Jimma University

Jimma Institute of Technology

School of Graduate Studies

Faculty of Civil and Environmental Engineering

Department of Civil Engineering

Highway Engineering Stream


# Effects of Subgrade and Sub-Base Materials Quality on Flexible Pavement: A Case Study along Ajip to Gebrel Church of Jimma Town

A Thesis Submitted to School of Graduate Studies of Jimma University, In Partial Fulfillment of the Requirements of Degree of Master of Science in Civil Engineering (Highway Engineering Stream)


By: GetuTamiru



June, 2017

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By: Getu Tamiru

Advisor: Prof. Emer T. Quezon

Co-Advisor: Eng. Tarekegn kumela

June, 2017
Jimma, Ethiopia

# DECALERATION

I, the undersigned, declare that this thesis entitled "effects of subgrade and sub base materials quality on flexible pavement: A case study along Ajip to Gegrel church of Jimma Town." Is my original work and has not been presented by any other University, and all sources of Materials used for thesis have been dually acknowledged

Candidate:

Mr. GetuTamiru

Signature ________________

Date ___________________

As master research advisors, we here by certify that we have read and evaluate this MSc research prepared under our guidance, by Mr. Getu Tamiru Entitled: Effects of subgrade and sub base materials quality on flexible pavement: A case study Ajip to Gebrel Church of Jimma town.

We recommend that it can be submitted as fulfilling the MSc thesis requirements.

| | | |
|---|---|---|
| Prof. Emer T. Quezon | ______________________ | _____________________ |
| Advisor | Signature | Date |
| Eng. Tarekegn Kumela | ______________________ | _____________________ |
| Co- Advisor | Signature | Date |

# ACKNOWLEGMENT

First of all I would like to thank the almighty God for his unspeakable Gift of life, health, peace, help, protection, knowledge, opportunity and Wisdom to accomplish this thesis work and he is still in my side throughout my life. The secret of my success is Jesus Christ. The lord!!

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# ABSTRACT

*Flexible pavements are composed of Asphaltic layer, base course; sub base materials which laid over a well compacted and strong sub grade foundation. Sub grade and Natural sub base materials basic engineering properties are required for Design and Coarse grained soils serves as good subgrade for supporting pavements whereas fine grained soils, particularly clayey soils pose problem to pavement. Jimma is a big trade center and coffee production areas but, the current existing condition most parts of the road are deteriorated. So, the objective of this research was to investigate effects of subgrade and sub-base materials quality on flexible pavement.*

*The researcher was identified the distress and categorized by level of severity according to* ***ERA*** *standard specification manual to get* ***4-stations high deterioration of block crack, 6-stations medium deterioration of Alligator crack and 5-stations low deterioration of edge crack*** *of the studied stretch along Ajip to Gebrel church (total 10kms) of Jimma town. Then, randomly samples taken from the deteriorated area of the subgrade and sub-base materials a total of 15 stations and the laboratory work was conducted and also the results were discussed compared with the standard specification of* ***ERA, AASHTO*** *and* ***ASTM****. Finally, Conclusions would be developed and recommended appropriate remedial measure would be drowning.*

*Laboratory tests result* ***NMC>OMC*** *indicated that excess water in the subgrade and sub-base materials according to* ***AASHTO D-180*** *standard specification, compaction of subgrade and sub-base layers are below the minimum requirement (****MDD≥97% laboratory density****) of* ***AASHTO*** *standard specification, poor strength (****CBR≤1.76gm/cc****) of* ***AASHTO T-193*** *and* ***ERA*** *specification, sieve analysis for gradation out of the upper and lower limit of* ***AASHTO T-27*** *standard specification for the subgrade and sub-base materials. These can be causes of pavement deterioration on flexible pavement. But, the Atterberg's limit test results satisfy the standard specification of* ***ASTM D-4318****.*

*The researcher recommended that the designer and contractor should be follow the minimum requirement set by standard specification regarding the engineering properties of materials, the side ditch must be constructed so as to prevent infiltration of water to the under lining strata, seal coats shall be applied to prevent infiltration of water through cracked surfaces to subgrade layer of the pavement.*

**Keyword**: - Deterioration, distress, moisture content, pavement, sub-base and subgrade.

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# ACRONYMS

| | |
|---|---|
| AASHTO | American Association of State of Highway and Transportation Officials |
| AC | Asphalt Concrete |
| ASTM | American Society for Testing and Material |
| CBR | California Bearing Ratio |
| Cc | Coefficient of curvature |
| Cu | Coefficient of Uniformity |
| DCP | Depth cone penetration |
| DS | Design Standard |
| ERA | Ethiopia Road Authority |
| ESAL | Equivalent single axle load |
| FDRE | Federal Democratic Republic of Ethiopia |
| GPS | Global positioning system |
| GS | Sub-base |
| Gs | Specific gravity |
| HMA | Hot mix Asphalt |
| IDA | International Development Association |
| IDCON | Infrastructure Development consultant private limited company |
| JiT | Jimma institute of Technology |
| LL | Liquid Limit |
| LOS | Level of service |
| MDD | Maximum Dry Density |
| NMC | Natural moisture content |
| NP | Non-plastic |
| OMC | Optimum moisture content |
| PCI | Pavement Condition Index |
| PCS | Pavement Condition Survey |
| PI | Plastic Index |
| PL | Plastic Limit |
| PM | Plasticity modules |

| | |
|---|---|
| SL | Semi liquid |
| SPG | Specific purpose grant |
| TM | Technical manual |
| TOR | Traffic oriented road |
| TRL | Transport Research laboratory |
| ULGDP | Urban local government development project |
| USCS | Unified Soil Classification System |
| NMC | Natural moisture content |

# CHAPTER ONE

## INTRODUCTION

### 1.1. Background of the study

Asphalt pavements designed and constructed properly for the roads deliver a smooth, quiet, and durable solution. However, the success of any asphalt pavement is depending on the construction materials being designed for its environment, construction methodology and Drainage and work man ship [16].

Flexible pavement composed of Asphaltic layer, base layer, sub-base layer which laid over a well compacted and strong sub grade foundation. The main structural function of pavement are to support the wheal loads applied to the carriage way and ultimately distribute to the subgrade layer [6].

Major problem of flexible pavements were not being Designed and constructed to sufficiently long lasting and cost effective. At the same time, there is road deterioration. The severity Include such problems as early cracking, rutting and moisture damage. The pavement Industry has invested too much dollars in search for remedies to pavement distress [14].

Sub grade and Natural sub base materials basic engineering properties are required for Design. Coarse grained soils serves as subgrade good for supporting pavements but, fine grained soils pose problem (clay soil) to pavement [16].

This research was conducted on Jimma city. Which is a big trade center in south western part of Ethiopia where people from different direction comes to the city for business exchange. Besides these Jimma Zone is one of the country's coffee production areas. Hence this coffee product is mostly packed and loaded to the center of country from warehouses found in Jimma town.

The Topography of an area is predominantly flat to rolling climatically the town is classified as Woinadega. It has mild effective temperature vary from 14 $c^0$to 20 $c^0$. The moisture index (ratio of precipitation to evapo-transpiration) of the area is greater than one which makes it humid. The town receives mean rain fall is 1600mm. The monthly distribution of the rainfall indicates that the minimum rainfall is received in the month of December and January which amount 525mm while the maximum rainfall is registered at month of August is 300mm [18].

## 1.2. Statement of the problem`

Pavement deterioration mostly happen poor (unsuitable) construction of the subgrade and sub-base materials. This permanent deterioration in a well-designed pavement is fairly load distributed between the pavement layers of materials [12].

In Ethiopia, Road deterioration could be in the form of cracks, potholes, surface Deformation, and surface Defects which makes unsafe the road network and unsuitable to the road users. The performance of the pavement mostly depends up on the quality of the sub base materials and existing condition of the road bed [14].

Jimma is a typical example for pavement deterioration in Ethiopia. For the effect of result to:-Loss of lives, properties and human injuries 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 Robby attacks along affected area. These effects need to investigate on effects of subgrade and sub base materials quality on flexible pavement: A case study along Ajip to Gebrel of Jimma town.

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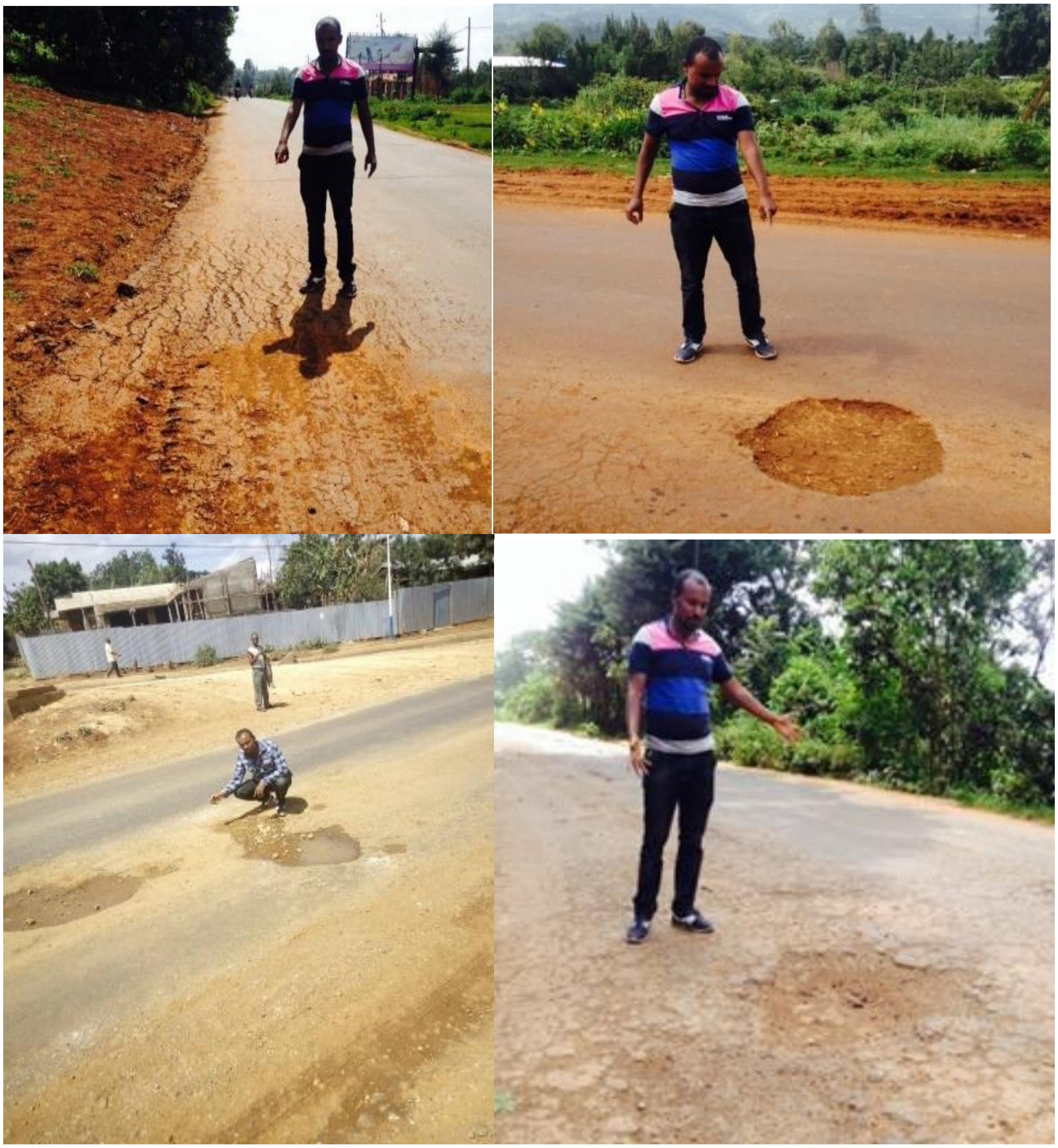

**Figure 1.1** Photos for the current existing condition of the studied stretch pavement (photo captured date 08-04-2017 @2:00 – 5:00p.m.)

## 1.3. Research questions

1. What types of flexible pavement distresses and level of severity in the selected road stretch?
2. What are the existing engineering properties of subgrade and sub-base layers and how much deviation of the observed values from the standard specification?
3. What are the remedial measures to improve the existing condition of sub-base and subgrade materials?

## 1.4. Objectives of the Research

### 1.4.1. General objective

The general objective of this research was effects of subgrade and sub base materials quality on flexible pavement distress: A case study along Ajip to Gebrel Church of Jimma Town.

### 1.4.2. Specific Objectives

The specific objectives of the study are:

1. To identify the type of distress and categorizes by the level of severity of the selected stretch.
2. To analyze the quality of materials in relation with engineering properties of subgrade and sub-base materials and to compare with the standard specifications.
3. To suggest remedial measure to improve the existing condition of the subgrade and sub base materials.

## 1.5. Significance of the study

In Ethiopia, there are numerous road projects being constructed and to be construct in the future with Asphalt. So, subgrade and sub-base materials have significant role on flexible asphalt construction. For this reason the researcher had arrived with the following significance of the study:-

A. In the future, it could be used as reference material for related post graduate studies;
B. It could be served as an aid to users on how to construct the asphalt pavement of subgrade and sub base layer properly;

C. Proper understanding the type of distress and possible causes of damage on asphalt pavement especially poor subgrade and sub base materials may lead to correct application of remedial measures and

D. Feasibility of appropriate remedial measure and proactive approach like "right activity at the right place, and at the right time".

## 1.6. Scope of the study and limitation

### 1.6.1. Scope of the study

Based on the existing theories and principles this research study should be addressed the general objective to investigate effect of subgrade and sub-base materials quality on flexible pavement: A case study along Ajip to Gebrel Church of Jimma town comprised the following main tasks:-

I. Identified type of distresses on the studied stretch;
II. Categorized by level of severity;
III. Extracted samples form the deteriorated stations of the subgrade and sub-base materials;
IV. Conduced Laboratory tests;
V. Compared the laboratory results with standard specification of ERA, AASHTO and ASTM;
VI. Conclusions would be developed and
VII. Recommended appropriate remedial measures.

### 1.6.2. Limitation

❖ Shortage of finance

Due to the shortage of finance difficult to extend the remaining layers and studies area.

❖ Unable to get enough information about the construction and maintenance.

## 1.7. Structure of the thesis

This research study comprised of five chapter and their contents are outlined below. In the first chapter an overview of the background of the research, statement of the problem, research questions, and objectives of the research, significant of the study, scope and Limitation of the thesis work were discussed. The second chapter deals with the literature review about pavement, type of pavement, pavement distress and types of pavement distress, subgrade and sub base materials, and type of laboratory test conducted for sub grade and sub base materials (natural moisture content, sieve analysis, compaction, Atterberg's limit and CBR tests) and types of maintenance and maintenance option. The third chapter deals with the materials and methodology. The fourth chapter results and discussion deals with assessments of test results and that are gathered from field and laboratory test compare with standard specification of ERA, AASHTO and ASTM. Finally fifth chapter a conclusion and recommended remedial measures are derived based on the results of chapter four.

# CHAPTER TWO

## LITERATURE REVIEW

## 2.1 Introduction

Roads have helped in developing, cultural and social among the people by transporting them from one corner to the other corner of the country. Thus, we see that the progress made by any country and well-being of a nation depends much on road facilities. Moreover, the development, civilization and efficiency of a nation can be easily judged by the extent of its roads facilities [19].

## 2.2 Types of Roads

Roads are typically divided into the following three general categories: flexible, rigid and unpaved (gravel**).**

### 2.2.1 Flexible (Bituminous Pavements) Roads

Flexible pavements are constructed of several layers of natural granular material covered with one or more waterproof bituminous surface layers, and as the name imply is considered to be flexible. A flexible pavement will flex (bend) under the load of a tire. The objective with the design of a flexible pavement is to avoid the excessive flexing of s 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 [16].

### 2.2.2 Rigid pavement Roads

Rigid (or concrete) pavement is made up of Portland cement concrete. The terms flexible and rigid are somewhat arbitrary and were primarily established to differentiate between asphalt and Portland cement concrete pavements. The essential difference between the two types of pavements is the manner in which they distribute the load over the subgrade. The rigid pavement, because of its rigidity and high modulus of elasticity, tends to distribute the load over a relatively wide area of soil; thus, the slab itself supplies a major portion of the structural capacity. The major factor considered in the design of rigid Pavements are the structural strength of the concrete, and a certain amount of variation in subgrade strength has little influence upon the structural capacity of the pavement. This volume of the Pavement Design Manual is devoted to flexible pavements and gravel roads. Designers should refer to Volume 2 for rigid pavements [13].

### 2.2.3 Gravel Roads

Unpaved roads consist of gravel wearing courses. Gravel pavements are also designed to a minimum thickness required to avoid excessive strain at the subgrade level. This in turn ensures that the subgrade is not subject to significant deformations. At the same time, the gravel materials themselves should not deteriorate to such an extent as to affect the riding quality and functionality of the pavement. These goals must be achieved throughout a specific design period. Deteriorations which affect the riding quality of a gravel road include rutting, potholes, corrugations, and other such distresses.

Gravel wearing courses must also be designed for an additional thickness to compensate for gravel loss under traffic during the period between re gravelling operations. Such thicknesses are dependent on the subgrade strength class and the traffic class [12].

## 2.3 Pavement

That with which anything is paved; a floor or covering of solid material, laid so as to make a hard or convenient surface to travel ;a paved road or side walk; a decorative interior floor of tiles colored bricks.

Asphalt pavements are composed of coarse and fine aggregates and a filler of aggregate dust, asphalt cement as a binder and air voids. Hot-Mix-Asphalt mixture consists of two basic ingredients: mineral aggregate and asphalt binder. The process in HMA mix design involves determining what type of aggregate to use, what asphalt binder to use and what proportion of these two ingredients to use so as to achieve the desired bituminous mixture performance. HMA is a complex material where different, and sometimes conflicting, performance demands are placed. It must resist deformation and cracking, be durable over time, resist water damage, and yet be inexpensive, readily made and easily placed [14].

## 2.4 Flexible pavement

Flexible pavements composed of Asphalt (fine and course aggregate, filler and bitumen) layer, base course layer, sub-base layer and subgrade soil.

## 2.5 Subgrade soil materials

Soil is an accumulation or deposit of earth material, derived naturally from the disintegration of rocks or decay of vegetation that can be excavated readily with power equipment in the field or disintegrated by gentle mechanical means in the laboratory. The supporting soil beneath pavement and its special under courses is called sub-grade. Undisturbed soil beneath the pavement is called natural sub-grade. Compacted sub-grade is the soil compacted by controlled movement of heavy compactors.

### 2.5.1 Desirable properties of subgrade material

The desirable properties of sub grade soil as a highway material are

- Stability;
- Incompressibility;
- Permanency of strength ;
- Minimum changes in volume and stability under adverse conditions of weather and ground water;
- Good drainage, and
- Ease of compaction

The sub-grade in flexible pavement is more vulnerable to failure under the vehicular traffic loading due to non-uniform distribution of the load from overlying layers and the presence of high moisture contents. This layer gets less emphasis compared to other layers in pavement despite the fact that most of the pavement failure is being caused due to the bearing capacity failure of the sub-grade layer. Some sub-grade soils, especially clayey soils, have great strength at low moisture content; however they become very weak and less workable with the increase in water content beyond the optimum value. Such soil should be either replaced with superior quality fill material or treated with suitable treatment process.

The strength of the road subgrade for flexible pavements is commonly accessed in terms of California bearing ratio (CBR). This is dependent on the type of soil, its density and its moisture content. Direct assessment of the CBR of the subgrade soil under the completed road pavement is often different to undertaken. However, it can be inferred from an estimate of the density and moisture content of the subgrade together with knowledge of the relation between strength, density and moisture content for the soil in question. This relationship must be determined in the laboratory. The density of the subgrade soil can be control within the limits by compaction at suitable moisture content at the time of construction. The moisture content of subgrade soil is governed by the local climate and the depth of the water table below the road surface [17].

A minimum CBR of 15% is specified at the highest anticipated moisture content measured on sample compacted in the laboratory at the specified field density. The density is usually specified as a minimum of 95% of the maximum dry density in the ASTM test method D 1557(Heavy compaction).

### 2.5.2 Organization of subgrade soil investigation

Soil investigation should be organized as follows [6]:-

i) Reconnaissance: is the first phase, it includes the use of map, field or Arial observations, and local experience to locate potential problem areas. The information is then used to define the scope of the preliminary investigation.

ii) Preliminary investigation: This investigation may include some preliminary subsurface sample and initial laboratory testing and analysis.

iii) Detailed investigation: include detailed definition of the soil profile, determination of the soil properties, and quantification on the effect of subgrade materials at the site

The structural catalog given in the ERA pavement design manual volume requires that the subgrade strength for design be assigned to one of six strength classes reflective the sensitivity of thickness design to subgrade strength ,the classes are defined in the table 2.2 [30] .

**Table 2.1**: Subgrade strength classes

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

According to the ERA pavement design manual, the main categories of unbounded pavement materials with a brief summary of their characteristics in table 2.3 [36].

**Table 2.2** properties of unbounded materials

| **Code** | **Description** | **Summary of specification** |
|---|---|---|
| GB1 | Fresh, crushed rock | Dense graded, unweather crushed stone, non-plastic parent fines |
| GB2 | Crushed weathered rock, gravel or boulders | Dense grading, PI<6,soil or person fines |
| GB3 | Natural coarsely graded granular material, including processed and modified gravels | Dense grading, PI<6<br>CBR after soaking>80 |
| GS | Natural Gravel(sub base) | CBR after socking>30 |
| GC | Gravel or gravel-soil | Dense graded :CBR after socking>15 |

1. This specifications are sometimes modified according to the site condition, material type and principal use

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

**Table 2.3** CBR requirements for the pavement materials layers

| **Description** | **Pavement material type** | **Requirement** |
|---|---|---|
| 4-Day socked CBR value (AASHTO T193) at 98%of MDD. | Crushed stone Base material(GB1) | Not less than 100% |
| 4-Day socked CBR value (AASHTO T193) at 97%of MDD of AASHTO T180 Method D. | Crushed sub base | Not less than 30% |
| | Gravel sub base material | Not less than 30% |
| Laboratory CBR at 95%of MDD of (AASHTO T180) | Capping layer(select layer | Not less than 15% |
| | Subgrade soil | CBR>5% |

Thickness requirements of the pavement material layer based on Jimma project working drawing [18].

**Table 2.4** Design Pavement layer design thickness (from ERA Jimma district)

| **Road section** | **Pavement layer thickness** | | |
|---|---|---|---|
| Jimma road section | AC | GB | GS |
| | 5 | 20 | 25 |
| | 5 | 20 | 25 |
| | 5 | 20 | 25 |

**Table 2.5** Accepted criteria for selected subgrade fill material and subgrade

| Standard specification (acceptance) limit | | |
|---|---|---|
| **Test description** | **Subgrade** | **Capping layer (Selected subgrade fill material)** |
| Liquid limit | <60 | <40 |
| Plastic limit | <30 | <20 |

Pavement failure occurs due to two mechanisms, one is due to combination of densification and repetitive shear and the second is due to the deformation of pavement component layers with more contribution from sub grade, particularly in clayey soils.

## 2.6 Sub-Base materials (GS)

Compaction by ASTM test method D 1557

1. Under the condition of good drainage use light compaction (the water table not near to the ground surface);

2. under the condition of bad drainage use heavy compaction (the water table near to the ground surface) highly anticipated moisture content (CBR>30) and field density>95%of MDD. In this case laboratory test was done unsaturated state;

3. Plasticity index (%) <25;

4. Plasticity modulus (PM) <500;

5. CBR (%) >30, and

6. Sub-base as a filler or separating layer

**Table 2.6** Recommend plasticity characteristics for granular Sub bases (GS)

| Climate | Typical Annual Rainfall | Liquid Limit | Plasticity Index | Linear Shrinkage |
|---|---|---|---|---|
| Most tropical and wet tropical | >500 | <36 | <6 | <3 |
| Seasonally wet tropical | >500 | <45 | <12 | <6 |
| Arid and semi-Arid | <500 | <55 | <20 | <10 |

**Table 2.7** Typical particle size distribution for sub-bases (GS)

| 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 |

This may require to protect a drainage layer from blockage by a finer material or to prevent migration of fines and the mixing of two layers. The two functions are similar except that for use as a filler the materials needs to be capable of allowing drainage to take place and therefore the amount of material passing the 0.075mm sieve must be restricted. The criteria according to the ERA pavement design manual [1].

## 2.7 Flexible pavement failure

Pavement is an Engineering structure placed on subgrade, sub base and base course layers designed to with stand the traffic loading and the action of the climate with minimal deterioration and in the most economical way. Asphalt pavement roads are designed and constructed to serve the upcoming traffic that reveal during the service life of the road. Different factor taken in to account in the Design and construction of pavements includes the material as well as structural properties and other elements which have significant impact on the overall performance of the road [7].

Poor quality of materials in flexible pavement causes deformation, fatigue cracking, instability and other form of deterioration which ultimate degrade the serviceability and durability pavement structure [6].

Flexible pavement were not being designed and constructed to sufficient long lasting and cost effective.It develop deterioration such as early cracking, rutting and moisture damage. So, the pavement industry invested too much dollars in search solution to pavement distress [27].

Flexible pavement structure are placed on natural soils.Mostly deterioration happened by materials quality and the climate with minimal deterioration [26].

Pavement distress by different reasons, such as through age, poor design and construction, poor maintenance practice, poor quality of materials, climate condition, over loading and poor drainage [19].

Asphalt pavement deterioration is a very series problem that cause delay in traffic flow, distorts pavement aesthetics ,damage of vehicles,traffic accident that have resulted in to loss of live and properties [23].

The most road failures observed by poor highway facilities, not understanding standard specification, poor laboratory materials and skilled man power, poor design and construction, management and supervisor system [5].

Poor quality of material for flexible pavement construction will affect flexible pavement performance [21].

To determine surface and subsurface conditions of highway project the primary work is geotechnical investigation; which gives the way to what types test will be needed and how those tests will be conducted for soils and road making materials for highway project.

For quality of materials with standards of pavement design, selecting layers and bearing capacity of sub-grade soil for road pavement design [12].
Road study and design pass through three stages

- Feasibility study
- Preliminary study and
- Final design.

The stress distribution in pavement layers depends on behavior of materials used.

Consideration behaviors are the fatigue and durability of the materials. The aggregate shall be hard, strong and required size and gradation to bear the stresses [3].

There are different failures in the flexible pavement the localized settlement of any one component layer of the flexible pavement structure could be enough to cause pavement failure. This demands that each one of the layers should be carefully designed and laid. Thus to maintain the stability of the pavement structure as a whole, each layer should be stable within itself and thereby making the total pavement maintain its stability. One of the major challenges facing pavement engineers is how to select the optimal repair strategy for a flexible pavement that is aging and exhibiting distress. This selection process can be relatively straightforward if the cause of the pavement distress is known. Unfortunately, finding the cause of the distress is often complex [13].

It is necessary to have clear understanding of type of pavements distress before discussing the different methods of evaluation, cause identification and treatment selection. There are two basic types of pavement distress. The first is structural distress and it includes damage of different pavement components of such magnitude to make the pavement incapable of sustaining the loads imposed upon its surface. The second can be classified as functional distress which may or may not progressively changed into structural distress but is such that the pavement will not carry out its intended faction without causing discomfort to users [16].

Asphalt Pavement distresses – Rutting and cracking Pavement deterioration is the process by which distresses develop in pavement under the combined effects of traffic loading and environmental conditions. Deterioration of pavement greatly affects serviceability, safety and riding quality of the road. After construction, roads deteriorate with age as a result of use and therefore, they need to be maintained to ensure that the requirements for safety, efficiency and durability are satisfied. Normally, new paved roads deteriorate very slowly in the first ten to fifteen years of their life, and then go on to deteriorate much more rapidly unless timely maintenance is undertaken [8].

Rutting is a longitudinal surface depression in the wheel path accompanied, in most cases, by pavement upheaval along the sides of the rut. Pavement rutting which result in distorted pavement surface is the accumulation of permanent deformation in all or a portion of the layers in pavement structure. Longitudinal variability in the magnitude of rutting causes roughness. Water may become trapped in ruts resulting in reduced skid resistance. Increased potential for hydroplaning and spray that reduces visibility. Progression of rutting can lead to cracking and eventually complete disintegration.

Repetitive application of heavy trucks with increasingly high pressure tires drives rut formation in high quality layers. The stresses induced near surface layers by the high pressure tires may exceed the ability of the materials to resist densification below critical void levels and subsequent densification. Rutting can occur in all layers of the pavement structure and generally results from lateral distortion and densification. Moreover, rutting represents a continuous accumulation of incrementally small permit deformation from each load application [7].

Pavement movements due to swelling and/or shrinkage of sub grade soil can cause very extensive cracking and distortion which may finally lead to total failure of the entire structure. The overburden weight of the pavement is small – usually about 10 $KN/m^2$, thus the pavement is easily lifted and distorted by swelling subsoil. The distortion creates humps and bumps and when tolerable limits are exceeded cracks develop. Through these cracks moisture migrates to the sub grade which when loaded, soaked and untrained excessive deformations occur which lead to failure of the pavement.

Cracks can result from both sub grade shrinkage and sub grade swelling. Sub grade shrinkage, which is produced under continuous drying condition, makes the soil warp and induce tension to the pavement. Swelling on the other hand causes compression in the pavement which itself is not detrimental but the resulting differential have causes severe cracking of the pavement in the form of longitudinal cracks [12].

The different types of distress/failure in flexible pavement in Table 2.1

## 2.8 Types of Flexible pavement Distresses

**Table 2.8**: Types of Distresses in Flexible Pavement [9].

| No | Type of failure | Description |
|---|---|---|
| 1 | Fatigue (alligator) cracking | Series of interconnected cracks caused by fatigue failure under repeated traffic loading |
| 2 | Bleeding | Film of asphalt binder on the pavement surface |

| | | |
|---|---|---|
| 3 | Block cracking | Interconnected cracks that divide the pavement up into rectangular blocks (approximately 0.1 m2 to 9 m2) |
| 4 | Corrugation and shoving | A form of plastic movement typified by ripples(corrugation) or an abrupt wave (shoving) across the pavement surface |
| 5 | Depression | Localized pavement surface areas with slightly lower elevations than the surrounding pavement |
| 6 | Joint reflection cracking | Cracks in a flexible overlay of a rigid pavement which occur directly over the underlying rigid pavement joints |
| 7 | Longitudinal cracking | Cracks parallel to the pavement's centerline or laydown direction (a type of fatigue cracking) |
| 8 | Patching | An area of pavement that has been replaced with new material to repair the existing pavement |
| 9 | Polished aggregate | Areas where the portion of aggregate extending above the asphalt binder is either very small or there are no rough or angular aggregate particles |
| 10 | Potholes | Small, bowl-shaped depressions in the pavement surface that penetrate all the way through the HMA layer down to the base course |
| 11 | Raveling | The progressive disintegration of an HMA layer from the surface downward as a result of the dislodgement of aggregate particles |
| 12 | Rutting | Surface depression in the wheel path |
| 13 | Slippage cracking | Crescent or half-moon shaped cracks generally having two ends pointed into the direction of traffic |
| 14 | Stripping | The loss of bond between aggregates and asphalt binder that typically begins at the bottom of the HMA layer and progresses upward |
| 15 | Transvers | Cracks perpendicular to the pavement's centerline or lay down direction is usually thermal direction |

Pavements should be designed and constructed to provide. During the design life,a riding quality acceptable for both private and commercial vehicles. The assumption is often made that road pavements begin to deteriorate as soon as they are opened to traffic. However, there should be no visible premature deterioration at the early stage of the design life except due to faulty design [11].

Longitudinal cracks are indicial cracks that basically run parallel to the centerline of the roadway. They most often occur at the joint between adjacent lanes of asphalt mixture or at the edges of the wheel paths in a rutted pavement. These cracks allow water to penetrate into the underlying layers, possible softening of stabilized layers and accelerating the development of fatigue cracks radiating outward from the longitudinal crack. Raveling of asphalt mix material adjacent to the longitudinal crack often widens and cracks and accelerates the overall damage to the pavement structure [8].

## 2.9 Pavement condition survey

Pavement condition surveys are essentially required to access a pavement physical distress and categorizes by level of severity from the basis of a diagnosis regarding the maintained and rehabilitation needs [6].

## 2.10 Laboratory tests

To determine the engineering properties of the sub-base and subgrade construction materials different tests should be conducted. They are Atterbergs limit test, Sieve Analysis test, Compaction test and California Bearing Ratio Test (CBR), Natural moisture content(NMC) and Specific gravity.

### 2.10.1 Atterbergs limit

This lab test is performed to determine the plastic and liquid limits of a fine-grained material and then determine the value of plasticity of the material and which are based on the moisture content of the material. The water contents corresponding to the transition from one state to another are termed as Atterberg Limits. The three Atterberg limits, which are liquid limit, plastic limit, and shrinkage limits are the boundary between each of the two consecutive states of the soil-water phases. The liquid limit and plastic limit test are performed only on that portion of a soil, which passes the 425mm (No. 40) Sieve.

**2.10.1.1** Liquid Limit (AASHTO T89): The liquid limit (LL) is the water content, expressed in percent, at which the soil changes from a liquid state to a plastic state and water content at which the soil part cut using standard groove closes for about a distance of 13cm (1/2 in) at 25 blows of the liquid limit machine (Casagrande Apparatus). The liquid limit of a soil highly depends upon the clay mineral present. The conventional liquid limit test is carried out in accordance of test procedures of AASHTO T 89 or ASTM D 431.

**2.10.1.2** Plastic Limit (AASHTO T90): The plastic limit (PL) is the water content, expressed in percentage, below which the soil stops behaving as a plastic material and it begin to crumble when rolled into a thread of soil of 3.0mm diameter. The conventional plastic limit test is carried out as per the procedure of AASHTO T 90 or ASTM D 4318.

**2.10.1.3** Plasticity Index (PI = LL - PL): is the numerical difference between the liquid and plastic limits. Thus, it indicates the range of moisture content over which the soil remains deformable (in plastic state).

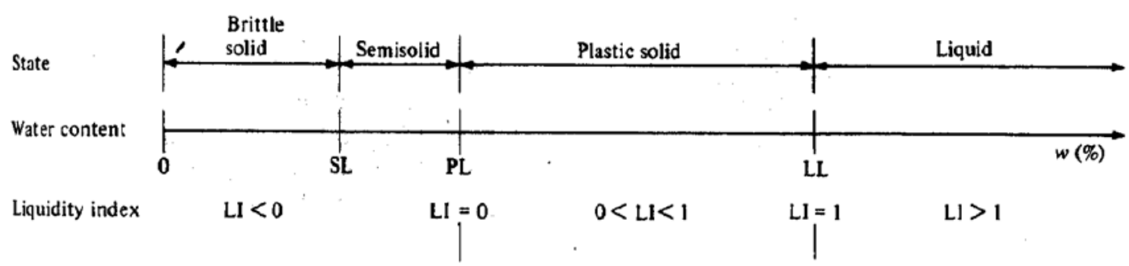


**Chart 2.1** Atterberg limit

Generally, soils having high values of liquid limit and plasticity index are poor as sub-grades/engineering materials. Soils that cannot be rolled to a thread at any water content are termed as Non-Plastic (NP).“Limit of consistency” of fine grained soils were defined by Albert Attereberg. Degrees of fineness of fine grained soils. This establishes four state of consistency.

**Table 2.9** Acceptable Atterberg limit result of clay soil sample

| **Results** | **Lower limit** | **Mean** | **Upper limit** |
|---|---|---|---|
| LL | 30.4 | 32.7 | 35.0 |
| PL | 17.3 | 19.0 | 20.7 |
| PI | 11.0 | 13.8 | 16.6 |

### 2.10.2 Particle size distribution

Soil in nature exists in different sizes, shapes and appearance. Depending on these attributes, the soil at a site can be packed either densely or loosely. Hence, it is important to determine the percentage of various sized soil particles in a soil mass [2].

This test is performed to determine the percentage of different grain sizes contained within a soil. The grain size analysis or gradation is measured in the laboratory using two tests: a mechanical sieve analysis for the sand and coarser fraction (soil particles larger than 0.075(0.063) mm, and a hydrometer test for the silt and finer clay material (smaller particles) (AASHTO T27/T11 or ASTM D) [14].

Grain size Analysis was carried out to determine the grain size distribution of sub-grade and sub-base materials and used in the classification of the soils 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 result are plotted below and the data is given in the appendix A.

This test is performed to determine the percentage of different grain sizes contained within a soil or aggregate and it is used to determine the textural classification of soils (i.e., gravel, sand, silty clay, etc.) which in turn is useful in evaluating the engineering characteristics such as permeability, strength, and swelling potential.

Therefore, a mechanical sieve analysis was carried out in accordance of test procedures of AASHTOT-27/ASTM C-136 for sub-base & base course materials [1].

### 2.10.3 Compaction test

This test is to obtain relationship between compacted dry density and soil moisture content, using two magnitudes of manual compactive effect. The test is used to provide a guide for specification on field compaction.

A light compaction test using a 2.5kg rammer (standard proctor).For this test a compaction mold of one liter interval volume is used for soil in which all particle passes a 20mm test sieve .For soil containing up to 10% material coarser than 37.5mm and up to 30% material coarser than 20mm, equivalent test are carried out in the larger CBR mold [10].

This laboratory test is a standard method of compaction using a standard amount of comp active effort to produce a soil density against which site density values can be compared. The original test involved compacting the soil in three approximately equal layers in a standard mold, using a 2.5kg hammer falling through a height of 305mm (standard compaction test). However, with the advent of heavier compaction equipment, greater densities were now achievable in the field. A modified version of the test was developed to allow the application of greater compactive effort (and achieve greater density), compacting the soil of the same height in five approximately equal layers using a 4.5kg hammer falling through 457mm height (modified or heavy compaction test). Material or soil compaction tests are performed using disturbed soil sample. The tests are done in the laboratory according to AASHTO T-99 (Standard proctor test) for subgrade and AASHTO T-180 (Modified Proctor Test) is used for sub-base and base materials.

The soil sample is first air dried and sieved (usually through the 4.75-mm (No.4) sieve or 19mm sieve), mixed thoroughly with water and then compacted in layers. The mass of the compacted sample is measured (W), and a small sample taken to measure the corresponding moisture content (w). More water is then added to the soil, and the procedure repeated until the dry density obtained decreases. Comparison of standard and modified compaction tests is given in Table 2.10.

**Table 2-10**: Standard and Modified compaction tests

| Items | Standard Compaction Test (AASHTO T99) | Modified (Heavy) Compaction Test (AASHTO T180) |
|---|---|---|
| Diameter of mold (mm) | 101.6/152.4 | 101.6/152.4 |
| Height of sample (mm) | 117 | 117 |
| Number of lifts (layers) | 3 | 5 |
| Number of blows per lift | 25/56 | 25/56 |
| Weight of Hammer | 2.5kg | 4.5kg |
| Diameter of end face of hammer (mm) | 51 | 51 |
| Free fall height (mm) | 305 | 457 |
| Net volume of mold (cm3) | 944/2124 | 944/2124 |

**Note**: - larger diameter mold (152.5mm) is used for gravelly soils (soils with a significant amount of gravel).

At Natural moisture content higher than the OMC, the air and water in the soil mass tend to keep particles apart and prevent compaction. The dry density at higher moisture contents than OMC, thus, decreases and the total voids decrease.

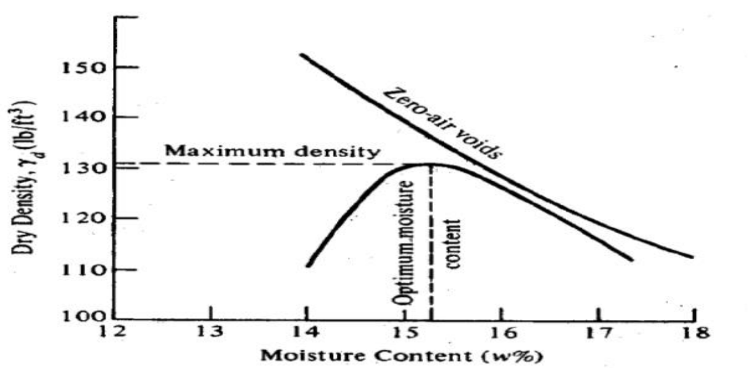


**Chart 2.2:** Typical compaction curve

### 2.10.4 California Bearing ratio test (CBR)

The strength of the subgrade is the main factor is determining the required thickness of flexible pavement for roads and air fields. The strength of subgrade, sub-base and base course materials are expressed in terms of their California bearing ratio (CBR) values.

The CBR value is a requirement is design for pavement materials of natural gravel.

The CBR is a measure of shearing resistance of the material under controlled density and moisture conditions the test consists of causing a cylindrical plunger of 50mm diameter to penetrate pavement component materials at 1.25mm/minute. The Loads for 2.54mm and 5.08mm are recorded .This load is express as percentage of standard load value at respective deformation level to obtain CBR value.

The CBR is the most widely used methods for designing pavement structures. The method is primarily intended. But not limited to evaluate the strength of cohesive materials. The test procedure is based on, American society for testing and materials, AASHTO T193. The CBR Value for a soil depends upon its density, molding moisture content and moisture content after soaking. The points CBR was conducted for sub-grade soil in the laboratory and design CBR value considered at 95% of MDD.

The California bearing ratio (CBR) was used to evaluating the suitability of sub-grade and the materials used in sub base course of disturbed sample were performed to evaluate the CBR of sub base and subgrade layers. Three point CBR test is made for all of the samples.

The different layers such as subgrade, sub-base and base course materials strength are classified according to the CBR values. In addition to the AASHTO Soil Classification tests, the 4 days soaked CBR tests are performed on the material samples to determine the highway construction material shear strengths. The CBR number is obtained as the ratio of the unit load (in KN/m2) required to effect a certain depth of penetration of the penetration piston in to a compacted specimen of material at some water content and density to the standard unit load. This is required to obtain the same depth of penetration on a standard sample of crushed stone. The resulting load-penetration curve is compared with that obtained for a standard crushed rock material, which is considered an excellent base course material [8].

$$\text{CBR}\ (\%) = 100\ \left(\frac{x}{y}\right)$$ ------------------------------------------------------- CBR

**Formula (2.1)** Determination of CBR

Where: x = material resistance or the unit load on the piston (pressure)

For 2.54mm (0.1”) or 5.08mm (0.2”) of penetration

y = standard unit load (pressure) for well graded crushed stone

= for 2.54mm penetration = 6.9MPa (1000psi)

= for 5.08mm penetration = 10.3MPa (1500psi)

The results from the laboratory tests combined with the relevant pavement condition survey provide an evaluation of pavement performance to be made.

### 2.10.5 Natural moisture content

Water content is defined as the ratio of weight of water present in a given soil mass by the weight of dry soil. Water content is usually expressed in percent. Most natural soils, which are sandy and gravelly in nature, may have water contents up to about 15 to 20%. In natural fine grained (Silty or clayer) soils, water contents up to about 50 to 80% can be found However, peat and highly organic soils with water contents up to about 500% are not uncommon [11].

## 2.11 Maintenance and rehabilitation Alternatives

The pavement maintenance problem is not simple. Many factors are involved that affect the performance of a pavement. Hence the type of maintenance that will be required for any particular pavement will depend on a number of conditions; the traffic system to which the pavement is subjected; Climate; the structure of the pavement; the quality of construction; the frequency and extent of inspection performed, both during construction and during maintenance; engineering talent involved, maintenance practices; discipline; and money; not necessarily in that order. In general, it is necessary to have the following in order to have the best maintenance program [16].

1. Organize the maintenance crew with experienced engineering and maintenance personnel;
2. Keep records of all pavement structures that are as precise as possible. These should include records of sub grade soils, sub base and base course, wearing courses and drainage system;
3. Arrange a pavement condition survey program to check and record the pavement condition at regular intervals and
4. Reviews and analyze the condition survey reports systematically.

# CHAPTER THREE

## MATERIALS AND METHODS

## 3.1. Study area

### 3.1.1. Location and accessibility of the study area

The research was conducted at Jimma Zone of Oromia region in Ethiopia. This located in 346 km from south west of capital city of Ethiopia (Addis Ababa). It has latitude and longitude of $7^0$ 40'N to $7^0$ 45'N, $36^0$ 50E to $36^0$ 45'N and total population about 220, 573.Investigations were carried out along "Ajip to Gebrel Church" of Jimma town which is 10 km and more attention to the deteriorated stations of the studied stretch of existing road.

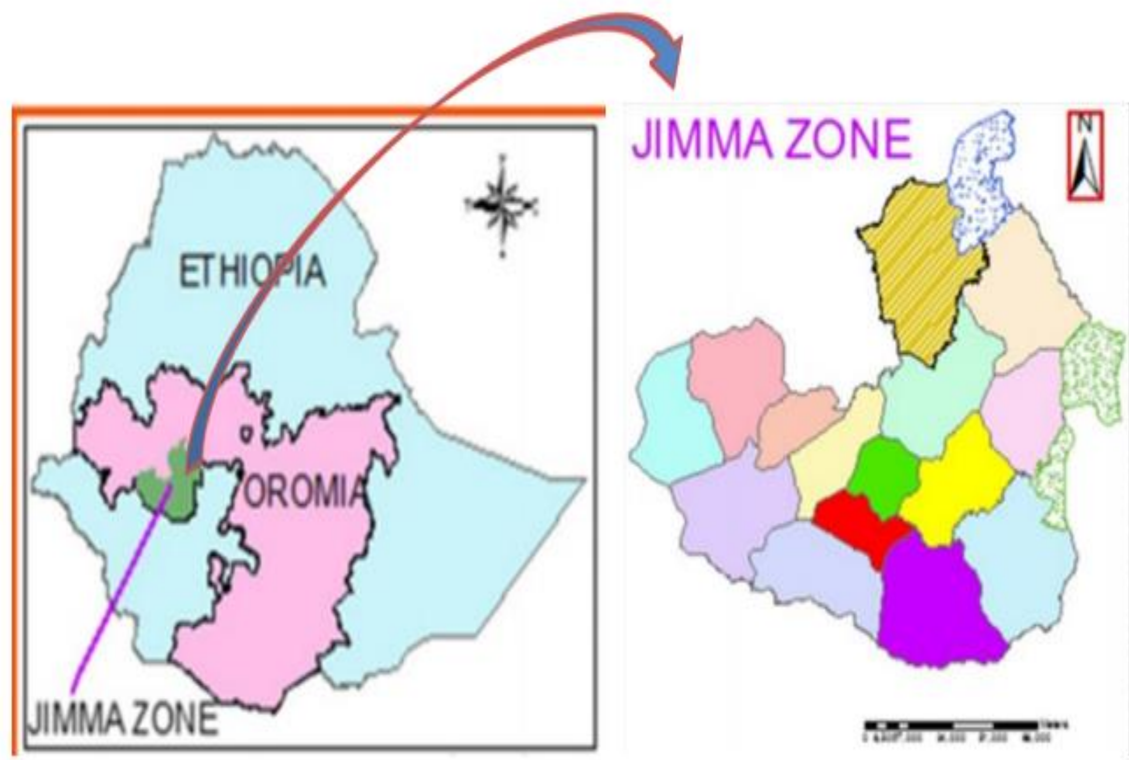


**Figure 3.1** Location of Jimma zone

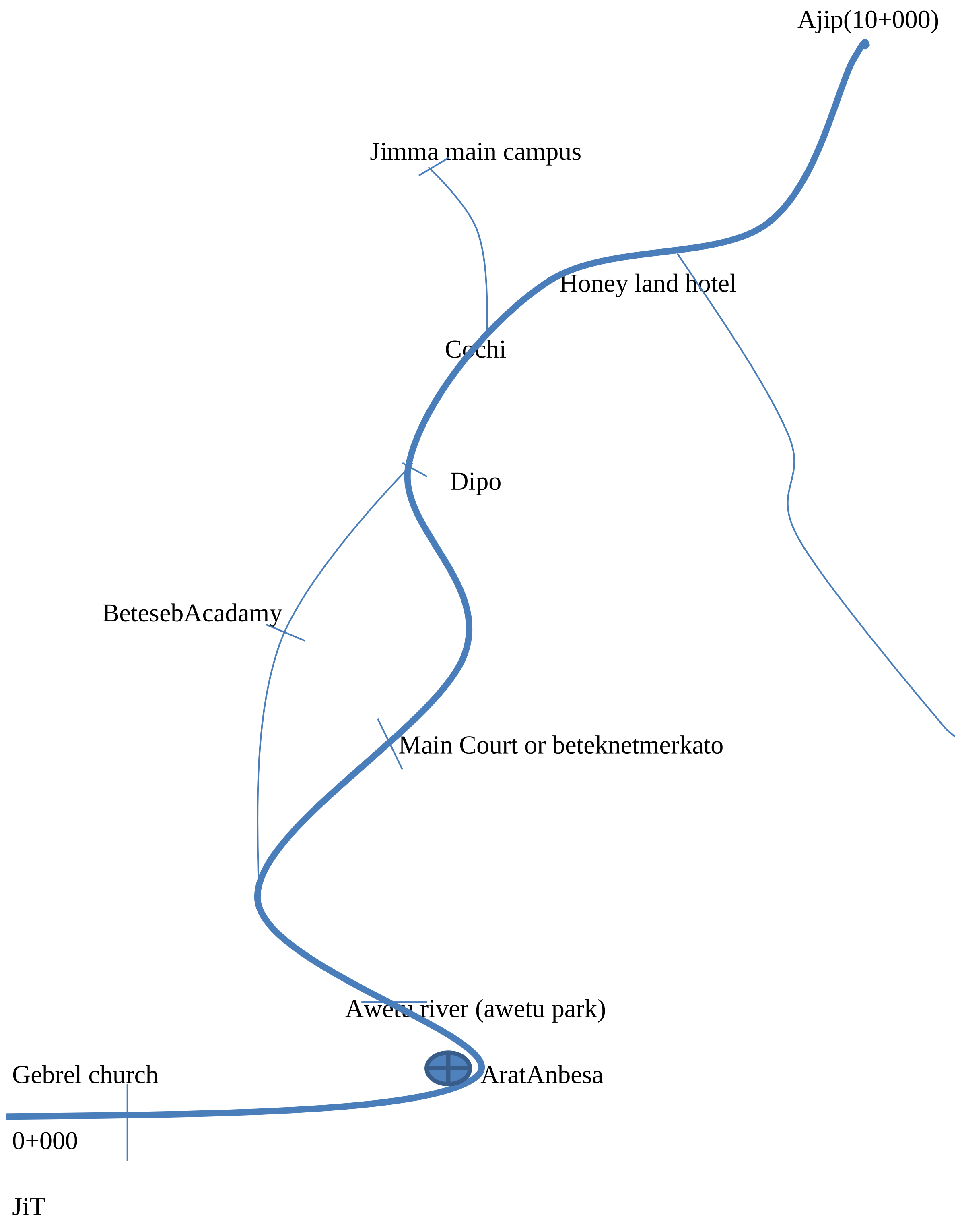


**Figure 3.2** the Horizontal alignment of existing road (studied area) from Ajip to Gebrel church of Jimma town.

### 3.1.2. Project location and topography

Average elevation of the studied area is 1,700m above mean sea level and the topography of the studied stretch flat and rolling (source from ERA Jimma district).

### 3.1.3. Climate of the study area

The climate of the area is moderate temperature and rainfall. The mean annual temperature of the area is $18^0$C. The mean annual rainfall ranges 800 to 1200mm. The wind direction of the area is east to west (source from Jimma district meteorology branch)

### 3.1.4. Geology and soils of study area

The major dominate rocks are naturally light in color and highly susceptible to physical and chemical weathering and the major dominant types of soils of the town are clay soil.

### 3.1.5. Drainage of the study area

Drainage is one of the major problems in Jimma city. In some sections of the road shallow earth ditches are available. On the other hand there is no drainage structure which facilitates flow of water alongside of road. Most of observed drainage structures are currently under poor condition both structurally and functionally. The city has natural flood problem which have negative impact on existing pavement.

## 3.2. Study design

The study was analyzed in relation to theoretical propositions. The overall approach was six stages process: Identified the types of distress of studied stretch, categorized by level of severity (high, medium and low), necessary sample extracted by using random sampling method of the distress stations and conducted in the laboratory and the laboratory test results are compared with the standard specification and finally conclusions and recommendations have been made based on the findings. The studied period January-to-June 2017.

## 3.3. Study procedure

- The researcher was identified the study stretch (block cracking, alligator cracking and edge cracking);
- Categorized according to ERA standard specification of 4-stations high deteriorations of block cracking, 6-stations medium deterioration of alligator cracking and 5-Stations low deterioration of edge cracking;
- Samples extracted by random sampling method of the distress stations;
- Laboratory tests conducted (Natural moisture content, Atterberg's limit, Compaction, Sieve analysis and California bearing ratio);
- The results are discussed compared with standard specification of ERA, AASHTO and ASTM;
- Conclusions would be developed and
- Recommended appropriate remedial measure.

## 3.4. Study variables

The research variables are both the independent and dependent variables

### 3.4.1. Independent variables

- Grain size Analysis of particle size distribution;
- Atterbeg's limit (LL, PL and PI);
- Compaction (relation between OMC and MDD);
- California bearing ratio (CBR) and
- Natural moisture content (NMC)

### 3.4.2. Dependent Variables

- Effects of Subgrade and sub base materials quality on flexible pavement.

## 3.5. Sample size and data collection process

### 3.5.1. Sample size

In order to generate data for the general and specific objective, field survey and laboratory test were carried out on distress stations. The researcher first identified the distress and categorized by level of severity (high, medium and low deterioration). Collect the primary data of samples were taken from subgrade and sub-base materialsof the deteriorated flexible pavement along Ajip to Gebrel church of Jimma.

**Figure 3.3** Sample extracted photos captured date 08/04/2017@3:00p.m

**Figure 3.4** Sample extracted photos captured date 08/04/2017@3:00p.m

### 3.5.2. Data collection process

Quantitative and qualitative data utilized based on the necessarily input parameters for analysis and compare with ERA, AASHTO and ASTM specification manuals. Data collection process included but not limited to: reviewing letter for correspondence reports, design documents, field visual inspection and inventory, identified the type of distress (edge cracking, block cracking and alligator cracking), categorized by level of severity (5-low deteriorated stations of edge cracking, 4-high deteriorated stations of block cracking and 6-medium deteriorated stations of alligator cracking) by ERA (2002) standard specification manual, samples extracted from the deteriorated area.

## 3.6. Field observation

Field observation was necessary to begin by site visit was taken on the whole portion of roads and at the same time identifies the type of distresses of studied stretch (Ajip to Gebrel church).Then, categorized by level of severity by ERA manual, samples were taken from the studied stretch for distress stations of subgrade and sub base materials for laboratory test a total length of 10km. 15 samples extracted for subgrade and sub base layer of the distress stations, 200kgs from high deterioration, 400kgsfrom medium deterioration and 300kgs from low deterioration were collected samples were tested in the laboratory.

## 3.7. Sampling Technique

By random sampling technique was used by Samples extracted from the deteriorated area of sub-base and subgrade materials to make it sure as the engineering parameters had certain characteristics as applied for this study.

**Figure 3.5** photos for measuring the Current Existing pavement Distress (Photos captured date15/04/2017@8:00 a.m.)

**Figure 3.6** photos for measuring the Current Existing pavement Distress (Photos captured date15/04/2017@8:00 a.m.)

## 3.8. Instrument used

The following software and instruments were used for this study: Mater tape, Hand GPS, Polyetene bags or plastic bags, hand tools, laboratory equipment's, digital camera for documentation, Ms Word and Ms excel to analysis laboratory data and display research data were used in the study.

## 3.9. Laboratory test materials

Sample extracted and laboratory performed are Atterbegs limit (for comparison and determination of liquid limit and plastic limit), Grain size analysis (distribution of particle size analysis), compaction test (for determination of maximum dry density and optimum moisture contents), California Bearing ratio (CBR) test (for Determine of shear strength of materials), Natural moisture content (percentage of water by dry soil). The tests are performed according to AASHTO, ERA and ASTM specification.

### 3.9.1. Grain size analysis test


**Figure 3.7**:Apparatuses for grain size analysis test

Purpose: To determine the grain size distribution curve of soil samples and is useful for soil fraction larger than 75µm.

Apparatus: Series of standard sieves (for gravel fraction 4.75-75mm aperture size, and for sand fraction 0.075-2mm aperture size), Lid (cover), Pan (receiver), sieve shaker, Balance sensitive to 0.1g, Soft wire brush, Sample splitter, Mortar, and rubber-covered pestle for breaking up aggregates of soil particles, &Oven.

### 3.9.2. Compaction test


**Figure 3.8**:Apparatuses for compaction test

Purpose: To get the maximum dry density (MDD) for the soil and optimum moisture content (OMC).

Apparatus: mold, compaction with full accessories (hummer 2.5kg) and Oven dry machine

### 3.9.3. Atterberg's limit test

**Figure 3.9**:Apparatuses for atterberg's limit test

Purpose: To measure the plasticity and shrinkage nature of the soil.

Apparatus: Grooving tools, Casagrande, tools and spatula.

### 3.9.4. Natural moisture content test


**Figure 3.10:**Apparatuses for natural moisture content test

Purpose: The amount of water exists in a given subgrade and sub-base materials mass.

Apparatus: Sampling trey, weight balance and Oven dry machine

### 3.9.5. California bearing ratio (CBR)


**Figure 3.11:**Apparatuses for CBR test

Purpose: To determine the shear strength of subgrade and sub-base materials.

Apparatus: Mold, a separate base plate, an extension collar and a spacer disc.

# CHAPTER FOUR

## RESULTS AND DISCUSSIONS

### 4.1. Identified types of distress and categorized by level of severity

**Table 4.1**. Identified the types of distress and categorized by level of severity of the studied stretch of all distressed stations

| Section | Station | Location (GPS) | Distress types | Level of Damage (Severity) (ERA 2002) | Distress Direction |
|---|---|---|---|---|---|
| Section -1 (0-2km) | 0+020 | N=0567853 E=0969637 Z=1218 | Alligator crock | Medium deterioration (Severity) | Left side |
| | 0+920 | N=0567852 E=0969639 Z=1219 | Block crack | High deterioration (More sever) | Center |
| | 1+840 | N=0567856 E=0969638 Z=1217 | Edge crack | Low deterioration (Low severe) | Right side |
| Section -2 (2-4km) | 2+160 | N=0566782 E=0968827 Z=1219 | Edge crack | Low deterioration (Low severe) | Left side |
| | 3+160 | N=0566784 E=0968829 Z=1218 | Alligator crack | Medium deterioration (Severe) | Both side |
| | 3+740 | N=0566781 E=0968827 Z=1217 | Block crack | High deterioration (more severe) | Center |
| Section -3 (4-6 km) | 4+240 | N=0566785 E=0968827 Z=1218 | Alligator crack | Medium deterioration (Severe) | Both |
| | 4+300 | N=0566787 E=0968826 Z=1219 | Edge crack | Low deterioration (Low severe) | Right side |
| | 5+500 | N=0566789 E=0968827 Z=1220 | Alligator crack | Medium deterioration (Severe) | Both |

| | | | | | |
|---|---|---|---|---|---|
| Section -4 (6-8km) | 6+720 | N=0567851 E=0969637 Z=1221 | Block crack | High deterioration (more Severe) | Center |
| | 7+740 | N=0567853 E=0969638 Z=1220 | Alligator crack | Medium deterioration (Severe) | Both side |
| | 7+820 | N=0567854 E=0967636 Z=1219 | Edge crack | Low deterioration (Low severe) | Left side |
| Section 5 (8-10km) | 9+140 | N=0568119 E=0968834 Z=1220 | Edge crack | High deterioration | Left side |
| | 9+420 | N=0568121 E=0968830 Z=1221 | Block crock | High deterioration (More severe) | Center |
| | 9+720 | N=0568122 E=0968632 Z=1222 | Alligator crack | Medium deterioration (Severe) | Both |

**Table 4.2**. Categorized by level of severity.

| **Type of distress (cracking)** | **Level of Deterioration(severity) for degree of distress** | **Measure the distress pavement** | | | |
|---|---|---|---|---|---|
| | | **Average Length (m)** | **Average Diameter (width) of Distress (cm)** | **Average Depth of distress (cm)** | **ERA Standard specification of severity(Jimma standard)** |
| Block cracking | High | 0.78 | 52 | 50 | (Length x Width) >(50cm x50cm) |
| Alligator cracking | Medium | 18 | 28.67 | 50 | >15cm Diameter of distress |
| Edge cracking | Low | 17.41 | 34.84 | 50 | >17cm width of distress |

These study sections were observed4-stations block crack of high deterioration (more severe), 6-stations alligator crack of medium deterioration (severe) and 5-stations edge crackof low deterioration (low severe).Level of severity (damage) is classified by ERA manual, depend upon length, depth and width of the crack. These measured by using Tape meter.

## 4.2. Engineering properties and qualities of materials

### 4.2.1. Grain size Analysis

At the whole stretch of the road of sub base and subgrade materials were used performed on laboratory test and the results showed for the samples have been tested were out of Minimum and maximum range limit of AASHTO T-27 standard specification. Which implies those have been constructed was not uniformly graded at all. The detail results are attached in appendix A.

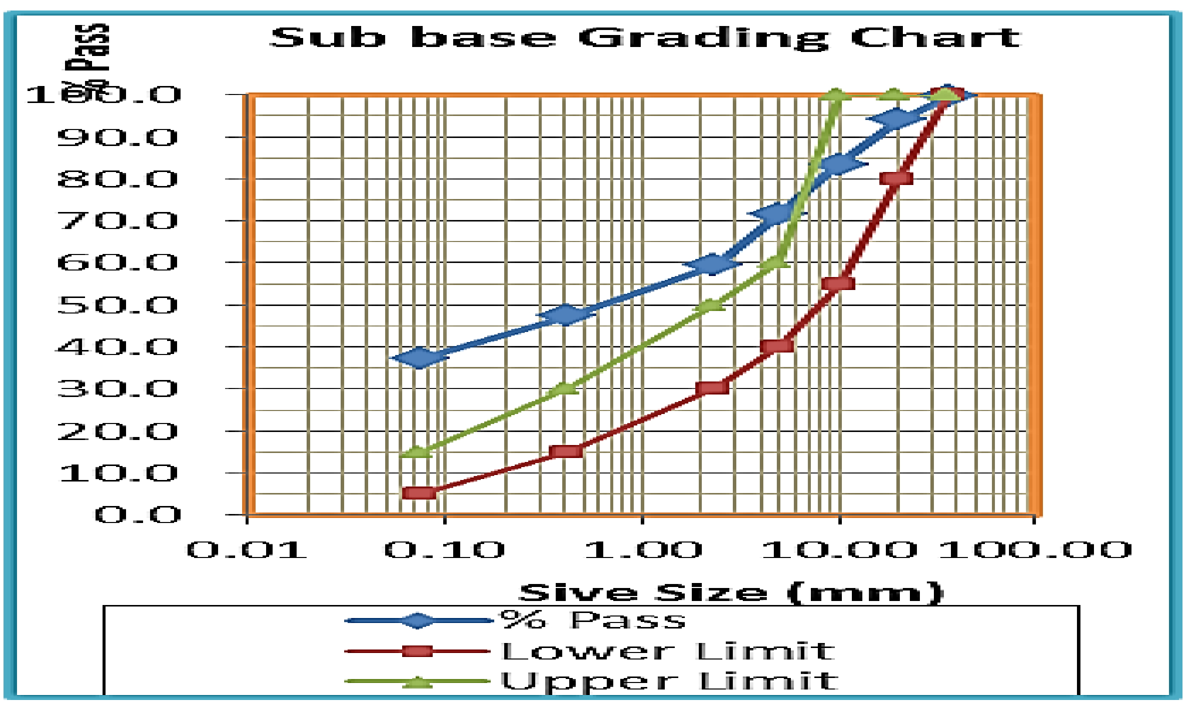


**Chart4.1** Laboratory test result for the grain size analysis of sub base.

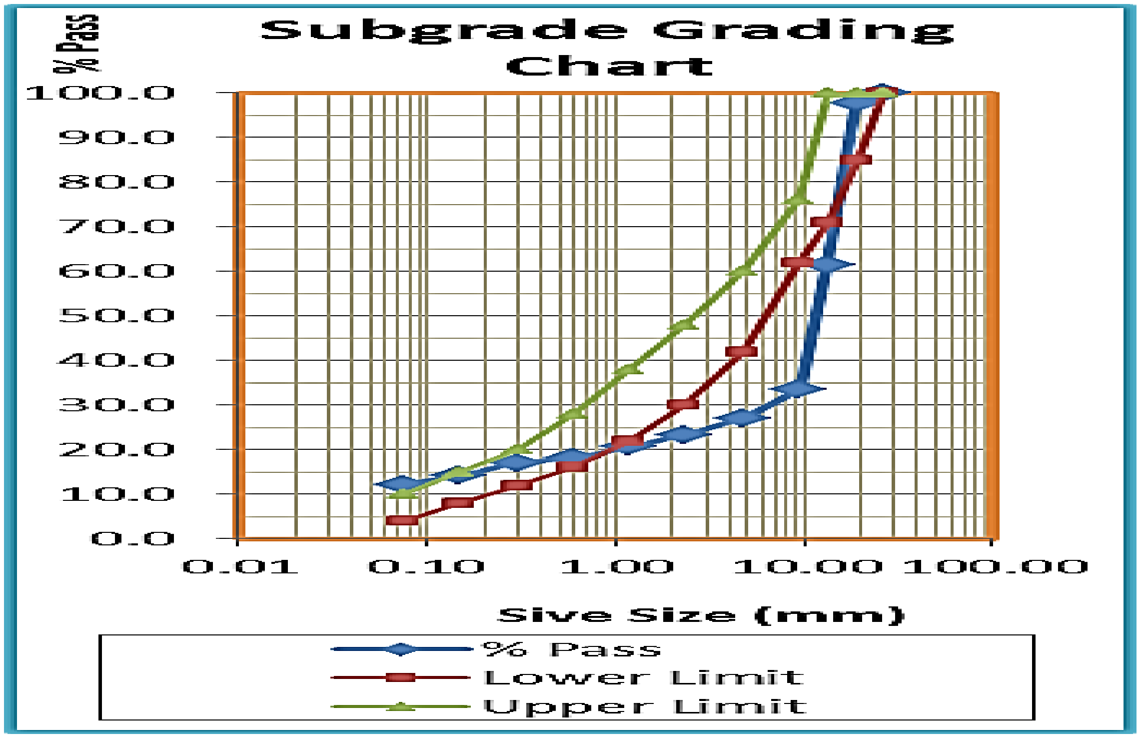


**Chart4.1** Laboratory test result for the grain size analysis of sub base

At all sample stations it is out of minimum and maximum limit of AASHTO T-11 Standard specification (the material passing 0.075mm sieve size by sieve analysis method) which implies not uniformly graded (poor graded).

The detailed result is attach in appendix A.

The researcher was observed that the gradation of the sub-grade and the sub-base materials was not with in the recommended range (out of the range).

### 4.2.2. Atterberg's limit

**Table 4.3**.Atterberg limit test results of subgrade and sub base materials of the studied stretch.

| Level of damage (severe) | Station | Sub-grade materials | | | Sub-base materials | | |
|---|---|---|---|---|---|---|---|
| | | Liquid limit (LL) | Plastic limit (PL) | Plasticity Index (PI) | Liquid Limit (LL) | Plastic Limit (PL) | Plasticity Index (PI) |
| High deterioration (More severe) | 0+920 | 67.15 | 32.41 | 34.74 | 38.16 | 27.12 | 11.04 |
| | 3+740 | 62.14 | 34.82 | 27.32 | 43.14 | 28.46 | 14.68 |
| | 6+720 | 60.70 | 32.82 | 27.89 | 42.78 | 29.16 | 13.62 |
| | 9+420 | 68.84 | 35.07 | 33.77 | 39.15 | 29.68 | 9.47 |
| | Average | 64.71 | 37.78 | 30.93 | 40.81 | 28.61 | 12.20 |
| Medium deterioration (Severe) | 0+020 | 55.09 | 28.74 | 26.35 | 34.08 | 25.63 | 8.45 |
| | 3+160 | 57.63 | 29.84 | 27.79 | 33.71 | 26.18 | 7.53 |
| | 4+240 | 53.95 | 30.16 | 23.79 | 30.89 | 24.73 | 6.16 |
| | 5+500 | 51.81 | 31.09 | 20.72 | 32.92 | 26.19 | 6.73 |
| | 7+740 | 52.07 | 30.74 | 21.33 | 35.01 | 25.82 | 9.19 |
| | 9+720 | 55.71 | 31.88 | 23.83 | 31.93 | 27.01 | 4.92 |
| | Average | 54.38 | 30.41 | 23.97 | 33.09 | 25.93 | 7.16 |
| Low deterioration (Low severe) | 1+840 | 51.71 | 28.55 | 23.16 | 24.88 | 22.35 | 2.53 |
| | 2+160 | 50.89 | 25.92 | 24.97 | 28.16 | 23.81 | 4.35 |
| | 4+300 | 50.14 | 26.67 | 23.47 | 30.43 | 20.98 | 9.45 |
| | 7+820 | 50.65 | 28.16 | 22.49 | 30.11 | 21.65 | 8.45 |
| | 9+140 | 50.12 | 27.05 | 23.07 | 27.81 | 21.87 | 5.94 |
| | Average | 50.70 | 27.27 | 23.43 | 28.27 | 22.13 | 6.14 |
| **Total Average** | | **56.59** | **31.82** | **24.77** | **33.85** | **25.89** | **7.96** |

The Laboratory test results (from the table 4.3), It could be seen that the sub-grade and sub-base materials average liquid limits are 56.59 and 33.85 and average plasticity Index

24.77 and 7.96 respectively. The sub-base LL and PI of the ASTM D 4318 specified value are LL ≤ 45% and PI≤ 12% and sub-grade LL≤80% and PI ≤ 55% in general the average value of PI for sub-base and sub-grade with is the recommended specification. Both sub-base and sub-grade materials are satisfy the requirement.

### 4.2.3. Natural moisture content

**Table 4.4.** Natural moisture content test results of subgrade and sub base materials of the studied stretch.

| Level of Damage (severe) | Station | Natural moisture content (%) | |
|---|---|---|---|
| | | Sub-grade layers | Sub base layer |
| High deterioration (More severe) | 0+920 | 39.32 | 18.67 |
| | 3+740 | 38.67 | 14.91 |
| | 6+720 | 33.71 | 17.74 |
| | 9+420 | 34.45 | 15.65 |
| | Average | 36.76 | 15.08 |
| Medium deterioration (Severe) | 0+020 | 20.34 | 15.72 |
| | 3+160 | 20.15 | 13.11 |
| | 4+240 | 38.82 | 10.01 |
| | 5+500 | 39.43 | 13.98 |
| | 7+740 | 38.97 | 12.34 |
| | 9+720 | 39.65 | 12.58 |
| | Average | 32.44 | 32.27 |
| Low deterioration (Low severe) | 1+840 | 27.52 | 28.42 |
| | 2+160 | 27.94 | 28.81 |
| | 4+300 | 26.98 | 27.93 |
| | 7+820 | 27.05 | 28.77 |
| | 9+140 | 28.74 | 27.63 |
| | Average | 27.64 | 28.31 |
| **Total Average =** | | **32.28** | **25.22** |

The detailed laboratory results specified on the Appendix C.

The average natural moisture content (NMC) test of subgrade and sub base materials obtained from the laboratory more deterioration, medium deterioration and less deterioration are36.76%, 32.44%, 27.64% and 15.08%, 32.27%, 28.31% respectively and optimum moisture content (OMC) of AASHTO D-180standard specification of the subgrade and the sub base materials are 30.05%, 12.06%, 11.08% and 14.44%, 30.44%. 26.06% respectively. So. NMC>OMC.

### 4.2.4. Compaction (Moisture – density relation)

**Table 4.5.** Compaction test results of subgrade and sub base materials of the studied stretch.

The relation between maximum dry densities MDD Versus optimum moisture content (OMC) of the selected stretch

| Level of Damage (severe) | Station | Sub grade layers | | Sub base Layers | |
|---|---|---|---|---|---|
| | | OMC (%) | MDD (g/cc) | OMC (%) | MDD (g/cc) |
| High deterioration (More severe) | 0+920 | 35.12 | 1.27 | 14.52 | 1.72 |
| | 3+740 | 34.86 | 1.29 | 14.11 | 1.84 |
| | 6+720 | 32.80 | 1.31 | 14.46 | 1.65 |
| | 9+420 | 37.24 | 1.28 | 14.67 | 1.82 |
| | Average | 35.01 | 1.29 | 14.44 | 1.76 |
| Medium deterioration (Severe) | 0+020 | 30.92 | 1.32 | 11.90 | 1.73 |
| | 3+160 | 31.46 | 1.36 | 12.80 | 1.79 |
| | 4+240 | 30.76 | 1.29 | 11.97 | 1.86 |
| | 5+500 | 31.01 | 1.25 | 12.56 | 1.52 |
| | 7+740 | 29.82 | 1.26 | 11.46 | 1.51 |
| | 9+720 | 28.68 | 1.30 | 11.62 | 1.82 |
| | Average | 30.44 | 1.30 | 12.06 | 1.71 |
| Low deterioration (Low severe) | 1+840 | 26.31 | 1.31 | 8.13 | 1.96 |
| | 2+160 | 25.45 | 1.26 | 7.14 | 1.98 |
| | 4+300 | 24.97 | 1.22 | 6.98 | 1.92 |
| | 7+820 | 26.42 | 1.32 | 6.50 | 1.97 |
| | 9+140 | 27.15 | 1.35 | 5.02 | 1.93 |
| | Average | 26.06 | 1.29 | 6.75 | 1.95 |

| | | | | |
|---|---|---|---|---|
| **Total Average =** | **30.50** | **1.29** | **11.08** | **1.81** |

The sub-grade soil samples were subjected to the determination of maximum dry density (MMD) and optimum moisture content (OMC) in the Laboratory. The Laboratory test result reveals that the range of maximum dry density of the sub-grade and sub base materials lies in the range of 1.22g/cc - 1.36 g/cc and1.51g/cc - 1.98g/cc and optimum

Moisture content (OMC) lies in between 24.97% to 37.24% and 5.02%-14.67%. But, AASHTO D-180 standard specification of the subgrade and sub base materials are MMD≥1.76g/cc and MMD2g/cc respectively. So, the subgrade and the sub base laboratory results under the specification.

The detailed results are attached in appendix D.

#### 4.2.5. California Bearing Ratio (CBR).

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

**Table 4.6** Three point California bearing ratio (CBR) test results of subgrade and sub base materials of the studied stretch.

| **Level of Damage) High** | **Station** | **Sub-grade layers** | | | | | | **Sub-base layer** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2.54mm** | | | **5.08mm** | | | **2.54mm** | | | **5.08mm** | | |
| | | **No. of blows** | | | **No. of blows** | | | **No. of blows** | | | **No. of blows** | | |
| | | 10 | 30 | 65 | 10 | 30 | 65 | 10 | 30 | 65 | 10 | 30 | 65 |
| deterioration | 0+920 | 3.6 | 4.2 | 4.2 | 3.2 | 4.1 | 4.3 | 13.2 | 18.1 | 19.2 | 6.0 | 9.6 | 10.4 |
| (More | 3+740 | 3.4 | 3.5 | 4.1 | 3.6 | 4.2 | 3.9 | 13.9 | 18.3 | 29.4 | 6.1 | 10.1 | 9.8 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| severe) | 6+720 | 3.2 | 3.4 | 4.3 | 3.1 | 3.8 | 4.2 | 14.5 | 17.9 | 18.6 | 9.4 | 11.6 | 7.9 |
| | 9+420 | 3.9 | 3.2 | 4.2 | 3.3 | 3.7 | 4.8 | 14.1 | 18.2 | 19.0 | 8.2 | 10.7 | 12.6 |
| | Average | 3.5 | 3.6 | 4.2 | 3.3 | 4.0 | 4.1 | 13.9 | 18.1 | 21.5 | 7.7 | 10.0 | 10.2 |
| Medium deterioration (Severe) | 0+020 | 3.2 | 4.1 | 4.5 | 3.1 | 3.8 | 4.2 | 4.8 | 8.3 | 20.2 | 6.5 | 16.2 | 12.5 |
| | 3+160 | 3.1 | 3.3 | 4.9 | 3.3 | 3.7 | 4.8 | 3.2 | 8.6 | 28.7 | 6.4 | 17.6 | 11.2 |
| | 4+240 | 3.5 | 3.6 | 4.7 | 3.2 | 4.1 | 4.3 | 6.2 | 8.5 | 29.2 | 6.3 | 15.2 | 14.6 |
| | 5+500 | 3.6 | 3.7 | 4.9 | 3.6 | 4.2 | 3.9 | 3.7 | 8.9 | 28.4 | 6.8 | 14.6 | 15.3 |
| | 7+740 | 3.4 | 3.6 | 4.8 | 3.3 | 3.7 | 4.2 | 6.6 | 8.2 | 21.6 | 6.2 | 18.2 | 13.9 |
| | 9+720 | 4.2 | 4.2 | 4.7 | 3.6 | 4.9 | 4.2 | 6.8 | 8.7 | 28.6 | 6.3 | 10.7 | 12.1 |
| | Average | 3.6 | 3.8 | 4.6 | 2.9 | 3.7 | 4.1 | 4.4 | 8.5 | 26.1 | 6.4 | 15.4 | 13.3 |
| Low deterioration (Low severe) | 1+840 | 3.6 | 4.4 | 4.7 | 3.4 | 4.5 | 4.6 | 7.1 | 7.1 | 10.1 | 6.6 | 18.2 | 10.2 |
| | 2+160 | 4.6 | 4.1 | 4.8 | 3.2 | 3.7 | 3.9 | 7.9 | 10.6 | 19.8 | 6.5 | 19.6 | 14.5 |
| | 4+300 | 4.2 | 4.2 | 4.9 | 2.6 | 3.6 | 3.6 | 6.3 | 7.4 | 29.6 | 6.9 | 17.5 | 19.3 |
| | 7+820 | 2.9 | 3.4 | 4.8 | 4.1 | 3.9 | 3.7 | 6.5 | 9.8 | 20.4 | 6.8 | 20.6 | 16.4 |
| | 9+140 | 3.8 | 4.2 | 4.9 | 3.5 | 3.5 | 4.7 | 7.8 | 6.2 | 21.3 | 6.7 | 18.3 | 20.4 |
| | Average | 4.2 | 3.3 | 4.8 | 2.6 | 3.8 | 4.2 | 7.1 | 9.6 | 22.24 | 6.7 | 18.8 | 16.16 |
| **Total Average** | | **3.9** | **4.1** | **4.5** | **3.5** | **3.9** | **4.3** | **7.4** | **8.7** | **23.3** | **6** | **14** | **13.2** |

The average CBR test values of high, medium and low deterioration (sever) of sub base results are 21.5, 26.1 and 22.24 respectively .But, AASHTO T-193 specification for the standard minimum requirement for sub base indicate as 30% (CRR≥30%) tableand also the average value of subgrade soil laboratory test results were 4.2,4.6 and 4.82 at High ,Medium and Low Deterioration .But, ERA specification for the standard minimum requirement for sub base indicate as 5% (CRR≥5%).From the point of view the CBR value of laboratory test of sub base and subgrade materials are under the specification

# CHAPTER FIVE

## CONCLUSIONS AND RECOMMENDATIONS

## 5.1. Conclusions

### 5.1.1. Identified types of distress and level of severity

By field Survey investigation to identifying the distress and Categorizes level of severity. The studied stretch (along Ajip to Gebrel church of Jimma town with a total 10kms) had 15 distress stations and categorized in: 4- stations high deterioration (more Severe) of Block crack, 6-stations Medium deterioration (severe) of Alligator crack and 5-stations Low deterioration (less Severe) of Edge crack by ERA standard specification manual.

### 5.1.2. Analyze quality of subgrade and sub-base materials

After identify the distress and categorized the level of severity sample extracted and conducted laboratory tests. The following conclusions are drawn:-

- The subgrade and the sub base materials are poor graded because of weak compaction, high void and moisture fluctuation .Since this moisture fluctuation can be affected or washed out of the fine ingredient and the materials can't interlock each other.
- NMC greater than OMC because of excess air and water in the sub grade and sub base materials it tends to keep particle apart.
- The sub grade and sub base layers of the studied stretch should not compact well and not achieve at least a relative density of 95%.
- The subgrade and the sub base materials are poor strength or unsuitable for road construction as a result the sub base materials can't carry the base course because low CBR value from the standard specification.
- The measure causes of deterioration can be excess water ,poor materials, lack of proper drainage, lack of drainage, lack of routine and timely maintained ,poor shoulder design, seepage and infiltration of water in to pavement layers ,poor

compaction (poor method of compaction) and construction of pavement layers during rainy season. **These can be cause of deteriorations**.

- But, The Atterberg's limit tests of the sub-base and subgrade materials were observed in the laboratory satisfy the standard specification.

## 5.2. Recommended appropriate remedial measures

Based on the above concussion the following recommendations are drawn:-

- The designer and contractor should follow the minimum requirement set by standard specification regarding the engineering properties of the materials.
- The sub base and the subgrade materials should be properly selected, properly compacted at least a relative density of 95% of MDD achieved by heavy compaction and adequate shoulder constructed unless too much money invested for maintenance.
- Asphalt surface adequate surface or subsurface drain, run out and protection should be provided. Seal coats shall be applied to prevent infiltration and seepage of water through cracked surfaces to different layers of the pavement.
- The possible recommended remedial measure of edge cracking type deformations are elimination of excess moisture by building shoulder and providing proper drainage with good materials important to enhance both serviceability and structural capacity levels.
- The strength values that are used for design should be based on the results of a thorough study of moisture-density-strength relationships that can be attained after construction and during the life time of the pavement.
- The subgrade and the sub base layers of materials are Poor strength (CBR) this is not suitable for road construction. So, either removed unsuitable materials and replace suitable materials or maintenance and rehabilitation alternative.
- The voids beneath of the pavement should be filled with high soften under sealing asphalt to prevent the intrusion of water in to the subgrade and sub base.
- Temporary repair through filling with pre-mixed asphalt patching materials and Permant repair through filling with new subgrade and sub The problem of the subgrade drainage, the attention must be given to ground water pumping, seepage and water infiltration that needs in depth geochemical investigation .To control the points.

Construction of consultant must be identified location of bad ground water table condition when encountered during excavation and determine the proper location of subgrade drains or out lets. Likewise water bearing strata which will possibly feed water in to the pavement structure should be intercepted at some distance away from the road way section.

Further investigation should be done on the remaining layers of the pavement and other part of Ethiopia for road constructed on similar road pavement layers.

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# APPENDEX A. PARTICLE SIZE DISTRIBUTION

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**PARTICAL SIZE DISTRIBUTION OF SIEVE ANALYSIS (TEST METHOD AASHTO T-27 )**

**Natural sub base material**

| | | | |
|---|---|---|---|
| Material Type :- | **Sub base** | Date sampled: | **Mar.,20/2017** |
| Sample Station :- | **High deteriorations(more severe)** | Date tested | **Apr.,28/2017** |
| Represent Stat.:- | **Average(0+460,1+870,3+360,4+710)** | Sample No:- | **2011** |
| Material Source :- | **Bedabuna(source from ERA jimma district)** | Test No:- | **2011** |

Sampled by:- Getu Tamiru    Tested by:- Getu Tamiru

**Grading Requirement**    **Technical Specification Type 1 of Table 5403/1**

**Dry Sieve** [ ]    **Wet Sieve** [√]

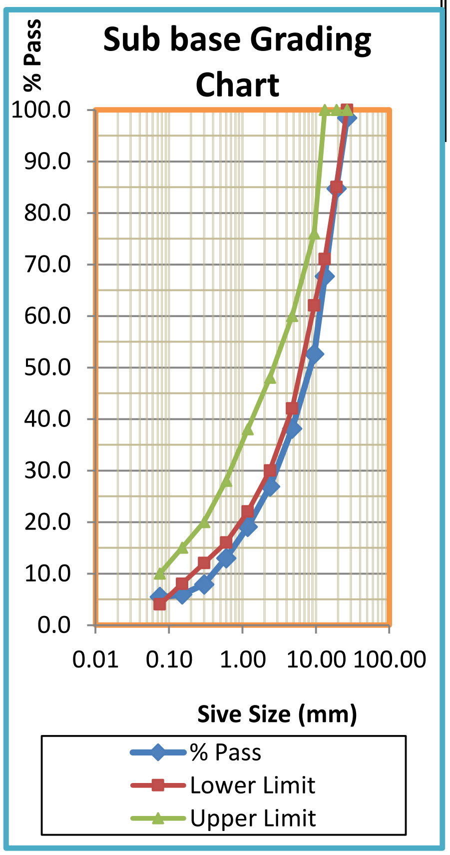
**Grading test trial No 1**

**(1) Wt. before Washing** 7984 **(gm)**

**(2) Wt. after Washing** 5023 **(gm)**

**Wt. Retaining no the pan** **(1)-(2)=** **2961** **(gm)**

| Sieve Size (mm) | Weight Retained (g) | Percent Retained (%) | Cumm. Retained (%) | %Pass (%) | Specification Limit | |
|---|---|---|---|---|---|---|
| | | | | | Lower Limit | Upper Limit |
| **37** | 20 | 0.3 | 0.3 | **99.7** | 100 | 100 |
| **20** | 453 | 5.7 | 5.9 | **94.1** | 80 | 100 |
| **10** | 843 | 10.6 | 16.5 | **83.5** | 55 | 100 |
| **5** | 942 | 11.8 | 28.3 | **71.7** | 40 | 60 |
| **2.36** | 984 | 12.3 | 40.6 | **59.4** | 30 | 50 |
| **0.425** | 956 | 12.0 | 52.6 | **47.4** | 15 | 30 |
| **0.075** | 825 | 10.3 | 62.9 | **37.1** | 5 | 15 |
| **Pan** | **2961** | 37.1 | 100 | | | |
| **Total** | 7984 | 100 | | | | |



**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**PARTICAL SIZE DISTRIBUTION OF SIEVE ANALYSIS (TEST METHOD AASHTO T-27 )**

**Natural sub base material**

| | | | |
|---|---|---|---|
| Material Type :- | **Sub base** | Date sampled: | **Mar.,20/2017** |
| Sample Station :- | **Medium deterioration(more severe)** | Date tested | **Apr.,28/2017** |
| Represent Stat.:- | **Average(0+010,1+580,2+120,2+750 ,3+870,4+860)** | Sample No:- | **2012** |
| Material Source :- | **Bedabuna(source from ERA jimma district)** | Test No:- | **2012** |

**Sampled and Tested by:- Getu Tamiru**

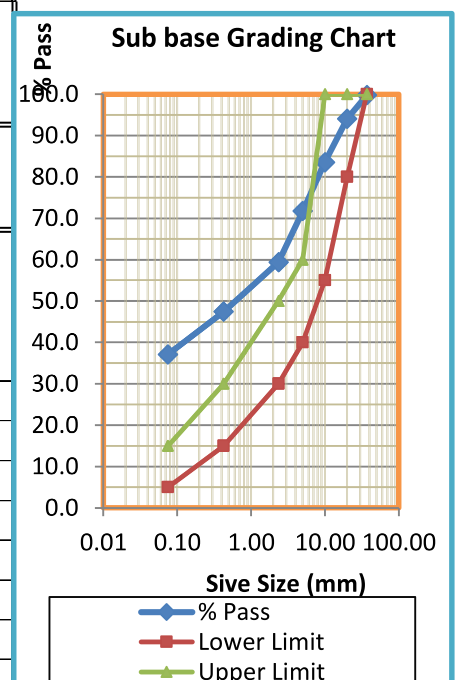
**Grading Requirement** **Technical Specification Type 1 of Table 5403/1**

**Dry Sieve** | **Wet Sieve** √

**Grading test trial No 2**

| | | |
|---|---|---|
| **(1) Wt. before Washing** | 5429 | **(gm)** |
| **(2) Wt. after Washing** | 4458 | **(gm)** |
| **Wt. Retaining no the pan** **(1)-(2)=** | **971** | **(gm)** |

| **Sieve Size (mm)** | **Weight Retained (g)** | **Percent Retained (%)** | **Cumm. Retained (%)** | **%Pass (%)** | **Specification Limit** Lower Limit | Upper Limit |
|---|---|---|---|---|---|---|
| **37** | 40 | 0.7 | 0.7 | **99.3** | 100 | 100 |
| **20** | 522 | 9.6 | 10.4 | **89.6** | 80 | 100 |
| **10** | 843 | 15.5 | 25.9 | **74.1** | 55 | 100 |
| **5** | 916 | 16.9 | 42.8 | **57.2** | 40 | 60 |
| **2.36** | 822 | 15.1 | 57.9 | **42.1** | 30 | 50 |
| **0.425** | 714 | 13.2 | 71.0 | **29.0** | 15 | 30 |
| **0.075** | 601 | 11.1 | 82.1 | **17.9** | 5 | 15 |
| **Pan** | **971** | 17.9 | 100 | | | |
| **Total** | 5429 | 100 | | | | |
| | | | | | | |



**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**PARTICAL SIZE DISTRIBUTION OF SIEVE ANALYSIS (TEST METHOD AASHTO T-27 )**

**Natural sub base material**

| | | | |
|---|---|---|---|
| Material Type :- | **Sub base** | Date sampled: | **Mar.,20/2017** |
| Sample Station :- | **Low deterioration(Less severe)** | Date tested | **Apr.,28/2017** |
| Represent Stat.:- | **Average(0+920,1+080,2+150,3+910,4+570)** | Sample No:- | **2013** |
| Material Source :- | **Bedabuna(source from ERA jimma district)** | Test No:- | **2013** |

Sampled by:- Getu Tamiru    Tested by:- Getu Tamiru

**Grading Requirement**    **Technical Specification Type 1 of Table 5403/1**

**Dry Sieve** [ ]    **Wet Sieve** [√]

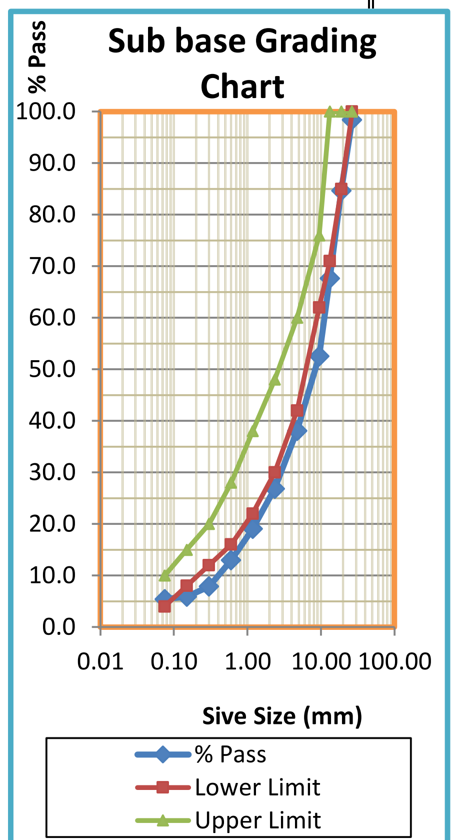
**Grading test trial No 3**

**(1) Wt. before Washing** 6845 **(gm)**

**(2) Wt. after Washing** 4422 **(gm)**

**Wt. Retaining no the pan** **(1)-(2)=** **2423** **(gm)**

| Sieve Size (mm) | Weight Retained (g) | Percent Retained (%) | Cumm. Retained (%) | %Pass (%) | Specification Limit | |
|---|---|---|---|---|---|---|
| | | | | | Lower Limit | Upper Limit |
| **37** | 40 | 0.6 | 0.6 | **99.4** | 100 | 100 |
| **20** | 652 | 9.5 | 10.1 | **89.9** | 80 | 100 |
| **10** | 645 | 9.4 | 19.5 | **80.5** | 55 | 100 |
| **5** | 540 | 7.9 | 27.4 | **72.6** | 40 | 60 |
| **2.36** | 890 | 13.0 | 40.4 | **59.6** | 30 | 50 |
| **0.425** | 810 | 11.8 | 52.3 | **47.7** | 15 | 30 |
| **0.075** | 845 | 12.3 | 64.6 | **35.4** | 5 | 15 |
| **Pan** | **2423** | 35.4 | 100 | | | |
| **Total** | 6845 | 100 | | | | |



**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**PARTICAL SIZE DISTRIBUTION OF SIEVE ANALYSIS (TEST METHOD AASHTO T-27/T-11 )**

**Subgrade material**

| | | | |
|---|---|---|---|
| Material Type :- | **Subgrade** | **Date sampled:** | **Mar.,20/2017** |
| Sample Station :- | **High detereioration(more severe)** | **Date tested** | **Apr.,28/2017** |
| Represent Stat.:- | **Average(0+460,1+870,3+360, 4+710)** | **Sample No:-** | **2031** |
| Material Source :- | | **Test No:-** | **2031** |
| Sampled by:- Getu Tamiru | | Tested by:- Getu Tamiru | |

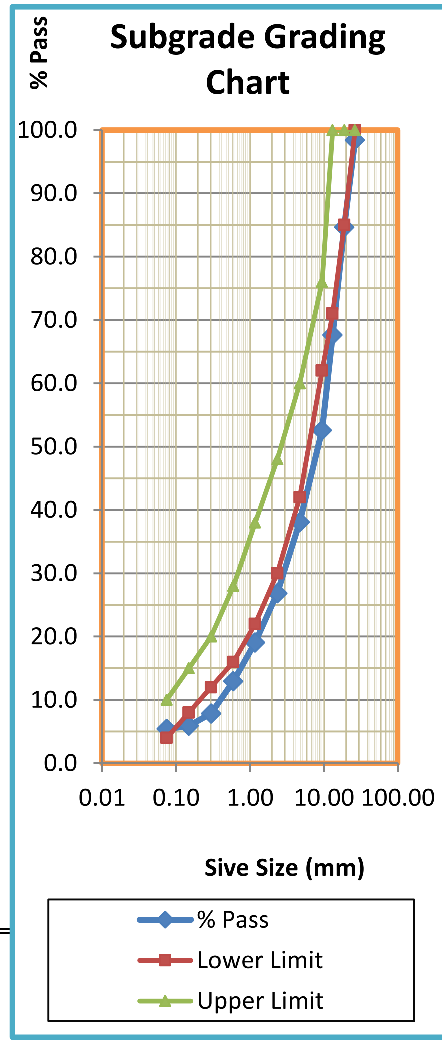
**Grading Requirement** **Technical Specification Type 1 of Table 5403/2**

**Dry Sieve** [ ] **Wet Sieve** [√]

**Grading test trial No 1**

| | | | |
|---|---|---|---|
| **(1) Wt. before Washing** | | 1619.4 | **(gm)** |
| **(2) Wt. after Washing** | | 1611 | **(gm)** |
| **Wt. Retaining no the pan** | **(1)-(2)=** | **8.4** | **(gm)** |

| Sieve Size (mm) | Weight Retained (g) | Percent Retained (%) | Cum. Retained (%) | %Pass (%) | Specification Limit | |
|---|---|---|---|---|---|---|
| | | | | | Lower Limit | Upper Limit |
| **26.5** | 10 | 0.6 | 0.6 | **99.4** | 100 | 100 |
| **19** | 45 | 2.8 | 3.4 | **96.6** | 85 | 100 |
| **13.2** | 659 | 40.7 | 44.1 | **55.9** | 71 | 100 |
| **9.5** | 184 | 11.4 | 55.5 | **44.5** | 62 | 76 |
| **4.75** | 205 | 12.7 | 68.1 | **31.9** | 42 | 60 |
| **2.36** | 195 | 12.0 | 80.2 | **19.8** | 30 | 48 |
| **1.18** | 93 | 5.7 | 85.9 | **14.1** | 22 | 38 |
| **0.6** | 68 | 4.2 | 90.1 | **9.9** | 16 | 28 |
| **0.3** | 52 | 3.2 | 93.3 | **6.7** | 12 | 20 |
| **0.15** | 61 | 3.8 | 97.1 | **2.9** | 8 | 15 |
| **0.075** | 39 | 2.4 | 99.5 | **0.5** | 4 | 10 |
| **Pan** | **8.4** | 0.5 | 100.0 | | | |
| **Total** | 1619.4 | 100.0 | 200.0 | | | |



**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**PARTICAL SIZE DISTRIBUTION OF SIEVE ANALYSIS (TEST METHOD AASHTO T-27/T-11 )**

**Subgrade material**

| | | | |
|---|---|---|---|
| Material Type :- | **Subgrade** | Date sampled: | **Mar.,20 /2017** |
| Sample Station | **Medium deteriorations(severe)** | Date teste | **Apr.28/ 2017** |
| Represent Stat. | **Average(0+010,1+580,2+120,2+750,3+870,4+860** | Sample No:- | **2032** |
| Material Source | | Test No:- | **2032** |
| Sampled and tested by:- Getu Tamiru | | | |

**Grading Requirement** **Technical Specification Type 1 of Table 5403/2**

**Dry Sieve** | | **Wet Sieve** √

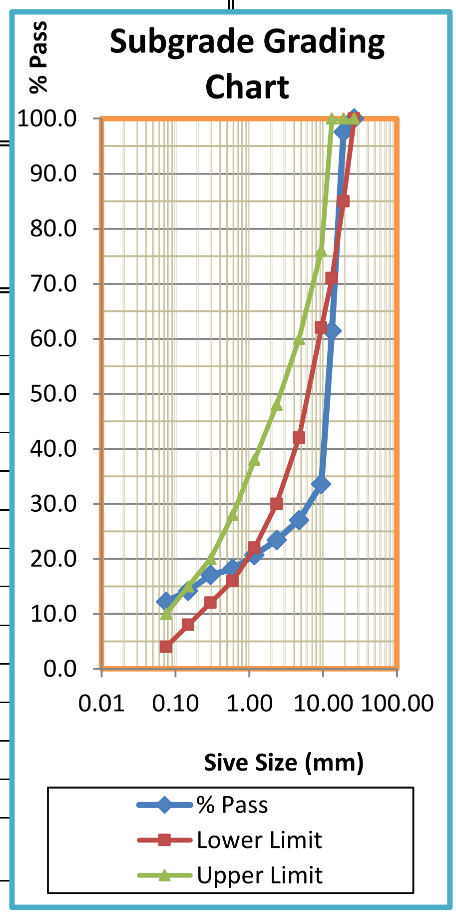
**Grading test trial No 2**

**(1) Wt. before Washing** 2337.9 **(gm)**

**(2) Wt. after Washing** 2052 **(gm)**

**Wt. Retaining no the pan** **(1)-(2)=** **285.9** **(gm)**

| Sieve Size (mm) | Weight Retained (g) | Percent Retained (%) | Cumm. Retained (%) | %Pass (%) | Specification Limit | |
|---|---|---|---|---|---|---|
| | | | | | Lower Limit | Upper Limit |
| **26.5** | 0 | 0.0 | 0.0 | **100.0** | 100 | 100 |
| **19** | 56 | 2.4 | 2.4 | **97.6** | 85 | 100 |
| **13.2** | 846 | 36.2 | 38.6 | **61.4** | 71 | 100 |
| **9.5** | 650 | 27.8 | 66.4 | **33.6** | 62 | 76 |
| **4.75** | 154 | 6.6 | 73.0 | **27.0** | 42 | 60 |
| **2.36** | 85 | 3.6 | 76.6 | **23.4** | 30 | 48 |
| **1.18** | 63 | 2.7 | 79.3 | **20.7** | 22 | 38 |
| **0.6** | 59 | 2.5 | 81.8 | **18.2** | 16 | 28 |
| **0.3** | 26 | 1.1 | 82.9 | **17.1** | 12 | 20 |
| **0.15** | 67 | 2.9 | 85.8 | **14.2** | 8 | 15 |
| **0.075** | 46 | 2.0 | 87.8 | **12.2** | 4 | 10 |
| **Pan** | **285.9** | 12.2 | 100.0 | | | |
| **Total** | 2337.9 | | | | | |



**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of Jimma town from Ajip to Gebrel church**

**PARTICAL SIZE DISTRIBUTION OF SIEVE ANALYSIS (TEST METHOD AASHTO T-27/T-11 )**

**Subgrade material**

| | | | |
|---|---|---|---|
| Material Type :- | **Subgrade** | Date sampled: | **Mar.,20/ 2017** |
| Sample Station :- | **Low deteriorations(Less severe)** | Date tested | **Apr.,28/ 2017** |
| Represent Stat.:- | **Average(0+920,1+080,2+150,3+910, 4+570)** | Sample No:- | **2033** |
| Material Source :- | | Test No:- | **2033** |
| Sampled by:- Getu Tamiru | | Tested by:- Getu Tamiru | |

**Grading Requirement** **Technical Specification Type 1 of Table 5403/2**

**Dry Sieve** [ ] **Wet Sieve** √

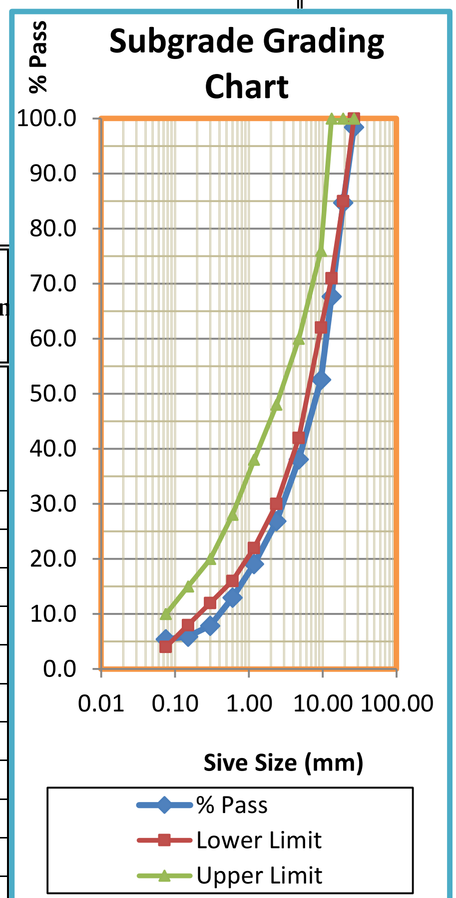
**Grading test trial No 3**

**(1) Wt. before Washing** 4079.9 **(gm)**

**(2) Wt. after Washing** 3859 **(gm)**

**Wt. Retaining no the pan** **(1)-(2)=** **220.9** **(gm)**

| Sieve Size (mm) | Weight Retained (g) | Percent Retained (%) | Cumm. Retained (%) | %Pass (%) | Specification Limit Lower Limit | Specification Limit Upper Limit |
|---|---|---|---|---|---|---|
| **26.5** | 65 | 1.6 | 1.6 | **98.4** | 100 | 100 |
| **19** | 560 | 13.7 | 15.3 | **84.7** | 85 | 100 |
| **13.2** | 695 | 17.0 | 32.4 | **67.6** | 71 | 100 |
| **9.5** | 615 | 15.1 | 47.4 | **52.6** | 62 | 76 |
| **4.75** | 591 | 14.5 | 61.9 | **38.1** | 42 | 60 |
| **2.36** | 458 | 11.2 | 73.1 | **26.9** | 30 | 48 |
| **1.18** | 318 | 7.8 | 80.9 | **19.1** | 22 | 38 |
| **0.6** | 249 | 6.1 | 87.0 | **13.0** | 16 | 28 |
| **0.3** | 208 | 5.1 | 92.1 | **7.9** | 12 | 20 |
| **0.15** | 80 | 2.0 | 94.1 | **5.9** | 8 | 15 |
| **0.075** | 20 | 0.5 | 94.6 | **5.4** | 4 | 10 |
| **Pan** | **220.9** | 5.4 | 100.0 | | | |
| **Total** | 4079.999 | 100.0 | | | | |



# APPENDEX B .ATTERBERG LIMIT

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

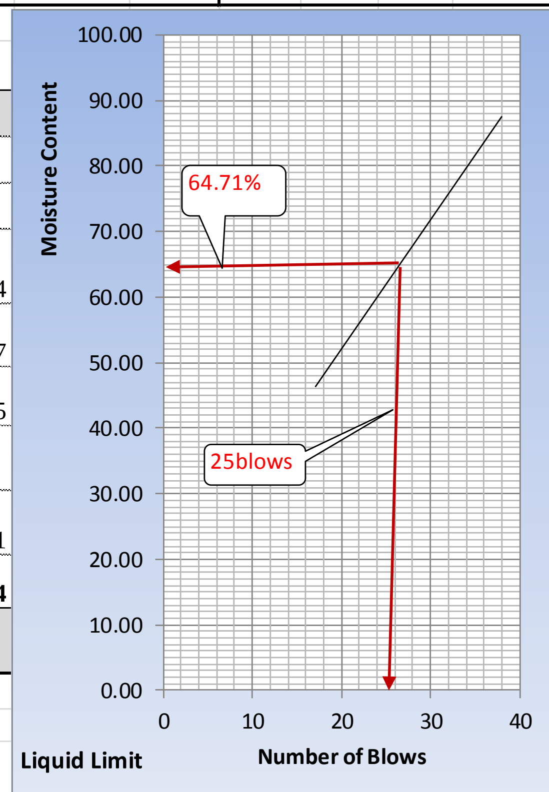
**Liquid & plastic limit (TEST METHOD AASHTO T-27/T-11 )**

**Subgrade material**

| | |
|---|---|
| **Sampled and Tested by:- Getu Tamiru** | **Sampled date:- Mar,20/2017** |
| **Sample Station :- High deterioration(more severe)** | **Tested Date:- Apr.,26/2017** |
| Represent Stat.:-Average(0+460,1+870,3+360,4+710) | |

## *Liquid Limit*

| Test number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Number of blows (drops) | 38 | 26 | 20 | 17 |
| Container number | 3/5 | 42/10 | 13/11 | 2/2 |
| Mass of container Mc (gm) | 27.8 | 27.1 | 26.47 | 26.04 |
| Mass of container + wet soil M1 (gm) | 60.00 | 60.00 | 65.00 | 67.57 |
| Mass of container + ovendry soil M2 | 45.00 | 48.20 | 48.00 | 58.45 |
| Mass of water M3=M1-M2 | 15.00 | 11.80 | 17.00 | 9.12 |
| Mass of ovendry soil M4=M2-Mc | 17.20 | 21.10 | 21.53 | 32.41 |
| Moisture content M3/M4 (%) | **87.21** | **55.92** | **78.96** | **28.14** |
| **Liquid Limit at 25 Blows** | = | **64.71 %** | | |




## *Plastic Limit*

| Observation number | 1 | 2 | 3 |
|---|---|---|---|
| weight of can + moist soil $w_1$ | 29.71 | 29 | 33.02 |
| weight of can + dry soil $w_2$ | 28.25 | 28.76 | 32.78 |
| Weight of can wc | 26.48 | 26.9 | 31.41 |
| Weight of dry soil $w_3$=$w_2$-wc | 1.77 | 1.86 | 1.37 |
| weight of water $w_4$=$w_1$-$w_2$ | 1.46 | 0.24 | 0.24 |
| Water content $w_4/w_3$ (%) | 82.49 | 12.90 | 17.52 |
| **Plastic limit** | | **37.78** | % |

| | | |
|---|---|---|
| LL = | **64.71** | % |
| PL = | **37.78** | % |
| PI = | **30.93** | % |

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**Liquid & plastic limit (TEST METHOD AASHTO T-27/T-11 )**

**Subgrade material**

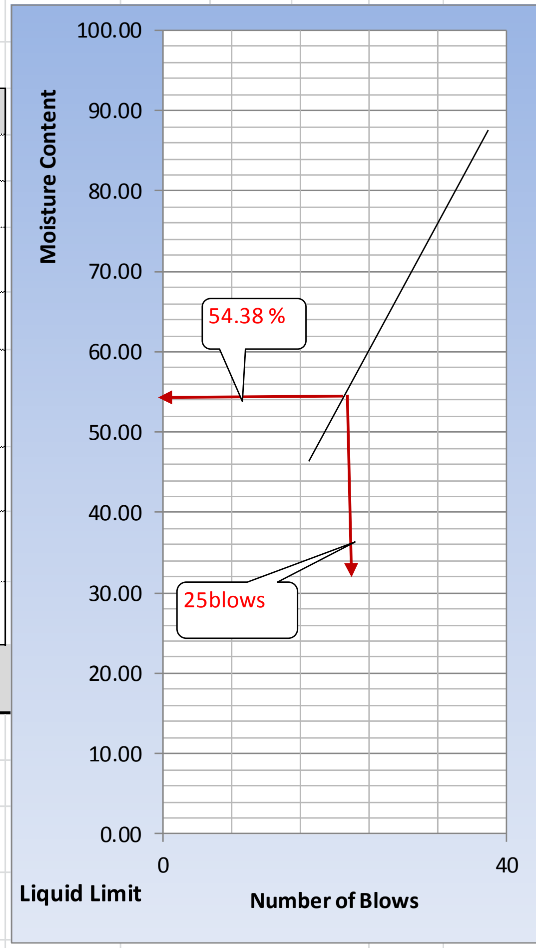
**Sampled and Tested by:- Getu Tamiru** | **Sampled date:- Mar,20/2017**

**Sample Station :- Medium deterioration(severe)** | **Tested Date:- Apr.,26/2017**

Represent Stat.:-Average(0+010,1+580,2+120,2+750,3+870,4+860)

## *Liquid Limit*

| Test number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Number of blows (drops) | 38 | 26 | 20 | 17 |
| Container number | 4/8 | 21/58 | 7/10 | 8/30 |
| Mass of container Mc (gm) | 27.8 | 27.1 | 26.47 | 26.04 |
| Mass of container + wet soil M1 (gm) | 60.00 | 62.00 | 65.00 | 67.57 |
| Mass of container + ovendry soil M2 (gm) | 49.42 | 48.20 | 48.00 | 55.00 |
| Mass of water M3=M1-M2 | 10.58 | 13.80 | 17.00 | 12.57 |
| Mass of ovendry soil M4=M2-Mc | 21.62 | 21.10 | 21.53 | 28.96 |
| Moisture content M3/M4 (%) | **48.94** | **65.40** | **78.96** | **43.40** |
| **Liquid Limit at 25 Blows** | = | **54.38 %** | | |




## *Plastic Limit*

| Observation number | 1 | 2 | 3 | | | |
|---|---|---|---|---|---|---|
| weight of can + moist soil $w_1$ | 28.78 | 29.55 | 31.2 | | | |
| weight of can + dry soil $w_2$ | 28 | 28.9 | 30.9 | | | |
| Weight of can wc | 26.48 | 26.9 | 26.7 | | | |
| Weight of dry soil $w_3=w_2$-wc | 1.52 | 2 | 4.2 | LL = | **54.38** | % |
| weight of water $w_4=w_1-w_2$ | 0.78 | 0.65 | 0.3 | PL = | **30.41** | % |
| Water content $w_4/w_3$ (%) | 51.32 | 32.50 | 7.14 | PI = | **23.97** | % |
| **Plastic limit** | | **30.41 %** | | | | |

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

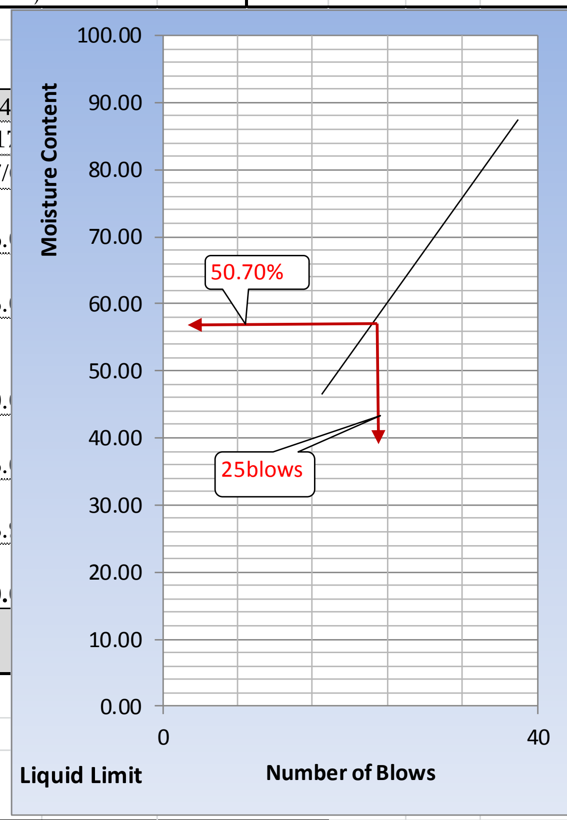
**Liquid & plastic limit (TEST METHOD AASHTO T-27/T-11 )**

**Subgrade material**

| | |
|---|---|
| **Sampled and Tested by:- Getu Tamiru** | **Sampled date:- Mar,20/2017** |
| **Sample Station :- Low deterioration(less severe)** | **Tested Date:- Apr.,26/2017** |
| Represent Stat.:-Average(0+920,1+080,2+150,3+910,4+570) | |

## *Liquid Limit*

| Test number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Number of blows (drops) | 38 | 26 | 20 | 17 |
| Container number | 5/9 | 13/34 | 9/46 | 17/ |
| Mass of container Mc (gm) | 27.8 | 27.1 | 26.47 | 26. |
| Mass of container + wet soil M1 (gm) | 60.00 | 62.00 | 63.00 | 65. |
| Mass of container + ovendry soil M2 (gm) | 49.42 | 48.20 | 48.00 | 50. |
| Mass of water M3=M1-M2 | 10.58 | 13.80 | 15.00 | 15. |
| Mass of ovendry soil M4=M2-Mc | 21.62 | 21.10 | 21.53 | 23. |
| Moisture content M3/M4 (%) | **48.94** | **65.40** | **69.67** | **50.** |
| **Liquid Limit at 25 Blows** | = | **50.7 %** | | |




## ***Plastic Limit***

| Observation number | 1 | 2 | 3 |
|---|---|---|---|
| weight of can + moist soil $w_1$ | 29.5 | 28.81 | 32.9 |
| weight of can + dry soil $w_2$ | 28.25 | 28.76 | 32.78 |
| Weight of can wc | 26.48 | 26.9 | 31.41 |
| Weight of dry soil $w_3=w_2$-wc | 1.77 | 1.86 | 1.37 |
| weight of water $w_4=w_1-w_2$ | 1.25 | 0.05 | 0.12 |
| Water content $w_4/w_3$ (%) | 70.62 | 2.69 | 8.76 |
| **Plastic limit** | | **27.27** | |

| | | |
|---|---|---|
| LL = | **50.70** | % |
| PL = | **27.27** | % |
| PI = | **23.43** | % |

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

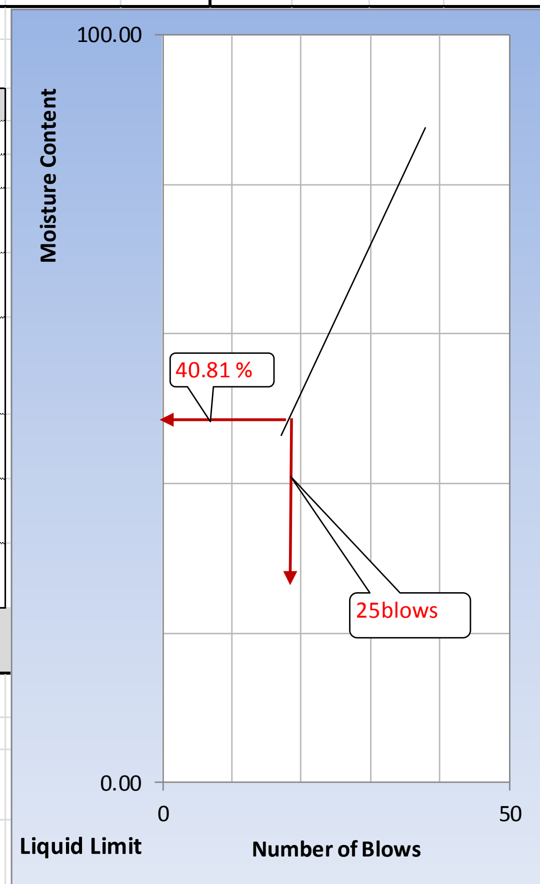
**Liquid & plastic limit (TEST METHOD AASHTO T-27/T-11 )**

**Sub base material**

**Sampled and Tested by:- Getu Tamiru**
**Sampled date:- Mar,20/2017**
**Sample Station :- High deterioration(more severe)**
**Tested Date:- Apr.,26/2017**
Represent Stat.:-Average(0+460,1+870,3+360,4+710)

## *Liquid Limit*

| Test number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Number of blows (drops) | 38 | 26 | 20 | 17 |
| Container number | 5/25 | 65/85 | 14/46 | 24/57 |
| Mass of container Mc (gm) | 27.8 | 27.1 | 26.47 | 26.04 |
| Mass of container + wet soil M1 (gm) | 62.35 | 60.14 | 59.50 | 63.25 |
| Mass of container + ovendry soil M2 (gm) | 50.00 | 49.00 | 48.30 | 48.00 |
| Mass of water M3=M1-M2 | 12.35 | 11.14 | 11.20 | 15.25 |
| Mass of ovendry soil M4=M2-Mc | 22.20 | 21.90 | 21.83 | 21.96 |
| Moisture content M3/M4 (%) | **45.00** | **39.84** | **40.00** | **39.00** |
| **Liquid Limit at 25 Blows** = | **40.81 %** | | | |




## ***Plastic Limit***

| Observation number | 1 | 2 | 3 |
|---|---|---|---|
| weight of can + moist soil $w_1$ | 29.1 | 29.14 | 33.02 |
| weight of can + dry soil $w_2$ | 28.25 | 28.76 | 32.78 |
| Weight of can wc | 26.48 | 26.9 | 31.41 |
| Weight of dry soil $w_3=w_2$-wc | 1.77 | 1.86 | 1.37 |
| weight of water $w_4=w_1-w_2$ | 0.85 | 0.38 | 0.24 |
| Water content $w_4/w_3$ (%) | 48.02 | 20.43 | 17.52 |
| **Plastic limit** | **28.61** | | |

| | | |
|---|---|---|
| LL = | **40.81** | % |
| PL = | **28.61** | % |
| PI = | **12.20** | % |

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**Liquid & plastic limit (TEST METHOD AASHTO T-27/T-11 )**

**Sub base material**

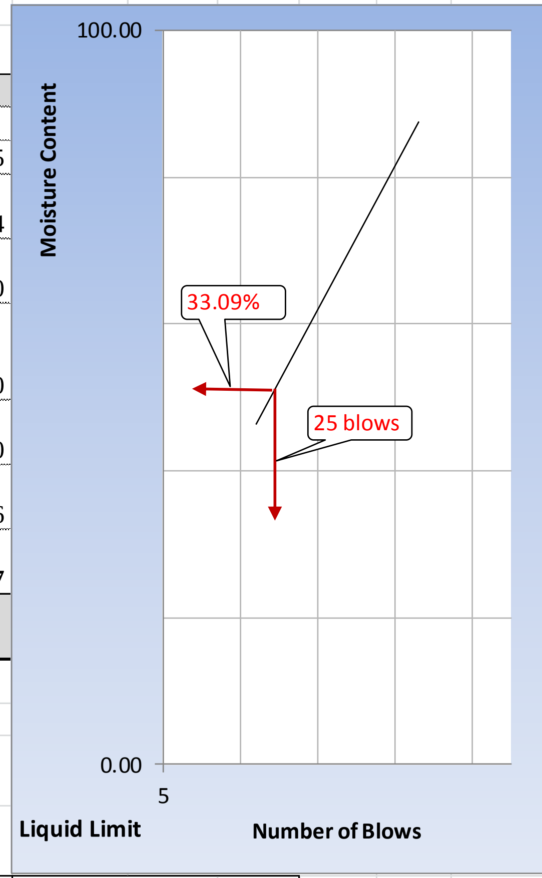
**Sampled and Tested by:- Getu Tamiru** | **Sampled date:- Mar,20/2017**

**Sample Station :- Medium deterioration(severe)** | **Tested Date:- Apr.,26/2017**

Represent Stat.:-Average(0+010,1+580,2+120,2+750,3+870,4+860)

## *Liquid Limit*

| Test number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Number of blows (drops) | 38 | 26 | 20 | 17 |
| Container number | 45/85 | 24/64 | 13/41 | 44/55 |
| Mass of container Mc (gm) | 27.8 | 27.1 | 26.47 | 26.04 |
| Mass of container + wet soil M1 (gm) | 54.30 | 55.01 | 56.00 | 58.60 |
| Mass of container + ovendry soil M2 (gm) | 45.00 | 44.90 | 45.50 | 47.60 |
| Mass of water M3=M1-M2 | 9.30 | 10.11 | 10.50 | 11.00 |
| Mass of ovendry soil M4=M2-Mc | 17.20 | 17.80 | 19.03 | 21.56 |
| Moisture content M3/M4 (%) | **34.07** | **36.45** | **31.44** | **30.17** |
| **Liquid Limit at 25 Blows** | = | **33.09** | | |




## *Plastic Limit*

| Observation number | 1 | 2 | 3 |
|---|---|---|---|
| weight of can + moist soil $w_1$ | 28.6 | 29.19 | 33.02 |
| weight of can + dry soil $w_2$ | 28.1 | 28.68 | 32.78 |
| Weight of can wc | 26.48 | 26.9 | 31.41 |
| Weight of dry soil $w_3=w_2$-wc | 1.62 | 1.78 | 1.37 |
| weight of water $w_4=w_1-w_2$ | 0.5 | 0.51 | 0.24 |
| Water content $w_4/w_3$ (%) | 30.86 | 28.65 | 17.52 |
| **Plastic limit** | | **25.93** | |

| | | |
|---|---|---|
| LL = | **33.09** | % |
| PL = | **25.93** | % |
| PI = | **7.16** | % |

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**Liquid & plastic limit (TEST METHOD AASHTO T-27/T-11 )**

**Sub base material**

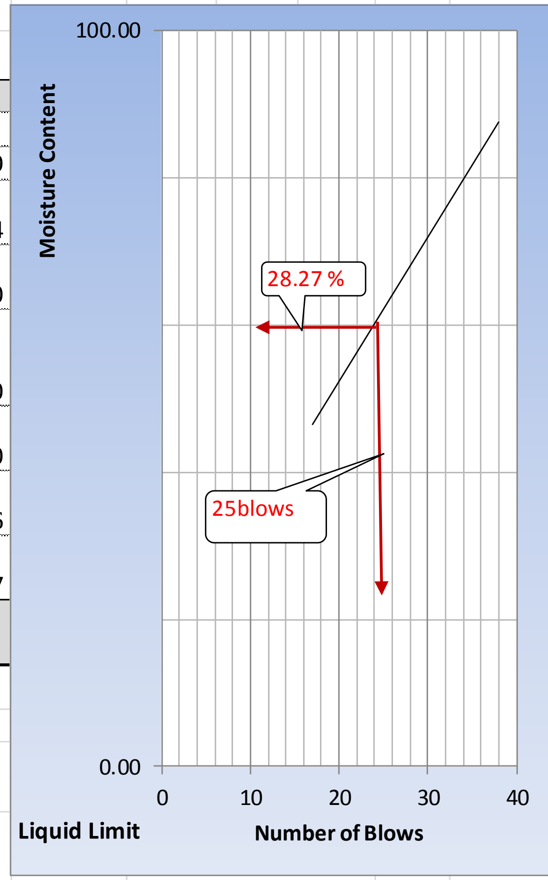
**Sampled and Tested by:- Getu Tamiru** | **Sampled date:- Mar,20/2017**

**Sample Station :- Low deterioration(less severe)** | **Tested Date:- Apr.,26/2017**

Represent Stat.:-Average(0+920,1+080,2+150,3+910,4+570)

*Liquid Limit*

| Test number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Number of blows (drops) | 38 | 26 | 20 | 17 |
| Container number | 24/24 | 34/89 | 44/88 | 57/99 |
| Mass of container Mc (gm) | 27.8 | 27.1 | 26.47 | 26.04 |
| Mass of container + wet soil M1 (gm) | 56.90 | 55.80 | 54.80 | 65.90 |
| Mass of container + ovendry soil M2 (gm) | 45.80 | 45.60 | 44.50 | 50.20 |
| Mass of water M3=M1-M2 | 11.10 | 10.20 | 10.30 | 15.70 |
| Mass of ovendry soil M4=M2-Mc | 18.00 | 18.50 | 18.03 | 24.16 |
| Moisture content M3/M4 (%) | **20.48** | **25.49** | **23.88** | **38.97** |
| **Liquid Limit at 25 Blows** | = | **28.27** | | |




***Plastic Limit***

| Observation number | 1 | 2 | 3 |
|---|---|---|---|
| weight of can + moist soil $w_1$ | 28.54 | 29.08 | 32.9 |
| weight of can + dry soil $w_2$ | 28.25 | 28.9 | 32.78 |
| Weight of can wc | 26.48 | 26.9 | 31.41 |
| Weight of dry soil $w_3=w_2$-wc | 1.77 | 2 | 1.37 |
| weight of water $w_4=w_1-w_2$ | 0.29 | 0.18 | 0.12 |
| Water content $w_4/w_3$ (%) | 16.38 | 9.00 | 8.76 |
| **Plastic limit** | | **11.38** | |

| | | |
|---|---|---|
| LL = | **28.27** | % |
| PL = | **11.38** | % |
| PI = | **16.89** | % |

# APPENDEX C. NATURAL MOISTURE CONTENT

| PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church | | | | | | |
|---|---|---|---|---|---|---|
| Moisture Content (TEST METHOD AASHTO T-78) | | | | | | |
| Sampled and Tested by:- Getu Tamiru | | Sampled date:- Mar,20/2017 | | | | |
| | | Tested Date:- Apr.,28/2017 | | | | |
| | SUB GRADE LAYERS (Average value) | | | SUB BASE LAYERS (Average value) | | |
| | High deterioration (more severe) | | | | High deterioration (more severe) | |
| Moisture | Container number | | 36/15 | Moisture | Container number | 46/56 |
| | Mass of wet soil + container | (gm) | 65.26 | | Mass of wet soil + container | 57.14 |
| | Mass of dry soil + container | (gm) | 52.49 | | Mass of dry soil + container | 52.92 |
| | Mass of water, $m_w$ | (gm) | 12.77 | | Mass of water, $m_w$ | 4.22 |
| | Mass of container, $m_c$ | (gm) | 26.58 | | Mass of container, $m_c$ | 26.58 |
| | Mass of dry soil ms | (gm) | 25.91 | | Mass of dry soil ms | 26.34 |
| | Moisture Content, w=mw/ms | (%) | 36.76 | | Moisture Content, w=mw/ms | 15.08 |

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**Moisture Content (TEST METHOD AASHTO T-78)**

**Sampled and Tested by:- Getu Tamiru** | **Sampled date:- Mar,20/2017** | **Tested Date:- Apr.,28/2017**

| | SUB GRADE LAYERS | (Average value) | | SUB BASE LAYERS | (Average value) |
|---|---|---|---|---|---|
| | **Medium deterioration ( severe)** | | | **Medium deterioration ( severe)** | |
| Moisture | Container number | 56/98 | Moisture | Container number | 48/79 |
| | Mass of wet soil + container (gm) | 60.25 | | Mass of wet soil + container | 52.48 |
| | Mass of dry soil + container (gm) | 50.74 | | Mass of dry soil + container | 48.67 |
| | Mass of water, $m_w$ (gm) | 9.51 | | Mass of water, $m_w$ | 3.81 |
| | Mass of container, $m_c$ (gm) | 26.58 | | Mass of container, $m_c$ | 26.58 |
| | Mass of dry soil ms (gm) | 24.16 | | Mass of dry soil ms | 22.09 |
| | Moisture Content, w=mw/ms (%) | 32.44 | | Moisture Content, w=mw/ms | 32.27 |

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**Moisture Content (TEST METHOD AASHTO T-78)**

**Sampled and Tested by:- Getu Tamiru** | **Sampled date:- Mar,20/2017** | **Tested Date:- Apr.,28/2017**

| | SUB GRADE LAYERS | (Average value) | | SUB BASE LAYERS | (Average value) |
|---|---|---|---|---|---|
| | **Low deterioration ( less severe)** | | | **Low deterioration ( less severe)** | |
| Moisture | Container number | 74/56 | Moisture | Container number | 96/23 |
| | Mass of wet soil + container (gm) | 58.96 | | Mass of wet soil + container | 51.45 |
| | Mass of dry soil + container (gm) | 40.62 | | Mass of dry soil + container | 47.35 |
| | Mass of water, $m_w$ (gm) | 18.34 | | Mass of water, $m_w$ | 4.10 |
| | Mass of container, $m_c$ (gm) | 26.58 | | Mass of container, $m_c$ | 26.58 |
| | Mass of dry soil ms (gm) | 14.04 | | Mass of dry soil ms | 20.77 |
| | Moisture Content, w=mw/ms (%) | 27.64 | | Moisture Content, w=mw/ms | 28.31 |

# APPENDEX D. COMPACTION

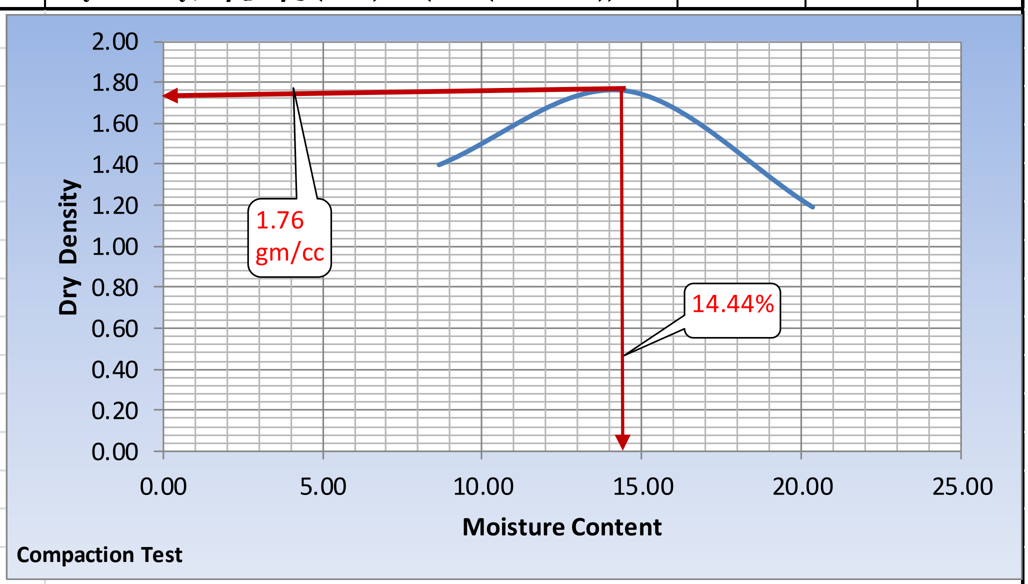
**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**COMPACTION (TEST METHOD AASHTO -180 - D )**

**Sub base material**

| | |
|---|---|
| Sampled and Tested by:- Getu Tamiru | Sampled date:- Mar,20/2017 |
| Sample Station :- High deterioration(more severe) | Tested Date:- Apr.,23/2017 |
| Represent Stat.:-Average(0+460,1+870,3+360,4+710) | |

| | | | | |
|---|---|---|---|---|
| | Trial number | 1 | 2 | 3 |
| Density | Weight of wet soil + mold(gm) (A) | 5820 | 6663 | 5735 |
| | Weight of mold (gm) (B) | 4294 | 4294 | 4294 |
| | Weight of Wet soil ws (gm) (C=A-B) | 1526 | 2369 | 1441 |
| | Volume of mold v (cc) (D) | 1005.00 | 1005.00 | 1005.00 |
| | Wet density of soil $\rho_{b=}$ws/v(gm/cc) (E=C/D) | 1.52 | 2.36 | 1.43 |
| Moisture | Container number | 30/43 | 31/31 | 8/38 |
| | Mass of wet soil + container (gm) (F) | 254.30 | 201.00 | 73.48 |
| | Mass of dry soil + container (gm) (G) | 236.90 | 174.00 | 66.26 |
| | Mass of water, $m_w$ (gm)(H=F-G) | 17.40 | 27.00 | 7.22 |
| | Mass of container, $m_c$ (gm) (I) | 35.80 | 34.20 | 30.80 |
| | Mass of dry soil ms (gm) (J=G-I) | 201.10 | 139.80 | 35.46 |
| | Moisture Content, w=mw/ms (%) (K=H/Jx100) | 8.65 | 14.44 | 20.36 |
| | Dry density, $\rho_d = \rho_b/(1+w)$ (L=E(1+K/100)) | 1.40 | 1.76 | 1.19 |




| | |
|---|---|
| MDD | 1.76g/cc |
| OMC | 14.44% |

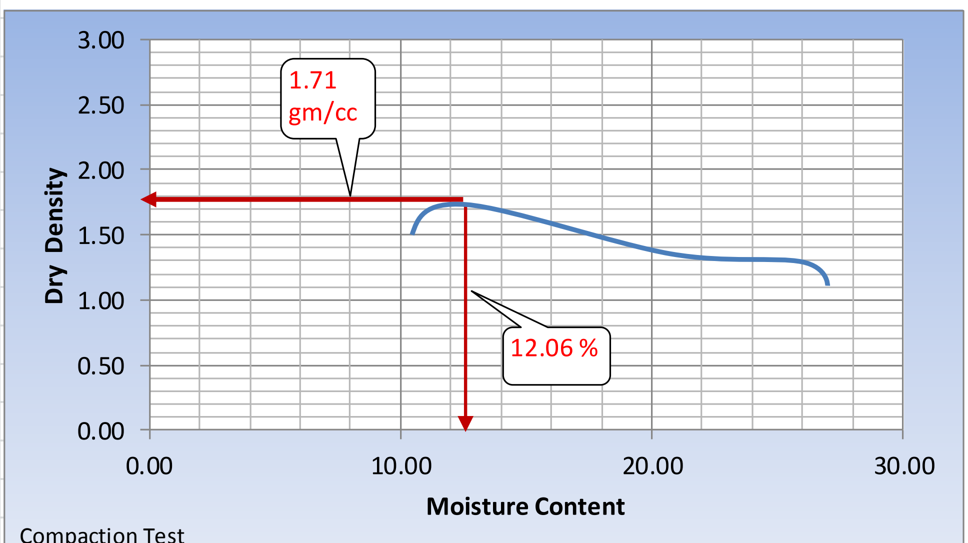
**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**COMPACTION (TEST METHOD AASHTO -180 - D )**

**Subgrade material**

| | |
|---|---|
| Sampled and Tested by:- Getu Tamiru | Sampled date:- Mar,20/2017 |
| Sample Station :- Medium deterioration(severe) | Tested Date:- Apr.,23/2017 |
| Represent Stat.:- Average(0+010,1+580,2+120,2+750+3+870,4+860) | |

| | | 1 | 2 | 3 |
|---|---|---|---|---|
| Density | Trial number | 1 | 2 | 3 |
| | Weight of wet soil + mold(gm) (A) | 5742 | 5745 | 6082 |
| | Weight of mold (gm) (B) | 4287 | 4287 | 4287 |
| | Weight of Wet soil ws (gm) (C=A-B) | 1455 | 1458 | 1795 |
| | Volume of mold v (cc) (D) | 1005.00 | 1005.00 | 1005.00 |
| | Wet density of soil $\rho_{b=}$ws/v(gm/cc) (E=C/D) | 1.45 | 1.45 | 1.79 |
| Moisture | Container number | 30/43 | 31/31 | 8/38 |
| | Mass of wet soil + container (gm) (F) | 166.10 | 185.40 | 184.10 |
| | Mass of dry soil + container (gm) (G) | 138.30 | 162.30 | 158.20 |
| | Mass of water, $m_w$ (gm)(H=F-G) | 27.80 | 23.10 | 25.90 |
| | Mass of container, $m_c$ (gm) (I) | 32.70 | 33.50 | 33.40 |
| | Mass of dry soil ms (gm) (J=G-I) | 105.60 | 128.80 | 124.80 |
| | Moisture Content, w=mw/ms (%) (K=H/Jx100) | 26.33 | 12.06 | 20.75 |
| | Dry density, $\rho_d = \rho_b/(1+w)$ (L=E(1+K/100)) | 1.15 | 1.71 | 1.48 |




| | |
|---|---|
| MDD | 1.71g/cc |
| OMC | 12.06% |

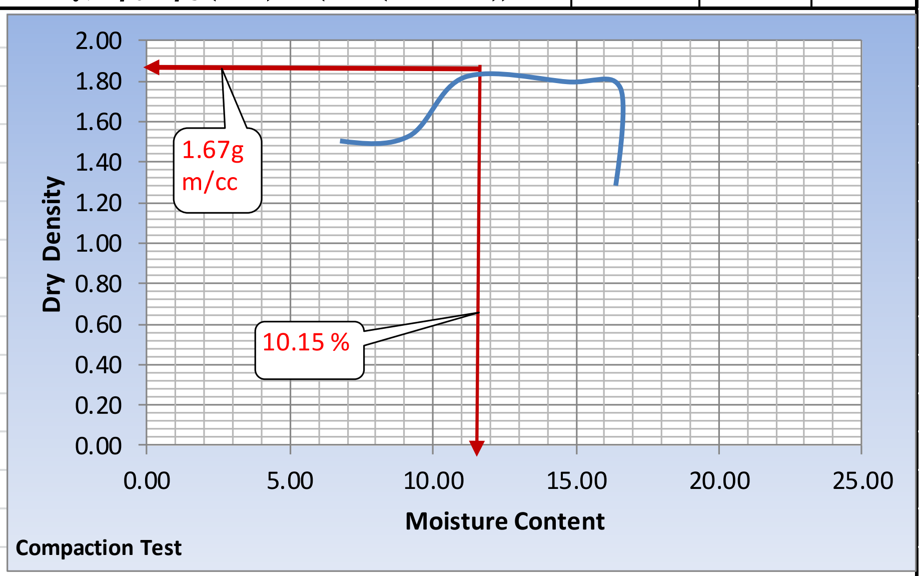
**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**COMPACTION (TEST METHOD AASHTO -180 - D )**

**Subgrade material**

| | |
|---|---|
| Sampled and Tested by:- Getu Tamiru | Sampled date:- Mar,20/2017 |
| Sample Station :- Low deterioration(less severe) | Tested Date:- Apr.,23/2017 |
| Represent Stat.:-Average(0+920,1+080,2+150,3+910,4+570) | |

| | Trial number | 1 | 2 | 3 |
|---|---|---|---|---|
| Density | Weight of wet soil + mold(gm) (A) | 9435 | 9599 | 9837 |
| | Weight of mold (gm) (B) | 5681 | 5681 | 5681 |
| | Weight of Wet soil ws (gm) (C=A-B) | 3754 | 3918 | 4156 |
| | Volume of mold v (cc) (D) | 2124.00 | 2124.00 | 1224.00 |
| | Wet density of soil $\rho_{b=}$ws/v(gm/cc) (E=C/D) | 1.77 | 1.84 | 3.40 |
| Moisture | Container number | 30/43 | 31/31 | 8/38 |
| | Mass of wet soil + container (gm) (F) | 215.40 | 219.20 | 202.80 |
| | Mass of dry soil + container (gm) (G) | 204.10 | 202.30 | 183.70 |
| | Mass of water, $m_w$ (gm)(H=F-G) | 11.30 | 16.90 | 19.10 |
| | Mass of container, $m_c$ (gm) (I) | 34.80 | 35.80 | 32.70 |
| | Mass of dry soil ms (gm) (J=G-I) | 169.30 | 166.50 | 151.00 |
| | Moisture Content, w=mw/ms (%) (K=H/Jx100) | 6.67 | 11.08 | 16.47 |
| | Dry density, $\rho_d = \rho_b/(1+w)$ (L=E(1+K/100)) | 1.45 | 1.81 | 1.29 |




| | |
|---|---|
| MDD | 1.81g/cc |
| OMC | 11.08% |

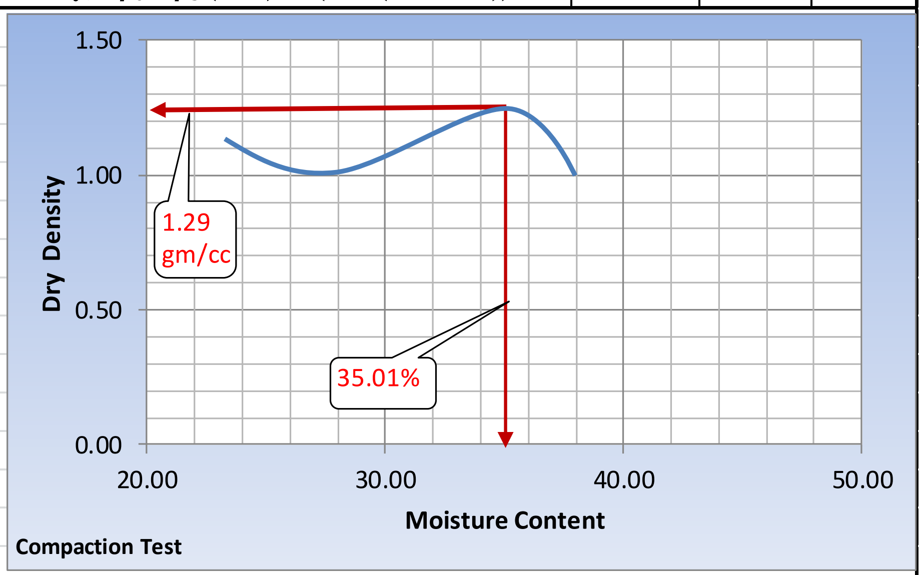
**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**COMPACTION (TEST METHOD AASHTO -180 - D )**

**Sub grade material**

| | |
|---|---|
| Sampled and Tested by:- Getu Tamiru | Sampled date:- Mar,20/2017 |
| Sample Station :- High deterioration(more severe) | Tested Date:- Apr.,23/2017 |
| Represent Stat.:-Average(0+460,1+870,3+360,4+710) | |

| | | | | |
|---|---|---|---|---|
| Density | Trial number | 1 | 2 | 3 |
| | Weight of wet soil + mold(gm) (A) | 3601 | 3667 | 3689 |
| | Weight of mold (gm) (B) | 1724 | 1726 | 1723 |
| | Weight of Wet soil ws (gm) (C=A-B) | 1877 | 1941 | 1966 |
| | Volume of mold v (cc) (D) | 943.00 | 943.00 | 943.00 |
| | Wet density of soil $\rho_{b=}$ws/v(gm/cc) (E=C/D) | 1.99 | 2.06 | 2.08 |
| Moisture | Container number | 30/43 | 31/31 | 8/38 |
| | Mass of wet soil + container (gm) (F) | 135.00 | 74.00 | 150.00 |
| | Mass of dry soil + container (gm) (G) | 113.00 | 63.00 | 121.00 |
| | Mass of water, $m_w$ (gm)(H=F-G) | 22.00 | 11.00 | 29.00 |
| | Mass of container, $m_c$ (gm) (I) | 27.00 | 17.00 | 17.00 |
| | Mass of dry soil ms (gm) (J=G-I) | 86.00 | 46.00 | 104.00 |
| | Moisture Content, w=mw/ms (%) (K=H/Jx100) | 35.01 | 23.91 | 27.88 |
| | Dry density, $\rho_d = \rho_b/(1+w)$ (L=E(1+K/100)) | 1.29 | 1.15 | 1.02 |




| | |
|---|---|
| MDD | 1.29g/cc |
| OMC | 35.01% |

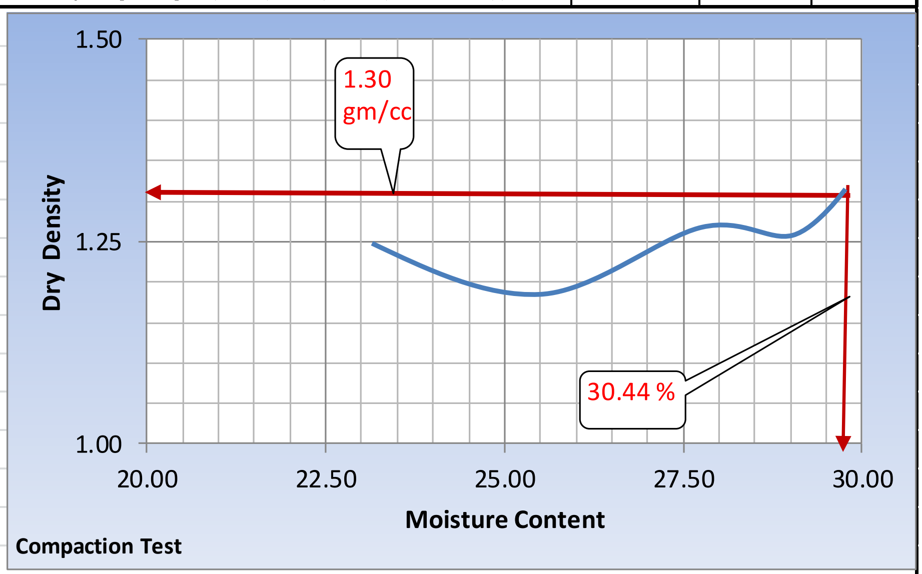
**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**COMPACTION (TEST METHOD AASHTO -180 - D )**

**Sub base material**

| | |
|---|---|
| Sampled and Tested by:- Getu Tamiru | Sampled date:- Mar,20/2017 |
| Sample Station :- Medium deterioration(severe) | Tested Date:- Apr.,23/2017 |
| Represent Stat.:-Average(0+010,1+580,2+120,2+750+3+870,4+86 | |

| | | 1 | 2 | 3 |
|---|---|---|---|---|
| Density | Trial number | 1 | 2 | 3 |
| | Weight of wet soil + mold(gm) (A) | 3175 | 3280 | 3325 |
| | Weight of mold (gm) (B) | 1725 | 1725 | 1725 |
| | Weight of Wet soil ws (gm) (C=A-B) | 1450 | 1555 | 1600 |
| | Volume of mold v (cc) (D) | 944.00 | 944.00 | 944.00 |
| | Wet density of soil $\rho_{b=}$ws/v(gm/cc) (E=C/D) | 1.54 | 1.65 | 1.69 |
| Moisture | Container number | 30/43 | 31/31 | 8/38 |
| | Mass of wet soil + container (gm) (F) | 89.00 | 77.00 | 89.00 |
| | Mass of dry soil + container (gm) (G) | 76.00 | 64.00 | 73.00 |
| | Mass of water, $m_w$ (gm)(H=F-G) | 13.00 | 13.00 | 16.00 |
| | Mass of container, $m_c$ (gm) (I) | 19.00 | 17.00 | 18.00 |
| | Mass of dry soil ms (gm) (J=G-I) | 57.00 | 47.00 | 55.00 |
| | Moisture Content, w=mw/ms (%) (K=H/Jx100) | 22.81 | 27.66 | 30.44 |
| | Dry density, $\rho_d = \rho_b/(1+w)$ (L=E(1+K/100)) | 1.25 | 1.29 | 1.30 |



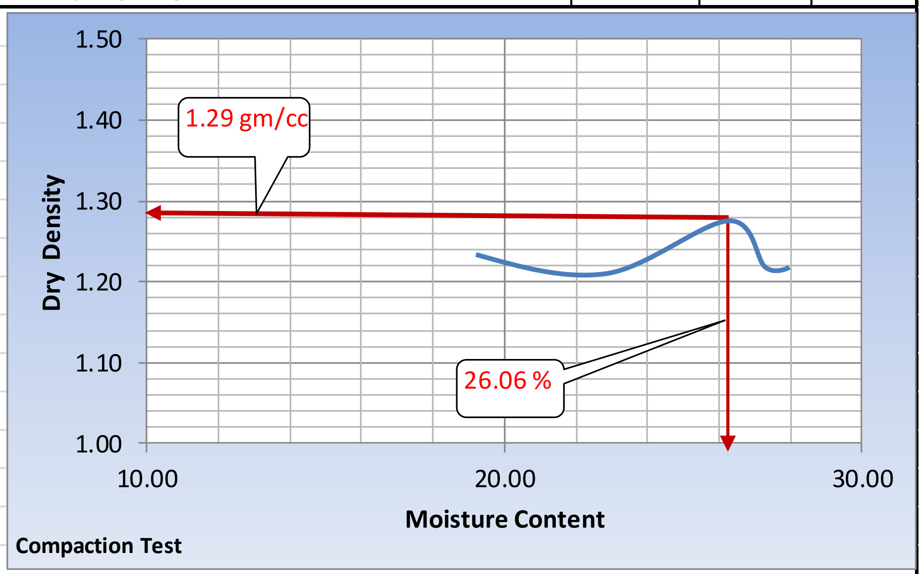

| | |
|---|---|
| MDD | 1.3g/cc |
| OMC | 30.44% |

**PROJECT NAME:-The effect of sub base and subgrade materials quality on pavement distress: A case of jimma town from Ajip to Gebrel church**

**COMPACTION (TEST METHOD AASHTO -180 - D )**

**Sub base material**

| | | | | |
|---|---|---|---|---|
| Sampled and Tested by:- Getu Tamiru | | Sampled date:- Mar,20/2017 | | |
| Sample Station :- Low deterioration(less severe) | | Tested Date:- Apr.,23/2017 | | |
| Represent Stat.:-Average(0+920,1+080,2+150,3+910,4+570) | | | | |
| Density | Trial number | 1 | 2 | 3 |
| | Weight of wet soil + mold(gm) (A) | 3300 | 3370 | 3390 |
| | Weight of mold (gm) (B) | 1725 | 1725 | 1725 |
| | Weight of Wet soil ws (gm) (C=A-B) | 1575 | 1645 | 1665 |
| | Volume of mold v (cc) (D) | 944.00 | 945.00 | 945.00 |
| | Wet density of soil $\rho_{b=}$ws/v(gm/cc) (E=C/D) | 1.67 | 1.74 | 1.76 |
| Moisture | Container number | 30/43 | 31/31 | 8/38 |
| | Mass of wet soil + container (gm) (F) | 83.00 | 104.00 | 77.00 |
| | Mass of dry soil + container (gm) (G) | 67.00 | 81.00 | 61.00 |
| | Mass of water, $m_w$ (gm)(H=F-G) | 16.00 | 23.00 | 16.00 |
| | Mass of container, $m_c$ (gm) (I) | 19.00 | 18.00 | 18.00 |
| | Mass of dry soil ms (gm) (J=G-I) | 48.00 | 63.00 | 43.00 |
| | Moisture Content, w=mw/ms (%) (K=H/Jx100) | 22.89 | 24.53 | 26.06 |
| | Dry density, $\rho_d = \rho_b/(1+w)$ (L=E(1+K/100)) | 1.36 | 1.40 | 1.29 |




| | |
|---|---|
| MDD | 1.29g/cc |
| OMC | 26.06% |

# APPENDEX E. CALIFORNIA BEARING RATIO

**Project title:-The effect of sub base and subgrade materials quality on flexible asphalt pavement distress**

| | | | |
|---|---|---|---|
| Date Sample: | Mar.10-2017 | Lab Test No | 2376.0 |
| Date soak: | Mar.22-2017 | Sampling Station: | Average Medium deterioration station |
| Date Tested: | Mar.23-2017 | Sapled by | Getu Tamiru |
| Purpose | Sub base | Tested by | Getu Tamiru |
| Sample taken from | Existing pavement | Sourse station | |
| | | Ring factor | 128,27N/DIV |

**CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Mold No. | | K1 | K1 | K2 | K2 | K3 | K3 |
| Mold + wet soil (g) | W1 | 10761 | 10954 | 11108 | 11236 | 11201 | 11315 |
| Mold (g ) | W2 | 6393 | 6393 | 6394 | 6394 | 6390 | 6390 |
| Wet soil (g) | W3=W1-W2 | 4368 | 4561 | 4714 | 4842 | 4811 | 4925 |
| Wet density (g / cm3) | Ww=W3/V | 2.06 | 2.15 | 2.22 | 2.28 | 2.27 | 2.32 |
| Dry density (g / cm3) | W=$W_w$/(100+m)*100 | 1.84 | 1.86 | 1.99 | 2.01 | 2.03 | 1.99 |
| Average | (Before + After) /2 | | | | | | |

**MOISTURE CONTENT DETERMINATION**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Container No. | | B8 | F5 | B5 | B11 | B12 | B2 |
| Wet soil + cont. | a | 262.69 | 282.94 | 260.44 | 260.46 | 246.06 | 272.00 |
| Dry soil + cont. | b | 239.89 | 250.89 | 238.35 | 234.63 | 224.84 | 246.91 |
| Container (g) | c | 41.00 | 41.19 | 44.30 | 41.64 | 42.29 | 45.59 |
| Dry soil (g) | d=b-c | 198.89 | 209.70 | 194.05 | 192.99 | 182.55 | 201.32 |
| Moisture (g) | e=a-b | 22.80 | 32.05 | 22.09 | 25.83 | 21.22 | 25.09 |
| Moisture cont. (%) | m=e/d*100 | 11.46 | 15.28 | 11.38 | 13.38 | 11.62 | 12.46 |

**PENETRATION TEST DATA**

| IETRATI | 10 BLOWS | | | | | | 30 BLOWS | | | | | | 65 BLOWS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bottom | | | Top | | | Bottom | | | Top | | | Bottom | | | Top | | |
| (mm) | Dial | LOAD | CBR % | Dial | LOAD | CBR % | Dial | LOAD | CBR % | Dial | LOAD | CBR % | Dial | LOAD | CBR % | Dial | LOAD | CBR % |
| | RDG | (Kn) | | RDG | (Kn) | | RDG | (Kn) | | RDG | (Kn) | | RDG | (Kn) | | RDG | (Kn) | |
| 0 | 0 | 0.00 | | 0 | 0.00 | | 0 | 0.00 | | 0 | 0.00 | | 0 | 0.00 | | 0 | 0.00 | |
| 0.64 | 6 | 0.77 | | 5 | 0.64 | | 5 | 0.64 | | 10 | 1.28 | | 9 | 1.15 | | 3 | 0.38 | |
| 1.27 | 11 | 1.41 | | 7 | 0.90 | | 12 | 1.54 | | 16 | 2.05 | | 17 | 2.18 | | 6 | 0.77 | |
| 1.91 | 15 | 1.92 | | 10 | 1.28 | | 20 | 2.57 | | 22 | 2.82 | | 25 | 3.21 | | 8 | 1.03 | |
| 2.54 | 18 | 2.31 | 17.31 | 12 | 1.54 | 11.54 | 28 | 3.59 | 26.92 | 27 | 3.46 | 25.96 | 30 | 3.85 | 28.85 | 11 | 1.41 | 10.58 |
| 3.18 | 21 | 2.69 | | 14 | 1.80 | | 36 | 4.62 | | 37 | 4.75 | | 36 | 4.62 | | 14 | 1.80 | |
| 3.81 | 23 | 2.95 | | 16 | 2.05 | | 44 | 5.64 | | 39 | 5.00 | | 41 | 5.26 | | 18 | 2.31 | |
| 4.45 | 26 | 3.34 | | 19 | 2.44 | | 52 | 6.67 | | 46 | 5.90 | | 46 | 5.90 | | 22 | 2.82 | |
| 5.08 | 28 | 3.59 | 17.96 | 21 | 2.69 | 13.47 | 60 | 7.70 | 38.48 | 53 | 6.80 | 33.99 | 51 | 6.54 | 32.71 | 25 | 3.21 | 16.03 |
| 7.62 | 31 | 3.98 | | 25 | 3.21 | | 75 | 9.62 | | 66 | 8.47 | | 60 | 7.70 | | 31 | 3.98 | |
| 10.16 | | | | | | | | | | | | | | | | | | |
| 12.70 | | | | | | | | | | | | | | | | | | |

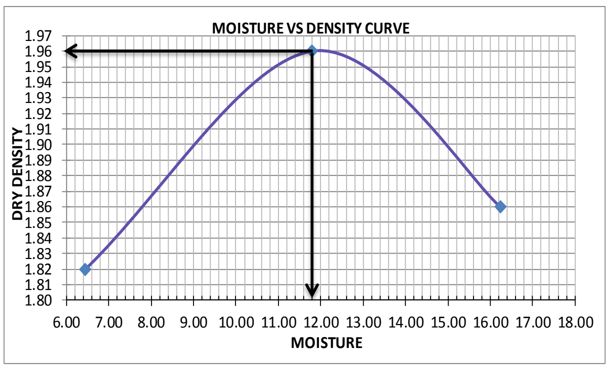
**SWELL**

| NO. OF BLOWS | 10 | 30 | 65 |
|---|---|---|---|
| RDG. BEFORE SOAKING | 0.06 | 0.06 | 0.05 |
| RDG. AFTER SOAKING | 0.26 | 0.15 | 0.39 |
| PERCENT SWELL | 0.172 | 0.077 | 0.292 |

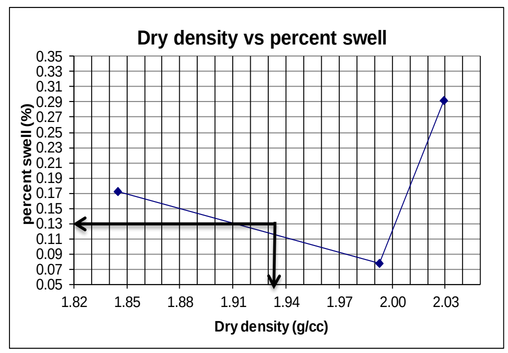
**Project title:-The effect of sub base and subgrade materials quality on flexible asphalt pavement distress**

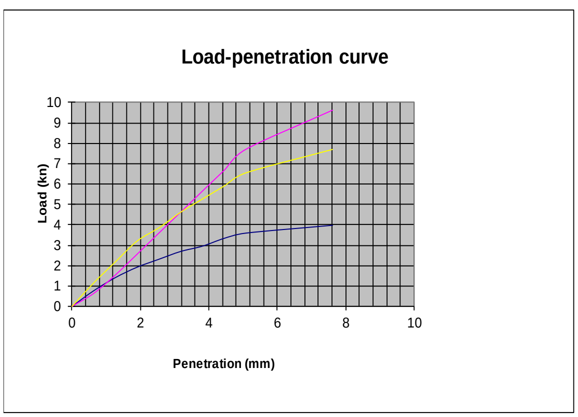
| | |
|---|---|
| **Date Sample:** | Mar.10-2017 |
| **Date soak:** | Mar.22-2017 |
| **Date Tested:** | Mar.23-2017 |
| **Purpose** | Sub base |
| **Sample taken from** | Existing pavement |

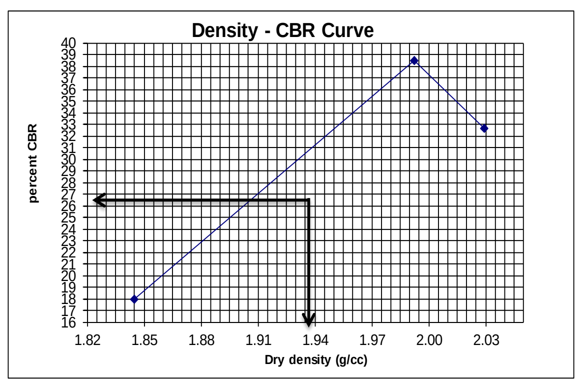
| | |
|---|---|
| **Lab Test No** | |
| **Sampling Station:** | verage Medium deterioration statio |
| **Sapled by** | Getu Tamiru |
| **Tested by** | Getu Tamiru |
| **Sourse station** | |
| **Ring factor** | 128,27N/DIV |




| | before soaking | | after soaking | |
|---|---|---|---|---|
| Blows | DD (g/cc) | Moisture % | DD (g/cc | Moisture % |
| 10.00 | 1.84 | 11.46 | 1.86 | 15.28 |
| 30.00 | 1.99 | 11.38 | 2.01 | 13.38 |
| 65.00 | 2.03 | 11.62 | 1.99 | 12.46 |




| | LOAD (KN) | | CBR(%) | | |
|---|---|---|---|---|---|
| Blows | 2.54mm | 5.08mm | 2.54mm | 5.08mm | Swell(%) |
| 10.00 | 2.31 | 3.59 | 17.31 | 17.96 | 0.17 |
| 30.00 | 3.59 | 7.70 | 26.92 | 38.48 | 0.08 |
| 65.00 | 3.85 | 6.54 | 28.85 | 32.71 | 0.29 |

| Blows | 10.00 | 30.00 | 65.00 |
|---|---|---|---|
| DD | 1.84 | 1.99 | 2.03 |
| Swell | 0.17 | 0.08 | 0.29 |

| Blows | dry density | CBR% |
|---|---|---|
| 10.00 | 1.84 | 18 |
| 30.00 | 1.99 | 38 |
| 65.00 | 2.03 | 33 |
| **CBR at 95%:** | **26.1 %** | |

# Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress

| | | | | |
|---|---|---|---|---|
| **Date Sample:** | 10 Mar.2017 | | **Lab Test No** | 033 |
| **Date soak:** | 22 Mar.2017 | | **Sampled by** | Getu Tamiru |
| **Date Tested:** | 23 Mar.2017 | | **Tested by** | Getu Tamiru |
| **Purpose** | sub base | | **Rep. station** | Average high deterioration station |

**CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Mold No. | | X1 | X1 | X2 | X2 | X3 | X3 |
| Mold + wet soil (g) | **W1** | 10322 | 10451 | 10461 | 10553 | 11092 | 11152 |
| Mold (g ) | **W2** | 6420 | 6420 | 6393 | 6393 | 6907 | 6907 |
| Wet soil (g) | **W3=W1-W2** | 3902 | 4031 | 4068 | 4160 | 4185 | 4245 |
| Wet density (g / cm3) | **Ww=W3/V** | 1.84 | 1.90 | 1.92 | 1.96 | 1.97 | 2.00 |
| Dry density (g / cm3) | **$W=W_w/(100+m)*100$** | 1.44 | 1.46 | 1.50 | 1.52 | 1.55 | 1.56 |
| Average | (Before + After) /2 | | | | | | |

**MOISTURE CONTENT DETERMINATION**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Container **No.** | | B10 | F1 | B15 | F2 | B18 | F4 |
| Wet soil + cont. (g) | **a** | 262.50 | 236.90 | 246.00 | 258.50 | 246.20 | 231.10 |
| Dry soil + cont. (g) | **b** | 214.40 | 192.90 | 202.10 | 209.70 | 203.70 | 190.20 |
| Container (g) | **c** | 41.70 | 44.10 | 45.10 | 42.70 | 45.00 | 44.90 |
| Dry soil (g) | **d=b-c** | 172.70 | 148.80 | 157.00 | 167.00 | 158.70 | 145.30 |
| Moisture (g) | **e=a-b** | 48.10 | 44.00 | 43.90 | 48.80 | 42.50 | 40.90 |
| Moisture cont. (%) | m=e/d*100 | 27.85 | 29.57 | 27.96 | 29.22 | 26.78 | 28.15 |

**PENETRATION TEST DATA**

| ENETRATIO | 10 BLOWS | | | | 30 BLOWS | | | | 65 BLOWS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (mm) | Dial | LOAD | CORRECTED | CBR % | Dial | LOAD | CORRECTED | CBR % | Dial | LOAD | CORRECTED | CBR % |
| | RDG | (Kn) | LOAD (Kn) | | RDG | (Kn) | LOAD (Kn) | | RDG | (Kn) | LOAD (Kn) | |
| 0 | 0 | 0.00 | | | 0 | 0.00 | | | 0 | 0.00 | | |
| 0.64 | 5 | 0.64 | | | 7 | 0.90 | | | 6 | 0.77 | | |
| 1.27 | 11 | 1.41 | | | 16 | 2.05 | | | 15 | 1.92 | | |
| 1.96 | 15 | 1.92 | | | 22 | 2.82 | | | 22 | 2.82 | | |
| 2.54 | 17 | 2.18 | 2.18 | 16.35 | 24 | 3.08 | 3.08 | 23.08 | 25 | 3.21 | 3.21 | 24.04 |
| 3.18 | 19 | 2.44 | | | 25 | 3.21 | | | 26 | 3.34 | | |
| 3.81 | 20 | 2.57 | | | 25 | 3.21 | | | 28 | 3.59 | | |
| 4.45 | 21 | 2.69 | | | 26 | 3.34 | | | 29 | 3.72 | | |
| 5.08 | 22 | 2.82 | 2.82 | 14.11 | 27 | 3.46 | 3.46 | 17.32 | 30 | 3.85 | 3.85 | 19.24 |
| 7.62 | 24 | 3.08 | | | 30 | 3.85 | | | 34 | 4.36 | | |
| 10.16 | | | | | | | | | | | | |
| 12.70 | | | | | | | | | | | | |

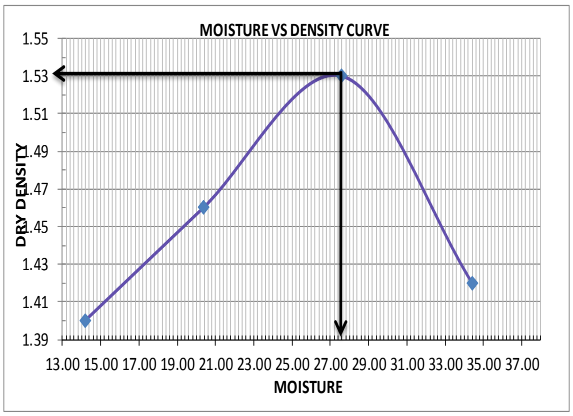
| | | | |
|---|---|---|---|
| NO. OF BLOWS | 10 | 30 | 65 |
| RDG. BEFORE SOAKING | 0.00 | 4.00 | 0.00 |
| RDG. AFTER SOAKING | 55.00 | 46.00 | 22.00 |
| | | | |

**Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress**

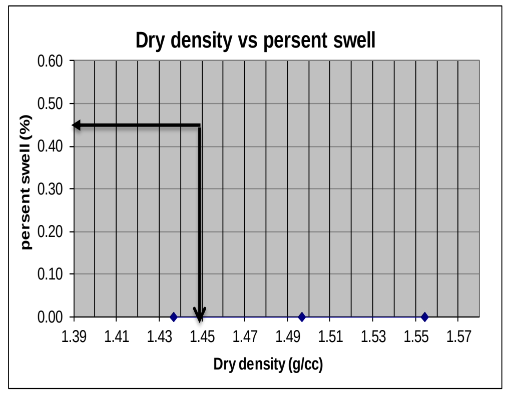
## CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193

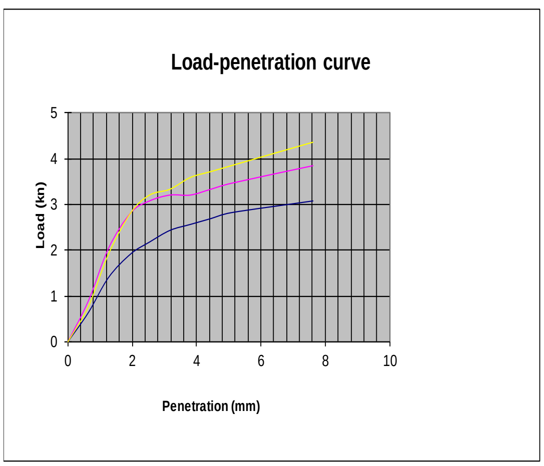
| | |
|---|---|
| **Date Sample:** | 10 Mar.2017 |
| **Date soak:** | 22 Mar.2017 |
| **Date Tested:** | 23 Mar.2017 |
| **Purpose** | sub base |

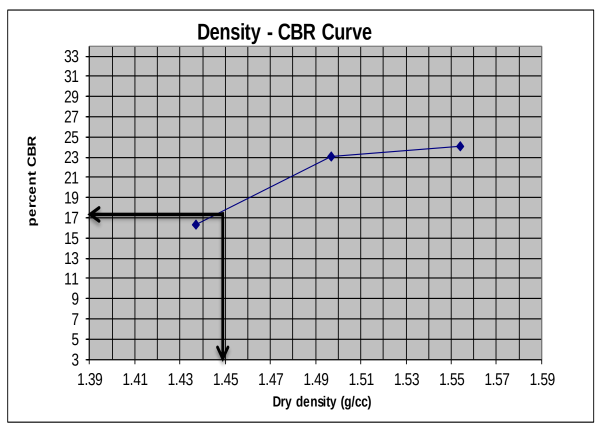
| | |
|---|---|
| **Lab Test No** | 033 |
| **Sampled by** | Getu Tamiru |
| **Tested by** | Getu Tamiru |
| **Rep. station** | Average high deterioration station |




| Blows | before soaking | | after soaking | |
|---|---|---|---|---|
| | DD (g/cc) | Moisture % | DD (g/cc | Moisture % |
| 10.00 | 1.44 | 27.85 | 1.46 | 29.57 |
| 30.00 | 1.50 | 27.96 | 1.52 | 29.22 |
| 65.00 | 1.55 | 26.78 | 1.56 | 28.15 |




| Blows | LOAD (KN) | | CBR(%) | | Swell(%) |
|---|---|---|---|---|---|
| | 2.54mm | 5.08mm | 2.54mm | 5.08mm | |
| 10.00 | 2.18 | 2.82 | 16.35 | 14.11 | 0.00 |
| 30.00 | 3.08 | 3.46 | 23.08 | 17.32 | 0.00 |
| 65.00 | 3.21 | 3.85 | 24.04 | 19.24 | 0.00 |

| Blows | dry density | CBR% |
|---|---|---|
| 10.00 | 1.44 | 16 |
| 30.00 | 1.50 | 23 |
| 65.00 | 1.55 | 24 |
| **CBR at 95%:** | | **21.5** |
| | | |

| | | | |
|---|---|---|---|
| Blows | 10.00 | 30.00 | 65.00 |
| DD | 1.44 | 1.50 | 1.55 |
| Swell | 0.00 | 0.00 | 0.00 |

**Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress**

| | | | | |
|---|---|---|---|---|
| **Date Sample:** | 10 Mar.2017 | | **Lab Test No** | 033 |
| **Date soak:** | 22 Mar.2017 | | **Sampled by** | Getu Tamiru |
| **Date Tested:** | 23 Mar.2017 | | **Tested by** | Getu Tamiru |
| **Purpose** | subgrade | | **Rep. station** | Average high deterioration station |

**CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Mold No. | | H1 | H1 | H2 | H2 | H3 | H3 |
| Mold + wet soil (g) | **W1** | 9976 | 10300 | 10240 | 10458 | 10452 | 10589 |
| Mold (g ) | **W2** | 6453 | 6453 | 6439 | 6439 | 6907 | 6907 |
| Wet soil (g) | **W3=W1-W2** | 3523 | 3847 | 3801 | 4019 | 3545 | 3682 |
| Wet density (g / cm3) | **Ww=W3/V** | 1.66 | 1.81 | 1.79 | 1.89 | 1.67 | 1.73 |
| Dry density (g / cm3) | **$W=W_w/(100+m)*100$** | 1.31 | -0.40 | 1.41 | -0.43 | 1.31 | -0.42 |
| Average | (Before + After) /2 | | | | | | |

**MOISTURE CONTENT DETERMINATION**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Container **No.** | | B19 | B12 | B16 | B13 | B3 | B14 |
| Wet soil + cont. (g) | **a** | 215.00 | 234.71 | 209.00 | 246.96 | 225.00 | 224.94 |
| Dry soil + cont. (g) | **b** | 179.00 | 0.00 | 173.00 | 0.00 | 186.00 | 0.00 |
| Container (g) | **c** | 46.00 | 42.22 | 41.00 | 45.95 | 43.00 | 44.18 |
| Dry soil (g) | **d=b-c** | 133.00 | -42.22 | 132.00 | -45.95 | 143.00 | -44.18 |
| Moisture (g) | **e=a-b** | 36.00 | 234.71 | 36.00 | 246.96 | 39.00 | 224.94 |
| Moisture cont. (%) | m=e/d*100 | 27.07 | -555.92 | 27.27 | -537.45 | 27.27 | -509.14 |

**PENETRATION TEST DATA**

| ENETRATIO | 10 BLOWS | | | | 30 BLOWS | | | | 65 BLOWS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (mm) | Dial | LOAD | CORRECTED | CBR % | Dial | LOAD | CORRECTED | CBR % | Dial | LOAD | CORRECTED | CBR % |
| | RDG | (Kn) | LOAD (Kn) | | RDG | (Kn) | LOAD (Kn) | | RDG | (Kn) | LOAD (Kn) | |
| 0 | 0 | 0.00 | | | 0 | 0.00 | | | 0 | 0.00 | | |
| 0.64 | 6 | 0.33 | | | 10 | 0.55 | | | 25 | 1.38 | | |
| 1.27 | 10 | 0.55 | | | 11 | 0.61 | | | 39 | 2.15 | | |
| 1.96 | 12 | 0.66 | | | 13 | 0.72 | | | 48 | 2.64 | | |
| 2.54 | 13 | 0.72 | 0.72 | 5.37 | 14 | 0.77 | 0.77 | 5.78 | 55 | 3.03 | 3.03 | 22.72 |
| 3.18 | 14 | 0.77 | | | 16 | 0.88 | | | 60 | 3.31 | | |
| 3.81 | 16 | 0.88 | | | 17 | 0.94 | | | 65 | 3.58 | | |
| 4.45 | 16 | 0.88 | | | 18 | 0.99 | | | 68 | 3.75 | | |
| 5.08 | 17 | 0.94 | 0.94 | 4.68 | 19 | 1.05 | 1.05 | 5.23 | 73 | 4.02 | 4.02 | 20.11 |
| 7.62 | 18 | 0.99 | | | 24 | 1.32 | | | 87 | 4.79 | | |
| 10.16 | | | | | | | | | | | | |
| 12.70 | | | | | | | | | | | | |

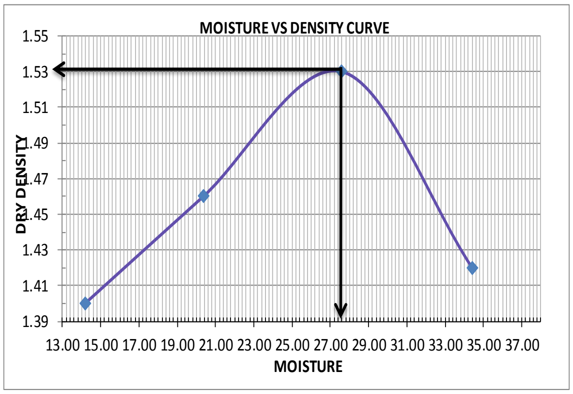
| | | | |
|---|---|---|---|
| NO. OF BLOWS | 10 | 30 | 65 |
| RDG. BEFORE SOAKING | 0.00 | 4.00 | 0.00 |
| RDG. AFTER SOAKING | 74.00 | 66.00 | 53.00 |
| | 0.64 | 0.53 | 0.46 |

# Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress

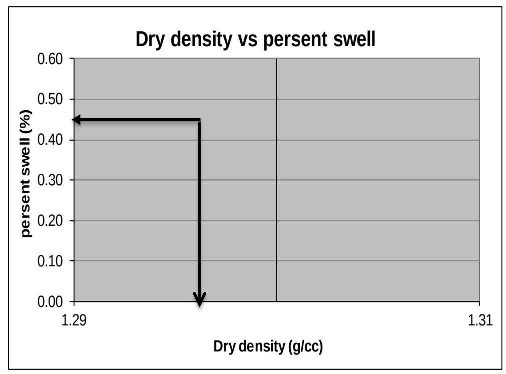
## CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193

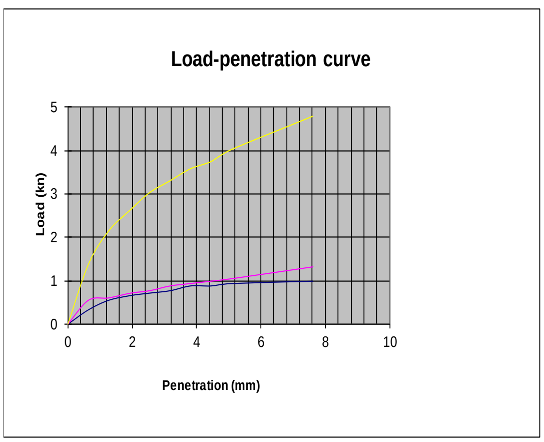
| | |
|---|---|
| **Date Sample:** | 10 Mar.2017 |
| **Date soak:** | 22 Mar.2017 |
| **Date Tested:** | 23 Mar.2017 |
| **Purpose** | subgrade |

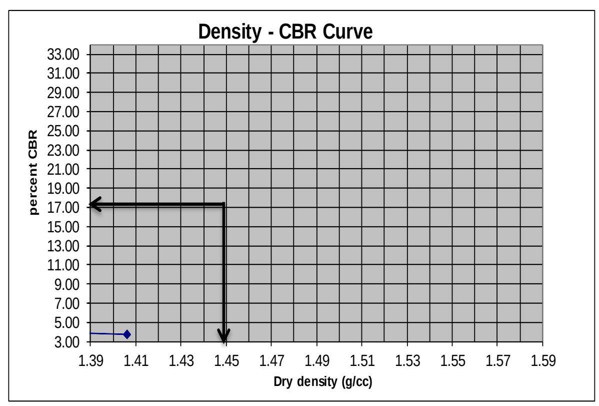
| | |
|---|---|
| **Lab Test No** | 033 |
| **Sampled by** | Getu Tamiru |
| **Tested by** | Getu Tamiru |
| **Rep. station** | Average high deterioration station |




| | before soaking | | after soaking | |
|---|---|---|---|---|
| Blows | DD (g/cc) | Moisture % | DD (g/cc | Moisture % |
| 10.00 | 1.31 | 27.07 | -0.40 | -555.92 |
| 30.00 | 1.41 | 27.27 | -0.43 | -537.45 |
| 65.00 | 1.31 | 27.27 | -0.42 | -509.14 |




| | LOAD (KN) | | CBR(%) | | |
|---|---|---|---|---|---|
| Blows | 2.54mm | 5.08mm | 2.54mm | 5.08mm | Swell(%) |
| 10.00 | 0.72 | 0.94 | 5.37 | 4.68 | 0.64 |
| 30.00 | 0.77 | 1.05 | 5.78 | 5.23 | 0.53 |
| 65.00 | 3.03 | 4.02 | 22.72 | 20.11 | 0.46 |

| Blows | dry density | CBR% |
|---|---|---|
| 10.00 | 1.31 | 4.50 |
| 30.00 | 1.41 | 3.80 |
| 65.00 | 1.31 | 4.30 |
| **CBR at 95%:** | | **4.20** |

| | | | |
|---|---|---|---|
| Blows | 10.00 | 30.00 | 65.00 |
| DD | 1.31 | 1.41 | 1.31 |

**Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress**

| | | | |
|---|---|---|---|
| **Date Sample:** | 10 Mar.2017 | **Lab Test No** | 14 |
| **Date soak:** | 22 Mar.2017 | **Sampled by** | Getu Tamiru |
| **Date Tested:** | 23 Mar.2017 | **Tested by** | Getu Tamiru |
| **Purpose** | subgrade | **Rep. station** | Average medium deterioration stations |

**CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Mold No. | | L1 | L1 | L2 | L2 | L3 | L3 |
| Mold + wet soil (g) | **W1** | 9802 | 10133 | 10359 | 10484 | 10446 | 10547 |
| Mold (g ) | **W2** | 6414 | 6414 | 6478 | 6478 | 6449 | 6449 |
| Wet soil (g) | **W3=W1-W2** | 3388 | 3719 | 3881 | 4006 | 3997 | 4098 |
| Wet density (g / cm3) | **Ww=W3/V** | 1.60 | 1.75 | 1.83 | 1.89 | 1.88 | 1.93 |
| Dry density (g / cm3) | **$W=W_w/(100+m)*100$** | 1.23 | 1.26 | 1.40 | 1.41 | 1.45 | 1.47 |
| Average | (Before + After) /2 | | | | | | |

**MOISTURE CONTENT DETERMINATION**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Container **No.** | | B1 | C3 | B2 | B15 | B3 | B19 |
| Wet soil + cont. (g) | **a** | 232.78 | 246.97 | 237.51 | 222.54 | 224.54 | 211.19 |
| Dry soil + cont. (g) | **b** | 189.96 | 189.52 | 192.68 | 178.04 | 183.00 | 171.65 |
| Container (g) | **c** | 45.02 | 41.44 | 45.56 | 45.06 | 43.13 | 46.25 |
| Dry soil (g) | **d=b-c** | 144.94 | 148.08 | 147.12 | 132.98 | 139.87 | 125.40 |
| Moisture (g) | **e=a-b** | 42.82 | 57.45 | 44.83 | 44.50 | 41.54 | 39.54 |
| Moisture cont. (%) | m=e/d*100 | 29.54 | 38.80 | 30.47 | 33.46 | 29.70 | 31.53 |

**PENETRATION TEST DATA**

| PENETRATION | 10 BLOWS | | | | 30 BLOWS | | | | 65 BLOWS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (mm) | Dial | LOAD | CORRECTED | CBR % | Dial | LOAD | CORRECTED | CBR % | Dial | LOAD | CORRECTED | CBR % |
| | RDG | (Kn) | LOAD (Kn) | | RDG | (Kn) | LOAD (Kn) | | RDG | (Kn) | LOAD (Kn) | |
| 0 | 0 | 0.00 | | | 0 | 0.00 | | | 0 | 0.00 | | |
| 0.64 | 7 | 0.39 | | | 19 | 1.05 | | | 20 | 1.10 | | |
| 1.27 | 11 | 0.61 | | | 28 | 1.54 | | | 31 | 1.71 | | |
| 1.96 | 12 | 0.66 | | | 33 | 1.82 | | | 36 | 1.98 | | |
| 2.54 | 13 | 0.72 | 0.72 | 5.37 | 37 | 2.04 | 2.04 | 15.28 | 40 | 2.20 | 2.20 | 16.52 |
| 3.18 | 14 | 0.77 | | | 38 | 2.09 | | | 43 | 2.37 | | |
| 3.81 | 15 | 0.83 | | | 41 | 2.26 | | | 45 | 2.48 | | |
| 4.45 | 15 | 0.83 | | | 43 | 2.37 | | | 48 | 2.64 | | |
| 5.08 | 16 | 0.88 | 0.88 | 4.41 | 44 | 2.42 | 2.42 | 12.12 | 51 | 2.81 | 2.81 | 14.05 |
| 7.62 | 18 | 0.99 | | | 47 | 2.59 | | | 55 | 3.03 | | |
| 10.16 | | | | | | | | | | | | |
| 12.70 | | | | | | | | | | | | |

**SWELL**

| NO. OF BLOWS | 10 | 30 | 65 |
|---|---|---|---|
| RDG. BEFORE SOAKING | 5.00 | 4.00 | 0.00 |
| RDG. AFTER SOAKING | 79.00 | 62.00 | 44.00 |
| PERCENT SWELL | 0.64 | 0.50 | 0.38 |

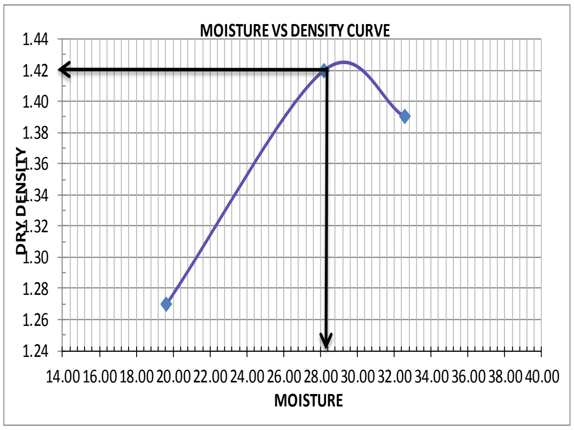
**REMARK :**

**Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress**

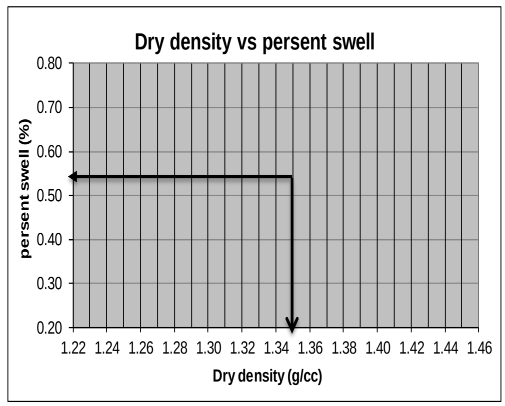
## CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193

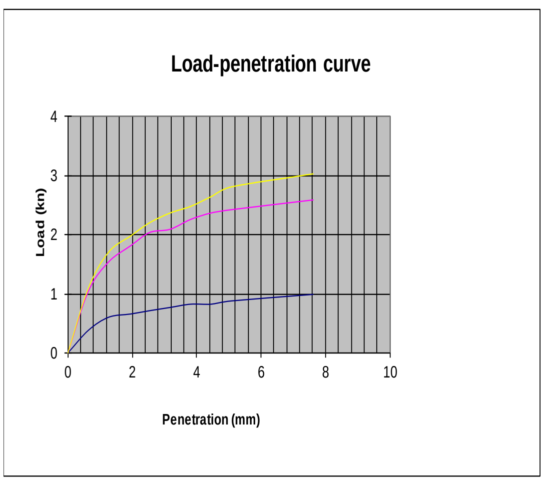
| | |
|---|---|
| **Date Sample:** | 10 Mar.2017 |
| **Date soak:** | 22 Mar.2017 |
| **Date Tested:** | 23 Mar.2017 |
| **Purpose** | subgrade |

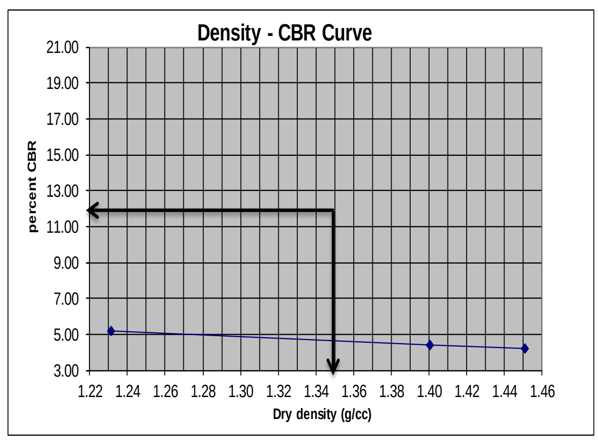
| | |
|---|---|
| **Lab Test No** | 14 |
| **Sampled by** | Getu Tamiru |
| **Tested by** | Getu Tamiru |
| **Rep. station** | Average medium deterioration stations |




| | before soaking | | after soaking | |
|---|---|---|---|---|
| Blows | DD (g/cc) | Moisture % | DD (g/cc | Moisture % |
| 10.00 | 1.23 | 29.54 | 1.26 | 38.80 |
| 30.00 | 1.40 | 30.47 | 1.41 | 33.46 |
| 65.00 | 1.45 | 29.70 | 1.47 | 31.53 |




| | LOAD (KN) | | CBR(%) | | |
|---|---|---|---|---|---|
| Blows | 2.54mm | 5.08mm | 2.54mm | 5.08mm | Swell(%) |
| 10.00 | 0.72 | 0.88 | 5.37 | 4.41 | 0.64 |
| 30.00 | 2.04 | 2.42 | 15.28 | 12.12 | 0.50 |
| 65.00 | 2.20 | 2.81 | 16.52 | 14.05 | 0.38 |

| | | | |
|---|---|---|---|
| Blows | 10.00 | 30.00 | 65.00 |
| DD | 1.23 | 1.40 | 1.45 |
| | | | |

| Blows | dry density | CBR% |
|---|---|---|
| 10.00 | 1.23 | 5.20 |
| 30.00 | 1.40 | 4.40 |
| 65.00 | 1.45 | 4.20 |
| **CBR at 95%:** | **4.60** | |
| | | |

**Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress**

| | | | |
|---|---|---|---|
| **Date Sample:** | 10 Mar.2017 | **Lab Test No** | 033 |
| **Date soak:** | 22 Mar.2017 | **Sampled by** | Getu Tamiru |
| **Date Tested:** | 23 Mar.2017 | **Tested by** | Getu Tamiru |
| **Purpose** | Subgrade | **Rep. station** | Average Low Deterioration stations |

**CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Mold No. | | G1 | G1 | G2 | G2 | G3 | G3 |
| Mold + wet soil (g) | **W1** | 10124 | 10311 | 10282 | 10450 | 10430 | 10570 |
| Mold (g ) | **W2** | 6449 | 6449 | 6451 | 6451 | 6437 | 6437 |
| Wet soil (g) | **W3=W1-W2** | 3675 | 3862 | 3831 | 3999 | 3993 | 4133 |
| Wet density (g / cm3) | **Ww=W3/V** | 1.73 | 1.82 | 1.80 | 1.88 | 1.88 | 1.95 |
| Dry density (g / cm3) | **$W=W_w/(100+m)*100$** | 1.32 | 1.32 | 1.39 | 1.41 | 1.44 | 1.48 |
| Average | (Before + After) /2 | | | | | | |

**MOISTURE CONTENT DETERMINATION**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Container No. | | C2 | B6 | C4 | B8 | B10 | B4 |
| Wet soil + cont. (g) | **a** | 248.73 | 269.20 | 262.00 | 237.48 | 216.00 | 214.60 |
| Dry soil + cont. (g) | **b** | 200.44 | 207.49 | 212.00 | 187.81 | 175.00 | 173.66 |
| Container (g) | **c** | 46.88 | 45.09 | 46.00 | 40.92 | 41.00 | 44.55 |
| Dry soil (g) | **d=b-c** | 153.56 | 162.40 | 166.00 | 146.89 | 134.00 | 129.11 |
| Moisture (g) | **e=a-b** | 48.29 | 61.71 | 50.00 | 49.67 | 41.00 | 40.94 |
| Moisture cont. (%) | m=e/d*100 | 31.45 | 38.00 | 30.12 | 33.81 | 30.60 | 31.71 |

**PENETRATION TEST DATA**

| ENETRATIO | 10 BLOWS | | | | 30 BLOWS | | | | 65 BLOWS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (mm) | Dial | LOAD | CORRECTED | CBR % | Dial | LOAD | CORRECTED | CBR % | Dial | LOAD | CORRECTED | CBR % |
| | RDG | (Kn) | LOAD (Kn) | | RDG | (Kn) | LOAD (Kn) | | RDG | (Kn) | LOAD (Kn) | |
| 0 | 0 | 0.00 | | | 0 | 0.00 | | | 0 | 0.00 | | |
| 0.64 | 11 | 0.61 | | | 18 | 0.99 | | | 16 | 0.88 | | |
| 1.27 | 16 | 0.88 | | | 30 | 1.65 | | | 30 | 1.65 | | |
| 1.96 | 19 | 1.05 | | | 36 | 1.98 | | | 36 | 1.98 | | |
| 2.54 | 21 | 1.16 | 1.16 | 8.67 | 39 | 2.15 | 2.15 | 16.11 | 40 | 2.20 | 2.20 | 16.52 |
| 3.18 | 21 | 1.16 | | | 39 | 2.15 | | | 41 | 2.26 | | |
| 3.81 | 21 | 1.16 | | | 40 | 2.20 | | | 44 | 2.42 | | |
| 4.45 | 21 | 1.16 | | | 41 | 2.26 | | | 46 | 2.53 | | |
| 5.08 | 22 | 1.21 | 1.21 | 6.06 | 42 | 2.31 | 2.31 | 11.57 | 48 | 2.64 | 2.64 | 13.22 |
| 7.62 | 24 | 1.32 | | | 45 | 2.48 | | | 57 | 3.14 | | |
| 10.16 | | | | | | | | | | | | |
| 12.70 | | | | | | | | | | | | |

**SWELL**

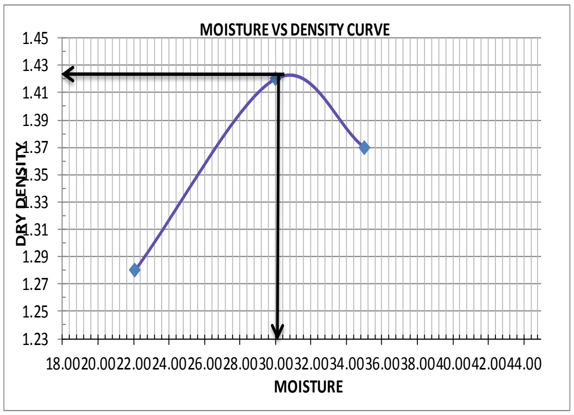
| | | | |
|---|---|---|---|
| NO. OF BLOWS | 10 | 30 | 65 |
| RDG. BEFORE SOAKING | 0.00 | 0.40 | 0.00 |
| RDG. AFTER SOAKING | 89.00 | 60.00 | 45.00 |
| PERCENT SWELL | 0.76 | 0.51 | 0.39 |

**Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress**

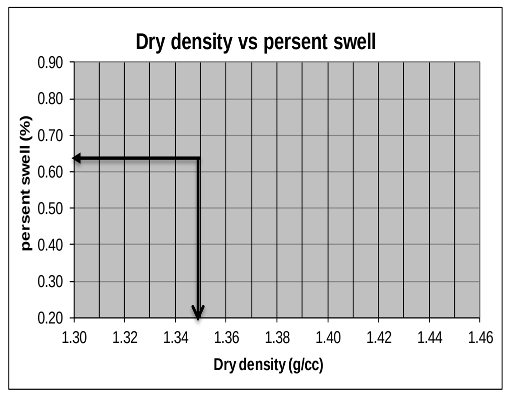
## CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193

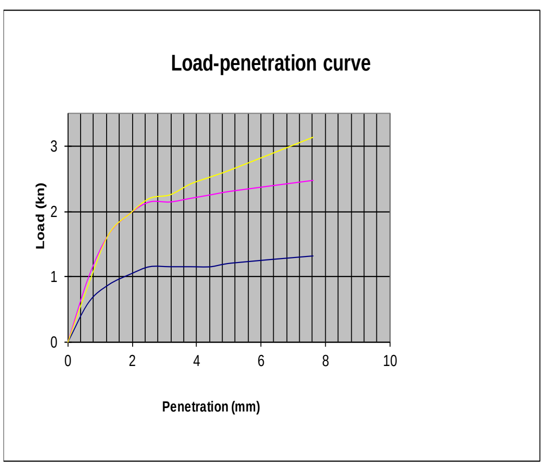
| | |
|---|---|
| **Date Sample:** | 10 Mar.2017 |
| **Date soak:** | 22 Mar.2017 |
| **Date Tested:** | 23 Mar.2017 |
| **Purpose** | Subgrade |

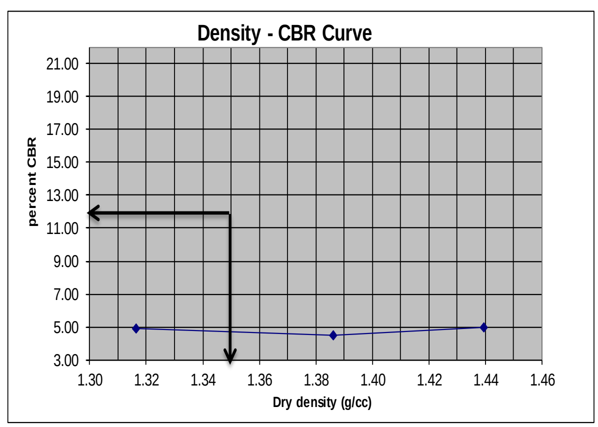
| | |
|---|---|
| **Lab Test No** | 033 |
| **Sampled by** | Getu Tamiru |
| **Tested by** | Getu Tamiru |
| **Rep. station** | Average Low Deterioration stations |




| | before soaking | | after soaking | |
|---|---|---|---|---|
| Blows | DD (g/cc) | Moisture % | DD (g/cc | Moisture % |
| 10.00 | 1.32 | 31.45 | 1.32 | 38.00 |
| 30.00 | 1.39 | 30.12 | 1.41 | 33.81 |
| 65.00 | 1.44 | 30.60 | 1.48 | 31.71 |




| | LOAD (KN) | | CBR(%) | | |
|---|---|---|---|---|---|
| Blows | 2.54mm | 5.08mm | 2.54mm | 5.08mm | Swell(%) |
| 10.00 | 1.16 | 1.21 | 8.67 | 6.06 | 0.76 |
| 30.00 | 2.15 | 2.31 | 16.11 | 11.57 | 0.51 |
| 65.00 | 2.20 | 2.64 | 16.52 | 13.22 | 0.39 |

| Blows | 10.00 | 30.00 | 65.00 |
|---|---|---|---|
| DD | 1.32 | 1.39 | 1.44 |
| | | | |

| Blows | dry density | CBR% |
|---|---|---|
| 10.00 | 1.32 | 4.90 |
| 30.00 | 1.39 | 4.50 |
| 65.00 | 1.44 | 5.00 |
| **CBR at 95%:** | **4.80** | |
| | | |

**Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress**

| | |
|---|---|
| Date Sample: | 5/3/2012 |
| Date soak: | 8/3/2012 |
| Date Tested: | 12/3/2012 |
| Purpose | Sub base |
| Sample taken from | Road way |

| | |
|---|---|
| Lab Test No | 24.0 |
| Sampling Station: | Getu Tamiru |
| Visual Description | Getu Tamiru |
| Rep. station | Average low deterioration stations |
| Sourse station | |
| Ring factor | 128,27N/DIV |

**CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Mold No. | | N1 | N1 | N2 | N2 | N3 | N3 |
| Mold + wet soil (g) | W1 | 10838 | 10995 | 11152 | 11238 | 11160 | 11239 |
| Mold (g ) | W2 | 6405 | 6405 | 6425 | 6425 | 6431 | 6431 |
| Wet soil (g) | W3=W1-W2 | 4433 | 4590 | 4727 | 4813 | 4729 | 4808 |
| Wet density (g / cm3) | Ww=W3/V | 2.09 | 2.16 | 2.23 | 2.27 | 2.23 | 2.26 |
| Dry density (g / cm3) | $W=W_w/(100+m)*100$ | 1.82 | 1.85 | 1.93 | 1.91 | 1.93 | 1.94 |
| Average | (Before + After) /2 | | | | | | |

**MOISTURE CONTENT DETERMINATION**

| SOAKING CONDITION | | 10 BLOWS | | 30 BLOWS | | 65 BLOWS | |
|---|---|---|---|---|---|---|---|
| | | BEFORE | AFTER | BEFORE | AFTER | BEFORE | AFTER |
| Container No. | | B13 | B8 | F2 | B6 | B8 | B11 |
| Wet soil + cont. | a | 270.72 | 209.98 | 290.14 | 250.35 | 271.81 | 296.71 |
| Dry soil + cont. | b | 242.09 | 185.31 | 257.69 | 218.09 | 240.72 | 260.90 |
| Container (g) | c | 45.97 | 40.98 | 42.80 | 45.04 | 41.00 | 41.62 |
| Dry soil (g) | d=b-c | 196.12 | 144.33 | 214.89 | 173.05 | 199.72 | 219.28 |
| Moisture (g) | e=a-b | 28.63 | 24.67 | 32.45 | 32.26 | 31.09 | 35.81 |
| Moisture cont. (%) | m=e/d*100 | 14.60 | 17.09 | 15.10 | 18.64 | 15.57 | 16.33 |

**PENETRATION TEST DATA**

| IETRATI | 10 BLOWS | | | | | | 30 BLOWS | | | | | | 65 BLOWS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bottom | | | Top | | | Bottom | | | Top | | | Bottom | | | Top | | |
| (mm) | Dial | LOAD | CBR % | Dial | LOAD | CBR % | Dial | LOAD | CBR % | Dial | LOAD | CBR % | Dial | LOAD | CBR % | Dial | LOAD | CBR % |
| | RDG | (Kn) | | RDG | (Kn) | | RDG | (Kn) | | RDG | (Kn) | | RDG | (Kn) | | RDG | (Kn) | |
| 0 | 0 | 0.00 | | 0 | 0.00 | | 0 | 0.00 | | 0 | 0.00 | | 0 | 0.00 | | 0 | 0.00 | |
| 0.64 | 15 | 1.92 | | 0 | 0.00 | | 17 | 2.18 | | 0 | 0.00 | | 11 | 1.41 | | 0 | 0.00 | |
| 1.27 | 16 | 2.05 | | 0 | 0.00 | | 23 | 2.95 | | 0 | 0.00 | | 19 | 2.44 | | 0 | 0.00 | |
| 1.91 | 18 | 2.31 | | 0 | 0.00 | | 28 | 3.59 | | 0 | 0.00 | | 25 | 3.21 | | 0 | 0.00 | |
| 2.54 | 20 | 2.57 | 19.23 | 0 | 0.00 | 0.00 | 30 | 3.85 | 28.85 | 0 | 0.00 | 0.00 | 28 | 3.59 | 26.92 | 0 | 0.00 | 0.00 |
| 3.18 | 21 | 2.69 | | 0 | 0.00 | | 33 | 4.23 | | 0 | 0.00 | | 31 | 3.98 | | 0 | 0.00 | |
| 3.81 | 23 | 2.95 | | 0 | 0.00 | | 35 | 4.49 | | 0 | 0.00 | | 33 | 4.23 | | 0 | 0.00 | |
| 4.45 | 24 | 3.08 | | 0 | 0.00 | | 37 | 4.75 | | 0 | 0.00 | | 35 | 4.49 | | 0 | 0.00 | |
| 5.08 | 25 | 3.21 | 16.03 | 0 | 0.00 | 0.00 | 40 | 5.13 | 25.65 | 0 | 0.00 | 0.00 | 37 | 4.75 | 23.73 | 0 | 0.00 | 0.00 |
| 7.62 | 28 | 3.59 | | 0 | 0.00 | | 43 | 5.52 | | 0 | 0.00 | | 40 | 5.13 | | 0 | 0.00 | |
| 10.16 | | | | | | | | | | | | | | | | | | |
| 12.70 | | | | | | | | | | | | | | | | | | |

**SWELL**

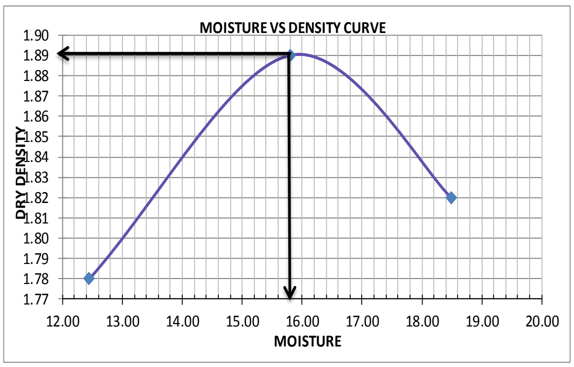
| NO. OF BLOWS | 10 | 30 | 65 |
|---|---|---|---|
| RDG. BEFORE SOAKING | 0.05 | 0.05 | 0.05 |
| RDG. AFTER SOAKING | 0.88 | 0.55 | 0.62 |
| | | | |

**Title name:- the effect of sub base and subgrade materials quality on flexible pavement distress**

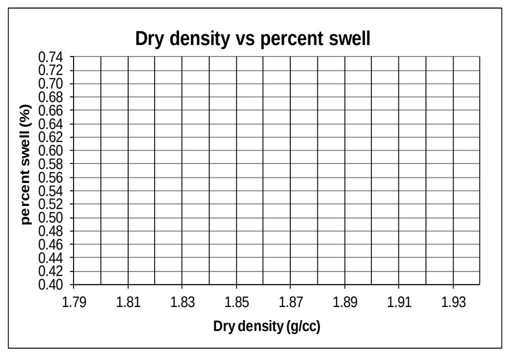
## CALIFORNIA BEARING RATIO - DATA Test method : AASHTO T-193

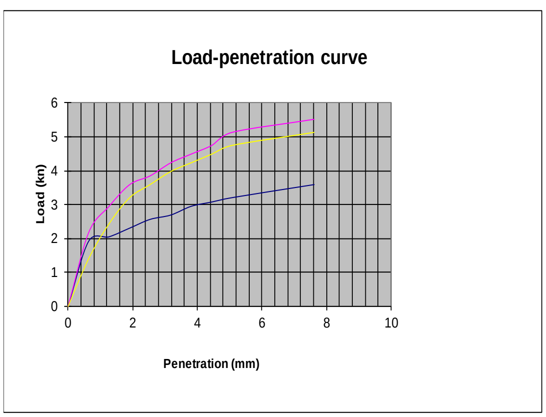
| | |
|---|---|
| **Date Sample:** | 10 Mar.2017 |
| **Date soak:** | 22 Mar.2017 |
| **Date Tested:** | 23 Mar.2017 |
| **Purpose** | sub base |
| **Sample taken from** | Road way |

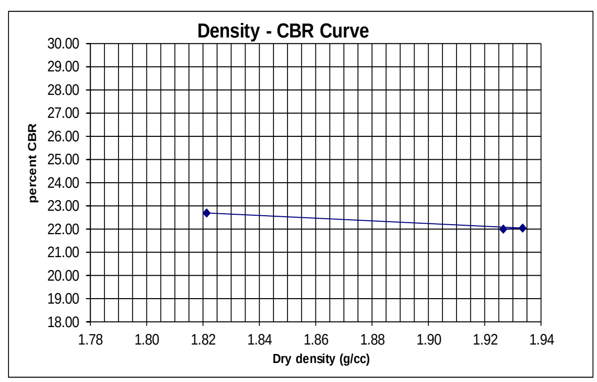
| | |
|---|---|
| **Lab Test No** | 24.00 |
| **Sampled by** | Getu Tamiru |
| **Tested by** | Getu Tamiru |
| **Rep. station** | Average low deterioration stations |
| **Course station** | |
| **Ring . Factor** | 128,27N/DIV |




| | before soaking | | after soaking | |
|---|---|---|---|---|
| Blows | DD (g/cc) | Moisture % | DD (g/cc | Moisture % |
| 10.00 | 1.82 | 14.60 | 1.85 | 17.09 |
| 30.00 | 1.93 | 15.10 | 1.91 | 18.64 |
| 65.00 | 1.93 | 15.57 | 1.94 | 16.33 |




| | LOAD (KN) | | CBR(%) | | |
|---|---|---|---|---|---|
| Blows | 2.54mm | 5.08mm | 2.54mm | 5.08mm | Swell(%) |
| 10.00 | 2.57 | 3.21 | 19.23 | 16.03 | 0.00 |
| 30.00 | 3.85 | 5.13 | 28.85 | 25.65 | 0.00 |
| 65.00 | 3.59 | 4.75 | 26.92 | 23.73 | 0.00 |

| Blows | dry density | CBR% |
|---|---|---|
| 10.00 | 1.82 | 22.68 |
| 30.00 | 1.93 | 22.04 |
| 65.00 | 1.93 | 22.00 |
| **CBR at 95%:** | **22.24** | |
| | | |

| Blows | 10.00 | 30.00 | 65.00 |
|---|---|---|---|
| DD | 1.82 | 1.93 | 1.93 |
| | | | |

# APPENDEX F. PHOTOGRAPHS OF LABORATORY TEST


Laboratory test photo captured date10-04-2017 @6:00 p.m.


Laboratory test of preparation for particle size analysis (photo captured date10-04-2017 @3:00 p.m)

Laboratory test after particle size analysis (photo captured date10-04-2017 @3:00 p.m)

Laboratory test of Atterberg's limit (photo captured date10-04-2017 @5:00 p.m)

Laboratory test photo captured date10-04-2017 @4:00 p.m.