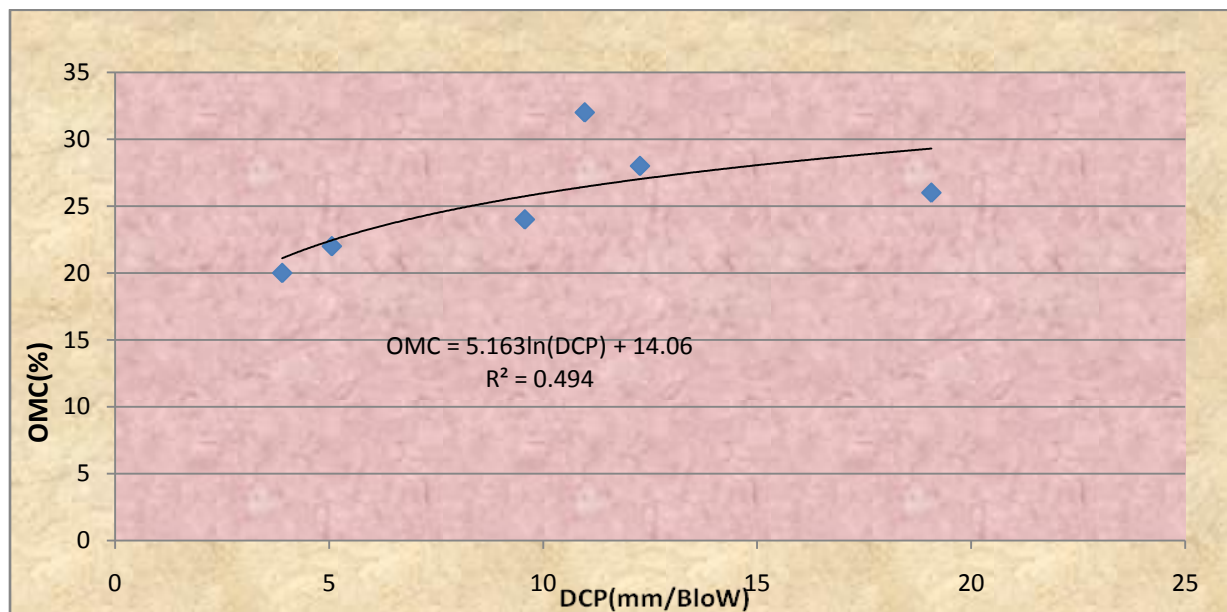


Figure 4.18 Correlation between OMC and DCP for clay soil

Table 4-7 Summary of the regression analysis for the correlation between CBR and DCP

Soil Types According to USCS Classification	Regression Types	Model Name	R ²	Standard Error Estimate (α)	Significance Test Result	Developed Equation
GW & GP Soil	Simple Non-linear regression	Model- 1	0.56	0.013	<0.05	$Ln(CBR) = -0.39 \ln(DCP) + 4.828$
GC Soil	Simple Non-linear regression	Model- 2	0.84	0.004	<0.05	$Ln(CBR) = -0.65 \ln(DCP) + 5.415$
ML & SM Soils	Simple Non-linear regression	Model- 3	0.87	0.006	<0.05	$Ln(CBR) = 1.69 \ln(DCP) - 2.107$
MH Soil	Simple Non-linear regression	Model- 4	0.88	0.002	<0.05	$Ln(CBR) = -1.96 \ln(DCP) + 7.375$
Expansive (CH) Soil	Simple Non-linear regression	Model- 5	0.90	0.013	<0.05	$Ln(CBR) = -1.22 \ln(DCP) + 4.025$
CH & CL Soils	Simple Non-linear regression	Model- 6	0.76	0.023	<0.05	$Ln(CBR) = -1.29 \ln(DCP) + 4.772$

Table 4-8 Summary of the regression analysis for the correlation between MDD and DCP

Soil Types According to USCS Classification	Regression Types	Model Name	R ²	Standard Error Estimate (α)	Significance Test Result	Developed Equation
GW & GP Soil	Simple Non-linear regression	Model- 7	0.65	0.04	<0.05	$MDD = 1.907 \exp(-0.03 * DCP)$
GC Soil	Simple Non-linear regression	Model- 8	0.02	0.755	>0.05	$MDD = -0.25 \ln(DCP) + 2.336$
ML & SM Soils	Simple linear regression	Model- A	0.71	0.033	>0.05	$MDD = -0.006 * (DCP) + 1.587$
MH Soil	Simple Non-linear regression	Model- 9	0.50	0.075	>0.05	$MDD = 0.12 \ln(DCP) + 1.138$
Expansive (CH) Soil	Simple Non-linear regression	Model- 10	0.99	0.0001	<0.05	$MDD = 1.593 \exp(-0.001 * DCP)$
CH & CL Soils	Simple Non-linear regression	Model- 11	0.056	0.651	>0.05	$MDD = 1.503 \exp(-0.001 * DCP)$

Table 4-9 Summary of the regression analysis for the correlation between OMC and DCP

Soil Types According to USCS Classification	Regression Types	Model Name	R ²	Standard Error Estimate (σ)	Significance Test Result	Developed Equation
GW & GP Soil	Simple Non-linear regression	Model- 12	0.42	0.041	<0.05	$OMC = 9.964 \exp(0.037 * DCP)$
GC Soil	Simple Non-linear regression	Model- 13	0.02	0.741	>0.05	$OMC = 0.879 \ln(DCP) + 14.67$
ML & SM Soils	Simple non-linear regression	Model- 14	0.38	0.188	>0.05	$OMC = 27.25 \exp(-0.01 * DCP)$
MH Soil	Simple Non-linear regression	Model- 15	0.23	0.276	>0.05	$OMC = 22.92 \exp(0.01 * DCP)$
Expansive (CH) Soil	Simple Non-linear regression	Model- 16	0.99	0.0001	<0.05	$OMC = 26.16 \exp(0.001 * DCP)$
CH & CL Soils	Simple Non-linear regression	Model- 17	0.54	0.093	>0.05	$OMC = 5.163 \ln(DCP) + 14.06$

CHAPTER -5

DISCUSION ON CORRELATION RESULTS

5.1. Evaluation of the Developed and Existing Correlations

The validation of created equation for all categories of soil types classified according to USCS soil classification system are made by comparing known test results and predicted results by using developed and existing correlation equation. Comparisons have been made between the newly developed and most commonly used correlation in Ethiopia (TRL, overseas Road Note 8). The detail comparisons for soils of the same characteristics are indicated here under from table: 5.1.1 to 5.1.6

Table 5.1 Comparison of actual CBR ,Predicted CBR of developed and CBR of existing correlation for GW and GP soils

S.No	DCP	Actual CBR	New Developed Correlation Equation		TRL, Overseas Road Note 8 Correlation	
			$\ln(\text{CBR}) = -0.39 * \ln(\text{DCP}) + 4.828$		$\log(\text{CBR}) = 2.48 - 1.0571 * \log(\text{DCP})$	
			New predicted CBR	New Developed Variation(%)	Existing Predicted. CBR	TRL, Overseas Road Note 8 Variation(%)
1	26.56	33	34.78	-5.39	9.43	71.43
2	14.39	75	44.17	41.11	18.02	75.97
3	23.66	29	36.38	-25.46	10.65	63.26
4	17.75	43	40.70	5.35	14.44	66.43
5	6.04	44	61.97	-40.84	45.12	-2.54
6	4.73	67	68.17	-1.74	58.43	12.80
7	4.66	64	68.57	-7.13	59.35	7.26
8	4.57	103	69.09	32.92	60.59	41.17
9	6.04	58	61.97	-6.84	45.12	22.21
10	7.65	45	56.51	-25.58	35.15	21.90
Average		56.1	54.23	-3.36	35.63	37.99

Table 5.2 Comparison of actual CBR , Predicted CBR of new developed and CBR of existing correlation for GC soils

S.No	DCP	Actual CBR	New Developed Correlation Equation		TRL, Overseas Road Note 8 Correlation	
			$\ln(\text{CBR}) = -0.65 * \ln(\text{DCP}) + 5.415$		$\log(\text{CBR}) = 2.48 - 1.0571 * \log(\text{DCP})$	
			New predicted CBR	New Developed Variation(%)	Existing Predicted. CBR	TRL, Overseas Road Note 8 Variation(%)
1	7.24	68	62.07	8.72	37.25	45.22
2	6.04	44	69.83	-58.70	45.12	-2.54
3	9.65	60	51.49	14.18	27.50	54.17
4	15.98	50	37.10	25.80	16.13	67.74
5	9.5	41	52.02	-26.88	27.95	31.82
6	4.56	110	83.83	23.79	60.73	44.79
7	35	20	22.29	-11.44	7.04	64.78
Average		56.142857	54.09	-3.50	31.68	43.71

Table 5.3 Comparison of actual CBR , Predicted CBR of new developed and CBR of existing correlation for ML & SM soils

S.No	DCP	Actual CBR	New Developed Correlation Equation		TRL, Overseas Road Note 8 Correlation	
			$\ln(\text{CBR}) = 1.692 * \ln(\text{DCP}) - 2.107$		$\log(\text{CBR}) = 2.48 - 1.0571 * \log(\text{DCP})$	
			New predicted CBR	New Developed Variation(%)	Existing Predicted. CBR	TRL, Overseas Road Note 8 Variation(%)
1	29.5	34	37.31	-9.75	8.44	75.18
2	9.9	5	5.88	-17.65	26.76	-435.23
3	32.14	41	43.14	-5.22	7.71	81.20
4	11.8	7	7.92	-13.10	22.23	-217.55
5	26.32	30	30.77	-2.55	9.52	68.27
6	15.62	20	12.72	36.38	16.53	17.37
Average		22.833333	22.96	-1.98	15.20	-68.46

Table 5.4 Comparison of actual CBR , Predicted CBR of new developed and CBR of existing correlation for MH soils

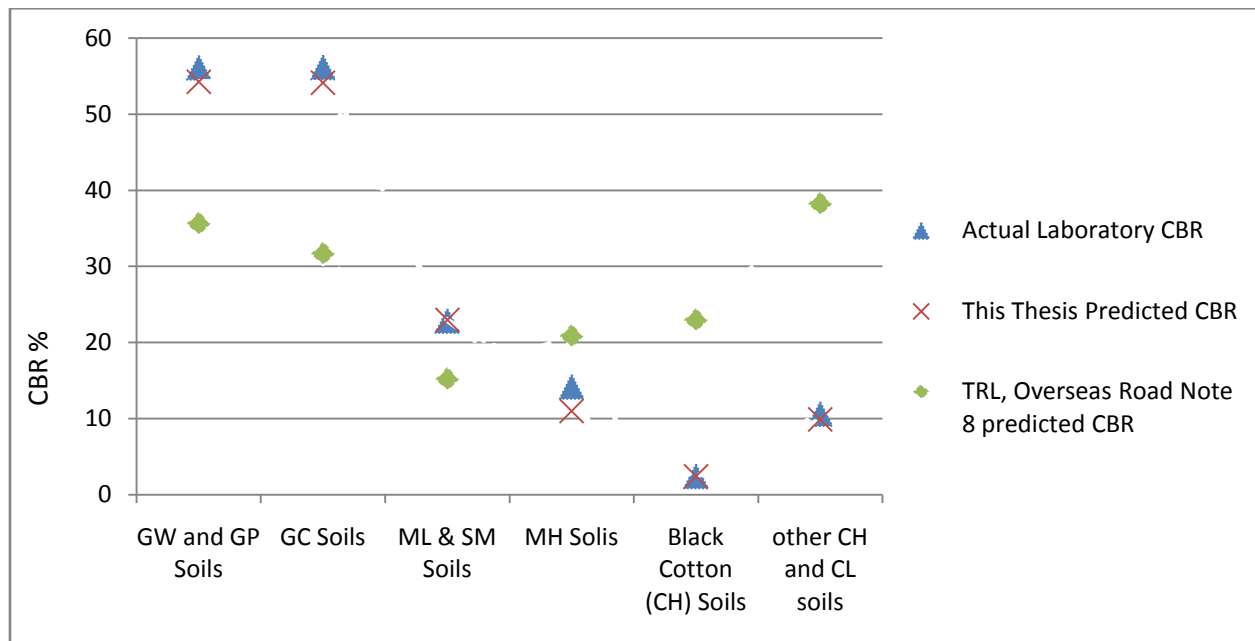
S.No	DCP	Actual CBR	New Developed Correlation Equation		TRL, Overseas Road Note 8 Correlation	
			$\ln(\text{CBR}) = -1.96 * \ln(\text{DCP}) + 7.375$		$\log(\text{CBR}) = 2.48 - 1.0571 * \log(\text{DCP})$	
			New predicted CBR	New Developed Variation(%)	Existing Predicted. CBR	TRL, Overseas Road Note 8 Variation(%)
1	23.32	2	3.33	-66.40	10.82	-440.93
2	5.87	39	49.70	-27.45	46.50	-19.24
3	18.92	3	5.01	-67.12	13.49	-349.83
4	10.87	18	14.86	17.46	24.24	-34.69
5	13.19	18	10.17	43.51	19.76	-9.78
6	24.5	5	3.02	39.58	10.27	-105.37
7	15.13	7	7.77	-11.00	17.09	-144.17
Average		13.142857	13.41	-10.20	20.31	-157.72

Table 5.5 Comparison of actual CBR, Predicted CBR of new developed and CBR of existing correlation for CH (Black Cotton clay) soils

S.No	DCP	Actual CBR	New Developed Correlation Equation		TRL, Overseas Road Note 8 Correlation	
			$\ln(\text{CBR}) = -1.22 * \ln(\text{DCP}) + 4.025$		$\log(\text{CBR}) = 2.48 - 1.0571 * \log(\text{DCP})$	
			New predicted CBR	New Developed Variation(%)	Existing Predicted. CBR	TRL, Overseas Road Note 8 Variation(%)
1	15.78	2	1.93	3.32	16.35	-717.43
2	9.76	3	3.47	-15.82	27.17	-805.59
3	13.18	2	2.41	-20.42	19.78	-888.80
4	10.5	4	3.18	20.54	25.15	-528.70
5	26.85	1	1.01	-1.09	9.32	-832.10
Average		2.4	2.40	-2.69	19.55	-754.52

Table 5.6 Comparison of actual CBR , Predicted CBR of new developed and CBR of existing correlation for CH & CL soils

S.No	DCP	Actual CBR	New Developed Correlation Equation		TRL, Overseas Road Note 8 Correlation	
			$\ln(\text{CBR}) = -1.29 * \ln(\text{DCP}) + 4.772$		$\log(\text{CBR}) = 2.48 - 1.0571 * \log(\text{DCP})$	
			New predicted CBR	New Developed Variation(%)	Existing Predicted. CBR	TRL, Overseas Road Note 8 Variation(%)
1	5.06	20	14.59	27.04	54.41	-172.03
2	3.9	21	20.42	2.78	71.64	-241.17
3	10.97	3	5.38	-79.25	24.01	-700.34
4	9.57	5	6.41	-28.26	27.74	-454.76
5	19.07	4	2.64	34.12	13.38	-234.57
6	12.26	5	4.66	6.82	21.35	-326.96
Average		9.6666667	9.02	-6.13	35.42	-354.97

**Figure 5.1** Comparison of the Actual Laboratory CBR, the present study CBR and TRL reported CBR.

From the comparisons , it is seen that the newly developed correlation yields a lower CBR values than TRL, Overseas Road Note 8 correlation for fine grained soils and higher CBR values for coarse grained soils.

The laboratory and field test results used for the regression analysis and development of new correlation equations in this thesis were conducted on fine and course grained soils of the same characteristics separately. whereas, TRL, Overseas Road Note 8 correlation was developed using laboratory and field test results conducted on both course and fine grained soils simultaneously . The, TRL, Overseas Road Note 8 developed single equation is used for both fine and course grained soils to predict CBR values. But, Course grained soils usually have higher CBR values than fine grained soils in nature. Therefore using the same equation to predict CBR values for both fine and course grained soils yields higher values for course grained and lower value for fine grained. Thus, it is for this reason that the CBR values obtained by TRL, Overseas Road Note 8 correlation is greater than CBR values obtained by developed correlation for fine grained soils and lower CBR values obtained by TRL, Overseas Road Note 8 correlation than CBR values predicted in this research work for course grained soils.

CHAPTER -6

Conclusions and Recommendations

6.1. Conclusions

1. The research was conducted to find correlation between soaked CBR , OMC & MDD and field Dynamic Cone Penetration test.
2. The laboratory tests were conducted on samples collected from different geological area of Oromia, Amhara, Afar, Addis Ababa and SNNP regions. The samples were collected after field DCP had been conducted.
3. Analysis of the field and laboratory test results indicates that it is impossible to get strong correlation between soaked CBR and DCP if granular and cohesive soils are considered simultaneously.
4. It was observed that Granular materials of the same field DCP value indicates different soaked CBR Values in the laboratory. Granular material of clay binder shows less Soaked CBR than granular material without clay binder.
5. In this thesis, soils of the same behavior are considered as one group and relatively strong correlation equations for six classes of soils such as GW&GP, ML& SM, MH, CH(expansive clay) and other CH & CL clay soils are developed.
6. The validity of the developed correlation equations are evaluated by utilizing actual test results and comparing with existing correlation(TRL, Overseas Road Note 8) which has been extensively utilized for road design in Ethiopia.
7. The developed correlations are based on small number of sample ranging from six to ten. This resulted in moderate correlation strength.

8. To predict Soaked CBR value by utilizing developed correlation equations, field soil identification is necessary. This can be done by relating FAO soils with USCS soils. FAO soils with ARCGIS software enable to identify field soil type without laboratory soil classification. Thus, field DCP testing can be used to predict soaked CBR for all types of soils without relying on laboratory testing.

9. The developed correlations enable to preliminarily predict Soaked CBR by DCP testing of sub grade, sub base and base course materials.

6.2. Recommendations

The experience encountered in conducting the current research has revealed areas where further trial may be improved in the future. In relation to the subject study, the followings are some of the recommendations suggested :

1. It is recommended to carry out this correlation with large number of samples for each categories of soil types including geographical areas in Ethiopia regions which are not covered by this work.
2. Mechanism should be developed to avoid skin friction affect on field DCP conduction.
3. It is advisable to conduct comparative correlations between soaked and unsoaked CBR values with DCP.
4. Further it is recommended to conduct correlation between DCP with resilient modulus(MR) for different types of soils in Ethiopia.
5. It is advisable to develop relationship between FAO soils classification with Engineering soils Classifications (AASHTO & USCS systems) to use with Arc GIS software for preliminary soil types identification in Ethiopia.

References

- [1] Geotechnical Aspects of Pavement Reference Manuals/participant work book i.e. department of transportation publication No=FHWANHI-05-037,may (2006),NHI,Course No-132040, 37-39
- [2] Ethiopian Road Authority and Pavement Design Manual Volume I, Chapter 3,subgrade,Brehawna Selam Printing Enterprise Addis Ababa,2002.
- [3] ASTM D698,&D1557 And AASHTO T99 OR T180,12-23
- [4] Standard Specifications for Transportation Materials and Method of Sampling and Testing 28th edition ,2008,part 2A tests and AASHTO T193-99, 2007.
- [5] Peter ,M. Semen ,U.S. Army Engineer Research 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,2006
- [6] American Society for Testing and Materials, Designation:D1883-99,Laboratory CBR testing, Annual Book of ASTM Standards, volume 04.08,West Conshohocken, Pennsylvania,2000.
- [7] Standard Specifications for Transportation Materials and Method of Sampling and Testing 28th edition ,2008,part 2A tests AASHTO Designation: T 99-01, 2004, Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 300-mm (12-in.) Drop,20-36
- [8] ASTM Standards: D 4429-93, Test Method for CBR (California Bearing Ratio) of Soils in Place, volume 04,08 soil and rock,1-4
- [9] Arora, K.R, soil mechanical and foundation engineering , re – print standard publisher distributors , nag sarak , Delhi, 2004

- [10] Fredrics, M. Standard hand book for civil engineering , M.Standard Hand Book For Civil Engineers, McGraw- Hill book company, new York, 1983
- [11] American Society for Testing and Material D 2487-00 Standard Practice for Classification for soils for engineering purpose (Unified Classification System) , Annual Book of ASTM Standard Volume 04.08, West Conshohocken, Pennsylvania, 2000
- [12] Geotechnical Laboratory Measurements for Engineers John J. Germaine and any V. Germaine , 2009.
- [13] User Guide to Dynamic Cone Penetrometer Office of the Minnesota Road Research Pretoria, September 2009.
- [14] User Guide to the Dynamic Cone Penetration, Office of Minnesota Road Research.
- [15] The Use and Interpretation of the Dynamic Cone Penetrometer(DCP) Test, Paige-Green and Du plisses, CSIR Built Environment.
- [16] Use of Dynamic Cone Penetrometer in Sub grade and Base Acceptance, Ohio University, Ohio Research Institute for Transportation and the Environment Stocker Center 141 Athens, ohio & 1701-2979, Final Report, April 2007.
- [17] Field Evaluation of In-situ Test Technology for QC/QA During Construction of Pavements Layers and Embankment, A thesis in partial fulfillment of the requirement for the degree of master of science in civil engineering ,Munir D,Nazzal,Birzeit University, December 2003.
- [18] A Laboratory Investigation on Relationship Between Dynamic Cone Penetrations Value and Soaked California Bearing Ratio K.A.K. Karunaproma and A.G.H.J Edrisingha, university of peradeniya.

- [19] Experimental Study to Correlate the Test Result of PBT, UCS, and CBR with DCP on Various Soils in Soaked Condition, Mukash A. Pater, Research Scholar, Ganpat University, Mehsana 384 002,-Gujarat, and Dr.H.S.Patel, Department of Applied Mechanics, L.D. Collage of Engineering, Ahmadabad, Gujarat, India.
- [20] How-to- convert FAO to USDA , soil type conversion, Baylor et al, 2013. Available on line / [http:// www. research gate-net/post/](http://www.research gate-net/post/).
- [21] Douglas, C.M and George C. Runger, Applied Statistics and Probability for Engineers, Third Edition John Wiley & Sons. Inc, USA, 2003.
- [22] California Bearing Ratio device. Available online /<http://www.ele.com/geot/cali;htm>).
- [23] MUKASH A.PATEL and H.S.PATEL ,"Experimental Study On Various Soils to Correlate DCP With PBT,UCS and CBR Results, "Volume 05,October 2012".
- [24] International Journal of Modern Trends in Engineering and Research, ISSN(ONLINE): 2349-9745; ISSN(PRINT): 2393-8161.
- [25] Potential Application of Dynamic and Static Cone Penetrometer In MDOT Pavement Design and Construction, Farshad Amin, Department of Civil Engineering , Jackson University, et.al Mississippi Department of Transportation, et.al U.S .Department of Transportation Federal High way Administration, Jackson State University, September 2003.
- [26] MSc Thesis By Yitagesu Desalegn , Developing correlation between DCP and CBR for locally used sub grade materials. 2012

Appendices

Appendix - A Laboratory Test Results

1.1 Grain Size Analysis

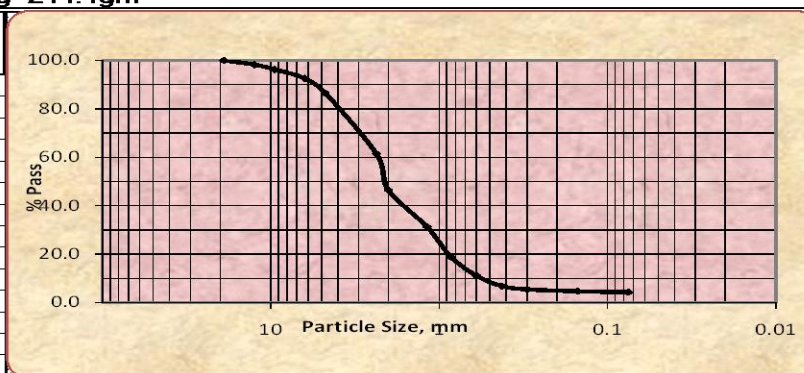
TEST METHOD : AASHTO T - 27

Sample Code- OASS 1

Depth of Sampling:-125cm

Weight Before Washing =255.2 gm, Weight After Washing=244.1gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
19	0.0	0.0	100.0
12.5	4.4	1.7	98.3
9.5	9.5	3.7	96.3
6.3	18.8	7.4	92.6
4.75	34.4	13.5	86.5
2.36	98.4	38.6	61.4
2	136.8	53.6	46.4
1.18	175.2	68.7	31.3
0.85	207.0	81.1	18.9
0.6	226.6	88.8	11.2
0.425	237.5	93.1	6.9
0.3	241.0	94.4	5.6
0.15	243.1	95.3	4.7
0.075	244.1	95.7	4.3



1.2 Atterberg Limit Test

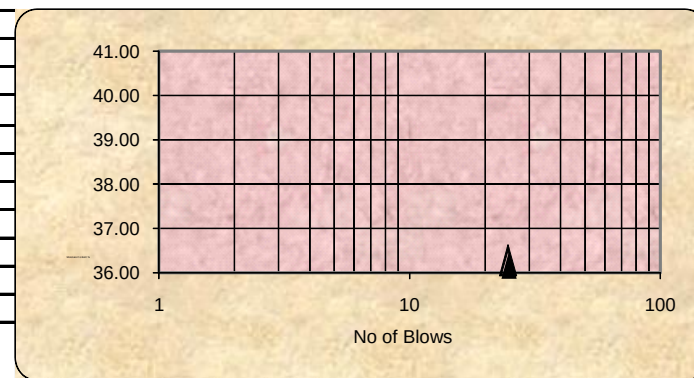
TEST METHOD : AASHTO T89 - T91

Sample Code- OASS 1

Depth of Sampling:-125cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N						
Tare	n ^o						
Wt. tare + wet soil	g						
Wt. tare + dry soil	g		NP				
Wt. water	g						
Wt. of tare	g						
Wt. of dry soil	g						
No. of blows	N						
Moisture content	%						

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL %)=NP, PLASTICITY INDEX (P.I.)=LL-PL=0

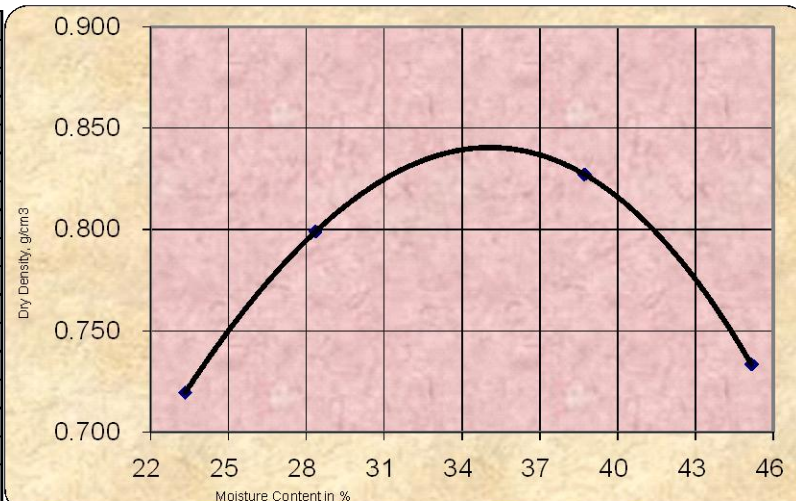


2.2 Atterberg Limit Test

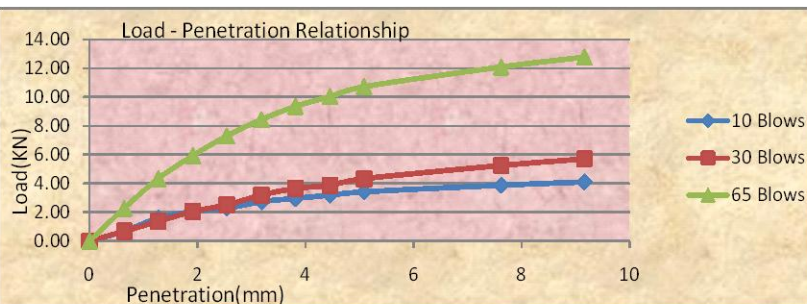
1.3 Modified Proctor Test**TEST METHOD : AASHTO T- 180 METHOD C****Sample Code-OASS1****Depth of Sampling:-125cm**

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	3850	3980	4095	4017
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	836	966	1081	1003
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	0.89	1.03	1.15	1.06
G	Container	No.	G29	G21	F11	G18
H	Wt. Cont + Wet soil	grams	180.39	187.08	235.39	209.45
I	Wt. Cont + Dry soil	grams	154.68	155.56	181.39	157.60
J	Weight of Water	grams	25.71	31.52	54.00	51.85
K	Weight of Container	grams	44.50	44.39	41.95	42.78
L	Weight of Dry Soil	grams	110.18	111.17	139.44	114.82
M	Moisture Content	%	23.3	28.4	38.7	45.2
N	Dry Density	gr/cu.cm.	0.720	0.799	0.827	0.734

Maximum Dry Density(MDD)=0.842, Optimum Moisture Content(OMC)=35%

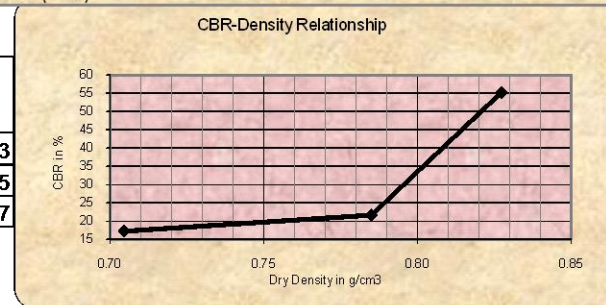
**1.4 California Bearing Ration Test****TEST METHOD : AASHTO T- 193****Sample Code-OASS1****Depth of Sampling:-125cm**

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	3	0.68	3	0.68	10	2.28
1.27	7	1.60	6	1.37	19	4.33
1.91	9	2.05	9	2.05	26	5.93
2.54	10	2.28	11	2.51	32	7.30
3.18	12	2.74	14	3.19	37	8.44
3.81	13	2.97	16	3.63	41	9.33
4.45	14	3.19	17	3.88	44	10.04
5.08	15	3.42	19	4.33	47	10.72
5.62	17	3.88	23	5.25	53	12.09
6.16	18	4.11	25	5.70	56	12.77



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	0.70457836	2.28	3.4215	13.2	20	17.2803	17.1075	17.2803
30	0.78500811	2.5091	4.3339	13.2	20	19.00833	21.6695	21.6695
65	0.82731677	7.2992	10.7207	13.2	20	55.29697	53.6035	55.29697

CBR at 95% MDD i.e 0.799gm/cc and at OMC of 35% is 33%



2.1 Grain Size Analysis

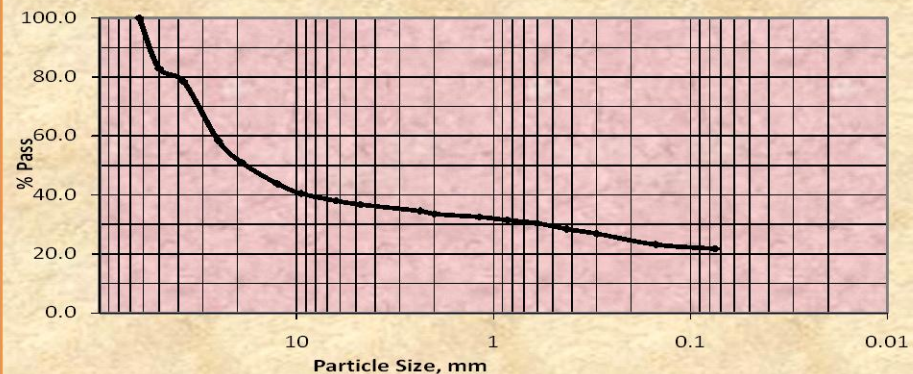
TEST METHOD : AASHTO T - 27

Sample Code- OESAS 2

Depth of Sampling:-52.1cm

Weight Before Washing =919.7 gm, Weight After Washing=719.4gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
63	0.0	0.0	100.0
50	156.8	17.0	83.0
37.5	197.7	21.5	78.5
25	382.3	41.6	58.4
19	450.6	49.0	51.0
12.5	517.2	56.2	43.8
9.5	546.8	59.5	40.5
6.3	569.9	62.0	38.0
4.75	581.5	63.2	36.8
2.36	601.6	65.4	34.6
2	610.9	66.4	33.6
1.18	620.1	67.4	32.6
0.85	629.9	68.5	31.5
0.6	640.0	69.6	30.4
0.425	657.5	71.5	28.5
0.3	672.0	73.1	26.9
0.15	706.1	76.8	23.2
0.075	719.4	78.2	21.8



2.2 Atterberg Limit Test

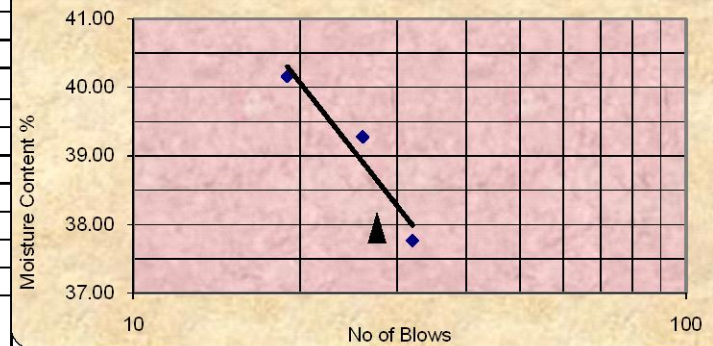
TEST METHOD : AASHTO T89 - T91

Sample Code- OESAS 2

Depth of Sampling:-52.1cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	32	26	19			
Tare	n ^o	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	33.1	30.98	33.3		22.8	24.68
Wt. tare + dry soil	g	27.96	26.53	28.16		21.2	22.94
Wt. water	g	5.14	4.45	5.14		1.60	1.74
Wt. of tare	g	14.4	15.20	15.36		14.8	16.01
Wt. of dry soil	g	13.61	11.33	12.80		6.33	6.93
No. of blows	N	32	26	19			
Moisture content	%	37.77	39.28	40.16		25.28	25.11

LIQUID LIMIT (LL%)=39, PLASTIC LIMIT (PL %)=25, PLASTICITY INDEX (P.I)=LL-PL=14



2.3 Modified Proctor Test

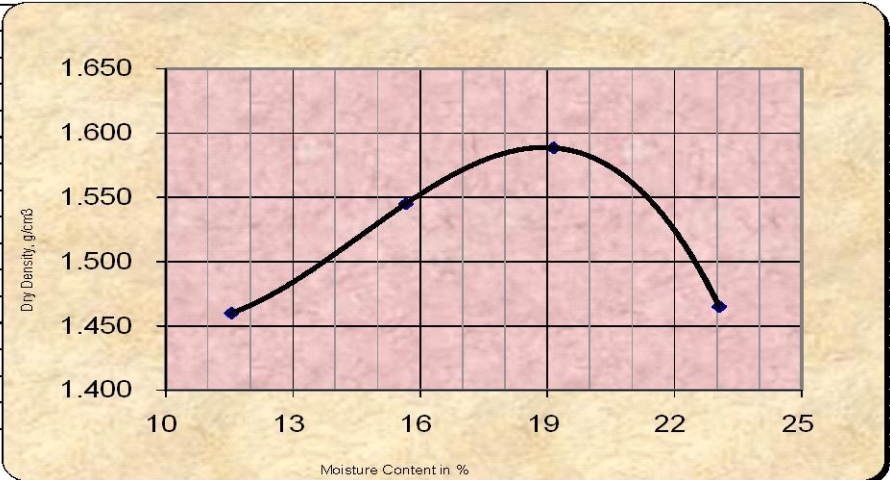
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-OESAS2

Depth of Sampling:-52.1cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4550	4700	4800	4715
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1544	1694	1794	1709
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.63	1.79	1.89	1.80
G	Container	No.	F61	F62	F11	B3
H	Wt. Cont + Wet soil	grams	235.52	228.31	249.47	239.80
I	Wt. Cont + Dry soil	grams	214.60	204.67	217.70	206.44
J	Weight of Water	grams	20.92	23.64	31.77	33.36
K	Weight of Container	grams	33.59	53.76	51.75	61.73
L	Weight of Dry Soil	grams	181.01	150.91	165.95	144.71
M	Moisture Content	%	11.6	15.7	19.1	23.1
N	Dry Density	gr/cu.cm.	1.460	1.545	1.588	1.465

Maximum Dry Density(MDD)=1.59, Optimum Moisture Content(OMC)=19%



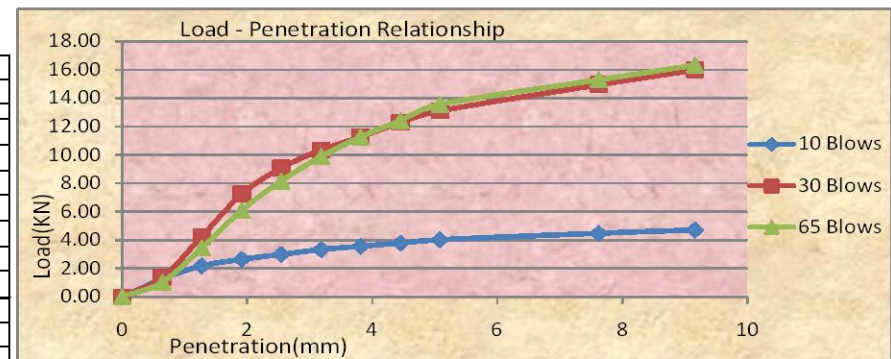
2.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-OESAS2

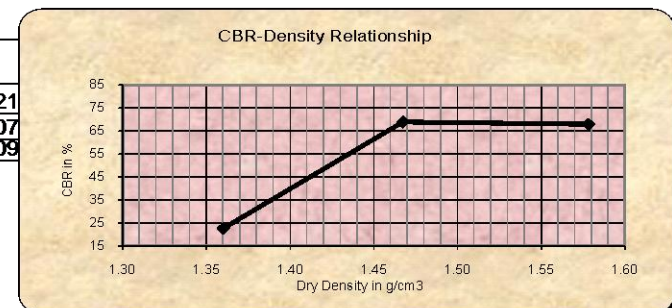
Depth of Sampling:-52.1cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0.64	11	1.27	12	1.38	9	1.04
1.27	19	2.19	37	4.26	30	3.45
1.91	23	2.65	63	7.25	53	6.10
2.54	26	2.99	79	9.09	71	8.17
3.18	29	3.34	90	10.36	86	9.90
3.81	31	3.57	98	11.28	98	11.28
4.45	33	3.80	107	12.32	108	12.43
5.08	35	4.03	114	13.12	118	13.58
7.62	39	4.49	130	14.96	133	15.31
9.16	41	4.72	139	16.00	142	16.34



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.36002	2.99	4.03	13.2	20	22.67121	20.1425	22.67121
30	1.467348	9.09	13.12	13.2	20	68.88561	65.607	65.607
65	1.57818	8.17	13.58	13.2	20	61.90985	67.909	67.909

CBR at 95% MDD i.e 1.51gm/cc and at OMC of 19% is 68%



3.1 Grain Size Analysis

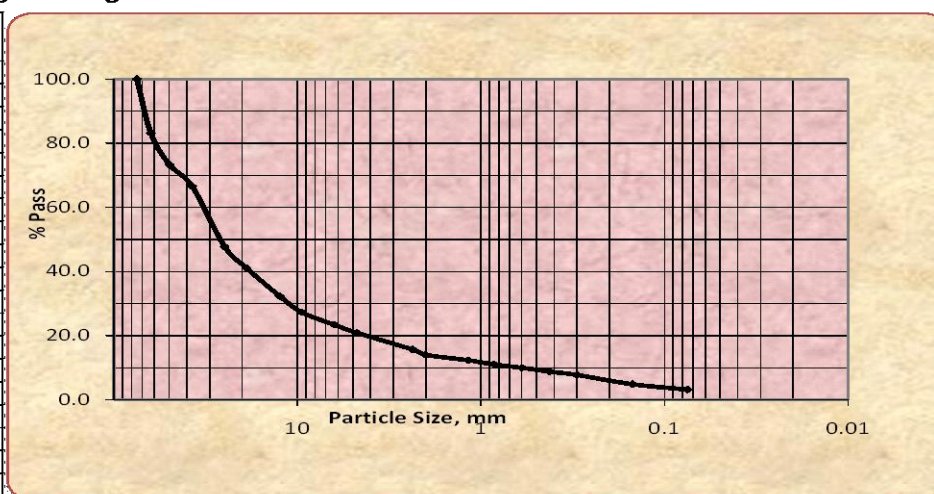
TEST METHOD : AASHTO T - 27

Sample Code- OESAS 3

Depth of Sampling:-86cm

Weight Before Washing =829.9 gm, Weight After Washing=803.1gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
75	0.0	0.0	100.0
63	139.9	16.9	83.1
50	221.0	26.6	73.4
37.5	277.7	33.5	66.5
25	433.4	52.2	47.8
19	488.8	58.9	41.1
12.5	561.2	67.6	32.4
9.5	603.1	72.7	27.3
6.3	635.9	76.6	23.4
4.75	656.6	79.1	20.9
2.36	699.9	84.3	15.7
2	713.7	86.0	14.0
1.18	727.5	87.7	12.3
0.85	738.5	89.0	11.0
0.6	746.8	90.0	10.0
0.425	756.6	91.2	8.8
0.3	765.5	92.2	7.8
0.15	789.4	95.1	4.9
0.075	803.1	96.8	3.2

**3.2 Atterberg Limit Test**

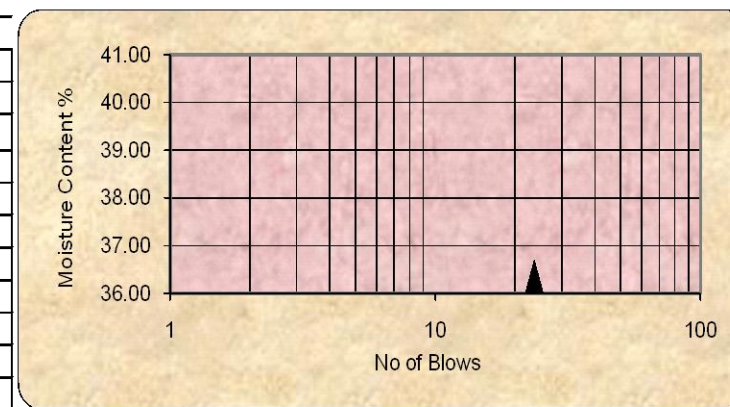
TEST METHOD : AASHTO T89 - T91

Sample Code- OESAS 3

Depth of Sampling:-86cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N						
Tare	n°						
Wt. tare + wet soil	g		NP				
Wt. tare + dry soil	g						
Wt. water	g						
Wt. of tare	g						
Wt. of dry soil	g						
No. of blows	N						
Moisture content	%						

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL %)=NP, PLASTICITY INDEX (P.I.)=LL-PL=0



3.3 Modified Proctor Test

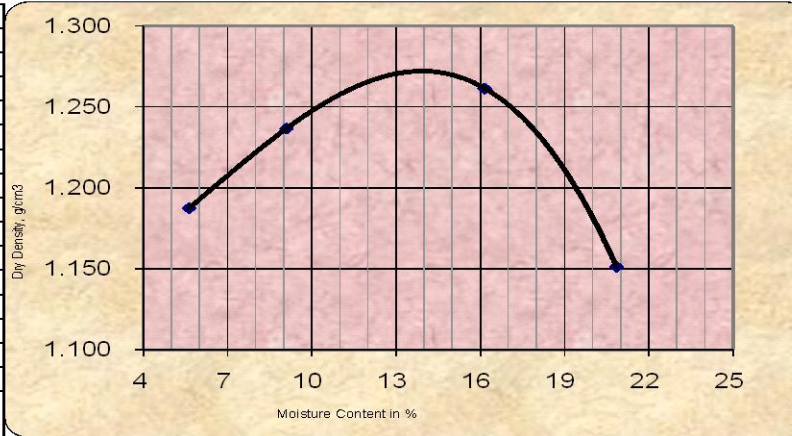
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-OESAS3

Depth of Sampling:-86cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4195	4285	4395	4325
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1189	1279	1389	1319
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.25	1.35	1.47	1.39
G	Container	No.	A3	A11	E18	A21
H	Wt. Cont + Wet soil	grams	214.71	207.51	220.76	247.73
I	Wt. Cont + Dry soil	grams	206.48	194.45	196.86	215.03
J	Weight of Water	grams	8.23	13.06	23.90	32.70
K	Weight of Container	grams	60.07	50.86	48.95	58.16
L	Weight of Dry Soil	grams	146.41	143.59	147.91	156.87
M	Moisture Content	%	5.6	9.1	16.2	20.8
N	Dry Density	gr/cu.cm.	1.187	1.237	1.261	1.151

Maximum Dry Density(MDD)=1.274, Optimum Moisture Content(OMC)=14%

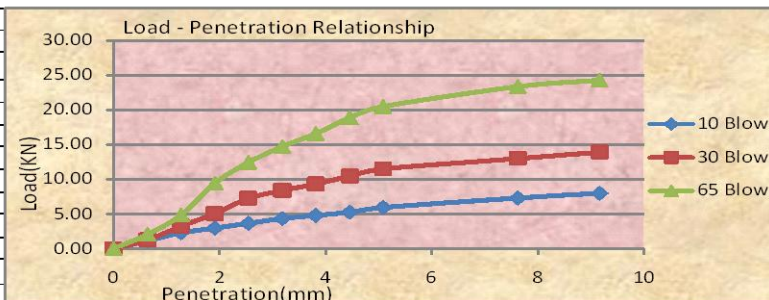
**3.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-OESAS3

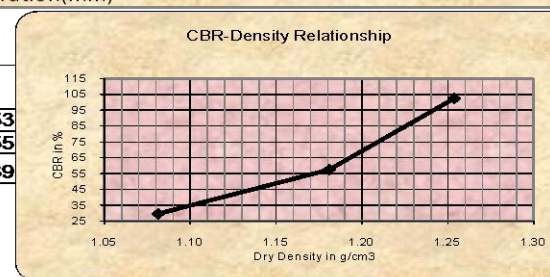
Depth of Sampling:-86cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	5	1.14	11	1.27	18	2.07
1.27	10	2.28	28	3.22	42	4.83
1.91	13	2.97	44	5.06	82	9.44
2.54	16	3.65	63	7.25	108	12.43
3.18	19	4.33	73	8.40	128	14.73
3.81	21	4.79	81	9.32	144	16.57
4.45	23	5.25	91	10.47	164	18.88
5.08	26	5.93	100	11.51	178	20.49
7.62	32	7.30	113	13.01	203	23.37
9.16	35	7.98	121	13.93	211	24.29



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.08131519	3.65	5.93	13.2	20	27.64848	29.653	29.653
30	1.18083535	7.25	11.51	13.2	20	54.93409	57.55	57.55
65	1.25360846	12.43	20.49	13.2	20	94.17273	102.439	102.439

CBR at 95% MDD i.e 1.2103gm/cc and at OMC of 14% is 75%



4.1 Grain Size Analysis

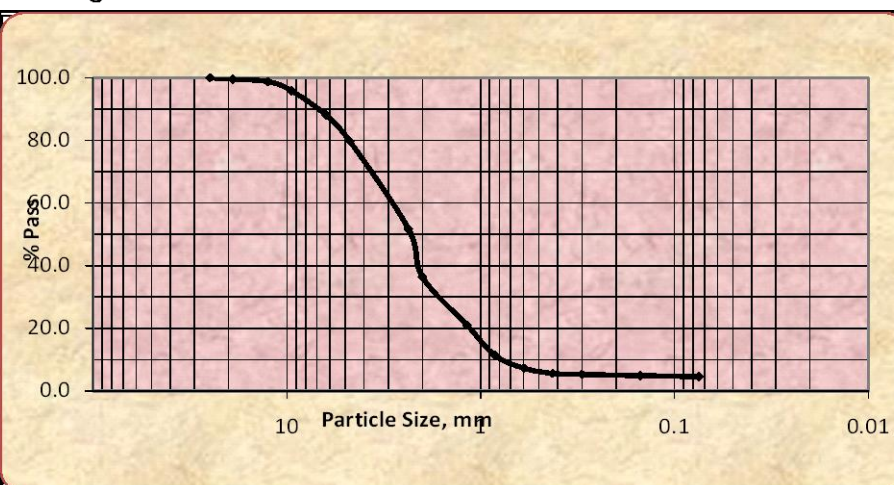
TEST METHOD : AASHTO T - 27

Sample Code- OESOS 4

Depth of Sampling:-98.2cm

Weight Before Washing =460.7gm, Weight After Washing=439.6gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
25	0.0	0.0	100.0
19	2.0	0.4	99.6
12.5	5.7	1.2	98.8
9.5	19.0	4.1	95.9
6.3	54.7	11.9	88.1
4.75	93.2	20.2	79.8
2.36	222.3	48.3	51.7
2	292.9	63.6	36.4
1.18	363.4	78.9	21.1
0.85	407.5	88.5	11.5
0.6	427.2	92.7	7.3
0.425	434.8	94.4	5.6
0.3	436.4	94.7	5.3
0.15	438.1	95.1	4.9
0.075	439.6	95.4	4.6

**4.2 Atterberg Limit Test**

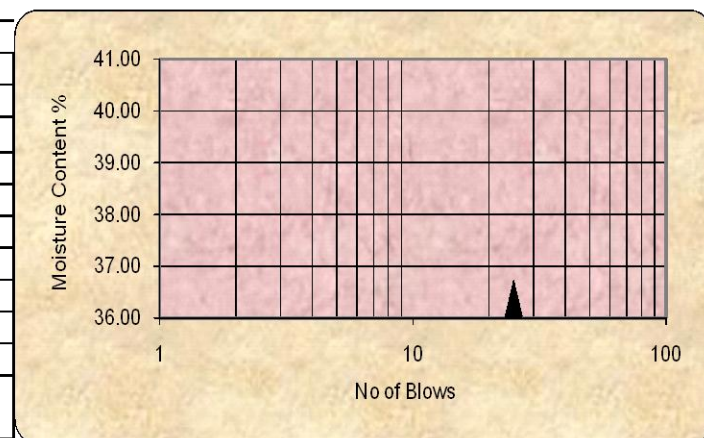
TEST METHOD : AASHTO T89 - T91

Sample Code- OESOS 4

Depth of Sampling:-98.2cm

	LIQUID LIMIT				PLASTIC LIMIT	
	1	2	3	4	1	2
No. of blows	N					
Tare	n°					
Wt. tare + wet soil	g	NP				
Wt. tare + dry soil	g					
Wt. water	g					
Wt. of tare	g					
Wt. of dry soil	g					
No. of blows	N					
Moisture content	%					

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL %)=NP, PLASTICITY INDEX (P.I.)=LL-PL=0



4.3 Modified Proctor Test

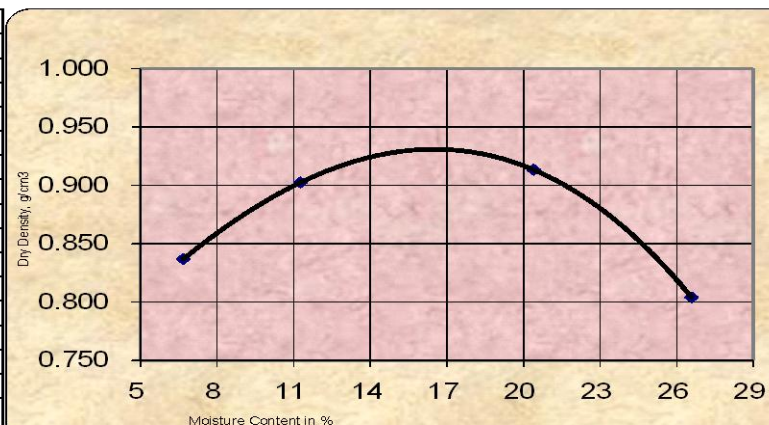
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-OESOS4

Depth of Sampling:-98.2cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	3855	3960	4050	3973
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	841	946	1036	959
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	0.89	1.00	1.10	1.02
G	Container	No.	A10	F65	F61	B9
H	Wt. Cont + Wet soil	grams	188.86	191.86	177.21	198.88
I	Wt. Cont + Dry soil	grams	180.95	178.37	155.24	169.36
J	Weight of Water	grams	7.91	13.49	21.97	29.52
K	Weight of Container	grams	62.47	58.63	47.52	58.29
L	Weight of Dry Soil	grams	118.48	119.74	107.72	111.07
M	Moisture Content	%	6.7	11.3	20.4	26.6
N	Dry Density	gr/cu.cm.	0.837	0.903	0.913	0.804

Maximum Dry Density(MDD)=0.932, Optimum Moisture Content(OMC)=17%



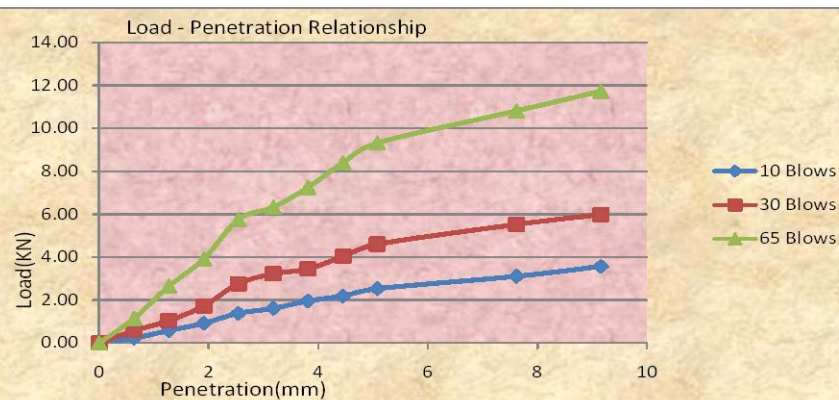
4.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-OESOS4

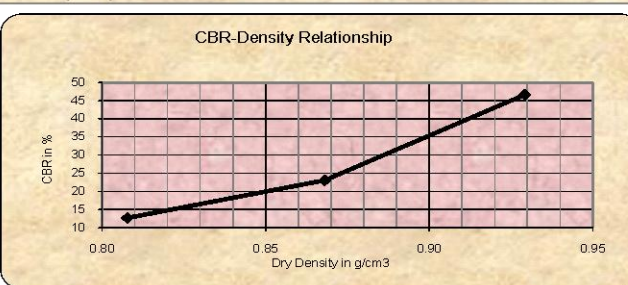
Depth of Sampling:-98.2cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	2	0.23	5	0.58	10	1.15
1.27	5	0.58	9	1.04	23	2.65
1.91	8	0.92	15	1.73	34	3.91
2.54	12	1.38	24	2.76	50	5.76
3.18	14	1.61	28	3.22	55	6.33
3.81	17	1.96	30	3.45	63	7.25
4.45	19	2.19	35	4.03	73	8.40
5.08	22	2.53	40	4.60	81	9.32
7.62	27	3.11	48	5.52	94	10.82
9.16	31	3.57	52	5.99	102	11.74



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	0.80768123	1.38	2.53	13.2	20	10.46364	12.661	29.653
30	0.86809143	2.76	4.60	13.2	20	20.92727	23.02	57.55
65	0.92922895	5.76	9.32	13.2	20	43.59848	46.6155	102.439

CBR at 95% MDD i.e 0.8854gm/cc and at OMC of 17% is 29%



5.1 Grain Size Analysis

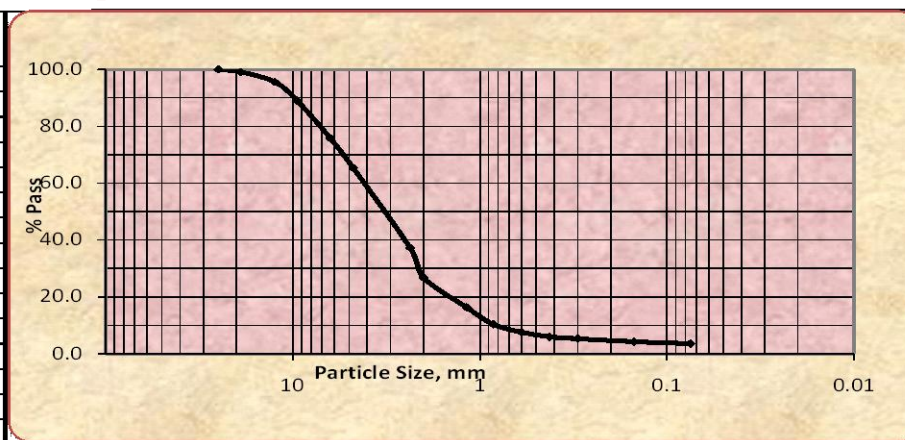
TEST METHOD : AASHTO T - 27

Sample Code- OESOS 5

Depth of Sampling:-92.1cm

Weight Before Washing =232.3gm, Weight After Washing=223.9gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
25	0.0	0.0	100.0
19	2.0	0.9	99.1
12.5	10.2	4.4	95.6
9.5	25.5	11.0	89.0
6.3	56.3	24.2	75.8
4.75	80.5	34.7	65.3
2.36	145.9	62.8	37.2
2	170.2	73.3	26.7
1.18	194.5	83.7	16.3
0.85	208.3	89.7	10.3
0.6	214.6	92.4	7.6
0.425	218.3	94.0	6.0
0.3	219.9	94.7	5.3
0.15	222.3	95.7	4.3
0.075	223.9	96.4	3.6

**5.2 Atterberg Limit Test**

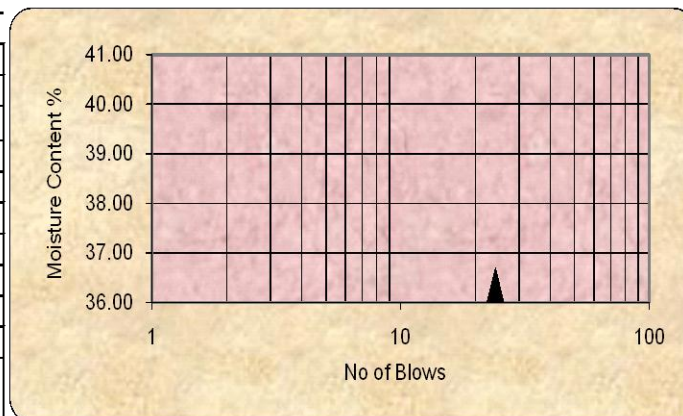
TEST METHOD : AASHTO T89 - T91

Sample Code- OESOS 5

Depth of Sampling:-92.1cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N						
Tare	n°						
Wt. tare + wet soil	g		NP				
Wt. tare + dry soil	g						
Wt. water	g						
Wt. of tare	g						
Wt. of dry soil	g						
No. of blows	N						
Moisture content	%						

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL %)=NP, PLASTICITY INDEX (P.I.)=LL-PL=0



CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

5.3 Modified Proctor Test

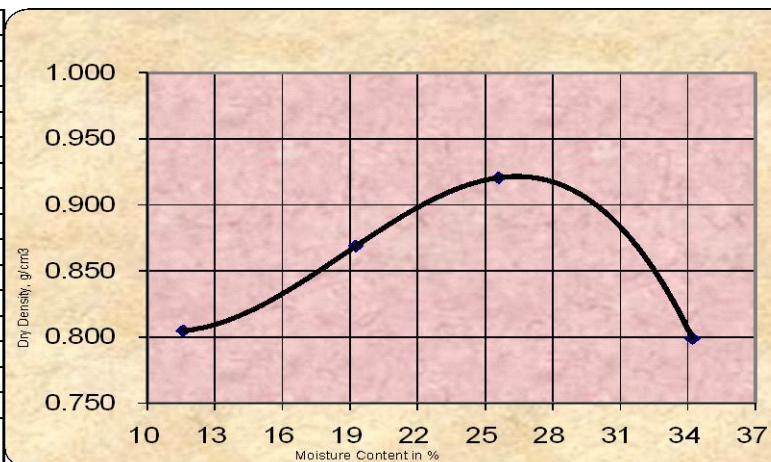
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-OESOS5

Depth of Sampling:-92.1cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	3860	3990	4103	4024
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	846	976	1089	1010
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	0.90	1.04	1.16	1.07
G	Container	No.	G22	E3	G33	G6
H	Wt. Cont + Wet soil	grams	197.88	209.76	217.66	217.42
I	Wt. Cont + Dry soil	grams	183.52	182.82	181.88	172.71
J	Weight of Water	grams	14.36	26.94	35.78	44.71
K	Weight of Container	grams	59.58	42.95	42.06	42.01
L	Weight of Dry Soil	grams	123.94	139.87	139.82	130.70
M	Moisture Content	%	11.6	19.3	25.6	34.2
N	Dry Density	gr/cu.cm.	0.805	0.869	0.920	0.799

Maximum Dry Density(MDD)=0.924, Optimum Moisture Content(OMC)=27%



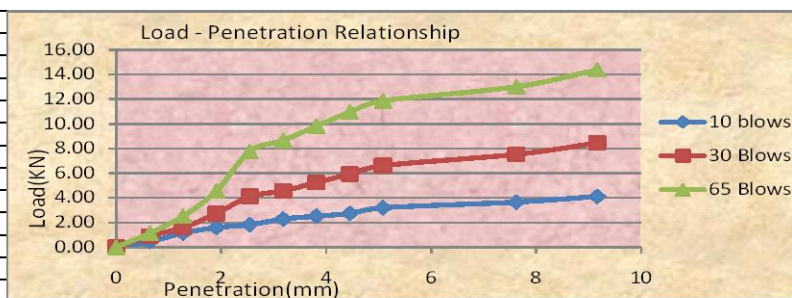
5.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-OESOS5

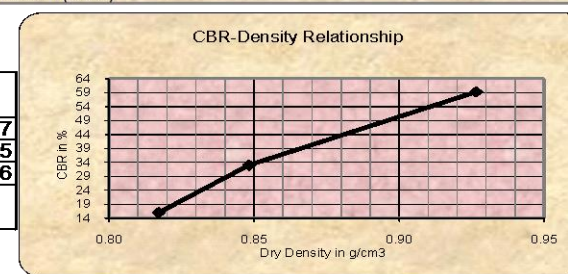
Depth of Sampling:-92.1cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	2	0.46	4	0.91	5	1.14
1.27	5	1.14	7	1.60	11	2.51
1.91	7	1.60	12	2.74	20	4.56
2.54	8	1.82	18	4.11	34	7.76
3.18	10	2.28	20	4.56	38	8.67
3.81	11	2.51	23	5.25	43	9.81
4.45	12	2.74	26	5.93	48	10.95
5.08	14	3.19	29	6.61	52	11.86
7.62	16	3.65	33	7.53	57	13.00
9.16	18	4.11	37	8.44	63	14.37



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	0.81711207	1.82	3.19	13.2	20	13.82424	15.967	15.967
30	0.84828542	4.11	6.61	13.2	20	31.10455	33.0745	33.0745
65	0.92656854	7.76	11.86	13.2	20	58.75303	59.306	59.306

CBR at 95% MDD i.e 0.8778 gm/cc and at OMC of 27% is 43%



6.1 Grain Size Analysis

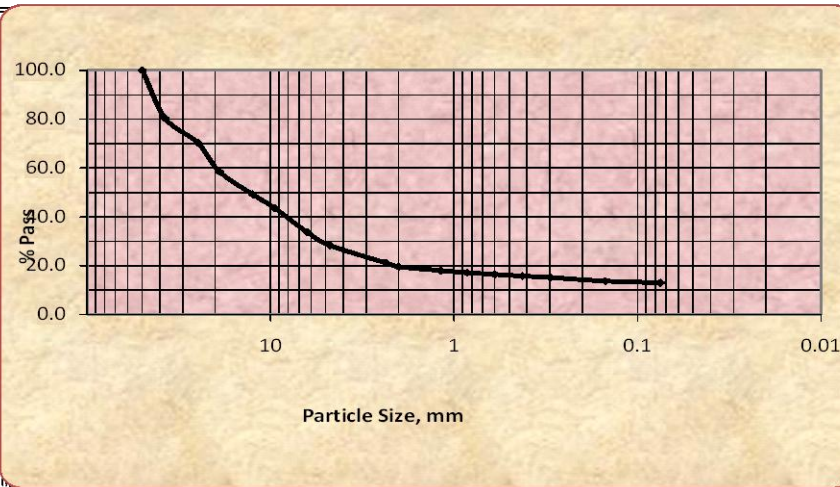
TEST METHOD : AASHTO T - 27

Sample Code- OES08 6

Depth of Sampling:-57.1cm

Weight Before Washing =1288.3gm, Weight After Washing=1120.2gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
50	0.0	0.0	100.0
37.5	251.4	19.5	80.5
25	380.9	29.6	70.4
19	534.1	41.5	58.5
12.5	653.8	50.7	49.3
9.5	726.0	56.4	43.6
6.3	855.0	66.4	33.6
4.75	923.0	71.6	28.4
2.36	1015.9	78.9	21.1
2	1035.7	80.4	19.6
1.18	1055.5	81.9	18.1
0.85	1067.6	82.9	17.1
0.6	1076.3	83.5	16.5
0.425	1085.0	84.2	15.8
0.3	1093.4	84.9	15.1
0.15	1111.4	86.3	13.7
0.075	1120.2	87.0	13.0

**6.2 Atterberg Limit Test**

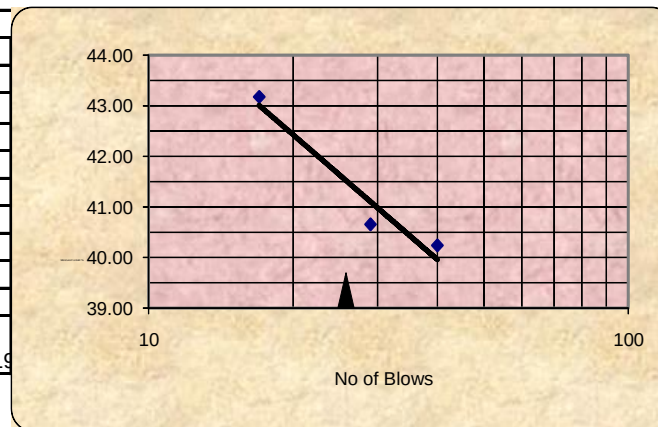
TEST METHOD : AASHTO T89 - T91

Sample Code- OESOS 6

Depth of Sampling:-57.1cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	40	29	17			
Tare	h	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	42.3	41	40.85		24.6	25.41
Wt tare + dry soil	g	34.83	33.37	33.51		22.9	23.48
Wt. water	g	7.42	7.59	7.34		1.73	1.93
Wt. of tare	g	16.4	14.7	16.51		15.6	15.22
Wt. of dry soil	g	18.44	18.67	17.00		7.34	8.26
No. of blows	N	40	29	17			
Moisture content	%	40.24	40.65	43.18		23.57	23.37

LIQUID LIMIT (LL%)=42, PLASTIC LIMIT (PL %) =23, PLASTICITY INDEX (P.I.)=LL-PL=19



6.3 Modified Proctor Test

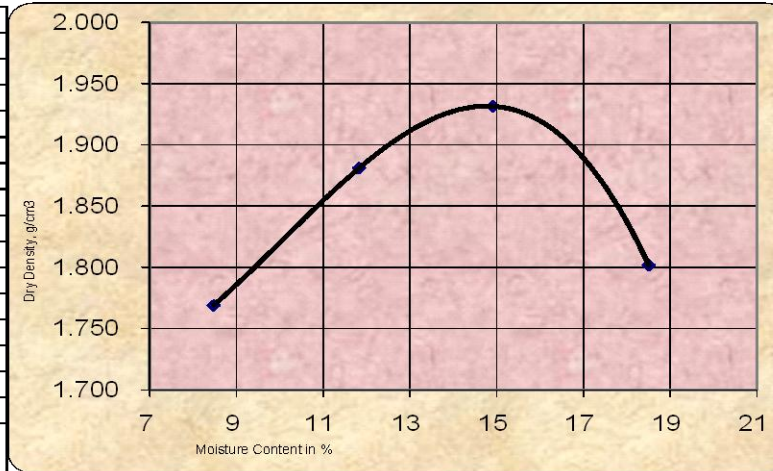
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-OESOS6

Depth of Sampling:-57.1cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4825	5000	5110	5030
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1819	1994	2104	2024
E	Volume of Mold	cu.cm	948	948	948	948
F	Wet Density	gr/cu.cm	1.92	2.10	2.22	2.14
G	Container	No.	L6	A1	A8	A21
H	Wt. Cont + Wet soil	grams	248.29	250.11	333.79	308.66
I	Wt. Cont + Dry soil	grams	232.33	229.36	298.09	270.22
J	Weight of Water	grams	15.96	20.75	35.70	38.44
K	Weight of Container	grams	43.89	53.86	58.56	62.47
L	Weight of Dry Soil	grams	188.44	175.50	239.53	207.75
M	Moisture Content	%	8.5	11.8	14.9	18.5
N	Dry Density	gr/cu.cm	1.769	1.881	1.932	1.802

Maximum Dry Density(MDD)=1.94, Optimum Moisture Content(OMC)=15%

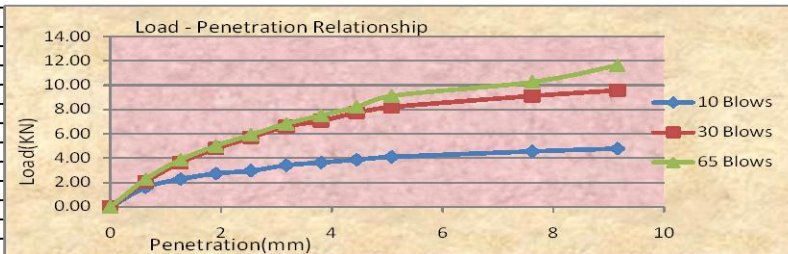
**6.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-OESOS6

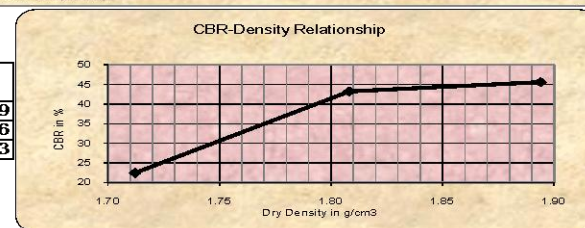
Depth of Sampling:-57.1cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	7	1.60	9	2.05	10	2.28
1.27	10	2.28	16	3.65	17	3.88
1.91	12	2.74	21	4.79	22	5.02
2.54	13	2.97	25	5.70	26	5.93
3.18	15	3.42	29	6.61	30	6.84
3.81	16	3.65	31	7.07	33	7.53
4.45	17	3.88	34	7.76	36	8.21
5.08	18	4.11	36	8.21	40	9.12
7.62	20	4.56	40	9.12	45	10.26
9.16	21	4.79	42	9.58	51	11.63



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.7122173	2.97	4.11	13.2	20	22.46439	20.529	22.46439
30	1.80819458	5.70	8.21	13.2	20	43.20076	41.058	43.20076
65	1.89393259	7.76	9.12	13.2	20	58.75303	45.62	58.75303

CBR at 95% MDD i.e 1.843 gm/cc and at OMC of 15% is 44%



7.1 Grain Size Analysis

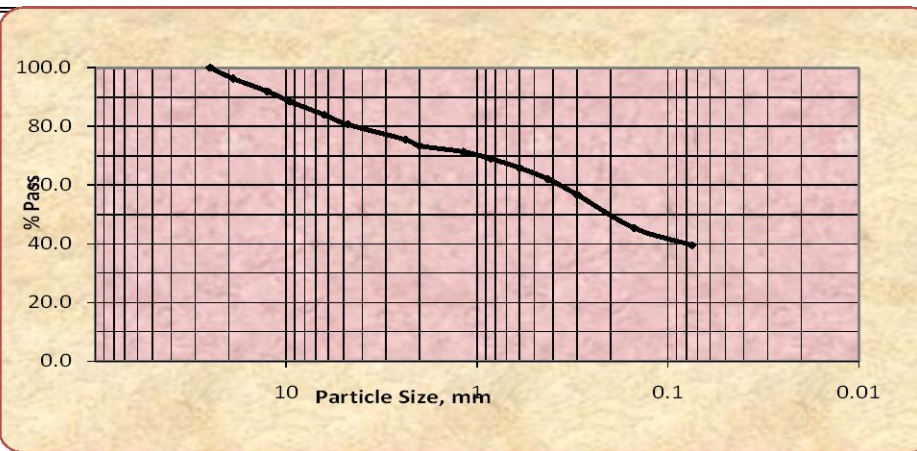
TEST METHOD : AASHTO T - 27

Sample Code- OESOS 7

Depth of Sampling:-80.5cm

Weight Before Washing =690.5gm, Weight After Washing=417.2gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
25	0.0	0.0	100.0
19	25.2	3.6	96.4
12.5	55.7	8.1	91.9
9.5	79.8	11.6	88.4
6.3	110.6	16.0	84.0
4.75	133.6	19.3	80.7
2.36	169.2	24.5	75.5
2	183.5	26.6	73.4
1.18	197.8	28.6	71.4
0.85	214.0	31.0	69.0
0.6	235.5	34.1	65.9
0.425	261.9	37.9	62.1
0.3	298.6	43.2	56.8
0.15	377.3	54.6	45.4
0.075	417.2	60.4	39.6

**7.2 Atterberg Limit Test**

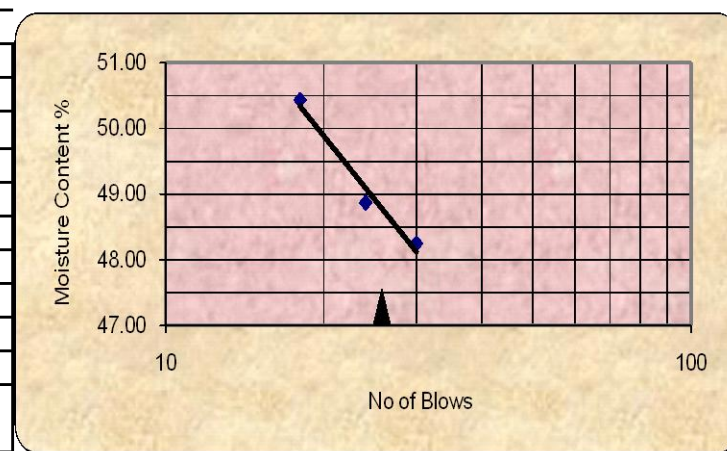
TEST METHOD : AASHTO T89 - T91

Sample Code- OESOS 7

Depth of Sampling:-80.5cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	30	24	18			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	32.6	32.1	33.1		27.6	23.26
Wt. tare + dry soil	g	26.92	26.65	27.29		26	21.54
Wt. water	g	5.64	5.41	5.81		1.67	1.72
Wt. of tare	g	15.2	15.6	15.77		20.4	15.92
Wt. of dry soil	g	11.69	11.07	11.52		5.58	5.62
No. of blows	N	30	24	18			
Moisture content	%	48.25	48.87	50.43		29.93	30.60

LIQUID LIMIT (LL%)=49, PLASTIC LIMIT (PL %)=30, PLASTICITY INDEX (P.I.)=LL-PL=19



7.3 Modified Proctor Test

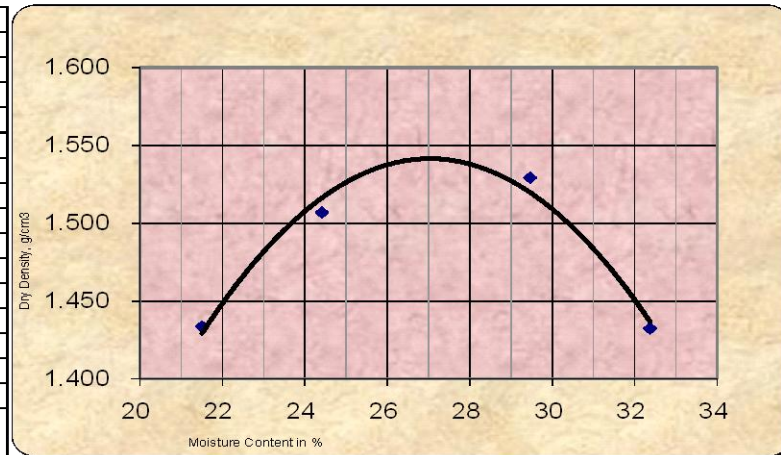
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-OESOS7

Depth of Sampling:-80.5cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4655	4780	4879	4800
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1641	1766	1865	1786
E	Volume of Mold	cu.cm	942	942	942	942
F	Wet Density	gr/cu.cm	1.74	1.87	1.98	1.90
G	Container	No.	E17	E4	F33	G13
H	Wt. Cont + Wet soil	grams	308.98	310.00	336.00	360.00
I	Wt. Cont + Dry soil	grams	261.19	258.06	269.76	282.25
J	Weight of Water	grams	47.79	51.94	66.24	77.75
K	Weight of Container	grams	38.99	45.34	44.92	42.06
L	Weight of Dry Soil	grams	222.20	212.72	224.84	240.19
M	Moisture Content	%	21.5	24.4	29.5	32.4
N	Dry Density	gr/cu.cm	1.434	1.507	1.529	1.432

Maximum Dry Density(MDD)=1.542, Optimum Moisture Content(OMC)=27%

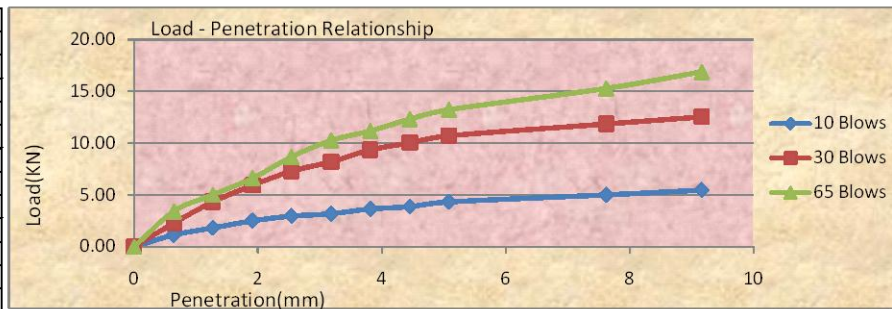
**7.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-OESOS7

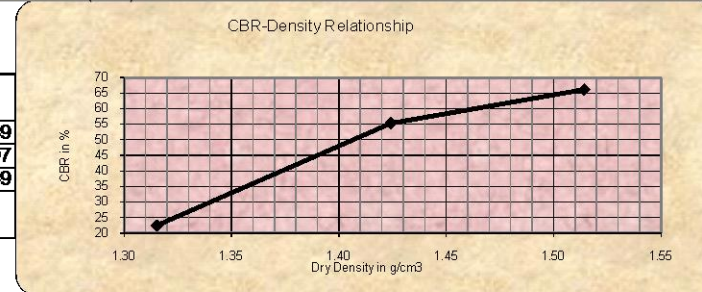
Depth of Sampling:-80.5cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	5	1.14	10	2.28	15	3.42
1.27	8	1.82	19	4.33	22	5.02
1.91	11	2.51	26	5.93	29	6.61
2.54	13	2.97	32	7.30	38	8.67
3.18	14	3.19	36	8.21	45	10.26
3.81	16	3.65	41	9.35	49	11.18
4.45	17	3.88	44	10.04	54	12.32
5.08	19	4.33	47	10.72	58	13.23
7.62	22	5.02	52	11.86	67	15.28
9.16	24	5.47	55	12.55	74	16.88



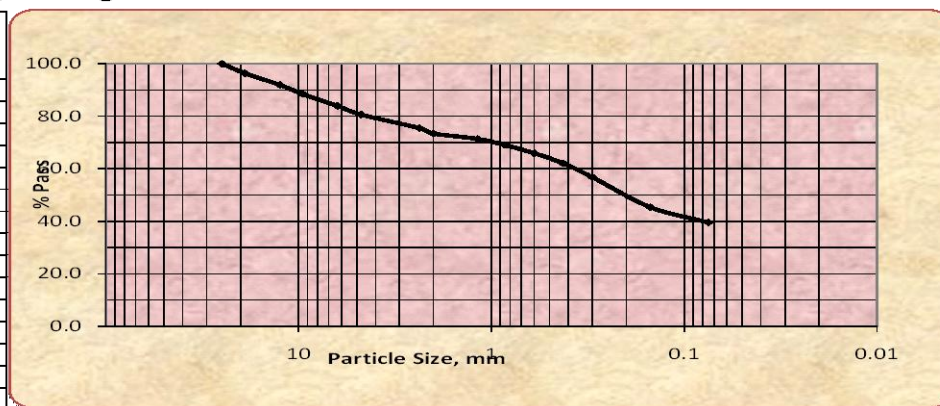
No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.7122173	2.97	4.33	13.2	20	22.46439	21.6695	22.46439
30	1.80819458	7.30	10.72	13.2	20	55.29697	53.6035	55.29697
65	1.89393259	8.67	13.23	13.2	20	65.66515	66.149	66.149

CBR at 95% MDD i.e 1.4649 gm/cc and at OMC of 27% is 60%



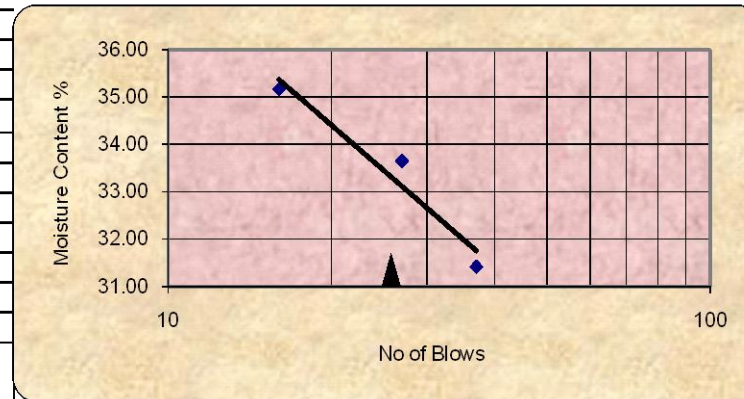
7.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27****Sample Code- OESOS 7****Depth of Sampling:-80.5cm****Weight Before Washing =690.5gm, Weight After Washing=417.2gm**

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
25	0.0	0.0	100.0
19	25.2	3.6	96.4
12.5	55.7	8.1	91.9
9.5	79.8	11.6	88.4
6.3	110.6	16.0	84.0
4.75	133.6	19.3	80.7
2.36	169.2	24.5	75.5
2	183.5	26.6	73.4
1.18	197.8	28.6	71.4
0.85	214.0	31.0	69.0
0.6	235.5	34.1	65.9
0.425	261.9	37.9	62.1
0.3	298.6	43.2	56.8
0.15	377.3	54.6	45.4
0.075	417.2	60.4	39.6

**8.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91****Sample Code- OESMS 8****Depth of Sampling:-50cm**

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	37	27	16			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	40.2	38.7	43.42		20.7	23.79
Wt. tare + dry soil	g	34.45	32.63	36.01		19.7	22.81
Wt. water	g	5.73	6.07	7.41		1.03	0.98
Wt. of tare	g	16.2	14.6	14.94		14.9	18.17
Wt. of dry soil	g	18.24	18.04	21.07		4.85	4.64
No. of blows	N	37	27	16			
Moisture content	%	31.41	33.65	35.17		21.24	21.12

LIQUID LIMIT (LL%)=33, PLASTIC LIMIT (PL %)=21, PLASTICITY INDEX (P.I.)=LL-PL=12



8.3 Modified Proctor Test

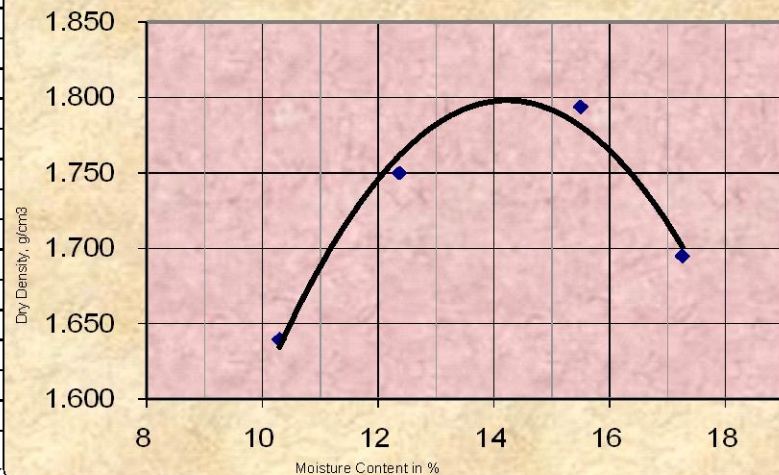
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-OESMS8

Depth of Sampling:-50cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4720	4870	4970	4890
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1714	1864	1964	1884
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm	1.81	1.97	2.07	1.99
G	Container	No.	Y5	Y8	V	C10
H	Wt. Cont + Wet soil	grams	263.70	241.15	280.05	268.02
I	Wt. Cont + Dry soil	grams	244.57	218.63	248.24	237.35
J	Weight of Water	grams	19.13	22.52	31.81	30.67
K	Weight of Container	grams	58.63	36.45	42.95	59.58
L	Weight of Dry Soil	grams	185.94	182.18	205.29	177.77
M	Moisture Content	%	10.3	12.4	15.5	17.3
N	Dry Density	gr/cu.cm	1.639	1.750	1.794	1.695

Maximum Dry Density(MDD)=1.80, Optimum Moisture Content(OMC)=14.5%

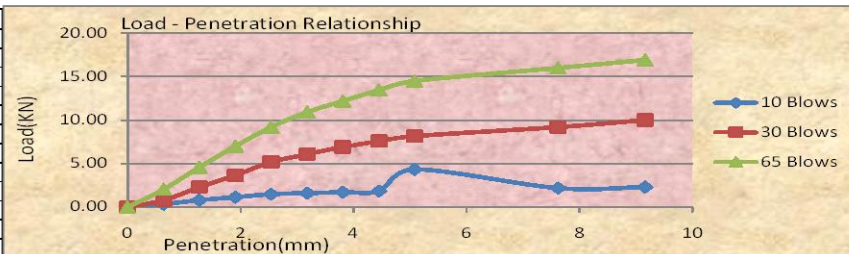
**8.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-OESMS8

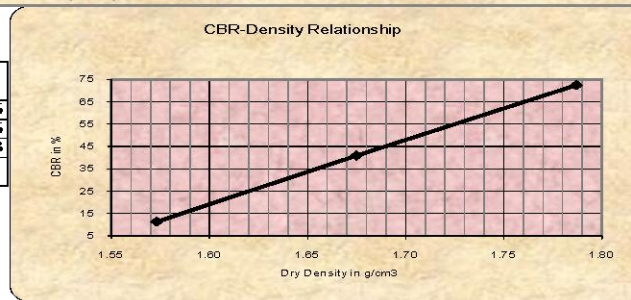
Depth of Sampling:-50cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	3	0.35	7	0.81	18	2.07
1.27	7	0.81	20	2.30	40	4.60
1.91	10	1.15	32	3.68	61	7.02
2.54	13	1.50	45	5.18	80	9.21
3.18	14	1.61	53	6.10	95	10.93
3.81	15	1.73	60	6.91	106	12.20
4.45	16	1.84	66	7.60	117	13.47
5.08	17	4.33	71	8.17	126	14.50
7.62	19	2.19	80	9.21	139	16.00
9.16	20	2.30	87	10.01	147	16.92



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.57307071	1.50	4.33	13.2	20	11.33561	21.6695	21.6695
30	1.67491816	5.18	8.17	13.2	20	39.23864	40.8605	40.8605
65	1.78695022	9.21	14.50	13.2	20	69.75758	72.513	72.513

CBR at 95% MDD i.e 1.71 gm/cc and at OMC of 14.5% is 50%



9.1 Grain Size Analysis

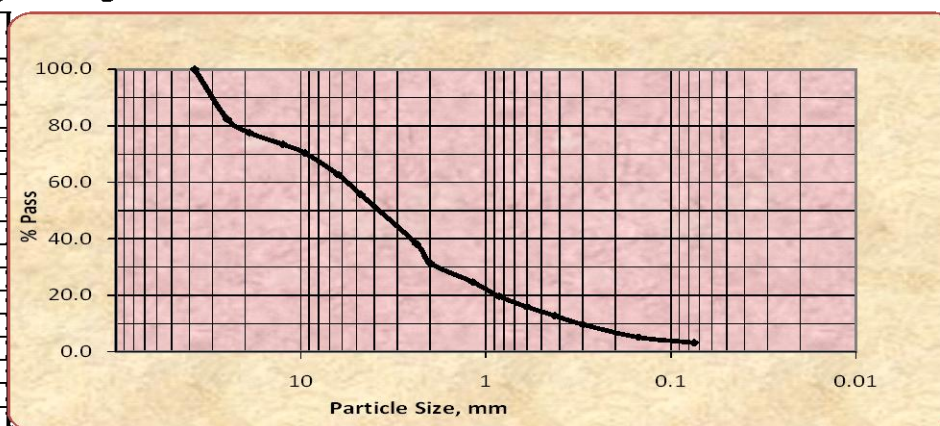
TEST METHOD : AASHTO T - 27

Sample Code- OESMS 9

Depth of Sampling:-52cm

Weight Before Washing =635.4gm, Weight After Washing=614.5gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
37.5	0.0	0.0	100.0
25	112.3	17.7	82.3
19	142.4	22.4	77.6
12.5	168.7	26.6	73.4
9.5	188.2	29.6	70.4
6.3	236.5	37.2	62.8
4.75	281.8	44.4	55.6
2.36	392.9	61.8	38.2
2	435.5	68.5	31.5
1.18	478.1	75.2	24.8
0.85	510.3	80.3	19.7
0.6	534.0	84.0	16.0
0.425	553.6	87.1	12.9
0.3	573.4	90.2	9.8
0.15	602.2	94.8	5.2
0.075	614.5	96.7	3.3

**9.2 Atterberg Limit Test**

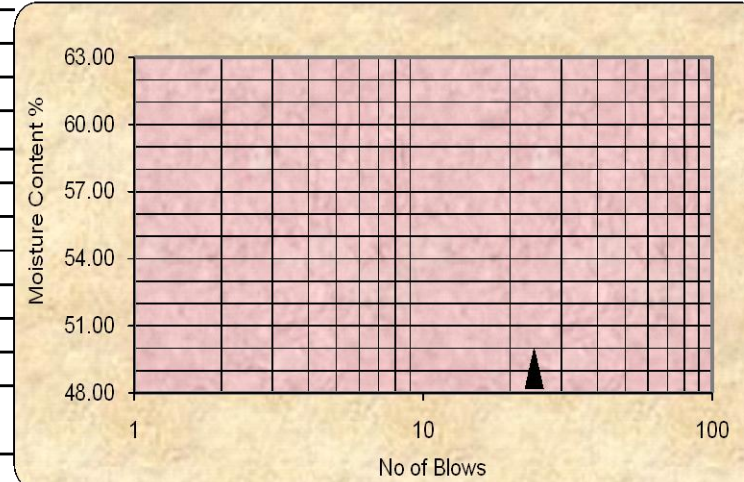
TEST METHOD : AASHTO T89 - T91

Sample Code- OESMS 9

Depth of Sampling:-52cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N						
Tare	n°						
Wt. tare + wet soil	g		NP				
Wt. tare + dry soil	g						
Wt. water	g						
Wt. of tare	g						
Wt. of dry soil	g						
No. of blows	N						
Moisture content	%						

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL %)=NP, PLASTICITY INDEX (P.I)=LL-PL=0



9.3 Modified Proctor Test

TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-OESMS9

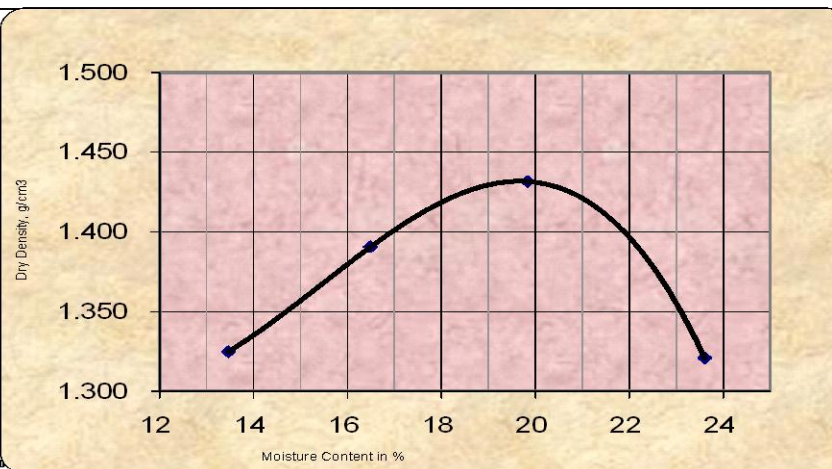
Depth of Sampling:-52cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4430	4540	4630	4552
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1416	1526	1616	1538
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.50	1.62	1.72	1.63

G	Container	No.	E21	GH	C1	E2
H	Wt. Cont + Wet soil	grams	220.65	228.20	310.82	260.32
I	Wt. Cont + Dry soil	grams	200.28	202.62	265.84	221.74
J	Weight of Water	grams	20.37	25.58	44.98	38.58
K	Weight of Container	grams	48.95	47.52	39.03	58.29
L	Weight of Dry Soil	grams	151.33	155.10	226.81	163.45

M	Moisture Content	%	13.5	16.5	19.8	23.6
N	Dry Density	gr/cu.cm.	1.325	1.391	1.432	1.321

Maximum Dry Density(MDD)=1.433, Optimum Moisture Content(OMC)=12.0%

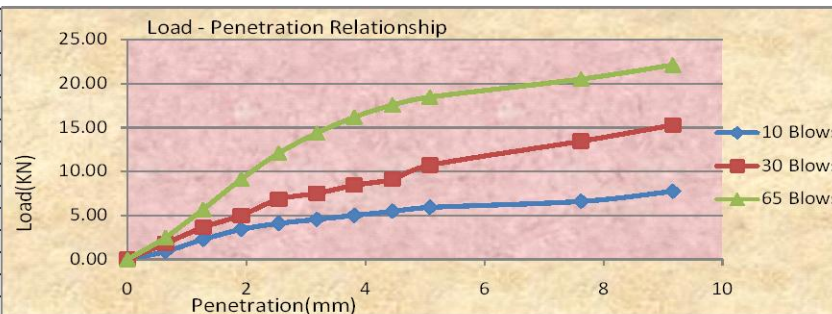
**9.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-OESMS9

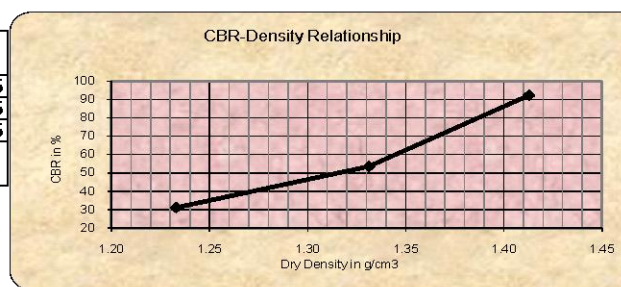
Depth of Sampling:-52cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	4	0.91	8	1.82	11	2.51
1.27	10	2.28	16	3.65	25	5.70
1.91	15	3.42	22	5.02	40	9.12
2.54	18	4.11	30	6.84	53	12.09
3.18	20	4.56	33	7.53	63	14.37
3.81	22	5.02	37	8.44	71	16.20
4.45	24	5.47	40	9.12	77	17.56
5.08	26	5.93	47	10.72	81	18.48
7.62	29	6.61	59	13.46	90	20.53
9.16	34	7.76	67	15.28	97	22.13



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.23299778	4.11	5.93	13.2	20	31.10455	29.653	31.10455
30	1.33125929	6.84	10.72	13.2	20	51.84091	53.6035	53.6035
65	1.4127929	12.09	18.48	13.2	20	91.58561	92.3805	92.3805

CBR at 95% MDD i.e 1.36135 gm/cc and at OMC of 20 % is 67 %



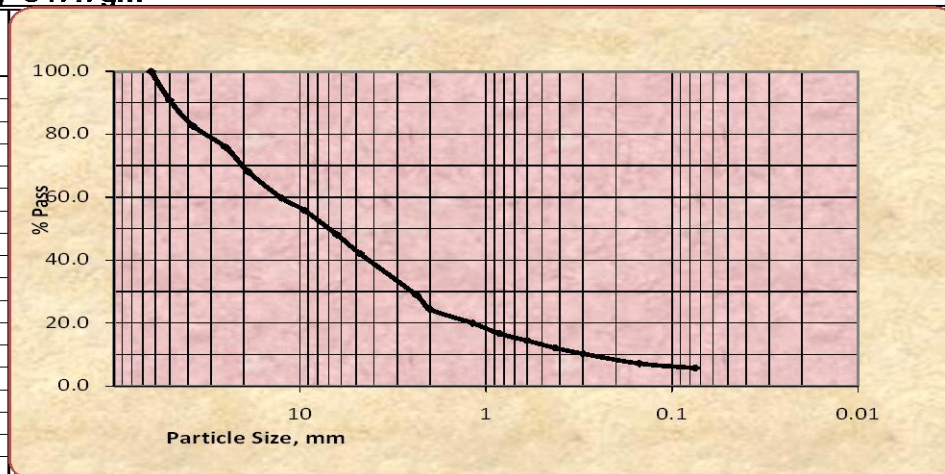
10.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27**

Sample Code- OESMS 10

Depth of Sampling:-52cm

Weight Before Washing =899.2gm, Weight After Washing=847.7gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
63	0.0	0.0	100.0
50	83.1	9.2	90.8
37.5	155.9	17.3	82.7
25	217.7	24.2	75.8
19	286.4	31.9	68.1
12.5	362.2	40.3	59.7
9.5	396.8	44.1	55.9
6.3	466.8	51.9	48.1
4.75	520.8	57.9	42.1
2.36	639.3	71.1	28.9
2	679.4	75.6	24.4
1.18	719.4	80.0	20.0
0.85	748.9	83.3	16.7
0.6	769.3	85.6	14.4
0.425	790.0	87.9	12.1
0.3	806.6	89.7	10.3
0.15	835.0	92.9	7.1
0.075	847.7	94.3	5.7

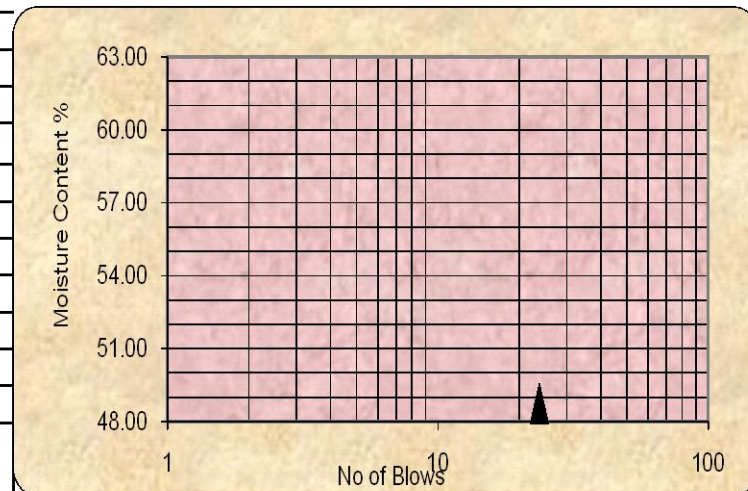
**10.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91**

Sample Code- OESMS 10

Depth of Sampling:-52cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N						
Tare	n°						
Wt. tare + wet soil	g		NP				
Wt tare + dry soil	g						
Wt. water	g						
Wt. of tare	g						
Wt. of dry soil	g						
No. of blows	N						
Moisture content	%						

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL %)=NP, PLASTICITY INDEX (P.I.)=LL-PL=0



10.3 Modified Proctor Test

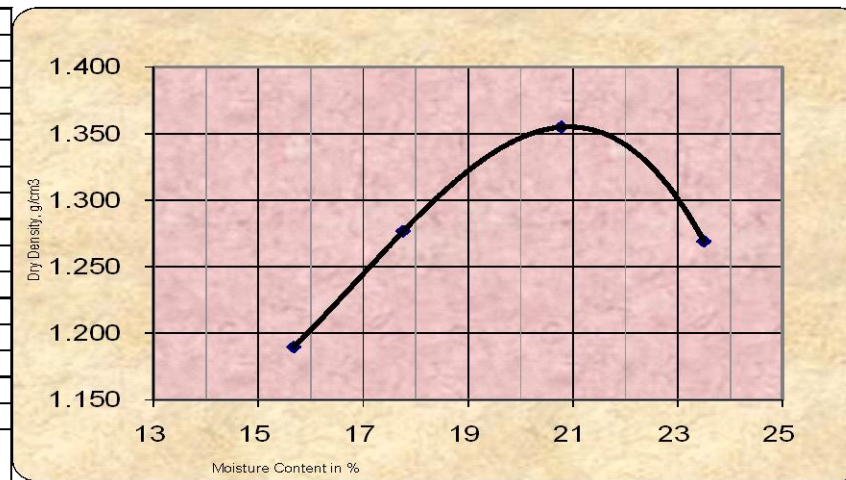
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-OESMS10

Depth of Sampling:-52cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4275	4395	4520	4455
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1295	1415	1540	1475
E	Volume of Mold	cu.cm.	941	941	941	941
F	Wet Density	gr/cu.cm	1.38	1.50	1.64	1.57
G	Container	No.	A9	F12	F63	F31
H	Wt. Cont + Wet soil	grams	222.42	200.49	212.45	232.47
I	Wt. Cont + Dry soil	grams	200.17	177.87	185.15	198.75
J	Weight of Water	grams	22.25	22.62	27.30	33.72
K	Weight of Container	grams	58.16	50.52	53.76	55.24
L	Weight of Dry Soil	grams	142.01	127.35	131.39	143.51
M	Moisture Content	%	15.7	17.8	20.8	23.5
N	Dry Density	gr/cu.cm	1.190	1.277	1.355	1.269

Maximum Dry Density(MDD)=1.360, Optimum Moisture Content(OMC)=21.0%

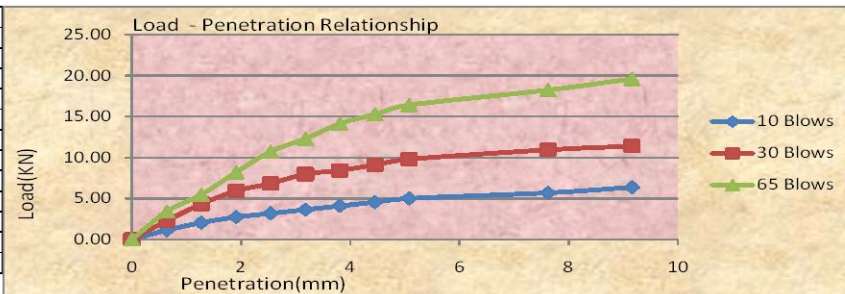
**10.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-OESMS10

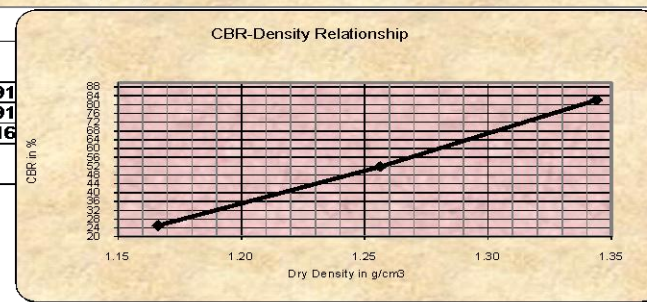
Depth of Sampling:-52cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	5	1.14	10	2.28	15	3.42
1.27	9	2.05	19	4.33	24	5.47
1.91	12	2.74	26	5.93	36	8.21
2.54	14	3.19	30	6.84	47	10.72
3.18	16	3.65	35	7.98	54	12.32
3.81	18	4.11	37	8.44	62	14.14
4.45	20	4.56	40	9.12	67	15.28
5.08	22	5.02	43	9.81	72	16.42
7.62	25	5.70	48	10.95	80	18.25
9.16	28	6.39	50	11.41	86	19.62



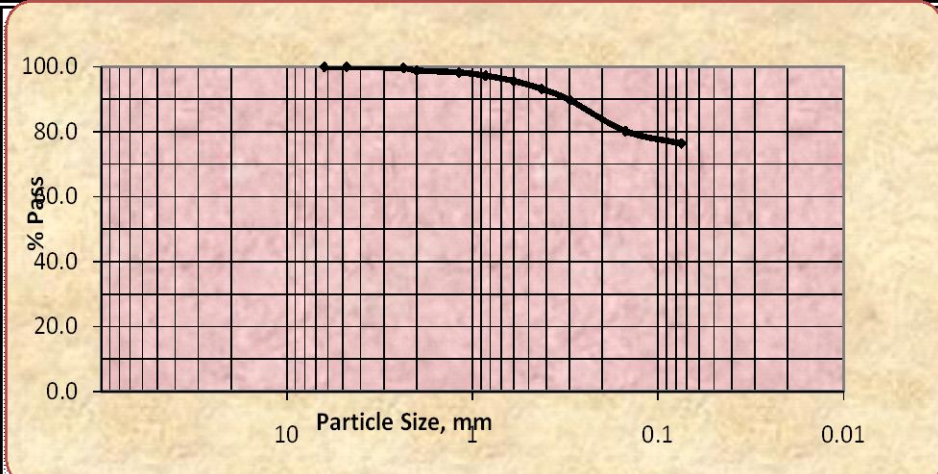
No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.16625975	3.19	5.02	13.2	20	24.19242	25.091	25.091
30	1.25624887	6.84	9.81	13.2	20	51.84091	49.0415	51.84091
65	1.34385797	10.72	16.42	13.2	20	81.21742	82.116	82.116

CBR at 95% MDD i.e 1.292 gm/cc and at OMC of 21 % is 64 %



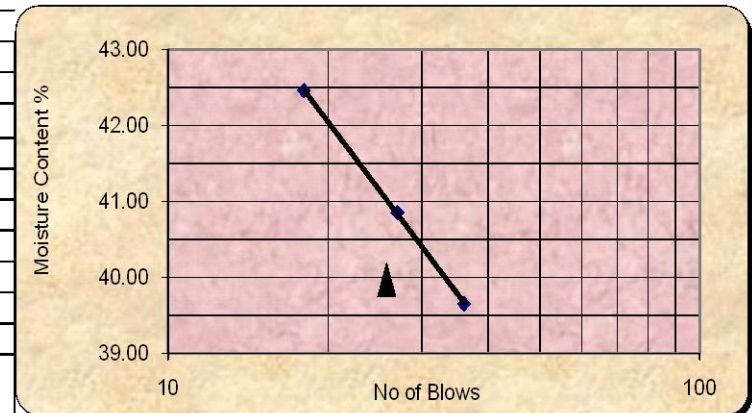
11.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27****Sample Code- ARNSS 11****Depth of Sampling:-50cm****Weight Before Washing =778.5gm, Weight After Washing=183.9gm**

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
6.3	0.0	0.0	100.0
4.75	0.1	0.0	100.0
2.36	3.2	0.4	99.6
2	8.2	1.1	98.9
1.18	13.2	1.7	98.3
0.85	21.0	2.7	97.3
0.6	33.4	4.3	95.7
0.425	52.5	6.7	93.3
0.3	79.2	10.2	89.8
0.15	153.8	19.8	80.2
0.075	183.9	23.6	76.4

**11.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91****Sample Code- ARNSS 11****Depth of Sampling:-50cm**

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	36	27	18			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	35.9	35.5	36.63		21.9	23.93
Wt. tare + dry soil	g	29.92	29.6	30.38		20.3	22.21
Wt. water	g	5.94	5.92	6.25		1.63	1.72
Wt. of tare	g	14.9	15.1	15.66		15.1	16.84
Wt. of dry soil	g	14.98	14.49	14.72		5.17	5.37
No. of blows	N	36	27	18			
Moisture content	%	39.65	40.86	42.46		31.53	32.03

LIQUID LIMIT (LL%)=41, PLASTIC LIMIT (PL %)=32, PLASTICITY INDEX (P.I)=LL-PL=9



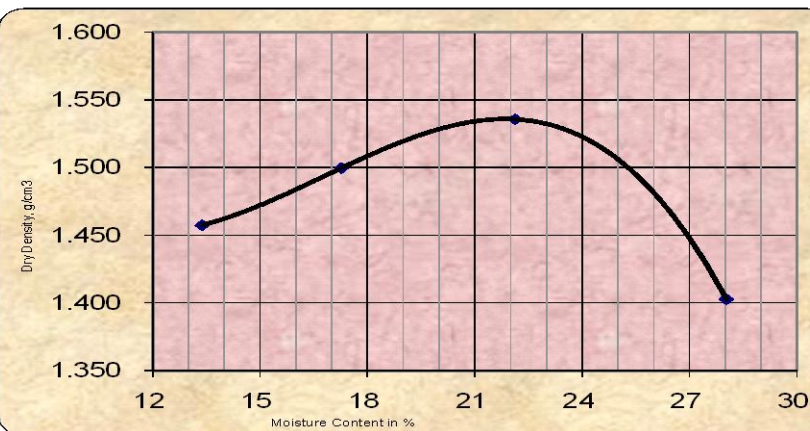
11.3 Modified Proctor Test**TEST METHOD : AASHTO T- 180 METHOD C**

Sample Code-ARNSS11

Depth of Sampling:-50cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4535	4635	4745	4670
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1555	1655	1765	1690
E	Volume of Mold	cu.cm.	941	941	941	941
F	Wet Density	gr/cu.cm.	1.65	1.76	1.88	1.80
G	Container	No.	P100	P17	L9	B2
H	Wt. Cont + Wet soil	grams	236.00	243.00	232.16	291.88
I	Wt. Cont + Dry soil	grams	211.94	215.10	196.39	237.72
J	Weight of Water	grams	24.06	27.90	35.77	54.16
K	Weight of Container	grams	32.06	53.54	34.73	44.50
L	Weight of Dry Soil	grams	179.88	161.56	161.66	193.22
M	Moisture Content	%	13.4	17.3	22.1	28.0
N	Dry Density	gr/cu.cm.	1.458	1.500	1.536	1.403

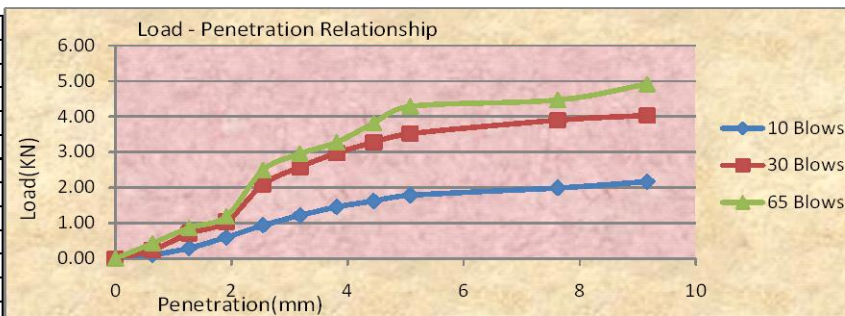
Maximum Dry Density(MDD)=1.54, Optimum Moisture Content(OMC)=22.0%

**11.4 California Bearing Ration Test****TEST METHOD : AASHTO T- 193**

Sample Code-ARNSS11

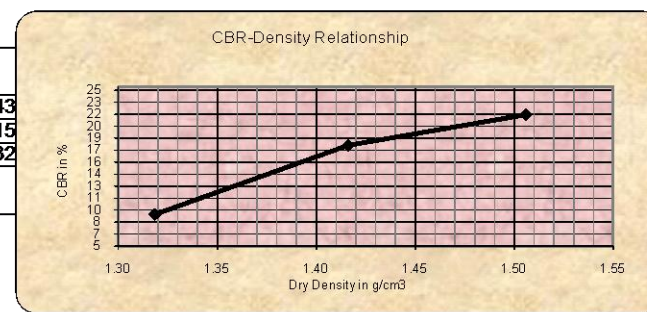
Depth of Sampling:-50cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	20	0.11	45	0.24	80	0.43
1.27	55	0.30	131	0.71	160	0.87
1.91	111	0.60	192	1.04	220	1.19
2.54	173	0.94	385	2.09	460	2.49
3.18	225	1.22	476	2.58	546	2.96
3.81	269	1.46	549	2.98	605	3.28
4.45	300	1.63	605	3.28	705	3.82
5.08	330	1.79	650	3.52	792	4.29
7.62	368	1.99	720	3.90	825	4.47
9.16	401	2.17	745	4.04	908	4.92



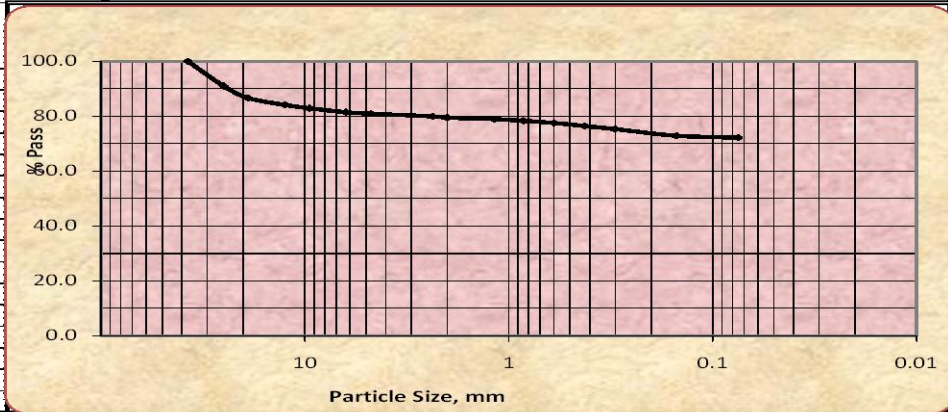
No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.31846716	0.94	1.79	13.2	20	7.103485	8.943	8.943
30	1.41625672	2.09	3.52	13.2	20	15.80833	17.615	17.615
65	1.50592593	2.49	4.29	13.2	20	18.88788	21.4632	21.4632

CBR at 95% MDD i.e 1.463 gm/cc and at OMC of 22 % is 20 %



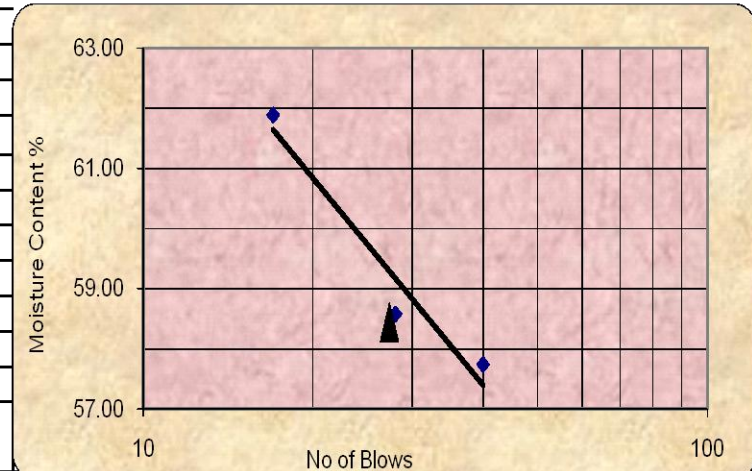
12.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27****Sample Code- AROZKS 12****Depth of Sampling:-120cm****Weight Before Washing =886.7gm, Weight After Washing=246.9gm**

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
37.5	0.0	0.0	100.0
25	80.2	9.0	91.0
19	118.4	13.4	86.6
12.5	140.9	15.9	84.1
9.5	151.5	17.1	82.9
6.3	164.4	18.5	81.5
4.75	169.0	19.1	80.9
2.36	177.9	20.1	79.9
2	182.3	20.6	79.4
1.18	186.6	21.0	79.0
0.85	192.4	21.7	78.3
0.6	199.2	22.5	77.5
0.425	209.1	23.6	76.4
0.3	219.3	24.7	75.3
0.15	240.6	27.1	72.9
0.075	246.9	27.8	72.2

**12.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91****Sample Code- AROZKS 12****Depth of Sampling:-120cm**

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	40	28	17			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	37.4	44.7	37.41		22.2	21.62
Wt. tare + dry soil	g	29.12	34.91	28.82		20.5	20.70
Wt. water	g	8.28	9.8	8.59		1.67	0.92
Wt. of tare	g	14.8	18.2	14.94		15	17.72
Wt. of dry soil	g	14.34	16.73	13.88		5.53	2.98
No. of blows	N	40	28	17			
Moisture content	%	57.74	58.58	61.89		30.20	30.87

LIQUID LIMIT (LL%)=60, PLASTIC LIMIT (PL %)=31, PLASTICITY INDEX (P.I.)=LL-PL=29



12.3 Modified Proctor Test

TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-AROKS12

Depth of Sampling:-120cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4710	4800	4900	4820
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1704	1794	1894	1814
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.80	1.89	2.00	1.91
G	Container	No.	G19	G13	G9	B9
H	Wt. Cont + Wet soil	grams	228.69	238.69	242.84	247.16
I	Wt. Cont + Dry soil	grams	200.25	199.88	195.72	195.46
J	Weight of Water	grams	28.44	38.81	47.12	51.70
K	Weight of Container	grams	58.56	32.26	32.06	34.73
L	Weight of Dry Soil	grams	141.69	167.62	163.66	160.73
M	Moisture Content	%	20.1	23.2	28.8	32.2
N	Dry Density	gr/cu.cm.	1.497	1.537	1.551	1.448

Maximum Dry Density(MDD)=1.567, Optimum Moisture Content(OMC)=27.0%



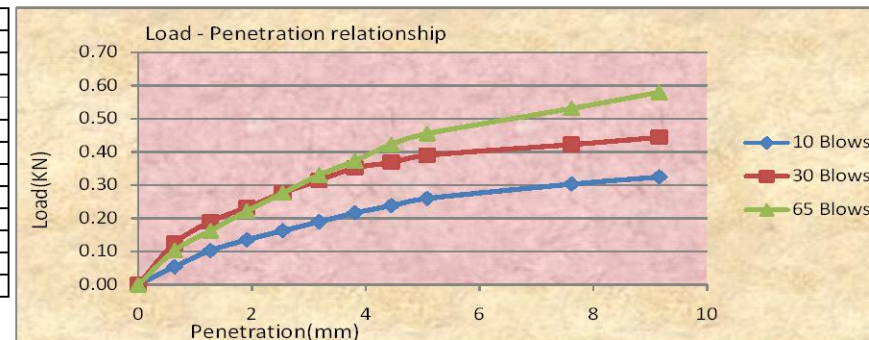
12.4 California Bearing Ratio Test

TEST METHOD : AASHTO T- 193

Sample Code-AROKS12

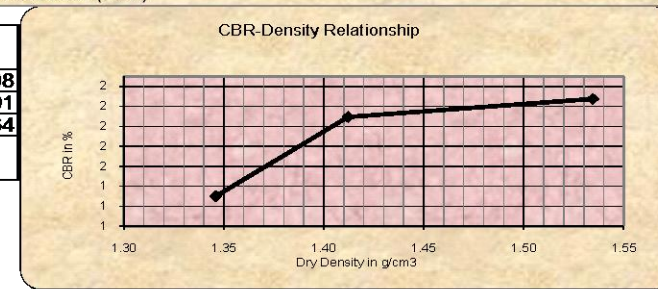
Depth of Sampling:-120cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	10	0.05	23	0.12	19	0.10
1.27	19	0.10	35	0.19	30	0.16
1.91	25	0.14	43	0.23	41	0.22
2.54	30	0.16	51	0.28	51	0.28
3.18	35	0.19	58	0.31	61	0.33
3.81	40	0.22	65	0.35	69	0.37
4.45	44	0.24	68	0.37	78	0.42
5.08	48	0.26	72	0.39	84	0.46
7.62	56	0.30	78	0.42	98	0.53
9.16	60	0.33	82	0.44	107	0.58



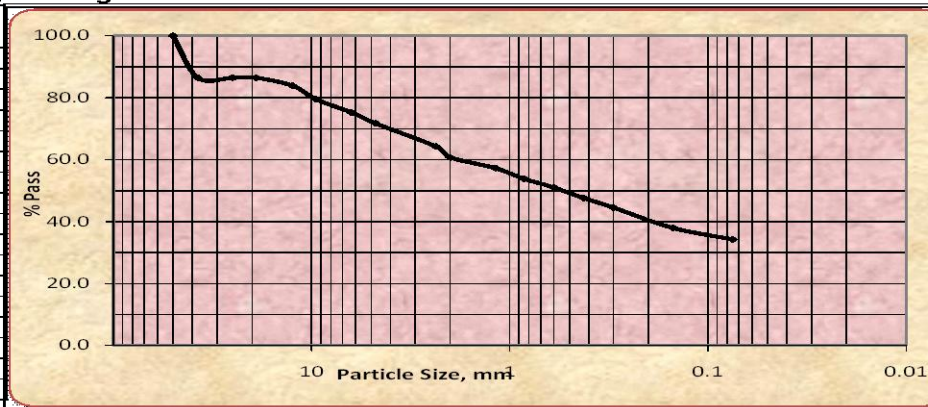
No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.34597578	0.16	0.26	13.2	20	1.231818	1.3008	1.3008
30	1.41207559	0.28	0.39	13.2	20	2.094091	1.9512	2.094091
65	1.53456008	0.28	0.46	13.2	20	2.094091	2.2764	2.2764

CBR at 95% MDD i.e 1.4887 gm/cc and at OMC of 27 % is 2 %



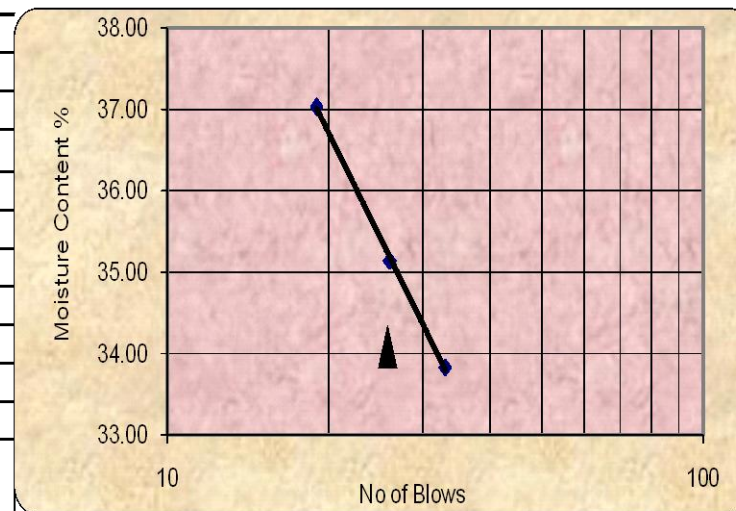
13.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27****Sample Code- AROZKS 13****Depth of Sampling:-100cm****Weight Before Washing =443.9gm, Weight After Washing=291.7gm**

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
50	0.0	0.0	100.0
37.5	60.2	13.6	86.4
25	60.2	13.6	86.4
19	60.2	13.6	86.4
12.5	71.4	16.1	83.9
9.5	90.9	20.5	79.5
6.3	109.8	24.7	75.3
4.75	125.5	28.3	71.7
2.36	158.7	35.8	64.2
2	174.3	39.3	60.7
1.18	189.9	42.8	57.2
0.85	204.7	46.1	53.9
0.6	217.3	49.0	51.0
0.425	232.5	52.4	47.6
0.3	246.2	55.5	44.5
0.15	275.4	62.0	38.0
0.075	291.7	65.7	34.3

**13.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91****Sample Code- AROZKS 13****Depth of Sampling:-100cm**

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	33	26	19			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	35	33.2	28.64		17.7	17.33
Wt. tare + dry soil	g	31.15	28.9	24.60		16.2	15.90
Wt. water	g	3.84	4.34	4.04		1.49	1.43
Wt. of tare	g	19.8	16.5	13.69		9.43	9.53
Wt. of dry soil	g	11.35	12.35	10.91		6.81	6.37
No. of blows	N	33	26	19			
Moisture content	%	33.83	35.14	37.03		21.88	22.45

LIQUID LIMIT (LL%)=35, PLASTIC LIMIT (PL %)=22, PLASTICITY INDEX (P.I.)=LL-PL=13



13.3 Modified Proctor Test

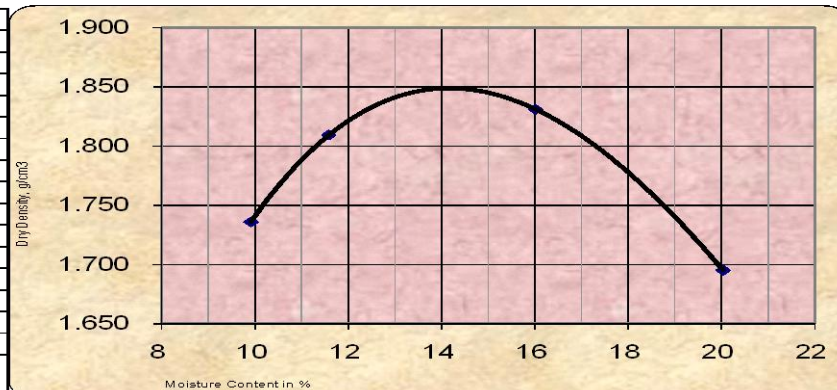
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-AROKS13

Depth of Sampling:-100cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4815	4920	5020	4935
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1809	1914	2014	1929
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.91	2.02	2.12	2.03
G	Container	No.	F5	A2	F1	F33
H	Wt. Cont + Wet soil	grams	266.50	239.00	254.00	240.00
I	Wt. Cont + Dry soil	grams	246.40	217.32	226.79	208.58
J	Weight of Water	grams	20.10	21.68	27.21	31.42
K	Weight of Container	grams	43.65	30.17	56.85	51.75
L	Weight of Dry Soil	grams	202.75	187.15	169.94	156.83
M	Moisture Content	%	9.9	11.6	16.0	20.0
N	Dry Density	gr/cu.cm.	1.736	1.809	1.831	1.695

Maximum Dry Density(MDD)=1.850, Optimum Moisture Content(OMC)=14.4%

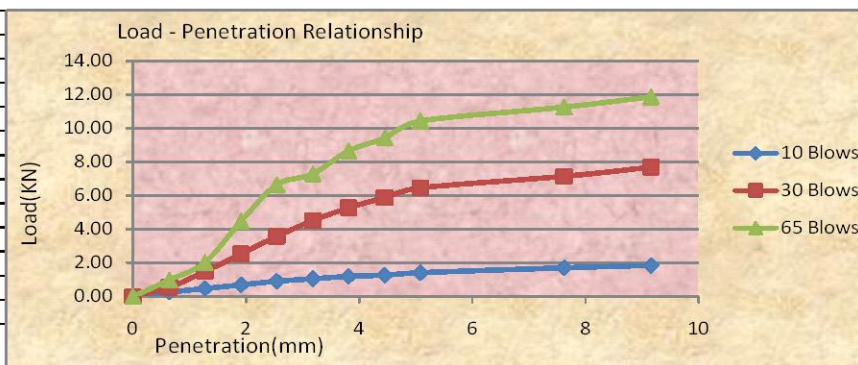
**13.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-AROKS13

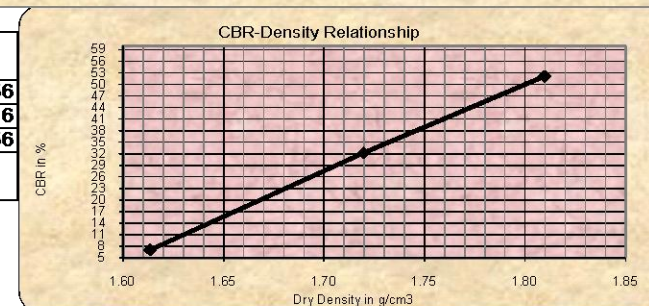
Depth of Sampling:-100cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	7	0.25	15	0.54	27	0.97
1.27	13	0.47	41	1.48	56	2.02
1.91	19	0.69	70	2.53	124	4.47
2.54	25	0.90	99	3.57	184	6.64
3.18	29	1.05	125	4.51	202	7.29
3.81	33	1.19	146	5.27	240	8.66
4.45	35	1.26	163	5.88	261	9.42
5.08	39	1.41	179	6.46	289	10.43
7.62	47	1.70	198	7.14	312	11.26
9.16	51	1.84	213	7.69	329	11.87



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.61337941	0.90	1.41	13.2	20	6.833333	7.0356	7.0356
30	1.71977239	3.57	6.46	13.2	20	27.06	32.2916	32.2916
65	1.80962725	6.64	10.43	13.2	20	50.29333	52.1356	52.1356

CBR at 95% MDD i.e 1.7575 gm/cc and at OMC of 14.4 % is 41 %



14.1 Grain Size Analysis

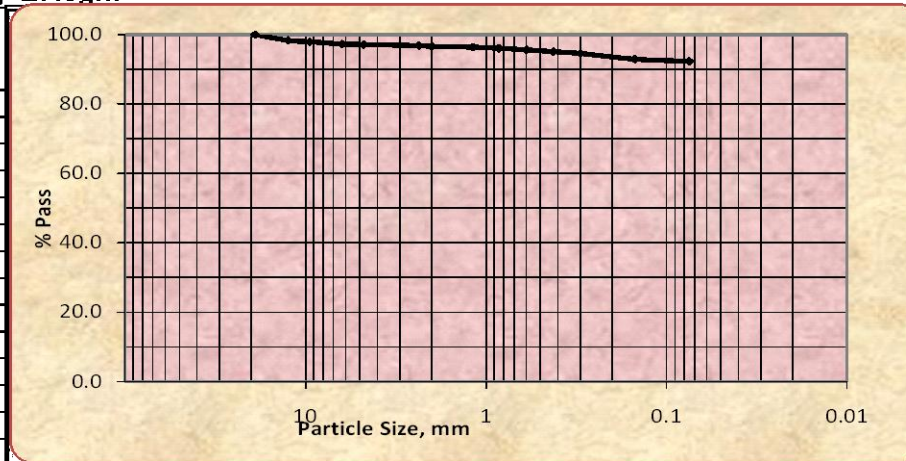
TEST METHOD : AASHTO T - 27

Sample Code- ARWZKS 14

Depth of Sampling:-120cm

Weight Before Washing =359.6gm, Weight After Washing=27.6gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
19	0.0	0.0	100.0
12.5	6.2	1.7	98.3
9.5	7.5	2.1	97.9
6.3	9.9	2.8	97.2
4.75	10.4	2.9	97.1
2.36	11.6	3.2	96.8
2	12.4	3.4	96.6
1.18	13.2	3.7	96.3
0.85	14.2	3.9	96.1
0.6	15.8	4.4	95.6
0.425	17.7	4.9	95.1
0.3	19.6	5.5	94.5
0.15	25.5	7.1	92.9
0.075	27.6	7.7	92.3

**14.2 Atterberg Limit Test**

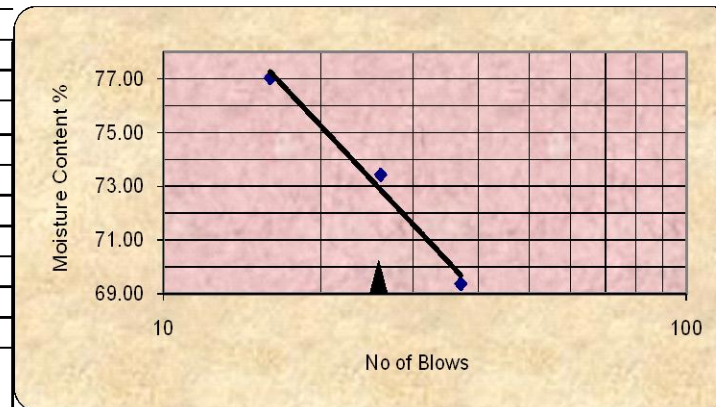
TEST METHOD : AASHTO T89 - T91

Sample Code- ARWZKS 14

Depth of Sampling:-120cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	37	26	16			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	39.3	44.5	38.98		24.7	21.63
Wt. tare + dry soil	g	29.75	34.2	29.32		23.1	20.02
Wt. water	g	9.51	10.3	9.66		1.62	1.61
Wt. of tare	g	16	20.2	16.78		17.52	14.63
Wt. of dry soil	g	13.71	14.00	12.54		5.55	5.39
No. of blows	N	37	26	16			
Moisture content	%	69.37	73.43	77.03		29.19	29.87

LIQUID LIMIT (LL%)=73, PLASTIC LIMIT (PL %)=30, PLASTICITY INDEX (P.I.)=LL-PL=43



14.3 Modified Proctor Test

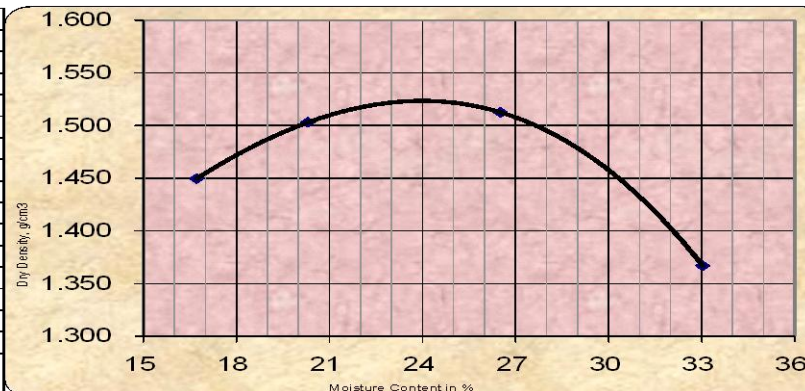
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-ARWZKS14

Depth of Sampling:-120cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4610	4720	4820	4730
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1604	1714	1814	1724
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.69	1.81	1.91	1.82
G	Container	No.	F5	F64	E4	B21
H	Wt. Cont + Wet soil	grams	243.99	256.28	248.94	240.14
I	Wt. Cont + Dry soil	grams	216.28	218.13	208.06	189.76
J	Weight of Water	grams	27.71	38.15	40.88	50.38
K	Weight of Containe	grams	50.50	30.17	53.86	37.22
L	Weight of Dry Soil	grams	165.78	187.96	154.20	152.54
M	Moisture Content	%	16.7	20.3	26.5	33.0
N	Dry Density	gr/cu.cm.	1.450	1.503	1.513	1.367

Maximum Dry Density(MDD)=1.525, Optimum Moisture Content(OMC)=24.0%



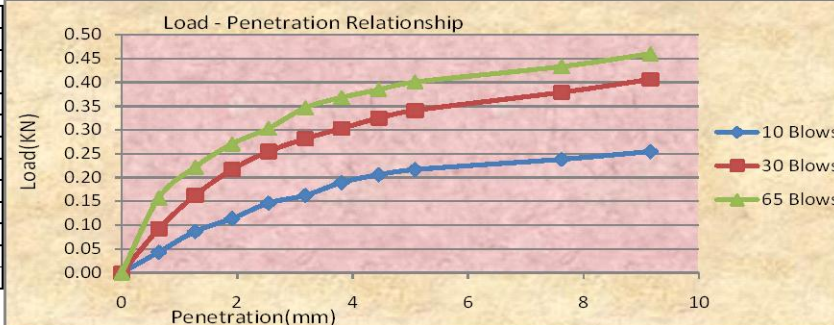
14.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-ARWZKS14

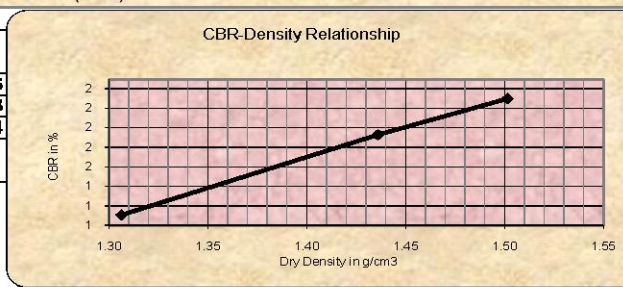
Depth of Sampling:-120cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	8	0.04	17	0.09	29	0.16
1.27	16	0.09	30	0.16	41	0.22
1.91	21	0.11	40	0.22	50	0.27
2.54	27	0.15	47	0.25	56	0.30
3.18	30	0.16	52	0.28	64	0.35
3.81	35	0.19	56	0.30	68	0.37
4.45	38	0.21	60	0.33	71	0.38
5.08	40	0.22	63	0.34	74	0.40
7.62	44	0.24	70	0.38	80	0.43
9.16	47	0.25	75	0.41	85	0.46



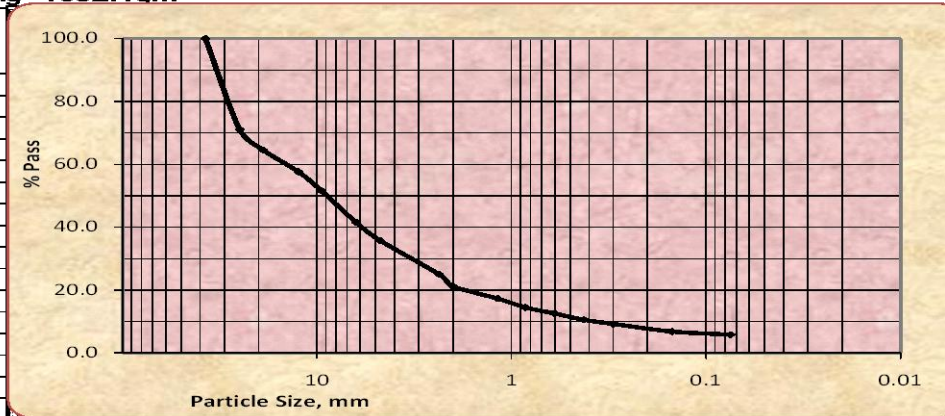
No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.30630316	0.15	0.22	13.2	20	1.108636	1.084	1.108636
30	1.43601791	0.25	0.34	13.2	20	1.929848	1.7073	1.929848
65	1.50142132	0.30	0.40	13.2	20	2.299394	2.0054	2.299394

CBR at 95% MDD i.e 1.449 gm/cc and at OMC of 24 % is 2 %



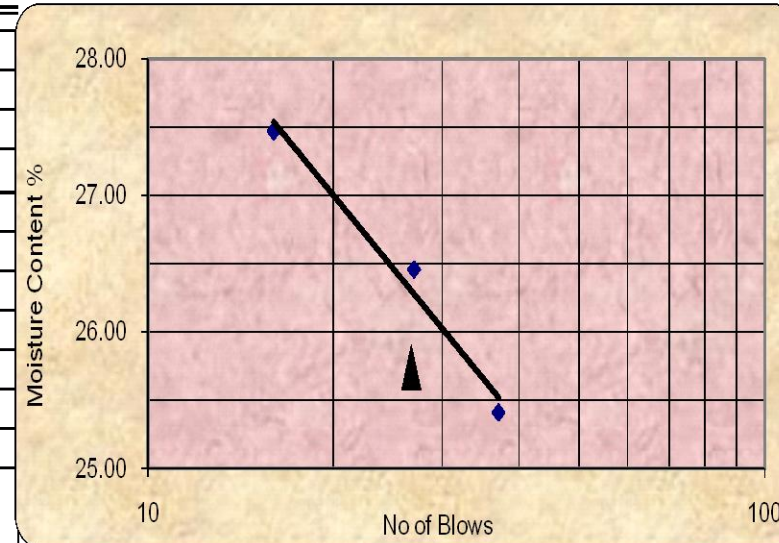
15.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27****Sample Code- ARWZBS 15****Depth of Sampling:-60cm****Weight Before Washing =1117.1gm, Weight After Washing=1052.1gm**

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
37.5	0.0	0.0	100.0
25	321.9	28.8	71.2
19	395.1	35.4	64.6
12.5	473.2	42.4	57.6
9.5	540.9	48.4	51.6
6.3	652.8	58.4	41.6
4.75	716.5	64.1	35.9
2.36	837.8	75.0	25.0
2	880.6	78.8	21.2
1.18	923.3	82.7	17.3
0.85	954.9	85.5	14.5
0.6	976.8	87.4	12.6
0.425	999.0	89.4	10.6
0.3	1013.6	90.7	9.3
0.15	1041.0	93.2	6.8
0.075	1052.1	94.2	5.8

**15.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91****Sample Code-ARWZBS 15****Depth of Sampling:-60cm**

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	37	27	16			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	42.1	41.1	43.19		19	19.58
Wt. tare + dry soil	g	36.72	35.8	37.15		18.4	18.97
Wt. water	g	5.4	5.35	6.04		0.55	0.61
Wt. of tare	g	15.5	15.6	15.16		15.2	15.41
Wt. of dry soil	g	21.25	20.22	21.99		3.26	3.56
No. of blows	N	37	27	16			
Moisture content	%	25.41	26.46	27.47		16.87	17.13

LIQUID LIMIT (LL%)=26, PLASTIC LIMIT (PL %)=17, PLASTICITY INDEX (P.I.)=LL-PL=9



15.3 Modified Proctor Test

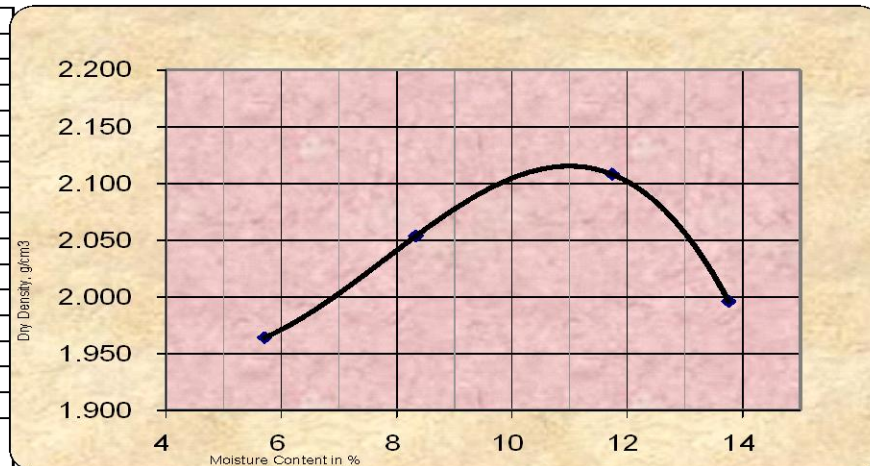
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-ARWZBS15

Depth of Sampling:-60cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4970	5110	5233	5153
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1956	2096	2219	2139
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	2.08	2.23	2.36	2.27
G	Container	No.	G6	B2	P17	P4
H	Wt. Cont + Wet soil	grams	304.00	358.50	384.00	406.50
I	Wt. Cont + Dry soil	grams	289.40	334.00	348.35	362.86
J	Weight of Water	grams	14.60	24.50	35.65	43.64
K	Weight of Container	grams	33.59	39.98	44.49	45.62
L	Weight of Dry Soil	grams	255.81	294.02	303.86	317.24
M	Moisture Content	%	5.7	8.3	11.7	13.8
N	Dry Density	gr/cu.cm.	1.964	2.054	2.108	1.996

Maximum Dry Density(MDD)=2.120, Optimum Moisture Content(OMC)=11.0%

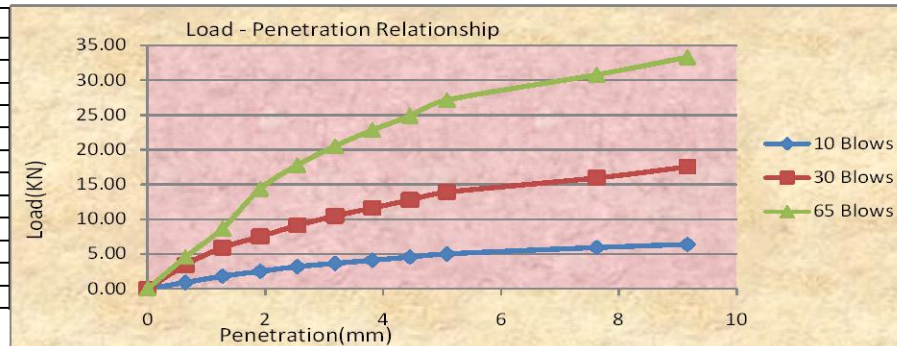
**15.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ARWZBS15

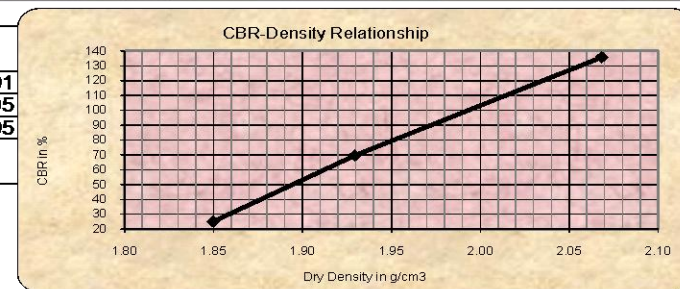
Depth of Sampling:-60cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	4	0.91	15	3.42	20	4.56
1.27	8	1.82	26	5.93	38	8.67
1.91	11	2.51	33	7.53	63	14.37
2.54	14	3.19	40	9.12	78	17.79
3.18	16	3.65	46	10.49	90	20.53
3.81	18	4.11	51	11.63	100	22.81
4.45	20	4.56	56	12.77	109	24.86
5.08	22	5.02	61	13.91	119	27.14
7.62	26	5.93	70	15.97	135	30.79
9.16	28	6.39	77	17.56	146	33.30



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.84981046	3.19	5.02	13.2	20	24.19242	25.091	25.091
30	1.92942898	9.12	13.91	13.2	20	69.12121	69.5705	69.5705
65	2.06828199	17.79	27.14	13.2	20	134.7864	135.7195	135.7195

CBR at 95% MDD i.e 2.014 gm/cc and at OMC of 11 % is 110 %



16.1 Grain Size Analysis

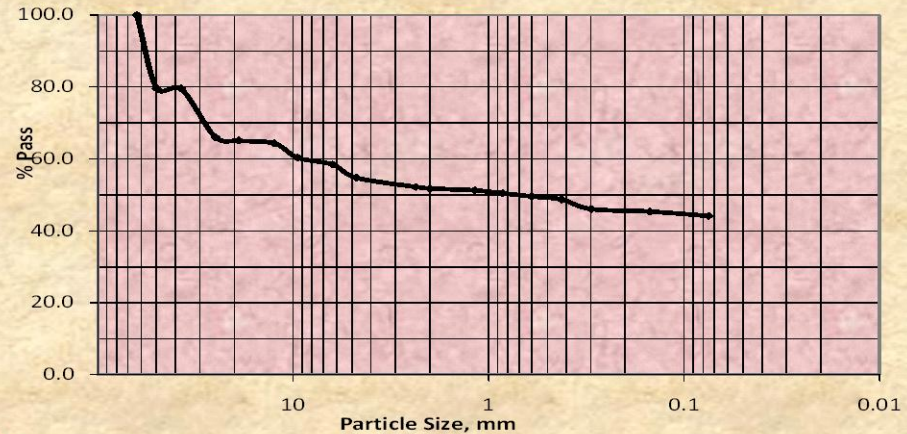
TEST METHOD : AASHTO T - 27

Sample Code-AFRAWS 16

Depth of Sampling:-110cm

Weight Before Washing =1051.9gm, Weight After Washing=587.2gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
63	0.0	0.0	100.0
50	214.7	20.4	79.6
37.5	214.7	20.4	79.6
25	357.4	34.0	66.0
19	367.3	34.9	65.1
12.5	375.3	35.7	64.3
9.5	417.4	39.7	60.3
6.3	437.4	41.6	58.4
4.75	475.5	45.2	54.8
2.36	502.2	47.7	52.3
2	507.3	48.2	51.8
1.18	512.3	48.7	51.3
0.85	521.1	49.5	50.5
0.6	530.6	50.4	49.6
0.425	539.4	51.3	48.7
0.3	566.9	53.9	46.1
0.15	574.3	54.6	45.4
0.075	587.2	55.8	44.2

**16.2 Atterberg Limit Test**

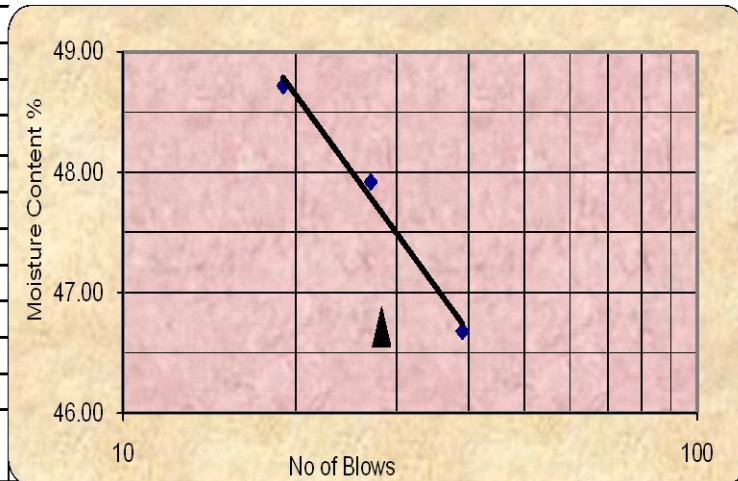
TEST METHOD : AASHTO T89 - T91

Sample Code-AFRAWS 16

Depth of Sampling:-110cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	39	27	19			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	45.00	38.4	41.66		24.5	23.51
Wt. tare + dry soil	g	36.21	30.8	32.91		22.8	21.87
Wt. water	g	8.79	7.61	8.75		1.77	1.64
Wt. of tare	g	17.4	14.9	14.95		15.9	15.65
Wt. of dry soil	g	18.83	15.88	17.96		6.84	6.22
No. of blows	N	39	27	19			
Moisture content	%	46.68	47.92	48.72		25.88	26.37

LIQUID LIMIT (LL%)=48, PLASTIC LIMIT (PL %)=26, PLASTICITY INDEX (P.I.)=LL-PL=22



16.3 Modified Proctor Test

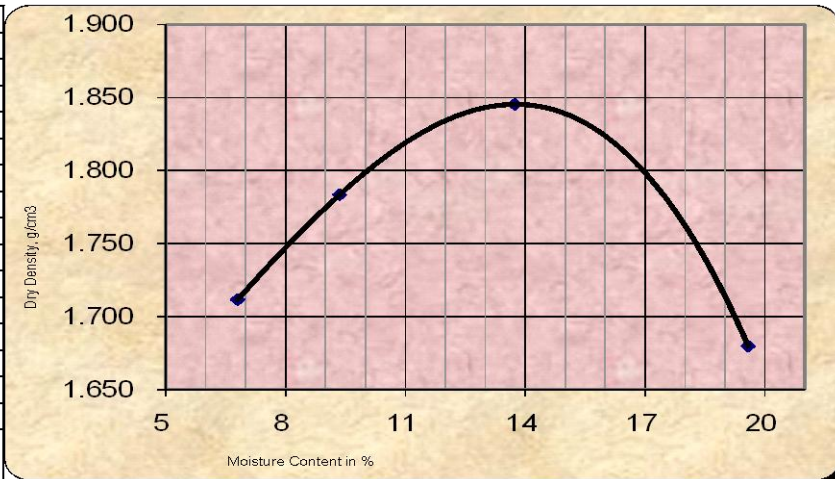
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-AFRAWS16

Depth of Sampling:-110cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4700	4815	4955	4870
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1720	1835	1975	1890
E	Volume of Mold	cu.cm.	941	941	941	941
F	Wet Density	gr/cu.cm.	1.83	1.95	2.10	2.01
G	Container	No.	T	T	A8	C4
H	Wt. Cont + Wet soil	grams	329.20	247.72	299.04	259.14
I	Wt. Cont + Dry soil	grams	311.45	230.77	266.82	225.04
J	Weight of Water	grams	17.75	16.95	32.22	34.10
K	Weight of Container	grams	50.23	49.38	32.26	50.86
L	Weight of Dry Soil	grams	261.22	181.39	234.56	174.18
M	Moisture Content	%	6.8	9.3	13.7	19.6
N	Dry Density	gr/cu.cm.	1.712	1.783	1.845	1.680

Maximum Dry Density(MDD)=1.850, Optimum Moisture Content(OMC)=14%

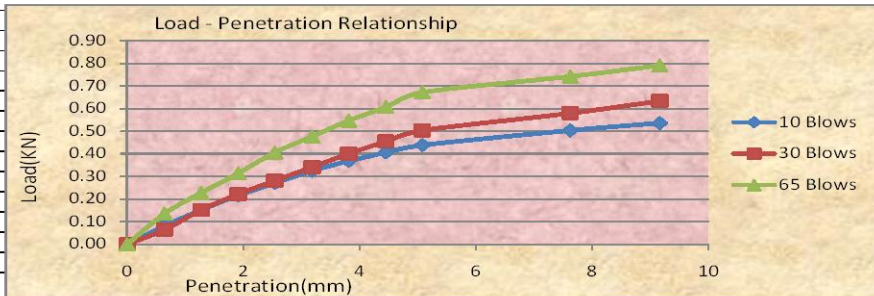
**16.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-AFRAWS16

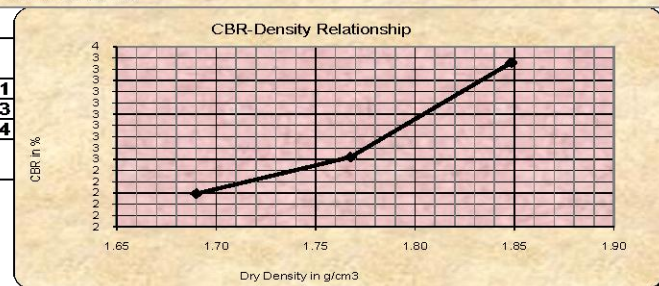
Depth of Sampling:-110cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	15	0.08	12	0.07	25	0.14
1.27	28	0.15	28	0.15	42	0.23
1.91	40	0.22	41	0.22	58	0.31
2.54	50	0.27	52	0.28	75	0.41
3.18	60	0.33	63	0.34	88	0.48
3.81	68	0.37	74	0.40	101	0.55
4.45	75	0.41	84	0.46	112	0.61
5.08	81	0.44	93	0.50	124	0.67
7.62	93	0.50	107	0.58	137	0.74
9.16	99	0.54	117	0.63	146	0.79



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.69005121	0.27	0.44	13.2	20	2.05303	2.1951	2.1951
30	1.76751604	0.28	0.50	13.2	20	2.135152	2.5203	2.5203
65	1.84837114	0.41	0.67	13.2	20	3.079545	3.3604	3.3604

CBR at 95% MDD i.e 1.7575 gm/cc and at OMC of 14 % is 3 %



17.1 Grain Size Analysis

TEST METHOD : AASHTO T - 27

Sample Code-AFRNMS 17

Depth of Sampling:-150cm

Weight Before Washing =380.5gm, Weight After Washing=110.2am

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
25	0.0	0.0	100.0
19	12.7	3.3	96.7
12.5	27.1	7.1	92.9
9.5	34.7	9.1	90.9
6.3	41.0	10.8	89.2
4.75	45.0	11.8	88.2
2.36	55.0	14.5	85.5
2	55.3	14.5	85.5
1.18	55.6	14.6	85.4
0.85	55.8	14.7	85.3
0.6	55.9	14.7	85.3
0.425	56.1	14.7	85.3
0.3	58.7	15.4	84.6
0.15	76.0	20.0	80.0
0.075	110.2	29.0	71.0

**17.2 Atterberg Limit Test**

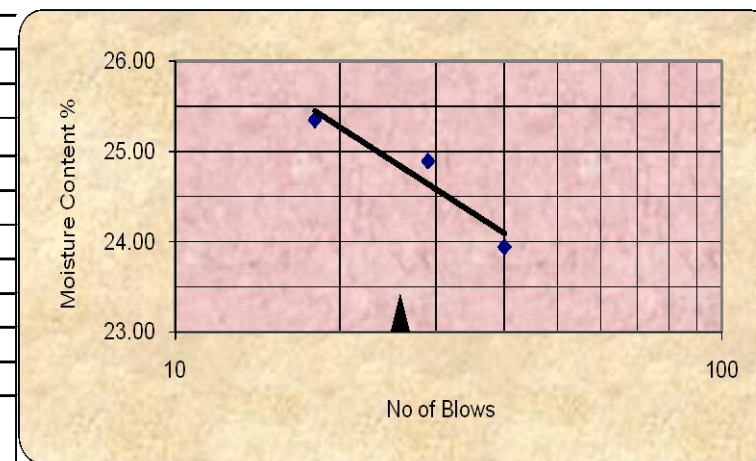
TEST METHOD : AASHTO T89 - T91

Sample Code-AFRNMS 17

Depth of Sampling:-150cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	40	29	18			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	43.06	43.7	44.95		25.7	25.09
Wt tare + dry soil	g	38.02	38	39.31		24.4	23.76
Wt. water	g	5.04	5.7	5.64		1.27	1.33
Wt. of tare	g	17	15.1	17.06		17.7	16.95
Wt. of dry soil	g	21.05	22.90	22.25		6.65	6.81
No. of blows	N	40	29	18			
Moisture content	%	23.94	24.89	25.35		19.10	19.53

LIQUID LIMIT (LL%)=25, PLASTIC LIMIT (PL %)=19, PLASTICITY INDEX (P.I.)=LL-PL=6



17.3 Modified Proctor Test

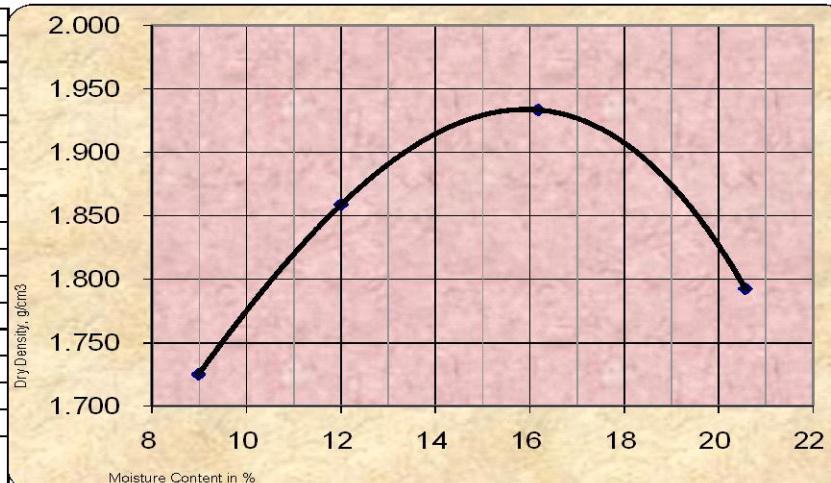
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-AFRNMS17

Depth of Sampling:-150cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4785	4975	5130	5050
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1771	1961	2116	2036
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.88	2.08	2.25	2.16
G	Container	No.	G14	A12	F43	F33
H	Wt. Cont + Wet soil	grams	301.82	274.05	254.22	299.03
I	Wt. Cont + Dry soil	grams	281.90	250.64	223.44	258.55
J	Weight of Water	grams	19.92	23.41	30.78	40.48
K	Weight of Container	grams	60.07	55.50	33.19	61.73
L	Weight of Dry Soil	grams	221.83	195.14	190.25	196.82
M	Moisture Content	%	9.0	12.0	16.2	20.6
N	Dry Density	gr/cu.cm.	1.725	1.859	1.933	1.793

Maximum Dry Density(MDD)=1.94, Optomum Moisture Content(OMC)=16.0%

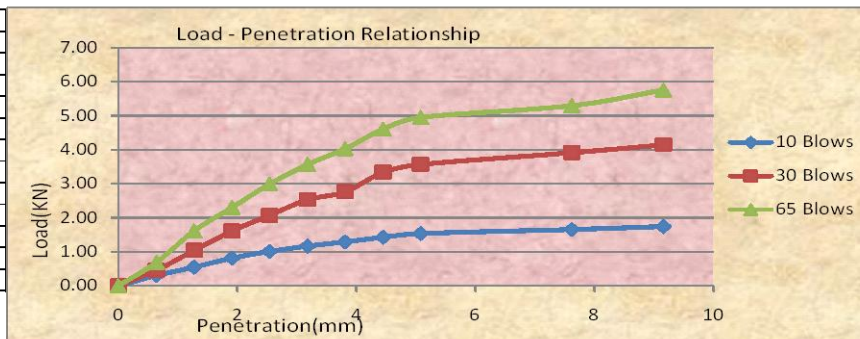
**17.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-AFRNMS17

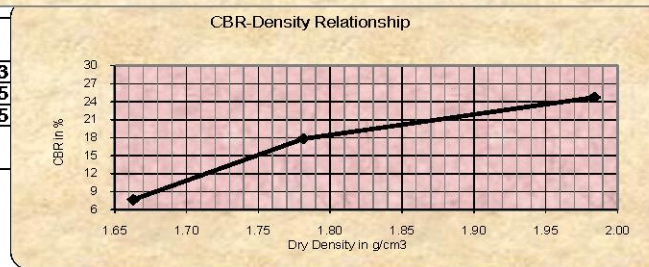
Depth of Sampling:-110cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	56	0.30	4	0.46	6	0.69
1.27	101	0.55	9	1.04	14	1.61
1.91	150	0.81	14	1.61	20	2.30
2.54	186	1.01	18	2.07	26	2.99
3.18	215	1.17	22	2.53	31	3.57
3.81	238	1.29	24	2.76	35	4.03
4.45	263	1.43	29	3.34	40	4.60
5.08	283	1.53	31	3.57	43	4.95
7.62	305	1.65	34	3.91	46	5.29
9.16	321	1.74	36	4.14	50	5.76



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.663033	1.01	1.53	13.2	20	7.637273	7.6693	7.6693
30	1.78144309	2.07	3.57	13.2	20	15.69545	17.8405	17.8405
65	1.98404849	2.99	4.95	13.2	20	22.67121	24.7465	24.7465

CBR at 95% MDD i.e 1.843 gm/cc and at OMC of 16 % is 20 %



18.1 Grain Size Analysis

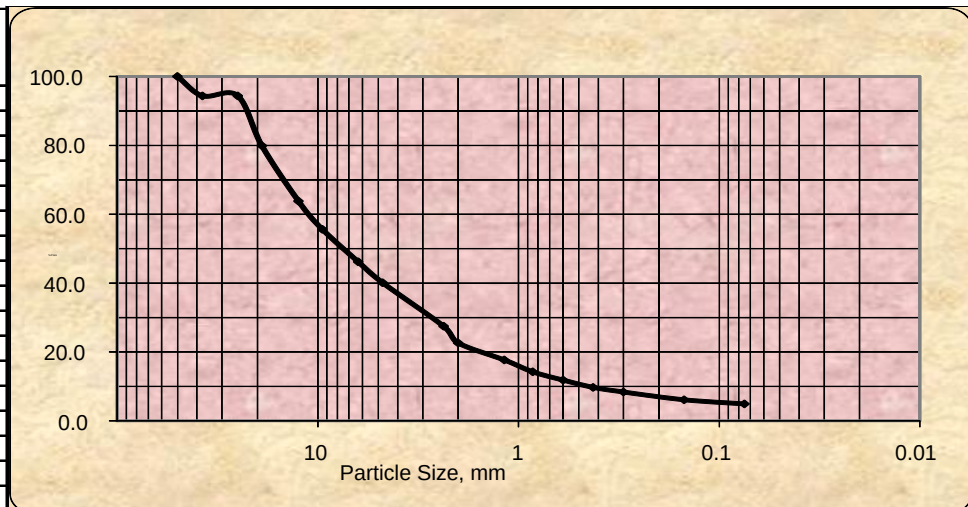
TEST METHOD : AASHTO T - 27

Sample Code-ORESMS 18

Depth of Sampling:-60cm

Weight Before Washing =1127.2gm, Weight After Washing=1071.8gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
50	0.0	0.0	100.0
37.5	63.1	5.6	94.4
25	63.1	5.6	94.4
19	226.4	20.1	79.9
12.5	407.7	36.2	63.8
9.5	500.1	44.4	55.6
6.3	606.4	53.8	46.2
4.75	675.2	59.9	40.1
2.36	817.6	72.5	27.5
2	872.5	77.4	22.6
1.18	927.4	82.3	17.7
0.85	966.7	85.8	14.2
0.6	993.9	88.2	11.8
0.425	1017.6	90.3	9.7
0.3	1032.6	91.6	8.4
0.15	1057.8	93.8	6.2
0.075	1071.8	95.1	4.9

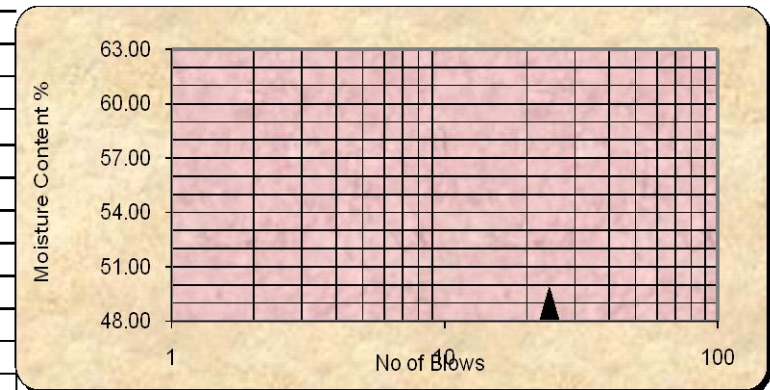
**18.2 Atterberg Limit Test**

TEST METHOD : AASHTO T89 - T91

Sample Code-AFRNMS 18

Depth of Sampling:-60cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N						
Tare	n°						
Wt. tare + wet soil	g		NP				
Wt. tare + dry soil	g						
Wt. water	g						
Wt. of tare	g						
Wt. of dry soil	g						
No. of blows	N						
Moisture content	%						



LIQUID LIMIT (LL%)=25, PLASTIC LIMIT (PL %)=19, PLASTICITY INDEX (P.I.)=LL-PL=6

18.3 Modified Proctor Test

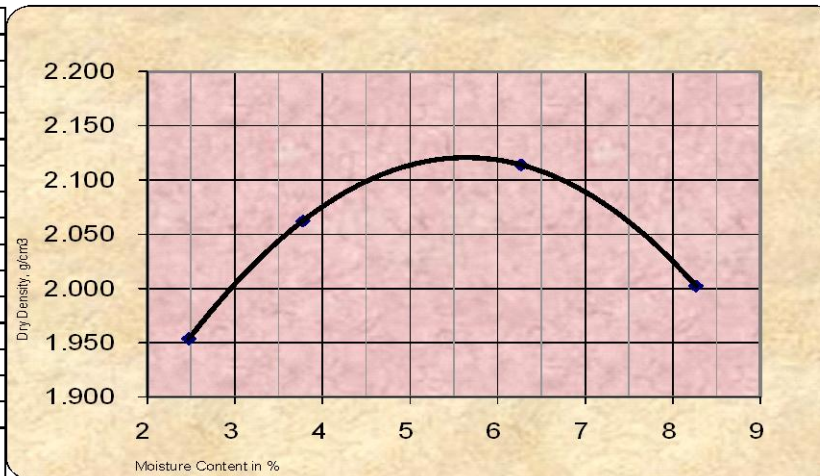
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-ORESMS18

Depth of Sampling:-60cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet	grams	4900	5030	5130	5056
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1886	2016	2116	2042
E	Volume of Mold	cu.cm	942	942	942	942
F	Wet Density	gr/cu.cm	2.00	2.14	2.25	2.17
G	Container	No.	G21	F25	P	G33
H	Wt. Cont + Wet soil	grams	330.51	365.94	352.84	382.35
I	Wt. Cont + Dry soil	grams	323.40	354.24	334.72	356.59
J	Weight of Water	grams	7.11	11.70	18.12	25.76
K	Weight of Container	grams	36.38	44.49	45.62	44.92
L	Weight of Dry Soil	grams	287.02	309.75	289.10	311.67
M	Moisture Content	%	2.5	3.8	6.3	8.3
N	Dry Density	gr/cu.cm	1.954	2.062	2.114	2.002

Maximum Dry Density(MDD)=2.122, Optimum Moisture Content(OMC)=6.0%

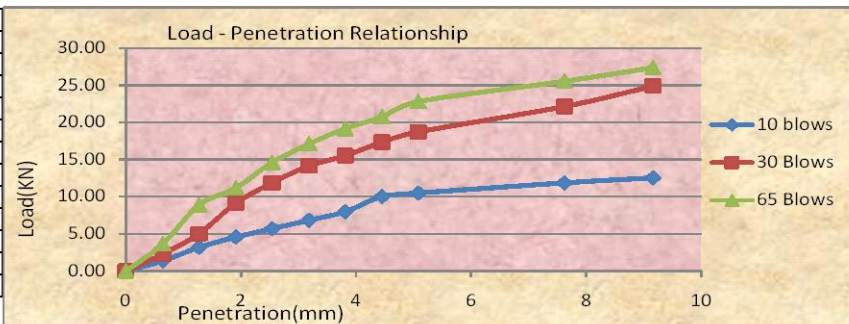
**18.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORESMS18

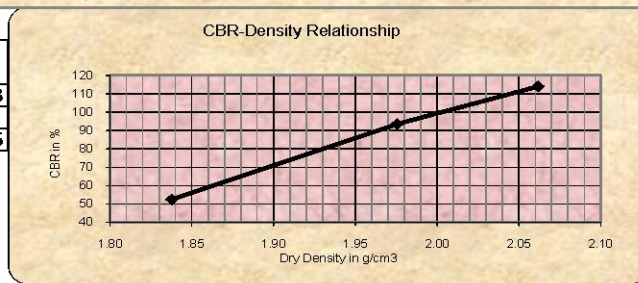
Depth of Sampling:-60cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	6	1.37	10	2.28	16	3.65
1.27	14	3.19	22	5.02	39	8.90
1.91	20	4.56	40	9.12	49	11.18
2.54	25	5.70	52	11.86	64	14.60
3.18	30	6.84	62	14.14	75	17.11
3.81	35	7.98	68	15.51	84	19.16
4.45	44	10.04	76	17.34	91	20.76
5.08	46	10.49	82	18.70	100	22.81
7.62	52	11.86	97	22.13	112	25.55
9.16	55	12.55	109	24.86	120	27.37



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.8378253	5.70	10.49	13.2	20	43.20076	52.463	52.463
30	1.97564497	11.86	18.70	13.2	20	89.85758	93.521	93.521
65	2.0617534	14.60	22.81	13.2	20	110.5939	114.05	114.05

CBR at 95% MDD i.e 2.016 gm/cc and at OMC of 6 % is 103 %



20.1 Grain Size Analysis

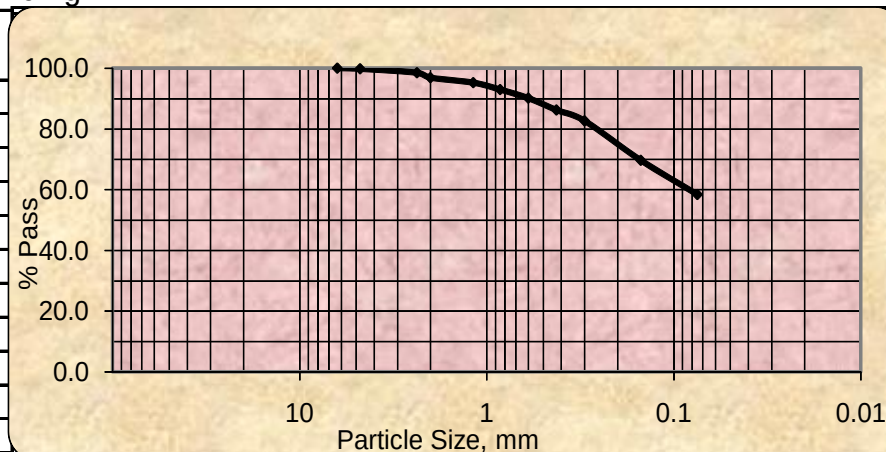
TEST METHOD : AASHTO T - 27

Sample Code-ORWASS 20

Depth of Sampling:-80cm

Weight Before Washing =184gm, Weight After Washing=110.2gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
6.3	0.0	0.0	100.0
4.75	0.4	0.2	99.8
2.36	2.8	1.5	98.5
2	5.8	3.2	96.8
1.18	8.8	4.8	95.2
0.85	12.9	7.0	93.0
0.6	18.0	9.8	90.2
0.425	25.2	13.7	86.3
0.3	31.8	17.3	82.7
0.15	55.7	30.3	69.7
0.075	76.4	41.5	58.5

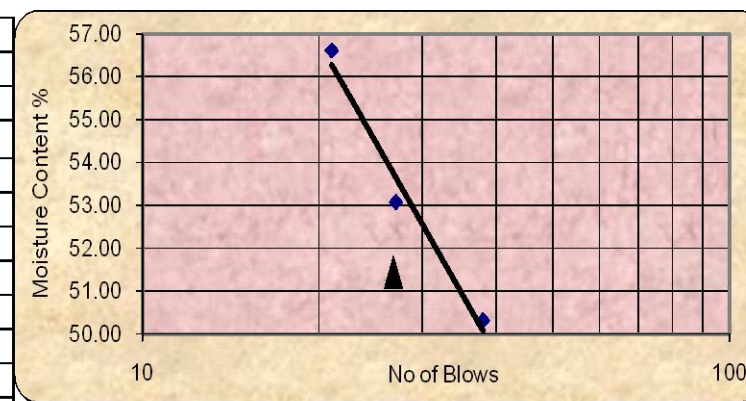
**20.2 Atterberg Limit Test**

TEST METHOD : AASHTO T89 - T91

Sample Code-ORWASS 20

Depth of Sampling:-80cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	38	27	21			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	32.31	32.02	32.96		23.8	21.41
Wt. tare + dry soil	g	26.79	26.76	26.67		22.4	19.73
Wt. water	g	5.52	5.26	6.29		1.48	1.68
Wt. of tare	g	15.82	16.85	15.56		17.7	14.35
Wt. of dry soil	g	10.97	9.91	11.11		4.63	5.38
No. of blows	N	38	27	21			
Moisture content	%	50.32	53.08	56.62		31.97	31.23



LIQUID LIMIT (LL%)=54, PLASTIC LIMIT (PL %)=32, PLASTICITY INDEX (P.I.)=LL-PL=22

20.3 Modified Proctor Test

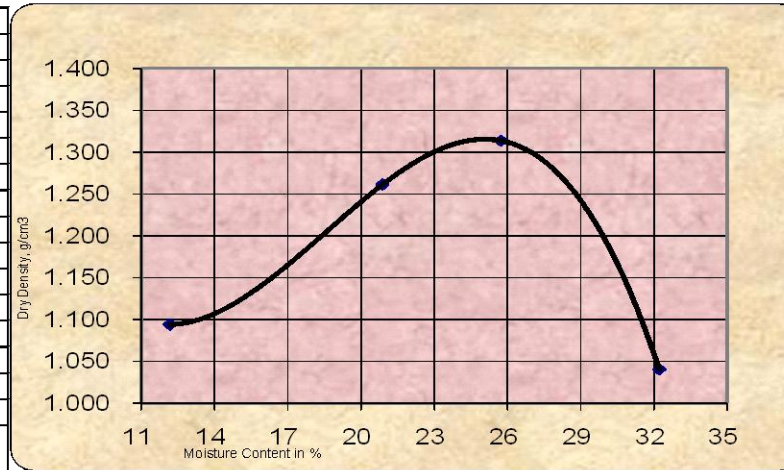
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-ORWASS#20

Depth of Sampling:-80cm

A	Mold	No.	1	2	3	4	5
B	Wt. of Mold + Wet Soil	grams	4170	4310	4450	4570	4500
C	Wt. of Mold	grams	3014	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1156	1296	1436	1556	1486
E	Volume of Mold	cu.cm	942	942	942	942	943
F	Wet Density	gr/cu.cm	1.23	1.38	1.52	1.65	1.58
G	Container	No.	G14	A12	F43	F33	F34
H	Wt. Cont + Wet soil	grams	197.81	186.46	180.11	210.58	194.58
I	Wt. Cont + Dry soil	grams	181.18	149.21	154.49	179.63	159.81
J	Weight of Water	grams	16.63	37.25	25.62	30.95	34.77
K	Weight of Container	grams	44.57	33.58	31.76	59.35	47.73
L	Weight of Dry Soil	grams	136.61	115.63	122.73	120.28	112.08
M	Moisture Content	%	12.2	32.2	20.9	25.7	31.0
N	Dry Density	gr/cu.cm	1.094	1.041	1.261	1.314	1.203

Maximum Dry Density(MDD)=1.325, Optimum Moisture Content(OMC)=25.0%

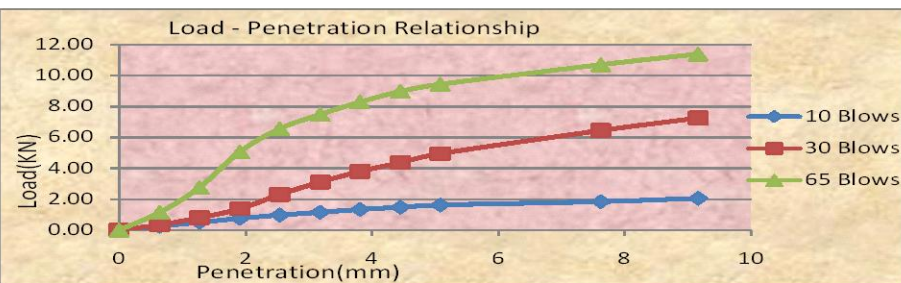
**20.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORWASS#20

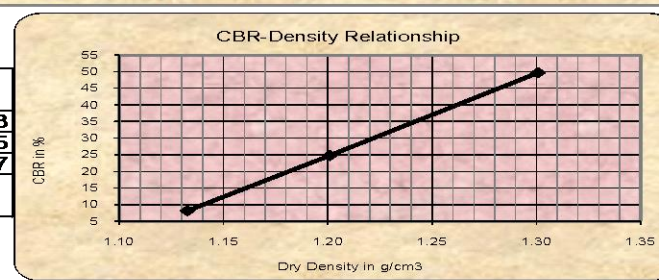
Depth of Sampling:-80cm

Penetration (mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	7	0.25	3	0.35	10	1.15
1.27	14	0.51	7	0.81	24	2.76
1.91	21	0.76	12	1.38	44	5.06
2.54	27	0.97	20	2.30	57	6.56
3.18	32	1.15	27	3.11	65	7.48
3.81	37	1.33	33	3.80	72	8.29
4.45	41	1.48	38	4.37	78	8.98
5.08	45	1.62	43	4.95	82	9.44
7.62	51	1.84	56	6.45	93	10.70
9.16	57	2.06	63	7.25	99	11.39



No Of Blow	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.1326	0.97	1.6236	13.2	20	7.38	8.118	8.118
30	1.2009	2.302	4.9493	13.2	20	17.44	24.7465	24.7465
65	1.3008	6.5607	9.4382	13.2	20	49.7	47.191	49.70227

CBR at 95% MDD i.e 1.2588 gm/cc and at OMC of 25 % is 39 %



21.1 Grain Size Analysis

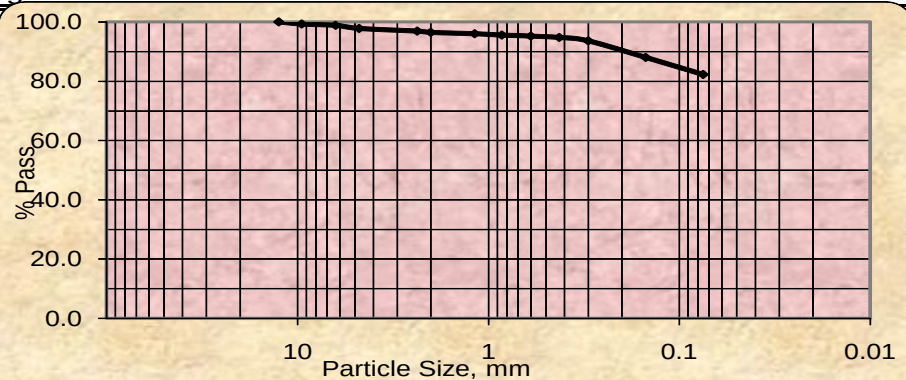
TEST METHOD : AASHTO T - 27

Sample Code-ORAZOS 21

Depth of Sampling:-80cm

Weight Before Washing =158gm, Weight After Washing=28gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
12.5	0.0	0.0	100.0
9.5	1.2	0.8	99.2
6.3	1.9	1.2	98.8
4.75	3.5	2.2	97.8
2.36	5.0	3.2	96.8
2	5.7	3.6	96.4
1.18	6.3	4.0	96.0
0.85	7.0	4.4	95.6
0.6	7.6	4.8	95.2
0.425	8.3	5.3	94.7
0.3	10.1	6.4	93.6
0.15	18.9	12.0	88.0
0.075	28.0	17.7	82.3

**21.2 Atterberg Limit Test**

TEST METHOD : AASHTO T89 - T91

Sample Code-ORAZOS 21

Depth of Sampling:-80cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	35	27	20			
Tare	n°	A44	E10	E87		E80	E46
Wt. tare + wet soil	g	30.25	29.8	34.68		26.9	23.35
Wt. tare + dry soil	g	24.86	24.4	29.34		25.1	21.6
Wt. water	g	5.39	5.44	5.34		1.81	1.75
Wt. of tare	g	15.11	15	20.37		19.8	15.99
Wt. of dry soil	g	9.75	9.42	8.97		5.28	5.61
No. of blows	N	35	27	20			
Moisture content	%	55.28	57.75	59.53		34.28	31.19

LIQUID LIMIT (LL%)=54, PLASTIC LIMIT (PL %)=32, PLASTICITY INDEX (P.I.)=LL-PL=22



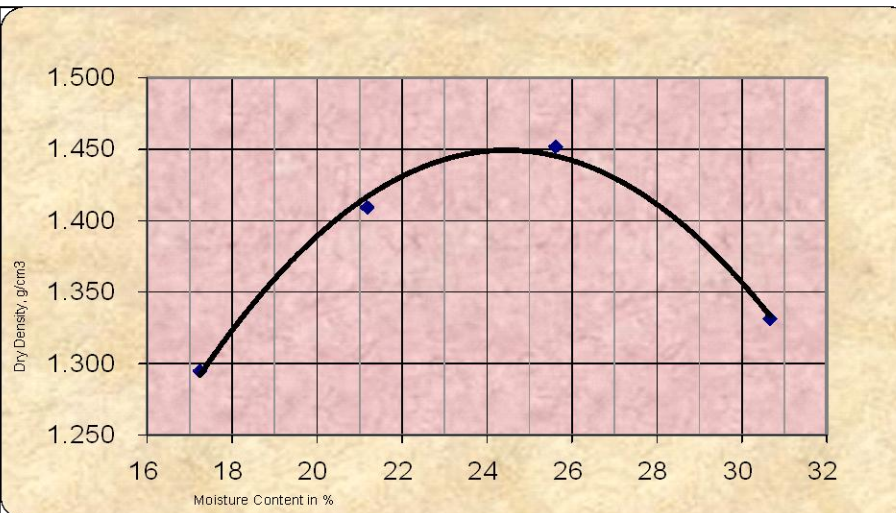
21.3 Modified Proctor Test**TEST METHOD : AASHTO T- 180 METHOD C**

Sample Code-ORAZOS#21

Depth of Sampling:-80cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4445	4625	4735	4655
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1439	1619	1729	1649
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.52	1.71	1.82	1.74
G	Container	No.	Y5	Y8	V	C10
H	Wt. Cont + Wet soil	grams	294.71	251.09	272.65	270.59
I	Wt. Cont + Dry soil	grams	257.90	215.05	226.35	217.54
J	Weight of Water	grams	36.81	36.04	46.30	53.05
K	Weight of Container	grams	44.39	44.92	45.62	44.51
L	Weight of Dry Soil	grams	213.51	170.13	180.73	173.03
M	Moisture Content	%	17.2	21.2	25.6	30.7
N	Dry Density	gr/cu.cm.	1.295	1.409	1.452	1.331

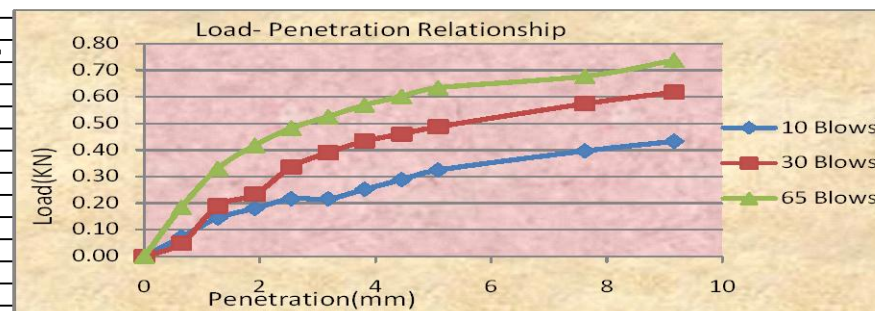
Maximum Dry Density(MDD)=1.450, Optimum Moisture Content(OMC)=24.0 %

**21.4 California Bearing Ration Test****TEST METHOD : AASHTO T- 193**

Sample Code-ORAZOS#21

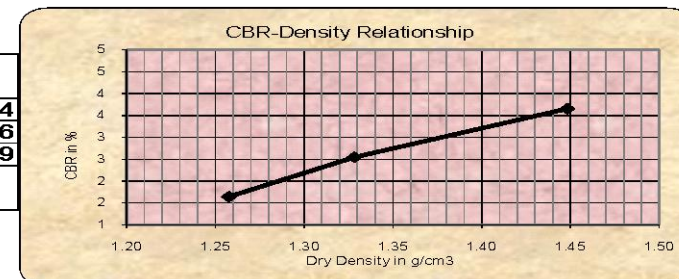
Depth of Sampling:-80cm

Penetration(mm)	10 Blows			30 Blows			65 Blows		
	Dial RDG	Load(KN)		Dial RDG	Load(KN)		Dial RDG	Load(KN)	
0	0	0.00		0	0.00		0	0.00	
0.64	2	0.07		9	0.05		34	0.18	
1.27	4	0.14		35	0.19		61	0.33	
1.91	5	0.18		43	0.23		77	0.42	
2.54	6	0.22		62	0.34		89	0.48	
3.18	6	0.22		72	0.39		97	0.53	
3.81	7	0.25		80	0.43		105	0.57	
4.45	8	0.29		85	0.46		111	0.60	
5.08	9	0.32		90	0.49		117	0.63	
7.62	11	0.40		106	0.57		125	0.68	
9.16	12	0.43		114	0.62		136	0.74	



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.25757	0.22	0.32472	13.2	20	1.64	1.624	1.64
30	1.328186	0.336	0.49	13.2	20	2.545758	2.439	2.54576
65	1.448184	0.4824	0.63414	13.2	20	3.654394	3.171	3.65439

CBR at 95% MDD i.e 1.3775 gm/cc and at OMC of 24 % is 3 %



22.1 Grain Size Analysis

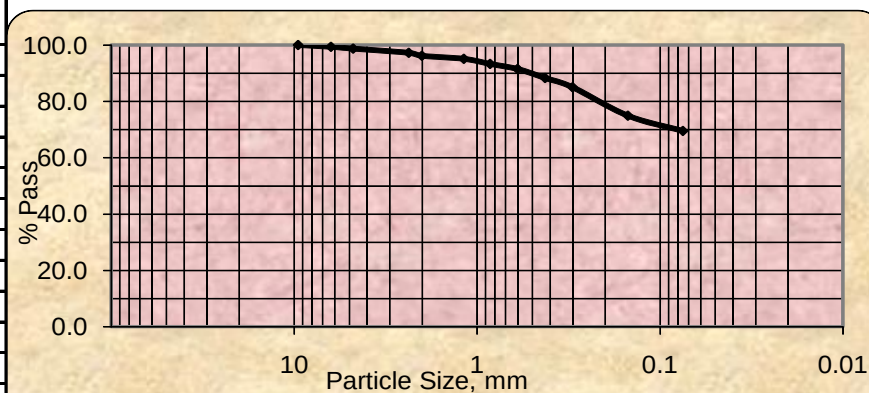
TEST METHOD : AASHTO T - 27

Sample Code-ORAZOS 22

Depth of Sampling:-80cm

Weight Before Washing =153gm, Weight After Washing=46.7gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
9.5	0.0	0.0	100.0
6.3	0.9	0.6	99.4
4.75	1.9	1.2	98.8
2.36	4.2	2.7	97.3
2	5.9	3.8	96.2
1.18	7.5	4.9	95.1
0.85	10.2	6.7	93.3
0.6	13.0	8.5	91.5
0.425	17.9	11.7	88.3
0.3	22.9	15.0	85.0
0.15	38.4	25.1	74.9
0.075	46.7	30.5	69.5

**22.2 Atterberg Limit Test**

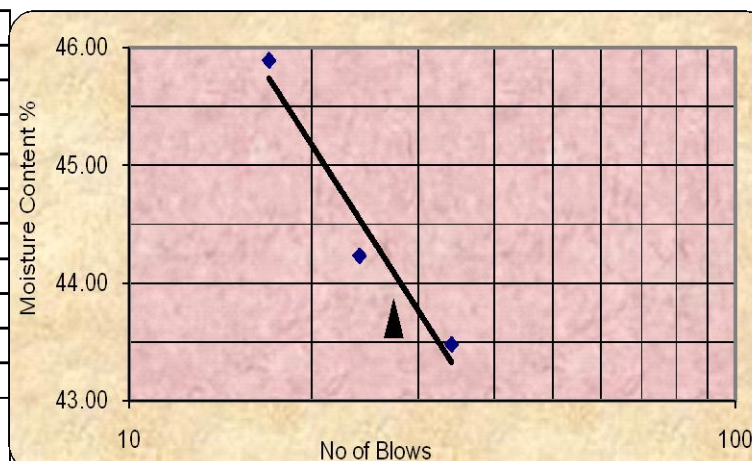
TEST METHOD : AASHTO T89 - T91

Sample Code-ORAZOS 22

Depth of Sampling:-80cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	34	24	17			
Tare	n°	A69	E63	A78		A22	E62
Wt. tare + wet soil	g	34.78	37.3	37.9		21.9	21.77
Wt. tare + dry soil	g	28.81	31.00	30.64		20.4	20.35
Wt. water	g	5.97	6.29	7.26		1.43	1.42
Wt. of tare	g	15.08	16.8	14.82		15.6	15.59
Wt. of dry soil	g	13.73	14.22	15.82		4.82	4.76
No. of blows	N	34	24	17			
Moisture content	%	43.48	44.23	45.89		29.67	29.83

LIQUID LIMIT (LL%)=44, PLASTIC LIMIT (PL %)=30, PLASTICITY INDEX (P.I.)=LL-PL=14



22.3 Modified Proctor Test

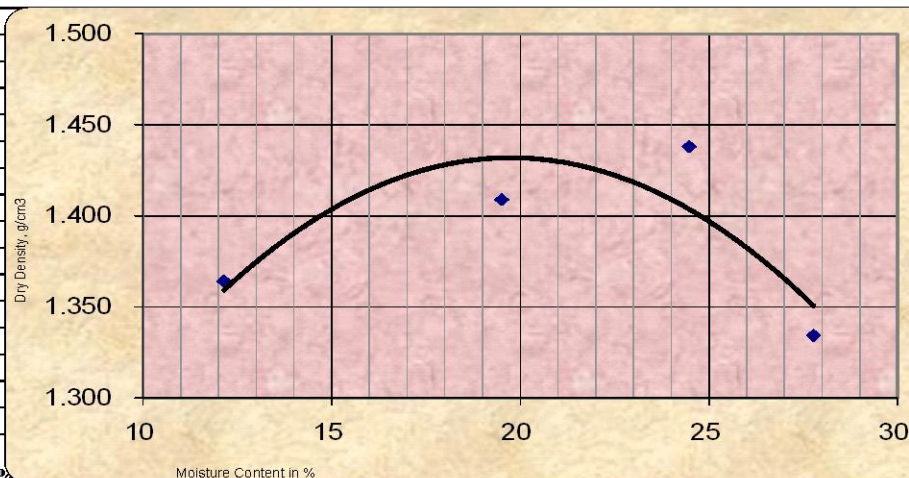
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-ORAZOS-22

Depth of Sampling:-80cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4455	4600	4700	4620
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1441	1586	1686	1606
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.53	1.68	1.79	1.70
G	Container	No.	E17	E4	F33	G13
H	Wt. Cont + Wet soil	grams	218.50	253.50	249.50	232.30
I	Wt. Cont + Dry soil	grams	199.97	219.76	215.45	188.88
J	Weight of Water	grams	18.53	33.74	34.05	43.42
K	Weight of Container	grams	47.41	46.79	76.33	32.54
L	Weight of Dry Soil	grams	152.56	172.97	139.12	156.34
M	Moisture Content	%	12.1	19.5	24.5	27.8
N	Dry Density	gr/cu.cm.	1.364	1.409	1.438	1.334

Maximum Dry Density(MDD)=1.430, Optimum Moisture Content(OMC)=20.0 %

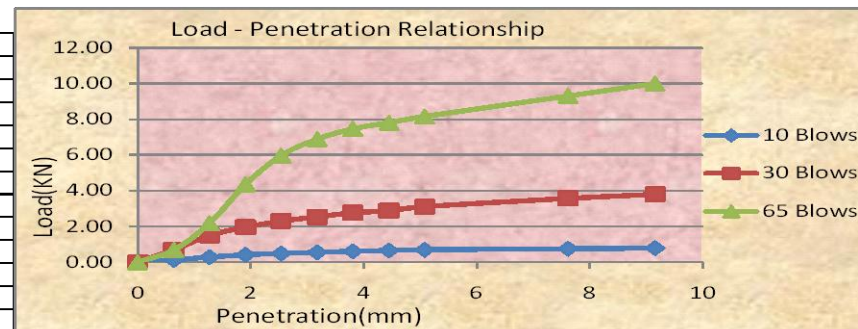
**22.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORAZOS#22

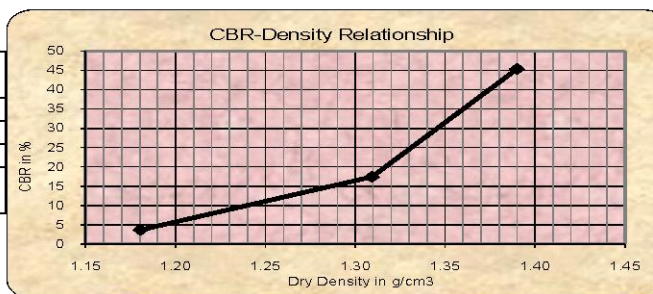
Depth of Sampling:-80cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	23	0.12	6	0.69	6	0.69
1.27	52	0.28	13	1.50	19	2.19
1.91	76	0.41	17	1.96	38	4.37
2.54	90	0.49	20	2.30	52	5.99
3.18	102	0.55	22	2.53	60	6.91
3.81	112	0.61	24	2.76	65	7.48
4.45	121	0.66	25	2.88	68	7.83
5.08	128	0.69	27	3.11	71	8.17
7.62	139	0.75	31	3.57	81	9.32
9.16	145	0.79	33	3.80	87	10.01



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.180528	0.49	0.69376	13.2	20	3.695455	3.469	3.69545
30	1.309305	2.302	3.11	13.2	20	17.43939	15.54	17.4394
65	1.389891	5.9852	8.1721	13.2	20	45.34242	40.86	45.3424

CBR at 95% MDD i.e 1.33585 gm/cc and at OMC of 20 % is 34 %

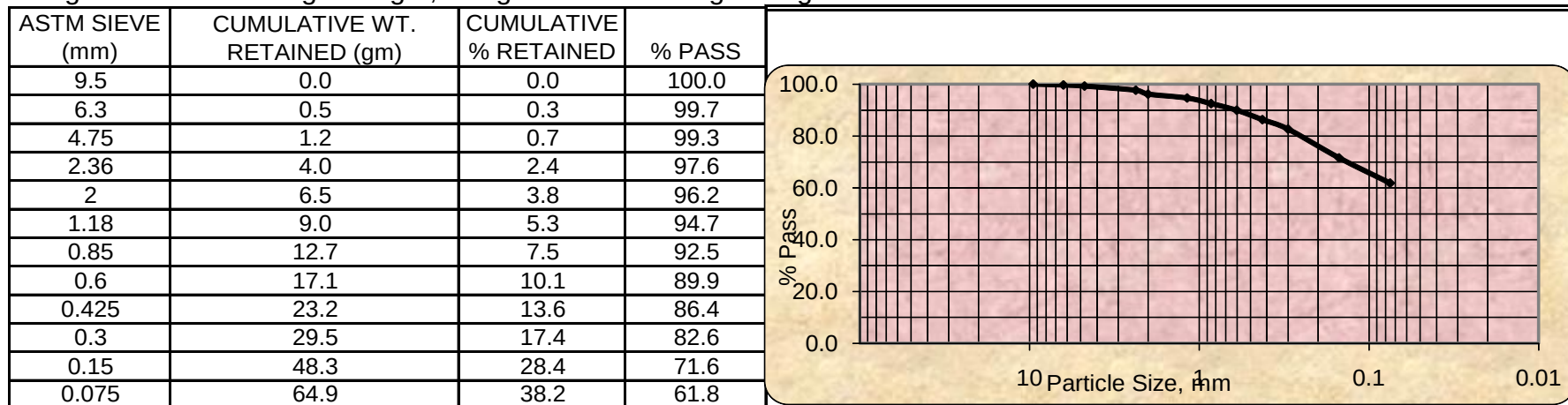


23.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27**

Sample Code-ORESA 23

Depth of Sampling:-120cm

Weight Before Washing =170gm, Weight After Washing=64.9gm

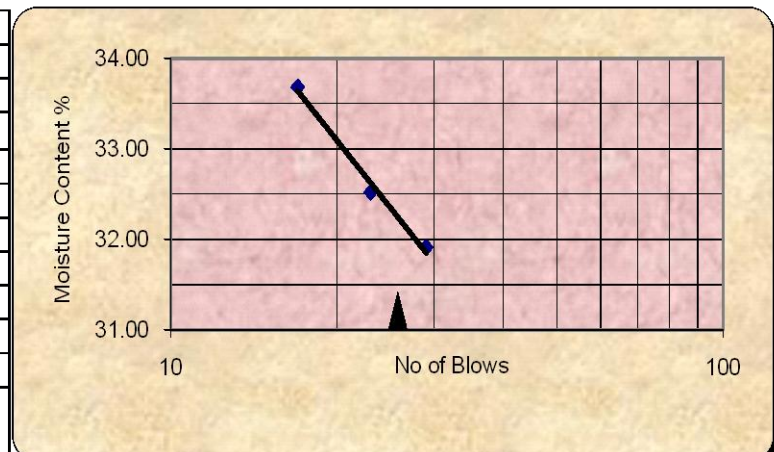
**23.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91**

Sample Code-ORESA 23

Depth of Sampling:-120cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	29	23	17			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	40.2	35.75	35.7		20.6	21.15
Wt. tare + dry soil	g	34.81	30.81	30.58		20.1	20.56
Wt. water	g	5.39	4.94	5.12		0.47	0.59
Wt. of tare	g	17.92	15.62	15.38		15.7	15.23
Wt. of dry soil	g	16.89	15.19	15.20		4.44	5.33
No. of blows	N	29	23	17			
Moisture content	%	31.91	32.52	33.68		10.59	11.07

LIQUID LIMIT (LL%)=32, PLASTIC LIMIT (PL %)=11, PLASTICITY INDEX (P.I.)=LL-PL=21



23.3 Modified Proctor Test

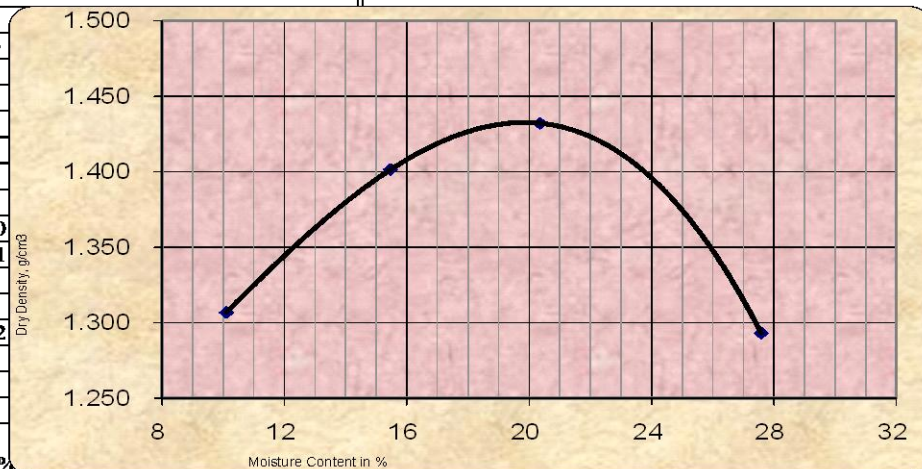
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-ORESA-23

Depth of Sampling:-120cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4370	4540	4640	4570
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1364	1534	1634	1564
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.44	1.62	1.72	1.65
G	Container	No.	M1	B2	Q4	F3
H	Wt. Cont + Wet soil	grams	207.11	229.70	289.40	314.00
I	Wt. Cont + Dry soil	grams	191.85	205.00	247.85	262.91
J	Weight of Water	grams	15.26	24.70	41.55	51.09
K	Weight of Container	grams	40.81	45.29	43.65	77.69
L	Weight of Dry Soil	grams	151.04	159.71	204.20	185.22
M	Moisture Content	%	10.1	15.5	20.3	27.6
N	Dry Density	gr/cu.cm.	1.307	1.401	1.432	1.293

Maximum Dry Density(MDD)=1.44, Optimum Moisture Content(OMC)=20.0 %

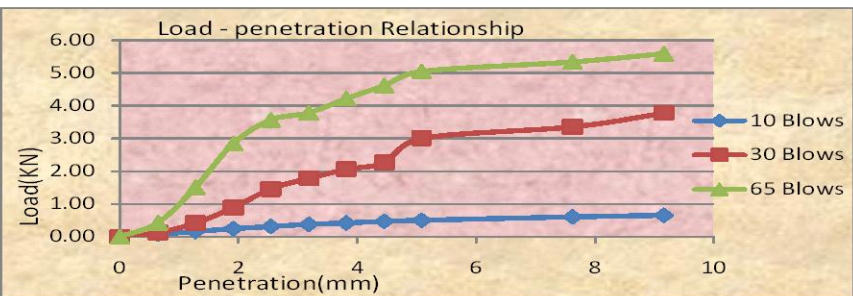
**23.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORESZAS#23

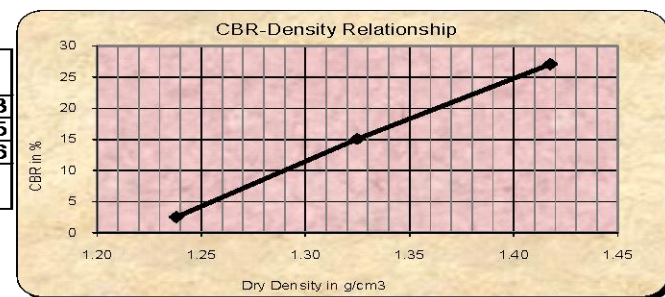
Depth of Sampling:-80cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	15	0.08	24	0.13	12	0.43
1.27	30	0.16	77	0.42	42	1.52
1.91	46	0.25	165	0.89	79	2.85
2.54	58	0.31	270	1.46	99	3.57
3.18	70	0.38	330	1.79	105	3.79
3.81	78	0.42	380	2.06	117	4.22
4.45	87	0.47	418	2.27	128	4.62
5.08	93	0.50	555	3.01	140	5.05
7.62	112	0.61	620	3.36	148	5.34
9.16	121	0.66	697	3.78	155	5.59



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.237791	0.31	0.50406	13.2	20	2.381515	2.52	2.5203
30	1.324843	1.4634	3.01	13.2	20	11.08636	15.04	15.0405
65	1.417558	3.5719	5.0512	13.2	20	27.06	25.26	27.06

CBR at 95% MDD i.e 1.368 gm/cc and at OMC of 20 % is 21 %



24.1 Grain Size Analysis

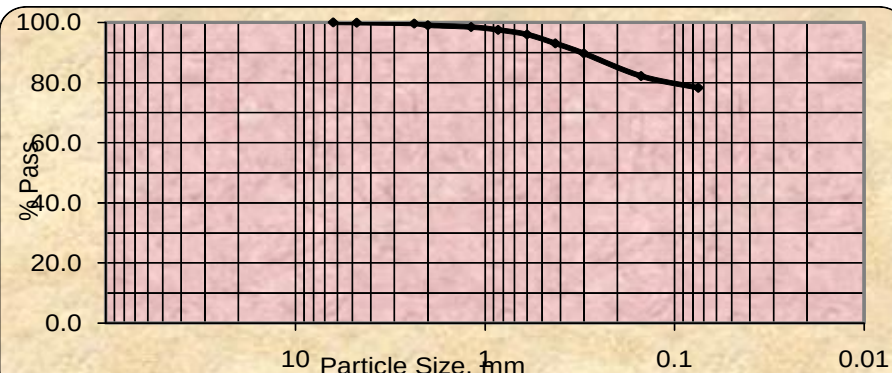
TEST METHOD : AASHTO T - 27

Sample Code-ORESAS 24

Depth of Sampling:-100cm

Weight Before Washing =174gm, Weight After Washing=37.8gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
6.3	0.0	0.0	100.0
4.75	0.1	0.1	99.9
2.36	0.6	0.3	99.7
2	1.7	0.9	99.1
1.18	2.7	1.6	98.4
0.85	4.3	2.5	97.5
0.6	7.0	4.0	96.0
0.425	12.1	7.0	93.0
0.3	17.9	10.3	89.7
0.15	31.0	17.8	82.2
0.075	37.8	21.7	78.3

**24.2 Atterberg Limit Test**

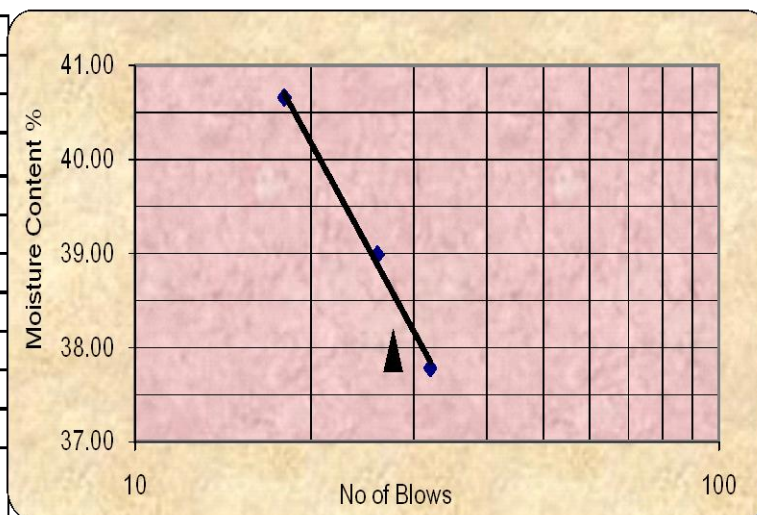
TEST METHOD : AASHTO T89 - T91

Sample Code-ORESAS 24

Depth of Sampling:-100cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	32	26	18			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	28.57	29.94	31.11		21.2	21.45
Wt. tare + dry soil	g	24.75	25.62	26.41		20	20.20
Wt. water	g	3.82	4.32	4.7		1.20	1.25
Wt. of tare	g	14.64	14.54	14.85		15.4	15.39
Wt. of dry soil	g	10.11	11.08	11.56		4.60	4.81
No. of blows	N	32	26	18			
Moisture content	%	37.78	38.99	40.66		26.09	25.99

LIQUID LIMIT (LL%)=39, PLASTIC LIMIT (PL %)=26, PLASTICITY INDEX (P.I.)=LL-PL=13



24.3 Modified Proctor Test

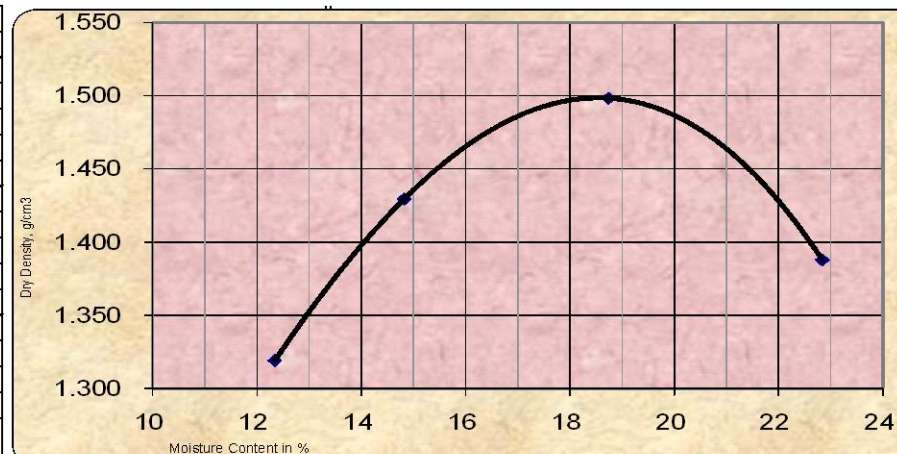
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-ORWAZSSS-24

Depth of Sampling:-100cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4410	4560	4690	4620
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1396	1546	1676	1606
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.48	1.64	1.78	1.70
G	Container	No.	G8	G8	P4	E7
H	Wt. Cont + Wet soil	grams	213.00	233.50	213.00	239.50
I	Wt. Cont + Dry soil	grams	196.00	210.22	184.71	201.39
J	Weight of Water	grams	17.00	23.28	28.29	38.11
K	Weight of Container	grams	58.29	53.13	33.77	34.51
L	Weight of Dry Soil	grams	137.71	157.09	150.94	166.88
M	Moisture Content	%	12.3	14.8	18.7	22.8
N	Dry Density	gr/cu.cm.	1.319	1.429	1.498	1.388

Maximum Dry Density(MDD)=1.50, Optimum Moisture Content(OMC)=19.0 %

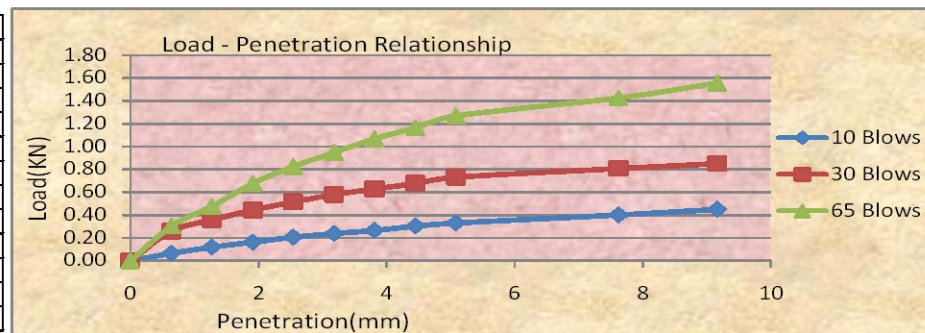
**24.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORESZA#24

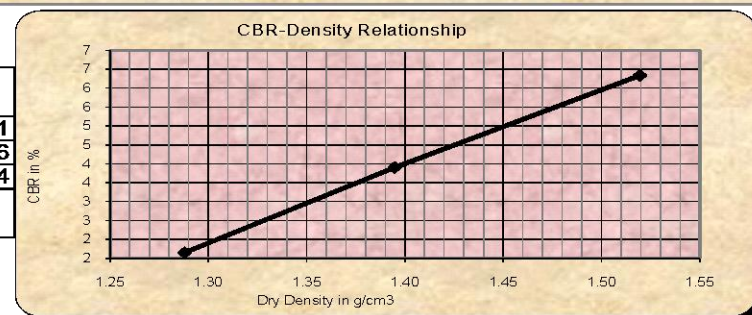
Depth of Sampling:-100cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	12	0.07	48	0.26	56	0.30
1.27	22	0.12	66	0.36	88	0.48
1.91	30	0.16	82	0.44	125	0.68
2.54	38	0.21	95	0.51	152	0.82
3.18	44	0.24	107	0.58	175	0.95
3.81	49	0.27	116	0.63	197	1.07
4.45	56	0.30	125	0.68	215	1.17
5.08	61	0.33	135	0.73	234	1.27
7.62	74	0.40	149	0.81	263	1.43
9.16	83	0.45	157	0.85	287	1.56



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.287933	0.21	0.33062	13.2	20	1.560303	1.653	1.6531
30	1.394635	0.5149	0.73	13.2	20	3.900758	3.659	3.90076
65	1.519476	0.8238	1.26828	13.2	20	6.241212	6.341	6.3414

CBR at 95% MDD i.e 1.425 gm/cc and at OMC of 19 % is 5 %



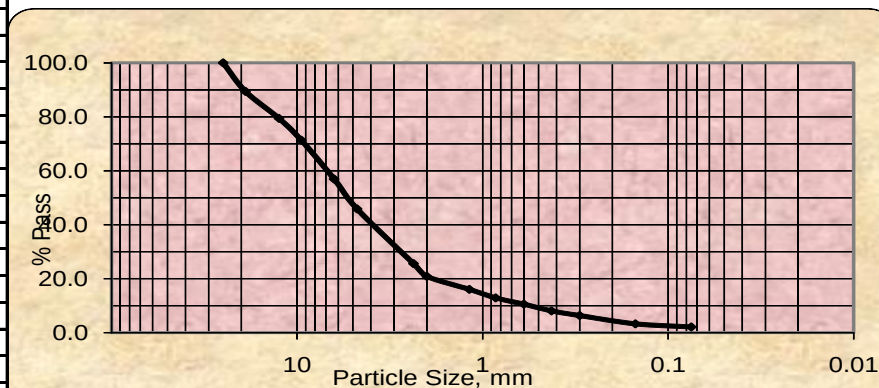
25.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27**

Sample Code-ORESOS 25

Depth of Sampling:-50cm

Weight Before Washing =448gm, Weight After Washing=438.7gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
25	0.0	0.0	100.0
19	47.5	10.6	89.4
12.5	92.4	20.6	79.4
9.5	128.5	28.7	71.3
6.3	193.2	43.1	56.9
4.75	242.6	54.2	45.8
2.36	333.5	74.4	25.6
2	354.8	79.2	20.8
1.18	376.0	83.9	16.1
0.85	390.2	87.1	12.9
0.6	400.9	89.5	10.5
0.425	411.7	91.9	8.1
0.3	419.5	93.6	6.4
0.15	433.3	96.7	3.3
0.075	438.7	97.9	2.1

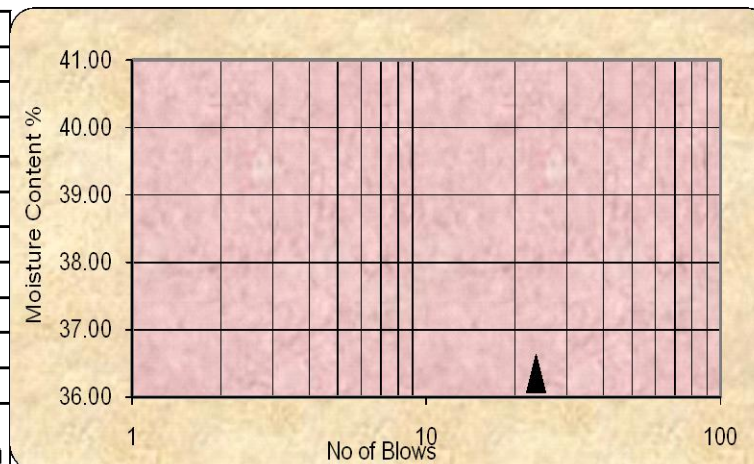
**25.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91**

Sample Code-ORESOS 25

Depth of Sampling:-50cm

		LIQUID LIMIT				PLASTIC LIMIT		
		1	2	3	4	1	2	
No. of blows	N							
Tare	n°							
Wt. tare + wet soil	g		NP					
Wt tare + dry soil	g							
Wt. water	g							
Wt. of tare	g							
Wt. of dry soil	g							
No. of blows	N							
Moisture content	%							

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL %)=NP, PLASTICITY INDEX (P.I)=LL-PL=0



25.3 Modified Proctor Test

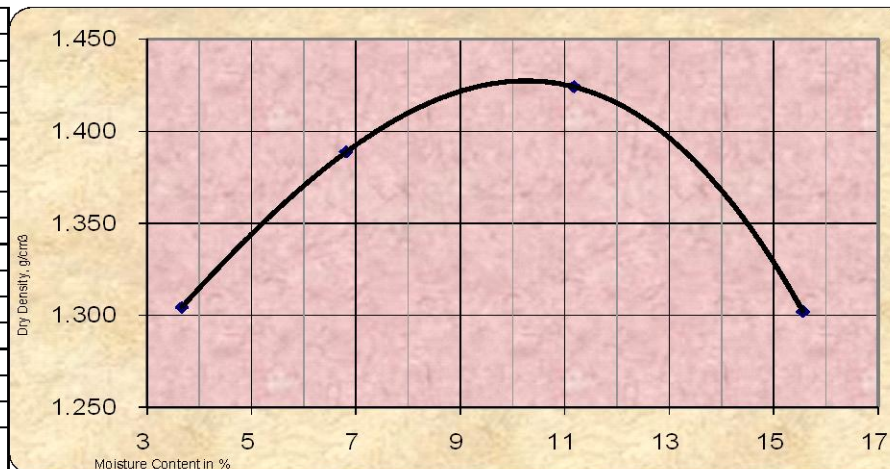
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-ORES0S-25

Depth of Sampling:-50cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4320	4450	4549	4471
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1340	1470	1569	1491
E	Volume of Mold	cu.cm.	991	991	991	991
F	Wet Density	gr/cu.cm.	1.35	1.48	1.58	1.50
G	Container	No.	X11	A9	G8	G24
H	Wt. Cont + Wet soil	grams	239.50	212.00	256.50	252.00
I	Wt. Cont + Dry soil	grams	232.39	201.12	235.19	223.85
J	Weight of Water	grams	7.11	10.88	21.31	28.15
K	Weight of Container	grams	38.29	41.42	44.50	42.95
L	Weight of Dry Soil	grams	194.10	159.70	190.69	180.90
M	Moisture Content	%	3.7	6.8	11.2	15.6
N	Dry Density	gr/cu.cm.	1.304	1.389	1.424	1.302

Maximum Dry Density(MDD)=1.448, Optimum Moisture Content(OMC)=10.0 %

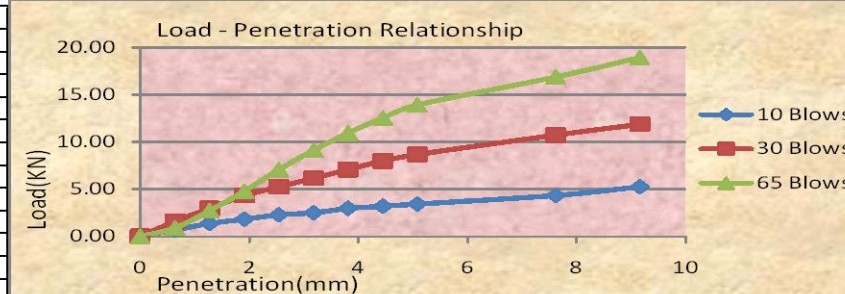
**25.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORESAS#25

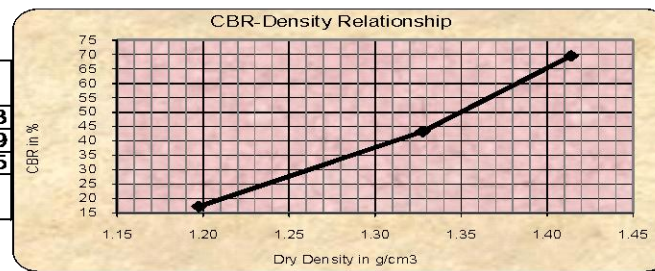
Depth of Sampling:-50cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	3	0.68	7	1.60	4	0.91
1.27	6	1.37	13	2.97	12	2.74
1.91	8	1.82	19	4.33	21	4.79
2.54	10	2.28	23	5.25	31	7.07
3.18	11	2.51	27	6.16	40	9.12
3.81	13	2.97	31	7.07	48	10.95
4.45	14	3.19	35	7.98	55	12.55
5.08	15	3.42	38	8.67	61	13.91
7.62	19	4.33	47	10.72	74	16.88
9.16	23	5.25	52	11.86	83	18.93



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.197469	2.28	3.4215	13.2	20	17.2803	17.11	17.2803
30	1.327728	5.2463	8.67	13.2	20	39.7447	43.34	43.339
65	1.413835	7.0711	13.9141	13.2	20	53.56894	69.57	69.5705

CBR at 95% MDD i.e 1.3756 gm/cc and at OMC of 10 % is 58 %



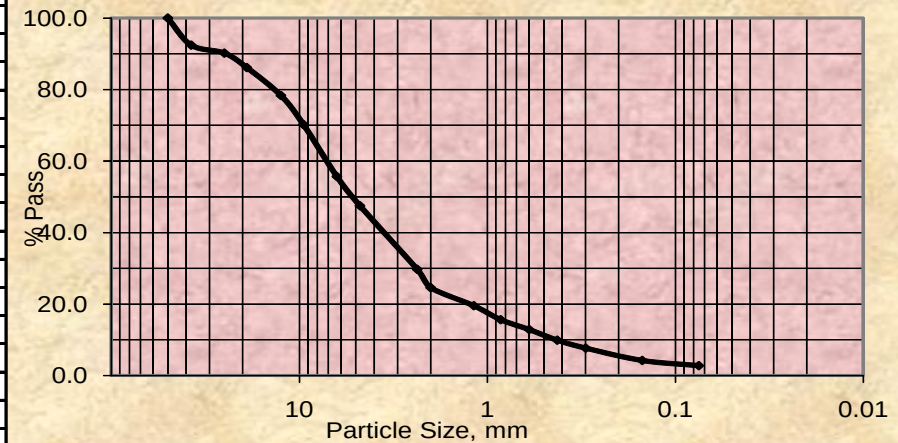
26.1 Grain Size Analysis**TEST METHOD : AASHTO T - 27**

Sample Code-ORESAS 26

Depth of Sampling:-50cm

Weight Before Washing =965gm, Weight After Washing=938.6gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
50	0.0	0.0	100.0
37.5	73.2	7.6	92.4
25	94.4	9.8	90.2
19	134.0	13.9	86.1
12.5	209.3	21.7	78.3
9.5	287.6	29.8	70.2
6.3	428.0	44.4	55.6
4.75	507.0	52.5	47.5
2.36	678.7	70.3	29.7
2	727.7	75.4	24.6
1.18	776.7	80.5	19.5
0.85	814.7	84.4	15.6
0.6	841.1	87.2	12.8
0.425	869.9	90.1	9.9
0.3	891.0	92.3	7.7
0.15	924.8	95.8	4.2
0.075	938.6	97.3	2.7

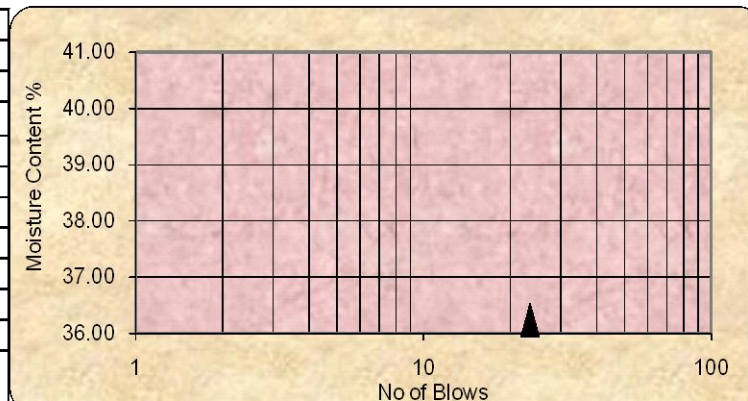
**26.2 Atterberg Limit Test****TEST METHOD : AASHTO T89 - T91**

Sample Code-ORESAS 26

Depth of Sampling:-50cm

		LIQUID LIMIT				PLASTIC LIMIT		
		1	2	3	4	1	2	
No. of blows	N							
Tare	n°							
Wt. tare + wet soil	g		NP					
Wt. tare + dry soil	g							
Wt. water	g							
Wt. of tare	g							
Wt. of dry soil	g							
No. of blows	N							
Moisture content	%							

LIQUID LIMIT (LL%)=NP.PLASTIC LIMIT (PL %)=NP.PLASTICITY INDEX (P.I.)=LL-PL=0



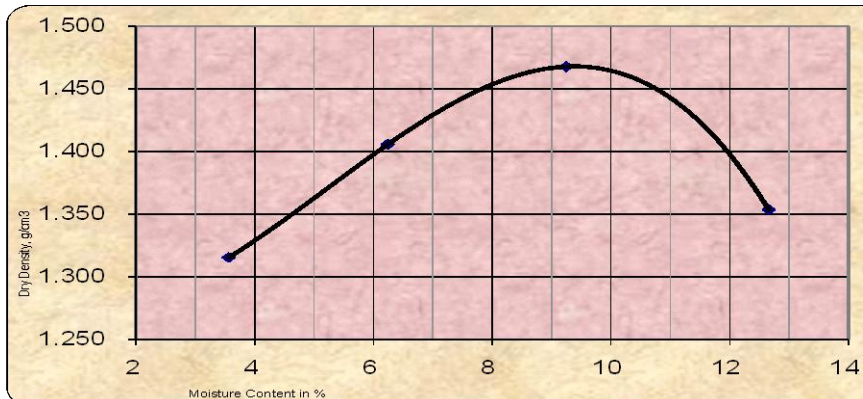
26.3 Modified Proctor Test**TEST METHOD : AASHTO T- 180 METHOD C**

Sample Code-ORESAS-26

Depth of Sampling:-50cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4330	4460	4569	4491
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1350	1480	1589	1511
E	Volume of Mold	cu.cm	991	991	991	991
F	Wet Density	gr/cu.cm	1.36	1.49	1.60	1.52
G	Container	No.	L6	A1	A8	A21
H	Wt. Cont + Wet soil	grams	203.00	251.50	232.50	291.50
I	Wt. Cont + Dry soil	grams	198.02	238.46	215.51	262.17
J	Weight of Water	grams	4.98	13.04	16.99	29.33
K	Weight of Container	grams	58.16	29.50	31.68	30.42
L	Weight of Dry Soil	grams	139.86	208.96	183.83	231.75
M	Moisture Content	%	3.6	6.2	9.2	12.7
N	Dry Density	gr/cu.cm	1.315	1.406	1.468	1.353

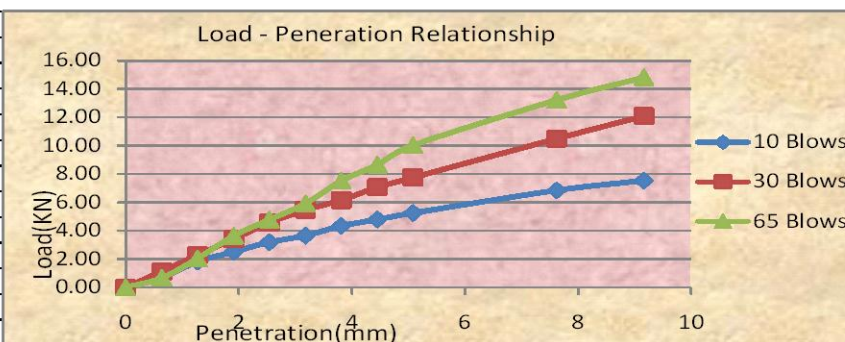
Maximum Dry Density(MDD)=1.454, Optimum Moisture Content(OMC)=9.0%

**26.4 California Bearing Ration Test****TEST METHOD : AASHTO T- 193**

Sample Code-ORESAS#26

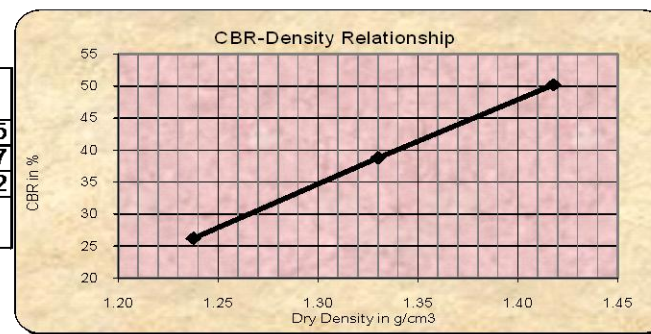
Depth of Sampling:-50cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	3	0.68	5	1.14	3	0.68
1.27	8	1.82	10	2.28	9	2.05
1.91	11	2.51	15	3.42	16	3.65
2.54	14	3.19	20	4.56	21	4.79
3.18	16	3.65	24	5.47	26	5.93
3.81	19	4.33	27	6.16	33	7.53
4.45	21	4.79	31	7.07	38	8.67
5.08	23	5.25	34	7.76	44	10.04
7.62	30	6.84	46	10.49	58	13.23
9.16	33	7.53	53	12.09	65	14.83



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.237655	3.19	5.2463	13.2	20	24.19242	26.23	26.2315
30	1.329952	4.562	7.76	13.2	20	34.56061	38.78	38.777
65	1.417875	4.7901	10.0364	13.2	20	36.28864	50.18	50.182

CBR at 95% MDD i.e 1.3873 gm/cc and at OMC of 9 % is 45 %



27.1 Grain Size Analysis

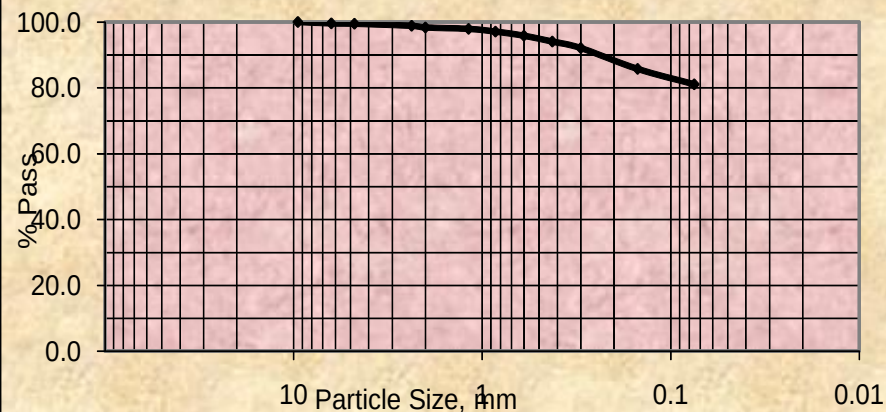
TEST METHOD : AASHTO T - 27

Sample Code-ORAZGS 27

Depth of Sampling:-70cm

Weight Before Washing =168gm, Weight After Washing=31.7gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
9.5	0.0	0.0	100.0
6.3	0.7	0.4	99.6
4.75	0.9	0.5	99.5
2.36	2.0	1.2	98.8
2	2.8	1.6	98.4
1.18	3.5	2.1	97.9
0.85	4.9	2.9	97.1
0.6	7.0	4.2	95.8
0.425	10.0	6.0	94.0
0.3	13.3	7.9	92.1
0.15	24.0	14.3	85.7
0.075	31.7	18.9	81.1

**27.2 Atterberg Limit Test**

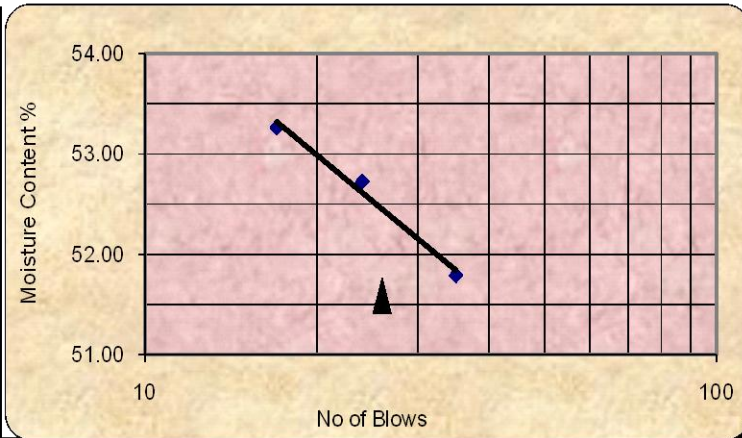
TEST METHOD : AASHTO T89 - T91

Sample Code-ORAZGS 27

Depth of Sampling:-70cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	35	24	17			
Tare	n°	E94	E65	A64		A46	A84
Wt. tare + wet soil	g	38.48	44.2	38.33		22.8	21.65
Wt. tare + dry soil	g	30.82	35.96	30.17		21.1	20.01
Wt. water	g	7.66	8.22	8.16		1.70	1.64
Wt. of tare	g	16.03	20.4	14.85		15.8	14.82
Wt. of dry soil	g	14.79	15.59	15.32		5.33	5.19
No. of blows	N	35	24	17			
Moisture content	%	51.79	52.73	53.26		31.89	31.60

LIQUID LIMIT (LL%)=52, PLASTIC LIMIT (PL %)=32, PLASTICITY INDEX (P.I.)=LL-PL=20



27.3 Modified Proctor Test

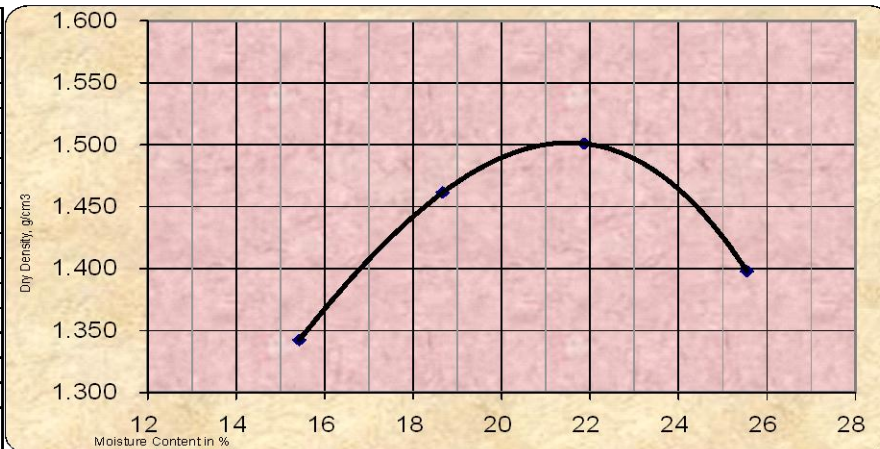
TEST METHOD : AASHTO T- 180 METHOD C

Sample Code-ORAZGS-27

Depth of Sampling:-70cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4475	4650	4740	4670
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1469	1644	1734	1664
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.55	1.73	1.83	1.76
G	Container	No.	E21	GH	C1	E2
H	Wt. Cont + Wet soil	grams	208.98	231.37	220.06	245.05
I	Wt. Cont + Dry soil	grams	188.33	203.36	189.72	207.31
J	Weight of Water	grams	20.65	28.01	30.34	37.74
K	Weight of Container	grams	54.43	53.28	50.94	59.58
L	Weight of Dry Soil	grams	133.90	150.08	138.78	147.73
M	Moisture Content	%	15.4	18.7	21.9	25.5
N	Dry Density	gr/cu.cm.	1.343	1.461	1.501	1.398

Maximum Dry Density(MDD)=1.508, Optimum Moisture Content(OMC)=22.0%

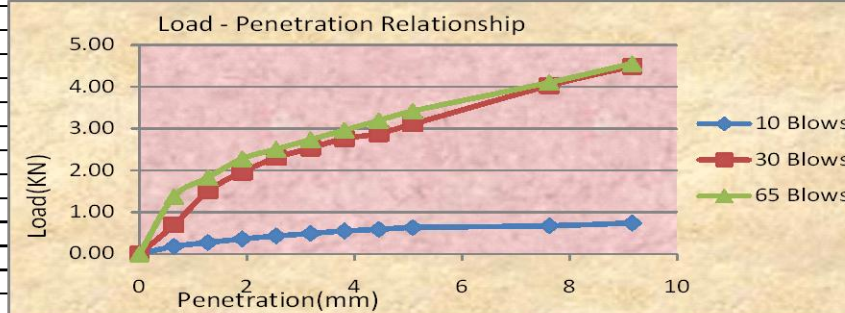
**27.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORAZGS#27

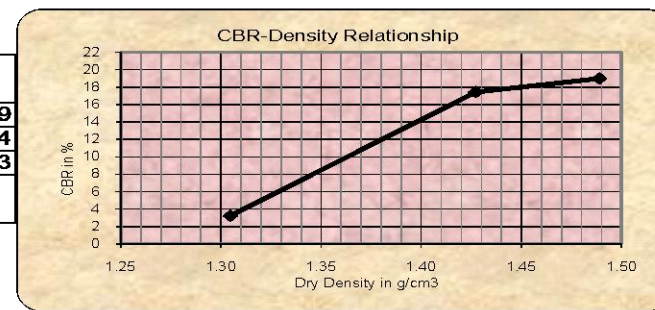
Depth of Sampling:-70cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	33	0.18	6	0.69	6	1.37
1.27	50	0.27	13	1.50	8	1.82
1.91	66	0.36	17	1.96	10	2.28
2.54	79	0.43	20	2.30	11	2.51
3.18	90	0.49	22	2.53	12	2.74
3.81	101	0.55	24	2.76	13	2.97
4.45	108	0.59	25	2.88	14	3.19
5.08	116	0.63	27	3.11	15	3.42
7.62	124	0.67	35	4.03	18	4.11
9.16	136	0.74	39	4.49	20	4.56



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.30461	0.43	0.62872	13.2	20	3.243788	3.144	3.24379
30	1.427277	2.302	3.11	13.2	20	17.43939	15.54	17.4394
65	1.489039	2.5091	3.4215	13.2	20	19.00833	17.11	19.0083

CBR at 95% MDD i.e 1.4326 gm/cc and at OMC of 22 % is 18 %



28.1 Grain Size Analysis

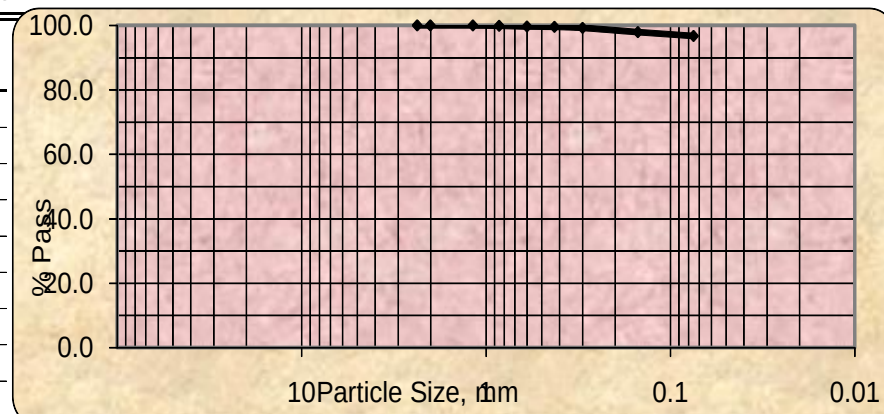
TEST METHOD : AASHTO T - 27

Sample Code-ORAZCHS 28

Depth of Sampling:-80cm

Weight Before Washing =155gm, Weight After Washing=5gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
2.36	0.0	0.0	100.0
2	0.0	0.0	100.0
1.18	0.0	0.0	100.0
0.85	0.1	0.1	99.9
0.6	0.4	0.3	99.7
0.425	0.6	0.4	99.6
0.3	1.1	0.7	99.3
0.15	3.1	2.0	98.0
0.075	5.0	3.2	96.8

**28.2 Atterberg Limit Test**

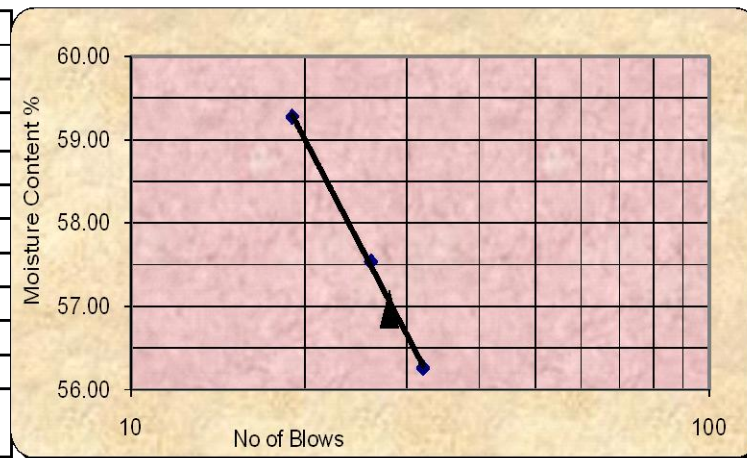
TEST METHOD : AASHTO T89 - T91

Sample Code-ORAZCHS 28

Depth of Sampling:-80cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	32	26	19			
Tare	n°	E94	E65	A64		A46	A84
Wt. tare + wet soil	g	33.56	30.3	32.68		23.4	21.71
Wt. tare + dry soil	g	27.54	24.70	27.28		21.7	20.05
Wt. water	g	6.02	5.61	5.40		1.66	1.66
Wt. of tare	g	16.84	15	18.17		16.5	14.95
Wt. of dry soil	g	10.70	9.75	9.11		5.27	5.10
No. of blows	N	32	26	19			
Moisture content	%	56.26	57.54	59.28		31.50	32.55

LIQUID LIMIT (LL%)=58, PLASTIC LIMIT (PL %)=32, PLASTICITY INDEX (P.I.)=LL-PL=26



28.3 Modified Proctor Test

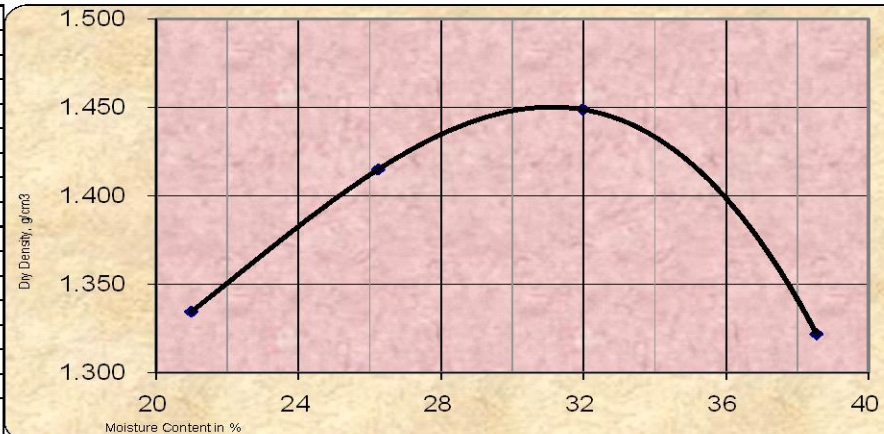
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-ORAZCHS-28

Depth of Sampling:-80cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4580	4750	4875	4795
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1600	1770	1895	1815
E	Volume of Mold	cu.cm.	991	991	991	991
F	Wet Density	gr/cu.cm.	1.61	1.79	1.91	1.83
G	Container	No.	G6	B2	P17	P4
H	Wt. Cont + Wet soil	grams	221.98	227.70	250.06	248.85
I	Wt. Cont + Dry soil	grams	192.82	187.40	201.61	190.15
J	Weight of Water	grams	29.16	40.30	48.45	58.70
K	Weight of Container	grams	53.86	33.73	50.07	37.82
L	Weight of Dry Soil	grams	138.96	153.67	151.54	152.33
M	Moisture Content	%	21.0	26.2	32.0	38.5
N	Dry Density	gr/cu.cm.	1.334	1.415	1.449	1.322

Maximum Dry Density(MDD)=1.450, Optimum Moisture Content(OMC)=31.0%

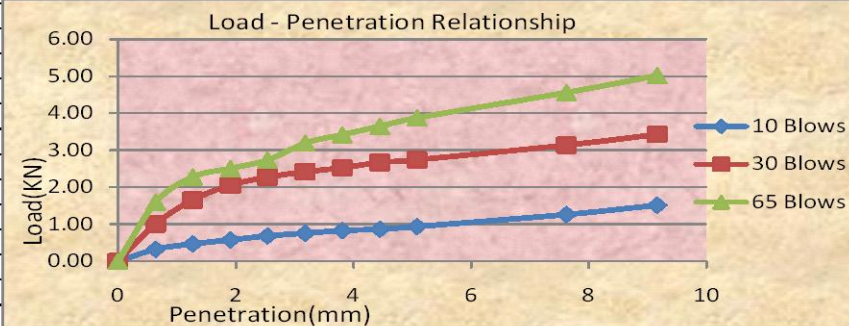
**28.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORAZCHS#28

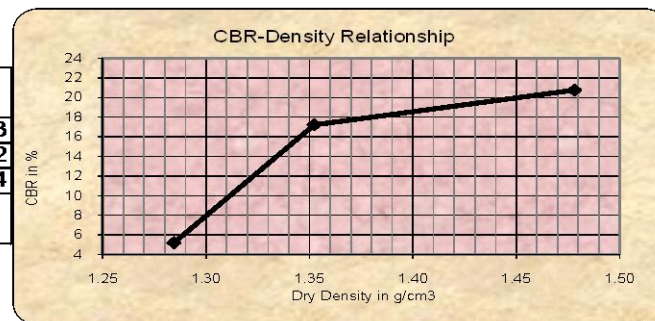
Depth of Sampling:-80cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	9	0.32	28	1.01	7	1.60
1.27	13	0.47	46	1.66	10	2.28
1.91	16	0.58	57	2.06	11	2.51
2.54	19	0.69	63	2.27	12	2.74
3.18	21	0.76	67	2.42	14	3.19
3.81	23	0.83	70	2.53	15	3.42
4.45	24	0.87	74	2.67	16	3.65
5.08	26	0.94	76	2.74	17	3.88
7.62	35	1.26	87	3.14	20	4.56
9.16	42	1.52	95	3.43	22	5.02



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.284325	0.69	0.93808	13.2	20	5.193333	4.69	5.19333
30	1.352241	2.273	2.74	13.2	20	17.22	13.71	17.22
65	1.478059	2.7372	3.8777	13.2	20	20.73636	19.39	20.7364

CBR at 95% MDD i.e 1.3775 gm/cc and at OMC of 31 % is 18 %



29.1 Grain Size Analysis

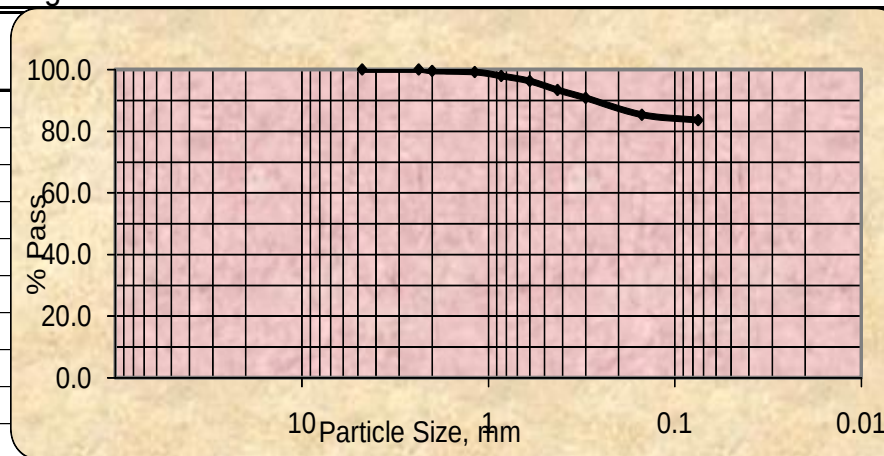
TEST METHOD : AASHTO T - 27

Sample Code-ORWAZFS 29

Depth of Sampling:-80cm

Weight Before Washing =178gm, Weight After Washing=29.3gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
4.75	0.0	0.0	100.0
2.36	0.1	0.1	99.9
2	0.8	0.4	99.6
1.18	1.5	0.8	99.2
0.85	3.7	2.1	97.9
0.6	6.7	3.8	96.2
0.425	11.8	6.6	93.4
0.3	16.5	9.3	90.7
0.15	26.1	14.7	85.3
0.075	29.3	16.5	83.5



29.2 Atterberg Limit Test

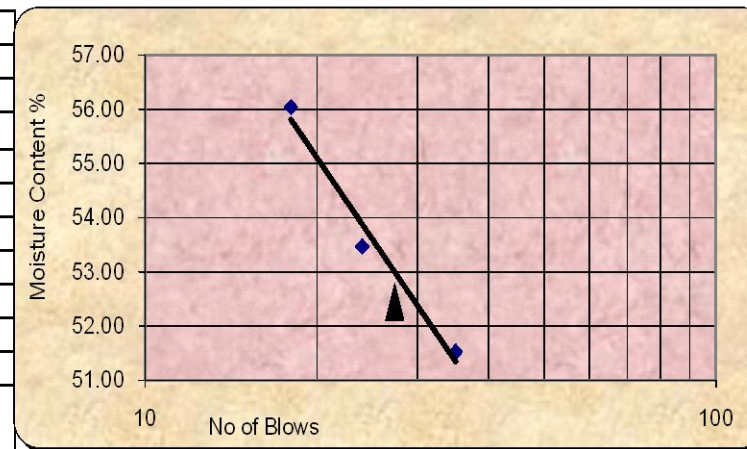
TEST METHOD : AASHTO T89 - T91

Sample Code-ORWAZFS 29

Depth of Sampling:-80cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	35	24	18			
Tare	n°	E94	E65	A64		A46	A84
Wt. tare + wet soil	g	41.97	41.2	41.9		21.1	21.14
Wt. tare + dry soil	g	33.01	31.94	33.32		19.7	19.65
Wt. water	g	8.96	9.25	8.58		1.42	1.49
Wt. of tare	g	15.62	14.6	18.01		15	14.54
Wt. of dry soil	g	17.39	17.30	15.31		4.77	5.11
No. of blows	N	35	24	18			
Moisture content	%	51.52	53.47	56.04		29.77	29.16

LIQUID LIMIT (LL%)=53, PLASTIC LIMIT (PL %)=29, PLASTICITY INDEX (P.I.)=LL-PL=24



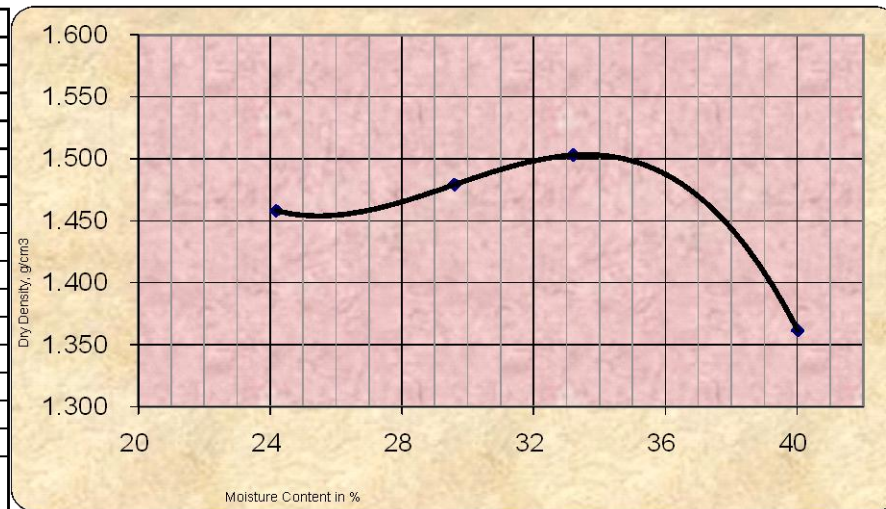
29.3 Modified Proctor Test**TEST METHOD : AASHTO T- 180 METHOD A**

Sample Code-ORKIAZES-29

Depth of Sampling:-80cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4720	4820	4900	4810
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1706	1806	1886	1796
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.81	1.92	2.00	1.91
G	Container	No.	G29	G21	F11	G18
H	Wt. Cont + Wet soil	grams	205.75	227.40	254.44	295.60
I	Wt. Cont + Dry soil	grams	172.25	193.05	208.87	233.70
J	Weight of Water	grams	33.50	34.35	45.57	61.90
K	Weight of Container	grams	33.77	76.99	71.63	79.00
L	Weight of Dry Soil	grams	138.48	116.06	137.24	154.70
M	Moisture Content	%	24.2	29.6	33.2	40.0
N	Dry Density	gr/cu.cm.	1.458	1.479	1.503	1.362

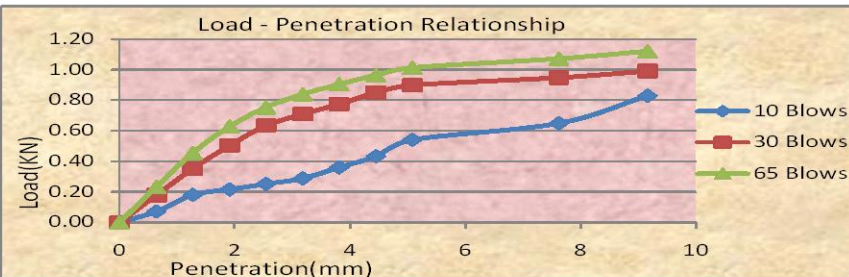
Maximum Dry Density(MDD)=1.505, Optimum Moisture Content(OMC)=34.0%

**29.4 California Bearing Ration Test****TEST METHOD : AASHTO T- 193**

Sample Code-ORWAZFS#29

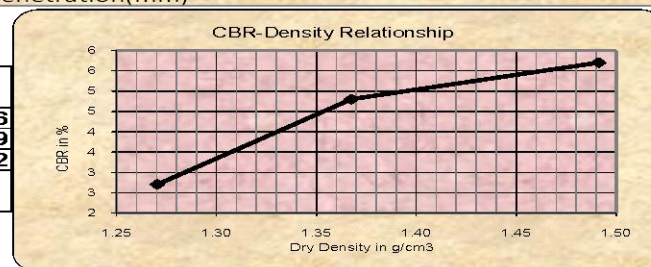
Depth of Sampling:-80cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	2	0.07	33	0.18	43	0.23
1.27	5	0.18	65	0.35	84	0.46
1.91	6	0.22	93	0.50	116	0.63
2.54	7	0.25	117	0.63	139	0.75
3.18	8	0.29	131	0.71	155	0.84
3.81	10	0.36	143	0.78	167	0.91
4.45	12	0.43	157	0.85	178	0.96
5.08	15	0.54	166	0.90	187	1.01
5.72	18	0.65	175	0.95	198	1.07
9.16	23	0.83	183	0.99	207	1.12



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.270348	0.25	0.5412	13.2	20	1.913333	2.706	2.706
30	1.367457	0.6341	0.90	13.2	20	4.804091	4.499	4.80409
65	1.491354	0.7534	1.01354	13.2	20	5.707424	5.068	5.70742

CBR at 95% MDD i.e 1.42975 gm/cc and at OMC of 34 % is 5 %



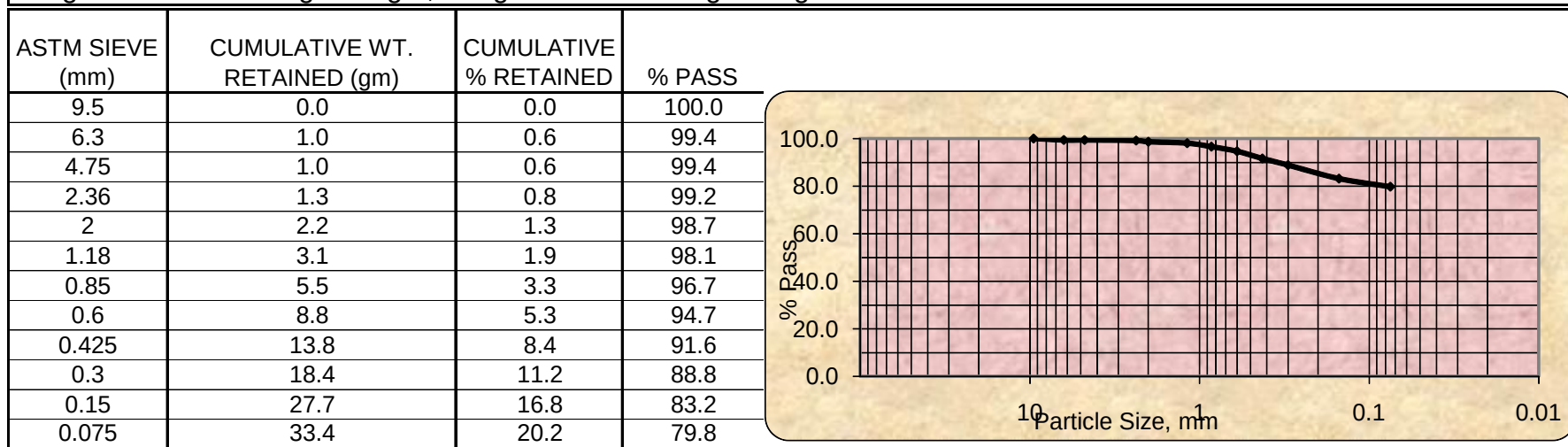
30.1 Grain Size Analysis

TEST METHOD : AASHTO T - 27

Sample Code-ORAWAZS 30

Depth of Sampling:-80cm

Weight Before Washing =165gm, Weight After Washing=33.4gm

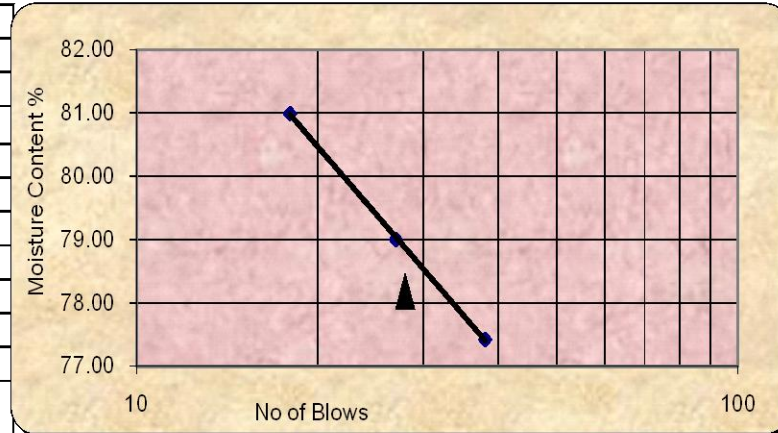
**30.2 Atterberg Limit Test**

TEST METHOD : AASHTO T89 - T91

Sample Code-ORAWAZSSS 30

Depth of Sampling:-80cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	38	27	18			
Tare	n°	E94	E65	A64		A46	A84
Wt. tare + wet soil	g	37.79	40.4	36.87		24	20.16
Wt. tare + dry soil	g	27.88	30.60	27.41		22.4	19.12
Wt. water	g	9.91	9.82	9.46		1.60	1.04
Wt. of tare	g	15.08	18.2	15.73		17.6	16.11
Wt. of dry soil	g	12.80	12.43	11.68		4.77	3.01
No. of blows	N	38	27	18			
Moisture content	%	77.42	79.00	80.99		33.54	34.55



LIQUID LIMIT (LL%)=79, PLASTIC LIMIT (PL %)=34, PLASTICITY INDEX (P.I.)=LL-PL=45

30.3 Modified Proctor Test

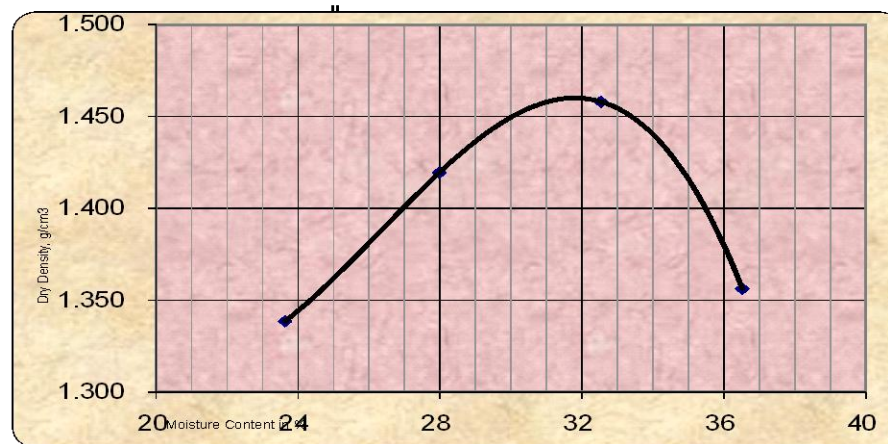
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-ORAWAZSS-30

Depth of Sampling:-80cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4620	4780	4895	4815
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1640	1800	1915	1835
E	Volume of Mold	cu.cm.	991	991	991	991
F	Wet Density	gr/cu.cm.	1.65	1.82	1.93	1.85
G	Container	No.	A9	F12	F63	F31
H	Wt. Cont + Wet soil	grams	232.84	212.16	188.74	238.33
I	Wt. Cont + Dry soil	grams	195.29	174.24	155.65	189.31
J	Weight of Water	grams	37.55	37.92	33.09	49.02
K	Weight of Container	grams	36.38	38.68	53.95	55.10
L	Weight of Dry Soil	grams	158.91	135.56	101.70	134.21
M	Moisture Content	%	23.6	28.0	32.5	36.5
N	Dry Density	gr/cu.cm.	1.339	1.419	1.458	1.356

Maximum Dry Density(MDD)=1.452, Optomum Moisture Content(OMC)=32.0%



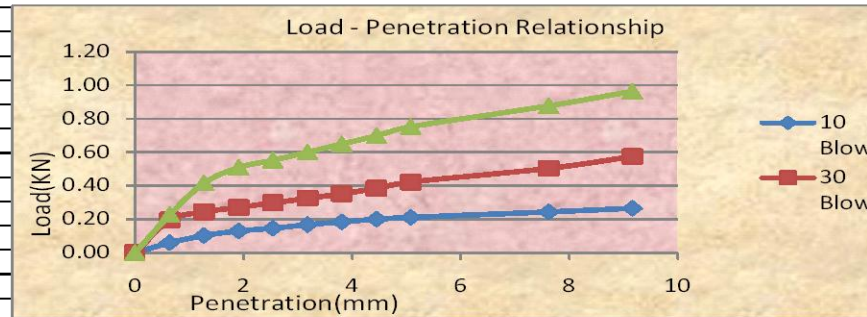
30.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-ORWAZSS#30

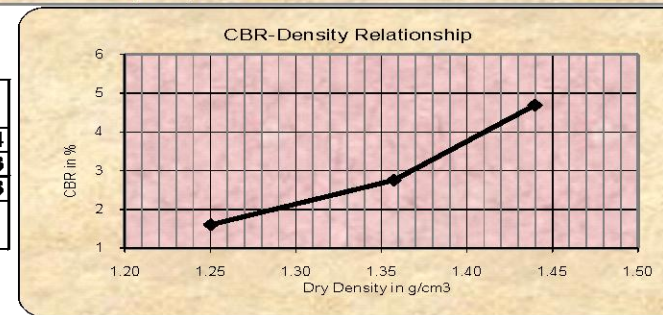
Depth of Sampling:-80cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	11	0.06	36	0.20	42	0.23
1.27	19	0.10	45	0.24	77	0.42
1.91	24	0.13	50	0.27	94	0.51
2.54	27	0.15	55	0.30	102	0.55
3.18	31	0.17	60	0.33	111	0.60
3.81	34	0.18	65	0.35	120	0.65
4.45	37	0.20	71	0.38	129	0.70
5.08	39	0.21	78	0.42	139	0.75
7.62	45	0.24	93	0.50	162	0.88
9.16	49	0.27	106	0.57	178	0.96



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.250245	0.15	0.21138	13.2	20	1.108636	1.057	1.10864
30	1.357169	0.2981	0.42	13.2	20	2.258333	2.114	2.25833
65	1.439796	0.5528	0.75338	13.2	20	4.188182	3.767	4.18818

CBR at 95% MDD i.e 1.3794 gm/cc and at OMC of 32 % is 3 %



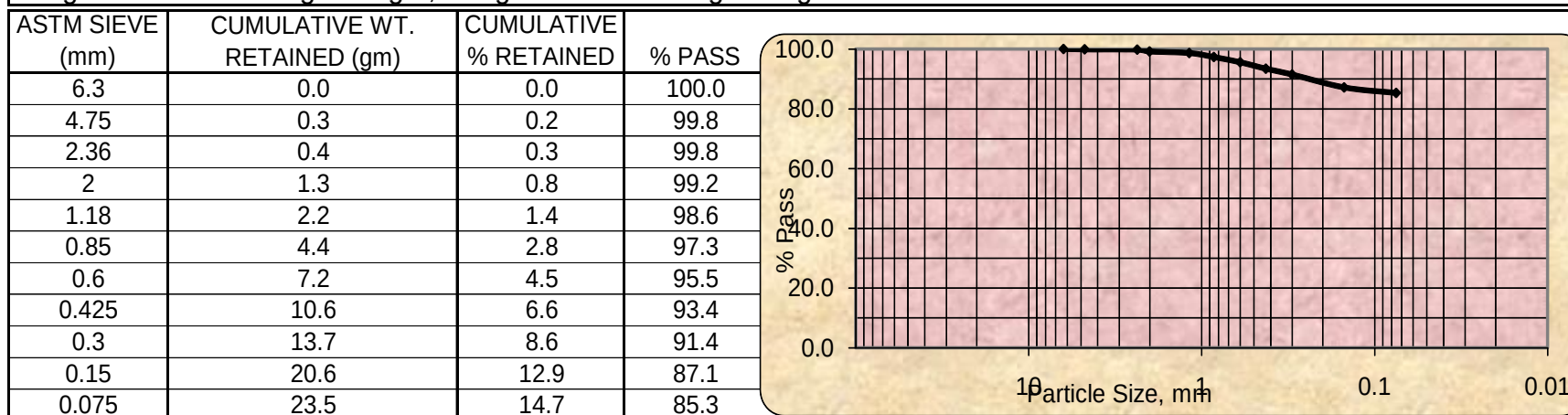
31.1 Grain Size Analysis

TEST METHOD : AASHTO T - 27

Sample Code-SRNZSS 31

Depth of Sampling:-80cm

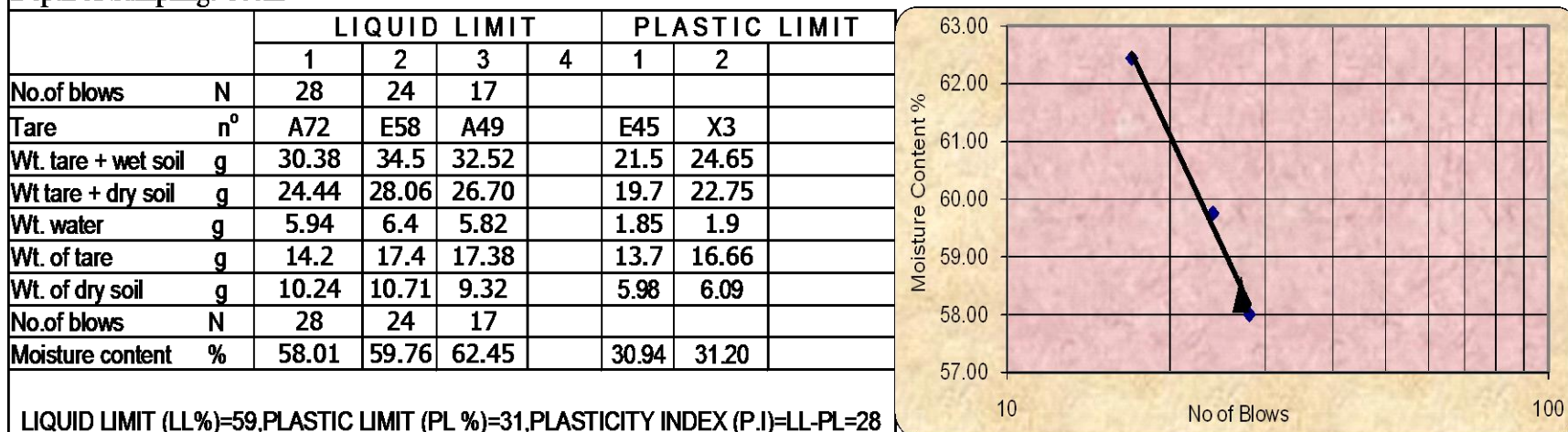
Weight Before Washing =160gm, Weight After Washing=23.5gm

**31.2 Atterberg Limit Test**

TEST METHOD : AASHTO T89 - T91

Sample Code-SRHZSS 31

Depth of Sampling:-80cm



31.3 Modified Proctor Test

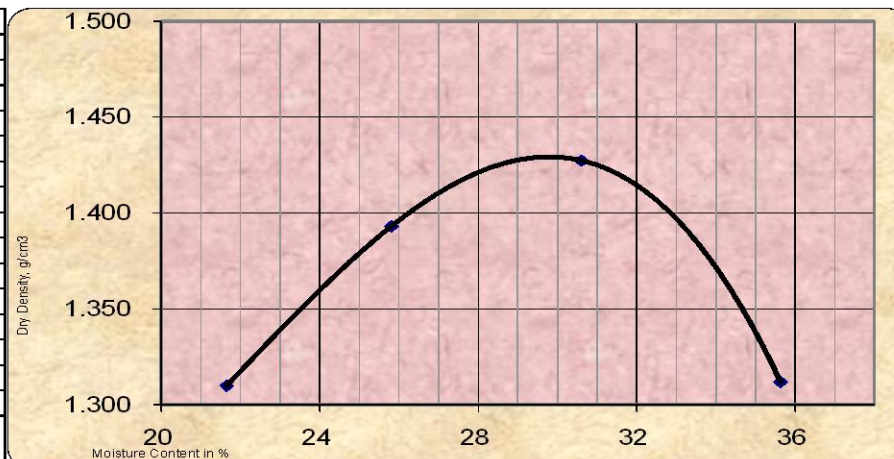
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-SRHZSS-31

Depth of Sampling:-80cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4515	4665	4770	4690
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1501	1651	1756	1676
E	Volume of Mold	cu.cm	942	942	942	942
F	Wet Density	gt/cu.cm	1.59	1.75	1.86	1.78
G	Container	No.	T	T	A8	C4
H	Wt. Cont + Wet soil	grams	190.24	198.18	235.54	241.98
I	Wt. Cont + Dry soil	grams	162.18	164.37	190.91	189.78
J	Weight of Water	grams	28.06	33.81	44.63	52.20
K	Weight of Container	grams	32.55	33.37	45.07	43.28
L	Weight of Dry Soil	grams	129.63	131.00	145.84	146.50
M	Moisture Content	%	21.6	25.8	30.6	35.6
N	Dry Density	gt/cu.cm	1.310	1.393	1.427	1.312

Maximum Dry Density(MDD)=1.432, Optimum Moisture Content(OMC)=30.0%

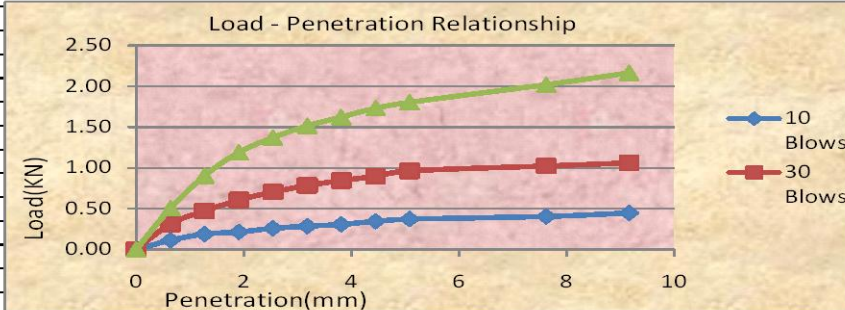
**31.4 California Bearing Ratio Test**

TEST METHOD : AASHTO T- 193

Sample Code-SRHZSS#31

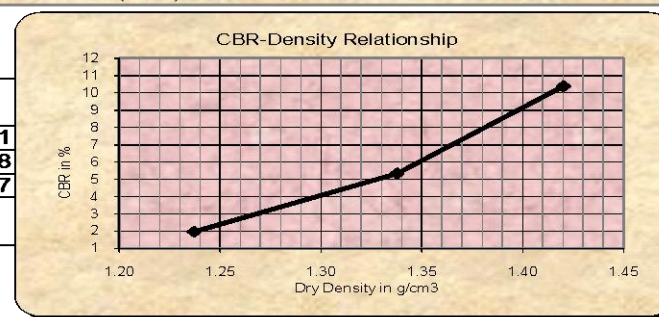
Depth of Sampling:-80cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	21	0.11	58	0.31	14	0.51
1.27	35	0.19	87	0.47	25	0.90
1.91	40	0.22	112	0.61	33	1.19
2.54	48	0.26	130	0.70	38	1.37
3.18	53	0.29	145	0.79	42	1.52
3.81	57	0.31	156	0.85	45	1.62
4.45	64	0.35	166	0.90	48	1.73
5.08	69	0.37	178	0.96	50	1.80
7.62	75	0.41	189	1.02	56	2.02
9.16	83	0.45	196	1.06	60	2.16



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.23714	0.26	0.37398	13.2	20	1.970909	1.87	1.97091
30	1.337644	0.7046	0.96	13.2	20	5.337879	4.824	5.33788
65	1.420258	1.371	1.804	13.2	20	10.38667	9.02	10.3867

CBR at 95% MDD i.e 1.3604 gm/cc and at OMC of 30 % is 7 %



32.1 Grain Size Analysis

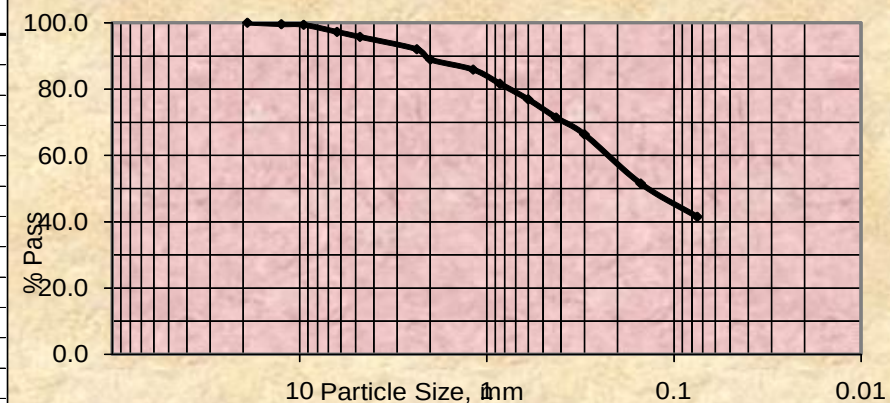
TEST METHOD : AASHTO T - 27

Sample Code-ORWAZSS 32

Depth of Sampling:-120cm

Weight Before Washing =196gm, Weight After Washing=114.7gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
19	0.0	0.0	100.0
12.5	0.9	0.5	99.5
9.5	1.2	0.6	99.4
6.3	5.3	2.7	97.3
4.75	8.3	4.2	95.8
2.36	15.7	8.0	92.0
2	21.7	11.1	88.9
1.18	27.7	14.1	85.9
0.85	36.0	18.4	81.6
0.6	45.3	23.1	76.9
0.425	56.1	28.6	71.4
0.3	66.0	33.7	66.3
0.15	95.1	48.5	51.5
0.075	114.7	58.5	41.5

**32.2 Atterberg Limit Test**

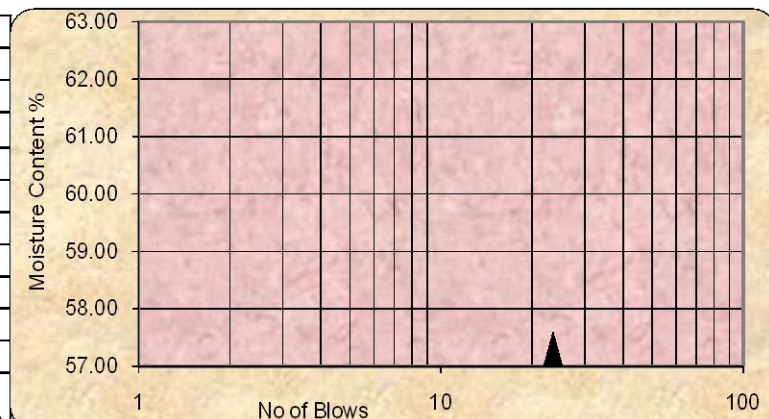
TEST METHOD : AASHTO T89 - T91

Sample Code-ORWAZSSS 32

Depth of Sampling:-120cm

		LIQUID LIMIT				PLASTIC LIMIT		
		1	2	3	4	1	2	
No. of blows	N							
Tare	n°							
Wt. tare + wet soil	g		NP					
Wt. tare + dry soil	g							
Wt. water	g							
Wt. of tare	g							
Wt. of dry soil	g							
No. of blows	N							
Moisture content	%							

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL%)=NP, PLASTICITY INDEX (PI)=LL-PL=0



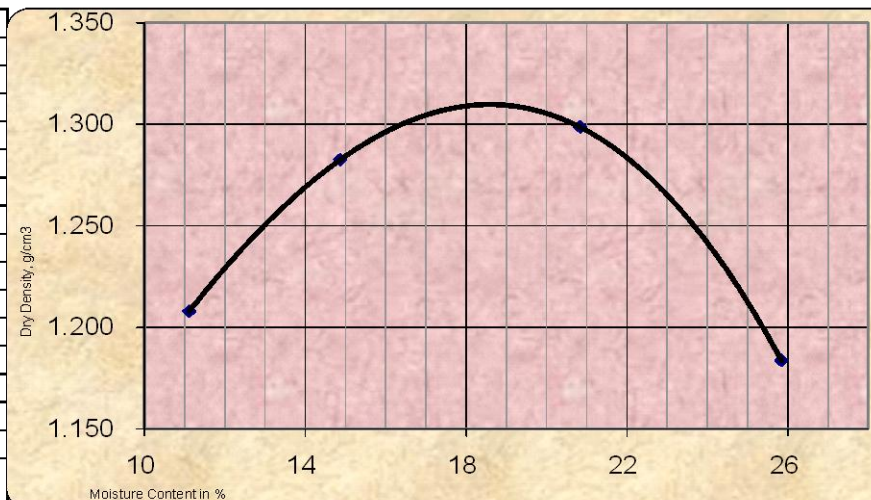
32.3 Modified Proctor Test**TEST METHOD : AASHTO T- 180 METHOD C**

Sample Code-ORWAZSSS-32

Depth of Sampling:-120cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4310	4440	4535	4456
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1330	1460	1555	1476
E	Volume of Mold	cu.cm.	991	991	991	991
F	Wet Density	gr/cu.cm.	1.34	1.47	1.57	1.49
G	Container	No.	F63	F67	F43	E25
H	Wt. Cont + Wet soil	grams	288.71	193.42	287.00	263.00
I	Wt. Cont + Dry soil	grams	267.53	175.97	250.98	223.90
J	Weight of Water	grams	21.18	17.45	36.02	39.10
K	Weight of Container	grams	76.99	58.63	78.04	72.55
L	Weight of Dry Soil	grams	190.54	117.34	172.94	151.35
M	Moisture Content	%	11.1	14.9	20.8	25.8
N	Dry Density	gr/cu.cm.	1.208	1.283	1.299	1.184

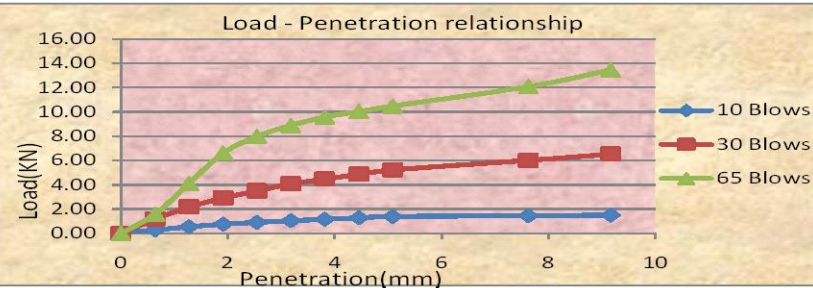
Maximum Dry Density(MDD)=1.310, Optomum Moisture Content(OMC)=19.0%

**32.4 California Bearing Ration Test****TEST METHOD : AASHTO T- 193**

Sample Code-ORWAZSS#32

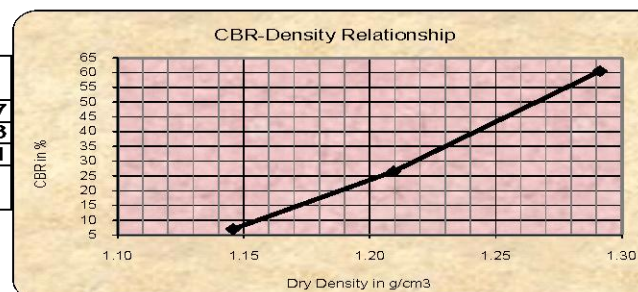
Depth of Sampling:-120cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	52	0.28	33	1.19	7	1.60
1.27	101	0.55	60	2.16	18	4.11
1.91	140	0.76	81	2.92	29	6.61
2.54	168	0.91	97	3.50	35	7.98
3.18	194	1.05	113	4.08	39	8.90
3.81	215	1.17	124	4.47	42	9.58
4.45	238	1.29	135	4.87	44	10.04
5.08	257	1.39	145	5.23	46	10.49
7.62	269	1.46	167	6.03	53	12.09
9.16	278	1.51	181	6.53	59	13.46



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.145807	0.91	1.39294	13.2	20	6.898182	6.965	6.9647
30	1.209478	3.4998	5.23	13.2	20	26.51333	26.16	26.5133
65	1.291329	7.9835	10.4926	13.2	20	60.48106	52.46	60.4811

CBR at 95% MDD i.e 1.2445 gm/cc and at OMC of 19 % is 41 %



33.1 Grain Size Analysis

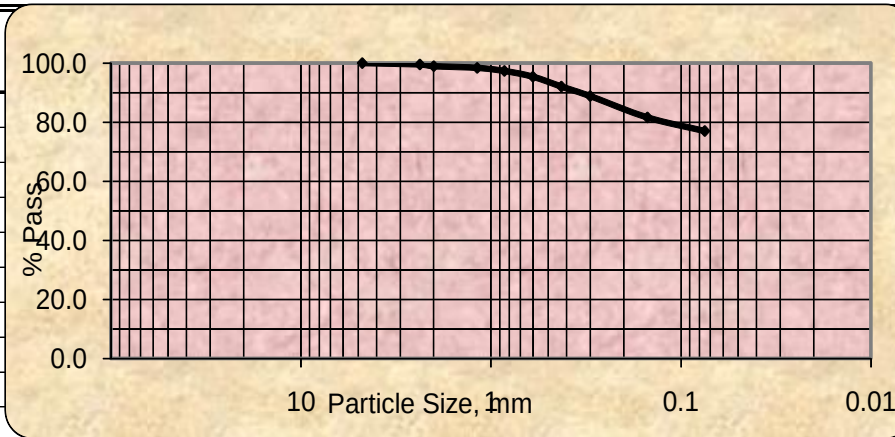
TEST METHOD : AASHTO T - 27

Sample Code-ORESRE 33

Depth of Sampling:-100cm

Weight Before Washing =232gm, Weight After Washing=53.4gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
4.75	0.0	0.0	100.0
2.36	1.1	0.5	99.5
2	2.4	1.0	99.0
1.18	3.7	1.6	98.4
0.85	6.2	2.7	97.3
0.6	10.6	4.6	95.4
0.425	18.3	7.9	92.1
0.3	25.9	11.2	88.8
0.15	42.6	18.4	81.6
0.075	53.4	23.0	77.0

**33.2 Atterberg Limit Test**

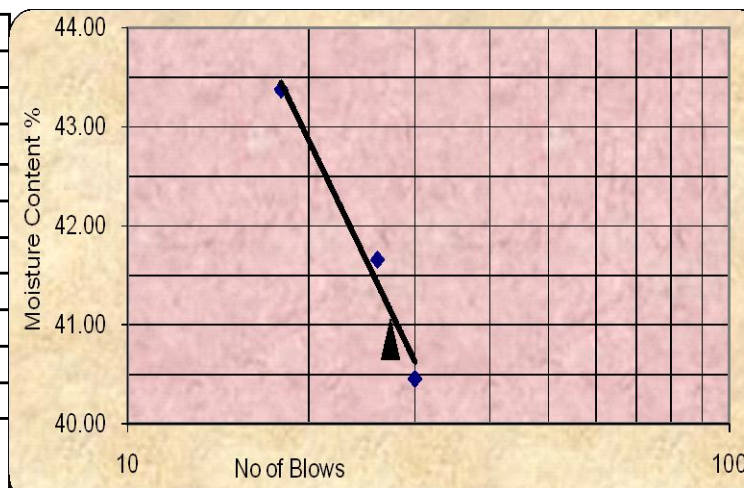
TEST METHOD : AASHTO T89 - T91

Sample Code-ORESBE 33

Depth of Sampling:-100cm

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	30	26	18			
Tare	n°	A55	A2	E28		A50	E81
Wt. tare + wet soil	g	34.98	32.4	31.91		21.9	26.02
Wt. tare + dry soil	g	30.36	27.72	27.13		20.3	24.58
Wt. water	g	4.62	4.67	4.78		1.52	1.44
Wt. of tare	g	18.94	16.5	16.11		14.8	19.21
Wt. of dry soil	g	11.42	11.21	11.02		5.58	5.37
No. of blows	N	30	26	18			
Moisture content	%	40.46	41.66	43.38		27.24	26.82

LIQUID LIMIT (LL%)=42, PLASTIC LIMIT (PL %)=27, PLASTICITY INDEX (P.I.)=LL-PL=15



33.3 Modified Proctor Test

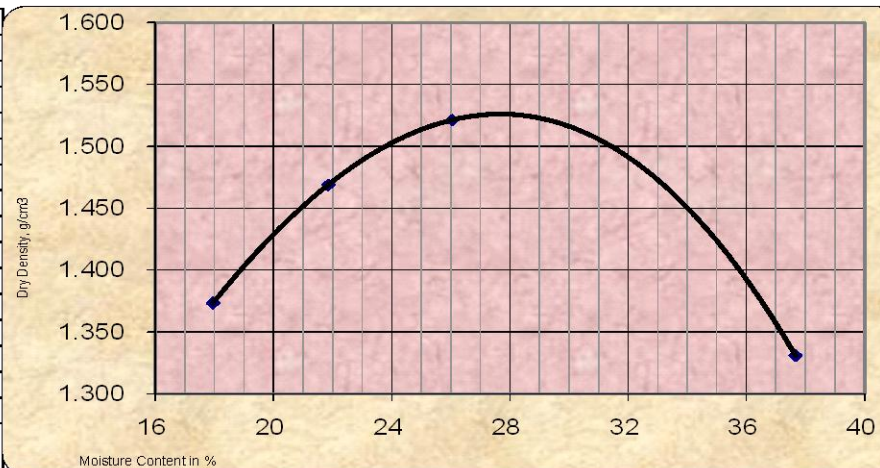
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code-ORES ZBE-33

Depth of Sampling:-100cm

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4540	4700	4820	4740
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1526	1686	1806	1726
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.62	1.79	1.92	1.83
G	Container	No.	X11	A9	G8	G24
H	Wt. Cont + Wet soil	grams	196.50	227.00	225.00	210.00
I	Wt. Cont + Dry soil	grams	175.00	195.79	187.19	162.07
J	Weight of Water	grams	21.50	31.21	37.81	47.93
K	Weight of Container	grams	55.24	52.97	41.98	34.83
L	Weight of Dry Soil	grams	119.76	142.82	145.21	127.24
M	Moisture Content	%	18.0	21.9	26.0	37.7
N	Dry Density	gr/cu.cm.	1.373	1.469	1.521	1.331

Maximum Dry Density(MDD)=1.530, Optimum Moisture Content(OMC)=28.0%

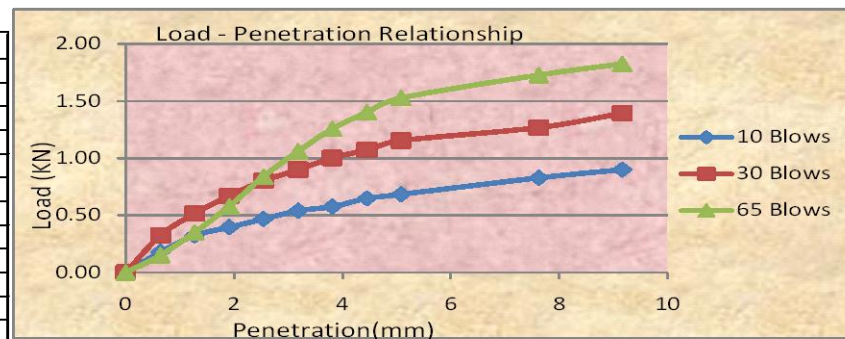
**33.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORESBES#33

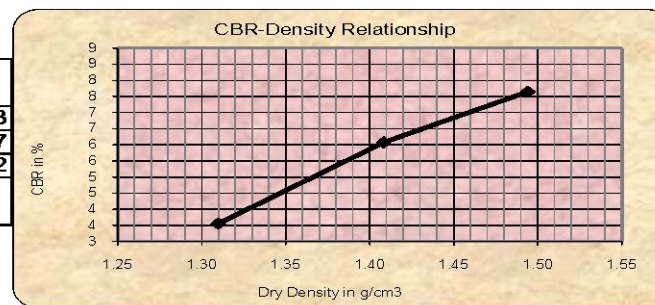
Depth of Sampling:-100cm

Penetration(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	5	0.18	60	0.33	28	0.15
1.27	9	0.32	95	0.51	65	0.35
1.91	11	0.40	124	0.67	107	0.58
2.54	13	0.47	148	0.80	155	0.84
3.18	15	0.54	166	0.90	196	1.06
3.81	16	0.58	185	1.00	232	1.26
4.45	18	0.65	198	1.07	259	1.40
5.08	19	0.69	213	1.15	282	1.53
7.62	23	0.83	234	1.27	319	1.73
9.16	25	0.90	257	1.39	337	1.83



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.309888	0.47	0.68552	13.2	20	3.553333	3.428	3.55333
30	1.408246	0.8022	1.15	13.2	20	6.07697	5.772	6.07697
65	1.493992	0.8401	1.52844	13.2	20	6.364394	7.642	7.6422

CBR at 95% MDD i.e 1.4835 gm/cc and at OMC of 28 % is 7 %



34.1 Grain Size Analysis

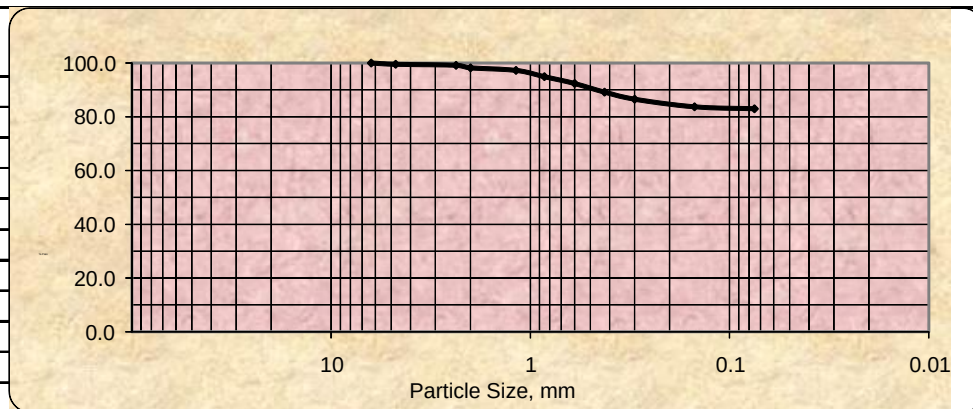
TEST METHOD : AASHTO T - 27

Sample Code:- ORWASLS#34

Depth Sampled:- 80 cm.

Weight Before Washing = 503.3gm, Weight After Washing = 85.7gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
6.3	0.0	0.0	100.0
4.75	2.4	0.5	99.5
2.36	4.6	0.9	99.1
2	9.3	1.8	98.2
1.18	14.0	2.8	97.2
0.85	25.6	5.1	94.9
0.6	38.4	7.6	92.4
0.425	54.9	10.9	89.1
0.3	68.0	13.5	86.5
0.15	82.3	16.4	83.6
0.075	85.7	17.0	83.0



34.2 ATTERBERG LIMIT TEST

TEST METHOD : AASHTO T89 - T91

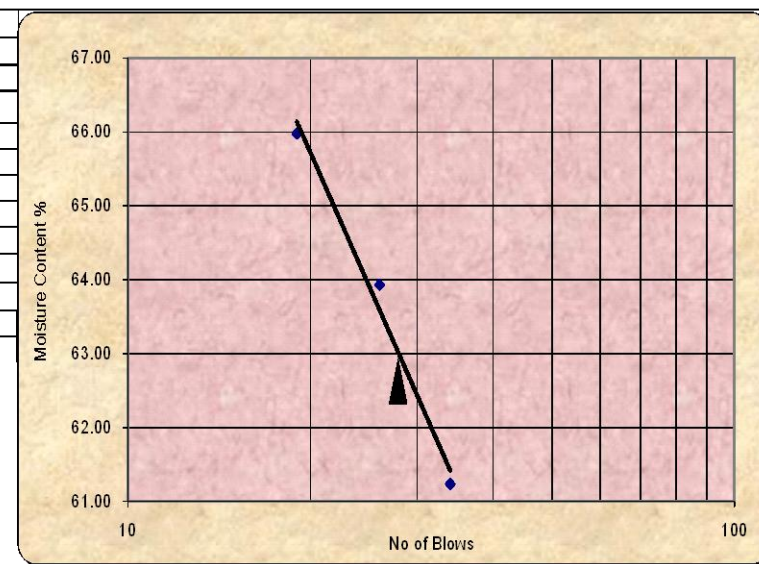
Sample Code:- ORWASLS#34

Depth Sampled:- 80 cm.

	LIQUID LIMIT				PLASTIC LIMIT		
	1	2	3	4	1	2	
No. of blows	N	34	26	19			
Tare	n°	A72	E58	A49	E45	X3	
Wt. tare + wet soil	g	30.05	31.55	31.26	22.72	20.75	
Wt. tare + dry soil	g	24.49	25.79	25.21	21.02	19.33	
Wt. water	g	5.56	5.76	6.05	1.70	1.42	
Wt. of tare	g	15.41	16.78	16.04	15.56	14.83	
Wt. of dry soil	g	9.08	9.01	9.17	5.46	4.50	
No. of blows	N	34	26	19			
Moisture content	%	61.23	63.93	65.98	31.14	31.56	
					AVERAGE PLASTIC LIMIT		31

LIQUID LIMIT (LL%)		PLASTICITY INDEX (P.I)	
64		33	
PLASTIC LIMIT (PL %)		SOIL CLASSIFICATION (AASHTO)	
31		A-7-5(20)	

PASSING SIEVE %		
2.00mm (no 10)	0.425mm (no 40)	0.075mm (no 200)
98	89	83



34.3 Modified Proctor Test

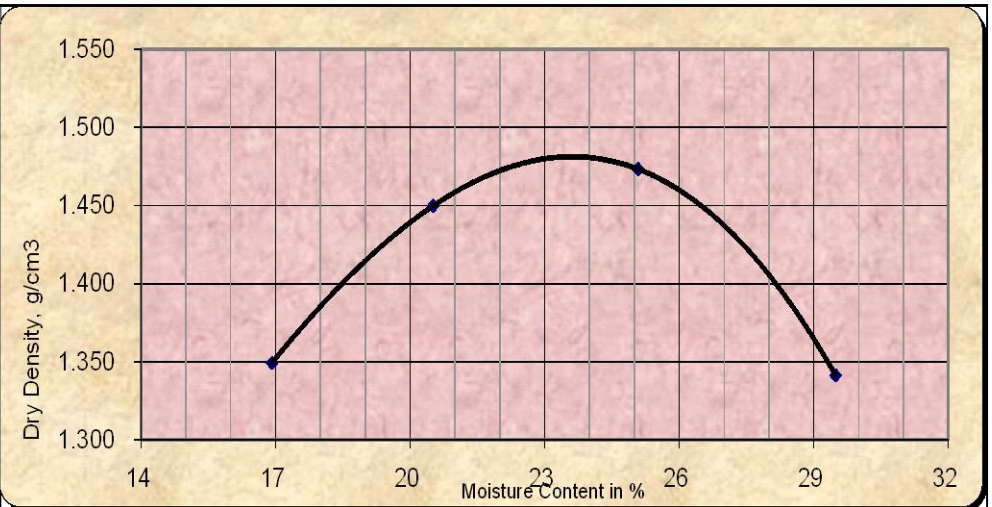
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:- ORWASLS#34

Depth Sampled:- 80 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4500	4660	4750	4650
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1486	1646	1736	1636
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.58	1.75	1.84	1.74
G	Container	No.	T	T	A8	C4
H	Wt. Cont + Wet soil	grams	270.69	230.40	224.69	253.95
I	Wt. Cont + Dry soil	grams	237.59	198.65	187.94	206.19
J	Weight of Water	grams	33.10	31.75	36.75	47.76
K	Weight of Container	grams	41.93	43.89	41.42	44.22
L	Weight of Dry Soil	grams	195.66	154.76	146.52	161.97
M	Moisture Content	%	16.9	20.5	25.1	29.5
N	Dry Density	gr/cu.cm.	1.349	1.450	1.473	1.341

Maximum Dry Density(MDD)=1.482g/cc, Optimum Moisture Content(OMC)24.0%



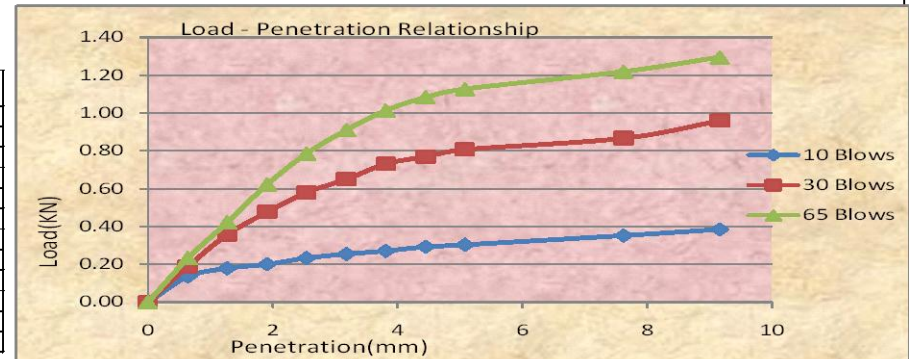
34.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-ORWASLS#34

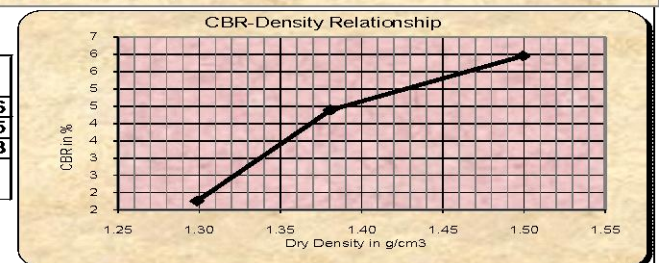
Depth of Sampling:-80cm

Penetration n(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	25	0.14	35	0.19	43	0.23
1.27	33	0.18	66	0.36	78	0.42
1.91	37	0.20	88	0.48	115	0.62
2.54	43	0.23	107	0.58	145	0.79
3.18	47	0.25	120	0.65	168	0.91
3.81	50	0.27	135	0.73	187	1.01
4.45	54	0.29	142	0.77	200	1.08
5.08	56	0.30	149	0.81	208	1.13
7.62	65	0.35	160	0.87	225	1.22
9.16	71	0.38	177	0.96	239	1.30



No Of Blows	DD	Load		Standard Load		CBR	
		2.54	5.08	2.54	5.08	2.54	5.08
10	1.298706	0.23	0.30352	13.2	20	1.765606	1.5176
30	1.380835	0.57994	0.81	13.2	20	4.393485	4.0379
65	1.499359	0.7859	1.12736	13.2	20	5.953788	5.6368

CBR at 95% MDD i.e 1.4079 gm/cc and at OMC of 24 % is 5 %



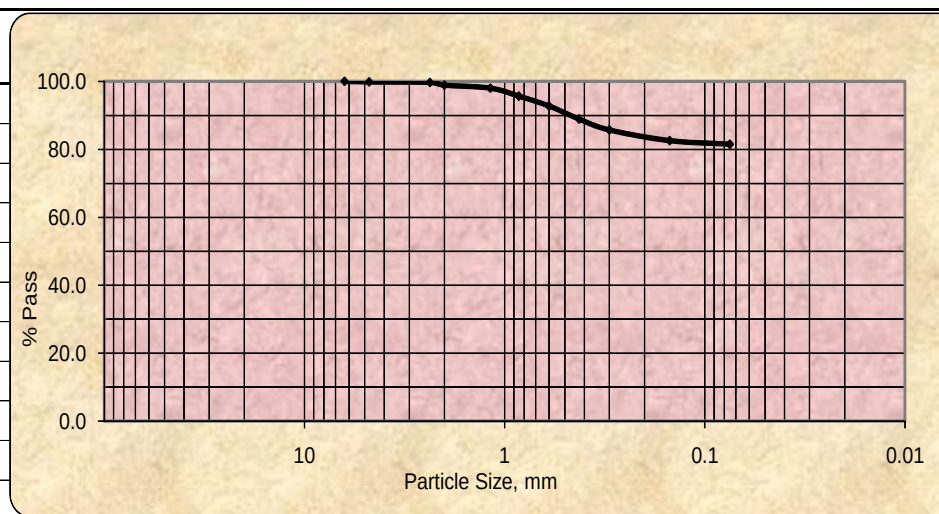
TEST METHOD : AASHTO T - 27

Sample Code:- ORWAZSLGK#35

Depth Sampled:- 120 cm.

Weight Before Washing = 608.6gm, Weight After Washing = 112.2gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
6.3	0.0	0.0	100.0
4.75	0.9	0.1	99.9
2.36	1.8	0.3	99.7
2	6.9	1.1	98.9
1.18	12.0	2.0	98.0
0.85	26.3	4.3	95.7
0.6	43.9	7.2	92.8
0.425	67.3	11.1	88.9
0.3	86.9	14.3	85.7
0.15	105.9	17.4	82.6
0.075	112.2	18.4	81.6



35.2 ATTERBERG LIMIT TEST

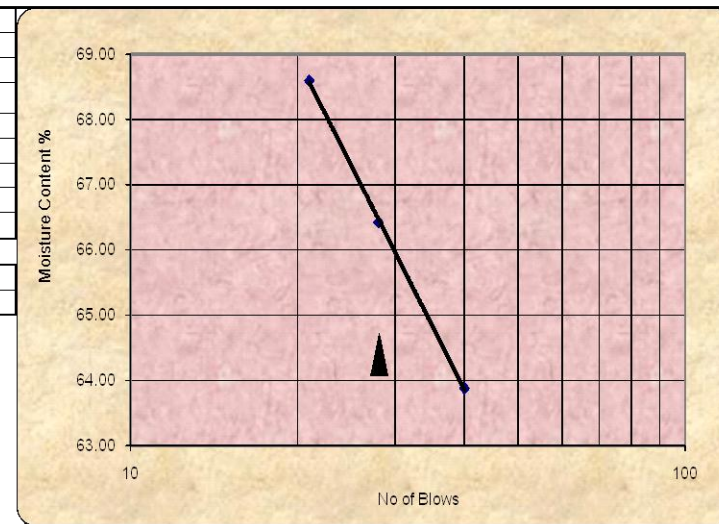
TEST METHOD : AASHTO T89 - T91

Sample Code:- ORWAZSLGK#35

Depth Sampled:- 120 cm.

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	40	28	21			
Tare	n°	A44	E10	E87		E80	E46
Wt. tare + wet soil	g	30.65	30.39	33.79		24.37	21.16
Wt. tare + dry soil	g	25.31	24.91	28.33		22.6	19.67
Wt. water	g	5.34	5.48	5.46		1.77	1.49
Wt. of tare	g	16.95	16.66	20.37		16.5	14.57
Wt. of dry soil	g	8.36	8.25	7.96		6.10	5.10
No. of blows	N	40	28	21			
Moisture content	%	63.88	66.42	68.59		29.02	29.22
						AVERAGE PLASTIC LIMIT	
						29	

LIQUID LIMIT (LL%)		PASSING SIEVE %		
		2.00mm (no 10)	0.425mm (no 40)	0.075mm (no 200)
67				
PLASTIC LIMIT (PL %)		99	89	82
29		SOIL CLASSIFICATION (AASHTO)		
PLASTICITY INDEX (P.I)		A-7-6(20)		
38				



35.3 Modified Proctor Test

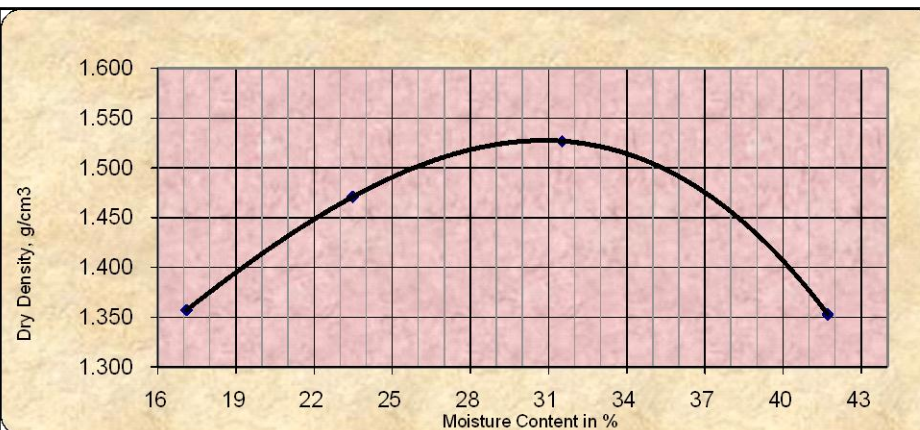
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:- ORWAZSLGK#35

Depth Sampled:- 120 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4555	4780	4970	4880
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1575	1800	1990	1900
E	Volume of Mold	cu.cm.	991	991	991	991
F	Wet Density	gr/cu.cm.	1.59	1.82	2.01	1.92
G	Container	No.	L6	A1	A8	A21
H	Wt. Cont + Wet soil	grams	323.20	199.05	245.10	255.30
I	Wt. Cont + Dry soil	grams	287.59	167.57	196.44	196.23
J	Weight of Water	grams	35.61	31.48	48.66	59.07
K	Weight of Container	grams	79.45	33.51	42.05	54.63
L	Weight of Dry Soil	grams	208.14	134.06	154.39	141.60
M	Moisture Content	%	17.1	23.5	31.5	41.7
N	Dry Density	gr/cu.cm.	1.357	1.471	1.527	1.353

Maximum Dry Density(MDD)=1.530g/cc, Optimum Moisture Content(OMC)31.0%

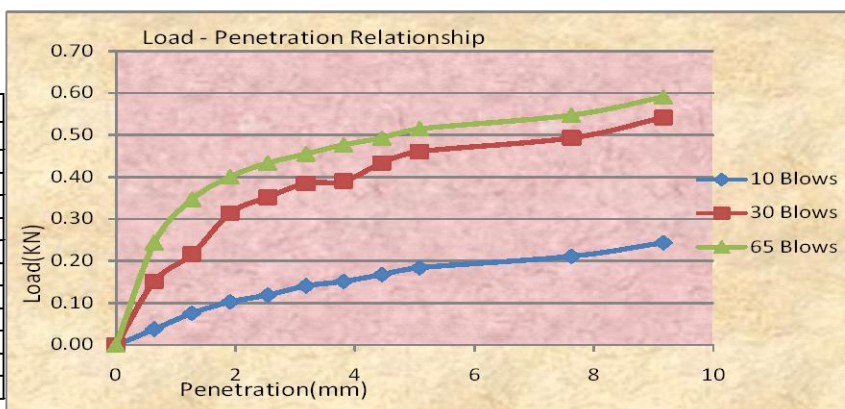
**35.4 California Bearing Ratio Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORWAZSLGK#35

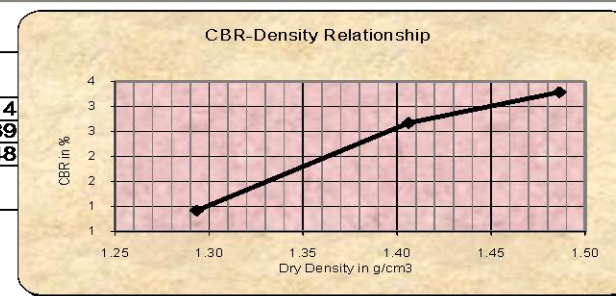
Depth of Sampling:-100cm

Penetration n(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	7	0.04	28	0.15	45	0.24
1.27	14	0.08	40	0.22	64	0.35
1.91	19	0.10	58	0.31	74	0.40
2.54	22	0.12	65	0.35	80	0.43
3.18	26	0.14	71	0.38	84	0.46
3.81	28	0.15	72	0.39	88	0.48
4.45	31	0.17	80	0.43	91	0.49
5.08	34	0.18	85	0.46	95	0.51
7.62	39	0.21	91	0.49	101	0.55
9.16	45	0.24	100	0.54	109	0.59



No Of Blow	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.293415	0.12	0.18428	13.2	20	0.903333	0.9214	0.9214
30	1.406136	0.3523	0.46	13.2	20	2.668939	2.3035	2.668939
65	1.486292	0.4336	0.5149	13.2	20	3.284848	2.5745	3.284848

CBR at 95% MDD i.e 1.4535 gm/cc and at OMC of 31 % is 3 %



36.1 Grain Size Analysis

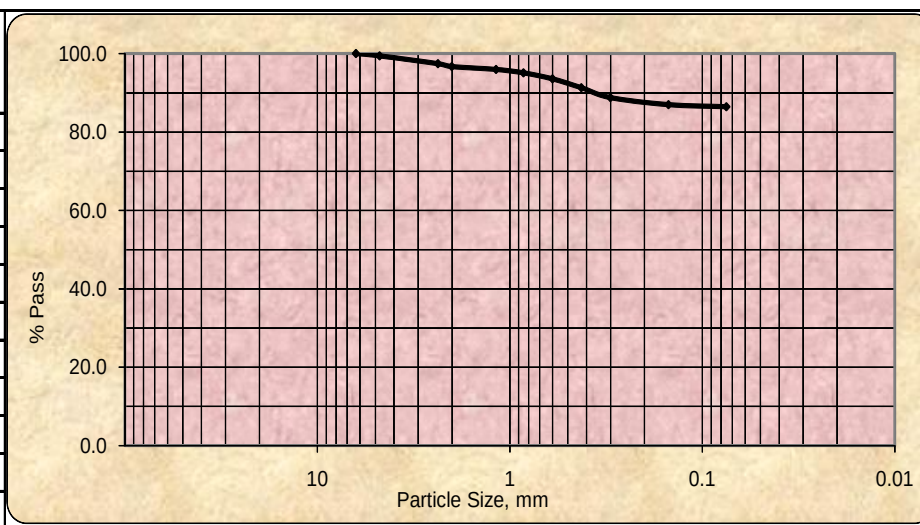
TEST METHOD : AASHTO T - 27

Sample Code:- ORWAZSLGS#36

Depth Sampled:- 80 cm.

Weight Before Washing = 417.7kg, Weight After Washing = 56.7kg

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
6.3	0.0	0.0	100.0
4.75	2.3	0.6	99.4
2.36	10.7	2.6	97.4
2	13.8	3.3	96.7
1.18	16.9	4.0	96.0
0.85	20.6	4.9	95.1
0.6	27.0	6.5	93.5
0.425	36.4	8.7	91.3
0.3	46.8	11.2	88.8
0.15	54.4	13.0	87.0
0.075	56.7	13.6	86.4



36.2 ATTERBERG LIMIT TEST

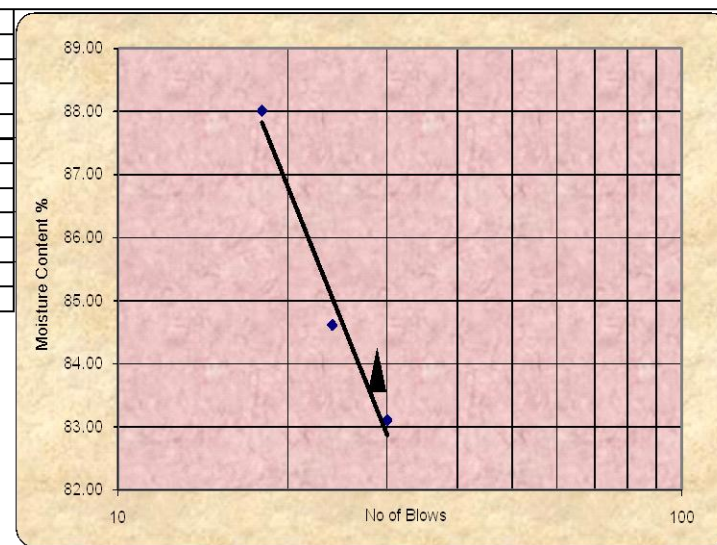
TEST METHOD : AASHTO T89 - T91

Sample Code:- ORWAZSLGS#36

Depth Sampled:- 80 cm.

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	30	24	18			
Tare	n°	A69	E63	A78		A22	E62
Wt. tare + wet soil	g	30.35	30.96	28.87		23.86	20.28
Wt. tare + dry soil	g	23.56	24.80	22.63		22.38	18.92
Wt. water	g	6.79	6.16	6.24		1.48	1.36
Wt. of tare	g	15.39	17.52	15.54		17.8	14.95
Wt. of dry soil	g	8.17	7.28	7.09		4.58	3.97
No. of blows	N	30	24	18			
Moisture content	%	83.11	84.62	88.01		32.31	34.26
						AVERAGE PLASTIC LIMIT	
						33	

LIQUID LIMIT (LL%)	PASSING SIEVE %		
	2.00mm (no 10)	0.425mm (no 40)	0.075mm (no 200)
84			
PLASTIC LIMIT (PL %)	84	33	51
33	PLASTICITY MODULUS		
PLASTICITY INDEX (P.I)			
51	SOIL CLASSIFICATION (AASHTO)		
	A-7-5(20)		



36.3 Modified Proctor Test

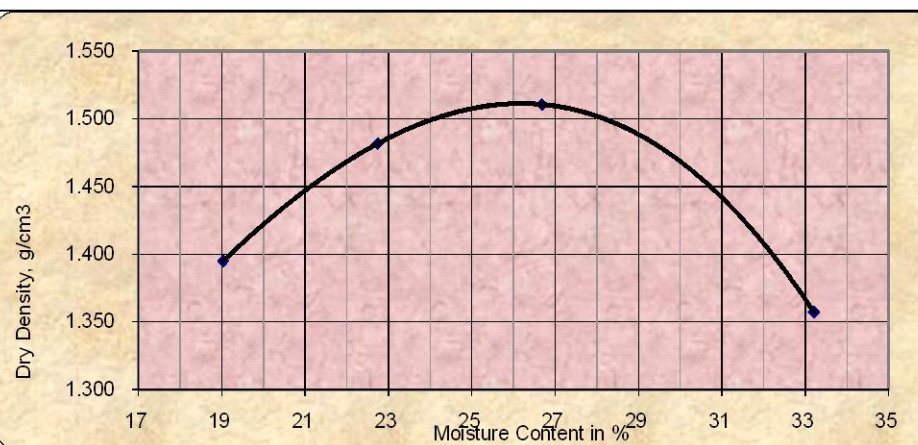
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:- ORWAZSLGS#36

Depth Sampled:- 80 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4580	4730	4820	4720
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1574	1724	1814	1714
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.66	1.82	1.91	1.81
G	Container	No.	G14	A12	F43	F33
H	Wt. Cont + Wet soil	grams	274.11	278.69	219.98	187.21
I	Wt. Cont + Dry soil	grams	236.88	233.81	183.40	153.22
J	Weight of Water	grams	37.23	44.88	36.58	33.99
K	Weight of Container	grams	41.24	36.45	46.30	50.86
L	Weight of Dry Soil	grams	195.64	197.36	137.10	102.36
M	Moisture Content	%	19.0	22.7	26.7	33.2
N	Dry Density	gr/cu.cm.	1.395	1.482	1.510	1.357

Maximum Dry Density(MDD)=1.513/cc, Optimum Moisture Content(OMC)26.5%

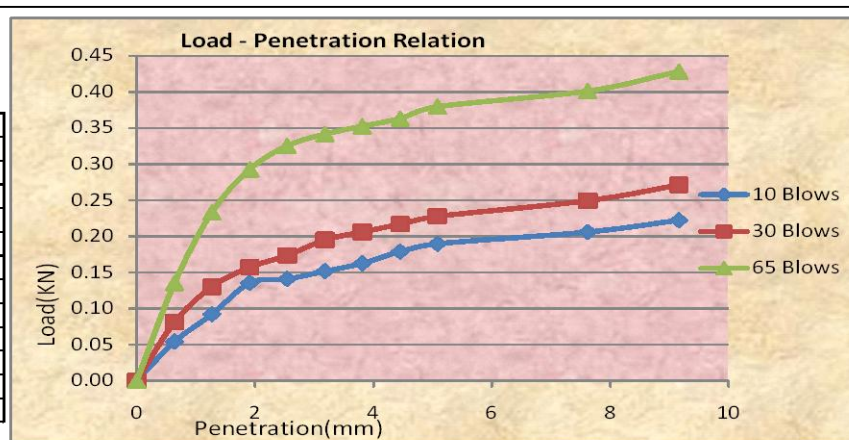
**36.4 California Bearing Ratio Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORWAZSLGS#36

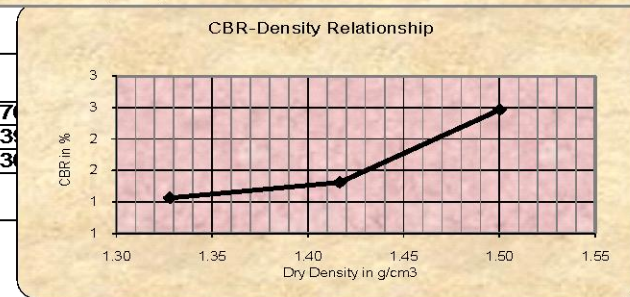
Depth of Sampling:-80cm

Penetration n(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	10	0.05	15	0.08	25	0.14
1.27	17	0.09	24	0.13	43	0.23
1.91	25	0.14	29	0.16	54	0.29
2.54	26	0.14	32	0.17	60	0.33
3.18	28	0.15	36	0.20	63	0.34
3.81	30	0.16	38	0.21	65	0.35
4.45	33	0.18	40	0.22	67	0.36
5.08	35	0.19	42	0.23	70	0.38
7.62	38	0.21	46	0.25	74	0.40
9.16	41	0.22	50	0.27	79	0.43



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.327833	0.14	0.1897	13.2	20	1.067576	0.9485	1.067576
30	1.416533	0.17344	0.23	13.2	20	1.313939	1.1382	1.313939
65	1.500057	0.3252	0.3794	13.2	20	2.463636	1.897	2.463636

CBR at 95% MDD i.e 1.43735 gm/cc and at OMC of 26.5 % is 2 %



37.1 Grain Size Analysis

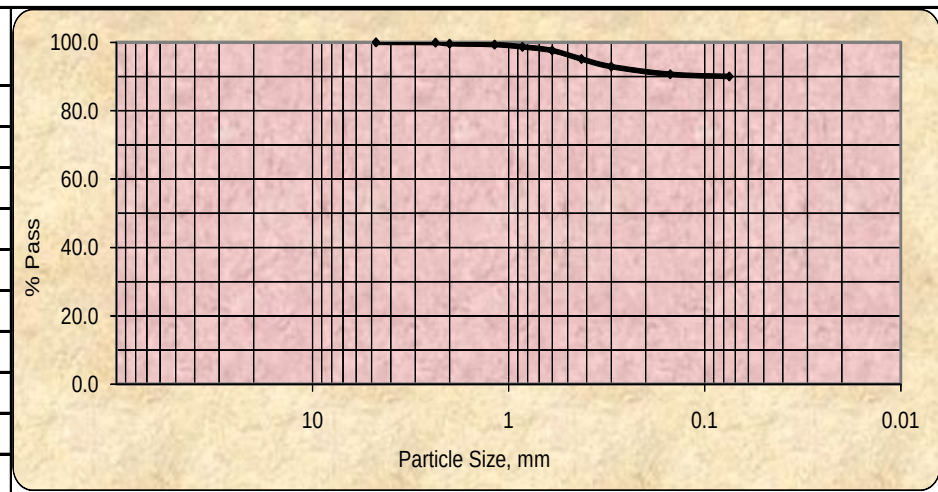
TEST METHOD : AASHTO T - 27

Sample Code:- ORWAZANK#37

Depth Sampled:- 120 cm.

Weight Before Washing = 460.1gm, Weight After Washing = 45.9gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
4.75	0.0	0.0	100.0
2.36	0.4	0.1	99.9
2	1.7	0.4	99.6
1.18	2.9	0.6	99.4
0.85	5.9	1.3	98.7
0.6	10.9	2.4	97.6
0.425	22.4	4.9	95.1
0.3	32.7	7.1	92.9
0.15	43.0	9.3	90.7
0.075	45.9	10.0	90.0



37.2 ATTERBERG LIMIT TEST

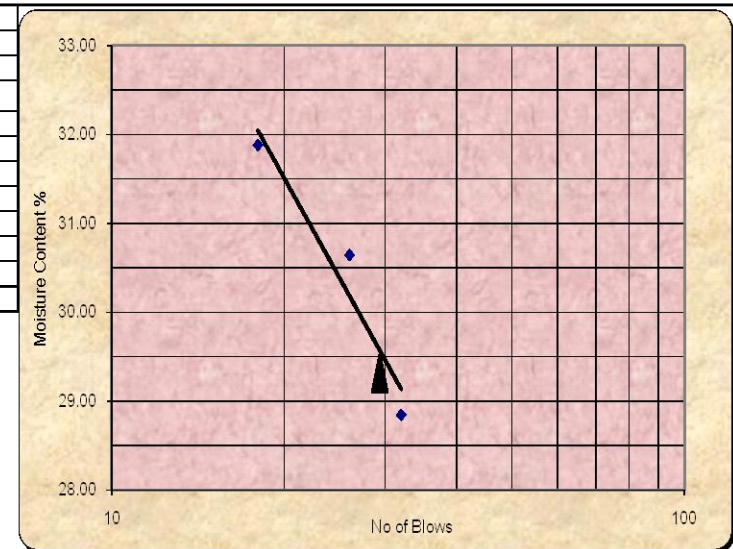
TEST METHOD : AASHTO T89 - T91

Sample Code:- ORWAZANK#37

Depth Sampled:- 120 cm.

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	32	26	18			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	33.88	32.46	29.78		22.07	22.01
Wt. tare + dry soil	g	30.28	28.36	26.2		20.88	20.91
Wt. water	g	3.6	4.1	3.58		1.19	1.1
Wt. of tare	g	17.8	14.98	14.97		14.94	15.55
Wt. of dry soil	g	12.48	13.38	11.23		5.94	5.36
No. of blows	N	32	26	18			
Moisture content	%	28.85	30.64	31.88		20.03	20.52
						AVERAGE PLASTIC LIMIT	
						20	

LIQUID LIMIT (LL%)		PASSING SIEVE %		
		2.00mm (no 10)	0.425mm (no 40)	0.075mm (no 200)
30				
PLASTIC LIMIT (PL %)		100	95	90
20		PLASTICITY MODULUS		
PLASTICITY INDEX (P.I)				
10		SOIL CLASSIFICATION (AASHTO)		
		A-4(8)		



37.3 Modified Proctor Test

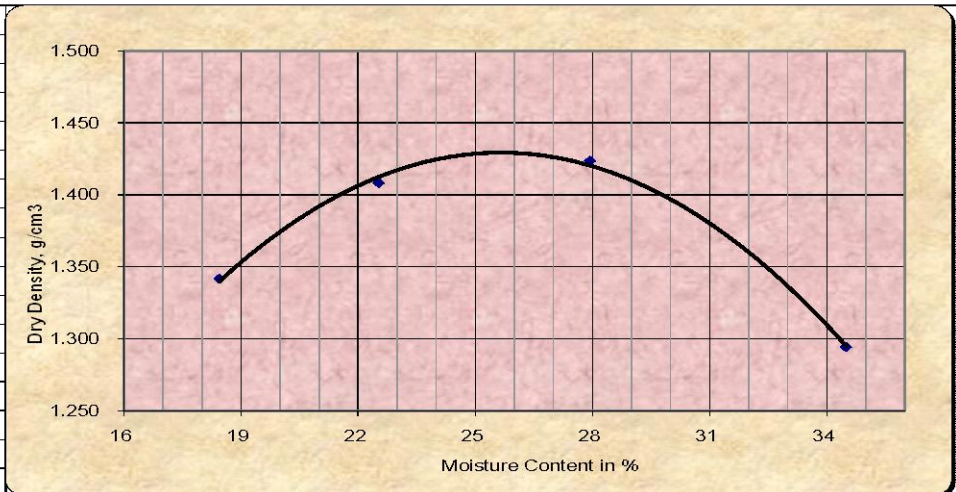
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:- ORWAZANK#37

Depth Sampled:- 120 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4555	4690	4785	4705
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1575	1710	1805	1725
E	Volume of Mold	cu.cm.	991	991	991	991
F	Wet Density	gr/cu.cm.	1.59	1.73	1.82	1.74
G	Container	No.	E21	GH	C1	E2
H	Wt. Cont + Wet soil	grams	255.80	235.84	236.36	270.51
I	Wt. Cont + Dry soil	grams	223.78	198.66	191.57	209.99
J	Weight of Water	grams	32.02	37.18	44.79	60.52
K	Weight of Container	grams	50.23	33.59	31.24	34.51
L	Weight of Dry Soil	grams	173.55	165.07	160.33	175.48
M	Moisture Content	%	18.5	22.5	27.9	34.5
N	Dry Density	gr/cu.cm.	1.342	1.408	1.424	1.294

Maximum Dry Density(MDD)=1.432g/cc, Optimum Moisture Content(OMC)26.0%



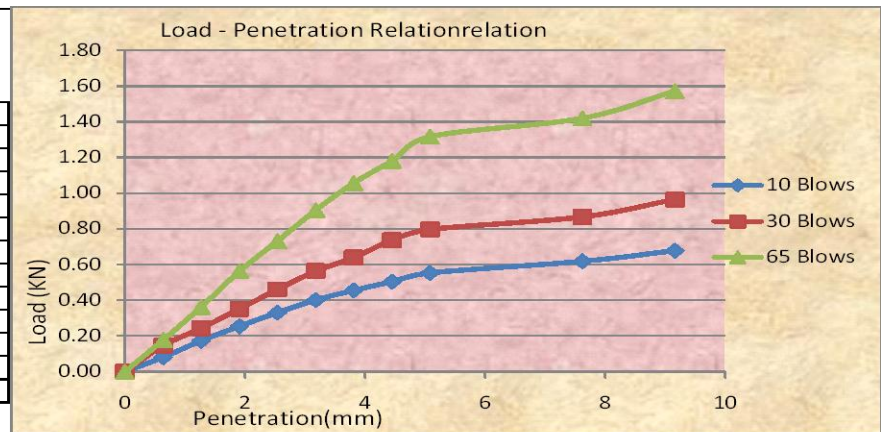
37.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-ORWAZANK#37

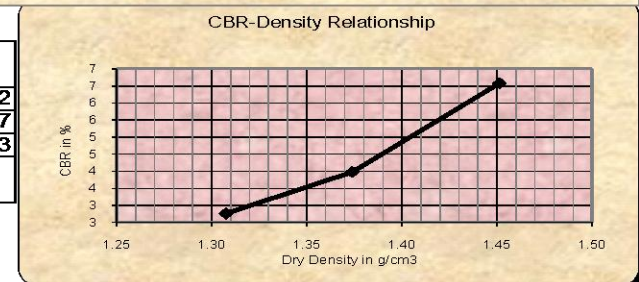
Depth of Sampling:- 120cm

Penetration n(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	15	0.08	27	0.15	33	0.18
1.27	32	0.17	45	0.24	67	0.36
1.91	47	0.25	65	0.35	104	0.56
2.54	61	0.33	85	0.46	135	0.73
3.18	74	0.40	104	0.56	167	0.91
3.81	84	0.46	118	0.64	195	1.06
4.45	93	0.50	136	0.74	218	1.18
5.08	102	0.55	147	0.80	243	1.32
7.62	114	0.62	160	0.87	262	1.42
9.16	125	0.68	178	0.96	290	1.57



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.307562	0.33	0.55284	13.2	20	2.504697	2.7642	2.7642
30	1.373866	0.4607	0.80	13.2	20	3.490152	3.9837	3.9837
65	1.451294	0.7317	1.31706	13.2	20	5.543182	6.5853	6.5853

CBR at 95% MDD i.e 1.3604 gm/cc and at OMC of 26 % is 4 %



38.1 GRAIN Grain Size Analysis

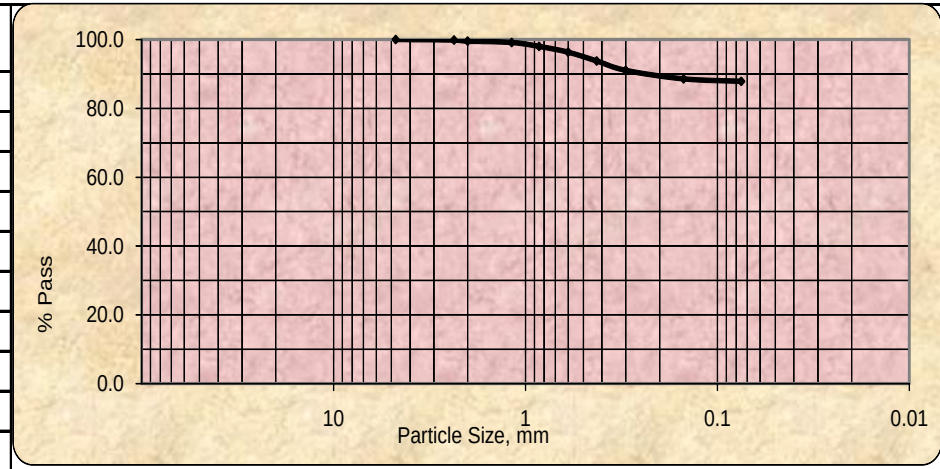
TEST METHOD : AASHTO T - 27

Sample Code:- ORWAZANW#38

Depth Sampled:-120 cm.

Weight Before Washing = 631.1gm, Weight After Washing = 76.8gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
4.75	0.0	0.0	100.0
2.36	1.1	0.2	99.8
2	3.3	0.5	99.5
1.18	5.4	0.9	99.1
0.85	12.8	2.0	98.0
0.6	23.2	3.7	96.3
0.425	39.2	6.2	93.8
0.3	56.6	9.0	91.0
0.15	72.2	11.4	88.6
0.075	76.8	12.2	87.8



38.2 ATTERBERG LIMIT TEST

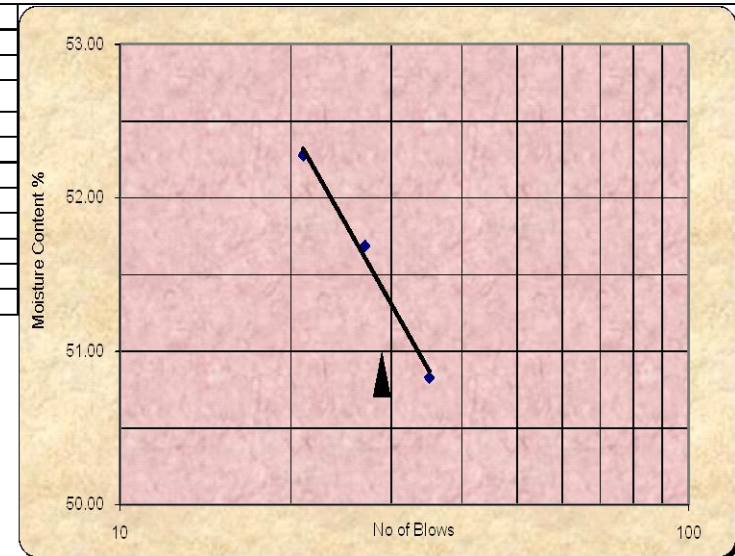
TEST METHOD : AASHTO T89 - T91

Sample Code:- ORWAZANW#38

Depth Sampled:-120 cm.

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	35	27	21			
Tare	n°	A72	E58	A49		E45	X3
Wt. tare + wet soil	g	30.49	28.46	34.15		21.89	22.68
Wt. tare + dry soil	g	25.59	24.02	29.10		20.55	21.22
Wt. water	g	4.90	4.44	5.05		1.34	1.46
Wt. of tare	g	15.95	15.43	19.44		15.35	15.58
Wt. of dry soil	g	9.64	8.59	9.66		5.20	5.64
No. of blows	N	35	27	21			
Moisture content	%	50.83	51.69	52.28		25.77	25.89
						AVERAGE PLASTIC LIMIT	26

LIQUID LIMIT (LL%)	PASSING SIEVE %		
	2.00mm (no 10)	0.425mm (no 40)	0.075mm (no 200)
52			
PLASTIC LIMIT (PL %)	100	94	88
26	PLASTICITY MODULUS		
PLASTICITY INDEX (P.I)			
26	SOIL CLASSIFICATION (AASHTO)		
	A-7-6(17)		



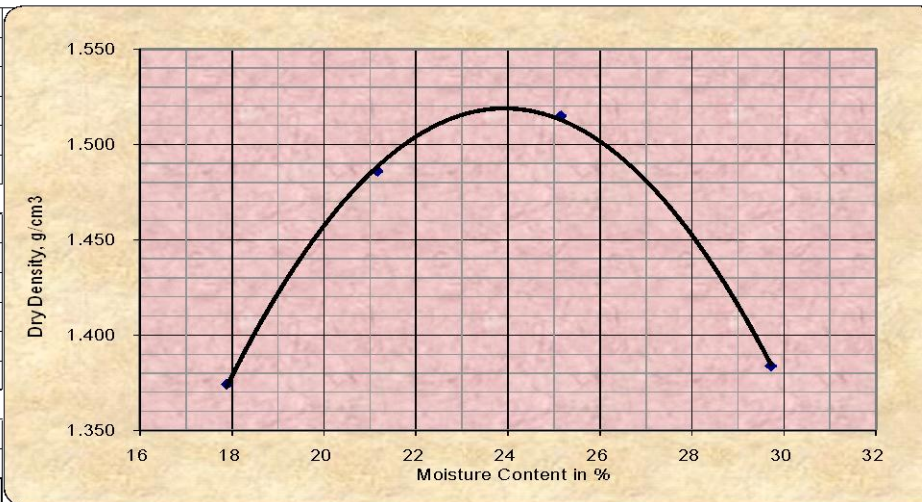
38.3 Modified Proctor Test

TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:- ORWAZANW#38

Depth Sampled:-120 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4540	4710	4800	4705
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1526	1696	1786	1691
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.62	1.80	1.90	1.80
G	Container	No.	Y5	Y8	V	C10
H	Wt. Cont + Wet soil	grams	272.74	267.23	284.11	258.72
I	Wt. Cont + Dry soil	grams	238.09	227.03	236.07	209.86
J	Weight of Water	grams	34.65	40.20	48.04	48.86
K	Weight of Container	grams	44.34	37.08	45.06	45.46
L	Weight of Dry Soil	grams	193.75	189.95	191.01	164.40
M	Moisture Content	%	17.9	21.2	25.2	29.7
N	Dry Density	gr/cu.cm.	1.374	1.486	1.515	1.384
Maximum Dry Density(MDD)=1.520g/cc, Optimum Moisture Content(OMC)24.0%						

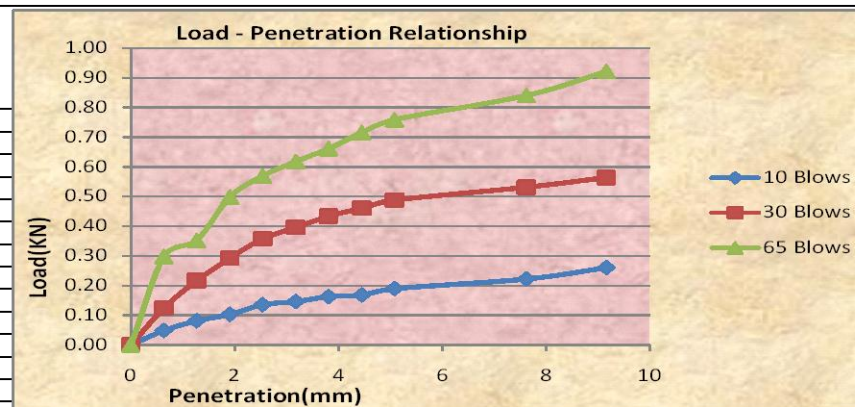
**38.4 California Bearing Ration Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORWAZANK#37

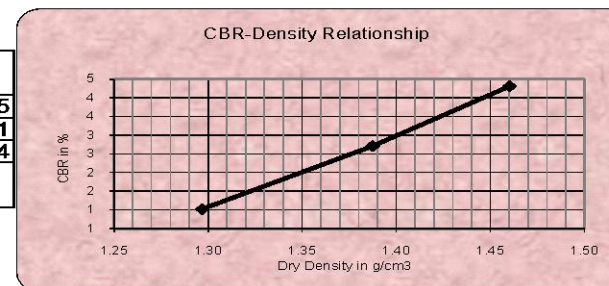
Depth of Sampling:-120cm

Penetration n(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	9	0.05	23	0.12	55	0.30
1.27	15	0.08	40	0.22	65	0.35
1.91	19	0.10	54	0.29	92	0.50
2.54	25	0.14	66	0.36	105	0.57
3.18	27	0.15	73	0.40	114	0.62
3.81	30	0.16	80	0.43	122	0.66
4.45	31	0.17	85	0.46	132	0.72
5.08	35	0.19	90	0.49	140	0.76
7.62	41	0.22	98	0.53	155	0.84
9.16	48	0.26	104	0.56	170	0.92



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.296754	0.14	0.1897	13.2	20	1.026515	0.9485	1.026515
30	1.387478	0.35772	0.49	13.2	20	2.71	2.439	2.71
65	1.460209	0.5691	0.7588	13.2	20	4.311364	3.794	4.311364

CBR at 95% MDD i.e 1.444 gm/cc and at OMC of 24 % is 4 %



39.1 Grain Size Analysis

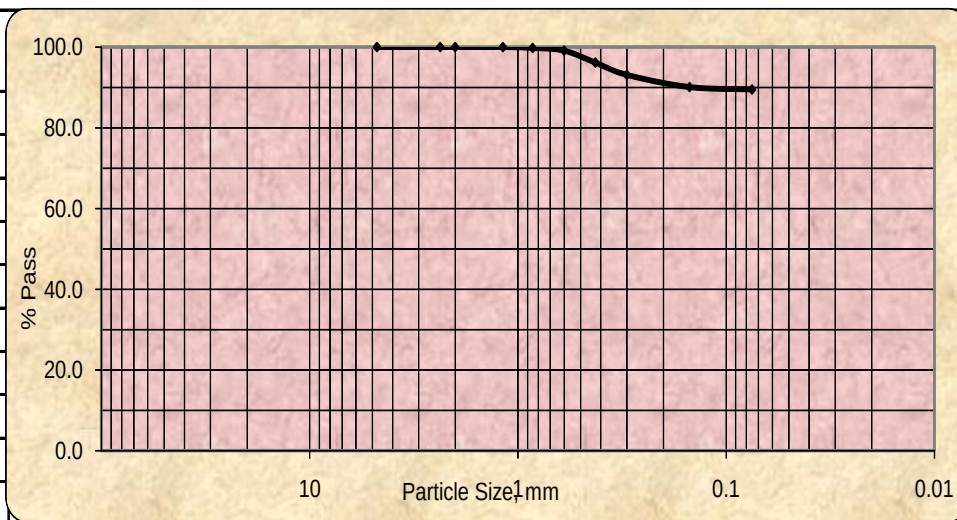
TEST METHOD : AASHTO T - 27

Sample Code:-ORESZDS#39

Depth Sampled:-120 cm.

Weight Before Washing = 448gm, Weight After Washing = 47.4gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
4.75	0.0	0.0	100.0
2.36	0.0	0.0	100.0
2	0.1	0.0	100.0
1.18	0.2	0.0	100.0
0.85	1.0	0.2	99.8
0.6	4.0	0.9	99.1
0.425	17.4	3.9	96.1
0.3	31.0	6.9	93.1
0.15	44.6	10.0	90.0
0.075	47.4	10.6	89.4

**39.2 Atterberg Limit Test**

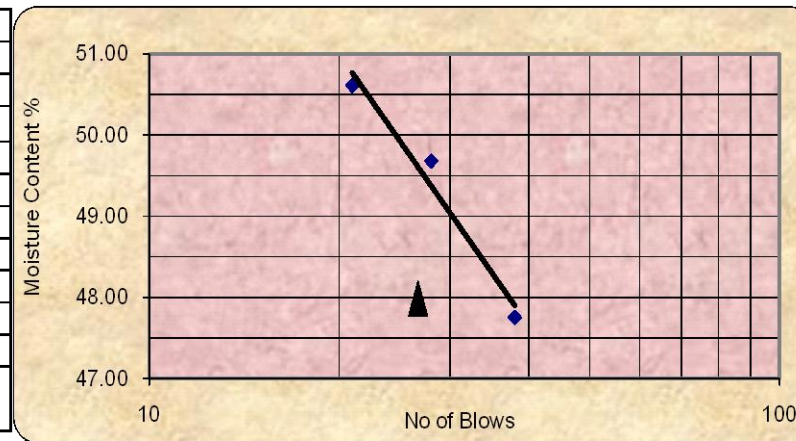
TEST METHOD : AASHTO T89 - T91

Sample Code-ORESZDS#39

Depth of Sampling:-120cm

	LIQUID LIMIT				PLASTIC LIMIT		
	1	2	3	4	1	2	
No. of blows	38	28	21				
Tare	A25	E9	A9		A2	A7	
Wt. tare + wet soil	28.67	31.59	29.02		24.54	24.84	
Wt. tare + dry soil	24.31	26.16	24.04		22.75	23.24	
Wt. water	4.36	5.43	4.98		1.79	1.60	
Wt. of tare	15.18	15.23	14.2		16.51	17.52	
Wt. of dry soil	9.13	10.93	9.84		6.24	5.72	
No. of blows	38	28	21				
Moisture content	47.75	49.68	50.61		28.69	27.97	

LIQUID LIMIT (LL%)=50, PLASTIC LIMIT (PL %)=28, PLASTICITY INDEX (P.I.)=LL-PL=22



39.3 Modified Proctor Test

TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:-ORESZDS#39

Depth Sampled:-120 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4420	4610	4748	4668
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1440	1630	1768	1688
E	Volume of Mold	cu.cm	991	991	991	991
F	Wet Density	gr/cu.cm	1.45	1.64	1.78	1.70
G	Container	No.	G6	B2	P17	P4
H	Wt. Cont + Wet soil	grams	309.00	284.30	259.10	267.44
I	Wt. Cont + Dry soil	grams	274.21	246.36	211.77	207.08
J	Weight of Water	grams	34.79	37.94	47.33	60.36
K	Weight of Container	grams	71.40	75.72	36.88	37.82
L	Weight of Dry Soil	grams	202.81	170.64	174.89	169.26
M	Moisture Content	%	17.2	22.2	27.1	35.7
N	Dry Density	gr/cu.cm	1.240	1.346	1.404	1.256

Maximum Dry Density(MDD)=1.41g/cc, Optimum Moisture Content(OMC)28.0%



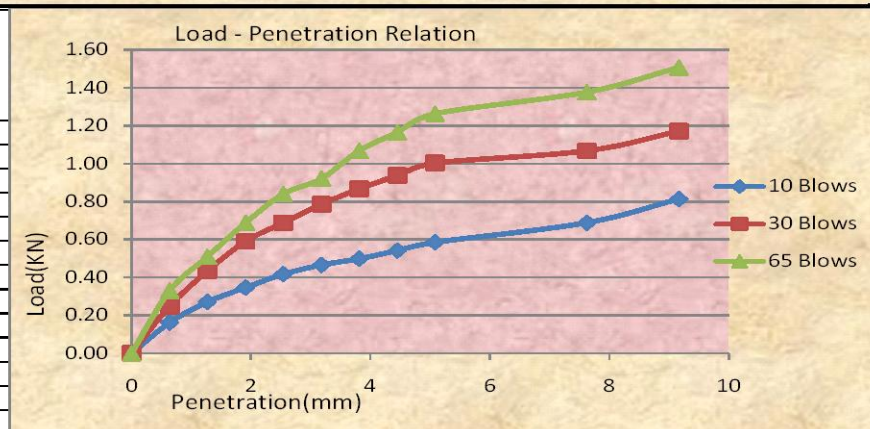
39.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-ORESZDS#39

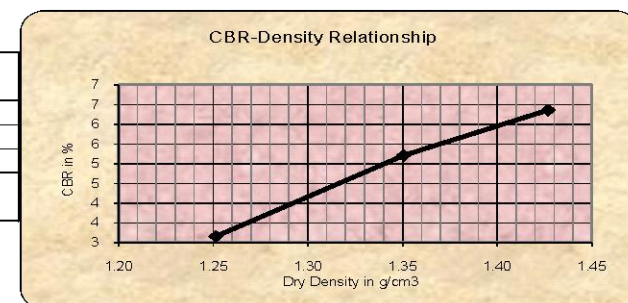
Depth of Sampling:-120cm

Penetration	10 Blows		30 Blows		65 Blows	
n(mm)	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	30	0.16	46	0.25	61	0.33
1.27	50	0.27	80	0.43	94	0.51
1.91	64	0.35	109	0.59	127	0.69
2.54	77	0.42	127	0.69	155	0.84
3.18	86	0.47	145	0.79	170	0.92
3.81	92	0.50	160	0.87	197	1.07
4.45	100	0.54	173	0.94	215	1.17
5.08	108	0.59	185	1.00	233	1.26
7.62	127	0.69	197	1.07	254	1.38
9.16	150	0.81	216	1.17	278	1.51



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.251333	0.42	0.58536	13.2	20	3.161667	2.9268	3
30	1.350537	0.68834	1.00	13.2	20	5.214697	5.0135	5
65	1.426925	0.8401	1.26286	13.2	20	6.364394	6.3143	6

CBR at 95% MDD i.e 1.3395 gm/cc and at OMC of 28 % is 5 %



40.1 Grain Size Analysis

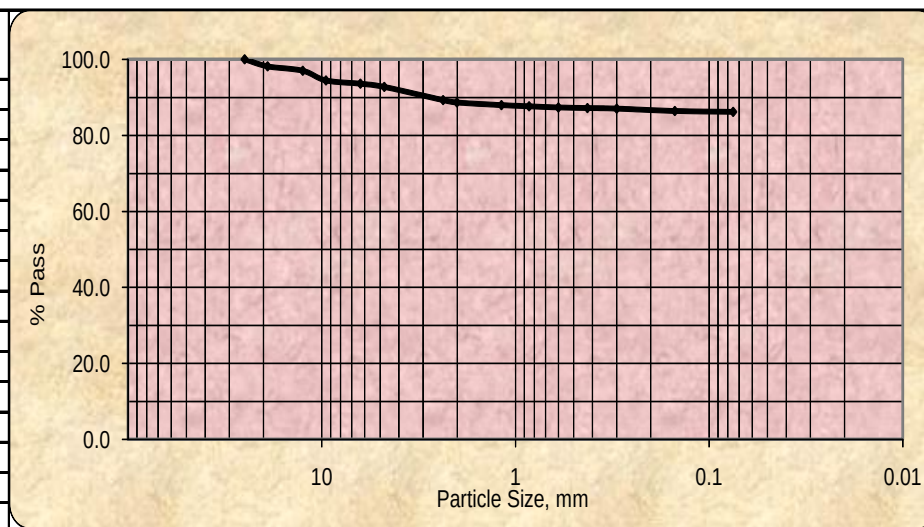
TEST METHOD : AASHTO T - 27

Sample Code:- ARABS#40

Depth Sampled:- 80 cm.

Weight Before Washing = 420.6gm, Weight After Washing = 58.1gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
25	0.0	0.0	100.0
19	7.8	1.9	98.1
12.5	12.5	3.0	97.0
9.5	23.2	5.5	94.5
6.3	26.8	6.4	93.6
4.75	30.4	7.2	92.8
2.36	45.1	10.7	89.3
2	47.8	11.4	88.6
1.18	50.5	12.0	88.0
0.85	51.8	12.3	87.7
0.6	53.1	12.6	87.4
0.425	53.8	12.8	87.2
0.3	54.4	12.9	87.1
0.15	57.2	13.6	86.4
0.075	58.1	13.8	86.2



40.2 ATTERBERG LIMIT TEST

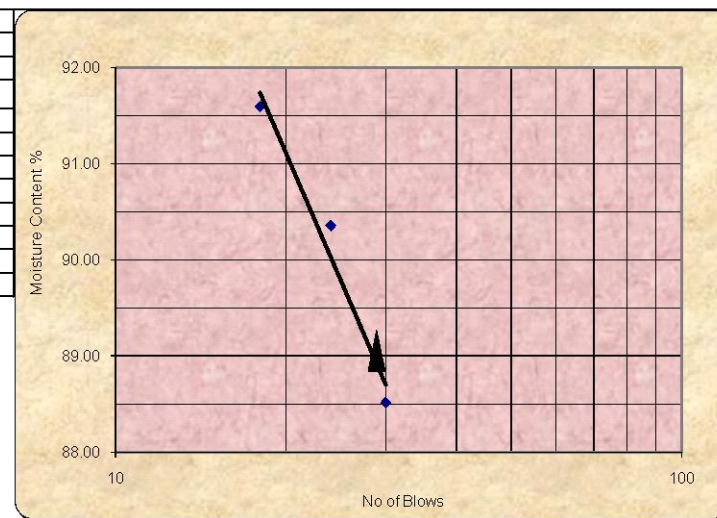
TEST METHOD : AASHTO T89 - T91

Sample Code:- ARABS#40

Depth Sampled:- 80 cm.

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	30	24	18		1	2
Tare	n°	A25	E9	A9		A2	A7
Wt. tare + wet soil	g	29.38	27.22	28.78		19.81	20.2
Wt. tare + dry soil	g	23.06	21.41	23.44		18.41	18.71
Wt. water	g	6.32	5.81	5.34		1.40	1.49
Wt. of tare	g	15.92	14.98	17.61		14.78	14.97
Wt. of dry soil	g	7.14	6.43	5.83		3.63	3.74
No. of blows	N	30	24	18			
Moisture content	%	88.52	90.36	91.60		38.57	39.84
						AVERAGE PLASTIC LIMIT	
						39	

LIQUID LIMIT (LL%)	PASSING SIEVE %		
	2.00mm (no 10)	0.425mm (no 40)	0.075mm (no 200)
90			
PLASTIC LIMIT (PL %)	89	87	86
39	PLASTICITY MODULUS		
PLASTICITY INDEX (P.I)			
51	SOIL CLASSIFICATION (AASHTO)		
	A-7-5(20)		



40.3 Modified Proctor Test

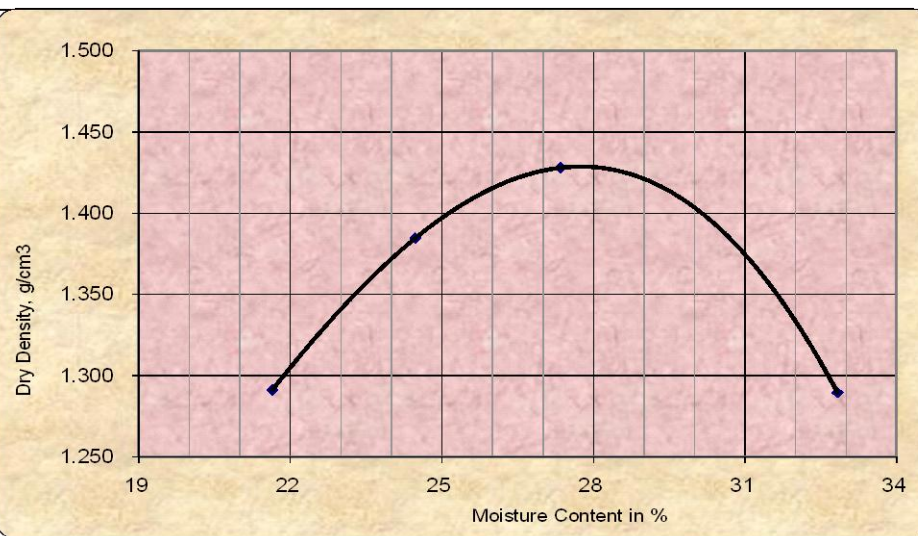
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:- ARABS#40

Depth Sampled:- 80 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4495	4640	4730	4630
C	Wt. of Mold	grams	3006	3006	3006	3006
D	Wt. Wet Soil	grams	1489	1634	1724	1624
E	Volume of Mold	cu.cm.	948	948	948	948
F	Wet Density	gr/cu.cm.	1.57	1.72	1.82	1.71
G	Container	No.	G14	A12	F43	F33
H	Wt. Cont + Wet soil	grams	224.82	285.61	284.17	247.09
I	Wt. Cont + Dry soil	grams	194.03	237.64	233.17	196.40
J	Weight of Water	grams	30.79	47.97	51.00	50.69
K	Weight of Container	grams	51.75	41.64	46.67	41.98
L	Weight of Dry Soil	grams	142.28	196.00	186.50	154.42
M	Moisture Content	%	21.6	24.5	27.3	32.8
N	Dry Density	gr/cu.cm.	1.291	1.385	1.428	1.290

Maximum Dry Density(MDD)=1.43g/cc, Optimum Moisture Content(OMC)28.0%



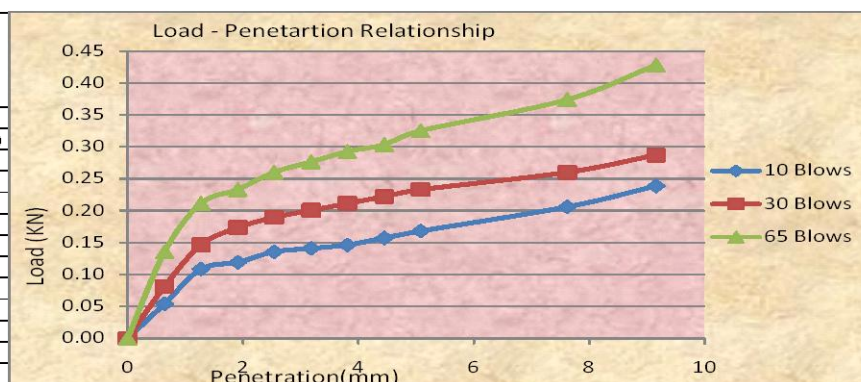
40.4 California Bearing Ratio Test

TEST METHOD : AASHTO T- 193

Sample Code-ARABS#40

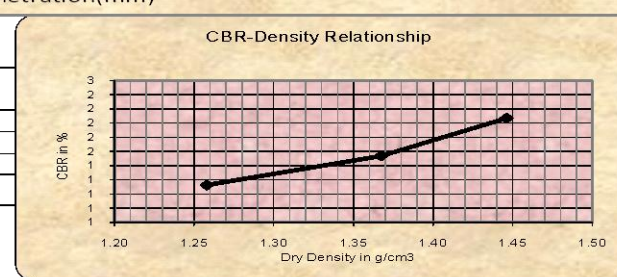
Depth of Sampling:-80cm

Penetration n(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	10	0.05	15	0.08	25	0.14
1.27	20	0.11	27	0.15	39	0.21
1.91	22	0.12	32	0.17	43	0.23
2.54	25	0.14	35	0.19	48	0.26
3.18	26	0.14	37	0.20	51	0.28
3.81	27	0.15	39	0.21	54	0.29
4.45	29	0.16	41	0.22	56	0.30
5.08	31	0.17	43	0.23	60	0.33
7.62	38	0.21	48	0.26	69	0.37
9.16	44	0.24	53	0.29	79	0.43



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.257934	0.14	0.16802	13.2	20	1.026515	0.8401	1
30	1.367392	0.1897	0.23	13.2	20	1.437121	1.1653	1
65	1.446168	0.26016	0.3252	13.2	20	1.970909	1.626	2

CBR at 95% MDD i.e 1.3585 gm/cc and at OMC of 28 % is 1 %



41.1 Grain Size Analysis

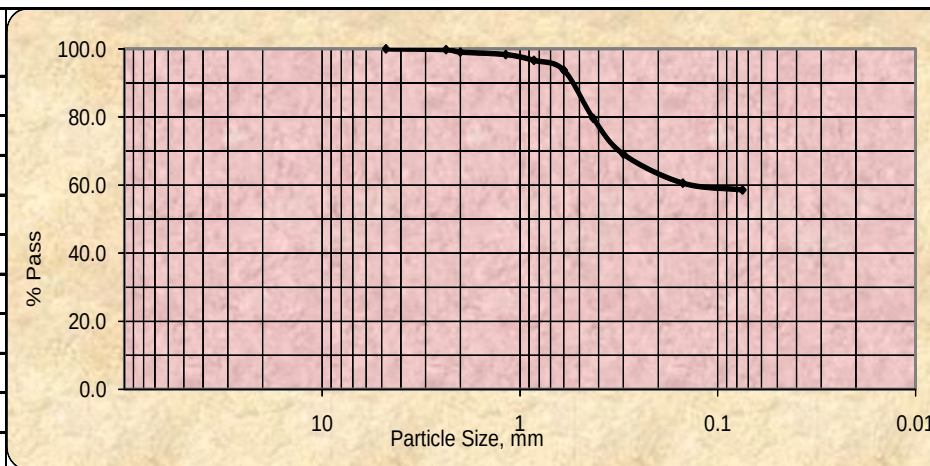
TEST METHOD : AASHTO T - 27

Sample Code:- ORESZATS#41

Depth Sampled:- 110 cm.

Weight Before Washing = 548.3gm, Weight After Washing = 227.4gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
4.75	0.0	0.0	100.0
2.36	1.4	0.3	99.7
2	5.4	1.0	99.0
1.18	9.3	1.7	98.3
0.85	18.6	3.4	96.6
0.6	34.1	6.2	93.8
0.425	112.2	20.5	79.5
0.3	169.8	31.0	69.0
0.15	216.1	39.4	60.6
0.075	227.4	41.5	58.5



41.2 Atterberg Limit Test

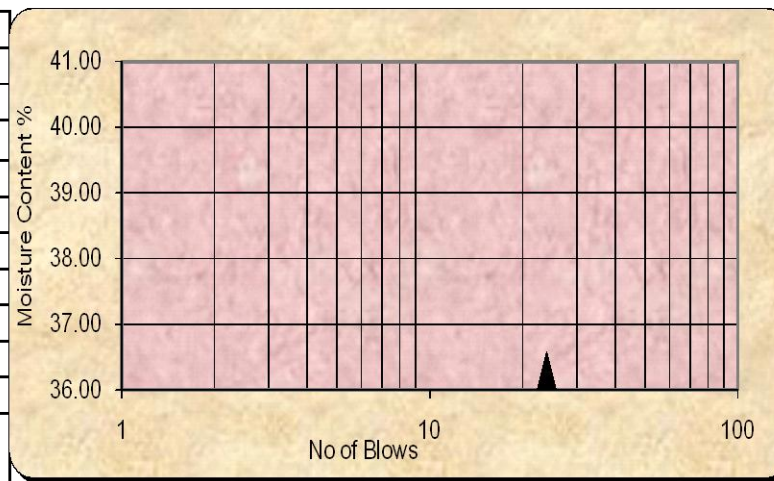
TEST METHOD : AASHTO T89 - T91

Sample Code-ORESZATS#41

Depth of Sampling:-110cm

	LIQUID LIMIT				PLASTIC LIMIT		
	1	2	3	4	1	2	
No. of blows	N						
Tare	n°						
Wt. tare + wet soil	g	NP					
Wt tare + dry soil	g						
Wt. water	g						
Wt. of tare	g						
Wt. of dry soil	g						
No. of blows	N						
Moisture content	%						

LIQUID LIMIT (LL%)=NP, PLASTIC LIMIT (PL %)=NP, PLASTICITY INDEX (P.I.)=LL-PL=0



41.3 Modified Proctor Test

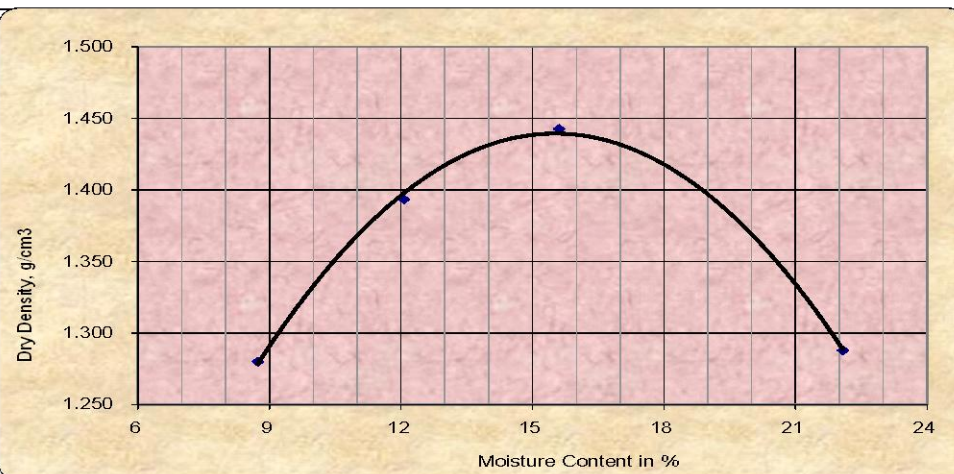
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:- ORESZATS#41

Depth Sampled:- 110 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4325	4485	4585	4495
C	Wt. of Mold	grams	3014	3014	3014	3014
D	Wt. Wet Soil	grams	1311	1471	1571	1481
E	Volume of Mold	cu.cm.	942	942	942	942
F	Wet Density	gr/cu.cm.	1.39	1.56	1.67	1.57
G	Container	No.	E17	E4	F33	G13
H	Wt. Cont + Wet soil	grams	242.86	225.32	276.61	281.27
I	Wt. Cont + Dry soil	grams	226.98	205.84	245.36	238.52
J	Weight of Water	grams	15.88	19.48	31.25	42.75
K	Weight of Container	grams	45.12	44.39	45.07	44.92
L	Weight of Dry Soil	grams	181.86	161.45	200.29	193.60
M	Moisture Content	%	8.7	12.1	15.6	22.1
N	Dry Density	gr/cu.cm.	1.280	1.393	1.443	1.288

Maximum Dry Density(MDD)=1.45g/cc, Optimum Moisture Content(OMC) 16.0%



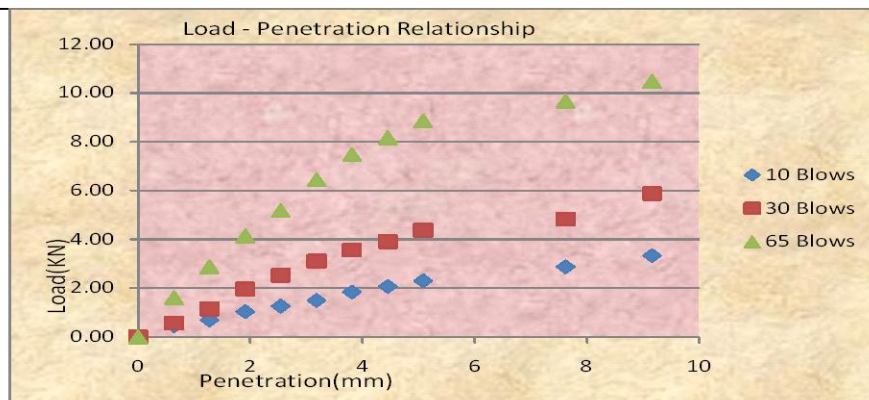
41.4 California Bearing Ration Test

TEST METHOD : AASHTO T- 193

Sample Code-ORESZATS#41

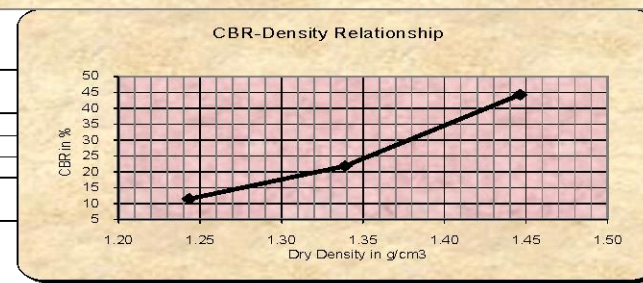
Depth of Sampling:- 110cm

Penetration n(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	4	0.46	5	0.58	14	1.61
1.27	6	0.69	10	1.15	25	2.88
1.91	9	1.04	17	1.96	36	4.14
2.54	11	1.27	22	2.53	45	5.18
3.18	13	1.50	27	3.11	56	6.45
3.81	16	1.84	31	3.57	65	7.48
4.45	18	2.07	34	3.91	71	8.17
5.08	20	2.30	38	4.37	77	8.86
7.62	25	2.88	42	4.83	84	9.67
9.16	29	3.34	51	5.87	91	10.47



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.243397	1.27	2.302	13.2	20	9.591667	11.51	12
30	1.338861	2.5322	4.37	13.2	20	19.18333	21.869	22
65	1.446257	5.1795	8.8627	13.2	20	39.23864	44.3135	44

CBR at 95% MDD i.e 1.3775 gm/cc and at OMC of 16 % is 30 %



42.1 Grain Size Analysis

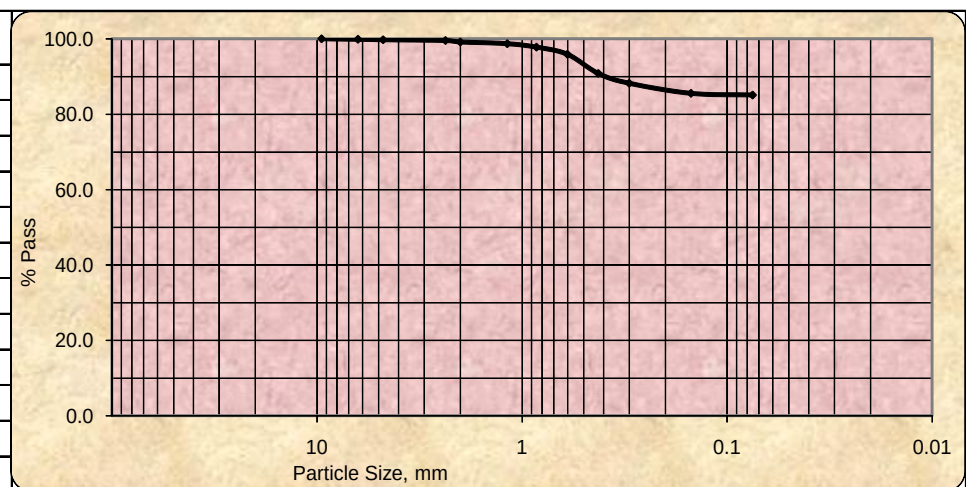
TEST METHOD : AASHTO T - 27

Sample Code:-ORESZAAS#42

Depth Sampled:- 120 cm.

Weight Before Washing = 606.4gm, Weight After Washing= 90.2gm

ASTM SIEVE (mm)	CUMULATIVE WT. RETAINED (gm)	CUMULATIVE % RETAINED	% PASS
9.5	0.0	0.0	100.0
6.3	0.8	0.1	99.9
4.75	1.2	0.2	99.8
2.36	2.5	0.4	99.6
2	5.1	0.8	99.2
1.18	7.6	1.3	98.7
0.85	13.3	2.2	97.8
0.6	24.7	4.1	95.9
0.425	55.7	9.2	90.8
0.3	71.3	11.8	88.2
0.15	87.5	14.4	85.6
0.075	90.2	14.9	85.1

**42.2 ATTERBERG LIMIT TEST**

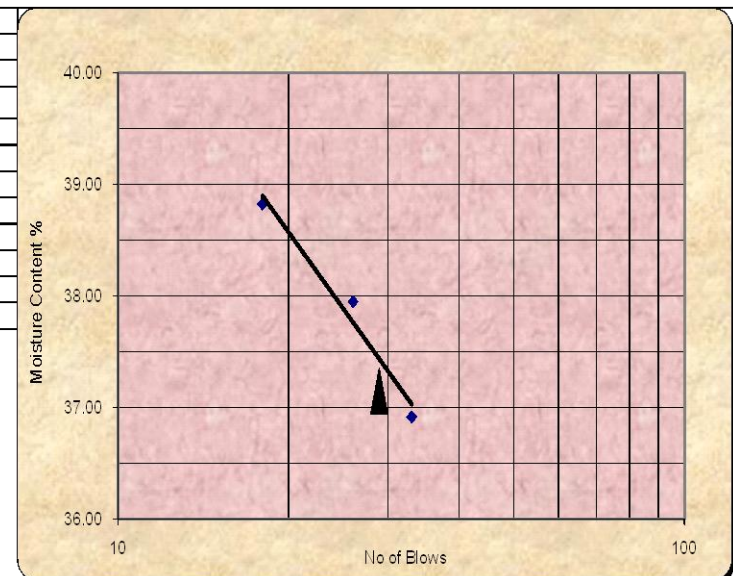
TEST METHOD : AASHTO T89 - T91

Sample Code:-ORESZAAS#42

Depth Sampled:- 120 cm.

		LIQUID LIMIT				PLASTIC LIMIT	
		1	2	3	4	1	2
No. of blows	N	33	26	18			
Tare	n°	E94	E65	A64		A46	A84
Wt. tare + wet soil	g	29.60	30.28	36.19		23.19	21.69
Wt. tare + dry soil	g	25.96	26.17	30.84		21.84	20.38
Wt. water	g	3.64	4.11	5.35		1.35	1.31
Wt. of tare	g	16.1	15.34	17.06		16.84	15.39
Wt. of dry soil	g	9.86	10.83	13.78		5.00	4.99
No. of blows	N	33	26	18			
Moisture content	%	36.92	37.95	38.82		27.00	26.25
						AVERAGE PLASTIC LIMIT	
						27	

LIQUID LIMIT (LL%)	PASSING SIEVE %		
	2.00mm (no 10)	0.425mm (no 40)	0.075mm (no 200)
38			
PLASTIC LIMIT (PL %)	99	91	85
27	PLASTICITY MODULUS		
PLASTICITY INDEX (P.I)			
11	SOIL CLASSIFICATION (AASHTO)		
	A-6(8)		



42.3 Modified Proctor Test

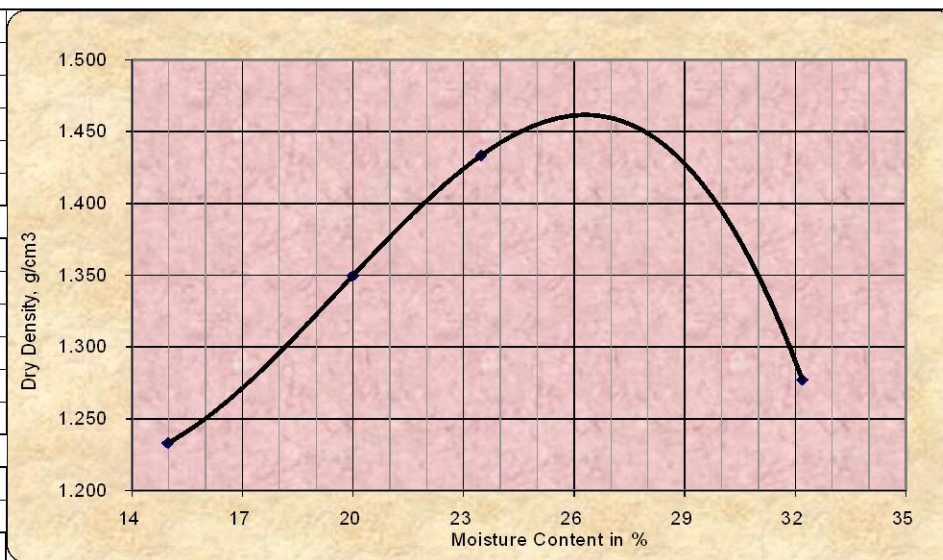
TEST METHOD : AASHTO T- 180 METHOD A

Sample Code:-ORESZAASS#42

Depth Sampled:- 120 cm.

A	Mold	No.	1	2	3	4
B	Wt. of Mold + Wet Soil	grams	4385	4585	4734	4653
C	Wt. of Mold	grams	2980	2980	2980	2980
D	Wt. Wet Soil	grams	1405	1605	1754	1673
E	Volume of Mold	cu.cm.	991	991	991	991
F	Wet Density	gr/cu.cm.	1.42	1.62	1.77	1.69
G	Container	No.	A9	F12	F63	F31
H	Wt. Cont + Wet soil	grams	319.30	312.60	274.49	306.60
I	Wt. Cont + Dry soil	grams	287.25	273.72	236.56	243.68
J	Weight of Water	grams	32.05	38.88	37.93	62.92
K	Weight of Container	grams	73.16	79.26	74.99	48.23
L	Weight of Dry Soil	grams	214.09	194.46	161.57	195.45
M	Moisture Content	%	15.0	20.0	23.5	32.2
N	Dry Density	gr/cu.cm.	1.233	1.350	1.433	1.277

Maximum Dry Density(MDD)=1.463g/cc, Optimum Moisture Content(OMC)26.5%

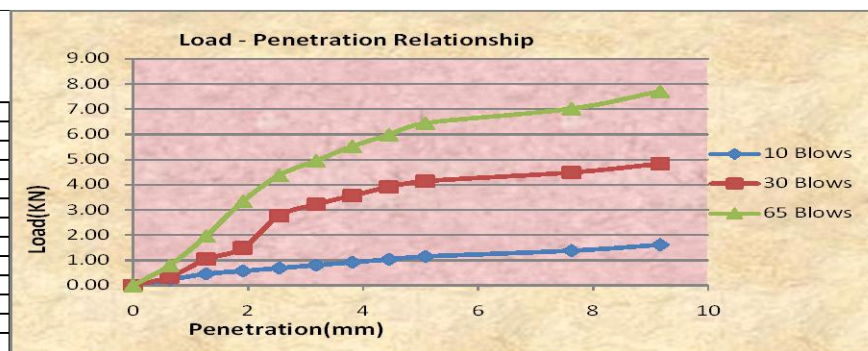
**42.4 California Bearing Ratio Test**

TEST METHOD : AASHTO T- 193

Sample Code-ORESZAASS#42

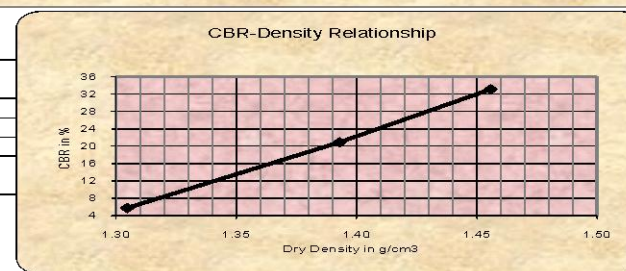
Depth of Sampling:-120cm

Penetration n(mm)	10 Blows		30 Blows		65 Blows	
	Dial RDG	Load(KN)	Dial RDG	Load(KN)	Dial RDG	Load(KN)
0	0	0.00	0	0.00	0	0.00
0.64	2	0.23	3	0.35	7	0.81
1.27	4	0.46	9	1.04	17	1.96
1.91	5	0.58	13	1.50	29	3.34
2.54	6	0.69	24	2.76	38	4.37
3.18	7	0.81	28	3.22	43	4.95
3.81	8	0.92	31	3.57	48	5.52
4.45	9	1.04	34	3.91	52	5.99
5.08	10	1.15	36	4.14	56	6.45
7.62	12	1.38	39	4.49	61	7.02
9.16	14	1.61	42	4.83	67	7.71



No Of Blows	DD	Load		Standard Load		CBR		CBR
		2.54	5.08	2.54	5.08	2.54	5.08	
10	1.304588	0.69	1.151	13.2	20	5.231818	5.755	6
30	1.392903	2.7624	4.14	13.2	20	20.92727	20.718	21
65	1.455693	4.3738	6.4456	13.2	20	33.13485	32.228	33

CBR at 95% MDD i.e 1.38985 gm/cc and at OMC of 28.5 % is 20 %



Appendix - B Details of the SPSS Regression Analysis Outputs

1) Correlation For well(GW) and poorly graded(GP) soil with DCP

Model 1 Correlation Between CBR and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.747061398	0.558100732	0.502863324	0.414

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	4.345	.170			25.522	.000
DCP	-.033	.010	-.747	.235	-3.179	.013

Model 7 Correlation Between MDD and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.810858397	0.657491339	0.614677757	0.258

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	1.842	.145			12.669	.000
DCP	-.040	.010	-.811	.207	-3.919	.004

Model 12 Correlation Between OMC and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.651001424	0.423802854	0.35177821	0.041

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	9.512	3.946			2.410	.042
DCP	.680	.280	.651	.268	2.426	.041

2) Correlation For gravell clay(GC) soil

Model 2 Correlation Between CBR and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.916915998	0.840734947	0.808881937	0.586308292

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	4.403	.168			26.274	.000
DCP	-.040	.008	-.917	.178	-5.138	.004

Model 8 Correlation Between MDD and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.164780126	0.02715249	-0.216059388	0.443

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	1.848	.235			7.848	.001

Model 13 Correlation Between OMC and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.154647174	0.023915748	-0.171301102	11.851

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	17.836	3.387			5.266	.003
DCP	-.055	.156	-.155	.442	-.350	.741

3) Correlation For Low plastic silt(ML) and sandy silty(SM) soil

Model 3 Correlation Between CBR and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.936136785	0.876352082	0.845440102	0.921

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	1.194	.379			3.147	.035
DCP	.081	.015	.936	.176	5.324	.006

Model A Correlation Between MDD and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.848467643	0.719897341	0.649871675	0.064

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	1.585	.045			34.996	.000
DCP	-.007	.002	-.848	.265	-3.206	.033

Model 14 Correlation Between OMC and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.621300895	0.386014803	0.232518504	11.56

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	27.825	4.758			5.848	.004
DCP	-.303	.191	-.621	.392	-1.586	.188

4) Correlation for Highly Plasti Silt(MH) Soil

Model 4 Correlation Between CBR and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.9383073	0.88042064	0.85650477	0.166

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	4.517	.370			12.223	.000
DCP	-.150	.025	-.938	.155	-6.067	.002

Model 9 Correlation Between MDD and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.70854042	0.50202952	0.40243543	0.138

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	1.344	.063			21.226	.000
DCP	.008	.003	.709	.316	2.245	.075

Model 15 Correlation Between OMC and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.48002219	0.23042130	0.07650556	4.109

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	22.702	4.272			5.314	.003
DCP	.305	.249	.480	.392	1.224	.276

5) Correlation of Black cotton clay(CH) soil

Model 5 Correlation Between CBR and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.95161623	0.90557344	0.87409793	0.522

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	1.812	.234			7.756	.004
DCP	-.069	.013	-.952	.177	-5.364	.013

Model 10 Correlation Between MDD and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.99964034	0.99928081	0.99904108	23.679

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	1.660	.004			466.235	.000
DCP	-.009	.000	-1.000	.015	-64.563	.000

Model 16 Correlation Between OMC and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.99795891	0.99592199	0.99456265	0.644

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	18.355	.356			51.510	.000
DCP	.359	.013	.998	.037	27.068	.000

6) Correlation of Clay(CH & CL) soil

Model 6 Correlation Between CBR and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.872479219	0.761219988	0.701524985	0.243

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	3.559	.386			9.218	.001
DCP	-.156	.044	-.872	.244	-3.571	.023

Model 11 Correlation Between MDD and DCP

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.237281654	0.056302588	-0.179621771	0.425

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	1.450	.036			40.417	.000
DCP	-.001	.002	-.237	.486	-.489	.651

Model 17 Correlation Between OMC and DCP

Model Summary

Multiple R	R Square	Adjusted R Square	Std. Error of the Estimate
0.739924758	0.547488648	0.434360811	1.649

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta	Std. Error		
(Constant)	18.611	2.615			7.117	.002

Appendix - C Field DCP Test Results

Field DCP test data from different location of Ethiopia										
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm			
1	125	OASS#1	X	Y						
							0	86	0	
							1	113	27	
							2	140	27	
							3	162	22	
							4	185	23	
							5	206	21	
							6	227	21	
							7	248	21	
							8	272	24	
							9	292	20	
							10	312	20	
							11	332	20	
							12	352	20	
							13	371	19	
							14	390	19	
							15	410	20	
							16	430	20	
							17	452	22	
							18	475	23	
							19	507	32	
							20	544	37	
							21	588	44	
							22	627	39	
				23	678	51				
				24	750	72				
						26.56				

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
2	52.1	OESAS#2	470090	866458	0	53	0
					1	72	19
					2	83	11
					3	94	11
					4	104	10
					5	114	10
					6	119	5
					7	124	5
					8	127	3
					9	129	2
					10	132	3
					11	134	2
					12	138	4
					13	142	4
					14	144	2
					15	147	3
					16	150	3
					17	151	1
					18	154	3
					19	157	3
					20	161	4
					21	167	6
					22	174	7
					23	180	6
					24	186	6
					25	195	9
					26	202	7
					27	215	13
					28	224	9
					29	235	11
					30	247	12
					31	258	11
					32	270	12
					33	283	13
					34	296	13
					35	308	12
36	321	13					
							7.24

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
3	86	OESAS#3	470079	866411	0	70	0
					1	83	13
					2	91	8
					3	103	12
					4	116	13
					5	126	10
					6	139	13
					7	150	11
					8	161	11
					9	170	9
					10	179	9
					11	185	6
					12	192	7
					13	200	8
					14	206	6
					15	210	4
					16	220	10
					17	225	5
					18	235	10
					19	251	16
					20	272	21
					21	304	32
					22	332	28
					23	371	39
					24	442	71
					25	480	38
					26	518	38
					27	540	22
					28	555	15
					29	567	12
					30	575	8
					31	582	7
					32	592	10
					33	602	10
					34	612	10
					35	622	10
					36	632	10
					37	642	10
					38	648	6
					39	652	4
					40	654	2
					41	660	6
							14.39

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
4	98.2	OESOS#4	549660	947363	0	154	0
					1	184	30
					2	224	40
					3	257	33
					4	285	28
					5	314	29
					6	338	24
					7	363	25
					8	386	23
					9	406	20
					10	429	23
					11	453	24
					12	477	24
					13	502	25
					14	525	23
					15	549	24
					16	572	23
					17	594	22
					18	615	21
					19	637	22
					20	659	22
					21	680	21
					22	700	20
					23	722	22
					24	740	18
					25	765	25
					26	785	20
					27	807	22
					28	830	23
					29	850	20
					30	877	27
					31	904	27
					32	933	29
					33	957	24
34	982	25					
							23.66

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
5	92.1	WCS#5			0	69	0
					1	90	21
					2	110	20
					3	127	17
					4	147	20
					5	165	18
					6	184	19
					7	203	19
					8	221	18
					9	239	18
					10	256	17
					11	273	17
					12	291	18
					13	307	16
					14	325	18
					15	342	17
					16	357	15
					17	373	16
					18	386	13
					19	401	15
					20	415	14
					21	428	13
					22	445	17
					23	461	16
					24	483	22
					25	501	18
					26	518	17
					27	540	22
					28	555	15
					29	572	17
					30	588	16
					31	606	18
					32	625	19
					33	643	18
					34	660	17
					35	678	18
					36	695	17
					37	713	18
					38	731	18
					39	743	12
					40	766	23
					41	785	19
					42	807	22
					43	830	23
					44	849	19
					45	869	20
					46	888	19
					47	904	16
48	921	17					
							17.75

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
6	57.1	OESOS#6	X	Y			
					0	63	0
					1	73	10
					2	83	10
					3	92	9
					4	102	10
					5	111	9
					6	121	10
					7	129	8
					8	137	8
					9	144	7
					10	151	7
					11	157	6
					12	164	7
					13	171	7
					14	178	7
					15	186	8
					16	193	7
					17	198	5
					18	202	4
					19	207	5
					20	209	2
					21	211	2
					22	214	3
					23	217	3
					24	222	5
					25	226	4
					26	231	5
					27	236	5
					28	240	4
					29	243	3
					30	248	5
					31	252	4
					32	257	5
					33	262	5
					34	268	6
					35	273	5
					36	278	5
					37	283	5
					38	290	7
					39	296	6
					40	302	6
					41	308	6
					42	314	6
					43	320	6
					44	327	7
					45	333	6
					46	340	7
					47	347	7
					48	353	6
					49	359	6
					50	365	6
		51	371	6			
6.04							

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
7	80.5	OESOS#7	542026	963438	0	74	0
					1	91	17
					2	103	12
					3	114	11
					4	125	11
					5	135	10
					6	145	10
					7	158	13
					8	169	11
					9	180	11
					10	193	13
					11	205	12
					12	215	10
					13	227	12
					14	237	10
					15	246	9
					16	255	9
					17	263	8
					18	271	8
					19	280	9
					20	291	11
					21	304	13
					22	315	11
					23	327	12
					24	338	11
					25	350	12
					26	360	10
					27	370	10
					28	380	10
					29	390	10
					30	402	12
					31	412	10
					32	423	11
					33	434	11
					34	445	11
					35	455	10
					36	466	11
					37	476	10
					38	485	9
					39	494	9
					40	502	8
					41	510	8
					42	519	9
					43	524	5
					44	530	6
					45	538	8
					46	543	5
					47	553	10
					48	558	5
					49	564	6
					50	570	6
					51	576	6
					52	583	7
					53	591	8
					54	599	8
55	605	6					
9.65							

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
8	50	OESMS#8	516122	949747	0	51	0
					1	57	15
					2	61	15
					3	66	15
					4	68	17
					5	71	17
					6	74	17
					7	77	18
					8	80	15
					9	83	15
					10	85	15
					11	90	16
					12	93	16
					13	94	16
					14	100	16
					15	103	16
					16	107	16
					17	111	16
					18	114	16
					19	116	16
					20	118	16
					21	121	16
					22	127	13
					23	130	13
					24	134	13
					25	137	13
					26	140	13
					27	143	13
					28	147	13
					29	151	15
					30	154	15
					31	158	15
					32	161	15
					33	163	15
					34	167	15
					35	170	15
					36	172	15
					37	177	15
					38	182	18
					39	186	18
					40	191	18
					41	194	18
					42	197	18
					43	200	18
					44	204	18
					45	210	18
					46	214	18
					47	217	18
					48	220	18
					49	225	18
					50	230	18
					51	235	18
					52	240	18
					53	247	18
					54	253	18
					55	260	18
					56	265	18
					57	268	18
					58	270	18
					59	273	18
					60	275	18
15.98							

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
9	52	OESMS#9	516171	949985	0	60	0
					1	70	10
					2	77	7
					3	84	7
					4	89	5
					5	92	3
					6	95	3
					7	99	4
					8	104	5
					9	113	9
					10	117	4
					11	125	8
					12	133	8
					13	137	4
					14	143	6
					15	148	5
					16	153	5
					17	156	3
					18	165	9
					19	169	4
					20	171	2
					21	175	4
					22	178	3
					23	183	5
					24	187	4
					25	191	4
					26	195	4
					27	199	4
					28	203	4
					29	208	5
					30	211	3
					31	215	4
					32	220	5
					33	224	4
					34	228	4
					35	232	4
					36	237	5
					37	241	4
					38	246	5
					39	251	5
					40	255	4
					41	260	5
					42	264	4
					43	268	4
					44	273	5
					45	277	4
					46	281	4
					47	286	5
					48	291	5
					49	296	5
					50	301	5
					51	305	4
					52	310	5
					53	315	5
54	320	5					
							4.73

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
10	52	OESMS#10	516267	949930	0	59	0
					1	71	12
					2	79	8
					3	82	3
					4	89	7
					5	92	3
					6	96	4
					7	101	5
					8	105	4
					9	109	4
					10	114	5
					11	120	6
					12	125	5
					13	130	5
					14	134	4
					15	135	1
					16	142	7
					17	146	4
					18	152	6
					19	156	4
					20	163	7
					21	167	4
					22	171	4
					23	177	6
					24	181	4
					25	187	6
					26	190	3
					27	194	4
					28	199	5
					29	201	2
					30	206	5
					31	211	5
					32	216	5
					33	221	5
					34	225	4
					35	229	4
					36	234	5
					37	238	4
					38	242	4
					39	247	5
					40	252	5
					41	256	4
					42	260	4
					43	265	5
					44	269	4
					45	272	3
					46	279	7
					47	283	4
					48	289	6
					49	292	3
					50	299	7
					51	300	1
					52	304	4
					53	309	5
					54	312	3
					55	316	4
					56	320	4
4.66							

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
11	50	ARNSS#11	573318	1079843	0	52	0
					1	63	11
					2	70	7
					3	76	6
					4	80	4
					5	86	6
					6	92	6
					7	98	6
					8	104	6
					9	108	4
					10	113	5
					11	117	4
					12	122	5
					13	127	5
					14	131	4
					15	135	4
					16	140	5
					17	145	5
					18	151	6
					19	156	5
					20	160	4
					21	165	5
					22	169	4
					23	175	6
					24	180	5
					25	185	5
					26	189	4
					27	195	6
					28	200	5
					29	204	4
					30	208	4
					31	213	5
					32	218	5
					33	223	5
					34	226	3
					35	231	5
					36	236	5
					37	240	4
					38	245	5
					39	249	4
					40	252	3
					41	258	6
					42	263	5
					43	268	5
					44	272	4
					45	278	6
					46	284	6
					47	289	5
					48	294	5
					49	300	6
5.06							

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			107	Y			
12	120	AROKS#12	604638	1112031	0	525	0
					10	542	17
					11	554	12
					12	565	11
					13	580	15
					14	590	10
					15	603	13
					16	613	10
					17	623	10
					18	633	10
					19	643	10
					20	653	10
					21	663	10
					22	673	10
					23	683	10
					24	691	8
					25	700	9
					26	711	11
					27	721	10
					28	731	10
					29	741	10
					30	751	10
					31	764	13
					32	775	11
					33	785	10
					34	798	13
					35	810	12
					36	821	11
					37	832	11

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
13	100	AROKS#13	x	Y			
			600732	1175926			
					0	157	0
					1	167	10
					2	175	8
					3	185	10
					4	195	10
					5	204	9
					6	213	9
					7	223	10
					8	233	10
					9	243	10
					10	253	10
					11	262	9
					12	272	10
					13	282	10
					14	290	8
						9.50	

Field DCP test data from different location of Ethiopia										
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm			
14	120	ARWZK#14	x	Y	3	111	0			
			588727	1197153						
								4	131	20
								5	141	10
								6	149	8
								7	161	12
								8	174	13
								9	185	11
								10	196	11
								11	207	11
								12	219	12
								13	231	12
								14	244	13
								15	256	12
								16	270	14
								17	283	13
								18	296	13
								19	312	16
								20	327	15
								21	342	15
								22	355	13
								23	372	17
								24	387	15
								25	402	15
								26	421	19
								27	439	18
								28	457	18
								29	474	17
								30	493	19
								31	511	18
								32	531	20
								33	553	22
								34	576	23
								35	600	24
								36	622	22
								37	648	26
								38	679	31

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
15	60	ARWZBS#15	589706	1227710	0	59	0
					1	65	6
					2	71	6
					3	76	5
					4	81	5
					5	86	5
					6	91	5
					7	96	5
					8	99	3
					9	104	5
					10	106	2
					11	108	2
					12	112	4
					13	116	4
					14	119	3
					15	122	3
					16	125	3
					17	128	3
					18	132	4
					19	137	5
					20	142	5
					21	147	5
					22	152	5
					23	156	4
					24	160	4
					25	165	5
					26	170	5
					27	173	3
					28	176	3
					29	180	4
					30	184	4
					31	189	5
					32	194	5
					33	199	5
					34	206	7
					35	211	5
					36	216	5
					37	222	6
					38	228	6
					39	234	6
					40	240	6
					41	245	5
					42	251	6
					43	256	5
					44	262	6
					45	268	6
					46	272	4
					47	277	5
					48	284	7
					49	288	4
					50	293	5
					51	297	4
					52	301	4
					53	305	4
					54	310	5
					55	314	4
56	319	5					
							4.56

Field DCP test data from different location of Ethiopia						
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm
			x	Y		
16	110	AFRAWS#16	650699	1244223		215
						0
						250
					9	285
					10	320
					11	355
					12	390
						35.00

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
17	150	AFRNMS#17	x	Y			
			667339	1249966	1	670	0
					2	698	28
					3	735	37
					4	775	40
					5	810	35
					6	840	30
					7	877	37
					8	913	36
					9	947	34
					10	985	38
						35.00	

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location				
			x	Y	No of Blow	Depth of penetration in mm	
18	60	ORESSMS#18	598088	985115		Depth of penetration in mm	
					0	99	0
					3	106	7
					4	113	7
					5	120	7
					6	126	6
					7	133	7
					8	140	7
					9	147	7
					10	150	3
					11	152	2
					12	152	0
					13	154	2
					14	157	3
					15	159	2
					16	163	4
					17	167	4
					18	172	5
					19	177	5
					20	186	9
					21	193	7
					22	199	6
					23	204	5
					24	209	5
					25	214	5
					26	219	5
					27	224	5
					28	229	5
					29	234	5
					30	238	4
					31	242	4
					32	243	1
					33	247	4
					34	251	4
					35	256	5
					36	261	5
					37	267	6
					39	274	7
					40	278	4
					41	282	4
					42	285	3
					43	288	3
44	291	3					
						4.57	

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia						
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm
			X	Y		
1	80	ORWASS#20	460540	794408	0	56
					1	80
					2	99
					3	119
					4	139
					5	159
					6	179
					7	199
					8	224
					9	261
					10	279
					11	293
					12	313
					13	326
					14	339
					15	352
					16	366
					17	379
					18	392
					19	406
					20	420
					21	434
					22	452
					23	470
					24	493
					25	517
					26	543
					27	566
					28	583
					29	598
					30	613
					31	630
					32	645
					33	661
					34	677
					35	706
					36	745
					37	764
					38	775
						18.92105263

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
2	80	ORAZOS#21	X	Y			
					0	71	0
					1	89	18
					2	99	10
					3	109	10
					4	120	11
					5	130	10
					6	141	11
					7	153	12
					8	163	10
					9	172	9
					10	180	8
					11	190	10
					12	195	5
					13	203	8
					14	211	8
					15	219	8
					16	229	10
					17	237	8
					18	245	8
					19	253	8
					20	261	8
					21	269	8
					22	275	6
					23	283	8
					24	290	7
					25	298	8
					26	305	7
					27	313	8
					28	319	6
					29	326	7
					30	333	7
					31	341	8
					32	349	8
					33	357	8
					34	364	7
					35	373	9
					36	382	9
					37	392	10
					38	400	8
					39	410	10
					40	416	6
					41	424	8
					42	437	13
					43	439	2
					44	448	9
					45	456	8
					46	462	6
					47	469	7
					48	476	7
					49	482	6
					50	487	5
					51	494	7
		52	500	6			
							8.25

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
3	80	ORAZOS#22	507399	898810	0	90	0
					1	110	20
					2	140	30
					3	159	19
					4	176	17
					5	195	19
					6	217	22
					7	246	29
					8	277	31
					9	307	30
					10	336	29
					11	362	26
					12	382	20
					13	422	40
					14	451	29
					15	479	28
					16	506	27
					17	534	28
					18	565	31
					19	594	29
					20	625	31
					21	660	35
					22	692	32
					23	730	38
					24	770	40
					25	810	40
					26	850	40
					27	880	30
					28	910	30
					29	946	36
					30	975	29
29.5							

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
4	120	ORESAS#23	X	Y			
			476063	869082			

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
5	100	ORESAS#24	455215	869257	0	66	0
					1	85	19
					2	98	13
					3	109	11
					4	120	11
					5	128	8
					6	136	8
					7	145	9
					8	153	8
					9	162	9
					10	171	9
					11	177	6
					12	187	10
					13	196	9
					14	204	8
					15	213	9
					16	222	9
					17	231	9
					18	240	9
					19	249	9
					20	256	7
					21	265	9
					22	273	8
					23	282	9
					24	290	8
					25	300	10
					26	310	10
					27	316	6
					28	325	9
					29	332	7
					30	340	8
					31	347	7
					32	354	7
					33	361	7
					34	370	9
					35	378	8
					36	386	8
					37	394	8
					38	402	8
					39	412	10
					40	424	12
					41	436	12
					42	449	13
					43	460	11
					44	471	11
					45	482	11
					46	494	12
					47	509	15
					48	522	13
					49	535	13
					50	549	14
					51	562	13
					52	577	15
					53	589	12
					54	600	11
					55	610	10
					56	620	10
					57	630	10
					58	640	10
							9.896551724

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			X	Y			
6	50	ORESAS#25	502042	969910	0	73	0
					1	83	10
					2	93	10
					3	101	8
					4	109	8
					5	117	8
					6	125	8
					7	131	6
					8	139	8
					9	148	9
					10	156	8
					11	164	8
					12	171	7
					13	179	8
					14	187	8
					15	195	8
					16	201	6
					17	212	11
					18	221	9
					19	231	10
					20	241	10
					21	249	8
					22	256	7
					23	260	4
					24	267	7
					25	272	5
					26	276	4
					27	281	5
					28	289	8
					29	294	5
					30	301	7
					31	305	4
					32	308	3
					33	315	7
					34	319	4
					35	324	5
					36	330	6
					37	335	5
					38	342	7
					39	346	4
					40	354	8
					41	359	5
6.04							

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
7	50	ORESAS#26	X	Y			
					0	88	0
					1	114	26
					2	129	15
					3	149	20
					4	165	16
					5	179	14
					6	191	12
					7	201	10
					8	210	9
					9	215	5
					10	218	3
					11	224	6
					12	229	5
					13	235	6
					14	240	5
					15	244	4
					16	250	6
					17	260	10
					18	269	9
					19	273	4
					20	286	13
					21	290	4
					22	292	2
					23	300	8
					24	302	2
					25	312	10
					26	315	3
					27	322	7
					28	341	19
					29	354	13
					30	364	10
					31	371	7
					32	382	11
					33	387	5
					34	393	6
					35	398	5
					36	402	4
					37	403	1
					38	409	6
					39	416	7
					40	422	6
					41	429	7
					42	437	8
					43	444	7
					44	452	8
					45	458	6
					46	464	6
					47	467	3
					48	470	3
					49	475	5
					50	481	6
					51	485	4
		52	486	1			
7.653846154							

CORRELATION OF CBR, OMC AND MDD WITH FIELD DCP TEST FOR LOW VOLUME ROAD IN ETHIOPIA

Field DCP test data from different location of Ethiopia										
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm			
8	70	ORAZGS#27	X	Y	0	76	0			
			522686	890497						
								1	93	17
								2	105	12
								3	110	5
								4	133	23
								5	143	10
								6	154	11
								7	167	13
								8	179	12
								9	190	11
								10	202	12
								11	218	16
								12	232	14
								13	249	17
								14	259	10
								15	272	13
								16	284	12
								17	295	11
								18	305	10
								19	315	10
								20	325	10
								21	336	11
								22	347	11
								23	357	10
								24	369	12
								25	379	10
								26	389	10
								27	400	11
								28	409	9
								29	419	10
								30	427	8
								31	437	10
								32	445	8
								33	452	7
								34	460	8
								35	468	8
								36	475	7
								37	483	8
								38	492	9
39	500	8								
							10.87			

Field DCP test data from different location of Ethiopia										
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm			
9	80	ORAZCHS#28	X	Y	0	90	0			
			527255	836932						
								1	114	24
								2	130	16
								3	145	15
								4	160	15
								5	175	15
								6	185	10
								7	200	15
								8	213	13
								9	225	12
								10	237	12
								11	250	13
								12	261	11
								13	275	14
								14	289	14
								15	302	13
								16	316	14
								17	330	14
								18	344	14
								19	360	16
								20	373	13
								21	387	14
								22	401	14
								23	415	14
								24	427	12
								25	440	13
								26	453	13
								27	464	11
								28	476	12
								29	488	12
								30	500	12
31	512	12								
							13.1875			

Field DCP test data from different location of Ethiopia										
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm			
10	80	ORWAZFS#29	X	Y	0	67	0			
			463972	791727						
								1	97	30
								2	124	27
								3	151	27
								4	177	26
								5	205	28
								6	231	26
								7	255	24
								8	278	23
								9	300	22
								10	321	21
								11	341	20
								12	363	22
								13	387	24
								14	409	22
								15	430	21
								16	451	21
								17	471	20
								18	491	20
19	510	19								
23.32										

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
11	80	ORWAZSS#30	x	Y			
			469785	817150	0	50	0
					1	65	15
					2	78	13
					3	90	12
					4	101	11
					5	114	13
					6	124	10
					7	137	13
					8	150	13
					9	161	11
					10	172	11
					11	183	11
					12	193	10
					13	203	10
					14	213	10
					15	223	10
					16	233	10
					17	243	10
					18	253	10
					19	263	10
					20	273	10
					21	283	10
					22	294	11
					23	305	11
					24	316	11
					25	326	10
					26	337	11
					27	348	11
					28	358	10
					29	368	10
30	379	11					
						10.97	

Field DCP test data from different location of Ethiopia							
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			107	Y			
12	80	SRHZSS#31	434071	759599	0	75	0
					1	91	16
					2	104	13
					3	116	12
					4	128	12
					5	141	13
					6	158	17
					7	172	14
					8	189	17
					9	204	15
					10	221	17
					11	236	15
					12	251	15
					13	266	15
					14	289	23
					15	306	17
					16	321	15
					17	336	15
					18	347	11
					19	361	14
					20	376	15
					21	390	14
					22	403	13
					23	417	14
					24	433	16
					25	451	18
					26	468	17
					27	484	16
					28	500	16
					29	516	16
					30	532	16
					31	546	14
32	559	13					
15.13							

Field DCP test data from different location of Ethiopia										
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm			
13	120	ORWAZSS#32	x	Y	0	65	0			
			436195	812680						
								1	111	46
								2	127	16
								3	150	23
								4	172	22
								5	194	22
								6	214	20
								7	244	30
								8	274	30
								9	304	30
								10	335	31
								11	367	32
								12	402	35
								13	440	38
								14	475	35
								15	512	37
								16	547	35
								17	580	33
								18	619	39
								19	660	41
								20	700	40
			21	740				40		
32.14285714										

Field DCP test data from different location of Ethiopia										
S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm			
14	100	ORESBS#33	x	Y	0	51	0			
			493693	920142						
								1	73	22
								2	90	17
								3	100	10
								4	110	10
								5	118	8
								6	127	9
								7	136	9
								8	146	10
								9	155	9
								10	165	10
								11	175	10
								12	185	10
								13	195	10
								14	205	10
								15	215	10
								16	225	10
								17	235	10
								18	245	10
								19	255	10
								20	268	13
								21	285	17
								22	301	16
								23	315	14
								24	332	17
25	346	14								
							11.80			

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
1	80	ORWASLS#34	469918	817226	0	60	
					1	81	21
					2	100	19
					3	110	10
					4	120	10
					5	131	11
					6	143	12
					7	154	11
					8	164	10
					9	176	12
					10	188	12
					11	200	12
					12	210	10
					13	220	10
					14	227	7
					15	236	9
					16	246	10
					17	254	8
					18	264	10
					19	273	9
					20	282	9
					21	290	8
					22	298	8
					23	307	9
					24	316	9
					25	324	8
					26	333	9
					27	341	8
					28	349	8
					29	356	7
					30	363	7
					31	372	9
					32	380	8
					33	389	9
					34	397	8
					35	405	8
					36	413	8
					37	423	10
					38	430	7
					39	438	8
					40	446	8
					41	456	10
					42	465	9
					43	474	9
					44	483	9
					45	491	8
46	500	9					
							9.57

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
2	120	ORWAZSLGK#35	471131	816592	0	86	
					1	100	14
					2	117	17
					3	131	14
					4	146	15
					5	161	15
					6	172	11
					7	182	10
					8	191	9
					9	201	10
					10	211	10
					11	217	6
					12	226	9
					13	234	8
					14	244	10
					15	254	10
					16	264	10
					17	271	7
					18	285	14
					19	294	9
					20	301	7
					21	310	9
					22	316	6
					23	324	8
					24	332	8
					25	340	8
					26	348	8.00
					27	356	8
					28	366	10
					29	374	8
					30	383	9
					31	391	8
					32	401	10
					33	408	7
							9.76

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
3	80	ORWAZSLGS#36	469644	817146	0	45	
					1	63	18
					2	75	12
					3	87	12
					4	101	14
					5	114	13
					6	130	16
					7	145	15
					8	158	13
					9	172	14
					10	186	14
					11	204	18
					12	220	16
					13	240	20
					14	254	14
					15	272	18
					16	285	13
					17	296	11
					18	309	13
					19	322	13
					20	339	17
					21	356	17
					22	372	16
					23	383	11
					24	394	11
					25	403	9
					26	414	11.00
					27	423	9
					28	433	10
					29	444	11
					30	454	10
					31	463	9
					32	473	10
					33	483	10
34	493	10					
							13.18

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
4	120	ORWAZANK#37	463071	812502	0	67	
					1	91	24
					2	111	20
					3	131	20
					4	156	25
					5	182	26
					6	201	19
					7	241	40
					8	271	30
					9	300	29
					10	327	27
					11	351	24
					12	373	22
					13	393	20
					14	412	19
					15	430	18
					16	450	20
					17	465	15
					18	482	17
					19	495	13
					20	506	11
					21	518	12
					22	530	12
					23	542	12
					24	557	15
					25	570	13
					26	585	15.00
					27	596	11
					28	607	11
29	620	13					
							19.07

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
5	120	ORWAZANW#38	462404	812580	0	85	
					1	100	15
					2	112	12
					3	128	16
					4	140	12
					5	152	12
					6	162	10
					7	172	10
					8	180	8
					9	190	10
					10	199	9
					11	209	10
					12	219	10
					13	229	10
					14	239	10
					15	247	8
					16	257	10
					17	265	8
					18	274	9
							10.5

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
6	120	ORESZDS#39	475741	900676	0	71	
					1	88	17
					2	103	15
					3	118	15
					4	130	12
					5	142	12
					6	155	13
					7	168	13
					8	179	11
					9	191	12
					10	203	12
					11	216	13
					12	228	12
					13	241	13
					14	254	13
					15	266	12
					16	279	13
					17	291	12
					18	304	13
					19	317	13
					20	330	13
					21	343	13
					22	355	12
					23	368	13
					24	381	13
					25	395	14
					26	408	13
					27	421	13
					28	433	12
					29	446	13
					30	458	12
					31	471	13
					32	483	12
					33	495	12
					34	506	11
					35	516	10
					36	526	10
					37	536	10
					38	546	10
					39	556	10
					40	566	10
					41	576	10
					42	586	10
							12.26

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
7	80	ARABS#40	478446	979535	0	80	
					1	108	28
					2	136	28
					3	164	28
					4	192	28
					5	220	28
					6	245	25
					7	272	27
					8	296	24
					9	321	25
					10	343	22
					11	375	32
					12	397	22
					13	416	19
					14	443	27
					15	463	20
					16	488	25
					17	514	26
					18	548	34
					19	578	30
					20	602	24
					21	622	20
					22	647	25
					23	675	28
					24	705	30
					25	735	30
					26	770	35
					27	805	35
							26.85

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
8	110	ORESATS#41	464699	869206	0	97	
					1	116	19
					2	135	19
					3	150	15
					4	168	18
					5	187	19
					6	207	20
					7	232	25
					8	259	27
					9	284	25
					10	317	33
					11	351	34
					12	385	34
					13	412	27
					14	450	38
					15	481	31
					16	512	31
					17	540	28
					18	570	30
					19	594	24
					20	622	28
					21	651	29
					22	679	28
					23	704	25
					24	730	26
					25	755	25
							26.32

Field DCP test data from different location of Ethiopia

S.No	Depth of sampling in cm	Sample Code	Location		No of Blow	Depth of penetration in mm	Depth of penetration in mm
			x	Y			
9	120	ORESZAASS#42	455442	869445	0	75	
					1	110	35
					2	138	28
					3	165	27
					4	195	30
					5	226	31
					6	256	30
					7	279	23
					8	303	24
					9	325	22
					10	342	17
					11	359	17
					12	379	20
					13	400	21
					14	419	19
					15	434	15
					16	446	12
					17	459	13
					18	472	13
					19	482	10
					20	494	12
					21	505	11
					22	515	10
					23	525	10
					24	535	10
					25	545	10
					26	550	5
					27	558	8
					28	566	8
					29	573	7
					30	579	6
					31	586	7
					32	592	6
					33	599	7
					34	606	7
							15.62