ADDIS ABABA UNIVERSITY

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SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

ASSESSMENT OF THE IMPACT OF DRAINAGE STRUCTURES ON ROAD ASSET IN ETHIOPIA; THE CASE OF BURAYU TOWN

By

Lemessa wagari

A Thesis Submitted to School of Graduate Studies in Partial Fulfillment of the Requirement for Degree of Master of Science

In

Road and Transport Engineering

Advisor

Dr. Bikila Teklu

November, 2016

Addis Ababa, Ethiopia

Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

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CERTIFICATION

I, the undersigned certify that I have read the thesis entitled "**Assessment of the impact of drainage structures on road asset in Ethiopia; the case of Burayu town**" and here by recommend for acceptance by Addis Ababa University in Partial fulfillment of Master of Science in Road and Transport Engineering.

Dr. Bikila Tekilu (Supervisor)

DECLARATION

I, the undersigned, declare that this thesis is my original work performed under the supervision of my research advisor Dr. Bikila Teklu and has not been presented as a thesis for a degree in any other university. All sources of materials used for this thesis have also been duly acknowledged.

Name Lemessa Wagari

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Place Addis Ababa Institute of Technology

Addis Ababa University, Addis Ababa.

Date November, 2016

Table of Contents

CHPTER THREE

RESEARCH METHODOLOGY AND MATERIALS

CHAPTER FOUR
EVALUATION AND ANALYSIS OF PAVEMENT DISTRESS AND DRAINAGE STRUCTURES

CHAPTER FIVE
RESULT AND DISCUSSION

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

Abstract:

Drainage is one of the most important factors to be considered in the road design, construction and maintenance projects. It is generally accepted that road structures work well and last longer to give the desired service. When a road fails, whether it is concrete, asphalt or gravel, inadequate drainage is often a major factor to be considered. A pavement distress that occurs at the surface can have a number of different causes which must be properly identified before corrective action is taken. The visible manifestation of the problem at the surface may be the same; however, the solution for each cause may be different. Therefore, if the remedial action is to be effective, the cause of the problem must be identified and corrected.

The present road condition of Burayu shows rapid deterioration. The severity of pavement distresses is even more critical on the major arterial roads were the traffic volume of busses, heavy trucks, passenger vehicles and taxies is comparatively higher than other road network. Such severe distresses summed up with inadequate road signs and markings are resulting congestion and consequently causing further deterioration of roads due to maximum static load sustained from the vehicular traffic waiting in a queue on the pavement.

This research mainly focuses on making assessment of road pavement condition, identifying causes of pavement distress and proposing maintenance options for the arterial roads of Burayu. These roads are most widely utilized, and therefore prone to severe distress and consequently exhibiting repeated maintenance and repair. Visual distress assessment, and other necessary investigations were carried out on selected test road sections in order to have better understanding of the pavement response and come up with identification of probable causes. Major causes of pavement distress associated with load, drainage and durability are tried to be identified.

The visual survey analysis indicates that almost all test roads have very low PCI value. Raveling, corrugation, Bumps and sags are the most dominant type of distresses constituting more than 75% of the distress densities in the arterial road network. The majority of test sections showing low PCI values. The investigation and analysis also showed that moisture and drainage associated distresses are predominant in the arterial roads and most likely on the whole network as well. Moreover, it is also observed that most of the existing pavements lack structural adequacy and hence require reconstruction than doing a routine maintenance and/or rehabilitation.

Keywords: Road Drainage System, Urban Road, Maintenance, Flood damage,

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ABBRIVATIONS

1. AACRA : Addis Ababa City Roads Authority
2. AADT : Average Annual Daily Traffic
3. AASHTO : American Association of State Highway & Transport Officials
4. ASTM : American Society for testing and Materials
4. CBR : California Bearing Ratio
5. CDV : Corrected Deduct Value
6. CESA : Cumulative Equivalent Standard Axle Load
7. DCP : Dynamic Cone Penetration
8. EAL : Equivalent Axle Load
9. ERA : Ethiopian Roads Authority
10. FHWA : Federal Highway Authority
11. IRI : International Roughness Index
12. MERLIN : Measuring Roughness using Low cost Instrumentation
13. PCI : Pavement Condition Index
14. PMS : Pavement Management System
15. PSI : Pavement Serviceability Index
18. TRL : Transport Research Laboratory
16. RRD : Representative Rebound Deflection
17. RTRRM : Response Type Road Roughness Meter
19. VDF : Vehicle Damaging Factor
20. WASHO : Western Association of State Highway Officials

LIST OF TABLES

LIST OF FIGURES **Page**

CHAPTER ONE

INTRODUCTION

1. Introduction

Pavements are usually classified as either flexible (Hot Mix Asphalt, HMA) or rigid (Portland Cement Concrete (PCC). Both flexible pavements and rigid pavements are susceptible to environmental factors and traffic related damages. Environment condition, such as excessive moisture and flooding, can negatively impact the performance of pavement structures. Moisture induced damage that may be caused by poor drainage structure is one of the most significant damages that can affect the performance of flexible or rigid pavements. The main focus of this study is on the analysis of effects of poor drainage on flexible pavements.

Though Water is very essential for all life on earth, it can also cause devastation through erosion and flooding. Due to the development of infrastructures as a result of urbanization, the surface runoff water greatly increased in the town damaging the roads. The contributed runoff water thus need to be safely disposed to the rivers/outlet channels so that the functional utility of the road infrastructure maintained and thereby avoid the damages which otherwise occurred to the road and property.

Adequate drainage is very essential in the design of roads since it affects the road's serviceability and usable life. If ponding on the traveled way occurs, hydroplaning becomes an important safety concern. Drainage design involves providing facilities that collect, transport and remove storm water from the highway.

Inadequate urban storm water drainage problems represent one of the most common sources of compliant from the citizens in many towns of Ethiopia[GTZ-IS,2006],and this problem is getting worse and worse with the ongoing high rate of urbanization indifferent parts of the country.

The pattern of urbanization and modernization in Ethiopia has meant increase densification along with urban infrastructure development. This has led to deforestation, use of corrugated roofs and paved surfaces. The combined effect of this results in higher rain fall intensity and consequently accelerated and concentrated runoff in the urban areas. Due to inadequate integration between road and urban storm water drainage infrastructure provision, many areas are exposed to flooding problems and road damages in urban roads [Belete, 2011].

1.1 History of road construction in Ethiopia

A road construction work, just like any other social endeavor or undertaking, has vast and wonderful history of its own, since it evolved with the social development of mankind.

Amidst those early Emperors that ought to be mentioned in line with those that played a significant role in this constructive field of endeavor in early Ethiopia, are Emperors such as Emperor Fasil, Tewodros, Yohannes and Menelik(20).

The main reason that prompted these Emperors to give emphasis to the need for development of road construction was because of their appreciation of the value that could be gained from the expansion of territory and from ensuring the unity of the nation.

If we look back to Ethiopian history and briefly try to visualize the genesis of road construction works, we note that some roads and bridges were constructed in early times. Emperors during their royal trips, used to exert efforts to make the roads suitable for their trips by having forests cleared and difficult terrains leveled. Some of the achievements that need to be quoted as an example are the bridge built on the Abay River during the times of Emperor Fasil in order to connect Gojam with Gondar.

The populace, being pleased with the bridge that is located on the Gondar -Gojam route, and built by Emperor Fasil, used to tell tales to traders and other pioneers who traverse thisbridge. Emperor Tewodros frequently used these routes that start from Debretabor leading to Mota Keranio and Mertu-Lemariam and then through Wadla Delanta to reach Mekdela. The population always remembered the Emperor. The enormous effort exerted by the Emperor in 1859 G.C. to connect Debretabor, the capital city at the time, with Gondar, Gojam and Mekdela was an achievement that could not be easily ignored. Tewodros has contributed in the expansion of road construction works not only during his reign but also during the declining days of his rule.

The English army that came to Ethiopia on a military expedition to free its citizens had to construct roads to transport its heavy weapons and wagons from Zula, a red sea port to Senafe, Adigrat, Lake Ashange,Ambalage and finally to Mekdela. It is believed that Emperor Yohannes during his war campaign against the Derbuishes, the Egyptians and the Turkys did contribute to the expansion of roads in order to facilitate his military expedition.

It is to be recalled that the Italian occupants having occupied Massawa and settled there in defiance of Ethiopia's territorial integrity in 1885 did start road construction works to connect them with the hinterland.

The modern approach in road construction work commenced during the reign of Emperor Menelik. Blasting of mountains with dynamite was unknown during that period. And, as such, when a hard rock was encountered during road construction, it was told that a fire is lit and the rock is subsequently heated up and then cooled with water in order that it may crack when a change from a hot medium to a cold medium occurs. The bridge built on Awash River with the supervision of the Swiss, Alfred Elg, the Emperor's consultant and the bridge that was also built over Gibe were some of the major examples that need to be quoted to show how much emphasis was given for road works.

The Diredawa -Harar road was built as result of the agreement reached by the Emperor in 1894 GC in connection with rigging of railway line from Addis Ababa to Djibouti. And as consequence of which, the road connecting Addis Ababa with Gulf of Aden provided a good opportunity for road development. Subsequent to this development, Emperor Menelik in order to set an example to the nobility and orient them the application of the art of modern engineering skill, he himself went and participated in road construction work with ordinary workmen. The Gore - Gambella road which was constructed in by the late 1890 and the Addis Ababa to Addis Alem Mariam road (the test road under study) were ones that needs to be awarded first place in the annals of Ethiopian road construction history.

It is recalled that when the road that was begun in 1902 GC with the participation of the Italian war prisoners and other foreign nationalities, was completed, the Emperor traveled on this road on a Roller driven by steam power. The Roller was imported to Ethiopia for the first time in 1904 GC and did participate in road construction work. In the ensuing years and particularly in 1907 GC the arrival of two vehicles in Addis Ababa has contributed in invoking emphasis to the importance and the necessity of road construction development.

1.2 Road Construction and maintenance in Addis Ababa

Although Ethiopian history has been recorded for thousands of years, its present capital city, Addis Ababa, is comparatively new, the first settlement occurred during the time of Emperor Minelik in 1886. It was during the Italian occupation (1935-41) that a network of good roads radiating from Addis Ababa, and connecting the capital with the main administrative regions was constructed. These roads were built almost by human power and the pavement structure was made of Telford base constructed by hand laid stones.

It was since 1942 that road maintenance and rehabilitation duty within Addis Ababa was made to be the responsibility of the Roads and Building Department of the Addis Ababa municipality. However, the municipality was unable to cope up with its maintenance duties due to lack of resource particularly experienced personnel in the field of road construction [7].

Besides lack of resource in the road and building department, the maintenance and rehabilitation operation was at a very dangerous position when a new city organization formed in 1981.This new organization had created three administrative levels namely the Kebele Urban Dwellers Association (UDA), Higher UDA and Central UDA. Each of the three Administrative levels was responsible for the city roads construction, maintenance and rehabilitation without proper coordination and clear division of work.

No proper engineering work was done in advance or during construction of a kebele road. The road construction and maintenance division was not even consulted during preparation of the annual program leave alone making of proper pavement evaluation and site investigation. Little attention was given to drainage and pedestrian walk ways.

In general, the road construction and maintenance works in Addis Ababa until1996 were not organized with proper human power, equipment and material resources. Such inadequate resources coupled with organizational shortcomings within the municipality such as lack of formal policy and standards for road construction and maintenance has resulted in substandard maintenance services which directly or indirectly affect the pavement performance as follows (23):

- Materials and construction quality control & tests were not performed at all. As a result, it was not uncommon to encounter pavement failures distresses within short time after the new roads are opened to traffic.
- Lack of integrated infrastructure development is the other problem affecting the road network. There is no proper coordination with local Agencies, which carry out utility constructions such as waterworks, telephone lines, power lines and etc. Due to this, there is repetitive destruction of the existing road pavement and drainage structures, which consequently cause bumps, sags, patch deterioration and other damages on the asphalt due to water infiltrating in to the cracks.
- There is high rural-urban interaction in the town of Burayu. As a result, there are many open-air minimarkets in many different locations. This in turn has resulted in the use of traditional means of Transportation such as horses and donkeys. This has resulted traffic congestion on the road network and damage on the asphalt and drainage system.

- Lack of adequate parking area is the other major problem that greatly affects the road network. Drivers usually make on street parking which led to minimizing the effective carriage way width and moreover aggravate the rate of pavement damage.
- Many of the town roads do not have footpath. Due to this, pedestrians move on the carriage way. This on the other hand reduces the effective road width that still aggravates pavement deterioration and accident rate.

1.3 Description of the Study Area

Burayu city was founded in 1938 by a land lord of that area named “Grazmatch” Robi Kelecha. The name “Burayu” was derived from one of the indigenous trees of the region. The term “Burayu” is an Afan oromo word, which means “TiqurInchet”in Amharic. During Imperial era, Burayu used to be administered within “Menagesha Awuraja”of Shoa Province. During the Derg regime Burayu used to have two different entities namely: Urban Dwellers Association (UDA) and Peasant Association (PA). Until 1991, it was one kebele of Wolmera district under the West Shoa Administration Zone. In 1996, the municipality of Burayu city was established over the area between Ketta and Gefersa.

Nevertheless, its jurisdiction was restricted only on houses, which had been given house number. It has become third grade city and the administration has become unified and reformed to be administrated by the municipality in 2005. In 2006, Burayu City became first grade City and had got its master plan in December 2007. Now the City has 6 kebeles namely: Laku keta, Burayu ketta, Gefersa Burayu, Gefersa Guje, Melka Gefersa and Gefersa Nono.

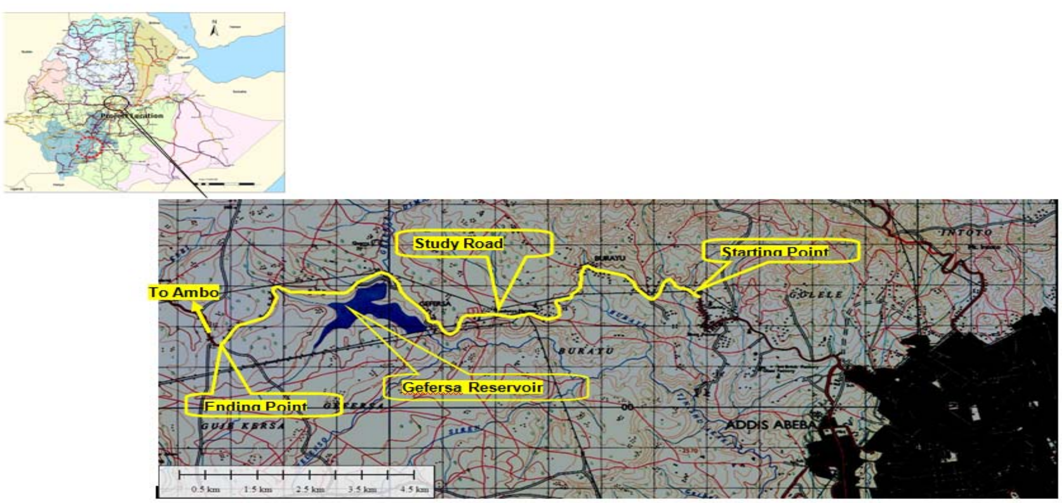


Figure 1-1: Location Map

Figure 1.1 Location Map

1.4 Justification and relevance of the study

1.4.1 Research motivation

The research motivation has been originated from the practical problems of the existing road asset (pavement) deteriorated due to drainage in the town. The aim of this study is to investigate the magnitude of impact on road pavement due to storm water drainage on road asset.

1.4.2 Significance

This research will provide significant contribution to generate best road asset (Pavement) management scenario in Burayu town in line with the city administration´s vision. Moreover it will render academic advantages that will be used as reference or guideline while designing projects and can be used as precursor for further scientific research.

1.5 Scope of the study

The scope of this research is spatially limited to Burayu town as case study area. Thematically, it investigates the magnitude of impact on road asset (pavement) due to improper management of drainage system and valuation; in the other hand, extensive research outputs and works on related topics and real world application of the topic will be explored in order to build a general insight about the topic under study.

Finally, it attempts to identify appropriate principles and standards for the development of road asset management that plays crucial role in urban road asset evaluation and in the city development processes.

1.6 Expected limitation of the study

Due to externalities the researcher will be expecting to face the following limitations among all other limitations will be financial problem, difficulties in accessing timely all information.

1.7 Statement of the problem

Roads have over time become an essential part of every society and as well a meaningful resource for use by people. To manage the challenge faced by roads in Ethiopia, past and present governments have put in measures to remedy this situation.

In this statement, the government outlined its projects and programs regarding road networks in the country, which included road maintenance and rehabilitation. Contrary to the outlined projects, very few of these projects were undertaken and these constraints were attributed to the lack of funds in the roads sector. Although governments, past and present, have made some effort, roads are still plagued with potholes, cracks, eroded sections of the roads, amongst others.

Figure1.2 Some deteriorated roads (lack of proper drainage)

PROBLEMS

In addition the existence of deteriorated bridges due to drainage, that have now become death traps in the town.

This research is being conducted to address the problem in the town road. This research seeks to assess the efficient use of road asset (pavement) management practices in the sector, identify potential gaps hindering its progress, and make appropriate recommendations to this effect.

1.8 Objective of the study

1.8.1 General objective

The general objective of the study is to identify observed impacts of lack of proper management of road assets (drainage structures) on road and detailed gaps in preparing and implementing maintenances of road. The study is intended to produce the magnitude of impacts on road asset (pavement) by miss managing drainage structures.

1.8.2 Specific objectives

- To analyze the magnitude of damages seen due to drainage on selected road corridors in Burayu Town
- Identify the root cause of drainage problems in terms of design, operation and maintenance on road asset
- To recommend proper design, operational, and maintenance conditions to address drainage-related impacts on road asset.

CHAPTER TWO
LITERATURE REVIE

2.1 Introduction

One of the most important aspects of the design of a road is the provision made for protecting the road from surface water and groundwater. Water on the pavement slows traffic and contributes to accidents from hydroplaning and loss of visibility from splash and spray. If water is allowed to enter the structure of the road, the strength and deformation resistance of the pavement and sub grade will be weakened, and it will be much more susceptible to damage by the traffic. Water can enter the road as a result of rain penetrating the surface, or as a result of the infiltration of groundwater. When roads fail, it is often due to inadequate drainage. Water can also have a harmful effect on shoulders, slopes, ditches, and other features. Failures can arise spectacularly as, for example, when cuttings collapse or when embankments and bridges are carried away by flood-water. High water velocities can cause severe erosion, possibly leading to the road being cut. On the other hand, low velocities at drainage structures can lead to silt being deposited which, in turn, can lead to blockage. Blockages often results in further erosion or overtopping and possibly wash-out.

A drainage system includes the pavement and the water handling system. They must be properly designed, built, and maintained. The water handling system includes: road surface, shoulders, drains and culverts; curb, gutter and storm sewer. When a road fails, whether it's concrete, asphalt or gravel, inadequate drainage often is a major factor. Poor design can direct water back onto the road or keep it from draining away. Too much, water remaining on the surface combines with traffic action to cause potholes, cracks and pavement failure.

Pavement failure is defined interims of decreasing serviceability caused by the development of surface distresses such as cracks, potholes and ruts,[2]

This chapter thoroughly discusses the following major topics:

- Functions and failure of road drainage structures
- Performance and failure criteria of asphalt pavements with their causes
- Methods of asphalt pavement distress survey,
- Methods of pavement maintenance and rehabilitations

Having good understanding of the above topics is very necessary, as they will serve as an input in the methodology, analysis, discussion and conclusion to be covered in subsequent chapters.

2.2 Functions of Road Drainage Structures

Drainage structures collect, transport, and dispose of surface/sub-surface water originating on or near the roadway right of way or flowing in streams crossing bordering the right of way. It prevents erosion of the back slope by runoff from the hill above. It intercepts water, not allowing it to enter side drain that may cause greater discharge in side drains.

In steep terrain, culvert capacity is usually governed by inlet control. The water depth at the entrance conditions governs the capacity of culverts subject to inlet control. The entrance conditions include the geometry of the opening, the wing walls, head walls, the angle of wing walls & head walls and the protection of the culvert in to the headwater pond.

Pipe roughness, outlet conditions including tail water level do not influence flow capacity of culverts operating under inlet control. When the culvert barrel is not capable of conveying as much flow as the inlet opening will accept the outlet control occurs (FHWA, 2001).

2.3 Failures of Road Drainage Structures

The roadway shall not obstruct the general flow of surface water or stream water in any unreasonable manner to cause an unnecessary accumulation either of water flooding or water soaking uplands, or an unreasonable accumulation and discharge of surface water flooding or water soaking lowlands.

The failure of drainage structure occurred on our test road due to vegetation on shoulders, shoulders lower than ditch, shoulder higher than carriage way, inadequate capacity of the ditches and culvert, badly maintained shoulders etc. Badly maintained shoulders cause Penetration of water into the pavement structure or foundation and resulting loss of bearing strength of pavements. If the failure is sudden and catastrophic, it can result in injury or loss of life and property.

Water passing through undersized culverts will scour away the surrounding soil over time. This can cause a sudden failure during rain events. Degradation in streams can cause the loss of bridge piers in stream channels, as well as piers and abutments in caving banks and failure on asphalt pavements.

2.4 Performance and Failure Criteria of Asphalt pavement

Pavement performance evaluation is an important activity in the maintenance and rehabilitation works. It includes evaluation of existing distresses, road roughness, structural adequacy, traffic analysis, material testing and study of drainage condition. This section deals with types of bituminous surfaces, types and causes of distresses. Photographs all taken during distress surveys are incorporated for illustration.

A typical flexible or bituminous pavement structure consists of the following pavement courses: sub-base, base, and bituminous wearing surface. The wearing surface is the upper most layer of the pavement structure. In a flexible pavement, it is a mixture of bituminous binder material and aggregate. The binder maybe sprayed on the surface followed by application of aggregate and referred to as a bituminous surface treatment. The binder and aggregate may be mixed in a central plant or mixed in place on the road and referred to as hot or cold mixes. The wearing surface may range in thickness from less than 2.5cm,as in the case of a surface treatment, to several centimeters of high-quality paving mixture such as hot-mix asphalt concrete.

The wearing surface has four principal functions: to protect the base from abrasive effects of traffic, to distribute loads to the underlying layers of pavement structure, to prevent surface water from penetrating into the base and sub-grade, and to provide a smooth riding surface for traffic[24].

The base and sub-base are made using different materials designated the upper and lower base or sub-base. Where the soil is considered to be very weak, a capping layer may also be introduced between the sub-base and the soil foundation. This may be of an inferior type of sub-base material, or it may be the upper part of the soil improved by some form of stabilization(e.g. with lime or cement).The soil immediately below the sub base(or capping layer)is generally referred to as the sub grade and the surface of the sub grade is termed the formation level. The elements of a flexible pavement as defined above are shown in figure 2.1

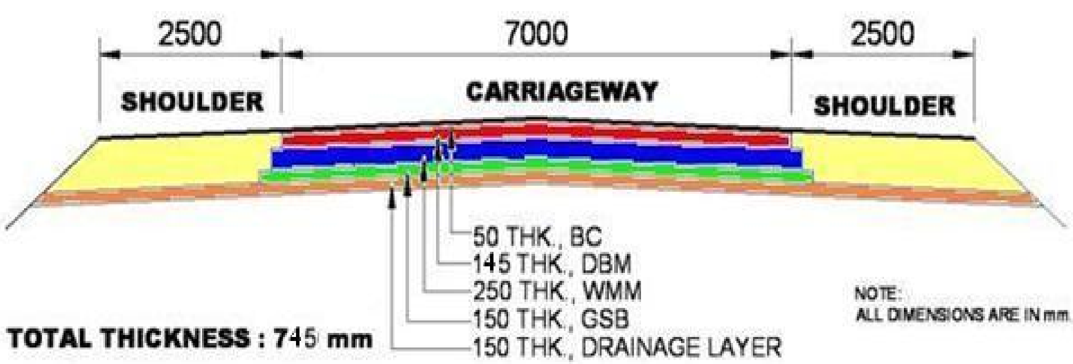


*Figure 2.1: - Section of Flexible Pavement designed as per **IRC: 37-2012***

2.4.1 Pavement deterioration

The rate of pavement deterioration is directly affected by the standards of maintenance applied to repair defects on the pavement surface such as cracking, raveling, potholes, etc., or to preserve the structural integrity of the pavement (for example, surface treatments, overlays, overall long-term condition of the road pavement directly depends on the maintenance or the improvement standards applied to the road.

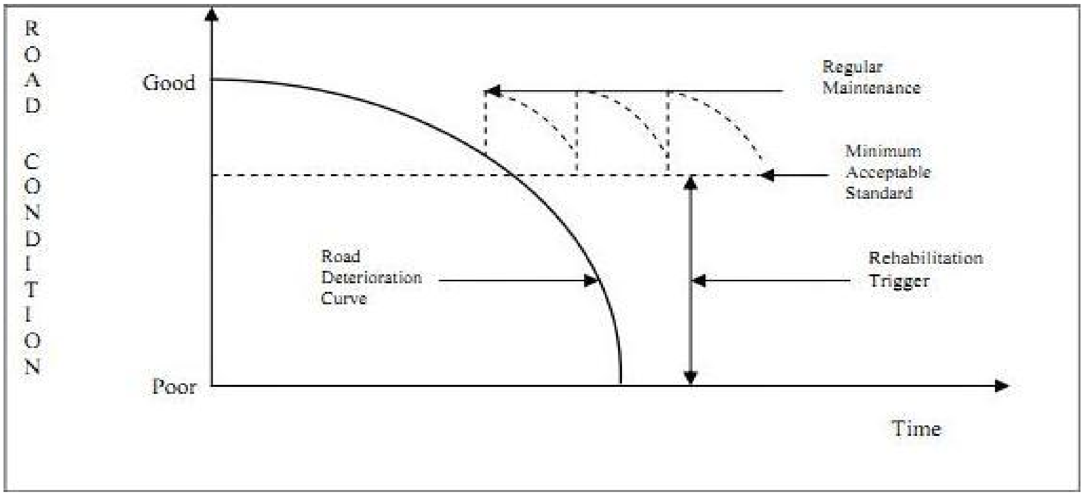


Figure 2.2: Pavement Deterioration Curve [Hass & Hudson, 1978]

2.4.2 Types of bituminous pavement distress and their probable causes

It is necessary to have clear understanding of type of pavements distress, before discussing the different methods of evaluation, cause identification and treatment selection. There are two basic types of pavement distress. The first is structural distress and it includes damage of different pavement components of such magnitude to make the pavement incapable of sustaining the loads imposed upon its surface. The second can be classified as functional distress which may or may not progressively changed in to structural distress but is such that the pavement will not carry out its intended function without causing discomfort to users. These verity of distress for both types of distress is gradual and the range is largely matter of opinion of the person observing the distress [19].

1. ***Alligator Fatigue cracks***

Alligator cracks are inter connected cracks forming series of small blocks resembling an alligator skin. The lengths of the cracked pieces are usually less than 15 cms on the longest side **(Figure 2.3).** In some cases, alligator cracking is caused by excessive deflection of the surface over unstable sub grade or lower courses of the structure. The unstable support is usually the result of saturation of the bases or sub grade. Although the affected areas in most cases are not large, occurring principally in traffic lanes, occasionally, will cover entire sections of pavements.

a. Severity levels

Low level of intensity (L): fine, longitudinal hair line cracks running parallel to each other with one or only a few interconnecting cracks. The cracks are not spalled.

Average level of intensity (M): further development of light alligator cracks in to a pattern or network of cracks that may be lightly spalled.

Higher level of intensity (H): network or pattern cracking has progressed so that the pieces are well defined and spilled at the edges. Some of the pieces may rock under traffic. Potholes of all sizes are recorded as high severity alligator cracking.

b. How to Measure

Alligator cracking is measured in square meter of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity of ten exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately, however, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity level present.

d. Possible causes

Causesincludetheexpectedalligatorcracksoneormoreofthefollowingreasons (GTC, 1998):

1. Damagedlayerofasphaltconcreteasaresultofdamagetothesubstratedueto repeated traffic loads.
2. Instabilityofthefoundationlayerofasphaltcaseorlayerunderthefoundation because of the drop surface.
3. Double layer foundation stone, making it unable to land resulting from excessive loads of traffic.
4. Aging of asphalt materials by the time.
5. Insufficient thickness of the pavement.
6. Poor drainage in the base layers and under the foundation.

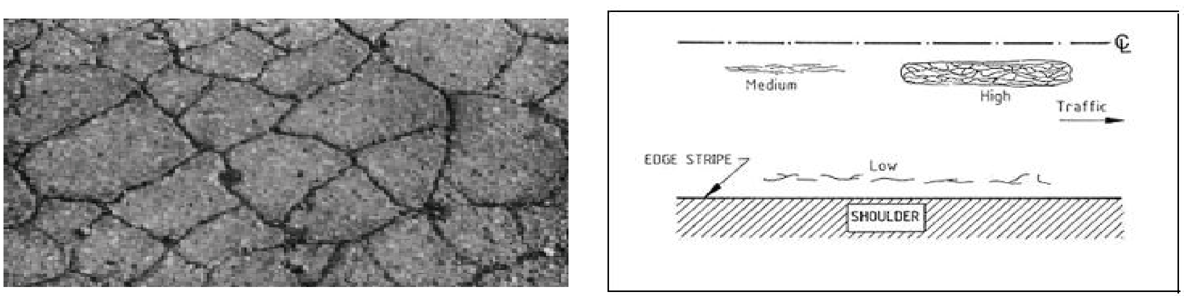


Figure2.3 Alligator cracking from site survey & severity level as per (GTC, 1998)

6. ***Bleeding***

Bleeding is the upward movement of the binder material in the pavement creating a film of bituminous material on the surface (Figure2.4). This condition usually occurs during hot weather and will cause an extremely slippery surface. The most common cause of bleeding is excess asphalt binder in one or more of the pavement courses. This can result from arich mix, variations in aggregate blending, improperly constructed seal coat, or heavy prime or tack coat. Traffic volume, tire pressure, or load in excess of design quantities can cause over compaction of bituminous layers forcing the binder to the surface particularly in a mix of very low void.

b. S e v e r i t y levels

- **Low level of intensity (L):** the case where the bleeding very slightly and watched this only in a few days of the year and at this level, do not stick to the asphalt shoes or tires.
- **Medium level of intensity (M):** is the level at which the asphalt adhere to shoes or tires, and this happens in a few weeks per year.
- **Higher level of intensity (H):**high intensity bleeding when the asphalt adhere to shoes or tires for period of not less than several weeks and be completely covered with a layer of gravel bitumen.

b. How to Measure

Bleeding is measured in square meters of surface area. If bleeding is counted, polished aggregate is not counted in the same area.

c. P o s s i b l e causes

Bleeding occurs due to the increasing quantities of asphalt or increases the binding of asphalt in the mix asphalt, and increases the spraying of asphalt materials (paint layer and adhesive layer) or the lack of air spaces resulting in hot weather to extend the asphalt and fill in the blanks and then grows out of the surface. Therefore, the bleeding process does not have reflection or effect in cold climates and pool are on the asphalt surface.

Figure2.4*Bleeding*

7. ***Block cracking***

Block cracking is an interconnected series of cracks that divide the pavement in to approximately rectangular pieces. Block cracking is differentiated from alligatorcrackingbysizeandbynotbeingloadrelated.Theblocksusually range from 30 by 30cm to 300 by 300cm (Figure2.5).The cracking is caused mainly by daily temperature cycling and by shrinkage of the asphalt concrete. This distress is not load related but is usually associated with the asphalt aging and hardening.

Block cracking can also be caused by oxidative hardening of the asphalt if mixed too long in the pug mill of asphalt batch facility, mixed too hot, or stored too long in silos. All these mechanisms make the asphalt cement especially susceptible to tensile strains, which can exceed the tensile strain capacity of the asphalt mixture and cause the block cracking.

Block cracking is more often seen in large paved areas, such as parking lots or airfield pavements, than on roads and streets. It can be very serious, especially if the cracks begin to exhibit raveling and other advanced stages of deterioration, such as development of secondary cracks. Because the cracks can be closely spaced, the underlying layers can be exposed to significant quantities of infiltrating surface water. These cracks should be sealed to prevent or minimize intrusion of water [1]

A. S e v e r i t y levels

Low level of intensity (L): the classification of the low level of network cracks must provide one case:

i. Non-filled cracks (Non-Filled) offer less than (10mm).

ii. Cracks filled with insulation any offer was in acceptable condition.

Medium level of intensity (M): the classification of moderate cracks network must provide one of the following:

i. Width of cracks more than 10 mm and less than 75 mm.

ii. Cracks introduced less than or equal to 75mm and surrounded by light random badly broken.

iii. C r a c k s filled with any offer and is surrounded by light random badly broken.

Higher level of intensity (H): it is for the classification of high intensity of the cracks network there must be one of the following:

i. Any cracks filled or not filled with badly broken surrounded by random high or medium severity.

ii. Showing unfilled cracks greater than 75 mm.

iii. C r a c k s introducedabout100mm and surrounded by very badly broken and broken.

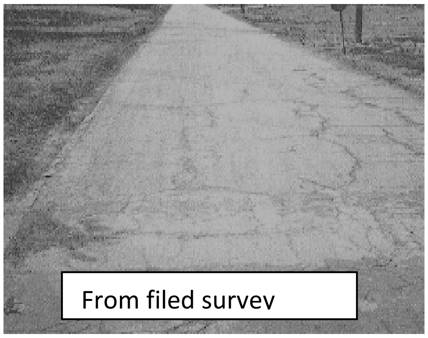
B. How to Measure

Blockcrackingismeasuredinsquaremeterofsurfacearea.Itusuallyoccursatone severity level in a given pattern section; however, any areas of the pavement section having distinctly different levels of severity should be measured and recorded separately.

C. P o s s i b l e causes

Cracks are the retina of the functional and structural defect sand the underlying cause. Of these cracks is a heat shrink material asphalt Association as a result of emotion and stress (GTC, 1998).The league, as the appearance of these cracks the asphalt to harden significantly.

However, cracks the retina of the defects of earlier pregnancies despite the increase in the level of intensity as a result of the impact loads, and the asphalt concrete vulnerable accelerate the onset of these cracks.



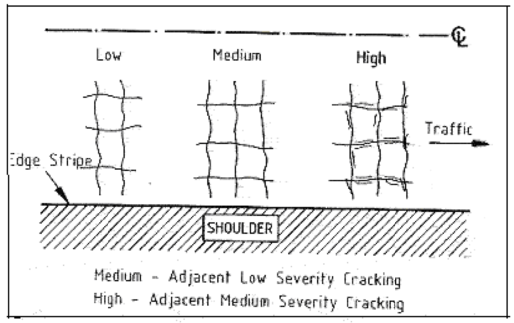


Figure2.5 Block Cracking from site survey & severity level as per(GTC, 1998)

8. ***Bumps and sags***

Bumps and sags are small, localized, upward and downward displacements of the pavement surface (Figure 2.6). Bumps can be caused by differential heave or settlement over utilities, the buildup of material in crack in combination with loading. Sags are caused by a localized failure of the underlying material resulting in subsidence.

a. Severity levels

Low level of intensity (L): a level which affects the quality of a simple command (Riding quality).

Medium level of intensity (M): a level which affects the average quality of leadership.

Higher level of intensity (H): a level which severely affects the quality of leadership.

b. How to Measure

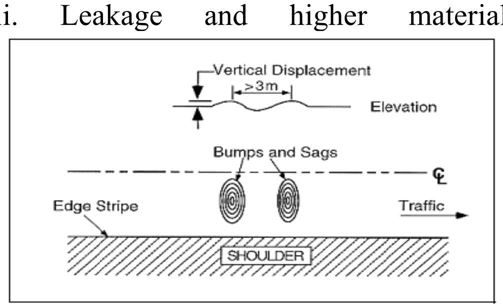
The measured concavities and Convexities Surface longitudinal, and if met this defect with cracks they record as well. Measured by the area affected by the defect length of the affected area multiplied by one meter, and the defect density is calculated by dividing the area affected by the total area of the section scanned multiplied by one hundred.

c. Possible causes

These reasons include the following:

i. Bulge or curvature of the concrete slabs of concrete under the asphalt surface.

ii. Leakage and higher materials in the cracks due to traffic loads.



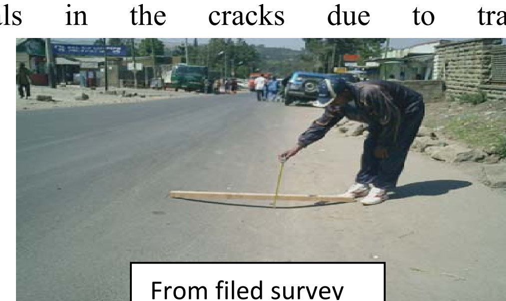


Figure2.6***Bumps and sags*** from site survey & severity level as p(GTC, 1998)

9. ***Corrugation***

Corrugation is a form of plastic surface movement typified by ripples across the bituminous pavement surface (Figure2.7). The cause of corrugations is usually lack of stability in the bituminous mix. Lack of stability can be caused by the mix being rich, the aggregate having excessive amounts of fines, rounded or smooth textured particles, poor bond between material layers, or the use of soft binder.

A. Severity levels

Low level of intensity (L): corrugations are minor and do not significantly affect ride quality.

Medium level of intensity (M): corrugations are noticeable and significantly affect ride quality.

Higher level of intensity (H): corrugations are easily noticed and severely affect ride quality.

B. How to Measure

Corrugation is measured square meters of surface area. The mean elevation difference between the ridges and valleys of the corrugations indicates the level of severity. To determine the mean elevation difference, a 3-meter straightedge should be placed perpendicular to the corrugations so that the depth of the valleys can be measured in millimeters.

C. Possible causes

I. Poor stability of asphalt concrete mixture or weak foundation.
II. Excess moisture in the lower soil layers.
III. Increase in asphalt and/or increase the soft material in the mix, or use a round pebble mixture.
IV. Pollution mixture Contamination of mix.

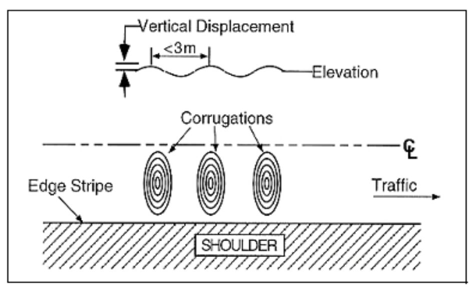


Figure2.7 Corrugations from site survey & severity level as per (GTC, 1998)

10. ***Depressions***

Depressions are localized low areas of limited size which may or may not be accompanied by cracking **(Figure 2.8).** Depressions dip below grade and water collects in them. Depressions may be caused by traffic heavier than that for which the pavement was designed, by settlement of the underlying pavement layers, or by poor construction methods.

A. Severity levels

Low level of intensity (L): it is noted that level depression in the areas of spots, and have mild impact on the quality of leadership and can cause ups and downs of the car at high speeds.Ranges from a maximum depth of depression between 13-25 mm in the case of low-intensity.

Medium level of intensity (M): it is noted that the defect easily at this level and moderately affect the quality of leadership, where a depression the rise and fall of car at high speeds.Estimated depth of this level of intensity between 25-50 mm.

Higher level of intensity (H): it can be seen this level of intensity of depression easily and is severely affecting the quality of leadership, causing vibration and clear of the car at high speeds, and greater depth of the decline is more than 50mm.

B. How to Measure

Depressions are measured in(square meters) of surface area. The maximum depth of the depression determines the level of severity. This depth can be measured by placing a (3-meters) straight edge across the depressed area and measuring the maximum depth in (millimeters).Depressions larger than (3meters) across must be measured by either visual estimation or direct measurement when filled with water**.**

C. Possible causes

Can be summarized depression potential causes of the following points (GTC, 1998):

I. Depression occurs due to falling base layers or arise during construction.

II. Basis because of the drop, as a result of excess loads, which is pressing basis or because of the decline that occurs during the immediate implementation of the rate of movement of the upper lower classes. Inadequate compaction of hard cores and the inability of the substrate to withstand loads of reasons depression.

III. Traffic loads, temperature, materials and disadvantages of implementation are all factors that contribute to the emergence depression and accelerate the deployment.

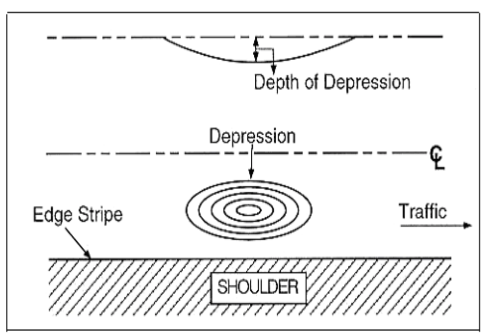


Figure2.8Depressionfrom site survey & severity level as per (GTC, 1998)

11. ***Edge cracking***

Edge cracks are parallel to and usually within30to60cmoftheedgeofthe pavement **(Figure2.9).** This distress is accelerated by traffic loading and is caused by a weakened base or sub base at the pavement edge. Weakening of the base or sub base can normally be associated with a drainage problem causing water intrusion.

a. Severity levels

Low level of intensity (L): It is a shallow surface cracks do not cause breaks and loss of materials on the pavement.

Medium level of intensity (M): Moderate cracks are classified when they contain break and loss of materials in the lengthofupto10%ofthelengthofthepavingof the area affected.

Higher level of intensity (H): It is a deep and many cracks and contains break and lossofmaterialsinthelengthofmorethan10%ofthelengthofthe paving of the area affected.

b. How **to Measure**

Surface cracks measured longitudinal profiles for each level of severity alone. Measured by the area affected by the defect length of the affected area multiplied by one meter, and the defect density is calculated by dividing the area affected by the total area of the section scanned multiplied by one hundred.

c. Possible causes

Side show cracks due to poor layers of the foundation and bedrock near the edge of pavement (GTC, 1998).

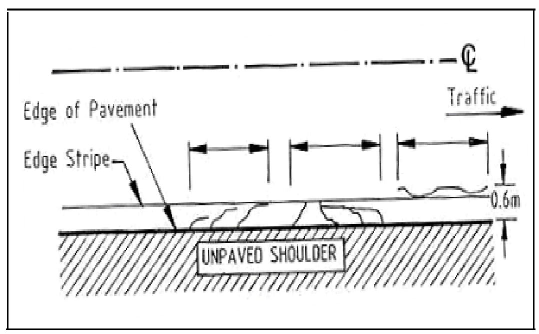


Figure 2.9EdgeCrackingfrom site survey & severity level as per (GTC, 1998)

12. ***Lane/shoulder drop-off***

Lane/shoulder drop-off is a difference in elevation between the pavement edge and the shoulder **(Figure 2.10)**. This distress is caused by either shoulder erosion or settlement, or by building up the road way (i.e., overlay) without correcting the shoulder height.

a. Severity levels

Low level of intensity (L): the difference between the level of the edge of pavement and shoulders between 25-50 mm.

Medium level of intensity (M): the difference between the level of the edge of pavement and shoulders from 51 to 100 mm.

Higher level of intensity (H): the difference between the level of the edge of pavement and shoulders more than 100 mm.

b. How to Measure

Measured drop shoulders Surface longitudinal tracks. Measured by the area affected by the defect length of the affected area multiplied by one meter, and the defect density is calculated by dividing the area affected by the total area of the section scanned multiplied by one hundred.

c. Possible causes

Include the causes for the decline and fall of the shoulders exposé the shoulders, or the implementation of the tracks without carrying carriageway adjusts the shoulders (GTC, 1998).

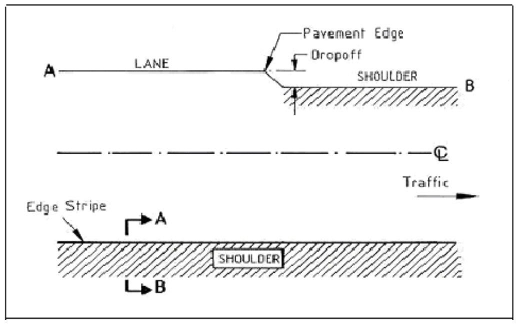


Figure2.10 LaneShoulderDropfrom site survey & severity level as per (GTC, 1998)

13. ***Longitudinal/transverse cracking***

Longitudinal cracks are those which run parallel to the pavement while transverse cracks extend perpendicularly across the pavement (Figure 2.11). This cracking may be caused by poorly constructed paving joints, temperature effects (shrinkage or expansion), hardened or oxidized asphalt, or cracks reflecting up from cracked underlying asphalt layers or stabilized base material.

Longitudinal cracks between adjacent lanes can be indicted by low temperature, since the density at the joint between pavings lanes is lowest, resulting in low tensile strength. Typically the density of the asphalt mix near a longitudinal joint is at least 2 to 3 percent lower than the remaining pavement. Low tensile strength, coupled with the possibility of oxidative hardening of the asphalt due to high voids in the mixture in the joint area, makes the material particularly susceptible to cracking and subsequent raveling. Poor adhesion between the asphalt and the aggregate can aggravate the problem adjacent to longitudinal cracking and cause more rapid deterioration [1].

a. How to Measure

Longitudinal and transverse cracks are measured in linear meter. The length and severity of each crack should be recorded after identification. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. If a bump or sag occurs at a crack it is also recorded as a distortion.

b. Possible causes

i. A poorly constructed paving lane joint.

ii. Shrinkageofthesurfaceduetolowtemperaturesorhardeningoftheasphaltand daily temperatures cycling.

iii. A reflective crack caused by joints and cracks beneath the surface course.

iv. Decreased support or thickness near the edge of the pavement(GTC, 1998).

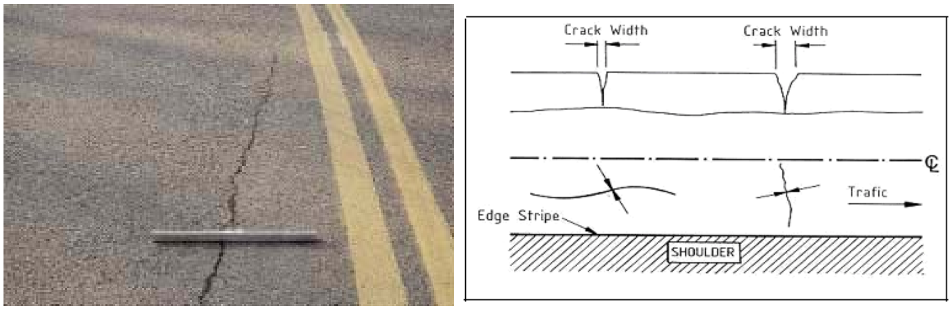


Figure2.11Longitudinal and Transverse Cracks from site survey & severity level as per (GTC, 1998)

14. ***Utility cut patching***

Patching and utility cut patching are areas where the original pavement was removed and replaced with new material **(Figure 2.12).** These areas are considered defects because the patched area or adjacent area usually does not perform well as the original pavement.

a. Severity levels

Low level of intensity (L): is the level that affects the quality of a simple command and where the patching in good condition.

Medium level of intensity (M): is the level that affects the average level of quality leadership and where patching deteriorating moderate deterioration.

Higher level of intensity (H): level is severely affecting the quality of leadership and where patching deteriorates significantly and maintenance needs to be immediate.

b. How to Measure

Patches in the case of large-scale service, the registration of these defects are measured separately and located within the same patch work method of measuring these deficiencies separately. Density is calculated by dividing the area affected by the total area of the section scanned multiplied by one hundred.

c. Possible causes

Possible reasons include a defect patching traffic loads, not controlling the quality of materials or poor implementation of reclamation and re-asphalting (GTC, 1998).

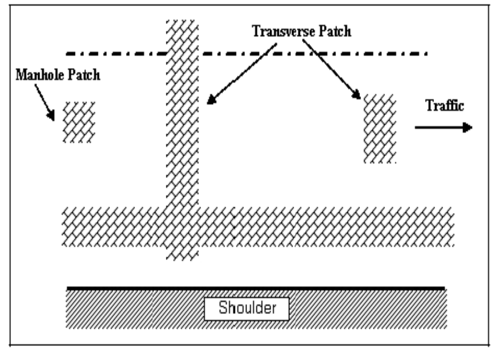


Figure2.12 Utility Patchesfrom site survey & severity level as per (GTC, 1998)

15. ***Polished aggregate***

Polishedaggregateisatermappliedtoasphaltpavementsinwhichthesurface aggregate has been worn smooth. Polished aggregate causes a reduction in skid resistance, especially when wet **(Figure 2.13).** This distress is caused by low quality aggregate and repeated traffic applications.

a. Severity levels

No degrees of severity are defined. However, the degree of polishing should be significant before it is included in the condition survey.

b. How to Measure

Polished aggregate is measured in square meters of surface area. If bleeding is counted, polished aggregate is not counted in the same area.

c. Possible causes

i. Repeated traffic loads. ii. Erosion of gravel.

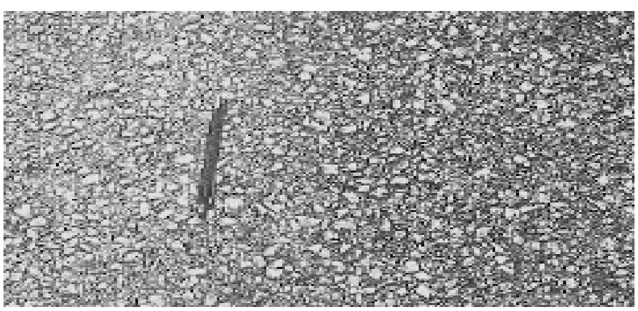


Figure 2.13polished aggregate

16. ***Potholes***

Potholes are usually caused by a localized weakness in the pavement resulting from a combination of such factors as too little asphalt, thin surface thickness, too many fines, too few fines, or poor drainage **(Figure 2.14).**Unless repaired promptly, their growth will be accelerated by traffic and moisture collected in the pothole.

a. **Severity levels**

Table 2.1 severity levels of potholes (GTC, 1998)

Maximum Depth (mm)	Median Diameter (mm)		
	100 -200	201 -450	451 -750
13 -25	Low	Low	Medium
26 – 50	Low	Medium	Higher
More than 50	Medium	Medium	Higher

b. How to Measure:

If a hole more than (750) is scaled mm Surface Area and then divided by (0.5) half ammeter box to find the equivalent number of craters, but if the depth of excavation is less than 25mm are considered moderate, and high intensity in the case of depth of more than 25 mm .

c. Possible causes

i. Break the surface of the pavement as a result of alligator cracks.

ii. Turn the place of the surface layer of paving.

iii. The presence of moisture and do accelerate the movement from the emergence of drilling.

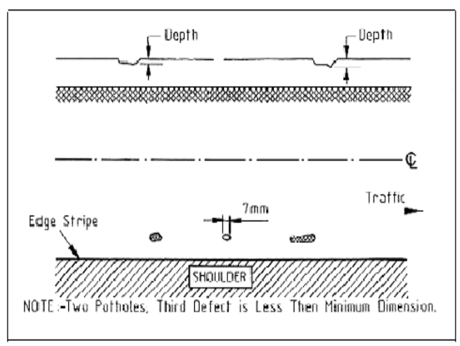


Figure2.14Potholesfrom site survey & severity level as per (GTC, 1998)

17. ***Raveling***

Raveling is a progressive separation of the aggregate from the binder **(Figure2.15)**. Raveling is the failure of bond between the aggregate and the bituminous binder. Raveling may be caused by insufficient compaction during construction, construction during wet or cold weather, dirty or disintegrating aggregate, insufficient binder in mix, or over-heating of the surface mix.

18. ***Rutting***

Rutting is a depression in the wheel path **(Figure2.16).**In extreme cases there may be up lift between the wheel paths in conjunction with the rutting. Rutting may be caused by a permanent deformation in the pavement layer or the sub grade due to traffic loads. Pavements constructed of low stability asphalt mix or unsatisfactory compacted asphalt mix is leading causes for the deformation in the pavement layers.

Figure 2.16 *Rutting*

19. Shoving

Shoving is a localized plastic movement in the bituminous surface **(Figure 2.17).**Areas subjected to frequent vehicular braking action can exhibit shoving. The cause of shoving is usually lack of stability in the bituminous mix. Lack of stability can be caused by the mix being too rich, the aggregate having excessive amounts of fines or rounded or smooth textured particles, poor bond between material layers, or the use of a soft binder. Plastic flow in patching materials can also be caused by excessive moisture in the mix, contamination by oil spillage, or too much volatile material remaining when a cold-laid patch is placed.

Bus stops are often the first locations to exhibit premature distortion in the form of shoving. Shoving can be easily detected at edge lane markings where these lines bend outward in the vicinity of the shoving.

Shoving occurs when the applied forces exceed the shear strength of the asphalt mix or underlying layers. Shoving can also occur when thin asphalt layer are placed over granular bases and sub base. Shoving is primarily due to unstable asphalt layers.

20. *Slippage cracking*

Slippage cracks are usually crescent shaped cracks that normally point in the direction of the thrust of the wheels during braking (Figure2.18).Allow strength surface mix or alack of bond between the surface layer and the course beneath causes this distress. This slippage or delaminating can cause failures on the pavement surface under traffic. The slippage can be caused by poor drainage, which could aggravate a stripping problem, or by construction.

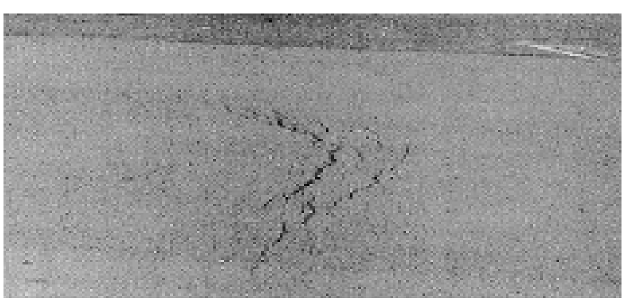


Figure 2.18 Slippage cracks

21. ***Swell***

Swell is the localized upward displacement of a pavement due to the upheaval of the sub-grade or some portion of the pavement structure (Figure2.19). Swell or heave is commonly caused by infiltration of moisture into an expansive-type soil.

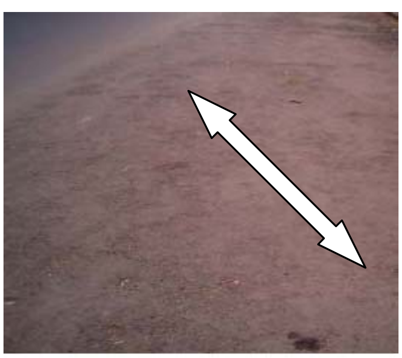
Figure 2.19 Swelling

22. ***Weathering***

Weathering is a process in which the more volatile parts of the asphalt are lost which results in the hardening or aging of the asphalt binder in a pavement (Figure 2.20). Defects such as cracks or holes in the pavement or low pavement density will allow more area of the pavement to be exposed to air and water and increase the weathering process. Raveling is often associated with weathering and is often a direct result of it. Weathering can be a problem in open-graded pavement surfaces due to the increased surface area exposed to weathering conditions.

23. ***Raveling from fuel spills***

Raveling from fuel spills is similar to the raveling described earlier (Figure 2.21). However, in this case the raveling is caused by fuel leaching away the asphalt binder. This distress will accelerate if more fuel is spilled on a surface that had previously started raveling. Fuel spills on pavement surface cause distress due to the void space provided in the pavement surface.



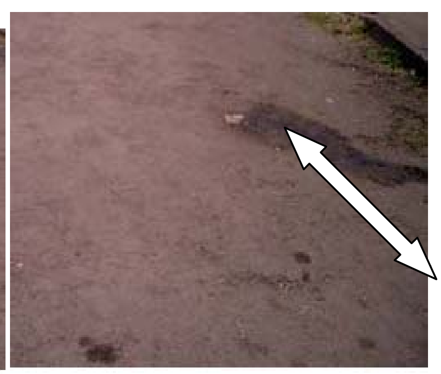


Figure 2.20Weathering *Figure2.21Raveduetofuel spills*

24. ***Low skid resistance***

Low skid resistance can be caused by a variety of factors including excessive asphalt binder and the type of aggregate used in the mixtures. The options available to alleviate this distress are to overlay or recycle the pavement, groove the pavement, or apply a surface treatment. When the pavement is structurally sound, the first alternative is unnecessary and the grooving of asphalt pavements may be the best solution. Surface treatments include seal coats and slurry seals.

2.5 Methods of pavement maintenance and rehabilitations

Pavement maintenance programmers are required to perform the task of preserving, repairing and restoring different damaged elements of a pavement system to its designed or accepted standard.

In general, maintenance of pavements is similar in concept to maintenance of one's home or car. If one doesn't want to repair his leaking roof, it will be further damaged and cause extraction in the house. If one does not want to timely change oil filter, he will certainly pay for the engine in a short time. The same is true to pavement maintenance. The longer one waits to maintain a pavement, the more it will cost to repair.

According to the Foundation for Pavement Preservation, pavement maintenance involves doing the right treatment, at the right place, at the right time. To achieve this, good management and an understanding of the choices are required [David, 2006].

There are different categories of maintenance activities. Some can be performed before significant deterioration occurs .An example is a chip sealed one before cracks develop. Preventive maintenance must be done before even moderate cracking occurs, or it will not last as long as it should. Pavement maintenance can be described by two different categories [Lavin, 2003]:

There is no uniform terminology with regard to definitions concerning pavement maintenances and rehabilitation. It varies from country to country and even from authority to authority as well. Maintenance programs can be categorized into routine, periodic and extraordinary maintenances. Each can be discussed in a little more detail as follows:

Routine Maintenance

A routing maintenance program comprises different activities that are to be carried out as frequently as required in order to ensure serviceability at all time.

Major activities include the following:

a. Clearingroadwaypavement,ditches,drains,signs,andsafetybarriers,etc, as well as grass cutting and tree pruning,

b. Repair of minor damage to pavement, drainage system as well as any urgent repairs to restore disrupted traffic movement

c. Maintenances during rainy season such as provision of turn out ditch form storm water, clearing of mud and debris etc.

Periodic maintenance

A periodic maintenance includes operations to be carried out under a long term program within the design period of the pavement. These operations can be divided in to the following two main groups:

- Renovation of the wearing surface of the existing pavement that become worn or damaged; e.g. resealing or surface dressing of existing asphalt road.
- Restoration of drainage systems, road markings and ancillary items

Extraordinary Maintenance

Extra ordinary maintenance consists of activities necessary to restore highly distressed pavements to their original design requirement. The tasks include:

- Strengthening and or/reconstruction of pavement structure which has severely deteriorated (e.g. overlays)
- Activities to protect roads against external agents (Such as slope stabilization, retaining structures & flood control measures).

Maintenance Priorities

It is also very important to allocate the limited resources available for the maintenance purpose in such a way that it satisfies objectives and maintenance polices of the roads authority. The following basic approaches can be used to determine priorities for pavement maintenance:

i. **Urgent maintenance-** such as emergency repairs to pavements that are cut, removal of debris and other foreign objects.
ii. **Routine drainage maintenance**; ditch cleaning and deepening, cleaning bridges and culverts, backfilling scoured areas, constructing check dams and etc.
iii. **Routine maintenance of pavement-** such as patching, sealing and repairing of road furniture.
iv. **Periodic maintenance-** such as resurfacing

C. Repair Types and Options

After the inspected the road way and examine the types of distress. Two different factors need to be examined: density and the severity levels of distress ***[David,2006]***. Maintenance is an essential practice in providing for the long-term performance and the esthetic appearance of an asphalt pavement. The purpose of pavement maintenance is to correct deficiencies caused by distresses and to protect the pavement from further damage. Various degrees or levels of maintenance can be applied to all pavements, regardless of the end user ***[Lavin,2003].***Table 2.2 Type of Repair Options.

Table 2.2 Type of Repair Options [GTC, 1998]

Type of distress			Density		
			Low	Medium	High
Potholes	Severity leve	L	Surface patching	Surface patching	Surface patching
		M	Surface patching	Surface patching	Surface patching
		H	Deep patching	Deep patching	Deep patching
	Severity leve	L	Do nothing	Do nothing	Do nothing
		M	Repair distress in patch	Repair distress in patch	Replace patch
		H	Deep patching	Deep patching	Deep patching

Type of distress			Density Low	Medium	High
Alligator Cracking	Severity level	L	Do nothing	Slurry seal	overlay
		M	depth patch	overlay	reconstruction
		H	depth patch	overlay	reconstruction
Block cracking	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Crack sealing	Crack sealing	Recycle surface
		H	Slurryseal	Recyclesurface	Thinoverlay
Transverse &Longitudinal cra	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Cracksealing	Cracksealing	Cracksealing
		H	Slurryseal	Slurryseal	Thinoverlay
Edge cracking	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Cracksealing	Cracksealing	Cracksealing
		H	Repair shoulder / Deeppatching	Repair shoulder / Deeppatching	`Repair shoulder / Deeppatching
Reflection cracking	Severity level	L	Do nothing	Cracksealing	Cracksealing
		M	Cracksealing	Cracksealing	Cracksealing
		H	Surfacepatching	Surfacepatching	Surfacepatching
Slippage cracks	Severity level	L	Do nothing	Slurryseal	Slurryseal
		M	Surfacepatching	Surfacepatching	Surfacepatching
		H	Deeppatching	Deeppatching	Deeppatching
Shoving	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Deeppatching	Deeppatching	Deeppatching
		H	Deeppatching	Deeppatching	Reconstruction
Rutting	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Millingandrepave	Millingandrepave	Millingandrepave
		H	Deeppatching	Deeppatching	Reconstruction
Bumpsand Sags	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Surfacepatching	Surfacepatching	Surfacepatching
		H	Deeppatching	Deeppatching	Deeppatching
Corrugation	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Surfacepatching	Surfacepatching	Surfacepatching
		H	Deeppatching	Baserepairandrepave	Baserepairandrepave
Bleedingor Flushing	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Do nothing	Spryhotsandandroll	Millingandrepave
		H	Millingandrepave	Millingandrepave	Millingandrepave
Ravelingand Weathering	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Slurryseal	Slurryseal	Slurryseal
		H	Thinoverlay	Thinoverlay	Thinoverlay
Polished Aggregate			Do nothing	Slurryseal	Slurryseal
Swell	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Deeppatching	Deeppatching	Deeppatching
		H	Deeppatching	Deeppatching	Deeppatching
Depression	Severity level	L	Do nothing	Do nothing	Do nothing
		M	Surfacepatching	Surfacepatching	Surfacepatching
		H	Deeppatching	Baserepairandrepave	Baserepairandrepave
eshoulder drop	Severity level	L	Refillshoulder	Refillshoulder	Refillshoulder
		M	Refillshoulder	Refillshoulder	Refillshoulder
		H	Refillshoulder	Refillshoulder	Refillshoulder

i. Selection of Treatments for Each Condition

Maintenance is an essential practice in providing for the long-term performance and the esthetic appearance of an asphalt pavement. The purpose of pavement maintenance is to correct deficiencies caused by distresses and to protect the pavement from further damage. Various degrees or levels of maintenance can be applied to all pavements, regardless of the end use. A condition rating of the pavement will help determine what pavement maintenance technique is necessary [Lavin, 2003].

Figure 2.22 below shows nine renewal activities which restore the condition of pavement from a downstream condition (worse) to an upstream condition (better) [Akyildiz,2008]. Two type of maintenance that routine and preventive maintenance are the most economical options. Reconstruction techniques are the most expensive, and are usually done when there is no other choice. Although not shown, there are times in the life of a pavement when the best alternative is to do nothing. This is usually when the pavement is not a candidate for maintenance, and rehabilitation or reconstruction is not yet justifiable [David, 2006].

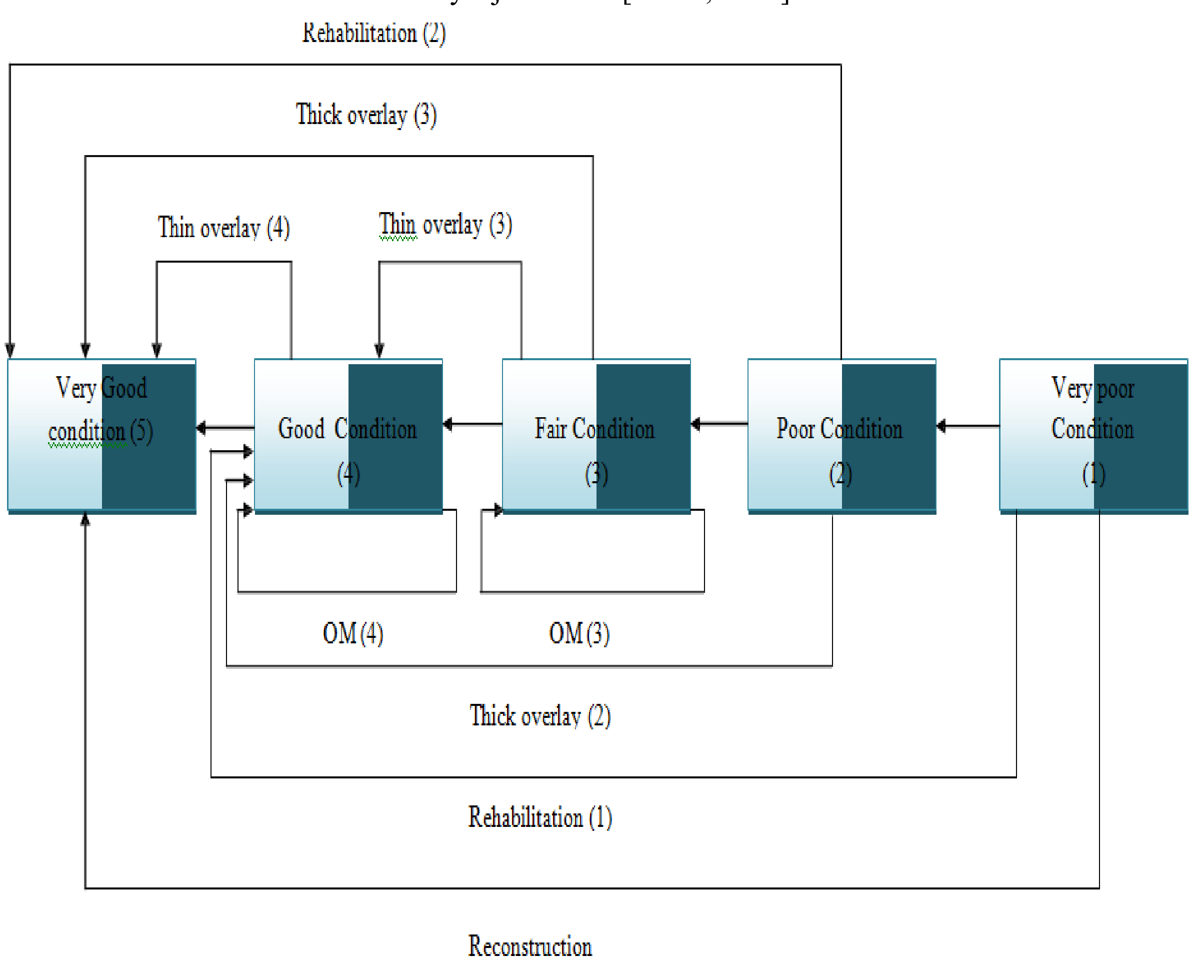


Fig 2.22 Pavement condition & maintenance activities (Akyildiz, 2008)

Definition of Sets

a. Pavement Condition: This set represents the pavement's condition state. There are 5 predefinedpavementconditionstatesavailable.Theseconditionstatesareas follows [Akyildiz, 2008].

1. Very Poor Condition
2. Poor Condition
3. Fair Condition
4. Good Condition
5. Very Good Condition

b. Set of Treatments: A set of treatments represents the treatment types to be used in the model. There are 9 predefined treatment types available. These treatments and their definitions areas follow [Akyildiz, 2008]:

1 **-Reconstruction** applied to pavement in very poor condition: This treatment type restores pavement in very poor condition to excellent condition.

2- **Rehabilitation (1)** applied to pavement in very poor condition: This treatment type restores pavement in very poor condition to good condition.

3- **Rehabilitation (2)** applied to pavement in poor condition: This treatment type restores pavement in poor condition to excellent condition.

4- **Thick Overlay (2)** applied to pavement in poor condition: This treatment type restores pavement in poor condition to good condition.

5- **Thick Overlay (3)** applied to pavement in fair condition: This treatment type restores pavement in fair condition to excellent condition.

6- **Thin Overlay (3)** applied to pavement in fair condition: This treatment type restores pavement in fair condition to good condition.

7- **Thin Overlay (4)** applied to pavement in good condition: This treatment type restores pavement in good condition to excellent condition.

8- **Ordinary Maintenance (OM3)** applied to pavement in fair condition: This treatment type preserves pavement in fair condition.

9- **Ordinary Maintenance (OM4)** applied to pavement in good condition: This treatment type preserves pavement in good condition.

CHPTER THREE
RESEARCH METHODOLOGY AND MATERIALS

3.1 Introduction

This chapter provides an over view of the applied procedures in order to attain the objective of the research. The goal of this study is to recommend proper design, operational, and maintenance considerations to address drainage related impacts **on road asset.** It shows methods followed for the investigation, evaluation and analysis of the pavement condition to identify cause of distress and propose maintenance options.

This section describes procedures followed to establish the nature, severity and extent of pavement distress due to lack of proper drainage structures. It provides guidance on the use of non- destructive pavement tests and describes how the results of these tests can be utilized, both to identify the causes and magnitude of distresses and to assess the strength of the existing pavement.

3.2 Procedure

3.2.1 Selection of test Roads, test blocks and delineation of water shed basin on selected test roads and test blocks

a. Selection of test roads and test blocks

The Pavement evaluation under this research has concentrated on the two road corridors across the town connecting the town's kebele administration. Exact location of representative test sections within the selected roads are identified considering factors affecting potential pavement performance such as the sub-grade soil type, pavement type, pavement cross-section (layer material type& thickness) traffic loading and, pavement condition as major criteria[8].Existing information from AACRA pavement design manual, Sec 11)(5) are also utilized for selecting test sections. Name of test roads and their corresponding number of test section is as shown in Table 3.1 below.

The following major criteria were considered when making the study on the two road corridors: -

- ❖ These roads can fairly represent arterial roads in the town.
- ❖ These roads are the most utilized sections and convey higher traffic and hence are prone to damage than others.
- ❖ These roads traverse through different geographic location of the town and comprise different sub grade soil types.

Table 3.1 Test Roads & Test Sections

Test Road No.	Test Road Name	Number of Test Sections	Total Length (km)
1	Main Ambo road (fromSansusi to Burayu Town Adminstration Office)	13	4.0
2	Main Ambo Road (fromDire to Kella)	12	3.6
3	Nono Road (fromMelka Gefersa kebele to Gefersa Nono kebele)	8	2.4
Total		33	10

The start and end chain age of the test sections are selected following a preliminary site visit. Each test section is selected in such a way that it will have certain consistent characteristics throughout its area or length as follows:

- Similar drainage structures
- Similar Soil physical property
- Similar in maintenance characteristics

b. Delineation of water shed basin

Along the test road, there are about 33 catchments. Of these, one accommodates major stream crossings, whilst the rest are medium, small streams and local flows. These catchments, showing the limits of the watersheds (or basins) were delineate from the available Nortek maps and contours. The delineated catchments are given in the figure below

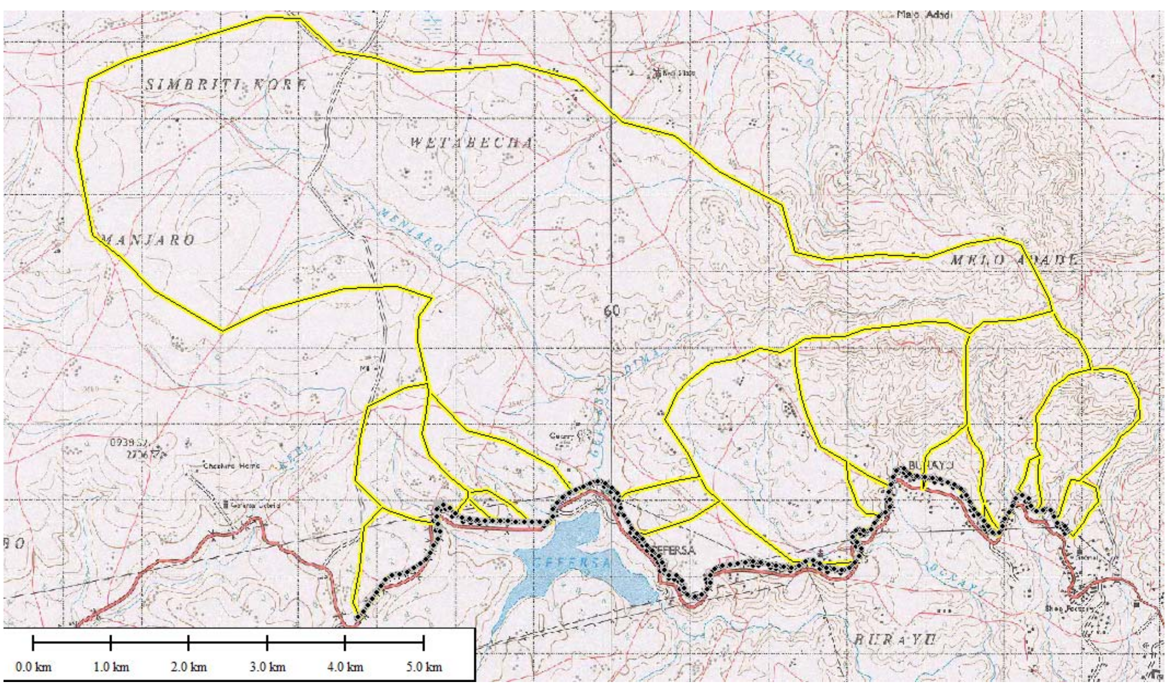


Figure **3-**1: Delineated Catchment of the surveyed road

3.3 Visual Condition Survey

The visual Condition survey is made in order to measure various types and degrees or severity of distress related. The measured components are surface defects (such as longitudinal joint cracks, potholes, raveling, bleeding and lacy edge), permanent deformation or distortion, fatigue cracking and patch deterioration.

These evaluations are also necessary for defining, and subdividing sections of road in similar condition when the uniform sections are relatively short, the detailed condition survey can be best carried out over the entire length of the section. For time and resource limitation a maximum of 2.4–4km length of road is used for visual survey from each road corridor. These selected test roads are further subdivided in to blocks of 50-100 meter length.

The condition survey procedure offers a method for identifying pavement distress types, defining the levels of severity associated with each distress. The visual survey is made using commonly used recording formats and guide lines for determining pavement condition that involves observing and recording the presence of specific types and severities of defects or distresses on the pavement surface.

For all section survey, the surveyor walks over each sample unit, measures each distress type and severity, and records the data on the Asphalt Pavement Inspection Sheet. The letter **L**(low), **M**(medium), or **H**(high) is included along with the distress number code to indicate the severity level of the distress.

3.3.1 Methods of recording data for each distress during visual condition survey

The type of data collection is primary data from the field; a total length of 100- 150m is taken as one block survey. The area of pavement affected by each distress is recorded in special tables and a picture of each severity level is taken and categorized by the magnitude of measurement of distress.

The equipments used during this data collection were:

1. Data Sheets: for recording the following information: Date, location, branch, section, sample unit size, distress types, severity levels, quantities, and names of surveyors. As show in **Figure 3.2**.
2. Digital Camera: for taking some photos.
3. Hand Odometer Wheel.
4. Layout Plan, for network to be inspected.
5. Safety equipment.

Figure3.2 Flexible Pavement Condition Survey Data Sheet for Sample Unit

Asphalt surfaced roads Condition survey data sheet for sample unit Street: ------------Block No. ----------- Surveyed by: -------Date: ---------------	Sketch

1.Alligator/Fatigue cracking	6 .Depression	11.Patching &Utility patch	16 Shoving
2. Bleeding	7. Edge cracking	12 .Polished Aggregate	17 Slippage
3 .Block cracking	8 .Reflection cracking	13. Potholes	18 Swell
4 .Bumps and sags	9. Lane shoulder drop	14 Rutting	19 .Raveling &Weathering
5 .Corrugation	10 .Longitudinal &Transverse	15 Railroad crossing	

Distres s	Quantity										Total	Density	Deduct Value

3.3.2 Calculation of pavement condition index (PCI) to estimate the magnitude of damage.

By definition, PCI is a subjective evaluation of pavement condition by experienced pavement engineers, based on a user-defined scale. It summarizes the pavement conditions in terms of individual distress; sot that pavement performance may be evaluated, predicted, and improved using effective treatment [11].

Because PCI method is a good indicator of pavement valuation to:

- Monitor pavement performance
- Develop maintenance programs
- Assist in preparation of multi-year rehabilitation plans

The PCI value can tell us about:

- Functional pavement condition.
- Indication of Structural Condition.
- Rate of Deterioration.
- Specific Distress Information.

The Pavement Condition Index (PCI) is determined by measuring pavement distress with a numerical indicator based on a scale of 0 to100.

The following pavement condition ranking is given to PCI values:

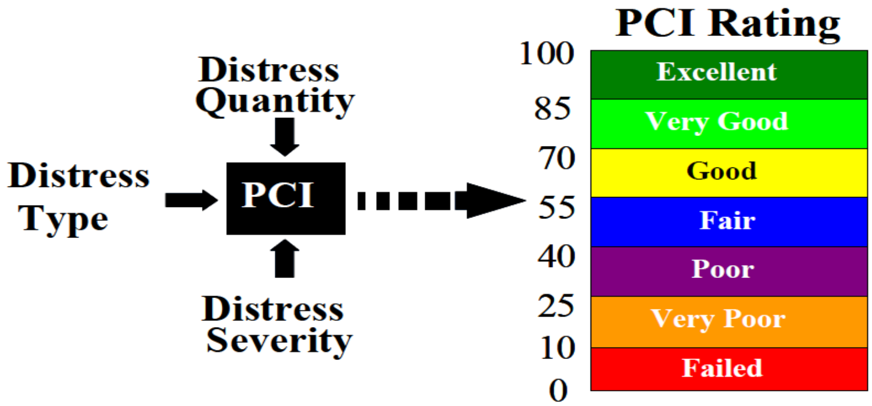


Figure 3.1 PCI Procedures (Hein and Burak, 2007)

During the condition survey, the surveyor walks over the road section, measure each data on the inspection sheet (Refer samples of filled forms in APPENDIX- A). Thee equipment used for this survey is hand odometer to measure distress lengths and areas, a 2mt straightedge, and ruler to measure the depth of or depressions. One form is used for each sample unit (i.e. test section).

Calculation of the PCI is done using the PAVER (which is a data management system for **P**avement **E**valuation and **R**ehabilitation) method which involves the following five steps [12]:

Step 1: Inspect each sample unit and record distress

Each sample unit is inspected and distress data (type and severity levels) recorded on data sheet form as shown in Figure3.1.

Step 2: Determine deduct values for each distress type and severity

Add up total quantity of each distress type at each severity level and record them in the "Total Severity" section. Divide the total quantity of each distress type at each severity level by the total area of the sample unit and multiply by100 to obtain the percent density. Determine the deduct value (DV) for each distress type and severity level combination from the distress deduct value in Appendix (B).

Step 3: Compute total deducted value by summing all individual distress

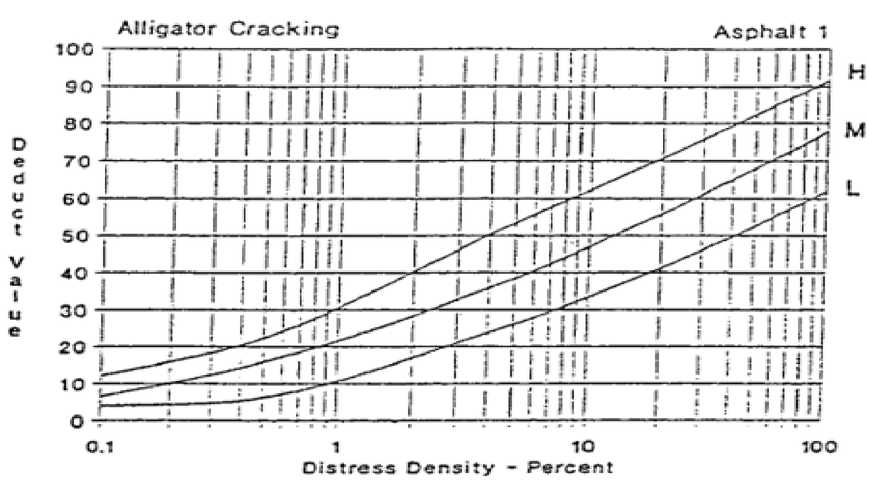


Figure3.2Deductvaluesfor Alligator cracking (ASTM standard D6433)

Step 4: Compute the corrected Deduct values using correction curves. The following procedure must be used to determine the maximum CDV:

a. If none or only one individual deduct value is greater than two, the total value is used in place of the maximum CDV in determining the PCI; otherwise, maximum CDV must be determined using the procedure described in ASTM standard D 6433.

b. List the individual deduct values in descending order.

C. Determine the allowable number of deducts, **m**, from **Figure 3.6**. or using the following formula in ASTM standard D 6433:

$$\mathbf{m} = 1 + (9/98)(100 - \mathbf{HDV}) \leq 10$$

Where: **m**= allowable number of deducts including fractions (must be less than or equal to ten).

HDV=highest individual deduct value.

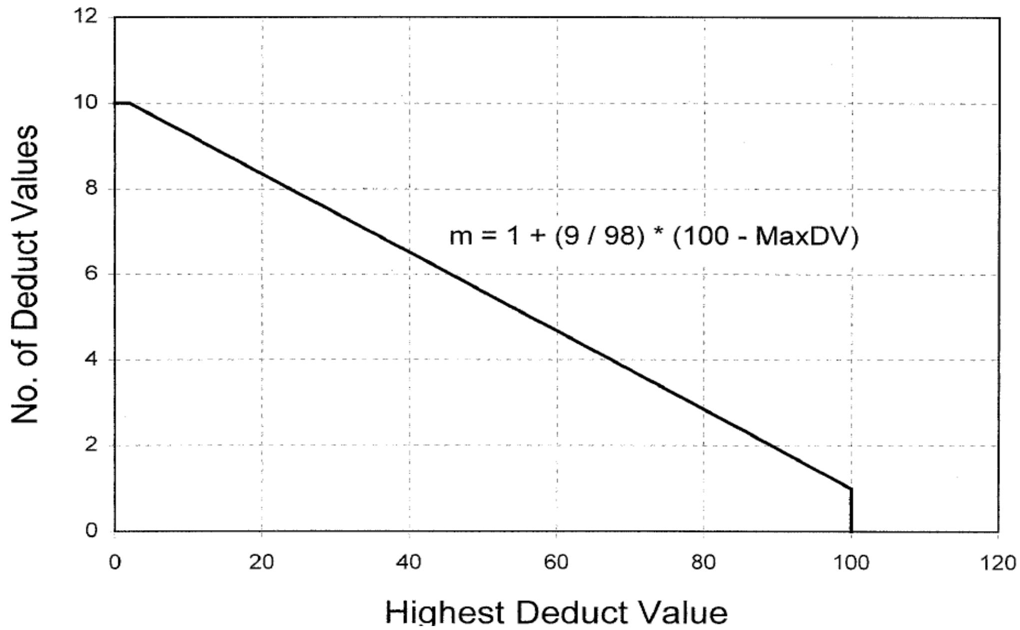


Figure 3.3 Adjustment of Number of Deduct Values (**ASTM standard D 6433**)

d. The number of individual deduct values is reduced to the (m) largest deduct values, including the fractional part if less than (m) deduct values are available, all of the deduct values are used.

e. Determine maximum CDV iteratively.

f. Determine total deduct value by summing individual deduct values.

g. Determine q as the number of deducts with a value greater than 2.0.

h. Determine the CDV from total deduct value and q by looking up the appropriate correction curve for AC pavements in **figure 3.4**

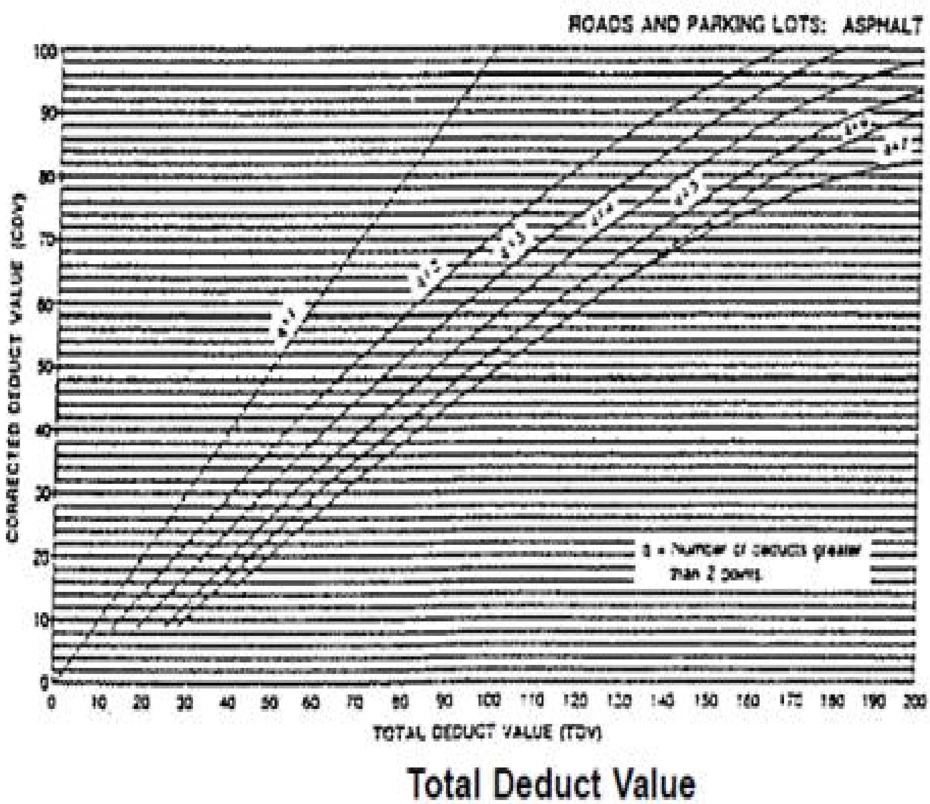


Figure 3.4 Corrected deduct values (**ASTM standard D 6433**)

i. Reduce the smallest individual deduct value greater than 2.0 to 2.0

m=1+ (9/98) (100-Max DV) ≤ 10

m=1+ (9/98) (100-25.1) =7.9

0.9*5.3=4.8 table 3.2 below

Table 3.2 Calculation of CDV value Flexible Pavement (ASTM standard D6433)

No	**Deduct value**									**Total**	**q**	**Max CDV**
1	25.1	23.4	17.9	11.2	7.9	7.5	6.9	4.8		104.7	8	51.0
2	25.1	23.4	17.9	11.2	7.9	7.5	6.9	2		101.9	7	50.0
3	25.1	23.4	17.9	11.2	7.9	7.5	2	2		97.0	6	46.0
4	25.1	23.4	17.9	11.2	7.9	2	2	2		91.5	5	47.0
5	25.1	23.4	17.9	11.2	2	2	2	2		85.6	4	48.0
6	25.1	23.4	17.9	2	2	2	2	2		76.4	3	48.0
7	25.1	23.4	2	2	2	2	2	2		60.5	2	44.0
8	25.1	2	2	2	2	2	2	2		39.1	1	38.0

Max CDV = 51
PCI=100-Max CDV = 49
Rating = Fair

j. Maximum CDV is the largest of the CDVs.

Step 5: Compute the PCI by subtracting all corrected deduct values from100;

i.e. PCI = 100 max CDV. If all sample units in a section are surveyed, the PCI of the section is computed by averaging the PCIs of all its sample units.

3.3.3 Definition of Pavement Condition

a. Excellent

Pavement is new construction. Nothing would improve the road way at this time.

b. Very Good

Pavement structure is stable, with no cracking, no patching, and no deformation evident. Roadways in this category are usually fairly new. Riding qualities are excellent. Nothing would improve the roadway at this time.

c. Good

Pavement structure is stable, little cracking and no deformation evident. Little maintenance would improve the road way at this time.

d. Fair

Pavement structure is generally stable with minor areas of structural weakness evident. Cracking is easier to detect. The pavement may be patched but not excessively. Although riding qualities are good, deformation is more pronounced and easily noticed.

e. Poor

Areas of instability, marked evidence of structural deficiency, large crack patterns (alligator) heavy and numerous patches, deformation very noticeable. Riding qualities range from acceptable to poor.

f. Very Poor

Pavement is in extremely deteriorated condition. Numerous areas of instability. Majority of section is showing structural deficiency. Riding quality is unacceptable (probably should slow down).

g. Failed

Pavement structure is failed, with cracking and deformation evident. Road ways in this category are usually failed. Reconstruction at this time (Bashir, 2006).

3.3.4 Methods of collecting data on Drainage structures during visual condition survey

Descriptive and exploratory types of research are used for this section. The descriptive type of research is used to describe the existing performance condition whereas exploratory type of research is used to explore the existing performance condition of drainage structures.

Topography field visiting of the selected road section is carried out to determine existing performance condition of drainage structures. Observing flood marks, measuring the size of the existing drainage structures, measuring the elevation difference between river/stream bed and flood mark as well as gathering information is carried out about the overall performance of drainage structures during the rainy season.

Generally, the procedure followed for visual inspection of the drainage structures is:

- ✓ For the sections of the test road, as the area is developing; hence, the section of the road is treated with the principle of urban hydrology.
- ✓ Field surveys were carried out to gather hydrological and hydraulic data related to the road's drainage system. The following important data and information was gathered during these visits.
  - Existing drainage systems
  - Land cover and land use of the catchments;
  - Soil types of the catchments;
  - Topography of the catchments and stream lines;
  - Stream / river channel characteristics;
  - Intercepted ground water
  - Delineation of water shed basin

Drainage condition surveys were also made as part of the visual condition surveys. A five point assessment scale is used as follows:

A. **Very good:** where the shape and level of drains is as designed.

B. **Good:** where drainage functions can be easily fulfilled.

C. **Average:** where drainage condition is slightly impeded.

D. **Poor:** where drainage function is impeded due to sedimentation, vegetation or scour.

E. **Very poor:** drainage non-existent.

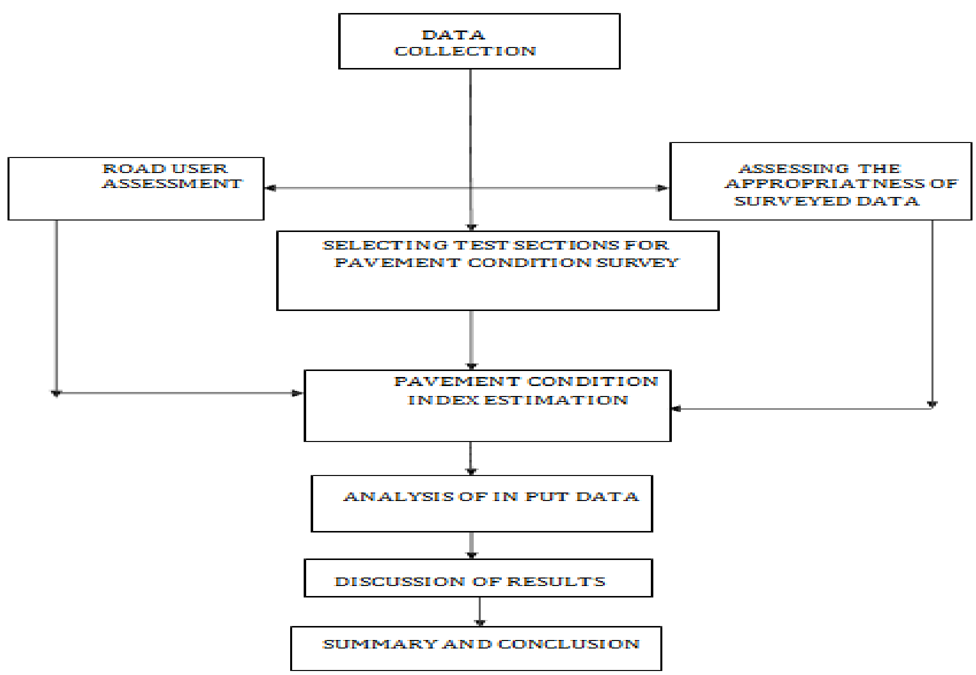


Figure 3.5: Flow chart showing the major activities carried out during the research work

3.4 Data Analysis

3.4.1 Analysis of pavement distress

The analysis consists of classification and quantification of distresses so as to identify causes of distress and propose possible maintenance options. The following steps are followed:

I. Classification of distresses

Classify the type of distresses into possible causes such as load associated, climate/durability associated and moisture/drainage associated distresses based on the results of the visual condition survey [3,6]

II. Identify Probable Cause of Pavement distress

The last stage in the data analysis is to establish causes of pavement distress by interpreting the data collected during the visual condition survey and other field investigations [5,6]

(a) Analysis of Visual Distress Survey

- Quantify the existing distresses with relation to their severity for each test section.
- Classify the quantified distresses in to their probable causes such as Load associated, material durability associated and drainage associated distresses.
- Quantify the most dominate distresses in the whole test roads.

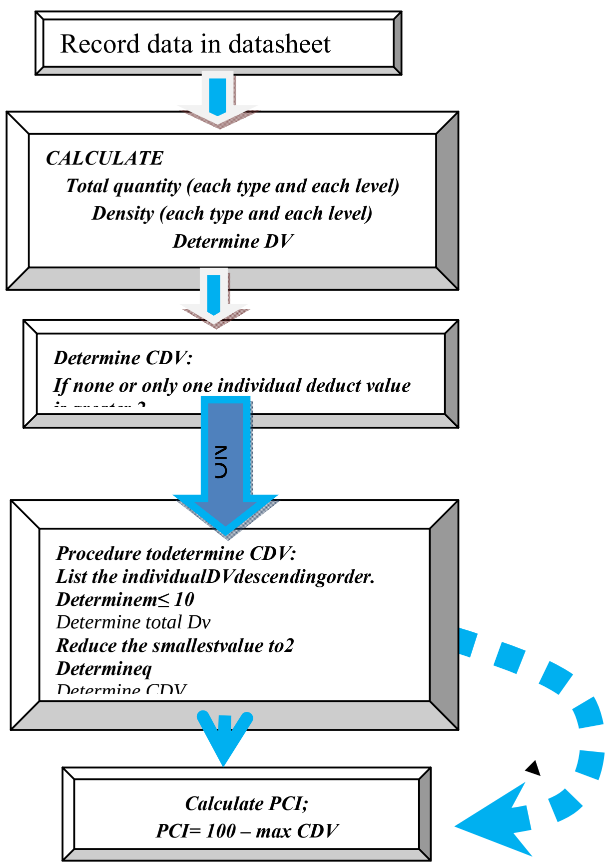


Figure3.6 Analysis steps of PCI

3.3.2. Data Analysis of drainage structures

In order to apply the available rainfall data for the computation of discharges, the readily available and collected rainfall data were analyzed and processed as follows.

1. **Probabilistic extrapolation of maximum annual rainfall**

The analysis and processing will be aimed at determination of appropriate intensity duration relationship applicable for the test road. Using the short period data to be obtained for the research will be used to establish intensity-duration curve. From rainfall data with duration of 0.17, 0.33, 0.50, and 24 hours collected from the NMSA by developing the trend line of the intensity-duration curve, the trend equation applicable for research is developed.

The rainfall depth computation for the return periods of 100, 50, 25, 10, 5 years of the respective rain gauge stations is carried out using the following relationship:

$$h_T = X_{avg} + K_T * \sigma$$

Where h_T = Rainfall depth at return period T years
X_{avg} = Mean value of rainfall data (hourly or daily)
σ = Standard deviation
K_T = Gumbel's distribution frequency factor

And $$\overline{X} = \frac{1}{n}\sum_{i=1}^{i=n} X_i$$

$$\sigma = \left[\frac{1}{n-1}\sum\left(X_i - \overline{X}\right)^2\right]^{\frac{1}{2}}$$

Where X_i =hydrological data rainfall depths

n = total number of individual data

2. **Rainfall-duration relationship**

For rainfall intensity duration curve computation, rainfall data of Bole and observatory metrological stations are used, whichever is closer to the study area.

Using Gumbel probabilistic methods of analysis the value rainfall depth (h)and intensity(I)for different return periods, which are rainfall in mm and rainfall intensity (mm/hr), are given for different duration as shown in tables 3-3 and 3-4.

Table 3.3: Rainfall depth for different duration and different return period

Duration	Rainfall depth, h [mm]				
	Return period				
	5 ear	10 year	25 year	50 year	100 year
10.0 minute	14.9	17.0	19.6	21.6	23.5
20.0 minute	22.0	23.8	26.1	27.8	29.4
30.0 minute	27.6	30.2	33.4	35.9	38.3
60.0 minute	35.3	40.1	46.1	50.5	54.9

Table 3-4: Rainfall intensity for different duration and different return period

Duration	Rainfall depth, h [mm]				
	Return period				
	5 year	10 year	25 year	50 year	100 year
10.0 minute	89.7	102.1	117.7	129.3	140.9
20.0 minute	66.0	71.4	78.2	83.3	88.3
30.0 minute	55.1	60.3	66.9	71.8	76.6
60.0 minute	35.3	40.1	46.1	50.5	54.9

Taking into account the values for the study area, the following relationships between rainfall h (in mm) and duration T (in minutes) were determined for different return periods:

$h_{50} = 6.891*T^{0.4827} h_{25} = 6.3581*T^{0.4829}$

$h_{10} = 5.6354*T^{0.4834} h_{5} = 5.0591*T^{0.4839}$

The following relationships between rainfall intensity I (in mm/hour) and duration T (in minutes) correspond to those above indicated:

$I_{100} = 445.15*T^{-0.5175}$ $I_{50} = 413.11*T^{-0.5170}$

$I_{25} = 380.71*T^{-0.5164}$ $I_{10} = 338.05*T^{-0.5165}$ $I_{5} = 304.24*T^{-0.5168}$

3.3.2.1 Hydrological Analysis Methodology

A. Return Periods for Peak Design Floods

Different Drainage Design Manuals were compared in selecting return periods of different types of drainage structures. Out of those drainage structures compared it was found out that ERA's Drainage Design Manual gives more reasonable return period as shown in table 3.5.

Table 3-5: Return period used for design of pick flood (ERA'S Drainage Design Manual, 2013)

Type of drainage structure	Return period to be used
Gutters and Inlets	10/5
Culverts (span <2m)	25
Culverts (2m<span <6m)	50
Short span Bridge (6m<span<15m	50
Medium span Bridge (15m<span<50m)	100
Long span Bridges (span>50m)	100

B. Methods of Maximum Flood Computations

In the flood computation when the catchments area is less than 0.5km2 as per ERA Drainage Design Manual, 2013, the **Rational Formula** will be used and if the catchments areas are greater than 0.5 km2 **SCS method** will be used.

i. Rational Formula

This relationship is believed to provide adequate results for catchments less than 50hac.as per ERA Drainage Design Manual, 2013. The main assumption in this formula is that the maximum rate of flow results from a uniform rainfall intensity over the entire drainage area where the rainfall has duration equal to the time of concentration. The principal requirement for determining the time of concentration is to select the average rainfall intensity for a selected frequency of recurrence.

$$Q_T = 0.00278\ CIA$$

Where: Q_T = Peak discharge (m^3/sec) for return period T years

C = Runoff coefficient

A = catchment's area (ha)

I = Average rainfall intensity for a duration equal to the time of concentration, for a selected return period, mm/hr

The rational equation given above is applicable for return periods 5 to 10 years. For less frequent flood computation the rational equation should be multiplied by 1.1, 1.2, and 1.25 for return periods 25, 50 and 100 years recurrence interval respectively.

Time of Concentration:

Time of concentration is the time required for water to flow from hydraulically remote point of catchments area to the point under investigation. The most intense rainfall that contributes at drainage structures crossing will be that the duration equal to the time of concentration.

The time of concentration is the sum of sheet flow travel time, shallow concentrated flow travel time and open channel flow travel time. Sheet flow occurs in the upper reaches of the watershed. Such flow occurs over short distance and at shallow depths prior to the point where topographic and surface characteristics cause the flow to concentrate in rills and swales. Concentrated flow is the runoff that occurs in rills and swales with depth on the order of 0.04m to 0.10m where as depth of sheet flow is 0.02 and 0.03m or less. Velocity in the open channels is usually determined assuming bank-full depth.

Sheet flow travel time is computed using Manning's kinematic equation

$$T_t = \frac{0.091 \times [nL]^{0.4}}{[P_2]^{0.5} \times s^{0.4}}$$

Where

T_t = travel time, hr

n =Manning's roughness coefficient (given the table below)

L = flow length, m

P_2 =2-years, 24 hours rainfall, mm

S =Land slope, m/m

Table 3.6: Roughness Coefficients (Manning's n) for Sheet Flow

Surface Description	$\mathbf{n_1}$
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover < 20%	0.06
Residue cover > 20%	0.17
Grasses:	
Short grass	0.15
Dense Grasses	0.24
Range (natural)	0.13
Woods:2	
Light underbrush	0.4
Dense underbrush	0.8

The n values are a composite of information compiled by Engman (1986).
2 When selecting n, consider cover to a height of about 0.03 m. This is the only part of the plant cover that will obstruct sheet flow.
Source: ERA Design Drainage Manual

Travel time for shallow concentrated flow is determined from average velocity computed in from the following expression

$$V = 4.9178\,(s)^{0.5} \quad \text{For unpaved channel}$$

$$V = 6.1961(s)^{0.5} \quad \text{For paved channel}$$

The above equations is based on the solution Manning's equation with the following assumption

n =0.050 and r =0.12 for unpaved area and

n =0,025 and r =0.06 for paved area

Then the travel time of sheet flow is computed using

$$T_t = \frac{L}{V}$$

Where; T_t =travel time of the sheet flow, second

L = flow length, meter

V = average velocity in m/s computed by the above equation

When cross sectional information of the open channel (stream cross section parameter for the entire reach) is acquired, the average velocity of the open channel flow can be calculated using Manning's equation.

$$V = \frac{1}{n} r^{2/3} s^{1/2}$$ Where;

V = Average velocity, m/s

r =Hydraulic radius, m (equal to A/P_w)

A =Cross section area of the flow, m^2

P_w =Wetted perimeter, m

S =Slope of the hydraulic grade line, m/m

n =Manning's roughness coefficient

The travel time can be computed for each stream segment from average velocity of flow computed using the above expression and reach length.

As it is known, the cross section of the stream varies along reach for large catchment area. Acquiring the cross sectional information of the stream along entire length is difficult (it varies). But Kirpich's equation for time of concentration computation in the open channel depends only on the stream length and stream slope. These parameters can be easily determined on the topographic map. Hence, Kirpich's equation was used for time of computation in open channel with caution for large catchment (long stream length) in order not to under estimate the time of concentration. Depending on the slope of the river, the time of concentration is computed on reach bases

$$T_c = \sum_{i=1}^{i=n} \frac{0.00032 \ L_i^{0.77}}{S_i^{0.385}}$$

Where:

T_c =Time of concentration, in hr

L_i =Length of stream segment, in m

S_i = Slope equal to H/L, where H is the difference in elevation between in the segment (reach), in m

For small catchments areas, where the maximum elevation difference of the watershed could not be determined on the available map scale. The velocity method is adopted. It is based on the concept of travel time (Tv) for a flow segment is a function of length of flow (L) and the velocity. The following equations were used:

$T_C = \frac{L}{60 * V}$ Where: T_C = Time of concentration [minutes]

L[m] = Distance from remote point to the point of crossing

V = Average velocity [m/sec] (Table 3-7)

Table 3-7: Average velocity for ground type and terrain condition

Ground Type / Cover	Average Velocity in meter per second				
	Terrain Condition				
	Very flat	Flat	Rolling	Hilly	Mountainous
Wood land	0.15	0.30	0.50	0.55	0.95
Bare soil	0.60	1.00	1.30	1.60	2.00
Cultivated	0.30	0.61	0.92	1.20	1.45
Rocky area	1.00	1.30	1.60	2.00	2.40
Grass land	0.20	0.40	0.75	0.95	1.20
Bushes & shrubs	0.18	0.35	0.67	0.75	1.10

Source ERA/TCDE design manual

ii. Soil Conservation Service (SCS) Unit Hydrograph Method

The US Soil Conservation Service developed this method, which is applicable for urban environment. The inputs for peak discharge estimation includes variables reflect the size of the contributing areas, the amount of rainfall, the potential watershed storage, and the time-area distribution of the watershed.

The SCS runoff equation is a method of estimating direct runoff from 24-hour or 1-day storm rainfall. The equation is:

$$P_C = \frac{(P - 0.2\,S)^2}{P + 0.8\,S}$$ Where Pc= direct runoff (mm), P= design rainfall (mm) and

S = potential infiltration or potential maximum soil water retention

The potential maximum soil water retention, S, is related to hydrologic soil properties, land cover and management conditions as well as, the soil moisture status of the catchment's prior to rainfall event and expressed by a dimensionless response index termed the catchment's curve number (CN). The CN and S are related as follows:

$$S = \frac{25400}{CN} - 254$$

The CN number is selected according to the soil, moisture and the land cover of the watershed area.

The SCS Unit Hydrograph method peak rate of flow is computed using the following equation:

$$Q = \frac{0.2083\ A\ P_C}{0.5\ T_C^{0.5} + 0.6\ T_C} = \frac{0.2083\ A\ P_C}{t_p}$$

Where t_p = time to peak (hrs) $=0.5\ T_C^{0.5} + 0.6\ T_C$

Q_p = peak discharge (m^3/sec)

A = catchment's area (km^2)

P_C = storm flow depth or direct runoff (mm)

T_C = concentration time (hrs)

The discharge computation of crossing structures is given in **appendix D&E** for both Rational & SCS the methods respectively.

3.5 Limitations in the Data Collection

The whole Pavement Evaluation Data is collected in three months time, i.e. from OctobertoFebruary2016.Asaresultallcollectedpavementperformancedata could only give accurate information of that time. On the other hand, some portion of the analysis such as determining predominant distresses in the network, developing functional Relationship between different pavement distresses, pavement response variables and material properties require long historical data and other details as noted below:

- Total service time of each Test Road
- Historicaldataofmeasureddistressescategorizedatdifferentseasonsof the year.
- Design details of each pavement structure and the sub grade material.
- Detail information regarding maintenance history of each test section.
- Seasonal data about moisture fluctuation on each test road.

Generally, collection of the above relevant data would only be much easier on experimental test sections that are carefully made in such a way to reasonably model the road network under study. In view of such remarks, one can understand that the analysis and findings of this research could only be considered as an initial assessment that may serve as a springboard to further carry out detailed assessment within the Burayu road network.

CHAPTER FOUR

EVALUATION AND ANALYSIS OF PAVEMENT DISTRESS AND DRAINAGE STRUCTURES

4.1 General

The evaluation of pavement distress on the three test roads includes consideration of specific problems that exist in the pavement. This requires the determination of he types and causes of distress, as well as the extent of pavement deterioration. This inspection is conducted on test blocks which area small segment of road section selected in manageable size to inspect in detail. The distress found in the test block is used for calculating the PCI value. The PCI values of the inspected test block in the section are then used to represent the condition of the entire section of the block.

When a small area of pavement is found to be much worse than the majority of the pavement, it can be inspected and identified as a “special" test block. This was used to identify areas of localized deterioration caused by utility cuts or other localized problems. A weighted average value was used to calculate the PCI of test roads.

The data were collected by walking though each test blocks as set in chapter three and recording the type, severity and amount of each distress present in the test block. The type, severity and amount of distress measured was tabulated in **Appendix A,B and C**.

The quantities and severities should normally be estimated and calculated as accurate as the measurement unit for each type of distress as given in (ASTM, 1999).

4.2 Condition Survey of pavement distress

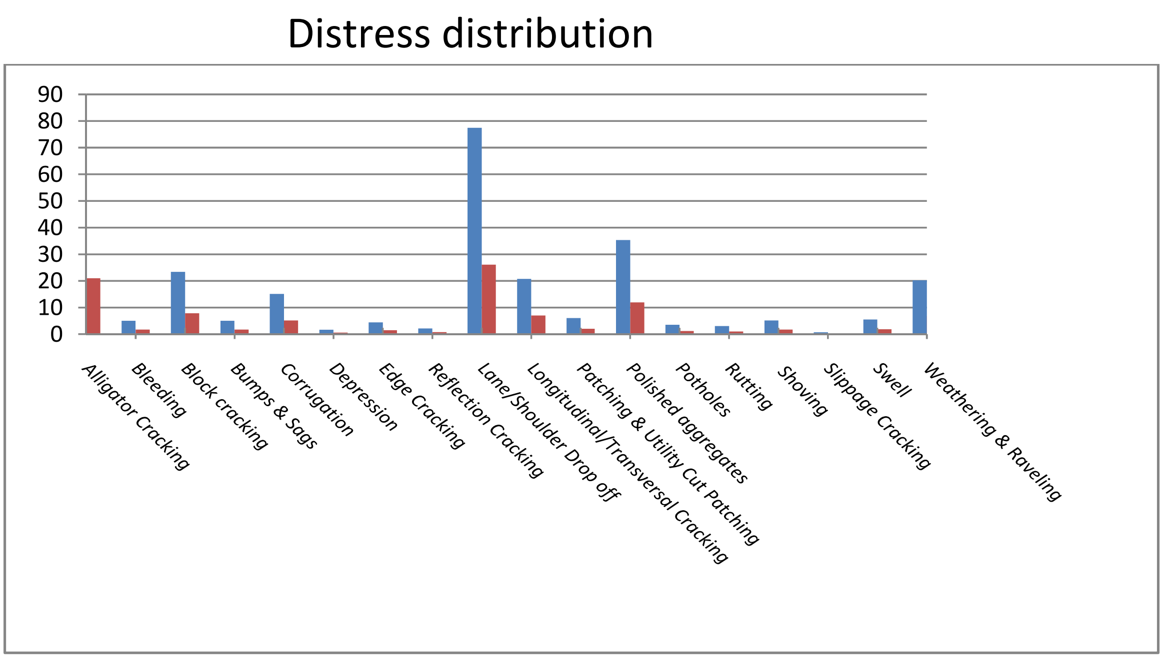
4.2.1 Distribution of Pavement Distress

The detail distribution of surveyed pavement distress type, measured quantity and extent of severity for the three test roads in each test block are given in **Appendix A,B and C**. The summery of distress density and percentage of distress indicator is given in table 4.1 below.

The main reason for some distresses of reflection cracking, depression type to be ranked low is due to the fact that the Ethiopian Roads Authority usually patches cracked asphalt pavements immediately after the rainy seasons.

Table 4.1 Distribution of Pavement Distress in the three test Roads

Distress No.	Distress Type	Total Distress Density(m^2)	%age Distress Indicator
1	Alligator Cracking	62.45	21.03
2	Bleeding	5.03	1.69
3	Block cracking	23.36	7.87
4	Bumps & Sags	5.03	1.69
5	Corrugation	15.16	5.11
6	Depression	1.66	0.56
7	Edge Cracking	4.41	1.49
8	Reflection Cracking	2.16	0.73
9	Lane/Shoulder Drop off	77.48	26.09
10	Longitudinal/Transversal Cracking	20.79	7.00
11	Patching & Utility Cut Patching	6.03	2.03
12	Polished aggregates	35.33	11.90
13	Potholes	3.51	1.18
14	Rutting	3.04	1.02
15	Shoving	5.12	1.72
16	Slippage Cracking	0.69	0.23
17	Swell	5.46	1.84
18	Weathering & Raveling	20.24	6.82
Total		296.94	100.00



4.2.2 Identifying Dominant Distresses

It is also tried to estimate the distribution of particular distresses in each test block and the whole test roads as well using the measured data during survey. Distribution of majordistressesinalltestroadsisasshowninTable4.1andFigure4.1.Details about intensity of individual distress densities on each test section can be referred in Appendix A to C.

Accordingly it is observed that around nine types of distresses contribute around 90% of the pavement defects in the three test road.

They are:-

1. Lane/Shoulder drop off -------------------------------------- 26.09 %
2. Alligator Cracking -- 20. 10 %
3. Polished Aggregate --- 11.90 %
4. Block cracking --- 7.87 %
5. Longitudinal/Transversal Cracking --------------------------- 7.00%
6. Weathering & Raveling ---6.82 %
7. Corrugation ---5.11 %
8. Patching & Utility Cut Patching --------------------------------2.03 %
9. Swell --2.84%

Total : <u>89.75%</u>

4.2.3 Classification of Distresses by possible Causes

The major causes for the above mentioned distresses can be grouped in to three categories. The first is due to over loading that includes excessive gross loads, high repletion of loads and high tire pressure. Second climatic or environmental conditions may cause surface irregularities and structural weaknesses on the pavement.

A third causes may be drainage of the paved materials it may be caused by method of construction and quality of construction material. Use of contaminated aggregate and inadequate construction supervisor are also factors that may aggravate pavement distress.

Distresses identified during condition surveys can be grouped into three major categories of possible causes as follows:

Load Associated Distress:

1. Alligator cracking
2. Patching load cause distress
3. Slippage cracking
4. Shoving
5. Block cracking
6. Polished aggregate
7. Depression
8. Bumps and Sags

Climate /Durability Associated Distress

1. Bleeding
2. Joint reflection cracking
3. Line cracking (longitudinal/ transversal/
4. Weathering and raveling
5. Depression

Drainage/ moisture Associated Distress

1. Corrugation
2. Lane/ Shoulder drop off
3. Pothole
4. Swell
5. Edge Cracking

Each recorded distress measured during the test block survey can be rated as follows by considering the probable causes for each test block. Summary of condition survey data for the three Test Roads (Refer APPENDIXA, B and C) is used for computing the probable causes as shown in Table 4.2 below:

Table 4.2Computing magnitude of probable causes for dominant distresses

(Distress No) Distress type	Total Distress Density	%age Distress Indicator	Probable cause
(9)Lane/Shoulder Drop off	77.48	26.09	Drainage
(1) Alligator Cracking	62.45	20.10	load
(12) Polished aggregates	35.33	11.90	load
(3) Block cracking	23.36	7.87	load
(10) Longitudinal/Transversal Cracking	20.79	7.00	Climate
(18) Weathering & Raveling	20.24	6.82	Drainage
(5) Corrugation	15.16	5.11	Drainage
(11) Patching & Utility Cut Patching	6.03	2.03	Climate
(17) Swell	5.46	2.84	Drainage

The magnitude of distresses associated with each probable cause can be computed as follows:

Moisture/ drainage associated distress = 40.85 %

Climate/durability associated distress = 9.03 %

Load associated distress =39.86 %

The same kind of computation is made for each blocks of Test Road. Details are given in Appendix B and C.

4.2.4 Calculation of PCI values

Details of the PCI values calculated ,deduct value read from charts for each type of distress, severity extent are shown on Appendix A – C and summery of the PCI values are tabulated below.

Table 4.3 Summery of PCI values for Test Roads

Test Road No.1		Test Road No.2		Test Road No.3	
Block No	**PCI**	**Block No**	**PCI**	**Block No**	**PCI**
3	18	1	19	5	66
4	29	2	34	6	64
5	19	3	17	7	60
6	12	4	15	8	52
7	20	5	19	9	50
9	22	6	20	10	54
11	42	7	17	11	53
12	35	8	22	12	52
13	46	9	24		
14	58	10	25		
15	53	11	21		
16	32	12	18		
17	34				
Avg	32		21		56

* These block numbers are end chain age of the preceding road number

The visual condition survey results can be summarized identifying the probable dominant Cause of distress as shown in Table 4.4 below:

Table 4.4 Mean Pavement Condition Index for Test Roads

Test road	**Description**	**Dominant Cause of Distress**	**PCI**
1	Main Ambo road (from Sansusi to Burayu Town Adminstration	Moisture &Drainage	32%
2	Main Ambo Road (fromDire to Kella)	Moisture &Drainage	21%
3	Nono Road (fromUrga building to Diasphora site)	Load	56 %

The three test roads (No.1, 2 & 3) shows serious reduction in PCI value and moisture/drainage associated distresses are dominant within these test sections.

4.3 Condition Survey of Drainage Structures

Field survey was conducted to assess the performance of existing drainage facilities. The numbers of structures are small. In top of that most of the existing structures have the following main problem.

Those observed existing drainage problems during site survey are the following:

- From twenty fife surveyed existing pipe culverts siltation problem in eleven of the existing pipe culverts as the area is located in town section; some of the crossings are clocked with debris in the downstream as shown in picture below.

Figure 4.1 Siltation of existing Culvert

- Three of the crossing channels are missing which requires proper crossing
- Overtopping problems in some major & minor crossings from local consultation & observed flood mark during the study as shown in picture below

Figure 4.2Improper site selections

- Four crossings in a valley with respect to both approach roads in steep topography which requires rise of the structure opening height for the sake of the geometry.
- Additional cut off ditch for the first test section of 4km for the right side cut section for properly intercepting the flow from the right side hill as shown below

Figure 4.3 Few crossing structures of existing Culvert

- Proper Drainage problem in all town sections of the project as shown in picture below

Figure 4.4Proper drainage problems

4.3.1 Hydraulic Design of major Structures

I. Opening Requirements

To determine the highest flood level corresponding to pick discharge a stage-discharge curve has been generated based on the river geometry, roughness coefficient and the slope of the riverbed. After obtaining the stage-discharge curve, an appropriate stage has been read from the graph that corresponds to the design discharge.

Safe opening is determined to safeguard against scour due to constriction and general scour. In the hydraulic computation, important local hydrologic and geomorphologic characteristics have been taken into consideration.

Consideration is paid to ensure restricting the flow does not causes backwater above the limit given in the manual or scour that may damage the structure.

II. Scour Checks

There is one major channel requiring bridge structure in the test roads to span the crossing. The foundation of this river at the crossing is rock, in which it shows scouring is not serious problem. To avoid localized scouring in the joint of the rock constriction of channel is avoided.

4.3.2 Hydraulic Design of Culverts

a. Size Selection

Culverts are operating under inlet and outlet control. For inlet control, size selection will be carried out using available culvert design monographs (flow charts) for the various pipe culvert sizes and slab culvert sizes.

b. Proposed minor structures

Concrete culverts (pipes and slabs/box) have been envisaged for minor watercourse crossings. Slab culverts are used up to 6-meter span. The minimum size of pipe culverts is 1060 mm (42 inch) diameter and 1200mm diameter has been taken as the largest size. When a single 1200 pipe culvert is insufficient for the design flow, box/slab culverts or multiple cell culverts will be utilized. The Hydraulic computation of crossing culverts is given in **appendix D**& schedule is presented in **appendix E.**

` **Hydraulic Computation of Crossing Culverts for the Computed Discharges**

Sr. No	Catch. ID	Location	Catch. Area	Flow Direction	Selected Return period	QD	REQUIRED STRUCTURE SIZE							Adequacy
							Culvert type	No. Cell	Height	Width	Hw/D=1	Hw/D=1.25	Hw/D=1.5	
		Km	(km^2)		Year	m^3/s			m	m	m^3/s	m^3/s	m^3/s	
1	A1	0+120	0.23	R to L	25	9.35	B/SC	1	2	2	8.5	11.9	14.1	ok
2	A2	0+400	1.57	R to L	50	49.30	B/SC	1	3.5	4	39.3	55.0	65.5	ok
3	A3	0+840	0.12	R to L	25	5.00	B/SC	1	2	2	8.5	11.9	14.1	ok
4	A4	0+960	2.4	R to L	50	67.37	B/SC	1	4	5	60.0	84.0	100.0	ok
5	A5	1+690	0.06	R to L	25	2.74	B/SC	1	1.5	2	5.5	7.7	9.2	ok
6	A6	2+740	0.51	R to L	50	32.33	B/SC	1	3	3	23.4	32.7	39.0	ok
7	A7	3+160	3.5	R to L	50	88.56	B/SC	1	4	5	60.0	84.0	100.0	ok
8	A8	3+500	0.23	R to L	25	9.59	B/SC	1	2	3	12.7	17.8	21.2	ok
9	A9	4+380	4.3	R to L	50	61.25	B/SC	1	3	5	39.0	54.6	65.0	ok
10	A10	5+920	0.07	R to L	25	3.20	PC	1	1.22	1.22	2.1	3.1	3.6	ok
11	A11	6+080	0.07	R to L	25	3.20	PC	1	1.22	1.22	2.1	3.1	3.6	ok
12	A12	6+675	0.15	R to L	25	6.60	B/SC	1	1.5	2	5.5	7.7	9.2	ok
13	A13	6+860	0.09	R to L	25	3.35	PC	1	1.22	1.22	2.1	3.1	3.6	ok
14	A14	7+060	0.09	R to L	25	3.35	PC	1	1.22	1.22	2.1	3.1	3.6	ok
15	A15	7+520	0.09	R to L	25	3.35	PC	1	1.22	1.22	2.1	3.1	3.6	ok
16	A16	7+960	0.09	R to L	25	3.35	PC	1	1.22	1.22	2.1	3.1	3.6	ok
17	A17	8+700	0.59	R to L	50	21.27	B/SC	1	2	4	17.0	23.8	28.3	ok
18	A18	9+970	1.35	R to L	50	33.43	B/SC	1	2.5	4	23.7	33.2	39.5	ok
19	A19	10+720	0.17	R to L	25	5.23	B/SC	1	1.5	2	5.5	7.7	9.2	ok
20	A20	10+880	0.04	R to L	25	1.53	PC	1	1.22	1.22	2.1	3.1	3.6	ok
21	A21	10+990	0.04	R to L	25	1.53	PC	1	1.22	1.22	2.1	3.1	3.6	ok
22	A22	11+200	0.04	R to L	25	1.53	PC	1	1.22	1.22	2.1	3.1	3.6	ok
23	A23	11+340	0.04	R to L	25	1.53	PC	1	1.22	1.22	2.1	3.1	3.6	ok
24	A24	11+660	1.5	R to L	50	37.14	B/SC	1	3	3	23.4	32.7	39.0	ok
25	A25	11+820	0.17	R to L	25	4.99	B/SC	1	1.5	2	5.5	7.7	9.2	ok
26	A26	12+020	0.08	R to L	25	2.67	PC	1	1.22	1.22	2.1	3.1	3.6	ok
27	A27	12+180	0.08	R to L	25	2.67	PC	1	1.22	1.22	2.1	3.1	3.6	ok
28	A28	12+440	0.08	R to L	25	2.67	PC	1	1.22	1.22	2.1	3.1	3.6	ok
29	A29	12+600	0.045	R to L	25	1.72	PC	1	1.22	1.22	2.1	3.1	3.6	ok
30	A30	12+900	0.045	R to L	25	1.72	PC	1	1.22	1.22	2.1	3.1	3.6	ok
31	A31	13+130	0.045	R to L	25	1.72	PC	1	1.22	1.22	2.1	3.1	3.6	ok
32	A32	13+620	0.025	R to L	25	0.95	PC	1	1.22	1.22	2.1	3.1	3.6	ok

4.3.3 Intercepting Ditches

The test road is to be built as town section and one side cut in most stretches. As such, requirement of intercepting drains (side ditches) is mandatory for the cut as well as town sections. The purpose of roadside channels is to collect surface runoff from the road and areas that drain towards the road and convey the accumulated runoff to acceptable outlet points or guide the water to cross-drainage structures.

For right side cutting section of the road from km 0+000 to 4+000, additional intercepting channel with grate cover for capturing the left side catchment flow has been proposed & the computation for the proposed secondary channel has been presented in **appendix F**

Sr.No.	Required secondary channel section	Maximum Water flowing length	Contributing width (m)	Catchment Area (km2)	Weighted average runoff Coefficient	Water Drainaging slope	Time of Concentration, Tc (min)	Design Rainfall Intensity, I-10 (mm/hr)	Design Discharge Q-25 (m3/s)	Width	Flow depth (m)	X-section Area (m2)	perimeter (m)	H. Radius (m)	V (m/s)	Q (m3/s)
1	0+000 to 4+0 b/n proposed crossings	450	250	0.1125	0.65	0.036	10.28	129.77	2.81	0.8	1	0.8	2.4	0.33	3.11	3.273

4.3.4 Design of Storm Sewers

The storm sewer system that receives runoff from inlets and conveys the runoff to some point where it is then discharged into a channel, water body, or piped system. Storm sewers should be designed to avoid surcharging, i.e. the situation where flow is under pressure and water is pushed up through inlets and other facilities. The designed sewers are designed to surcharge with a maximum tolerated frequency (return period). Some of the typical decisions that are made in the design of the drainage are:

- Dimension of pipes
- Spacing of inlets
- Slope of pipes

4.3.5 Hydraulic Design of Gutter, Inlets, Manholes and longitudinal pipes

I. Gutter

Curbs are normally used at the outside edge of pavements. They serve for the following purposes:

- Contain the surface runoff within the roadway and away from adjacent properties
- Prevent erosion on fill slopes
- Provide pavement delineation
- Enable the orderly development of property adjacent to the roadway

Gutters formed in combination with curbs are available in 0.3 through 1.0 meter width. Gutter cross slopes may be the same as that of the pavement or may be designed with a steeper cross slope, usually 80 mm per meter steeper than the shoulder or parking lane (if used). AASHTO geometric guidelines state that an 8% slope is a common maximum cross slope.

A curb and gutter combination forms a triangular channel that can convey runoff equal to or less than the design flow without interruption of the traffic. When a design flow occurs, there is a spread or widening of the conveyed water surface.

Gutter flow calculations are necessary to establish the capacity of the gutter within the spread and puddle depth criteria. Gutter capacity is determined based on a modified form of Manning's equation, the Izzard formulae, modified for triangular sections having a single cross fall cross slope.

$$Q = (0.375\,F)d^{8/3}S_o^{\,0.5}Z/n$$

Where, Q = the total flow (m^3/s)

F = flow correction factor (0.9 for simple triangular sections and 0.8 for gutter sections having different slope from the cross slope of roadway

n = Manning's roughness coefficient (for asphalt pavement of rough texture n is taken 0.016)

T = width of flow or spread in the gutter [m]

d = the greatest gutter depth (m)

S_o = the longitudinal slope (m/m)

Desirable gutter grades should not be less than 0.5%. Minimum pavement cross slope should not be less than 2% for new construction/re-construction. Bridge deck drainage is similar to that of curbed roadway sections.

II. Inlet

Types of Inlets:

Storm drain inlets are used to collect runoff and discharge it to an underground storm drainage system. Inlets are typically located in gutter sections, paved medians, and roadside and median ditches. Inlets used for the drainage of highway surfaces can be divided into the following four classes:

- Grate inlets
- Curb-opening inlets
- Slotted inlets
- Combination inlets

Grate inlets consist of an opening in the gutter or ditch covered by a grate. Grate inlets, as a class, perform satisfactorily over a wide range of gutter grades. Grate inlets generally lose capacity with increase in grade, but to a lesser degree than curb opening inlets. The principal advantage of grate inlets is that they are installed along the roadway where the water is flowing. Their principal disadvantage is that they may be clogged by floating trash or debris. Curb-opening inlets are vertical openings in the curb covered by a top slab. Curb-opening inlets are most effective on flatter slopes, in sags, and with flows which typically carry significant amounts of floating debris. The interception capacity of curb-opening inlets decreases as the gutter grade steepens. Consequently, the use of curb-opening inlets is recommended in sags and on grades less than **3%**.

Slotted inlets consist of a pipe cut along the longitudinal axis with bars perpendicular to the opening to maintain the slotted opening. Slotted drain inlets can be used in areas where it is desirable to intercept sheet flow before it crosses onto a section of roadway.

Combination inlets consist of both a curb-opening inlet and a grate inlet placed in a side-by-side configuration, but the curb opening may be located in part upstream of the grate. Combination inlets provide the advantages of both curb opening and grate inlets. This combination results in a high capacity inlet which offers the advantages of both grate and curb opening inlets.

When the curb opening precedes the grate in a "Sweeper" configuration, the curb-opening inlet acts as a trash interceptor during the initial phases of a storm. Used in a sag configuration, the sweeper inlet can have a curb opening on both sides of the grate.

Location of Inlets:

Inlets are located at the following critical locations of the road independent of hydraulic calculations:

- Low points in road side drains
- Super elevation transitions
- In advance of pedestrian crossings
- In advance of intersections or other important access points; and
- At locations for maintenance purposes such as at changes in direction or maximum spacing for cleaning purposes (100m maximum spacing)

In most drainage design manuals the minimum spacing of the inlets is 90m (300 feet). In Burayu town there is higher proportion of unpaved access roads connected to the Arterial or collector roads which results in higher sediment transport to the paved road. In addition to this there is spread of garbage (solid waste) along the road. This will force us to keep the minimum spacing of inlets to lower value. For this design minimum spacing of inlets is taken 50m.

In locations where significant ponding may occur, such as at underpasses or sag vertical curves in depressed sections, it is a recommended practice to place supplemental inlets on each side of the inlet at low point in the sag.

III. Storm drains

Storm sewers should be designed such that velocities of flow will not be less than 0.91m/s at design flow. For very flat grades, the general practice is to design components so that flow velocities will increase progressively throughout the length of the pipe system. The storm sewer system should be checked to be sure there is sufficient velocity in all of the drains to deter settling of particles. Minimum slopes are given in table 4.5.

Both minimum and maximum cover limits must be considered in the design of storm drainage systems. Minimum cover limits are established to ensure the conduits structural stability under live and impact loads. With increasing fill heights, dead load becomes the controlling factor. For highway applications, a minimum cover depth of 0.9 m (3.0 ft) should be maintained Maximum cover limits are controlled by fill and other dead loads.

Table 4-5: Minimum Sewer Slopes

Pipe Size [mm]	Pipe Size [inch]	% Grade for self-cleansing
760	30	0.15
915	36	0.12
1070	42	0.12
1220	48	0.10

IV. Manhole

The following general design guidance for location and spacing of manholes to be used:

- For trunk sewers 36" (915mm) diameter and under, space approximately 100m apart to facilitate maintenance.
- For trunk sewers 42" (1070mm) diameter and over, space approximately 100 pipe diameters apart.
- At angles in the main sewer
- At points where the size of the sewer changes
- At points where the grade of the sewer changes
- At the junction of sewer lines
- At street intersections or other points, such as connecting lines to catch basins or inlets
- Access manholes for sewer inspection on large tunnel sewers shall be spaced at approximately 360m centers
- At points where pipe material changes

The hydraulic recommendation for under drain and masonry drains has been presented in **appendix E** for this particular test road.

4.4 Relationship of Pavement condition Index and Remarks on Drainage structures

Results of pavement evaluations performed on different test roads and test sections are as summarized and discussed in the preceding sections, each method of evaluation stands on its own merit by indicating the pavement performance and / or identifying the probable cause of distress.

In this section, a statistical analysis is made to further check whether the different performance variables within test roads are associated with each other.

The correlation between different pavement evaluations results were made considering major causes of pavement failure due to possible effects of drainage condition. It is only tried hereto check the relationship among distresses, different pavement response variables (PCI) in order to get some clue son the cause of pavement distress which can serve as a supplementary feedback for the already conducted functional and structural evaluations.

Table 4.6 ***Possible effects of Drainage Condition on Distress Densities PCI on test road No.1***

Test Road No.1		
Block No	**PCI**	**Remark On Drainage structures**
3	18	Replace with the new proposed size
4	29	Replace with the new proposed size
5	19	New Proposed
6	12	Replace with the new proposed size
7	20	Replace with the new proposed size
9	22	Replace with the new proposed size
11	42	New Proposed
12	35	New Proposed
13	46	New Proposed
14	58	Replace with the new proposed size
15	53	New Proposed
16	32	New Proposed
17	34	Replace with the new proposed size

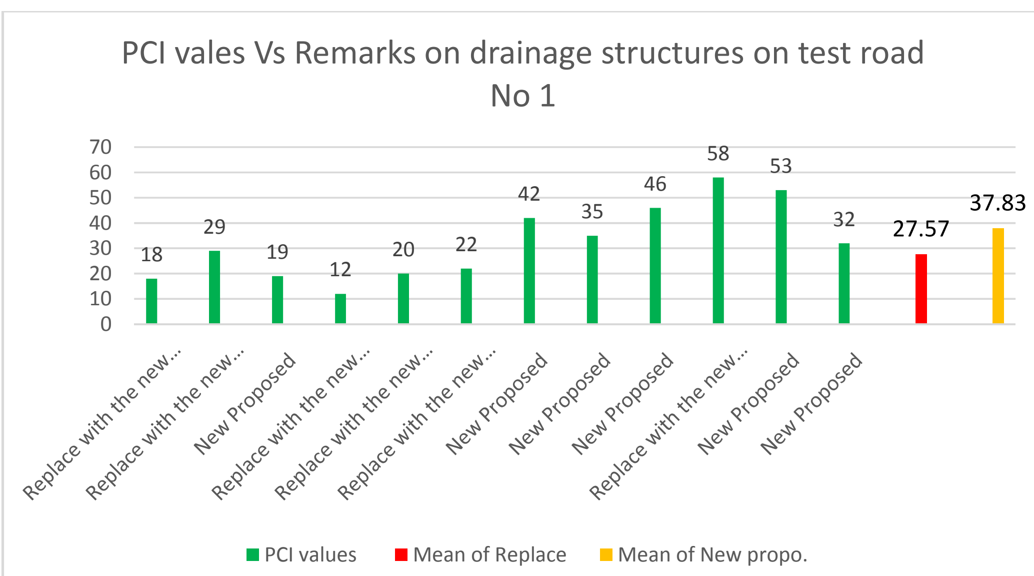


Table 4.7 ***Possible effects of Drainage Condition on Distress Densities PCI on test road No.2***

Test Road No.2		
Block No	**PCI**	**Remark On Drainage structures**
1	19	Replace with the new proposed size
2	34	New Proposed
3	17	New Proposed
4	15	Replace with the new proposed size
5	19	Replace with the new proposed size
6	20	Replace with the new proposed size
7	17	Replace with the new proposed size
8	22	Replace with the new proposed size
9	24	Replace with the new proposed size
10	25	Replace with the new proposed size
11	21	Replace with the new proposed size
12	18	Replace with the new proposed size

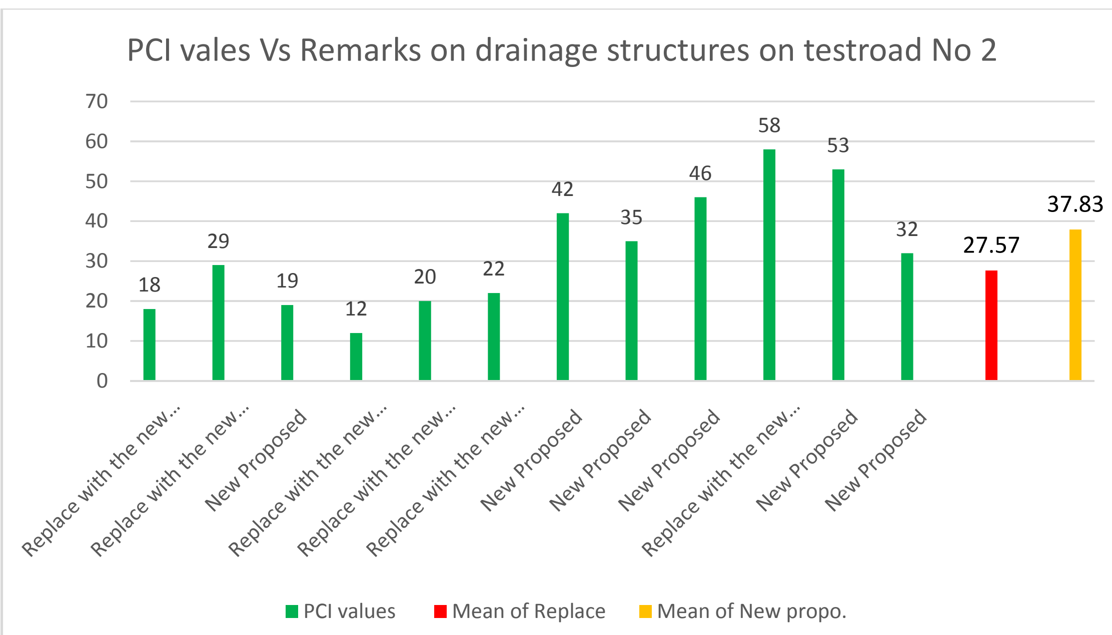


Table 4.8 ***Possible effects of Drainage Condition on Distress Densities PCI on test road No.3***

Test Road No.3		
Block No	**PCI**	**Remark On Drainage structures**
5	66	Replace with the new proposed size
6	64	Replace with the new proposed size
7	60	Replace with the new proposed size
8	52	Replace with the new proposed size
9	50	Replace with the new proposed size
10	54	Replace with the new proposed size
11	53	New Proposed
12	52	Replace with the new proposed size

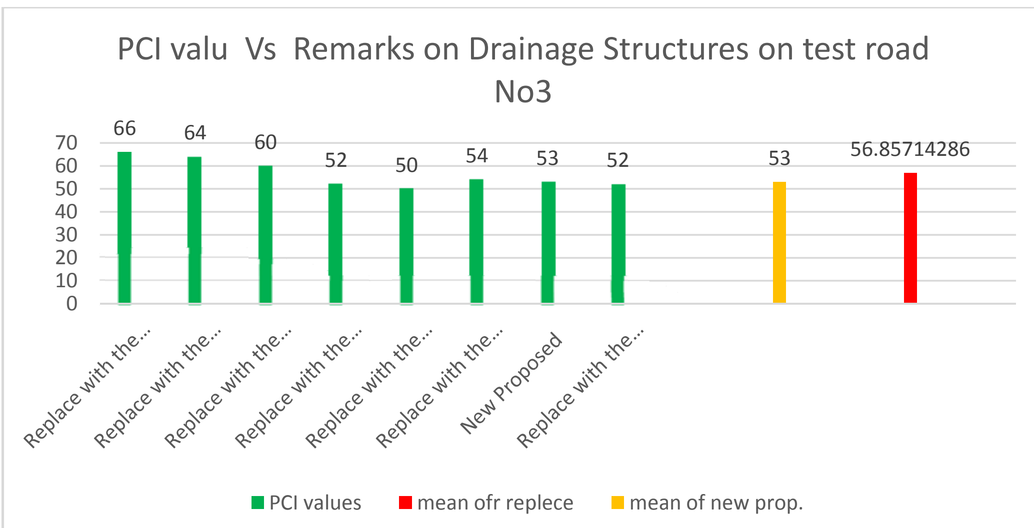
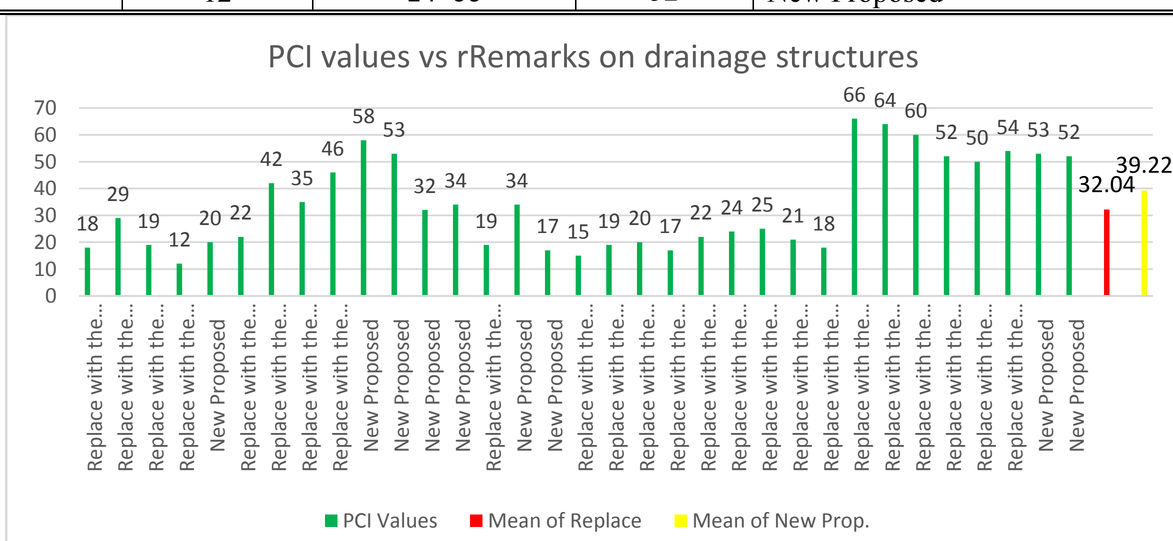


Table 4.9 Summary of Pavement Evaluation Data for Test Roads

Test Roads	Block No	Station (km)	PCI	Remark on Drainage Structures
Test Road No.1	1	0+120	18	Replace with the new proposed size
	2	0+400	29	Replace with the new proposed size
	3	0+840	19	Replace with the new proposed size
	4	0+960	12	Replace with the new proposed size
	5	1+690	20	New Proposed
	6	2+740	22	Replace with the new proposed size
	7	3+160	42	Replace with the new proposed size
	8	3+500	35	Replace with the new proposed size
	9	4+380	46	Replace with the new proposed size
	10	5+920	58	New Proposed
	11	6+080	53	New Proposed
	12	6+675	32	New Proposed
	13	6+860	34	New Proposed
Test Road No.2	1	7+060	19	Replace with the new proposed size
	2	7+520	34	New Proposed
	3	7+960	17	New Proposed
	4	8+700	15	Replace with the new proposed size
	5	9+970	19	Replace with the new proposed size
	6	10+720	20	Replace with the new proposed size
	7	10+880	17	Replace with the new proposed size
	8	10+990	22	Replace with the new proposed size
	9	11+200	24	Replace with the new proposed size
	10	11+340	25	Replace with the new proposed size
	11	11+660	21	Replace with the new proposed size
	12	11+820	18	Replace with the new proposed size
Test Road No.3	5	12+020	66	Replace with the new proposed size
	6	12+180	64	Replace with the new proposed size
	7	12+440	60	Replace with the new proposed size
	8	12+600	52	Replace with the new proposed size
	9	12+900	50	Replace with the new proposed size
	10	13+130	54	Replace with the new proposed size
	11	13+620	53	New Proposed
	12	14+00	52	New Proposed



Results of SPSS on Descriptive Statistics and t- test

The results of descriptive statistics based on Summary of Pavement Evaluation Data for test roads, showed in table below that of the total 33 observations, 27.3 percent are found needed new design drainage system i.e. no drainage system proposed (9 observations) and the remaining 72.7 percent exists (replaced with the new proposed size) i.e. before there was proposed drainage system but should be replaced by new one (24 observations).

Independent Samples t-test

The Independent Samples t test can only compare the means for two (and only two) groups. It cannot make comparisons among more than two groups. The Independent Samples *t* Test output also includes an approximate *t* statistic that is not based on assuming equal population variances; this alternative statistic, called the Welch *t* Test statistic, may be used when equal variances among populations cannot be assumed. The Welch *t* Test is also known an Unequal Variance t-test or Separate Variances t-test. To carry out the t-test the total 33 test section result of remarks on drainage structures are grouped in to two groups (group 1, New Proposed, group 2, Replace with the new proposed size)

Table 4.10 Data of PCI and Remark on Drainage System

S/N	PCI value	Remark on Drainage Structures	Group
1	18	Replace with the new proposed size	2
2	29	Replace with the new proposed size	2
3	19	Replace with the new proposed size	2
4	12	Replace with the new proposed size	2
5	20	New Proposed	1
6	22	Replace with the new proposed size	2
7	42	Replace with the new proposed size	2
8	35	Replace with the new proposed size	2
9	46	Replace with the new proposed size	2
10	58	New Proposed	1
11	53	New Proposed	1
12	32	New Proposed	1
13	34	New Proposed	1
14	19	Replace with the new proposed size	2
15	34	New Proposed	1
16	17	New Proposed	1
17	15	Replace with the new proposed size	2
18	19	Replace with the new proposed size	2
19	20	Replace with the new proposed size	2
20	17	Replace with the new proposed size	2
21	22	Replace with the new proposed size	2
22	24	Replace with the new proposed size	2
23	25	Replace with the new proposed size	2
24	21	Replace with the new proposed size	2
25	18	Replace with the new proposed size	2
26	66	Replace with the new proposed size	2
27	64	Replace with the new proposed size	2
28	60	Replace with the new proposed size	2
29	52	Replace with the new proposed size	2
30	50	Replace with the new proposed size	2
31	54	Replace with the new proposed size	2
32	53	New Proposed	1
33	52	New Proposed	1

Summary of PCI values and Remark on Drainage System

		S/No		Block No	PCI Value
Remarks on drainage structures	New Proposed	1		5	20
		2		10	58
		3		11	53
		4		12	32
		5		13	34
		6		15	34
		7		16	17
		8		32	53
		9		33	52
		Total	N		**9**
			Mean		**39.222**
	Replace with the new proposed size	1		1	18
		2		2	29
		3		3	19
		4		4	12
		5		6	22
		6		7	42
		7		8	35
		8		9	46
		9		14	19
		10		17	15
		11		18	19
		12		19	20
		13		20	17
		14		21	22
		15		22	24
		16		23	25
		17		24	21
		18		25	18
		19		26	66
		20		27	64
		21		28	60
		22		29	52

		23		30	50
		24		31	54
		Total	N		24
			Mean		32.042
	Total	N			33
		Mean			34

An independent sample T-test is conducted to compare the remarkable drainage system (New proposed and Replaced with the new proposed size). There is a significant difference in score between the two groups t = 1.060, p < .05, two-tailed with New proposed (M = 39.22, SD = 14.39) scoring higher than Replace with the new proposed size (M = 24, SD = 18.24).

Group Statistics

	Remark on drainage system	N	Mean	Std. Deviation	Std. Error Mean
PCI	New proposed	9	39.22	14.39	4.797
	Replace with the new proposed size	24	32.04	18.24	3.723

When we have a continuous variable and we want to know if its mean differs in value between two groups, we use a T-test.

Levene's Test for Equality of Variances homogeneity of variance, called **Levene's Test**, whenever you run an independent samples T test. Recall that the independent samples T test requires the assumption of homogeneity of variance.

Look at Levene's test first if significant (p < .05), the variances of the two samples are not equal and a correction must be applied. To decide which *t* test results to use, we must look at the significance level (Sig.) of Levene's Test for Equality of Variances

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI	
									Lower	Upper
PCI	Equal variances assumed	1.607	0.2335	1.060	31	.0297	7.180	6.773	-6.095	20.455
	Equal variances not assumed			1.182	18.241	.0252	7.180	6.072	-4.721	19.081

Interpret SPSS Output: The statistics for the test are in the above table. The Levene's Test for Equal variances yields a p-value of **0.2335**. This means

i. Since the significance level is greater than .05, then we can assume that group variances are equal and need to use the first row of *t* test results.
ii. That the difference between the variances is statistically insignificant and we should use the statistics in the **first row**.

The p-value 0.0297, less than 0.05, indicates that there is significant different between average weights for Replace with the new proposed size and new proposed. The 95% confidence interval for the difference between two means is (-6.095, 20.455). (This is for the average weight of New proposed minus average weight of Replace with the new proposed size, because we have defined Group 1 as New proposed and Group 2 as replace with the new proposed size.

Summary

As we observed, most of the roads in Burayu town having inadequate drainage systems, deterioration often begins with the origin of cracks or pot holes on the road pavements either at the edges or along the drive way which differs by their shapes, configuration, and amplitude of loading, movement of traffic and rate of deformation.

Generally it can be concluded that road surface drainage of the study area found to be inadequate due insufficient road profile, insufficient drainage structures provision, improper maintenance and lack of proper interconnection between the road and drainage infrastructures thereby resulting damages to road surfacing material and flooding problems in the area.

CHAPTER FIVE

RESULT AND DISCUSSION

5.1 General

These chapters mainly discuss the maintenance and rehabilitation for different distresses investigated earlier. As already discussed in Chapter 2, pavement distresses can be classified as being caused either by traffic loads or non load factors, including design, construction, poor-durability materials, drainage and climate factors. Such classification helps to determine appropriate maintenance and/or rehabilitation alternative.

The distress types, severity and extent are the best source of information on the impact of past traffic loadings on the pavement. If load-associated distresses are predominant in the test section, then the structural adequacy of the existing pavement must be questioned. Pertinent information gathered during the visual condition survey need to be utilized in identifying probable causes, which in turn assists for proposing the maintenance alternatives.

5.2 Discussion of Visual condition survey

The visual distress surveys were made on selected test sections following the methodsasdiscussedin***Section3.2.1***above.Detailresultofthevisualsurveyis as shown below.

5.2.1. Defects observed on drainage structures on the three test roads

- Obstructions, silting ,Ponding in drains and on shoulders, Drain Cross-Section Destroyed (Unlined Drain), Invert and Sides of Drains are Eroded, Drain Lining is Damaged, Defect at Drain Outfall, Silting or Debris Blocking on culverts, Erosion of Culvert Bed at Outlet, Minor Headwall Damage

5.2.2. Calculating pavement condition index (PCI) on test road No.1

- The Visual survey for this test road is carried out on Main Ambo road (from Sansusi to Burayu Town Administration Office) which is 4.0 Km length.
- Thirteen homogeneous test blocks ranging from 150mts to300mts length are surveyed. The minimum and maximum block PCI values are 12 and 58 respectively
- The weighted average PCI value (i.e. considering area of pavement) for Test Road No. 1 is 32%, which can be rated as poor pavement surface.
- The detail PCI values for each block is as shown in Table 4.2

5.2.3. Calculating pavement condition index (PCI) on test road No.2

- This test road covers the section on main Ambo Road (from Dire to Kela) and the visual survey is carried out on the whole chain age of 3.6 Km length.

- Twelve homogenous test blocks having different length (ranging from 100mts to 150mts) are incorporated in this test road. The minimum and maximum block PCI values recorded in this test road are 15% and 34% respectively.
- TheweightedaveragePCIvaluefortestRoadNo.2is21%whichcanberated as very poor pavement surface.
- The detail PCI values for each block is as shown in Table 4.2

5.2.4. Calculating pavement condition index (PCI) on test road No.3

- This Test Road covers the section from Melka Gefersa Kebele administration to Gefersa nono Kebele administration. A total of 2.4Kms length visual survey is performed within this section.
- Eighthomogeneoustestblocksrangingfrom100mtsto150mtslengthare surveyed. The minimum and maximum Block PCI values are 52 and 66 respectively. The detail PCI values for each block are as shown in Table 4.2.
- TheweightedaveragePCIvalueforTestRoadNo.3 is 56%, which can be rated as fair to good road surface.

5.3 Discussion of maintenance alternatives

As discussed in Chapter4, all test roads exhibit several types of distresses and thus require a combination of different maintenance and/or rehabilitation. The following steps should in general be followed for proposing the appropriate maintenance and rehabilitation option:

- Themaintenanceoptionsneedtobedecidedafterathoroughdataanalysisas indicated in Section 2.3 above.
- Causes of distresses were grouped into three broad categories namely load associated, climate /durability associated and drainage /moisture associated.
- Severityandextentofdamagearegoverningcriterionstochooseappropriate maintenance and/or rehabilitation option.
- The maintenance option for localized surface defects only were out rightly prescribed without any further structural investigation.

Table 5. 1 Summary of maintenance options for Test Roads

Test roads	Evaluation of Results	Remark	Maintenance& Rehabilitation Option
Main Ambo road (from Sansusi to Burayu Town Adminstration Office)	**Functional:** PCI = 32% **Drainage:** No drainage facilities **Preliminary Design**: Requires complete strengthening	➢ Very Poor condition ➢ Bad pavement material ➢ Poor drainability	As pavement evaluation result of this road section, this section has fail the intended functional purposes. Hence it needs routine maintenance.
Main Ambo road (fromDire to Kela)	**Functional:** PCI = 21% **Drainage:** drainage slightly impeded **Preliminary Design**: Requires complete strengthening	➢ Poor condition ➢ Bad pavement material ➢ Good Earthen drainage	As pavement evaluation result of this road section, confirms that the section fails to serve for the intended purpose. Hence, routine maintenance to correct the existing surface.
Nono Road (fromMelka Gefersa Kebele to Gefersa nono kebele)	**Functional:** PCI = 56% **Drainage:drainage impeded** **Preliminary Design**: Requires complete strengthening	➢ Fair condition ➢ Bad pavement material ➢ Poor drainability	As pavement evaluation result of this road section, this section is in a good condition. Hence, routine maintenance to correct the existing surface.

CHAPTER SIX
CONCLUSION AND RECOMMENDATION

Conclusions are drawn from the investigations of the results of the research. Recommendations are provided based on the findings of the results of the research.

6.1 CONCLUSION

The pavement evaluation and analysis made on the three test roads shows that most of the pavements exhibit severe distress (expressed with very low PCI value).

As a results of the above mentioned ones on the selected roads showed that their PCI value range from(21-56) i.e. all sections of road were in a fair condition, most of the deterioration seen was potholes, longitudinal and transverse cracks etc .are seen as a result of poor drainage structures.

The drainage condition on all test roads has strong association with PCI, and all major distresses. Such strong relationship confirms that drainage condition has significant impact, than any other cause, to affect the structural and functional condition of the pavement performance. Hence, it can be concluded that the predominant cause of distress in those pavements which failed functionally and structurally is mainly due to drainage problem.

The failure of these drainage structures are due to inadequate size of drainage structures caused by negligence of hydrological analysis and hydraulic design. Moreover, improper site selection for drainage structures, drainage structures at critical points where failure of carriageway due to over saturation and overtopping is seen, improper alignment of drainage structures at sections where scouring due to flooding crosscurrent occurs and poor construction workmanship contribute to the problem.

As summarized in chapter five above pavements can be maintained close to its original condition for a longer period of time. Timely application of successive treatment can maintain the pavement in good condition and prolong the need for more expensive roadway rehabilitation and reconstruction strategies, if the pavement is not maintained effectively; it will eventually deteriorate to appoint where the only choice is the reconstruction which is the most costly option. Here in these test roads the pavement needs thick overlay and it does not need complete reconstruction.

6.2. RECOMMENDATION

1. Collection of accurate data for determining dominant distresses in a road network, identifying primary causes of distress would only be easier on experimental test sections which are carefully designated in such a way to reasonably model the road network under study. To this effect one can understand that the analysis and findings of this research could only be considered as a preliminary assessment that may serve as a spring board to further carry out detailed assessment within the road network. Hence, it is advisable to develop a continuous system of data collection for distresses, classified traffic counts, pavement evaluation results, and maintenance and construction records on representative test sections for a longer period of time. Such strategic data collection and analysis could certainly enable to develop clear functional relationship among different pavement evaluation parameters.

2. No detail material test of the existing pavement structure is carried out under this research. Hence, it is also advisable to perform some destructive tests such as coring and component analysis techniques to further check the structural capacity of the pavement.

3. As observed from the visual survey, nearly 68% of the test roads were constructed without side drain of any kind. This can easily indicate that the road design and construction traditionally adopted has fully ignored the effect of excess water in the pavement layer. According to the survey made for this thesis purpose, even some of the existing surface drains are not properly functioning. On the other hand, ERA traditional maintenance practice until now, to repair damaged pavements, is patching or providing additional thickness of asphalt without an attempt to improve the drainage conditions.

4. Siltation problem was considered in the design of the opening size. Since most of the roads connected to the roads under study are gravel or earth road siltation will be serious problem, and for this reason the size of the structures were taken to be larger than the actual requirement. To give provision for siltation the minimum pipe size recommended is 1060mm.

5. Along the road to avoid spread of water gutter is designed on both side of the road for road width above 15m. The gutter is connected to curve inlet at a minimum spacing of 50m and the inlets are connected to longitudinal drainage pipes (storm sewers).

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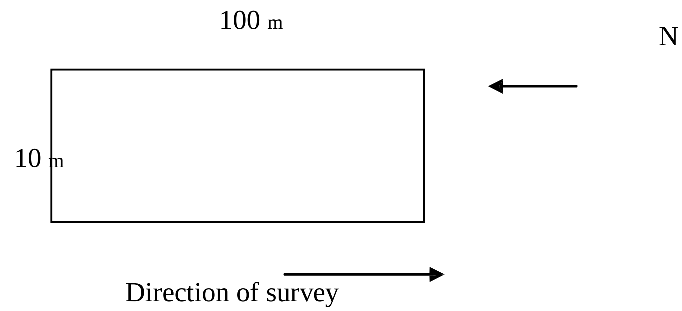
APPENDIX A

SAMPLE CALCULATION OF PCI FOR TEST ROAD N<u>o</u> ONE

Table A.1 Pavement condition survey data sheet for road No 1

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Sansusi - Municipality Block No. 3
Surveyed by: Group Date: May,2016



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity**										**Total**	**Density**	**Deduct Value**
1 L	2.4*3.6	0.4*0.8	8*2.5	1.2*5.6	1.5*6	1.2*0.6					**45.4**	**4.54**	**35**
1 H	1.8*19.2	1.1*4.1	2.0*30	3.8*0.80	0.9*2.2	1.0*4.3	1.2*3.0	2*3	2.2*1.8		**124.59**	**12.46**	**82**
3M	1*3	1.6*0.8	1.8*2	2.2*3	2.6*2.0	3*5	1.6*4	2.6*4.6			**53.04**	**5.304**	**50**
10 L	2.4	2.9	2.4	2.6	2.4	2.4	2.4	2.8	1.3	2.1			
	2.7	1.6									**29.4**	**3.7**	**2.5**
10 M	2.5	2.0	7.5	2.2	2.5	3.65					**20.35**	**2.6**	**15**
9M	1.8	2.0	2.4	1.6	1.5	1.7	1.4	1.2	2.1	1.3	**17**	**0.17**	**4.6**
9H	2.3	2.2	1.2	2.8	2.6	1.8	1.6	2.8	1.8	1.4	**20.5**	**2.05**	**36**
12	8*30	8*5									**280**	**35**	**9**
13 L	4										**4**	**0.5**	**12**

Table A2 Calculation of corrected PCI value

m = 1+ (9/98) (100-82) = 7.65

Use highest 7 deducts and 0.65 of six deduct

0.65*2.5=1.62

#	Deduct value										Total	q	CDV
1	82	50	36	35	15	12	9	1.62			**245.2**	6	**56**
2	82	50	36	35	15	12	2	1.62			**246.6**	5	**56**
3	82	50	36	35	15	2	2	1.62			**235.6**	4	**56**
4	82	50	36	35	2	2	2	1.62			**225.6**	3	**55**
5	82	50	36	2	2	2	2	1.62			**179.6**	2	**58**
6	82	50	2	2	2	2	2	1.62			**145.6**	1	**82**
7	82	2	2	2	2	2	2	1.62			**97.6**	0	**53**

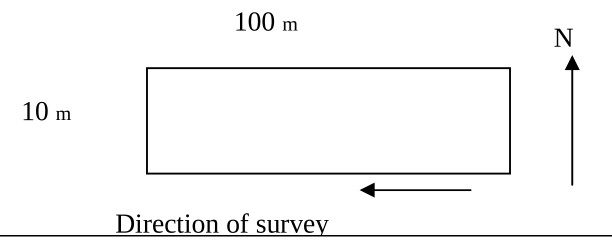
Max CDV = 82

PCI = 100- Max CDV = 18
Rating = very poor

Table A.3 Pavement condition survey data sheet for test road No 1

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Sansusi - Municipality Block No. 4
Surveyed by: Group Date: May,2016



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distres s severit	**Quantity**										**Total**	**Densit y**	**Deduct Value**
1 L	2*3.5	3.5*3.0	5.4*2.	2.35*5.	2.45*3	3.5*3					**71.82**	**7.2**	**30**
1 M	1.5*3	2.25*3	1.7*3.	1.9*2	1.6*1.8	2.4*2.2	1.8*1.6				**32.38**	**3.24**	**31**
3 M	1*3	1.5*0.6									**3.9**	**0.39**	**0**
9M	4	3.8	5.4	6	3.2	1.8					**24.2**	**2.42**	**8**
10 M	6.80	2.70	4.00	2.90	2.40	2.20	2.50	2.16	2.80	3.80			
	3.50	3.90	4.05										
											43.45	**5.4**	**12**
11 L	12										**12**	**1.5**	**5**
13M	1										**3**	**0.125**	**7**

Table A.4 Calculation of corrected PCI value

m = 1+ (9/98) (100-58) = 4.90

Use highest 4 deducts and 0.90 of six deduct

0.90 *5=4.50

#	**Deduct value**										**Total**	**q**	**CDV**
1	31	30	12	7	4.50						**84.5**	**5**	**44**
2	31	30	12	7	2						**82**	**4**	**48**
3	31	30	12	2	2						**77**	**3**	**71**
4	31	30	2	2	2						**67**	**2**	**50**
5	31	2	2	2	2						**39**	**1**	**40**

Max CDV = 71

PCI = 100- Max CDV = 29

Rating = poor

Table A.5 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Sansusi - Municipality   Block No. 5
Surveyed by: Group   Date: May,2016

100 m   N

10 m

Direction of survey

1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	**Quantity**										**Total**	**Density**	**Deduct Value**
1 L	8.6	22.64	4.328	5.608	16.08	12.04	5.02	20.65			**94.966**	**9.5**	**33.5**
1 H	6.25	4.34	2.2	2.24							**15.03**	**1.503**	**31**
3 H	12.4	2.6	0.3								**15.3**	**1.91**	**7.5**
9M	3.8	3.6	2.8	2.2	1.6	1.8					**55.8**	**5.58**	10
11 L	10.4	8.2	4.4								**22**	**2.75**	**5**
13 M	2	1.6	1.4								5	**0.25**	**12.5**
18	1.62	2.84	5.04								9.5	0.95	0

Table A.6 Calculation of corrected PCI value

m = 1+ (9/98)(100-32.5) = 4.19

Use highest 6 deducts and 0.96 of six deduct

0.19 *5=0.95

#	**Deduct value**										**Total**	**q**	**CDV**
1	32.5	28	12.5	7.5	0.95						**81.45**	**4**	**48**
2	32.5	28	12.5	2	0.95						**75.95**	**3**	**50**
3	32.5	28	2	2	0.95						**65.45**	**1**	**81**
4	32.5	2	2	2	0.95						**39.45**	**0**	**40**

Max CDV = 81

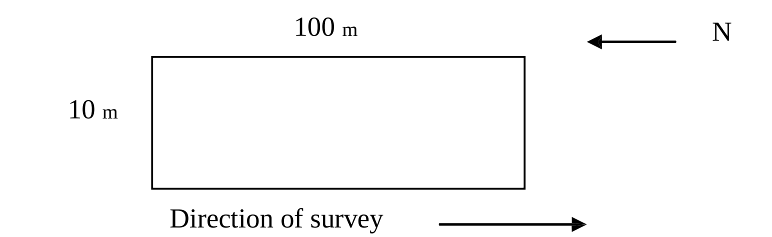
PCI = 100- Max CDV = 19

Rating = very poor

Table A.7 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Sansusi - Municipality Block No. 6
Surveyed by: Group Date: May,2016



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress	**Quantity**										**Total**	**Densit**	**Deduct Value**
1 M	3.3*0.	3.4*1.2	0.5*1.3	5.3*4.4	1.7*8.5						**44.48**	**5.56**	**40**
9L	5.04	6.8	3.42	4.24	2.2	1.6					**23.3**	**2.33**	**45.5**
10 L	2.20	2.00	0.70	2.50	2.00	1.20	2.80	1.80	2.50	1.50	**35.8**	**3.58**	
	2.10	2.40	2.10								**25.80**	**3.30**	**5**
10 M	3.30	1.80	3.20	2.30	2.40	3.00	2.20	3.30	3.90		**25.40**	**3.20**	**7**
11 L	4										**4**	**0.50**	**2.5**
13 L	1										**1**	**0.20**	**5**
19 M	8*10										**80**	**10**	**18**

Table A.8 Calculation of corrected PCI value

#	**Deduct value**										**Total**	**q**	**CDV**
1	45.5	40	18	7	5	0.0125					115.512	**5**	**38**
2	45.5	40	18	7	2	0.0125					112.512	**4**	**42**
3	45.5	40	18	2	2	0.0125					107.512	**3**	**46**
4	45.5	40	2	2	2	0.0125					91.512	**0**	**48**
5	45.5	2	2	2	2	0.0125					53.512	**1**	**88**

Max CDV = 88

PCI = 100- Max CDV = 12

Rating = very poor

Table A.9 Pavement condition survey data sheet for road

Street : Sans--Municipality   No. of sample: 07
Surveyed by: Group   Date: May,2016

Direction of survey   N

1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress	**Quantity**										**Total**	**Density**	**Deduct**
1 L	1.0*23	1.70*6.	1.40*5.	1.30*1.7	0.90*6.2	5.22	5.4	4.6			**64.53**	**6.453**	**29**
1 M	2.0*6.	2.2*5.3	2.00*4.	3.7*3.0	4.8	3.02	3.22				**55**	**5.5**	**40**
10 L	2.15	2.10	3.15	1.50	1.80	1.40	1.10	2.20	1.50	3.70			
	1.60	1.40									**29.5**	**2.95**	**2**
10 M	3.70	2.70	1.20								**9,5**	**0.95**	**3**
11 L	2	3									**5**	**0.50**	**2.50**
13 L	1.67	2.08									**3.75**	**0.375**	**7**

Table A.10 Calculation of corrected PCI value

m = 1+ (9/98)(100-40) = 5.51

Use highest 5 deducts and 0.51 of six deduct

0.51 *2=1.02

#	**Deduct value**										**Total**	**q**	**CDV**
1	40	29	7	3	2.5	1.02					**82.52**	**5**	**44**
2	40	29	7	3	2	1.02					**82.02**	**4**	**48**
3	40	29	7	2	2	1.02					**81.02**	**3**	**54**
4	40	29	2	2	2	1.02					**76.02**	**0**	**80**
5	40	2	2	2	2	1.02					**49.02**	**1**	**50**

Max CDV = 80

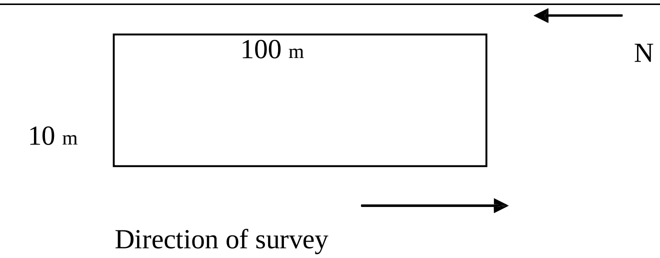
PCI = 100- Max CDV = 20

Rating = very poor

Table A.11 Pavement condition survey data sheet for road No.1

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Sans--Municipality   No. of sample: 09
Surveyed by: Date: May,2016



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress	**Quantity**										**Total**	**Density**	**Deduct**
1 L	1.1*6.3	1.0*6.4	7.0*5.0	2.5*3.6							**57.33**	**7.1**	**30**
1 M	0.95*4.	1.5*0.5	0.55*5.	1.0*16.							**23.76**	**2.97**	**32**
3 L	5.0*0.4	2.3*3.2	0.9*8.1	6.80*3.							**40.70**	**5.1**	**5**
3 M	2.2*0.9										**1.98**	**0.25**	**-**
10 L	1.00	1.80	1.90	0.70	2.70	3.10	5.30				**16.5**	**2.10**	**-**
10 M	1.60	2.60	3.00	0.70	1.30	1.50	2.65	3.40	1.00		**17.75**	**2.22**	**6**
11 M	8										**8**	**1**	**10**
12	8*20										**160**	**20**	**7**

Table A.12 Calculation of corrected PCI value

m = 1+ (9/98)(100-32) = 5.24

Use highest 5 deducts and 0.24 of six deduct

0.24 *5=4.35

#	**Deduct value**										**Total**	**q**	**CDV**
1	32	30	10	7	6	1.2					**86.2**	**5**	**46**
2	32	30	10	7	2	1.2					**82.2**	**4**	**46**
3	32	30	10	2	2	1.2					**77.2**	**3**	**50**
4	32	30	2	2	2	1.2					**69.2**	**0**	**50**
5	32	2	2	2	2	1.2					**41.2v**	**1**	**44**

Max CDV = 50

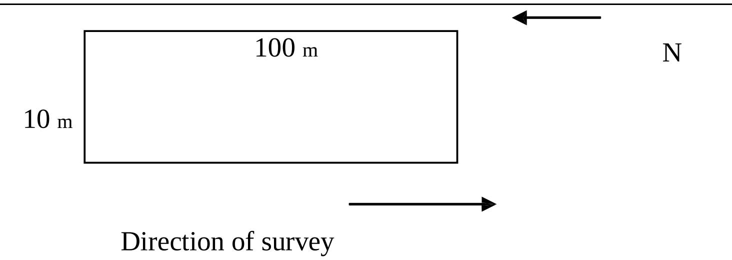
PCI = 100- Max CDV = 40

Rating = Fair

Table A.13 Pavement condition survey data sheet of road No.1

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Sans--Municipality   No. of sample: 11
Surveyed by: Date: May,2016



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severit	**Quantity**										**Total**	**Density**	**Deduct Value**
1 L	2.4*0.8	2.0*3.7		1.0*1.4	1.0*1.0	2.30*2.3	0.60*2.3				**18.39**	**2.29**	**18**
1 M	1.1*5.6	3.0*6.7	0.80*2.8	3.40*4							**42.10**	**5.26**	**40**
3 L	15*2.4	10.5*3.									**76.95**	**9.60**	**8**
3 M	3.4*3.1	2.6*3.2									**18.86**	**2.35**	**7**
10 M	1.60	2.20	1.00	2.40	3.00	2.30	3.20	2.30			**18**	**2.25**	**6**
13 L	4										**4**	**0.50**	**12**

Table A.14 Calculation of corrected PCI value

m = 1+ (9/98) (100-40) = 6.50

Use highest 6 deducts and 0.51 of six deduct

0.50 *6=3

#	Deduct value										Total	q	CDV
1	40	18	12	8	7	3					**88**	**6**	**42**
2	40	18	12	8	7	2					**87**	**5**	**46**
3	40	18	12	8	2	2					**82**	**4**	**48**
4	40	18	12	2	2	2					**76**	**3**	**50**
5	40	18	2	2	2	2					**66**	**2**	**50**
6	40	2	2	2	2	2					**50**	**1**	**50**

Max CDV = 50

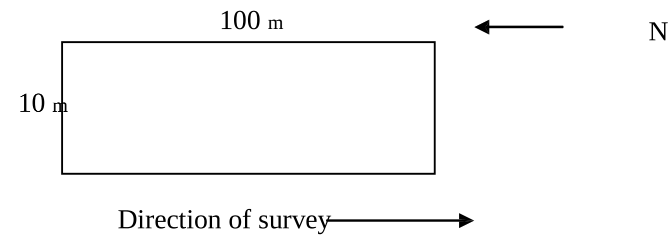
PCI = 100- Max CDV = 50

Rating = Fair

Table A.15 Pavement condition survey data sheet of road No.1

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Sans--Municipality No. of sample: 12
Surveyed by: Date: May,2016



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity**										**Total**	**Density**	**Deduct Value**
1 L	2.1*4.3	5.2*1.70	2*1.90	1.9*1.3	1.0*3	1.8*3.8	1.7*1.3	1.0*6.3			**42.49**	**5.31**	**28**
1 M	0.9*1.6	0.8*2.0	1.0*4.7								**51.25**	**6.4**	**40**
3 L	0.3*3.3	0.7*4.8	0.8*1.0	0.9*3.2							**6.03**	**0.75**	**-**
3 M	0.5*2.7	1.1*0.4									**2.03**	**0.25**	**-**
10 L	3.5	2.00	1.50	1.30	1.00	3.80	4.30	0.90	2.40	1.50			
	2.00	2.50									**26.70**	**3.3**	**3**
10 M	1.90	2.60	2.00	2.45	3.20	2.10	2.90	3.80	2.60		**23.55**	**2.9**	**8**
19 M	8*10										**80**	**10**	**18**

Table A.16 Calculation of corrected PCI value

m = 1+ (9/98) (100-40) = 6.50 ≤ 10

Use highest 6 deducts and 0.50 of six deduct

0.50 *3=1.50

#	**Deduct value**										**Total**	**q**	**CDV**
1	40	28	18	8	1.50						**95.5**	**4**	**56**
2	40	28	18	2	1.50						**89.5**	**3**	**58**
3	40	28	2	2	1.50						**73.5**	**2**	**54**
4	40	2	2	2	1.50						**47.5**	**1**	**48**

Max CDV = 58

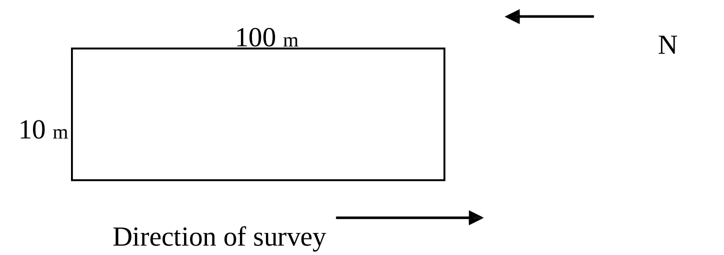
PCI = 100- Max CDV = 42

Rating = Fair

Table A.17 Pavement condition survey data sheet of road No.1

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Sans--Municipality No. of sample: 13
Surveyed by: Date: May,2016



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity**										**Total**	**Density**	**Deduct Value**
1 L	1.2*1.	0.7*1.7	0.3*0.9	1,80*0.	0.3*1.7	0.6*2.1					**6.11**	**0.76**	**8**
1 M	0.4*3	1.7*3	2.3*1.7								**10.21**	**1.27**	**23**
1 H	0.8*3	1*0.7	1.1*0.9	2*4.40							**12.89**	**1.61**	**36**
3 L	0.2*0.	0.6*1.7	3.4*3.8	2,5*4.3							**24.79**	**3.1**	**4**
3 M	1.8*2.	3.5*4.2									**19.2**	**2.4**	**7**
3 H	2.4*2.										**4.8**	**0.6**	**5**
10 M	2.60	2.90	4.30	3.90	2.40						**25.55**	**3.2**	**9**

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-36) = 6.87

Use highest 6 deducts and 0.87 of six deduct

0.87 *4=2.40

#	Deduct value										Total	q	CDV
1	36	22	9	8	7	5	3.48				**90.48**	**7**	**46**
2	36	22	9	8	7	5	2				**89**	**6**	**46**
3	36	22	9	8	7	2	2				**86**	**5**	**46**
4	36	22	9	8	2	2	2				**81**	**4**	**46**
5	36	22	9	2	2	2	2				**75**	**3**	**48**
6	36	22	2	2	2	2	2				**68**	**2**	**50**
7	36	2	2	2	2	2	2				**48**	**1**	**48**

Max CDV = 50

PCI = 100- Max CDV = 50

Rating = Fair

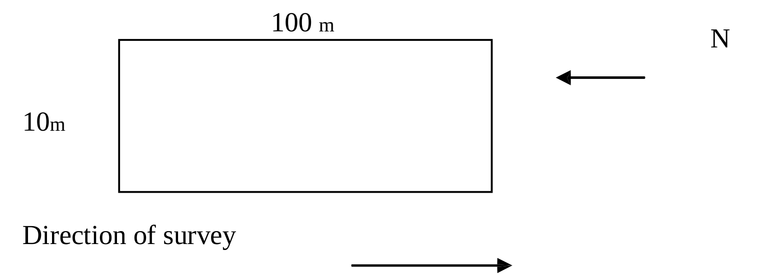
APPENDIX B

SAMPLE CALCULATION OF **PCI** FOR TEST ROAD No TWO AND THREE

Table A.2 Pavement condition survey data sheet for road No. 2

Asphalt surfaced roads
Condition survey data sheet for sample unit

reet : **Dire to Kela** Block No: **01**
ırveyed by: **Group** Date: **May,2008EC**



Alligator/Fatigue cracking 6 Depression 11 Patching &Utility patch 16 Shoving
Bleeding 7 Edge cracking 12 Polished Aggregate 17 Slippage
Block cracking 8 Reflection cracking 13 Potholes 18 Swell
Bumps and sags 9 Lane shoulder drop 14 Rutting 19 Raveling &Weathering
corrugation 10 Longitudinal & Transverse 15 Railroad crossing

Distress everity	**Quantity**									**Tot**	**Densi**	**Deduct Value**
1 L	3*3.5	2*0.6	9*2.7	1*5.8						**16.**	**1.7**	**17.5**
1 M	8*19.2	1*4.1	0*30	8*0.80	9*2.2	0*4.3	2*3.0			**114**	**11.46**	**50**
9H	*1	6*1	8*1							**18.**	1.84	
10 L	4	9	4	6	4	4	4	2.8	1.3	2.1		
	7	6								**29.**	**2.94**	**2.5**
10 M	5	0	5	2	5	65				**20.**	**2.035**	**15**
12	*30	*5								**280**	**28**	**9**
13 L										**4**	**0.4**	**12**

Table A-2 Calculation of corrected PCI value

m = 1+ (9/98) (100-50) = 5.59

Use highest 5 deducts and 0.59 of six deduct

0.59*2.5=1.5

#	**Deduct value**										**Total**	**q**	**CDV**
1	50	17.5	15	12	9	1.5					**105**	**5**	**56**
2	50	17.5	15	12	2	1.5					**89**	**4**	**56**
3	50	17.5	15	2	2	1.5					**99**	**3**	**56**
4	50	17.5	2	2	2	1.5					**55**	2	**55**
5	50	2	2	2	2	1.5					**58.5**	**1**	**81**

Max CDV = 81

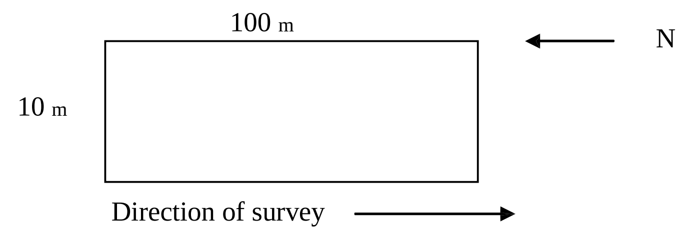
PCI = 100- Max CDV = 19

Rating = Very poor

Table A.3 Pavement condition survey data sheet for road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **02**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	Quantity (m^2)										Total	Density	Deduct Value
5 L	2*1.5	2.5*3.5	4.4*2.6	1.35*3.4	1. 50*2.8	2.6*2					**37.18**	**3.72**	**30**
4 M	2.5*3	2.45*2.7	1.8*2.8	1.6*2							**22.4**	**2.24**	**31**
6 M	2.1*3.2	2.9*0.6									**8.46**	**0.85**	**0**
9 H	6.80	2.70	4.00	2.90	2.40	2.20	2.50	2.16	2.80	3.80			
	3.50	3.90	4.05	4.4	6	8	4						
											65.85	**6.6**	**12**
11 L	12										**12**	**1.5**	**5**
13M	3										**3**	**0.125**	**7**

Table A.4 Calculation of corrected PCI value

m = 1+ (9/98) (100-58) = 4.90

Use highest 4 deducts and 0.90 of six deduct

0.90 *5=4.50

#	**Deduct value**										**Total**	**q**	**CDV**
1	31	30	12	7	4.50						**84.5**	**5**	**44**
2	31	30	12	7	2						**82**	**4**	**48**
3	31	30	12	2	2						**77**	**3**	**66**
4	31	30	2	2	2						**67**	**2**	**50**
5	31	2	2	2	2						**39**	**1**	**40**

Max CDV = 66

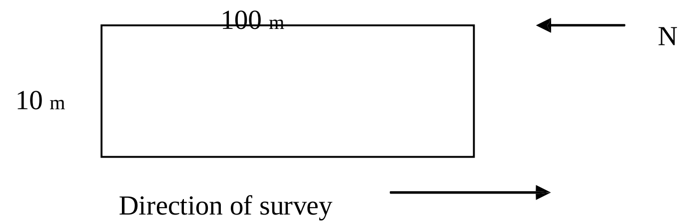
PCI = 100- Max CDV = 34

Rating = **poor**

Table A.5 Pavement condition survey data sheet for road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **03**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
1 L	5.07	26.25	2.325	5.04	14.04	19.25					**71.97**	**8.99**	**32.5**
1 H	2.25	2.34	2.1								**12.27**	**0.8**	**28**
3 H	15.3										**15.3**	**1.91**	**7.5**
11 L	22										**22**	**2.75**	**5**
13 M	2										**2**	**0.25**	**12.5**

Table A.6 Calculation of corrected PCI value

m = 1+ (9/98)(100-32.5) = 7.19

Use highest 6 deducts and 0.19 of six deduct

0.19 *5=0.95

#	Deduct value										Total	q	CDV
1	32.5	28	12.5	7.5	0.95						**81.45**	**4**	**48**
2	32.5	28	12.5	2	0.95						**75.95**	**3**	**50**
3	32.5	28	2	2	0.95						**65.45**	**2**	**50**
4	32.5	2	2	2	0.95						**39.45**	**1**	**40**

Max CDV = 83

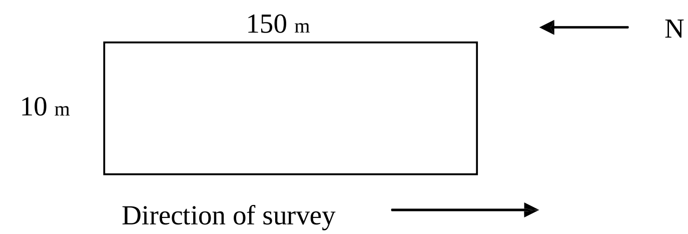
PCI = 100- Max CDV = 17

Rating = **Very poor**

Table A.7 Pavement condition survey data sheet for road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **04**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
9H	3.5*1	2.6*1	6*1	13*1	5.4*1	11*1	9.8*1	14*1	6.5*1				
											198	**13.2**	**40**
10 L	0.6	1.02	0.75	0.8	1.15	1.21	0.4	1.25	1.8	1.4			
	2.15	1.24	2.34	0.55	1.2	1.1					**18.96**	1.264	**2**
10 M	2.5	1.4	1.6	1.5	2	1.8	1.4	1.3	1.64	1.06	**16.2**	**1.08**	**7**
12	4*2	2.8*6	3.3*2.4								**21.92**	**1.15**	**2.5**
13 H	2										**2**	**0.133**	**5**
16L	3*2	7*2.8									**25.6**	**1.71**	**18**

m = 1+ (9/98)(100-40) = 6.51

Use highest 6 deducts and 0.51 of six deduct

0.51 *2=1.02

#	**Deduct value**										**Total**	**q**	**CDV**
1	40	18	7	5	2.5	1.02					**72.78**	**5**	**38**
2	40	18	7	5	2	1.02					**72.28**	**4**	**42**
3	40	18	7	2	2	1.02					**69.28**	**3**	**46**
4	40	18	2	2	2	1.02					**64.28**	**2**	**48**
5	40	2	2	2	2	1.02					**48.28**	**1**	**85**

Max CDV = 85

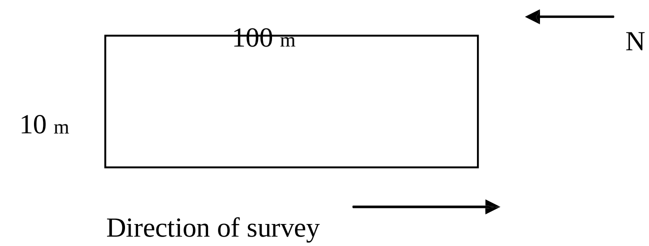
PCI = 100- Max CDV = **15**

Rating **= very poor**

Table A.11 Pavement condition survey data sheet for road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **05**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
4 M	1.1*6.30	1.0*6.4	7.0*5.0	2.5*3.6							**57.33**	**5.73**	**30**
5M	0.95*4.2	1.5*0.50	0.55*5.5	1.0*16.0							**23.76**	**2.4**	**32**
9 H	5.0*0.45	2.3*3.2	0.9*8.1	6.80*3.5							**40.70**	**4.07**	**5**
9M	2.2*0.90										**1.98**	**0.2**	**-**
10 L	1.00	1.80	1.90	0.70	2.70	3.10	5.30				**16.5**	**1.65**	**-**
10 M	1.60	2.60	3.00	0.70	1.30	1.50	2.65	3.40	1.00		**17.75**	**1.8**	**6**
11 M	1.5*2	2.5*2.3									8.75	0.875	**10**
12	8*2										**16**	**1.6**	**7**

Table A.12 Calculation of corrected PCI value

m = 1+ (9/98)(100-32) = 7.24

Use highest 7 deducts and 0.24 of six deduct

0.24 *5=1.2

#	Deduct value										Total	q	CDV
1	32	30	10	7	6	1.2					**86.2**	**5**	**46**
2	32	30	10	7	2	1.2					**82.2**	**4**	**46**
3	32	30	10	2	2	1.2					**77.2**	**3**	**50**
4	32	30	2	2	2	1.2					**69.2**	**2**	**50**
5	32	2	2	2	2	1.2					**41.2**	**1**	**81**

Max CDV = 81

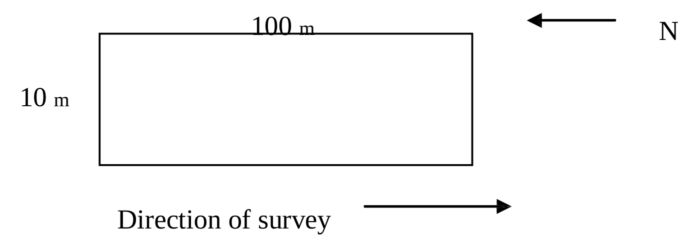
PCI = 100- Max CDV = **19**

Rating = Very poor

Table A.13 Pavement condition survey data sheet of road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **06**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
1 M	1.1*5.6	3.0*6.70	0.80*2.80	3.40*4							**42.10**	**5.26**	**40**
3 M	2.4*0.8	2.0*3.70	1.4*1.6	1.0*1.40	1.0*1.0	2.30*1.9	0.60*2.3				**19.71**	**2.29**	**18**
3 H	15*2.4	10.5*3.9									**76.95**	**9.60**	**8**
4 H	3.4*3.1	2.6*3.2									**18.86**	**2.35**	**7**
7H	1.3*1.8	2.1*4	1.21*1.85								**12.97**	1.30	9
10 M	1.60	2.20	1.00	2.40	3.00	2.30	3.20	2.30			**18**	**2.25**	**6**
13 L	4										**4**	**0.50**	**12**

Table A.14 Calculation of corrected PCI value

m = 1+ (9/98) (100-40) = 6.50

Use highest 6 deducts and 0.51 of six deduct

0.50 *6=3

#		Deduct value										Total	q	CDV
1	40	18	12	9	8	7	3					**97**	**7**	**42**
2	40	18	12	9	8	7	2					**96**	**6**	**46**
3	40	18	12	9	8	2	2					**89**	**5**	**48**
4	40	18	12	9	2	2	2					**85**	**4**	**50**
5	40	18	12	2	2	2	2					**78**	**3**	**50**
6	40	18	2	2	2	2	2					**68**	**2**	**80**
7	40	2	2	2	2	2	2					**52**	**1**	

Max CDV = 80

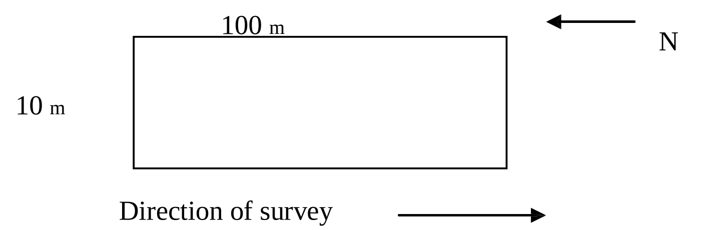
PCI = 100- Max CDV = 20

Rating = Fair

Table A.15 Pavement condition survey data sheet of road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **07**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 Corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress/ severity	**Quantity (m^2)**									**Total**	**Density**	**Deduct Value**
1M	2.8	2.18	7.2	1.84	3.24					**17.26**	**1.73**	28
2M	4	6.2	5.32	4.24						**19.76**	**1.98**	6.5
3 M	2.25	2.34	2.1							**12.27**	**1.227**	**7**
3 H	15.3									**15.3**	**1.53**	**7.5**
7M	1.6	0.84	1.68	2.14						**6.26**	**0.63**	8.5
8 L	2.3	1.2								**3.5**	**0.35**	0
9 H	5.07	26.25	2.325	5.14	14.04	19.25	6.2	18.4	12.4	**89.075**	**8.91**	**15**
11 L	22									**22**	**2.2**	**5**
13 M	2									**2**	**0.20**	**10**
16M	1.54	2.8	3.2							**7.54**	**0.754**	8
17 H	2.46	1.24	1.4	3.12						**8.22**	**0.822**	32.5

Table A.6 Calculation of corrected PCI value

m = 1+ (9/98)(100-32.5) = 7.19

Use highest 7 deducts and 0.19 of six deduct

0.19 *5=0.95

#	**Deduct value**										**Total**	**q**	**CDV**
1	32.5	28	15	10	8.5	8	7.5	7	6.5	0.95	**123.95**	8	50
2	32.5	28	15	10	8.5	8	7.5	7	2	0.95	**119.45**	7	50
3	32.5	28	15	10	8.5	8	7.5	2	2	0.95	**114.45**	6	51
4	32.5	28	15	10	8.5	8	2	2	2	0.95	**108.95**	5	52
5	32.5	28	15	10	8.5	2	2	2	2	0.95	**102.95**	4	54
6	32.5	28	15	10	2	2	2	2	2	0.95	**96.45**	3	48
7	32.5	28	15	2	2	2	2	2	2	0.95	**88.45**	2	50
8	32.5	28	2	2	2	2	2	2	2	0.95	**75.45**	1	83

Max CDV = 83

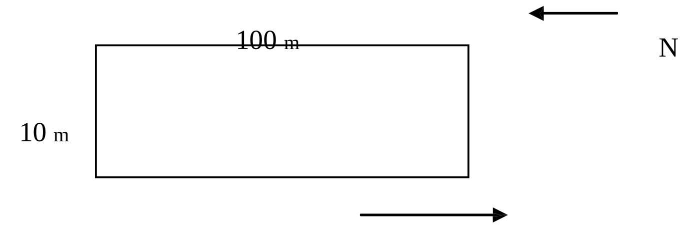
PCI = 100- Max CDV = 17

Rating = **Very poor**

Table A.17 Pavement condition survey data sheet of road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **08**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	Quantity (m^2)										Total	Density	Deduct Value
1 L	1.92	1.19	0.27	0.9	0.51	1.26					6.05	0.605	8
1 M	1.2	5.1	3.91								10.21	1.021	23
1 H	2.4	0.7	9.9	8.8							21.8	2.18	36
3 L	0.1	1.02	12.92	10.7							24.79	2.479	4
3 M	4.5	14.7									19.2	1.92	7
3 H	4.8										4.8	0.48	5
5H	2.78	3	1.68								7.46	0.746	34
9H	2.8	3.4	12	1.8	8.98	2.6	3.8	4.92			40.3	4.03	8.5
10 M	2.6	2.9	4.3	3.9	2.4						16.1	1.61	9

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-36) = 6.87

Use highest 6 deducts and 0.87 of six deduct

0.87 *4=2.40

#		**Deduct value**										**Total**	**q**	**CDV**
1	36	34	23	9	8.5	8	7	5	2			**132.5**	**7**	**65**
2	36	34	23	9	8.5	8	7	2	2			**129.5**	**6**	**58**
3	36	34	23	9	8.5	8	2	2	2			**124.5**	**5**	**62**
4	36	34	23	9	8.5	2	2	2	2			**118.5**	**4**	**78**
5	36	34	23	9	2	2	2	2	2			**112**	**3**	**70**
6	36	34	23	2	2	2	2	2	2			**105**	**2**	**72**
7	36	2	2	2	2	2	2	2	2			**52**	**1**	**48**

Max CDV = 78

PCI = 100- Max CDV = 22

Rating = Poor

Table A.17 Pavement condition survey data sheet of road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **09**
Surveyed by: **Group** Date: **May,2008EC**

100 m ← N
10 m
Direction of survey →

1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
1 L	1.92	1.19	0.27	0.51	1.26						5.15	0.515	7
4 H	1.4	2.7	8.98	8.8							21.8	2.188	45
5 L	2.22	1.4	1.6	2	1.64						8.86	0.886	4
6 M	3.2	2.26									5.46	0.546	8
7 H	4.8										4.8	0.48	7
9H	2.8	3.4	12	1.8	8.98	2.6	3.8	4.92			40.3	4.03	9
10 M	2.6	2.9	4.3	3.9	2.4						16.1	1.61	12
16H	4	5.4	2.6	7.8							19.8	1.98	27
17L	2.5	2.4									4.9	0.49	13

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-45) = 6.05

Use highest 6 deducts and 0.05 of six deduct

0.05 *4=0.2

#	Deduct value										Total	q	CDV
1	45	27	13	12	9	8	7	0.2			**121.2**	**7**	**65**
2	45	27	13	12	9	8	2	0.2			**116.2**	**6**	**58**
3	45	27	13	12	9	2	2	0.2			**110.2**	**5**	**62**
4	45	27	13	12	2	2	2	0.2			**103.2**	**4**	**78**
5	45	27	13	2	2	2	2	0.2			**93.2**	**3**	**70**
6	45	27	2	2	2	2	2	0.2			**82.2**	**2**	**72**
7	45	2	2	2	2	2	2	0.2			**57.2**	1	76

Max CDV = 76

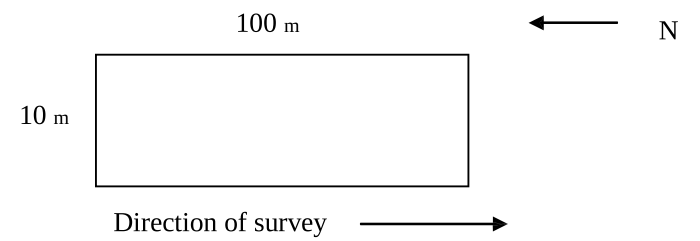
PCI = 100- Max CDV = 24

Rating = Poor

Table A.17 Pavement condition survey data sheet of road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **10**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	Quantity (m^2)										Total	Density	Deduct Value
1H	2	1.6	2.32	5.6	7.8	9.87					29.1	2.919	51
3M	1.28	5.6	4.32	1.8	2						15	1.5	6
5H	3.46	7.8	1.2								12.4	1.246	38
6M	1.8	2.4	2.54	1.92							8.66	0.866	9
7H	3	1.72	2.22								6.94	0.694	9.5
9H	12	8.54	2.64	1.6	1.2	2.832	7.4	4.24			40.4	4.0452	8.5
13H	4										4	0.4	33
18H	2.21	2.02									4.23	0.423	0

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-51) = 5.68

Use highest 6 deducts and 0.68 of six deduct

0.68 *6=4.8

#	Deduct value										Total	q	CDV
1	51	38	33	9.5	9	8.5	2				**151**	6	**70**
2	51	38	33	9.5	9	2	2				**144.5**	5	**72**
3	51	38	33	9.5	2	2	2				**137.5**	4	**72**
4	51	38	33	2	2	2	2				**130**	3	**75**
5	51	38	2	2	2	2	2				**99**	2	**60**
6	51	2	2	2	2	2	2				**63**	1	**62**

Max CDV = 75

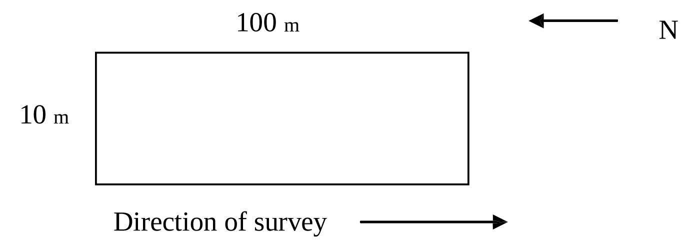
PCI = 100- Max CDV = 25

Rating = Poor

Table A.17 Pavement condition survey data sheet of road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **11**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
1 L	2	1.4	1.8	2.8	1.92						9.92	0.992	12
1H	1.8	2.46	2.1								6.36	0.636	24
2L	1.24	1.74									2.98	0.298	0
8H	2.2	1.12	1.72								5.04	0.504	5
9H	10.24	2.76	4.6	8.64	2.28	12	5.6	7.42			53.5	5.354	10
10M	1.8	1.5	1.3	1.25							5.85	0.585	0
11H	2.12	1.34	4.12								7.58	0.758	18
12	6.4										6.4	0.64	0

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-45) = 6.97

Use highest 6 deducts and 0.97 of six deduct

0.97 *5= 4.85

#	Deduct value										Total	q	CDV
1	24	18	12	10	2						**66**	4	79
2	24	18	12	2	2						**58**	3	32
3	24	18	2	2	2						**48**	2	38
4	24	2	2	2	2						**32**	1	34

Max CDV = 79

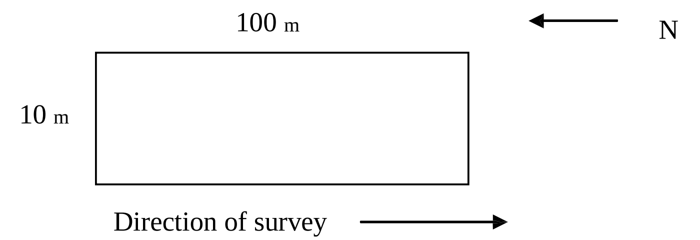
PCI = 100- Max CDV = 21

Rating = Poor

Table A.17 Pavement condition survey data sheet of road No.2

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **Dire to Kela** Block No: **12**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
1H	4.2	1.24	2	1.3	1.8	1.2	2.31				14.05	1.405	33
3M	3.32	3	5.78	1.28	1.08						14.46	1.446	7
4H	2	2.42	3.4	1.24	3.4	5.2					17.66	1.766	45
9H	12	13.4	16	8.4	8.54	7.8	18	1.8	14.2	5.3	105.46	10.546	23
13M	2	3.6									5.6	0.56	22
14H	4.8	1.72									6.52	0.652	22
17M	2.68										2.68	0.268	5
18L	4.2	2.8	3.68								10.68	1.068	35

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-45) = 6.05

Use highest 6 deducts and 0.05 of six deduct

0.05 *5=0.25

#	Deduct value										Total	q	CDV
1	45	35	33	23	22	7	0.25				**165.25**	6	78
2	45	35	33	23	22	2	0.25				**160.25**	5	74
3	45	35	33	23	2	2	0.25				**140.25**	4	76
4	45	35	33	2	2	2	0.25				**119.25**	3	82
5	45	35	2	2	2	2	0.25				**88.25**	2	61
6	45	2	2	2	2	2	0.25				**55.25**	1	53

Max CDV = 82

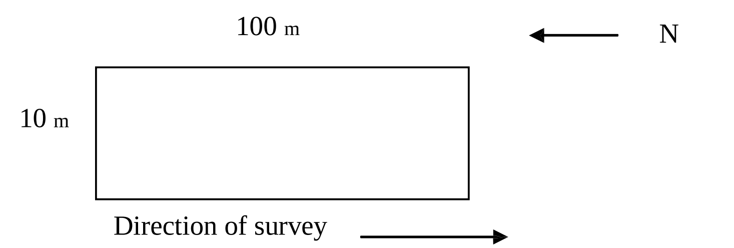
PCI = 100- Max CDV = 18

Rating = Poor

Table A.17 Pavement condition survey data sheet of road No.3

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **M/G Kebele to G/N Kebele** Block No: **5**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
2L	2.36	1.6	5.7	3.4							13.06	1.306	0
4M	1.6	1.84	2								5.44	0.544	8
9H	13.4	14	2	11.84	16	15.3					72.54	7.254	12
14M	2	1.98									3.98	0.398	11
18H	1.68										1.68	0.168	0
19L	4.8	6									10.8	1.08	3

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-45) = 6.05

Use highest 6 deducts and 0.05 of six deduct

0.05 *5=0.25

#	Deduct value										Total	q	CDV
1	12	11	8	3	0.25						**34.25**	4	44
2	12	11	8	2	0.25						**33.25**	3	22
3	12	11	2	2	0.25						**27.25**	2	20
4	12	2	2	2	0.25						**18.25**	1	16

Max CDV = 44

PCI = 100- Max CDV = 66

Rating = Faair

Table A.17 Pavement condition survey data sheet of road No.3

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **M/G Kebele to G/N Kebele** Block No: **6**
Surveyed by: **Group** Date: **May,2008EC**

100 m ← N
10 m
Direction of survey →

1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
1 M	3.3*0.6	3.4*1.2	0.5*1.3	5.3*4.4	1.7*8.5						**44.48**	**5.56**	**40**
10 L	2.20	2.00	0.70	2.50	2.00	1.20	2.80	1.80	2.50	1.50			
	2.10	2.40	2.10								**25.80**	**3.30**	**2**
10 M	3.30	1.80	3.20	2.30	2.40	3.00	2.20	3.30	3.90		**25.40**	**3.20**	**7**
11 L	4										**4**	**0.50**	**2.5**
13 L	1										**1**	**0.20**	**5**
19 M	8*10										**80**	**10**	**18**

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-45) = 6.05

Use highest 6 deducts and 0.05 of six deduct

0.05 *5=0.28

#	**Deduct value**									**Total**		**q**	CDV
1	40	18	7	5	2.5	0.28					**72.78**	**5**	**38**
2	40	18	7	5	2	0.28					**72.28**	**4**	**42**
3	40	18	7	2	2	0.28					**69.28**	**3**	**46**
4	40	18	2	2	2	0.28					**64.28**	**2**	**46**
5	40	2	2	2	2	0.28					**48.28**	**1**	**44**

Max CDV = 46

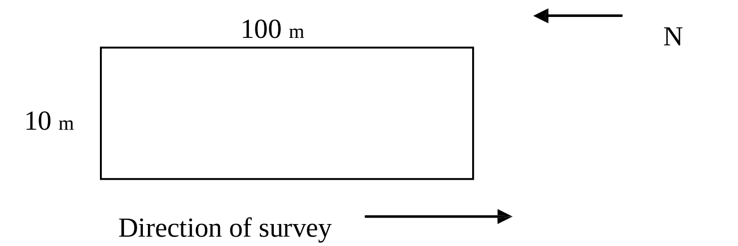
PCI = 100- Max CDV = 64

Rating = Fair

Table A.17 Pavement condition survey data sheet of road No.3

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **M/G Kebele to G/N Kebele** Block No: **7**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress/ severity	Quantity (m^2)										Total	Density	Deduct Value
2M	4.32	1.86	1.4	2.04	1.78						11.4	1.14	6
4L	3.62	1.64	3.98	1.68	2.24	1.2					14.36	1.436	9
5H	4	2.34	1.4								7.74	0.774	32
9H	8	9.86	10.42	12.42	7.64	4	2.2				54.54	5.454	10
14M	2.2	3.62	5.8								11.62	1.162	25
18M	4.42	1.8									6.22	0.622	0
19L	1.74	4	1.4								7.14	0.714	12

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-32) = 6.25

Use highest 5 deducts and 0.25 of six deduct

0.25 *6=0.25

#	Deduct value										Total	q	CDV
1	32	25	12	10	9	2					**90**	5	52
2	32	25	12	10	2						**81**	4	48
3	32	25	12	2	2	2					**75**	3	44
4	32	25	2	2	2	2					**65**	2	46
5	32	2	2	2	2	2					**42**	1	40

Max CDV = 40

PCI = 100- Max CDV = 60

Rating = Fair

Table A.17 Pavement condition survey data sheet of road No.3

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **M/G Kebele to G/N Kebele** Block No: **8**
Surveyed by: **Group** Date: **May,2008EC**

100 m ← N
10 m
Direction of survey →

1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 Corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress/ severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
3H	2.6	4.2	2.1	1.78	4.6						15.28	1.528	8
4H	3.624	2.86	5.2								11.684	1.1684	42
5M	1.6	1.64	2.16	1.8							7.2	0.72	12
7H	4	2.14									6.14	0.614	9
9H	6.8	13.4	4.68	8	2.74						35.62	3.562	8.5
13H	3.6										3.6	0.36	32
16L	1.46	2.52	4.6								8.58	0.858	4
18M	3.2	6									9.2	0.92	-

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-42) = 6.32

Use highest 6 deducts and 0.32 of six deduct

0.32 *4= 1.28

#	Deduct value										Total	q	CDV
1	42	32	12	9	8.5	8	2				**113.5**	6	46
2	42	32	12	9	8.5	2	2				**107.5**	5	42
3	42	32	12	9	2	2	2				**101**	4	48
4	42	32	12	2	2	2	2				**94**	3	40
5	42	32	2	2	2	2	2				**84**	2	46
6	42	2	2		2	2	2				**52**	1	42

Max CDV = 48

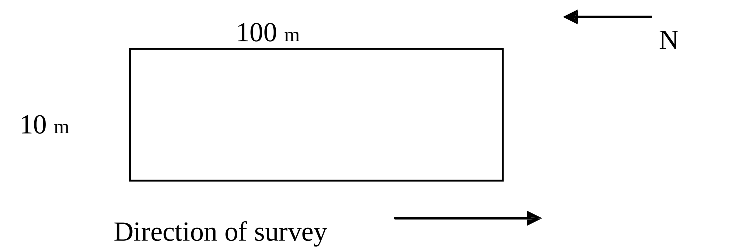
PCI = 100- Max CDV = 52

Rating = Fair

Table A.17 Pavement condition survey data sheet of road No.3

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **M/G Kebele to G/N Kebele** Block No: **9**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
1H	2.4	1.2	3.2	1.12							7.92	0.792	36
2H	4	2.2									6.2	0.62	5
4H	4.8	1.84	2.64	1.21	3.12						13.61	1.361	34
9H	8.4	2	12	5.68	6.74	5.82	1.82				42.46	4.246	8.5
13H	4	1.62									5.62	0.562	22
14M	2.86										2.86	0.286	9.5
18L	2										2	0.2	-
19M	8										8	0.8	8

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-36) = 6.88

Use highest 6 deducts and 0.88 of six deduct

0.88 *5=4.4

#	Deduct value										Total	q	CDV
1	36	34	22	9.5	8.5	8	2				**120**	6	49
2	36	34	22	9.5	8.5	2	2				**114**	5	46
3	36	34	22	9.5	2	2	2				**107.5**	4	48
4	36	34	22	2	2	2	2				**100**	3	48
5	36	34	2	2	2	2	2				**80**	2	50
6	36	2	2	2	2	2	2				**48**	1	47

Max CDV = 50

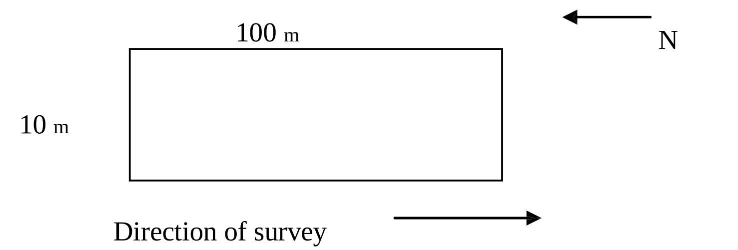
PCI = 100- Max CDV = 50

Rating = Fair

Table A.17 Pavement condition survey data sheet of road No.3

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **M/G Kebele to G/N Kebele** Block No: **10**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking
2 Bleeding
3 Block cracking
4 Bumps and sags
5 corrugation
6 Depression
7 Edge cracking
8 Reflection cracking
9 Lane shoulder drop
10 Longitudinal & Transverse
11 Patching &Utility patch
12 Polished Aggregate
13 Potholes
14 Rutting
15 Railroad crossing
16 Shoving
17 Slippage
18 Swell
19 Raveling &Weathering

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
1M	2.4	4.46	8.74	6.2	2.84						24.64	2.464	28
4H	3.42	2	2.14								7.56	0.756	34
5H	4	2.46	2	2.6							11.06	1.106	36
7H	2.8	1.98	3.68	4.8	1.64						14.9	1.49	9.5
9H	14.6	10.84	15.72								41.16	4.116	9
16H	2	5.8									7.8	0.78	18
18H	4.2	2.24									6.44	0.644	-
19H	6.24										6.24	0.624	14

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-36) = 6.88

Use highest 6 deducts and 0.88 of six deduct

0.88 *9=7.92

#	Deduct value									Total	q	CDV
1	36	34	28	18	14	9.5	2			**141.5**	6	40
2	36	34	28	18	14	2	2			**134**	56	44
3	36	34	28	18	2	2	2			**122**	4	45
4	36	34	28	2	2	2	2			**106**	3	44
5	36	34	2	2	2	2	2			**80**	2	42
6	36	2	2	2	2	2	2			**48**	1	46

Max CDV = 46

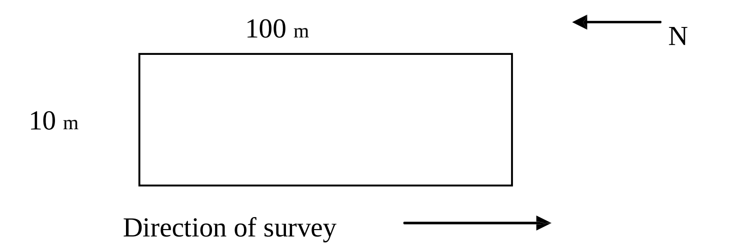
PCI = 100- Max CDV = 54

Rating = Fair

Table A.17 Pavement condition survey data sheet of road No.3

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **M/G Kebele to G/N Kebele** Block No: **11**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
2H	2.6	1.2	1.4								5.2	0.52	4
4H	3.4	6.2									9.6	0.96	34
5M	2.42	1.26	1.82	1.64	2.22	1.72					11.08	1.108	10.5
6H	4	2									6	0.6	16
9H	12	16.78	10.08	3.6							42.46	4.246	8
14H	6										6	0.6	24
18M	4										4	0.4	-

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-34) = 7.06

Use highest 6 deducts and 0.06of six deduct

0.06 *4= 0.24

#	Deduct value										Total	q	CDV
1	34	24	16	10.5	8	0.24					**92.74**	5	48
2	34	24	16	10.5	2	0.24					**86.74**	4	46
3	34	24	16	2	2	0.24					**78.24**	3	47
4	34	24	2	2	2	0.24					**64.24**	2	26
5	34	2	2	2	2	0.24					**42.24**	1	43

Max CDV = 47

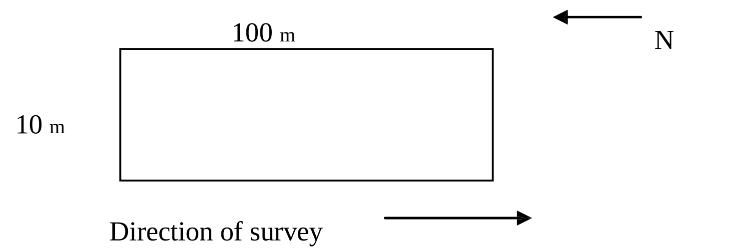
PCI = 100- Max CDV = 53

Rating = Fair

Table A.17 Pavement condition survey data sheet of road No.3

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **M/G Kebele to G/N Kebele** Block No: **12**
Surveyed by: **Group** Date: **May,2008EC**



1 Alligator/Fatigue cracking	6 Depression	11 Patching &Utility patch	16 Shoving
2 Bleeding	7 Edge cracking	12 Polished Aggregate	17 Slippage
3 Block cracking	8 Reflection cracking	13 Potholes	18 Swell
4 Bumps and sags	9 Lane shoulder drop	14 Rutting	19 Raveling &Weathering
5 corrugation	10 Longitudinal & Transverse	15 Railroad crossing	

Distress severity	**Quantity (m^2)**										**Total**	**Density**	**Deduct Value**
3H	2.6	4.2	2.1	1.78	4.6						15.28	1.528	8
4H	3.624	2.86	5.2								11.684	1.1684	42
5M	1.6	1.64	2.16	1.8							7.2	0.72	12
7H	4	2.14									6.14	0.614	9
9H	6.8	13.4	4.68	8	2.74						35.62	3.562	8.5
13H	3.6										3.6	0.36	32
16L	1.46	2.52	4.6								8.58	0.858	4
18M	3.2	6									9.2	0.92	-

Table A.18 Calculation of corrected PCI value

m = 1+ (9/98) (100-42) = 6.88

Use highest 6 deducts and 0.88 of six deduct

0.88 *4=4.4

#	Deduct value										Total	q	CDV
1	42	32	12	9	8.5	8	2				**113.5**	6	46
2	42	32	12	9	8.5	2	2				**107.5**	5	42
3	42	32	12	9	2	2	2				**101**	4	48
4	42	32	12	2	2	2	2				**94**	3	40
5	42	32	2	2	2	2	2				**84**	2	46
6	42	2	2		2	2	2				**52**	1	42

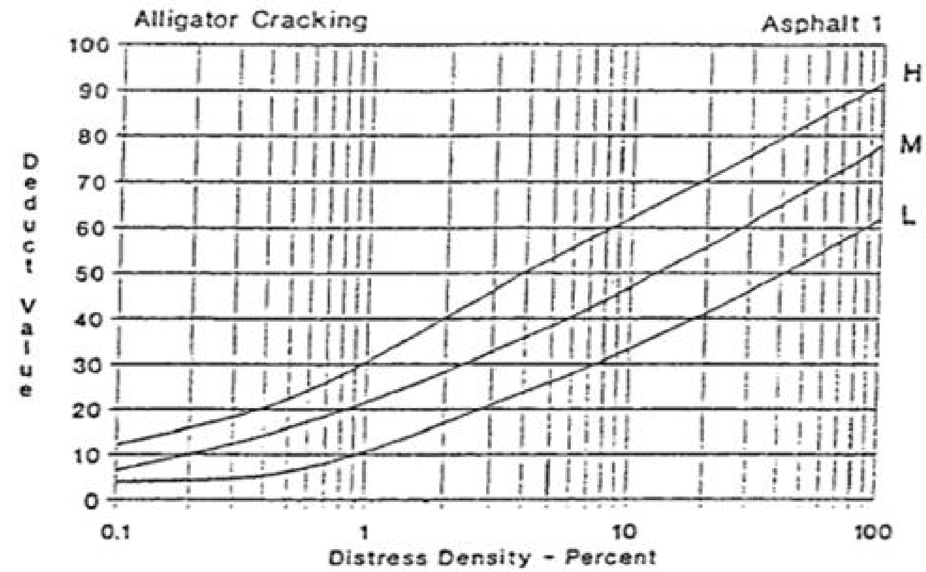
Max CDV = 48

PCI = 100- Max CDV = 52

Rating = Fair

APPENDIX C

DEDUCT VALUE CURVES FOR ASPHALT



FigureB.1 Alligator Cracking

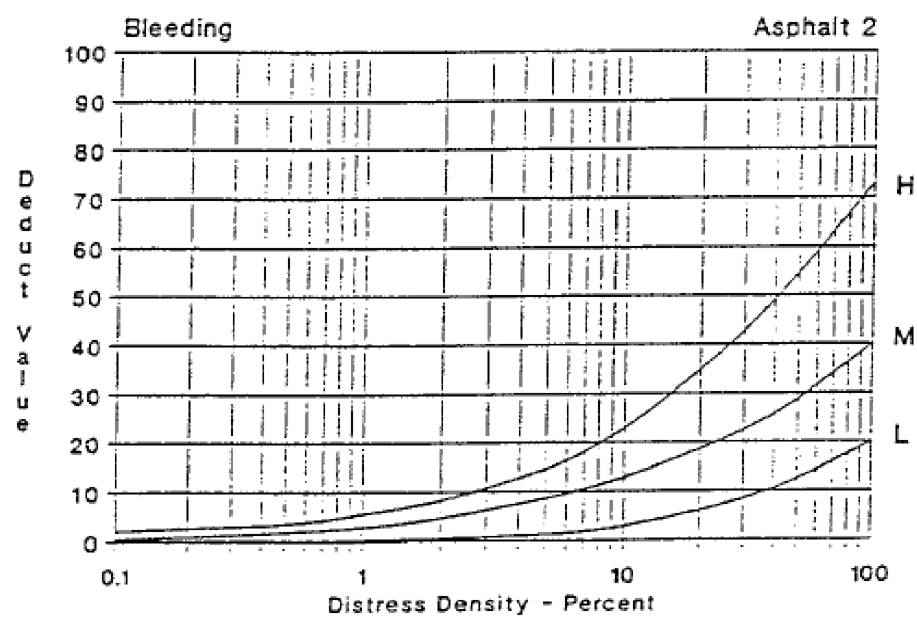


Figure B.2 Bleeding

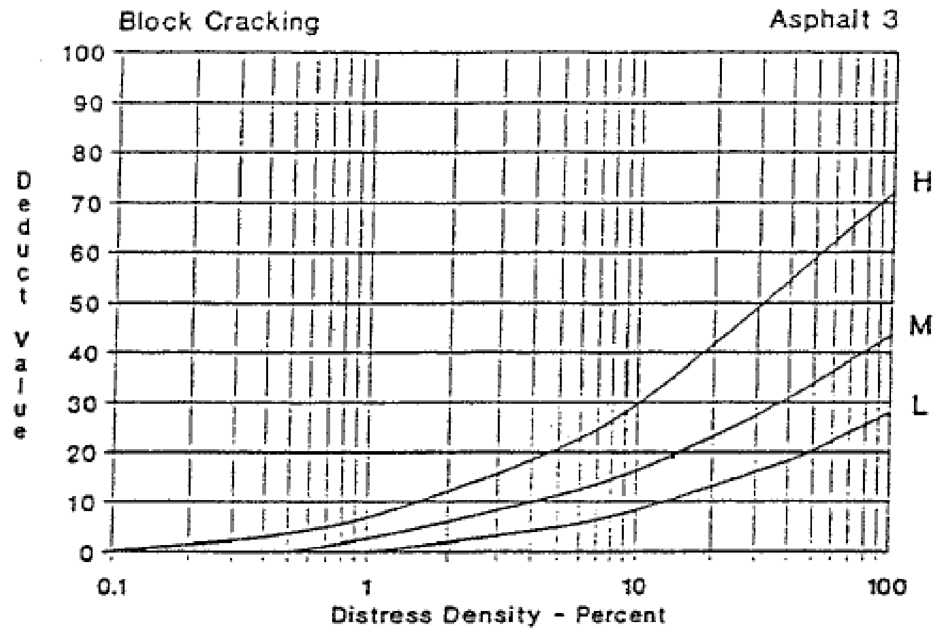


Figure B.3 Block cracking

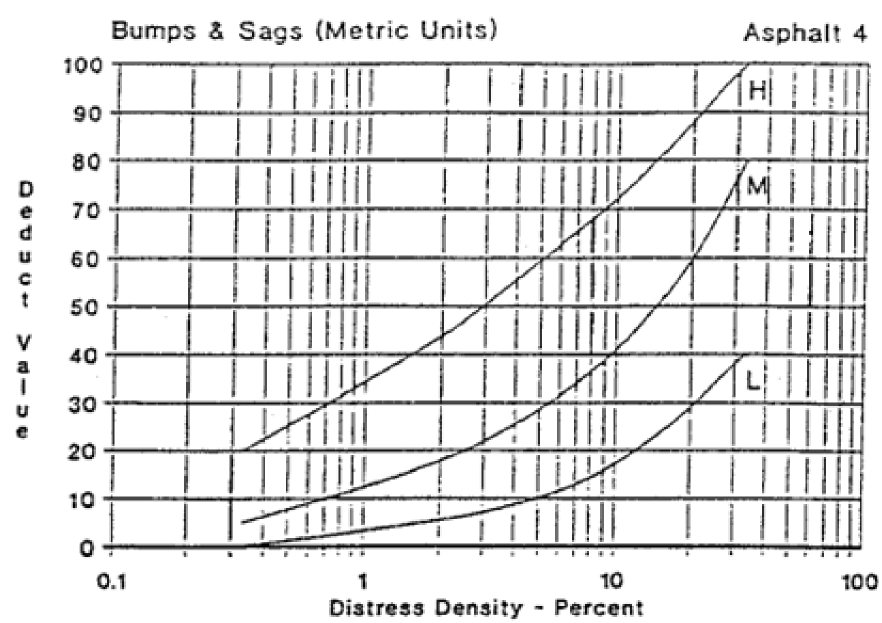


Figure B.4 Bumps & Sags

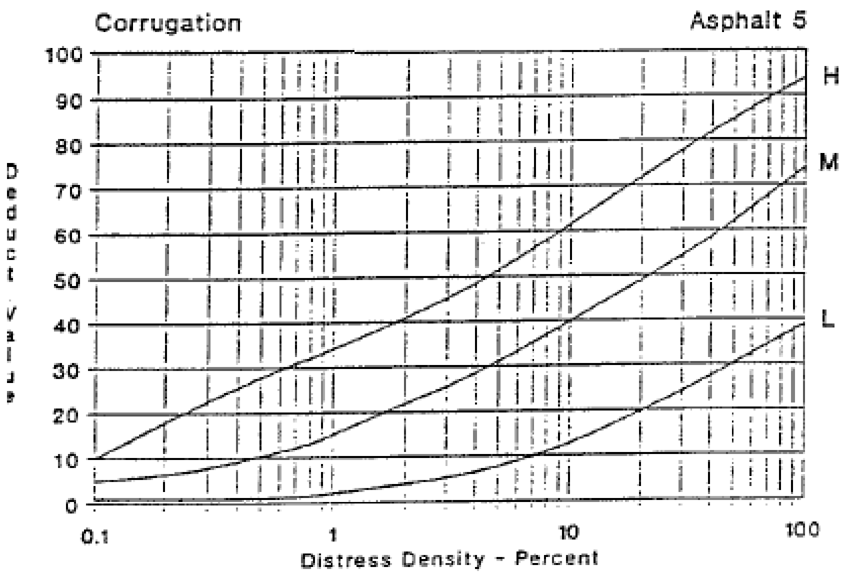


Figure B.5 Corrugation

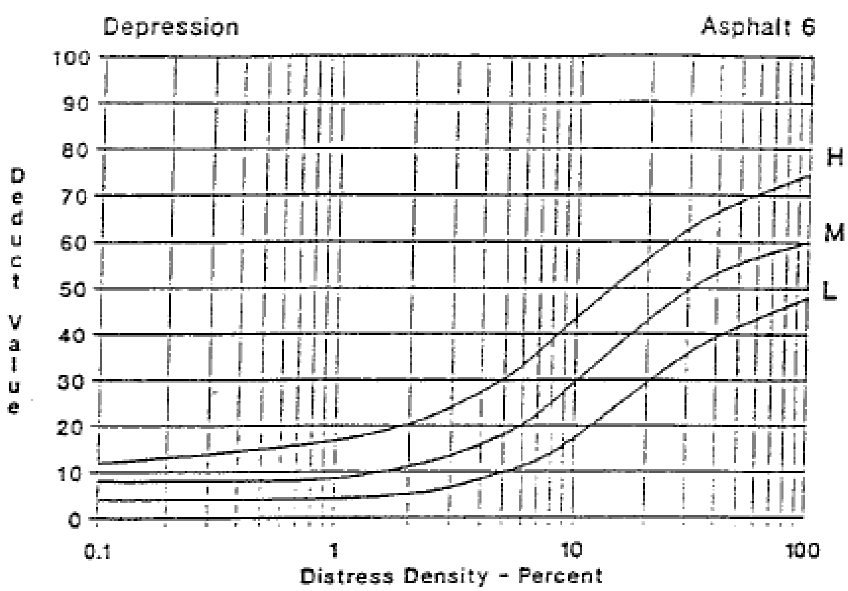


Fig B.6 Depression

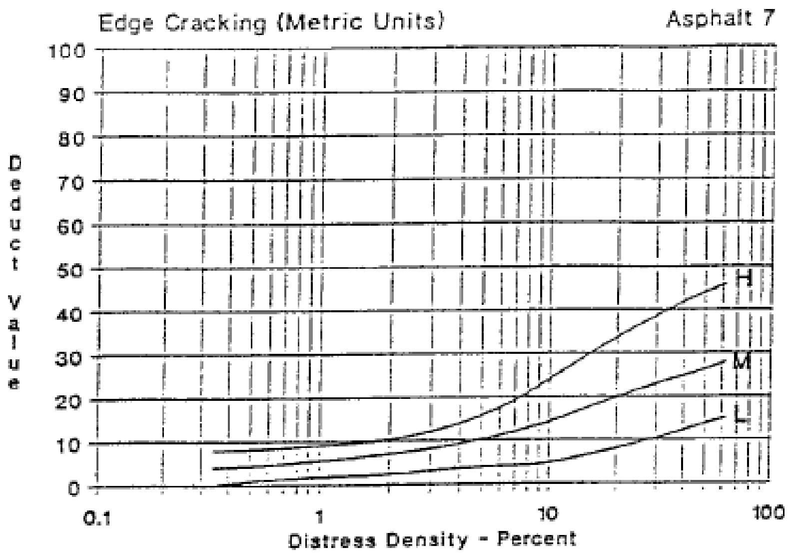


Fig B.7 Edge Cracking

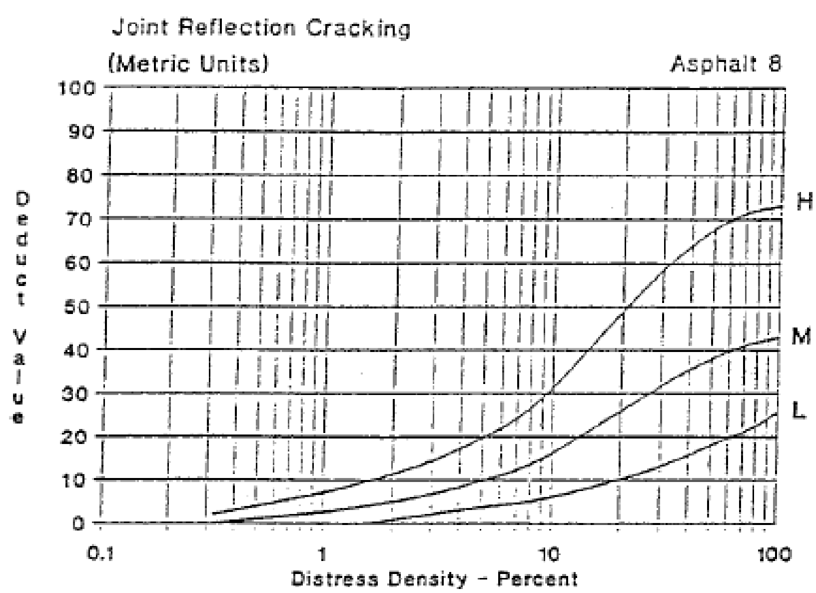


Fig B.8 Reflection Cracking

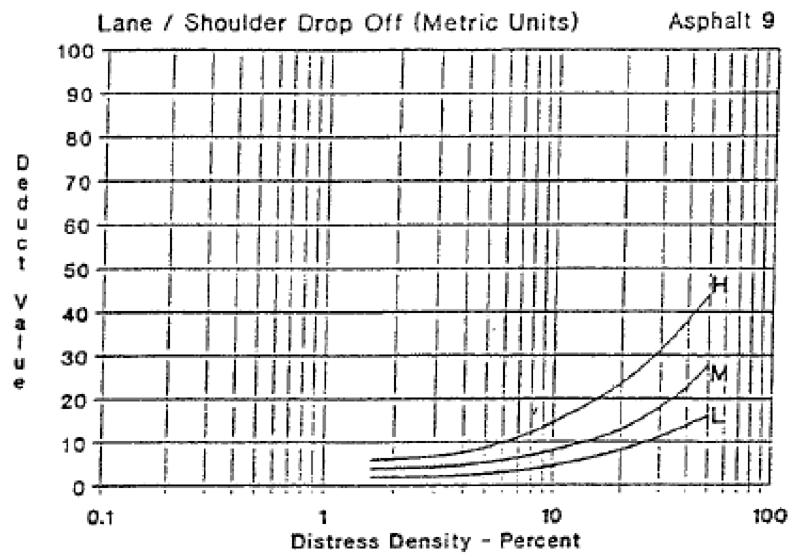


Figure B.9 Lane/Shoulder Drop off

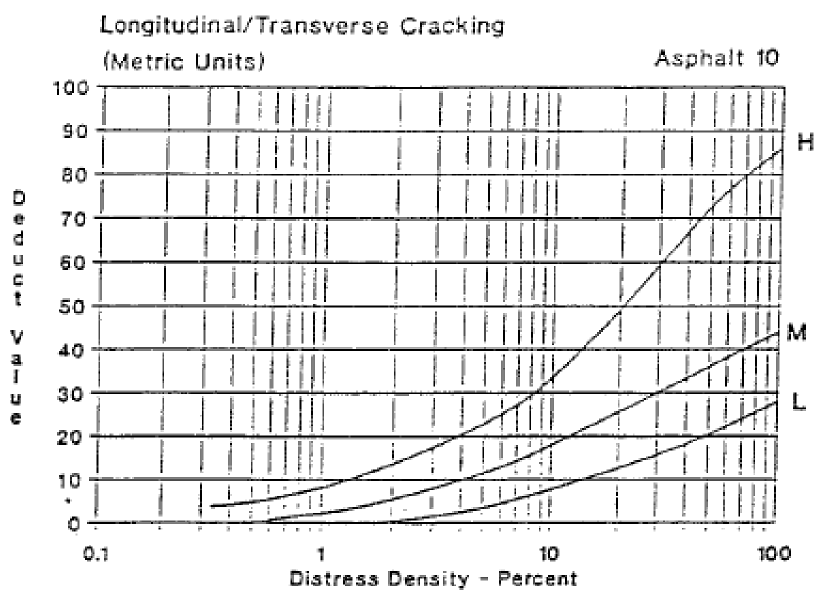


Figure B.10 Longitudinal /Transverse cracking

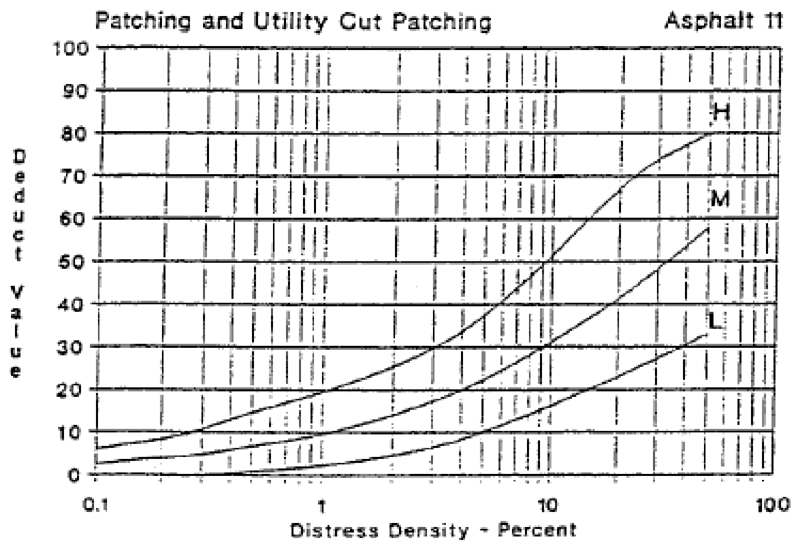


Figure B.11 Patching and Utility cut patching

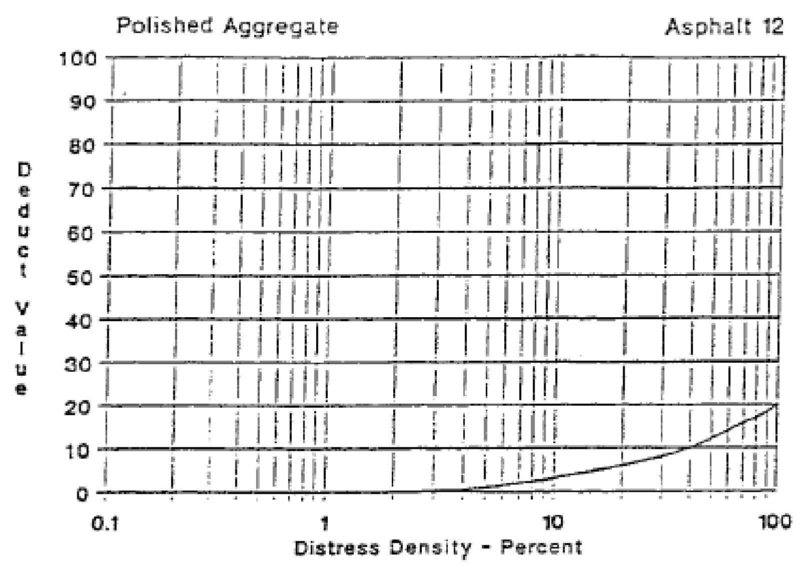


Figure B.12 Polished Aggregate

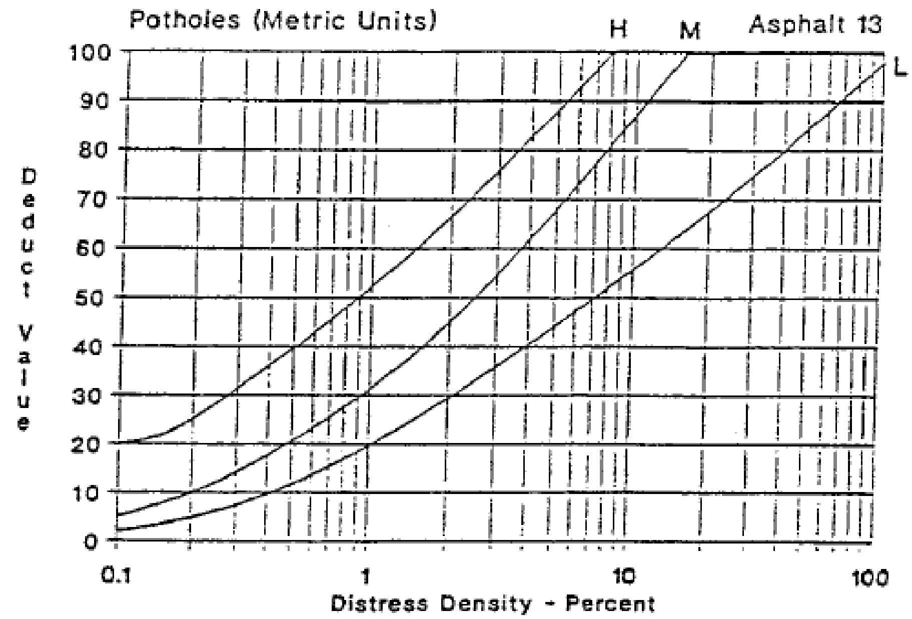


Figure B.13 Potholes

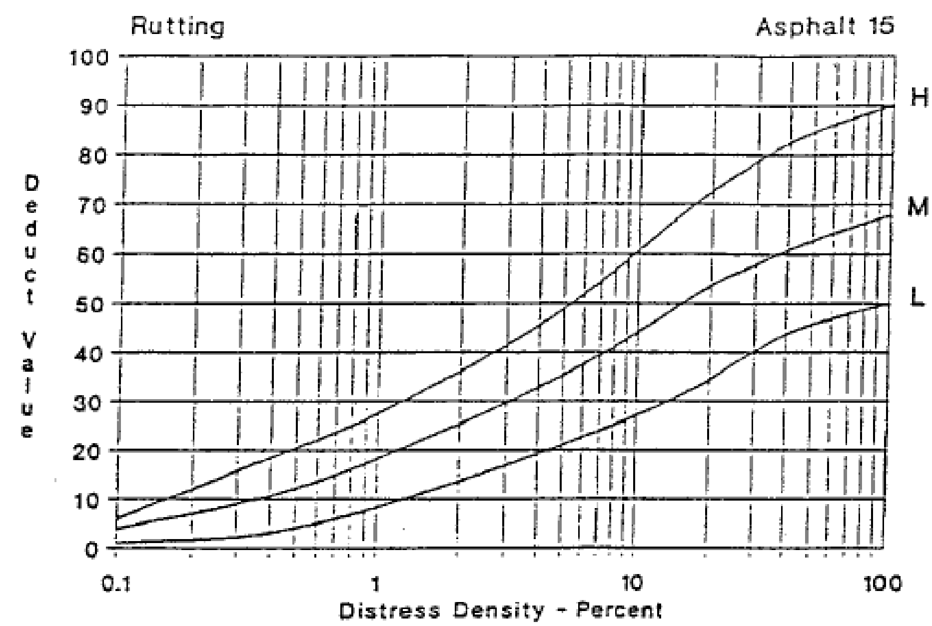


Figure B.14 Rutting

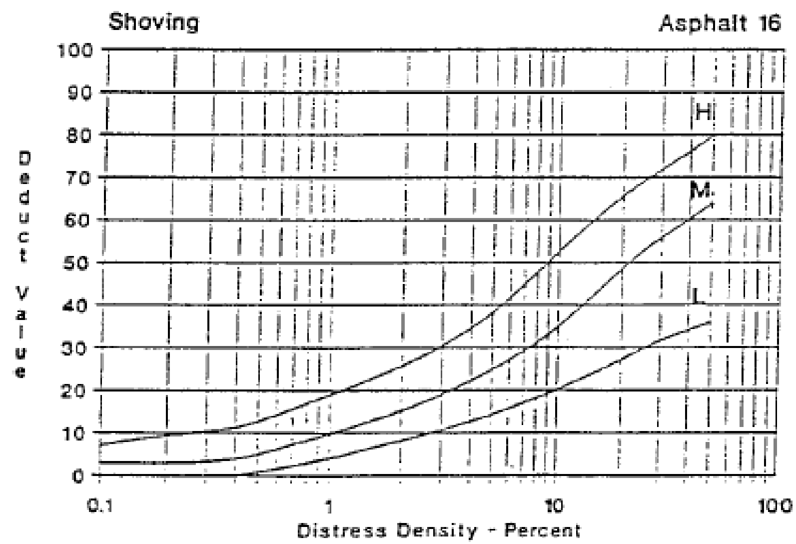


Figure B.15 Shoving

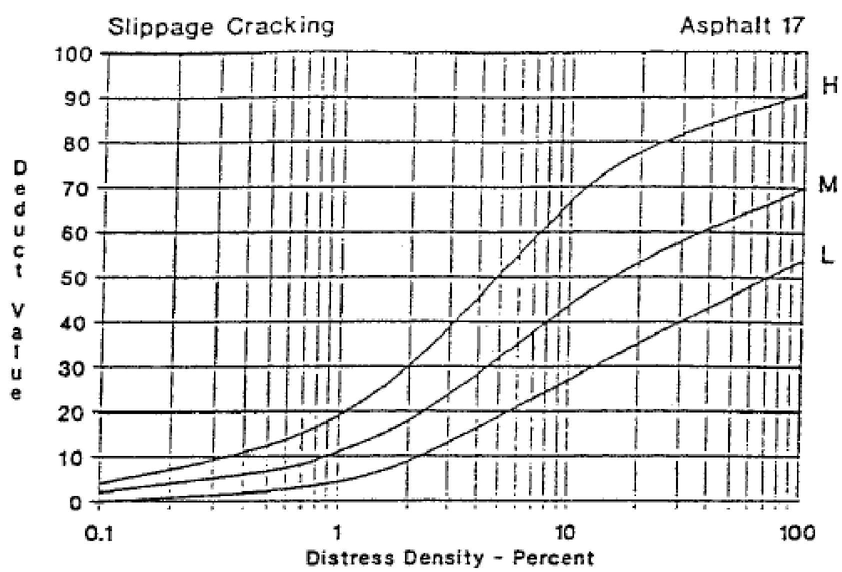


Figure B.16 Slippage Cracking

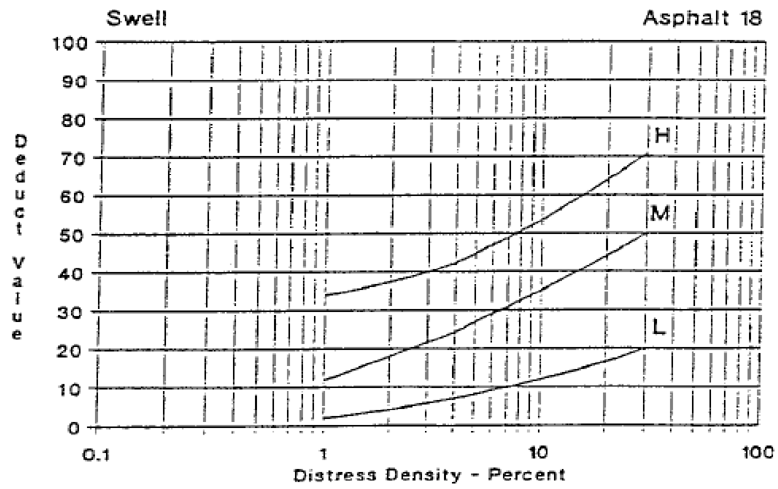


Figure B.17 Swell

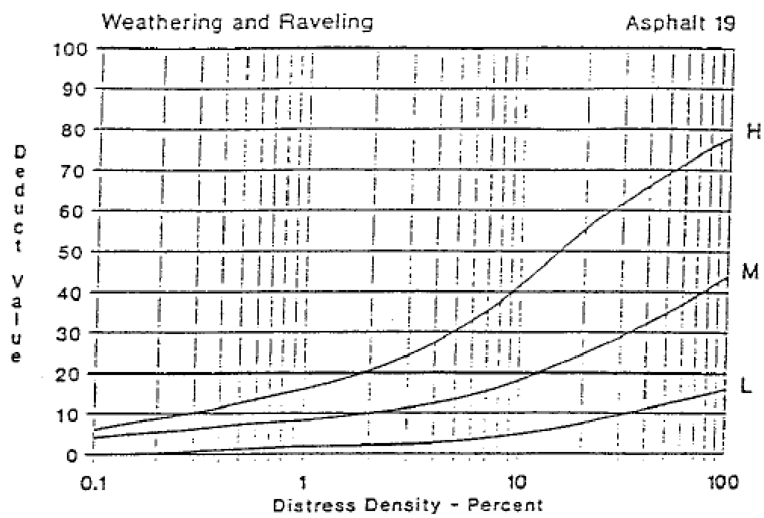


Figure B.18 Weathering and Raveling

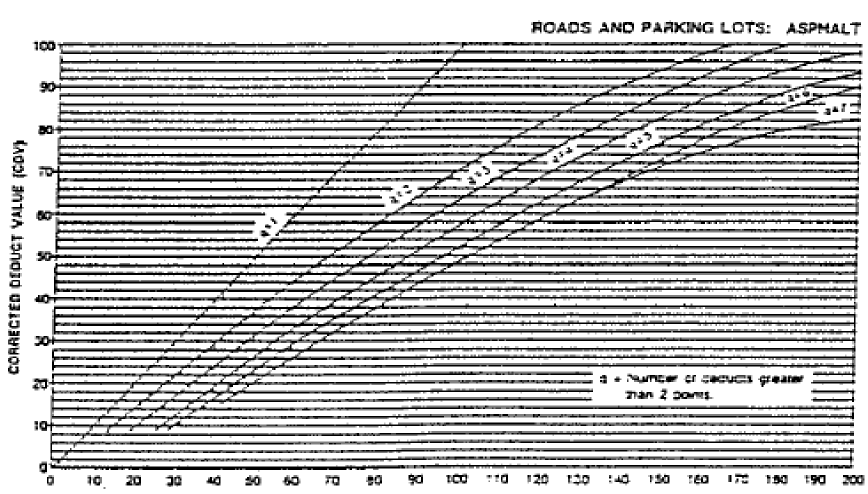


Figure B.19 Total Deduct Value

APPENDEX D DISTRESS SURVEYED ON TEST ROADS

Distress Surveyed on test Road No.1

Distress	Severity	Test Block													Total	Density	Total Density Of each distress
		3	4	5	6	7	9	11	12	13	14	15	16	17			
Alligator	H	124.59		15.03											139.62	6.64	
	M		32.38		44.48	55.00	23.76	42.10	51.25						248.97	11.85	
	L	45.4	71.82	94.97		64.53	57.33	18.39	42.49						394.93	18.79	37.28
Bleeding	H														-	-	
	M														-	-	
	L														-	-	-
Block Crack	H			15.30											15.30	0.73	
	M	53.04	3.90				1.98	18.86	2.04						79.82	3.80	
	L						40.70	76.95	6.03						123.68	5.88	10.41
Bumps &Sags	H														-	-	
	M														-	-	
	L														-	-	-
corrugation	H														-	-	
	M														-	-	
	L														-	-	-
Depretion	H														-	-	
	M														-	-	
	L														-	-	-
Edge Cracking	H														-	-	
	M														-	-	
	L														-	-	-
Reflection cracking	H	20.5													20.50	0.98	
	M	17													17.00	0.81	
	L														-	-	1.78
lane/Shoulder drop off	H				35.80										35.80	1.70	
	M	10.23	24.2	55.80											90.23	4.29	
	L	29.4			23.30										52.70	2.51	8.50

Longitudinal/Transversal	H														-	-	
	M		43.45		25.40	9,5	17.75	18.00	23.55						128.15	6.10	
	L					29.50	16.5		26.70						72.70	3.46	9.56
putching &Utility Cut	H														-	-	
	M						8								8.00	0.38	
	L		12.00	22.00	4.00	5.00									43.00	2.05	2.43
Polished aggregate		285					160								445.00	21.17	21.17
Potholes	H														-	-	
	M		3.00	5.00											8.00	0.38	
	L				1.00	3.75		4.00							8.75	0.42	0.80
Rutting	H														-	-	
	M														-	-	
	L														-	-	-
Shoving	H														-	-	
	M														-	-	
	L														-	-	-
Slipage crack	H														-	-	
	M														-	-	
	L														-	-	-
Swell	H			9.50											9.50	0.45	
	M														-	-	
	L														-	-	0.45
Weathering &Raveling	H														-	-	
	M				80.00			80.00							160.00	7.61	
	L														-	-	7.61
Total															2,101.65	100.00	100.00

Distress Surveyed on test Road No.2

Distress	Severity	Test Block 1	2	3	4	5	6	7	8	9	10	11	12	Total	Density	Total Density Of each distress
Alligator e	H			12.27					21.80		29.19	6.36	14.05	83.67	3.65	
	M	114.63					42.10	17.26	10.21					184.20	8.04	
	L	**16.98**		71.97					6.05	5.15		9.92		110.07	4.80	16.50
Bleeding	H													-	-	
	M							19.76						19.76	0.86	
	L											2.98		2.98	0.13	0.99
Block Crack	H			15.30			76.95	15.30	4.80					112.35	4.90	
	M						19.71	12.27	19.20		15.00		14.46	80.64	3.52	
	L								24.79					24.79	1.08	9.51
Bumps &Sags	H						18.86			21.88			17.66	58.40	2.55	
	M		22.40			57.33								79.73	3.48	
	L													-	-	6.03
corrugati on	H								7.46		12.46			19.92	0.87	
	M					23.76								23.76	1.04	
	L		37.18							8.86				46.04	2.01	3.92
Depretio n	H													-	-	
	M		8.46							5.46	8.66			22.58	0.99	
	L													-	-	0.99
Edge Crackin	H						12.98			4.80	6.94			24.72	1.08	1.35

g	M							6.26						6.26	0.27	
	L													-	-	
Reflection cracking	H											5.04		5.04	0.22	
	M													-	-	
	L							3.50						3.50	0.15	0.37
lane/Shoulder drop off	H	18.40	65.85		198.00	40.70		89.08	40.30	40.30	40.45	53.54	105.46	692.08	30.21	
	M	20.35												20.35	0.89	
	L	29.40				1.98								31.38	1.37	32.47
Longitudinal/Transversal	H													-	-	
	M				16.20	17.75	18		16.10	16.10		5.85		90.00	3.93	
	L				18.96	16.50								35.46	1.55	5.48
putching &Utility Cut	H											7.58		7.58	0.33	
	M					8.75								8.75	0.38	
	L		12.00	22.00				22.00						56.00	2.44	3.16
polished aggregate		280.00			21.92	16.00						6.40		324.32	14.16	14.16
Potholes	H				2.00						4.00			6.00	0.26	
	M		3.00	2.00			4.00	2.00					5.60	16.60	0.72	
	L	4.00												4.00	0.17	1.16
Rutting	H												6.52	6.52	0.28	
	M													-	-	
	L													-	-	0.28
Shoving	H									19.80				19.80	0.86	
	M							7.54						7.54	0.33	
	L				25.60									25.60	1.12	2.31

Slipage crack	H													-	-	
	M												2.68	2.68	0.12	
	L							8.22		4.90				13.12	0.57	0.69
Swell	H										4.23			4.23	0.18	
	M												10.68	10.68	0.47	
	L													-	-	0.65
Weathering &Raveling	H													-	-	
	M													-	-	
	L													-	-	-
			Total											2,291.10	100.00	100.00

Distress Surveyed on test Road No.3

Distress	Severity	Block No. 5	6	7	8	9	10	11	12	Total	Density	Total Density Of each distress
Alligatore	H					7.92				7.92	0.89	
	M		44.48				24.64			69.12	7.78	
	L									-	-	8.67
Bleeding	H					6.20		5.20		11.40	1.28	
	M			11.40						11.40	1.28	
	L	13.06								13.06	1.47	4.04
Block Crack	H				15.28				15.28	30.56	3.44	
	M									-	-	
	L									-	-	3.44
Bumps &Sags	H				11.68	13.61	7.56	9.60	11.68	54.14	6.09	
	M	5.44			7.20					12.64	1.42	
	L			14.36						14.36	1.62	9.13
corrugation	H			7.74			11.06			18.80	2.12	
	M							11.08	7.20	18.28	2.06	
	L									-	-	4.17
Depretion	H							6.00		6.00	0.68	
	M									-	-	
	L									-	-	0.68
Edge Cracking	H				6.14		14.90		6.14	27.18	3.06	
	M									-	-	3.06

	L									-	-	
Reflection cracking	H									-	-	
	M									-	-	
	L									-	-	-
lane/Shoulder drop off	H	72.54		54.54	35.62	42.46	41.16	42.46	35.62	324.40	36.51	
	M									-	-	
	L									-	-	36.51
Longitudinal/Transversal	H									-	-	
	M		25.40							25.40	2.86	
	L		25.80							25.80	2.90	5.76
putching &Utility Cut	H									-	-	
	M									-	-	
	L		4.00							4.00	0.45	0.45
polished aggregate										-	-	
Potholes	H				3.60	5.62			3.60	12.82	1.44	
	M									-	-	
	L		1.00							1.00	0.11	1.56
Rutting	H							6.00		6.00	0.68	
	M	3.98		11.62		2.86				18.46	2.08	
	L									-	-	2.75
Shoving	H						7.80		8.58	16.38	1.84	
	M									-	-	
	L				8.58					8.58	0.97	2.81
Slipage crack	H									-	-	
	M									-	-	-

	L									-	-	
Swell	H	1.68					6.44			8.12	0.91	
	M			6.22	9.20			4.00	9.20	28.62	3.22	
	L					2.00				2.00	0.23	4.36
Weathering &Raveling	H						6.24			6.24	0.70	
	M		80.00			8.00				88.00	9.90	
	L	10.80		7.14						17.94	2.02	12.62
	Total									**888.62**	**100.00**	**100.00**

Appendix E: Pick flood computation using rational method (for area < 0.5km^2)

Sr. No	STATION	CAT. AREA	STREAM L.		VELOCITY	TIME OF CONCE.	INTENSITY (mm/hr)		FREQ. FACTOR		RUNOFF COE.	DESIGN DISCHARGE (m^3/s)			
	Km	Km^2	m		m/s	Hr	I_{10}	I_{25}	C_{f10}	C_{f25}		Q_{10}	Q_{25}	Design Return Period (years)	Design discharge (m^3/s)
1	0+120	0.23	650	650	1.2	9.02778	159.67	204.63	1	1.1	0.65	6.64	9.35	25	9.35
2	0+840	0.12	600	600	1.2	8.33333	164.16	209.70	1	1.1	0.65	3.56	5.00	25	5.00
3	1+690	0.06	400	400	1.2	5.55556	186.89	230.00	1	1.1	0.65	2.03	2.74	25	2.74
4	3+500	0.23	600	600	1.2	8.33333	164.16	209.70	1	1.1	0.65	6.82	9.59	25	9.59
5	5+920	0.07	400	400	1.2	5.55556	186.89	230.00	1	1.1	0.65	2.36	3.20	25	3.20
6	6+080	0.07	400	400	1.2	5.55556	186.89	230.00	1	1.1	0.65	2.36	3.20	25	3.20
7	6+675	0.15	500	500	1.2	6.94444	174.38	221.27	1	1.1	0.65	4.73	6.60	25	6.60
8	6+860	0.09	500	500	1.2	6.94444	174.38	221.27	1	1.1	0.55	2.40	3.35	25	3.35
9	7+060	0.09	500	500	1.2	6.94444	174.38	221.27	1	1.1	0.55	2.40	3.35	25	3.35
10	7+520	0.09	500	500	1.2	6.94444	174.38	221.27	1	1.1	0.55	2.40	3.35	25	3.35
11	7+960	0.09	500	500	1.2	6.94444	174.38	221.27	1	1.1	0.55	2.40	3.35	25	3.35
12	10+720	0.17	700	700	0.92	12.6812	140.62	183.07	1	1.1	0.55	3.66	5.23	25	5.23
13	10+880	0.04	350	350	0.92	6.34058	179.48	227.04	1	1.1	0.55	1.10	1.53	25	1.53
14	10+990	0.04	350	350	0.92	6.34058	179.48	227.04	1	1.1	0.55	1.10	1.53	25	1.53
15	11+200	0.04	350	350	0.92	6.34058	179.48	227.04	1	1.1	0.55	1.10	1.53	25	1.53
16	11+340	0.04	350	350	0.92	6.34058	179.48	227.04	1	1.1	0.55	1.10	1.53	25	1.53
17	11+820	0.17	800	800	0.92	14.4928	133.13	174.60	1	1.1	0.55	3.46	4.99	25	4.99
18	12+020	0.08	550	550	0.92	9.96377	154.14	198.37	1	1.1	0.55	1.89	2.67	25	2.67
19	12+180	0.08	550	550	0.92	9.96377	154.14	198.37	1	1.1	0.55	1.89	2.67	25	2.67
20	12+440	0.08	550	550	0.92	9.96377	154.14	198.37	1	1.1	0.55	1.89	2.67	25	2.67
21	12+600	0.045	350	350	0.92	6.34058	179.48	227.04	1	1.1	0.55	1.23	1.72	25	1.72
22	12+900	0.045	350	350	0.92	6.34058	179.48	227.04	1	1.1	0.55	1.23	1.72	25	1.72
23	13+130	0.045	350	350	0.92	6.34058	179.48	227.04	1	1.1	0.55	1.23	1.72	25	1.72
24	13+620	0.025	350	350	0.92	6.34058	179.48	227.04	1	1.1	0.55	0.69	0.95	25	0.95

APPENDIX F Discharge Computation for Cross Drainage Structures

Sr.No	Location	Area	Stream Length	ΔH	Slope	Tc	CN	Soil Water Retention S	24 HOUR RAINFALL DEPTH(mm)				DIRECT RUNOFF [mm]				PEAK DISCHARGE [m^3/s]				Design Return period (years)	Design discharge (m3/s)
	(km)	Km^2	Km	m	m/m	hr			P_{10}	P_{25}	P_{50}	P_{100}	P_{C10}	P_{C25}	P_{C50}	P_{C100}	Q_{10}	Q_{25}	Q_{50}	Q_{100}		
1	0+400	1.57	2.50	280	0.112	0.307	86	41.35	79	95	107	118	44.6	58.7	69.6	79.7	31.6	41.6	49.3	56.5	50	49.3
2	0+960	2.40	3.00	320	0.107	0.360	86	41.35	79	95	107	118	44.6	58.7	69.6	79.7	43.2	56.9	67.4	77.2	50	67.4
3	2+740	0.51	0.80	140	0.175	0.108	86	41.35	79	95	107	118	44.6	58.7	69.6	79.7	20.7	27.3	32.3	37.0	50	32.3
4	3+160	3.50	2.50	240	0.096	0.326	81	59.58	79	95	107	118	35.5	48.4	58.5	67.9	53.8	73.3	88.6	102.9	50	88.6
5	4+380	4.30	4.50	180	0.040	0.718	81	59.58	79	95	107	118	35.5	48.4	58.5	67.9	37.2	50.7	61.3	71.2	50	61.3
6	8+700	0.59	1.10	40	0.036	0.252	86	41.35	79	95	107	118	44.6	58.7	69.6	79.7	13.6	18.0	21.3	24.4	50	21.3
7	9+150	36.44	11.00	145	0.013	2.192	81	59.58	79	95	107	118	35.5	48.4	58.5	67.9	131.2	178.7	215.9	250.9	50	215.9
8	9+970	1.35	2.20	80	0.036	0.429	86	41.35	79	95	107	118	44.6	58.7	69.6	79.7	21.4	28.2	33.4	38.3	50	33.4
9	11+660	1.50	2.20	80	0.036	0.429	86	41.35	79	95	107	118	44.6	58.7	69.6	79.7	23.8	31.3	37.1	42.5	50	37.1

APPENDIX G Hydraulic Computation of Crossing Culverts for the Computed Discharges

Sr. No	Catch. ID	Location	Catch. Area	Flow Direction	Selected Return period	QD	REQUIRED STRUCTURE SIZE							Adequacy
							Culvert type	No. Cell	Height	Width	Hw/D=1	Hw/D=1.25	Hw/D=1.5	
		Km	(km²)		Year	m³/s			m	m	m³/s	m³/s	m³/s	
1	A1	0+120	0.23	R to L	25	9.35	B/SC	1	2	2	8.5	11.9	14.1	ok
2	A2	0+400	1.57	R to L	50	49.30	B/SC	1	3.5	4	39.3	55.0	65.5	ok
3	A3	0+840	0.12	R to L	25	5.00	B/SC	1	2	2	8.5	11.9	14.1	ok
4	A4	0+960	2.4	R to L	50	67.37	B/SC	1	4	5	60.0	84.0	100.0	ok
5	A5	1+690	0.06	R to L	25	2.74	B/SC	1	1.5	2	5.5	7.7	9.2	ok
6	A6	2+740	0.51	R to L	50	32.33	B/SC	1	3	3	23.4	32.7	39.0	ok
7	A7	3+160	3.5	R to L	50	88.56	B/SC	1	4	5	60.0	84.0	100.0	ok
8	A8	3+500	0.23	R to L	25	9.59	B/SC	1	2	3	12.7	17.8	21.2	ok
9	A9	4+380	4.3	R to L	50	61.25	B/SC	1	3	5	39.0	54.6	65.0	ok

10	A10	5+920	0.07	R to L	25	3.20	PC	1	1.22	1.22	2.1	3.1	3.6	ok
11	A11	6+080	0.07	R to L	25	3.20	PC	1	1.22	1.22	2.1	3.1	3.6	ok
12	A12	6+675	0.15	R to L	25	6.60	B/SC	1	1.5	2	5.5	7.7	9.2	ok
13	A13	6+860	0.09	R to L	25	3.35	PC	1	1.22	1.22	2.1	3.1	3.6	ok
14	A14	7+060	0.09	R to L	25	3.35	PC	1	1.22	1.22	2.1	3.1	3.6	ok
15	A15	7+520	0.09	R to L	25	3.35	PC	1	1.22	1.22	2.1	3.1	3.6	ok
16	A16	7+960	0.09	R to L	25	3.35	PC	1	1.22	1.22	2.1	3.1	3.6	ok
17	A17	8+700	0.59	R to L	50	21.2 7	B/SC	1	2	4	17.0	23.8	28. 3	ok
18	A18	9+970	1.35	R to L	50	33.4 3	B/SC	1	2.5	4	23.7	33.2	39. 5	ok
19	A19	10+720	0.17	R to L	25	5.23	B/SC	1	1.5	2	5.5	7.7	9.2	ok
20	A20	10+880	0.04	R to L	25	1.53	PC	1	1.22	1.22	2.1	3.1	3.6	ok
21	A21	10+990	0.04	R to L	25	1.53	PC	1	1.22	1.22	2.1	3.1	3.6	ok
22	A22	11+200	0.04	R to L	25	1.53	PC	1	1.22	1.22	2.1	3.1	3.6	ok
23	A23	11+340	0.04	R to L	25	1.53	PC	1	1.22	1.22	2.1	3.1	3.6	ok
24	A24	11+660	1.5	R to L	50	37.1 4	B/SC	1	3	3	23.4	32.7	39. 0	ok

25	A25	11+820	0.17	R to L	25	4.99	B/SC	1	1.5	2	5.5	7.7	9.2	ok
26	A26	12+020	0.08	R to L	25	2.67	PC	1	1.22	1.22	2.1	3.1	3.6	ok
27	A27	12+180	0.08	R to L	25	2.67	PC	1	1.22	1.22	2.1	3.1	3.6	ok
28	A28	12+440	0.08	R to L	25	2.67	PC	1	1.22	1.22	2.1	3.1	3.6	ok
29	A29	12+600	0.045	R to L	25	1.72	PC	1	1.22	1.22	2.1	3.1	3.6	ok
30	A30	12+900	0.045	R to L	25	1.72	PC	1	1.22	1.22	2.1	3.1	3.6	ok
31	A31	13+130	0.045	R to L	25	1.72	PC	1	1.22	1.22	2.1	3.1	3.6	ok
32	A32	13+620	0.025	R to L	25	0.95	PC	1	1.22	1.22	2.1	3.1	3.6	ok

APPENDIX H Cross Drainage Structures Schedule

No.	Structural ID	Easting	Northing	Station (km)	Flow Direction	Area (km^2)	Stream Length (km)	ΔH (m)	Existing Structure size					New Proposed Structure					Remark
									Type of structure	No. Cell	Width (m)	Height (m)	Dia. (m)	Type of structure	No. Cell	Width (m)	Height (m)	Dia. (m)	
1	SC-001	465699	1002563	0+120	R to L	0.23	0.65		PC	1			1.06	B/SC	1	2	2		Replace with the new proposed size
2	BC-001	465546	1002754	0+400	R to L	1.57	2.5	280	SC	1	2	2		B/SC	1	3	3.5		Replace with the new proposed size
3	SC-002	465237	1002932	0+840	R to L	0.12	0.6		PC	3			1.06	B/SC	1	2	2		Replace with the new proposed size
4	SC-003	465117	1002927	0+960	R to L	2.4	3	320	SC	1	3	3		B/SC	1	5	4		Replace with the new proposed size
6	SC-004	464758	1002524	1+690	R to L	0.06	0.4							B/SC	1	2	1.5		New Proposed
7	SC-005	463995	1003170	2+740	R to L	0.51	0.8	140	Arch Culvert	1	2	2.5		B/SC	1	3	3		Replace with the new proposed size
8	BC-002	463610	1003280	3+160	R to L	3.5	2.5	240	Arch Culvert	1	4	3		B/SC	1	5	4		Replace with the new proposed size
10	SC-006	463472	1002979	3+500	R to L	0.23	0.6		PC	1			1.06	B/SC	1	3	2		Replace with the new proposed size
11	BC-003	463018	1002425	4+380	R to L	4.3	4.5	180	PC	1			1.06	B/SC	1	5	3		Replace with the new proposed size
12	PC-001	462007	1002026	5+920	R to L	0.07	0.4							PC	1			1.22	New Proposed
13	PC-002	461848	1002051	6+080	R to L	0.07	0.4							PC	1			1.22	New Proposed
15	SC-007	461275	1001987	6+675	R to L	0.15	0.5							B/SC	1	2	1.5		New Proposed
16	PC-003	461192	1001829	6+860	R to L	0.09	0.5							PC	1			1.22	New Proposed
17	PC-004	461123	1001664	7+060	R to L	0.09	0.5		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
18	PC-005	460820	1001842	7+520	R to L	0.09	0.5							PC	1			1.22	New Proposed
19	PC-006	460562	1002110	7+960	R to L	0.09	0.5							PC	1			1.22	New Proposed
20	SC-008	460089	1002670	8+700	R to L	0.59	1.1	40	PC	1			1.06	B/SC	1	4	2		Replace with the new

																			proposed size
21	SC-009	459236	1002817	9+970	R to L	1.35	2.2	80	PC	1			0.61	B/SC	1	4	2.5		Replace with the new proposed size
22	SC-010	458585	1002596	10+720	R to L	0.17	0.7		PC	1			0.61	B/SC	1	2	1.5		Replace with the new proposed size
23	PC-007	458433	1002600	10+880	R to L	0.04	0.35		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
24	PC-008	458334	1002605	10+990	R to L	0.04	0.35		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
25	PC-009	458131	1002618	11+200	R to L	0.04	0.35		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
26	PC-010	457978	1002660	11+340	R to L	0.04	0.35		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
27	SC-012	457741	1002796	11+660	R to L	1.5	2.2	80	PC	1			0.61	B/SC	1	3	3		Replace with the new proposed size
28	SC-013	457703	1002638	11+820	R to L	0.17	0.8		PC	1			0.61	B/SC	1	2	1.5		Replace with the new proposed size
29	PC-011	457743	1002438	12+020	R to L	0.08	0.55		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
30	PC-012	457683	1002294	12+180	R to L	0.08	0.55		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
31	PC-013	457554	1002078	12+440	R to L	0.08	0.55		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
32	PC-014	457422	1001987	12+600	R to L	0.045	0.35		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
33	PC-015	457139	1001891	12+900	R to L	0.045	0.35		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
34	PC-016	456978	1001727	13+130	R to L	0.045	0.35		PC	1			0.61	PC	1			1.22	Replace with the new proposed size
35	PC-017	456699	1001327	13+620	R to L	0.025	0.3							PC	1			1.22	New Proposed

APPENDIX I. Hydrological & Hydraulic Analyses of Proposed intercepting Channel (0+000 to 4+000)

Sr. No.	Required secondary channel section	Maximum Water flowing length	Contributing width (m)	Catchment Area (km2)	Weighted average runoff Coefficient	Water Drainage slope	Time of Concentration, Tc (min)	Design Rainfall Intensity, I-10 (mm/hr)	Design Discharge Q-25 (m3/s)	Width	Flow depth (m)	X-section Area (m2)	perimeter (m)	H. Radius (m)	V (m/s)	Q (m3/s)
1	0+000 to 4+000 b/n proposed crossings	450	250	0.1125	0.65	0.036	10.28	129.77	2.81	***0.8***	***1***	0.8	2.4	0.33	3.11	3.273

For the project with a design of under Drain, the following Design Hydraulic recommendations are important

Sr. No	***Design parameters***	***Recommendations for the specific Project case***
1	Dimension Of pipe	42"
2	Inlet types on grades less than **3%.**	Curb-opening inlets
3	Inlet types on grades Greater than **3%.**	Grate Inlet
4	Maximum Spacing of inlets	30m
5	Slope of pipes (minimum adopted invert slope for cleansing purpose)	0.0012
For Right side cutting section of the road from km 0+000 to 4+000, additional intercepting channel with grate cover for capturing the left side catchment flow has been proposed		
1	Clear Width	0.8m
2	Clear Depth including free board	1m