Jimma University

School of Graduate Studies

Jimma Institute of Technology

School of Civil and Environmental Engineering

Department of Civil Engineering

Construction Engineering and Management Stream

Assessment of Pavement Distress and Remedial Measures from Addis Ababa to Gibe River Trunk Road

A Thesis Submitted to the School of Graduate Studies of Jimma University, In Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering and Management

By: - Michael Agonafir

October, 2016

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Main Advisor: - Eng. Elmer C. Agon (MSc)

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October, 2016

Jimma, Ethiopia

SCHOOL OF POST GRADUATE STUDIES JIMMA UNIVERSITY

DECLARATION

As member of the examining board of the final MSc open defense, we certify that we have read and evaluated the thesis prepared by **Michael Agonafir** entitled: **"Assessment Of Pavement Distress And Remedial Measure From Addis Ababa To Gibe River Trunk Road."** and recommended that it would be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Construction Engineering and Management.

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ABSTRACT

The current condition of Addis Ababa- Gibe River road corridor is subjected to heavy defects. As a result of inappropriate sub base and embankment material, crack was the dominant problem from Tefki to Weliso town. In addition to this, due to a significant growth of traffic and inappropriate maintenance technique the rates of deterioration accelerated exponentially.

The objective of this study was to make an assessment on pavement distress and provide remedial measures from Addis Ababa to Gibe River trunk road. In order to achieve this research objective, necessary investigations have been conducted during the study period such as road condition survey, laboratory and field test, traffic volume and traffic load analysis.

Road condition survey was performed from station km 0+000 (Wolete Suk) to station km 100+000 (Weliso Town) to assess the current condition of the pavement, Failing head method was used to determine the permeability of soil sample, DCP test was conducted to determine the bearing capacity of pavement layer and axle load analysis was made based on the data acquired from BEZA Construction Engineering PLC.

Except for the cracks, the severity and extent of defect was analyzed according to ERA condition survey manual of 2005 edition. Purposive sampling technique was used to analyze the permeability of soil and bearing capacity of pavement layers. Comparative approach was used to analyze the effect of axle load from 2015 to 2018 GC.

The cumulative number of vehicle and ESAL from Addis Ababa to Weliso road section was significantly accelerating, which has great contribution to dislodge the pavement cracks. Accordingly, the result from road condition survey indicates that approximately 49 % of the defects have low severity and a round 67 % of the defects have high extent of deterioration.

Based on the research result, the problem related to cracking is highly related to the permeability of sub base and fill material. Red cinder gravel was widely used material as sub base and fill material from Tefki to Tulu Bolo town; the permeability of red cinder soil is 2.303×10^{-2} *cm/sec which is not suitable in ponding condition. And the research finally recommend to use impermeable material as sub base and fill material in area of ponding condition during rehabilitation.*

Key words: *Pavement crack, permeability, traffic load, AADT, DCP, CBR, sub base and fill material.*

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ACRONYMS

AADT	Annual Average Daily Traffic
AASHTO	American Association of Highway and Transportation Organization
AC	Asphalt Concrete
ACP	Asphaltic Concrete Pavement
ADT	Annual Daily Traffic
ATR	Automatic Traffic Record
BS	British Standard
BST	Bituminous Surface Treatment
C^o	Degree Celsius
CPT	Cone Penetration Test
cm	Centimeter
DCP	Di Cone Penetration
DCPT	Di Cone Penetration Test
DPI	Di Cone Penetration Index
EF	Equivalency Factor
ERA	Ethiopian Road Authority
ESA	Equivalent Standard Axle
ESAL	Equivalent Single Axle Load
GC	Gregorian calendar
HMA	Hot Mini Asphalt
H/Truck	Heavy Truck
JIT	Jimma University Institute of Technology
Kg	Kilogram
Km	Kilo Meter
KN	Kilo Newton

L/Bus	Large Bus
LDV	Land Rover
MADT	Monthly Average Daily Traffic
mm	millimeter
MSc	Masters of Science
M/Truck	Medium Truck
NCDOT	North Carolina Department of Transportation
PCC	Portland Cement Concrete
S/Bus	Small Bus
Sec	Second
SPT	Standard Penetration Test
S/Truck	Small Truck
TF	Traffic Factor
T &Trailer	Truck and Trailer
%	Percentage

CHAPTER ONE

1. INTRODUCTION

Pavement management systems typically use pavement condition data to prioritize pavement maintenance and rehabilitation projects, predict pavement performance, and to develop optimum strategies for the future maintenance and rehabilitation of pavements on the country road network [37].

In the past, crack inspection and evaluation involved high degrees of subjectivity and hazardous exposure, as well as low production rates. Until now, visual inspection techniques have been explored for evaluating pavements. These techniques involved the capture of, mostly on video and cameras, images collected using specially equipped vehicles [14].

Pavement cracks, as the most common type of asphalt concrete-surfaced pavement distress, can be caused by fractures due to excessive loading, fatigue, thermal changes, moisture damage, slippage, or contraction. Usually, in regard to shape and position, cracking is grouped into one of the following types: fatigue, longitudinal, alligator, edge, reflection, block, and transverse [15], [23].

If the distresses identified in a pavement are related to structural deficiencies, the pavement section is most likely not a candidate for preventive maintenance treatment, and should be scheduled for rehabilitation or reconstruction [2].

Pavement condition data has been gathered three times annually by teams of evaluators from Ethiopian Road Authority(ERA), who determine the whole distresses on various uniform pavement sections as they drive slowly through the sections.

Visual surveys conducted by engineers in the field are still the most widely used means to inspect and evaluate pavements, although such evaluations involve high degrees of subjectivity and inconsistent from year to year [5]. This is because of lack of assessing the root cause of pavement distress and inappropriate provision of maintenance.

Therefore, there is a need to make an assessment on pavement distress and adopt an appropriate remedial measure.

1.1 Research Background

Addis Ababa - Jimma Road segment have total length of 336.4 km, which had been reconstructed under rehabilitation project during 2003, to have a service life of 15 years (up to 2018 GC). The road was constructed under the supervision of Ethiopian Road Authority and DIWI Consult International GmbH (Company of Germany) and the contractor was JV Dragados J&P Avax SA.

Due to accelerated pavement deterioration and cracking problem CSIR Transportek (subsequently redesignated CSIR Knowledge Services) was appointed to undertake technical audit. According to CSIR Technical Report in 2006 indicate that" the original pavement structural design was undertaken by Studio Pietrageli (Italy), ostensibly during 1996 and 1997, with the bid documentation completed in July 1997".

The Frank Netterberg preliminary report on cracking problem in January 2001 says that "the red cinder gravel and the Tulu Bolo weathered tuff are probably highly porous and permeable materials unsuitable for fill or backfill under ponding condition and which may also possess a collapsible grain fabric".

1.2 Project Description

Addis Ababa - Gibe River Road segment starts at an area called Wolete Suk which is 14+000 km from the center of Addis Ababa and ends at Gibe River which is located at 185+000 km from Addis Ababa. The road is located at southwestern direction of Ethiopia. And this corridor will serve as one of the gateways for the country by connecting Oromia and Southern Region with the central parts of Ethiopia. The segment extends to Jimma town, which is the major coffee growing area. Addis Ababa - Gibe River road was categorized under flexible pavement, having two lanes of carriageway that is constructed by 5 cm thick Asphalt concrete surfacing and shoulders were constructed with single surface treatment.

Pavement management system of Addis Ababa - Jimma road has been controlled and monitored by two (2) districts of Ethiopian Road Authority namely Alem Gena and Jimma district. Therefore, Addis Ababa-Gibe River road is under supervision of Alem Gena district. The current condition of Addis- Gibe road segment is subject to high defect mostly cracking, shoulder damage, potholes, rutting and defects due to patching is common.

1.3 Statement of the Problem

The developing countries have lost precious infrastructure worth billions of dollars through the deterioration of their roads. If they do not immediately begin to do much more to preserve their roads, they will lose billions more. Large road networks, built at great expense, have been under maintained and more heavily used and abused than expected. If this neglect continues, the deterioration of roads will accelerate as old pavements crumble and new ones outlive the initial period during which the effects of neglect are barely perceptible [4].

The current condition of the Addis Ababa- Gibe River road segment was subjected to heavy defects. As a result of inappropriate backfill and embankment material crack was the dominant problem from Tefki to Weliso town. In addition to this due to increase in traffic volume and different factors including inappropriate maintenance techniques the rates of deterioration accelerated exponentially.

Defects found in this road segment include rutting, longitudinal cracks, edge damage, settlement/depression, shoulder damage, crocodile cracks and potholes. Therefore, the aim of this research was to make an assessment on the current condition of the flexible pavement defects and prepare appropriate mitigation measures to develop optimum strategies for the future maintenance of pavement.

1.4 Significance of the Research

The research primary focused on assessment of pavement distress from Addis – Gibe River road segment. During study period the possible causes of pavement distress were identified and categorized with their level of severity and extent of deterioration.

The major significance of this research study is:-

- It has assessed the current condition of the pavement using visual inspection, and laboratory and field test.
- It has identified that how the permeability of sub base and fill material affect the performance of the pavement.
- It has assessed the impact of traffic load based on the original design AADT data and current AADT data.
- It has identified the remedial measures of pavement distress.

Generally this research study has great contribution in managing future maintenance activity.

1.5 Research Questions

The research questions that would be answered by this study were:-

- What is the current condition of road pavement from Addis Ababa to Gibe River?
- What is the difference between the current situations of the road with the original design?
- What are appropriate remedial measures for the defect?

1.6 Objective of the Study

1.6.1 General Objective

The general objective of this study was to make an assessment on pavement distress and provide remedial measures from Addis Ababa to Gibe River trunk road.

1.6.2 Specific Objective

To achieve the above mentioned general objective, the following specific objective was performed:-

- Assess current condition of road pavement.
- Compare the current situation of the road with the original design.
- Adopt an appropriate remedial measure for the defects.

1.7 Scope and Limitation of the Research

The research mainly focused on the assessment of flexible pavement distress from Addis Ababa to Gibe River truck road which covers a total of 171 km from Wolete Suk. In order to assess the current condition of the pavement the following investigation was performed during study period namely road condition survey by visual inspection, permeability test, CBR test and traffic load analysis. AADT data from Welkite to Jimma is used to analyze the road condition between Welkite to Gibe River, because Welkite - Gibe River road segment is a part of Welkite - Jimma road. The weather condition was the major problem encountered during the research period and causes difficulty during field visit and field test.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 General

Road construction work is composed of Earthwork (Clearing & Grubbing, Excavation, Embankment, and Sub grade), Base construction work (Sub base & Base), Prime & Tack Coat and Asphalt Pavement work. Earth structure and pavement structure must support the traffic load certainly, and traffic should be safe. Earth structure should be constructed without settlement, collapse and landslide, and has to keep the safety [1].

Most of materials are used for earthwork are natural soil and rock. Earthwork construction is affected by weather. Especially, quality will be changed by weather, construction method and relation with structures as culvert, retaining wall and bridge abutment [1].

The roadway is the paved or otherwise improved portion of a public highway ordinarily used for vehicular travel. The roadway surface is normally classified as rigid (consisting of PCC) or flexible (consisting of asphaltic materials). A smooth surface with good skid resistance, free of alligator cracks, pumping, pushing, wheel rutting, raveling, frost heaving, and pot holing, is desirable for safe travel by the people we serve.

Maintenance of the roadways must include a program to preserve these characteristics. Ideally, the maintenance of pavement should be accomplished with minimum expense and with the least possible traffic disruption. Maintenance of pavements is a necessary investment made to protect the pavement from costly renovation or reconstruction.

Preventive maintenance is much more cost effective than performing major repairs. Area maintenance staff are required to inspect each section of highway at least once a year to detect and schedule deficiency repairs prior to their becoming a major problem [2].

2.2 Pavement Management System

The use of a pavement management system provides reliable information on the condition of a network at any point in time, reliable evidence on the performance of materials and proprietary products over time, reliable proof of the consequences of historical budget allocations and reliable estimates of the need of future funding levels. A pavement management system allows fund managers to defend budget requests and to evaluate quickly and accurately the implications of alternative funding profiles on the resulting condition of the highway [22].

The goal of pavement management is to produce optimized pavement work programs at the network level, as well as optimized pavement rehabilitation designs at the project level. Within the pavement management process, performance predictions are very important in developing optimized multiyear work programs, as well as for evaluating the life cycle cost-effectiveness of project designs [3].

2.3 Maintenance of Flexible Pavements

Flexible pavements generally are referred to as Asphaltic Concrete Pavement (ACP) or Bituminous Surface Treatment (BST). Flexible pavements develop strength from the tight interlocking of crushed rocks with an asphalt material binding them together. This mixture deflects when loaded by traffic and exerts pressure on the sub grade. Consequently, both the pavement and the sub grade must be in good condition to avoid maintenance problems [37].

2.4 Pavement Deficiencies

Damage and deterioration of pavements will become apparent in a variety of ways. A number of factors can contribute to the appearance of pavement deficiencies. For example, an overlay with excess asphalt or poorly graded or inadequately fractured paving material may not have adequate particle interlock; thus pushing, rutting, and humps may develop. Poor sub grade drainage, heavy tonnage, and accelerating or decelerating traffic are all potential sources of surface irregularities. Pavement deficiencies are explained in more detail as follows [37].

2.4.1 Longitudinal Cracking

Longitudinal cracks are long cracks that run parallel to the center line of the roadway. These may be caused by frost heaving or joint failures or they may be load induced. Understanding the cause is critical to selecting the proper repair. Multiple parallel cracks may eventually form from the initial crack. This phenomenon, known as deterioration, is usually a sign that crack repairs are not the proper solution [33].

Severity levels are [20]:

Low

- A crack with a mean width ≤ 6 mm; or a sealed crack with sealant material in good condition and with a width that cannot be determined.

Moderate

- Any crack with a mean width > 6 mm and 19 mm; or any crack with a mean width 19 mm and adjacent low severity random cracking.

High

- Any crack with a mean width > 19 mm; or any crack with a mean width 19 mm and adjacent moderate to high severity random cracking

Figure 2.1: Longitudinal Cracking

2.4.2 Longitudinal Lane Joint Cracking

Longitudinal lane joint cracking is typically occurring near the edges of the lane. A longitudinal paving joint is only classified as a distress when the joint has cracked and will allow water to penetrate the joint [20].

2.4.3 Transverse Cracking

Transverse cracks form at approximately right angles to the centerline of the roadway. They are regularly spaced and have some of the same causes as longitudinal cracks. Transverse cracks will initially be widely spaced (over 20 feet apart). They usually begin as hairline or very narrow cracks and widen with age. If not properly sealed and maintained, secondary or multiple cracks develop, parallel to the initial crack. The reasons for transverse cracking, and the repairs, are similar to those for longitudinal cracking. In addition, thermal issues can lead to low-temperature cracking if the asphalt cement is too hard [33].

Severity Levels are [20]:

Low

- An unsealed crack with a mean width ≤ 6 mm; or a sealed crack with sealant material in good condition and with a width that cannot be determined.

Moderate

- Any crack with a mean width > 6 mm and ≤ 19 mm; or any crack with a mean Width ≤ 19 mm and adjacent low severity random cracking.

High

- Any crack with a mean width > 19 mm; or any crack with a mean width ≤ 19 mm and adjacent moderate to high severity random cracking

Figure 2.2: Transverse Cracking

2.4.4 Alligator Cracking

Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt surface under repeated traffic loading. The cracking initiates at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain is highest under a wheel load. The cracks propagate to the surface initially as a series of parallel cracks. After repeated traffic loading, the cracks connect and form many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are less than 2-feet (0.6 meters) on the longest side [12].

Location: Alligator cracking occurs only in areas that are subjected to repeated traffic loadings, such as wheel paths.

Therefore, it would not occur over an entire area unless the entire area was subjected to traffic loading.

Causation: Repeated dynamic loading on the asphalt surface that leads to fatigue failure of the asphalt causes the distress. Alligator cracking is considered a major structural distress.

Severity Levels are [112]:

1) Low (L). Fine, longitudinal hairline cracks running parallel to each other with no or only a few interconnecting cracks. The cracks are not spalled.

2) Medium (M). Further development of light alligator cracking into a pattern or network of cracks that may be lightly spelled.

3) High (H). Network or pattern cracking progressed so that pieces are well defined and spalled at the edges; some of the pieces rock under traffic

Figure 2.3: Alligator Cracking

2.4.5 Potholes

Potholes are small, bowl-shaped depressions in the pavement surface that penetrate all the way through the hot mix asphalt (HMA) layer down to the base course. They generally have a sharp edges and vertical sides near the top of the hole.

Causes: Generally, potholes are the end result of fatigue cracking. As fatigue cracking becomes severe, the interconnected cracks create small chunks of pavement which can be dislodged as vehicles pass over them. The remaining hole after the pavement chunk is dislodged is called a pothole [35].

Severity Levels are [12]:

Low

- < 25 mm deep.

Moderate

- 25 mm to 50 mm deep.

High

- 50 mm deep.

Figure 2.4: Potholes

2.4.6 Delamination

A delamination is an area of pavement surface missing due to the loss of adhesion between the surface and underlying layers. Delamination's typically are one layer thick, i.e. the thickness of the surface course. They may range from one-foot square to hundreds of square feet in extent and often occur in the wheel paths or along shoulders [37].

Figure 2.5: Delamination

2.4.7 Bleeding or Flushing

Bleeding is a film of bituminous material on the pavement surface that creates a shiny, glass-like; reflecting surface that usually becomes quite sticky.

Location: Bleeding can occur anywhere on the surface of the asphalt because it is caused by and during construction.

Causation: Bleeding is caused by excessive amounts of asphalt cement or tars in the mix and/or low air-void content. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the surface of the pavement. Since the bleeding process is not reversible during cold weather, asphalt or tar will accumulate on the surface [12].

Severity Levels are [12]:

No degrees of severity are defined. Bleeding should be noted when it is extensive enough to cause a reduction in skid resistance

Figure 2.6: Bleeding or Flushing

2.4.8 Rutting

Surface depression in the wheel path. Pavement uplift (shearing) may occur along the sides of the rut. Ruts are particularly evident after a rain when they are filled with water.

There are two basic types of rutting: Mix rutting and Sub grade rutting [31].

- Mix rutting occurs when the sub grade does not rut the pavement surface & exhibits wheel path depressions as a result of compaction/mix design problems.
- Sub grade rutting occurs when the sub grade exhibits wheel path depressions due to loading. In this case, the pavement settles into the sub grade ruts causing surface depressions in the wheel path.

Problem: Ruts filled with water can cause vehicle hydroplaning, can be hazardous because ruts tend to pull a vehicle towards the rut path as it is steered across the rut.

Possible Causes: Permanent deformation in any of a pavement's layers or sub grade usually caused by consolidation or lateral movement of the materials due to traffic loading. Specific causes of rutting can be [31].

- Insufficient compaction of HMA layers during construction. If it is not compacted enough initially,
- HMA pavement may continue to density under traffic loads.

Figure 2.7: Rutting

2.4.9 Raveling and Pitting

Raveling is the wearing away of the pavement surface caused by the dislodging of aggregate particles or loss of asphalt binder. Raveling is much more common on chip seal or slurry surfaces than on plant mix surfaces and is sometimes noted on open graded friction course or ultra-thin bonded wearing course surfaces. Raveling indicates either a hardening or poor application of asphalt binder [28].

Severity Levels are [28]:

Low Severity

- Aggregate loss within the pavement lanes is not great; small amounts of stripping may be detected; aggregate has started to wear away.

Moderate Severity

- Some stripping evident; random stripping with small areas (less than one square foot) or strips of aggregate broken away.

High Severity

- Stripping very evident; aggregate accumulation may be a problem, particularly along the shoulders; large sections (greater than one square foot) of stripping with aggregate layer broken away

Figure 2.8: Raveling and Pitting

2.4.10 Block Cracking

Block cracking is an interconnected series of cracks that divides the pavement into irregular pieces. This is sometimes the result of transverse and longitudinal cracks intersecting. They can also be due to lack of compaction during construction. Low severity block cracking may be repaired by a thin wearing course. As the cracking gets more severe, overlays and recycling may be needed. If base problems are found, reclamation or reconstruction may be [33].

Severity Levels are [20]:

Low

- Cracks with a mean width ≤ 6 millimeters (mm); or sealed cracks with sealant material in good condition and with a width that cannot be determined.

Moderate

- Cracks with a mean width > 6 mm and ≤ 19 mm; or any crack with a mean Width ≤ 19 mm and adjacent low severity random cracking.

High

- Cracks with a mean width > 19 mm; or any crack with a mean width ≤ 19 mm and adjacent moderate to high severity random cracking.

Figure 2.9: Block Cracking

2.4.11 Stripping

The loss of bond between aggregates and asphalt binder that typically begins at the bottom of the HMA layer and progresses upward. When stripping begins at the surface and progresses downward it is usually called raveling [24].

Problem: Decreased structural support, rutting, shoving/corrugations, raveling, or cracking (alligator and longitudinal)

Possible Causes: Bottom-up stripping is very difficult to recognize because it manifests itself on the pavement surface as other forms of distress including rutting, shoving/corrugations, raveling, or cracking. Typically, a core must be taken to positively identify stripping as a pavement distress [24].

- Poor aggregate surface chemistry
- Water in the HMA causing moisture damage
- Overlays over an existing open-graded surface course.

Figure 2.10: Stripping

2.5 Field Test

2.5.1 Dynamic Cone Penetration Test (DCPT)

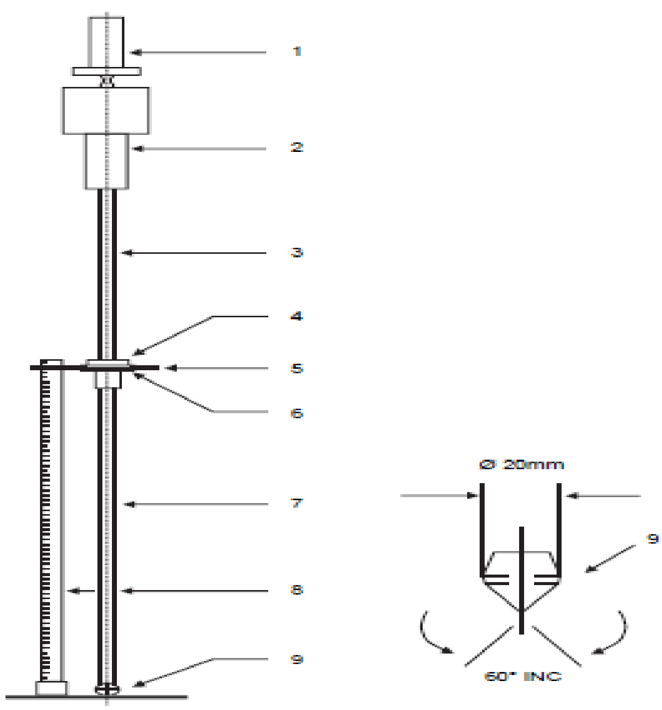
In-situ penetration tests have been widely used in geotechnical and foundation engineering for site investigation in support of analysis and design. The standard penetration test (SPT) and the cone penetration test (CPT) are two typical in-situ penetration tests. The dynamic cone penetration test shows features of both the CPT and the SPT. The DCPT is similar to the SPT in test. It is performed by dropping a hammer from a certain fall height and measuring a penetration depth per blow for each tested depth. The shape of the dynamic cone is similar to that of the penetrometer used in the CPT [17].

The Dynamic Cone Penetrometer (DCP) is an instrument which can be used for the rapid measurement of the in situ strength of existing pavements constructed with unbound materials. Measurements can be made down to a depth of approximately 800mm or, when an extension rod is fitted, to a depth of 1200mm. Where pavement layers have different strengths, the boundaries between them can be identified and the thickness of each layer estimated [7].

DCP tests are particularly useful for identifying the cause of road deterioration when it is associated with one of the unbound pavement layers, e.g. shear failure of the road base or Sub-base. A comparison between DCP test results from sub-sections that are just beginning to fail and those that are sound will quickly identify the pavement layer which is the cause of the problem [7].

The significant advantages of the DCP are that it is a low cost, robust apparatus that is quick and simple to use. Very little damage is done to the pavement being tested (effectively nondestructive) and very useful information is obtained. One of the major advantages of the test is that the pavement is tested in the condition at which it performs. The simplicity of the test allows repeated testing to minimize errors and also to account for temporal effects [29].

The underlying soil strength is determined by measuring the penetration of the lower shaft into the soil after each hammer drop. This value is recorded in millimeters (inches) per blow and is known as the DCP penetration index (DPI). The penetration index can be plotted versus depth to identify thicknesses and strengths of different pavement layers or can be corrected to other soil strength parameters such as the California Bearing Ratio (CBR) [25].



KEY

1-Handle

2- Hammer (8kg)

3 -Hammer shaft

4 -Coupling

5- Hand guard

6 -Clamp Ring

7- Standard Shaft

8 -One (1) Meter Rule

9- 60^0Cone

Figure 2.11: Dynamic Cone Penetrometer (DCP) [25]

2.6 Traffic Volume and Traffic Loading

2.6.1Effect of Traffic Load on Pavement System

Traffic loads applied to a pavement system, in combination with the effects of climate; determine the service life of a pavement. The AASHTO road test demonstrated that a highway structure deteriorates with increasing levels of load and the number of load repetitions. Thus, the estimated traffic loads expected to be applied to the pavement system are critical in determining the life expectancy of a given pavement system/structure. Traffic loads applied to the pavement system are usually in various combinations of axle loads and configurations, each having a specific damage effect. These mixed axles can be equated to an arbitrary chosen reference single-axle load, generally 18 kip, for pavement design purposes [18].

2.6.2 Projection of Traffic Data

Traffic projection is a mathematical modeling process used to estimate traffic loads from samples of monitoring traffic data and other information. Projected traffic data are data that have been obtained by the projection process involving factoring or expanding sampled traffic data to obtain traffic data for an entire period. If the period used to factor or expand the data is a year, the result is annual estimates. If the period is the entire period the pavement was open to traffic, the result is cumulative estimates [19].

Predictions of future truck volume are often based on traffic history. Several factors can influence future truck volume such as land use changes, economic conditions and new or competing roadways. Truck volume may decrease, remain constant, or increase. The change may be described as a straight line, an accelerating (compound) rate, or a decelerating rate [34].

2.6.3 Average Daily Traffic

Average Daily Traffic (ADT) is the average number of vehicles (two-way) passing a specific point in a 24-hour period. ADT is obtained by short-term traffic counts. ADT is typically a seven day, 24 hours per day, traffic count divided by seven. For traffic forecasts, the Seasonal Factor and Axle Factor (if needed) should be used to convert ADT to AADT [27].

2.6.4 Annual Average Daily Traffic

Annual Average Daily Traffic (AADT) is the estimate of typical daily traffic on a roadway segment for all seven days of the week over the period of one year. Conceptually, AADT is determined by dividing the total volume of traffic on a roadway segment for one year by the number of days in the year. In order to calculate AADT from Automatic Traffic Record (ATR) data, the data for each day of the week is averaged for the month. Following this and as noted in part above, the seven average days (Sunday through Saturday) are averaged, which provides Monthly Average Daily Traffic (MADT). The 12 MADTs (January through December) are then averaged, which yields the AADT [27].

According to ERA Flexible Pavement Design Manual 2013, for each vehicle class, estimate the traffic in the first year that the road is opened to traffic. For normal traffic this is given by;-

$$AADT\,(m)_1 = AADT\,(m)_0\,(1+i)^n$$

Where, $AADT\,(m)_1$= the AADT of traffic class m in the first year

$AADT\,(m)_0$ = initial traffic volume of each traffic class (m)

i= the annual growth rate of traffic in percent

n= the design period in years

And cumulative traffic volume of vehicle classes over the design life of the road in one direction is determined as follow;-

$$T\,(m) = 0.5*365*AADT\,(m)_1\,[(1+i/100)^n - 1]/(i/100)$$

Where, T (m) = the cumulative traffic of traffic class m

2.6.5 Axle Equivalency Factor

The damage that vehicles do to a paved road is highly dependent on the axle loads of the vehicles. For pavement deign purposes the damaging power of axles is related to a "standard" axle of 8.16 metric tons using empirical equivalency factors. in order to determine the cumulative axle load damage that a pavement will sustain during its design life, it is necessary to express the total number of equivalent standard axles(ESA) .A vehicle's damaging power, or Equivalency Factor (EF), can be expressed as the number of ESAs, in units of 80 KN. The design lives of pavements are expressed in terms of the ESAs they are designed to carry [6].

The number of equivalent standard axles (ESA) of an axle is related to the axle load as follows;

$$ESA = (L/8160)^{n} \text{ (for loads in kg)} \quad \text{or}$$

$$ESA = (L/80)^{n} \text{ (for loads in kN)}$$

Where, ESA= equivalent standard axles

L= Axle load (in kg or kN)

n= Damage Exponent (4.5)

2.6.6 Equivalent Single Axle Load

Equivalent Single Axle Load (ESAL) is a quantity that is related to pavement damage caused by a Standard axle load of 80 Kilo Newton (KN) (18,000 pound force (Ibf)) carried by a single axle with dual tires. Axle load spectrum is defined as a frequency distribution of axle weights, of a given axle type, into weight ranges. Truck Factor (TF) is the number of ESALs per truck [23].

Design ESALs is a cumulative traffic load summary statistic. The statistic represents a mixed stream of traffic of different axle loads and axle configurations predicted over the design or analysis period and then converted into an equivalent number of 18,000-lb. single axle loads summed over that period [36].

Load equivalence factors measure the relative effects of different types of loadings on pavements. Pavement engineers generally use the concept of an equivalent single-axle load (ESAL) to measure the effects of axle loads on pavement. For example, that a given vehicle on a given type of pavement is 3.0 ESALs means that one pass by the vehicle has the same effect on the pavement as three passes by an 18,000-pound single axle [30].

Increased traffic loadings require thicker pavements which, in turn, increase the construction cost of pavements. There are, however, considerable economies of scale in designing new pavements for higher traffic loadings. In the AASHTO pavement design procedures used by many states, a given percentage increase in traffic loadings can be accommodated by a much smaller increase in pavement thickness and costs [30].

The cumulative traffic for each class of vehicle is multiplied by the average number of equivalent standard axles of vehicles in that class to calculate the cumulative total number of equivalent standard axles over the life of the road [6].

2.7 Condition Survey and Inventory Model

The Pavement Condition Survey forms have been specifically designed to determine the amounts and severities of several distresses for flexible, rigid, and overlays over rigid pavements. Each rater should pay attention to all instructions so that the condition survey can be correctly completed. Missing or improperly marked data will require correction and possible considerable time and effort in rechecking a particular section [13].

It is necessary to know the condition of the road every year for doing proper maintenance works. Routine maintenance should be initiated directly after construction and continue on regular basis. Thereafter periodic maintenance will come. By maintaining the road in this way it will reach its required design life, and thereby beneficial from economic point of view [32].

The road condition survey is an important part of maintenance management. The road condition survey collects data on the condition of the road network. It is used to plan and quantify the maintenance required on the road network. The road condition survey data can then be used to prepare the annual work program. It can also be used to highlight recurrent and periodic maintenance requirements [10].

CHAPTER THREE

3. METHODS OF RESEARCH

3.1 Study Area

The study area of this research was started at area called Wolete Suk (14+000 km from the center of Addis Ababa) and ends at Gibe River which is 185+000 km from Addis Ababa. The research was passes through different Villages and towns which are listed in Table 3.1.

Table 3.1: Location of villages and towns

No.	Name of Location	Station (Km)	Remark
1	Wolete Suk	0+000	Town
2	Alem Gena (Kenteri)	3+500	Town
3	Sebeta	8+500	Town
4	Dima	14+000	Village
5	Tefki	26+000	Town
6	Awash Belo	33+000	Village
7	Teji	39+600	Town
8	Asgori	46+000	Town
9	Awash Buni	54+000	Village
10	Tulu Bolo	65+000	Town
11	Kora	78+000	Town
12	Dilela	85+000	Town
13	Weliso	99+500	Town
14	Gurara	112+000	Town
15	Guru	120+000	Town
16	Welkite	141+000	Town
17	Gibe Bridge	171+300	Village

3.2 Study Design

The research analyzed the current condition of road pavement by conducting road condition survey. During study time laboratory and field test were conducted to determine the permeability and CBR value of sub base and fill material and analyzed as per Karl Terzage soil classification and ERA standard technical specification. DCP test was conducted to determine the CBR value of the field soil. Traffic load analysis was made based on comparative approach.

3.3 Study Variable

3.3.1 Independent Variable

- AADT
- CBR
- Permeability
- Traffic Load
- Traffic Volume

3.3.2 Dependent Variable

- Asphalt pavement damage

3.4 Data Collection Process

The data collection process during the study period was from laboratory test result for permeability and field test result of CBR to determine the permeability property and strength of soil respectively.

The current (2015) AADT data was taken from ERA head office and all Axle load data's were gathered from the survey conducted for the Design of Addis – Gibe River Road Overlay Project in 2012 by Beza Consulting Engineering PLC.

3.4.1 Road Condition Survey

Road condition survey of the road segment was performed from station km 0+000 (Wolete Suk) to station km100+000 (Weliso). The survey was conducted by driving survey vehicle slowly through the section and defects were identified by visual inspection to determine the current condition of pavement. All Pavement defects on the carriageway and shoulders were properly recorded.

3.4.2 Laboratory and Field test

For laboratory test disturbed soil sample was taken from the sub base at station 66+500 km in order to determine the soil permeability capacity. Station 66+500 km (sample area) was selected because of the existence of large ponding of water in the area which causes different pavement crack.

The field test result was obtained from twenty four (24) stations where different cracks, depressions, rutting and base failures were found. The Location of field test are at station 66+500, 105+000, 114+100, 126+000, 126+400, 126+600, 127+100, 163+700, 166+000, 168+160, 168+840, 170+000. In general the data collection process for both laboratory and field test investigation were based on purposive sampling technique.

3.4.3 Traffic Load

Annual Average Daily Traffic (AADT) data of original design was taken CSIR technical Report of March 2006. And current axle load distribution data's of 2015 GC have been gathered from BEZA Construction Engineering PLC and the 2015 AADT data from ERA head office was taken to analyze the traffic load.

3.5 Data Processing and Analysis

The data collected during study period would be analyzed by identifying and categorizing the whole types of defect in to the right category with their level of severity. And then make an assessment on the possible causes of distress and appropriate mitigation action for the defect.

3.5.1 Road Condition Survey

Except for the pavement cracks the severity and extent of all defects were categorized and analyzed according to ERA Condition Survey Manual of 2005 edition. The pavement cracks (Alligator, Block, Longitudinal and Transverse crack) have been analyzed according to "US Department of Transportation Federal High Way Administration of June 2003 edition".

In order to identify the possible causes of pavement deterioration that found during the road condition survey, investigation on laboratory and field test and traffic load analysis was made.

3.5.2 Laboratory and Field Test

The permeability test was necessary to investigate the causes of pavement crack due to the existence of large ponding of water on both sides of the road during winter season. During the research time the laboratory test result of permeability was analyzed according to Karl, T. 1967.

During the study period Kleyn and Van Heerdeen (60^0cone) DCP test was used to determine the California Bearing Ratio (CBR). The test analyzes the strength of sub base and fills material. After taking field data's on field data sheet necessary computation were made. Then result was finally plotted using computer excel (penetration versus number of blows). The thickness of each pavement layer was identified by the rate change of penetration.

3.5.3 Traffic Load Analysis

After all data's have been gathered then necessary computations were made by projecting traffic data's from 2015 to 2018 (end of service life of the original design) based on original design data and current AADT data, the 2015 AADT data was used as current AADT to know the traffic growth up the end of the service life of the road. AADT data from Welkite to Jimma is used to analyze the road condition between Welkite to Gibe River, because Welkite - Gibe River road segment is a part of Welkite to Jimma road. During computation of Equivalency Factor (EF) or Truck Factor (TF) **4th** power law was used to quantify the exponential damaging effect of all vehicle axle loads. Then finally compare the difference between the original design and current design. Therefore, comparative approach method was used to analyze the result.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Laboratory Test Result

Table 4.1: Permeability of Soil

Trial No.	Head (H1) (cm)	Head (H2) (cm)	Time (sec)	Permeability (K) (cm/sec)	Ratio of, Viscosity at 20.7 ^{0}C / Viscosity at 20 ^{0}C	Permeability (K 20) (cm/sec)
1	132.3	117.3	17	$2.24*10^{-2}$	0.983	$2.202*10^{-2}$
2	117.3	102.3	20.1	$2.16*10^{-2}$	0.983	$2.123*10^{-2}$
3	102.3	82.3	26.2	$2.63*10^{-2}$	0.983	$2.585*10^{-2}$

Average permeability of Soil = **$2.303*10^{-2}$ cm/sec**

The laboratory test result of permeability on Table 4.1indicate that the permeability of sub base is **K20 (Average) = 2.303 x10^{-2} cm/sec**. According to Karl, T. (1967)the soil type is categorized under clean gravel, sand or gravel mixture and this type soil have good drainage property that means the soil have high permeability property (see Appendix-A on Table A5).

And also after washing the soil in laboratory the result shows that the soil was practically red cinder (red ash) as presented in Figure below 4.1.

Figure 4.1: Red Cinder (Red Ash)

Due to flat terrain type of the region there is high ponding of water of from Tefki to Tulu Bolo. And crack was the dominant problem in the region because of the permeability of sub base and fill material.

Figure 4.2: High Ponding of Water

4.2 Field Test Result

According to ERA Standard Technical Specification 2002 and 2013 Edition, the sub base material should have a minimum soaked **Californian Bearing Ratio (CBR)** value of **30 %** when determined in accordance with the requirement of AASHTO T-193. The Californian Bearing Ratio (CBR) shall be determined at a density of 95 % of the maximum dry density when determined in accordance with the requirement of AASHTO T-180 Method D. And fill material shall have a minimum soaked Californian Bearing Ratio (CBR) of not less than **4%** [9], [8].

CBR- Value at Station 66+500 km

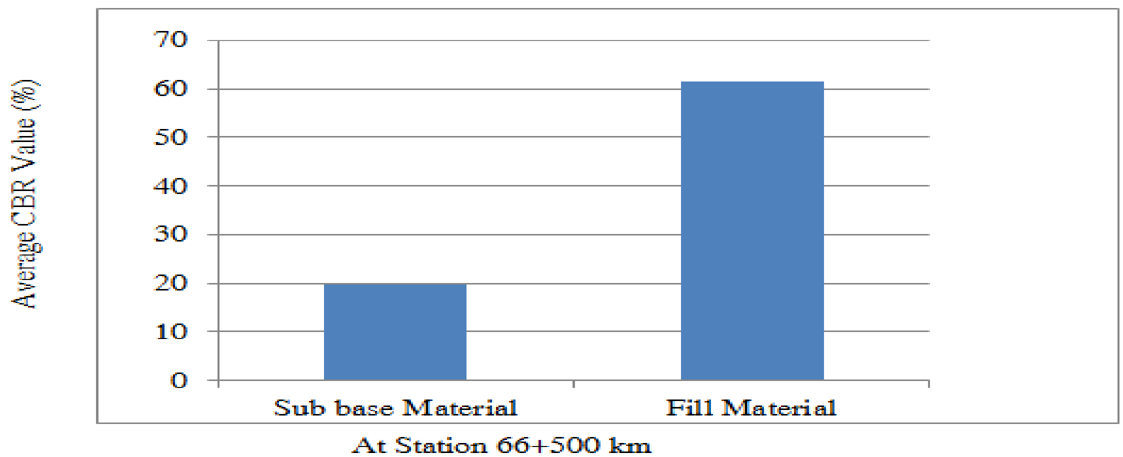


Figure 4.3: Average CBR Value of Sub base and Fill Material at Alligator Crack

Table 4.2: Summary of DCP-CBR test for sub base and fill material at Alligator Crack

Depth below Base Course	**0- 300 mm**	**300-900 mm**
Averaged DCP Value (mm/blow)	11.056	5.060
Average CBR Value (%)	19.78	61.505
Remark on Average CBR Value	Poor compaction (less than 30%)	Good compaction (greater than 4%)

The Average California Bearing Ratio (CBR) at station 66+500 indicates that:-

- The average CBR value of sub base material is 19.78% which does not satisfy ERA standard technical specification; therefore it is categorized under **poor** compaction (see Table 4.2).
- But the embankment material was properly compaction; because the CBR value is greater than 4 % (see Table 4.2).

Due to poor compaction of the sub base and highly permeable material at Station 66+500 it was dominantly affected by different types of pavement cracks. The embankment materials have good compaction but due to the soil type which is red cinder, the embankment allows moisture infiltration as a result of this shrinkage of pavement layer occurs, which finally propagates to the upper surface.

CBR- Value from Station 105+100 to 127+100 km

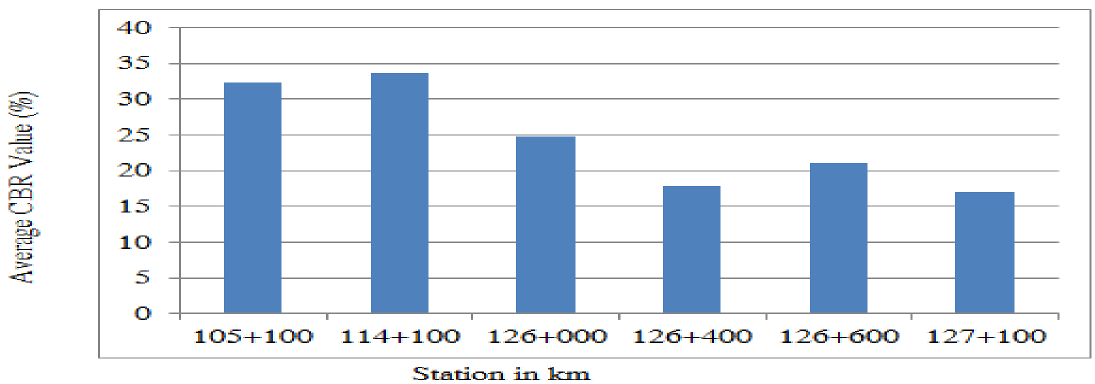


Figure 4.4: Average CBR Value of Sub base Material at Settlement or Depression area

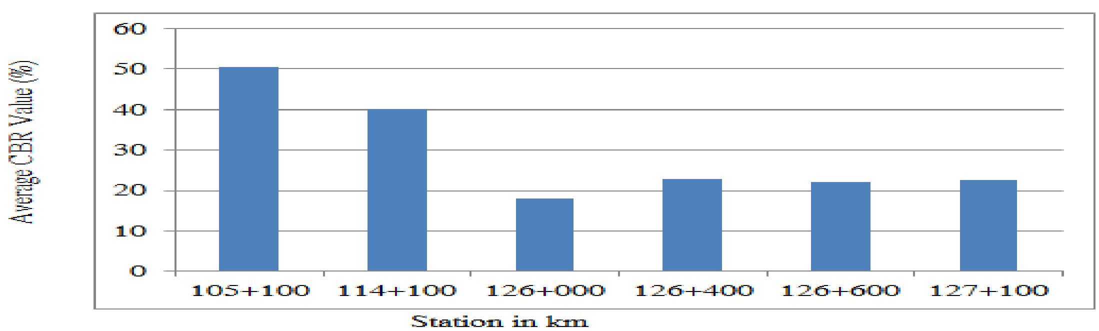


Figure 4.5: Average CBR Value of Fill Material at Settlement or Depression area

Table 4.3: Summary of DCP-CBR test for sub base and fill material at Settlement or Depression.

Depth below Base Course	0-300 mm	300-900 mm
Average DCP Value(mm/blow)	9.847	10.971
Average CBR Value (%)	24.428	28.932
Remark on Average CBR Value	Poor compaction (less than 30%)	Good compaction (greater than 4%)

The average CBR value from station 105+100 to 127+100 km indicate that 67% of the sub base material have less than 30% value which is categorized under **poor** condition. And the CBR value of the embankment material has **good** compaction which has value greater than 4 % compaction (See Appendix- A on Table A9).

Therefore, the CBR value indicates that settlement or depression of the pavement on the above station was occur due to poor compaction of sub base material.

CBR- Value from Station 163+700 to 170+000 km

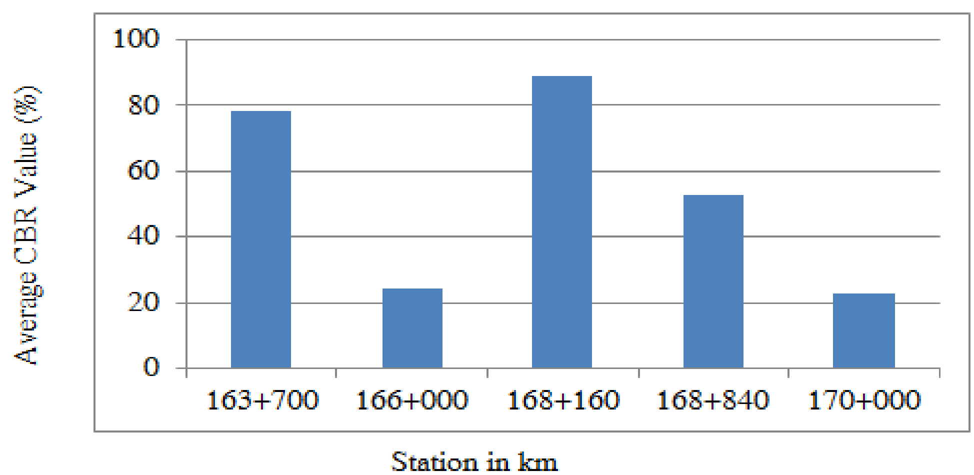


Figure 4.6: Average CBR Value of Sub base Material at Rutting and Base Failure area

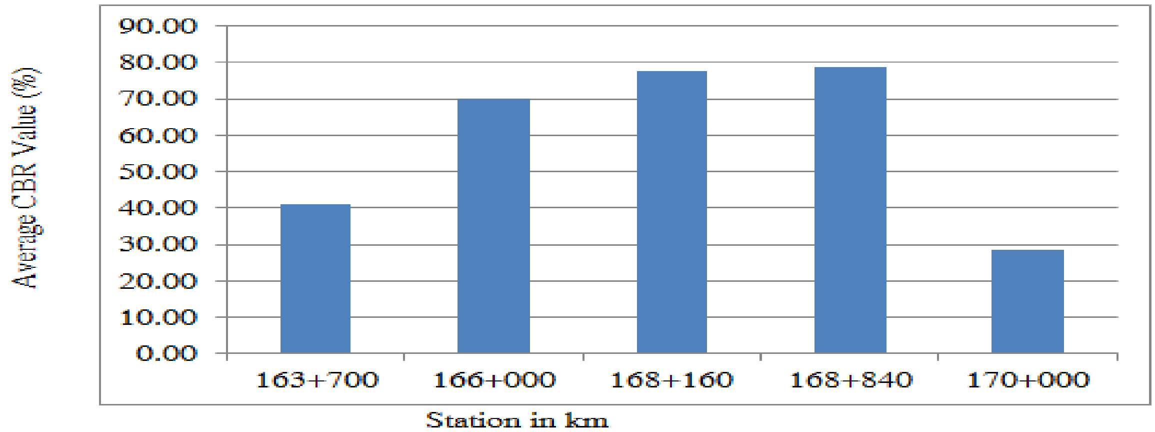


Figure 4.7: Average CBR Value of Fill Material at Rutting and Base Failure area

Table 4.4: Summary of DCP-CBR test for sub base and fill material at Rutting and Base Failure

Depth below Base Course	**0-300 mm**	**300-900 mm**
Average DCP Value(mm/blow)	6.319	5.4
Average CBR Value (%)	53.528	61.812
Remark on Average CBR Value	Good compaction (greater than 30%)	Good compaction (greater than 4%)

The Average CBR value from station 163+700 to 170+000 km indicates that 60 % of the sub base materials have greater than 30 % value which is categorized under good compaction. The CBR value of the embankment material has good compaction, which has value greater than 4 % (See Appendix A on Table A10).

Rutting and Base failure is most common in Gibe Mountainous area, but the sub base and fill materials at this station have good CBR value. However, the test indicates the main cause of rutting in the area is not because of poor compaction rather it may be because of excessive exertion of heavy vehicles at mountainous curve and due to shrinkages of

Asphalt layer because of high temperature. Most of the base failures in the area were the result of excessive defect of rutting.

4.3 Analysis and Discussion on Road Condition Survey

The road condition survey result on Appendix- C indicates that most of the defect from Wolete Suk to Woliso town has low severity with high extent of deterioration.

Table 4.5: Summary of Severity and Extent of Defects

Station	Total Number of Defect Severity		
km	**Low**	**Medium**	**High**
0 -5	29	38	11
6 – 10	22	15	4
11 – 15	27	19	8
16 – 20	23	12	0
21 – 25	21	11	0
26 – 30	18	16	5
31 - 35	30	1	11
36 - 40	13	6	11
41 – 45	19	5	10
46 - 50	22	5	10
51 – 55	25	13	0
56 - 60	18	2	10
61 – 65	7	14	3
66 – 70	20	44	16
71 – 75	32	19	9
76 – 80	6	6	4
81 – 85	5	2	10
86 – 90	2	11	0
91 – 95	14	10	0
96 - 100	8	0	10
Subtotal	**361**	**249**	**132**

Station	Total Number of Defect Extent		
km	**Low**	**Medium**	**High**
0 -5	1	15	62
6 – 10	2	1	38
11 – 15	7	4	43
16 – 20	5	2	28
21 – 25	2	0	30
26 – 30	4	6	29
31 - 35	8	2	32
36 - 40	7	3	20
41 – 45	18	3	13
46 - 50	10	12	15
51 – 55	10	7	21
56 - 60	5	7	18
61 – 65	5	1	18
66 – 70	8	23	49
71 – 75	20	22	18
76 – 80	6	0	10
81 – 85	3	3	11
86 – 90	2	1	10
91 – 95	3	0	21
96 - 100	8	0	10
Subtotal	**134**	**112**	**496**

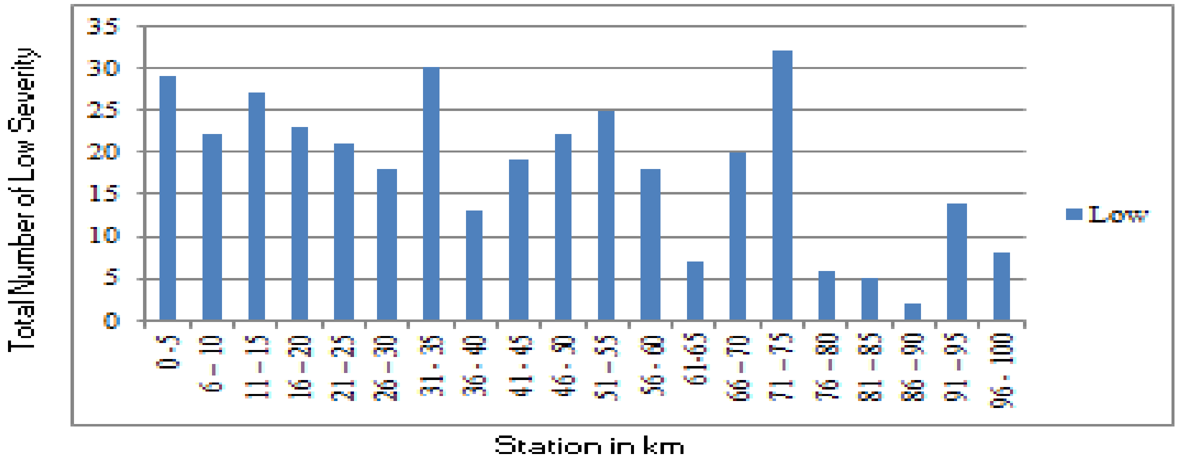


Figure 4.8: Total Number of Low Severity Defect

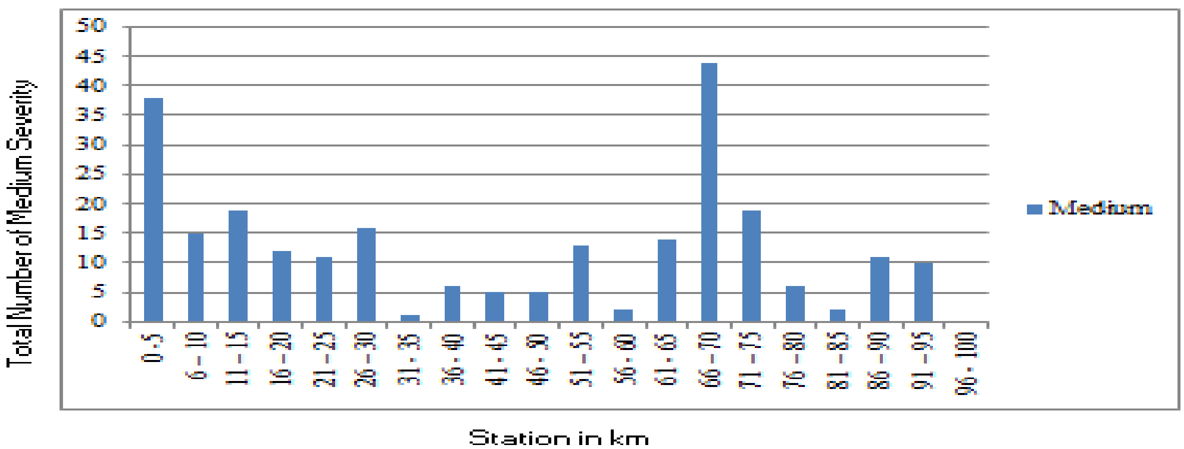


Figure 4.9: Total Number of Medium Severity Defect

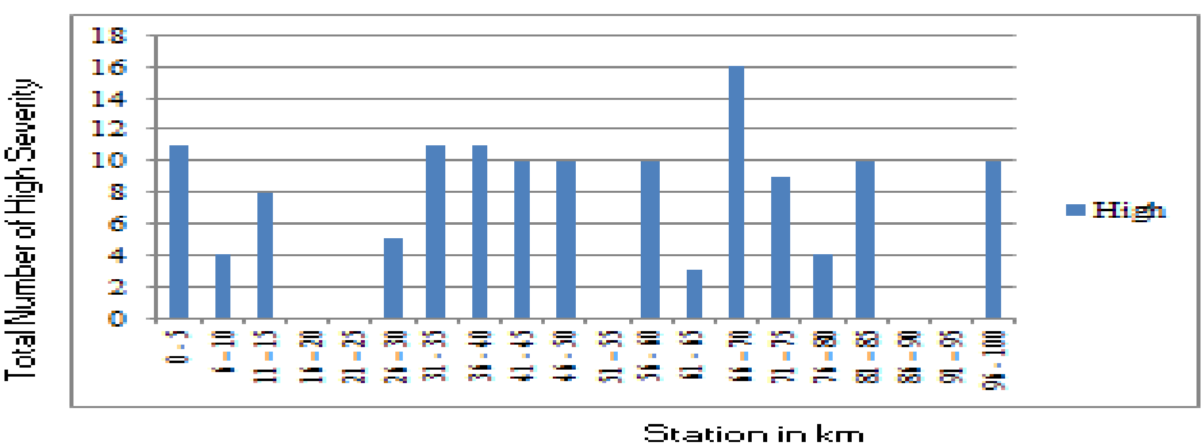


Figure 4.10: Total Number of High Severity Defect

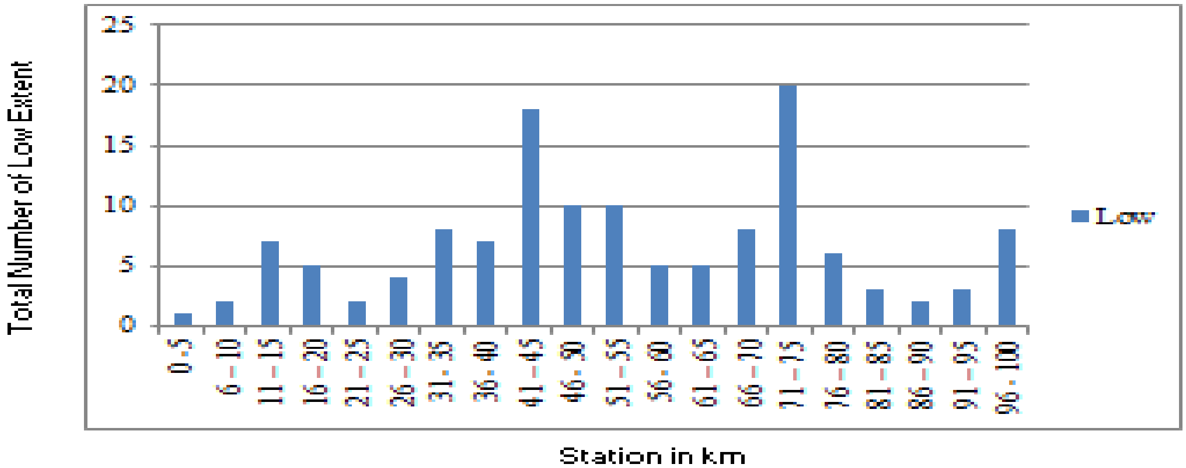


Figure 4.11: Total Number of Low Extent Defect

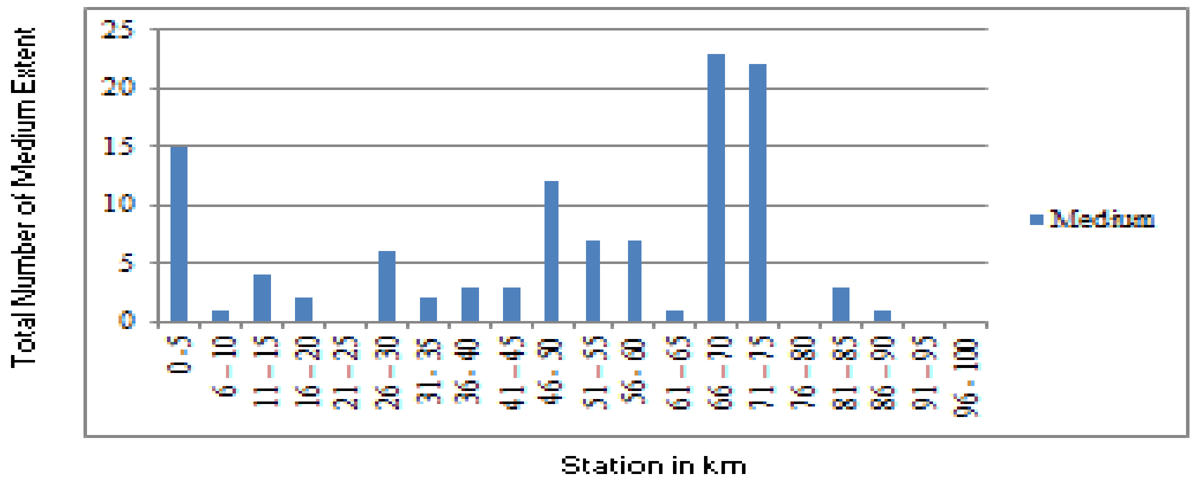


Figure 4.12: Total Number of Medium Extent Defect

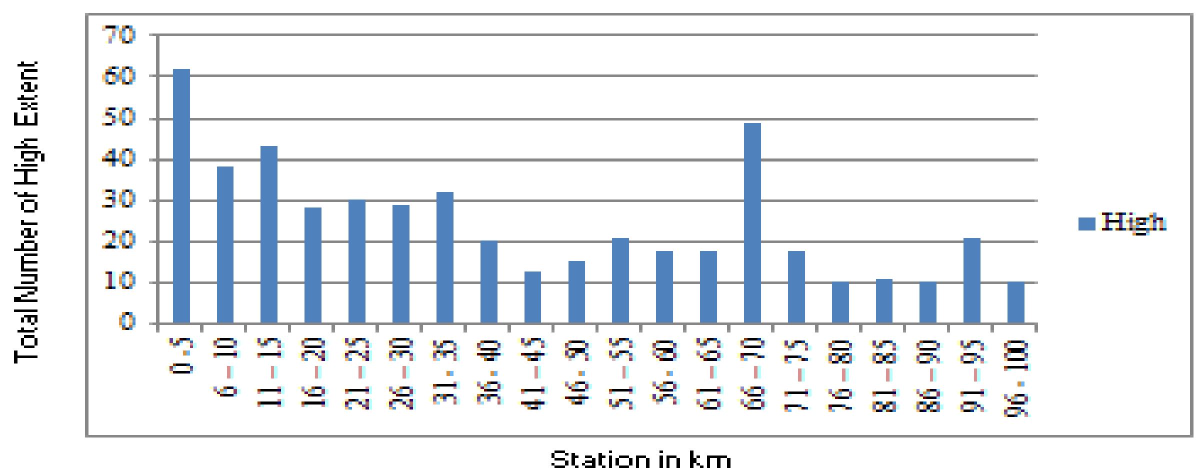


Figure 4.13: Total Number of High Extent Defect

Table 4.6: Percentage of Severity and Extent of Defect

Percentage of Severity (%) from total defect			**Total (%)**
Low	**Medium**	**High**	
49	33	18	**100**

Percentage of Extent (%) from total defect			**Total (%)**
Low	**Medium**	**High**	
18	15	67	**100**

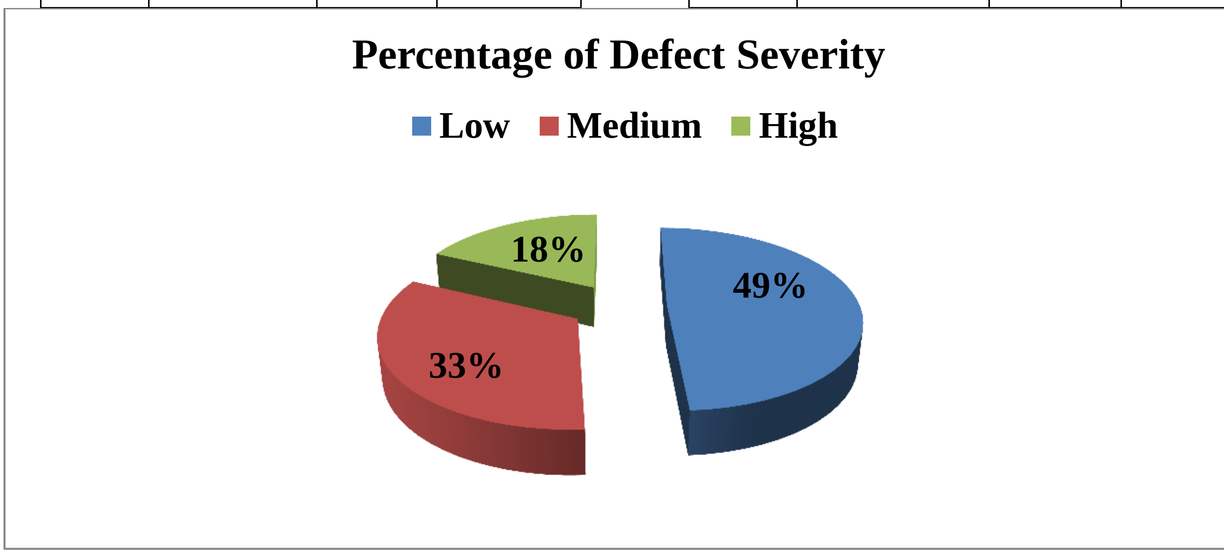


Figure 4.14: Percentage of Defect Severity

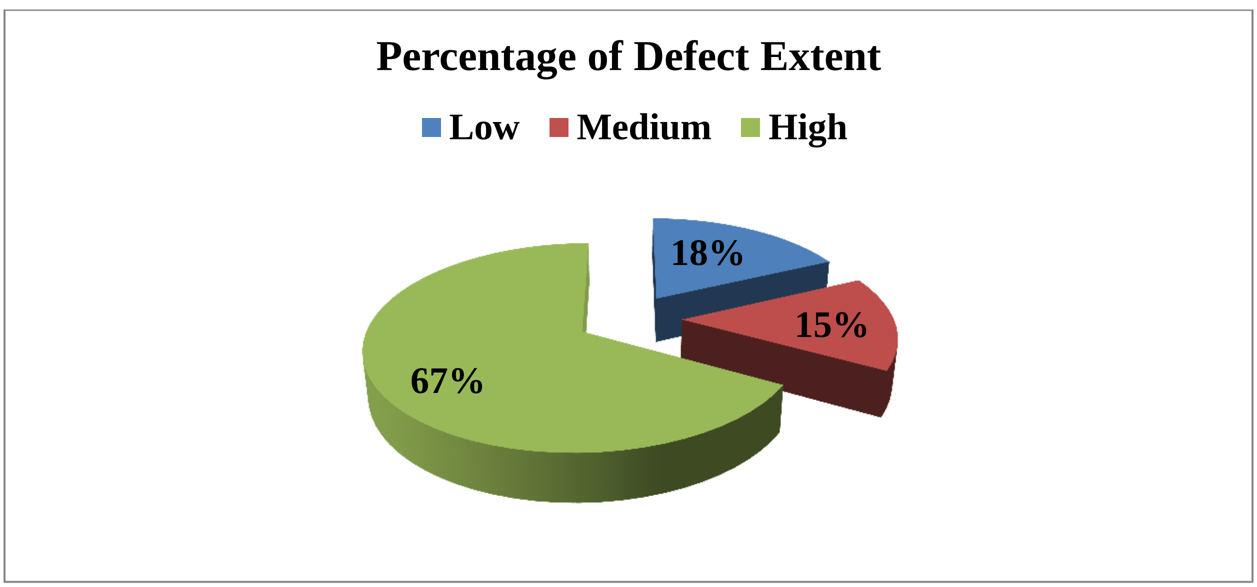


Figure 4.15: Percentage of Defect Extent

Result from Table 4.6 indicates that approximately half (49 %) of the defects have low severity and a round 67 % of the defects have high extent.

Due to continuous and regular maintenance activity of the road section throughout year or routine maintenance, the pavement defects were maintained earlier so that severity of defects would not be wider. But the extents of defect become wider due to the significant growth of traffic load and poor patching techniques by the contractor.

4.4 Analysis and Discussion on Traffic Load Analysis

4.4.1 Analysis of Cumulative number of vehicle from 2015-2018

Table 4.7: Summary of Cumulative Number of Vehicle Based on Original Design AADT data

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative Number of Vehicle
Addis Ababa-Weliso	708,233	1,426,820	1,097,554	244,361	3,476,967
Weliso - Welkite	304,416	627,469	894,610	89,047	1,915,542
Welkite - Jimma	242,290	283,707	586,052	70,409	1,182,459

Table 4.8: Summary of Cumulative Number of Vehicle Based on Current AADT data

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative Number of Vehicle
Addis Ababa -Weliso	1,314,140	1,495,060	1,507,396	1,262,331	5,578,927
Weliso - Welkite	361,018	685,853	700,655	289,473	2,036,999
Welkite - Gibe River	185,855	412,005	383,222	282,071	1,263,153

Table 4.9: Comparing the Cumulative Number of Vehicle from 2015-2018

Road Section	Cumulative Number of Vehicle (Based on Original Design AADT)	Cumulative Number of Vehicle (Based on Current AADT)	Percentage (%) Increase
Addis Ababa -Weliso	3,476,967	5,578,927	**60.454**
Weliso - Welkite	1,915,542	2,036,999	**6.341**
Welkite - Gibe River	1,182,459	1,263,153	**6.824**

Table 4.9 shows that the Cumulative Number of Vehicle from 2015 up to the end of the service life of the road (2018) based on Current AADT data is higher than that projected by the original design, Especially Addis Ababa-Weliso Road section which has significant traffic growth.

These significant growths of traffic from Addis Ababa to Weliso road section are also the main cause of different cracks in addition to sub base and embankment material problem. Weliso - Welkite and Welkite - Gibe River have small increase in traffic but this also have great impact on the pavement.

Welkite to Gibe River road is a part of Welkite to Jimma road section, which is mainly characterized by rutting and base failures .This rut and base failures, was caused by the combined effect of traffic growth rate and shrinkage of asphalt due to high temperature in addition to vehicle impact during stoppage time (deceleration) on mountain curves.

4.4.2Analysis of Cumulative ESAL/million from 2015-2018

Table 4.10: Summary of Cumulative ESAL Based On Original Design AADT Data

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative ESAL/million
Addis Ababa-Weliso	0.000	0.585	3.150	1.315	5.050
Weliso - Welkite	0.000	0.257	2.568	0.479	3.304
Welkite - Jimma	0.000	0.116	1.682	0.379	2.177

Table 4.11: Summary of Cumulative ESAL Based on Current AADT data

Section	Length	Cumulative ESAL/Annum (million)
Addis Ababa- Weliso	km 14-114	8.094
Weliso - Welkite	km 114-155	0.883
Welkite - Gibe River	km 155-185	1.326

Table 4.12: Comparing the Cumulative ESAL/million from 2015-2018

Road Section	Cumulative ESAL/Million(Based on Original Design AADT)	Cumulative ESAL/Million (Based on Current AADT)	% (Percentage) Increase(+) or Decrease(-)
Addis Ababa-Weliso	5.050	8.094	**+60.277**
Weliso-Welkite	3.304	0.883	**-73.275**
Welkite - Gibe River	2.177	1.326	**-39.090**

Tables 4.12 indicate that the Cumulative ESAL from Addis Ababa to Weliso road section based on the current AADT data would increase by 60.277% from the original design. The same as sub base problem and high traffic volume the pavement is also highly affected by the traffic load.

4.5 Cause and Remedial Measure of Pavement Distress

4.5.1 Alligator Crack

Alligator crack is also called crocodile or fatigue crack, this type of crack is mostly found between Tefki and Weliso town.

Cause of Alligator Crack

- Due to high permeability of sub base material.
- Due to Continues (repetitive) and heavy traffic loading.
- Due to Flat terrain type of the area there is high ponding of water in both sides of the embankment during rainy season. Accordingly, during this season the embankment allows moisture infiltration, so that the embankment become rich in

moisture this leads to increase in volume. However, during summer season the water/moisture become evaporate these results to shrink in volume (or the embankment become contract). Therefore, this contraction and expansion of embankment results stress that cause surface crack on the road.

Alligator crack allows moisture infiltration and divided in to a small area which dislodged by continues traffic loading and then develops to further deterioration like potholes and other.

Remedial Measure

- In order to maintain low severity crack, first the crack shall be individually cleaned using a stiff broom followed by wire brushes. The crack shall be cleaned until it is visually open to a depth of at least 5 mm. Where this cannot be achieved by hand, air compressors shall be used. Then fill the crack using seal coat [11].
- For high severity crack removal of the cracked pavement area then digging out and replacing the area of poor subgrade and improving the drainage of that area if necessary. Patch over the repaired sub-grade. Alternatively, place the HMA overlay over the entire pavement surface. This overlay must be strong enough structurally to carry the anticipated loading [35].
- Use impermeable material for sub base and embankment near the ponding condition.

Figure 4.16: Alligator crack

4. 5.2 Block Crack

Block crack is a crack which divided the road pavement in to a number of rectangular pieces, when this crack become wider it is classified as longitudinal and transverse cracking. Block cracks are observed on the top surface of road pavement and through time it is going to sub layer.

Cause of Block crack

- Due to shrinkage and daily temperature cycling (temperature variation).
- Due to permeability of embankment material.
- Due to Continues (repetitive) and heavy traffic loading.
- Due to inability of asphalt binder to contract and expand, this is mainly caused by aging of asphalt binder or inadequate choice of asphalt binder in mix design.
- Due to drying out of mix.

Remedial Measure

- Low severity block cracking may be repaired by a thin wearing course. As the cracking gets more severe, overlays and recycling may be needed. If base problems are found, reclamation or reconstruction may be needed [33].

Figure 4.17: Block Crack

4.5.3 Longitudinal Crack

Longitudinal crack is a crack which is parallel to the road way or centerline of the road. Mostly found at the center or edge of the road. This crack type allows moisture infiltration and roughness.

Cause of Longitudinal Crack

- Most of Longitudinal crack are mainly caused by poor joint construction especially during patching time, this is because joints are the least dense area of the pavement so they a can easily allow moisture.
- Longitudinal cracks are also caused by expansion and widening of block cracks.
- Shrinkage of asphalt layer due daily temperature cycling.
- Cracks propagate from road base moving to the surface.

Remedial Measure

- Joints should be constructed outside the wheel path.
- The possible treatment depends on whether the pavement is structurally sound or unsound. Where the pavement is structurally sound, the cracks should be filled with low viscosity binder or slurry seal or fog seal depending on the width of the cracks. Unsound cracked pavements would need strengthening or rehabilitation treatment [35].

Figure 4.18: Longitudinal Crack

4.5.4 Transverse Crack

Transverse crack is a crack which is perpendicular to the centerline of the road. This crack type allows moisture infiltration and roughness.

Cause of Transverse Crack

- This type of crack is mostly cause by an extension (propagation) of crack from road base moving to the surface of the pavement.
- Due to Shrinkage of asphalt layer due to daily temperature cycling..

Remedial Measures

For Low severity cracks[26]:

- Crack & Joint Seal/Fill
- Partial/Full Depth Slab Repair
- Thin Hot Mix Overlay.

Before placing sealant, all cracks must be thoroughly cleaned to ensure a clean, dry crack channel and to optimize adhesion between the sealant and the pavement surface [38]

Sealing crack prevents [35]:-

- Entry of moisture in to the sub-grade through the cracks.
- Further raveling of the cracked edges.

HMA can however provide years of satisfactory service after developing small cracks if they are kept sealed [11]

For high severity cracks remove and replace the cracked pavement layer with an overlay [24].

Figure 4.19: Transverse Crack

4. 5.5 Edge/ Corner Crack

Causes of Edge/ Corner Crack

- Due to Settlement of road base material
- Due to high permeability of sub base and subgrade material
- Poor drainage system
- Lack of lateral support and daily temperature cycling

Remedial Measures

- Crack fill or thin hot mix overlay and shoulder maintenance [26].
- Provide lateral support like curb stone or concrete material at the edge especially in the area of high temperature.
- Provide proper drainage system.
- As the severity increases, patches and replacement of distress areas may be needed. In all the cases, the excessive moisture should be eliminated and the shoulders rebuild with good [35].

Figure 4.20: Edge/ Corner Crack

4. 5.6 Shoulder Defect

Vegetation near to Shoulder is most common around Gibe mountainous area and this vegetation's causes difficulty to see for the drivers on curve during winter season and sometimes causes accident. Shoulder deformation and scouring are mainly observed on town section.

Causes of Shoulder Defect

- Shrubs and big trees are growing during rainy season.
- Shoulder deformations in town section are mainly caused by heavy vehicles which use the shoulder as parking lane and at location of junctions with the link roads.
- Vegetation's though their root system causes surface crack and allows moisture infiltration to the asphalt layer.
- Shoulder silt up is mainly caused by inadequate drainage system

Remedial Measure

- The area to receive bush clearing shall normally extend at least to the outer edge of the side drains [11].
- Vegetation shall be removed by cutting. The finished cut height shall be between 50 – 75 mm above ground surface. Plants shall not be uprooted as the root structure contributes to erosion resistance [11].

A. Vegetation on shoulder

B. Vegetation on shoulder

C. Silt- up on shoulder

D. Scour on shoulder

E. Shoulder deformation

Figure 4.21: Shoulder Defect

4.5.7 Edge Step

Edge step is elevation difference between the carriage way and shoulder.

Cause of Edge Step

- This defect is mostly cause by design difference of the carriage way and shoulder, the carriageway is constructed by asphalt concrete (AC) and the shoulders are single surface treatment. Due to this the elevation difference is visible.
- Due to overlay and patching activity during maintenance.

Remedial Measures

- Patching or the overlaying activity should be level with the surrounding surface

Figure 4.22: Edge Step

4. 5.8 Edge Damage

Cause of Edge Damage

- Lateral movement of pavement layer due to high traffic load
- Due to inadequate drainage system
- When vehicles cross on town sections or during parking time

Remedial Measures

- Provide proper drainage system
- As the severity increases, patches and replacement of distress areas may be needed. In all the cases, the excessive moisture should be eliminated and the shoulders rebuild with good [35].

Figure 4.23: Edge Damage

4. 5.9 Rutting

Rutting is a permanent longitudinal deformation of the pavement along the wheel path. This type of distress is most common at Gibe Mountainous area mainly from station 165+000 - 168+000 km.

Cause of Rutting

- Lateral movement of pavement layer due to high traffic load.
- Due to shrinkages of asphalt layer because of high temperature.

- Due to the terrain (mountainous) type of the region, heavy trucks exert high traffic load before they reach to stopping sight distance particularly at curves.
- Poor quality of sub base and sub grade material.

Remedial Measure

According to Surajo A.W. 2016 edition the possible remedial measure for rutting is

- Cleaning the affected surface.
- Application of tack coat and covering the ruts.
- Filling the ruts using either a dense graded bituminous mix or open graded pre-mix followed by seal coat
- Compaction by rolling
- Providing a thin bituminous resurfacing course to achieve good riding quality.

The remedial measures may include either total reconstruction of the pavement starting from laying new subgrade or partial reconstruction of the affected portion along the pavement, starting from the subgrade depending upon the severity of the failure [11].

A heavily rutted pavement should be investigated to determine the root cause of failure (e.g. insufficient compaction, subgrade rutting, poor mix design or studded tire wear).Slight ruts (< 1/3 inch deep) can generally be left untreated. Pavement with deeper ruts should be leveled and overlaid [17].

Figure 4.24: Rutting depth 10 cm (High Severity)

4.5.10 Raveling

Raveling is disintegration of a pavement surface through loss of both binder and aggregate. It is mostly observed on patched area.

Cause of Raveling

- The primarily cause for the loss of the binder is the presence of water on the pavement, while vehicular traffic gradually ravels away the aggregate which has been loosened due to binder loss.
- Poor quality of mixture and it mostly exists on patched area.

Remedial Measures

- A raveled pavement can be repaired with a wearing course or an overlay [11].
- For small, localized areas of raveling, remove the raveled pavement and patch [24].
- For large raveled areas indicative of general HMA failure, remove the damaged pavement and overlay [24].

Figure 4.25: Raveling

4.5.11 Patching Defect

Cause of Asphalt Patching Defect

- Due to insufficient amount of binding material (like prime and tack coat).
- Due to inadequate spraying technique of bituminous material so this decreases the bond between the existing and the new patched layer.
- Due to lack of removal of dust from the defect area before spraying bitumen.
- Poor joint construction.
- Materials gradation which is different from the surrounding material.
- Poor compaction of the newly patched area.
- Due to patching over the defect without removing or scarifying the defect.
- Due to poor mixing.
- Due to improper mixing temperature, for example during production of Hot -Mini Mix if the production site is far the temperature will decrease before reaching the maintenance project.
- Using aggregate of having dust and high moisture content during production.

Remedial Measures

- First remove highly defected area or properly clear dusts from the surface before spraying bitumen.
- Material gradation should be similar to the surrounding material.
- Apply proper compaction using roller [11].
- Care should be taken during joint construction.
- Production of asphalt mix should be at maintenance site or very nearby.
- Don't patch over the defect.
- Keep the Mix Temperature as per the specification for hot- mix asphalt.
- Use dry aggregate for mix [11].
- The maintenance should be level with the surrounding pavement.

A. Patching on existing crack

B. Raveling Due To Patching Problem

C. Poor Jointing Of Patching

Figure 4.26: Patching Defect

4.5.12 Potholes

Cause of Potholes

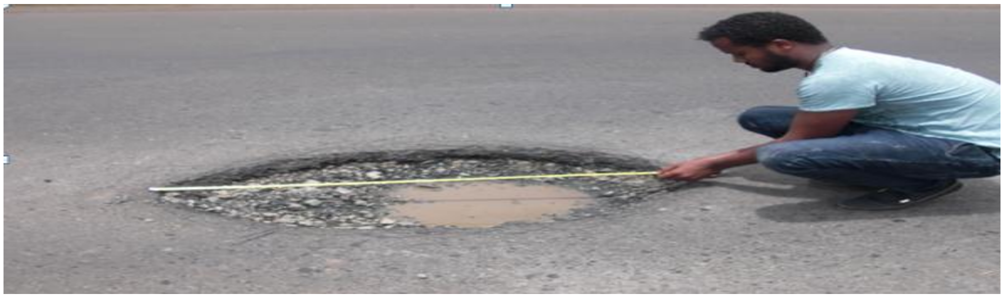
- Due to high deterioration of other defect such as alligator crack, block cracks and patching.
- Due to continues traffic flow over the crack.
- Due to patching problem, this includes patching over the defect area.
- Due to raveling or loose of aggregate from the surface
- Due to poor surface mixture

Remedial Measures

- Remove water and dusts inside the pot hole using air compressor.
- Mark the area to be patched, extending outside the distressed area. The Outline should be rectangular with two sides at right angles to the direction of traffic. Cut the outline of the patch with a saw. Excavate as much pavement as necessary, including granular base and subgrade, to reach firm support. The faces of the excavation should be straight, vertical, and solid. Trim and compact the granular base or subgrade to establish a firm foundation. Apply tack to the vertical edges of the excavation, and a prime or tack coat to the base of the excavation [2].

A. Pothole of low severity

B. Pothole of high severity



C. Pothole high severity

Figure 4.27: Potholes

4.5.13 Base Failure

Cause of Base Failure

- Due to poor quality of sub base and subgrade material.
- Due to high daily temperature.
- Due to the maximum or final stage of rutting.
- Due to Lateral movement of pavement layer due to high traffic load.
- Due to Insufficient thickness of pavement layer.

Remedial Measure

- Cut off) the defect and then change base material.
- Properly compact the sub base and base course material.
- Material should be similar to the surrounding material.
- Cut off) the defect and then change base material.

Figure 4.28: Base Failure

4.5.14 Lane Marking

Cause of Lane Marking

- Due to aging of the paint

Remedial Measure

- Repainting

4.4.15 Depressions

Cause of Depression

ERA Pavement Rehabilitation 2013 manual says that "A Localized depressions caused by settlement of the pavement layers, construction faults and differential movement at structures…" These are easy to see after periods of rain because they take longer to dry than the rest of the road [7]. In the meantime, the field tests indicate that the sub base material has low CBR value in the area of depression.

Remedial Measure

- Depressions should be repaired by removing the affected pavement, then digging out and replacing the area of poor sub base and subgrade. Patch over the repaired sub baser or subgrade [24].
- Use hot mix patch and String line for limit of patch [16].

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

According to the research analysis result that drawn up from road condition survey, laboratory and field tests, and axle load analysis regarding on the cause of pavement distress; the following conclusions and recommendation were drawn.

5.1 Conclusion

- The problem related to cracking is highly related to the permeability of sub base and fill material. Red cinder gravel was widely used material as sub base and fill material from Tefki to Tulu Bolo town; the permeability of red cinder soil is 2.303 x 10^{-2} cm/sec which is not suitable in ponding condition. This permeability property would lead to shrinkage of pavement layer which finally results to pavement crack.
- The traffic load and traffic volume from Wolete Suk to Weliso town increases by 60%, this significant growth of traffic has great contribution for the occurrence of high severity and extent of crack in the road segment.
- Defects in Gibe Mountainous area like rutting and base failure, was not mainly caused by compaction problem of sub base and fill material rather it may be occurred by excessive impact of heavy vehicles on mountainous curve and due to shrinkages of asphalt layer as a result of high temperature.
- 49% of the defect from Wolete Suk to Weliso town has low severity but 67% of the defect has high extent of deterioration.
- Poor patching technique and method by the contractor was the main reason for different types of defect like longitudinal crack, potholes, raveling and edge step defect on the pavement.
- Settlement or pavement depression on the road segment was mainly caused by poor compaction of sub base or in general the compaction requirement of sub base material was below the ERA Standard Technical Specification in the areas of defect.

5.2 Recommendation

- Change the sub base and embankment material (red cinder gravel) in areas of ponding condition and use impermeable material as a replacement.
- During maintenance time patching should be made after properly clearing or removing the defect and material's quality should be as per the standard specification.
- Adequate compaction should be necessary after changing the pavement layers and during patching time.
- Temperature should be maintained as per the specification at a time of using hot-mix asphalt for patching.
- Further investigation should be applied on pavement layers in Gibe mountainous area periodically and seasonally.

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APPENDEX A - LABORATORY AND FIELD TEST RESULT

I. SPECIFIC GRAVITY TEST OF SOIL

Calculation of specific gravity:-

Sample –A

1. Pycnometer Weight (Mp g) =43.96 g
2. (Pycnometer + water) Weight (Ma' g) = 146.66 g
3. Temperature of water at Ma' measured (T' ^{0}C) = 16.7 ^{0}C
4. Density of water at T' ^{0}C (ρ w (T')) was taken from Table A2.

   ρ w (T') = 0.99883 g/ml
5. (Pycnometer + material + water) Weight (Mb g) = 155.20 g
6. Temperature of Mb Measured (T ^{0}C) = 23.5 ^{0}C
7. Density of water at T ^{0}C (ρ w (T)) was taken from Table A2.

   ρ w (T) = 0.99742 g/ml
8. (Pycnometer + water) Weight at T ^{0}C (Ma g)

$$\text{Ma g} = \frac{\rho\, w(T)}{\rho\, w(T')} * (Ma' - Mp) + Mp$$

$$= \frac{0.99742}{0.99883} * (146.66 - 43.96) + 43.96$$

$$\text{Ma g} = 146.52 \text{ g}$$

9. Material Weight (After Drying) (Ms g) = 13.34 g
10. Specific Gravity of Soil at T ^{0}C (G_T) =

$$G_T = \frac{Ms}{(Ms + Ma) - Mb} * \rho\, w(T)$$

$$G_T = \frac{13.34 \text{ g}}{(13.34+146.52) \text{ g} - 155.2 \text{ g}} * 0.099742$$

$$G_T = 2.855$$

11. Temperature correction factor (K) was Taken from table A2 Temperature of 23.5 ^{0}C

K= 0.99921

12. Specific Gravity of soil at 20 ^{0}C (G_{20})

$$G_{20} = G_T * K$$

$$\mathbf{G_{20} = 2.853}$$

Sample – B was determined the same as previous calculation. Then finally make average the specific gravity of the two soil sample.

Table A1: Specific Gravity of Soil

Test Number		**1**	**2**
Sample		**A**	**B**
1. Pycnometer Weight	Mp g	43.96	34.11
2. (Pycnometer + water) Weight	Ma' g	146.66	134.14
3. Temperature of water at Ma' measured	T' ^{0}C	16.7	16.9
4. Density of water at T' ^{0}C	ρ w (T')	0.99883	0.99879
5. (Pycnometer + material + water) Weight	Mb g	155.2	142.14
6. Temperature of Mb Measured	T ^{0}C	23.5	23.5
7. Density of water at T ^{0}C	ρ w (T)	0.99742	0.99742
8. (Pycnometer + water) Weight at T ^{0}C	Ma g	146.52	134
9. Material Weight (After Drying)	Ms g	13.34	12.58
10. Specific Gravity of Soil at T ^{0}C	G_T	2.855	2.826
11. Correction Factor	K	0.99921	0.99921
12. Specific Gravity of Soil at 20 ^{0}C	G_{20}	2.853	2.824
	Average	2.839	

Table A2: Density of Water and Temperature Coefficient [1]

Temperature (°C)	Density (g/mL)[A]	Temperature Coefficient (K)	Temperature (°C)	Density (g/mL)[A]	Temperature Coefficient (K)	Temperature (°C)	Density (g/mL)[A]	Temperature Coefficient (K)	Temperature (°C)	Density (g/mL)[A]	Temperature Coefficient (K)
15.0	0.99910	1.00090	16.0	0.99895	1.00074	17.0	0.99878	1.00057	18.0	0.99860	1.00039
.1	0.99909	1.00088	.1	0.99893	1.00072	.1	0.99876	1.00055	.1	0.99858	1.00037
.2	0.99907	1.00087	.2	0.99891	1.00071	.2	0.99874	1.00054	.2	0.99856	1.00035
.3	0.99906	1.00085	.3	0.99890	1.00069	.3	0.99872	1.00052	.3	0.99854	1.00034
.4	0.99904	1.00084	.4	0.99888	1.00067	.4	0.99871	1.00050	.4	0.99852	1.00032
.5	0.99902	1.00082	.5	0.99886	1.00066	.5	0.99869	1.00048	.5	0.99850	1.00030
.6	0.99901	1.00080	.6	0.99885	1.00064	.6	0.99867	1.00047	.6	0.99848	1.00028
.7	0.99899	1.00079	.7	0.99883	1.00062	.7	0.99865	1.00045	.7	0.99847	1.00026
.8	0.99898	1.00077	.8	0.99881	1.00061	.8	0.99863	1.00043	.8	0.99845	1.00024
.9	0.99896	1.00076	.9	0.99879	1.00059	.9	0.99862	1.00041	.9	0.99843	1.00022
19.0	0.99841	1.00020	20.0	0.99821	1.00000	21.0	0.99799	0.99979	22.0	0.99777	0.99957
.1	0.99839	1.00018	.1	0.99819	0.99998	.1	0.99797	0.99977	.1	0.99775	0.99954
.2	0.99837	1.00016	.2	0.99816	0.99996	.2	0.99795	0.99974	.2	0.99773	0.99952
.3	0.99835	1.00014	.3	0.99814	0.99994	.3	0.99793	0.99972	.3	0.99770	0.99950
.4	0.99833	1.00012	.4	0.99812	0.99992	.4	0.99791	0.99970	.4	0.99768	0.99947
.5	0.99831	1.00010	.5	0.99810	0.99990	.5	0.99789	0.99968	.5	0.99766	0.99945
.6	0.99829	1.00008	.6	0.99808	0.99987	.6	0.99786	0.99966	.6	0.99764	0.99943
.7	0.99827	1.00006	.7	0.99806	0.99985	.7	0.99784	0.99963	.7	0.99761	0.99940
.8	0.99825	1.00004	.8	0.99804	0.99983	.8	0.99782	0.99961	.8	0.99759	0.99938
.9	0.99823	1.00002	.9	0.99802	0.99981	.9	0.99780	0.99959	.9	0.99756	0.99936
23.0	0.99754	0.99933	24.0	0.99730	0.99909	25.0	0.99705	0.99884	26.0	0.99679	0.99858
.1	0.99752	0.99931	.1	0.99727	0.99907	.1	0.99702	0.99881	.1	0.99676	0.99855
.2	0.99749	0.99929	.2	0.99725	0.99904	.2	0.99700	0.99879	.2	0.99673	0.99852
.3	0.99747	0.99926	.3	0.99723	0.99902	.3	0.99697	0.99876	.3	0.99671	0.99850
.4	0.99745	0.99924	.4	0.99720	0.99899	.4	0.99694	0.99874	.4	0.99668	0.99847
.5	0.99742	0.99921	.5	0.99717	0.99897	.5	0.99692	0.99871	.5	0.99665	0.99844
.6	0.99740	0.99919	.6	0.99715	0.99894	.6	0.99689	0.99868	.6	0.99663	0.99842
.7	0.99737	0.99917	.7	0.99712	0.99892	.7	0.99687	0.99866	.7	0.99660	0.99839
.8	0.99735	0.99914	.8	0.99710	0.99889	.8	0.99684	0.99863	.8	0.99657	0.99836
.9	0.99732	0.99912	.9	0.99707	0.99887	.9	0.99681	0.99860	.9	0.99654	0.99833
27.0	0.99652	0.99831	28.0	0.99624	0.99803	29.0	0.99595	0.99774	30.0	0.99565	0.99744
.1	0.99649	0.99828	.1	0.99621	0.99800	.1	0.99592	0.99771	.1	0.99562	0.99741
.2	0.99646	0.99825	.2	0.99618	0.99797	.2	0.99589	0.99768	.2	0.99559	0.99738
.3	0.99643	0.99822	.3	0.99615	0.99794	.3	0.99586	0.99765	.3	0.99556	0.99735
.4	0.99641	0.99820	.4	0.99612	0.99791	.4	0.99583	0.99762	.4	0.99553	0.99732
.5	0.99638	0.99817	.5	0.99609	0.99788	.5	0.99580	0.99759	.5	0.99550	0.99729
.6	0.99635	0.99814	.6	0.99607	0.99785	.6	0.99577	0.99756	.6	0.99547	0.99726
.7	0.99632	0.99811	.7	0.99604	0.99783	.7	0.99574	0.99753	.7	0.99544	0.99723
.8	0.99629	0.99808	.8	0.99601	0.99780	.8	0.99571	0.99750	.8	0.99541	0.99720
.9	0.99627	0.99806	.9	0.99598	0.99777	.9	0.99568	0.99747	.9	0.99539	0.99716

II. Permeability of Test of Fine Grain Soil Using Falling Head Method

[A] Unit Weight Determination

Table A3: Unit Weight of Soil Sample

1. Weight Of Permeameter + Soil Specimen (g)	3824.2
2. Weight Of Permeameter Mold (g)	1986.9
3. Weight Of Specimen (g)	1837.3
4. Diameter Of Specimen (cm)	10
5. Length Of Specimen (cm)	12.7
6. Unit Weight Of Specimen (Air – Dried)	1.842
7. Moisture Content (%)	12.77
8. Dry Unit Weight (g/cm^3)	1.633
9. Specific Gravity	2.839
10. Volume Of Solids (cm^3)	0.575
11. Volume Of Voids (cm^3)	0.425
12. Void Ratio Of Soil Specimen	0.739
13. Cross Sectional Area Of The Specimen Pipe (cm^2)	19.63

For Moisture Content W (%) determination:-

- Weight of can = 40.1 g
- Weight of can plus air dried soil= 225.5 g
- Weight of can plus oven – dried soil (After 24 hour in oven) = 204.5 g

$$W (\%) = \frac{\text{Weight of can plus air – dried soil – weight of can plus oven-dried soil}}{\text{Weight of can plus oven-dried soil - weight of can}} \times 100 \%$$

W (%) = 12.77 %

[B] Permeability Test

Cross sectional area of stand pipe (α) = 19.635 cm^2

Length of specimen (L) = 12.7 cm

Cross section area of soil specimen (A) = 78.54 cm^2

Temperature of water inside the stand pipe = 20.7 ^{0}C

Permeability of soil $K = \frac{2.3\, \alpha\, L}{At} \log \frac{H1}{H2}$

Table A4: Viscosity of Water

T^0C	0	1	2	3	4	5	6	7	8	9
0					1.565	1.516	1.470	1.425	1.383	1.343
10	1.304	1.267	1.233	1.199	1.167	1.136	1.107	1.078	1.078	1.025
20	**1.000**	**0.976**	0.953	0.931	0.909	0.888	0.869	0.849	0.849	0.813
30	0.796	0.779	0.765	0.747	0.732	0.718	0.704	0.690	0.690	0.664

Table 4.1: Permeability of Soil Sample

Trial No.	**Head (H1) (cm)**	**Head (H2) (cm)**	**Time (sec)**	**Permeability (K) (cm/sec)**	**Ratio of, Viscosity at 20.7 ^{0}C / Viscosity at 20 ^{0}C Use Table A4**	**Permeability (K 20) (cm/sec)**
1	132.3	117.3	17	$2.24*10^{-2}$	0.983	$2.202*10^{-2}$
2	117.3	102.3	20.1	$2.16*10^{-2}$	0.983	$2.123*10^{-2}$
3	102.3	82.3	26.2	$2.63*10^{-2}$	0.983	$2.585*10^{-2}$

Average permeability of **Soil** = $\frac{(2.202+2.123+2.585)}{3} * 10^{-2} = 2.303 *10^{-2}$ cm/sec

Average permeability of **Soil = 2.303 $*10^{-2}$ cm/sec**

Table A5: Permeability and Drainage Characteristics [21]

<table>
<tr><th></th><th>10^{2}</th><th>10^{1}</th><th>1</th><th>10^{-1}</th><th>10^{-2}</th><th>10^{-3}</th><th>10^{-4}</th><th>10^{-5}</th><th>10^{-6}</th><th>10^{-7}</th><th>10^{-8}</th><th>10^{-9}</th></tr>
<tr><td>Drainage</td><td colspan="6">GOOD</td><td colspan="3">POOR</td><td colspan="3">Practically Impervious</td></tr>
<tr><td rowspan="2">Soil Type</td><td colspan="2" rowspan="2">Clean gravel</td><td colspan="3">Clean sands, clean sand gravel mixture</td><td colspan="4">Very fine sands, organic and inorganic silts, mixtures of sand silt and clay, glacial till, stratified clay deposits, etc.</td><td colspan="3" rowspan="2">"Impervious" soils, e.g., homogeneous clays below zone of weathering</td></tr>
<tr><td colspan="2"></td><td colspan="5">"Impervious" soils modified by effects of vegetation and weathering</td></tr>
<tr><td rowspan="2">Direct Determination of k</td><td colspan="6">Direct testing of soil in its original position - pumping tests; reliable if properly conducted; considerable experience required</td><td colspan="6"></td></tr>
<tr><td colspan="5">Constant-Head permeability ; little experience required</td><td colspan="7"></td></tr>
<tr><td rowspan="2">Indirect Determination of k</td><td colspan="2"></td><td colspan="3">Falling-Head permeameter; reliable; little experience required</td><td colspan="3">Falling-Head permeameter; unreliable; much experience required</td><td colspan="4">Falling-Head permeameter; fairly reliable; considerable experience necessary</td></tr>
<tr><td colspan="5">Computation from grain - size distribution; applicable only to clean cohesion less sands and gravels</td><td colspan="4"></td><td colspan="3">Computation based on results of consolidation tests; reliable; considerable experience required</td></tr>
</table>

III. DI CONE PENETRATION TEST (DCP)

Table A6: Stations for DCP Test

Station (km)	DCP Test for Defect Type	Direction (RHS/LHS)
66+500	Alligator crack	both side
105+100, 114+100, 126+000, 126+400, 126+600, 127+100	Settlement	both side
163+700, 166+500, 168+160, 168+840, 170+000	Rutting and Base Failure	both side

The number of blows and reading (mm) was obtained from the field test and Corrected reading of a particular DCP test was obtained by deducting the zero reading (30mm) from each field reading.

Table A7: DCP Test Data

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site……………………… **Zero Reading 30mm**

Chainage 66+500 **Date……**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	70	40
2	1	2	85	55
3	1	3	100	70
4	1	4	123	93
5	1	5	137	107
6	1	6	152	122
7	1	7	167	137
8	1	8	178	148
9	1	9	187	157
10	2	11	200	170
11	2	13	212	182
12	2	15	225	195
13	2	17	237	207
14	2	19	250	220
15	2	21	260	230
16	2	23	273	243
17	2	25	285	255
18	2	27	296	266
19	2	29	310	280
20	2	31	324	294
21	2	33	336	306
22	2	35	344	314
23	3	38	354	324
24	4	42	364	334
25	4	46	377	347
26	3	49	388	358
27	3	52	400	370
28	3	55	411	381
29	3	58	424	394
30	3	61	437	407
31	3	64	451	421
32	3	67	464	434
33	3	70	476	446
34	3	73	488	458
35	3	76	498	468
36	4	80	508	478

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
37	3	83	518	488
38	4	87	530	500
39	4	91	540	510
40	5	96	551	521
41	4	100	565	535
42	4	104	575	545
43	4	108	592	562
44	3	111	603	573
45	3	114	614	584
46	3	117	625	595
47	3	120	636	606
48	3	123	647	617
49	3	126	660	630
50	3	129	671	641
51	3	132	682	652
52	3	135	692	662
53	3	138	702	672
54	5	143	715	685
55	4	147	727	697
56	3	150	738	708
57	3	153	748	718
58	4	157	762	732
59	4	161	776	746
60	3	164	786	756
61	3	167	801	771
62	3	170	816	786
63	3	173	830	800
64	3	176	844	814
65	3	179	856	826
66	3	182	872	842
67	2	184	882	852
68	2	186	892	862
69	2	188	904	874
70	2	190	915	885
71	2	192	930	900
72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………… **Zero Reading 30mm**

Chainage 66+500 **Date……**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	78	48
2	1	2	92	62
3	2	4	105	75
4	1	5	115	85
5	2	7	130	100
6	2	9	145	115
7	2	11	160	130
8	1	12	170	140
9	2	14	185	155
10	1	15	195	165
11	1	16	205	175
12	2	18	219	189
13	2	20	233	203
14	2	22	247	217
15	2	24	260	230
16	2	26	272	242
17	2	28	284	254
18	2	30	297	267
19	2	32	313	283
20	2	34	326	296
21	2	36	340	310
22	2	38	355	325
23	2	40	367	337
24	2	42	380	350
25	2	44	390	360
26	2	46	400	370
27	2	48	410	380
28	2	50	422	392
29	2	52	433	403
30	2	54	445	415
31	2	56	455	425
32	2	58	465	435
33	2	60	475	445
34	2	62	485	455
35	2	64	495	465
36	2	66	506	476
37	2	68	518	488
38	2	70	528	498
39	2	72	537	507
40	2	74	544	514
41	3	77	558	528
42	3	80	572	542
43	3	83	585	555
44	3	86	600	570
45	3	89	614	584
46	3	92	630	600
47	2	94	640	610
48	2	96	650	620
49	2	98	660	630
50	2	100	670	640
51	2	102	680	650
52	2	104	690	660
53	3	107	701	671
54	3	110	710	680
55	5	115	720	690
56	5	120	730	700
57	3	123	750	720
58	3	126	765	735
59	3	129	780	750
60	3	132	795	765
61	3	135	810	780
62	3	138	825	795
63	3	141	840	810
64	3	144	855	825
65	3	147	875	845
66	2	149	897	867
67	1	150	911	881
68	1	151	927	897
69	1	152	934	904
70				
71				
72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site……………….. **Zero Reading 30mm**

Chainage 105+100 **Date……**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	69	39
2	1	2	87	57
3	1	3	96	66
4	2	5	111	81
5	2	7	126	96
6	2	9	142	112
7	2	11	157	127
8	2	13	172	142
9	2	15	182	152
10	2	17	197	167
11	2	19	209	179
12	2	21	226	196
13	2	23	244	214
14	2	25	255	225
15	2	27	265	235
16	2	29	275	245
17	1	30	285	255
18	2	32	295	265
19	2	34	305	275
20	2	36	312	282
21	2	38	324	294
22	2	40	334	304
23	2	42	345	315
24	2	44	357	327
25	2	46	367	337
26	2	48	378	348
27	2	50	393	363
28	2	52	406	376
29	2	54	416	386
30	2	56	426	396
31	2	58	434	404
32	3	61	444	414
33	3	64	452	422
34	3	67	462	432
35	3	70	475	445
36	3	73	491	461

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
37	2	75	504	474
38	4	79	531	501
39	2	81	545	515
40	2	83	560	530
41	2	85	575	545
42	2	87	590	560
43	2	89	607	577
44	2	91	625	595
45	2	93	645	615
46	2	95	663	633
47	2	97	681	651
48	2	99	702	672
49	2	101	723	693
50	2	103	740	710
51	2	105	759	729
52	2	107	784	754
53	2	109	809	779
54	2	111	824	794
55	2	113	834	804
56	2	115	846	816
57	2	117	857	827
58	2	119	870	840
59	2	121	895	865
60	2	123	935	905
61				
62				
63				
64				
65				
66				
67				
68				
69				
70				
71				
72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………… **Zero Reading 30mm**

Chainage 105+100 **Date……**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	58	28	37	5	91	491	461
2	1	2	70	40	38	4	95	501	471
3	1	3	81	51	39	4	99	511	481
4	1	4	92	62	40	4	103	525	495
5	1	5	102	72	41	5	108	535	505
6	2	7	118	88	42	3	111	546	516
7	2	9	133	103	43	3	114	558	528
8	2	11	148	118	44	3	117	571	541
9	1	12	158	128	45	3	120	585	555
10	2	14	177	147	46	3	123	599	569
11	2	16	192	162	47	3	126	610	580
12	2	18	204	174	48	3	129	623	593
13	2	20	215	185	49	3	132	636	606
14	2	22	226	196	50	3	135	647	617
15	2	24	236	206	51	3	138	667	637
16	2	26	246	216	52	2	140	677	647
17	2	28	256	226	53	2	142	688	658
18	4	32	268	238	54	2	144	699	669
19	3	35	280	250	55	2	146	710	680
20	3	38	292	262	56	2	148	724	694
21	3	41	304	274	57	2	150	736	706
22	3	44	314	284	58	2	152	750	720
23	3	47	324	294	59	2	154	766	736
24	3	50	338	308	60	2	156	784	754
25	3	53	349	319	61	2	158	800	770
26	3	56	359	329	62	2	160	813	783
27	3	59	372	342	63	2	162	826	796
28	2	61	383	353	64	2	164	842	812
29	2	63	395	365	65	2	166	856	826
30	2	65	407	377	66	2	168	872	842
31	2	67	420	390	67	2	170	885	855
32	2	69	430	400	68	2	172	897	867
33	3	72	444	414	69	2	174	907	877
34	4	76	456	426	70	2	176	917	887
35	5	81	467	437	71	2	178	926	896
36	5	86	479	449	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………….. **Zero Reading 30mm**

Chainage 114+100 **Date……**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	2	2	60	30
2	1	3	70	40
3	1	4	80	50
4	2	6	93	63
5	2	8	108	78
6	2	10	126	96
7	2	12	138	108
8	2	14	148	118
9	2	16	160	130
10	2	18	170	140
11	2	20	180	150
12	1	21	195	165
13	1	22	205	175
14	1	23	215	185
15	1	24	226	196
16	2	26	236	206
17	1	27	246	216
18	2	29	257	227
19	4	33	271	241
20	4	37	283	253
21	4	41	296	266
22	4	45	311	281
23	3	48	322	292
24	3	51	333	303
25	3	54	345	315
26	3	57	358	328
27	3	60	372	342
28	2	62	382	352
29	2	64	393	363
30	2	66	404	374
31	2	68	414	384
32	2	70	424	394
33	3	73	434	404
34	4	77	444	414
35	4	81	456	426
36	4	85	467	437
37	5	90	477	447
38	5	95	488	458
39	4	99	500	470
40	4	103	511	481
41	4	107	524	494
42	4	111	536	506
43	3	114	547	517
44	3	117	558	528
45	3	120	572	542
46	3	123	586	556
47	3	126	602	572
48	2	128	612	582
49	3	131	626	596
50	2	133	635	605
51	3	136	645	615
52	3	139	656	626
53	3	142	666	636
54	3	145	680	650
55	3	148	692	662
56	3	151	704	674
57	3	154	716	686
58	3	157	731	701
59	3	160	747	717
60	2	162	758	728
61	2	164	772	742
62	2	166	786	756
63	2	168	801	771
64	2	170	816	786
65	2	172	830	800
66	2	174	842	812
67	2	176	854	824
68	2	178	866	836
69	2	180	877	847
70	2	182	887	857
71	2	184	897	867
72	2	186	908	878
73	2	188	920	890
74	2	190	933	903

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………… **Zero Reading 30mm**

Chainage 114+100 **Date………**

Position LHS

No:	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	57	27	37	2	75	522	492
2	1	2	65	35	38	2	77	539	509
3	1	3	74	44	39	2	79	555	525
4	2	5	91	61	40	2	81	571	541
5	2	7	105	75	41	2	83	589	559
6	2	9	115	85	42	2	85	606	576
7	1	10	125	95	43	1	86	617	587
8	1	11	139	109	44	1	87	629	599
9	1	12	146	116	45	1	88	642	612
10	2	14	160	130	46	1	89	657	627
11	2	16	171	141	47	1	90	681	651
12	2	18	184	154	48	1	91	697	667
13	2	20	199	169	49	1	92	712	682
14	2	22	210	180	50	1	93	726	696
15	2	24	220	190	51	1	94	747	717
16	2	26	230	200	52	1	95	785	755
17	3	29	244	214	53	1	96	807	777
18	3	32	259	229	54	1	97	823	793
19	3	35	275	245	55	1	98	837	807
20	3	38	292	262	56	1	99	853	823
21	3	41	312	282	57	1	100	874	844
22	3	44	330	300	58	1	101	892	862
23	3	47	353	323	59	1	102	910	880
24	2	49	367	337	60	1	103	923	893
25	2	51	377	347	61	1	104	939	909
26	2	53	389	359	62				
27	2	55	399	369	63				
28	2	57	410	380	64				
29	2	59	420	390	65				
30	2	61	430	400	66				
31	2	63	442	412	67				
32	2	65	454	424	68				
33	2	67	468	438	69				
34	2	69	482	452	70				
35	2	71	495	465	71				
36	2	73	507	477	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………. **Zero Reading 30mm**

Chainage 126 +000 **Date….**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	63	33	37	1	63	551	521
2	1	2	74	44	38	2	65	569	539
3	2	4	94	64	39	2	67	583	553
4	1	5	105	75	40	2	69	596	566
5	1	6	115	85	41	2	71	610	580
6	2	8	131	101	42	2	73	626	596
7	2	10	148	118	43	2	75	643	613
8	1	11	159	129	44	2	77	660	630
9	1	12	169	139	45	2	79	680	650
10	1	13	180	150	46	1	80	691	661
11	2	15	195	165	47	1	81	703	673
12	2	17	210	180	48	1	82	714	684
13	2	19	228	198	49	1	83	725	695
14	1	20	239	209	50	1	84	740	710
15	1	21	245	215	51	1	85	757	727
16	2	23	265	235	52	1	86	790	760
17	2	25	277	247	53	1	87	833	803
18	2	27	290	260	54	1	88	887	857
19	2	29	305	275	55	1	89	950	920
20	2	31	316	286	56				
21	2	33	328	298	57				
22	2	35	342	312	58				
23	2	37	354	324	59				
24	2	39	367	337	60				
25	2	41	380	350	61				
26	2	43	392	362	62				
27	2	45	403	373	63				
28	2	47	417	387	64				
29	2	49	433	403	65				
30	2	51	447	417	66				
31	2	53	463	433	67				
32	2	55	480	450	68				
33	2	57	496	466	69				
34	2	59	511	481	70				
35	2	61	530	500	71				
36	1	62	541	511	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………… **Zero Reading 30mm**

Chainage 126 +000 **Date…….**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	103	73	37	2	58	658	628
2	1	2	113	83	38	2	60	675	645
3	1	3	124	94	39	2	62	699	669
4	1	4	132	102	40	1	63	710	680
5	2	6	146	116	41	1	64	722	692
6	2	8	161	131	42	1	65	735	705
7	2	10	179	149	43	1	66	748	718
8	2	12	195	165	44	1	67	763	733
9	2	14	217	187	45	1	68	775	745
10	2	16	236	206	46	1	69	790	760
11	2	18	252	222	47	1	70	802	772
12	2	20	277	247	48	1	71	823	793
13	1	21	290	260	49	1	72	851	821
14	1	22	300	270	50	1	73	882	852
15	2	24	312	282	51	1	74	920	890
16	2	26	330	300	52	1	75	942	912
17	2	28	350	320	53				
18	1	29	360	330	54				
19	1	30	371	341	55				
20	1	31	382	352	56				
21	1	32	394	364	57				
22	1	33	411	381	58				
23	2	35	437	407	59				
24	1	36	445	415	60				
25	2	38	460	430	61				
26	1	39	474	444	62				
27	1	40	502	472	63				
28	1	41	533	503	64				
29	1	42	552	522	65				
30	2	44	565	535	66				
31	2	46	575	545	67				
32	2	48	585	555	68				
33	2	50	597	567	69				
34	2	52	612	582	70				
35	2	54	627	597	71				
36	2	56	643	613	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………… **Zero Reading 30mm**

Chainage 126 +400 **Date……**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	65	35	37	3	72	538	508
2	1	2	85	55	38	3	75	550	520
3	1	3	100	70	39	3	78	562	532
4	1	4	119	89	40	2	80	573	543
5	2	6	137	107	41	2	82	583	553
6	1	7	150	120	42	3	85	597	567
7	1	8	160	130	43	2	87	609	579
8	1	9	171	141	44	2	89	621	591
9	1	10	183	153	45	2	91	632	602
10	1	11	194	164	46	2	93	644	614
11	1	12	204	174	47	2	95	657	627
12	1	13	214	184	48	2	97	674	644
13	1	14	225	195	49	2	99	689	659
14	2	16	238	208	50	2	101	705	675
15	2	18	254	224	51	1	102	715	685
16	2	20	265	235	52	2	104	731	701
17	2	22	278	248	53	1	105	741	711
18	2	24	291	261	54	2	107	757	727
19	2	26	303	273	55	1	108	767	737
20	2	28	317	287	56	1	109	777	747
21	2	30	330	300	57	1	110	787	757
22	2	32	341	311	58	1	111	801	771
23	2	34	355	325	59	1	112	814	784
24	2	36	374	344	60	1	113	826	796
25	2	38	391	361	61	1	114	840	810
26	2	40	408	378	62	1	115	855	825
27	2	42	422	392	63	1	116	871	841
28	3	45	435	405	64	1	117	886	856
29	3	48	445	415	65	1	118	901	871
30	3	51	457	427	66	1	119	917	887
31	3	54	468	438	67	1	120	936	906
32	3	57	478	448	68	1	121	953	923
33	3	60	490	460	69				
34	3	63	500	470	70				
35	3	66	514	484	71				
36	3	69	525	495	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site……………………… **Zero Reading 30mm**

Chainage 126 +400 **Date…**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	62	32	37	2	45	571	541
2	1	2	78	48	38	2	47	586	556
3	1	3	92	62	39	1	48	596	566
4	1	4	102	72	40	2	50	615	585
5	2	6	123	93	41	1	51	625	595
6	1	7	137	107	42	1	52	637	607
7	1	8	147	117	43	2	54	660	630
8	1	9	158	128	44	1	55	672	642
9	1	10	168	138	45	1	56	685	655
10	1	11	179	149	46	1	57	700	670
11	1	12	189	159	47	1	58	720	690
12	1	13	204	174	48	1	59	742	712
13	1	14	214	184	49	1	60	769	739
14	1	15	225	195	50	1	61	796	766
15	1	16	235	205	51	1	62	817	787
16	2	18	255	225	52	1	63	840	810
17	2	20	267	237	53	1	64	862	832
18	1	21	280	250	54	1	65	893	863
19	1	22	295	265	55	1	66	937	907
20	1	23	305	275	56				
21	2	25	323	293	57				
22	2	27	341	311	58				
23	2	29	361	331	59				
24	2	31	392	362	60				
25	1	32	414	384	61				
26	1	33	434	404	62				
27	1	34	444	414	63				
28	1	35	456	426	64				
29	1	36	468	438	65				
30	1	37	478	448	66				
31	1	38	490	460	67				
32	1	39	502	472	68				
33	1	40	517	487	69				
34	1	41	535	505	70				
35	1	42	547	517	71				
36	1	43	556	526	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………… **Zero Reading 30mm**

Chainage 126 +600 **Date…**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	75	45
2	1	2	85	55
3	1	3	95	65
4	1	4	105	75
5	1	5	115	85
6	1	6	127	97
7	1	7	140	110
8	1	8	150	120
9	1	9	165	135
10	1	10	181	151
11	1	11	196	166
12	1	12	209	179
13	1	13	223	193
14	1	14	237	207
15	1	15	247	217
16	1	16	256	226
17	1	17	262	232
18	2	19	272	242
19	2	21	286	256
20	1	22	295	265
21	1	23	305	275
22	1	24	319	289
23	1	25	334	304
24	1	26	350	320
25	1	27	366	336
26	1	28	382	352
27	1	29	394	364
28	1	30	405	375
29	1	31	415	385
30	1	32	422	392
31	1	33	431	401
32	1	34	443	413
33	1	35	459	429
34	1	36	480	450
35	1	37	500	470
36	1	38	514	484

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
37	1	39	529	499
38	1	40	542	512
39	1	41	556	526
40	1	42	569	539
41	1	43	583	553
42	1	44	600	570
43	1	45	616	586
44	1	46	633	603
45	1	47	655	625
46	1	48	680	650
47	1	49	704	674
48	1	50	725	695
49	1	51	745	715
50	1	52	765	735
51	1	53	786	756
52	1	54	803	773
53	1	55	815	785
54	1	56	827	797
55	1	57	847	817
56	1	58	875	845
57	1	59	914	884
58	1	60	942	912
59				
60				
61				
62				
63				
64				
65				
66				
67				
68				
69				
70				
71				
72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………… **Zero Reading 30mm**

Chainage 126 +600 **Date………**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	73	43	37	2	59	519	489
2	1	2	92	62	38	2	61	534	504
3	1	3	105	75	39	2	63	549	519
4	1	4	122	92	40	2	65	569	539
5	1	5	131	101	41	1	66	579	549
6	1	6	140	110	42	1	67	592	562
7	2	8	153	123	43	1	68	601	571
8	1	9	162	132	44	2	70	616	586
9	2	11	180	150	45	2	72	630	600
10	2	13	195	165	46	2	74	643	613
11	2	15	205	175	47	2	76	655	625
12	1	16	215	185	48	2	78	668	638
13	1	17	224	194	49	2	80	680	650
14	2	19	234	204	50	2	82	694	664
15	2	21	244	214	51	2	84	703	673
16	2	23	255	225	52	2	86	714	684
17	2	25	267	237	53	2	88	724	694
18	2	27	278	248	54	2	90	737	707
19	2	29	290	260	55	2	92	753	723
20	2	31	301	271	56	2	94	772	742
21	2	33	316	286	57	1	95	783	753
22	2	35	334	304	58	1	96	793	763
23	1	36	345	315	59	1	97	805	775
24	1	37	355	325	60	1	98	816	786
25	1	38	363	333	61	1	99	831	801
26	2	40	375	345	62	1	100	850	820
27	2	42	387	357	63	1	101	871	841
28	2	44	401	371	64	1	102	892	862
29	2	46	416	386	65	1	103	913	883
30	1	47	429	399	66	1	104	933	903
31	1	48	440	410	67	1	105	947	917
32	1	49	448	418	68	1	106	955	925
33	2	51	462	432	69				
34	2	53	478	448	70				
35	2	55	490	460	71				
36	2	57	504	474	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………… **Zero Reading 30mm**

Chainage 127+100 **Date……**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	76	46
2	1	2	86	56
3	1	3	100	70
4	1	4	110	80
5	1	5	126	96
6	1	6	137	107
7	1	7	151	121
8	1	8	165	135
9	1	9	180	150
10	1	10	198	168
11	1	11	209	179
12	1	12	220	190
13	1	13	230	200
14	2	15	250	220
15	1	16	260	230
16	1	17	271	241
17	1	18	287	257
18	1	19	303	273
19	1	20	315	285
20	1	21	328	298
21	1	22	345	315
22	1	23	361	331
23	2	25	376	346
24	2	27	387	357
25	2	29	402	372
26	1	30	414	384
27	1	31	426	396
28	1	32	437	407
29	1	33	452	422
30	1	34	470	440
31	1	35	486	456
32	1	36	504	474
33	1	37	517	487
34	1	38	532	502
35	1	39	546	516
36	1	40	559	529

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
37	1	41	576	546
38	1	42	595	565
39	1	43	615	585
40	1	44	635	605
41	1	45	654	624
42	1	46	664	634
43	1	47	675	645
44	1	48	690	660
45	1	49	705	675
46	1	50	724	694
47	1	51	742	712
48	1	52	754	724
49	1	53	765	735
50	2	55	784	754
51	1	56	795	765
52	1	57	806	776
53	1	58	817	787
54	1	59	827	797
55	1	60	836	806
56	2	62	855	825
57	2	64	865	835
58	1	65	875	845
59	1	66	885	855
60	1	67	896	866
61	1	68	907	877
62	1	69	919	889
63	1	70	932	902
64	1	71	947	917
65				
66				
67				
68				
69				
70				
71				
72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………………. **Zero Reading 30mm**

Chainage 127+100 **Date……**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	70	40	37	1	52	560	530
2	1	2	82	52	38	1	53	570	540
3	1	3	98	68	39	1	54	583	553
4	2	5	125	95	40	1	55	596	566
5	1	6	140	110	41	1	56	610	580
6	1	7	154	124	42	1	57	627	597
7	1	8	168	138	43	1	58	638	608
8	1	9	178	148	44	2	60	655	625
9	1	10	193	163	45	2	62	667	637
10	1	11	204	174	46	2	64	683	653
11	1	12	214	184	47	2	66	698	668
12	1	13	224	194	48	2	68	715	685
13	1	14	236	206	49	2	70	731	701
14	1	15	247	217	50	2	72	745	715
15	1	16	258	228	51	2	74	764	734
16	1	17	271	241	52	1	75	775	745
17	1	18	281	251	53	2	77	796	766
18	1	19	292	262	54	1	78	807	777
19	2	21	308	278	55	1	79	817	787
20	2	23	326	296	56	2	81	837	807
21	1	24	337	307	57	1	82	848	818
22	2	26	349	319	58	1	83	861	831
23	2	28	361	331	59	1	84	872	842
24	2	30	373	343	60	1	85	888	858
25	2	32	388	358	61	1	86	906	876
26	1	33	398	368	62	1	87	926	896
27	2	35	417	387	63	1	88	953	923
28	1	36	426	396	64				
29	1	37	436	406	65				
30	2	39	452	422	66				
31	2	41	466	436	67				
32	2	43	480	450	68				
33	2	45	496	466	69				
34	2	47	512	482	70				
35	2	49	530	500	71				
36	2	51	548	518	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………… **Zero Reading 30mm**

Chainage 162+700 **Date……**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	61	31
2	1	2	71	41
3	3	5	82	52
4	2	7	97	67
5	2	9	110	80
6	2	11	121	91
7	2	13	130	100
8	2	15	141	111
9	2	17	155	125
10	1	18	166	136
11	2	20	176	146
12	5	25	186	156
13	2	27	209	179
14	2	29	221	191
15	1	30	237	207
16	1	31	248	218
17	2	33	266	236
18	2	35	280	250
19	4	39	294	264
20	2	41	305	275
21	2	43	320	290
22	2	45	333	303
23	2	47	348	318
24	2	49	362	332
25	2	51	374	344
26	2	53	385	355
27	2	55	394	364
28	3	58	410	380
29	2	60	426	396
30	2	62	436	406
31	2	64	456	426
32	1	65	467	437
33	1	66	482	452
34	1	67	496	466
35	1	68	508	478
36	2	70	520	490

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
37	1	71	531	501
38	4	75	542	512
39	3	78	555	525
40	2	80	565	535
41	3	83	575	545
42	3	86	585	555
43	3	89	595	565
44	3	92	607	577
45	3	95	618	588
46	3	98	630	600
47	2	100	640	610
48	4	104	650	620
49	4	108	660	630
50	4	112	670	640
51	5	117	682	652
52	5	122	693	663
53	4	126	705	675
54	3	129	716	686
55	3	132	730	700
56	3	135	745	715
57	3	138	760	730
58	2	140	771	741
59	2	142	784	754
60	2	144	795	765
61	2	146	808	778
62	2	148	820	790
63	2	150	835	805
64	2	152	845	815
65	2	154	855	825
66	2	156	868	838
67	1	157	878	848
68	2	159	890	860
69	3	162	900	870
70	2	164	910	880
71	2	166	920	890
72	3	169	934	904
73	2	171	946	916

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………… **Zero Reading 30mm**

Chainage 163+700 **Date……**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	65	35	37	2	102	565	535
2	6	7	75	45	38	2	104	575	545
3	5	12	85	55	39	2	106	590	560
4	4	16	100	70	40	2	108	609	579
5	2	18	112	82	41	1	109	619	589
6	2	20	122	92	42	1	110	630	600
7	2	22	132	102	43	1	111	645	615
8	2	24	145	115	44	1	112	656	626
9	3	27	160	130	45	1	113	666	636
10	4	31	173	143	46	1	114	676	646
11	4	35	190	160	47	1	115	690	660
12	4	39	200	170	48	1	116	706	676
13	4	43	212	182	49	1	117	716	686
14	4	47	222	192	50	1	118	726	696
15	3	50	244	214	51	1	119	738	708
16	2	52	266	236	52	1	120	752	722
17	2	54	292	262	53	1	121	764	734
18	1	55	310	280	54	1	122	775	745
19	2	57	320	290	55	1	123	785	755
20	2	59	330	300	56	1	124	795	765
21	5	64	343	313	57	1	125	805	775
22	2	66	354	324	58	1	126	815	785
23	2	68	372	342	59	1	127	823	793
24	2	70	390	360	60	1	128	835	805
25	2	72	410	380	61	1	129	843	813
26	2	74	425	395	62	1	130	853	823
27	3	77	440	410	63	1	131	865	835
28	3	80	455	425	64	1	132	886	856
29	2	82	467	437	65	1	133	905	875
30	2	84	480	450	66	1	134	915	885
31	2	86	494	464	67	1	135	932	902
32	3	89	505	475	68	1	136	950	920
33	3	92	515	485	69				
34	3	95	525	495	70				
35	3	98	540	510	71				
36	2	100	555	525	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site……… **Zero Reading 30mm**

Chainage 166+000 **Date…….**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	60	30
2	3	4	75	45
3	3	7	87	57
4	2	9	102	72
5	2	11	115	85
6	2	13	132	102
7	3	16	145	115
8	3	19	155	125
9	4	23	165	135
10	4	27	175	145
11	2	29	195	165
12	1	30	207	177
13	1	31	216	186
14	1	32	224	194
15	1	33	230	200
16	2	35	243	213
17	2	37	255	225
18	2	39	267	237
19	2	41	279	249
20	2	43	290	260
21	2	45	300	270
22	2	47	310	280
23	3	50	324	294
24	3	53	335	305
25	3	56	349	319
26	3	59	362	332
27	3	62	375	345
28	3	65	385	355
29	3	68	395	365
30	3	71	410	380
31	3	74	429	399
32	3	77	451	421
33	2	79	467	437
34	2	81	485	455
35	2	83	500	470
36	2	85	512	482

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
37	2	87	530	500
38	2	89	544	514
39	2	91	554	524
40	3	94	565	535
41	3	97	578	548
42	2	99	586	556
43	2	101	599	569
44	2	103	610	580
45	3	106	621	591
46	3	109	632	602
47	6	115	643	613
48	7	122	653	623
49	8	130	664	634
50	7	137	675	645
51	6	143	690	660
52	6	149	710	680
53	6	155	720	690
54	5	160	740	710
55	3	163	760	730
56	4	167	775	745
57	3	170	795	765
58	2	172	805	775
59	2	174	817	787
60	2	176	825	795
61	3	179	835	805
62	4	183	846	816
63	4	187	855	825
64	7	194	867	837
65	7	201	882	852
66	4	205	894	864
67	4	209	904	874
68	5	214	914	884

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………… **Zero Reading 30mm**

Chainage 166+500 **Date………**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	100	70	37	1	85	594	564
2	1	2	112	82	38	2	87	612	582
3	1	3	121	91	39	1	88	622	592
4	1	4	134	104	40	2	90	640	610
5	1	5	147	117	41	1	91	651	621
6	1	6	162	132	42	2	93	661	631
7	1	7	176	146	43	3	96	671	641
8	1	8	189	159	44	3	99	690	660
9	1	9	207	177	45	2	101	705	675
10	1	10	227	197	46	1	102	715	685
11	1	11	246	216	47	1	103	730	700
12	1	12	259	229	48	1	104	743	713
13	1	13	285	255	49	2	106	762	732
14	1	14	309	279	50	2	108	778	748
15	1	15	324	294	51	1	109	785	755
16	1	16	334	304	52	2	111	800	770
17	2	18	350	320	53	2	113	819	789
18	2	20	372	342	54	1	114	830	800
19	1	21	384	354	55	1	115	842	812
20	1	22	397	367	56	1	116	856	826
21	1	23	405	375	57	2	118	880	850
22	1	24	411	381	58	1	119	890	860
23	4	28	420	390	59	2	121	905	875
24	5	33	430	400	60	2	123	917	887
25	3	36	440	410	61	2	125	925	895
26	5	41	450	420	62	2	127	937	907
27	8	49	462	432	63	2	129	950	920
28	7	56	472	442	64				
29	5	61	487	457	65				
30	5	66	517	487	66				
31	6	72	530	500	67				
32	2	74	545	515	68				
33	2	76	555	525	69				
34	5	81	566	536	70				
35	2	83	575	545	71				
36	1	84	585	555	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………… **Zero Reading 30mm**

Chainage 168+160 **Date………**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	2	2	63	33
2	2	4	75	45
3	3	7	90	60
4	2	9	101	71
5	3	12	115	85
6	3	15	126	96
7	5	20	140	110
8	3	23	151	121
9	3	26	161	131
10	5	31	172	142
11	5	36	189	159
12	4	40	202	172
13	3	43	213	183
14	3	46	230	200
15	3	49	244	214
16	3	52	254	224
17	4	56	265	235
18	4	60	275	245
19	4	64	288	258
20	3	67	302	272
21	3	70	312	282
22	3	73	322	292
23	4	77	336	306
24	4	81	350	320
25	4	85	363	333
26	4	89	375	345
27	4	93	385	355
28	5	98	396	366
29	5	103	408	378
30	4	107	420	390
31	4	111	433	403
32	4	115	443	413
33	3	118	454	424
34	4	122	465	435
35	4	126	483	453
36	2	128	493	463
37	2	130	503	473
38	2	132	513	483

No.	No. of Blows	Total Blows	Readin g (mm)	Corrected Reading (mm)
39	2	134	524	494
40	2	136	534	504
41	2	138	545	515
42	3	141	558	528
43	3	144	567	537
44	3	147	580	550
45	3	150	593	563
46	3	153	606	576
47	3	156	621	591
48	2	158	631	601
49	2	160	641	611
50	3	163	651	621
51	6	169	662	632
52	8	177	673	643
53	9	186	684	654
54	5	191	696	666
55	3	194	707	677
56	3	197	720	690
57	4	201	731	701
58	4	205	742	712
59	4	209	754	724
60	5	214	765	735
61	4	218	775	745
62	4	222	787	757
63	3	225	799	769
64	2	227	809	779
65	3	230	821	791
66	4	234	832	802
67	4	238	842	812
68	3	241	853	823
69	3	244	866	836
70	3	247	883	853
71	3	250	894	864
72	3	253	905	875
73	4	257	915	885
74	5	262	925	895
75	4	266	935	905
76	4	270	945	915

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………………………. **Zero Reading 30mm**

Chainage 168+160 **Date……**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	2	2	64	34
2	8	10	80	50
3	4	14	92	62
4	3	17	104	74
5	3	20	118	88
6	3	23	130	100
7	2	25	140	110
8	3	28	153	123
9	2	30	165	135
10	2	32	178	148
11	2	34	192	162
12	2	36	203	173
13	2	38	217	187
14	2	40	232	202
15	2	42	248	218
16	2	44	266	236
17	2	46	282	252
18	2	48	300	270
19	2	50	317	287
20	2	52	334	304
21	2	54	346	316
22	2	56	355	325
23	2	58	367	337
24	2	60	383	353
25	2	62	394	364
26	5	67	405	375
27	5	72	420	390
28	5	77	435	405
29	5	82	450	420
30	4	86	462	432
31	3	89	478	448
32	3	92	500	470
33	2	94	513	483
34	2	96	525	495
35	2	98	539	509
36	2	100	550	520

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
37	7	107	563	533
38	4	111	573	543
39	3	114	583	553
40	4	118	597	567
41	4	122	610	580
42	3	125	624	594
43	3	128	635	605
44	3	131	650	620
45	2	133	660	630
46	3	136	672	642
47	3	139	685	655
48	3	142	700	670
49	3	145	715	685
50	3	148	726	696
51	3	151	735	705
52	3	154	745	715
53	4	158	757	727
54	4	162	763	733
55	4	166	773	743
56	4	170	784	754
57	4	174	805	775
58	2	176	814	784
59	3	179	830	800
60	2	181	840	810
61	2	183	851	821
62	2	185	864	834
63	2	187	880	850
64	2	189	890	860
65	3	192	904	874
66	2	194	914	884
67	3	197	930	900
68	2	199	942	912
69	2	201	954	924
70				
71				
72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………… **Zero Reading 30mm**

Chainage 168+840 **Date……..**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	79	49	37	3	115	570	540
2	1	2	90	60	38	3	118	583	553
3	1	3	104	74	39	3	121	596	566
4	1	4	114	84	40	4	125	610	580
5	1	5	123	93	41	7	132	621	591
6	1	6	134	104	42	10	142	634	604
7	1	7	144	114	43	12	154	643	613
8	2	9	160	130	44	10	164	655	625
9	2	11	171	141	45	8	172	670	640
10	2	13	185	155	46	8	180	682	652
11	2	15	200	170	47	8	188	700	670
12	2	17	215	185	48	5	193	711	681
13	2	19	233	203	49	5	198	729	699
14	2	21	248	218	50	4	202	740	710
15	2	23	258	228	51	4	206	760	730
16	6	29	270	240	52	3	209	770	740
17	8	37	283	253	53	5	214	783	753
18	4	41	297	267	54	6	220	795	765
19	4	45	312	282	55	4	224	807	777
20	4	49	327	297	56	3	227	816	786
21	5	54	340	310	57	3	230	826	796
22	3	57	357	327	58	3	233	839	809
23	3	60	378	348	59	3	236	851	821
24	2	62	393	363	60	3	239	863	833
25	3	65	408	378	61	3	242	873	843
26	4	69	425	395	62	3	245	886	856
27	4	73	443	413	63	3	248	904	874
28	5	78	460	430	64	3	251	920	890
29	4	82	474	444	65	3	254	933	903
30	4	86	486	456	66	3	257	945	915
31	4	90	497	467	67				
32	4	94	507	477	68				
33	4	98	519	489	69				
34	5	103	530	500	70				
35	5	108	543	513	71				
36	4	112	557	527	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………… **Zero Reading 30mm**

Chainage 168+840 **Date……**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	2	2	53	23
2	6	8	64	34
3	6	14	83	53
4	8	22	95	65
5	6	28	105	75
6	11	39	115	85
7	7	46	128	98
8	8	54	140	110
9	6	60	152	122
10	4	64	162	132
11	7	71	173	143
12	4	75	183	153
13	7	82	198	168
14	4	86	213	183
15	2	88	223	193
16	2	90	241	211
17	3	93	254	224
18	3	96	265	235
19	2	98	278	248
20	2	100	291	261
21	2	102	305	275
22	2	104	320	290
23	2	106	330	300
24	2	108	341	311
25	2	110	353	323
26	2	112	365	335
27	2	114	380	350
28	2	116	400	370
29	2	118	412	382
30	3	121	425	395
31	3	124	435	405
32	6	130	450	420
33	5	135	465	435
34	3	138	481	451
35	3	141	492	462
36	4	145	504	474

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
37	5	150	524	494
38	3	153	537	507
39	3	156	560	530
40	3	159	580	550
41	2	161	592	562
42	2	163	602	572
43	2	165	612	582
44	2	167	622	592
45	1	168	632	602
46	2	170	642	612
47	3	173	657	627
48	3	176	671	641
49	3	179	682	652
50	4	183	694	664
51	2	185	704	674
52	2	187	714	684
53	3	190	722	692
54	3	193	733	703
55	3	196	747	717
56	3	199	760	730
57	3	202	774	744
58	4	206	785	755
59	3	209	795	765
60	3	212	806	776
61	3	215	820	790
62	3	218	837	807
63	3	221	858	828
64	2	223	870	840
65	2	225	882	852
66	2	227	905	875
67	1	228	917	887
68	1	229	935	905
69	1	230	943	913

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site…………………….. **Zero Reading 30mm**

Chainage 170+000 **Date………**

Position LHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	82	52	37	3	71	579	549
2	1	2	95	65	38	3	74	592	562
3	1	3	104	74	39	3	77	607	577
4	2	5	116	86	40	3	80	622	592
5	1	6	128	98	41	3	83	638	608
6	1	7	145	115	42	3	86	658	628
7	1	8	162	132	43	3	89	675	645
8	1	9	180	150	44	2	91	690	660
9	1	10	198	168	45	2	93	707	677
10	1	11	215	185	46	2	95	724	694
11	1	12	231	201	47	2	97	743	713
12	1	13	252	222	48	2	99	763	733
13	1	14	267	237	49	2	101	784	754
14	1	15	281	251	50	2	103	803	773
15	1	16	297	267	51	2	105	830	800
16	1	17	310	280	52	2	107	847	817
17	1	18	320	290	53	2	109	863	833
18	1	19	330	300	54	2	111	897	867
19	2	21	340	310	55	2	113	920	890
20	2	23	353	323	56	2	115	934	904
21	2	25	364	334	57	2	117	940	910
22	2	27	375	345	58				
23	2	29	385	355	59				
24	3	32	402	372	60				
25	3	35	413	383	61				
26	3	38	423	393	62				
27	3	41	435	405	63				
28	3	44	454	424	64				
29	3	47	473	443	65				
30	3	50	492	462	66				
31	3	53	508	478	67				
32	3	56	523	493	68				
33	3	59	532	502	69				
34	3	62	543	513	70				
35	3	65	556	526	71				
36	3	68	568	538	72				

DCP Test Data Sheet

Road Name ADDIS - GIBE ROAD PROJECT

Site………… **Zero Reading 30mm**

Chainage 170+000 **Date………**

Position RHS

No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)	No.	No. of Blows	Total Blows	Reading (mm)	Corrected Reading (mm)
1	1	1	104	74	37	1	81	604	574
2	1	2	127	97	38	1	82	617	587
3	1	3	140	110	39	1	83	630	600
4	2	5	156	126	40	1	84	643	613
5	2	7	169	139	41	1	85	660	630
6	2	9	180	150	42	1	86	671	641
7	2	11	193	163	43	1	87	687	657
8	1	12	202	172	44	1	88	702	672
9	2	14	216	186	45	1	89	717	687
10	2	16	227	197	46	1	90	727	697
11	2	18	237	207	47	1	91	739	709
12	2	20	245	215	48	1	92	750	720
13	2	22	252	222	49	1	93	760	730
14	3	25	267	237	50	1	94	770	740
15	3	28	282	252	51	1	95	780	750
16	2	30	292	262	52	1	96	792	762
17	2	32	313	283	53	1	97	801	771
18	2	34	329	299	54	3	100	815	785
19	2	36	344	314	55	3	103	827	797
20	2	38	360	330	56	3	106	840	810
21	2	40	370	340	57	2	108	852	822
22	4	44	382	352	58	2	110	870	840
23	4	48	395	365	59	2	112	887	857
24	4	52	410	380	60	2	114	901	871
25	3	55	427	397	61	2	116	916	886
26	2	57	442	412	62	2	118	929	899
27	3	60	456	426	63	2	120	937	907
28	3	63	475	445	64				
29	3	66	491	461	65				
30	3	69	510	480	66				
31	3	72	535	505	67				
32	1	73	545	515	68				
33	2	75	558	528	69				
34	2	77	570	540	70				
35	2	79	580	550	71				
36	1	80	590	560	72				

Draw a graph for each station using the total number of blows as x-axis and corrected reading (mm) as y-axis. Each layer has approximately similar slop, and then fined the slop for each layer. The DCP value was obtained by dividing the change in penetration (mm) to the number of blow (blow).

For example, in order to convert the DCP value to CBR, use the following equation.

Log (CBR) = 2.632 – 1.28X Log (DCP)

Calculation of CBR Value for Alligator Crack (Station 66+500 km)

Take coordinates from the graph in both directions.

For Layer A

- RHS(1, 48), (38,325)
- LHS (1,40), (9,157)

Then find the change in penetration (Thickness)

- Penetration(RHS)=325 – 48 = 277mm
- Penetration(LHS)=157 – 40 = 117mm

Then find the DCP value (mm/blow)

DCP = change in penetration /change in number blow

- DCP (RHS) = 277/ (38-1) =7.486 mm/blow
- DCP (RHS) = 117/ (9-1) =14.625 mm/blow

The Average DCP Value is:-

DCP (Average) = (7.486+14.625) /2 = 11.056 mm/blow

Calculate the CBR value using the above equation;

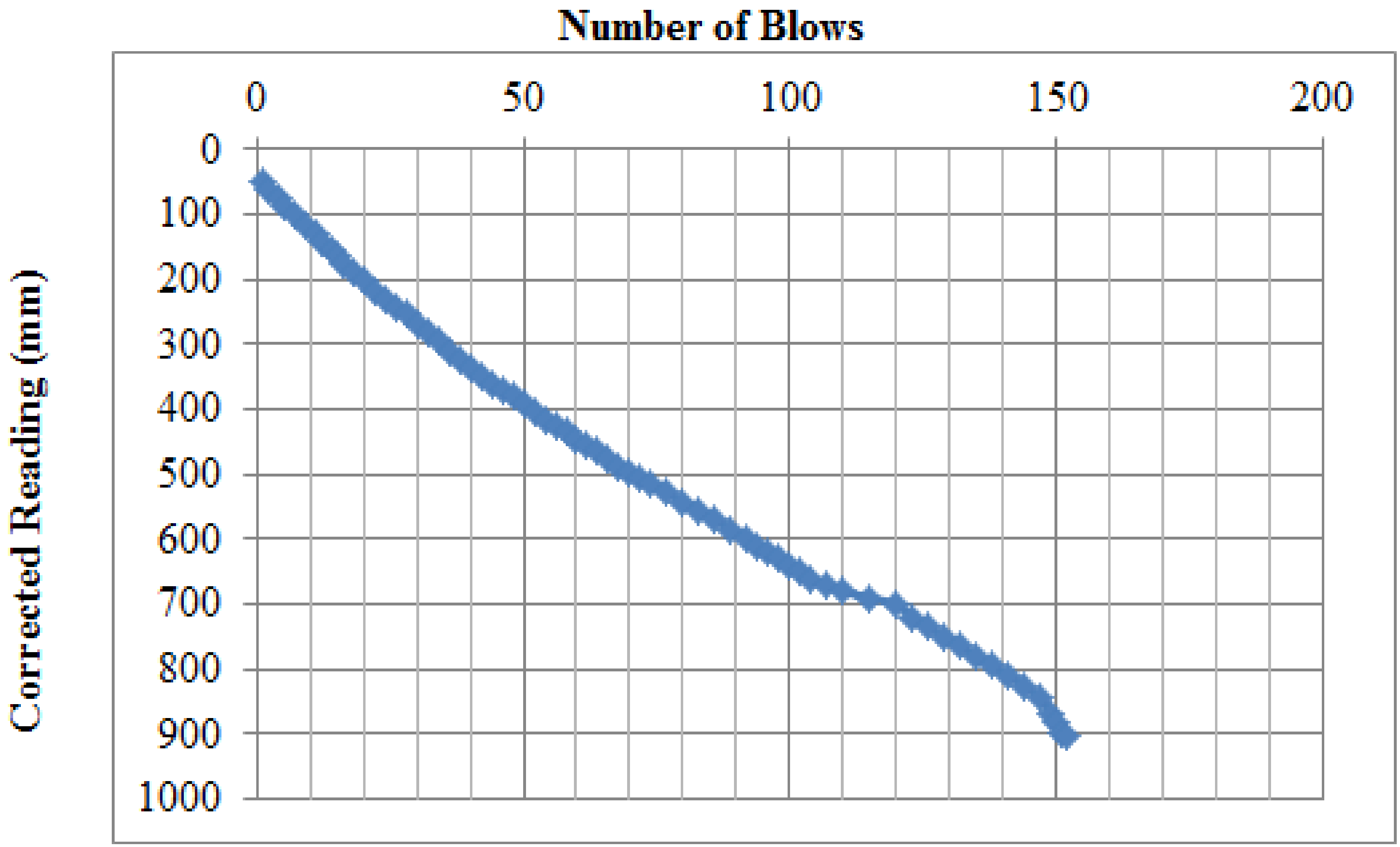
Log (CBR) = 2.632 – 1.28X Log(DCP)

Log (CBR) = 2.632 – 1.28 X Log (11.056)

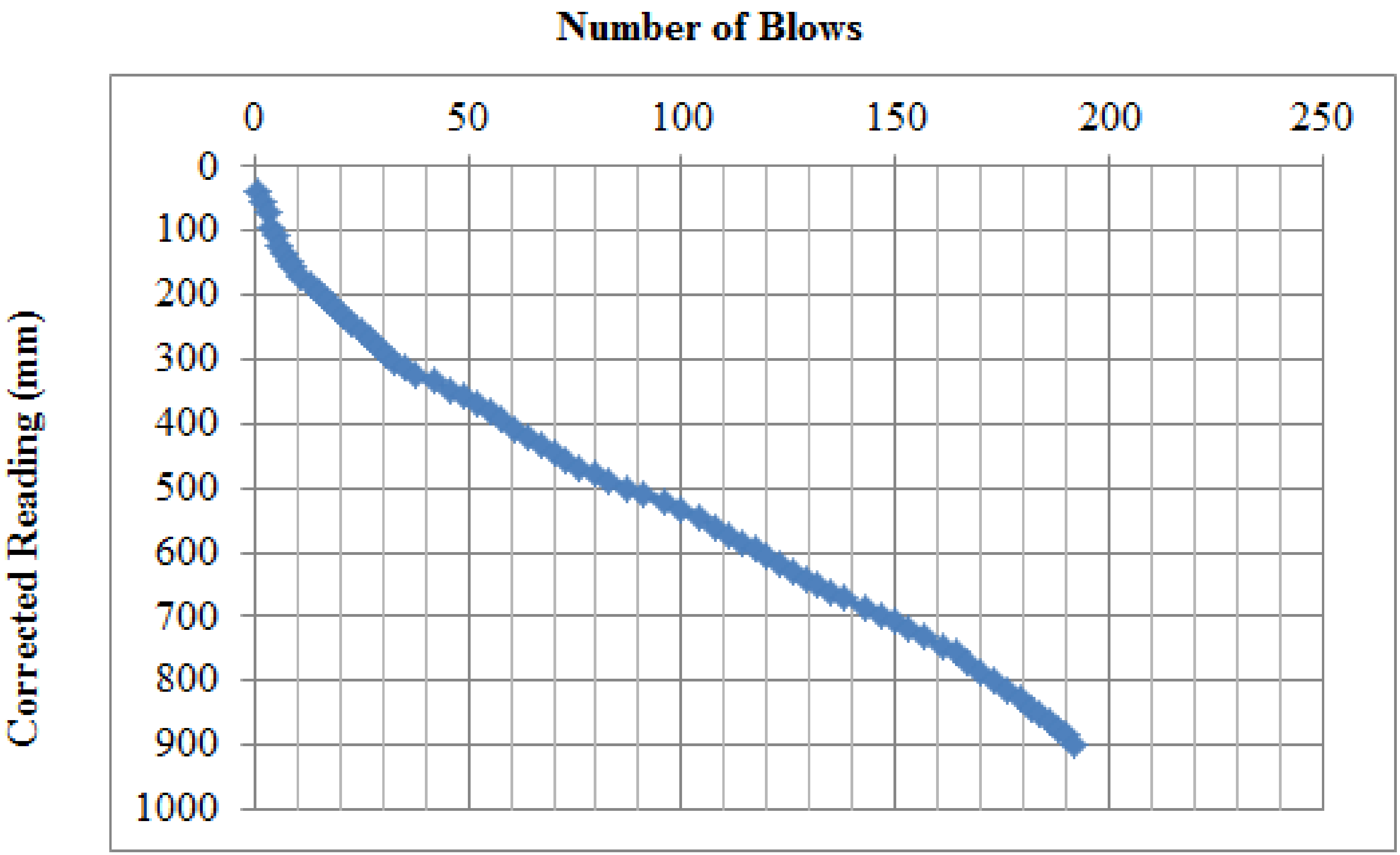
Log (CBR) = 1.296

CBR = $10^{1.296}$

CBR =19.779% ≈ 19.78%



Graph 1: Station 66+500 km –RHS (1.55 m from Edge of Asphalt)



Graph 2: Station 66+500 km –LHS (1.40 m from Edge of Asphalt)

TableA8: Summary of DCP-CBR Test for Alligator Crack

Station (km)	Site Description	Layer	Coordinate (X,Y)		Thickness (mm)		DCP (mm/blow)		DCP (Average) (mm/blow)	CBR (%) (Average)	Remark
			RHS	LHS	RHS	LHS	RHS	LHS			
66+500	Alligator Crack	**A**	(1,48),(38,325)	(1,40), (9,157)	277	117	7.486	14.625	11.056	19.780	Poor
		B	(38,325),(107,671)	(9,157),(38,324)	346	167	5.014	5.759	5.387	49.651	Good
		C	(107,671),(123,720)	(38,324),96,521)	49	197	3.063	3.397	3.230	95.548	Good
		D	(123,720),(144,825)	(96,521),(147,697)	105	176	5.000	3.451	4.226	67.745	Good
		F	(144,825),(151,897)	(147,697),(192,900)	72	203	10.286	4.511	7.399	33.075	Good

Table A9: Summary of DCP-CBR Test for Settlement or Depression

Station (km)	Site Description	Layer	Coordinate (X,Y)		Thickness (mm)		DCP (mm/blow)		DCP (Average) (mm/blow)	CBR (%) (Average)	Remark
			RHS	LHS	RHS	LHS	RHS	LHS			
105+100	Good Condition	**A**	(1,28),(28,226)	(1,39), (25,225)	198	186	7.33	7.75	7.54	32.27	Good
		B	(28,226),(67,690)	(25,255),(61,414)	464	159	4.21	5.25	4.73	58.68	Good
		C	(67,390),(108,505)	(61,414),79,501)	115	87	2.81	4.83	3.82	77.11	Good
		D	(108,505),(144,669)	(79,501),(107,754)	164	253	4.56	9.04	6.80	36.87	Good
		E	(144,669),(178,896)	(107,754),(123,905)	227	151	6.68	9.44	8.06	29.66	Good
114+100	Depression on Patching	**A**	(2,30),(29,227)	(1,27),(22,180)	197	153	7.30	7.29	7.29	33.70	Good
		B	(29,227),(70,394)	(22,180),(41,282)	167	102	4.07	5.37	4.72	58.79	Good
		C	((70,394),(107,494)	(41,282),(83,559)	100	277	2.70	6.60	4.65	59.95	Good
		D	(107,494),(157,701)	(83,559),(94,717)	207	158	4.14	14.36	9.25	24.84	Good
		E	(157,701),(190,903)	(94,717),(104,909)	202	192	6.12	19.20	12.66	16.63	Good
126+000	Low Depression	**A**	(1,73),(32,364)	(1,33),(23,235)	291	202	9.39	9.18	9.28	24.73	Poor
		B	(32,364),(39,444)	(23,235),(51,417)	80	182	11.43	6.50	8.96	25.87	Good
		C	(39,444),(42,522)	(51,417),(65,539)	78	122	26.00	8.71	17.36	11.10	Good
		D	(42,522),(60,645)	(65,539),(79,650)	123	111	6.83	7.93	7.38	33.18	Good
		E	(60,645),(71,793)	(79,650),(85,727)	148	77	13.46	12.83	13.14	15.85	Good

		F	(71,793),(75,912)	(85,727),(89,920)	119	193	29.75	48.25	39.00	3.94	Poor
126+400	High Depression	**A**	(1,32),(15,195)	(1,35),(14,195)	163	160	11.64	12.31	11.98	17.86	Poor
		B	(15,195),(29,331)	(14,195),(42,392)	136	197	9.71	7.04	8.38	28.22	Good
		C	(29,331),(43,526)	(42,392),(82,553)	195	161	13.93	4.03	8.98	25.82	Good
		D	(43,526),(56,655)	(82,553),(107,727)	129	174	9.92	6.96	8.44	27.94	Good
		E	(56,655),(66,907)	(107,727),(121,923)	252	196	25.20	14.00	19.60	9.50	Good
126+600	High Depression	**A**	(1,45),(17,232)	(1,43),(15,175)	187	132	11.69	9.43	10.56	20.98	Poor
		B	(17,232),(23,275)	(15,175),(35,304)	43	129	7.17	6.45	6.81	36.79	Good
		C	(23,275),(34,413)	(35,304),(70,586)	138	282	12.55	8.06	10.30	21.65	Good
		D	(34,413),(46,603)	(70,586),(92,723)	190	137	15.83	6.23	11.03	19.84	Good
		E	(46,603),(60,912)	(92,723),(106,925)	309	202	22.07	14.43	18.25	10.41	Good
127+100	Low Depression	**A**	(1,46),(23,331)	(1,40),(21,278)	285	238	12.96	11.90	12.43	17.03	Poor
		B	(23,331),(30,384)	(21,278),(49,500)	53	222	7.57	7.93	7.75	31.17	Good
		C	(30,384),(52,724)	(49,500),(60,625)	340	125	15.46	11.36	13.41	15.45	Good
		D	(52,724),(62,825)	(60,625),(74,734)	101	109	10.10	7.79	8.94	25.95	Good
		E	(62,825),(71,917)	(74,734),(88,923)	92	189	10.22	13.50	11.86	18.08	Good

Table A10: Summary of DCP-CBR Test for Rutting and Base Failure

Station (km)	Site Description	Layer	Coordinate (X,Y)		Thickness (mm)		DCP (mm/blow)		DCP (Average) (mm/blow)	CBR (%) (Average)	Remark
			RHS	LHS	RHS	LHS	RHS	LHS			
163+700	Base Failure	A	(1,35),(16,70)	(1,31), (25,156)	35	125	2.330	5.208	3.769	78.421	Good
		B	(16,70),(47,192)	(25,156),(58,380)	122	224	3.935	6.788	5.362	49.947	Good
		C	(47,192),(59,300)	(58,380),(70,490)	108	110	9.000	9.167	9.084	25.435	Good
		D	(59,300),(108,579)	(70,490),(129,686)	279	196	5.694	3.322	4.508	62.359	Good
		E	(108,579),(135,902)	(129,686),(171,916)	323	230	11.963	5.476	8.720	26.802	Good
166+000	Rutting	A	(1,70),(23,375)	(1,30),(29,165)	305	135	13.864	4.821	9.343	24.536	Poor
		B	(23,375),(61,457)	(29,165),(109,602)	82	437	2.158	5.463	3.811	77.329	Good
		C	(61,457),(81,536)	(109,602),(155,690)	79	88	3.950	1.913	2.932	108.175	Good
		D	(81,536),(99,660)	(155,690),(183,816)	124	126	6.889	4.500	5.695	46.240	Good
		E	(99,660),(129,920)	(183,816),(214,884)	260	68	8.667	2.194	5.431	49.137	Good
168+160	Rutting	A	(2,34),(28,123)	(2,33),(111,403)	89	370	3.423	3.394	3.409	89.191	Good
		B	(28,123),(56,325)	(111,403),(160,611)	202	208	7.214	4.245	5.730	45.879	Good
		C	(56,325),(158,724)	(160,611),(191,666)	399	55	3.912	1.774	2.843	112.503	Good
		D	(158,724),(201,924)	(191,666),(270,915)	200	249	4.651	3.152	3.902	75.028	Good
168+840	Good Condition	A	(2,23),(82,168)	(1,49),(21,218)	145	169	1.813	8.450	5.132	52.831	Good
		B	(82,168),(121,395)	(21,218),(121,566)	227	348	5.821	3.480	4.651	59.924	Good
		C	(121,395),(153,507)	(121,566),(180,652)	112	86	3.500	1.458	2.479	134.068	Good
		D	(153,507),(215,790)	(180,652),(227,786)	283	134	4.565	2.851	3.708	80.076	Good
		E	(215,790),(230,913)	(227,786),(257,915)	123	129	8.200	4.300	6.250	41.046	Good
170+000	Base Failure	A	(1,74),(79,550)	(1,52),(19,300)	476	248	6.103	13.778	9.941	22.663	Poor
		B	(79,550),(95,750)	(19,300),(91,660)	200	360	12.500	5.000	8.750	26.683	Good
		C	(95,750),(120,907)	(91,660),(117,910)	157	250	6.280	9.615	7.948	30.179	Good

Table 4.2: Summary of DCP-CBR test for sub base and fill material at Alligator Crack

Depth below Base Course	**0- 300 mm**	**300-900 mm**
Averaged Value(mm/blow)	11.056	5.060
Average CBR Value (%)	19.78	61.505
Remark on Average CBR Value	Poor compaction (less than 30%)	Good compaction (greater than 4%)

Table 4.3: Summary of DCP-CBR test for sub base and fill material at Settlement or Depression.

Depth below Base Course	**0-300 mm**	**300-900 mm**
Average DCP Value(mm/blow)	9.847	10.971
Average CBR Value (%)	24.428	28.932
Remark on Average CBR Value	Poor compaction (less than 30%)	Good compaction (greater than 4%)

Table 4.4: Summary of DCP-CBR test for sub base and fill material at Rutting and Base Failure

Depth below Base Course	**0-300 mm**	**300-900 mm**
Average DCP Value(mm/blow)	6.319	5.4
Average CBR Value (%)	53.528	61.812
Remark on Average CBR Value	Good compaction (greater than 30%)	Good compaction (greater than 4%)

APPENDEX B - TRAFFIC LOAD ANALYSIS

Table B1: Axle load survey result at Alem Gena weight station

Vehicle Category	No. of Axles	Right (Jimma lane)							Left (Addis Ababa lane)						Weighted ESA
		Axle Load and ESA per Vehicle							Axle Load and ESA per Vehicle						
		1	2	EF	EF	TF			1	2	EF	EF	TF		
Small Buses	2	2585	4860	0.010	0.126	0.136			2050	4180	0.004	0.07	0.07		0.21
	2	2485	3815	0.009	0.048	0.056			2140	4220	0.005	0.07	0.08		
	2	2405	3755	0.008	0.045	0.052			2205	3990	0.005	0.06	0.06		
	2	2645	3725	0.011	0.043	0.054			2245	4030	0.006	0.06	0.07		
	2	2125	4410	0.005	0.085	0.090			3050	5140	0.020	0.16	0.18		
	2	2090	3510	0.004	0.034	0.039			2530	4460	0.009	0.09	0.10		
	2	2520	3955	0.009	0.055	0.064			2400	3870	0.007	0.05	0.06		
	2	2875	3840	0.015	0.049	0.064			2835	3559	0.015	0.04	0.05		
	2	2935	5200	0.017	0.165	0.182			2645	3915	0.011	0.05	0.06		
	2	2330	4620	0.007	0.103	0.109			2540	4345	0.009	0.08	0.09		
	2	3675	11300	0.041	3.678	3.719			2165	2730	0.005	0.01	0.02		
	2	2170	4800	0.005	0.120	0.125			2375	2330	0.007	0.01	0.01		
	2	2505	5965	0.009	0.286	0.294			2775	4470	0.013	0.09	0.10		
	2	2620	4380	0.011	0.083	0.094			2500	3960	0.009	0.06	0.06		
	2	2700	3240	0.012	0.025	0.037									
	Mean EF					0.34			Mean EF				0.07		
Large Buses	No. of Axles	1	2	EF	EF	TF			1	2	EF	EF	TF		2.75
	2	7190	9800	0.60	2.08	2.68			4800	10260	0.12	2.50	2.62		
	2	5535	10530	0.21	2.77	2.98			4160	8620	0.07	1.25	1.31		
	2	4655	10680	0.11	2.93	3.04			5460	10115	0.20	2.36	2.56		
	2	5485	8530	0.20	1.19	1.40			4170	12160	0.07	4.93	5.00		
	2	5910	13985	0.28	8.63	8.90			6130	7230	0.32	0.62	0.93		
	2	6240	9980	0.34	2.24	2.58			5780	10930	0.25	3.22	3.47		
	2	5890	12310	0.27	5.18	5.45			4935	9150	0.13	1.58	1.71		
	2	5980	9220	0.29	1.63	1.92			4275	10455	0.08	2.69	2.77		

	2	4230	11670	0.07	4.18	4.26			5365	8965	0.19	1.46	1.64		
	2	4940	7580	0.13	0.74	0.88			4395	11160	0.08	3.50	3.58		
									6425	10945	0.38	3.24	3.62		
									6365	7275	0.37	0.63	1.00		
									5215	8000	0.17	0.92	1.09		
									7240	8560	0.62	1.21	1.83		
									5135	8820	0.16	1.36	1.52		
									4970	11990	0.14	4.66	4.80		
									6950	9010	0.53	1.49	2.01		
									5390	7810	0.19	0.84	1.03		
									5105	9380	0.15	1.75	1.90		
									4155	14150	0.07	9.04	9.11		
									4980	7835	0.14	0.85	0.99		
									6195	9610	0.33	1.92	2.26		
									6155	7140	0.32	0.59	0.91		
									5340	9025	0.18	1.50	1.68		
		Mean EF				**3.41**			**Mean EF**				**2.47**		
Small Truck	**No. of Axles**	**1**	**2**	**EF**	**EF**	**TF**			**1**	**2**	**EF**	**EF**	**TF**		**0.06**
	2	2115	2750	0.00	0.01	0.02			2205	3205	0.01	0.02	0.03		
	2	1970	1460	0.00	0.00	0.00			1530	1790	0.00	0.00	0.00		
	2	1875	1580	0.00	0.00	0.00			2050	2780	0.00	0.01	0.02		
	2	2610	4155	0.01	0.07	0.08			2005	2470	0.00	0.01	0.01		
	2	2665	3870	0.01	0.05	0.06			2345	3025	0.01	0.02	0.03		
	2	1850	1575	0.00	0.00	0.00			1915	2035	0.00	0.00	0.01		
	2	2765	2985	0.01	0.02	0.03			2000	3600	0.00	0.04	0.04		
	2	2669	3050	0.01	0.02	0.03			1755	3820	0.00	0.05	0.05		

	2	2250	1915	0.01	0.00	0.01			2350	3760	0.01	0.05	0.05		
	2	2160	2440	0.00	0.01	0.01			2215	3400	0.01	0.03	0.04		
	2	2860	3260	0.02	0.03	0.04			2144	3640	0.00	0.04	0.04		
	2	2324	3770	0.01	0.05	0.05			1780	1345	0.00	0.00	0.00		
	2	2095	2629	0.00	0.01	0.02			2990	3990	0.02	0.06	0.08		
	2	2095	2620	0.00	0.01	0.01			2800	5435	0.01	0.20	0.21		
	2	2405	3235	0.01	0.02	0.03			2595	3935	0.01	0.05	0.06		
	2	2205	4920	0.01	0.13	0.14			2960	6105	0.02	0.31	0.33		
	2	2010	2294	0.00	0.01	0.01			2785	5905	0.01	0.27	0.29		
	2	1880	2530	0.00	0.01	0.01			2355	4130	0.01	0.07	0.07		
	2	1950	1530	0.00	0.00	0.00			2270	2635	0.01	0.01	0.02		
	2	2105	1530	0.00	0.00	0.01			2965	5570	0.02	0.22	0.23		
	2	2105	3430	0.00	0.03	0.04			2790	4455	0.01	0.09	0.10		
	2	2160	3120	0.00	0.02	0.03			3045	5535	0.02	0.21	0.23		
	2	1820	1390	0.00	0.00	0.00			3220	4520	0.02	0.09	0.12		
	2	2325	3770	0.01	0.05	0.05			2105	2040	0.00	0.00	0.01		
	2	2340	2950	0.01	0.02	0.02			2675	5820	0.01	0.26	0.27		
	2	2870	3460	0.02	0.03	0.05			2665	3887	0.01	0.05	0.06		
	2	2671	3290	0.01	0.03	0.04			2559	3021	0.01	0.02	0.03		
	2	2579	2925	0.01	0.02	0.03			2590	2632	0.01	0.01	0.02		
	2	2332	3105	0.01	0.02	0.03			2553	2888	0.01	0.02	0.03		
	2	2345	3379	0.01	0.03	0.04			2657	3102	0.01	0.02	0.03		
									2285	2562	0.01	0.01	0.02		
									2397	2934	0.01	0.02	0.02		
	Mean EF					**0.03**			**Mean EF**				**0.08**		
Medium Truck	**No. of Axles**	**1**	**2**	**3**	**EF**	**EF**	**EF**	**TF**	**1**	**2**	**EF**	**EF**	**TF**		**0.55**
	2	2060	4040	0	0.00	0.06	0.00	0.06	2505	3800	0.01	0.05	0.06		

2	2970	3060	0	0.02	0.02	0.00	0.04	2810	5950	0.01	0.28	0.30	
2	5945	6230	0	0.28	0.34	0.00	0.62	4060	5920	0.06	0.28	0.34	
2	4105	12395	0	0.06	5.32	0.00	5.39	2844	4020	0.01	0.06	0.07	
2	3005	4100	0	0.02	0.06	0.00	0.08	2415	3750	0.01	0.04	0.05	
2	3035	5532	0	0.02	0.21	0.00	0.23	2630	3630	0.01	0.04	0.05	
2	3755	3325	0	0.04	0.03	0.00	0.07	5469	8095	0.20	0.97	1.17	
2	4770	7970	0	0.12	0.91	0.00	1.03	2805	3480	0.01	0.03	0.05	
2	3415	4155	0	0.03	0.07	0.00	0.10	4065	8850	0.06	1.38	1.45	
2	4950	8700	0	0.14	1.29	0.00	1.43	4010	6405	0.06	0.38	0.44	
2	2710	2620	0	0.01	0.01	0.00	0.02	2555	3485	0.01	0.03	0.04	
2	2195	4785	0	0.01	0.12	0.00	0.12	3560	5115	0.04	0.15	0.19	
2	2205	4875	0	0.01	0.13	0.00	0.13	4335	2910	0.08	0.02	0.10	
2	2425	5820	0	0.01	0.26	0.00	0.27	7385	12605	0.67	5.69	6.36	
2	3385	6075	0	0.03	0.31	0.00	0.34	4160	7910	0.07	0.88	0.95	
2	3665	4530	0	0.04	0.09	0.00	0.14	3825	6385	0.05	0.37	0.42	
2	4500	5470	0	0.09	0.20	0.00	0.29	2665	2880	0.01	0.02	0.03	
2	3930	5625	0	0.05	0.23	0.00	0.28	3375	5460	0.03	0.20	0.23	
2	5035	8730	0	0.14	1.31	0.00	1.46	2790	4890	0.01	0.13	0.14	
2	4890	10660	0	0.13	2.91	0.00	3.04	5180	7410	0.16	0.68	0.84	
2	3370	7115	0	0.03	0.58	0.00	0.61	4820	3730	0.12	0.04	0.17	
2	5000	6550	0	0.14	0.42	0.00	0.56						
2	3810	8745	0	0.05	1.32	0.00	1.37						
2	6220	7400	0	0.34	0.68	0.00	1.01						
2	3370	4304	0	0.03	0.08	0.00	0.11						
2	2825	4534	0	0.01	0.10	0.00	0.11						
2	2831	4755	0	0.01	0.12	0.00	0.13						
2	3680	5055	0	0.04	0.15	0.00	0.19						
2	3477	4772	0	0.03	0.12	0.00	0.15						
2	3557	3976	0	0.04	0.06	0.00	0.09						
2	2888	3289	0	0.02	0.03	0.00	0.04						
2	4813	5909	0	0.12	0.27	0.00	0.40						

	2	3432	4141	0	0.03	0.07	0.00	0.10							
	2	3020	4190	0	0.02	0.07	0.00	0.09							
	2	4368	6285	0	0.08	0.35	0.00	0.43							
	2	3113	3893	0	0.02	0.05	0.00	0.07							
	2	2807	4122	0	0.01	0.07	0.00	0.08							
	2	4135	6470	0	0.07	0.40	0.00	0.46							
	2	2690	3996	0	0.01	0.06	0.00	0.07							
	2	2891	3863	0	0.02	0.05	0.00	0.07							
	2	2687	3881	0	0.01	0.05	0.00	0.06							
	2	2804	3969	0	0.01	0.06	0.00	0.07							
		Mean EF				**0.51**			**Mean EF**				**0.64**		
	No. of Axles	**1**	**2**	**3**	**EF**	**EF**	**EF**	**TF**	**1**	**2**	**3**	**EF**	**EF**	**EF**	**TF**
	3	7650	9800	8145	0.77	2.08	0.99	3.85	4705	3405	3275	0.11	0.03	0.03	0.17
	3	7180	4920	7310	0.60	0.13	0.64	1.38	4855	2875	3625	0.13	0.02	0.04	0.18
	3	4015	3155	2825	0.06	0.02	0.01	0.10	5480	4825	3610	0.20	0.12	0.04	0.36
	3	5395	2030	2530	0.19	0.00	0.01	0.20	4385	3755	3085	0.08	0.04	0.02	0.15
	3	6030	8730	7530	0.30	1.31	0.73	2.33	4420	3195	2865	0.09	0.02	0.02	0.12
	3	5655	4850	4290	0.23	0.12	0.08	0.43	5575	10110	9075	0.22	2.36	1.53	4.10
	3	5185	9285	9490	0.16	1.68	1.83	3.67	4026	3205	3305	0.06	0.02	0.03	0.11
Heavy Truck	3	5965	8772	8605	0.29	1.34	1.24	2.86	7550	9680	8330	0.73	1.98	1.09	3.80
	3	4195	3555	3520	0.07	0.04	0.03	0.14	9955	8825	8113	2.22	1.37	0.98	4.56
	3	5350	10065	8790	0.18	2.31	1.35	3.85	5354	7860	6440	0.19	0.86	0.39	1.43
	3	4775	4460	4630	0.12	0.09	0.10	0.31	5035	4415	3815	0.14	0.09	0.05	0.28
	3	4965	10350	8390	0.14	2.59	1.12	3.84	7340	11405	9290	0.65	3.82	1.68	6.15
	3	6395	9425	7095	0.38	1.78	0.57	2.73	6400	12355	11440	0.38	5.26	3.86	9.50
	3	5470	5010	6345	0.20	0.14	0.37	0.71	6125	12465	12590	0.32	5.45	5.67	11.43
	3	6235	7460	11025	0.34	0.70	3.33	4.37	4650	3359	3190	0.11	0.03	0.02	0.16
	3	5910	9185	13920	0.28	1.61	8.47	10.35	6620	13790	12200	0.43	8.16	5.00	13.59
	3	7290	6405	6005	0.64	0.38	0.29	1.31	4585	4035	3585	0.10	0.06	0.04	0.20
	3	4995	11175	8120	0.14	3.52	0.98	4.64	4330	3550	3890	0.08	0.04	0.05	0.17
	3	6255	9830	9150	0.35	2.11	1.58	4.03	4980	3315	3385	0.14	0.03	0.03	0.20

3	6825	12140	11930	0.49	4.90	4.57	9.96	4950	3615	3365	0.14	0.04	0.03	0.20	
3	3925	3340	2955	0.05	0.03	0.02	0.10	6685	8685	9090	0.45	1.28	1.54	3.27	
3	3945	3340	2955	0.05	0.03	0.02	0.10	5160	3674	4055	0.16	0.04	0.06	0.26	
3	4040	3170	3800	0.06	0.02	0.05	0.13	4340	3995	3490	0.08	0.06	0.03	0.17	
3	6785	12115	11520	0.48	4.86	3.97	9.31	5805	2805	2790	0.26	0.01	0.01	0.28	
3	5570	10720	11700	0.22	2.98	4.23	7.42	6320	4480	4820	0.36	0.09	0.12	0.57	
3	6040	9700	8335	0.30	2.00	1.09	3.39	5200	12395	12510	0.16	5.32	5.52	11.01	
3	8740	7475	5955	1.32	0.70	0.28	2.30	7070	12100	12380	0.56	4.83	5.30	10.70	
3	4635	3420	3120	0.10	0.03	0.02	0.16	4725	8380	8680	0.11	1.11	1.28	2.51	
3	4280	3410	3360	0.08	0.03	0.03	0.13	6055	3030	2855	0.30	0.02	0.01	0.34	
3	5290	3665	3425	0.18	0.04	0.03	0.25	6830	7070	7295	0.49	0.56	0.64	1.69	
3	5830	8045	8380	0.26	0.94	1.11	2.32	6135	8080	8555	0.32	0.96	1.21	2.49	
3	5280	3930	3220	0.18	0.05	0.02	0.25	4925	2060	3800	0.13	0.00	0.05	0.18	
3	5740	10650	10195	0.24	2.90	2.44	5.58	6475	6910	8505	0.40	0.51	1.18	2.09	
3	6010	7399	8675	0.29	0.68	1.28	2.25	4435	10090	10860	0.09	2.34	3.14	5.56	
3	6830	7835	8705	0.49	0.85	1.30	2.64	6165	8585	8700	0.33	1.23	1.29	2.84	
3	5100	3480	3030	0.15	0.03	0.02	0.20	9870	4920	5120	2.14	0.13	0.15	2.43	
3	5385	6405	7559	0.19	0.38	0.74	1.31	6370	5130	4070	0.37	0.16	0.06	0.59	
3	6850	6600	7220	0.50	0.43	0.61	1.54	6075	4940	4408	0.31	0.13	0.09	0.53	
3	8340	11290	11460	1.09	3.66	3.89	8.65	5580	10100	10010	0.22	2.35	2.26	4.83	
3	7185	11050	10230	0.60	3.36	2.47	6.43	4850	3695	3540	0.12	0.04	0.04	0.20	
3	5312	9580	9850	0.18	1.90	2.12	4.20	6470	13810	11375	0.40	8.20	3.78	12.38	
3	4205	3850	3875	0.07	0.05	0.05	0.17	4570	4145	3985	0.10	0.07	0.06	0.22	
3	5365	9390	7490	0.19	1.75	0.71	2.65	6535	9320	9955	0.41	1.70	2.22	4.33	
3	6294	9769	9400	0.35	2.05	1.76	4.17	9155	11470	11375	1.58	3.90	3.78	9.26	
3	5365	9390	8090	0.19	1.75	0.97	2.91	4960	9460	9020	0.14	1.81	1.49	3.44	**2.95**
3	8240	9769	9400	1.04	2.05	1.76	4.85	4660	4495	3700	0.11	0.09	0.04	0.24	
3	5360	9640	8165	0.19	1.95	1.00	3.14	5015	4570	4815	0.14	0.10	0.12	0.36	
3	7430	9499	8890	0.69	1.84	1.41	3.93	3980	3030	3355	0.06	0.02	0.03	0.10	
3	5925	7425	6820	0.28	0.69	0.49	1.45	5895	3556	3610	0.27	0.04	0.04	0.35	
3	7369	11580	10520	0.67	4.06	2.76	7.48	9080	4240	4270	1.53	0.07	0.07	1.68	
3	4715	3735	3515	0.11	0.04	0.03	0.19	5210	3280	3485	0.17	0.03	0.03	0.23	
3	4835	3705	3435	0.12	0.04	0.03	0.20	4670	3715	3435	0.11	0.04	0.03	0.18	
3	6640	7755	7570	0.44	0.82	0.74	1.99	4950	7180	6655	0.14	0.60	0.44	1.18	

3	6625	11910	11680	0.43	4.54	4.20	9.17	4640	3470	3140	0.10	0.03	0.02	0.16
3	5009	3625	3390	0.14	0.04	0.03	0.21	6280	15865	15730	0.35	14.29	13.81	28.45
3	4385	3395	3055	0.08	0.03	0.02	0.13	7505	11145	11205	0.72	3.48	3.56	7.75
3	7390	12060	11840	0.67	4.77	4.43	9.88	4935	6050	5235	0.13	0.30	0.17	0.61
3	8755	10760	10905	1.33	3.02	3.19	7.54	5355	3405	3160	0.19	0.03	0.02	0.24
3	5205	4000	4055	0.17	0.06	0.06	0.28	9580	12610	12610	1.90	5.70	5.70	13.31
3	4580	4790	5420	0.10	0.12	0.19	0.41	11480	14865	14360	3.92	11.01	9.59	24.52
3	4820	3280	6900	0.12	0.03	0.51	0.66	4680	3985	2885	0.11	0.06	0.02	0.18
3	5650	7850	8185	0.23	0.86	1.01	2.10	4440	4140	3815	0.09	0.07	0.05	0.20
3	6770	8310	8690	0.47	1.08	1.29	2.84	5120	4395	4410	0.15	0.08	0.09	0.32
3	4885	3840	3530	0.13	0.05	0.04	0.21	6940	9568	8230	0.52	1.89	1.03	3.45
3	5085	3810	3700	0.15	0.05	0.04	0.24	6260	13120	12755	0.35	6.68	5.97	13.00
3	6670	10530	10170	0.45	2.77	2.41	5.63	6945	13080	11050	0.52	6.60	3.36	10.49
3	6836	7896	9795	0.49	0.88	2.08	3.45	8430	9490	8415	1.14	1.83	1.13	4.10
3	4930	3630	3630	0.13	0.04	0.04	0.21	8780	12380	12260	1.34	5.30	5.10	11.73
3	6690	10205	10419	0.45	2.45	2.66	5.56	7070	10050	10295	0.56	2.30	2.53	5.40
3	5590	3970	4020	0.22	0.06	0.06	0.34	5950	10210	11990	0.28	2.45	4.66	7.40
3	5990	4605	3920	0.29	0.10	0.05	0.45	5685	4540	4060	0.24	0.10	0.06	0.39
3	5455	11020	10855	0.20	3.33	3.13	6.66	4425	4130	3805	0.09	0.07	0.05	0.20
3	10290	11380	11235	2.53	3.78	3.59	9.91	4180	3740	3825	0.07	0.04	0.05	0.16
3	4425	3810	3415	0.09	0.05	0.03	0.16	4115	3710	3880	0.06	0.04	0.05	0.16
3	4595	4005	3800	0.10	0.06	0.05	0.21	6040	11735	11585	0.30	4.28	4.06	8.64
3	4100	2935	3210	0.06	0.02	0.02	0.10	4355	3850	3710	0.08	0.05	0.04	0.17
3	3850	3145	3250	0.05	0.02	0.03	0.10	4805	2885	2765	0.12	0.02	0.01	0.15
3	4440	3570	3250	0.09	0.04	0.03	0.15	6045	4050	3870	0.30	0.06	0.05	0.41
3	4180	3440	3215	0.07	0.03	0.02	0.12	5010	3130	2985	0.14	0.02	0.02	0.18
3	8025	4305	6750	0.94	0.08	0.47	1.48	5570	4000	4320	0.22	0.06	0.08	0.35
3	5485	9165	9990	0.20	1.59	2.25	4.04	5950	3805	4428	0.28	0.05	0.09	0.42
3	5800	9220	8295	0.26	1.63	1.07	2.95	4660	3600	3260	0.11	0.04	0.03	0.17
3	5055	4670	5035	0.15	0.11	0.14	0.40	8240	12480	11320	1.04	5.47	3.70	10.21
3	5255	3390	3015	0.17	0.03	0.02	0.22	4980	3730	3690	0.14	0.04	0.04	0.22
3	4790	2675	3160	0.12	0.01	0.02	0.15	6533	4820	4770	0.41	0.12	0.12	0.65
3	5050	3210	3220	0.15	0.02	0.02	0.19							
3	5865	3180	2610	0.27	0.02	0.01	0.30							

	3	5865	3180	2610	0.27	0.02	0.01	0.30							
	3	6800	8835	11930	0.48	1.37	4.57	6.43							
	3	4840	3535	3320	0.12	0.04	0.03	0.19							
	3	4770	4275	4068	0.12	0.08	0.06	0.25							
	3	4625	3430	3270	0.10	0.03	0.03	0.16							
	3	4540	4120	4260	0.10	0.06	0.07	0.24							
	3	4195	4240	3815	0.07	0.07	0.05	0.19							
	3	4945	4880	4080	0.13	0.13	0.06	0.33							
	3	5590	3969	4020	0.22	0.06	0.06	0.34							
		Mean EF				**2.48**			**Mean EF**					**3.50**	
	No. of Axles	**1**	**2**	**3**	**4**	**5**	**6**	**TF**	**1**	**2**	**3**	**4**	**5**	**6**	**TF**
Articulated Truck	5,6	7330.00	9045	8655.00	9745	5150.00		5.62	5780	4390	4080	2585	2760	2940	0.44
	5,6	6295.00	8460	10270.00	10200	11360.00		10.22	7315	12730	12460	8430	10651	9690	18.04
	5,6	6350.00	11325	9690.00	7250	8740.00		8.00	5560	4345	4710	3110	3775	3215	0.50
	6	5760.00	3835	3610.00	2290	2645.00	3300	0.38	6850	12610	11920	9900	11850	10105	19.72
	6	5240.00	3650	3535.00	4360	3365.00	3545	0.39	7940	11620	11030	14860	9180	9820	23.04
	5,6	5195.00	4325	5600.00	5665	4800.00		0.82	10520	6640	6410	4645	6175	5340	4.20
	5	4870.00	4540	4280.00	3115	3030.00		0.34	5750	4905	5125	3670	4015		0.63
	6,5	5455.00	4115	3680.00	3865	3575.00	2845	0.41	5900	4160	5055	2945	2920		0.52
	6	5420.00	4260	3980.00	3115	3780.00	3390	0.42	5350	4900	4820	3555	3680	2980	0.53
	6	8740.00	12455	12140.00	9840	13110.00	11635	24.55	5345	4150	4475	2910	2755	2810	0.38
	6	7335.00	12790	9800.00	9170	7645.00	7415	11.82	6090	4360	4100	3190	3710	3605	0.56
	6	6995.00	13465	13440.00	10915	9055.00	7450	20.73	8345	13185	13120	10040	12483	12660	28.16
	6	6775.00	12610	10050.00	7530	9065.00	8980	12.19	5820	5565	4665	4130	4385	4508	0.82
	6	7800.00	12195	11565.00	9085	8805.00	10850	15.88	5460	4440	4150	3145	3280	3155	0.43
	6	7330.00	10280	8805.00	10120	9815.00	10790	12.04	7380	14210	13840	10435	12010	12150	30.42

6	5130.00	3340	2790.00	3085	2900.00	3010	0.25	6960	8220	9610	8080	10600	8880	8.69
6	8110.00	12015	10620.00	10290	8670.00	8360	13.45	6520	9950	10600	7380	11543	9720	12.15
6	4675.00	4165	3590.00	3680	3080.00	3330	0.30	6420	9180	9340	12335	11880	12915	19.69
6	5553.00	4775	3990.00	3790	3955.00	3425	0.52	5090	5360	4330	3520	2740		0.46
5	5280.00	2980	2555.00	3805	3420.00		0.28	5870	12990	11185	8890	11790	10740	18.99
6	5995.00	4050	3520.00	2790	2720.00	2400	0.42	5930	4940	4360	3400	3450	3935	0.61
6	5800.00	4290	4620.00	3540	3635.00	3810	0.56	4265	3740	3525	3200	2550	2870	0.20
6	6705.00	13110	12760.00	8640	9060.00	8490	17.05	6345	8605	7100	10500	10580	12285	12.88
6	5545.00	4220	3840.00	3680	3295.00	4025	0.46	6980	12580	13400	8895	14140	12215	28.91
6	5600.00	4630	3960.00	3060	3040.00	3370	0.45	5395	3910	3760	3595	3225	3870	0.40
6	4785.00	3805	3090.00	2970	3430.00	3550	0.27	5270	4850	4170	2865	3145	3035	0.42
6	5440.00	4255	3730.00	2730	3340.00	3070	0.38	6620	14940	12360	8610	9245	8820	21.19
6,5	4515.00	3635	3470.00	3100	2330.00	2550	0.20	11330	12520	11445	10588	12210	10560	23.78
5,6	5620.00	5465	4951.00	4915	4540.00		0.79	6540	8555	10460	9990	8745	8690	9.17
5,6	5700.00	3920	3100.00	3275	3380.00		0.37	8235	10420	10545	11450	11075		13.76
6,5	6027.00	9900	9790.00	12540	13110.00	11945	21.37	6150	6520	7200	4240	4270	4375	1.57
6	6660.00	7240	7620.00	8965	9010.00	13170	11.55	6560	7680	10000	8010	9020		5.88
6	5120.00	3870	3345.00	3075	2750.00	2965	0.28	8680	10340	10740	9000	8800	8810	11.05
6	5445.00	3830	3680.00	3110	2310.00	2695	0.33	7740	12200	12800	8210	10700	10400	18.48
6	5090.00	4290	3855.00	2875	2815.00	2435	0.32							
6,5	6430.00	5420	3835.00	3450	3865.00	3380	0.74							
6	5965.00	4290	4180.00	3450	2795.00	4055	0.54							
6,5	5540.00	4700	5940.00	3140	3670.00	3800	0.71							
6	5660.00	9910	8830.00	5275	4630.00	5960	4.34							

6	6105.00	3780	3450.00	2635	2890.00	2620	0.43								
6	6220.00	12140	12300.00	9480	9615.00	9155	15.73								
6	6345.00	4540	4460.00	3220	4680.00	3555	0.72								
6	6915.00	12840	8805.00	6360	7030.00	6300	9.28								
6	5065.00	3305	3375.00	2580	3820.00	3600	0.30								
6	5550.00	4625	4500.00	2840	3460.00	4570	0.56								
6	6550.00	11005	10105.00	6995	9185.00	7170	8.82								
6	8130.00	10945	12220.00	9395	11255.00	10870	17.78								
6	5885.00	6745	8000.00	4510	4810.00	5805	2.13								
6	6915.00	10610	8475.00	12100	9805.00	10270	13.97								
6	5530.00	6980	7000.00	3210	7580.00	7690	2.85								
6	5800.00	4240	3990.00	3205	2955.00	2660	0.44								**7.15**
6	6160.00	8160	9560.00	2915	3440.00	3090	3.28								
6	5990.00	8385	8295.00	4800	6445.00	7480	3.69								
6	7305.00	11180	9810.00	10115	8465.00	8240	10.81								
6	6430.00	9573	9900.00	6035	6025.00	6360	5.41								
6	4850.00	3540	3095.00	2550	2735.00	3080	0.22								
6	5620.00	10180	10840.00	7580	9280.00	7470	8.88								
6	4165.00	4910	3855.00	3880	15400.00	4780	13.10								
6	5920.00	11190	10555.00	7295	8795.00	9620	10.53								
Mean EF					**5.57**			**Mean EF**				**9.90**			

Table B2: Axle load survey result at Welkite weight station

Vehicle Category	No. of Axles	Right (Jimma lane)							Left (Addis Ababa lane)						Weighted ESA
		Axle Load and ESA per Vehicle							Axle Load and ESA per Vehicle						
		1	2	EF	EF	TF			1	2	EF	EF	TF		
Small Buses	2	2370	4330	0.007	0.08	0.09			2975	4020	0.018	0.06	0.08		0.08
	2	2900	4890	0.016	0.13	0.14			2800	4040	0.014	0.06	0.07		
	2	2745	2805	0.013	0.01	0.03			3456	4610	0.032	0.10	0.13		
	2	2180	3780	0.005	0.05	0.05			2940	3980	0.017	0.06	0.07		
	2	2650	4230	0.011	0.07	0.08			2560	3940	0.010	0.05	0.06		
	2	2060	4680	0.004	0.11	0.11			2790	3915	0.014	0.05	0.07		
	2	2995	4180	0.018	0.07	0.09			3190	3970	0.023	0.06	0.08		
	2	2800	5290	0.014	0.18	0.19									
	2	2740	3710	0.013	0.04	0.06									
	2	2570	4545	0.010	0.10	0.11									
	2	2465	3145	0.008	0.02	0.03									
	2	2170	4610	0.005	0.10	0.11									
	2	2080	4750	0.004	0.11	0.12									
	2	2460	5100	0.008	0.15	0.16									
	2	2220	4085	0.005	0.06	0.07									
	2	3450	4420	0.032	0.09	0.12									
	2	2475	3755	0.008	0.04	0.05									
	2	2225	3935	0.006	0.05	0.06									
	2	2655	3190	0.011	0.02	0.03									
	2	2130	3770	0.005	0.05	0.05									
	2	1920	2960	0.003	0.02	0.02									
	2	2400	2390	0.007	0.01	0.01									
	2	2040	3590	0.004	0.04	0.04									

	2	3160	4800	0.022	0.12	0.14									
	2	2795	4200	0.014	0.07	0.08									
	2	2835	4260	0.015	0.07	0.09									
	2	2245	2880	0.006	0.02	0.02									
	2	2585	4820	0.010	0.12	0.13									
	2	2645	4650	0.011	0.11	0.12									
	2	2385	3780	0.007	0.05	0.05									
	2	2255	2960	0.006	0.02	0.02									
	2	2130	3260	0.005	0.03	0.03									
	2	2630	3930	0.011	0.05	0.06									
	Mean TF					**0.08**			**Mean TF**					**0.08**	
	No. of Axles	**1**	**2**	**EF**	**EF**	**TF**			**1**	**2**	**EF**	**EF**	**TF**		
	2	6715	9050	0.46	1.51	1.97			4965	7350	0.14	0.66	0.80		
	2	5210	10975	0.17	3.27	3.44			5570	7040	0.22	0.55	0.77		
	2	7838	10930	0.85	3.22	4.07			4745	8395	0.11	1.12	1.23		
	2	5630	10790	0.23	3.06	3.28			4170	6040	0.07	0.30	0.37		
Large Buses	2	5800	10800	0.26	3.07	3.32			4050	6940	0.06	0.52	0.58		**1.95**
	2	5340	10590	0.18	2.84	3.02			4380	8370	0.08	1.11	1.19		
	2	4835	9105	0.12	1.55	1.67			4720	7915	0.11	0.89	1.00		
	2	5230	9325	0.17	1.71	1.87			7360	10745	0.66	3.01	3.67		
	2	8150	9030	1.00	1.50	2.49			7500	10110	0.71	2.36	3.07		
	2	6665	11125	0.45	3.45	3.90			7180	9240	0.60	1.64	2.24		
	2	5100	8870	0.15	1.40	1.55			6050	10780	0.30	3.05	3.35		
	2	7360	9105	0.66	1.55	2.21			6265	8960	0.35	1.45	1.80		

2	4425	8430	0.09	1.14	1.23			7075	9615	0.57	1.93	2.49	
2	5155	7940	0.16	0.90	1.06			6640	12010	0.44	4.69	5.13	
2	6130	11075	0.32	3.39	3.71			5895	6735	0.27	0.46	0.74	
2	6145	11110	0.32	3.44	3.76			4850	8361	0.12	1.10	1.23	
2	6100	8830	0.31	1.37	1.68			6185	8170	0.33	1.00	1.33	
2	6650	11085	0.44	3.41	3.85			7910	8880	0.88	1.40	2.29	
2	6830	8930	0.49	1.43	1.93			6130	8390	0.32	1.12	1.44	
2	7450	8480	0.69	1.17	1.86			5015	7975	0.14	0.91	1.06	
2	4920	7915	0.13	0.89	1.02			6130	12245	0.32	5.07	5.39	
2	6260	8190	0.35	1.01	1.36			6040	10270	0.30	2.51	2.81	
2	6030	6880	0.30	0.51	0.80			7900	10100	0.88	2.35	3.23	
2	4750	7600	0.11	0.75	0.87			4425	7475	0.09	0.70	0.79	
2	5035	8950	0.14	1.45	1.59			6530	8305	0.41	1.07	1.48	
2	4265	6785	0.07	0.48	0.55								
2	5425	10155	0.20	2.40	2.59								
2	4150	5255	0.07	0.17	0.24								
2	4880	8555	0.13	1.21	1.34								
2	4340	7790	0.08	0.83	0.91								
2	4620	8020	0.10	0.93	1.04								
2	5440	10270	0.20	2.51	2.71								
2	8000	9600	0.92	1.92	2.84								
2	4525	7435	0.09	0.69	0.78								
2	6660	10105	0.44	2.35	2.80								
2	4835	9210	0.12	1.62	1.75								
2	4880	9175	0.13	1.60	1.73								
2	4470	7135	0.09	0.58	0.67								
2	5435	10355	0.20	2.59	2.79								
2	4180	7200	0.07	0.61	0.67								
2	4280	8490	0.08	1.17	1.25								
2	4415	7570	0.09	0.74	0.83								
2	5045	8580	0.15	1.22	1.37								

	2	5115	9425	0.15	1.78	1.93									
	2	5450	7610	0.20	0.76	0.96									
	2	6195	7655	0.33	0.77	1.11									
	2	6480	8450	0.40	1.15	1.55									
	2	5955	10200	0.28	2.44	2.73									
	Mean TF					**1.93**			**Mean TF**				**1.98**		
Small Truck	**No. of Axles**	**1**	**2**	**EF**	**EF**	**TF**			**1**	**2**	**EF**	**EF**	**TF**		**0.11**
	2	2765	3880	0.01	0.05	0.06			2520	4950	0.01	0.14	0.14		
	2	2700	3779	0.01	0.05	0.06			2720	5160	0.01	0.16	0.17		
	2	2375	3770	0.01	0.05	0.05			2520	4650	0.01	0.11	0.11		
	2	1970	2000	0.00	0.00	0.01			2720	5169	0.01	0.16	0.17		
	2	2800	3479	0.01	0.03	0.05			3200	5579	0.02	0.22	0.24		
	2	2520	3840	0.01	0.05	0.06			2500	2770	0.01	0.01	0.02		
	2	3040	5170	0.02	0.16	0.18			2650	5110	0.01	0.15	0.16		
	2	2385	6165	0.01	0.33	0.33			2380	4150	0.01	0.07	0.07		
	2	2429	3454	0.01	0.03	0.04									
	2	2575	3445	0.01	0.03	0.04									
	2	2380	3270	0.01	0.03	0.03									
	2	1855	2135	0.00	0.00	0.01									
	2	2535	4225	0.01	0.07	0.08									
	2	2745	6065	0.01	0.31	0.32									
	2	2535	2930	0.01	0.02	0.03									
	2	2175	3200	0.01	0.02	0.03									
	2	2415	3105	0.01	0.02	0.03									
	2	2555	4040	0.01	0.06	0.07									

	2	2180	2990	0.01	0.02	0.02									
	2	1750	1250	0.00	0.00	0.00									
	2	2185	4945	0.01	0.13	0.14									
	2	2760	5640	0.01	0.23	0.24									
	2	1700	2030	0.00	0.00	0.01									
	2	2455	5400	0.01	0.19	0.20									
	2	2580	5840	0.01	0.26	0.27									
		Mean TF				**0.09**			**Mean EF**				**0.14**		
	No. of Axles	**1**	**2**	**EF**	**EF**	**TF**			**1**	**2**	**EF**	**EF**	**TF**		
		3665	4600	0.04	0.10	0.14			2790	3695	0.01	0.04	0.06		
		3215	5155	0.02	0.16	0.18			3200	4980	0.02	0.14	0.16		
		3770	4500	0.05	0.09	0.14			3225	6245	0.02	0.34	0.37		
		3235	4015	0.02	0.06	0.08			2970	4300	0.02	0.08	0.09		
		4005	6335	0.06	0.36	0.42			2655	4370	0.01	0.08	0.09		
		2715	3800	0.01	0.05	0.06			2995	4220	0.02	0.07	0.09		
Medium truck		3650	5890	0.04	0.27	0.31			2575	4240	0.01	0.07	0.08		**0.23**
		3940	7250	0.05	0.62	0.68			2580	4070	0.01	0.06	0.07		
		3180	6745	0.02	0.47	0.49			3215	4130	0.02	0.07	0.09		
		3740	7065	0.04	0.56	0.61			2505	3410	0.01	0.03	0.04		
		2415	3580	0.01	0.04	0.04			3095	6105	0.02	0.31	0.33		
		3395	5940	0.03	0.28	0.31			3510	4390	0.03	0.08	0.12		
		2710	4270	0.01	0.07	0.09			2800	4315	0.01	0.08	0.09		
		3095	5420	0.02	0.19	0.22			4920	7610	0.13	0.76	0.89		
		2760	4435	0.01	0.09	0.10			2645	4590	0.01	0.10	0.11		
		2795	4795	0.01	0.12	0.13			3560	5200	0.04	0.16	0.20		
		3250	6350	0.03	0.37	0.39			3120	4240	0.02	0.07	0.09		
		3600	5460	0.04	0.20	0.24			3145	4205	0.02	0.07	0.09		

		2560	3270	0.01	0.03	0.04			2620	3670	0.01	0.04	0.05			
		2805	4565	0.01	0.10	0.11			3990	4955	0.06	0.14	0.19			
		3440	6495	0.03	0.40	0.43			2760	3825	0.01	0.05	0.06			
		2735	3980	0.01	0.06	0.07			3435	4645	0.03	0.10	0.14			
		4930	8060	0.13	0.95	1.09			2725	2435	0.01	0.01	0.02			
		3470	7110	0.03	0.58	0.61			2400	3310	0.01	0.03	0.03			
		4040	8440	0.06	1.14	1.20			3845	5810	0.05	0.26	0.31			
		2490	4245	0.01	0.07	0.08			2965	4920	0.02	0.13	0.15			
		2525	3760	0.01	0.05	0.05			3270	4050	0.03	0.06	0.09			
		2735	3760	0.01	0.05	0.06			2800	4900	0.01	0.13	0.14			
		4415	7465	0.09	0.70	0.79			3175	4375	0.02	0.08	0.11			
		3170	3640	0.02	0.04	0.06			2800	5880	0.01	0.27	0.28			
		2605	4280	0.01	0.08	0.09			3245	7890	0.03	0.87	0.90			
		2890	4060	0.02	0.06	0.08			3190	6815	0.02	0.49	0.51			
									2940	4810	0.02	0.12	0.14			
									3670	6195	0.04	0.33	0.37			
									3780	5080	0.05	0.15	0.20			
									3590	5400	0.04	0.19	0.23			
									2795	3420	0.01	0.03	0.04			
									3120	4185	0.02	0.07	0.09			
									2805	6510	0.01	0.41	0.42			
									2580	4000	0.01	0.06	0.07			
									2995	6200	0.02	0.33	0.35			
									2730	4040	0.01	0.06	0.07			
									2620	4878	0.01	0.13	0.14			
	Mean TF					**0.29**			**Mean EF**				**0.19**			
Heavy Truck	**No. of Axles**	**1**	**2**	**3**	**EF**	**EF**	**EF**	**TF**	**1**	**2**	**3**	**EF**	**EF**	**EF**	**TF**	

	3	4715	3735	3515	0.11	0.04	0.03	0.19	4750	4015	3505	0.11	0.06	0.03	0.21	
	3	4835	3405	3435	0.12	0.03	0.03	0.18	5430	4775	3925	0.20	0.12	0.05	0.37	
	3	6640	7755	9570	0.44	0.82	1.89	3.15	4850	3450	3485	0.12	0.03	0.03	0.19	
	3	5000	3625	3390	0.14	0.04	0.03	0.21								
	3	4385	3395	3055	0.08	0.03	0.02	0.13								
	3	4840	3535	3320	0.12	0.04	0.03	0.19								
	3	4770	4275	4068	0.12	0.08	0.06	0.25								**0.43**
	3	4625	3430	3270	0.10	0.03	0.03	0.16								
	3	4540	4120	4260	0.10	0.06	0.07	0.24								
	3	4195	4240	3815	0.07	0.07	0.05	0.19								
	3	4945	4880	4080	0.13	0.13	0.06	0.33								
	3															
	Mean EF					**0.47**			**Mean EF**						**0.25**	
Articulated Truck	**No. of Axles**	**1**	**2**	**3**	**4**	**5**	**6**	**TF**	**1**	**2**	**3**	**4**	**5**	**6**	**TF**	
	6	7980.00	13620	12360.00	9684	10415.00	9800	20.66	8185	12450	12340	6360	8000	9220	14.58	
	6,5	8140.00	12330	12260.00	8565	8240.00	8645	14.81	6385	4860	4925	4810	4440		0.84	
	6	8060.00	14480	13860.00	9375	11430.00	10615	27.65	8500	12160	10655	7455	8635	9700	12.96	
	6,5	9790.00	8685	8690.00	7045	10275.00	10400	10.35	6285	12910	11580	6410	12805		17.12	**9.53**
	6	6430.00	12960	14140.00	12810	8690.00	11100	26.55	6285	4075	3565	3285	3805	3350	0.55	
	5,6	5700.00	3400	3190.00	2550	2480.00		0.31	6390	9770	9279	6670	6640	5950	5.27	
	5,6	5525.00	6760	6710.00	7390	7350.00		2.47	6150	10155	8565	6635	8980	6680	6.29	
	5,6	5560.00	8090	8405.00	6660	11360.00		6.51	6380	4305	3875	3035	2200	2045	0.53	
	6	7300.00	8450	8355.00	6140	8730.00	8620	5.77	5905	9805	9980	8030	7325	8035	7.12	
	6	5210.00	5140	5453.00	4505	3730.00	4025	0.72								
	Mean EF					**11.58**			**Mean EF**						**7.25**	

Table B3: Projection of Cumulative Number of Vehicle in One Direction from (2015-2018) Based On Original Design Data

Cumulative Number of Vehicle in One Direction

Road Section	Year	Cars	Bus	Truck	Truck &Trailer	Total AADT	Cars	Bus	Truck	Truck &Trailer	Total Vehicle	Cumulative No. Vehicle
Addis Ababa-Weliso	2015	861	1735	1335	297	4228	157,172	316,641	243,570	54,229	771,611	771611
	2016	930	1874	1441	321	4566	169,745	341,972	263,056	58,567	833,340	1,604,951
	2017	1005	2024	1557	347	4932	183,325	369,330	284,100	63,252	900,008	2,504,959
	2018	1085	2186	1681	374	5326	197,991	398,876	306,828	68,313	972,008	3,476,967

Road Section	Year	Cars	Bus	Truck	Truck &Trailer	Total AADT	Cars	Bus	Truck	Truck &Trailer	Total Vehicle	Cumulative No. Vehicle
Weliso-Welkite	2015	370	763	1088	108	2329	67,556	139,249	198,533	19,761	425,099	425,099
	2016	400	824	1175	117	2516	72,961	150,388	214,415	21,342	459,106	884,205
	2017	432	890	1269	126	2717	78,798	162,419	231,568	23,050	495,835	1,380,040
	2018	466	961	1370	136	2934	85,101	175,413	250,094	24,894	535,502	1,915,542

Road Section	Year	Cars	Bus	Truck	Truck &Trailer	Total AADT	Cars	Bus	Truck	Truck &Trailer	Total Vehicle	Cumulative No. Vehicle
Welkite-Jimma	2015	295	345	713	86	1438	53,769	62,961	130,057	15,625	262,412	262412
	2016	318	373	770	92	1553	58,071	67,997	140,462	16,875	283,405	545,817
	2017	344	402	831	100	1677	62,716	73,437	151,699	18,225	306,078	851,895
	2018	371	435	898	108	1811	67,734	79,312	163,835	19,683	330,564	1,182,459

Summary of Cumulative Number of Vehicle

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative Number of Vehicle
Addis Ababa-Weliso	708,233	1,426,820	1,097,554	244,361	3,476,967
Weliso- Welkite	304,416	627,469	894,610	89,047	1,915,542
Welkite-Jimma	242,290	283,707	586,052	70,409	1,182,459

Table B4: Projection of Cumulative Number of Vehicle in One Direction from (2015-2018) Based On Current Design Data

Cumulative Number of Vehicle in One Direction

Road Section	Year	Cars	Bus	Truck	Truck &Trailer	Total AADT	Cars	Bus	Truck	Truck &Trailer	Total Vehicle	Cumulative No. Vehicle
Addis Ababa-Weliso	2015	1598	1818	1833	1535	6784	291,635	331,785	334,523	280,138	1,238,080	1,238,080
	2016	1726	1963	1980	1658	7327	314,966	358,328	361,284	302,549	1,337,126	2,575,206
	2017	1864	2121	2138	1790	7913	340,163	386,994	390,187	326,752	1,444,097	4,019,303
	2018	2013	2290	2309	1934	8546	367,376	417,954	421,402	352,893	1,559,624	5,578,927

Road Section	Year	Cars	Bus	Truck	Truck &Trailer	Total AADT	Cars	Bus	Truck	Truck &Trailer	Total Vehicle	Cumulative No. Vehicle
Weliso-Welkite	2015	439	834	852	352	2477	80,118	152,205	155,490	64,240	452,053	452,053
	2016	474	901	920	380	2675	86,527	164,381	167,929	69,379	488,217	940,270
	2017	512	973	994	411	2889	93,449	177,532	181,364	74,930	527,274	1,467,544
	2018	553	1051	1073	443	3120	100,925	191,734	195,873	80,924	569,456	2,037,000

Road Section	Year	Cars	Bus	Truck	Truck &Trailer	Total AADT	Cars	Bus	Truck	Truck &Trailer	Total Vehicle	Cumulative No. Vehicle
Welkite - Gibe River	2015	226	501	466	343	1536	41,245	91,433	85,045	62,598	280,320	280320
	2016	244	541	503	370	1659	44,545	98,747	91,849	67,605	302,746	583,066
	2017	264	584	544	400	1792	48,108	106,647	99,196	73,014	326,965	910,031
	2018	285	631	587	432	1935	51,957	115,179	107,132	78,855	353,122	1,263,153

Summary of Cumulative Number of Vehicle

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative Number of Vehicle
Addis Ababa -Weliso	1,314,140	1,495,060	1,507,396	1,262,331	5,578,927
Weliso -Welkite	361,018	685,853	700,655	289,473	2,036,999
Welkite -Gibe River	185,855	412,005	383,222	282,071	1,263,153

Table B5: Projection of Cumulative ESAL Based on Current Design Data

Road Section No. 1 Alem Gena-Weliso

Traffic and Cumulative ESAL Projection for 4 Year Design Life (2015 - 2018)

Year	Cars	LDV	S/Bus	L/Bus	S/Truck	M/Truck	H/Truck	T & Trailer	Total
2015	628	970	1258	560	758	1075	851	684	6784
2016	678	1048	1359	605	819	1161	919	739	7327
2017	732	1131	1467	653	884	1254	993	798	7913
2018	791	1222	1585	705	955	1354	1072	862	8546
Traffic Factor	0	0	0.21	2.75	0.06	0.55	2.95	7.15	

Year	ESAL/Annum (million)								TOTAL ESAL
2015	0.000	0.000	0.048	0.281	0.008	0.108	0.458	0.893	1.796
2016	0.000	0.000	0.052	0.304	0.009	0.117	0.495	0.964	1.940
2017	0.000	0.000	0.056	0.328	0.010	0.126	0.534	1.041	2.095
2018	0.000	0.000	0.061	0.354	0.010	0.136	0.577	1.124	2.263
								Cumulative ESAL=	8.094

Road Section No. 2 Weliso–Welkite

Traffic and Cumulative ESAL Projection for 4 Year Design Life (2015 - 2018)

Year	Cars	LDV	S/Bus	L/Bus	S/Truck	M/Truck	H/Truck	T & Trailer	Total
2015	64	375	781	53	409	443	285	67	2477
2016	69	405	843	57	442	478	308	72	2675
2017	75	437	911	62	477	517	332	78	2889
2018	81	472	984	67	515	558	359	84	3120
Traffic Factor	0	0	0.08	1.95	0.11	0.23	0.43	9.53	

Year	ESAL/Annum (million)								TOTAL ESAL
2015	0.000	0.000	0.011	0.019	0.008	0.019	0.022	0.117	0.196
2016	0.000	0.000	0.012	0.020	0.009	0.020	0.024	0.126	0.212
2017	0.000	0.000	0.013	0.022	0.010	0.022	0.026	0.136	0.229
2018	0.000	0.000	0.014	0.024	0.010	0.023	0.028	0.147	0.247
								Cumulative ESAL=	0.883

Road Section No. 3 Welkite- Gibe River

Traffic and Cumulative ESAL Projection for 4 Year Design Life (2015 - 2018)

Year	Cars	LDV	S/Bus	L/Bus	S/Truck	M/Truck	H/Truck	T & Trailer	Total
2015	52	174	397	104	200	266	217	126	1536
2016	56	188	429	112	216	287	234	136	1659
2017	61	203	463	121	233	310	253	147	1792
2018	66	219	500	131	252	335	273	159	1935
Traffic Factor	0	0	0.08	1.95	0.11	0.23	0.43	9.53	

Year	ESAL/Annum (million)								TOTAL ESAL
2015	0.000	0.000	0.006	0.037	0.004	0.011	0.017	0.219	0.294
2016	0.000	0.000	0.006	0.040	0.004	0.012	0.018	0.237	0.318
2017	0.000	0.000	0.007	0.043	0.005	0.013	0.020	0.256	0.343
2018	0.000	0.000	0.007	0.047	0.005	0.014	0.021	0.276	0.371
								Cumulative ESAL=	1.326

Table B6: Summery of Cumulative ESAL from 2015-2018 Based on Current Design Data

Section	**Length**	**Cumulative ESAL/Annum (million)**
Addis Ababa- Weliso	km 14-114	8.094
Weliso - Welkite	km 114-155	0.883
Welkite – Gibe River	km 155-185	1.326

Table B7: Projection of Cumulative ESAL Based on Original Design Data

Cumulative ESAL/Million from 2015-2018

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative ESAL/million
Addis Ababa-Weliso	708,233	1,426,820	1,097,554	244,361	
Equivalence Factor	0.00045	0.41	2.87	5.38	
ESAL/million	**0.000**	**0.585**	**3.150**	**1.315**	**5.050**

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative ESAL/million
Weliso-Welkite	304,416	627,469	894,610	89,047	
Equivalence Factor	0.00045	0.41	2.87	5.38	
ESAL/million	**0.000**	**0.257**	**2.568**	**0.479**	**3.304**

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative ESAL/million
Welkite-Jimma	242,290	283,707	586,052	70,409	
Equivalence Factor	0.00045	0.41	2.87	5.38	
ESAL/million	**0.000**	**0.116**	**1.682**	**0.379**	**2.177**

Table B8: Summary of Projection of Cumulative ESA from 2015-2018 Based on Original Design Data

Summary of Cumulative ESAL/Million from 2015-2018

Road Section	Cars	Bus	Truck	Truck &Trailer	Cumulative ESAL/million
Addis Ababa-Weliso	0.000	0.585	3.150	1.315	5.050
Weliso-Welkite	0.000	0.257	2.568	0.479	3.304
Welkite-Jimma	0.000	0.116	1.682	0.379	2.177

APPENDEX C- ROAD CONDITION SURVEY ANALYSIS

Table C1: Road Condition Survey

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey | Date | Inspector | District | Section | Page 1 of 20

Road No | Start Km | Segment No | Start Km | Direction | Calibration Factor

		Kilometre 0+000km	Km 1				Km 2				Km 3				Km 4				Km 5				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt	1	2	3	3			1	3	2	3	2	3	2	3	1	3					
		Scour																					
	Shoulder	Deform	2	3	2	3	2	3	2	3	1	2	2	2			1	2	1	2	1	3	
		Scour							1	3	1	3			1	2							
		Vegetation																					
	Edge Step		1	3			1	3	3	3	2	3	2	3	1	3	1	3	2	3	1	3	
	Edge Damage								1	3	2	3			2	3	2	3	1	2	1	3	
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator																					
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage						1	2	3	3	3	3			1	1	2	3			1	3	
	Edge Step		1	3			1	2	1	3	2	3	1	3	1	2	1	3	2	3	2	3	
	Shoulder	Vegetation																					
		Scour							1	3	3	3	3	2									
		Deform	3	3	3	3	2	3	2	3	2	2			2	2	2	3	3	2	3	3	
	Side Drain/Turnout	Scour																					
		Silt	2	3	3	3	2	2	1	3			2	3	2	3	2	3					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey	Date	Inspector	District	Section	Page 2 of 20
Road No / Start Km	Segment No	Start Km	Direction		Calibration Factor

		Kilometre	Km 6				Km 7				Km 8				Km 9				Km 10				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform			2	3	2	3	3	3													
		Scour													1	1					1	1	
		Vegetation																					
	Edge Step		1	3			1	3	1	3	1	3	1	3			1	3	1	3			
	Edge Damage		1	2	1	3																	
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator																					
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage																						
	Edge Step		1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3			
	Shoulder	Vegetation																					
		Scour	1	3	2	3	1	3															
		Deform	2	3	3	3	2	3	3	3					3	3							
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector						District				Section						Page 3 of 20
Road No		Start Km	Segment No				Start Km								Direction								Calibration Factor
		Kilometre	Km 11				Km 12				Km 13				Km 14				Km 15				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt	1	1	2	1									2	3	2	2			2	3	
		Scour													1	3	2	3					
	Shoulder	Deform													2	3	3	3	3	3	2	3	
		Scour																					
		Vegetation															1	2	1	3			
	Edge Step				1	3					1	3	1	3	1	3							
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator																					
		Block																					
		Longitudinal													1	1							
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes										3	3											
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage																1	1					
	Edge Step				1	3	1	3					1	3	1	3	1	3	1	3	1	3	
	Shoulder	Vegetation																					
		Scour															1	3	1	3			
		Deform			3	3	3	3	1	1	1	3	3	3	2	3	2	3	3	3	3	3	
	Side Drain/Turnout	Scour			1	1	1	1	1	2									1	3	1	3	
		Silt																			1	2	
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey	Date		Inspector	District	Section	Page 4 of 20
Road No	Start Km	Segment No	Start Km	Direction		Calibration Factor

			Km				Km				Km				Km				Km				Action Required
		Kilometre	0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt	1	1			1	2															
		Scour																					
	Shoulder	Deform	1	3	1	3																	
		Scour															1	1	1	1			
		Vegetation																					
	Edge Step		1	3			1	3	1	3	1	3	1	3	1	3	1	3	1	3			
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator																					
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage																						
	Edge Step		1	3	1	3	1	3									1	3	1	3	1	3	
	Shoulder	Vegetation																					
		Scour															1	1	1	2			
		Deform	2	3													2	2	2	3			
	Side Drain/Turnout	Scour																					
		Silt	1	1																			
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector					District				Section					Page 5 of 20
Road No		Start Km	Segment No				Start Km								Direction								Calibration Factor
		Kilometre	Km 21				Km 22				Km 23				Km 24				Km 25				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step		1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator																					
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage																						
	Edge Step		1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	
	Shoulder	Vegetation																					
	-	Scour	1	1							2	1											
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector						District				Section						Page 6 of 20
Road No		Start Km	Segment No				Start Km						Direction										Calibration Factor
		Kilometre	Km 26				Km 27				Km 28				Km 29				Km 30				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step		1	3	1	3			2	1	1	2	1	3	2	3							
	Edge Damage								3	3													
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator											3	3	3	3							
		Block																					
		Longitudinal			1	1			1	3	1	3	1	1	2	1	1	2					
		Transverse																					
	Raveling										1	2	1	2	1	3							
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage								3	3													
	Edge Step		1	3	1	3	1	2	2	2	1	3	1	3	1	3							
	Shoulder	Vegetation																					
		Scour																					
		Deform	2	3	3	3			2	3													
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey	Date	Inspector	District	Section	Page 7 of 20
Road No / Start Km	Segment No	Start Km	Direction		Calibration Factor

		Kilometre	Km 31				Km 32				Km 33				Km 34				Km 35				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																	1	3	1	3	
		Scour																					
		Vegetation																					
	Edge Step		1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator																					
		Block																					
		Longitudinal					1	1	1	1	1	1	1	1	1	2	3	2	1	1			
		Transverse					1	1							1	1							
	Raveling												2	1									
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Right	Edge Damage																						
	Edge Step		1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	
	Shoulder	Vegetation																					
		Scour																					
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector						District				Section						Page 2 of 20
Road No		Start Km	Segment No				Start Km						Direction										Calibration Factor
		Kilometre	Km 36				Km 37				Km 38				Km 39				Km 40				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step						1	1	1	1	1	3	2	3	2	3	1	3	1	3			
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator																					
		Block																					
		Longitudinal					2	1	2	1	1	1	1	1	1	1							
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Right	Edge Damage																						
	Edge Step										1	3	2	3					2	3	1	3	
	Shoulder	Vegetation																					
		Scour																					
		Deform									1	2	1	2	1	2			3	3			
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector						District				Section				Page 9 of 20
Road No		Start Km	Segment No				Start Km						Direction								Calibration Factor

			Km 41				Km 42				Km 43				Km 44				Km 45				Action Required
		Kilometre	0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step		1	3	1	2																	
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator													1	1							
		Block									1	1											
		Longitudinal	1	1	2	1	1	1			1	1	1	1									
		Transverse																					
	Raveling		2	1	2	1					1	1	1	1	1	1	1	1					
	Stripping/Fretting		2	1																			
	Potholes		2	1	2	1											1	1					
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Right	Edge Damage																						
	Edge Step				1	2	1	2															
	Shoulder	Vegetation																					
		Scour	1	1																			
		Deform																	1	3	1	3	
	Side Drain/Turnout	Scour	1	1																			
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector						District				Section						Page 10 of 20
Road No		Start Km	Segment No				Start Km								Direction								Calibration Factor
		Kilometre	Km 46				Km 47				Km 48				Km 49				Km 50				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step						1	2															
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	1	2	1	2	2	2	1	3	1	3	1	3	1	2	1	2	1	2	1	2	
		Block	1	2	1	2	1	1															
		Longitudinal																					
		Transverse																					
	Raveling												2	3	1	1	1	1	1	1	1	2	
	Stripping/Fretting																						
	Potholes										1	1	1	1	2	1	2	1	2	1	1	1	
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Right	Edge Damage																						
	Edge Step						1	2			1	3											
	Shoulder	Vegetation																					
		Scour																					
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey		Date		Inspector		District		Section		Page 11 of 20	
Road No		Start Km		Segment No		Start Km		Direction		Calibration Factor	

		Kilometre	Km 51				Km 52				Km 53				Km 54				Km 55				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step		1	3	1	3	1	3	1	3	1	3											
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	1	1	1	1	1	1									1	2	1	1	1	1	
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling		1	1	1	2			1	1	1	2			1	2	1	1	1	2			
	Stripping/Fretting																						
	Potholes		1	2	1	2																	
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage																						
	Edge Step		1	3	1	3	1	3	1	3	2	3	1	3									
	Shoulder	Vegetation																					
		Scour																					
		Deform																	2	1	2	1	
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector				District				Section						Page 12 of 20
Road No		Start Km	Segment No				Start Km						Direction								Calibration Factor
		Kilometre	Km 56				Km 57				Km 58				Km 59				Km 60			Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step																						
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	1	2	1	2	1	3	1	1			1	1	1	2			1	1	1	1	
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling		1	2	1	2	1	1	2	3	1	2	1	3	1	3							
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Right	Edge Damage																						
	Edge Step												1	3	2	2	1	3	1	3			
	Shoulder	Vegetation																					
		Scour																					
		Deform													1	3							
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector								District				Section				Page 13 of 20
Road No		Start Km	Segment No				Start Km								Direction								Calibration Factor
		Kilometre	Km 61				Km 62				Km 63				Km 64				Km 65				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step																						
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator			1	1	2	3	2	3	2	3	1	3	1	3	1	3	1	2	2	3	
		Block											1	1	1	1							
		Longitudinal																	3	1	3	1	
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage						3	3															
	Edge Step																						
	Shoulder	Vegetation																					
		Scour																					
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector								District				Section				Page 14 of 20
Road No		Start Km	Segment No				Start Km								Direction								Calibration Factor
		Kilometre	Km 66				Km 67				Km 68				Km 69				Km 70				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform	2	3	2	3	1	2	2	2							2	2	2	2	2	2	
		Scour													2	1	1	2					
		Vegetation									2	3											
	Edge Step		2	3	2	3	2	2	3	3	2	2	2	2	2	2	2	2	2	3	2	3	
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	2	3	2	3	2	3	2	3	2	3	1	3	1	2	1	3					
		Block	1	3			1	3	1	3	1	3											
		Longitudinal									1	1	1	1	1	1	1	1	1	2			
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes		2	3	2	3	1	2	1	2													
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Right	Edge Damage		2	2	2	3	2	3	2	3	3	3	2	3	2	3	2	3	2	1	1	1	
	Edge Step		2	3	3	3	3	3	2	3	3	3	2	2	2	2	1	2	1	3	2	2	
	Shoulder	Vegetation																					
		Scour													2	2	1	2	2	1			
		Deform	2	3	3	3	2	2							2	3	2	3	2	3			
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector				District				Section					Page 15 of 20
Road No		Start Km	Segment No				Start Km								Direction					Calibration Factor
		Kilometre	Km 71				Km 72				Km 73				Km 74				Km 75				Action Required

Side	Item	Type	Km 71 0-500 Sev	Km 71 0-500 Ext	Km 71 500-1000 Sev	Km 71 500-1000 Ext	Km 72 0-500 Sev	Km 72 0-500 Ext	Km 72 500-1000 Sev	Km 72 500-1000 Ext	Km 73 0-500 Sev	Km 73 0-500 Ext	Km 73 500-1000 Sev	Km 73 500-1000 Ext	Km 74 0-500 Sev	Km 74 0-500 Ext	Km 74 500-1000 Sev	Km 74 500-1000 Ext	Km 75 0-500 Sev	Km 75 0-500 Ext	Km 75 500-1000 Sev	Km 75 500-1000 Ext	Action Required
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform	2	3	1	1			1	1	1	1											
		Scour																					
		Vegetation																					
	Edge Step		3	3			1	2	1	2	1	2	1	2	1	3							
	Edge Damage		2	1	1	2	2	3	1	3	1	1	1	2	1	1	1	1	1	2	2	1	
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	1	1	1	2	2	2	2	1	1	1	1	1	1	2	1	2	2	2	2	3	
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	2	3	2	3	2	3	3	3	3	3	
Right	Edge Damage		3	2	1	2			1	1					1	1			2	1	2	2	
	Edge Step		2	2	2	3	1	1							1	1							
	Shoulder	Vegetation																					
		Scour																					
		Deform	2	3	2	2	1	2	1	2	1	2	1	1	1	1	1	1	2	2	2	2	
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector				District				Section								Page 16 of 20
Road No		Start Km	Segment No				Start Km						Direction										Calibration Factor
		Kilometre	Km 76				Km 77				Km 78				Km 79				Km 80				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step																						
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	1	1							1	1	1	1									
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes												1	1	1	1	1	1					
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	3	3	2	3	3	3	3	3	3	3	2	3	2	3	2	3	
Right	Edge Damage																						
	Edge Step																						
	Shoulder	Vegetation																					
		Scour																					
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey	Date		Inspector		District	Section	Page 17 of 20
Road No	Start Km	Segment No	Start Km		Direction		Calibration Factor

		Kilometre	Km 81				Km 82				Km 83				Km 84				Km 85				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step																						
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	2	2	1	2	2	3	1	2	1	1	1	1									
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes						1	1															
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Right	Edge Damage																						
	Edge Step																						
	Shoulder	Vegetation																					
		Scour																					
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector							District				Section					Page 18 of 20
Road No		Start Km	Segment No				Start Km								Direction								Calibration Factor
		Kilometre	Km 86				Km 87				Km 88				Km 89				Km 90				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step																						
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	2	1	1	1	1	2															
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage																						
	Edge Step																						
	Shoulder	Vegetation																					
		Scour																					
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey	Date	Inspector	District	Section	Page 19 of 20
Road No	Start Km	Segment No	Start Km	Direction	Calibration Factor

		Kilometre	Km 91				Km 92				Km 93				Km 94				Km 95				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step		1	1	1	3																	
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	1	1	1	1																	
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
Right	Edge Damage																						
	Edge Step		1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	
	Shoulder	Vegetation																					
		Scour																					
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

Ethiopian Road Authority - Paved Road Condition Form

Paved Road Condition Survey			Date				Inspector						District				Section						Page 20 of 20
Road No		Start Km	Segment No				Start Km								Direction								Calibration Factor
		Kilometre	Km 96				Km 97				Km 98				Km 99				Km 100				Action Required
			0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		0-500		500-1000		
			Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	Sev	Ext	
Left	Side Drain/Turnout	Silt																					
		Scour																					
	Shoulder	Deform																					
		Scour																					
		Vegetation																					
	Edge Step																						
	Edge Damage																						
Carriageway	Rutting																						
	Corrugation																						
	Cracking	Alligator	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
		Block																					
		Longitudinal																					
		Transverse																					
	Raveling																						
	Stripping/Fretting																						
	Potholes																						
	Bleeding																						
	Failures																						
	Safety																						
	Lane Marking		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Right	Edge Damage																						
	Edge Step																						
	Shoulder	Vegetation																					
		Scour																					
		Deform																					
	Side Drain/Turnout	Scour																					
		Silt																					
Notes																							

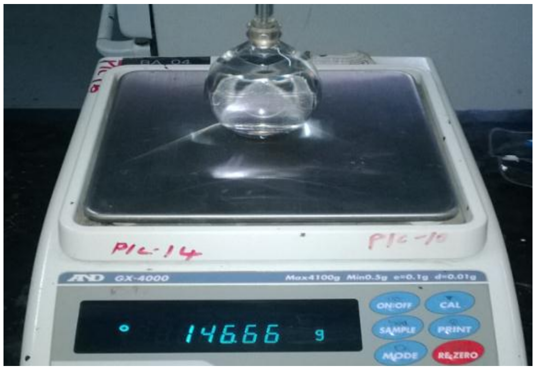
Table 4.5: Summary of Severity and Extent of Defects

Station	**Total Number of Defect Severity**		
	Low	**Medium**	**High**
0 -5	29	38	11
6 – 10	22	15	4
11 – 15	27	19	8
16 – 20	23	12	0
21 – 25	21	11	0
26 – 30	18	16	5
31 - 35	30	1	11
36 - 40	13	6	11
41 – 45	19	5	10
46 - 50	22	5	10
51 – 55	25	13	0
56 - 60	18	2	10
61 – 65	7	14	3
66 – 70	20	44	16
71 – 75	32	19	9
76 – 80	6	6	4
81 – 85	5	2	10
86 – 90	2	11	0
91 – 95	14	10	0
96 - 100	8	0	10
Subtotal	**361**	**249**	**132**

Station	**Total Number of Defect Extent**		
	Low	**Medium**	**High**
0 -5	1	15	62
6 – 10	2	1	38
11 – 15	7	4	43
16 – 20	5	2	28
21 – 25	2	0	30
26 – 30	4	6	29
31 - 35	8	2	32
36 - 40	7	3	20
41 – 45	18	3	13
46 - 50	10	12	15
51 – 55	10	7	21
56 - 60	5	7	18
61 – 65	5	1	18
66 – 70	8	23	49
71 – 75	20	22	18
76 – 80	6	0	10
81 – 85	3	3	11
86 – 90	2	1	10
91 – 95	3	0	21
96 - 100	8	0	10
Subtotal	**134**	**112**	**496**

APPENDEX D- PHOTO GALLERY

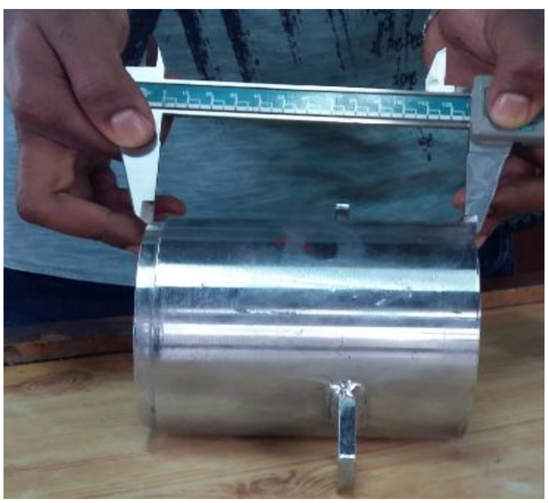
Specific Gravity test



A. Weighting water plus pycnometer B. fine soil plus water inside pycnometer

C. Boiling the pycnometer using electronic stove D. Measuring Temperature

Permeability test



A. Measuring the permeameter B. Compacting the soil specimen

C. Constant Failing Head D. $Q_{in} = Q_{out}$ (if the specimen is fully saturated)

Di Cone Penetration Test

A .Measuring position of the test from the edge of asphalt

B. Record field reading

C. operating DCP