ADDIS ABABA UNIVERSITY (AAU)
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING

DEVELOPING CORRELATION BETWEEN DCP AND CBR FOR LOCALLY USED SUBGRADE MATERIALS

A Thesis Submitted to the School of Graduate Studies in the Partial Fulfillment of a Masters Degree in Civil Engineering

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MSc Thesis

By
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ABSTRACT

California Bearing Ratio (CBR) is a commonly used indirect method to assess the sub grade soil strength in pavement design works. However, since CBR cannot be easily determined in the field, civil engineers always encounter difficulties in obtaining representative CBR values for design of pavement. Consequently, prediction of CBR va1ues from other direct soil field tests such as Dynamic Cone Penetrometer (DCP) is found to be a valuable alternative.

The dynamic cone Penetrometer (DCP) is the most versatile rapid, in situ evaluation device currently available. Its correlations to CBR and its use in performance evaluation of pavement layers make it an attractive alternative to more expensive and time consuming procedures. Many useful correlations had been proposed by various researchers for soils of their locality in which the DCP penetration index was used to develop these correlations.

A study was carried out to find the correlation between Cone Penetrometer (DCP) with CBR values that best suit the type of soils in Ethiopia. Accordingly, several laboratory tests and field tests on Jimma – Mizan, Contract 1: Jimma – Bonga road project from km 100+000 to km 105+000 has been conducted. From the tests, the Atterberg limits (PI, LL, PL), In situ density, classification (sieve analysis, hydrometer analysis), California bearing ratio, insitu Moisture Content, and Dynamic cone penetration results are acquired. Based on this laboratory and field test results analyses were carried out using SPSS software and the applicability of the existing correlations for Ethiopia soil on the aforesaid data was checked. From the analysis results, it is observed that the published correlations are not suitable to be used in Ethiopia. Consequently, a correlation had been proposed in the study to predict the CBR values of the sub grade soil from dynamic cone penetration test results.

The relation obtained from statistical analysis relationship has an R^2 of 0.943 and is shown below.

$$\log(CBR) = 2.954 - 1.496\log(DCPI) \text{ with } R^2 = 0.943$$

The results of the statistical analysis show that good correlation does exist between the dynamic cone penetration indexes (DCPI) and unsoaked CBR values.

ABBREVIATION

1.AASHTO	American Association of State Highway and Transportation Officials
2. DCP	Dynamic Cone Penetration
3. DCPI	Dynamic Cone Penetration Index
3. OMC	Optimum Moisture Content
4. MDD	Maximum Dry Density
5. LL	Liquid Limit
6. PL	Plastic Limit
7. PI	Plasticity Index
8. ASTM	American Society for Testing and Materials
9. CBR	California Bearing Ratio
10. LFWD	Light Falling Weight Deflectometer
11. MnDOT	Minnesota Department of Transportation
12. ABC	Aggregate Base Course
13. TRL	Transport Research Laboratory
14. km	Kilometer
15. NCHRP	National Cooperative Highway Research Program
16. CPT	Cone Penetration Test
17. m	Meter
18. mm	Mili meter
19.cm	Centimeter
20.R^2	Coefficient of determination
21. N	Newton
22. KN	Killo newton
23. MPa	Mega Pascal
24. Kg	Kilogram
25. BS	British Standards
26 U.S	United States
27.VS.	Versus
28. NCDOT	North Carolina Department of Transportation
29. FDT	Field Density Test
30. NMC	Natural Moisture Content

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Chapter One
Introduction

1.1 Background

The DCP was initially developed in South Africa for in-situ evaluation of pavements [1].The DCP is an instrument designed to provide a measure of the in-situ strength of fine grained and granular sub grades, granular base materials, and weakly Cemented material and etc.

The DCP has been intended to alleviate many of the deficiencies of systems that are manually pushed into soil or paving materials. The device is relatively simple in design and operation, and operator variability is reduced and thus correlations with strength parameters are more accurate. The DCP consists of a steel rod with a steel cone attached to one end driven into the pavement structure or sub grade using a sliding hammer.

DCP testing is conducted according to Illinois Test Procedure, in which the number of blows to achieve 150 mm of penetration is counted. Alternatively, the depth of penetration may be measured after each blow when extremely soft materials are encountered. In either case, the output of the DCP test is a penetration rate (PR), expressed in mm per blow.

The California Bearing Ratio test was developed by the California State Highways Department in the 1930's. It is in essence a simple penetration test developed to evaluate the strength of road sub grades (soil below the pavement) and makes no attempt to determine any of the standard soil properties such as density. It is merely a value and it is integral to the process of road design. It is however, by far the most commonly used in Pavement Design. The CBR test should be used with soil at the calculated equilibrium moisture content. Almost all design charts for the road foundations are based on the CBR value of the sub grade materials. [2]

In the construction industry of the country (Ethiopia), particularly in road construction, the use of dynamic cone penetration is limited to few design offices. This is due to the absence of developed design charts which correlate DCP and CBR test results for Ethiopian soils.

Thus, due to the relatively fast and easy use of DCP test the development of correlations between CBR and DCP test for locally available sub grade materials will reduce cost and time required for design and construction.

Besides, since the currently available correlations were not developed based on the test made on local soil, it may either underestimate or overestimate the soil strength. In either case, it may have a negative impact on the economy of the country in general and on the construction industry in particular.

1.2 Statement of the Problem

California Bearing Ratio (CBR) test is most widely used for analysis and design of pavement layers. Virtually, all design charts for the road foundations are based on the CBR value of the sub grade materials. However, California Bearing Ratio (CBR) test is expensive, relatively slow to conduct and generally not favored by Highway Engineers. There is much interest in finding quick, cheap test methods to carry out the required design and analysis efficiently with short time.

DCP, being light and portable offers an attractive means of determining in situ soil strength at a comparative speed and ease of operation and its higher repeatability from CBR, various correlations have been developed by different researchers from samples of their locality. Hence, adopting those developed correlations without adjustment for locally available sub grade soils leads misinterpretation of the local soil behavior.

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

1.3 Objectives

In Ethiopia, almost all the pavement design has been made using California bearing ratio values (CBR) obtained from Dynamic cone penetration test using correlations developed for soils of other localities (outside Ethiopia).

The main objective of this thesis is, therefore, to check the applicability of the correlations developed for Dynamic Cone Penetrometer test and California Bearing Ratio tests to locally available sub grade materials and if not applicable, to develop a new correlations to be adopted for designing and constructing different buildings, roads and other structures within the country.

1.4 Methodology

Literatures regarding Dynamic Cone penetration (DCP) and California bearing ratio (CBR) has been thoroughly studied and reviewed at the early stage of the study. Technical papers, journals and published reports were reviewed to keep up to date on the published correlations that relate the CBR values with Dynamic cone penetration. Summary of the literature review is presented in Chapter two. Following this, several laboratory tests and field tests on Jimma – Mizan road project have been conducted. From the tests, the Atterberg limits (PI, LL, PL), optimum moisture content, California bearing ratio, insitu moisture content, insitu density and Dynamic cone penetration results are acquired. Based on this laboratory and field test results the applicability of the existing correlations for Ethiopia soil on the aforesaid data was checked.

Thus, the collected DCP data for the analysis is substituted into the existing correlations to find the estimated CBR values. The estimated CBR values from the existing correlations were compared with the CBR values obtained from the laboratory. Comparison results were reported and discussed in the study to assess the suitability of the correlations for Ethiopia.

Furthermore, statistical regression analysis of the test results obtained was also made and new correlation that suit with the collected CBR and DCP data is produced. Finally, Conclusions and recommendations are made.

1.5 Thesis Organization

This thesis is divided into five Chapters. The introduction chapter highlights the background, objective, the statement of problems and the methodology employed while conducting the thesis.

Chapter two discuses the Dynamic cone penetration test, California bearing ratio test and their application, factors that affect the test results, and the existing correlations between DCP and CBR test results.

Chapter three describes the sources and the selection of data for which the analysis is made.

In chapter four, regression analysis between the CBR and DCP test results is carried out, the applicability of the existing correlations checked and subsequently new correlation between DCP and CBR test results is developed.

Overall conclusions on the output of the thesis and recommendations for further study are presented in chapter five.

Finally, references and relevant appendices are presented.

Chapter Two
Literature Review

2.1 Dynamic Cone Penetration

When required to assess the strength of a pavement or to design improvement works, the pavement engineer needs to know as much as possible about the thicknesses of the existing pavement layers and their condition. In some cases the quickest and easiest way to do this is to inspect the design to which the pavement was originally built and perhaps also the as-built records made during construction. However, designs indicate only an intended construction and as-built records are often only indicative of the construction work carried out. Furthermore, both designs and as-built records give no information as to what has happened to the pavement since construction and the condition it is currently in. To give useful information, it is therefore necessary to investigate the current pavement condition using some form of destructive or non destructive testing.

The usual method of destructive testing is to dig test pits at suitable intervals along the road. These are very useful as pavement thicknesses can be measured and sample can be easily taken for laboratory testing. However, test pits are expensive to dig and reinstate and are rarely dug at intervals of less than 2-3 kilometers.

The Dynamic Cone Penetrometer is an efficient way of testing pavement at more frequent intervals. Tests using the DCP generate data which can be analyzed to produce accurate information on in situ pavement layer thicknesses and strengths. Tests can be carried out very rapidly and test sites can be repaired extremely easily. The DCP can therefore give information of sufficient quality and quantity to allow the pavement strength to be estimated and improvement works designed. Results from DCP tests can also be used to locate test pits in the most suitable positions. [3]

The dynamic cone penetration test (DCPT) was originally developed as an alternative for evaluating the properties of flexible pavement or sub grade soils. The conventional approach to evaluate strength and stiffness properties of asphalt and sub grade soils involves a core sampling procedure and a complicated laboratory testing program such as resilient modulus, Marshall tests and others**.**

Thus, the development of DCP was in response to the need for a simple and rapid device for the characterization of sub grade soils (e.g., Melzer and Smoltczyk, 1982; McGrath, 1989; McGrath, et al., 1989; and Mitchell, 1988) Due to its economy and simplicity, better understanding of the DCPT results can reduce significantly the effort and cost involved in the evaluation of pavement and sub grade soils. The Dynamic Cone Penetrometer has been increasingly used in many parts of the world in soil (sub grade), granular material, and lightly stabilized soils through its correlation with California Bearing Ratio (CBR).

The basic design of the Dynamic Cone Penetration **(**DCP) has been relatively unchanged since its inception in the 1950s. The mass of the falling weight has been altered several times. The cone tip has also undergone numerous revisions to its basic design.

Development of the hand-held DCP is credited to Scala of Australia in the mid- 1950's. Pavement design procedures in Australia then did not specifically require in-situ strength tests of the sub grade soils because of the time and complexity of available test methods. The device Scala developed included a 9.1-kg drop hammer falling a distance of 508 mm. A 15.9 mm diameter rod calibrated in 50.8 mm increments was used to determine the penetration. The configuration used a 30 degree included angle cone tip. Scala conducted tests correlating CBR with DCP data and proposed a pavement design procedure based on this correlation. Use of this DCP device was adopted by the Country Roads Board, Victoria, and gained widespread acceptance.

The next generation of DCP equipment was developed by Van Vuuren from South Africa. Basically it was similar to the DCP apparatus developed by Scala except the weight of the drop hammer was changed to 10 kg and the drop height was changed to 383.5 mm. The shaft diameter measured 16 mm) while the apex angle remained at 30 degrees. The development was prompted by the need to alleviate problems associated with performing field CBR tests. In the ensuing study, the CBR/DCP correlation resulted in a better correlation when compared to CBR/CPT correlation. Additionally, Van Vuuren concluded that the DCP is suited for use with soils having CBR values of 1 to 50. The present version of the DCP used in this study was developed by Kleyn of the Transvaal Roads Department, South Africa. Van Vuuren's basic design was utilized in Kleyn's work; however, the hammer weight was reduced to 8 kg and the height of the drop was increased to 576 mm. Kleyn studied two cone angle configurations of 30 degrees and 60 degrees. The cone angle utilized in this study was based on the 60 degree included angle. More recently, the automated dynamic cone Penetrometer has been suggested to automate the operation, data collection and analysis procedures (e.g., Hammons, et al., 1998). [11]

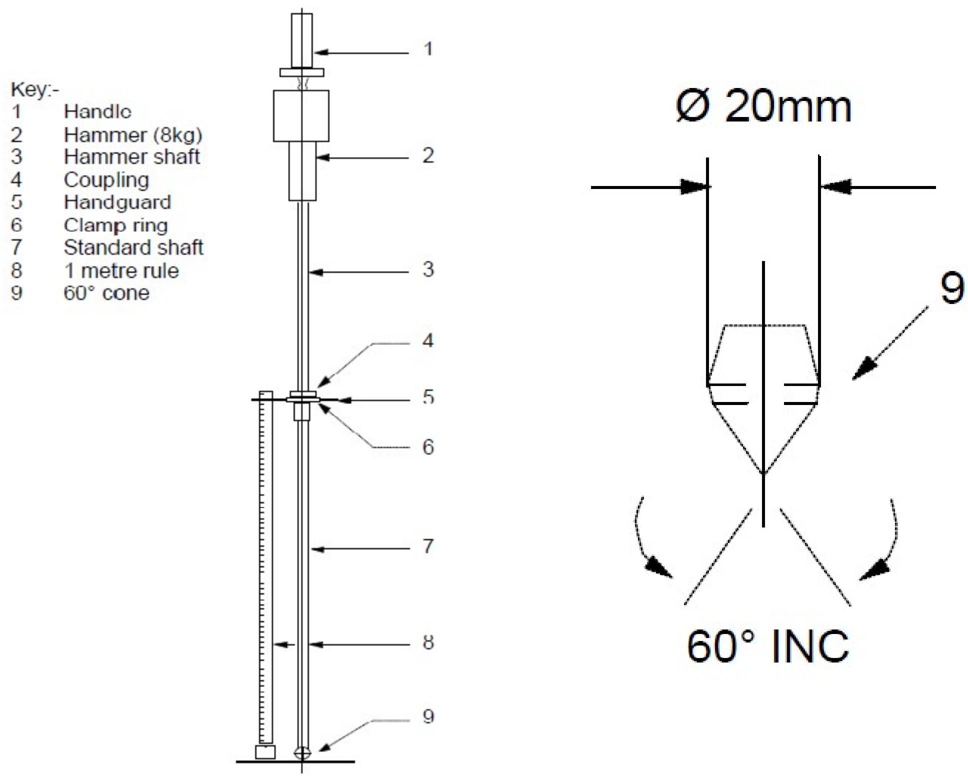


Figure 2.1 Typical configuration of Dynamic Cone Penetrometer (DCP).

As shown in Fig 2.1, the DCP consists of upper and lower shafts. The upper shaft has 8 kg (17.6 lb) drop hammer with a 575 mm (22.6 in) drop height and is attached to the lower shaft through the anvil. The lower shaft contains an anvil and a cone attached at the end of the shaft. The cone is replaceable and has a 60 degree cone angle. As a reading device, an additional rod is used as an attachment to the lower shaft with marks at every 5.1 mm (0.2 in).

In order to run the DCPT three operators, two laborers and one supervisor are required. The supervisor controls the reading and recording of the results, whilst the two laborers alternate between holding the apparatus vertical and operating the hammer. The first step of the test is to put the cone tip on the testing surface. The lower shaft containing the cone moves independently from the reading rod sitting on the testing surface throughout the test. The initial reading is not usually equal to 0 due to the disturbed loose state of the ground surface and the self-weight of the testing equipment. The value of the initial reading is counted as initial penetration corresponding to blow 0.

Figure 2.2 shows the penetration result from the first drop of the hammer. Hammer blows are repeated and the penetration depth is measured for each hammer drop. This process is continued until a desired penetration depth is reached. DCPT results consist of number of blow counts versus penetration depth. Since the recorded blow counts are cumulative values, results of DCPT in general are given as incremental values defined as follows,

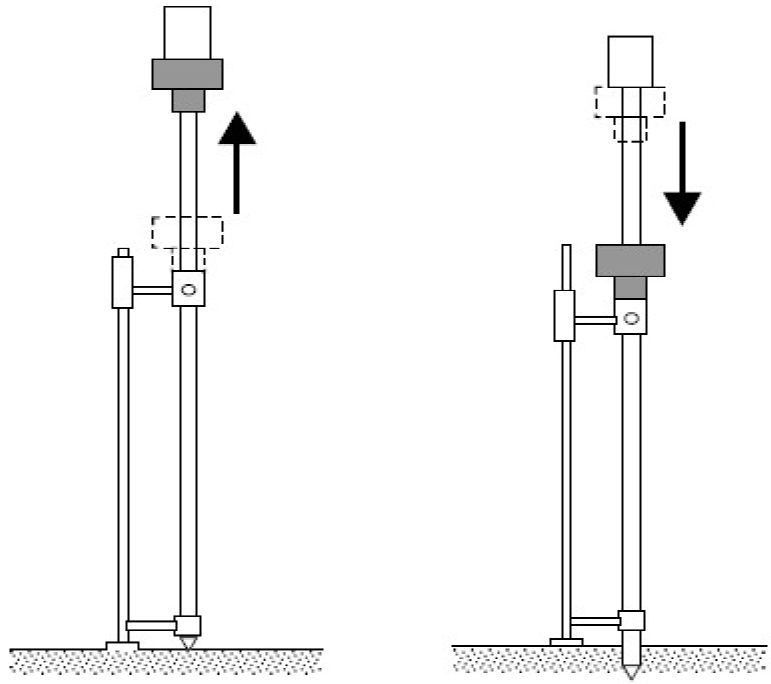
$$PI = \frac{\Delta Dp}{\Delta BC} \quad \text{--------------------------------} 2.1$$

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

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

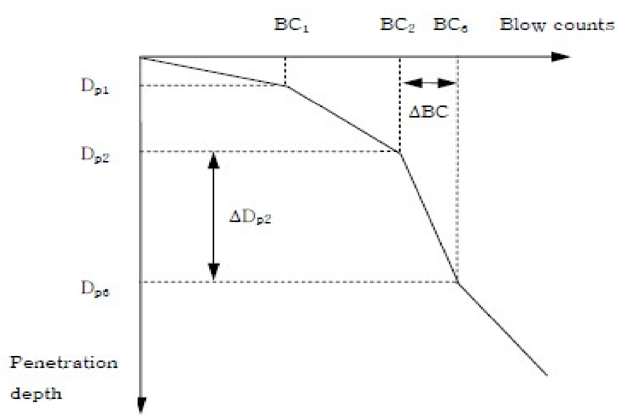
The DCP results, when plotted, describes the number of blows to reach a certain depth affording an instantaneous visual illustration of in-situ material strength (Fig 2.3). The slope of the curve at any point expressed in terms of mm/blow is called the dynamic cone penetration index (DCPI) which represents the resistance offered by the material; the lower the DCPI the stiffer the material, and vice versa.[4]

As a result, values of the penetration index (PI) represent DCPT characteristics at certain depths.



(a) Before hammer dropping (b) After hammer dropping

Figure 2.2 Dynamic Cone Penetration Test



(a)

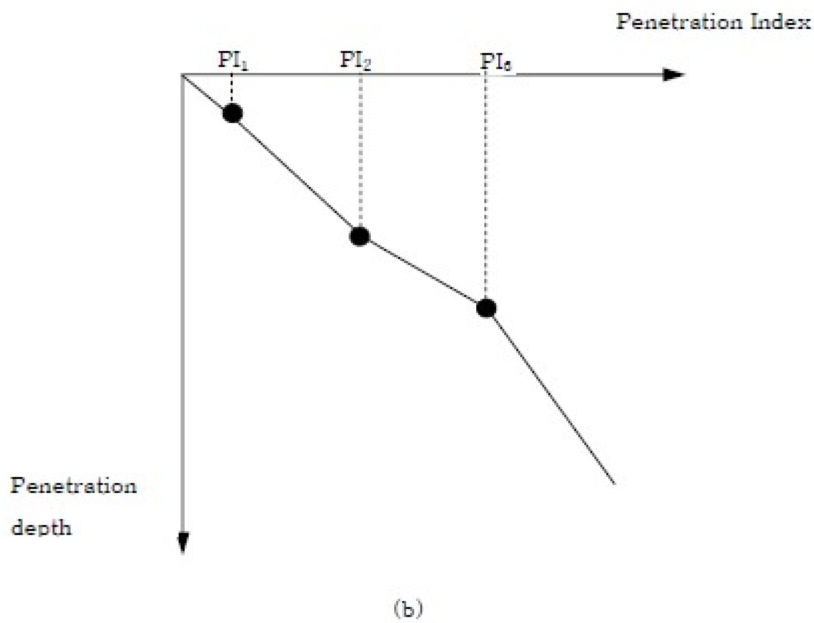


Figure 2.3, Typical DCP test results

The DCP cannot penetrate some strong surface and base materials such as hot mix asphalt or cement treated bases. These layers must be removed before the test can begin and their strength assessed using different criteria. Thus, if the cone does not penetrate 25 millimeters after 10 blows with the 8kg hammer (20 blows with the 5.05 kg hammer), the test should be stopped. If this firm material is a stabilized soil or high-strength aggregate base layer, it should be cored or drilled with an auger to allow access of the DCP cone to underlying layers. The DCP test can then proceed through the access hole after the depth of the material layer has been recorded. The material layer is assigned a CBR value of 100+. However, if a core or auger drill is not available, the 8kg DCP hammer can normally be used to drive the lower rod and cone through the firm material. If the cone penetration was stopped by a large rock or other object, the DCP should be extracted and another attempt made within a few meter of the initial test. The DCP is generally not suitable for soils having significant amounts of aggregate greater than a 2-inch-sieve size.

Besides, if repeated DCP tests are conducted longitudinally, a longitudinal picture of the selected section can also be developed which allows delineation of the area into homogeneous sections.[3]

2.2 Application of DCP

2. 2.1 Application of DCP for Quality Control of Compaction

2.2.1.1 Cohesive and Selected Backfill Materials

Historically, the compaction levels of pavement sub grade and base layers have been determined by means of in-place density testing such as sand replacement and nuclear gauge methods. In an effort to determine whether there is a reasonable correlation between the DCPI and in-place compaction density of cohesive and select backfill materials, some testing has been performed on these materials to determine if such a correlation exits. Most results of DCP testing have indicated too much variability in DCP results to practically apply a correlation (Burnham, 1997). Siekmeier et al. (1999), as part of the Minnesota Department of Transportation study, investigated the correlation between DCP results and compaction of soils consisting of mixture of clayey and silty sand fills. They first correlated DCPI to the CBR. CBR was then related to the modulus using published relationships. They examined the relations between the modulus and percent compaction. It was concluded that a good correlation did not exist between the DCP results and percent compaction, partly because a typical range of soil mixtures at the site was not truly uniform.[5]

2.2.1.2 Granular Base Layer Compaction

The Minnesota Department of Transportation suggests this application to reduce testing time and effort while providing more consistent quality control of base layer compaction (Burnham, 1977). Using this procedure, immediately after the compaction of each layer of granular base material, DCP tests are conducted to insure that the DCPI is less than 19 mm per blow. The DCPI limiting value is valid for all freshly compacted base materials. The DCPI dramatically decreases as the density of the material increase and under traffic loading. Using this method, the DCP testing will only indicate those adequately compacted base layers that pass. Test failure, however, must be confirmed by other methods such as the nuclear gauge or the sand cone density method. Based on general agreement between the DCPI and percent compaction, the Minnesota Department of

Transportation has revised the limiting penetration rate to the following (Siekmeier et al., 1998):

a) 15 mm/blow in the upper 75 mm;

b) 10 mm/blow at depths between 75 and 150 mm ; and

c) 5 mm/blow at depths below 150 mm.

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

a) The test is performed consistently and not more than one day after compaction while the base material is still damp;

b) The construction traffic be distributed uniformly by requiring haul trucks to vary their path; and

c) At least two dynamic cone Penetrometer tests be conducted at selected sites within each 800 cubic meters of constructed base course. They proposed a Penetration Index Method (Trial MnDOT Specifications 2211.3C4) which described a step-by-step procedure for determining the pass and fail tests (Siekmeier, et al. 1998). Siekmeier et al. (1999), as part of the Minnesota Department of Transportation study, studied the correlation between DCP results and compaction of soils consisting of sand and gravel mixture with less than 10-percent fine. They first correlated DCPI to the CBR. CBR was then correlated to the modulus using published relationships. They examined the relations between the modulus and percent compaction. It was concluded a good correlation existed between the DCP results and percent compaction.[5]

2.2.1.3 Granular Materials around Utilities

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

The commonly used standard proctor test for granular materials cannot be used because it does not provide a well-defined moisture-density relationship. In addition, this approach requires density measurements on each lift of the compacted fill for the entire length of the pipe. Recent studies indicate that DCP blow count profiles provide a basis for comparison between compaction equipment, level of compaction energy, and materials. But, it should be noted that these data alone do not reveal what level of compaction must be achieved with each type of backfill material in order to achieve the specific performance criteria. The results have also indicated that the DCPI values are very sensitive to the depth of measurements (Jayawickrama, et al., 2000).[5]

2.2.1.4 Backfill Compaction of Pavement Drain Trenches

The Minnesota Department of Transportation has indicated that the DCP testing is reliable and effective in improving the compaction of these trenches. Using this procedure, immediately after installation of the pavement edge drainpipe and fine filter granular backfill material, DCP testing is conducted to insure that the DCPI is less than 75 mm per blow. In this approach, each 150 mm of compacted backfill material is tested for compliance (Burnham, 1997).[5]

2.2.2 Application of DCP for Performance Evaluation of Pavement Layers

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

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

The above values are based on the assumption that adequate confinement exists near the testing surface. In the event that higher values than the above mentioned limiting values are encountered, additional testing methods are needed. It should be noted that the above values are independent of the moisture content. Moisture content can cause large variability in DCP test results. Nevertheless, a limiting value was recognized. Gabr et al.

(2000) proposed a model by which the DCP data are utilized to evaluate the pavement distress state. They proposed a model to predict the distress level of pavement layers using penetration resistance of the sub grade and aggregate base course (ABC) layers based on coupled contribution of the sub grade and the aggregate base course (ABC) materials. They provided a step-by-step procedure, based on the correlation of the DCPI with CBR, by which the DCP data can be used to evaluate the pavement distress state for categorizing the need for rehabilitation measures. Although their pavement stress model was specific in this study regarding the type of the aggregate base course (ABC) material tested, the framework of the procedure can be used at other sites.[5]

2.2.3 Application of DCP to Obtain Layer Thickness

DCP can also be used effectively to determine the soil layer thickness from the changing slope of the depth versus the profile of the accumulated blows. Livneh (1987) showed that the layer thickness obtained from DCP tests correspond reasonably well to the thickness obtained from the test pits. It was concluded that the DCP test is a reliable alternative for project evaluation.[5]

2.2.4 Complementing falling weight deflectometer (FWD) during Back calculation

It has been shown that the DCP is very useful when the moduli back calculated from FWD data are in question, such as when the asphalt concrete is less than 76 mm or when shallow bedrock is present (e.g., Little et al., 1995). These two situations often cause a misinterpretation of FWD data. The DCP can be readily applied in these two situations to increase the accuracy of the stiffness measurement. In addition, it is not possible to conduct a FWD test directly on weak sub grade or base layers because of the large deflections that can exceed the equipment's calibration limit.[5]

2.3 Factors Affecting DCP Results

Many studies have been conducted to determine the general trends and behavior of the DCP index in regard to various soil and material factors. These factors include soil type, density, gradation, maximum aggregate size, plasticity index, and moisture content.[4]

2.3.1 Material Effects

In his study to investigate the effect of several different variables on DCP index for fine-grained soils, Hassan (1996) reported that DCPI is significantly affected by moisture content, AASHTO soil classification, and dry density. Kleyn concluded that gradation, density, moisture content, and plasticity were important material properties affecting the DCP values.

For granular materials, coefficient of uniformity and maximum size aggregate size are reported to be the primary factors. An increase in the percentage of the fines generally decreases the DCP value for the same target density. Similarly, an increase in the density for a similar gradation or individual material type decreases the DCP value.[4]

2.3.2 Side Friction Effect

Because the DCP device may not be always vertical while penetrating through the soil, the penetration resistance would be apparently higher due to side friction. This apparent higher resistance may also be caused when penetrating in a collapsible granular material. This effect is usually small in cohesive soils. Livneh (2000) suggested the use of a correction factor to correct the DCP/CBR values for the side friction effect.[5]

2.4 California Bearing Ratios (CBR)

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

During World War II, the US corps of engineers adopted the test for use in airfield construction [6].

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

$$\text{CBR (\%)} = \frac{\text{Test Unit Load}}{\text{Standard Unit Load}} * 100 \qquad \text{……………………………………………………2.2}$$

From the above equation, it can be seen that the CBR number is a percentage of the standard unit Load. In practice, the percentage symbol is dropped and the ratio is simply a number, such as 3, 45, and 60. Values of standard unit loads to use in equation 2.2 are listed in Table 2.1 below .

Table 2.1 Penetration corresponding to standard unit load applied to standard gravel [6].

Penetration (mm)	Standard unit load (MPa)
2.5	6.9
5.0	10.3
7.5	13.0
10.0	16.0
12.7	18.0

The CBR values are usually calculated for penetration of 2.54 mm and 5.04 mm. Generally the CBR value at 2.54 mm will be greater that at 5.04 mm and in such a case/the former shall be taken as CBR for design purpose. If CBR for 5.04 mm exceeds that for 2.54 mm, the test should be repeated. If identical results follow, the CBR corresponding to 5.04 mm penetration should be taken for design. [6]

The CBR value for a given soil will depend upon its density, molding moisture content, and moisture content after soaking. Since the product of laboratory compaction should closely represent the results of field compaction, the first two of these variables must be carefully controlled during the preparation of laboratory samples for testing. Unless it can be ascertained that the soil being tested will not accumulate moisture and be affected by it in the field after construction, the CBR tests should be performed on soaked samples [14]. In addition, the result of a CBR test also depends on the resistance to the penetration of the piston. Therefore, the CBR indirectly estimates the shear strength of the material being tested (Rodriguez et al. 1988).[7]

Relative ratings of supporting strengths as a function of CBR values are given in Table 2.2

Table 2.2: Relative CBR values for sub base and sub grade soils [8]

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

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

2.4.1 Test Methods

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

2.4.1.1 In Situ CBR Test

This test method is used for the determination of the California Bearing Ratio (CBR) of soil tested in place by comparing the penetration load of the soil to that of a standard material. It is mainly designated for the evaluation of the relative quality of sub grade soils, but is applicable to sub base and some base-course materials. Field in-place tests are used to determine the relative strength of soils, sub base, and some base materials in the condition at which they exist at the time of testing. Such results have direct application in test section work and in some expedient construction, military, or similar operations.

Thus, field in-place CBR tests are used for evaluation and design of flexible pavement components such as base and sub base course and sub grades and for other applications (such as unsurfaced roads) for which CBR is the desired strength parameter. If the field CBR is to be used directly for evaluation or design without consideration for variation due to change in water content, the test should be conducted under one of the following conditions:
(*a*) when the degree of saturation (percentage of voids filled with water) is 80 % or greater, (*b*) when the material is coarse grained and cohesion less so that it is not significantly affected by changes in water content, or
(*c*) when the soil has not been modified by construction activities during the two years preceding the test. In the last-named case, the water content does not actually become constant, but generally fluctuates within a rather narrow range. Therefore, the field in-place test data may be used to satisfactorily indicate the average load-carrying capacity.

As indicated above, field in-place tests can be used for design under conditions of nominal stability of water, density, and general characteristics of the material tested. However, any significant treating, disturbing, handling, compaction, or water change can affect the soil strength and make the prior to test determination inapplicable, leading to the need for retest and reanalysis. [9]

The field CBR testing is not commonly practiced in Ethiopia. Instead, a more popular test method known as dynamic cone Penetrometer test or commonly referred as Dynamic Cone Penetration (DCP) test is widely used due to its being economical, simple and quick in operation.

2.4.1.2 Laboratory CBR Test

The laboratory testing for determination of California Bearing Ratio (CBR) values is almost similar to the in situ CBR field testing as described above, except the latter soil sample is undisturbed. The test is carried out using the procedure outlined in AASHTO T193- 63 or ASTM D1883-73. The main difference between the two standards is on sample preparation. [10]

CBR tests are usually made on test specimens at the optimum moisture value for the soil as determined using the standard (or modified) compaction test using method 2 or 4 of ASTM D698-70 or of D1557-70 (for the 15.2cm diameter mold). The specimens are made using compaction energy shown in Table 2.3 below.

Table 2.3 the number of blows and corresponding number of layers for different grade of soils. [1]

Method	Layers	Blows	Hammer weight (N)
D698:2(fine grained soil)	3	56	24.4
D698:4(coarse grained soil)	3	56	24.4
D1557:2(fine grained soil)	5	56	24.4
D1557:4(coarse grained soil)	5	56	24.4

Two molds of soil are often compacted-one for immediate penetration testing and one for testing after soaking for a period of 96 hours. The second specimen is soaked for a period of 96 hours with a surcharge approximately equal to the pavement weight used in the field but in no case the surcharge weight is less than 45N. Swell readings are taken during this period at arbitrary selected times. At the end of the soaking period, the CBR penetration test is made to obtain a CBR value for the soil in saturated condition. In both penetration tests for the CBR values, a surcharge of the same magnitude as for the swell test is placed on the soil sample. The test on soaked gives information concerning the expected soil expansion beneath the pavement when the soil becomes saturated.

Penetration testing is accomplished in a compression machine using a strain rate of 1.27mm/min. reading of load vs. penetration are taken at each 0.5mm of penetration to include the value of 5.08 mm, and then at 2.54 mm increment thereafter until the total penetration is 12.7mm. Typical test results are illustrated in Figure 2.4. It sometimes happens that the plunger is still not perfectly bedded in the specimen and, because of this and other factors, a load-penetration curve with a shape similar to that of the curve for Test -2 in Figure 2.4 may be obtained instead of the more normal shaped curve illustrated by the curve for Test 1. When this happens, the curve must be corrected by drawing a tangent at the point of greatest slope and then transposing the axis of load so that zero penetration is taken as the point where the tangent cuts the axis of penetration. The corrected load-penetration curve is the tangent from the new origin to the point of tangency. The typical CBR test results are shown in table 2.4 below.

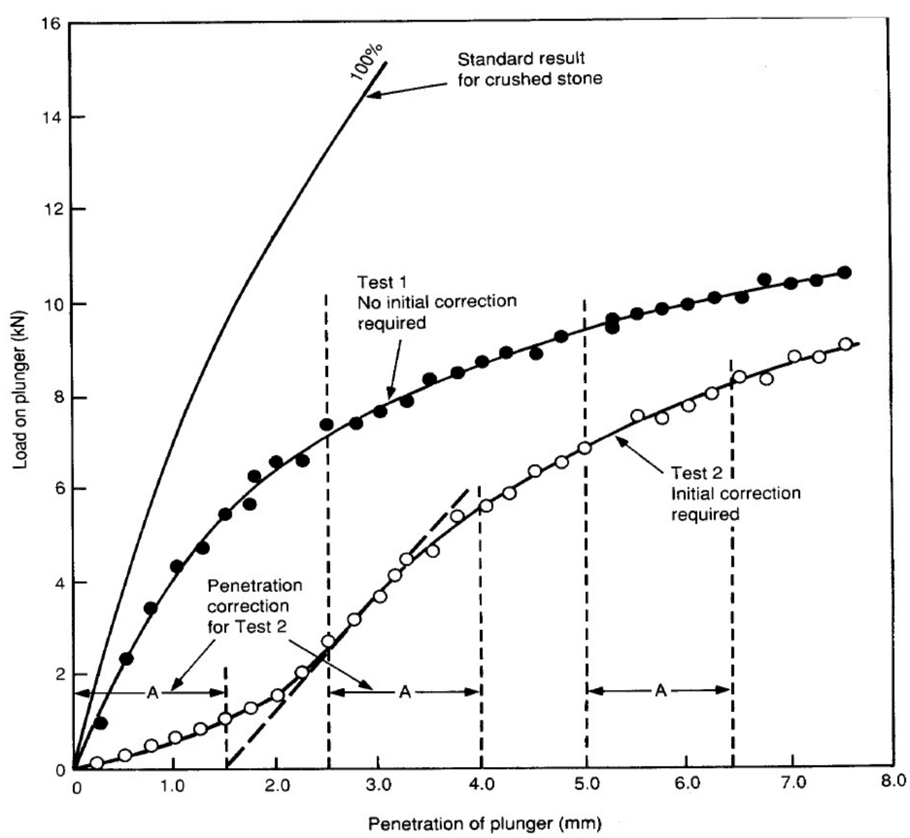


Fig 2.4 Typical CBR Test Result

The CBR values is then determined by reading from the curve the load that causes a penetration of 2.54 mm and 5.08 mm and dividing these values by the standard load 6.9 MPa and 10.3 MPa respectively required producing the same penetration in the standard crushed stone as

$$\textbf{CBR (\%)} = \frac{\textbf{Unit load for 2.54 /5.08mm penetration in the test specimen}}{\textbf{Unit load for 2.54/5.08 mm penetration in standard crushed rocks}} * \textbf{100} \qquad \ldots\ldots\ldots\ldots 2.3$$

The two values are then compared, generally the CBR value at 2.54 mm will be greater that at 5.08 mm and in such a case the former shall be taken as CBR for design purpose If CBR for 5.08mm exceeds that for 2.54mm, the test should be repeated. If identical results follow, the CBR corresponding to 5.08 mm penetration should be taken for design.[12]

2.4.2 Application of CBR Value

Numerous pavement design charts are published in which one enters a chart with the CBR (Structural Number) together with design traffic class and reads directly the thickness of sub base, base-course, and/or flexible pavement thickness based on expected wheel loads .Sometimes the CBR is converted to a sub grade modulus (also using charts) before entering the paving design charts using the formula. [12]

The main application of California Bearing Ratio (CBR) is to evaluate the stiffness modulus and shear strength of sub grade. Generally, the sub grade soil cannot bear the construction and commercial traffic without any distress, therefore; a layer of rigid or flexible pavement is required to be laid on top of the sub grade to carry the traffic load.

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

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

If the CBR value of sub grade is high, it means that the sub grade is strong. Accordingly, the design of pavement thickness can be reduced in conjunction with the stronger sub grade. Thus, it will give a considerable cost saving in term of construction besides an optimum design. However, if the CBR value of sub grade indicates that the sub grade is weak i.e. low reading of CBR reading, the thickness of pavement shall be increased in order to spread the traffic load over a greater area of the weak sub grade. This is important to prevent the weak sub grade material to deform excessively and causing the road pavement fail.[10]

Alternatively, the easiest method to overcome this weak sub grade before the construction of pavement is by replacing the soil with adequately compacted soil in layers. Otherwise, the sub grade can be stabilized by lime, cement, or the use of a geotextile to produce a stable platform for construction equipment and traffic load in long term. It should also be noted that the change in pavement thickness needed to carry a given traffic load is not directly proportional to the change in CBR value of the sub grade soil. For example, a one-unit change in CBR from 5 to 4 requires a greater increase in pavement thickness than does a one-unit change in CBR from 10 to 9.[8]

The CBR test is used exclusively in conjunction with pavement design methods and the method of sample preparation and testing must relate to the assumptions made in the design method as well as the assumed site conditions. For instance, the design may assume that soaked CBR values are always used, regardless of actual site conditions (Carter and Bentley, 1991). [10]

2.5 CBR Correlation with DCP

A number of studies have been conducted to develop empirical relationship between DCP (Dynamic Cone Penetrometer) resistance and CBR measurements. (e.g.Kleyn, 1975; Harison, 1987; Livneh, 1987; Livneh and Ishai, 1988; Chua, 1988; Harison, 1983; Van Vuuren, 1969; Livneh, et. al., 1992; Livneh and Livneh, 1994; Ese et. al., 1994; and Coonse, 1999). Based on the results of past studies, many of the relationships between DCP and CBR have the following form. [7]

Log (CBR) = $a + b$ log (DCPI)………………………………………..…………..…… 2.4

Where:-

DCPI = DCP penetration resistance (mm/blow);

a and b = dimensionless constants

A summary of some of these correlations with corresponding authors is presented in Table 2.4

Table 2.4 summary of correlation between CBR and DCPI by various authors [5]

Correlation Equation	Material tested	Reference
log(CBR) = 2.56 - 1.16 log	Cohesive	Harison (1987)
log(CBR) = 3.03-1.51 log (DCPI)	Granular	Harison (1987)
log (CBR) = 2.46 -. 1.12 log	Granular and	Livneh et al. (1992)
log(CBR) = 2.62 -1.27 log	Unknown	Kleyn (1975)
log(CBR) = 2.44 -1.07 log	Aggregate base	Ese et al. (1995)
Log(CBR) = 2.60 -1.07 log	Aggregate base	NCDOT(Pavement,
Log(CBR) = 1.4 -0.55 log (DCPI)	Aggregate base	Gabrel 2000
Log(CBR) = 2.53 - 1.14 log	Piedmont residual	Coonse (1999)
Log *CBR* = 2.465 – 1.12 (log *PR*)	granular and	U.S. Army Corps of
log10(CBR) = 2.48 – 1.057	For all Soil Types	TRL

loge(CBR) = 6.15 – 1.248	PI > 6 materials	Sampson
loge(CBR) = 5.93 – 1.1 loge(DN)	Plastic Materials	
loge(CBR) = 5.7 – 0.82 loge(DN)	PI < 6 materials	
loge(CBR) = 5.86 – 0.69	PI =0 materials	
Log(CBR) =2.555 –1.145 log	For all Soil Types	Smith and Pratt(30o

Although good correlations have been obtained, all studies have found that the results are material and moisture dependent, and that equations should be used with care and only with a full understanding of the material properties of the soils on which the equation was developed and the soil being tested. [6]

It should also be remembered that strengths predicted from DCP penetration are determined at the in-situ moisture content and density of the sub grade soils at the time of testing, which must be taken into consideration when relating these values back to those determined in a laboratory. [11]

There is no published information so far on the correlation of CBR-value and DCP in Ethiopia. As a substitute, correlations developed outside of Ethiopia for soils with different mode of formation on different locality have been used. Due to the significant variation in the properties and moisture contents of sub grade soils in Ethiopia, care would need to be taken when attempting to develop any such relationship.

Chapter Three
Data Collection

3.1 Source of Data

Adequate data is important for carrying out the required analyses in order to achieve the objectives of this study.

The data for the study were collected by conducting field and laboratory tests in Jimma – Bonga Road Project from km 100+200 to km 105+050 (from Jimma town) along the road. The project is located in the western part of the country (Ethiopia) in Oromia and South Nations and Nationalities Regional State along the road from Jimma to Mizan. The area is characterized by a heavy seasonal rainfall from June to October.

About 30 data on the soil properties and unsoaked California Bearing Ratio (CBR) conducted by remolding the samples at the in situ moisture content and density were obtained from the laboratory tests. Laboratory testing such as sieve analysis, Atterberg limits, in situ moisture content determination tests were also conducted.

The field (in situ) data collected comprises of field density using sand cone apparatus and Dynamic Cone Penetration tests. In order to avoid the seasonal variations of the soil properties due to rainfall and other factors, both the laboratory and field tests are conducted on the same period, during the month of November 2011.

3.2 Data Selection

As stated above, the data was acquired by conducting field and laboratory test data on Jimma – Mizan Road project.

The Construction at the above mentioned site was to rehabilitate the existing gravel road to DS4 asphalt road. The tests were done on the natural sub grade soils**.** Thirty DCP tests were conducted at several different locations from station km 100+200 to km 105+050. For each testing location, in addition to the DCP test unsoaked CBR value, particle size distribution (Sieve analysis), plastic limit, liquid limit, plasticity index, in-situ soil densities and insitu moisture contents were also measured.

Different Laboratory tests as mentioned above were performed to characterize soils of the test site. Table 3.1 indicates the Summary of different laboratory test results conducted on various locations of the selected construction site. The summary of the remaining test results are attached as an appendix to this thesis. Similarly, for the sake of illustration, the result of the DCP test carried out at km 100+200 and the corresponding Penetration Index are shown in Table 3.2 and 3.3 respectively and the corresponding graphs of Penetration Depth versus the Summation of Blows and Penetration Index versus Summation of Blows are also plotted in Figure 3.1 and 3.2 respectively.

The CBR test is conducted in accordance to Method 5 in BS 1377 (1990) Part 4 in which it refer to the rammer compaction to specified effort except that this samples are not subjected to four days soaking and conducted at the insitu moisture content. Thus, 4.5kg rammer method had been adopted to compact the soil samples in the moulds. CBR values at insitu moisture content and density were used in the analyses.

Table 3.1 Field and Laboratory test results

Sr.No.	Station	Direction	Sampling Depth(cm)	Lab. CBR (%)	DCPI (mm/blow)	PI (%)	LL (%)	FDT (gm/cm³)	NMC (%)	Classification(AASHTO)
1	100+200	RHS	40-67	18.5	13.8	35	62	1.729	27.3	Red Clay(A-7-6)
2	100+420	LHS	28- 55	12.4	18.7	37	66	1.612	34.4	Red Clay(A-7-6)
3	100+600	RHS	38-70	8.86	21.6	35	67	1.536	21.6	Red Clay(A-7-5)
4	100+800	LHS	29-67	13.0	17.1	38	69	1.629	20.2	Light Brown Clay (A-7-5)
5	101+050	RHS	50-90	13.3	16.6	38	68	1.66	27.2	Brown Clay(A-7-5)
6	101+250	LHS	31-66	18	13.4	34	71	1.731	27.2	Light Brown Clay(A-7-5)
7	101+450	RHS	40-70	24	10	32	63	1.847	36.1	Brown Clay(A-7-5)
8	101+650	RHS	48-62	16.7	14.8	34	65	1.703	25.7	Light Brown Clay(A-7-5)
9	101+850	RHS	30-70	16.5	15.4	35	65	1.694	24.1	Light Brown Clay(A-7-5)
10	102+050	LHS	65-80	6.44	25.1	34	64	1.481	26.1	Brown Clay(A-7-5)
11	102+250	RHS	73-108	12.5	17.3	34	63	1.613	27.6	Brown Clay(A-7-6)
12	102+650	LHS	46-78	10.1	19.8	31	63	1.595	31.7	Dark Red Clay(A-7-5)
13	102+850	RHS	42-67	11.1	19.4	34	64	1.608	38	Red Clay(A-7-5)
14	103+050	LHS	50-70	16.2	16.3	33	66	1.692	25	Dark Red Clay(A-7-5)
15	103+250	RHS	63-79	34	7.5	32	65	2.009	12.3	Brown Clay(A-7-5)
16	103+450	LHS	49-68	10.1	20.6	35	68	1.587	25.6	Brown Clay(A-7-5)
17	103+650	RHS	39-66	6.28	24.6	37	68	1.415	27.8	Brown Clay(A-7-5)
18	103+850	LHS	34-68	10.1	20.3	32	69	1.588	32.4	Light Brown Clay(A-7-5)

19	103+950	LHS	43-77	15.9	16.4	34	67	1.676	26.8	Red Clay(A-7-5)
20	104+050	RHS	53-78	19.5	13.1	34	68	1.736	28.99	Brown Clay(A-7-5)
21	104+150	RHS	39-74	17.9	14.5	58	92	1.713	30.6	Light Brown Clay(A-7-5)
22	104+250	LHS	42-76	7.81	22.5	33	65	1.496	31.6	Brown Clay(A-7-5)
23	104+350	RHS	48-68	14.6	16.5	32	66	1.67	29.6	Red Clay(A-7-5)
24	104+450	LHS	47-88	8.75	21.8	33	66	1.519	30.6	Light brown Clay(A-7-5)
25	104+550	RHS	49-78	22	13	32	66	1.751	31.5	Red Silty Clay(A-7-5)
26	104+650	LHS	47-82	18	14.2	32	67	1.721	33.4	light brown Clay(A-7-5)
27	104+750	RHS	66-106	5.65	26.5	33	68	1.265	26.8	Brown Clay(A-7-5)
28	104+850	LHS	47-120	22.8	11.3	33	66	1.766	28.6	Brown Clay(A-7-5)
29	104+950	RHS	50-90	9.06	21.00	32	66	1.547	30.5	Brown Clay(A-7-5)
30	105+050	LHS	47-81	16	16.2	37	72	1.692	29.6	Brown Clay(A-7-5)

Table 3.2 Sample DCP test Result
Chainage: km 100+200
Direction: LHS

No. Blows	∑ Blows	Depth (cm)	No. Blows	∑ Blows	Depth (cm)	No. Blow	∑ Blows	Depth (cm)
0	0	1.4	2	46	73	2	92	133
2	2	6.2	2	48	76	2	94	136
2	4	10.1	2	50	78.1	2		138
2	6	14.7	2	52	81.8	2	98	140
2	8	19	2	54	84.7	2	10	143
2	10	22	2	56	87.6	2	10	146
2	12	24.9	2	58	90.4	2	10	148
2	14	27.8	2	60	92.2	2	10	151
2	16	30.9	2	62	94.4	2	10	154
2	18	34.3	2	64	96.6	2	11	156
2	20	37.7	2	66	99.9	2	11	159
2	22	40.8	2	68	10	2	11	161
2	24	43.7	2	70	10	2	11	163
2	26	46.5	2	72	10		6	.5
2	28	49.1	2	74	10			
2	30	51.8	2	76	11			
2	32	54	2	78	11			
2	34	56.4	2	80	11			
2	36	58.9	2	82	12			
2	38	61.8	2	84	12			
2	40	64.7	2	86	12			
2	42	67.6	2	88	12			
2	44	70.6	2	90	13			
					0.			

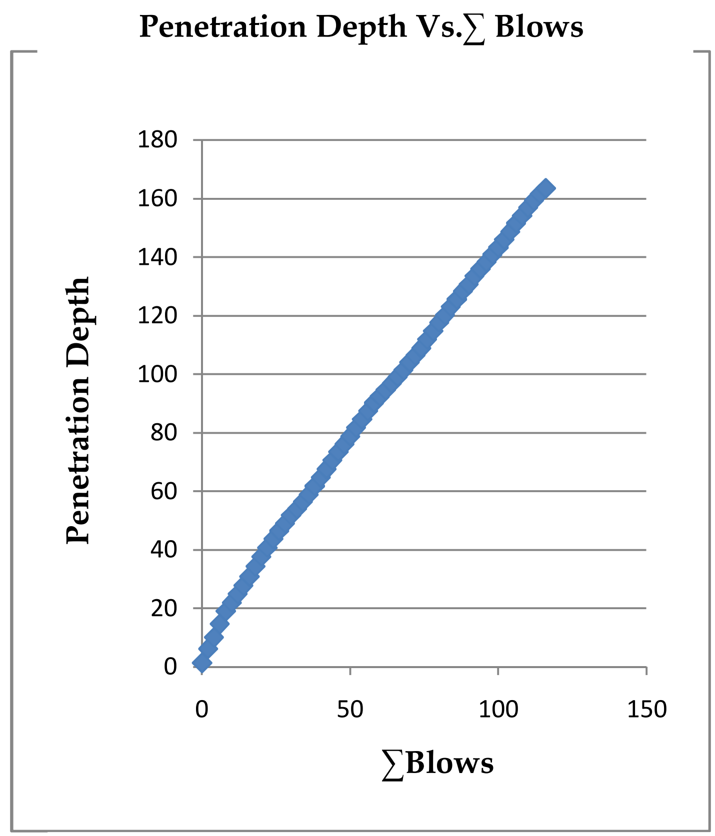
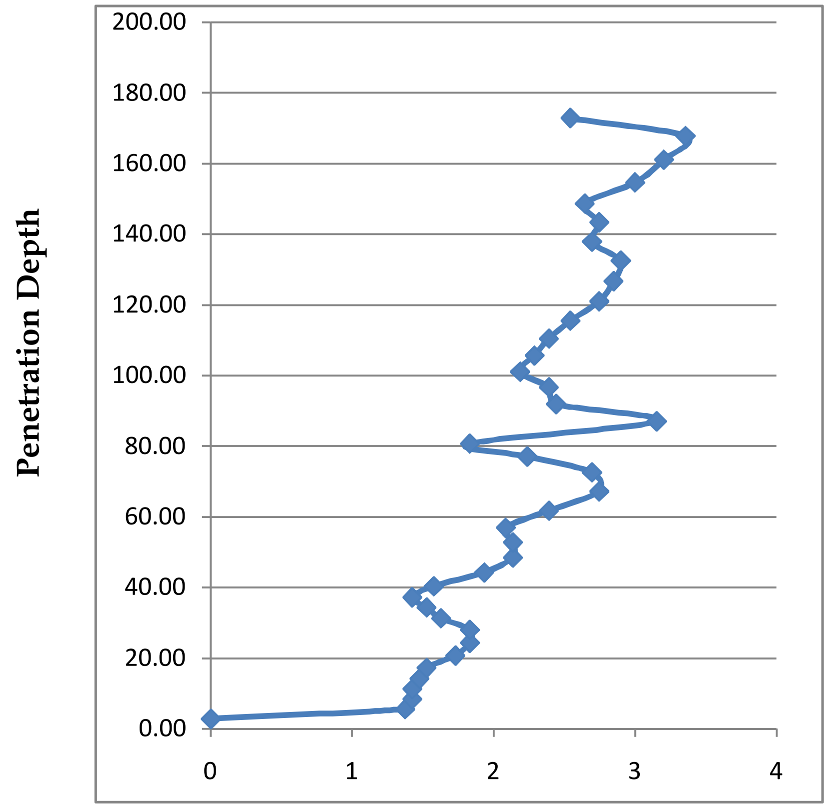


Figure 3.1 Plot of Sample DCP Test Result

Table 3.3 Typical Penetration Index values
Section No/Chainage: 100+200 RHS
Direction: RHS

ΔBc	ΔDp	PI	ΔBc	ΔDp	PI
0	2.84	0	2	4.77943	2.38
2	2.74	1.372	2	4.37267	2.18
2	2.84	1.423	2	4.57605	2.28
2	2.84	1.423	2	4.77943	2.38
2	2.94	1.474	2	5.0845	2.54
2	3.05	1.525	2	5.49126	2.74
2	3.45	1.728	2	5.69464	2.84
2	3.66	1.830	2	5.79633	2.89
2	3.66	1.830	2	5.38957	2.69
2	3.25	1.627	2	5.49126	2.74
2	3.05	1.525	2	5.28788	2.64
2	2.84	1.423	2	5.99971	2.99
2	3.15	1.576	2	6.40647	3.20
2	3.86	1.932	2	6.71154	3.35
2	4.27	2.135	2	5.0845	2.54
2	4.27	2.135			
2	4.16	2.084			
2	4.77943	2.389715			
2	5.49	2.745			
2	5.38	2.694			
2	4.47	2.237			
2	3.66	1.830			
2	6.30	3.152			
2	4.88	2.440			

Penetration Depth Vs. Penetration Index



3.3 Checking the applicability of the existing correlation (TRL, Overseas Road Note 8)

The collected DCP data for the analysis is substituted into the existing correlation of TRL, Overseas Road Note 8(commonly used correlation in Ethiopia), to find the estimated CBR values. The estimated CBR values obtained from TRL, Overseas Road Note 8, were compared with the CBR values obtained from the laboratory in Table 3.4. The Comparison shows the unsuitability of the previously developed correlations of, TRL, Overseas Road Note 8, for the data collected from the project site. In view of this, it is imperative that new correlation that suits the collected CBR and DCP data to be used for soils of same type.

From the comparison it has been observed that about 90% of the data that were collected from the site yield high CBR value in comparison with its computed value using TRL, Overseas Road Note 8 correlation.

Table 3.4 Comparisons of Laboratory measured CBR Value and CBR values obtained from other Correlations ((Harrison, Sampson, Smith and Pratt and TRL, Overseas Road Note 8)

Table 3.4 Comparisons of Laboratory CBR Value and CBR values obtained from other correlations (Harrison, Sampson, Smith and Pratt and TRL)

Sr. No.	DCPI (mm/blow	Lab CBR (%)	Computed CBR (%)						Variation (%)					
			Harrison		Sampson		smith & Pratt (30^ocone)	TRL	Harrison		Sampson		smith & Pratt (30^ocone)	TRL
			Unsoaked Sample	Clay	PI>6	Plastic Material			Unsoaked Sample	Clay	PI>6	Plastic Material		
1	13.8	18.5	20.60	17.29	17.72	20.97	12.71	18.96	-10.21	7.01	4.43	-11.76	45.57	-2.41
2	18.7	12.4	13.75	12.15	12.12	15.01	20.09	13.76	-9.85	2.04	2.27	-17.38	-38.29	-9.88
3	21.6	8.86	11.35	10.28	10.13	12.81	29.52	11.82	-21.97	-13.82	-12.52	-30.82	-69.99	-25.03
4	17.1	13.04	15.49	13.48	13.56	16.56	18.97	15.12	-15.83	-3.27	-3.81	-21.26	-31.25	-13.76
5	16.6	13.37	16.12	13.95	14.07	17.11	18.43	15.60	-17.04	-4.18	-4.96	-21.86	-27.46	-14.30
6	13.4	18	21.43	17.89	18.38	21.65	13.11	19.55	-15.99	0.63	-2.05	-16.88	37.26	-7.95
7	10	24	31.62	25.12	26.48	29.88	9.43	26.63	-24.11	-4.45	-9.36	-19.68	154.42	-9.86
8	14.8	16.75	18.77	15.94	16.23	19.41	14.24	17.61	-10.78	5.08	3.18	-13.71	17.63	-4.88
9	15.4	16.59	17.81	15.22	15.45	18.58	14.40	16.89	-6.84	8.99	7.39	-10.72	15.23	-1.75
10	25.1	6.44	9.30	8.64	8.40	10.86	42.54	10.09	-30.74	-25.44	-23.30	-40.69	-84.86	-36.16
11	17.3	12.56	15.25	13.30	13.36	16.35	19.80	14.94	-17.66	-5.57	-5.99	-23.18	-36.56	-15.91
12	19.8	10.18	12.75	11.37	11.29	14.09	25.18	12.95	-20.14	-10.49	-9.83	-27.77	-59.58	-21.41
13	19.4	11.1	13.10	11.65	11.58	14.41	22.81	13.24	-15.26	-4.68	-4.15	-22.99	-51.33	-16.14
14	16.3	16.27	16.51	14.25	14.39	17.46	14.72	15.90	-1.46	14.16	13.05	-6.80	10.52	2.30
15	7.5	34	46.36	35.07	37.92	41.00	6.33	36.06	-26.67	-3.05	-10.33	-17.08	437.06	-5.72
16	20.6	10.15	12.09	10.86	10.74	13.49	25.27	12.42	-16.07	-6.56	-5.54	-24.78	-59.83	-18.30

17	24.6	6.28	9.55	8.84	8.61	11.10	43.79	10.30	-34.25	-28.97	-27.07	-43.43	-85.66	-39.05
18	20.3	10.16	12.33	11.05	10.94	13.71	25.24	12.62	-17.61	-8.04	-7.16	-25.91	-59.75	-19.48
19	16.4	15.9	16.38	14.15	14.28	17.34	15.11	15.80	-2.92	12.36	11.33	-8.30	5.20	0.62
20	13.1	19.5	22.08	18.36	18.90	22.20	11.96	20.03	-11.69	6.19	3.15	-12.17	62.98	-2.63
21	14.5	17.97	19.29	16.32	16.65	19.85	13.14	17.99	-6.85	10.09	7.90	-9.49	36.77	-0.13
22	22.5	7.81	10.75	9.81	9.62	12.25	34.11	11.32	-27.38	-20.35	-18.85	-36.22	-77.11	-31.01
23	16.5	14.69	16.25	14.05	14.17	17.22	16.55	15.70	-9.58	4.54	3.64	-14.71	-11.23	-6.44
24	21.8	8.75	11.22	10.17	10.01	12.68	29.95	11.70	-21.99	-13.98	-12.60	-30.98	-70.78	-25.24
25	13	22	22.31	18.53	19.09	22.39	10.42	20.19	-1.38	18.74	15.27	-1.74	111.10	8.97
26	14.2	18	19.84	16.72	17.09	20.32	13.11	18.39	-9.26	7.63	5.30	-11.40	37.26	-2.14
27	26.5	5.65	8.65	8.11	7.85	10.23	49.42	9.53	-34.69	-30.34	-28.00	-44.76	-88.57	-40.69
28	11.3	22.8	26.88	21.80	22.73	26.12	10.00	23.41	-15.17	4.59	0.29	-12.71	127.91	-2.59
29	21	9.06	11.79	10.62	10.49	13.21	28.78	12.17	-23.14	-14.71	-13.63	-31.42	-68.52	-25.58
30	16.2	16	16.65	14.35	14.50	17.58	15.01	16.01	-3.89	11.47	10.33	-8.96	6.62	-0.05

Chapter Four
Data Analysis

4.1 General

Regression analysis is a statistical technique for modeling and investigating the relationship between two or more variables. Many problems in engineering and science involve exploring and making use of the relationships between two or more variables. Regression analysis may take the form linear, parabolic, logarithmic etc depending on the trend that may exist between the dependent and independent variables.

Regression analysis divided into either simple regression or multiple regression analysis pertinent to the number of variables involved in the system. A regression model that contains more than one regressor variable is called multiple regression model. Alternatively, a regression model containing one independent variable or regressor is termed as simple regression model.

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).

The development and subsequent Fitting of 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. 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. This is indeed fundamental assumption of any tests of hypothesis and interval estimation. [12].

4.2 Scatter Plot

For the purpose of this thesis, the CBR value is the dependent variable where as DCP is the regressor variable. In carrying out the whole statistical analysis, a statistical software program called SPSS software was used.

Using the thirty laboratory and field test results the relationship between CBR and DCP CBR was studied. In order to study the relationship existing between the two variables, first a diagram called scatter diagram is applied. It can be defined as a visual method used to display the relationship between two variables.

The scatter plot of the dependent variable (CBR) and the regressor variable (DCP) are shown in Figure 4.1 below.

Dynamic Cone Penetration Index Vs CBR

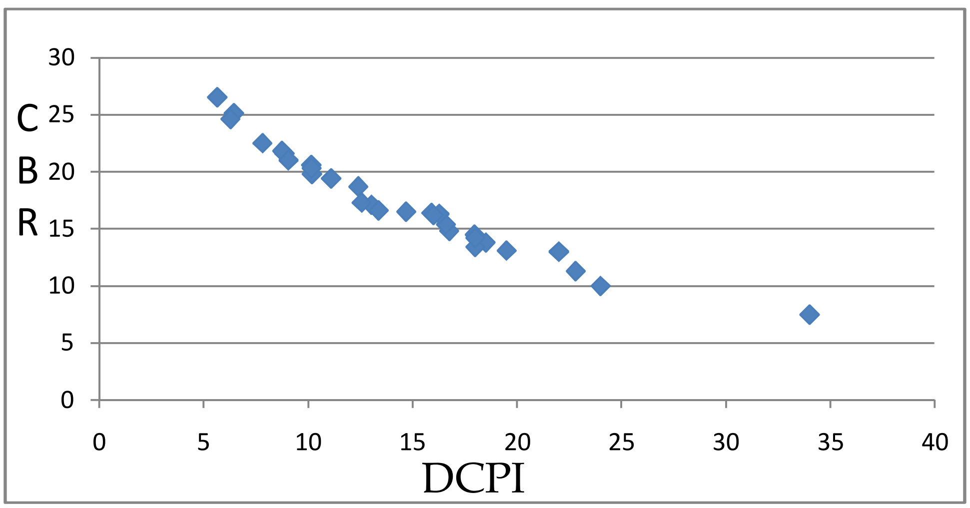


Fig 4.1 Scatter Plot of Penetration Index Vs CBR

The scatter diagram is a graph on which each dependent variable (CBR) and the regressor variable (DCPI) is represented as a point plotted in a two-dimensional coordinate system. The above scatter diagram was produced by making use of the excel spreadsheet, by selecting an option that shows dot diagrams of the (DCPI) and (CBR) making it easy to see the distributions of the individual variables. Inspection of the above scatter diagrams indicate that, although no simple curve will pass exactly through all the points, there is a reasonable indication that the points are randomly scattered in exponential pattern.

Thus, from the above scatter plot, it can be construed that a linear correlation does not exist between the dependent and the independent variable.

For this thesis, the relationship between the dependent and independent variables, based on the above discussions and results of past studies is approximated by logarithmic regression models of the following form.

log (CBR) = a + b log (DCPI)

Where:-

DCPI = the independent variables (regressors)

a and b = coefficients of the independent variables

CBR = the response (dependent variable)

4.3 Regression Analysis

As discussed in section 4.2, statistical software called SPSS is employed to study the relation between the regressor variables and the response to be predicted and the analysis is presented in this section. Accordingly, the following result is observed

log (CBR) = 2.954 – 1.496log (DCPI) with R^2 = 0.943 (n=30)

The details of the output of the SPSS software analysis have also been shown in the tables below

Table 4.1 Results of regression analysis between CBR and DCPI

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.971	.943	.941	.045

The independent variable is LOGDCPI.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.955	1	.955	465.607	.000
Residual	.057	28	.002		
Total	1.012	29			

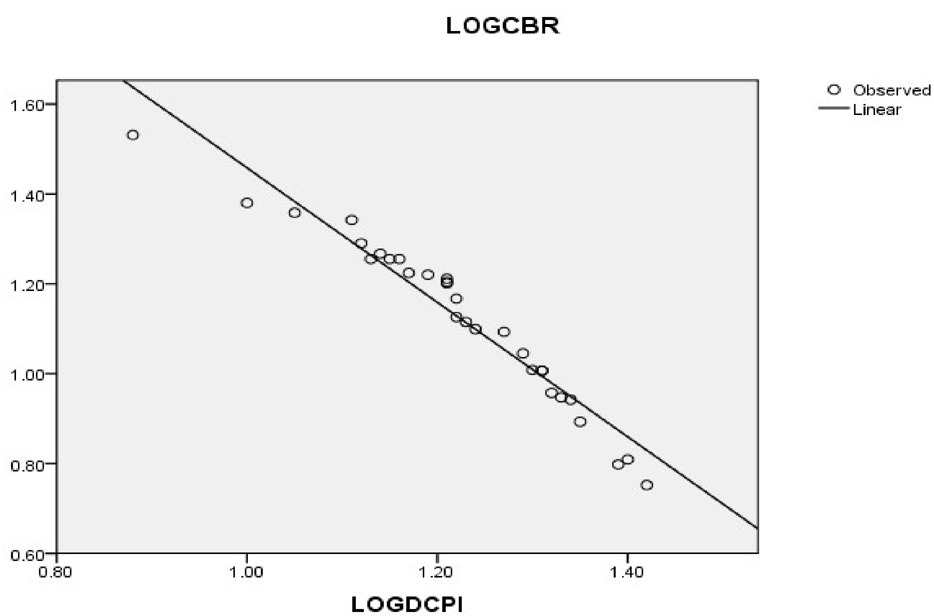
Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.971	.943	.941	.045

The independent variable is LOGDCPI.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
LOGDCPI	-1.496	.069	-.971	-21.578	.000
(Constant)	2.954	.085		34.691	.000



4 .4 Comparisons between the Existing and the Developed Equations

Comparisons have been made between the newly developed correlation and the most commonly used correlation in our country (TRL, Overseas Road Note 8) CBR values in Table 4.2. From the comparison it is observed that the newly developed correlation yields a lower CBR value than TRL, Overseas Road Note 8 correlation.

The laboratory and field test results used for the development of the new correlation is conducted on fine grained soil (clay soil). Whereas, the TRL, Overseas Road Note 8 correlation is developed using laboratory and field test results conducted on coarse and fine grained soils and applicable for both types of soils. Furthermore, coarse grained soils usually have higher CBR values when compared to fine grained soils. Thus, it is due to these reasons that the CBR values obtained by the new correlation is lower than the CBR values obtained from TRL, Overseas Road Note 8 correlation.

Table 4.2 Comparisons among Laboratory measured, newly developed and TRL, Overseas Road Note correlations CBR values

Sr.No.	DCPI	Actual CBR value	Computed CBR value using		Variation of TRL, Overseas Road Note 8 output from actual CBR (%)	Variation of TRL, Overseas Road Note 8 output from Newly Developed Formula output (%)
			New Correlation	TRL, Overseas Road Note 8 correlation		
			Log CBR=2.954-1.496Log DCPI	Log CBR=2.48 - 1.057 Log DCPI		
1	13	18.	17.73	19	1.8	-6
2	18	12.	11.25	14	9.3	-21
3	21	8.8	9.07	12	24.5	-29
4	17	13.	12.87	15	13.2	-17
5	16	13.	13.45	16	13.7	-15
6	13	18	18.53	19	7.4	-5
7	10	24	28.71	26	9.4	8
8	14	16.	15.97	17	4.3	-10
9	15	16.	15.05	17	1.1	-12
10	25	6.4	7.25	10	35.7	-38
11	17	12.	12.64	15	15.4	-17
12	19	10.	10.33	13	20.9	-25
13	19	11.	10.65	13	15.6	-23
14	16	16.	13.82	16	-3.0	-14
15	7.	34	44.15	36	5.3	19
16	20	10.	9.74	12	17.7	-27
17	24	6.2	7.47	10	38.6	-37
18	20	10.	9.95	13	18.9	-26
19	16	15.	13.70	16	-1.3	-15
20	13	19.	19.17	20	2.1	-4
21	14	17.	16.47	18	-0.5	-9
22	22	7.8	8.53	11	30.5	-32
23	16	14.	13.57	16	5.8	-15
24	21	8.7	8.95	12	24.7	-30
25	13	22	19.39	20	-9.6	-4
26	14	18	16.99	18	1.5	-8
27	26	5.6	6.68	9	40.2	-42
28	11	22.	23.91	23	2.0	3
29	21	9.0	9.46	12	25.1	-28
30	16	16	13.95	16	-0.6	-14

Chapter Five
Conclusions and Recommendations

5.1 Conclusions

The results of the statistical analysis show that good correlation does exist between the dynamic cone penetration indexes (DCPI) and unsoaked California Bearing Ratio (CBR) values. The relation obtained from statistical analysis has R^2 of 0.943 and is shown below.

$$\log(CBR) = 2.954 - 1.496\log(DCPI) \text{ with } R^2 = 0.943$$

Thus, the result of this study suggests that the correlation can be reliably used to predict unsoaked CBR values from field dynamic cone penetration test. However, care should have to be made while using the formula as the CBR values obtained from the correlation indicates the insitu CBR value at the time of testing rather than the CBR values at the worst condition (Soaked CBR). Nevertheless, it can be used directly at any time for the delineation of the area into homogeneous sections.

Comparison has also been made between the estimated CBR values obtained from the relation proposed in this study and, TRL, Overseas Road Note 8, the most commonly used relationship in our country. The results of comparison showed that the actual CBR values determined in the laboratory exhibits lower deviation when compared with the CBR values obtained from DCP– CBR relation proposed in this study than TRL, Overseas Road Note 8 relation.

Finally, comparison has also been made between DCP– CBR relation proposed in this study and some other works done by other researchers for soils of their locality. The results of comparison showed that the DCP– CBR relation proposed in this study has better resemblance with the relation suggested by Sampson for plasticity Index greater than six materials than the others.

5.2 Recommendations

1. The correlations developed in this study were developed for locally used sub grade soils. It is recommended that the applicability of the DCP– CBR relation proposed in this study for other pavement layers; sub base and base courses should be investigated.

2. The correlations developed in this study were using the CBR values at the time of testing i.e. the test conducted at the in situ density and moisture content rather than CBR values at the worst condition (soaked CBR). Hence, it may not be employed directly for design purpose unless the DCP be made when the soil is at its worst condition (saturated or partially saturated). Therefore, in order to use this correlation for design and/ or analysis directly it is recommended that future research on the strength reduction factor should be conducted.

3. The DCP– CBR relation proposed in this study was developed by conducting limited number of field and laboratory tests on limited location (part of western Ethiopia). Hence, it is recommended that its applicability for soils of similar type in other part of the country should be studied.

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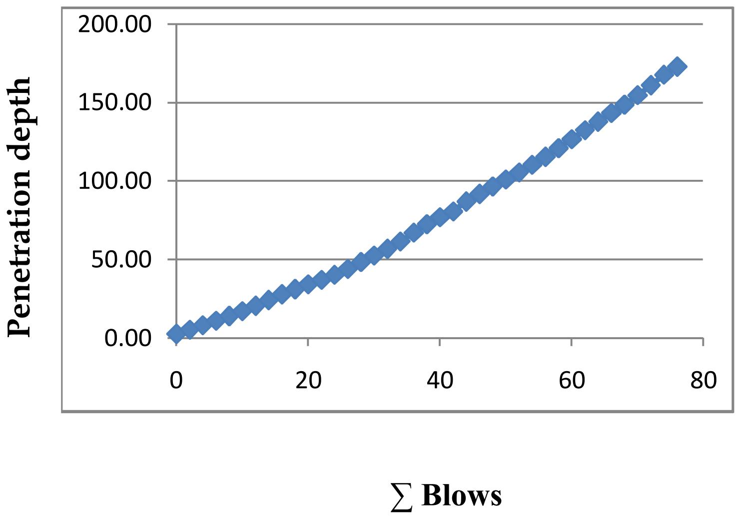
APPENDIXES

Plot of DCP Vs.∑ Blows

Section No/Chainage: 100+200
Direction: RHS
Penetration Depth Vs ∑ Blows



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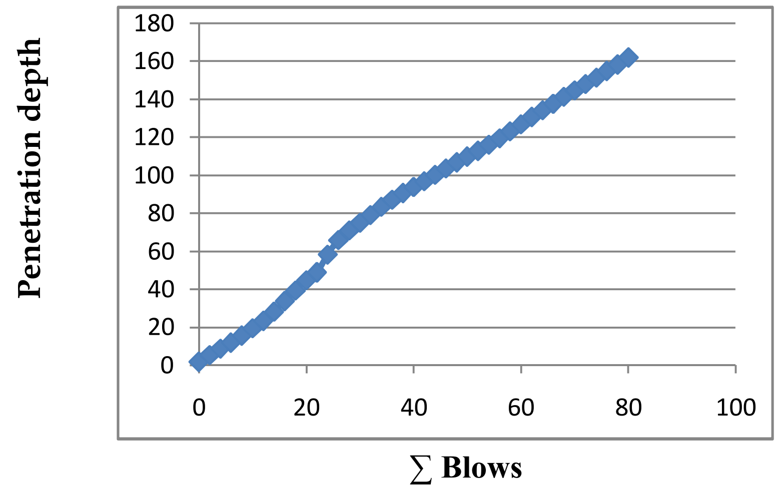

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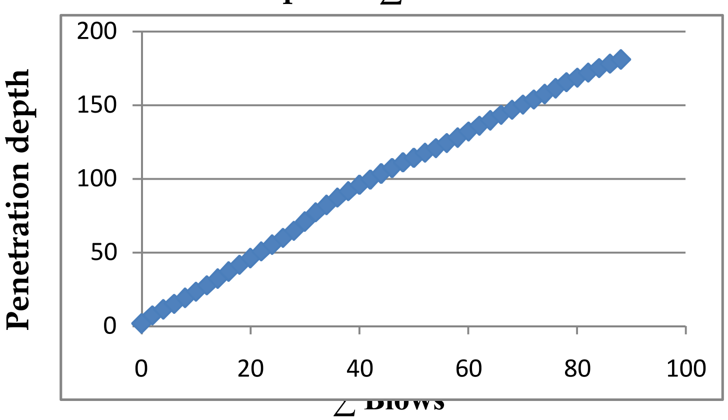
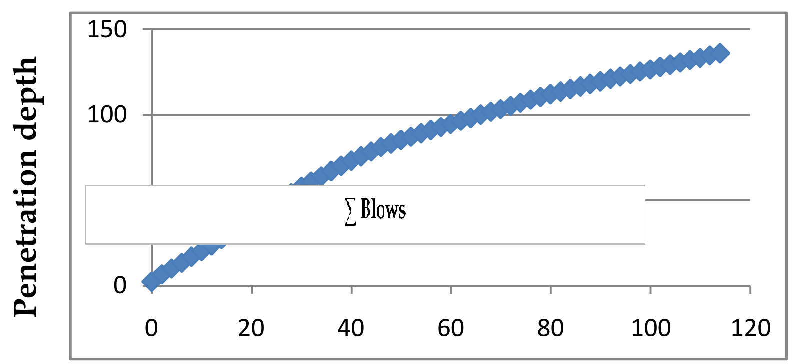


Section No/Chainage: 100+850
Direction: LHS

Penetration Depth Vs ∑ Blows



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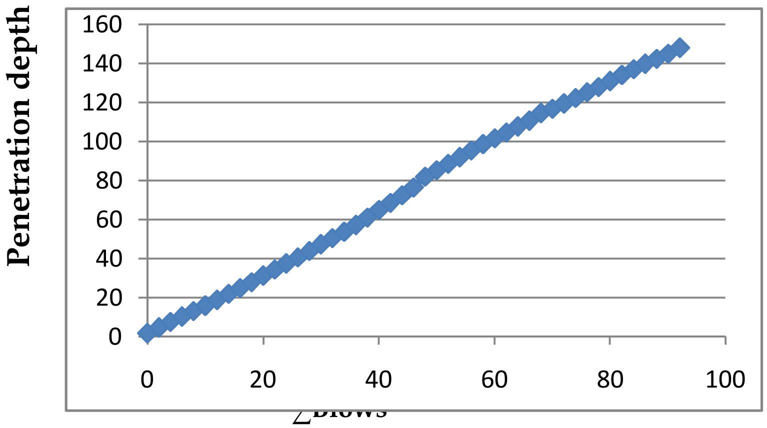

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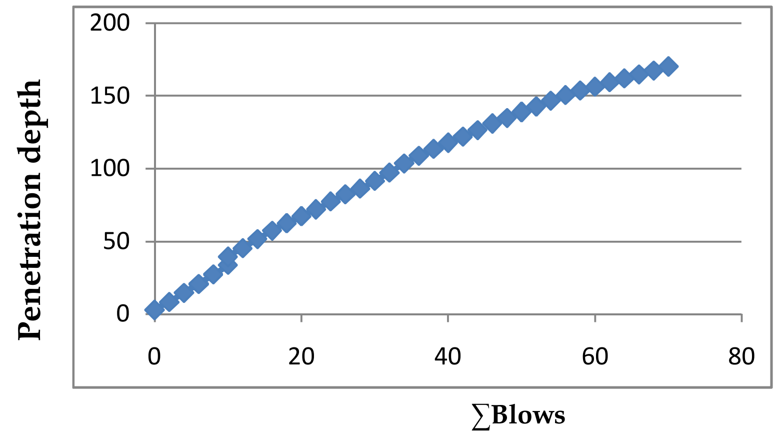

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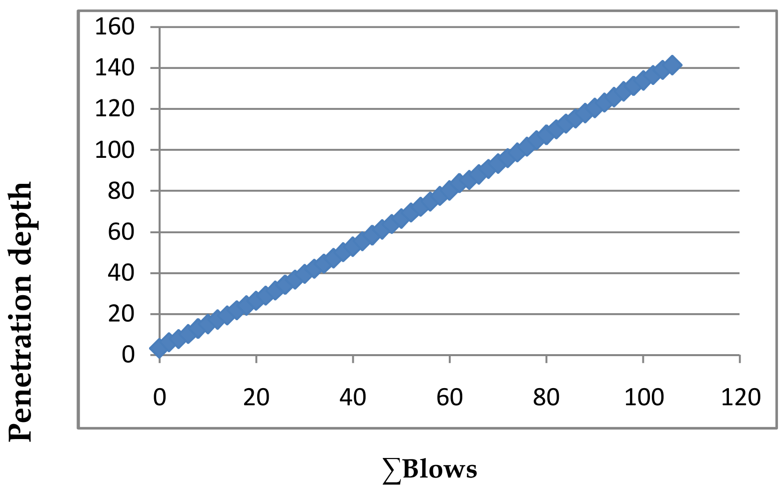

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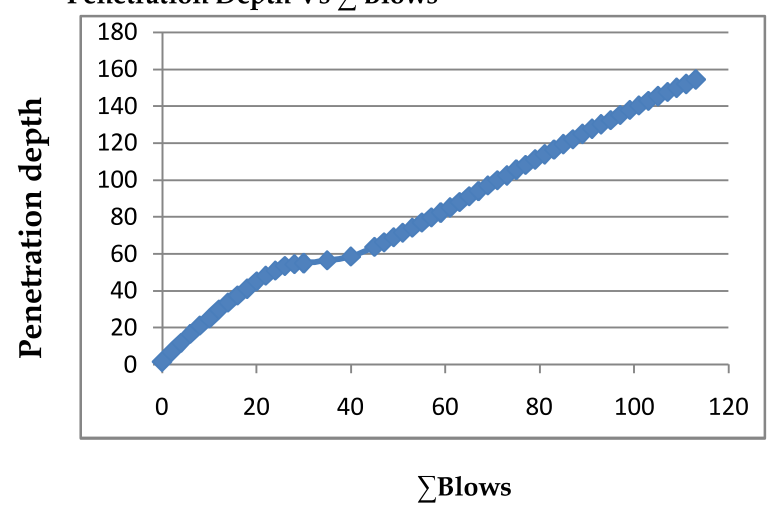
Penetration Depth Vs ∑ Blows



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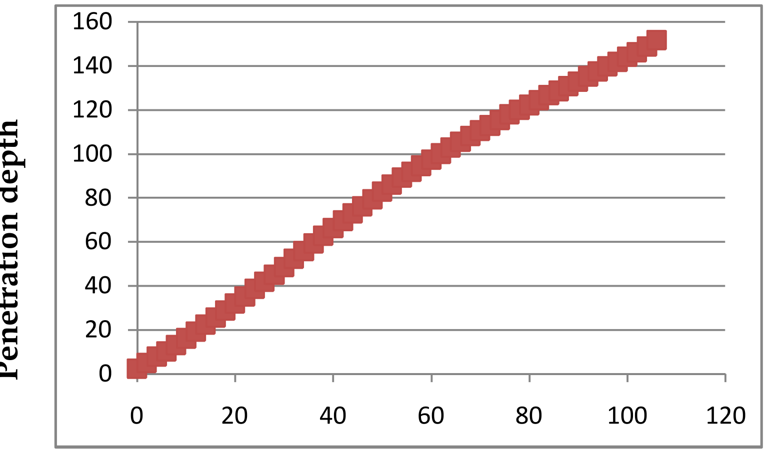

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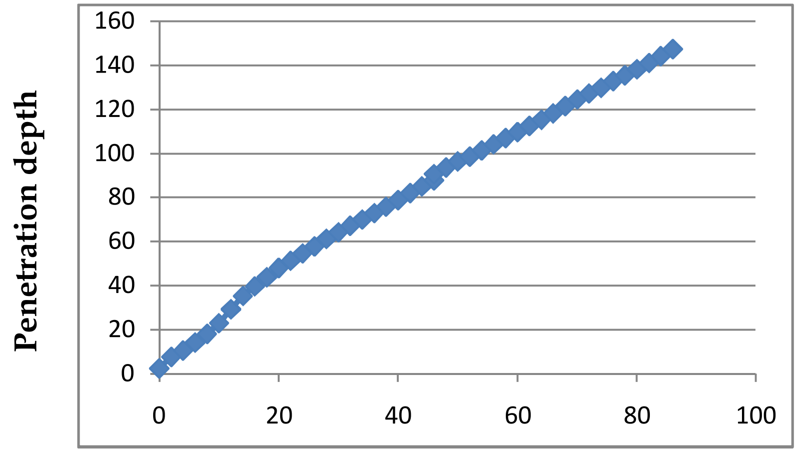

∑Blows ∑Blows

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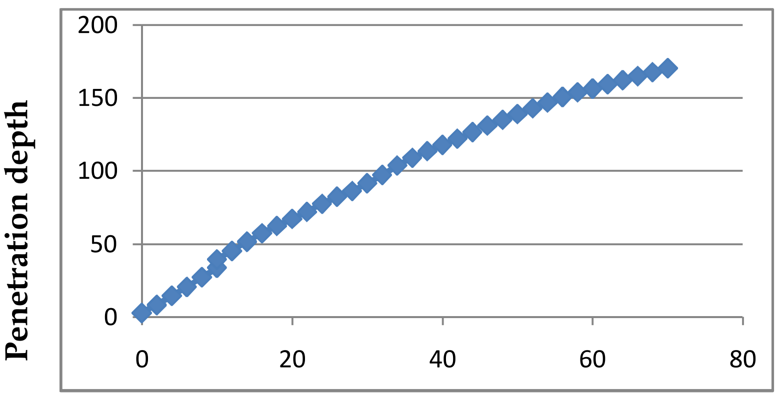
Direction: RHS
Penetration Depth Vs ∑ Blows



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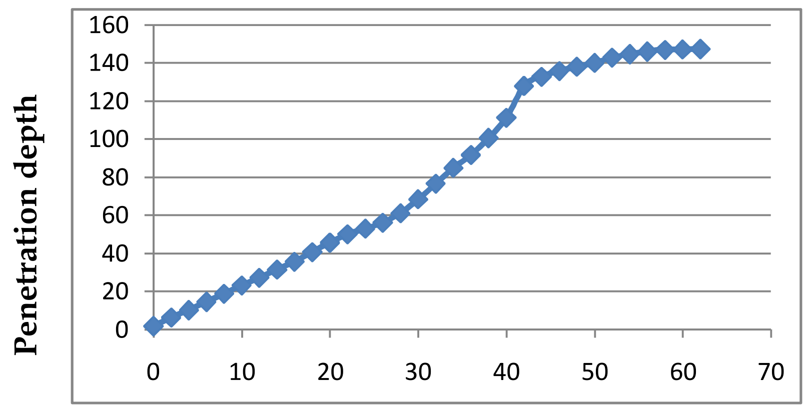
Penetration Vs∑ Blows



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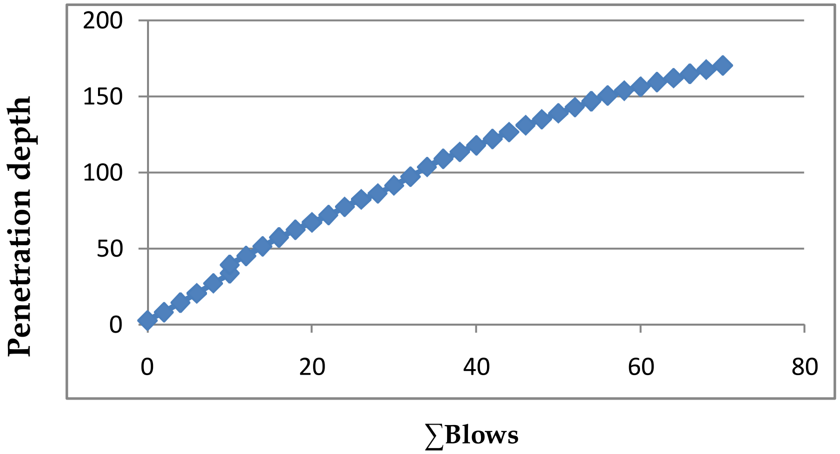

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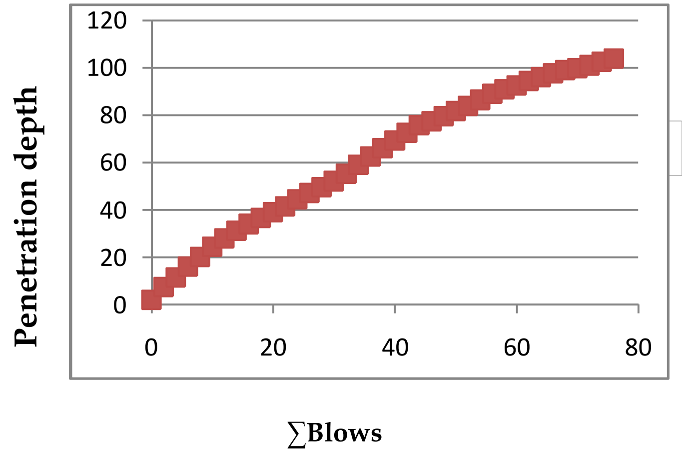

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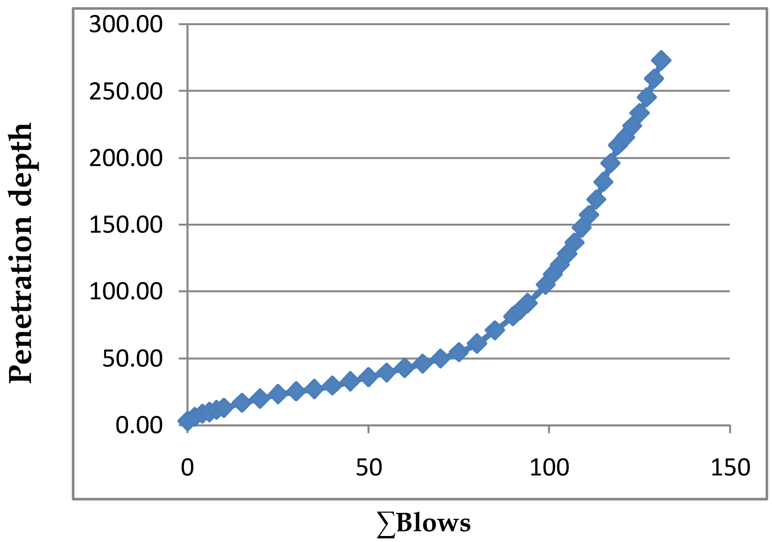

Direction: RHS

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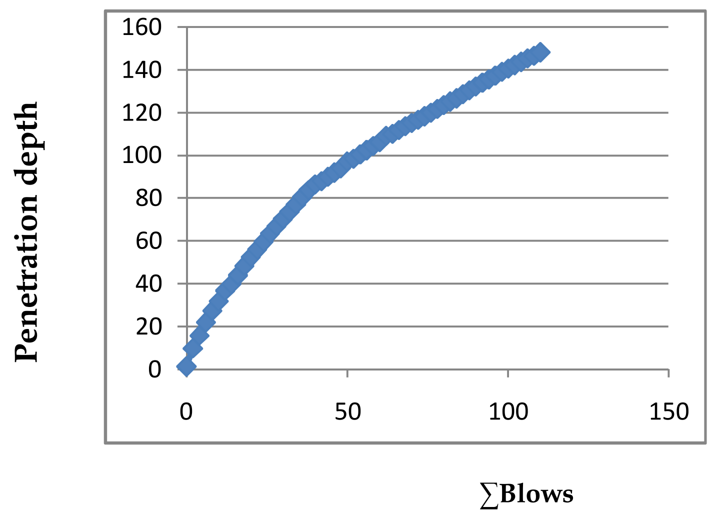
Penetration Depth Vs ∑Blows



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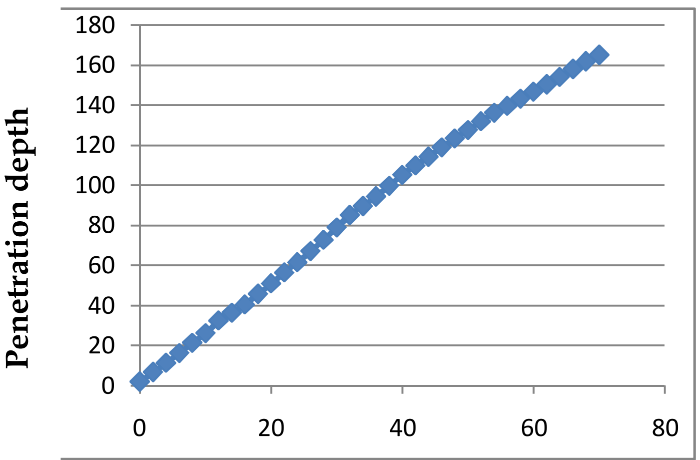

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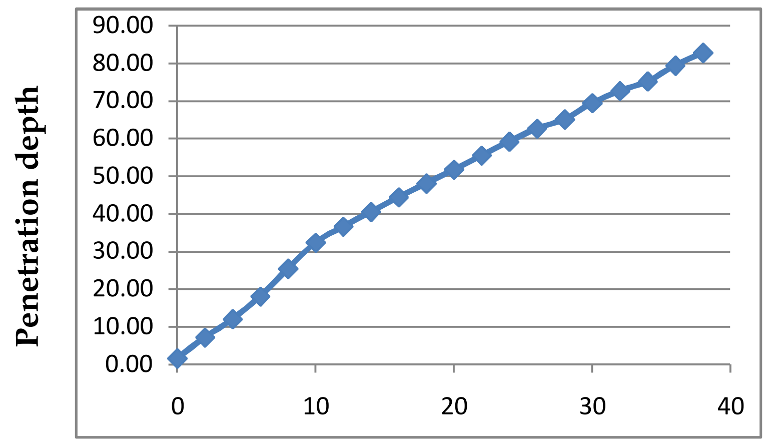
Penetration Depth ∑Blows



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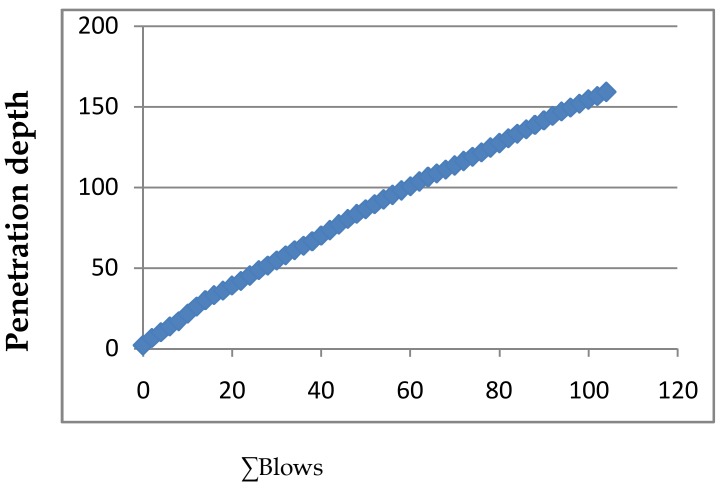

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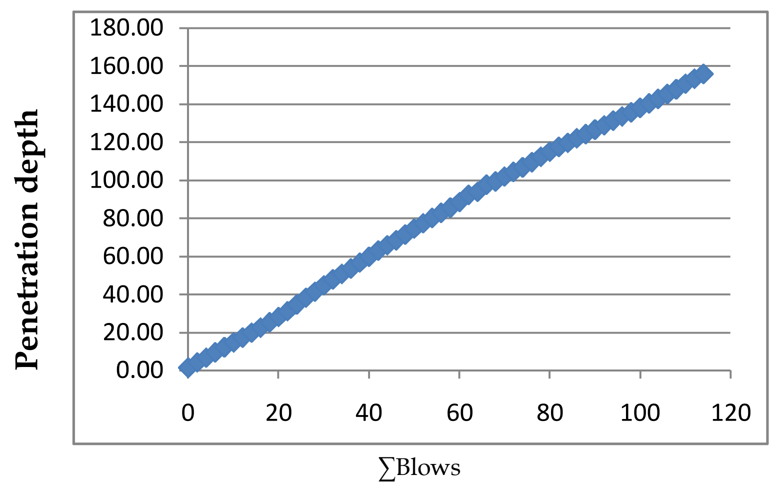

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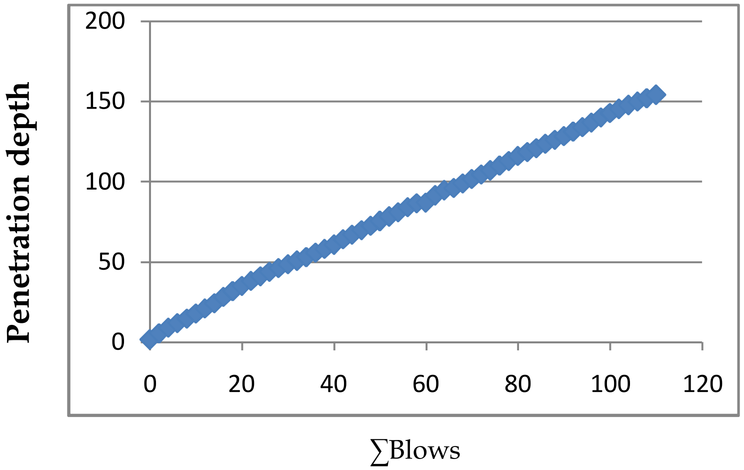

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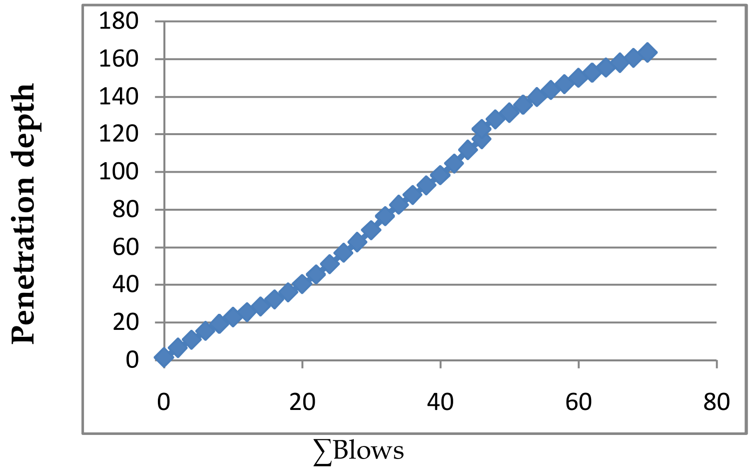

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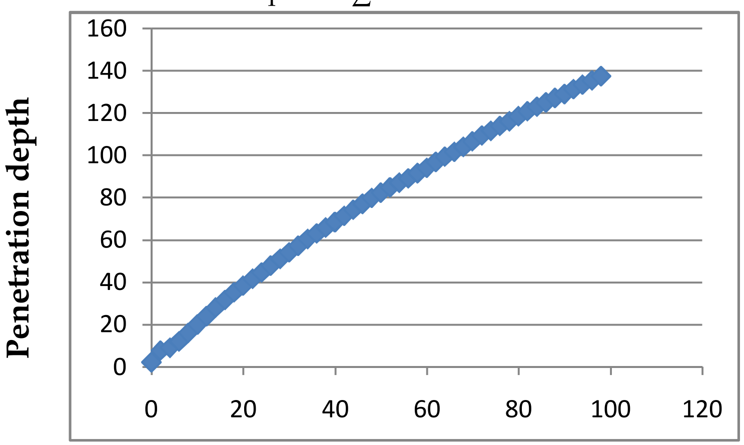

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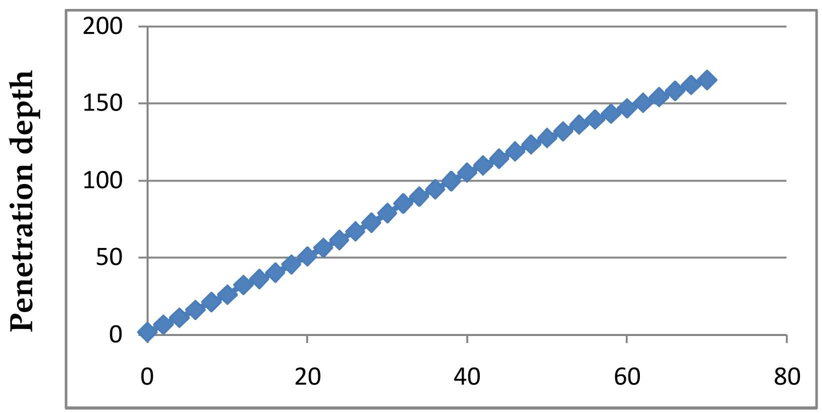

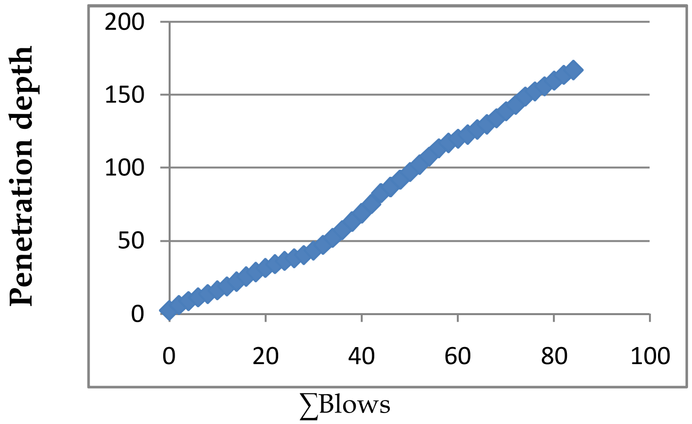

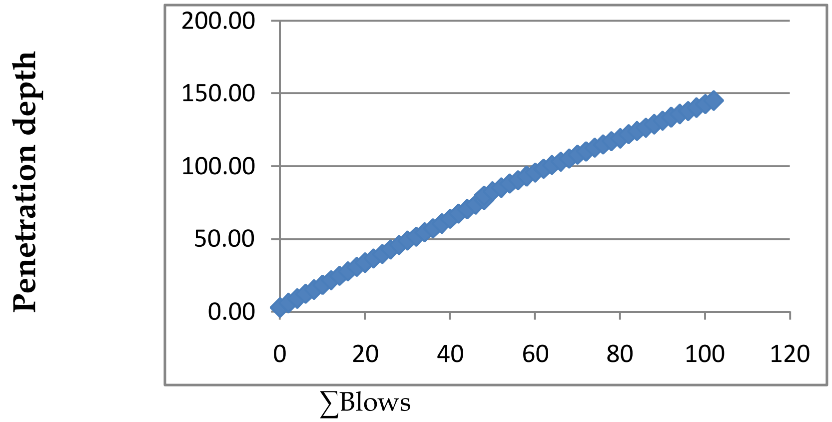

Section No/Chainage: 104+750
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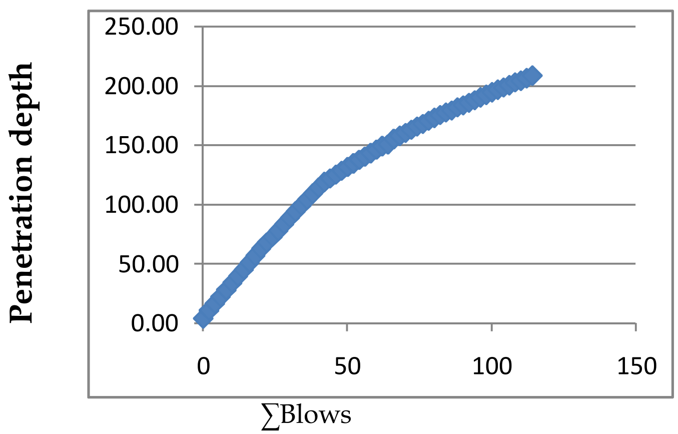
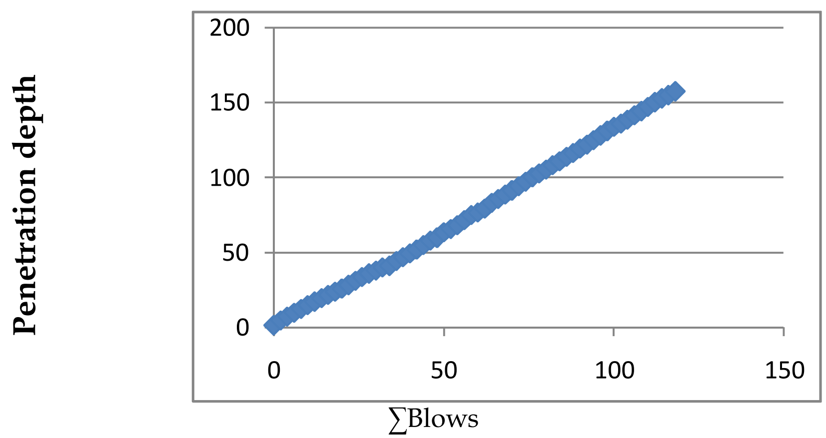
Penetration Depth Vs ∑ Blows

Section No/Chainage: 104+850
Direction: LHS
Penetration Depth Vs ∑ Blows

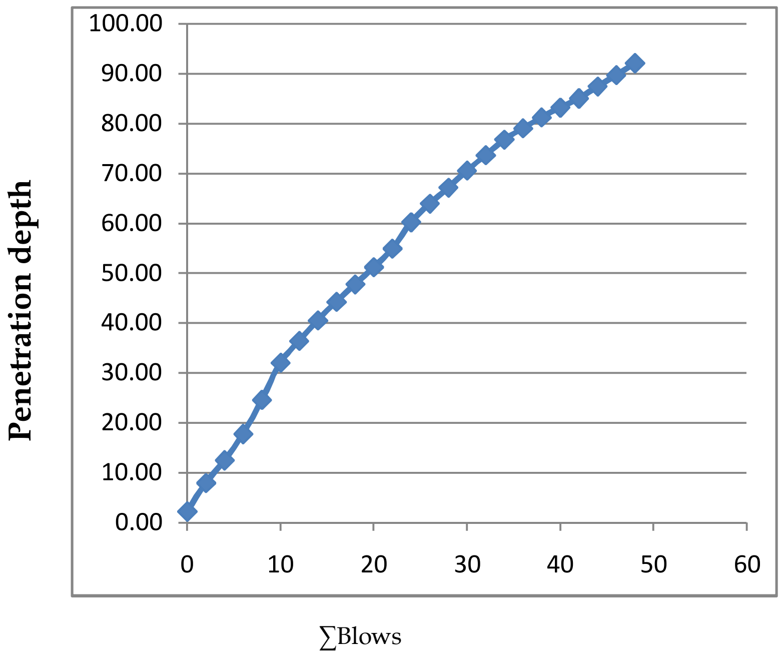




Section No/Chainage:104+950

Direction: RHS

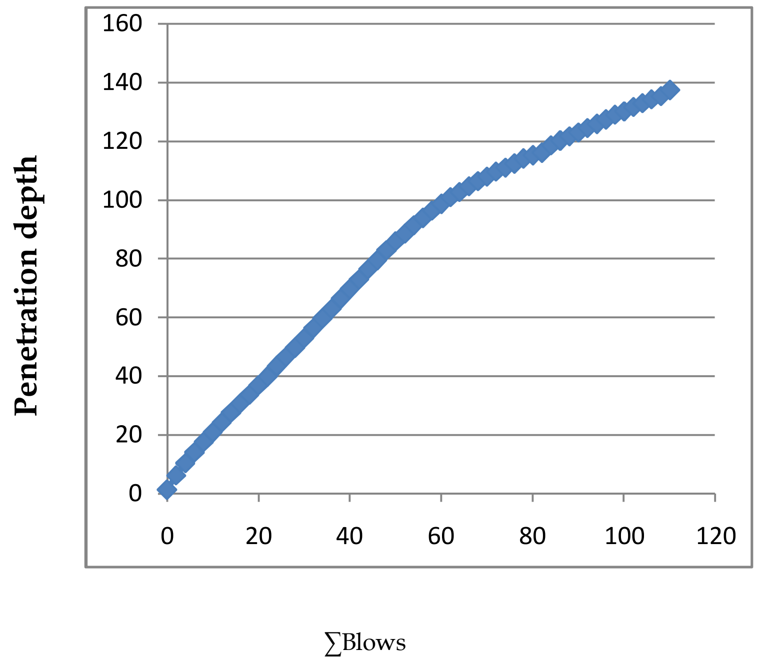
Penetration Depth Vs ∑ Blows



Section No/Chainage:105+050

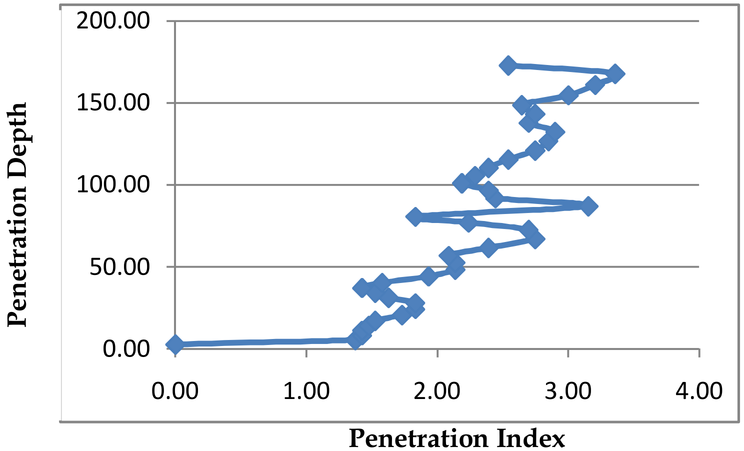
Direction: LHS

Penetration Depth Vs ∑ Blows

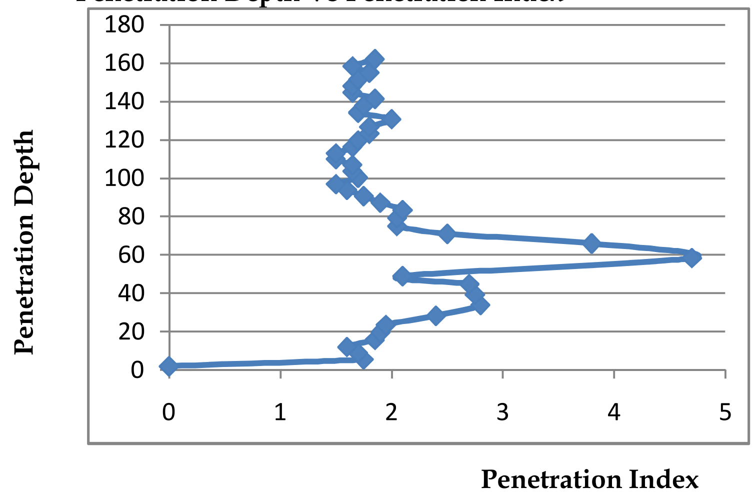


Plot of Dynamic Cone Penetration versus Dynamic Cone Penetration Index (DCP vs. DCPI)

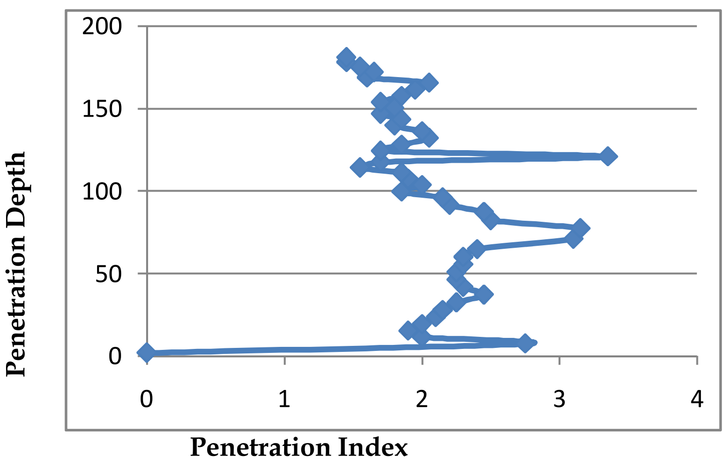
Section No/Chainage: 100+200
Direction: RHS
Penetration Depth Vs Penetration Index



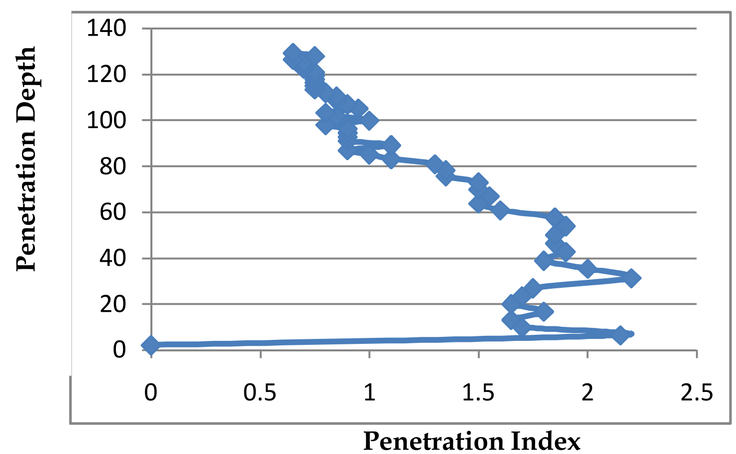
Section No/Chainage:100+420
Direction: LHS
Penetration Depth Vs Penetration Index

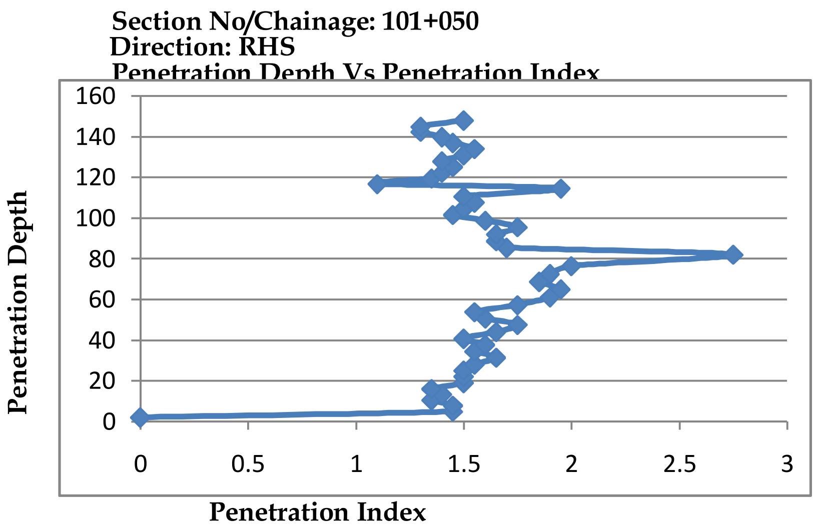


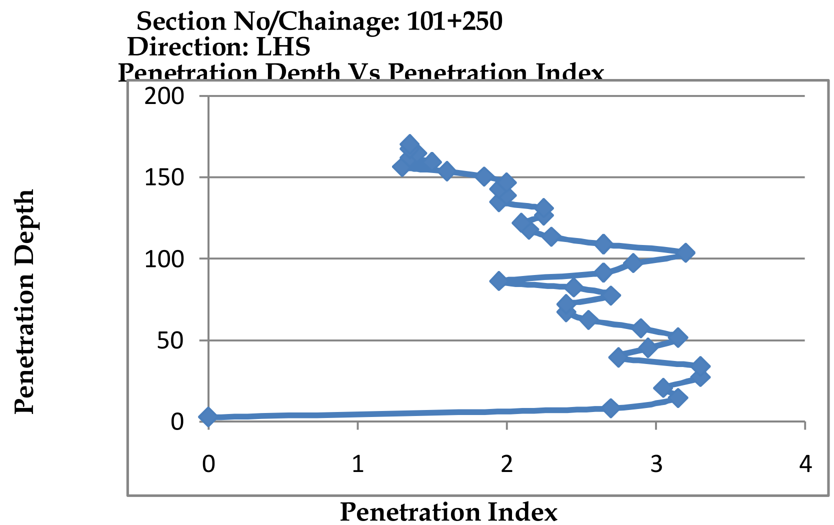
Penetration Depth Vs Penetration Index
Section No/Chainage: 100+600
Direction: RHS

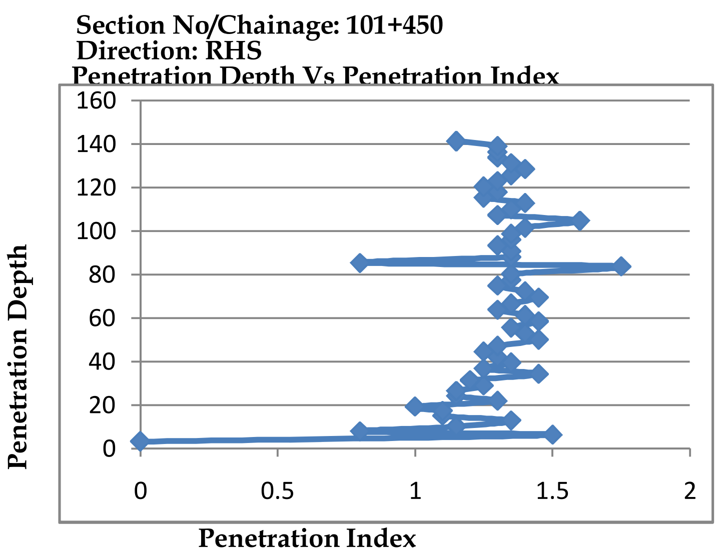


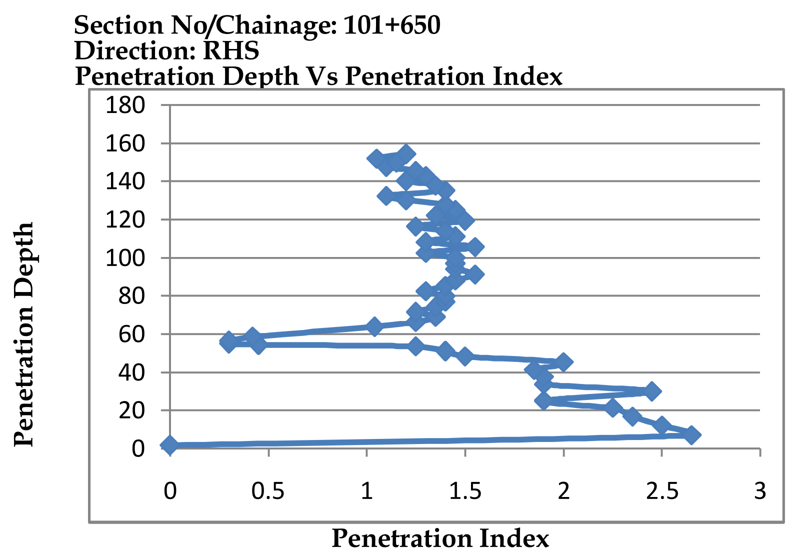
Penetration Depth Vs Penetration Index
Section No/Chainage:100+800
Direction: LHS



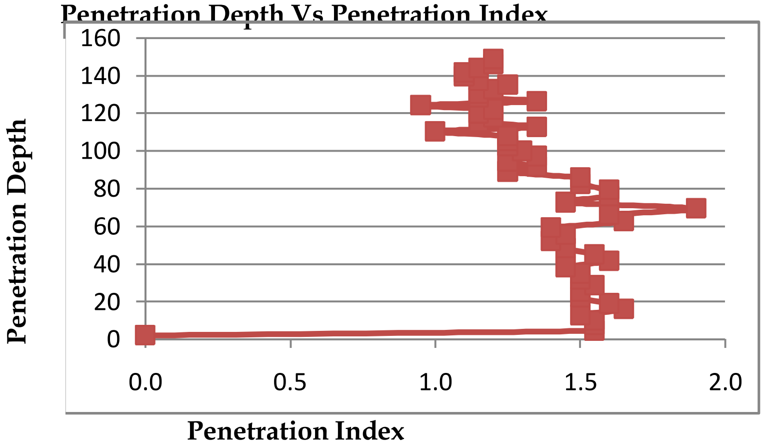

Section No/Chainage: 101+050
Direction: RHS
Penetration Depth Vs Penetration Index
Penetration Depth
Penetration Index
0
20
40
60
80
100
120
140
160
0
0.5
1
1.5
2
2.5
3


Section No/Chainage: 101+250
Direction: LHS
Penetration Depth Vs Penetration Index
Penetration Depth
Penetration Index
0
50
100
150
200
0
1
2
3
4

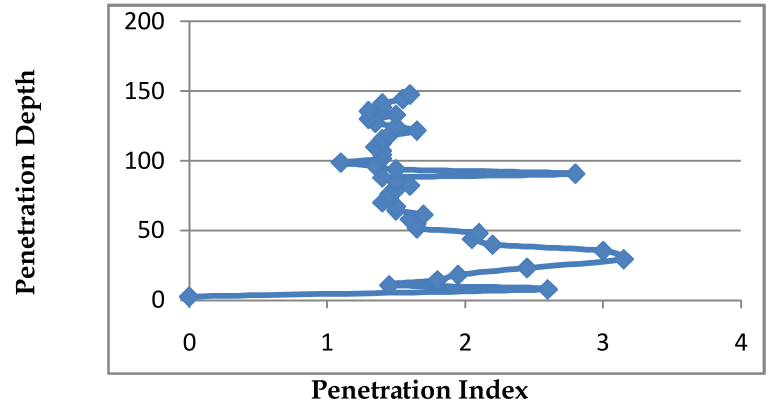

Section No/Chainage: 101+450
Direction: RHS
Penetration Depth Vs Penetration Index
Penetration Depth
Penetration Index
0
20
40
60
80
100
120
140
160
0
0.5
1
1.5
2


Section No/Chainage: 101+650
Direction: RHS
Penetration Depth Vs Penetration Index
Penetration Depth
Penetration Index
0
20
40
60
80
100
120
140
160
180
0
0.5
1
1.5
2
2.5
3

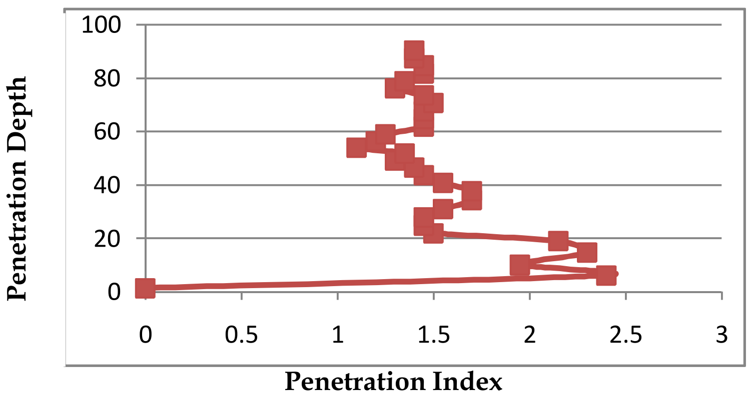
Section No/Chainage: 101+850
Direction:RHS
Penetration Depth Vs Penetration Index



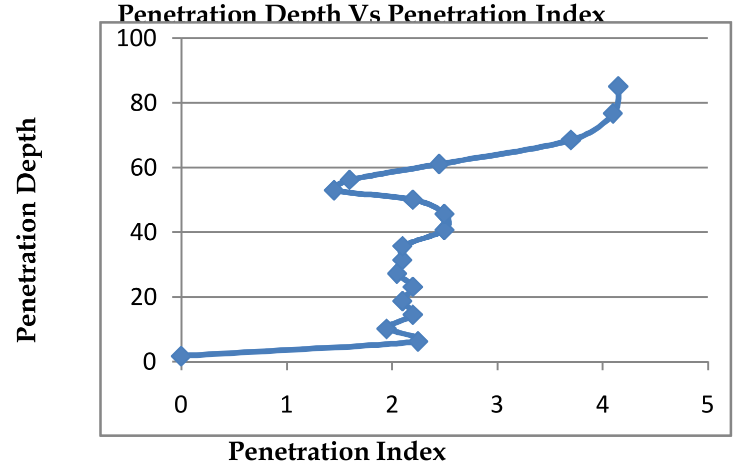
Section No/Chainage: 102+050
Direction: LHS
Penetration Depth Vs Penetration Index



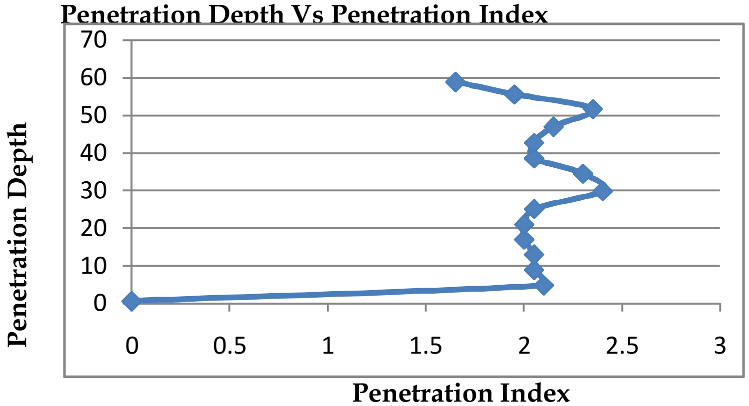
Section No/Chainage: 102+250
Direction: RHS
Penetration Depth Vs Penetration Index



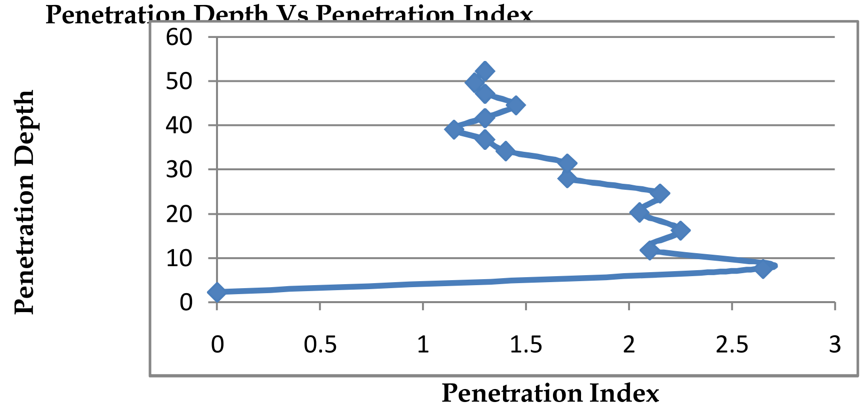
Section No/Chainage: 102+650
Direction: LHS
Penetration Depth Vs Penetration Index



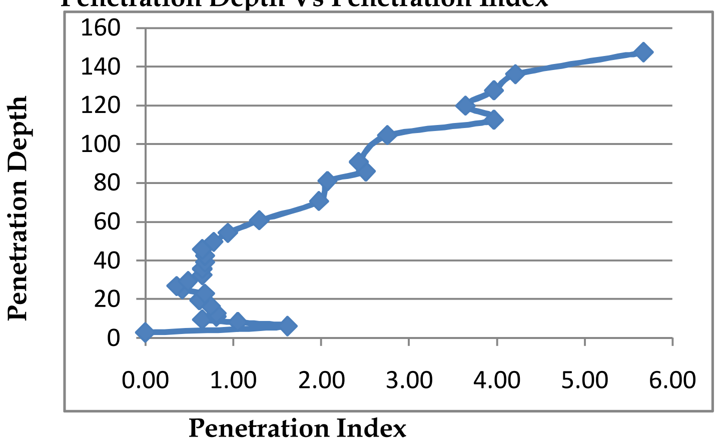
Section No/Chainage: 102+850
Direction: RHS
Penetration Depth Vs Penetration Index



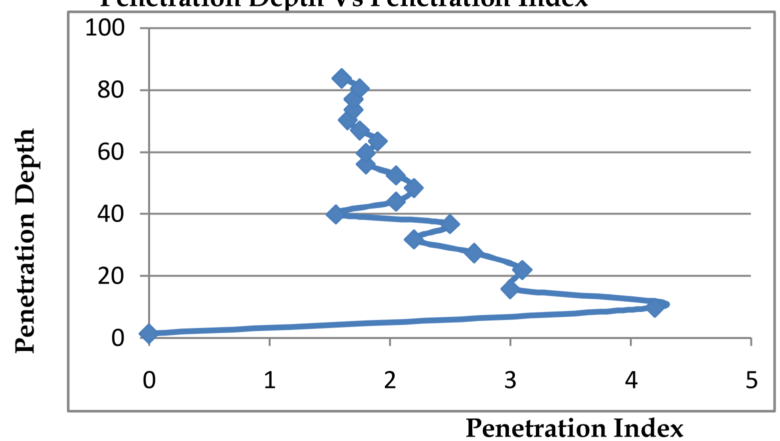
Section No/Chainage: 103+050
Direction: LHS
Penetration Depth Vs Penetration Index



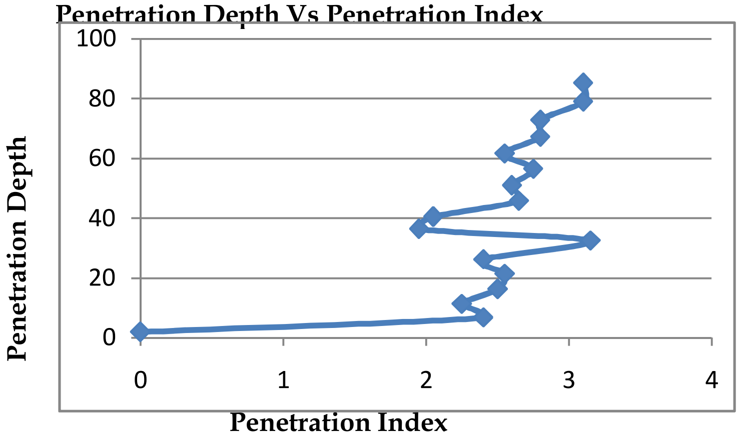
Section No/Chainage: 103+250
Direction: RHS
Penetration Depth Vs Penetration Index



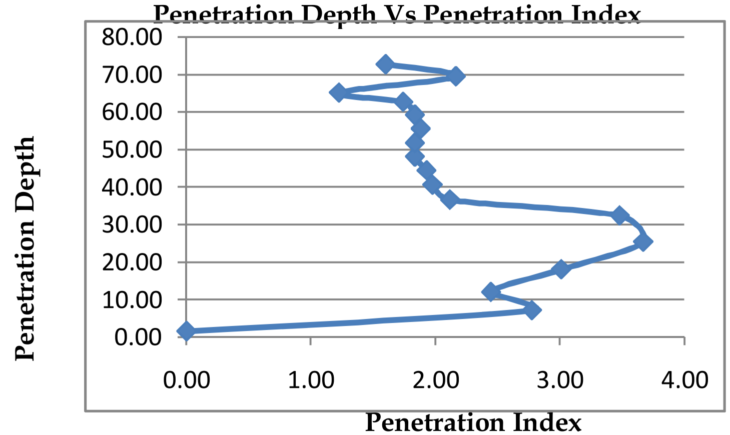
Section No/Chainage: 103+450
Direction: LHS
Penetration Depth Vs Penetration Index



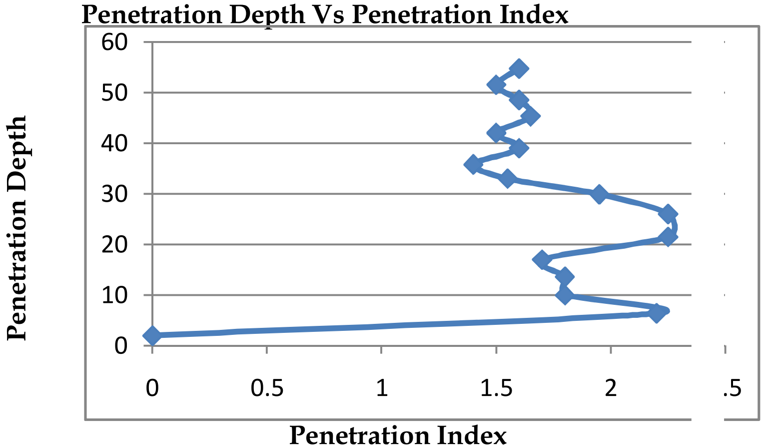
Section No/Chainage: 103+650
Direction: RHS
Penetration Depth Vs Penetration Index



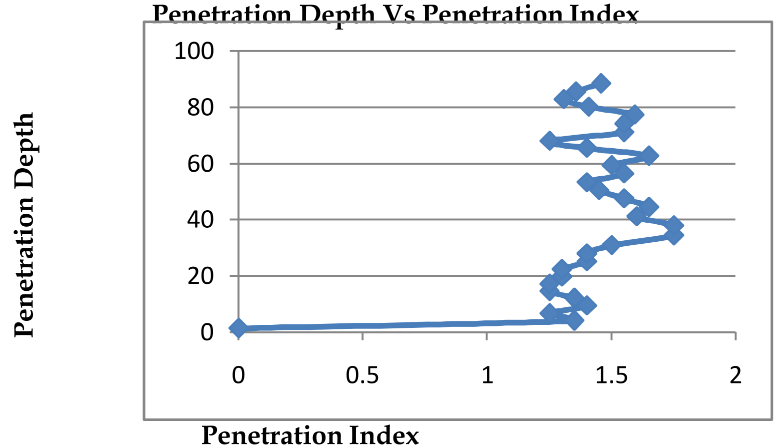
Section No/Chainage: 103+850
Direction: LHS
Penetration Depth Vs Penetration Index



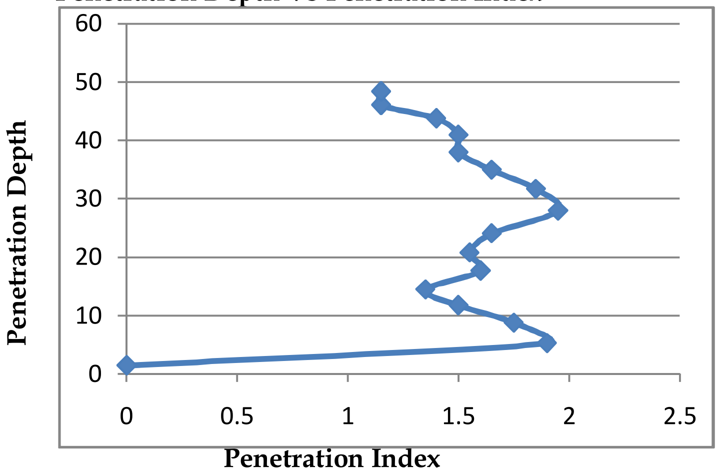
Section No/Chainage: 103+950
Direction: LHS
Penetration Depth Vs Penetration Index



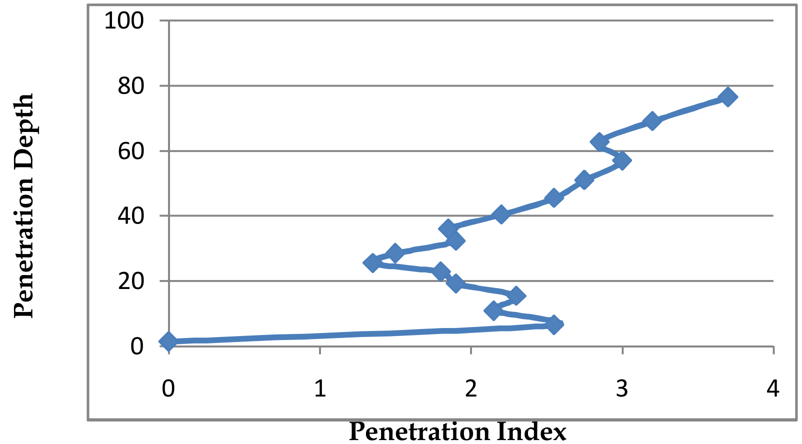
Section No/Chainage: 104+050
Direction: RHS
Penetration Depth Vs Penetration Index



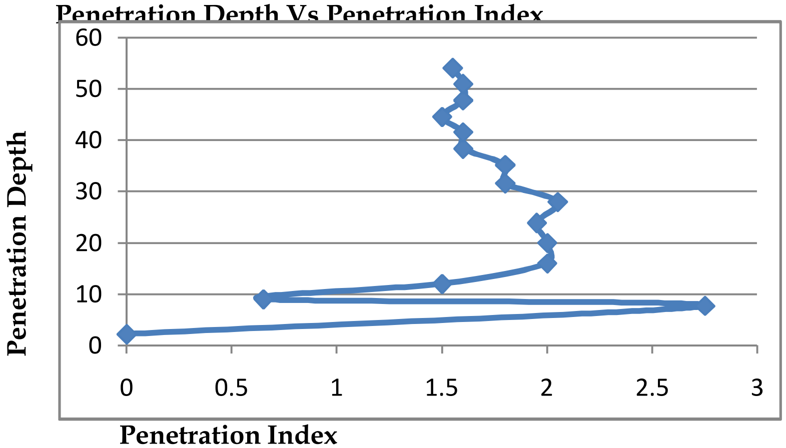
Section No/Chainage: 104+150
Direction: RHS
Penetration Depth Vs Penetration Index



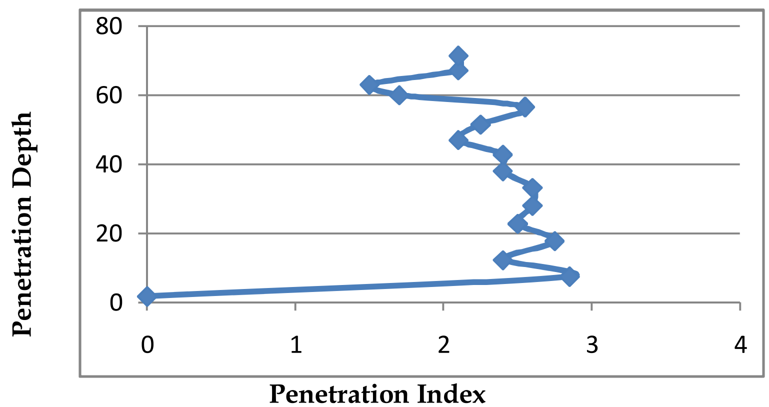
Section No/Chainage: 104+250
Direction: LHS
Penetration Depth Vs Penetration Index



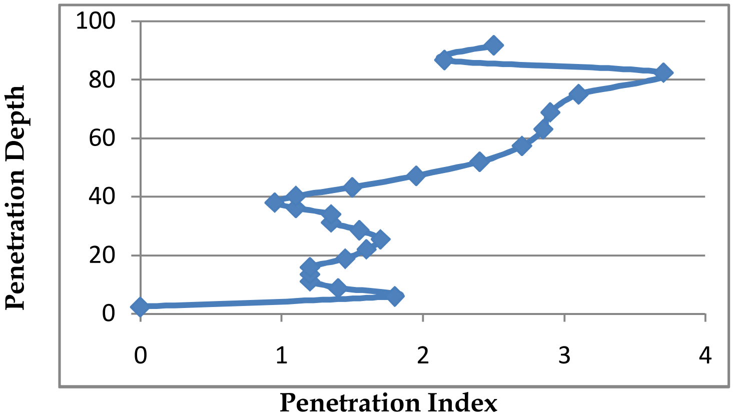
Section No/Chainage: 104+350
Direction: RHS
Penetration Depth Vs Penetration Index



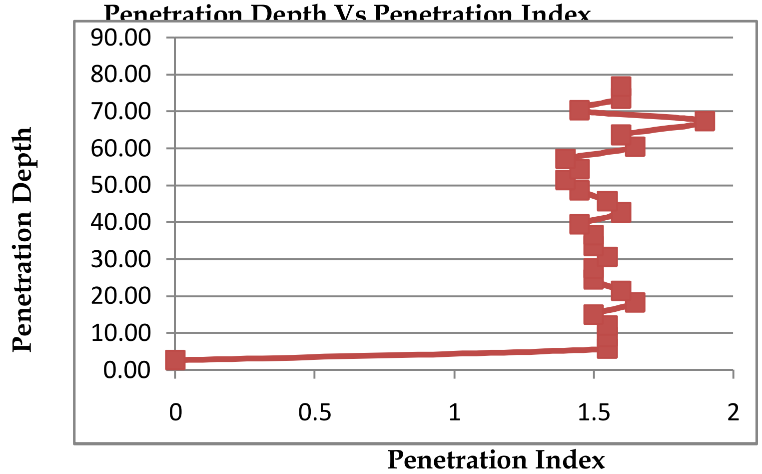
Section No/Chainage: 104+450
Direction: LHS
Penetration Depth Vs Penetration Index



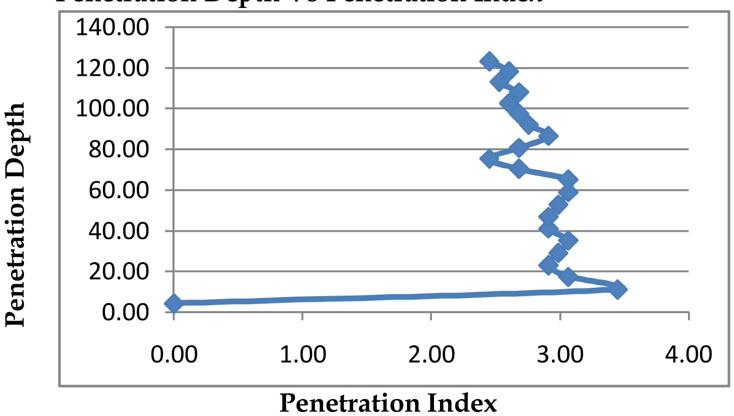
Section No/Chainage: 104+550
Direction: RHS
Penetration Depth Vs Penetration Index



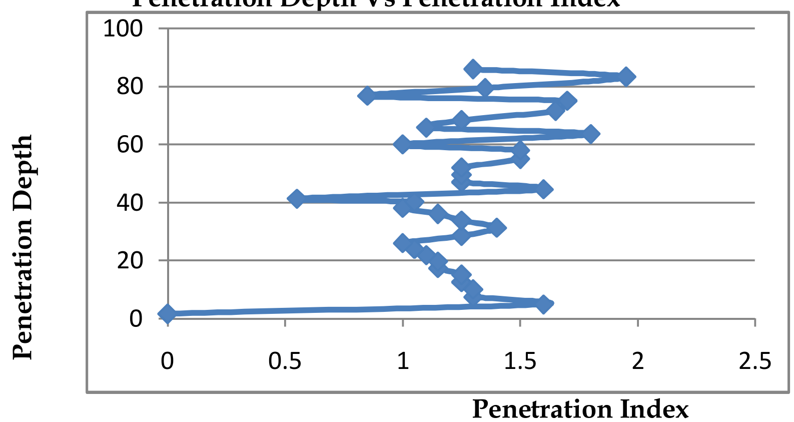
Section No/Chainage: 104+650
Direction: LHS
Penetration Depth Vs Penetration Index



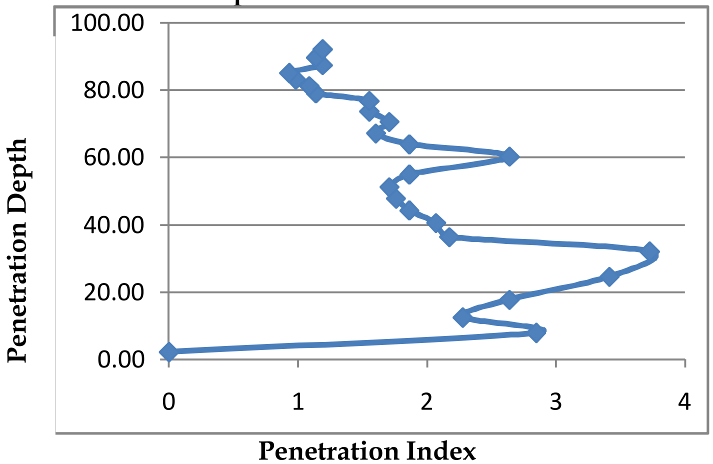
Section No/Chainage: 104+750
Direction: RHS
Penetration Depth Vs Penetration Index



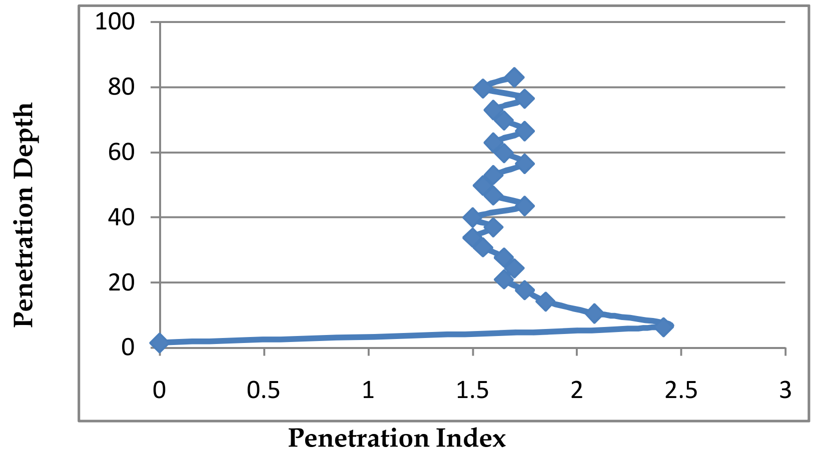
Section No/Chainage: 104+850
Direction: LHS
Penetration Depth Vs Penetration Index



Section No/Chainage: 104+950
Direction: RHS
Penetration Depth Vs Penetration Index



Section No/Chainage: 105+050
Direction: LHS
Penetration Depth Vs Penetration Index



California Bearing Ratio Test Results (CBR)

UNSOAKED CALIFORNIA BEARING RATIO

Ring Factor: 21.48

Location:km 100+200

Sample No: 01

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	15.0		
1.27	78.0		
1.91	108.0		
2.54	115.0	2.4702	18.5
3.18	143.0		
3.81	148.0		
4.45	156.0		
5.08	161.0	3.45830	17.28
7.62			
10.16			

Location:km100+420

Sample No:02

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	18.0		
1.27	31.0		
1.91	68.0		
2.54	77.0	1.869	12.40
3.18	87.0		
3.81	95.0		
4.45	98.0		
5.08	99.0	2.13	10.63
7.62			
10.16			

Location:km100+600

Sample No:03

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	25.0		
1.27	39.0		
1.91	47.0		
2.54	55.0	1.18140	8.86
3.18	58.0		
3.81	64.0		
4.45	69.0		
5.08	72.0	1.54660	7.73
7.62			
10.16			

Location: km100+800
Sample No: 04

Plunger	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	40.0		
1.27	56.0		
1.91	72.0		
2.54	81.0	1.00	13.05
3.18	86.0		
3.81	88.0		
4.45	96.0		
5.08	105.0	2.13	11.27
7.62			
10.16			

Location:km101+050
Sample No:05

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	15		
1.27	46		
1.91	64		
2.54	83	1.933	13.37
3.18	92		
3.81	106		
4.45	109		
5.08	122	2.6206	13.09
7.62			
10.16			

Location:101+250
Sample No:06

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	22.0		
1.27	55.0		
1.91	76.0		
2.54	111.0		18
3.18	120.0		
3.81	131.0		
4.45	136.0		
5.08	140.0		15.03
7.62			
10.16			

Location:km101+450
Sample No:07

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	72.0		
1.27	90.0		
1.91	115		
2.54	149.0	3.2020	24
3.18	158		
3.81	171		
4.45	195		
5.08	205.0	4.405	22.0
7.62			
10.16			

Location:km101+650
Sample No:08

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	22.0		
1.27	65.0		
1.91	90.0		
2.54	104.0	2.23	16.75
3.18	116.0		
3.81	123.0		
4.45	132.0		
5.08	146.0	3.14	15.67
7.62			
10.16			

Location:101+850
Sample No:09

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	26.0		
1.27	56.0		
1.91	74.0		
2.54	103	2.212	16.59
3.18	112.0		
3.81	126.0		
4.45	141.0		
5.08	150.0	3.222	16.09
7.62			
10.16			

Location:km102+050
Sample No:10

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	6.0		
1.27	17.0		
1.91	21.0		
2.54	40.0	0.8592	6.44
3.18	44		
3.81	48		
4.45	51		
5.08	56	1.2028	6.01
7.62			
10.16			

Location: km102+250
Sample No:11

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	16.0		
1.27	45.0		
1.91	59.0		
2.54	78.0	1.675	12.56
3.18	80.0		
3.81	89.0		
4.45	95.0		10.73
5.08	100.0	2.15	
7.62			
10.16			

Location:km102+650
Sample No:12

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	14.0		
1.27	32.0		
1.91	48.0		
2.54	62.0	1.33	10.18
3.18	71.0		
3.81	80.0		
4.45	88.0		
5.08	92.0	1.976	9.87
7.62			
10.16			

Location:km102+850
Sample No:13

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	11.0		
1.27	21.0		
1.91	45.0		
2.54	69	1.482	11.10
3.18	80.0		
3.81	90.0		
4.45	99.0		
5.08	102.0	2.191	10.95
7.62			
10.16			

Location:km103+050
Sample No:14

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	22.0		
1.27	73.0		
1.91	90.0		
2.54	101.0	2.17	16.27
3.18	110.0		
3.81	119.0		
4.45	125.0		
5.08	130.0	2.792	13.95
7.62			
10.16			

Location:km103+250
Sample No:15

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	12.0		
1.27	140.0		
1.91	182		
2.54	211	4.532	34
3.18	222		
3.81	237		
4.45	248		
5.08	261.0	5.606	28.01
7.62			
10.16			

Location:km103+450
Sample No:16

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	22.0		
1.27	36.0		
1.91	50.0		
2.54	63.0	1.3532	10.15
3.18	72.0		
3.81	75.0		
4.45	88.0		
5.08	93.0	2.0401	9.98
7.62			
10.16			

Location:km103+650
Sample No:17

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	22.0		
1.27	33.0		
1.91	35.0		
2.54	39.0	0.8377	6.28
3.18	42.0		
3.81	45.0		
4.45	46.0		
5.08	47.0	1.009	5.04
7.62			
10.16			

Location:km103+850
Sample No:18

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	18.0		
1.27	53.0		
1.91	62.0		
2.54	65.0	1.396	10.16
3.18	73.0		
3.81	76.0		
4.45	77.0		
5.08	85.0	1.826	8.01
7.62			
10.16			

Location:km103+950
Sample No:19

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	26		
1.27	25		
1.91	80		
2.54	99	2.126	15.9
3.18	115		
3.81	143		
4.45	148		
5.08	153	3.286	13.95
7.62			
10.16			

Location:km104+050
Sample No: 20

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	50.0		
1.27	90.0		
1.91	105		
2.54	121	3.544	19.5
3.18	133		
3.81	145		
4.45	153		
5.08	160	4.425	17.17
7.62			
10.16			

Location:km104+150
Sample No:21

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	55.0		
1.27	87.0		
1.91	102.0		
2.54	115.0	2.470	17.97
3.18	121.0		
3.81	127.0		
4.45	132.0		
5.08	136.0	2.921	14.16
7.62			
10.16			

Location:km104+250
Sample No:22

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	20.0		
1.27	30.0		
1.91	39.0		
2.54	49.0	1.0525	7.81
3.18	56.0		
3.81	63.0		
4.45	65.0		
5.08	70.0	1.5036	7.51
7.62			
10.16			

Location:km104+350
Sample No:23

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	22.0		
1.27	50.0		
1.91	75.0		
2.54	94.0	2.019	14.69
3.18	98.0		
3.81	106.0		
4.45	113.0		
5.08	121.0	2.599	12.60
7.62			
10.16			

Location:km104+450
Sample No: 24

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	33.0		
1.27	45.0		
1.91	53.0		
2.54	56.0	1.203	8.75
3.18	57.0		
3.81	61.0		
4.45	63.0		
5.08	66.0	1.417	6.87
7.62			
10.16			

Location:km104+550
Sample No: 25

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	53.0		
1.27	106.0		
1.91	125.0		
2.54	137	2.942	22.06
3.18	165.0		
3.81	173.0		
4.45	181		
5.08	190.00	4.081	20.39
7.62			
10.16			

Location:km104+650
Sample No: 26

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	15.0		
1.27	83.0		
1.91	102.0		
2.54	112.0	2.406	18
3.18	142.0		
3.81	151.0		
4.45	160.0		
5.08	165.0	3.544	17.7
7.62			
10.16			

Location:km 104+750
Sample No:27

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	8.0		
1.27	15.0		
1.91	21.0		
2.54	35	1.933	5.65
3.18	39		
3.81	42		
4.45	45		
5.08	51	2.685	5.47
7.62			
10.16			

Location:km104+850
Sample No: 28

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	20.0		
1.27	55.0		
1.91	125.0		
2.54	141	3.029	22.8
3.18	165		
3.81	178		
4.45	189		
5.08	195	4.189	20.93
7.62			
10.16			

Location:km104+950
Sample No:29

Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	15.0		
1.27	32.0		
1.91	43.0		
2.54	58.0	1.246	9.06
3.18	59.0		
3.81	61.0		
4.45	63.0		
5.08	66.0	1.418	7.41
7.62			
10.16			

Location:105+050
Sample No:30

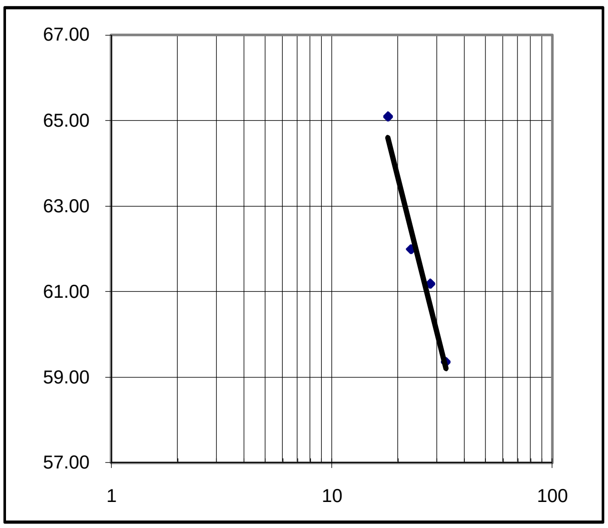
Plunger Penetration,mm	DLAL RDG.	COR.LOAD(kn)	CBR%
0.0			
0.64	25.0		
1.27	63.0		
1.91	85.0		
2.54	100.0	2.148	16.00
3.18	107.0		
3.81	117.0		
4.45	122.0		
5.08	128.0	2.749	13.74
7.62			
10.16			

Atterberg Limit Test Results (PI, LL & PL)

ATTERBERG LIMIT TEST

Location : Km 100+200 LHS
Sample No:01

LIQUID LIMIT				
Container No.	C-5	A-66	C-3	N
Wt of wet soil + container, gm	28.34	28.50	28.65	30.30
Wt of dry soil + container, gm	24.85	25.49	25.42	26.59
Wt of water	3.49	3.01	3.23	3.71
Wt of container	18.97	20.57	20.21	20.89
Wt of dry soil, gm	5.88	4.92	5.21	5.70
Water content, %	59.35	61.18	62.00	65.09
No. of blows	33	28	23	18

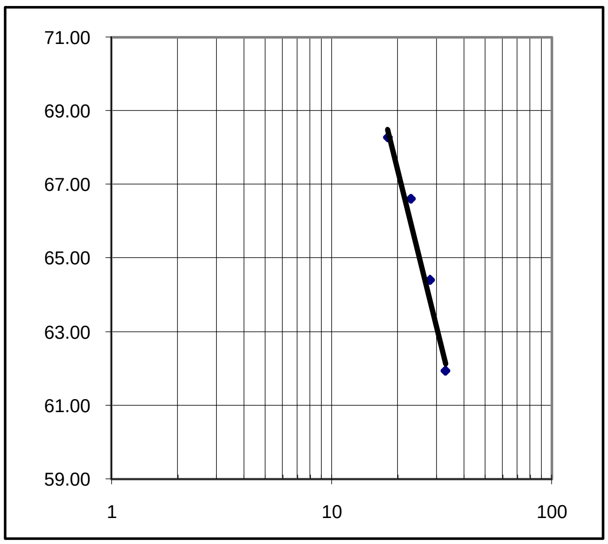


Liquid Limit	**62%**
Plastic Limit	**27%**
Plasticity Index	**35**

PLASTIC LIMIT				
Container No.	C-4	G-5		**Average**
Wt of wet soil + container, gm	22.77	23.75		
Wt of dry soil + container, gm	22.21	23.10		
Wt of water	0.56	0.65		
Wt of container	20.12	20.75		
Wt of dry soil, gm	2.09	2.35		
Water content, %	26.79	27.66		**27.2**

Location : Km 100+420 RHS
Sample No:02

LIQUID LIMIT				
Container No.	A-38	A-28	C-14	R-3
Wt of wet soil + container, gm	28.84	27.59	29.92	27.59
Wt of dry soil + container, gm	25.52	24.75	26.23	24.34
Wt of water	3.32	2.84	3.69	3.25
Wt of container	20.16	20.34	20.69	19.58
Wt of dry soil, gm	5.36	4.41	5.54	4.76
Water content, %	61.94	64.40	66.61	68.28
No. of blows	33	28	23	18

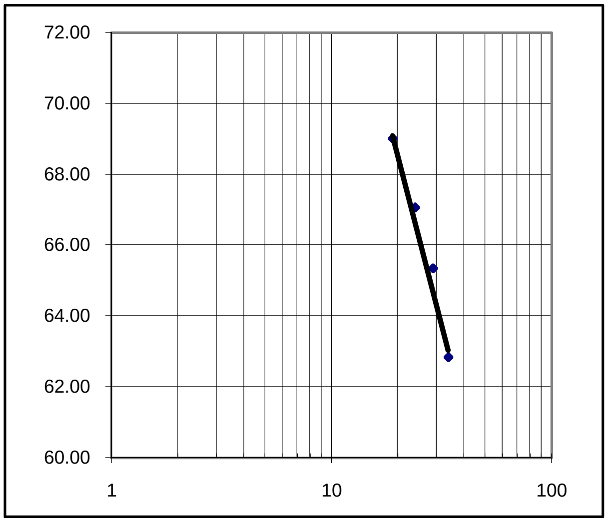


Liquid Limit	66%
Plastic Limit	**28 %**
Plasticity Index	**37**

PLASTIC LIMIT				
Container No.	7	A-36		**Average**
Wt of wet soil + container, gm	23.14	23.59		
Wt of dry soil + container, gm	22.51	22.96		
Wt of water	0.63	0.63		
Wt of container	20.29	20.69		
Wt of dry soil, gm	2.22	2.27		
Water content, %	28.38	27.75		**28.1**

Location :Km 100+600 RHS
Sample No:03

LIQUID LIMIT				
Container No.	AA	AB	SQ	450
Wt of wet soil + container, gm	27.95	28.04	30.68	29.94
Wt of dry soil + container, gm	25.43	24.57	26.67	25.91
Wt of water	2.52	3.47	4.01	4.03
Wt of container	21.42	19.26	20.69	20.07
Wt of dry soil, gm	4.01	5.31	5.98	5.84
Water content, %	62.84	65.35	67.06	69.01
No. of blows	34	29	24	19

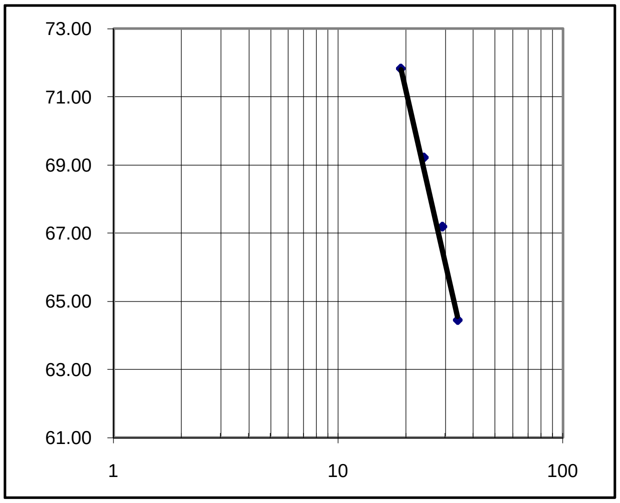


Liquid Limit	67%
Plastic Limit	32%
Plasticity Index	**35**

PLASTIC LIMIT				
Container No.	Z-50	A-35		**Average**
Wt of wet soil + container, gm	24.18	23.03		
Wt of dry soil + container, gm	23.48	22.29		
Wt of water	0.70	0.74		
Wt of container	21.30	19.91		
Wt of dry soil, gm	2.18	2.38		
Water content, %	32.11	31.09		**31.6**

Location : Km 100+800 LHS
Sample No:04

LIQUID LIMIT				
Container No.	MN	MS	ZO	24
Wt of wet soil + container, gm	29.15	27.00	31.07	27.83
Wt of dry soil + container, gm	25.76	23.66	26.75	24.26
Wt of water	3.39	3.34	4.32	3.57
Wt of container	20.50	18.69	20.51	19.29
Wt of dry soil, gm	5.26	4.97	6.24	4.97
Water content, %	64.45	67.20	69.23	71.83
No. of blows	34	29	24	19

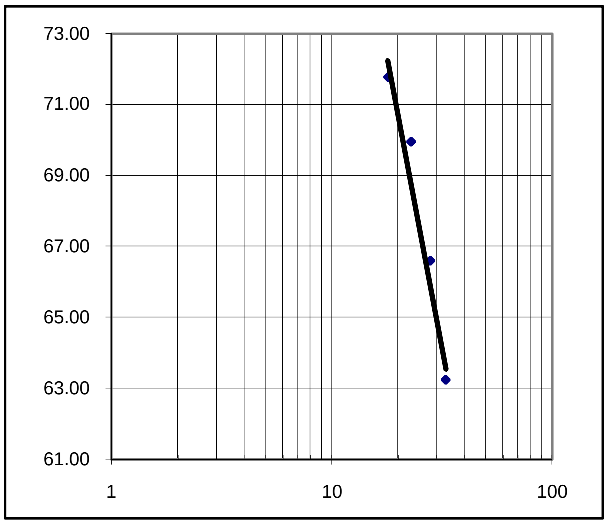


Liquid Limit	69%
Plastic Limit	31%
Plasticity Index	**38**

PLASTIC LIMIT				
Container No.	PS	Z-3		**Average**
Wt of wet soil + container, gm	23.66	19.86		
Wt of dry soil + container, gm	23.05	19.16		
Wt of water	0.61	0.70		
Wt of container	21.05	16.87		
Wt of dry soil, gm	2.00	2.29		
Water content, %	30.50	30.57		**30.5**

Location: Km 101+050 LHS
Sample No: 05

LIQUID LIMIT				
Container No.	Z-60	Z-2	N-10	DN
Wt of wet soil + container, gm	28.96	29.44	29.12	28.92
Wt of dry soil + container, gm	25.83	25.99	25.35	25.41
Wt of water	3.13	3.45	3.77	3.51
Wt of container	20.88	20.81	19.96	20.52
Wt of dry soil, gm	4.95	5.18	5.39	4.89
Water content, %	63.23	66.60	69.94	71.78
No. of blows	33	28	23	18

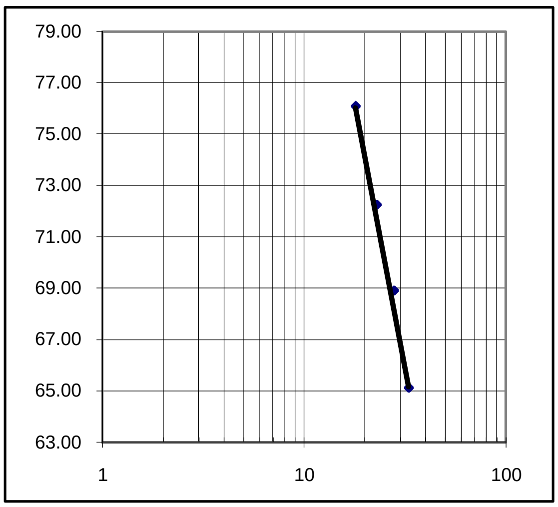


Liquid Limit	68%
Plastic Limit	31%
Plasticity Index	**38**

PLASTIC LIMIT				
Container No.	Z-50	A-38		**Average**
Wt of wet soil + container, gm	23.97	22.72		
Wt of dry soil + container, gm	23.35	22.05		
Wt of water	0.62	0.67		
Wt of container	21.27	19.91		
Wt of dry soil, gm	2.08	2.14		
Water content, %	29.81	31.31		**30.6**

Location : Km 101+250 LHS
Sample No:06

LIQUID LIMIT				
Container No.	24	TX	23	Q
Wt of wet soil + container, gm	29.61	30.00	25.81	29.77
Wt of dry soil + container, gm	25.54	26.32	22.06	25.89
Wt of water	4.07	3.68	3.75	3.88
Wt of container	19.29	20.98	16.87	20.79
Wt of dry soil, gm	6.25	5.34	5.19	5.10
Water content, %	65.12	68.91	72.25	76.08
No. of blows	33	28	23	18

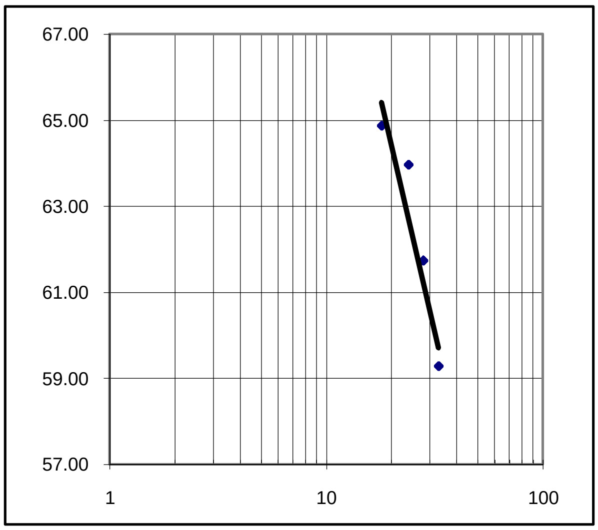


Liquid Limit	71%
Plastic Limit	37%
Plasticity Index	**34**

PLASTIC LIMIT				
Container No.	G-5	B-30		**Average**
Wt of wet soil + container, gm	23.66	23.44		
Wt of dry soil + container, gm	22.87	22.61		
Wt of water	0.79	0.83		
Wt of container	20.75	20.40		
Wt of dry soil, gm	2.12	2.21		
Water content, %	37.26	37.56		**37.4**

Location: Km 101+450 RHS
Sample No:07

LIQUID LIMIT				
Container No.	19	BF	A-25	A-100
Wt of wet soil + container, gm	29.63	29.25	28.95	29.43
Wt of dry soil + container, gm	26.15	25.75	24.85	25.09
Wt of water	3.48	3.50	4.10	4.34
Wt of container	20.28	20.08	18.44	18.40
Wt of dry soil, gm	5.87	5.67	6.41	6.69
Water content, %	59.28	61.73	63.96	64.87
No. of blows	33	28	24	18

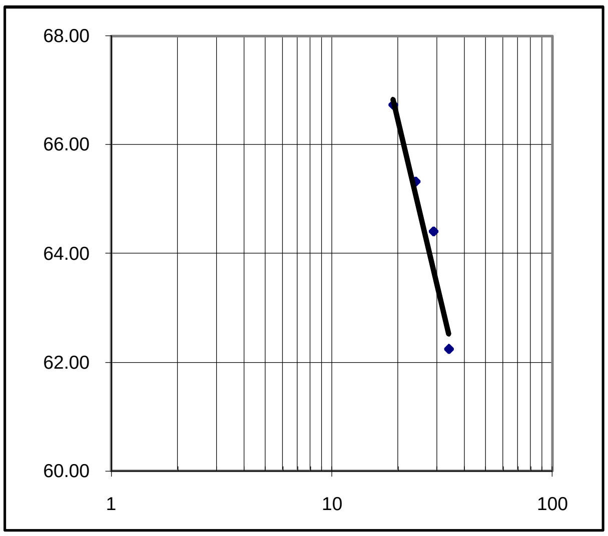


Liquid Limit	63%
Plastic Limit	31%
Plasticity Index	**32**

PLASTIC LIMIT				
Container No.	29	SY		**Average**
Wt of wet soil + container, gm	23.00	23.18		
Wt of dry soil + container, gm	22.56	22.44		
Wt of water	0.44	0.74		
Wt of container	21.13	20.00		
Wt of dry soil, gm	1.43	2.44		
Water content, %	30.77	30.33		**30.5**

Location :Km 101+650 LHS
Sample No:08

LIQUID LIMIT				
Container No.	PB	DN	25	K
Wt of wet soil + container, gm	30.02	30.44	29.66	29.28
Wt of dry soil + container, gm	26.74	26.55	26.08	25.75
Wt of water	3.28	3.89	3.58	3.53
Wt of container	21.47	20.51	20.60	20.46
Wt of dry soil, gm	5.27	6.04	5.48	5.29
Water content, %	62.24	64.40	65.33	66.73
No. of blows	34	29	24	19

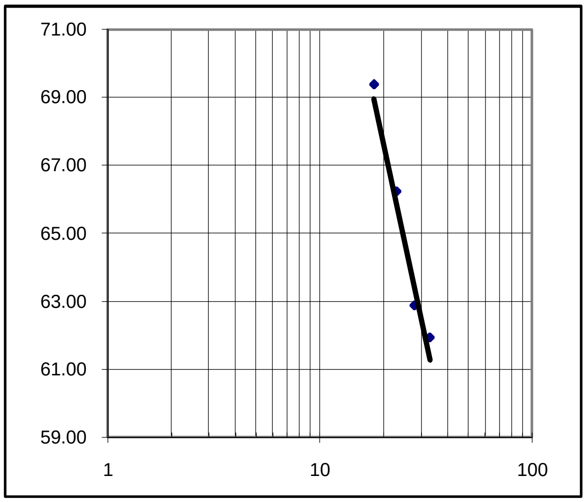


Liquid Limit	65%
Plastic Limit	31%
Plasticity Index	**34**

PLASTIC LIMIT				
Container No.	A-25	19		**Average**
Wt of wet soil + container, gm	21.69	21.80		
Wt of dry soil + container, gm	20.92	21.44		
Wt of water	0.77	0.36		
Wt of container	18.44	20.28		
Wt of dry soil, gm	2.48	1.16		
Water content, %	31.05	31.03		**31.0**

Location : Km 101+850 RHS
Sample No:09

LIQUID LIMIT				
Container No.	AC	A-38	21	WO
Wt of wet soil + container, gm	30.50	29.65	29.06	29.84
Wt of dry soil + container, gm	28.14	25.89	26.45	26.17
Wt of water	2.36	3.76	2.61	3.67
Wt of container	24.33	19.91	22.51	20.88
Wt of dry soil, gm	3.81	5.98	3.94	5.29
Water content, %	61.94	62.88	66.24	69.38
No. of blows	33	28	23	18

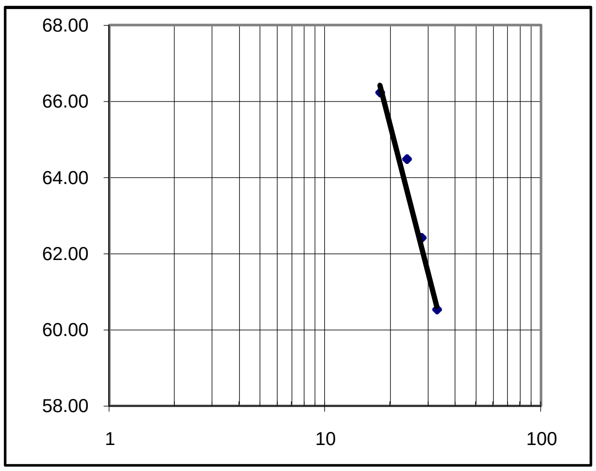


Liquid Limit	65%
Plastic Limit	30%
Plasticity Index	**35**

PLASTIC LIMIT				
Container No.	Z	DD		**Average**
Wt of wet soil + container, gm	24.56	24.18		
Wt of dry soil + container, gm	23.66	23.20		
Wt of water	0.90	0.98		
Wt of container	20.68	19.94		
Wt of dry soil, gm	2.98	3.26		
Water content, %	30.20	30.06		**30.1**

Location :Km 102+050 LHS
Sample No:10

LIQUID LIMIT				
Container No.	B-30	Z-3	Q	AC
Wt of wet soil + container, gm	30.08	29.75	31.63	30.58
Wt of dry soil + container, gm	26.43	24.80	27.38	26.01
Wt of water	3.65	4.95	4.25	4.57
Wt of container	20.40	16.87	20.79	19.11
Wt of dry soil, gm	6.03	7.93	6.59	6.90
Water content, %	60.53	62.42	64.49	66.23
No. of blows	33	28	24	18

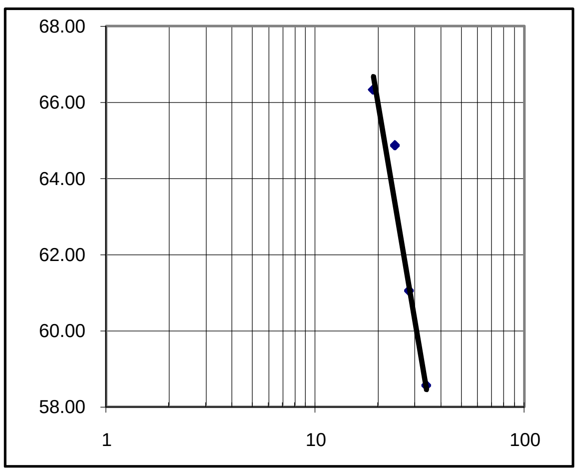


Liquid Limit	64%
Plastic Limit	30%
Plasticity Index	**34**

PLASTIC LIMIT				
Container No.	B-65	ZM		**Average**
Wt of wet soil + container, gm	22.21	22.89		
Wt of dry soil + container, gm	21.70	22.54		
Wt of water	0.51	0.35		
Wt of container	20.01	21.37		
Wt of dry soil, gm	1.69	1.17		
Water content, %	30.18	29.91		**30.0**

Location : KM 102+250 RHS
Sample No:11

LIQUID LIMIT				
Container No.	Z-60	Z-2	N-10	A-38
Wt of wet soil + container, gm	29.95	30.28	30.32	29.89
Wt of dry soil + container, gm	26.60	26.69	26.24	25.91
Wt of water	3.35	3.59	4.08	3.98
Wt of container	20.88	20.81	19.95	19.91
Wt of dry soil, gm	5.72	5.88	6.29	6.00
Water content, %	58.57	61.05	64.86	66.33
No. of blows	34	28	24	19

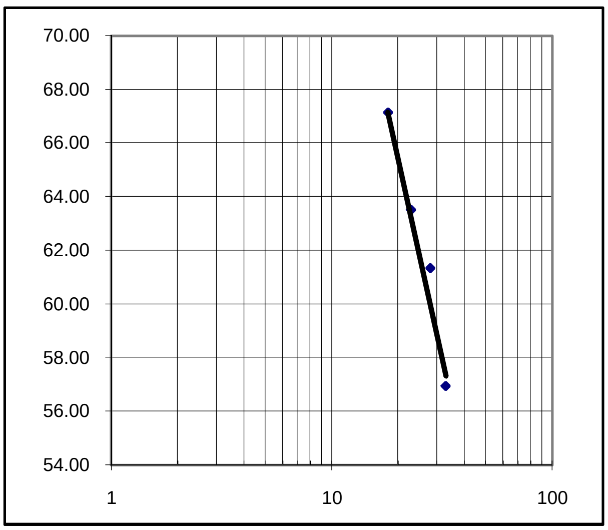


Liquid Limit	63%
Plastic Limit	30%
Plasticity Index	**34**

PLASTIC LIMIT				
Container No.	TX	Z-50		**Average**
Wt of wet soil + container, gm	23.40	23.65		
Wt of dry soil + container, gm	22.85	23.10		
Wt of water	0.55	0.55		
Wt of container	20.98	21.27		
Wt of dry soil, gm	1.87	1.83		
Water content, %	29.41	30.05		**29.7**

Location : Km 102+650 LHS
Sample No:12

LIQUID LIMIT				
Container No.	AC	B-65	A-38	ZM
Wt of wet soil + container, gm	26.00	27.06	27.17	29.46
Wt of dry soil + container, gm	23.50	24.38	24.35	26.21
Wt of water	2.50	2.68	2.82	3.25
Wt of container	19.11	20.01	19.91	21.37
Wt of dry soil, gm	4.39	4.37	4.44	4.84
Water content, %	56.95	61.33	63.51	67.15
No. of blows	33	28	23	18

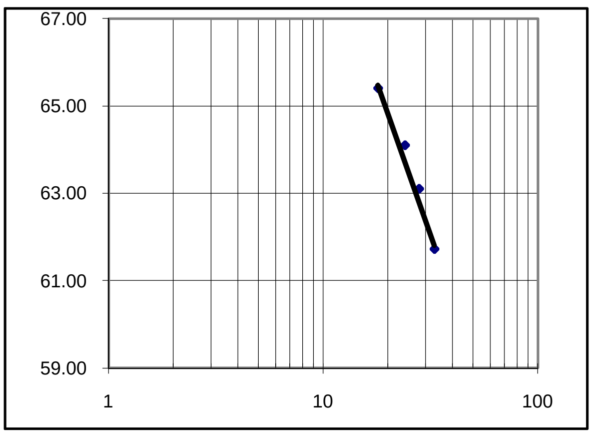


Liquid Limit	63%
Plastic Limit	32%
Plasticity Index	**31**

PLASTIC LIMIT				
Container No.	Z-50	AR		**Average**
Wt of wet soil + container, gm	24.78	24.33		
Wt of dry soil + container, gm	23.93	23.37		
Wt of water	0.85	0.96		
Wt of container	21.27	20.38		
Wt of dry soil, gm	2.66	2.99		
Water content, %	31.95	32.11		**32.0**

Location: Km 102+850 RHS
Sample No:13

LIQUID LIMIT				
Container No.	A-35	AA	460	SQ
Wt of wet soil + container, gm	30.05	31.63	29.67	28.96
Wt of dry soil + container, gm	26.18	27.68	25.92	25.69
Wt of water	3.87	3.95	3.75	3.27
Wt of container	19.91	21.42	20.07	20.69
Wt of dry soil, gm	6.27	6.26	5.85	5.00
Water content, %	61.72	63.10	64.10	65.40
No. of blows	33	28	24	18

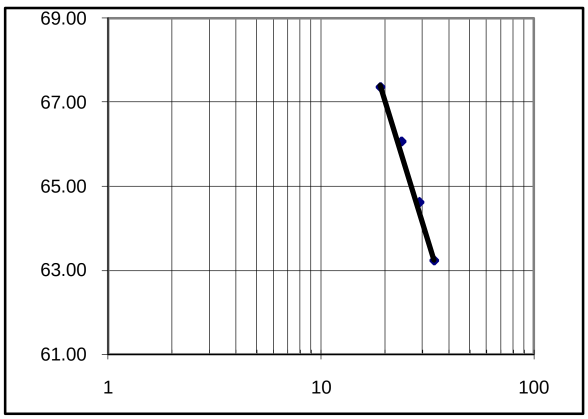


Liquid Limit	64%
Plastic Limit	30%
Plasticity Index	**34**

PLASTIC LIMIT				
Container No.	AB	DN		**Average**
Wt of wet soil + container, gm	23.13	23.24		
Wt of dry soil + container, gm	22.25	22.61		
Wt of water	0.88	0.63		
Wt of container	19.26	20.52		
Wt of dry soil, gm	2.99	2.09		
Water content, %	29.43	30.14		**29.8**

Location : Km 103+050 LHS
Sample No:14

LIQUID LIMIT				
Container No.	ZO	MN	PS	24
Wt of wet soil + container, gm	30.63	29.85	28.34	29.65
Wt of dry soil + container, gm	26.71	26.18	25.44	25.48
Wt of water	3.92	3.67	2.90	4.17
Wt of container	20.51	20.50	21.05	19.29
Wt of dry soil, gm	6.20	5.68	4.39	6.19
Water content, %	63.23	64.61	66.06	67.37
No. of blows	34	29	24	19

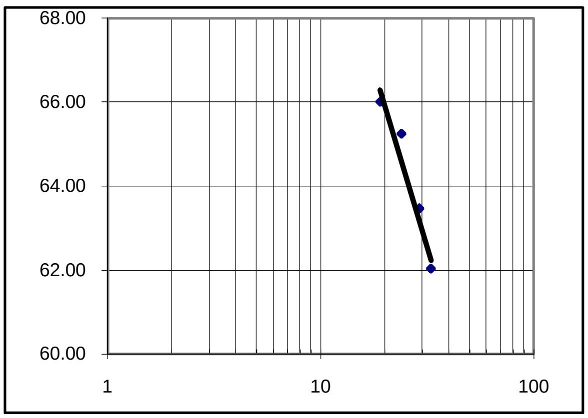


Liquid Limit	66%
Plastic Limit	33%
Plasticity Index	**33**

PLASTIC LIMIT				
Container No.	AA	AB		**Average**
Wt of wet soil + container, gm	24.35	23.86		
Wt of dry soil + container, gm	23.62	22.72		
Wt of water	0.73	1.14		
Wt of container	21.42	19.26		
Wt of dry soil, gm	2.20	3.46		
Water content, %	33.18	32.95		**33.1**

Location :Km 103+250 RHS
Sample No:15

LIQUID LIMIT				
Container No.	A-36	24	MS	Z-3
Wt of wet soil + container, gm	30.12	29.67	31.43	30.35
Wt of dry soil + container, gm	26.51	25.64	26.40	24.99
Wt of water	3.61	4.03	5.03	5.36
Wt of container	20.69	19.29	18.69	16.87
Wt of dry soil, gm	5.82	6.35	7.71	8.12
Water content, %	62.03	63.46	65.24	66.01
No. of blows	33	29	24	19

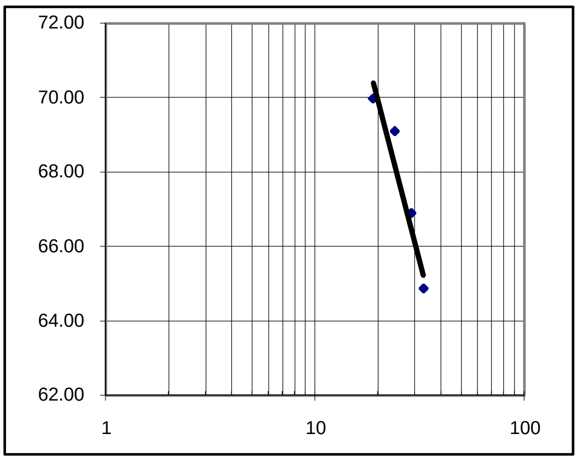


Liquid Limit	65%
Plastic Limit	33%
Plasticity Index	**32**

PLASTIC LIMIT				
Container No.	250	AB		**Average**
Wt of wet soil + container, gm	24.35	23.96		
Wt of dry soil + container, gm	23.60	22.79		
Wt of water	0.75	1.17		
Wt of container	21.30	19.26		
Wt of dry soil, gm	2.30	3.53		
Water content, %	32.61	33.14		**32.9**

Location :Km 103+450 LHS
Sample No:16

LIQUID LIMIT				
Container No.	C-4	G-5	A-28	R-3
Wt of wet soil + container, gm	29.65	30.03	29.15	28.30
Wt of dry soil + container, gm	25.90	26.31	25.55	24.71
Wt of water	3.75	3.72	3.60	3.59
Wt of container	20.12	20.75	20.34	19.58
Wt of dry soil, gm	5.78	5.56	5.21	5.13
Water content, %	64.88	66.91	69.10	69.98
No. of blows	33	29	24	19

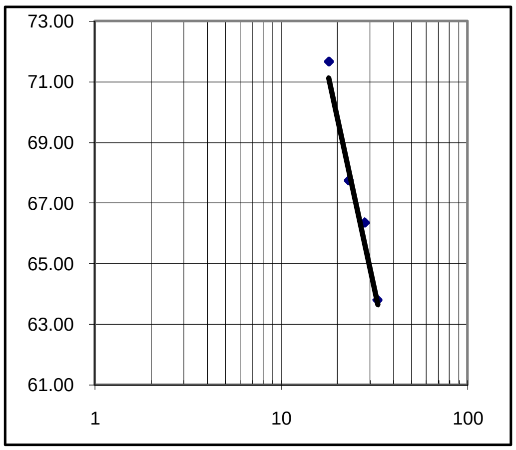


Liquid Limit	68%
Plastic Limit	33%
Plasticity Index	**35**

PLASTIC LIMIT				
Container No.	250	AB		**Average**
Wt of wet soil + container, gm	24.35	23.96		
Wt of dry soil + container, gm	23.60	22.79		
Wt of water	0.75	1.17		
Wt of container	21.30	19.26		
Wt of dry soil, gm	2.30	3.53		
Water content, %	32.61	33.14		**32.9**

Location : Km 103+650 RHS
Sample No:17

LIQUID LIMIT				
Container No.	21	WO	DD	2
Wt of wet soil + container, gm	30.52	29.53	27.27	29.04
Wt of dry soil + container, gm	27.40	26.08	24.31	25.55
Wt of water	3.12	3.45	2.96	3.49
Wt of container	22.51	20.88	19.94	20.68
Wt of dry soil, gm	4.89	5.20	4.37	4.87
Water content, %	63.80	66.35	67.73	71.66
No. of blows	33	28	23	18

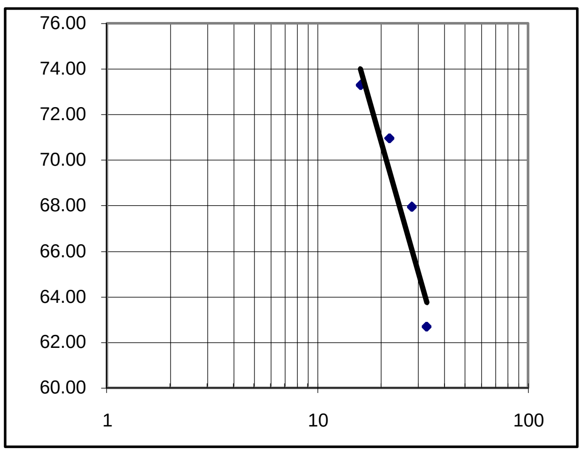


Liquid Limit	68%
Plastic Limit	31%
Plasticity Index	**37**

PLASTIC LIMIT				
Container No.	PB	DN		**Average**
Wt of wet soil + container, gm	24.36	23.77		
Wt of dry soil + container, gm	23.69	23.00		
Wt of water	0.67	0.77		
Wt of container	21.47	20.51		
Wt of dry soil, gm	2.22	2.49		
Water content, %	30.18	30.92		**30.6**

Location : **Km 103+850 LHS**
Sample No **18**

LIQUID LIMIT				
Container No.	29	SY	A-100	MB
Wt of wet soil + container, gm	28.89	30.53	24.64	27.82
Wt of dry soil + container, gm	25.90	26.27	22.05	24.61
Wt of water	2.99	4.26	2.59	3.21
Wt of container	21.13	20.00	18.40	20.23
Wt of dry soil, gm	4.77	6.27	3.65	4.38
Water content, %	62.68	67.94	70.96	73.29
No. of blows	33	28	22	16

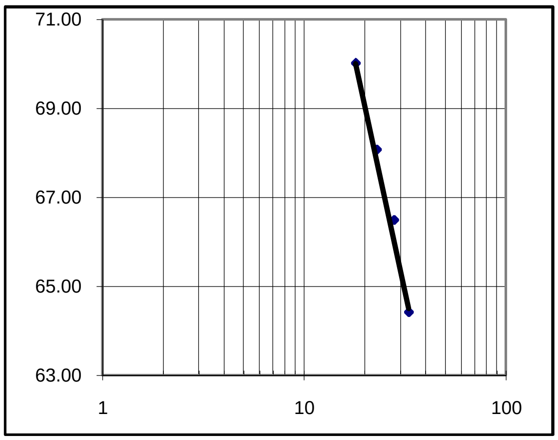


Liquid Limit	69%
Plastic Limit	37%
Plasticity Index	**32**

PLASTIC LIMIT				
Container No.	ZO	A-45		**Average**
Wt of wet soil + container, gm	23.28	23.39		
Wt of dry soil + container, gm	22.53	22.80		
Wt of water	0.75	0.59		
Wt of container	20.51	21.19		
Wt of dry soil, gm	2.02	1.61		
Water content, %	37.13	36.65		**36.9**

Location: km 103+950 LHS
Sample No: 19

LIQUID LIMIT				
Container No.	U	C-4	B-65	WO
Wt of wet soil + container, gm	27.36	26.39	28.38	30.01
Wt of dry soil + container, gm	24.68	23.89	24.99	26.25
Wt of water	2.68	2.50	3.39	3.76
Wt of container	20.52	20.13	20.01	20.88
Wt of dry soil, gm	4.16	3.76	4.98	5.37
Water content, %	64.42	66.49	68.07	70.02
No. of blows	33	28	23	18

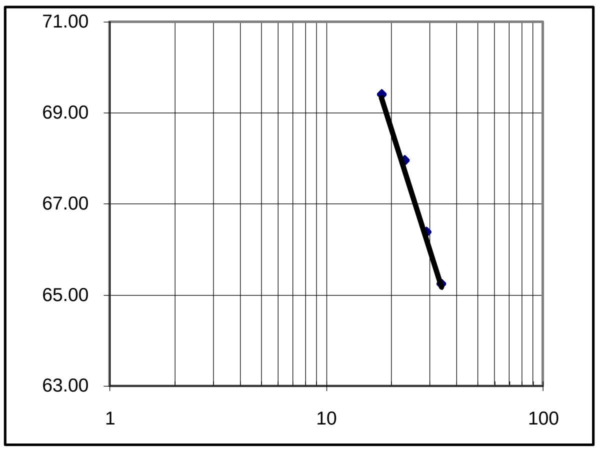


Liquid Limit	67%
Plastic Limit	33%
Plasticity Index	**34**

PLASTIC LIMIT				
Container No.	PA	PB		**Average**
Wt of wet soil + container, gm	24.03	25.00		
Wt of dry soil + container, gm	23.47	24.12		
Wt of water	0.56	0.88		
Wt of container	21.80	21.48		
Wt of dry soil, gm	1.67	2.64		
Water content, %	33.53	33.33		**33.4**

Location :km 104+050 LHS
Sample No: 20

LIQUID LIMIT				
Container No.	N-30	C-3	C-5	A-66
Wt of wet soil + container, gm	30.54	29.86	28.98	29.65
Wt of dry soil + container, gm	26.73	26.01	24.93	25.93
Wt of water	3.81	3.85	4.05	3.72
Wt of container	20.89	20.21	18.97	20.57
Wt of dry soil, gm	5.84	5.80	5.96	5.36
Water content, %	65.24	66.38	67.95	69.40
No. of blows	34	29	23	18

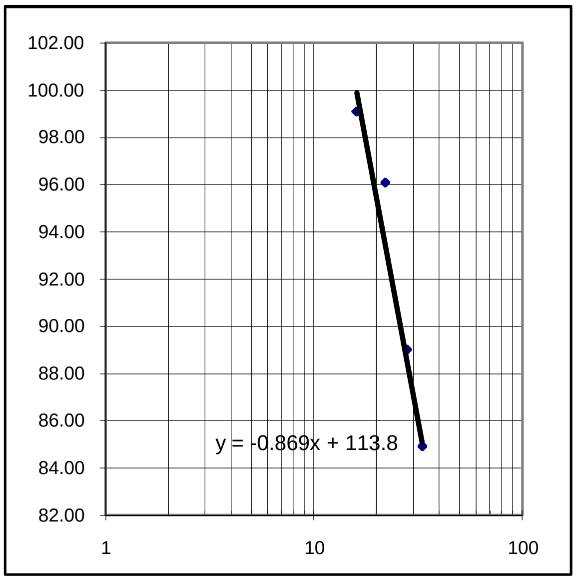


Liquid Limit	68%
Plastic Limit	33%
Plasticity Index	**34**

PLASTIC LIMIT				
Container No.	7	A-36		**Average**
Wt of wet soil + container, gm	23.45	24.69		
Wt of dry soil + container, gm	22.66	23.70		
Wt of water	0.79	0.99		
Wt of container	20.29	20.69		
Wt of dry soil, gm	2.37	3.01		
Water content, %	33.33	32.89		**33.1**

Location :Km 104+150 RHS
Sample No:21

LIQUID LIMIT				
Container No.	RZ	BK	ZL	A-99
Wt of wet soil + container, gm	29.14	29.46	29.49	29.66
Wt of dry soil + container, gm	25.37	25.33	25.32	25.25
Wt of water	3.77	4.13	4.17	4.41
Wt of container	20.93	20.69	20.98	20.80
Wt of dry soil, gm	4.44	4.64	4.34	4.45
Water content, %	84.91	89.01	96.08	99.10
No. of blows	33	28	22	16

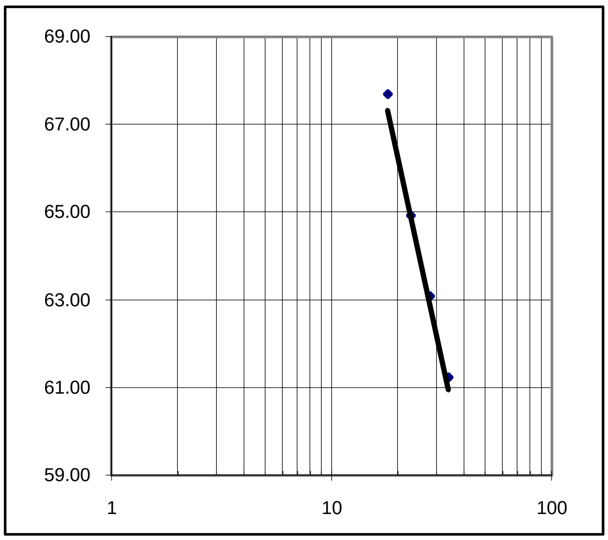


Liquid Limit	92%
Plastic Limit	34%
Plasticity Index	**58**

PLASTIC LIMIT				
Container No.	XY	ZS		**Average**
Wt of wet soil + container, gm	22.51	22.50		
Wt of dry soil + container, gm	22.01	21.97		
Wt of water	0.50	0.53		
Wt of container	20.54	20.44		
Wt of dry soil, gm	1.47	1.53		
Water content, %	34.01	34.64		**34.3**

Location :km 104+250 LHS
Sample No: 22

LIQUID LIMIT				
Container No.	A-45	ZO	MB	XY
Wt of wet soil + container, gm	30.30	30.54	29.35	29.84
Wt of dry soil + container, gm	26.84	26.66	25.76	26.11
Wt of water	3.46	3.88	3.59	3.73
Wt of container	21.19	20.51	20.23	20.60
Wt of dry soil, gm	5.65	6.15	5.53	5.51
Water content, %	61.24	63.09	64.92	67.70
No. of blows	34	28	23	18

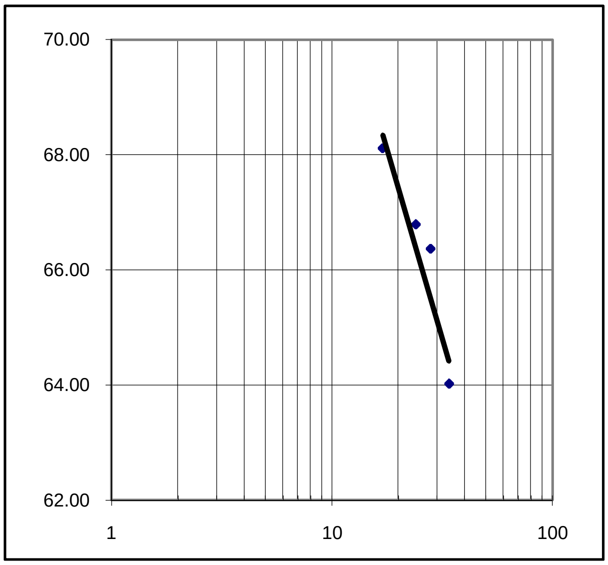


Liquid Limit	65 %
Plastic Limit	31%
Plasticity Index	**33**

PLASTIC LIMIT				
Container No.	RZ	BK		**Average**
Wt of wet soil + container, gm	21.65	22.06		
Wt of dry soil + container, gm	21.48	21.73		
Wt of water	0.17	0.33		
Wt of container	20.93	20.69		
Wt of dry soil, gm	0.55	1.04		
Water content, %	30.91	31.73		**31.3**

Location : Km 104+350 RHS
Sample No:23

LIQUID LIMIT				
Container No.	IJ	30	N	TX
Wt of wet soil + container, gm	29.93	30.24	30.19	31.09
Wt of dry soil + container, gm	26.14	26.49	26.47	26.99
Wt of water	3.79	3.75	3.72	4.10
Wt of container	20.22	20.84	20.90	20.97
Wt of dry soil, gm	5.92	5.65	5.57	6.02
Water content, %	64.02	66.37	66.79	68.11
No. of blows	34	28	24	17

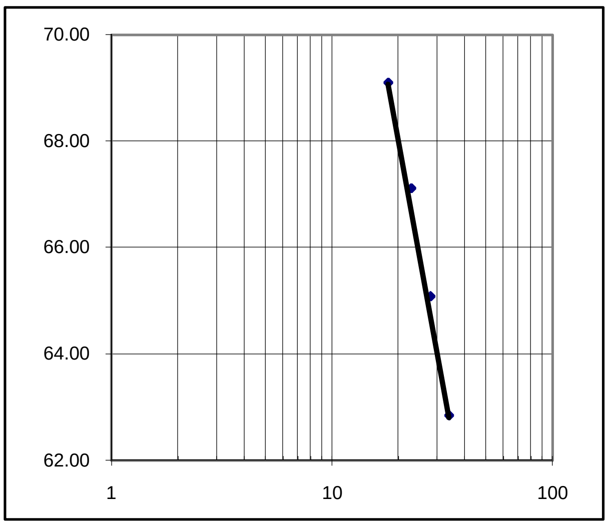


Liquid Limit	66%
Plastic Limit	35%
Plasticity Index	**32**

PLASTIC LIMIT				
Container No.	IJ	30		**Average**
Wt of wet soil + container, gm	23.18	23.51		
Wt of dry soil + container, gm	22.41	22.82		
Wt of water	0.77	0.69		
Wt of container	20.22	20.83		
Wt of dry soil, gm	2.19	1.99		
Water content, %	35.16	34.67		**34.9**

Location : Km 104+450 LHS
Sample No:24

LIQUID LIMIT				
Container No.	A-36	JQ	AM	A-4
Wt of wet soil + container, gm	28.36	29.30	30.03	31.02
Wt of dry soil + container, gm	25.40	26.02	26.01	26.57
Wt of water	2.96	3.28	4.02	4.45
Wt of container	20.69	20.98	20.02	20.13
Wt of dry soil, gm	4.71	5.04	5.99	6.44
Water content, %	62.85	65.08	67.11	69.10
No. of blows	34	28	23	18

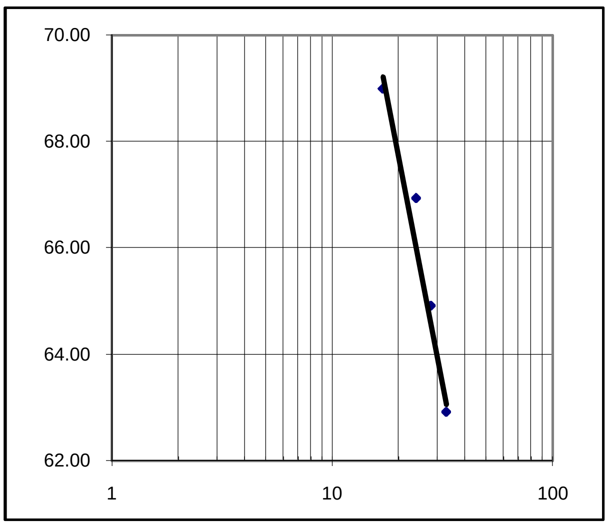


Liquid Limit	66%
Plastic Limit	33%
Plasticity Index	**33**

PLASTIC LIMIT				
Container No.	Z-50	A-24		**Average**
Wt of wet soil + container, gm	25.30	25.10		
Wt of dry soil + container, gm	24.30	23.59		
Wt of water	1.00	1.51		
Wt of container	21.28	19.03		
Wt of dry soil, gm	3.02	4.56		
Water content, %	33.11	33.11		**33.1**

Location :Km 104+550 RHS
Sample No: 25

LIQUID LIMIT				
Container No.	SA	BM	Z-40	AC
Wt of wet soil + container, gm	31.20	33.30	32.18	32.19
Wt of dry soil + container, gm	26.84	27.86	27.12	26.85
Wt of water	4.36	5.44	5.06	5.34
Wt of container	19.91	19.48	19.56	19.11
Wt of dry soil, gm	6.93	8.38	7.56	7.74
Water content, %	62.91	64.92	66.93	68.99
No. of blows	33	28	24	17

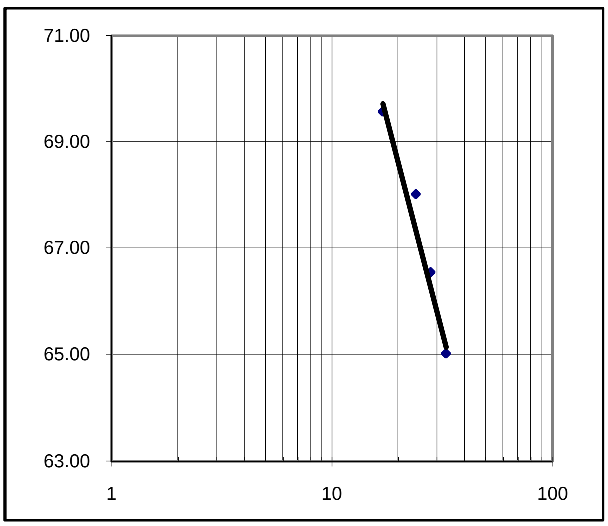


Liquid Limit	66%
Plastic Limit	34%
Plasticity Index	**32**

PLASTIC LIMIT				
Container No.	P-5	SQ		**Average**
Wt of wet soil + container, gm	23.66	24.00		
Wt of dry soil + container, gm	22.99	23.16		
Wt of water	0.67	0.84		
Wt of container	21.04	20.69		
Wt of dry soil, gm	1.95	2.47		
Water content, %	34.36	34.01		**34.2**

Location : km 104+650 RHS
Sample No:26

LIQUID LIMIT				
Container No.	7	YS	G-5	AD
Wt of wet soil + container, gm	32.31	29.93	30.31	33.02
Wt of dry soil + container, gm	27.57	26.27	26.44	27.42
Wt of water	4.74	3.66	3.87	5.60
Wt of container	20.28	20.77	20.75	19.37
Wt of dry soil, gm	7.29	5.50	5.69	8.05
Water content, %	65.02	66.55	68.01	69.57
No. of blows	33	28	24	17

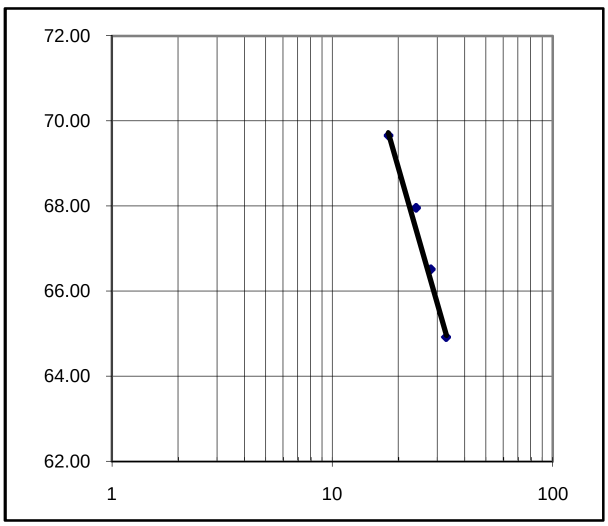


Liquid Limit	67%
Plastic Limit	35%
Plasticity Index	**32**

PLASTIC LIMIT				
Container No.	4-A	29		**Average**
Wt of wet soil + container, gm	23.20	23.90		
Wt of dry soil + container, gm	22.80	23.18		
Wt of water	0.40	0.72		
Wt of container	21.66	21.13		
Wt of dry soil, gm	1.14	2.05		
Water content, %	35.09	35.12		**35.1**

Location :Km 104+750 RHS
Sample No:27

LIQUID LIMIT				
Container No.	MN	D-4	Z-5	IU
Wt of wet soil + container, gm	30.28	31.21	33.02	33.80
Wt of dry soil + container, gm	26.43	26.86	27.93	27.74
Wt of water	3.85	4.35	5.09	6.06
Wt of container	20.50	20.32	20.44	19.04
Wt of dry soil, gm	5.93	6.54	7.49	8.70
Water content, %	64.92	66.51	67.96	69.66
No. of blows	33	28	24	18

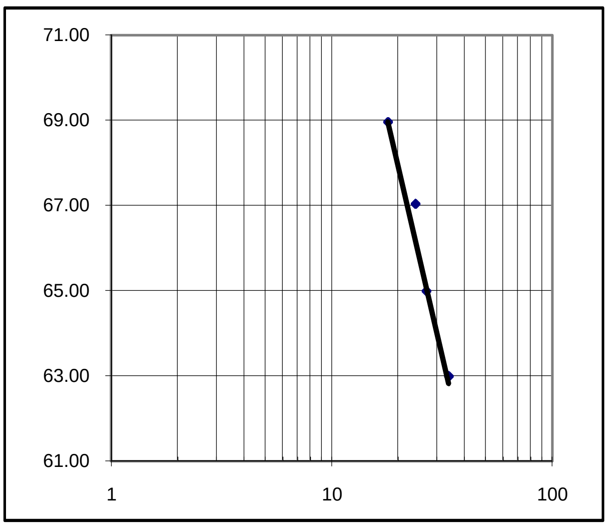


Liquid Limit	68%
Plastic Limit	34%
Plasticity Index	**33**

PLASTIC LIMIT				
Container No.	Z	A-650		**Average**
Wt of wet soil + container, gm	28.69	28.08		
Wt of dry soil + container, gm	26.65	26.17		
Wt of water	2.04	1.91		
Wt of container	20.69	20.62		
Wt of dry soil, gm	5.96	5.55		
Water content, %	34.23	34.41		**34.3**

Location : km 104+850 LHS
Sample No: 28

LIQUID LIMIT				
Container No.	23	K	25	**C-3**
Wt of wet soil + container, gm	31.31	32.85	33.01	**33.22**
Wt of dry soil + container, gm	25.73	27.97	28.03	**27.91**
Wt of water	5.58	4.88	4.98	**5.31**
Wt of container	16.87	20.46	20.60	**20.21**
Wt of dry soil, gm	8.86	7.51	7.43	**7.70**
Water content, %	62.98	64.98	67.03	**68.96**
No. of blows	34	27	24	**18**

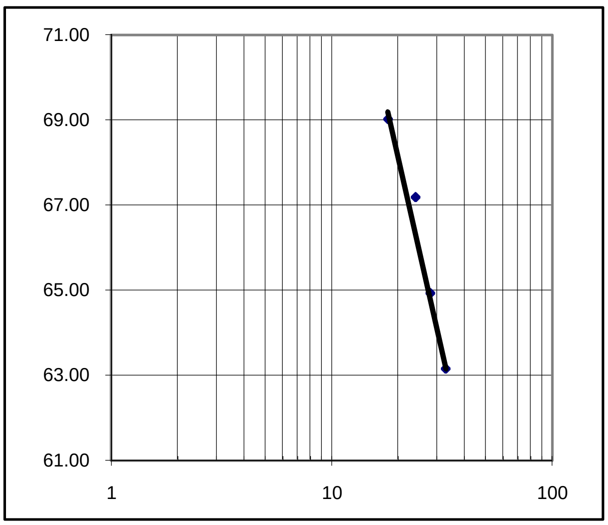


Liquid Limit	**66%**
Plastic Limit	**33%**
Plasticity Index	**33**

PLASTIC LIMIT				
Container No.	MB	LL		**Average**
Wt of wet soil + container, gm	26.02	27.00		
Wt of dry soil + container, gm	24.59	25.32		
Wt of water	1.43	1.68		
Wt of container	20.24	20.24		
Wt of dry soil, gm	4.35	5.08		
Water content, %	32.87	33.07		**33.0**

Location: Km 104+950 RHS
Sample No:29

LIQUID LIMIT				
Container No.	CM	EF	21	BK
Wt of wet soil + container, gm	29.66	28.86	29.03	30.00
Wt of dry soil + container, gm	26.25	25.51	26.41	26.19
Wt of water	3.41	3.35	2.62	3.81
Wt of container	20.85	20.35	22.51	20.67
Wt of dry soil, gm	5.40	5.16	3.90	5.52
Water content, %	63.15	64.92	67.18	69.02
No. of blows	33	28	24	18

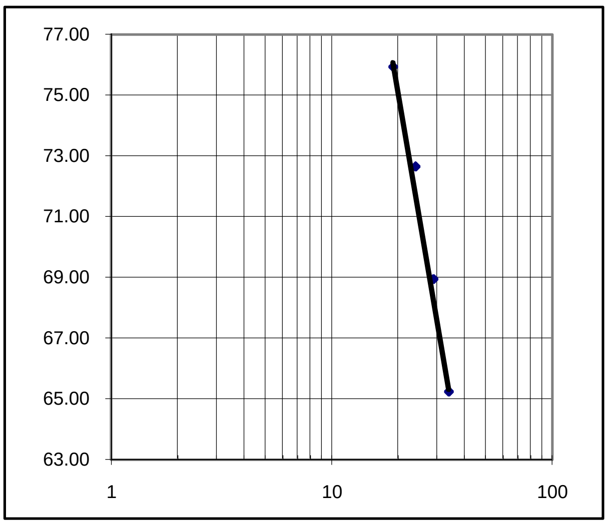


Liquid Limit	66%
Plastic Limit	34%
Plasticity Index	**32**

PLASTIC LIMIT				
Container No.	Q	A-2		**Average**
Wt of wet soil + container, gm	24.01	24.10		
Wt of dry soil + container, gm	23.20	23.50		
Wt of water	0.81	0.60		
Wt of container	20.80	21.74		
Wt of dry soil, gm	2.40	1.76		
Water content, %	33.75	34.09		**33.9**

Location :km 105+050 LHS
Sample No:30

LIQUID LIMIT				
Container No.	LM	EF	N-10	4-U
Wt of wet soil + container, gm	29.31	30.24	28.72	32.04
Wt of dry soil + container, gm	25.97	26.20	25.03	27.56
Wt of water	3.34	4.04	3.69	4.48
Wt of container	20.85	20.34	19.95	21.66
Wt of dry soil, gm	5.12	5.86	5.08	5.90
Water content, %	65.23	68.94	72.64	75.93
No. of blows	34	29	24	19



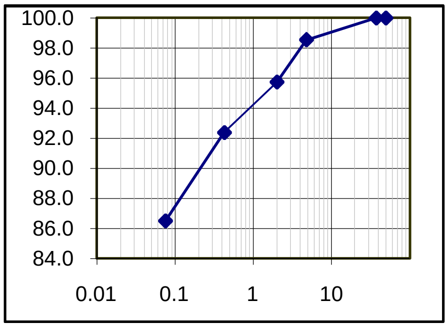
Liquid Limit	72%
Plastic Limit	35%
Plasticity Index	**37**

PLASTIC LIMIT				
Container No.	IJ	30		**Average**
Wt of wet soil + container, gm	23.18	23.51		
Wt of dry soil + container, gm	22.41	22.82		
Wt of water	0.77	0.69		
Wt of container	20.22	20.83		
Wt of dry soil, gm	2.19	1.99		
Water content, %	35.16	34.67		**34.9**

Sieve Analysis

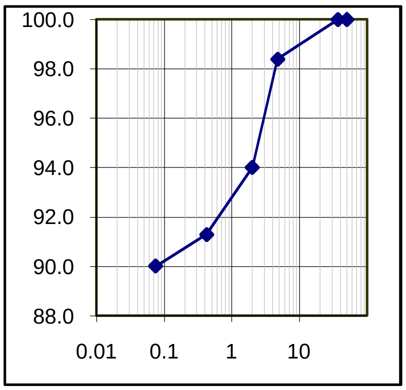
PARTICLE SIZE DISTRIBUTION(AASHTO T-11/T27)

Location: km100+200 LHS
Sample No.01



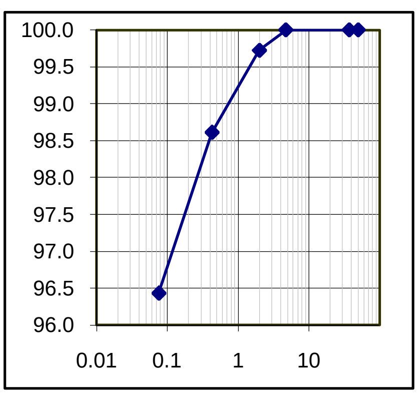
sieve size	Weight retained	% retained	% passing
37.5	0.0	0.0	100.0
4.75	7.0	1.5	98.5
2.00	13.3	2.8	95.7
0.425	15.9	3.3	92.4
0.075	28.0	5.9	86.5
Pan	0.0	0.0	
Dry weight before washing	475.0	100.0	

Location: km 100+420 RHS
Sample No: 02



sieve Size(mm)	weight retained	% retained	% passing
37.5	0.0	0.0	100.0
4.75	6.7	1.6	98.4
2.00	18.2	4.4	94.0
0.425	11.3	2.7	91.3
0.075	5.3	1.3	90.0
Pan	0.0	0.0	
Dry weight before washing	415.5	100.0	

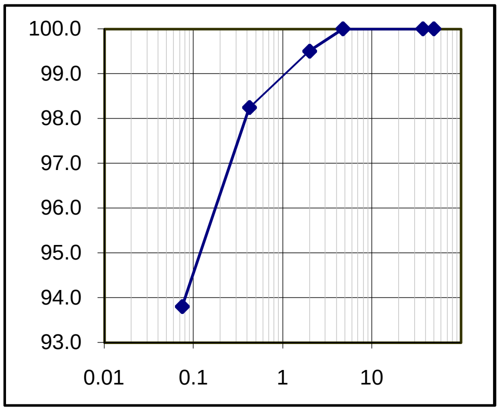
Location: km 100+600RHS
Sample No: 03



Sieve Size	Weight	% retained	% passing
37.5	0.0	0.0	100.0
4.75	0.0	0.0	100.0
2.00	1.4	0.3	99.7
0.425	5.7	1.1	98.6
0.075	11.1	2.2	96.4
Pan	0.0	0.0	
Dry weight before washing	510.0	100.0	

Location :Km 100+800 LHS

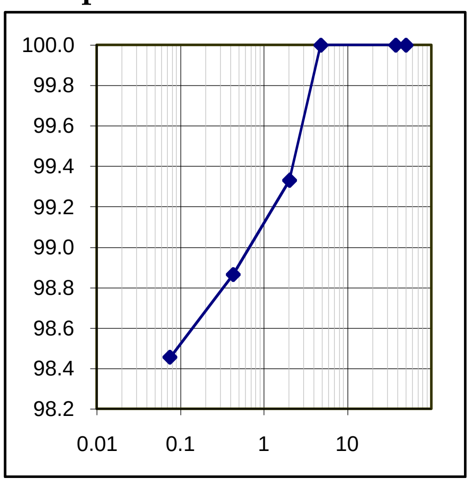
Sample No:04



sieve Size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	0.0	0.0	100.0
2.00	2.1	0.5	99.5
0.425	5.4	1.3	98.2
0.075	18.9	4.4	93.8
Pan	0.0	0.0	
Dry weight before washing	425.7	100.0	

Location: Km 101+050 LHS

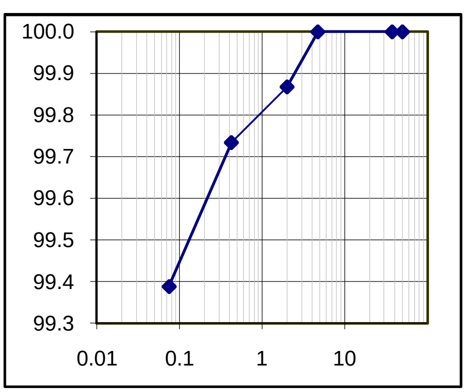
Sample No: 05



Sieve size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	0.0	0.0	100.0
2.00	2.3	0.7	99.3
0.425	1.6	0.5	98.9
0.075	1.4	0.4	98.5
Pan	0.0	0.0	
Dry weight before washing	343.3	100.0	

Location: Km 101+250 LHS

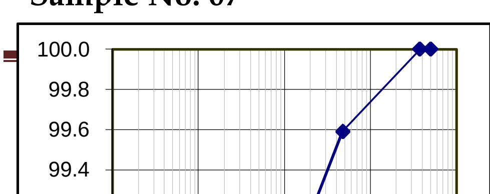
Sample No:06



Sieve Size	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	0.0	0.0	100.0
2.00	0.5	0.1	99.9
0.425	0.5	0.1	99.7
0.075	1.3	0.3	99.4
Pan	0.0	0.0	
Dry weight before washing	376.0	100.0	

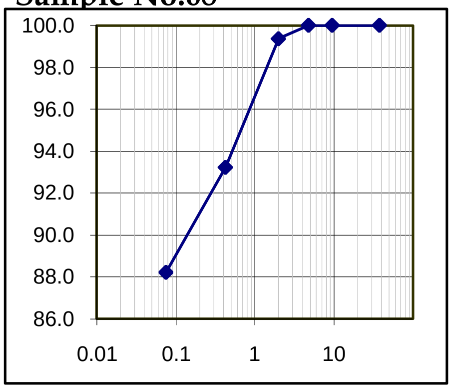
Location: Km 101+250 LHS

Sample No: 07



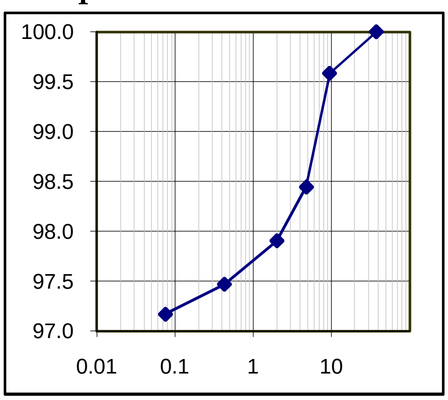
Sieve size(mm)	Weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	1.4	0.4	99.6
2.00	1.4	0.4	99.2
0.425	1.0	0.3	98.9
0.075	0.8	0.2	98.7
Pan	0.0	0.0	
Dry weight before washing	342.0	100.0	

Location: Km 101+650 LHS
Sample No:08



sieve Size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
9.5	0.0	0.0	100.0
4.75	0.0	0.0	100.0
2.00	2.8	0.6	99.4
0.425	28.0	6.1	93.2
0.075	22.9	5.0	88.2
Pan	0.0	0.0	
Dry weight before washing	456.0	100.0	

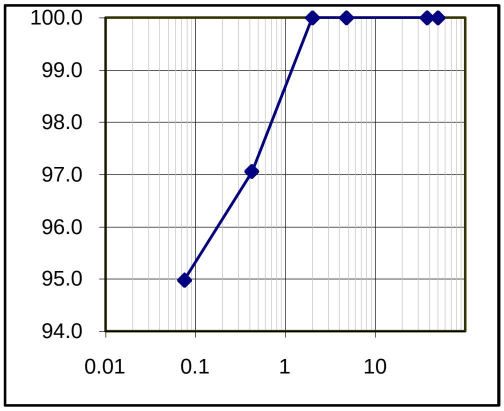
Location : Km 101+850 RHS
Sample No: 09



sieve size(mm)	weight retained	% retained	% passing
37.5	0.0	0.0	100.0
9.5	2.4	0.4	99.6
4.75	6.5	1.1	98.4
2.00	3.1	0.5	97.9
0.425	2.5	0.4	97.5
0.075	1.7	0.3	97.2
Pan	0.0	0.0	
Dry weight before washing	572.0	100.0	

Location :Km 102+050 LHS

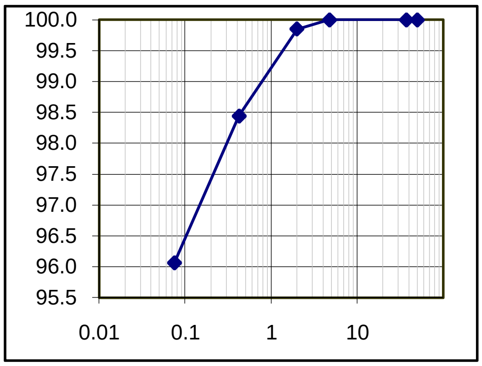
Sample No:10



sieve size, mm.	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	0.0	0.0	100.0
2.00	0.0	0.0	100.0
0.425	12.5	2.9	97.1
0.075	8.8	2.1	95.0
Pan	0.0	0.0	
Dry weight before washing	424.0	100.0	

Location : Km 102+250 RHS

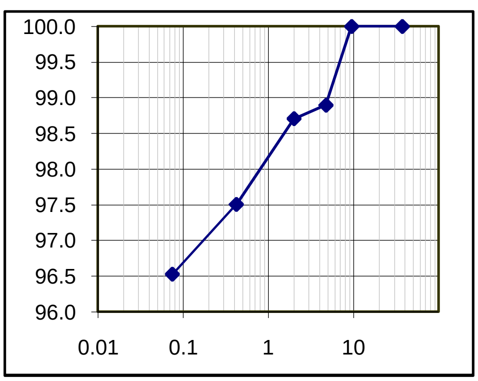
Sample No: 11



sieve size, mm.	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	0.0	0.0	100.0
2.00	0.7	0.2	99.8
0.425	6.5	1.4	98.4
0.075	11.0	2.4	96.1
Pan	0.0	0.0	
Dry weight before washing	462.0	100.0	

Location : Km 102+650 LHS

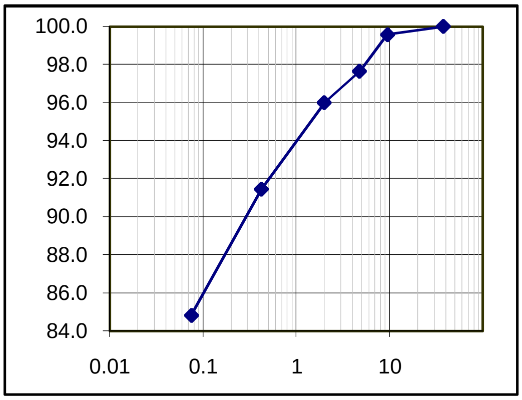
Sample No: 12



sieve size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
9.5	0.0	0.0	100.0
4.75	5.7	1.1	98.9
2.00	1.0	0.2	98.7
0.425	6.2	1.2	97.5
0.075	5.1	1.0	96.5
Pan	0.0	0.0	
Dry weight before washing	518.0	100.0	

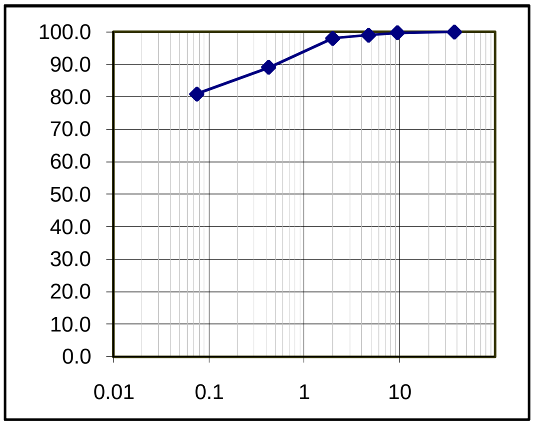
Location : Km 102+850 RHS

Sample No: 13



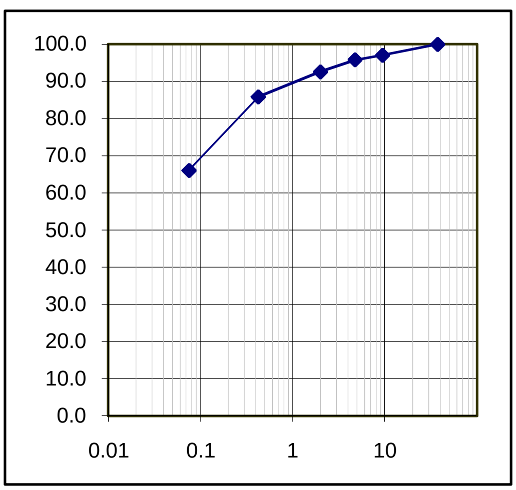
Sieve Size(	weight retained	% retaine	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
9.5	2.5	0.4	99.6
4.75	11.4	1.9	97.6
2.00	9.7	1.6	96.0
0.425	26.6	4.5	91.5
0.075	39.0	6.6	84.8
Pan	0.0	0.0	
Dry weight before washing	588.0	100.0	

Location : Km 103+050 LHS
Sample No: 14



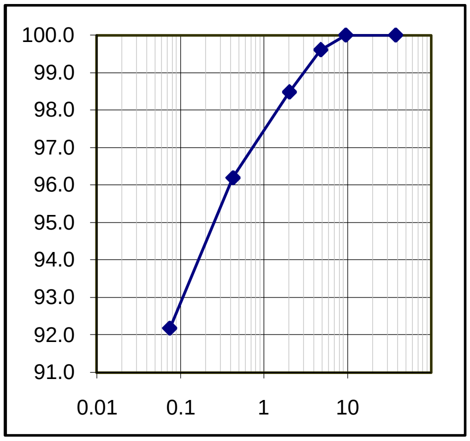
sieve Size(mm)	weight retaine d	% retaine d	% passing
50	0 0	0	100
37.5	0.0	0.0	100.0
9.5	1.4	0.2	99.8
4.75	4.1	0.7	99.1
2.00	6.2	1.1	98.0
0.425	52.5	8.9	89.1
0.075	48.0	8.2	80.9
Pan	0.0	0.0	
Dry weight before washing	588.0	100.0	

Source : Km 103+250 RHS
Sample No: 15



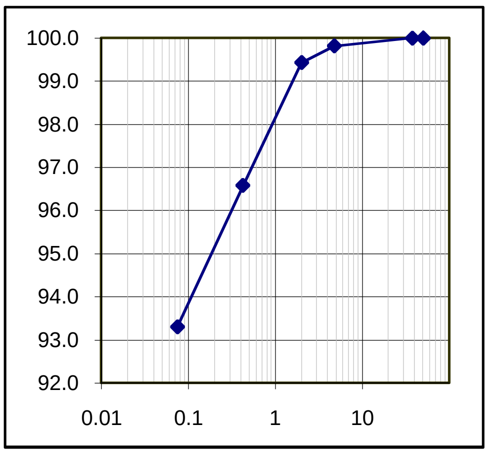
sieve size(mm	weight retaine	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
9.5	14.9	3.0	97.0
4.75	6.5	1.3	95.8
2.00	16.1	3.2	92.6
0.425	33.6	6.7	85.9
0.075	99.8	19.8	66.1
Pan	0.0	0.0	
Dry weight before washing	504.0	100.0	

Location : Km 103+450 LHS
Sample No: 16



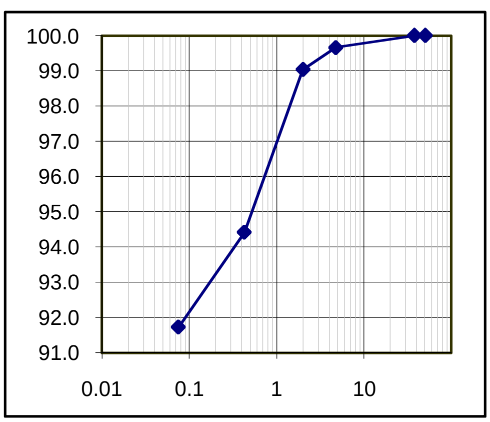
Sieve (mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
9.5	0.0	0.0	100.0
4.75	2.2	0.4	99.6
2.00	6.3	1.1	98.5
0.425	12.7	2.3	96.2
0.075	22.4	4.0	92.2
Pan	0.0	0.0	
Dry weight before washing	558.0	100.0	

Location : Km 103+650 RHS
Sample No:17



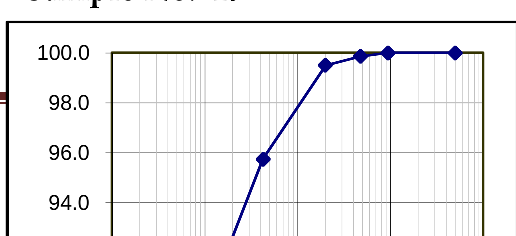
Sieve (mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	0.8	0.2	99.8
2.00	1.7	0.4	99.4
0.425	12.6	2.9	96.6
0.075	14.5	3.3	93.3
Pan	0.0	0.0	
Dry weight before	442.0	100.0	

Location : Km 103+850 LHS
Sample No: 18



sieve size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	1.8	0.3	99.7
2.00	3.4	0.6	99.0
0.425	25.1	4.6	94.4
0.075	14.6	2.7	91.7
Pan	0.0	0.0	
Dry weight before	543.0	100.0	

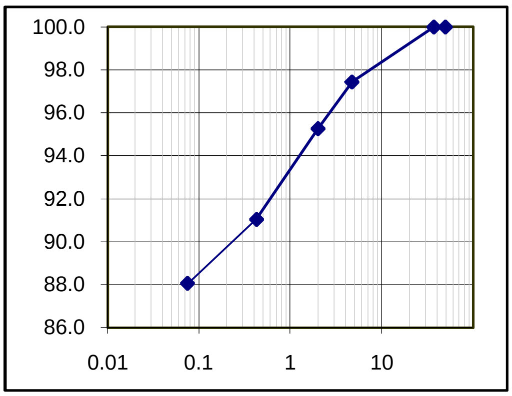
Location : Km 103+950 LHS
Sample No: 19



sieve	weight	%	%

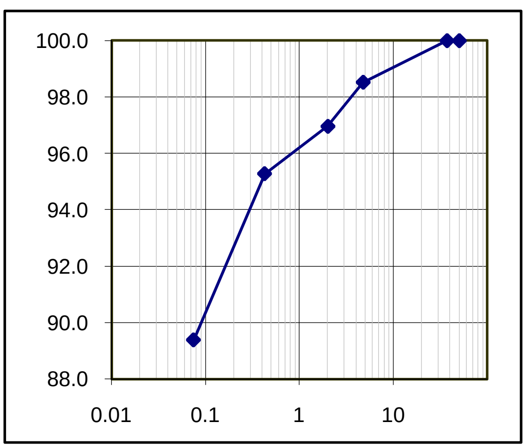
size(mm)	retained	retained	passing
50	0.0	0.0	100.0
9.5	0.0	0.0	100.0
4.75	0.7	0.1	99.9
2.00	1.8	0.4	99.5
0.425	18.9	3.8	95.7
0.075	36.0	7.2	88.6
Pan	0.0	0.0	
Dry weight before washing	502.0	100.0	

Location: Km 104+250 LHS
Sample No: 20



sieve size((mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	**100.0**
4.75	13.2	2.6	97.4
2.00	11.3	2.2	95.3
0.425	21.7	4.2	91.0
0.075	15.5	3.0	88.0
Pan	0.0	0.0	
Dry weight before washing	516.0	100.0	

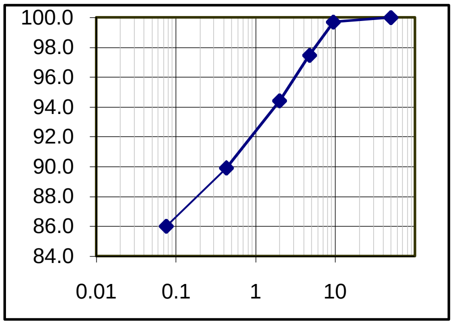
Location: Km 104+150 RHS
Sample No 21



sieve size, mm.	weight retaine	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	6.5	1.5	98.5
2.00	6.8	1.6	97.0
0.425	7.4	1.7	95.3
0.075	25.8	5.9	89.4
Pan	0.0	0.0	
Dry weight before washing	438.0	100.0	

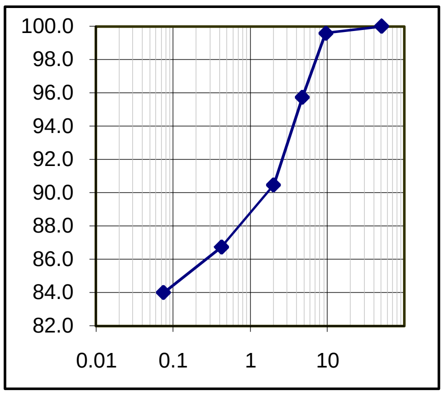
Location : Km 104+550 RHS

Sample No: 25



sieve size(mm)	Weight retained	% retained	% passed
50	0.0	0.0	50
9.5	1.7	0.3	9.5
4.75	12.4	2.2	4.75
2.00	16.9	3.0	2.00
0.425	25.1	4.5	0.425
0.075	21.6	3.9	0.075
Pan	0.0	0.0	Pan
Dry weight before washing	555.0	100.0	

Location : Km 104+650 LHS
Sample No: 26



sieve size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
9.5	2.2	0.4	99.6
4.75	20.1	3.8	95.7
2.00	27.6	5.3	90.5
0.425	19.4	3.7	86.7
0.075	14.4	2.8	84.0
Pan	0.0	0.0	
Dry weight before washing	523.0	100.0	

Location : Km 104+750 RHS
Sample No: 27

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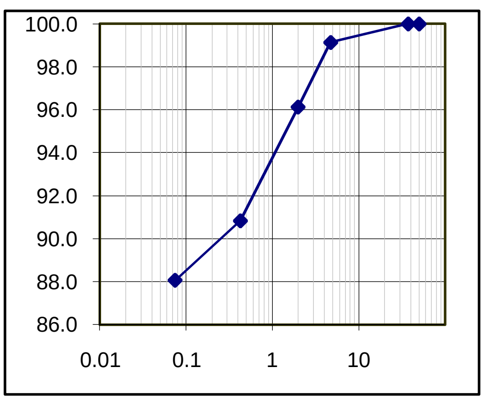

sieve size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	4.9	0.9	99.1
2.00	17.0	3.0	96.1
0.425	30.1	5.3	90.8
0.075	15.6	2.8	88.1
Pan	0.0	0.0	
Dry weight before washing	566.0	100.0	

Location : Km 104+850 LHS
Sample No: 28

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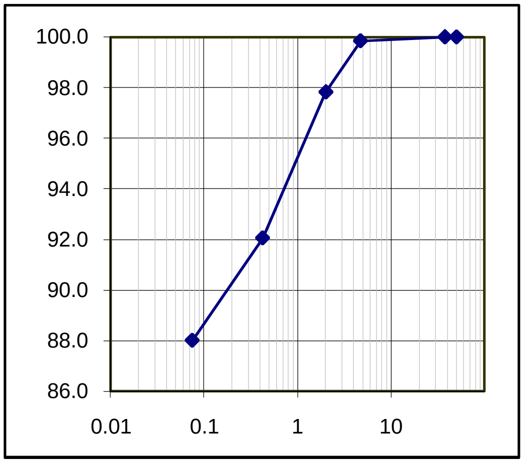
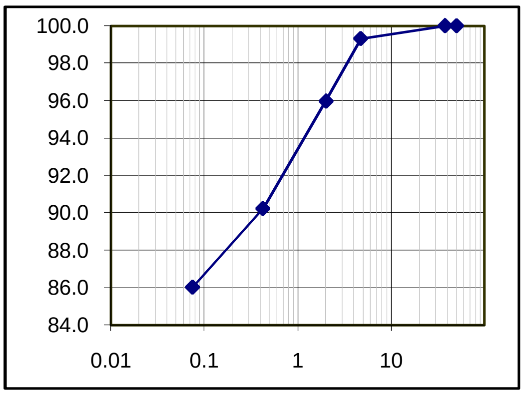


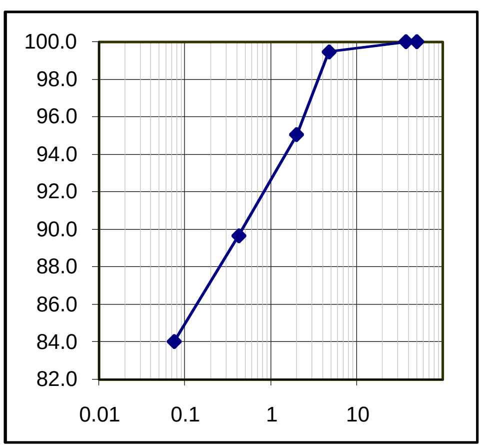
sieve size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	0.9	0.1	99.9
2.00	12.4	2.0	97.8
0.425	35.4	5.8	92.1
0.075	24.8	4.0	88.0
Pan	0.0	0.0	
Dry weight before washing	613.0	100.0	

Location :Km 104+950 RHS
Sample No:29



sieve size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	4.2	0.7	99.3
2.00	20.3	3.3	96.0
0.425	35.1	5.8	90.2
0.075	25.6	4.2	86.0
Pan	0.0	0.0	
Dry weight before washing	609.0	100.0	

Location : Km 105+050 LHS
Sample No: 30



sieve size(mm)	weight retained	% retained	% passing
50	0.0	0.0	100.0
37.5	0.0	0.0	100.0
4.75	2.6	0.5	99.5
2.00	22.1	4.4	95.0
0.425	26.8	5.4	89.7
0.075	28.1	5.6	84.0
Pan	0.0	0.0	
Dry weight before washing	498.0	100.0	

Natural Moisture Content (NMC)

Determination of Natural Moisture Content

Sampling Station: 100+200

Sample No: 01

Container No.	1
Weight of wet soil +Container,gm	433
Weight of dry soil +Container,gm	354.5
Weight of Container,gm	67.4
Weight of moisture,gm	78.5
Weight of dry soil ,gm	287.1
Moisture Content,%(m)	27.34

Sampling Station: 100+420

Sample No: 02

Container No.	2
Weight of wet soil +Container,gm	441.6
Weight of dry soil +Container,gm	349.3
Weight of Container,gm	80.9
Weight of moisture,gm	92.3
Weight of dry soil ,gm	268.4
Moisture Content,%(m)	34.4

Sampling Station 100+600

Sample No 03

Container No.	3
Weight of wet soil +Container,gm	433.2
Weight of dry soil +Container,gm	369.8
Weight of Container,gm	76.5
Weight of moisture,gm	63.4
Weight of dry soil ,gm	293.3
Moisture Content,%(m)	21.6

Sampling Station 100+850

Sample No 04

Container No.	4
Weight of wet soil +Container,gm	387.5
Weight of dry soil +Container,gm	336
Weight of Container,gm	80.8
Weight of moisture,gm	51.5
Weight of dry soil ,gm	255.2
Moisture Content,%(m)	20.2

Sampling Station: 101+050
Sample No:05

Container No.	5
Weight of wet soil +Container,gm	432.7
Weight of dry soil +Container,gm	356.5
Weight of Container,gm	76.6
Weight of moisture,gm	76.2
Weight of dry soil ,gm	279.9
Moisture Content,%(m)	27.2

Sampling Station:101+250
Sample No:06

Container No.	6
Weight of wet soil +Container,gm	514.4
Weight of dry soil +Container,gm	420.8
Weight of Container,gm	76.3
Weight of moisture,gm	93.6
Weight of dry soil ,gm	344.5
Moisture Content,%(m)	27.2

Sampling Station: 101+450
Sample No:07

Container No.	7
Weight of wet soil +Container,gm	400.4
Weight of dry soil +Container,gm	315
Weight of Container,gm	78.5
Weight of moisture,gm	85.4
Weight of dry soil ,gm	236.5
Moisture Content,%(m)	36.1

Sampling Station: 101+650
Sample No: 08

Container No.	8
Weight of wet soil +Container,gm	435.5
Weight of dry soil +Container,gm	358.3
Weight of Container,gm	57.7
Weight of moisture,gm	77.2
Weight of dry soil ,gm	300.6
Moisture Content,%(m)	25.7

Sampling Station : 101+850

Sample No :09

Container No.	9
Weight of wet soil +Container,gm	358.8
Weight of dry soil +Container,gm	300.5
Weight of Container,gm	58.8
Weight of moisture,gm	58.3
Weight of dry soil ,gm	241.7
Moisture Content,%(m)	24.1

Sampling Station: 102+050

Sample No:10

Container No.	10
Weight of wet soil +Container,gm	347.8
Weight of dry soil +Container,gm	284
Weight of Container,gm	52.8
Weight of moisture,gm	63.8
Weight of dry soil ,gm	231.2
Moisture Content,%(m)	27.6

Sampling Station: 102+250

Sample No:11

Container No.	11
Weight of wet soil +Container,gm	440.7
Weight of dry soil +Container,gm	360.6
Weight of Container,gm	57.8
Weight of moisture,gm	80.1
Weight of dry soil ,gm	302.8
Moisture Content,%(m)	26.45

Sampling Station: 102+450

Sample No:12

Container No.	12
Weight of wet soil +Container,gm	190.2
Weight of dry soil +Container,gm	153.2
Weight of Container,gm	36.4
Weight of moisture,gm	37
Weight of dry soil ,gm	116.8
Moisture Content,%(m)	31.7

Sampling Station: 102+650

Sample No:13

Container No.	13
Weight of wet soil +Container,gm	335
Weight of dry soil +Container,gm	261.7
Weight of Container,gm	68.9
Weight of moisture,gm	73.3
Weight of dry soil ,gm	192.8
Moisture Content,%(m)	38.0

Sampling Station: 102+850

Sample No: 14

Container No.	14
Weight of wet soil +Container,gm	193.5
Weight of dry soil +Container,gm	168.58
Weight of Container,gm	68.9
Weight of moisture,gm	24.92
Weight of dry soil ,gm	99.68
Moisture Content,%(m)	25.00

Sampling Station: 103+050

Sample No: 15

Container No.	7
Weight of wet soil +Container,gm	351
Weight of dry soil +Container,gm	321.2
Weight of Container,gm	78.5
Weight of moisture,gm	29.8
Weight of dry soil ,gm	242.7
Moisture Content,%(m)	12.3

Sampling Station: 03+250

Sample No: 16

Container No.	9
Weight of wet soil +Container,gm	452.3
Weight of dry soil +Container,gm	372.2
Weight of Container,gm	58.8
Weight of moisture,gm	80.1
Weight of dry soil ,gm	313.4
Moisture Content,%(m)	25.6

Sample No :17

Container No.	6
Weight of wet soil +Container,gm	365.8
Weight of dry soil +Container,gm	302.8
Weight of Container,gm	76.3
Weight of moisture,gm	63
Weight of dry soil ,gm	226.5
Moisture Content,%(m)	27.8

Sampling Station : 103+650

Sample No :18

Container No.	10
Weight of wet soil +Container,gm	356.4
Weight of dry soil +Container,gm	282.1
Weight of Container,gm	52.8
Weight of moisture,gm	74.3
Weight of dry soil ,gm	229.3
Moisture Content,%(m)	32.4

Sampling Station : 103+850

Sample No:19

Container No.	14
Weight of wet soil +Container,gm	430.8
Weight of dry soil +Container,gm	345
Weight of Container,gm	24.92
Weight of moisture,gm	85.8
Weight of dry soil ,gm	320.08
Moisture Content,%(m)	26.8

Sampling Station: 104+050

Sample No: 20

Container No.	12
Weight of wet soil +Container,gm	201.4
Weight of dry soil +Container,gm	164.4
Weight of Container,gm	36.4
Weight of moisture,gm	37
Weight of dry soil ,gm	128
Moisture Content,%(m)	28.9

Sampling Station: 104+150

Sample No: 21

Container No.	8
Weight of wet soil +Container,gm	345
Weight of dry soil +Container,gm	277.7
Weight of Container,gm	57.7
Weight of moisture,gm	67.3
Weight of dry soil ,gm	220
Moisture Content,%(m)	30.6

Sampling Station: 104+250

Sample No: 22

Container No.	11
Weight of wet soil +Container,gm	208.4
Weight of dry soil +Container,gm	172.2
Weight of Container,gm	57.8
Weight of moisture,gm	36.2
Weight of dry soil ,gm	114.4
Moisture Content,%(m)	31.6

Sampling Station: 104+350

Sample No: 23

Container No.	1
Weight of wet soil +Container,gm	436
Weight of dry soil +Container,gm	351.8
Weight of Container,gm	67.4
Weight of moisture,gm	84.2
Weight of dry soil ,gm	284.4
Moisture Content,%(m)	29.6

Sampling Station: 104+450

Sample No: 24

Container No.	13
Weight of wet soil +Container,gm	451.2
Weight of dry soil +Container,gm	361.6
Weight of Container,gm	68.9
Weight of moisture,gm	89.6
Weight of dry soil ,gm	292.7
Moisture Content,%(m)	30.6

Sampling Station: 104+550
Sample No: 25

Container No.	5
Weight of wet soil +Container,gm	405.8
Weight of dry soil +Container,gm	326.9
Weight of Container,gm	76.6
Weight of moisture,gm	78.9
Weight of dry soil ,gm	250.3
Moisture Content,%(m)	31.5

Sampling Station: 104+650
Sample No: 26

Container No.	2
Weight of wet soil +Container,gm	415.2
Weight of dry soil +Container,gm	331.5
Weight of Container,gm	80.9
Weight of moisture,gm	83.7
Weight of dry soil ,gm	250.6
Moisture Content,%(m)	33.4

Sampling Station: 104+750
Sample No: 27

Container No.	3
Weight of wet soil +Container,gm	304.9
Weight of dry soil +Container,gm	256.6
Weight of Container,gm	76.5
Weight of moisture,gm	48.3
Weight of dry soil ,gm	180.1
Moisture Content,%(m)	26.8

Sampling Station: 101+850
Sample No: 28

Container No.	4
Weight of wet soil +Container,gm	491.2
Weight of dry soil +Container,gm	399.9
Weight of Container,gm	80.8
Weight of moisture,gm	91.3
Weight of dry soil ,gm	319.1
Moisture Content,%(m)	28.6

Sampling Station: 04+950
Sample No: 29

Container No.	9
Weight of wet soil +Container,gm	374.6
Weight of dry soil +Container,gm	300.8
Weight of Container,gm	58.8
Weight of moisture,gm	73.8
Weight of dry soil ,gm	242
Moisture Content,%(m)	30.5

Sampling Station: 105+050
Sample No: 30

Container No.	10
Weight of wet soil +Container,gm	411.3
Weight of dry soil +Container,gm	329.4
Weight of Container,gm	52.8
Weight of moisture,gm	81.9
Weight of dry soil ,gm	276.6
Moisture Content,%(m)	29.6

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university and that all sources of materials used for the thesis have been dully acknowledged.

Name: Yitagesu Desalegn
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Signature: ____________________