JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY (JIT)

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

GEOTECHNICAL ENGINEERING STREAM

Causes of Asphalt Pavement Distresses and their Remedies; A Case Study of Mekenajo-Nejo Asphalt Road; Ethiopia.

A thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Civil Engineering (Geotechnical Engineering).

BY: FIKRU BENTI

January, 2018

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January, 2018

Jimma, Ethiopia

Declaration

This thesis is my original work and has not been presented for a degree in any other university.

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Researcher Signature Date

This thesis has been submitted for examination with my approval with university supervisors.

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Abstract

This study has been conducted on Mekenajo-Nejo Road segment which is located in west Wollega zone of Oromiya regional state to identify causes of pavement distresses and to recommend remedial measures. A pavement distresses that occurs at the surface can have a number of different causes which must be properly identified before corrective action is taken. The objective of this study is to examine the causes and remedial measures for asphalt pavement distresses. It is also intended to compare the engineering properties of the existing pavement layers with the standards and finally, recommendations on how to address possible problems associated with the different types of pavement distresses and deterioration. This research mainly focus on making assessment of asphalt pavement condition, identifying causes of pavement distresses and proposing remedial measures for the Mekenajo-Nejo roads in west Wollega. Visual distress assessment, DCP tests and other necessary laboratory investigations were carried out on selected test sections in order to have better understanding of the pavement response and come up with identification of probable causes. During condition surveying some localized pavement distresses like potholes, alligator cracks, raveling, Corrugation, rutting and poor drainage condition was observed. The average thickness of each layers were measured and Asphalt 3.9cm, Base 14.5cm, and Sub-base 18.0cm. From field investigation and laboratory test result, the AASHTO and Unified Soil Classification are Subgrade A-7 and SC, sub-base A-2-4 and GP and base course A-1-a and GW. Average liquid limit (LL), and plasticity index(PI) in percent were base course (5,5), sub-base(23,7) and sub-grade(47,15) and compaction, MDD(g/cc) and OMC(%), base course(1.86,6.63), sub base(1.81,8.26) and sub-grade(1.64,17.77), CBR% were base course 94%, sub-base 86% and sub-grade14% obtained. Based on the laboratory test result and condition survey the following are cause of pavement damages; Subgrade soil, degree of compaction, improper pavement layer thickness, and Poor drainage. Finally surface treatments, Fill cracks with asphalt emulsion slurry, full- depth patching, and removing vegetation close to the ditches are some of the recommendation forwarded.

Keywords:*-Pavement distresses, Causes of distresses, remedial measures*

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Lists of Abbreviations

AASHTO: - American Association of State Highway and Transportation Officials;

ASTM: -American Society for Testing Materials;

BH: - Boreholes;

CBR: - California Bearing Ratio

CC: - Coefficient of Curvature

CU: -Coefficient of Uniformity

DCP: - Dynamic Cone Penetration

ERA: -Ethiopian Road Authority

GB: - Granular Base course,

GC: - Granular Capping layer

GS: - Granular Sub base layer

GW: – Well graded gravel

JIT: - Jimma Institute of Technology

LL: - Liquid Limit

MDD: - Maximum Dry Density

OMC: - Optimum Moisture Content

PI: -Plastic Index

PL: - Plastic Limit

SC: - Sandy Clay soil

TRRL: -Transport and Road Research Laboratory;

USCS: -Unified Soil Classification System;

CHAPTER ONE

INTRODUCTION

1.1 Background

Asphalt pavements provide a smooth surface over which vehicles may safely pass under all climatic conditions for the specific performance period of the pavement. At the age of globalization, transportation is fundamental to the development and operation of any society. It permits that geographically distant resources to become accessible, connect people, exchange of technology and also goods needed in different places. This make evident that the economic growth of any society in any part of the world is directly related to the availability of transportation. Road improvements bring immediate and sometimes dramatic benefits to road users. Therefore, a society without an advanced transportation system remains backward from the rest of the world, [4].

Road failure is defined as the inability of a normal road to carry out its functional service by not providing smooth running surface for operating vehicles. Factors that affect the pavement performances are climate, construction material properties, Workmanship, structure and Traffic load. Movement of subgrade is the major causes of road pavement failure which makes road network unsafe and not suitable to road users, [5].

Due to the Economic growth of a country the movement of traffic volume and loads on roads are going on increasing from year to year with alarming rate all over the world. Such heavy traffic growth demands need better performance roads for efficient transport of agricultural, commercial and industrial products without delay from one location to others. Factors affecting the pavement performance are climate, material properties, structure and traffic load. The repetitive traffic loading that the road experiences during its service life combined with environmental factors causes deformation, fatigue cracking, instability and other forms of deterioration which ultimately degrade/reduces the serviceability and durability of pavement structures, [6].

The researcher would like to ascertain whether certain types of pavement distress are progressive, lead to eventual failure of the road. Excessive movement of flexible pavements, which eventually result in uneven riding qualities, may mostly be caused by poor qualities of the sub-grade, sub-base, base course or wearing course and due to improper drainage system,

[7]. Considering remedial measures for defects or reconstruction or overlay, it is imperative that the engineer takes into account, various parameters that are necessary for proper evaluation of the existing pavement condition.

This study determined the causes of asphalt pavement distresses and their remedial measures along the route "Mekenajo to Nejo Towns" in West Wollega with estimated length of 61km through Visual distress assessment, DCP tests and other necessary laboratory investigations on selected test sections.

1.2 Statement of the Problem

There is no doubt that the quality and efficiency of roads affect the quality of life, the health of the social system and the continuity of economic and business activity. Deterioration and catastrophic failure of these roads may occur because of aging, overuse, misuse and/or mismanagement. Therefore, their maintenance and preservation should have a great national interest.

Among the national roads network of Ethiopia, Mekenajo-Nejo road segment is currently under severely damaged condition so that the communities leading their life by selling coffee cash crop to market as well as the general public travelling through this route has been affected. There are a significant number of asphalt pavement damages along Mekenajo-Nejo road and this pavement road suffers from a series of distresses and the pavement surface is not comfortable for riding.

This problem decreases its efficiency and safety, loss of life, property, increase vehicles operation cost, and human injuries through accidents, environmental pollution and degradation, Impedance of human movement and the flow of economic activities and numerous cases of armed robbery attacks along affected areas. The road has been experiencing different types of distresses and deterioration and causing traffic accident, increase vehicle operation cost and travel time and decrease comfort to passengers. Therefore, it is crucial to investigate the causes of asphalt pavement distresses and assess their remedial measures.

1.3 Objectives

1.3.1 General objective

- To investigate the causes of pavement distresses on Mekenejo-Nejo asphalt road and their remedial measures.

1.3.2 Specific Objectives

- To identify type of distresses occurred in the study area.
- To identify major causes of asphalt pavement distresses and subgrade failure.
- To estimate the engineering performance of the existing pavement layers and compare with the standard specifications.
- To suggest remedial measures for improving the existing condition of the asphalt pavement.

1.4 Research Questions

1. What are the major asphalt pavement distresses on Mekenejo-Nejo road?
2. How do you identify major causes of distresses on pavement with relation to condition of Subgrade, sub-base, base, pavement, drainage, poor specification and poor compaction?
3. What are the remedial measures to improve the existing condition of the asphalt Pavement?

1.5 Significant of the study

- Provide detail information on how the geotechnical properties of sub-grade/sub-base/base/pavement layer or any other affect pavement performance.
- Be helpful for stakeholders that directly involving in roads construction work and professionals evaluating similar project and Provide useful information in order to solve problems of failure and create safe government budget and transportation with proper designing period for ERA and any other agency who out score and control road projects.

1.6 Scope of the Study

The study was conducted about specifically on the paved roads along Mekenejo-Nejo road of 61km in West Wollega and a program of field and laboratory testing was performed to identify the causes of distresses and prevention for each of the distress types. Based on the existing theories and principles this research addresses the general objectives to investigate the causes of damages on the pavement and their remedies on asphalt pavement road. For this intended purpose, Soil samples were collected from the worst road failure locations and non-distress pavement location; the soil samples collected were analyzed based on geotechnical analysis and field test were carried out in order to compare the results. The most important works to be done are outlined in the research method. Tests were conducted and analyzed; the results of Laboratory and field tests were compared with ERA Standard Specifications. The following tests were done on pavement layers:- Particle size distribution/Grain size analysis, Atterberg Limit, Moisture - Density Relation of Soil (compaction test), CBR (both disturbed and DCP), Natural moisture content, Soil classification, and thickness measurement.

1.7 Structure of the thesis

This research study comprised of five chapters and their contents are outlined below: In the first chapter an overview of the background of the research, statement of the problem, research questions, objective, significance of the study and scope of the study was discussed. The second chapter deals with the literature review about characteristics of pavement condition and Properties of subgrade, sub-base course and base course materials, discussion was made about pavement materials especially subgrade materials related to subsurface courses material strength, stiffness and finally about the pavement distress types. The third chapter deals with the research methods. The fourth chapter deals with assessments of test results that are gathered from field and laboratory tests and analysis and discussion was carried out, whether it satisfies the requirements set in the specification of the Ethiopian Road Authority Manual and remedial measure to be taken on the failure section of a road. The last chapter five, a conclusions and recommendations are derived from results and discussions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of literature on the damages and its causes on asphalt pavement and proposed remedial measures. The main purpose of a literature review is to establish the academic and research areas that are relevant to the subject under study.

2.2 Definition of pavement

Pavement is that with which anything is paved; a floor or covering of solid material, laid so as to make a hard and convenient surface for travel; a paved road or sidewalk; a decorative interior floor of tiles colored bricks. The pavement consists of the higher quality (usually imported/borrowed) material above the sub-grade including the wearing course, the base course, and the sub base, [8].

2.2.1 Types of pavement

Pavements are typically divided into the following three general categories: flexible, rigid and unpaved (gravel or dirt), [8].

2.2.1.1 Flexible (Bituminous Pavements)

A flexible pavement are constructed of several layers of natural granular material covered with one or more waterproof bituminous surface layers, and as the name imply, is considered to be flexible. A flexible pavement will flex (bend) under the load of a tire. The objective with the design of a flexible pavement is to avoid the excessive flexing of any layer, failure to achieve this will result in the over stressing of a layer, which ultimately will cause the pavement to fail. In flexible pavements, the load distribution pattern changes from one layer to another, because the strength of each layer is different. The strongest material (least flexible) is in the top layer and the weakest material (most flexible) is in the lowest layer materials, [8].

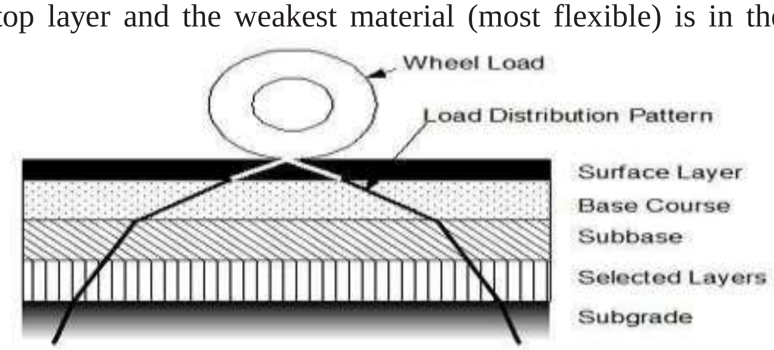

Figure 2.1: Load distribution of flexible pavement. [8]

2.3 Pavement Functions:

The functions of the pavement are:-

a) **Provide a reasonably smooth riding surface**:

A smooth riding surface (Low Roughness) is essential for riding comfort, and over the years it has become the measure of how road users perceive a road. Roughness can arise from a number of causes, most often however it is from pavement distress due to structural deformation. Provide Adequate Surface Friction (Skid Resistance): Safety, especially during wet conditions can be linked to a loss of surface friction between the tire and the pavement surface. A pavement must therefore provide sufficient surface friction and texture to ensure road user safety under all conditions.

b) **Protect the Subgrade**:

The supporting soil beneath the pavement is commonly referred to as the subgrade, should it be over-stressed by the applied axle loads it will deform and lose its ability to properly support these axle loads. Therefore, the pavement must have sufficient structural capacity (strength and thickness) to adequately reduce the actual stresses so that they do not exceed the strength of the Subgrade. The strength and thickness requirements of a pavement can vary greatly depending on the combination of sub grade type and loading condition (magnitude and number of axle loads).

c) **Provide waterproofing**:

The pavement surfacing acts as waterproofing surface that prevent the underlying support layers including the sub grade from becoming saturated through moisture ingress. When saturated, soil loses its ability to adequately support the applied axle loads, which will lead to premature failure of the pavement [8].

2.4 Factors influencing the performance of a pavement

1) **Traffic:** Traffic is the most important factor influencing pavement performance. The performance of pavements is mostly influenced by the loading magnitude, configuration and the number of load repetitions by heavy vehicles. The damage caused per pass to a pavement by an axle is defined relative to the damage per pass of a standard axle load, which is defined as an 80 KN single axle load (E80). Thus a pavement is designed to withstand a certain

number of standard axle load repetitions (E80's) that will result in a certain terminal condition of deterioration, [9].

2) **Moisture (water):** Moisture can significantly weaken the support strength of natural gravel materials, especially the subgrade. Moisture can enter the pavement structure through cracks and holes in the surface, laterally through the subgrade, and from the underlying water table through capillary action. The result of moisture ingress is the lubrication of particles, loss of particle interlock and subsequent particle displacement resulting in pavement failure, [9].
3) **Subgrade:** The subgrade is the underlying soil that supports the applied wheel loads. If the subgrade is too weak to support the wheel loads, the pavement will flex excessively which ultimately causes the pavement to fail. If natural variations in the composition of the subgrade are not adequately addressed by the pavement design, significant differences in pavement performance will be experienced [9].
4) **Construction quality:** Failure to obtain proper compaction, improper moisture conditions during construction, quality of materials, and accurate layer thickness (after compaction) all directly affect the performance of a pavement. These conditions stress the need for skilled staff and the importance of good inspection and quality control procedures during construction, [9].
5) **Maintenance:** Pavement performance depends on what, when, and how maintenance is performed. No matter how well the pavement is built, it will deteriorate over time based upon the mentioned factors. The timing of maintenance is very important, if a pavement is permitted to deteriorate to a very poor condition, as illustrated by point B in Error! Reference source not found, then the added life compared with point A, is typically about 2 to 3 years, [9].

2.5 Pavement deterioration and its types:

Pavement deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. A defect refers to the visible evidence of an undesirable condition in the pavement affecting serviceability, structural condition or appearance. Correct diagnosis of the cause of defects can only be made after careful inspection of the pavement by an observer on foot, and can be seen the defects at various angles, heights and distance, [10].

The four major categories of common asphalt pavement surface distresses are:

1) Cracking,
2) Surface deformation,
3) Disintegration (potholes, etc.), and
4) Surface defects (bleeding, etc.).

2.5.1 Cracking:

The most common types of cracking are: Fatigue cracking, Longitudinal, cracking Transverse cracking, Block cracking, Slippage cracking, Reflective cracking, and Edge cracking.

1. **Fatigue cracking (Alligator cracking):** Fatigue cracking is commonly called alligator cracking. This is a series of interconnected cracks creating small, irregular shaped pieces of pavement. It is caused by failure of the surface layer or base due to repeated traffic loading (fatigue). Eventually the cracks lead to disintegration of the surface, as shown in Figure. The final result is potholes. Alligator cracking is usually associated with base or drainage problems. Small areas may be fixed with a patch or area repair, [17].

Figure 2.2: Alligator cracking, [From study Area].

2. Longitudinal cracking: Longitudinal cracks are long cracks that run parallel to the center line of the roadway. These may be caused by frost heaving or joint failures or they may be load induced. Understanding the cause is critical to selecting the proper repair. Multiple parallel cracks may eventually form from the initial crack. This phenomenon, known as deterioration, is usually a sign that crack repairs are not the proper solution, [17].

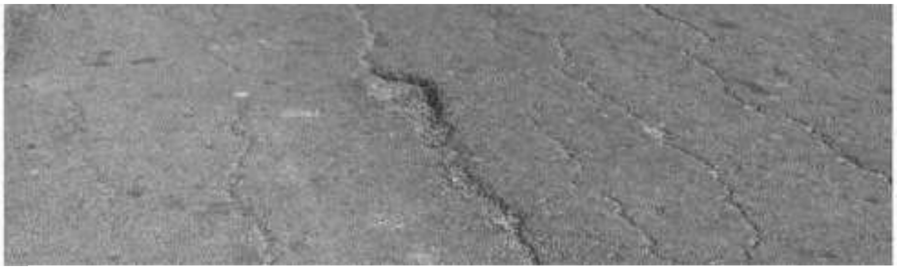

Figure 2.3 Longitudinal cracking, [11].

4. **Transverse cracking:** Transverse cracks form at approximately right angles to the centerline of the roadway. They are regularly spaced and have some of the same causes as longitudinal cracks. Transverse cracks will initially be widely spaced (over 20 feet apart). They usually begin as hairline or very narrow cracks and widen with age. If not properly sealed and maintained, secondary or multiple cracks develop, parallel to the initial crack. The reasons for transverse cracking, and the repairs, are similar to those for longitudinal cracking. In addition, thermal issues can lead to low-temperature cracking if the asphalt cement is too hard, [17].

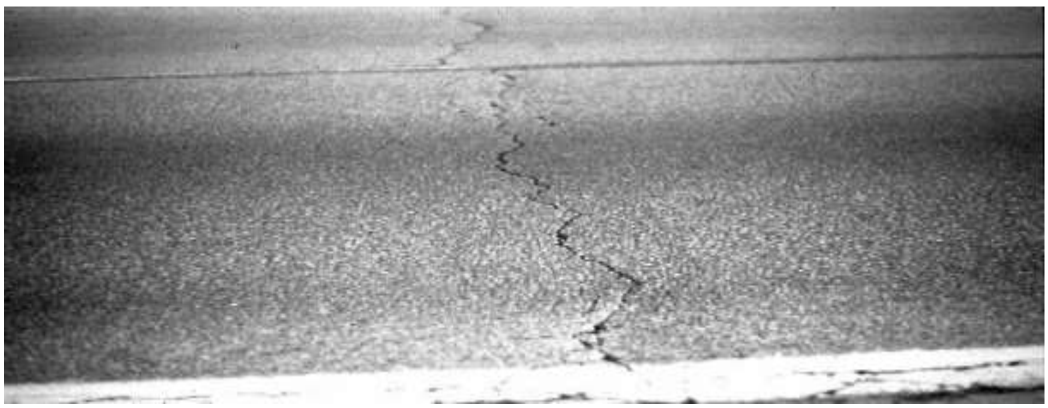

Figure 2.4 Transverse cracks, [17].

5. **Block cracking:** Block cracking is an interconnected series of cracks that divides the pavement into irregular pieces. This is sometimes the result of transverse and longitudinal cracks intersecting. They can also be due to lack of compaction during construction. Low severity block cracking may be repaired by a thin wearing course. As the cracking gets more severe, overlays and recycling may be needed. If base problems are found, reclamation or reconstruction may be needed, [13].

Figure 2.5 Block cracks, [13].

6. **Slippage cracking:** Slippage cracks are half-moon shaped cracks with both ends pointed towards the oncoming vehicles. They are created by the horizontal forces from traffic. They are usually a result of poor bonding between the asphalt surface layer and the layer below. The lack of a tack coat is a prime factor in many cases. Repair requires removal of the slipped area and repaving. Be sure to use a tack coat in the new pavement.[13]

Figure 2.6 Slippage cracks [13].

7. **Reflective cracking:** Reflective cracking occurs when a pavement is overlaid with hot mix asphalt concrete and cracks reflect up through the new surface. It is called reflective cracking because it reflects the crack pattern of the pavement structure below. As expected from the name, reflective cracks are actually covered over cracks reappearing in the surface. They can be repaired in similar techniques to the other cracking noted above. Before placing any overlays or wearing courses, cracks should be properly repaired, [14].

Figure 2.7 Reflective Cracking [14].

8. **Edge cracking:** Edge cracks typically start as crescent shapes at the edge of the pavement. They will expand from the edge until they begin to resemble alligator cracking. This type of cracking results from lack of support of the shoulder due to weak material or excess moisture. They may occur in a curbed section when subsurface water causes a weakness in the pavement. At low severity the cracks may be filled. As the severity increases, patches and replacement of distressed areas may be needed, [14].

Figure 2.8 Edge cracks, [14].

2.5.2 Surface deformation:

Pavement deformation is the result of weakness in one or more layers of the pavement that has experienced movement after construction. The deformation may be accompanied by cracking. Surface distortions can be a traffic hazard. The basic types of surface deformation are: Rutting, Corrugations, Shoving, Depressions and Swell.

1. **Rutting:** Rutting is the displacement of pavement material that creates channels in the wheel path. Very severe rutting will actually hold water in the rut. Rutting is usually a failure in one or more layers in the pavement. The width of the rut is a sign of which layer has failed.

Figure 2.9 Rutting, [15].

2. **Corrugation:** Corrugation is referred to as wash boarding because the pavement surface has become distorted like a washboard. The instability of the asphalt concrete surface course may be caused by too much asphalt cement, too much fine aggregate, or rounded or smooth textured course aggregate. Corrugations usually occur at places where vehicles accelerate or decelerate. Minor corrugations can be repaired with an overlay or surface milling. Severe corrugations require a deeper milling before resurfacing, [16].

Figure 2.10 Corrugation and Shoving, [16].

3. **Shoving:** Shoving is also a form of plastic movement in the asphalt concrete surface layer that creates a localized bulging of the pavement. Locations and causes of shoving are similar to those for corrugations. Figure shows an example of shoving. Repair minor shoving by removing and replacing. For large areas, milling the surface may be required, followed by an overlay, [16].
4. **Depressions:** Depressions are small, localized bowl-shaped areas that may include cracking. Depressions cause roughness, are a hazard to motorists, and allow water to collect. Depressions are typically caused by localized consolidation or movement of the supporting layers beneath the surface course due to instability. Repair by excavating and rebuilding the localized depressions. Reconstruction is required for extensive depressions, [16].
5. **Swell:** A swell is a localized upward bulge on the pavement surface. Swells are caused by an expansion of the supporting layers beneath the surface course or the subgrade. The expansion is typically caused by frost heaving or by moisture. Subgrades with highly plastic clays can swell in a manner similar to frost heaves (but usually in warmer months). Repair swells by excavating the inferior subgrade material and rebuilding the removed area, [16].

2.5.3 Disintegration

The progressive breaking up of the pavement into small, loose pieces is called disintegration. If the disintegration is not repaired in its early stages, complete reconstruction of the pavement may be needed. The two types of disintegration are: Potholes and Patches.

1. **Potholes**: Potholes are bowl-shaped holes similar to depressions. They are a progressive failure. First, small fragments of the top layer are dislodged. Over time, the distress will progress downward into the lower layers of the pavement. Potholes are often located in areas of poor drainage, as seen in Figure. Potholes are formed when the pavement disintegrates under traffic loading, due to inadequate strength in one or more layers of the pavement, usually accompanied by the presence of water. Most potholes would not occur if the root cause was repaired before development of the pothole. Repair by excavating and rebuilding. Area repairs or reconstruction may be required for extensive potholes, [13].

Figure 2.11 Potholes, [From study site].

2. **Patches:** A patch is defined as a portion of the pavement that has been removed and replaced. Patches are usually used to repair defects in a pavement or to cover a utility trench. Patch failure can lead to a more widespread failure of the surrounding pavement. Some people do not consider patches as a pavement defect. While this should be true for high quality patches as is done in a semi-permanent patch, the throw and roll patch is just a cover. The underlying cause is still under the pothole. To repair a patch, a semi-permanent patch should be placed. Extensive potholes may lead to area repairs or reclamation. Reconstruction is only needed if base problems are the root source of the potholes, [13].

Figure: 2.12 patch, [13].

2.5.4 Surface defects:

Surface defects are related to problems in the surface layer. The most common types of surface distress are: Raveling, Bleeding, Polishing and Delamination.

1. **Raveling:** Raveling is the loss of material from the pavement surface. It is a result of insufficient adhesion between the asphalt cement and the aggregate. Initially, fine aggregate breaks loose and leave small, rough patches in the surface of the pavement. As the disintegration continues, larger aggregate breaks loose, leaving rougher surfaces. Raveling can be accelerated by traffic and freezing weather. Some raveling in chip seals is due to improper construction technique. This can also lead to bleeding. Repair the problem with a wearing course or an overlay, [17].

Figure 2.13: Raveling of asphalt surface, [From study road].

2. **Bleeding:** Bleeding is defined as the presence of excess asphalt on the road surface which creates patches of asphalt cement. Excessive asphalt cement reduces the skid-resistance of a pavement, and it can become very slippery when wet, creating a safety hazard. This is caused by an excessively high asphalt cement content in the mix, using an asphalt cement with too low a viscosity (too flow able), too heavy a prime or tack coat, or an improperly applied seal coat. Bleeding occurs more often in hot weather when the asphalt cement is less viscous (more flow able) and the traffic forces the asphalt to the surface, [13].

Figure: 2.14 Bleeding, [13].

3. **Polishing:** Polishing is the wearing of aggregate on the pavement surface due to traffic. It can result in a dangerous low friction surface. A thin wearing course will repair the surface, [13].

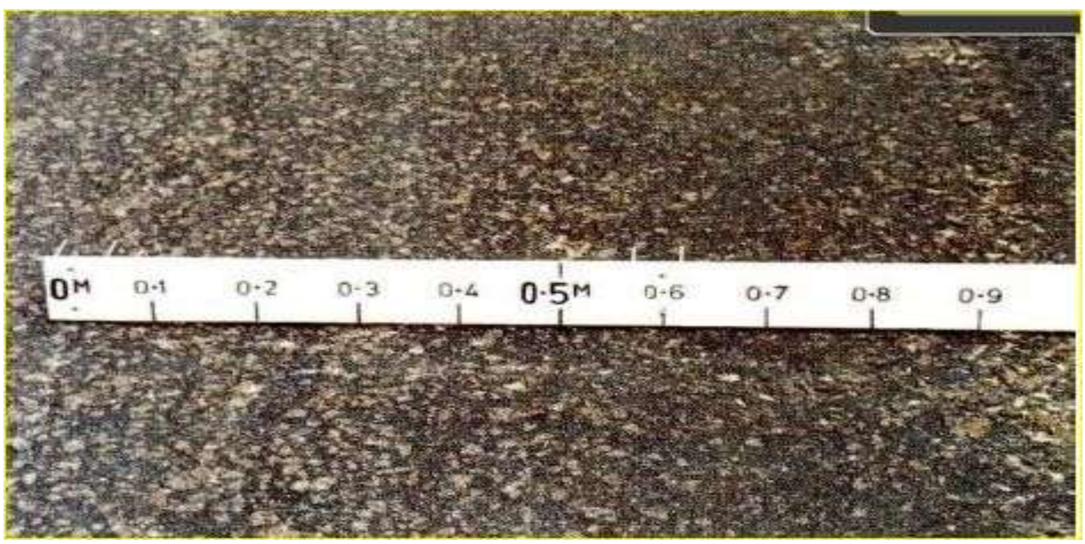

Figure: 2.15 Polishing, [13].

4. **Delamination:** Loss of a large area of pavement surface, usually there is a clear separation of the pavement surface from the layer below. Slippage cracking may often occur as a result of poor bonding or adhesion between layers, [15].

Figure 2.16: Delamination of an overlay, [15].

2.6 Causes of pavement deterioration

- Sudden increase in traffic loading especially on new roads where the design is based on lesser traffic is a major cause of cracking. After construction of good road, traffic of other roads also shifts to that road. This accelerates the fatigue failure (Alligator Cracking).
- Temperature variation ranging from 50º C to below zero conditions in the plain areas leads to bleeding and cracking.
- Provision of poor shoulders leads to edge failures.
- Provision of poor clayey subgrade results in corrugation at the surface and increase in unevenness.
- Poor drainage conditions especially during rainy seasons, force the water to enter the pavement from the sides as well as from the top surface. In case of open graded bituminous layer, this phenomenon becomes more dangerous and the top layer gets detached from the lower layers
- .If the temperature of bitumen/bituminous mixes is not maintained properly, and then it also leads to pavement failure. Overheating of bitumen reduces the binding property of bitumen.

2.7 Performance and Failure Criteria of Asphalt pavement

Pavement performance evaluation is an important activity in the maintenance and rehabilitation works. It includes evaluation of existing distresses, road roughness, structural adequacy, traffic analysis, material testing and study of drainage condition. This section deals with types of bituminous surfaces, types and causes of distresses, [18].

2.8 Pavement Evaluation Guidelines

The objective of this study is to establish guidelines describing systematic method for inspection and evaluation of pavement failures and to find out the possible causes of these failures. The proposed method has some basic steps are: (I) Inspection and Evaluation plan, (II) Documents and literature review, (III) Pavement condition survey (IV) Experimental work, (V) Determine probable cause(s) of failure (VI) Select the best maintenance option and (VII) Report on outcomes.

2.8.1 Inspection and evaluation plan

Planning is important to ensure that inspection and evaluation of pavement failures were carried out their intended tasks within a reasonable time frame and at the lowest cost. When planning the evaluation program, a general review of the problem should first be conducted, along with the possible scope of inspection and maintenance work that may need to be carried out. This plan should be drafted, addressing goals, budgeting constraints, operations planning and the investigative synthesis. The technical team should be decided upon, [19].

2.8.2 Documents and literature review

Reviewing documents and literature may involve the inspection of plans, pavement history, drainage design, pavement materials information and specifications, previous materials tests results, construction and previous maintenance records, testing methods and frequencies, and other relevant information such as traffic volumes and composition, soil or geological records, and temperature, weather or rainfall data. These collected data are very important for both the field survey task and the evaluation of pavement failures.

2.8.3 Pavement condition survey

The pavement condition survey may include visual examination of pavement failures, the effectiveness of drainage structures and other details such as topography and alignment should be recorded, and the soil and geology of the surrounding areas may also be of importance in determining the causes of the pavement failure. An effective visual survey of pavement failures is essential, to ensure that the cause of the failure can be diagnosed efficiently and it is a guide to what testing should be carried out and where. In addition, it will provide valuable site information that may have an influence on the best maintenance operation. Distress surveying should be carried out on failed pavement sections to find out the amount, type, and condition or severity level of distress, as well as the condition or effectiveness of any previously applied distress treatments, [20].

2.8.4 Experimental work

The experimental work includes filed and laboratory testing. Field testing program can assess the strength of the pavement materials. The conventional field tests may be carried out include Dynamic Cone Penetration (DCP) test,. Coring on pavement structure may be used to provide material samples for laboratory testing, and also allows visual examination of pavement layers. Laboratory testing should be conducted on representative samples taken from pavement layers to determine physical characteristics of the materials. The tests on soils and aggregates may aim to measure the index properties by particle size and shape, the plasticity and specific gravity and to assess the strength by the compaction and California Bearing Ratio (CBR) tests. [20].

2.8.5 Determine probable cause(s) of failure

It is quite important to find out the probable cause(s) of the pavement failure being investigated. The probable causes are normally stated, and there are often multiple factors that contributed to the failure. The first stage in determining the failure cause(s) is the investigative synthesis, where all the information gathered is listed. From this listed information, it is then necessary to determine which information supports or refutes each of the possible failure hypotheses. This may be initially done by considering general failure causes, such as those related to construction, materials, design, or the environment.

2.8.6 Selection of the best maintenance option

To select the best maintenance option, it is necessary to list a variety of alternatives that may be feasible, from an initial examination of the conditions. These possible alternatives can then be subjected to much more detailed examination of economic, design and construction factors. Other factors to consider include whether the treatment is accepted local practice, and whether a long lasting or simply an economical short-term treatment is required. Treatments may include surface treatments, overlays, in-situ stabilization, or any other maintenance treatments, [20].

2.8.7 Report on outcomes

A report on the outcomes of the pavement evaluation should be produced, as this enables others to learn from the failures, and should help reduce the chances of similar failures in the future. Information that should be included a general description of the project and its location, failures details, a description of any testing carried out, the probable cause(s) of failures expected, how it could be prevented in the future, and possible maintenance options

2.9 Subgrade Soils.

2.9.1 General Properties Subgrade Soils

Although a pavement's wearing course is important component of a road, the success or failure of a pavement is dependent on sub grade material upon which the pavement structure is built. Thus, the sub grade must be able to support the loads transmitted from the pavement structure without progressing excessive settlement. Its performance generally depends on its load bearing capacity, moisture content and volume changes. Moreover, its load bearing capacity depends on the degree of compaction, moisture content and soil type. Hence, the relationships among the strength, density and moisture content should be studied thoroughly, [21].

2.9.2 General Strength- Density-moisture relationship

Desirable properties that the sub grade should possess include strength, drainage, effortlessness of compaction, permanency of compaction, and permanency of strength. Since sub grades vary considerably, it is necessary to make a thorough study of the soils in place and, from this, to determine the design of the pavement. The determination of the sub grade strength in order to use for the design of the road pavement requires ascertaining the density-moisture content strength relationships specific to the sub grade soils encountered along the road under study. It is a must to select the density which will be representative of the compacted sub grade and the moisture content during and after construction, [21].

2.9.3 Estimated design moisture content of the sub grade

Moisture conditions in the sub grade are controlled primarily by the local environment. Since design concepts for flexible pavements are based upon model-prototype principles, wherein samples of soil are tested in the laboratory simulated field condition, it is necessary to predict the optimum moisture content of the sub grade so that this value can be used in the testing schedule, [21].

2.9.4 Representative density

The strength of the road sub grade for flexible pavements is commonly assessed in terms of the California Bearing Ratio (CBR) and this is dependent on the type of soil, its density, and its moisture content. Direct assessment of the likely strength or CBR of the sub grade soil under the completed road pavement is often difficult to make. Its value, however, can be inferred from an estimate of the density and moisture content of the sub grade together with knowledge of the relationship between strength, density and moisture content for the soil in question. This relationship must be determined in the laboratory. The density of the sub grade soil can be controlled within limits by compaction at suitable moisture content at the time of construction. According to the ERA Pavement Design Manual, [21], It is recommended that the top 25cm of all sub grades should be compacted to a relative density of at least 100% of the maximum dry density achieved by ASTM Test Method D 698 (light or standard compaction). The structural manual catalog given in the ERA Pavement Design Manual Volume I, requires that the sub grade strength for design be assigned to one of six strength classes reflecting the sensitivity of thickness design to sub grade strength.

Table 2.1 Subgrade strength classes [21].

Class	Range (CBR %)
S1	2
S2	3 – 4
S3	5 – 7
S4	8 – 14
S5	15 – 29
S6	30+

2.10 Granular pavement materials

2.10.1 General property of Granular Materials

Granular pavement material is one of the important components of a flexible pavement structure. This material include crushed rock, semi-crushed, mechanically stabilized, and modified or naturally occurring ‘as dug’ or ‘pit run’ gravels. The suitability of rocks for road construction depends on their mineral, chemical and physical properties, [21].

2.10.2 Properties of unbound pavement materials

Unbound granular materials are generally used in road pavements as base and sub-base courses, which are as important a component of roads as the surface composition and foundations. As a base course, they play a structurally important role, especially on medium and low volume roads. As a sub-base, they protect the soil, and act as a working platform and an insulating layer against frost action. Pavement failure due to inadequate support of upper layers, or to rutting, will usually necessitate complete pavement reconstruction, and not just the repair of the pavement surface where the problem is visible. According to the ERA Pavement Design Manual, the main categories of unbound pavement materials with a brief summary of their characteristics are shown in Table 2.2, [21]

Table 2.2 Properties of unbound materials, [23].

Code	Description	Summary of Specification
GB1	Fresh, crushed rock	Dense graded, unweather crushed stone, non-plastic parent fines
GB2	Crushed weathered rock, gravel or boulders	Dense grading, PI<6, soil or parent fines
GB3	Natural coarsely graded granular material, including processed and modified gravels.	Dense grading, PI < 6 CBR after soaking > 80
GS	Natural gravel	CBR after soaking > 30
GC	Gravel or gravel- soil	Dense graded; CBR after soaking>15

Note:-These specifications are sometimes modified according to site conditions, material type and principal use. Legend: GB = Granular base course, GS = Granular sub-base, GC = Granular capping layer.

i. Base course materials

The materials used for base courses such as crushed quarried rock, crushed and screened, mechanically stabilized, modified or naturally occurring "as dug" or "pit run" gravels can be used as a base course material. According to the ERA Pavement Design Manual the properties for base course materials is given below.

a. **Crushed stone Graded crushed stone (GB1)**. This material is produced by crushing fresh, quarried rock (GB1) and may be an all-in product, usually termed a 'crusher-run', or alternatively the material may be separated by screening and recombined to produce a desired particle size distribution, as per the specifications. Alternate gradation limits, depending on the local conditions for a particular project, are shown in Table 2.3, [21].

Table 2.3 Grading limits for graded crushed stone base course materials (GB1), [23].

Test sieve(mm)	Percentage by mass of total aggregate passing test sieve Nominal maximum particle size		
	37.5mm	28mm	20mm
50	100	-	-
37.5	95-100	100	-
28	-	-	100
20	60-80	70-85	90-100
10	40-60	50-65	60-75
5	25-40	35-55	40-60
2.36	15-30	25-40	30-45
0.425	7-19	12-24	13-27
0.075	5-12	5-12	5-12

Note. For paver-laid materials lower fines content may be accepted. The fine fraction of a GB1 material should be non-plastic. The in situ dry density of the placed material should be a minimum of 98% of the maximum dry density obtained in the ASTM Test Method D 1557 (Heavy Compaction). The compacted thickness of each layer should not exceed 200mm. Crushed stone base courses constructed with proper care with the materials described above should have CBR values well in excess of 100 percent. There is usually no need to carry out CBR tests during construction, [21].

b. Naturally occurring granular materials, boulders, weathered rocks

Normal Requirements for natural gravels and weathered rocks (GB2, GB3). A wide range of materials including lateritic, calcareous and quartzite gravels, river gravels, boulders and other transported gravels, or granular materials resulting from the weathering of rocks can be used successfully as base course materials. Table 2.4 contains three recommended particle size distributions for suitable materials corresponding to maximum nominal sizes of 37.5 mm, 20 mm and 10 mm. Only the two larger sizes should be considered for traffic in excess of 1.5 million equivalent standard axles. To ensure that the material has maximum mechanical stability, the particle size distribution should be approximately parallel with the grading envelope. To meet the requirements consistently, screening and crushing of the larger sizes may be required. The fraction coarser than 10 mm should consist of more than 40 percent of particles with angular, irregular or crushed faces. The mixing of materials from different sources may be warranted in order to achieve the required grading and surface finish. This may involve adding fine or course materials or combinations of the two. The fines of these materials should preferably be non-plastic but should normally never exceed a PI of 6, [21].

Table 2.4 Recommended particle size of rocks for use as base course material (GB2, GB3), [21].

Test sieve(mm)	Percentage by mass of total aggregate passing test sieve		
	Nominal maximum particle size		
	37.5mm	28mm	20mm
50	100	-	-
37.5	80-100	100	-
20	60-80	80-100	100
10	45-65	55-80	80-100
5	30-50	40-60	50-70
2.36	20-40	30-50	35-50
0.425	10-25	12-27	12-30
0.075	5-12	5-15	5-15

ii. Sub-bases (GS)

The sub-base is a pavement layer which enables traffic stresses to be reduced to acceptable levels in the sub-grade. According to the ERA Pavement Design Manual the requirements to use as a sub-base material is discussed below.

A. Bearing capacity

A minimum CBR of 30 percent is required at the highest anticipated moisture content when compacted to the specified field density, usually a minimum of 95 percent of the maximum dry density achieved in the ASTM Test Method D 1557 (Heavy Compaction). Under conditions of good drainage and when the water table is not near the ground surface the field moisture content under a sealed pavement will be equal to or less than the optimum moisture content in the ASTM Test Method D698 (Light Compaction).

The test should be conducted on samples prepared at the density and moisture content likely to be achieved in the field. In order to achieve the required bearing capacity, and for uniform support to be provided to the upper pavement, limits on soil plasticity and particle size distribution may be required. Materials which meet the recommendations of Table 2.5 and 2.6 will usually be found to have adequate bearing capacity, [21].

B. Use as a construction platform

In many circumstances the requirements of a sub-base are governed by its ability to support construction traffic without excessive deformation or raveling. A high quality sub-base is therefore required where loading or climatic conditions during construction are severe. Suitable material should possess properties similar to those of a good surfacing material for unpaved roads. In Ethiopia, laterite is one of the widely available materials and can be used as a sub-base material. Laterite meeting the graduation requirements of Table 2.5: can be used for traffic levels up to $3x10^6$ ESA provided the following criteria is satisfied, [21].

Plasticity Index (%)	<25
Plasticity Modulus (PM)	<500
CBR (%)	>30

Table 2.5 Recommended plasticity characteristics for granular sub-bases (GS), [21].

Climate	Typical annual rainfall	Liquid Limit	Plasticity Index	Linear shrinkage
Moist tropical and wet tropical	>500mm	<35	<6	<3
Seasonally wet Tropical	>500mm	<45	<12	<6
Arid and semi-arid	<500mm	<55	<20	<10

Table 2.6 Typical particle size distributions for sub-bases (GS), [21].

Test sieve (mm)	Total Mass of aggregate passing test sieve (%)
50	100
37.5	80-100
20	60-100
5	30-100
1.18	17-75
0.3	9-50
0.075	5-25

iii) Selected subgrade materials and capping layers (GC)

These materials are often required to provide sufficient cover on weak subgrades. They are used in the lower pavement layers as a substitute for a thick sub-base to reduce costs, and a cost comparison should be conducted to assess their cost effectiveness. As an illustrative example, approximately 30 cm of “GC” material placed on an S1 or S2 subgrade will allow selecting a pavement structure as for an S3 subgrade. An additional 5cm of “GC” material may allow considering an S4 subgrade class. The requirements are less strict than for sub-bases. A minimum CBR of 15 percent is specified at the highest anticipated moisture content measured on samples compacted in the laboratory at the specified field density. This density is usually specified as a minimum of 95 percent of the maximum dry density in the ASTMT test Method D 1557 (Heavy Compaction. The selection of materials which show the least change in bearing capacity from dry to wet is also beneficial, [21].

2.11 Description of Dynamic Cone Penetration Test (DCPT)

The dynamic cone penetration test (DCPT) was originally developed as an alternative for evaluating the properties of flexible pavement or subgrade soils. The conventional approach to evaluate strength and stiffness properties of asphalt and subgrade soils involves a core sampling procedure and a complicated laboratory testing program such as resilient modulus, Marshall tests and others (Livneh et al. 1994). 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 subgrade soils. Figure 2.17 shows a typical configuration of the dynamic cone penetrometer (DCP). As shown in the figure, the DCP consists of upper and lower shafts. The upper shaft has an 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 are required. One person drops the hammer, the second handle up the instrument and other records measurements. The first step of the test is to put the cone tip on the testing surface. 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. 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,

$$PI = \frac{\Delta D_p}{\Delta BC} \quad \text{.......} \quad (1)$$

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

ΔD_p = Penetration depth; BC = blow counts corresponding to penetration depth ΔDp. As a result, values of the penetration index (PI) represent DCPT characteristics at certain depths, [21].

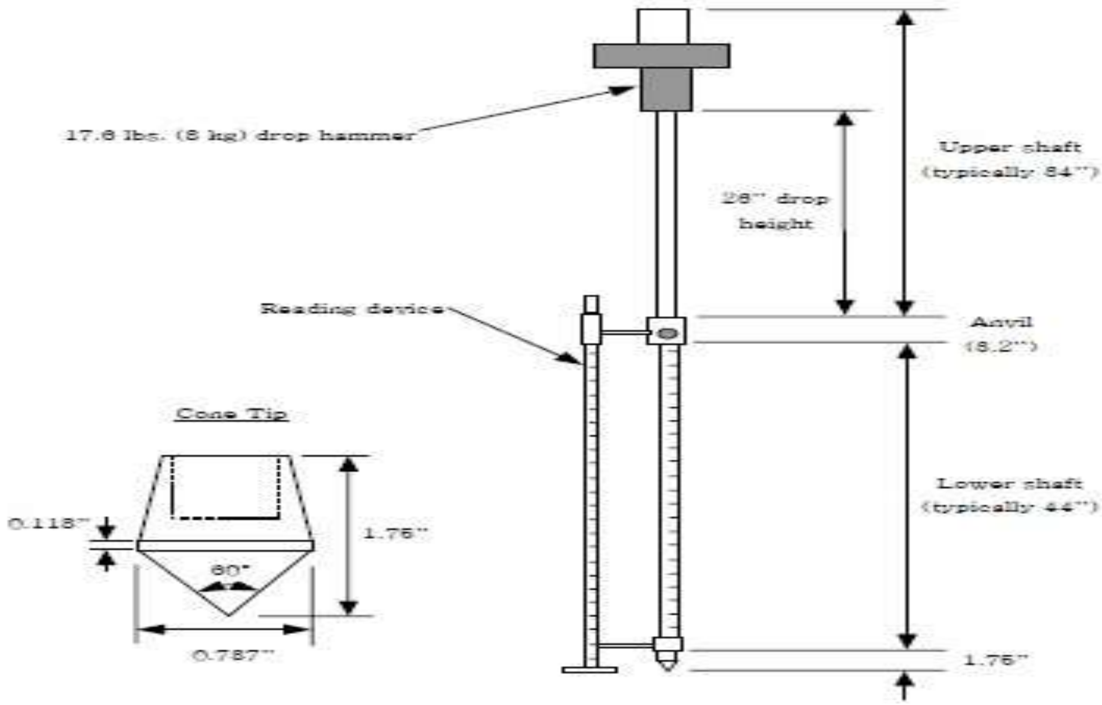

Figure 2.17 Structure of Dynamic Cone Penetrometer

2.12 Traffic Load

The deterioration of paved roads caused by traffic as a result of the magnitude of the individual wheel loads and the number of times these loads are applied. It is necessary to Consider not only the total number of vehicles that will use the road but also the wheel loads (or, for convenience, the axle loads) of these vehicles. Equivalency factors are used to convert traffic volumes into cumulative standard axle loads. Classes are defined for paved roads, for pavement design purposes, by ranges of cumulative Traffic number of equivalent standard axle's load, [21].

2.12.1 Determination of cumulative traffic volumes

In order to determine the cumulative number of vehicles over the design period of the road, the following procedure should be followed, [21].

1. Determine the initial traffic volume ($AADT_0$) using the results of the traffic survey and any other recent traffic count information that is available. For paved roads, detail the AADT in terms of car, bus, truck, and truck-trailer.

2. Estimate the annual growth rate "i" expressed as a decimal fraction, and the anticipated number of years "x" between the traffic survey and the opening of the road.
3. Determine $AADT_1$ the traffic volume in both directions on the year of the road opening by:

$AADT_1 = AADT_0\,(1+i)^{x}$ ………………………………………………………………. (2)

4. The cumulative number of vehicles, T over the chosen design period N (in years) is obtained

$T = 365\ AADT_1\,[(1+i)^{N} - 1] / (i)$……………………………..……………………….. (3)

2.12.2 Axle Load

The damage that vehicles do to a paved road is highly dependent on the axle loads of the vehicles. For pavement design purposes the damaging power of axles is related to a "standard" axle of 8.16 metric tons using empirical equivalency factors. In order to determine the cumulative axle load damage that a pavement will sustain during its design life, it is necessary to express the total number of heavy vehicles that will use the road over this period in terms of the cumulative number of equivalent standard axles (ESAs), [21].

Axle loads can be converted and compared using standard factors to determine the damaging power of different vehicle types. A vehicle's damaging power, or Equivalency Factor (EF), can be expressed as the number of equivalent standard axles (ESAs), in units of 80 kN. Finally, the cumulative ESAs over the design period (N) are calculated as the products of the cumulative one-directional traffic volume (T) for each class of vehicle by the mean equivalency factor for that class and added together for each direction. The relationship between a vehicle's EF and its axle loading is normally considered in terms of the axle mass measured in kilograms. The relationship takes the form [21].

$$\text{Equivalency factor} = \left(\frac{axle\ load\ i}{8160}\right)^{n} \quad \text{…………………………….…………………… (4)}$$

Where; axlei= mass of axle *i*,n = a power factor that varies depending on the pavement construction type and subgrade but which can be assumed to have a value of 4.5 and the standard axle load is taken as 8 160kg with the summation taken over the number of axles on the vehicle in question.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents and describes the approaches and techniques used to collect data and investigate the research problem. They include the research design, study population, sample size and selection, sampling techniques and procedure, data collection methods, procedure of data collection, and data analysis.

3.2 Study setting/Area

The study area undertaken was Mekenejo -Nejo road section which was found in West Wollega Zone in Oromiya Regional state. It was located approximately 450km from Addis Ababa and approximately 61km length from Mekenejo-Nejo Road section. The Road connects Gimbi woredas and Nejo town passes through different kebeles between the starting and end points of location.

A Mekenejo-Nejo road was constructed in 2002E.C by Chinas contractor. The pavement type Double Bituminous Surface Treatment (DBST) and the road width was7m. The estimated road length is 61 km along the Road section. The road traverses areas having significant natural resources, and intensive cultivation of cash crop, particularly coffee and cereals. This road provides a key link in the route from Addis Ababa to Assosa via Gimbi and Nejo.

This road is Part of secondary/link road connecting Assosa Town, the capital city of Region 6 (Beni Shangul Gumuz Regional state) to the primary road from Addis Ababa connecting the Town of Ambo, Nekempte and Gimbi. The total length of the road is 61 km. The road Mekenejo-Nejo starts off at the junction at 126km from Nekempte Town to Mekenajo, which is located on Nekempte - Gimbi - Hena – Nejo – Mendi – Bambasi - Assosa Road and goes in western direction to Nejo. Nekempte is 330 km west of Addis Ababa while Mekenajo and Nejo are located 126 km and 187 km from Nekempte respectively, [1].

The route between Mekenajo and Nejo passes through the western high lands characterized generally by high elevation and dissected terrain with rolling, rolling to hilly areas and steep Valley sides. The road traverses through flat and rolling terrain. The proportion of the terrain category is about 20% level, 75% rolling, and 5% Mountainous

The road from Mekenajo to Nejo town is the first section of Mekenajo -Mendi Road Upgrading Project. It is entirely in the Western highland of country in the national regional state of Oromiya as shown in map below..

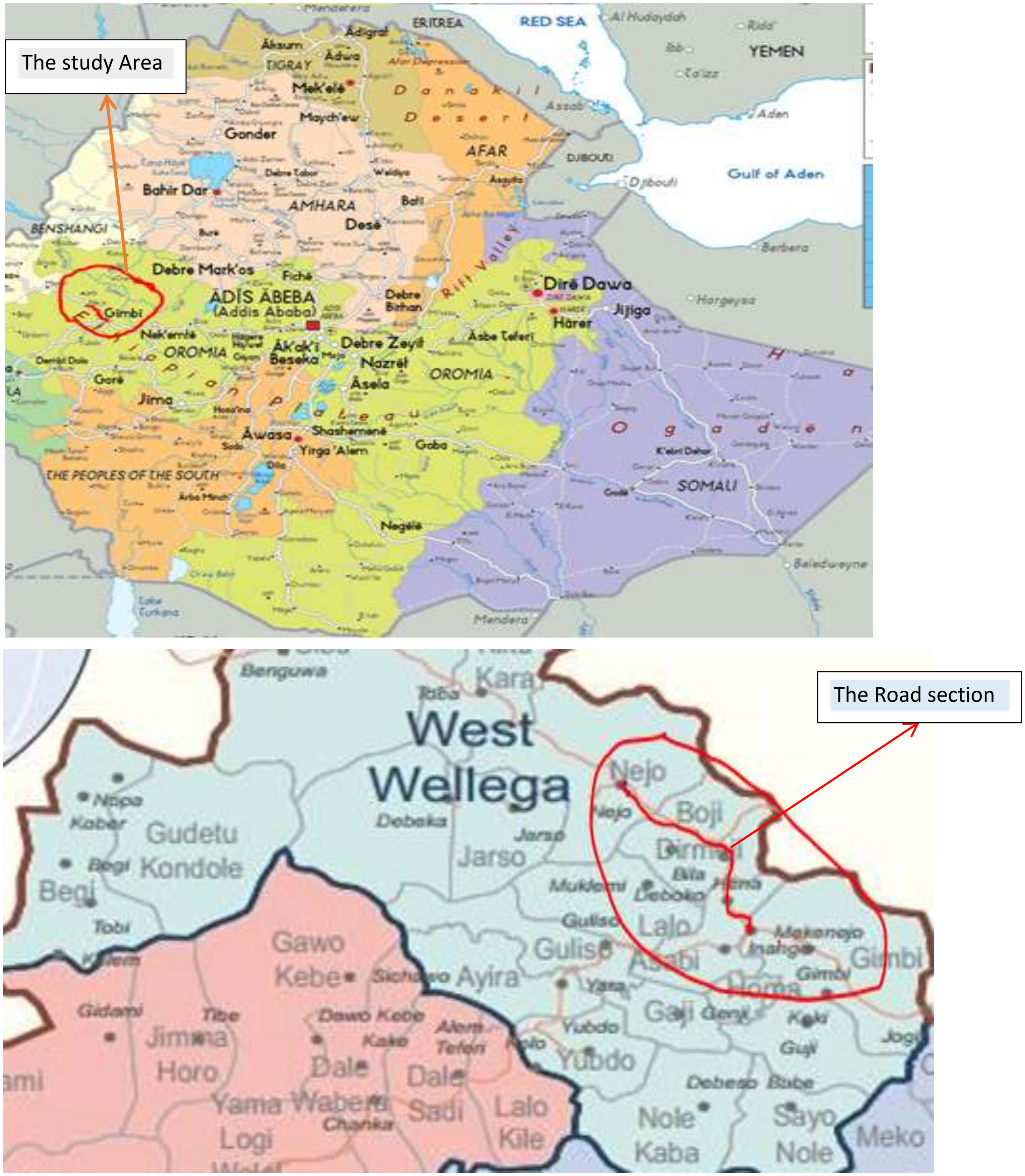

Figure 3.1 Project Location Area Map,[30]..

3.3 Climate Condition

The study area lies in medium to high rainfall area average annual rainfall of around 1614 mm, and about 80% of mean annual rainfall occurs during the period of four months, From June to September climate of the study area as shown below.

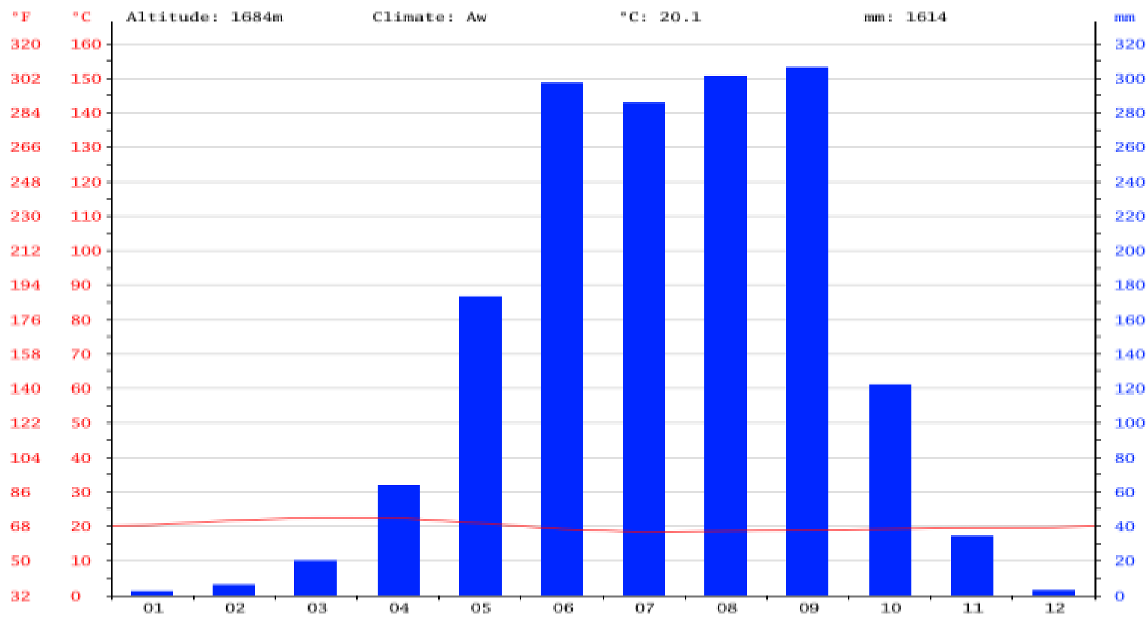

Figure 3.2: Monthly Average climate of the study areas.

3.4 Population: - Pavement damages were served as a population for the study Sample Size.

3.5 Sampling procedure: - Samples were collected from six test pits at a depth 1.5m of each borehole for details laboratory testing to determine geotechnical characteristics of the Soil. The pits are excavated manually with the size of the 1m×1m with the depth range of 0.4 to 1.5m .The excavation started to top and continued layer by layer properly during the stating of excavation of pavement from top layer, bituminous layer were removed carefully to avoid disturbance of the layer below and the thickness of each layer recorded and 45kg sample were taken from each test pits to Ethiopian Road Authority Nekepte Road Network Branch Directorate laboratory.

3.6 Study period:-The study was conducted from March to January, 2018.

3.7 Data collection technique:-Purposive collection technique was used by selecting particular parameters to make it sure that the parameters have certain characteristics as applied for this study. It is projected to be normally targets at particular geotechnical parameters.

3.8 Study design: The research study was conducted by using both experimental and analytical methods. Qualitative and quantitative studies were employed in this study area. Qualitative study gives impression on the findings where a quantitative study was used to describe the numerical aspects of the research findings, based on laboratory results.

3.9 Data process and analysis

By conducting laboratory tests, filed test, literature reviews, books, journals, articles and lecture notes the data were gathered. After sorting out the effective data the quantitative or numerical part of the data analyzed using different software's like excel.

3.10 Instruments or Material Used

The following instruments and software were used for this study: Meter tape, plastic bags, manual hand auger equipment, laboratory equipment's, GPS and field test instrument DCP test , Camera for documentation, and Excel to analysis laboratory data and display research data were used in this study.

3.11 Data Collection Process

In order to attain the purpose of this research work ethical considerations was concentrating on in the context of quantitative and qualitative research. Before starting any data collection formal letter was obtained from JIT and an official permission was obtained from ERA regional Nekempte district office. Quantitative and qualitative data were utilized based on the necessary input parameters for the analysis by comparing with ERA manuals. Data collection process included field visual inspection, Field investigation, sampling representative samples along study area, field test; Field measurements and laboratory tests were conducted. The surface of a Road distress along the Road section classified as according to their extent or rates of damages. To collect the primary data the samples were taken from different boreholes at the location where most damaged asphalt as shown below.

Figure 3.2 Borehole (BH-1) at station 129+400

Figure 3.3 Borehole (BH-2) at station 140+700

Figure 3.4 Borehole (BH-3) at station 150+300

Figure 3.5 Borehole (BH-4) at station 165+200

Figure 3.6 Borehole (BH-5) at station 172+300

Figure 3.7 Borehole (BH-6) at station 126+100 Non-damaged Asphalt for comparisons

Figure 3.8 DCP Tests (a) and (b

3.11.1 Field work

Preliminary visual survey was undertaken along Mekenajo-Nejo Road section. Field observations, Field tests and measurements were carried out and representative samples were taken to laboratory tests. Results from field tests and measurements were compared with the results from laboratory tests. Moreover, results from laboratory tests were compared with ERA Standard Specifications.

During the field observation, it was necessary to begin by conducting visual inspection and site inventory of the whole stretch of the Mekenajo-Nejo Road section. The initial site visit was taken on the whole portion of the road and at the same time the damaged and non-damage sections were identified for further detailed site observation. After finishing the initial visual inspection and categorizing the conditions of the road failures with that of non-failures along the road section. The next step was then to select the representative locations for sampling based on their failure conditions and non-failure location; the researcher selected six (6) samples test pits that represents the types of failures observed along the Road section and one non-distress samples from study area. For each condition test pits was extracted for laboratory testing as well as field tests. For each layer layers of embankment of Road section Approximately 45 Kg were collected for tested in the laboratory.

3.11.2 Pavement condition survey

In order determine the extent/rate of damage observed from the visual inspection would become reliable, proper identification was made to select representative sections and to evaluate the state of the existing pavement by assessing the physical conditions of the existing pavement along a road. Before the beginning of the detail pavement evaluation, the entire road length was visually assessed and it is attempted to identify the types of failures occurred on the road surface.

3.11.3 Field investigation of the existing pavement thickness.

Based on the field observation and investigation the width of the existing road surface is measured using a meter tape during test pitting and sampling. The road is on average of 7m carriage way, while the pavement edges were difficult to establish as the camber of the road had changed due to repetitive raveling and erosion. Hence the width of the road is established mostly by judgment and measured. The thickness of the road materials is measured in each test pit using a meter tape.

3.11.4 Laboratory tests

Laboratory tests are useful in providing reliable data for calculating ultimate bearing capacity of soil, stability and settlement behavior of foundation and for determining physical characteristics of soils. Most of the engineering properties of soil and granular materials are determined by laboratory testing. The samples were transported to the laboratory of Ethiopian Road Construction Cooperation Nekemte District Laboratory. Before starting Laboratory test, these samples were first air dried under the sun to allow moisture to evaporate before starting the required test. The tests were performed according to AASHTO Specification [23], [24] and ASTM following the procedures that have been discussed on the soil mechanics laboratory manual by Braja, M. D., [25]. The following tests were undertaken such as Atterberg Limits, Grain size Analysis, Compaction Tests, and California Bearing Ratio (CBR) Tests were made to understand the general behavior of the road materials of the failure section and Field test such as DCP test. The laboratory data analysis was given in their respective appendices.

i. Atterberg Limits

Most of the methods for soil identification and classification are based on certain physical properties of the soils. The commonly used properties for the classification are the grain size distribution, liquid limit and plasticity index. These properties have also been used in empirical design methods for flexible pavements, and in deciding the suitability of subgrade soils. Tests were undertaken on base course, sub-base, and subgrade fill materials at selected test pits of the three sections. The testing procedure was done according to ASTM D 4318, [26].

ii. Grading analysis

The mechanical analysis consists of the determination of the amount and proportion of coarse material by the use of sieves; and the analysis for the fine grained fraction by sedimentation method. For the materials passing 75 microns, hydrometer method was used. The combined grading of the material shall be a smooth continuous curve falling within the grading limits. When determined in accordance with the requirements of AASHTO T-27. The mass of material passing the 0.075 mm sieve shall be determined in accordance with the requirements of AASHTO T-11, [27].

iii. Soil compaction

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified comp active effort. The comp active effort is the amount of mechanical energy that is applied to the soil mass. The Compaction tests are designed to simulate the density of soils compacted by field methods. Modified Proctor Test was used for this study area. The soil tested was thoroughly mixed with measured quantity of water and, it was then filled in the mold in five layers of approximately equal thickness. Each layer was subjected to 25 numbers of blows using modified hammer weighing 44.5 N, which was allowed to drop freely from a height of 46 cm. After compaction of five layers, the soil was trimmed at the top of the mold. The mold with its content was removed from the base plate and weighed. Moisture content determination was undertaken on a sample of soil and the dry density was then calculated. This procedure was repeated with addition of water content and a compaction curve was drawn.

The co-ordinates of the curve that represents peak gave the maximum dry density and the optimum moisture content [22]. The compaction curve is shown in Appendix C.

$$\rho_d = \rho/1+w \qquad (5)$$

Where: w= moisture content in percent divided by 100, ρ = wet density in grams per centimeter cubic. The moisture content of each compacted soil specimen was calculated using the average of the two water contents. To compute the wet density in grams per cubic centimeter of the compacted soil sample was divided the wet mass by the volume of the mold used, then the dry density computed using the wet density and the water content, [28].

iv. California Bearing Ratio (CBR)

California Bearing Ratio is a measure of shearing resistance of the material under controlled density and moisture conditions. The test consisted of causing a cylindrical plunger of 50 mm diameter to penetrate a pavement component material at 1.25 mm/minute. The loads for 2.54 mm and 5.08 mm were recorded. This load is expressed as a percentage of standard load value at a respective deformation level to obtain CBR value. The equation to be compute the CBR vale is as follows [28].

$$CBR\ (\%) = 100 * (x/y) \qquad (6)$$

Where: 'x' = material resistance or the unit load on the piston (pressure) for 2.54mm or 5.08 mm of penetration. y = standard unit load (pressure) for well graded crushed stone. For 2.54mm Penetration = 6.9mpa and for 5.08mm penetration = 10.3mpa.The summary of the test result and the laboratory test analysis and plots are given in Appendix D.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Field Test results

4.1.1 Pavement Condition Survey results

Before the commencement of the detail pavement evaluation, the entire road length was visually assessed and identified. The pavement condition survey was carried out on the study section of the road in order to identify areas showing pavement defects and to assess causes of defects and its level of severity. The pavement condition surveys investigation along the study area shows that different types of distress observed along the Road section such as surface defect, surface deformation, disintegration and cracks failures along route section during pavement condition survey on the route was identified.

Table 4.1 Test pits location of distress and non-distress

Test Pit	Station(km)	Samples Location	Severity level	Dominant failure types
BH-1	129+400	9^{o}16’24.7’’N, 35^{o}41’21.7’’E	Severity level 3	Pothole and Patching
BH-2	140+700	9^{o}12’23.7’’N, 35^{o}’43’47’’E	Severity level 3	Raveling and stripping
BH-3	150+300	9^{o}12.0’06’’N, 35^{o}43’54’’E	Severity level 3	Corrugation
BH-4	165+200	9^{o}16’24.6’’N , 35^{o}41’21.8’’E	Severity level 3	Rutting and Wearing
BH-5	172+300	9^{o}12’13.2’’N, 35^{o}44’20.2’’E	Severity level 3	Alligator crack
BH-6	126+100	9^{o}18’37.4’’N , 35^{o}43v’12.1’’E	Severity level 3	Non-distress

Table 4.2 Existing thickness of the materials of the road layers.

Test Pit	Stations	Average thickness of road layers(cm)			Dominant failure types
		Asphalt	Base	Sub-base	
BH-1	129+400	3.4	14.6	17.5	Pothole and Patching
BH-2	140+700	4.2	14.4	18.2	Raveling and stripping
BH-3	150+300	3.5	14.0	17.7	Corrugation
BH-4	165+200	4.1	14.3	18.2	Rutting and Wearing
BH-5	172+300	4.4	14.7	17.4	Alligator crack
BH-6	126+100	3.5	14.8	19.0	Non-distress
Average thickness		3.9	14.5	18.0	

The following representative photographs can show the type and extent of failure along the road.

Figure 4.1: Pothole (a) and Patching (b)

Figure 4.2: Raveling (a) and stripping (b)

Figure 4.3Potholes (a) and Corrugation (b)

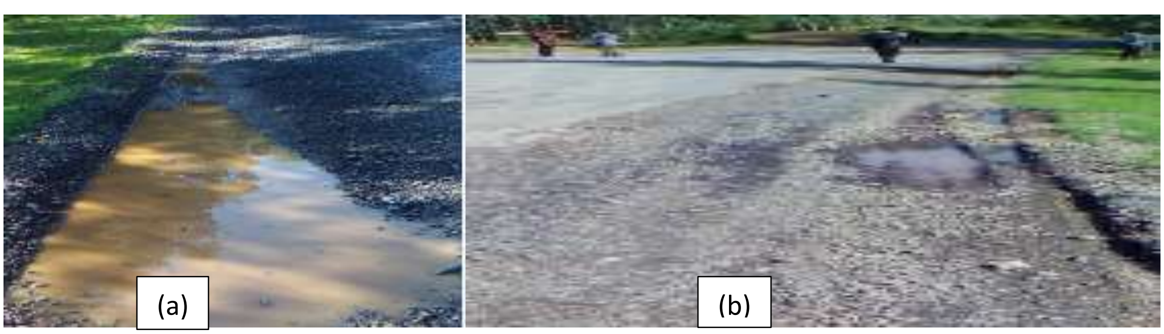

Figure 4.4 Rutting (a) and Wearing (b)

Figure 4.5 Alligator Crack (a) and (b)

Figure 4.6 Potholes (a) and Edge failure (b)

4.2 Laboratory Test results

4.2.1 Grain Size Analysis

The mechanical analysis consists of the determination of the amount and proportion of coarse material by the use of sieves analysis. The grain size analysis results are plotted below and the data is given in appendix A.

Table 4.2 Wash gradation results of **Base Course** Material with ERA specification.

Grain Size Analysis results of Base Course Material								
Material type: Base Course Failure type: All Types of Failures				Date of Sampling: 12-06- 2017 Sampled by: Fikru Benti				
Failure types.	Pothole	Raveling	Corrugation	Rutting	Alligator Crack	Non-Defect	ERA Grading Lower Limit	ERA Grading Upper Limit
Test Pit No.	BH-1	BH-2	BH-3	BH-4	BH-5	BH-6		
sieve size, mm	% passing	% passing	% passing	% passing	% passing	% Passing	% passing	% Passing
28	100	100	100	100	100	100	100	100
20	70.6	69.9	84.9	77.7	75.2	78.7	80	100
10	45.5	48.4	55.3	53.8	53.8	56.5	55	80
5	27.2	31.0	34.4	37.1	37.0	46.8	40	60
2.36	17.0	17.9	22.7	26.0	23.0	31.7	30	50
0.425	6.4	7.9	13.0	13.6	7.8	15.4	12	27
0.075	4.6	5.0	6.0	4.4	4.1	2.6	5	15
Pan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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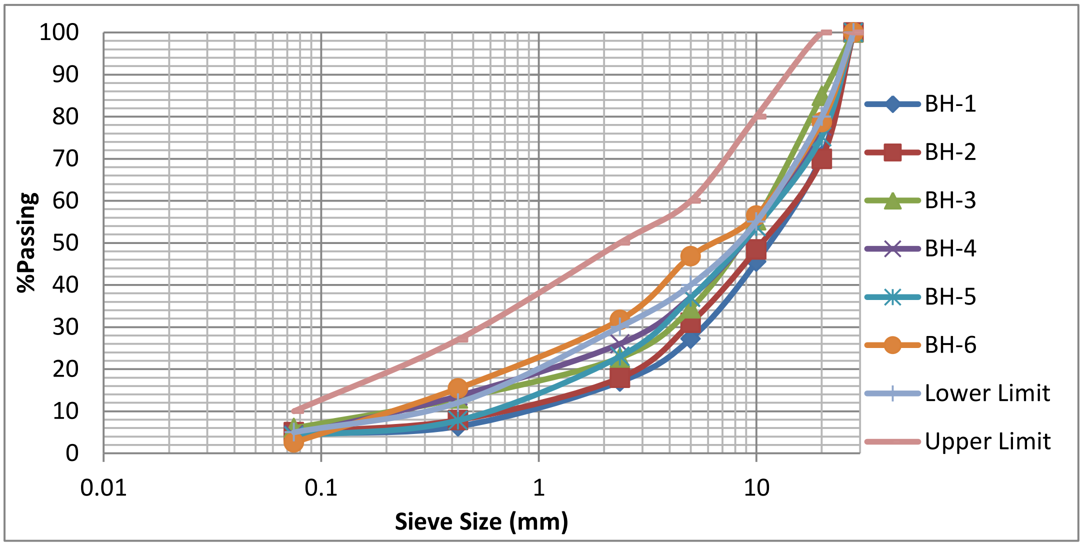

Figure 4.7 Wash gradation results of Base Course materials

Note: Average Uniformity Coefficient (Cu) and Coefficient Curvature (Cc) of all samples of Base Course materials are 32.4 and 3.45.

Table 4.3 Wash gradation results with ERA specification of **Sub-base course**.

Grain size Analysis results of Sub-base course with ERA specification								
Material type: sub-base Course				Failure type: All Types of Failures				
Failure Types.	Pothole	Raveling	Corrugation	Rutting	Alligator Crack	Non-defect	ERA Grading Lower Limit	ERA Grading Upper Limit
Test pits	BH-1	BH-2	BH-3	BH-4	BH-5	BH-6		
sieve size,mm	% passing	% passing	% passing	% passing	% passing	% Passing	% passing	% Passing
50	100	100	100	100	100	100	100	100
37.5	95.8	87.8	88.6	93.8	90.2	87.8	95	100
28	81.1	68.5	77.8	79.9	75.7	75.9	80	95
20	68.8	57.9	62.2	69.4	62.6	60.4	60	80
10	41.4	45.2	48.7	46.0	41.3	41.6	40	60
5	25.9	27.3	37.6	29.3	27.1	30.1	25	40
2.36	17.3	19.7	26.8	22.1	18.4	18.8	15	30
0.425	12.0	11.9	14.0	17.9	14.6	12.2	7	19
0.075	10.1	5.2	5.6	7.1	5.3	4.5	5	12
Pan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

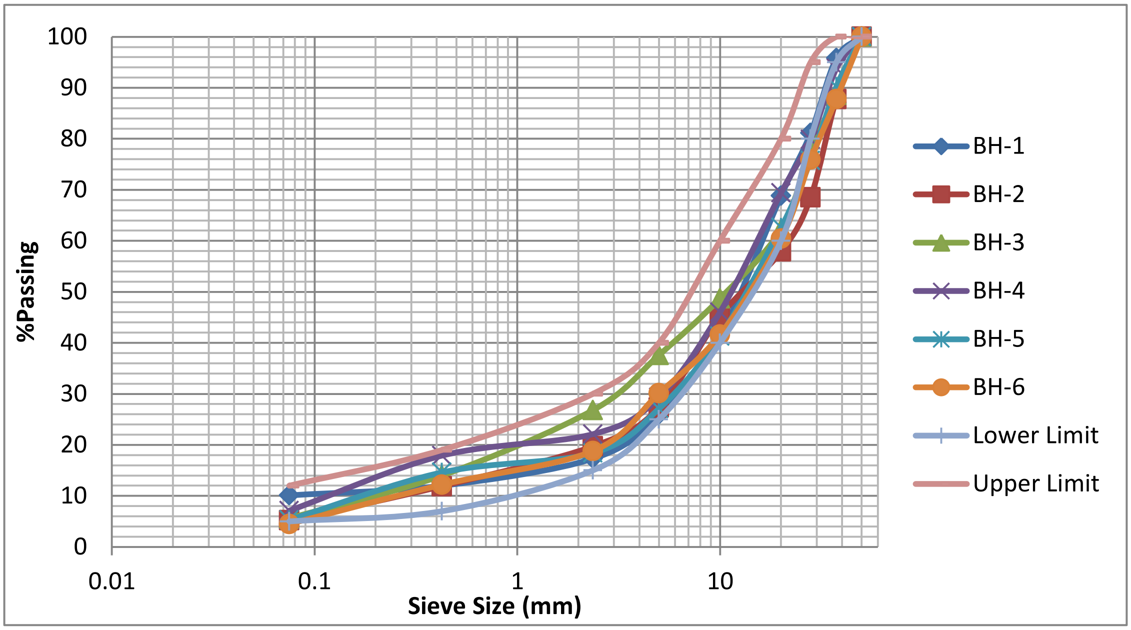

Figure 4.8Wash gradation results of sub-base course materials

Note: Average Uniformity Coefficient (Cu) and Coefficient Curvature (Cc) of all samples of Sub- base materials are 66.8 and 7.6

Table 4.4 Parameters from base coarse sieve analysis curve.

Test pit No.	% Gravel	% Sand	% Fines	D_{10} mm	D_{30} mm	D_{60} mm	Cu	Cc
BH-1	72.8	22.6	4.5	0.9	6.0	15	16.7	2.7
BH-2	69.0	26.0	4.9	0.7	5.0	16	22.9	2.2
BH-3	65.6	28.4	5.9	0.2	4.0	11	55.0	7.2
BH-4	62.9	32.7	4.5	0.2	3.0	11	55.0	4.1
BH-5	63.0	32.9	4.2	0.6	4.0	12	20.0	2.2
BH-6	52.2	45.2	2.8	0.2	2.2	4.6	25.0	2.5

Table 4.5 Parameters from sub-base sieve analysis curve.

Test pit No.	% Gravel	% Sand	% Fines	D_{10} Mm	D_{30} Mm	D_{60} Mm	Cu	Cc
BH-1	74.1	15	10.3	0.3	6.0	17	56.7	7.0
BH-2	72.7	22.1	2.8	0.3	6.0	20	66.0	6.0
BH-3	62.4	32.0	5.5	0.2	3.0	19.0	95.0	2.4
BH-4	70.7	22.2	7.0	0.1	5.0	15.0	150	9.3
BH-5	72.9	21.8	4.1	0.2	6.1	20.0	100	9.3
BH-6	69.9	25.6	4.5	0.3	5.0	20.0	66.7	4.2

Table 4.4 Wash gradation and hydrometer results of **sub-grade soil**

Gr.Size BH-1	Gr.Size BH-2	Gr.Size BH-3	Gr.Size BH-4	Gr.Size BH-5	Gr.Size BH-6	%pass bh-1	%pass bh-2	%pass bh-3	%pass bh-4	%pass bh-5	%pass bh-6
5.00	5.00	5.00	5.00	5.00	5.00	100	100	100	100	100	100
4.75	4.75	4.75	4.75	4.75	4.75	95.2	94.3	95.7	95.6	95.6	94.4
2.36	2.36	2.36	2.36	2.36	2.36	92.8	92.4	83.2	85.7	86.1	86.6
1.18	1.18	1.18	1.18	1.18	1.18	88.2	91.3	80	83.4	84.4	85
0.425	0.425	0.425	0.425	0.425	0.425	71.9	84.6	76.6	81.5	82.8	83.5
0.3	0.3	0.3	0.3	0.3	0.3	66.3	81.6	74.1	77.5	75.2	76.8
0.075	0.075	0.075	0.075	0.075	0.075	55.8	73.5	60.9	64.5	63.8	66.8
0.02549	0.0279	0.02729	0.02885	0.02555	0.02724	48.9	54.5	48.8	46.1	57.9	57.6
0.01709	0.01872	0.01837	0.01837	0.01686	0.01811	42.2	43.4	37.8	41.7	53.7	48.6
0.01014	0.01124	0.01106	0.01124	0.01018	0.01084	39	36.8	31.7	33.6	47.3	43.2
0.00748	0.00819	0.00813	0.00825	0.00738	0.00785	34.3	30.9	26.8	29.3	42.6	39.2
0.00545	0.00585	0.0058	0.00598	0.00556	0.00564	29.1	26.9	23.5	21.9	32.3	34.1
0.00399	0.00427	0.00428	0.00426	0.00419	0.00416	23.5	22.1	19.2	18.5	25.2	28.7
0.00291	0.00309	0.00303	0.00307	0.00302	0.00304	19.9	18.7	17	14.6	20.1	21.6
0.00211	0.00221	0.00221	0.00224	0.00221	0.00219	19.5	15.8	13.1	11.6	16.6	17.6
0.0015	0.0016	0.0016	0.001607	0.00159	0.00157	14.3	9.8	10.2	8.7	12.8	13.5
0.00128	0.00132	0.00133	0.001144	0.00132	0.00131	7.1	6.9	6.6	7.4	8.2	8.1

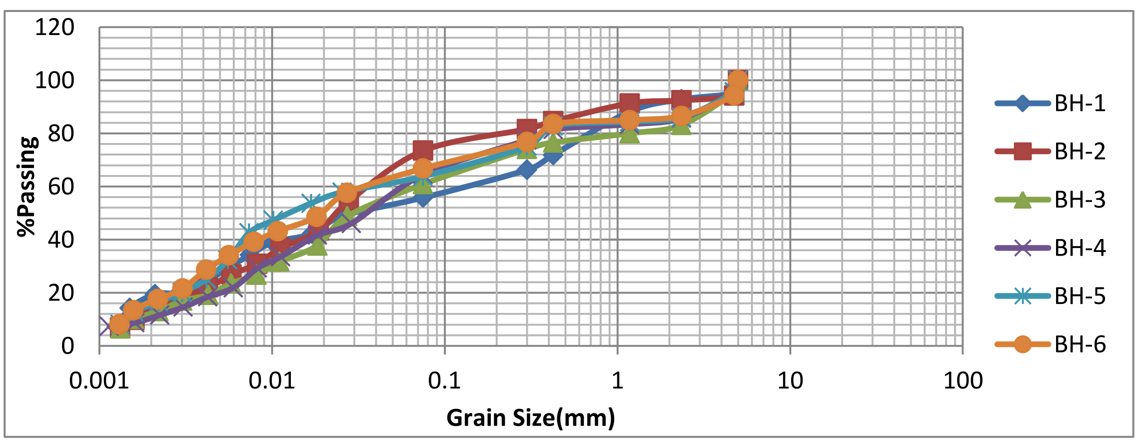

Figure 4.9 Wash gradation results of subgrade soil materials

Note: Average Uniformity Coefficient (Cu) and Coefficient Curvature (Cc) of all samples of Subgrade materials are 29.9 and 1.37.

4.2.2 Atterberg's limit test results

The Plasticity of base course, sub-base and sub-grade materials is tabulated below. The laboratory data analysis is attached in Appendix B.

Table 4.5 Atterberg's limit test results

Test Pit No.	Station (km)	Base-course			Sub-base Course			Sub-grade Soil		
		LL%	PL%	PI%	LL%	PL%	PI%	LL%	PL%	PI%
BH-1	129+400	4.0	0.0	4.0	31	24	7	43	31	12
BH-2	140+700	4.0	0.0	4.0	29	23	6	45	33	12
BH-3	150+300	4.0	0.0	4.0	28	22	7	50	27	23
BH-4	165+200	4.0	0.0	4.0	24	18	7	53	33	20
BH-5	172+300	5.0	0.0	5.0	24	18	7	44	32	12
BH-6	126+100	6.0	0.0	6.0	24	20	4	47	33	14

4.2.3 Laboratory Compaction test results

The soil was thoroughly mixed with measured quantity of water and then filled in the mold in five layers of approximately equal thickness. Each layer is compacted by 56 blows of a modified rammer weighing 44.5N which is allowed to drop freely from a height of 46cm at each blow. After compaction of five layers, the soil was trimmed to the top of the mold. The results of the maximum dry density and the optimum moisture contents are given in the Table below.

Table 4.6 Summarized Compaction Tests Results

Test Pit No.	Station (km)	Base-course		Sub-base		Sub-grade	
		OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)
BH-1	129+400	6.4	1.79	7.7	1.75	25.0	1.74
BH-2	140+700	6.9	1.75	7.2	1.78	24.8	1.67
BH-3	150+300	5.9	1.92	9.3	1.75	13.5	1.51
BH-4	165+200	6.7	1.73	9.1	1.84	15.5	1.37
BH-5	172+300	4.8	1.87	8.0	1.78	13.0	1.50
BH-6	126+100	5.8	2.00	8.3	1.88	12.9	1.84

Summarized Modified proctor test laboratory result curves.

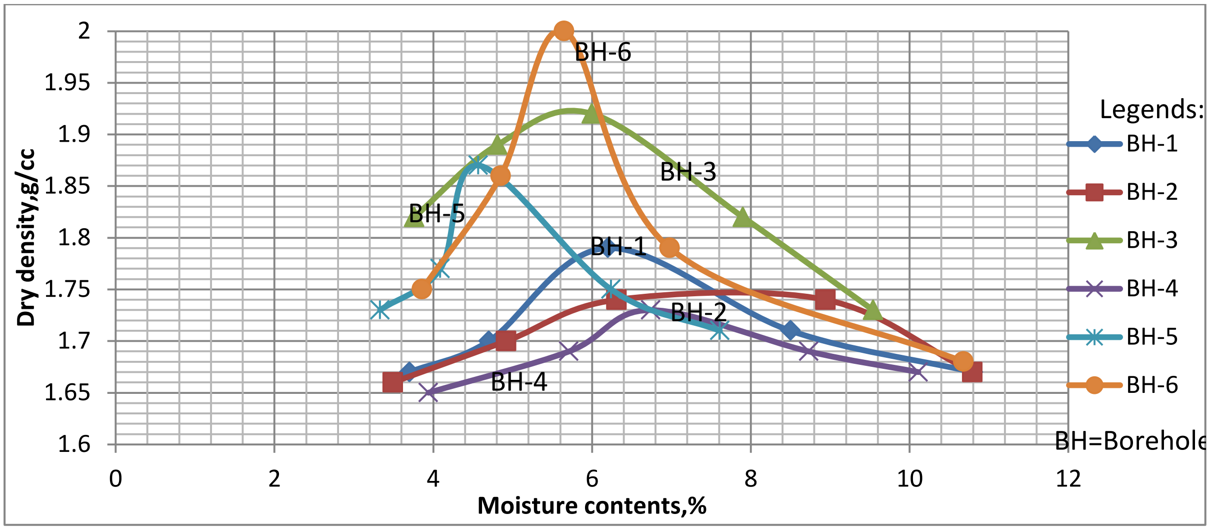

Figure 4.10 The Laboratory Test Result for OMC and MDD of **Base course** Layer

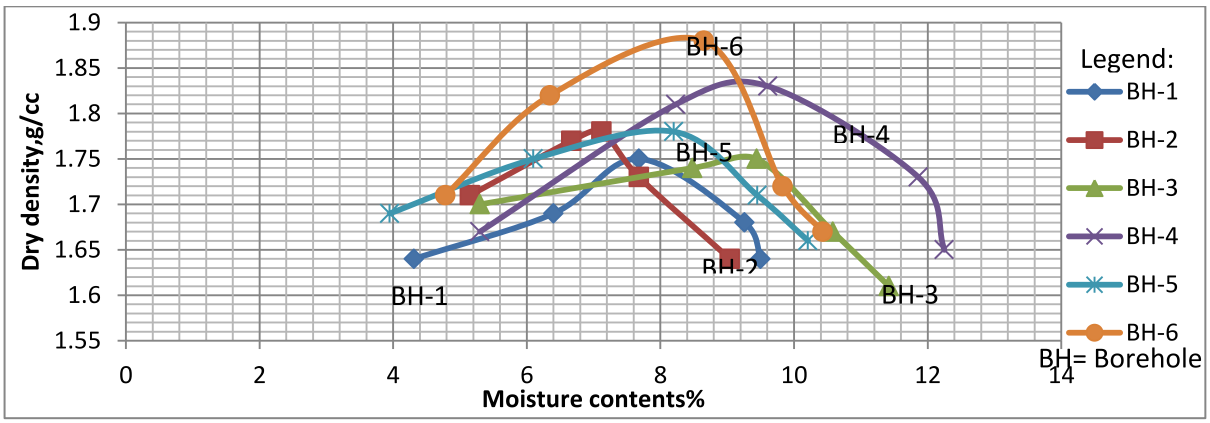

Figure 4.11 The Laboratory Test Result for OMC & MDD of **Sub-base Layer**

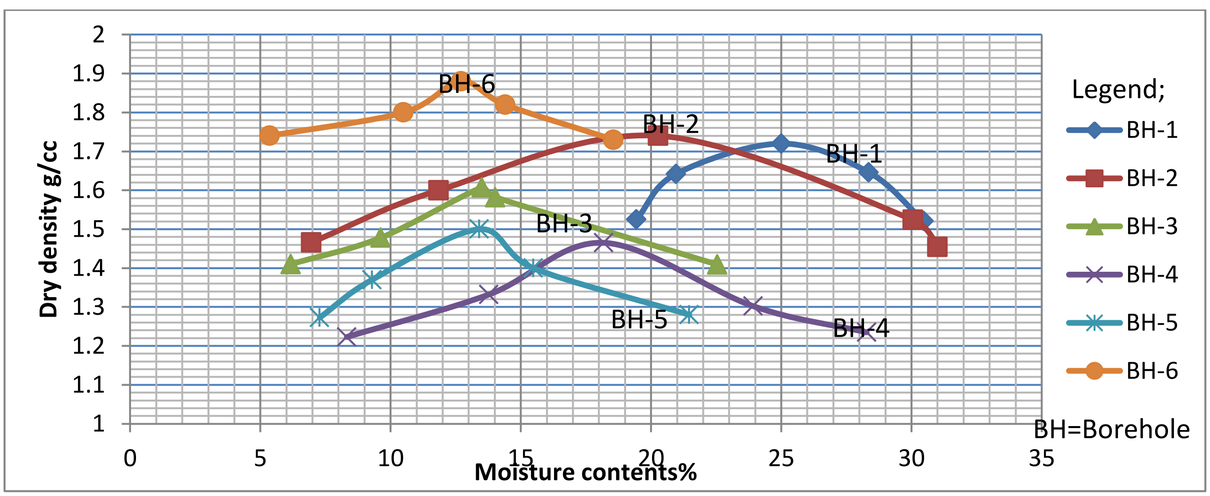

Figure 4.12 The Laboratory Test Result for OMC & MDD of **Subgrade soil**.

4.2.4 California Bearing Ratio (CBR) Tests

The California Bearing Ratio (CBR) was used for evaluating the suitability of sub-grade and the materials used in sub-base and base course. Both disturbed sample method and Undisturbed (DCP) methods were performed to evaluate the CBR of each layer. Three point CBR test is made for all of the samples. The following result were obtained during CBR test and summarized as below.

Table 4.7 California Bearing Ratio (CBR) Test results

Station	Base Course						Average% of swell	Sub-base						Average% of swell	Sub-grade soil						Average% of swell
	2.54mm			5.08mm				2.54mm			5.08mm				2.54mm			5.08mm			
	No of Blows			No of Blows				No of Blows			No of Blows				No of Blows			No of Blows			
	10	30	65	10	30	65		10	30	65	10	30	65		10	30	65	10	30	65	
129+400	23	40	93	22	45	99	0.66	16	24	40	18	46	49	0.99	9	11	12	8	10	12	1.15
140+700	20	49	64	23	68	91	0.44	18	60	73	27	64	90	0.62	9	10	16	9	10	16	1.18
150+300	23	40	93	25	47	99	0.44	15	62	91	18	65	99	0.48	10	11	14	10	10	14	1.04
165+200	24	45	60	27	65	85	0.56	23	45	60	30	65	85	0.39	10	11	13	9	10	13	1.08
172+300	23	60	75	25	65	90	0.59	19	59	77	22	65	96	0.66	8	10	13	9	11	15	0.99
126+100	16	35	65	27	68	99	0.02	14	43	61	24	70	97	0.51	8	8	15	10	11	15	0.53

4.2.5 Dynamic Cone penetration test results

Dynamic cone penetration (DCP) has been widely used as a simple, but effective means of determining the in situ shear strength of sub grade materials and pavement layers. California

Bearing Ratio (CBR) is the most commonly used measure of soil bearing capacity. The DCP test provides an indication of material in-situ resistance to penetration. If the DCP cone penetrates quickly in to the soil, it indicates the material has poor strength or insufficient compaction.

Table 4.8 Dynamic Cone penetration test results

Test Pits No.	Stations (Km)	Layer Types	Av. rate DCP (mm/blow)	CBR (%)
BH-1	129+400	Base Course	4.00	83
		Sub-Base	5.00	63
		Subgrade	22.00	10
BH-2	140+700	Base Course	4.00	84
		Sub-Base	6.00	62
		Subgrade	21.00	9
BH-3	150+300	Base Course	4.00	80
		Sub-Base	5.00	65
		Subgrade	19.00	10
BH-4	165+200	Base Course	4.00	80
		Sub-Base	5.00	66
		Subgrade	19.00	11
BH-5	172+300	Base Course	4.00	82
		Sub-Base	5.00	72
		Subgrade	18.00	18
BH-6	126+100	Base Course	4.00	85
		Sub-Base	4.00	74
		Subgrade	17.00	12

4.3 Discussions

4.3.1 Discussion on Pavement condition Survey

From the pavement condition survey, the road is in bad conditions. The pavement condition surveys investigation along the study area shows that different types of distress observed along the Road section such as surface defect, surface deformation, Disintegration, cracks and problems related to road failures along route section during pavement condition survey on the route was identified.

Table 4.9 Rating of Road failure on Mekenajo to Nejo road.

Distress Type		Existence		Level of Severity Rating			Remark
				high	Medium	Low	
		Yes	No				
1)Cracking	Alligator Crack	√		√			Measurements mean width 21mm > 19mm &TypeA damage.
	Longitudinal cracking	√			√		Measurements mean width7mm >6mm< 19mm type B damage
	Transverse cracking		√				Visual evaluation & type B damage
	Block cracking	√				√	Measurements 2x3mm & type B damage
	Slippage cracking		√				Visual evaluation & type B damage
	Reflective cracking		√				Visual evaluation & type B damage
	Edge cracking	√			√		Visual evaluation & type B damage
2)Surface deformation	Rutting	√		√			Measurements 4cm height & 5m length & type A damage
	Corrugations	√		√			Visual evaluation length & type A damage
	Shoving	√				√	Visual evaluation length & type A damage
	Depressions		√				Visual evaluation length & type A damage
3)Disintegration	Potholes	√					Measurements 0.95cm width & 25cm depth & type B damage
	Patches	√					Visual evaluation length & type A damage
4)Surface defects	Raveling	√		√			Visual evaluation length & type B damage
	Bleeding		√				Visual evaluation length & type B damage
	Polishing	√		√			Visual evaluation
	Delamination		√				Visual evaluation

4.3.2 Drainage and shoulder

Based on ERA Geometric Design Manual – 2002 Shoulders participate in the structural function of a road pavement, providing lateral support for the pavement layers. They should help in removing surface water from the road surface and facilitate the internal drainage of the pavement. They are especially important when unbound materials are used in the pavement. From a functional point of view a minimum width of 1m is recommended. If surface water penetrates in to the road body, it reduced the load carrying capacity of the pavement which may cause further damage to the road. but in this project area the shoulder width for some area is less than 0.5m in some place there is no constructed shoulder not only in rural area even if at town. In addition the shoulder missing problems as we can observe from pavement condition survey photos there are drainage problems.

Basically Pavement design depends on the expected level of traffic. From the traffic analysis made, the cumulative Standard Axle is 2.47 million. According to the ERA pavement design manual, the Traffic Class is "T_4" with ESAs ranging from 1.5-3 million. The thickness of each layer of embankment of road section is a function of the ESAs and the CBR of the sub-grade layer. From the CBR test, the sub-grade strength class can be classified as S_5 with CBR ranges 8%-16%. Hence, according to ERA road design manual, the thickness of the base course and sub-base course for traffic class T_4 with ESAs of 1.5-3million should be 15cm and 20cm respectively. From Table 3-1 it can be seen that the average thickness of the base course is 14.5 cm and that of the sub-base course is 18 cm. Hence this shows that the base and the sub-base course will not be able to carry the traffic loading at its service time. The result implies that majority of flexible pavement defects were exist in the study area this show that study project road is in bad condition

4.3.3 Grain size Analysis

Comparing the laboratory test results for gradation with that of the specification for Base, and sub base materials and to determine the percentage of gravel and sand from grain size curve depending on percentage of fines (fraction smaller than 75micron sieve size)coarse grained soils are classified as follows: less than 5%: GW,GP,SW and SP. And more than 12%: GM, GC, SM, and SC. 5%-12% border line case required use of dual symbols. According to Unified soil classification system:-

- In case of base course materials Cu =32.4, which is greater than 4 shows a wide variation of size particles. Cc =3.00, indicates well graded gravels particles, According to USCS, base material is classified as well graded gravels with sandy.
- For the sub-base materials Cu =66.8, which is greater than 4 shows a wide variation of size particles, Cc =7.6, indicates poor graded particles. According to USCS, the % of sand retained above 2mm was greater than 15% so; sub-base material at is classified as poor graded gravels with silt..
- The subgrade materials are classified as clay sand (SC) and sandy silt (ML).

4.3.4 Atterberg Limits

From the laboratory results, it can be seen that the average liquid limit of sub grade is 47, sub base is 26 and base course 4.5 and also the average plastic index of the sub grade is 15.5, sub-base is 5.8 and base course 4.5.According to AASHTO and USCS soil classification system:-

- In base course (i.e. Sieve analysis percent passing No. 10 < 50 max, No. 40 <30 max, No. 200<15 max and PI <6%) it satisfies the AASHTO specification; thus grouped into A-l-a in AASHTO soil classification system and USCS as poorly graded gravels with sand silt (GP).
- In sub-base course (i.e. LL < 40% and PI <10%) and percent passing No. 200<35 it satisfies the specification; thus grouped into A-2-4 in AASHTO soil classification system and USCS as poorly graded gravels with sand silt (GP).
- In subgrade soil (i.e. LL > 41% min and PI >11% min) it satisfies the specification; grouped into A-7-6 in AASHTO soil classification system and USCS as Clay sand with gravel (SC).

4.3.5 Compaction Test

From Table 4.5 the average value of MDD and OMC for base course is 1.86 gm/cc and 6.67% respectively which don't meet the specification (i.e. MDD>2gm/cc). For sub-base material OMC &MDD varied between 7.12% -9.61 % and 1.75gandcm^3 - 1.88g/m3 respectively. The MDD values of all sub-base don't meet the specified value (i.e. MDD>2gm/cc). For sub-grade material OMC & MDD varied between12.7% -25%and 1.37gandcm^3 - 1.84g/m3 respectively. Except BH-5 the MDD values of all sub grade don't meet the specified value (i.e. MDD>1.76gm/cc).

4.3.6 California Bearing Ratio (CBR) Test

From the recommendation given in Table 3.1 taken from ERA Pavement Design Manual volume I, for natural coarsely graded granular material, including processed and modified gravels (GB3), the CBR after soaking should be greater than 80%. The laboratory test results given in Table 4.6, the CBR of the base material use ranges from 64%-93%. When we see the case of sub-base course, the recommendation given in Table 3.1 for natural gravel (GS), the CBR after soaking should be greater than 30. And the result obtained from the laboratory is all greater than the specified values ranging from 40%-91%. From Table 3.1, it is observed that the soaked CBR values for sub-grade course materials varied between 8% and 16% in all the boreholes, which is in range of specified value (i.e. Soaked CBR >5%). From table 4.6, the subgrade strength class for CBR range on average 8%-16%. Since most of the laboratory results lay on the range 8%-16% it can be classified as S4.

4.3.7 Dynamic Cone penetration test results analysis:

- ✓ Average rate of DCP test for base courses 4mm/blow and CBR value 80% -85% satisfies the specification (i.e. CBR > 80%).
- ✓ Average rate of DCP test for Sub-base 4mm/blow-6mm/blow and CBR value 62%-74% satisfies the specification (i.e. CBR >30%).
- ✓ Average rate of DCP test for Sub grade soil 17mm/blow-22mm/blow and CBR value 9%-12%, less than the specification requirement of sub-grade strength class S4.

Remark: TRL DCP => Log10 (CBR) =2.632-1.28Log10 (mm/blow)

$$\Rightarrow CBR = 10^{2.632} / (mm/blow)^{1.28}$$

4.3.8 Subgrade Soil Classification:

Soil classification is the arrangement of soils into different group in order that the soils in a particular group would have similar behavior. The method of classification used in this study was the AASHTO System. The AASHTO Classification system is useful for classifying soils for highways. The particle size analysis and the plasticity characteristics are required to classify a soil. The soils with the lowest number, A-1, is the most suitable as a highway material or sub grade**.** Thus according to the AASHTO Classification system the sub-grade material is classified as A-7 .The table below shows the soil classification according to AASHTO standard and unified soil classification system.

Table 4.10 Soil classifications according to AASHTO and Unified soil classification system.

Test Pit No	Pavement Layers	Atterberg limit			AASHTOSoil Classification	Unified Soil Classification
		LL%	PL%	PI%		
BH-1	Base	4.34	0.00	4.34	A-1-a	GW
	Sub-base	31.0	24.30	6.70	A-2-4	GP-GM
	Sub-grade	42.30	30.95	11.35	A-7-5	ML
BH-2	Base	4.26	0.00	4.26	A-1-a	GW
	Sub-base	29.00	23.30	5.70	A-1-a	GP-GM
	Sub-grade	44.80	32.93	11.87	A-7-5	SM
BH-3	Base	4.21	0.00	4.21	A-1-a	GW
	Sub-base	28.00	21.40	6.60	A-2-4	GW-GM
	Sub-grade	49.80	26.87	22.93	A-7-6	CL
BH-4	Base	4.10	0.00	4.10	A-1-a	GP
	Sub-base	23.65	17.15	6.50	A-2-4	SP-SC
	Sub-grade	53.00	32.94	20.06	A-7-5	MH
BH-5	Base	5.10	0.00	5.10	A-1-a	GW
	Sub-base	23.80	17.30	6.50	A-2-4	GP-GC
	Sub-grade	44.80	32.41	12.39	A-7-5	ML
BH-6	Base	5.80	0.00	5.80	A-1-a	GP
	Sub-base	24.00	19.60	4.40	A-1-a	GP
	Sub-grade	39.00	28.03	10.97	A-7-6	SC

Table 4.11 Summary of laboratory test results of soil samples of distress type's boreholes with **base, sub-base and sub-grade** layers

Test Pit No	Pavement Layer	Layer thickness(cm)	AASHTO Classification of soil	Unified Classification of soil	Parameters analyzed					CBR
					Atterberg Limit			Compaction		
					LL%	PL%	PI%	OMC	MDD	2.54
BH-1	Base	14	A-1-a	GW	4.34	0.00	4.34	6.40	1.79	93
	Sub-base	11	A-2-4	GP-GM	31.0	24.30	6.70	8.30	1.88	40
	Sub-grade	-	A-7-5	ML	42.30	30.95	11.35	25.00	1.74	12
BH-2	Base	16	A-1-a	GW	4.26	0.00	4.26	6.91	1.75	64
	Sub-base	12	A-1-a	GP-GM	29.00	23.3	5.70	7.20	1.78	73
	Sub-grade	-	A-7-5	SM	44.80	32.93	11.87	24.80	1.67	23
BH-3	Base	14	A-1-a	GW	4.21	0.00	4.21	5.90	1.92	93
	Sub-base	11	A-2-4	GW-GM	28.00	21.40	6.60	9.30	1.75	91
	Sub-grade	-	A-7-6	CL	49.80	26.87	22.93	13.50	1.51	23
BH-4	Base	13	A-1-a	GP	4.10	0.00	4.10	5.80	2.00	60
	Sub-base	12	A-2-4	SP-SC	23.65	17.15	6.50	9.10	1.84	60
	Sub-grade	-	A-7-5	MH	53.00	32.94	20.06	15.50	1.37	13
BH-5	Base	15	A-1-a	GW	5.10	0.00	5.10	4.80	1.87	75
	Sub-base	13	A-2-4	GP-GC	23.80	17.30	6.50	8.00	1.78	77
	Sub-grade	-	A-7-5	ML	44.80	32.41	12.39	12.90	1.84	20
BH-6	Base	16	A-1-a	GP	5.80	0.00	5.80	6.74	1.73	65
	Sub-base	13	A-1-a	GP	24.00	19.60	4.40	7.68	1.75	61
	Sub-grade	-	A-7-6	SC	39.00	28.03	10.97	13.00	1.50	14

Table 4.12 Summery of relationship obtained between soil properties and road failures and suggested maintenance

Test Pits	Station (km)	Dominant Failure Types	Causes of Failure Obtained	Maintenance Suggestions
BH-1	129+400	Pothole	● Poor bonding to base ●Poor drainage ●Excessive Moisture	● Improve drainage. ● Full-depth patch ●Reconstructing the road. ●Square patching
BH-2	140+700	Raveling and Stripping	● loss of asphalt binder ●Separation of bituminous film from aggregates ●Disintegration of aggregates.	● surface dressing or thin overlay ● Cold mill and resurfacing. ●Square patching
BH-3	150+300	Corrugation	●Low in service stability of bituminous Road.	● Corrugated layers removed by cold milling and resurfacing with modified materials.
BH-4	165+200	Rutting and Wearing	●Inadequate compaction in surfacing or base. ●Settlement of underlying courses and sub grade under traffic. ●Excessive loading	● Dig down to bottom of distress material and replace by stiffer material. ●Leveling the pavement by regulating course and followed by a bituminous overlay
BH-5	172+300	Alligator crack	●Insufficient slab thickness ●Settlement of sub-base or subgrade ●Vehicle damage	●Filling the cracks for narrow crack. ●Full-depth repair for wide crack.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on pavement condition survey, visual inspection, laboratory, field test out puts and the monthly progress report document of the road during construction the following conclusions are drawn from the study:

- The pavement condition survey along the study area affected by different failures types such as cracks, deformation, disintegration and surface defect failures were identified during field investigation; this indicates that lack of routine and periodic maintenance along on a road section.
- The results of the sub grade soils investigation along Mekenajo-Nejo road showed that the road pavement structures are underlined by A-7-5 and A-7-6 category of soils which shows that the soils fair to poor sub-grade materials according to AASHTO and USCS shows that the soil categorize in to Clay sand (SC). The liquid limit varies from 42.92% - 53.13% and Plasticity index from 11.98% - 23.49%. The soaked CBR values of sub-grade soil materials are between 8% - 16% compared with 15% minimum specified, therefore, the failures observed on the road surface are significantly influenced by sub-grade soil.
- Insufficient thickness of sub-base and base material used to distribute the wheel load stress to a safe value on the sub-grade soil. Compared to the ERA standard for base and sub-base material layer thickness, which depend on CBR value and sub-grade soil strength, the pavement layer thicknesses are too thin to support the traffic load. From the CBR value of sub-grade soil, value ranges 8%-16% according to ERA road design manual from chart-2 granular road base, the thickness of the base course and sub-base course for traffic class T_4 with ESAL of 2.47 million and S_4 should be 15cm and 20cm respectively. Average thickness of the existing road layer of the base course is 14.5 cm and that of the sub-base course is 18 cm; this shows that the base and the sub-base course will not be able to carry the traffic loading at its service time; therefore traffic load with insufficient layer thickness is one of the major causes of road failures along study area.
- Lack of properly managed water flow causes road deteriorates seriously and occurs more rapidly. Based on laboratory test result of liquid limit and moisture content there is high

water content and liquid limit. This excess moisture in the subgrade soil resulted to degradation of material quality, strength reduction, deformation increase, and loss of bond between pavement layers of the pavement.

- Proctor test for all base, sub-base and sub grade layer shows that the MDD is below the specified value given by ERA technical specification, which causes road failures along study area. These results in cracks and deformations due to sub-grade, sub-base and base layers are not well compacted and there is higher air voids.

5.2 Recommendation

The following recommendations are suggested based on the result of the study.

- The sections with various sizes of potholes should be patched with good quality asphalt and distress sections of pavement with poor material due to drainage problems should be removed and replaced to required depth. Adequate longitudinal drainage, cross drainages and other drainage facilities should be provided in order to control the drainage problem.
- Existing road base and sub-base thickness of pavement shall be modified based on the CBR value of sub grade and expected traffic load.
- The material should be compacted with suitable depth until well enough to support the pavement and attainable compressive strength value based on standard specification limit
- ERA should follow proper pavement maintenance and management practice in order to reduce pavement failure.

5.3 Proposed for future research

- For future research, it is recommended that detailed in-depth investigation should be carried out on related project; compliance with quality of materials and construction methods in accordance with ERA Standard Specifications in order to avoid future failure.

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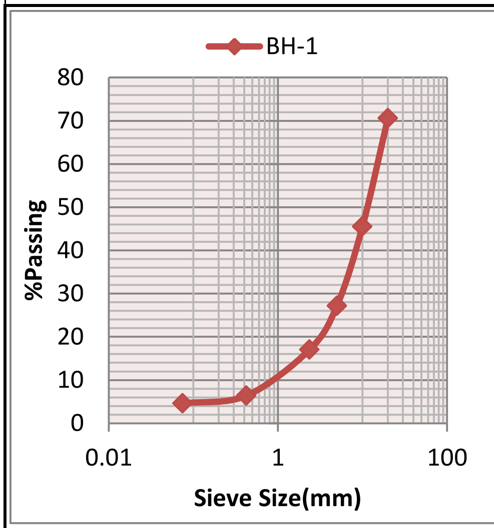
Appendix A: Grain size analysis data

i) Grain size analysis data: Base Course

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

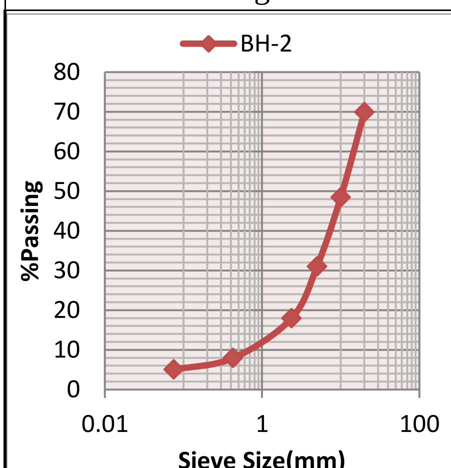
Type of Material: - Base Course Failure type:-Pothole Source :- BH-1 Method of sieving: - wet sieving	Date of Sampled:-12/06/2017 Date of Tested: - 20/06/2017 Sampled by: - Fikru Benti Nominal maximum particle size 20 mm



Sieve Opening , mm	Wt. Retained ,gm	% Retained	Cumulative %Retained	% Pass
20	1410	29.4	29.4	70.6
10	1205	25.1	54.5	45.5
5	880	18.3	72.8	27.2
2.36	490	10.2	83.0	17.0
0.425	510	10.6	93.6	6.4
0.075	90	1.8	95.4	4.6
Pan	215	4.5	100.0	0.0
Total Wt.	4800			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

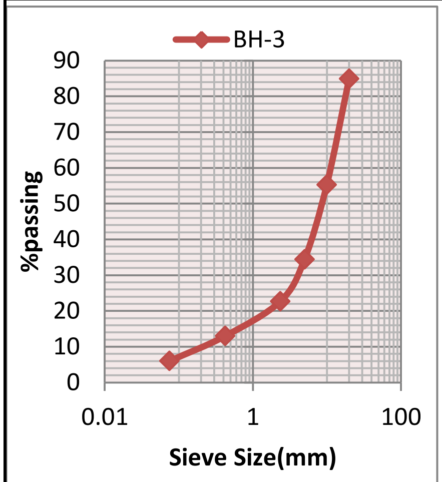
Type of Material: - Base Course Failure type:- Raveling & stripping Source :- BH-2 Method of sieving: - wet sieve	Date of Sampled:-12/06/2017 Date of Tested: - 20/06/2017 Sampled by: - Fikru Benti Nominal maximum particle size 20 mm



Sieve Opening, mm	Wt. Retained ,gm	% Retained	Cumulative Retained	% Pass
20	1540	30.1	30.1	69.9
10	1100	21.5	51.6	48.4
5	890	17.4	69.0	31.0
2.36	670	13.1	82.1	17.9
0.425	510	10.0	92.1	7.9
0.075	147	2.9	95.0	5.0
Pan	250	4.9	100	0.0

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

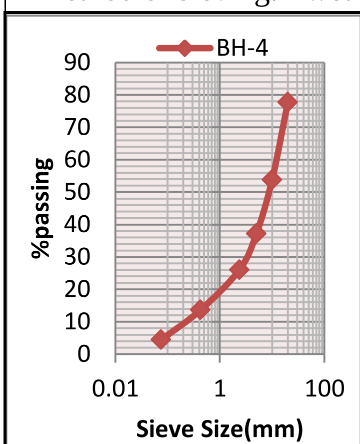
Type of Material: - Base Course | Date of Sampled:-12/06/2017
Failure type:- Corrugation | Date of Tested: - 20/06/2017
Source :- BH-3 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 20 mm



Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
20	890	15.1	15.1	84.9
10	1745	29.6	44.7	55.3
5	1230	20.9	65.6	34.4
2.36	690	11.7	77.3	22.7
0.425	569	9.7	87.0	13.0
0.075	410	7.0	94.0	6.0
Pan	350	5.9	100	0.0
Total Wt.	5890			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Type of Material: - Base Course | Date of Sampled:-12/06/2017
Failure type:- Rutting and Wear | Date of Tested: - 20/06/2017
Source :- BH-4 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 20 mm



Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Passing
20	1190	22.3	22.3	77.7
10	1280	23.9	46.2	53.8
5	894	16.7	62.9	37.1
2.36	592	11.1	74.0	26.0
0.425	660	12.4	86.4	13.6
0.075	490	9.2	95.6	4.4
Pan	240	4.5	100	0.0
Total Wt.	5346			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

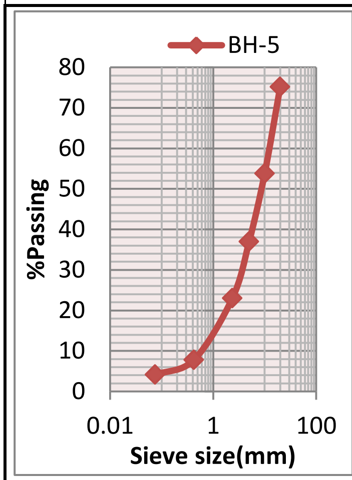
Type of Material: - Base Course | Date of Sampled:-12/06/2017

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Failure type:- Alligator Crack — Date of Tested: - 20/06/2017

Source :- BH- 5 — Sampled by: - Fikru Benti

Method of sieving: - wet sieve — Nominal maximum particle size 20 mm



Sieve Opening, mm	Wt. Retained, gm	% Retained	Cumulative Retained	% Passing
20	1490	24.8	24.8	75.2
10	1285	21.4	46.2	53.8
5	1005	16.8	63.0	37.0
2.36	840	14.0	77.0	23.0
0.425	910	15.2	92.2	7.8
0.075	220	3.7	95.9	4.1
Pan	250	4.2	100	0.0
Total Wt.	6000.0			

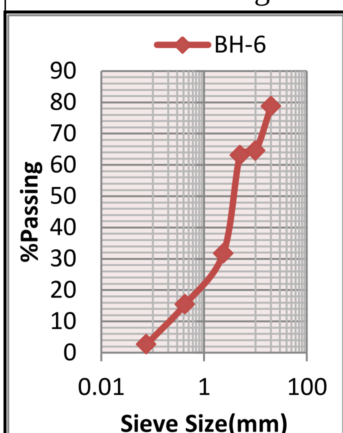
PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Type of Material: - Base Course — Date of Sampled:-12/06/2017

Failure type:- Non-defect — Date of Tested: - 20/06/2017

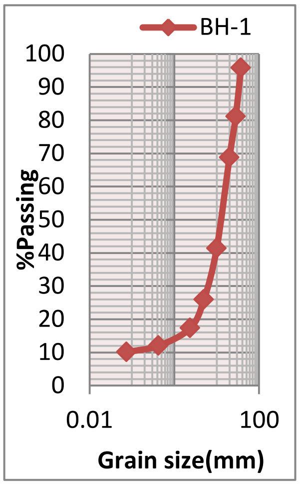
Source :- BH-6 — Sampled by: - Fikru Benti

Method of sieving: - wet sieve — Nominal maximum particle size 20 mm



Sieve Opening, mm	Wt. Retained, gm	% Retained	Cumulative Retained	% Passing
20	1279	21.3	21.3	78.7
10	854	14.2	35.5	64.5
5	1004	16.7	52.2	63.0
2.36	967	16.1	68.3	31.7
0.425	978	16.3	84.6	15.4
0.075	767	12.8	97.4	2.6
Pan	169	2.8	100	0.0
Total Wt.	6018.0			

Type of Material: - Sub-base Course | Date of Sampled:-12/06/2017
Failure type:- Pothole & Patching | Date of Tested: - 20/06/2017
Source :- BH-1 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 37.5 mm

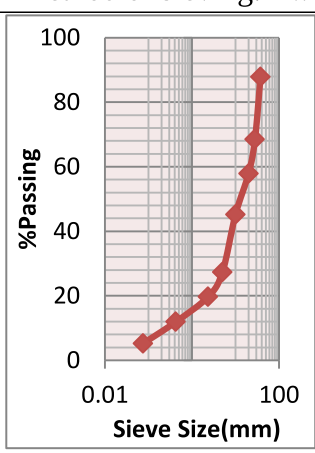


Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Passing
37.5	150.0	4.2	4.2	95.8
28	530.0	14.7	18.9	81.1
20	440.0	12.3	31.2	68.8
10	990.0	27.4	58.6	41.4
5	560.0	15.5	74.1	25.9
2.36	310.0	8.6	82.7	17.3
0.425	190.0	5.3	88.0	12.0
0.075	70.0	1.9	89.9	10.1
Pan	370.0	10.3	100.0	0.0
Total weight	3610.0			

ii) **Grain size analysis data: Sub-base Course**

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Type of Material: - Sub-base Course | Date of Sampled:-12/6/2017
Failure type:- Raveling & stripping | Date of Tested: - 20/06/2017
Source :- BH-2 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 37.5 mm

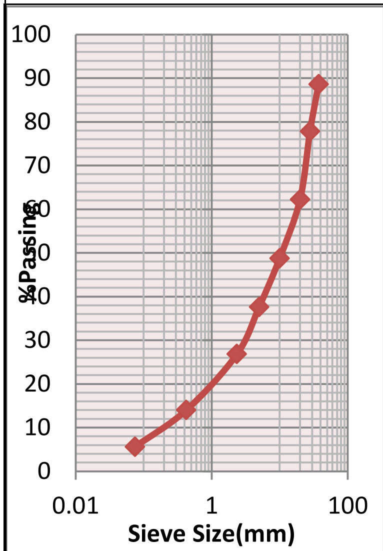


Sieve size, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Passing
37.5	612.0	12.2	12.2	87.8
28	965.0	19.3	31.5	68.5
20	530.0	10.6	42.1	57.9
10	636.0	12.7	54.8	45.2
5	897.0	17.9	72.7	27.3
2.36	382.0	7.6	80.3	19.7
0.425	391.0	7.8	88.1	11.9
0.075	335.0	6.7	94.8	5.2
Pan	250.0	5.0	100	0.0

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Total Wt.	4998.0			

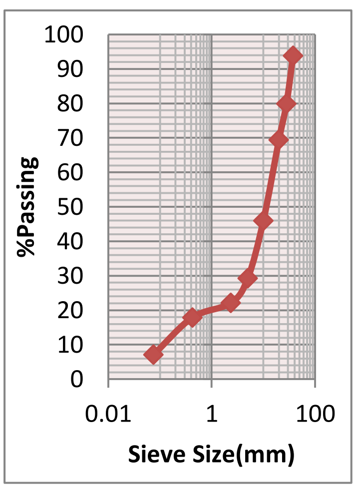
Type of Material: - Sub-base Course | Date of Sampled:-12/06/2017
Failure type:- Corrugation | Date of Tested: - 20/06/2017
Source :- BH-3 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 37.5 mm



Sieve Opening, mm	Wt. Retained ,gm	% Retained	Cumulative Retained	% Passing
37.5	594.0	11.4	11.4	88.6
28	563.0	10.8	22.2	77.8
20	810.0	15.6	37.8	62.2
10	703.0	13.5	51.3	48.7
5	582	11.1	62.4	37.6
2.36	563.0	10.8	73.2	26.8
0.425	667.0	12.8	86.0	14.0
0.075	431	8.3	94.4	5.6
Pan	287.0	5.5	100.0	0.0
Total weight	5200.0			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Type of Material: - Sub-base Course | Date of Sampled:-12/06/2017
Failure type:- Rutting and Wear | Date of Tested: - 20/06/2017
Source :- BH-4 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 37.5 mm



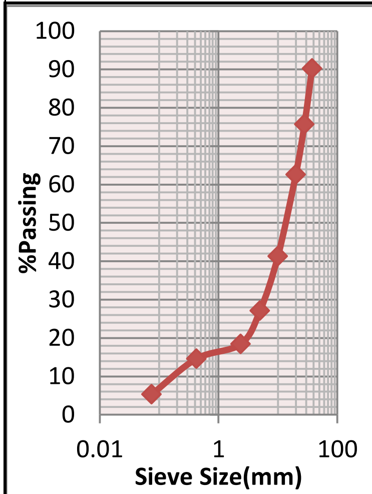
Sieve Opening, (mm)	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
37.5	280.0	6.7	6.7	93.8
28	540.0	13.4	20.1	79.9
20	420.0	10.5	30.6	69.4
10	940.0	23.4	54.0	46.0
5	670.0	16.7	70.7	29.3
2.36	290.0	7.2	77.9	22.1
0.425	170.0	4.2	82.1	17.9
0.075	430.0	10.7	92.9	7.1
Pan	280.0	7.0	100.0	0.0

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Type of Material: -Sub-base course | Date of Sampled:-12/06/2017
Failure type:-Alligator Crack | Date of Tested: - 20/06/2017

Source :- BH-5 | Sampled by: - Fikru Benti

Method of sieving: - wet sieve | Nominal maximum particle size 37.5 mm



Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Passing
37.5	360.0	9.8	9.8	90.2
28	530.0	14.5	24.3	75.7
20	480.0	13.1	37.4	62.6
10	780.0	21.3	58.7	41.3
5	520.0	14.2	72.9	27.1
2.36	320.0	8.7	81.6	18.4
0.425	340.0	3.8	85.4	14.6
0.075	180.0	9.3	94.7	5.3
Pan	150.0	4.1	100.0	0.0
Total Wt.	3660			

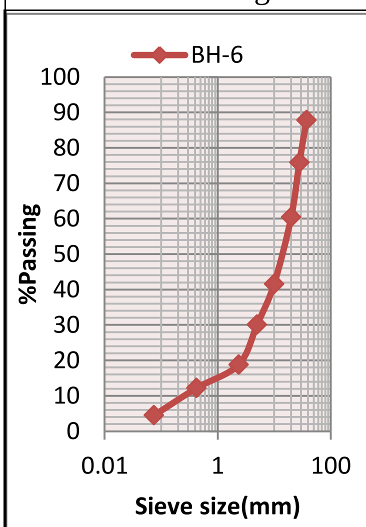
PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Type of Material: - Sub base course | Date of Sampled:-12/06/2017

Failure type:-Non-defect | Date of Tested: - 20/06/2017

Source :- BH-6 | Sampled by: - Fikru Benti

Method of sieving: - wet sieve | Nominal maximum particle size 37.5 mm



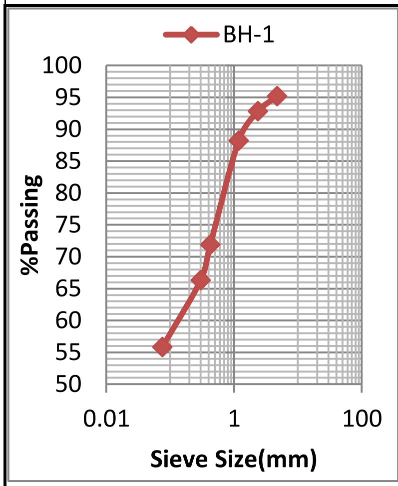
Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Passing
37.5	450.0	12.2	12.2	87.8
28	440.0	11.9	24.1	75.9
20	570.0	15.5	39.6	60.4
10	693.0	18.8	58.4	41.6
5	425.0	11.5	69.9	30.1
2.36	415.0	11.3	81.2	18.8
0.425	244.0	6.6	87.8	12.2
0.075	285.0	7.7	95.5	4.5
Pan	160.0	4.5	100.0	0.0
Total Wt.	3682			

iii) **Grain size analysis data: Subgrade Soil**

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Type of Material: - Subgrade | Date of Sampled:-12/06/2017

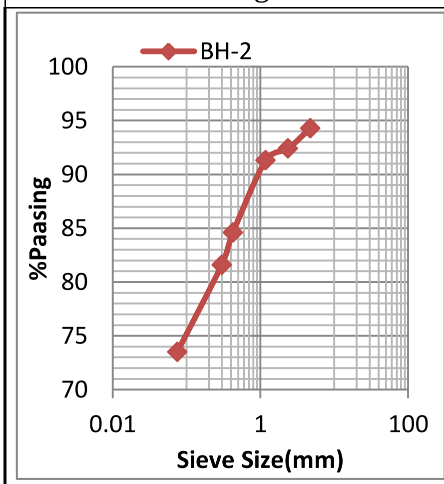
Failure type:-Pothole | Date of Tested: - 20/06/2017
Source :- BH-1 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 4.75 mm



Sieve Opening, mm	Wt. Retained, gm	% Retained	Cumulative Retained	% Passing
4.75	120	4.8	4.8	95.2
2.36	60	2.4	7.2	92.8
1.18	120	4.8	12.0	88.2
0.425	400	16.1	28.1	71.9
0.3	140	5.6	33.7	66.3
0.075	260	10.4	44.2	55.8
Pan	1390	55.8	100	0.0
Total Wt.	2490			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

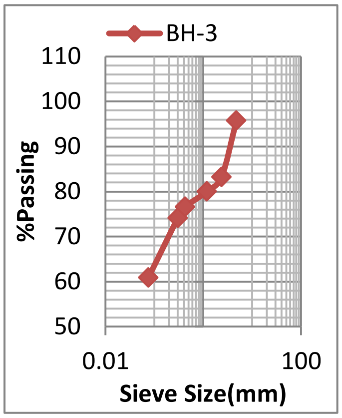
Type of Material: - Subgrade | Date of Sampled:-12/06/2017
Failure type:- Raveling & stripping | Date of Tested: - 20/06/2017
Source :- BH-2 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 4.75 mm



Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
4.75	210	5.7	5.7	94.3
2.36	70	1.9	7.6	92.4
1.18	40	1.1	8.7	91.3
0.425	250	6.7	15.4	84.6
0.3	110	3.0	18.4	81.6
0.075	300	8.1	26.5	73.6
Pan	2730	73.6	100	0.0
Total Wt.	3710			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

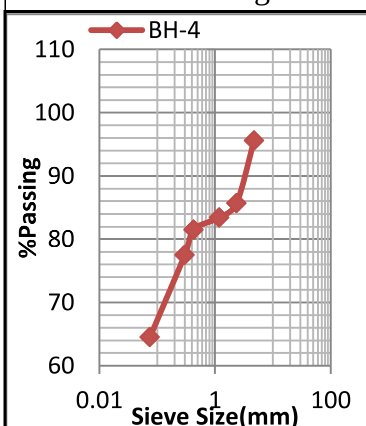
Type of Material: - Subgrade | Date of Sampled:-12/06/2017
Failure type:- Corrugation | Date of Tested: - 20/06/2017
Source :- BH-3 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 4.75 mm



Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Passing
4.75	197	4.3	4.3	95.7
2.36	570	12.5	16.8	83.2
1.18	146	3.2	20.0	80.0
0.425	154	3.4	23.4	76.6
0.3	112	2.5	25.9	74.1
0.075	604	13.2	39.1	61.0
Pan	2783	61.0	100	0.0
Total Wt.	4566.0			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

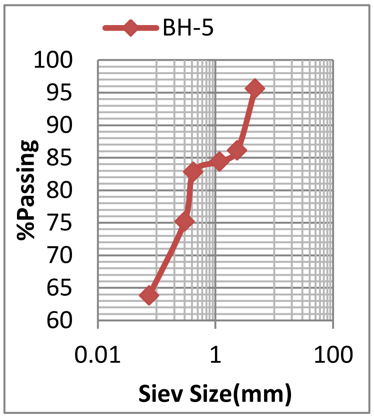
Type of Material: - Subgrade | Date of Sampled:-12/06/2017
Failure type:- Rutting and Wearing | Date of Tested: - 20/06/2017
Source :- BH-4 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 4.75 mm



Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Passing
4.75	230	4.4	4.4	95.6
2.36	523	9.9	14.3	85.7
1.18	120	2.3	16.6	83.4
0.425	99	1.9	18.5	81.5
0.3	212	4.0	22.5	77.5
0.075	688	13.0	35.5	64.6
Pan	3408	64.6	100	0.0
Total Wt.	5280.0			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

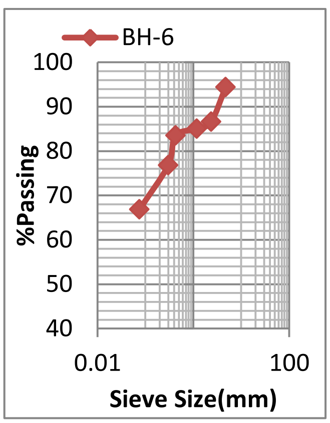
Type of Material: - Subgrade | Date of Sampled:-12/06/2017
Failure type:- Alligator crack | Date of Tested: - 20/06/2017
Source :- BH-5 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 4.75 mm



Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Passing
4.75	267	4.4	4.4	95.6
2.36	570	9.5	13.9	86.1
1.18	100	1.7	15.6	84.4
0.425	94	1.6	17.2	82.8
0.3	458	7.6	24.8	75.2
0.075	683	11.4	36.2	63.8
Pan	3842	63.9	100	0.0
Total Wt.	6014.0			

PARTICLE SIZE DISTRBUTION: (AASHTO T-11 /T 27)

Type of Material: - Subgrade | Date of Sampled:-12/06/2017
Failure type:- Non-defect | Date of Tested: - 20/06/2017
Source :- BH-6 | Sampled by: - Fikru Benti
Method of sieving: - wet sieve | Nominal maximum particle size 4.75 mm



Sieve Opening, mm	Wt. Retained,gm	% Retained	Cumulative Retained	% Pass
4.75	333	5.6	5.6	94.4
2.36	468	7.8	13.4	86.6
1.18	98	1.6	15.0	85.0
0.425	89	1.5	16.5	83.5
0.3	399	6.7	23.2	76.8
0.075	597	10.0	33.2	66.8
Pan	3993	66.8	100.0	0.0
Total Wt.	5977.0			

✓ From Grain Size Distribution Curve of Base Course material

Test pit No.	% Gravel	% Sand	% Fines	D_{10} mm	D_{30} mm	D_{60} mm	Cu	Cc
BH-1	72.8	22.6	4.5	0.9	6.0	15	16.7	2.7
BH-2	69.0	26.0	4.9	0.7	5.0	16	22.9	2.2
BH-3	65.6	28.4	5.9	0.2	4.0	11	55.0	7.2
BH-4	62.9	32.7	4.5	0.2	3.0	11	55.0	4.1
BH-5	63.0	32.9	4.2	0.6	4.0	12	20.0	2.2
BH-6	52.2	45.2	2.8	0.2	2.2	4.6	25.0	2.5

✓ From Grain Size Distribution Curve of sub-base material

Test pit No.	% Gravel	% Sand	% Fines	D_{10} mm	D_{30} Mm	D_{60} Mm	Cu	Cc
BH-1	74.1	15	10.3	0.3	6.0	17	56.7	7.0
BH-2	72.7	22.1	2.8	0.3	6.0	20	66.0	6.0
BH-3	62.4	32.0	5.5	0.2	3.0	19.0	95.0	2.4
BH-4	70.7	22.2	7.0	0.1	5.0	15.0	150	9.3
BH-5	72.9	21.8	4.1	0.2	6.1	20.0	100	9.3
BH-6	69.9	25.6	4.5	0.3	5.0	20.0	66.7	4.2

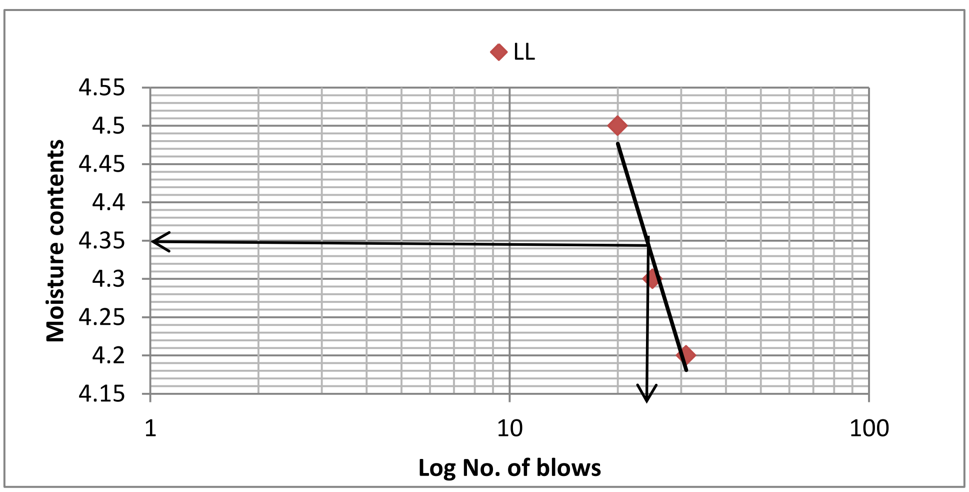
✓ From Grain Size and Hydrometer Size Distribution Curve of subgrade soil.

Test pit No.	% Gravel	% Sand	% Fines	D_{10} mm	D_{30} Mm	D_{60} mm	Cu	Cc
BH-1	4.8	39.4	55.8	0.002	0.006	0.15	75.0	0.12
BH-2	5.7	20.8	73.6	0.0015	0.0017	0.04	26.7	0.05
BH-3	4.3	34.8	61.0	0.0011	0.011	0.019	17.3	5.8
BH-4	4.4	31.1	64.6	0.002	0.009	0.03	15.0	1.35
BH-5	4.4	31.8	63.9	0.0015	0.005	0.04	26.7	0.42
BH-6	5.6	27.6	66.8	0.0016	0.0049	0.03	18.8	0.5

Appendix B: Atterberg limit test

i) Atterberg limit test / Base Course

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Base Course Source:-BH-1 Failure Type:- Pothole and Patching Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing:-23/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 °C		
	Liquid Limit				Plastic Limit	
Container No.	D	B	C		T2	T3
No. of Blows	31	25	20		-	-
Wgt.of Wet soil + Cont.(gm)	53.8	55.6	56.1			
Wgt. of Dry soil + Cont.(gm)	52.2	53.9	54.2			
Wgt. of Moisture (gm)	1.6	1.7	1.9			
Wgt. of Container (gm)	13.9	13.9	14.0			
Wgt. of Dry soil (gm)	38.3	40.0	42.1			
Moisture Content, %	4.2	4.3	4.5		0.0	0.0
	Avg. LL	4.33		Avg.PL	0.0	
Summary , Liquid Limit	4.33					
Plasticity Limit	0.0					
Plasticity Index	4.33%					

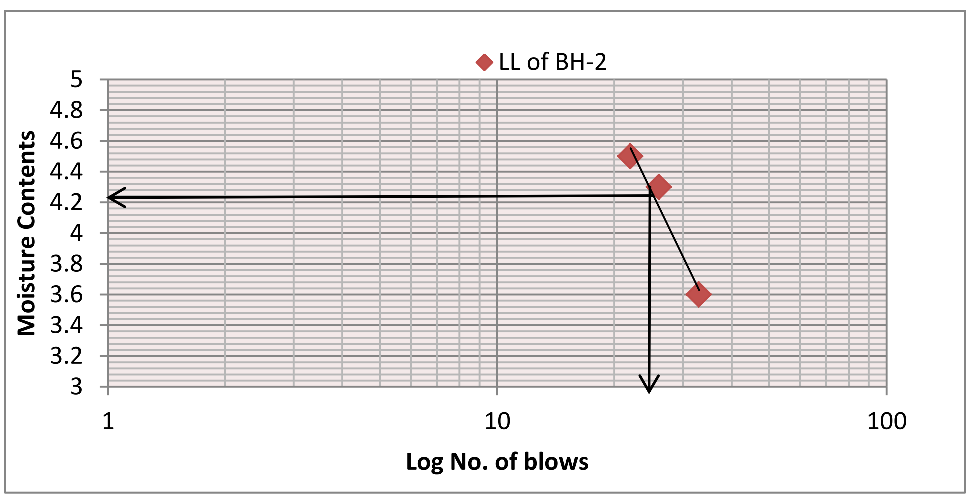


Final Results: Liquid Limit = 4.35

Plastic Limit = 0.00

Plasticity Index =4.34

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Base Course Source:- BH-2 Failure Type:-Raveling &stripping Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing: - 23/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 °C		
	Liquid Limit				Plastic Limit	
Container No.	R1	T2	Y3		D2	D1
No. of Blows	33	26	22		-	-
Wgt. of Wet soil + Cont.(gm)	54.1	55.2	55.8			
Wgt. of Dry soil + Cont.(gm)	52.7	53.5	54.0			
Wgt. of Moisture (gm)	1.4	1.7	1.8			
Wgt. of Container (gm)	14.0	13.9	14.0			
Wgt. of Dry soil (gm)	38.7	39.6	40.0			
Moisture Content, %	3.6	4.3	4.5		0.0	0.0
	Avg. LL	4.13		Avg.PL	0.0	
Summary , Liquid Limit	4.13					
Plasticity Limit	0.0					
Plasticity Index	4.13%					

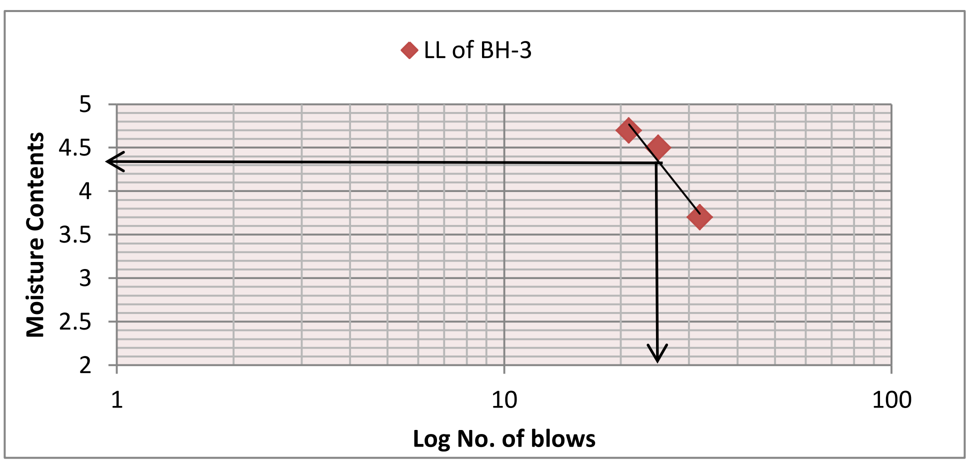


Final Results: Liquid Limit = 4.26

Plastic Limit = 0.00

Plasticity Index =4.26

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Base Course Source:- BH-3 Failure Type:- Corrugation Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing: - 23/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 °C		
	Liquid Limit				Plastic Limit	
Container No.	Q2	S2	H2		D1	B1
No. of Blows	32	25	21		-	-
Wgt.of Wet soil + Cont.(gm)	55.1	55.2	55.9			
Wgt. of Dry soil + Cont.(gm)	53.6	53.4	54.0			
Wgt. of Moisture (gm)	1.5	1.8	1.9			
Wgt. of Container (gm)	13.0	13.2	13.1			
Wgt. of Dry soil (gm)	40.6	40.2	40.9			
Moisture Content, %	3.7	4.5	4.7		0.0	0.0
	Avg. LL	4.3		Avg.PL	0.0	
Summary , Liquid Limit	4.3					
Plasticity Limit	0.0					
Plasticity Index	4.3%					

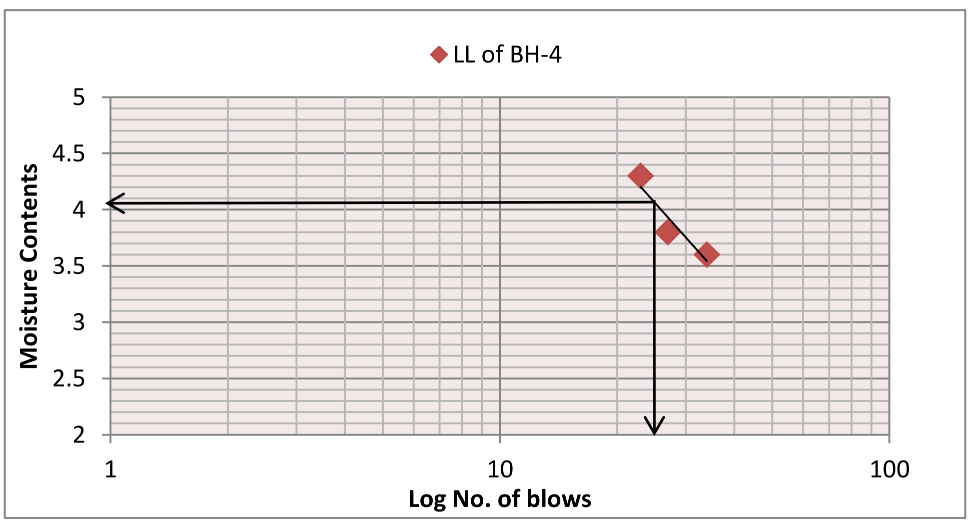


Final Results: Liquid Limit = 4.81

Plastic Limit = 0.00

Plasticity Index =4.81

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Base Course Source:- BH-4 Failure Type:- Rutting and Wearing Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing: -23/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 ^{o}C		
	Liquid Limit				Plastic Limit	
Container No.	C4	S1	D1		L1	L5
No. of Blows	34	27	23		-	-
Wgt.ofWet soil + Cont.(gm)	55.3	55.5	56.0			
Wgt. of Dry soil + Cont.(gm)	53.9	54.0	54.3			
Wgt. of Moisture (gm)	1.4	1.5	1.7			
Wgt. of Container (gm)	14.6	14.8	14.5			
Wgt. of Dry soil (gm)	39.3	39.2	39.8			
Moisture Content, %	3.6	3.8	4.3		0.0	0.0
	Avg.LL	3.9		Avg.PL	0.0	
Summary , Liquid Limit	3.9					
Plasticity Limit	0.0					
Plasticity Index	3.9%					

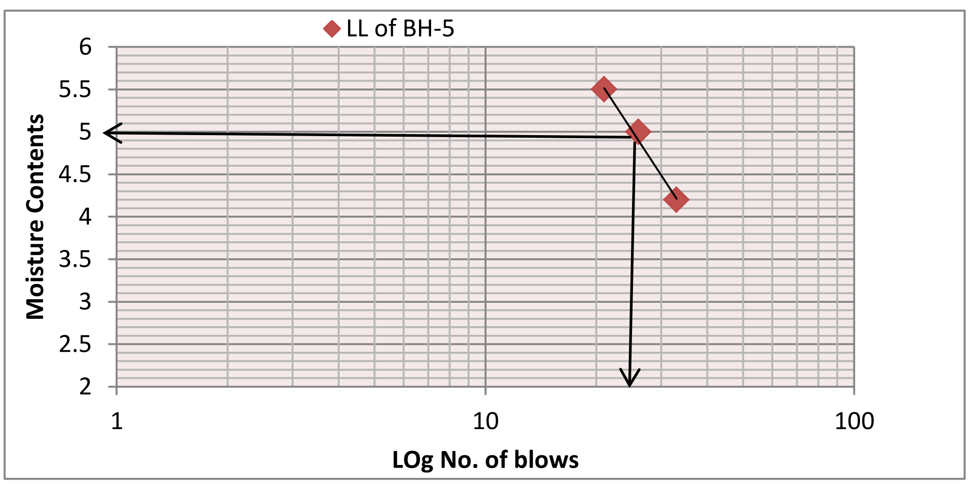


Final Results: Liquid Limit = 4.10

Plastic Limit = 0.00

Plasticity Index =4.10

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Base Course Source:- BH-5 Failure Type:- Alligator crack Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing: -23/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 °c		
	Liquid Limit				Plastic Limit	
Container No.	H1	R2	M3		M1	M2
No. of Blows	33	26	21		-	-
Wgt.of Wet soil + Cont.(gm)	57.4	58.3	59.2			
Wgt. of Dry soil + Cont.(gm)	55.6	56.2	56.8			
Wgt. of Moisture (gm)	1.8	2.1	2.4			
Wgt. of Container (gm)	13.0	13.3	13.2			
Wgt. of Dry soil (gm)	42.6	42.9	43.6			
Moisture Content, %	4.2	5.0	5.5		0.0	0.0
	Avg.LL	4.9		Avg.PL	0.0	
Summary , Liquid Limit	4.9					
Plasticity Limit	0.0					
Plasticity Index	4.9%					

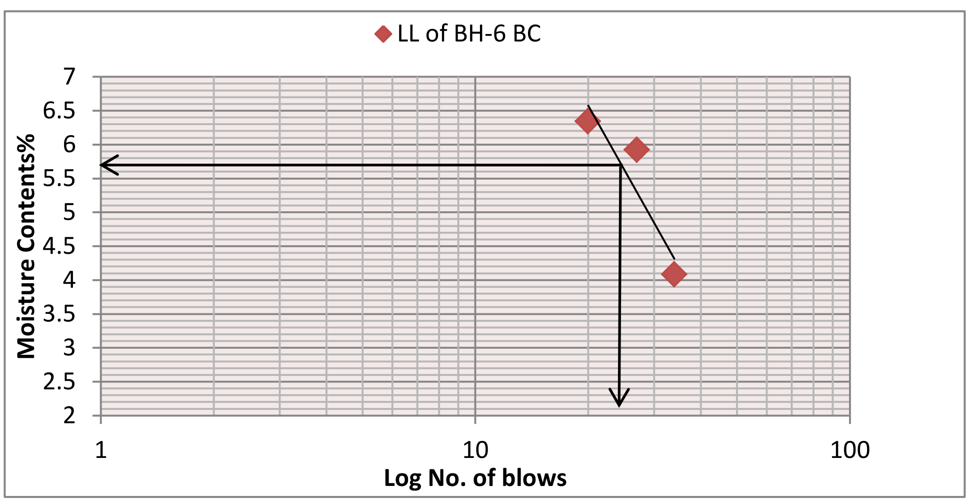


Final Results: Liquid Limit = 5.10

Plastic Limit = 0.00

Plasticity Index =5.10

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Base Course Source:- BH-6 Failure Type:-Non defect Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing: -23/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 °c		
	Liquid Limit				Plastic Limit	
Container No.	D	F	S		T	B
No. of Blows	34	27	20		-	-
Wgt.ofWet soil + Cont.(gm)	66.4	69.5	70.7			
Wgt. of Dry soil + Cont.(gm)	64.3	66.3	67.2			
Wgt. of Moisture (gm)	2.1	3.2	3.5			
Wgt. of Container (gm)	12.9	12.2	12.0			
Wgt. of Dry soil (gm)	51.4	54.1	55.2			
Moisture Content, %	4.08	5.92	6.34		0.0	0.0
	Avg.LL	5.67		Avg.PL	0.0	
Summary , Liquid Limit	5.57					
Plasticity Limit	0.0					
Plasticity Index	5.45%					



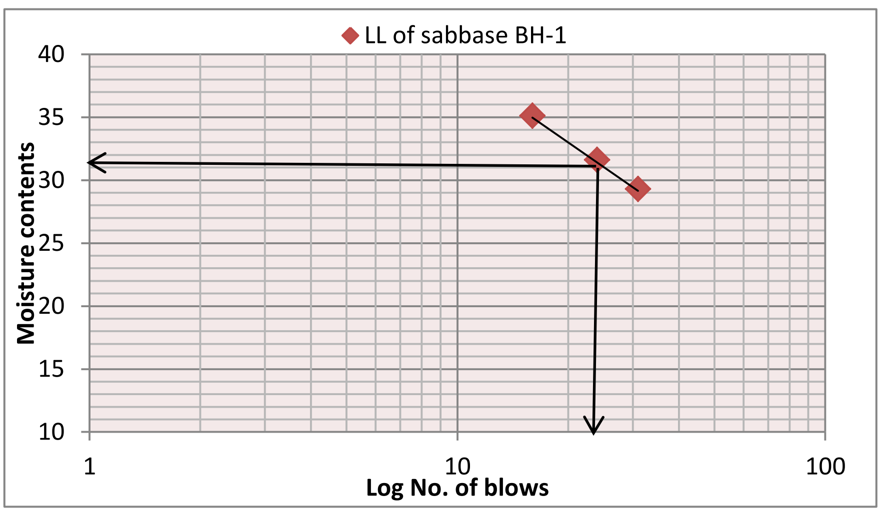
Final Results: Liquid Limit = 5.80

Plastic Limit = 0.00

Plasticity Index =5.80

ii) Atterberg limit test / Sub-Base Course

ATTERBERG LIMIT:AASHTO T-89 & T-90					
Type of Material: - Sub base Course Source: - BH-1 Failure Type:- Pothole and Patching Proportion retained on 0.425mm Sieve			Date of Sampling: -13/06/2017 Date of Testing: -23/06/2017 Sampled by: - Fikru Benti Oven Dried at: -110 ^{o}c		
	Liquid Limit			Plastic Limit	
Number of Blows	31	24	16	-	-
container Number	A1	A2	A3	B1	B2
Wet Soil + container (gram)	79.2	62.6	78.3	10.2	12.3
Dry Soil + container (gram)	67.8	55.4	66.6	9.9	11.6
Mass of container (gram)	32.7	32.6	33.2	9.4	9.0
Mass of Moisture (gram)	10.3	7.2	11.7	0.5	0.7
Mass of Dry Soil (gram)	35.1	22.8	33.4	2.3	2.6
Moisture Content %	29.3	31.6	35.1	21.7	26.9
Avg.LL	33.1		Avg.PL	24.3	
Liquid Limit :	33.1				
Plastic Limit :	24.3				
Plastic Index :	8.7				

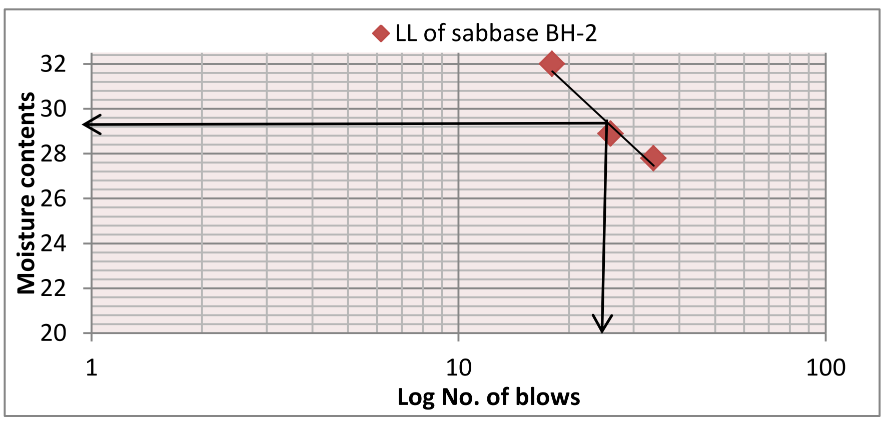


Final Results: Liquid Limit = 31.0

Plastic Limit = 24.30

Plasticity Index = 6.70

ATTERBERG LIMIT: AASHTO T-89 & T-90					
Type of Material: - Sub base Course Source: - BH-2 Failure Type:- Raveling &stripping Proportion retained on 0.425mm Sieve			Date of Sampling: -13/06/2017 Date of Testing: -23/06/2017 Sampled by: - Fikru Benti Oven Dried at: -110 ^{o}c		
	Liquid Limit			Plastic Limit	
Number of Blows	34	26	18	-	-
container Number	Q2	E3	X4	Q1	R2
Wet Soil + container (gram)	72.6	76.7	74.8	18.5	20.3
Dry Soil + container (gram)	63.8	66.8	64.4	17.3	19.5
Mass of container (gram)	32.2	32.6	33.2	12.6	15.7
Mass of Moisture (gram)	8.8	9.9	10.4	1.2	0.8
Mass of Dry Soil (gram)	31.6	34.2	32.5	4.7	3.8
Moisture Content %	27.8	28.9	32.0	25.5	21.0
Avg.LL	29.6		Avg.PL	23.3	
Liquid Limit	29.6				
Plastic Limit	23.3				
Plastic Index	6.35				

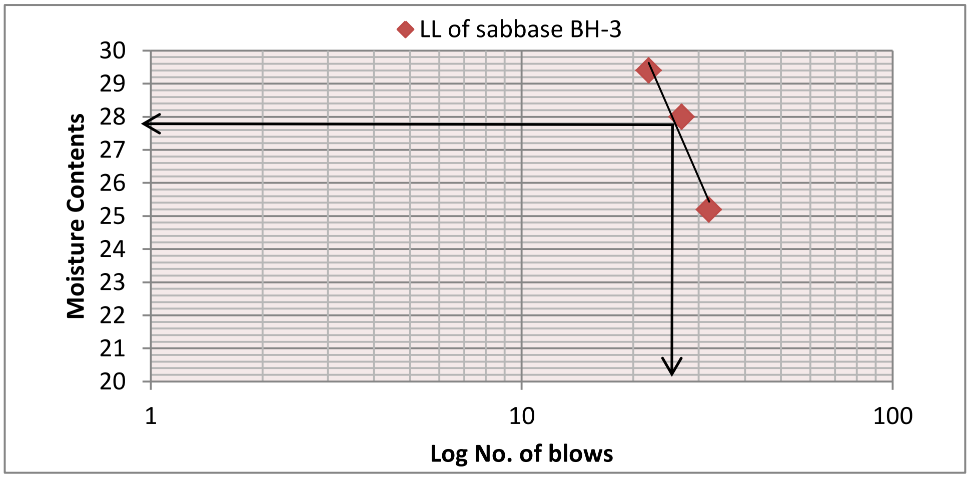


Final Results: Liquid Limit = 29.00

Plastic Limit = 23.30

Plasticity Index = 5.70

ATTERBERG LIMIT: AASHTO T-89 & T-90					
Type of Material: - Sub base Course Source: - BH-3 Failure Type:- Corrugation Proportion retained on 0.425mm Sieve			Date of Sampling: -13/06/2017 Date of Testing: -23/06/2017 Sampled by: - Fikru Benti Oven Dried at: -110 ^{o}c		
	Liquid Limit			Plastic Limit	
Number of Blows	32	27	22	-	-
container Number	D2	D3	D4	X1	X2
Wet Soil + container (gram)	80.5	70.4	76.7	19.3	21.6
Dry Soil + container (gram)	71.9	63.5	67.6	18.5	20.9
Mass of container (gram)	37.0	36.3	33.2	14.8	17.6
Mass of Moisture (gram)	8.6	7.1	9.7	0.8	0.7
Mass of Dry Soil (gram)	34.1	27.3	33.0	3.7	3.3
Moisture Content %	25.2	28.0	29.4	21.6	21.2
Avg.LL	27.5		Avg.PL	21.4	
Liquid Limit	27.50				
Plastic Limit	21.80				
Plastic Index	5.73				

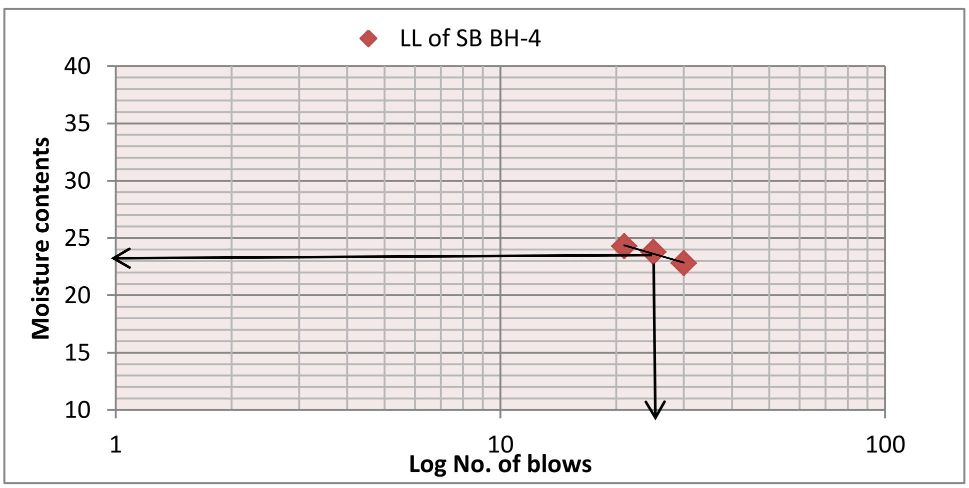


Final Results: Liquid Limit = 28.00

Plastic Limit = 21.40

Plasticity Index = 6.70

ATTERBERG LIMIT: AASHTO T-89 & T-90					
Type of Material: - Sub-base Course			Date of Sampling: -13/06/2017		
Source: - BH-4			Date of Testing: -23/06/2017		
Failure Type:- Rutting and Wearing			Sampled by: - Fikru Benti		
Proportion retained on 0.425mm Sieve			Oven Dried at: -110 ^{o}c		
	Liquid Limit			Plastic Limit	
Number of Blows	30	25	21	-	-
container Number	C1	C2	C3	N1	N2
Wet Soil + container (gram)	72.6	68.3	76.7	20.6	18.8
Dry Soil + container (gram)	64.2	61.6	68.4	20.0	18.2
Mass of container (gram)	33.1	33.4	34.2	16.4	14.8
Mass of Moisture (gram)	7.1	6.7	8.3	0.6	0.6
Mass of Dry Soil (gram)	31.1	28.2	34.2	3.6	3.4
Moisture Content %	22.8	23.8	24.3	16.7	17.6
Avg.LL	23.6		Avg.PL	17.15	
Liquid Limit	23.6				
Plastic Limit	18.8				
Plastic Index	4.8				

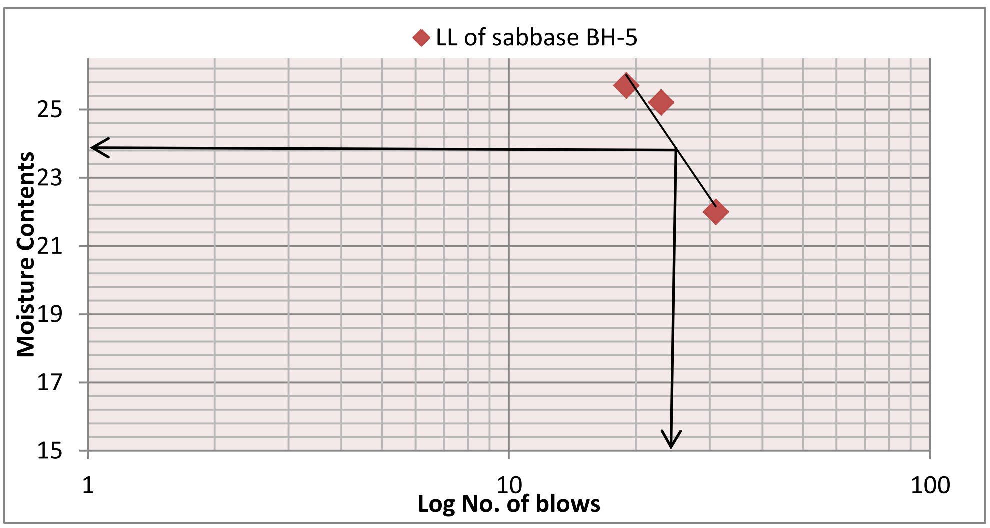


Final Results: Liquid Limit = 23.65

Plastic Limit = 17.15

Plasticity Index =6.5

ATTERBERG LIMIT: AASHTO T-89 & T-90					
Type of Material: - Sub-base Course Source: - BH-5 Failure Type:- Alligator crack Proportion retained on 0.425mm Sieve			Date of Sampling: -13/06/2017 Date of Testing: -23/06/2017 Sampled by: - Fikru Benti Oven Dried at: -110 ^{o}c		
	Liquid Limit			Plastic Limit	
Number of Blows	31	23	19	-	-
container Number	T2	T3	T4	D3	D4
Wet Soil + container(gram)	80.4	68.5	78.7	24.1	21.4
Dry Soil + container (gram)	72.3	62.1	69.8	23.2	20.6
Mass of container (gram)	35.5	36.7	42.6	17.4	16.4
Mass of Moisture (gram)	8.1	6.4	8.9	0.9	0.8
Mass of Dry Soil (gram)	36.8	25.4	34.6	5.8	4.2
Moisture Content %	22.0	25.2	25.7	15.5	19.1
Avg.LL	24.3		Avg.PL	17.3	
Liquid Limit	24.3				
Plastic Limit	17.3				
Plastic Index	7.0				

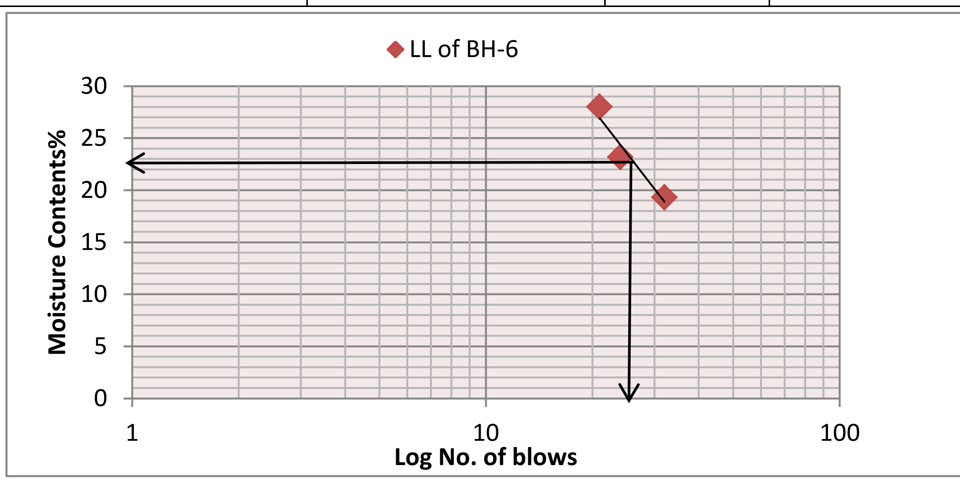


Final Results: Liquid Limit = 23.80

Plastic Limit = 17.30

Plasticity Index = 6.50

ATTERBERG LIMIT: AASHTO T-89 & T-90					
Type of Material: - Sub-base Course Source: - BH-6 Failure Type:-Non-defect Proportion retained on 0.425mm Sieve			Date of Sampling: -13/06/2017 Date of Testing: -23/06/2017 Sampled by: - Fikru Benti Oven Dried at: -110 °c		
	Liquid Limit			Plastic Limit	
Number of Blows	32	24	21	-	-
container Number	Z1	Z2	Z3	C2	C3
Wet Soil + container(gram)	80.2	68.4	76.5	22.8	19.5
Dry Soil + container (gram)	73.3	62.1	67.2	21.6	18.7
Mass of container (gram)	33.5	33.2	34.0	16.0	14.2
Mass of Moisture (gram)	6.9	6.7	9.3	1.2	0.8
Mass of Dry Soil (gram)	39.8	28.9	33.2	5.6	4.5
Moisture Content %	19.3	23.18	28.01	21.43	17.80
Avg.LL	23.50		Avg.PL	19.60	
Liquid Limit	23.50				
Plastic Limit	19.60				
Plastic Index	4.2				



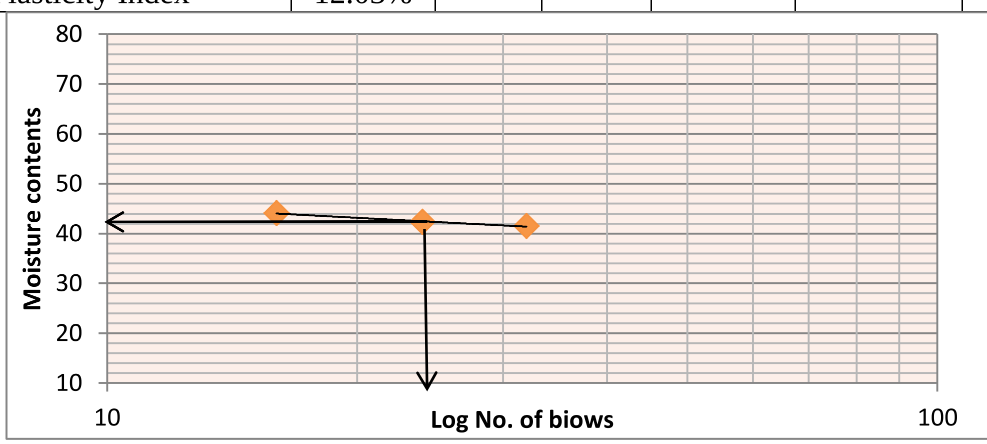
Final Results: Liquid Limit = 24.00

Plastic Limit = 19.60

Plasticity Index = 4.40

iii) Atterberg limit test / Sub-grade soil

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Sub grade Source:-BH-1 Failure Type:- Pothole and Patching Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing:-24/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 °C		
	Liquid Limit				Plastic Limit	
Container No.	B	C	D		E1	B4
No. of Blows	32	24	16		-	-
Wgt.of Wet soil + Cont.(gm)	54.1	58.8	59.1		22.9	23.4
Wgt. of Dry soil + Cont.(gm)	43.4	46.4	46.4		21.7	21.9
Wgt. of Moisture (gm)	10.7	12.4	12.7		1.2	1.5
Wgt. of Container (gm)	17.6	17.1	17.6		17.4	17.2
Wgt. of Dry soil (gm)	25.8	29.3	28.8		4.1	4.7
Moisture Content, %	41.47	42.32	44.09		29.27	31.91
	Avg.LL	42.05		Avg.PL	30.59	
Summary , Liquid Limit	42.62					
Plasticity Limit	30.59					
Plasticity Index	12.03%					

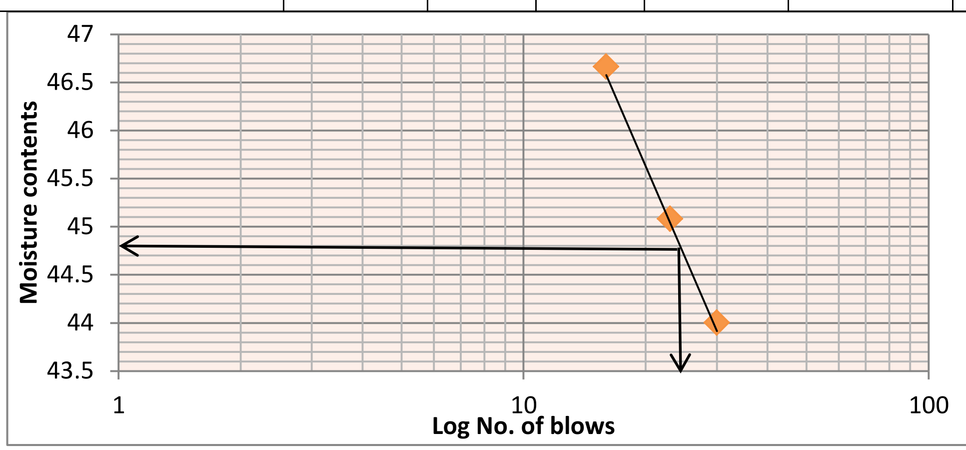


Final Results: Liquid Limit = 42.3

Plastic Limit = 30.95

Plasticity Index = 12.30

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Sub grade Source:-BH-2 Failure Type:- Raveling &stripping Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing:-24/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 ^{o}C		
	Liquid Limit				Plastic Limit	
Container No.	D5	B1	B2		A3	B3
No. of Blows	30	23	16		-	-
Wgt.of Wet soil + Cont.(gm)	49.4	60.6	62.0		21.9	22.4
Wgt. of Dry soil + Cont.(gm)	39.5	47.3	48.0		20.7	21.2
Wgt. of Moisture (gm)	9.9	13.0	14.0		1.2	1.2
Wgt. of Container (gm)	17.0	18.1	17.6		16.9	17.7
Wgt. of Dry soil (gm)	22.5	29.5	30.0		3.8	3.5
Moisture Content, %	44.00	45.08	46.66		31.58	34.29
	Avg.LL	44.91		Avg.PL	32.93	
Summary , Liquid Limit	44.91					
Plasticity Limit	32.93					
Plasticity Index	11.98%					

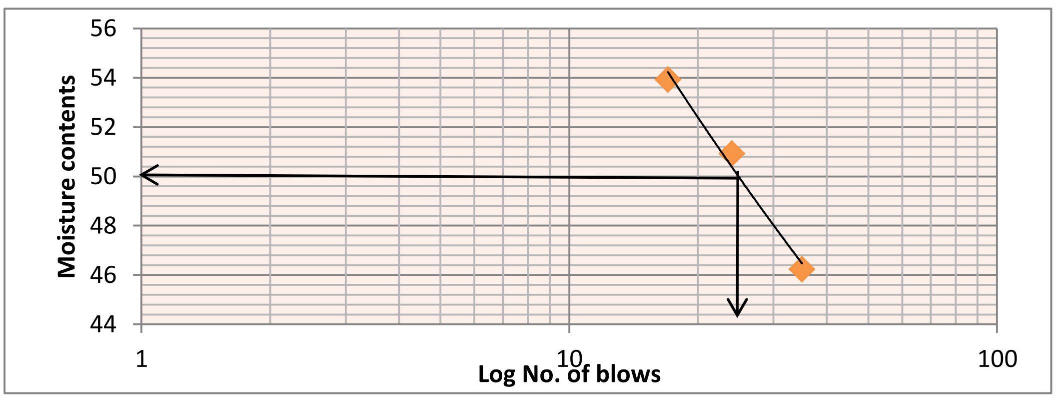


Final Results: Liquid Limit = 44.80

Plastic Limit = 32.93

Plasticity Index =11.87

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Sub grade Source:-BH-3 Failure Type:- Corrugation Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing:-24/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 °C		
	Liquid Limit				Plastic Limit	
Container No.	T5	T1	T2		D2	D3
No. of Blows	35	24	17		-	-
Wgt.of Wet soil + Cont.(gm)	48.4	60.5	61.2		24.4	25.7
Wgt. of Dry soil + Cont.(gm)	38.6	46.7	46.1		23.1	24.2
Wgt. of Moisture (gm)	9.8	13.8	15.1		1.3	1.5
Wgt. of Container (gm)	17.4	19.6	18.1		18.7	18.0
Wgt. of Dry soil (gm)	21.2	27.1	28.0		4.4	6.2
Moisture Content, %	46.23	50.92	53.93		29.55	24.19
	Avg.LL	50.94		Avg.PL	26.87	
Summary , Liquid Limit	50.36					
Plasticity Limit	26.87					
Plasticity Index	23.49%					

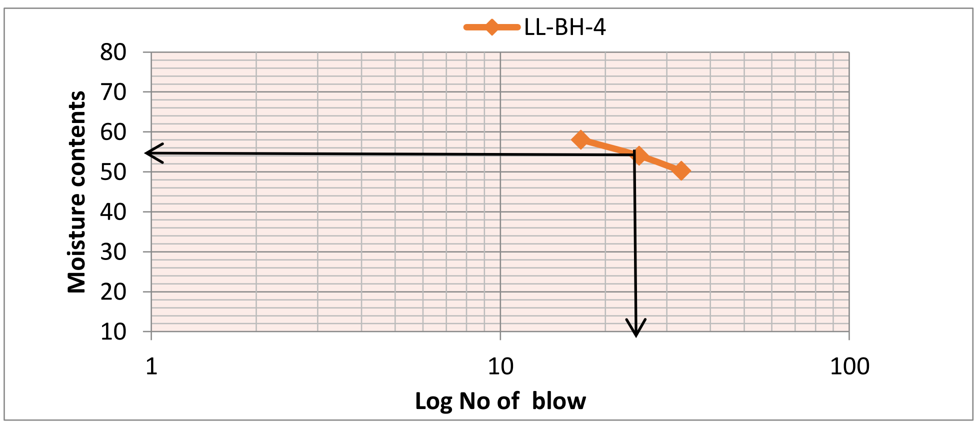


Final Results: Liquid Limit = 49.80

Plastic Limit = 26.87

Plasticity Index =22.93

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Sub grade Source:-BH-4 Failure Type:- Rutting and Wear Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing:-24/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 ^{o}C		
	Liquid Limit				Plastic Limit	
Container No.	F2	B3	B4		G3	G1
No. of Blows	33	25	17		-	-
Wgt. of Wet soil + Cont.(gm)	52.3	63.6	66.1		22.5	23.6
Wgt. of Dry soil + Cont.(gm)	40.2	47.9	48.9		21.3	22.1
Wgt. of Moisture (gm)	12.1	15.7	17.2		1.2	1.5
Wgt. of Container (gm)	17.2	19.9	17.5		16.6	17.3
Wgt. of Dry soil (gm)	23	29.6	48.6		4.7	4.8
Moisture Content, %	52.26	53.04	54.08		31.58	34.29
	Avg. LL	53.13		Avg.PL	32.94	
Summary , Liquid Limit	53.13					
Plasticity Limit	32.94					
Plasticity Index	20.19%					

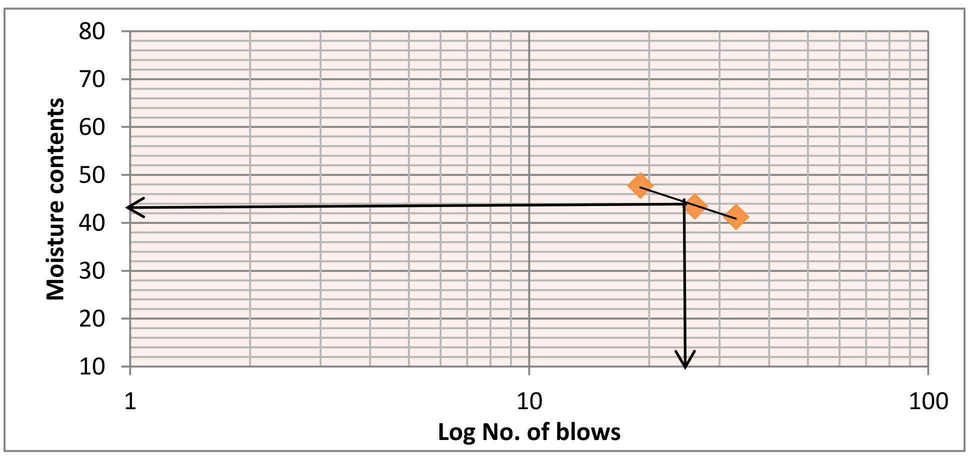


Final Results: Liquid Limit = 53.00

Plastic Limit = 32.94

Plasticity Index =20.06

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Sub grade Source:-BH-5 Failure Type:- Alligator crack Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing:-24/062017 Sampled by:- Fikru Benti Oven Dried at: -110 °C		
	Liquid Limit				Plastic Limit	
Container No.	R1	R2	R4		E2	E3
No. of Blows	33	26	19		-	-
Wgt.of Wet soil + Cont.(gm)	52.2	55.5	56.3		21.8	22.7
Wgt. of Dry soil+ Cont.(gm)	42.1	43.9	43.3		20.5	21.2
Wgt. of Moisture (gm)	10.1	11.6	13.0		1.3	1.5
Wgt. of Container (gm)	17.6	17.2	16.1		16.7	16.3
Wgt. of Dry soil (gm)	24.5	26.7	27.2		3.8	4.9
Moisture Content, %	41.22	43.44	47.79		34.21	30.61
	Avg.LL	43.66		Avg.PL	32.41	
Summary , Liquid Limit	44.15					
Plasticity Limit	32.41					
Plasticity Index	11.74					

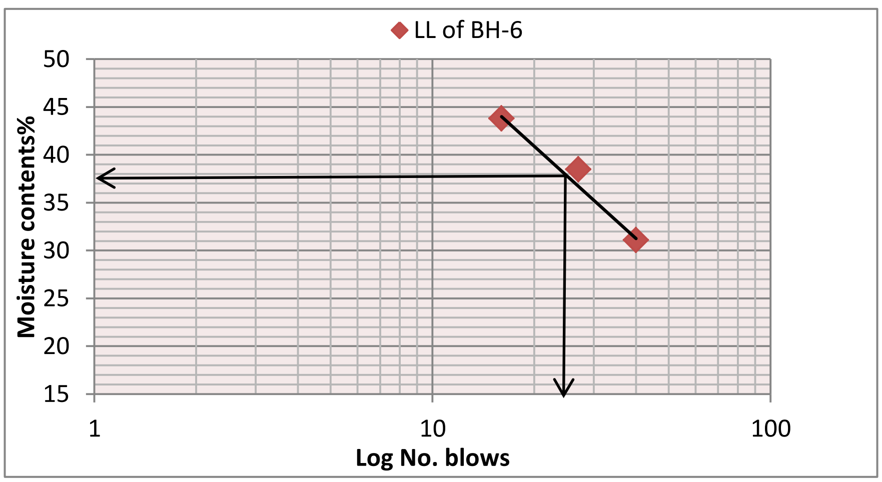


Final Results: Liquid Limit = 44.80

Plastic Limit = 32.41

Plasticity Index =12.39

ATTERBERG LIMITS: AASHTO T-89 & T – 90						
Type of Material: - Subgrade Source:-BH-6 Failure Type:- Non-defect Proportion retained on 0.425mm Sieve				Date of Sampling: -13/06/2017 Date of Testing:-24/06/2017 Sampled by:- Fikru Benti Oven Dried at: -110 °C		
	Liquid Limit				Plastic Limit	
Container No.	N1	N2	N3		N5	N4
No. of Blows	40	27	16		-	-
Wgt.of Wet soil + Cont.(gm)	53.0	51.6	56.2		22.1	25.7
Wgt. of Dry soil+ Cont.(gm)	47.2	44.9	47.7		21.2	24.5
Wgt. of Moisture (gm)	5.80	6.70	8.50		0.90	1.20
Wgt. of Container (gm)	29.2	27.5	28.30		18.6	18.9
Wgt. of Dry soil (gm)	18.0	17.4	19.4		2.6	5.6
Moisture Content, %	31.11	38.50	43.81		34.62	21.45
	Avg.LL	37.81		Avg.PL	28.03	
Summary , Liquid Limit	37.81					
Plasticity Limit	28.03					
Plasticity Index	9.78					



Final Results: Liquid Limit = 39.0

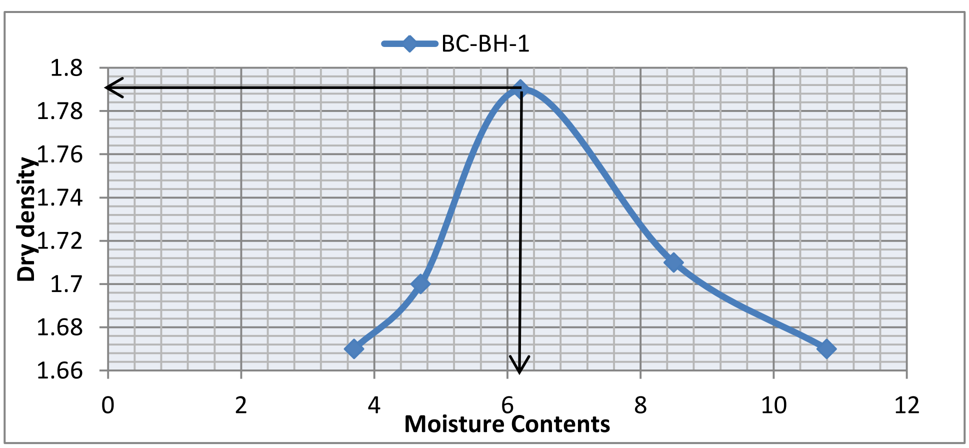
Plastic Limit = 28.03

Plasticity Index =9.97

Appendix C: Modified Proctor Test

i) Modified Proctor Test: Base Course

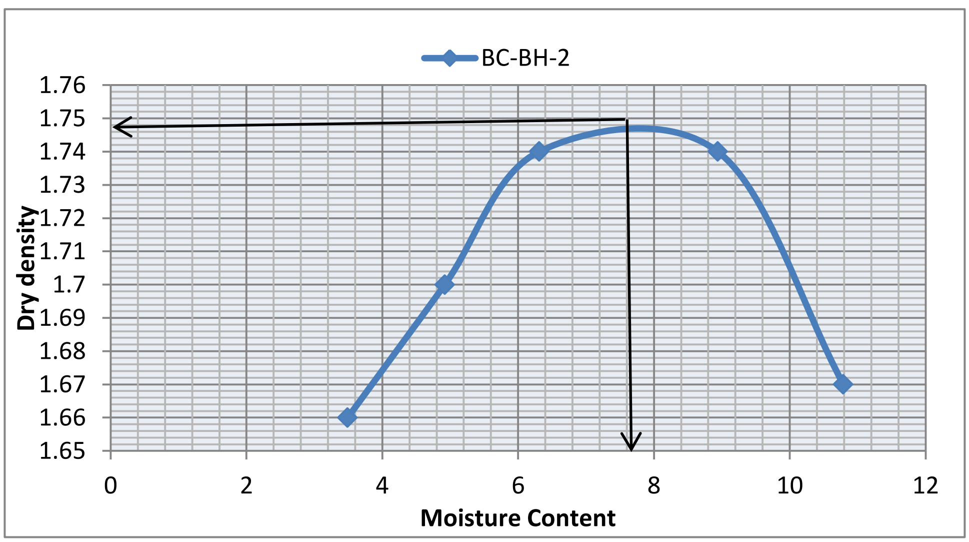
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Base course Source: - BH-1 No. of Layers: 5 No. of Blows : 56			Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	10230	10340	10590	10500	10475
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3640	3750	4000	3910	3885
Wet Density (gm/cc)	1.73	1.78	1.9	1.86	1.85
Moisture content determination					
Container No.	A2	T1	G1	O1	O2
Wgt. of Wet soil + Cont.(gm)	278.1	244.0	253.0	265.8	240.7
Wgt. of Dry soil + Cont.(gm)	269.4	234.6	240.1	247.6	220.6
Wgt. of Container (gm)	34.8	33.9	32.3	32.5	34.4
Wgt. of Moisture (gm)	8.6	9.4	12.9	18.2	20.1
Wgt. of Dry soil (gm)	234.6	200.7	207.8	215.1	186.2
Moisture Content, %	3.70	4.70	6.20	8.50	10.80
Dry Density (gm/cc)	1.67	1.70	1.79	1.71	1.67



Optimum Moisture Content = 6.4 %

Maximum Dry Density = 1.795 g/cm3

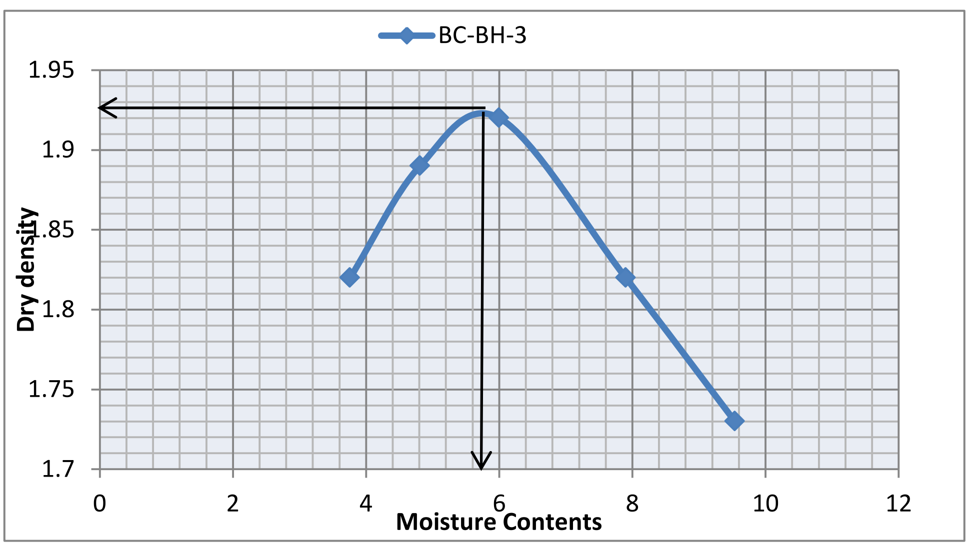
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Base course Source: - BH-2 No. of Layers: 5 No. of Blows : 56			Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	10220	10331	10474	10570	10470
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3630	3741	3884	3980	3880
Wet Density (gm/cc)	1.72	1.78	1.85	1.89	1.84
Moisture content determination					
Container No.	G2	G3	U1	U2	M2
Wgt. of Wet soil + Cont.(gm)	280.7	254.0	262.0	268.9	250.2
Wgt. of Dry soil + Cont.(gm)	272.4	243.7	248.5	249.6	229.1
Wgt. of Container (gm)	34.2	34.3	34.5	33.8	33.7
Wgt. of Moisture (gm)	8.3	10.3	13.5	19.3	21.1
Wgt. of Dry soil (gm)	238.2	209.4	214.0	215.8	195.4
Moisture Content, %	3.49	4.92	6.31	8.94	10.79
Dry Density (gm/cc)	1.66	1.70	1.74	1.74	1.67



Optimum Moisture Content = 6.91 %

Maximum Dry Density = 1.745 g/cm3

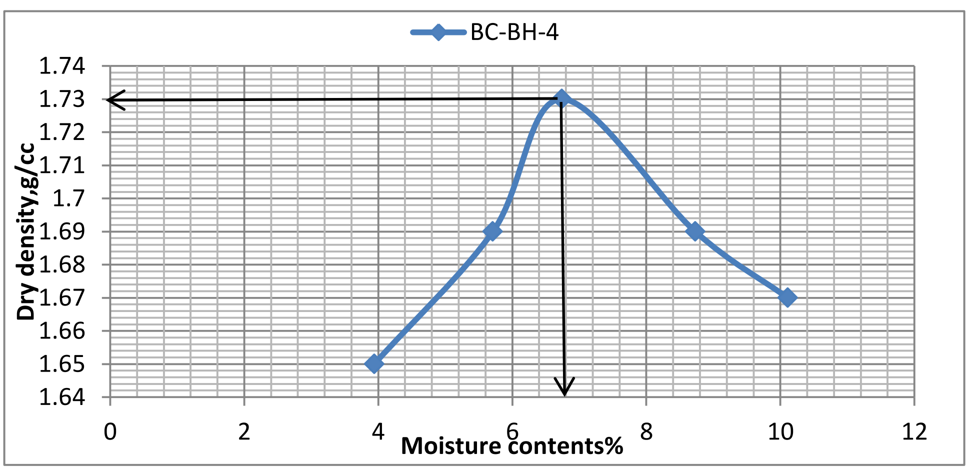
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Base course Source: - BH-3 No. of Layers: 5 No. of Blows : 56	Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105				
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	10560	10750	10890	10706	10590
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3970	4160	4300	4116	4000
Wet Density (gm/cc)	1.89	1.98	2.04	1.96	1.90
Moisture content determination					
Container No.	X2	X4	V2	N1	N2
Wgt. of Wet soil + Cont.(gm)	280.3	256.2	264.1	276.6	254.5
Wgt. of Dry soil + Cont.(gm)	271.4	246.0	251.1	258.9	235.3
Wgt. of Container (gm)	34.6	34.1	34.3	34.2	34.0
Wgt. of Moisture (gm)	8.9	10.2	13.0	17.7	19.2
Wgt. of Dry soil (gm)	236.8	211.9	216.8	224.7	201.3
Moisture Content, %	3.76	4.81	6.00	7.90	9.54
Dry Density (gm/cc)	1.82	1.89	1.92	1.82	1.73



Optimum Moisture Content = 5.9 %

Maximum Dry Density = 1.92g/cm3

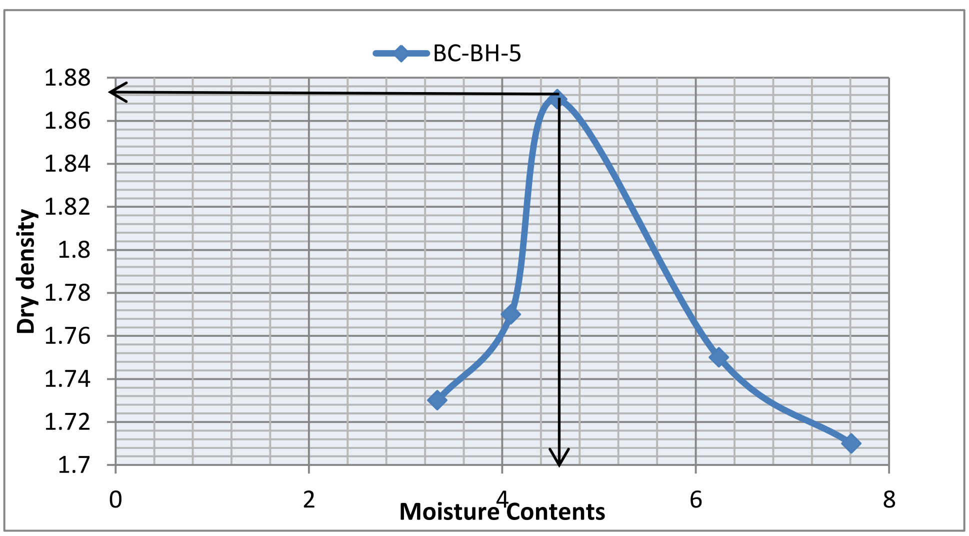
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Base course Source: - BH-4 No. of Layers: 5 No. of Blows : 56	Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105				
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	10190	10360	10490	10470	10460
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3600	3770	3900	3880	3870
Wet Density (gm/cc)	1.71	1.79	1.85	1.84	1.84
Moisture content determination					
Container No.	G2	G3	U1	U2	M2
Wgt. of Wet soil + Cont.(gm)	274.3	249.2	259.5	263.8	254.6
Wgt. of Dry soil + Cont.(gm)	265.2	237.6	245.3	245.3	234.3
Wgt. of Container (gm)	34.3	34.4	34.6	33.5	33.6
Wgt. of Moisture (gm)	9.1	11.6	14.2	18.5	20.3
Wgt. of Dry soil (gm)	230.9	203.2	210.7	211.8	200.7
Moisture Content, %	3.94	5.71	6.74	8.73	10.11
Dry Density (gm/cc)	1.65	1.69	1.73	1.69	1.67



Optimum Moisture Content = 6.74 %

Maximum Dry Density = 1.73 g/cm

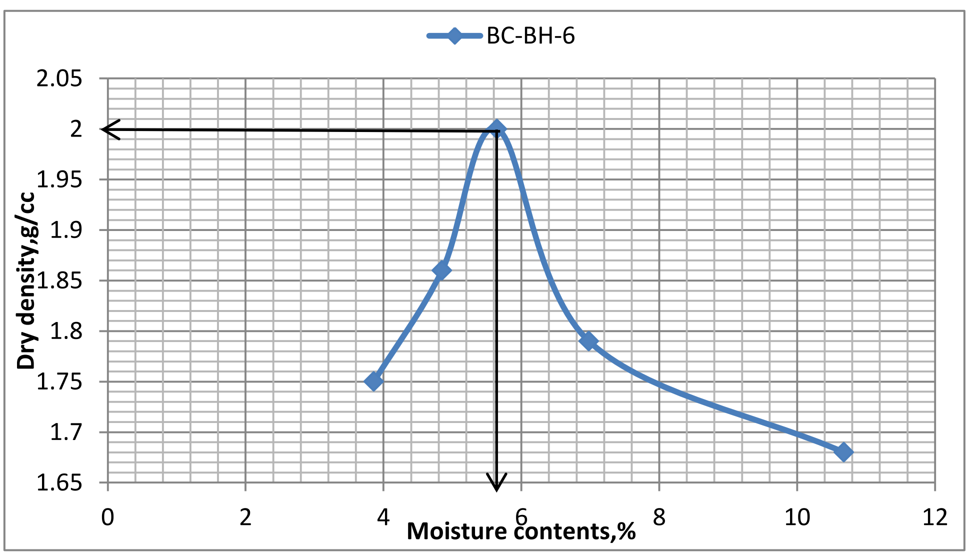
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Base course Source: - BH-5 No. of Layers: 5 No. of Blows : 56			Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	10350	10465	10690	10506	10490
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3760	3875	4100	3916	3900
Wet Density (gm/cc)	1.79	1.84	1.95	1.86	1.85
Moisture content determination					
Container No.	M3	M2	K2	K1	T2
Wgt. of Wet soil + Cont.(gm)	279.6	260.0	274.3	269.6	258.8
Wgt. of Dry soil + Cont.(gm)	271.7	250.3	263.8	255.8	242.9
Wgt. of Container (gm)	34.3	34.4	34.2	34.5	34.1
Wgt. of Moisture (gm)	7.9	9.7	10.5	13.8	15.9
Wgt. of Dry soil (gm)	237.4	237.4	229.6	221.3	208.8
Moisture Content, %	3.33	4.09	4.57	6.24	7.61
Dry Density (gm/cc)	1.73	1.77	1.87	1.75	1.71



Optimum Moisture Content = 4.8 %

Maximum Dry Density = 1.87 g/cm3

MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Base course Source: - BH-6 No. of Layers: 5 No. of Blows : 56	Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105				
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	10413	10700	11050	10640	10509
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3823	4110	4460	4050	3919
Wet Density (gm/cc)	1.82	1.95	2.12	1.92	1.86
Moisture content determination					
Container No.	B3	B4	B1	B2	G1
Wgt. of Wet soil + Cont.(gm)	282.1	265.6	273.5	268.9	250.8
Wgt. of Dry soil + Cont.(gm)	272.9	254.9	260.7	253.6	220.6
Wgt. of Container (gm)	34.4	34.3	34.1	34.4	34.2
Wgt. of Moisture (gm)	9.2	10.7	12.8	15.3	19.9
Wgt. of Dry soil (gm)	238.5	220.6	226.6	219.2	186.4
Moisture Content, %	3.86	4.85	5.65	6.98	10.68
Dry Density (gm/cc)	1.75	1.86	2.00	1.79	1.68

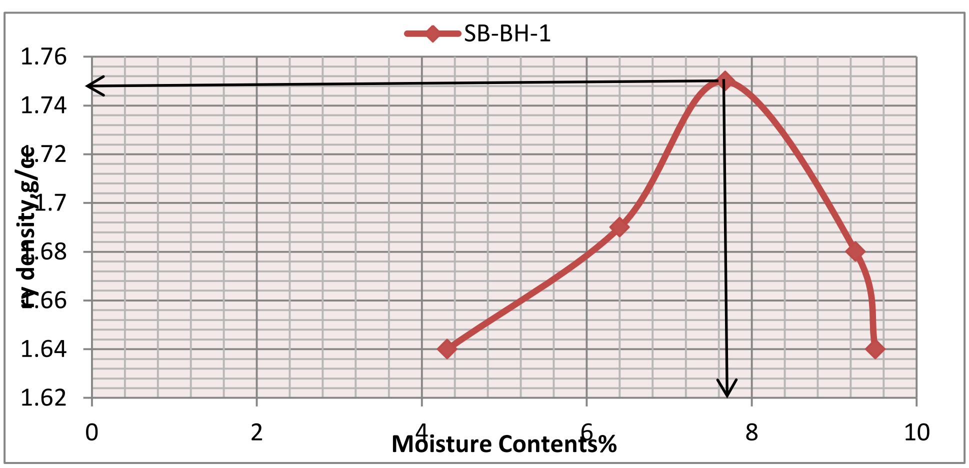


Optimum Moisture Content = 5.8 %

Maximum Dry Density = 2.0 g/cm3

ii) Modified Proctor Test: Sub-base Course

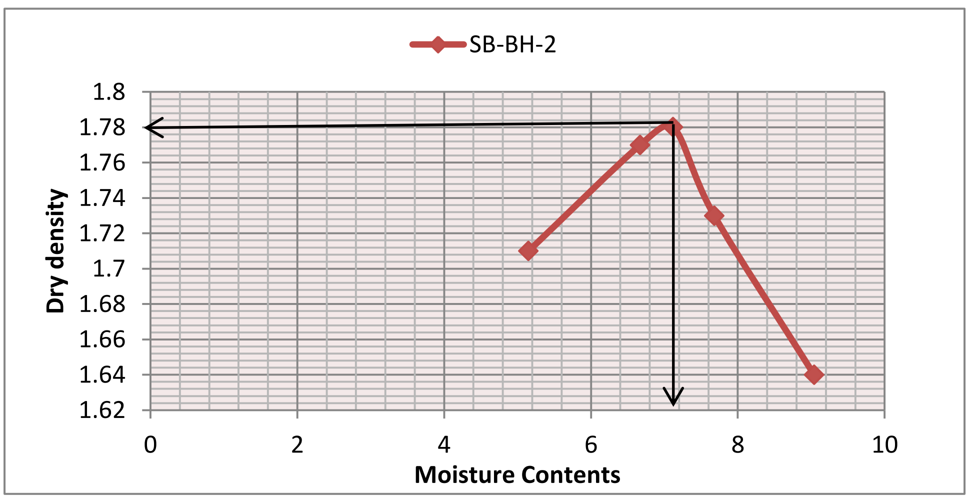
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-base course Source: - BH-1 No.of Layers: 5 No.of Blows : 56			Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	10216	10390	10589	10467	10390
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3626	3800	3999	3877	3800
Wet Density (gm/cc)	1.72	1.80	1.89	1.84	1.80
Moisture Content Determination					
Container No.	Z1	X1	Z2	X3	X2
Wgt. of Wet soil + Cont.(gm)	276.4	240.5	251.1	265.2	241.0
Wgt. of Dry soil + Cont.(gm)	266.4	228.1	235.5	245.5	222.6
Wgt. of Container (gm)	34.3	34.4	32.5	32.7	34.6
Wgt. of Moisture (gm)	10.0	12.4	15.6	19.7	19.4
Wgt. of Dry soil (gm)	232.1	193.7	203.0	212.8	204.2
Moisture Content, %	4.31	6.40	7.68	9.26	9.50
Dry Density (gm/cc)	1.64	1.69	1.75	1.68	1.64



Optimum Moisture Content = 7.68.0 %

Maximum Dry Density = 1.75 g/cm3

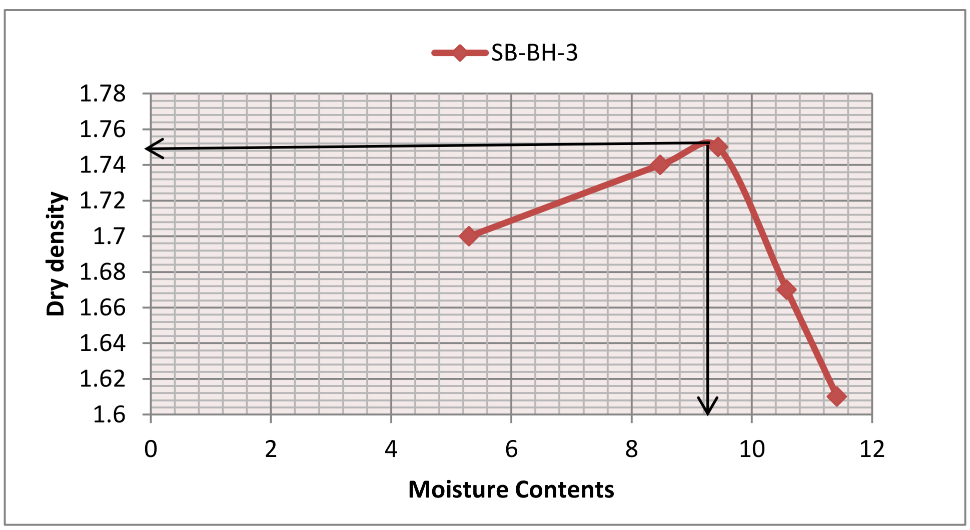
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-base course			Date of Sampling:-13/06/2017		
Source: - BH-2			Date of Tested:- 27/06/2017		
No. of Layers: 5			Weight of Hammer Kg :- 4.5		
No. of Blows : 56			Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	10386	10577	10600	10499	10368
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3796	3987	4010	3909	3778
Wet Density (gm/cc)	1.80	1.89	1.90	1.86	1.79
Moisture Content Determination					
Container No.	H	K	M	L1	L2
Wgt. of Wet soil + Cont.(gm)	265.6	268.2	240.7	256.4	213.9
Wgt. of Dry soil + Cont.(gm)	254.3	253.6	227.0	240.6	199.0
Wgt. of Container (gm)	34.7	34.8	34.5	34.8	34.1
Wgt. of Moisture (gm)	11.3	14.6	13.7	15.8	14.9
Wgt. of Dry soil (gm)	219.6	218.8	192.5	205.8	164.9
Moisture Content, %	5.15	6.67	7.12	7.68	9.04
Dry Density (gm/cc)	1.71	1.77	1.78	1.73	1.64



Optimum Moisture Content = 7.2 %

Maximum Dry Density = 1.78 g/cm3

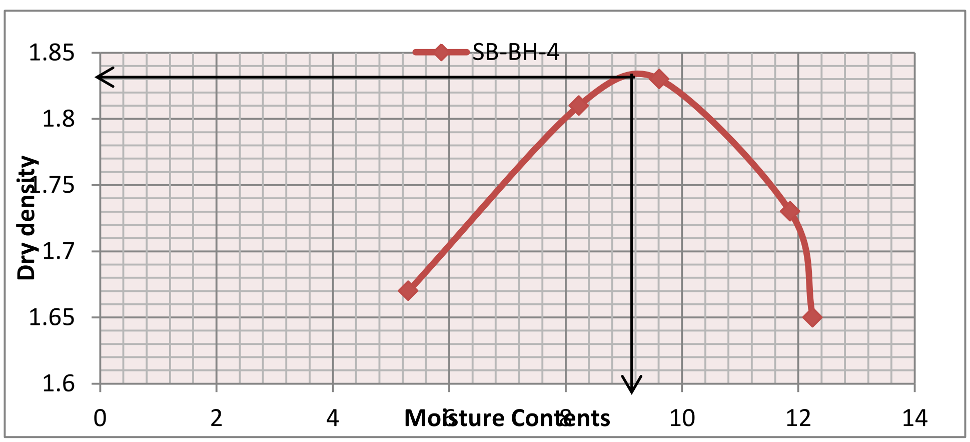
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-base course			Date of Sampling:-13/06/2017		
Source: - BH-3			Date of Tested:- 27/06/2017		
No. of Layers: 5			Weight of Hammer Kg :- 4.5		
No. of Blows : 56			Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	10365	10563	10617	10486	10379
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3775	3973	4027	3896	3789
Wet Density (gm/cc)	1.79	1.89	1.91	1.85	1.80
Moisture Content Determination					
Container No.	S1	S2	S3	S4	S5
Wgt. of Wet soil + Cont.(gm)	248.5	238.2	250.1	213.3	223.6
Wgt. of Dry soil + Cont.(gm)	237.7	222.3	231.5	196.2	204.2
Wgt. of Container (gm)	34.3	34.7	34.4	34.5	34.3
Wgt. of Moisture (gm)	10.8	15.9	18.6	17.1	19.4
Wgt. of Dry soil (gm)	203.4	187.6	197.1	161.7	169.9
Moisture Content, %	5.30	8.48	9.44	10.58	11.42
Dry Density (gm/cc)	1.70	1.74	1.75	1.67	1.61



Optimum Moisture Content = 9.3 %

Maximum Dry Density = 1.75 g/cm3

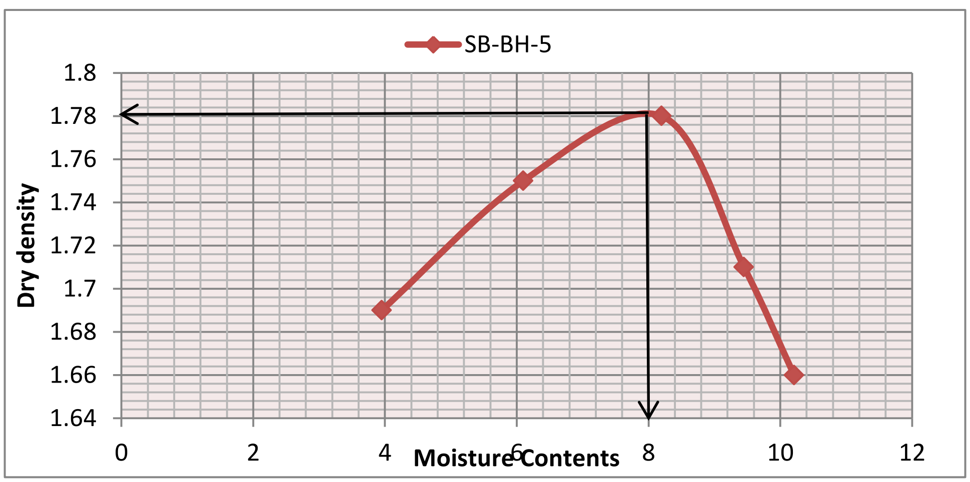
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-base course Source: - BH-4 No. of Layers: 5 No. of Blows : 56	Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105				
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	10284	10723	10761	10687	10512
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3694	4133	4171	4097	3922
Wet Density (gm/cc)	1.75	1.96	1.98	1.94	1.86
Moisture Content Determination					
Container No.	Z1	X1	Z2	X3	X2
Wgt. of Wet soil + Cont.(gm)	238.7	241.1	210.2	236.7	220.4
Wgt. of Dry soil + Cont.(gm)	228.4	225.4	194.8	215.3	200.1
Wgt. of Container (gm)	34.2	34.7	34.5	34.8	34.4
Wgt. of Moisture (gm)	10.3	15.7	15.4	21.4	20.3
Wgt. of Dry soil (gm)	194.2	190.7	160.3	180.5	165.7
Moisture Content, %	5.30	8.23	9.61	11.86	12.25
Dry Density (gm/cc)	1.67	1.81	1.83	1.73	1.65



Optimum Moisture Content = 9.1 %

Maximum Dry Density = 1.84 g/cm3

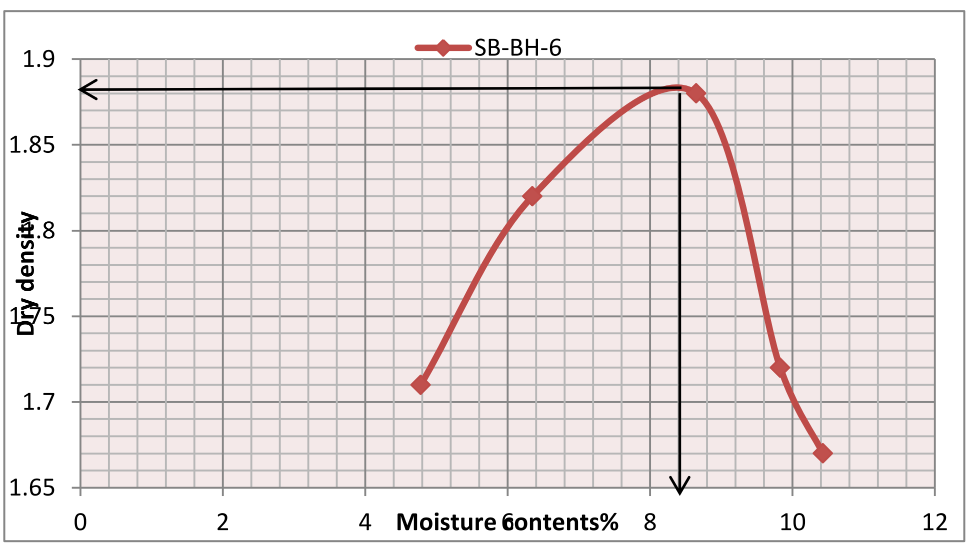
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-base course Source: - BH-5 No. of Layers: 5 No. of Blows : 56			Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	10283	10497	10621	10518	10450
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3693	3907	4031	3928	3860
Wet Density (gm/cc)	1.75	1.86	1.92	1.87	1.83
Moisture Content Determination					
Container No.	Z1	X1	Z2	X3	X2
Wgt. of Wet soil + Cont.(gm)	282.3	245.6	253.9	268.2	244.7
Wgt. of Dry soil + Cont.(gm)	272.9	233.5	237.1	247.8	225.2
Wgt. of Container (gm)	34.6	34.0	32.2	32.0	34.3
Wgt. of Moisture (gm)	9.4	12.1	16.8	20.4	19.5
Wgt. of Dry soil (gm)	238.3	199.5	204.9	215.8	190.9
Moisture Content, %	3.95	6.10	8.20	9.45	10.21
Dry Density (gm/cc)	1.69	1.75	1.78	1.71	1.66



Optimum Moisture Content = 8.0 %

Maximum Dry Density = 1.78 g/cm3

MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-base course			Date of Sampling:-13/06/2017		
Source: - BH-6			Date of Tested:- 27/06/2017		
No. of Layers: 5			Weight of Hammer Kg :- 4.5		
No. of Blows : 56			Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	10357	10680	10890	10565	10458
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3767	4090	4300	3975	3868
Wet Density (gm/cc)	1.79	1.94	2.04	1.89	1.84
Moisture Content Determination					
Container No.	H	K	M	L1	L2
Wgt. of Wet soil + Cont.(gm)	246.8	267.8	268.9	259.9	270.4
Wgt. of Dry soil + Cont.(gm)	237.1	253.8	250.3	239.7	248.0
Wgt. of Container (gm)	34.3	34.9	34.8	34.1	34.5
Wgt. of Moisture (gm)	9.7	13.9	18.6	20.2	22.4
Wgt. of Dry soil (gm)	202.8	218.9	215.5	205.6	214.8
Moisture Content, %	4.78	6.35	8.65	9.83	10.43
Dry Density (gm/cc)	1.71	1.82	1.88	1.72	1.67

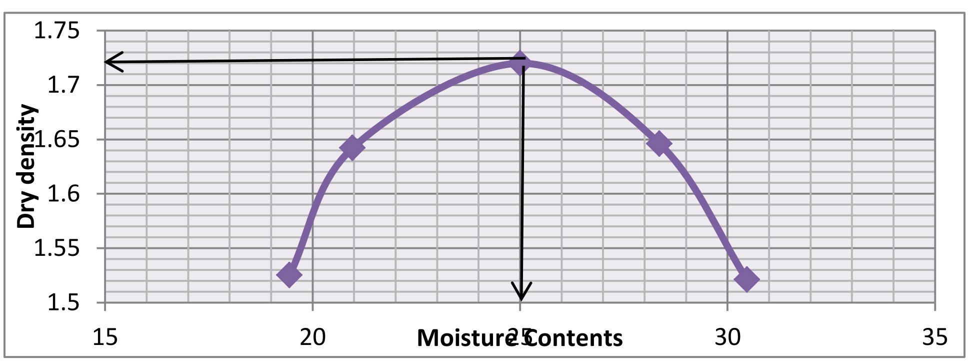


Optimum Moisture Content = 8.3 %

Maximum Dry Density = 1.88 g/cm3

iii) Modified Proctor Test: Sub-grade soil

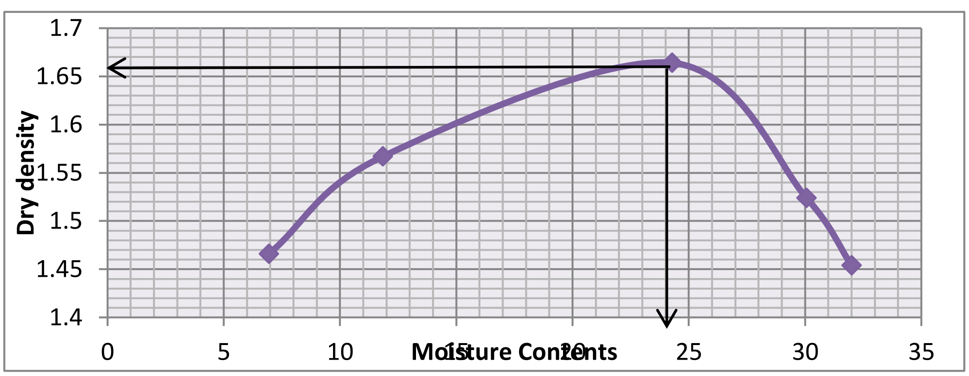
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-grade Source: - BH-1 No. of Layers: 5 No. of Blows : 56	Date of Sampling:- 13/06/2017 Date of Testing:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105				
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	10423	10772	11109	10993	10768
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3833	4182	4519	4403	4178
Wet Density (gm/cc)	1.821	1.987	2.147	2.092	1.985
Moisture Content Determination					
Container No.	A3	D5	B2	C3	R4
Wgt. of Wet soil + Cont.(gm)	141.5	150.2	152.5	132.7	123.7
Wgt. of Dry soil + Cont.(gm)	121.2	127.1	117.5	107.0	98.9
Wgt. of Container (gm)	16.8	16.9	17.5	17.6	17.5
Wgt. of Moisture (gm)	20.3	23.1	25.0	25.7	24.8
Wgt. of Dry soil (gm)	104.4	110.2	100.0	90.6	81.4
Moisture Content, %	19.44	20.96	25.00	28.36	30.47
Dry Density (gm/cc)	1.525	1.642	1.720	1.646	1.521



Optimum Moisture Content = 25.0 %

Maximum Dry Density = 1.74 g/cm3

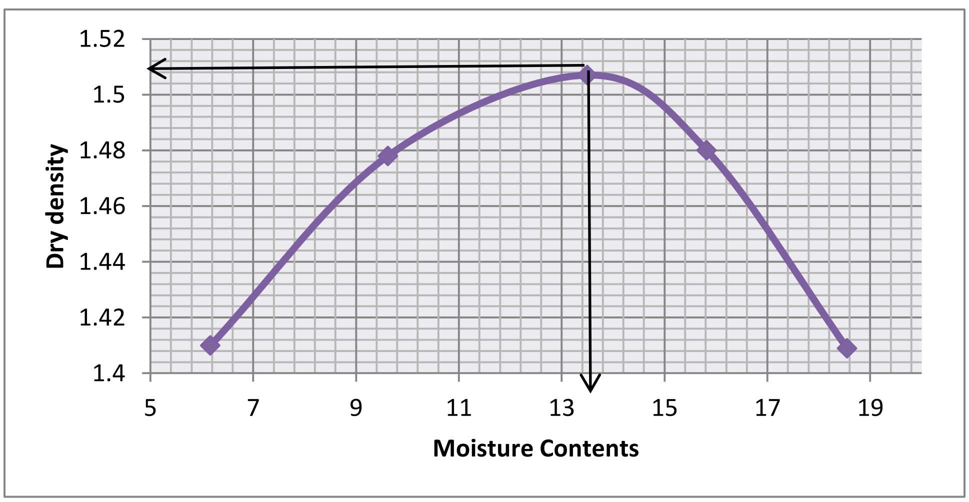
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub grade Source: - BH-2 No. of Layers: 5 No. of Blows : 56			Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	9890	10280	10942	10764	10630
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3300	3390	4352	3974	4040
Wet Density (gm/cc)	1.568	1.753	2.067	1.983	1.919
Moisture Content Determination					
Container No.	T1	T2	T3	T4	T5
Wgt. of Wet soil + Cont.(gm)	185.3	180.5	187.0	174.0	179.4
Wgt. of Dry soil + Cont.(gm)	174.9	164.3	155.8	140.0	137.0
Wgt. of Container (gm)	25.4	27.6	27.3	27.1	24.5
Wgt. of Moisture (gm)	10.4	16.2	31.2	34.0	42.4
Wgt. of Dry soil (gm)	149.5	136.7	128.5	113.1	132.5
Moisture Content, %	6.95	11.85	24.28	30.06	32.00
Dry Density (gm/cc)	1.466	1.567	1.664	1.524	1.454



Optimum Moisture Content = 24.8 %

Maximum Dry Density = 1.67 g/cm3

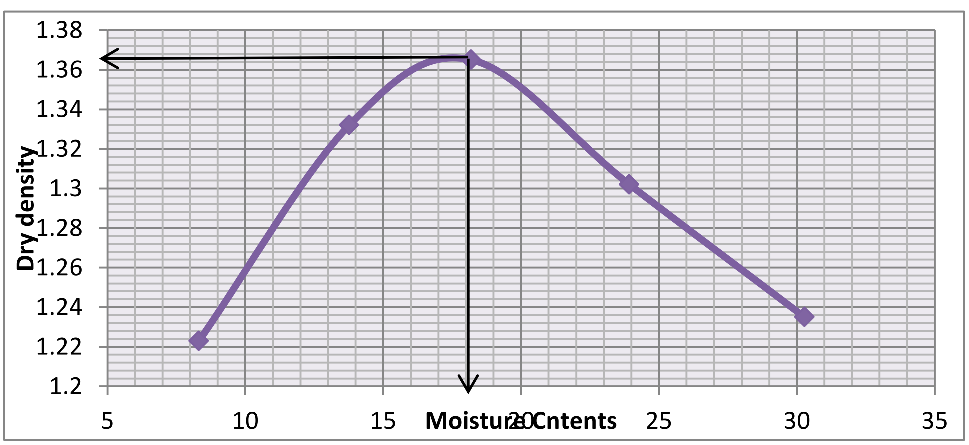
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-grade			Date of Sampling:-13/06/2017		
Source: - BH-3			Date of Tested:- 27/06/2017		
No. of Layers: 5			Weight of Hammer Kg :- 4.5		
No. of Blows : 56			Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	9747.5	10000.0	10190.0	10126.0	9860
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3157.5	3410	3600	3536	3515
Wet Density (gm/cc)	1.500	1.620	1.710	1.680	1.670
Moisture Content Determination					
Container No.	D1	C1	B1	A1	B2
Wgt. of Wet soil + Cont.(gm)	185.3	180.5	187.0	168.5	173.0
Wgt. of Dry soil + Cont.(gm)	176	168	168	150	150
Wgt. of Container (gm)	25.3	27.6	27.3	25.0	26.0
Wgt. of Moisture (gm)	9.3	12.5	19.0	18.5	23.0
Wgt. of Dry soil (gm)	150.7	130.4	140.7	132.0	124.0
Moisture Content, %	6.17	9.62	13.5	14.02	18.55
Dry Density (gm/cc)	1.410	1.478	1.507	1.482	1.409



Optimum Moisture Content = 13.5 %

Maximum Dry Density = 1.51 g/cm3

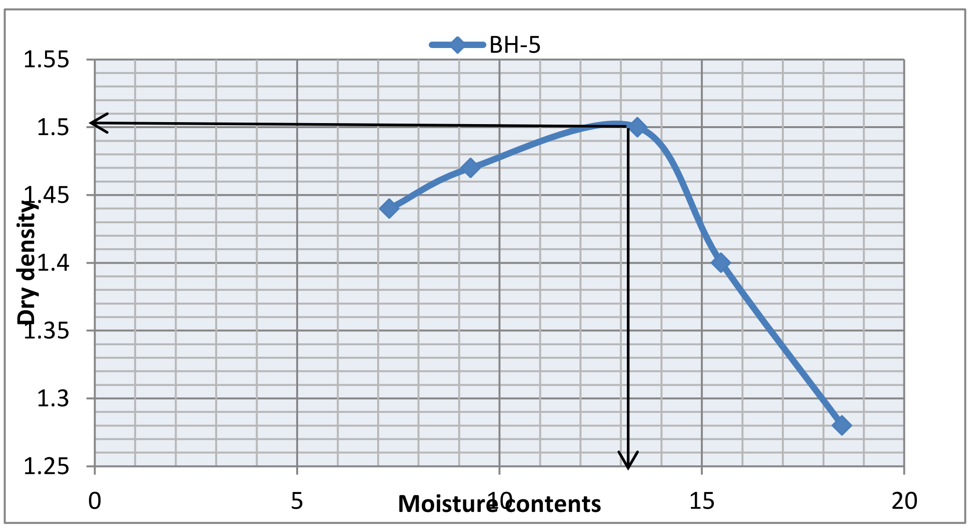
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub grade			Date of Sampling:-13/06/2017		
Source: - BH-4			Date of Tested:- 27/06/2017		
No. of Layers: 5			Weight of Hammer Kg :- 4.5		
No. of Blows : 56			Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil (gm)	9379	9780	9987	9989	9978
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	2789	3190	4352	3399	3388
Wet Density (gm/cc)	1.325	1.515	2.067	1.615	1.610
Moisture Content Determination					
Container No.	R1	R2	R3	R4	R5
Wgt. of Wet soil + Cont.(gm)	178.7	179.6	185.0	173.0	176.1
Wgt. of Dry soil + Cont.(gm)	167.0	161.2	159.2	145.0	139.0
Wgt. of Container (gm)	26.4	27.6	27.4	27.1	24.5
Wgt. of Moisture (gm)	11.7	18.4	25.8	28.0	37.1
Wgt. of Dry soil (gm)	140.6	133.6	141.8	117.9	122.5
Moisture Content, %	8.32	13.77	18.19	23.93	30.28
Dry Density (gm/cc)	1.223	1.332	1.365	1.302	1.235



Optimum Moisture Content = 15.5 %

Maximum Dry Density = 1.37 g/cm3

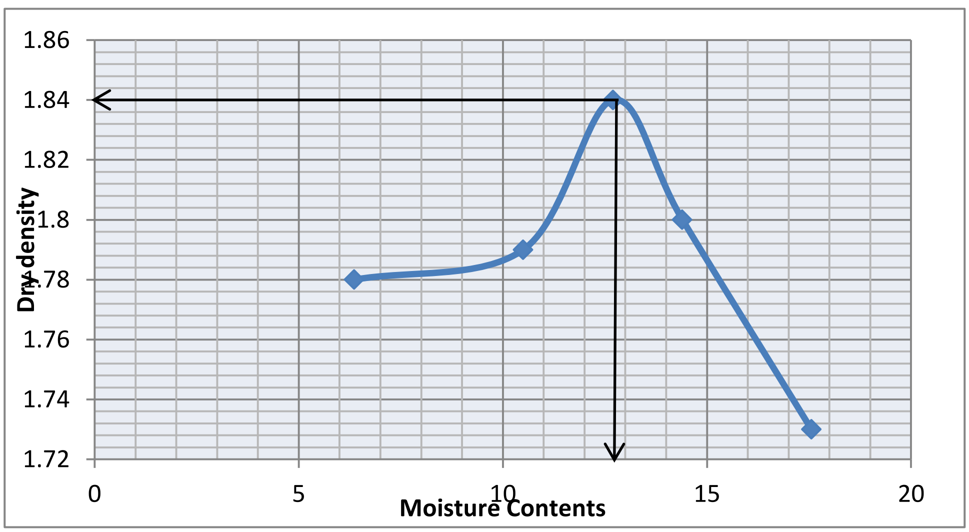
MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub grade			Date of Sampling:-13/06/2017		
Source: - BH-5			Date of Tested:- 27/06/2017		
No. of Layers: 5			Weight of Hammer Kg :- 4.5		
No. of Blows : 56			Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	9833	9987	10180	10004	9799
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3243	3397	3590	3414	3209
Wet Density (gm/cc)	1.54	1.61	1.71	1.62	1.52
Moisture Content Determination					
Container No.	D1	C1	B1	A1	B2
Wgt. of Wet soil + Cont.(gm)	183.1	181.4	186.9	167.7	170.2
Wgt. of Dry soil + Cont.(gm)	172.4	168.3	168.0	148.6	147.8
Wgt. of Container (gm)	25.5	27.4	27.1	25.2	26.5
Wgt. of Moisture (gm)	10.7	13.1	18.9	19.1	22.4
Wgt. of Dry soil (gm)	146.9	140.9	140.9	123.4	121.3
Moisture Content, %	7.28	9.29	13.41	15.48	18.47
Dry Density (gm/cc)	1.44	1.47	1.50	1.40	1.28



Optimum Moisture Content = 13.0 %

Maximum Dry Density = 1.50 g/cm3

MOISETURE DENSITY RELATION: (AASHTO T-180)					
Type of Material :Sub-grade Source: - BH-6 No. of Layers: 5 No. of Blows : 56			Date of Sampling:-13/06/2017 Date of Tested:- 27/06/2017 Weight of Hammer Kg :- 4.5 Volume of Molds, cm3:- 2105		
Trial No.	1	2	3	4	5
Amount of water added,%	2	4	6	8	10
Volume of Mould (cc)	2105	2105	2105	2105	2105
Wgt. of Mould + Wet soil	10560	10755	10945	10925	10875
Wgt. of Mould (gm)	6590	6590	6590	6590	6590
Wgt. of Wet soil (gm)	3970	4165	4355	4335	4285
Wet Density (gm/cc)	1.89	1.98	2.07	2.06	2.04
Moisture content determination					
Container No.	T1	T2	T3	M1	M2
Wgt. of Wet soil + Cont.(gm)	188	182	186	165	174
Wgt. of Dry soil + Cont.(gm)	178.3	167.1	168.3	146.7	152
Wgt. of Container (gm)	25.7	27.6	27.5	25.4	26.7
Wgt. of Moisture (gm)	9.7	14.9	17.7	17.5	22.0
Wgt. of Dry soil (gm)	152.6	142.5	139.7	121.3	125.3
Moisture Content, %	6.36	10.5	12.7	14.4	17.56
Dry Density (gm/cc)	1.78	1.79	1.84	1.8	1.73



Optimum Moisture Content = 12.9 %

Maximum Dry Density = 1.84 g/cm3

Appendix D: California Bearing Ratio Test

i. California Bearing Ratio Test/ Base Course

CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Base Course**	Date of Sampling: 13-06- 2017
Failure type: Pothole and Patching	Date of Testing: 09-07-2017
Source-BH-1	Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433	Plunger cross-section 1935.5mm^2

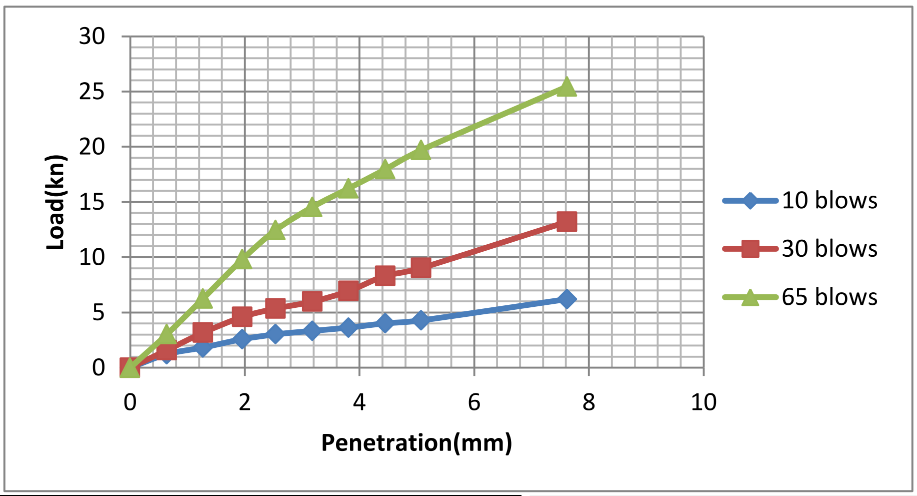
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	B1		N2		L2	
Weight of soil + mold (gm)	14476	14652	14482	14913	13775	13956
Weight of mold (gm)	7990	7990	7730	7730	6660	6660
Weight of soil (gm)	6486	6662	6752	7183	7115	7296
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.86	2.94	2.98	3.17	3.14	3.22
Dry density of soil (g/cc)	2.65	2.71	2.77	2.94	2.99	3.00

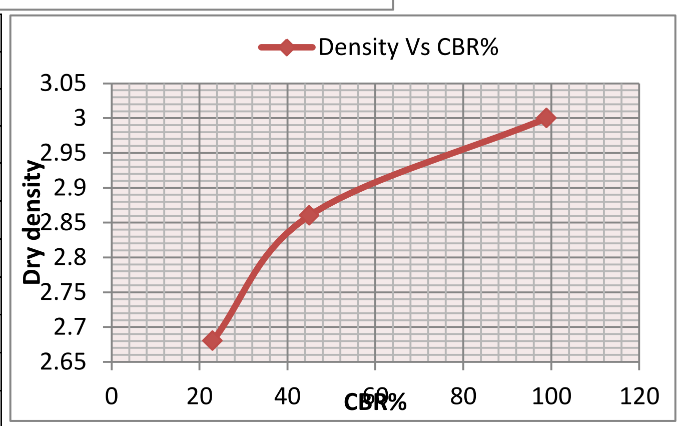
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	T2	T3		T1	T4		B1	G2	
Wet soil + container (gm)	252.2	230.4	241.3	245.7	222.4	234.1	228.1	233.9	231.0
Dry soil + container (gm)	236.6	215.3	225.9	230.9	208.7	219.8	218.7	220.3	219.5
Weight of water (gm)	15.6	15.1	15.4	14.8	13.7	14.3	9.4	13.6	11.5
Weight of container (gm)	35.6	35.7	35.7	34.9	34.8	34.9	35.3	35.7	35.1
Weight of dry soil (gm)	201.0	179.6	190.3	196.0	173.9	184.9	183.4	184.6	184.0
Moisture content (%)	7.76	8.41	8.09	7.55	7.88	7.73	5.13	7.37	6.25
Average moisture contents	7.35								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	50	1.2165			65	1.5815			124	3.0169		
1.27	75	1.8248			130	3.1629			257	6.2528		
1.96	106	2.5790			189	4.5984			404	9.8293		
2.54	124	3.0169	3	23	220	5.3526	5	40	512	12.4569	13	93
3.18	137	3.3332			246	5.9852			598	14.5493		
3.81	149	3.6252			285	6.9341			667	16.2281		
4.45	165	4.0144			342	8.3209			738	17.9555		
5.08	176	4.2821	4	22	371	9.0264	9	45	810	19.7073	20	99
7.62	255	6.2042			543	13.2112			1046	25.4492		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	0.98	0.21	0.11
Percent Swell	0.84	0.18	0.09
Average Percent swell	0.66		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	23	45	99
Density gm/cm3	2.68	2.86	3.00



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Base Course** — Date of Sampling: 13-06- 2017

Failure type: Raveling, stripping — Date of Testing: 09-07-2017

Source-BH-2 — Sampled by: Fikru Benti

Ring Factor: N/Division = 0.02433 — Plunger cross-section 1935.5mm^2

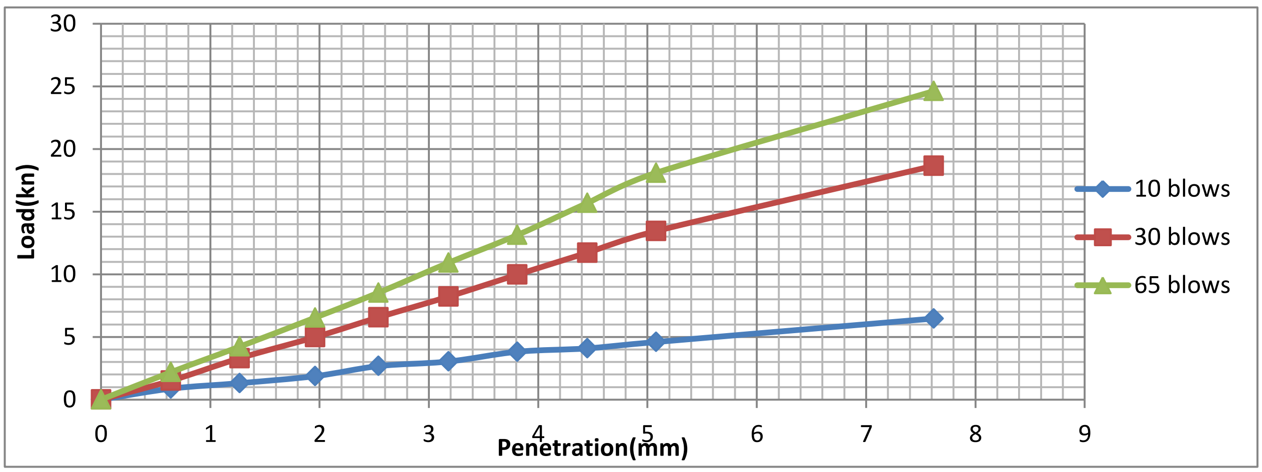
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	D1	D1	D2	D2	D3	D3
Weight of soil + mold (gm)	13679	13756	14833	14913	15778	15958
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	7019	7096	7103	7183	7788	7968
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	3.09	3.13	3.13	3.17	3.44	3.52
Dry density of soil (g/cc)	2.90	2.92	2.94	2.96	3.19	3.29

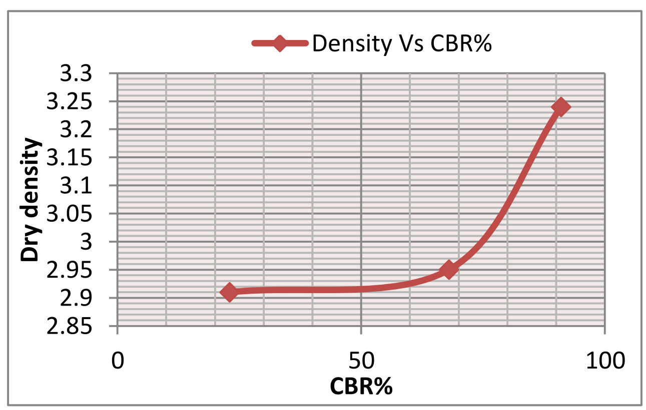
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	F1	F2		E1	E2		G1	G3	
Wet soil + container (gm)	235.9	246.7	241.3	263.1	239.2	251.2	229.5	254.8	242.2
Dry soil + container (gm)	223.6	232.1	227.9	248.9	225.3	237.1	218.1	239.1	228.6
Weight of water (gm)	12.3	14.6	13.5	14.2	13.9	14.1	11.4	15.7	13.6
Weight of container (gm)	35.3	34.9	35.2	34.7	35.2	35.3	35.1	35.6	35.4
Weight of dry soil (gm)	188.3	197.2	192.7	214.2	190.1	201.8	183.0	203.5	193.2
Moisture content (%)	6.53	7.40	7.01	6.63	7.31	6.98	6.23	7.72	7.04
Average moisture contents	6.98								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	36	0.8759			62	1.5085			90	2.1897		
1.27	54	1.3138			136	3.3089			174	4.2334		
1.96	77	1.8734			205	4.9877			269	6.5448		
2.54	110	2.6763	3	20	270	6.5691	7	49	351	8.5398	9	64
3.18	125	3.0413			338	8.2235			449	10.9242		
3.81	157	3.8198			410	9.9753			540	13.1382		
4.45	168	4.0874			482	11.7270			645	15.6929		
5.08	189	4.5984	5	23	553	13.4545	14	68	744	18.1015	19	91
7.62	266	6.4718			767	18.6611			1012	24.6220		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.00	0.40	0.14
Percent Swell	0.86	0.34	0.12
Average Percent swell	0.44		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	23	68	91
Density gm/cm3	2.91	2.95	3.24



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Base Course** Date of Sampling: 13-06- 2017
Failure type: Corrugation and segregation Date of Testing: 09-07-2017
Source-BH-3 Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433 Plunger cross-section 1935.5mm^2

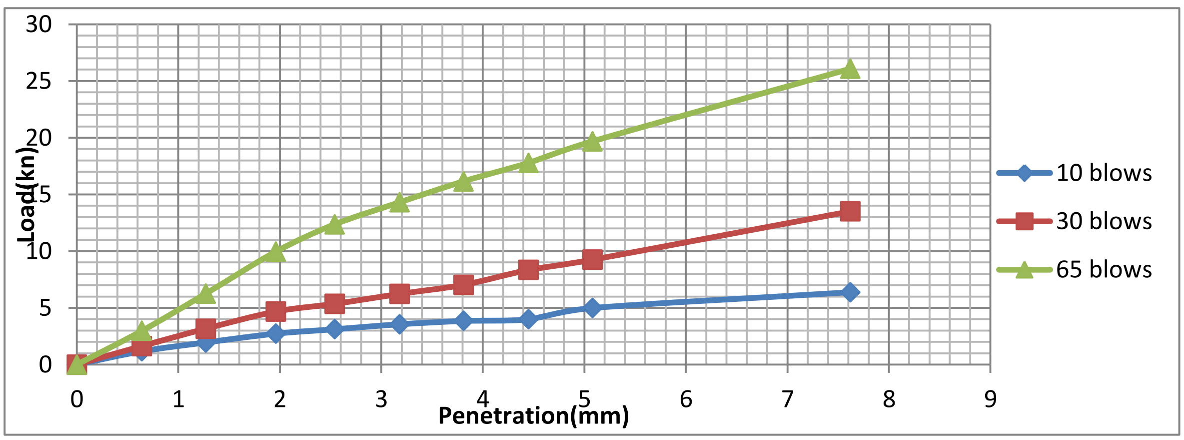
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	K2	K2	K3	K3	L1	L1
Weight of soil + mold (gm)	12914	13118	14369	14482	14810	15309
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	6254	6458	6639	6752	6820	7319
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.76	2.85	2.93	2.98	3.01	3.23
Dry density of soil (g/cc)	2.60	2.64	2.69	2.72	2.75	2.95

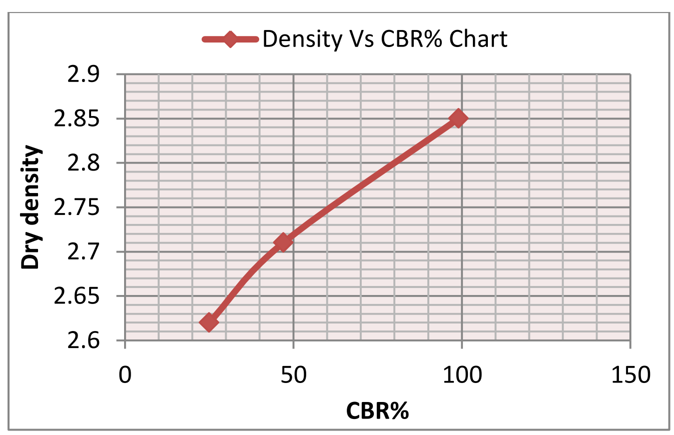
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	H2	H3		A2	B2		C2	D2	
Wet soil + container (gm)	264.2	258.4	261.3	243.8	267.2	255.5	225.2	246.1	260.7
Dry soil + container (gm)	250.8	241.9	246.4	226.7	247.6	237.2	208.8	227.2	218.0
Weight of water (gm)	13.4	16.5	15.0	17.1	19.6	18.4	16.4	18.9	17.7
Weight of container (gm)	35.6	35.4	35.5	34.8	35.2	35.0	35.1	35.0	35.1
Weight of dry soil (gm)	215.2	206.5	210.9	191.9	212.4	202.2	173.7	192.2	182.9
Moisture content (%)	6.23	7.99	7.11	8.91	9.23	9.09	9.44	9.83	9.64
Average moisture contents	8.61								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	48	1.1678			67	1.6301			122	2.9683		
1.27	80	1.9464			130	3.1629			257	6.2528		
1.96	112	2.7249			192	4.6714			409	9.9510		
2.54	128	3.1142	3	23	220	5.3526	5	40	508	12.3596	12	93
3.18	146	3.5522			256	6.2285			588	14.3060		
3.81	158	3.8441			289	7.0314			664	16.1551		
4.45	164	3.9901			343	8.3452			731	17.7852		
5.08	205	4.9877	4	25	380	9.2454	9	47	809	19.6830	20	99
7.62	262	6.3745			555	13.5032			1072	26.0818		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.06	0.52	0.20
Percent Swell	0.91	0.45	0.17
Average Percent swell	0.44		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	25	47	99
Density gm/cm3	2.62	2.71	2.85



CALIFORNIA BEARING RATIO TEST-AASHTO T 193		
Material type: **Base Course**	Date of Sampling: 13-06- 2017	
Failure type: Rutting and Wear	Date of Testing: 08-07-2017	
Source -BH-4	Sampled by: Fikru Benti	
Ring Factor: N/Division = 0.02433	Plunger cross-section 1935.5mm^2	

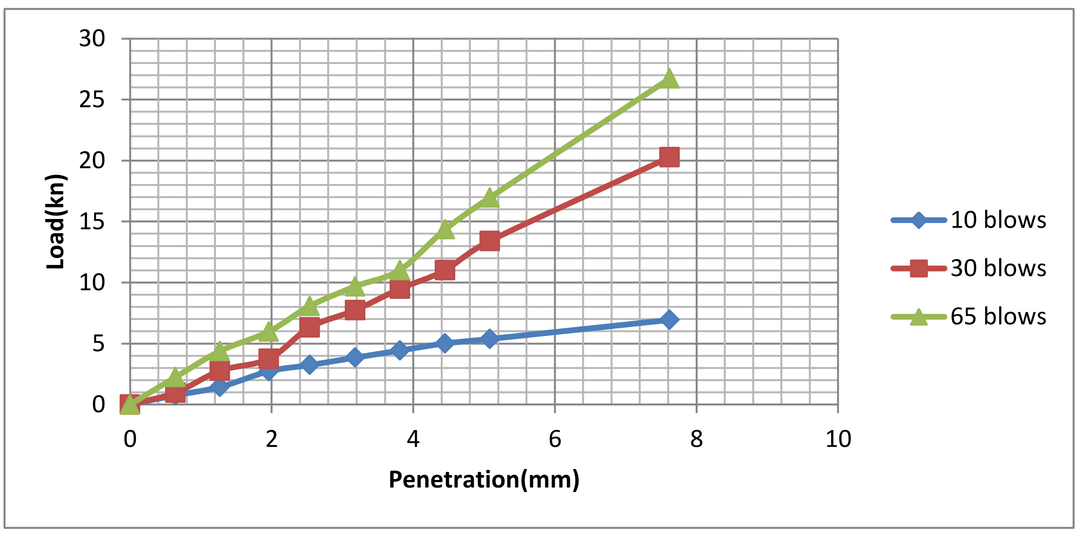
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	X11	X11	J33	J33	Z1	Z1
Weight of soil + mold (gm)	13916	14296	13991	13983	14998	15902
Weight of mold (gm)	7730	7730	6660	6660	7990	7990
Weight of soil (gm)	6186	6566	7331	7323	7008	7912
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.73	2.89	3.24	3.23	3.09	3.49
Dry density of soil (g/cc)	2.54	2.68	2.98	3.02	2.85	3.21

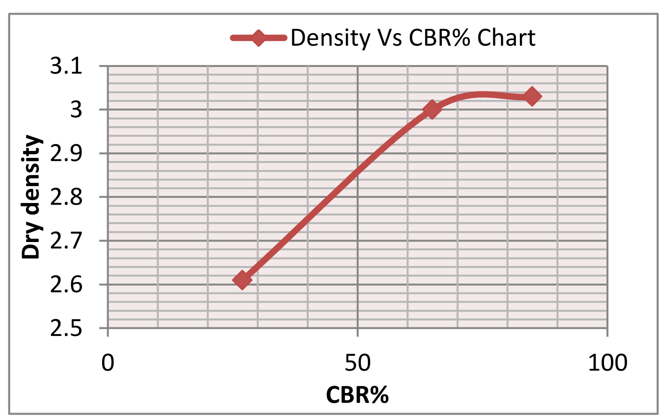
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	X	V		N	L		P	G	
Wet soil + container (gm)	249.4	264.1	256.8	252.7	273.3	263.0	260.4	252.6	256.5
Dry soil + container (gm)	234.5	247.3	240.9	235.3	258.0	246.7	243.7	235.4	239.6
Weight of water (gm)	14.9	16.8	15.9	17.4	15.3	16.4	16.7	17.2	17.0
Weight of container (gm)	35.3	34.6	35.0	34.5	35.0	34.8	35.2	35.4	35. 3
Weight of dry soil (gm)	199.2	212.7	205.9	200.8	223.0	211.9	208.5	200.0	204.3
Moisture content (%)	7.48	7.90	7.72	8.67	6.86	7.74	8.01	8.60	8.32
Average moisture contents	7.92								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	31	0.7542			40	0.9732			92	2.2384		
1.27	59	1.4355			114	2.7736			180	4.3794		
1.96	112	2.7250			154	3.7468			246	5.9852		
2.54	133	3.2359	3	24	260	6.3258	6	45	332	8.0775		60
3.18	158	3.8442			318	7.7369			398	9.6833		
3.81	182	4.4281			390	9.4887			453	11.0215		
4.45	206	5.0119			452	10.9972			590	14.3547		
5.08	221	5.3769	5	27	551	13.4058	13	65	697	16.9580	17	85
7.62	285	6.9341			833	20.2669			1098	26.7143		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.12	0.58	0.25
Percent Swell	0.96	0.50	0.22
Average Percent swell %	0.56		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	27	65	85
Density gm/cm3	2.61	3.00	3.03



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Base Course** Date of Sampling: 13-06- 2017
Failure type: Alligator crack Date of Testing: 08-07-2017
Source-BH-5 Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433 Plunger cross-section 1935.5mm^2

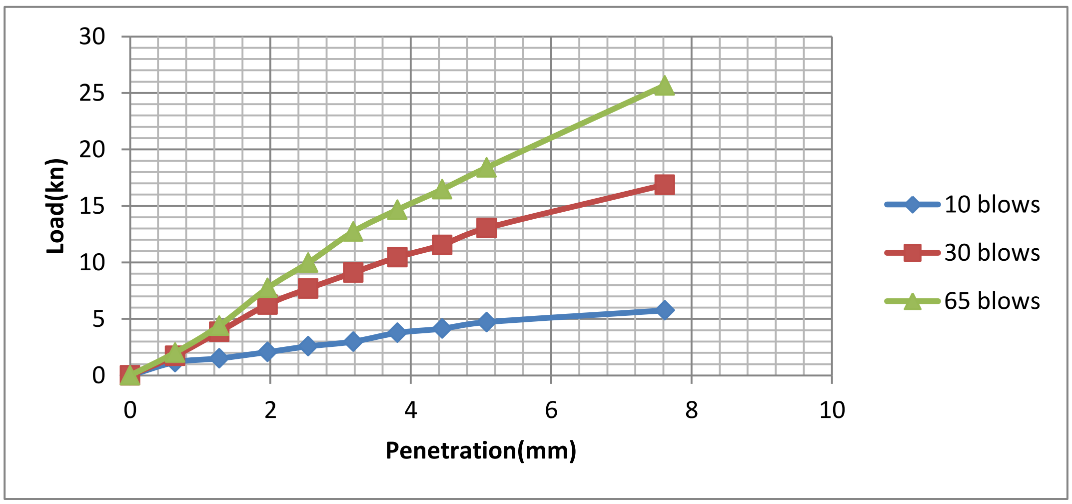
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	H		R		T	
Weight of soil + mold (gm)	14402	14697	13571	13911	14754	15185
Weight of mold (gm)	7990	7990	6660	6660	7730	7730
Weight of soil (gm)	6412	6707	6911	7251	7024	7455
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.83	2.96	3.05	3.20	3.10	3.29
Dry density of soil (g/cc)	2.63	2.74	2.83	2.94	2.89	3.05

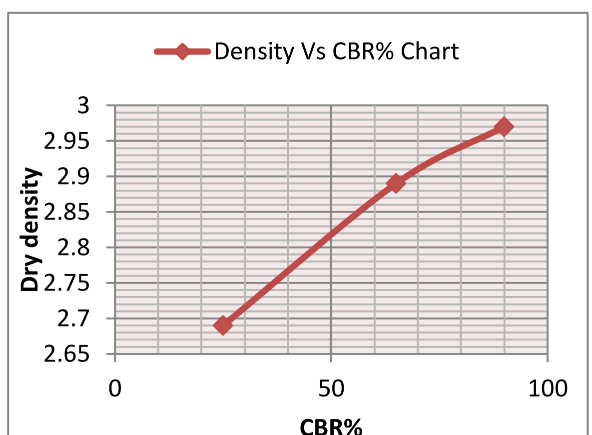
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	H2	H3		A2	B2		C2	D2	
Wet soil + container (gm)	258.1	272.6	265.4	266.7	258.8	262.8	240.3	248.5	244.4
Dry soil + container (gm)	242.6	255.3	249.0	249.8	240.6	245.2	226.6	233.0	229.8
Weight of water (gm)	15.5	17.3	16.4	16.9	18.2	17.6	13.7	15.5	14.6
Weight of container (gm)	35.7	35.3	35.6	34.5	35.3	35.2	35.5	35.4	35.7
Weight of dry soil (gm)	206.9	220.0	213.4	215.3	205.3	210.0	191.1	197.6	194.1
Moisture content (%)	7.48	7.86	7.69	7.85	8.87	8.38	7.17	7.84	7.52
Average moisture contents	7.85								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	48	1.1678			71	1.7274			83	2.0194		
1.27	62	1.5085			159	3.8685			181	4.4037		
1.96	85	2.0681			258	6.2772			318	7.7369		
2.54	106	2.5789	3	23	316	7.6883	8	60	410	9.9753	10	75
3.18	123	2.9926			374	9.0994			523	12.7246		
3.81	155	3.7712			430	10.4619			603	14.6710		
4.45	170	4.1361			475	11.5568			677	16.4714		
5.08	194	4.7200	5	25	536	13.0409	13	65	756	18.3935	18	90
7.62	247	5.7551			694	16.8850			1055	25.6682		



SWELL DATA			
Height of specimen (mm)	116.43		
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.32	0.43	0.30
Percent Swell	1.13	0.37	0.26
Average Percent swell %	0.59		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	25	65	90
Density gm/cm3	2.69	2.89	2.97



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Base Course** Date of Sampling: 13-06- 2017
Failure type: Non-distress Date of Testing: 08-07-2017
Source-BH-6 Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433 Plunger cross-section 1935.5mm2

Density Determination

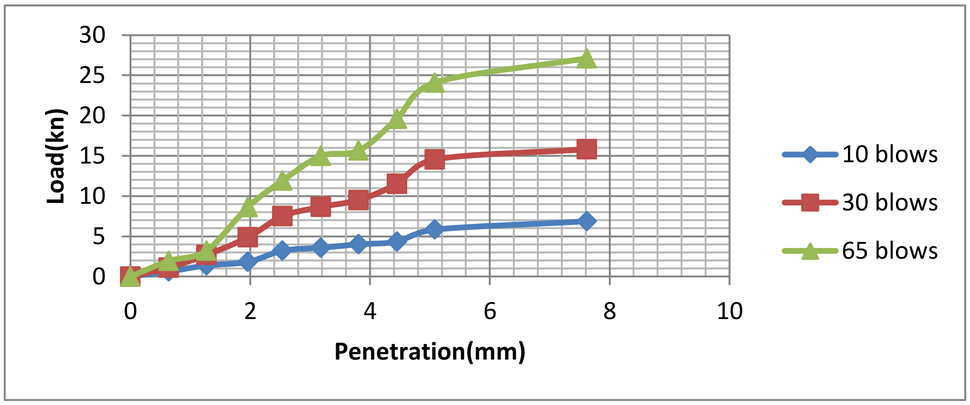
Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	B		C		F	
Weight of soil + mold (gm)	13095	13344	14709	15026	15717	15807
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	6435	6684	6979	7296	7727	7817
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.84	2.95	3.08	3.22	3.41	3.45
Dry density of soil (g/cc)	2.64	2.77	2.88	3.01	3.21	3.29

Moisture Determination

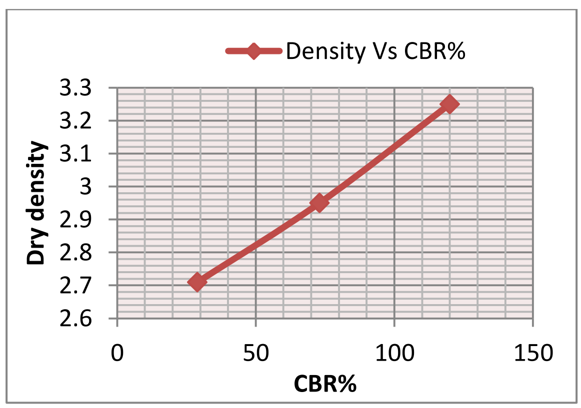
Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	F1	T2		F2	R3		M	N	
Wet soil + container (gm)	225.3	232.6	228.9	255.7	225.9	240.8	220.2	270.4	245.3
Dry soil + container (gm)	211.9	220.5	212.6	241.3	213.4	227.4	209.1	259.7	228.3
Weight of water (gm)	13.4	12.1	16.3	14.4	12.5	13.5	11.1	10.7	17.0
Weight of container (gm)	34.2	34.3	34.3	34.9	34.7	35.8	35.5	34.3	34.9
Weight of dry soil (gm)	177.7	186.2	178.4	206.4	178.7	191.6	173.6	225.4	199.5
Moisture content (%)	7.54	6.50	7.02	6.98	6.99	7.05	6.39	4.75	5.57
Average moisture contents	6.53								

Penetration Test Data

Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	26	0.6326			45	1.0949			80	1.9464		
1.27	57	1.3868			111	2.7006			132	3.2116		
1.96	75	1.8248			200	4.8660			355	8.6372		
2.54	132	3.2117	3	24	308	7.5013	8	60	490	11.9217	12	90
3.18	147	3.5765			356	8.6615			616	14.9873		
3.81	165	4.0146			391	9.5130			643	15.6442		
4.45	186	4.3338			473	11.5081			805	19.5857		
5.08	240	5.8392	6	29	598	14.5493	15	73	990	24.0867	24	120
7.62	282	6.8611			650	15.8145			1114	27.1036		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.01	0.13	0.07
Percent Swell	0.87	0.11	0.06
Average Percent swell %		0.35	
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	29	73	120
Density gm/cm3	2.71	2.95	3.25



ii) California Bearing Ratio Test/ Sub-base Course

CALIFORNIA BEARING RATIO TEST-AASHTO T 193	
Material type: **Sub-base Course**	Date of Sampling: 13-06- 2017
Failure type: Pothole and Patching	Date of Testing: 09-07-2017
Source-BH-1	Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433	Plunger cross-section 1935.5mm^2

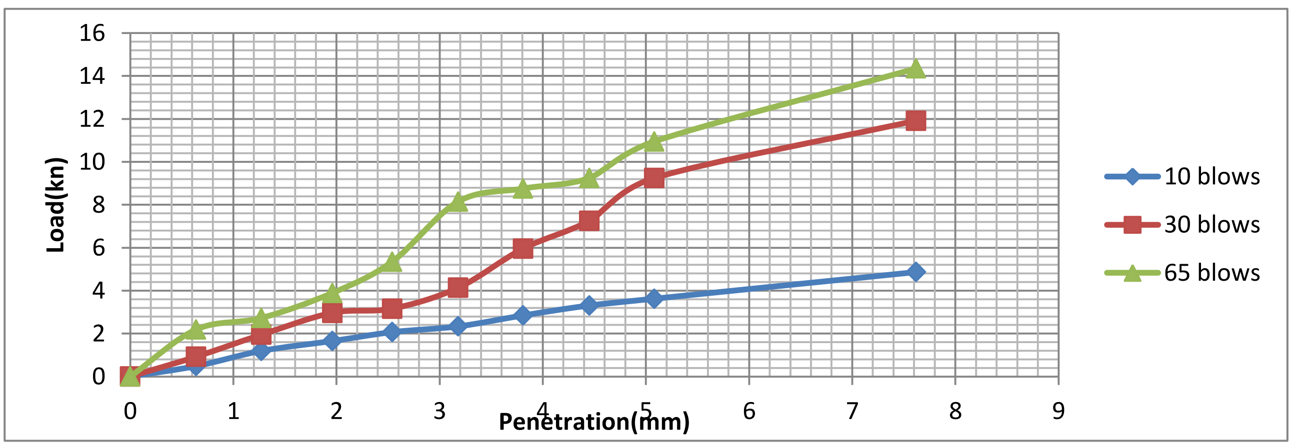
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	B2		Y1		N1	
Weight of soil + mold (gm)	13245	13962	15276	15388	16519	16729
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	6585	7302	7546	7658	8529	8739
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.91	3.22	3.33	3.38	3.76	3.86
Dry density of soil (g/cc)	2.72	2.93	3.04	3.12	3.54	3.58

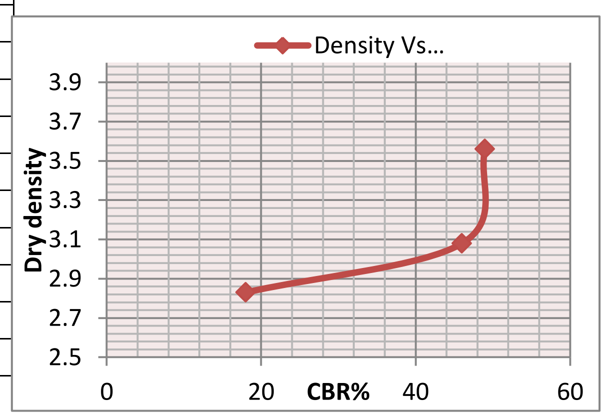
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	R1	R2		H1	H2		U1	U2	
Wet soil + container (gm)	276.4	267.9	272.2	223.9	376.5	300.2	298.1	290.3	294.2
Dry soil + container (gm)	260.5	246.6	253.6	207.6	350.4	279.0	282.7	271.6	277.2
Weight of water (gm)	15.9	21.3	18.6	16.3	26.1	21.2	15.4	18.7	17.1
Weight of container (gm)	32.7	33.9	33.3	34.9	33.8	34.4	35.1	34.7	34.9
Weight of dry soil (gm)	227.8	212.7	220.3	172.7	316.6	244.6	247.6	236.9	242.3
Moisture content (%)	6.98	10.01	8.44	9.44	8.24	8.67	6.22	7.90	7.10
Average moisture contents	8.11								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	20	0.4866			38	0.9245			90	2.1897		
1.27	49	1.1921			80	1.9464			112	2.7249		
1.96	68	1.6544			122	2.9683			160	3.8928		
2.54	85	2.0681	1	16	130	3.1629	3	24	220	5.3526	5	40
3.18	96	2.3356			170	4.1361			335	8.1505		
3.81	117	2.8466			245	5.9609			360	8.7588		
4.45	136	3.3089			298	7.2503			380	9.2454		
5.08	149	3.6252	4	18	380	9.2454	9	46	450	10.9485	11	49
7.62	200	4.8660			490	11.9217			590	14.3547		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.43	0.67	0.12
Percent Swell	1.22	0.58	0.10
Average Percent swell %	0.99		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	18	46	49
Density gm/cm3	2.83	3.08	3.56



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Sub-base Course** Date of Sampling: 13-06- 2017
Failure type: Raveling, stripping Date of Testing: 09-07-2017
Source-BH-2 Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433 Plunger cross-section 1935.5mm^2

Density Determination

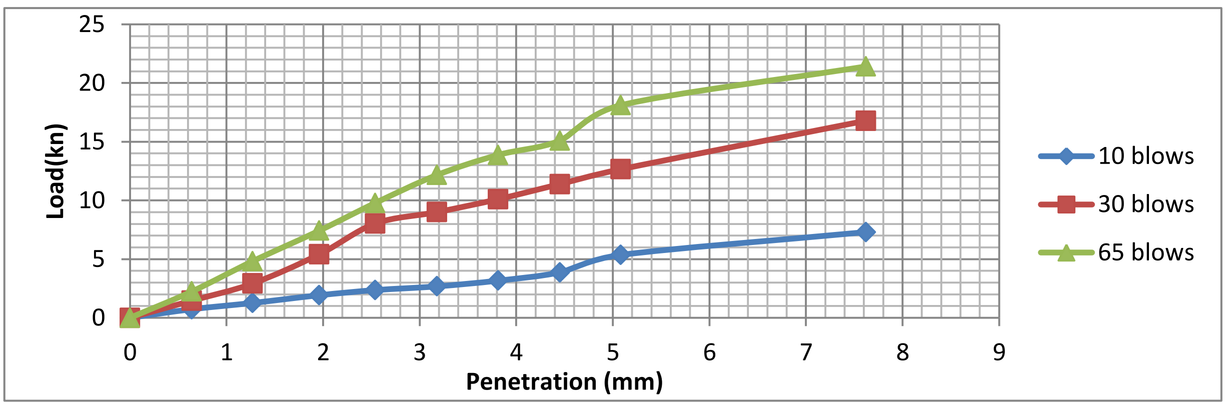
Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	K1		K3		L1	
Weight of soil + mold (gm)	12775	12992	14496	14994	15542	15731
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	6115	6332	6766	7264	7552	7741
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.70	2.80	2.99	3.21	3.33	3.42
Dry density of soil (g/cc)	2.52	2.54	2.69	2.94	3.11	3.18

Moisture Determination

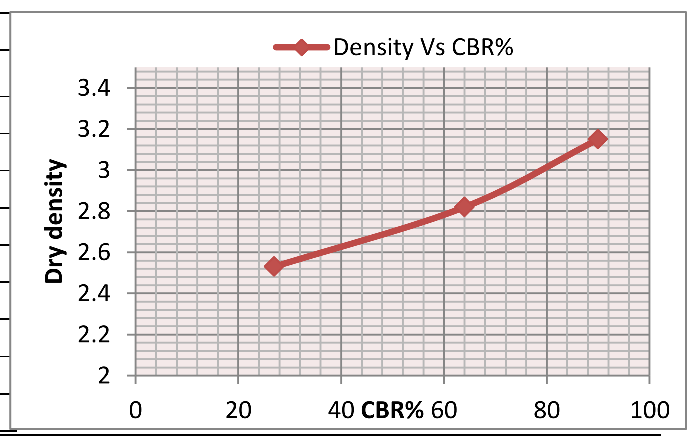
Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	H1	H2		G1	G2		T1	T2	
Wet soil + container (gm)	253.2	287.5	270.4	269.8	276.7	273.3	228.4	250.1	239.3
Dry soil + container (gm)	239.3	263.9	251.6	253.1	256.5	254.8	215.8	234.7	225.3
Weight of water (gm)	13.9	23.6	18.8	16.7	20.2	18.5	12.6	15.4	14.0
Weight of container (gm)	33.9	33.1	33.3	35.1	35.2	35.2	33.0	34.1	33.6
Weight of dry soil (gm)	205.4	230.8	218.1	218.0	221.3	219.6	182.8	200.6	191.7
Moisture content (%)	6.77	10.22	8.62	7.66	9.13	8.42	6.89	7.68	7.30
Average moisture contents	8.08								

Penetration Test Data

Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	30	0.7299			60	1.4598			92	2.2384		
1.27	52	1.2652			120	2.9196			198	4.8173		
1.96	79	1.9221			222	5.4013			305	7.4207		
2.54	97	2.3601	2	18	330	8.0289	8	60	402	9.7807	10	73
3.18	110	2.6763			370	9.0021			500	12.1650		
3.81	130	3.1629			415	10.0970			570	13.8681		
4.45	159	3.8685			468	11.3864			620	15.0846		
5.08	220	5.3526	5	27	520	12.6516	13	64	744	18.1015	18	90
7.62	300	7.2990			690	16.7877			880	21.4104		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.51	0.45	0.18
Percent Swell	1.30	0.39	0.15
Average Percent swell %	0.62		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	27	64	90
Density gm/cm3	2.53	2.82	3.15



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Sub-base Course**	Date of Sampling: 13-06- 2017
Failure type: Corrugation and segregation	Date of Testing: 09-07-2017
Source-BH-3	Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433	Plunger cross-section 1935.5mm^2

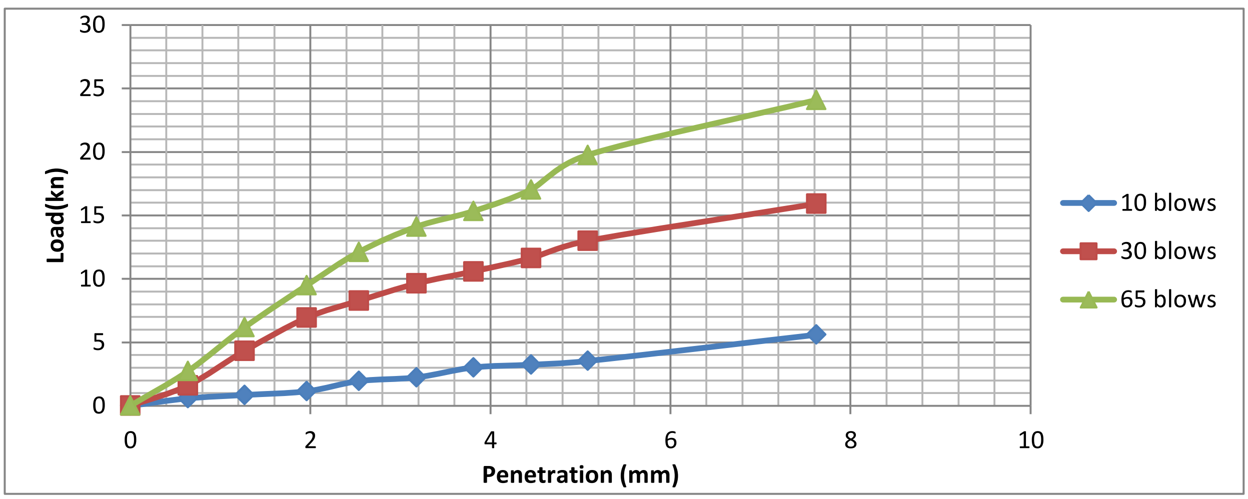
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	A1	R2	A3	R4	R1	A2
Weight of soil + mold (gm)	12645	12988	14312	14844	15633	15766
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	5985	6328	6582	7114	7643	7776
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.64	2.79	2.91	3.14	3.37	3.43
Dry density of soil (g/cc)	2.45	2.58	2.68	2.87	3.11	3.18

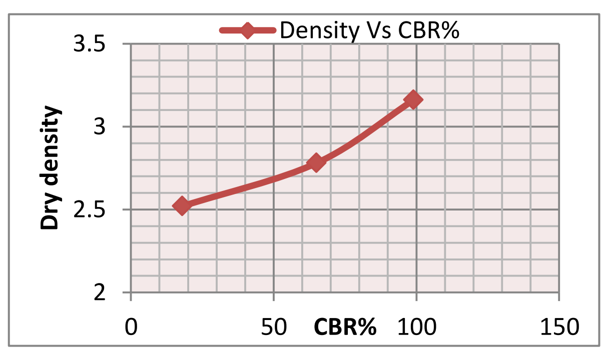
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	G3	G5		C1	C2		P1	P3	
Wet soil + container (gm)	248.9	259.4	254.2	219.7	260.1	239.9	249.6	298.3	273.9
Dry soil + container (gm)	233.8	242.7	236.3	205.3	240.9	223.1	233.6	278.8	256.0
Weight of water (gm)	15.1	16.7	17.9	14.4	19.2	16.8	16.3	19.5	17.9
Weight of container (gm)	34.2	36.0	35.1	33.6	33.9	33.8	35.1	35.2	35.2
Weight of dry soil (gm)	199.6	206.7	201.2	171.7	207.0	189.3	198.5	243.6	220.9
Moisture content (%)	7.57	8.08	8.90	8.39	9.28	8.89	8.21	8.01	8.10
Average moisture contents	8.38								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	24	0.5839			66	1.6058			112	2.7245		
1.27	35	0.8515			178	4.3307			254	6.1798		
1.96	47	1.1435			285	6.9341			390	9.4887		
2.54	80	1.9464	2	15	340	8.2722	8	62	498	12.1163	12	91
3.18	92	2.2384			396	9.6347			580	14.1114		
3.81	124	3.0169			435	10.5836			630	15.3279		
4.45	133	3.2359			478	11.6297			700	17.0310		
5.08	145	3.5279	4	18	534	12.9922	13	65	790	19.2207	19	95
7.62	230	5.5959			654	159118			990	24.0867		



SWELL DATA			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.10	0.40	0.19
Percent Swell	0.95	0.34	0.16
Average Percent swell		0.48	
Density-CBR Chart			
Socked C.B.R in%	18	65	95
Density gm/cm3	2.52	2.78	3.16



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Sub-base Course** Date of Sampling: 13-06- 2017
Failure type: Rutting and Wear Date of Testing: 09-07-2017
Source-BH-4 Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433 Plunger cross-section 1935.5mm^2

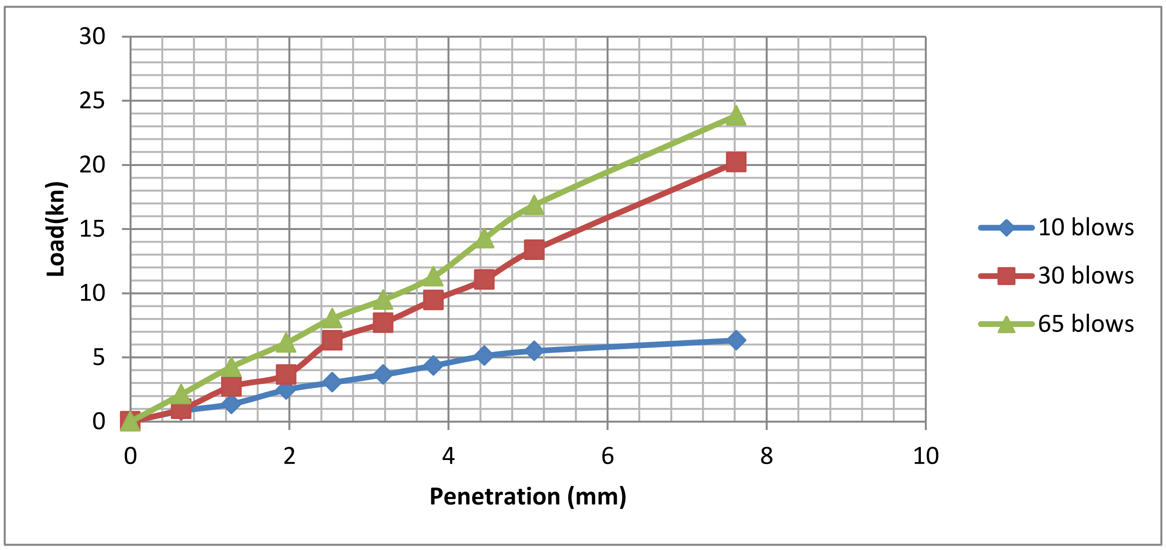
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	Q3		Q2		U2	
Weight of soil + mold (gm)	13322	13941	15211	15434	15832	15873
Weight of mold (gm)	6660	6660	7481	7730	7990	7990
Weight of soil (gm)	6662	7281	6482	7704	7842	7883
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.94	3.21	3.30	3.39	3.46	3.48
Dry density of soil (g/cc)	2.75	2.97	3.07	3.16	3.19	3.21

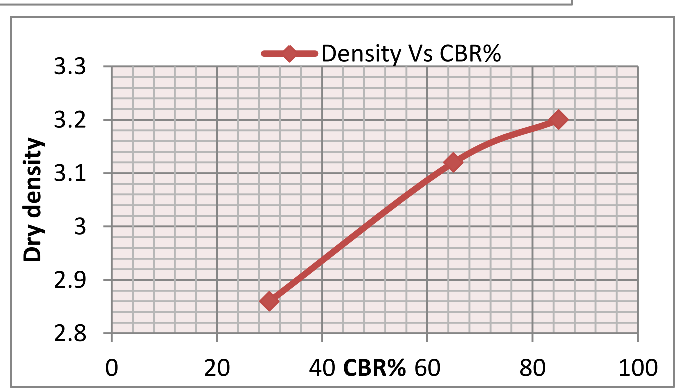
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	N1	N2		L1	L2		M1	M3	
Wet soil + container (gm)	253.4	268.2	260.8	245.5	276.9	261.2	264.7	268.1	266.4
Dry soil + container (gm)	239.2	250.8	245.0	230.8	261.1	245.9	247.3	249.9	248.6
Weight of water (gm)	14.2	17.4	15.8	14.7	15.8	15.3	17.4	18.2	17.8
Weight of container (gm)	34.1	35.4	35.6	34.2	34.0	34.5	35.3	35.1	35.0
Weight of dry soil (gm)	205.1	215.4	209.4	196.6	227.1	211.4	212.0	214.8	213.6
Moisture content (%)	6.92	8.08	7.55	7.48	6.96	7.24	8.21	8.47	8.33
Average moisture contents	7.69								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	34	0.8272			40	0.9732			87	2.1167		
1.27	56	1.3625			112	2.7249			175	4.2578		
1.96	102	2.4817			150	3.6495			252	6.1311		
2.54	125	3.0413	3	23	260	6.3258	6	45	330	8.0289	8	60
3.18	150	3.6495			316	7.6883			390	9.4887		
3.81	179	4.3551			389	9.4644			464	11.2891		
4.45	210	5.1093			454	11.0458			586	14.2574		
5.08	226	5.4986	6	30	550	13.3815	13	65	693	16.8607	17	85
7.62	290	6.3258			830	20.1939			980	23.8434		



SWELL DATA			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.23	0.36	0.12
Percent Swell	1.06	0.3	0.1
Average Percent swell	0.49		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	30	65	85
Density gm/cm3	2.86	3.12	3.20



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Sub-base Course**	Date of Sampling: `13-06- 2017
Failure type: Alligator crack	Date of Testing: 09-07-2017
Source-BH-5	Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433	Plunger cross-section 1935.5mm^2

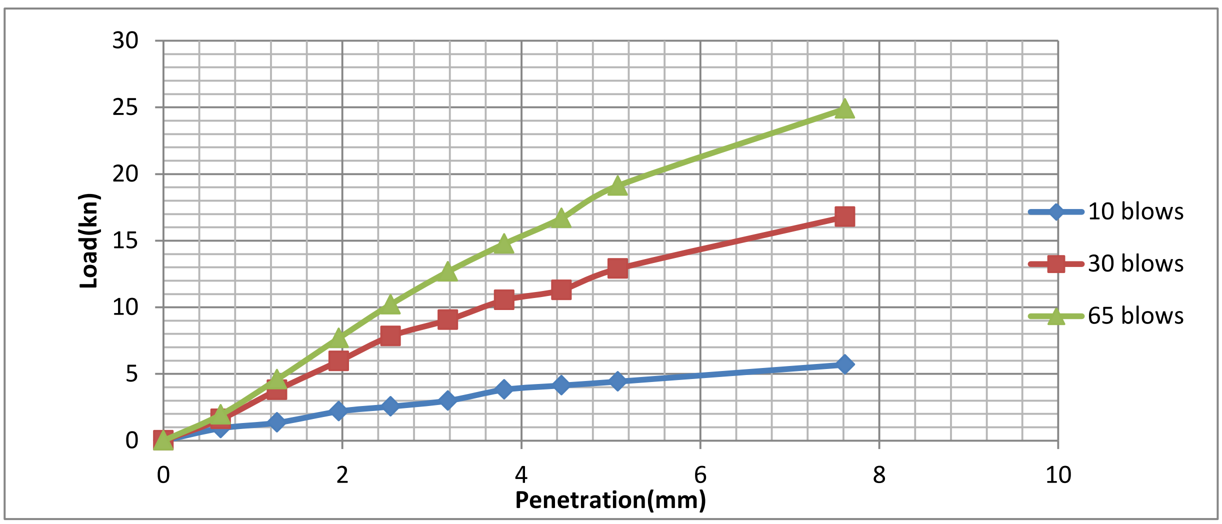
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	C1		C2		G2	
Weight of soil + mold (gm)	12674	12967	14498	14697	15591	16295
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	6014	6307	6768	6967	7601	8305
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.65	2.78	2.99	3.07	3.35	3.66
Dry density of soil (g/cc)	2.44	2.56	2.78	2.85	3.02	3.30

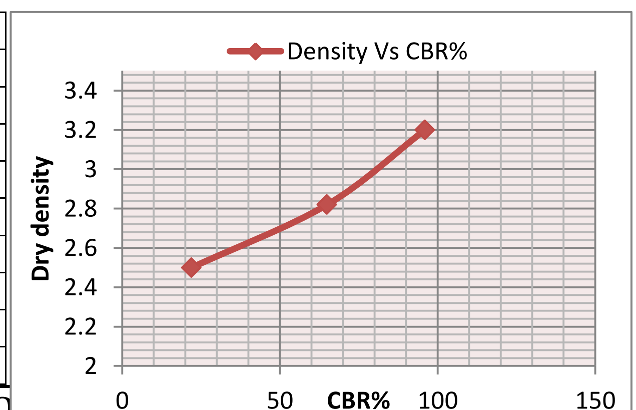
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	R1	R2		R3	R4		W1	W2	
Wet soil + container (gm)	245.5	270.2	257.9	284.5	286.9	285.7	230.8	245.4	238.1
Dry soil + container (gm)	229.1	251.7	240.5	267.2	268.8	268.0	211.4	225.1	218.3
Weight of water (gm)	16.4	18.5	17.5	17.3	18.1	17.7	19.4	20.3	19.9
Weight of container (gm)	34.2	35.3	35.4	34.5	34.6	34.1	35.6	35.2	35.1
Weight of dry soil (gm)	194.9	216.4	205.1	232.7	234.2	233.9	175.8	189.9	183.2
Moisture content (%)	8.41	8.55	8.53	7.43	7.73	7.57	11.03	10.69	10.86
Average moisture contents	8.98								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	38	0.9245			66	1.6059			80	1.9464		
1.27	55	1.3382			156	3.7955			189	4.5983		
1.96	90	2.1897			245	5.9609			316	7.6883		
2.54	105	2.5546	3	19	322	7.8343	8	59	420	10.2186	10	77
3.18	123	2.9926			372	9.0508			521	12.6759		
3.81	157	3.8198			433	10.5349			607	14.7683		
4.45	170	4.1361			464	11.2891			686	16.6904		
5.08	182	4.4281	4	22	530	12.8949	13	65	786	19.1234	20	96
7.62	234	5.6932			690	16.7877			1023	24.8896		



SWELL DATA			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.56	0.55	0.20
Percent Swell	1.33	0.47	0.17
Average Percent swell		0.66	
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	22	65	96
Density gm/cm3	2.50	2.82	3.20



CALIFORNIA BEARING RATIO

Material type: **Sub-base Course** Date of Sampling: 13-06- 2017
Failure type: Non-defect Date of Testing: 09-07-2017
Source-BH-6 Sampled by: Fikru Benti
Ring Factor: N/Division = 0.02433 Plunger cross-section 1935.5mm^2

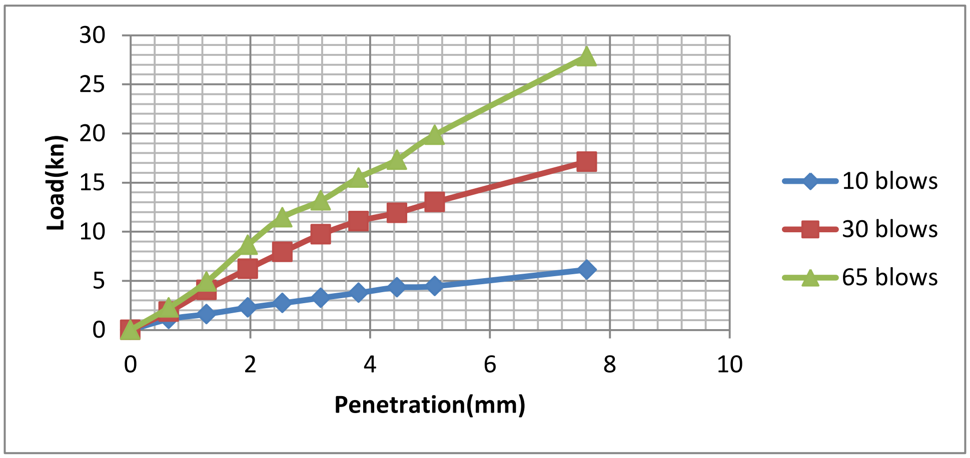
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	T		R		S	
Weight of soil + mold (gm)	13254	13367	14867	15071	15309	15558
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	6594	6707	7137	7341	7319	7568
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.91	2.96	3.15	3.24	3.23	3.34
Dry density of soil (g/cc)	2.75	2.78	2.99	3.07	3.07	3.17

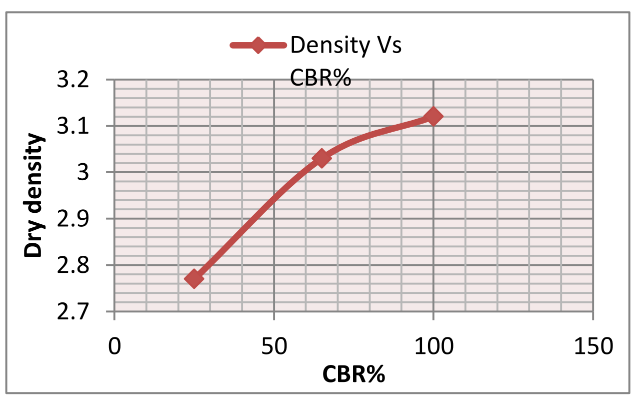
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	M	P		R	G		H	X	
Wet soil + container (gm)	256.3	261.6	258.9	266.9	276.2	271.6	223.5	232.8	228.2
Dry soil + container (gm)	243.9	247.9	245.8	255.8	255.0	255.4	214.0	223.0	218.5
Weight of water (gm)	12.4	13.7	13.1	11.1	12.2	11.7	9.5	9.8	9.7
Weight of container (gm)	34.3	35.4	34.9	34.2	34.5	34.4	35.1	35.3	35.2
Weight of dry soil (gm)	209.6	212.5	210.9	221.6	220.5	221.0	178.9	187.7	183.3
Moisture content (%)	5.92	6.45	6.21	5.01	5.53	5.29	5.30	5.22	5.29
Average moisture contents	5.58								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	45	1.0948			76	1.8491			93	2.2627		
1.27	66	1.6059			167	4.0631			202	4.9147		
1.96	93	2.2627			255	6.2041			358	8.6615		
2.54	112	2.7249	3	23	326	7.9316	8	60	471	11.4594	12	90
3.18	134	3.2602			400	9.7320			541	13.1625		
3.81	155	3.7711			455	11.0702			637	15.4982		
4.45	178	4.3307			490	11.9217			712	17.3229		
5.08	183	4.4524	5	25	535	13.0165	13	65	816	19.8532	20	100
7.62	252	6.1312			704	17.1283			1145	27.8578		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	0.90	0.11	0.07
Percent Swell	0.77	0.09	0.06
Average Percent swell	0.31		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	25	65	100
Density gm/cm3	2.77	3.03	3.12



iii) California Bearing Ratio Test/ Sub-grade Soil

CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Subgrade**
Failure type: Pothole and Patching
Source-BH-1
Plunger cross-section 1935.5mm^2

Date of Sampling: 13-06-2017
Date of Testing: 09-07-2017
Sampled by: Fikru Benti
Ring Factor: N/Division = 0.01207

Density Determination

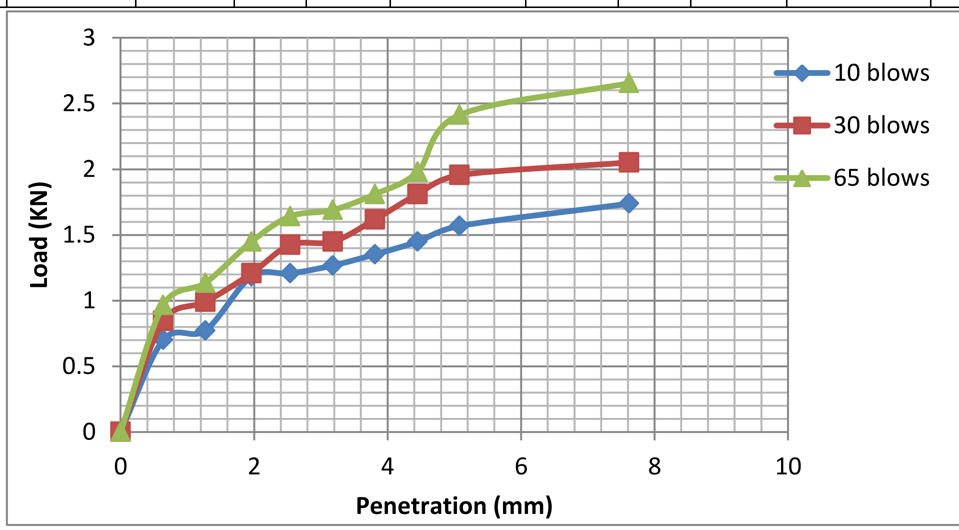
Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	A1		B1		C1	
Weight of soil + mold (gm)	11520	11660	12810	12100	13010	12900
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	4860	5000	5080	4370	5020	4910
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.14	2.21	2.24	1.93	2.22	2.17
Dry density of soil (g/cc)	1.69	1.34	1.78	1.49	1.74	1.59

Moisture Determination

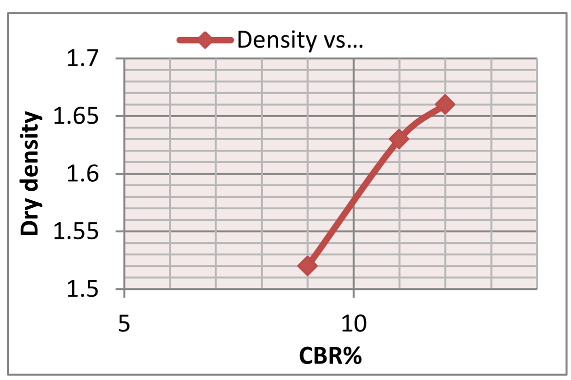
Soaking condition	10 blows			30 blows			65 blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	B1	B2		T1	A1		A2	C1	
wet soil + container gm	164.2	123.8	144.0	166.3	194.2	180.3	186.7	115.5	151.1
Dry soil + container (gm)	135.3	84.8	110.1	137.3	156.2	146.8	152.0	98.5	112.2
Weight of water (gm)	28.9	39.0	33.9	29.0	38.0	33.5	34.5	17.0	38.9
Weight of container (gm)	25.8	25.2	25.5	26.3	25.6	25.9	25.7	26.0	25.9
Weight of dry soil (gm)	109.5	59.6	169.1	111.0	130.6	120.8	126.3	46.3	86.3
Moisture content (%)	26.39	65.44	45.91	26.13	29.10	55.23	27.32	36.72	32.02
Average moisture	38.25								

Penetration Test Data

Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg.	Load (kn)	Cor. Load(kn)	Cbr %	Dial rdg	Load (kn)	Cor. Load (kn)	Cbr %	Dial rdg	Load (kn)	Cor. load (kn)	Cbr %
0	0	0			0	0			0	0		
0.64	58	0.70006			70	0.84490			80	0.96560		
1.27	64	0.77248			82	0.98974			94	1.13458		
1.96	98	1.18286			100	1.20700			120	1.44840		
2.54	100	1.20700	1	9	118	1.42426	1	11	136	1.64152	2	12
3.18	105	1.26735			120	1.44840			140	1.68980		
3.81	112	1.35184			134	1.61738			150	1.81050		
4.45	120	1.44840			150	1.81050			164	1.97948		
5.08	130	1.56810	2	8	162	1.95534	2	10	200	2.41400	2	12
7.62	144	1.73808			170	2.05190			220	2.6554		



SWELL DATA			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	2.16	1.16	0.68
Percent Swell	1.86	0.99	0.59
Average Percent swell	1.15		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	9	11	12
Density gm/cm3	1.52	1.63	1.66



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Subgrade**	Date of Sampling: 13-06-2017
Failure type: Pothole and Patching	Date of Testing: 09-07-2017
Source-BH-2	Sampled by: Fikru Benti
Plunger cross-section 1935.5mm^2	Ring Factor: N/Division = 0.01207

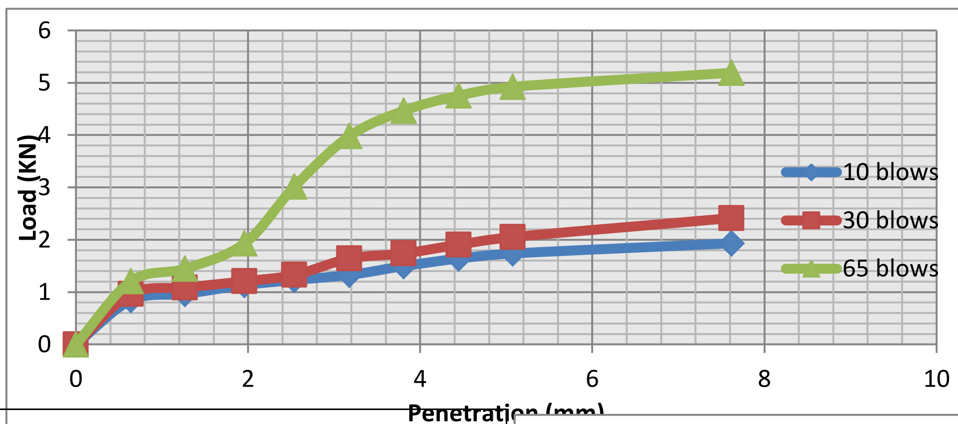
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	A2		B2		C2	
Weight of soil + mold (gm)	12460	13520	12090	13010	12690	12610
Weight of mold (gm)	7730	7730	6960	6960	7490	7490
Weight of soil (gm)	4730	5790	5130	6050	5200	5120
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.2	2.30	2.71	2.76	2.88	2.91
Dry density of soil (g/cc)	1.94	1.88	2.33	2.56	2.49	2.73

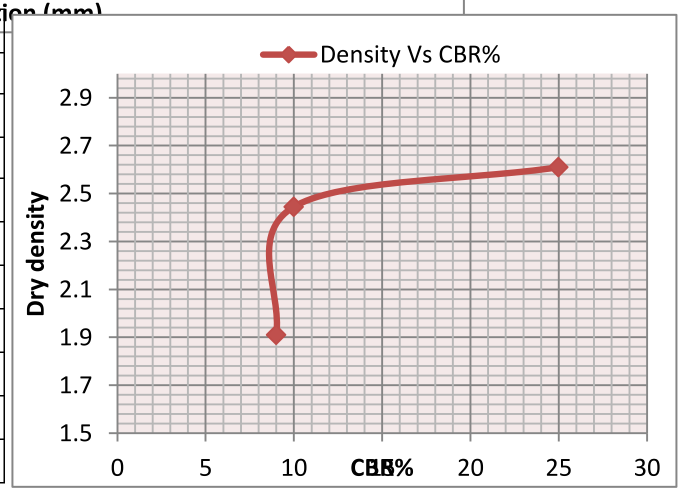
Moisture Determination

Soaking condition	10 blows			30 blows			65 blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	C	B		G1	G2		D1	D2	
Wet soil + container (gm)	188.4	193.4	190.9	173.3	191.4	182.4	197.8	183.4	190.6
Dry soil + container (gm)	168.9	162.5	165.7	152.8	179.5	166.2	175.0	173.9	174.5
Weight of water (gm)	19.5	30.9	25.2	20.5	11.9	16.2	22.8	9.5	16.2
Weight of container (gm)	25.1	25.3	25.2	26.9	25.3	26.1	27.4	27.3	27.4
Weight of dry soil (gm)	143.8	137.2	140.5	125.9	154.2	140.1	147.6	146.6	147.1
Moisture content (%)	13.56	22.53	17.94	16.28	7.72	11.56	15.45	6.48	11.01
Average moisture contents	13.73								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn)	CBR %	Dial Rdg	Load (kn)	Cor load (kn)	CB R %
0	0	0			0	0			0	0		
0.64	70	0.8449			80	0.9656			95	1.1466		
1.27	80	0.9656			90	1.0863			105	1.2673		
1.96	94	1.1346			100	1.2070			150	1.8105		
2.54	102	1.2311	1	9	110	1.3277	1	10	180	2.1726	2	16
3.18	110	1.3277			136	1.6415			195	2.3536		
3.81	124	1.4967			144	1.7381			205	2.4743		
4.45	136	1.6415			158	1.9071			230	2.7761		
5.08	144	1.7381	2	9	170	2.0519	2	10	260	3.1382	3	16
7.62	160	1.9312			200	2.4140			330	3.9831		



SWELL DATA			
Height of specimen (mm)	116.43		
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	2.16	1.32	0.65
Percent Swell	1.86	1.13	0.56
Average Percent swell %		1.18	
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	9	10	25
Density gm/cm3	1.910	2.445	2.610



CALIFORNIA BEARING RATIO TEST-AASHTO T 193	
Material type: **Sub-grade Soil**	Date of Sampling: 13-06- 2017
Failure type: Corrugation	Date of Testing: 08-07-2017
Source-BH-3	Plunger cross-section 1935.5mm^2
Sampled by: Fikru Benti	Ring Factor: N/Division = 0.01207

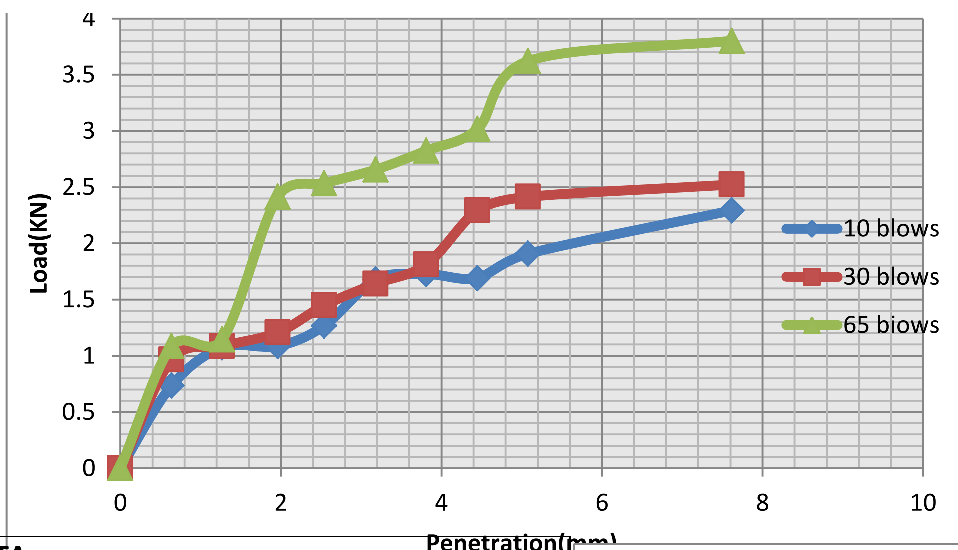
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	T1	T2	E1	E2	D1	D6
Weight of soil + mold (gm)	11261	11775	12376	13118	13714	13121
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	4601	5115	4646	5388	5724	5131
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.03	2.26	2.05	2.38	2.53	2.26
Dry density of soil (g/cc)	1.50	1.64	1.70	1.84	1.98	1.71

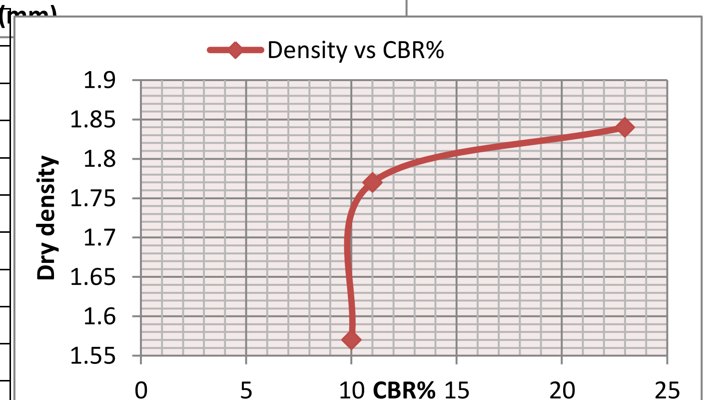
Moisture Determination

Soaking condition	10 Blows			30 Blows			65 Blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	F1	F2		G1	G2		H1	H2	
Wet soil + container (gm)	189.9	235	212.5	184.1	218.6	201.4	177.9	250.7	214.3
Dry soil + container (gm)	159.1	188.0	173.6	158.6	177.7	168.2	147.0	198.2	172.6
Weight of water (gm)	30.8	57.9	44.4	25.5	40.9	33.2	30.9	52.5	41.7
Weight of container (gm)	33.6	33.5	33.6	34.8	34.7	34.8	36.3	34.2	35.3
Weight of dry soil (gm)	125.5	154.5	140.0	123.8	143.0	133.4	110.7	164.0	137.4
Moisture content (%)	24.54	37.48	31.71	20.60	28.60	24.88	27.91	32.01	30.35
Average moisture contents	28.68								

Penetration Test Data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn)	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn)	CBR %	Dial Rdg	Load (kn)	Cor Load (kn	CBR %
0	0	0			0	0			0	0		
0.64	61	0.73627			80	0.96560			90	1.08630		
1.27	89	1.07423			90	1.08630			95	1.14665		
1.96	90	1.08630			100	1.20700			150	1.81050		
2.54	105	1.26735	1	10	120	1.44840	2	11	160	1.93120	2	14
3.18	139	1.67773			136	1.64152			190	2.29332		
3.81	143	1.72601			150	1.81050			195	2.35365		
4.45	140	1.68980			190	2.29330			200	2.41400		
5.08	158	1.90706	2	10	200	2.41400	2	10	230	2.77610	3	14
7.62	190	2.29330			209	2.52263			300	3.62100		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.45	1.23	0.95
Percent Swell	1.25	1.06	0.82
Average Percent swell		1.04 %	
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	10	11	23
Density gm/cm3	1.57	1.77	1.84



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Subgrade**	Date of Sampling: 13-06-2017
Failure type: Rutting and Wear	Date of Testing: 07-07-2017
Source: - BH-4	Sampled by: Fikru Benti
Plunger cross-section 1935.5mm^2	Ring Factor: N/Division = 0.01207

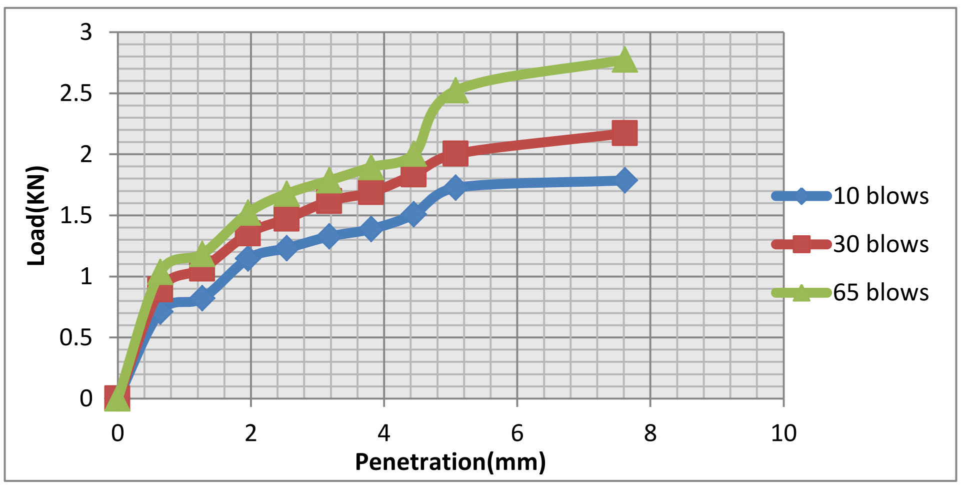
Density Determination

Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	R2		T2		Y1	
Weight of soil + mold (gm)	10521	10662	11813	12105	12916	12988
Weight of mold (gm)	6660	6660	7730	7730	7990	7990
Weight of soil (gm)	3861	4002	4083	4375	4926	4998
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	1.70	1.77	1.81	1.93	2.17	2.21
Dry density of soil (g/cc)	1.33	1.23	1.46	1.58	1.62	1.64

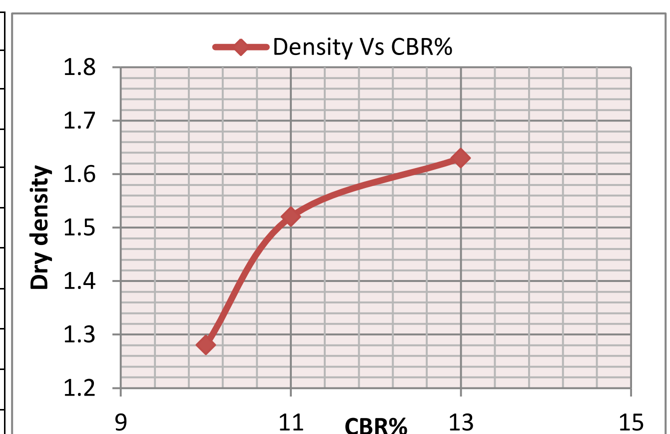
Moisture Determination

Soaking condition	10 blows			30 blows			65 blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	T1	T2		T3	A2		A1	W2	
Wet soil + container (gm)	167.6	133.7	150.7	176.3	199.8	188.1	196.6	125.4	161.0
Dry soil + container (gm)	137.5	102.4	119.9	147.1	169.9	158.5	162.0	100.0	131.0
Weight of water (gm)	30.1	31.3	30.7	29.2	29.9	29.6	34.6	25.4	30
Weight of container (gm)	25.6	25.4	25.7	26.2	25.5	25.7	25.8	26.1	25.3
Weight of dry soil (gm)	111.9	71.1	91.5	120.9	144.4	132.7	136.2	73.9	105.7
Moisture content (%)	26.89	44.02	33.55	24.15	20.71	22.30	25.40	34.37	28.38
Average moisture contents	32.75								

Penetration test data												
Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn)	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn)	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	59	0.71213			74	0.89318			86	1.03802		
1.27	68	0.82076			88	1.06216			98	1.18286		
1.96	95	1.14665			112	1.35184			126	1.52082		
2.54	102	1.23114	1	10	122	1.47254	2	11	139	1.6773	2	13
3.18	110	1.32770			134	1.61738			148	1.78636		
3.81	115	1.38805			140	1.6898			157	1.89499		
4.45	125	1.50875			152	1.83464			166	2.00362		
5.08	143	1.72601	2	9	166	2.00362	2	10	209	2.52263	3	13
7.62	148	1.78636			180	2.1726			230	2.77610		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	2.01	1.12	0.65
Percent Swell	1.73	0.96	0.56
Average Percent swell	1.08		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	10	11	13
Density gm/cm3	1.28	1.52	1.63



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Sub-grade Soil** | Date of Sampling: 13- 06-2017

Failure type: Alligator crack | Date of Testing:- 06-07-2017

Source: - BH-5 | Sampled by: Fikru Benti

Ring Factor: N/Division = 0.01207 | Plunger cross-section 1935.5mm^2

Density Determination

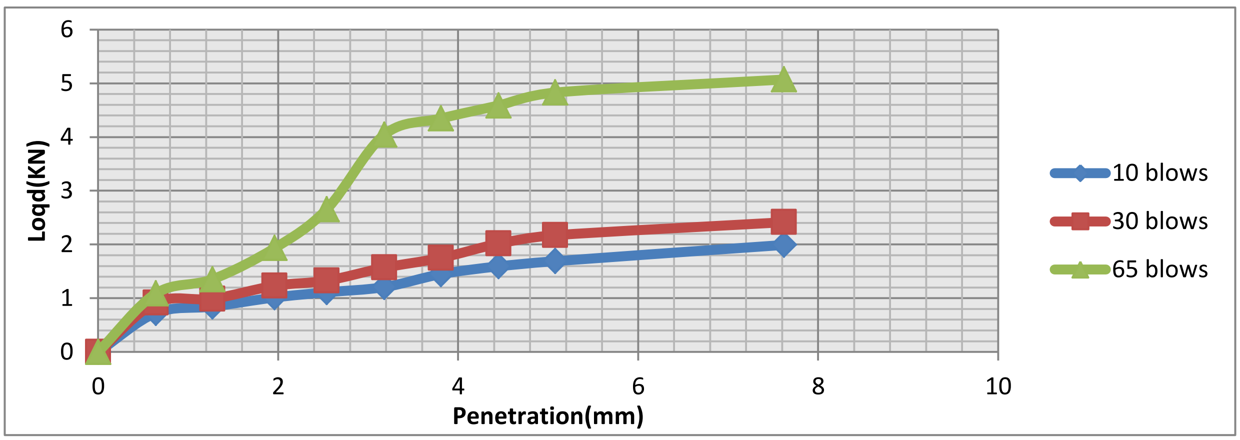
Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	K2		N2		Z2	
Weight of soil + mold (gm)	12571	13611	12201	13121	13991	13822
Weight of mold (gm)	7490	7490	6960	6960	7730	7730
Weight of soil (gm)	5081	6121	5241	6160	6261	6092
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.24	2.70	2.31	2.72	2.76	2.69
Dry density of soil (g/cc)	1.97	2.25	2.00	2.43	2.40	2.49

Moisture Determination

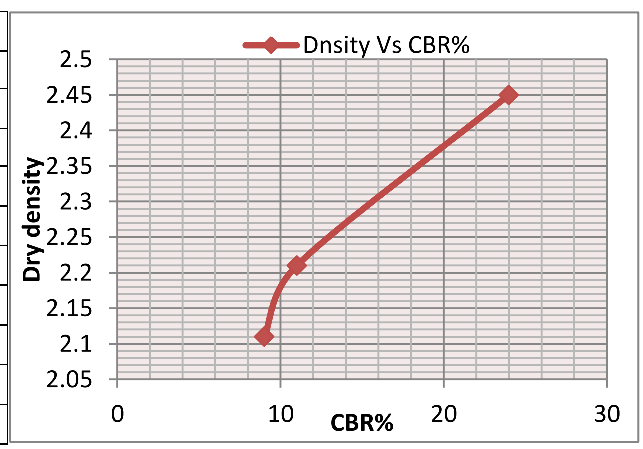
Soaking condition	10 blows			30 blows			65 blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	C4	C3		A1	A2		Q1	Q2	
Wet soil + container (gm)	198.3	190.6	194.6	183.7	192.4	188.1	197.5	185.6	191.6
Dry soil + container (gm)	177.5	162.7	170.1	162.9	175.2	169.1	175.2	174.2	174.7
WEIGHT OF WATER (gm)	20.8	27.9	24.4	20.8	17.2	19.0	22.3	11.4	16.9
Weight of container (gm)	25.4	25.2	25.3	26.8	25.5	26.2	27.7	27.1	27.4
Weight of dry soil (gm)	152.1	137.5	144.8	136.1	149.7	142.9	147.5	147.1	147.3
Moisture content (%)	13.67	20.29	16.85	15.28	11.49	13.38	15.12	7.75	11.43
Average moisture contents %	13.92								

Penetration Test Data

Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	60	0.72420			76	0.91732			80	1.08630		
1.27	70	0.84490			82	0.98974			90	1.08630		
1.96	84	1.01388			102	1.23114			100	1.20700		
2.54	92	1.11044	1	8	110	1.32770	1	10	150	1.81050	2	13
3.18	100	1.20700			130	1.56910			180	2.17260		
3.81	120	1.44840			145	1.75015			195	2.35365		
4.45	132	1.59324			167	2.01569			200	2.41400		
5.08	140	1.68980	2	9	180	2.17260	2	11	260	3.13820	3	15
7.62	165	1.99155			200	2.41400			320	3.86240		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.89	1.11	0.45
Percent Swell	1.62	0.95	0.38
Average Percent swell %	0.99		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	9	11	24
Density gm/cm3	2.11	2.21	2.45



CALIFORNIA BEARING RATIO TEST-AASHTO T 193

Material type: **Sub-grade Soil** Date of Sampling: 13- 06-2017
Failure type: Non-defect Date of Testing: 09-07-2017
Source- BH-6 Sampled by: Fikru Benti
Ring Factor: N/Division = 0.01207 Plunger cross-section 1935.5mm^2

Density Determination

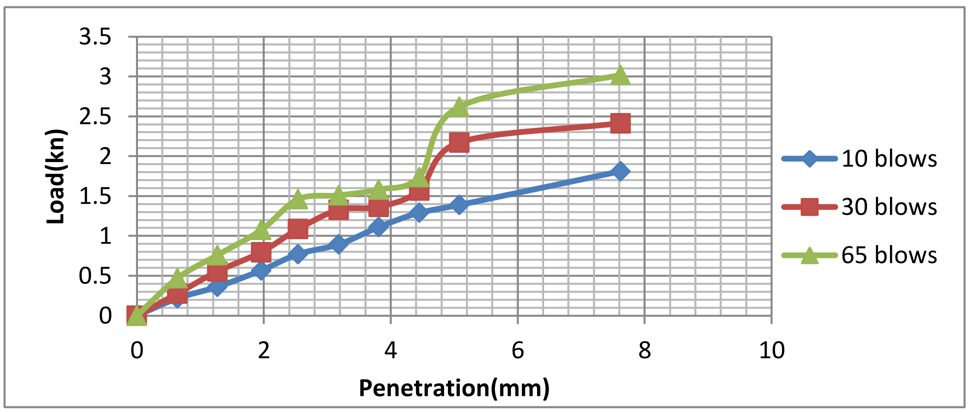
Soaking condition	10 blows		30 blows		65 blows	
	Before	After	Before	After	Before	After
Mold number	F		B		G	
Weight of soil + mold (gm)	13041	13290	12965	13124	14210	14346
Weight of mold (gm)	7490	7490	6960	6960	7730	7730
Weight of soil (gm)	5551	5800	6004	6163	6480	6616
Volume of mold (cc)	2266	2266	2266	2266	2266	2266
Wet density of soil (g/cc)	2.45	2.56	2.65	2.72	2.86	2.92
Dry density of soil (g/cc)	2.09	2.18	2.15	2.19	2.31	2.34

Moisture Determination

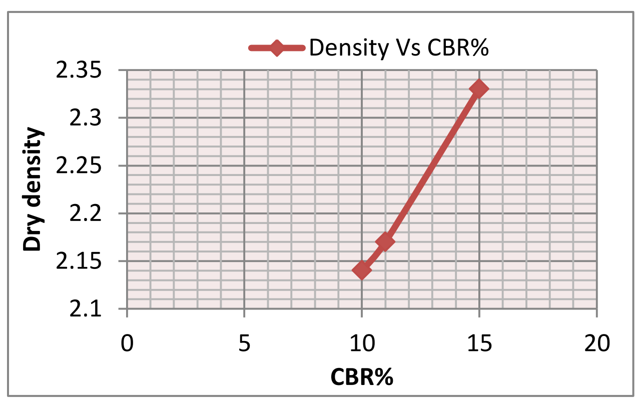
Soaking condition	10 blows			30 blows			65 blows		
	Before	After		Before	After		Before	After	
		Top 1 in.	Avg.		Top 1 in.	Avg.		Top 1 in.	Avg.
Container number	D1	D22		E11	O2		Q12	H4	
Wet soil + container (gm)	186.9	227.2	207.1	205.4	247.4	226.4	172.5	221.2	196.9
Dry soil + container (gm)	164.6	198.5	181.6	173.3	205.0	189.1	146.3	183.9	165.1
Weight of water (gm)	22.3	28.7	25.5	32.1	42.4	37.3	26.2	37.3	31.8
Weight of container (gm)	33.4	33.2	33.3	34.1	33.6	33.9	34.8	34.7	34.8
Weight of dry soil (gm)	131.2	165.3	148.3	139.2	171.4	155.2	111.5	149.2	130.3
Moisture content (%)	17.0	17.36	17.19	23.06	24.74	24.03	23.50	25.0	24.41
Average moisture content%	19.90								

Penetration Test Data

Penetration (mm)	10 blows				30 blows				65 blows			
	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. Load (kn))	CBR %	Dial Rdg	Load (kn)	Cor. load (kn)	CBR %
0	0	0			0	0			0	0		
0.64	18	0.2173			23	0.2776			39	0.4707		
1.27	30	0.3621			46	0.5552			63	0.7604		
1.96	47	0.5673			66	0.7966			89	1.0742		
2.54	64	0.7725	1	8	90	1.0863	1	8	121	1.4605	2	15
3.18	74	0.8932			110	1.3277			125	1.5088		
3.81	92	1.1104			113	1.3639			131	1.5811		
4.45	107	1.2914			130	1.5691			144	1.7388		
5.08	115	1.3881	2	10	180	2.1726	2	11	217	2.6192	3	15
7.62	150	1.8105			200	2.4140			250	3.0175		



SWELL DATA			
Height of specimen (mm) 116.43			
No. of blows	10	30	65
RDG (before soaking)	0.00	0.00	0.00
RDG (after Soaking)	1.07	0.9	0.36
Percent Swell	0.92	0.77	0.30
Average Percent swell %	0.66		
Density-CBR Chart			
Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	10	11	15
Density gm/cm3	2.14	2.17	2.33



Appendix E: Traffic Data Analysis

Annual average daily traffic by road section in 2014 traffic year 2014.

Route	Length	Cars	Land Rover	Small Buses	Large	Small Trucks	Medium Trucks	Heavy Trucks	Truck & Trailer	Total
Mekenejo-Nejo	61	0	70	78	14	7	63	59	39	330

Source: Annual Average Daily Traffic by Road Section Traffic Year 2015 ERA Asset Management Data.

Type of vehicles	$AADT_o$ in one directional flow	Traffic growth rate(i) TGR%
Car	70	2.8%
Buses	92	5.0%
Trucks	129	4.0%
Truck and Trailer	39	2.0%

Source: Ethiopian Road Asset Management System; Nekemte district.

i. Determination of $AADT_1$for each Vehicles: $AADT1=AADT_o\ (1+i)^n$=is a years between traffic survey ($AADT_0$ in 2015 and Opening of traffic 2017) =2year i= growth rates for each vehicles types.

Type of vehicles	$AADT_o$	$AADT_1$
Car	70	$70*1.028^2=73.97$
Buses	92	$92*1.05^2=101.43$
Truck	129	$129*1.04^2=139.53$
Truck and trailer	39	$39*1.02^2= 42.18$

ii. Determination of One directional traffic flow , T over the design period for each Class of Vehicles

Investigation period for research(x) =10 years up to now i= growth rates for each vehicles types

Lane distribution factor =1

$$\mathbf{T} = 365 * 1 * AADT1\ [(1+i)^{x} - 1] / (i)$$

Type of vehicles	$AADT_1$	T
Car	$70*1.028^2$=73.97	0.307 million
Buses	$92*1.05^2$=101.43	0.466 million
Trucks	$129*1.04^2$=139.53	0.612 million
Truck and trailer	$39*1.02^2$=42.18	0.169 million

iii. Compute vehicles Damage factors for each types of vehicles :- DF= $(\text{Axle Load}_i/8160)^{4.5}$

a) DF(Car)=0.0004
b) DF(Buses)=0.48
c) DF(Truck)=1.84
d) DF(Truck and Trailer)=7.8

iv. Cumulative Equivalent Standard Axil load $(CESAL)_{total}$

CESAL=Design traffic*DF

CESAL (Car) =0.307*0.0004=0.0001228 million

CESAL (Buses) =0.466*0.48=0.224 million

CESAL (Truck) =0.612*1.84=1.126 million

CESAL (Truck) =0.169*7.8= 1.318 million

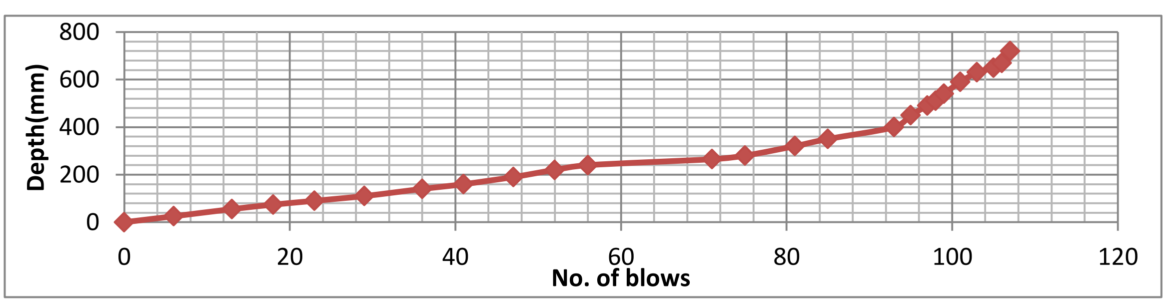
CESAL (total) =**2.467 million**

Traffic Classes for Flexible Pavement Design the traffic class is categorized as T4.

Appendix F: Dynamic Cone penetration test result

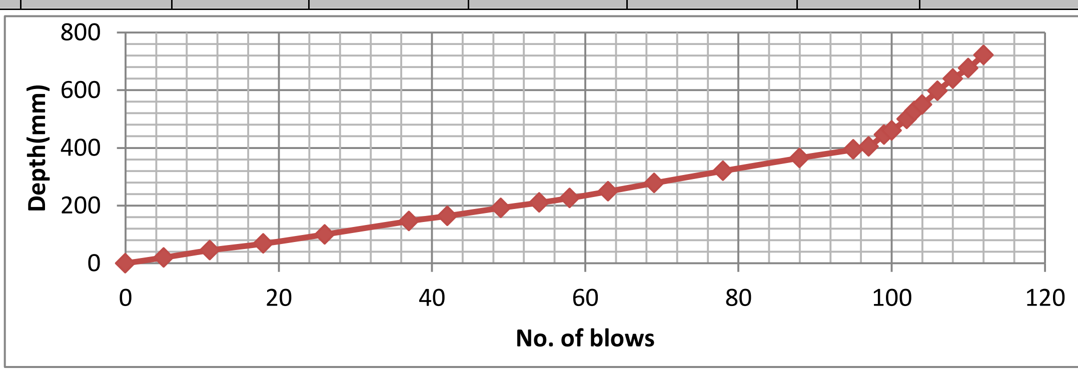
Test pit No.: BH-1 Tested by: Fikru Benti

	Zero reading(mm) 50.00						
No. of blows	Cumulative No. of blows	Adjusted depth, mm	Meter reading, mm	Increment. (mm)	mm/blow	CBR	Geotechnical Layers
0	0	0	50	0	0.0		
7	6	25	75	25	3.6	83	
8	13	55	105	30	3.8	78	
6	18	74	124	19	3.2	97	Base Course
5	23	90	140	20	4.0	73	Av. Rate=4
6	29	110	160	20	3.3	93	CBR=83%
8	36	140	190	30	3.8	78	
6	41	160	210	20	3.3	93	
7	47	190	240	30	4.3	66	
5	52	220	270	30	6.0	43	
4	56	240	290	20	5.0	55	
5	71	265	315	25	5.0	55	Sub-base
4	75	280	330	15	3.8	78	Av. Rate=5
6	81	320	370	40	3.3	93	CBR=63%
4	85	350	400	30	3.8	78	
8	93	400	450	50	6.3	40	
2	95	450	500	50	25	7	
2	97	490	540	40	20	9	
1	98	510	560	20	20	9	
1	99	540	590	30	30	6	subgrade
2	101	590	640	50	25	7	Av. rate=22
2	103	630	680	40	20	9	CBR=10%
2	105	650	700	20	10	22	
1	106	670	720	20	20	9	
2	106	720	770	50	25	7	



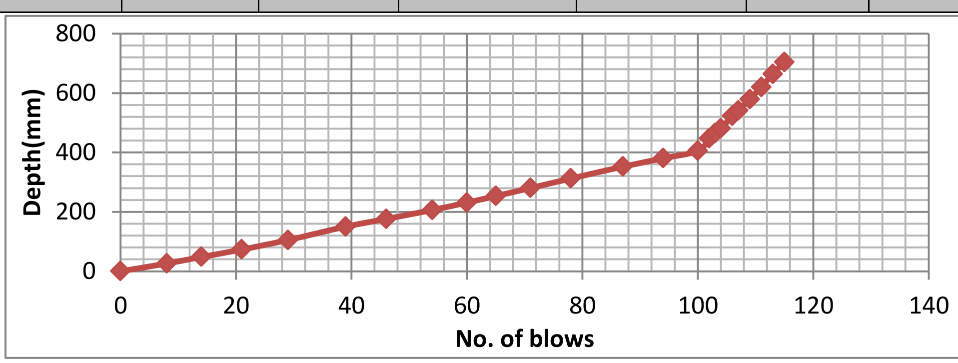
Test pit No.: BH-2 Tested by: Fikru Benti

	Zero reading(mm) 50.00						
No. of blows	Cumulative No. of blows	Adjusted depth, mm	Meter reading, mm (B)	Increment. (mm)	mm/blow	CBR	Geotechnical Layers
0	0	0	50	0	0.0	0	
6	5	20	70	20	3.3	93	
7	11	45	95	25	3.6	83	
7	18	68	118	23	3.3	93	Base Course
8	26	100	150	32	4.0	73	Av. Rate=4
11	37	146	196	46	4.2	68	CBR=84%
6	42	164	214	18	3.0	105	
7	49	192	242	28	4.0	73	
5	54	210	260	18	3.6	83	
4	58	226	276	16	4.0	73	
5	63	249	299	23	4.6	61	
6	69	278	328	29	4.8	58	Sub-base
9	78	320	370	42	4.7	59	Av. Rate=6
10	88	365	415	45	4.5	63	CBR=62%
7	95	394	444	29	4.1	71	
2	97	405	455	11	5.5	49	
2	99	445	495	40	20.0	9	
1	100	460	510	15	15.0	14	
2	102	500	550	40	20.0	9	
1	103	528	578	28	28.0	6	Subgrade
1	104	550	600	22	22.0	8	Av. rate=21
2	106	597	647	47	23.5	8	CBR=9%
2	108	640	690	43	21.5	9	
2	110	676	726	36	18.0	11	
2	112	722	772	46	23.0	8	



Test pit No.: BH-3 Tested by: Fikru Benti

	Zero reading(mm) 50.00						
No. of blows	Cumulative No. of blows A	Adjusted depth, mm	Meter reading, mm (B)	Increment. (mm)	mm/blow	CBR	Geotechnical Layers
0	0	0	50	0	0.0	0	
8	8	26	72	26	3.3	93	
6	14	48	98	22	3.7	80	
7	21	73	123	25	3.6	83	Base Course
9	29	105	155	32	3.6	83	Av. Rate=4
10	39	150	200	45	4.5	63	CBR=80%
7	46	176	226	26	3.7	80	
8	54	206	256	30	3.8	78	
6	60	231	281	25	4.2	68	
5	65	253	303	23	4.6	61	
6	71	280	330	27	4.5	63	Sub-base
7	78	312	362	32	4.6	61	Av. Rate=5
9	87	352	402	40	4.4	64	CBR=65%
7	94	380	430	28	4.0	73	
6	100	405	460	25	4.2	68	
2	102	447	497	42	21.0	9	
1	103	464	514	17	17.0	12	
1	104	480	530	16	16.0	13	
2	106	523	573	43	21.5	9	subgrade
1	107	541	591	18	18.0	11	Av. rate=19
2	109	579	629	38	19.0	10	CBR=10%
2	111	620	670	41	20.5	9	
2	113	664	714	44	22.0	8	
2	115	704	754	40	20.0	9	



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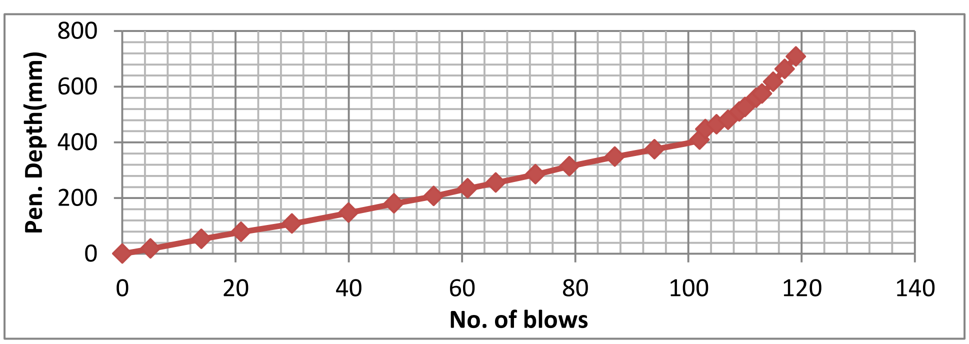
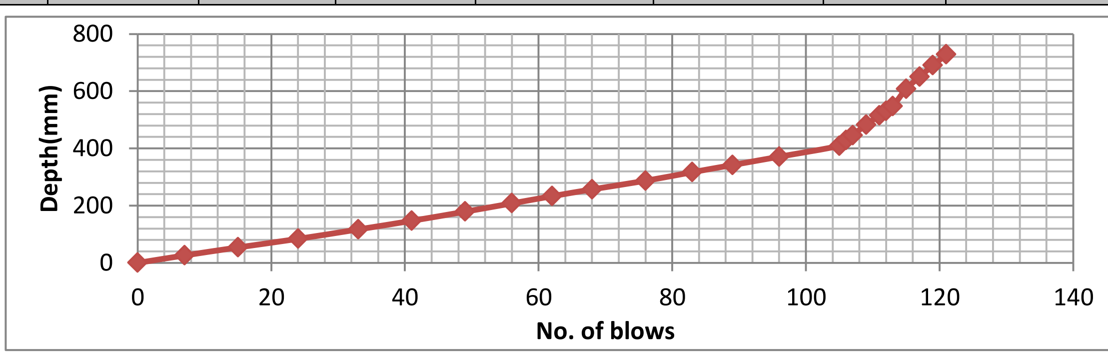
Test pit No.: BH-4 Tested by: Fikru Benti

	Zero reading(mm) 50.00						
No. of blows	Cumulative No. of blows (A)	Adjusted depth, mm	Meter reading, mm (B)	Increment. (mm)	mm/blow	CBR	Geotechnical Layers
0	0	0	50	0	0.0	0	
5	5	18	68	18	3.6	83	
9	14	53	103	35	3.9	75	
7	21	78	128	25	3.6	83	Base Course
9	30	108	158	30	3.3	93	Av. Rate=4
10	40	147	197	39	3.9	75	CBR=80%
8	48	180	230	33	4.1	71	
7	55	207	257	27	3.8	78	
6	61	234	284	27	4.5	63	
5	66	255	305	21	4.2	68	
7	73	285	335	30	4.3	66	Sub-base
6	79	314	364	29	4.8	58	Av. Rate=5
8	87	348	398	34	4.3	66	CBR=66%
7	94	375	425	27	3.9	75	
8	102	409	459	34	4.3	66	
1	103	447	497	23	23.0	8	
2	105	464	514	39	19.5	10	
2	107	480	530	35	17.5	11	
2	109	510	560	30	15.0	14	Subgrade
1	110	526	576	16	16.0	13	Av. rate=19
2	112	559	609	33	16.5	12	CBR=11%
1	113	574	624	15	15.0	14	
2	115	617	667	43	21.5	9	
2	117	663	713	46	23.0	8	
2	119	708	758	45	22.5	8	



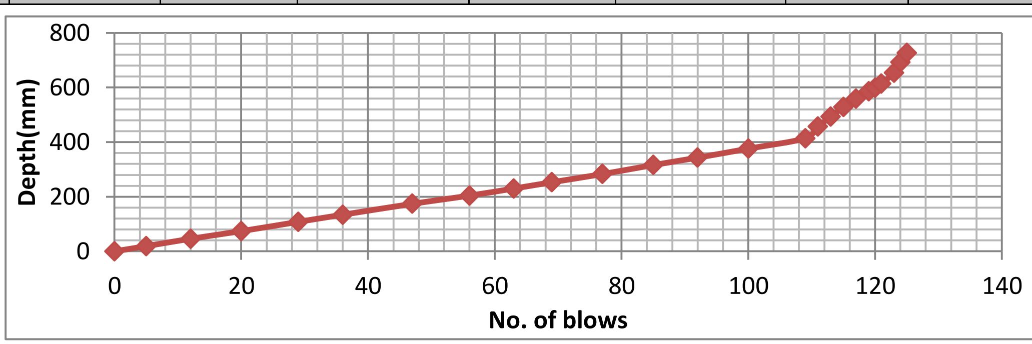
Test pit No.: BH-5 Tested by: Fikru Benti

	Zero reading(mm) 50.00						
No. of blows	Cumulative No. of blows (A)	Adjusted depth, mm	Meter reading, mm (B)	Increment. (mm)	mm/blow	CBR	Geotechnical Layers
0	0	0	50	0	0.0	0	
7	7	26	76	26	3.7	80	
8	15	54	104	28	3.5	86	
9	24	84	134	30	3.3	93	Base Course
9	33	117	167	33	3.6	83	Av. Rate=4
8	41	147	197	30	3.8	78	CBR=82%
8	49	179	229	32	4.0	73	
7	56	208	258	29	4.1	78	
6	62	233	283	25	4.2	68	
6	68	257	307	24	4.0	73	
8	76	287	337	30	3.8	78	Sub-base
7	83	317	367	30	4.3	66	Av. Rate=5
6	89	342	392	25	4.2	68	CBR=72%
7	96	371	421	29	4.1	78	
9	105	409	459	36	4.0	73	
1	106	429	479	20	20.0	9	
1	107	446	496	17	17.0	12	
2	109	483	533	37	18.5	10	
2	111	515	565	32	16.0	13	Subgrade
1	112	531	581	14	14.0	15	Av. rate=18
1	113	547	597	16	16.0	13	CBR=11%
2	115	608	658	34	17.0	12	
2	117	650	700	42	21.0	9	
2	119	690	740	40	20.0	9	
2	121	728	778	38	19.0	10	



Test pit No.: BH-6 Tested by: Fikru Benti

	Zero reading(mm) 50.00						
No. of blows	Cumulative No. of blows (A)	Adjusted depth, mm	Meter reading, mm (B)	Increment. (mm)	mm/blow	CBR	Geotechnical Layers
0	0	0	50	0	0.0	0	
6	5	19	69	19	3.2	97	
7	12	46	96	27	3.9	75	
8	20	74	124	28	3.5	86	Base Course
9	29	108	158	34	3.8	78	Av. Rate=4
7	36	134	184	26	3.7	80	CBR=85%
11	47	174	224	40	3.6	83	
9	56	204	254	30	3.3	93	
7	63	230	280	26	3.7	80	
6	69	253	303	23	3.8	78	
8	77	283	333	30	3.8	78	Sub-base
8	85	316	366	33	4.1	70	Av. Rate=4
7	92	343	393	27	3.9	75	CBR=74%
8	100	376	426	33	4.1	70	
9	109	414	464	38	4.2	68	
2	111	457	507	43	21.5	9	
2	113	493	543	36	18.0	11	
2	115	528	578	35	17.5	11	
2	117	559	609	31	15.5	13	Subgrade
2	119	586	636	27	13.5	16	Av. rate=17
1	120	599	649	13	13.0	16	CBR=12%
1	121	614	664	15	15.0	14	
2	123	654	704	40	20.0	9	
1	124	692	742	38	19.0	10	
1	125	727	777	35	17.5	11	



Appendix G: Photographs of Laboratory and Field during test.

Soil samples before the starting of laboratory tests during air dried.

Sample preparation for laboratory tests by using sample splitter

Grain size Distribution Test

Atterberg limit test

Modified proctor and three point CBR Test

DCP Tests on field

The following Figures show the different photos taken from the field Observation of the different types of distress along Mekenejo-Nejo Road section.

Raveling of asphalt surface

Potholes and Alligator crack

Rutting on side

Disintegrations and Potholes

Potholes

Drainage problem