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EVALUATING PAVEMENT CONDITION FOR SELECTED SEGMENTS OF ROAD NETWORK IN AL-MUTHANNA CITY

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KEYWORDS: Maintenance, pavement condition index (PCI), Pavement management system (PMS), PAVER 5.2.3, and distress type.

ABSTRACT

To identify effective management and maintenance, Pavement management system (PMS) involves systematic activities to this, based on Pavement condition index (PCI). To calculate PCI value for "Al Shahid Mohammed Ali Al Hassani" road branch in Al-Muthanna governorate, Al- Rumaitha city, used PAVER 5.2.3 program. The length of the selected road is 2 km and two lanes in each direction. After sampling process, visual survey is managed for studying type, level of severity and quantity of distress in the sample units at the selected road. Further, collection road for selected road are inventoried and estimated using PAVER 5.2.3 to compute the PCI. As the PCI of the inspected pavement was "85" that means the pavement needs preventive maintenance. Each type of distresses has been studied to identify failure causes. The treatments of each type of distresses have been suggested as a countermeasure. These treatments include pothole patching, crack filling and isolated overlay.

INTRODUCTION

Pavements are complicated structures including several variables, as construction, performance, loads, materials, economics, maintenance and environment. Therefore, different procedure and economic elements must be taken into consideration when design, build and maintain better pavements. Furthermore, the road maintenance problems are still more compound because of road networks' dynamic nature where the network elements are changing continuously, may be removed or added. SO, these components must be maintained in good condition needs substantial expenditure, because these elements deteriorate with time (Mubarki, 2010). Roads which new paved, depreciate very slowly, and unnoticeably in the first (10-15) years of their life, after that depreciate more fast except timely repair is assumed. Accordingly, there is a require to use a controlled methodology to manage maintenance roads networks maintenance efficiently. A suitable system is able to allocate with total these variables, and recognize priorities for management so as to ensure the accomplishment of wanted goals of maintenance to perfect. Modifying PMS will assist highway agencies to accomplish and repair the networks in an active way (The word bank 1988). Determination of pavement condition in Al-Muthanna City is the key component in deciding the extent and nature of the road repair should receive. This is being done by relying on field inspections and using computer software, in order to determining the maintenance needs at its numerous levels during the right time**.**

Pavement Management System (PMS)

(PMS) is "a system" which includes identification of ideal techniques at different administration levels and sustains pavements at a satisfactory level of serviceability, also, involves systematic strategies to plan maintenance and rehabilitation exercises based on profits optimization and costs minimization (Flynn, 1997). Furthermore, PMS is an important tool, can minimize cost and maximize benefits for the system of the highway. PMS may be set analytical tools or strategies help decision maker in finding ideal methodologies for maintaining pavements in a usable condition over a given time (Hussain and Al-Jameel, 2018) It has become gradually popular among agencies of local highway, there are the realized benefits in many countries that have a decision support system which in turn helps them to find cost effective strategies to keep their pavements of road in good level of serviceability (Fitch *et.al*, 2001; Zhou, 2011).

Failures of Flexible Pavement

- Functional failure: may be accomplished by the structural distress. The functional distress caused discomfort to vehicle rides.
- Structural failure: involves breakdown or collapse the components of the pavement structure into one layer or more, and become not capable for carrying the loads upon its surface (Yoder & Witzack, 1975).

The largest proportions of roads in Al-Muthanna governorate were structured utilizing asphalt (flexible) pavement. The present paper aimed to focus on distresses types that occur in flexible pavement. Pavement distress is a vital component for evaluating pavement level. The estimating process of surface distresses is known as condition survey (FHWA, 2003). There are many factors lead to pavement distress, these factors including inadequate design, weak structural capacity, inferior material quality (Kaloush, 2006), weak preventive maintenance and poor construction techniques (A-Mansou and Al- Mubaraky, 2007). The five major groups of distresses of asphalt pavement surface are (Miller and Bellinger, 2003):

- Cracking: Slippage cracking, Fatigue (Alligator) cracking, (longitudinal and transverse cracking), block cracking, edge cracking, and joint reflective cracking)
- Surface effects: Polishing, weathering and raveling, bleeding).
- Disintegration: Patching, potholes.
- Surface Deformation: Bumps and sags, corrugations, depressions, rutting, shoving.
- Others: Railroad crossing, lane or shoulder drops off.

Pavement Maintenance Strategies

Pavement maintenance procedures are characterized as plans of activity embodying the proceeding application pavement maintenance methods that are designed to make strides maintain the condition of a pavement section over some predetermined minimum requirement (NCHRP, 1981). Johnson (2000) categorized pavement maintenance strategies into three types as stated by the type and level of defects. Firstly, preventive maintenance which performed to improve functional life of pavement involves surface treatments and operations to retard progressive failures and reduce the demand for maintenance routine. Secondly, corrective maintenance this type performed when failure happens in the pavement, such as loss of friction, moderate to severe rutting or developed cracking. Thirdly, emergency maintenance includes activities applied during an emergency site, for example blowout or harsh pothole which requires healing immediately. It also involves short-term healings planned to keep the surface jointly, up to long-term healings applied.

Condition Rating System

Depending on surface distress, roughness, deflection and skid resistance, pavements can be allocated a score that indicates their overall condition. Sometimes, this score named pavement condition rating. It quantifies overall performance of pavement and utilizes to assist accomplish pavement networks. Rating scale is a sequence of numbers utilized to state pavement condition. Typical pavement indicators may be depended on measure of (0 - 100) or (0 to 5). The correct pavement condition indicator bases on the PMS goals. This study depends on the pavement condition index (PCI) to evaluate pavement condition using PAVER which considers automated PMS.

5.1 Pavement Condition Index (PCI)

PCI is advanced by the U.S Corps of Engineers and approved by American Society for Testing and Materials (ASTM) and the American Public Works Association (APWA), because of this attained accurate data and evaluated condition based on conditions in the field. It measures the structural integrity of pavement and surface condition on a scale of 0 to 100 as shown in Figure 1. The PCI score of roadway is depended on detected pavement distresses.

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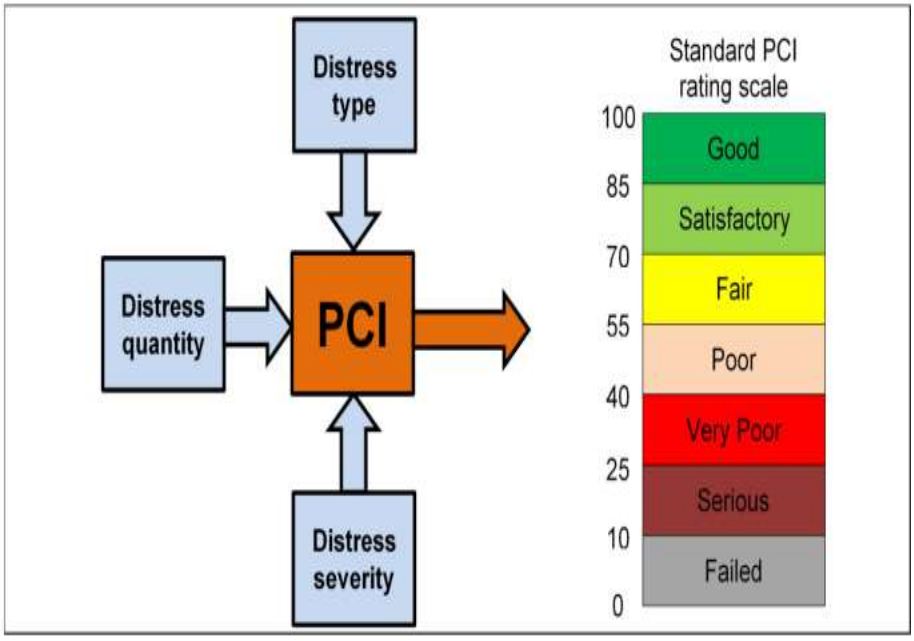

Figure 1 Rating scale used for Pavement Condition Index (PCI) Method (Shahin , 2005)

PAVER software

In the previous years at 1980, the U.S (Army Corps of Engineering) were developed PAVER software. It is helped engineers with in a systematic methodology to knowing maintenance and rehabilitation requires and also priorities (Shahin and Walther, 1990). The funds for this activity about $ 250,000, in Canada and the United states about 80 local agencies incorporated their works to evaluate and test PAVER software. PAVER has been adapted for utilizing on microcomputer (APWA, 2012). The paver system is depended on (PCI) survey and rating method. It is requires the formation of a data in the network inventory to implemented network and project analysis. There are many important capabilities provided by PAVER (U.S Army Corps of Engineers, 2011) involving:

1- Condition analysis: determination of pavement condition at present and future;
2- Development of pavement condition depreciation models;
3- Inventory of pavement network;
4- Pavement condition rating;
5- Project Formulation;
6- Work planning: Identification the needs of M&R and studying the result of budget planning.

METHODOLOGY

Study area description

Al-Rumaitha is one of the cities of the province of Al-Muthanna in the south part of Iraq as illustrate in Figure 2. One road was chosen to inspection for PCI calculations. This road is a branch named "Al-Shahid Mohamed Al Hassani street"which is two kilometers long, one end at "Al-Atfa'a street" and the other at "Hay Al-Askri branch street" The number of lanes in each direction are two lanes, width of each direction is 7.5 meter separated by 4 meter width of median as illustrate in Figure 3 . The road is an asphalt pavement; construct 3 years earlier and also used transport people and goods. Visual condition inspection was achieved via walking on the area of pavement and accurately inspected, identified, and recorded each defect pavement surface distress.

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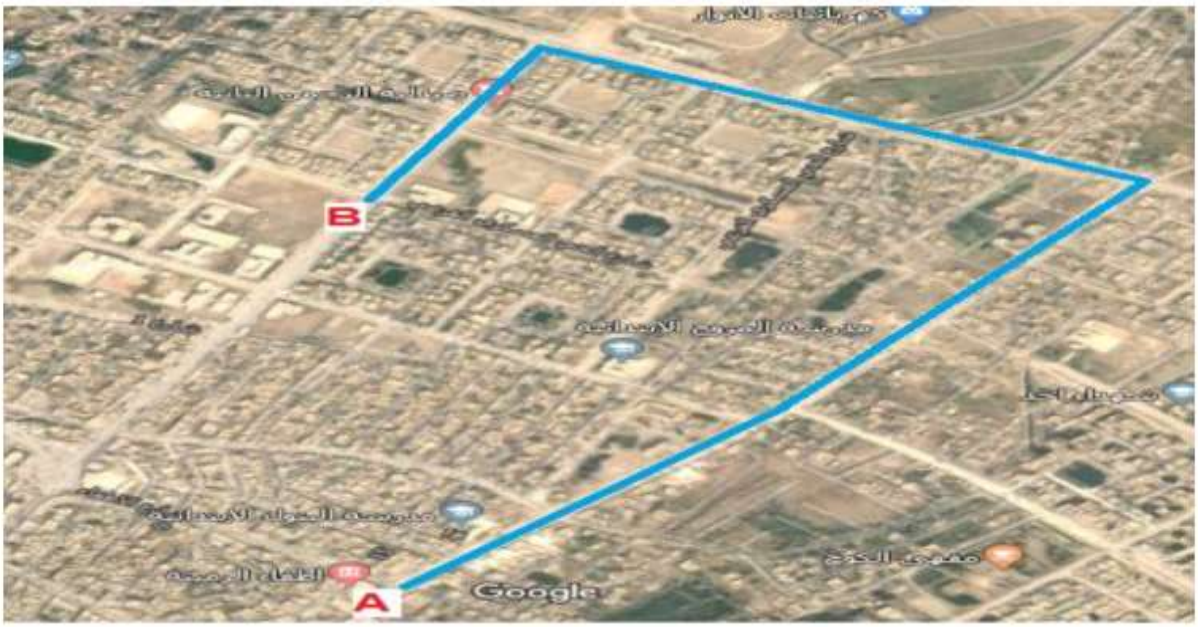

Figure 2 Study area (Al-Muthanna governate, Al-Rumaitha city)

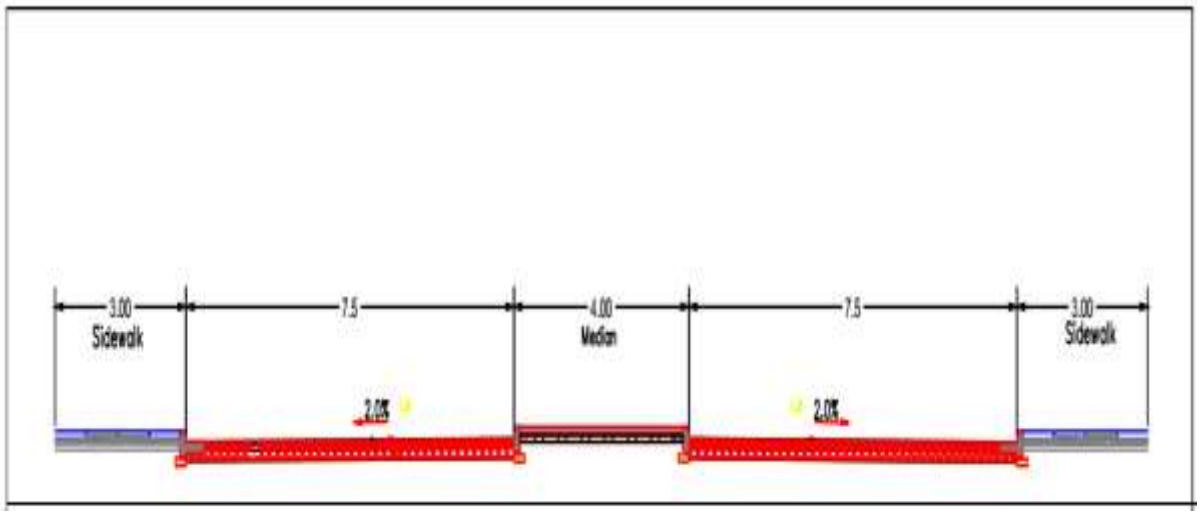

Figure 3 Typical cross section of study area

DATA COLLECTION

The category of data collection considers primary as of the field, as identified the segment was taken by length 2 kilometer. Recorded data for all types by Visual condition inspection was achieved via walking on the area of pavement and accurately inspected, identified, and recorded each defect pavement surface distress. Also, took pictures of each level severity. The study area that is divided into two sections, this dividing based on two directions, (A-B) and (B-A).Each section is divided into units, named sample units, after the process of collecting data that include distress type, level of severity and quantity, the PCI calculates for the sample units and the road section by using PAVER software.

2.1 Sample Units to Be Studied

The type of pavement surface determines the procedures of a performance PCI condition survey, because these procedures differ depending on it. For all types of surface, pavement section must be divided into a number of

sample units. Pavement sample unit defined as part of pavement section, its size depended on type of pavement section, for AC pavement, it has an area 225±90 m2 (2500±1000 ft2) (Shahin, 2005). For PAVER system, a sampling plan is used to obtain a reasonably accurate PCI calculated with inspecting a restricted number of sample units per section. The needed number of samples depends on pavement use as well as on either project or network level. When managing at project level involves accurate data for formulation of contracts and work procedures. So, the number of sample units studied more than typically inspected for network level managing. Determination the smallest sample units' number (n) is the initial step in the process of sampling this number must be inspected to estimate the PCI of section. Using the curves illustrate in Figure 4 to determine the minimum number; it used so as a sensible predict of the section's PCI will be taken. The confidence level is 95%, so the evaluate value is with ±5 points of mean PCI. For clarification when all sample units surveyed true PCI is obtained. The curves shown in Figure 4 were created using Equation (1).

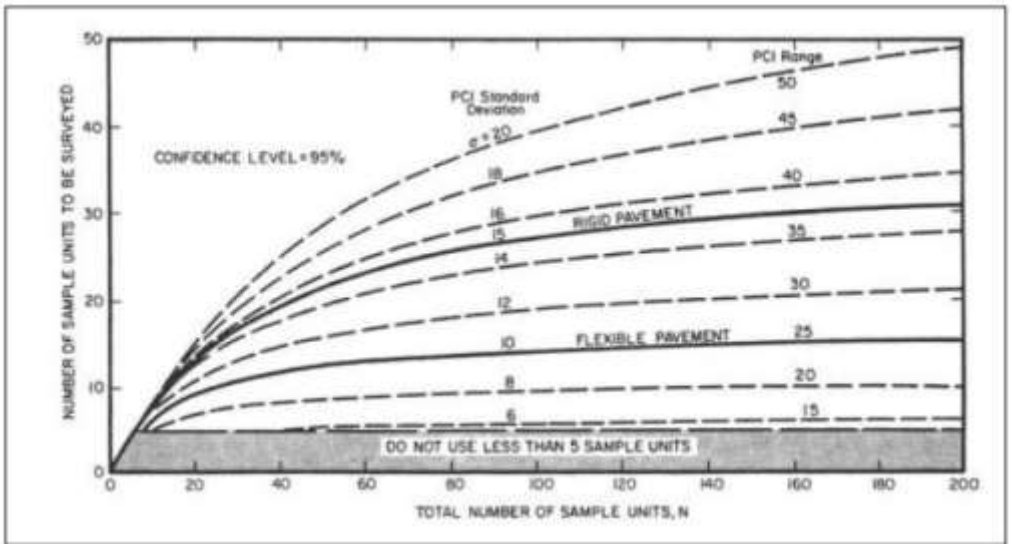

Figure 4 Selection of the Minimum Number of Sample Units (Shahin et al. 1976-84).

$$n = \frac{N\,s^2}{\left(\frac{e^2}{4}\right)(N-1) + s^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots Eq.(1)$$

Where:
s: is the standard deviation of PCI from one to another sample unit within the section. It is taken 10 for AC pavements but taken 15 for PPC pavements.
e: is the acceptable error in estimating section's PCI(e = 5).
N: is the total number of sample units in the section of pavement.

$$N = \frac{Area\ of\ section}{Area\ of\ sample} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots Eq.2$$

Area of section = 2000* 7.5= 15000 m^2
Sample unit area = 250 m^2
$N = \frac{15000}{250} = 60$ (total sample units' number)
$n = \frac{60*10^2}{\left(\frac{5^2}{4}\right)(60-1)+10^2}$ = 12.8 =13(minimum number of samples)
As a result, each section of the pavement in the study area surveyed with 13 random sample units.

2.2 Selecting Sample Units to Inspected

According to (Shahin, 2005), the spaces between the sample units to be inspected should be equal through section and the first sample is selected randomly based on a technique known as "systematic random". The following steps described this technique:

- Sampling interval "i": Can be limited by i= N/. Where N is the whole number of obtainable sample units, while n is smallest number of samples to be inspected. The spacing interval "i" rounds to the smaller total number (e.g., 1.6 is rounded to 1.0).
- Random start "s": Randomly taken among sample unit 1 and "i" that is calculated by the first step. For example, when i equal 5, the random starts are number of 1 to 5.
- Sample units to be studied are determined as (s, s+i, s+2i, etc.). When the select beginning is 1, and "i" is 3, the sample unit to be inspected will be 1, 5, 9, etc.

i = N/n = 60/13 = 4.6 ~ = 3

Since i=3 then the first sample to be inspected is sample 1, the sequential samples will be as follows:

1, 1+3, 1+2*3, 1+3*3……..

1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49

To show location of the sample units to be inspected sees Figure 5.

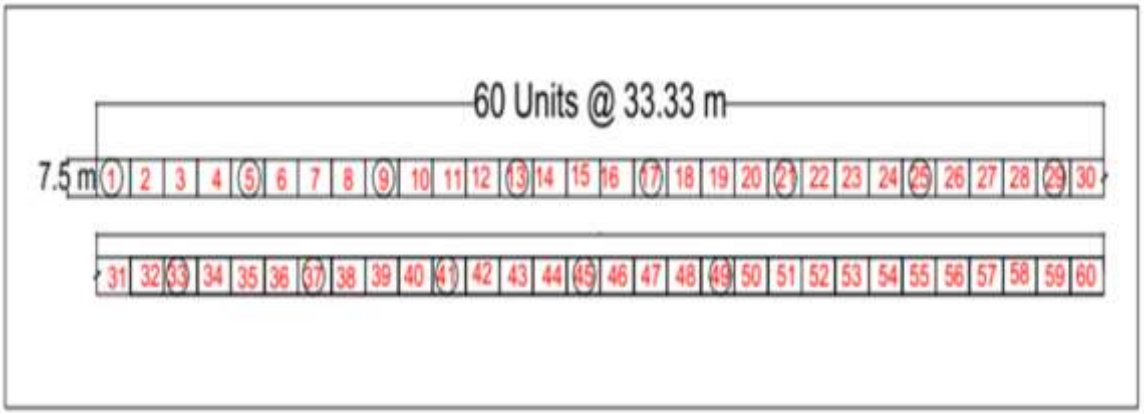

Figure 5 locations of the sample units to be inspected in the case study

FIELD MEASUREMENT

In the present study, the field measurement involves distress type, quantity, and identifies severity related with the distress according to its related criteria. The study area distresses can be categorized based on the following articles:

1. Longitudinal and Transverse Cracking: longitudinal crack is parallel to the center line of pavement, while transverse is perpendicular to the center line. The distress severity of these types can be identified according to the average width of cracks. The quantity of these distresses is measured manually via use of the tape in linear (m). These distresses show in Figure 6.

2. Alligator Crack: The distress severity can be limited according to the development degree of cracks into pattern or network. The distress quantity is quantified manually via use of the tape in area unit (m2). Figure 7 shows the alligator crack in the study area.

3. Edge crack: Those cracks begin on the side of the pavement and then extent toward the center of the road over time. The distress severity is determined based on the average width of crack, while its quantity measured by the use of tape in linear (m). This type of distress shows in Figure 8.

4. Polished Aggregate: This type of distress can be seen frequently in the sample units of the study area. The quantity of polish aggregate is measured manually by the use of tape in area unit (m2). Figure 9 presents this type of distress in study area.

5. Weathering: The severity level of this distress can be identified depend on amount of loss of binder and fine aggregate matrix. The quantity of weathering is measured manually by square meter (m2) of surface area. This distress shows in Figure 10.

a. Longitudinal crack ***b. Transverse crack***

Figure 6 Longitudinal and transverse crack in study area

Figure 7 Alligator cracks in study area

6. Potholes: The distress severity depends on the depth and diameter of pothole. The quantity of this distress is quantified based on the number of the pothole. Figure 11 displays pothole in the study area.

7. Shoving: This type is longitudinal movement of localized area of pavement. The causes of this distress, is accelerating vehicles or breaking and is situated on turns or at intersection. The distress severity is determined depend on the relative effect on ride quality. This type of distress presents in Figure 12.

8. Depression: Is localized pavement surface area, it has slight elevation inferior than elevation of the near pavement, when depression is light which not obvious until then a rain. "birthbad" areas is created by ponding water . The severity level can be defined by mean depressions depth and the quantity of this type determined according to area unit (m2). This distress presents in Figure 13.

Figure 8 Edge crack in study area

Figure 9 Polished aggregate in study area

Figure 10 weathering in study area

Figure 11 Pothole in study area

Figure 12 Shoving in study area

Figure 13 Depression in study area

9. Patching /Utility cuts: This distress is a part of pavement surface, larger than 0.1 m2. This distress occurs when removes and replaces the deterioration pavement or extra a suitable material utilized to pavement later original construction. The severity of this distress depends on ride quality while its quality determined by measuring surface area in square meter. Figure 14 shows this type of distress.

Figure 14Patching and utility cuts in study area

Modeling and Analysis using PAVER Software

To evaluate pavement status, PAVER program has the capabilities to accomplish the analysis of pavement condition. The wanted network/ branch/ section should be confirmed and assessment information from the fields is inserted to computes pavement condition index (PCI).

4.1 Pavement inventory

Identify in expressions of network, branch and section. The section is minimum management part for studying major (M&R) project. There are key features must be take into consideration in section delineation; these features are type of pavement, structure, construction history and functional classification (Shahin, 2005). The branch may contain one/more sections. The system of PAVER categorizes pavement network into branches and sections previous performing analysis of condition, by way of inventory key runs devices to edit, view and identify pavement networks. There are two windows in inventory button (U.S Army Corps of Engineers, 2011): inventory data is one of windows and other is list selector. Creating each of cards of the inventory can be described by the following articles:

1. Creating a Network: In the structure of pavement inventory, creating a network is the first step. For pavement inventory items there is hierarchical structure in PAVER system. The parentages of branches are networks, while the parentages of sections are branches (U.S Army Corps of Engineers, 2011).
2. Creating a Branch: The branches can be created through inventory existing on bar of PAVER button. The branch window includes three area fields, these area are calculated area (sum of area of all the section), area adjustment and true area. “Calculated area” represents sum of real areas of sections of branches, while “Area adjustment” is utilized to indicate specific information may have by the user about branch area, these information don’t included in “calculated area”. Decline in area of branch must be inserted as negative values. In section tab there is also “adjustment area” field, therefore there is no require to reflect area adjustments of section in the area adjustment filed of the branch. True area represents calculated area with area adjustments (U.S Army Corps of Engineers, 2011). True area is a quantity used in calculations as well as reports of PAVER program.
3. Creating a Section: The section can be created through inventory button existing on bar of PAVER button. There are three fields in the section file card they are: calculated area, area adjustment, and true area. The value of the calculated area is result of information inputted by the user which is length and width of section and cannot be able to edit it. “Area adjustment field” allows the user to expose specific information about section area. Decline in section area producing from items such as cut outs must be inserted as negative values. Calculated area with

area adjustments to calculate true area, this value is utilized in the computations and reports of the PAVER. The true area field could be edited directly when the true area of the section is known, then the area adjustment will estimate by program (U.S Army Corps of Engineers, 2011).

4.2 Inserting Inspection Information

To insert inspection information, the first step confirm the wanted network/branch/section that taken with option of inventory window. Enter inspection data window in the PAVER is created to be sample utilize and to permit users to insert great extent of inspection data quickly. The user can be entered the inspection data by either the keyboard or the mouse activities to insert all inspection information. The most frequent portion of inspection data entry is entering the distress data. By two-digit numbers codes which show at left side of distress type can be defined distresses type. The severity level of distress is selected by pointing on "L" denotes to Low, "M" denotes to Medium and "H" denotes to High, the cursor automatically shifts to distress quantity filed to type in it as shown in Figure 15. By typing "A" or by double clicks on "Enter" key, the distress is added.

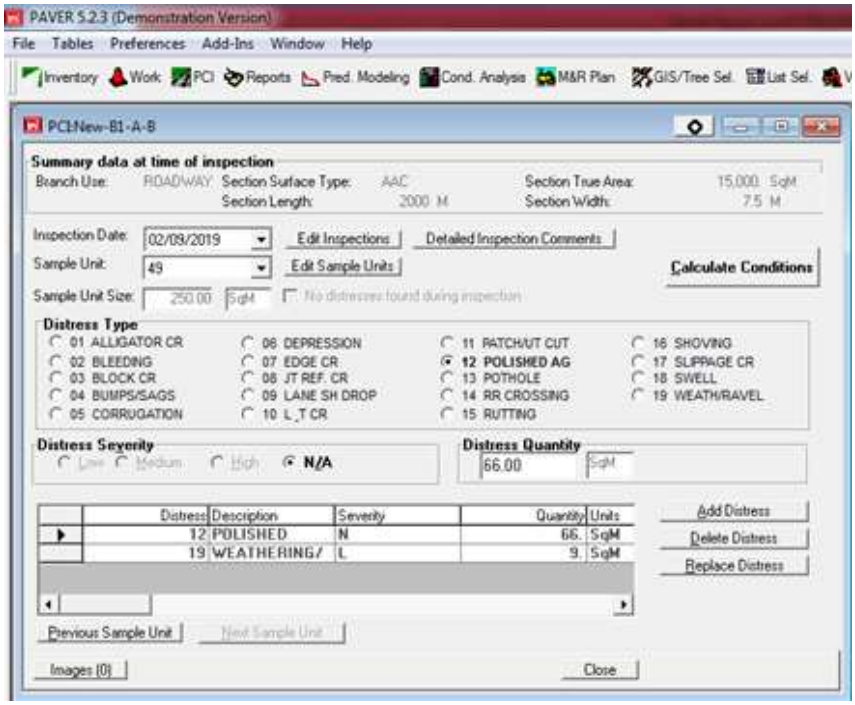

Figure 15 Inspection data entry window

THE PAVER PROGRAM RESULTS

The software automatically estimates PCI value for each sample unit studied and states the PCI value for the whole section, in addition to it determines extrapolated distress quantities. It can also calculate ratio of deduct values depended on section distress mechanism (climate, load and other). The basic for identifying the primary causes of pavement deterioration, is the percentage of deducted values interrelated to each distress mechanism.

5.1 Calculate PCI after Inspection

When the information entry for all sample units is ended, the PCI value is estimated for each surveyed sample units, also, calculated for the whole section. Calculation of the PCI is made by depending on deduct values, the weighting elements start from "0" to "100" denote to influence of distress on the pavement condition. If the deduct value is 0, the distress has no influence on the pavement surface operational condition and/ or structural integrity, whereas the deduct value is "100" this means a very serious distress (Shahin, 2005).

The user can be view the section status after completing the distress data entry, by simply pressing on "calculate conditions" order. In the top of window, section properties are presented, while in the middle of it Inspection data,

condition index, condition value are presented. There is also basic information about the pavement section given in this window (U.S Army Corps of Engineers, 2011), which is showing:

- Condition indices: illustrate PCI value for the whole pavement section, as illustrated in Figure 16.
- Sample distresses: shows the sample units surveyed of the section and corresponding distress codes, descriptions, quantity, density, severity and deduct value.
- Sample conditions: in the top part shows the surveyed sample units of section besides the specific unit of type and size of sample and value of PCI. While the bottom presents the number of the inspected sample unit and contrasts the sample's total number to the optional samples for project level survey.
- Section Extrapolated distresses: illustrates each distress type survives in the surveyed section. Distresses are accumulated depended on the type and level of severity. In other words, the PAVER program deals with each level of severity of each type of distress as a separate distress. The regulated quantities of distress are also showed to reflect extrapolated value depended on the entire area of the section.

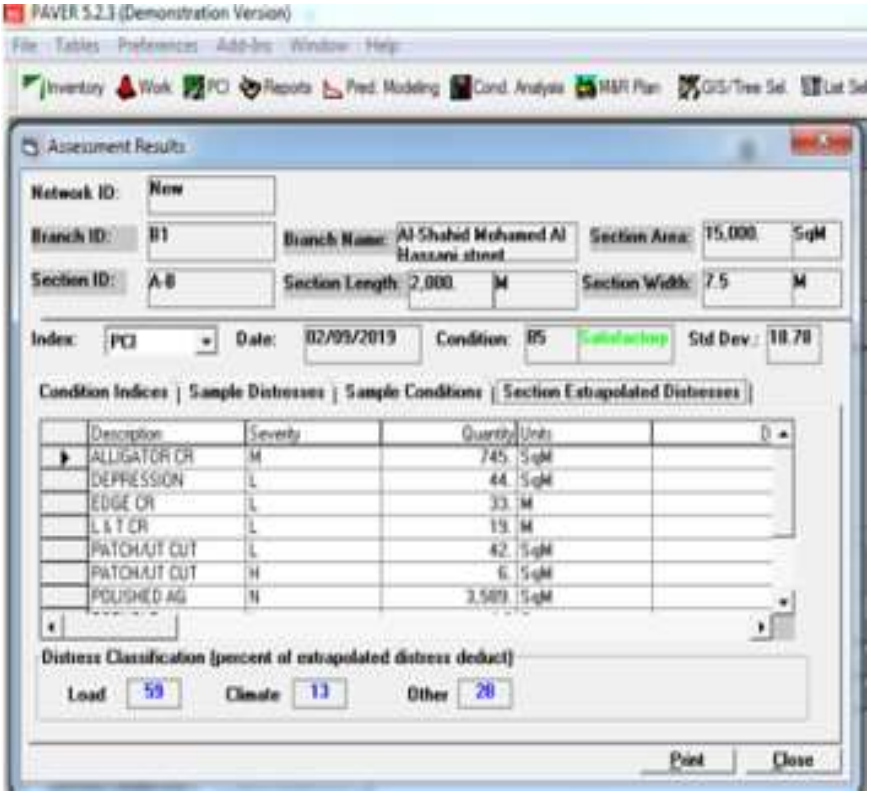

Figure 16 A sample section PCI calculation in PAVER 5.2.3.

DISCUSSION OF RESULTS

The PCI considers a simple, convenience and inexpensive manner to examine the surface's condition of roads, determine (M&R) requires, and in addition ensure that budgets of road maintenance are spent wisely. The condition of the pavement was evaluated based on the pavement distresses which existing at field prediction time. The results of this chapter have been obtained using PAVER software, the PCI value of the selected pavement section are 85 for both sections A-B and B-A. Based on PCI category, the studied road is classified as in "Satisfactory" condition because the PCI value falls in the rang 70-85, that means the pavement in the studied road needs preventive maintenance that includes patching and crack sealing.

Techniques of maintenance repair of pavement

According to Washington State Department of Transportation (WSODT), 2002 maintenance repair classified into four type that should be consider for road surface, those repair are :

1. Crack sealing: it is involve that asphalt sealing material applied in cracks to avoid moisture from interning pavement and street failure and causing pothole.
2. Slurry seal: this repair include that too thin stratum of asphalt or sand or small aggregate mixture above the pavement to decrease moisture penetration, reduces rate of deterioration, and improve skid resistance. It expands pavement life about 3-5 years.
3. Routine patching: it is applied when occurs a minor pavement failure produced by pavement construction or subgrade problems. This involves filling potholes, cover trenches and other miscellaneous repair.
4. Cape seal: Activities include spraying of liquid asphalt on pavement, after that followed with a stratum of small stone chip followed 1week latter with slurry seal to slow moisture penetration. It expands pavement life about 5-7 years.

Pavement Maintenance Alternatives

Selecting the right treatment technique is influenced by many variables. Even if the right treatment is chosen, there are still many choices in determining the procedures to be applied and the materials to be used. The early discovery and repair of deficiencies in pavement will inhibit minor distresses from growing into pavement failure. Knowing the causes of the distress helps the engineer choose the approach required to repairing it. Table 2 shows the convenient maintenance repair of each distress observed in the study area.

Table 2 Type of distress, repair of it

Distress type	Repair
1. longitudinal crack	For low severity crack (its wide < 1/2 inch and infrequent) cracking seal is operated to inhibit entering water through cracks into subgrade, and prevent raveling edges of crack. HMA is used to offer satisfied service years after processing small cracks if kept sealed.
2. Transverse crack	In the low severity case (its wide < 1/2 and infrequent), the suitable repair is a crack seal. But, in the high severity case (its wide > 1/2 and numerous cracks), use overlay surface or applying to thin overlay.
3. Alligator crack	Small, localized alligator cracking signify a loss of subgrade encouragement. To repair this, the collapse area is removed after that digs out and poor subgrade area is replaced and the drainage of this area is improved if needed. Finally, the healing subgrade is patching.
4. Edge crack	When edge cracks with surface distortion case (cracks < 1/4 inch wide) no maintenance is need. In the case, edge cracks with distortion of undamaged Surfaces where the distortion ≤ 1 inch and the surviving surface is undamaged, the suitable repair for this case is applied a skin patch. If the distortion > 1 inch and the surviving surface is undamaged, tack area and construct with asphalt concrete.
5. Polished aggregate	The correct treatments for this failure are applied a skid-resistance slurry seal, aggregate (crushed rock), asphalt emulsion and use additives added to the surface of the existing pavement.
6.Raveling/Weathering	When localized areas of raveling is small. The raveled pavement is removing and patching. But area of raveling is large revealing of failure of general HMA. The best solution is to overlay the distressed area.
7. Potholes	Patching process is the suitable repair to fill the pothole in the asphalt pavement. The potholes should be repair to limit further deterioration and prevent expensive pavement repair.
8. Shoving	When area of shoving is small. The failure area is removing and patching. In the case, shoved areas are large refer to the failure of general HMA. The damaged pavement is removed after that placed overlay.
9. Depression	As definition of depressions are small localized areas. Depression should be treated by removing the distorted pavement after digging out the poor subgrade area and replacing it, at last patching is placed over the repaired subgrade.

10. Patching/ Utility cuts	Considering patch itself repair. To remove these patches from the surface of the pavement, one way is an overlay, whether a structural or non- structural.

CONCLUSION AND RECOMMENDATION

1. Through the survey process conducted in Al- Rumaitha city and based on distress data collected from Al- Shahid Mohamed Al Hassani street's pavement, it's found that most of the distress observed in the road are classified as surface defects, Where the least distresses are cracks while the most percent are polished aggregate and weathering that observing on the most of the sample units of the study area.
2. The results of the inspected pavement that are evaluated presented the pavement condition index (PCI) value "85" ,both sections of road (A-B), (B-A) were satisfactory condition between the range (70-85).
3. According to PCI value, it can be concluded that the study area's pavement needs preventive maintenance which includes pothole patching, crack filling and isolated overlay.
4. To evaluate PCI and determine optimum maintenance, it is recommended to use PAVER software. This program may assist decision makers and local engineers of PMS agencies to select the optimal pavement maintenance.
5. Periodic inspection is essential for providing current and useful data of evaluation. It is recommended that the ratings should be updated annually. In general, roads must be monitored continuously to evaluate their condition to find out their problems and repair them.

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