Development of Pavement Maintenance Management System for Baghdad Urban Roadway Network

Prof. Saad Issa Sarsam  
Department of Civil Engineering  
College of Engineering  
University of Baghdad  
Email: saadisarsam3@hotmail.com

Asst. Lect. Amina Talal Abdulhameed  
Department of Civil Engineering  
College of Engineering  
University of Baghdad  
Email: eng_aminaa@yahoo.com

ABSTRACT

The road transportation system is considered as major component of the infrastructure in any country, it affects the developments in economy and social activities. The Asphalt Concrete which is considered as the major pavement material for the road transportation system in Baghdad is subjected to continuous deterioration with time due to traffic loading and environmental conditions, it was felt that implementing a comprehensive pavement maintenance management system (PMMS), which should be capable for preserving the functional and structural conditions of pavement layers, is essential. This work presents the development of PMMS with Visual inspection technique for evaluating the Asphalt Concrete pavement surface condition; common types of Asphalt Concrete distress including (bleeding of Asphalt, patching, block cracking, edge cracking, longitudinal and transverse cracking, rutting, pot holes, longitudinal and transverse deformation) with their various severity and intensity conditions have been included in the system as data base. The surface of the pavement was divided into sections, and the pavement condition is visually evaluated by the raters using specially designed forms, each type of defect was measured, classified, and rated according to type, severity, and extent. Data will be fed to the system using the computer, various types of intensity and severity of distress were analyzed by the system, the present condition rating (PCR) of the pavement section is determined, and the system suggests the required maintenance action. The developed system which is assigned (PMMS-09) was verified in evaluating the pavement surface condition at AL-Jaderiah campus roadway network. The results indicated that the system is sound in evaluation of the pavement condition and in suggestion of the proper maintenance to reserve the pavement condition.

Keywords: asphalt concrete, condition, maintenance, pavement.

استنباط نظام إدارة صيانة الرصف لشبكة الطرق الحضرية في بغداد

م.م. أمنة طلال عبد الحميد
قسم الهندسة المدنية
كلية الهندسة / جامعة بغداد

Prof. Saad Issa Sarsam
Department of Civil Engineering
College of Engineering
University of Baghdad
Email: saadisarsam3@hotmail.com

Asst. Lect. Amina Talal Abdulhameed
Department of Civil Engineering
College of Engineering
University of Baghdad
Email: eng_aminaa@yahoo.com

المستخلص:

يعتبر نظام النقلشبكة الطرق من المكونات الرئيسية في البنية التحتية لأي بلد، حيث يكون مؤثراً على تطوير الاقتصاد والفعاليات الاجتماعية. تتعرض الخرسانة الإسفليتية التي تكون المادة الرئيسية في رصف شبكة الطرق في بغداد للخرباب المستمر...
1. INTRODUCTION

Pavement maintenance management systems are designed to manage maintenance and rehabilitation activities to optimize pavement condition with available funds. The use of (PMMS) is becoming increasingly more prevalent due to benefits achieved. It considers current and future pavement condition, priorities, funding, and can reduce pavement deterioration, this helps maintain pavement structural capacity, and may extend pavement life by slowing or limiting future pavement degradation. Pavement condition can be quantified by the pavement condition rating (PCR) which rates the pavement according to the extent and severity of distress types present (cracking, raveling, bleeding, shoving ...etc). (PCR) ranges from 100 to zero (best to worst). A major goal of (PMMS) is to keep pavement condition in the upper (PCR) range of (60-90) by limiting surface structural degradation to keep down rehabilitation cost.

1.1 The Study Area

The road network at Al-Jaderiah campus was constructed and opened to traffic at 1980. It consists of 25cm of compacted sub grade with CBR value ≥5%, 40 cm of sub base type B with CBR value ≥35%, 10cm of Asphalt stabilized base course, 7cm of binder course and 6cm of surface course. The network was subjected to resurfacing with 6cm resurfacing course during the year 2000. Fig. 1 shows the roadway sections at Al-Jaderiah campus, Sarsam (2008).
3. ASSESSING PAVEMENT SURFACE CONDITION

The first step in the procedure starts when the whole Pavement surface was divided into sections of 100 meter length, then it involves identification of both type and severity of the pavement distresses present in the study area of the road sections by establishing the existing pavement condition using the visual walk through survey. Graphic plots of various types of pavement surface distress of each pavement section were obtained from Sarsam, 2008 and shown in Plate 2. This procedure was performed with the use of the South Dakota DOT Manual, 1997, Miller & Bellinger Manual, 2003, WSDOT Manual, 2007, and McGhee, 2002, Sarsam and Talal, 2009 which contains definitions and information concerning pavement distresses. Table 1 illustrates various types of distress fed to the data base of the software, and the distress types identified at AL-Jaderiah campus.

In the second step, each of the various types of Pavement distresses was identified and measured (i.e. units of linear meter or square meters). In addition, for each distress, a level of severity was determined [low (L), Medium (M), High (H)]. The distresses data were to the Inspection Sheet shown in Plate 3, of the system. Once the visual assessment of the road area was complete, calculations were performed by the system using the data collected in the field, through these calculations, a pavement condition rating (PCR) for the road network was determined.

3.1 Assessment Calculations:

Using the data obtained through the assessment procedure shown in Plate1, the following calculations were performed by the system to determine the pavement condition rating (PCR) for the road network. For each of the different types and severity of distresses, a distress density (extent) was calculated by the system. The following are the formulas Eqs. 5 through 7 that were fed and used to calculate the distress densities:

\[ \text{Density} = \left( \frac{\text{Distress amount in square meters}}{\text{Unit area in square meters}} \right) \times 100\% \]  \hspace{1cm} (5)

\[ \text{Density} = \left( \frac{\text{Distress amount in linear meter}}{\text{Unit length in linear meter}} \right) \times 100\% \]  \hspace{1cm} (6)

\[ \text{Density} = \left( \frac{\text{Number of potholes, patches}}{\text{Unit area in square meters}} \right) \times 100\% \]  \hspace{1cm} (7)

3.2 Distress Severity Assessment

The most common form used for the knowledge representation of the system is (IF-THEN) rule; such forms are fed to the system as described below.

3.3 Block Cracking

IF crack mean width ≤ 6mm, THEN severity is low.
IF crack mean width > 6mm and ≤ 19mm, THEN severity is moderate.
IF crack mean width > 19mm, THEN severity is high.

Record square meters of affected area at each severity level.

3.4 Longitudinal, Reflection, and Transverse Cracking

IF crack mean width ≤ 6mm, THEN severity is low.
IF crack mean width > 6mm and ≤ 19mm, THEN severity is moderate.
IF crack mean width > 19mm, THEN severity is high.

Record the length in meter at each severity level for longitudinal cracks, and the length and number of reflection or transverse cracks at each severity level.

3.5 Potholes

IF pothole depth < 25mm, THEN severity is low.
IF pothole depth > 25mm and < 50mm, THEN severity is moderate.
IF pothole depth > 50mm, THEN severity is high.
Record number of potholes and square meters of affected area at each severity level.

3.6 Rutting, Bleeding, Raveling, Polished Aggregate and Shoving

Record maximum rut depth in millimeters, and number of occurrences and square meters of affected area, severity level is not applicable.

3.7 Fatigue Cracking (in the wheel path)

IF an area of cracks with few fine parallel cracks connected, THEN severity is low.
IF interconnected cracks forming alligator pattern, THEN severity is moderate
IF interconnected cracks forming alligator pattern with sapling and distortion, THEN severity is high
Record square meters of affected area at each severity level.

3.8 Patching
IF patch shows no visual distress, THEN severity is low.
IF patch shows medium distress with notable roughness, THEN severity is moderate.
IF patch shows high distress with distinct roughness, THEN severity is high.
Record number of patches and square meters of affected area at each severity level.

3.9 Edge Cracking (area within 0.6m of the pavement edge)

IF cracks are light with no breakup or loss of material, THEN severity is low.
IF cracks are well defined with some breakup and loss of material, THEN severity is moderate.
IF cracks are well developed with significant breakup and loss of material, THEN severity is high.

3.10 Distress Extent Assessment

3.11 Transverse Cracking

IF crack spacing > 15 m, THEN extent is low.
IF crack spacing > 7.5 m and < 15 m, THEN extent is moderate.
IF crack spacing < 7.5 m, THEN extent is high.

3.12 Fatigue Cracking

IF crack is 1% to 9% of wheel path, THEN extent is low.
IF crack is 10% to 24% of wheel path, THEN extent is moderate.
IF crack is 25% to 49% of wheel path, THEN extent is high.

3.13 Patching

IF patching is 1% to 9% of section, THEN extent is low.
IF patching is 10% to 24% of section, THEN extent is moderate.
IF patching is 25% to 49% of section, THEN extent is high.

3.14 Block Cracking

IF cracking is 1% to 9% of section, THEN extent is low.
IF cracking is 10% to 49% of section, THEN extent is moderate.
IF cracking is > 49% of section, THEN extent is high.

The values for the densities (extent) were recorded. Next, using the calculated densities and the severity (i.e. L, M, or H) a deduct value for each distress type was determined. The deduct values were determined through the use of the "Deduct Value Curves" for each of the various distress types identified. The curves are part of the U.S. Army Corps of Engineers Technical Report TR97/104. The mathematical models for each
Deduct values for all the distresses were then summed to produce a "Deduct Total" using the mathematical equation below.

\[ \text{Deduct total DT} = \sum_{D=1}^{16} \text{Deduct (patching)} + \text{Deduct (cracking)} + \text{Deduct (bleeding)} \quad (8) \]

Given the "Deduct Total" and a value for the number of deducts greater than 5 points, Equation 8 will be used by the system to determine a "Corrected Deduct Value" or (CDV). Finally, the pavement condition rating (PCR) was calculated using the following equation:

\[ \text{PCR} = 100 - \text{CDV} \quad (9) \]

Plate 4 illustrates the final calculations for the physical condition of the pavement by the software.

3.15 Pavement Surface Condition Rating

Given the value of the PCR for the road section, a pavement condition rating was determined using the most common form used for the knowledge representation of the system (IF-THEN) rule, and the information and limitations illustrated in the distress identification manuals previously referred to as below:

- IF PCR > 0 and ≤ 40, THEN PCR = Very poor
- IF PCR > 40 and ≤ 55, THEN PCR = Poor
- IF PCR > 55 and ≤ 65, THEN PCR = Fair to poor
- IF PCR > 65 and ≤ 75, THEN PCR = Fair
- IF PCR > 75 and ≤ 90, THEN PCR = Good
- IF PCR > 90 and ≤ 100, THEN PCR = Very good

4. PAVEMENT MAINTENANCE TREATMENTS DECISION

The selection of the right maintenance strategy at the right time will be influenced by the type, severity, and extent of the pavement surface distresses and the structural and roughness condition of the pavement. Choosing the right treatment also depends on the extent or frequency that the distress occurs. Some of the treatments may be most applicable when very little distress is present. For each distress, a number of possible maintenance treatments exist. The maintenance treatment strategies were obtained from Pavement maintenance manuals (NDOT-2004; OhioDOT-1999; SHRP-1993), and fed to the system.

4.1 System Logic

Based on the work done by Misra and Rohanirad, 2003, Fred, 1997, Sarsam, 2008, the system describes what to do in particular distress circumstances. There are six major treatments decisions which should be taken into consideration as illustrated below:

1. Do Nothing
2. Crack filling and sealing
3. Patching
4. Milling
5. Thin hot mix overlay application
6. Shoulder maintenance

Each type of pavement distress will lead the system to consider more than one treatment alternatives depending on distress severity, extent and the required extension in Pavement life as follows:

- IF Alligator cracking exists, THEN select 1, 3, 5
- IF Distortion exists, THEN select 1, 2, 3, 5
- IF Edge cracking exists, THEN select 1, 2, 6
- IF Rutting exists, THEN select 1, 4, 5
- IF Longitudinal cracking, THEN select 1, 2, 3
- IF Bleeding exists, THEN select 1, 4, 5
- IF Block cracking exists, THEN select 1, 2, 5
- IF Raveling or weathering exists THEN select 1, 5
- IF Transverse cracking, THEN select 1, 2, 3, 4
- IF Coarse texture THEN select 1, 4, 5

It must be emphasized that such treatments could be applied and may be effective in treating the distress, and increasing the expected life of the pavement. The Do Nothing strategy may be the most appropriate under certain circumstances. Plate 2 illustrates typical output of the system. Plate 5 demonstrates the software output, the software decided the maintenance alternative, and calculate the cost of maintenance of the section by...
multiplying the unite cost of the selected alternative by the area of the defected section. The unite cost data must be upgraded periodically.

4.2 Software Environments

Microsoft ACCESS 2003 (which was selected for the development of PMMS for Baghdad urban roadway network) employs three programming languages to enable user to add fine – tuning to an application. The Structured Query Language (SQL) is the language access used behind the scenes in queries that can extract, manipulate and relate data from one or more tables. Macros consist of list of actions that execute in response to an event such a button click or data in a form changes. The developed system processes in four steps, the first step involves field data collection and tabulation while the second step involves creating the table definitions and key field requirements, and data validation rule, define tables linked to look up. Finally data were added to tables to be able to test application thoroughly. The third step is the data entry form, the fields in the form carefully arranged in logical order and with meaning full label to help prevent entry errors. The fourth step considers macros and event procedure , function were added to the form design that it would be perform appropriately to user action as shown in plate 6.

5. ANALYSIS AND DISCUSSION OF VISUAL ASSESSMENT OF PAVEMENT SURFACE CONDITION

The original raw data that was collected in the field and the results of the calculation described in the previous section are included in Plates 2 and 5 which is a summary of the data and results. As shown, there were different types of distresses identified during the inspection of the representative area. The levels of severity for the distresses identified ranged from low severity (L) to high severity (H). The total amount of “deduct” and the corrected deduct value “CDV” was calculated by the system and illustrated in Plate 4. The pavement condition rating (PCR) was determined to be in the range of (99-45) % which results in a rating of "poor to very good" for the road sections based on the rating index provided.

6. CONCLUSIONS AND RECOMMENDATIONS

This paper has produced a methodology that can use the visual data obtained in the field and perform analysis of distress using an expert system. The developed system was tested in a small project that include most of distress types, it could provide a better environment to assess and analyze data about the condition and maintenance of Asphalt concrete pavement, it combines detailed inventory and evaluation procedures with analytical software routines. It is simple to perform, use less expensive techniques and individuals to subjectively rate Asphalt pavement sections based on observed distress, provides job opportunities for Engineers and technicians. Based on the information obtained during this evaluation, it is recommended to consider using the software, and it should be tested in bigger project to evaluate whether it will be labor intensive.

7. REFERENCES


Plate 1. Roadway identification and section information.
Figure 1. Sections of road network at AL-Jaderiah campus, Sarsam, 2008.

Table 1. Distress types included in the software, Sarsam and Talal, 2009.

<table>
<thead>
<tr>
<th>Distress types included</th>
<th>Distress types observed at AL Jaderiah campus road network</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Cracking</td>
<td>Block cracking</td>
</tr>
<tr>
<td>Fatigue cracking</td>
<td>Pavement edge cracking</td>
</tr>
<tr>
<td>Block cracking</td>
<td>Transverse cracking</td>
</tr>
<tr>
<td>Pavement edge cracking</td>
<td>Longitudinal wheel path cracking</td>
</tr>
<tr>
<td>Transverse cracking</td>
<td>Longitudinal non-wheel path cracking</td>
</tr>
<tr>
<td>Reflection cracking</td>
<td></td>
</tr>
<tr>
<td>Longitudinal wheel path cracking</td>
<td></td>
</tr>
<tr>
<td>Longitudinal non-wheel path cracking</td>
<td></td>
</tr>
<tr>
<td>2- Surface deformation, Rutting, Shoving</td>
<td>Rutting</td>
</tr>
<tr>
<td>3- Patching and potholes</td>
<td>Patch, Pothole</td>
</tr>
<tr>
<td>4- Surface defect</td>
<td>Bleeding</td>
</tr>
<tr>
<td>Bleeding, Lane to shoulder drop off, Polished aggregate, Raveling and Coarse Macro-texture</td>
<td>Coarse Macro-texture</td>
</tr>
</tbody>
</table>
Plate 2. Plots showing pavement surface condition at AL-Jaderiah campus, Sarsam, 2008.
Plate 3. Type of pavement distress.
Plate 4. Physical characteristics of the pavement.
Plate 5. PMMS system output.
Plate 6. Sample of data entry form.