EVALUATION PAVEMENT DISTRESSES

USING PAVEMENT CONDITION INDEX

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Submitted as Partial Fulfilling of the Requirement for the Degree of Master of Civil Engineering Diponegoro University

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Herewith I stated that this thesis has never been published in other institution and there were no part of thesis has been directly from published sources except citing from listed bibliographies attached.

Semarang, March 2011

Ali Mohamed Zaltuom

DEDICATION

To all those who love me and those that I love.

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Firstly, I would like to thank God almighty, for this blessed opportunity.

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ABSTRACT

Pavement deterioration is resulted by both environmental and structural causes. It is difficult to maintain the road on the same specification that was owned at the opening and problems start to appear represented in the pavement cracks, holes and undulations and so on. Recognizing defects and understanding their causes helps us rate pavement condition and select cost-effective repairs. Periodic inspection is necessary to provide current and useful evaluation data. It is recommended that ratings be updated every year.

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. A condition rating of the pavement will help determine what pavement maintenance technique is necessary.

A methodology was proposed to investigate the pavement condition; this study focuses on flexible pavement. A manual survey is performed following ASTM D 6433. The pavement is divided into sections. Each section is divided into sample units. The type and severity of sample distress is assessed by visual inspection of the pavement sample units and the quantity of each distress is measured. Typically, this procedure requires a team of at least two engineers.

The pavement evaluation results from the manual PCI survey revealed that all sections of road were fair condition. Considered the section of road that surveyed, describing the condition pavement of the all road. The pavement that has been studied at Koums area would seem to require maintenance. Thick overlay (sometimes called surface treating) is needed in a comprehensive pavement.

Keywords

Pavement defects, pavement evaluation, type and severity level of distress, PCI value, pavement maintenance.

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CHAPTER 1

INTRODUCTION

1.1 Background

Roads play a major role in the development of all countries and societies by providing the essential links between different parts of the country to facilitate the movement of people and transport of goods. The importance of roads increases as the area of the country increases, especially in the absence of other means of transport such as railways and waterways, which is often occurred in developing countries.

The history of road engineering gives us an idea about the roads of ancient times. Roads in Rome were constructed in a large scale and it radiated in many directions helping them in military operations. Thus they are considered to be pioneers in road construction.

Since early 70's there has been vigorous economic development of countries on the Mediterranean coast of North Africa. However, this area lies completely or partially within regions of so called hot arid climates (Bashir, 2006).

The road network density is generally satisfactory, the total length of Libya's paved road network is about 34,000 **km** (2010), of which about 15000 **km** main roads, the secondary and agricultural road network is about at 18,000 **km**. The unpaved network is about 3,000 km long. There is also a network of seasonal tracks about 50,000 km (RLTA, 2010).

The highway network is classified into four main roadway types

1- Expressways: Roads arteries outside municipal borders link the cities and regions with two carriage ways and at least four lanes (two lanes or more in each direction).
2- Main roads: Roadways linking cities and regions or serving cities within municipal boundaries, there are single carriageway roads for good paved standard or dual carriage ways with 2 lanes in each direction.
3- Secondary roads: These link district centers and villages.

4- Agricultural roads: Roads linking agricultural land and farms with markets.

Most of these roads have been implemented during the seventies and early eighties of the last century, and, therefore, most of them have reached old design. The weakness and lack of periodic maintenance programs and delayed repairs of the damage suffered by paving the roads in that there have contributed on functional and structural damage.

It is difficult to maintain the road on the same specification that was owned at the opening and problems start to appear represented in the pavement cracks, holes and undulations and so on (Bashir, 2006).

Many exposed pavements have problems lead to a reduction of the quality of the road and reduce the degree of safety and comfort to road users. Some of these problems occur in asphalt layers, such as cracks and bleeding, and some of the lower classes occur, such as crawl and swell. Studies and researches have been shown that most of the problems faced by asphalt roads in Libya linked mainly with hot, dry climate prevail in most areas.

Most of the problems are various types of cracks, hardening, raveling and weathering asphalt materials which are mainly due to a number of environment factors, namely:

- High temperatures, especially in the summer.
- The daily temperature range.
- The intensity of solar radiation.

Although the roads in Libya exposed to various types of damage suffered by the asphalt pavement in the rest of the world, it is characterized by the emergence of certain types of damage specific to this region and is due to the influence of environmental factors (OECO, 2008a).

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

It is easy to see why pavements deteriorate at various rates and why we find them in various stages of disrepair. Recognizing defects and understanding their causes help us of evaluate pavement condition and select cost-effective repairs. The pavement defects shown on the following pages provide a background for this process. Periodic inspection is necessary to provide current and useful evaluation data. It is recommended that ratings be updated every year.

Obviously, most pavement deterioration results from both environmental and structural causes. However, it is important to try to distinguish between the two in order to select the most effective rehabilitation techniques.

1.2 Problem of Study:

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

Due to variations in construction and material quality, the age of a pavement structure may not accurately indicate the condition or the performance of the pavement. However, the age of the pavement may be used to further categorize pavement sections and may provide a relative condition of those sections (ADO, 1999).

At the opening of the road, usually with high quality and specifications. But the passage of time and with the use of the road because of traffic loads applied on the road on a daily basis and continuous in addition air factors such as daily and seasonal rains and changes in temperatures, it is difficult to maintain the road on the same specification that was owned at the opening and problems start to appear represented in the pavement cracks, holes and undulations and so on (RLTA, 2010).

Generally, good design does not prevent the occurrence of such defects in case of default in the construction or in the case of non-construction according to engineering specifications (cases of non-compliance with specifications) .The cost of maintenance expense exceeds the cost of construction itself because it was disrupting traffic generated by the delay in the establishment of these roads.

Preventive maintenance is an essential tool for extending the life of a pavement. Used early in a pavement's life, preventive maintenance corrects small problems before they become big problems, saves money, reduces delays and improves safety and ride ability.

Therefore profession engineer maintained until the roads are always safety ways and the movement for passengers or goods are a comfortable and economical at all times (Bashir, 2006).

Not all pavement structures are constructed alike, nor do all pavement structures perform identically. Therefore, it is necessary to monitor the maintenance requirements of each general type of pavement. By monitoring the performance of pavement sections of similar construction and usage, sufficient information can be developed to forecast maintenance requirements (ADO, 1999).

1.3 Objective of Study:

The key element to surface evaluation management programs is to identify the different types of pavement distresses and determine their causes. Knowing what caused the pavement distress allows the appropriate maintenance treatment to be applied (Lavin, 2003).

Basic objective of this study is to

1. Investigate and evaluate the asphalt pavement defects by using pavement condition index (PCI).
2. Estimate the maintenance options.

1-4 Location of Study:

Libya is located in North Africa on the coast of the Mediterranean Sea. It is bordered on the east by Egypt; on the south by Sudan, Chad, and Niger; and on the west by Algeria and Tunisia see figure 1.1(Federal Research Division, 2005).

Figure 1.1 Map of Libya (FRD, 2005)

The study road lies in the north east part of Libya in Koms city. It is called Mslata road, classified it is secondary road, this link district centers and villages.

Figure 1.2 Roads network in Koms city (Google earth)

1-5 Scope of Study:

This study focuses on the estimation of roads flexible pavement condition through visual surveys using the Pavement Condition Index (PCI) method (following ASTM D6433 standard) of quantifying pavement condition. To accomplish this goal, part of the road network in Al-khoms area was used.

CHAPTER 2

LITERATURE REVIEW

Road transport is one of the most common modes of transport. Roads in the form of track ways, human pathways etc. were used even from the pre-historic times. Since then many experiments were going on to make the riding safe and comfort. Thus road construction became an inseparable part of many civilizations and empires.

Pavement is the most common element of the transportation infrastructure and is built to provide a safe and comfortable ride for the public. To maintain a pavement system with an acceptable ride quality (Feng and Dar, 2009).

In recent years there has been a constant need for rehabilitation and construction of the infrastructure, particularly highways. The increased volume of traffic, load, and environmental conditions are factors that have created enormous amounts of wear and tear on the highway systems. More research is needed to determine the influences of these factors upon pavement performance.

2.1 Flexible Pavement

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material each of which receives the loads from the above layer, spreads them out and then passes them on to the layer below. Thus, the further down in the pavement structure a particular layer is, the less load (in terms of force per area) it must carry. Other pavements that are surfaced with asphalt materials, such as bituminous surface treatments are also classified as flexible pavements.

2.1.1 Flexible pavement structure

A typical flexible pavement structure (Figure 2.1) consists of the surface course and the underlying base and subbase courses. Each of these layers contributes to structural support and drainage. The surface course (typically an HMA layer) is the stiffest (as measured by resilient modulus) and contributes the most to pavement strength. The underlying layers are less stiff but are still important to pavement strength as well as drainage and frost protection. A typical structural design results in a series of layers that gradually decrease in material quality with depth (Haffman, 2008)

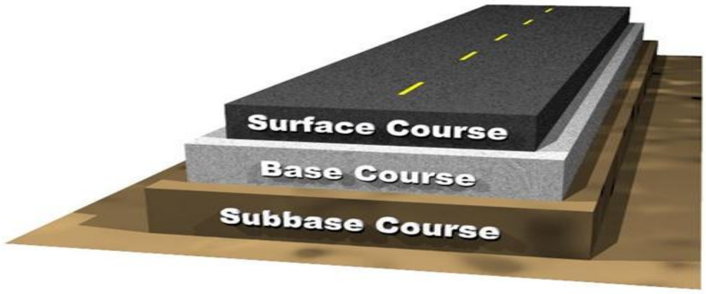


Figure 2.1 Basic flexible pavement structure (Haffman, 2008)

a. Surface Course

The surface course is the layer in contact with traffic loads and normally contains the highest quality materials. It provides characteristics such as friction, smoothness, noise control, rut and shoving resistance and drainage. In addition, it serves to prevent the entrance of excessive quantities of surface water into the underlying base, subbase and subgrade. This top structural layer of material is sometimes subdivided into two layers (Haffman, 2008):

- **Wearing Course:** This is the layer in direct contact with traffic loads. It is meant to take the brunt of traffic wear and can be removed and replaced as it becomes worn. A properly designed (and funded) preservation program should be able to identify pavement surface distress while it is still confined to the wearing course. This way, the wearing course can be rehabilitated before distress propagates into the underlying intermediate/binder course.
- **Intermediate/Binder Course**: This layer provides the bulk of the HMA structure. Its chief purpose is to distribute load.

b. Base Course

The base course is immediately beneath the surface course. It provides additional load distribution and contributes to drainage and frost resistance. Base courses are usually constructed out of:

- **Aggregate**: Base courses are most typically constructed from durable aggregates that will not be damaged by moisture or frost action. Aggregates can be either stabilized or unstabilized.

- **HMA**: In certain situations where high base stiffness is desired, base courses can be constructed using a variety of HMA mixes. In relation to surface course HMA mixes, base course mixes usually contain larger maximum aggregate sizes, are more open graded and are subject to more lenient specifications.

c. Sub Base Course

The subbase course is between the base course and the subgrade. It functions primarily as structural support but it can also:

1- Minimize the intrusion of fines from the subgrade into the pavement structure.
2- Improve drainage.
3- Minimize frost action damage.
4- Provide a working platform for construction.

The subbase generally consists of lower quality materials than the base course but better than the subgrade soils. A subbase course is not always needed or used. For example, a pavement constructed over a high quality, stiff subgrade may not need the additional features offered by a subbase course so it may be omitted from design. However, a pavement constructed over a low quality soil such as swelling clay may require the additional load distribution characteristic that a subbase course can offer. In this scenario the subbase course may consist of high quality fill used to replace poor quality subgrade (Haffman, 2008).

2.1.2 The Cause of Failure

The key to a useful evaluation is identifying different types of pavement distress and linking them to a cause. Understanding the cause for current conditions is extremely important in selecting an appropriate maintenance or rehabilitation technique.

The causes of pavement distresses and deterioration are environmental and structural. Environmental induced distresses are due to weathering, moisture, and aging. Loading causes structural induced distresses. Pavement deterioration usually occurs from both loading and weathering (Lavin, 2003).

Pavement deterioration is usually caused by a combination of factors such as traffic load, environment, initial design, and quality of construction. Therefore, pavement deterioration may result from traffic -induced distress, environmentally associated distress, and the interaction of these two. For example ,rutting and alligator cracking are regarded as traffic -induced distresses, whereas longitudinal and transverse cracking are viewed as environmental or non -load-related distresses.

Several factors are responsible for the degradation of pavements over time, affecting the service life of the pavement. The initial design of the pavement, based on anticipated traffic volumes and loads, is a major factor influencing its life. Cumulative traffic volume, especially truck traffic, is another major factor in the life of pavements. Finally, environmental factors such as moisture infiltration into the supporting base, and heat and cold cycles, affect how well the subsurface is able to support the pavement. The routine maintenance effort applied to a pavement also affects pavement life.

The rate at which pavement deteriorates depends on its environment, traffic loading conditions, original construction quality, and interim maintenance procedures. Poor quality materials or poor construction procedures can significantly reduce the life of a pavement. As a result, two pavements constructed at the same time may have significantly different lives, or certain portions of a pavement may deteriorate more rapidly than others. On the other hand, timely and effective maintenance can extend a pavement's life. Crack sealing and seal coating can reduce the effect of moisture in aging of asphalt pavement.

With all of these variables, it is easy to see why pavements deteriorate at various rates and why we find them in various stages of disrepair. Recognizing defects and understanding their causes helps us rate pavement condition and select cost-effective repairs. The pavement defects shown on the following pages provide a background for this process. Periodic inspection is necessary to provide current and useful evaluation data (Walker, 2002).

Environmental due to weathering and aging, and structural caused by repeated traffic loadings. The temperature is one of the most important factors affecting the design and performance of both flexible and rigid pavements. Temperature variations within pavement structure contribute in many different ways to distress and possible failure of that structure. Knowledge of temperature effects is essential for the determination of the design and maintenance requirements especially in the desert climates.

The problem of thermal cracking of flexible pavements in hot prevail regions can be considered as a new kind of pavement distress. It has been observed recently in those parts of the world (Abdulwahhab et al., 1998).

Fluctuation in temperatures significantly affects pavement stability and the selection of asphalt grading to be used in pavements. Ability to accurately predict the asphalt pavement temperature at different depths and horizontal locations based on ambient air temperatures will greatly help pavement engineers in performing back-calculations of pavement modulus values. In addition, it will help engineers in selecting the asphalt grade to be used in various pavement lifts (Bashir, 2006).

Thermal condition, if not addressed, can lead to significant problems, including the following (OECO, 2008b):

a. Cracking caused by large temperature differentials between the interior of concrete and the external environment.
b. Strength loss caused by the freezing of concrete before it has reached sufficient strength.
c. Strength loss caused by high internal temperatures within the concrete mass.

The sun also has a strong influence on the pavement temperatures. It can help heat the pavement and it speeds up the melting process. Air and pavement temperatures can often differ by many degrees. On a bitterly cold early winter day when the air temperature is well below freezing, the pavement or surface temperature may be somewhat warmer, primarily because the subsurface temperature has not yet cooled.

The amount of rain, sleet, snow or hail which falls in a specified time is expressed as the depth of water it would produce on a large, level impermeable surface. Precipitation is measured daily (24 hours) by means of a rain gauge. Today's rain gauges are simple to use with pre-calibrated scales on their sides. The administration involves the expenditure of hundreds of millions of dollars annually for construction, reconstruction and maintenance. Also, it imposes the responsibility of selecting and designing new roads, and the planning of future construction and development. Design of new structure to serve the volume and type of traffic a roadway will carry. Selection of new routes to serve the greatest residential area and maximum number of motorists while maintaining cost efficiency.

Pavement engineers recognize the importance of good drainage in the design, construction, and maintenance of any pavement.The amount of moisture within a pavement layer will greatly affect the strength, and thereby, the performance of the layer. As the moisture content of a layer increases, the strength decreases. If subsurface drainage is provided, the overall strength of the pavement section will be higher. Some pavement sections have drainable layers built into the structure for additional drainage capacity. These drainage features should be strongly considered when grouping pavement sections (OECO, 2008b).

The accumulation of water in the sub-grade or in an untreated aggregate base course usually creates problems. When the condition of soil is saturated, is ability to bear any loan is weaker than the dry soil condition. Some soils exhibit swells by adding water that causes differential heaving. These factors (rain, snow, etc) are weakening the pavement structure and minimize its capability to support traffic loads. Water in the pavement's asphalt layers can strip or could be stripped out get segregated separate the asphalt film from the aggregate.

Traffic loading is known as one of the important factors affecting the performance of pavements. A higher number of traffic loadings will cause more damage to the pavement than that of a lower value. The available traffic data in the database include the average daily traffic (ADT), average daily truck traffic (ADTT) and average equivalent.

The rate at which pavement deteriorates depends on its environment, traffic loading conditions, original construction. Quality and interim maintenance procedures. Poor quality materials or poor construction procedures can significantly reduce the life of a pavement.

As a result, two pavements constructed at the same time may have significantly different lives, or certain portions of a pavement may deteriorate more rapidly than others. On the other hand, timely and effective maintenance can extend a pavement's life. Crack sealing and surface treatments can reduce the effect of moisture in aging of asphalt pavement.

With all of these variables, it is easy to see why pavements deteriorate at various rates and why we find them in various stages of disrepair. Recognizing defects and understanding their causes helps us rate pavement condition and select cost-effective repairs. The pavement defects shown on the following pages provide a background for this process. Periodic inspection is necessary to provide current and useful evaluation data. It is recommended that ratings be updated every year.

2.1.3 Collapse of the Flexible Pavement

The flexible pavement is composed of the mixture applied asphalt surface layers of the foundation and under the foundation can be from non-treatment (Macadam - stone broken) or from materials handling one of the links asphalt treatment may be limited treatment only on a Base or the Sub-base layer.

Distresses can be divided into two groups: structural distress and functional distress. Structural distress is associated with the ability of the pavement to carry the design load. Functional distress is mainly associated with ride quality and safety of pavement surface (Luo, 2005).

A decline in any layer of the pavement caused by the decline in each sector, and therefore must be attention of pavement when the layers design ,and construction and each layer to be stable in itself and this sector is stable and showing the status of the following forms of collapse of the flexible pavement. Figure 2.2 show collapse forms of the flexible pavement (Bashir, 2006).

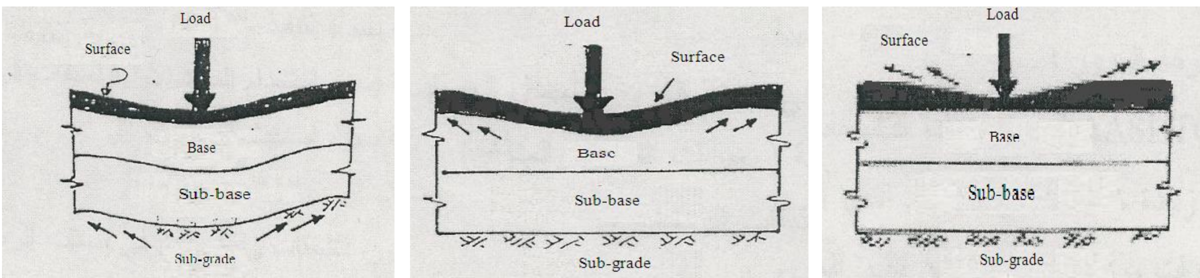


Figure 2.2 Collapse of the Flexible Pavement

2.1.4 Reasons of the pavement collapse

Most of the researches indicated that reasons for the emergence of such defects and damage can be for technical reasons, geometric, or operational or administrative errors. Which can be summarized as follows (OECO, 2008):

a. Engineering or technical reasons

The body of the road can summery it because of the failure of terminate is surface of the pavement may be good or bad mix asphalt, it may defect in the base or subbase layers.

b. Operational reasons

The method used in the road which negligence by the users of the road may impact on the pavement.

c. Management reasons

These defects in the selection of the contractor or supervising engineering the construction of road. When the contractor does not have sufficient experience. It is difficult to do this job.

2.2 Deterioration in Flexible Pavement

Assessment of the pavement condition is by the visual observation and recording of types of defects on the surface of the pavement.Pavement condition survey includes detection of surface distresses, such as cracking, rutting, and other surface defects, and can also include survey of pavement roughness in certain cases.

The elements of visual assessment of the situation as follows:

a. Type of distress.
b. Severity of distress.
c. The intensity of the impact of defect layer pavement.

Before any inspection of the site must follow the safety means so as to ensure the safety and conduct of the examination process.

This manual is prepared to assist user of the Pavement Management System (**PMS**) in identifying surface distress in a uniform and repeatable manner. The distresses included in this manual are used to calculate the Pavement Condition Index (**PCI**) for pavements surfaced with asphalt concrete and surface treatments.

This part contains general descriptions of the major types of distress that may be encountered in both flexible (asphalt concrete) and rigid pavements. Also noted is a typical description of three distress severity levels associated with each distress.

A pavement moisture accelerated distress identification system". These descriptions are provided as a guide to user agencies only and should not be viewed as a standard method for distress type severity identification. This information, along with an estimate of the amount of each distress severity combination, represents an example of the minimum information needs required for a thorough condition (distress) survey(AASHTO, 1993).

2.3 Pavement Distress

Pavement distresses are those defects visible on the pavement surface. They are symptoms, indicating some problem or phenomenon of pavement deterioration such as cracks, patches and ruts. The type and severity of distress a pavement has can provide great insight into what its future maintenance and/or rehabilitation needs will be. The distress is generally described in terms of severity, extent and distress type. However, the distress identification and measurement procedures may slightly vary from agency to agency (Luo,2005). Defects in the asphalt pavement can be classified groups on the basis of appearance as follows (David, 2006):

2.3.1 Cracks

2.3.1.1 Alligator or Fatigue Cracking

a. Description

Alligator cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading .cracking begins at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many sided, sharp angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are less than 2 m. (6ft) on the longest side. Alligator cracking is shown in Figure 2.3 (ASTM D6433, 1999) (David, 2006).

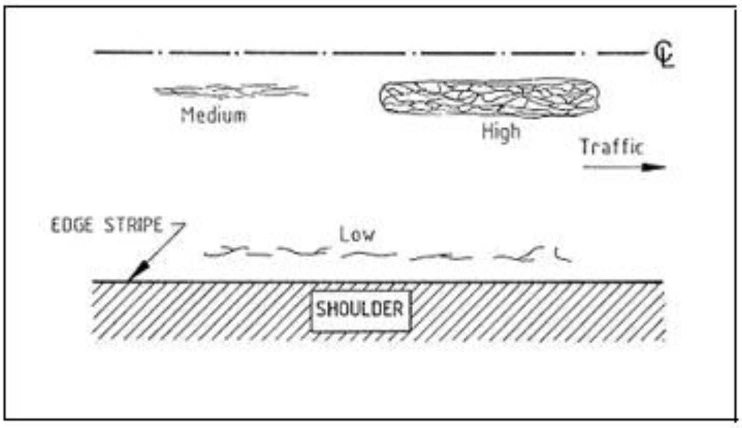


Figure 2.3 Alligator Cracking (GTC, 1998)

b. Severity levels

Low level of intensity (L): fine, longitudinal hairline 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 into 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 spalled at the edges. Some of the pieces may rock under traffic .Potholes of all sizes are recorded as high severity alligator cracking.

c. 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 often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately, however, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity level present.

d. Possible causes

Causes include the expected alligator cracks one or more of the following reasons (GTC, 1998):

1- Damaged layer of asphalt concrete as a result of damage to the substrate due to repeated traffic loads.
2- Instability of the foundation layer of asphalt case or layer under the foundation 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.

2.3.1.2 Block cracking

a. Description

Blocks are interconnected cracks that divide the pavement into approximately rectangular pieces.

The blocks may range in size from approximately (3 by 3cm) to (3 by 3m).Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large proportion of pavement area, but sometimes will occur only in nontraffic areas. This type of distress differs from alligator cracking in that alligator cracks from smaller, many sided pieces with sharp angles. Also, unlike block cracks, alligator cracks are caused by repeated traffic loadings, and are therefore found only in traffic areas (wheel paths). Figure 2.4 cracks and network levels of severity (David, 2006).

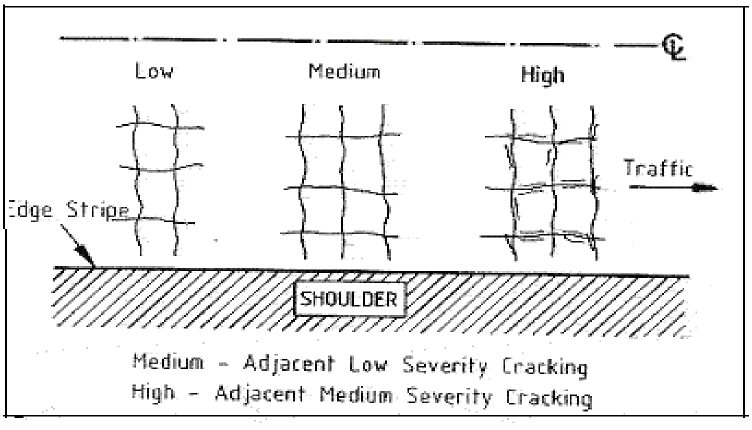


Figure 2.4 Block Cracking (GTC, 1998)

b. Severity 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 (10 mm).
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 75 mm and surrounded by light random badly broken.
iii. Cracks 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. Cracks introduced about 100 mm and surrounded by very badly broken and broken.

c. How to Measure

Block cracking is measured in square meter of surface area. It usually occurs at one 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.

d. Possible causes

Cracks are the retina of the functional and structural defects and 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.

2.3.1.3 Longitudinal and Transverse Cracks:

a. Description

Longitudinal cracks are parallel to the pavement's center-line or laydown direction. They may be adjacent to the pavement edge.

Transverse cracking occurs predominantly perpendicular to the pavement centerline. It can occur anywhere within the lane. See Figure 2.5 Longitudinal and Transverse Cracks.

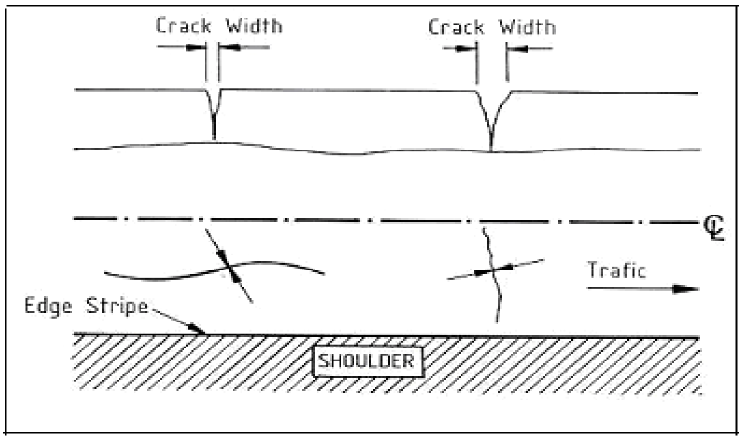


Figure 2.5 Longitudinal and Transverse Cracks (GTC, 1998)

b. 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.

c. Possible causes

i. A poorly constructed paving lane joint.
ii. Shrinkage of the surface due to low temperatures or hardening of the asphalt and 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).

2.3.1.4 Edge Cracking

a. Description

Edge cracking is crack in the side is parallel to the edge of the pavement and away from a distance ranging between 0.3-0.5 meters from the edge, and extends these cracks longitudinal and transverse direction and branching towards the shoulders. And increasing the cracks as a result of side-load traffic is classified as the area enclosed between the part and the edge of pavement as volatile if there has been a break. Edge cracking is shown in Figure 2.6 (David, 2006).

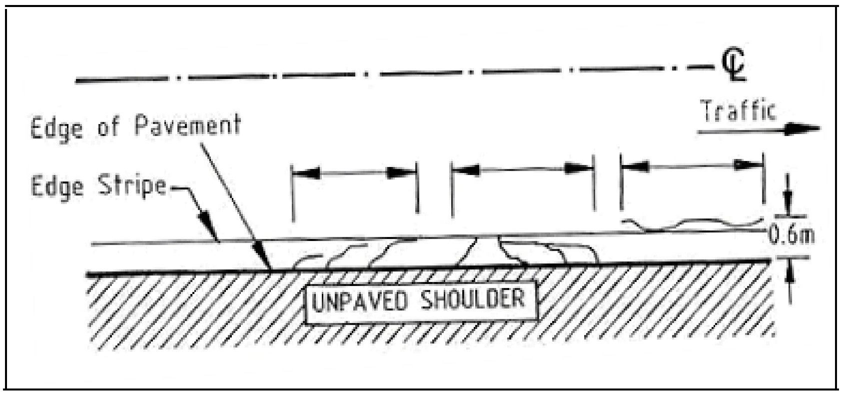


Figure 2.6 Edge Cracking (GTC, 1998)

b. 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 length of up to 10% of the length of the paving of the area affected.

Higher level of intensity (H): It is a deep and many cracks and contains break and loss of materials in the length of more than 10% of the length of the paving of the area affected.

c. **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.

d. Possible causes

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

2.3.1.5 Reflection Cracking

a. Description

These cracks appear only on the surfaces of asphalt that would be implemented cement concrete slabs, cracks and does not include the reflectivity of the base layers. (See Figure 2.7)These cracks arise as a result of traffic generated by heat and moisture between the concrete slab and the bottom surface of the concrete asphalt, in regard to this defect earlier pregnancy, however, the traffic loads can cause the asphalt to break the surface near the cracks which destroy. If you know the dimensions of concrete slab on the bottom, it helps to know this defect (ASTM D6433, 1999) (David, 2006).

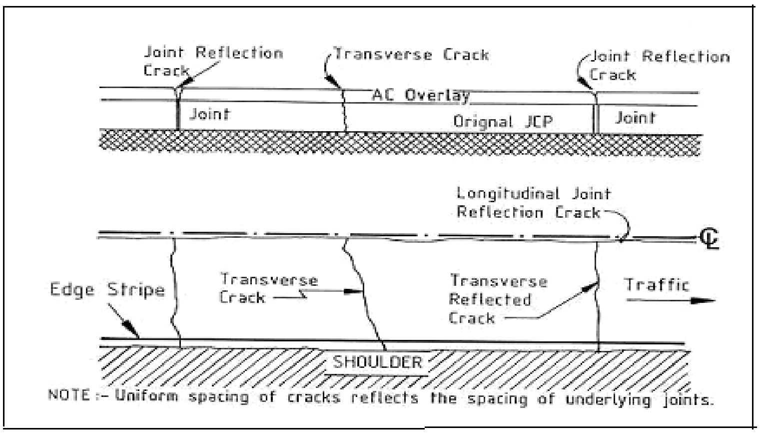


Figure 2.7 Reflection Cracking (GTC, 1998)

b. Severity levels

Low level of intensity (L): There can be such a level in the following cases:

- Is full of cracks introduced less than 10 mm.
- Isolated cracks with insulation in good condition can be determined display**.**

Medium level of intensity (M): There is one of the following cases:

- Non-filled cracks with a width of between 10 - 70 mm.

- Cracks filled with non-display greater than 75 mm surrounded by a badly broken secondary.
- Cracks filled with any offer and is surrounded by secondary badly broken

Higher level of intensity (H): There is in any of the following cases

- Cracks filled or not filled surrounded by strongly medium or high of secondary cracks.
- Cracks filled with non-display greater than 75 mm.
- Cracks introduced about 100 mm and surrounded by volatile badly broken or broken.

c. How to Measure

Measured cracks reflective linear meter intervals, and must record length and level of intensity for each slot. In some cases several different levels of intensity in one sector, in this case must be recorded along the cracks and the level of intensity and intensity of each separately. 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.

d. Possible causes

Movement is the concrete slab of concrete resulting from the heat and humidity, which in turn reflected on the surface of asphalt pavement is the main cause of reflective cracking joints.

2.3.1.6 Slippage Cracks (Sliding Cracks):

a. Description

Slippage cracks are crescent- or half-moon shaped cracks having two ends pointed away from the direction of traffic. (see figure 2.8)They are produced when braking or turning wheels cause the pavement surface to slide and deform. This usually occurs when there is a low-strength surface mix or poor bond between the surface and next layer of pavement structure.

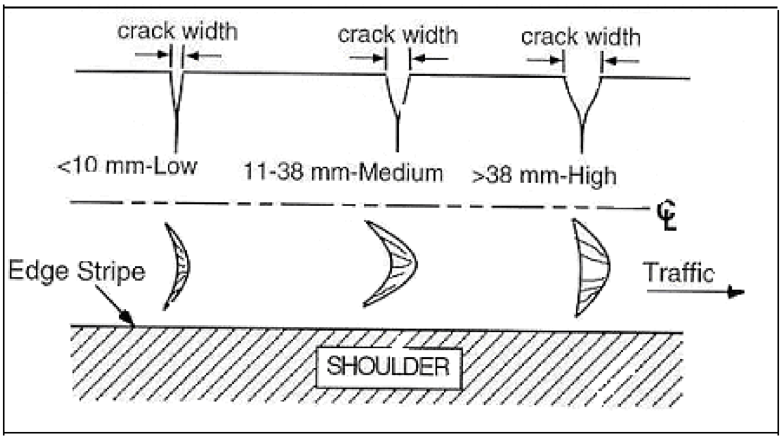


Figure 2.8 Slippage Cracks (GTC, 1998)

b. Severity levels

Low level of intensity (L): the width of cracks less than 10 mm.

Medium level of intensity (M): you can encounter one of the following cases:

- Average width of cracks between 11-40 mm.
- Break the average in the surrounding area cracks happened to her and / or that the region is surrounded by secondary badly broken.

Higher level of intensity (H): one case occurring

- Average width of cracks greater than 40 mm.
- The area around the cracks has broken into pieces easy removal.

c. How to Measure

Measured by the area affected cracks Sliding surface box. Density is calculated by dividing the area affected by the defect on the total area of the section scanned.

d. Possible causes

i. Weak linkage between the surface layer and successive layers of the structure or building pavement.

ii. Low resistance of asphalt mixture.

2.3.2 Pavement Defects

2.3.2.1 Crawl or Shoving

a. Description:

Crawl or longitudinal movement of the offset is localized to the area of the surface of the road towards the traffic generated as a result of motor traffic loads, when the pavement layer drive traffic it generates a short, high waves on the surface layer of pavement (see Figure 2.9). This occurs in the defect sites intersections (and slower acceleration) and before traffic signals where to stop and start of a movement or in areas adjoining cement concrete layer with a layer of asphalt floppy.

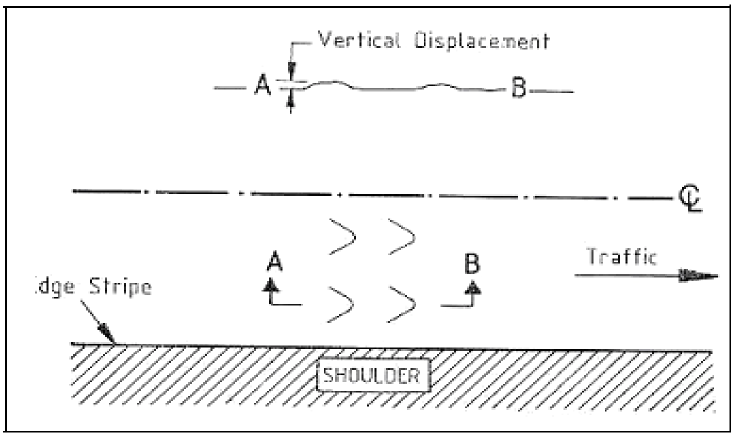


Figure 2.9 Crawl or Shoving (GTC, 1998)

b. Severity levels

Low level of intensity (L): is the level that affects the quality of a simple command.

Medium level of intensity (M): is the level that affects the average level of quality leadership.

Higher level of intensity (H): level is severely affecting the quality of leadership.

c. How to Measure

Surface creep is measured by the box of the affected area for each level of severity, but when it happens to crawl sites recorded as patching only. Density is calculated by dividing the area affected by the defect on the total area of the section scanned multiplied by one hundred.

d. Possible causes

i. Shear stresses generated by the movement of vehicles on sites with steep slope or at the intersections of traffic signals.
ii. Poor stability pavement surface because of the increased proportion of asphalt or increase the proportion of the soft material in the mix or the use of rubble circular shape.
iii. Stability of weak layers under the foundation stone and the foundation is reflected on the surface of pavement.

2.3.2.2 Rutting

a. Description

A rut is a surface depression in the wheel paths (see Figure 2.10). Pavement uplift may occur along the sides of the rut, but in many instances, ruts are noticeable only after a rainfall, when the wheel paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or sugared, usually caused by consolidated or lateral movement of the materials due to traffic loads. Significant rutting can lead to major structural failure of the pavement**.**

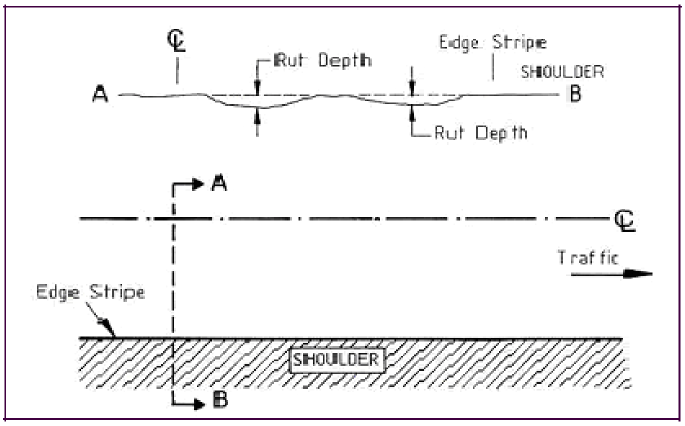


Figure 2.10 Rutting (GTC, 1998)

b. Severity levels

- **Low level of intensity (L):** the average depth for this level between 6 - 13 mm.
- **Medium level of intensity (M):** the average depth of between 14-25 mm.
- **Higher level of intensity (H):** the average depth of rutting at this level more than 25 mm.

c. How to Measure

Rutting is measured in square meter of surface area. The rut depth is determined by laying a (3m) straight edge across the rut and measuring its depth.

d. Possible causes

Contribute to poor materials or poor design materials mixture in compression classes, in addition to inadequate father during implementation, the smoothness of asphalt mix, the softer substrate material as a result of water leakage or shock frames (Studded tires), pavement thickness are all causes of rutting

.

2.3.2.3 Convexities and concavities (Bumps and Sags)

a. Description

Bumps are small, localized, upward displacements of the pavement surface. They are different from shoves in that shoves are caused by unstable pavement. Sags are small, abrupt, downward displacements of the pavement surface. If bumps appear in a pattern perpendicular to traffic flow and are spaced at less than 3 m (10 ft), the distress is called corrugation. Distortion and displacement that occur over large areas of the pavement surface, causing large or long dips Figure 2.11 show Bumps and Sags (ASTM D6433).

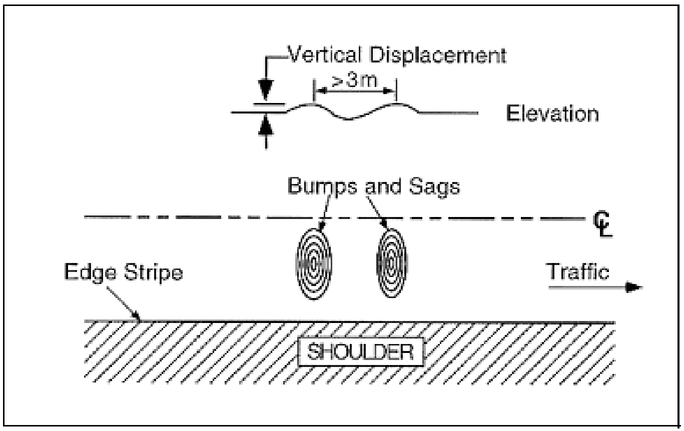


Figure 2.11 Convexities and Concavities (GTC, 1998)

b. 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.

c. 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.

d. 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.

2.3.2.4 Corrugation

a. Description

Corrugation is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals (1.5 meters) along the pavement (see Figure 2.12). The ridges are perpendicular to the traffic direction. Traffic action combined with an unstable pavement surface or base usually causes this type of distress.

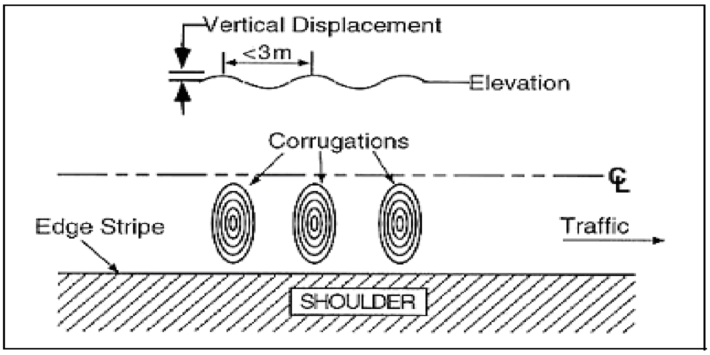


Figure 2.12 Corrugations (GTC, 1998)

b. 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.

c. 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 straight edge should be placed perpendicular to the corrugations so that the depth of the valleys can be measured in millimeters.

d. Possible causes

ii. Poor stability of asphalt concrete mixture or weak foundation.
iii. Excess moisture in the lower soil layers.
iv. Increase in asphalt and / or increase the soft material in the mix, or use a round pebble mixture.
v. Pollution mixture Contamination of mix.

2.3.2.5 Bleeding or Flushing Asphalt

a. Description

Bleeding is a film of bituminous material on the pavement surface which creates a shiny, glass-like, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphalt cement or tars in the mix and/or low air-void content. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the surface of the pavement. Since the bleeding process is not reversible during cold weather, asphalt or tar will accumulate on the surface

b. Severity 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 a period of not less than several weeks and be completely covered with a layer of gravel bitumen.

c. 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.

d. Possible 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 a reflection or effect in cold climates and pool are on the asphalt surface.

2.3.2.6 Raveling and Weathering

a. Description

Weathering and raveling are the wearing away of the pavement surface caused by the loss of asphalt or tar binder and dislodged aggregate particles. This distress indicates that either the asphalt binder has hardened appreciably or that a poor quality mixture is present .In addition, raveling may be caused by certain types of traffic (e.g., tracked vehicles) .Softening of the surface and dislodging of the aggregate due to oil or fuel spillage and surface seal loss are also in cluded under raveling.

b. Severity levels

- **Low level of intensity (L):** Aggregate or binder of the pavement or surface seal has started to wear away .In some area, the surface is starting to pit .In the case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.
- **Medium level of intensity (M):** Aggregate and or binder has worn away or the original pavement is showing through the surface seal in a few places. The surface texture is moderately rough and pitted .In the case of oil spillage.
- **Higher level of intensity (H):** Aggregate and or binder have been considerably worn away or much of the surface seal has been lost. The surface texture is very rough and severely pitted. The edge of the pavement has broken up to the extent that pieces are missing with in(3m to 6m)of the edge .In the case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose.

c. How to Measure

Weathering and raveling are measured in square meter of surface area.

d. Possible causes

i. Horizontal shear stress as a result of traffic.
ii. Oxidation or aging of asphalt materials and the separation of gravel Association, and the lack of materials, excess heat to the mixture, and the lack of asphalt content and insufficient compaction and the use of gravels weak in the mix asphalt.
iii. The presence of water (that has permeated into the class by spaces), which leads to the hydrostatics pressure at the impact of the movement.

iv. Emission of hydrocarbons for a long period of car engines (works hydrocarbon solvent for asphalt materials).

2.3.2.7 Polished Aggregate (Polished gravel)

a. Description

Aggregate polishing is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small or there are no rough or angular aggregate particles to provide good skid resistance. Existence of this type of distress is also indicated when the number on a skid resistance rating test is low or has dropped significantly from previous ratings.

b. Severity levels

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

c. 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.

d. Possible causes

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

2.3.2.8 Swell

a. Description

Swell is characterized by an upward bulge in the pavement's surface, a long, gradual wave more than 3 m (10 ft) long (see Figure. 2.13). Swelling can be accompanied by surface cracking. This distress usually is caused by frost action in the subgrade or by swelling soil (ASTM D6433).

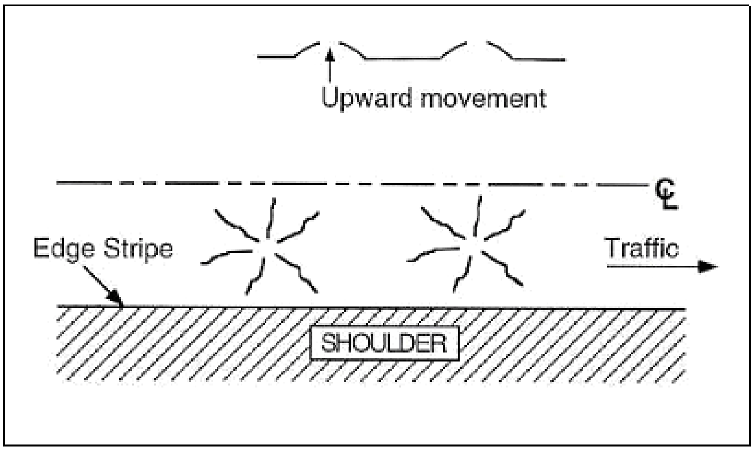


Figure 2.13 Swell (GTC, 1998)

b. Severity levels

- **Low level of intensity (L):** Swell is barely visible and has a minor effect on the pavement's ride quality as determined at the normal aircraft speed for the pavement section under consideration. (Low-severity swells may not always be observable, but their existence can be confirmed by driving a vehicle over the section at the normal aircraft speed. An upward acceleration will occur if the swell is present).

- **Medium level of intensity (M):** Swell can be observed without difficulty and has a significant effect on the pavement's ride quality as determined at the normal aircraft speed for the pavement section under consideration.
- **Higher level of intensity (H):** Swell can be readily observed and severely affects the pavement's ride quality at the normal aircraft speed for the pavement section under consideration.

c. How to Measure

The surface area of the swell is measured in square meters. The severity rating should consider the type of pavement section (i.e., runway, taxiway, or apron). For example, a swell of sufficient agnitude to cause considerable roughness on a runway at high speeds would be rated as more severe than the same swell located on the apron or taxiway where the normal aircraft operating speeds are much lower.

d. Possible causes

i. By freezing on the substrate, or swelling of the soil or poor drainage of water under the surface.
ii. High cement concrete slab bottom.

2.3.3 Pavement deformation

2.3.3.1 Depression

a. Description

Depressions are localized pavement surface areas with elevations slightly lower than those of the surrounding pavement (see Figure 2.14). In many instances, light depressions are not noticeable until after a rain, when ponding water creates a "birdbath" area; on dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of improper construction. Depressions cause some roughness, and when deep enough or filled with water, can cause hydroplaning.

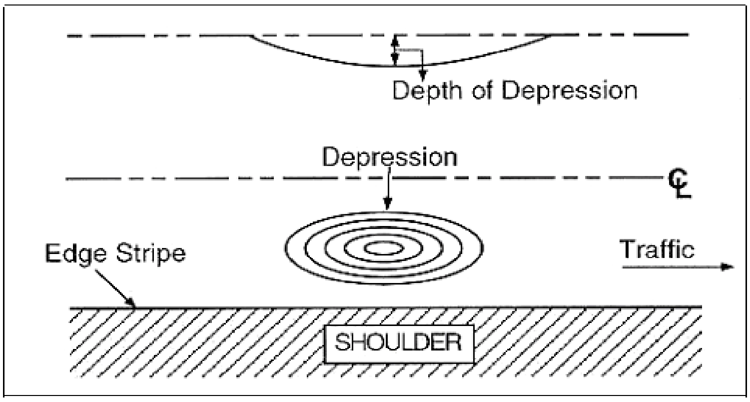


Figure 2.14 Depression (GTC, 1998)

b. Severity levels

- **Low level of intensity (L):** it is noted that level depression in the areas of spots, and have a 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 a 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 50 mm.

c. 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 (3 meters) across must be measured by either visual estimation or direct measurement when filled with water**.**

d. 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 hardcore sand 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.

2.3.3.2 Lane Shoulder Drop

a. Description

Lane shoulder drop is the difference between the level of the edge of pavement and the surface of the shoulders, and usually the level of the shoulders below the level of the adjacent track. Figure 2.15 Lane Shoulder Drop.

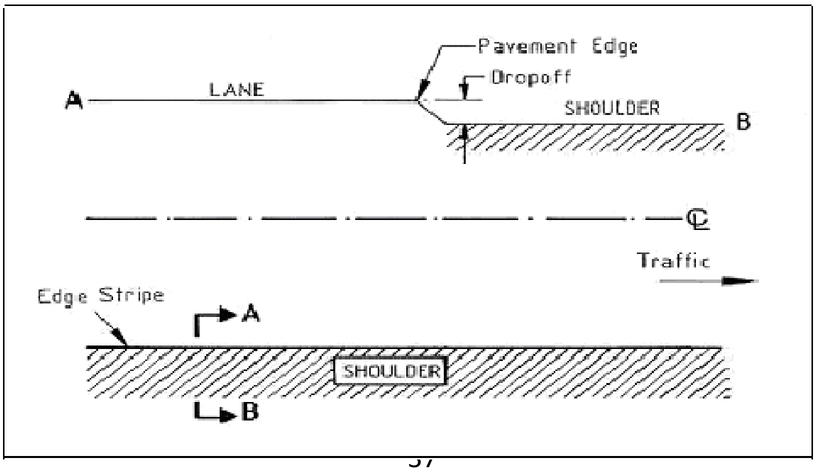


Figure 2.15 Lane Shoulder Drop (GTC, 1998)

b. 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.

c. 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.

d. Possible causes

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

2.3.3.3 Potholes

a. Description

Are usually Basin drilling diameters of about 750 mm, as have aspects of vertical near the top of the pit, which occur on the road surface and vary in depth and breadth. If there are cracks Alligator drilling because of high intensity should be defined and not digging flying (Weathering). Figure (2.16) the form and location of drilling in the road. Potholes are bowl-shaped holes of various sizes occurring in the pavement surface (ASTM D6433, 1999).

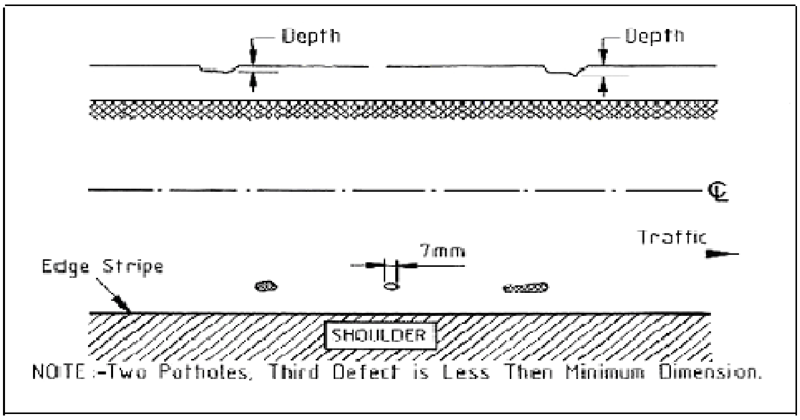


Figure 2.16 Potholes (GTC, 1998)

b. 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

c. How to Measure:

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

d. 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.

2.3.4 Surface patches

2.3.4.1 Patching

a. Description

A patch is an area of pavement which has been replaced with new material to repair the existing pavement (see Figure 2.17). A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section) (ASTM D6433).

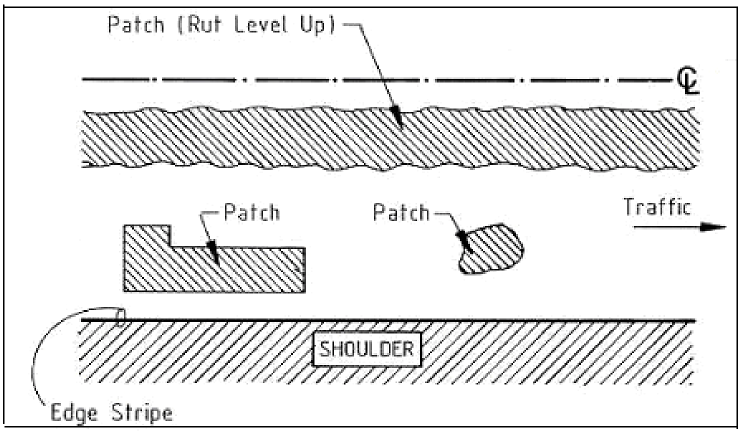


Figure 2.17 Patching (GTC, 1998)

b. 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): patch is moderately deteriorated and ride quality is rated as medium severity.

Higher level of intensity (H): patch is badly deteriorated and ride quality is rated as high severity. Patch needs replacement (maintenance needs to be immediate).

c. How to Measure

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

d. Possible causes

Possible reasons include a defect patching traffic loads, not controlling the quality of materials or poor implementation of re-filling and the poor operation of asphalt.

2.3.4.2 Utility Cut Patching (Services Patches)

a. Description

Services patching is a manifestation of urban roads in cities and villages, which include telephone services, electricity, water and sanitation, which are characterized along the length which could be up to the length of the road itself, in addition to patching sewer inspection chambers to be localized and deployed anywhere in the road surface. Figure 2.18 Services Patches.

The disadvantages of such patches affect the quality of leadership and these defects include the following:

i. Longitudinal and Edge cracks.
ii. Depression.
iii. Potholes.
iv. Raveling and Weathering (Erosion).

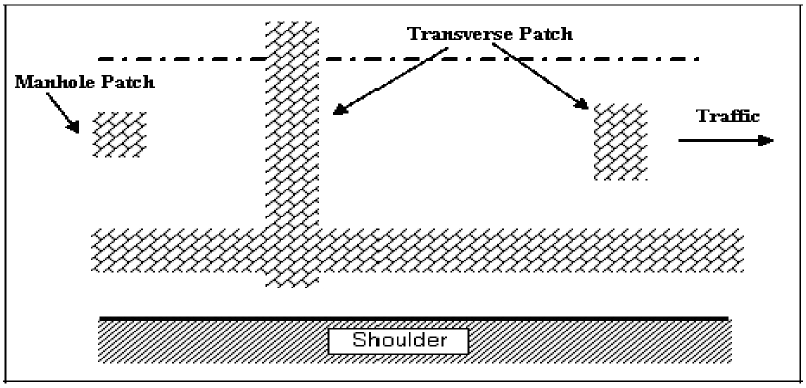


Figure 2.18 Services Patches (GTC, 1998)

b. 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.

c. How to Measure

Patches in the case of large-scale service, the registration of these defects are measured separately and located within the same patchwork 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.

d. 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).

2.4 Assessment of Surface Condition

The inspection method is designed to allow the calculation of a composite rating index called the pavement condition index .The steps for determining the PCI of an inspection unit are shown in next chapter .The PCI scale is shown in (table 2.2). The distress types, severity levels, and methods of estimating quantities are keyed to the deduct curves presented in the area.

This effort investigates to obtain field data that both increases safety and reduce labor requirements during the data collection for streets, roads and parking lots. The primary objectives are to evaluate the ability of the PCI survey system to assess the condition of roadway pavement, to use the resulting data to create and populate database **(**Cline et al,2002).

Using visual inspection to evaluate pavement surface conditions. The key to a useful evaluation is identifying different types of pavement distress and linking them to a cause. Understanding the cause for current conditions is important in selecting an appropriate maintenance or rehabilitation technique (Walker, 2002).

2.4.1 Pavement Condition Index (PCI)

The detailed field inspections categorize and quantify the pavement deficiencies such as cracks, patches and utility trench cuts. These deficiencies are entered into the PMS program that calculates a Pavement Condition index (PCI) for each roadway. PCI values range from zero (very poor) to 100 (excellent) (Weil, 2009).

2.4.2 Pavement Condition Rating

The pavement condition rating is a description of pavement condition as a function of the PCI value that varies from failed to excellent as shown in Table 2.2.

Table 2.2 pavement condition ratings and pavement condition index ranges (Seiler, 2009.Weil, 2009.U.S DOT, 2009).

Pavement Condition Rating	**Pavement Condition Index**
Excellent	86-100
Very Good	71-85
Good	56-70
Fair	41-55
Poor	26-40
Very Poor	11-25
Failed	0-10

The PCI is a quick method of comparing the overall condition of pavement and magnitude of rehabilitation needs. The following figure shows how pavement condition typically deteriorates over time. The new pavement holds its good condition for a long period, but once it begins to fail; its condition drops rapidly (Weil, 2009).

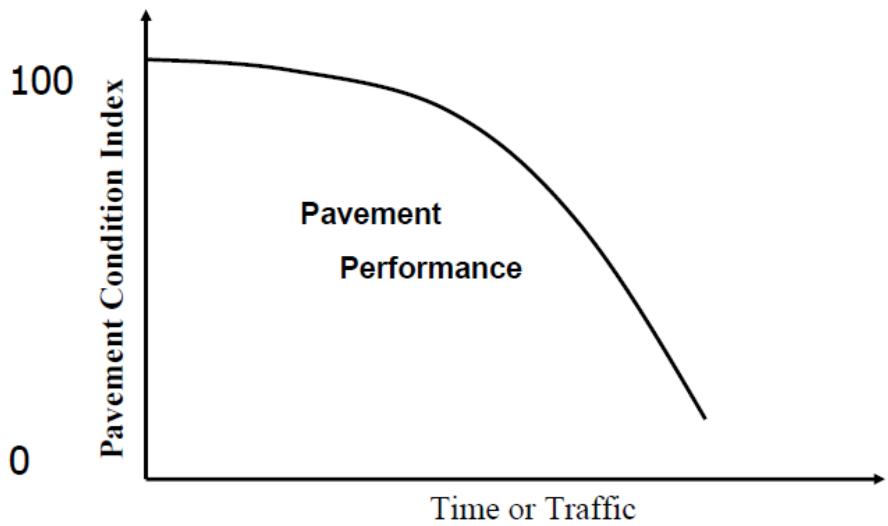


Figure 2.19 Relationship between pavement condition and time (U.S DOT, 2009).

2.4.3 Definition Pavement Condition

a. Excellent

Pavement is new construction .Nothing would improve the roadway 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 roadway 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. Roadways in this category are usually failed. Reconstruction at this time (Bashir, 2006).

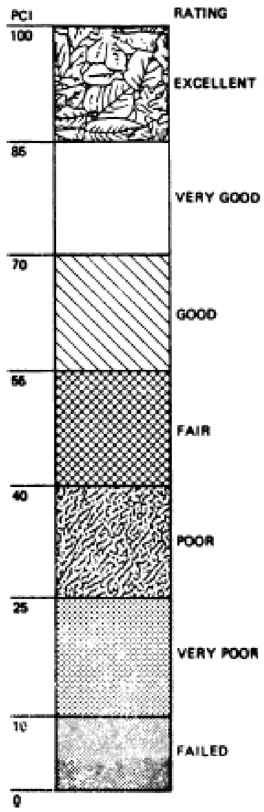


Fig 2.20 Pavement Condition Index (PCI) and Rating Scale
(ASTM standard D 6433)

2.5 Maintenance Activities

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 seal done 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):

a. **Preventative maintenance**: Activities that prevent or reduce further damage to the pavement.

Crack filling and sealing.

The most common and widely used maintenance activity for pavements, regardless of use, is crack sealing or filling. Crack sealing and filling is an inexpensive maintenance procedure that will significantly delay further deterioration of the pavement (Lavin, 2003).

Crack sealing and crack filling is actually two separate procedures:

- Crack sealing is the installation of a specially formulated crack sealing material either above or into working cracks using unique configurations to prevent the intrusion of water into the crack.
- Crack filling is the placement of crack filling material into non-working cracks to substantially reduce the intrusion of water into the crack.

Slurry sealing

A slurry seal is a homogenous mixture of emulsified asphalt, water, well-graded fine aggregate and mineral filler that has a creamy fluid-like appearance when applied. Slurry seals are used to fill existing pavement surface defects as either a preparatory treatment for other maintenance treatments or as a wearing course (Hoffman, 2008).

Recycling

Recycling is the reuse of the asphalt surface, but it does not usually reuse the base. This environmentally-friendly technique fixes cracks and restores the surface, but it does not fix any base quality or drainage problems. Any isolated base or drainage problems should be repaired prior to recycling (David, 2006).

b. Structural maintenance: Activities that repair or improve the structural integrity of the pavement.

Patching

Patching is a year-round activity that is done to keep road surfaces drivable. Most patching is done to fill potholes. Ruts, slippage and other pavement defects may also be fixed best by patching. Patching does not fix base problems (David, 2006). Types of patches include (US Army, 2001):

- **Shallow**. A stable, compact leveling course is placed in depressions to level the surface.
- **Partial-depth**. Deteriorated area of the pavement is removed and replaced.
- **Full-depth**. Deteriorated area of the pavement, base course, and subgrade is removed and replaced. The subgrade should be recomputed.

Overlays

Overlays do not involve extensive structural design and generally contribute little, if anything, to a pavement's structural capacity. Non-structural overlays are generally thin surface overlays on the order of 12.5 mm (0.5 in.) to 37.5 mm (1.5 in.) (Hoffman, 2009).

Reconstruction

This is a very expensive technique, but it may be the only option for a badly deteriorated road. Total reconstruction can be cost-effective if done in conjunction with utility replacement. This choice is usually a last resort (David, 2006).

2.6 Type of Repair Options

After the inspected the roadway 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 2.3 Type of Repair Options .

Table 2.3 Type of Repair Options (GTC, 1998)

Type of distress			Density		
			Low	**Medium**	**High**
Alligator Cracking	**Severity levels**	**L**	Do nothing	Slurry seal	overlay
		M	depth patch	overlay	reconstruction
		H	depth patch	overlay	reconstruction
Block cracking	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Crack sealing	Crack sealing	Recycle surface
		H	Slurry seal	Recycle surface	Thin overlay
Transverse &Longitudinal cracks	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Crack sealing	Crack sealing	Crack sealing
		H	Slurry seal	Slurry seal	Thin overlay
Edge cracking	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Crack sealing	Crack sealing	Crack sealing
		H	Repair shoulder / Deep patching	Repair shoulder / Deep patching	Repair shoulder / Deep patching

Reflection cracking	**Severity levels**	**L**	Do nothing	Crack sealing	Crack sealing
		M	Crack sealing	Crack sealing	Crack sealing
		H	Surface patching	Surface patching	Surface patching
Slippage cracks	**Severity levels**	**L**	Do nothing	Slurry seal	Slurry seal
		M	Surface patching	Surface patching	Surface patching
		H	Deep patching	Deep patching	Deep patching
Shoving	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Deep patching	Deep patching	Deep patching
		H	Deep patching	Deep patching	Reconstruction
Rutting	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Milling and repave	Milling and repave	Milling and repave
		H	Deep patching	Deep patching	Reconstruction
Type of distress			**Density**		
			Low	**Medium**	**High**
Bumps and Sags	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Surface patching	Surface patching	Surface patching
		H	Deep patching	Deep patching	Deep patching
Corrugation	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Surface patching	Surface patching	Surface patching
		H	Deep patching	Base repair and repave	Base repair and repave
Bleeding or Flushing	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Do nothing	Spry hot sand and roll	Milling and repave
		H	Milling and repave	Milling and repave	Milling and repave
Raveling and Weathering	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Slurry seal	Slurry seal	Slurry seal
		H	Thin overlay	Thin overlay	Thin overlay

Polished Aggregate			Do nothing	Slurry seal	Slurry seal
Swell	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Deep patching	Deep patching	Deep patching
		H	Deep patching	Deep patching	Deep patching
Depression	**Severity levels**	**L**	Do nothing	Do nothing	Do nothing
		M	Surface patching	Surface patching	Surface patching
		H	Deep patching	Base repair and repave	Base repair and repave
Lane shoulder drop	**Severity levels**	**L**	Refill shoulder	Refill shoulder	Refill shoulder
		M	Refill shoulder	Refill shoulder	Refill shoulder
		H	Refill shoulder	Refill shoulder	Refill shoulder

Type of distress			**Density**		
			Low	**Medium**	**High**
Potholes	**Severity levels**	**L**	Surface patching	Surface patching	Surface patching
		M	Surface patching	Surface patching	Surface patching
		H	Deep patching	Deep patching	Deep patching
Patching	**Severity levels**	**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

2.7 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 2.21 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 in Figure 4.11 , 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).

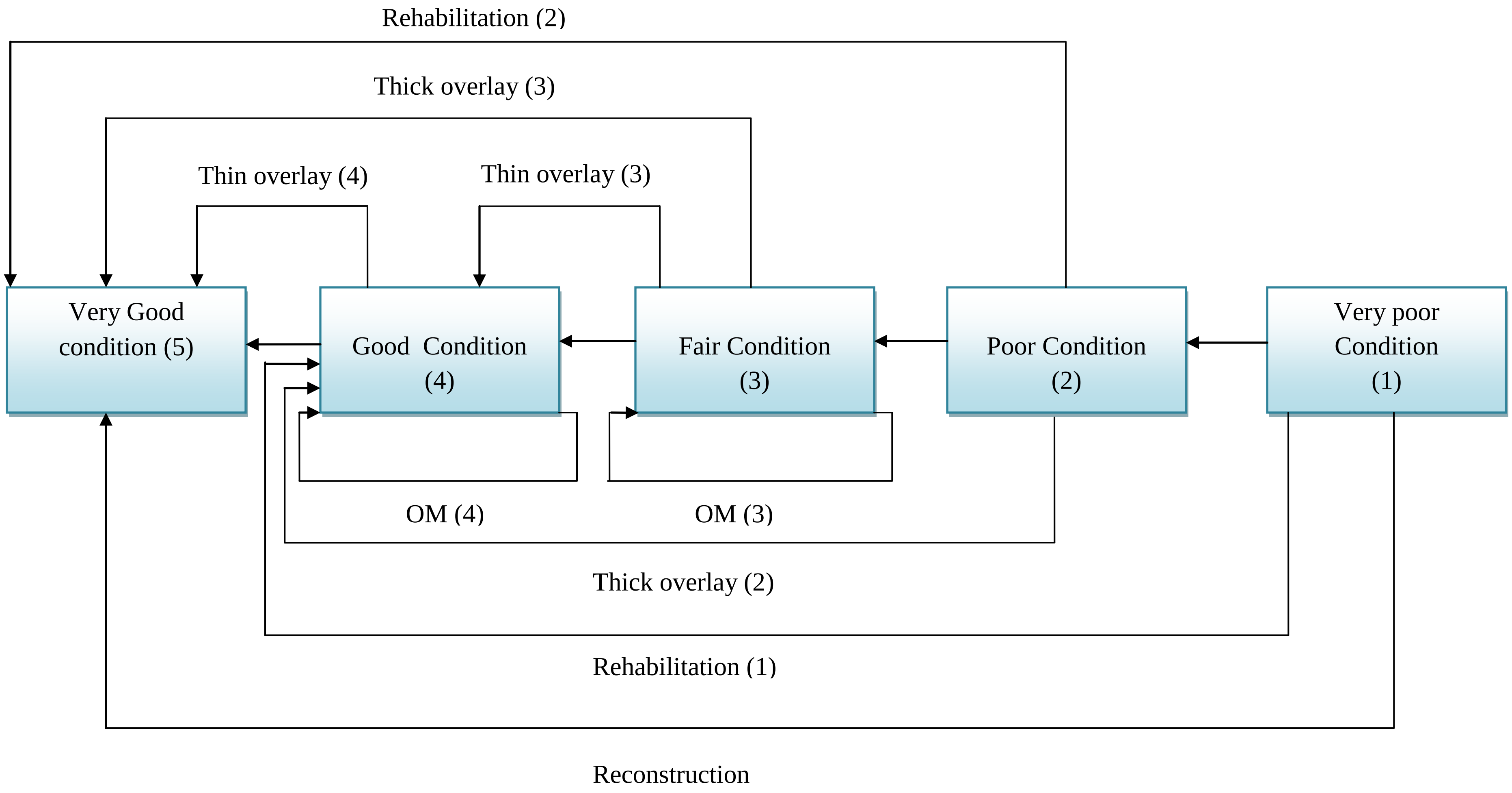


Fig 2.21 pavement condition & maintenance activities (Akyildiz, 2008)

Definition of Sets

a. Pavement Condition: This set represents the pavement's condition state. There are 5 predefined pavement condition states available. These condition states are as follows (Akyildiz, 2008).

1. Very Poor Condition
2. Poor Condition
3. Fair Condition
4. Good Condition
5. 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 are as follows (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.

CHAPTER 3

METHODOLOGY

3.1 PCI Method

The PCI is a numerical indicator that rates the surface condition of the pavement. The PCI provides a measure of the present condition of the pavement based on the distress observed on the surface of the pavement, which also indicates the structural integrity and surface operational condition (localized roughness and safety). The PCI cannot measure structural capacity nor does it provide direct measurement of skid resistance or roughness. It provides an objective and rational basis for determining maintenance and repair needs and priorities. Continuous monitoring of the PCI is used to establish the rate of pavement deterioration, which permits early identification of major rehabilitation needs. The PCI provides feedback on pavement performance for validation or improvement of current pavement design and maintenance procedures (ASTM D6433, 1999).

The determination of the Pavement Condition Index (PCI) is often a useful tool in the evaluation of road pavements. The PCI is a numerical rating of the surface condition of a pavement and is a measure of functional performance with implications of structural performance. PCI values range from 100 for a pavement with no defects to 0 for a pavement with no remaining functional life. The index is useful in describing distress and comparing pavements on an equal basis. ASTM standard contains information on PCI surveys. The FAA recommends that roads follow ASTM D 6433, Standard Test Method for road Pavement Condition Index Surveys (ASTM D6433, 1999).

ASTM's manual is prepared to assist user of the Pavement Management System (PMS) in identifying surface distress in a uniform and repeatable manner. The distresses included in this manual are used to calculate the Pavement Condition Index (PCI) for pavements surfaced with asphalt concrete and surface treatments.

This practice covers the determination of roads and parking lots pavement condition through visual survey using the Pavement Condition Index (**PCI**) method of quantifying pavement condition. The PCI for roads and parking lots was developed by the U.S Army Corps Engineers (ASTM D6433, 1999).

3.2 Data requirement

The type of data collection is primary data from the field, as known the part was taken by a length of 1000 km. Recorded data for each type, calculated the area affected and recorded in special tables. And took a picture of each level of severity. The data collected using survey method by some people. The data requirement for this study is Type and severity levels of distress.

3.3 Data collection equipment

1. Data Sheets: for recording the following information:
   Date, location, branch, section, sample unit size, slab number and size, distress types, severity levels, quantities, and names of surveyors. As show in Figure 3.1.
2. Digital Camera: for take some photos.
3. Hand Odometer Wheel.
4. Layout Plan, for network to be inspected.
5. Safety equipment.

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

SKETCH:

BRANCH ____________ SECTION _________ SAMPLE UNIT _________
SURVEYED BY __________ DATE _________ SAMPLE AREA _________

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

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE

Figure 3.1 Flexible Pavement Condition Survey Data Sheet for Sample Unit (**ASTM D6433, 1999**)

3.4 Methodology of the research

In order to achieve the proposed objectives in this research, it was first necessary to select a Pavement Section for study, covering the range of possible conditions (good, fair, poor, and new).

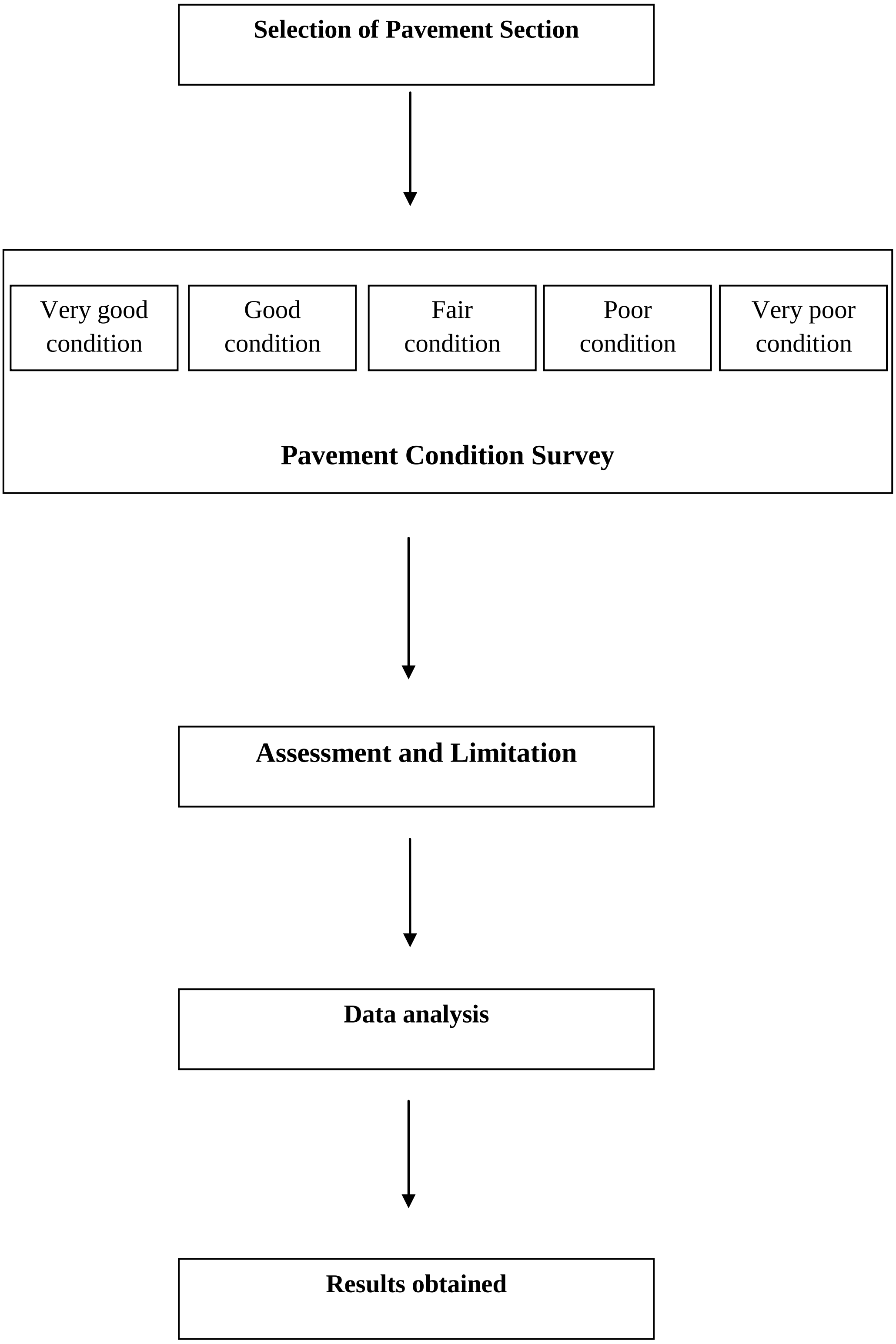


Figure 3.2 Flow chart of the research

3.4.1 Selection of Pavement Section

Selection of pavement sections for the study had to be conducted by an objective process that would allow discrimination among the different pavement distresses to be studied.

Pavement inspection is conducted on inspection units. An inspection unit is a small segment of a pavement section or management unit selected of convenient size which is then inspected in detail. The distress found in the inspection unit is used to calculate the PCI for the inspection unit inspected. The PCI of the inspected inspection unit in the section are then used to represent the condition of the entire section.This project is a field study of a road length of 1000 m (two directions), and was divided into 10 parts a length of 100 m of each part.

3.4.2 Pavement Condition Survey

This study focused on flexible pavements; in general, both flexible and rigid pavements can be designed for long life.

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

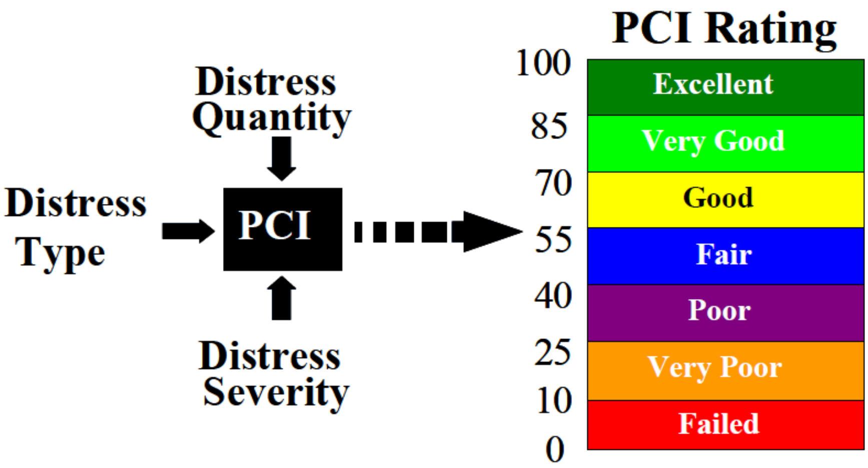


Fig 3.3 PCI Procedure (Hein and Burak, 2007)

The surface condition of a pavement at any time reflects the degree of damage caused by traffic and the environment based upon a visual evaluation of the pavement surface. The surface condition rating is useful as an input for predicting the remaining life of a pavement. It also assists in the preliminary evaluation and programming of appropriate maintenance and rehabilitation treatments (AGRA Earth, 1997).

The evaluation of pavement performance is a complex task and it is important for pavement design, rehabilitation, and management. Generally speaking, the main components of the pavement performance include the evaluation of pavement roughness, distress, friction and structure.

3.4.3 Assessment and Limitation:

During the field condition surveys and validation of the PCI, several questions are commonly asked about the identification and measurement of some of the distresses. The answers to these questions for each distress are included under the heading “How to Measure”(see chapter II). However, the most frequently raised issues are addressed below (**ASTM standard D 6433, 1999**):

- If alligator cracking and rutting occur in the same area, each is recorded separately at its respective severity level.
- If bleeding is counted, polished aggregate is not counted in the same area.
- If a 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, however, the different levels of severity in a portion of a crack cannot be easily divided, that portion should be rated at the highest severity level present.
- If any distress, including cracking and potholes, is found in a patched area, it is not recorded; its effect on the patch, however, is considered in determining the severity level of the patch.
- Significant amount of polished aggregate should be present before it is counted.

3.4.4 Analysis of data

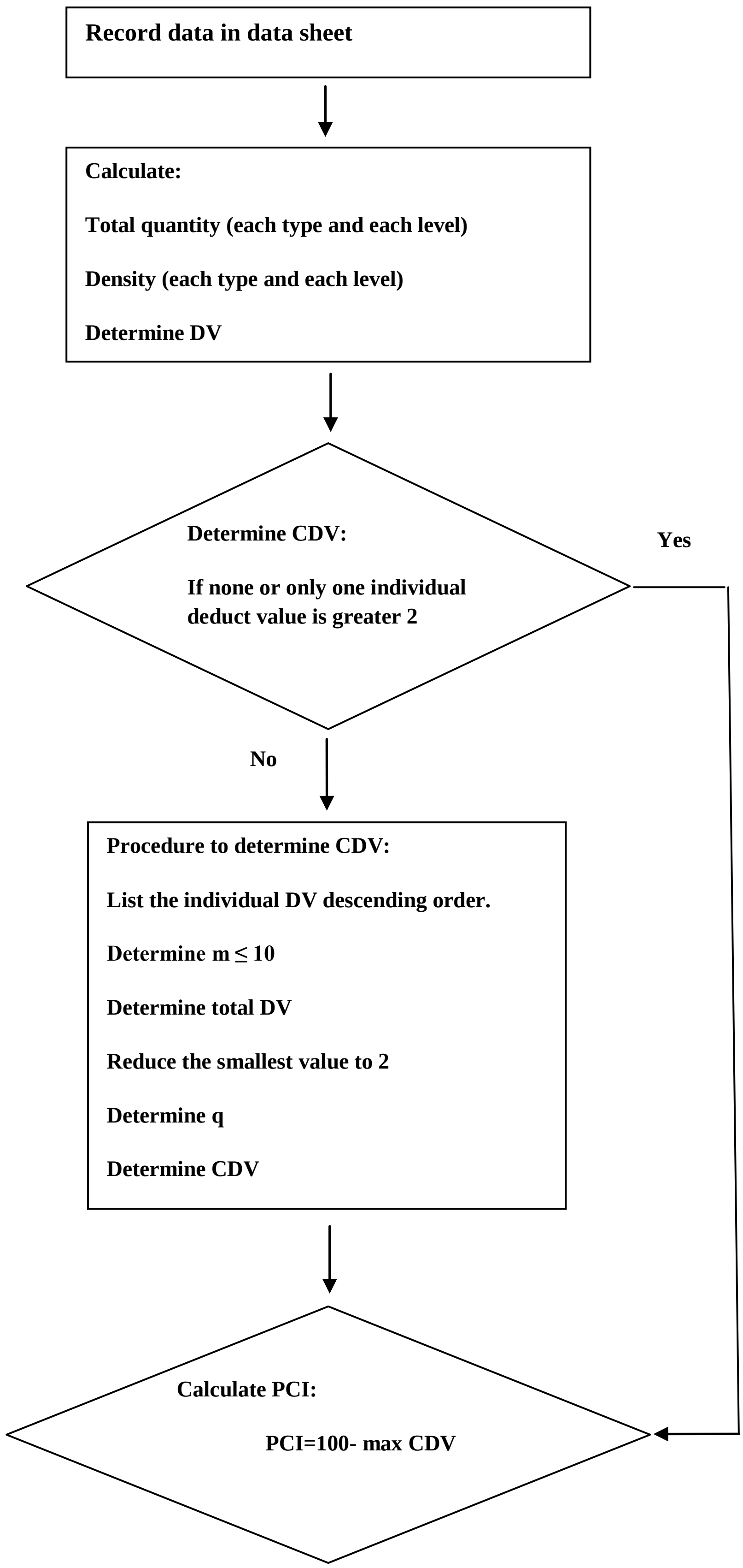


Figure 3.4 Analysis steps

Calculation of PCI for Asphalt Concrete (AC) Pavement (**ASTM standard D 6433, 1999**)**:**

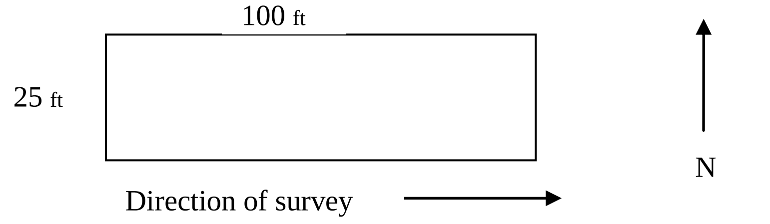
1. Inspect sample units. Determine distress types, severity levels and measure density:

   Add up the total quantity of each distress type at each severity level, and record them in the "Total Severities" section. The units for the quantities may be either in square feet (square meters), linear feet (meters), or number of occurrences, depending on the distress type. For example as show in Table 3.1.

Table 3.1 Example of a flexible Pavement Condition Survey Data Sheet for Sample Unit (ASTM standard D 6433)

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : **SPRING FLEED** No. of sample: **Section 01 sample 1**
Surveyed by: **KAK** Date: **Jul 93**



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	1*5	1*5	1*4							**13**	**0.52**	**7.9**
1 H	1*8	1*6								**14**	**0.56**	**23.4**
7 L	32	15	18	24	41					**130**	**5.20**	**7.5**
8 M	20	15	18	24	41					**143**	**5.72**	**25.1**
11 H	3*4	2*5								**22**	**0.88**	**17.9**
13 L	1									**1**	**0.04**	**11.2**
15 L	4	9	8							**21**	**0.84**	**6.9**
19 L	250									**250**	**10.0**	**5.30**

2. Divide the total quantity of each distress type at each severity level by the total area of the sample unit and multiply by 100 to obtain the percent density of each distress type and severity.
3. Determine the deduct value (DV) for each distress type and severity level combination from the distress deduct value curves in ASTM standard D 6433, as show in figure 3.5 deduct value curves for asphalt for Alligator Cracking.

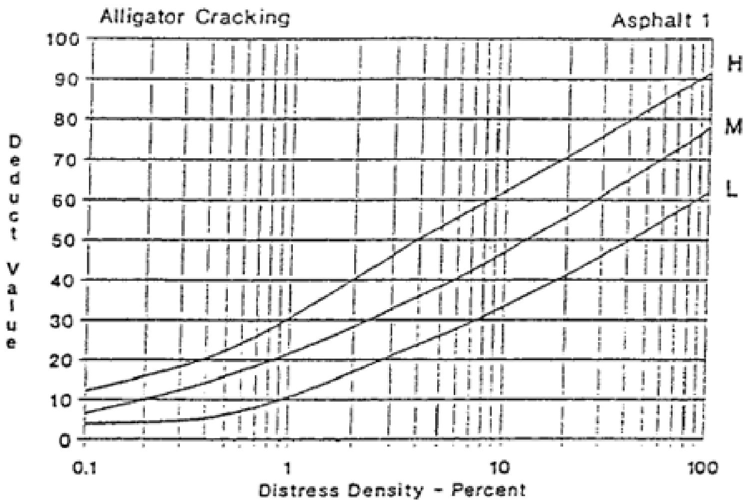


Figure 3.5 Deduct values for Alligator cracking (ASTM standard D 6433)

4. Determine the maximum Corrected Deduct Value (CDV). The procedure for determining maximum CDV from individual DV is identical for both AC.
5. 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.

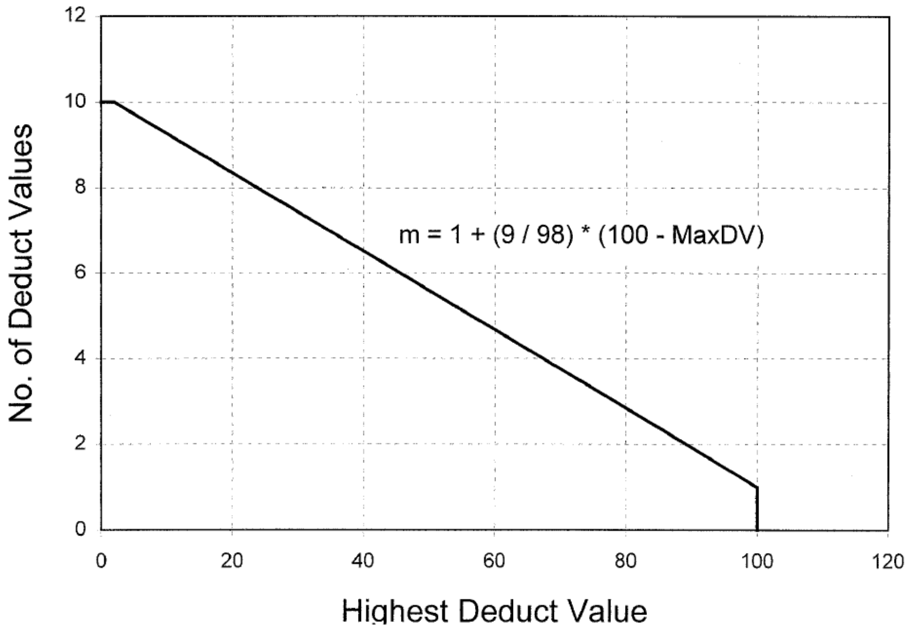


Figure 3.6 Adjustment of Number of Deduct Values

(**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 3.7.

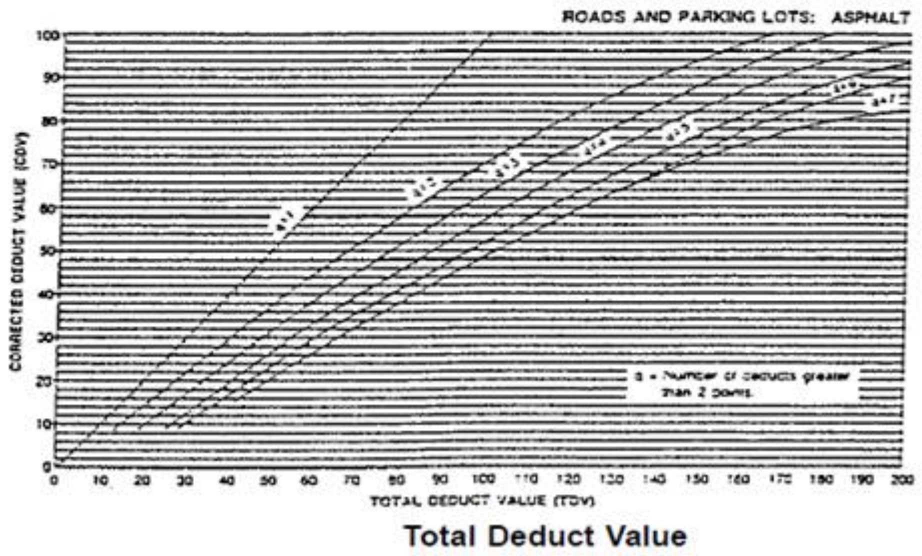


Figure 3.7 Corrected deduct values (**ASTM standard D 6433**)

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

Table 3.2 Calculation of CDV value—Flexible Pavement (ASTM standard D 6433)

m=1+ (9/98) (100-Max DV) ≤ 10
m=1+ (9/98) (100-25.1) =7.9
0.9*5.3=4.8

#	Deduct value										Total	q	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.

6. Calculate PCI by subtracting the maximum CDV from 100:

PCI=100-max CDV (**ASTM standard D 6433**)

CHAPTER 4

DATA PRESENTATION AND DISCUSSION

4.1 General

Pavement condition affects travel cost, including vehicle operation, delay and crash expenses. Assessment of pavement condition is usually divided in to:

1. Condition survey.
2. Evaluation survey.

Poor road surfaces cause additional wear or even damage to vehicle suspensions, wheels and tires. Delay occurs when vehicle slow for potholes or very rough pavement. In heavy traffic, such slowing can create significant queuing and subsequent delay. Unexpected changes in the surface condition can lead to crashes and inadequate road surfaces may reduce road friction, which affects the stopping ability of vehicles.

Choosing the Standard Practice for Roads and Parking Lots Pavement Condition Survey (ASTM standard 6433) are good and easy for road pavements.

4.2 Historical structure of pavement

The road of study consists of two directions, as shown in Figure 4.1 one lane by width 3.25 m and width of road shoulder 0.75m for two directions. A typical pavement structure consists of three different layers with different material and stiffness properties.

All pavement structures are designed in layers of progressively stronger materials. These layers consist of the subgrade, subbase(s), base, and surface course. The surface course is defined as the uppermost layer that makes direct contact with wheel loads. The layer of material directly under the surface course is considered as the base course. Under the base course is the subbase, and under the subbase is the subgrade (natural soils). The type of material in each layer and the thickness of the layer will directly affect the strength of the pavement. Sections of pavement that have an identical surface course (ADO, 1999).

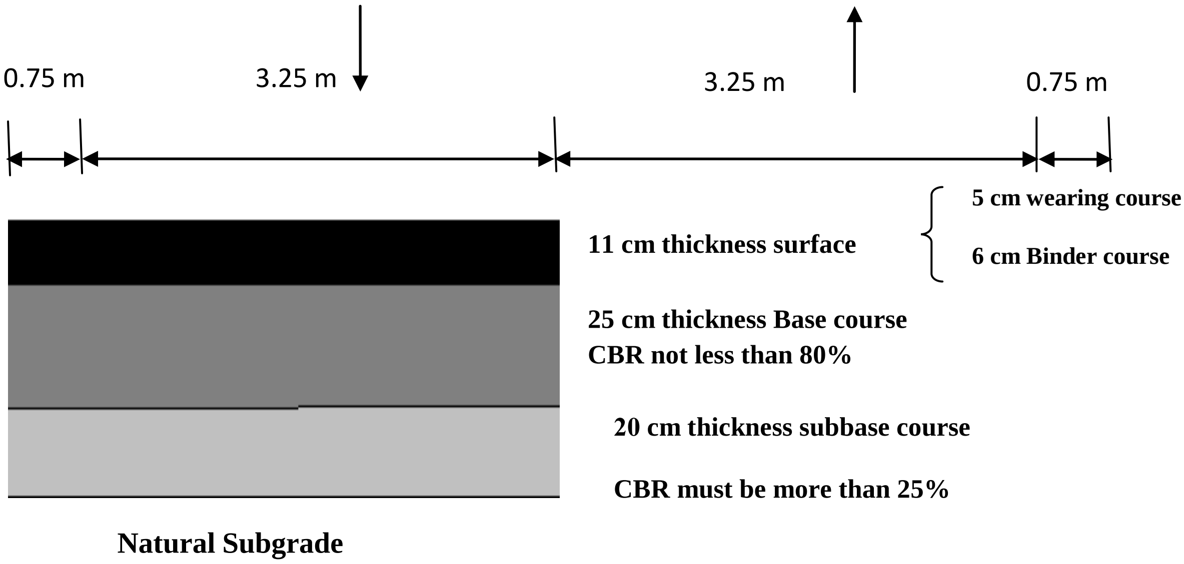


Figure 4.1 cross section and pavement layer thickness in secondary roads (OECO, 2008)

a. Subgrade course

The subgrade is the in situ material upon which the pavement structure is placed. Although there is a tendency to look at pavement performance is terms of pavement structure and mix design alone, the subgrade can often be the overriding factor in pavement performance and must be investigated (OECO,2008).

The experimental results obtained on the soils beneath the cracked pavement section, from these results the following observations were made (Bashir 2006) see Table 4.1:

1- Soil contains low percentage of clay and in general a relatively high percentage of sand.

2- Soil low in plasticity.

3- The relative compaction of the soil under the pavement was good for the required standards of pavement construction. Therefore according to AASHTO the soil is considered to be a good soil.

Table 4.1 the summary of subgrade soil properties (Bashir 2006).

Property	**Unit**	
Depth of sample	m	0.75
Sieves analysis	%	
Percent of passing from sieve 10	%	100
Percent of passing from sieve 40	%	100
Percent of passing from sieve 200		53.7
Consistency limits		
Liquid limit LL	%	15.70
Plastic Limit PL	%	8.80
Plasticity PI	%	6.90
Compaction		
Optimum water content	%	10.00
Max .dry density	Mg/m^3	1.865
Degree of compaction	%	97.3
Unified soil classification		A4

b. Sub base course

The subbase course is between the base course and the subgrade. It functions primarily as structural support but it can also (OECO, 2008):

1- Minimize the intrusion of fines from the subgrade into the pavement structure.

2- Improve drainage.
3- Minimize frost action damage.
4- Provide a working platform for construction.

The subbase consists of (OECO, 2008):

1- Consists of solid thick gravel or remnants of quarries and the bonding materials to fill in the voids.
2- Materials should be conspecific, clean and free of any impurities.
3- Must not exceed the maximum size of half the thickness of the layer (not more than 3 inches) with the exclusion of larger sizes.
4- Should not increase percentage passing the No. 4 sieve is than 70%.
5- the properties of material passing the No. 10 sieve as follows:

No. sieve	No 10	No 40	No 200
Percent passing	`100	25-70	0-35

- The liquid limit not more than 25 and plastic limit must be between (0-10).
- CBR value must be more than 25 %.

c. Base Course

The base course is immediately beneath the surface course. It provides additional load distribution and contributes to drainage and frost resistance. Base courses are usually constructed out of:

Required Materials (OECO, 2008):

No. of sieve	o.375in	0.75in	1.5in	2in	4 in	10 in	40 in	200 in
Percent passing	40-70	50-80	70-100	100	30-60	20-50	10-25	5-10

1- The liquid limit of material passing the No. 40 sieve should be not more than 25 and plastic limit ranges from 0 to 6.

2- CBR ratio for a sample submerged and compressed to the maximum density should be not less than 80%.
3- Would rather be a regular gradient-General should also not exceed the pass-through the No. 200 sieve 0.5 from passing No. 40 sieve.

The thickness of base course is 25 cm

d. Prime coat

It is a (MC) asphalt mixture by the kerosene is sprayed over the base layer before placing the asphalt.

e. Tack Coat

Consists of adding gasoline to the bituminous is sprayed on the first layer of asphalt for preparation to serve second layer, for paste layers.

f. Surface Course

the surface course of a flexible structure consists of a mixture of mineral aggregates and bituminous materials placed as the upper course and usually constructed on a base course .In addition to its major function as a structural portion of the pavement, it must also be designed to resist the abrasive forces of traffic, to reduce the amount of surface water penetrating the pavement, to provide a skid resistance surface, and to provide a smooth and uniform riding surface.

Thickness of This top structural layer of material is 11 cm subdivided into 6 cm layer the first layer is called Binder Course and 5 cm and a second layer called wearing Course.

4.3 Inspection procedures

The evaluation of pavement condition included consideration of specific problems that existed in the pavement. This requires a determination of the types and causes of distress, as well as the extent of pavement deterioration. Pavement inspection is conducted on inspection units. An inspection unit is a small segment of a pavement section or management unit selected of convenient size which is then inspected in detail. The distress found in the inspection unit is used to calculate the PCI for the inspection unit inspected. The PCI of the inspected inspection units in the section are then used to represent the condition of the entire section.

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" inspection unit. This was used to identify areas of localized deterioration such as an area damaged by utility cuts, crossing of construction traffic or other localized problems. A weighted average was used to calculate the PCI when special inspection units are inspected.

The inspector inspects the sample unit by walking the inspection unit or standing on the curb/shoulder, and recording the type, severity and amount of each distress present in the inspection unit. The type, severity and amount must correspond to those defined in this distress identification manual. The quantities and severities should normally be estimated using measuring techniques as accurate as pacing when the inspector can walk the inspection unit and by visual estimation when he stands on the curb or shoulder (ASTM, 1999).

The inspection method is designed to allow the calculation of a composite rating index called the pavement condition index (PCI). The steps for determining the PCI of an inspection unit are shown in analysis of data in(Chapter III).The PCI scale is shown in figure 2.20 in (Chapter II) .The distress types ,severity levels descriptions must be carefully followed since they were used in the development of the deduct curves. Failure to do so could invalidate the PCI calculated.

THE study road lie in north east part of Libya in Koms city .Type of road is secondary road; it is link by length 20 km between city center and Mslata village. This project was a field study of a road length of 1000 m (two directions), and was divided into 10 parts a length of 100 m of each part.

Inspection of all pavement section may be necessary, however, such inspection require considerable effort and time, especially if the section is large such as the road that chosen. Therefore, the sample selected randomly by length 1000 m, may be it has been allow adequate determination of the PCI for road.

4.4 Data and Types of pavement distress

An asphalt pavement, when designed and constructed properly, will provide years of service. All pavements will eventually require some type of maintenance. Asphalt pavements for parking facilities may require an application of sealer just to maintain or give a new appearance to the pavement for aesthetic reasons. Pavements continually undergo various types of stresses that induce minor defects into the pavement (Lavin, 2003).

The early detection and repair of defects in the pavement will prevent minor distresses from developing into a pavement failure. The identification of the distress aids the engineer or maintenance professional in identifying what caused the distress and the required approach in repairing it. Cracks and other defects start appearing very small and are usually only detectable when walking along the pavement.

For entire section inspections, the inspector walks over each sample unit, measures each distress type and severity, and records the data on the Asphalt Pavement Inspection Sheet. The letter **L** (low), **M** (medium), or **H** (high) is included along with the distress number code to indicate the severity level of the distress. Distresses and severity level definitions are listed in Chapter 2.

To understand which repair to choose, it is important to understand the distresses that occur in a pavement (David, 2006). Assessing condition of pavement by visual observation and recording of types of defects on the surface layer of the pavement. And include elements to assess the situation visually as follows:

1. Type of distress
2. Severity of distress
3. Density

The following sections describe he major problem that found in area of study during the field condition surveys:

4.4.1 Longitudinal Cracks

Low severity **Medium severity** **High severity**

Figure 4.2 Severity levels of longitudinal cracking

a. Description

Cracks parallel to the pavement's center line or lay down direction. They may be adjacent to the pavement edge. Usually a type of fatigue cracking.

b. Problem

Allows moisture infiltration, roughness, indicates possible onset of alligator cracking and structural failure.

c. Possible Causes

Pavement that is fatigued or "worn out" from heavy traffic (especially that due to high pressure truck tires); an unstable base; poor Construction.

d. Options for Repair (Cures)

Also treatment these cracks depend on the severity and intensity. In the case of low severity do not do something in the medium severity resort to fill the cracks. In the case of high severity use overlays surface, or implementing to thin overlay.

4.4.2 Alligator/Fatigue Cracking:

Low severity Medium severity High severity

Figure 4.3 Severity levels of Alligator cracking

a. Description:

Alligator fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. Cracking begins at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of crocodile, see Figure 4.3.

Alligator cracking is considered a major structural distress.

b. Problem

Indicator of structural failure, cracks allow moisture infiltration, roughness, may further deteriorate to a pothole.

c. Possible Causes

1- Repeated traffic loading.
2- Poor materials used in pavement.
3- Insufficient thickness of the pavement.
4- Poor drainage.

d. Options for Repair (Cures)

Treatment based on the severity and intensity of cracks starting using overlays, surface patching or re-construction.

4.4.3 Block cracking

Low severity Medium severity High severity

Figure 4.4 Severity levels of Block cracking

a. Description

Blocks are interconnected cracks that divide the pavement up into rectangular pieces. Blocks range in size from approximately 0.1m^2 (1 ft^2) to 9m^2 (100 ft^2).larger blocks are generally classified as longitudinal and transverse cracking. Block cracking normally occurs over a large portion of pavement area but sometimes will occur only in non-traffic areas (see Figure 4.4).

b. Problem

Allows moisture infiltration, roughness.

c. Possible Causes

Typically caused by an inability of asphalt binder to expand and contract with temperature cycles because of:

- Asphalt binder aging
- Poor choice of asphalt binder in the mix design.

d. Options for Repair (Cures):

Treatment based on the severity and intensity of cracks starting using overlays, surface patching or re-construction.

4.4.4 Transverse Cracks

Low severity Medium severity High severity

Figure 4.5 Severity levels of Transverse Cracks

a. Description

Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or lay down direction. These types of cracks are not normally load-associated.

b. Problem

Allows moisture infiltration, roughness.

c. Possible Causes

- Shrinkage of the pavement surface due to low temperatures or asphalt binder hardening.
- Reflective crack caused by cracks beneath the surface layer.

d. Options for Repair (Cures)

Treatment these cracks depend on the severity and intensity. In the case of low severity do not do something in the medium severity resort to fill the cracks.

In the case of high severity use overlays surface, or implementing to thin overlay.

4.4.5 Potholes

Low severity

Medium severity

Figure 4.6 Severity levels of Potholes

a. Description

Small, bowl-shaped depressions in the pavement surface that penetrate all the way through the asphalt layer down to the base course. They generally have sharp edges and vertical sides near the top of the hole. Potholes are most likely to occur on roads with thin asphalt surface (25 to 50 mm) and seldom occur on roads with 100 mm or deeper asphalt surface see Figure 4.6.

b. Problem

Roughness (serious vehicular damage can result from driving across potholes at higher speeds), moisture infiltration.

c. Possible Causes

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

d. Options for Repair (Cures)

The treatments are surface patching or deep depend on depth of the hole. No matter what cure is chosen, it is important to fix the situation which caused the pothole.

4.5.6 Patching

Figure 4.7 Patching

a. Description

An area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it performs.

b. Problem

Roughness.

c. Possible Causes

- Previous localized pavement deterioration that has been removed and patched.
- Utility cuts.

d. Options for Repair (Cures)

Repair distress in patch, Replace patch.

4.4.7 Polished Aggregate

Figure 4.8 Polished Aggregate

a. Description

Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small or there are no rough or angular aggregate particles to provide good skid resistance.

b. Problem

Roughness.

c. Possible Causes

Aggregate polishing is caused by repeated traffic applications.

d. Options for Repair

Surface treatment using polish resistant aggregate.

4.4.8 Raveling and Weathering

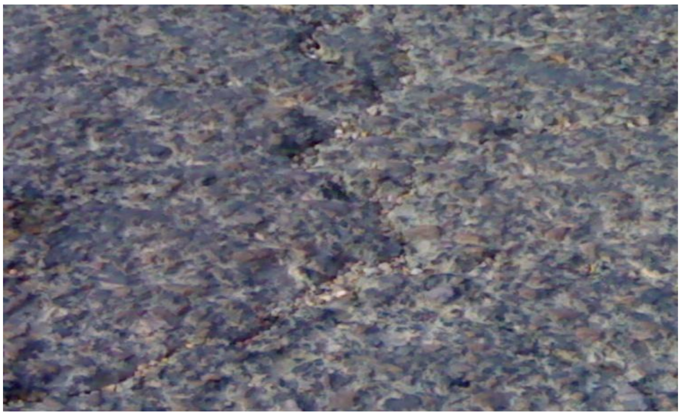


Figure 4.9 Raveling and Weathering

a. Description

Weathering and raveling are the wearing away of the pavement surface caused by the loss of asphalt or tar binder and dislodged aggregate particles. This distress indicates that either the asphalt binder has hardened appreciable or that a poor quality mixture is present.

Loose materials (usually aggregate) that "ravel" from the surface or edges of the pavement, resulting in depressions which may fill with moisture and loose aggregate which may pose problems.

b. Problem

Roughness, potholes.

c. Possible Causes

- May be caused by certain types of traffic (tracked vehicles).
- Poor quality mixture.
- Segregation of the mix during construction.

d. Options for Repair (Cures)

If the cause is superficial, a surface treatment will solve the problem. If poor drainage is causing a stripping problem, the drainage should be corrected.

4.5 Data analysis

The PCI is calculated for each inspected sample unit. The PCI cannot be computed for the entire pavement section without computing the PCI for the sample units first. The PCI calculation is based on the deduct-weighing factors from 0 to 100 that indicate the impact each distress has on pavement condition. A deduct value of 0 indicates that a distress has no effect on pavement structural integrity and/or surface operational condition, whereas a value of 100 indicates an extremely serious distress . (SHAHIN, 2005).

The entire net work was divided into 10 parts. For example, to calculate PCI next page for part no.1 of section road as show in Table 4.2 .Calculate PCI for other parts see Appendix (A).

Steps for calculating PCI of flexible pavement:

Data collected during either method of inspection are used to calculate the PCI. This paragraph explains how to calculate the PCI for a particular sample unit. An important item in the calculation of the PCI is the "deduct value." A deduct value is a number from 0 to 100, with 0 indicating the distress has no impact on pavement condition, and 100 indicating an extremely serious distress which causes the pavement to fail.

1- Determine distress types and severity levels and measure density:

   Each sample unit is inspected and distress data (type and severity levels) recorded on data sheet form as shown in Figure 3.1.

2- Determine deduct values:

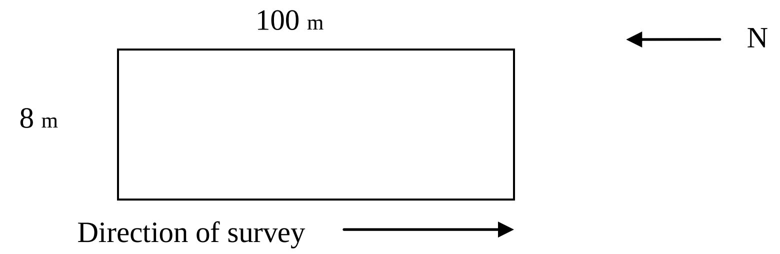
   Add up total quantity of each distress type at each severity level and record them in the “Total Severity” section. Divide the total quantity of each distress type at each severity level by the total area of the sample unit and multiply by 100 to obtain the percent density.

   Determine the deduct value (DV) for each distress type and severity level combination from the distress deduct value in Appendix (B).

Table 4.2 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Mslata Road   No. of sample: 01
Surveyed by: Group   Date: OCT /2010



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**
1L	2.5*4.7	0.5*1.5	0.4*8	1.3*6.5	1*1.8	1*4.5					**30.45**	**3.80**	**23**
1 M	2.5*5	4.5*3.3	1.8*2.3	1.3*1	1.3*1.2	1.1*1.2	1.4*4.5	1.6*6.5	3.5*6.6	4*1.1			
	0.6*0.5										**80.17**	**10.02**	**48**
3 L	0.8*6.1										**4.88**	**0.61**	**0**
3 H	1.4*4.5										**6.3**	**0.78**	**5**
10 L	2.4	2.1	3.6	1.8	2.1	2.1	2.9	1.05	3.35		**21.4**	**2.7**	**6**
10 M	7.5	3.8	3.4	3.3	4.8	4.9	1.45	3.36	4.44	3.37			
	1.4	2.5	3.37	3.56	4.25	3.45	1.4	4.2	1.48	3.42	**69.35**	**8.67**	**18**

3- Determine the corrected deduct value (CDV):

If none or only one individual deduct 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.

List the individual deduct values in descending order.

Determine the allowable number of deducts **m**, from figure (Figure 3.5 in chapter 3) or using the following formula:

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

Where:

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

HDV=highest individual deduct value.

For example:

m = 1+ (9/98) (100-48) = 5.77

The number of individual deduct values is reduced to the m largest deduct values, including the fractional part. For the example in table (2), the values are 48, 23, 18, 6 and 3.85.(the 3.85 is obtained by multiplying 5.0 by (5.77-5.0)= 3.85).

4- Determine total deduct value by summing individual deduct values.

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

6- Copy DVs on current line to the next line, changing the smallest DV greater than two to two. Repeat 4,5,6 until q=1

7- Determine the CDV from total deduct value and q by looking up the appropriate correction curve for AC pavements in Figure 3.6.

8- Calculate PCI by subtracting the maximum CDV from 100

PCI=100-max CDV (**ASTM standard D 6433**)

Table 4.3 Calculation of corrected PCI value

m = 1+ (9/98)(100-Max DV) ≤ 10

m = 1+ (9/98)(100-48) = 5.77

0.77*5=3.85

#	Deduct value										Total	q	CDV
1	48	23	18	6	3.85						**98.85**	**5**	**52**
2	48	23	18	6	2						**97**	**4**	**56**
3	48	23	18	2	2						**93**	**3**	**60**
4	48	23	2	2	2						**77**	**2**	**56**
5	48	2	2	2	2						**56**	**1**	**56**

Max CDV = 60

PCI = 100- Max CDV = 40

Rating = Fair

4.6 Summary and Discussion

PCI of the section road lie in the north east part of Libya in Koums area. As show in Tables 4.4 describe the results for road condition.

Table 4.4 PCI results.

Part No.	Class and type of road	PCI	PCR
01	Secondary road, Double (two directions)	40	Fair
02		42	Fair
03		48	Fair
04		50	Fair
05		50	Fair
06		44	Fair
07		40	Fair
08		50	Fair
09		42	Fair
10		50	Fair

The following section deal with evaluation secondary road .The road of study as known, divided into 10 parts (length of each part 100 m). The pavement evaluation results from the manual PCI survey revealed that all sections of road were fair condition. Considered the section of road that surveyed, describing the condition pavement of the all road.

During the field condition surveys and the validation of the PCI, there are several Distresses in Asphalt Pavement; nineteen distress types for AC pavements are listed alphabetically.

Table 4.5 Distresses types for flexible pavement

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

Figure 4.10 shows the types of distresses and severity levels in each part. From visual inspection of the road, there is more than defect. Seven distresses are observed and quantified for a 10-samples pavement unit, almost of them are alligator cracking with low, medium and high severity, block cracking with low medium and high severity, longitudinal & transverse cracking with low and medium severity, patching with low and medium severity, polished aggregate, potholes with low and medium severity and weathering & raveling with medium severity.

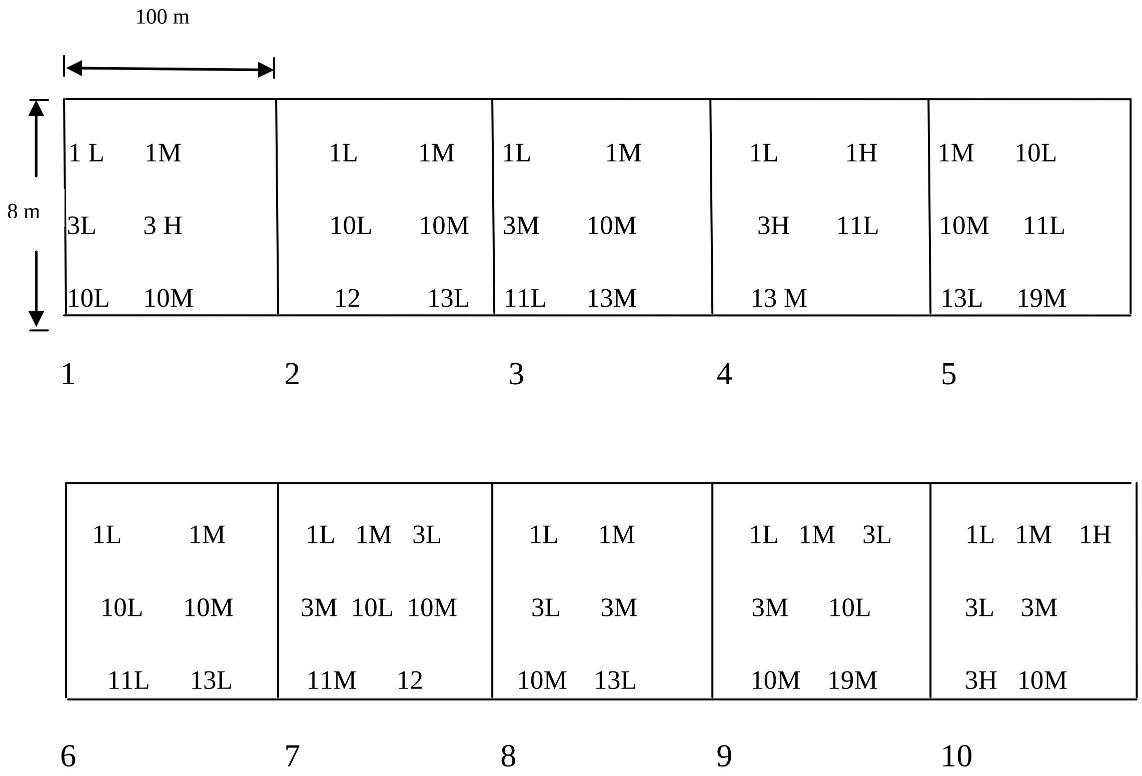


Figure 4.10 Sketch for the sample unit

All types of maintenance are needed in a comprehensive pavement. Pavement maintenance describes all the methods and techniques used to prolong pavement life by slowing its deterioration rate. The performance of a pavement is directly tied to the timing, type and quality of the maintenance it receives.

4.7 Estimation of the maintenance options

According to PCI finding and Figure 2.21, the pavement that has been studied at Koums area would seem to require maintenance. Thick overlay (sometimes called surface treating) is needed in a comprehensive pavement.

The Overlays will perform one or more of the following functions:

1. Improve ride quality.
2. Correct minor surface defects.

3. Provide a skid resistant surface.
4. Fill distortions or rutting.
5. Improve safety characteristics such as skid resistance and drainage.
6. Reduce road-tire noise.

Therefore, thick overlay is considered for rehabilitation, although it typically have some maintenance-type benefits as well.

CHAPTER V

.CONCLUSION & RECOMMENDATION

5.1 CONCLUSION

The results of the selected road that are evaluated showed the PCI value range (40-50) all sections of road were fair condition, most of the deterioration is caused by longitudinal and transverse cracks. Pavement life can be extended at relatively low cost by timely maintenance. According to PCI finding most of the deterioration in road, maybe caused by environmental factors. To further improve the obtained results, continuous pavement monitoring is needed.

This research was carried out to estimate of roads flexible pavement condition through visual surveys using the Pavement Condition Index (PCI) method (following standard ASTM D6433).

PCI method is a good indicator of pavement evaluation:

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

The PCI value can tell us about:

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

The timing of the application of the treatment has a significant influence on the effectiveness of the treatment in prolonging the performance of the pavement; the pavement can be maintained close to its original condition for a longer period of time. Timely application of a 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 a point where the only choice is the reconstruction which is the most costly option. This pavement needs thick overlay, and it does not need complete reconstruction.

5.2 RECOMMENDATION

In particular the following suggestions may be considered in future study:

1- New technology developments have produced a methodology that can quickly inspect roads and streets by using automated inspection equipment .The automated system has the ability to assess the condition of the pavement and use the resulting data to create and populate a database. This can be conducted at the same cost or less than manual survey procedures and the surveys become safer and less labor intensive.

   Therefore, it is recommended to consider using automated survey techniques to reduce labor needs and increase safety of any personnel (in-house or contractor) that may conduct the surveys.

2- Effective maintenance can extend a pavement's life. Crack sealing and surface treatments can reduce in aging of asphalt pavement.

3- Axle-load of vehicles must be controlling the load for preserving the Pavement condition.

4- The superintendence of any tarmac way since the beginning of its implementation to find out defects and their causes and its maintenance

5- The provision of necessary equipment for maintenance work in order to raise the level of efficiency of maintenance.

6- Training of special teams for maintenance working under the supervision of engineers who have experience.

7- Attention of water drainage away from the road surface till does not lead to the collapse of the pavement .Attention of water drainage away from the road surface till does not lead to the collapse of the pavement.

8- Make a study the current traffic volume, which is expected in the future.

9- Interest in the implementation of the specifications during construction.

10- Periodic inspection is necessary to provide current and useful evaluation data. It is recommended that ratings be updated every year.

All the roads must be continuously monitored to improve the future data.

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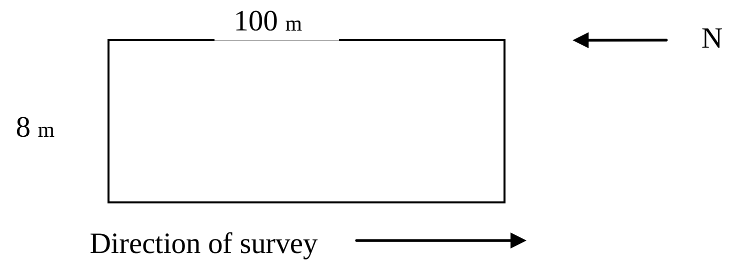
APPENDIX A

CALCULATION PCI FOR OTHER PARTS

Table A.1 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Mslata Road No. of sample: 02
Surveyed by: Group Date: OCT 2010



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	2.3*3.5	0.2*0.6	0.9*2.7	1.1*5.8							**16.98**	**2.12**	**17.5**
1 M	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				**114.63**	**14.32**	**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**
12	8*30	8*5									**280**	**35**	**9**
13 L	4										**4**	**0.5**	**12**

Tab

le B.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					**98**	**4**	**56**
3	50	17.5	15	2	2	1.5					**88**	**3**	**56**
4	50	17.5	2	2	2	1.5					**75**	**2**	**55**
5	50	2	2	2	2	1.5					**59.5**	**1**	**58**

Max CDV = 58

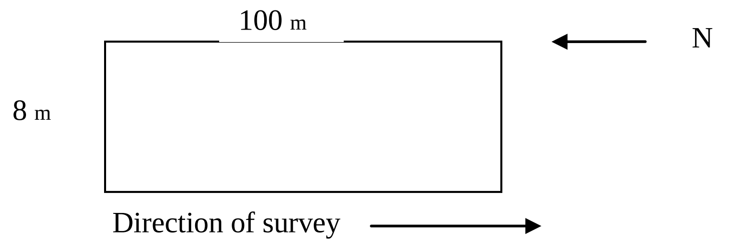
PCI = 100- Max CDV = 42

Rating = Fair

Table A.3 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Mslata Road   No. of sample: 03
Surveyed by: Date:



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*3.5	3.5*3.0	5.4*2.7	2.35*5.1	2.45*3	3.5*3					**61.91**	**7.74**	**30**
1 M	1.5*3	2.25*3	1.7*3.7	1.9*2							**21.34**	**2.66**	**31**
3 M	1*3	1.5*0.6									**3.9**	**0.48**	**0**
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**	**52**
4	31	30	2	2	2						**67**	**2**	**50**
5	31	2	2	2	2						**39**	**1**	**40**

Max CDV = 52

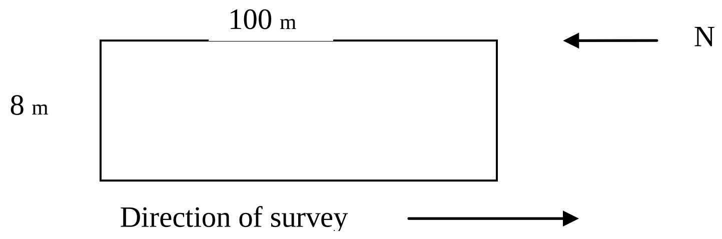
PCI = 100- Max CDV = 48

Rating = Fair

Table A.5 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Mslata Road No. of sample: 04
Surveyed by: Date:



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	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 0.96 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**	**2**	**50**
4	32.5	2	2	2	0.95						**39.45**	**1**	**40**

Max CDV = 50

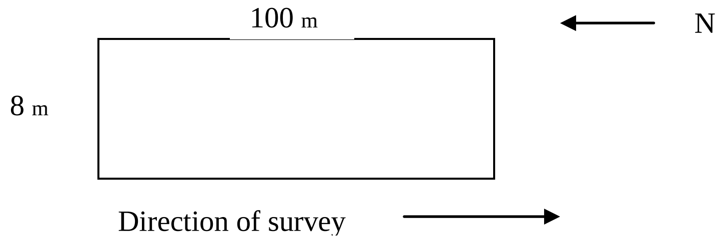
PCI = 100- Max CDV = 50

Rating = Fair

Table A.7 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

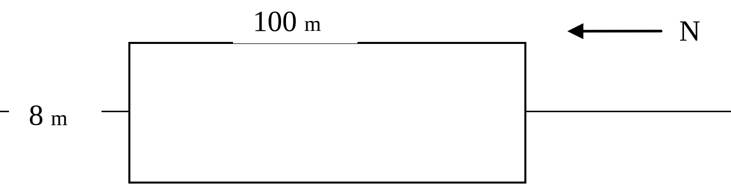
Street : Mslata Road No. of sample: 05
Surveyed by: Date:



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 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.8 Calculation of corrected PCI value

Asphalt surfaced roads Condition survey data sheet for sample unit	

Direction of survey →

#	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**	**48**
5	40	2	2	2	2	0.28						**48.28**	**1**	**50**

Max CDV = 50

PCI = 100- Max CDV = 50

Rating = Fair

Table A.9 Pavement condition survey data sheet for road

Street : Mslata Road No. of sample: 06
Surveyed by: Date:

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	1.0*23	1.70*6.2	1.40*5.7	1.30*1.70	0.90*6.2						**49.31**	**6.16**	**29**
1 M	2.0*6.6	2.2*5.30	2.00*4.0	3.7*3.0							**43.96**	**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									**23.60**	**2.95**	**2**
10 M	3.70	2.70	1.20								**7.60**	**0.95**	**3**
11 L	4										**4**	**0.50**	**2.50**
13 L	3										**3**	**0.375**	**7**

Table A.10 Calculation of corrected PCI value

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

Use highest 6 deducts and 0.51 of six deduct

0.51 *2.0=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**	**2**	**56**
5	40	2	2	2	2	1.02					**49.02**	**1**	**50**

Max CDV = 56

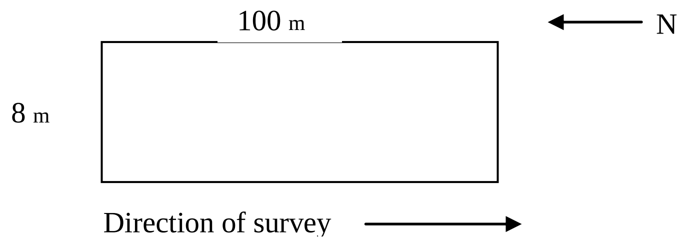
PCI = 100- Max CDV = 44

Rating = Fair

Table A.11 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Mslata Road No. of sample: 07
Surveyed by: Date:



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	1.1*6.30	1.0*6.4	7.0*5.0	2.5*3.6							**57.33**	**7.1**	**30**
1 M	0.95*4.2	1.5*0.50	0.55*5.5	1.0*16.0							**23.76**	**2.97**	**32**
3 L	5.0*0.45	2.3*3.2	0.9*8.1	6.80*3.5							**40.70**	**5.1**	**5**
3 M	2.2*0.90										**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) = 7.24

Use highest 7 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**	**2**	**50**
5	32	2	2	2	2	1.2					**41.2v**	**1**	**44**

Max CDV = 50

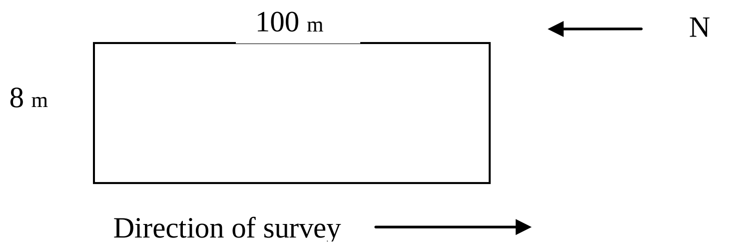
PCI = 100- Max CDV = 40

Rating = Fair

Table A.13 Pavement condition survey data sheet of road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Mslata Road   No. of sample: 08
Surveyed by: Group   Date: Oct 2010



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*0.8	2.0*3.70		1.0*1.40	1.0*1.0	2.30*2.30	0.60*2.3				**18.39**	**2.29**	**18**
1 M	1.1*5.6	3.0*6.70	0.80*2.80	3.40*4							**42.10**	**5.26**	**40**
3 L	15*2.4	10.5*3.9									**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

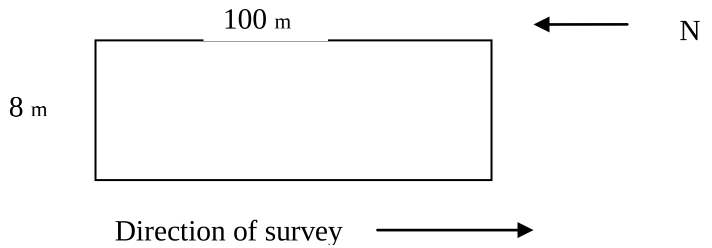
PCI = 100- Max CDV = 50

Rating = Fair

Table A.15 Pavement condition survey data sheet of road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street :   Mslata Road   No. of sample: 09
Surveyed by: Group   Date: Oct 2010



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	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

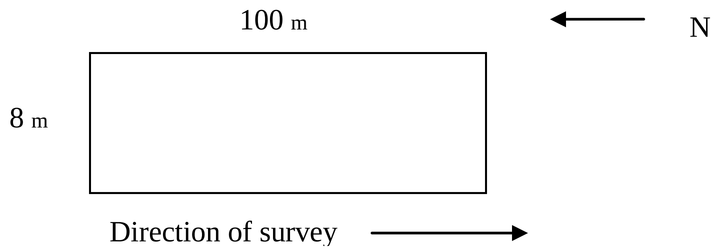
PCI = 100- Max CDV = 42

Rating = Fair

Table A.17 Pavement condition survey data sheet of road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street : Mslata Road   No. of sample: 10
Surveyed by: Group   Date: Oct 2010



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*1.6	0.7*1.70	0.3*0.9	1,80*0.5	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*0.5	0.6*1.7	3.4*3.8	2,5*4.3							**24.79**	**3.1**	**4**
3 M	1.8*2.5	3.5*4.2									**19.2**	**2.4**	**7**
3 H	2.4*2.0										**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

DEDUCT VALUE CURVES FOR ASPHALT

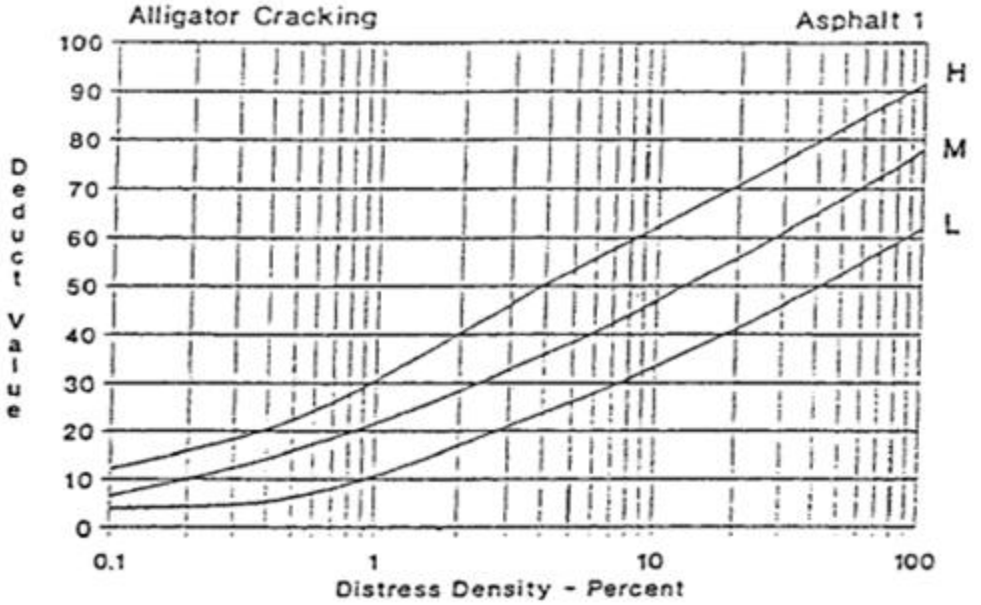


Figure B.1 Alligator Cracking

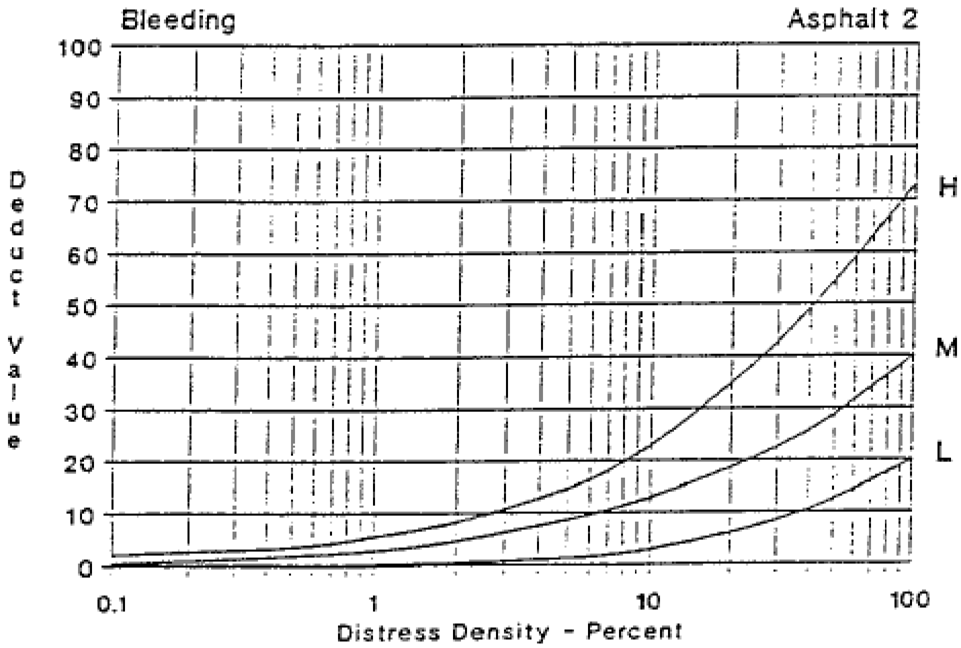


Figure B.2 Bleeding

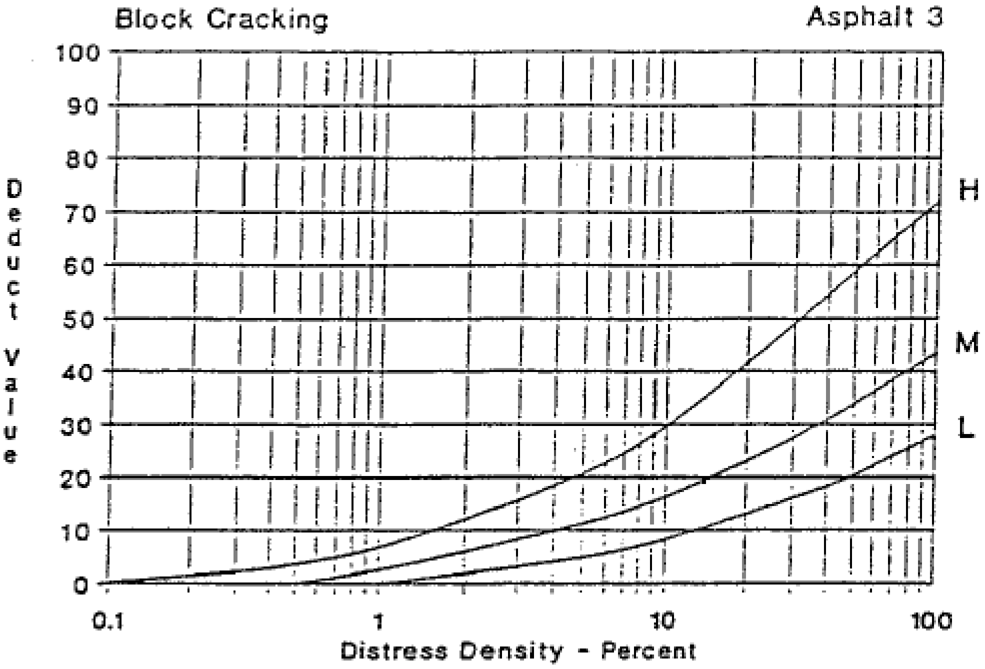


Figure B.3 Block cracking

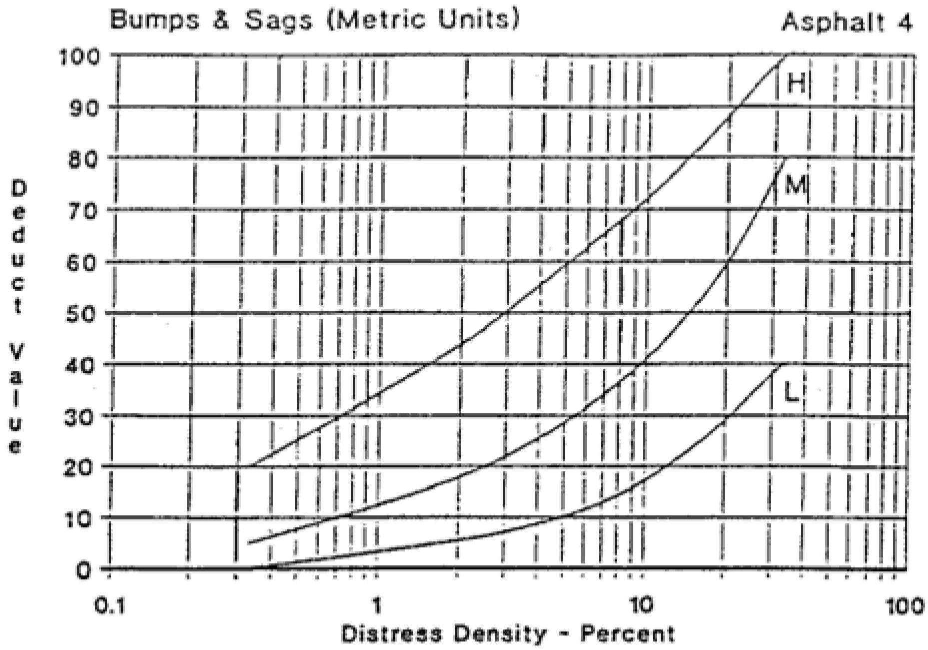


Figure B.4 Bumps & Sags

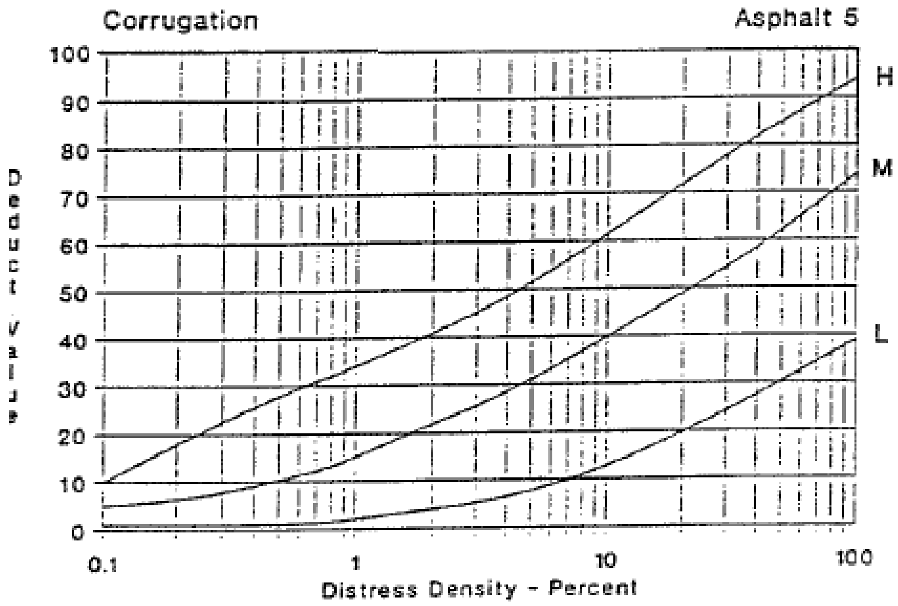


Figure B.5 Corrugation

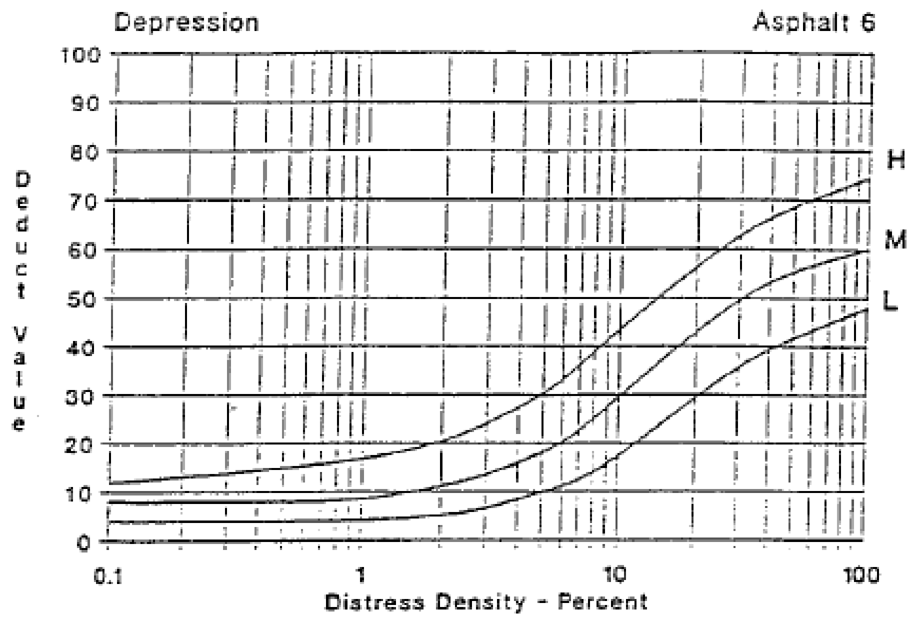


Fig B.6 Depression

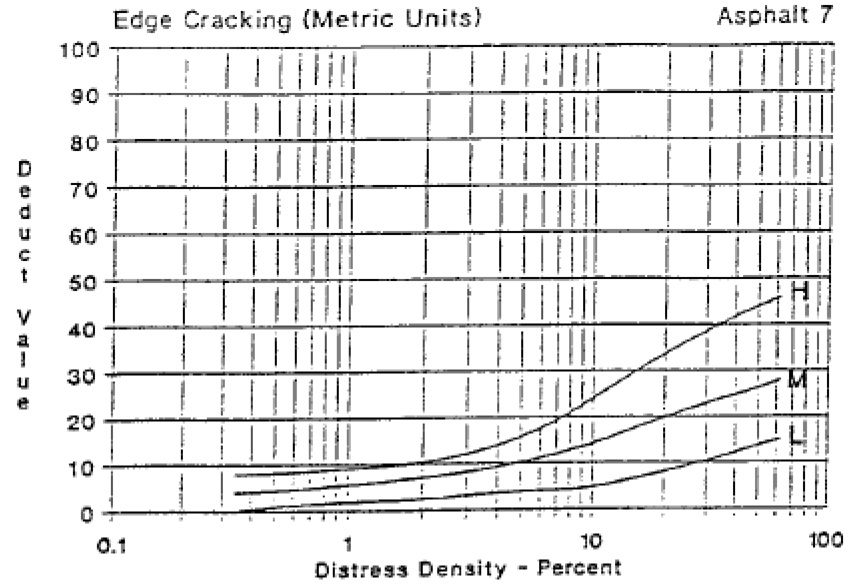


Fig B.7 Edge Cracking

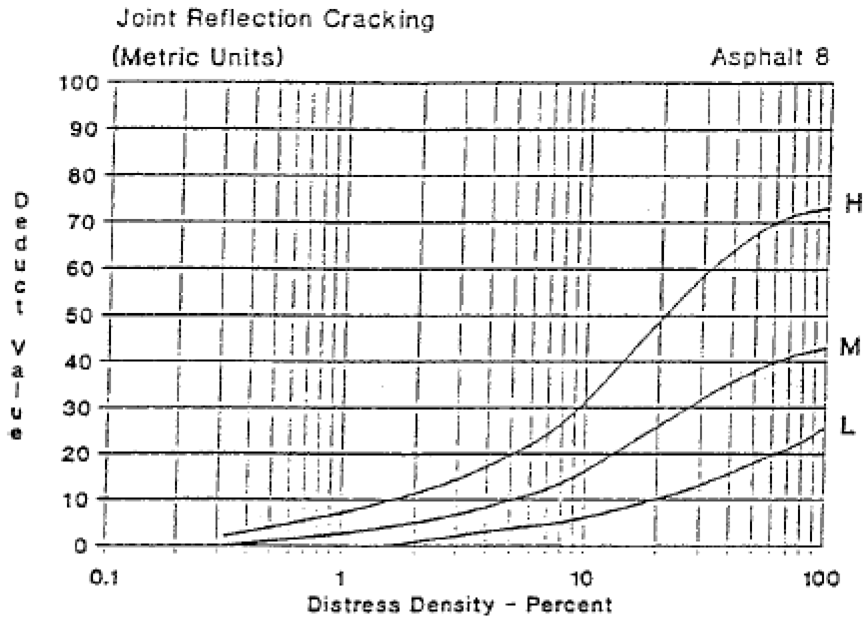


Fig B.8 Reflection Cracking

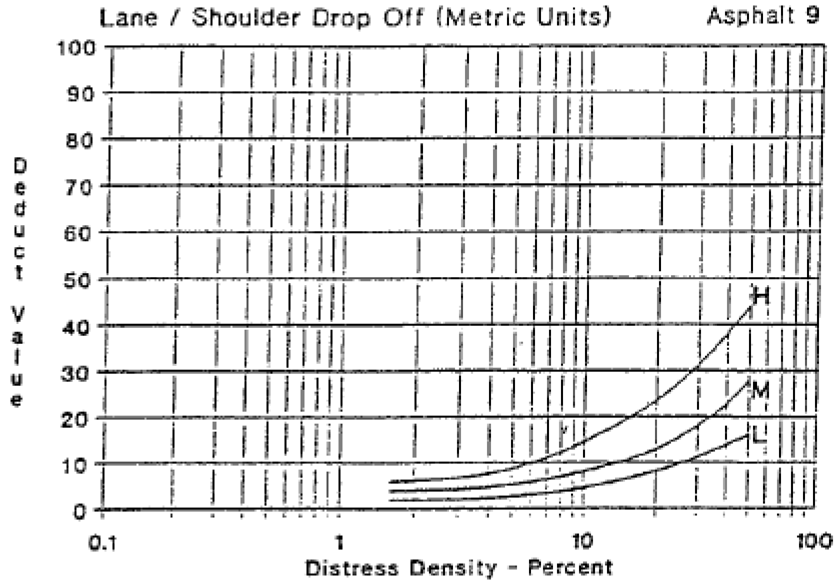


Figure B.9 Lane/Shoulder Drop off

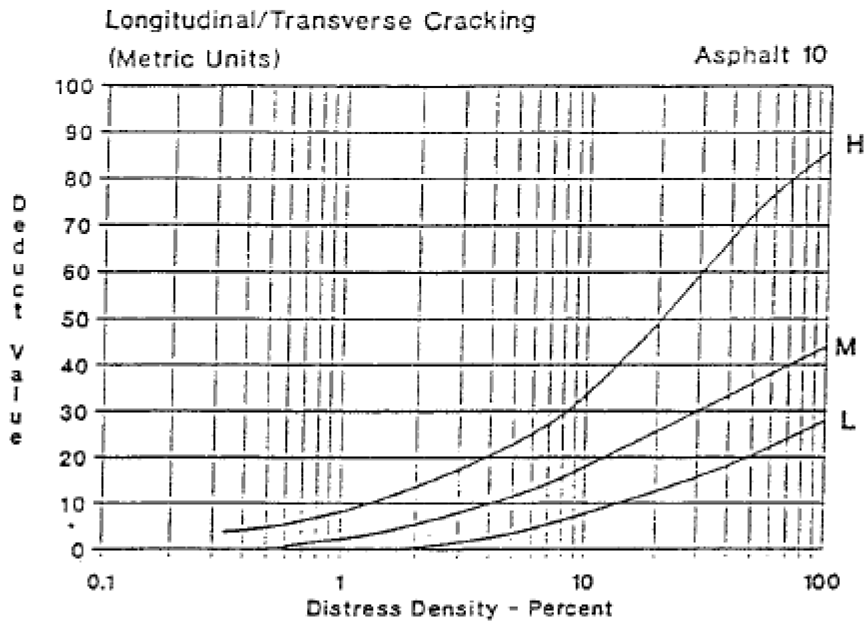


Figure B.10 Longitudinal /Transverse cracking

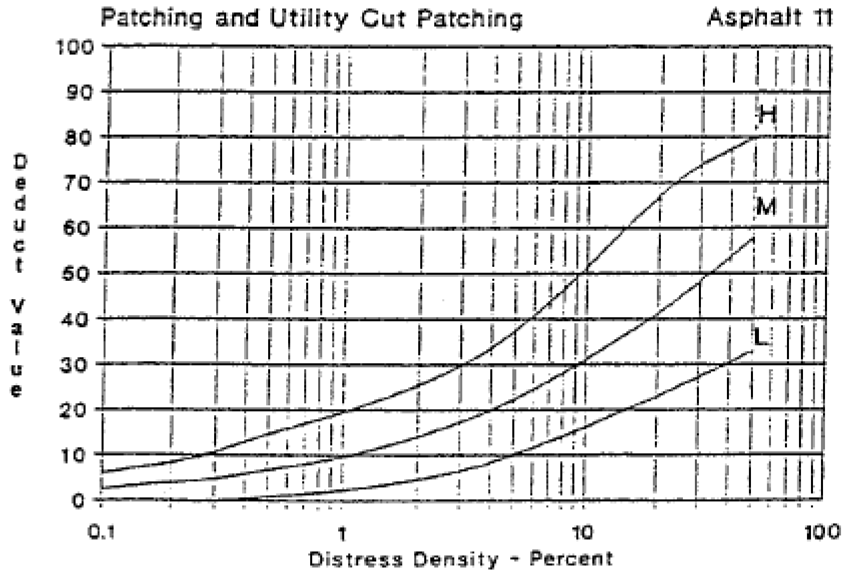


Figure B.11 Patching and Utility cut patching

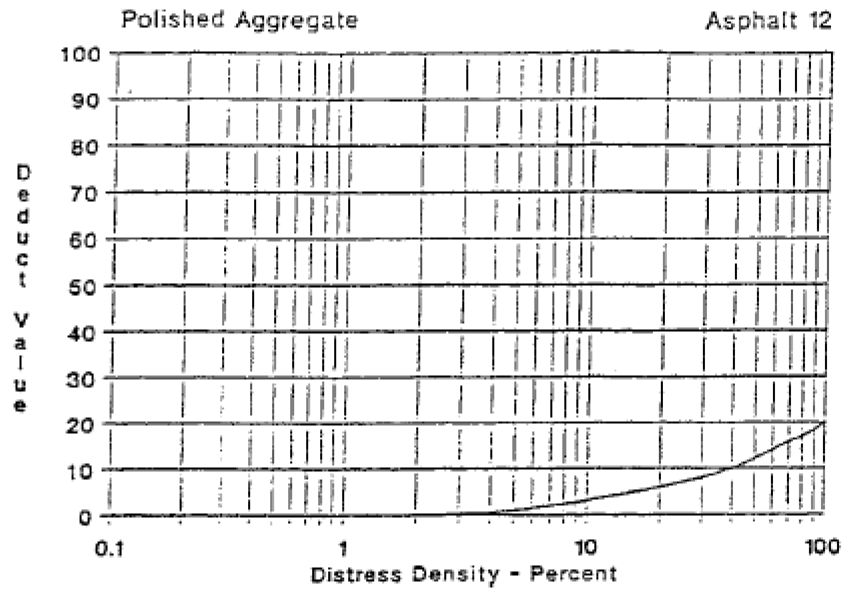


Figure B.12 Polished Aggregate

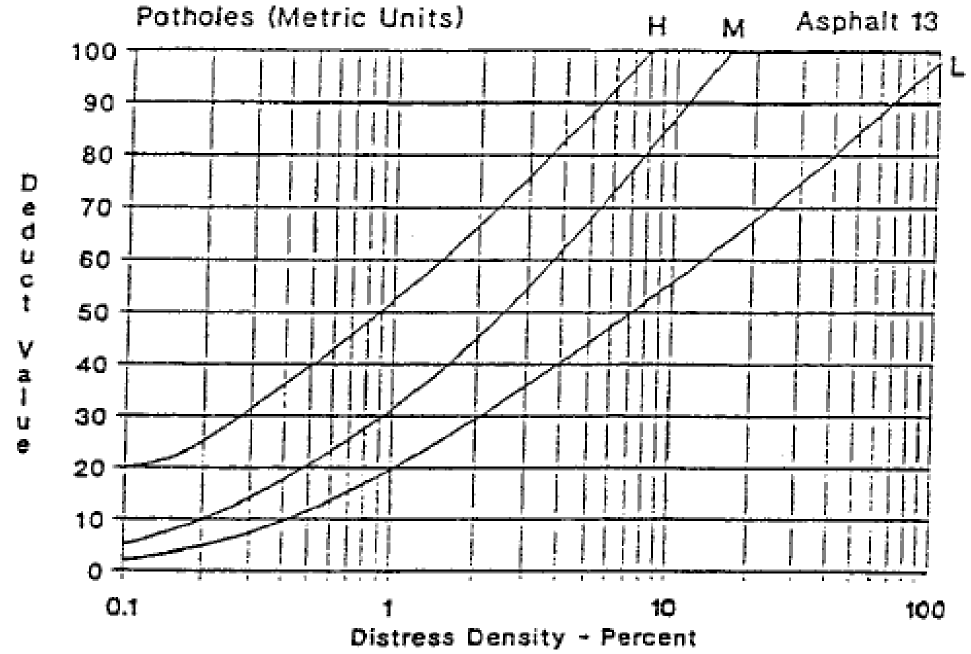


Figure B.13 Potholes

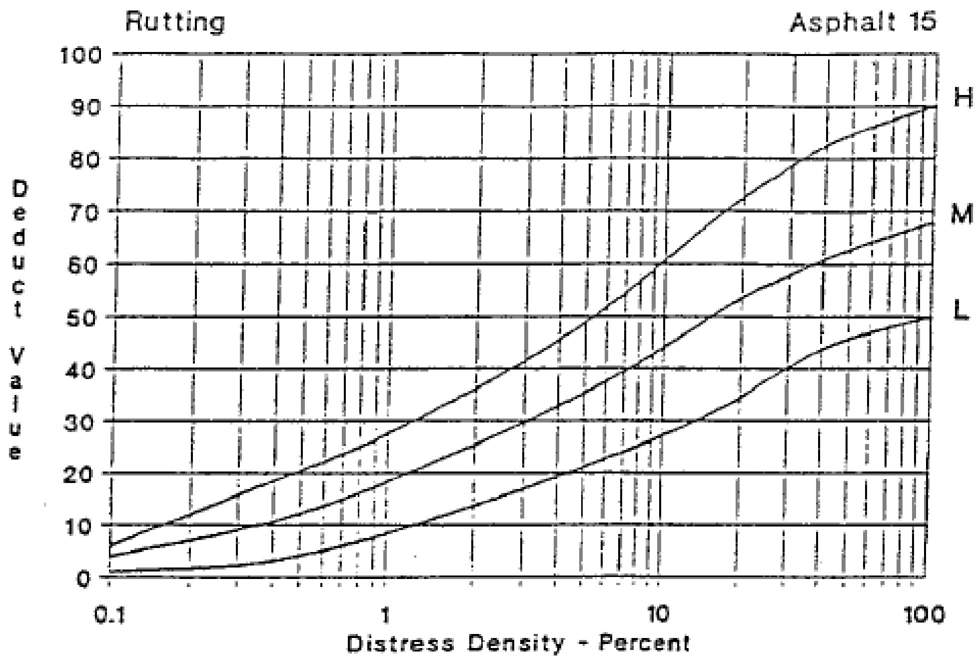


Figure B.14 Rutting

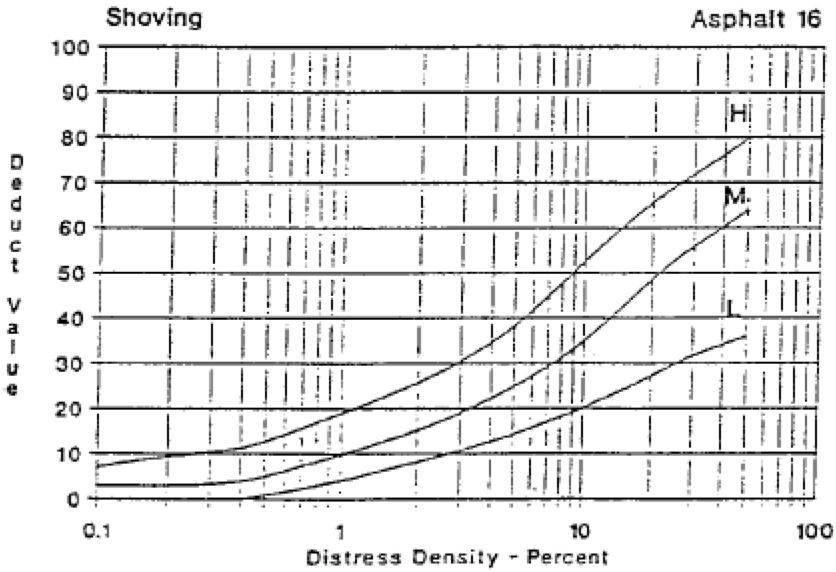


Figure B.15 Shoving

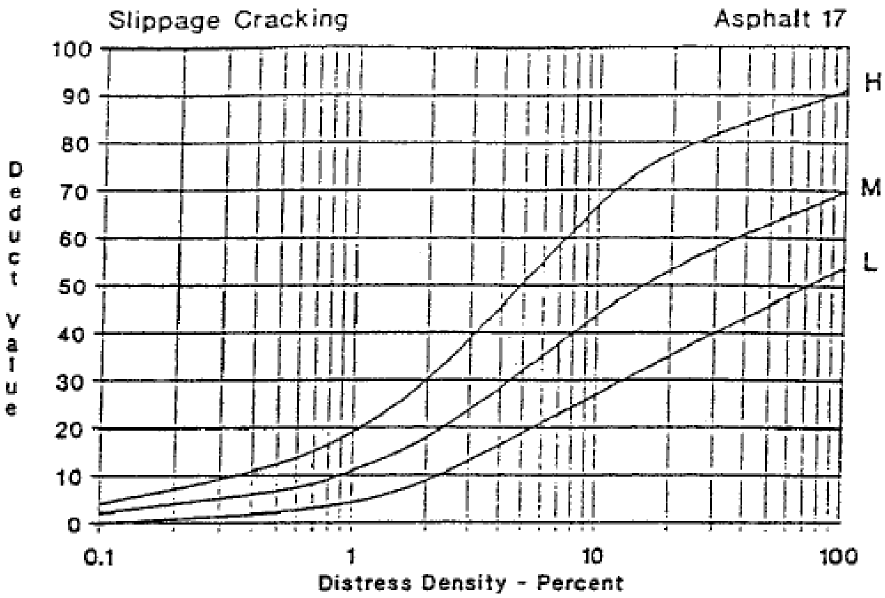


Figure B.16 Slippage Cracking

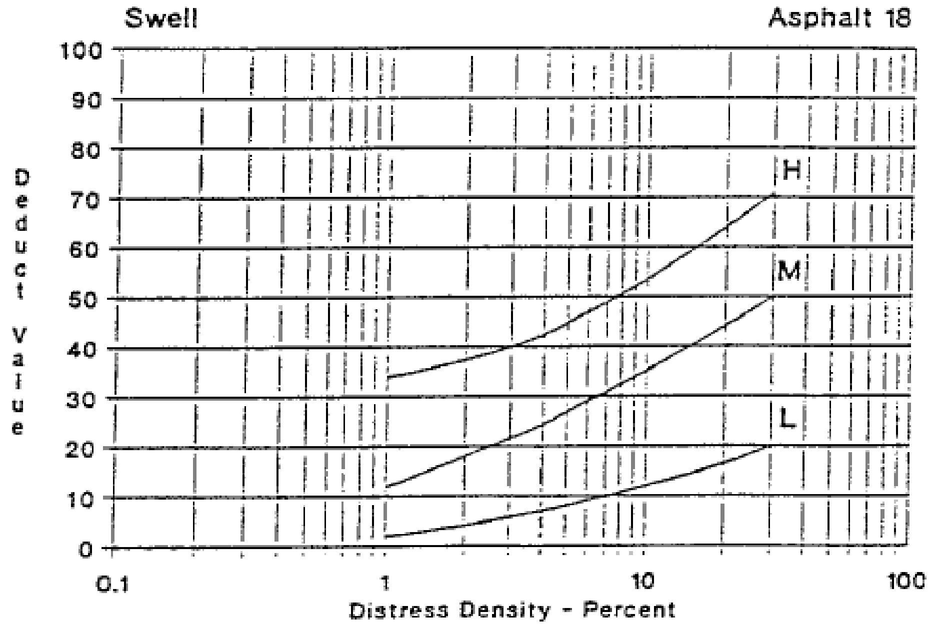


Figure B.17 Swell

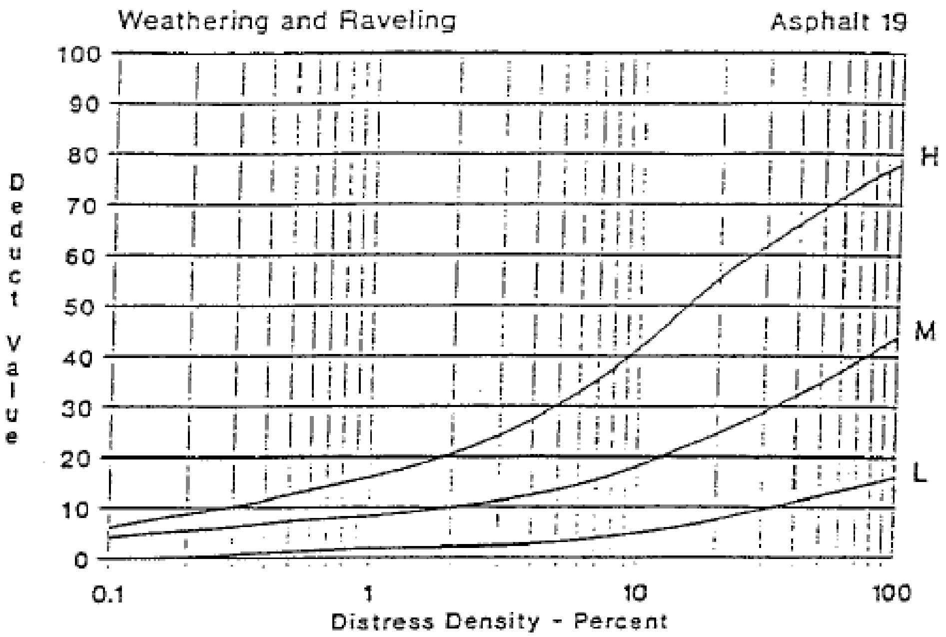


Figure B.18 Weathering and Raveling

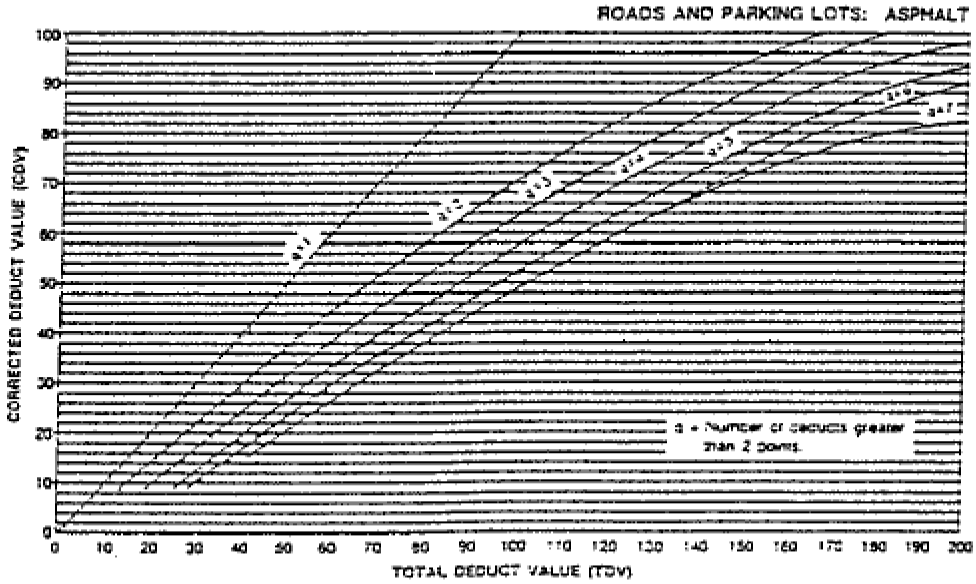


Figure B.19 Total Deduct Value