JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HIGH WAY ENGINEERING STREAM

Causes of Defects of Asphalt Pavement and Its Remedies

A Case Study In Agaro Town

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 Highway Engineering

By: Markos Tsegaye

July, 2016
Jimma, Ethiopia

JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HIGH WAY ENGINEERING STREAM

Causes of Defects of Asphalt Pavement and Its Remedies

A Case Study In Agaro Town

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 Highway Engineering

By: Markos Tsegaye

Advisor: **EMERT. QUEZON (**Associate Professor)
Co-Advisor: Getachew Kebede (Msc)

July, 2016
Jimma, Ethiopia

Declaration

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

Name	**Signature**	**Date**
----------------------------	**-------------------**	**---------------**

This thesis has been submitted for examination with my approval as university supervisor

Approved by Board of Examiners:

Name	**Signature**	**Date**
Name		
1. ________________________	_____________	/_______/________/_____
Chairman		
2. ________________________	_____________	/_______/________/_____
Principal advisor		
3. ________________________	_____________	/_______/________/_____
Co-advisor		
4. ________________________	_____________	/_______/________/_____
Internal Examiner		
5. ________________________	_____________	/_______/________/_____
External Examiner		

ABSTRACT

Asphalt pavements provide an excellent material for roadways when designed and constructed properly and deliver a smooth, quiet, and durable solution. However, the success of any asphalt pavement is dependent on the paving material being designed for its environment, construction methodology, and drainage and work man ship. Based on the level of accuracy achieved by various approaches and tools available, frequent design defects, discrepancies and work redundancy are obvious in road design project which ultimately leads to damages and deterioration. Due to those mentioned problems, the government and road user in general is suffering from loss of huge sum of money due to pavement damages and deterioration

The objective of this Study is to examine the Causes and remedial measures *for asphalt concrete pavement damages. 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 damages and deterioration.*

*The study was conducted in Agaro town a route from "*Bulbulo Kebele - *KoyeBer"* cover around *15km length. Based on the existing theories and principles this research study addresses the general objectives to investigate the causes of asphalt concrete pavement failures and its remedial measures. For this planned purpose, the samples from sub grade, sub bases, base course and asphalt layer disturbed samples were collected from the worst road failure location of the road. The study used both primary and secondary data. The secondary data were obtained from various published and unpublished sources of the governmental and the non-governmental organization. The primary data were obtained through field survey and condition surveying, and laboratory analysis.*

During condition surveying some localized pavement distresses like shoving, potholes, alligator cracks, block cracks, edge cracks, longitudinal cracks, ravelling ,rutting and poor drainage condition were observed. The average thickness of each layers were measured and Asphalt 3.95cm, Base 13.37cm, and Sub base 19.25cm. From field investigation and laboratory test result the AASHTO and Unified soil classification are Sub grade A-7&MH, sub base A-2-6&GM and base course A-2-4 & GW, Atterberg limits parameters Average LL, and PI in percent were base course (4,4), sub base(27,12.99) and sub-grade(54,20.5) and compaction, MDD g/cc and OMC% were base course(2.7,6.21), sub base(1.83,9.67) and sub-grade(1.61,14.64), CBR% were base course 145.9%, sub base 84.7% and sub-grade10.1% obtained, Bitumen content Non-damaged asphalt 4.97%, BH1=3.12%, BH2=2.64%,BH3=2.16% and BH4=2.29%

Based on the laboratory test result and condition survey the following are cause of pavement damages; Sub grade soil, degree of compaction, pavement material thickness, improper bitumen content and Poor drainage. Finally surface treatments, Fill cracks with asphalt emulsion slurry, Full-depth patching, removing vegetation close to the ditches are some of the *recommendation forwarded.*

***Keywords*:-** Asphalt Pavement Damages, Causes, Condition Survey, Non Damaged Asphalt, Traffic Class, engineering property.

Acknowledgments

First of all I would like to thank the almighty GOD for his unspeakable gift, help and protection and I am heartily thankful to St. Virgin Mary and all Saints supporting and protecting me during my work.

I would like to express my thanks and gratitude to Ethiopian Road Authority for granting me this opportunity to pursue my Master degree under Highway engineering stream. I am also grateful to my employer Jimma University, Jimma Institute of Technology.

I would like to express my genuine gratitude and appreciation to my advisor Emert.Quezon (Associate Professor) and Co. Advisor Getachew Kebede (Msc), for their unlimited support, guidance, and close supervision, throughout the thesis work from the start to the completion of the study.

I am very grateful to Ethiopian Road construction Corporation Jimma District, Geotechnical laboratory workers, especially Ato Tamirat Mulken for his contribution in carrying out the laboratory test.

Finally, I am greatly indebted to the love and support of my family specially my wife Serkalem Haile and my baby girl Wengelawit Markos. Thus, I would like to say “Thank You”.

Last but not least, my heartfelt gratitude goes to those who assisted me on this research work to reach final, particularly Mr.Mamuye Busier (Msc) for his unreserved support and encouragement throughout my journey.

TABLE OF CONTENT

List of Figures

List of Tables

Acronyms

- AACRA-Addis Ababa city road authority
- 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
- CORD-Catalogue of Road Defects
- CU-Coefficient of uniformity
- DCP- Dynamic Cone Penetration
- DS3-Design standard three
- ERA -Ethiopian Road Authority
- ERA- Ethiopian Road Authority
- GB- Granular base course,
- GC - Granular capping layer
- GM-Medium graded gravel
- GS - Granular sub-base,
- GS-Granular Sub base layer
- GW – Well graded gravel
- JIT- Jimma Institute of Technology
- LL- Liquid limit
- MDD- Maximum dry Density

- MH-Inorganic silt
- NDOR-note defect of road
- OMC- Optimum Moisture content
- PCC-Portland cement concrete
- PI-Plastic index
- PL-Plastic limit
- TRRL-Transport and Road Research Laboratory
- USCS-Unified Soil Classification System

CHAPTER ONE

INTRODUCTION

1.1 Background

Asphalt pavements provide an excellent material for roadways; when designed and constructed properly these roads deliver a smooth, quiet, and durable solution. However, the success of any asphalt pavement is dependent on the paving material being designed for its environment, construction methodology, and Drainage and work man ship. Road network is considered very important in the economies, especially in the developing countries that require roads and highways for transportation of most goods and services. [27]

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 performance are Climate, Construction material properties, Work man sheep, structure and Traffic load. Movement of sub grade is the major causes of road pavement failure which makes road network unsafe and not suitable to road users. [29]

Most asphalt concrete pavement road damages are characterized by failure of all kinds like Cracking, Surface deformation, Disintegration (potholes) and Surface defects (bleeding).

Due to the huge lump sum of investment being made for Asphalt concrete pavement road and due to high safety requirements, continuous improvements and advances on pavement maintenance and management technologies are being made. Based on the level of accuracy achieved by various approaches and tools available, frequent design defects, discrepancies and work redundancy are obvious in road design project which ultimately leads to damages and deterioration. Due to those mentioned problems, the government and road user in general is suffering from loss of huge sum of money due to pavement damages and deterioration. Pavement damages and deterioration are the challenge for road user in Agaro town and affect the vehicle operating cost.

This study determine the causes of asphalt concrete damages and its remedial measures along the route "Bulbulo Kebele-Koye Ber" in Agaro town with estimated length of 15km.

1.2 Statement of the Problem

The present condition of most of the roads in the south western Ethiopia and the sedimentary terrain of the region has stimulated the interest of various stakeholders in the usage and maintenance of our road ways. Rehabilitating these roadways has become a financial burden on the Federal, State, and Local Governments. The Jimma to Bedele road is a typical example of Ethiopians roads whose failure bugs the mind of regular users. Almost every section of the road has failed, resulting to;

- Loss of lives and properties, human injuries etc. through accidents,
- Retardation of the rate of economic growth and development in affected areas,
- Environmental pollution and degradation,
- Impedance of human movement and the flow of economic activities and
- Numerous cases of armed robbery attacks along affected areas.

In the light of the foregoing therefore, some questions constantly come to mind: what exactly is the cause of this problem? Again, since not all sections of the road failed, or at least failed equally, does a geotechnical property, road thickness, workman ship play any role in the durability of the roads. Considering the cost of constructing and maintaining this road, the answers to these questions have become a necessity particularly now that the impacts are multiplying. It is to this effect that a need to investigate on the place of the geotechnical characteristics of the soil on which the road is built arises.

The pavement industry has invested millions of birr in search for remedies to pavement distress. Theses remedies included the improvement in the design of asphalt mixes, development of new and engineering asphalt binders, using new materials and establishment of new research efforts and also the properties of asphalt materials in the laboratories. However these improvements did not appear in the field performance of asphalt roads.

In the road from "Bulbulo Kebele- Koye Ber" in Agaro town were constructed in 2008GC and year by year the road have been experiencing different types of damages 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 damages and assess its remedial measures.

1.3 Research Questions

1. Which locations in the study area are mostly affected or severely damaged including the factor that causes defects?
2. What are the existing engineering properties of pavement layers and how much it deviated from the standard specifications?
3. What are the remedial measures to improve the existing condition of the asphalt pavement?

1.4. Objective of the Study

General Objective

The general objective of study is to investigate the causes of pavement defects and its remedies on asphalt concrete pavement in Agaro town.

Specific Objectives

- To identify the locations of severely damage asphalt pavement and the factors which causes defects.
- To determine the existing engineering properties of pavement layers and compare with the standard specifications.
- To suggest remedial measures to improve the existing condition of the asphalt pavement.

1.5 Significance of the Study

The findings of the research will be expected:

- Provide information to Agaro Town Administration and ERA regarding the location of the most damaged asphalt pavement, the causes of defects and recommend the possible remedial measures for different type of pavement damage.
- Determines the existing engineering properties of pavement layers and compare with the standard specifications.

1.6 Scope of the Study

The study was conducted in Agaro town a route from "Bulbulo Kebele-Koye Ber" cover around 15km length. Based on the existing theories and principles this research study addresses to investigate the causes of asphalt concrete pavement failures/defects and its remedial measures. For this planned purpose, the samples from sub grade layer, sub base layers, base course layers and asphalt layer disturbed and undisturbed samples were collected from the worst road failure location of the road. These samples were analyzed based on Geotechnical analysis. The most important works to be done are outlined in the Methodology section.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

This chapter discusses various types of Asphalt pavements damages and the most common causes of each. Asphalt concrete damage can be a result of load associated (e.g. traffic) and others are non-load associated (e.g. environmental, material properties, construction methodology, poor construction practice, utility cut and poor drainage).

2.1.1 What is 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 coarse, the base course, and the sub base [13].

2.1.2 Types of pavement

Pavements are typically divided into the following three general categories: flexible, rigid and unpaved (gravel or dirt [13].

Flexible (Bituminous Pavements)

Flexible pavements are constructed of several layers of natural granular material covered with one or more water proof bituminous surface layers, and as the name imply, are considered to be flexible. A flexible pavement will flex (bend) under the load of a tyre. 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. The reason for this is that at the surface the wheel load is applied to a small area, the result is high stress levels, deeper down in the pavement, the wheel load is applied to larger area, and the result is lower stress levels thus enabling the use of weaker materials [13].

2.3 Pavement Functions:

The primary functions of a pavement are to:

- **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):**

In addition to a riding comfort, the other road user requirement is that of safety. Safety, especially during wet conditions can be linked to a loss of surface friction between the tyre and the pavement surface. A pavement must therefore provide sufficient surface friction and texture to ensure road user safety under all conditions.

- **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 sub grade. 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).

- **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 [13].

2.4. Factors Influencing the Performance of a Pavement

I. Traffic:

The performance of pavements is mostly influenced by the loading magnitude, configuration and the number of load repetitions by heavy vehicles. According to 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 a 80kN 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. The idea of traffic factor which affects the performance of pavement is also supported by ERA [2].

II. Moisture (Water)

Moisture can significantly weaken the support strength of natural gravel materials, especially the sub grade. Moisture can enter the pavement structure through cracks and holes in the surface, laterally through the sub grade, 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 [2].

III. Sub grade

The sub grade is the underlying soil that supports the applied wheel loads. If the sub grade 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 sub grade are not adequately addressed by the pavement design, significant differences in pavement performance will be experienced [2].

IV. 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 [2].

V. 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 Thus, postponing maintenance because of budget constraints will result in a significant financial penalty within a few years.

"Pavement maintenance is not easy to define. Maintenance departments generally agree what it is, but there are some minor differences. Some call pavement improvement "Maintenance". Others include only the work that keeps the pavement in its as constructed condition. Taking all these into consideration, the definition that seems to fit best is: Pavement maintenance is work performed from time to time to keep a pavement, under normal conditions of traffic and forces of nature, as nearly as possible in its as-constructed condition. Distinctions are usually made between forms of maintenance, based on their required frequency. The International Road Maintenance Handbook [29] uses the grouping of "routine" and "periodic" maintenance, while other sources. TRRL [31] use "routine", "recurrent", "periodic" and "urgent".

There are four categories:

• **Routine** maintenance, required continually on every road, whatever its engineering characteristics or traffic volume

• **Recurrent** maintenance, required at intervals during the year with a frequency that depends on the volume of traffic using the road

• **Periodic** maintenance, required only at intervals of several years

• **Urgent** maintenance, needed to deal with emergencies and problems calling for immediate action when a road is blocked.

Pavement maintenance is the key to pavement preservation. An effective pavement preservation program integrates many maintenance strategies and treatments. There are three types of pavement maintenance:

Preventive Maintenance: Planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without increasing the structural capacity)

Corrective Maintenance: Performed after a deficiency occurs in the pavement, such as moderate to severe rutting, raveling or extensive cracking. This may also be referred to as "reactive" maintenance.

Emergency Maintenance: Performed during an emergency situation, such as a blowup or severe pothole that needs repair immediately. This could also include temporary treatments that hold the surface together until a more permanent treatment can be performed [29].

2.5 Types of Pavement Damages and Deterioration:

Pavement deterioration or damages or distress 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 [11] , [32].

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

1. Cracking

2. Surface deformation

3. Disintegration (potholes, etc.)

4. Surface defects (bleeding, etc.)

2.5.1 Cracking:

The most common types of cracking are:

i. Fatigue cracking

ii. Longitudinal cracking

iii. Transverse cracking

iv. Block cracking

v. Slippage cracking

vi. Reflective cracking

vii. Edge cracking

i. Fatigue Cracking (Alligator Cracking):

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. 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. Larger areas require reclamation or reconstruction. Drainage must be carefully examined in all cases. Factors which influence the development of alligator cracking are the number and magnitude of applied loads, the structural design of the pavement (layer materials and thicknesses), the quality and uniformity of foundation support, the consistency of the asphalt cement, the asphalt content, the air voids and aggregate characteristics of the asphalt concrete mix, and the climate of the site (i.e., the seasonal range and distribution of temperatures).drainage effect is not considered.

Figure 2.1: Alligator cracks (Pavement Distress Identification Manual, July 2011)

ii. 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. Non wheel path longitudinal cracking in an asphalt pavement may reflect up from the edges of an underlying old pavement or from edges and cracks in a stabilized base, or may be due to poor compaction at the edges of longitudinal paving lanes. Longitudinal cracking may also be produced in the wheel paths by the application of heavy loads or high tire pressures.

Figure 2.2. Longitudinal cracks (Pavement Distress Identification Manual, July 2011).

iii. 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.

Figure 2.3. Transverse cracks (Catalogue of Road Defects (CORD) January 2013).

iv. 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, in other hand according to [16]. Block cracking is the cracking of an asphalt pavement into rectangular pieces ranging from about 1 ft to 10 ft on a side. Block cracking occurs over large paved areas such as parking lots, as well as roadways, primarily in areas not subjected to traffic loads, but sometimes also in loaded areas.

Figure 2.4. Block cracks (Catalogue of Road Defects (CORD) January 2013).

v. 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.

Figure 2.5. Slippage cracks (Catalogue of Road Defects (CORD) Division January 2013).

Vi. 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.

Figure 2.6. Reflective cracking (Pavement Distress Identification Manual, July)

vii. Edge Cracking:

Edge cracks typically start as crescent shapes at the edge of the pavement. According to Shahin, M. Y.,1994. 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. In all cases, excess moisture should be eliminated, and the shoulders rebuilt with good materials.

Figure 2.7. Edge cracks (Pavement Distress Identification Manual, July 2011)

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:

i. Rutting

ii. Corrugations

iii. Shoving

vi. Depressions

v. Swell

i. 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. A very narrow rut is usually a surface failure, while a wide one is indicative of a subgrade failure. Inadequate compaction can lead to rutting. Minor surface rutting can be filled with micro paving or paver-placed surface treatments. Deeper ruts may be shimmed with a truing and leveling course, with an overlay placed over the shim. If the surface asphalt is unstable, recycling of the surface may be the best option. If the problem is in the sub grade layer, reclamation or reconstruction may be needed. This type of surface deformation is also explained according toMiller,J.S.,Rogers,R.b. 1993. Rutting is the formation of longitudinal depression of the wheel paths, most often due to consolidation or movement of material in either the base or sub grade or in the asphalt concrete layer. Another, unrelated, cause of rutting is abrasion due to studded tires and tire chains.

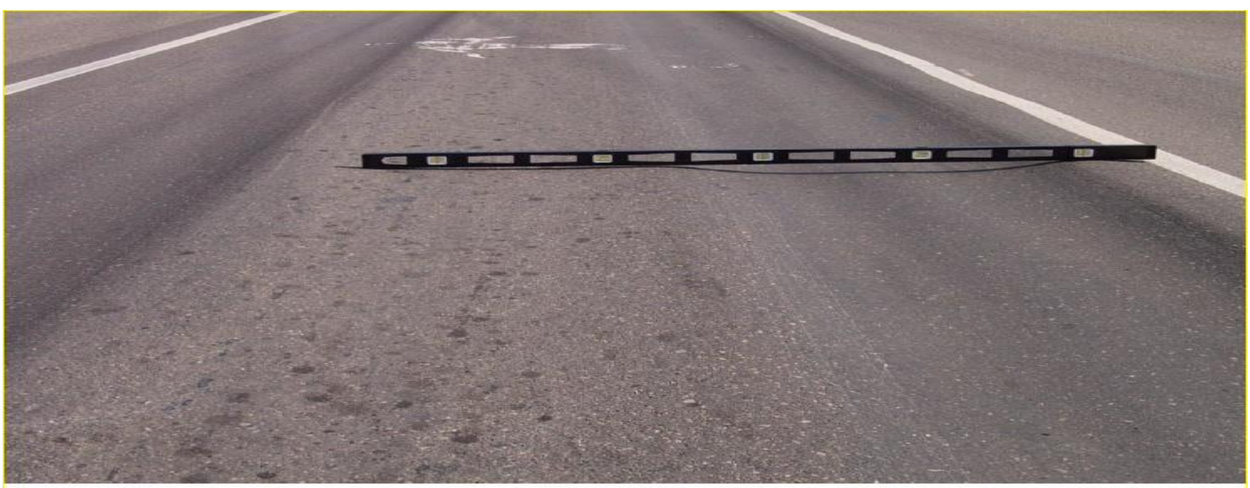


Figure 2.8.Rutting (Miller, J. S., Rogers, R. B. and Rada, G. R., 1993)

ii. 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 coarse 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. According to Shahin, M. Y.,1994 Shoving and corrugation are produced by traffic loading, but are indicative of an unstable liquid asphalt mix (e.g., cutback or emulsion)

Figure 2.9.Corrugation and Shoving. (Miller, J. S., Rogers, R. B. and Rada, G. R., 1993)

iii. 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 above 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.

iv. 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. According to Transportation Research Board, Guide to Earthwork Construction, 1990. Settlements/depressions in asphalt pavements may be due to frost heave, swelling or collapsing soil, or localized consolidation (such as that which occurs in poorly compacted backfill material at culverts and bridge approaches). Frost heave, soil swelling, and soil collapsing produce longer-wavelength surface distortions than localized consolidation.

Figure 2.10.Depressions (Catalogue of Road Defects (CORD) January 2013).

v. Swell

According to Dr.J.J.Magdum,1990. 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 sub grade. The expansion is typically caused by frost heaving or by moisture. Sub grades with highly plastic clays can swell in a manner similar to frost heaves (but usually in warmer months). Repair swells by excavating the inferior sub grade material and rebuilding the removed area. Reconstruction may be required for extensive swelling.

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 most common types of disintegration are:

i. Potholes

ii. Patches

i. 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. 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 .This idea is also supported by Shahin, M. Y., 1994. Potholes begin to form when fragments of asphalt concrete are displaced by traffic wheels, e.g., in alligator-cracked areas. Potholes grow in size and depth as water accumulates in the hole and penetrates into the base and subgrade, weakening support in the vicinity of the pothole.

Figure 2.11:- Potholes (Catalogue of Road Defects (CORD) January 2013).

ii. Patches:

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.

Figure: 2.12 patch(Catalogue of Road Defects (CORD) January 2013).

2.5.4 Surface Defects:

Surface defects are related to problems in the surface layer. The most common types of surface distress are:

i. Ravelling

ii. Bleeding

iii. Polishing

iv. Delamination

i. Ravelling:

Ravelling 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 break loose and leaves small, rough patches in the surface of the pavement. As the disintegration continues, larger aggregate breaks loose, leaving rougher surfaces. Ravelling can be accelerated by traffic and freezing weather. Some ravelling 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. According to Roberts, F. L., Kandahl, P. S., Brown, E. R., Lee, D.-Y., and Kennedy, T. W., 1991.and Shahin, M. Y., 1994. Ravelling and weathering occur as a result of loss of bond between aggregates and the asphalt binder. This may occur due to hardening of the asphalt cement, dust on the aggregate which interferes with asphalt adhesion, localized areas of segregation in the asphalt concrete mix where fine aggregate particles are lacking, or low in-place density of the mix due to inadequate compaction. High air void contents are associated with more rapid aging and increased likelihood of raveling

Figure: 2.13Ravelling (Catalogue of Road Defects (CORD) January 2013).

ii. Bleeding:

Distress Identification Manual for the Long-Term Pavement Performance Project, third edition, and 1993.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 flowable), 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 flowable) and the traffic forces the asphalt to the surface.[17]

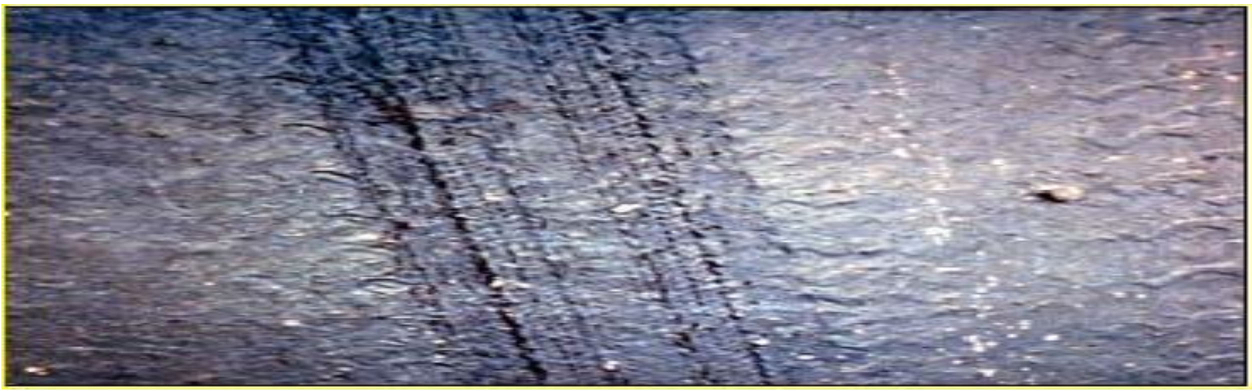


Figure:2.14 Bleeding(Catalogue of Road Defects (CORD) January 2013).

iii. 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[2].

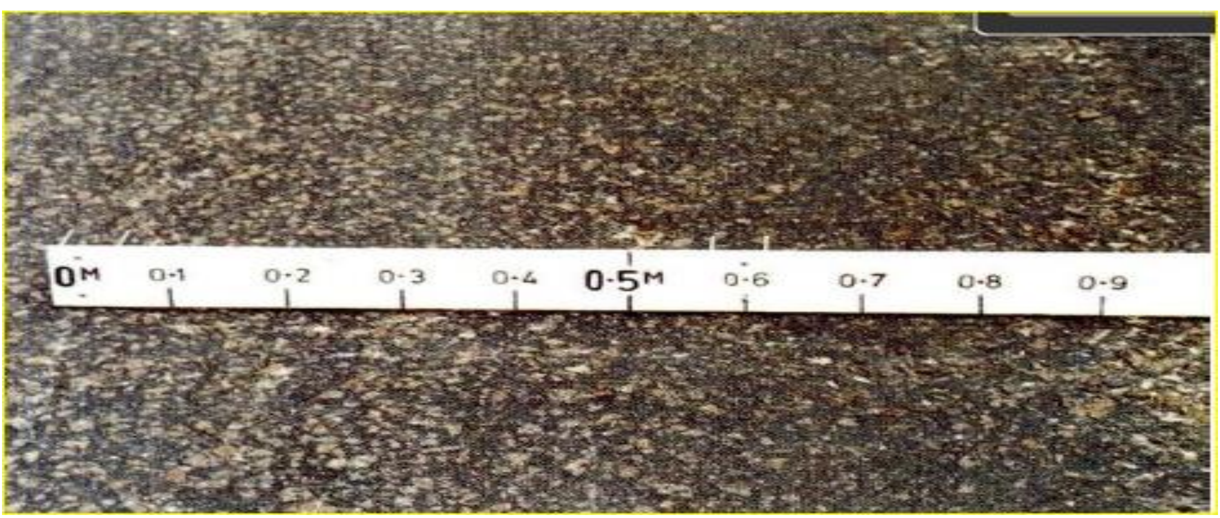


Figure: 2.15Polishing (Catalogue of Road Defects (CORD) January 2013).

iv. Delamination

Delamination is the localized loss of the entire thickness of an overlay. It is caused by the lack of a bond between the overlay and the original pavement. Water again is the culprit when it gets between the two layers of pavement. Delamination is usually confined to the wheel path area and takes several years after the overlay to become a serious problem. Once they occur, they are difficult to properly patch.

Cleaning the old surface and applying a light asphalt emulsion tack coat will go a long way toward alleviating this problem. A tack coat is especially helpful when the overlay thickness is two inches or less.

Figure 2.16: Delamination of an overlay (Miller, J. S., Rogers, R. B. and Rada, G. R., 1993)

2.6 Granular Pavement Materials

2.6.1 General

Granular pavement material is one of the important components of a flexible pavement structure. This material includes crushed rock, semi-crushed, mechanically stabilized, and modified or naturally occurring gravel “as dug” or “pit run”. The suitability of rocks for road construction depends on their mineral, chemical and physical properties.

2.6.2 Properties of unbound Pavement Materials

Unbound granular materials are generally used in road pavement as base and sub-base courses, which are an important component of roads as the surface compositions and foundation. 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. 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 below.

Table.2.1 properties of unbound materials.

Code	Description	Summary of Specification
GB1	Fresh, crushed rock	Dense graded, un weathered crushed stone, on-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

Notes: 1. These specifications are sometimes modified according to site conditions, material type and principal use.

2. GB = Granular base course, GS = Granular sub-base, GC = Granular capping layer.

I. **Base Course Materials**

Materials such as crushed quarried rock, crushed and screened, mechanically stabilized, modified or naturally occurring “as dug” or “pit run” gravels can be used as base course material.

According to the ERA pavement design manual the properties for base course materials is given below.

a. 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 below.

Table 2-2: Grading Limits for Graded Crushed Stone Base Course Materials (GB1).

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

Source: ERA Standard Technical Specification – 2002

Note 1. For paver-laid materials a lower fine 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 per cent. There is usually no need to carry out CBR tests during construction.

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 quartzitic 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 2-2 contains three recommended particle size distributions for suitable materials corresponding to maximum nominal sizes of 37.5 mm, 28 mm and 20 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 per cent 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 coarse 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. When used as a base course, the material should be compacted to a density equal to or greater than 98 per cent of the maximum dry density achieved in the ASTM Test Method D 1557 (Heavy Compaction). When compacted to this density in the laboratory, the material should have a minimum CBR of 80% after four days immersion in water (ASTM D 1883).

Table 2.3: Recommended Particle Size Distributions for Mechanically Stable Natural Gravels and Weathered Rocks for Use as Base Course Material (GB2, GB3)

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--15	5--15	5--15

Source: ERA Standard Technical Specification – 2002

II. Sub-Base(GS)

The sub-base is an important load spreading layer in the completed pavement. It enables traffic stresses to be reduced to acceptable levels in the subgrade, it acts as a working platform for the construction of the upper pavement layers and it acts as a separation layer between subgrade and base course.. According to the ERA pavement design manual the requirements to use as sub-base material is discussed below.

a. Bearing Capacity

A minimum CBR of 30 per cent is required at the highest anticipated moisture content when compacted to the specified field density, usually a minimum of 95 per cent 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 D 698 (Light Compaction). In such conditions, the sub-base material should be tested in the laboratory in an unsaturated state. Except in arid areas, if the base course allows water to drain into the lower layers, as may occur with unsealed shoulders and under conditions of poor surface maintenance where the base course is pervious, saturation of the sub-base is likely. In these circumstances, the bearing capacity should be determined on samples soaked in water for a period of four days. 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.

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 ravelling. 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. The material should be well graded and have a plasticity index at the lower end of the appropriate range for an ideal unpaved road wearing course under the prevailing climatic conditions. These considerations form the basis of the criteria given in Tables 2-4 and 2-5. Material meeting the requirements for severe conditions will usually be of higher quality than the standard sub-base (GS). If materials to these requirements are unavailable, trafficking trials should be conducted to determine the performance of alternative materials under typical site conditions. In Ethiopia, laterite is one of the widely available materials and can be used as a sub-base material. Laterite meeting the gradation requirements of Table 2-5 can be used for traffic levels up to 3x106 ESA provided the following criteria is satisfied:

Plasticity Index (%) < 25

Plasticity Modulus (PM) < 500

CBR (%) > 30

Table 2-4: Recommended Plasticity Characteristics for Granular Sub-Bases (GS)

Climate	Typical Annual Rainfall	Liquid Limit	Plasticity Index	Shrinkage
Moist tropical and wet tropical	>500mm	<35	<6	<3
Seasonally wet trop	>500mm	<45	<12	<6
Arid and semi-arid	<500mm	<55	<20	<10

Source: ERA Standard Technical Specification – 2002

Table 2-5: Typical Particle Size Distribution for Sub-Bases (GS) Which Will Meet Strength Requirements

Test Sieve (mm)	Percentage by mass of total 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

Source: ERA Standard Technical Specification – 2002

III. **Selected Subgrade Materials and Capping Layers (GC)**

IV. 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 (as described below) placed on an S1 or S2 subgrade will allow to select a pavement structure as for an S3subgrade. An additional 5 cm of "GC" material may allow to consider an S4 subgrade class.

The requirements are less strict than for sub-bases. A minimum CBR of 15 per cent 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 per cent of the maximum dry density in the ASTM Test Method D 1557(Heavy Compaction).

In estimating the likely soil moisture conditions, the designer should take into account the functions of the overlying sub-base layer and its expected moisture condition and the moisture conditions in the subgrade. If either of these layers is likely to be saturated during the life of the road, then the selected layer should also be assessed in this state. Recommended grading or plasticity criteria are not given for these materials. However, it is desirable to select reasonably homogeneous materials since overall pavement behavior is often enhanced by this. The selection of materials which show the least change in bearing capacity from dry to wet is also beneficial.

Table 2-6: Sub-grade strength class

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

2.7 ERA Classification and Quantification of Damages.

According to [6] The damage classified in the VIZIR method is relevant primarily to flexible pavements with Bituminous surfacing's. This damage is divided into two categories:

Type A damage

This characterizes the structural condition of a pavement, affecting either all of its courses and the ground or the surfacing only. This damage is caused by a structural deficiency of the pavement, and its identification is used in the search for a solution in conjunction with other criteria, in particular the bearing capacity as characterized by the static deflection.

Type damage includes four types:

- Deformation
- rutting
- (fatigue) cracking
- crazing

Type B damage

This damage leads to repairs that are generally unrelated to the pavement's structural capacity. Itnmay be caused by defective placement, by deficient product quality, or by some special local condition, possibly aggravated by traffic.

Type B damage includes:

• Cracking other than fatigue cracking, i.e. longitudinal joint cracks, transverse thermal shrinkage cracks, and longitudinal and transverse clay shrinkage (desiccation) cracks,

• Potholes,

• Raveling and, more generally, all surfacing defects such as fretting, bleeding, etc.

- **Survey and Grading of Damage**
  - The survey is intended to record, for any damage:
    - its type
    - its severity
    - its extent, i.e. the length of road affected, or, as appropriate, the area
  - The survey can be done manually, while travelling along the road on foot or by car.
  - The operator in this case enters his observations (identification of damage and estimate of its severity) on a route diagram, a document representing the route as a straight line, the scale and precision of which are appropriate to the type of study
  - In the route diagram, damage is represented by a rectangle of which the background (white, grayish, or black) indicates the level of severity, while the two sides represent the co-ordinates of the beginning and end of the damaged zone, or in other words, its extent.

Table 2-7: Level of severity of Type A damage

Damage \ Severity	1	2	3
Deformation rutting	Perceptible to user but small f < 2 cm	Severe deformations, localised subsidence or rutting 2 ≤ f ≤ 4 cm	Deformation severely affecting safety or travel time f ≥ 4 cm
Cracking	Hair line cracks in wheel tracks or centerline	Open and / or branching cracks	Markedly branched and/or wide open cracks: edges sometimes damaged
Crazing	Fine crazing with no loss of materials large mesh (> 50 cm)	Tighter crazing (< 50 cm) sometimes accompanied by loss of materials, stripping, and incipient potholes	Very open crazing forming blocks (< 20 cm), sometimes accompanied by loss of materials
Patching and Repair	☐ Either rebuilding of part or all of pavement	Surface work related to type A defects	
	☐ Or surface work related to type B defects	☐ Repair has stood up well	☐ Visible damage to repair itself

Table 2-8: Level of severity of Type B damage

Damage \ Severity	1	2	3
Longitudinal joint crack	Hair line isolated	• Wide (1 cm or more) without stripping or • Hair line & branching	• Wide with spalling of edges or • Wide and branching
Pothole	• Number < 5 • Dia, not more than 30 cm	5 to 10 <5 or Dia. 30 cm Dia. 100 cm	> 10 5 to 10 or Dia. 30 cm Dia. 100 cm
	Per 100 m of pavement		
Movement of material Ravelling, fretting, bleeding, etc.	Localised. Roadbase not visible	Continuous or localised but roadbase visible	Continuous and roadbase visible
	Localised.	Continuous in one wheel track	Continuous and "marked" in one wheel track

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Area

The research was conducted in Agaro town which is located in Oromia National Regional State and situated390km from Addis Ababa. It sits at latitude and longitude of 7°51′N36°35′Eand 7°51′N36°35′E, and an elevation of 1560 meters above sea level. Regarding infrastructure the town has asphalt and gravel roads connecting it to different weredas in the zone and surrounding zones. In the town, there are four main roads but the asphalt concrete road covers on the way from Jimma to Bedele town.

Recently most of the existing Asphalt has been deteriorated and damaged badly and besides the city has been experiencing a continuous growth and change. Economically the city is transforming from a predominantly administrative and service center in to a financial and trade center. Due to rapid economic growth and change, there is high mobility of goods and passengers which leads to high transportation demand.

Investigations were carried out from “Bulbulo Kebele-Koye Ber” in Agaro town which is around 15km and more attention were given to more damage section of the road. In this study the researcher carried out in-situ test and laboratory tests from the worst road failure section pits from the existing road on different layers (Asphalt Concrete, Base course, sub base and subgrade). The latest traffic count was performed previously and presented under this report which has been done from ERA, In this section all the test results were presented in tables and charts in order to quick understanding of the properties of the materials used along with the project specification and the latest traffic count data analysis were discussed at the end of this chapter

Figure.3.1.Agaro map (Google Earth accessed on April19, 2015)

3.2 Research design

The research strategies adapted for this research were qualitative and quantitative research of exploratory type. The overall approach was four stages process; the basis of the research was established, necessary data collected, analyzed, and conclusions and recommendations had been made based on the findings. The methods of data collections employed for the research was case study (cross-sectional study), desk study, and Laboratory test. The case study and desk study were analyzed in relation to theoretical propositions, and the laboratory test results were compared with standards set by national and international highway manuals.

3.3 Study Variables

The research variables are both the independent and dependent variables.

Dependent variable:

Causes of Defects

Independent variables:

- Distress Types
- Gradation
- Atterberg's Limit
- Natural moisture content
- CBR
- Thickness measurement
- traffic loading
- locations of severely pavement damage
- Remedial measures

3.4 Test Sample collection and Process of Results

The scope of this detail investigation for failed section of the road is to addresses the general objectives to investigate the causes of asphalt concrete pavement failures/defects and its remedial measures. For this planned purpose, the samples from sub grade layer, sub base layers, base course layers and asphalt layer disturbed and undisturbed were collected, observations and the corresponding engineering assessment were done by Geotechnical Engineering principles. Therefore in this research the researcher basically identify the causes of Asphalt pavement damages and its remedial measures to minimize the maintenance cost and support the economic growth of our country.

Some localized pavement distresses like shoving or corrugations, potholes, alligator cracks, block cracks, edge cracks, longitudinal cracks, Ravelling deformation and Rutting were observed.

Major pavement distresses observed on this road section are as a result of the pavement structure failure. This road section suffers a pavement failure as clearly shown during the condition survey. The sub base is entirely saturated with water and loses its strength and changes its grading as well. Refer the attached pictures in Figure 19-26 which shows the pavement failure type.

3.5 Sampling Frame

The research was coveronly15km Asphalt concrete pavement from “Bulbulo Kebele-KoyeBer” in Agaro town. In order to attain the purpose of this research work the following three sampling frames were adopted during the study period.

i. **Cracking**

The most common types of cracking are Fatigue cracking, longitudinal cracking, transverse cracking, block cracking Slippage cracking, Reflective cracking and Edge cracking.

ii. Surface Deformation

Pavement deformation is the result of weakness in one or more layers ofthe pavement that has experienced movement after construction. The Deformation May be accomplished by cracking. The basic types of surface deformation are Rutting, corrugation or shoving, Depression and swell.

iii. 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 most common types of disintegration are potholes and patches.

iv. Surface Defects:

Surface defects are related to problems in the surface layer. The most common types of surface distress are:

i. Ravelling

ii. Bleeding

iii. Polishing

iv. Delamination

3.6 Sampling Size and Procedure

For the effective distribution of the research instruments, it was focused on purposive sampling. The sample size covered route from “Bulbulo Kebele-Koye Ber” which contains the most damaged and non-damaged Asphalt concrete pavement in Agaro town. The list of pavement damages and deterioration were obtained from these routes. In this method from medium damage to highly sever damaged were analyzed.

During field observation quantitative and qualitative data were collected from the worst failure portions of road based on standards. The qualitative data refers to the existence of poor road making materials on different layers, construction quality, and drainage related problems and pavement maintenance. While the quantitative data refers to the disturbed soil samples which are collected at different locations of the road showing with worst failure rates for laboratory test.

To determine the relation between Asphalt, base course, sub base and sub grade with road pavement failure the following tests were done in the laboratory.

i. **Sub grade**

The sub-grade is the under most layer of a pavement and as such is one of the main concerns of a pavement design. Many pavement failures could be traced to insufficient consideration given to the natural sub-grade material, especially in the case of problematic soils, the identification of which is of paramount importance and half the solution towards the mitigation measures.

The pavement sub-grade material was investigated using test pitting to a depth up to 1.2m from the top surface[8]. The result of the analysis is used to identify problematic soils along the study road stretch, classify the whole road stretch into uniform sections of identical sub-grade strength only on most damaged part of the roads.

The following tests were done on sub grade layers:-

- Particle size distribution/Grain size analysis
- Atterberg Limit

- Moisture - Density Relation of Soil (compaction test)
- CBR(both disturbed & DCP)
- Natural moisture content
- Soil classification
- Thickness measurement

ii. Sub base

All the tests done for the sub-grade described above are also carried out on the sub-base of the failed pavement

iii. Base course

The following tests were done on base course layers:-

- Wet & dry Density
- Moisture - Density Relation of Soil (compaction test)
- CBR
- Natural moisture content
- Gradation
- Thickness measurement

iv. Asphalt

- Asphalt extraction from non-damaged part

3.7 Data Collection Process

In order to attain the purpose of this research work ethical considerations were considered and official letter were collected from JIT and Regional ERA office to collect the actual data and to perform laboratory tests.

In order to generate data for the general and specific objective, field survey, laboratory test and reconnaissance survey were carried out on selected route. To collect the primary data the following samples are taken from different boreholes at the location where most damaged asphalt.

Figure 3.1 Borehole BH-1 at station 385+000(Nov-15)

Figure 3.2 Borehole (BH-2) at station 398+000 (29-Nov-15)

Figure 3.3 Borehole BH-3 at station 386+000 (30-Nov-15)

Figure3.4 Borehole BH-4 at station 397+000 (30-Nov-15)

Figure 3.5 Borehole BH-5 at station 396+000 none damaged Asphalt for comparisons. (30-Nov-15)

Figure 3.6: Borehole Number BH-6 (Lat7°51′12.5568’′N & Lon. 36°35′46.1859’′E) DCP test (9 December 2015)

3.7.1 Field observation

i. Pavement condition survey

The main objective of the pavement condition survey was to evaluate the state of the existing pavement by assessing the physical conditions of the existing pavement. Before the commencement of the detail pavement evaluation, the entire road length was visually assessed and it is attempted to identify the type of failure occurred on the road surface.

ii. Existing pavement thickness and roadway width

The width of the existing road surface is measured using a meter tape and during pit excavation and sampling in some areas the pavement edges were difficult to establish, as the camber of the road is changed due to repetitive raveling and erosion .Hence the width of the road is established mostly by judgment and measurement. The thickness of the road material is measured in each test pit using a meter tape. The width of the road is around 7m and the thickness of the road material is given in the result part.

3.7.2 Laboratory Tests

Samples were obtained from the most failed section of the road at different layers. These samples were collected from 4 different location of the road with worst failure rates and then brought to the laboratory using a rented vehicle for testing. These samples were first air dried under the sun to allow moisture to escape before basic test were performed. Basic tests were performed in the laboratory, these are Atterbergs limit (for comparison and determination of liquid limit and plastic limit), Grain size analysis (for determination of percentage of clay, silt and, sand and determination of coefficient of uniformity & curvature), Compaction test (for determination of Maximum dry density and optimum moisture contents), California Bearing ratio (CBR) test (for evaluation of mechanical strength of different layers), Natural Moisture content, Soil classification, Gradation, and Asphalt extraction test.

Enough samples (50kg samples from each layer) were collected from each test pit for every pavement layer to perform the necessary tests. The tests are performed according to AASHTO specification. The necessary tests were conducted for all the samples and the summary of the result is presented in a tabulated form.

CHAPTER FOUR

Result and Discussion

4.1 Field Test Result

4.1.1 Condition Survey

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.

Table 4.1 Pavement condition survey

No.	Station	Failure Type	Test pit	Level of severity	Remark
1	385+000	Block cracks	BH-1	Severity level 3	Visual inspection & measurement, ERA type B damage
2	398+000	Edge cracks	BH-2	Severity level 3	Visual inspection & measurement, ERA type B damage
3	386+000	Alligator carracks	BH-3	Severity level 3	Visual inspection & measurement, ERA type A damage
4	397+000	Alligator cracks	BH-4	Severity level 3	Visual inspection & measurement, ERA type A damage
5	396+500	Non damaged	BH-5	Non damaged	For comparisons

The severity level is determined according to ERA manuals, actual measurement of defects and visual inspection (APPENDIX H)

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

Figure 4.1: Shoving or Corrugations (29-Nov-15)

Figure 4.2: Alligator cracks (29-Nov-15)

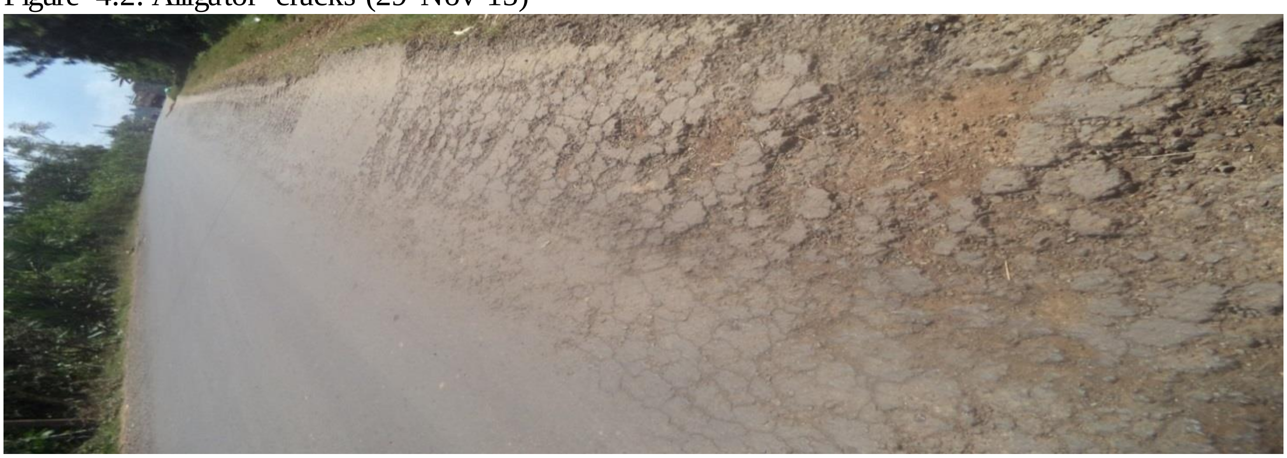


Figure 4.3: Edge cracking (29-Nov-15)

Figure 4.4: Potholes (29-Nov-15)

Figure 4.5 longitudinal cracks and edge cracks (29-Nov-15)

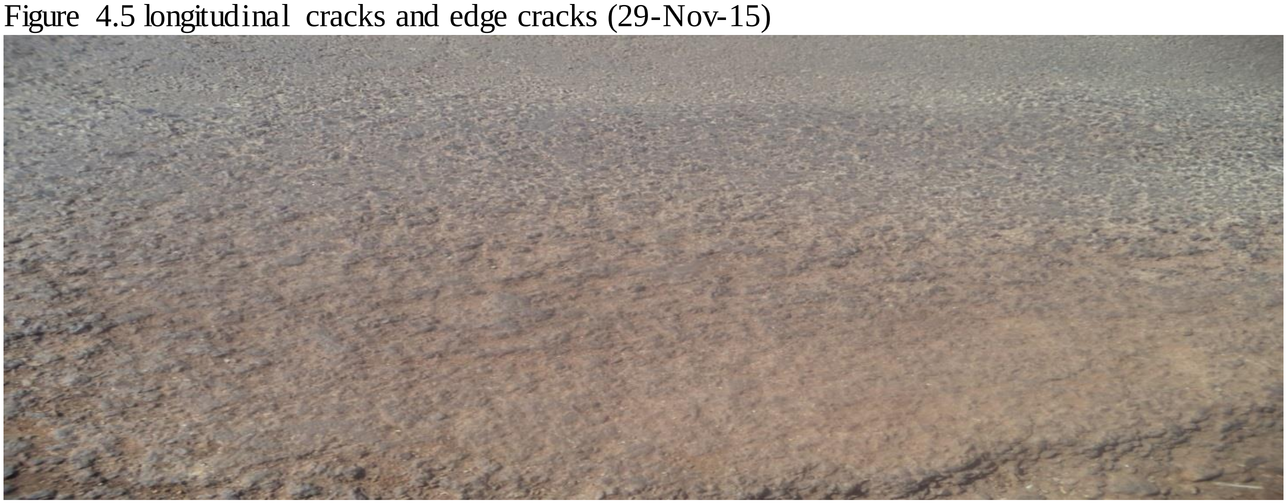


Figure 4.6: Ravelling (29-Nov-15)

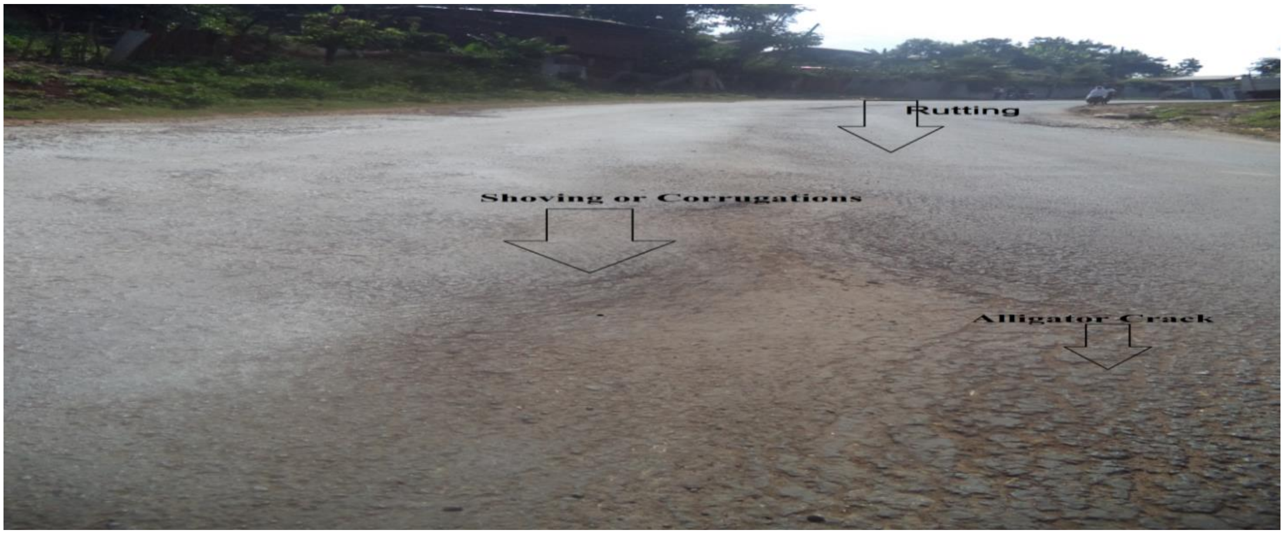


Figure 4.7: Rutting, alligator cracks and shoving (29-Nov-15)

Figure 4.8: Edge cracking (29-Nov-15)

4.1.2 Field Investigation Result

Based on the actual pavement measurement at different pit location the following result were obtained.

Table 4.2.Summary of actual pavement thickness

BH No.	Station	Failure Type	Thickness of road layers (cm)			Remark
			Asphalt	Base	Sub base	
BH-1	385+000	Block cracks	4	13	20	
BH-2	398+000	Edge cracks	3.5	12	19	
BH-3	386+000	Alligator carracks	4.3	13.5	18	
BH-4	397+000	Alligator cracks	4	15	20	
BH-5	396+500	Non damaged	4.5	15	20	

4.1.3 Field Density Test

Table 4.3 Field density test

Sample No.	Station	Pavement layers									Remark
		Base Course			Sub base			Sub grade			
		Moisture content %	Bulk density (g/cc)	Dry density (g/cc)	Moisture content %	Wet density(g/cc)	Dry density (g/cc)	Moisture content %	Bulk density(g/cc)	Dry density(g/cc)	
BH-1	385+000	5.30	2.86	2.70	11.40	1.85	1.64	14.60	1.54	1.31	
BH-2	398+000	4.80	2.78	2.63	15.00	1.97	1.71	13.50	1.60	1.41	
BH-3	386+000	3.80	2.18	2.09	5.90	2.10	1.98	14.40	1.58	1.38	
BH-4	397+000	4.80	2.93	2.78	7.90	1.90	1.80	14.70	1.75	1.53	

4.2 Laboratory Tests

4.2.1Atterberg Limits Test Results

Atterberg limit test was made on Base course, Sub base and Sub grade on each boreholes. The testing procedure was done according to AASHTO T89, T90 and M145. The plastic limits, liquid limits and plastic index are summarized and tabulated below.

Table 4.4Atterberg limits of pavement layers

Sample No.	Station	Type of Failure	Atterberg limits									Remark
			Base Course			Sub base			Sub grade			
			LL	PL	PI	LL	PL	PI	LL	PL	PI	
BH-1	385+000	Block cracks	3.00	0.0	3.00	43.02	20.06	22.96	59.0	28.00	31.00	
BH-2	398+000	Edge cracks	3.00	0.0	3.00	34.00	27.00	7.00	38.0	25.00	13.00	
BH-3	386+000	Alligator carracks	6.00	0.0	6.00	8.00	4.00	4.00	57.0	28.00	29.00	
BH-4	397+000	Alligator carracks	4.00	0.0	4.00	23.00	5.00	18.00	62.0	53.00	9.00	
	Average		**4.00**	**0.0**	**4.00**	**27.00**	**14.01**	**12.99**	**54.0**	**33.50**	**20.50**	

4.2.2 Grain size Analysis Result

The distribution of particles of different size in the soil mass is called Grading and the grading of soil can be obtained from the particle size distribution curve. The mechanical analysis consists of determination of the amount and portion of coarse material by the use of sieve. The grain size analysis results are plotted below and the data is given in Appendix.

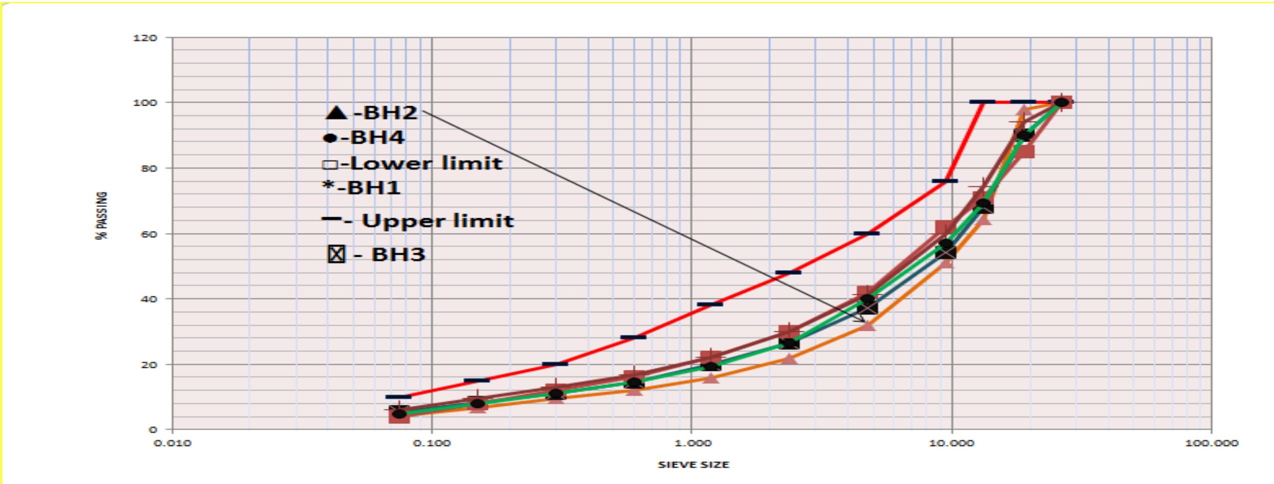


Figure 4.9 Grain size distribution of sub grade material.

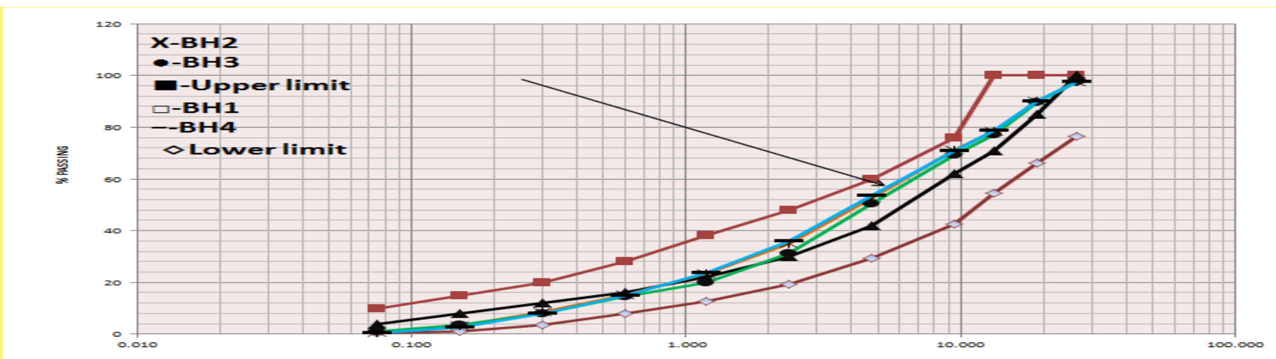


Figure 4.10Grain size distribution of Sub base material.

Remark:Average Uniformity coefficent(Cu) and Coefficent of curvature(Cc) of the fourborholes of sub base materila are 0.03 and 16.68 respecively.

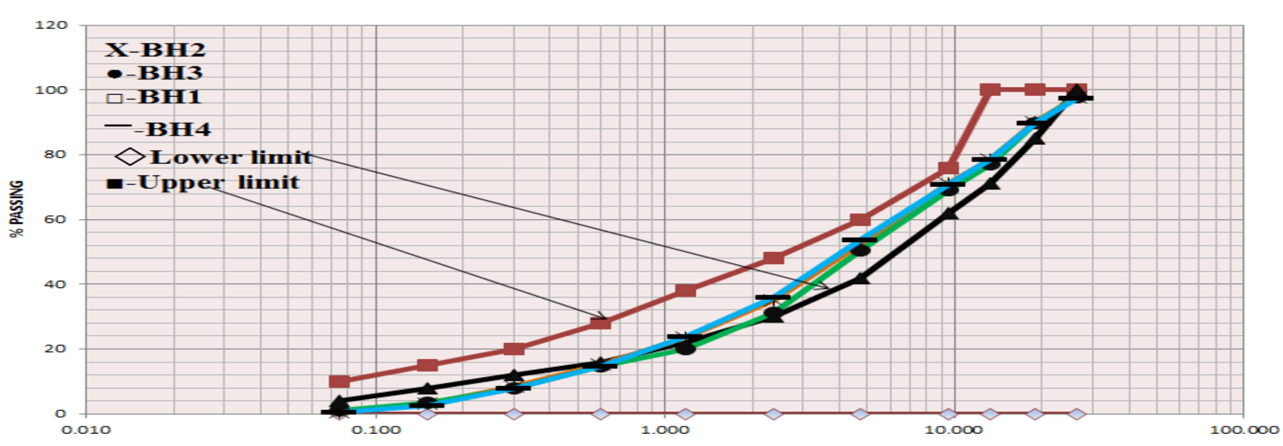


Figure 4.11Wash gradation result for four boreholes of base course material.

Remark:Average Uniformity coefficent(Cu) and Coefficent of curvature(Cc) of the four borholes of base course materila are 0.11 and 10.62 respectively.

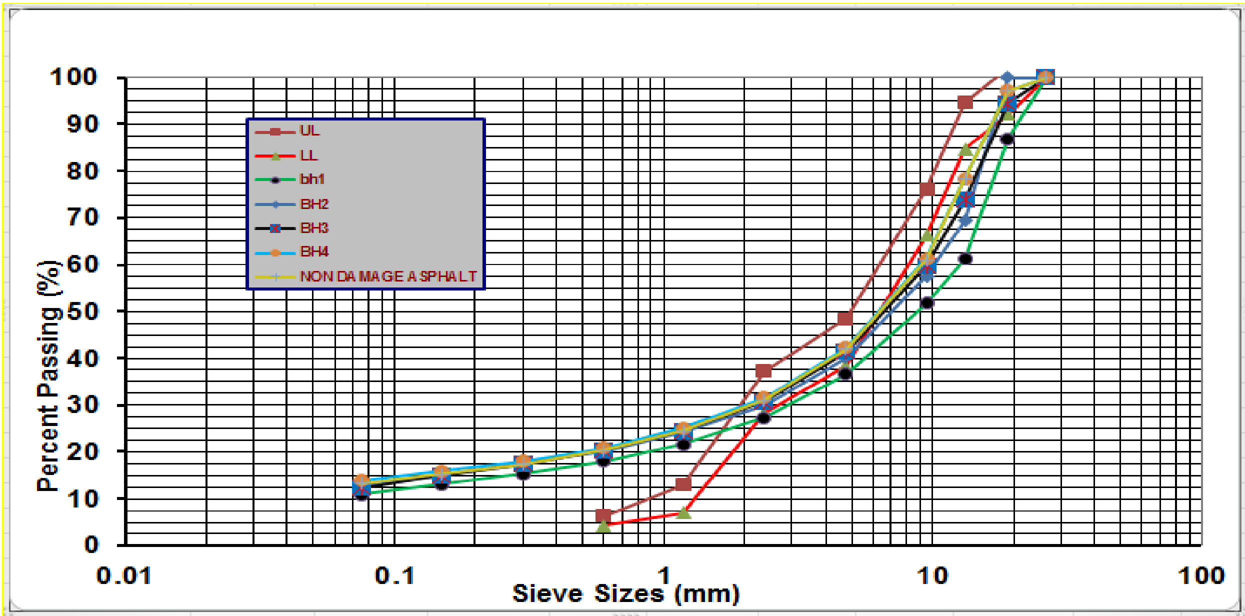


Figure 4.12 Gradation result for four boreholes and non-damage asphalt.

4.2.3 Compaction Tests

Compaction of a soil may be defined as the process of closely packing the soil particles together by reducing the air voids in the soils, by mechanical means.

The soil to be tested is thoroughly mixed with measured quantity of water and is 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 is trimmed to the top of the mold. The result of maximum dry density and optimum moisture content are given in the table and figures below.

Table 4.5Summarized Modified proctor test laboratory result

Sample No.	Location /Station	Type of Failure	Pavement layers						Remark
			Base Course		Sub base		Sub grade		
			MDD(g/cc)	OMC (%)	MDD(g/cc)	OMC (%)	MDD(g/cc)	OMC (%)	
BH-1	385+000	Block cracks	2.77	6.80	1.69	11.79	1.56	14.32	
BH-2	398+000	Edge cracks	2.73	6.40	1.82	14.50	1.59	16.83	
BH-3	386+000	Alligator carracks	2.21	5.23	1.98	6.13	1.48	14.55	
BH-4	397+000	Alligator carracks	3.09	6.40	1.85	6.26	1.80	12.84	
	Average		**2.70**	**6.21**	**1.83**	**9.67**	**1.61**	**14.64**	

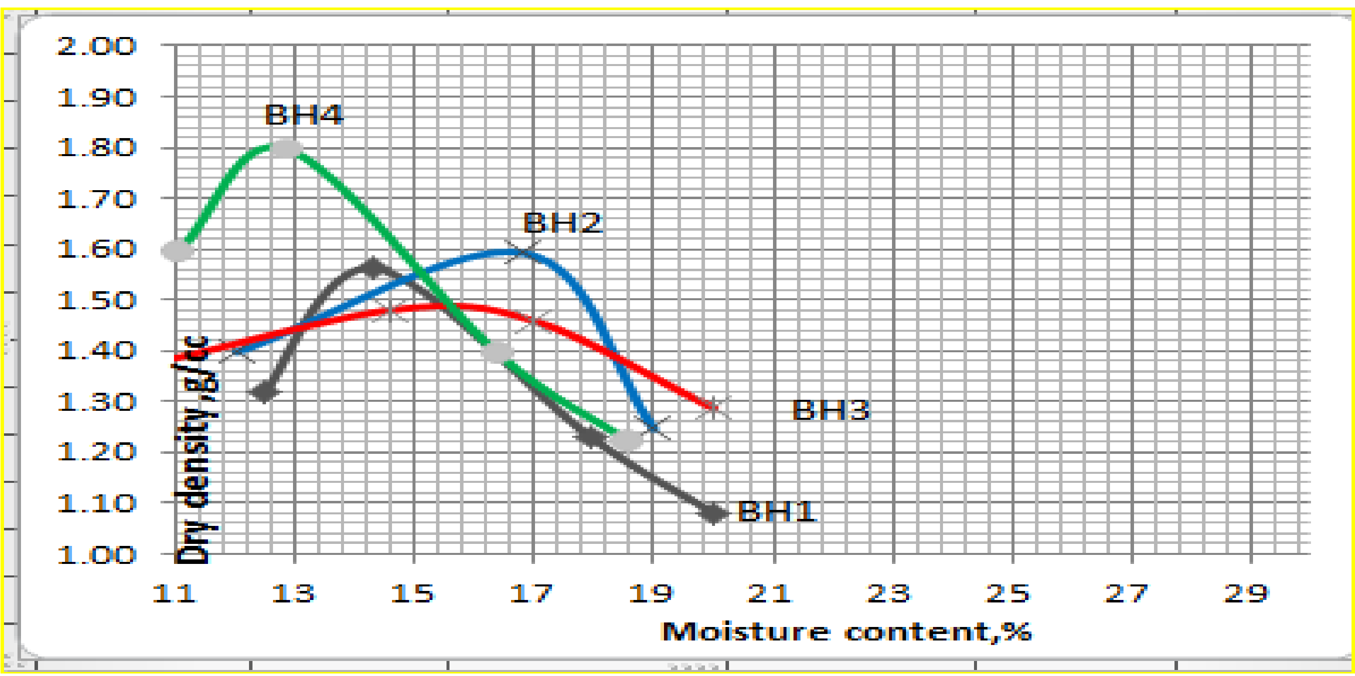


Figure4.13 The Laboratory Test Result for OMC & MDD of Subgrade Layer

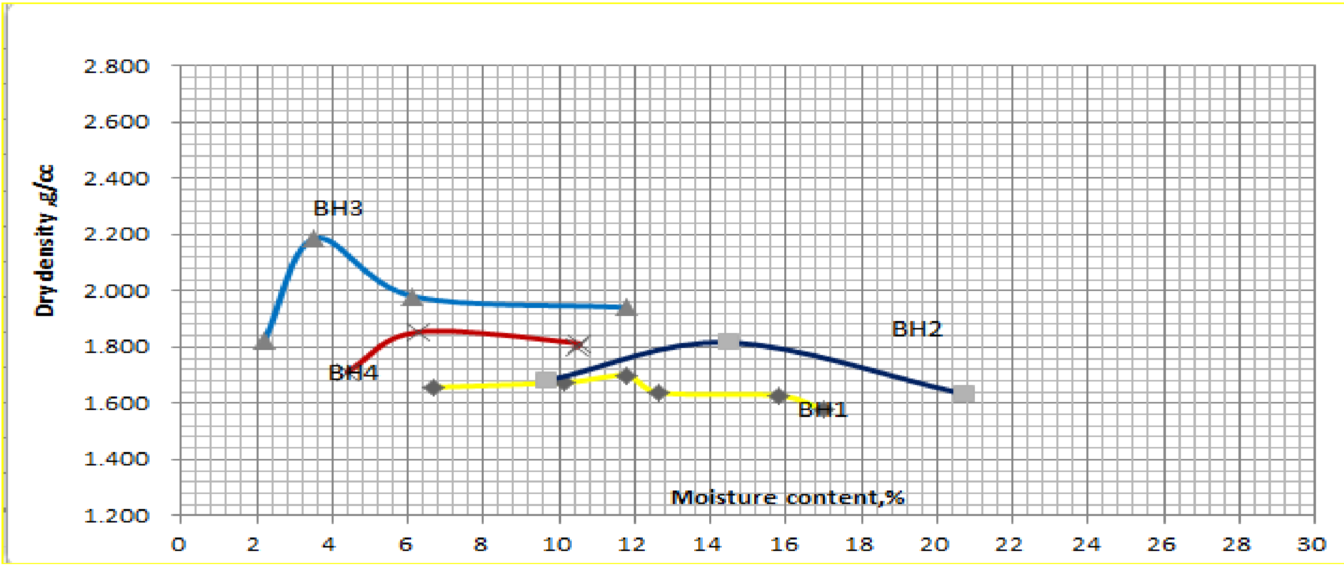


Figure4.14 The Laboratory Test Result for OMC and MDD of Sub base Layer

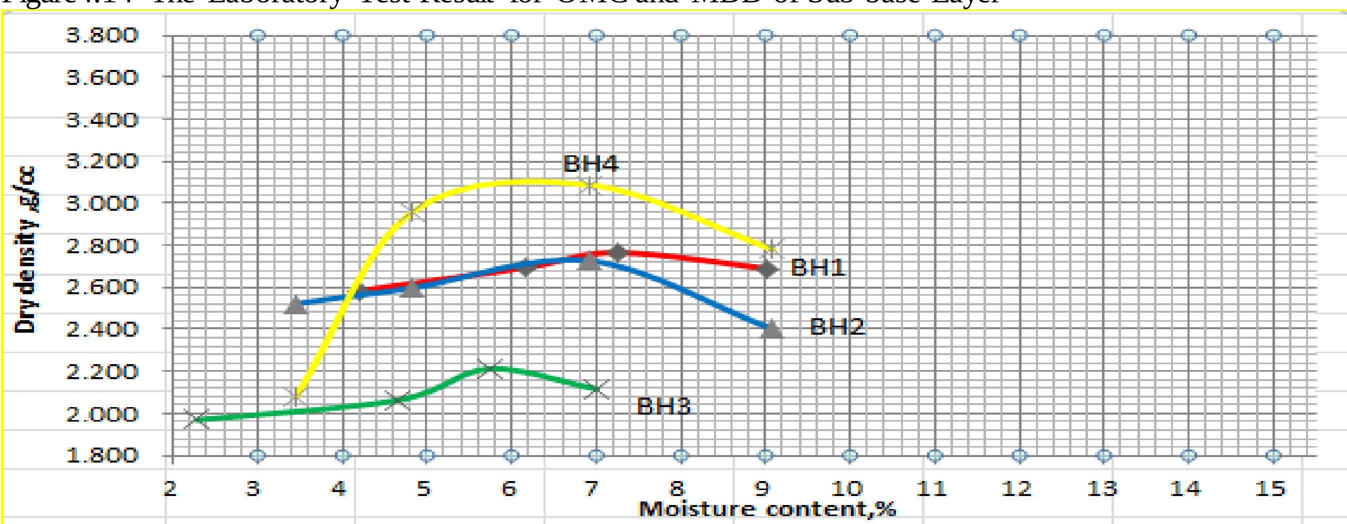


Figure4.15 The Laboratory Test Result for OMC and MDD of Base course Layer

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 CBR for 65 blows is determined from the graph for maximum dry density. The following result were obtained during CBR test and summarized below as.

Table 4.6Three point California bearing ratio Laboratory Test result

Sample No.	Station	Type of Failure	Pavement layers																	
			Base Course						Sub base						Sub grade					
			2.54mm			5.08mm			2.54mm			5.08mm			2.54mm			5.08mm		
			No. blows			No. blows			No. blows			No. blows			No. blows			No. blows		
			10	30	65	10	30	65	10	30	65	10	30	65	10	30	65	10	30	65
BH-1	385+000	Block cracks	36.0	74.4	173.5	44.4	148.5	275.3	42.6	51.7	48.0	112.7	120.1	83.1	7.4	14.8	15.0	9.2	36.9	17.7
BH-2	398+000	Edge cracks	25.4	90.5	122.2	37.1	154.1	319.6	36.8	75.9	177.0	45.3	151.5	280.8	5.9	14.2	10.0	7.8	17.0	16.1
BH-3	386+000	Alligator carracks	69.0	106.2	140.3	133.6	154.1	205.7	43.6	56.0	61.9	72.6	91.1	115.0	3.3	4.5	7.8	5.3	6.9	13.2
BH-4	397+000	Alligator carracks	15.9	33.9	147.6	28.4	98.0	287.9	44.4	53.7	51.7	117.1	124.8	86.4	3.1	4.3	7.4	4.5	6.3	11.8
	Average		**36.6**	**76.3**	**145.9**	**60.9**	**138.7**	**272.1**	**41.8**	**59.3**	**84.7**	**86.9**	**121.8**	**141.3**	**4.9**	**9.5**	**10.1**	**6.7**	**16.8**	**14.7**

4.3 Extraction of Bitumen & Mechanical Analysis of Extracted Aggregate

The mechanical extraction of bituminous content from both the damaged and non-damaged asphalt were done according to AASHTO-T 30-06, T164 test procedure. The extracted aggregates were washed with Solvent Benzene to remove fines smaller than 0.075mm and the remaining aggregates were used for sieve analyses. The extracted aggregate soaked for 24hours using solvent and Centrifuge extractor were used to detach the aggregates from the bitumen. The following results were obtained from the Extraction test.

Table 4.7 Laboratory result of Bitumen content and sieve analysis of Asphalt

EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE											Test Method- AASHTO T 30-06			
	Non-Damage		BH-1		BH-2		BH-3		BH-4		ERA		
Sieve(mm)	% passing	Bitumen Content (%)	% passing	Bitumen Content (%)	% passing	Bitumen Content (%)	% passing	Bitumen Content (%)	% passing	Bitumen Content (%)	Spec. L. Limit	Spec. U. Limit	Remark
26.5	100.00	5.00	100.00	3.12	100.00	2.64	100.00	2.16	100.00	2.29	100	100	
19	97.17		86.93		100.00		90.74		96.04		85	100	
13.2	78.33		61.19		69.39		68.95		65.27		71	100	
9.5	61.07		51.76		57.54		57.62		53.33		62	76	
4.75	41.95		36.56		40.15		41.79		35.73		42	60	
2.36	31.05		27.34		29.95		31.89		27.54		30	48	
1.18	24.56		21.62		24.13		25.50		22.36		22	38	
0.6	20.35		17.98		20.29		21.23		19.22		16	28	
0.3	17.38		15.29		17.55		18.21		17.31		12	20	
0.15	15.31		13.2		15.02		15.70		14.92		8	15	
0.075	13.31		10.96		12.42		13.06		12.94		4	10	
Pan	9.58		6.21		7.97		8.83		9.53				
Total			1465.71										

4.4 Dynamic Cone Penetration (DCP)

Dynamic cone peneteration (DCP) has been widely used as a simple, but effective means of determing the insitu shear strength of sub grade materials and pavemnt layers.California Bearing Ratio (CBR) is the most commonly used measure of soil bearing capacity. The DCP test provide an indication of material in-situ resistance to peneteration. If the DCP cone peneterates quickly in to the soil , it indicates the material has poor strength or insufficent compaction.

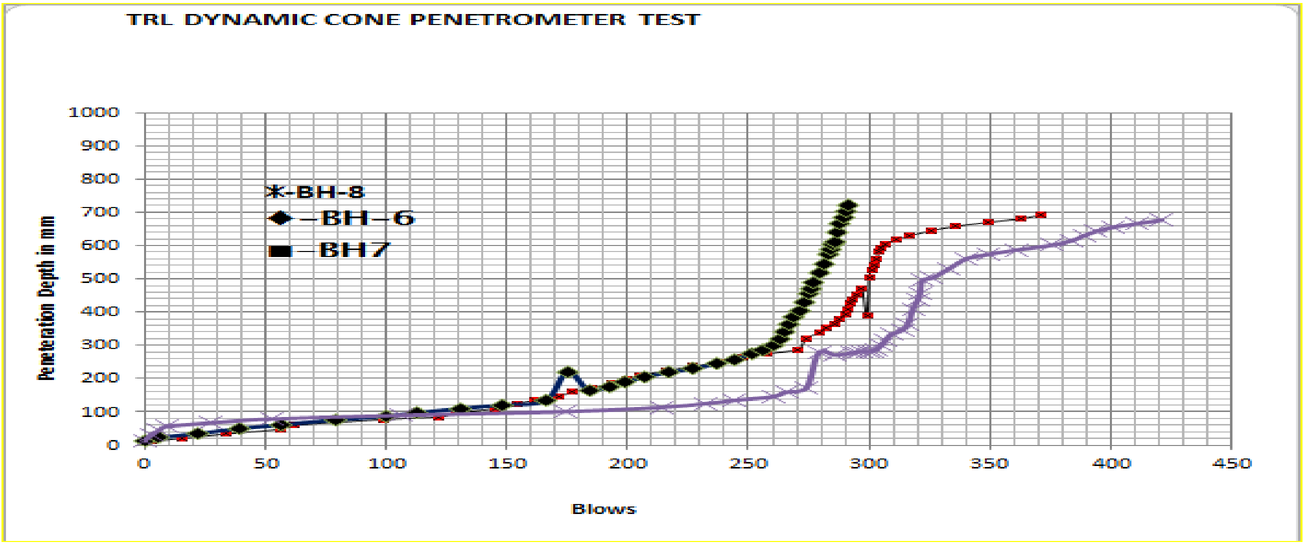


Figure 4.16 Dynamic cone penetration results at three boreholes

5. Discussions

5.1 Road Surface defects

From the pavement condition survey, the road is in bad conditions. Shoving or corrugation, alligator cracks, edge cracks, potholes, longitudinal cracks, deformation, raveling and rutting are the most common defects observed along the study area. The Table below shows the different types of failures obtained in Agaro road and rating of defects.

Table 4.8 Rating of road failure in Agaro town.

No.	Distress Type		Existence		Level of Severity Rating			Remark
					high	Medium	Low	
			Yes	No				
1	Cracking	Fatigue cracking	√		√			Visual evaluation & Type A damage
		Longitudinal cracking	√			√		Visual evaluation & Type B damage
		Transverse cracking		√				Visual evaluation & type B damage
		Block cracking	√		√			Measurements5x5mm &

								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 & 4m 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
		Swell		√				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	Ravelling	√			√		Visual evaluation length & type B damage
		Bleeding		√				Visual evaluation length & type B damage
		Polishing		√				Visual evaluation
		Delamination		√				Visual evaluation

From the traffic and sub grade strength analysis, the subgrade strength class is S4 and the traffic class is T5 (Appendix G). Hence according to ERA pavement design manual, the thickness of the base course and sub base should be 20cm and 25cm respectively. From table 4.2 it can be seen that the average thickness of the base course is 13.7 and sub base is 19.4cm therefore the sub base and base will not able to carry the traffic loading at its service time.

5.2 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 the base course has Cu is greater than 4, Cc less than 3 and average PI is 4% which is Silty gravel GM and according to AASHTO classification A-2-4. For the sub-base material at all boreholes the average Cu greater than 4 and Cc less than 3 with average PI 12.9% so it is classified as well graded gravel GW.The sub grade materials of all bore holes are classified as MH inorganic silts of high plasticity.

The comparisons of particle size distribution curve of the laboratory test results and the recommended particle size distribution for mechanically stable natural gravels and weathered rocks for use as Base course material (GB2, GB3) Table 2.3, and for granular sub-base material (GS) (Table 2.5) given by ERA Pavement Design Manual it can be seen that the gradation of Base course and Sub base at all borehole station almost near to the recommended range.

Table 4.9: Specification limits for sub-grade/fill material for road

Material/layer	Test	Specified limits	Desired limits
Sub-grade/fill	**Plasticity test**		
	a) LL	≤ 80%	≤ 50%
	b) PI	≤ 55%	≤ 30%
	Grading test		
	a) Sieve analysis	≤ 35% passing 200 sieve	
	Density moisture content		
	a) Compaction test	B.S. Compaction	
	In situ dry density test		
	top 600mm	≥ 100% of the MDD in BS compaction	
	After 600mm	≥ 95% of the MDD in BS compaction	

	Next to structure	≥ 100% of the MDD in BS compaction	
Unsuitable	a) peat, logs ,stumps, roots, and other perishable or combustible materials		
	b) Material from swamps marshes & bogs		
	c) Top soil and highly organic clay & silts		
	d) clay having a LL exceeding 80% or PI exceeding 55%		
Source: Extracted from General specification for Roads and Bridges F.M.W.(1997)			

5.3 Atterberg Limits

From the laboratory results, it can be seen that the average liquid limit of sub grade is 54, sub base is 27 and base course 4 and also the average plastic index of the sub grade is 20.5, sub base is 12.98 and base course 4.

From Table 4.4 it is observed that both LL and PI values are less than the respective specified values (i.e. LL ≤ 80% and PI ≤ 55%) for the sub grade material in all boreholes sampling point locations thus meet the required specification for the sub-grade material. AASHTO soil classification system BH1&3 grouped in to A-2-7, BH-2 as A-2-6 and BH-4 as A-2-5 and based on Unified soil classification system sub grade is classified as MH.

From Table 5.2 it also observed that both LL and PI values are lower than the respective values (i.e. LL≤ 45% and PI ≤12%) for sub base material of BH-2& BH-4 and does not satisfy the required PI value for BH1&3. In general the average value of PI for sub base is within the recommended specification.

According to ERA standard technical specification the Base Course is Crushed stone material the PI shall not exceed 6 and base material shall be non-plastic or shall have a maximum PI of 6 when determined in accordance with AASHTO T-90. Thus this shows all base course material satisfy the requirement.

5.4 Compaction Test

From Table 5.3 the average value of MDD and OMC for base course is 2.7gm/cc and 6.21% respectively which meet the specification (i.e. MDD>2gm/cc). For sub base material OMC & MDD varied between 6.26% to 15.5% and 1.69gm/cc to 1.98gm/cc 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 between 12.84% and 16.83% and 1.48gm/cc 1.8gm/cc respectively. The MDD values of all sub grade except BH4, they don't meet the specified value (i.e. MDD>1.76gm/cc).

5.5 California Bearing Ratio (CBR) Test

From the recommendation given in Table 2.1 taken from ERA Pavement Design Manual Volume I, for naturally coarsely graded granular material, including processed and modified gravel GB3, the CBR after soaking should be greater than 80%.According to the laboratory result given in Table 5.4 the average CBR of base material is 145.9% which is greater than 80% therefore it is suitable to use as base course when compacted at optimum moisture content & its maximum dry density.

When we see the case of sub-base layer, the recommendation given ERA is CBR>30% after soaking and the result obtained from Table 5.4 CBR value for sub base ranges from 48%to 177% which satisfy ERA requirements. From Table 2.1, it is observed that the average soaked CBR value of sub grade material which is greater than 10.1%, in which it satisfies the requirement because of it is greater than the ERA specification (i.e. soaked CBR ≥5%). From Table 2.5, the sub-grade strength class for CBR ranges from 8%-14% is S4. Since the average CBR value of sub grade is within this range it is classified as S4.

5.6 Drainage conditions

As we all know the drainage is the most important part of Pavement management system and plays important role in extending the design life of a highway. During the rains, part of the rain water flows on surface and part of it percolates through the soil mass as gravitational water until it reaches the ground water. Some water is retained in the pores of the soil mass and on the surface of soil particles which cannot be drained by normal gravitational methods and this retained water is termed Held water. It is required that the surface water from the carriageway and shoulder should effectively be drained off without allowing it percolate the sub grade. The surface water from adjoining land should also be prevented from entering the roadway. The side drains should have sufficient capacity and longitudinal slopes to carry away all the surface water collected. This improper drainage system causes the failure of road pavements due to many reasons such as increase in moisture content, decrease in strength, mud pumping, and formation of waves and corrugations, stripping of bitumen, cutting of edges of pavement and frost action. Poor drainage system causes soils swelling which intern result different type of defects. During site investigation, the researcher observe problem on longitudinal and transverse drainage and waters are allowed to travel a long distance. In general there is a poor drainage system in the town.

5.7 The relation between Road failures with test result

The table below shows the relationship between the types of distress with the result obtained from Laboratory.

Table 4.10 The Relation between Laboratory result obtained with road pavement failure along Agaro Town

Sample No.	Type of Failure	Result Obtained	Relationships	Remark
1	**Block Cracks**	**Gradation**		BH-1
		● GM,GW and MH for Base, sub base and subgrade	The laboratory result obtained meet the specification for base, sub-base & subgrade layers	
		Atterberg limits		
		● LL& PI Base course (3,3), Sub base (43,22.96) and sub grade(59,31) respectively	The laboratory results obtained from sub base do not meet the requirement. LL≤ 35% and PI ≤12%)	
		Compaction		
		● MDD and OMC for Base course (2.77gm/cc,6.8%),Sub base (1.69gm/cc,11.79%) and sub grade(1.56gm/cc,14.32%)	The laboratory result obtained for sub grade and sub base does not meet the requirement MDD≥2gm/cc and this cracks occurs the sub grade and sub base are not well compacted due to these there is higher air voids	
		CBR Test		
		● CBR for base course 173.4%,sub base 48% and Sub grade 15%	The laboratory result obtained meet the specification for base, sub-base & subgrade layers	
		Layer thickness		
		Asphalt 4cm,base 13cm and sub grade 20cm		
		Asphalt extraction		
		Bitumen Content is 3.12 (%)	The laboratory result obtained does not meet the specification for Asphalt bitumen content (4-5%)	
2	**Edge cracks**	**Gradation**		BH-2
		● GM,GW and MH for Base, sub base and subgrade	The laboratory result obtained almost meet the specification for base, sub-base & subgrade layers	
		Atterberg limits		
		● LL, & PI Base course (3,3), Sub base (34,7) and sub grade(38,13) respectively	The laboratory result obtained meet the specification for base & sub-base but the subgrade layers does not meet and the problem is high plastic sub grade soil	

		Compaction		
		● MDD and OMC for Base course (2.77gm/cc,6.8%),Sub base (1.69gm/cc,11.79%) and sub grade(1.56gm/cc,14.32%)	The laboratory result obtained for sub grade and sub base does not meet the requirement MDD≥2gm/cc and this cracks occurs because of absence of shoulder support in most part of the road , poor compaction and drainage system	
		CBR Test		
		● CBR for base course 122.24%,sub base 176.9% and Sub grade 10%	The laboratory result obtained meet the specification for base, sub-base & subgrade layers	
		Layer thickness		
		Asphalt 3.5cm,base 12cm and sub grade 19cm		
		Asphalt extraction		
		Bitumen Content 2.64 %	The laboratory result obtained does not meet the specification for Asphalt bitumen content (4-5%)	
3	**Alligator cracks**	**Gradation test**		BH-3
		● GM,GW and MH for Base, sub base and subgrade	The laboratory result obtained almost meet the specification for base, sub-base & subgrade layers	
		Atterberg limits test		
		● LL, & PI Base course (6,6), Sub base (8,4) and sub grade(57,29.5) respectively	The laboratory result obtained almost meet the specification for base, sub-base & subgrade layers	
		Compaction Test		
		● MDD and OMC for Base course (2.21gm/cc,5.23%),Sub base (1.98gm/cc,6.13%) and sub grade(1.48gm/cc,14.55%)	The laboratory result obtained for sub grade and sub base does not meet the requirement MDD≥2gm/cc and this cracks occurs because of absence of shoulder support in most part of the road , poor compaction and drainage system	
		CBR Test		
		● CBR for base course 140.35%,sub base 61.93% and Sub grade 7.79%	The laboratory result obtained meet the specification for base, sub-base & subgrade layers	
		Layer thickness		

		Asphalt 4.3cm,base 13.5cm and sub grade 18cm	The basic problem is the thickness of each layers and the bituminous content which is less than the standard	
		Asphalt extraction Test		
		Bitumen Content is 2.16 %		
4	**Alligator carracks**	**Gradation test**		BH-4
		● GM,GW and MH for Base, sub base and subgrade	The laboratory result obtained almost meet the specification for base, sub-base & subgrade layers	
		Atterberg limits test		
		● LL, & PI Base course (4,4), Sub base (23,18) and sub grade(62,9) respectively	The laboratory result obtained does not meet the specification for sub-base which is high plastic in nature and when sub grade soil saturated due to poor drainage during rainy season the dry density will decrease.	
		Compaction Test		
		● MDD and OMC for Base course (3.09gm/cc,6.4%),Sub base (1.85gm/cc,6.126) and sub grade(1.8gm/cc,12.84%)	The laboratory result obtained for sub grade and sub base does not meet the requirement MDD≥2gm/cc and this cracks occurs because of absence of shoulder support in most part of the road , poor compaction and drainage system	
		CBR Test		
		● CBR for base course 147.59%,sub base 51.7% and Sub grade 7.42%	The laboratory result obtained meet the specification for base, sub-base & subgrade layers	
		Layer thickness		
		Asphalt 4cm,base 15cm and sub grade 20cm	the basic problem is the thickness of each layers and the bituminous content which is less than the standard	
		Asphalt extraction Test		
		Bitumen Content is 2.29%		

Table 4.11 Summery of relationship obtained between soil properties and road failures and suggested maintenance.

Sample No.	Station	Type of Failure	Causes of Failure obtained	Main source of failure obtained	Maintenance Suggestions
BH-1	385+000	Block Cracks	● Poor drainage ●Compaction problem, ●Bitumen content of asphalt, ●Expansive sub grade soil	▪Surface course layer ▪Sub grade layer,	√ Improve drainage. Remove vegetation close to edge& removing the source that traps the water √ Any surface treatment or thin overlay
BH-2	398+000	Edge cracks	● Poor drainage shoulder support ●Compaction problem of sub grade & sub base, ●Bitumen content of asphalt, ●Expansive sub grade soil	▪ Surface course layer ▪Sub grade layer, ▪ Sub base layer	√ Improve drainage. Remove vegetation close to edge. Fill cracks with asphalt emulsion slurry or emulsified asphalt Crack seal/fill
BH-3	386+000	Alligator carracks	● Poor drainage ●Compaction problem of sub grade & sub base, ●Bitumen content of asphalt,	▪ Surface course layer ▪Sub grade layer, ▪ Sub base layer	√ Improve drainage. Remove vegetation close to edge& removing the source that traps the water √Full-depth patch
BH-4	397+000	Alligator carracks	● Poor drainage ●Compaction problem of sub grade & sub base, ●Bitumen content of asphalt, ●High plastic sub base material	▪ Surface course layer ▪Sub grade layer, ▪ Sub base layer	√ Improve drainage. Remove vegetation close to edge& removing the source that traps the water √ Full-depth patch

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusions

The work conducted in this study is to investigate the causes of pavement defects and it's remedial on asphalt concrete pavement in Agaro town. The objectives of the study were analyzed and the following conclusions are given based on the field survey and laboratory test results.

- From the pavement condition survey, shoving or corrugation, alligator cracks, edge cracks, potholes, longitudinal cracks, deformation, raveling and rutting are the most common defects observed along the study area.
- Based on the data collected from laboratory test and condition survey on highly severed damaged section of the road the following are cause of pavement damages on the area.
    - ✓ The sub grade soil is classified as MH inorganic silt which is poor as a sub grade material.
    - ✓ Proctor test for all sub base and sub grade layer shows that the MDD is below the specified value given by ERA technical specification. These results in cracks (Block, Edge and Alligator)due to sub grade and sub base layers are not well compacted and there is higher air voids.
    - ✓ Pavement material thickness of all bore holes shows below the specified value given by ERA Technical Standard specification for sub grade strength S4 and Traffic class T5 (base course and sub base should be 20cm and 25cm respectively), these results to a serious of block, alligator and edge cracks.

  - ✓ Improper bitumen content on asphalt concrete mix causes pavement damage in all boreholes and creates a chance water to penetrate beneath the surface course layer.

- ➢ Because of the absence of good drainage structure, the impact on road pavement is very high. It is causes pavement distresses and deterioration which also affect the safety and riding quality on.
- ➢ Due to pavement damages and deteriorations vehicle operation cost and travel time increased and creates traffic congestion, accident and delay.

5.2. Recommendations

Based on this thesis work, I have come up with the following recommendations which may be vital to note for further implementations.

- ✓ **Recommendation to the Client**
  - ➢ Immediate improvement of drainage is required by removing concentrated weed growth in ditch line or edge of pavement and Standing water in ditch lines
  - ➢ The client is recommended to maintain the existing severely damaged part located on BH1,BH2 and BH3
  - ➢ ERA should follow proper pavement maintenance and management practice in order to reduce pavement failure.
  - ➢ Careful choice of consulting engineers and prosecution of corrupt consulting engineers and ministry officials
  - ➢ It is also recommended to carry out such a study in other parts of Ethiopia especially in regions where Pavement damages and deterioration is a concern.
- ✓ **Recommendation to the Contractor**
  - ➢ Knowledge of soil geotechnical characteristics and underlying geology of an area is very essential before any construction project commence as the stability of the foundation layers particularly depends on this.
  - ➢ Due to complex characteristics of road construction projects, the contractor should follow the standard procedure while construction on progress.
- ✓ **Recommendation to the Consultant**
  - ➢ Fill materials must be tested and treated before use to avoid problems after the construction

- ERA and the consultant should carefully revise the design and the Geotechnical property of road making material before rushing in to construction stage.
- During construction stage, continuous supervision should be implemented by the client and consultant engineers.
- Good drainage should be provided to avoid the entrance of water in to the road pavement.
- 100% compaction must be observed during construction to avoid failure after construction due to Settlement
- A guaranteed period of use before affecting repairs and before final payment is made.
- Evaluation on the effectiveness of different construction and design techniques which are currently in use for road construction can be area of further research in order to avoid Pavement damages and deterioration.

REFERENCES

[1]. AASHTO (1988) Manual of sub surface investigation.

[2]. Ankit Gupta (2004). Report on Case Studies on Failure of Bituminous Pavements Report Submitted to PWD, Aligarh. 2004. pp-1-14

[3]. Dr.J.J.Magdum College of Engineering, Jaysingpur

[4]. Dr.K.R.ARORA (2003). Soil mechanics and foundation engineering, sixth edition

[5]. Estimating Highway Pavement Damage Costs Attributed to Truck Traffic

[6]. Federal Democratic Republic Of Ethiopia, Ethiopian Road Authority Standard technical specifications 2002

[7]. Federal Democratic Republic Of Ethiopia, Ethiopian Road Authority (2002). Pavement Design manual, Volume I&II

[8]. Federal Democratic Republic Of Ethiopia, Ethiopian Road Authority(ERA) Pavement Rehabilitation And Asphalt Overlay Manual

[9]. Final report forensic investigation of pavement distress: old airport road in Bristol, Virginia by Thomas e. freeman, p.e. senior research engineer

[10]. Finn, F. N., Nair, K., and Hilliard, J. M., Minimizing Premature Cracking in Asphaltic Concrete Pavement, NCHRP Report No. 195, Transportation Research Board, Washington, D.C., 1978

[11]. Guidance Notes Catalogue of Road Defects (CORD) Research & Development Division January 2013

[12]. Hall, K. T. and Darter, M. I., "Rehabilitation Performance and Cost-Effectiveness: A Ten-Year Case Study," Transportation Research Record No. 1215, 1990.

[13]. Highway materials, soils, and concrete 3rd edition by Harold N. Atkins,PE

[14]. Investigation of Conditions for Moisture Damage in Asphalt Concrete and Appropriate Laboratory Test Methods by Qing Lu

[15]. Maintenance Solutions For Bleeding And Flushing Pavements By Texas Department Of Transportation Malaysia By: Hjh. Juraidah Ahmad Prof. Madya Ir. Dr. MohdYusof Abdul Rahman Jezan Mohd Diah Sabariah Arbai December 2004

[16]. Miller, J. S., Rogers, R. B. and Rada, G. R., Distress Identification Manual for the Long-Term Pavement Performance Project, third edition, 1993.

[17]. NDOR Nebraska department of roads pavement maintenance manual

[18]. Pavement Deterioration and its Causes by Sharad.S.Adlinge, Prof.A.K.Gupta.

[19]. Pavement Distress Evaluation and Characterization Institute Penyelidikan, Pembangunan Dan Pengkomersilan (Irdc) Universiti Teknologi Mara 4040 Shah Alam, Selangor

[20]. Pothole Identification, Assessment and Repair Guidelines August 2012 Commissioned by: Communities of Tomorrow Leveraged Municipal Innovation Fund Prepared by: Clifton Associates Ltd. Sponsoring Municipalities: Prince Albert, Saskatoon

[21]. Praveen Kumar (2004), Case Studies on Failure of Bituminous Pavements. Paper from first international conference on pavement preservation (paper 52). Pp-1-5.

[22]. Road Deterioration in Developing Countries Causes and Remedies By World bank policy study

[23]. Road Sector Development and Economic Growth in Ethiopia by Ibrahim Worku

[24]. Stark, D., "Field and Laboratory Studies of the Effects of Sub base Type on the Development of D-Cracking," Highway Research Record No. 342, 1970

[25]. Study of the Causes and Remedies of Premature Surface Cracking of Asphalt Pavement EPAM3- 3rd European Pavement and Asset Management Conference Coimbra, Portugal,7-9 July,2008

[26]. Study of Water Effects on Asphalt and Porous Asphalt Report Nr 5 June 2010

[27]. Superior Performing Asphalt Pavements (Superpave)'.The Product Of The SHRP Asphalt Research Program Thomas W. Kennedy University Of Texas At Austin Gerald A. Huber Heritage Research Group

[28]. The International Road Maintenance Handbook

[29]. The Place of Soil Geotechnical Characteristics in Road Failure, a Study of the Onitsha-Enugu Expressway, Southeastern Nigeria by Onuoha, David Chijioke1 and Onwuka, Shalom Udeagha

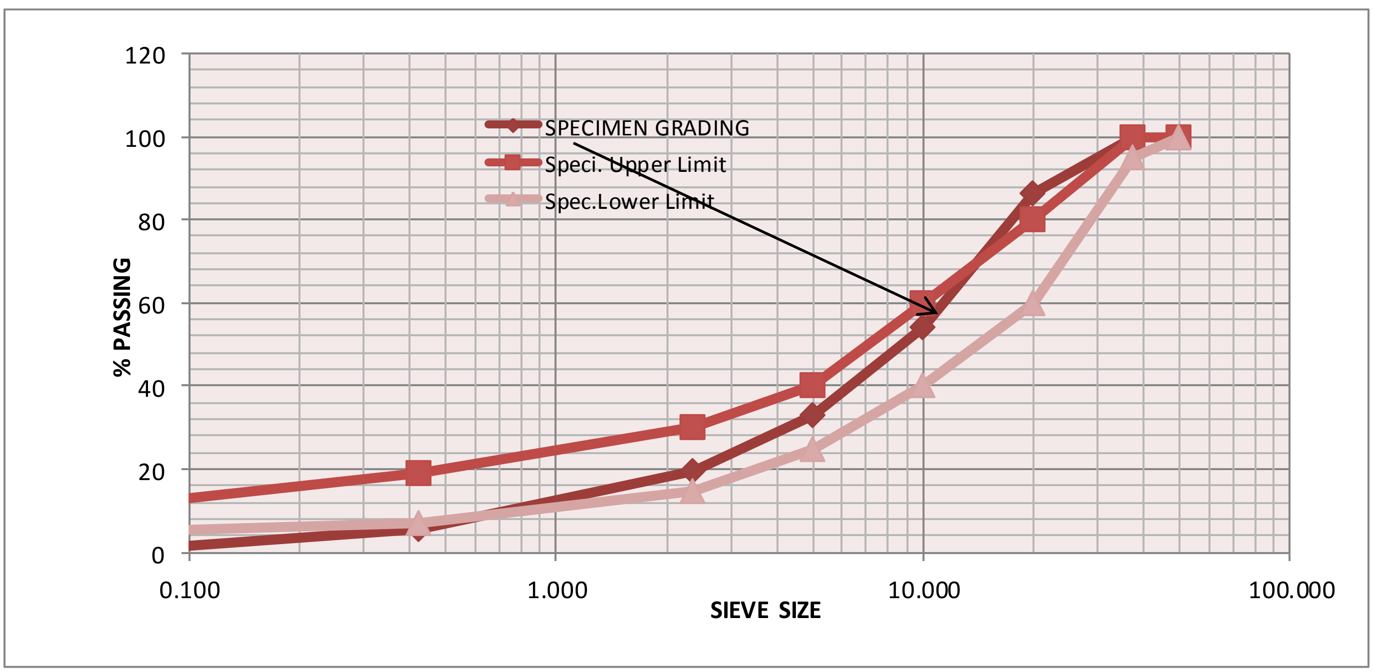
[30]. Transport and Road Research Laboratory (TRRL)

[31]. WSDOT Maintenance Manual M 51-01.05, August 2013

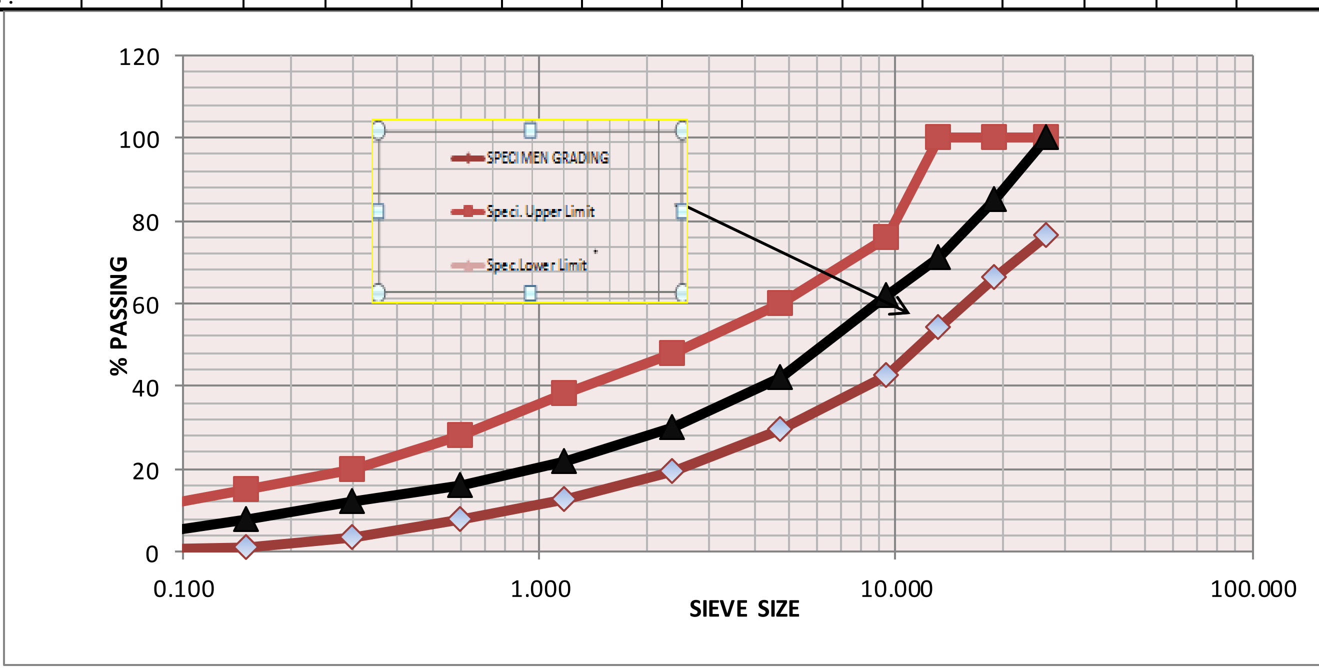
[32]. Yield General Specification for Roads and Bridges F.M.W. (1997)

APPENDEX A. PARTICLE SIZE DISTRIBUTION

Particle size distribution												
Sieve Analysis(Test Method AASHTO T- 11/T - 27)												
(Nominal Size 37.5 mm)												
Sampling Station :			*385+000*			**Material Type :**		**Base-Coarse**				
Sampling Date :			*29-Nov-15*		**AVERAGE of Trial 1&2 for BH-1**							
Testing Date :			*21-Dec-15*		-	**Source**		**BH-1**			-	-
Sieve Sizes			50.00	37.50	20.00	10.00	5.000	2.36	0.425	0.075	Pan	Total
Weight Retained(gm)			0.0	0.0	353.0	815.0	532.0	346.0	358.0	122.0	18.0	2544.0
% Retained			**0.00**	**0.00**	**13.88**	**32.04**	**20.91**	**13.60**	**14.07**	**4.80**	**0.71**	
% Passing			**100.0**	**100.0**	**86.12**	**54.09**	**33.18**	**19.58**	**5.50**	**0.71**	**0.00**	
Specification Limits			**100**	**95--100**	**60--80**	**40--60**	**25--40**	**15--30**	**7--19**	**5--12**		
Upper Limit			**100.00**	**100.00**	**80.00**	**60.00**	**40.00**	**30.00**	**19.00**	**12.00**		
Lower Limit			**100.00**	**95.00**	**60.00**	**40.00**	**25.00**	**15.00**	**7.00**	**5.00**		
Grading Modulus :		**2.74**										



Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27)													
(Nominal Size 37.5 mm)													
Sampling Station :	*385+000*			**Material Type :**	**Sub Base**								
Sampling Date :	*29-Nov-15*		**Trial 1&2 Average**										
Testing Date :	*17-Dec-15*		-	**Source**	**BH-1**								
Total Weight (gm)=			1427										
Sieve Sizes	**26.50**	**19.00**	**13.20**	**9.50**	**4.750**	**2.36**	**1.180**	**0.600**	**0.300**	**0.150**	**0.075**	**Pan**	**Total**
Weight Retained(gm)	**334.5**	**150.5**	**165.5**	**168.5**	**189.0**	**144.0**	**95.5**	**67.0**	**60.0**	**38.0**	**9.5**	**4.5**	**1426.5**
% Retained	**23.45**	**10.55**	**11.60**	**11.81**	**13.25**	**10.09**	**6.69**	**4.70**	**4.21**	**2.66**	**0.67**	**0.32**	
% Passing	**76.6**	**66.0**	**54.4**	**42.6**	**29.34**	**19.24**	**12.55**	**7.85**	**3.65**	**0.98**	**0.32**	**0.00**	
Specification Limits	**100**	**85-100**	**71-100**	**62-76**	**42-60**	**30-48**	**22-38**	**16-28**	**12--20**	**8--15**	**4--10**		
Upper Limit	**100.00**	**100.00**	**100.00**	**76.00**	**60.00**	**48.00**	**38.00**	**28.00**	**20.00**	**15.00**	**10.00**		
Lower Limit	**100.00**	**85.00**	**71.00**	**62.00**	**42.00**	**30.00**	**22.00**	**16.00**	**12.00**	**8.00**	**4.00**		
Grading Modulus : 2.77													

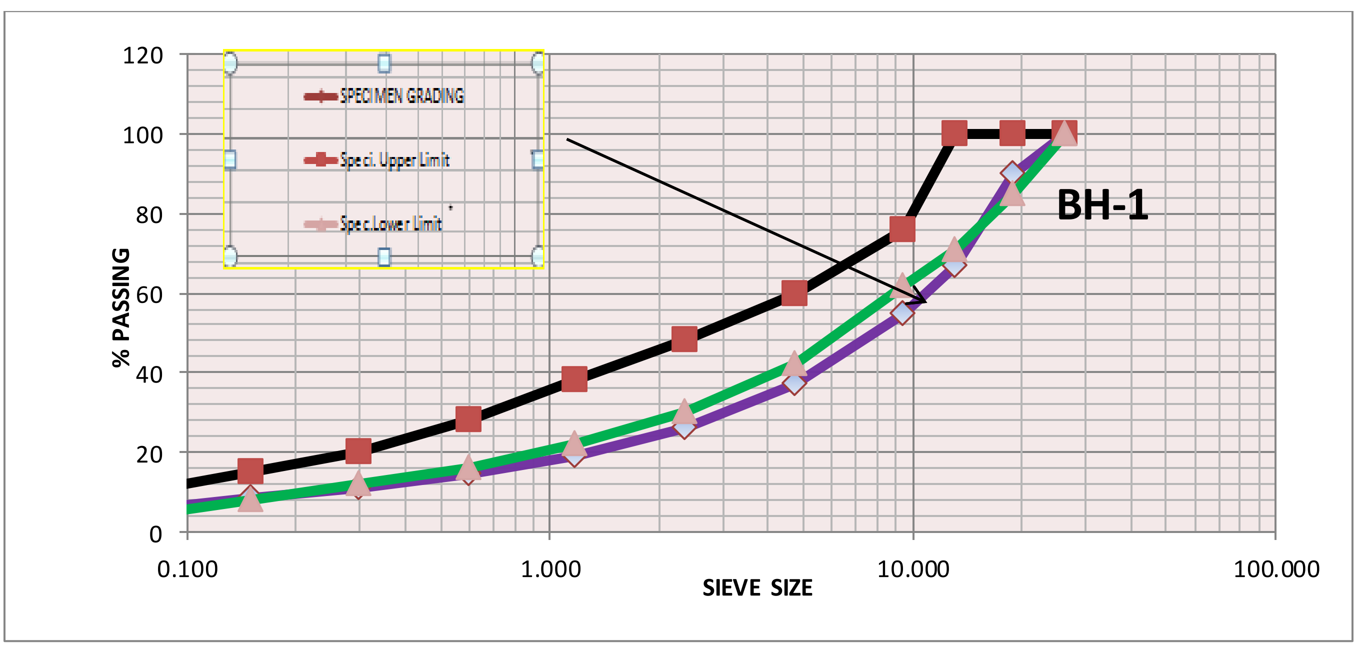


Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27)(Nominal Size 37.5 mm)

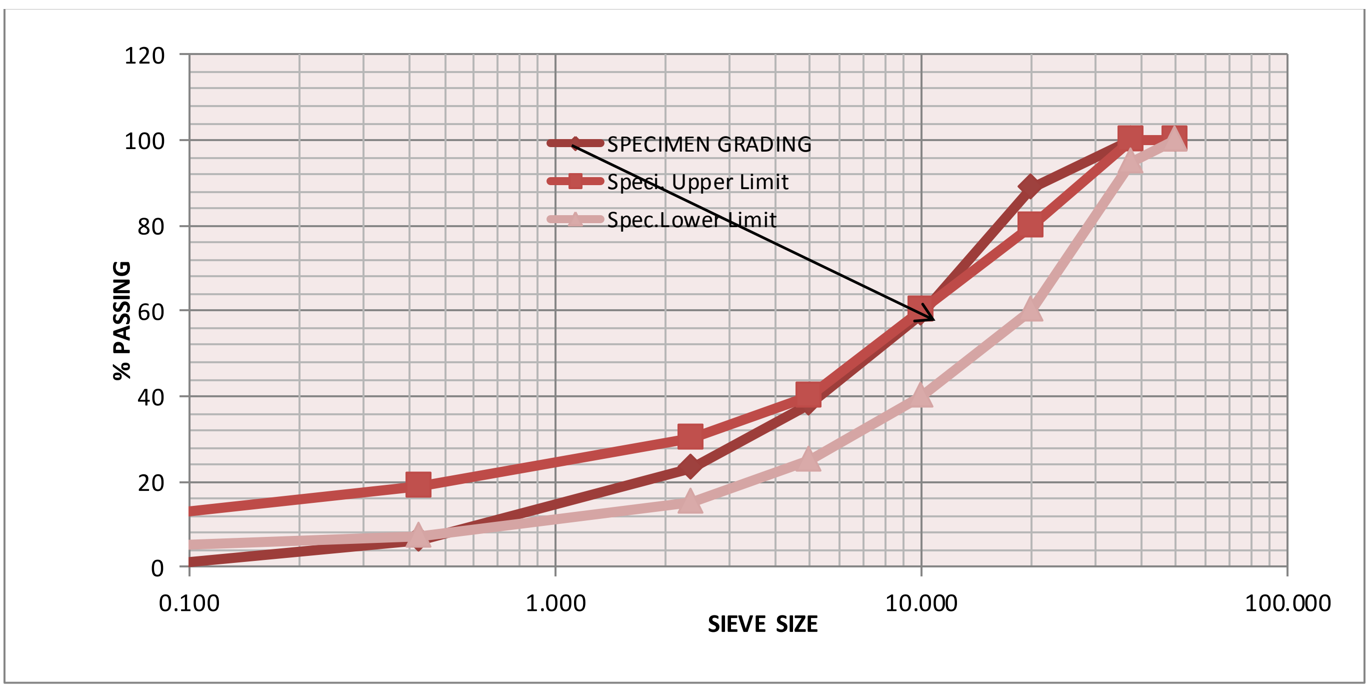
Sampling Station :	*385+000*	**Material Type :**	**Sub Grade**
Sampling Date :	**29-Nov-15**	**AVERAGE Trial 1&2**	
Testing Date :	*9-Dec-15*	**Source**	**BH1**

Total Weight (gm)= 1324

Sieve Sizes	**26.50**	**19.00**	**13.20**	**9.50**	**4.750**	**2.36**	**1.180**	**0.600**	**0.300**	**0.150**	**0.075**	**Pan**	**Total**
Weight Retained(gm)	0.0	134.0	302.5	165.0	230.0	144.0	93.0	62.0	44.0	36.5	38.5	74.0	1323.5
% Retained	0.00	10.12	22.86	12.47	17.38	10.88	7.03	4.68	3.32	2.76	2.91	5.59	
% Passing	100.0	89.9	67.0	54.6	37.17	26.29	19.27	14.58	11.26	8.50	5.59	0.00	
Specification Limits	100	85-100	71-100	62-76	42-60	30-48	22-38	16-28	12--20	8--15	4--10		
Upper Limit	100.00	100.00	100.00	76.00	60.00	48.00	38.00	28.00	20.00	15.00	10.00		
Lower Limit	100.00	85.00	71.00	62.00	42.00	30.00	22.00	16.00	12.00	8.00	4.00		
Grading Modulus : 2.57													

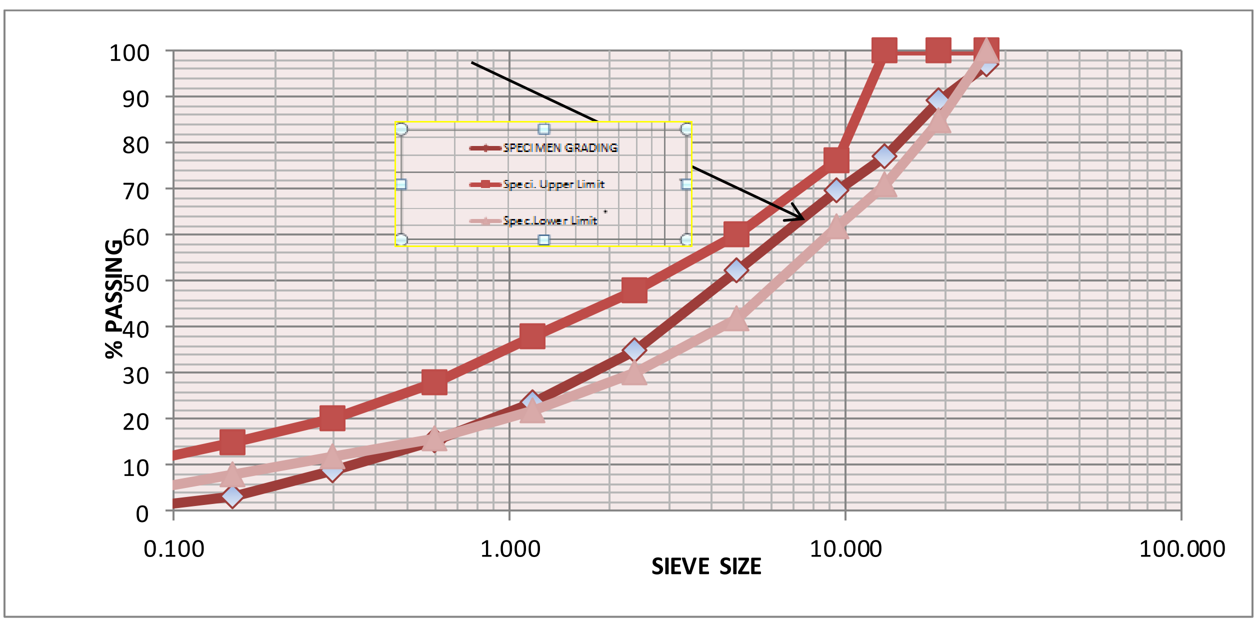


Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27) (Nominal Size 37.5 mm)										
Sampling Station :	*398+000*			Material Type :		Base-Coarse				
Sampling Date :	29-Nov-15			Average Trial 1&2						
Testing Date :	*3-Jan-16*			Source		BH-2				
Sieve Sizes	50.00	37.50	20.00	10.00	5.000	2.36	0.425	0.075	Pan	Total
Weight Retained(gm)	0.0	0.0	337.0	911.0	649.5	449.0	515.5	185.5	10.5	3058.0
% Retained	0.00	0.00	11.02	29.79	21.24	14.68	16.86	6.07	0.34	
% Passing	100.0	100.0	88.98	59.19	37.95	23.27	6.41	0.34	0.00	
Specification Limits	100	95--100	60--80	40--60	25--40	15--30	7--19	5--12		
Upper Limit	100.00	100.00	80.00	60.00	40.00	30.00	19.00	12.00		
Lower Limit	100.00	95.00	60.00	40.00	25.00	15.00	7.00	5.00		
Grading Modulus 2.70										



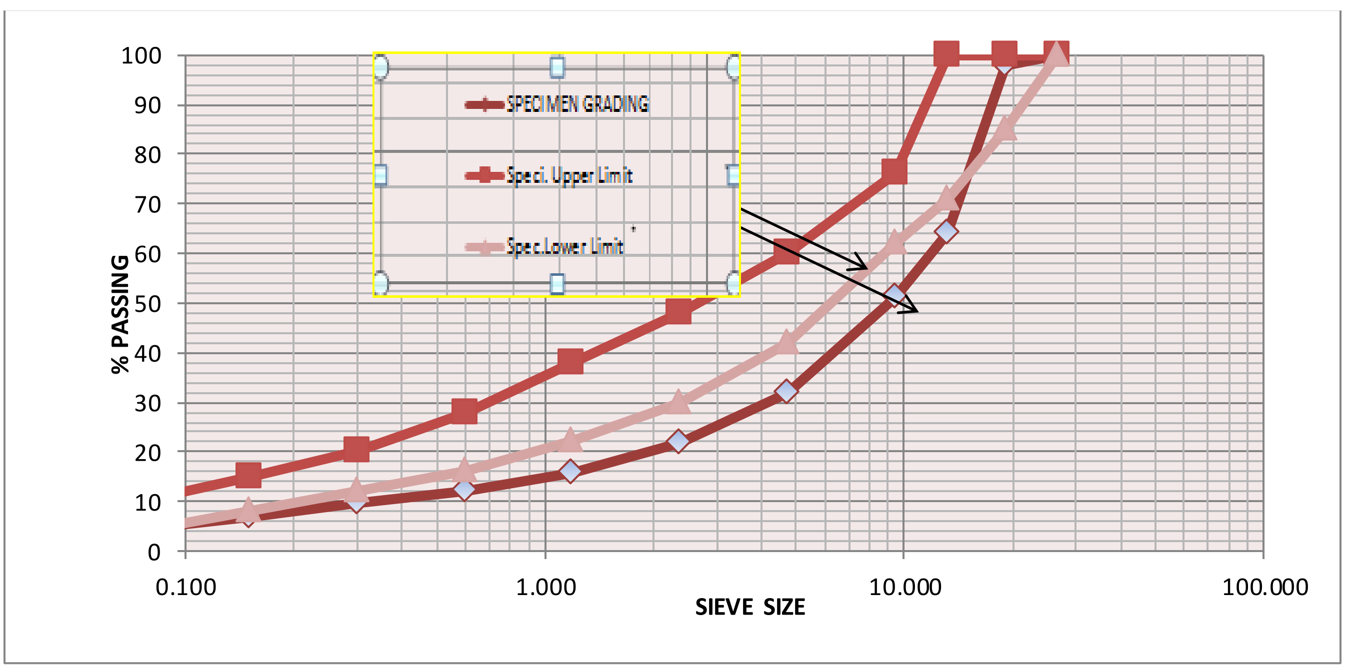
Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27) (Nominal Size 37.5 mm)

Sampling Station :	*398+000*			**Material Type :**		**Sub Base**							
Sampling Date :	*29-Nov-15*			**Trial**		Average 1&2							
Testing Date :	*29-Dec-15*		-	**Source**		**BH2**						-	-
	Total Weight(gm)=		**1610**										
Sieve Sizes	**26.50**	**19.00**	**13.20**	**9.50**	**4.750**	**2.36**	**1.180**	**0.600**	**0.300**	**0.150**	**0.075**	**Pan**	**Total**
Weight Retained(gm)	**50.0**	**126.0**	**195.0**	**115.0**	**283.0**	**277.0**	**185.0**	**131.0**	**108.0**	**87.0**	**42.0**	**11.0**	**1610.0**
% Retained	**3.11**	**7.83**	**12.11**	**7.14**	**17.58**	**17.20**	**11.49**	**8.14**	**6.71**	**5.40**	**2.61**	**0.68**	
% Passing	**96.9**	**89.1**	**77.0**	**69.8**	**52.24**	**35.03**	**23.54**	**15.40**	**8.70**	**3.29**	**0.68**	**0.00**	
Specification Limits	**100**	**85-100**	**71-100**	**62-76**	**42-60**	**30-48**	**22-38**	**16-28**	**12--20**	**8--15**	**4--10**		
Upper Limit	**100.00**	**100.00**	**100.00**	**76.00**	**60.00**	**48.00**	**38.00**	**28.00**	**20.00**	**15.00**	**10.00**		
Lower Limit	**100.00**	**85.00**	**71.00**	**62.00**	**42.00**	**30.00**	**22.00**	**16.00**	**12.00**	**8.00**	**4.00**		
Grading Modulus :	**2.56**												

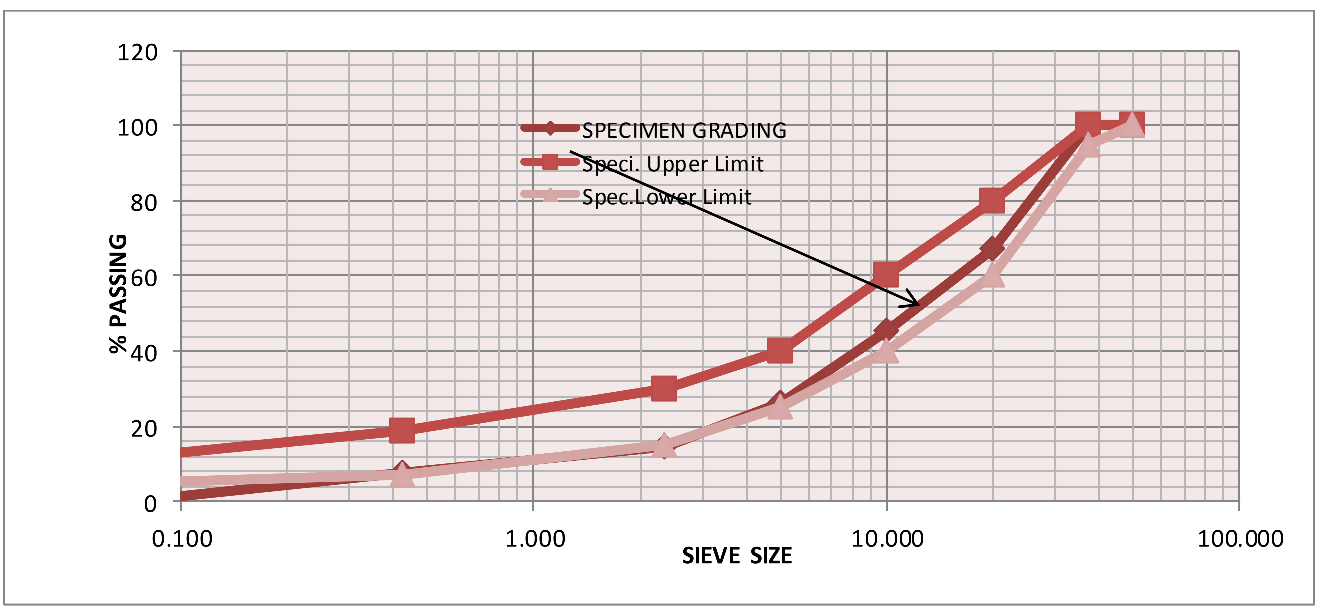


Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27) (Nominal Size 37.5 mm)

Sampling Station :	***398+000***			**Material Type :**		**Sub Grade**							
Sampling Date :	29-Nov-15					Average **Trial** 1&2							
Testing Date :	25-Dec-15		-	**Source**		**Agaro town BH-2**						-	-
	Total Weight(gm)=		**1335**										
Sieve Sizes	26.50	19.00	13.20	9.50	4.750	2.36	1.180	0.600	0.300	0.150	0.075	Pan	Total
Weight Retained(gm)	0.0	29.0	449.0	174.0	256.0	134.5	80.5	51.0	34.0	36.0	33.5	57.5	1335.0
% Retained	**0.00**	**2.17**	**33.63**	**13.03**	**19.18**	**10.07**	**6.03**	**3.82**	**2.55**	**2.70**	**2.51**	**4.31**	
% Passing	**100.0**	**97.8**	**64.2**	**51.2**	**31.99**	**21.91**	**15.88**	**12.06**	**9.51**	**6.82**	**4.31**	**0.00**	
Specification Limits	**100**	**85-100**	**71-100**	**62-76**	**42-60**	**30-48**	**22-38**	**16-28**	**12--20**	**8--15**	**4--10**		
Upper Limit	**100.00**	**100.00**	**100.00**	**76.00**	**60.00**	**48.00**	**38.00**	**28.00**	**20.00**	**15.00**	**10.00**		
Lower Limit	**100.00**	**85.00**	**71.00**	**62.00**	**42.00**	**30.00**	**22.00**	**16.00**	**12.00**	**8.00**	**4.00**		
Grading Modulus : **2.64**													

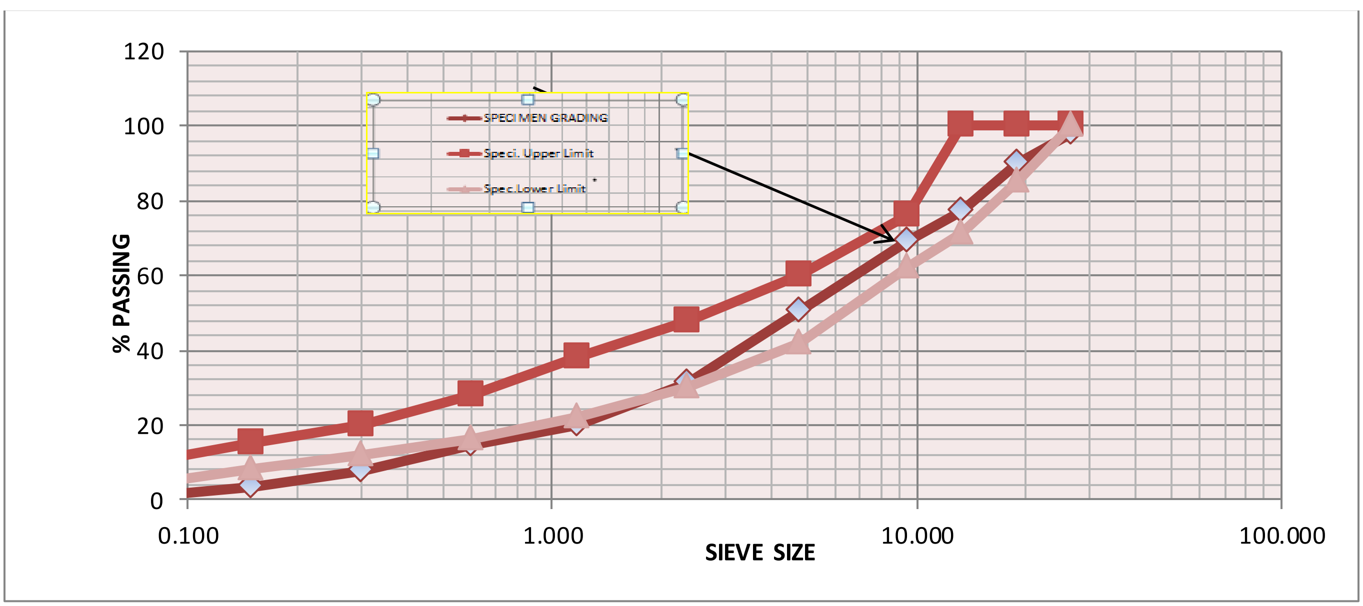


Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27) (Nominal Size 37.5 mm)										-	-
Sampling Station :		***386+000***			**Material Type :**		**Base-Coarse**				
Sampling Date :		***30-Nov-15***			**Trial**		**Average 1&2**				
Testing Date :		***15-Jan-16***		-	**Source**		**BH-3**			-	-
Total Weight (gm)=				**3003**							
Sieve Sizes		**50.00**	**37.50**	**20.00**	**10.00**	**5.000**	**2.36**	**0.425**	**0.075**	**Pan**	**Total**
AVG. Weight Retained(gm)		**0.0**	**0.0**	**981.5**	**660.7**	**570.4**	**354.8**	**212.8**	**210.5**	**12.0**	**3002.6**
AVG % Retained		**0.00**	**0.00**	**32.69**	**22.00**	**19.00**	**11.82**	**7.09**	**7.01**	**0.40**	
AVG % Passing		**100.0**	**100.0**	**67.31**	**45.31**	**26.31**	**14.49**	**7.41**	**0.40**	**0.00**	
Specification Limits		**100**	**95--100**	**60--80**	**40--60**	**25--40**	**15--30**	**7--19**	**5--12**		
Upper Limit		**100.00**	**100.00**	**80.00**	**60.00**	**40.00**	**30.00**	**19.00**	**12.00**		
Lower Limit		**100.00**	**95.00**	**60.00**	**40.00**	**25.00**	**15.00**	**7.00**	**5.00**		
Grading Modulus :	**2.78**										



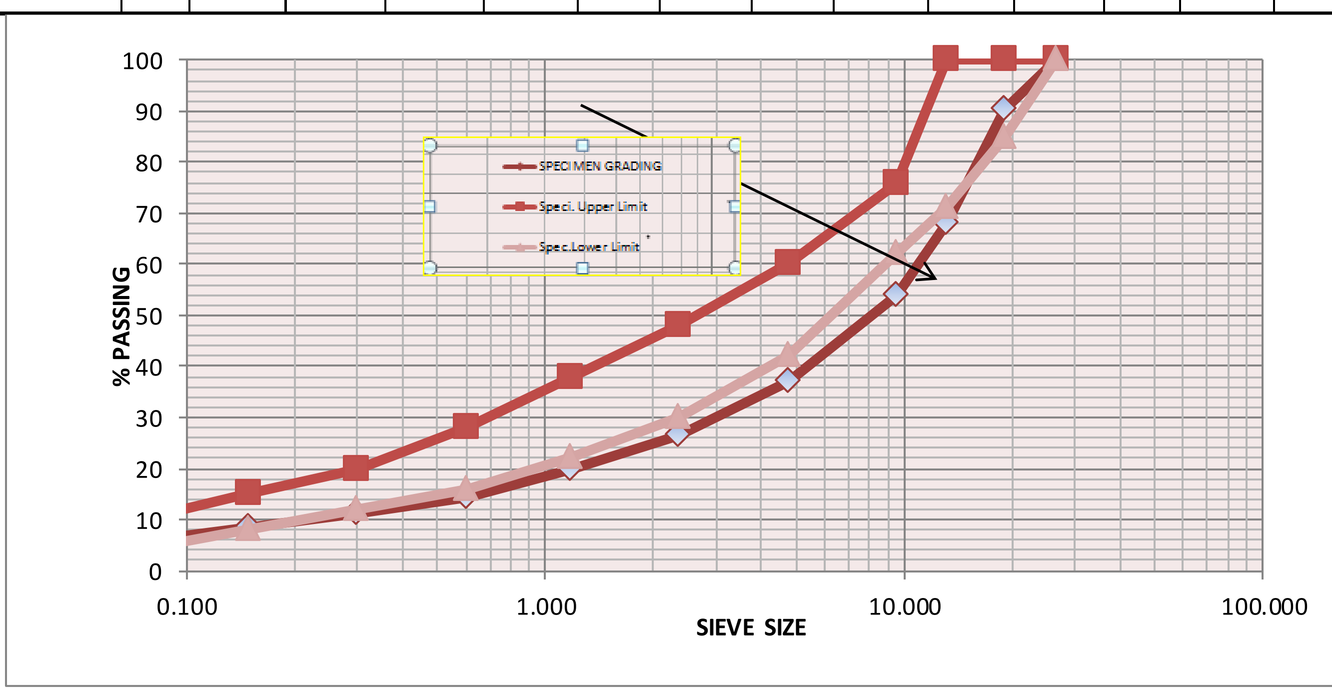
Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27)(Nominal Size 37.5 mm)

Sampling Station :	***386+000***			**Material Type :**		**Sub Base**							
Sampling Date :	***30-Nov-15***			**Trial**		Average 1&2							
Testing Date :	***11-Jan-16***		-	**Source**		**BH3**						-	-
Total Weight(gm.)=			**1466**										
Sieve Sizes	26.50	19.00	13.20	9.50	4.750	2.36	1.180	0.600	0.300	0.150	0.075	Pan	Total
Weight Retained(gm.)	34.1	117.4	185.0	115.0	276.0	279.0	168.0	78.0	98.0	66.0	35.0	15.0	1466.5
% Retained	**2.32**	**8.01**	**12.62**	**7.84**	**18.82**	**19.03**	**11.46**	**5.32**	**6.68**	**4.50**	**2.39**	**1.02**	
% Passing	**97.7**	**89.7**	**77.1**	**69.2**	**50.39**	**31.37**	**19.91**	**14.59**	**7.91**	**3.41**	**1.02**	**0.00**	
Specification Limits	**100**	**85-100**	**71-100**	**62-76**	**42-60**	**30-48**	**22-38**	**16-28**	**12--20**	**8--15**	**4--10**		
Upper Limit	**100.00**	**100.00**	**100.00**	**76.00**	**60.00**	**48.00**	**38.00**	**28.00**	**20.00**	**15.00**	**10.00**		
Lower Limit	**100.00**	**85.00**	**71.00**	**62.00**	**42.00**	**30.00**	**22.00**	**16.00**	**12.00**	**8.00**	**4.00**		
Grading Modulus **2.60**													



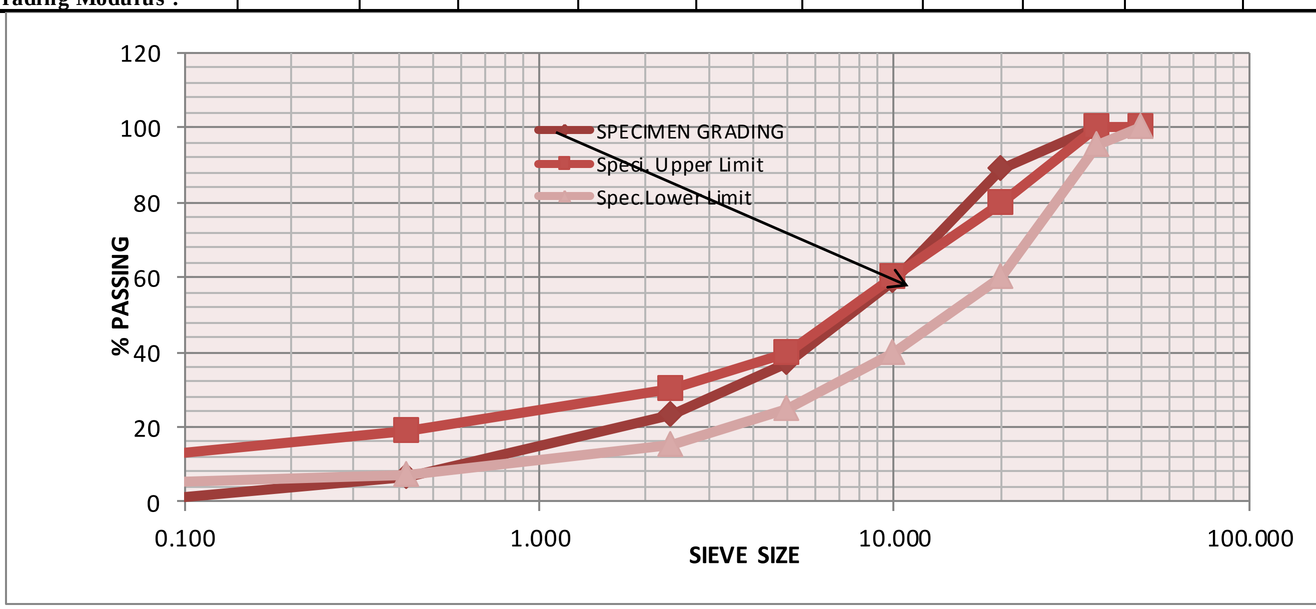
Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27)(Nominal Size 37.5 mm)

Sampling Station :	***386+000***		Material Type :		Sub Grade							
Sampling Date :	30-Nov-15		Trial		Average 1&2							
Testing Date :	7-Jan-16	-	Source		BH-3						-	-
Total Weight (gm.)=		1383										
Sieve Sizes	26.50	19.00	13.20	9.50	4.750	2.36	1.180	0.600	0.300	0.150	0.075	Pan	Total
Weight Retained(gm.)	0.0	136.3	307.3	192.0	233.4	146.1	94.3	73.0	48.0	37.0	39.0	76.7	1383.2
% Retained	0.00	9.85	22.21	13.88	16.87	10.56	6.82	5.28	3.47	2.68	2.82	5.54	
% Passing	100.0	90.1	67.9	54.1	37.18	26.61	19.79	14.51	11.04	8.37	5.54	0.00	
Specification Limits	100	85-100	71-100	62-76	42-60	30-48	22-38	16-28	12--20	8--15	4--10		
Upper Limit	100.00	100.00	100.00	76.00	60.00	48.00	38.00	28.00	20.00	15.00	10.00		
Lower Limit	100.00	85.00	71.00	62.00	42.00	30.00	22.00	16.00	12.00	8.00	4.00		
Grading Modulus : 3.48													

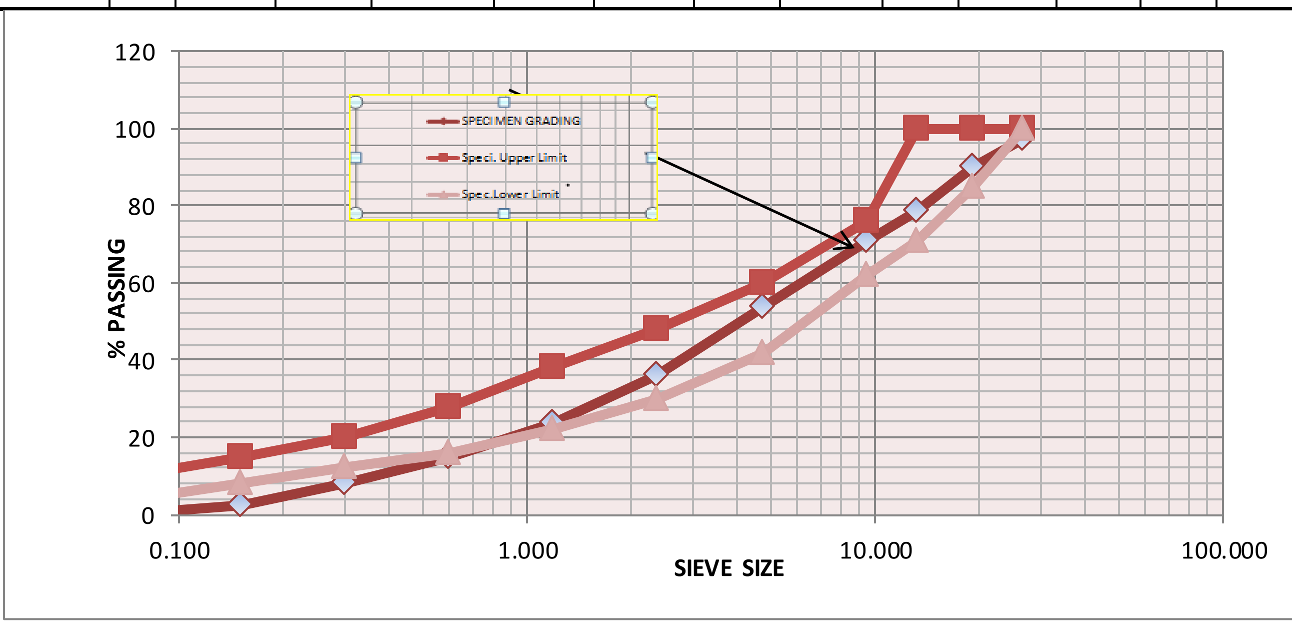


Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27) (Nominal Size 37.5 mm)

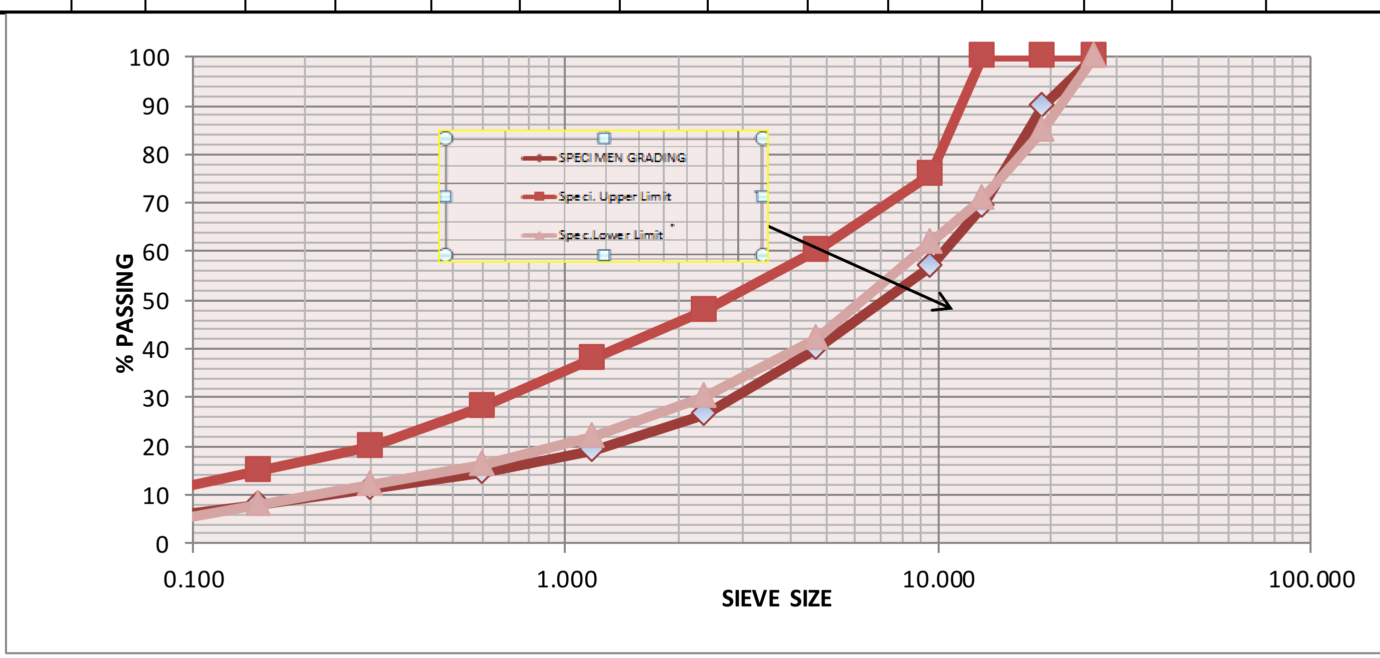
Sampling Station :	***397+000***			**Material Type :**		**Base-Coarse**				
Sampling Date :	***30-Nov-15***			**Trial**		**Average 1&2**				
Testing Date :	***27-Jan-16***		-	**Source**		**BH-4**			-	-
	Total Weight (gm.)=		**3201**							
Sieve Sizes	**50.00**	**37.50**	**20.00**	**10.00**	**5.000**	**2.36**	**0.425**	**0.075**	**Pan**	**Total**
AVG. Weight Retained(gm.)	**0.0**	**0.0**	**345.5**	**935.0**	**683.5**	**426.5**	**527.0**	**196.5**	**9.0**	**3123.0**
AVG % Retained	**0.00**	**0.00**	**11.06**	**29.94**	**21.89**	**13.66**	**16.87**	**6.29**	**0.29**	
AVG % Passing	**100.0**	**100.0**	**88.94**	**59.00**	**37.11**	**23.46**	**6.58**	**0.29**	**0.00**	
Specification Limits	**100**	**95--100**	**60--80**	**40--60**	**25--40**	**15--30**	**7--19**	**5--12**		
Upper Limit	**100.00**	**100.00**	**80.00**	**60.00**	**40.00**	**30.00**	**19.00**	**12.00**		
Lower Limit	**100.00**	**95.00**	**60.00**	**40.00**	**25.00**	**15.00**	**7.00**	**5.00**		
Grading Modulus :	**2.70**									



Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27) (Nominal Size 37.5 mm)													
Sampling Station :	*397+000*			Material Type :		Sub Base							
Sampling Date :	*30-Nov-15*			Trial		Average Trial 1&2							
Testing Date :	*23-Jan-16*			Source		BH4							
Total Weight (gm.)=			1477										
Sieve Sizes	26.50	19.00	13.20	9.50	4.750	2.36	1.180	0.600	0.300	0.150	0.075	Pan	Total
Weight Retained(gm.)	37.7	111.3	165.8	117.2	253.2	260.5	179.6	133.8	100.9	79.7	31.6	5.4	1476.6
% Retained	2.55	7.54	11.23	7.94	17.14	17.64	12.16	9.06	6.83	5.40	2.14	0.37	
% Passing	97.4	89.9	78.7	70.7	53.60	35.96	23.79	14.73	7.90	2.50	0.37	0.00	
Specification Limits	100	85-100	71-100	62-76	42-60	30-48	22-38	16-28	12--20	8--15	4--10		
Upper Limit	100.00	100.00	100.00	76.00	60.00	48.00	38.00	28.00	20.00	15.00	10.00		
Lower Limit	100.00	85.00	71.00	62.00	42.00	30.00	22.00	16.00	12.00	8.00	4.00		
Grading Modulus : 2.56													



Particle size distribution Sieve Analysis(Test Method AASHTO T- 11/T - 27)(Nominal Size 37.5 mm)									-	-	-	-	-
Sampling Station :	***397+000***			**Material Type :**		**Sub Grade**							
Sampling Date :	**30-Nov-15**			**Trial**		**Average trial 1&2**							
Testing Date :	***19-Jan-16***		-	**Source**		**BH4**						-	-
Sieve Sizes	**26.50**	**19.00**	**13.20**	**9.50**	**4.750**	**2.36**	**1.180**	**0.600**	**0.300**	**0.150**	**0.075**	**Pan**	**Total**
Weight Retained(gm)	**0.0**	**139.9**	**289.0**	**170.1**	**239.2**	**186.0**	**102.0**	**65.1**	**48.3**	**45.0**	**40.9**	**69.0**	**1394.5**
% Retained	**0.00**	**10.03**	**20.72**	**12.20**	**17.15**	**13.34**	**7.31**	**4.67**	**3.46**	**3.23**	**2.93**	**4.95**	
% Passing	**100.0**	**90.0**	**69.2**	**57.0**	**39.89**	**26.56**	**19.24**	**14.57**	**11.11**	**7.88**	**4.95**	**0.00**	
Specification Limits	**100**	**85-100**	**71-100**	**62-76**	**42-60**	**30-48**	**22-38**	**16-28**	**12--20**	**8--15**	**4--10**		
Upper Limit	**100.00**	**100.00**	**100.00**	**76.00**	**60.00**	**48.00**	**38.00**	**28.00**	**20.00**	**15.00**	**10.00**		
Lower Limit	**100.00**	**85.00**	**71.00**	**62.00**	**42.00**	**30.00**	**22.00**	**16.00**	**12.00**	**8.00**	**4.00**		
Grading Modulus : **3.50**													



APPENDEX B. ATTERBERG LIMIT

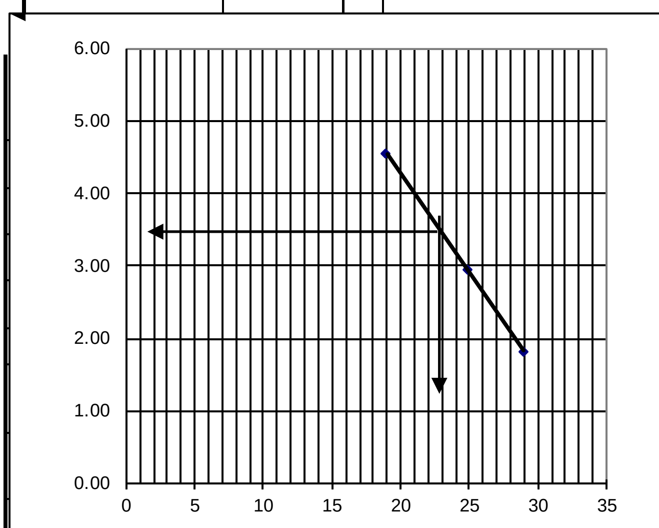
Material Type :	**Base-Coarse**		**Date sampled :**	**29-Nov-10**
Source : Station	**385+000**		**Sate tested :**	**23-Dec-15**
			Sample No	**BH1**

ATTERBERG LIMIT

AASHTO T-89 & T- 90

LIQUID LIMIT

Container No.	1	2	3	MB
Wt of wet soil + container, gm	107.40	101.00	108.70	
Wt of dry soil + container, gm	106.40	99.60	106.20	
Wt of water	1.00	1.40	2.50	
Wt of container	51.00	52.00	51.00	
Wt of dry soil, gm	55.40	47.60	55.20	
Water content, %	1.81	2.94	4.53	
No. of blows	29	25	19	



Sample preparation

	☐
As received	☐
Washed on 0.425mm sieve	☑
Air dried at ......30 °C	☐
Oven dried at 110 °C	
Proportion retained on 0.425mm sieve %	

Liquid Limit	**3**	%
Plastic Limit	**0**	%
Plasticity Index	**3**	

PLASTIC LIMIT

Container No.	1	2		**Average**
Wt of wet soil + container, gm				
Wt of dry soil + container, gm				
Wt of water				
Wt of container				
Wt of dry soil, gm				
Water content, %				**0.0**

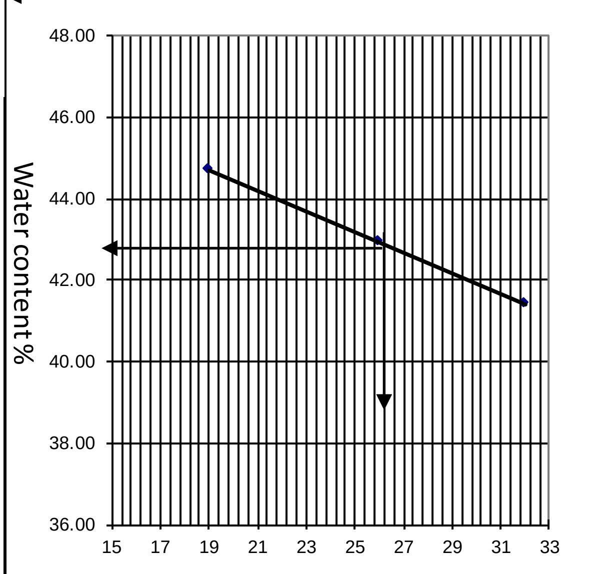
Material Type:	Sub Base			Date sampled :	29-Nov-15
Source :	385+000			tested date :	19-Dec-15
				Sample No	BH1

ATTERBERG LIMIT

AASHTO T-89 & T- 90

LIQUID LIMIT

Container No.	MS	GO	A	
Wt of wet soil + container, gm	46.60	49.40	49.70	
Wt of dry soil + container, gm	38.40	40.30	40.40	
Wt of water	8.20	9.10	9.30	
Wt of container	18.60	19.10	19.60	
Wt of dry soil, gm	19.80	21.20	20.80	
Water content, %	41.41	42.92	44.71	
No. of blows	32	26	19	



No. of blows

Sample preparation

As received	☐
Washed on 0.425mmsieve	☑
Air dried at ……30°C	☐
Oven dried at 110 °C	
Proportion retained on 0.425mm sieve %	

Liquid Limit	**43**	%
Plastic Limit	**20.1**	%
Plasticity Index	**23**	

PLASTIC LIMIT

Container No.	1	2		**Average**
Wt of wet soil + container, gm	13.20	12.40		
Wt of dry soil + container, gm	12.80	11.90		
Wt of water	0.40	0.50		
Wt of container	10.50	9.70		
Wt of dry soil, gm	2.30	2.20		
Water content, %	17.39	22.73		**20.1**

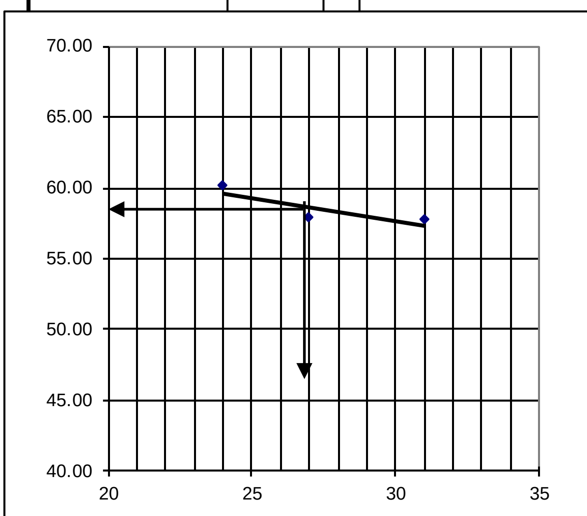
Material Type :	**Sub Grade**	**Date sampled :** **29-Nov-15**
Source :	**385+000**	**Sate tested :** **15-Dec-15**
		Sample No **BH1**

ATTERBERG LIMIT

AASHTO T-89 & T- 90

LIQUID LIMIT

Container No.	23	14	O9
Wt of wet soil + container, gm	62.30	64.20	66.60
Wt of dry soil + container, gm	51.80	53.80	54.40
Wt of water	10.50	10.40	12.20
Wt of container	33.60	35.80	34.10
Wt of dry soil, gm	18.20	18.00	20.30
Water content, %	57.69	57.78	60.10
No. of blows	31	27	24



Number of blows

Sample preparation

As received	☐
Washed on 0.425mmsieve	☑
Air dried at ……30°C	☐
Oven dried at 110 °C	
Proportion retained on 0.425mm sieve %	

Liquid Limit	**58.52**
Plastic Limit	**27.40**
Plasticity Index	**31.12**

PLASTIC LIMIT

Container No.	1	2	**Average**
Wt of wet soil + container, gm	15.20	14.30	
Wt of dry soil + container, gm	14.20	13.30	
Wt of water	1.00	1.00	
Wt of container	10.50	9.70	
Wt of dry soil, gm	3.70	3.60	
Water content, %	27.03	27.78	**27.4**

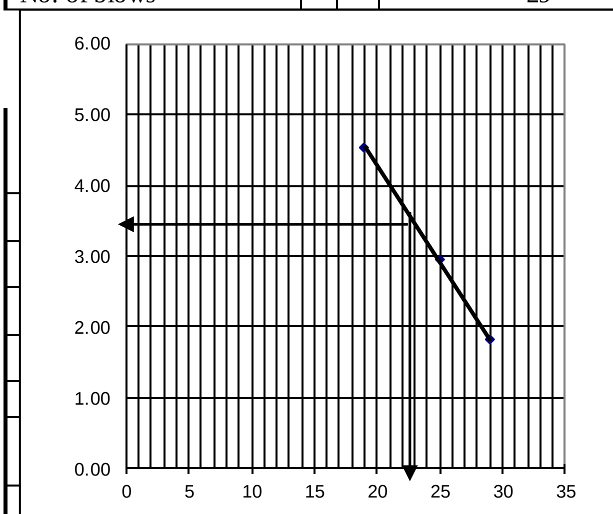
Material Type :	**Base-Coarse**	**Date sampled :**	**29-Nov-15**
Source :	**398+000**	**Sate tested :**	**5-Jan-16**
		Sample No	**BH2**

ATTERBERG LIMIT

AASHTO T-89 & T- 90

LIQUID LIMIT

Container No.	1	2	3	MB
Wt of wet soil + container, gm	107.40	101.00	108.70	
Wt of dry soil + container, gm	106.40	99.60	106.20	
Wt of water	1.00	1.40	2.50	
Wt of container	51.00	52.00	51.00	
Wt of dry soil, gm	55.40	47.60	55.20	
Water content, %	1.81	2.94	4.53	
No. of blows	29	25	19	



Number of Blows

Sample preparation

As received	☐
Washed on 0.425mmsieve	☑
Air dried at ……30°C	☐
Oven dried at 110 °C	
Proportion retained on 0.425mm sieve %	

Liquid Limit	**3**	%
Plastic Limit	**0**	%
Plasticity Index	**3**	

PLASTIC LIMIT

Container No.	1	2		**Average**
Wt of wet soil + container, gm				
Wt of dry soil + container, gm				
Wt of water				
Wt of container				
Wt of dry soil, gm				
Water content, %				**0.0**

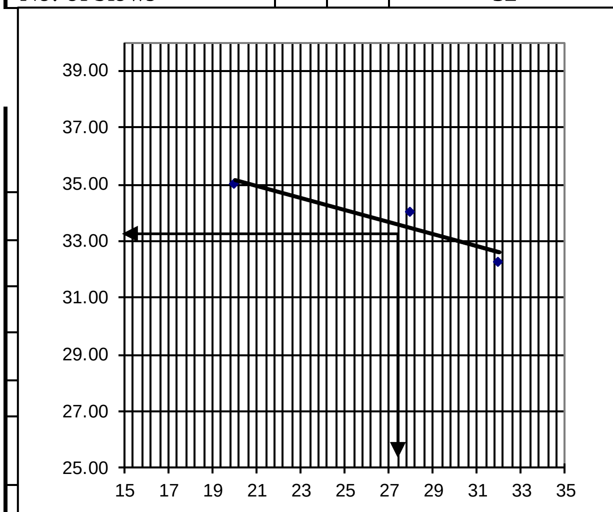
Material Type :	**Sub Base**				**Date sampled :**	**29-Nov-15**
Source :	**398+000**				**Sate tested :**	**2-Jan-16**
					Sample No	**BH2**

ATTERBERG LIMIT

AASHTO T-89 & T- 90

LIQUID LIMIT

Container No.			B1	A-66	TT	
Wt of wet soil + container, gm			43.90	42.20	41.30	
Wt of dry soil + container, gm			38.10	36.70	35.60	
Wt of water			5.80	5.50	5.70	
Wt of container			20.10	20.50	19.30	
Wt of dry soil, gm			18.00	16.20	16.30	
Water content, %			32.22	33.95	34.97	
No. of blows			32	28	20	



No. of blows

Sample preparation

	☐	
As received	☐	
Washed on 0.425mmsieve	☑	
Air dried at ……30°C	☐	
Oven dried at 110 °C		
Proportion retained on 0.425mm sieve %		
Liquid Limit	**34**	%
Plastic Limit	**26.7**	%
Plasticity Index	**7**	

PLASTIC LIMIT

Container No.			16	20		**Average**
Wt of wet soil + container, gm			23.20	22.20		
Wt of dry soil + container, gm			22.10	20.90		
Wt of water			1.10	1.30		
Wt of container			17.50	16.50		
Wt of dry soil, gm			4.60	4.40		
Water content, %			23.91	29.55		**26.7**

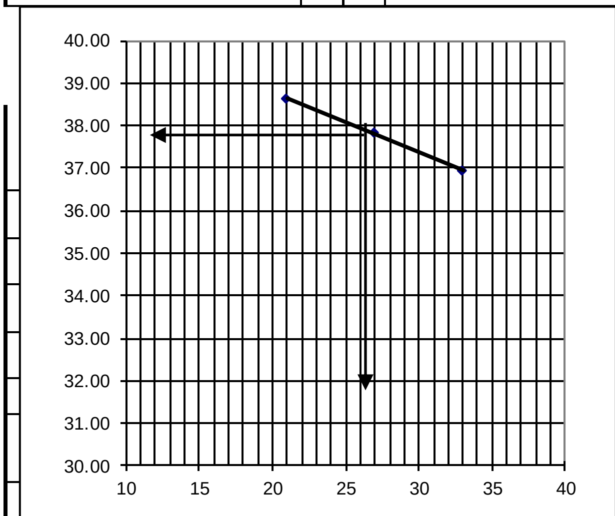
Material Type :	**Subgrade**	**Date sampled :**	**29-Nov-15**
Source :	**398+000**	**Sate tested :**	**27-Dec-15**
		Sample No	**BH2**

ATTERBERG LIMIT

AASHTO T-89 & T- 90

LIQUID LIMIT

Container No.	121	23	15A	
Wt of wet soil + container, gm	65.80	66.40	63.30	
Wt of dry soil + container, gm	57.90	57.40	54.80	
Wt of water	7.90	9.00	8.50	
Wt of container	36.50	33.60	32.80	
Wt of dry soil, gm	21.40	23.80	22.00	
Water content, %	36.92	37.82	38.64	
No. of blows	33	27	21	



Sample preparation

As received	☐
Washed on 0.425mm sieve	☑
Air dried at ……30^{o}C	☐
Oven dried at 110 ^{o}C	
Proportion retained on 0.425mm sieve %	

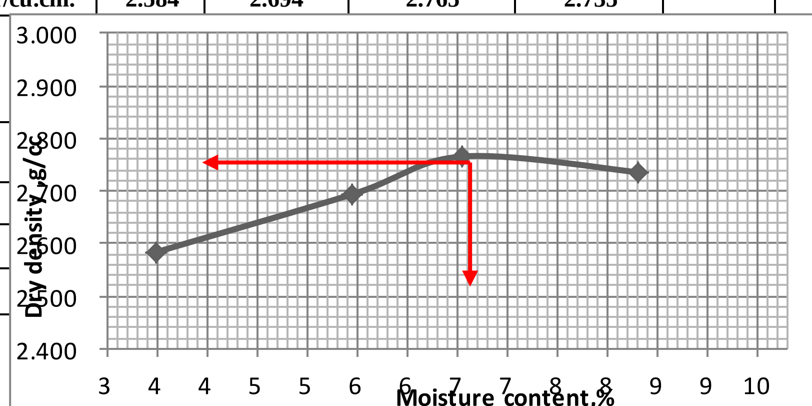
Liquid Limit	**38**	%
Plastic Limit	**24.7**	%
Plasticity Index	**13**	

PLASTIC LIMIT

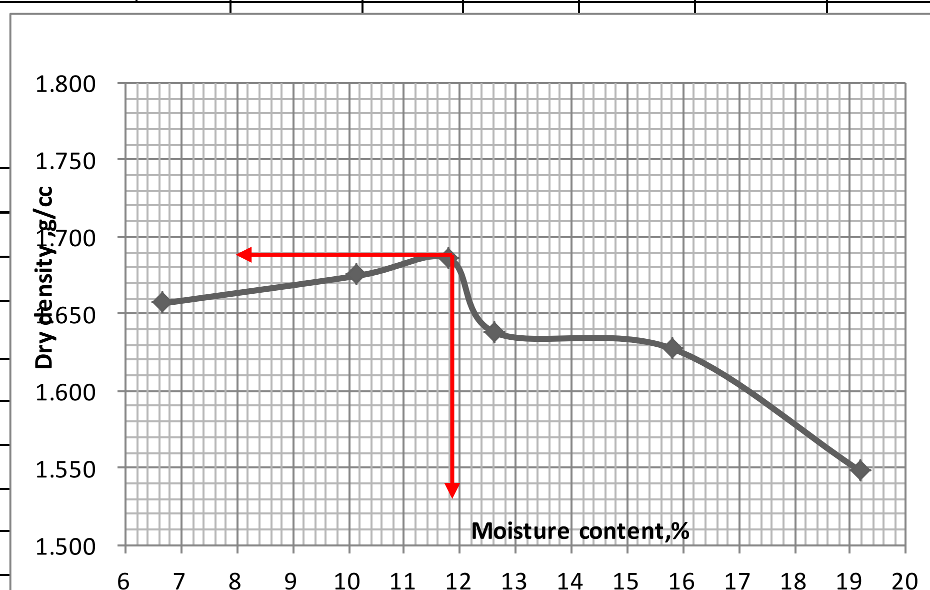
Container No.	1	2		**Average**
Wt of wet soil + container, gm	13.20	12.20		
Wt of dry soil + container, gm	12.70	11.67		
Wt of water	0.50	0.53		
Wt of container	10.50	9.70		
Wt of dry soil, gm	2.20	1.97		
Water content, %	22.73	26.71		**24.7**

APPENDEX C. MODIFIED PROCTOR TEST

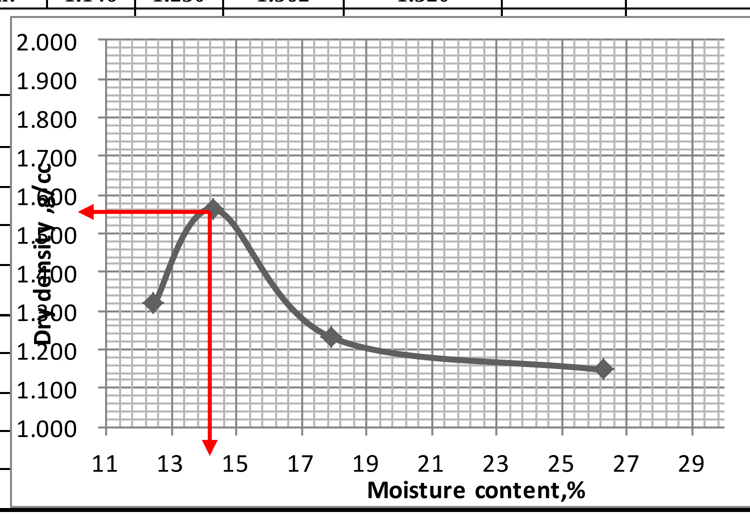
Material Type	**Base course**				**Date sampled :**		**29-Nov-15**	
Source	**385+000**			**Sample No**	**BH1**	**Test date**	**22-Dec-15**	
MOISTURE - DENSITY RELATION OF SOIL								
AASHTO T 180								
No. of blows :	**56**				**Weight of hammer, kg :**		**4.5**	
No. of layers :	**5**				**Volume of mold,cm^3 :**		**1572.7**	
Proportion retained on 19mm sieve size:				**Single sample / Separate batches :**				
(pass 50mm sieve and retained on 19mm sieve)				**Apparent specific gravity :**				
A	**Mold**	**No.**	**1**	**2**	**3**	**4**	**5**	**NMC**
B	**Wt. of Mold + Wet Soil**	**grams**	**10357.0**	**10619.0**	**10786.0**	**10811.0**		
C	**Wt. of Mold**	**grams**	**6143.0**	**6143.0**	**6143.0**	**6143.0**		
D	**Wt. Wet Soil**	**grams**	**4214.0**	**4476.0**	**4643.0**	**4668.0**		
E	**Volume of Mold**	**cu.cm.**	**1572.7**	**1572.7**	**1572.7**	**1572.7**		
F	**Wet Density**	**gr/cu.cm.**	**2.679**	**2.846**	**2.952**	**2.968**		
G	**Container**	**No.**	**5**	**23**	**142**	**9**		**AL**
H	**Wt. Cont + Wet soil**	**grams**	**197.1**	**239.2**	**233.8**	**231.5**		**338.2**
I	**Wt. Cont + Dry soil**	**grams**	**191.3**	**228.2**	**221.3**	**216.0**		**333.6**
J	**Weight of Water**	**grams**	**5.8**	**11.0**	**12.5**	**15.5**		**4.6**
K	**Weight of Container**	**grams**	**34.4**	**33.6**	**36.2**	**33.9**		**66.9**
L	**Weight of Dry Soil**	**grams**	**156.9**	**194.6**	**185.1**	**182.1**		**266.7**
M	**Moisture Content**	**%**	**3.7**	**5.7**	**6.8**	**8.5**		**1.7**
N	**Dry Density**	**gr/cu.cm.**	**2.584**	**2.694**	**2.765**	**2.735**		
Maximum Dry Density (MDD):								
MDD (gm/cc)=	**2.765**							
Optimum Moisture Content (OMC) :								
OMC(%) =	**6.8**							



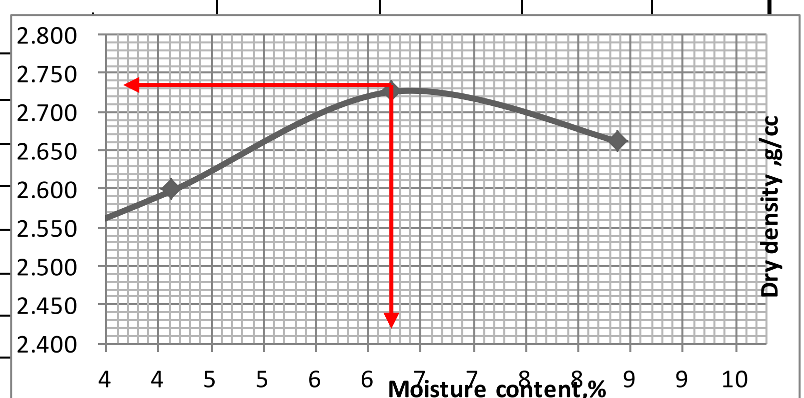
Material Type	**Sub Base**			**Date sampled :**		**29-Nov-15**			
Source	**385+000**		**Sample No**	**BH1**	**Date tested :**			**18-Dec-15**	
MOISTURE - DENSITY RELATION OF SOIL									
AASHTO T 180									
A	**Mold**	**No.**	**1**	**2**	**3**	**4**	**5**	**6**	**NMC**
B	**Wt. of Mold + Wet Soil**	**grams**	**9435.0**	**9599.0**	**9684.0**	**9837.0**	**10061.0**	**10036.0**	
C	**Wt. of Mold**	**grams**	**5681.0**	**5681.0**	**5681.0**	**5681.0**	**5681.0**	**5681.0**	
D	**Wt. Wet Soil**	**grams**	**3754.0**	**3918.0**	**4003.0**	**4156.0**	**4380.0**	**4536.0**	
E	**Volume of Mold**	**cu.cm.**	**2124.0**	**2124.0**	**2124.0**	**2124.0**	**2124.0**	**2124.0**	
F	**Wet Density**	**gr/cu.cm.**	**1.767**	**1.845**	**1.885**	**1.845**	**1.885**	**1.845**	
G	**Container**	**No.**	**50**	**14**	**10**	**25**	**44**	**15**	**BC-1**
H	**Wt. Cont + Wet soil**	**grams**	**215.4**	**219.2**	**208.1**	**202.8**	**201.8**	**172.5**	**393.0**
I	**Wt. Cont + Dry soil**	**grams**	**204.1**	**202.3**	**189.7**	**183.7**	**178.8**	**150.0**	**382.1**
J	**Weight of Water**	**grams**	**11.3**	**16.9**	**18.4**	**19.1**	**23.0**	**22.5**	**10.9**
K	**Weight of Container**	**grams**	**34.8**	**35.8**	**33.7**	**32.7**	**33.5**	**32.8**	**78.5**
L	**Weight of Dry Soil**	**grams**	**169.3**	**166.5**	**156.0**	**151.0**	**145.3**	**117.2**	**303.6**
M	**Moisture Content**	**%**	**6.7**	**10.2**	**11.8**	**12.6**	**15.8**	**19.2**	**3.6**
N	**Dry Density**	**gr/cu.cm.**	**1.657**	**1.675**	**1.686**	**1.638**	**1.627**	**1.548**	
Maximum Dry Density (MDD):									
MDD (gm/cc)=	**1.686**								
Optimum Moisture Content (OMC) :									
OMC(%) =	**11.8**								



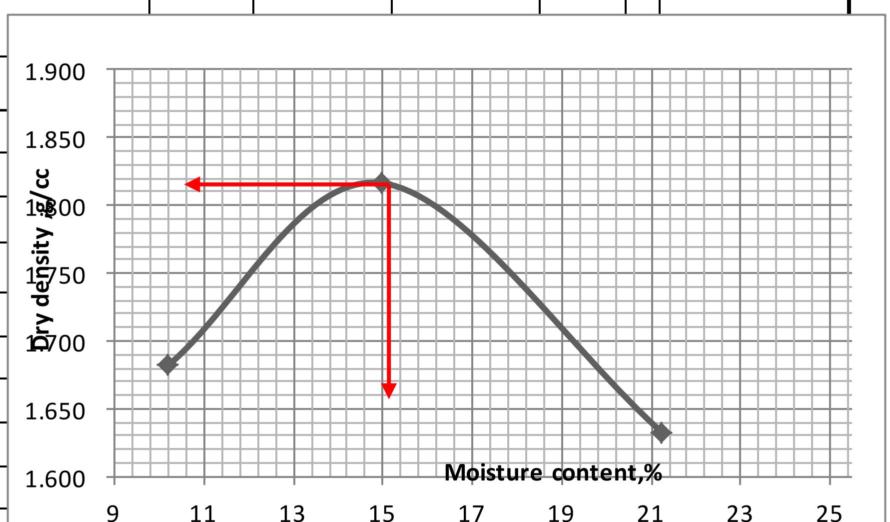
Material Type	**Sub grade**					**Date sampled :**	**29-Nov-15**	
Source	**7°51′12.69’′N 36°36′09.4821’′E**					**Date tested :**	**12-Dec-15**	
						Sample No	**BH1**	
MOISTURE - DENSITY RELATION OF SOIL								
AASHTO T180								
No. of blows :	**56**				**Weight of hammer, kg :**		**4.5**	
No. of layers :	**5**				**Volume of mold,cm^3 :**		**2124**	
Proportion retained on 19mm sieve size:				**Single sample / Separate batches :**				
(pass 50mm sieve and retained on 19mm sieve)				**Apparent specific gravity :**				
A	**Mold**	**No.**	**1**	**2**	**3**	**4**	**5**	**NMC**
B	**Wt. of Mold + Wet Soil**	**grams**	**5742.0**	**5745.0**	**6082.0**	**5779.0**		
C	**Wt. of Mold**	**grams**	**4287.0**	**4287.0**	**4287.0**	**4287.0**		
D	**Wt. Wet Soil**	**grams**	**1455.0**	**1458.0**	**1795.0**	**1492.0**		
E	**Volume of Mold**	**cu.cm.**	**1005.0**	**1005.0**	**1005.0**	**1005.0**		
F	**Wet Density**	**gr/cu.cm.**	**1.448**	**1.451**	**1.786**	**1.485**		
G	**Container**	**No.**	**10**	**25**	**44**	**50**		**AE**
H	**Wt. Cont + Wet soil**	**grams**	**166.1**	**185.4**	**189.2**	**191.6**		**316.2**
I	**Wt. Cont + Dry soil**	**grams**	**138.3**	**162.3**	**169.7**	**174.2**		**311.7**
J	**Weight of Water**	**grams**	**27.8**	**23.1**	**19.5**	**17.4**		**4.5**
K	**Weight of Container**	**grams**	**32.7**	**33.5**	**33.5**	**34.8**		**81.7**
L	**Weight of Dry Soil**	**grams**	**105.6**	**128.8**	**136.2**	**139.4**		**230.0**
M	**Moisture Content**	**%**	**26.3**	**17.9**	**14.3**	**12.5**		**2.0**
N	**Dry Density**	**gr/cu.cm.**	**1.146**	**1.230**	**1.562**	**1.320**		
Maximum Dry Density (MDD):								
MDD (gm/cc)=	**1.562**							
Optimum Moisture Content (OMC):								
OMC % =	**14.3**							



Material Type	**Base course**	**Sample No**	**BH2**			**Date sampled :**	**29-Nov-15**	
Source	**398+000**					**Date tested :**	**4-Jan-16**	
MOISTURE - DENSITY RELATION OF SOIL								
AASHTO T180								
No. of blows :	**56**				**Weight of hammer, kg :**		**4.5**	
No. of layers :	**5**				**Volume of mold,cm^3 :**		**1572.7**	
Proportion retained on 19mm sieve size:				**Single sample / Separate batches :**				
(pass 50mm sieve and retained on 19mm sieve)				**Apparent specific gravity :**				
A	**Mold**	**No.**	**1**	**2**	**3**	**4**	**5**	**NMC**
B	**Wt. of Mold + Wet Soil**	**grams**	**10080.0**	**10257.0**	**10558.0**	**10540.0**		
C	**Wt. of Mold**	**grams**	**5995.0**	**5995.0**	**5995.0**	**5995.0**		
D	**Wt. Wet Soil**	**grams**	**4085.0**	**4262.0**	**4563.0**	**4545.0**		
E	**Volume of Mold**	**cu.cm.**	**1572.7**	**1572.7**	**1572.7**	**1572.7**		
F	**Wet Density**	**gr/cu.cm.**	**2.597**	**2.710**	**2.901**	**2.890**		
G	**Container**	**No.**	**9**	**121**	**140**	**141**		**CM**
H	**Wt. Cont + Wet soil**	**grams**	**229.0**	**215.0**	**199.4**	**194.6**		**356.9**
I	**Wt. Cont + Dry soil**	**grams**	**223.4**	**207.6**	**189.4**	**182.2**		**352.9**
J	**Weight of Water**	**grams**	**5.6**	**7.4**	**10.0**	**12.4**		**4.0**
K	**Weight of Container**	**grams**	**34.0**	**36.5**	**33.9**	**37.8**		**78.2**
L	**Weight of Dry Soil**	**grams**	**189.4**	**171.1**	**155.5**	**144.4**		**274.7**
M	**Moisture Content**	**%**	**3.0**	**4.3**	**6.4**	**8.6**		**1.5**
N	**Dry Density**	**gr/cu.cm.**						
Maximum Dry Density (MDD):								
MDD(gm/cc) =	**2.726**							
Optimum Moisture Content (OMC) :								
OMC% =	**6.4**							



Material Type	Sub Base	Sample No		BH2		Date Sampling:	29-Nov-15		
Source		398+000				Date tested:	30-Dec-15		
MOISTURE - DENSITY RELATION OF SOIL									
AASHTO T180									
No. of blows:	56				Weight of hammer, kg:		4.5		
No. of layers:	5				Volume of mold, cm^3:		2124		
Proportion retained on 19mm sieve size:				Single sample / Separate batches:					
(pass 50mm sieve and retained on 19mm sieve)				Apparent specific gravity:					
A	Mold	No.	1	2	3	4	5		NMC
B	Wt. of Mold + Wet Soil	grams	10062.0	10558.0	10327.0				
C	Wt. of Mold	grams	6142.0	6142.0	6142.0				
D	Wt. Wet Soil	grams	3920.0	4417.0	4186.0				
E	Volume of Mold	cu.cm.	2124.0	2124.0	2124.0				
F	Wet Density	gr/cu.cm.	1.846	2.080	1.971				
G	Container	No.	O1	O2	20				AB
H	Wt. Cont+Wet soil	grams	231.0	225.2	184.1				378.9
I	Wt. Cont+Dry soil	grams	213.5	201.0	158.2				368.6
J	Weight of Water	grams	17.5	24.2	25.9				10.3
K	Weight of Container	grams	33.2	34.1	33.4				78.2
L	Weight of Dry Soil	grams	180.3	166.9	124.8				290.4
M	Moisture Content	%	9.7	14.5	20.8				3.5
N	Dry Density	gr/cu.cm.							
Maximum Dry Density (MDD):									
MDD (gm/cc)=	1.816								
Optimum Moisture Content (OMC):									
OMC (%) =	14.5								

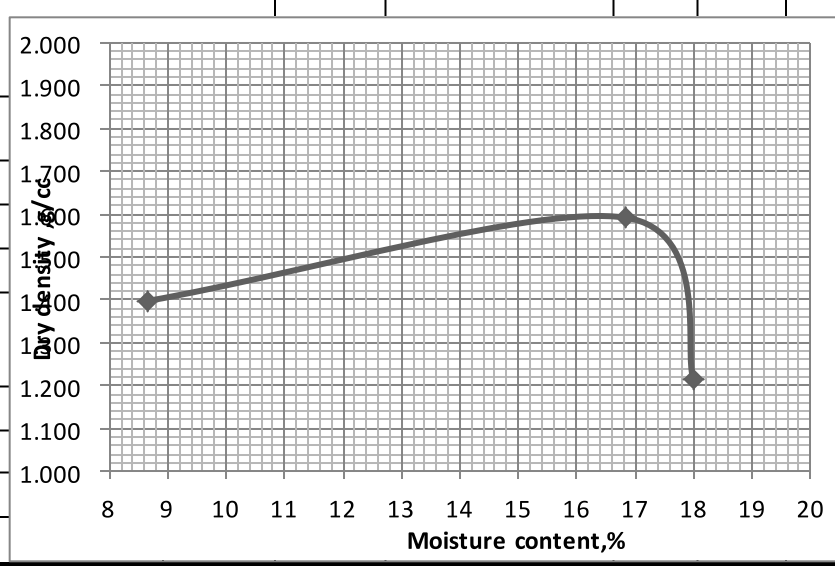


MOISTURE - DENSITY RELATION OF SOIL

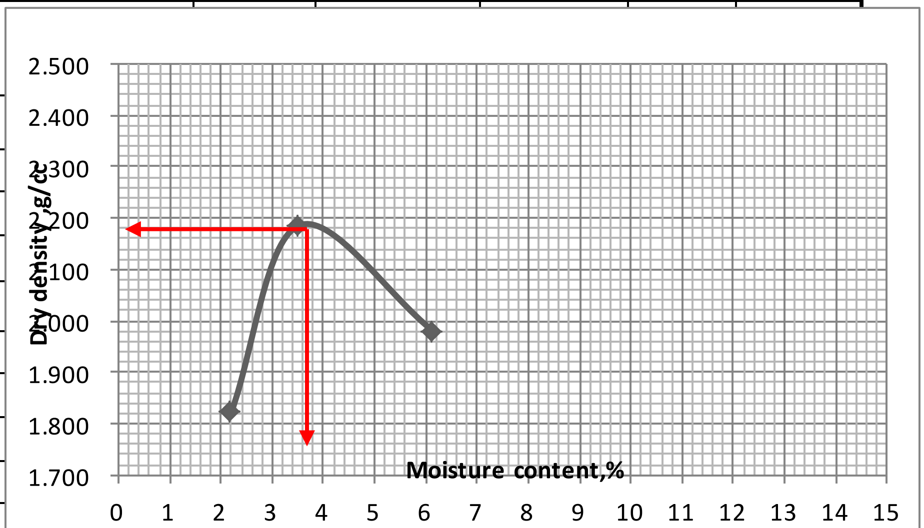
AASHTO T 180

No. of blows :	56					Weight of hammer,kg :		4.5	
No. of layers :	5		BH2			Volume of mold,cm^3 :		2124	
Proportion retained on 19mm sieve size:			Subgrade		Single sample / Separate batches :				
(pass 50mm sieve and retained on 19mm sieve)					Apparent specific gravity :				
A	Mold		No.	1	2	3	4	5	NMC
B	Wt. of Mold + Wet Soil		grams	5820.0	6163.0	5735.0			
C	Wt. of Mold		grams	4294.0	4294.0	4294.0			
D	Wt. Wet Soil		grams	1526.0	1869.0	1441.0			
E	Volume of Mold		cu.cm.	1005.0	1005.0	1005.0			
F	Wet Density		gr/cu.cm.	1.518	1.860	1.434			
G	Container		No.	14	2	9	12		AE
H	Wt. Cont + Wet soil		grams	254.3	201.5	249.2			311.7
I	Wt. Cont + Dry soil		grams	236.9	177.4	221.0			303.7
J	Weight of Water		grams	17.4	24.1	28.2			8.0
K	Weight of Container		grams	35.8	34.2	34.1			78.2
L	Weight of Dry Soil		grams	201.1	143.2	186.9			225.5
M	Moisture Content		%	8.7	16.8	18.0			3.5
N	Dry Density		gr/cu.cm.	1.397	1.592	1.215			

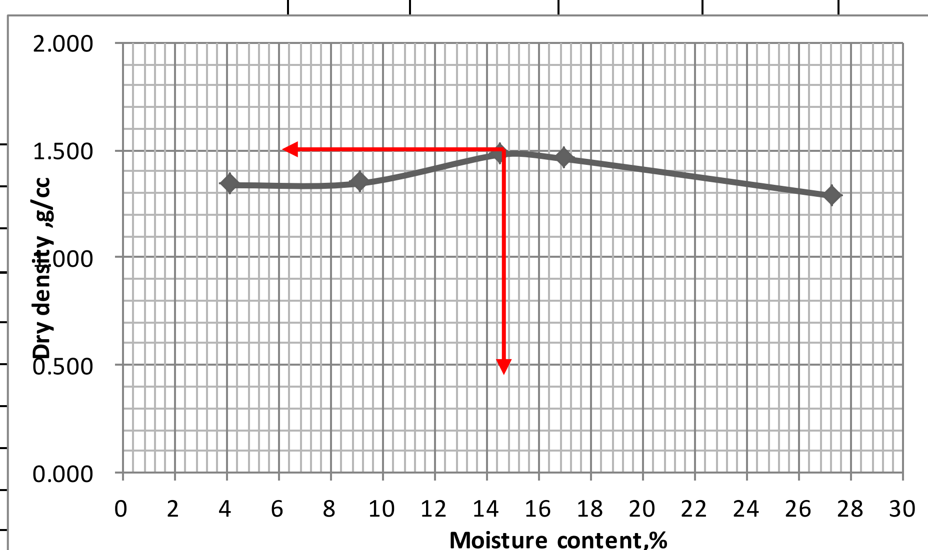
Maximum Dry Density (MDD):		
MDD =	1.592	gm/cc
Optimum Moisture Content (OMC) :		
OMC =	16.8	%



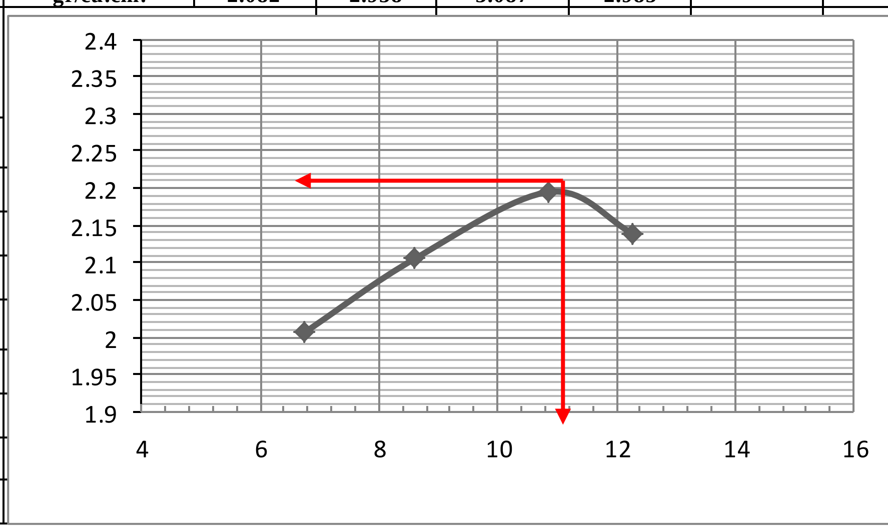
Material Type	Sub Base				Date sampled :		30-Nov-15	
Source	386+000			BH3	Date tested :		12-Jan-16	
MOISTURE - DENSITY RELATION OF SOIL								
AASHTO T 180								
No. of blows :	56				Weight of hammer, kg :		4.5	
No. of layers :	5				Volume of mold, cm^3 :		2413.0	
Proportion retained on 19mm sieve size:				Single sample / Separate batches :				
(pass 50mm sieve and retained on 19mm sieve)				Apparent specific gravity :				
A	Mold	No.	1	2	3	4	5	NMC
B	Wt. of Mold + Wet Soil	grams	9458.0	10424.2	10036.8	10199.3		
C	Wt. of Mold	grams	4964.0	4964.0	4964.0	4964.0		
D	Wt. Wet Soil	grams	4494.0	5460.2	5072.8	5235.3		
E	Volume of Mold	cu.cm.	2413.0	2413.0	2413.0	2413.0		
F	Wet Density	gr/cu.cm.	1.862	2.263	2.102	2.170		
G	Container	No.	5	9	7	15		G
H	Wt. Cont + Wet soil	grams	213.5	241.7	229.5	244.8		397.8
I	Wt. Cont + Dry soil	grams	210.0	235.3	219.3	224.4		387.0
J	Weight of Water	grams	3.5	6.4	10.2	20.4		10.8
K	Weight of Container	grams	51.0	53.0	53.0	51.0		78.2
L	Weight of Dry Soil	grams	159.0	182.3	166.3	173.4		308.8
M	Moisture Content	%	2.2	3.5	6.1	11.8		3.5
N	Dry Density	gr/cu.cm.	1.822	2.186	1.981	1.941		
Maximum Dry Density (MDD):								
MDD(gm/cc) =	1.981							
Optimum Moisture Content (OMC) :								
OMC %=	6.1							



Material Type		Sub-Grade	Sample No	BH3		Date sampled:	30-Nov-15	
Source	386+000					Date tested:	8-Jan-16	
MOISTURE - DENSITY RELATION OF SOIL								
AASHTO T180								
No. of blows:	56				Weight of hammer, kg:		4.5	
No. of layers:	5				Volume of mold, cm^3:		2413	
Proportion retained on 19mm sieve size:				Single sample / Separate batches:				
(pass 50mm sieve and retained on 19mm sieve)				Apparent specific gravity:				
A	Mold	No.	1	2	3	4	5	NMC
B	Wt. of Mold + Wet Soil	grams	8321.8	8506.0	9054.0	9081.0	8916.0	
C	Wt. of Mold	grams	4964.0	4964.0	4964.0	4964.0	4964.0	
D	Wt. Wet Soil	grams	3357.8	3542.0	4090.0	4117.0	3952.0	
E	Volume of Mold	cu.cm.	2413.0	2413.0	2413.0	2413.0	2413.0	
F	Wet Density	gr/cu.cm.	1.392	1.468	1.695	1.706	1.638	
G	Container	No.	5	8	9	10	21	AE
H	Wt. Cont + Wet soil	grams	242.6	223.6	246.2	231.0	207.3	314.5
I	Wt. Cont + Dry soil	grams	235.0	209.1	221.4	205.0	174.0	309.5
J	Weight of Water	grams	7.6	14.5	24.8	26.0	33.3	5.0
K	Weight of Container	grams	52.0	50.0	51.0	52.0	52.0	80.0
L	Weight of Dry Soil	grams	183.0	159.1	170.4	153.0	122.0	229.5
M	Moisture Content	%	4.2	9.1	14.6	17.0	27.3	2.2
N	Dry Density	gr/cu.cm.	1.336	1.345	1.480	1.458	1.287	
Maximum Dry Density (MDD):								
MDD(gm/cc)=	1.480							
Optimum Moisture Content (OMC):								
OMC5 =	14.6							

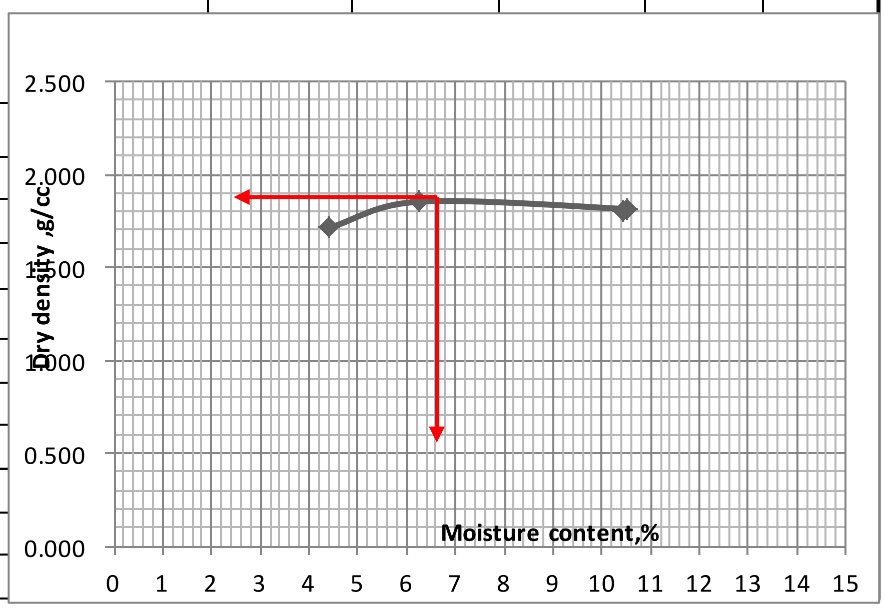


Material Type	Base course		Sample No	BH-3	Date sampled :		30-Nov-15	
Source	397+000				Date tested :		28-Jan-16	
MOISTURE - DENSITY RELATION OF SOIL								
AASHTO T 180								
No. of blows :	56				Weight of hammer, kg :		4.5	
No. of layers :	5				Volume of mold,cm^3 :		2123.0	
Proportion retained on 19mm sieve size:				Single sample / Separate batches :				
(pass 50mm sieve and retained on 19mm sieve)				Apparent specific gravity :				
A	Mold	No.	1	2	3	4	5	NMC
B	Wt. of Mold + Wet Soil	grams	10545.0	10849.0	11162.0	11093.0		
C	Wt. of Mold	grams	5995.0	5995.0	5995.0	5995.0		
D	Wt. Wet Soil	grams	4550.0	4854.0	5167.0	5098.0		
E	Volume of Mold	cu.cm.	2123.0	1572.7	1572.7	1572.7		
F	Wet Density	gr/cu.cm.	2.143	3.086	3.285	3.242		
G	Container	No.	9	121	140	141		CM
H	Wt. Cont + Wet soil	grams	229.0	215.0	199.4	194.6		356.9
I	Wt. Cont + Dry soil	grams	223.4	207.6	189.4	182.2		352.9
J	Weight of Water	grams	5.6	7.4	10.0	12.4		4.0
K	Weight of Container	grams	34.0	36.5	33.9	37.8		78.2
L	Weight of Dry Soil	grams	189.4	171.1	155.5	144.4		274.7
M	Moisture Content	%	3.0	4.3	6.4	8.6		1.5
N	Dry Density	gr/cu.cm.	2.082	2.958	3.087	2.985		
Maximum Dry Density (MDD):								
MDD(gm/cc) =	3.087							
Optimum Moisture Content (OMC) :								
OMC % =	6.4							



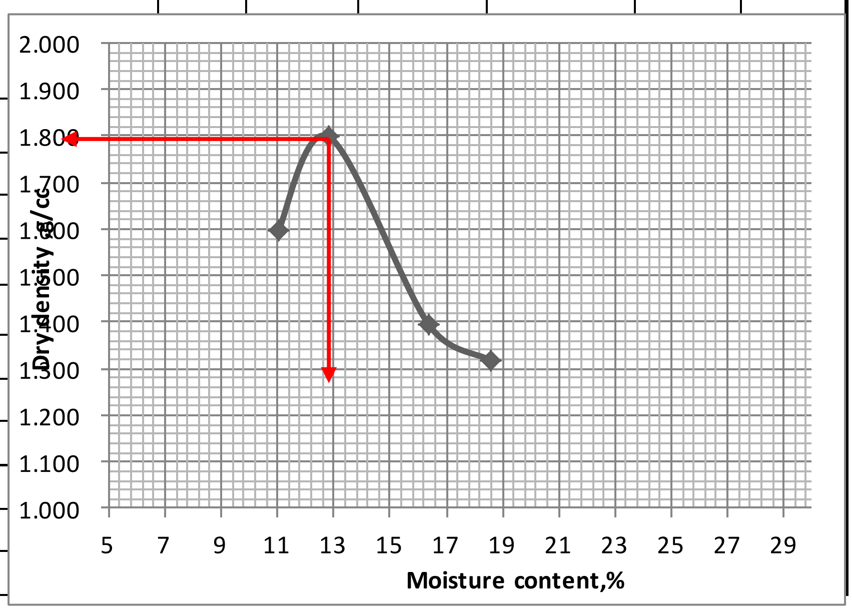
Material Type	**Sub Base**				**Date sampled :**		**30-Nov-15**	
Source	**397+000**	**Sample No**	**BH4**		**Date tested :**		**24-Jan-16**	
MOISTURE - DENSITY RELATION OF SOIL								
AASHTO T 180								
No. of blows :	**56**				**Weight of hammer, kg :**		**4.5**	
No. of layers :	**5**				**Volume of mold, cm^3 :**		**2413.0**	
Proportion retained on 19mm sieve size:					**Single sample / Separate batches :**		**-**	
(pass 50mm sieve and retained on 19mm sieve)					**Apparent specific gravity :**		**-**	
A	**Mold**	**No.**	**1**	**2**	**3**	**4**	**5**	**NMC**
B	**Wt. of Mold + Wet Soil**	**grams**	**9265.0**	**9705.0**	**9788.0**	**9752.0**		
C	**Wt. of Mold**	**grams**	**4952.0**	**4952.0**	**4952.0**	**4952.0**		
D	**Wt. Wet Soil**	**grams**	**4313.0**	**4753.0**	**4836.0**	**4800.0**		
E	**Volume of Mold**	**cu.cm.**	**2413.0**	**2413.0**	**2413.0**	**2413.0**		
F	**Wet Density**	**gr/cu.cm.**	**1.8**	**2.0**	**2.0**	**2.0**		
G	**Container**	**No.**	**O 7**	**O 5**	**O 9**	**15.0**		**X**
H	**Wt. Cont + Wet soil**	**grams**	**242.0**	**248.0**	**240.0**	**226.8**		**397.8**
I	**Wt. Cont + Dry soil**	**grams**	**234.0**	**236.4**	**222.0**	**210.3**		**387.0**
J	**Weight of Water**	**grams**	**8.0**	**11.6**	**18.0**	**16.5**		**10.8**
K	**Weight of Container**	**grams**	**52.0**	**51.0**	**51.0**	**52.5**		**78.2**
L	**Weight of Dry Soil**	**grams**	**182.0**	**185.4**	**171.0**	**157.8**		**308.8**
M	**Moisture Content**	**%**	**4.4**	**6.3**	**10.5**	**10.5**		**3.5**
N	**Dry Density**	**gr/cu.cm.**	**1.712**	**1.854**	**1.813**	**1.801**		

Maximum Dry Density (MDD):	
MDD(gm/cc) =	**1.854**
Optimum Moisture Content (OMC) :	
OMC % =	**6.3**



Material Type	**Sub grade**				**Date sampled :**		**30-Nov-15**	
Source	**397+000**	**Sample No**	**BH4**		**Date tested :**		**20-Jan-16**	
MOISTURE - DENSITY RELATION OF SOIL								
AASHTO T180								
No. of blows :	**56**				**Weight of hammer, kg :**		**4.5**	
No. of layers :	**5**				**Volume of mold, cm^3 :**		**2124**	
Proportion retained on 19mm sieve size:				**Single sample / Separate batches :**				
(pass 50mm sieve and retained on 19mm sieve)				**Apparent specific gravity :**				
A	**Mold**	**No.**	**1**	**2**	**3**	**4**	**5**	**NMC**
B	**Wt. of Mold + Wet Soil**	**grams**	**5856.8**	**5917.4**	**6325.3**	**6068.0**		
C	**Wt. of Mold**	**grams**	**4287.0**	**4287.0**	**4287.0**	**4287.0**		
D	**Wt. Wet Soil**	**grams**	**1569.8**	**1630.4**	**2038.3**	**1781.0**		
E	**Volume of Mold**	**cu.cm.**	**1005.0**	**1005.0**	**1005.0**	**1005.0**		
F	**Wet Density**	**gr/cu.cm.**	**1.562**	**1.622**	**2.028**	**1.772**		
G	**Container**	**No.**	**10**	**25**	**44**	**50**		**AE**
H	**Wt. Cont + Wet soil**	**grams**	**169.4**	**191.0**	**196.8**	**201.2**		**328.8**
I	**Wt. Cont + Dry soil**	**grams**	**148.0**	**168.8**	**178.2**	**184.7**		**327.3**
J	**Weight of Water**	**grams**	**21.4**	**22.2**	**18.6**	**16.5**		**1.6**
K	**Weight of Container**	**grams**	**32.7**	**33.5**	**33.5**	**34.8**		**81.7**
L	**Weight of Dry Soil**	**grams**	**115.3**	**135.3**	**144.7**	**149.9**		**245.6**
M	**Moisture Content**	**%**	**18.6**	**16.4**	**12.8**	**11.0**		**0.6**
N	**Dry Density**	**gr/cu.cm.**	**1.317**	**1.394**	**1.797**	**1.596**		

Maximum Dry Density (MDD):	
MDD(gm/cc) =	**1.797**
Optimum Moisture Content (OMC) :	
OMC % =	**12.8**



APPENDIX D. CALIFORNIA BEARING TEST

CALIFORNIAN BEARING RATIO(CBR) AASHTO T-180

Project:	**Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town**				
Client:	-	**Sample of:**	Base course	**Date Sampled:**	29-Nov-15
Station:	385+000	**Depth:**	-	**Date Started:**	24-Dec-15
Testpit(Sample) No:	BH-1	**Material Desc.:**	Base course	**Date completed:**	27-Dec-15

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mould No.						
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	10905	11246	12350	12497	12194	12370
Wt.ofmould	6586	6587	7645	7646	7339	7340
Wt.of wet sample	4319	4659	4705	4851	4855	5030
Volume of mould	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	2.75	2.96	2.99	3.08	3.08	3.19

MOISTURE DETERMINATION

Can No.	11	5	8	9	21	23
Wt.wet sample + can	207.4	240.7	201.4	242.2	209.9	218.5
Wt.dry sample +can	199.3	216.1	191.7	225.2	199.9	204.6
Wt.of water	8.1	24.6	9.7	17	10	13.9
Wt.of can	34.2	34.4	34.7	34	34.4	33.6
Wt.dry sample	165.1	181.7	157	191.2	165.5	171
% Moisture content	4.9	13.5	6.2	8.9	6.0	8.1
Dry unit weight	2.62	2.61	2.81	2.83	2.90	2.95

SWELL DATA

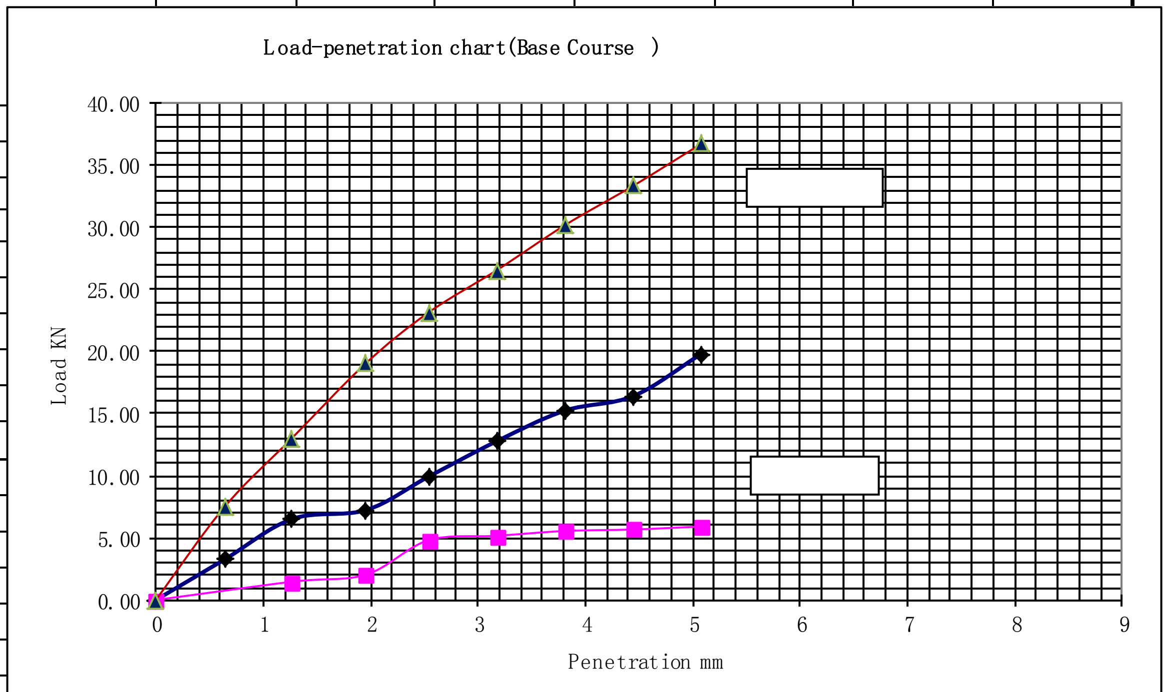
Day of month	Elapse time (day)	Mold 1			Mold 2			mold 3		
		gauge reading	swell		gauge reading	swell		gauge reading	swell	
			mm	%		mm	%		mm	%
12/24/2015		4.96	0.01	0.01	1.99	0.01	0.01	1.1	0.0018	0.0016
12/27/2015		5.77			2.9			1.28		

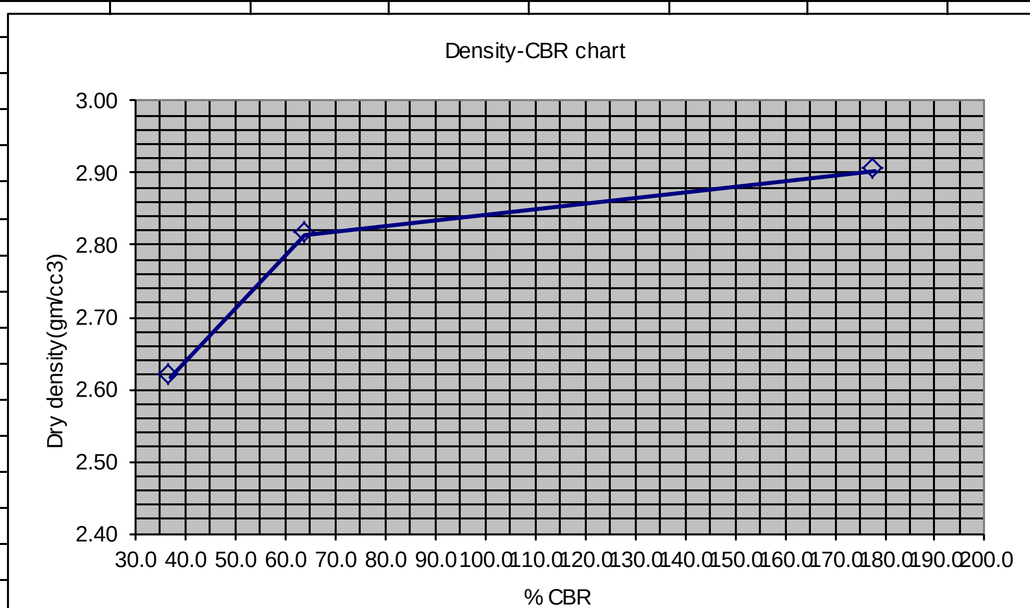
CBR DATA

Penetration (mm)	Std load (KN)	10 Blows				30 Blows				65 Blows			
		Gauge reading	test load	Corr.CBR		Gauge reading	test load	corr.CBR		Gauge reading	test load	corr.CBR	
			KN	KN	%		KN	KN	%		KN	KN	%
0		0	0			0	0			0	0		
0.64		45	1.09			135	3.26			310	7.49		
1.27		61	1.47			270	6.52			540	13.04		
1.96		85	2.05			300	7.25			790	19.08		
2.54	13	199	4.81	4.81	**37.0**	411	9.93	9.93	**76.4**	958	23.14	23.1	**178.0**
3.18	20	214	5.17	5.17	**25.8**	530	12.80	12.80	**64.0**	1100	26.57	26.6	**132.8**
3.81		230	5.55			631	15.24			1249	30.16		
4.45		235	5.68			680	16.42			1381	33.35		
5.08		245	5.92			820	19.80			1520	37		

Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	37.0	64.0	178.0

10 blows	
0	0.00
1.27	1.47
1.96	2.05
2.54	4.81
3.18	5.17
3.81	5.55
4.45	5.68
5.08	5.92
30 blows	
0	0.00
0.64	3.26
1.27	6.52
1.96	7.25
2.54	9.93
3.18	12.80
3.81	15.24
4.45	16.42
5.08	19.80
65 blows	
0	0.00
0.64	7.49
1.27	13.04
1.96	19.08
2.54	23.14
3.18	26.57
3.81	30.16
4.45	33.35
5.08	36.71
Density Vs CBR	
37.0	**2.62**
64.0	**2.81**
178.0	**2.90**





CALIFORNIAN BEARING RATIO (CBR) AASHTO T-180

Project:	**Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town**				
Client:	-	**Sample of:**	Sub base	**Date Sampled:**	29-Nov-15
Station:	385+000	**Depth:**	-	**Date Started:**	20-Dec-15
Testpit(Sample) No:	BH-1	**Material Desc.:**	Sub base	**Date completed:**	23-Dec-15

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mould No.						
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	11450.25	11470.92	12597	12746.94	12437.88	12617.4
Wt.ofmould	6586	6587	7645	7646	7339	7340
Wt.of wet sample	4864.25	4883.92	4952	5100.94	5098.88	5277.4
Volume of mould	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	3.09	3.10	3.14	3.24	3.23	3.34

MOISTURE DETERMINATION

Can No.	C	12	11	JB	15	6
Wt.wet sample + can	297.3	242.3	203.5	242.2	211.2	218.5
Wt.dry sample +can	218.6	217.2	192.8	225.2	198.8	203.6
Wt.of water	78.7	25.1	10.7	17	12.4	14.9
Wt.of can	34	34.4	34.7	34	34.4	34
Wt.dry sample	184.6	182.8	158.1	191.2	164.4	169.6
% Moisture content	42.6	13.7	6.8	8.9	7.5	8.8
Dry unit weight	2.17	2.73	2.95	2.97	3.01	3.07

SWELL DATA

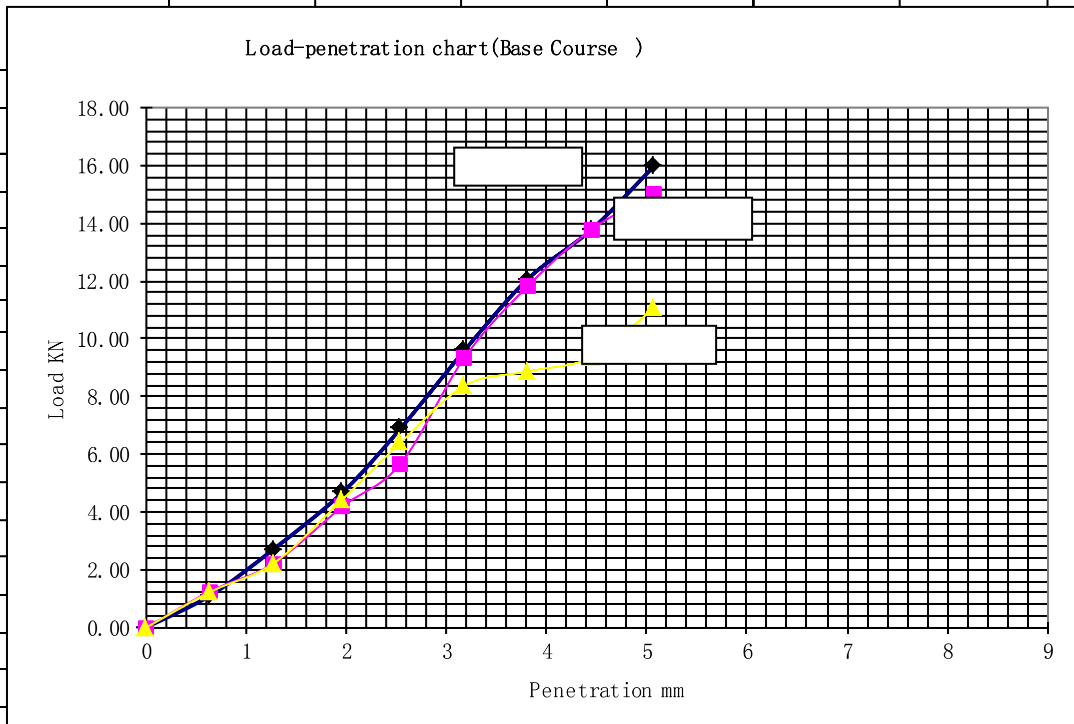
Day of month	Elapse time (day)	Mold 1			Mold 2			mold 3		
		gauge reading	swell		gauge reading	swell		gauge reading	swell	
			mm	%		mm	%		mm	%
12/20/2015		1.76	0.04	0.03	1.82	0.01	0.01	1.4	0.0028	0.0024
12/23/2015		5.66			2.7			1.68		

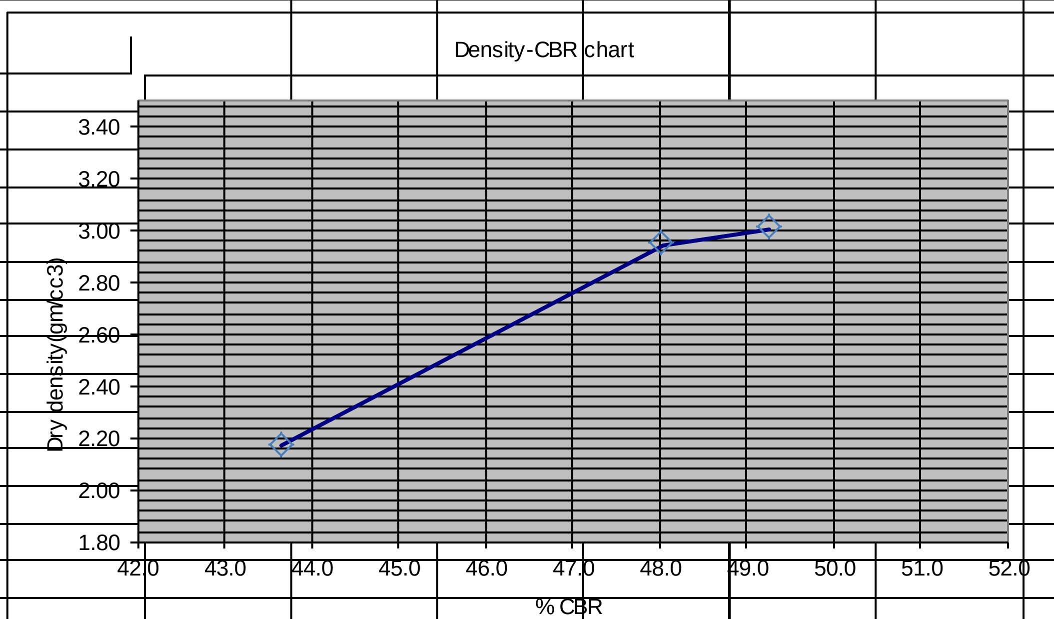
CBR DATA

Penetration (mm)	Std load (KN)	10 Blows				30 Blows				65 Blows			
		Gauge reading	test load	corr.CBR		Gauge reading	test load	corr.CBR		Gauge reading	test load	corr.CBR	
			KN	KN	%		KN	KN	%		KN	KN	%
0		0	0			0	0			0	0		
0.64		52	1.26			46	1.11			51	1.23		
1.27		92	2.22			112	2.71			92	2.22		
1.96		173	4.19			194	4.68			184	4.43		
2.54	13	235	5.68	5.68	**43.7**	286	6.90	6.90	**53.1**	265	6.40	6.4	**49.3**
3.18	20	388	9.36	9.36	**46.8**	398	9.61	9.61	**48.0**	347	8.38	8.4	**41.9**
3.81		490	11.82			500	12.07			367	8.87		
4.45		571	13.79			571	13.79			388	9.36		
5.08		622	15.03			663	16.01			459	11		

Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	43.7	48.0	49.3
Density gm/cm3	2.168	2.945	3.007

10 blows	
0	0.00
0.64	1.26
1.27	2.22
1.96	4.19
2.54	5.68
3.18	9.36
3.81	11.82
4.45	13.79
5.08	15.03
30 blows	
0	0.00
0.64	1.11
1.27	2.71
1.96	4.68
2.54	6.90
3.18	9.61
3.81	12.07
4.45	13.79
5.08	16.01
65 blows	
0	0.00
0.64	1.23
1.27	2.22
1.96	4.43
2.54	6.40
3.18	8.38
3.81	8.87
4.45	9.36
5.08	11.08
Dry density Vs CBR	
43.7	2.17
48.0	2.95
49.3	3.01





CALIFORNIAN BEARING RATIO (CBR) AASHTO T-180

Project:	**Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town**				
Client:	**-**	**Sample of:**	**Sub Grade**	**Date Sampled:**	**29-Nov-15**
Station:	**385+000**			**Date Started:**	**16-Dec-15**
Test pit(Sample) No:	**BH-1**	**Layer Desc.:**	**Sub Grade**	**Date completed:**	**19-Dec-15**

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mould No.						
No. of layers	**5**		**5**		**5**	
No. of blows per layer	**10**		**30**		**65**	
CONDITION OF SAMPLE	**Before soaking**	**After soaking**	**Before soaking**	**After soaking**	**Before soaking**	**After soaking**
Wt.of wet sample+mould	**11350**	**11842**	**12680**	**12861**	**12437.88**	**12619**
Wt.of mould	**6586**	**6587**	**7645**	**7646**	**7339**	**7340**
Wt.of wet sample	**4764**	**5255**	**5035**	**5215**	**5098.88**	**5279**
Volume of mould	**1572.7**	**1573.7**	**1574.7**	**1575.7**	**1576.7**	**1577.7**
Wet unit weight	**3.03**	**3.34**	**3.20**	**3.31**	**3.23**	**3.35**

MOISTURE DETERMINATION

Can No.	**CB1**	**CK**	**JR**	**MN**	**PT**	**K**
Wt.wet sample + can	**404.5**	**353.7**	**416**	**442**	**451**	**458**
Wt.dry sample +can	**356.1**	**322**	**370**	**378**	**376**	**390**
Wt.of water	**48.4**	**31.7**	**46**	**64**	**75**	**68**
Wt.of can	**67**	**63**	**65**	**64.8**	**64**	**60**
Wt.dry sample	**289.1**	**259**	**305**	**313.2**	**312**	**330**
% Moisture content	**16.7**	**12.2**	**15.1**	**20.4**	**24.0**	**20.6**
Dry unit weight	**2.59**	**2.98**	**2.78**	**2.75**	**2.61**	**2.77**

SWELL DATA

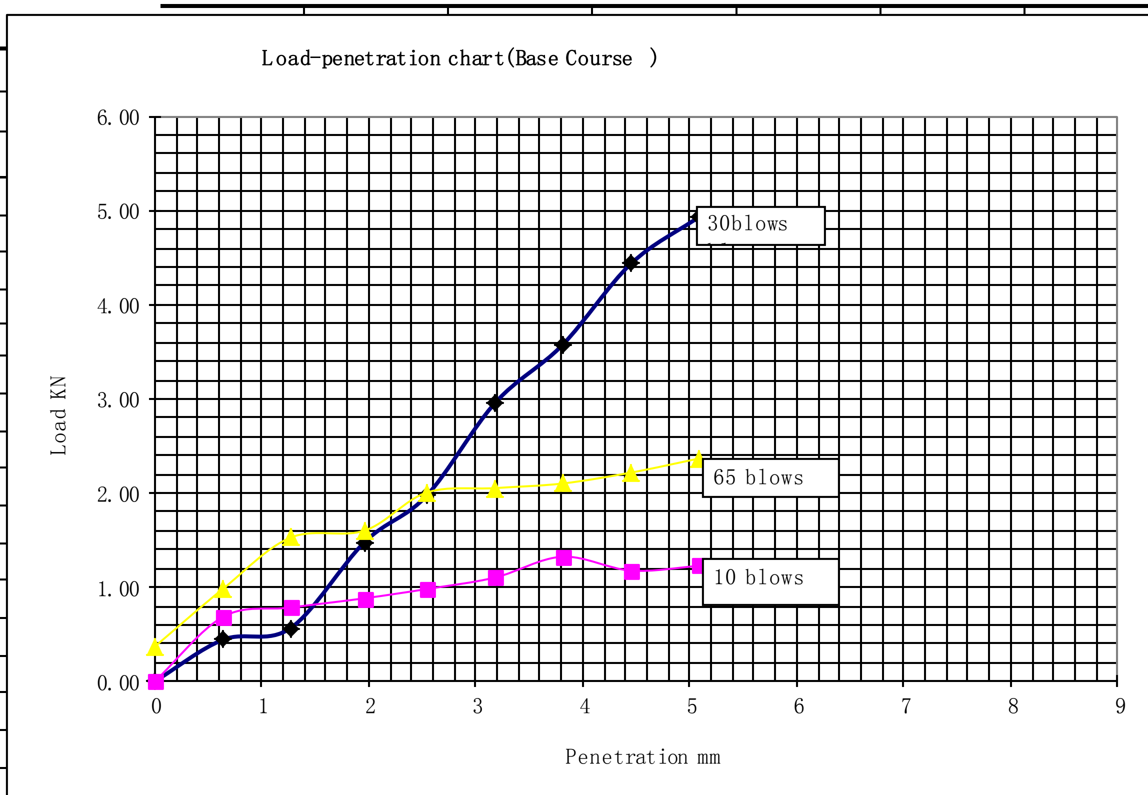
Day of month	**Elapse time (day)**	**Mould 1**			**Mould 2**			**mould 3**		
		gauge reading	**swell mm**	**swell %**	**gauge reading**	**swell mm**	**swell %**	**gauge reading**	**swell mm**	**swell %**
12/16/2015		**8**	**0.01**	**0.01**	**1.82**	**0.01**	**0.01**	**1.4**	**0.0028**	**0.0024**
12/19/2015		**9.39**			**2.7**			**1.68**		

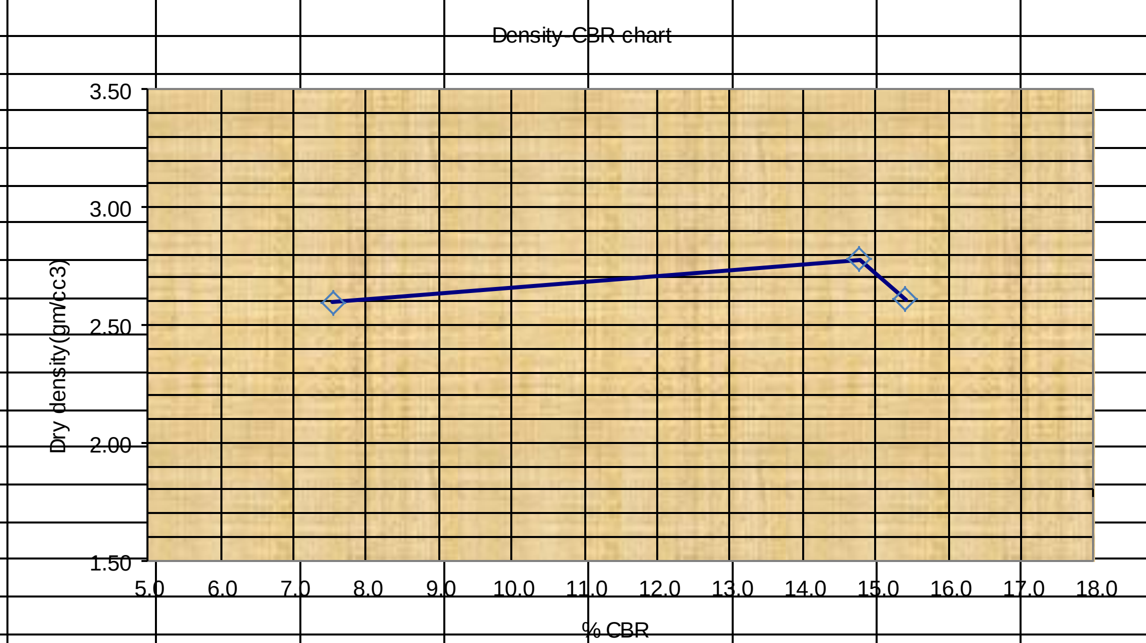
CBR DATA

Penetration (mm)	**Std load (KN)**	**10 Blows Gauge reading**	**10 Blows test load KN**	**10 Blows Corr.CBR KN**	**10 Blows %**	**30 Blows Gauge reading**	**30 Blows test load KN**	**30 Blows corr.CBR KN**	**30 Blows %**	**65 Blows Gauge reading**	**65 Blows test load KN**	**65 Blows Corr.CBR KN**	**65 Blows %**
0		**0.0**	**0**			**0**	**0**			**15**	**0.3695**		
0.64		**28.4**	**0.69**			**18**	**0.44**			**41**	**0.99**		
1.27		**32.5**	**0.78**			**23**	**0.57**			**63**	**1.53**		
1.96		**36.5**	**0.88**			**61**	**1.48**			**66**	**1.60**		
2.54	**13**	**40.6**	**0.98**	**0.98**	**7.5**	**82**	**1.97**	**1.97**	**15.2**	**83**	**2.00**	**2.0**	**15.4**
3.18	**20**	**45.7**	**1.10**	**1.10**	**5.5**	**122**	**2.96**	**2.96**	**14.8**	**85**	**2.05**	**2.1**	**10.3**
3.81		**54.8**	**1.32**			**148**	**3.57**			**87**	**2.10**		
4.45		**48.7**	**1.18**			**184**	**4.43**			**92**	**2.22**		
5.08		**50.8**	**1.23**			**204**	**4.93**			**98**	**2**		

Blows/Layer	**10/5**	**30/5**	**65/5**
Socked C.B.R in%	**7.5**	**14.8**	**15.4**
Density gm/cm3	**2.595**	**2.778**	**2.607**

10 blows	
0	0.00
0.64	0.69
1.27	0.78
1.96	0.88
2.54	0.98
3.18	1.10
3.81	1.32
4.45	1.18
5.08	1.23
30 blows	
0	0.00
0.64	0.44
1.27	0.57
1.96	1.48
2.54	1.97
3.18	2.96
3.81	3.57
4.45	4.43
5.08	4.93
65 blows	
0	0.37
0.64	0.99
1.27	1.53
1.96	1.60
2.54	2.00
3.18	2.05
3.81	2.10
4.45	2.22
5.08	2.36
Density Vs CBR	
7.5	2.59
14.8	2.78
15.4	2.61





CALIFORNIAN BEARING RATIO (CBR) AASHTO T-180

Project:	**Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town**				
Client:	-	**Sample of:**	Base course	**Date Sampled:**	11/29/15
Station:	398+000	**Depth:**	-	**Date Started:**	6-Jan-16
Testpit(Sample) No:	BH-2	**Material Desc.:**	Base course	**Date completed:**	9-Jan-16

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mould No.						
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	10663	10866	12118	12330	12563	12697
Wt.of mould	6431	6431	7412	7412	7610	7610
Wt.of wet sample	4232	4435	4706	4918	4953	5087
Volume of mould	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	2.69	2.82	2.99	3.12	3.14	3.22

MOISTURE DETERMINATION

Can No.	A2	140	AJ	141	BG1	121
Wt.wet sample + can	351.3	215.1	371.4	205.3	338.4	215.7
Wt.dry sample +can	336.7	199.1	353.8	190.7	323.1	202.9
Wt.of water	14.6	16	17.6	14.6	15.3	12.8
Wt.of can	67.8	34	76.3	37.8	76.8	36.6
Wt.dry sample	268.9	165.1	277.5	152.9	246.3	166.3
% Moisture content	5.4	9.7	6.3	9.5	6.2	7.7
Dry unit weight	2.55	2.57	2.81	2.85	2.96	2.99

SWELL DATA

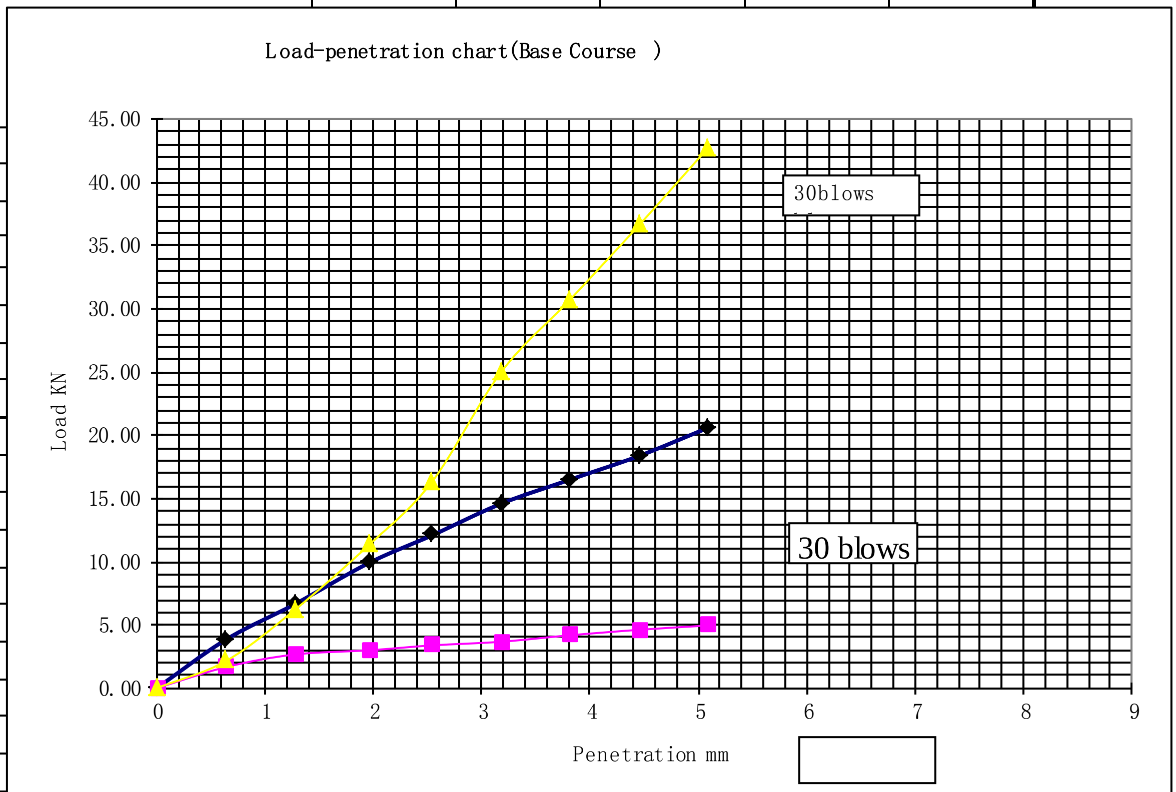
Day of month	Elapse time (day)	Mould 1			Mould 2			mould 3		
		gauge reading	swell		gauge reading	swell		gauge reading	swell	
			mm	%		mm	%		mm	%
1/6/2016		7.9	0.0002	0.0002	3.23	0.0006	0.0005	2.1	0.0003	0.00003
1/9/2016		7.92			3.29			2.13		

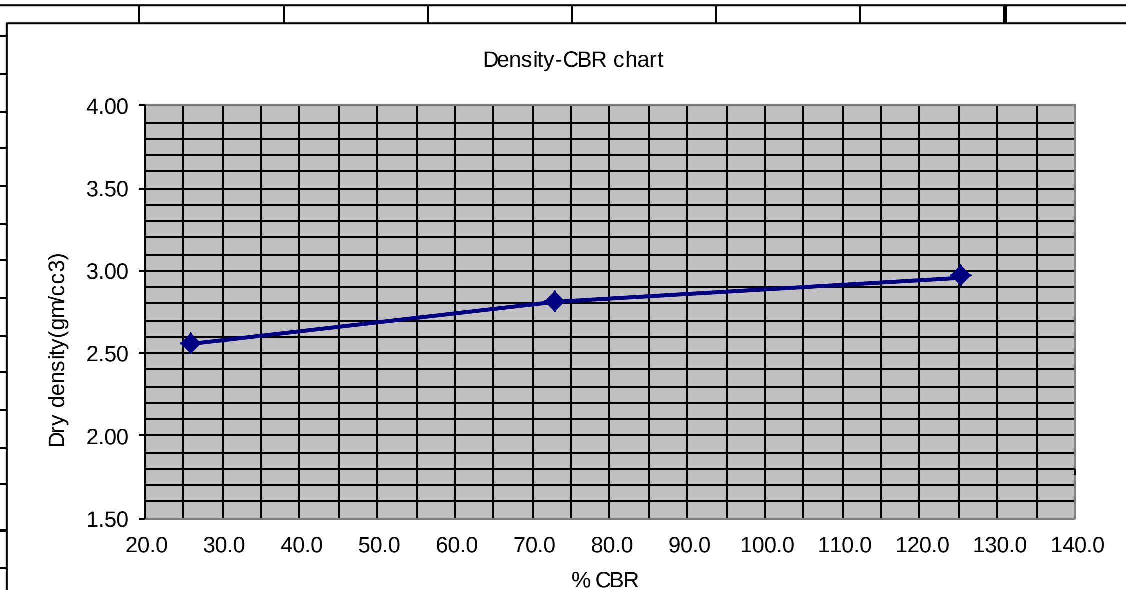
CBR DATA

Penetration (mm)	Std load (KN)	10 Blows Gauge reading	10 Blows test load KN	10 Blows corr.CBR KN	10 Blows corr.CBR %	30 Blows Gauge reading	30 Blows test load KN	30 Blows corr.CBR KN	30 Blows corr.CBR %	65 Blows Gauge reading	65 Blows test load KN	65 Blows corr.CBR KN	65 Blows corr.CBR %			
0		0	0			0	0			0	0					
0.64		69	1.67			159	3.84			89	2.15					
1.27		110	2.66			274	6.62			255	6.16					
1.96		124	2.99			410	9.90			469	11.33					
2.54	13	140	3.38	3.38	**26.0**	500	12.08	12.08	**92.9**	675	16.30	16.3	**125.4**			
3.18	20	152	3.67	3.67	**18.4**	604	14.59	14.59	**72.9**	1035	25.00	25.0	**125.0**			
3.81		173	4.18			682	16.47			1270	30.67					
4.45		191	4.61			760	18.35			1515	36.59					
5.08		205	4.95			851	20.55			1765	43					

Blows/Layer	10/5	30/5	65/5				
Socked C.B.R in%	26.0	72.9	125.4				
Density gm/cm3	2.552	2.810	2.958				

10 blows	
0	0.00
0.64	1.67
1.27	2.66
1.96	2.99
2.54	3.38
3.18	3.67
3.81	4.18
4.45	4.61
5.08	4.95
30 blows	
0	0.00
0.64	3.84
1.27	6.62
1.96	9.90
2.54	12.08
3.18	14.59
3.81	16.47
4.45	18.35
5.08	20.55
65 blows	
0	0.00
0.64	2.15
1.27	6.16
1.96	11.33
2.54	16.30
3.18	25.00
3.81	30.67
4.45	36.59
5.08	42.62
Density Vs CBR	
26.0	2.55
72.9	2.81
125.4	2.96





CALIFORNIAN BEARING RATIO (CBR) AASHTO T-180

Project:	**Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town**				
Client:	-	**Sample of:**	**Sub base**	**Date Sampled:**	**29-Nov-15**
Station:	398+000	**Depth:**	-	**Date Started:**	**2-Jan-16**
Test pit(Sample) No:	BH-2	**Material Desc.:**	Sub base	**Date completed:**	**5-Jan-16**

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mold No.						
No. of layers	**5**		**5**		**5**	
No. of blows per layer	**10**		**30**		**65**	
CONDITION OF SAMPLE	**Before soaking**	**After soaking**	**Before soaking**	**After soaking**	**Before soaking**	**After soaking**
Wt.of wet sample+mould	**11014.05**	**11358.46**	**12473.5**	**12621.97**	**12315.94**	**12493.7**
Wt.of mould	**6586**	**6587**	**7645**	**7646**	**7339**	**7340**
Wt.of wet sample	**4428.05**	**4771.46**	**4828.5**	**4975.97**	**4976.94**	**5153.7**
Volume of mould	**1572.7**	**1573.7**	**1574.7**	**1575.7**	**1576.7**	**1577.7**
Wet unit weight	**2.82**	**3.03**	**3.07**	**3.16**	**3.16**	**3.27**

MOISTURE DETERMINATION

Can No.	**13**	**2**	**6**	**8**	**11**	**99**
Wt.wet sample + can	**209.474**	**243.107**	**203.414**	**244.622**	**211.999**	**220.685**
Wt.dry sample +can	**199.3**	**216.1**	**191.7**	**225.2**	**199.9**	**204.6**
Wt.of water	**10.174**	**27.007**	**11.714**	**19.422**	**12.099**	**16.085**
Wt.of can	**35**	**34.4**	**34.6**	**34**	**34.3**	**34.4**
Wt.dry sample	**164.3**	**181.7**	**157.1**	**191.2**	**165.6**	**170.2**
% Moisture content	**6.2**	**14.9**	**7.5**	**10.2**	**7.3**	**9.5**
Dry unit weight	**2.65**	**2.64**	**2.85**	**2.87**	**2.94**	**2.98**

SWELL DATA

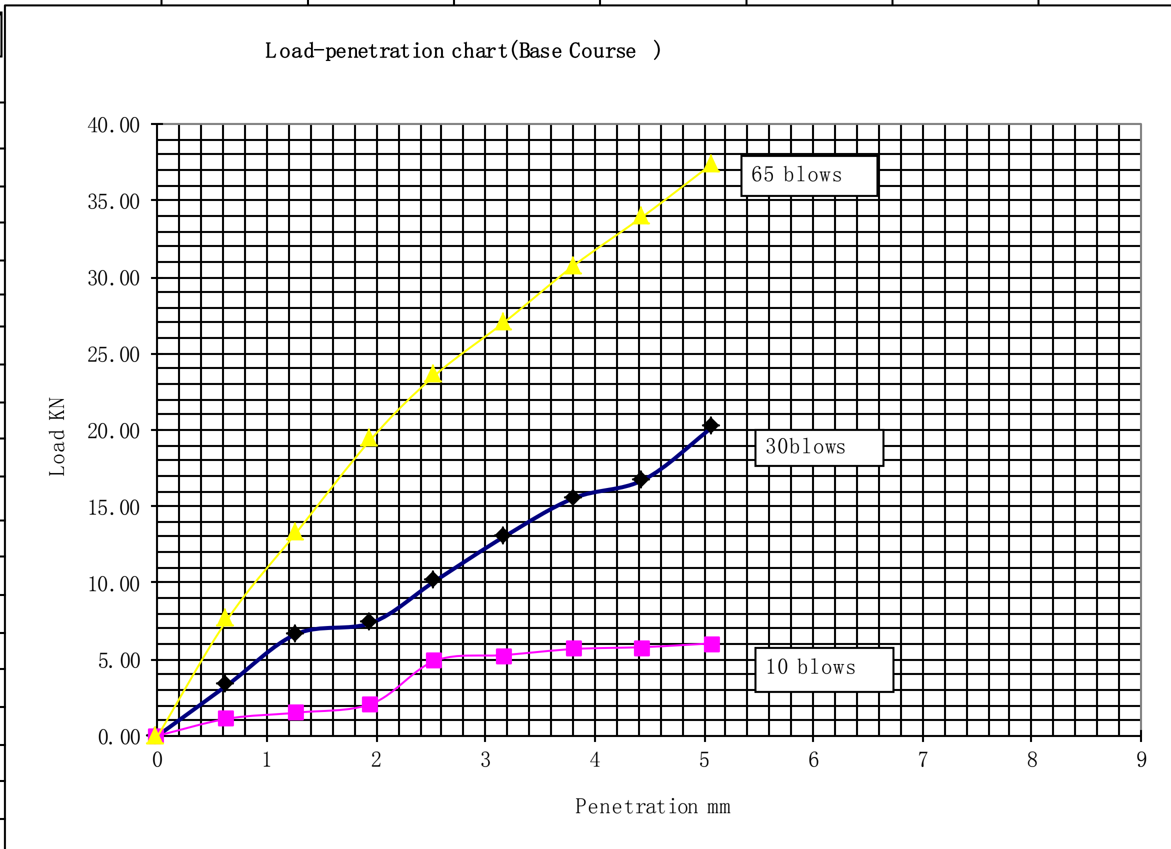
Day of month	**Elapse time (day)**	**Mould 1**			**Mould 2**			**mould 3**		
		gauge reading	**swell**		**gauge reading**	**swell**		**gauge reading**	**swell**	
			mm	**%**		**mm**	**%**		**mm**	**%**
1/2/2016		**1.76**	**0.01**	**0.01**	**1.89**	**0.01**	**0.01**	**1.23**	**0.0022**	**0.0019**
1/5/2016		**2.63**			**2.78**			**1.45**		

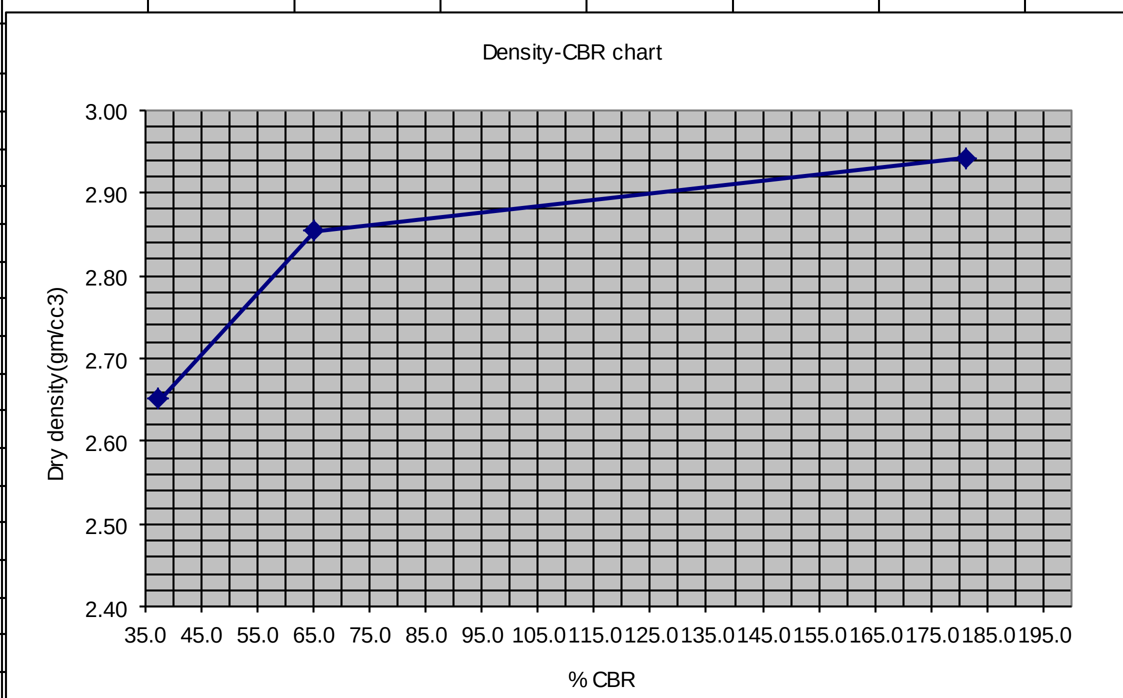
CBR DATA

Penetration (mm)	**Std load (KN)**	**10 Blows**				**30 Blows**				**65 Blows**					
		Gauge reading	**test load**	**corr. CBR**		**Gauge reading**	**test load**	**corr. CBR**		**Gauge reading**	**test load**	**corr.CBR**			
			KN	**KN**	**%**		**KN**	**KN**	**%**		**KN**	**KN**	**%**		
0		**0**	**0**			**0**	**0**			**0**	**0**				
0.64		**45.9**	**1.11**			**137.7**	**3.33**			**316.2**	**7.64**				
1.27		**62.22**	**1.50**			**275.4**	**6.65**			**550.8**	**13.30**				
1.96		**86.7**	**2.09**			**306**	**7.39**			**805.8**	**19.46**				
2.54	**13**	**202.98**	**4.90**	**4.90**	**37.7**	**419.22**	**10.12**	**10.12**	**77.9**	**977.16**	**23.60**	**23.6**	**181.5**		
3.18	**20**	**218.28**	**5.27**	**5.27**	**26.4**	**540.6**	**13.06**	**13.06**	**65.3**	**1122**	**27.10**	**27.1**	**135.5**		
3.81		**234.6**	**5.67**			**643.62**	**15.54**			**1274**	**30.77**				
4.45		**239.7**	**5.79**			**693.6**	**16.75**			**1408.6**	**34.02**				
5.08		**249.9**	**6.04**			**836.4**	**20.20**			**1550.4**	**37**				

Blows/Layer	**10/5**	**30/5**	**65/5**			
Socked C.B.R in%	**37.7**	**65.3**	**181.5**			
Density gm/cm3	**2.651**	**2.854**	**2.942**			

10 blows	
0	0.00
0.64	1.11
1.27	1.50
1.96	2.09
2.54	4.90
3.18	5.27
3.81	5.67
4.45	5.79
5.08	6.04
30 blows	
0	0.00
0.64	3.33
1.27	6.65
1.96	7.39
2.54	10.12
3.18	13.06
3.81	15.54
4.45	16.75
5.08	20.20
65 blows	
0	0.00
0.64	7.64
1.27	13.30
1.96	19.46
2.54	23.60
3.18	27.10
3.81	30.77
4.45	34.02
5.08	37.44
Dry densityVs CBR	
37.7	2.65
65.3	2.85
181.5	2.94





CALIFORNIAN BEARING RATIO(CBR) AASHTO T-181

Project:	**Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town**				
Client:	-	**Sample of:**	**Sub Grade**	**Date Sampled:**	**29-Nov-15**
Station:	398+000	**Depth:**	-	**Date Started:**	**28-Dec-15**
Testpit(Sample) No:	**BH-2**	**Layer Desc.:**	**Sub Grade**	**Date completed:**	**31-Dec-15**

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mould No.						
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	**Before soaking**	**After soaking**	**Before soaking**	**After soaking**	**Before soaking**	**After soaking**
Wt.of wet sample+mould	10168	10592	10883	11011	11066	11199
Wt.of mold	6736	6737	6797	6798	6813	6814
Wt.of wet sample	3432	3855	4086	4213	4253	4385
Volume of mould	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	2.18	2.45	2.59	2.67	2.70	2.78

MOISTURE DETERMINATION

Can No.	22	22	10	10	2	2
Wt.wet sample + can	219.5	218.8	203.1	217.59	229.3	221.5
Wt.dry sample +can	182.9	181.6	167.6	176.2	186.4	182.3
Wt.of water	36.6	37.2	35.5	41.39	42.9	39.2
Wt.of can	56.5	53.3	53.3	52.8	52	51.5
Wt.dry sample	126.4	128.3	114.3	123.4	134.4	130.8
% Moisture content	29.0	29.0	31.1	33.5	31.9	30.0
Dry unit weight	1.69	1.90	1.98	2.00	2.04	2.14

SWELL DATA

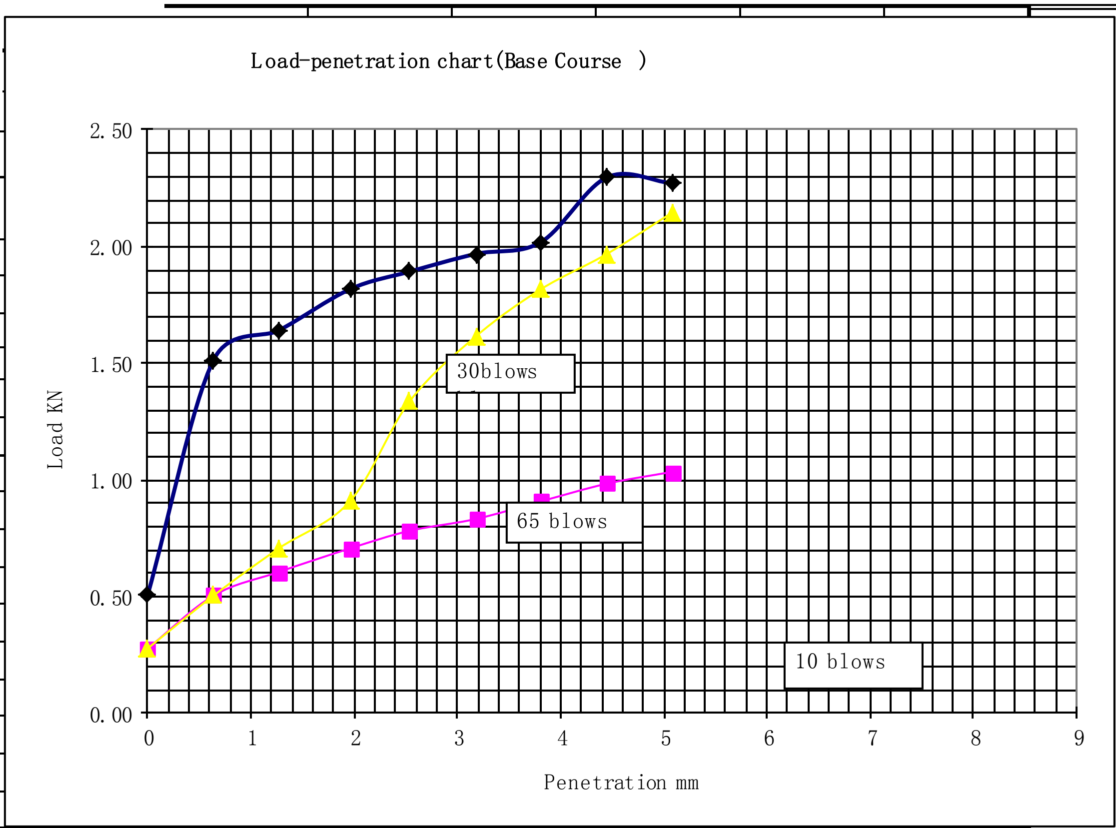
Day of month	**Elapse time (day)**	**Mold 1**			**Mold 2**			**mold 3**		
		gauge reading	**swell**		**gauge reading**	**swell**		**gauge reading**	**swell**	
			mm	**%**		**mm**	**%**		**mm**	**%**
12/28/2015		1.6	0.04	0.03	1.8564	0.01	0.01	1.428	0.0030	####
12/31/2015		5.35			2.754			1.7304		

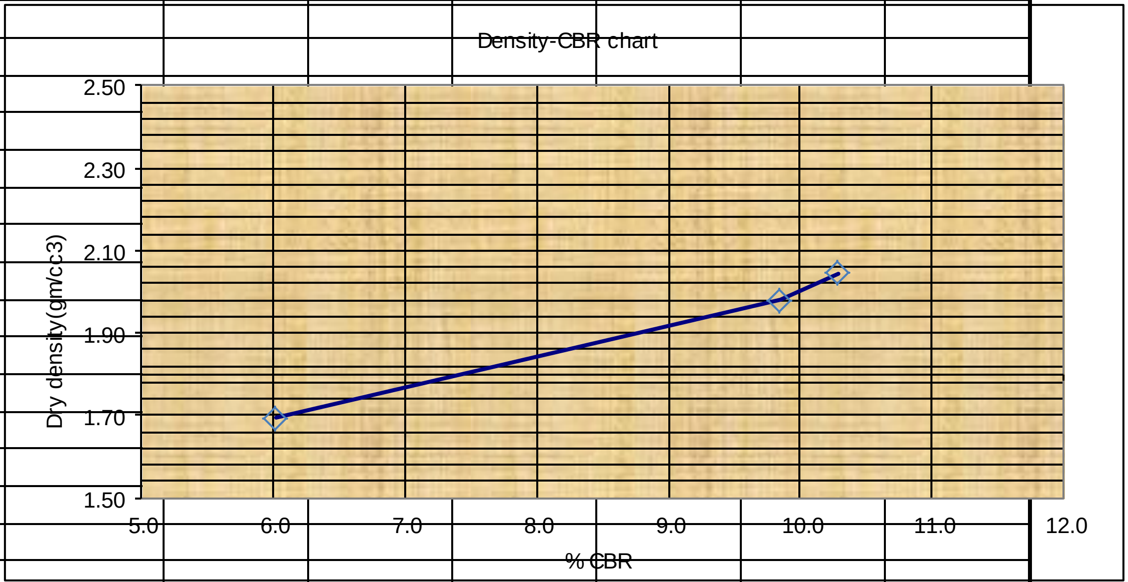
CBR DATA

Penetration (mm)	**Std load (KN)**	**10 Blows**				**30 Blows**				**65 Blows**			
		Gauge reading	**test load**	**corr.CBR**		**Gauge reading**	**test load**	**Corr.CBR**		**Gauge reading**	**test load**	**corr.CBR**	
			KN	**KN**	**%**		**KN**	**KN**	**%**		**KN**	**KN**	**%**
0		11	0.28			21	0.5			11	0.2776		
0.64		21	0.50			63	1.51			21	0.50		
1.27		25	0.61			68	1.64			29	0.71		
1.96		29	0.71			75	1.82			38	0.91		
2.54	13	32	0.78	0.78	6.0	78	1.89	1.89	14.6	55	1.34	1.3	10.3
3.18	20	34	0.83	0.83	4.2	82	1.97	1.97	9.8	67	1.62	1.6	8.1
3.81		38	0.91			84	2.02			75	1.82		
4.45		41	0.98			95	2.30			82	1.97		
5.08		43	1.03			94	2.27			89	2		

Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	6.0	9.8	10.3
Density gm/cm3	1.692	1.980	2.045

10 blows	
0	0.28
0.64	0.50
1.27	0.61
1.96	0.71
2.54	0.78
3.18	0.83
3.81	0.91
4.45	0.98
5.08	1.03
30 blows	
0	0.50
0.64	1.51
1.27	1.64
1.96	1.82
2.54	1.89
3.18	1.97
3.81	2.02
4.45	2.30
5.08	2.27
65 blows	
0	0.28
0.64	0.50
1.27	0.71
1.96	0.91
2.54	1.34
3.18	1.62
3.81	1.82
4.45	1.97
5.08	2.15
Density Vs CBR	
6.0	1.69
9.8	1.98
10.3	2.04





CALIFORNIAN BEARING RATIO(CBR) AASHTO T-181

Project: Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town

Client:	-	**Sample of:**	Base course	**Date Sampled:**	11/30/15
Station:	386+000	**Depth:**	-	**Date Started:**	18-Jan-16
Test pit(Sample) No:	BH-3	**Layer Desc.:**	Base course	**Date completed:**	21-Jan-16

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES						
Mold No.	1		2		3	
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	10786.5	10827.8	11231.9	11265.5	11209.6	11277.6
Wt.of mold	6656	6546	6663	6655	6155	6159
Wt.of wet sample	4130.5	4281.8	4568.92	4610.52	5054.55	5118.62
Volume of mold	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	2.63	2.72	2.90	2.93	3.21	3.24
MOISTURE DETERMINATION						
Can No.	2	5	9	VG	QS	DE
Wt.wet sample + can	257.7	241.1	266.8	254.0	262.3	244.8
Wt.dry sample +can	241.8	238.25	266.5	245.2	245.6	230.5
Wt.of water	15.94	2.83	0.256	8.8	16.7	14.3
Wt.of can	50.5	51	51	50.5	50.3	51
Wt.dry sample	191.3	187.25	215.5	194.7	195.3	179.5
% Moisture content	8.3	1.5	0.1	4.5	8.6	8.0
Dry unit weight	2.42	2.68	2.90	2.80	2.95	3.00

SWELL DATA

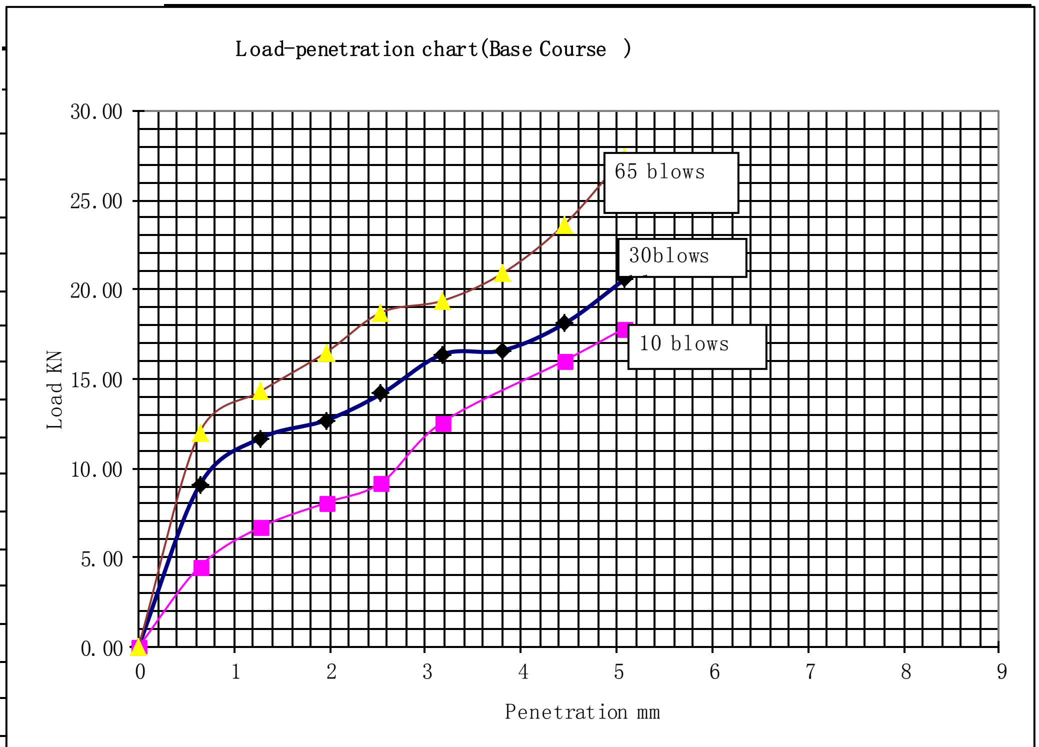
Day of month	Elapse time (day)	Mold 1			Mold 2			mold 3		
		gauge reading	swell mm	swell %	gauge reading	swell mm	swell %	gauge reading	swell mm	swell %
1/18/2016		1.6	0.0632	0.0545	1.25	0.0131	0.0113	1.35	0.0115	0.0099
1/21/2016		7.92			2.56			2.5		

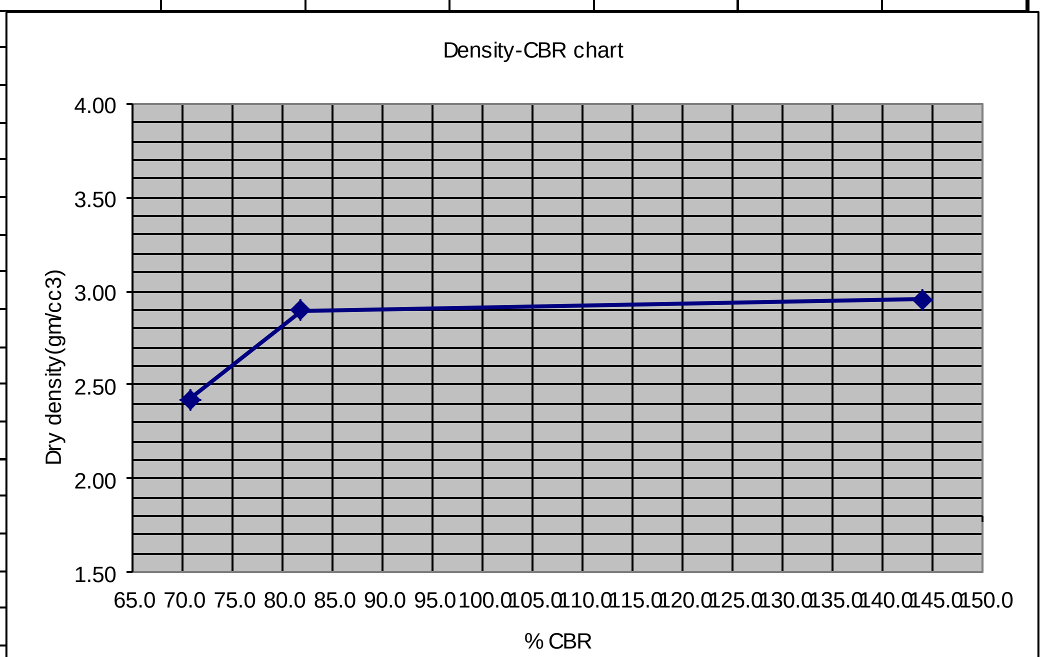
CBR DATA

Penetration (mm)	Std load (KN)	10 Blows Gauge reading	10 Blows test load KN	10 Blows Corr.CBR KN	10 Blows Corr.CBR %	30 Blows Gauge reading	30 Blows test load KN	30 Blows corr.CBR KN	30 Blows corr.CBR %	65 Blows Gauge reading	65 Blows test load KN	65 Blows corr.CBR KN	65 Blows corr.CBR %
0		0	0			0	0			0	0		
0.64		186	4.49			375	9.06			497	12.00		
1.27		277	6.69			483	11.66			591	14.27		
1.96		334	8.07			525	12.68			682	16.47		
2.54	13	381	9.20	9.20	70.8	586.5	14.16	14.16	109.0	775	18.72	18.7	144.0
3.18	20	521	12.58	12.58	62.9	678	16.37	16.37	81.9	802	19.37	19.4	96.8
3.81		588	14.20			687	16.59			866	20.91		
4.45		663	16.01			748.5	18.08			978	23.62		
5.08		738	17.82			851	20.55			1136	27		

Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	70.8	81.9	144.0
Density gm/cm3	2.424	2.898	2.953

10 blows	
0	0.00
0.64	4.49
1.27	6.69
1.96	8.07
2.54	9.20
3.18	12.58
4.45	16.01
5.08	17.82
30 blows	
0	0.00
0.64	9.06
1.27	11.66
1.96	12.68
2.54	14.16
3.18	16.37
3.81	16.59
4.45	18.08
5.08	20.55
65 blows	
0	0.00
0.64	12.00
1.27	14.27
1.96	16.47
2.54	18.72
3.18	19.37
3.81	20.91
4.45	23.62
5.08	27.43
Density Vs CBR	
70.8	2.42
81.9	2.90
144.0	2.95





CALIFORNIAN BEARING RATIO(CBR) AASHTO T-181

Project:	Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town				
Client:	-	Sample of:	Sub base	Date Sampled:	30-Nov-15
Station:	386+000	Depth:	-	Date Started:	12-Jan-16
Testpit(Sample) No:	BH-3	Material Desc.:	Sub base	Date completed:	15-Jan-16

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mould No.	1		2		3	
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	11224	11306	12041	12198	12039	12018
Wt.of mould	6428	6431	6855	6891	6856	6822
Wt.of wet sample	4796	4875	5186	5307	5183	5196
Volume of mould	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	3.05	3.10	3.29	3.37	3.29	3.29

MOISTURE DETERMINATION

Can No.	JK	MN	Q	R	C	F
Wt.wet sample + can	236.138	244.42	267.953	240	269.67	225.23
Wt.dry sample +can	216.648	231.54	237.15	209	238	202.164
Wt.of water	19.49	12.88	30.803	31	31.67	23.066
Wt.of can	52	51	50.5	51	52	52
Wt.dry sample	164.648	180.54	186.65	158	186	150.164
% Moisture content	11.8	7.1	16.5	19.6	17.0	15.4
Dry unit weight	2.73	2.89	2.83	2.82	2.81	2.85

SWELL DATA

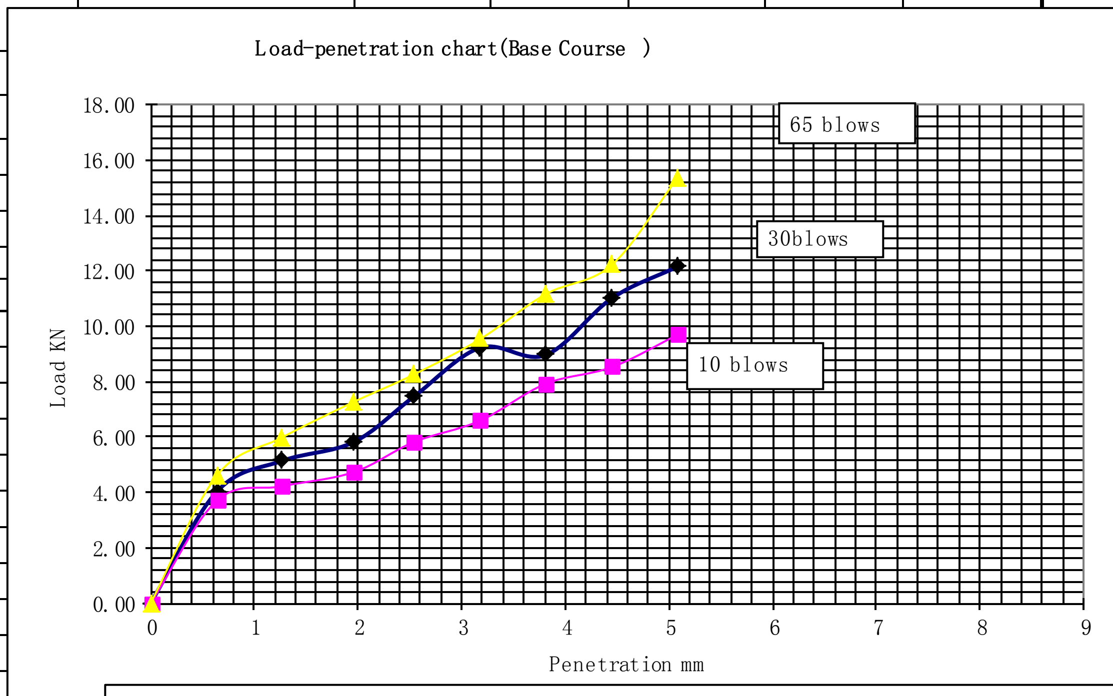
Day of month	Elapse time (day)	Mould 1			Mould 2			mould 3		
		gauge reading	swell		gauge reading	swell		gauge reading	swell	
			mm	%		mm	%		mm	%
1/12/2016		2.56	0.03	0.03	2.35	0.06	0.05	2.39	0.0525	0.0453
1/15/2016		5.67			8.6			7.64		

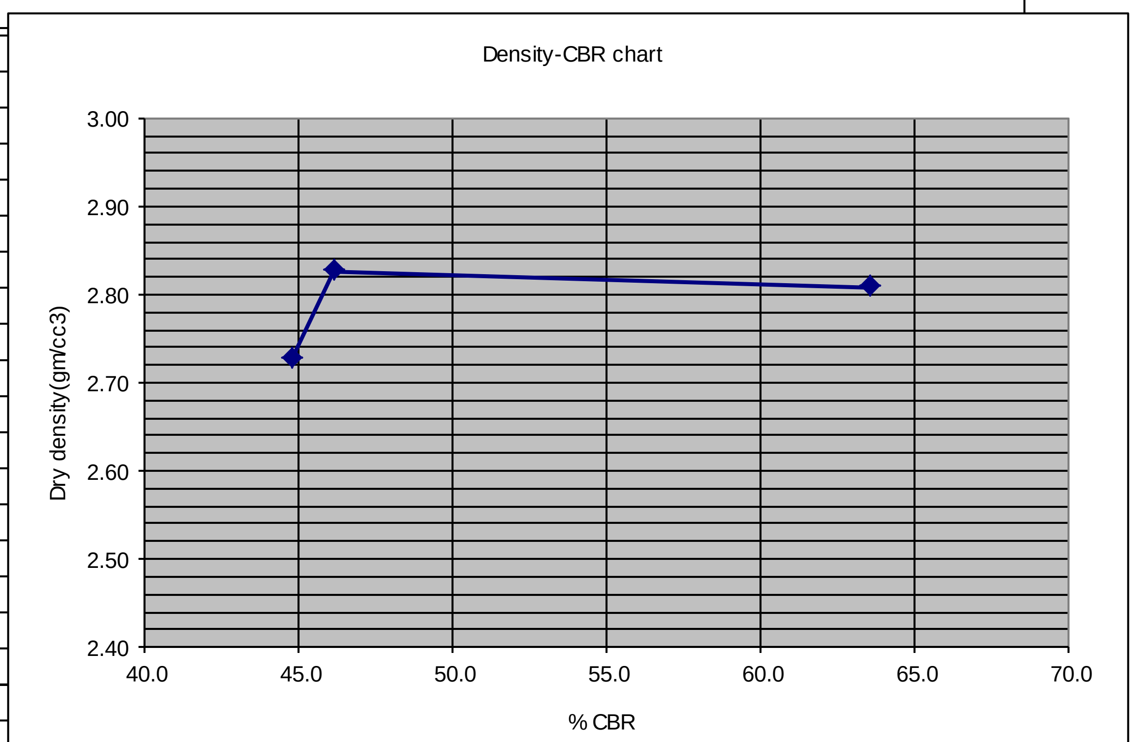
CBR DATA

Penetration (mm)	Std load (KN)	10 Blows				30 Blows				65 Blows			
		Gauge reading	test load	corr. CBR		Gauge reading	test load	corr. CBR		Gauge reading	test load	Corr .CBR	
			KN	KN	%		KN	KN	%		KN	KN	%
0		0	0			0	0			0	0		
0.64		153.5	3.71			167	4.03			191	4.61		
1.27		175	4.23			213	5.14			248	5.99		
1.96		196	4.73			241	5.82			301	7.27		
2.54	13	241	5.82	5.82	44.8	309	7.46	7.46	57.4	342	8.26	8.3	63.5
3.18	20	273	6.59	6.59	33.0	382	9.23	9.23	46.1	395	9.54	9.5	47.7
3.81		328	7.92			371	8.96			462	11.16		
4.45		353	8.52			456	11.01			506	12.22		
5.08		401	9.68			503	12.15			635	15		

Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	44.8	46.1	63.5
Density gm/cm3	2.727	2.827	2.809

10 blows	
0	
0.64	
1.27	
1.96	
2.54	
3.18	
3.81	
4.45	
5.08	
30 blows	
0	
0.64	
1.27	
1.96	
2.54	
3.18	
3.81	8.96
4.45	11.01
5.08	12.15
65 blows	
0	0.00
0.64	4.61
1.27	5.99
1.96	7.27
2.54	8.26
3.18	9.54
3.81	11.16
4.45	12.22
5.08	15.34
Dry densiity Vs CBR	
44.8	2.73
46.1	2.83
63.5	2.81





CALIFORNIAN BEARING RATIO(CBR) AASHTO T-181

Project:	Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town				
Client:	-	Sample of:	Sub Grade	Date Sampled:	30-Nov-15
Station:	386+000	Depth:	-	Date Started:	10-Jan-16
Test pit(Sample) No:	BH-3	Layer Desc.:	Sub Grade	Date completed:	13-Jan-16

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mold No.						
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	10264	10796.8	10310	10310	10729	11014.5
Wt.of mould	6587	6587	6759	6759	6385	6385
Wt. of wet sample	3677	4209.8	3551	3551	4344	4629.5
Volume of mould	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	2.34	2.68	2.26	2.25	2.76	2.93

MOISTURE DETERMINATION

Can No.	6	5	19	22	25	28
Wt. wet sample + can	219.6	218.5	214	201.2	218.6	223
Wt. dry sample +can	171	192.3	179.6	166.8	182.9	203.4
Wt. of water	48.6	26.2	34.4	34.4	35.7	19.6
Wt. of can	51.5	52	50	50.5	52	53
Wt. dry sample	119.5	140.3	129.6	116.3	130.9	150.4
% Moisture content	40.7	18.7	26.5	29.6	27.3	13.0
Dry unit weight	1.66	2.25	1.78	1.74	2.16	2.60

SWELL DATA

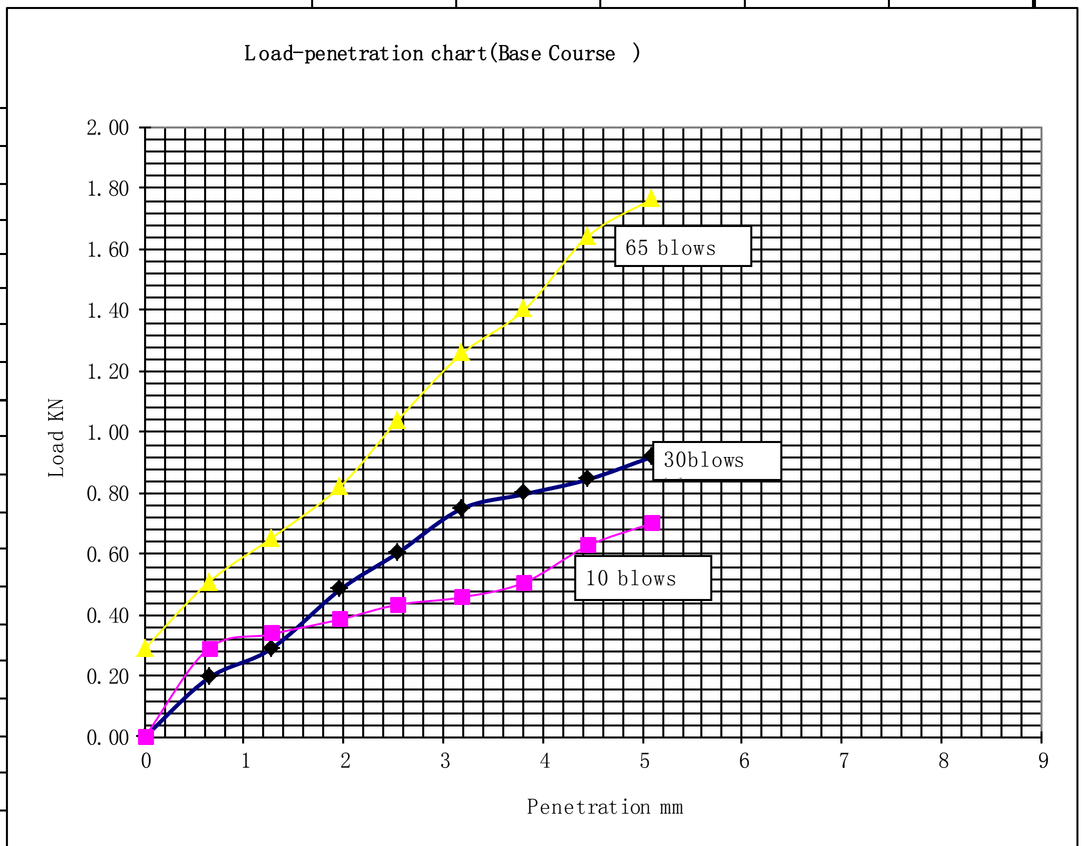
Day of month	Elapse time (day)	Mold 1			Mold 2			mold 3		
		gauge reading	swell		gauge reading	swell		gauge reading	swell	
			mm	%		mm	%		mm	%
1/10/2016		7	0.02	0.01	1.95	0.01	0.01	1.65	0.0021	0.0018
1/13/2016		8.5			2.8			1.86		

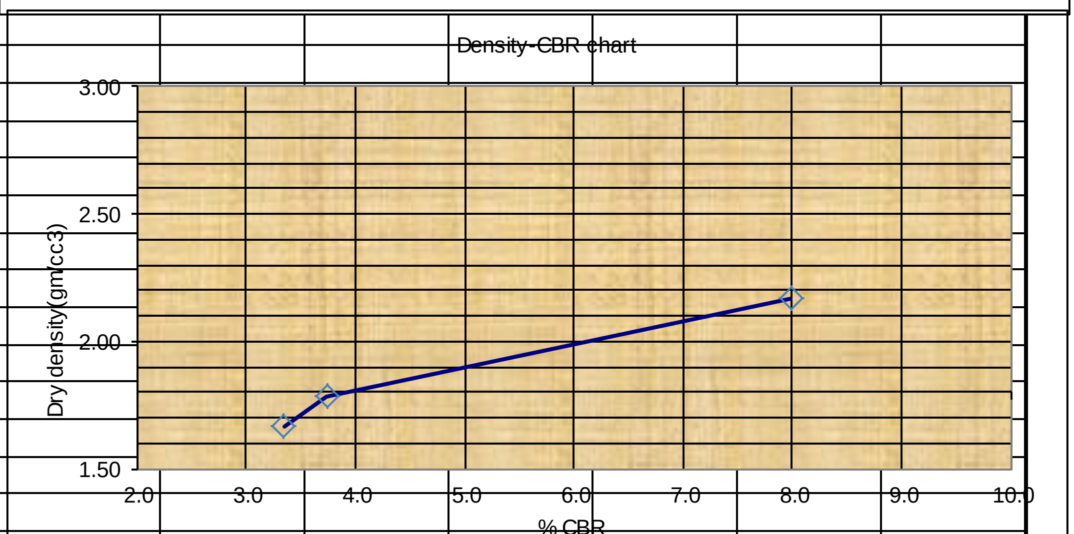
CBR DATA

Penetration (mm)	Std load (KN)	10 Blows				30 Blows				65 Blows			
		Gauge reading	test load	Corr .CBR		Gauge reading	test load	corr. CBR		Gauge reading	test load	Corr .CBR	
			KN	KN	%		KN	KN	%		KN	KN	%
0		0.0	0			0	0			12	0.2898		
0.64		12.0	0.2898			8	0.19			21	0.5072		
1.27		14.0	0.3381			12	0.29			27	0.6521		
1.96		16.0	0.3864			20	0.48			34	0.8211		
2.54	13	18.0	0.4347	0.43	3.3	25	0.6	0.60	4.6	43	1.0385	1.0	8.0
3.18	20	19.0	0.45885	0.46	2.3	31	0.75	0.75	3.7	52	1.2558	1.3	6.3
3.81		21.0	0.50715			33	0.8			58	1.4007		
4.45		26.0	0.6279			35	0.85			68	1.6422		
5.08		29.0	0.70035			38	0.92			73	1.763		

Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	3.3	3.7	8.0
Density gm/cm3	1.662	1.782	2.165

10 blows	
0	0.00
0.64	0.29
1.27	0.34
1.96	0.39
2.54	0.43
3.18	0.46
3.81	0.51
4.45	0.63
5.08	0.70
30 blows	
0	0.00
0.64	0.19
1.27	0.29
1.96	0.48
2.54	0.60
3.18	0.75
3.81	0.80
4.45	0.85
5.08	0.92
65 blows	
0	0.29
0.64	0.51
1.27	0.65
1.96	0.82
2.54	1.04
3.18	1.26
3.81	1.40
4.45	1.64
5.08	1.76
CBR Vs Dry density	
3.3	1.66
3.7	1.78
8.0	2.16





CALIFORNIAN BEARING RATIO(CBR) AASHTO T-181

Project:	Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town				
Client:	-	Sample of:	Base course	Date Sampled:	30-Nov-15
Station:	397+000	Depth:	-	Date Started:	30-Jan-16
Testpit(Sample) No:	BH-4	Material Desc.:	Base course	Date completed:	2-Feb-16

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mould No.						
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	12188	12430	12395	12565	12730	12851
Wt. of mould	7720	7720	7520	7520	7625	7625
Wt. of wet sample	4468	4710	4875	5045	5105	5226
Volume of mould	2121	2121	2121	2121	2121	2121
Wet unit weight	2.11	2.22	2.30	2.38	2.41	2.46
MOISTURE DETERMINATION						
Can No.	5	10	5	22	5	7
Wt. wet sample + can	244.68	307	244.68	298.8	244.68	281.39
Wt. dry sample +can	230.09	279.57	230.59	276.09	230.59	262.66
Wt. of water	14.59	27.43	14.09	22.71	14.09	18.73
Wt. of can	83.76	83.32	83.76	83.15	83.76	84.07
Wt. dry sample	146.33	196.25	146.83	192.94	146.83	178.59
% Moisture content	10.0	14.0	9.6	11.8	9.6	10.5
Dry unit weight	1.92	1.95	2.10	2.13	2.20	2.23

SWELL DATA Initial height of sample = 116mm

Day of month	Elapse time (day)	Mould 1			Mould 2			mould 3		
		gauge reading	swell		gauge reading	swell		gauge reading	swell	
			mm	%		mm	%		mm	%
1/30/2016		327	0.18	0.16	436	0.14	0.12	212	0.28	0.24
2/2/2016		345			450			240		

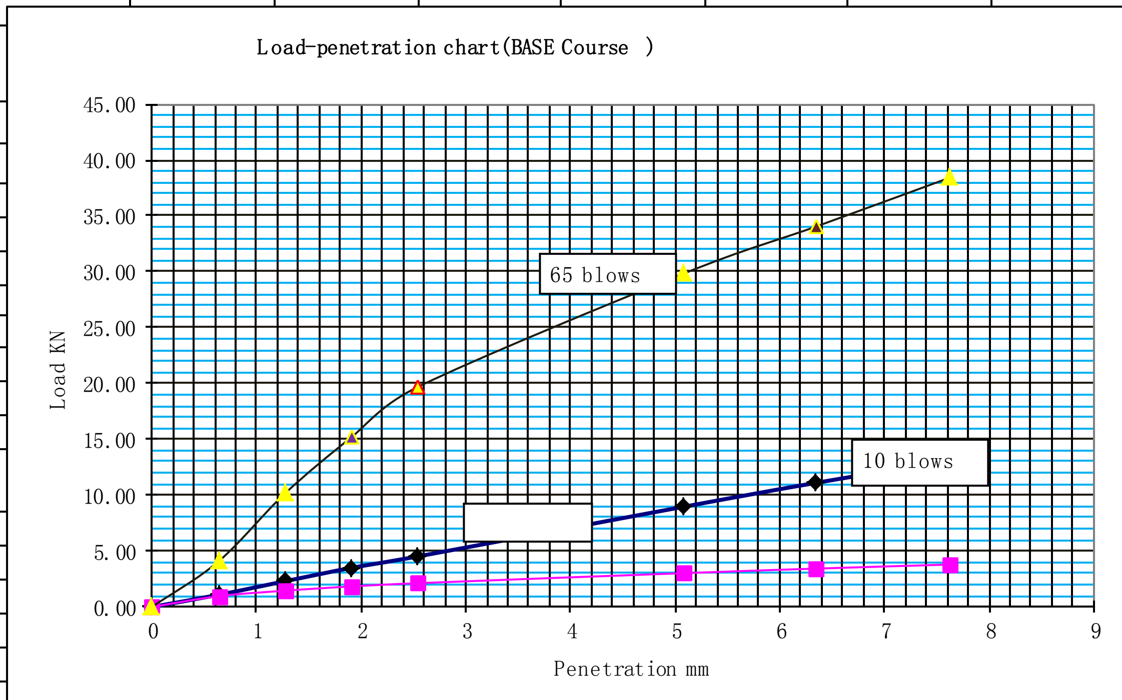
CBR DATA

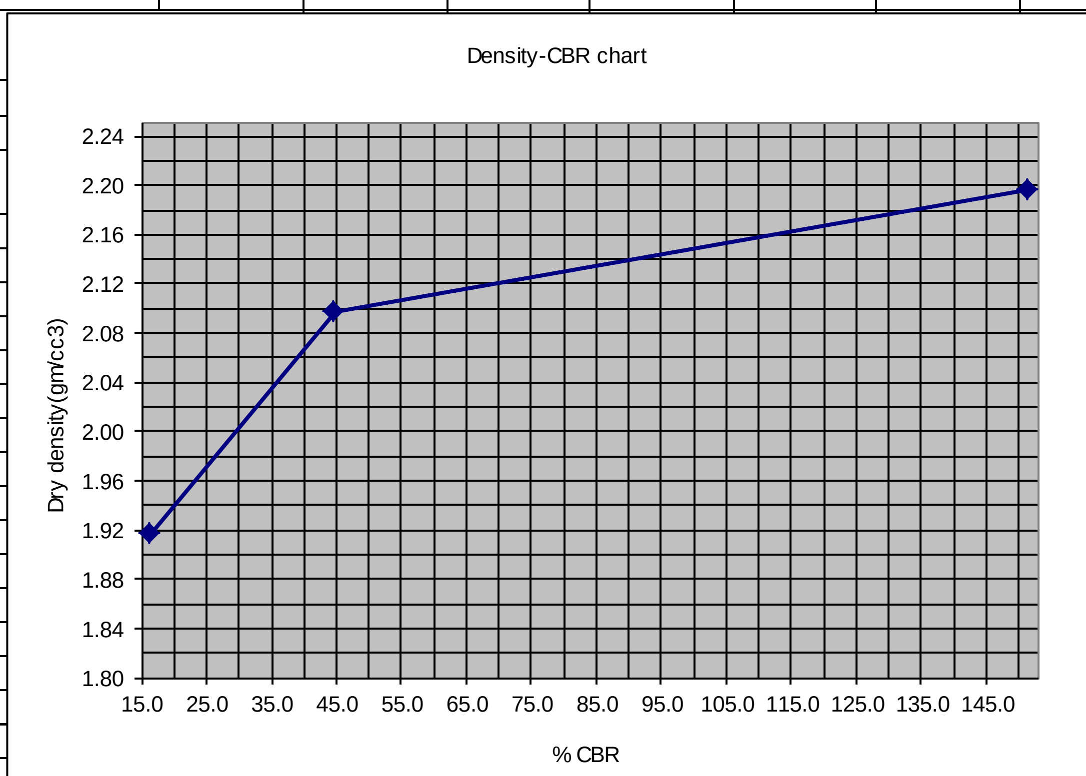
Penetration (mm)	Std load (KN)	10 Blows				30 Blows				65 Blows			
		Gauge reading	test load	corr.CBR		Gauge reading	test load	corr.CBR		Gauge reading	test load	corr.CBR	
			KN	KN	%		KN	KN	%		KN	KN	%
0		0	0			0	0			0	0		
0.64		40	0.97			45	1.09			170	4.11		
1.27		60	1.45			95	2.29			420	10.14		
1.91		76	1.84			145	3.50			630	15.21		
2.54	13	88	2.13	2.13	16.3	187	4.52	4.52	34.7	815	19.68	19.7	151
5.08	20	125	3.02	3.02	15.1	371	8.96	8.96	44.8	1235	29.83	29.8	
6.35		142	3.43			460	11.11			1410	34.05		
7.62		157	3.79			541	13.07			1590	38.40		

Blows/Layer	10/5	30/5	65/5	MDD	2.17	OMC	10.00
Socked C.B.R in%	16.3	44.8	151.4	Density requirement:	95%	Target	2.06

						density:	
Density gm/cm3	1.916	2.097	2.196	CBR	39.0	swell	0.24

penetration(mm)	Test load (KN)
10 blows	
0	0.00
0.64	0.97
1.27	1.45
1.91	1.84
2.54	2.13
5.08	3.02
6.35	3.43
7.62	3.79
penetration(mm)	Test load (KN)
30 blows	
0	0.00
0.64	1.09
1.27	2.29
1.91	3.50
2.54	4.52
5.08	8.96
6.35	11.11
7.62	13.07
penetration(mm)	Test load (KN)
65 blows	
0	0.00
0.64	4.11
1.27	10.14
1.91	15.21
2.54	19.68
5.08	29.83
6.35	34.05
7.62	38.40
CBR	Dry density
16.3	1.92
44.8	2.10
151.4	2.20





CALIFORNIAN BEARING RATIO(CBR) AASHTO T-181

Project:	Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town				
Client:	-	Sample of:	Sub base	Date Sampled:	30-Nov-15
Station:	397+000	Depth:	-	Date Started:	26-Jan-16
Testpit(Sample) No:	BH-4	Material Desc.:	Sub base	Date completed:	29-Jan-16

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mould No.	1		2		3	
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	11238	11306	12011	12035	12004	12026
Wt.of mould	6431	6431	6846	6846	6826	6826
Wt.of wet sample	4807	4875	5165	5189	5178	5200
Volume of mould	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	3.06	3.10	3.28	3.29	3.28	3.30

MOISTURE DETERMINATION

Can No.	5	8	9	13	44	23
Wt.wet sample + can	251	202.5	276	211	278.5	205.9
Wt.dry sample +can	234.3	189.3	255.5	199.2	258.3	195.2
Wt.of water	16.7	13.2	20.5	11.8	20.2	10.7
Wt.of can	51	50	53	51	52	52
Wt.dry sample	183.3	139.3	202.5	148.2	206.3	143.2
% Moisture content	9.1	9.5	10.1	8.0	9.8	7.5
Dry unit weight	2.80	2.83	2.98	3.05	2.99	3.07

SWELL DATA

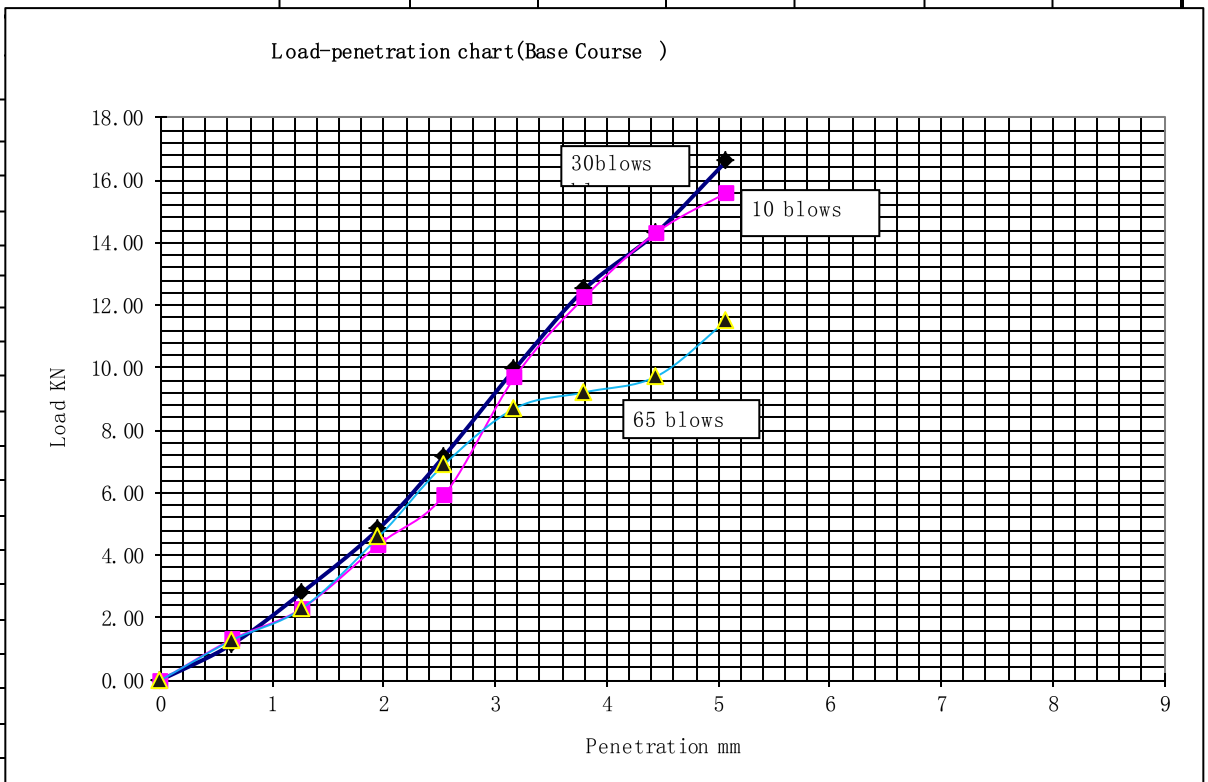
Day of month	Elapse time (day)	Mold 1			Mold 2			mold 3		
		gauge reading	swell		gauge reading	swell		gauge reading	swell	
			mm	%		mm	%		mm	%
1/26/2016		1.89	0.01	0.01	2.1	0.00	0.00	1.25	0.0020	0.0017
1/29/2016		2.76			2.3			1.45		

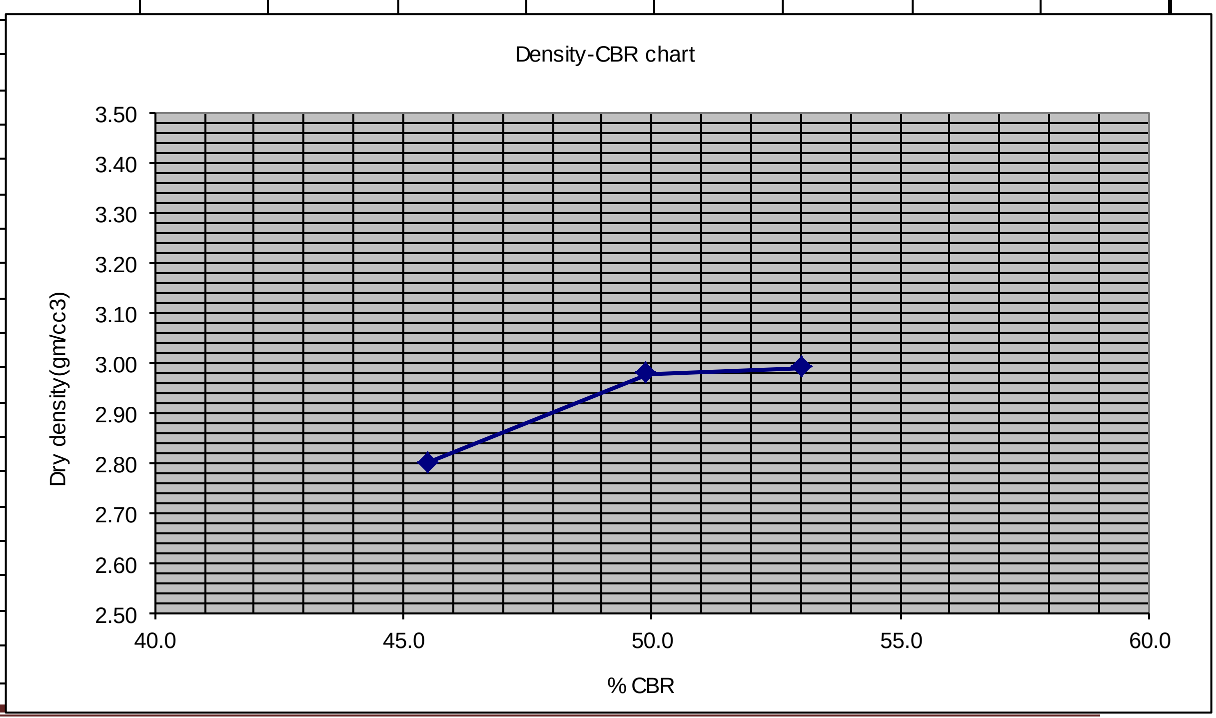
CBR DATA

Penetration (mm)	Std load (KN)	10 Blows				30 Blows				65 Blows			
		Gauge reading	test load	Corr.CBR		Gauge reading	test load	corr.CBR		Gauge reading	test load	Corr.CBR	
			KN	KN	%		KN	KN	%		KN	KN	%
0		0	0			0	0			0	0		
0.64		54.06	1.31			47.7	1.15			53	1.28		
1.27		95.4	2.30			116.6	2.82			95.4	2.30		
1.96		180.2	4.35			201.4	4.86			190.8	4.61		
2.54	13	245	5.92	5.92	45.5	296.8	7.17	7.17	55.1	285.5	6.89	6.9	53.0
3.18	20	402.8	9.73	9.73	48.6	413.4	9.98	9.98	49.9	360.4	8.70	8.7	43.5
3.81		508.8	12.29			519.4	12.54			381.6	9.22		
4.45		593.6	14.34			593.6	14.34			402.8	9.73		
5.08		646.6	15.62			689	16.64			477	12		

Blows/Layer	10/5	30/5	65/5
Socked C.B.R in%	45.5	49.9	53.0
Density gm/cm3	2.801	2.978	2.991

10 blows	
0	0.00
0.64	1.31
1.27	2.30
1.96	4.35
2.54	5.92
3.18	9.73
3.81	12.29
4.45	14.34
5.08	15.62
30 blows	
0	0.00
0.64	1.15
1.27	2.82
1.96	4.86
2.54	7.17
3.18	9.98
3.81	12.54
4.45	14.34
5.08	16.64
65 blows	
0	0.00
0.64	1.28
1.27	2.30
1.96	4.61
2.54	6.89
3.18	8.70
3.81	9.22
4.45	9.73
5.08	11.52
Dry densityVs CBR	
45.5	2.80
49.9	2.98
53.0	2.99





CALIFORNIAN BEARING RATIO (CBR) AASHTO T-181

Project:	Causes of Defects on Asphalt Pavement and Its Remedies: Case Study in Agaro Town				
Client:	-	Sample of:	Sub Grade	Date Sampled:	30-Nov-15
Station:	397+000	Depth:	-	Date Started:	22-Jan-16
Test pit(Sample) No:	BH-4	Material Desc.:	Sub Grade	Date completed:	25-Jan-16

MOISTURE CONTENT AND UNIT WEIGHT OF TEST SAMPLES

Mold No.						
No. of layers	5		5		5	
No. of blows per layer	10		30		65	
CONDITION OF SAMPLE	Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample+mould	10467.2	11011.9	10514.2	11024.2	10941.5	11236.3
Wt.of mold	6587	6587	6759	6759	6385	6385
Wt.of wet sample	3880.2	4424.9	3755.2	4265.2	4556.5	4851.3
Volume of mold	1572.7	1573.7	1574.7	1575.7	1576.7	1577.7
Wet unit weight	2.47	2.81	2.38	2.71	2.89	3.07

MOISTURE DETERMINATION

Can No.	5	6	8	12	14	99
Wt.wet sample + can	223.0	221.6	216.2	203.6	221.4	458.0
Wt.dry sample +can	173.706	194.31	182.172	167.892	186.558	206.958
Wt.of water	49.266	27.336	34.068	35.7	34.884	251.042
Wt.of can	51.5	52	50.1	50.5	52.3	49.8
Wt.dry sample	122.206	142.31	132.072	117.392	134.258	157.158
% Moisture content	40.3	19.2	25.8	30.4	26.0	159.7
Dry unit weight	1.76	2.36	1.90	2.08	2.29	1.18

SWELL DATA

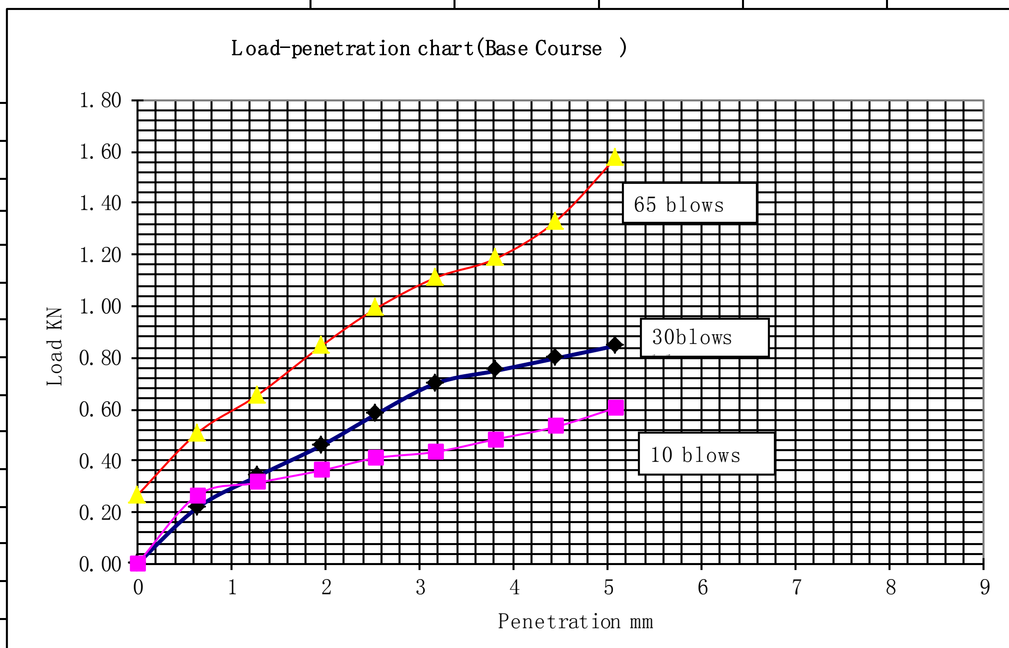
Day of month	Elapse time (day)	Mold 1			Mold 2			mold 3		
		gauge reading	swell mm	swell %	gauge reading	swell mm	swell %	gauge reading	swell mm	swell %
22-Jan-16		4.5	0.05	0.04	1.57	0.04	0.03	2	0.0450	0.0388
25-Jan-16		9.5			5.6			6.5		

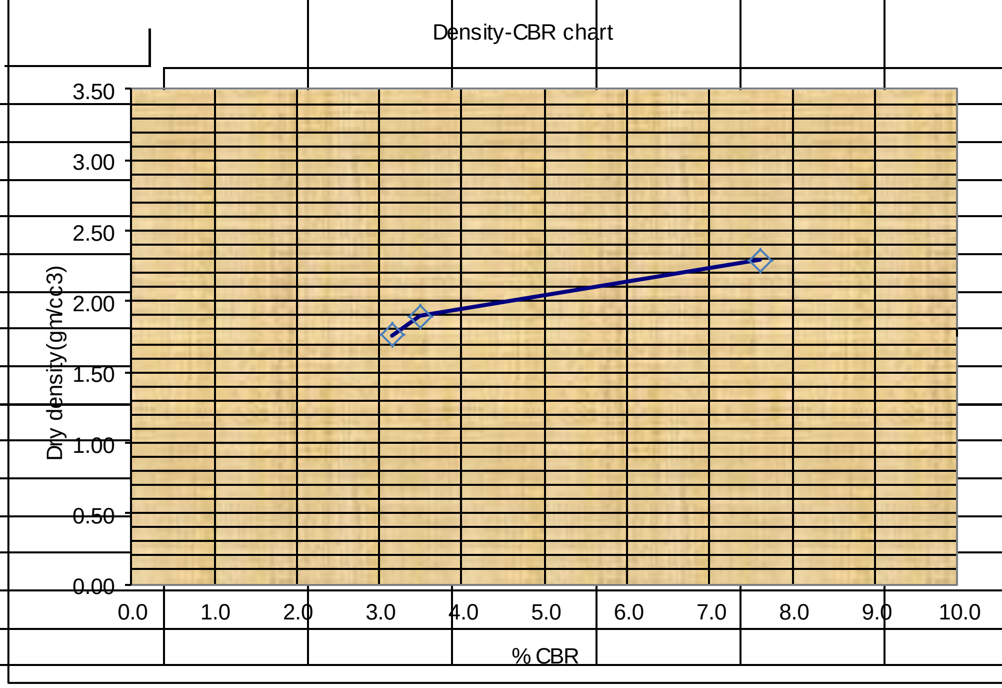
CBR DATA

Penetration (mm)	Std load (KN)	10 Blows				30 Blows				65 Blows			
		Gauge reading	test load KN	corr.CBR KN	corr.CBR %	Gauge reading	test load KN	Corr.CBR KN	Corr.CBR %	Gauge reading	test load KN	corr.CBR KN	corr.CBR %
0		0.0	0			0	0			11	0.2657		
0.64		11.0	0.27			9	0.22			21	0.51		
1.27		13.0	0.31			14	0.34			27	0.65		
1.96		15.0	0.36			19	0.46			35	0.85		
2.54	13	17.0	0.41	0.41	3.2	24	0.58	0.58	4.5	41	0.99	1.0	7.6
3.18	20	18.0	0.43	0.43	2.2	29	0.70	0.70	3.5	46	1.11	1.1	5.6
3.81		20.0	0.48			31	0.75			49	1.18		

4.45		22.0	0.53			33	0.80			55	1.33
5.08		25.0	0.60			35	0.85			65	2
Blows/Layer		10/5		30/5		65/5					
Socked C.B.R in%		3.2		3.5		7.6					
Density gm/cm3		1.758		1.896		2.294					

10 blows	
0	0.00
0.64	0.27
1.27	0.31
1.96	0.36
2.54	0.41
3.18	0.43
3.81	0.48
4.45	0.53
5.08	0.60
30 blows	
0	0.00
0.64	0.22
1.27	0.34
1.96	0.46
2.54	0.58
3.18	0.70
3.81	0.75
4.45	0.80
5.08	0.85
65 blows	
0	0.27
0.64	0.51
1.27	0.65
1.96	0.85
2.54	0.99
3.18	1.11
3.81	1.18
4.45	1.33
5.08	1.57
CBR Vs Dry density	
3.2	1.76





3.5	1.90							
7.6	2.29							

APPENDIX E. ASPHALT EXTRACTION TEST

PROJECTNAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"

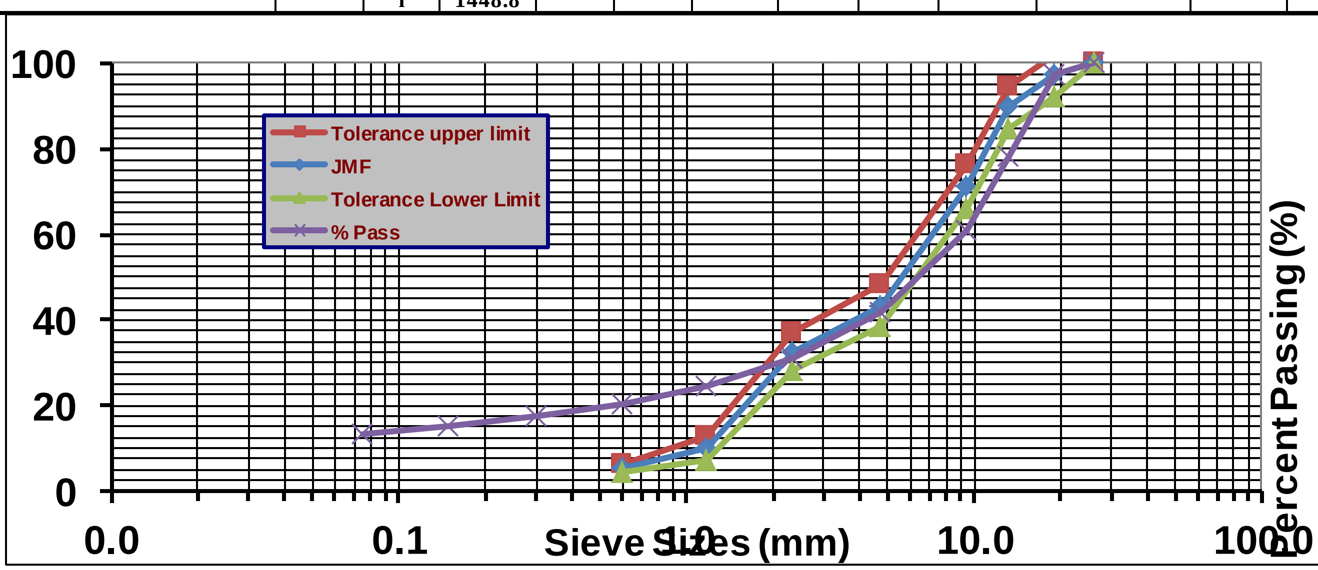
Host	Program	Laboratory
Jimma Institute of Technology	HIGH WAY ENGINEERING STREAM	Jimma Roads Maintenance Laboratory

Placing Station :-	396+500	Sample Date:-	30-Nov-15
Aggregate Source:-	Avg. NON-DAMAGE ASPHALT	Test Date:-	7-Dec-15

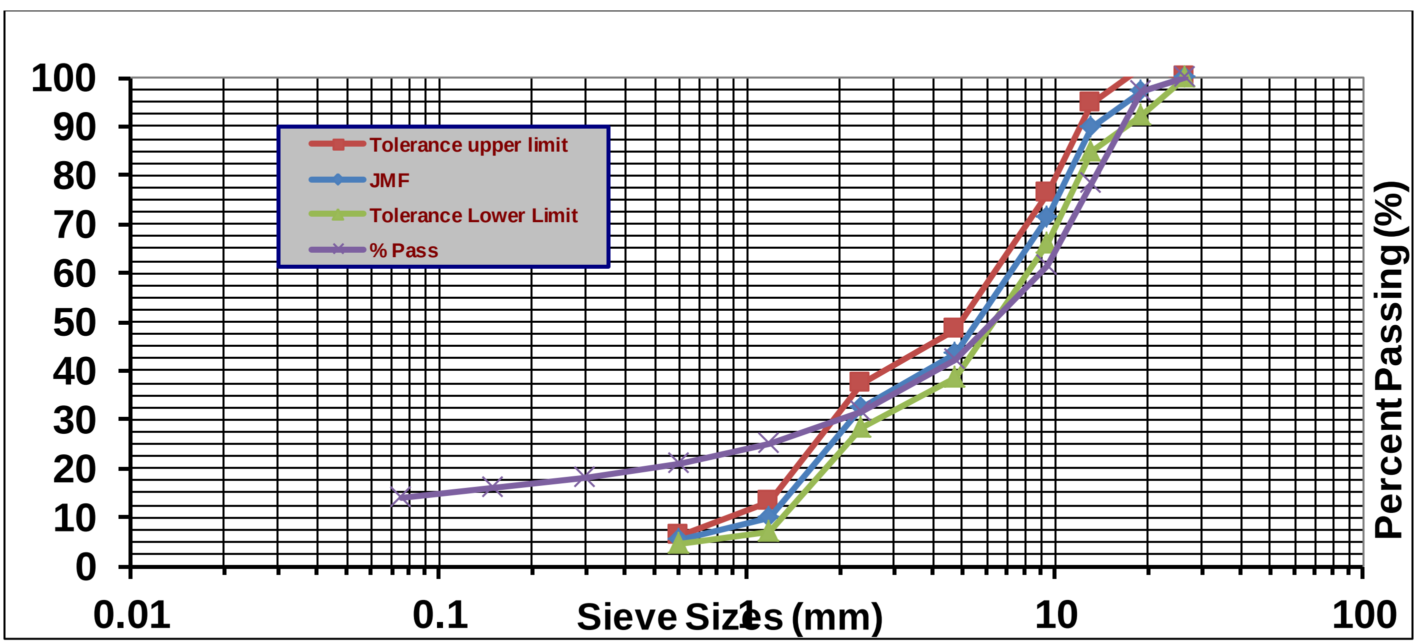
AVERAGE XTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE

Test Method- AASHTO T30-06

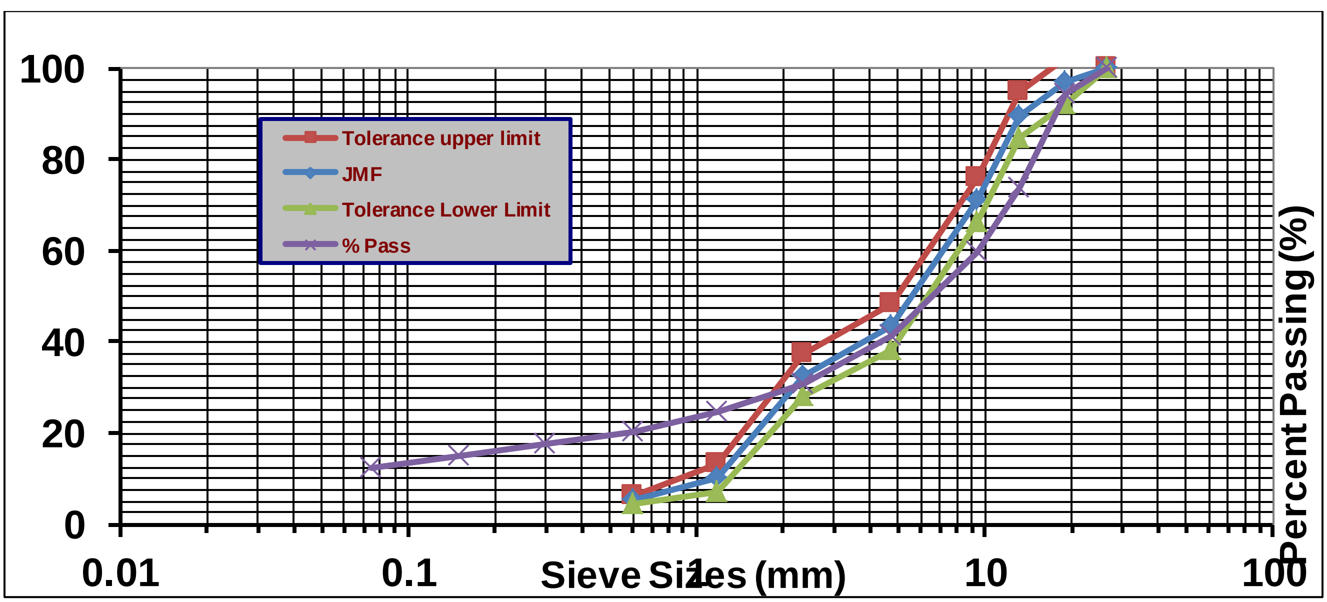
BH-1,Trial -A	Wt.(gm)	Sieve (mm)	Wt.Ret .(gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	Tolerance U. Limit	Tolerance From JMF	Remark
Mass of Sample(gm) (A)	1524.5	26.5	0.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0		
Mass of Aggregate in bowl after Extraction(gm) (B)	1350.5	19.0	41.0	2.8	97.2	97.2	85.0	100.0	92.2	102.2	±5	
Mass of Filler + Filter (gm) (C)	4.1	13.2	273.0	18.8	78.3	89.7	71.0	100.0	84.7	94.7	±5	
Mass of Filter(gm) (D)	3.7	9.5	250.0	17.3	61.1	71.2	62.0	76.0	66.2	76.2	±5	
Mass of Filler(gm) (E=C-D)	0.4	4.8	277.0	19.1	42.0	43.4	42.0	60.0	38.4	48.4	±4	
Mass of Total Aggregate(gm) (F=B+E+K)	1448.8	2.4	158.0	10.9	31.0	32.3	30.0	48.0	28.3	37.3	±4	
Mass of Bitumen(gm) (G=A-F)	75.7	1.2	94.0	6.5	24.6	10.0	22.0	38.0	7.0	13.0	±3	
Bitumen Content (%) (H=G/A*100)	5.0	0.6	61.0	4.2	20.3	5.4	16.0	28.0	4.4	6.4	±1	
Total Volume Extracted(ml)	5.0	0.3	43.0	3.0	17.4		12.0	20.0				
Mass of Filler per 100ml of Extraction	3.2	0.2	30.0	2.1	15.3		8.0	15.0				
Mass of Filler per Total Volume Extracted (K)	0.2	0.1	29.0	2.0	13.3		4.0	10.0				
		Pan	54.0	3.7	9.6							
		Total	1448.8									



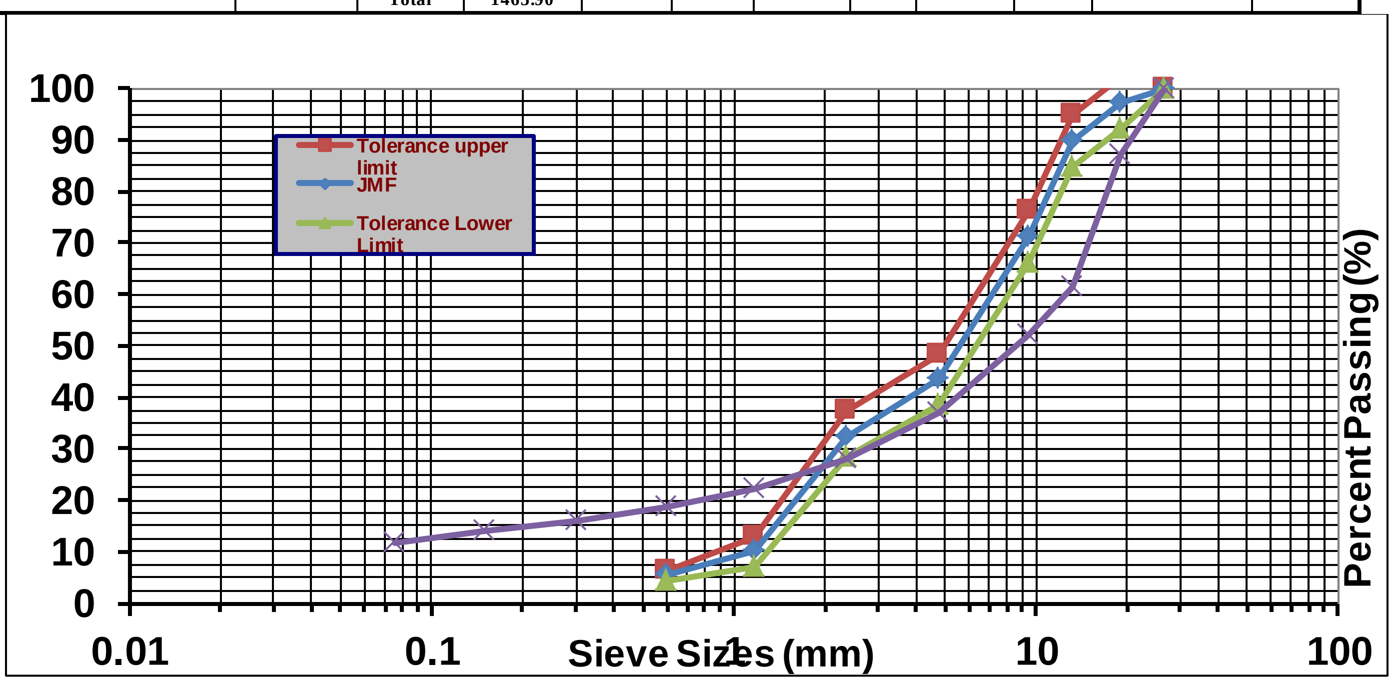
PROJECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from “BulbuloKebele to KoyeBer”											
Host		Program					Laboratory				
Jimma Institute of Technology		HIGH WAY ENGINEERING STREAM					Jimma Roads Maintenance Laboratory				
Placing Station :-	396+500			Sample Date:-			30-Nov-15				
Aggregate Source:-	BH5 NON DAMAGE ASPHALT			Test Date:-			7-Dec-15			Trial-1	
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							Test Method- AASHTO T 30-06				
BH-1,Trial -A	Wt.(gm)	Sieve(mm)	Wt.Ret.(gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	ToleranceU.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1544.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1341.00	19	41.00	2.81	97.19	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.10	13.2	273.00	18.71	78.48	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.70	9.5	250.00	17.13	61.35	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.40	4.75	277.00	18.98	42.37	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1459.20	2.36	158.00	10.83	31.54	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	84.80	1.18	94.00	6.44	25.10	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	5.49	0.6	61.00	4.18	20.92	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3100	0.3	43.00	2.95	17.97		12	20			
Mass of Filler per 100ml of Extraction	3.8	0.15	30.0	2.06	15.91		8	15			
Mass of Filler per Total Volume Extracted (K)	117.80	0.075	29.00	1.99	13.93		4	10			
		Pan	54.00	3.70	10.22						
		Total	1459.20								



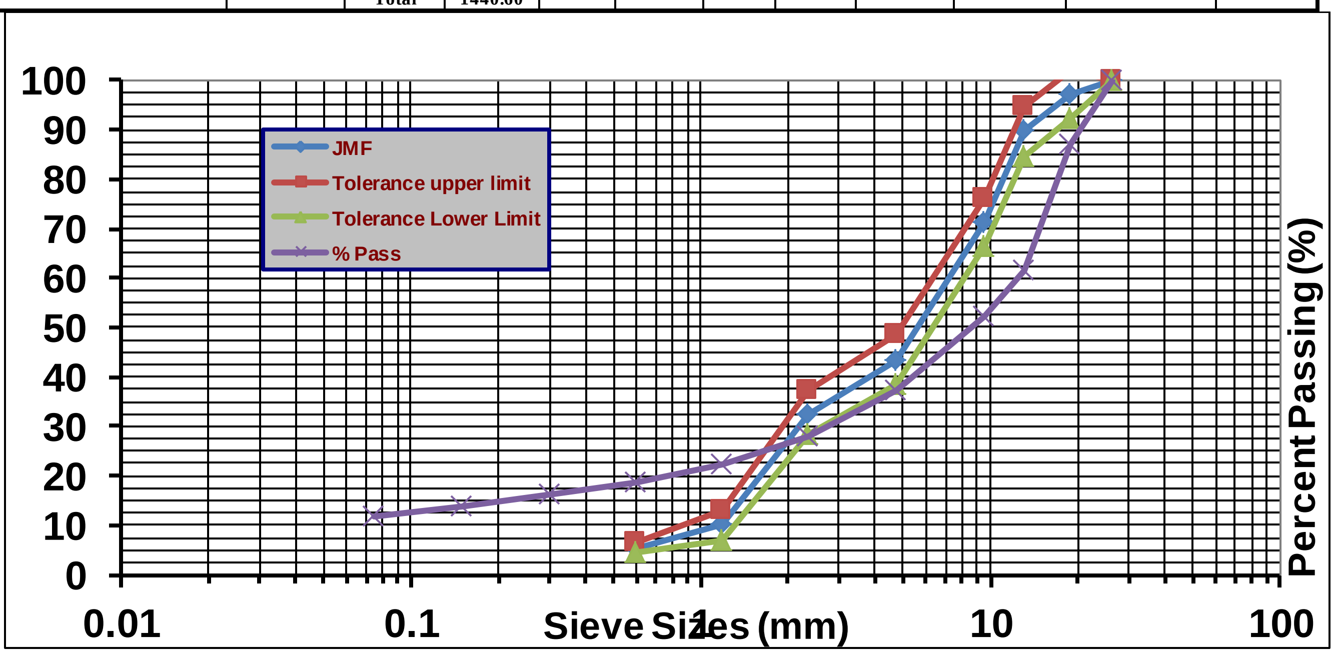
PROJECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from “Bulbulo Kebele to Koye Ber”											
Host		Program					Laboratory				
Jimma Institute of Technology		HIGH WAY ENGINEERING STREAM					Jimma Roads maintenance Laboratory				
Placing Station :-	396+500				Sample Date:-		30-Nov-15			Trial-2	
Aggregate Source:-	BH5 NON DAMAGE ASPHALT				Test Date:-		7-Dec-15				
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							Test Method- AASHTO T 30-06				
BH-1,Trial -A	Wt.(gm)	Sieve(mm)	Wt.Ret.(gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	ToleranceU.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1505.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1360.00	19	80.00	5.56	94.44	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.10	13.2	296.00	20.58	73.86	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.70	9.5	203.00	14.11	59.75	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.40	4.75	265.00	18.42	41.32	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1438.40	2.36	151.00	10.50	30.83	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	66.60	1.18	92.00	6.40	24.43	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	4.43	0.6	59.00	4.10	20.33	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3120	0.3	42.00	2.92	17.41		12	20			
Mass of Filler per 100ml of Extraction	2.5	0.15	35.0	2.43	14.97		8	15			
Mass of Filler per Total Volume Extracted (K)	78.00	0.075	38.00	2.64	12.33		4	10			
		Pan	87.00	6.05	6.28						
		Total	1438.40								



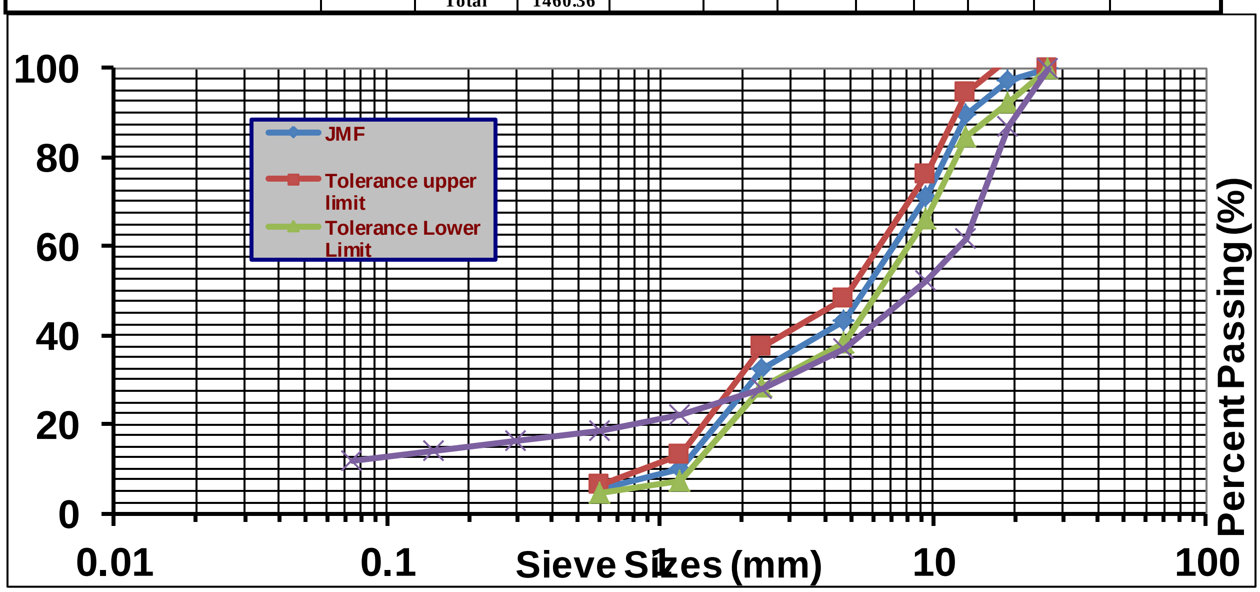
PROJECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"											
Host		**Program**					**Laboratory**				
Jimma Institute of Technology		**HIGH WAY ENGINEERING STREAM**					**Jimma Roads maintenace Laboratory**				
Placing Station :-	**385+000**					**Sample Date:-**		**29-Nov-15**			
Aggregate Source:-	**BH1 Trial -1**					**Test Date:-**		**6-Dec-15**			
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							**Test Method- AASHTO T 30-06**				
BH-1,Trial -A	**Wt.(gm)**	**Sieve(mm)**	**Wt.Ret.(gm)**	**% Ret.**	**% passing**	**JMF**	**Spec. L.Limit**	**Spec. U.Limit**	**Tolerance L.Limit**	**Tolerance U. Limit**	**Tolerance From JMF**
Mass of Sample(gm) (A)	**1500.00**	**26.5**	**0.00**	**0.00**	**100.00**	**100.00**	**100**	**100**	**100**	**100**	
Mass of Aggregate in bowl after Extraction(gm) (B)	**1369.10**	**19**	**190.00**	**12.96**	**87.04**	**97.17**	**85**	**100**	**92.17**	**102.17**	**±5**
Mass of Filler + Filter (gm) (C)	**4.70**	**13.2**	**374.00**	**25.51**	**61.53**	**89.71**	**71**	**100**	**84.71**	**94.71**	**±5**
Mass of Filter(gm) (D)	**3.90**	**9.5**	**137.00**	**9.35**	**52.18**	**71.19**	**62**	**76**	**66.19**	**76.19**	**±5**
Mass of Filler(gm) (E=C-D)	**0.80**	**4.75**	**221.00**	**15.08**	**37.10**	**43.38**	**42**	**60**	**38.38**	**48.38**	**±4**
Mass of Total Aggregate(gm) (F=B+E+K)	**1465.90**	**2.36**	**134.00**	**9.14**	**27.96**	**32.32**	**30**	**48**	**28.32**	**37.32**	**±4**
Mass of Bitumen(gm) (G=A-F)	**34.10**	**1.18**	**83.00**	**5.66**	**22.30**	**10.04**	**22**	**38**	**7.04**	**13.04**	**±3**
Bitumen Content(%) (H=G/A*100)	**2.27**	**0.6**	**53.00**	**3.62**	**18.68**	**5.38**	**16**	**28**	**4.38**	**6.38**	**±1**
Total Volume Extracted(ml)	**3200**	**0.3**	**39.00**	**2.66**	**16.02**		**12**	**20**			
Mass of Filler per 100ml of Extraction	**3**	**0.15**	**31.0**	**2.11**	**13.91**		**8**	**15**			
Mass of Filler per Total Volume Extracted (K)	**96.00**	**0.075**	**32.00**	**2.18**	**11.73**		**4**	**10**			
		Pan	**69.00**	**4.71**	**7.02**						
		Total	**1465.90**								



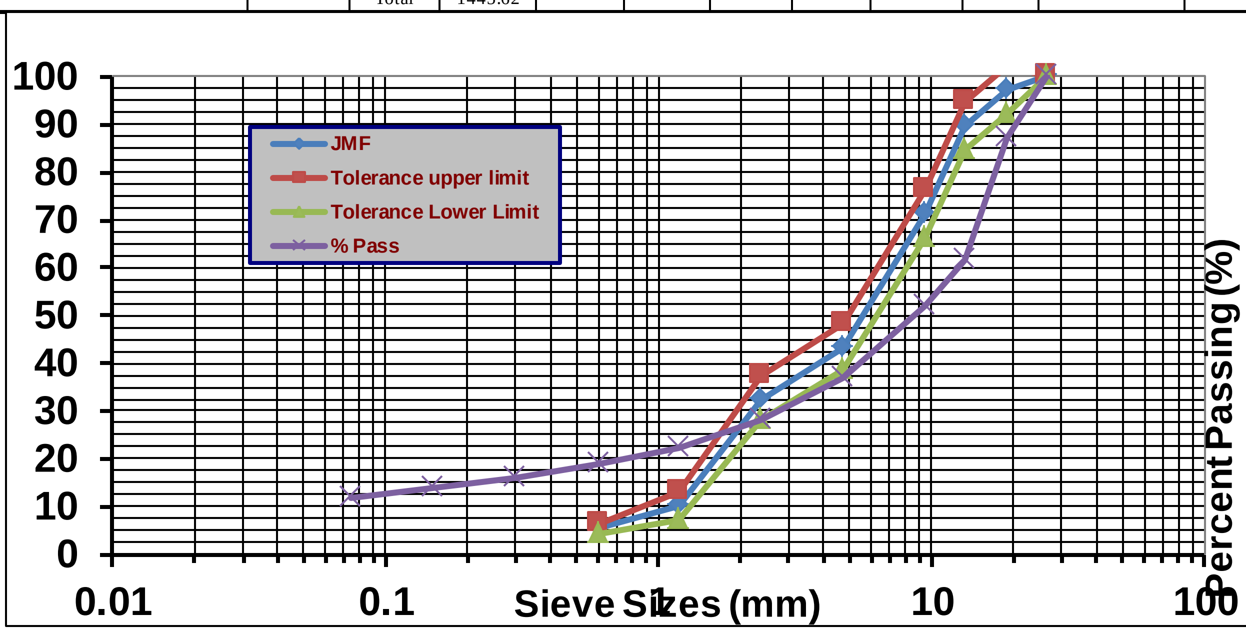
PROJECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"											
Host		Program					Laboratory				
Jimma Institute of Technology		HIGH WAY ENGINEERING STREAM					Jimma Roads maintenance Laboratory				
Placing Station :-	398+000			Sample Date:-			29-Nov-15				
Aggregate Source:-	BH1 Trial -2			Test Date:-			6-Dec-15				
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							Test Method- AASHTO T 30-06				
BH-1,Trial -A	Wt.(gm)	Sieve(mm)	Wt.Ret. (gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	ToleranceU.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1341.00	19	78.00	5.41	94.59	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.10	13.2	258.00	17.91	76.68	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.70	9.5	193.00	13.40	63.28	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.40	4.75	239.00	16.59	46.69	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1440.60	2.36	154.00	10.69	36.00	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	59.40	1.18	103.00	7.15	28.85	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	3.96	0.6	71.00	4.93	23.92	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3100	0.3	49.00	3.40	20.52		12	20			
Mass of Filler per 100ml of Extraction	3.2	0.15	42.0	2.92	17.60		8	15			
Mass of Filler per Total Volume Extracted (K)	99.20	0.075	45.00	3.12	14.48		4	10			
		Pan	79.00	5.48	9.00						
		Total	1440.60								



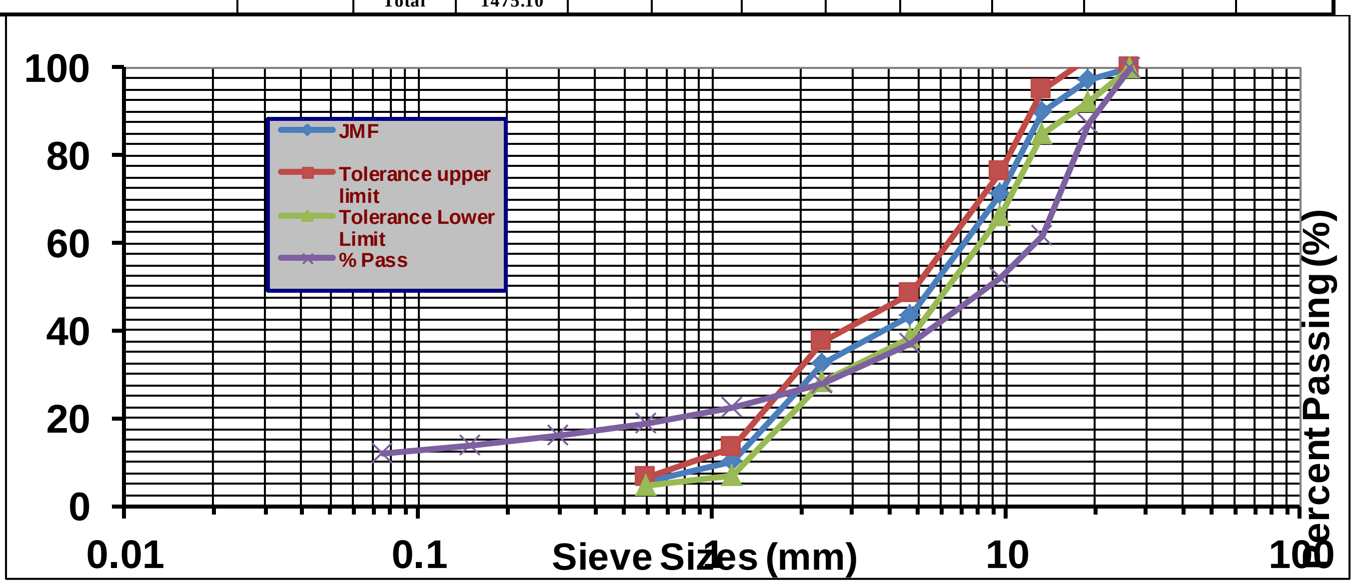
PROJECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"											
Host			Msc Program				Laboratory				
Jimma Institute of Technology			HIGH WAY ENGINEERING STREAM				Jimma Roads maintenance Laboratory				
Placing Station :-	398+000				Sample Date:-		29-Nov-15				
Aggregate Source:-	BH-2 Average				Test Date:-		7-Dec-15				
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							Test Method- AASHTO T 30-06				
BH-1,Trial -A	Wt.(gm)	Sieve(mm)	Wt.Ret.(gm)	% Ret.	% passing	JMF	Spec. L. Limit	Spec. U. Limit	Tolerance L.Limit	Tolerance U.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1373.50	19	0.00	0.00	100.00	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.05	13.2	447.00	30.61	69.39	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.75	9.5	173.00	11.85	57.54	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.30	4.75	254.00	17.39	40.15	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1460.36	2.36	149.00	10.20	29.95	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	39.64	1.18	85.00	5.82	24.13	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	2.64	0.6	56.00	3.83	20.29	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3085.00	0.3	40.00	2.74	17.55		12	20			
Mass of Filler per 100ml of Extraction	2.75	0.15	37.0	2.53	15.02		8	15			
Mass of Filler per Total Volume Extracted (K)	86.56	0.075	38.00	2.60	12.42		4	10			
		Pan	65.00	4.45	7.97						
		Total	1460.36								



PROJECTNAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"										
Host		**Msc Program**					**Laboratory**			
Jimma Institute of Technology		**HIGH WAY ENGINEERING STREAM**					**Jimma Roads maintenance Laboratory**			
Placing Station :-	**398+000**			**Sample Date:-**				**29-Nov-15**		
Aggregate Source:-	**BH-2 trial-1**			**Test Date:-**				**7-Dec-15**		
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							**Test Method- AASHTO T30-06**			
BH-1,Trial -A	**Wt.(gm)**	**Sieve(mm)**	**Wt.Ret. (gm)**	**% Ret.**	**% passing**	**JMF**	**Spec. L.Limit**	**Spec. U.Limit**	**Tolerance L.Limit**	**ToleranceU.Limit**	**Tolerance From JMF**
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregatein bowl after Extraction(gm) (B)	1386.00	19	0.00	0.00	100.00	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.20	13.2	447.00	30.92	69.08	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.80	9.5	173.00	11.97	57.11	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.40	4.75	254.00	17.57	39.54	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1445.62	2.36	149.00	10.31	29.23	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	54.38	1.18	85.00	5.88	23.35	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	3.63	0.6	56.00	3.87	19.48	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	2820	0.3	40.00	2.77	16.71		12	20			
Mass of Filler per 100ml of Extraction	2.1	0.15	37.0	2.56	14.15		8	15			
Mass of Filler per Total Volume Extracted (K)	**59.22**	0.075	38.00	2.63	11.53		4	10			
		Pan	65.00	4.50	7.03						
		Total	1445.62								



JECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"											
Host		MSc Program					Laboratory				
Jimma Institute of Technology		HIGH WAY ENGINEERING STREAM					Jimma Roads maintenance Laboratory				
Placing Station :-	398+000			Sample Date:-			29-Nov-15				
Aggregate Source:-		BH-2 trial-2		Test Date:-			7-Dec-15				
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							Test Method- AASHTO T 30-06				
Test Method- AASHTO T 30-06											
BH-2,Trial -A	Wt.(gm)	Sieve(mm)	Wt.Ret.(gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance Limit	ToleranceU.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregatein bowl after Extraction(gm) (B)	1361.00	19	58.00	3.93	96.07	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	3.90	13.2	451.00	30.57	65.49	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.70	9.5	175.00	11.86	53.63	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.20	4.75	258.00	17.49	36.14	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1475.10	2.36	120.00	8.14	28.00	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	24.90	1.18	76.00	5.15	22.85	10.04	22	38	7.04	13.04	±3
Bitumen Content (%) (H=G/A*100)	1.66	0.6	46.00	3.12	19.73	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3350	0.3	28.00	1.90	17.84		12	20			
Mass of Filler per 100ml of Extraction	3.4	0.15	35.0	2.37	15.46		8	15			
Mass of Filler per Total Volume Extracted (K)	113.90	0.075	29.00	1.97	13.50		4	10			
		Pan	50.00	3.39	10.11						
		Total	1475.10								



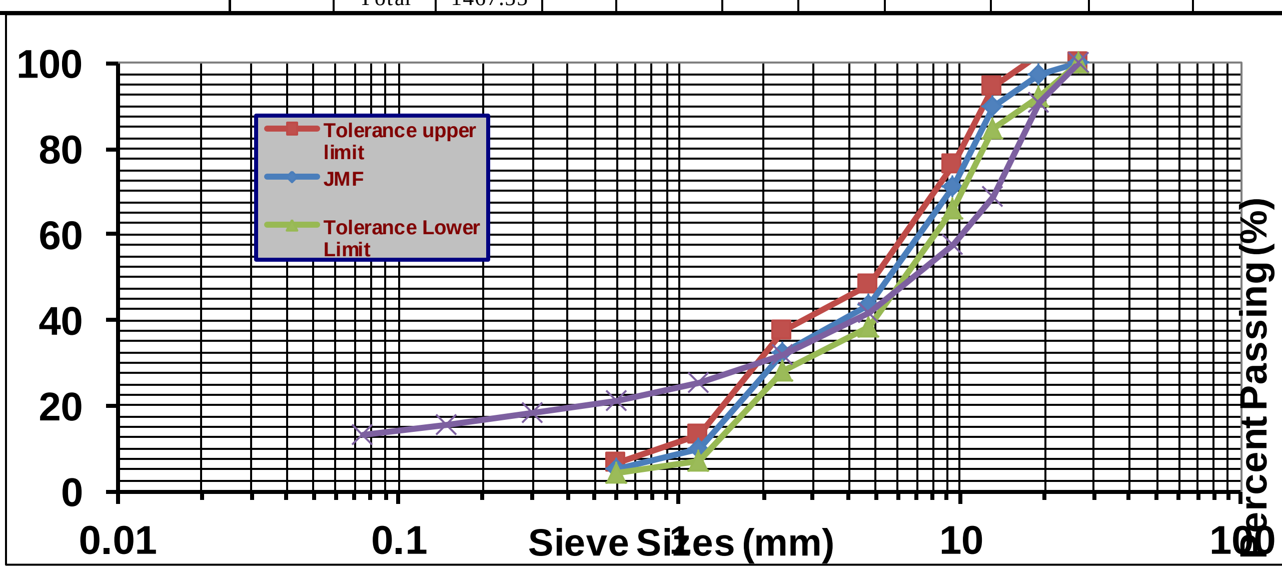
PROJECTNAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"

Host	Program	Laboratory
Jimma Institute of Technology	HIGH WAY ENGINEERING STREAM	Jimma Roads maintenance Laboratory

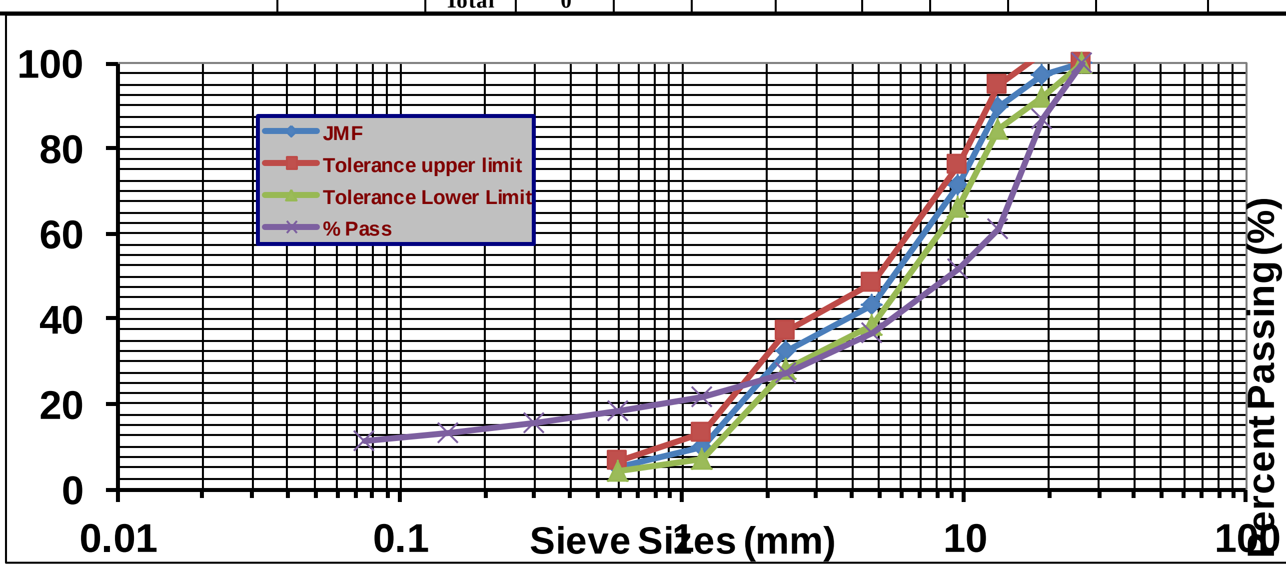
Placing Station :-	**386+000**	Sample Date:-	**30-Nov-15**
Aggregate Source:-	**BH3 Trial -1**	Test Date:-	**8-Dec-15**

AVERAGE EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE — **Test Method- AASHTO T30-06**

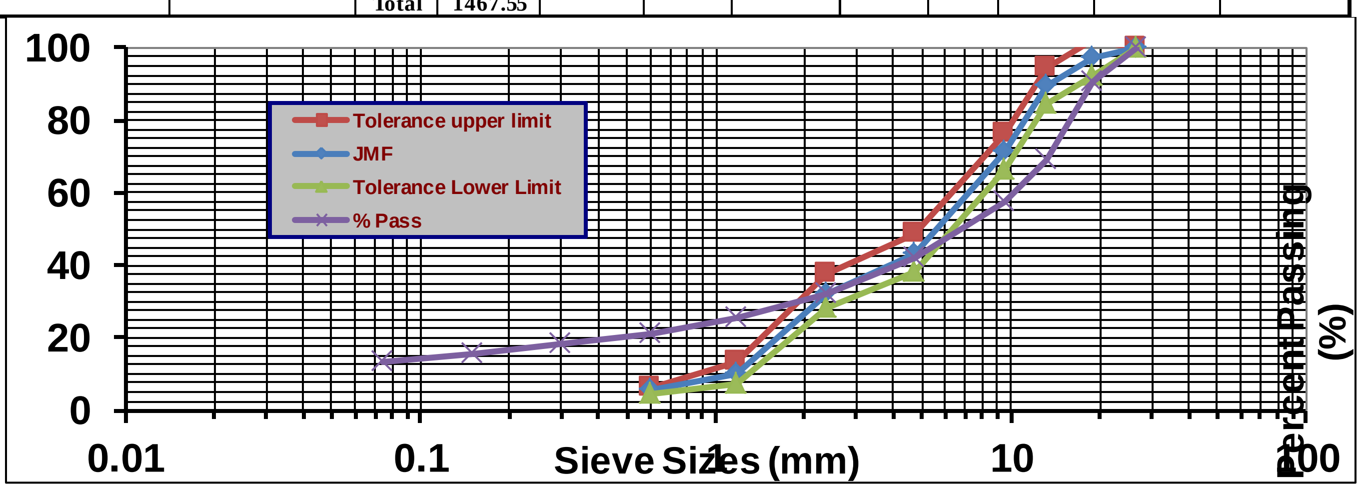
BH-3,Trial -1	Wt.(gm)	Sieve(mm)	Wt.Ret.(gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	Tolerance U.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1363.70	19	135.90	9.26	90.74	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.30	13.2	319.74	21.79	68.95	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.84	9.5	166.37	11.34	57.62	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.46	4.75	232.21	15.82	41.79	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1467.55	2.36	145.34	9.90	31.89	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	32.45	1.18	93.83	6.39	25.50	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	2.16	0.6	62.53	4.26	21.23	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3100	0.3	44.39	3.02	18.21		12	20			
Mass of Filler per 100ml of Extraction	3.1	0.15	36.81	2.51	15.70		8	15			
Mass of Filler per Total Volume Extracted (K)	**96.10**	0.075	38.82	2.65	13.06		4	10			
		Pan	62.00	4.22	8.83						
		Total	1467.55								



PROJECTNAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"											
Host		Program					Laboratory				
Jimma Institute of Technology		HIGH WAY ENGINEERING STREAM					Jimma Roads maintenance Laboratory				
Placing Station :-	386+000			Sample Date:-			30-Nov-15				
Aggregate Source:-	BH3 Trial -2			Test Date:-			8-Dec-15				
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							Test Method- AASHTO T30-06				
BH-3,Trial -2	Wt.(gm)	Sieve(mm)	Wt.Ret.(gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	Tolerance U.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1352.00	19	78.00	5.38	94.62	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.30	13.2	258.00	17.79	76.83	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.80	9.5	193.00	13.31	63.52	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.50	4.75	239.00	16.48	47.04	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1450.10	2.36	154.00	10.62	36.42	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	49.90	1.18	103.00	7.10	29.32	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	3.33	0.6	71.00	4.90	24.42	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3050	0.3	49.00	3.38	21.04		12	20			
Mass of Filler per 100ml of Extraction	3.2	0.15	42.0	2.90	18.14		8	15			
Mass of Filler per Total Volume Extracted (K)	97.60	0.075	45.00	3.10	15.04		4	10			
		Pan	79.00	5.45	9.59						
		Total	1450.10								



PROJECTNAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"											
Host			Program				Laboratory				
Jimma Institute of Technology			HIGH WAY ENGINEERING STREAM				Jimma Roads maintenance Laboratory				
Placing Station :-	386+000				Sample Date:-		30-Nov-15				
Aggregate Source:-	BH3 AVERAGE				Test Date:-		8-Dec-15				
AVERAGE EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							Test Method- AASHTO T30-06				
BH-3-Avg	Wt.(gm)	Sieve (mm)	Wt.Ret. (gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	Tolerance U.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1363.70	19	135.90	9.26	90.74	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.30	13.2	319.74	21.79	68.95	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.84	9.5	166.37	11.34	57.62	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.46	4.75	232.21	15.82	41.79	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1467.55	2.36	145.34	9.90	31.89	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	32.45	1.18	93.83	6.39	25.50	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	2.16	0.6	62.53	4.26	21.23	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3100	0.3	44.39	3.02	18.21		12	20			
Mass of Filler per 100ml of Extraction	3.1	0.15	36.81	2.51	15.70		8	15			
Mass of Filler per Total Volume Extracted (K)	96.10	0.075	38.82	2.65	13.06		4	10			
		Pan	62.00	4.22	8.83						
		Total	1467.55								



PROJECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from “BulbuloKebele to KoyeBer”

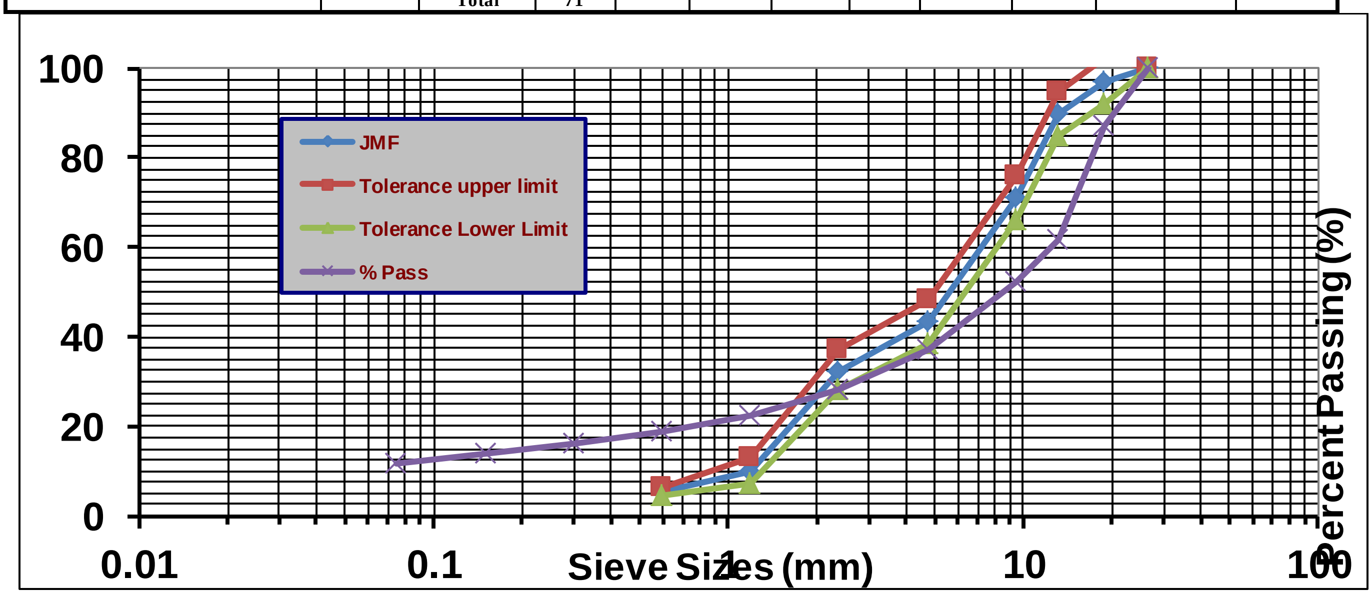
Host	Msc Program	Laboratory
Jimma Institute of Technology	HIGH WAY ENGINEERING STREAM	Jimma Roads maintenance Laboratory

Placing Station :-	396+500	Sample Date:-	30-Nov-15		
Aggregate Source:-	AVERAGE BH4	Test Date:-	8-Dec-15		

EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE — Test Method- AASHTO T 30-06

Test Method- AASHTO T 30-06

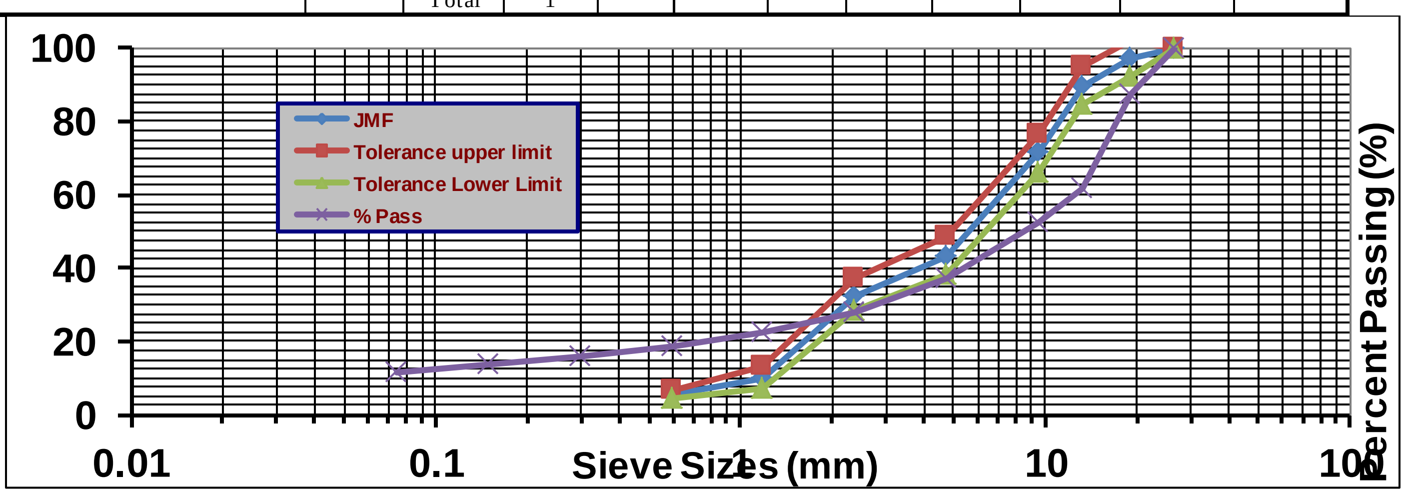
BH-4,Avg	Wt.(gm)	Sieve(mm)	Wt.Ret.(gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	ToleranceU.Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1374.00	19	58.00	3.96	96.04	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.00	13.2	451.00	30.77	65.27	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.73	9.5	175.00	11.94	53.33	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.28	4.75	258.00	17.60	35.73	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1465.71	2.36	120.00	8.19	27.54	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	34.30	1.18	76.00	5.19	22.36	10.04	22	38	7.04	13.04	±3
Bitumen Content(%) (H=G/A*100)	2.29	0.6	46.00	3.14	19.22	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3085	0.3	28.00	1.91	17.31		12	20			
Mass of Filler per 100ml of Extraction	3.6	0.15	35.0	2.39	14.92		8	15			
Mass of Filler per Total Volume Extracted (K)	111.06	0.075	29.00	1.98	12.94		4	10			
		Pan	50.00	3.41	9.53						
		Total	1465.71								



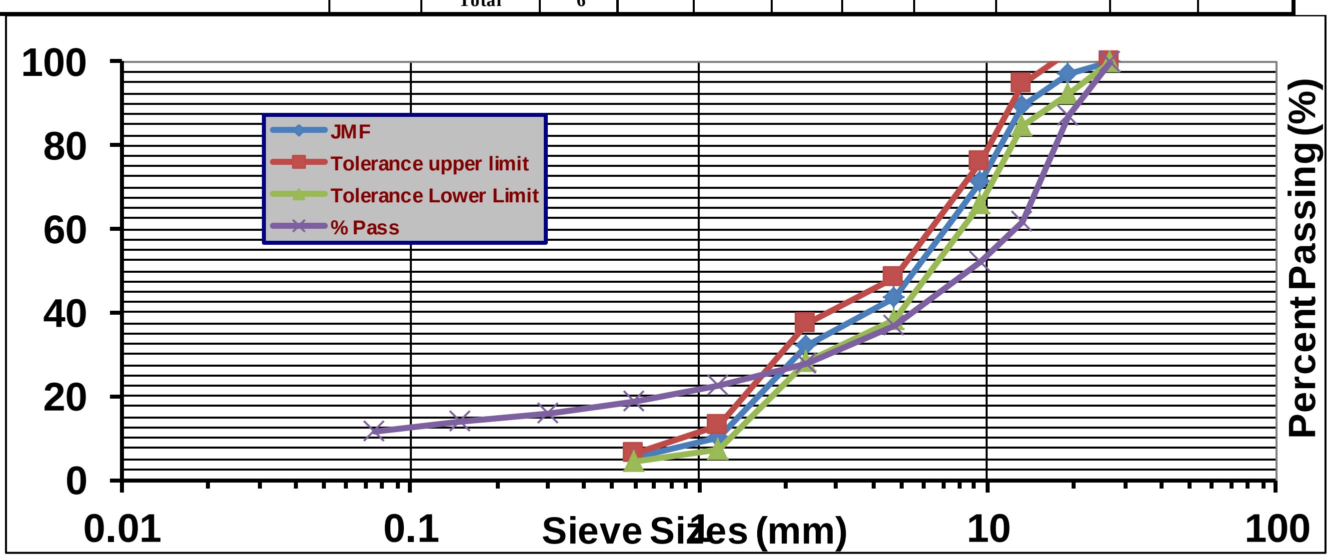
PROJECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"

Host	Msc Program	Laboratory
Jimma Institute of Technology	HIGH WAY ENGINEERING STREAM	Jimma Roads maintenance Laboratory

Placing Station :-	397+000					Sample Date:-		30-Nov-15			
Aggregate Source:-	BH4 TRIAL-1					Test Date:-		9-Dec-15			
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							Test Method- AASHTO T 30-06				
BH-4,Trial -1	Wt.(gm)	Sieve(mm)	Wt.Ret .(gm)	% Ret.	% passing	JMF	Spec. L.Limit	Spec. U.Limit	Tolerance L.Limit	Tolerance U. Limit	Tolerance From JMF
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1392.00	19	0.00	0.00	100.00	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	4.30	13.2	438.06	29.97	70.03	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.95	9.5	171.27	11.72	58.32	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.35	4.75	251.46	17.20	41.11	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1461.81	2.36	150.49	10.29	30.82	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	38.19	1.18	87.55	5.99	24.83	10.04	22	38	7.04	13.04	±3
Bitumen Content (%) (H=G/A*100)	2.55	0.6	61.60	4.21	20.62	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3020	0.3	45.00	3.08	17.54		12	20			
Mass of Filler per 100ml of Extraction	2.3	0.15	39.0	2.67	14.87		8	15			
Mass of Filler per Total Volume Extracted (K)	69.46	0.075	40.10	2.74	12.13		4	10			
		Pan	54.00	3.69	8.43						
		Total	1461.81								



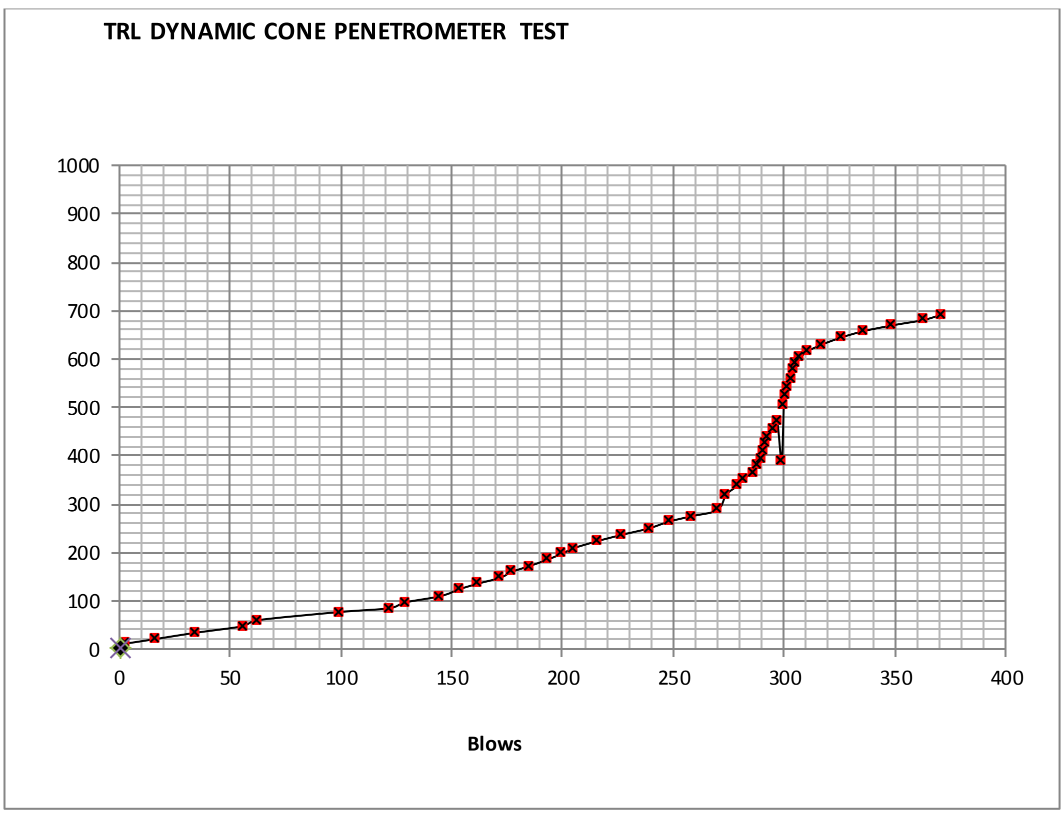
PROJECT NAME:-Causes and Remedial for Asphalt Concrete Pavement Damages a Case Study in Agaro Town from "BulbuloKebele to KoyeBer"											
Host		**Msc Program**					**Laboratory**				
Jimma Institute of Technology		**HIGH WAY ENGINEERING STREAM**					**Jimma Roads maintenance Laboratory**				
Placing Station :-	**397+000**				**Sample Date:-**		**30-NOV-15**				
Aggregate Source:-	**BH4 TRIAL-2**				**Test Date:-**		**9-Dec-15**				
EXTRACTION OF BITUMEN & MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE							**Test Method- AASHTO T 30-06**				
Test Method- AASHTO T 30-06											
BH-4,Trial -2	**Wt.(gm)**	**Sieve(mm)**	**Wt.Ret.(gm)**	**% Ret.**	**% passing**	**JMF**	**Spec. L.Limit**	**Spec. U.Limit**	**Tolerance L.Limit**	**ToleranceU.Limit**	**Tolerance From JMF**
Mass of Sample(gm) (A)	1500.00	26.5	0.00	0.00	100.00	100.00	100	100	100	100	
Mass of Aggregate in bowl after Extraction(gm) (B)	1356.00	19	58.00	3.95	96.05	97.17	85	100	92.17	102.17	±5
Mass of Filler + Filter (gm) (C)	3.70	13.2	451.00	30.69	65.36	89.71	71	100	84.71	94.71	±5
Mass of Filter(gm) (D)	3.50	9.5	175.00	11.91	53.46	71.19	62	76	66.19	76.19	±5
Mass of Filler(gm) (E=C-D)	0.20	4.75	258.00	17.56	35.90	43.38	42	60	38.38	48.38	±4
Mass of Total Aggregate(gm) (F=B+E+K)	1469.60	2.36	120.00	8.17	27.74	32.32	30	48	28.32	37.32	±4
Mass of Bitumen(gm) (G=A-F)	30.40	1.18	76.00	5.17	22.56	10.04	22	38	7.04	13.04	±3
Bitumen Content (%) (H=G/A*100)	2.03	0.6	46.00	3.13	19.43	5.38	16	28	4.38	6.38	±1
Total Volume Extracted(ml)	3150	0.3	28.00	1.91	17.53		12	20			
Mass of Filler per 100ml of Extraction	3.6	0.15	35.0	2.38	15.15		8	15			
Mass of Filler per Total Volume Extracted (K)	113.40	0.075	29.00	1.97	13.17		4	10			
		Pan	50.00	3.40	9.77						
		Total	1469.6								



APPENDIX F. DYNAMIC CONE PENETERATION TEST

Layer Description :-	ALL layers	First layer selected sub grade			Date of Test	9 December 2015		
Chainage (Km) :-		Lat.7°51'48.4704"N & Long.36°34'31.4539"E			DCP Zero Reading :		50 mm	
Test spot :-								
Test No. :-	1	1(BH-6)						
No. Blows	Cumulative No. Blows	Depth in mm	mm/Blow	CBR				
3	3	12	-	-				
13	16	21	1.3	226.6				
18	34	34	1.0	302.0				
22	56	48	0.9	355.4				
6	62	60	1.0	312.6				
37	99	77	0.8	393.9				
23	122	85	0.7	442.5				
7	129	97	0.8	408.2				
16	145	110	0.8	404.4				
9	154	125	0.8	376.5				
8	162	136	0.8	363.3				
10	172	148	0.9	354.0				
5	177	160	0.9	336.0				
8	185	172	0.9	326.2				
8	193	185	1.0	315.8				
7	200	198	1.0	305.2				
5	205	209	1.0	295.9				
11	216	224	1.0	290.6				
11	227	237	1.0	288.5				
12	239	250	1.0	288.0				
9	248	264	1.1	282.7				
10	258	275	1.1	282.3				
12	270	288	1.1	282.1				
4	274	320	1.2	256.3				
5	279	338	1.2	246.6				
3	282	353	1.3	238.2				
4	286	365	1.3	233.4				
2	288	380	1.3	225.3				
2	290	395	1.4	217.8				
1	291	410	1.4	210.2				
1	292	427	1.5	202.1				
1	293	439	1.5	197.0				
2	295	454	1.5	191.5				
2	297	470	1.6	185.9				
2	299	390	1.3	228.0				
1	300	505	1.7	174.2				
1	301	525	1.7	167.7				
1	302	540	1.8	163.4				
1	303	560	1.8	157.8				
1	304	580	1.9	152.6				

1	305	591	1.9	150.1			
2	307	602	2.0	148.2			
4	311	617	2.0	146.4			
6	317	630	2.0	146.1			
9	326	645	2.0	146.8			
10	336	658	2.0	148.4			
13	349	670	1.9	151.6			
14	363	681	1.9	155.3			
8	371	692	1.9	156.3			
Layer No.	**Depth (mm)**			**Layer thickness (mm)**	**No. Blows**	**mm/blow**	**CBR**
	From	**To**					
Layer 1	**12**	**60.0**		**48.0**	**62**	**0.8**	**396**
Layer 2	**60**	**209.0**		**197.0**	**205**	**1.0**	**315**
Layer 3	**209**	**410.0**		**398.0**	**291**	**1.4**	**217**
Layer 4	**410**	**692.0**		**680.0**	**371**	**1.8**	**159**
Remark:	**TRL DCP => Log $_{10}$ (CBR)=2.48-1.057Log $_{10}$ (mm/blow) => CBR=$10^{2.48}$/(mm/blow)$^{1.057}$**						

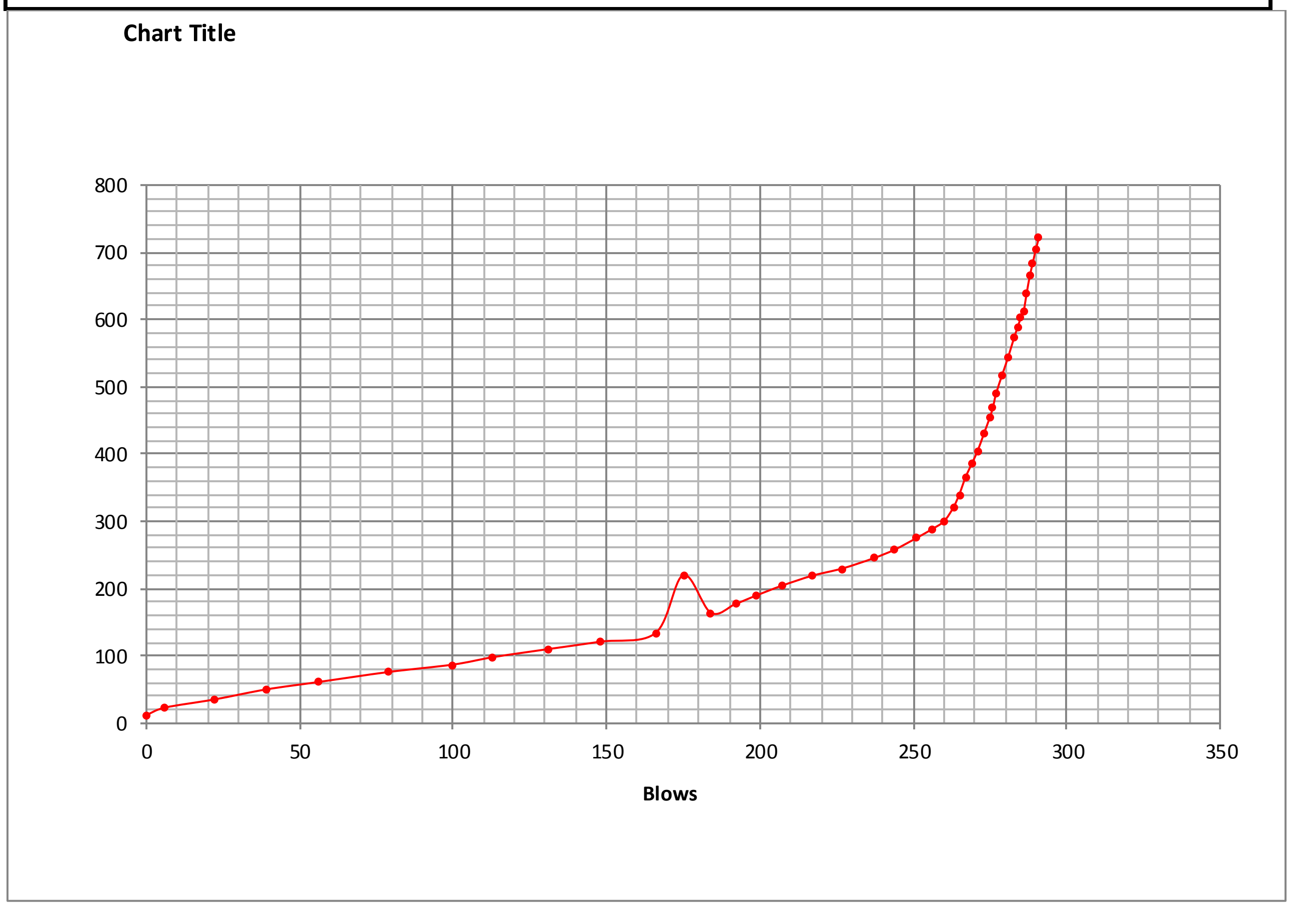


TRL DYNAMIC CONE PENETROMETER TEST

Layer Descriptio n :-		First layer selected sub grade				Date of Test:	9-Dec. 2015
Chainage (Km) :-	Lat.7°51'13.2480"N & Long.36°36'10.2293"E			DCP Zero Reading :			50 mm
Test spot :-							
Test No. :-		1(BH-7)					
No. Blows	Cumulative No. Blows	Depth in mm	mm/Blo w				
3	0	12	-				
6	6	23	3.8				
16	22	35	1.6				
17	39	50	1.3				
17	56	61	1.1				
23	79	76	1.0				
21	100	87	0.9				
13	113	98	0.9				
18	131	110	0.8				
17	148	121	0.8				
18	166	134	0.8				
9	175	220	1.3				
9	184	164	0.9				
8	192	177	0.9				
7	199	190	1.0				
8	207	204	1.0				
10	217	219	1.0				
10	227	230	1.0				
10	237	245	1.0				
7	244	258	1.1				
7	251	275	1.1				
5	256	288	1.1				
4	260	300	1.2				
3	263	320	1.2				
2	265	340	1.3				
2	267	365	1.4				
2	269	385	1.4				
2	271	405	1.5				
2	273	430	1.6				
2	275	455	1.7				
1	276	470	1.7				
1	277	490	1.8				
2	279	518	1.9				

2	281	545	1.9				
2	283	575	2.0				
1	284	588	2.1				
1	285	602	2.1				
1	286	613	2.1				
1	287	640	2.2				
1	288	665	2.3				
1	289	685	2.4				
1	290	705	2.4				
1	291	722	2.5				
Layer No.	Depth (mm)		Layer thickness (mm)	No. Blows	mm/blow	CBR	
	From	To					
Layer 1	12	722.0	722.0	291	2.5	116	

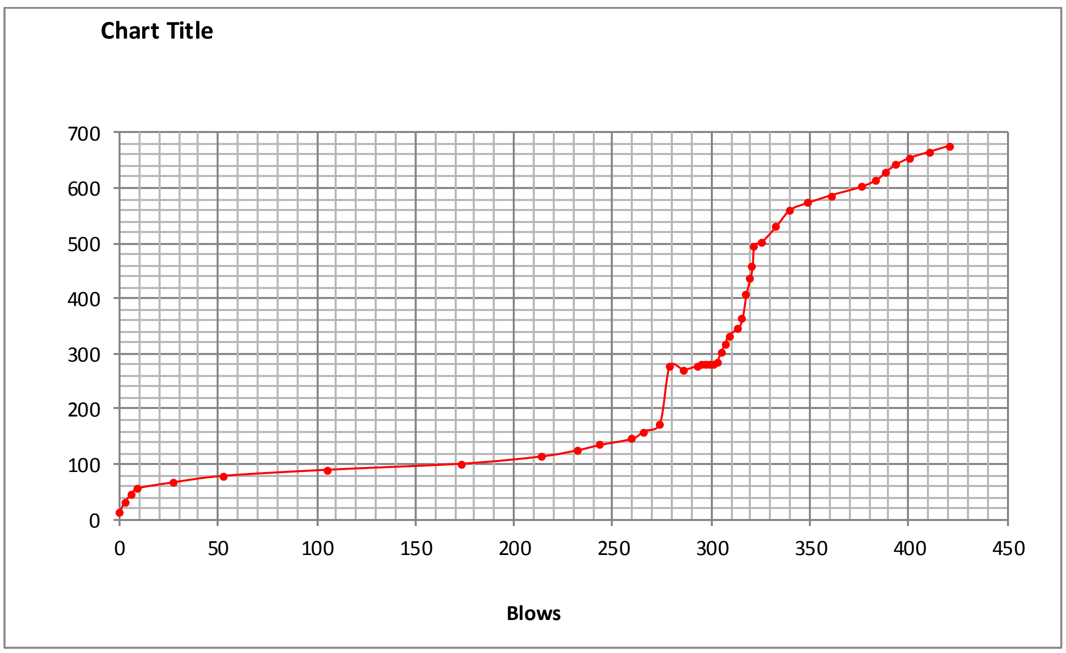
Remark:
TRL DCP => $Log_{10}(CBR)=2.48-1.057Log_{10}(mm/blow)$ => $CBR=10^{2.48}/(mm/blow)^{1.057}$



TRL DYNAMIC CONE PENETROMETER TEST							
Layer Description :-		First layer selected sub grade				Date of Test :	9 Dec. 2015
Chain age (Km) :-	Lat.7°51'12.5568"N & Long.36°35'46.1859"E				DCP Zero Reading :		65 mm
Test spot :-							
Test No. :-		1(BH-8)					
No. Blows	Cumulative No. Blows	Depth in mm	mm/Blow				
2	0	13	-				
3	3	33	11.0				
3	6	45	7.5				
3	9	56	6.2				
18	27	67	2.5				
26	53	79	1.5				
53	106	90	0.8				
68	174	101	0.6				
40	214	114	0.5				
18	232	125	0.5				
12	244	135	0.6				
16	260	146	0.6				
6	266	160	0.6				
8	274	173	0.6				
5	279	278	1.0				
7	286	271	0.9				
7	293	278	0.9				
2	295	280	0.9				
2	297	281	0.9				
2	299	282	0.9				
2	301	283	0.9				
2	303	286	0.9				
2	305	302	1.0				
2	307	317	1.0				
2	309	333	1.1				
5	314	347	1.1				
2	316	364	1.2				
2	318	409	1.3				
2	320	436	1.4				
1	321	457	1.4				
1	322	495	1.5				
4	326	503	1.5				
7	333	530	1.6				
7	340	560	1.6				

9	349	573	1.6				
12	361	587	1.6				
15	376	602	1.6				
8	384	615	1.6				
5	389	630	1.6				
5	394	643	1.6				
7	401	655	1.6				
10	411	666	1.6				
10	421	677	1.6				
	Layer No.	Depth (mm)		Layer thickness (mm)	No. Blows	mm/blow	CBR
		From	To				
	Layer 1	13	677.0	677.0	421	1.6	183

TRL DCP => $\log_{10}(CBR)=2.48-1.057\log_{10}(mm/blow)$ => $CBR=10^{2.48}/(mm/blow)^{1.057}$



APPENDIX G. TRAFFIC ANALYSIS

Traffic Year 2014

route	Length	Cars	Land Rover	Small Bus	Medium truck	Truck & Trailer	Total
Agaro-Bedele	93	6	67	146	111	55	385

Source: Annual Average Daily Traffic By Road Section Traffic Year 2014 ERA Asset Management Data

Traffic Analysis

Based on the given traffic data the following results are obtained and tabulated as below in the table

Category	2014AADT	TGR(%)	2016AADT	T = 365 AADT1 [(1+i)N – 1] / (i)(millions)	$EF=[Axle_i/8160]^{4.5}$	ESAs
Car	73.00	2.8	77.145	0.3198416	0	0
Bus	146.00	5	160.965	0.738979	0.48	0.35471
trucks	111.00	4	120.05	0.52608545	1.84	0.967997
Track & track trailer	55.00	2	57.22	0.2286871	7.8	1.783759
Total	**385.00**					**3.106467**

From ERA Pavement Design manual Volume I Flexible Pavements and Gravel Roads – 2002, Table 2-5: Traffic Classes for Flexible Pavement Design the traffic class is categorized as **T5**

APPENDIX H. PHOTOGRAPHS OF FIELD INSPECTION AND LABORATORY TEST

Measurement of level of severity

Locating of Defects using GPS

Drainage problem

Moisture condition on pavemnt layer

DCP test

DCP test

Proctor test

Base course Gradation

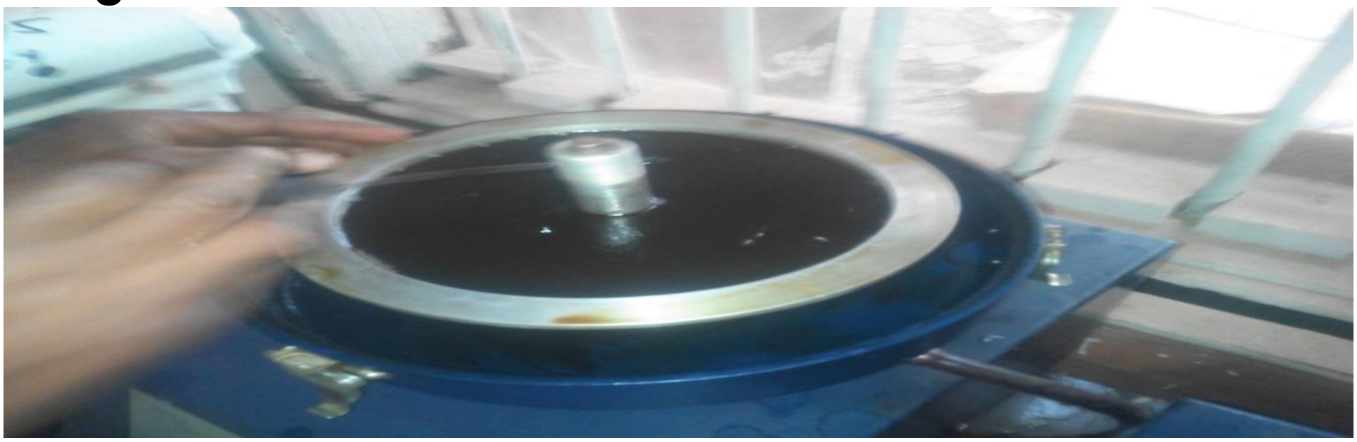
Soaking of sample for CBR Test

After Soaking for 3days CBR Test is following

Marshall STABLITY CBR test machine ready for Testing

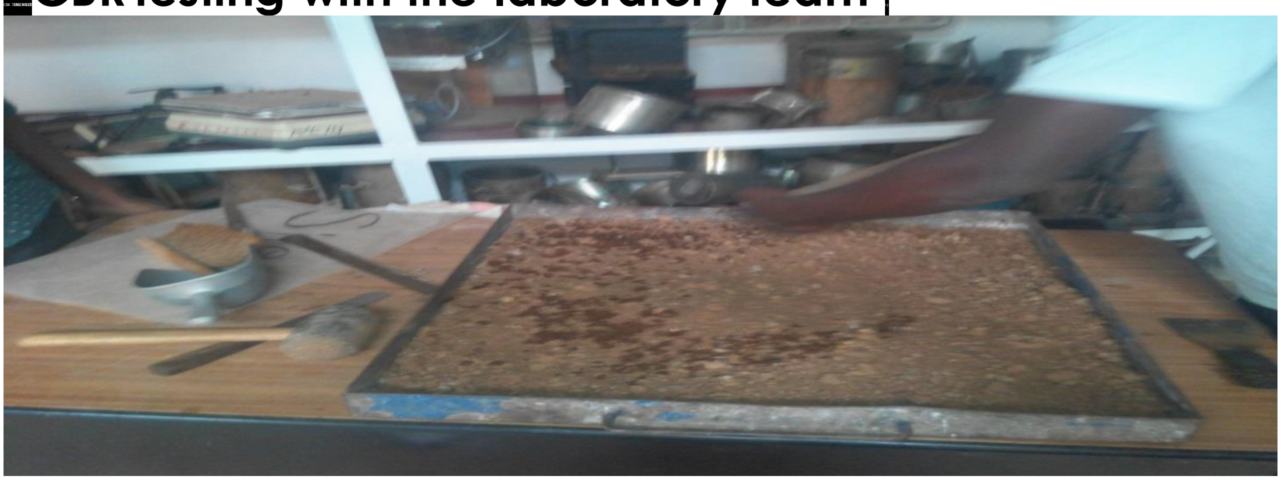
During centrifuging of aggregate bitumen sample

using benzene



Asphalt extraction using Centrifugal machine

CBR testing with the laboratory team

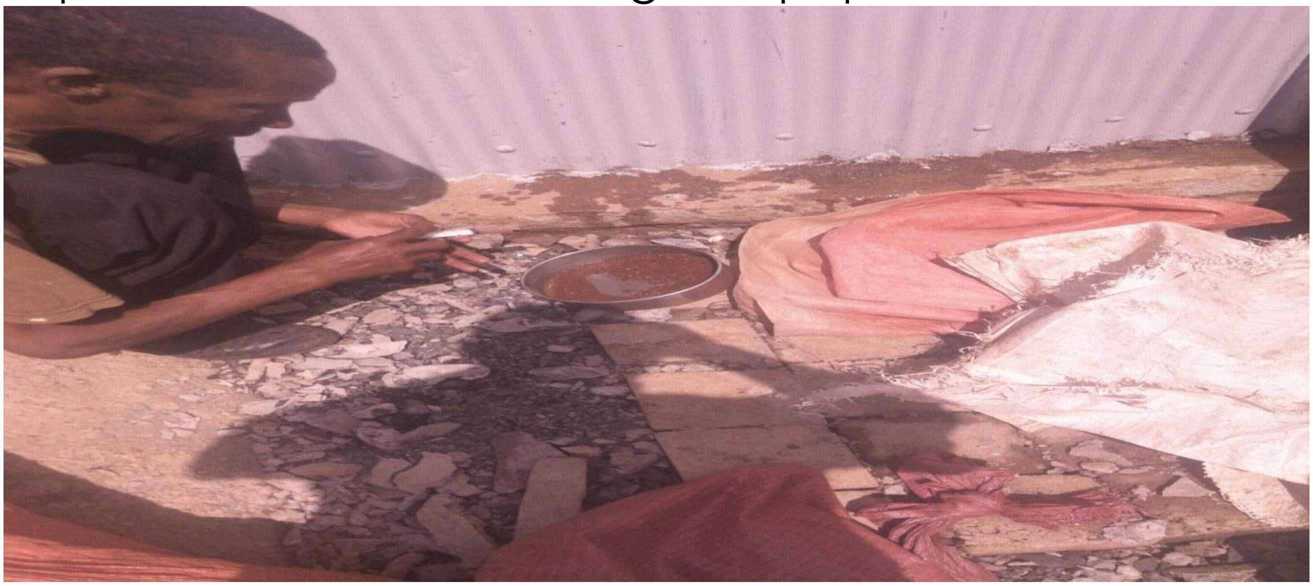


Preparation for three point CBR

Absence of shoulder support and drainage problem

Sieve analysis and ready for classification

Asphalt extraction test using filter paper



Soil classification before oven dry

Air drying of samples

Deep potholes

Less sever potholes

Collecting 50kg of samples from each layers

DCP test