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HIGHWAY ENGINEERING CHAIR

EVALUATION OF PAVEMENT DISTRESS FOR ASPHALT PAVEMENT USING PAVEMENT CONDITION INDEX: CASE STUDY FROM ADAMA TO AWASH ARBA

By

ASHEBIR BELETE

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfilment of the Requirements for the Degree of Master Science in Civil Engineering. (Highway Engineering Stream)

October, 2016

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Advisor: Dr.-Ing Esayas Alemayehu (PhD)

Co-Advisor: Mr Fikadu Kitessa (MSc)

October, 2016

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DECLARATION

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

	Signature	Date
Ashebir Belete (Student)	___________________	___________________

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

Name of Main advisor	signature	Date
Dr.-Ing Esayas Alemayehu (PhD)	________________	_____________
Name of Co-Advisor	**signature**	**Date**
Engr. Fikadu Kitessa (MSc)	______________	_____________

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Abstract

Pavement distress is a common problem for an opening road network and this distress is caused due to overloading of vehicles, poor maintenance, rapid traffic growth and improper design and implementation. This research study focused in Adama to Awash-Arba road section. The main objective of this research work was to evaluate the pavement distress using pavement condition index for the road section from Adama to Awash Arba. In order to achieve the desired objectives, a systematic methodology was performed which include field survey to capture the road surface condition such as type of distress, level of severity and quantity on each 1000metre sample unit and laboratory test was performed for failed and serious pavement condition. The pavement condition survey along the selected road shows that it was affected by different failure type such as alligator cracking, bleeding, block cracking, corrugation, depression, edge cracking, longitudinal and transverse cracking, patching, polished aggregate, potholes, railroad crossing, rutting and swell. The result of the research show that the PCI value range from 8 to 97.1 and this shows that all section of the road have all types of pavement condition rating (Good, Satisfactory, Fair, Very Poor, Poor, Serious and Failed) in which 12.12% good, 9.09% satisfactory, 18.18% fair, 21.21% poor, 18.18% very poor, 18.18% serious and 3.03% was failed. Based on the pavement condition rating, seven soil samples was collected for the failed and serious road section using manual hand auger. Samples were air-dried before taken to laboratory test determination of subgrade soil.

The soil samples collected were analyzed based on the geotechnical analysis: Gradation, Atterberg limit, Standard proctor test and California bearing ratio (CBR), analysis has been carried out for failed and serious pavement condition rating for the subgrade soil. For subgrade soil the liquid limit varies from 33.02% -44.48% and Plasticity index from 11.3% - 25.56% According to ERA manual, soils with LL< 50% and PI > 25% are suitable subgrade materials so all station are good. The soils were classified by ASSHTO under the A-6 and A-7-6 category which showed that the soils were fair to poor as a sub-grade material. The soaked CBR values of subgrade soil materials are between 7.9% -10.4% so according to ERA manual this quarry site soil are satisfy suitability property of natural subgrade soils. Therefore, from the laboratory test results the subgrade soil was not the cause of pavement failure for failed and serious pavement condition rating.

According to the pavement condition survey the road section from Adama to Awash Arba required maintenance and based on this, possible maintenance option had been recommended for pavement distress with respect to level of severity on the pavement condition of the study area in order to sustain the design life of the Pavement.

Key word: Pavement Condition Index (PCI), Pavement Condition Rating (PCR), Pavement defects, Type and Severity level of distress

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Acronyms

AADT	Average Annual Daily Traffic
AASHTO	American Association of State of Highway and Transportation Officials
AC	Asphalt Concrete
ASTM	American Society for Testing and Material
CDV	Corrected Deduct Value
CL	Low Plasticity Clay
CBR	California Bearing Ratio
DV	Deduct Value
ERA	Ethiopia Road Authority
G.C	Gregorian Calendar
JiT	Jimma institute of Technology
Km	Kilo meter
LL	Liquid Limit
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PCI	Pavement Condition Index
PCR	Pavement Condition Rating
PCS	Pavement Condition Survey
PI	Plastic Index
PL	Plastic Limit
USCS	Unified Soil Classification System
VOC	Vehicle Operating Cost

CHAPTER ONE

INTRODUCTION

1.1 Background

Pavements form a greater part of our society's infrastructure system whose proper functioning is essential for development. Similar to other types of infrastructure assets, pavements deteriorate over time. Therefore, there is the need to find ways to preserve these capital intensive assets to ensure they perform as expected. (Offie, 2013)

The increasing traffic intensity, high tire pressure, increasing axle loads etc… are causing early signs of distress to bituminous pavements throughout the world. The deterioration of the paved roads in tropical and subtropical countries differs from those in the more temperate regions of the world. This can be due to the harsh climatic conditions and sometimes due to the lack of good pavement materials and construction practices. (AASHTO, 1993)

Highways in 2002, Ethiopia has a total of 33297km of road, both paved and gravel road. This is the first part of Road Sector Development Program which ends last 2002 G.C. The second part which is scheduled to complete on 2007 G.C includes the upgrading and construction of 7500km of roads which will improved the density from 30 to 35km per 1000sq.km. As of 2006 G.C, Ethiopia only had one expressway that is the Addis Ababa Ring Road. This is a four-lane limited-access divided highway, which forms a beltway around the capital. Ethiopian Roads Authority and China Communications Construction Consultancy just finished building the new six-lane expressway between Addis Ababa and Adama. The expressway is 80 km long, will shorten the distance by 20 km. (Elmer, 2015).

Large structures are usually constructed with materials that exhibit distresses after construction because of loading, environmental conditions, and aging. The large structures include pavement, chimneys of nuclear power plants, skyscrapers, pipelines, and others. The distresses are presented in the form of surface cracking in most situations (David et al., 2004).

Heavy vehicles load on the pavements subjects to high stresses causing damage. However, not all trucks have the same damaging effects; the damage on the road pavement depends on speed, wheel loads, number and location of axles, load distributions, type of suspension, number of wheels, tire types, inflation pressure and other factors (Michael, 1973).

Damage appears slowly at first, and then gradually accelerates, accumulating to become visible as structural distress and tangible as ride quality reduced. If distress is observed and corrected in a timely manner, low cost strategies will restore the road to nearly its original condition. However, if early treatment is neglected or postponed, the accumulated damage will require a more costly repair treatment. Recognizing that damage accumulation and acceleration is a key to understanding the need for early, low-level, low-cost preventive maintenance treatments (Hoffman, 2009).

Lack of necessary maintenance results in deterioration of the pavement, which in turn cause damage to the vehicles and higher fuel consumption, thereby increasing the vehicle operating (VOC) and user costs. To ensure an acceptable level of service, comfort and safety on these roads, road maintenance activities are very essential.

Subgrades play an important role in imparting structural stability to the pavement structure as it receives loads imposed on it by road traffic. The loads on the pavement are ultimately received by the soil subgrade for dispersion to the earth mass. It is essential that in no time the soil subgrade is over stressed. It means that the pressure transmitted on the top of subgrade is within allowable limit, not to cause excessive stress condition to deform the same beyond the elastic limit. Therefore it is desirable that at least the top 50 cm layer of subgrade soil is more suitable and well compacted under controlled conditions of optimum moisture content and maximum dry density (Deepika, 2012).

The behavior how the soil responds for the applied mechanical load can be taken as the mechanical behavior of the soil. The mechanical behaviors of soils are different for various types of soil and affected by several conditions (Merihun, 2010). The volume change, deformation, strength and hydraulic conductivity of fine grained soils are very important for engineering problems (Mitchel, 1976).

1.2 Statement of the problems

Pavement deterioration is a result of complex distress as pavement cracking through fatigue under repeated loadings and environmental cycles; deformation of the pavement structure through shearing; and disintegration of materials when mechanical or chemical bonds are broken through weathering, infiltration, or loading. Underground conditions, structures, traffic characteristics, and environmental contexts all have a tremendous impact on the performance of highway pavements (Gary et al., 2009).

Road failure is a common problem in developing countries, including Ethiopia. Some of the problems plaguing these roads are faulty design, inadequate drainage system, poor maintenance, weak subgrade materials, poor construction techniques and corruption practices (Mohammed et al., 2012). The strength of subgrade soil is a major factor for the performance of the pavement. So the movement of the sub-grade is one of the causes of road pavement failure. Road failure could be in the forms of cracks, potholes, deformation, disintegration, surface defects etc. which makes the road network unsafe and not suitable to the road users. The performance of a pavement depends on the quality of its embankments and existing condition of road bed (ERA Manual, 2002).

Addis-Djoubuti trunk road is the main source of economic development for Ethiopia, Adama to Awash-Arba road is located in between this cities.

The current condition of a road from Adama-Awash Arba is failed by more than ten different types of pavement distress during field condition survey such as alligator cracking, block cracking, longitudinal/transverse cracking, pothole, rutting etc…, so it’s not suitable for driving even also affect the vehicle operating cost for the road users and the study area have all types of pavement condition rating (Good, Satisfactory, Very Poor, Poor, Serious and Failed). Misapprehension of the nature of the soil and their engineering properties leads to construction error for asphalt pavement. It is for this reason that the research study also focuses on, a laboratory investigation of a subgrade soil for failed and serious pavement condition rating (PCR) along Adama-Awash Arba truck road was performed.

1.3 Objectives

1.3.1 General objectives

- To evaluate the pavement distress for asphalt pavement by using Pavement Condition Index from Adama to Awash Arba as per ASTM D6433 Standards.

1.3.2 Specific objectives

- To identify the types and level of severity of pavement distress.
- To rate the condition of pavement using ASTM D 6433.
- To identify one of the cause of pavement distress for Failed and Serious Pavement Condition Rating (PCR).
- To identify the maintenance option for the pavement distress.

1.4 Research question

1. What type and severity level of pavement distress exists in the study area?
2. What is the current asphalt condition of the study area?
3. Does the natural subgrade soils are the main causes of pavement distress?
4. What types of maintenance technique are used for the pavement distress type?

1.5 Significance of the study

This research attempts to contribute the Proper understanding of the types of distresses and possible causes of damage on asphalt pavement due to subgrade soil properties, this may lead to one of the correct application of remedial measures.

. The study motivates those who are interested to conduct further research on pavement distress. The lesson from the study contributes to the efforts of sustainable road sector development and management for Ethiopia Road Authority (ERA).

1.6 Scope of the study

The scope of the research study was focus on the estimation of roads flexible pavement condition through visual surveys using the Pavement Condition Index (PCI) method (following ASTM D6433 standard, 2007) of quantifying pavement condition and to identify one of the cause of pavement distress due to the subgrade soil by using laboratory test like Atterberg limits, Grain size analysis, Compaction test and CBR value. To fulfil this goal, a road network from Adama to Awash Arba was used. The most important works to be done are outlined in the research methodology.

1.7 Structure of the thesis

This research consists of five chapters. The first chapter discusses briefly the background of the research, statement of the problem, objectives, research questions, scope, and significance of the study. The second chapter is a literature review about pavement distress types including the severity level and how to measure each distress type, and asphalt maintenance techniques and Properties of subgrade materials strength. The third chapter deals with the research methodology. The fourth chapter deals with analysis and discussion of test results that are gathered from field and laboratory and remedial measure to be taken on the failure section of a road. The fifth chapter consists of conclusions and recommendations of the thesis.

CHAPTER TWO

LITRATURE REVIEW

2.1 Road Functional Classification and Numbering

The functional classification in Ethiopia includes five functional classes. The following are the functional classes with their description.

I. **Trunk Roads (Class I)**

Centers of international importance and roads terminating at international boundaries are linked with Addis Ababa by trunk roads. They are numbered with an "A" prefix: an example is the Addis-Gondar Road (A3). Trunk roads have a present AADT≥ 1000, although they can have volumes as low as 100 AADT (ERA, 2002).

II. **Link Roads (Class II)**

Centres of national or international importance, such as principal towns and urban centers, must be linked between each other by link roads. A typical link road has over 400 - 1000 first year AADT, although values can range between 50-10,000 AADT. They are numbered with a "B" prefix. An example of a typical link road is the Woldiya-Debre Tabor- Woreta Road (B22), which links, for instance, Woldiya on Road A2 with Bahir Dar of Road A3.(ERA, 2002).

III. **Main Access Roads (Class III)**

Centers of provincial importance must be linked between each other by main access roads. First year AADTs are between 30-1,000. They are numbered with a "C"prefix. (ERA, 2002).

IV. **Collector Roads (Class IV)**

Roads linking locally important centers to each other, to a more important center, or to higher class roads must be linked by a collector road. First year AADTs are between 25-400. They are numbered with a "D" prefix. (ERA, 2002).

V. **Feeder Roads (Class V)**

Any road link to a minor center such as market and local locations is served by a feeder road. First year AADTs are between 0-100. They are numbered with an "E" prefix. (ERA, 2002).

Table 2.1 Numbering of Roads in Ethiopia (ERA, 2002)

Number	Road section	Length (km)	Section type
	I. Truck Roads		Paved
A1	Addis-Asseb	853	
A1-1	Addis-Modjo	71	
A1-2	Modjo-Nazreth	25	
A1-3	Nazreth-Metehara	95	
A1-4	Metehara-Awash Junction	46	
A1-5	Awash Junction-Gewane	153	
A1-6	Gewane-Mille	150	
A1-7	Mille-Semera	75	
A1-8	Semera-Serdo	30	
A1-9	Serdo-Dobi	50	
A1-10	Dobi-Burie	130	
A1a	Dobi-Galafi	28	

2.2 Flexible Pavements

A flexible pavement is one, which has low flexural strength, and the load is largely transmitted to the subgrade soil through the lateral distribution of stresses with increasing depth as shown in Figure below. The pavement trickiness is designed such that the stresses on the subgrade soil are kept within its bearing capacity and the subgrade is prevented from excessive deformation. The strength and smoothness of flexible pavement structure depends to a large extent on the deformation of the subgrade soil.

Generally, two types of construction have been used for flexible pavements: conventional flexible pavement and full-depth asphalt pavement. A third type, known as contained rock asphalt mat (CRAM) construction is still in the experimental stage and has not been widely accepted for practical use. (Gupta, et al., 1999)

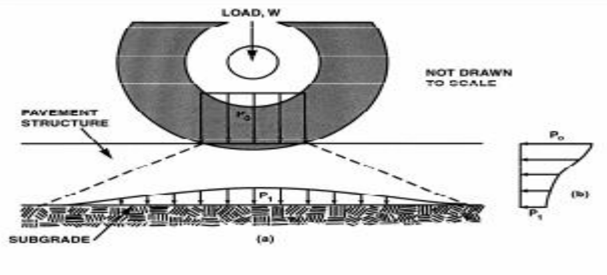

Figure 2.1: Stress distribution through flexible pavement structure (Gupta, et al., 1999)

2.2.1 Conventional Flexible pavements

Conventional flexible pavements are multi-layered structures with better materials on top where the intensity of stress is high and inferior materials at the bottom where the intensity is low. This design principle makes possible to use local materials and usually results in a most economical design. This is particularly true in regions where high-quality materials are expensive but local materials of inferior quality are readily available. Figure 1.2 shows the cross section of a conventional flexible pavement. Starting from the top, a conventional flexible pavement normally consists of surface course, base course, subbase course, compacted subgrade, and natural subgrade. The use of the various courses is based on either necessity or economy and some of the courses may be omitted.

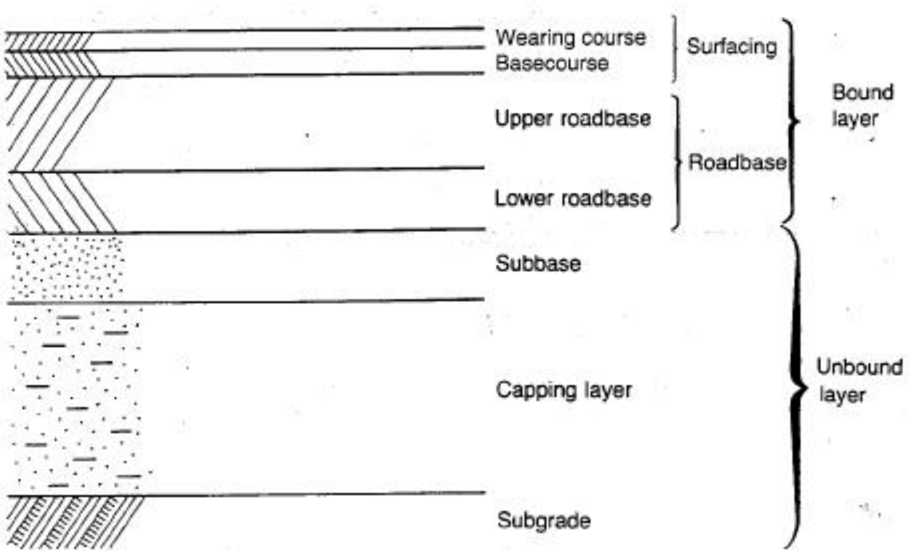

Figure 2.2: Section through a flexible pavement (Gupta, et al., 1999)

Surface Course: The surface course is the top course of an asphalt pavement, sometimes called the wearing course. It is usually constructed by dense graded hot-mix asphalt. It is a structural part of the pavement, which must be tough to resist distortion under traffic and provide a smooth and skid-resistant riding surface. The surface course must be waterproof to protect the entire pavement and subgrade from the weakening effect of water.

Base Course: The base course is the layer of material immediately beneath the surface course. It may be composed of well-graded crushed stone (unbounded), granular material mixed with binder, or stabilized materials. It is the main structural part of the pavement and provides a level surface for laying the surface layer. If constructed directly over the subgrade, it prevents intrusions of the fine subgrade soils into the pavement structure.

Subbase Course: The subbase course is the layer of material beneath the base course constructed using local and cheaper materials for economic reason on top of the subgrade. It provides additional help to the base and the upper layers in distributing the load. It facilitates drainage of free water that might get accumulated below the pavement. If the base course is open graded, the subbase course with more fines can serve as a filter between the subgrade and the base course.

Subgrade: Subgrade is the foundation on which the vehicle load and the weight of the pavement layers finally rest. It is an in situ or a layer of selected material compacted to the desirable density near the optimum moisture content. It is graded into a proper shape, properly drained, and compacted to receive the pavement layers.

2.2.2 Full-Depth Asphalt Pavements

Full-depth asphalt pavements are constructed by placing one or more layers of hot-mix asphalt directly on the subgrade or improved subgrade. This concept was conceived by the Asphalt Institute and is generally considered the most cost-effective and dependable type of asphalt pavement for heavy traffic and quite popular in areas where local materials are not available.

2.3 Manual Pavement Condition Surveys

While the use of automated pavement condition surveys are becoming more and more common, many agencies still rely on manual pavement condition surveys to provide their pavement condition data..

2.4 Pavement deterioration and its type

Pavement deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. (Gupta, et al., 1999)

2.4.1 Types of pavement deterioration

The four major categories of common asphalt pavement surface distresses are: (Gupta, et al., 1999)

1. Cracking
2. Surface deformation
3. Disintegration
4. Surface defects

A. Cracking

The most common types of cracking are:

i. Fatigue cracking
ii. Longitudinal cracking
iii. Transverse cracking
iv. Block cracking
v. Slippage cracking
vi. Reflective cracking
vii. Edge cracking

B. Surface deformation

Pavement deformation is the result of weakness in one or more layers of the pavement that has experienced movement after construction. The deformation may be accompanied by cracking. Surface distortions can be a traffic hazard.

The basic types of surface deformation are:

i. Rutting
ii. Corrugation

iii. Shoving

iv. Depressions

v. Swell

C. Disintegration

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

The two most common types of disintegration are:

i. Potholes

ii. Patches

D. Surface defects

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

i. Ravelling

ii. Bleeding

iii. Polishing

iv. delamination

2.5 Distresses in asphalt pavement

2.5.1 Alligator cracking (Fatigue)

A. Description

Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. Cracking begins at the bottom of the asphalt surface, or stabilized base, where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are generally less than 0.5 m (1.5 ft) on the longest side. Alligator cracking occurs only in areas subjected to repeated traffic loading, such as wheel paths. Pattern-type cracking that occurs over an entire area not subjected to loading is called “block cracking,” which is not a load- associated distress (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Fine, longitudinal hairline cracks running parallel to each other with no, or only a few interconnecting cracks. The cracks are not spalled
- **Moderate level of severity (M):-**Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled
- **Higher level of severity (H):-** Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges. Some of the pieces may rock under traffic (ASTM D6433, 2007).

C. How to Measure

Alligator cracking is measured in square meters (square feet) of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately; however, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity present. If alligator cracking and rutting occur in the same area, each is recorded separately as its respective severity level (ASTM D6433, 2007).

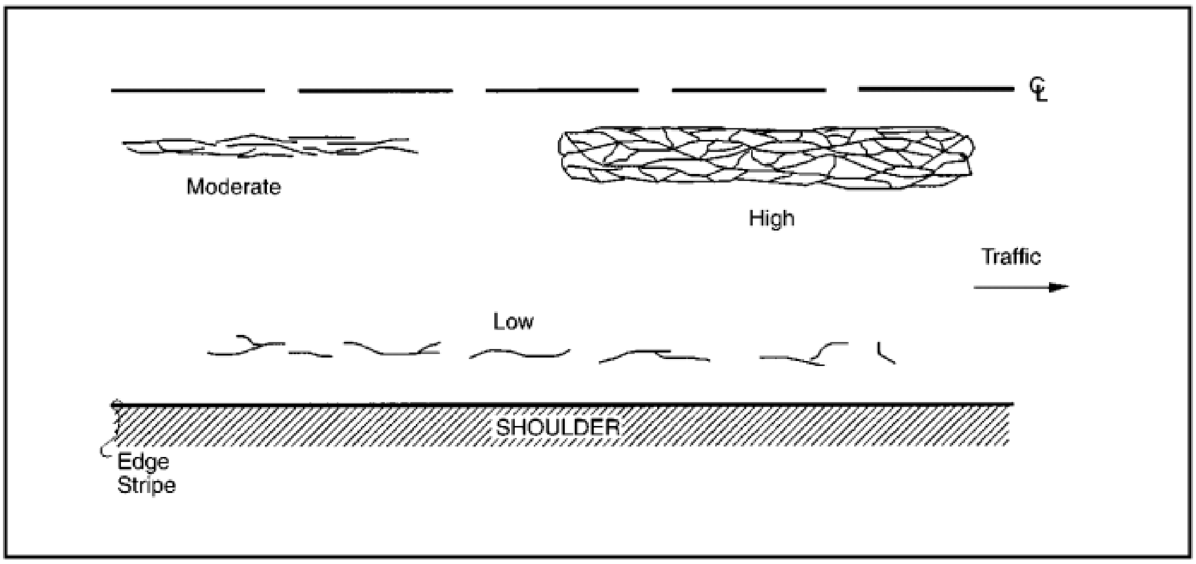

Figure 2.3 Fatigue Cracking (John, et al., 2003)

2.5.2 Bleeding

A. Description

Bleeding is a film of bituminous material on the pavement surface that creates a shiny, glasslike, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphaltic cement or tars in the mix, excess application of a bituminous sealant, or low air void content, or a combination thereof. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the pavement surface. Since the bleeding process in not reversible during cold weather, asphalt or tar will accumulate on the surface (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Bleeding only has occurred to a very slight degree and is noticeable only during a few days of the year. Asphalt does not stick to shoes or vehicles
- **Moderate level of severity (M):-**Bleeding has occurred to the extent that asphalt sticks to shoes and vehicles during only a few weeks of the year.
- **Higher level of severity (H):-** Bleeding has occurred extensively and considerable asphalt sticks to shoes and vehicles during at least several weeks of the year (ASTM D6433, 2007).

C. How to Measure

Bleeding is measured in square meters (square feet) of surface area. If bleeding is counted, polished aggregate should not be counted (ASTM D6433, 2007).

2.5.3 Block cracking

A. Description

Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 0.3 by 0.3 m (1 by 1 ft) to 3 by 3 m (10 by 10 ft). Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling, which results in daily stress/strain cycling. It is not load-associated. Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large portion of the pavement area, but sometimes will occur only in non-traffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many-sided pieces with sharp angles. Also, unlike block, alligator cracks are caused by repeated traffic loadings, and therefore, are found only in traffic areas, that is, wheel paths (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Blocks are defined by low-severity cracks
- **Moderate level of severity (M):-**Blocks are defined by medium-severity cracks
- **Higher level of severity (H):-** Blocks are defined by high-severity cracks (ASTM D6433, 2007).

C. How to Measure

Block cracking is measured in m^2 given pavement section; however, if areas of different severity levels can be distinguished easily from one another, they should be measured and recorded separately (ASTM D6433, 2007).

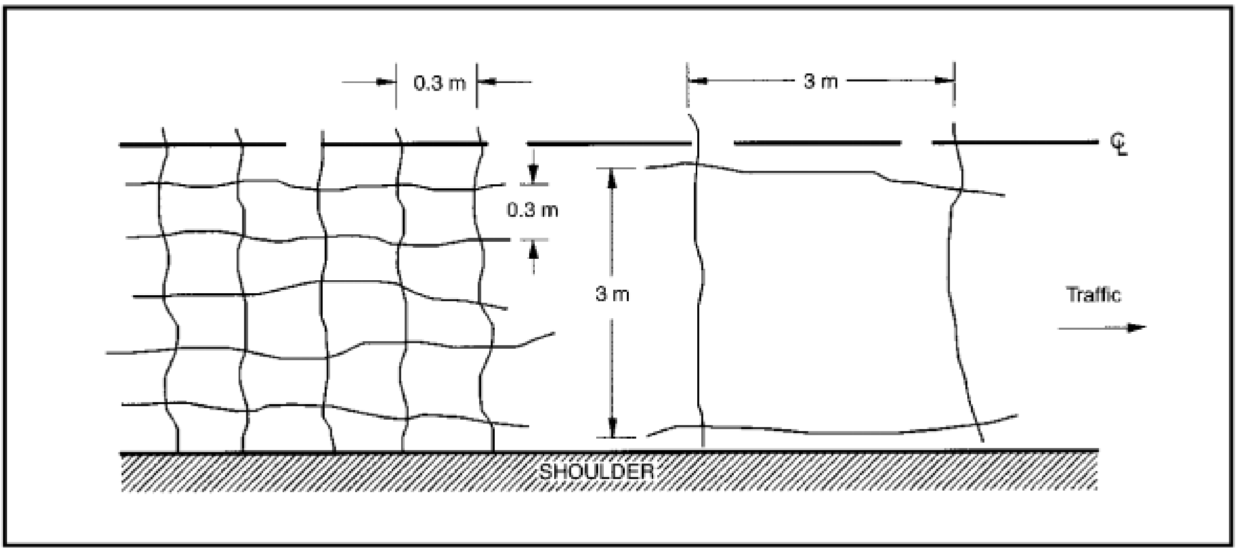

Figure 2.4 Block Cracking (John, et al., 2003)

2.5.4 Bumps and sags

A. Description:

Bumps are small, localized, upward displacements of the pavement surface. They are different from shoves in that shoves are caused by unstable pavement. Bumps, on the other hand, can be caused by several factors, including:

- Buckling or bulging of underlying PCC slabs in AC overlay over PCC pavement.
- Frost heaves (ice, lens growth).
- Infiltration and build-up of material in a crack in combination with traffic loading (sometimes called “tenting”).

Sags are small, abrupt, downward displacements of the pavement surface. If bumps appear in a pattern perpendicular to traffic flow and are spaced at less than 3 m (10 ft), the distress is called corrugation. Distortion and displacement that occur over large areas of the pavement surface, causing large or long dips, or both, in the pavement should be recorded as "swelling." (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Bump or sag causes low-severity ride quality.
- **Moderate level of severity (M):-**Bump or sag causes medium-severity ride quality.
- **Higher level of severity (H):-** Bump or sag causes high-severity ride quality.

C. **How to Measure**

Bumps or sags are measured in linear meters (feet). If the bump occurs in combination with a crack, the crack also is recorded (ASTM D6433, 2007).

2.5.5 Corrugation

A. Description

Corrugation, also known as "wash-boarding", is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals, usually less than 3 m (10ft) along the pavement. The ridges are perpendicular to the traffic direction. This type of distress usually is caused by traffic action combined with an unstable pavement surface or base (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Corrugation produces low-severity ride quality .
- **Moderate level of severity (M):-**Corrugation produces medium-severity ride quality
- **Higher level of severity (H):-** Corrugation produces high-severity ride quality

C. How to Measure

Corrugation is measured in square meters (square feet) of surface area (ASTM D6433, 2007).

2.5.6 Depression

A. Description

Depressions are localized pavement surface areas with elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are not noticeable until after a rain, when ponding water creates a "birdbath" area; on dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of improper construction. Depressions cause some roughness, and when deep enough or filled with water, can cause hydroplaning (ASTM D6433, 2007).

B. Severity Levels (Maximum Depth of Depression):

- **Low level of severity (L):-**13 to 25 mm (1⁄2 to 1 in.)
- **Moderate level of severity (M):-**25 to 50 mm (1 to 2 in.)
- **Higher level of severity (H):-** More than 50 mm (2 in.) (ASTM D6433, 2007).

C. How to Measure

Depressions are measured in square meters (square feet) of surface area (ASTM D6433, 2007).

2.5.7 Edge cracking

A. Description

Edge cracks are parallel to and usually within 0.3 to 0.5 m (1 to 1.5 ft) of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or subgrade near the edge of the pavement. The area between the crack and pavement edge is classified as raveled if it is broken up (sometimes to the extent that pieces are removed) (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Low or medium cracking with no breakup or ravelling
- **Moderate level of severity (M):-**Medium cracks with some breakup and ravelling
- **Higher level of severity (H):-** Considerable breakup or ravelling along the edge (ASTM D6433, 2007).

C. How to Measure

Edge cracking is measure in linear meters (feet) (ASTM D6433, 2007).

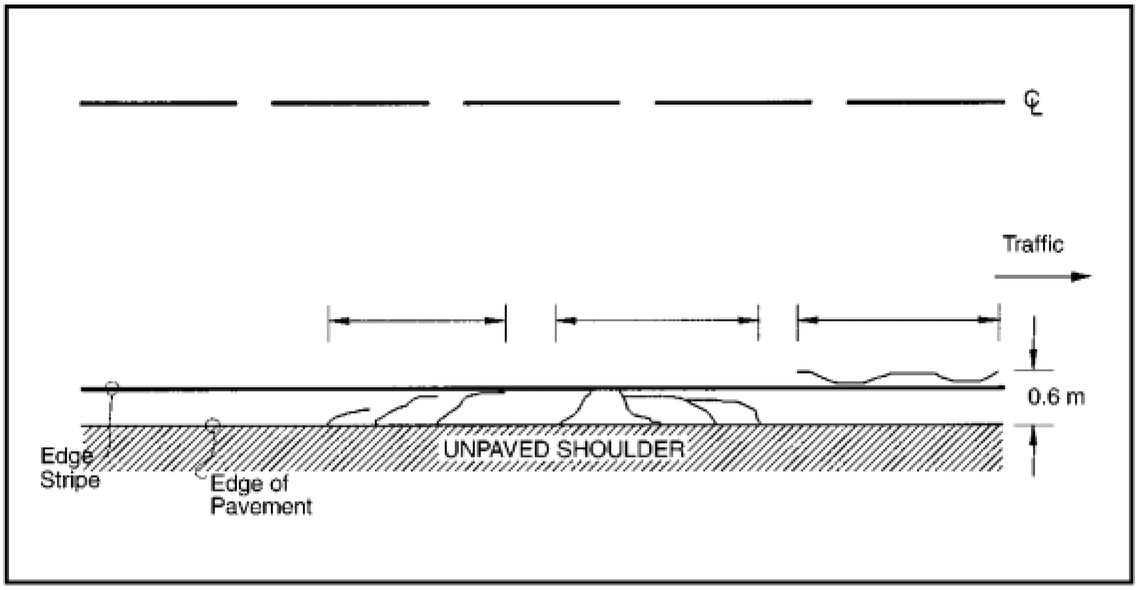

Figure 2.5 Edge Cracking (John, et al., 2003)

2.5.8 Reflection cracking

A. Description

This distress occurs only on asphalt-surfaced pavements that have been laid over a PCC slab. It does not include reflection cracks from any other type of base, that is, cement- or lime-stabilized; these cracks are caused mainly by thermal- or moisture-induced movement of the PCC slab beneath the AC surface. This distress is not load-related; however, traffic loading may cause a breakdown of the AC surface near the crack. If the pavement is fragmented along a crack, the crack is said to be spalled. A knowledge of slab dimension beneath the AC surface will help to identify these distresses (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**One of the following conditions exists. Non filled crack width is less than 10 mm (3⁄8 in.), or filled crack of any width (filler in satisfactory condition).
- **Moderate level of severity (M):-**One of the following conditions exists: Nonfilled crack width is greater than or equal to 10 mm (3⁄8 in.) and less than 75 mm (3 in.); nonfilled crack less than or equal to 75 mm (3 in.) surrounded by light secondary cracking; or, filled crack of any width surrounded by light secondary cracking
- **Higher level of severity (H):-** One of the following conditions exists

Any crack filled or nonfilled surrounded by medium or high-severity secondary cracking; nonfilled cracks greater than 75 mm (3 in.); or, a crack of any width where approximately 100 mm (4 in.) of pavement around the crack are severely ravelled or broken (ASTM D6433, 2007).

C. How to Measure

Joint reflection cracking is measured in linear meters (feet). The length and severity level of each crack should be identified and recorded separately. For example, a crack that is 15 m (50 ft) long may have 3 m (10ft) of high severity cracks, which are all recorded separately. If a bump occurs at the reflection crack, it is recorded also (ASTM D6433, 2007).

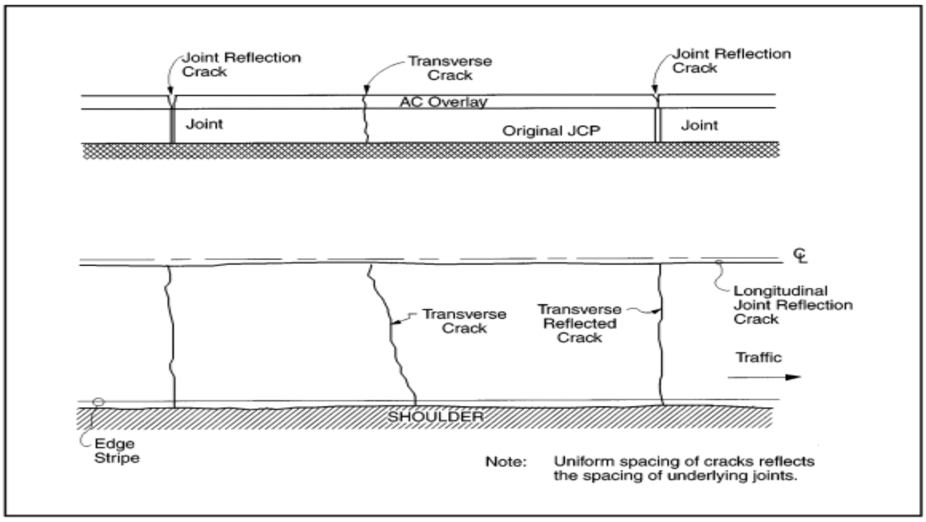

Figure 2.6 Reflections Cracking at Joints (John, et al., 2003)

2.5.9 Lane shoulder drop

A. Description

Lane/shoulder drop-off is a difference in elevation between the pavement edge and the shoulder. This distress is caused by shoulder erosion, shoulder settlement, or by building up the roadway without adjusting the shoulder level (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**The difference in elevation between the pavement edge and shoulder is > 25 mm (1 in.) and< 50 mm (2 in.)
- **Moderate level of severity (M):-**The difference in elevation is > 50 mm (2in) and < 100 mm (4 in)

- **Higher level of severity (H):-** The difference in elevation is > 100 mm (4in)

C. How to Measure

Lane/shoulder drop-off is measured in linear meters (feet) (ASTM D6433, 2007).

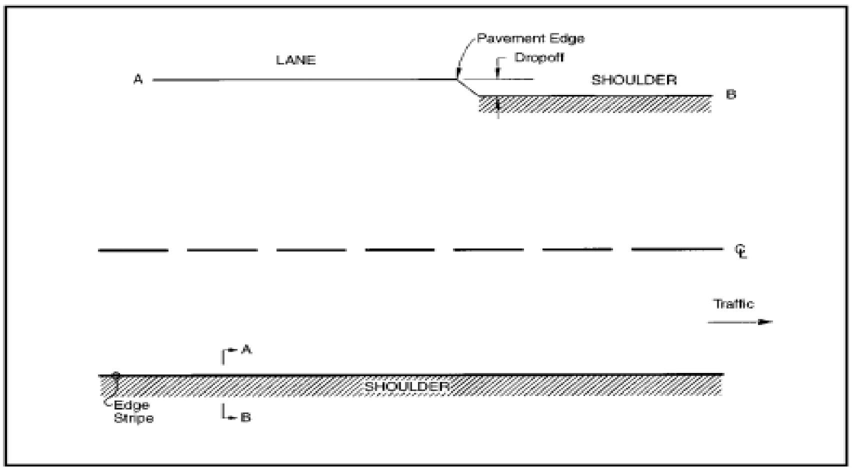

Figure 2.7 Lane-to-Shoulder Drop-off (John, et al., 2003)

2.5.10 Longitudinal & Transverse

A. Description

Longitudinal cracks are parallel to the pavement's centerline or laydown direction. They may be caused by:

- A poorly constructed paving lane joint.
- Shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or daily temperature cycling, or both.
- A reflective crack caused by cracking beneath the surface course, including cracks in PCC slabs, but not PCC joints.
- Transverse cracks extend across the pavement at approximately right angles to the pavement centreline or direction of laydown. These types of cracks are not usually load-associated (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**One of the following conditions exists: non-filled crack width is less than 10 mm (3⁄8 in.), or filled crack of any width (filler in satisfactory condition).
- **Moderate level of severity (M):-**One of the following conditions exists: non-filled crack width is greater than or equal to 10 mm and less than 75 mm (3⁄8 to 3 in.); non-filled crack is less than or equal to 75 mm (3 in.) surrounded by light and

random cracking; or, filled crack is of any width surrounded by light random cracking.

- **Higher level of severity (H):-** One of the following conditions exists: any crack filled or non-filled surrounded by medium- or high-severity random cracking; non-filled crack greater than 75m (3 in.); or, a crack of any width where approximately 100mm (4 in.) of pavement around the crack is severely broken (ASTM D6433, 2007).

C. How to Measure

Longitudinal and transverse cracks are measured in linear meters (feet). The length and severity of each crack should be recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately (ASTM D6433, 2007).

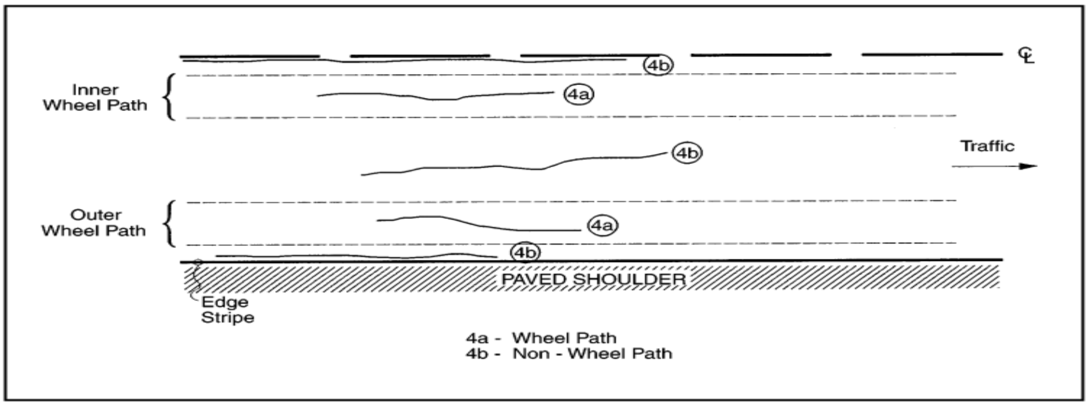

Figure 2.8 Longitudinal Cracking (John, et al., 2003)

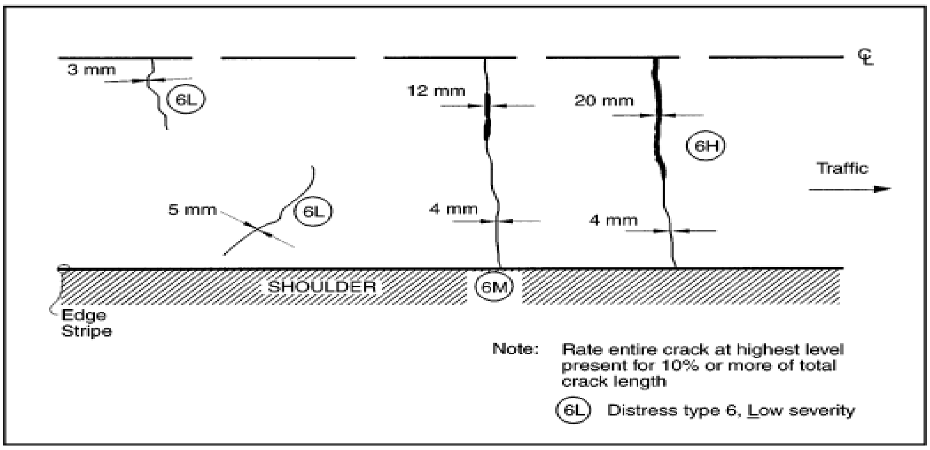

Figure 2.9 Transverse Cracking Asphalt Concrete Surfaces (John, et al., 2003)

2.5.11 Patching &Utility patch

A. Description

A patch is an area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section). Generally, some roughness is associated with this distress (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Patch is in good condition and satisfactory. Ride quality is rated as low severity or better
- **Moderate level of severity (M):-**Patch is moderately deteriorated, or ride quality is rated as medium severity, or both
- **Higher level of severity (H):-** Patch is badly deteriorated, or ride quality is rated as high severity, or both; needs replacement soon (ASTM D6433, 2007).

C. How to Measure

Patching is rated in ft2 of surface area; however, if a single patch has areas of differing severity, these areas should be measured and recorded separately. For example, a 2.5 m^2 (27.0 ft2) patch may have 1 m^2 (11 ft2) of medium severity and 1.5 m2 (16 ft2) of low severity. These areas would be recorded separately. Any distress found in a patched area will not be recorded; however, its effect on the patch will be considered when determining the patch's severity level. No other distresses, for example, are recorded within a patch. Even if the patch material is shoving or cracking, the area is rated only as a patch. If a large amount of pavement has been replaced, it should not be recorded as a patch but considered as new pavement, for example, replacement of a complete intersection (ASTM D6433, 2007).

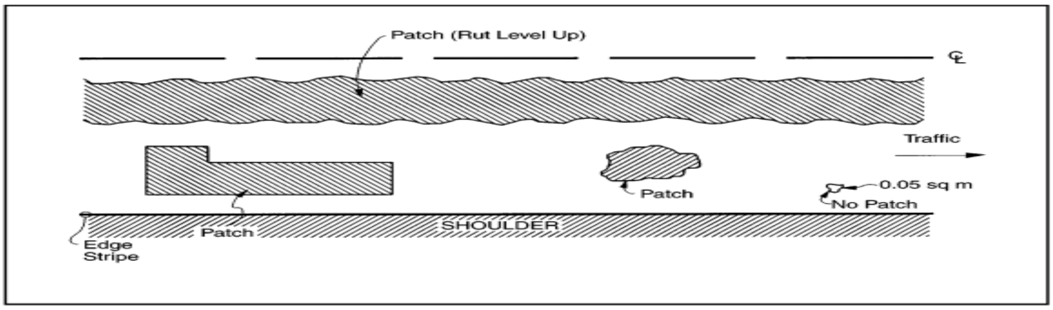

Figure 2.10 Patch/Patch Deterioration (John, et al., 2003)

2.5.12 Polished Aggregate

A. Description

This distress is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small, or there are no rough or angular aggregate particles to provide good skid resistance. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examination reveals that the aggregate extending above the asphalt is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from a previous rating (ASTM D6433, 2007).

B. Severity Levels

No degrees of severity are defined; however, the degree of polishing should be clearly evident in the sample unit in that the aggregate surface should be smooth to the touch

C. How to Measure

Polished aggregate is measured in square meters (square feet) of surface area. If bleeding is counted, polished aggregate should not be counted (ASTM D6433, 2007).

2.5.13 Potholes

A. Description

Potholes are small usually less than 750 mm (30 in.) in diameter bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. When holes are created by high-severity alligator cracking, they should be identified as potholes, not as weathering (ASTM D6433, 2007).

B. Severity Levels:

- The levels of severity for potholes less than 750mm (30 in.) in diameter are based on both the diameter and the depth of the pothole, according to Table 2.2

- If the pothole is more than 750 mm (30 in.) in diameter, the area should be determined in square feet and divided by 0.5 m2 (5.5 ft2) find the equivalent number of holes. If the depth is 25 mm (1 in.) or less, the holes are considered medium-severity. If the depth is more than 25 mm (1 in.), they are considered high-severity (ASTM D6433, 2007).

Table 2.2 Levels of severity for potholes (ASTM D6433, 2007).

Maximum depth of pothole	Average diameter (mm)(in.)		
	100 to 200mm (4 to 8in.)	200 to 450mm (8 to 18in.)	450 to 750mm (18 to 30in.)
13 to ≤25mm (1/2 to 1in.)	L	L	M
>25 and ≤50mm (1 to 2in.)	L	M	H
>50mm (2in.)	M	M	H

C. How to Measure

Potholes are measured by counting the number that are low-, medium-, and high-severity and recording them separately (ASTM D6433, 2007).

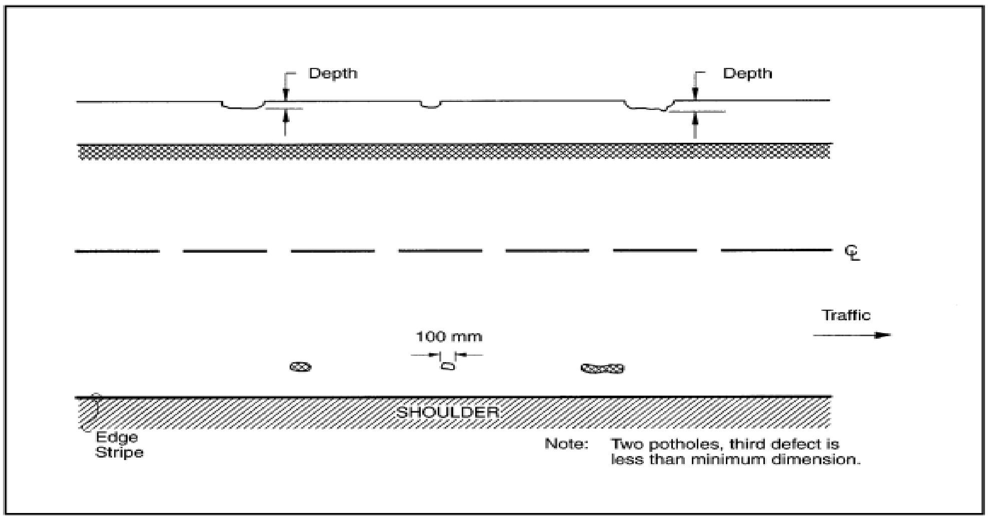

Figure 2.11 Potholes (John, et al., 2003)

2.5.14 Rutting

A. Description

A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut, but, in many instances, ruts are noticeable only after arainfall when the paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrades, usually caused by consolidated or lateral movement of the materials due to traffic load (ASTM D6433, 2007).

B. Severity Levels (Mean Rut Depth):

- **Low level of severity (L):-**6 to 13 mm (1⁄4 to 1⁄2 in.)
- **Moderate level of severity (M) :-**> 13 to 25 mm (>1⁄2 to 1 in.)
- **Higher level of severity (H):-** >25 mm (>1 in.)

C. How to Measure

Rutting is measured in square meters (square feet) of surface area, and its severity is determined by the mean depth of the rut. The mean rut depth is calculated by laying a straight edge across the rut, measuring its depth, then using measurements taken along the length of the rut to compute its mean depth in millimetres (ASTM D6433, 2007).

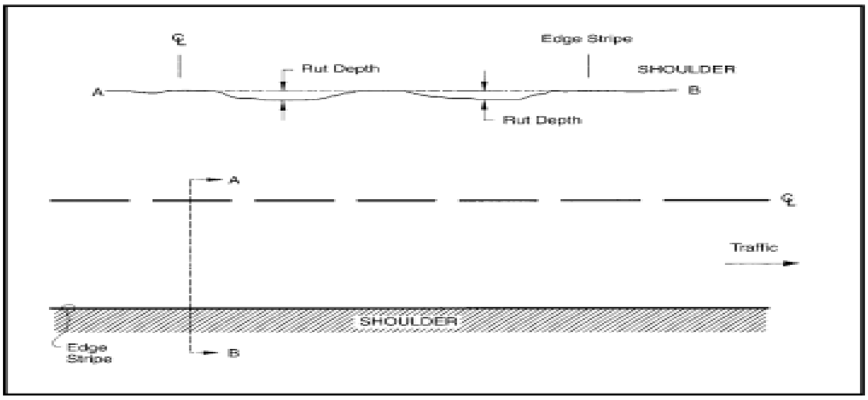

Figure 2.12 Rutting (John, et al., 2003)

2.5.15 Railroad crossing

A. Description

Railroad crossing defects are depressions or bumps around, or between tracks, or both.

B. Severity Levels:

- **Low level of severity (L):-**Railroad crossing causes low-severity ride quality
- **Moderate level of severity (M):-** Railroad crossing causes medium-severity ride quality
- **Higher level of severity (H):-** Railroad crossing causes high-severity ride quality (ASTM D6433, 2007).

C. How to Measure

The area of the crossing is measured in square meters (square feet) of surface area. If the crossing does not affect ride quality, it should not be counted. Any large bump created by the tracks should be counted as part of the crossing (ASTM D6433, 2007).

2.5.16 Shoving

A. Description:

Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements. Shoves also occur where asphalt pavements abut PCC pavements. The PCC pavements increase in length and push the asphalt pavement, causing the shoving (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Shove causes low-severity ride quality.
- **Moderate level of severity (M):-** Shove causes medium-severity ride quality.
- **Higher level of severity (H):-** Shove causes high-severity ride quality (ASTM D6433, 2007).

C. How to Measure

Shoves are measured in square meters (feet) of surface area. Shoves occurring in patches are considered in rating the patch, not as a separate distress (ASTM D6433, 2007).

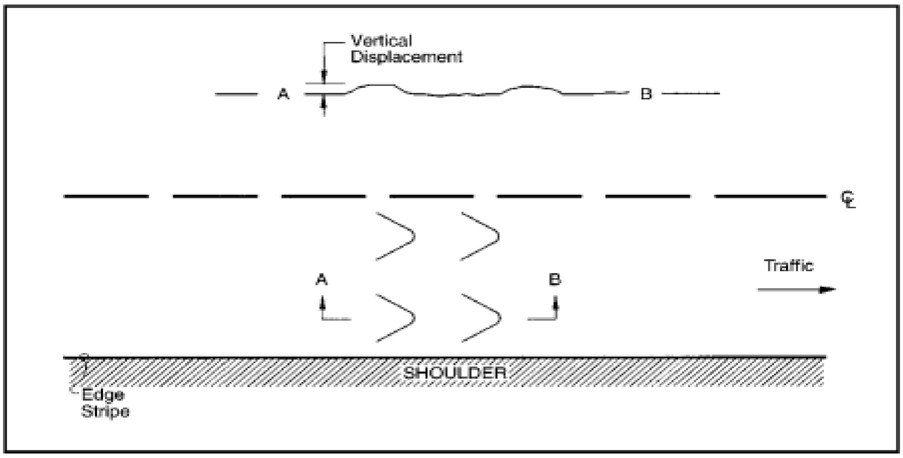

Figure 2.13 Shoving (John, et al., 2003)

2.5.17 Slippage

A. Description

Slippage cracks are crescent or half-moon shaped cracks, usually transverse to the direction of travel. They are produced when braking or turning wheels cause the pavement surface to slide or deform. This distress usually occurs in overlaps when there is a poor bond between the surface and the next layer of the pavement structure (ASTM D6433, 2007).

B. Severity Level:

- **Low level of severity (L):-**Average crack width is < 10 mm (3⁄8 in.).
- **Moderate level of severity (M):-** One of the following conditions exists : average crack width is $ 10 and < 40 mm ($ 3⁄8 and<1-1⁄2 in.); or the area around the crack is moderately spalled, or surrounded with secondary cracks.
- **Higher level of severity (H):-** One of the following conditions exists: the average crack width is > 40 mm (1-1⁄2 in.) or the area around the crack is broken into easily removed pieces (ASTM D6433, 2007).

C. How to Measure

The area associated with a given slippage crack is measured in square meters (square feet) and rated according to the highest level of severity in the area (ASTM D6433, 2007).

2.5.18 Swell

A. Description

Swell is characterized by an upward bulge in the pavement's surface, a long, gradual wave more than 3 m (10 ft) long. Swelling can be accompanied by surface cracking. This distress usually is caused by frost action in the subgrade or by swelling soil (ASTM D6433, 2007).

B. Severity Level:

- **Low level of severity (L):-**Swell causes low-severity ride quality. Low-severity swells are not always easy to see but can be detected by driving at the speed limit over the pavement section. An upward motion will occur at the swell if it is present.
- **Moderate level of severity (M):-** Swell causes medium-severity ride quality.

- **Higher level of severity (H):-** Swell causes high-severity ride quality (ASTM D6433, 2007).

C. How to Measure

The surface area of the swell is measured in square meters (square feet) (ASTM D6433, 2007).

2.5.19 Ravelling &Weathering

A. Description

Weathering and ravelling are the wearing away of the pavement surface due to a loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicate that either the asphalt binder has hardened appreciably or that a poor-quality mixture is present. In addition, ravelling may be caused by certain types of traffic, for example, tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage also are included under ravelling (ASTM D6433, 2007).

B. Severity Levels:

- **Low level of severity (L):-**Aggregate or binder has started to wear away. In some areas, the surface is starting to pit. In the case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.
- **Moderate level of severity (M):-** Aggregate or binder has worn away. The surface texture is moderately rough and pitted. In the case of oil spillage, the surface is soft and can be penetrated with a coin.
- **Higher level of severity (H):-** Aggregate or binder has been worn away considerably. The surface texture is very rough and severely pitted. The pitted areas are less than 10 mm (4 in.) in diameter and less than 13 mm (1⁄2 in.) deep; pitted areas larger than this are counted as potholes. In the case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose (ASTM D6433, 2007).

C. How to Measure

Weathering and ravelling are measured in square meters (square feet) of surface area (ASTM D6433, 2007).

Table 2 .3 Distresses types for flexible pavement (ASTM D6433, 2007)

#	Distresses
1	Alligator Cracking
2	Bleeding
3	Block Cracking
4	Bumps and Sags
5	Corrugation
6	Depression
7	Edge Cracking
8	Joint Reflection Cracking
9	Lane/Shoulder Drop Off
10	Long and Trans Cracking
11	Patching Util Cut Patching
12	Polished Aggregate
13	Potholes
14	Railroad Crossing
15	Rutting
16	Shoving
17	Slippage Cracking
18	Swell
19	Weathering/Ravelling

2.6 Measurement of pavement distress

Table 2.4: paver distress classification for road and parking areas (Shahin, 2002)

number	**Distress**	**Unit of measurement**
1	Alligator cracking	m^2
2	bleeding	m^2
3	Block cracking	m^2
4	Bumps and Sags	m
5	corrugation	m^2
6	depression	m^2
7	Edge cracking	m

8	Joint reflection	m
9	Lane/Shoulder drop-off	m
10	Longitudinal and traverse cracking	m
11	Patching and utility cut patching	m^2
12	Polished aggregate	m^2
13	Potholes	Number
14	Railroad crossing	m^2
15	Rutting	m^2
16	Shoving	m^2
17	Slippage cracking	m^2
18	Swell	m^2
19	Weathering and Raveling	m^2

2.7 Visual assessment of pavement surface

Surveys are conducted visually by foot, which provides the best vantage point for observing the actual condition of the pavement surface. By standing or walking the pavement surface, the pavement rater has the opportunity to closely observe pavement distresses such as cracks, weathering, ravelling, and rutting, allowing for a better assessment of the amount of distress in a specific survey location (ASTM D6433, 2007).

2.7.1 Pavement condition index (PCI)

Pavement Condition Index rates the condition of the surface of a road network. The PCI provides a numerical rating for the condition of road segments within the road network, where 0 is the worst possible condition and 100 is the best (OGRAS, 2009).

2.7.2 Pavement condition rating

A verbal description of pavement condition as a function of the PCI value that varies from “failed” to “good” (ASTM D6433, 2007).

Table 2.5 Pavement condition ratings and pavement condition index (ASTM D6433, 2007).

Pavement condition index	Pavement condition rating
0-10	Failed
10-25	serious
25-40	Very poor
40-55	poor
55-70	Fair
70-85	Satisfactory
85-100	Good

2.8 Asphalt maintenance operations

Today's increasing budget constraints require that state and local agencies perform more work with less money. Historically, the emphasis of local highway departments has been on building new roads, but the new focus is on maintaining and preserving existing pavement surfaces. This shift has resulted in three types of pavement maintenance operations (Ann. et al., 2000).

- Preventive Maintenance: Performed to improve or extend the functional life of a pavement. It is a strategy of surface treatments and operations intended to retard progressive failures and reduce the need for routine maintenance and service activities (Ann. et al., 2000).
- Corrective Maintenance: Performed after a deficiency occurs in the pavement, such as loss of friction, moderate to severe rutting, or extensive cracking. May also be referred to as "reactive" maintenance (Ann. et al., 2000).
- Emergency Maintenance: Performed during an emergency situation, such as a blowout or severe pothole that needs repair immediately. This also describes temporary treatments designed to hold the surface together until more permanent repairs can be performed (Ann. et al., 2000).

2.9 Types of Maintenance Treatments Technique

Crack repair with sealing: A localized treatment method used to prevent water and debris from entering a crack, which might include routing to clean the entire crack and to create a reservoir to hold the sealant. It is only effective for a few years and must be repeated. However, this treatment is very effective at prolonging the pavement life (Ann. et al., 2000).

Crack filling: Differs from crack sealing mainly in the preparation given to the crack prior to treatment and the type of sealant used. Crack filling is most often reserved for more worn pavements with wider, more random cracking (Ann. et al., 2000).

Full-depth crack repair: A localized treatment method to repair cracks that are too deteriorated to benefit from sealing. Secondary cracking requires the reestablishment of the underlying base materials. Involves milling a trench centered over an existing crack, placing hot-mix asphalt (HMA) into the reservoir in one or more lifts, and compacting to achieve density (Ann. et al., 2000).

Fog seal: A fog seal is an application of diluted asphalt emulsion without a cover aggregate, used to seal and enrich the asphalt pavement surface, seal minor cracks, prevent raveling, and provide shoulder delineation. An asphalt distributor is normally used to apply the fog seal. An application of diluted emulsion (typically at a rate of 1:1) to enrich the pavement surface and delay raveling and oxidation. Considered a temporary treatment (Ann. et al., 2000).

Seal coat: A seal coat is an application of asphalt followed immediately with an aggregate cover. Applications with two layers are referred to as a double chip seal. Rapid-setting asphalt emulsions are normally used when placing a seal coat. Seal coats can waterproof the surface, provide low-severity crack sealing, and restore surface friction. Used to waterproof the surface, seal small cracks, reduce oxidation of the pavement surface, and improve friction (Ann. et al., 2000).

Double chip seal: This treatment involves the application of two single seal coats. The second coat is placed immediately after and directly over the first. Sixty percent of the total asphalt binder required is placed in the first pass, with larger aggregate. The remaining forty percent is placed in the second pass, with aggregates half as large as those placed first (Ann. et al., 2000).

Slurry seal: A slurry seal is a mixture of fine aggregate, asphalt emulsion, water, and mineral filler. The mineral filler most often used is Portland cement. Slurry seals are used to seal the existing asphalt pavement surface, slow surface raveling, seal small cracks, and improve surface friction. Slurry seals are similar to chip seals in that they use a thermal break process, requiring heat from the sun and pavement. This process takes anywhere from two to eight hours depending on the heat and humidity (Ann. et al., 2000).

Microsurfacing: Microsurfacing is sometimes incorrectly referred to as a polymer-modified slurry seal. The major difference is that the curing process for microsurfacing is chemically controlled, whereas slurry seals and chip seals use the thermal process. Microsurfacing was designed for use as a rut-filling material in Europe in the 1970s and introduced to the United States in 1980. Since then, many states have used this treatment for both surfacing and rut filling on roads with moderate- to heavy-volume traffic (Ann. et al., 2000).

Thin hot-mix overlays: Thin hot-mix asphalt (HMA) overlays are blends of aggregate and asphalt cement. Three types of HMAs (dense-graded, open-graded friction courses, and gap-graded) have been used in the United States to improve the functional (non-structural) condition of the pavement. Thicknesses typically range from 3/4 to 1-1/2 inch. These mixes are often modified with polymers to meet high performance expectations (Ann. et al., 2000).

Pothole patching: Includes using cold- and hot-asphalt mixture, spray injection methods, as well as slurry and microsurfacing materials, to repair distress and improve ride quality (Ann. et al., 2000).

2.10 Pavement Management Systems

A Pavement Management System (PMS) is the name given to a tool or method that assists in optimizing strategies for providing and maintaining pavements in a serviceable condition over a given period of time. One of the primary benefits of a pavement management system is that it helps users select cost-effective alternatives for pavement maintenance and rehabilitation. (Ann.et al., 2000)

Table 2.6 Crack treatment (Ann, et al., 2000)

Type of Crack	Treatment							
	Full-depth crack Repair	Crack Repair w/sealing			Crack filling	Patching	Chip seal or seal coat	Thin hot-mix Overlay
		Clean and Seal	Crack filling	Patching				
Alligator								
Low severity							X	
Medium severity						X		
High severity						X		
Transverse								
Low severity		X		X			X	
Medium severity		X		X	X		X	
High severity	X				X	X	X	
Longitudinal								
Low severity		X		X	X			
Medium severity	X	X		X	X			
High severity	X				X	X		
Block								
Low severity		X		X			X	
Medium severity							X	X
High severity					X	X		X
Reflection								
Low severity		X		X				
Medium severity		X		X	X			
High severity		X			X	X		X

Table 2.7 Treatments for Surface Defects (Ann, et al., 2000)

Type of Crack	Treatment						
	Patching	**Fog seal**	**Seal coat**	**Double chip seal**	**Slurry seal**	**Micro-surfacing**	**Thin hot-mix overlay**
Potholes							
Low severity	X						
Medium severity	X						
High severity	X						
Patch deterioration							
Low severity							
Medium severity	X						
High severity	X						
Surface Defects							
Rutting							
Low severity	X				X	X	
Medium severity	X				X	X	X
High severity	X					X	X
Shoving							
Low severity							
Medium severity	X						
High severity	X						
Bleeding							
Low severity			X	X	X	X	
Medium severity			X	X	X	X	
High severity			X	X	X	X	X
Polished aggregate							
Low severity			X	X	X	X	
Medium severity			X	X	X	X	X
High severity			X	X	X	X	X
Raveling							
Low severity		X					
Medium severity		X	X				
High severity	X		X	X	X	X	X

2.11 Laboratory tests for subgrade soils

2.11.1 General Properties Sub grade Soils.

Although a pavement's wearing course is important component of a road, the success or failure of a pavement is dependent on sub grade material upon which the pavement structure is built. Thus, the sub grade must be able to support the loads transmitted from the pavement structure without progressing excessive settlement. Its performance generally depends on its load bearing capacity, moisture content and volume changes. Moreover, its load bearing capacity depends on the degree of compaction, moisture content and soil type. Hence, the relationships among the strength, density and moisture content should be studied thoroughly (ERA, 2002).

Subgrade soil is the integral part of the road pavement structure which provides support to the pavement. The subgrade and its different properties are very much important in the pavement design structure. The major function of the subgrade is to provide the support to the pavement against traffic loading and for this the subgrade that should possess sufficient stability under adverse climate and heavy loading conditions (Deepika, 2012).

2.11.2 Grain size distribution

The shapes of the curves indicate the nature of the soil tested. On the basis of the shapes we can classify soils as:-

1. Uniformly graded or poorly graded.
2. Well graded.
3. Gap graded.

A sample of dry soil (of about 500 g) is mechanically shaken through a series of Sieves and the percentage retained or passing through each sieve is weighted. The results are then plotted as a cumulative curve against the sieve size and because the range of possible particles is of the order of 106 (from over 100mm to less than 0.001 mm), the grain size distribution is usually represented versus the logarithm of the average grain diameter. fine sand ranges from 0.06 to 0.2mm and coarse sand from 0.6 to 2 mm (Renata .L,.2002).

2.11.3 Moisture content

The moisture content of the soil which is defined as the ratio between mass of water to mass of soil solid was determine immediately after the sample was taken from the site. The samples were kept in plastic bag to prevent moisture loss during transportation from site to laboratory. The method employed for determining the moisture content was oven drying method. The measured amount of wet soil was put in an oven of 105 degree centigrade and kept for 24 hours and examined for weight loss.

2.11.4 Atterberge limits

The expected behavior of coarse-grained soils can be inferred from the grain distribution curve, the shape of particles and the degree of packing. On the contrary, the behaviour of fine-grained soils depends on the amount of clay sized particles and on the mineral composition. On the basis of this latter observation, to establish a criterion to classify fine-grained soils, we can formulate the following working hypothesis: if the mineral composition affects the behaviour of the particles and their interaction with water, in given circumstances the water content must reflect the mineral composition. According to such a hypothesis, a reliable procedure requires to single out a clearly defined and standardized physical condition and to make measurements of water content, in correspondence of which a given behavior is observed. Moving from the observation that a clay sample can be in a liquid, plastic, semi-solid or solid state (this physical state is called **consistency**), depending on its water content. The upper and lower limits of water content within which a clay element exhibits a plastic behavior are defined as **liquid limit** and **plastic limit** and the term **plasticity** must be intended as the ability of a soil sample to be worked and remolded,i.e.the ability of undergoing plastic deformations without cracking or crumbling. Casagrande (1932) developed the following standard procedure for the determination of the liquid limit. A clayey soil paste (a mass of about 100 g from passing the sieve 40) is mixed with water to form a creamy paste and is placed in a metal cup. It is levelled off and a V-groove is then cut through the sample and the cup is tapped, by counting the numbers of blows required just to close the groove. The sample is then removed and its water content is measured. The remaining sample is remixed to different water content and the test is repeated. Water content is finally plotted against the number of blows and the liquid limit is defined as the water content at which the groove is closed after being tapped 25 times (Murthy, 1990).

2.11.5 General Strength- density-moisture relationship

The level of compaction to be achieved in the field during construction is normally specified as a percentage of the maximum dry density obtained in a compaction test in the laboratory. The traditional laboratory tests are the 'standard' and the 'modified' AASHTO compaction or the 'light' and 'heavy' British Standard (BS) compaction (Gainesville, 2000).

- **Standard Proctor test**

This test method uses a 5.5-pound (2.5 kg) rammer dropped from a height of 12 inches (305 mm). The sample is compacted in three layers. Tests shall be performed in accordance with ASTM D 698 (AASHTO T 99) (Gainesville, 2000).

- **Modified Proctor test**

This test method uses a 10-pound (4.54 kg) rammer dropped from a height of 18 inches (457 mm). The sample is compacted in five layers. Tests shall be performed in accordance with ASTM D 1557 (Gainesville, 2000).

Desirable properties that the sub grade should possess include strength, drainage, effortlessness of compaction, permanency of compaction, and permanency of strength. Since sub grades vary considerably, it is necessary to make a thorough study of the soils in place and, from this, to determine the design of the pavement. The determination of the sub grade strength in order to use for the design of the road pavement requires ascertaining the density-moisture content-strength relationships specific to the sub grade soils encountered along the road under study. It is a must to select the density which will be representative of the compacted sub grade and the moisture content during and after construction (ERA, 2002).

2.11.6 Subgrade soil strength

The strength of a soil or subgrade can be determined by using a test known as California Bearing Ratio (CBR) test which was developed by corps of engineer in California in the year 1930's and it is way to determine the standard soil properties such as density (Bowles, 1984).

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. The California Bearing Ratio Test (CBR Test) is a penetration test developed by California State Highway Department (U.S.A.) for evaluating the bearing capacity of subgrade soil for design of flexible pavement. Tests are carried out on natural or compacted soils in water soaked or un-soaked conditions and the results so obtained are compared with the curves of standard test to have an idea of the soil strength of the sub grade soil (Bahailu, 2015).

Direct assessment of the likely strength or CBR of the sub grade soil under the completed road pavement is often difficult to make. Its value, however, can be inferred from an estimate of the density and moisture content of the sub grade together with knowledge of the relationship between strength, density and moisture content for the soil in question. This relationship must be determined in the laboratory. The density of the sub grade soil can be controlled within limits by compaction at suitable moisture content at the time of construction (ERA, 2002). It is recommended that the top 25cm of all sub grades should be compacted to a relative density of at least 100% of the maximum dry density achieved by ASTM Test Method D 698 (light or standard compaction).

CHAPTER THREE

METHODOLOGY

3.1 Study area

The study area is located in Oromia and Afar regional state which covers a distance of 141km from Adama to Awash Arba main trunk road for pavement distress.

The road traverses areas are hot weather condition and the road have different types of horizontal and vertical curves. This road provides a key link in the route from Addis Ababa to Djibouti for import and export of commodities. The road has a typical section of 7.2m road width.

3.1.1 Location, climate and topography of the study area

Adama is a city in central Ethiopia and the previous capital of Oromia Region. Adama forms a Special Zone of Oromia and is surrounded by Misraq Shewa zone. It is located at an elevation of 1712 meters and 99 km southeast of Addis Ababa. The city sites between the base of an escarpment to the west, and the Great Rift valley to the east.

Table 3.1 Location of Adama town (www.location-Data.org)

Coordinates	$8^0$33'35''N - $8^0$3'46''N latitude and $39^0$11'57''E – $39^0$21'15''E longitude
Country	Ethiopia
Region	Oromia
Zone	Adama special zone
Elevation	1,712m (5,617ft)
Population (2015) Total	324,000
Time Zone	EAT (UTC+3)
Area Code(s)	(+251) 22

Table 3.2 Climate Data for Adama (Storm247, 2015)

Climate Data for Adama													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average High °C (°F)	27 (81)	28.1 (82.6)	29.6 (85.3)	30.1 (86.2)	30.5 (86.9)	29.6 (85.3)	24.4 (75.9)	26.1 (79)	27.5 (81.5)	27.9 (82.2)	26.7 (80.1)	25.7 (78.3)	27.77 (82.03)
Daily mean °C (°F)	19.2 (66.6)	20.4 (68.7)	21.9 (71.4)	22.6 (72.2)	22.5 (72.5)	22.4 (72.3)	18.4 (65.1)	20.6 (69.1)	21.1 (70)	20.1 (68.2)	18.7 (65.7)	18.1 (64.6)	20.5 (68.91)
Average low °C (°F)	11.4 (52.5)	12.8 (55)	14.3 (57.7)	15.2 (59.4)	14.6 (58.3)	15.3 (59.5)	12.5 (54.5)	15.1 (59.2)	14.7 (58.5)	12.3 (54.1)	10.8 (51.4)	10.6 (51.1)	13.3 (55.93)
Average precipitation mm (inches)	11 (0.43)	22 (0.87)	45 (1.77)	58 (2.28)	43 (1.69)	74 (2.91)	201 (7.91)	210 (8.27)	101 (3.98)	24 (0.94)	13 (0.51)	7 (0.28)	809 (31.84)

Awash Araba is a market town in central Ethiopia. Located in Administrative zone 3 of the Afar Region, above a gorge on the Awash River, after which the town is named, the town lies on the Addis Ababa-Djibouti Railway, which crosses the gorge by a bridge there. It is the largest settlement in Awash Fentale Woreda.

Awash lies outside the Awash National Park, which is known for its wildlife, for the Mount Fentale caldera and for the Filwoha Hot Springs. Its market is held on Mondays, where Afar and Kereyu crafts can be found.

Table 3.3 Location of Awash Arba town (www.location-Data.org)

Coordinates	$8^0$59'26''N - $8^0$12'38''N latitude and $40^0$110'23''E – $40^0$26'35''Elongitude
Country	Ethiopia
Region	Afar Region
Zone	Administrative zone 3
Elevation	986m (3,235ft)
Population (2005) Total	11,053

Table 3.4 Rainfall data for Awash Arba

Average rainfall data in Awash Arba													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average rainfall (mm)	14	10	50	34	23	22	122	120	30	28	9	10	473

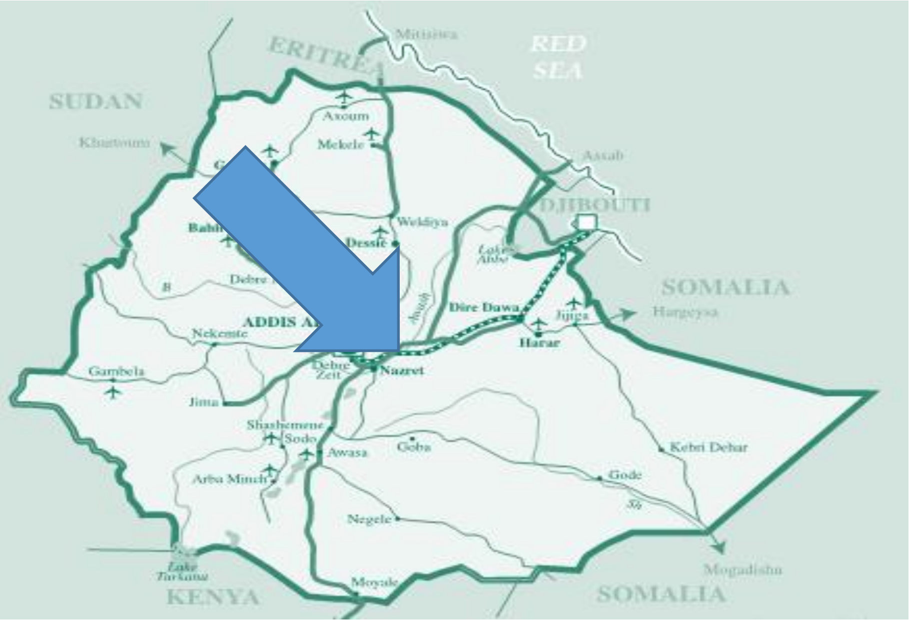

Figure 3.1: Ethiopia road network map (ERA, 2002)

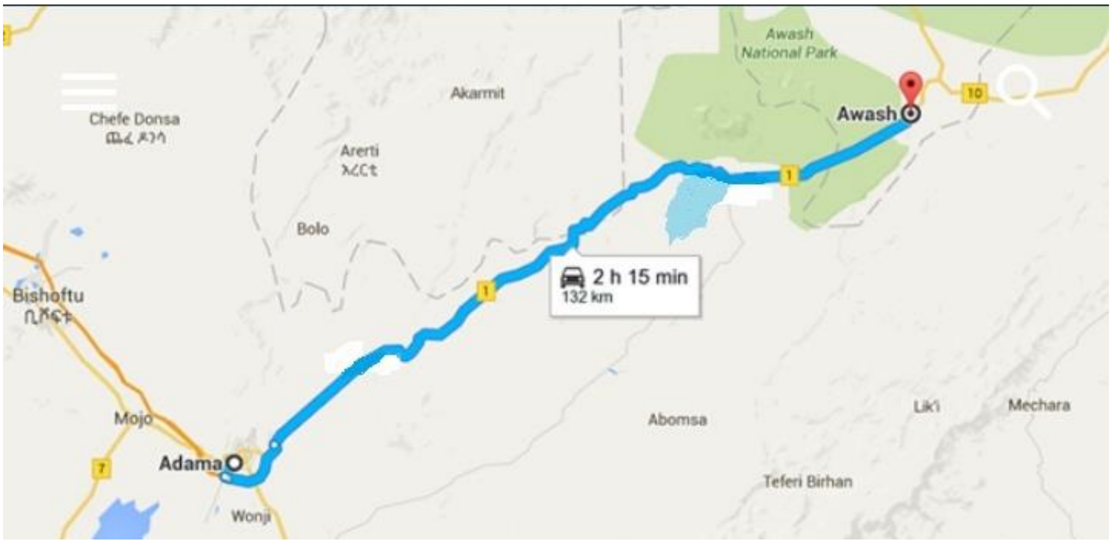

Figure 3.2 Road map of the study area (Wikipedia, 2016)

3.2 Study period

The study period set for this research was from March to September, 2016.

3.3 Study design

The research study was conducted by using both experimental and analytical method. Qualitative and quantitative data were gathered in the study area. Qualitative study gives focuses on the findings where a quantitative study was used to describe the numerical values of the research findings, based on field investigation and laboratory results.

3.4 Population

The total number of populations that was considered in the study area is the pavement distress existing within the range of study area which covers a distance of 141km from Adama to Awash Arba along the main trunk roads.

3.5 Sample size and Sampling procedures

The procedure utilized throughout the conduct of this research study is as follows: a Continuous reviewed related literature on relevant areas of pavement distress evaluation techniques includes articles, reference books, research papers, and standards specifications.

Based on the pavement Condition Rating (PCR), for the section which exhibits a failed and serious condition, a laboratory investigation has been conducted for the engineering properties of subgrade soil to check the subgrade soil is the result of the pavement distress. A conclusion and recommendation are drawn on based on the results, also appropriate remedial measure for types of pavement failures.

3.6 Study variable

The study variables both dependent and independent are assessed in this research. Which display the pavement distress from Adama to Awash Arba.

Independent variables

- Pavement Condition Index
- Grain Size/Gradation
- Atterberg Limits
- Compaction test
- California Bearing Ratio (CBR)

Dependent variable

- Asphalt pavement distress

3.7 Data collection instruments

- Measuring wheel/Hand odometer wheel as shown in Figure 3.2
- Straightedge
- Ruler
- Data sheet: to collect information like; date, location, branch, section, sample units, sample size, distress types, severity levels and name of surveyor as shown in Table 3.5
- Laboratory equipment's
- Digital camera: for documentation
- Ms word and Ms excel: for analysis of field and laboratory data

Figure 3.3 measuring wheel/Hand odometer wheel

Table 3.5 Flexible pavement survey data sheet (ASTM D6433, 2007)

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH:
BRANCH………… SECTION………….. SAMPLE UNIT………………. SURVEYED BY………….. DATE…… SAMPLE AREA……………..	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE

3.8 Data collection process

In order to attain the purpose of this research work ethical considerations was concentrating on in the context of quantitative and qualitative research. Before starting any data collection formal letter was obtained from JIT and an official permission was obtained from concerned bodies. Data collection process included field visual inspection, Field measurements and laboratory tests were conducted.

The type of data was collected from the field with in an interval length 1000m by width of 7.2m for the study 141Km and the data (type and severity levels of distress) was recorded on the data sheet for PCI determination shown in figure 3.4. The data was collected using visual survey method by the researcher and daily labour. And for the section which show failed and serious pavement condition rating a laboratory test were conducted for subgrade soils.

Figure 3.4 Pavement Condition Index (PCI), Rating scale and suggested colour (ASTM D6433, 2007)

3.9 Data processing and analysis

The field work and laboratory data was processed and analysis using Microsoft word and excel.

3.9.1 Field work

A manual survey is performed following ASTM D 6433. The pavement was divided into sections. Each section was divided into sample units. The type and severity of sample distress was assessed by visual inspection of the pavement sample units and the quantity of each distress was measured. Typically, this procedure requires a team of at least two engineers (US Army, 2001).

Before starting of the detail pavement evaluation, the entire road length was visually assessed and it is attempted to identify the types of failures occurred on the road surface. After finishing of the pavement condition survey, seven soil samples were collected for failed and serious road condition rating. The following representative photographs can show the type of failures and measurement along Adama to Awash Arba Road section the road.

3.9.2 Laboratory tests

I) Atterberg limit

Atterberg limit correspond to values of moisture content where the consistency of the soils change as it is progressively dried from slurry. Plasticity is the response of a soil to changes in moisture content. When adding water to a soil it changes its consistency from hard and rigid to soft and pliable, the soil is said to exhibit plasticity. Clays can be very plastic, silts are only slightly plastic, and sands and gravels are non-plastic. For fine-grained soils, engineering behavior is often more closely correlated with plasticity than gradation (Robert, et., 1981).

II) Grain Size Distributions (Gradation)

Gradation, or the distribution of particle size within a soil, is an essential descriptive feature of soils. Soil texture such as gravel, sand, silty and clay and engineering classifications are based large on gradation. Many engineering properties like relative compaction, permeability, strength, swelling potential, and susceptibility to frost action are closely correlated with gradation parameters. Gradation is measured in the laboratory using two tests: a mechanical sieve analysis for the sand and coarser fraction, and a hydrometer test for the silt and finer clay material (FHWA, 2006).

III) Soil compaction

Compaction tests are performed using disturbed, prepared soils with or without additives. Normally, soil passing the No. 4 (4.75mm) or 19mm sieve is mixed with water to form samples at various moisture contents ranging from the dry state to wet state. These samples are compacted in three layers in a mold by a hammer in accordance with specified nominal compaction energy. Dry density is determined based on the moisture content and the unit weight of compacted soil. The water content at which this dry density occurs is termed as the optimum moisture content (OMC). The test is done in the laboratory according to AASHTO T-99(Standard proctor test).

IV) Subgrade soil classification

Soil classification is the arrangement of soils into different group in order that the soils in a particular group would have similar behaviour. The method of classification used in this study was the AASHTO System. The AASHTO Classification system is useful for classifying soils for highways. The particle size analysis and the plasticity characteristics are required to classify a soil. The soils with the lowest number, A-1, is the most suitable as a highway material or subgrade.

V) California Bearing Ratio (CBR)

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

3.10 Ethical consideration

While doing anything concerned research without any harm and oppressed of the community in the study area, rather with great respects.

3.11 Data quality assurance

The quality of data collection was assured without any hesitations because I have been followed primary source of data collection (the first witness of a fact) and secondary source of data collection (books). Therefore; the assurance of those data are highly recognized and those data are true.

3.12 Limitation of the research

The research has been limited by the following

- Limited budget was one problem during study period.
- During subgrade soil sampling the local people didn't understand at the first time.

3.13 Operational definition

- **Asphalt concrete (AC) surface**:- aggregate mixture with an asphalt cement binder
- **Pavement distress: -** external indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination thereof. Typical distresses are cracks, rutting, and weathering of the pavement surface. (ASTM D 6433, 2007)
- **Deterioration**: - is the reduction in the performance level of the pavement with time.
- **Pavement condition index (PCI):-** a numerical rating of the pavement condition that ranges from 0 to 100 with 0 is being the worst possible condition and 100 being the best possible condition. (ASTM D 6433, 2007)
- **Pavement condition rating (PCR):-** a verbal description of pavement condition as a function of the PCI value that varies from "failed" to "excellent". (ASTM D 6433, 2007)

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 General

Asphalt Concrete (AC) Surfaced Pavement—individually inspect each sample unit chosen. Sketch the sample unit. Record the branch and section number and the number and type of the sample unit. Record the sample unit size measured with the hand odometer. Conduct the distress inspection by walking over the sidewalk/shoulder of the sample unit being surveyed, measuring the quantity of each severity level of every distress type present, and recording the data. Each distress must correspond in type and severity to that described in Appendix A. The method of measurement is included with each distress description. Repeat this procedure for each sample unit to be inspected.

4.2 Field condition survey result and discussion

4.2.1 Types of pavement distress

For entire section inspections, the inspector walks over each sample unit, measures each distress type and severity, and records the data on the Asphalt Pavement Inspection Sheet. The letter L (low), M (medium), or H (high) is included along with the distress number code to indicate the severity level of the distress. Distresses and severity level definitions are listed in Chapter two.

There are more than 10 pavement distresses in the study area. The following table shows the types of pavement exists along the study area.

Table 4.1 Types of pavement exist on the study area

Types of pavement distress	Level of severity		
	Low	Medium	High
Alligator cracking	✓	✓	✓
Bleeding	✓	✓	

Block cracking		✓	
Corrugation		✓	✓
Depression	✓		
Edge cracking	✓	✓	✓
Long & travs cracking	✓	✓	✓
Patching		✓	✓
Polished aggregate			
Potholes	✓	✓	✓
Railroad crossing		✓	
Rutting	✓	✓	✓
swell	✓	✓	

The following images describe the major pavement distresses that are found in the study area along the road section from Adama to Awash Arba during the field condition surveys:

A. Alligator Cracking

Low Medium High

Figure 4.1 Alligator cracking severity levels

B. Bleeding


Low Medium

Figure 4.2 Bleeding severity levels

C. Block Cracking

Medium

Figure 4.3 Block cracking severity levels

D. Corrugation


Medium High

Figure 4.4 Corrugation level of severity

E. Depression

Low

Figure 4.5 Depression severity level

F. Edge Cracking

Low Medium High

Figure 4.6 Edge cracking severity level

G. Longitudinal and Transverse Cracking

Low Medium High

Figure 4.7 longitudinal and transverse cracking severity levels

H. Patching and Utility Cut Patching

Medium High

Figure 4.8 Patching and Utility Cut Patching severity levels

I. Polished Aggregate

Figure 4.9 Polished Aggregate

J. Potholes

Low Medium High

Figure 4.10 Potholes severity level

K. Railroad Crossing

Medium

Figure 4.11 Railroad Crossing severity level

L. Rutting

Low Medium High

Figure 4.12 Rutting severity level

M. Swell

Low **Medium**

Figure 4.13 Swell severity levels

4.2.2 Pavement condition rating

Pavement Condition Rating (PCR) is a verbal description of pavement condition as a function of the Pavement Condition Index (PCI) value that varies from "failed" to "good". Based on the field condition survey, all types of pavement condition rating were exist in the study area along the road section from Adama to Awash Arba and the condition of each results is show in the following tables

The following table show the result of pavement condition rating along the selected road section from Adama to Awash Arba and the calculation of these values is shown in Appendix A and the deduct value curves for each distress type is shown in Appendix B.

Table 4.2 Flexible pavement condition survey data sheet for Good PCR

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Adama-Awash Arba **SECTION**: 065+000-066+000 **SAMPLE UNIT**:15
SURVEYED By: Ashebir **DATE**: 17/5/2016 **SAMPLE AREA**: 7200m^2

SKETCH: 1000m

7.2m

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
10M	7.12	6.33									13.45	0.19	0
11M	1.25*2.65	1.15*3.65									7.51	0.10	2.9

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

Max CDV=2.9

PCI=100-Max CDV=100-2.9=97.1

PCR=Good

Table 4.3 Flexible pavement condition survey data sheet for Satisfactory PCR

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH: 1000m × 7.2m

BRANCH: Adama-Awash Arba **SECTION**: 082+000-083+000 **SAMPLE UNIT**:28

SURVEYED By: Ashebir **DATE**: 21/5/2016 **SAMPLE AREA**: 7200m^2

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	9.32*1.07	6.29*1.54	11.34*2.45								47.442	0.66	18.2
3M	13.5*3.54										47.79	0.66	2.1
10M	6.23	8.47	12.35	10.11	6.12	9.44	7.58				60.3	0.84	2.4
12	21.08*7.2	18.36*7.2									283.968	3.94	1.3
13M	1										1	0.01	-

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 18.2) = 8.51<10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=8.51>4)

Table 4.4 Calculation of corrected PCI value for Satisfactory PCR

#	Deduct Values										Total	q	CDV
1	18.2	2.4	2.1	1.3							24	3	14
2	18.2	2.4	2	1.3							23.9	2	18
3	18.2	2	2	1.3							23.5	1	22

Max CDV=22, PCI=100-Max CDV=100-22=78 and PCR=Satisfactory

Table 4.5 Flexible pavement condition survey data sheet for Fair PCR

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Adama-Awash Arba **SECTION**: 005+000-006+000 **SAMPLE UNIT**:5
SURVEYED By: Ashebir **DATE**: 5/5/2016 **SAMPLE AREA**: 7200m^2

SKETCH: 1000m

7.2m

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Sags	9. Lane/Shoulder Drop Off	14. Railroad Crossing	19. Weathering/Ravelling
5. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3M	15.23*4.53	23.84*5.26	45.62*4.35	25.38*5.36	45.32*4.52						733.721	10.19	17.3
6L	1.14*0.96										1.0944	0.02	-
7M	9.23	11.23	3.23								23.69	0.33	4.1
12	35.63*7.2	45.23*6.21									537.414	7.46	2.9
15M	22.23*2.54	26.95*2.86	14.56*2.75								173.581	2.41	27.6

$$m = 1 + \left(\frac{9}{98}\right)x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right)x(100 - 27.6) = 7.65<10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used.(m=7.65>4)

Table 4.6 Calculation of corrected PCI value for Fair PCR

#	Deduct Values										Total	q	CDV
1	27.6	17.3	4.1	2.9							51.9	4	28
2	27.6	17.3	4.1	2							51	3	36
3	27.6	17.3	2	2							48.9	2	36
4	27.6	2	2	2							33.6	1	30

Max CDV=36, PCI=100-Max CDV=100-36=64 and PCR=Fair

Table 4.7 Field work Summary of PCI and PCR

#	Start/end Station(km+m)	PCI	PCR
1	000+000-001+000	90.3	Good
2	001+000-002+000	50	Poor
3	003+000-004+000	8	Failed
4	004+000-005+000	38	Very Poor
5	005+000-006+000	64	Fair
6	011+000-012+000	38	Very Poor
7	012+000-013+000	48	Poor
8	017+000-018+000	18	Serious
9	021+000-022+000	50	Poor
10	036+000-037+000	58	Fair
11	037+000-038+000	16	Serious
12	038+000-039+000	32	Poor
13	039+000-040+000	62	Fair
14	041+000-042+000	94.4	Good
15	065+000-066+000	97.1	Good
16	066+000-067+000	28	Very Poor
17	067+000-068+000	16	Serious
18	068+000-069+000	36	Very Poor
19	069+000-070+000	56	Fair
20	070+000-071+000	93.9	Good
21	071+000-072+000	42	Poor
22	072+000-073+000	32	Very Poor
23	073+000-074+000	54	Poor
24	074+000-075+000	68	Fair
25	075+000-076+000	12	Serious
26	076+000-077+000	28	Very Poor
27	081+000-082+000	48	Poor
28	082+000-083+000	78	Satisfactory

29	083+000-084+000	18	Serious
30	084+000-085+000	64	Fair
31	101+000-102+000	74	Satisfactory
32	102+000-103+000	18	Serious
33	140+000-141+000	74	Satisfactory

Table 4.8 Percentage of pavement condition rating

PCR	TOTAL NUMBER of PCR	Percentage of PCR (%)
Good	4	12.12
Satisfactory	3	9.09
Fair	6	18.18
Poor	7	21.21
Very poor	6	18.18
Serious	6	18.18
Failed	1	3.03

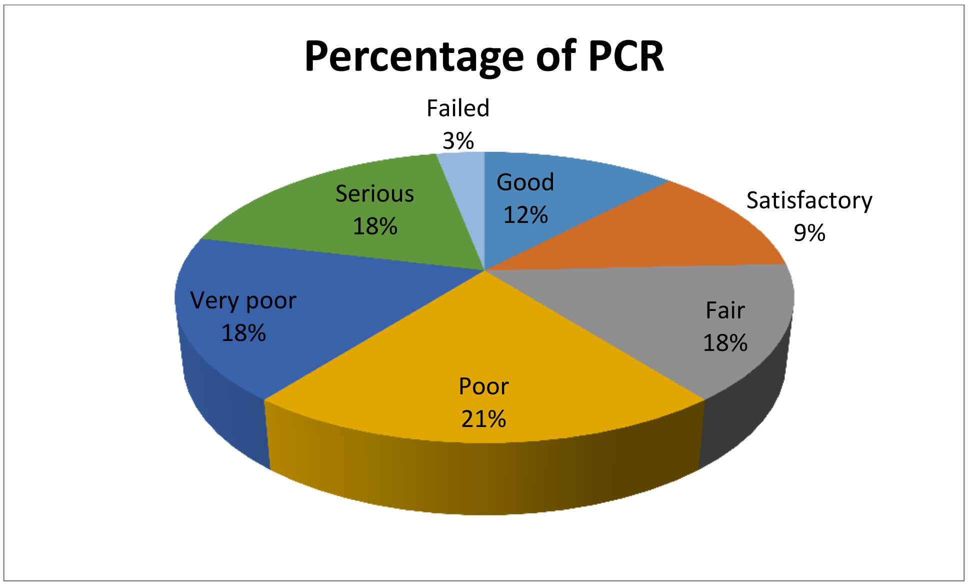

Figure 4.14 Percentage Pavement condition rating

The starting point of this research was at Adama town Derartu Tulu roundabout and ends at Awash Arba entrance.

The selected road section was the station which has pavement distresses.

4.3 Laboratory test result and discussion for Failed and Serious PCR

4.3.1 Grain size analysis

Gradation, or the distribution of particle size within a soil, is an essential descriptive feature of soils. Soil texture such as gravel, sand, silty and clay and engineering classifications are based large on gradation (FHWA, 2006).

The result of grain size distribution is shown in the table below and the data is shown in Appendix C.

Table 4.9 Result of grain size distribution

Station	PCR	% passing sieve size					
		19mm	12.5mm	4.75mm	2mm	0.425mm	0.075mm
003+000-004+000	Failed	100	100	95.6	90.8	74.4	60.6
017+000-018+000	Serious	100	100	100	96.5	92.17	88.17
037+000-038+000	Serious	100	100	100	98.2	82.2	64
067+000-068+000	Serious	100	100	95.6	94.8	93.4	89.8
075+000-076+000	Serious	100	100	82.01	70	58.82	50.14
083+000-084+000	Serious	100	100	80.6	76.2	72.4	64.8
102+000-103+000	Serious	100	100	93.2	88.4	72.6	61.5

According to AASHTO soil classification system a soil is generally classified in to two, one is granular materials of which 35% or less of the particles pass through the No. 200 (0.075mm) sieve and the other is soils of which more than 35% pass through the No. 200 (0.075mm) sieve are classified under groups. These soils are mostly silt and clay-type materials.

As observed from Table 4.4 grain size analysis tests revealed that, all the samples result shows that more than 35% passes No. 200 (0.075mm)sieve. Therefore all the samples are silt and clay type soil.

The soils were classified by ASSHTO under the A-6 and A-7-6 category which showed that usual types of significant constituent materials was clayey with general rating of a soil fair to poor as a sub-grade material.

4.3.2 Atterbergs limit test result and discussion

The plasticity of the subgrade soil is shown in the table below and the data analysis is attached in Appendix D.

Table 4.10 Results of Atterberg limits

Station	PCR	Subgrade soil		
		LL	PL	PI
003+000-004+000	Failed	44.48	18.92	25.56
017+000-018+000	Serious	41.48	21.38	20.1
037+000-038+000	Serious	38.42	21.11	17.31
067+000-068+000	Serious	42.23	18.89	23.34
075+000-076+000	Serious	35.35	23.53	11.82
083+000-084+000	Serious	33.02	21.71	11.31
102+000-103+000	Serious	36.72	19.99	16.73

The sub-grade soil (i.e. LL < 80% and PI <55%) it satisfies the specification; grouped into A-6 and A-7-6 in AASHTO soil classification system and USCS as Sand lean clay (CL) for all stations except for station 83+000-84+000 which is Gravelly lean clay with sand.

According to ERA manual (2002), soils with PI values less than 25% and LL< 50 are suitable subgrade materials so that all station show suitable subgrade materials for failed and serous pavement condition rating (PCR).

4.3.3 Compaction test

A soil was mixed with water to form samples at various moisture contents ranging from the dry state to wet state. Soil compaction tests were performed using disturbed soil sample. These samples are compacted in three layers in a mold by a hammer in accordance with specified nominal compaction energy. Dry density is determined based on the moisture content and the unit weight of compacted soil. The water content at which this dry density occurs is termed as the optimum moisture content (OMC). The test is done in the laboratory according to AASHTO T-99(Standard proctor test). The result of MDD and OMC are given in the following table and the data analysis is shown in Appendix E.

Table 4.11 Result of compaction test

Station	PCR	Subgrade	
		OMC	**MDD**
003+000-004+000	Failed	23.2	1.430
017+000-018+000	Serious	21.2	1.384
037+000-038+000	Serious	15.8	1.478
067+000-068+000	Serious	12.0	1.533
075+000-076+000	Serious	18.5	1.452
083+000-084+000	Serious	20.9	1.460
102+000-103+000	Serious	24.1	1.338

The Subgrade soil laboratory test maximum dry (MDD) densities are between 1.338g/cm – 1.533g/m3 while optimum moisture content (OMC) ranges from 12% - 24.1%.

4.3.4 Subgrade soil classification

AASHTO soil classification system usually used for highway construction. The method of classification used in this study was the AASHTO soil classification system. The particle size analysis and the plasticity characteristics are required to classify a soil. The table below shows the soil classification according to AASHTO standard and unified soil classification system.

Table 4.12 result of subgrade soil classification

Station	PCR	Atterberg limit			AASHTO soil classification system	Unified soil classification system
		LL	PL	PI		
003+000-004+000	Failed	44.48	18.92	25.56	A-7-6	CL
017+000-018+000	Serious	41.48	21.38	20.1	A-7-6	CL
037+000-038+000	Serious	38.42	21.11	17.31	A-6	CL
067+000-068+000	Serious	42.23	18.89	23.34	A-7-6	CL
075+000-076+000	Serious	35.35	23.53	11.82	A-6	CL

083+000-084+000	Serious	33.02	21.71	11.31	A-6	CL
102+000-103+000	Serious	36.72	19.99	16.73	A-6	CL

The soils were classified by ASSHTO under the A-6 and A-7-6 category which showed that usual types of significant constituent materials was clayey with general rating of a soil fair to poor as a sub-grade material.

4.3.5 California Bearing Ratio

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 soil at some water content and density to the standard unit load required to obtain the same depth of penetration on a standard sample of crushed stone. The result of the CBR is shown in the table below and the analysis is attached in Appendix F.

Table 4.13 result of California bearing ratio test

Station	PCR	Subgrade CBR value	% swell
003+000-004+000	Failed	10.4	0.27
017+000-018+000	Serious	9.9	0.36
037+000-038+000	Serious	8.5	0.24
067+000-068+000	Serious	8.5	0.29
075+000-076+000	Serious	8.1	0.28
083+000-084+000	Serious	7.9	0.47
102+000-103+000	Serious	9.1	0.40

The results of the CBR test show that samples from all sites have CBR values greater than 5%. These samples are therefore good subgrade materials and suitable borrow fill materials.

The percent swell test results are found below 1% which is an indication of less expansiveness of the soil which is very good as a subgrade material. Therefore these values indicate that the cause of pavement failure for failed and serious pavement condition rating was not the subgrade soil.

4.4 Estimation of the maintenance option for pavement distress

According to the pavement condition survey the study pavement from Adama to Awash Arba required maintenance. The following table shows maintenance option for cracking, surface deformation, disintegration and surface defects with their severity level.

Table 4.14 Maintenance suggestion for Cracking

Pavement distress	Severity level	Maintenance option
Alligator cracking	low	seal coat
	medium	Seal coat or Patching
	high	Thin hot-mix Overlay
Block cracking	medium	Chip seal, seal coat or Thin hot-mix Overlay
Edge cracking	low	Seal coat
	medium	Patching
	high	Patching
Long & travs cracking	low	Clean and Seal
	medium	Clean and Seal or Full-depth crack Repair
	high	Full-depth crack Repair

Table 4.15 Maintenance suggestion for surface deformation

Pavement distress	Severity level	Maintenance option
Corrugation	medium	Thin hot-mix overlay
	high	Thin hot-mix overlay
Depression	low	Patching
Rutting	low	Slurry seal, Patching
	medium	Slurry seal, Patching, or Thin hot-mix overlay
	high	Patching, or Thin hot-mix overlay
swell	low	Thin hot-mix overlay
	medium	Thin hot-mix overlay

Table 4.16 Maintenance suggestion for disintegration

Pavement distress	Severity level	Maintenance option
Patching	medium	Patching
	high	Patching
Potholes	low	Patching
	medium	Patching
	high	Patching

Table 4.17 Maintenance suggestion for surface defects

Pavement distress	Severity level	Maintenance option
Polished aggregate		Slurry seal or Thin hot-mix overlay
Bleeding	low	Seal coat, Double chip seal or Slurry seal
	medium	Seal coat, Double chip seal or Slurry seal

The selected road section condition was full of cracking, surface deformation, disintegration and surface defects. For Cracking use one of this technique Clean and Seal, Full-depth crack Repair, seal coat or Thin hot-mix Overlay and for surface treatment technique such as seal coat, double chip seal, slurry seal or Thin hot-mix overlay by observing level of severity. And the sections with various sizes of potholes should be patched with good quality of asphalt.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on field work pavement condition survey and laboratory results the conclusion is as follows:

The pavement condition survey along the selected road shows that there were different failure type such as alligator cracking, bleeding, block cracking, corrugation, depression, edge cracking, longitudinal and transverse cracking, patching, polished aggregate, potholes, railroad crossing, rutting and swell.

The result of the research show that the PCI value range from 8 to 97.1 which shows that all section of the road had all types of pavement condition Rating (Good, Satisfactory, Fair, Very Poor, Poor, Serious and Failed). From the field work pavement condition survey was collected as 12.12% good, 9.09% satisfactory, 18.18% fair, 21.21% poor, 18.18% very poor, 18.18% serious and 3.03% failed.

A laboratory soil investigation for failed and serious pavement condition rating show that the liquid limit varies from 33.02% -44.48% and Plasticity index from 11.3% - 25.56%, according to ERA manual, soils with LL< 50% and PI > 25% are suitable subgrade materials so all station are good. The soils were classified by ASSHTO under the A-6 and A-7-6 category which showed that the soils were fair to poor as a sub-grade material. The soaked CBR values of subgrade soil materials are between 7.9% -10.4%. According to ERA manual CBR values greater than 5% are good subgrade materials. Therefore, from the laboratory test results the subgrade soil was not the cause of pavement failure for failed and serious pavement condition rating.

Generally, the selected road section condition was full of cracking, surface deformation, disintegration and surface defects. For Cracking use one of this technique Clean and Seal, Full-depth crack Repair, seal coat or Thin hot-mix Overlay and for surface treatment technique such as seal coat, double chip seal, slurry seal or Thin hot-mix overlay by observing level of severity. And the sections with various sizes of potholes should be patched with good quality of asphalt.

5.2 Recommendation

- Periodic inspection is necessary to provide current and useful evaluation data. It is recommended that ratings be updated every year.
- Periodic pavement maintenance practices should be employed to reduce aging of pavement failure.
- Effective maintenance can extend a pavement's life. Crack sealing and surface treatments can reduce in aging of asphalt pavement.
- Training of special teams for maintenance working under the supervision of engineers who have experience.
- New technology developments have produced a methodology that can quickly inspect roads and streets by using automated inspection equipment. Therefore, it is recommended to consider using automated survey techniques to reduce labour needs and increase safety of any personnel contractor that may conduct the surveys.
- Further works are required to determine the additional study on Sub-base, base-course material and axle load to be one of the causes of pavement distress.

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APPENDIX A: PAVEMENT CONDITION INDEX (PCI) CALCULATION

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Adama-Awash Arba **SECTION**: 000+000-001+000 **SAMPLE UNIT**:1

SURVEYED By: Ashebir **DATE**: 4/5/2016 **SAMPLE AREA**: 7200m^2

SKETCH: 1000m 7.2m

6. Alligator Cracking
7. Bleeding
8. Block cracking
9. Bumps and Sags
10. Corrugation

6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking

11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting

16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	12.18*1.52	10.97*2.20									42.6476	0.59	7.9
10M	12.63	7.20	6.37	9.22	6.81	11.57					53.8	0.75	1.8

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

Max CDV=7.9+1.8=9.7

PCI=100-Max CDV=100-9.7=90.3

PCR=Good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH: 1000m × 7.2m

BRANCH: Adama-Awash Arba **SECTION**: 003+000-004+000 **SAMPLE UNIT**:3
SURVEYED By: Ashebir **DATE**: 4/5/2016 **SAMPLE AREA**: 7200m^2

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	3.19*2.24	2.94*2.51	1.68*2.46	6.02*2.53	4.23*2.24						43.3636	0.60	17.6
7L	15.50	11.00	8.96								35.46	0.49	2.8
7M	11.73	2.64	6.97								21.34	0.30	4.9
7H	24.63	11.69									36.32	0.50	8.7
10M	12.45										12.45	0.17	0
15H	92.35*5.32	84.21*2.97	81.70*4.93	102.38*2.96	97.93*4.84								
	78.84*5.61										2363.51	32.83	78.1

$m = 1 + \left(\frac{9}{98}\right) x(100 - HDV) = 1 + \left(\frac{9}{98}\right) x(100 - 78.1) = 3.01$, Use highest 3 deducts and 0.01 of five deduct value (0.01*2.8=0.028)

#	Deduct Values										Total	q	CDV
1	78.1	17.6	8.7	4.9	0.028						109.328	4	62
2	78.1	17.6	8.7	2	0.028						106.428	3	64
3	78.1	17.6	2	2	0.028						99.728	2	72
4	78.1	2	2	2	0.028						84.128	1	92

Max CDV=92 PCI=100-Max CDV=100-92=8 PCR=Failed

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 004+000-005+000 **SAMPLE UNIT**:4 **SURVEYED By**: Ashebir **DATE**: 4/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	18.56*1.94	14.23*2.05	9.37*1.57	21.06*1.72							116.112	1.61	26.1
15M	231.23*3.32	156.64*3.11	111.73*3.22	124.22*3.11	95.52*3.14								
	104.88*3.16										2632.282	36.56	59.3

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 59.3) = 4.74$$

If less than m deduct values are available, all of the deduct values are used.(m=4.74>2)

#	Deduct Values										Total	q	CDV
1	59.3	26.1									85.4	2	60
2	59.3	2									61.3	1	62

Max CDV=62

PCI=100-Max CDV=100-62=38

PCR=Very Poor

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m
BRANCH: Adama-Awash Arba **SECTION**: 005+000-006+000 **SAMPLE UNIT**:5 **SURVEYED By**: Ashebir **DATE**: 5/5/2016 **SAMPLE AREA**: 7200m^2	7.2m

6. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
7. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
8. Block cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
9. Bumps and Sags	9. Lane/Shoulder Drop Off	14. Railroad Crossing	19. Weathering/Ravelling
10. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3M	15.23*4.53	23.84*5.26	45.62*4.35	25.38*5.36	45.32*4.52						733.721	10.19	17.3
6L	1.14*0.96										1.0944	0.02	-
7M	9.23	11.23	3.23								23.69	0.33	4.1
12	35.63*7.2	45.23*6.21									537.414	7.46	2.9
15M	22.23*2.54	26.95*2.86	14.56*2.75								173.581	2.41	27.6

$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 27.6) = 7.65 < 10$ (OK!)

If less than m deduct values are available, all of the deduct values are used.(m=7.65>4)

#	Deduct Values										Total	q	CDV
1	27.6	17.3	4.1	2.9							51.9	4	28
2	27.6	17.3	4.1	2							51	3	36
3	27.6	17.3	2	2							48.9	2	36
4	27.6	2	2	2							33.6	1	30

Max CDV=36, PCI=100-Max CDV=100-36=64 and PCR=Fair

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY	SKETCH: 1000m

DATA SHEET FOR SAMPLE UNIT	
BRANCH: Adama-Awash Arba **SECTION**: 0011+000-0012+000 **SAMPLE UNIT**:6	7.2m
SURVEYED By: Ashebir **DATE**: 6/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
5M	10.25*2.35	18.63*3.04	6.85*3.61								105.4512	1.46	17.5
15M	96.38*2.94	72.35*3.01	82.10*2.99	88.59*2.97	102.34*3.06								
	92.31*3.00	84.67*3.16	105.89*2.98								2182.9218	30.32	58.1

$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 58.1) = 4.85 < 10$ (OK!)

If less than m deduct values are available, all of the deduct values are used.(m=4.85>2)

#	Deduct Values										Total	q	CDV
1	58.1	17.5									75.6	2	52
2	58.1	2									60.1	1	62

Max CDV=62

PCI=100-Max CDV=100-62=38

PCR=Very Poor

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 012+000-013+000 **SAMPLE UNIT**:7 **SURVEYED By**: Ashebir **DATE**: 6/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Sags	9. Lane/Shoulder Drop Off	14. Railroad Crossing	19. Weathering/Ravelling
5. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3M	9.89*1.36	11.56*2.11	8.74*0.98	14.89*2.11							79.9351	1.11	3.2
13H	1										1	0.01	0
15M	56.35*5.64	68.91*5.63	72.28*5.66	78.72*5.42	52.22*3.10								
	45.39*3.11	80.74*2.94									2081.97	28.92	50.8

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 50.8) = 5.52<10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used.(m=5.52>2)

#	Deduct Values										Total	q	CDV
1	50.8	3.2									54	2	40
2	50.8	2									52.8	1	52

Max CDV=52

PCI=100-Max CDV=100-52=48

PCR=Poor

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m × 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 017+000-018+000 **SAMPLE UNIT**:8 **SURVEYED By**: Ashebir **DATE**: 7/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
13M	1	4	3								8	0.11	6.5
15M	56.23*5.63	75.18*5.59	62.63*5.61	95.53*5.62	89.37*5.57	78.73*5.58					2381.67	33.08	58.1
15H	72.37*2.97	65.69*3.02	84.58*3.06								852.636	11.84	61.1

$$m = 1 + \left(\frac{9}{98}\right)x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right)x(100 - 61.1) = 4.57<10\ (\text{OK!})$$

If less than m deduct values are available, all of the deduct values are used.(m=4.57>3)

#	Deduct Values										Total	q	CDV
1	61.1	58.1	6.5								125.7	3	80
2	61.1	58.1	2								121.2	2	82
3	61.1	2	2								65.1	1	66

Max CDV=82

PCI=100-Max CDV=100-82=18

PCR=Serious

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m, 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 021+000-022+000 **SAMPLE UNIT**:9 **SURVEYED By**: Ashebir **DATE**: 8/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Sags	9. Lane/Shoulder Drop Off	14. Railroad Crossing	19. Weathering/Ravelling
5. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	12.34*0.99										12.2166	0.17	8.9
2M	29.67*2.07										61.4169	0.85	3.2
13H	1	2	5	10	24	22					64	0.89	49.6

$$m = 1 + \left(\frac{9}{98}\right)x(100 - HDV) = 1 + \left(\frac{9}{98}\right)x(100 - 49.6) = 5.63 < 10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=5.63>3)

#	Deduct Values										Total	q	CDV
1	49.6	8.9	3.2								61.7	3	48
2	49.6	8.9	2								60.5	2	46
3	49.6	2	2								53.6	1	50

Max CDV=50

PCI=100-Max CDV=100-50=50

PCR=Poor

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Adama-Awash Arba **SECTION**: 036+000-037+000 **SAMPLE UNIT**:10

SURVEYED By: Ashebir **DATE**: 11/5/2016 **SAMPLE AREA**: 7200m^2

SKETCH: 1000m × 7.2m

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
13H	11										11	0.15	22.5
15L	92.31*3.01	62.37*2.99	87.23*3.10	64.23*2.98	52.37*3.01								
	67.10*2.97										1283.08	17.82	32.8

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 32.8) = 7.17 < 10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=7.17>2)

#	Deduct Values										Total	q	CDV
1	32.8	22.5									55.3	2	42
2	32.8	2									34.8	1	38

Max CDV=42

PCI=100-Max CDV=100-42=58

PCR=Fair

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m, 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 037+000-038+000 **SAMPLE UNIT**:11 **SURVEYED By**: Ashebir **DATE**: 11/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	17.45*2.38	4.51*2.14									51.1824	0.71	19.2
13H	24										24	0.33	32.7
15H	112.28*2.96	93.21*4.92	84.25*2.41	121.56*4.61	59.22*3.11								
	68.23*5.44	61.67*3.22									2308.3	32.06	80.3

$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 80.3) = 2.81 < 10$ (OK!)

Use highest 2 deducts and 0.81 of three deduct

0.81*19.2=15.55

#	Deduct Values										Total	q	CDV
1	80.3	32.7	15.55								128.55	3	80
2	80.3	32.7	2								115	2	72
3	80.3	2	2								84.3	1	84

Max CDV=84, PCI=100-Max CDV=100-84=16 and PCR=Serious

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY	SKETCH: 1000m

DATA SHEET FOR SAMPLE UNIT	
BRANCH: Adama-Awash Arba **SECTION**: 066+000-067+000 **SAMPLE UNIT**:16 **SURVEYED By**: Ashebir **DATE**: 18/5/2016 **SAMPLE AREA**: 7200m^2	7.2m

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Sags	9. Lane/Shoulder Drop Off	14. Railroad Crossing	19. Weathering/Ravelling
5. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
15M	62.38*3.15	54.33*3.20	52.82*3.14								536.208	7.45	39.9
15H	65.39*3.01	72.36*2.97	82.67*2.98	75.36*3.04	68.81*3.09								
	60.65*3.13										1289.6415	17.91	69.8

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 69.8) = 3.77 < 10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=3.77>2)

#	Deduct Values										Total	q	CDV
1	69.8	39.9									100.9	2	72
2	69.8	2									71.8	1	70

Max CDV=72

PCI=100-Max CDV=100-72=28

PCR=Very Poor

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m, 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 067+000-068+000 **SAMPLE UNIT**:17 **SURVEYED By**: Ashebir **DATE**: 18/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	21.24*3.25	18.28*2.11	14.32*1.98	8.56*2.18							154.615	2.15	28.8
15H	56.23*2.76	89.58*4.66	103.19*2.99	125.26*5.43	96.35*3.54								
	111.11*5.21	75.22*2.94	67.48*5.72								3088.432	42.89	83.2

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 83.2) = 2.54<10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=2.54>2)

#	Deduct Values										Total	q	CDV
1	83.2	28.8									112	2	80
2	83.2	2									85.2	1	84

Max CDV=84

PCI=100-Max CDV=100-84=16

PCR=Serious

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH: 1000m × 7.2m

BRANCH: Adama-Awash Arba **SECTION**: 070+000-071+000 **SAMPLE UNIT**:20
SURVEYED By: Ashebir **DATE**: 19/5/2016 **SAMPLE AREA**: 7200m^2

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
10M	6.92	4.52	8.94								20.38	0.28	0
10H	11.61	10.47	3.33	8.75	4.87						39.03	0.54	6.1
13L	1										1	0.01	-

Only one deduct value is greater than two, therefore the total deduct value is used in place of the maximum corrected deduct value in determining the PCI (ASTM D6433 standard, 2007)

Max CDV=6.1

PCI=100-Max CDV=100-6.1=93.9

PCR=Good

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

BRANCH: Adama-Awash Arba **SECTION**: 074+000-075+000 **SAMPLE UNIT**:24
SURVEYED By: Ashebir **DATE**: 19/5/2016 **SAMPLE AREA**: 7200m^2

SKETCH: 1000m × 7.2m

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	12.56*0.98	6.28*1.25	10.25*0.94								29.7938	0.41	15.6
7L	8.36	1.38	4.25	7.65	12.54	10.12					44.3	0.62	2.1
12	20.36*7.20	17.39*5.21	13.25*7.2	19.23*5.36							435.667	6.05	2.3
14M	7.31*1.31										9.5761	0.13	0
15M	19.35*2.32	10.64*2.78	13.56*2.54								108.914	1.51	22.3

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 22.3) = 8.14<10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=8.14>4)

#	Deduct Values										Total	q	CDV
1	22.3	15.6	2.3	2.1							42.3	4	24
2	22.3	15.6	2.3	2							42.2	3	28
3	22.3	15.6	2	2							41.9	2	32
4	22.3	2	2	2							28.3	1	30

Max CDV=32, PCI=100-Max CDV=100-32=68 and PCR=Fair

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 075+000-076+000 **SAMPLE UNIT**:25 **SURVEYED By**: Ashebir **DATE**: 20/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
15L	62.31*3.11	53.33*2.96	48.96*5.43	66.97*3.24							834.477	11.59	28.3
15M	92.36*3.27	75.25*5.43	62.88*3.21	71.62*3.11							1135.21	15.77	49.4
15H	46.64*3.13	89.95*5.21	62.14*2.97	74.23*5.51	56.29*3.22								
	62.37*5.11										1708.15	23.72	74.9

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 74.9) = 3.31<10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=3.31>3)

#	Deduct Values										Total	q	CDV
1	74.9	49.4	28.3								152.6	3	88
2	74.9	49.4	2								126.3	2	86
3	74.9	2	2								78.9	1	80

Max CDV=86, PCI=100-Max CDV=100-88=12 and PCR=Serious

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA	SKETCH: 1000m

SHEET FOR SAMPLE UNIT

BRANCH: Adama-Awash Arba **SECTION**: 081+000-082+000 **SAMPLE UNIT**:27 7.2m

SURVEYED By: Ashebir **DATE**: 21/5/2016 **SAMPLE AREA**: $7200m^2$

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	12.23*0.85	6.35*1.24	9.25*2.10								37.6945	0.52	17.3
1H	9.12*1.35	10.23*2.31									35.9433	0.50	22.1
10M	9.32	6.21	3.25	4.51							23.29	0.32	0
12	22.64*7.2										163.008	2.26	0
18L	20.45*3.68	28.94*3.84									186.386	2.59	4.9
18M	18.92*4.02	20.65*3.98	12.84*3.59								204.341	2.84	37.3

$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 37.3) = 6.76 < 10$ (OK!)

If less than m deduct values are available, all of the deduct values are used. (m=6.76>4)

#	Deduct Values										Total	q	CDV
1	37.3	22.1	17.3	4.9							81.6	4	48
2	37.3	22.1	17.3	2							78.7	3	52
3	37.3	22.1	2	2							63.4	2	46
4	37.3	2	2	2							43.3	1	42

Max CDV=52, PCI=100-Max CDV=100-52=48 and PCR=Poor

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA | SKETCH: 1000m

SHEET FOR SAMPLE UNIT	
BRANCH: Adama-Awash Arba **SECTION**: 082+000-083+000 **SAMPLE UNIT**:28 **SURVEYED By**: Ashebir **DATE**: 21/5/2016 **SAMPLE AREA**: 7200m^2	7.2m

6. Alligator Cracking
7. Bleeding
8. Block cracking
9. Bumps and Sags
10. Corrugation

6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking

11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting

16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	9.32*1.07	6.29*1.54	11.34*2.45								47.442	0.66	18.2
3M	13.5*3.54										47.79	0.66	2.1
10M	6.23	8.47	12.35	10.11	6.12	9.44	7.58				60.3	0.84	2.4
12	21.08*7.2	18.36*7.2									283.968	3.94	1.3
13M	1										1	0.01	-

$$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 18.2) = 8.51 < 10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=8.51>4)

#	Deduct Values										Total	q	CDV
1	18.2	2.4	2.1	1.3							24	3	14
2	18.2	2.4	2	1.3							23.9	2	18
3	18.2	2	2	1.3							23.5	1	22

Max CDV=22, PCI=100-Max CDV=100-22=78 and PCR=Satisfactory

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY	SKETCH: 1000m

DATA SHEET FOR SAMPLE UNIT	
BRANCH: Adama-Awash Arba **SECTION**: 083+000-084+000 **SAMPLE UNIT**:29	7.2m
SURVEYED By: Ashebir **DATE**: 21/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
15L	123.36*3.11	92.35*3.27	75.23*3.24								929.3793	12.91	28.1
15M	102.37*3.23	65.39*3.25	96.67*3.22	104.97*3.26							1196.652	16.62	49.2
15H	89.91*3.27	92.36*3.26	81.62*3.24								859.5481	11.94	62.4

$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 62.4) = 4.45 < 10$ (OK!)

If less than m deduct values are available, all of the deduct values are used. (m=4.45>3)

#	Deduct Values										Total	q	CDV
1	62.4	49.2	28.1								139.7	3	82
2	62.4	49.2	2								113.6	2	78
3	62.4	2	2								66.4	1	68

Max CDV=82

PCI=100-Max CDV=100-82=18

PCR= Serious

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH: 1000m × 7.2m

BRANCH: Adama-Awash Arba **SECTION**: 001+084-085+000 **SAMPLE UNIT**:30
SURVEYED By: Ashebir **DATE**: 21/5/2016 **SAMPLE AREA**: 7200m^2

6. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
7. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
8. Block cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
9. Bumps and Sags	9. Lane/Shoulder Drop Off	14. Railroad Crossing	19. Weathering/Ravelling
10. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
3M	12.63*3.34	19.23*2.68	6.92*3.68								119.186	1.66	4.9
10M	13.23	10.88	8.23	4.69	6.75	2.36	8.81	7.10					
	12.92	6.83	9.64								91.44	1.27	2.6
13M	5										5	0.07	-
15M	35.26*2.65	18.54*4.12	20.84*3.55	17.55*2.56							288.734	4.01	32.4

$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 32.4) = 7.21 < 10$ (OK!)

If less than m deduct values are available, all of the deduct values are used. (m=7.21>3)

#	Deduct Values										Total	q	CDV
1	32.4	4.9	2.6								39.9	3	26
2	32.4	4.9	2								39.3	2	30
3	32.4	2	2								36.4	1	36

Max CDV=36, PCI=100-Max CDV=100-36=64 and PCR=Fair

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 101+000-102+000 **SAMPLE UNIT**:31 **SURVEYED By**: Ashebir **DATE**: 25/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Sags	9. Lane/Shoulder Drop Off	14. Railroad Crossing	19. Weathering/Ravelling
5. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1M	3.45*2.76	8.36*3.21									36.3576	0.50	16.3
10M	12.53	6.53	4.21	9.35							32.62	0.45	0
12	42.31*7.2	36.52*5.36									500.379	6.95	2.3
13M	1	2									3	0.04	-
15L	23.46*2.61	32.67*2.73									150.42	2.09	17.8

$$m = 1 + \left(\frac{9}{98}\right)x(100 - HDV) = 1 + \left(\frac{9}{98}\right)x(100 - 17.8) = 8.55<10 \text{ (OK!)}$$

If less than m deduct values are available, all of the deduct values are used. (m=8.55>3)

#	Deduct Values										Total	q	CDV
1	17.8	16.3	2.3								36.4	3	22
2	17.8	16.3	2								36.1	2	26
3	17.8	2	2								21.8	1	22

Max CDV=26, PCI=100-Max CDV=100-26=74 and PCR=Satisfactory

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m, 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 102+000-103+000 **SAMPLE UNIT**:32 **SURVEYED By**: Ashebir **DATE**: 25/5/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking
2. Bleeding
3. Block cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Ravelling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
15M	75.55*3.11	92.93*3.09	99.67*2.99	101.17*3.03	72.22*3.06								
	56.77*3.09										1523.085	21.15	54.3
15H	62.36*2.97	59.91*3.07	61.19*3.19	83.51*3.13							825.7153	11.47	73.6

$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 73.6) = 3.42<10$ (OK!)

If less than m deduct values are available, all of the deduct values are used. (m=3.42>2)

#	Deduct Values										Total	q	CDV
1	73.6	54.3									127.9	2	82
2	73.6	2									75.6	1	76

Max CDV=82

PCI=100-Max CDV=100-82=18

PCR=Serious

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH: 1000m 7.2m
BRANCH: Adama-Awash Arba **SECTION**: 140+000-141+000 **SAMPLE UNIT**:33 **SURVEYED By**: Ashebir **DATE**: 3/6/2016 **SAMPLE AREA**: 7200m^2	

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Sags	9. Lane/Shoulder Drop Off	14. Railroad Crossing	19. Weathering/Ravelling
5. Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE
1L	23.53*2.46	18.62*2.12	9.63*4.19	15.94*3.36							191.266	2.66	19.9
7L	6.32	8.56									14.88	0.21	0
15L	18.32*2.46	14.64*2.97	29.63*2.73								169.438	2.35	14.2

$m = 1 + \left(\frac{9}{98}\right) x(100 - \text{HDV}) = 1 + \left(\frac{9}{98}\right) x(100 - 19.9) = 8.36<10$ (OK!)

If less than m deduct values are available, all of the deduct values are used. (m=8.36>2)

#	Deduct Values										Total	q	CDV
1	19.9	14.2									34.1	2	26
2	19.9	2									21.9	1	22

Max CDV=26

PCI=100-Max CDV=100-26=74

PCR=Satisfactory

APPENDIX B: DEDUCT VALUE CURVE FOR ASPHALT CONCRETE PAVEMENT

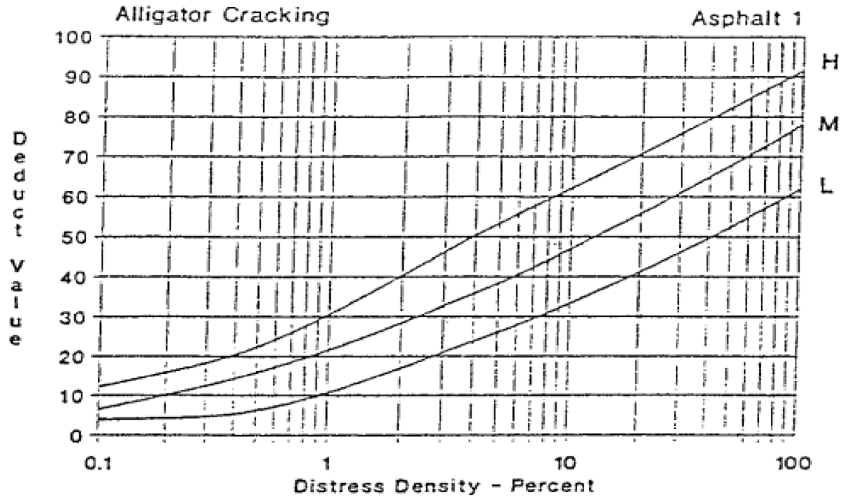


Fig: Alligator Cracking

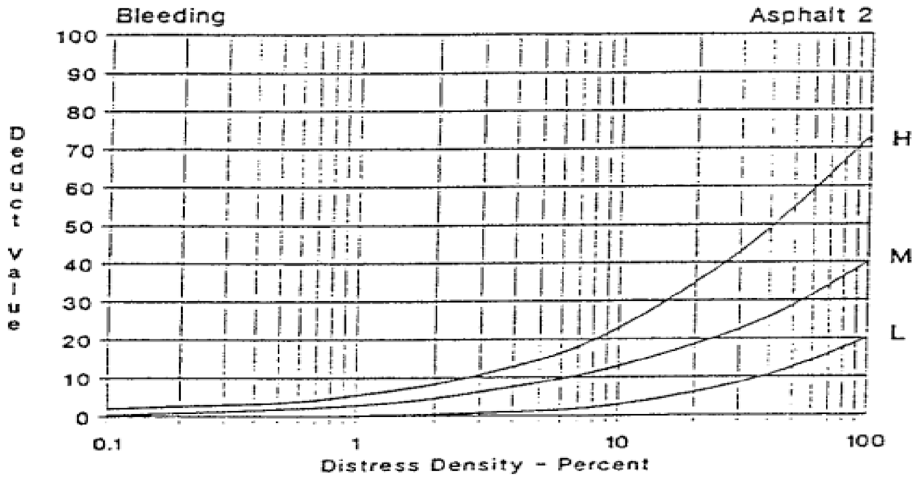


Fig: Bleeding

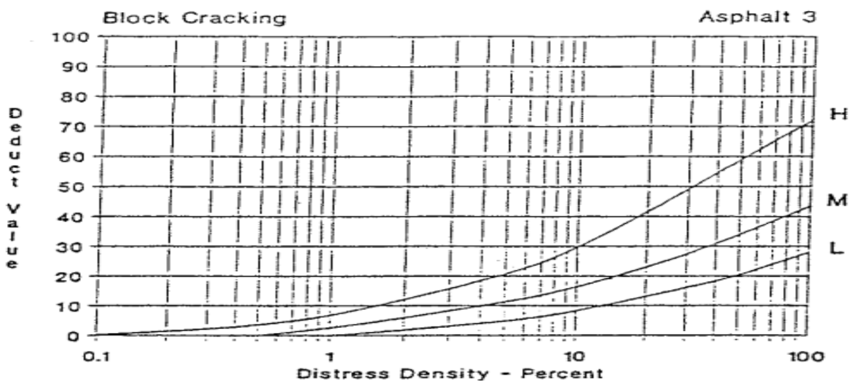


Fig: Block Cracking

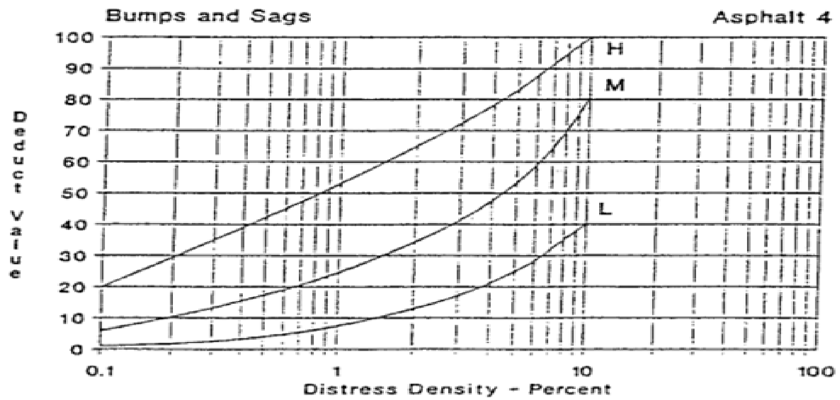


Fig: Bumps and Sags

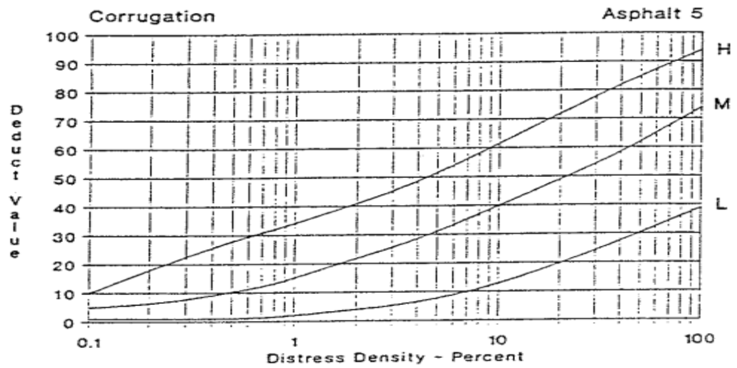


Fig: Corrugation

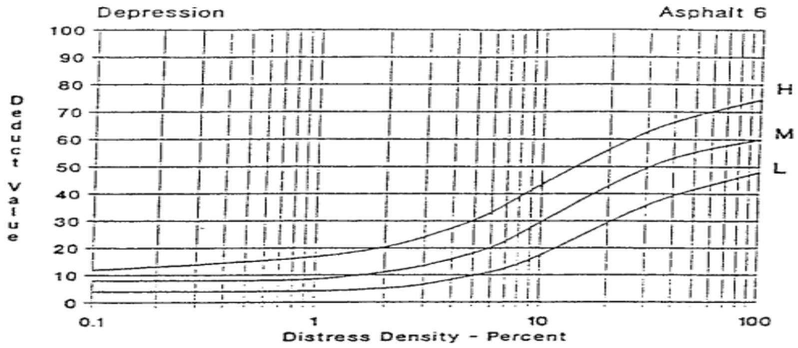


Fig: Depression

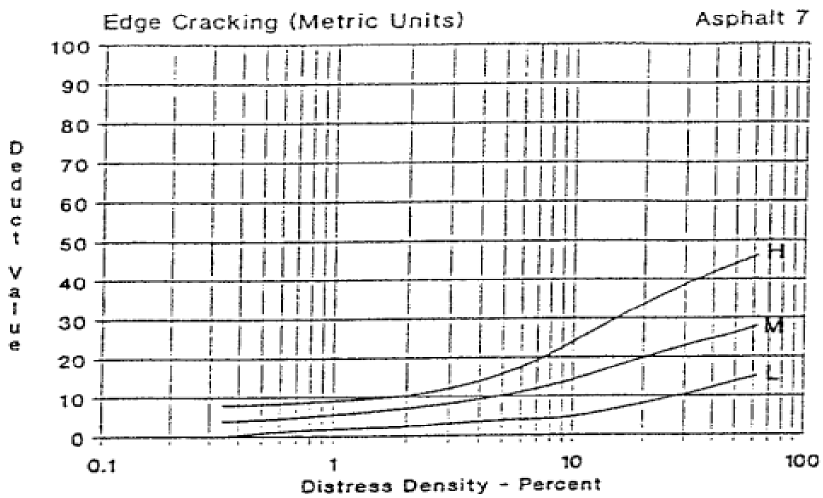


Fig: Edge Cracking (metric units)

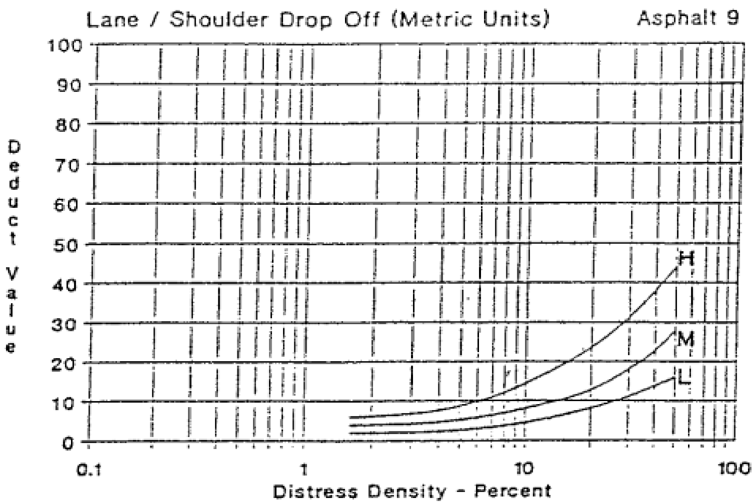


Fig: Lane/Shoulder Drop-Off (metric units)

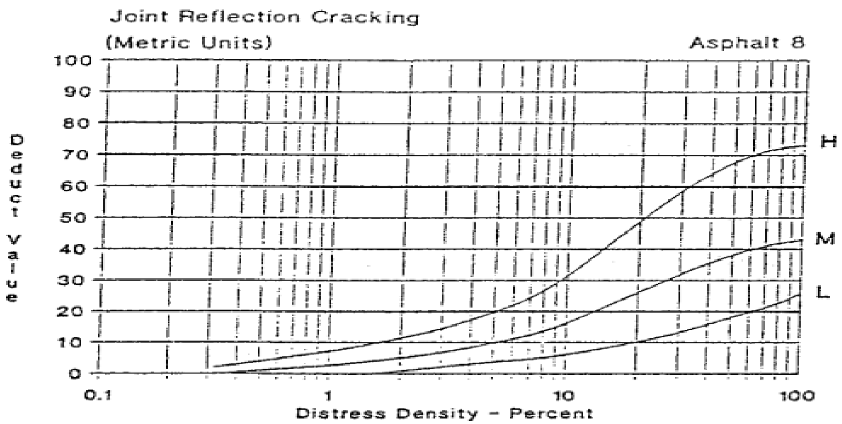


Fig: Joint Reflection Cracking (metric units)

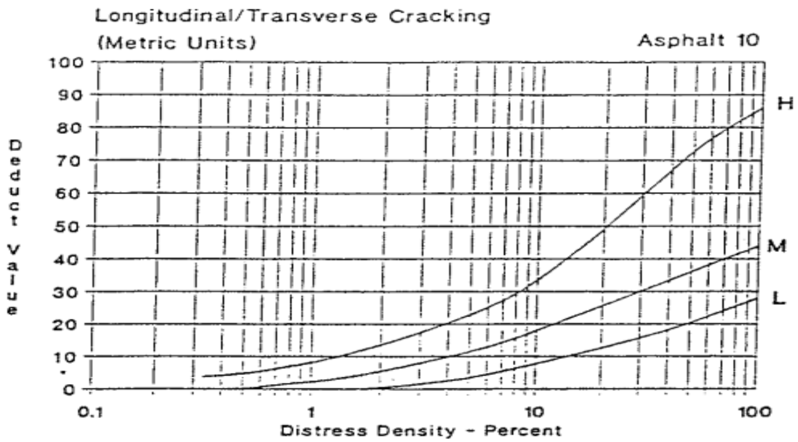


Fig: Longitudinal/Transverse Cracking (metric units)

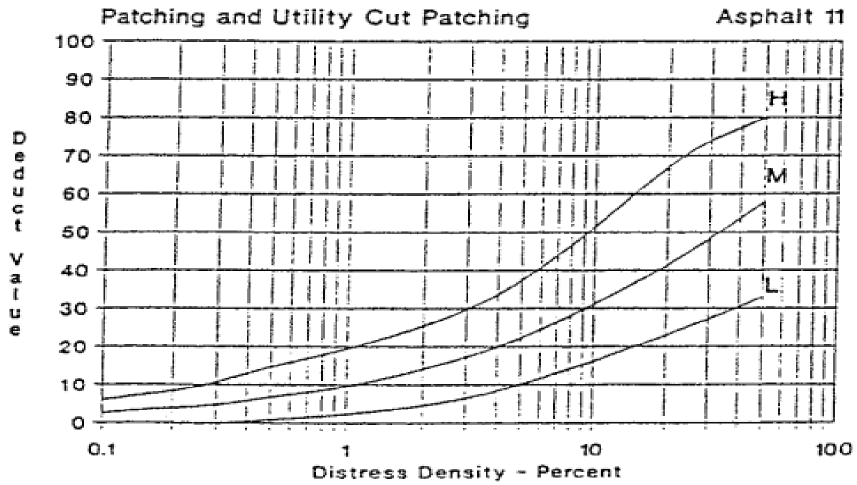


Fig: Polished Aggregate

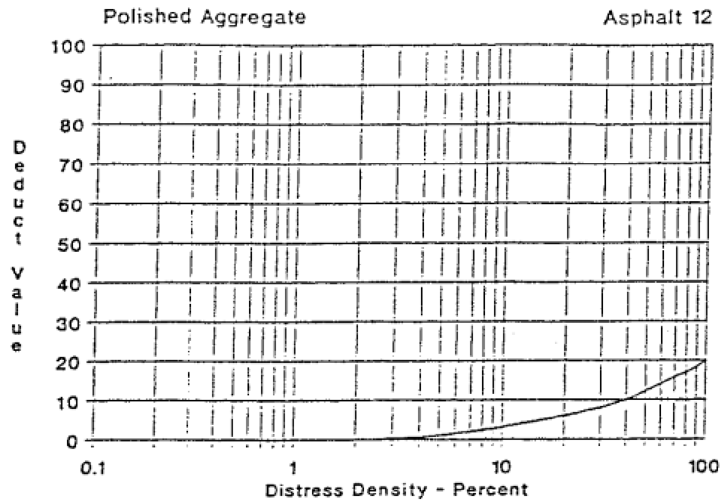


Fig: Patching and Utility Cut Patching

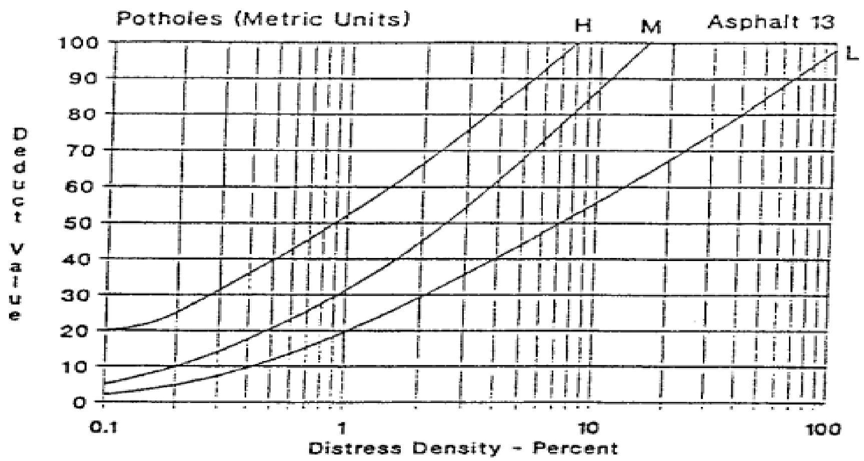


Fig: Potholes (metric units)

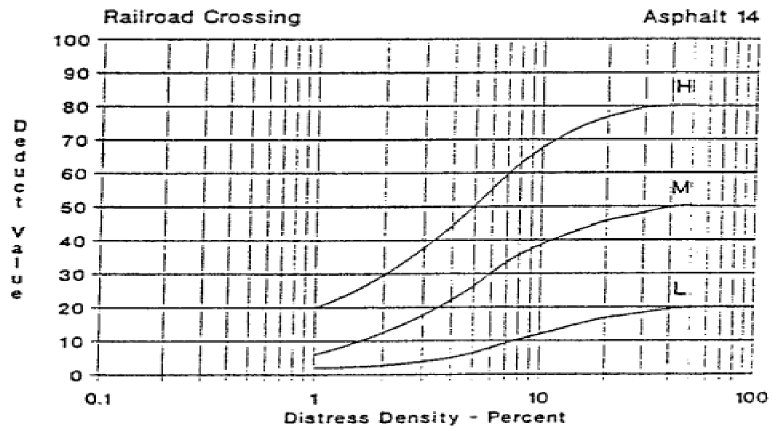


Fig: Railroad Crossing

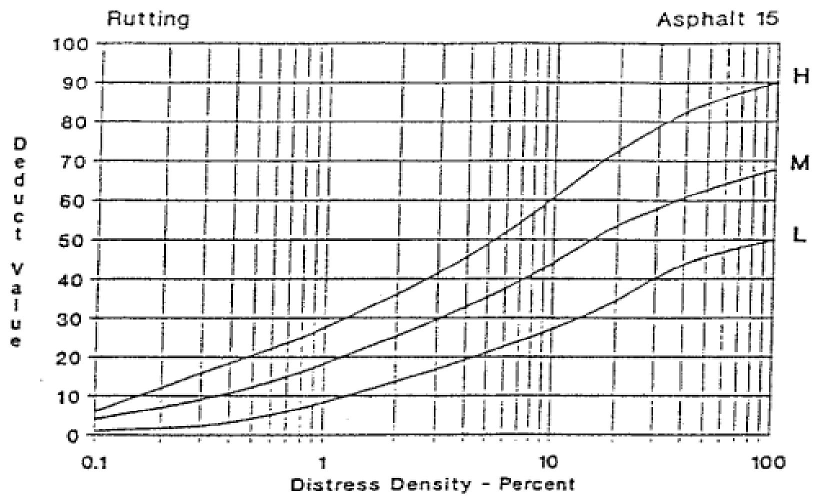


Fig: Rutting

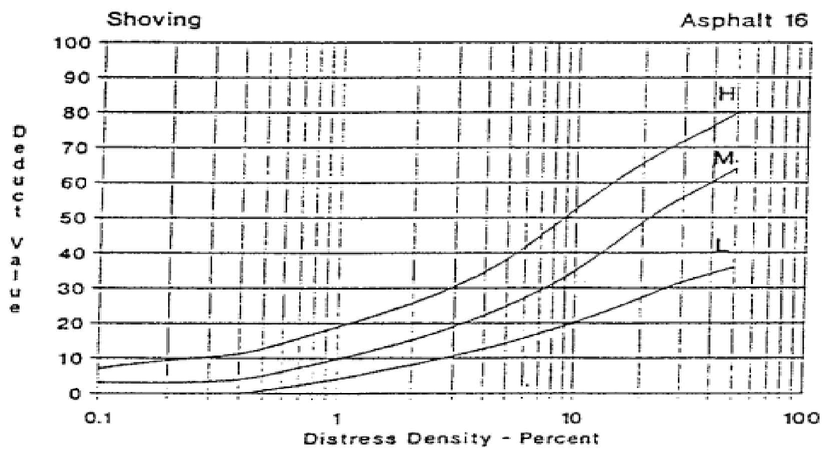


Fig: Shoving

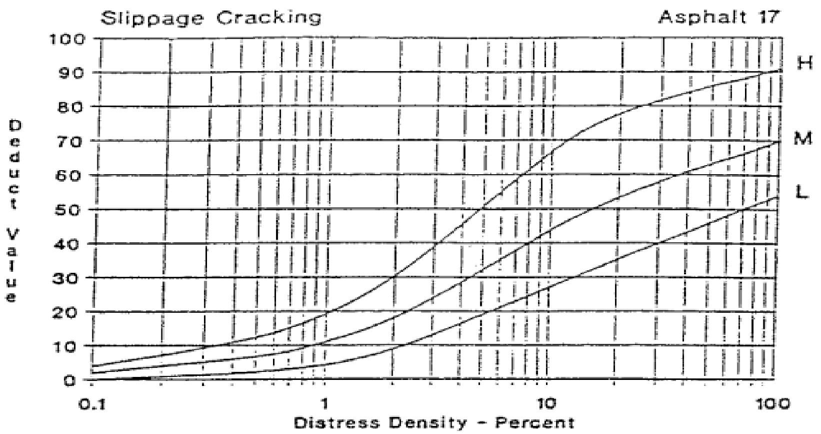


Fig: Slippage Cracking

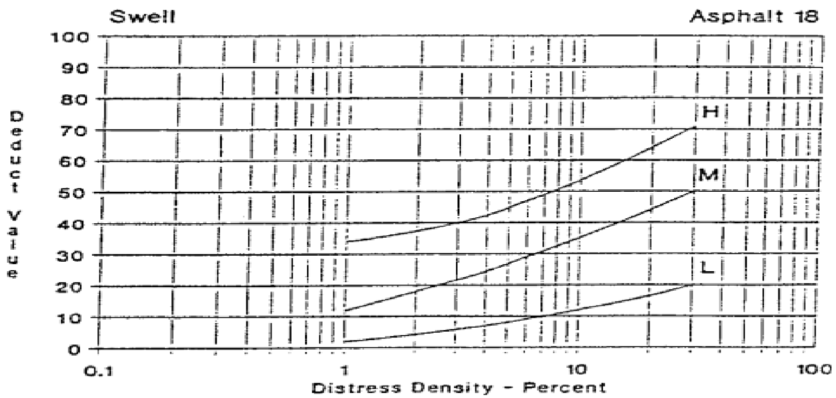


Fig: Swell

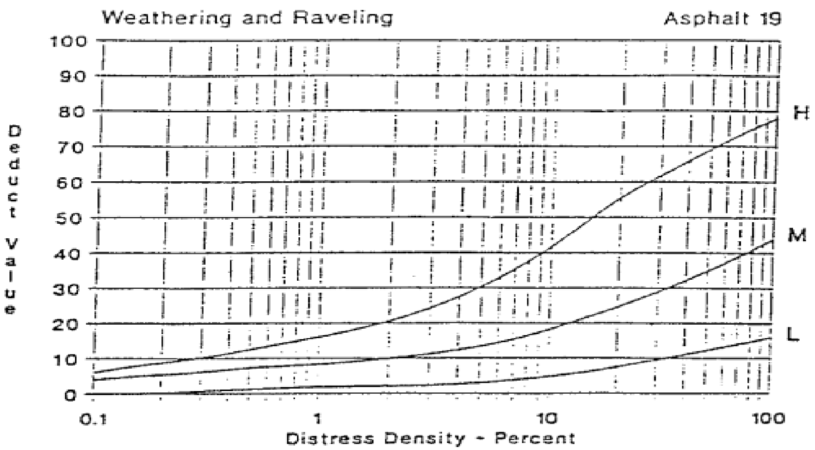


Fig: Weathering and Raveling

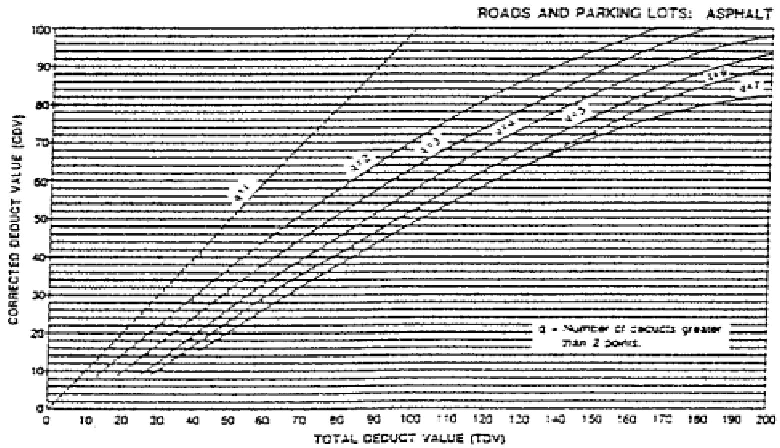


Fig: Total Deduct Value

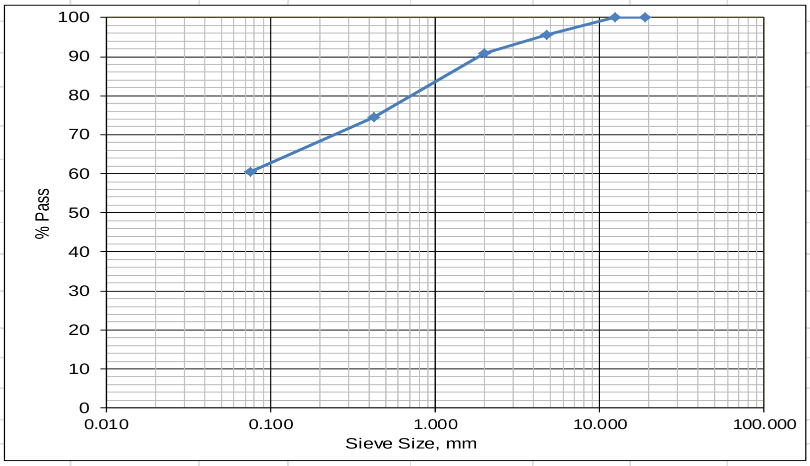
APPENDIX C: DETERMINATION OF GRAIN SIZE DISTRIBUTION

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Failed TEST REQUIRED: Gradation (Wet)

SAMPLE OF: Subgrade soil REPORTED TO: Jimma University

STATION: 003+000-004+000 Weight before wash=500gm



Sieve Size (mm)	% Passing
75.000	
63.000	
50.000	
37.500	
25.000	
19.000	100.00
12.500	100.00
4.750	95.60
2.000	90.80
0.425	74.40
0.075	60.60

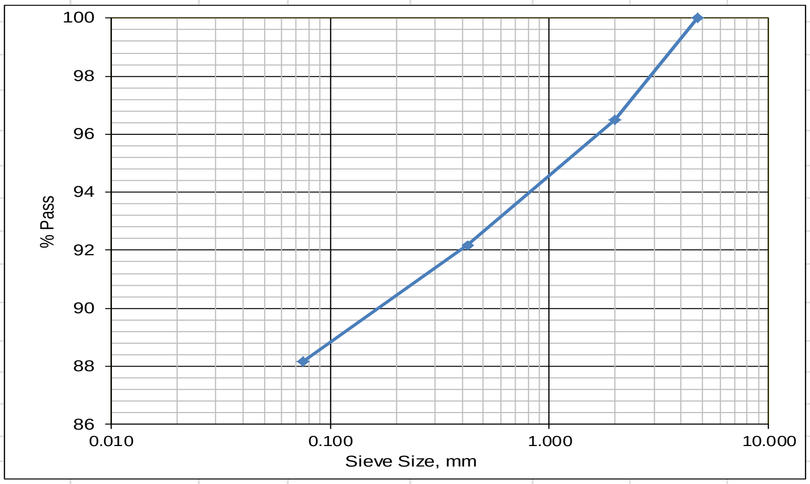
% Gravel	% Sand	% Fine
4.4	35.0	60.6

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Gradation (Wet)

SAMPLE OF: Subgrade soil REPORTED TO: Jimma University

STATION: 017+000-018+000 Weight before wash=500gm



Sieve Size (mm)	% Passing
75.000	
63.000	
50.000	
37.500	
25.000	
19.000	100.00
12.500	100.00
4.750	100.00
2.000	96.50
0.425	92.17
0.075	88.17

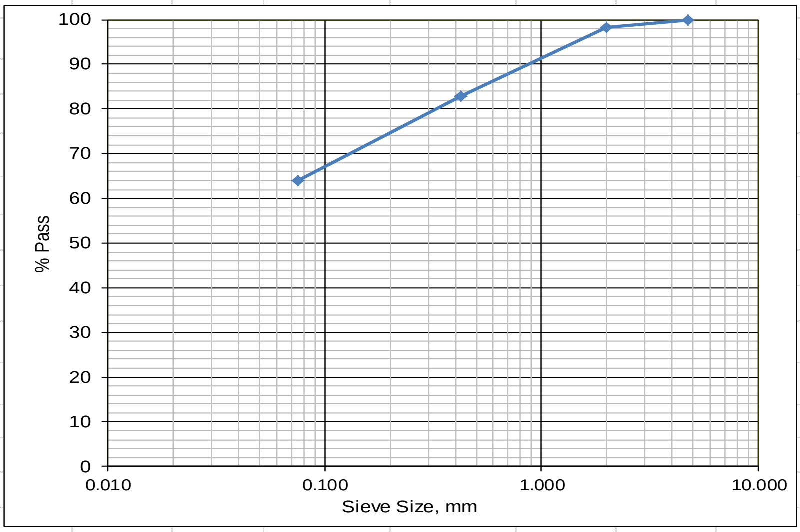
% Gravel	% Sand	% Fine
0.0	11.8	88.2

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Gradation (Wet)

SAMPLE OF: Subgrade soil REPORTED TO: Jimma University

STATION: 037+000-038+000 Weight before wash=500gm



Sieve Size (mm)	% Passing
75.000	
63.000	
50.000	
37.500	
25.000	
19.000	100.00
12.500	100.00
4.750	100.00
2.000	98.20
0.425	82.80
0.075	64.00

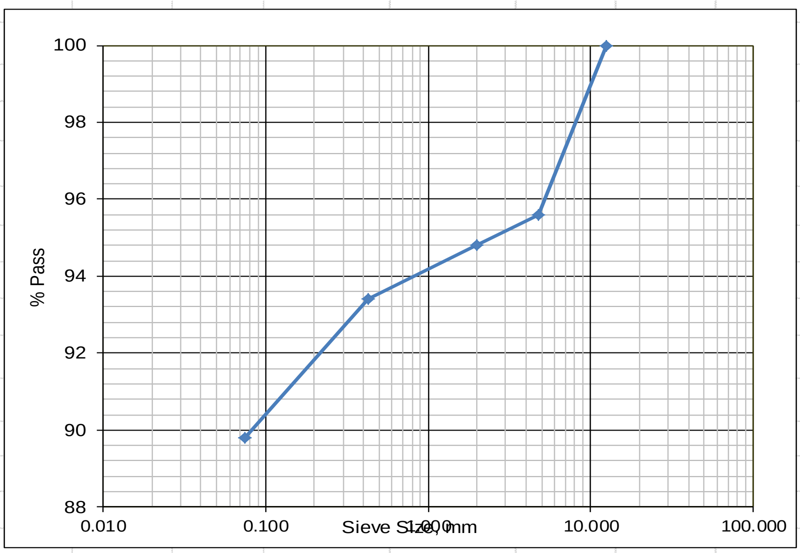
% Gravel	% Sand	% Fine
0.0	36.0	64.0

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Gradation (Wet)

SAMPLE OF: Subgrade soil REPORTED TO: Jimma University

STATION: 067+000-068+000 Weight before wash=500gm



Sieve Size (mm)	% Passing
75.000	
63.000	
50.000	
37.500	
25.000	
19.000	100.00
12.500	100.00
4.750	95.60
2.000	94.80
0.425	93.40
0.075	89.80

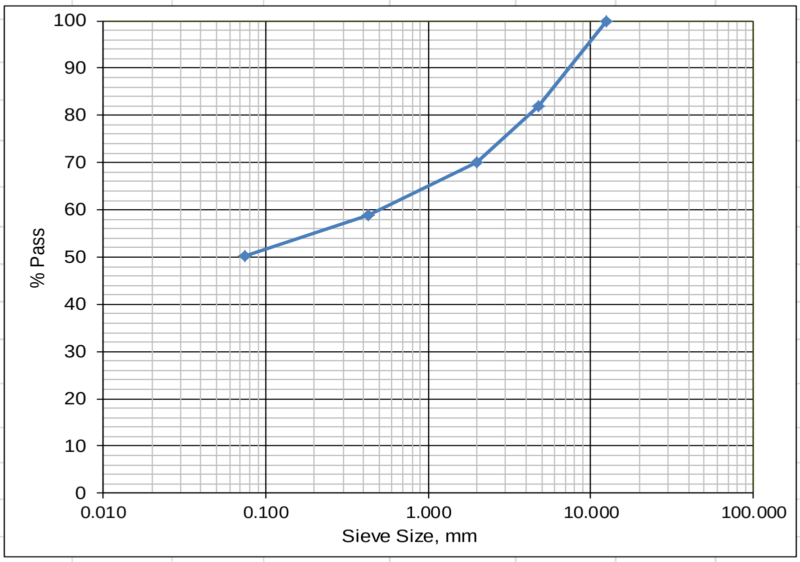
% Gravel	% Sand	% Fine
4.4	5.8	89.8

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Gradation (Wet)

SAMPLE OF: Subgrade soil REPORTED TO: Jimma University

STATION: 075+000-076+000 Weight before wash=500gm



Sieve Size (mm)	% Passing
75.000	
63.000	
50.000	
37.500	
25.000	
19.000	100.00
12.500	100.00
4.750	82.01
2.000	70.00
0.425	58.82
0.075	50.14

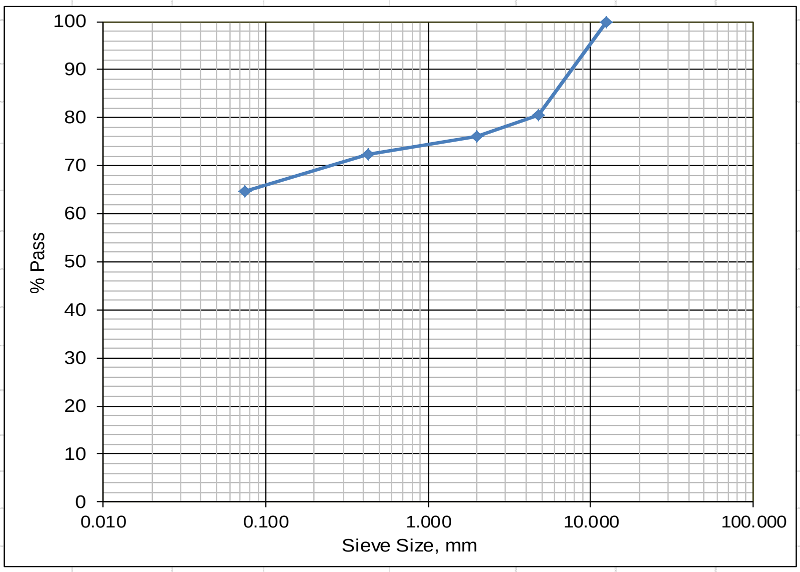
% Gravel	% Sand	% Fine
18.0	31.9	50.1

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Gradation (Wet)

SAMPLE OF: Subgrade soil REPORTED TO: Jimma University

STATION: 083+000-084+000 Weight before wash=500gm



Sieve Size (mm)	% Passing
75.000	
63.000	
50.000	
37.500	
25.000	
19.000	100.00
12.500	100.00
4.750	80.60
2.000	76.20
0.425	72.40
0.075	64.80

% Gravel	% Sand	% Fine
19.4	15.8	64.8

PROJECT: Adama to Awash Arba road network

DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious

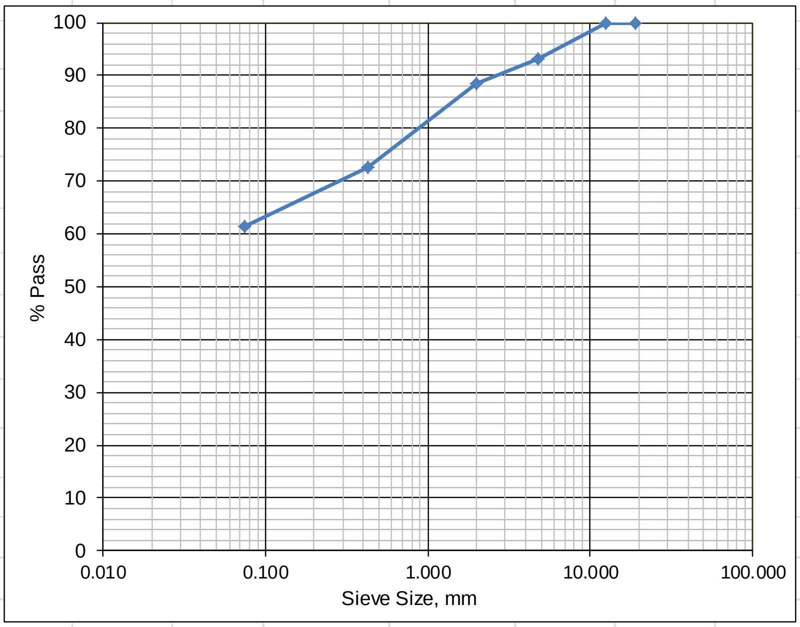
TEST REQUIRED: Gradation (Wet)

SAMPLE OF: Subgrade soil

REPORTED TO: Jimma University

STATION: 102+000-103+000

Weight before wash=500gm



Sieve Size (mm)	% Passing
75.000	
63.000	
50.000	
37.500	
25.000	
19.000	100.00
12.500	100.00
4.750	93.20
2.000	88.40
0.425	72.60
0.075	61.50

% Gravel	% Sand	% Fine
6.8	31.7	61.5

APPENDIX D: ATTERBERG'S LIMIT DETERMINATION

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Failed TEST REQUIRED: Atterberg's Limit

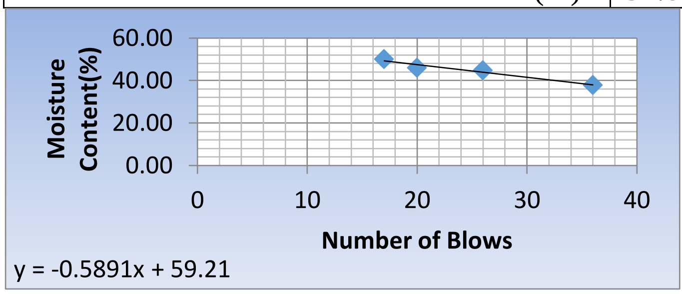
SAMPLE OF: Subgrade soil STATION: 003+000-004+000

Plastic Limit

Trial number	1	2	3
Container number	PT11	PT12	PT13
weight of can + moist soil w_1 (gm)	120	118	115
weight of can + dry soil w_2 (gm)	111	109	106
Weight of can wc (gm)	61	61	61
Weight of dry soil $w_3=w_2-wc$ (gm)	50	48	45
weight of water $w_4=w_1-w_2$ (gm)	9	9	9
Water content w_4/w_3 (%)	18.00	18.75	20.00
Plastic limit		**18.92**	

Liquid Limit

Test number	1	2	3	4
Number of blows (drops)	36	26	20	17
Container number	PT11	PT12	PT13	PT14
Mass of container Mc (gm)	61	61	61	61
Mass of container + wet soil M1 (gm)	112.00	116.00	115.00	118.00
Mass of container + oven dry soil M2 (gm)	98.00	99.00	98.00	99.00
Mass of water M3=M1-M2 (gm)	14.00	17.00	17.00	19.00
Mass of oven dry soil M4=M2-Mc (gm)	37.00	38.00	37.00	38.00
Moisture content M3/M4 (%)	**37.84**	**44.74**	**45.95**	**50.00**



LL=44.48

PI=LL-PL=44.48-18.92= 25.56

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Atterberg's Limit

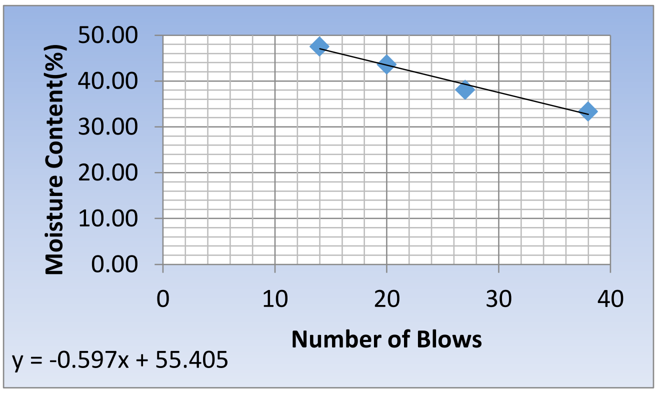
SAMPLE OF: Subgrade soil STATION: 017+000-018+000

Plastic Limit

Trial number	1	2	3
Container number	PT21	PT22	PT23
weight of can + moist soil w_1 (gm)	150	165	145
weight of can + dry soil w_2 (gm)	141	153	136
Weight of can wc (gm)	96	96	97
Weight of dry soil $w_3=w_2-wc$ (gm)	45	57	39
weight of water $w_4=w_1-w_2$ (gm)	9	12	9
Water content w_4/w_3 (%)	20.00	21.05	23.08
Plastic limit		**21.38**	

Liquid Limit

Test number	1	2	3	4
Number of blows (drops)	38	27	20	14
Container number	PT21	PT22	PT23	PT24
Mass of container Mc (gm)	60	60	61	61
Mass of container + wet soil M1(gm)	116	118	117	120
Mass of container + oven dry soil M2 (gm)	102	102	100	101
Mass of water M3=M1-M2 (gm)	14	16	17	19
Mass of oven dry soil M4=M2-Mc (gm)	42	42	39	40
Moisture content M3/M4 (%)	**33.33**	**38.10**	**43.59**	**47.50**



LL=40.48

PI=LL-PL=40.48-21.38=19.1

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Atterberg's Limit

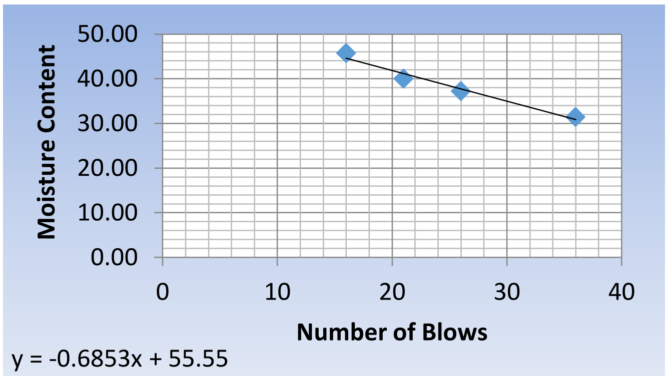
SAMPLE OF: Subgrade soil STATION: 037+000-038+000

Plastic Limit

Trial number	1	2	3
Container number	PT31	PT32	PT33
weight of can + moist soil w_1 (gm)	121	120	117
weight of can + dry soil w_2 (gm)	111	109	107
Weight of can wc (gm)	60	60	60
Weight of dry soil $w_3=w_2-wc$(gm)	51	49	47
weight of water $w_4=w_1-w_2$(gm)	10	11	10
Water content w_4/w_3 (%)	19.61	22.45	21.28
Plastic limit		**21.11**	

Liquid Limit

Test number	1	2	3	4
Number of blows (drops)	36	26	21	16
Container number	PT31	PT32	PT33	PT34
Mass of container Mc (gm)	96	96	97	97
Mass of container + wet soil M1 (gm)	142	155	160	148
Mass of container + oven dry soil M2(gm)	131	139	142	132
Mass of water M3=M1-M2 (gm)	11	16	18	16
Mass of oven dry soil M4=M2-Mc (gm)	35	43	45	35
Moisture content M3/M4 (%)	**31.43**	**37.21**	**40.00**	**45.71**



LL=38.42

PI=LL-PL=38.42-21.11= 17.31

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Atterberg's Limit

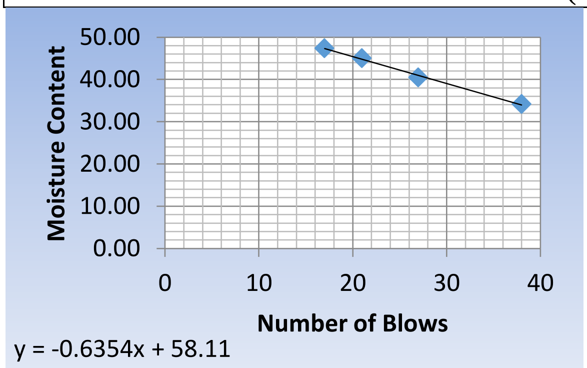
SAMPLE OF: Subgrade soil STATION: 067+000-068+000

Plastic Limit

Trial number	1	2	3
Container number	PT41	PT42	PT43
weight of can + moist soil w_1 (gm)	117	120	117
weight of can + dry soil w_2 (gm)	111	109	107
Weight of can wc (gm)	61	61	61
Weight of dry soil $w_3=w_2-wc$ (gm)	50	48	46
weight of water $w_4=w_1-w_2$ (gm)	6	11	10
Water content w_4/w_3 (%)	12.00	22.92	21.74
Plastic limit		**18.89**	

Liquid Limit

Test number	1	2	3	4
Number of blows (drops)	38	27	21	17
Container number	PT41	PT42	PT43	PT44
Mass of container Mc (gm)	61	61	62	61
Mass of container + wet soil M1 (gm)	116	120	120	117
Mass of container + oven dry soil M2 (gm)	102	103	102	99
Mass of water M3=M1-M2 (gm)	14	17	18	18
Mass of ovendry soil M4=M2-Mc (gm)	41	42	40	38
Moisture content M3/M4 (%)	**34.15**	**40.48**	**45.00**	**47.37**



LL=42.23

PI=LL-PL=42.23-18.89= 23.34

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Atterberg's Limit

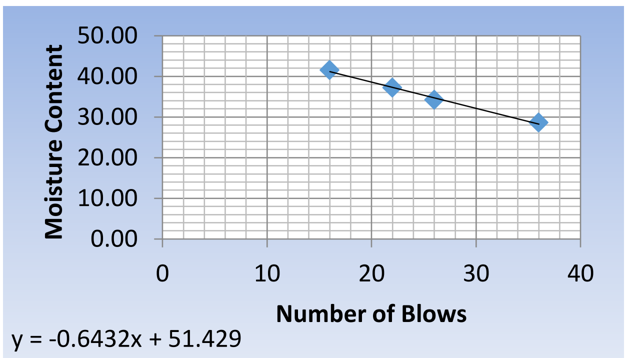
SAMPLE OF: Subgrade soil STATION: 075+000-076+000

Plastic Limit

Trial number	1	2	3
Container number	PT51	PT52	PT53
weight of can + moist soil w_1 (gm)	115	118	117
weight of can + dry soil w_2 (gm)	105	107	106
Weight of can wc (gm)	61	60	61
Weight of dry soil $w_3=w_2-wc$ (gm)	44	47	45
weight of water $w_4=w_1-w_2$ (gm)	10	11	11
Water content w_4/w_3 (%)	22.73	23.40	24.44
Plastic limit		**23.53**	

Liquid Limit

Test number	1	2	3	4
Number of blows (drops)	36	26	22	16
Container number	PT51	PT52	PT53	PT54
Mass of container Mc (gm)	61	61	61	61
Mass of container + wet soil M1 (gm)	115	116	120	119
Mass of container + oven dry soil M2 (gm)	103	102	104	102
Mass of water M3=M1-M2 (gm)	12	14	16	17
Mass of ovendry soil M4=M2-Mc (gm)	42	41	43	41
Moisture content M3/M4 (%)	**28.57**	**34.15**	**37.21**	**41.46**



LL=35.35

PI=LL-PL=35.35-23.53= 11.82

PROJECT: Adama to Awash Arba road network

DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious

TEST REQUIRED: Atterberg's Limit

SAMPLE OF: Subgrade soil

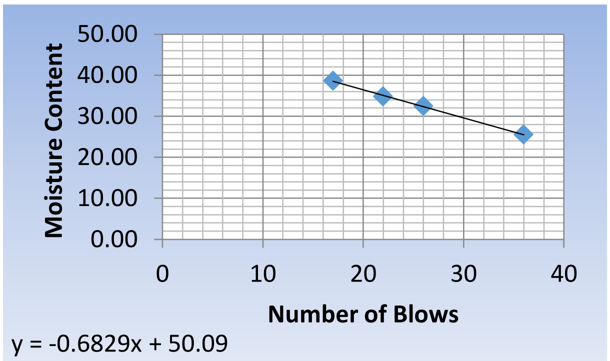
STATION: 083+000-084+000

Plastic Limit

Observation number	1	2	3
Container number	PT61	PT62	PT63
weight of can + moist soil w_1 (gm)	155	143	160
weight of can + dry soil w_2 (gm)	144	135	149
Weight of can wc (gm)	96	97	97
Weight of dry soil $w_3=w_2-wc$ (gm)	48	38	52
weight of water $w_4=w_1-w_2$ (gm)	11	8	11
Water content w_4/w_3 (%)	22.92	21.05	21.15
Plastic limit		**21.71**	

Liquid Limit

Test number	1	2	3	4
Number of blows (drops)	36	26	22	17
Container number	PT61	PT62	PT63	PT64
Mass of container Mc (gm)	96	97	97	97
Mass of container + wet soil M1(gm)	155	146	159	158
Mass of container + oven dry soil M2 (gm)	143	134	143	141
Mass of water M3=M1-M2 (gm)	12	12	16	17
Mass of ovendry soil M4=M2-Mc (gm)	47	37	46	44
Moisture content M3/M4 (%)	**25.53**	**32.43**	**34.78**	**38.64**



LL=33.02

PI=LL-PL=33.02-21.71= 11.31

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Atterberg's Limit

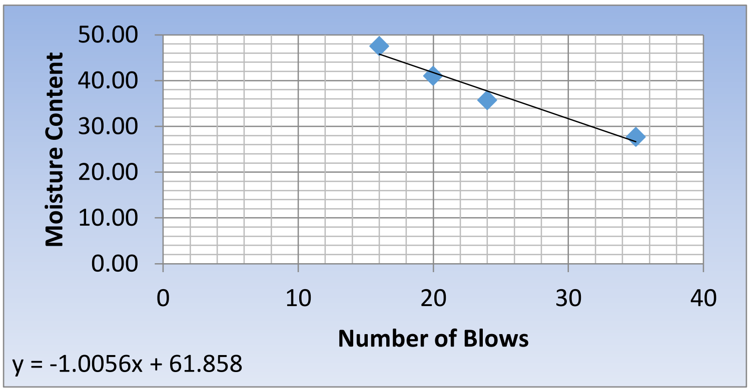
SAMPLE OF: Subgrade soil STATION: 102+000-103+000

Plastic Limit

Trial number	1	2	3
Container number	PT71	PT72	PT73
weight of can + moist soil w_1 (gm)	122	126	121
weight of can + dry soil w_2 (gm)	112	115	111
Weight of can wc (gm)	61	61	61
Weight of dry soil $w_3=w_2-wc$ (gm)	51	54	50
weight of water $w_4=w_1-w_2$ (gm)	10	11	10
Water content w_4/w_3 (%)	19.61	20.37	20.00
Plastic limit		**19.99**	

Liquid Limit

Test number	1	2	3	4
Number of blows (drops)	35	24	20	16
Container number	PT71	PT72	PT73	PT73
Mass of container Mc (gm)	61	61	61	61
Mass of container + wet soil M1 (gm)	121.00	118.00	116.00	120.00
Mass of container + oven dry soil M2 (gm)	108.00	103.00	100.00	101.00
Mass of water M3=M1-M2 (gm)	13.00	15.00	16.00	19.00
Mass of oven dry soil M4=M2-Mc (gm)	47.00	42.00	39.00	40.00
Moisture content M3/M4 (%)	**27.66**	**35.71**	**41.03**	**47.50**



LL=36.718

PI=LL-PL=36.718-19.99= 16.728

APPENDIX E: STANDARD COMPACTION TEST

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Failed TEST REQUIRED: Standard compaction

SAMPLE OF: Subgrade soil STATION: 003+000-004+000

MOISTURE - DENSITY RELATION OF SOIL

Standard (AASHTO T-99) :- ☑ Modified (AASHTO T-180) :- ☐

No. of blows : 25 Weight of hammer,kg : 2.5

No. of layers : 3 Volume of mold,cm^3 : **944**

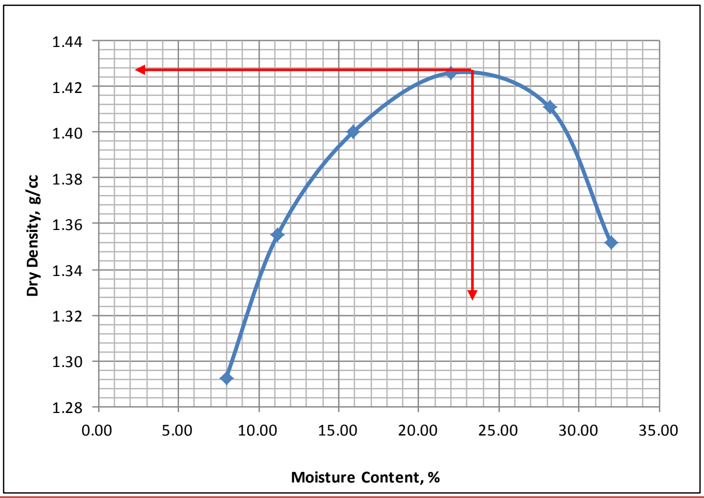
Trial number		1	2	3	4	5	6	
Weight of Mold + Wet Soil	gram	4056	4162	4271	4381	4446	4423.0	
Weight of Mold	gram	2739						
Weight of Wet Soil	gram	1317	1423	1532	1642	1707	1684	
Volume of Mold	cu.cm.	944						
Wet Density	gr/cu.cm.	1.395	1.507	1.623	1.739	1.808	1.784	
								I.M.C
Container Number		B	FB	S	H2	B	**K**	H
Weight of Container + Wet soil	grams	138	135	118	127	107	148	125
Weight of Container + Dry soil	grams	129	123	104	107	87	116	119
Weight of Water	grams	9	12	14	20	20	32	6
Weight of Container	grams	16	16	16	16	16	16	16
Weight of Dry Soil	grams	113	107	88	91	71	100	103
Moisture Content	%	7.96	11.21	15.91	21.98	28.17	32.00	5.83
Dry Density	gr/cu.cm.	1.292	1.355	1.400	1.426	1.411	1.351	

Maximum Dry Density (MDD)

MDD = 1.430 gm/cc

Optimum Moisture Content (OMC)

OMC = 23.2 %



PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Standard compaction

SAMPLE OF: Subgrade soil STATION: 017+000-018+000

MOISTURE - DENSITY RELATION OF SOIL

Standard (AASHTO T-99) :- ☑ Modified (AASHTO T-180) :- ☐

No. of blows : 25 Weight of hammer,kg : 2.5

No. of layers : 3 Volume of mold,cm^3 : **944**

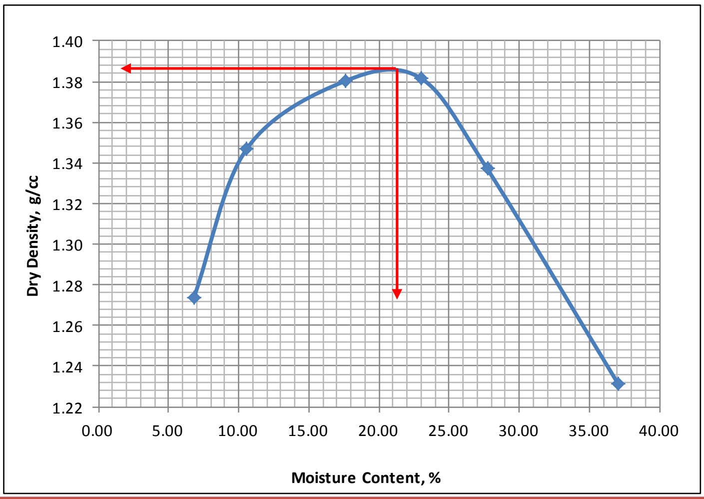
Trial number		1	2	3	4	5	6	
Weight of Mold + Wet Soil	gram	4023	4145	4271	4343	4351	4332.0	
Weight of Mold	gram	2739						
Weight of Wet Soil	gram	1284	1406	1532	1604	1612	1593	
Volume of Mold	cu.cm.	944						
Wet Density	gr/cu.cm.	1.360	1.489	1.623	1.699	1.708	1.688	
								I.M.C
Container Number		B1	B2	B3	B4	B5	**B6**	H
Weight of Container + Wet soil	grams	127	132	125	125	122	128	122
Weight of Container + Dry soil	grams	120	121	109	105	99	98	117
Weight of Water	grams	7	11	16	20	23	30	5
Weight of Container	grams	17	17	18	18	16	17	15
Weight of Dry Soil	grams	103	104	91	87	83	81	102
Moisture Content	%	6.80	10.58	17.58	22.99	27.71	37.04	4.90
Dry Density	gr/cu.cm.	1.274	1.347	1.380	1.382	1.337	1.231	

Maximum Dry Density (MDD)

MDD = 1.384 gm/cc

Optimum Moisture Content (OMC)

OMC = 21.2 %



PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Standard compaction

SAMPLE OF: Subgrade soil STATION: 037+000-038+000

MOISTURE - DENSITY RELATION OF SOIL

Standard (AASHTO T-99) :- ☑ Modified (AASHTO T-180) :- ☐

No. of blows : 25 Weight of hammer,kg : 2.5

No. of layers : 3 Volume of mold,cm^3 : **944**

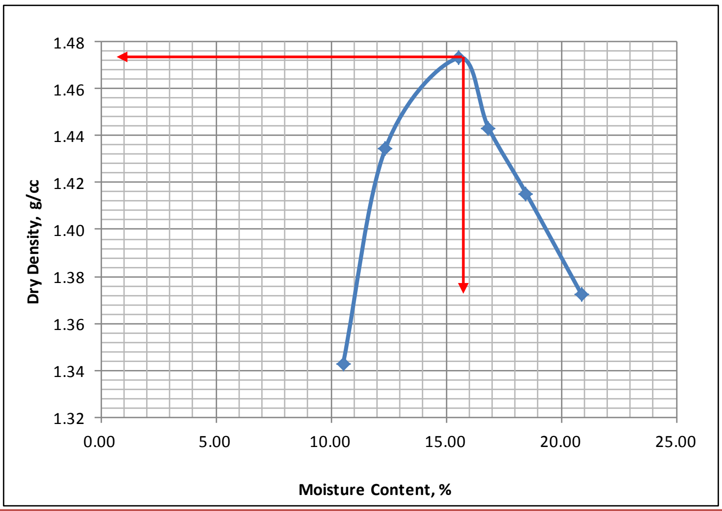
Trial number		1	2	3	4	5	6	
Weight of Mold + Wet Soil	gram	4140	4261	4346	4331	4322	4305.0	
Weight of Mold	gram	2739						
Weight of Wet Soil	gram	1401	1522	1607	1592	1583	1566	
Volume of Mold	cu.cm.	944						
Wet Density	gr/cu.cm.	1.484	1.612	1.702	1.686	1.677	1.659	
								I.M.C
Container Number		B6	B2	B4	M1	DA	S	LD
Weight of Container + Wet s	grams	120	125	121	127	125	127	119
Weight of Container + Dry s	grams	110	113	107	111	108	108	111
Weight of Water	grams	10	12	14	16	17	19	8
Weight of Container	grams	15	16	17	16	16	17	15
Weight of Dry Soil	grams	95	97	90	95	92	91	96
Moisture Content	%	10.53	12.37	15.56	16.84	18.48	20.88	8.33
Dry Density	gr/cu.cm.	1.343	1.435	1.473	1.443	1.415	1.372	

Maximum Dry Density (MDD)

MDD = 1.478 gm/cc

Optimum Moisture Content (OMC)

OMC = 15.8 %



PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Standard compaction

SAMPLE OF: Subgrade soil STATION: 067+000-068+000

MOISTURE - DENSITY RELATION OF SOIL

Standard (AASHTO T-99) :- ☑ Modified (AASHTO T-180) :- ☐

No. of blows : 25 Weight of hammer,kg : 2.5

No. of layers : 3 Volume of mold,cm^3 : **944**

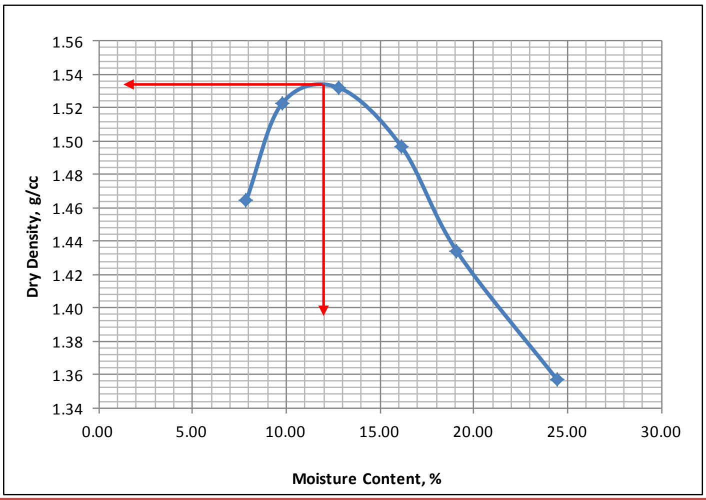
Trial number		1	2	3	4	5	6	
Weight of Mold + Wet Soil	gram	4230	4317	4370	4380	4351	4333.0	
Weight of Mold	gram	2739						
Weight of Wet Soil	gram	1491	1578	1631	1641	1612	1594	
Volume of Mold	cu.cm.	944						
Wet Density	gr/cu.cm.	1.579	1.672	1.728	1.738	1.708	1.689	
								I.M.C
Container Number		FB	B1	BA	TH	CA	**B**	BC
Weight of Container + Wet soil	grams	112	117	121	125	123	123	128
Weight of Container + Dry soil	grams	105	108	109	110	106	102	122
Weight of Water	grams	7	9	12	15	17	21	6
Weight of Container	grams	16	16	15	17	17	16	15
Weight of Dry Soil	grams	89	92	94	93	89	86	107
Moisture Content	%	7.87	9.78	12.77	16.13	19.10	24.42	5.61
Dry Density	gr/cu.cm.	1.464	1.523	1.532	1.497	1.434	1.357	

Maximum Dry Density (MDD)

MDD = 1.533 gm/cc

Optimum Moisture Content (OMC)

OMC = 12.0 %



PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Standard compaction

SAMPLE OF: Subgrade soil STATION: 075+000-076+000

MOISTURE - DENSITY RELATION OF SOIL

Standard (AASHTO T-99) :- ☑ Modified (AASHTO T-180) :- ☐

No. of blows : 25 Weight of hammer,kg : 2.5

No. of layers : 3 Volume of mold,cm^3 : **944**

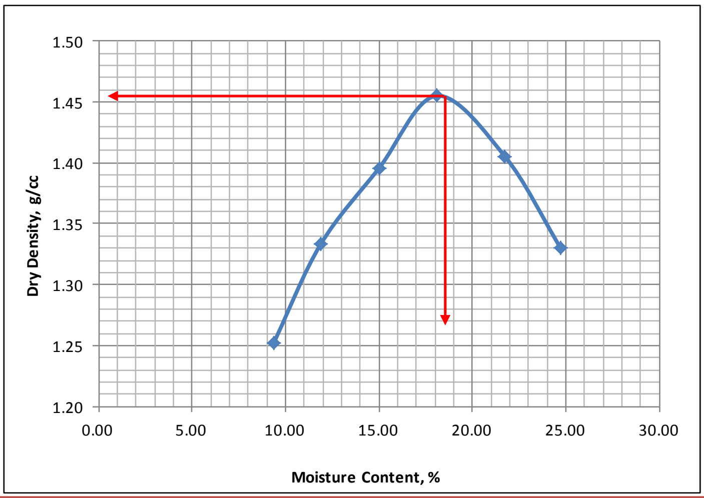
Trial number		1	2	3	4	5	6	
Weight of Mold + Wet Soil	gram	4032	4147	4254	4361	4354	4305.0	
Weight of Mold	gram	2739						
Weight of Wet Soil	gram	1293	1408	1515	1622	1615	1566	
Volume of Mold	cu.cm.	944						
Wet Density	gr/cu.cm.	1.370	1.492	1.605	1.718	1.711	1.659	
								I.M.C
Container Number		BH	SA	B2	CL	CA	**L**	CH
Weight of Container + Wet soil	grams	121	130	129	126	127	127	136
Weight of Container + Dry soil	grams	112	118	114	109	107	105	128
Weight of Water	grams	9	12	15	17	20	22	8
Weight of Container	grams	16	17	14	15	15	16	18
Weight of Dry Soil	grams	96	101	100	94	92	89	110
Moisture Content	%	9.38	11.88	15.00	18.09	21.74	24.72	7.27
Dry Density	gr/cu.cm.	1.252	1.333	1.396	1.455	1.405	1.330	

Maximum Dry Density (MDD)

MDD = 1.452 gm/cc

Optimum Moisture Content (OMC)

OMC = 18.5 %



PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Standard compaction

SAMPLE OF: Subgrade soil STATION: 083+000-084+000

MOISTURE - DENSITY RELATION OF SOIL

Standard (AASHTO T-99) :- ☑ Modified (AASHTO T-180) :- ☐

No. of blows : 25 Weight of hammer,kg : 2.5

No. of layers : 3 Volume of mold,cm^3 : **944**

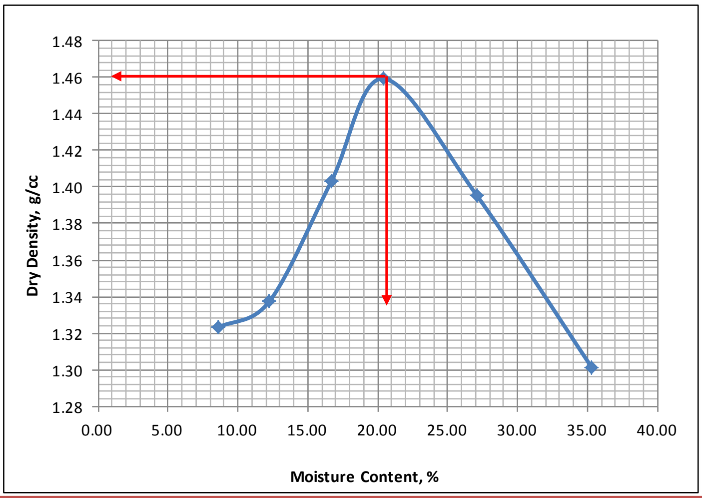
Trial number		1	2	3	4	5	6	
Weight of Mold + Wet Soil	gram	4095	4156	4284	4398	4413	4401.0	
Weight of Mold	gram	2739						
Weight of Wet Soil	gram	1356	1417	1545	1659	1674	1662	
Volume of Mold	cu.cm.	944						
Wet Density	gr/cu.cm.	1.436	1.501	1.637	1.757	1.773	1.761	
								I.M.C
Container Number		B1	SC	K	H	CL	**L**	M
Weight of Container + Wet soil	grams	130	127	120	127	124	132	129
Weight of Container + Dry soil	grams	121	115	105	108	101	102	122
Weight of Water	grams	9	12	15	19	23	30	7
Weight of Container	grams	16	17	15	15	16	17	17
Weight of Dry Soil	grams	105	98	90	93	85	85	105
Moisture Content	%	8.57	12.24	16.67	20.43	27.06	35.29	6.67
Dry Density	gr/cu.cm.	1.323	1.337	1.403	1.459	1.396	1.301	

Maximum Dry Density (MDD)

MDD = 1.460 gm/cc

Optimum Moisture Content (OMC)

OMC = 20.9 %



PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: Standard compaction

SAMPLE OF: Subgrade soil STATION: 102+000-103+000

MOISTURE - DENSITY RELATION OF SOIL

Standard (AASHTO T-99) :- ☑ Modified (AASHTO T-180) :- ☐

No. of blows : 25 Weight of hammer,kg : 2.5

No. of layers : 3 Volume of mold,cm^3 : **944**

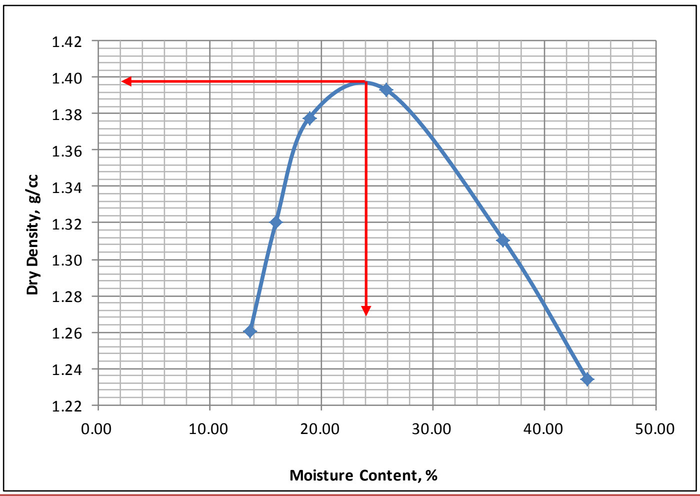
Trial number		1	2	3	4	5	6	
Weight of Mold + Wet Soil	gram	4092	4184	4286	4394	4426	4415.0	
Weight of Mold	gram	2739						
Weight of Wet Soil	gram	1353	1445	1547	1655	1687	1676	
Volume of Mold	cu.cm.	944						
Wet Density	gr/cu.cm.	1.433	1.531	1.639	1.753	1.787	1.775	
								I.M.C
Container Number		L	H	CH	BH	H	**TH**	CA
Weight of Container + Wet soil	grams	125	124	131	128	121	122	134
Weight of Container + Dry soil	grams	112	109	113	105	93	90	122
Weight of Water	grams	13	15	18	23	28	32	12
Weight of Container	grams	17	15	18	16	16	17	17
Weight of Dry Soil	grams	95	94	95	89	77	73	105
Moisture Content	%	13.68	15.96	18.95	25.84	36.36	43.84	11.43
Dry Density	gr/cu.cm.	1.261	1.320	1.378	1.393	1.311	1.234	

Maximum Dry Density (MDD)

MDD = 1.388 gm/cc

Optimum Moisture Content (OMC)

OMC = 24.1 %



APPENDIX F: CALIFORNIA BEARING RATIO TEST

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Failed TEST REQUIRED: CBR Value

SAMPLE OF: Subgrade soil STATION: 003+000-004+000

CALIFORNIA BEARING RATIO TEST (One Point CBR)

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		Blows/Layer	56
		☐	5 Layer
		☑	3 Layer
Mould Number		A-13	
Mass of Mould	g	6303	
Mass of Mould + Soil	g	10137	
Mass of Soil	g	3834	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.805	
Dry Density	g/cm^3	1.453	

SOAKING CONDITION	
Unsoaked	☐
Soaked	☑
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

CALIBRATION/STANDARD DATA		
Rammer 2.5kg	☑	
Rammer 4.5kg	☐	
Volume,cm^3	**2124**	
Height,mm	**116.43**	
Ring No.	-	
Ring Factor	0.02557 KN/div	
Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

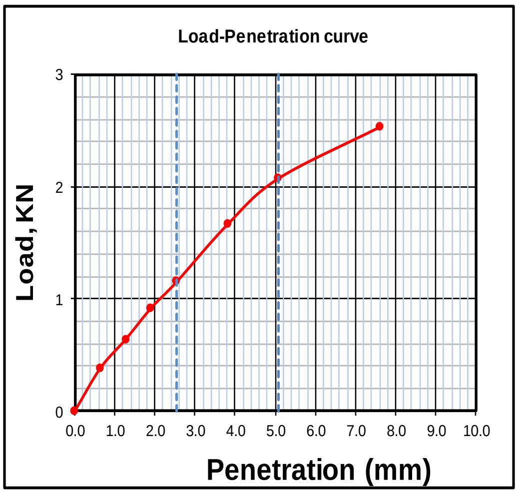
MOISTURE CONTENT DETERMINATION		
Container Number		A-12
Mass of Container	g	135
Mass of Container + Wet Soil	g	484
Mass of Container + Dry Soil	g	416
Moisture Content	%	24.20

SWELL	
Number of Blows	56
Reading Before Soaking, mm	185
Reading After Soaking, mm	217
Percent Swell	0.27

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
- mm -	- div -	- KN -	- KN -	%
0	0	0.00		
0.64	15	0.38		
1.27	25	0.64		
1.91	36	0.92		
2.54	45	1.15	1.15	8.7
3.81	65	1.66		
5.08	81	2.07	2.07	10.4
7.62	99	2.53		

Proctor Density (AASHTO T- 99)		96 hours Socked CBR Value (AASHTO T-193)	
O.M.C (%)	MDD (g/cc)	At 5.08 mm	(%) Swell
23.2	1.43	10.4	0.27



PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: CBR Value

SAMPLE OF: Subgrade soil STATION: 017+000-018+000

CALIFORNIA BEARING RATIO TEST (One Point CBR)

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION			
		Blows/Layer	56
		☐	5 Layer
		☑	3 Layer
Mould Number		A-11	
Mass of Mould	g	6317	
Mass of Mould + Soil	g	9886	
Mass of Soil	g	3569	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.680	
Dry Density	g/cm^3	1.396	

SOAKING CONDITION	
Unsoaked	☐
Soaked	☑
Surcharge Load, kg	4.54kg
Days Soaked	4

CALIBRATION/STANDARD DATA	
Rammer 2.5kg	☑
Rammer 4.5kg	☐
Volume,cm^3	2124
Height,mm	116.43
Ring No.	-
Ring Factor	0.02557 KN/div

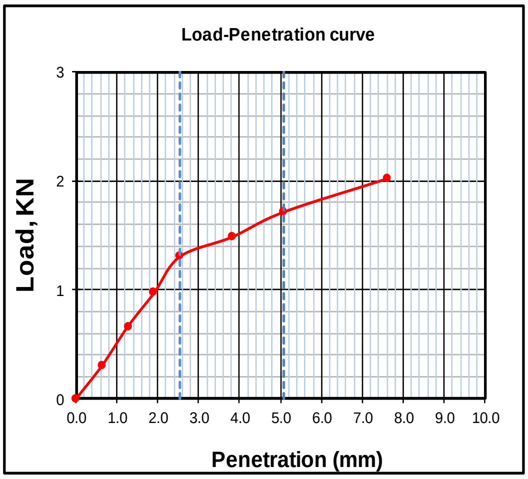
Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

MOISTURE CONTENT DETERMINATION		
Container Number		A-13
Mass of Container	g	102
Mass of Container + Wet Soil	g	480
Mass of Container + Dry Soil	g	416
Moisture Content	%	20.38

SWELL	
Number of Blows	56
Reading Before Soaking, mm	136
Reading After Soaking, mm	178
Percent Swell	0.36

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
- mm -	- div -	- KN -	- KN -	%
0	0	0.00		
0.64	12	0.31		
1.27	26	0.66		
1.91	38	0.97		
2.54	51	1.30	1.30	9.9
3.81	58	1.48		
5.08	67	1.71	1.71	8.6
7.62	79	2.02		



Proctor Density (AASHTO T- 99)		96 hours Socked CBR Value (AASHTO T-193)	
O.M.C (%)	MDD (g/cc)	At 2.54 mm	(%) Swell
21.2	1.384	9.9	0.36

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: CBR Value

SAMPLE OF: Subgrade soil STATION: 037+000-038+000

CALIFORNIA BEARING RATIO TEST (One Point CBR)

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		Blows/Layer	56
		☐	5 Layer
		☑	3 Layer
Mould Number		I-5	
Mass of Mould	g	6327	
Mass of Mould + Soil	g	9947	
Mass of Soil	g	3620	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.704	
Dry Density	g/cm^3	1.478	

SOAKING CONDITION	
Unsoaked	☐
Soaked	☑
Surcharge Load, kg	4.54kg
Days Soaked	4

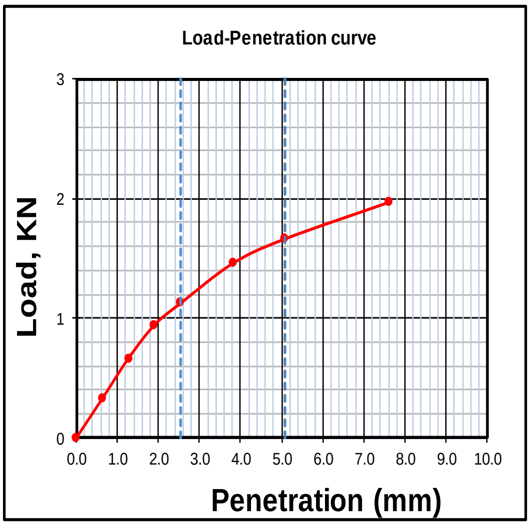
CALIBRATION/STANDARD DATA		
Rammer 2.5kg	☑	
Rammer 4.5kg	☐	
Volume,cm^3	2124	
Height,mm	116.43	
Ring No.	-	
Ring Factor	0.02557 KN/div	
Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

MOISTURE CONTENT DETERMINATION		
Container Number		B-6A
Mass of Container	g	128
Mass of Container + Wet Soil	g	512
Mass of Container + Dry Soil	g	461
Moisture Content	%	15.32

SWELL	
Number of Blows	56
Reading Before Soaking, mm	187
Reading After Soaking, mm	215
Percent Swell	0.24

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
- mm -	- div -	- KN -	- KN -	%
0	0	0.00		
0.64	13	0.33		
1.27	26	0.66		
1.91	37	0.95		
2.54	44	1.13	1.13	8.5
3.81	57	1.46		
5.08	65	1.66	1.66	8.3
7.62	77	1.97		



Proctor Density (AASHTO T- 99)		96 hours Socked CBR Value (AASHTO T-193)	
O.M.C (%)	MDD (g/cc)	At 2.54 mm	(%) Swell
15.8	1.478	8.5	0.24

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: CBR Value

SAMPLE OF: Subgrade soil STATION: 067+000-068+000

CALIFORNIA BEARING RATIO TEST (One Point CBR)

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION			
		Blows/Layer	56
		☐	5 Layer
		☑	3 Layer
Mould Number		A-13	
Mass of Mould	g	6303	
Mass of Mould + Soil	g	10002	
Mass of Soil	g	3699	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.742	
Dry Density	g/cm^3	1.543	

SOAKING CONDITION	
Unsoaked	☐
Soaked	☑
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

CALIBRATION/STANDARD DATA	
Rammer 2.5kg	☑
Rammer 4.5kg	☐
Volume,cm^3	**2124**
Height,mm	**116.43**
Ring No.	-
Ring Factor	0.02557 KN/div

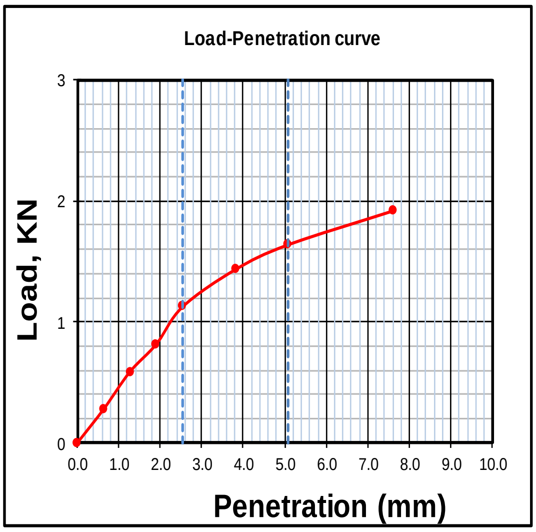
Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

MOISTURE CONTENT DETERMINATION		
Container Number		B-33
Mass of Container	g	142
Mass of Container + Wet Soil	g	502
Mass of Container + Dry Soil	g	461
Moisture Content	%	12.85

SWELL	
Number of Blows	56
Reading Before Soaking, mm	191
Reading After Soaking, mm	225
Percent Swell	0.29

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
- mm -	- div -	- KN -	- KN -	%
0	0	0.00		
0.64	11	0.28		
1.27	23	0.59		
1.91	32	0.82		
2.54	44	1.13	1.13	8.5
3.81	56	1.43		
5.08	64	1.64	1.64	8.2
7.62	75	1.92		



Proctor Density (AASHTO T- 99)		96 hours Socked CBR Value (AASHTO T-193)	
O.M.C (%)	MDD (g/cc)	At 2.54 mm	(%) Swell
12	1.533	8.5	0.29

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: CBR Value

SAMPLE OF: Subgrade soil STATION: 075+000-076+000

CALIFORNIA BEARING RATIO TEST (One Point CBR)

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION			
		Blows/Layer	56
		☐	5 Layer
		☑	3 Layer
Mould Number		A-1B	
Mass of Mould	g	6321	
Mass of Mould + Soil	g	10027	
Mass of Soil	g	3706	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.745	
Dry Density	g/cm^3	1.461	

SOAKING CONDITION	
Unsoaked	☐
Soaked	☑
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

CALIBRATION/STANDARD DATA	
Rammer 2.5kg	☑
Rammer 4.5kg	☐
Volume, cm^3	**2124**
Height, mm	**116.43**
Ring No.	-
Ring Factor	0.02557 KN/div

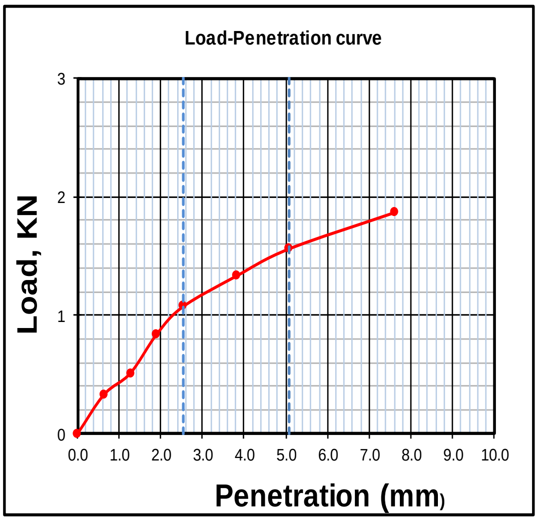
Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

MOISTURE CONTENT DETERMINATION		
Container Number		C-11
Mass of Container	g	142
Mass of Container + Wet Soil	g	462
Mass of Container + Dry Soil	g	410
Moisture Content	%	19.40

SWELL	
Number of Blows	56
Reading Before Soaking, mm	198
Reading After Soaking, mm	231
Percent Swell	0.28

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
- mm -	- div -	- KN -	- KN -	%
0	0	0.00		
0.64	13	0.33		
1.27	20	0.51		
1.91	33	0.84		
2.54	42	1.07	1.07	8.1
3.81	52	1.33		
5.08	61	1.56	1.56	7.8
7.62	73	1.87		



Proctor Density (AASHTO T- 99)		96 hours Socked CBR Value (AASHTO T-193)	
O.M.C (%)	MDD (g/cc)	At 2.54 mm	(%) Swell
18.5	1.452	8.1	0.28

PROJECT: Adama to Awash Arba road network   DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious   TEST REQUIRED: CBR Value

SAMPLE OF: Subgrade soil   STATION: 083+000-084+000

CALIFORNIA BEARING RATIO TEST (One Point CBR)

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		
	Blows/Layer	56
	☐	5 Layer
	☑	3 Layer
Mould Number		I-15
Mass of Mould	g	6327
Mass of Mould + Soil	g	10172
Mass of Soil	g	3845
Volume of Mould	cm^3	2124
Wet Density	g/cm^3	1.810
Dry Density	g/cm^3	1.485

SOAKING CONDITION	
Unsoaked	☐
Soaked	☑
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

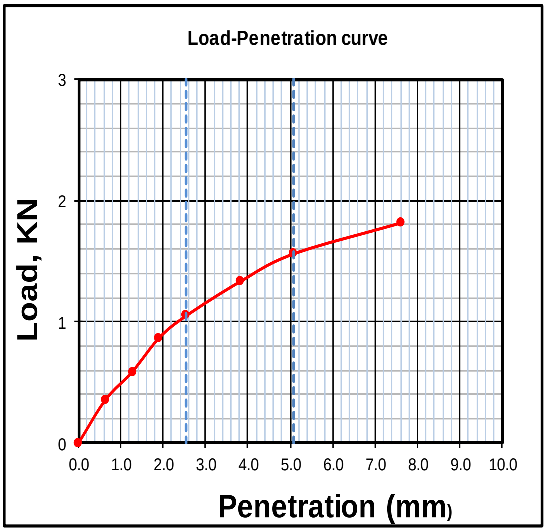
CALIBRATION/STANDARD DATA		
Rammer 2.5kg	☑	
Rammer 4.5kg	☐	
Volume, cm^3	**2124**	
Height, mm	**116.43**	
Ring No.	-	
Ring Factor	0.02557 KN/div	
Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

MOISTURE CONTENT DETERMINATION		
Container Number		D-1A
Mass of Container	g	119
Mass of Container + Wet Soil	g	481
Mass of Container + Dry Soil	g	416
Moisture Content	%	21.89

SWELL	
Number of Blows	56
Reading Before Soaking, mm	129
Reading After Soaking, mm	184
Percent Swell	0.47

PENETRATION TEST DATA

Penetration	56 Blows			
	Dial Read.	Load	Corr. Load	CBR
- mm -	- div -	- KN -	- KN -	%
0	0	0.00		
0.64	14	0.36		
1.27	23	0.59		
1.91	34	0.87		
2.54	41	1.05	1.05	7.9
3.81	52	1.33		
5.08	61	1.56	1.56	7.8
7.62	71	1.82		



Proctor Density (AASHTO T- 99)		96 hours Socked CBR Value (AASHTO T-193)	
O.M.C (%)	MDD (g/cc)	At 2.54 mm	(%) Swell
20.9	1.46	7.9	0.47

PROJECT: Adama to Awash Arba road network DATE SAMPLED: 11/10/2016

PAVEMENT CONDITION: Serious TEST REQUIRED: CBR Value

SAMPLE OF: Subgrade soil STATION: 102+000-103+000

CALIFORNIA BEARING RATIO TEST (One Point CBR)

TEST METHOD: AASHTO T 193

DENSITY DETERMINATION		Blows/Layer	56
		☐	5 Layer
		☑	3 Layer
Mould Number		A-23	
Mass of Mould	g	6312	
Mass of Mould + Soil	g	9876	
Mass of Soil	g	3564	
Volume of Mould	cm^3	2124	
Wet Density	g/cm^3	1.678	
Dry Density	g/cm^3	1.364	

SOAKING CONDITION	
Unsoaked	☐
Soaked	☑
Surcharge Load, kg	**4.54kg**
Days Soaked	**4**

CALIBRATION/STANDARD DATA		
Rammer 2.5kg	☑	
Rammer 4.5kg	☐	
Volume, cm^3	**2124**	
Height, mm	**116.43**	
Ring No.	-	
Ring Factor	0.02557 KN/div	
Standar Load		
@2.54mm	13.2	KN
@5.08mm	20	KN

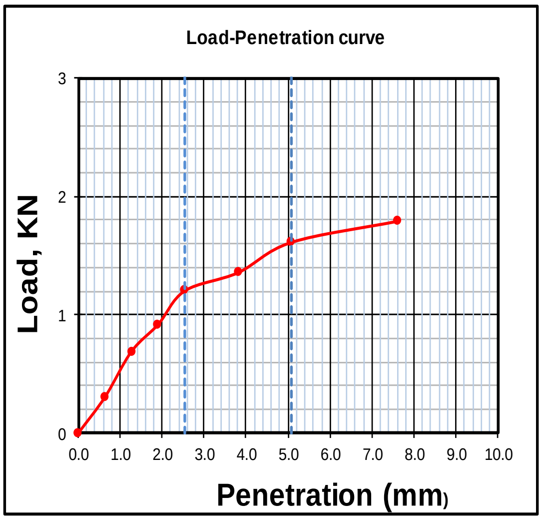
MOISTURE CONTENT DETERMINATION		
Container Number		A-15
Mass of Container	g	132
Mass of Container + Wet Soil	g	501
Mass of Container + Dry Soil	g	432
Moisture Content	%	23.00

SWELL	
Number of Blows	56
Reading Before Soaking, mm	145
Reading After Soaking, mm	192
Percent Swell	0.40

PENETRATION TEST DATA

Penetration - mm -	56 Blows Dial Read. - div -	Load - KN -	Corr. Load - KN -	CBR %
0	0	0.00		
0.64	12	0.31		
1.27	27	0.69		
1.91	36	0.92		
2.54	47	1.20	1.20	9.1
3.81	53	1.36		
5.08	63	1.61	1.61	8.1
7.62	70	1.79		

Proctor Density (AASHTO T- 99)		96 hours Socked CBR Value (AASHTO T-193)	
O.M.C (%)	MDD (g/cc)	At 2.54 mm	(%) Swell
24.1	1.388	9.1	0.40



Appendix G: LABORATORY SAMPLE TAKING PICTURE


TOYO