ASSESMENT OF CAUSE OF ROAD PAVEMENT FAILURE ALONG TEJI-TULU BOLO ROAD

EMEBET MULUNEH DABA

A Thesis Submitted to the Department of Civil Engineering School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Civil Engineering (Geotechnical Engineering)

Office of Graduate Studies

Adama Science and Technology University

August, 2023

Adama, Ethiopia

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Advisor

YADETA CHIMDESA (PhD)

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Declaration

I hereby declare that this Master Thesis entitled **"Assessment of Cause of Road Pavement Failure along Teji-Tulu Bolo Road"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

Emebet Muluneh		08/18/2023
Name of student	Signature	Date

Recommendation

we, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled **"Assessment of Cause of Road Pavement Failure along Teji-Tulu Bolo Road"** prepared under our guidance by Emebet Muluneh submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Civil Engineering (Geotechnical Engineering). Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

______________________________	___________________	_________________
Major Advisor	Signature	Date
______________________________	___________________	____________
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Approval Page

We, the advisors of the thesis entitled **"Assessment of Cause of Road Pavement Failure along Teji-Tulu Bolo Road"** and developed by Emebet Muluneh, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

______________________________	____________________	__________
Major Advisor	Signature	Date
______________________________	____________________	__________
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Approval of Board of Reviewers

We, the undersigned, members of the Board of Examiners of the thesis by Emebet Muluneh have read and evaluated the thesis entitled **"Assessment of Cause of Road Pavement Failure along Teji-Tulu Bolo Road"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Civil Engineering (Geotechnical Engineering).

______________________	______________	____________
Chairperson	Signature	Date
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Internal Examiner	Signature	Date
Dr. Tezera Firew Azmatch		24/09/2023
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Acronyms

AASHTO - American Association of State Highway and Transportation Officials

AADT- Average Annual Daily Traffic

ASTM - American Society of Testing and Materials

ERA - Ethiopian roads authority

Abbreviations

A.S.L – Above mean sea level

BS - British Standard

CBR - Californian Bearing Ratio

DC – Design class

E - East

FDT - Field dry density

F - Percentage of material that passes No. 200 sieve

GB1 - Graded crushed stone GB1

GI - group index

KM - kilometer

LL - Liquid Limit

MDD - Maximum Dry Density

MM - Millimeter

NMC- Natural Moisture Content

N - North

OMC - Optimum Moisture Content

PI- Plasticity Index

Abstract

A road pavement is a structure of superimposed layers of selected and processed materials that are placed on the basement soil or subgrade. Pavement deterioration process starts directly after opening the road to traffic. This process starts very slowly so that it may not be noticeable, and over time it accelerates at faster rates. Teji-Tulu Bolo Road is one of the roads which failed before reaching serving time and this research aimed at assessing the Causes of Pavement Failure along this road. To achieve the objectives of the research the sampling technique that was used is the nonprobability purposive sampling method. The idea is to collect soil samples at different locations of the road with the worst failure rates. Accordingly, 17 sample locations/stations of test pits that represent the type of failures observed along the road section were selected. And the sampling of the soil was accompanied with field density tests for each subsurface layer. To determine the causes of failures the laboratory tests such as grading analysis, Atterberg limits test, Soil compaction, CBR tests and Moisture content determination were performed. To check if the road failure was associated with traffic or not the traffic count (AADT) from 2014-2022 G.C was obtained and compared with the design AADT. From the comparison of field and lab results with ERA, 2013 Standard Technical Specification and Method of Measurement, most of the test results didn't complied with the requirement. The difference between the NMC and OMC for the subgrade ranges between 13.6 and 2.69 percent and swell of sub base range from 0.55%-1.2% which shows expansive sub base material. From the gradation test done on base course the material was finer at some spots and courser at other spots than ERA requirements. And also the base material shows CBR of ranges from 80%-185% and swell between 0.4 % and 0.85% which are an indication of presence of expansive soil in base course crushed stone. Additionally the soil exist under the road structure was black cotton soil and didn't replaced to required depth through full stretch of this segment. From the secondary data obtained from ERA the existing traffic was higher than the design traffic the road is capable to carry. The study has recommend to reconstruct the road with provision of extra depth, adopting mitigation measure for existing expansive soil, solving drainage issues and by reusing the material.

Keywords*: subgrade, pavement, CBR, AADT, OMC and NMC.*

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

A road pavement is a construction made up of layers of carefully chosen and processed materials that are positioned on the subgrade or basement soil. flexible pavements built for heavy vehicles are made up of asphaltic layers (wearing, binder, and base courses) and a solid sub base layer that are laid atop a solid, compacted subgrade foundation (Shiferaw & Dessalegn , 2019).

Pavements make up a larger portion of the infrastructure system in contemporary society, and their proper operation is necessary for development. Pavements lose their effectiveness with time, just like other kinds of infrastructure assets. To ensure that these capital-intensive assets work as envisaged, it is necessary to discover measures to conserve them (Ashebir & Bekele, 2020).

The process of pavement deterioration begins as soon as the road is made accessible to traffic. This process begins extremely slowly so that it would not be noticeable and then quickly speeds up as time goes on. The road must be planned, designed, built, and maintained using best practices to ensure that the danger of early deterioration is kept to a minimum. This can be done by looking at pavements that have prematurely failed, with the goal of figuring out the reasons why so that it can be avoided in the future. In-depth examinations may provide a clearer knowledge of pavement failures that could be helpful in lowering future expenditures related to pavement failures. In many cases, poor maintenance and insufficient evaluation procedures are the direct causes of pavement structure collapse. Finding a way to reduce the cost of maintenance on a tight budget is crucial (S. & M., 2010).

It is crucial to take into account a streamlined procedure for inspecting and assessing pavement failures for this reason. In Sudan, the examination of paving failures is frequently carried out in a way that is rather informal. The expense of the evaluation is not justified by the significance of the route where the failure is occurring or by the size of the failure, which is the main justification for this course of action. Additionally, some agencies might be reluctant to spend money on an evaluation of pavement failure rather than spending it for actual maintenance.

Due to these circumstances, the investigator's prior experience is relied upon when assessing the failure, deciding what testing is necessary, and coming to a final conclusion regarding the proper maintenance work. This indicates that if the wrong testing is used or the investigator lacks experience, the failure may be mistakenly diagnosed (Zumrawi M. M., 2015).

Both direct and indirect effects on the traveling public could result from the pavement flaws. The cost of maintaining the damaged areas is one of the primary effects. The project's benefits, which include decreased vehicle operating costs, travel times for road users, access to markets, social and economic facilities, and encouragement of market integration between Ethiopia's rural and urban areas in support of the government's program to reduce poverty, would also be greatly impacted by indirect effects (Shiferaw & Dessalegn , 2019).

Teji-Tulu Bolo Road is one of the roads which failed before reaching serving time (start manifesting failure immediately after one year of construction period). This road is a part of Addis Ababa to Jima Road starts in the center of Addis Ababa at Mexico Square. Under the Project, the rehabilitation work commences at the junction with the City’s Ring Road and terminates in Jima. The general direction of the road is to the southwest and it traverses Shewa and Kefa zone, in Oromia Administrative region.

A feasibility study for a project to rehabilitate the road between Addis Ababa and Jima was completed by Planco Consulting GmbH and DIWI Consult International GmbH in February 1995. Following this, detailed engineering designs were prepared by Studio Pietrangeli (SP) of Rome between May 1995 and September 1997 and tender documentation was prepared and the project tendered, in two separate Lots, in November 1997. Tenders were received in late February 1998 and Studio Pietrangeli undertook tender evaluation and provided recommendations for the award of the contract. Following posttender, pre-contract negotiations, the joint venture of Dragados / J & P (Hellas) S.A. Joint Venture were awarded the Contract.

The road is 26 km length and very important for transportation of goods, Ethiopian Electric Power Corporation (EEPCO) tower, pole and other heavy load from Addis Ababa to the new Gilgel Gibe I switchyard and agricultural products. The road segment is trunk road which belongs to the traffic class T_4 with Total ESAs $2.13*10^6$ flexible pavement.

To conserve the road network availability and comfort for the road users, road condition survey and detail geotechnical disquisition must be carried for better maintenance and reconstruction.

1.2 Statement of the Problem

In Ethiopia newly built roads frequently deteriorate in various ways right away after being opened to traffic for a variety of causes. Road pavement may deteriorate due to fatigue cracking, potholes, corrugations, and other issues. Due to the possibility of early breakdown and traffic dangers, these deteriorations have an impact on pavement safety and riding quality. Prior to doing maintenance and rehabilitation, determining the reasons of deterioration is a critical task for efficient resource usage and country budget preservation (Desta Degu, 2022).

The Teji-Tulu Bolo project road indicates that it undergoes failure before it achieves its design life. The planned road has undergone numerous maintenance methods to make it practical, but they have all continually failed. Before selecting a new maintenance approach for a failing road pavement, it is crucial to determine the type of failure and its source.

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of this research is to assess the Causes of Pavement Failure along Teji- Tulu Bolo Road.

1.3.2 Specific objective

The specific objectives of this study are:

- To identify the type of failure and categorizes by the level of severity of the selected stretch.
- To identify the cause of failures through testing the required properties for evaluation with respect to ERA 2013 standard specifications at highly severe station.
- To give recommendation of remedial measures based on the results.

1.4 Significance of the Study

This study examines the effects of inappropriate subgrade, sub base, and base course on the performance of a pavement/wearing course, as well as the main reason for failure along the Teji-Tulu bolo road segment and their relationship to the geotechnical properties of the soil used as a construction material.

Governmental organizations like consultants and road authorities will use it for the design of new highways. As this analysis would suggest appropriate road remedial measures, it will also help resolve difficulties with failing roads. Researchers will also make use of the study; they will review the literature for subsequent studies using the findings.

1.5 Scope of the Study

Using the Teji-Tulu bolo route as a case study, the study assessed the shortcomings of flexible pavement roads in the south-west shoa zone region. Laboratory testing and soil samples from the worst road failures were collected for the intended use. The pertinent laboratory tests include the CBR test, compaction tests, Atterberg limit tests, and particle size distribution (grading) was performed. After that, the test results are contrasted with the requirements. A conclusion regarding the cause of the road failure is reached also after checking secondary data on the traffic count (AADT) obtained from ERA. And feasible recommendations are produced on what shall be the best acceptable remedy methods.

1.6 Organization of the study

- The first chapter covers the introduction; the background of the study, the problem statement, the objectives of the research, its significance, its scope, and its organization.
- Chapter Two deals with review of related literature; factor affecting pavement failure, pavement condition survey, pavement distress type and severity description, material sources and requirements of road structures and AASHTO soil classification system.
- The topics covered in Chapter Three was overview of research methodology include the study area, research population, dependent and independent variables, research design, sampling techniques and procedure, as well as the data gathering and analysis processes.
- Chapter Four examines evaluations of test findings obtained from laboratory tests to see whether they adhere to the specifications outlined in the design specification.
- Chapter Five finally deals with the conclusions developed from analyzed results and technical recommendations forwarded to the drawback arise on Teji-Tulu bolo road segments.

2 CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Pavement failure is characterized as a decline in serviceability caused by the formation of cracks and ruts. We must first examine the factors that lead to flexible pavement breakdown before moving on to maintenance measures. Flexible pavement failures can be caused by a variety of factors or a combination of factors. The lifespan of maintenance projects and the strengthening layer will both be extended by applying correction to the current surface (Adlinge & Gupta, 2013).

Khaing and Htwe (2014), conducted research on "failures and maintenance of flexible pavement" for the special significance that the nation's transportation infrastructure plays in their economic development. Communication for people's movement, which is also necessary for the distribution of various items in the nation, will be made possible by means of an effective transportation system that is secure, swift, comfortable, and convenient. Fundamentally, this is critical for the advancement of the economy, society, and environment. They added that a robust highway system is crucial for a growing nation to catch up to modern civilization.Highway upkeep is crucial for effective traffic management overall. Numerous road faults and a poor maintenance system are the primary causes of accidents. Therefore, in order to be a successful engineer, a person must not only be able to construct the road but also have the necessary skills to keep it in good condition.

Pavement failures can be classified as structural, functional, or materials problems, according to Woods & Adeox (2002). A structural failure is when a portion of pavement can no longer support its own weight, necessitating expensive maintenance or replacement. A more general phrase is "functional failure," which can refer to the loss of any pavement function, including skid resistance, structural strength, usability, or passenger comfort. A materials failure occurs when one or more of the component materials disintegrates or loses its material properties.

The quality of highway pavement is greatly influenced by the subgrade materials, Poor soil properties/effect of subsurface courses materials, Effects of bad drainage on the road, the general geology of the area, and the materials used for construction, Inadequacies in the pavement or surface layer, Effect of stability/slope failure (Asnake, 2015).

2.2 Factors affecting pavement failures

There are different factors which affect the pavement failure. The major ones are listed below.

2.2.1 Heavy traffic loading

The main designing factor is traffic loading. The entire weight that the pavement will bear during its design life is known as the traffic load. Both the size of the individual wheel loads and the frequency with which these loads are delivered contribute to the wear and tear of paved roads brought on by traffic (ERA, Ethiopian Roads Authority 2013 Pavement Design Manual Volume I Flexible Pavements, 2013).

The main element affecting pavement performance is traffic. According to Adlinge and Gupta (2013), the frequency, configuration, and amplitude of the loading caused by heavy vehicles have a significant impact on the performance of pavements.

2.2.2 Environmental variation

The environment has a significant impact on the pavement's material choice and thickness design. Climate has a significant impact on pavement performance as well and can be somewhat taken into account in design (ERA, Ethiopian Roads Authority 2013 Pavement Design Manual Volume I Flexible Pavements, 2013) .

Temperatures affect the pavement failure by expanding and contracting during when change is occurred on the project location. Depending on the magnitude of expanding and contracting the pavement material which used to bind together will become weak then the degree of failure will increase. Similarly, Water or rainfalls also affect the pavement. To mitigate the effect of water or rainfall there must be proper drainage facility. Moisture (water) can seep into the pavement structure through surface cracks and holes, laterally through the subgrade, and through capillary action from the underlying water table (Adlinge & Gupta, 2013).

2.2.3 Poor Drainage

The ability of a given pavement to endure the effects of traffic and environment is significantly influenced by its drainage system (Abhijit & Jalindar, 2011). The pavement and the water handling system, which consists of the pavement surface, shoulders, drains, and culverts, are both parts of the highway drainage system. Poor drainage has a highly negative effect on the surface of roads. It results in pavement distresses and degeneration, which have an impact on pavement safety and ride quality (Zumrawi M. M., 2014).

When Abhijit & Jalindar (2011) looked at how poor drainage affected the condition of road pavement, they discovered that a rise in moisture content reduced the pavement's strength. Due to water's degradation of the pavement's composition, a rise in moisture content causes a decrease in pavement strength. When they are freed from their bonds, their connection to one another will weaken.

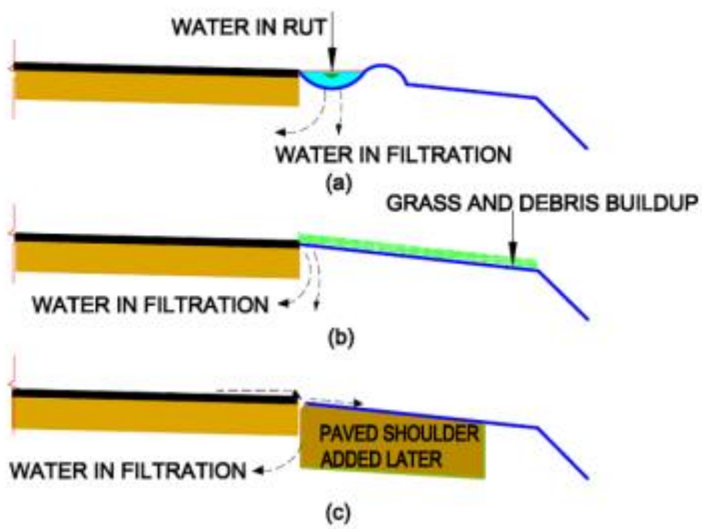


Figure 1: Typical drainage deficiencies associated with unsealed shoulders (ERA, Ethiopian Roads Authority 2013 Pavement Design Manual Volume I Flexible Pavements, 2013)

According to Farukh and Ravekar (2016), water-related damage to pavement can result in any one or more of the following deteriorations: a) reduced base, sub base, and sub grade strength; b) differential swelling in expansive sub-grade soils; c) stripping of asphalt in flexible pavements; d) frost heave and reduced strength during frost melt; and e) movement of fine particles into base or sub base materials, which significantly lowers hydraulic conductivity.

2.2.4 Construction Materials

The performance of a pavement is directly impacted by inappropriate compaction, poor moisture conditions during construction, the quality of the materials used, and accurate layer thickness (after compaction) (Adlinge & Gupta, 2013).

Pavements can be constructed using substandard materials rather than more expensive conventional ones, which can result in significant financial savings. These subpar materials, he are frequently difficult to evaluate and may refute common pavement design assumptions. Failure of the road pavement results from substandard geotechnical qualities of the materials

(Rollings, 1988).

2.2.5 Expansive Subgrade

The issue of expansive soils is caused by a variety of factors, including clay soil swelling and shrinkage due to moisture changes, the type of clay minerals present, drainage issues such as rising ground water levels or inadequate surface drainage, and compression of the soil strata as a result of applied loads (Asnake, 2015). Extremely expansive and cohesive soil is used as the subgrade, which causes the roadway to settle unnecessarily and undergo extended consolidation. According to the paper, using soil with a limited bearing capacity causes the subgrade soil to fail (Okigbo, 2012).

2.2.6 Poor Workmanship and Method of Construction

Workmanship and construction methods also have an impact on the failure of the pavement. The performance of the road and its pavement is directly impacted by faulty compaction, inadequate moisture conditions during construction, the quality of the materials, and accurate layer thickness (after compaction). Therefore, professional labor and quality control must be used during construction in accordance with the ERA maintenance specification handbook to decrease the amount of failure (Zewdu, 2018).

2.2.7 Soil Slope Instability (land slide)

According to Varnes (1958), a landslide is defined as a downward and outward movement of slope-forming materials made up of natural rocks, soils, man-made fills, or a combination of these elements. The likelihood of an unexpected slope failure will be greatly reduced by the study of local geological maps, record searching for landslides in comparable formations, site inspection by an expert geologist, geotechnical research, and stability analysis by a geotechnical engineer (Zewdu, 2018). By considering all of the above factors the designer and the engineer must construct the road to reduce, if possible, to avoid failure.

2.3 Pavement Condition Survey

The types of pavement failure, as well as the degrees of severity and extent connected to each failure, were identified using the condition survey. The 1993 AASHTO pavement design manual's process will be followed for conducting the pavement condition survey. For the Sample unit, flexible pavement condition Survey Data Sheets were used to capture the different kinds of distress, their severity levels, and their quantities (Desta Degu, 2022).

2.4 Pavement Distress Type and Severity Description

The following surface distresses and irregularities have frequently observed during the existing road condition survey. Each distress type and severity level description taken from AASHTO pavement design manual, (1993) and Ethiopian Roads Authority Pavement Rehabilitation and Asphalt Overlay Design, (2013) as follows.

a. Alligator or Fatigue Cracking

Alligator or fatigue cracking is a pattern of interconnected cracks brought on by the asphalt concrete surface or stabilized base failing from wear and tear after being subjected to repeated traffic loads. Where tensile stress and strain are at their highest under a wheel load, at the bottom of the asphalt surface or stabilized base, cracking first appears. The break originally spread to the surface as one or more longitudinal parallel cracks. Repeated traffic loading causes the fissures to join, generating sharp, angular pieces with multiple sides that take on the appearance of chicken wire or alligator skin. The longest side of the components is often less than one foot. Only regions that experience frequent traffic loadings are vulnerable to alligator cracking. Therefore, unless the entire area was subject to traffic loading, it would not happen over a large area.

Figure 2: Alligator crack

Possible causes

- Relative movement or consolidation of pavement layer materials.
- A decrease in the base, sub-base, or subgrade support of the pavement's load-bearing capability as a result of poor drainage or spring thaw problems.
- An increase in pavement load that is greater than the intended design load.
- An improperly designed pavement's structural integrity, i.e., a pavement that is too thin to support the intended loads.
- Poor pavement drainage planning.
- Inadequate compaction and subgrade preparation during pavement construction

Severity levels

Low - Unconnected hairline cracks that run parallel to one another. None of the fissures have spalled. The wheel path may initially simply have one crack.

Medium- Low-severity alligator cracking may continue to grow into a pattern of fragments that are mildly surface-spalled fractures that may be sealed.

High - Alligator cracking in the medium range has advanced to the point where fragments are more severely spalled at the edge and loosened, possibly revealing the cell rock beneath traffic pumping.

b. Block cracking

The pavement is divided into about rectangular parts by a pattern of cracks. Sizes of rectangular blocks range from roughly 0.1 to 10 m2.

Possible causes

Block cracking is the final stage of cracking. These cracks almost always start at the top of the surfacing and propagate downwards. Aging of the road and shrinkage of lower layer are the possible cause of this type of crack formation. These cracks are also observed most section on existing bituminous surfacing.

Figure 3: Block crack

Severity Levels

Low - Cracks having a mean width less than 6 mm or filled cracks using sound sealant material whose width is unknown.

Medium - Cracks having a mean width between 6 and 19 millimeters, or any crack with a mean width between 19 and millimeters and nearby random cracking of low severity. When random cracking is less than 0.3 meters from the main distress, it should be regarded as nearby.

High - Any crack with a mean width less than 19 mm or any crack with a mean width greater than 19 mm and nearby random cracking of moderate to high severity. When random cracking is less than 0.3 meters from the main distress, it should be regarded as nearby.

c. **Longitudinal Cracking**

The majority of longitudinal cracks run parallel to the pavement centerline. They are frequently brought on by a combination of moisture gradient pressures, repeated heavy loads, and lack of foundation support.

Potential causes

Along weak longitudinal construction joints and in regions with extreme temperature gradients, such as the edge of road markings, thermal strains can result in fractures. Both of these fracture kinds are not particularly dangerous when they are first developing, but if they are not sealed, they will eventually grow into the wheel pathways and cause more severe damage.

When longitudinal and transverse cracks coexist, they most likely represent reflection cracks that propagate from a lower stabilized layer or cracks resulting from heat or shrinkage pressures on the asphalt. Subgrade movement will typically result in longitudinal cracks that are quite long and can meander over the highway. They can be caused by subpar building work, swelling in a plastic subgrade or embankment materials, settlement, or embankment collapse. Both cracks induced by subgrade movement and cracks caused by embankment slippage frequently exhibit semi-circular patterns and are accompanied by a vertical displacement across the fracture.

Figure 4: Longitudinal crack

Severity Levels

Low - It is a crack with a mean width of less than 6 mm or a sealed crack with sealant material in acceptable condition and an undetermined width.

Medium - Any crack with a mean width of at least 6 mm and less than 19 mm, or any crack with a mean width of less than 19 mm with nearby random cracking of low severity. When random cracking is less than 0.3 meters from the main distress, it should be regarded as nearby.

High - Any crack with a mean width greater than 19 mm or any crack with a mean width less than 19 mm and nearby random cracking of moderate to high severity. When random cracking is less than 0.3 meters from the main distress, it should be regarded as nearby.

d. **Transverse Cracking**

Transverse cracks are those that are primarily perpendicular to the centerline of the pavement. These kinds of fractures frequently coexist with longitudinal fractures and, in extreme circumstances, block crack. Transverse cracks that are uneven or widely spaced were probably the result of some kind of construction error.

Transverse cracking in the surfacing can be brought on by differential vertical displacement brought on by consolidation or secondary compaction close to road structures and culverts. The bad longitudinal road profile brought on by the differential movement will be linked to these cracks. Transverse cracks that are limited to the surface, appear more often, and are spaced closely together are likely brought on by heat or shrinkage forces. Poor-quality surfacing materials will worsen this form of cracking, which is most prone to develop in regions with strong diurnal temperature variations, such as desert regions.

The increasing hardening of the binder has probably rendered the surfacing more 'brittle' and hence more prone to cracking when fractures appear after many years of satisfactory performance. Transverse thermal cracks will eventually join with longitudinal ones to generate block cracking as they advance. At transverse construction joints, thermal pressures can also lead to the development of cracks.

Figure 5: Transverse Crack

Severity Levels

Low - An unsealed crack with a mean width of less than 6 mm or a sealed crack with good sealant material but an undetermined width.

Medium -Any crack with a mean width of at least 6 mm and less than 19 mm, or any crack with a mean width of less than 19 mm with nearby random cracking of low severity. When random cracking is less than 0.3 meters from the main distress, it should be regarded as nearby.

High -Any crack with a mean width greater than 19 mm or any crack with a mean width less than 19 mm and nearby random cracking of moderate to high severity. When random cracking is less than 0.3 meters from the main distress, it should be regarded as nearby.

e. **Potholes**

In regions of a road surface known as potholes, the top layer, typically asphalt, creates holes in the pavement that are shaped like bowls and range in size. Plan dimensions must be at least 150 mm. A minimum of 150 mm should be the diameter of circular potholes. Potholes with erratic shapes should accommodate a circular with a diameter of 150 mm.

Figure 6: Pothole

Possible causes

Cracking of the road surface: An insufficient pavement construction causes asphalt fatigue cracking. The pavement will bend under wheel loads if the pavement layers are too weak and flexible for the imposed amount of traffic loading. This recurrent stress at the base of the asphalt leads to the initiation and spread of fatigue cracks in the asphalt layers. These are probably going to manifest as "alligator cracking," in which the surface separates into erratic pieces.

Water gets into the pavement: when water gets into the pavement, it soaks into the base and the aggregate sub base layers, softening the subgrade soil below

The pavement is being pounded by traffic: pavement is being pounded by traffic which is starting to crack the surface. A pothole is started when little slabs of asphalt are thrown out; the pothole then grows and gets deeper. Fine soil particles from the subgrade contaminate the aggregate sub base due to traffic-induced pumping action of water at the subgrade/sub base interface, further weakening the pavement and causing it to bend more under traffic.

Cycles of freeze-thaw speed up development: In areas where it is freezing, water in the pavement freezes and expands, creating fractures and breaking the asphalt surrounding the pothole.

The procedure is completed by standing water: After a rainstorm, water that collects in potholes scours and ejects material under the pressure of moving traffic, rapidly enlarging and deepening the pothole.

Severity Levels

Low - <25 mm in depth

Medium - 25 to 50 mm in depth

High - >50 mm in depth.

f. Rutting

Surface depression in the wheel paths is known as a rut. Ruts may have pavement uplifts along their sides, but often they are not visible until after a rainstorm when the water-filled wheel trails make them visible. Rutting systems are a type of permanent deformation that can occur in any layer of pavement or subgrade and are typically brought on by the consolidation or lateral displacement of the material as a result of traffic stresses.

Possible causes

Unstable Subgrade: The subgrade, or the earth below the pavement, determines how sturdy and stable an asphalt surface will be. The support required to keep your asphalt from rutting may be lost if the earth beneath the road compacted over time. There may be a natural tendency for the soil in some areas to be more unstable than in others. Fortunately, knowledgeable contractors are aware that compacting the subgrade prior to installing the asphalt can increase its stability.

Insufficient Sub base Thickness: However, no matter how highly compacted the subgrade is, asphalt cannot be laid directly on top of it. Simply put, soil is too unstable by nature, especially when it is saturated with moisture. The crushed gravel layer, often referred to as the sub base or the aggregate base, is required to be laid on top of asphalt in order for it to stay in place for many years to come. For a sub base to produce useful results, two things are necessary. It must first be carefully compacted, much like the subgrade (and the asphalt itself). The sub foundation also needs to be thick enough to sustain the asphalt.

Poor Mix Design: Rutting can occur even on asphalt surfaces with sufficient subgrade and sub base. In these situations, the problem typically results from issues with the asphalt's composition. Technically speaking, asphalt needs to have sufficient structural integrity to withstand the shear pressures imposed on it by the massive weight of automobiles. To put it another way, asphalt that will frequently be in contact with large cars moving quickly needs to have a substantially stiffer performance profile.

Figure 7: Rutting (Source: Google)

Severity Levels

Severity	Mean rut depth criteria (mm)
Low	**6-13**
Medium	**13-25**
High	**>25**

g. Depression

Depressions are small, isolated patches of pavement whose elevation is a little lower than the surrounding pavement's. Light depressions can sometimes go undetected until after a rain when ponding water forms "birdbath" patches, although they can sometimes be found without rain due to strain caused by oil dripping from moving automobiles. Depression may be "built in" during construction or result from the foundation soil settling.

Figure 8: Depression

Severity level

Low-Depression causes some car bouncing, but it doesn't hurt.

Medium-Depression causes the car to bounce a lot, which is uncomfortable.

High-Depression causes the car to bounce excessively, which causes severe pain, a safety danger, or even vehicle damage, necessitating a decrease in speed for safety.

h. Corrugation

Plastic movement known as corrugation is characterized by ripples on the asphalt pavement surface. It typically happens where traffic begins and ends. Corrugation typically occurs in asphalt layers that are unstable in warm weather, although it can also be caused by a subgrade with too much moisture, mix contamination, etc.

Severity level

Low - Corrugations cause some vibration in the car but don't make it uncomfortable

Medium- Corrugations make the vehicle to vibrate a lot, which is uncomfortable.

High - Corrugations cause the car to vibrate excessively, causing severe discomfort, and/or they can damage the vehicle, necessitating a reduction in speed for safety.

2.1 Material sources and requirement of road structure

The subgrade, the sub base that is placed on top of the sub grade, and the surface (wearing course) make up the majority of a flexible pavement road's construction.

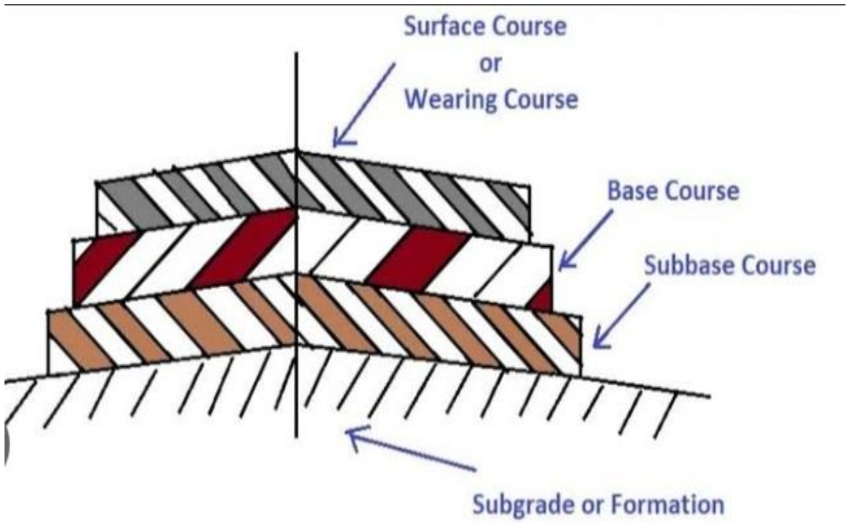


Figure 9: Flexible pavement structural layer (Source: Google)

The material source and expected requirement should be fulfilled by each layer discussed as per ERA, Ethiopian roads authority 2013 Standard Technical Specification and Method of Measurement,(2013) as follows.

2.1.1 Road bed layer

a) Particle Size

The material shall not, following initial breakdown for further processing and breakdown by grid rolling as part of the Works, contain any fragments with a maximum dimension exceeding 500mm. After breakdown with a grid roller, the material must be well graded with a maximum particle size of less than 150 mm in order to be easily positioned inside a 200 mm layer. The fill material cannot contain particles having a maximum dimension more than two-thirds of the prescribed layer thickness after compaction for lower layers of fill that are thicker than 200mm.

b) California Bearing Ratio (CBR)

When measured using AASHTO T-193 specifications at a modified AASHTO density of 95% of the maximum dry density determined in accordance with the requirements of AASHTO T-180 method D, the fill material must have a minimum soaked CBR of not less than 5% and a swell value of not more than 2% (with two surcharge rings).

c) **Liquid Limit (LL) and Plasticity Index (PI)**

When measured in accordance with the specifications of AASHTO T-89 and T-90, the fill material must have a liquid limit not exceeding 60 and a plasticity index not exceeding 30.

d) **Compaction**

As shown on the drawings or as directed by the engineer, the lower layers of embankment fill laid on the prepared roadbed must have minimum densities of 90, 93, or 95% of modified AASHTO density. According to the drawings or as directed by the engineer, the subgrade layer, which is the upper layer of the embankment fill, must be compacted to a minimum of 93% or 95% of modified AASHTO density

2.1.2 Sub base layer

Natural gravel, Scoria (Cinder Gravel), weathered rock, crushed gravel, crushed rock or crushed boulders, recycled pavement material, or any other granular material meeting the requirements of sub base material quality, as well as a combination of any of the aforementioned materials, shall be the materials used for the construction of sub-base layers.

a) **Particle Size Distribution**

The sub-base material must adhere to one of the grades listed in Table 1. Within the indicated boundaries, it must be smoothly graded with a continuous grading. To accommodate natural gravels, grade A is a broad grading. To reflect the higher control achievable with crushed stone, grading B and C are tighter grades for specified nominal size aggregate. A built layer must have a minimum thickness that is larger than 1.5 times the material's maximum particle size. After the material has been mixed and put on the road, tests to see if it conforms with the required grading criteria must be done.

Table 1: Grading Requirements for Sub-base Material

ISO Sieve Size (mm)	Percentage Passing by Mass		
	Natural Gravel	Crushed Stone	
	A	B (37.5 mm)	C (28 mm)
63	100		
50		100	
37.5	70 – 100	95 – 100	100
26.5			
20	50 – 100	60 – 80	70 – 85
9.5		40 – 60	50 – 65
4.75	30 – 100	25 – 40	35 – 55
2.36		15 – 30	25 – 40
1	17 – 75		
0.425	11 – 56	7 – 19	12 – 24
0.075	5 – 25	5 – 12	5 – 12

b) Plasticity

Natural gravel when calculated in accordance with AASHTO T-90, sub-base materials must have a maximum Plasticity Index dependent on the environment, as given in Table 2 or as shown on the drawings. When calculated using AASHTO T-90, the Plasticity Index for crushed stone sub-base must be less than 6.

Table 2: Plasticity Limits for Natural Gravel Sub-bases

Climate	Typical Annual Rainfall (mm)	Liquid Limit	Plasticity Index
Moist tropical and wet tropical	> 1000	< 35	< 6
Seasonally wet tropical	> 500 and < 1000	< 45	< 12
Arid and semi-arid	< 500	< 55	< 20

c) Density and Strength

Unless otherwise indicated, represented on the drawings, or required by the engineer, the minimum dry density to which the material shall be compacted shall be 95% of the MDD obtained in the AASHTO T-180 technique D. The sand replacement method described in AASHTO T 191 or any other method approved by the Engineer and calibrated with the sand replacement method must be used to obtain field dry densities. The minimum Californian Bearing Ratio (CBR) as calculated in line with AASHTO T-193 criteria shall be 30%. When calculated using the specifications of AASHTO T-180 method D, the Californian Bearing Ratio (CBR) must be measured at a density of 95% of the maximum dry density.

e) Use of Laterite as Sub-base

Laterite meeting the grading requirements can be used for sub-base for traffic levels up to 3 million ESA provided the following criteria are satisfied:

- CBR (%) (After soaking) > 30
- Plasticity Index (%) < 25

2.1.3 Road Base layer

The Contract specifies one of the following materials to be used in the construction of base layers for roads:

- Natural granular materials and weathered rock, either unstabilized or artificially stabilized;
- Crushed rock or stone.

Material Requirements for Crushed Stone

Graded crushed stone (GB1) must be made by crushing recently quarried rock. It can be an all-in product, known as a "crusher run," or it can be separated by screening and then recombined to achieve the specified particle size distribution. The substance must be free of organic materials, clay clumps, and other harmful elements. The material must be able to be easily dispersed, compacted, and transported without needing to be separated.

a) Particle Size Distribution

When calculated in line with the specifications of AASHTO T-27, the combined grading of the material must be a smooth continuous curve falling within the grading limits specified in Table 3. According to the specifications of AASHTO T-11, the mass of material passing the 0.075 mm sieve must be calculated

Table 3: Grading Limits for Graded Crushed Stone Road Base Materials (GB1)

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

b) Plasticity Index

When measured in accordance with AASHTO T-90, the fine fraction of a GB1 material must not be plastic.

c) Density and Strength

The material that has been put must have an in-situ dry density that is at least 98% of the maximum dry density determined by AASHTO T-180 technique D, or as specified on the drawings, in the particular specifications, on the engineer's instructions, or as otherwise indicated. Each layer shouldn't be more than 200 mm thick when crushed. CBR values should be greater than 100% for crushed stone road base made using GB1 materials and built with care.

Material Requirements for Natural Gravels

It covers Graded Natural Gravel (GB2 and GB3). As road base materials, a variety of substances including lateritic, calcareous, and quartzitic gravels, river gravels, boulders, and other transported gravels, as well as granular substances produced by the weathering of rocks, can be utilized successfully. The material must be able to be easily excavated, transported, dispersed, and compacted without needing to be divided.

a) Particle Size Distribution

To ensure that the material has the greatest possible mechanical stability within the grading limitations provided in Table 5205/1 when established in compliance with AASHTO T-27 criteria, the particle size distribution should be roughly parallel with the grading envelope. According to the specifications of AASHTO T-11, the mass of material passing the 0.075 mm sieve must be calculated. In accordance with maximum nominal sizes of 37.5 mm, 20 mm for unstabilized base material, and 37.5 mm for chemically stabilized material, Table 4 lists three recommended particle size distributions for acceptable materials.

Table 4: Recommended Particle Size Distributions for Natural Gravels (Unstabilized and Chemically Stabilized) for Road Base Material (GB2, GB3)

ISO Test sieve (mm)	Percentage by mass passing		
	Natural Gravel		Chemically stabilized
	37.5 mm	20 mm	37.5 mm
50	100	-	100
37.5	80 – 100	100	80 – 100
19	60 – 80	80 – 100	60 – 100
9.5	45 – 65	55 – 80	-
4.75	30 – 50	40 – 60	30 – 80
2	20 – 40	30 – 50	20 – 63
0.425	10 – 25	12 – 27	10 – 41
0.075	5 – 15	5 – 15	5 – 20

b) Plasticity Index

When measured in accordance with AASHTO T-90, the fine fraction of GB2 and GB3 material shall have a maximum Plasticity Index of 6. It is preferable to keep the fines content (passing 0.425 mm sieve) to the lower end of the range if the PI is getting close to the top limit of 6.

c) Density and Strength

The material should be compacted to a density that is equal to or higher than the maximum dry density attained using the AASHTO T-180 D technique before being used as a road base. The material shall have a minimum CBR of 80% after being submerged in water for four days when compacted in the laboratory to 98% of Modified AASHTO density.

2.2 AASHTO Soil Classification System

In order to determine the suitability of soils for earthworks, embankments, and road bed materials (subgrade, natural material beneath a constructed pavement; sub base, a layer of soil above the subgrade; and base, a layer of soil above the sub base that offers high stability to distribute wheel loads), the AASHTO soil classification system is used. According to AASHTO, granular soils are soils in which 35% or less are finer than the No. 200 sieve (0.075 mm. The AASHTO system classifies soils into seven major groups, A-1 through A-7. Granular (coarse-grained) soils make up the first three groups, A-1 through A-3, whereas silt-clay (fine-grained) soils make up the next four groups, A-4 through A-7 (Arora, 2004). The latter four categories, A-4 through A-7, consist of fine-grained silt-clay.

A-1, A-3, and A-2 soils are rated outstanding to good condition for highways with percentage passing Sieve No. 200 not exceeding 35%, whereas A-4 to A-7 soils are fair to bad with percentage passing Sieve No. 200 above 35%, according to the AASHTO soil classification of soil samples for highways. In other words, the group index of the soil is indicated by the number in the bracket, and the higher the group index (GI), the less favorable a soil is for highway construction. According to Desta, Basha, Anteneh, and Gelata (2022) a GI of 0 denotes a good subgrade material, whereas a GI of 20 or more denotes a very bad subgrade material.

General Classification	Granular Materials (35% or less passing No. 200)							Silt-Clay Materials (More than 35% passing No. 200)			
Group Classification	A–1		A–3	A–2				A–4	A–5	A–6	A–7
	A–1–a	A–1–b		A–2–4	A–2–5	A–2–6	A–2–7				A–7–5, A–7–6
Sieve analysis, % passing											
No. 10 (2.00 mm)	50 max	...	...	...	...	...	...	...	...	...	...
No. 40 (425 m)	30 max	50 max	51 min	...	...	...	...	...	...	...	...
No. 200 (75 m)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	35 min
Characteristics of fraction passing No. 40 (425 m)											
Liquid limit	...		...	40 max	41 max	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min^A
Usual types of significant constituent materials	Stone Fragments, Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General rating as subgrade	Excellent to Good							Fair to Poor			

Figure 10: AASHTO Classification of Soils and Soil-Aggregate Mixtures (Budhu, 2010)

To offer a measure of a soil's quality as a roadway subgrade material, a group index (GI) value is placed in parentheses to the primary group. Group Index: is how the group index is shown. GI= (F-35) [0.2+0.005(LL-40)] +0.01(F-15)(PI-10), where F is the percentage of material that passes No. 200 sieve (Budhu, 2010).

Groups A-1-a, A-1-b, A-2-4, A-2-5, and A-3 have GI values of 0. The following partial group index equation is used for groups A-2-6 and A-2-7.

GI= 0.011(F-15) (PI- 10)

The quality of the soil as a subgrade material declines with increasing group index. For any of groups A-4 through A-7, the GI shouldn't be higher than 20 (Arora, 2004).

3 CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Study Area

The 26 km Teji-Tulu Bolo road portion in the South West Shoa Zone of Oromia was the subject of the research study. The road section connects Addis to Giyon Numbered as A 5-1 on ERA Geometric design manual 2013 and is a part of a trunk road with 5cm AC surface, 20cm granular base course GB1 and 20cm granular base course GS1. Teji Town, which is situated at latitude 8^{o} 50'21" N and longitude 38^{o} 22'47" E and has an elevation of 2065m A.S.L., is where the study area begins. The topography of the area is dominantly flat.

The Bishoftu formation, which is a Pliocene-Pleistocene era of geological formation, is present in the project area's geology from Teji Km 0+000 to around Km 3+000, according to the geographical map of Ethiopia. The formation is chiefly comprises volcanic rock such as alkaline basalt and trachyte. From about Km 3+000 to about Km 20+000 cover with alluvial and lacustrine deposit formation of quaternary undifferentiated age geological formation. This formation is mostly found at upstream and downstream of Awash River. The formation is chiefly comprises sand, silt, clay, diatomite lime stone and beach sand. From about Km 20+000 to end is Nazrete Series formation. It is Neogene of Miocene-Pliocene age geological formation. The formation is chiefly comprises Ignimbrite, unwelded tuff, ash flows, rhyoltic flows, domes and trachyte.

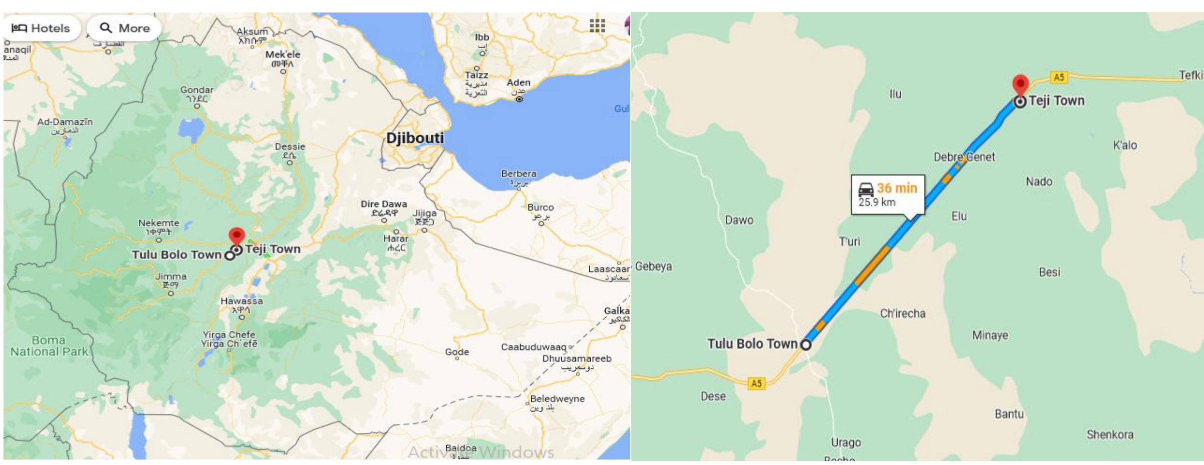


Figure 11: Study area Location (Source: Google 2019)

Most of the time the mean annual rainfall of this area ranges between 700mm – 1000mm which can represent the rainfall of the project area. The mean monthly rainfall varies in the range of 0.6mm – 315.7mm with major rainfall records in the months of May, June, July, August and September (which comprise about 82% of the annual rainfall) and insignificant records for the remaining months. On the basis of the climatic zone that prevail to the project area; the project route is characterized by cold to moderately hot weather with effective mean annual temperature varying in the order of 10 ^{0}C- 30 ^{0}C.

The weather information i.e. the town's weather information for temperature and rainfall I obtained from the meteorological service pertains to the town of Tulu Bolo, shown on figures 2 and 3.

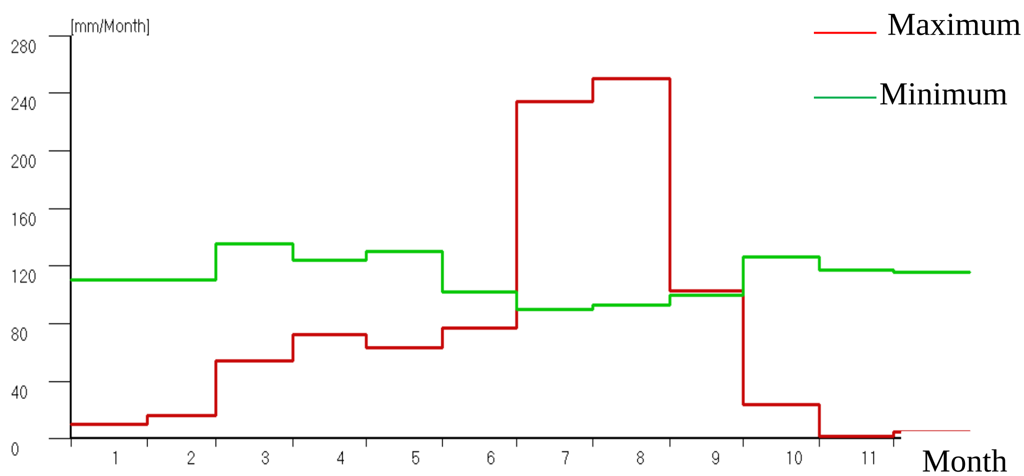


Figure 12: Average monthly rainfall data of project area

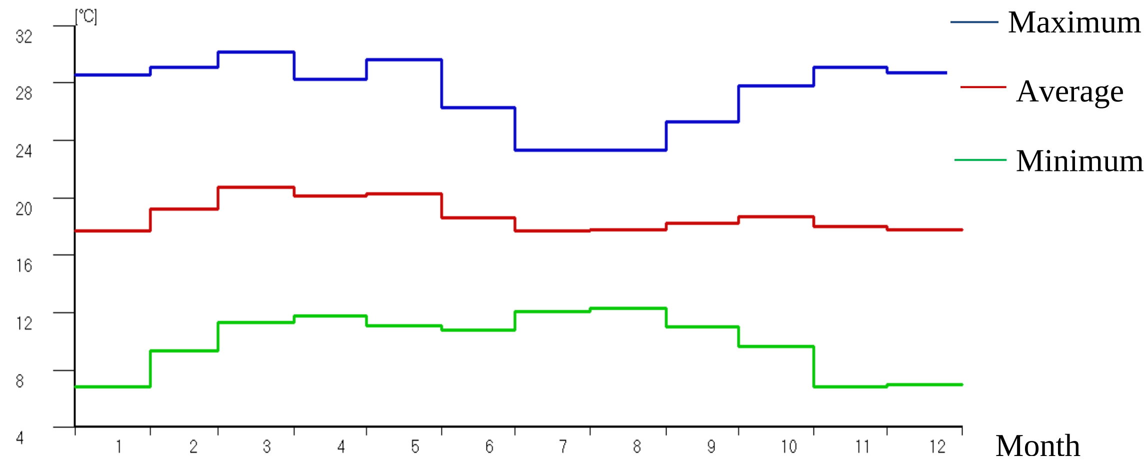


Figure 13: Average Maximum and minimum monthly temperature data of project area

3.2 Research Design

To achieve the desired objectives of this research study, the study is conducted in three phases; field work, laboratory tests and office work.

During the field work phase, the road environment was carefully observed, and samples were collected from various locations within the study area to look into potential causes of pavement distresses by examining the index properties, field density, and strength of subgrade, subbase, and base course soil. Field investigations were conducted, and road distresses were spotted visually. This included collecting soil samples from the location, conducting field density tests on each subterranean layer, and testing the soil samples in a lab.

In order to compare the traffic count (AADT) from 2014 to 2022 with the design AADT, secondary data were gathered from the Ethiopian Roads Authority.

In order to lessen the issues associated with distresses, laboratory tests were conducted on samples taken from the study area to measure the soil's index properties, the materials' strength, and the moisture content of the pavement. After these tests were completed and the results were evaluated, potential solutions were identified. Laboratory experiments were carried out during this phase of the investigation, including checks on grain size distribution, moisture content, the CBR test, standard sieve analysis, and the Atterberg limits test. The interpretation of the laboratory test results and the development of precise treatments were both required.

After applying the specs to assess the outcomes, a conclusion and suggestion were made. And the thesis's final draft was created.

3.3 Research variables

Dependent variables and independent variables are the two variables that will be considered.

Dependent variable: - The reasons for the teji-tulu bolo road segment's shortcomings.

Independent variables include the extent of failure, the nature and strength of the subgrade, the sub base and base course, the soil's particle size distribution, its index properties, and compaction.

3.4 Population

Failures on the Teji-Tulu Bolo road segment were used in this study as the study's population.

3.5 Sampling Procedures

The nonprobability purposive sample approach was employed as the sampling methodology to meet the research's goals. The goal is to gather soil samples at various points along the route that have the highest rates of failure. The disturbed soil was extracted from each site and put in a tight plastic bag with a reference tag indicating the depth and position of the sample. This was done to ensure that the sample wasn't contaminated during collection and to identify which sample came from where.

3.6 Data Collection process

Data were needed in order to complete the research's goals. Below is a discussion of the data collection strategies used. ERA and local governments' written consent was to be obtained as the initial step in the data gathering process. Samples were gathered from the common damaged road during field trips in the study region. Based on color and texture changes, base course, sub base, and subgrade materials were gathered at each failed segment. Photographs were taken at representative locations, and representative samples were placed in each test pit. On the basis of a condition survey, the route was divided into various road failures.

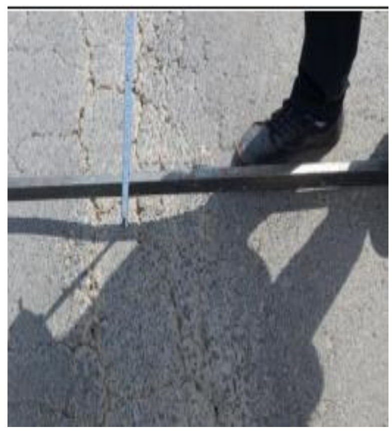
Alligator Crack

Longitudinal Crack

Block crack

Depression

Pothole



Depression

Figure 14: Few types of failure observed on Teji- Tulu Bolo road segment

Additionally, sufficient numbers of representative samples that passed visual inspection were carefully chosen. Finally, laboratory testing was done on the representative samples that were obtained.

A preliminary visual inspection of the Teji-Tulu Bolo road portion was conducted. Prior to beginning field observation, it was required to visually evaluate and catalog the whole extent of the road segment. On the entire stretch of road, the initial site visit was conducted. The conditions of the road failures along the road segment were categorized after completing the initial visual examination. Following that, representative areas for sampling were chosen based on the conditions and types of failure present. As a result, 17 sample test pit locations/stations that illustrate the kinds of failures seen along the road segment were chosen. Google Earth and a smartphone's GPS were used to map the locations of the sampling sites. Table 5 provides the stations of the sampling sites.

Table 5: location of sampling stations

S.NO	types of distress	Station	Section
1	Block crack	1+700-3+200	**A**
2	Pothole	2+980-3+200	
3	Alligator crack	3+300-6+440	
4	Depression	6+200-6+320	
5	Longitudinal crack	6+440-7+120	**B**
6	Transverse crack	7+085-7+100	
7	Corrugation	9+580-9+600	
8	Alligator crack	9+800-9+900	
9	pothole	9+995-9+997	
10	Rutting	11+400-11+500	
11	Block crack	11+700-11+800	
12	Depression	15+040-15+220	
13	Block crack	21+00-22+100	**C**
14	Rutting	23+040-23+340	
15	Longitudinal crack	24+580-24+700	
16	Alligator crack	25+800-25+900	
17	pothole	26+090-26+105	

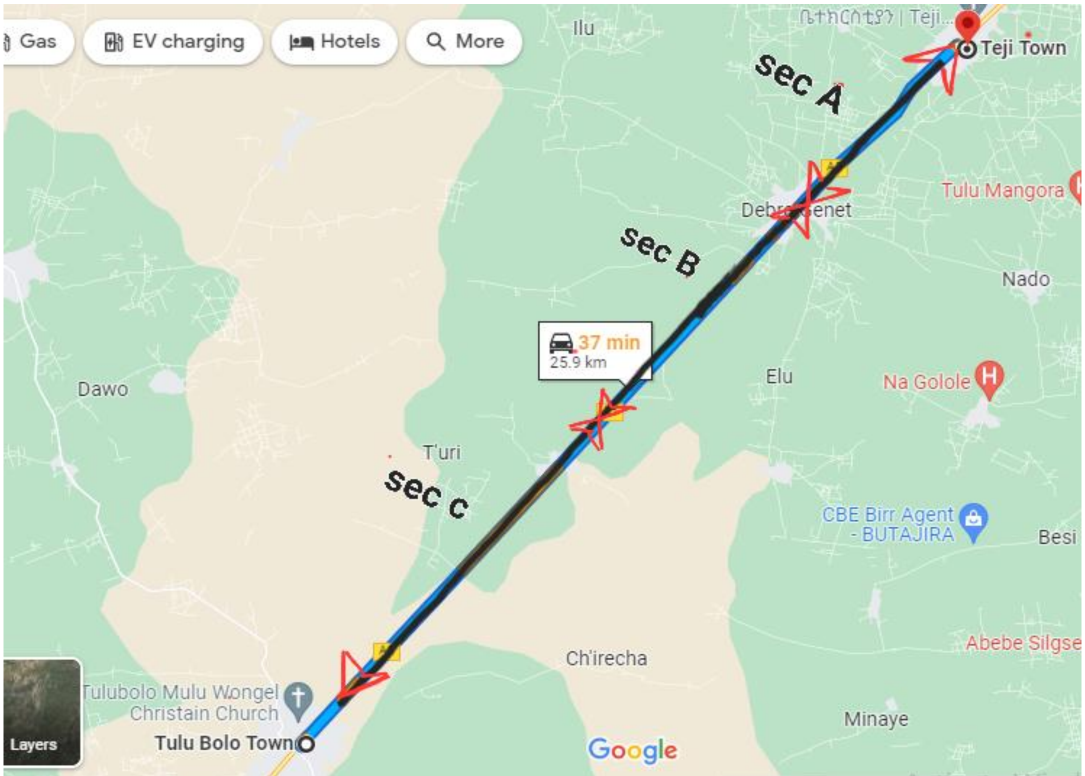


Figure 15: Sectioned road map

3.7 Processing and Analysis of Data

Depending on how severe the failure was, different sample stations were chosen. Additionally, each subsurface layer's field density tests were conducted concurrently with the soil sampling. The samples that are taken from the site will be subjected to laboratory testing that are conducted in accordance with ASTM and AASHTO standards. Additionally, the outcomes will be evaluated by comparison using the accepted criteria**.**

Figure 16: Field density test and pit after sampling at Km 9+580 and 6+230

To identify the reasons behind the laboratory's failures A variety of experiments were carried out, including grading analyses, Atterberg limits testing, soil compactions, CBR tests, and moisture content determination.

1. **A grading or sieve analysis**

The distribution of soil particle sizes was determined using a sieve analysis. After being washed and dried in the oven, a representative sample was used for the test. The material was sieved with a BS 200 sieve, and the fraction that was kept on the sieve was dried by air before being used for the sieve analysis. A set of automatic shakers and a set of sieves were used for the mechanical way of sieving.

Figure 17: Classification test done at BEAEKA laboratory

2. **Atterberg limits tests**

With the help of this test, you may assess the soil sample's plasticity, strength, and settling properties by determining the clay content in terms of liquid limit, plastic limit, and plasticity index. The soil sample that passed through a 425 mm screen and weighed 200 g was combined with water to create a thick, homogeneous paste in order to determine the liquid limit. In the Casagrande apparatus cup, the paste was collected, a grove was made, and the number of blows required to seal it was noted. On a graph, the moisture content vs. number of blows is shown, and the liquid limit is considered to be the moisture content equal to 25 blows. Similar to this, a soil sample weighing 200 g was extracted for the purpose of determining the plastic limit from material that passed through a 425 m test sieve, and it was then mixed with water until it was homogenous and plastic enough to form a ball. On a glass plate, the soil ball was rolled until the thread cracked at a diameter of around 3 mm. To find the plastic limit, a 3 mm diameter sample was heated to 105°C in an oven.

Figure 18: Atterberg test done at BEAEKA laboratory

3. **Compaction test**

Based on the AASHTO T-180 test protocol for compaction, compaction tests for sub-base, selected fill, and natural subgrade soil materials were conducted. Densification of soil through mechanical means involves moving soil particles into a more compact arrangement, which raises the ratio of horizontal effective size to vertical effective stress. The amount of compaction is determined by its dry weight, which raises the road foundation's carrying capacity, stabilizes slopes, regulates undesired volume changes, and prevents unwelcome structural settlement. Five layers of earth were added to the mold, then compressed using a 4.5 kg rammer. The soil's water content and density were both measured, and the moisture density relationship was used to calculate the soil’s dry density.

The maximum dry density (MDD) and optimal moisture content (OMC) are then determined by taking the highest points on the dry density vs. moisture content graph.

Figure 19: Compaction test done at BEAEKA laboratory

4. CBR/ California Bearing Ratio

A penetration test called the California bearing ratio (CBR) is used to assess the mechanical toughness of base course, sub-base, and sub-grade soil materials. To define the soil for usage as a base course, sub-base, and subgrade material, the soaking method of CBR was used. The ideal moisture content was combined with a portion of the air-dried soil sample. This was layered five times in three CBR molds. Before the test, each specimen was compressed by 65,30,10 blows and submerged in water for four days to create a saturation situation akin to what might happen in the field. A surcharge load that simulates the estimated weight of the pavement layers over the material being tested is applied onto the sample during this time.

A seating load was applied after the compacted earth and mold were weighed, placed beneath the CBR machine, and placed there. At penetrations of 0.625, 1.25, 1.875, 2.54, 3.75, 5.08, 7.5, 10 and 12.5 mm, loads were observed. The results were assessed by comparing them to ERA standards after the data were processed using the laboratory techniques previously described.

Figure 20: CBR test done at BEAEKA laboratory

The traffic count (AADT) from 2000 to 2008 and 2014 to 2022 G.C. was gathered and compared with each other to see if the failure of the road was related to traffic or not. The traffic count information is included in table 6 and table 7 and was gathered from the ERA Alemgena district.

Table 6: Traffic count (AADT) from 2000 to 2008

year	**Car**	**4wd**	**S.Bus**	**L.Bus**	**S.Truck**	**M.Truck**	**H.Truck**	**Truck Trailer**	**Total**
2002	155	234	306	127	189	203	215	322	1751
2003	314	485	419	186	252	268	283	228	2435
2004	260	319	306	217	825	264	304	267	2762
2005	247	224	282	287	989	307	312	262	2910
2006	250	270	348	223	261	320	274	254	2200
2007	245	279	369	233	254	329	302	308	2319
2008	247	414	438	385	318	405	390	361	2958
2009	349	481	505	334	382	480	477	415	3423
2010	297	438	573	284	446	555	565	468	3626

Table 7: Traffic count (AADT) from 2014 to 2022

Year	Car	4wd	S.Bus	L.Bus	S.Truck	M.Truck	H.Truck	Truck Trailer	Total
2014	465	704	918	382	567	814	645	645	5140
2015	628	970	1258	560	758	1075	851	684	6784
2016	803	956	1227	653	825	1059	912	803	7238
2017	990	1120	1412	863	989	1228	936	1049	8587
2018	1250	1370	1740	1117	1309	1604	1374	1272	11036
2019	1226	1393	1848	1166	1270	1649	1512	1540	11604
2020	2006	2191	2868	1928	2230	2777	2826	2344	19170
2021	1746	1925	2528	1674	1910	2401	2388	2076	16648
2022	1486	1659	2188	1420	1590	2025	1950	1808	14126

4 CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Visual Condition Survey Result

Investigation of existing pavement layers is made with the aim of assessing the in-situ condition and their environment. Investigations made for the existing pavement includes, condition survey of the road by walking over the road, digging test pit at representative sections to visually identify their type, record their thickness and assess their in-situ conditions under observed pavement distress.

From visually condition survey, the pavement’s base course is constructed with base course material obtained from crushed basaltic rock. It is found to be 200mm thick except in some section where lower thickness is measured due to damage under traffic and contamination with lower sub base layers. At spots were potholes are formed, pumping and contamination of the base course is seen. In the test pits, the base course layer it is seen to be wet due to surface water percolations through sever alligator and block cracking in the top asphalt layer. In order to know the in-situ conditions of the existing base course, field density (FDT) and field moisture content (FMC) test were done using sand cone replacement method.

Reddish scoria blended with grayish gravelly sand sub base material with 200mm thickness was seen in the test pits. Based on visual investigation made on the test pits their in-situ condition is related to observed pavement defects. In the deformed road section, they are seen to be wet and contaminated with underplaying embankment fill layer. As it was from road condition survey, the pavement ruts were severing and extend to sub base layer. Both base course and sub base layers are settled from excessive traffic loading or poor subgrade construction. Since the upper base course layer is granular material, surface runoff that has infiltrated to base course layer moistened and saturated the sub base layer as well.

From test pits dug and opened in this road segment grayish natural gravel, rock fragments with gravel and sand, clayey gravel (natural gravel), reddish scoria blended with grayish sandy silty soil, basaltic rock with brownish silty clay soil (natural gravel) and scoria material with thickness varying from 100 to 350mm was seen as embankment fill. The road bed through this road segment was black cotton and not replaced properly. Based on the requirements set in ERA standard specification Division 4105, such problematic soils should be replaced to minimum depth of 600mm below subgrade level.

Unless drainages measures are taken, there is moisture migration towards the road due to very flat terrain and flood plain of the road alignment in this stretch. Drainage structure was not installed sufficiently and the available one was damaged by siltation.

Figure 21: drainage problem along the road stretch

4.2 Field and Laboratory Test Results

Disturbed soil samples were collected for the laboratory tests based on visual inspections and condition survey findings. From the test pit of each layer of Pavement, representative samples were gathered, identified, and brought to the lab for testing. The laboratory analysis was carried out in accordance with British standard, ASTM, and AASHTO standards. The purpose of the laboratory test was to assess whether the soils could be used as base course, sub base, and sub-grade and to see if they could alter or create pavement distress. The following tests are carried out in accordance with AASHTO criteria on pre-existing base course, subbase, and subgrade pavement materials.

- Gradation test
- Atterberg's tests
- Compaction test
- CBR test

These tests are helpful for material quality determination in accordance with design guidelines and requirements, as well as for identification and categorization purposes.

4.2.1 Atterberg's Test results of the materials in existing pavement

To ascertain the properties of the soil's consistency, the LL and PL tests were applied to the soil sample. The difference of liquid limit and plastic limit is plasticity index which is important classification criteria for the engineering qualities of soils include Atterberg limit testing. Tables 7, 8, and 9 for sections A, B, and C, respectively, list the Atterberg Liquid Limits and Plasticity Index values of typical soil samples from the existing subgrade, sub-base, and base course at Teji-Tulu Bolo.

Table 8: Section A Atterberg's limit test result

types of distress	subgrade layer			sub base layer			base course layer		
	LL	PL	PI	LL	PL	PI	LL	PL	PI
Block crack	NP	NP	NP	NP	NP	NP	23	7	16
Pothole	26	17	9	32	19	13	26	20	6
Alligator crack	0	0	0	35	28	7	19	15	4
Depression	41	25	16	33	24	9	0	0	NP

Table 9: Section B Atterberg's limit test result

Atterberg's limit test result									
types of distress	subgrade layer			sub base layer			base course layer		
	LL	PL	PI	LL	PL	PI	LL	PL	PI
Longitudinal crack	31	19	12	28	15	13	18	13	5
Transverse crack	28	19	9	0	0	NP	19	14	5
Corrugation	42	36	6	0	0	NP	19	14	5
Alligator crack	25	18	7	0	0	NP	20	15	5
Pothole	0	0	NP	0	0	NP	19	17	2
Rutting	0	0	NP	28	16	12	19	14	5
Block crack	0	0	NP	31	17	14	18	13	5
Depression	0	0	NP	33	20	13	18	15	3

Table 10: Section C Atterberg's limit test result

Atterberg's limit test result									
types of distress	subgrade layer			sub base layer			base course layer		
	LL	PL	PI	LL	PL	PI	LL	PL	PI
Block crack	0	0	NP	0	0	NP	17	12	5
Rutting	0	0	NP	33	24	9	21	15	6
Longitudinal crack	0	0	NP	29	17	12	18	13	5
Alligator crack	0	0	NP	28	19	9	18	13	5
pothole	0	0	NP	0	0	NP	27	22	5

ERA Manual, 2013, recommend soils with PI values less than 30% and LL< 60 as suitable sub-grade materials. The PI of the sub-grade soil at all three sections meets the minimum requirement set by ERA and this implies that subgrade soil were not the cause of deterioration.

The plasticity index primarily used to distinguish between clays and silts, two types of fine-grained soil. The majority of fine-grained soils are silts when the soil's PI is low and clay when it is high. As a result, silt makes up the majority of the subgrade soil along this road length.

The ERA 2013 Standard Technical Specification and Method of Measurement, suggests that the PI for the sub base layer must be less than 12 percent and liquid limit less than 45% when determined by AASHTO T-90. This condition is satisfied for some except for section A pothole and section B longitudinal crack, block crack and depression. Out of standard PI value of pavement material cause the material sensitive to deformation and compressibility when subjected to loading. Therefore this unexpected plasticity of sub base may caused section A pothole and section B longitudinal crack, block crack and depression to manifested on the surface.

Even though the fine fraction of a Graded Crushed Stone Road Base Materials (GB1) material shall be non-plastic according to ERA Manual, 2013, all the base course material used on Teji-Tulu bolo road segments are almost have plastic property except at Depression of section A. hence inadequate base course material may be the cause of failure at all three section.

4.2.2 Sub-grade soil classification

Table 11: Section A Grain size distribution of Subgrade layer

Grain size distribution of Subgrade layer												
	% passing										AASHTO Soil classification	
selected station	38	25	19	13	9.5	4.75	2	1	0.425	0.075	Constituent material description	Group classification
Block crack	100	100	100	98	98	92	79	72	56	44	Silty soil	A-4
pothole	100	91	81	63	48	30.4	19.4	15.7	12.6	10.1	Silty or Clayed Gravel sand	A-2-4
Alligator crack	100	89	86	76	70.5	57.8	47.2	41.5	31.8	24.7	Stone Fragments Gravel and sand	A-1-b
Depression	100	96	93	88	85.8	77.2	70.3	66.2	58.3	51.2	clayey soil	A-7-6

Table 12: Section B Grain size distribution of Subgrade layer

selected station	% passing										AASHTO Soil classification	
	37.5	25	19	12.5	9.5	4.75	2	1	0.425	0.075	Constituent material description	Group classification
Longitudinal crack	100	93	81.8	62.3	50.2	31.2	19.7	16.2	12	8	Silty or clayed Gravel sand	A-2-6
Transverse crack	100	83.5	75.9	64.5	55.4	40.3	30.3	26.3	21	15.8	Silty or clayed Gravel sand	A-2-4
Corrugation	100	95.8	91.2	88	84.7	78.7	71.5	64.5	49.2	37.2	Silty soil	A-5
Alligator crack	100	97.6	87.8	74.2	65.4	50.5	37.9	32.3	26.8	22.3	Silty or clayed Gravel sand	A-2-4
Pothole	100	97.5	84.3	73.2	63.5	51.3	37.8	29.8	20.7	12.5	Stone fragments Gravel and sand	A-1-a
Rutting	100	96	96	91.8	88.3	73	51.8	42	24.5	14.2	Stone fragments Gravel and sand	A-1-b
Block crack	100	98.7	90	79	72.3	54.5	33.2	24.3	16	10.3	Stone fragments Gravel and sand	A-1-a
Depression	100	94.5	93.3	84.5	81	70.8	51.7	42.3	28.2	13.8	Stone fragments Gravel and sand	A-1-b

Table 13: Section C Grain size distribution of Subgrade layer

selected station	Grain size distribution of Subgrade layer											
	% passing										AASHTO Soil classification	
	37.5	25	19	12.5	9.5	4.75	2	1	0.425	0.075	Constituent material description	Group classification
Block crack	100	95.2	93.5	91.7	89	77	58	46.2	31	16.5	stone fragements Gravel and sand	A-1-b
Rutting	100	92.5	86.3	83.2	77.3	62.5	44.3	33.7	28	23.7	stone fragements Gravel and sand	A-1-b
Longitudinal crack	100	84.5	84.5	79	73.3	59.5	41.2	31.5	20.3	10.3	stone fragements Gravel and sand	A-1-a
Alligator crack	100	85.4	79.1	70.1	65.1	54.4	40.8	33.1	22.6	12.3	stone fragements Gravel and sand	A-1-a
pothole	100	100	95.3	89.8	81	62	38	26.3	13.3	7.7	stone fragements Gravel and sand	A-1-a

Based on AASHTO soil classification scheme the subgrade soils of the road are classified under group A-1-a, A-1-b, A-2-4, A-2-6, A-4, A-5 and A-7-6 soil. Their types of significant constituents of the materials are stone fragments Gravel and sand, Silty or clayed Gravel sand, silty soil and clayey soil. All section sub-grade soil Samples are classified good to poor subgrade soils types according to AASHTO. According to this soil at depression and block crack of section A and corrugation of section B are classified as fair to poor subgrade soils.

Poor sub-grade soils are clay and silt soils that exhibit swell-shrink behavior. Those Soils' volume increases since they absorb more water due to their mineralogical constituent. They also shrink when they dry out. This swell and shrinkage in sub-grade soils causes settlement in pavement layers, failure of pavement structures, and can result in road distress. Depending on this, I have conclude that depression and block crack of section A and corrugation of section B occurred at station (1+700-3+200), (6+200-6+320) and (9+580-9+600) respectively may occur due to the construction of pavement layers of poor subgrade soils.

4.2.3 Gradation Test Result for Sub Base

Table 14: Section A Grain size distribution of Sub Base layer

Grain size distribution of Sub Base layer												
	% passing										AASHTO Soil classification	
selected station	38	25	19	13	9.5	4.75	2	1	0.425	0.075	Constituent material description	Group classification
Block crack	100	95	78	63	54	40	36	30	23	17	Stone Fragments Gravel and sand	A-1-b
pothole	100	93	93	85	78.3	62.7	49	40.8	27.8	18.7	Silty or Clayed Gravel sand	A-2-6
Alligator crack	100	96	94	89	85.9	75.8	63.9	55.8	35.3	26.1	Silty or Clayed Gravel sand	A-2-4
Depression	100	98	96	93	87.8	79.7	67.2	58.7	40.5	26.5	Silty or Clayed Gravel sand	A-2-4

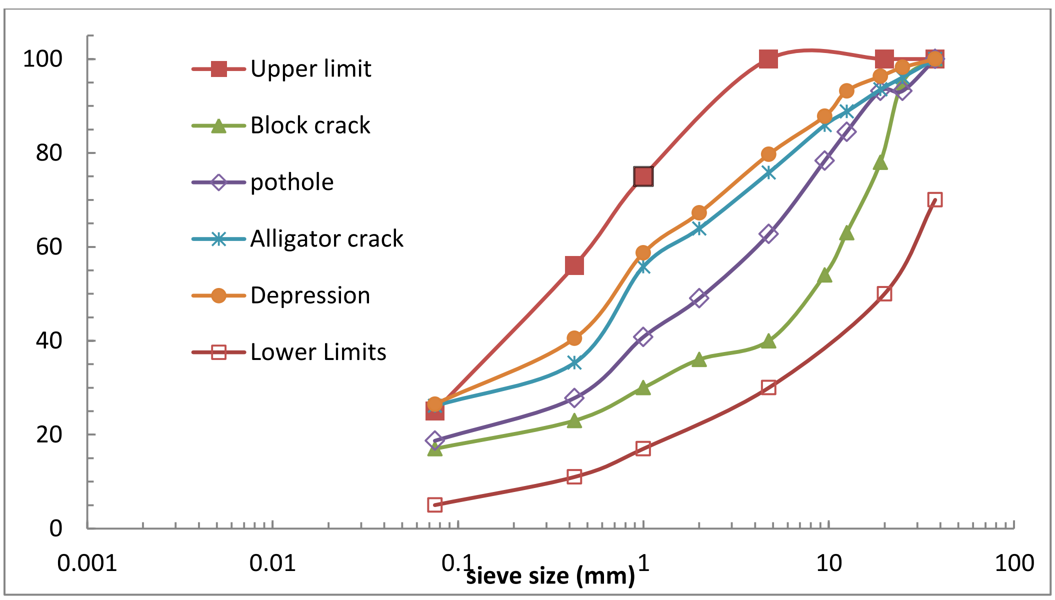


Figure 22: Section A Grain size distribution of Sub Base layer

Table 15: Section B Grain size distribution of sub base layer

Grain size distribution of sub base layer												
selected station	% passing										AASHTO Soil classification	
	37.5	25	19	12.5	9.5	4.75	2	1	0.425	0.075	Constituent material description	Group classification
Longitudinal crack	100	95	92.7	89.8	85.7	75.2	62.8	54.7	38.8	27.7	Silty or clayed Gravel sand	A-2-6
Transverse crack	100	100	91.7	84.8	76.5	69.9	57.6	46.6	30.2	19.3	Stone fragments Gravel and sand	A-1-b
Corrugation	100	97	95.8	88.7	84.8	71.5	57	47.7	34.3	23	Stone fragments Gravel and sand	A-1-b
Alligator crack	100	93.5	91.3	82	80	70	58.5	52.2	35.5	22.3	Stone fragments Gravel and sand	A-1-b
Pothole	100	97.5	94.7	88	82.7	71.8	57.8	48.3	31.2	20.3	Stone fragments Gravel and sand	A-1-b
Rutting	100	96.3	92.2	88.2	83.5	68.5	50.8	41.5	28	14.8	Silty or clayed Gravel sand	A-2-6
Block crack	100	95.8	91.3	86.5	81	65.3	48.3	38.5	24.3	12	Silty or clayed Gravel sand	A-2-6
Depression	100	100	98.5	95	90.8	79.2	63	53.5	35.8	23.5	Silty or clayed Gravel sand	A-2-6

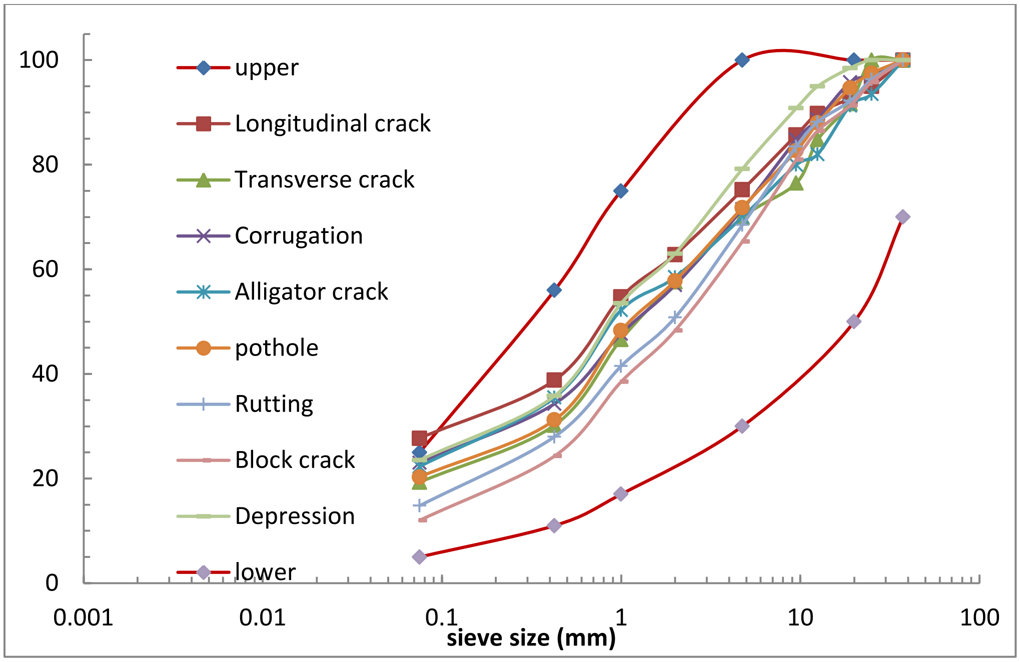


Figure 23: Section B Grain size distribution of sub base layer

Table 16: Section C Grain size distribution of sub base layer

Grain size distribution of sub base layer												
selected station	% passing										AASHTO Soil classification	
	37.5	25	19	12.5	9.5	4.75	2	1	0.425	0.075	Constituent material description	Group classification
Block crack	100	95.2	90.5	83.2	77.5	63.5	50.7	42.2	28.7	16.7	stone fragements Gravel and sand	A-1-b
Rutting	100	87.5	81.8	76.5	72.7	62.7	50	42.5	29	16.5	Silty or clayed Gravel sand	A-2-4
Longitudinal crack	100	100	97.3	86.5	80.2	63	45.8	38.3	29.3	20	Silty or clayed Gravel sand	A-2-6
Alligator crack	100	93.2	89	83.5	79.8	69.3	54.5	44.8	32.2	17.7	Silty or clayed Gravel sand	A-2-4
Pothole	100	98.5	93.7	87.8	83.2	70	55.3	46.3	32.7	19.2	stone fragements Gravel and sand	A-1-b

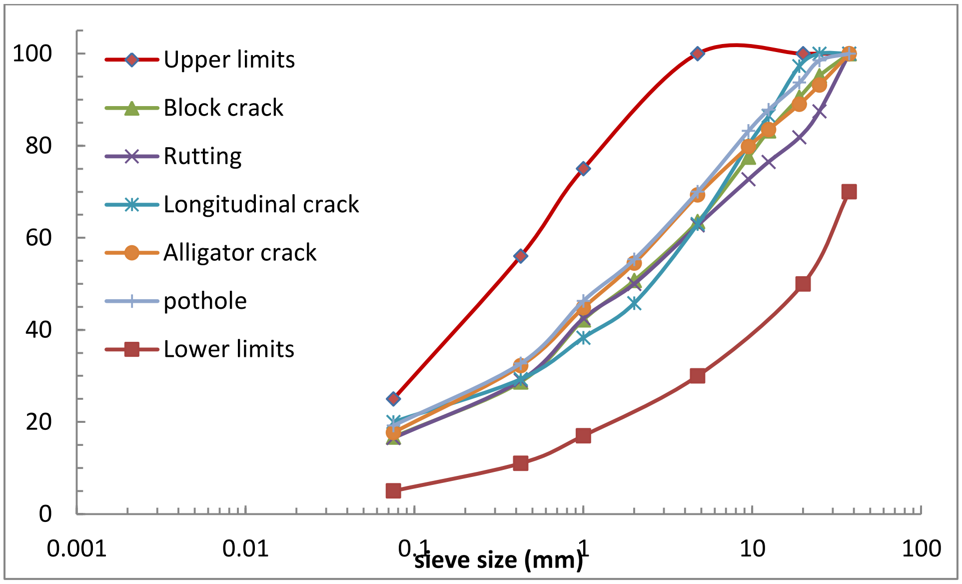


Figure 24: Section C Grain size distribution of sub base layer

In the whole stretch of Teji-Tulu Bolo road segments, the brown granular Reddish scoria blended with grayish gravelly sand material was used as a sub-base material. Based on ERA, Ethiopian roads authority 2013 Standard Technical Specification and Method of Measurement, the grading envelop for natural gravel sub base was used which is given in Table 1. When considering the gradation test results for sub base material at all three sections, the percentage passing for all sieve sizes are fully within the range of specifications based on ERA grading requirement. This indicates that the materials were well graded and this can insure the sub base at this section was compacted readily to form stable and firm layer which have good bearing capacity and shearing resistance.

4.2.4 Gradation Test Result for Base course Layer.

Table 17: Section A Grain size distribution of Base Course layer

Grain size distribution of Base Course layer									
	% passing							AASHTO Soil classification	
selected station	38	20	10	5	2.36	0.43	0.08	Constituent material description	Group classification
Alligator crack	100	78	63	45	30.9	11.6	7.6	stone fragements Gravel and sand	A-1-a
Block crack	100	75	50	32	18	8	6	Silty or clayed Gravel sand	A-2-6
Depression	100	80	51	30	18.3	8.2	5.8	stone fragements Gravel and sand	A-1-a
pothole	100	82	55	36	22.9	10.5	7.7	stone fragements Gravel and sand	A-1-a

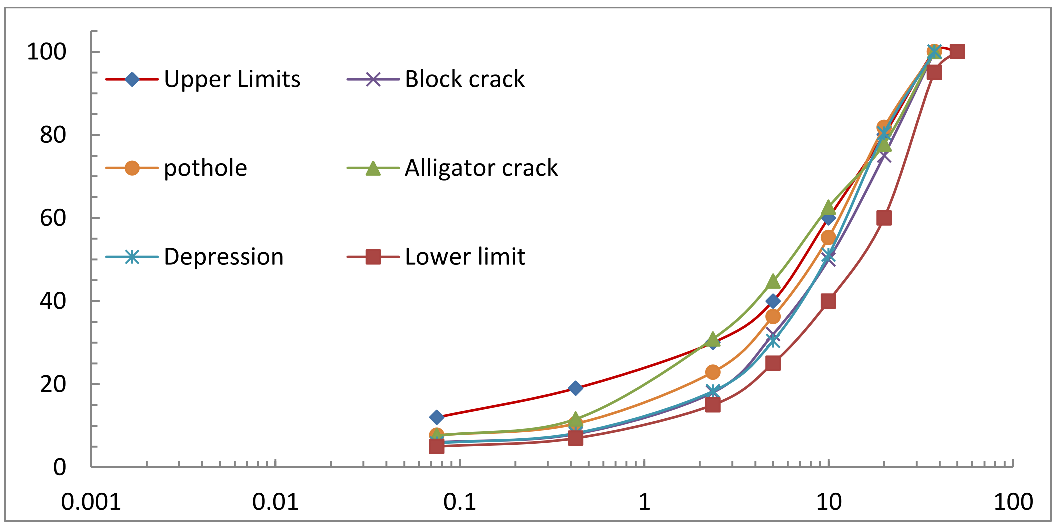


Figure 25: Section A Grain size distribution of Base Course layer

Table 18 : Section B Grain size distribution of Base Course layer

Grain size distribution of Base Course layer									
selected station	% passing							AASHTO Soil classification	
	37.5	20	10	5	2.36	0.425	0.075	Constituent material description	Group classification
Longitudinal crack	100	86.8	58.9	35	20.5	8.1	5.3	stone fragements Gravel and sand	A-1-a
Transverse crack	100	87.4	47.4	14.4	9	4.3	3.1	stone fragements Gravel and sand	A-1-a
Corrugation	100	71.5	33.5	19.2	12.2	5.7	4	stone fragements Gravel and sand	A-1-a
Alligator crack	100	66.9	38.8	22.8	14.9	13.3	9	stone fragements Gravel and sand	A-1-a
Pothole	100	67.1	39.4	22	11.8	4.8	3.4	stone fragements Gravel and sand	A-1-a
Rutting	100	82.9	58.5	38.7	24.5	9.6	7.5	stone fragements Gravel and sand	A-1-a
Block crack	100	87.3	53	29	14.8	5.6	4.2	stone fragements Gravel and sand	A-1-a
Depression	100	90.4	52.1	31.4	19.1	7.4	5.3	stone fragements Gravel and sand	A-1-a

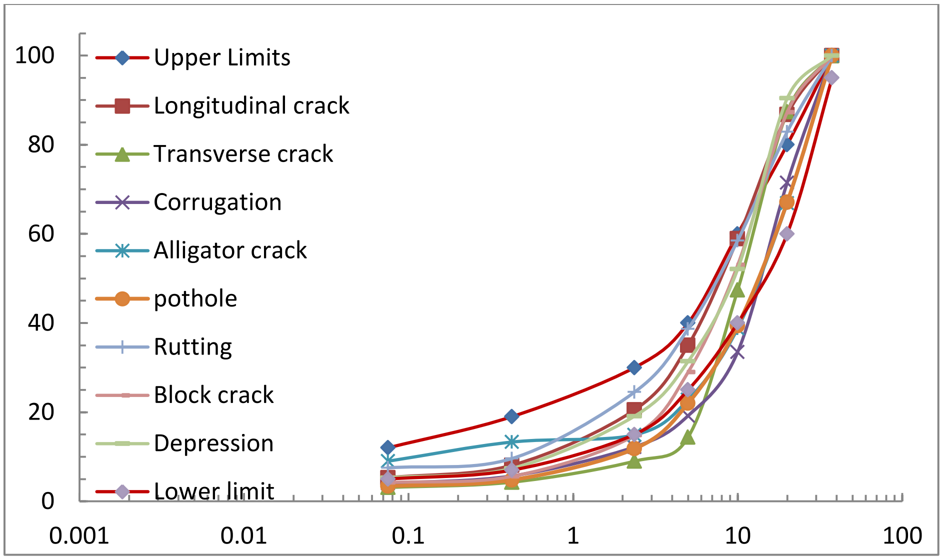


Figure 26 : Section B Grain size distribution of Base Course layer

Table 19: Section C Grain size distribution of Base Course layer

Grain size distribution of Base Course layer									
	% passing							AASHTO Soil classification	
selected station	37.5	20	10	5	2.36	0.425	0.075	Constituent material description	Group classification
Block crack	100	77.8	59.9	42.8	31.6	17.9	13.4	stone fragements Gravel and sand	A-1-a
Rutting	100	80.2	61.4	43.5	27.8	12.3	9.7	stone fragements Gravel and sand	A-1-a
Longitudinal crack	100	82.8	46.3	28.6	19.3	11.8	9.3	stone fragements Gravel and sand	A-1-a
Alligator crack	100	72.8	41	26.8	18.5	10.2	8.3	stone fragements Gravel and sand	A-1-a
Pothole	100	78.4	60	42.6	31.8	17.5	13.3	stone fragements Gravel and sand	A-1-a

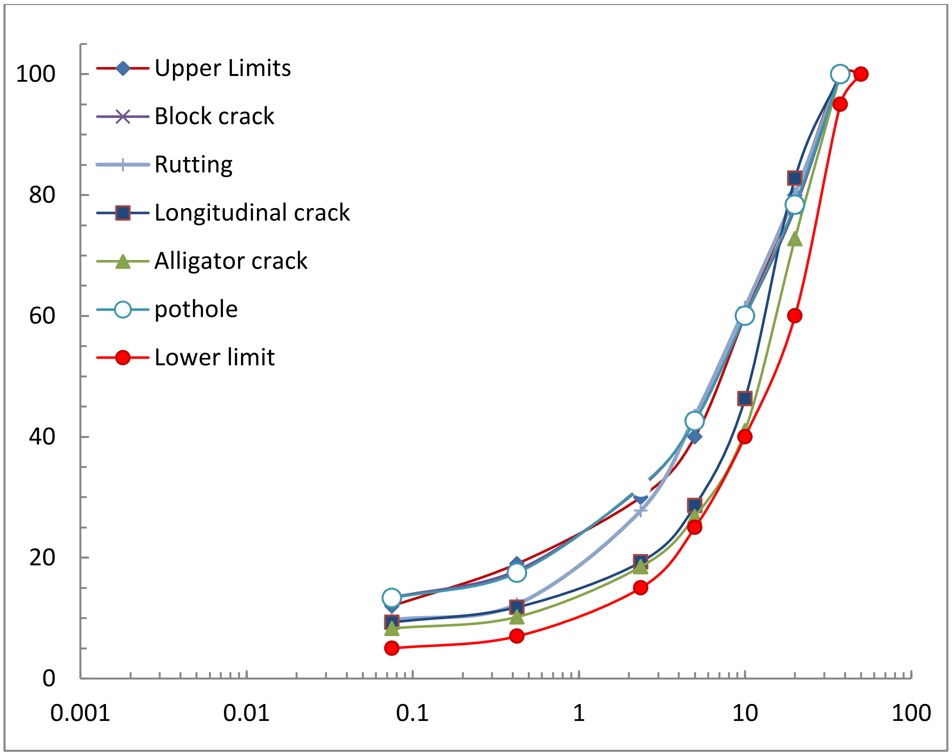


Figure 27: Section C Grain size distribution of Base Course layer

The base course layer at every section of this segment was constructed with base course material obtained from crushed basaltic rock. Therefore the laboratory test results for gradation is compared with gradation envelop of crushed rock. The results showed that from all the three sections only C sections was within the limit. On the contrary gradation curve of section A alligator crack shows the material is finer than expected since it occurs above the upper limits curve and gradation curve of section B transverse crack shows the material is courser than expected since it occurs below the lower limits curve and this implies base course material at this two spot is poorly graded.

Poorly graded material would never be dense and durable since it lack in mechanical interlocking of various particle sizes. Due to less supporting resistance, it was displaced under stress as a result. Therefore, poorly graded base course materials may be the reason for the manifestation of section A alligator crack and section B transverse crack on the road sections.

4.2.5 Compaction analysis of existing pavement materials

By comparing the results of the field and laboratory density tests with the amount of water required for compaction, we ascertain the grading features and the degree of compaction of the layer; hence Proctor tests were carried out in accordance with AASHTO T-180. The results for the subgrade soil samples' field density (FDT), optimum moisture content (OMC), and maximum dry density (MDD) are shown in Tables 20, 21, and 22, respectively, for sections A, B, and C.

Table 20: Section A Compaction and Field density test result for subgrade

Compaction and Field density test result for subgrade					
	Laboratory		Field		
types of distress	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	Degree of compaction %
Block crack	1.80	9.2	1.55	8.20	86
pothole	2.36	8.5	2.30	7.48	97.25
Alligator crack	2	8	1.87	6.50	93.63
Depression	1.74	18.4	1.73	18.06	99.35

Table 21: Section B Compaction and Field density test result for subgrade

Compaction and Field density test result for subgrade					
types of distress	Laboratory		Field		Degree of compaction %
	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	
Longitudinal crack	2.035	8.1	1.90	10.04	93.27
Transverse crack	1.884	11.5	1.87	7.72	99.06
Corrugation	1.731	11.8	1.32	25.40	76.24
Alligator crack	1.821	11	1.90	13.69	104.55
pothole	1.768	9.3	1.47	22.73	83.22
Rutting	1.792	10.8	1.41	12.46	78.77
Block crack	1.704	10.2	1.53	14.56	90.05
Depression	1.795	10.5	1.93	8.9	107

Table 22: Section C Compaction and Field density test result for subgrade

Compaction and Field density test result for subgrade					
types of distress	Laboratory		Field		Degree of compaction %
	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	
Block crack	1.711	11	1.52	15	89
Rutting	1.626	17	1.618	10.6	100
Longitudinal crack	1.663	12.3	1.547	11.4	93
Alligator crack	1.663	12.5	1.652	4.2	99
pothole	1.623	14.5	1.449	16.1	89

While comparing the field test results with the laboratory test results, the NMC for the entire test stations are within allowable tolerance which is 2±OMC except for section B corrugation, alligator crack, block crack and pothole and section c block crack. The subgrade's NMC and OMC discrepancies range from 13.6% to 2.69 percent. This deviation from allowable tolerance may cause the reduction of field density at section B corrugation, block crack and pothole and section c block crack at where their degree of compaction ranges from 76.24 to 90.05 percent. Additionally while taking into account the correlation between the dry density measured in the field and the laboratory for the subgrade soil sample at section A block crack and alligator crack, section B longitudinal crack and rutting and section c longitudinal crack and pothole did not attain the required degree of compaction recommended by ERA Pavement Design Manual , which states that All subgrades should have the top 25 cm compacted to at least 95% of the maximum dry density possible by heavy compaction.. The degree of compaction of those subgrade ranges from 78.77 to 93.27 percent. Therefore improper compaction of subgrade may cause the distress such as block crack, alligator crack, rutting, longitudinal crack and pothole along this stretch.

The samples retrieved from the sub base layer were subjected to the Proctor test, and tables 23, 24, and 25 shows the range of values for FDD, MDD, and OMC.

Table 23: Section A Compaction and Field density test result for sub base

Compaction and Field density test result for sub base					
	Laboratory		Field		
types of distress	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	Degree of compaction %
Block crack	1.76	11.4	1.67	15.90	95
pothole	1.81	14.4	1.64	15.71	90.88
Alligator crack	1.832	11.5	1.65	14.71	90.16
Depression	1.75	15.2	1.75	15.56	99.92

Table 24: Section B Compaction and Field density test result for sub base

Compaction and Field density test result for sub base					
types of distress	Laboratory		Field		Degree of compaction %
	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	
Longitudinal crack	1.802	9	1.59	16	88.41
Transverse crack	1.821	12.6	1.61	15.65	88.55
Corrugation	1.779	12	1.86	14.29	104.82
Alligator crack	1.782	11.3	1.68	11.92	94.44
pothole	1.765	11.8	1.61	18.91	91.39
Rutting	1.819	10.8	1.67	17.09	91.62
Block crack	1.782	12.2	1.60	16.79	89.66
Depression	1.764	8.6	1.59	18.9	90

Table 25: Section C Compaction and Field density test result for sub base

Compaction and Field density test result for sub base					
types of distress	Laboratory		Field		Degree of compaction %
	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	
Block crack	1.681	12.3	1.54	18	91
Rutting	1.744	9.4	1.66	13.7	95
Longitudinal crack	1.766	10.8	1.685	12.7	95
Alligator crack	1.689	11.4	1.322	33.9	78
pothole	1.663	12.4	1.567	12.9	94

The optimum moisture content of the sub base layer now ranges from 8.6% to 12.6%, and the maximum dry density ranges from 1.681 g/cm3 to 1.832 g/cm3.

The natural moisture content of the sub base is out of expected tolerance in all three sections except at section A pothole and depression, section B alligator crack and section C longitudinal crack and pothole. Increase in natural moisture content after compaction can cause soil to lose it shear strength and susceptible to settlement and shrinkage which is lead to failure such as depression, longitudinal crack, pothole and alligator crack.

Insufficient sub base material compaction were observed since degree of compaction of all section except section A depression and block crack, section B corrugation and section C rutting and longitudinal crack were below specification set by ERA which is 95% of maximum dry density. Therefore the manifestation of distress on this road segment may arise from improper compaction encountered there.

The compaction test results of base course was performed on the samples taken from the base course from all three section by depending color and material changes and the range of values for FDD, MDD and OMC is presented on table 26, 27 and 28.

Table 26: Section A Compaction and Field density test result for base course

Compaction and Field density test result for base course					
	Laboratory		Field		
types of distress	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	Degree of compaction %
Block crack	1.72	11.4	2.05	5.40	116
pothole	2.37	7.4	2.52	4.82	106.28
Alligator crack	2.286	7.8	2.34	4.42	102.17
Depression	2.32	7.5	2.35	4.69	101.54

Table 27: Section B Compaction and Field density test result for base course

Compaction and Field density test result for base course					
types of distress	Laboratory		Field		Degree of compaction %
	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	
Longitudinal crack	2.389	7	2.47	5.16	103.22
Transverse crack	2.398	7.8	2.26	7.61	94.20
Corrugation	2.379	6.8	2.57	2.70	107.87
Alligator crack	2.432	6.8	2.47	4.30	101.46
pothole	2.236	9.8	2.68	4.09	119.69
Rutting	2.28	7.5	2.34	4.67	102.67
Block crack	2.232	7.8	2.32	6.00	103.84
Depression	1.795	10.5	1.93	8.9	107

Table 28: Section C Compaction and Field density test result for base course

Compaction and Field density test result for base course					
types of distress	Laboratory		Field		Degree of compaction %
	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)	
Block crack	2.358	5.9	2.15	5.2	91
Rutting	2.242	7.7	1.93	5.9	86
Longitudinal crack	2.2	7.4	2.048	7.4	93
Alligator crack	2.3	6.9	1.915	5.4	83
pothole	2.308	7.3	1.97	6.3	85

While analyzing the laboratory and field density test results of base course layer, It was found that the field moisture content is within the given tolerance -2% or +2% of OMC in all section. With the exception of the section B transverse crack, which is compacted to 94.2% MDD only, the field dry density at sections A and B ranges from 101.46% to 119.69%, exceeding the standards set forth in the standard specification, which is comparatively larger than 98%.

The field dry density at section c ranges from 83% to 93%, which far from expected. Hence the cause for occurrences of rutting, pothole and other distresses encountered at section c may be insufficient compaction.

4.2.6 California bearing ratio analysis of the materials used in existing pavement

To investigate the impact of soaking on the strength characteristics of the subgrade soils and to determine the parameters of the soil's strength at its weakest state, soaked CBR tests were conducted. Tables 29, 30, and 31 indicate the range of CBR test results for sections A, B, and C.

Table 29: Section A CBR test value

CBR test value						
types of distress	subgrade layer		sub base layer		base course layer	
	CBR (%)	CBR swell (%)	CBR (%)	CBR swell (%)	CBR (%)	CBR swell (%)
Block crack	40	1.3	80	0.9	90	0.79
Pothole	80	1.39	109	0.8	122	0.4
Alligator crack	60	1.44	79	0.55	150	0.5
Depression	70	0.95	90	0.95	144	0.7

Table 30: Section B CBR test value

CBR test value						
types of distress	subgrade layer		sub base layer		base course layer	
	CBR (%)	CBR swell (%)	CBR (%)	CBR swell (%)	CBR (%)	CBR swell (%)
Longitudinal crack	75	0.7	87	0.6	170	0.65
Transverse crack	70	1	105	0.55	185	0.85
Corrugation	95	0.85	105	0.65	80	0.4
Alligator crack	65	0.7	120	0.9	110	0.45
pothole	75	0.9	110	0.75	120	0.75
Rutting	75	1.05	108	1.15	150	0.49
Block crack	110	0.95	118	0.9	145	0.69
Depression	75	1.2	100	1.1	108	0.49

Table 31: Section C CBR test value

CBR test value						
types of distress	subgrade layer		sub base layer		base course layer	
	CBR (%)	CBR swell (%)	CBR (%)	CBR swell (%)	CBR (%)	CBR swell (%)
Block crack	90	1.6	95	0.9	120	0.6
Rutting	90	1.19	80	0.6	120	0.65
Longitudinal crack	85	1.19	90	0.6	120	0.65
Alligator crack	80	1.19	90	1.2	110	0.6
pothole	85	1.15	87	1.15	115	0.45

From the recommendation given on ERA Pavement Design Manual volume I, for crushed rock (GB1), the CBR after soaking should be greater than 100 percent. The laboratory test results shows the CBR of the base material ranges from 80%-185%. Therefore base course materials have enough strength to serve as base course material except section A block crack and section B corrugation which have CBR of 90% and 80% respectively. The base course shows results of swell between 0.4 % and 0.85% which are an indication of presence of expansive soil in base course crushed stone. Hence insufficient CBR at section A block crack and section B corrugation and unexpected swell value of base course may be the cause of defects on road surface.

The CBR after soaking should be greater than 30 according to the ERA manual's recommendation for natural gravel (GS) in sub-base courses. Additionally, all of the laboratory results which range in value from 79% to 120% are higher than the predetermined values. The swell of sub base range from 0.55%-1.2%, four sub base sample (i.e. Section B rutting and depression and section C alligator crack and pothole) have swell value >1% which shows expansive sub base material and this may cause road defects such as rut and depression on road surface. it is observed that the soaked CBR values for sub-grade materials varied between 40% and 110% in all sections sample, which is highly greater than the specified value on ERA Pavement Design Manual volume I. the subgrade material also haven't show expansiveness and their swell result were < 2%.

4.3 Road bed or native subgrade investigation

Black cotton material has been observed immediately below embankment at depth 100mm to 350mm. These materials could be potentially expansive and/or have low bearing capacity.

However, along these flat stretches the existing road did not sufficiently replaced 60cm height recommend by ERA.

Table 32: Depth of replacement

section A	
station	depth of replacement/embankmnet height(cm)
Block crack	28
pothole	10
Alligator crack	10
Depression	10
section B	
Longitudinal crack	30
Transverse crack	25
Corrugation	25
Alligator crack	25
pothole	30
Rutting	28
Block crack	28
Depression	30
section C	
Block crack	35
Rutting	35
Longitudinal crack	35
Alligator crack	30
pothole	30

To determine the properties of the sub grade material, testes such as Atterberg limits, sieve analysis, modified proctor, 3-point CBR and CBR-swell were done; results and discussion are putted hereunder.

An indication as to the nature of the soil along the route may be given by the variation in Plasticity Index (PI).The PI is influenced by the type and proportion of clay minerals present within the material and high values of PI are an indication of expansivity. The variation of PI along the route is presented on Figure 28, 29 and 30.

types of distress	section A road bed atterberg		
	LL	PL	PI
Block crack	63	31	32
pothole	62	36	26
Alligator crack	55	32	23
Depression	40	20	20

Figure 28: section A road bed PI value

types of distress	section B road bed atterberg		
	LL	PL	PI
Longitudinal crack	63	35	28
Transverse crack	64	31	33
Corrugation	65	33	32
Alligator crack	59	30	29
Pothole	68	35	33
Rutting	96	45	51
Block crack	76	37	39
Depression	75	38	37

Figure 29: section B road bed PI value

types of distress	section C road bed atterberg		
	LL	PL	PI
Block crack	72	33	39
Rutting	63	31	32
Longitudinal crack	63	35	28
Alligator crack	64	31	33
pothole	65	33	32

Figure 30: section C road bed PI value

The plasticity index of the subgrade is required to be a maximum of 30% this did not satisfied in almost all samples except in five samples and obtained PI ranges from 20% to 51%.

Wet sieve analysis were done on sample collected from representative test pit to characterize the soil along this road segment as per their AASHTO class and the result is tabulated on table 31, 32 and 33.

Table 33: Section A grain size distribution of road bed soil

Grain size distribution of road bed					
selected station	% passing			Soil classification	
	2	0.425	0.075	material description	AASHTO Soil classification
Block crack	100	97	90	dark brown clay	A-7-5
pothole	100	98	89	black cotton	A-7-5
Alligator crack	95	88	63	black cotton	A-7-5
Depression	98	91	77	black cotton	A-7-5

Table 34: Section B grain size distribution of road bed soil

Grain size distribution of road bed soil					
selected station	% passing			Soil classification	
	2	0.425	0.075	material description	AASHTO Soil classification
Longitudinal crack	98	95	93	dark brown clay	A-7-5
Transverse crack	99	97	96	dark brown clay	A-7-5
Corrugation	97	95	94	back cotton	A-7-5
Alligator crack	99	95	92	black cotton	A-7-5
Pothole	100	98	97	back cotton	A-7-5
Rutting	100	91	83	back cotton	A-7-5
Block crack	99	97	88	black cotton	A-7-5
Depression	100	96	83	black cotton	A-7-5

Table 35: Section C grain size distribution of road bed soil

Grain size distribution of road bed soil					
selected station	% passing			Soil classification	
	2	0.425	0.075	material description	AASHTO Soil classification
Block crack	100	97	78	dark brown clay	A-7-5
Rutting	100	97	90	dark brown clay	A-7-5
Longitudinal crack	98	95	93	dark brown clay	A-7-5
Alligator crack	99	97	96	dark brown clay	A-7-5
pothole	97	95	94	dark brown clay	A-7-5

The classification tests showed that the alignment soil fall in to A-7-5 AASHTO soil group and are found to be poor subgrade material.

In order to check suitability of road bed material as subgrade of the road I have calculated the group index of each sample and the result were showed on Figure 31, 32 and 33.

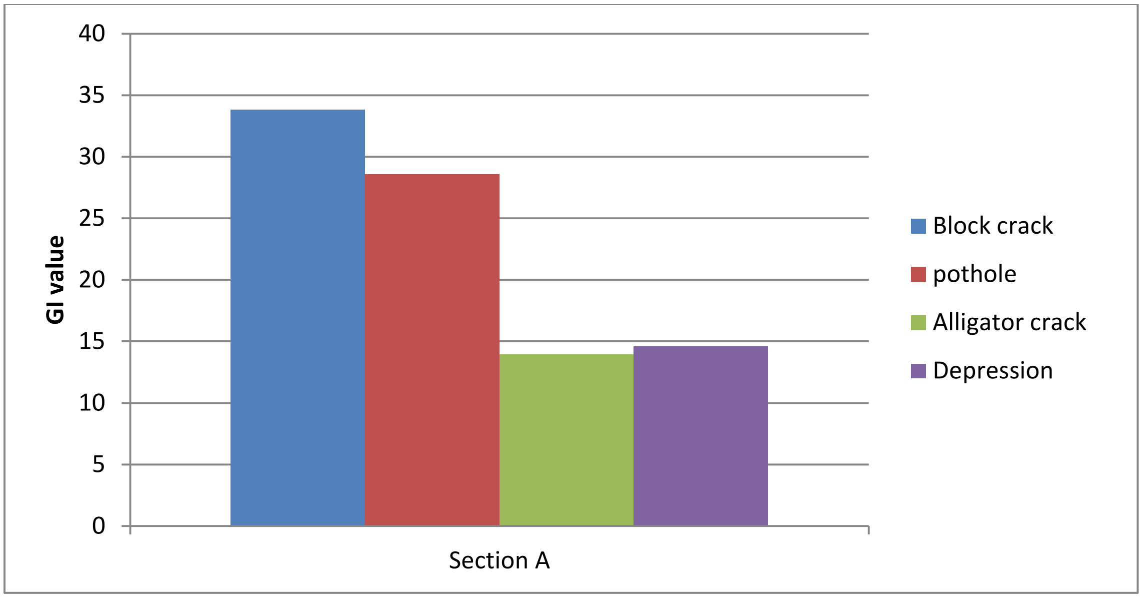


Figure 31: section A group index

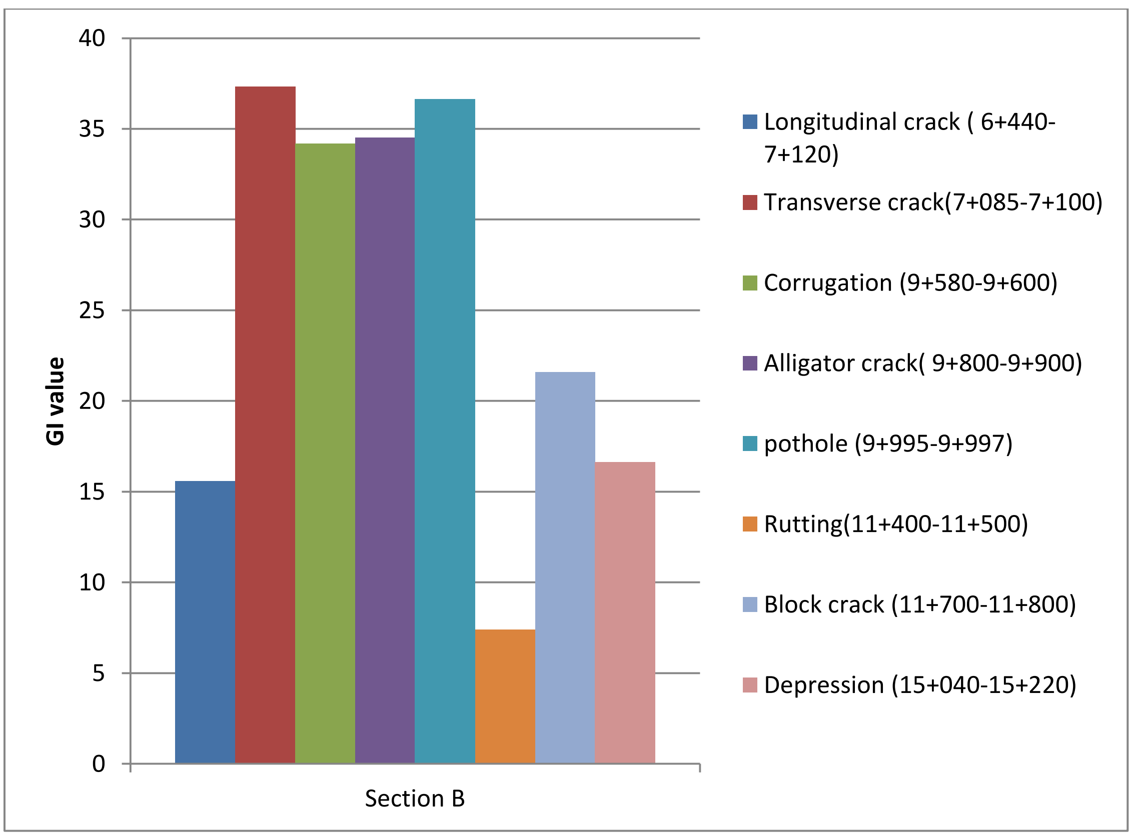


Figure 32: section B group index

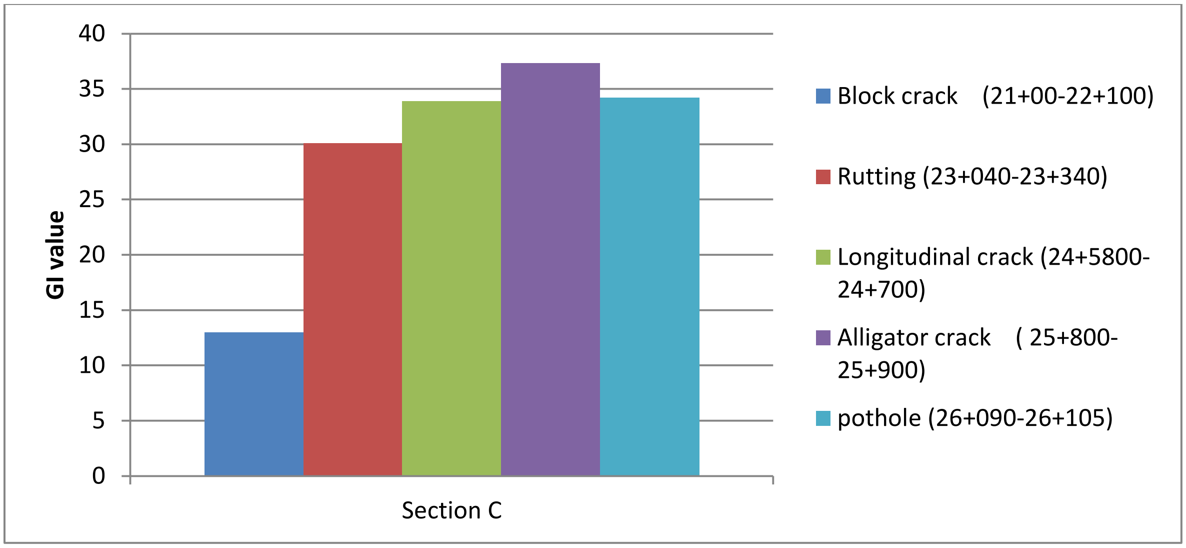


Figure 33: Section c group index

A group index of zero indicate good subgrade soil, on the other hand a group index of 20 or above shows very poor subgrade soil. Depending on this my finding shows that the native subgrade soil of teji-tulubolo road segment is very poor subgrade with GI value ranges from 8 to 40 and most of the samples have GI value greater than 20.

Soil samples obtained from test pits have been compacted in the laboratory at various moisture contents to derive a dry density versus moisture content relationship. Compaction was carried out in accordance to AASHTO T180 (4.5 kg hammer or heavy hammer). In situ density testing also has been carried out on the existing pavement layer to evaluate the field dry density (FDD) and field moisture content (FMC) of the pavement layer. The results obtained from those tests were summarized in table 37, 38 and 39.

Table 36: Section A Compaction and Field density test result for road bed

Compaction and Field density test result for road bed						
types of distress	Laboratory		Field		Degree of compaction %	NMC-OMC
	MDD (gm/cm3)	OMC (%)	Dry density (gm/cm3)	Moisture content (%)		
Block crack	1.54	23.7	1.3322	27.00	87	3.30
Pothole	1.52	27	1.3584	30.00	89	3.00
Alligator crack	1.54	27	1.353	31.00	88	4.00
Depression	1.56	20	1.3884	23.80	89	3.80

Table 37: Section B Compaction and Field density test result for road bed

Compaction and Field density test result for road bed						
types of distress	Laboratory		Field		Degree of compaction %	NMC-OMC
	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)		
Longitudinal crack	1.56	23.5	1.404	26.00	90.00	2.50
Transverse crack	1.54	25	1.2166	28.20	79.00	3.20
Corrugation	1.5	24	1.365	26.40	91.00	2.40
Alligator crack	1.5	24	1.35	27.35	90.00	3.35
pothole	1.46	25	1.2994	29.30	89.00	4.30
Rutting	1.34	30.2	1.206	32.79	90.00	2.59
Block crack	1.51	28	1.4647	27.00	97.00	-1.00
Depression	1.47	29	1.4406	27.87	98.00	-1.13

Table 38: Section C Compaction and Field density test result for road bed

Compaction and Field density test result for road soil						
types of distress	Laboratory		Field		Degree of compaction %	NMC-OMC
	MDD (gm/cm3)	OMC (%)	Dry density(gm/cm3)	Moisture content (%)		
Block crack	1.46	29	1.3162	32.75	90.15068	3.75
Rutting	1.54	23.7	1.363	26.00	88.50649	2.30
Longitudinal crack	1.56	23.5	1.3416	27.67	86	4.17
Alligator crack	1.54	25	1.315	29.53	85.38961	4.53
Pothole	1.5	24	1.35	26.30	90	2.30

An evaluation of the test results generally shows, MDD along road alignment predominately varying between 1.34 g/cm^3 and 1.56 g/cm^3 and optimum Moisture Content (OMC) varying between 23.5% and 30.2%. The moisture content of field was deviate more than 2% from laboratory optimum moisture content. These were caused by moisture infiltration from adjacent pond and flood plain as a result field density and degree of compaction was below standard.

Three-point CBRs (i,e, 10, 30 and 65 blows of the hammer) were undertaken in accordance with AASHTO T-193. This form of testing is preferred as it can give information of the variation of strength that can be developed with increasing compactive effort. The amount of CBR-swell also determined on disturbed samples of soil collected from proposed pits along the road corridor to evaluate potential to heave of the material. The CBR and CBR swell values at 95% MDD are shown on table 37, 38 and 39.

Table 39: section A road bed CBR and CBR swell value

types of distress	section A road bed CBR and CBR swell value	
	CBR (%)	CBR swell (%)
Block crack	1.18	2.79
Pothole	1.29	2.78
Alligator crack	4.85	1.79
Depression	8.77	1.87

Table 40: section B road bed CBR and CBR swell value

types of distress	section B road bed CBR and CBR swell value	
	CBR (%)	CBR swell (%)
Longitudinal crack	1.89	2.57
Transverse crack	1.94	2.57
Corrugation	1.26	2.68
Alligator crack	1.23	2.71
Pothole	1.4	3.12
Rutting	1.25	5.36
Block crack	1.23	6.61
Depression	1.93	7.68

Table 41: section C road bed CBR and CBR swell value

types of distress	section C road bed CBR and CBR swell value	
	CBR (%)	CBR swell (%)
Block crack	1.43	3.82
Rutting	1.18	2.79
Longitudinal crack	1.89	2.57
Alligator crack	1.94	2.57
pothole	1.25	2.68

The natural soil along stretch is covered by black cotton material of low CBR strength averagely less than 2% and high swell (>2%) values.

Hence the manifestations of distress on the surface of the road mainly caused by the expansive soils with low strength and high swell which are not sufficiently replaced.

4.4 Traffic loading evaluation

Even though failures that are observed on the road section can be caused due to weak material but also it is observed that the actual traffic of the road given on Table 6 and 7 are increase rapidly year to year.

The deterioration of paved roads caused by traffic results from both the magnitude of the individual wheel loads and the number of times these loads are applied. Therefore it is necessary to consider not only the total number of vehicles that will use the road but also the wheel loads (or, for convenience, the axle loads) of these vehicles and the analysis are presented in table 41 and 42.

Table 42: cumulative traffic volume from 2014 to 2022

	Cumulative Traffic							
year	Car	4wd	S.Bus	L.Bus	S.Truck	M.Truck	H.Truck	Truck Trailer
2014	0	0	0	0	0	0	0	0
2015	3,789,689	5,853,501	7,591,447	3,379,341	4,574,179	6,487,127	5,135,391	4,127,623
2016	4,845,733	5,769,017	7,404,376	3,940,552	4,978,493	6,390,574	5,503,497	4,845,733
2017	5,974,191	6,758,681	8,520,766	5,207,805	5,968,157	7,410,411	5,648,326	6,330,229
2018	7,543,171	8,267,315	10,500,094	6,740,577	7,899,208	9,679,397	8,291,453	7,675,931
2019	7,398,342	8,406,110	11,151,824	7,036,270	7,663,862	9,950,951	9,124,219	9,293,186
2020	8,967,321	10,011,296	13,203,566	8,569,042	9,594,913	12,219,937	11,767,346	10,910,442
2021	10,536,301	11,616,483	15,255,309	10,101,814	11,525,965	14,488,922	14,410,473	12,527,698
2022	12,105,280	13,221,670	17,307,051	11,634,587	13,457,017	16,757,908	17,053,600	14,144,954

Table 43: cumulative ESAs from 2014 to 2022

Year	Cumulative ESAs								Total ESA (106)
	Car	4wd	S.Bus	L.Bus	S.Truck	M.Truck	H.Truck	Truck Trailer	
2014	0	0	0	0	0	0	0	0	0
2015	0	0	1	3	3	16	26	25	74
2016	0	0	1	4	3	16	28	29	81
2017	0	0	1	5	4	19	28	38	95
2018	0	0	2	7	6	24	41	46	126
2019	0	0	2	7	5	25	46	56	140
2020	0	0	2	9	7	31	59	65	172
2021	0	0	2	10	8	36	72	75	204
2022	0	0	3	12	9	42	85	85	236

The road is designed for 2.13 mesas which is T_4. Currently the road accommodates more than 236 mesas which is T_{11} according to ERA geometric design manual. This over loading of traffic than expected by the road may cause to lose its serviceability.

Finally depending up on results of the finding cause for each failure type is summarized on table 43, 44 and 45 for section A, B and c respectively

Table 44: section A result summary

selected station	causes for distress
Block crack	• depth of replacement • traffic over loading • base course PI • Subgrade degree of compaction • moisture in sub base • poor embankment material • base course with low CBR • base course with swell properties
pothole	• depth of replacement • out of spec sub base PI • base course with plasticity properties • more than design traffic • sub base degree of compaction • base course with swell properties
Alligator crack	• depth of replacement • out of spec base course PI • subgrade compaction • traffic over loading • excesses fine material in base course • sub base degree of compaction • moisture in sub base • base course with swell properties
Depression	• depth of replacement • more than design traffic • poor embankment material • base course with swell properties

Table 45: Section B result summary

selected station	causes of distress
Longitudinal crack	• sub base PI • base course with plasticity properties • depth of replacement • traffic over loading • subgrade degree of compaction • sub base degree of compaction • sub base moisture base course CBR swell
Transverse crack	• base course with plasticity properties • depth of replacement • traffic over loading • courser base course material • sub base degree of compaction • sub base moisture • base course CBR swell
Corrugation	• base course with plasticity properties • depth of replacement • traffic over loading • subgrade degree of compaction • subgrade moisture • sub base moisture • base course CBR • base course CBR swell
Alligator crack	• base course with plasticity properties • depth of replacement • traffic over loading • subgrade moisture • sub base degree of compaction • base course CBR swell
Pothole	• base course with plasticity properties • depth of replacement • traffic over loading • subgrade degree of compaction • subgrade moisture • sub base degree of compaction • sub base moisture
Rutting	• base course with plasticity properties • depth of replacement • traffic over loading • subgrade degree of compaction • sub base degree of compaction • sub base CBR swell

Block crack	• base course with plasticity properties • depth of replacement • traffic over loading • subgrade degree of compaction • subgrade moisture • sub base degree of compaction • sub base moisture • base course CBR swell
Depression	• sub base PI • base course with plasticity properties • depth of replacement • traffic over loading • sub base degree of compaction • sub base moisture • sub base CBR swell • base course CBR swell

Table 46: section C result summary

selected station	causes of distress
Block crack	• depth of replacement • plasticity of base course • subgrade moisture • subgrade compaction • sub base moisture • sub base compaction • base course compaction
Rutting	• depth of replacement • plasticity of base course • sub base moisture • base course compaction
Longitudinal crack	• depth of replacement • plasticity of base course • subgrade compaction
Alligator crack	• depth of replacement • plasticity of base course • sub base moisture • sub base compaction • base course compaction
Pothole	• depth of replacement • plasticity of base course • subgrade compaction • sub base compaction • base course compaction

5 CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The purpose of this thesis was to determine the root of the Teji-Tulu Bolo flexible pavement road segment failure. The study's overall analysis is based on the state of the roads at the time of the inquiry. The road portion between Teji and Tulu Bolo was thoroughly studied, with a focus on the severely damaged section of the road because it serves as an example for the rest of the segment. Roadbed samples and pavement components (the subgrade, sub base, and base course) were taken for testing in the study. The pavement layers were characterized by using laboratory tests such as sieve analysis to check the soil layer grain size distribution, Atterberg limit (LL and PL test), to find out the soil's plasticity index, compaction test to obtain the soil's MDD and OMC, and finally California Bearing Ratio test to determine the strength and stability of the soil based on the test result.

Various forms of distresses were seen on the route after a visual check. Potholes, rutting, corrugation, longitudinal cracks, depressions, and block cracks were the most prevalent types of distresses that were seen. Based on measurements and coverage of the entire road segment, the types and severity of the road distresses were classified, and the spots with the highest severity were chosen for laboratory testing.

According to AASHTO, all section sub-grade soil samples are classed as having good to poor subgrade soil types by laboratory tests conducted on the subgrade for gradation. The difference or increase in the moisture content of the road can be seen when the NMC on the subgrade is compared to the OMC collected in the lab. For the subgrade, the gap between the NMC and OMC varies between 13.6 and 2.69 percent. Because of the NMC's departure from the permitted tolerance and the inadequate compaction energy brought on by poor workmanship and the construction method, the subgrade no longer receives the necessary level of compaction. Therefore, the road's dysfunction was caused by a subgrade with insufficient compaction.

From the subgrade strength tests along the road segment the replaced subgrade material have good CBR value but did not replaced to sufficient depth. For the traffic class that was classified as T_4, the subgrade strength was therefore inadequate. As a result, it has a serious issue with the structural thickness of the pavement to handle the current traffic.

From the tests done on the sub base the grading requirement based on ERA manual was satisfied and it was not the cause of failure. And also the CBR result obtained from the laboratory is all greater than the specified values ranging from 79%-120% and did not the cause of failure, but swell of sub base range from 0.55%-1.2% which shows expansive sub base material. And also the sub base material slightly has plasticity property than required by ERA.

From the test pit the sub base were observed wet and the comparison between NMC and OMC tells as this moisture is out of specification set by ERA. Insufficient sub base material compaction was observed since degree of compaction obtained where less than 95% and the failure observed on the surface of the road highly influenced by it.

From the gradation test done on base course the material was finer at some spots and courser at other spots than ERA requirements. Even though the fine fraction of a Graded Crushed Stone Road Base Materials (GB1) material shall be non-plastic according to ERA Manual, 2013, all the base course material used on Teji-Tulu bolo road segments are almost have plastic property. Hence inadequate base course material was the cause of failure at all three sections.

The base material shows CBR of ranges from 80%-185% and swell between 0.4 % and 0.85% which are an indication of presence of expansive soil in base course crushed stone. Hence insufficient CBR and unexpected swell value of base course were the cause of defects on road surface.

The soil exist under the road structure was black cotton soil with LL>60%, PI>30%, CBR<5%, CBR swell >2% and GI> 20 which is very poor and unsuitable subgrade soil. But didn't replaced to sufficient depth and this was the main cause of failure for this route.

5.2 Recommendation

Based on the analysis and discussion of the study, I have recommended the following points.

- Since the existing base course and sub base has excessively settled under traffic load and wetted due to infiltration of moisture through the alligator and block cracks, it should be reconstruct with provision of extra depth to restore the required serviceability.
- The existing sub base material should be used for embankment fill material alone or blended with embankment material or borrow material and The existing base course layer will be scarified and will be re-used as sub base layer since they have complied the requirement set by ERA.
- The mitigation measure for existing expansive soil should be adopted as stated in clause 4106 of ERA 2013 standard technical specification.
- Clogged inlets should be avoided by provision of silt traps or provision of silt control mechanisms and side drain should be provided sufficiently.
- While reconstructing the road layer, their thickness should be modified by considering the existing traffic.

APPENDICES

Appendix A: Summary of Pavement Condition Survey

Section A (Teji-Asgori)								
Station		**Type of Defect**	**Position (R,C,L)**	**Depth (mm)**	**Width (m)**	**Length (m)**	**Area in (m2)**	**Distress Severity Level**
3+300	6+440	Alligator Crack, Block Crack & Rutting	RHS	60	3.5	3140.00	10990.00	High
3+300	6+440	Alligator Crack, Block Crack & Rutting	LHS	60	3.5	3140.00	10990.00	High
1+700	3+200	Block Crack & Rutting	RHS	40	3.50	1500.00	5250.00	High
1+700	3+200	Block Crack & Rutting	LHS	40	3.50	1500.00	5250.00	High
3+200	3+300	Block Crack, Patching & Rutting	RHS	50	3.50	100.00	350.00	High
3+200	3+300	Block Crack, Patching & Rutting	LHS	50	3.50	100.00	350.00	High
5+930	5+990	Depression	RHS		3.5	60.00	210.00	Low
5+930	5+990	Depression	LHS		3.5	60.00	210.00	Medium
6+200	6+320	Depression	RHS		3.5	120.00	420.00	Low
6+200	6+320	Depression	LHS		3.5	120.00	420.00	Medium
1+700	1+760	Patching	RHS		3.50	60.00	210.00	Low
1+093	1+095	Potholes	RHS	80	3.00	2.00	6.00	High

1+150	1+153	Potholes	RHS	50	2.00	3.00	6.00	High
1+200	1+202	Potholes	RHS	60	2.00	2.00	4.00	High
1+720	1+740	Potholes	RHS	40	3.50	20.00	70.00	High
1+748	1+750	Potholes	RHS	60	1.00	2.00	2.00	High
1+760	1+761	Potholes	RHS	60	1.00	1.00	1.00	High
2+200	2+203	Potholes	CL	70	2.00	3.00	6.00	High
2+920	2+930	Potholes	CL	60	3.00	10.00	30.00	High
2+980	3+200	Potholes	RHS	50	3.50	220.00	770.00	High

Summary of Pavement Condition Survey Section B (Asgori-Awash Bune)								
Station		**Type of Defect**	**Position (R,C,L)**	**Depth (mm)**	**Width (m)**	**Length (m)**	**Area in (m2)**	**Distress Severity Level**
9+800	9+900	Alligator crack	LHS		3.5	100.00	350.00	Medium
10+200	10+300	Alligator crack	RHS		3.5	100.00	350.00	Medium
10+300	10+400	Alligator crack	RHS		3.5	100.00	350.00	Medium
11+200	11+300	Alligator crack	LHS		3.5	100.00	350.00	High
12+900	13+000	Alligator crack	LHS		3.5	100.00	350.00	High
14+500	14+600	Alligator, Potholes & patching	RHS		3.5	100.00	350.00	High
14+500	14+600	Alligator, Potholes & patching	LHS		3.5	100.00	350.00	High
9+300	9+350	Alligator Crack	RHS		3.5	50.00	175.00	Medium
9+260	9+300	Alligator Crack	LHS		3.5	40.00	140.00	Medium
9+860	9+900	Alligator crack	RHS		3.5	40.00	140.00	Medium
10+420	10+500	Alligator crack	LHS		1	80.00	80.00	High

7+680	7+700	Alligator Crack	RHS		3.5	20.00	70.00	High
7+680	7+700	Alligator Crack	LHS		3.5	20.00	70.00	High
10+280	10+300	Alligator crack	LHS		3.5	20.00	70.00	Medium
8+680	8+700	Alligator Crack	RHS		3	20.00	60.00	High
7+185	7+200	Alligator crack	RHS		3.5	15.00	52.50	High
16+590	16+600	Alligator & Potholes	CL		4	10.00	40.00	High
7+000	7+010	Alligator crack	RHS		3.5	10.00	35.00	Medium
7+020	7+030	Alligator crack	RHS		3.5	10.00	35.00	Medium
7+575	7+585	Alligator Crack	LHS		3.5	10.00	35.00	High
7+635	7+645	Alligator Crack	LHS		3.5	10.00	35.00	Medium
9+760	9+770	Alligator crack	RHS		3.5	10.00	35.00	Medium
11+090	11+100	Alligator crack	LHS		3.5	10.00	35.00	High
9+385	9+400	Alligator crack	RHS		2	15.00	30.00	Medium
10+400	10+420	Alligator crack	LHS		1	20.00	20.00	Medium
7+535	7+540	Alligator Crack	RHS		3.5	5.00	17.50	Medium
7+595	7+600	Alligator Crack	RHS		3.5	5.00	17.50	Medium
8+140	8+145	Alligator Crack	RHS		3.5	5.00	17.50	High
8+140	8+145	Alligator Crack	LHS		3.5	5.00	17.50	High
9+430	9+438	Alligator crack	RHS		1	8.00	8.00	Medium

7+100	7+120	Alligator & Transverse crack	LHS			3.50	0.00	Medium
7+135	7+145	Alligator & Transverse crack	LHS			3.50	0.00	High
11+700	11+800	Block crack	LHS		3.5	100.00	350.00	High
12+040	12+100	Block crack	LHS		3.5	60.00	210.00	High
13+140	13+200	Block crack	RHS		3.5	60.00	210.00	High
11+450	11+500	Block crack	RHS		3.5	50.00	175.00	High
12+800	12+840	Block crack	RHS		3.5	40.00	140.00	High
12+960	13+000	Block crack	RHS		3.5	40.00	140.00	High
13+060	13+100	Block crack	LHS		3.5	40.00	140.00	High
13+370	13+400	Block crack	RHS		3.5	30.00	105.00	High
13+370	13+400	Block crack	LHS		3.5	30.00	105.00	High
11+000	11+020	Block crack	LHS		3.5	20.00	70.00	High
9+580	9+600	Corrugation	LHS		3.5	20.00	70.00	High
8+255	8+265	Corrugation	LHS		3.5	10.00	35.00	High
15+040	15+220	Depression	LHS		3.5	180.00	630.00	High
15+740	15+920	Depression	LHS		3.5	180.00	630.00	High
7+360	7+500	Depression	LHS		3.5	140.00	490.00	High
14+940	14+980	Depression	LHS		3.5	40.00	140.00	High
7+420	7+450	Depression	RHS	60	2	30.00	60.00	High

13+715	13+730	Depression	LHS	30	3.5	15.00	52.50	High
13+715	13+730	Depression	RHS	30	3.5	15.00	52.50	High
7+120	7+200	Depression	LHS			3.50	0.00	High
6+440	7+120	Longitudinal Crack, Alligator Crack, Block Crack & Rutting	RHS	30	3.5	680.00	2380.00	High
6+440	7+120	Longitudinal Crack, Alligator Crack, Block Crack & Rutting	LHS	30	3.5	680.00	2380.00	High
11+400	11+500	Longitudial & block crack	LHS		3.5	100.00	350.00	High
10+300	10+400	Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
14+800	14+900	Longitudinal & Alligator crack	RHS		3.5	100.00	350.00	High
14+900	15+000	Longitudinal & Alligator crack	RHS		3.5	100.00	350.00	High
12+700	12+800	Longitudinal & block crack	LHS		3.5	100.00	350.00	High

14+300	14+400	Longitudinal, potholes & patching	RHS		3.5	100.00	350.00	High
14+300	14+400	Longitudinal, potholes & patching	LHS		3.5	100.00	350.00	High
14+400	14+500	Longitudinal, potholes & patching	RHS		3.5	100.00	350.00	High
14+400	14+500	Longitudinal, potholes & patching	LHS		3.5	100.00	350.00	High
14+600	14+700	Longitudinal, potholes & patching	RHS		3.5	100.00	350.00	High
14+600	14+700	Longitudinal, potholes & patching	LHS		3.5	100.00	350.00	High
14+800	14+900	Longitudinal, potholes & patching	LHS		3.5	100.00	350.00	High
9+200	9+300	Longutidinal & Alligator crack	LHS		3.5	100.00	350.00	High
14+750	14+800	Longitudinal crack	LHS		3.5	50.00	175.00	High

14+700	14+750	Longitudinal, potholes & patching	LHS		3.5	50.00	175.00	High
7+700	7+740	Longitudinal & Alligator crack	LHS		3.5	40.00	140.00	High
7+760	7+770	Longitudinal crack	RHS		###	10.00	100.00	Medium
8+180	8+200	Longitudinal & Alligator crack	RHS		3.5	20.00	70.00	High
7+860	7+885	Longitudinal & Alligator crack	LHS		1	25.00	25.00	Medium
9+450	9+500	Longitudinal crack	LHS		0.5	50.00	25.00	High
7+000	7+005	Longitudinal crack	RHS			5.00	0.00	Low
7+020	7+040	Longitudinal crack	LHS			20.00	0.00	Medium
7+080	7+100	Longitudinal crack	LHS			20.00	0.00	Medium
7+080	7+100	Longitudinal crack	RHS			20.00	0.00	Medium
7+100	7+110	Longitudinal crack	RHS			1.00	0.00	Medium
7+215	7+300	Longitudinal crack	LHS			85.00	0.00	Medium
7+820	7+840	Longitudinal crack	LHS			20.00	0.00	Medium
8+380	8+400	Longitudinal crack	LHS			20.00	0.00	Low
11+100	11+200	Longitudinal crack	LHS			100.00	0.00	High
11+600	11+640	Longitudinal crack	LHS			40.00	0.00	High

13+000	13+020	Longitudinal crack	RHS			20.00	0.00	High
13+120	13+170	Longitudinal crack	LHS			50.00	0.00	High
13+130	13+140	Longitudinal crack	RHS			10.00	0.00	Medium
13+350	13+360	Longitudinal crack	LHS			10.00	0.00	High
13+740	13+780	Longitudinal crack	RHS			40.00	0.00	High
7+860	7+865	Longutidinal crack	RHS			5.00	0.00	Low
9+590	9+600	Longutidinal crack	LHS			10.00	0.00	Medium
9+860	9+865	Longutidinal crack	LHS			5.00	0.00	High
9+600	9+700	Patching	RHS	40	3.5	100.00	350.00	Medium
11+800	11+900	Patching	LHS	50	3.5	100.00	350.00	Medium
11+900	12+000	Patching	LHS	50	3.5	100.00	350.00	Medium
12+000	12+100	Patching	LHS	40	3.5	100.00	350.00	Medium
13+400	13+500	Patching	RHS	30	3.5	100.00	350.00	Medium
13+400	13+500	Patching	LHS	30	3.5	100.00	350.00	Medium
10+900	11+000	Patching	LHS	50	3.5	100.00	350.00	Medium
13+300	13+400	Patching	LHS	30	3.5	100.00	350.00	Medium
10+900	11+000	Patching & Alligator crack	RHS	50	3.5	100.00	350.00	Medium
13+300	13+400	Patching & Alligator crack	RHS	30	3.5	100.00	350.00	Medium
10+100	10+200	Patching & Block Crack	LHS	50	3.5	100.00	350.00	Medium

14+900	15+000	Patching & Longitudinal crack	LHS		3.5	100.00	350.00	Medium
15+500	15+600	Patching & Longitudinal crack	LHS		3.5	100.00	350.00	Medium
15+600	15+700	Patching & Longitudinal crack	RHS		3.5	100.00	350.00	Medium
15+700	15+800	Patching & Longitudinal crack	LHS		3.5	100.00	350.00	Medium
15+800	15+900	Patching & Longitudinal crack	LHS		3.5	100.00	350.00	Medium
16+200	16+300	Patching & Longitudinal crack	LHS		3.5	100.00	350.00	Medium
16+300	16+400	Patching, Potholes & Longitudinal crack	LHS		3.5	100.00	350.00	Medium
16+300	16+400	Patching, Potholes & Longitudinal crack	RHS		3.5	100.00	350.00	Medium
12+840	12+900	Patching	RHS	50	3.5	60.00	210.00	Medium
12+840	12+900	Patching	LHS	50	3.5	60.00	210.00	Medium
8+300	8+360	Patching & Alligator crack	LHS	40	3.5	60.00	210.00	Medium

8+300	8+360	Patching & Alligator crack	RHS		3.5	60.00	210.00	Medium
14+200	14+250	Patching	LHS		3.5	50.00	175.00	Medium
14+250	14+300	Patching	LHS		3.5	50.00	175.00	Medium
7+700	7+740	Patching	RHS	50	3.5	40.00	140.00	Medium
9+660	9+700	Patching	LHS	40	3.5	40.00	140.00	Medium
13+100	13+140	Patching	RHS	30	3.5	40.00	140.00	Medium
10+100	10+140	Patching & Alligator crack	RHS	40	3.5	40.00	140.00	Medium
7+500	7+535	Patching	LHS	50	3.5	35.00	122.50	Medium
7+500	7+535	Patching	RHS	40	2	35.00	70.00	Medium
11+180	11+200	Patching	LHS	30	3.5	20.00	70.00	Medium
15+580	15+600	Patching, Transverse & Longitudinal crack	RHS		3.5	20.00	70.00	Medium
15+500	15+510	Patching, Transverse & Longitudinal crack	RHS		3.5	10.00	35.00	Medium
8+080	8+082	Patching	RHS			1.50	0.00	Medium
9+995	9+997	Pothole	LHS	30	2	2.00	4.00	High
11+140	11+142	Pothole	RHS	100	2	2.00	4.00	High
12+305	12+307	Pothole	LHS	100	2	2.00	4.00	High
12+650	12+652	Pothole	RHS	150	2	2.00	4.00	High
13+020	13+022	Pothole	RHS	600	2	2.00	4.00	High
13+980	13+982	Pothole	LHS	60	2	2.00	4.00	High
11+750	11+751	Pothole	RHS	180	3.5	1.00	3.50	High
8+020	8+022	Pothole	RHS	90	1.5	1.50	2.25	Medium

8+995	8+997	Pothole	RHS	60	1.5	1.50	2.25	High
8+580	8+582	Pothole	LHS	140	1	2.00	2.00	High
11+995	11+996	Pothole		150	2	1.00	2.00	High
7+190	7+191	Pothole	RHS	130	1	1.00	1.00	High
7+440	7+441	Pothole	RHS		1	1.00	1.00	Medium
7+580	7+581	Pothole	LHS	130	1	1.00	1.00	Medium
8+480	8+481	Pothole	RHS	90	1	1.00	1.00	Medium
8+430	8+431	Pothole	LHS	80	1	1.00	1.00	Medium
8+580	8+581	Pothole	RHS	100	1	1.00	1.00	Low
8+910	8+911	Pothole	LHS	100	1	1.00	1.00	Medium
8+970	8+971	Pothole	LHS	100	1	1.00	1.00	Medium
9+095	9+096	Pothole	RHS	100	1	1.00	1.00	Medium
9+097	9+098	Pothole	LHS		1	1.00	1.00	Medium
10+565	10+566	Pothole	RHS	150	1	1.00	1.00	Medium
10+570	10+571	Pothole	RHS	100	1	1.00	1.00	Medium
10+610	10+611	Pothole	LHS	150	1	1.00	1.00	Medium
10+620	10+621	Pothole	LHS	150	1	1.00	1.00	Medium
11+005	11+006	Pothole	RHS	60	1	1.00	1.00	Medium
12+590	12+591	Pothole	RHS	100	1	1.00	1.00	Medium
7+080		Pothole	LHS		0.4	0.40	0.16	Medium
11+400	11+500	Rutting	RHS	20	3.5	100.00	350.00	high
13+200	13+300	Rutting	RHS	20	3.5	100.00	350.00	Medium
15+900	16+000	Rutting	RHS		3.5	100.00	350.00	High
16+200	16+300	Rutting	RHS		3.5	100.00	350.00	High
9+200	9+300	Rutting	RHS	20	3.5	100.00	350.00	Medium
8+800	8+900	Rutting & Alligator crack	RHS	40	3.5	100.00	350.00	High
8+800	8+900	Rutting & Alligator crack	LHS	40	3.5	100.00	350.00	Medium
8+900	9+000	Rutting & Alligator crack	RHS	40	3.5	100.00	350.00	Medium

9+000	9+100	Rutting & Alligator crack	RHS	30	3.5	100.00	350.00	Medium
9+100	9+200	Rutting & Alligator crack	RHS	20	3.5	100.00	350.00	Medium
9+700	9+800	Rutting & Alligator crack	RHS	20	3.5	100.00	350.00	Medium
9+700	9+800	Rutting & Alligator Crack	LHS	40	3.5	100.00	350.00	High
9+800	9+900	Rutting & Alligator Crack	RHS	30	3.5	100.00	350.00	High
9+900	10+000	Rutting & Alligator crack	RHS	30	3.5	100.00	350.00	Medium
9+900	10+000	Rutting & Alligator crack	LHS	30	3.5	100.00	350.00	Medium
10+600	10+700	Rutting & Alligator crack	RHS	55	3.5	100.00	350.00	High
10+700	10+800	Rutting & Alligator crack	RHS	40	3.5	100.00	350.00	High
11+300	11+400	Rutting & Alligator crack	RHS	40	3.5	100.00	350.00	High
11+800	11+900	Rutting & Alligator crack	RHS	50	3.5	100.00	350.00	High
11+900	12+000	Rutting & Alligator crack	RHS	80	3.5	100.00	350.00	High
13+900	14+000	Rutting & Alligator crack	RHS	20	3.5	100.00	350.00	Medium
13+900	14+000	Rutting & Alligator crack	LHS	40	3.5	100.00	350.00	High

14+100	14+200	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
14+100	14+200	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
14+200	14+300	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
15+000	15+100	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
15+200	15+300	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
15+300	15+400	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
15+300	15+400	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
15+700	15+800	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
16+000	16+100	Rutting & Alligator crack	RHS		3.5	100.00	350.00	Low
16+100	16+200	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
16+500	16+600	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
16+600	16+700	Rutting & Alligator crack	RHS	60	3.5	100.00	350.00	High
16+600	16+700	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
16+800	16+900	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High

16+800	16+900	Rutting & Alligator crack	RHS	60	3.5	100.00	350.00	High
16+900	17+000	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
16+900	17+000	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
17+000	17+100	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
17+000	17+100	Rutting & Alligator crack	RHS	50	3.5	100.00	350.00	High
17+100	17+200	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
17+100	17+200	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
17+200	17+300	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
17+200	17+300	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
17+300	17+400	Rutting & Alligator crack	RHS		3.5	100.00	350.00	High
17+300	17+400	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
17+400	17+500	Rutting & Alligator crack	LHS		3.5	100.00	350.00	High
10+100	10+200	Rutting & Block crack	RHS		3.5	100.00	350.00	High
10+800	10+900	Rutting & block crack	LHS	5	3.5	100.00	350.00	High

11+000	11+100	Rutting & block crack	RHS	50	3.5	100.00	350.00	High
11+100	11+200	Rutting & block crack	RHS	50	3.5	100.00	350.00	High
11+200	11+300	Rutting & block crack	RHS	50	3.5	100.00	350.00	High
11+600	11+700	Rutting & block crack	RHS	60	3.5	100.00	350.00	High
11+600	11+700	Rutting & block crack	LHS	60	3.5	100.00	350.00	High
12+000	12+100	Rutting & block crack	RHS	50	3.5	100.00	350.00	High
12+100	12+200	Rutting & block crack	RHS	50	3.5	100.00	350.00	High
12+200	12+300	Rutting & block crack	RHS	40	3.5	100.00	350.00	High
12+200	12+300	Rutting & block crack	LHS	40	3.5	100.00	350.00	High
12+300	12+400	Rutting & block crack	RHS	40	3.5	100.00	350.00	High
12+400	12+500	Rutting & block crack	RHS	30	3.5	100.00	350.00	Medium
12+400	12+500	Rutting & block crack	LHS	30	3.5	100.00	350.00	Medium
12+500	12+600	Rutting & block crack	RHS	30	3.5	100.00	350.00	High
12+500	12+600	Rutting & block crack	LHS	30	3.5	100.00	350.00	High

12+600	12+700	Rutting & block crack	RHS	20	3.5	100.00	350.00	Medium
12+700	12+800	Rutting & block crack	RHS	20	3.5	100.00	350.00	Medium
13+500	13+600	Rutting & block crack	RHS	30	3.5	100.00	350.00	Medium
13+600	13+700	Rutting & block crack	RHS	40	3.5	100.00	350.00	High
13+600	13+700	Rutting & block crack	LHS	45	3.5	100.00	350.00	High
17+600	17+700	Rutting & block crack	RHS		3.5	100.00	350.00	High
17+600	17+700	Rutting & block crack	LHS		3.5	100.00	350.00	High
17+700	17+800	Rutting & block crack	RHS	30	3.5	100.00	350.00	High
17+700	17+800	Rutting & block crack	LHS		3.5	100.00	350.00	High
17+800	17+900	Rutting & block crack	RHS		3.5	100.00	350.00	High
17+800	17+900	Rutting & block crack	LHS		3.5	100.00	350.00	High
17+900	18+000	Rutting & block crack	RHS		3.5	100.00	350.00	High
7+200	7+300	Rutting & Longitudinal crack	RHS	40	3.5	100.00	350.00	High
10+800	10+900	Rutting & Longitudinal crack	RHS	20	3.5	100.00	350.00	Medium

11+700	11+800	Rutting & Longitudinal crack	RHS	60	3.5	100.00	350.00	High
12+600	12+700	Rutting & Longitudinal crack	LHS	20	3.5	100.00	350.00	Medium
15+000	15+100	Rutting & Longitudinal crack	LHS		3.5	100.00	350.00	High
15+200	15+300	Rutting & Longitudinal crack	LHS		3.5	100.00	350.00	High
15+600	15+700	Rutting & Longitudinal crack	LHS		3.5	100.00	350.00	High
15+900	16+000	Rutting & Longitudinal crack	LHS		3.5	100.00	350.00	High
16+700	16+800	Rutting & Longitudinal crack	LHS		3.5	100.00	350.00	High
7+300	7+400	Rutting & longitudinal crack	RHS	40	3.5	100.00	350.00	High
11+000	11+100	Rutting & longutidinal crack	LHS	30	3.5	100.00	350.00	High
15+400	15+500	Rutting, Alligator & Longitudinal crack	RHS		3.5	100.00	350.00	High
15+400	15+500	Rutting, Alligator & Longitudinal crack	LHS		3.5	100.00	350.00	High
15+800	15+900	Rutting, Alligator & Longitudinal crack	RHS		3.5	100.00	350.00	High

16+000	16+100	Rutting, Alligator & Longitudinal crack	LHS		3.5	100.00	350.00	High
7+300	7+400	Rutting, Depression, Longitudinal crack & Aligator crack	LHS	60	3.5	100.00	350.00	High
7+900	8+000	Rutting, Longitudinal & Alligator crack	RHS	40	3.5	100.00	350.00	High
8+400	8+500	Rutting, Longitudinal & Alligator crack	LHS	50	3.5	100.00	350.00	High
9+000	9+100	Rutting, Longitudinal & Alligator crack	LHS	50	3.5	100.00	350.00	High
9+100	9+200	Rutting, Longitudinal & Alligator crack	LHS	40	3.5	100.00	350.00	High
9+300	9+400	Rutting, longitudinal & alligator crack	LHS	25	3.5	100.00	350.00	High

10+600	10+700	Rutting, Longitudinal & Alligator crack	LHS	50	3.5	100.00	350.00	High
10+700	10+800	Rutting, Longitudinal & Alligator crack	LHS	50	3.5	100.00	350.00	High
13+200	13+300	Rutting, Longitudinal & Alligator crack	LHS	30	3.5	100.00	350.00	High
13+500	13+600	Rutting, Longitudinal & Alligator crack	LHS	20	3.5	100.00	350.00	Medium
13+800	13+900	Rutting, Longitudinal & Alligator crack	RHS	30	3.5	100.00	350.00	Medium
13+800	13+900	Rutting, Longitudinal & Alligator crack	LHS	30	3.5	100.00	350.00	Medium
14+700	14+800	Rutting, longitudinal & alligator crack	RHS		3.5	100.00	350.00	High
15+100	15+200	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High

15+100	15+200	Rutting, Longitudinal & Alligator crack	RHS		3.5	100.00	350.00	High
8+900	9+000	Rutting, longitudinal & block crack	LHS	50	3.5	100.00	350.00	High
10+500	10+600	Rutting, longitudinal & block crack	RHS	60	3.5	100.00	350.00	High
10+500	10+600	Rutting, longitudinal & block crack	LHS	40	3.5	100.00	350.00	High
11+300	11+400	Rutting, longitudinal & block crack	LHS	40	3.5	100.00	350.00	High
12+100	12+200	Rutting, longitudinal & block crack	LHS	30	3.5	100.00	350.00	High
12+300	12+400	Rutting, longitudinal & block crack	LHS	40	3.5	100.00	350.00	High
8+700	8+800	Rutting, Longitudinal, Alligator crack & Deformation	RHS	50	3.5	100.00	350.00	High

8+700	8+800	Rutting, Longitudinal, Alligator crack & Deformation	LHS	50	3.5	100.00	350.00	High
7+400	7+500	Rutting, Longitudinal, Transverse & Alligator crack	RHS	50	3.5	100.00	350.00	Medium
7+400	7+500	Rutting, Longitudinal, Transverse & Alligator crack	LHS	50	3.5	100.00	350.00	High
16+100	16+200	Rutting, Patching & Alligator crack	LHS		3.5	100.00	350.00	High
16+400	16+500	Rutting, Patching & Alligator crack	LHS		3.5	100.00	350.00	High
16+400	16+500	Rutting, Patching & Alligator crack	RHS		3.5	100.00	350.00	High
16+500	16+590	Rutting & Alligator crack	RHS		3.5	90.00	315.00	High
7+200	7+300	Rutting & Alligator crack	LHS	20	3	100.00	300.00	Medium

7+900	8+000	Rutting, Longitudinal & Alligator crack	LHS	25	3	100.00	300.00	Medium
10+020	10+100	Rutting & Alligator crack	LHS	30	3.5	80.00	280.00	Medium
8+400	8+480	Rutting, Longitudinal & Alligator crack	RHS	50	3.5	80.00	280.00	High
9+600	9+660	Rutting & Alligator crack	LHS	50	3.5	60.00	210.00	High
10+040	10+100	Rutting & Alligator crack	RHS	30	3.5	60.00	210.00	Medium
14+040	14+100	Rutting & Alligator crack	RHS		3.50	60.00	210.00	High
14+040	14+100	Rutting & Alligator crack	LHS		3.50	60.00	210.00	High
10+200	10+260	Rutting & block crack	LHS	50	3.5	60.00	210.00	High
11+540	11+600	Rutting & block crack	RHS	50	3.5	60.00	210.00	High
7+800	7+900	Rutting	LHS	25	2	100.00	200.00	Medium
8+100	8+200	Rutting	RHS	20	2	100.00	200.00	Low
8+300	8+400	Rutting	LHS	20	2	100.00	200.00	Medium
7+700	7+800	Rutting	RHS	25	2	100.00	200.00	Medium
7+700	7+800	Rutting	LHS	20	2	100.00	200.00	Medium
8+000	8+100	Rutting & Alligator crack	RHS	30	2	100.00	200.00	Medium
8+600	8+700	Rutting & Alligator crack	RHS	30	2	100.00	200.00	Medium

7+100	7+200	Rutting & longitudinal crack	LHS	35	2	100.00	200.00	High
7+600	7+700	Rutting & Longitudinal crack	LHS	30	2	100.00	200.00	High
7+600	7+700	Rutting & Longitudinal crack	RHS	35	2	100.00	200.00	High
8+100	8+200	Rutting & Longitudinal crack	LHS	30	2	100.00	200.00	High
8+510	8+600	Rutting & Alligator crack	RHS	20	2	90.00	180.00	Medium
11+700	11+750	Rutting	LHS	60	3.5	50.00	175.00	High
9+250	9+300	Rutting & Alligator crack	LHS	50	3.5	50.00	175.00	High
9+550	9+600	Rutting & Alligator crack	LHS	70	3.5	50.00	175.00	High
13+150	13+200	Rutting & block crack	LHS	25	3.5	50.00	175.00	Medium
8+200	8+280	Rutting, Longitudinal & Alligator crack	RHS	50	2	80.00	160.00	High
8+200	8+280	Rutting, Longitudinal & Alligator crack	LHS	50	2	80.00	160.00	High
8+500	8+580	Rutting, Longitudinal & Alligator crack	LHS	40	2	80.00	160.00	High
7+100	7+200	Rutting	RHS	40	1.5	100.00	150.00	High

16+700	16+800	Rutting & Longitudinal crack	RHS		1.5	100.00	150.00	High
7+000	7+100	Rutting and Block Crack	LHS	30	1.5	100.00	150.00	High
7+000	7+100	Rutting and Block Crack	RHS	40	1.5	100.00	150.00	High
11+260	11+300	Rutting	LHS	40	3.5	40.00	140.00	High
12+800	12+840	Rutting & block crack	LHS	50	3.5	40.00	140.00	High
13+700	13+740	Rutting & block crack	RHS	35	3.5	40.00	140.00	Medium
14+000	14+040	Rutting & Longitudinal crack	RHS		3.50	40.00	140.00	High
14+000	14+040	Rutting & Longitudinal crack	LHS		3.50	40.00	140.00	High
13+700	13+740	Rutting, Longitudinal & Alligator crack	LHS	30	3.5	40.00	140.00	Medium
11+560	11+600	Rutting, longitudinal & block crack	LHS	60	3.5	40.00	140.00	High
11+470	11+500	Rutting	LHS	60	3.5	30.00	105.00	High
9+770	9+800	Rutting & Alligator Crack	RHS		3.5	30.00	105.00	High
8+600	8+650	Rutting & Alligator crack	LHS	40	2	50.00	100.00	Medium

7+560	7+600	Rutting	RHS	20	2	40.00	80.00	low
7+560	7+600	Rutting	LHS	30	2	40.00	80.00	low
9+380	9+420	Rutting & Alligator crack	LHS		2	40.00	80.00	Medium
9+580	9+600	Rutting & Alligator crack	RHS	80	3.5	20.00	70.00	High
13+080	13+100	Rutting & block crack	RHS	40	3.5	20.00	70.00	High
10+430	10+450	Rutting & Longitudinal crack	RHS	30	3.5	20.00	70.00	Medium
8+380	8+400	Rutting, Longitudinal & Alligator crack	RHS	50	3.5	20.00	70.00	High
8+680	8+700	Rutting, Alligator & Longitudinal crack	LHS	50	3	20.00	60.00	High
9+200	9+210	Rutting & Alligator crack	LHS	50	3.5	10.00	35.00	High
17+400	17+500	Rutting & Alligator crack	RHS		0.3	100.00	30.00	High
7+800	7+830	Rutting & Longitudinal crack	RHS	20	1	30.00	30.00	Medium
7+085	7+100	Transverse crack	LHS		3.5	15.00	52.50	High
9+460	9+475	Transverse crack	LHS		3.5	15.00	52.50	Medium
7+765		Transverse crack	RHS		3.50	3.50	12.25	Medium
7+770		Transverse crack	RHS		3.50	3.50	12.25	High

7+160	7+161	Transverse crack	LHS		1	3.50	3.50	Medium
7+595	7+596	Transverse crack	RHS		1	3.50	3.50	Medium
7+860	7+861	Transverse crack	RHS		1	3.50	3.50	High
7+860	7+861	Transverse crack	LHS		1	3.50	3.50	High
8+380	8+381	Transverse crack	LHS		1	3.50	3.50	Medium
8+500	8+501	Transverse crack	LHS		3.5	1.00	3.50	High
9+310	9+311	Transverse crack	RHS		3.5	1.00	3.50	Medium
9+350	9+351	Transverse crack	RHS		3.5	1.00	3.50	Medium
9+310	9+311	Transverse crack	LHS		3.5	1.00	3.50	Medium
9+350	9+351	Transverse crack	LHS		3.5	1.00	3.50	Medium
7+570	7+571	Transverse crack	LHS		1	2.00	2.00	low
7+635	7+636	Transverse crack	RHS		1	2.00	2.00	Low
7+000	7+005	Transverse crack	RHS			3.50	0.00	Low
7+080		Transverse crack	RHS			1.00	0.00	Low
7+080		Transverse crack	LHS			1.50	0.00	High
7+215	7+220	Transverse crack	LHS			3.50	0.00	High
7+880	7+881	Transverse crack	RHS			3.50	0.00	Medium
13+040		Transverse crack	LHS			3.50	0.00	High
13+320	13+325	Transverse crack	RHS			3.50	0.00	High
13+320	13+325	Transverse crack	LHS			3.50	0.00	High
13+720	13+725	Transverse crack	LHS			3.50	0.00	High

13+720	13+725	Transverse crack	RHS			3.50	0.00	High
Summary of Pavement Condition Survey								
Section C (Awash Bune-Tulu Bolo)								
Station		**Type of Defect**	**Position (R,C,L)**	**Depth (mm)**	**Width (m)**	**Length (m)**	**Area in (m2)**	**Distress Severity Level**
Station								
25+800	25+900	Alligator crack	LHS		3.5	100.00	350.00	High
24+700	24+800	Alligator crack & Rutting	RHS		3.5	100.00	350.00	Medium
24+700	24+800	Alligator crack & Rutting	LHS		3.5	100.00	350.00	High
25+900	25+980	Alligator crack	LHS		3.5	80.00	280.00	High
26+610	26+680	Alligator crack	LHS		3.5	70.00	245.00	High
26+340	26+400	Alligator crack	LHS		3.5	60.00	210.00	High
26+340	26+400	Alligator crack	RHS		3.5	60.00	210.00	High
21+600	21+700	Alligator & Longitudinal crack	LHS		2	100.00	200.00	High
24+530	24+560	Alligator crack	RHS		3.5	30.00	105.00	High
24+530	24+560	Alligator crack	LHS		3.5	30.00	105.00	High
24+490	24+515	Alligator crack	LHS		3.5	25.00	87.50	High
24+610	24+620	Alligator crack	RHS		3.5	10.00	35.00	High
24+610	24+620	Alligator crack	LHS		3.5	10.00	35.00	High
24+695	24+709	Alligator crack	LHS		2.5	14.00	35.00	Medium

26+590	26+600	Alligator crack	LHS		3.5	10.00	35.00	High
24+685	24+693	Alligator crack	LHS		3.5	8.00	28.00	Medium
24+670	24+681	Alligator crack	LHS		2	11.00	22.00	Medium
24+420	24+425	Alligator crack & Rutting	RHS	30	3	5.00	15.00	High
24+645	24+647	Alligator crack	CL		3	2.00	6.00	Low
21+000	22+100	Block, patching & potholes	RHS		3.5	1100.00	3850.00	High
21+000	21+100	Block & Transverse crack	RHS		4	100.00	400.00	High
21+300	21+400	Block & Transverse crack	RHS		4	100.00	400.00	High
21+400	21+500	Block & Transverse crack	RHS		4	100.00	400.00	High
21+500	21+600	Block & Transverse crack	RHS		4	100.00	400.00	High
20+400	20+500	Block & Transverse crack	RHS		3.5	100.00	350.00	High
20+500	20+600	Block & Transverse crack	RHS		3.5	100.00	350.00	High
20+600	20+700	Block & Transverse crack	RHS		3.5	100.00	350.00	High
20+800	20+900	Block & Transverse crack	RHS		3.5	100.00	350.00	High
21+600	21+700	Block crack	RHS		3.5	100.00	350.00	High

22+600	22+700	Block crack	RHS		3.5	100.00	350.00	High
23+100	23+200	Block Crack, patching & potholes	RHS		3.5	100.00	350.00	High
23+100	23+200	Block Crack, patching & potholes	LHS		3.5	100.00	350.00	High
21+700	21+800	Block, patching & potholes	RHS		3.5	100.00	350.00	High
21+700	21+800	Block, patching & potholes	LHS		3.5	100.00	350.00	High
21+800	21+900	Block, patching & potholes	RHS		3.5	100.00	350.00	High
21+800	21+900	Block, patching & potholes	LHS		3.5	100.00	350.00	High
21+900	22+000	Block, patching & potholes	RHS		3.5	100.00	350.00	High
21+900	22+000	Block, patching & potholes	LHS		3.5	100.00	350.00	High
22+000	22+100	Block, patching & potholes	LHS		3.5	100.00	350.00	High

22+100	22+200	Block, patching & potholes	RHS		3.5	100.00	350.00	High
22+100	22+200	Block, patching & potholes	LHS		3.5	100.00	350.00	High
22+200	22+300	Block, patching & potholes	RHS		3.5	100.00	350.00	High
22+200	22+300	Block, patching & potholes	LHS		3.5	100.00	350.00	High
22+300	22+400	Block, patching & potholes	RHS		3.5	100.00	350.00	High
22+300	22+400	Block, patching & potholes	LHS		3.5	100.00	350.00	High
22+400	22+500	Block, patching & potholes	RHS		3.5	100.00	350.00	High
22+400	22+500	Block, patching & potholes	LHS		3.5	100.00	350.00	High
22+700	22+800	Block, patching & potholes	RHS		3.5	100.00	350.00	High
22+700	22+800	Block, patching & potholes	LHS		3.5	100.00	350.00	High

22+800	22+900	Block, patching & potholes	RHS		3.5	100.00	350.00	High
22+800	22+900	Block, patching & potholes	LHS		3.5	100.00	350.00	High
22+900	23+000	Block, patching & potholes	RHS		3.5	100.00	350.00	High
22+900	23+000	Block, patching & potholes	LHS		3.5	100.00	350.00	High
20+300	20+400	Block, Transverse & potholes	RHS		3.5	100.00	350.00	High
20+100	20+200	Block & Longitudinal crack	LHS		3	100.00	300.00	High
20+100	20+200	Block & Transverse crack	RHS		3	100.00	300.00	High
20+200	20+300	Block, longitudinal & potholes	RHS		3	100.00	300.00	High
20+900	20+980	Block & Transverse crack	RHS		3.5	80.00	280.00	High
19+920	20+000	Block crack	LHS		3.5	80.00	280.00	High
19+920	20+000	Block crack	RHS		3.5	80.00	280.00	High
22+600	22+680	Block crack	LHS		3.5	80.00	280.00	High

22+500	22+580	Block, patching & potholes	RHS		3.5	80.00	280.00	High
22+500	22+580	Block, patching & potholes	LHS		3.5	80.00	280.00	High
23+000	23+040	Block, patching & potholes	RHS		3.5	40.00	140.00	High
23+000	23+040	Block, patching & potholes	LHS		3.5	40.00	140.00	High
20+980	21+000	Block & Transverse crack	RHS		4	20.00	80.00	High
19+900	19+920	Block, Longitudinal Crack & Transverse crack	LHS		3.5	20.00	70.00	High
19+900	19+920	Block, Longitudinal Crack & Transverse crack	RHS		3.5	20.00	70.00	High
22+680	22+700	Block, patching & potholes	LHS		3.5	20.00	70.00	High
21+100	21+200	Block & Transverse crack	RHS		4	3.50	14.00	High
21+200	21+300	Block & Transverse crack	RHS		4	3.50	14.00	High

24+580	24+700	Longitudinal, Alligator crack & Rutting	LHS		3.5	120.00	420.00	Medium
26+400	26+500	Longitudinal & Alligator crack	LHS	40	3.5	100.00	350.00	High
20+200	20+300	Longitudinal Crack	LHS		3	100.00	300.00	High
20+300	20+340	Longitudinal Crack	LHS		3	40.00	120.00	High
26+500	26+530	Longitudinal & Alligator crack	LHS		3.5	30.00	105.00	High
26+150	26+200	Longitudinal & Alligator crack	LHS		2	50.00	100.00	High
24+400	24+450	Longitudinal Crack	LHS		2	50.00	100.00	High
24+580	24+600	Longitudinal & Alligator crack	LHS		3.5	20.00	70.00	High
24+880	24+900	Longitudinal & Alligator crack	LHS		3.5	20.00	70.00	High
24+580	24+600	Longitudinal, Alligator crack & Rutting	RHS	60	3.5	20.00	70.00	High
25+000	25+010	Longitudinal Crack	LHS		2	10.00	20.00	High
24+520	24+522	Longitudinal Crack	LHS		0.5	2.00	1.00	Medium
18+500	18+600	Patching & block crack	RHS		3.5	100.00	350.00	Low

18+500	18+600	Patching & block crack	LHS		3.5	100.00	350.00	Low
18+600	18+700	Patching & block crack	RHS		3.5	100.00	350.00	Medium
18+600	18+700	Patching & block crack	LHS		3.5	100.00	350.00	Low
18+700	18+800	Patching & block crack	LHS		3.5	100.00	350.00	Medium
18+700	18+800	Patching & block crack	RHS		3.5	100.00	350.00	Medium
18+800	18+900	Patching & block crack	RHS		3.5	100.00	350.00	Medium
18+800	18+900	Patching & block crack	LHS		3.5	100.00	350.00	Medium
18+900	19+000	Patching & block crack	RHS		3.5	100.00	350.00	Medium
18+900	19+000	Patching & block crack	LHS		3.5	100.00	350.00	Low
19+000	19+100	Patching & block crack	RHS		3.5	100.00	350.00	Low
19+000	19+100	Patching & block crack	LHS		3.5	100.00	350.00	Medium
19+100	19+200	Patching & block crack	RHS		3.5	100.00	350.00	Medium
19+100	19+200	Patching & block crack	LHS		3.5	100.00	350.00	Medium
19+200	19+300	Patching & block crack	RHS		3.5	100.00	350.00	Medium

19+200	19+300	Patching & block crack	LHS		3.5	100.00	350.00	Low
19+300	19+400	Patching & block crack	RHS		3.5	100.00	350.00	Medium
19+300	19+400	Patching & block crack	LHS		3.5	100.00	350.00	Medium
19+400	19+500	Patching & block crack	RHS		3.5	100.00	350.00	Medium
19+500	19+600	Patching & block crack	LHS		3.5	100.00	350.00	Medium
19+500	19+600	Patching & block crack	RHS		3.5	100.00	350.00	Medium
19+600	19+700	Patching & block crack	LHS		3.5	100.00	350.00	Medium
19+600	19+700	Patching & block crack	RHS		3.5	100.00	350.00	Low
19+700	19+800	Patching & block crack	LHS		3.5	100.00	350.00	Medium
19+700	19+800	Patching & block crack	RHS	30	3.5	100.00	350.00	Medium
19+800	19+900	Patching & block crack	LHS		3.5	100.00	350.00	Medium
19+800	19+900	Patching & block crack	RHS		3.5	100.00	350.00	Medium
20+000	20+100	Patching & block crack	RHS		3.5	100.00	350.00	Medium

20+000	20+100	Patching, longitudinal & block crack	LHS		3.5	100.00	350.00	Low
26+090	26+105	Pothole & Patching	LHS	45	3.50	15.00	52.50	High
26+096		Potholes	RHS	50	2.00	5.80	11.60	High
26+090		Potholes	RHS	50	2.00	4.70	9.40	High
26+108		Potholes	LHS	40	2.00	4.50	9.00	High
26+108		Potholes	RHS	40	1.50	4.50	6.75	High
25+335		Pothole	LHS	80	1.60	4.10	6.56	High
23+660	23+662	Pothole	CL	150	3	2.00	6.00	High
24+587		Pothole	RHS	50	1.70	2.70	4.59	High
24+622		Pothole & Block crack	CL	50	2.40	1.80	4.32	High
22+600	22+602	Pothole	LHS		2	2.00	4.00	High
23+490	23+492	Pothole	LHS	120	1.5	2.00	3.00	High
23+500	23+501	Pothole	RHS		1	1.00	1.00	High
23+600	23+601	Pothole	LHS		1	1.00	1.00	High
23+675	23+676	Pothole	RHS		1	1.00	1.00	High
23+685	23+686	Pothole	RHS		1	1.00	1.00	High
23+820	23+821	Pothole	LHS		1	1.00	1.00	High
24+200	24+201	Pothole	LHS		1	1.00	1.00	High
23+040	24+340	Rutting & block crack	RHS		3.5	1300.00	4550.00	High
23+040	24+340	Rutting & block crack	LHS		3.5	1300.00	4550.00	High
18+000	18+100	Rutting & block crack	LHS		3.5	100.00	350.00	High

18+000	18+100	Rutting & block crack	RHS		3.5	100.00	350.00	High
18+100	18+200	Rutting & block crack	RHS		3.5	100.00	350.00	High
18+100	18+200	Rutting & block crack	LHS		3.5	100.00	350.00	High
18+200	18+300	Rutting & block crack	RHS		3.5	100.00	350.00	High
18+200	18+300	Rutting & block crack	LHS		3.5	100.00	350.00	High
18+300	18+400	Rutting & block crack	LHS		3.5	100.00	350.00	High
18+300	18+400	Rutting & block crack	RHS		3.5	100.00	350.00	High
18+400	18+500	Rutting & block crack	RHS		3.5	100.00	350.00	High
18+400	18+500	Rutting & block crack	LHS		3.5	100.00	350.00	High
24+800	24+900	Rutting, Longitudinal & Alligator crack	RHS	40	3.5	100.00	350.00	High
24+900	25+000	Rutting, Longitudinal & Alligator crack	RHS	120	3.5	100.00	350.00	High
25+000	25+100	Rutting, Longitudinal & Alligator crack	RHS		3.5	100.00	350.00	High

25+100	25+200	Rutting, Longitudinal & Alligator crack	RHS		3.5	100.00	350.00	High
25+100	25+200	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
25+200	25+300	Rutting, Longitudinal & Alligator crack	RHS		3.5	100.00	350.00	High
25+200	25+300	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
25+300	25+400	Rutting, Longitudinal & Alligator crack	RHS		3.5	100.00	350.00	High
25+300	25+400	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
25+400	25+500	Rutting, Longitudinal & Alligator crack	RHS		3.5	100.00	350.00	High
25+400	25+500	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High

25+500	25+600	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
25+600	25+700	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
25+900	26+000	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
26+000	26+100	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
26+100	26+200	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
26+200	26+300	Rutting, Longitudinal & Alligator crack	LHS		3.5	100.00	350.00	High
25+700	25+800	Rutting & Longitudinal crack	RHS		3	100.00	300.00	High
25+800	25+900	Rutting & Longitudinal crack	RHS		3	100.00	300.00	High
25+900	26+000	Rutting & Longitudinal crack	RHS		3	100.00	300.00	High
26+000	26+100	Rutting & Longitudinal crack	RHS		3	100.00	300.00	High

26+100	26+200	Rutting & Longitudinal crack	RHS		3	100.00	300.00	High
26+200	26+300	Rutting & Longitudinal crack	RHS		3	100.00	300.00	High
25+020	25+100	Rutting, Longitudinal & Alligator crack	LHS		3.5	80.00	280.00	High
25+700	25+780	Rutting, Longitudinal & Alligator crack	LHS		3.5	80.00	280.00	High
27+210	27+320	Rutting & Longitudinal crack	LHS		2	110.00	220.00	High
25+500	25+560	Rutting, Longitudinal & Alligator crack	RHS		3.5	60.00	210.00	High
26+500	26+600	Rutting & Longitudinal crack	RHS		2	100.00	200.00	High
26+700	26+800	Rutting & Longitudinal crack	LHS		2	100.00	200.00	High
26+800	26+900	Rutting & Longitudinal crack	LHS		2	100.00	200.00	High
26+800	26+900	Rutting & Longitudinal crack	RHS	70	2	100.00	200.00	High
27+200	27+300	Rutting & Longitudinal crack	RHS		2	100.00	200.00	High
26+720	26+800	Rutting & Longitudinal crack	RHS		2	80.00	160.00	High

24+340	24+396	Rutting	RHS		2.5	56.00	140.00	Medium
26+400	26+440	Rutting & Longitudinal crack	RHS	30	3.5	40.00	140.00	High
26+040	26+110	Rutting & Longitudinal crack	LHS		2	70.00	140.00	High
25+660	25+700	Rutting & Longitudinal crack	RHS		3	40.00	120.00	High
26+900	26+960	Rutting & Longitudinal crack	RHS		2	60.00	120.00	High
26+040	26+100	Rutting & Longitudinal crack	RHS		2	60.00	120.00	High
26+900	26+950	Rutting & Longitudinal crack	LHS		2	50.00	100.00	High
26+150	26+200	Rutting & Longitudinal crack	RHS		2	50.00	100.00	High
24+695	24+720	Rutting	RHS	40	3	25.00	75.00	Medium
24+360	24+396	Rutting	LHS	30	2	36.00	72.00	Medium
24+640	24+652	Rutting	LHS		1.5	12.00	18.00	Low

Appendix B: road bed atterberg and CBR value

types of distress	section A road bed atterberg and CBR value				
	LL	PL	PI	CBR (%)	CBR swell (%)
Block crack	63	31	32	1.18	2.79
Pothole	62	36	26	1.29	2.78
Alligator crack	55	32	23	4.85	1.79
Depression	40	20	20	8.77	1.87

types of distress	section B road bed atterberg and CBR value				
	LL	PL	PI	CBR (%)	CBR swell (%)
Longitudinal crack	63	35	28	1.89	2.57
Transverse crack	64	31	33	1.94	2.57
Corrugation	65	33	32	1.26	2.68
Alligator crack	59	30	29	1.23	2.71
Pothole	68	35	33	1.4	3.12
Rutting	96	45	51	1.25	5.36
Block crack	76	37	39	1.23	6.61
Depression	75	38	37	1.93	7.68

types of distress	section C road bed atterberg and CBR value				
	LL	PL	PI	CBR (%)	CBR swell (%)
Block crack	72	33	39	1.43	3.82
Rutting	63	31	32	1.18	2.79
Longitudinal crack	63	35	28	1.89	2.57
Alligator crack	64	31	33	1.94	2.57
pothole	65	33	32	1.25	2.68

Appendix c: Improved subgrade group index

Section A						
Station	F	LL	PI	A	B	GI
Block crack	44	0	0	0	-2.9	-2.9
Pothole	10.1	26	9	-3.237	0.049	-3.188
Alligator crack	24.7	0	0	0	-0.97	-0.97
Depression	51.2	41	16	3.321	2.172	5.493

Section B						
Station	F	LL	PI	A	B	GI
Longitudinal crack	8	31	12	0	-0.14	-0.14
Transverse crack	15.8	28	9	-2.688	-0.008	-2.696
Corrugation	37.2	42	6	0.462	-0.888	-0.426
Alligator crack	22.3	25	7	-1.5875	-0.219	-1.8065
pothole	12.5	0	0	0	0.25	0.25
Rutting	14.2	0	0	0	0.08	0.08
Block crack	10.3	0	0	0	0.47	0.47
Depression	13.8	0	0	0	0.12	0.12

Section C						
Station	F	LL	PI	A	B	GI
Block crack	16.5	0	0	0	-0.15	-0.15
Rutting	23.7	0	0	0	-0.87	-0.87
Longitudinal crack	10.3	0	0	0	0.47	0.47
Alligator crack	12.3	0	0	0	0.27	0.27
pothole	7.7	0	0	0	0.73	0.73

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