ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Prediction of California Bearing Ratio (CBR-Value) from Index properties of soil for Modjo Dry Port Sub grade soil

A thesis Submitted to

School of Graduate Studies in Partial Fulfillment of the Requirement for the Degree of Master of Science in

Geotechnical Engineering

By:

Abreham Girma

Advisor:

Yoseph Birru (Dr.)

May, 2017

Abstract

The most classical parameter that is used to measure quality of subgrade material in constructing dry port infrastructure and container terminals is CBR, but routinely testing for this parameter is both costly and time taking.

Therefore, seeking other less costly and quick method of test that characterizes subgrade and material property will be a logical approach.

This study attempted to present the results of the correlation between soaked CBR and index properties of soils. Laboratory tests were carried out to determine soaked CBR, LL, PL, MDD and OMC on soil samples collected from Modjo dry Port construction site. A correlation between CBR and the soil index properties was developed for single and multiple linear regression analysis using SPSS software.

The laboratory test results indicated that soils around the study area lie in groups A-7-5 and A-7-6 based on the AASHTO classification system. Single and multiple linear regression analysis were performed on experimental data and correlations were developed to predict the CBR in terms of the index properties of the samples. Among the various parameters, MDD, OMC and the LL were found to be the most effective predictors.

From the regression analysis, better result was found when CBR is combined with MDD, OMC and LL and the value of R^2 in the combination was 0.909. This implies that 90.9% variation of CBR depends on the variation of those predictors.

The validation of the correlation result was checked using eight generated CBR test results and the result obtained is good when compared to other works. It reveals that the correlation of CBR value with soil index properties is more applicable for preliminary characterization of the strength of subgrade soils.

Declaration

This thesis is my original work and has not been presented for a degree in any Other university, and that all sources of material used for the thesis have been duly acknowledged.

Candidate's name: Abreham Girma

Signature: _____

Acknowledgement

First of all, I would like to thank my lord who is always with me in each and every step of my life.

My intense gratitude goes to my advisor, Dr. Yoseph Birru for his invaluable assistance, support and guidance offered in dealing with the problems encountered from the beginning of my thesis to its completion. And for this, I remain greatly thankful to him.

I would like to thank Ethiopian Construction Corporation Water Works Construction Enterprise (ECCWWCE) and China Railway Construction Corporation (CRCC) for their help and encouragement during laboratory work.

Finally, I am grateful to my friends and families for their assistance and encouragement.

Table of Content

List of Tables

List of Figures

List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
lASTM	American Society for Testing and Materials
CBR	California Bearing Ratio
CL	Inorganic Silts of Low to Medium Plasticity
DCP	Dynamic Cone Penetrometer
FCBR	Field California Bearing Ratio
FDD	Field Dry Density
GC	Clayey Gravels
GI	Group Index
GM	Silty Gravels
GP	Poorly Graded Gravels
GW	Well Graded Gravel
LI	Liquidity Index
LL	Liquid Limit
MDD	Maximum Dry Density
ML	Inorganic Silts of Low Plasticity
MH	Inorganic Silts of High Plasticity
NCHRP	National Cooperative Highway Research Program of United States of Am
OMC	Optimum Moisture Content
PI	Plasticity Index
PL	Plasticity Limit
S1	ERA Subgrade class with a CBR Range of 0 to 2
S2	ERA Subgrade class with a CBR Range of 3 to 4
S3	ERA Subgrade class with a CBR Range of 5 to 7
S4	ERA Subgrade class with a CBR Range of 8 to 14
SPSS	Statistical Package for Social Science Software
SI	Suitability Index of de-Graft Johnson Equation
USCS	Unified Soil Classification System

1. INTRODUCTION

1.1 Background

Ethiopia has experienced rapid and stable economic growth over the past decade. From 2004 to 2014, real gross domestic product (GDP) growth averaged 10.9 percent per year and it is the fastest growth in the Sub-Saharan African countries. Recent growth was also noticeably stable, as the country avoided the volatility brought by spells of drought and conflict, which weighed down growth in the past. [21]

To support fast economic growth, the government of Ethiopia upgraded economic infrastructure namely, road, railway, dry Port, air transport, energy, water, and irrigation schemes and so on. [8]

Among mentioned above, dry port is a transport and logistics terminal, located at some distance of the sea port, but providing the whole range of services, connected with cargo handling.

In Ethiopia, among ports, Modjo dry port is the first and the largest dry port which started without facilitated infrastructure with a command land area of 61.2ha, but, now a days enlarging to 200ha.with intensive different ongoing construction projects inside the compound.

At this time, even though the port is in intensive terminal infrastructure construction, only 35.5ha of the total land is fertile, even this also not handed over contractually.

This, in fact, is highly affecting the efficiency of the port in handling cargos which comes from Djibouti and examining the capacity of the enterprise.

In order to benefit out of research findings such initiatives that links industry problem with academics, believed to have a strong impact on the successful accomplishment of projects. One of project success manifestation is completion on schedule, that in turn dependent on many factors among which is presence of a correlation models for predicting competence of geo-materials by using simple index parameters avoiding laborious and complex tests.

Index properties of cohesive soils are used to characterize the physical and mechanical behavior of subgrade soils by making use of parameters such as moisture content, specific gravity, particle size distribution, Atterberg limits and moisture-density relationships. Such parameters are useful to classify cohesive soils and provide correlations with engineering soil properties.

To assess the structural properties of the port terminal pavement sub grade, the index properties of soils are usually correlated with the CBR value. The use of index properties of soil to predict CBR is preferred because it is simple and inexpensive and it enables rapid measurements of the in situ strength of pavement layers and sub-grades. During the early 1920s, the California Bearing Ratio (CBR) test was developed by O. J. Porter for the California Highway Department to evaluate the bearing capacity of pavement materials in laboratory conditions. Since then, several countries have developed or adopted pavement design methods based on the CBR value of the materials. The CBR is the most widely used strength parameter for fine-grained subgrade soils in flexible pavement design. Different correlations were suggested between the index properties of soil and CBR values for different sights. One of the objectives of this study is to increase the level of confidence of the index property usage for CBR prediction.

The output of this work will be helpful in determining CBR values using index property tests for terminal pavement layers and sub-grade of terminals thereby towards the development of simplified method of design for the ease of different construction works in the dry port.

1.2. Description of Study Area

The study area is located in Oromia Regional State, Eastern Shoa Zone, Lume wereda, and south of Modjo town 70 km from Addis Ababa. The dry port is connected with the main highway of Addis Ababa via Dukem, Bishoftu and Adama and the route further extends to the south east linking Djibouti and in the southwest up to Kenya. Mojo town is among one of the fast growing towns in industries and according to the master plan of the town different construction activities have been carried out, such as; construction of dry port, new express way from Modjo to Hawassa, railway including station, new tanneries and giant steel factory, and construction of low to high volume of roads are among others. Topography of the study area is predominantly plain to undulating dominantly forms isolated hills rather than ridges. According to the climatic classification of Ethiopia, Modjo and its surrounding are classified as warm temperate rainy climate. In this classification the mean annual total rainfall is 866_mm, and the temperature ranging from 8^{o}C to 25^{o}C. The temperature is high from March to May and strong rainfall is in July and August. [9]

The study area is located in the main Ethiopian rift valley region of Modjo town and its environs, is characterized by steep-sided escarpments competent rocks exposed along stream banks, relatively erosion and weathering resistant rocks that form volcanic cones, gentle slopes, flat plains and topographic breaks found on soft sediments.

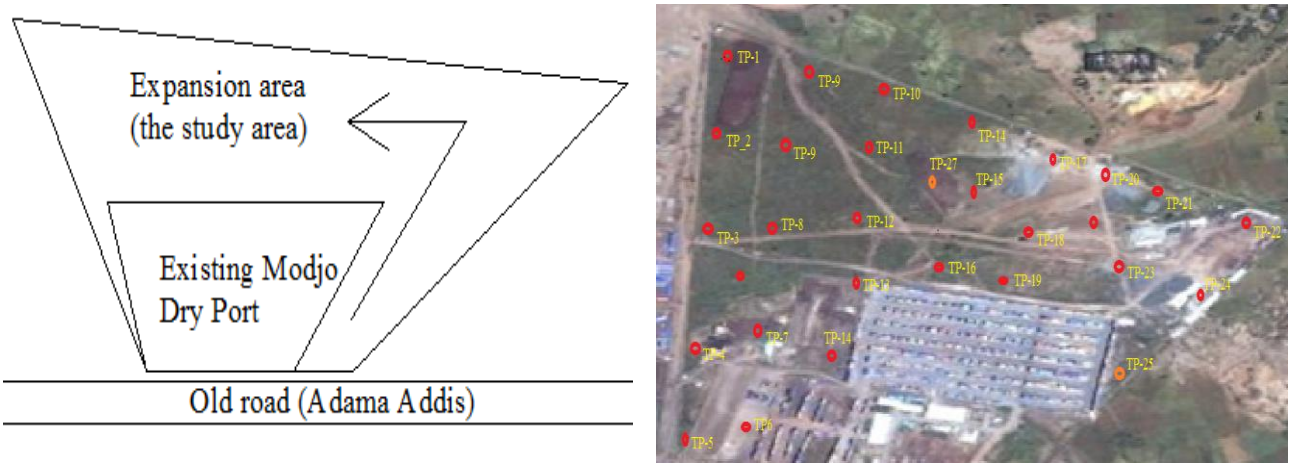


Figure1. 1 Description and layout of Modjo dry port and specific study area

1.3 Statement of the Problem

Soil has numerous information and characteristics, thus the correct prediction of its engineering properties is central in different civil engineering studies. The engineering behavior of soils has got both spatial and temporal components. The procedures for design and selection of port terminal pavement types are highly dependent in the use of CBR for sub grade material test results which is labor intensive and susceptible to uncertainties due to remolding of samples to the in-situ density, compaction errors, workmanship, cost and time consumption to conduct the test. [4]

Also due to limited budgets and poor planning conditions, insufficient soil investigation data are obtained in many cases. On the other hand, the laboratory CBR test is not only laborious and time consuming, but, sometimes, the results are not accurate due to the sample disturbance and poor quality of the laboratory testing conditions.

Hence; determination (prediction) of properties that influence the soil strength and finding out their relationship with CBR value on stratified soil sample has got paramount importance.

Deductively, appropriate projection from index property tests can be made to improve the problems associated with the port pavement design and constructions using CBR test results.

This study demonstrates the process of developing correlation of CBR with index properties of sub grade soils and tries to increase the level of confidence to use the correlation for CBR prediction.

Therefore, the development of prediction models would be useful also from the perspective of become a base for the judgment of the validity of the CBR values determined by other conventional methods.

1.4 Objectives

Main objectives of this study is to develop prediction model for CBR values from index properties of soils in an effort to decrease the amount of sub grade CBR testing done for deciding the thickness of the port pavement in Modjo dry port terminal construction.

Specific objectives

I. To develop a significant and reliable correlation which can be used to predicts CBR-values from Index Properties of sub grade soils for the specified site;

II. To characterize sub-grade soil based on the developed model; and

III. To validate and evaluate the prediction model developed from the correlations using a controlled test results.

2. LITRATURE REVIEW

2.1 California Bearing Ratio (CBR)

The CBR is a penetration test for evaluation of the mechanical strength of road subgrades and base-courses materials. This can be used as a means of designing the road and port terminal pavement required for a particular strength of subgrade by comparing the strength of different subgrade materials.

2.1.1 General:

CBR value is an important soil parameter for design of flexible pavements. It can also be used for determination of sub grade reaction of soil by using correlation. CBR is one of the most important engineering properties of soil for design of subgrade of both urban and rural roads.

The CBR, defined as the ratio of the resistance to penetration of a material to the penetration resistance of a standard crushed stone base material. CBR is the main design input in pavement construction to assess the stiffness modulus and shear strength of subgrade material. The method was developed by the California division of highways as part of their study in pavement failure at World War II. [22]

With an intention to adopt a more simplified test method to measure the stiffness modulus and shear strength of subgrade soil a simple test that can be used as an index test was devised. This is where CBR test comes into frame in measurement of subgrade strength. The CBR test is a simple strength test that compares the bearing capacity of a sub grade and material with that of a well graded standard crushed stone base kept in California division of highways laboratory. [22]

This means that the standard crushed stone material should have a CBR value of 100%. The resistance of the crushed stone under standardized conditions is well established. Therefore, the purpose of a CBR test is to determine the relative resistance of the subgrade material under the same conditions.

The CBR test is essentially a measure of the shearing resistance of a soil at a known moisture and density conditions. The method of evaluating CBR is standardized in AASHTO T 193 and ASTM D 1883.

2.1.2 Significance of California Bearing Ratio

The design of pavement thickness in port terminal construction requires the strength of subgrade soil, subbase and base-course material to be expressed in terms of CBR, so that a stable and economic design

method has been realized. A road section for which a pavement design is undertaken should be sub-divided into subgrade areas where the subgrade CBR can be reasonably expected to be delineated uniform, i.e. without significant variations, in order to utilize it in the design of pavement thickness.[6]

On the other hand, the value of CBR is an indicator of the suitability of natural subgrade soil as a construction material. If the CBR value of subgrade is high, it means that the subgrade is strong and as a result, the design of pavement thickness can be reduced in conjunction with the stronger subgrade. Conversely, if the subgrade soil has low CBR value it indicates that the thickness of pavement shall be increased in order to spread the traffic load over a greater area of the weak subgrade or alternatively, the subgrade soil shall be subjected to treatment or stabilization.

2.2 Test Methods

The CBR test can be carried out both in laboratory and in field. The samples may be prepared in two different ways. Accordingly;

1. Test can be performed on a remolded sample in laboratory.
2. On undisturbed sample carefully extracted from field and trimmed to closely fit the standard mold in laboratory.

2.2.1 In-Situ Field Testing

Field in-situ tests are used to determine the relative strength of soils and sub-base course materials in condition at which they exist at the time of testing. Field in-place CBR tests are used for design of flexible pavement components and for other applications in which CBR is the desired strength parameter.

If field CBR is to be used directly for evaluation or design without consideration for variation due to change in water content, the test should be conducted less than one of the conditions stated in ASTM D 4429-93 manual.

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

In order to get a reliable result care measures shall be taken for any construction test activities, such as grading or compacting carried out subsequent to the field in-situ test which will probably invalidate results of the test. It should be further noted that during in-situ testing the removal of larger-sized particles which may adversely affects the test result is not possible. [16]

Therefore, the in-situ test is likely to encounter such problems in coarser types of in-situ material, whereas the laboratory CBR test is limited to particles passing 3/4 inch (19 mm) sieve size. [10]

2.2.2 CBR Laboratory Testing

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

The Laboratory CBR test procedure is based on the principle of a plunger of standard area advancing into a remolded sample at a specified rate of penetration after determining optimum moisture content. Prepared remolded sample may be soaked for 96 hour. Swell readings are taken during this period at arbitrary selected times.

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

Using corrected value taken from the load-penetration curve for 2.54 mm and 5.08 mm penetration, the bearing ratio is calculated by dividing corrected load by the corresponding standard load, multiplied by 100%. Its value ranges from 0% to 100%, worst to best case respectively.

In the laboratory test, if the soil sample is remolded using one density and one moisture content, the design CBR value will be the one that satisfies the above bearing ratio criteria. Whereas in the case of a

range of densities are used in the test, after getting the bearing ratio for each sample, density versus CBR curve is plotted and the design CBR value of the soil will be the one corresponding to the desired dry density from the Density-CBR plot.

The later approach is widely practiced in different specifications and also this work has followed similar testing procedure.

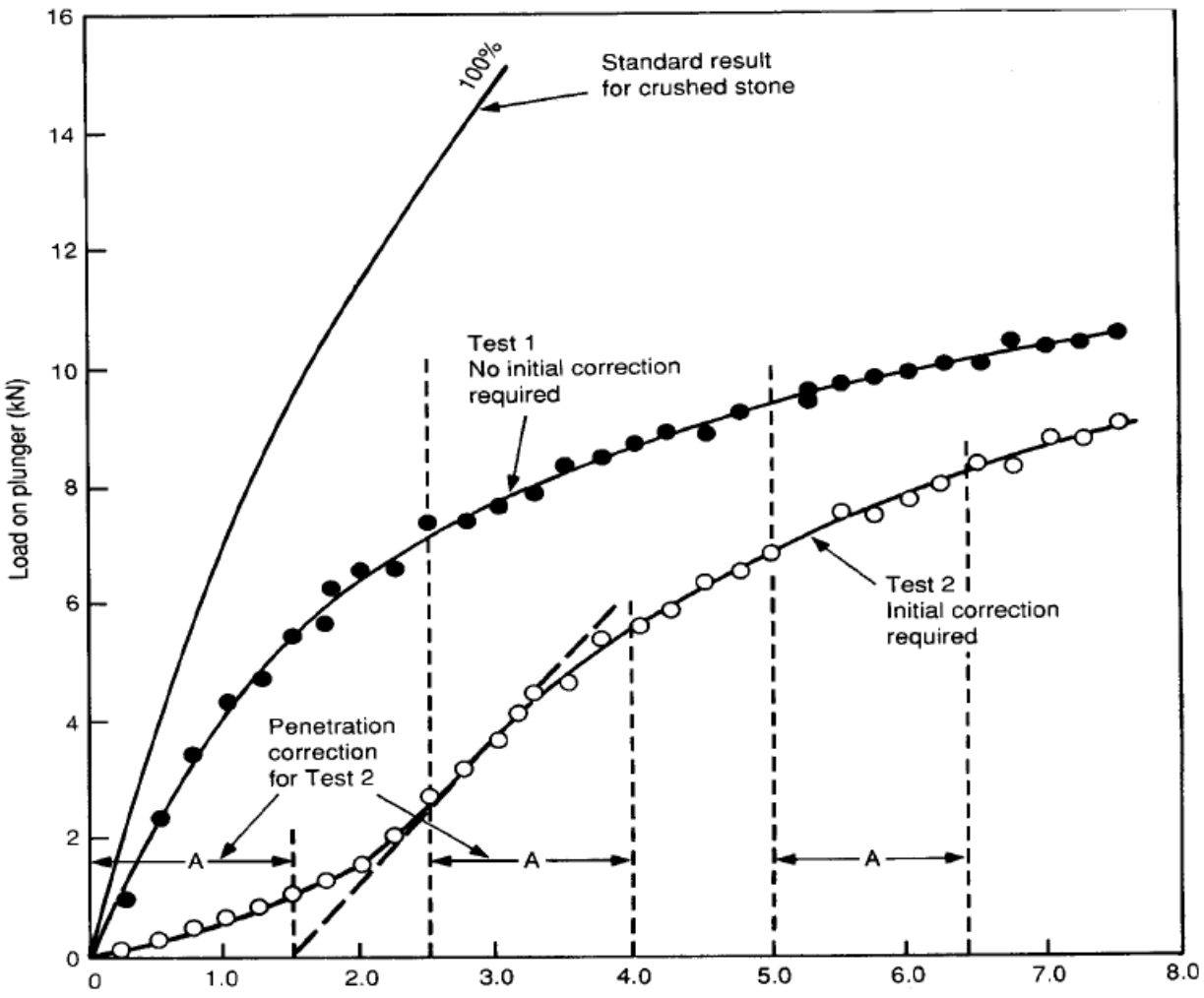


Figure 2. 1 Typical CBR Load-Penetration Correction Graphs [23]

2.3 Index Property Tests

In nature soil can be varied from place to places. Engineers are continually searching for simplified tests that will increase their knowledge of soils by employing a simple and rapid soil tests. These simplified tests which are indicative of the engineering properties of soils are called index properties. [4]

Index properties of cohesive soils are used to characterize the physical and mechanical behavior of soils as a result of making use of parameters such as moisture content, specific gravity, particle size distribution, Atterberg limits and compaction characteristics. Such parameters are useful to classify cohesive soils and provide correlations with engineering soil properties. [7]

2.4 Classification of Subgarde Soils

Soils exhibiting similar behavior can be grouped together to form a particular group under different standardized classification systems. A classification scheme provides a method of identifying soils in a particular group that would likely exhibit similar characteristics. There are different classification devises such as USCS and AASHTO classification systems, which are used to specify a certain soil type that is best suitable for a specific application. These classification systems divide the soil into two groups: cohesive (fine-grained) soils and non – cohesive (coarse-grained) soils.

2.4.1 Grain Size Analysis

In coarse grained materials, grain size distribution is determined by passing soil sample either by wet or dry shaken through a set of series of sieves placed in order of descending and there is a pan at the bottom of the stock. Percent passing on each sieve is used for further identifying the distribution and gradation of different grain sizes. Particle size analysis tests are carried out in accordance to ASTM D 422-63. Besides, distribution of different soil particles in a given soil is determined by a sedimentation process using hydrometer test for soil passing 0.075mm sieve size (fines). For a given cohesive soil having the same moisture content, as the percentage of finer material or clay content decreases the shear strength of the soil possibly of increases.

2.4.2 Moisture Content

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

2.4.3 Atterberg Limits

Depending on their mode of formation and mineralogical content, different soils respond differently for the same moisture content gave an idea of the consistency limit of cohesive soils and proposed a number

of tests for defining their properties. [3] Three Atterberg limits which are liquid limit, plastic limit and shrinkage limits are the boundary between each of the two consecutive states of the soil-water phases. Their test is performed only on that portion of a soil which passes the 425mm (No. 40) sieve Mittal et-al (2000)**.** Description of phases of soil-water system is shown with schematic diagram in Figure below.

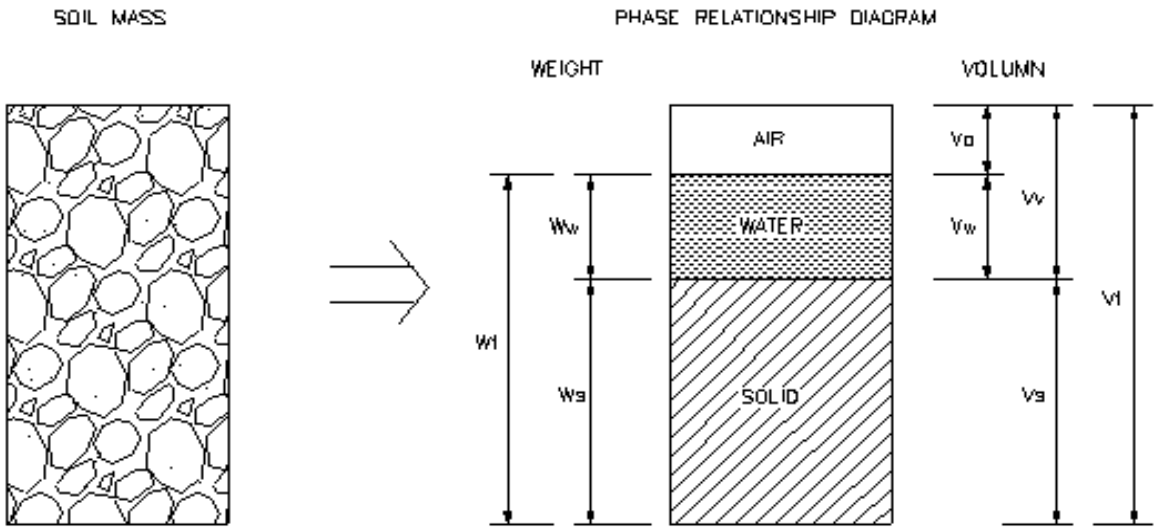


Figure 2. 2 phase relationship diagram of soil skeleton. [3]

I. Liquid Limit: The LL is the water content, expressed in percent, at which the soil changes from a liquid state to a plastic state **(shown in Figure 2.1)** and principally it is defined as the water content at which the soil pat cut using standard groove closes for about a distance of 13cm (1/2_in.) at 25 blows of the liquid limit machine (Casagrande Apparatus). The liquid limit of a soil highly depends upon the clay mineral present. The conventional liquid limit test is carried out in accordance of test procedures of AASHTO T 89 or ASTM D 4318. A soil containing high water content is in the liquid state and it offers no shearing resistance.

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

content is reduced the plasticity of the soil decreases changing into semisolid state and it cracks when remolded.

Atterberg limits are most useful for engineering purpose in order to classify the soils. During liquid limit states, soil possess small shear strength and exhibit some resistance to flow like a fluid conversely; during plastic limit states the soil begun to crumble and has better strength than liquid limit condition.[17]

The amount of water which must be added to change a soil from its plastic limit to liquid limit is an indication of the plasticity of the soil. The degree of plasticity is measured by the plasticity index (PI), which is the numerical difference between liquid limit and plastic limit (PI = LL – PL). The greater the plasticity index means that the soil is more plastic, compressible and the greater volume change characteristic of the soil.

The liquid limit, plastic limit and plasticity index parameters are an integral part of several engineering properties and characterize fractions fine grained soils as construction materials. The shear strength of a fine grained soil mainly depends on the consistency of the soil.

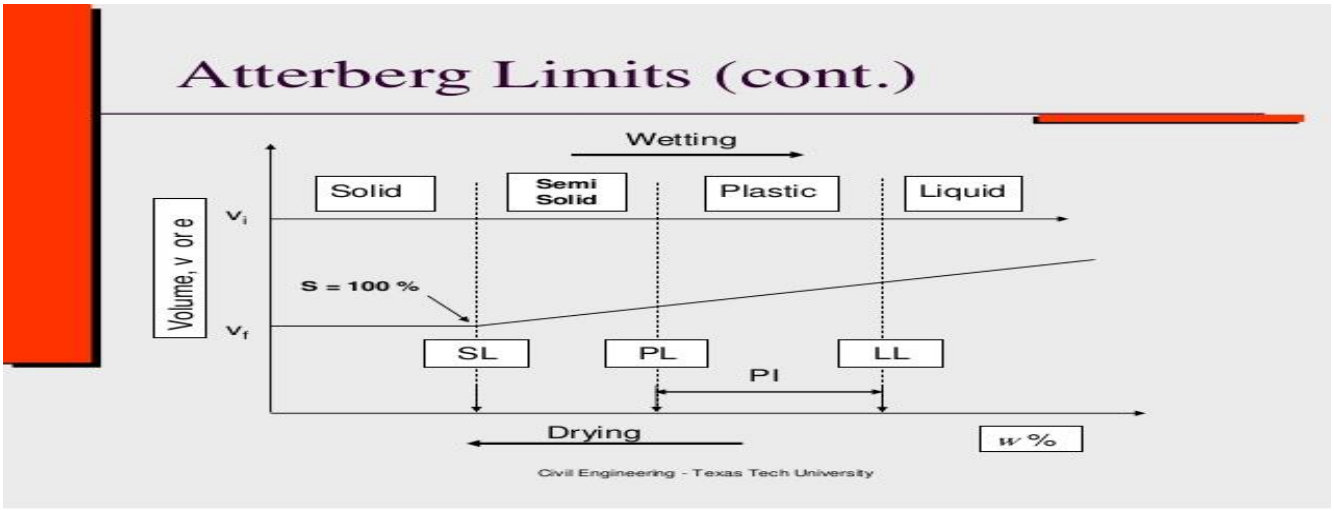


Figure 2. 3 Atterberg limit state of soil consistency [19]

2.5 Moisture - Density Relationship

Compaction improves the engineering properties of naturally existing subgrade soil, i.e. it increases the shear strength, bearing capacity and stiffness of the soil material. Thus, compaction reduces future settlement, void ratio and permeability. At lower water content than the optimum, soil is rather stiff and has a lot of void spaces and hence, dry density is become low. On the other hand, at water content more

than the optimum, additional water reduces the dry density as it occupies the space that might have been occupied by solid particles. [4]

The laboratory standard proctor and modified proctor tests are performed as per (AASHTO T 99 or ASTM D 698) and (AASHTO T 180 or ASTM D 1557) respectively. The tests are performed on disturbed samples of soil particles passing sieve sizes 4.75mm or 19mm mixed with water to form samples at various moisture contents ranging from the dry state to wet state. These samples are compacted in three or five layers at 25 blows per layer in accordance with the specified nominal compaction energy of standard or modified proctor test respectively. Dry density is determined based on the moisture content and the unit weight of compacted soil **(Figure 2.4)**. The corresponding water content at which the maximum dry density occurs is termed as the optimum moisture content. [13]
Grading and Atterberg limits alone are not sufficient to qualify the performance of construction materials since variation of moisture content and density play a considerable role. Different researches show that the moisture content and density conditions have a greater influence, on the value of shear strength of a soil, on coarser materials than fine grained materials.

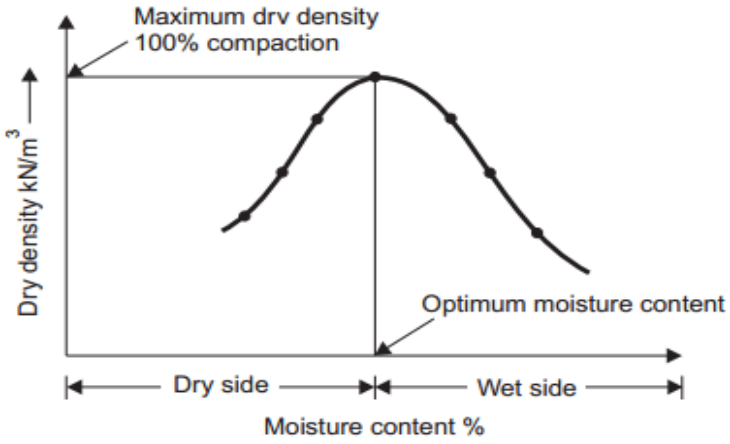


Figure 2.4 Soil compaction curve [13]

2.6 Reviewing of previously done prediction models

Looking as the CBR test is time - consuming, a good indication of CBR values from index tests would be very beneficial. Due to such reason various attempts have been made to relate index test parameters to CBR values.

Many researchers and agencies developed relationships between CBR with soil index parameters on the basis of samples obtained from a specific region and soil type. General relationships are also developed using universally accepted soil index properties, basically based on the OMC, MDD and USCS and AASHTO systems. These correlation methods take a general approach and attempt to encompass many or all possible soil types.

2.6.1 Correlation of CBR values with Consistency Limit

It is reasonable to assume California Bearing Ration (CBR) values are related to soil index properties in some ways. Many researches had been carried out to show the effect of soil types and characteristics on CBR values. [11]

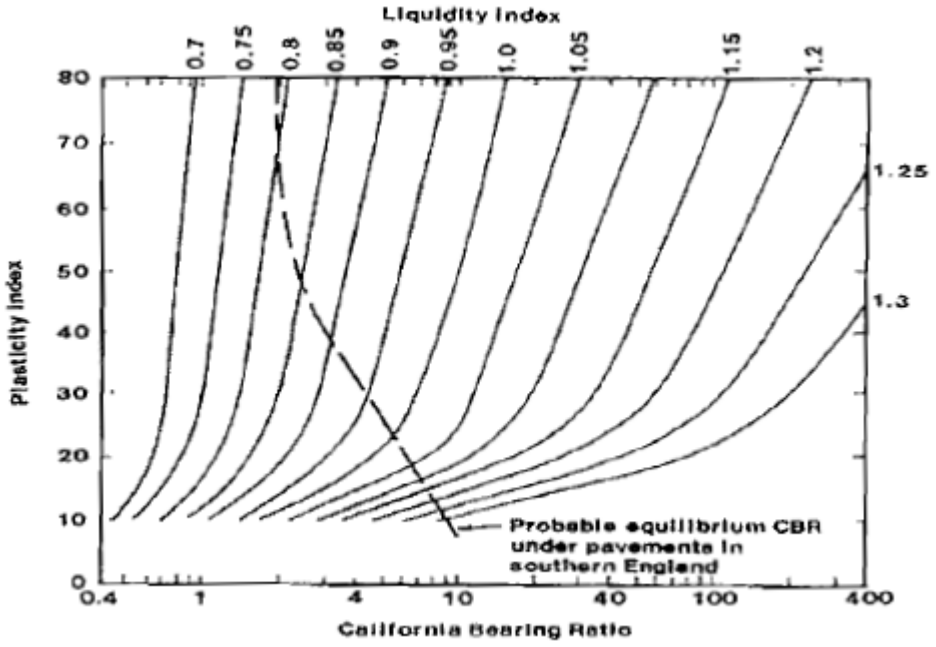


Figure 2. 5 Relationship between CBR, PI and liquidity index. [11]

Consistency limits and the PI vary for different soil types; hence, such properties are generally used as a tool to identify and classification of soils. Soils having high values of liquid limit and plasticity index are categorized under poor engineering materials.

LL and PL depends on the types and amount of clay mineralogy of soil Particles also plasticity index shows an indication of clay content in soil. Different attempts have been made to relate consistency test

parameters with soaked CBR values as shown **Figure 2.5**. The correlation has been carried out in different areas where soil type and climate also varies hence developed in place cannot represent for other study areas.

2.6.2 CBR with liquid limit Correlation

Co relationship of CBR with liquid limit is very significant in some areas and also insignificant in another place where soil type and climate varies. [23] Developed a relation between CBR with liquid limit properties of selected 15 soil samples from the road link connecting between Dudda to Kormangala Gate (Hassan district, Karnataka, India-2010) at every 100m interval for a distance of 1.5km from a depth of 3m below the existing pavement level. After conducting laboratory test both for CBR and liquid limit test the relationship was developed using regression analysis and graph is plotted between soaked CBR and liquid limit and presented in above figure. From their study it can be concluded that the relation between CBR with liquid limit satisfies power series, having a correlation coefficient (R^2) of 0.9252 which is almost very close to 1.0.

$$\boldsymbol{CBR = 7E + 06(LL)^{-4.226}}$$

Where: E = expected Values which is constant, and LL= Liquid limit

Therefore from their study it can be decided that correlation between CBR and LL is very significant. Conversely when we see the relation between CBR with LL in which it was investigated by it becomes insignificant. [18] The study was done in Sirsa town, India after collecting 10 representative soil samples. After conducting laboratory tests then correlation between liquid limit and CBR shows insignificant whereas negative trend line indicates that as the liquid limit increases CBR decreases. Cohesionless soils were highly distributed in the study area, which might be the reasons for having poor correlations between such parameters.

2.6.3 CBR with Plasticity Index Correlation

The numerical difference between the liquid limit and plastic limit is termed as plasticity index. Simple Linear Regression Analysis (SLRA) was carried out by considering soaked CBR value as dependent variable and liquid limit, plastic limit, plasticity index, shrinkage limit, are considered as independent variables. It has been carried out to develop the correlation between individual soil property (Plasticity index) and soaked CBR value.

Effect of soil properties on CBR value can be explained as liquid limit and plastic limit has less influence on CBR value. But CBR value varies with plasticity index such that as plasticity index increases CBR value decreases. This shows that there is a fair to good relationship exists between CBR values for plastic nature of soils only**.** [14]

In their study twenty numbers of disturbed soil samples were collected (having different liquid limit) from different locations from in and around the city of Bagalkot district of Karnataka, India and the corresponding laboratory test then carried out. It is known from simple linear regression analysis (SLRA) that CBR value decreases with increase in plasticity index and also increases with increase in maximum dry density; From SLRA coefficient of correlation R^2 for plasticity index is 0.72. Hence the regression analysis shows that the relation between them is significant.

2.6.4 Correlation of CBR with Specific Gravity

Specific gravity is an important index property of soils that is closely linked with mineralogy or chemical composition. [15]

It is the ratio of the weight in air of a given volume of dry soil solids to the weight of equal volume of distilled water at 4°C.

2.6.5 Correlation of CBR with optimum moisture content

The Optimum Water Content of soil is the water content at which a maximum dry unit weight can be achieved after a given compaction effort. [14] To establish a relationship of soaked CBR value with optimum moisture content. Accordingly, twenty number of disturbed soil samples were collected. On collected soil samples test like CBR, OMC and so on were performed also correlated using both simple and multiple regression analysis. From their result, correlation developed between soaked CBR and optimum moisture content is shown in **Figure 2.5.**

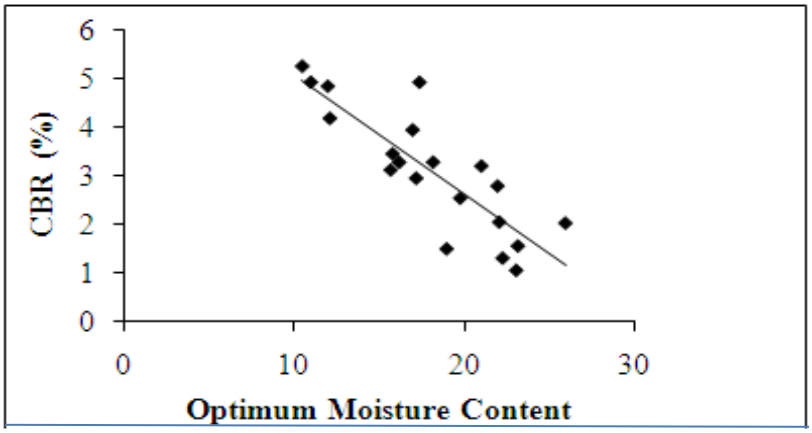


Figure 2. 6 Relation between optimum moisture content and CBR values.[14]

The above figure indicates that as moisture content increases CBR value decreases. The model developed for soaked CBR value has correlation coefficient R^2 =0.70, indicating a reasonable fit to the data and also it indicates that as optimum moisture content increases CBR value increases. It is found that good empirical relations obtained to predict CBR value from OMC and the correlation developed between them is almost very significant.

2.6.6 Correlation of CBR with maximum dry density

(Ahmed et al., 2016) try to develop a model to predict soaked CBR from dry density of soil subjected to different compactive efforts. According to them three soil samples were collected from three different chainage of the sub-grade of an existing flexible pavement in Savar Cantonment, Dhaka. Then CBR and compaction laboratory tests were carried out. A regression equation has been developed to relate soaked CBR values from available dry density data. The equation obtained is reported as follows:

CBR = 0.0007(Dry Density) $^{2.9181}$**, [**R^2**=0.921].** This model has R^2 value of 0.921 which is close to unity and thus can be used with good certainty for predicting soaked CBR value. Hence from the model it can be concluded that, the relationship that held between them is strong.

2.6.7 Correlation of CBR from index perimeters of soil using multiple regression analysis

(Yildirim Gunaydin., 2011), developed several models to predict soaked CBR from the following parameters namely percentage of gravel (%G), percentage of sand (%S), percentage of fines (%F), LL, PL, maximum MDD in g/cc unit and OMC.

Equation 5 and 6 are only applicable for particular type of soil. Equation **a,** is applicable for coarse grained soil whereas equation **b** is applicable for fine grained soil.

These two equations cannot predict CBR value of soil when it is contained with both fine and coarse particles. In equation number **c** and **d,** MDD and OMC are determined from standard Proctor compaction test. The proposed models are as follows:

$CBR_S = 0.2353G + 3.0798$…….……a

$CBR_S = -0.1805F + 18.508$.....….....b

$CBR_S = 0.22G + 0.045S + 4.739MDD + 0.122OMC$ ….....c

$CBR_S = 0.62OMC + 58.9\ MDD + 0.11LL + 0.53PL - 126.18$ ……..…...d

Where the subscript **s,** show soaked condition.

2.6.8 Correlation of CBR from index properties of soil using multiple regression analysis

(Winta A., 2016) developed a correlation for Addis Ababa subgrade specifically taking primary and secondary data from Gore, Bole arebsa and Koyefiche.

During her work, one hundred fourteen secondary sample were taken from different consultants as; Addis Ababa City Road Authority, Transport Construction Design, Best Consulting Engineering and used for developing the required model.

Using this datum, she was developed four models with the best one being as follows.

$CBR = 72.663-0.421LL-0.22OMC-55.86MDD+20.02MDD^2$

After doing this, she has examined the developed correlation by taking fresh samples (ten in numbers) from the specific site how the developed model works.

The value of R^2, which is the measure of the strength of the correlation, became 0.77, mean that 77% variation of CBR depends on the variation of those predictors.

As, the value of R^2 is greater than 0.55 the developed correlation was good. But, it may difficult to say the correlation works to the site because the datum she used were secondary.

Therefore, it had been better if she were doing this work by using primary data decreasing the number of sample size.

Table 2. 1 Summary of previously done prediction models of correlating CBR with various index properties

Equation	No of samples	R^2	Remarks	Country or investigator	Reference
CBR = -18.78(MDD) + 43.907 – 0.093(PI) – 0.3081(OMC)	**12**		**Fine Grained Soils**	**India**	**[11]**
CBR = 0.064(F) + 0.082(S) + 0.033(G) – 0.069(LL) + 0.157(PL) – 1.1810(MDD) – 0.061(OMC)	**25**	**0.92**	**Fine Grained Soils**	**India**	**[14]**
CBR = - 0.889(WLM) + 45.616 Where WLM = (LL – P425/100)	**18**	**0.92**	**Fine Grained Soils**	**India**	**[18]**
CBR = 75/1 + (0.728(wPI)	**-**	**0.67**	**plastic, fine-grained soils**	**(NCHRP, 2001)**	**[17]**
CBR=72.663-0.421LL-0.220OMC-55.86MDD+20.02MDD^2	**10**	**0.77**	**Fine Grained Soils**	**Addis Abeba**	**[20]**

Where: CBR = California Bearing Ratio (soaked); MDD=Maximum dry density; OMC=Optimum Moisture Content; GI=group index; CBR; LL = Liquid limit; PL = Plastic limit; PI=Plasticity index; SG = Specific gravity; P200 = passing No. 200 U.S. sieve; P425 = passing sieve size 0.425 mm; F=Fines, %; S=Sand, %; G=Gravel.

3. RESEARCH METHODOLOGY AND MATERIAL

3.1 Methodology

To meet the objective of this study, different related relevant publication were reviewed before conducting laboratory tests and then, disturbed soil samples were collected from specified location. Collection of soil sample is carried out as per ASTM standard practice for soil investigation and sampling (D1452 – 09).

3.1.1 Selection of study area for sample collection

The study area is located in central part of Ethiopia, in Oromia Regional State, Eastern Shoa Zone, Lume Woreda in Modjo town which is 70 km away from Addis Abeba. After identifying specific study area, 27 representative soil samples were collected from dry port.

3.1.2 Collection of disturbed soil samples

In this study, 27 soil samples were collected from judiciously selected locations of hand dug pits for laboratory determination of parameters to develop relationship between index properties and CBR. Disturbed soil samples were taken from open pits at (1.5 to 2) m depth, by digging using hand tools. Mostly depth of excavation from (1.0 up to 3) m is commonly known as the depth in which different pavement and shallow foundation structures are being constructed and for road construction it is desirable to locate the pavement on the stronger soils.

3.1.3 Laboratory Works

Representative sampling, proper test procedures and adequate test equipment are the most important requirements for good quality laboratory testing. After collection of the soil sample which was representative for the given specific site, the following laboratory tests were conducted;

- Uncured liquid limit, plastic limit and plasticity index is conducted (called Atterberg limit tests) in accordance with ASTM D4318 or AASHTO T89-90. It is the boundaries of several states of consistency for plastic soils. To do representative air dried soil samples which pass through sieve No 40 were taken and soaked for hours in order to moist the soil grains. In order to get accurate results multipoint method is chosen then LL and PL tests were carried out using the above testing procedures.
- Particle size analysis is done as per ASTM standards of D422 and AASHTO T27

- Modified immediate maximum dry density and optimum moisture content was conducted in accordance with BS: 1377 part 4 (1990) or AASHTO T99 standard test methods for laboratory compaction characteristics of soil using standard load.
- Long term strength of subgrade soil determined by measuring its CBR in accordance with ASTM D1883 or AASHTO T193 standard test method.

3.1.4 Laboratory Data Analysis and Result

After conducting different laboratory works, the results obtained in the form of both tables and graphs then clearly elaborated and briefly analyzed.

3.2 Materials

In order to accomplish the objectives of this thesis, different laboratory equipment was used such as:

Wet and dry sieve, CBR and Proctor testing mold with their accessories, 100 ml and 1000 ml cylinder, mold for swelling test, Casagrande apparatus, glass plates thermometer, and computer for analyzing and develop correlation model results using SPSS and Microsoft excel.

3.3 Proposed Model for Estimating Soaked CBR Value

In this study, regression models, both simple linear and multiple linear, were developed for estimating soaked CBR value in terms of index and compaction characteristics. Data pertaining to soil properties used for developing models to estimate soaked CBR value is presented. To develop the models, simple linear regression analysis and multiple linear regression analysis were carried out. Soaked CBR value is considered as dependent variable and Gravel (G), Fines (F), Sand (S), LL, PL, MDD and OMC are considered as the independent variables. Simple Linear Regression Analysis (SLRA) has been carried out to develop the correlation between individual soil property and soaked CBR value. SLRA can be carried out using standard statistical software like Data Analysis Tool Bar of Microsoft Excel in order to derive the relationship statistically. Statistical parameters of soaked CBR value predicted by various SLRA models are presented.

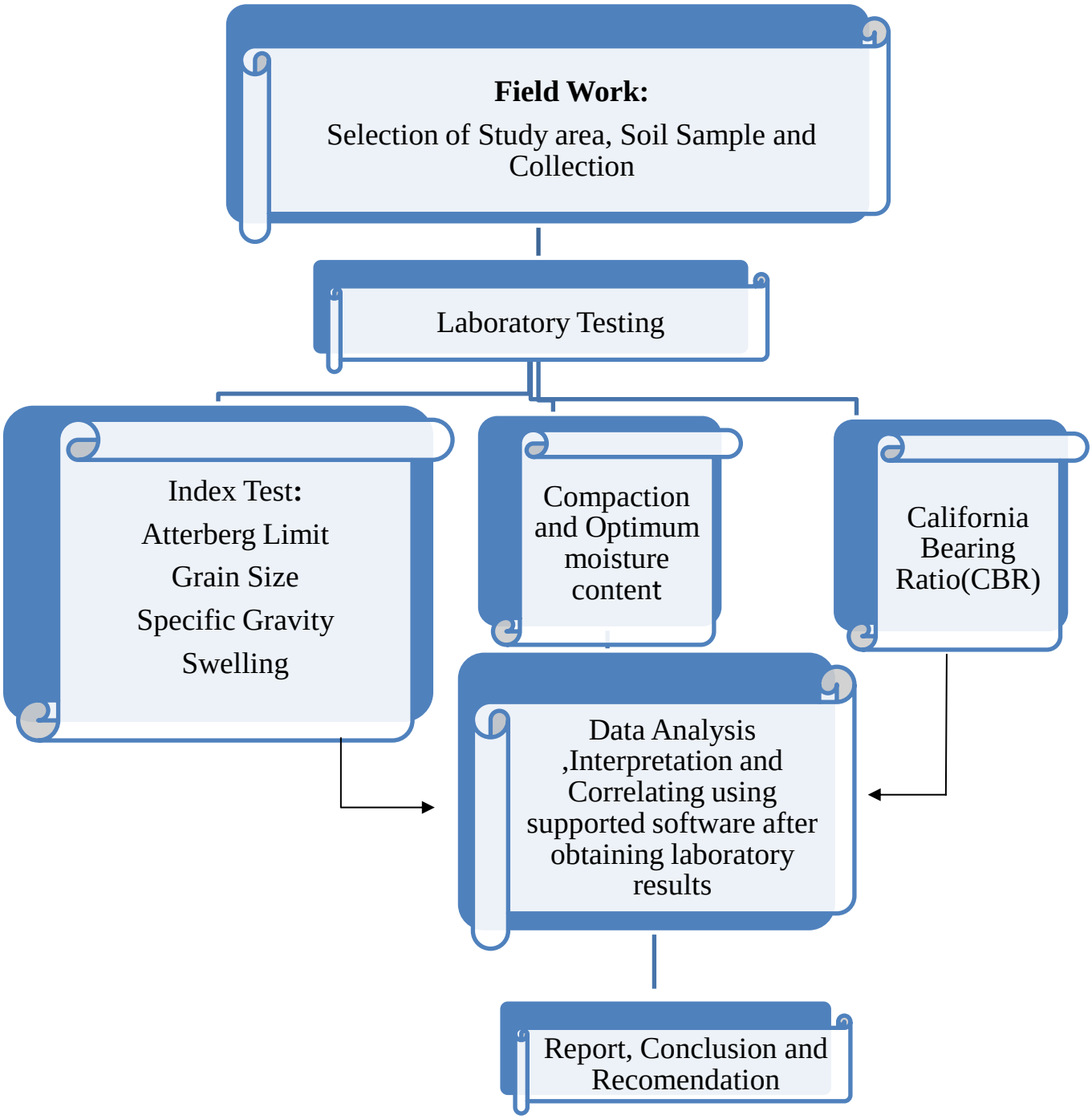


Figure 3.1 Research methodology flow design chart

4. LABORATORY TESTS AND RESULTS

4.1 Characterization of index and engineering properties of existing soil from Laboratory Test

Judiciously, after collecting 27 representative soil samples and conducting laboratory tests data were obtained. The data consist of subgrade one point CBR with corresponding consequent Atterberg limit test, compaction test, and necessary classification based on AASHTO standard, for the specific given study area. The obtained test result is for silty-clay soils.

The different kinds of tests carried out are listed as below.

- Sieve analysis ASTM standards of D422 or AASHTO T27
- Atterberg limit test ASTM D4318 or AASHTO T89-90
- Compaction test BS: 1377 part 4(1990) or AASHTO T99
- CBR test ASTM D1883 or AASHTO T193

The above conventional tests were conducted on collected 27 representative soil samples and a range of test results is achieved. Based on the obtained test results of plasticity and grain size distribution the soil classification was made and the result shows that most of the samples are classified as fine grained soil.
In accordance to the AASHTO classification system the soil is mainly classified as A-7-5 and A-7-6. From the conventional Atterberg limit tests, a liquid limit value ranging from 30.63 up to 74.48, plasticity limit value of 20.44 up to 38.75 and a plasticity index value of 10.19 up to 35.73 respectively in percent were obtained.
A modified proctor test conducted as per AASHTO T 180 D, through which samples compacted at 5 layers each compacted by 56 uniform blows using 4.54 kg weight of hammer.

From the modified proctor test, after plotting moisture-density curve, a range of maximum dry density along with the optimum moisture content were obtained. Similarly, the CBR test was carried out, on samples remolded with OMC using one point CBR of 56 blows of modified proctor density and soaked for 4 days.

Consequently, after the penetration test was carried out a CBR value ranging from 2.2% up to 24.95% was obtained.

For the sake of illustration and easy of reference, the typical test results of a soil sample have been demonstrated hereunder:

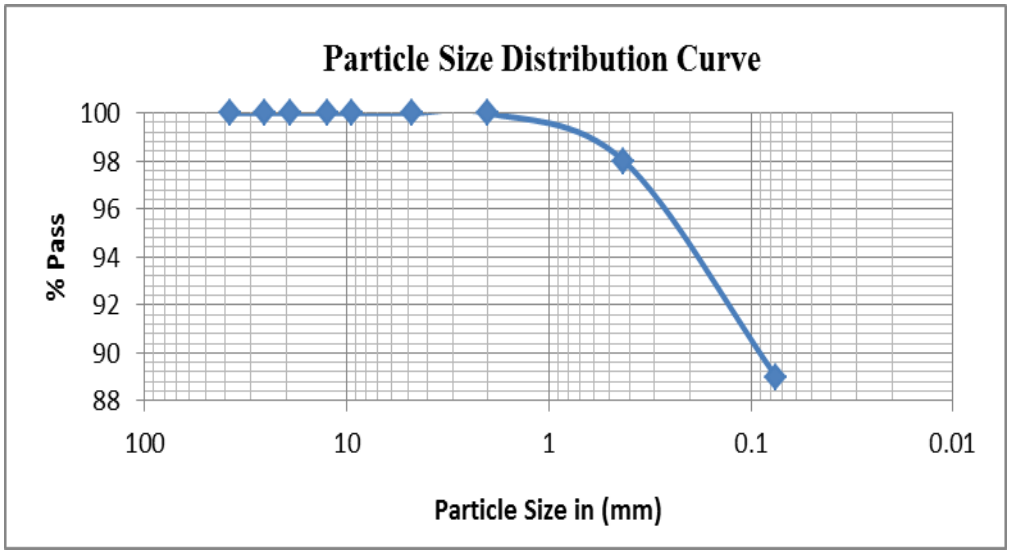


Figure 4.1 Percent passing Vs particle graph for reperesntative soil sample

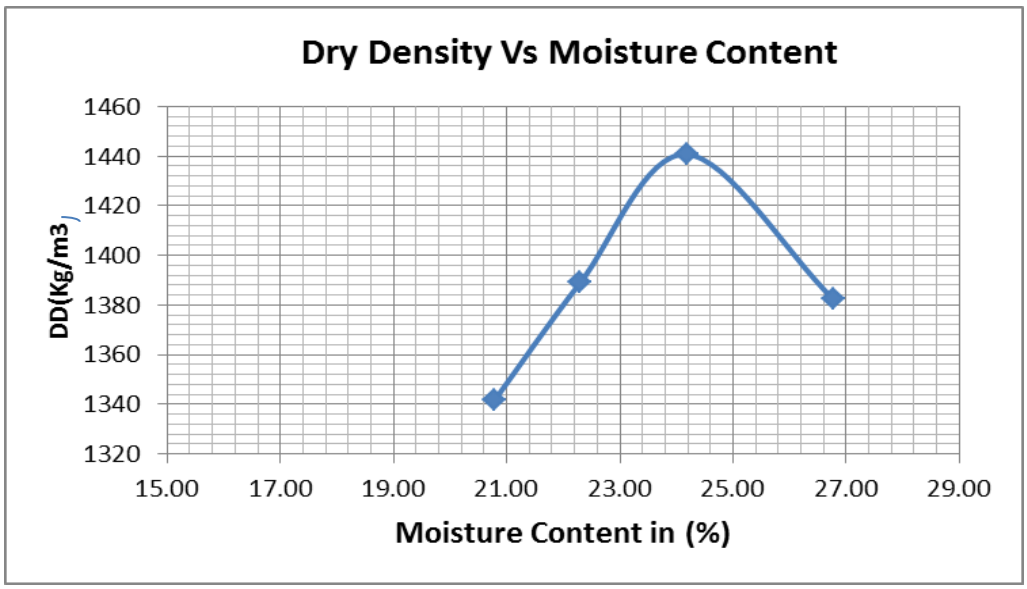


Figure 4.2 Moisture content Vs dry density representative graph

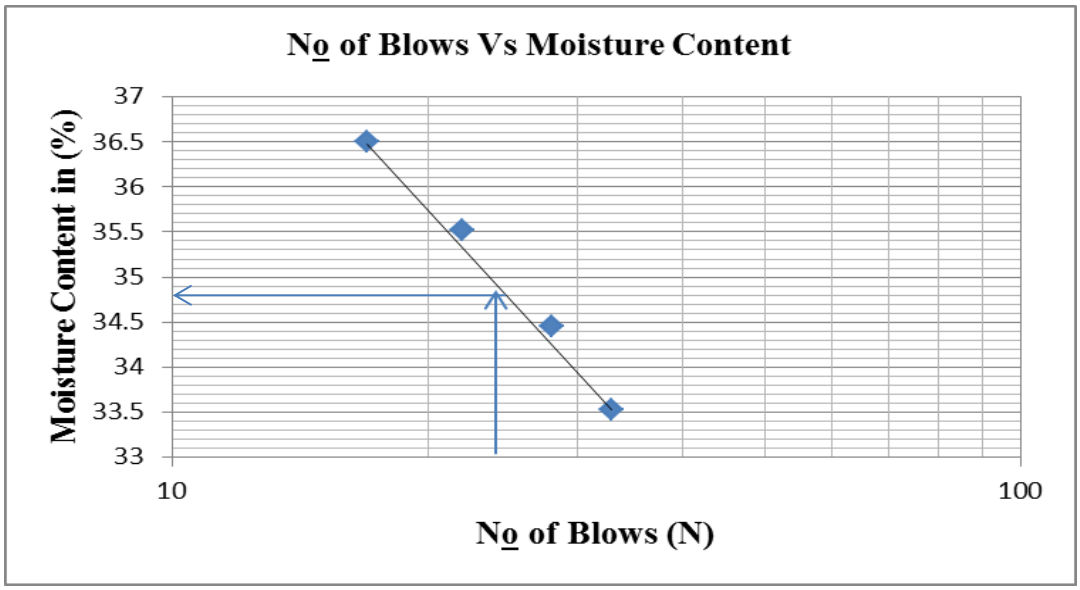


Figure 4.3 Moisture content Vs number of blows representative graph for liquid limit determination

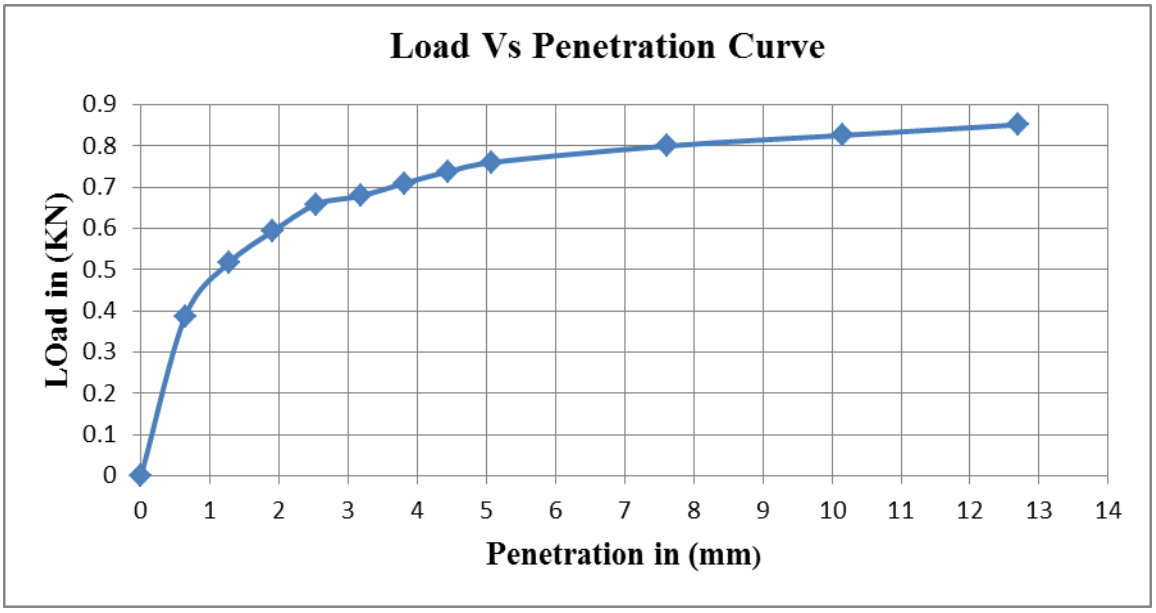


Figure 4. 4 Typical penetration Vs. load representative graph for saoked CBR determination

Table 4.1 Summary of laboratory test results conducted

Test pit, Depth	Seive Analysis, percent passing (%)									Atterberg limit			AASHTO	Modified Proctor Test		Soacked CBR value in (%)
	37.5 mm	25.4 mm	19 mm	12.5 mm	9.5 mm	(No.4) 4.75mm	(No.10) 2mm	(No.40) 0.425 mm	(No.200) 0.075 mm	LL	PL	PI		OMC (%)	MDD (g/cm3)	
1.53	100	100	100	100	98	95	94	92	85	64	38	31	A-7-5 (31)	25.75	1.43	4.16
1.53	100	100	100	99	98	97	96	79	74	55	32	23	A-7-5 (19)	24.18	1.44	4.71
1..8	100	100	100	99	98	98	97	94	71	52	37	14	A-7-5 (12)	28.89	1.47	2.22
1.5	100	98	96	95	94	93	91	89	79	55	37	18	A-7-5 (17)	29.15	1.51	4.99
1.5	84	79	73	64	61	54	50	48	42	35	20	22	A-7-5 (5)	23.34	1.65	16.64
1.5	100	100	100	100	100	100	99	98	94	59	31	27	A-7-6 (31)	31.74	1.28	4.85
1.7	91	85	82	79	77	73	68	56	41	31	25	12	A-7-6 (2)	14.23	1.99	24.95
1.5	100	100	100	100	100	99	98	96	91	40	31	27	A-7-6 (24)	22.34	1.72	13.86
1.5	100	100	100	100	100	100	100	99	94	57	32	25	A-7-6 (29)	25.00	1.55	8.73
1.8	100	100	100	100	100	100	100	98	89	61	39	27	A-7-5 (29)	23.30	1.36	3.88
1.53	100	100	100	100	100	100	100	98	95	40	26	36	A-7-6 (33)	14.34	1.80	19.69
1.53	100	100	100	100	100	100	100	97	94	69	39	40	A-7-6 (44)	30.45	1.57	4.71
1..83	100	100	100	100	100	100	100	97	95	58	31	29	A-7-6 (32)	25.45	1.67	11.09
1.53	100	100	100	100	100	100	100	92	90	68	39	29	A-7-5 (33)	31.46	1.57	4.85
1.53	100	100	100	100	100	100	100	91	83	71	35	36	A-7-5 (35)	23.01	1.64	6.24
1.53	100	100	100	100	100	100	100	95	87	47	38	29	A-7-6 (26)	17.34	1.78	16.36
1.53	100	100	100	100	100	100	100	96	89	67	28	39	A-7-6 (39)	29.90	1.59	4.99
1.53	100	100	100	100	100	100	100	96	90	74	37	37	A-7-5 (41)	24.65	1.62	6.65
1.83	100	100	100	100	100	100	100	96	91	66	33	33	A-7-5 (36)	24.54	1.52	3.88
1.83	100	100	100	100	100	100	100	89	84	49	37	39	A-7-6 (32)	22.45	1.68	12.20
1.83	100	100	100	100	100	100	100	92	88	65	35	30	A-7-5 (32)	26.39	1.63	6.65
1.83	100	100	100	100	100	100	100	97	85	68	39	32	A-7-5 (32)	28.23	1.54	5.96
1.53	100	100	100	100	98	95	94	92	85	64	33	31	A-7-5 (31)	25.75	1.43	4.16
1.8	100	98	96	95	94	93	91	89	79	52	37	14	A-7-5 (14)	28.89	1.50	2.22
1.7	91	85	82	79	77	73	68	56	41	38	25	12	A-7-5 (2)	16.80	1.96	21.95
1.5	100	100	100	100	100	99	98	96	91	48	36	12	A-7-5 (15)	20.21	1.68	13.86
1.5	84	79	73	64	61	54	50	48	42	36	24	11	A-7-5 (2)	18.45	1.88	16.64

5. REGRESSION ANALYSIS and DISCUSSIONS

5.1 General Overview

Regression analysis is a statistical technique for modeling and investigating the relationship between two or more variables. A variable whose value is predicted is called dependent variable or response. A variable(s) used to predict the value of dependent variable is termed independent or regressor variable (s). [5]

A regression model that contains more than one regressor variable is called multiple regression models. Alternatively, Regression model containing one independent variable or regressor is termed as simple regression model. Fitting a regression model requires several assumptions. Estimation of the model parameters requires the assumption that, the residuals (actual values less estimated values) corresponding to different observations are uncorrelated random variables with zero mean and constant variance (σ^2).
Tests of hypotheses and interval estimation require that the errors be normally distributed. In addition, we assume that the order of the model is correct; that is, if we fit a simple linear regression model, we are assuming that the phenomenon actually behaves in a linear or first order manner.

A number of techniques can be used to indicate the adequacy of a multiple regression model, some of which are standard error, the multiple regression R-squared values, and the t-test.
The standard error of a statistic gives some idea about the precision of an estimate. Estimated standard errors are computed based on sample estimates, as population values are not obtainable using sample surveys.
As per (Douglas, 2003) the estimated standard errors of a variable with mean X bar and standard deviation of SD are given by:

$$\hat{\sigma} = \frac{SD}{\sqrt{n}}$$

Where $\hat{\sigma}$ = is the standard error of the sample and n = number of sample size
During regression analysis modeling, variable that shows the least standard error of estimates is the one to be relatively chosen. The coefficient of determination, R^2, shows the percentage of variation of the dependent variable explained by regression is often used to judge the adequacy of a regression model and is given by the quantity:

$$R^2 = \frac{SS_R}{SS_T} = 1 - \frac{SS_E}{SS_T}$$

Where:

$$SS_T = \sum_{i=0}^{n} (y - \bar{y})^2$$

$$SS_T = \sum_{i=0}^{n} (y_i - \bar{y})$$

And $SS_R = SS_T - SS_E$ = sum of regression squares

SS_E = error of sum of squares

SS_T = total sum of squares

y_i = i^{th} value of the response variables

y = ith value of the fitted variable

y = average value of the response variable

Another useful criterion used to check the adequacy of a regression model is using a modified R^2 that accounts the usefulness of a variable in a model. This statistic is called the adjusted R^2 defined as:

$$R_p^2 = 1 - \frac{n-1}{n-pp}(1 - R^2)$$

Where: pp is number of regressors in the regression model

n = sample size and R_p^2 = coefficient of adjusted determination

Maximizing the value of R^2 by adding variables is inappropriate unless variables are added to the equation for sound theoretical reason. In the extreme case, when n-1 variables are added to a regression equation, R^2 will be 1, but this result is meaningless. Adjusted R^2 is used as a conservative reduction to R^2 to penalize for adding variables and is required when the number of independent variables is high relative to the number of cases or when comparing models with different numbers of independents

During regression analysis, a regression model with higher value of adjusted R^2 is usually accepted. Pearson's correlation coefficient or simply correlation coefficient, R, measures the strength of linear association between two measurement variables. It is calculated as:

Where:

$$R = \frac{cov(x,y)}{sd(x) \cdot sd(y)}$$

$$cov(x,y) = \sum_{i=0}^{n} (x_i - \bar{x})(y_i - \bar{y}) = covariance\ of\ x\ and\ y\ variable.$$

$$sd(x) = \sqrt{\sum_{i=0}^{n} (x_i - \bar{x})} = standard\ deviation\ of\ variable\ x.$$

$$sd(y) = \sqrt{\sum_{i=0}^{n} (y_i - \bar{y})} = standard\ deviation\ of\ variable\ y.$$

The value of R ranges from -1 to +1. A value of the correlation coefficient close to +1 indicates a strong positive linear relationship (i.e. one variable increases with the other) A value close to -1 indicates a strong negative linear relationship (i.e. one variable decreases as the other increases).A value close to 0 indicates no linear relationship; however, there could be a nonlinear relationship between the variables. Many problems in engineering require that we decide whether to accept or reject a statement about some parameter. The statement is called a *hypothesis***,** and the decision-making procedure about the hypothesis is called *hypothesis testing.* This is one of the most useful aspects of statistical inference, since many types of decision-making problems, tests, or experiments in the engineering world can be formulated as hypothesis-testing problems.

The t-test is one of the methods used to accept or reject a given hypothesis. The t- value is simply calculated as:

$$t_{value} = \frac{B}{SE} = \frac{Coefficient\ of\ a\ variable\ in\ the\ regression\ equestion}{Standard\ error\ of\ the\ estimated\ coofficient}$$

Suppose we want to test the validity of a hypothesis, the hypothesis can be formulated as follows:

$$\begin{cases} H_o: \mu = a \\ H_o: \mu \neq a \end{cases}$$

For an arbitrary population value of **α**, here $\mathbf{H_0}$ and $\mathbf{H_1}$ are the null hypothesis and alternative hypothesis, respectively. Let **α** denote the probability of rejecting a true hypothesis (level of significance of the test), then the tabulated t-value (t-tab) that is used to test the importance of a variable in the model is obtained by reading from the t-table with **α /2** as column an **n** as row, and **α** as row and **n-1** as column for two and one-sided hypothesis, respectively. Here **n-1** denotes the degree of freedom. After doing so, it will be decided on the importance of each regression variable in the model. If t-cal exceeds t-tab, then $\mathbf{H_1}$ is accepted; otherwise, the null hypothesis is accepted. If **α =0**, for instance, accepting $\mathbf{H_0}$ means the particular variable has no importance in explaining.

Nowadays, commercial statistical software can provide p-values. Hence, we may not need t-tables for our particular decision. The P-value is the smallest level of significance at which a variable is significant. If **p- value** is smaller than **α**, the particular variable is important in explaining the variation of the response in the model. If Z_0 is the computed value of the test statistics, then the p- value is $\mathbf{2(1- \emptyset (Z_0))}$ for two-tailed test. where, $\mathbf{\emptyset (Z_0)}$ is the standard normal cumulative distribution at Z_0.

In this work, the CBR value is the dependent variable whereas, LL, PL, F_{200}, MDD and OMC for silty-clay (fine grained) soils. In carrying out the whole statistical analysis, statistical software program called SPSS software was being used.

5.2 Scatter plot

Since MS excel spreadsheet is found to be the most powerful and manageable tool, analysis of scatter plot and determination of correlation between two variables is being done using such software.

In this work, the CBR value is the dependent variable whereas, LL, PL, F_{200}, MDD and OMC for silty-clay (fine grained) soils. In carrying out the whole statistical analysis, statistical software program called SPSS software was being used.

Relying on the aim of the study the scatter plots are done to express the degree of correlation strength of the dependent variable CBR by each independent variables of LL, PL, OMC, MDD and F_{200} for both primary and all collected data.

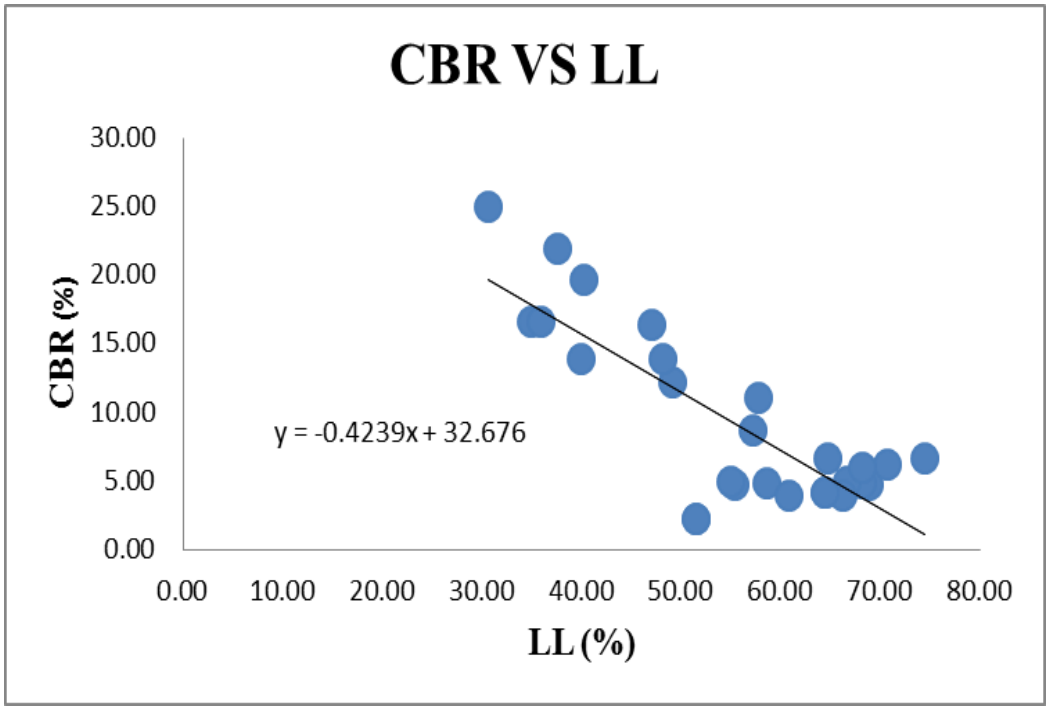


Figure 5.1 Scatter plot diagram of CBR vs. LL

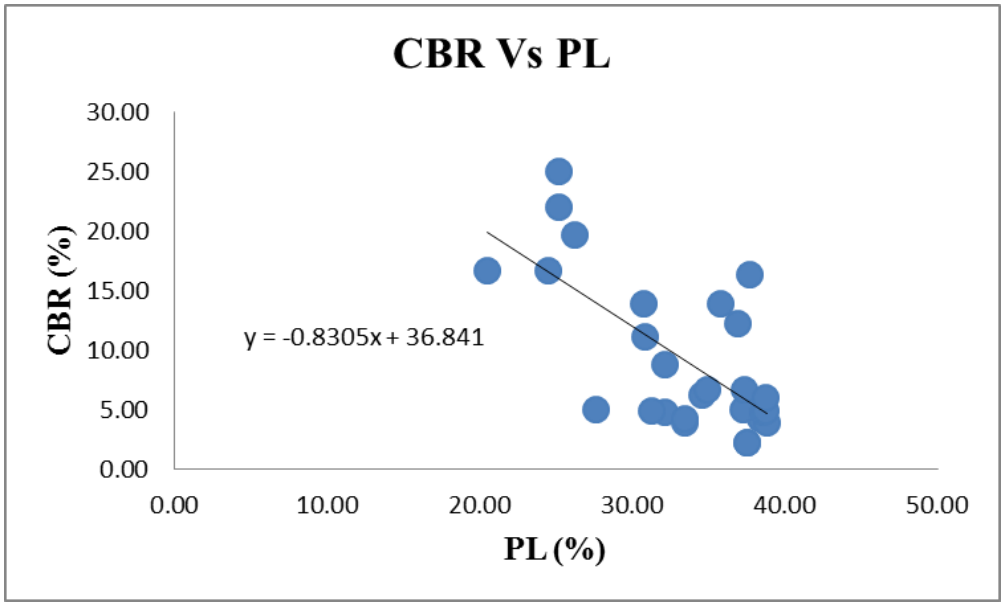


Figure 5.2 Scatter plot diagram of CBR vs. PL

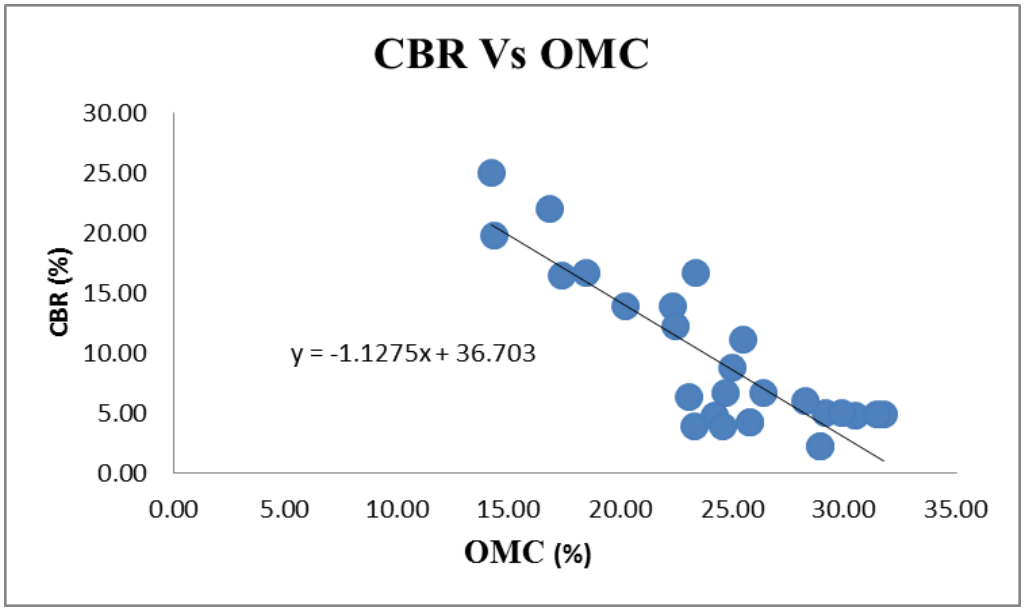


Figure 5.3 Scatter plot diagram of CBR vs. OMC

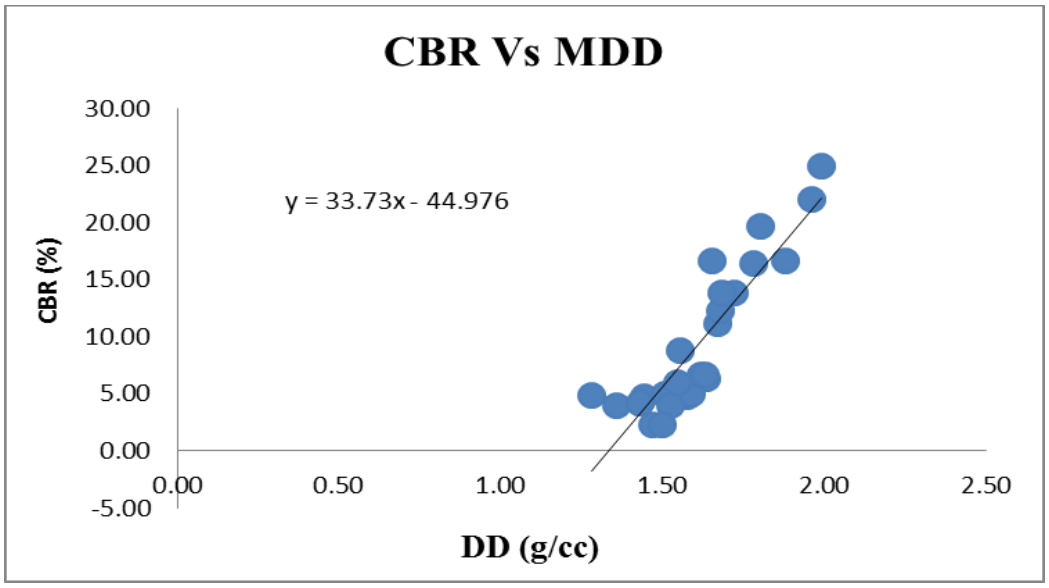


Figure 5.4 Scatter plot diagram of CBR vs. MDD

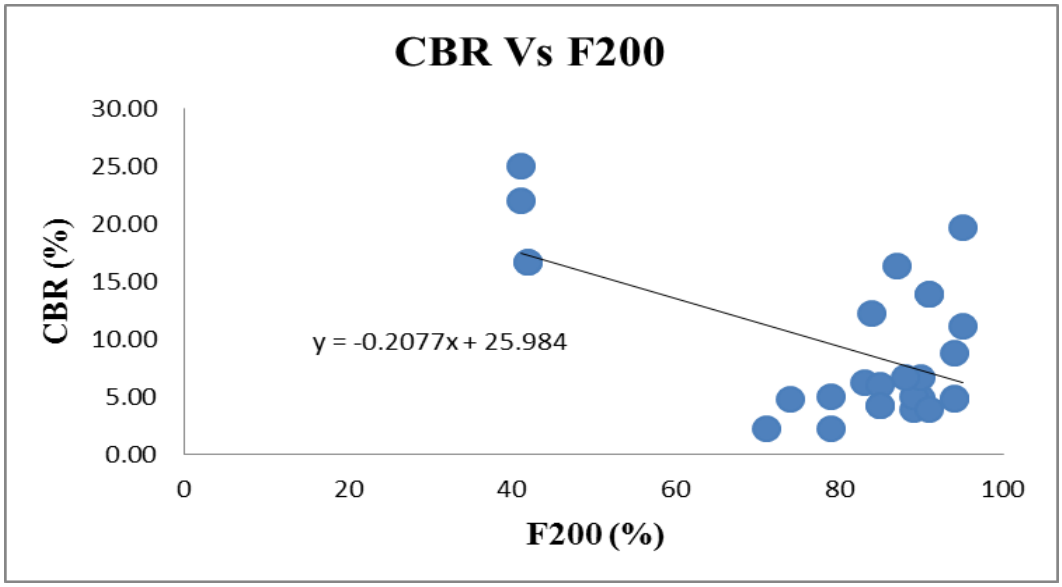


Figure 5.5 Scatter plot diagram of CBR vs. F200

5.3 Relationship between the Regressor Variables and the Response

Polynomial regression models are widely used when the response is curvilinear. They are generalized as:

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_1^2 + \alpha_5 x_2^2 + \alpha_6 x_3^2 + \cdots + \alpha_{n-2} x_1^n + \alpha_{n-1} x_2^n + \alpha_n x_3^n$$

Where:-

$\alpha_0, \alpha_1, \alpha_2, \alpha_3 \ldots \alpha_n$=coefficients of the independent variables

$x_1, x_2, x_3, \ldots, x_n$=the independent variables (regressors)

y=the response (dependent variable)

5.3.1 Single regression analysis between dependent and independent variables

Table 5.1 Regression analysis result between CBR and LL

Model Summary (1)				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.816[a]	.666	.652	3.81717

a.Predictors: (Constant),						
Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	32.676	3.394		9.627	.000
	LL	-.424	.060	-.816	-7.054	.000

a. Dependent Variable: CBR

The model equation for the given relationship is then:

CBR = 32.676 – 0.424(LL), with adjusted $\mathbf{R}^2$ value of 0.652

Where CBR and LL is expressed in percent (%)

Table 5. 2 Regression analysis between CBR and PL

Model Summary (2)				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.679[a]	.462	.440	4.84343

a. Predictors: (Constant), I

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	36.841	6.021		6.118	.000

	PL	-.831	.179	-.679	-4.630	.000

a. Dependent Variable: CBR

The model equation for the given relationship is then:

CBR = 36.841 – 0.831(PL), with adjusted $\mathbf{R}^2$ value of 0.440

Where CBR and PL is expressed in percent (%)

Table 5. 3 Regression analysis between CBR and OMC

Model Summary (3)				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.861[a]	.741	.730	3.36227

a. Predictors: (Constant), OMC

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	36.703	3.308		11.096	.000
	OMC	-1.127	.133	-.861	-8.447	.000

a. Dependent Variable: CBR

The model equation for the given relationship is then:

CBR = 36.703 – 1.127(OMC), with adjusted $\mathbf{R}^2$ value of 0.730

Where CBR and OMC is expressed in percent (%)

Table 5. 4 Linear regression analysis between CBR and MDD

Model Summary (4)				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.892[a]	.796	.787	2.98455

a. Predictors: (Constant), MDD

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-44.976	5.533		-8.129	.000
	MDD	33.730	3.420	.892	9.864	.000

a.Dependent Variable: CBR

The model equation for the given relationship is then:

CBR = -44.976 + 33.730(MDD), with adjusted $\mathbf{R}^2$ value of 0.787

Where CBR is expressed in percent (%) and MDD is in g/cm^3

Table 5. 5 Linear regression analysis between CBR and F200

Model Summary (5)				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.564[a]	.318	.290	5.45272

a. Predictors: (Constant), F_{200}

The model equation for the given relationship is then:

CBR = 25.984 – 0.208($\mathbf{F_{200}}$), with adjusted $\mathbf{R^2}$ value of 0.290

Where CBR and $\mathbf{F_{200}}$ is expressed in percent (%)

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	25.984	5.002		5.195	.000
	F200	-.208	.061	-.564	-3.411	.002

a. Dependent Variable: CBR

5.3.2 Multiple regression analysis between CBR and all independent parameters

From multiple regression analysis, it can be noticed that in order to determine the improved models stepwise regression analysis is being used. Such analysis is very helpful to exclude (remove) parameters which have less influence on the prediction of CBR and the analysis is as shown in below

Table 5. 6 Multiple regression analysis between CBR with LL and PL

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.837[a]	.700	.675	3.68996

a. Predictors: (Constant), PL, LL
b. Predictors: (Constant), LL

The model equation for the given relationship is then:

CBR = 38.014 – 0.339(LL) - 0.303(PL) with adjusted $\mathbf{R}^2$ value of 0.675

Where CBR, LL and PL were expressed in percent (%)

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	38.014	4.595		8.273	.000
LL	-.339	.078	-.652	-4.367	.000
PL	-.303	.182	-.248	-1.659	.110

a. Dependent Variable: CBR

Table 5. 7 Multiple regression analysis between CBR with OMC and MDD

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.931[a]	.867	.856	2.45670

a. Predictors: (Constant), MDD, OMC
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-11.500	10.375		-1.109	.279
	OMC	-.555	.155	-.424	-3.591	.001
	MDD	21.307	4.460	.563	4.778	.000

a. Dependent Variable: CBR

The model equation for the given relationship is then:

CBR = - 11. 5 – 0.555(OMC) + 21.307(MDD with adjusted $\mathbf{R}^2$ value of 0.856

Where CBR and OMC expressed in percent (%) and MDD in g/cm^3)

Table 5. 8 Multiple regression analysis between CBR and all parameters

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.966[a]	.934	.652	1.84961
2	.964[b]	.929	.856	1.87962
3	.959[c]	.919	.909	1.95270

a. Predictors: (Constant), F200, OMC, PL, MDD, LL
(no variables removed)

b. Predictors: (Constant), OMC, PL, MDD, LL (F200 removed)

c. Predictors: (Constant), OMC, MDD, LL (F200 and PL removed)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.981	9.046		.108	.915
	LL	-.158	.051	-.304	-3.092	.006
	PL	-.198	.098	-.162	-2.016	.007
	OMC	-.334	.129	-.255	-2.589	.017
	MDD	17.714	3.612	.468	4.905	.000
	F200	.040	.030	.107	1.311	.204
2	(Constant)	3.786	8.932		.424	.676
	LL	-.132	.048	-.253	-2.757	.011
	PL	-.160	.095	-.131	-1.680	.107
	OMC	-.363	.129	-.277	-2.819	.010
	MDD	16.722	3.589	.442	4.660	.000
3	(Constant)	-1.764	8.621		-.205	.840
	LL	-.169	.044	-.326	-3.871	.001
	OMC	-.350	.134	-.267	-2.619	.015
	MDD	17.965	3.648	.475	4.924	.000

a. Dependent Variable: CBR

From the above summarized table, three models are presented

- ✓ General equation for model 1;

$CBR = 0.981 – 0.158(LL) – 0.198(PL) – 0.334(OMC) + 17.714(MDD) + 0.4(_{F200})$ with adjusted F value of 0.652

- ✓ equation for model 2 when F_{200} variables removed;

$CBR = 3.786 – 0.132(LL) – 0.160(PL) – 0.\ 363(OMC) + 16.722(MDD)$ with adjusted R^2 value of 0.856

- ✓ equation for model 3 when F_{200} and PL variables removed;

$CBR = -1.764 – 0.169(LL) – 0.350(OMC) + 17.965(MDD)$ with adjusted R^2 value of 0.909

Where LL, PL, OMC and CBR is in percent (%) and MDD is in g/cm^3

From the above multiple regression analysis it can be observed that values of R square under model 1is become high compared to another model. r. Therefore; regarding multiple regression analysis model 3 is chosen as a high significant multiple regression model.

The above equation is therefore the final predicted equation of CBR value. Mean that the above equation model is being able to express 90.9 % of the variation of CBR. Conversely; about 9.1 % is not explained by the developed equation.

Table 5. 9 Summary of regression equation and their corresponding R^2 in predicting CBR values

M/N	Coefficients of predictors					Output developed equations	R^2
	LL	PL	OMC	MDD	F_{200}		
1	-0.424					CBR = 32.676 – 0.424(LL)	0.732
2		-0.831				CBR = 36.841 – 0.831(PL)	0.444
3			-1.13			CBR = 36.703 – 1.127(OMC)	0.730
4				33.37		CBR = -44.976 + 33.730(MDD)	0.787
5					-0.21	CBR = 25.984 – 0.208(**F_{200}**)	0.290

6	-0.34	-0.303				CBR = 38.014 – 0.339(LL) - 0.303(PL)	0.652
7			-0.56	21.307		CBR = - 11. 5 – 0.555(OMC) + 21.307(MDD	0.856
8	-0.158	-0.198	-0.34	17.714	0.4	CBR = -1.764 – 0.169(LL) – 0.350(OMC) + 17.965(MDD)	0.909

Where LL, PL, OMC, F_{200} and CBR is expressed in percent (%) and MDD in g/cm^3

Note that: M/N = model number, LL = liquid limit, PL = plastic limit, CBR = California bearing ratio, OMC optimum moisture content, F2 = percentage passing at sieve number 200 and MDD = maximum dry density.

Table 5. 10 Summary of regression analysis

Regression type	**Model Name**	**Adj. R^2**	**Standard error (**a)	**Significance order based on R^2**	**Significance order based on** A
Single linear regression model	Model 1	0.652	< 0.005	3	Ok
	Model 2	0.440	< 0.005	4	Ok
	Model 3	0.730	< 0.005	2	Ok
	Model 4	0.787	< 0.005	1	Ok
	Model 5	0.290	< 0.005	5	Ok
Multiple regression model	Model A	0.918	>0.005	1	Not Ok
	Model B	0.916	>0.005	2	Not Ok
	Model C	0.909	< 0.005	3	Ok

From the statistical output models (showed on the above table) R^2 value of Model A is better than all the above stated models. Conversely, the value of significance and standard error is lower and higher respectively than any other model. Therefore, instead of model A model C is chosen since the independent factors like PL and F_{200} which were weak in determination of CBR predicted value is removed.

Table 5. 11 Comparison that held between actual CBR and predicted one (developed equation)

S/N	Control Test Result						Developed CBR Value	Variation in (%)
	P_{200} (%)	LL (%)	PI (%)	MDD (g/cc)	OMC (%)	Actual CBR Value (%)		
1	80	55	25	1.73	13.46	13.79	15.32	10
2	70	48	22	1.65	18.1	12.29	13.36	8
3	67	45	22	1.60	19.68	11.12	12.50	11
4	75	70	5	1.54	22.04	5.57	6.40	13
5	50	61	28	1.81	14.04	14.67	15.52	6
6	82	57	25	1.78	13.36	14.55	15.99	9
7	45	60	23	1.61	19.64	9.21	9.63	8.9
8	76	71	5	1.57	11.51	9.27	10.48	11.5
Average						**11.31**	**12.48**	**9.67**

From the above table it can be concluded that, the developed correlation predicts CBR value with average variation of 9.75% from that of actual CBR value.

As illustrated in table 5.11, such prediction was obtained by using a control test results that were determined after collecting representative soil samples from different places of Modjo dry port area. Since; this study paper is limited only for Modjo dry port area, therefore it is difficult to compare with other studies both from local and published sources. This is may be due to the difference in test procedures and also the unique properties of the geological material and environmental situations where this correlation was developed.

6. DISCUSSIONS ON CORRELATION RESULTS

Since the objectives of this study is to formulate a correlation between the variables of identified parameters, which are expected to predict CBR values, an attempt is made to obtain which one of the predictors (independent variables) can be strongly related with dependent variables like CBR.

During prediction of CBR values from independent variables, statistical methods like single and multiple regressions have been used. For each independent variable its effect and prediction capacity is analyzed using regression analysis first. The analysis is expressed using equations, from these equations it can be observed that CBR the predicted one has relatively strong correlation with LL and OMC which is R^2 = 0.730 and R^2 = 0.787 respectively.

After having such developed equation, the corresponding coefficient of determination of values, multiple regressions is used by stepwise method. This is done to include and exclude more powerful and non-influential variables respectively. From multiple regression analysis 3 models were generated with their corresponding coefficient of determination values. According to the analysis models with higher R^2 value is the best one that explains or predicts CBR.

Therefore, from three derived models, model number 3 with R^2 = 0.909 is chosen as final equation to predict CBR. This means that CBR value is more influenced by LL, OMC and MDD of the given soil.

As the liquid limit of the soil increases, it shows that weak quality of the soil type for being used as a pavement material. On the other hand, since CBR is a measure of strength, higher maximum dry density results higher CBR values at constant moisture content. Such condition might be the possible reason for having good correlation of CBR with LL, OMC and MDD.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This study is carried out in order to find correlation between CBR value and soil index properties of F_{200}, LL, PL, MDD and OMC. For that reason, the required laboratory tests were conducted on collected soil samples from different geographical location of Modjo dry port area. After conducting laboratory test for 27 representative soil samples using single and multiple linear regression analysis model and the relationship was developed that predict CBR value. From predicted correlations the following correlations were drawn:

- MDD highly affects the value of predicted CBR with $R^2 = 0.787$, therefore as the values of MDD increases then correlated CBR also increases by 78.7% since they have direct relationship.
- Prediction of CBR value from PL and $F2_{00}$ resulted $R^2 = 0.444$ and $R^2 = 0.290$ respectively in which both can able to predict less than 50%. Hence, prediction of CBR from PL and F_{200} is weak.
- During prediction of CBR from index properties relatively better correlation was obtained when multiple regression is used than single regression as shown below:

  CBR= -1.764-0.169(LL)-0.350(OMC) + 17.965(MDD) with R^2 values of 0.909

- Therefore; combination of soil index properties like LL, OMC and MDD correlates better CBR characteristics strength value than individual index properties of natural subgrade soil.
- Validation of the above model prediction also confirmed by taking 8 freshly worked laboratory tests which gave very close results.

7.2 Recommendations

- In order to construct pavement for port terminals and highways, determination of CBR is very critical, therefore; it is recommended applying such correlation for preliminary determination of CBR values only.
- This study considers predicting soaked CBR from index properties of fine grained soil, further; it is advisable to develop correlation between unsoaked CBR with index properties in order to check the difference that held between them.
- In order to see the effect for comparison purpose further study might be required by using Ridge regression and Artificial Neural Networks.
- Further works are required to determine the extent of applicability of the developed relation.

8. REFERENCE

[1] Africa Development Bank "Analytical work on transport sector in Ethiopia." Addis Abeba, (2015).

[2] Ahmed Shahrial "Prediction of soaked CBR using index properties of soils" University of New York, Buffalo, (2016).

[3] Albert Atterberg, "Modern Soil Mechanics" Published in New York, (1911).

[4] Arora, K.R., (2004). Soil Mechanics and Foundation Engineering, Re-print Standard Publishers Distributer,Nai Sarak, Delhi,

[5] Douglas C., Montgomery. "Applied Statistics and Probability for Engineers" Fifth Edition, Arizona State University. (2002)

[6] Ethiopian Road Authority Manual, (2002).

[7] Fredrics, M., Standard Hand Book for Civil Engineers, McGraw-Hill Book Company, New York, (1983).

[8] Government of Ethiopia "National Freight Logistics Strategy for Ethiopia" Addis Abeba, (2016).

[9] Lema K., "Climate Classifications of Ethiopia" (1996).

[10] Martin W.B., "Liquefaction and In-situ Field Testing" New York, (2003).

[11] Magdi Z., "Prediction of CBR from Index Properties of Cohesive Soils" University of Khartoum, Sudan (2012).

[13] Mittal C., "Moisture Density Relationship of Clayey Soils" Ekiti State, Nigeria (2000).

[12] Nathan Associates "A strategy and Transformation Study for ESLSE" Addis Abeba, (2016).

[14] Naveen B., "Establishing Relationship between CBR-value and Physical Properties of Soil" BEC Bagalkot, India (2016).

[15] Oyediran A., et al "Getting CBR Using Index Properties of Soil" Braja, India (2011).

[16] Peter D., et al "ANN model for Predicting CBR from Index properties of Soil" Kolkata, India (2006).

[17] Prasad D., "Empirical Correlation between CBR-value and Physical Properties of Soil" New York, (1983).

[18] Surrendra R., "Predicting CBR-value Using Index Properties of Clayey Soil" New Delhi, India (2016).

[19] Texas, Civil Engineering, (2014)

[20] Winta Amare, "Prediction of Soaked California Bearing Ratio (CBR) of Fine Grained Soils from Index Properties; Case of Silty Clay Soils from Addis Ababa" Adama Scince and Technology University, Adama, (2016).

[21] World Bank Financial Report, (2014).

[22] Yang H., "Pavement Design and Analysis" Pearson Education Inc., New Saddle River., NJ, (2004).

[23] Yashas D., "Effect of CBR on the Properties of Soil" New Delhi, India, (2016).

[24] Yared Leliso, "Correlation of CBR value with Soil Index Properties for Addis Ababa Subgrade Soil" Addis Ababa University, Addis Ababa (2010).

[25] Zelalem Worku, "Prediction of California Bearing Ratio (CBR) value from Index Properties of Soil" Addis Ababa University, Addis Ababa, (2013).

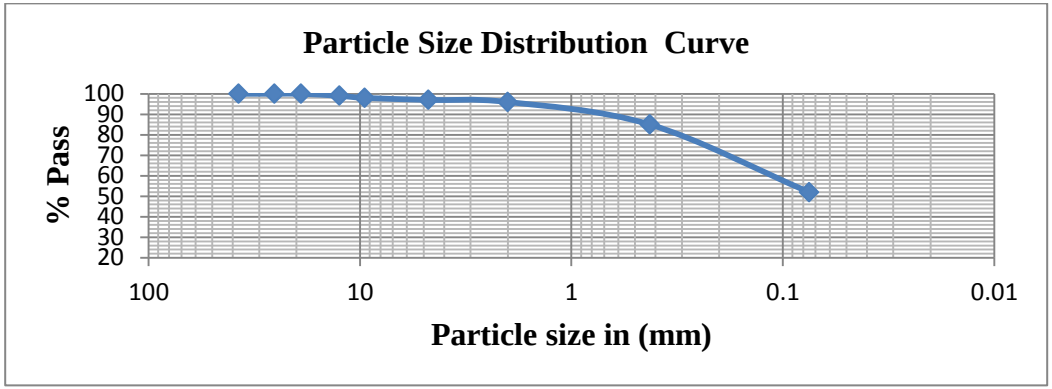
9. APPENDIX: Detail Laboratory work

The various kinds of tests that were performed for evaluating the validation of the correlation by eight laboratory sample tests were recorded as below.

Experiment No.1

1.1 **Particle Size Distribution Curve**

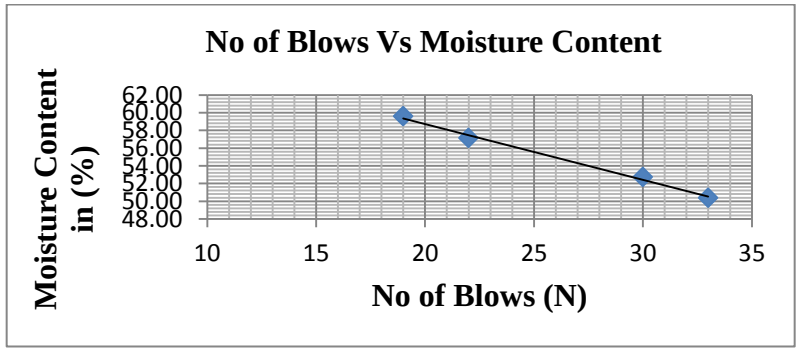
Laboratory Control Test No.1			
Sieve (mm)	**Wt. retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	15	1	99
9.5	15	1	98
4.75	15	1	97
2	15	1	96
0.425	45	11	85
0.075	195	33	52
Pan	1200	52	0
Total mass(gm.)	**1500**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	30	22	19		
container no	**11**	**415**	**329**	**64**	**218**	**318**
Wt. of cont. + wet soil	43.00	41.27	42.34	44.02	34.2	31.7
Wt. of cont. + dry soil	35.90	34.79	35.32	36.36	30.5	29.3
Wt. of container	21.80	22.50	23.03	23.50	21.51	21.60
Wt. of water	7.10	6.48	7.02	7.66	3.7	2.4
Wt. of dry soil	14.10	12.29	12.29	12.86	8.99	7.70
Moisture content in (%)	50.35	52.72	57.12	59.56	41.15	31.17



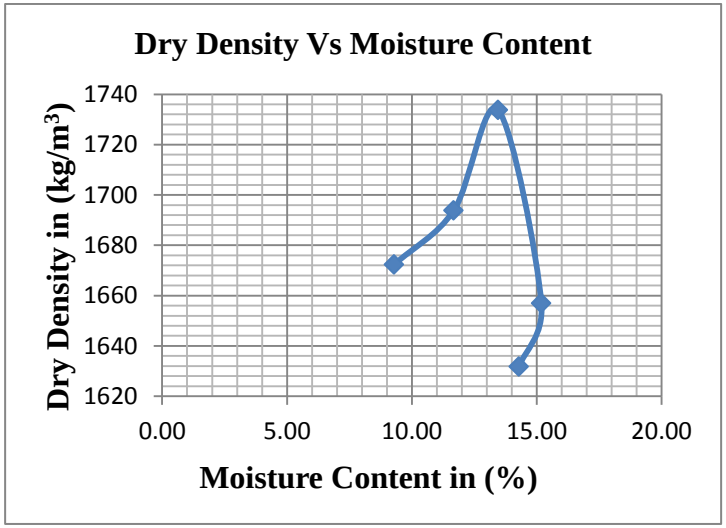
From the graph; moisture content at 25 blows (LL) = 54.8

PL = 36.16

PI = LL-PL = 54.8-36.16 = **18.64**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**AB**	**I**	**12**	**A_2**	**N**
Mass of Wet soil +Con(gm.)(F)	140.42	156.7	181.30	157.63	146.26
Mass of dry soil+ con(gm.)(G)	130.03	142.31	162.00	139.28	130.25
Mass of container(gm.)(H)	18.20	19.12	18.56	18.46	18.20
Mass of moisture(gm.)F-G=(I)	10.39	14.39	19.3	18.35	16.01
Mass of Dry soil(gm.)G-H=(J)	111.83	123.19	143.44	120.82	112.05
Moisture content % (I/J)*100=K	9.29	11.68	13.46	15.19	14.29
Dry Density g/cm^3 E/(100+K)*100	1.672	1.694	1.734	1.657	1.632
Dry density in kg/m^3	1672	1694	1734	1657	1632

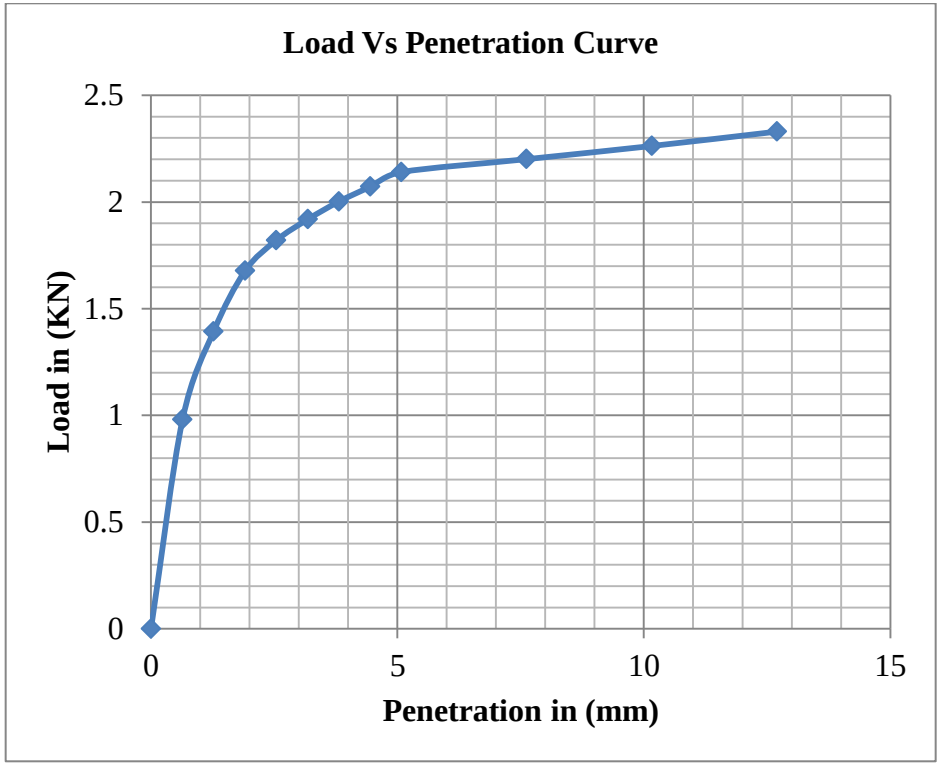


From the above plot; the value of MDD (Maximum Dry Density) = 1.734 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 13.46%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	38.00	0.0258	0.98	
1.27	54.00	0.0258	1.39	
1.91	65.00	0.0258	1.68	
2.54	70.54	0.0258	1.82	13.79
3.18	74.36	0.0258	1.92	
3.81	77.59	0.0258	2.00	
4.45	80.30	0.0258	2.07	
5.08	82.95	0.0258	2.14	10.70
7.62	85.30	0.0258	2.20	
10.16	87.69	0.0258	2.26	
12.7	90.30	0.0258	2.33	

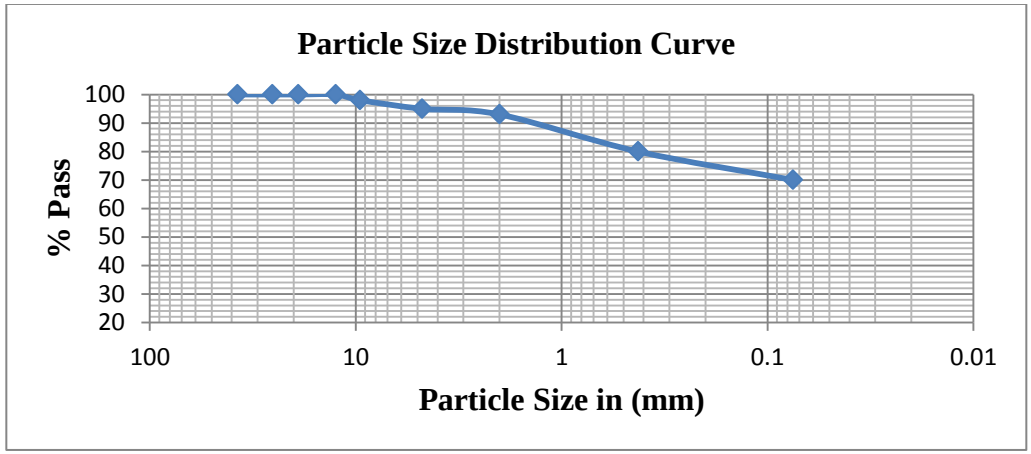


Therefore, from the above table and graph the value of CBR at **2.54**mm and **5.08**mm penetration is **13.79** and **10.7** percent respectively.

Experiment No.2

2.1 Particle Size Distribution Curve

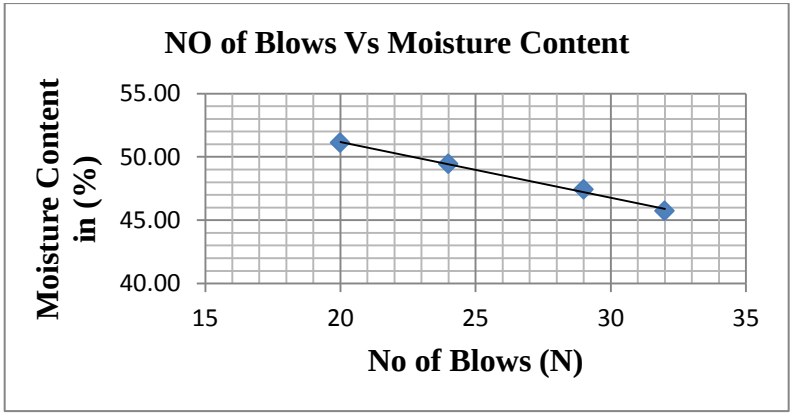
Laboratory Test No.2			
Sieve (mm)	**Wt. retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	15	0	100
9.5	30	2	98
4.75	45	3	95
2	30	2	93
0.425	195	13	80
0.075	150	10	70
Pan	1035	70	0
Total mass(gm.)	**1500**	**100**	



2.2 Atterburg limit test

2.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	32	29	24	20		
container no	**7**	**221**	**421**	**43**	**241**	**320**
Wt. of cont. + wet soil	42.75	41.03	40.07	44.32	35.13	32.26
Wt. of cont. + dry soil	35.80	35.23	34.29	36.5	32.25	30.43
Wt. of container	20.60	23.00	22.60	21.20	23.32	23.12
Wt. of water	6.95	5.8	5.78	7.82	2.88	1.83
Wt. of dry soil	15.20	12.23	11.69	15.30	8.93	7.31
Moisture content in (%)	45.72	47.42	49.44	51.11	32.25	25.03



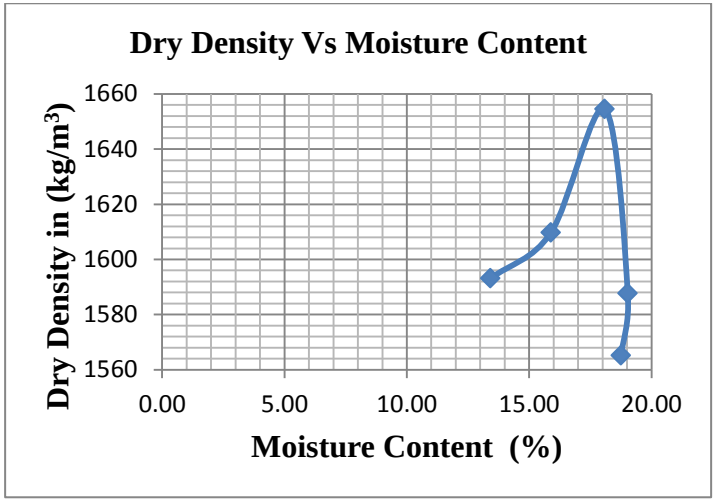
From the graph; moisture content at 25 blows (LL) = 48.3

PL = 28.64

PI = LL-PL = 48.3-28.64 = **19.66**

Experiment 2.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**A_2**	**AB**	**12**	**G**	**N**
Mass of Wet soil +Con(gm.)(F)	131.44	123.03	147.44	141.81	137.65
Mass of dry soil +con(gm.)(G)	117.92	108.62	127.66	122.28	121.48
Mass of container(gm.)(H)	17.20	17.91	18.35	19.66	35.26
Mass of moisture(gm.)F-G=(I)	13.52	14.41	19.78	19.53	16.17
Mass of Dry soil(gm.)G-H=(J)	100.72	90.71	109.31	102.62	86.22
Moisture content % (I/J)*100=K	13.42	15.89	18.10	19.03	18.75
Dry Density gm./cm^3 E/(100+K)*100	1.593	1.610	1.654	1.588	1.565
Dry density in kg/m^3	1593	1610	1654	1588	1565

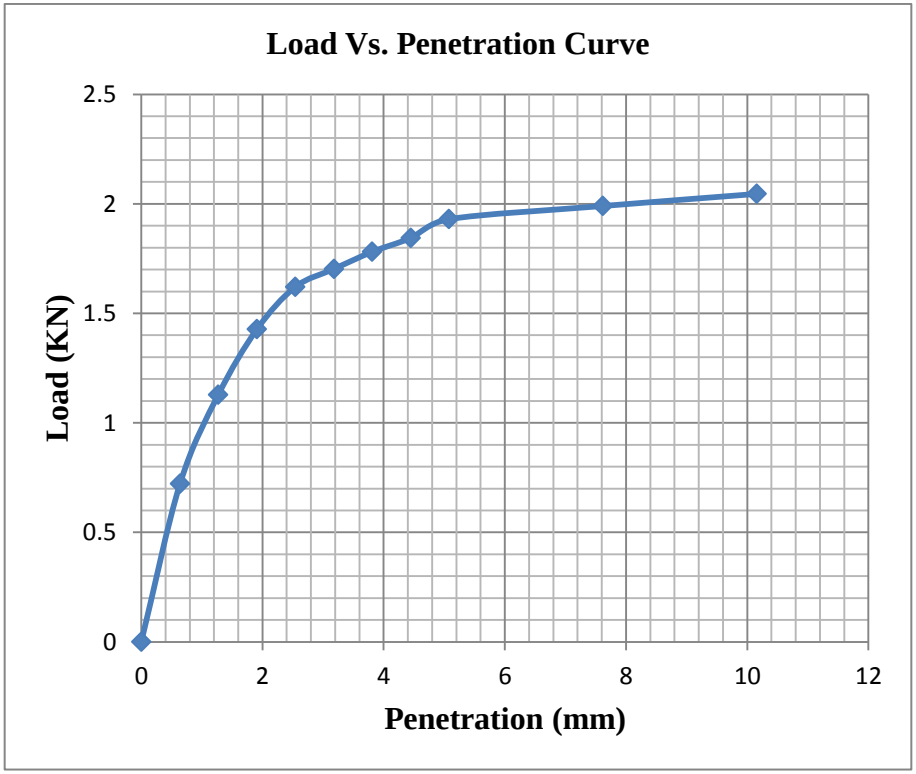


From the above plot; the value of MDD (Maximum Dry Density) = 1.654 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 18.10%

Experiment No. 2.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	28.00	0.0258	0.72	
1.27	43.71	0.0258	1.13	
1.91	55.34	0.0258	1.43	
2.54	62.79	0.0258	1.62	12.29
3.18	66.00	0.0258	1.70	
3.81	69.02	0.0258	1.78	
4.45	71.48	0.0258	1.84	
5.08	74.81	0.0258	1.93	9.67
7.62	77.14	0.0258	1.99	
10.16	79.28	0.0258	2.05	
12.7	81.02	0.0258	2.09	

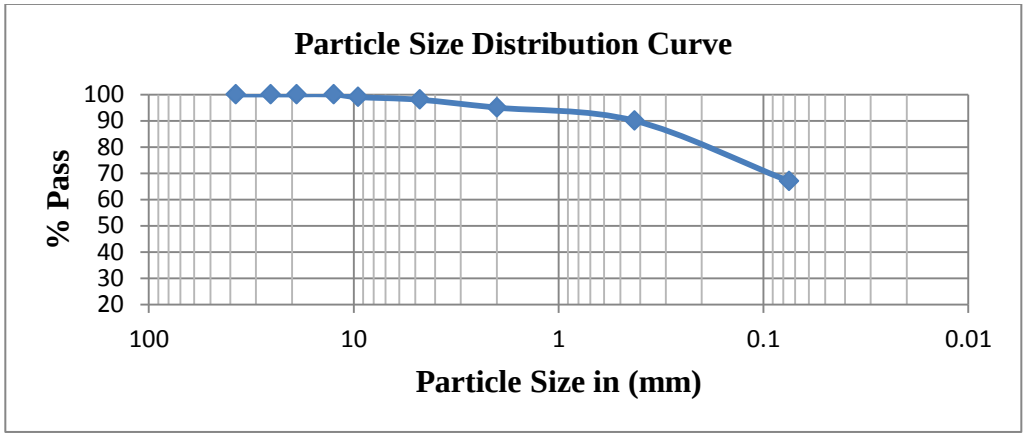


Therefore, from the above table and graph the value of CBR at **2.54**mm and **5.08**mm penetration is **12.29** and **9.67** percent respectively.

Experiment No.3

3.1 Particle Size Distribution Curve

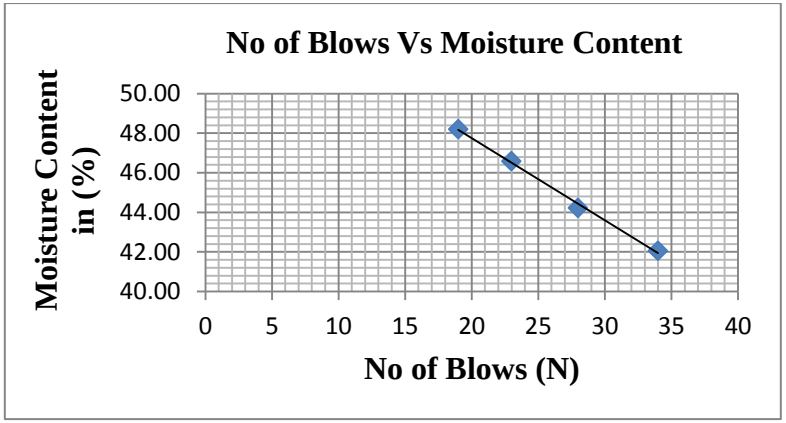
Laboratory Test No.3			
Sieve (mm)	**Wt. retained in(gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	15	0	100
9.5	15	1	99
4.75	15	1	98
2	45	3	95
0.425	75	5	90
0.075	345	23	67
Pan	990	67	0
Total mass(gm.)	**1500**	**100**	



3.2 Atterburg limit test

3.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	23	19		
container no	**9**	**254**	**325**	**36**	**115**	**124**
Wt. of cont. + wet soil	38.42	41.23	43.25	40.25	32.23	34.25
Wt. of cont. + dry soil	33.74	35.12	36.85	33.86	30.08	31.96
Wt. of container	22.61	21.30	23.11	20.60	23.27	23.05
Wt. of water	4.68	6.11	6.4	6.39	2.15	2.29
Wt. of dry soil	11.13	13.82	13.74	13.26	6.81	8.91
Moisture content (%)	42.05	44.21	46.58	48.19	31.57	25.70



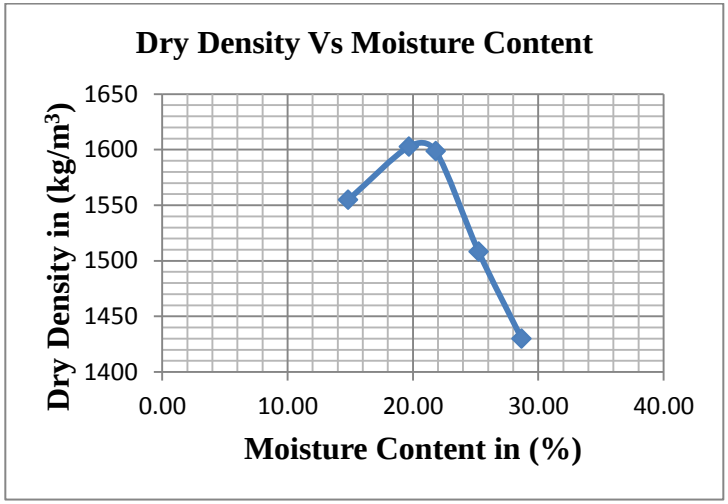
From the graph; moisture content at 25 blows (LL) = 45.26

PL = 28.24

PI = LL-PL = 45.26-28.24 = **17.02**

Experiment 3.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	F	G	H	M	N
Mass of Wet soil +Con(gm.)(F)	166.65	205.03	178.68	202.00	200.15
Mass of dry soil +con(gm.)(G)	147.35	175.47	149.96	165.25	160.00
Mass of container(gm.)(H)	17.20	25.29	18.35	19.66	20.03
Mass of moisture(gm.)F-G=(I)	19.30	29.56	28.72	36.75	40.15
Mass of Dry soil(gm.)G-H=(J)	130.15	150.18	131.61	145.59	139.97
Moisture content % (I/J)*100=K	14.83	19.68	21.82	25.24	24.68
Dry Density gm./cm^3 E/(100+K)*100	1.555	1.543	1.598	1.613	1.430
Dry density in kg/m^3	1555	1603	1598	1508	1430

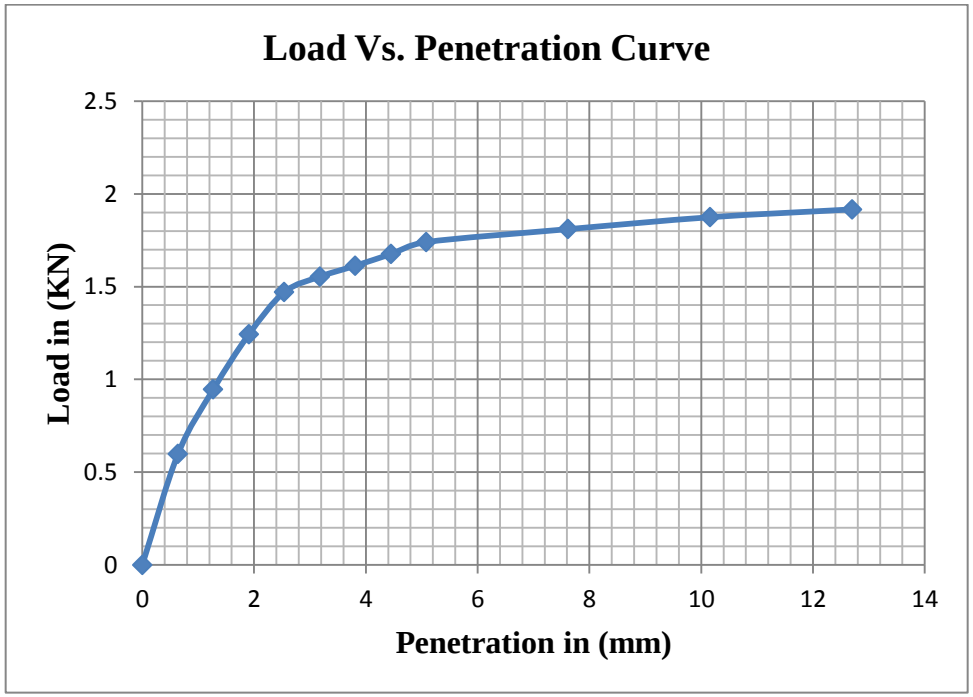


From the above plot; the value of MDD (Maximum Dry Density) = 1.613 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 25.24%

Experiment No. 3.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	23.21	0.0258	0.60	
1.27	36.66	0.0258	0.95	
1.91	48.21	0.0258	1.24	
2.54	56.98	0.0258	1.47	11.12
3.18	60.23	0.0258	1.55	
3.81	62.50	0.0258	1.61	
4.45	64.95	0.0258	1.68	
5.08	67.44	0.0258	1.74	8.72
7.62	70.15	0.0258	1.81	
10.16	72.64	0.0258	1.87	
12.7	74.28	0.0258	1.92	

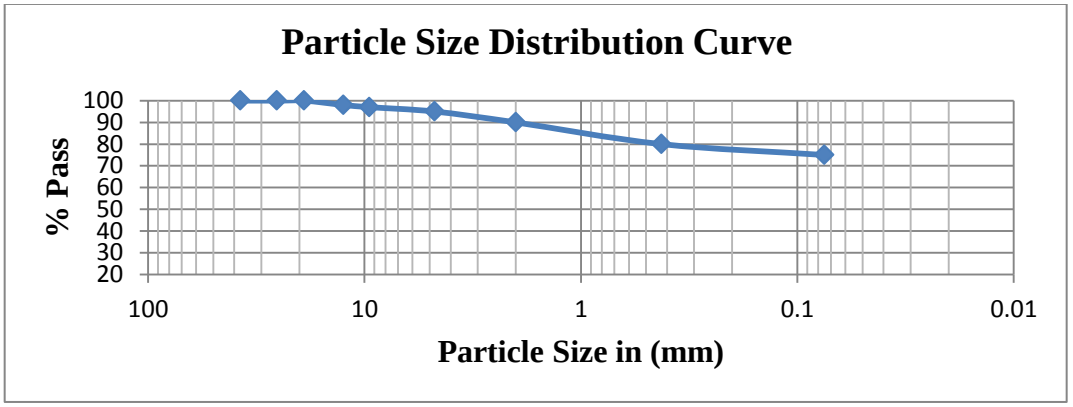


Therefore, from the above table and graph the value of CBR at **2.54**mm and **5.08**mm penetration is **11.12** and **8.72** percent respectively.

Experiment No.4

4.1 Particle Size Distribution Curve

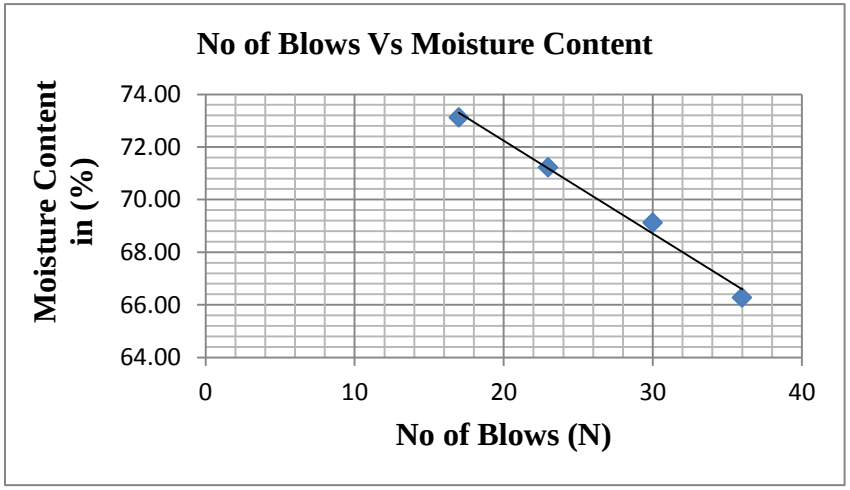
Laboratory Test No.4			
Sieve (mm)	**Wt. retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	15	2	98
9.5	15	1	97
4.75	30	2	95
2	75	5	90
0.425	150	10	80
0.075	75	5	75
Pan	1140	75	0
Total mass(gm.)	**1500**	**100**	



4.2 Atterburg limit test

4.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	36	30	23	17		
container no	**5**	**221**	**128**	**32**	**153**	**421**
Wt. of cont. + wet soil	41.23	42.15	43.26	40.18	33.21	31.25
Wt. of cont. + dry soil	33.25	34.45	34.25	33.05	31.25	29.33
Wt. of container	21.21	23.31	21.60	23.30	23.14	22.58
Wt. of water	7.98	7.7	9.01	7.13	1.96	1.92
Wt. of dry soil	12.04	11.14	12.65	9.75	8.11	6.75
Moisture content (%)	66.28	69.12	71.22	73.12	24.16	28.44



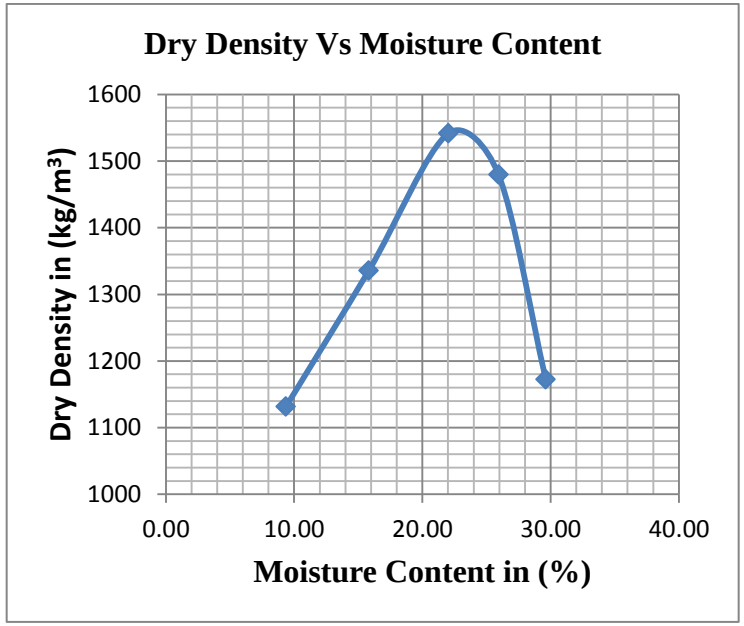
From the graph; moisture content at 25 blows (LL) = 68.8

PL = 26.31

PI = LL-PL = 68.8-26.31 = **42.49**

Experiment 4.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**A**	**2**	**B_4**	**K_1**	**D**
Mass of Wet soil +Con(gm.)(F)	147.79	115.4	119.62	164.37	164.29
Mass of dry soil +con(gm.)(G)	136.72	102.12	101.28	134.39	130.87
Mass of container(gm.)(H)	18.46	18.21	18.05	18.80	18.05
Mass of moisture(gm.)F-G=(I)	11.07	13.28	18.34	29.98	33.42
Mass of Dry soil(gm.)G-H=(J)	118.26	83.91	83.23	115.59	112.82
Moisture content % (I/J)*100=K	9.36	15.83	22.04	25.94	29.62
Dry Density gm./cm^3 E/(100+K)*100	1.131	1.336	1.542	1.480	1.172
Dry density in kg/m^3	1131	1336	1542	1480	1172

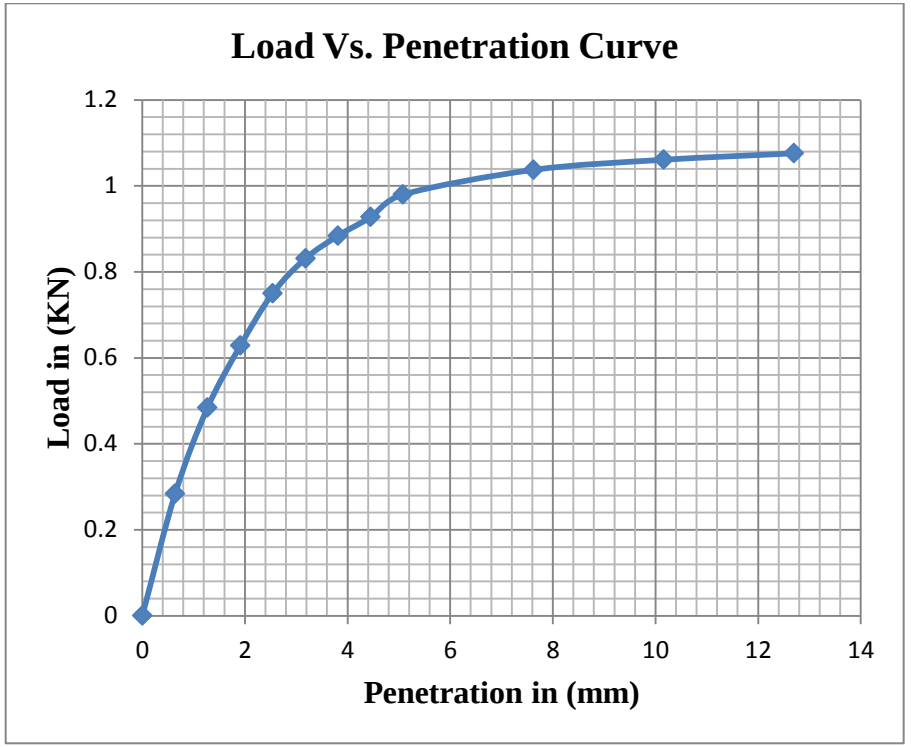


From the above plot; the value of MDD (Maximum Dry Density) = 1.542 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 25.04%

Experiment No. 4.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	11.00	0.0258	0.28	
1.27	18.75	0.0258	0.48	
1.91	24.35	0.0258	0.63	
2.54	29.07	0.0258	0.75	5.57
3.18	32.22	0.0258	0.83	
3.81	34.25	0.0258	0.88	
4.45	35.95	0.0258	0.93	
5.08	37.98	0.0258	0.98	4.92
7.62	40.21	0.0258	1.04	
10.16	41.12	0.0258	1.06	
12.7	41.70	0.0258	1.08	

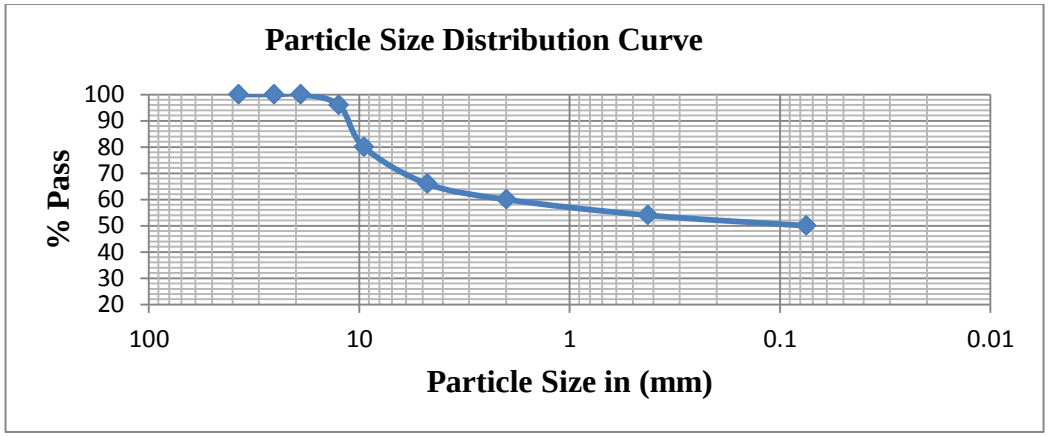


Therefore, from the above table and graph the value of CBR at **2.54**mm and **5.08**mm penetration is **5.57** and **4.92** percent respectively.

Experiment No.5

5.1 Particle Size Distribution Curve

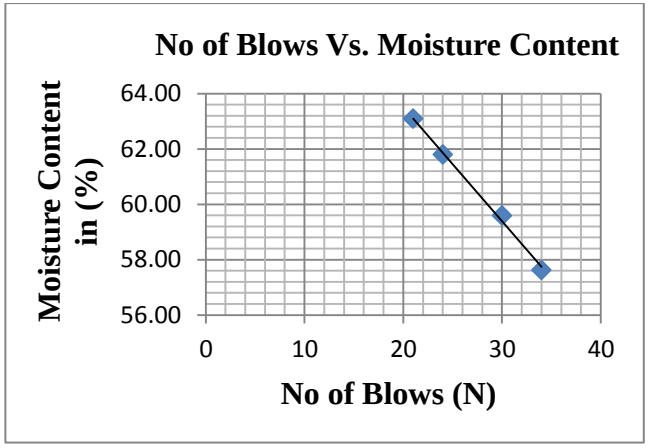
Laboratory Test No.5			
Sieve (mm)	**Wt. retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	15	4	96
9.5	240	16	80
4.75	210	14	66
2	90	6	60
0.425	90	6	54
0.075	60	4	50
Pan	795	50	0
Total mass(gm.)	**1500**	**100**	



5.2 Atterburg limit test

5.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	30	24	21		
container no	**3**	**215**	**135**	**48**	**135**	**328**
Wt. of cont. + wet soil	39.88	41.11	42.35	43.26	33.26	31.25
Wt. of cont. + dry soil	33.26	33.90	34.96	35.62	31.25	28.66
Wt. of container	21.77	21.80	23.00	23.51	22.79	22.70
Wt. of water	6.62	7.21	7.39	7.64	2.01	2.59
Wt. of dry soil	11.49	12.10	11.96	12.11	8.46	5.96
Moisture content (%)	57.62	59.58	61.78	63.08	23.75	43.46



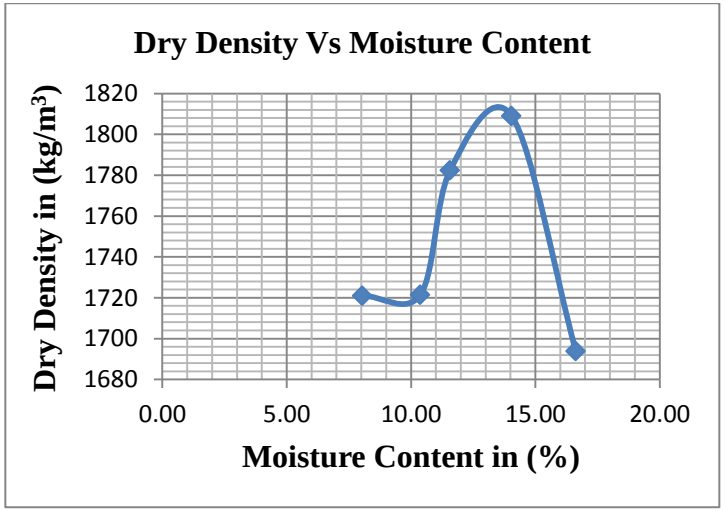
From the graph; moisture content at 25 blows (LL) = 61.5

PL = 33.6

PI = LL-PL = 61.5-33.6 = **27.9**

Experiment 5.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**K1**	**A_{04}**	**A_2**	**D**	**34**
Mass of Wet soil +Con(gm.)(F)	143.64	157.08	179.84	167.61	142.99
Mass of dry soil +con(gm.)(G)	134.34	144.16	163.10	149.29	125.22
Mass of container(gm.)(H)	18.80	19.66	18.46	18.80	18.35
Mass of moisture(gm.)F-G=(I)	9.30	12.92	16.74	18.32	17.77
Mass of Dry soil(gm.)G-H=(J)	115.54	124.5	144.64	130.49	106.87
Moisture content % (I/J)*100=K	8.05	10.38	11.57	14.04	16.63
Dry Density gm./cm^3 E/(100+K)*100	1.721	1.722	1.782	1.809	1.694
Dry density in kg/m^3	1721	1722	1782	1809	1694

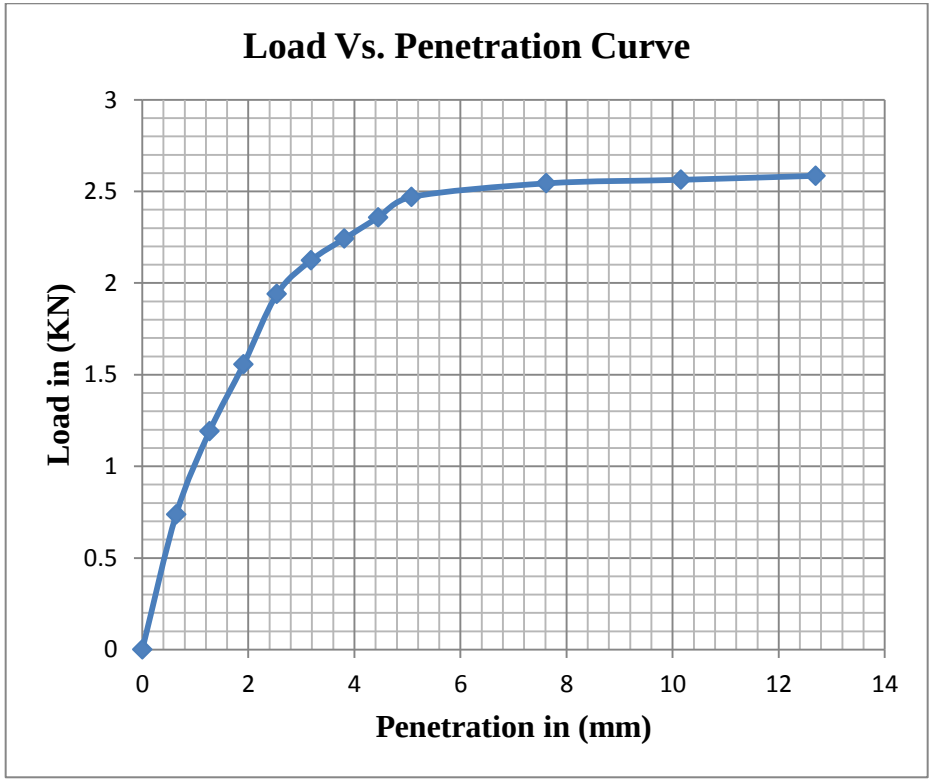


From the above plot; the value of MDD (Maximum Dry Density) = 1.81 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 14.04%

Experiment No. 5.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	28.60	0.0258	0.74	
1.27	46.20	0.0258	1.19	
1.91	60.32	0.0258	1.56	
2.54	75.19	0.0258	1.94	14.67
3.18	82.30	0.0258	2.12	
3.81	86.90	0.0258	2.24	
4.45	91.40	0.0258	2.36	
5.08	95.74	0.0258	2.47	12.36
7.62	98.60	0.0258	2.54	
10.16	99.35	0.0258	2.56	
12.7	100.20	0.0258	2.59	

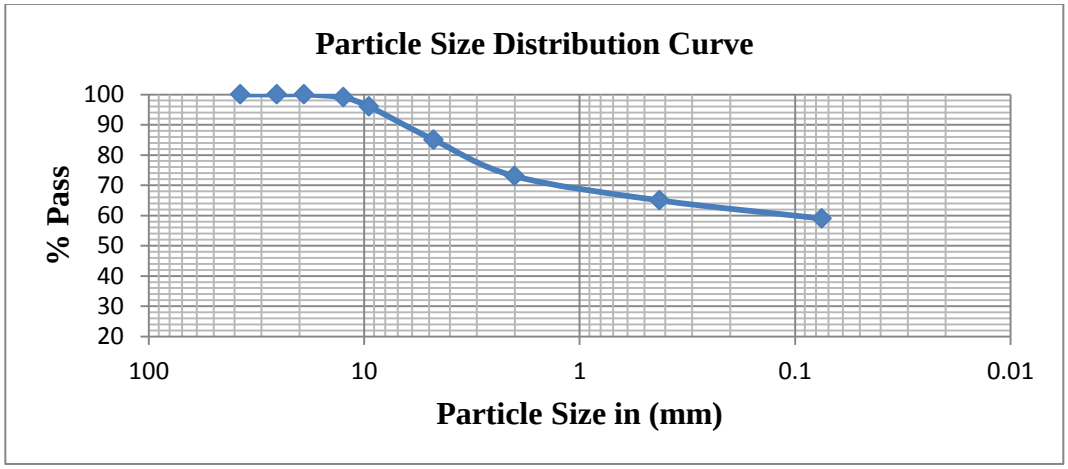


Therefore, from the above table and graph the value of CBR at **2.54**mm and **5.08**mm penetration is **14.67** and **12.36** percent respectively.

Experiment No.6

6.1 Particle Size Distribution Curve

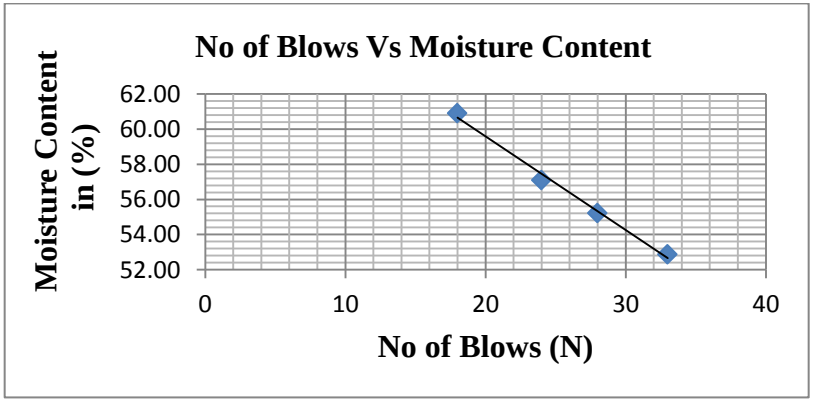
Laboratory Test No.6			
Sieve (mm)	**Wt. retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	15	1	99
9.5	45	3	96
4.75	165	11	85
2	180	12	73
0.425	120	8	65
0.075	90	6	59
Pan	885	59	0
Total mass(gm.)	**1500**	**100**	



6.2 Atterburg limit test

6.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	28	24	18		
container no	**2**	**425**	**382**	**14**	**111**	**301**
Wt. of cont. + wet soil	44.05	42.25	41.26	42.66	32.05	34.25
Wt. of cont. + dry soil	36.52	35.26	33.86	35.22	29.77	31.26
Wt. of container	22.28	22.60	20.90	23.00	21.80	21.79
Wt. of water	7.53	6.99	7.4	7.44	2.28	2.99
Wt. of dry soil	14.24	12.66	12.96	12.22	7.97	9.47
Moisture content (%)	52.88	55.21	57.09	60.88	28.60	31.6



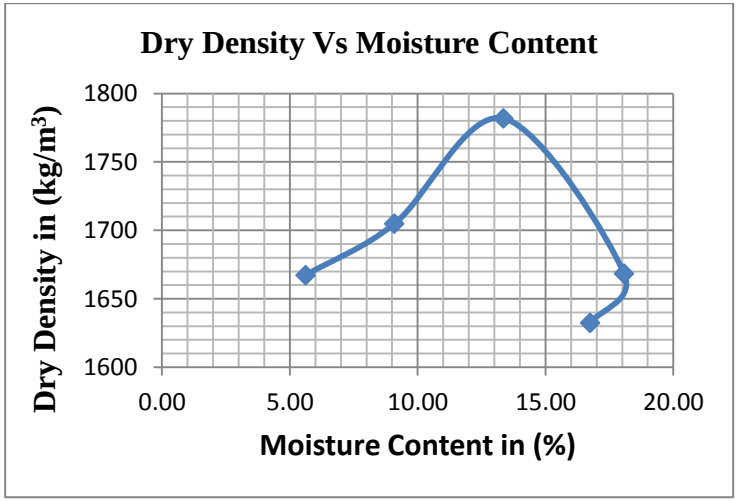
From the graph; moisture content at 25 blows (LL) = 57.4

PL = 30.1

PI = LL-PL = 57.4-30.1 = **27.3**

Experiment 6.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**I**	**B**	**14**	**AO_4**	**C**
Mass of Wet soil +Con(gm.)(F)	208.55	194.83	182.56	214.58	204.56
Mass of dry soil +con(gm.)(G)	198.46	180.19	163.27	184.74	178.01
Mass of container(gm.)(H)	18.75	19.10	18.85	19.66	19.51
Mass of moisture(gm.)F-G=(I)	10.09	14.64	19.29	29.84	26.55
Mass of Dry soil(gm.)G-H=(J)	179.71	161.09	144.42	165.08	158.5
Moisture content % (I/J)*100=K	5.61	9.09	13.36	18.08	16.75
Dry Density gm./cm^3 E/(100+K)*100	1.667	1.705	1.782	1.668	1.632
Dry density in kg/m^3	1667	1705	1782	1668	1632

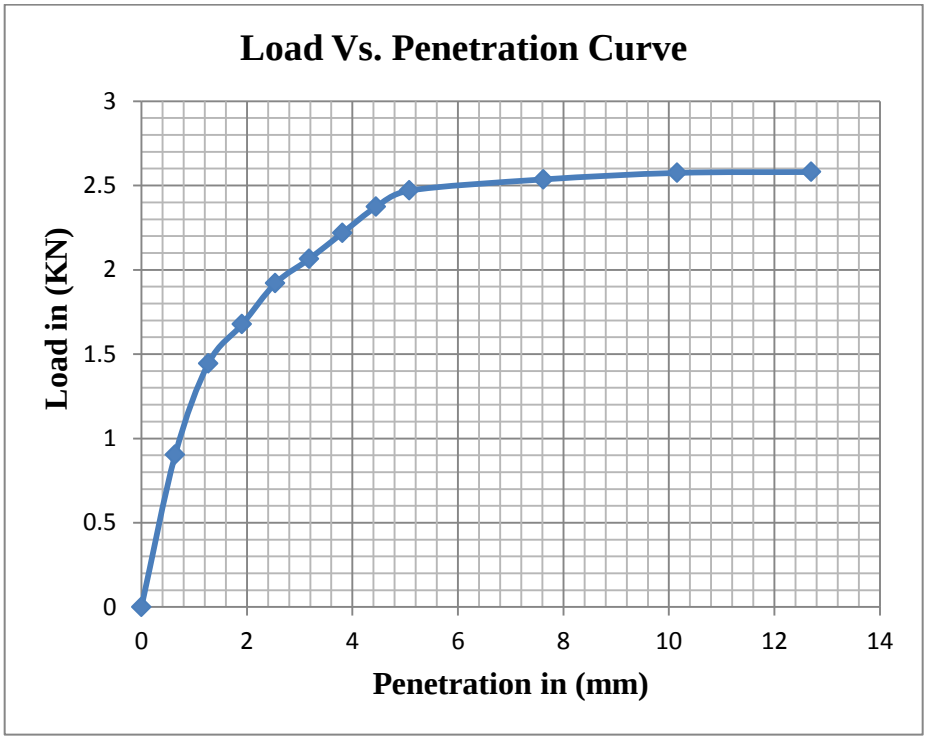


From the above plot; the value of MDD (Maximum Dry Density) = 1.782 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 13.36%

Experiment No.6.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	35.00	0.0258	0.90	
1.27	56.00	0.0258	1.44	
1.91	65.00	0.0258	1.68	
2.54	74.42	0.0258	1.92	14.55
3.18	80.00	0.0258	2.06	
3.81	86.00	0.0258	2.22	
4.45	92.00	0.0258	2.37	
5.08	95.74	0.0258	2.47	12.35
7.62	98.30	0.0258	2.54	
10.16	99.80	0.0258	2.57	
12.7	100.00	0.0258	2.58	

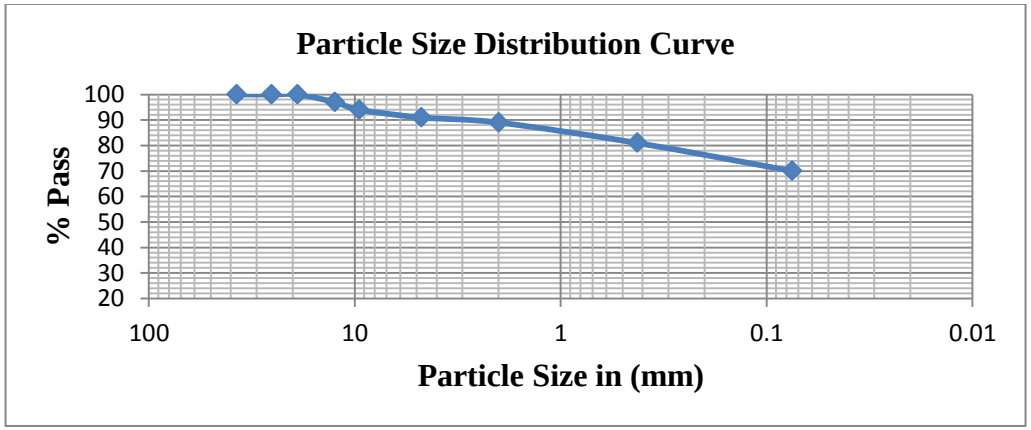


Therefore, from the above table and graph the value of CBR at **2.54**mm and **5.08**mm penetration is **14.55** and **12.35** percent respectively.

Experiment No.7

7.1 Particle Size Distribution Curve

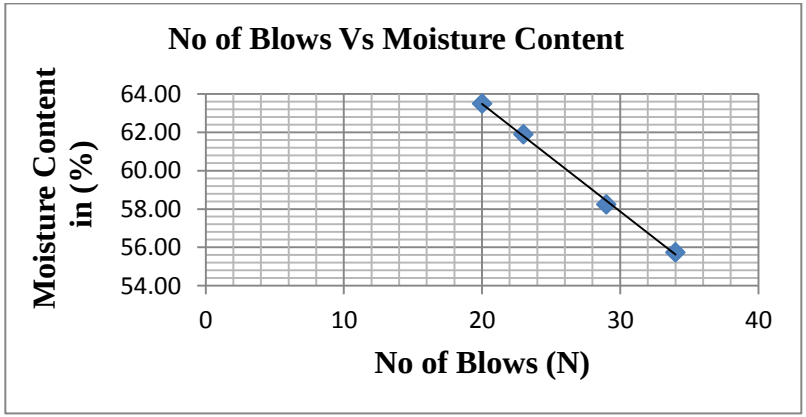
Laboratory Test No.7			
Sieve (mm)	**Wt. retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	15	3	97
9.5	45	3	94
4.75	45	3	91
2	30	2	89
0.425	120	8	81
0.075	165	11	70
Pan	1080	70	0
Total mass(gm.)	**1500**	**100**	



7.2 Atterburg limit test

7.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	29	23	20		
container no	**11**	**429**	**381**	**34**	**148**	**358**
Wt. of cont. + wet soil	43.33	42.15	40.29	42.55	31.52	33.26
Wt. of cont. + dry soil	36.23	34.65	33.68	34.26	28.96	30.28
Wt. of container	23.49	21.77	23.00	21.20	23.30	21.79
Wt. of water	7.10	7.5	6.61	8.29	2.56	2.98
Wt. of dry soil	12.74	12.88	10.68	13.06	5.66	8.49
Moisture content (%)	55.73	58.22	61.89	63.47	45.22	35.10



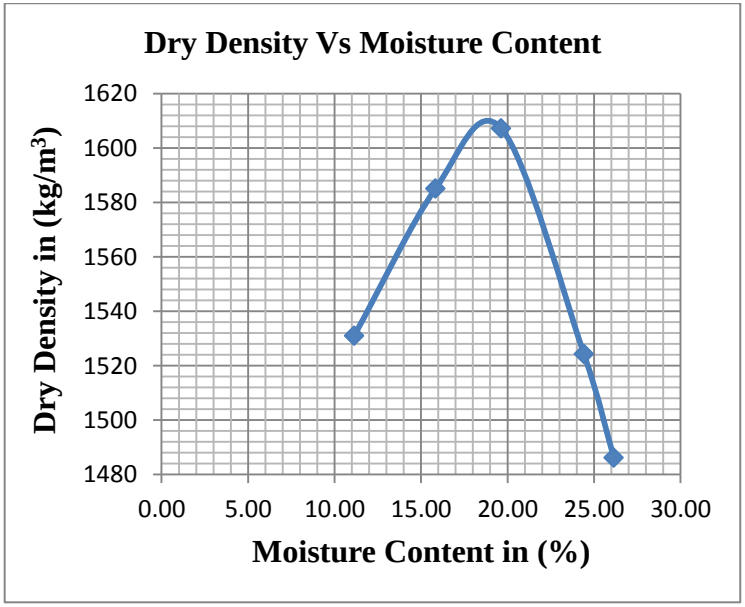
From the graph; moisture content at 25 blows (LL) = 63.2

PL = 40.31

PI = LL-PL = 63.2-40.31 = **22.89**

Experiment 7.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	A_2	BO_6	J_9	KO_9	I
Mass of Wet soil +Con(gm.)(F)	124.24	192.52	189.63	184.34	180.25
Mass of dry soil +con(gm.)(G)	113.60	168.75	161.59	151.92	146.59
Mass of container(gm.)(H)	18.05	18.70	18.80	19.12	17.86
Mass of moisture(gm.)F-G=(I)	10.64	23.77	28.04	32.42	33.66
Mass of Dry soil(gm.)G-H=(J)	95.55	150.05	142.79	132.8	128.73
Moisture content % (I/J)*100=K	11.14	15.84	19.64	24.41	26.15
Dry Density g/cm^3 E/(100+K)*100	1.531	1.585	1.607	1.524	1.486
Dry density in kg/m^3	1531	1585	1607	1524	1486

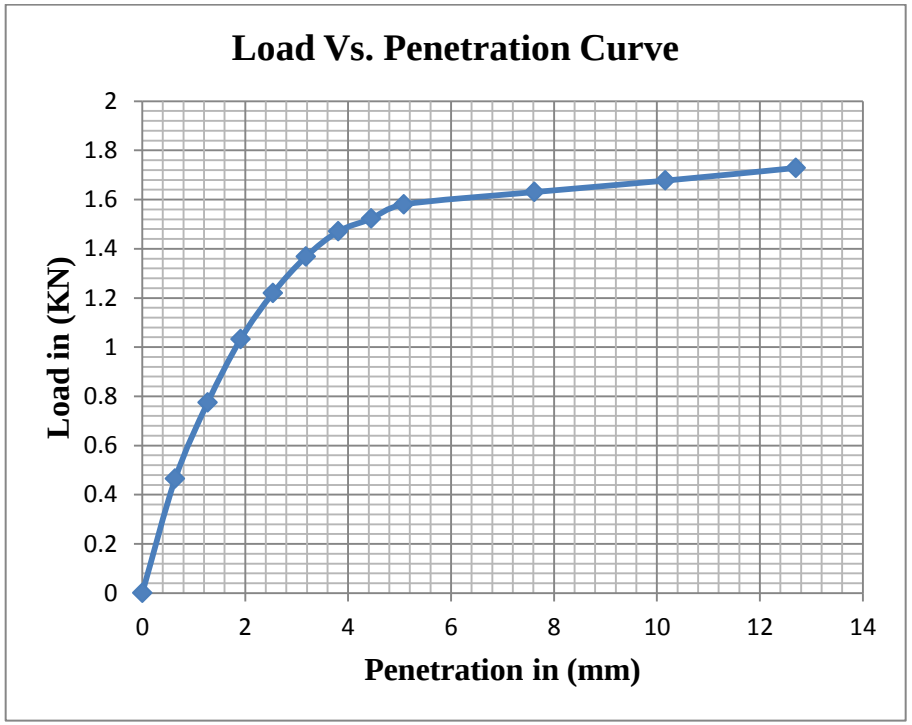


From the above plot; the value of MDD (Maximum Dry Density) = 1.61 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 19.64%

Experiment No.7.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	18.00	0.0258	0.46	
1.27	30.00	0.0258	0.77	
1.91	40.00	0.0258	1.03	
2.54	47.29	0.0258	1.22	9.21
3.18	53.00	0.0258	1.37	
3.81	57.00	0.0258	1.47	
4.45	59.00	0.0258	1.52	
5.08	61.24	0.0258	1.58	7.92
7.62	63.20	0.0258	1.63	
10.16	65.00	0.0258	1.68	
12.7	67.00	0.0258	1.73	

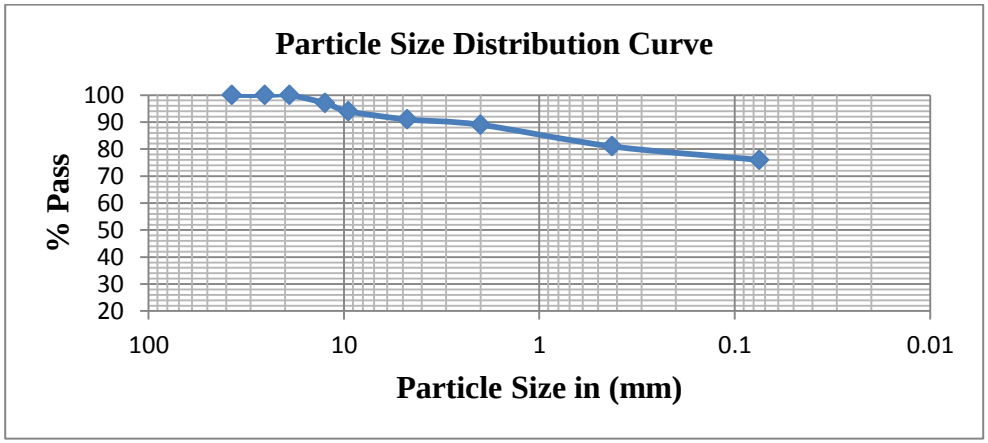


Therefore, from the above table and graph the value of CBR at **2.54**mm and **5.08**mm penetration is **9.21** and **7.92** percent respectively.

Experiment No.8

8.1 Particle Size Distribution Curve

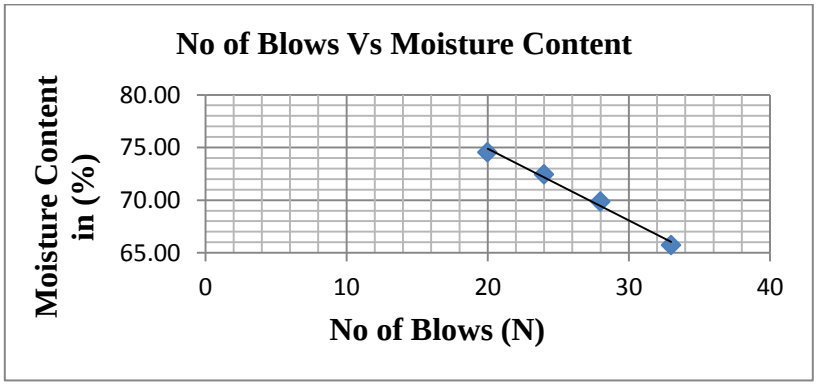
Laboratory Test No.8			
Sieve (mm)	**Wt. retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	16	3	97
9.5	48	3	94
4.75	48	3	91
2	32	2	89
0.425	128	8	81
0.075	80	5	76
Pan	1248	76	0
Total mass(gm.)	**1600**	**100**	



8.2 Atterburg limit test

8.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	28	24	20		
container no	**12**	**315**	**347**	**74**	**129**	**333**
Wt. of cont. + wet soil	42.15	41.37	40.87	44.25	30.06	31.28
Wt. of cont. + dry soil	34.56	33.86	32.86	34.65	28.01	28.68
Wt. of container	23.01	23.11	21.80	21.77	23.01	22.71
Wt. of water	7.59	7.51	8.01	9.60	2.05	2.6
Wt. of dry soil	11.55	10.75	11.06	12.88	5.00	5.97
Moisture content (%)	65.71	69.86	72.42	74.53	41	43.55



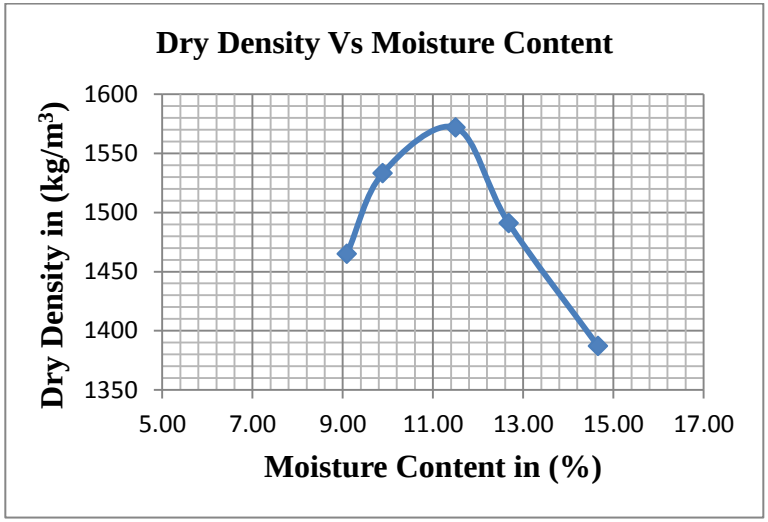
From the graph; moisture content at 25 blows (LL) = 72.1

PL = 42.23

PI = LL-PL = 72.1-42.23 = **29.87**

Experiment 8.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	K_1	AB	I	A_3	AO_4
Mass of Wet soil +Con(gm.)(F)	216.80	193.13	127.08	180.00	190.23
Mass of dry soil +con(gm.)(G)	200.29	177.42	115.91	161.82	168.42
Mass of container(gm.)(H)	18.70	18.50	18.85	18.46	19.66
Mass of moisture(gm.)F-G=(I)	16.51	15.71	11.17	18.18	21.81
Mass of Dry soil(gm.)G-H=(J)	181.59	158.92	97.06	143.36	148.76
Moisture content % (I/J)*100=K	9.09	9.89	11.51	12.68	14.66
Dry Density gm./cm^3 E/(100+K)*100	1.465	1.533	1.572	1.491	1.387
Dry density in kg/m^3	1465	1533	1572	1491	1387

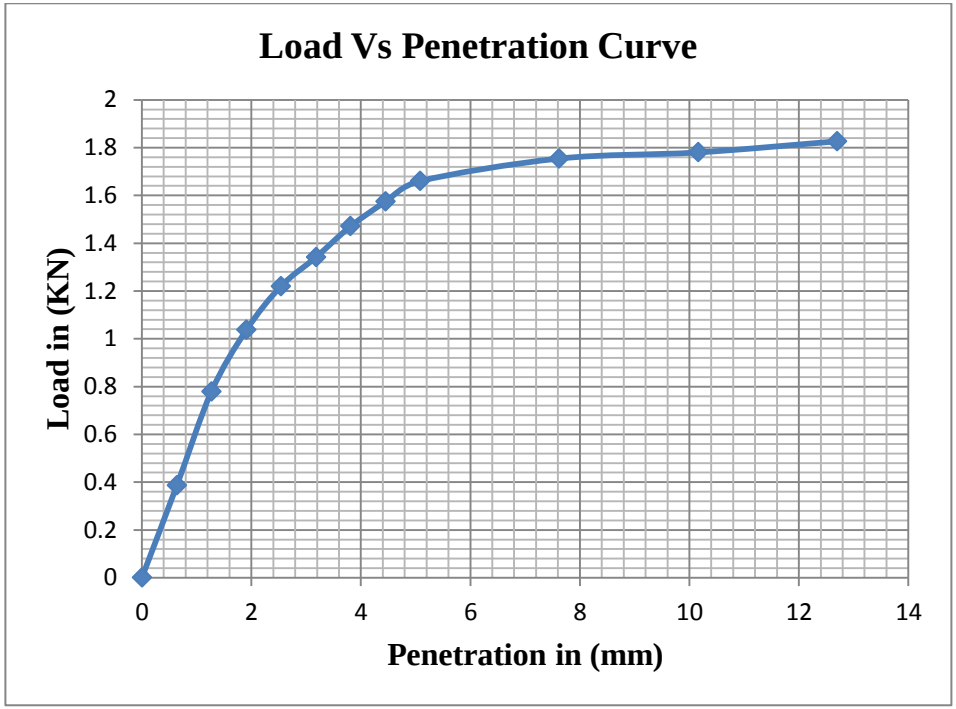


From the above plot; the value of MDD (Maximum Dry Density) = 1.57 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 11.51%

Experiment No.8.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load**	**CBR(%)**
0	0		0	
0.64	15.00	0.0258	0.39	
1.27	30.20	0.0258	0.78	
1.91	40.20	0.0258	1.04	
2.54	47.29	0.0258	1.22	9.27
3.18	52.00	0.0258	1.34	
3.81	57.00	0.0258	1.47	
4.45	61.00	0.0258	1.57	
5.08	64.34	0.0258	1.66	8.32
7.62	68.00	0.0258	1.75	
10.16	69.00	0.0258	1.78	
12.7	70.80	0.0258	1.83	



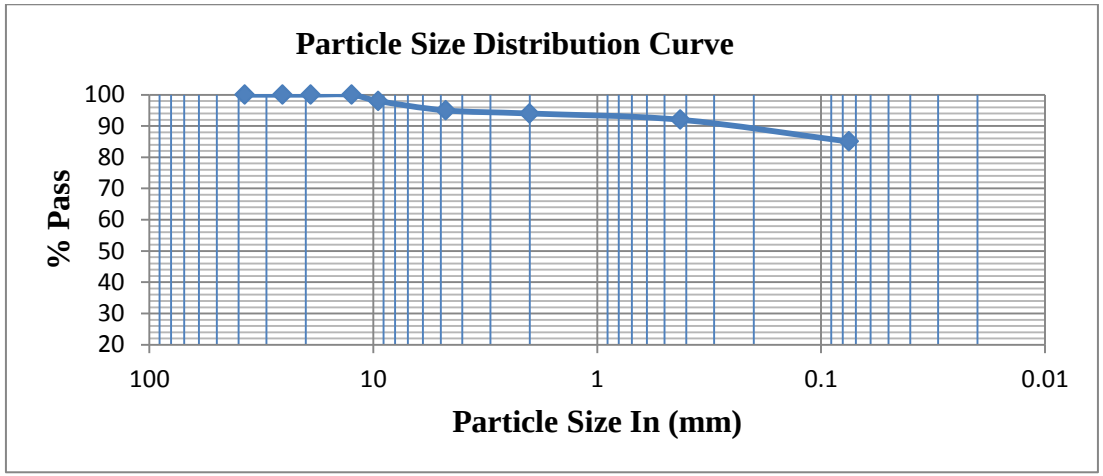
Therefore, from the above table and graph the value of CBR at **2.54**mm and **5.08**mm penetration is **9.27** and **8.32** respectively.

Laboratory experimental tests that were performed for this research statistical analysis works were as below.

Experiment No.1

1. Particle Size Distribution (Sieve Analysis)

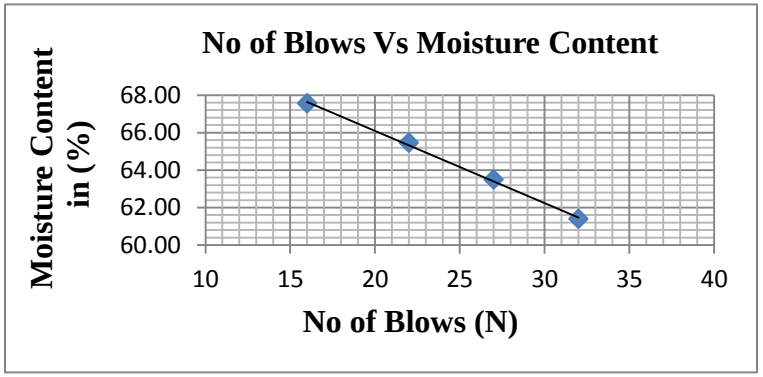
Laboratory Test No.1			
Sieve (mm)	**Wt. retained in (gm.)**	**% retained**	**% Pass**
37.5	0.00	0	100
25.4	0.00	0	100
19	0.00	0	100
12.5	0.00	0	100
9.5	40.00	2	98
4.75	60.00	3	95
2	20.00	1	94
0.425	40.00	2	92
0.075	140.00	7	85
Pan	1700.00	85	0
Total mass	**2000**	100	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	32	27	22	16		
container no	**319**	**47**	**314**	**340**	**27**	**144**
Wt. of cont. + wet soil	42.01	40.99	40.69	41.63	33.00	33.09
Wt. of cont. + dry soil	34.78	33.81	33.02	34.12	30.16	30.03
Wt. of container	23.00	22.50	21.30	23.00	22.73	22.10
Wt. of water	7.23	7.18	7.67	7.51	2.84	3.06
Wt. of dry soil	11.78	11.31	11.72	11.12	7.43	7.93
Moisture content %	61.38	63.48	65.44	67.54	38.22	38.59



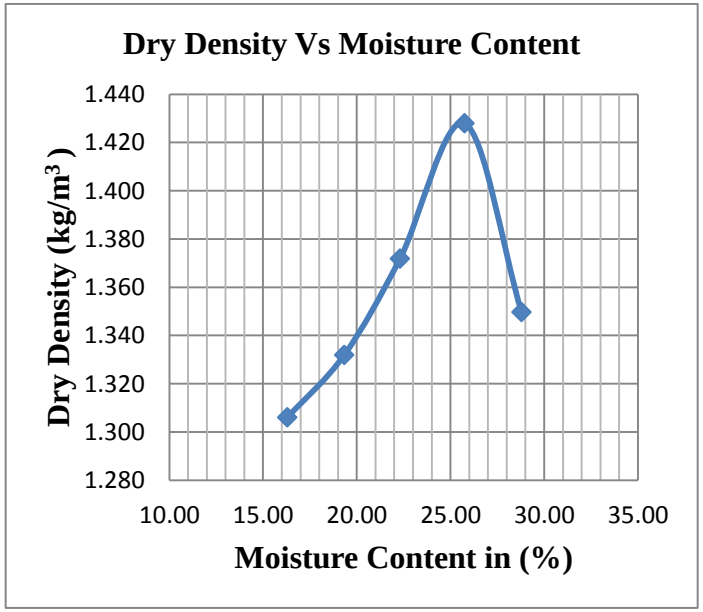
From the graph; moisture content at 25 blows (LL) = 64.46

PL = 38.41

PI = LL-PL = 64.46-38.41 = **26.05**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container No.	**B4**	**E**	**G**	**A2**	**J**
Mass of Wet soil +Con(gm.)(F)	194.76	186.17	189.76	173.61	178.51
Mass of dry soil +con(gm.)(G)	170.00	158.98	159.75	141.84	142.94
Mass of container(gm.)(H)	18.05	18.35	25.25	18.46	19.40
Mass of moisture(gm.)F-G=(I)	24.76	27.19	30.01	31.77	35.57
Mass of Dry soil(gm.)G-H=(J)	151.95	140.63	134.5	123.38	123.54
Moisture content % (I/J)*100=K	16.29	19.33	22.31	25.75	28.79
Dry Density g/cm^3 E/(100+K)*100	1.306	1.332	1.372	1.428	1.350
Dry density in kg/m^3	1306.02	1331.93	1371.87	1427.97	1349.64

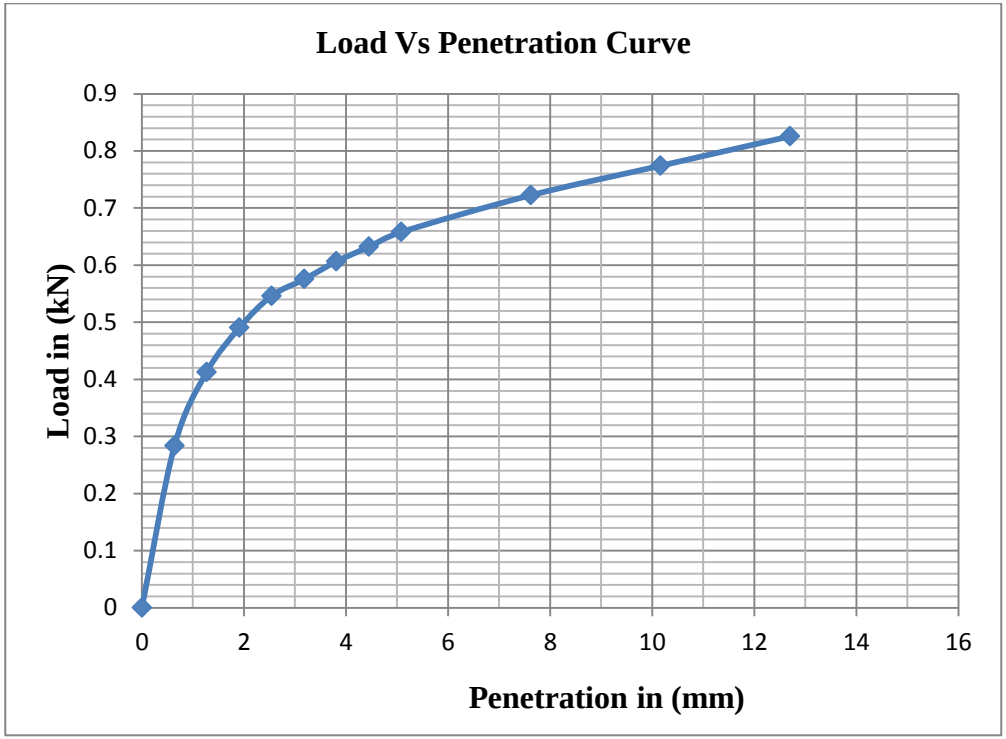


From the above plot; the value of MDD (Maximum Dry Density) = 1.428 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 25.75%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	11.00	0.0258	0.28	
1.27	16.00	0.0258	0.41	
1.91	19.00	0.0258	0.49	
2.54	21.20	0.0258	0.55	4.16
3.18	22.30	0.0258	0.58	
3.81	23.50	0.0258	0.61	
4.45	24.50	0.0258	0.63	
5.08	25.50	0.0258	0.66	3.29
7.62	28.00	0.0258	0.72	
10.16	30.00	0.0258	0.77	
12.7	32.00	0.0258	0.83	

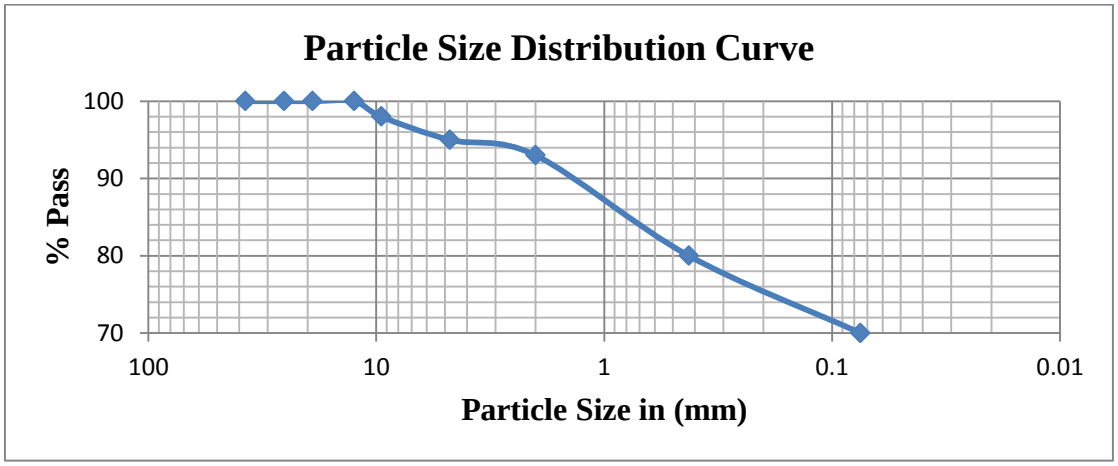


Therefore, based on calculation the value of CBR at **2.54**mm and **5.08**mm penetration is **4.16** and **3.29** respectively.

Experiment No. 2

1. Particle Size Distribution (Sieve Analysis)

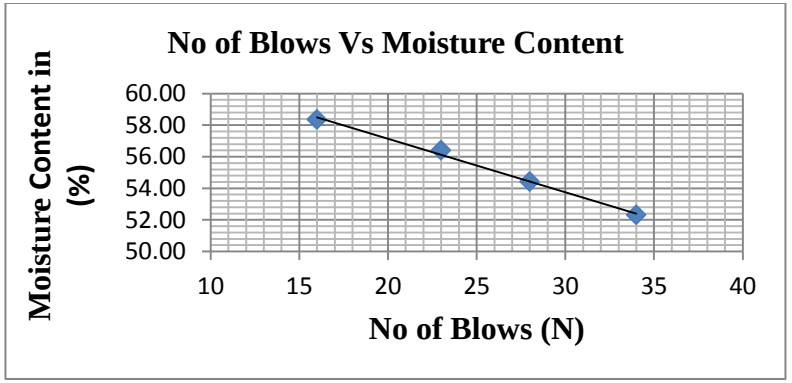
Laboratory Test No.2			
Sieve (mm)	**Wt. retained in (gm.)**	**% retained**	**% Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	19.6	1	99
9.5	19.6	1	98
4.75	19.6	1	97
2	19.6	1	96
0.425	333.2	17	79
0.075	98	5	74
Pan	1450.4	74	0
Total mass	**1960**	100	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	**34**	**28**	**23**	**16**		
Container no	306	132	311	32	321	370
Wt. of cont. + wet soil	42.25	39.98	41.08	44.34	36.86	32.58
Wt. of cont. + dry soil	35.64	33.74	34.60	36.33	33.40	30.14
Wt. of container	23.00	22.27	23.11	22.60	22.69	22.50
Wt. of water	6.61	6.24	6.48	8.01	3.46	2.44
Wt. of dry soil	12.64	11.47	11.49	13.73	10.71	7.64
Moisture content (%)	52.29	54.40	56.40	58.34	32.31	31.94



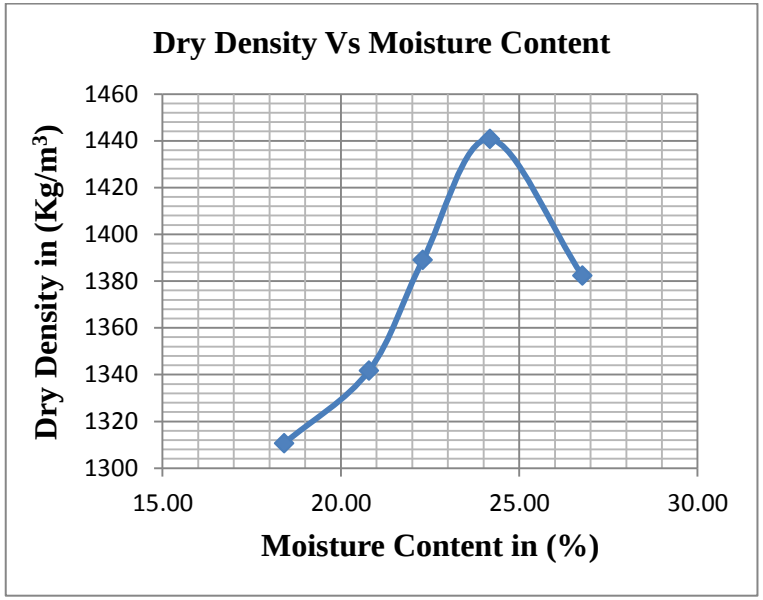
From the graph; moisture content at 25 blows (LL**)** = 55.36

PL = 32.12

PI = LL-PL = 55.36-32.12 = 23.24

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container No.	AB	I	F	M	K
Mass of Wet soil +Con(gm.)(F)	137.65	161.43	175.37	168.54	182.39
Mass of dry soil +con(gm.)(G)	119.08	136.94	148.00	139.32	147.97
Mass of container(gm.)(H)	18.20	19.12	25.25	18.46	19.40
Mass of moisture(gm.)F-G=(I)	18.57	24.49	27.37	29.22	34.42
Mass of Dry soil(gm.)G-H=(J)	100.88	117.82	122.75	120.86	128.57
Moisture content % (I/J)*100=K	18.41	20.79	22.30	24.18	26.77
Dry Density gm./cm3 E/(100+K)*100	1.311	1.342	1.389	1.441	1.382
Dry density in kg/m3	1311	1342	1389	1441	1382

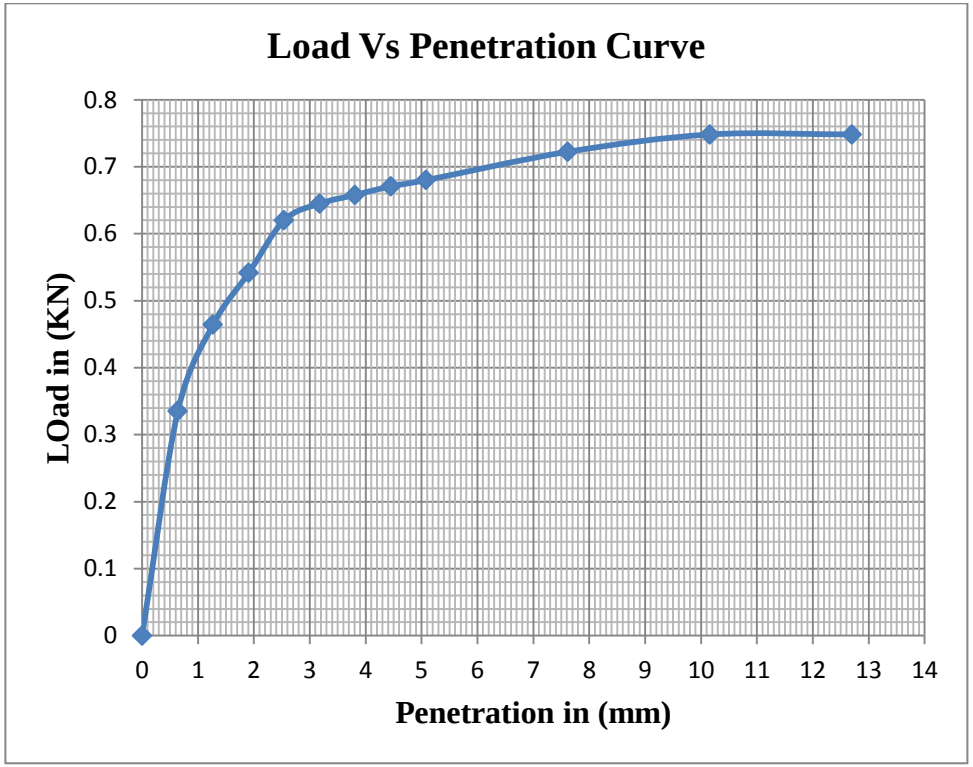


From the above plot; the value of MDD (Maximum Dry Density) = 1.441 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 24.18%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0	0.0258	0	
0.64	13.00	0.0258	0.34	
1.27	18.00	0.0258	0.46	
1.91	21.00	0.0258	0.54	
2.54	24.10	0.0258	0.62	4.71
3.18	25.00	0.0258	0.65	
3.81	25.50	0.0258	0.66	
4.45	26.00	0.0258	0.67	
5.08	26.28	0.0258	0.68	3.39
7.62	28.00	0.0258	0.72	
10.16	29.00	0.0258	0.75	
12.7	29.00	0.0258	0.7482	

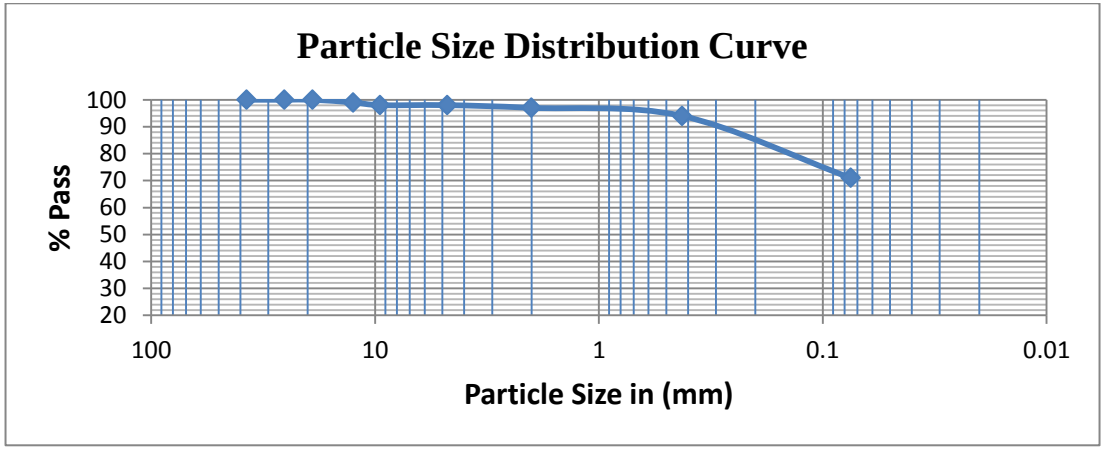


Therefore, based on the calculation the value of CBR at **2.54**mm and **5.08**mm penetration is **4.71** and **3.39** respectively.

Experiment No. 3

1. Particle Size Distribution (Sieve Analysis)

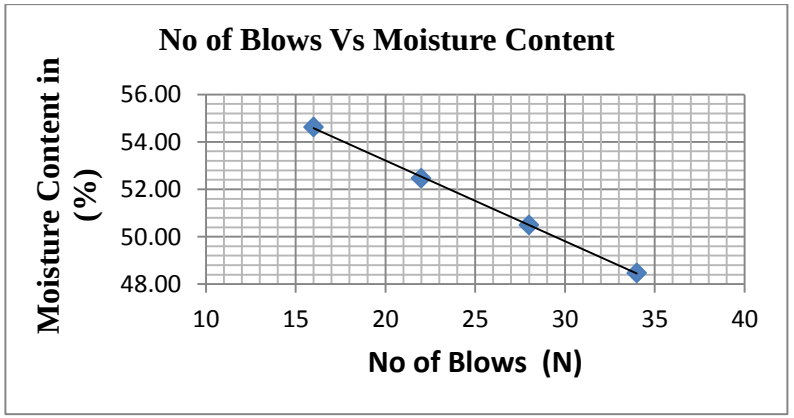
Laboratory Test No.3			
Sieve (mm)	**Weight retained in (gm.)**	**% retained**	**% Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	15	1	99
9.5	15	1	98
4.75	0	0	98
2	15	1	97
0.425	0	3	94
0.075	345	23	71
Pan	1110	71	0
Total mass	**1500**	100	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	22	16		
Container no	**301**	**315**	**369**	**42.44**	**324**	**27**
Wt. of cont. + wet soil	45.77	40.77	38.82	42.44	32.66	33.06
Wt. of cont. + dry soil	38.50	34.64	32.86	35.36	29.96	30.23
Wt. of container	23.50	22.50	21.50	22.40	22.71	22.73
Wt. of water	7.27	6.13	5.96	7.08	2.70	2.83
Wt. of dry soil	15	12.14	11.36	12.96	7.25	7.50
Moisture content (%)	48.47	50.49	52.46	54.63	37.24	37.73



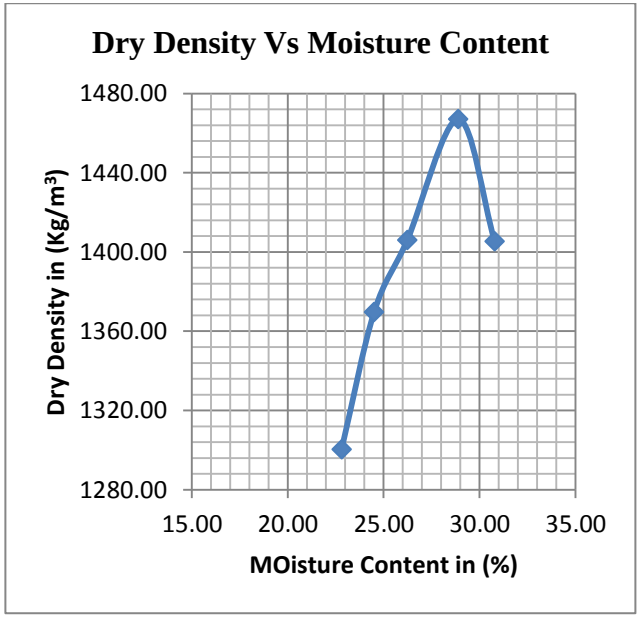
From the graph; moisture content at 25 blows (LL) = 51.51

PL = 37.49

PI = LL-PL = 64.17-38.41 = 14.03

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	A_3	B_4	A_3	O	J
Mass of Wet soil +Con(gm.)(F)	177.81	139.43	134.99	158.84	135.28
Mass of dry soil +con(gm.)(G)	148.00	115.54	110.82	127.42	108.00
Mass of container(gm.)(H)	17.31	18.05	18.70	18.65	19.40
Mass of moisture(gm.)F-G=(I)	29.81	23.89	24.17	31.42	27.28
Mass of Dry soil(gm.)G-H=(J)	130.69	97.49	92.12	108.77	88.6
Moisture content % (I/J)*100=K	22.81	24.51	26.24	28.89	30.79
Dry Density gm./cm^3 E/(100+K)*100	1.300	1.370	1.406	1.467	1.405
Dry density in kg/m^3	1300.38	1369.64	1406.04	1467.00	1405.34

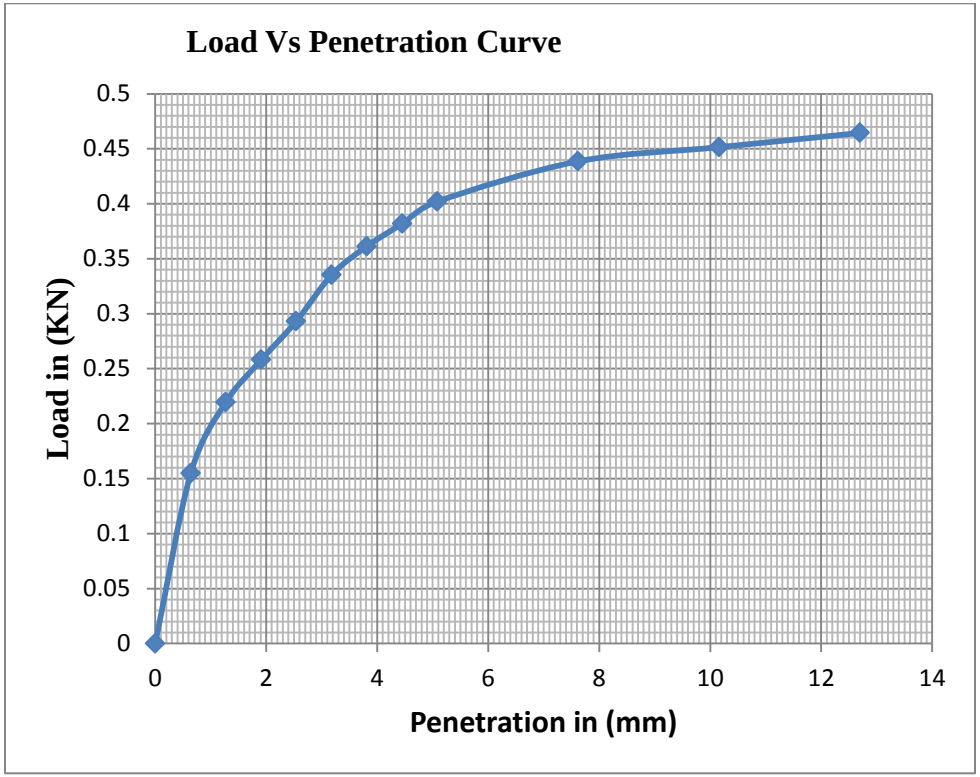


From the above plot; the value of MDD (Maximum Dry Density) = 1.467 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 28.89%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load(KN)**	**CBR (%)**
0	0	0	0	
0.64	6.00	0.0258	0.155	
1.27	8.50	0.0258	0.219	
1.91	10.00	0.0258	0.258	
2.54	11.36	0.0258	0.29	2.22
3.18	13.00	0.0258	0.34	
3.81	14.00	0.0258	0.36	
4.45	14.80	0.0258	0.38	
5.08	15.58	0.0258	0.40	2.01
7.62	17.00	0.0258	0.44	
10.16	17.50	0.0258	0.45	
12.7	18.00	0.0258	0.46	

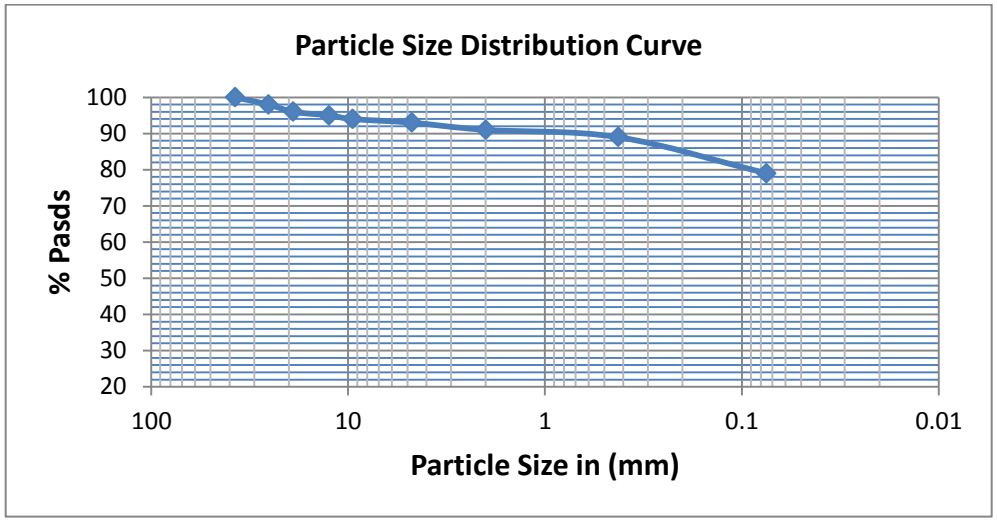


Therefore, based on the above table and graph the value of CBR at **2.54** and **5.08** is **2.22** and **2.01** respectively.

Experiment No. 4

1. Particle Size Distribution (Sieve Analysis)

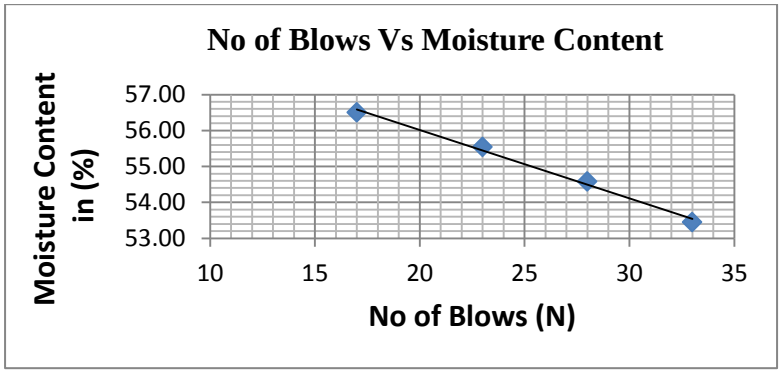
Laboratory Test No.4			
Sieve (mm)	**Weight retained in (gm.)**	**% retained**	**% Pass**
37.5	0.00	0	100
25.4	39.72	2	98
19	39.72	2	96
12.5	19.86	1	95
9.5	19.86	1	94
4.75	19.86	1	93
2	39.72	2	91
0.425	39.72	2	89
0.075	198.60	10	79
Pan	1568.94	79	0
Total mass	**1986**	100	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	28	23	17		
Container no	**5**	**301**	**324**	**340**	**24**	**27**
Wt. of cont. + wet soil	42.49	47.97	48.26	45.52	35.72	34.74
Wt. of cont. + dry soil	35.43	39.33	39.13	37.39	32.13	31.47
Wt. of container	22.22	23.50	22.69	23.00	22.44	22.74
Wt. of water	7.06	8.64	9.13	8.13	3.59	3.27
Wt. of dry soil	13.21	15.83	16.44	14.39	9.69	8.73
Moisture content %	53.44	54.58	55.54	56.50	37.05	37.46



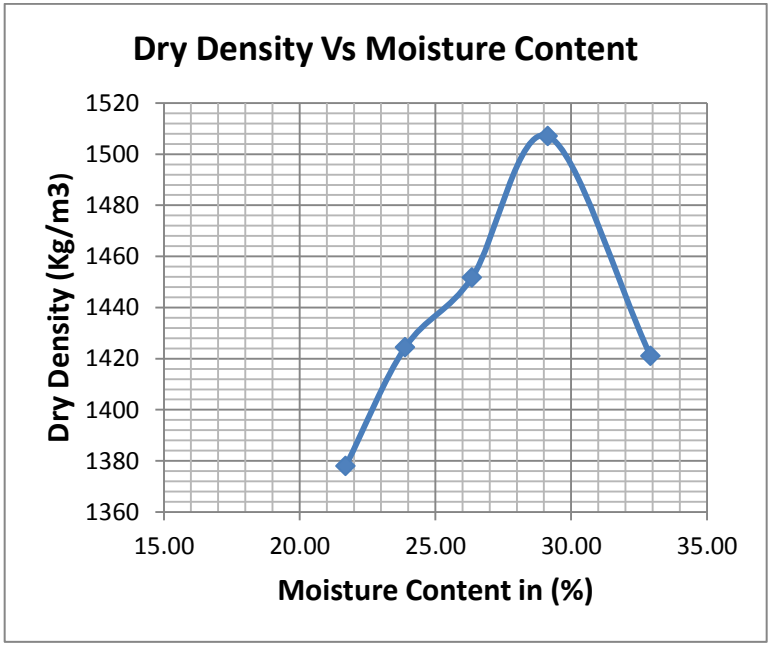
From the graph; moisture content at 25 blows (LL) = 55.01

PL = 37.25

PI = LL-PL = 55.01-37.25 = 17.76

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**A_3**	**1**	**A_{28}**	**B_4**	**K**
Mass of Wet soil +Con(gm.)(F)	150.50	153.65	133.19	121.29	142.57
Mass of dry soil +con(gm.)(G)	127.00	127.64	109.00	97.99	112.01
Mass of container(gm.)(H)	18.70	18.75	17.20	18.05	19.20
Mass of moisture(gm.)F-G=(I)	23.50	26.01	24.19	23.3	30.56
Mass of Dry soil(gm.)G-H=(J)	108.3	108.89	91.8	79.94	92.81
Moisture content % (I/J)*100=K	21.70	23.89	26.35	29.15	32.93
Dry Density gm./cm^3 E/(100+K)*100	1.378	1.424	1.452	1.507	1.421
Dry density in kg/m^3	1378	1424	1452	1507	1421

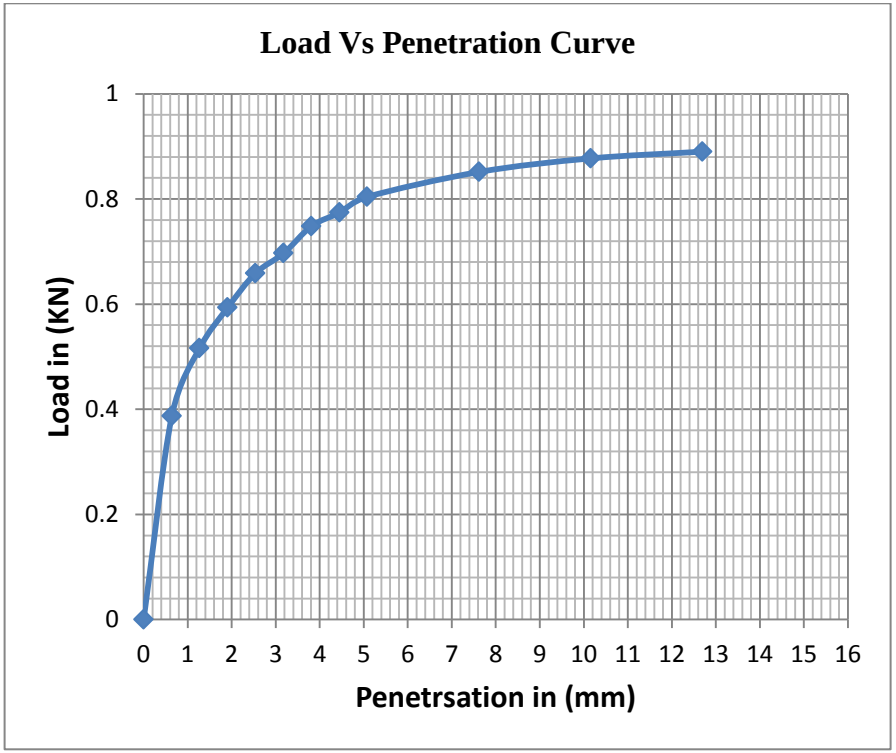


From the above plot; the value of MDD (Maximum Dry Density) = 1.507 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 29.15%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load(KN)**	**CBR(%)**
0	0	0	0	
0.64	15.00	0.0258	0.39	
1.27	20.00	0.0258	0.52	
1.91	23.00	0.0258	0.59	
2.54	25.53	0.0258	0.66	4.99
3.18	27.00	0.0258	0.70	
3.81	29.00	0.0258	0.75	
4.45	30.00	0.0258	0.77	
5.08	31.16	0.0258	0.80	4.02
7.62	33.00	0.0258	0.85	
10.16	34.00	0.0258	0.88	
12.7	34.50	0.0258	0.89	

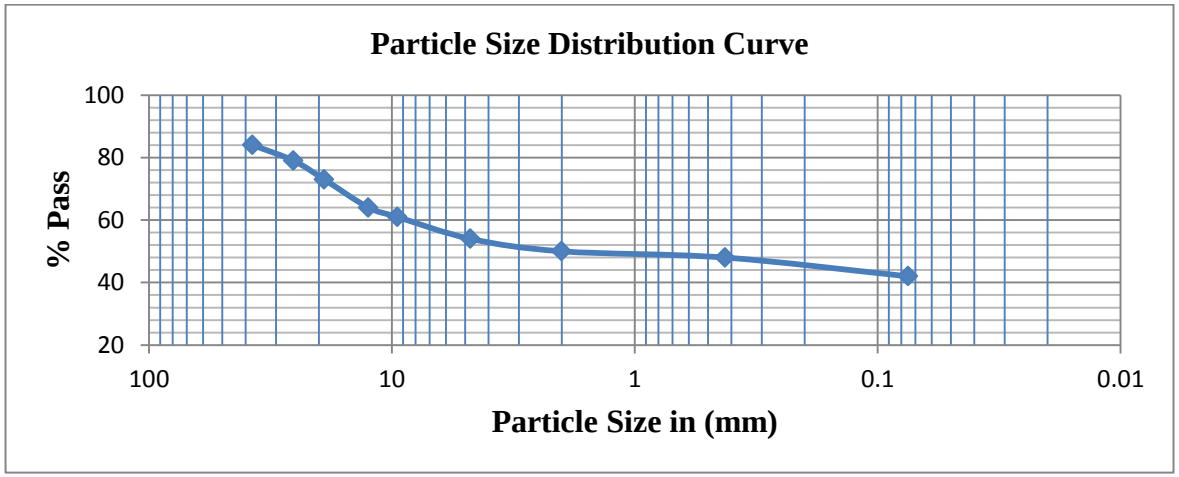


Therefore, based on the above table and graph the value of CBR at **2.54** and **5.08** is **4.99** and **4.02** respectively.

Experiment No. 5

1. Particle Size Distribution (Sieve Analysis)

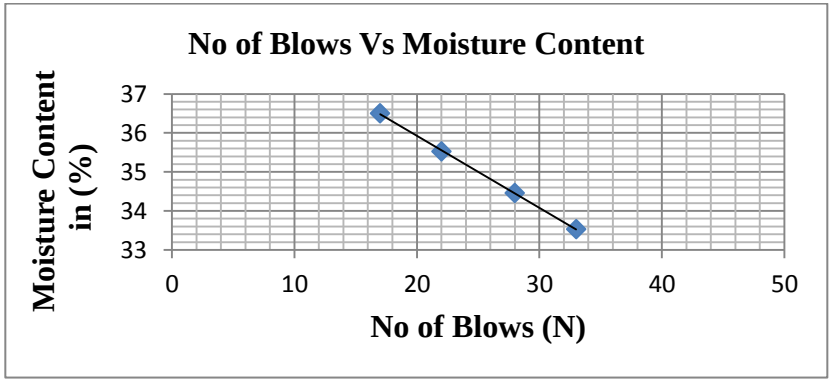
Laboratory Test No.5			
Sieve (mm)	**Weight retained in (gm.)**	**% retained**	**% Pass**
37.5	318.40	16	84
25.4	99.50	5	79
19	119.40	6	73
12.5	179.10	9	64
9.5	59.70	3	61
4.75	139.30	7	54
2	79.60	4	50
0.425	39.80	2	48
0.075	119.40	6	42
Pan	835.80	42	0
Total mass	**1990**	100	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	28	22	17		
container no	**132**	**27**	**301**	**364**	**331**	**349**
Wt. of cont. + wet soil	47.6	46.3	42.92	42.87	34.57	33.98
Wt. of cont. + dry soil	41.24	40.26	37.83	37.57	32.57	31.9
Wt. of container	22.27	22.73	23.5	23.05	22.7	21.8
Wt. of water	6.36	6.04	5.09	5.3	2	2.08
Wt. of dry soil	18.97	17.53	14.33	14.52	9.87	10.1
Moisture content %	33.52	34.45	35.519	36.50	20.26	20.59



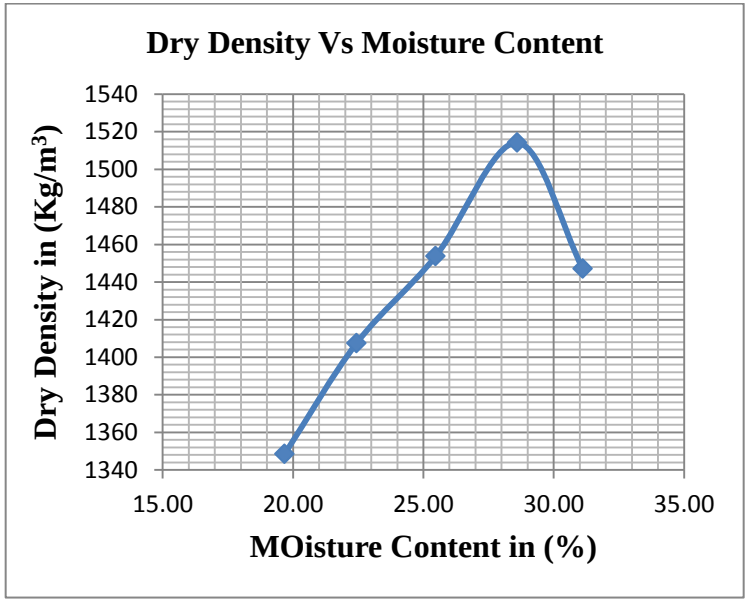
From the graph; moisture content at 25 blows (LL) = 35.00

PL = 37.25

PI = LL-PL = 64.17-38.41 = 14.57

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture content					
Container no.	**AB**	**E**	**2**	**B4**	**Z**
Mass of Wet soil +Con(gm.)(F)	165.20	168.65	172.90	174.33	146.34
Mass of dry soil +con(gm.)(G)	141.03	141.11	141.50	139.57	116.04
Mass of container(gm.)(H)	18.20	18.35	18.21	18.05	18.66
Mass of moisture(gm.)F-G=(I)	24.17	27.54	31.4	34.76	30.3
Mass of Dry soil(gm.)G-H=(J)	122.83	122.76	123.29	121.52	97.38
Moisture content % (I/J)*100=K	19.68	22.43	25.47	28.60	31.12
Dry Density gm./cm^3 E/(100+K)*100	1.349	1.407	1.454	1.514	1.447
Dry density in kg/m^3	1349	1407	1454	1514	1447

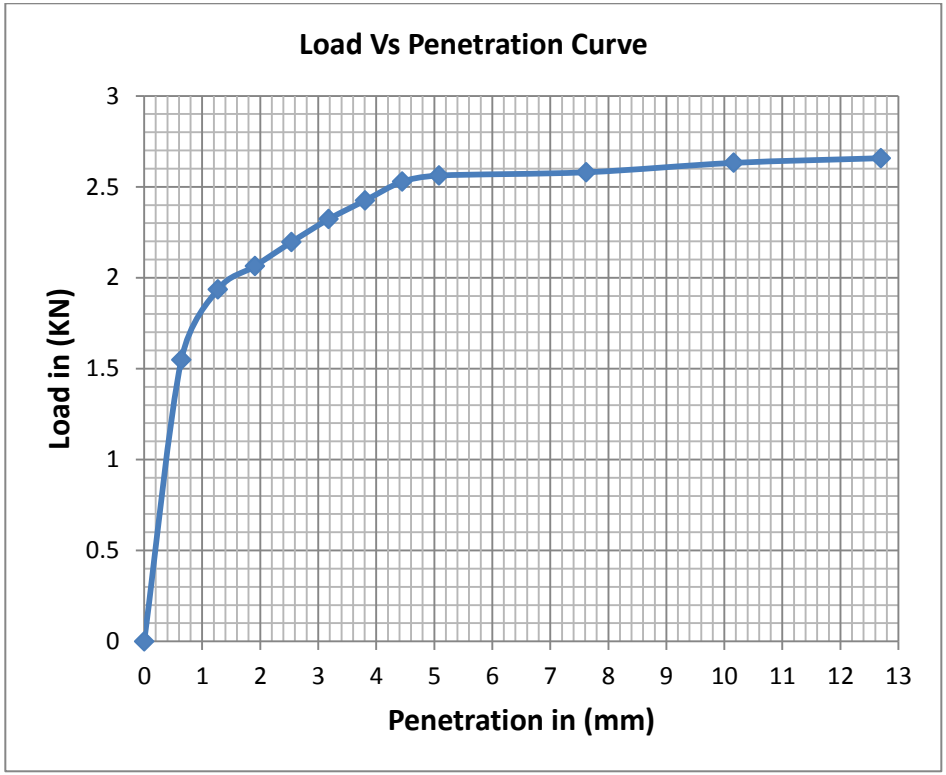


From the above plot; the value of MDD (Maximum Dry Density) = 1.514 Kg/m^3

And also the value of OMC (Optimum Moisture Content) = 28.60%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	60.00	0.0258	1.55	
1.27	75.00	0.0258	1.94	
1.91	80.00	0.0258	2.06	
2.54	85.13	0.0258	2.20	16.64
3.18	90.00	0.0258	2.32	
3.81	94.00	0.0258	2.43	
4.45	98.00	0.0258	2.53	
5.08	99.30	0.0258	2.56	12.81
7.62	100.00	0.0258	2.58	
10.16	102.00	0.0258	2.63	
12.7	103.00	0.0258	2.66	

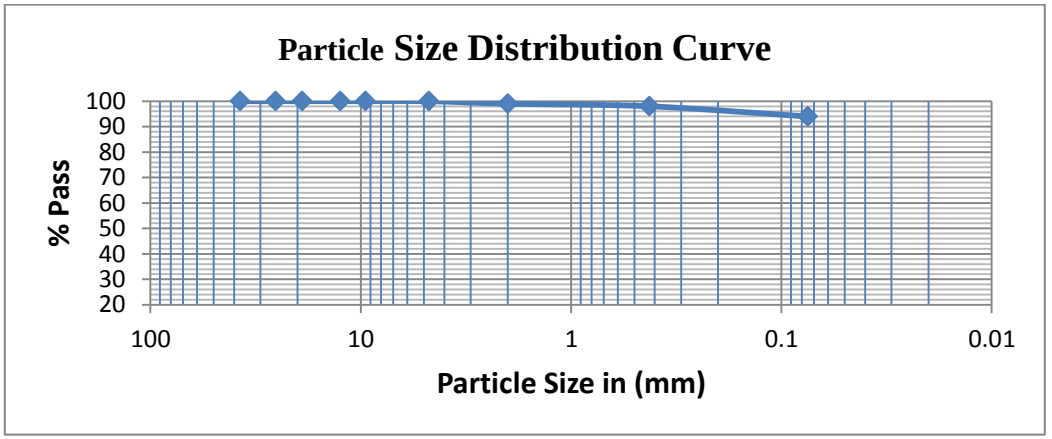


Therefore, based on the above table and graph the value of CBR at **2.54** and **5.08** is **16.64** and **12.81** respectively.

Experiment No. 6

1. Particle Size Distribution (Sieve Analysis)

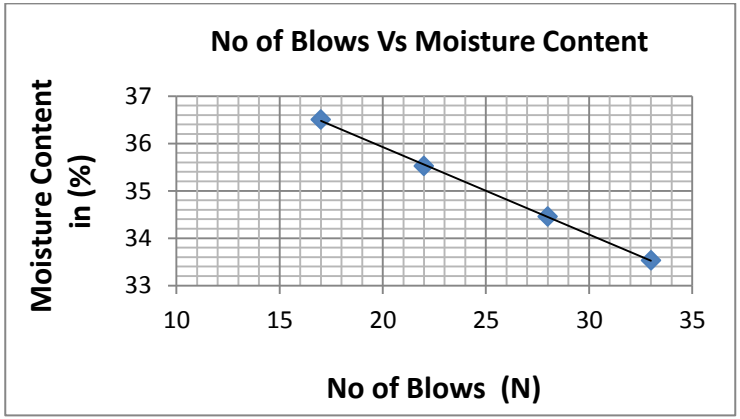
Laboratory Test No.6			
Sieve (mm)	**Weight retained in (gm.)**	**% retained**	**% Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	19.90	1	99
0.425	19.90	1	98
0.075	79.60	4	94
Pan	1870.60	94	0
Total mass	**1990**	100	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	29	23	18		
container no	**1**	**315**	**369**	**24**	**129**	**318**
Wt. of cont. + wet soil	44	41.37	40.92	43.95	32.87	31.35
Wt. of cont. + dry soil	36.22	34.48	33.67	35.74	30.39	28.8
Wt. of container	22.24	22.51	21.49	22.44	22.49	20.6
Wt. of water	7.78	6.89	7.25	8.21	2.48	2.55
Wt. of dry soil	13.98	11.97	12.18	13.3	7.9	8.2
Moisture content (%)	55.651	57.561	59.524	61.729	31.392	31.098



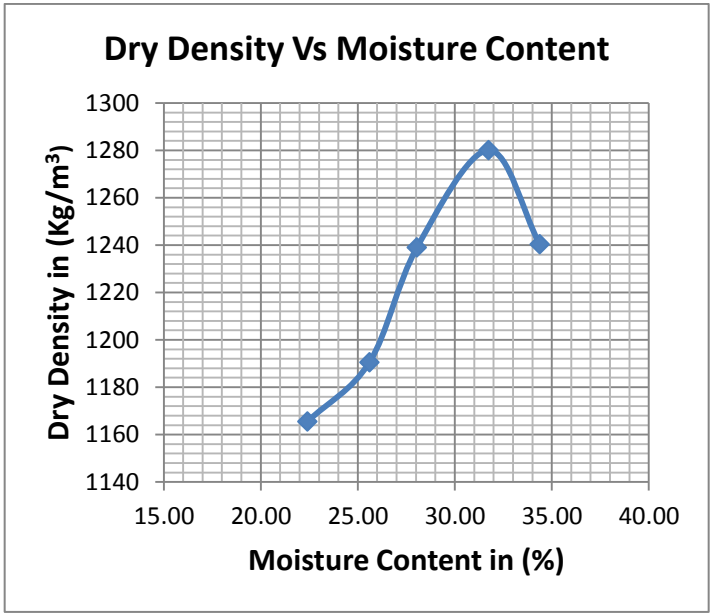
From the graph; moisture content at 25 blows (LL) = 58.62

PL = 31.24

PI = LL-PL = 58.62-31.24 = 27.37

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**A3**	**G**	**Z**	**B4**	**2**
Mass of Wet soil +Con(gm.)(F)	151.64	188.33	164.87	182.32	151.39
Mass of dry soil +con(gm.)(G)	127.31	155.09	132.84	142.74	117.32
Mass of container(gm.)(H)	18.70	25.25	18.66	18.05	18.21
Mass of moisture(gm.)F-G=(I)	24.33	33.24	32.03	39.58	34.07
Mass of Dry soil(gm.)G-H=(J)	108.61	129.84	114.18	124.69	99.11
Moisture content % (I/J)*100=K	22.40	25.60	28.05	31.74	34.38
Dry Density gm./cm^3 E/(100+K)*100	1.165	1.191	1.239	1.280	1.240
Dry density in kg/m^3	1165	1191	1239	1280	1240

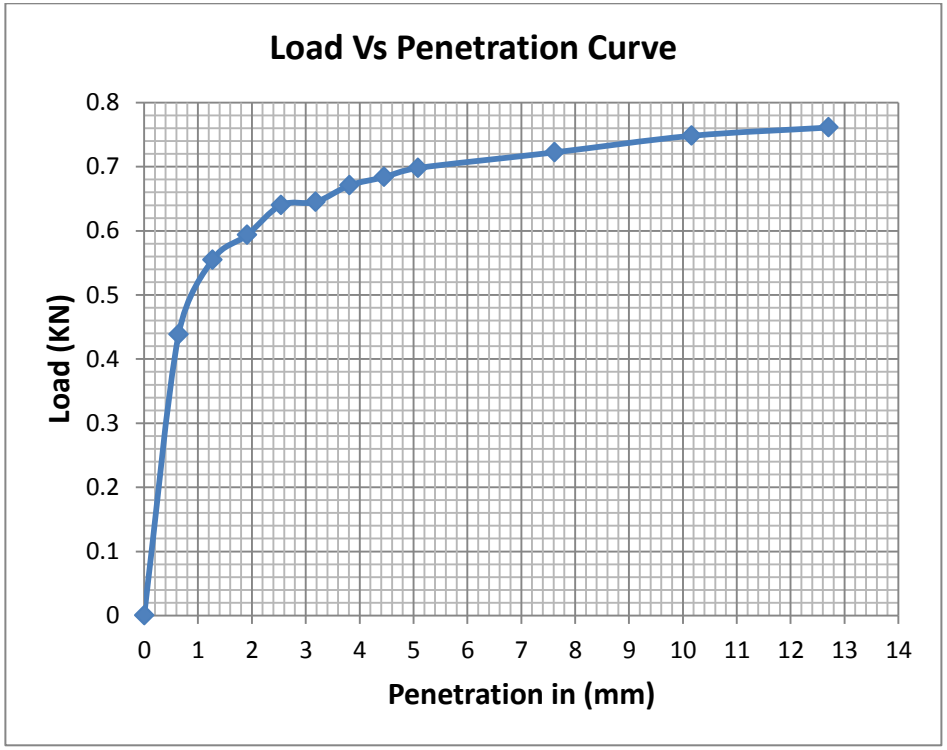


From the above plot; the value of MDD (Maximum Dry Density) = 1.507 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 31.74%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load(KN)**	**CBR(%)**
0	0		0	
0.64	17.00	0.0258	0.44	
1.27	21.50	0.0258	0.55	
1.91	23.00	0.0258	0.59	
2.54	24.81	0.0258	0.64	4.85
3.18	25.00	0.0258	0.65	
3.81	26.00	0.0258	0.67	
4.45	26.50	0.0258	0.68	
5.08	27.05	0.0258	0.70	3.49
7.62	28.00	0.0258	0.72	
10.16	29.00	0.0258	0.75	
12.7	29.50	0.0258	0.76	

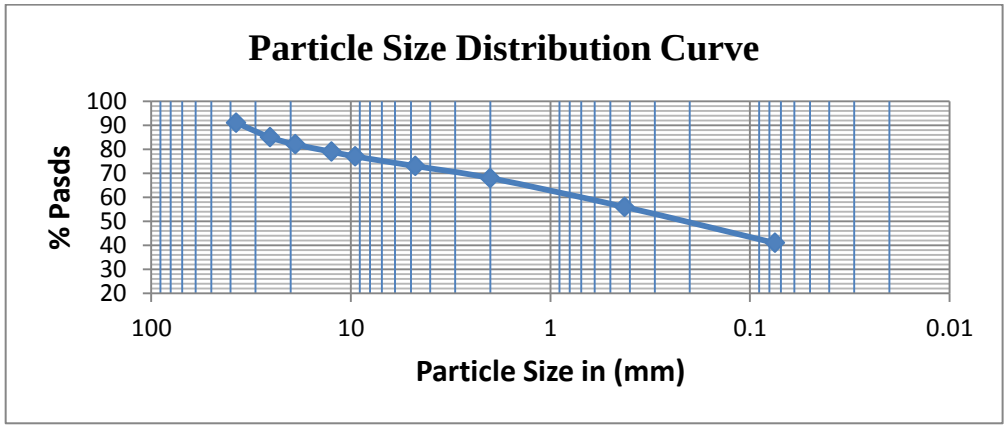


Therefore, based on the above table and graph the value of CBR at **2.54** and **5.08** is **4.85** and **3.49** respectively.

Experiment No. 7

1. Particle Size Distribution (Sieve Analysis)

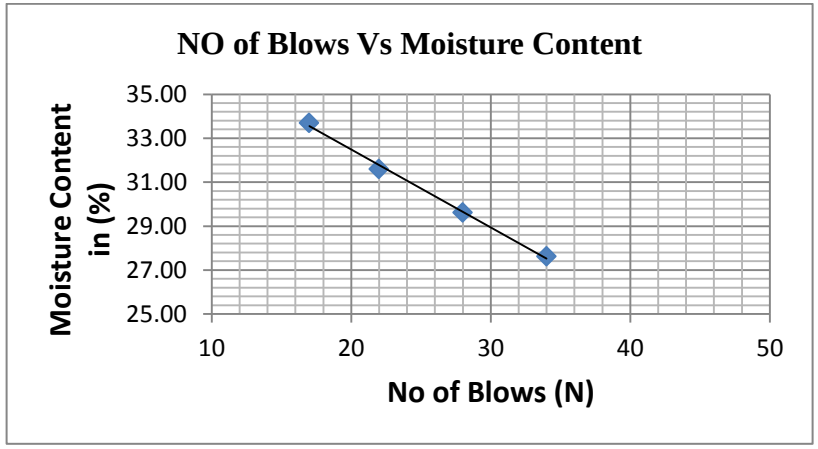
Laboratory Test No.7			
Sieve (mm)	**Weight retained in (gm.)**	**% retained**	**% Pass**
37.5	179.10	9	91
25.4	119.40	6	85
19	59.70	3	82
12.5	59.70	3	79
9.5	39.80	2	77
4.75	79.60	4	73
2	99.50	5	68
0.425	238.80	12	56
0.075	298.50	15	41
Pan	815.90	41	0
Total mass	**1990**	100	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	22	17		
container no	**331**	**27**	**301**	**132**	**349**	**364**
Wt. of cont. + wet soil	43	53.21	46.66	44.41	35.39	34.96
Wt. of cont. + dry soil	38.61	46.25	41.1	38.83	32.66	32.56
Wt. of container	22.71	22.74	23.5	22.27	21.79	23.05
Wt. of water	4.39	6.96	5.56	5.58	2.73	2.4
Wt. of dry soil	15.9	23.51	17.6	16.56	10.87	9.51
Moisture content %	27.61	29.60	31.59	33.70	25.11	25.24



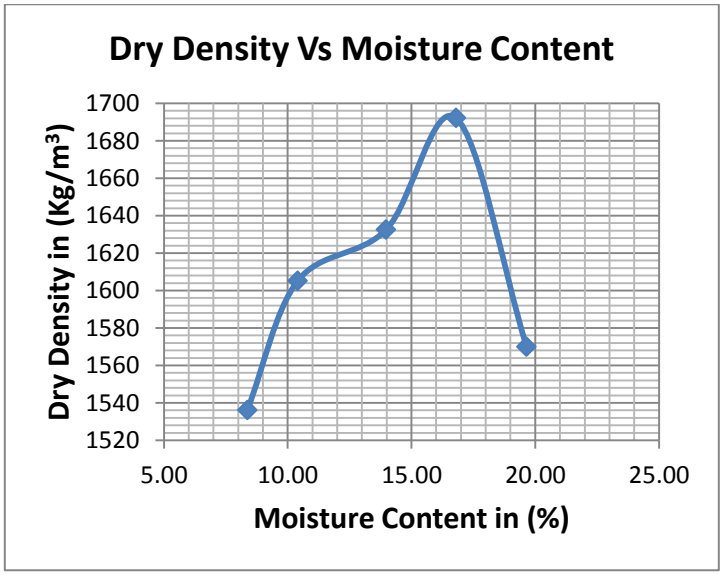
From the graph; moisture content at 25 blows (LL) = 30.00

PL = 25.18

PI = LL-PL = 30-25.18 = 5.45

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**2**	**1**	**N**	**3**	**4**
Mass of Wet soil +Con(gm.)(F)	140.44	159.24	110.81	121.51	143.65
Mass of dry soil +con(gm.)(G)	131.00	146.00	99.43	106.72	123.05
Mass of container(gm.)(H)	18.21	18.75	18.01	18.70	18.21
Mass of moisture(gm.)F-G=(I)	9.44	13.24	11.38	14.79	20.6
Mass of Dry soil(gm.)G-H=(J)	112.79	127.25	81.42	88.02	104.84
Moisture content % (I/J)*100=K	8.37	10.40	13.98	16.80	19.65
Dry Density gm./cm^3 E/(100+K)*100	1.536	1.605	1.632	1.692	1.570
Dry density in kg/m^3	1536	1605	1632	1692	1570

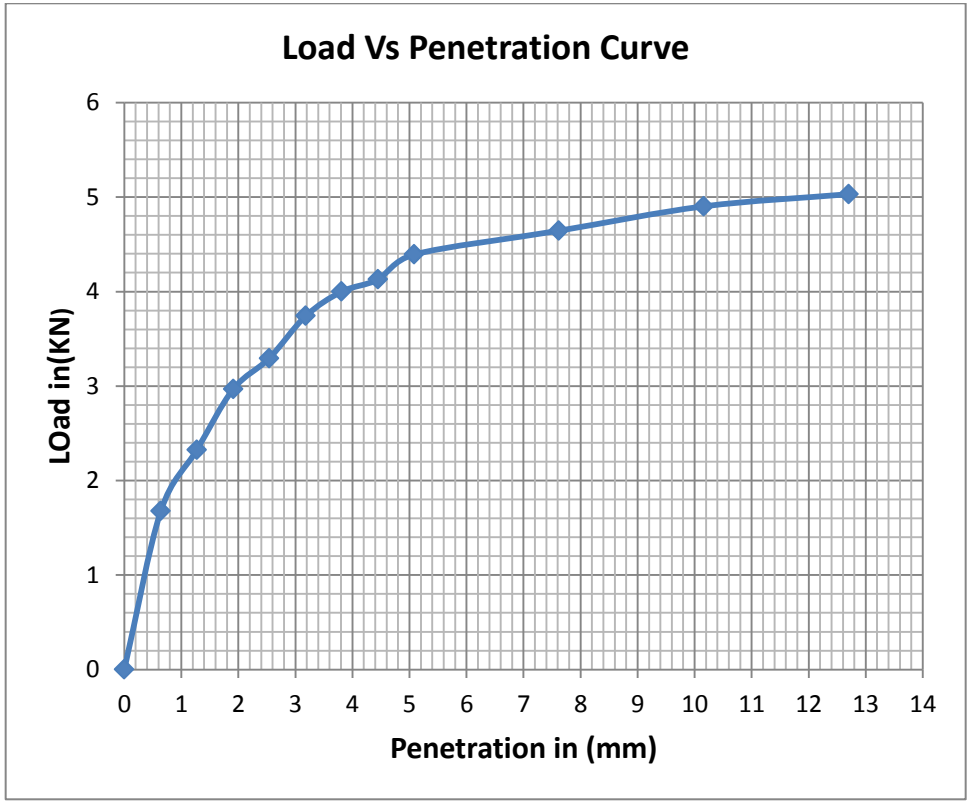


From the above plot; the value of MDD (Maximum Dry Density) = 1.692 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 16.80%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load(KN)**	**CBR (%)**
0	0		0	
0.64	65.00	0.0258	1.68	
1.27	90.00	0.0258	2.32	
1.91	115.00	0.0258	2.97	
2.54	127.65	0.0258	3.29	24.95
3.18	145.00	0.0258	3.74	
3.81	155.00	0.0258	4.00	
4.45	160.00	0.0258	4.13	
5.08	170.23	0.0258	4.39	21.96
7.62	180.00	0.0258	4.64	
10.16	190.00	0.0258	4.90	
12.7	195.00	0.0258	5.03	

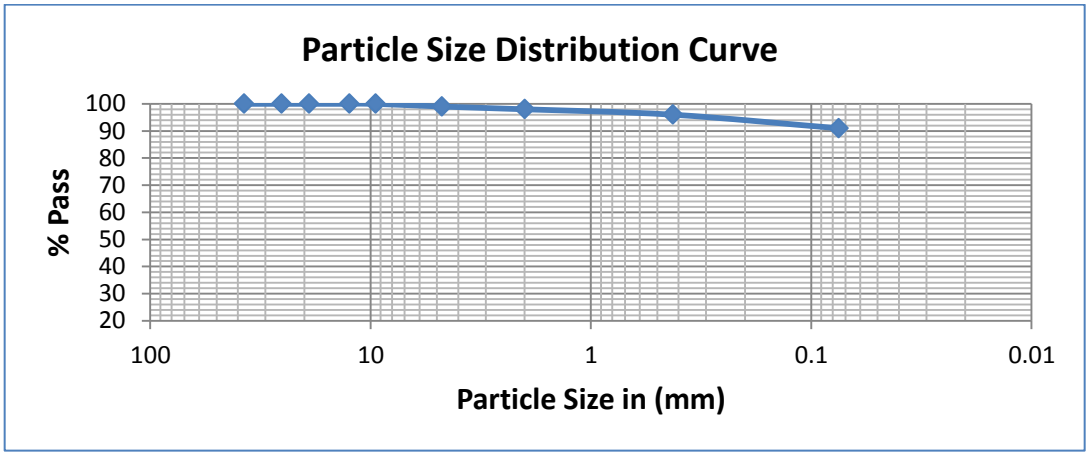


Therefore, based on the above table and graph the value of CBR at **2.54** and **5.08** is **24.95** and **21.96** respectively.

Experiment No. 8

1. Particle Size Distribution (Sieve Analysis)

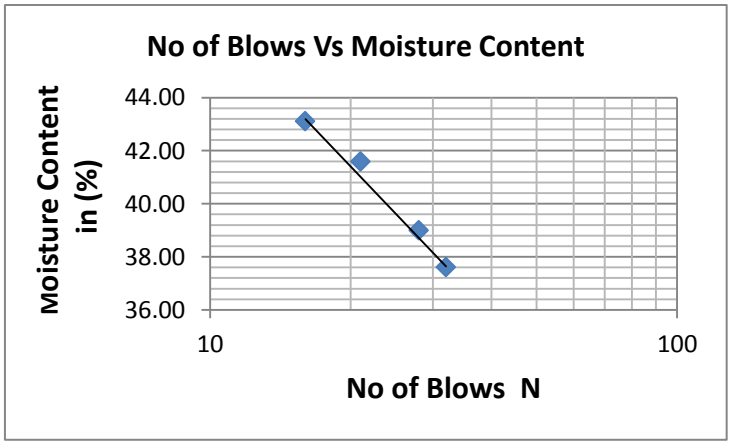
Laboratory Test No.8			
Sieve (mm)	**Weight retained in (gm.)**	**% retained**	**% Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	19.90	1	99
2	19.90	1	98
0.425	39.80	2	96
0.075	99.50	5	91
Pan	1810.90	91	0
Total mass	**1990**	100	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	32	28	21	16		
container no	**7**	**349**	**2**	**332**	**366**	**364**
Wt. of cont. + wet soil	51.31	43.5	53.7	46.77	31.49	32.41
Wt. of cont. + dry soil	44.66	37.56	45.82	39.7	29.22	30.2
Wt. of container	26.98	21.8	26.87	23.3	21.81	23.04
Wt. of water	6.65	5.94	7.88	7.07	2.27	2.21
Wt. of dry soil	17.68	15.76	18.95	16.4	7.41	7.16
Moisture content (%)	37.61	39.00	41.58	43.11	30.63	30.87



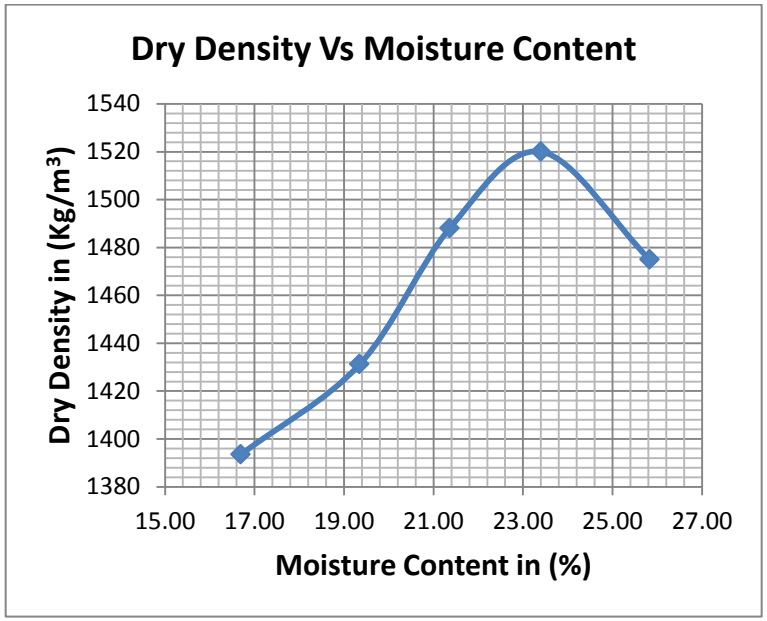
From the graph; moisture content at 25 blows (LL) = 40.33

PL = 30.75

PI = LL-PL = 40.33-30.75 = **9.58**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture content					
Container no.	D	E	3	N	C
Mass of Wet soil +Con(gm.)(F)	129.01	142.7	168.95	163.19	179.60
Mass of dry soil +con(gm.)(G)	113.22	122.54	142.50	135.64	146.47
Mass of container(gm.)(H)	18.65	18.35	18.70	17.91	18.21
Mass of moisture(gm.)F-G=(I)	15.79	20.16	26.45	27.55	33.13
Mass of Dry soil(gm.)G-H=(J)	94.57	104.19	123.8	117.73	128.26
Moisture content % (I/J)*100=K	16.70	19.35	21.37	23.40	25.83
Dry Density gm./cm^3 E/(100+K)*100	1.394	1.431	1.488	1.520	1.475
Dry density in kg/m^3	1394	1431	1488	1520	1475

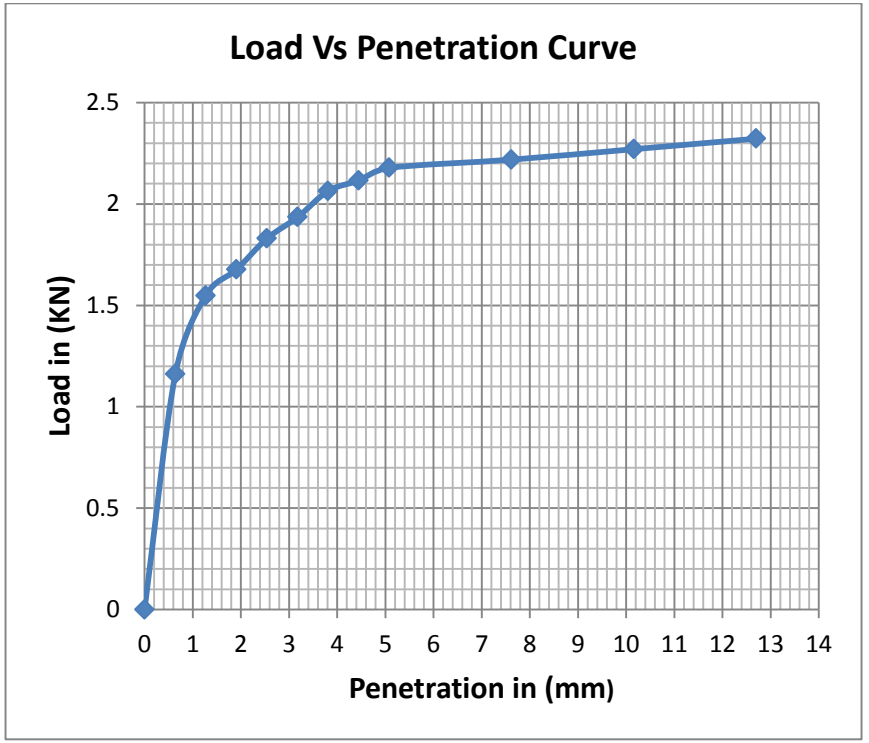


From the above plot; the value of MDD (Maximum Dry Density) = 1.52 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 23.4%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load(KN)**	**CBR(%)**
0	0		0	
0.64	45.00	0.0258	1.16	
1.27	60.00	0.0258	1.55	
1.91	65.00	0.0258	1.68	
2.54	70.91	0.0258	1.83	13.86
3.18	75.00	0.0258	1.94	
3.81	80.00	0.0258	2.06	
4.45	82.00	0.0258	2.12	
5.08	84.42	0.0258	2.18	10.89
7.62	86.00	0.0258	2.22	
10.16	88.00	0.0258	2.27	
12.7	90.00	0.0258	2.32	

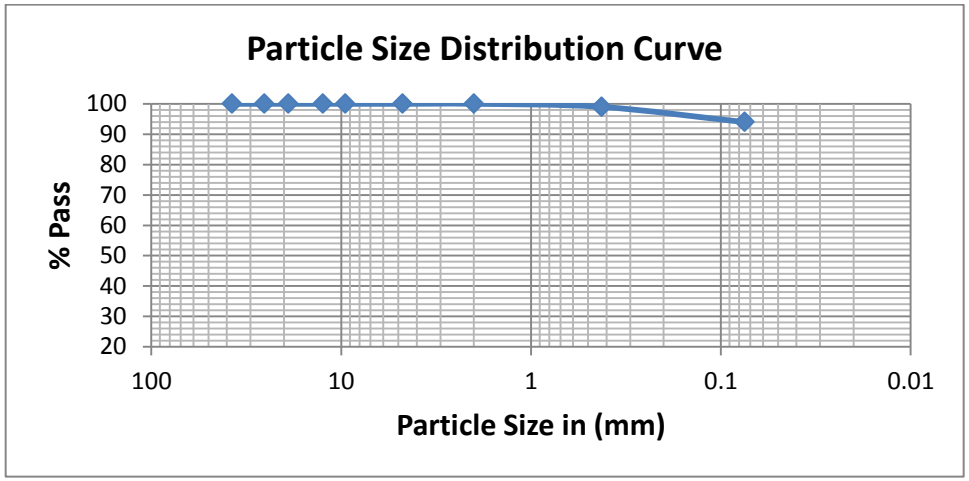


Therefore, based on the above table and graph the value of CBR at 2.54 and 5.08 is 13.86 and 10.89 respectively.

Experiment No. 9

1. Particle Size Distribution (Sieve Analysis)

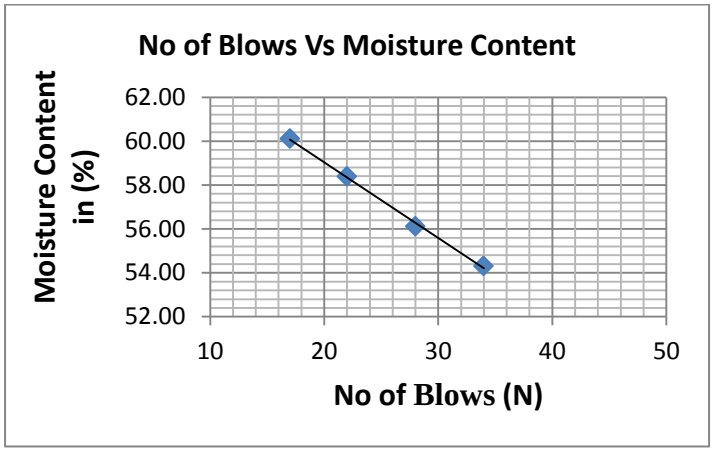
Laboratory Test No.9			
Sieve (mm)	**Weight retained in (gm.)**	**% retained**	**% Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	0.00	0.00	100
0.425	19.90	1	99
0.075	99.50	5	94
Pan	1870.60	94	0
Total mass	**1990**	100	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	22	17		
container no	**18**	**346**	**24**	**364**	**144**	**8**
Wt. of cont. + wet soil	45.64	42.36	41.32	41.6	41.02	42.86
Wt. of cont. + dry soil	37.25	35.33	34.36	34.73	36.41	37.85
Wt. of container	21.8	22.8	22.44	23.3	22.1	22.23
Wt. of water	8.39	7.03	6.96	6.87	4.61	5.01
Wt. of dry soil	15.45	12.53	11.92	11.43	14.31	15.62
Moisture content %	54.30	56.11	58.39	60.10	32.22	32.07



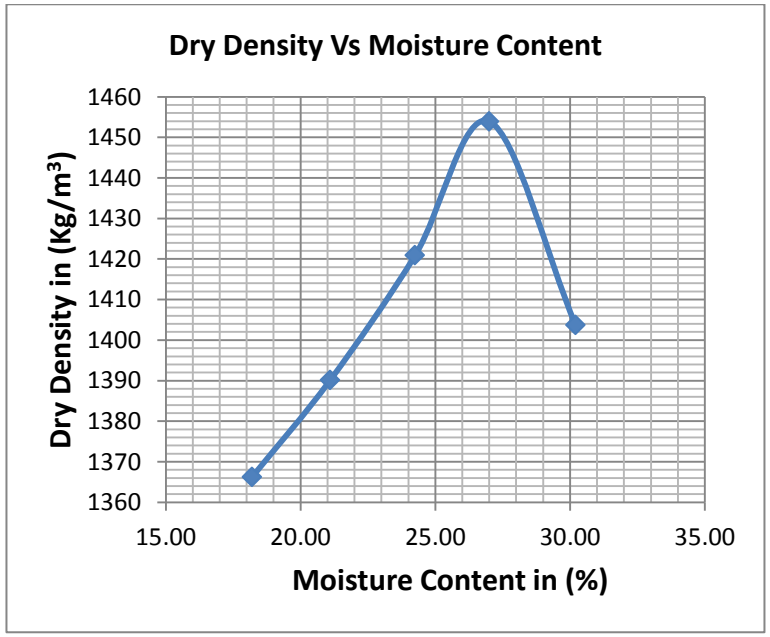
From the graph; moisture content at 25 blows (LL) = 57.23

PL = 32.14

PI = LL-PL = 64.17-38.41 = 25.08

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**A28**	**N**	**E**	**A04**	**7**
Mass of Wet soil +Con(gm.)(F)	101.63	104.09	108.62	123.56	83.71
Mass of dry soil +con(gm.)(G)	88.63	89.07	91.00	101.47	70.55
Mass of container(gm.)(H)	17.20	17.91	18.35	19.66	26.98
Mass of moisture(gm.)F-G=(I)	13.00	15.02	17.62	22.09	13.16
Mass of Dry soil(gm.)G-H=(J)	71.43	71.16	72.65	81.81	43.57
Moisture content % (I/J)*100=K	18.20	21.11	24.25	27.00	30.20
Dry Density gm./cm^3 E/(100+K)*100	1.366	1.390	1.421	1.454	1.404
Dry density in kg/m^3	1366	1390	1421	1454	1404

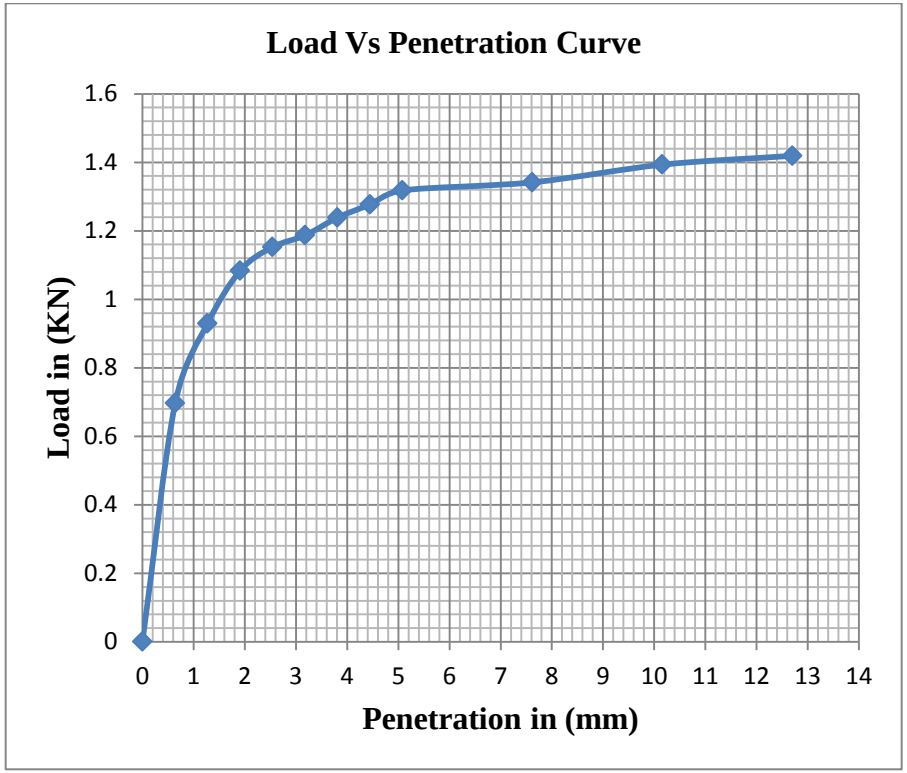


From the above plot; the value of MDD (Maximum Dry Density) = 1.454 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 27.00%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	27.00	0.0258	0.70	
1.27	36.00	0.0258	0.93	
1.91	42.00	0.0258	1.08	
2.54	44.67	0.0258	1.15	8.73
3.18	46.00	0.0258	1.19	
3.81	48.00	0.0258	1.24	
4.45	49.50	0.0258	1.28	
5.08	51.09	0.0258	1.32	6.59
7.62	52.00	0.0258	1.34	
10.16	54.00	0.0258	1.39	
12.7	55.00	0.0258	1.42	

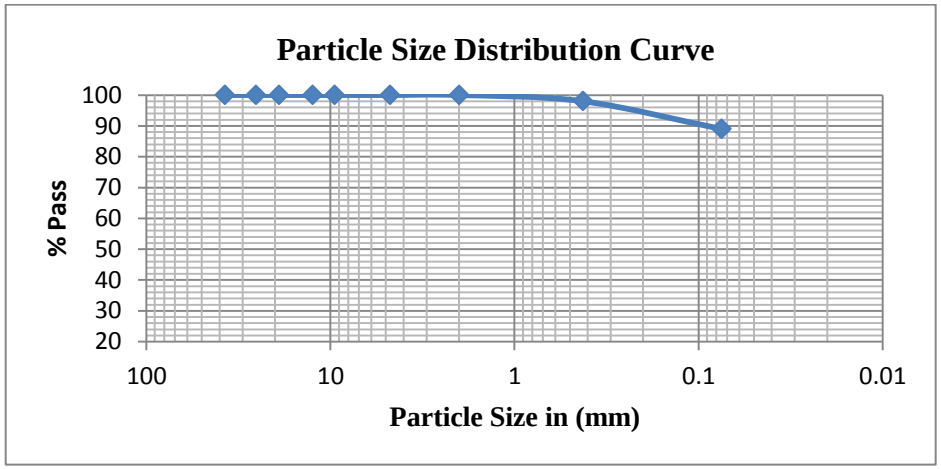


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **8.73** and **6.59** respectively.

Experiment No. 10

1. Particle Size Distribution (Sieve Analysis)

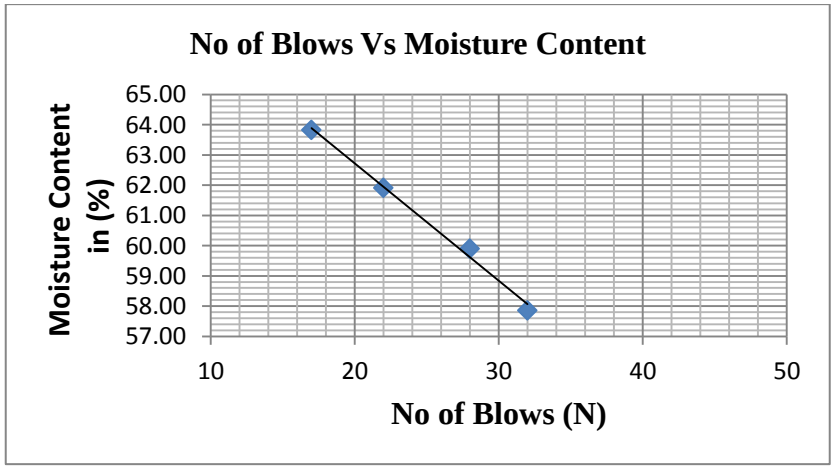
Laboratory Test No.10			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	0.00	0.00	100
0.425	39.00	2.00	98
0.075	175.50	9.00	89
Pan	1735.50	89	0
Total mass	**1950**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	32	28	22	17		
container no	**349**	**350**	**306**	**301**	**369**	**145**
Wt. of cont. + wet soil	43.49	42.04	43.14	41.16	35.7	35.42
Wt. of cont. + dry soil	35.54	34.72	35.45	34.28	31.73	31.56
Wt. of container	21.8	22.5	23.03	23.5	21.51	21.6
Wt. of water	7.95	7.32	7.69	6.88	3.97	3.86
Wt. of dry soil	13.74	12.22	12.42	10.78	10.22	9.96
Moisture content (%)	57.86	59.90	61.92	63.82	38.85	38.76



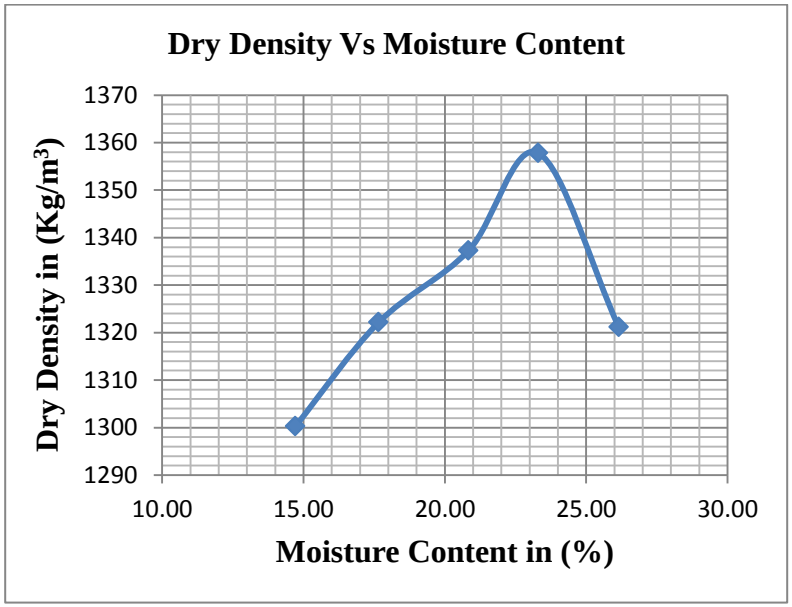
From the graph; moisture content at 25 blows (LL) = 61.3

PL = 38.75

PI = LL-PL = 61.3-38.75 = 22.55

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**AB**	**A_3**	**A_2**	**9**	**18**
Mass of Wet soil +Con(gm.)(F)	107.41	109	88.64	68.28	95.67
Mass of dry soil +con(gm.)(G)	95.97	95.45	76.54	59.57	80.74
Mass of container(gm.)(H)	18.20	18.70	18.46	22.19	23.65
Mass of moisture(gm.)F-G=(I)	11.44	13.55	12.1	8.71	14.93
Mass of Dry soil(gm.)G-H=(J)	77.77	76.75	58.08	37.38	57.09
Moisture content % (I/J)*100=K	14.71	17.65	20.83	23.30	26.15
Dry Density gm./cm^3 E/(100+K)*100	1.300	1.322	1.337	1.358	1.321
Dry density in kg/m^3	1300	1322	1337	1358	1321

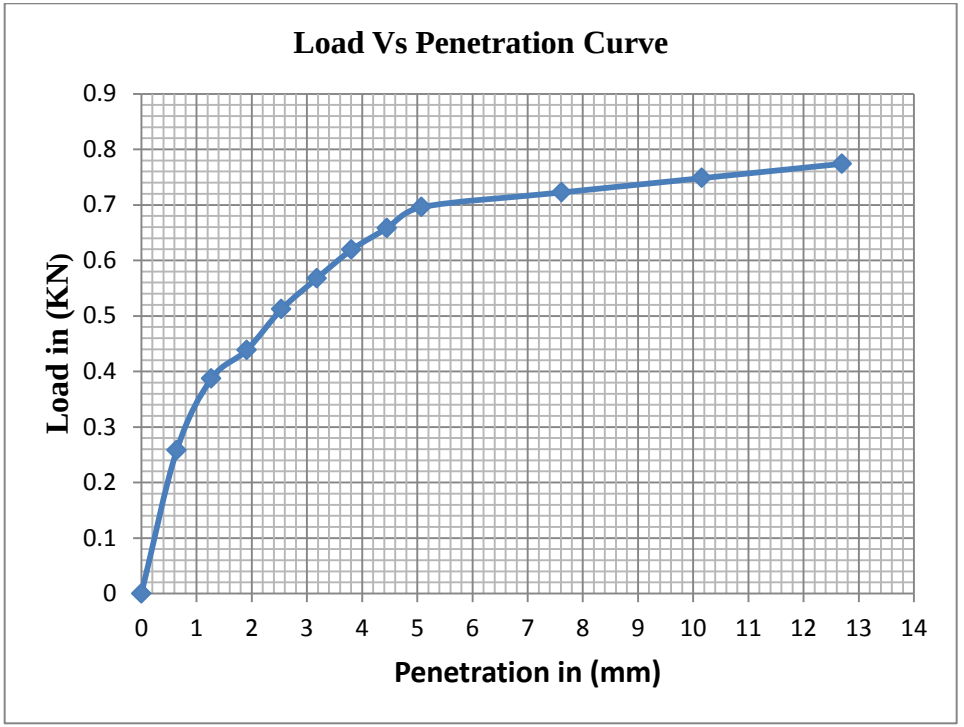


From the above plot; the value of MDD (Maximum Dry Density) = 1.358 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 23.30%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	10.00	0.0258	0.26	
1.27	15.00	0.0258	0.39	
1.91	17.00	0.0258	0.44	
2.54	19.85	0.0258	0.51	3.88
3.18	22.00	0.0258	0.57	
3.81	24.00	0.0258	0.62	
4.45	25.50	0.0258	0.66	
5.08	26.98	0.0258	0.70	3.48
7.62	28.00	0.0258	0.72	
10.16	29.00	0.0258	0.75	
12.7	30.00	0.0258	0.774	

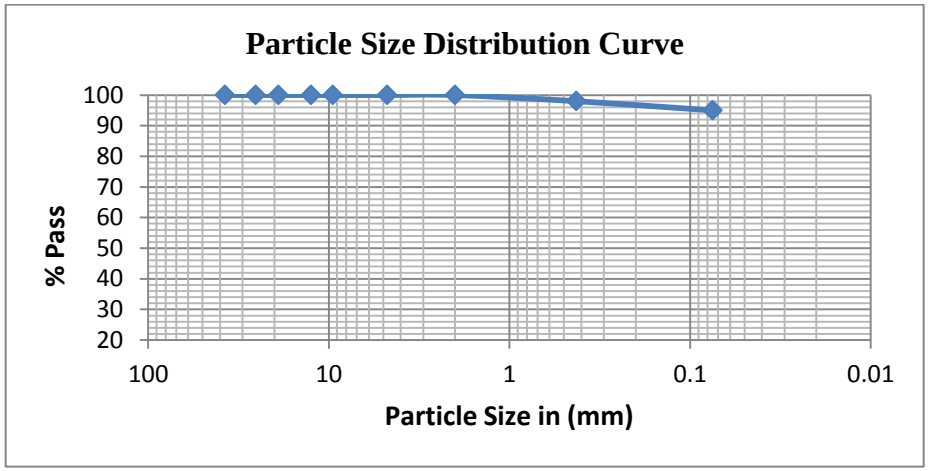


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **3.88** and **3.48** respectively.

Experiment No. 11

1. Particle Size Distribution (Sieve Analysis)

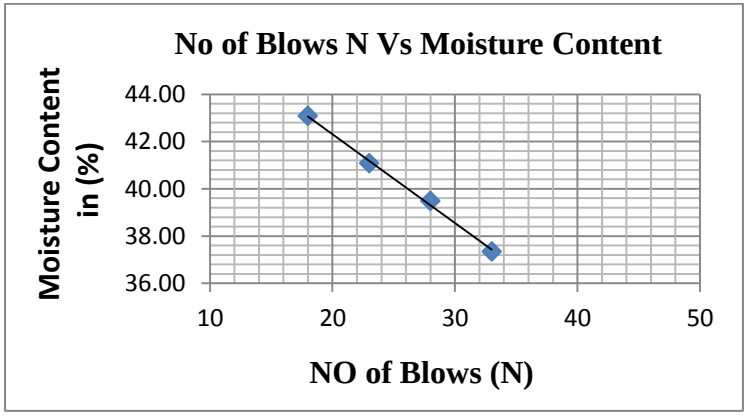
Laboratory Test No.11			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	0.00	0.00	100
0.425	39.80	2	98
0.075	59.70	3	95
Pan	1890.50	95	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	28	23	18		
container no	**318**	**340**	**32**	**314**	**332**	**311**
Wt. of cont. + wet soil	44.8	46	49.01	43.52	35.86	35.73
Wt. of cont. + dry soil	38.22	39.49	41.32	36.8	33.25	33.12
Wt. of container	20.6	23	22.6	21.2	23.32	23.12
Wt. of water	6.58	6.51	7.69	6.72	2.61	2.61
Wt. of dry soil	17.62	16.49	18.72	15.6	9.93	10
Moisture content (%)	37.34	39.48	41.08	43.08	26.28	26.10



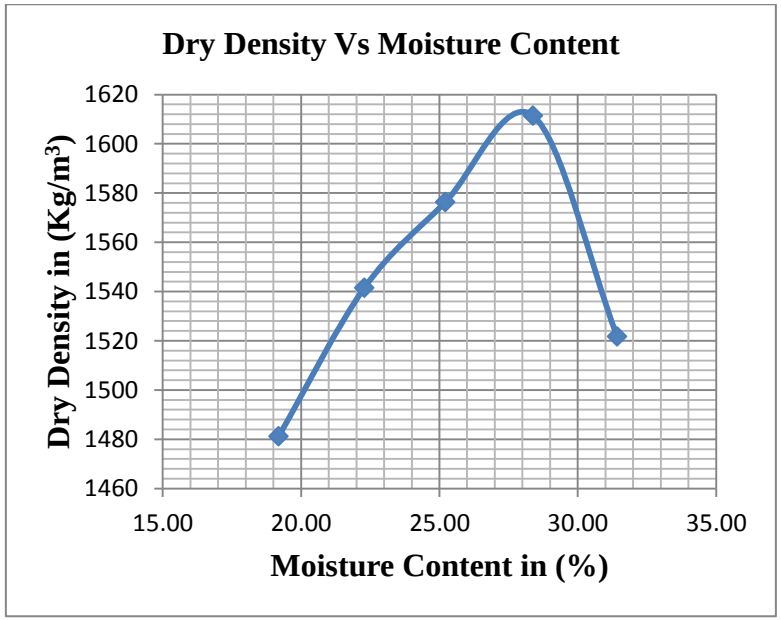
From the graph; moisture content at 25 blows (LL) = 40.24

PL = 26.19

PI = LL-PL = 40.24-26.19 = **14.05**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**12**	**34**	**B**	**B3**	**31**
Mass of Wet soil +Con(gm.)(F)	87.19	104.6	136.42	112.33	123.12
Mass of dry soil +con(gm.)(G)	76.14	88.88	112.80	93.09	98.07
Mass of container(gm.)(H)	18.56	18.35	19.10	25.29	18.35
Mass of moisture(gm.)F-G=(I)	11.05	15.72	23.62	19.24	25.05
Mass of Dry soil(gm.)G-H=(J)	57.58	70.53	93.7	67.8	79.72
Moisture content % (I/J)*100=K	19.19	22.29	25.21	28.38	31.42
Dry Density gm./cm^3 E/(100+K)*100	1.481	1.542	1.576	1.611	1.522
Dry density in kg/m^3	1481	1542	1576	1611	1522

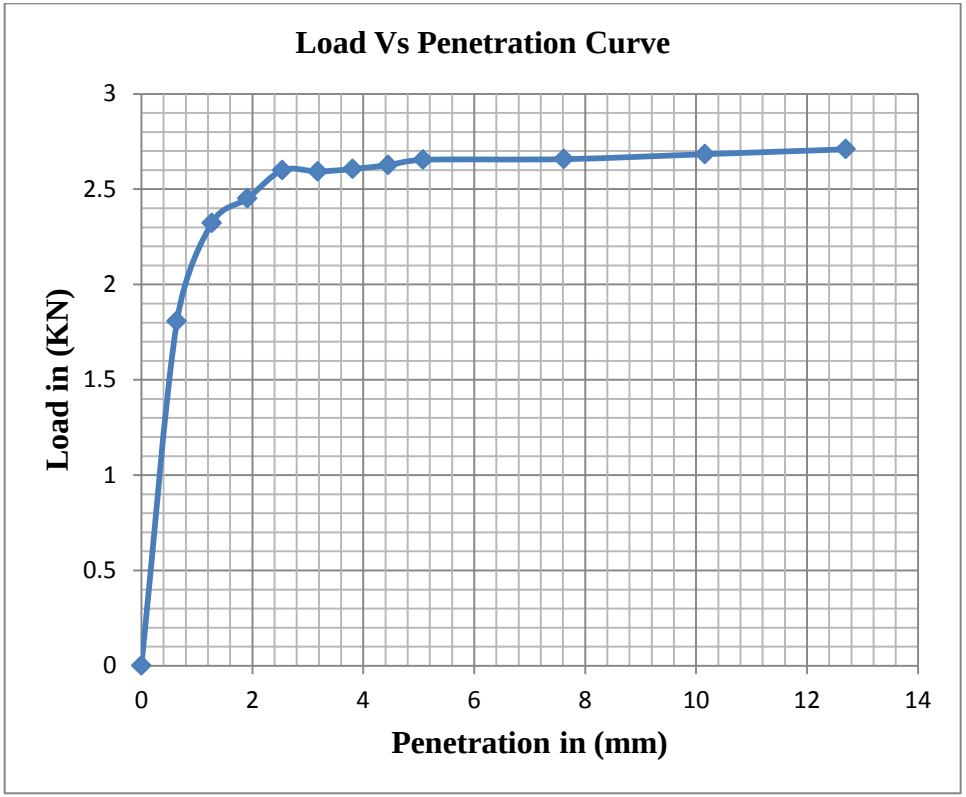


From the above plot; the value of MDD (Maximum Dry Density) = 1.61 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 28.38%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	70.00	0.0258	1.81	
1.27	90.00	0.0258	2.32	
1.91	95.00	0.0258	2.45	
2.54	100.74	0.0258	2.60	19.69
3.18	100.50	0.0258	2.59	
3.81	101.00	0.0258	2.61	
4.45	101.80	0.0258	2.63	
5.08	102.87	0.0258	2.65	13.27
7.62	103.00	0.0258	2.66	
10.16	104.00	0.0258	2.68	
12.7	105.00	0.0258	2.71	

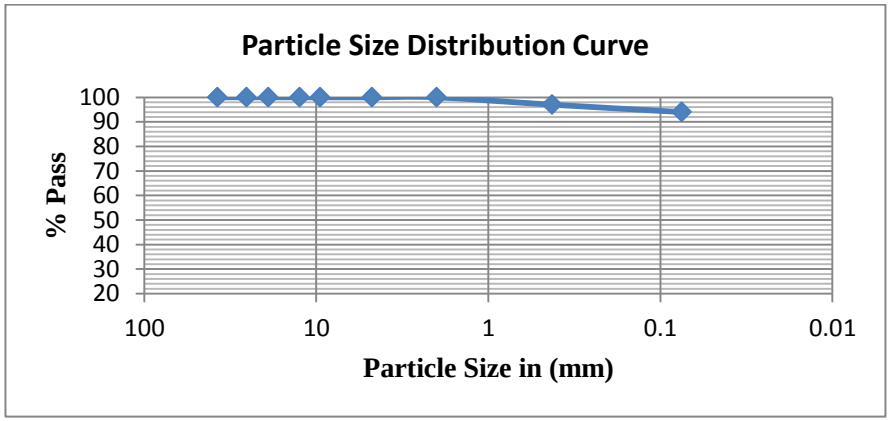


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **19.69** and **13.27** respectively.

Experiment No. 12

1. Particle Size Distribution (Sieve Analysis)

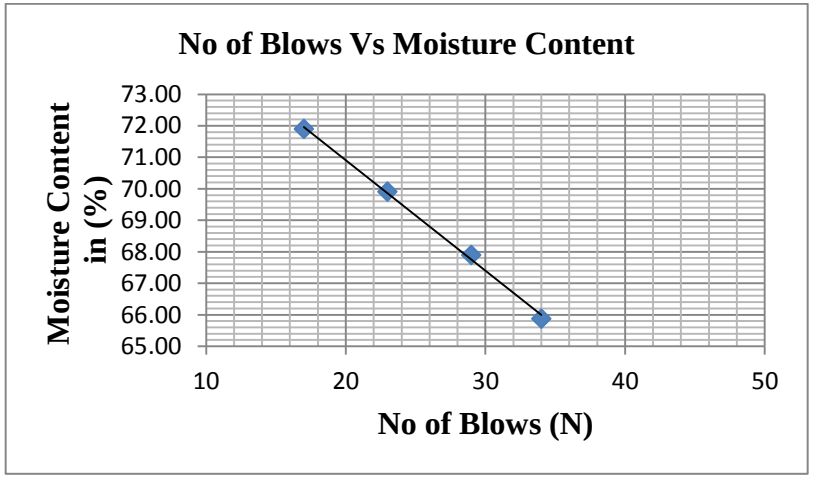
Laboratory Test No.12			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	0.00	0.00	100
0.425	60.00	3.00	97
0.075	60.00	3.00	94
Pan	1880.00	94.00	0
Total mass	**2000**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	29	23	17		
container no	**32**	**314**	**311**	**318**	**332**	**340**
Wt. of cont. + wet soil	42.1	39.55	42.36	37.6	34	33.25
Wt. of cont. + dry soil	34.36	32.17	34.44	30.49	31.01	30.42
Wt. of container	22.61	21.3	23.11	20.6	23.27	23.05
Wt. of water	7.74	7.38	7.92	7.11	2.99	2.83
Wt. of dry soil	11.75	10.87	11.33	9.89	7.74	7.37
Moisture content (%)	65.87	67.89	69.90	71.89	38.63	38.40



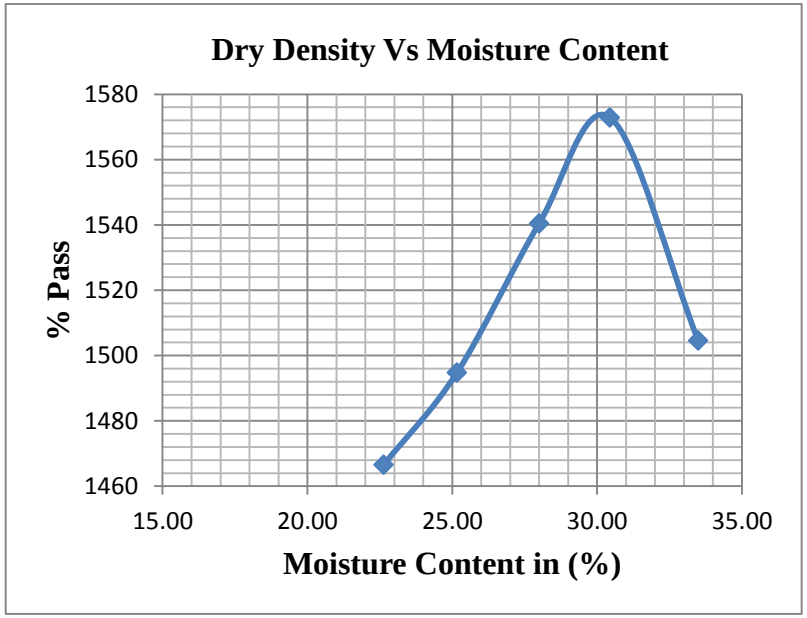
From the graph; moisture content at 25 blows (LL) = 68.89

PL = 38.51

PI = LL-PL = 68.89-38.51 = **30.38**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	K_1	G	14	D	27
Mass of Wet soil +Con(gm.)(F)	90.97	113.18	95.65	109.14	127.38
Mass of dry soil +con(gm.)(G)	77.65	95.50	78.85	88.04	100.00
Mass of container(gm.)(H)	18.80	25.25	18.85	18.74	18.25
Mass of moisture(gm.)F-G=(I)	13.32	17.68	16.8	21.1	27.38
Mass of Dry soil(gm.)G-H=(J)	58.85	70.25	60	69.3	81.75
Moisture content % (I/J)*100=K	22.63	25.17	28.00	30.45	33.49
Dry Density gm./cm^3 E/(100+K)*100	1.467	1.495	1.540	1.573	1.505
Dry density in kg/m^3	1467	1495	1540	1573	1505

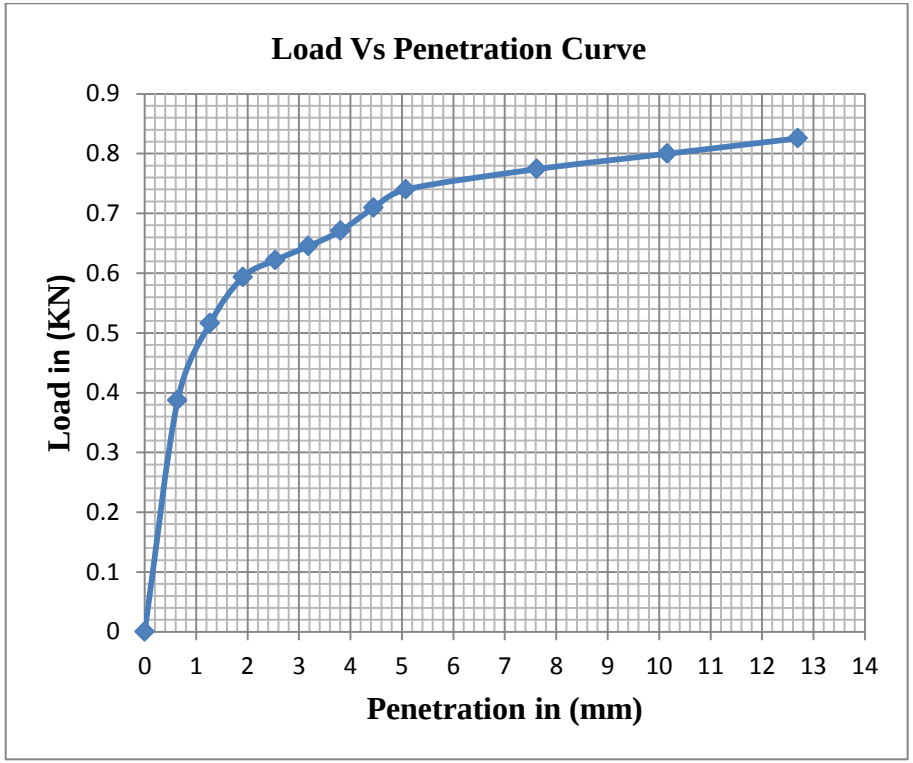


From the above plot; the value of MDD (Maximum Dry Density) = 1.573 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 30.45%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	15.00	0.0258	0.39	
1.27	20.00	0.0258	0.52	
1.91	23.00	0.0258	0.59	
2.54	24.10	0.0258	0.62	4.71
3.18	25.00	0.0258	0.65	
3.81	26.00	0.0258	0.67	
4.45	27.50	0.0258	0.71	
5.08	28.68	0.0258	0.74	3.70
7.62	30.00	0.0258	0.77	
10.16	31.00	0.0258	0.80	
12.7	32.00	0.0258	0.83	

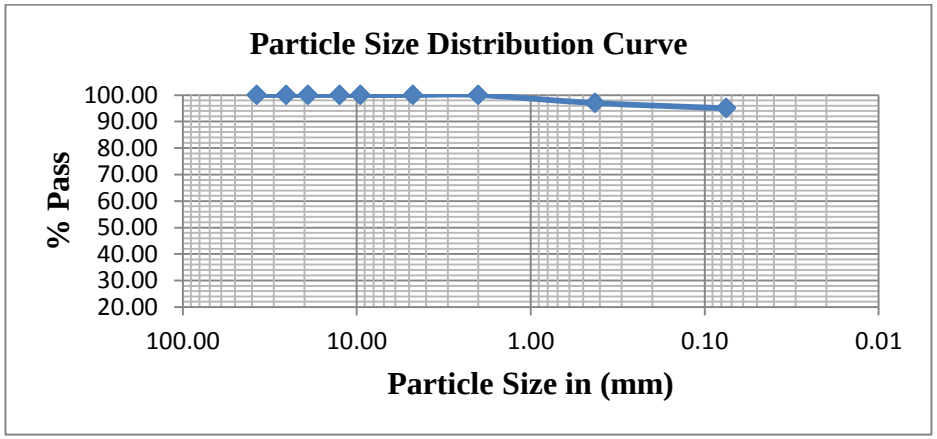


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **4.71** and **3.70** respectively.

Experiment No. 13

1. Particle Size Distribution (Sieve Analysis)

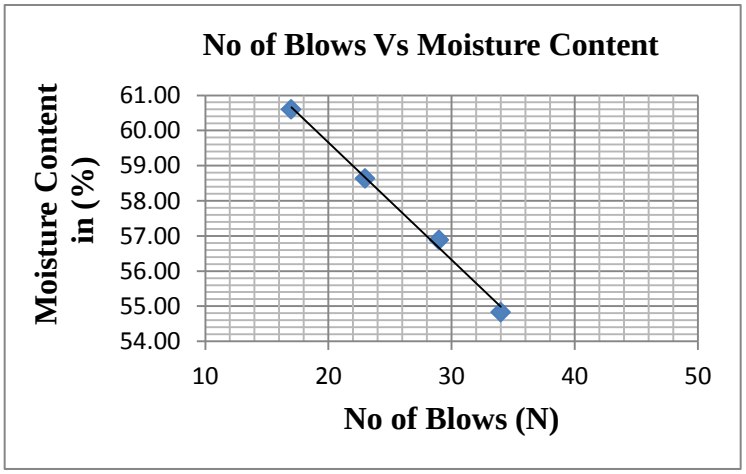
Laboratory Test No.13			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.50	0.00	0.00	100.00
25.40	0.00	0.00	100.00
19.00	0.00	0.00	100.00
12.50	0.00	0.00	100.00
9.50	0.00	0.00	100.00
4.75	0.00	0.00	100.00
2.00	0.00	0.00	100.00
0.43	58.80	3.00	97.00
0.08	39.20	2.00	95.00
Pan	1862.00	95.00	0.00
Total mass	**1960.00**	**100.00**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	29	23	17		
container no	**314**	**332**	**318**	**340**	**311**	**32**
Wt. of cont. + wet soil	37.42	40.05	32.99	38.83	33.29	33.13
Wt. of cont. + dry soil	31.68	33.98	28.78	32.97	30.89	30.66
Wt. of container	21.21	23.31	21.6	23.3	23.14	22.58
Wt. of water	5.74	6.07	4.21	5.86	2.4	2.47
Wt. of dry soil	10.47	10.67	7.18	9.67	7.75	8.08
Moisture content (%)	54.82	56.89	58.64	60.60	30.97	30.57



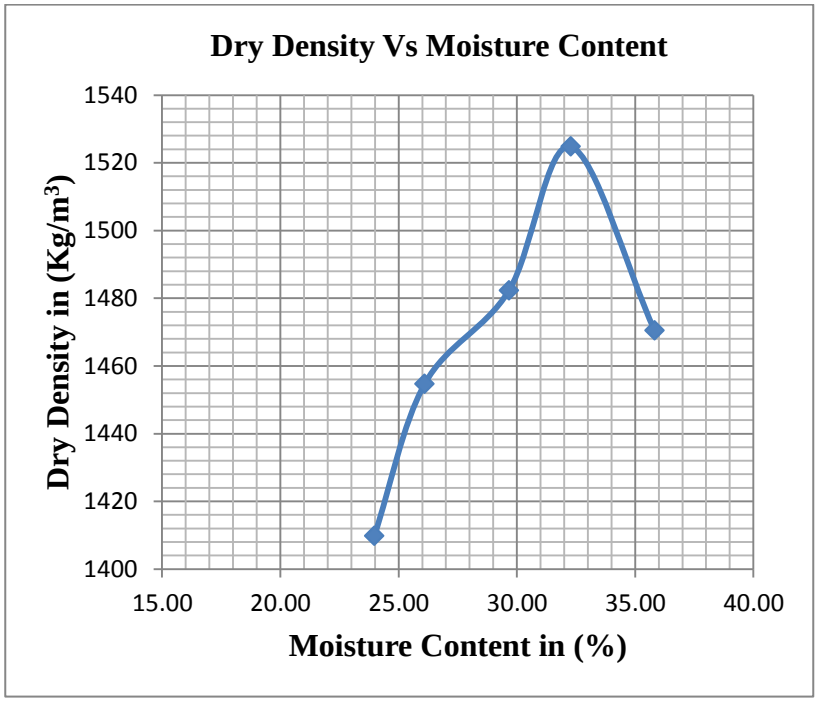
From the graph; moisture content at 25 blows (LL) = 57.3

PL = 30.56

PI = LL-PL = 57.3-30.56 = **26.74**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
container no.	Y	J	B_4	A_2	1
Mass of Wet soil +Con(gm.)(F)	99.41	109.03	109.46	102.30	70.85
Mass of dry soil +con(gm.)(G)	84.00	90.48	88.55	81.84	58.00
Mass of container(gm.)(H)	19.71	19.40	18.05	18.46	22.13
Mass of moisture(gm.)F-G=(I)	15.41	18.55	20.91	20.46	12.85
Mass of Dry soil(gm.)G-H=(J)	64.29	71.08	70.5	63.38	35.87
Moisture content % (I/J)*100=K	23.97	26.10	29.66	32.28	35.82
Dry Density gm./cm^3 E/(100+K)*100	1.410	1.455	1.482	1.525	1.470
Dry density in kg/m^3	1410	1455	1482	1525	1470

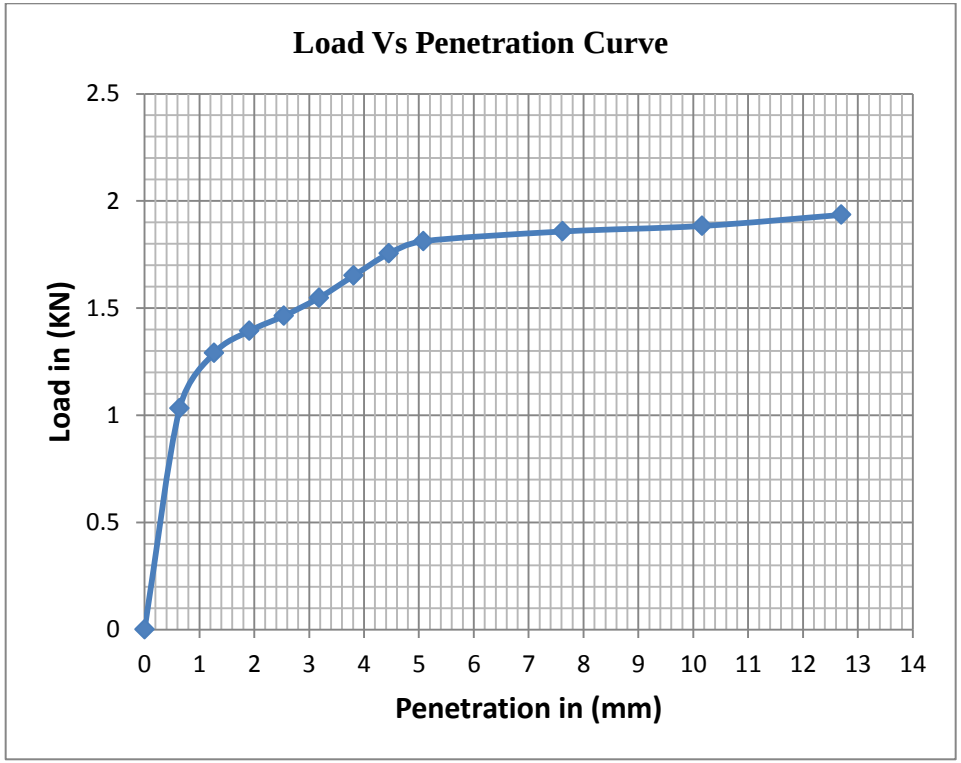


From the above plot; the value of MDD (Maximum Dry Density) = 1.525 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 32.28%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0		0	0	
0.64	40.00	0.0258	1.03	
1.27	50.00	0.0258	1.29	
1.91	54.00	0.0258	1.39	
2.54	56.74	0.0258	1.46	11.09
3.18	60.00	0.0258	1.55	
3.81	64.00	0.0258	1.65	
4.45	68.00	0.0258	1.75	
5.08	70.23	0.0258	1.81	9.06
7.62	72.00	0.0258	1.86	
10.16	73.00	0.0258	1.88	
12.7	75.00	0.0258	1.94	

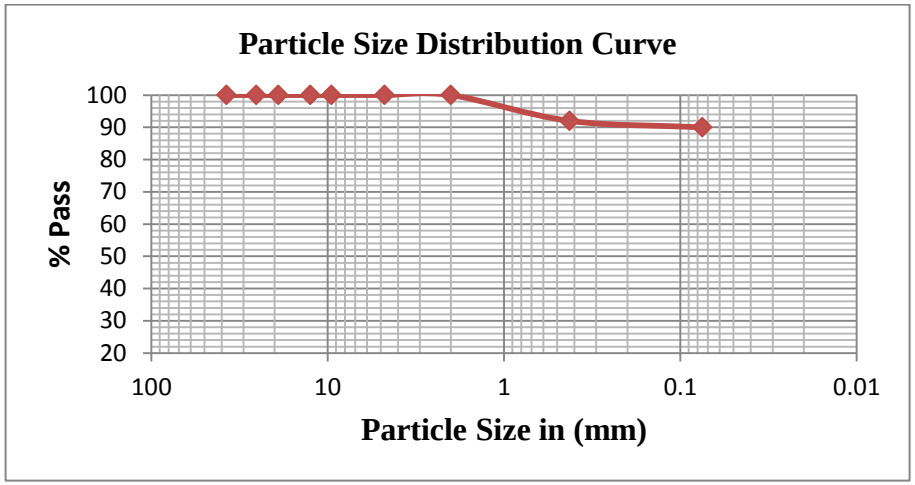


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **11.09** and **9.06** respectively.

Experiment No. 14

1. Particle Size Distribution (Sieve Analysis)

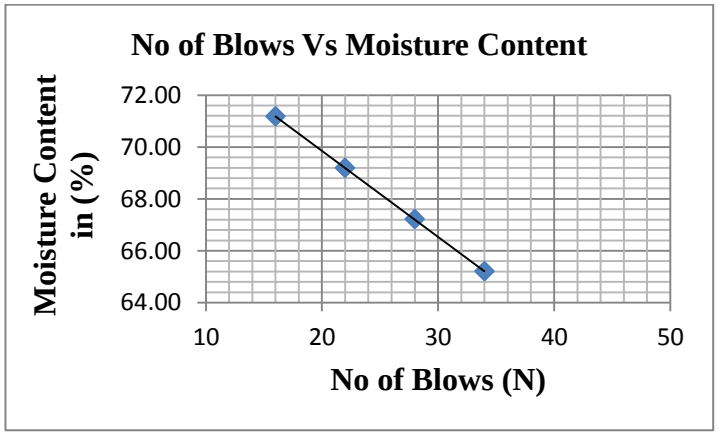
Laboratory Test No.14			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	0.00	0.00	100
0.425	157.60	8.00	92.00
0.075	39.40	2.00	90.00
Pan	1773	90.00	0.00
Total Mass(gm.)	**1970**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	22	16		
container no	**336**	**366**	**306**	**301**	**346**	**331**
Wt. of cont. + wet soil	45.18	48.22	44.2	45.3	35.75	36.13
Wt. of cont. + dry soil	35.94	37.6	35.53	36.24	32.13	32.38
Wt. of container	21.77	21.8	23	23.51	22.79	22.7
Wt. of water	9.24	10.62	8.67	9.06	3.62	3.75
Wt. of dry soil	14.17	15.8	12.53	12.73	9.34	9.68
Moisture content (%)	65.21	67.22	69.19	71.17	38.76	38.74



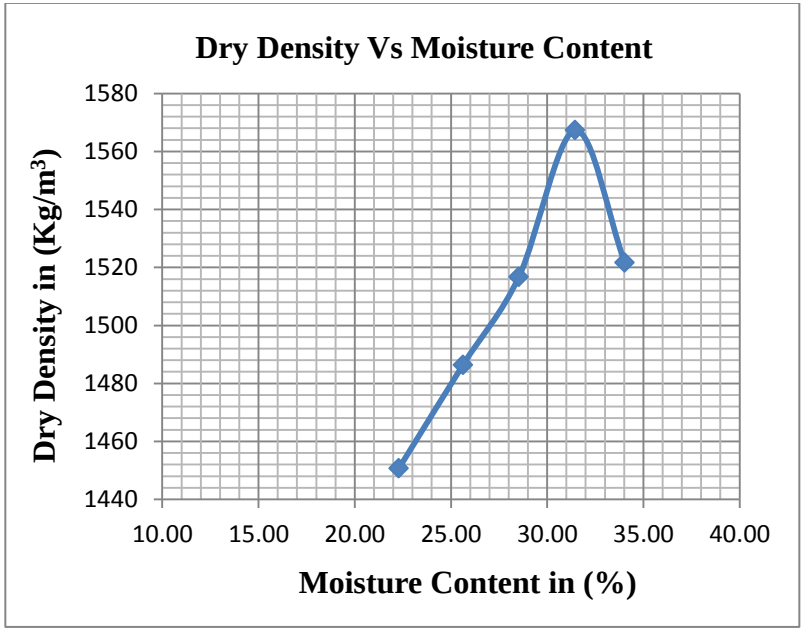
From the graph; moisture content at 25 blows (LL) = 68.89

PL = 38.75

PI = LL-PL = 68.89-38.75 = **29.45**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**AO_4**	**N**	**A_{28}**	**2**	**14**
Mass of Wet soil +Con(gm.)(F)	101.41	104	92.77	100.00	294.00
Mass of dry soil +con(gm.)(G)	86.51	86.44	76.00	80.43	224.34
Mass of container(gm.)(H)	19.66	17.91	17.20	18.21	19.66
Mass of moisture(gm.)F-G=(I)	14.90	17.56	16.77	19.57	69.66
Mass of Dry soil(gm.)G-H=(J)	66.85	68.53	58.8	62.22	204.68
Moisture content % (I/J)*100=K	22.29	25.62	28.52	31.45	34.03
Dry Density gm./cm^3 E/(100+K)*100	1.451	1.486	1.517	1.567	1.522
Dry density in kg/m^3	1451	1486	1517	1567	1522

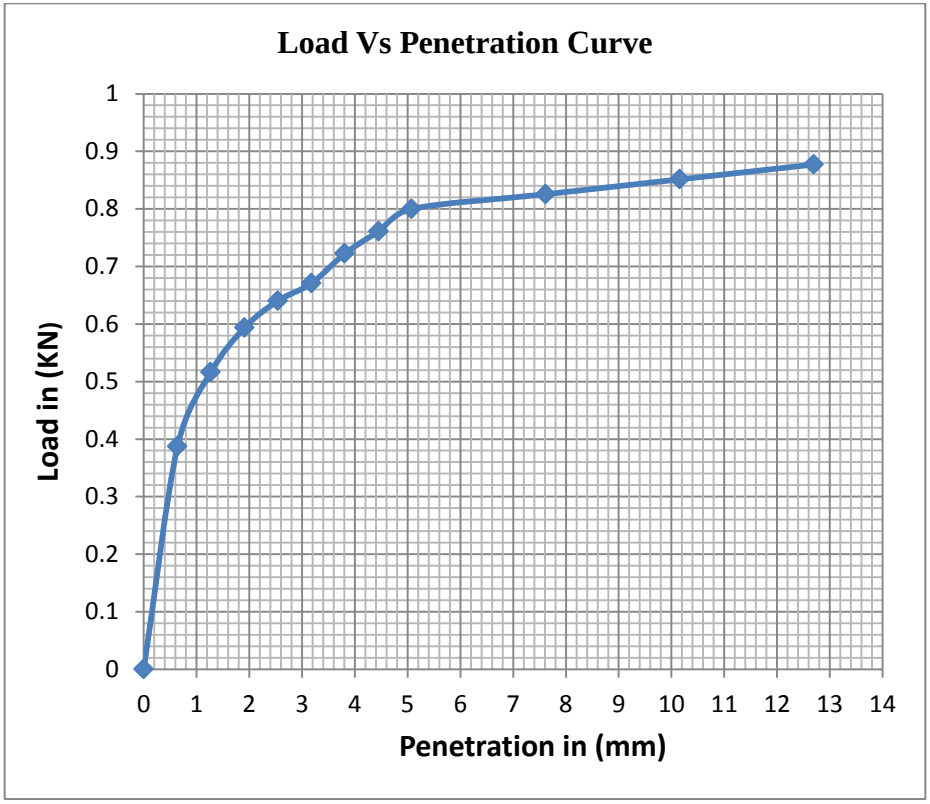


From the above plot; the value of MDD (Maximum Dry Density) = 1.567 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 31.45%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0	0	0	
0.64	15.00	0.0258	0.39	
1.27	20.00	0.0258	0.52	
1.91	23.00	0.0258	0.59	
2.54	24.81	0.0258	0.64	4.85
3.18	26.00	0.0258	0.67	
3.81	28.00	0.0258	0.72	
4.45	29.50	0.0258	0.76	
5.08	31.01	0.0258	0.80	4.00
7.62	32.00	0.0258	0.83	
10.16	33.00	0.0258	0.85	
12.7	34.00	0.0258	0.88	

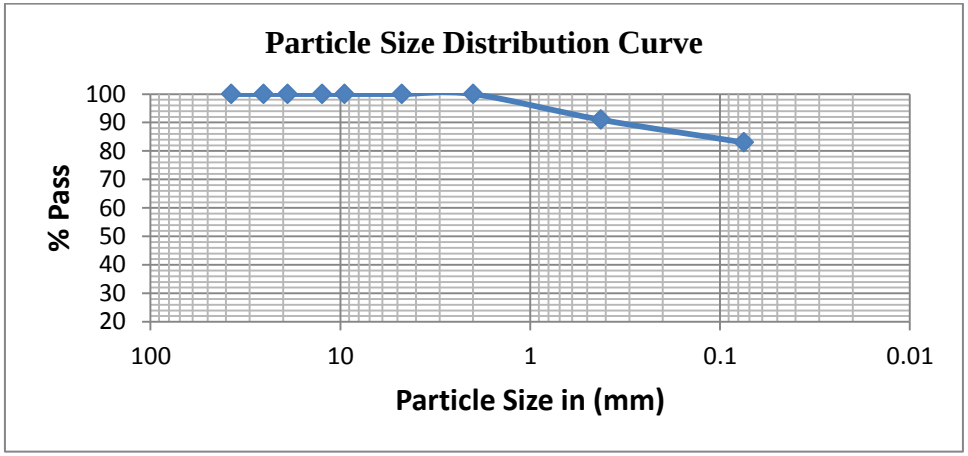


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **4.85** and **4.00** respectively.

Experiment No. 15

1. Particle Size Distribution (Sieve Analysis)

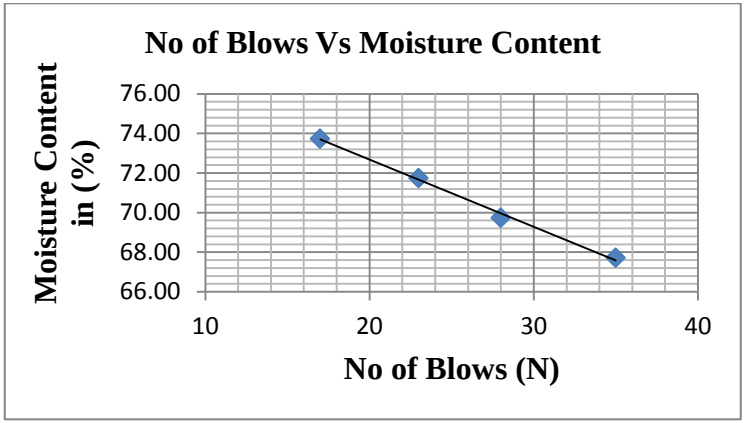
Laboratory Test No.15			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	0.00	0.00	100
0.425	178.74	9	91
0.075	158.88	8	83
Pan	1648.38	83	0
Total mass	**1986**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	35	28	23	17		
container no	**132**	**32**	**318**	**340**	**349**	**366**
Wt. of cont. + wet soil	44.4	45.7	46.66	49.65	41.32	41.52
Wt. of cont. + dry soil	35.47	36.21	35.9	38.34	36.32	36.45
Wt. of container	22.28	22.6	20.9	23	21.8	21.79
Wt. of water	8.93	9.49	10.76	11.31	5	5.07
Wt. of dry soil	13.19	13.61	15	15.34	14.52	14.66
Moisture content (%)	67.70	69.73	71.73	73.73	34.44	34.58



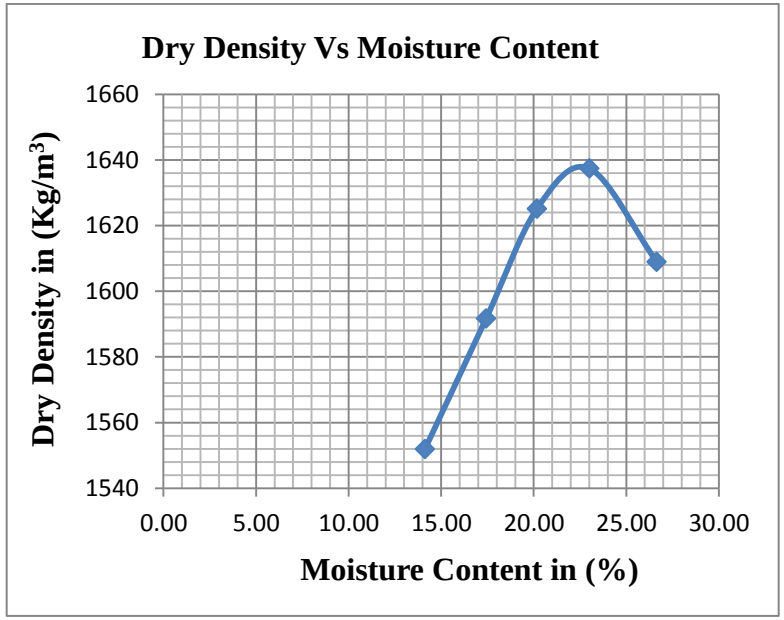
From the graph; moisture content at 25 blows (LL) = 70.72

PL = 34.51

PI = LL-PL = 70.72-34.51 = **36.21**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**AB**	**E**	**A_3**	**36**	**1**
Mass of Wet soil +Con(gm.)(F)	106.99	100.14	108.95	87.92	70.85
Mass of dry soil +con(gm.)(G)	96.00	88.00	93.80	74.88	60.60
Mass of container(gm.)(H)	18.20	18.35	18.70	18.21	22.13
Mass of moisture(gm.)F-G=(I)	10.99	12.14	15.15	13.04	10.25
Mass of Dry soil(gm.)G-H=(J)	77.8	69.65	75.1	56.67	38.47
Moisture content % (I/J)*100=K	14.13	17.43	20.17	23.01	26.64
Dry Density gm./cm^3 E/(100+K)*100	1.552	1.592	1.625	1.637	1.609
Dry density in kg/m^3	1552	1592	1625	1637	1609

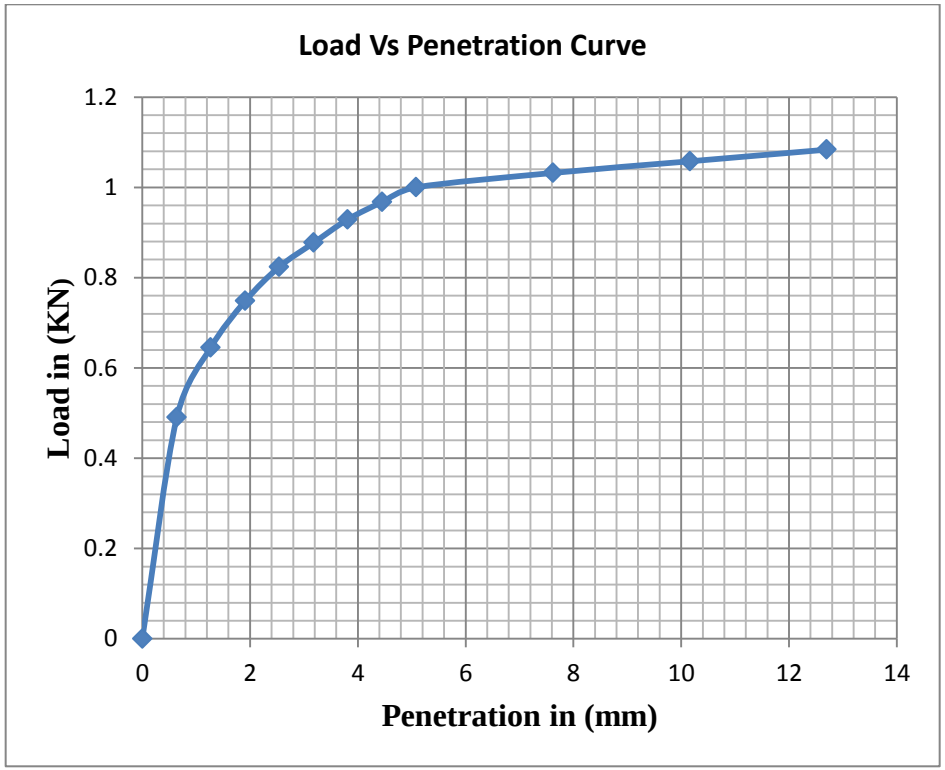


From the above plot; the value of MDD (Maximum Dry Density) = 1.637 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 31.45%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0	0	0	
0.64	19.00	0.0258	0.49	
1.27	25.00	0.0258	0.65	
1.91	29.00	0.0258	0.75	
2.54	31.93	0.0258	0.82	6.24
3.18	34.00	0.0258	0.88	
3.81	36.00	0.0258	0.93	
4.45	37.50	0.0258	0.97	
5.08	38.76	0.0258	1.00	5.00
7.62	40.00	0.0258	1.03	
10.16	41.00	0.0258	1.06	
12.7	42.00	0.0258	1.08	

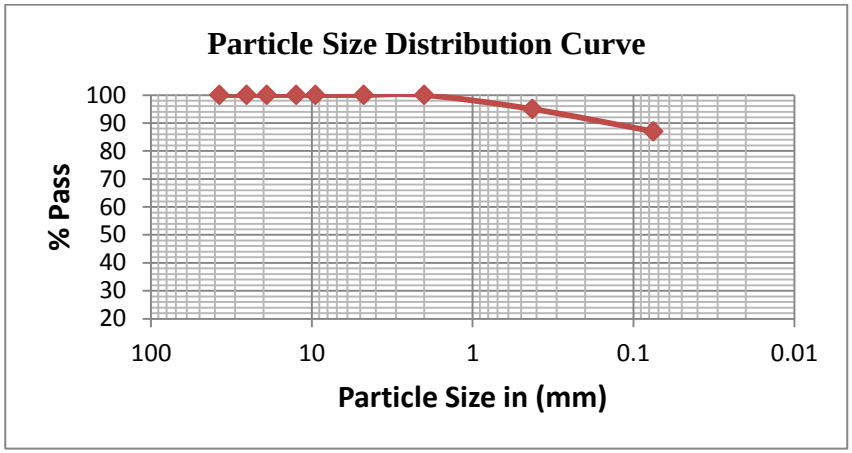


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **6.24** and **5.00** respectively.

Experiment No. 16

1. Particle Size Distribution (Sieve Analysis)

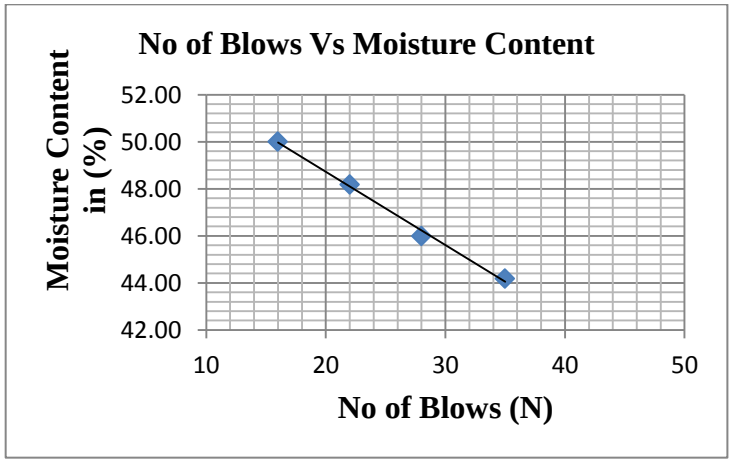
Laboratory Test No.16			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	0.00	0.00	100
0.425	99.50	5	95
0.075	159.20	8	87
Pan	1731.30	87	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	35	28	22	16		
container no	**301**	**336**	**306**	**314**	**332**	**311**
Wt. of cont. + wet soil	47.54	45.83	47.05	46.1	38.18	38.32
Wt. of cont. + dry soil	40.17	38.25	39.23	37.8	34.11	33.8
Wt. of container	23.49	21.77	23	21.2	23.3	21.79
Wt. of water	7.37	7.58	7.82	8.3	4.07	4.52
Wt. of dry soil	16.68	16.48	16.23	16.6	10.81	12.01
Moisture content (%)	44.18	46.00	48.18	50.00	37.65	37.64



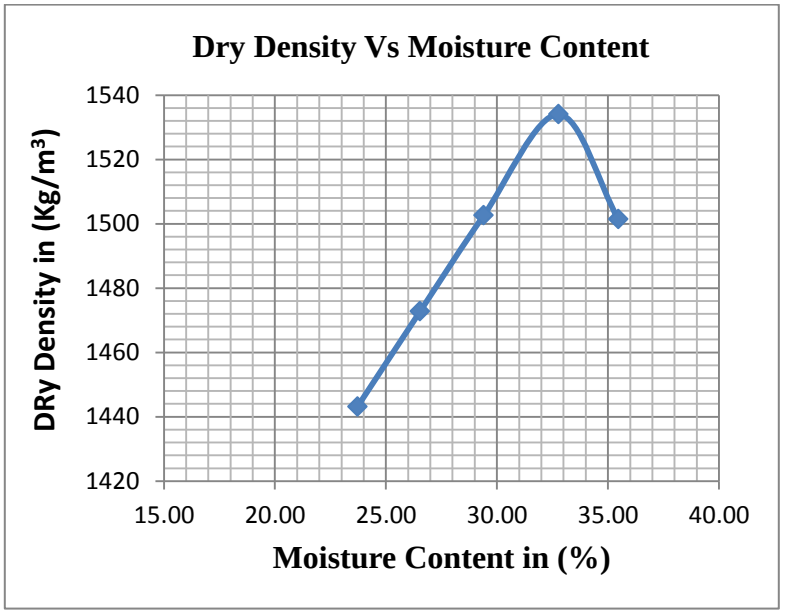
From the graph; moisture content at 25 blows (LL) = 47.09

PL = 37.64

PI = LL-PL = 47.09-37.64 = **9.45**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**A**	**2**	**A_4**	**K_1**	**D**
Mass of Wet soil +Con(gm.)(F)	147.79	115.4	119.62	164.37	164.29
Mass of dry soil +con(gm.)(G)	123.00	95.02	96.54	128.44	126.00
Mass of container(gm.)(H)	18.46	18.21	18.05	18.80	18.05
Mass of moisture(gm.)F-G=(I)	24.79	20.38	23.08	35.93	38.29
Mass of Dry soil(gm.)G-H=(J)	104.54	76.81	78.49	109.64	107.95
Moisture content % (I/J)*100=K	23.71	26.53	29.41	32.77	35.47
Dry Density gm./cm^3 E/(100+K)*100	1.443	1.473	1.503	1.534	1.501
Dry density in kg/m^3	1443	1473	1503	1534	1501

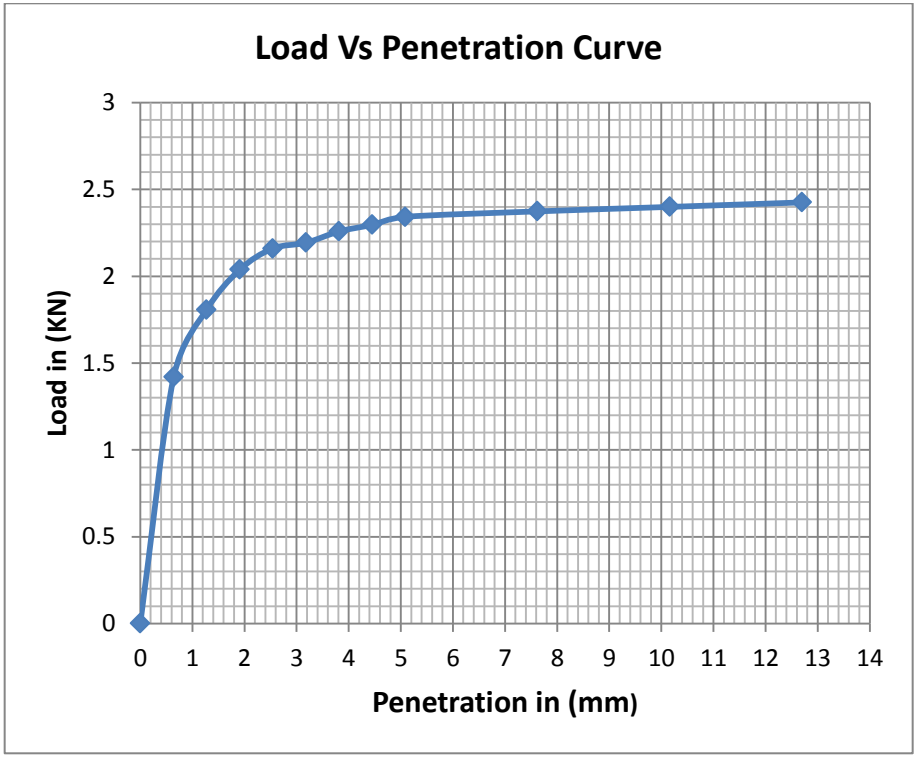


From the above plot; the value of MDD (Maximum Dry Density) = 1.534 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 32.77%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	55.00	0.0258	1.42	
1.27	70.00	0.0258	1.81	
1.91	79.00	0.0258	2.04	
2.54	83.70	0.0258	2.16	16.36
3.18	85.00	0.0258	2.19	
3.81	87.50	0.0258	2.26	
4.45	89.00	0.0258	2.30	
5.08	90.78	0.0258	2.34	11.71
7.62	92.00	0.0258	2.37	
10.16	93.00	0.0258	2.40	
12.7	94.00	0.0258	2.43	

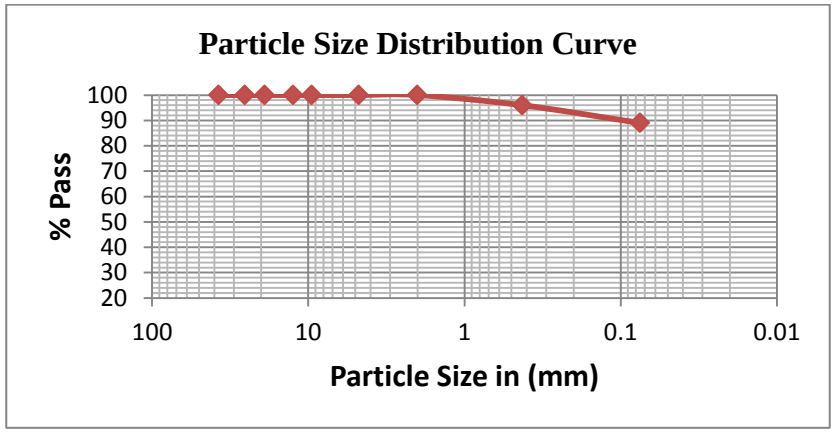


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **16.36** and **11.71** respectively.

Experiment No. 17

1. Particle Size Distribution (Sieve Analysis)

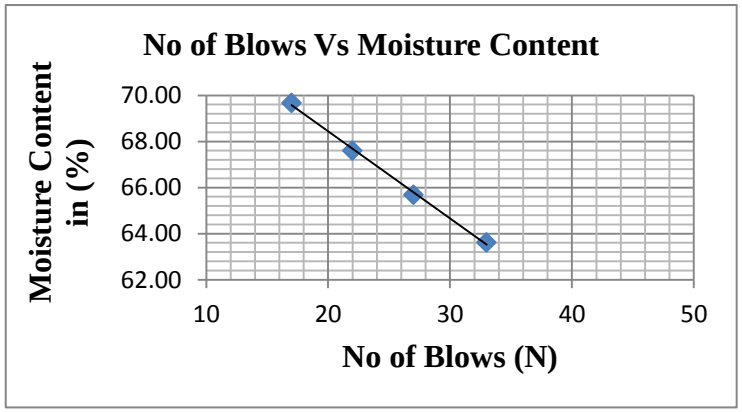
Laboratory Test No.17			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0.00	100
25.4	0.00	0.00	100
19	0.00	0.00	100
12.5	0.00	0.00	100
9.5	0.00	0.00	100
4.75	0.00	0.00	100
2	0.00	0.00	100
0.425	79.60	4	96
0.075	139.30	7	89
Pan	1771.10	89	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	27	22	17		
container no	**306**	**311**	**349**	**339**	**340**	**331**
Wt. of cont. + wet soil	44.23	43.24	45.65	44.59	36.08	36.63
Wt. of cont. + dry soil	35.98	35.26	36.03	35.22	33.26	33.61
Wt. of container	23.01	23.11	21.8	21.77	23.01	22.71
Wt. of water	8.25	7.98	9.62	9.37	2.82	3.02
Wt. of dry soil	12.97	12.15	14.23	13.45	10.25	10.9
Moisture content (%)	63.61	65.68	67.60	69.67	27.51	27.71



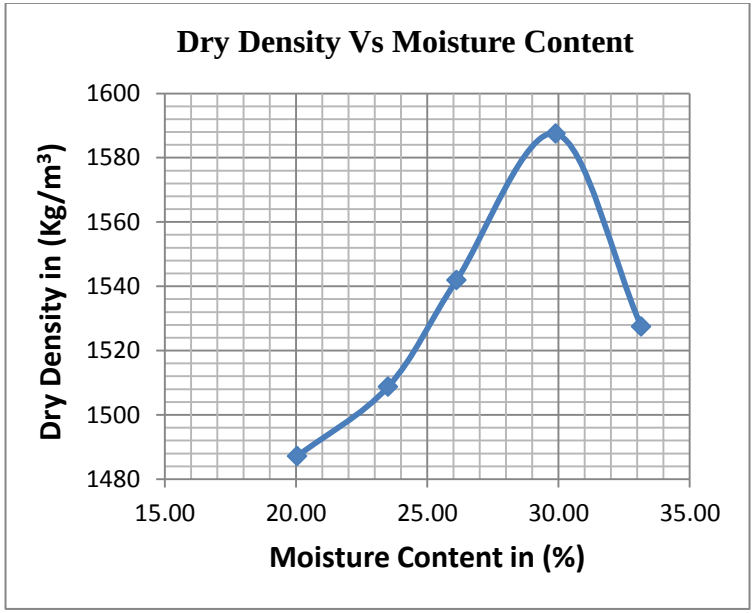
From the graph; moisture content at 25 blows (LL) = 66.64

PL = 27.61

PI = LL-PL = 66.64-27.61 = **39.09**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	A_2	N	AO_4	B_4	B
Mass of Wet soil +Con(gm.)(F)	135.34	122.98	132.14	143.98	110.71
Mass of dry soil +con(gm.)(G)	115.82	102.98	108.85	115.00	87.90
Mass of container(gm.)(H)	18.46	17.91	19.66	18.08	19.10
Mass of moisture(gm.)F-G=(I)	19.52	20	23.29	28.98	22.81
Mass of Dry soil(gm.)G-H=(J)	97.36	85.07	89.19	96.92	68.8
Moisture content % (I/J)*100=K	20.05	23.51	26.11	29.90	33.15
Dry Density gm./cm^3 E/(100+K)*100	1.487	1.509	1.542	1.587	1.527
Dry density in kg/m^3	1487	1509	1542	1587	1527

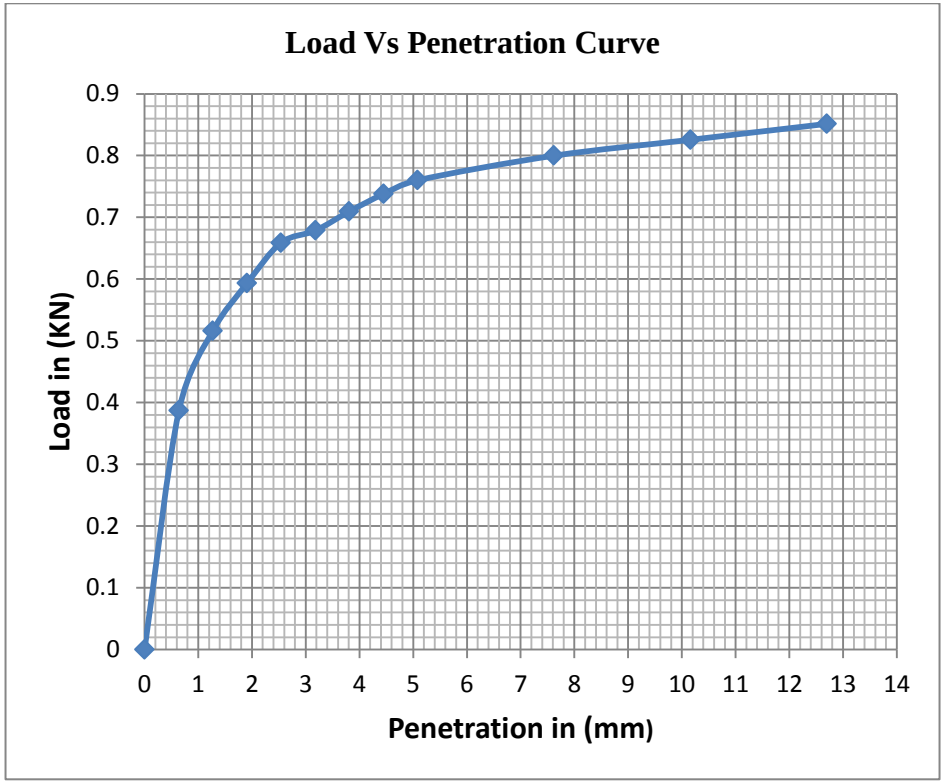


From the above plot; the value of MDD (Maximum Dry Density) = 1.587 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 29.9%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	15.00	0.0258	0.39	
1.27	20.00	0.0258	0.52	
1.91	23.00	0.0258	0.59	
2.54	25.53	0.0258	0.66	4.99
3.18	26.30	0.0258	0.68	
3.81	27.50	0.0258	0.71	
4.45	28.60	0.0258	0.74	
5.08	29.46	0.0258	0.76	3.80
7.62	31.00	0.0258	0.80	
10.16	32.00	0.0258	0.83	
12.7	33.00	0.0258	0.85	

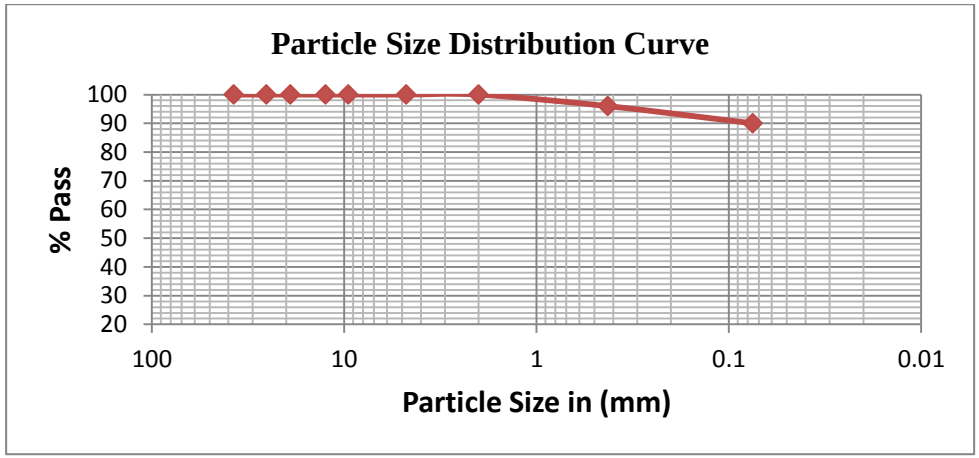


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **4.99** and **3.8** respectively.

Experiment No. 18

1. Particle Size Distribution (Sieve Analysis)

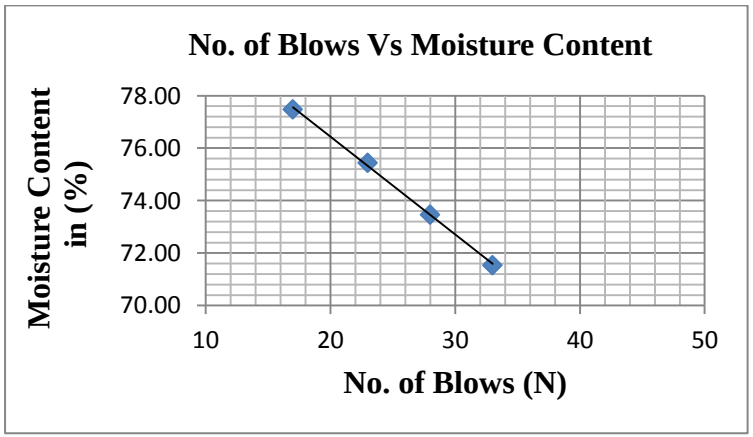
Laboratory Test No.18			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0	100
25.4	0.00	0	100
19	0.00	0	100
12.5	0.00	0	100
9.5	0.00	0	100
4.75	0.00	0	100
2	0.00	0	100
0.425	79.60	4	96
0.075	119.40	6	90
Pan	1791.00	90	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	28	23	17		
container no	**331**	**306**	**336**	**349**	**340**	**311**
Wt. of cont. + wet soil	46.56	48.76	43.49	42.92	38.34	38.27
Wt. of cont. + dry soil	36.61	37.85	34.15	33.7	34.15	34.17
Wt. of container	22.7	23	21.77	21.8	22.99	23.11
Wt. of water	9.95	10.91	9.34	9.22	4.19	4.1
Wt. of dry soil	13.91	14.85	12.38	11.9	11.16	11.06
Moisture content (%)	71.53	73.47	75.44	77.48	37.54	37.07



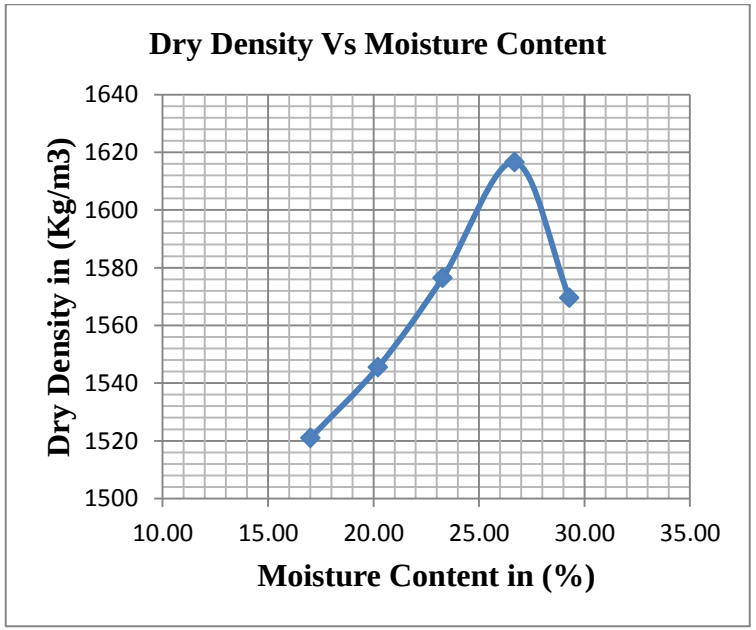
From the graph; moisture content at 25 blows (LL) = 74

PL = 37.31

PI = LL-PL = 74-37.31 = **37.17**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture content					
container no.	2	AB	B	OO	A_2
Mass of Wet soil +Con(gm.)(F)	92.79	146.63	148.01	113.35	120.73
Mass of dry soil +con(gm.)(G)	81.95	125.04	123.65	94.01	97.55
Mass of container(gm.)(H)	18.21	18.20	19.01	21.54	18.40
Mass of moisture(gm.)F-G=(I)	10.84	21.59	24.36	19.34	23.18
Mass of Dry soil(gm.)G-H=(J)	63.74	106.84	104.64	72.47	79.15
Moisture content % (I/J)*100=K	17.01	20.21	23.28	26.69	29.29
Dry Density gm./cm^3 E/(100+K)*100	1.521	1.546	1.576	1.617	1.570
Dry density in kg/m^3	1521	1546	1576	1617	1570

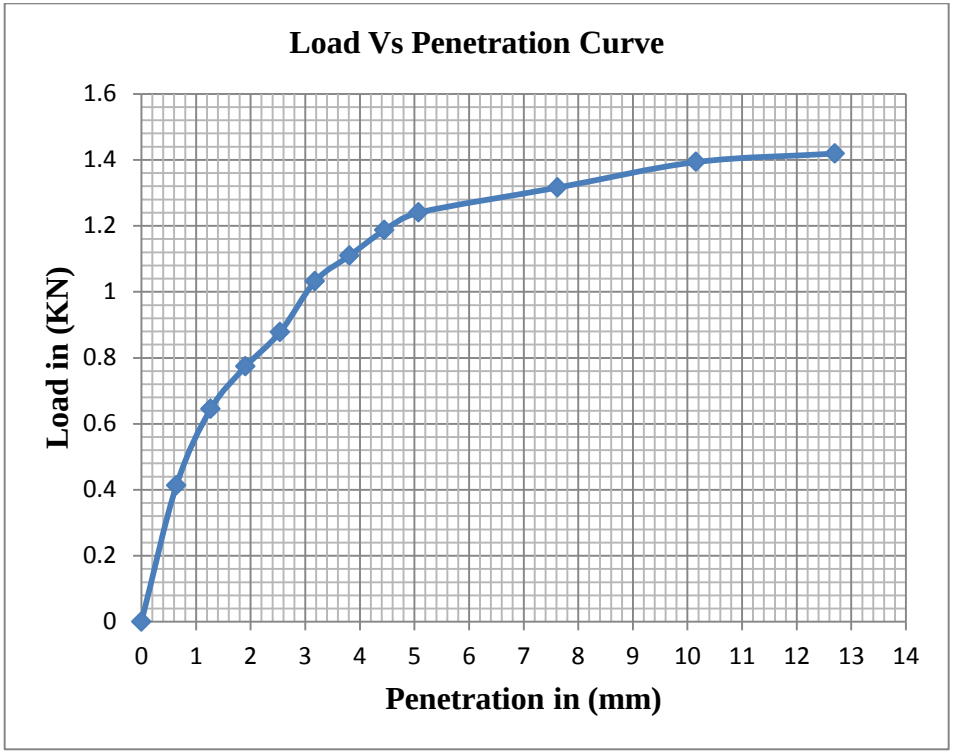


From the above plot; the value of MDD (Maximum Dry Density) = 1.617 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 26.69%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	16.00	0.0258	0.41	
1.27	25.00	0.0258	0.65	
1.91	30.00	0.0258	0.77	
2.54	34.02	0.0258	0.88	6.65
3.18	40.00	0.0258	1.03	
3.81	43.00	0.0258	1.11	
4.45	46.00	0.0258	1.19	
5.08	48.06	0.0258	1.24	6.20
7.62	51.00	0.0258	1.32	
10.16	54.00	0.0258	1.39	
12.7	55.00	0.0258	1.42	

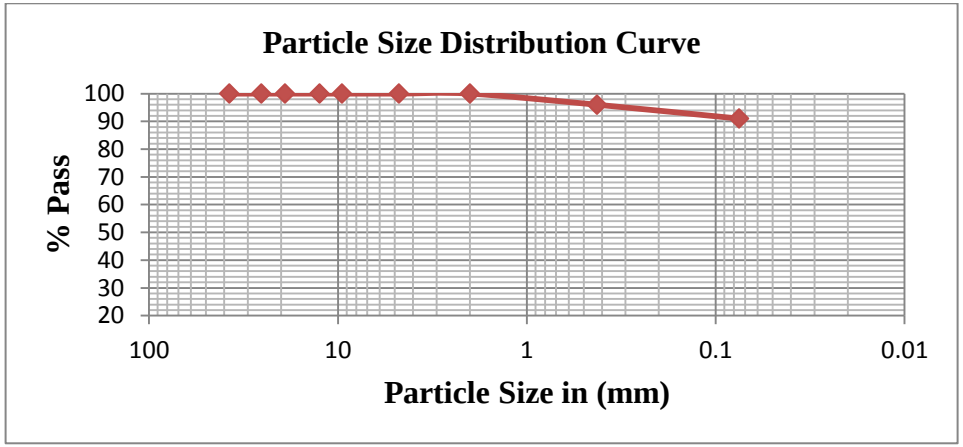


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **6.65** and **6.2** respectively.

Experiment No. 19

1. Particle Size Distribution (Sieve Analysis)

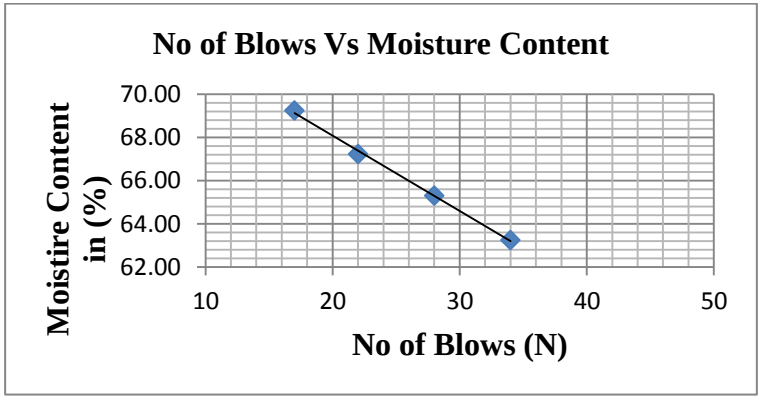
Laboratory Test No.19			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0	100
25.4	0.00	0	100
19	0.00	0	100
12.5	0.00	0	100
9.5	0.00	0	100
4.75	0.00	0	100
2	0.00	0	100
0.425	79.60	4	96
0.075	99.50	5	91
Pan	1810.90	91	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	22	17		
container no	**236**	**132**	**314**	**332**	**301**	**311**
Wt. of cont. + wet soil	40.63	41.45	42.72	44.86	36.96	37.07
Wt. of cont. + dry soil	33.32	33.87	34.11	36.04	33.59	33.57
Wt. of container	21.76	22.26	21.3	23.3	23.51	23.12
Wt. of water	7.31	7.58	8.61	8.82	3.37	3.5
Wt. of dry soil	11.56	11.61	12.81	12.74	10.08	10.45
Moisture content (%)	63.24	65.29	67.21	69.23	33.43	33.49



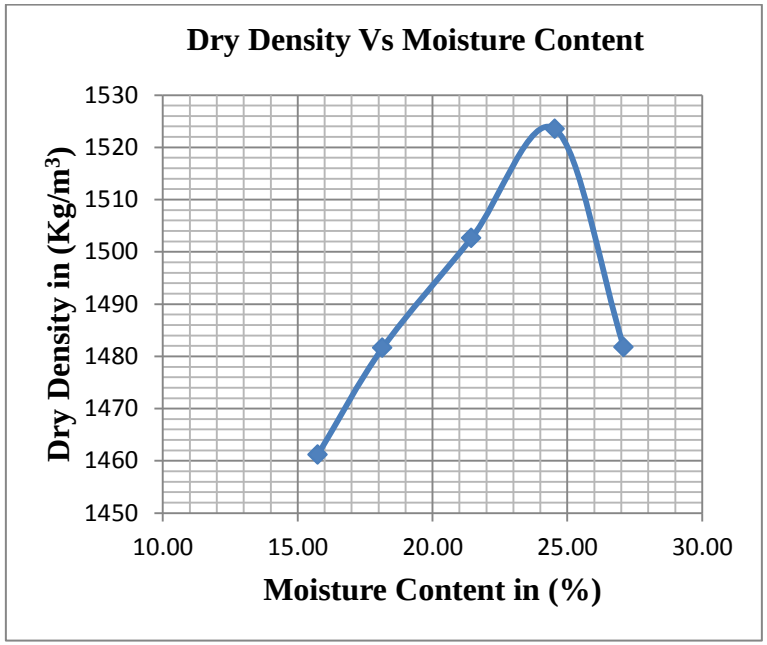
From the graph; moisture content at 25 blows (LL) = 65.24

PL = 33.46

PI = LL-PL = 65.24-33.46 = **31.78**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**B4**	**AO4**	**A28**	**Y**	**E**
Mass of Wet soil +Con(gm.)(F)	159.14	139.39	141.22	115.39	98.61
Mass of dry soil +con(gm.)(G)	139.95	121.00	119.32	96.54	81.50
Mass of container(gm.)(H)	18.05	19.66	17.20	19.72	18.35
Mass of moisture(gm.)F-G=(I)	19.19	18.39	21.9	18.85	17.11
Mass of Dry soil(gm.)G-H=(J)	121.9	101.34	102.12	76.82	63.15
Moisture content % (I/J)*100=K	15.74	18.15	21.45	24.54	27.09
Dry Density gm./cm^3 E/(100+K)*100	1.461	1.482	1.503	1.524	1.482
Dry density in kg/m^3	1461	1482	1503	1524	1482

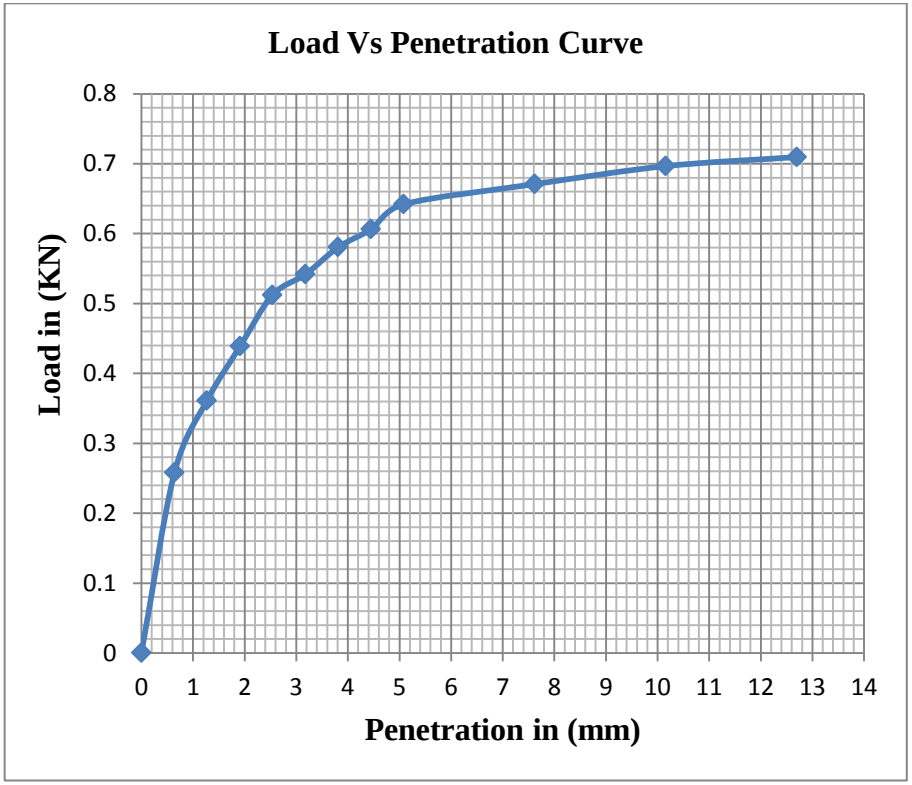


From the above plot; the value of MDD (Maximum Dry Density) = 1.524 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 24.54%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	10.00	0.0258	0.26	
1.27	14.00	0.0258	0.36	
1.91	17.00	0.0258	0.44	
2.54	19.85	0.0258	0.51	3.88
3.18	21.00	0.0258	0.54	
3.81	22.50	0.0258	0.58	
4.45	23.50	0.0258	0.61	
5.08	24.88	0.0258	0.64	3.21
7.62	26.00	0.0258	0.67	
10.16	27.00	0.0258	0.70	
12.7	27.50	0.0258	0.71	

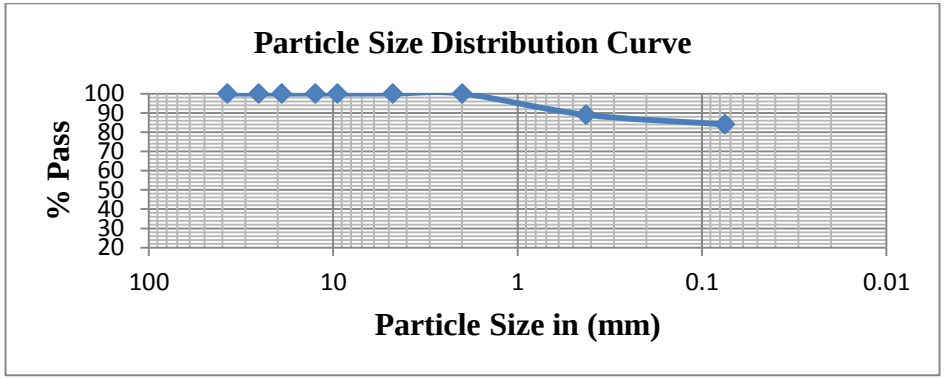


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **6.65** and **6.2** respectively.

Experiment No. 20

1. Particle Size Distribution (Sieve Analysis)

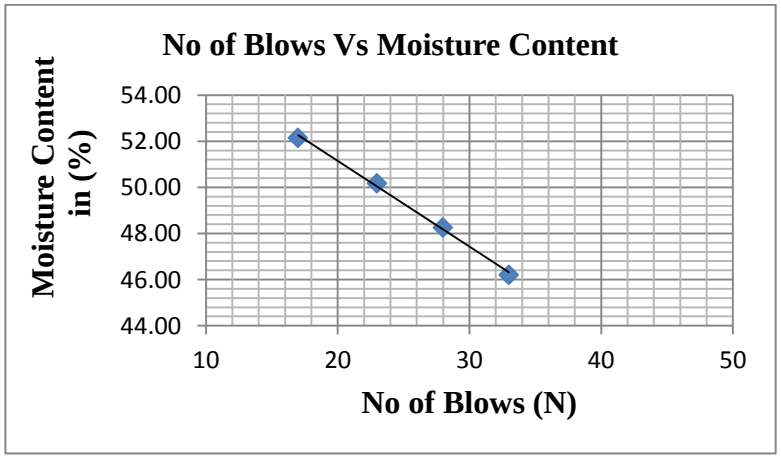
Laboratory Test No.20			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0	100
25.4	0.00	0	100
19	0.00	0	100
12.5	0.00	0	100
9.5	0.00	0	100
4.75	0.00	0	100
2	0.00	0	100
0.425	218.90	11	89
0.075	99.50	5	84
Pan	1671.60	84	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	33	28	23	17		
container no	**349**	**340**	**350**	**369**	**301**	**31**
Wt. of cent + wet soil	42.24	43.36	44.35	40.69	38.87	38.02
Wt. of cont. + dry soil	35.78	36.73	37.05	34.73	34.73	33.45
Wt. of container	21.8	22.99	22.5	23.3	23.5	21.1
Wt. of water	6.46	6.63	7.3	5.96	4.14	4.57
Wt. of dry soil	13.98	13.74	14.55	11.43	11.23	12.35
Moisture content (%)	46.21	48.25	50.17	52.14	36.87	37.00



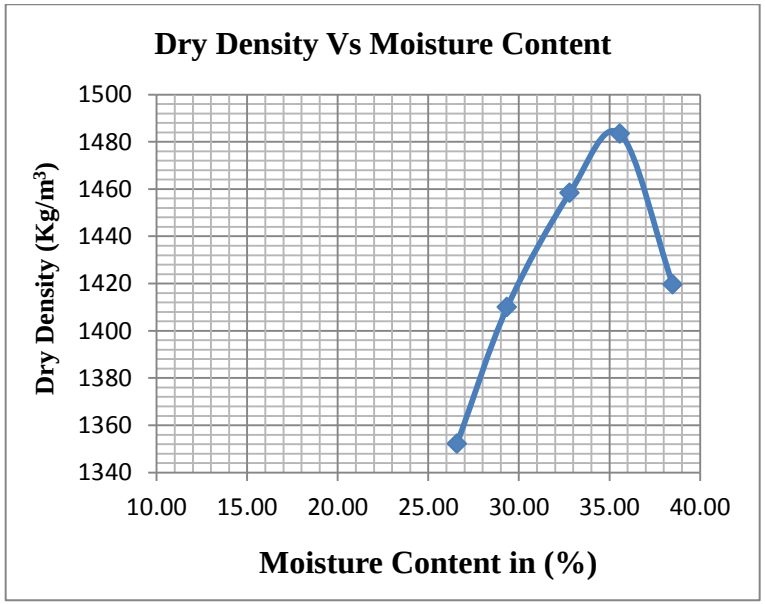
From the graph; moisture content at 25 blows (LL) = 49.3

PL = 36.46

PI = LL-PL = 49.3-36.46 = **12.84**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**2**	**34**	**12**	**G**	**Y**
Mass of Wet soil +Con(gm.)(F)	108.09	134.77	109.59	154.45	106.54
Mass of dry soil +con(gm.)(G)	89.21	108.35	87.10	120.54	82.03
Mass of container(gm.)(H)	18.21	18.35	18.56	25.25	18.35
Mass of moisture(gm.)F-G=(I)	18.88	26.42	22.49	33.91	24.51
Mass of Dry soil(gm.)G-H=(J)	71	90	68.54	95.29	63.68
Moisture content % (I/J)*100=K	26.59	29.36	32.81	35.59	38.49
Dry Density gm./cm^3 E/(100+K)*100	1.352	1.410	1.458	1.483	1.420
Dry density in kg/m^3	1352	1410	1458	1483	1420

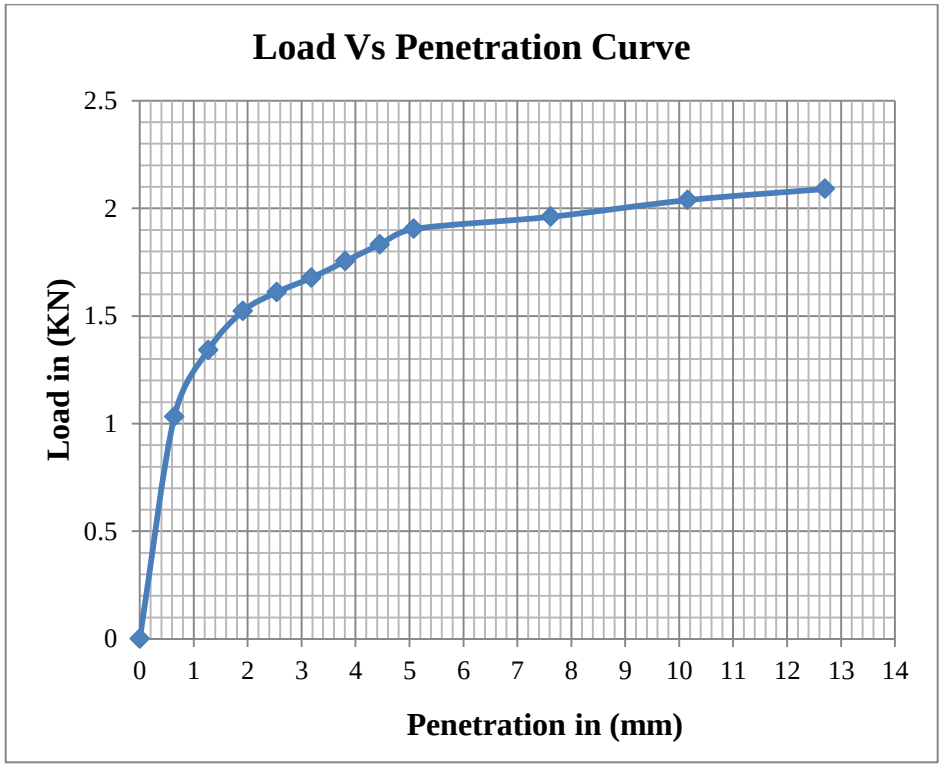


From the above plot; the value of MDD (Maximum Dry Density) = 1.483 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 35.59%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	40.00	0.0258	1.03	
1.27	52.00	0.0258	1.34	
1.91	59.00	0.0258	1.52	
2.54	62.42	0.0258	1.61	12.20
3.18	65.00	0.0258	1.68	
3.81	68.00	0.0258	1.75	
4.45	71.00	0.0258	1.83	
5.08	73.80	0.0258	1.90	9.52
7.62	76.00	0.0258	1.96	
10.16	79.00	0.0258	2.04	
12.7	81.00	0.0258	2.09	

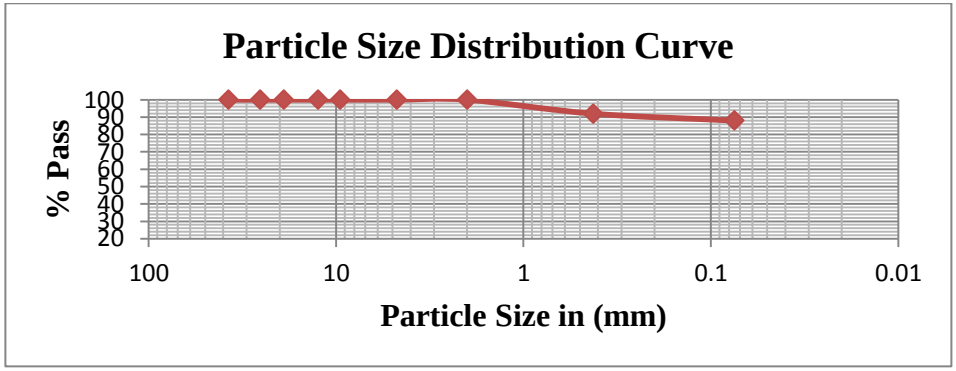


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **6.65** and **6.2** respectively.

Experiment No. 21

1. Particle Size Distribution (Sieve Analysis)

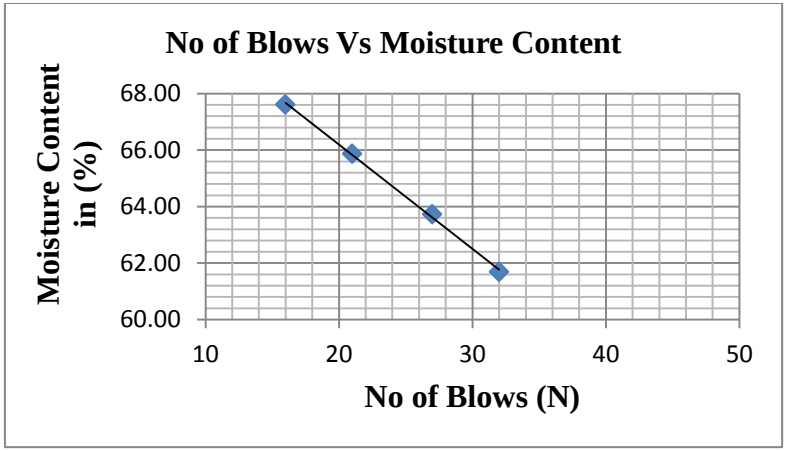
Laboratory Test No.21			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0	100
25.4	0.00	0	100
19	0.00	0	100
12.5	0.00	0	100
9.5	0.00	0	100
4.75	0.00	0	100
2	0.00	0	100
0.425	159.20	8	92
0.075	79.60	4	88
Pan	1751.20	88	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	32	27	21	16		
container no	**31**	**301**	**340**	**350**	**349**	**332**
Wt. of cont. + wet soil	39.37	37.58	39.42	39.73	32.4	32.24
Wt. of cont. + dry soil	32.4	32.1	32.9	32.78	29.66	29.93
Wt. of container	21.1	23.5	23	22.5	21.83	23.29
Wt. of water	6.97	5.48	6.52	6.95	2.74	2.31
Wt. of dry soil	11.3	8.6	9.9	10.28	7.83	6.64
Moisture content (%)	61.68	63.72	65.86	67.61	34.99	34.79



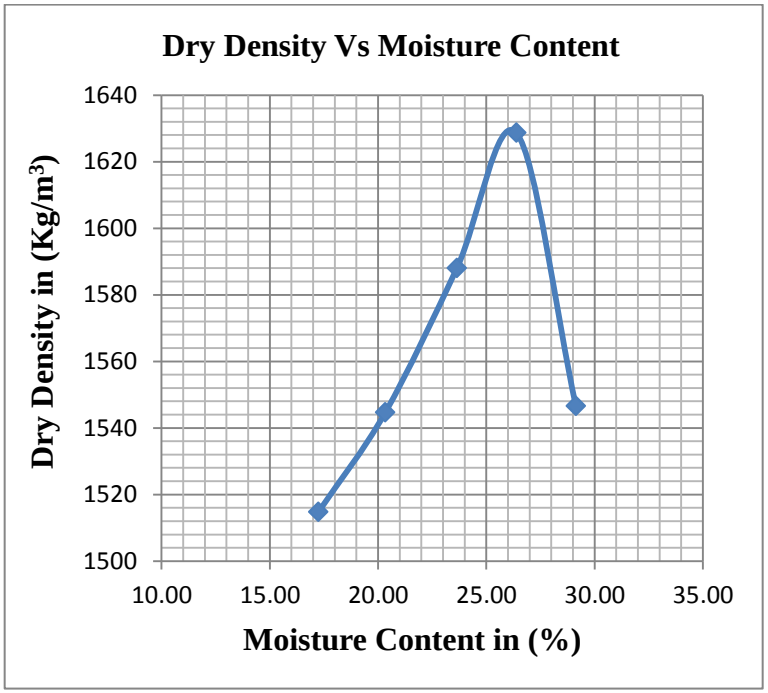
From the graph; moisture content at 25 blows (LL) = 64.72

PL = 34.89

PI = LL-PL = 64.72-34.89 = **29.83**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
container no.	OO	AB	B	A_2	I
Mass of Wet soil +Con(gm.)(F)	261.39	209.29	221.80	178.68	202.00
Mass of dry soil +con(gm.)(G)	227.00	177.00	183.05	145.23	160.74
Mass of container(gm.)(H)	27.54	18.20	19.10	18.46	19.12
Mass of moisture(gm.)F-G=(I)	34.39	32.29	38.75	33.45	41.26
Mass of Dry soil(gm.)G-H=(J)	199.46	158.8	163.95	126.77	141.62
Moisture content % (I/J)*100=K	17.24	20.33	23.64	26.39	29.13
Dry Density gm./cm^3 E/(100+K)*100	1.515	1.545	1.588	1.629	1.547
Dry density in kg/m^3	1515	1545	1588	1629	1547

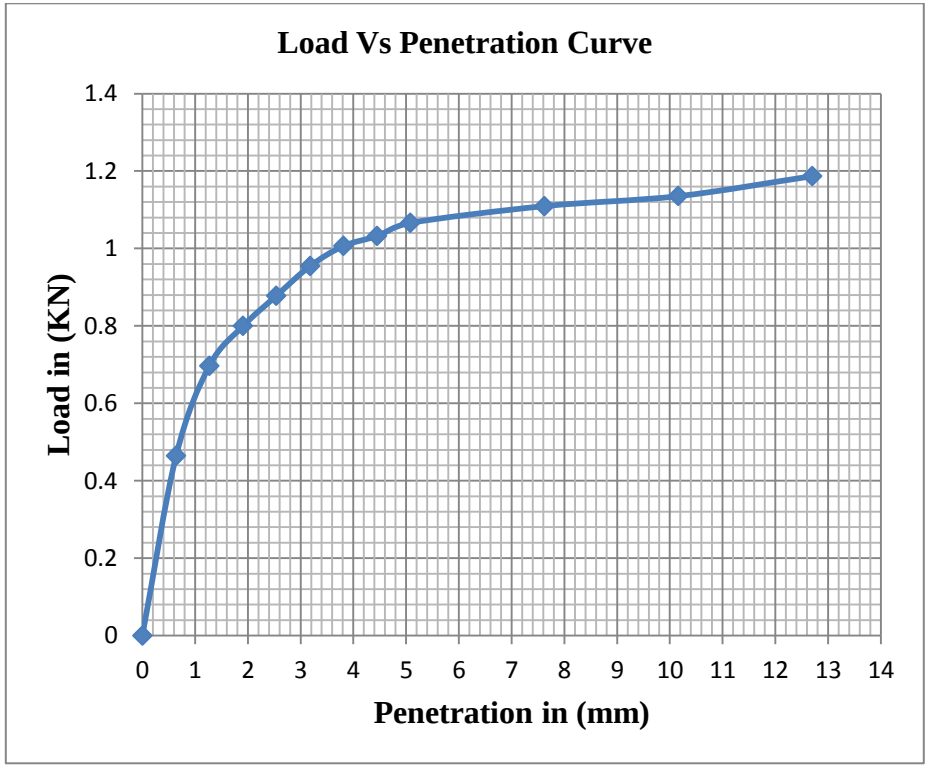


From the above plot; the value of MDD (Maximum Dry Density) = 1.629 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 26.39%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	18.00	0.0258	0.46	
1.27	27.00	0.0258	0.70	
1.91	31.00	0.0258	0.80	
2.54	34.02	0.0258	0.88	6.65
3.18	37.00	0.0258	0.95	
3.81	39.00	0.0258	1.01	
4.45	40.00	0.0258	1.03	
5.08	41.32	0.0258	1.07	5.33
7.62	43.00	0.0258	1.11	
10.16	44.00	0.0258	1.14	
12.7	46.00	0.0258	1.19	

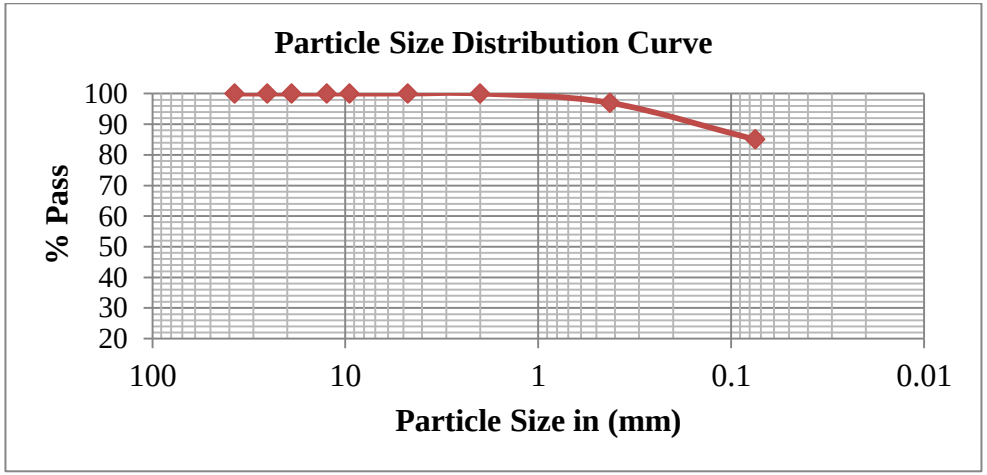


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **6.65** and **5.33** percent respectively.

Experiment No. 22

1. Particle Size Distribution (Sieve Analysis)

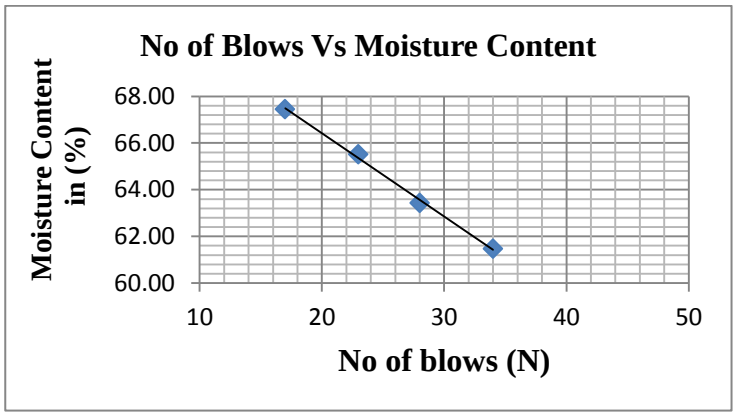
Laboratory Test No.22			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. Retained in (%)**	**(%) Pass**
37.5	0.00	0	100
25.4	0.00	0	100
19	0.00	0	100
12.5	0.00	0	100
9.5	0.00	0	100
4.75	0.00	0	100
2	0.00	0	100
0.425	59.70	3	97
0.075	238.80	12	85
Pan	1691.50	85	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	27	23	17		
container no	**145**	**319**	**308**	**307**	**319**	**306**
Wt. of cont. + wet soil	45.79	43.69	41.55	46.55	32.65	32.51
Wt. of cont. + dry soil	36.24	34.76	33.64	36.4	29.95	29.86
Wt. of container	21.6	21.5	22.21	22.15	23	22.99
Wt. of water	9.55	8.93	7.91	10.15	2.7	2.65
Wt. of dry soil	14.64	13.26	11.43	14.25	6.95	6.87
Moisture content (%)	65.23	67.35	69.20	71.23	38.85	38.57



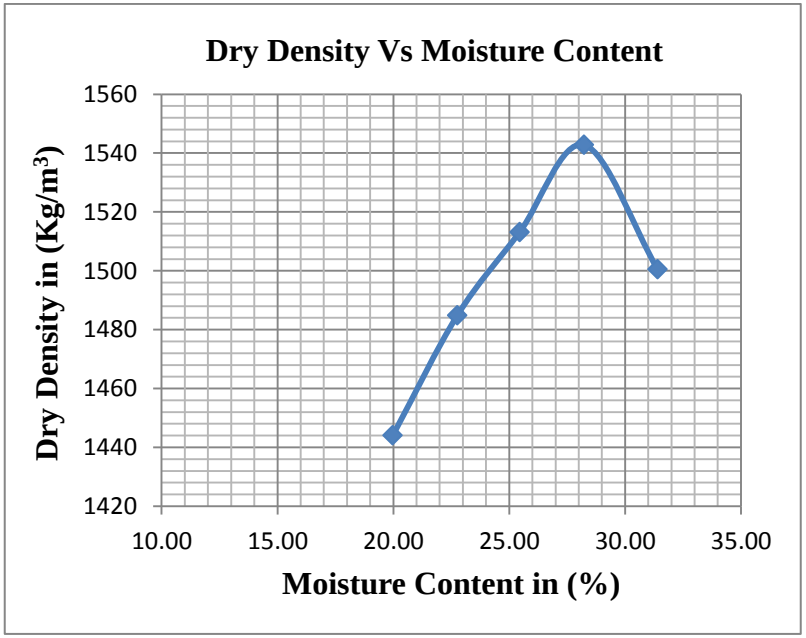
From the graph; moisture content at 25 blows (LL) = 68.25

PL = 38.71

PI = LL-PL = 68.25-38.71 = **29.54**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**I**	**A_3**	**B_4**	**A_2**	**B**
Mass of Wet soil +Con(gm.)(F)	137.31	134.8	164.29	151.62	110.02
Mass of dry soil +con(gm.)(G)	117.63	113.27	134.62	122.30	88.11
Mass of container(gm.)(H)	19.12	18.70	18.05	18.45	18.35
Mass of moisture(gm.)F-G=(I)	19.68	21.53	29.67	29.32	21.91
Mass of Dry soil(gm.)G-H=(J)	98.51	94.57	116.57	103.85	69.76
Moisture content % (I/J)*100=K	19.98	22.77	25.45	28.23	31.41
Dry Density gm./cm^3 E/(100+K)*100	1.444	1.485	1.513	1.543	1.500
Dry density in kg/m^3	1444	1485	1513	1543	1500

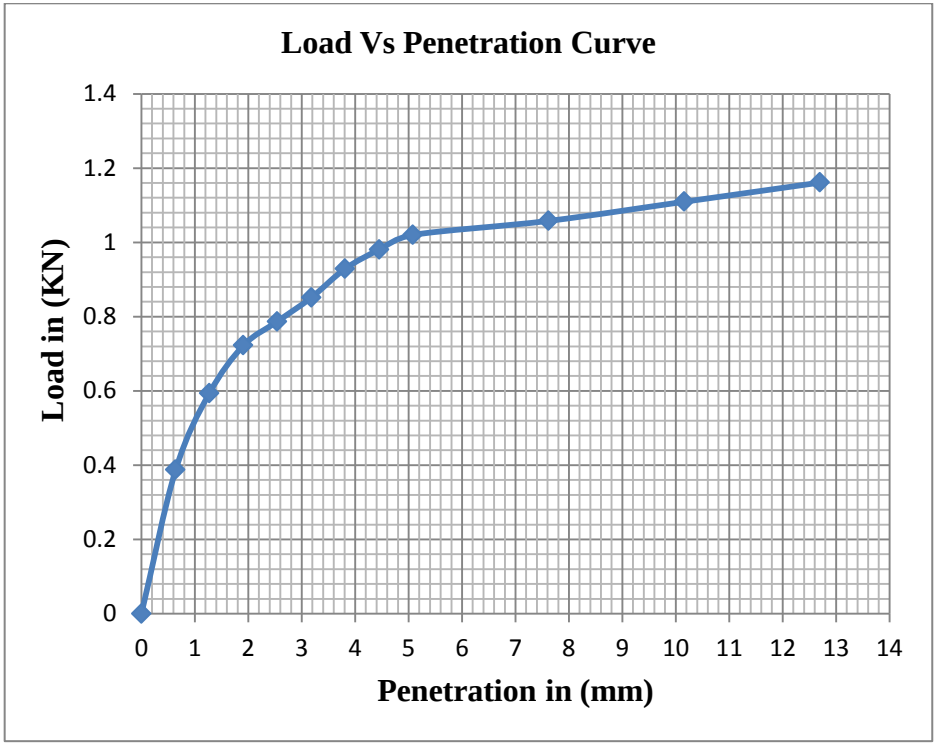


From the above plot; the value of MDD (Maximum Dry Density) = 1.543 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 28.23%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	15.00	0.0258	0.39	
1.27	23.00	0.0258	0.59	
1.91	28.00	0.0258	0.72	
2.54	30.49	0.0258	0.79	5.96
3.18	33.00	0.0258	0.85	
3.81	36.00	0.0258	0.93	
4.45	38.00	0.0258	0.98	
5.08	39.53	0.0258	1.02	5.10
7.62	41.00	0.0258	1.06	
10.16	43.00	0.0258	1.11	
12.7	45.00	0.0258	1.16	

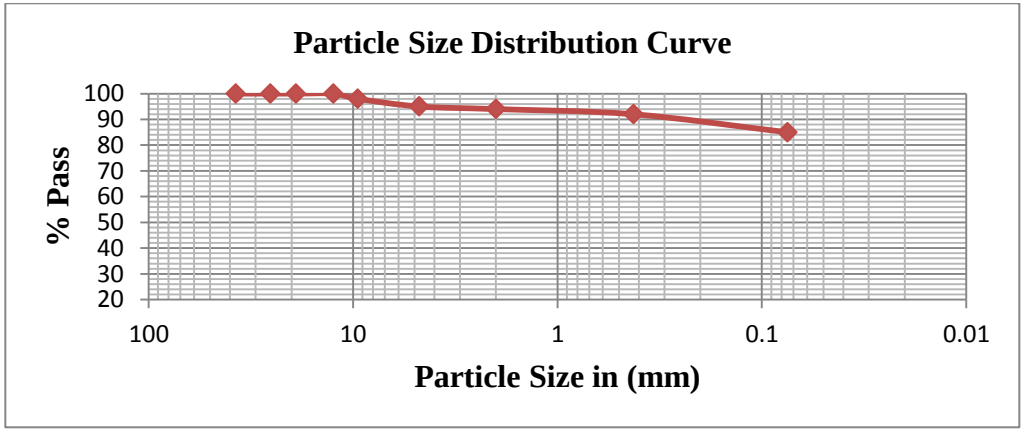


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **5.96** and **5.10** respectively.

Experiment No. 23

1. Particle Size Distribution (Sieve Analysis)

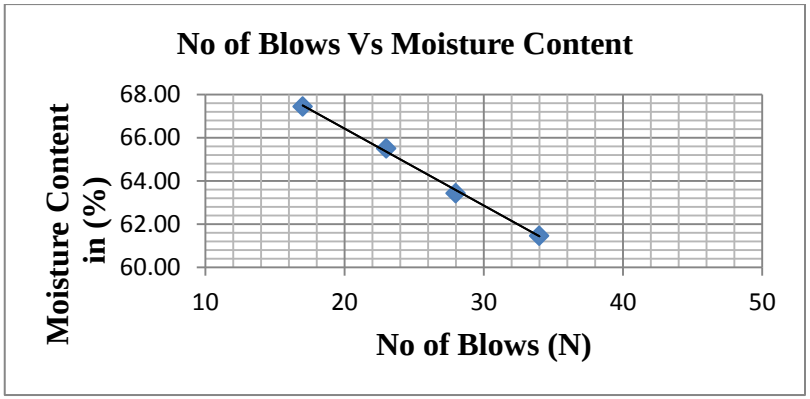
Laboratory Test No.23			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	0	0	100
19	0	0	100
12.5	0	0	100
9.5	40	2	98
4.75	60	3	95
2	20	1	94
0.425	40	2	92
0.075	140	7	85
Pan	1700	85	0
Total mass	**2000**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	23	17		
container no	**332**	**311**	**1**	**336**	**306**	**301**
Wt. of cont. + wet soil	43.38	48.67	40.22	42.7	33.62	31.48
Wt. of cont. + dry soil	35.74	38.75	33.1	34.25	30.96	29.48
Wt. of container	23.31	23.11	22.23	21.72	22.99	23.5
Wt. of water	7.64	9.92	7.12	8.45	2.66	2
Wt. of dry soil	12.43	15.64	10.87	12.53	7.97	5.98
Moisture content (%)	61.46	63.43	65.50	67.44	33.38	33.44



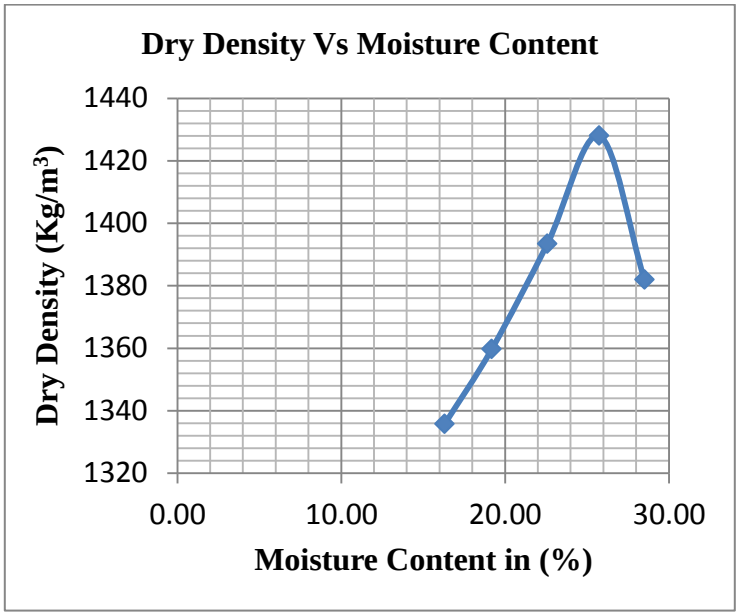
From the graph; moisture content at 25 blows (LL) = 64.46

PL = 33.41

PI = LL-PL = 64.46-33.41 = **31.05**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	**K**	**AO_4**	**A_2**	**D**	**34**
Mass of Wet soil +Con(gm.)(F)	143.64	157.08	179.84	167.61	142.99
Mass of dry soil +con(gm.)(G)	126.13	134.96	150.11	137.14	115.34
Mass of container(gm.)(H)	18.80	19.66	18.46	18.80	18.35
Mass of moisture(gm.)F-G=(I)	17.51	22.12	29.73	30.47	27.65
Mass of Dry soil(gm.)G-H=(J)	107.33	115.3	131.65	118.34	96.99
Moisture content % (I/J)*100=K	16.31	19.18	22.58	25.75	28.51
Dry Density gm./cm^3 E/(100+K)*100	1.336	1.360	1.393	1.428	1.382
Dry density in kg/m^3	1336	1360	1393	1428	1382

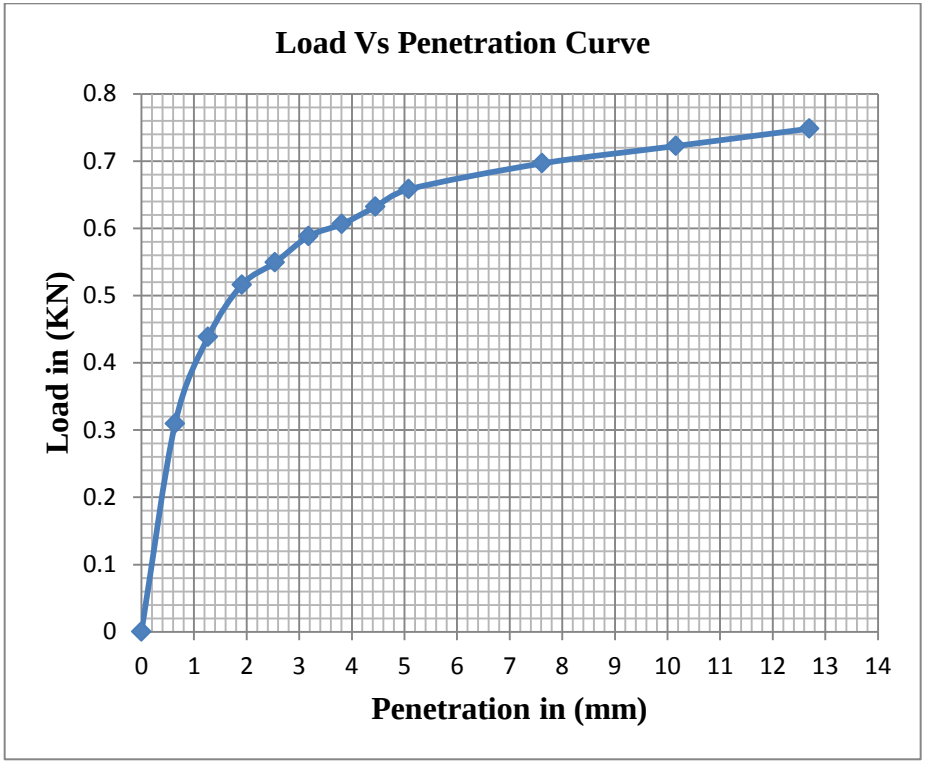


From the above plot; the value of MDD (Maximum Dry Density) = 1.428 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 25.75%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	12.00	0.0258	0.31	
1.27	17.00	0.0258	0.44	
1.91	20.00	0.0258	0.52	
2.54	21.28	0.0258	0.55	4.16
3.18	22.80	0.0258	0.59	
3.81	23.50	0.0258	0.61	
4.45	24.50	0.0258	0.63	
5.08	25.50	0.0258	0.66	3.29
7.62	27.00	0.0258	0.70	
10.16	28.00	0.0258	0.72	
12.7	29.00	0.0258	0.75	

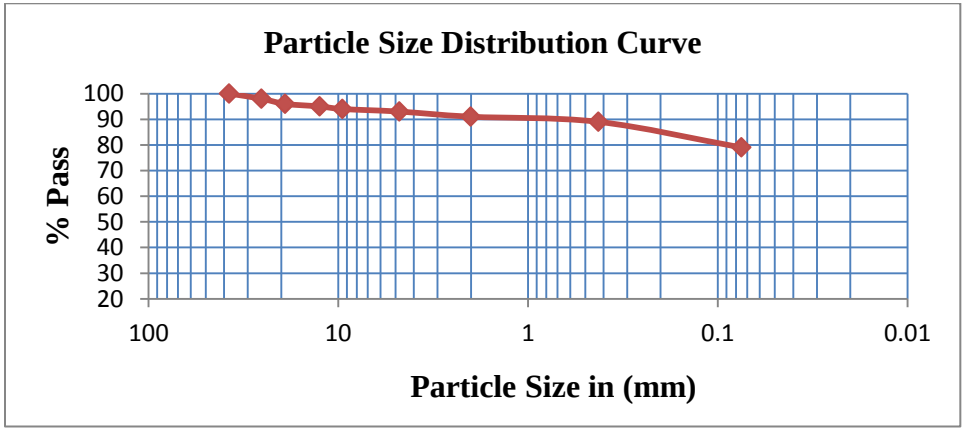


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **4.16** and **3.29** respectively.

Experiment No. 24

1.Particle Size Distribution (Sieve Analysis)

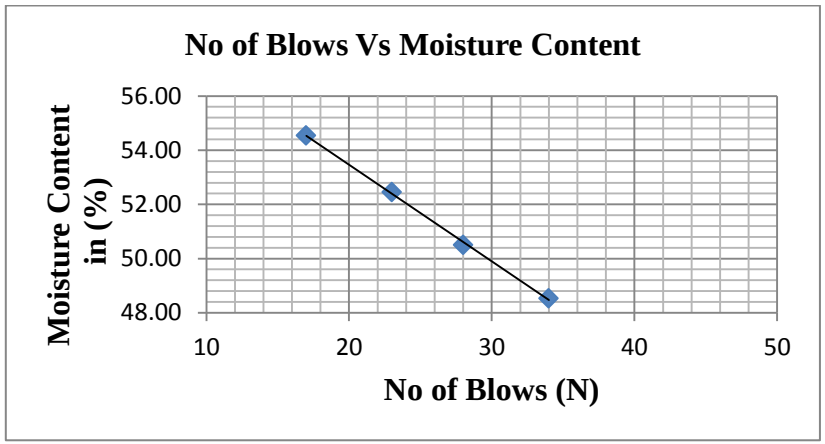
Laboratory Test No.24			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0	0	100
25.4	39.2	2	98
19	39.2	2	96
12.5	19.6	1	95
9.5	19.6	1	94
4.75	19.6	1	93
2	39.2	2	91
0.425	39.2	2	89
0.075	196	10	79
Pan	1548.4	79	0
Total mass	**1960**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	23	17		
container no	**319**	**336**	**41**	**332**	**314**	**301**
Wt. of cont. + wet soil	39.89	44.08	45.12	41.35	31.31	31.48
Wt. of cont. + dry soil	33.97	37.01	37.51	34.98	29.13	29.25
Wt. of container	21.77	23.01	23	23.3	23.31	23.3
Wt. of water	5.92	7.07	7.61	6.37	2.18	2.23
Wt. of dry soil	12.2	14	14.51	11.68	5.82	5.95
Moisture content (%)	48.52	50.50	52.45	54.54	37.46	37.48



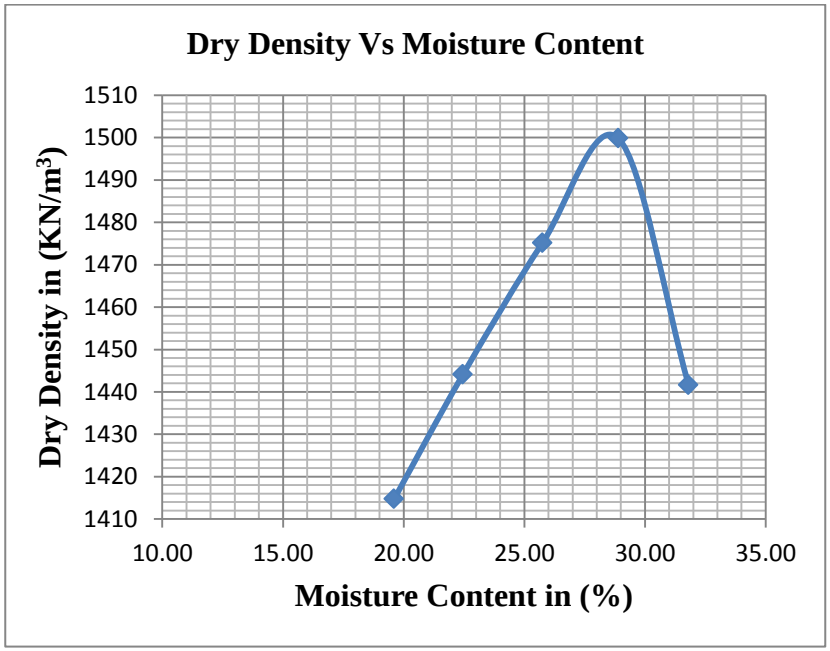
From the graph; moisture content at 25 blows (LL) = 51.50

PL = 37.47

PI = LL-PL = 51.50-37.47= **14.03**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
container no.	E	Z	N	R	I
Mass of Wet soil +Con(gm.)(F)	96.50	85.23	83.95	90.50	91.28
Mass of dry soil +con(gm.)(G)	83.69	73.03	70.67	74.29	73.79
Mass of container(gm.)(H)	18.35	18.70	19.10	18.19	18.80
Mass of moisture(gm.)F-G=(I)	12.81	12.2	13.28	16.21	17.49
Mass of Dry soil(gm.)G-H=(J)	65.34	54.33	51.57	56.1	54.99
Moisture content % (I/J)*100=K	19.61	22.46	25.75	28.89	31.81
Dry Density gm./cm^3 E/(100+K)*100	1.415	1.444	1.475	1.500	1.442
Dry density in kg/m^3	1415	1444	1475	1500	1442

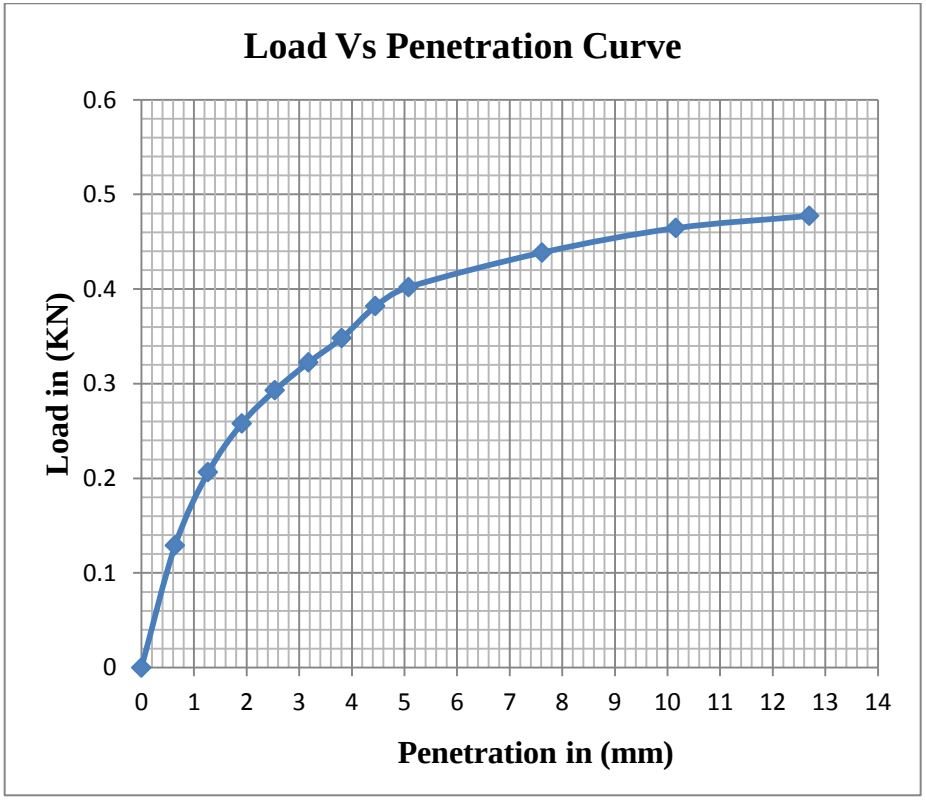


From the above plot; the value of MDD (Maximum Dry Density) = 1.5 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 28.23%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	5.00	0.0258	0.13	
1.27	8.00	0.0258	0.21	
1.91	10.00	0.0258	0.26	
2.54	11.36	0.0258	0.29	2.22
3.18	12.50	0.0258	0.32	
3.81	13.50	0.0258	0.35	
4.45	14.80	0.0258	0.38	
5.08	15.58	0.0258	0.40	2.01
7.62	17.00	0.0258	0.44	
10.16	18.00	0.0258	0.46	
12.7	18.50	0.0258	0.48	

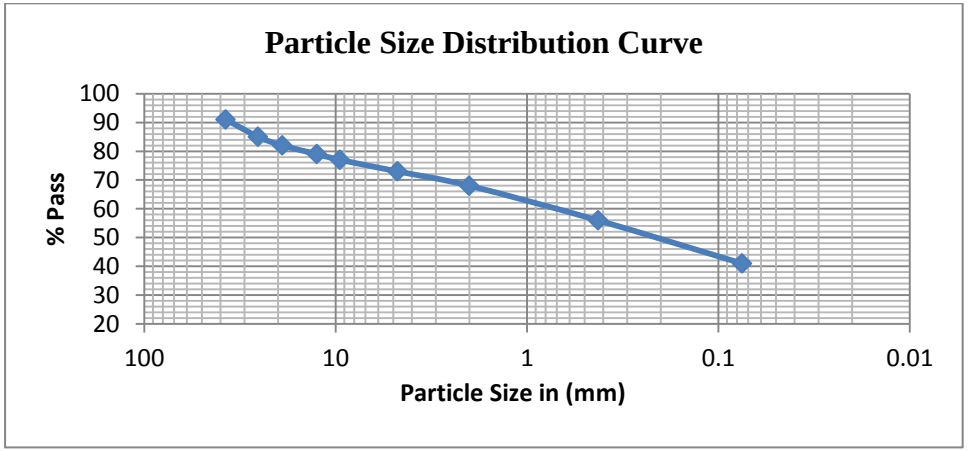


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **2.22** and **2.01** respectively.

Experiment No. 25

1.Particle Size Distribution (Sieve Analysis)

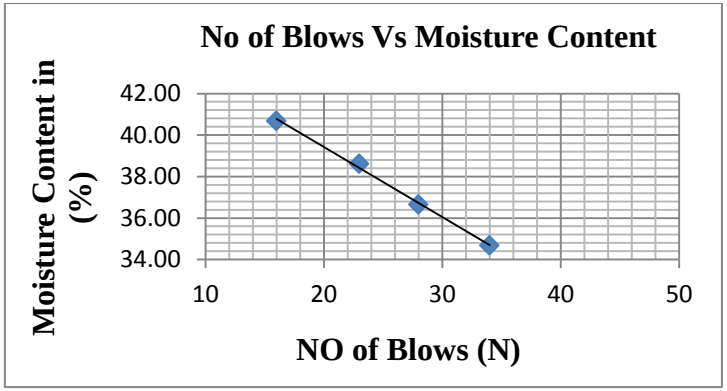
Laboratory Test No.25			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	177.3	9	91
25.4	118.2	6	85
19	59.1	3	82
12.5	59.1	3	79
9.5	39.4	2	77
4.75	78.8	4	73
2	98.5	5	68
0.425	236.4	12	56
0.075	295.5	15	41
Pan	807.7	41	0
Total mass	**1970**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	23	16		
container no	**306**	**47**	**32**	**314**	**332**	**311**
Wt. of cont. + wet soil	46.34	46.14	49.03	43.54	35.82	35.77
Wt. of cont. + dry soil	40.33	39.8	41.67	37.08	33.3	33.22
Wt. of container	23	22.5	22.61	21.2	23.24	23.14
Wt. of water	6.01	6.34	7.36	6.46	2.52	2.55
Wt. of dry soil	17.33	17.3	19.06	15.88	10.06	10.08
Moisture content (%)	34.68	36.65	38.61	40.68	25.05	25.30



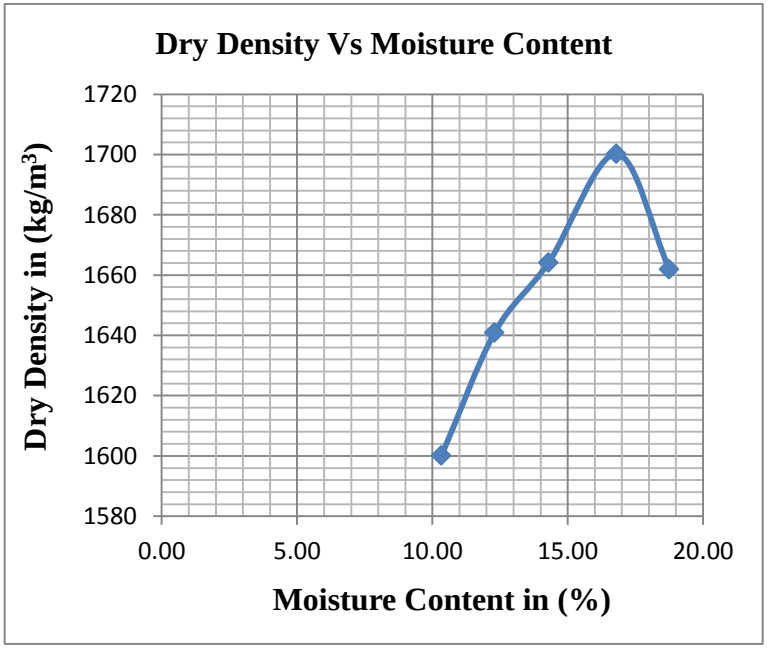
From the graph; moisture content at 25 blows (LL) = 37.66

PL = 25.17

PI = LL-PL = 37.66-25.17= **12.48**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	F	M	N	P	CD
Mass of Wet soil +Con(gm.)(F)	101.63	106.56	88.58	99.88	114.54
Mass of dry soil +con(gm.)(G)	93.72	96.85	79.89	88.13	99.42
Mass of container(gm.)(H)	17.20	17.91	19.10	18.19	18.80
Mass of moisture(gm.)F-G=(I)	7.91	9.71	8.69	11.75	15.12
Mass of Dry soil(gm.)G-H=(J)	76.52	78.94	60.79	69.94	80.62
Moisture content % (I/J)*100=K	10.34	12.30	14.30	16.80	18.75
Dry Density gm./cm^3 E/(100+K)*100	1.600	1.641	1.664	1.700	1.662
Dry density in kg/m^3	1600	1641	1664	1700	1662

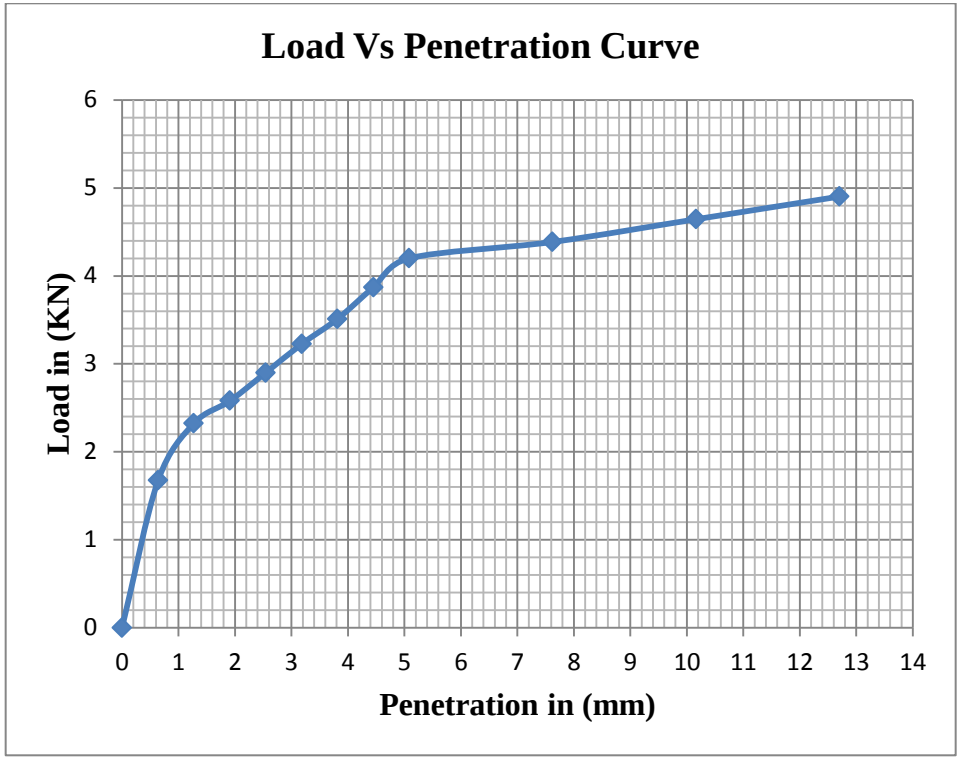


From the above plot; the value of MDD (Maximum Dry Density) = 1.7 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 16.80%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	65.00	0.0258	1.68	
1.27	90.00	0.0258	2.32	
1.91	100.00	0.0258	2.58	
2.54	112.30	0.0258	2.90	21.95
3.18	125.00	0.0258	3.23	
3.81	136.00	0.0258	3.51	
4.45	150.00	0.0258	3.87	
5.08	162.79	0.0258	4.20	21.00
7.62	170.00	0.0258	4.39	
10.16	180.00	0.0258	4.64	
12.7	190.00	0.0258	4.90	

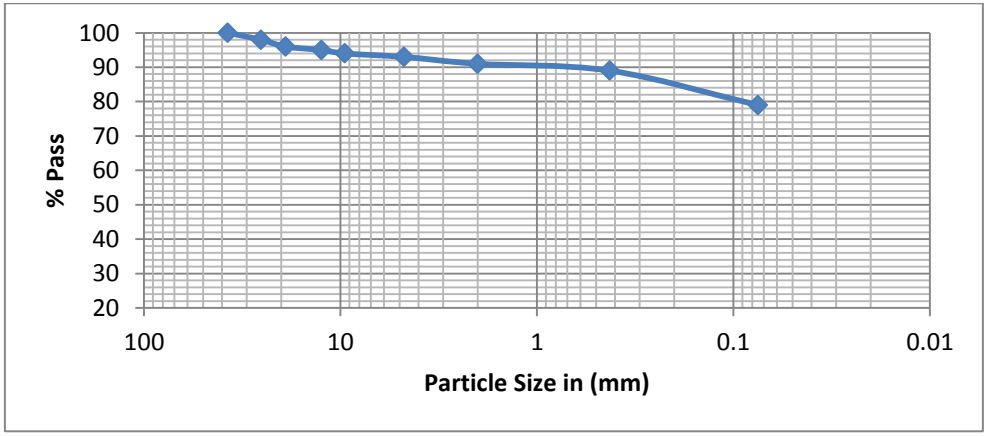


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **21.95** and **21** respectively.

Experiment No. 26

1. Particle Size Distribution (Sieve Analysis)

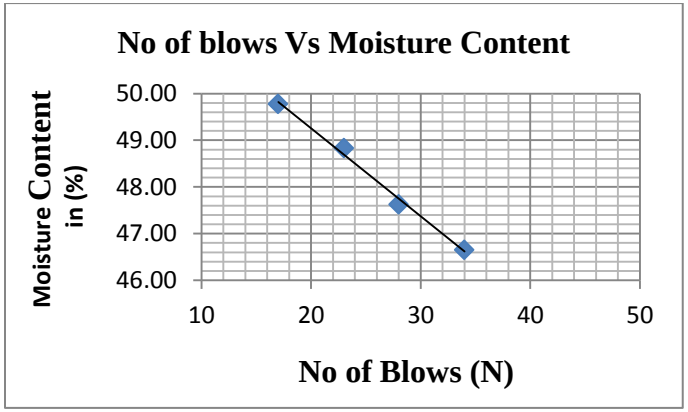
Laboratory Test No.26			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. retained in (%)**	**(%) Pass**
37.5	0.00	0	100
25.4	39.72	2	98
19	77.85	2	96
12.5	93.42	1	95
9.5	106.50	1	94
4.75	116.80	1	93
2	178.74	2	91
0.425	151.03	2	89
0.075	256.61	10	79
Pan	965.34	79	0
Total mass	**1986**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	23	17		
container no	**318**	**370**	**27**	**319**	**349**	**314**
Wt. of cont. + wet soil	41.19	38.65	40.47	42.59	32.28	31.49
Wt. of cont. + dry soil	34.64	33.44	34.65	36.08	29.51	28.79
Wt. of container	20.6	22.5	22.73	23	21.78	21.22
Wt. of water	6.55	5.21	5.82	6.51	2.77	2.7
Wt. of dry soil	14.04	10.94	11.92	13.08	7.73	7.57
Moisture content in (%)	46.65	47.62	48.83	49.77	35.83	35.67



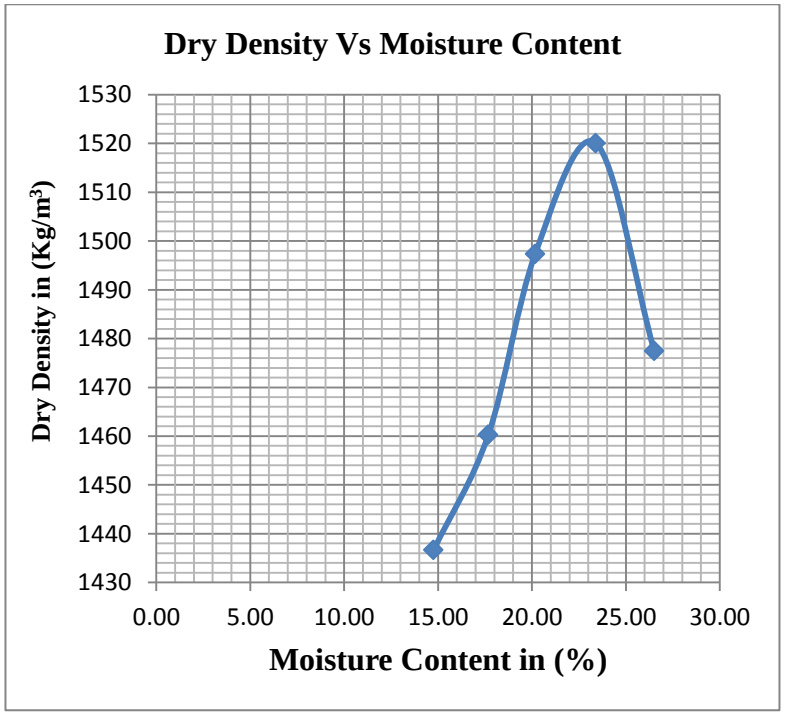
From the graph; moisture content at 25 blows (LL) = 48.22

PL = 35.75

PI = LL-PL = 48.22-35.75= **12.48**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	A	B	C	D	E
Mass of Wet soil +Con(gm.)(F)	93.14	152.32	151.25	99.88	114.54
Mass of dry soil +con(gm.)(G)	83.50	132.17	129.05	84.39	94.48
Mass of container(gm.)(H)	18.21	18.20	19.01	18.19	18.80
Mass of moisture(gm.)F-G=(I)	9.64	20.15	22.2	15.49	20.06
Mass of Dry soil(gm.)G-H=(J)	65.29	113.97	110.04	66.2	75.68
Moisture content % (I/J)*100=K	14.76	17.68	20.17	23.40	26.51
Dry Density gm./cm^3 E/(100+K)*100	1.437	1.460	1.497	1.520	1.477
Dry density in kg/m^3	1437	1460	1497	1520	1477

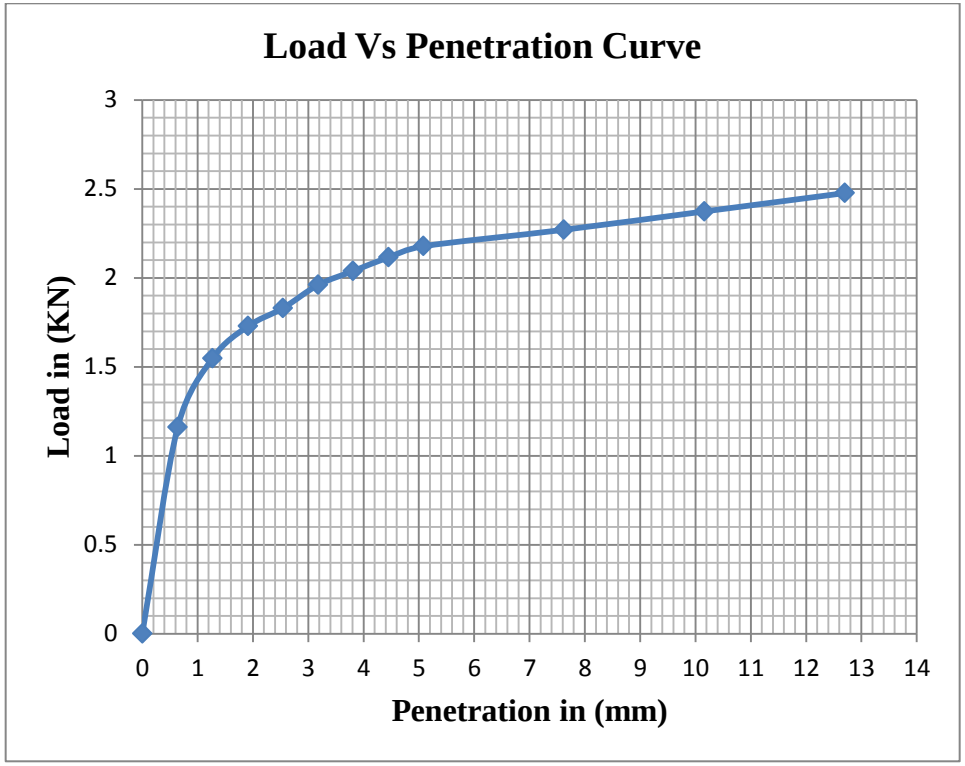


From the above plot; the value of MDD (Maximum Dry Density) = 1.52 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 23.40%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0		0	0	
0.64	45.00	0.0258	1.16	
1.27	60.00	0.0258	1.55	
1.91	67.00	0.0258	1.73	
2.54	70.91	0.0258	1.83	13.86
3.18	76.00	0.0258	1.96	
3.81	79.00	0.0258	2.04	
4.45	82.00	0.0258	2.12	
5.08	84.42	0.0258	2.18	10.89
7.62	88.00	0.0258	2.27	
10.16	92.00	0.0258	2.37	
12.7	96.00	0.0258	2.48	

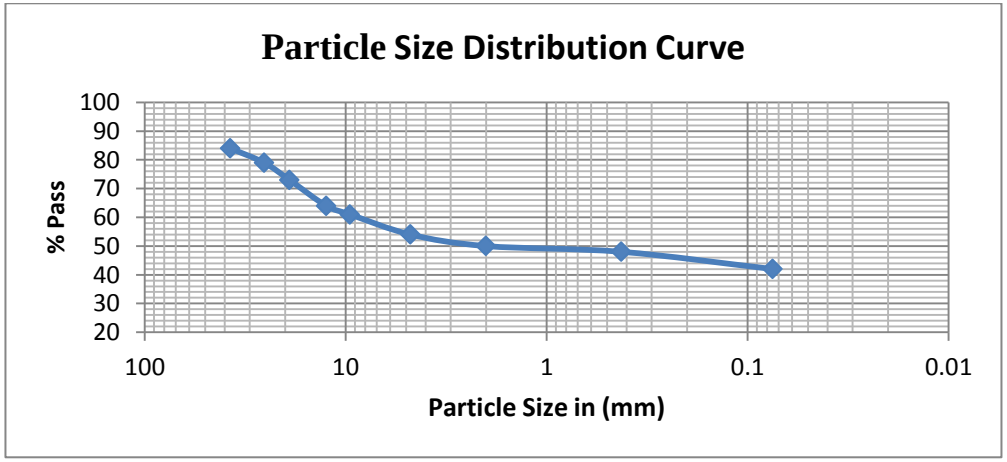


Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **13.86** and **10.89** percent respectively.

Experiment No. 27

1. Particle Size Distribution (Sieve Analysis)

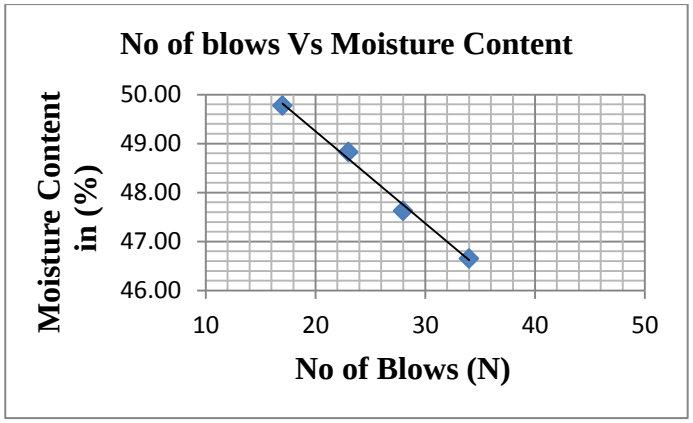
Laboratory Test No.27			
Sieve (mm)	**Weight retained in (gm.)**	**Wt. retained in (%)**	**% Pass**
37.5	318.40	16	84
25.4	99.50	5	79
19	119.40	6	73
12.5	179.10	9	64
9.5	59.70	3	61
4.75	139.30	7	54
2	79.60	4	50
0.425	39.80	2	48
0.075	119.40	6	42
Pan	835.80	42	0
Total mass	**1990**	**100**	



1.2 Atterburg limit test

1.2.1 Liquid limit and Plastic limit determination

LIQUID LIMIT					PLASTIC LIMIT	
No of blows	34	28	23	17		
container no	**318**	**370**	**27**	**319**	**349**	**314**
Wt. of cont. + wet soil	41.19	38.65	40.47	42.59	32.28	31.49
Wt. of cont. + dry soil	34.64	33.44	34.65	36.08	29.51	28.79
Wt. of container	20.6	22.5	22.73	23	21.78	21.22
Wt. of water	6.55	5.21	5.82	6.51	2.77	2.7
Wt. of dry soil	14.04	10.94	11.92	13.08	7.73	7.57
Moisture content in (%)	46.65	47.62	48.83	49.77	35.83	35.67



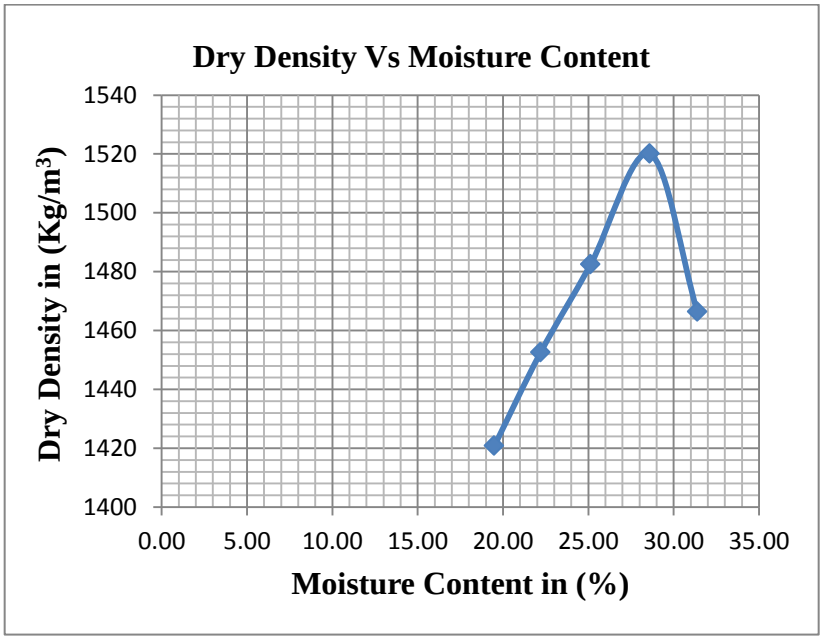
From the graph; moisture content at 25 blows (LL) = 48.35

PL = 35.75

PI = LL-PL = 48.35-35.75= **12.6**

Experiment 1.3 MDD (Maximum Dry Density) and OMC (Optimum Moisture Content) Determination

Moisture Content					
Container no.	F	G	H	M	N
Mass of Wet soil +Con(gm.)(F)	103.21	106.1	111.26	125.65	85.17
Mass of dry soil +con(gm.)(G)	89.18	90.08	92.60	102.08	71.27
Mass of container(gm.)(H)	17.20	17.91	18.35	19.66	26.98
Mass of moisture(gm.)F-G=(I)	14.03	16.02	18.66	23.57	13.9
Mass of Dry soil(gm.)G-H=(J)	71.98	72.17	74.25	82.42	44.29
Moisture content % (I/J)*100=K	19.49	22.20	25.13	28.60	31.38
Dry Density gm./cm^3 E/(100+K)*100	1.421	1.453	1.482	1.520	1.466
Dry density in kg/m^3	1421	1453	1482	1520	1466

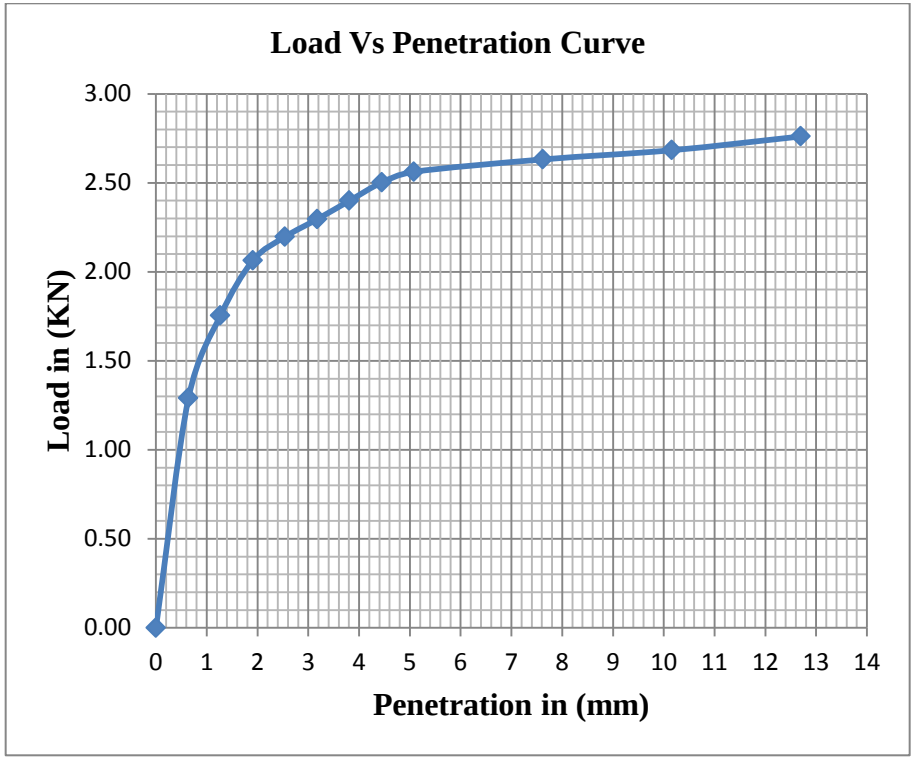


From the above plot; the value of MDD (Maximum Dry Density) = 1.52 g/cm^3

And also the value of OMC (Optimum Moisture Content) = 28.60%

Experiment No. 1.4 CBR test

Plunger area			1935mm^2	
Penetration rate			1.27mm/min	
Ring Factor			0.0258	
Penetration in (mm)	**Dial Reading**	**Ring Factor**	**Load (KN)**	**CBR (%)**
0	0		0	
0.64	15	0.0258	0.39	
1.27	30.2	0.0258	0.78	
1.91	40.2	0.0258	1.04	
2.54	47.29	0.0258	1.22	9.27
3.18	52	0.0258	1.34	
3.81	57	0.0258	1.47	
4.45	61	0.0258	1.57	
5.08	64.34	0.0258	1.66	8.32
7.62	68	0.0258	1.75	
10.16	69	0.0258	1.78	
12.7	70	0.0258	1.83	



Therefore, from the above table and graph the value of CBR at **2.54** and **5.08** is **16.64** and **12.81** percent respectively.