Evaluation Pavement Distresses Using Pavement Condition Index (Case Study: Secondary Road in the North East Part of Libya in Koums City)

Ali Mohamed Ali Zaltuom, Wahyudi Kushardjoko and Epf. Eko Yulipriyono

Master Program in Civil Engineering, Diponegoro University
Jl. Hayam Wuruk 5-7, Semarang, Indonesia

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. 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. 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.

1. INTRODUCTION

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 [1].

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.

The objective of this study is to Investigate and evaluate the asphalt pavement defects by using pavement condition index (PCI) and Estimate the maintenance options.

2. LITERATURE REVIEW

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.[2]. 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.

2.1 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 [3].

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.

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.[4].

2.2 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 [5]:

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 sub base 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.

2.3 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.

Before any inspection of the site must follow the safety means so as to ensure the safety and conduct of the examination process. 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 [4]:

1. Cracks.
2. Pavement Defects.
3. Pavement Deformation
4. Surface Patches.

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) [6].

Table 1 pavement condition ratings and Pavement condition index ran ,es

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

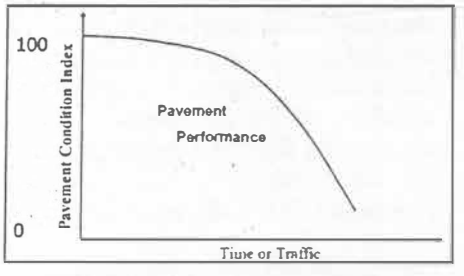


Fig. 1 Relationship between PCI and time [7]

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 [6].

3. METHODOLOGY

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. 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 [8].

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 [9][10].

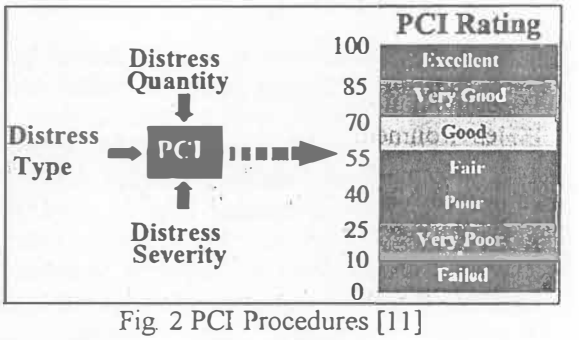


Fig. 2 PCI Procedures [11]

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 [12].

4. DATA PRESENTATION AND DISCUSSION

4.1 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 [13] [14].

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 .The PCI scale is shown in table 1 .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.

4.2 Pavement Distresses Survey

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. To understand which repair to choose, it is important to understand the distresses that occur in a pavement [15]. 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:

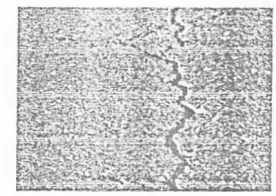


Fig. 3 Long and Transverse Crack

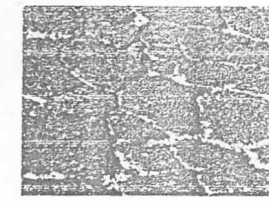


Fig. 4 Aligator Cracking

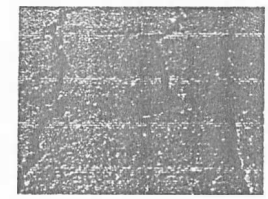


Fig. 5 Block Cracking

Fig. 6 Potholes

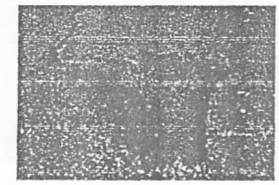


Fig. 7 Patching

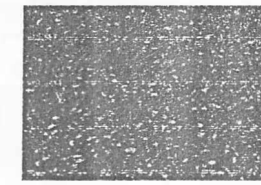


Fig. 8 Aggregates

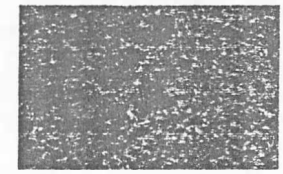


Fig. 9 Raveling and Weathering

4.3 Analysis of Data

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 [16].

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 (ASTM, 1999).

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.
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.
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, using the following formula:

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

   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.
6. Copy DVs on current line to the next line, changing the smallest DV greater than two to two. Repeat steps 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 Fig. 11.
8. Calculate PCI by subtracting the maximum CDV from 100.

$$PCI=100 - \max CDV \qquad (2)$$

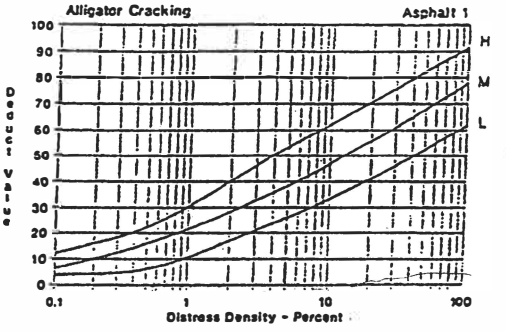


Fig 10 DV for Alligator cracking [13][14]

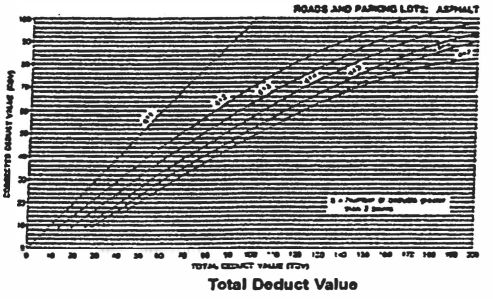


Fig. 11 Corrected deduct values [13][14]

4.4 Summary and Discussion

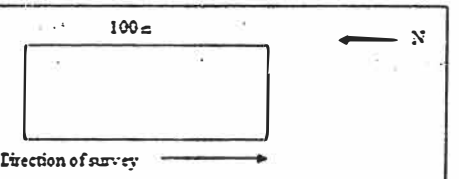
PCI of the section road lie in the north east part of Libya in Koums area. As shown in Table 4 describe the results for road condition.

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 2 Pavement condition survey data sheet for road

Asphalt surfaced roads
Condition survey data sheet for sample unit

Street. Makka Road — No. of sample. 01
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
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
1M	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
3L	0.8*6.1										4.88	0.61	0
3H	1.4*4.5										6.3	0.78	5
10L	2.4	2.1	3.6	1.8	2.1	2.1	2.9	1.05	3.35		21.4	2.7	6
10M	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

Table 3 Calculation of corrected PCI value

$m = 1 + (9/98)(100 - \text{Max DV}) \leq 10$

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

$0.77 * 5 = 3.85$

#	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

Table 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

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 ConclusionS

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

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

a. Improve ride quality.
b. Correct minor surface defects.
c. Provide a skid resistant surface.
d. Fill distortions or rutting.
e. Improve safety characteristics such as skid resistance and drainage.
f. Reduce road-tire noise.

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

5.2 Recommendations

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. Interest in the implementation of the specifications during construction.
4. Periodic inspection is necessary to provide current and useful evaluation data. It is recommended that ratings be updated every year.

REFERENCES

1. OECO (Omran Engineering Consultants Office), study of Performance Grade binder (PG) for Libya, Report No 109/06/008, (2008).
2. Feng, H and Dar, H., Effects of surface preparation, thickness, and material on asphalt pavement overlay transverse crack propagation, NRC Research Press, Can. J. Civ. Eng. Vol. 36, (2009), pp. 1411.
3. Lavin.P.G, Asphalt Pavement, Taylor & Francis e-Library, London and New York, (2003).
4. Walker, D., Pavement Surface Evaluation and Rating, University of Wisconsin–Madison, (2002).
5. OECO (Omran Engineering Consultants Office), Book of general technical specifications for the establishment and paving roads, — Roads and land Transportation Authority, Tripoli, Libya, (2008).
6. Weil R, State of the Streets in San Carlos, Report to Council, California, (2009).
7. U.S. Department of Transportation, Airport Pavement Design and Evaluation, Federal Aviation Administration, (2009).
8. ASTM, ASTM D 6433-09, Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys, American Society for Testing and Materials, (1999).
9. U.S. Army Corps of Engineers, Paver Asphalt Surfaced Airfields Pavement Condition Index (PCI), UNIFIED FACILITIES CRITERIA (UFC) UFC 3-270-06, (2001).
10. (http://www.wbdg.org/ccb/DOD/UFC/ufc_3_270_06.pdf), accessed on Nov 2010.
11. U.S. Army Corps of Engineers, Paver Asphalt Surfaced Airfields Pavement Condition Index (PCI), UNIFIED FACILITIES CRITERIA (UFC) UFC 3-270-05, (2001).
12. Hein, D. and Burak, R., Development Of A Pavement Condition Rating Procedure For Interlocking Concrete Pavements, Report prepared for the Transportation Association of Canada, (2007).
13. AGRA Earth & Environmental Limited, Pavement Design Manual, Alberta Transportation & Utilities, (1997).

14. ASTM, ASTM D 6433-99, Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys, American Society for Testing and Materials, (1999).
15. ASTM, ASTM D 6433-07, Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys, American Society for Testing and Materials, (2007).
16. David P., Pavement Maintenance, Report for Cornell Local Roads Program, New York, CLRP No.06-5, (2006).
17. Shahin, M. Y., Pavement management for airports, roads, and parking lots, second edition, New York, (2005).