Development of Pavement Maintenance Management System for Baghdad Urban Roadway Network

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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 ادارة صيانة الرصف لشبكة الطرق الحضرية في بغداد

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المستخلص:-
يعتبر نظام النقل بشبكة الطرق من المكونات الرئيسية في البنية التحتية لأي بلد، حيث يكون مؤثرا على تطوير الاقتصاد والفعاليات الاجتماعية. تتعرض الخرسانة الإسفلتية التي تكون المادة الرئيسية في رصف شبكة الطرق في بغداد للخراب المستمر

مع تقدم الزمن نتيجة التعرض لأحمال المرور والظروف المناخية، وهذا يتطلب وجود (نظام إدارة صيانة الرصفة) يكون قادرا على المحافظة على الوضع الخدمي والإنشائي لطبقات الرصفة المختلفة وذلك بالسيطرة على العيوب التي تتعرض لها. تم في الدراسة استنباط (نظام ادارة صيانة الرصف لشبكة الطرق الحضرية في بغداد) باستخدام الحاسوب مع تقنية الفحص البصري لتقييم حالة سطح رصفة الخرسانة الاسفلتية. تمت الاحاطة بكافة انواع عيوب الرصفة المعروفة والتي تشمل (نزف الاسفلت، الترقيع، الشقوق الكتلية، شقوق حافة الرصفة، الشقوق الطولية والمستعرضة، الحفر، والتخدد الطولي والمستعرض) مع درجة الشدة ومدى الانتشار لكل نوع من هذه العيوب وجدولتها في قاعدة بيانات داخل النظام. يتم تقييم سطح الرصفة بصريا باستخدام استمارات صممت لهذا الغرض بعد تقسيم السطح الى مقاطع، ثم ادخال المعلومات الى النظام بالحاسوب حيث يتم تحليل انواع شدة العيوب ومدى انتشارها،ويعطي النظام تقييما لحالة سطح الرصفة(PCR) لكل مقطع مع مقترح لنوع وطريقة الصيانة المناسبة وتكلفة المقترح. تم اختبار هذا النظام والذي تمت تسميته **PMMS-09** بتقييم حالة سطح الرصفة لشبكة طرق جامعة بغداد في مجمع الجادرية وتشير النتائج بان هذا النظام يعتبر سليما لتقييم حالة سطح رصفة الخرسانة الاسفلتية واقتراح طرق الصيانة المناسبة للمحافظة على حالة الرصفة.

الكلمات الرئيسية: خرسانة اسفلتية، حالة، صيانة، رصف

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)**.

2. SECTION LENGTH AND AREA CALCULATION

The actual length of each test section in meters (ACT Length) is calculated by the system using the following equation:

ACT Length = End station – Beginning station. (1)

Next, three areas are calculated, the pavement section area (PAV), the wheel path area (WP), and the non-wheel path area (NWP) using the formula below:

PAV area = ACT Length * lane width (3.5m) (2)

WP area = ACT Length * 50% of lane width (1.75m) (3)

NWP area = PAV area – W Parea (4)

Plate 1 shows the roadway identification and the section information.

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:

Density = (Distress amount in square meters / Unit area in square meters) x 100% (5)

Density = (Distress amount in linear meter / Unit length in linear meter) x100% (6)

Density = (Number of potholes, patches / Unit area in square meters) x100% (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 distress type curve were fed to the system. The deduct values for all the distresses were then summed to produce a "Deduct Total" using the mathematical equation below.

Deduct total DT = $\sum_{D=1}^{16}$ Deduct (patching) +Deduct (cracking) +Deduct (bleeding) (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:

PCR=100-CDV (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

Fred F, 1997, *Pavement Management System-Past, Present, And Future* National Workshop on pavement management in New Orleans-L .A. July 20.

Johanns M. &Craig J, 2004, *Pavement Maintenance Manual* Nebraska DOT.

Mcghee K.H, 2002, *Development and Implementation of Pavement Condition Indices* Virginia DOT., September.

Miller J.S. & Bellinger W.Y, 2003, *Distress Identification Manual for the Long Term Pavement Performance Program* FHWA-RD-03-031, US Department of transport, June.

Misra A. &Rohanirad A, 2003. *Guidelines for Roadway Management System for Local Governments* MTC Project A-01, October.

Ohio DOT, 1999. *Pavement Design and Rehabilitation Manual* January.

Sarsam S., 2008, *Development of Pavement Maintenance Management System using Visual Evaluation of Asphalt Concrete Surface Condition and Expert System, 2008.* Proceeding, 7th International Conference on managing Pavement Assets (ICMPA 7), Calgary, Alberta, Canada,25-27 June-.

Saad Sarsam and Amna Talal, 2009, *Development of Pavement Maintenance Management System for Baghdad Urban Roadway Network* Proceedings, 1st scientific conference of Civil Engineering College – AL Baath University, Industry of Engineering Constructions 11-13 May, Humus – Syria.

SHRP, 1993, *Distress Identification Manual for the Long-Term Pavement Performance Project* National research council, SHRP-P 338, Washington DC.

South Dakota DOT, 1997, *Enhanced Pavement Management System- Visual Survey Manual 2001*.

US Army Corps of Engineers, Technical report TR97/104 "Paver asphalt distress manual".

WSDOT, 2007, *Pavement Surface Condition Field Rating Manual for Asphalt Pavement* Northwest Pavement management association, January.

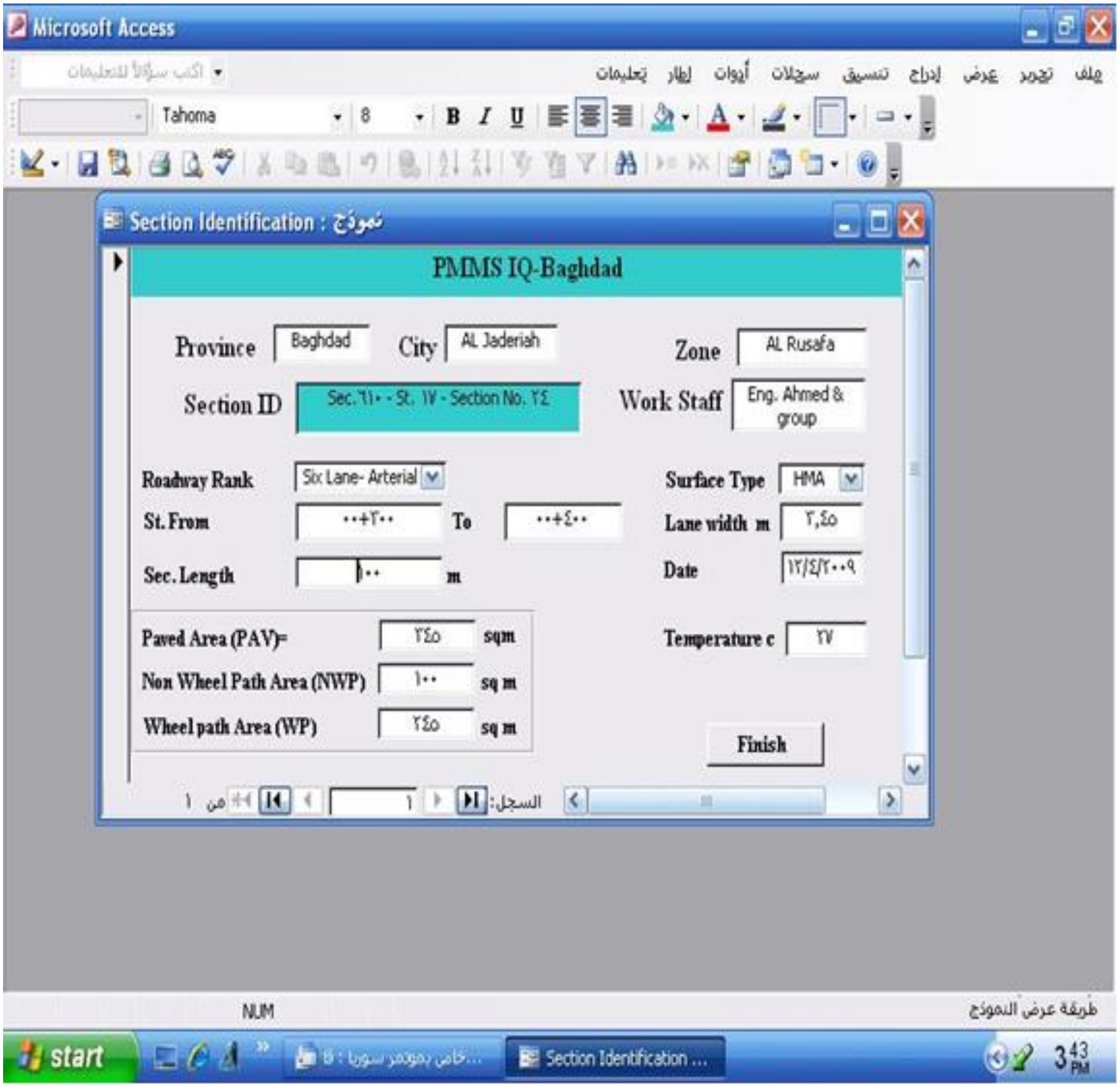

Plate 1. Roadway identification and section information**.**

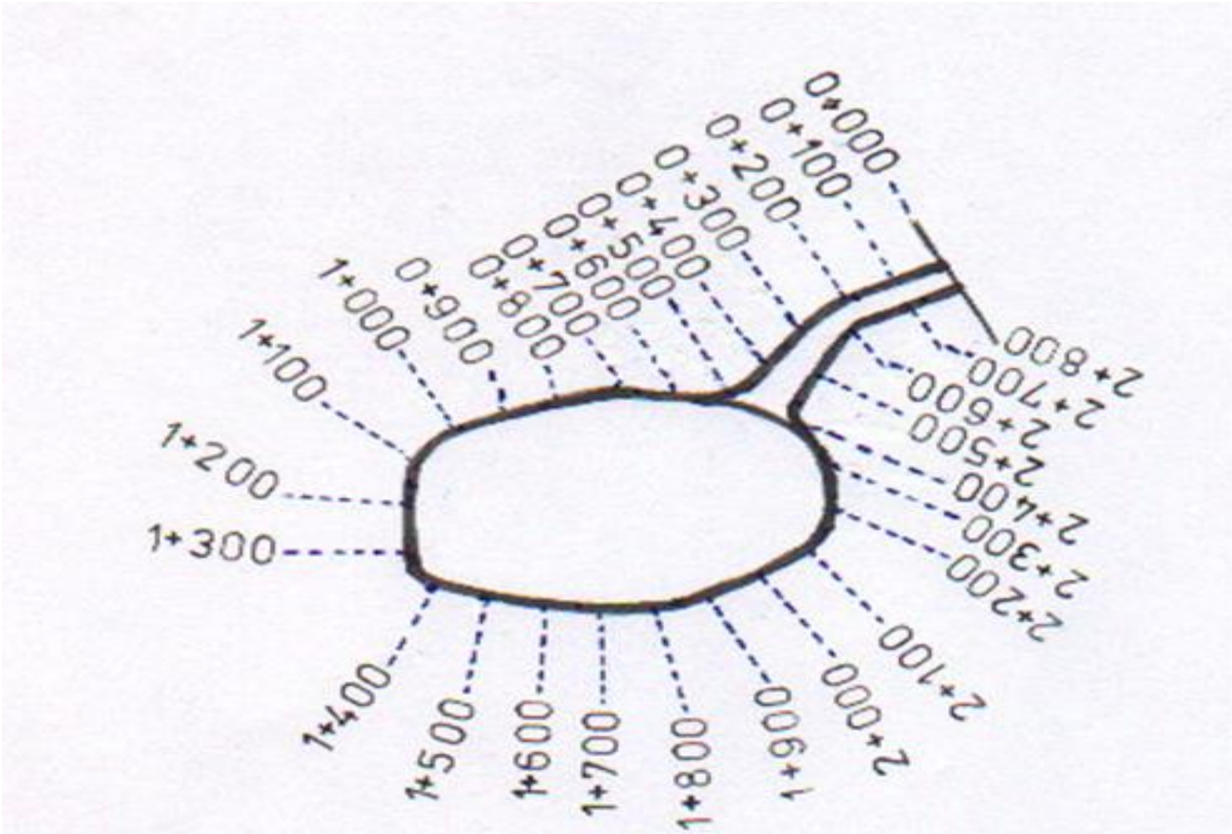

Figure 1. Sections of road network at AL-Jaderiah campus, Sarsam, 2008.

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

Distress types included	Distress types observed at AL Jaderiah campus road network
1- Cracking Fatigue cracking Block cracking Pavement edge cracking Transverse cracking Reflection cracking Longitudinal wheel path cracking Longitudinal non-wheel path cracking	Block cracking Pavement edge cracking Transverse cracking Longitudinal wheel path cracking Longitudinal non-wheel path cracking
2- Surface deformation, Rutting, Shoving	Rutting
3- Patching and potholes	Patch, Pothole
4- Surface defect Bleeding, Lane to shoulder drop off, Polished aggregate, Raveling and Coarse Macro-texture	Bleeding Coarse Macro-texture

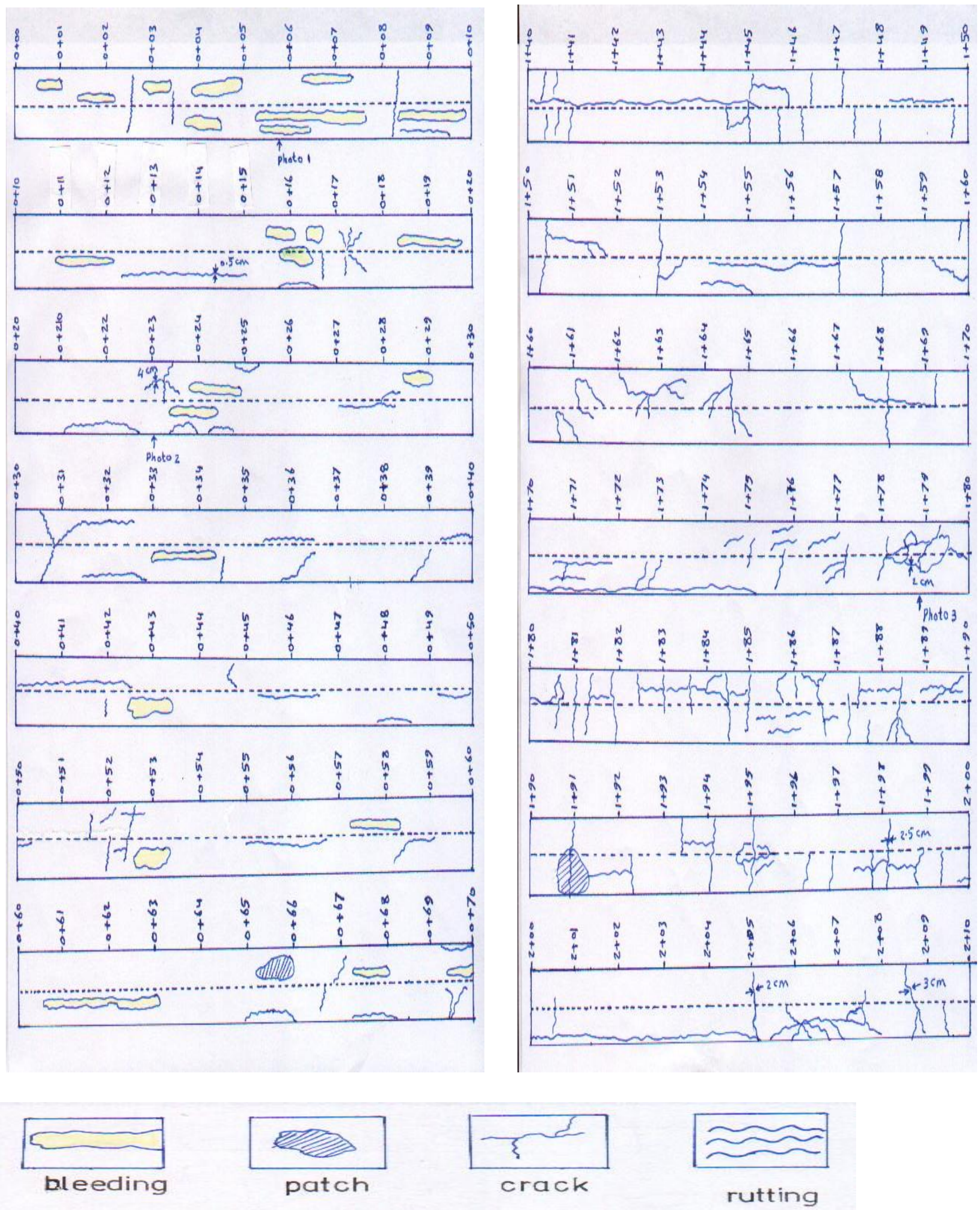

Plate 2. Plots showing pavement surface condition at AL-Jaderiah campus, Sarsam, 2008.

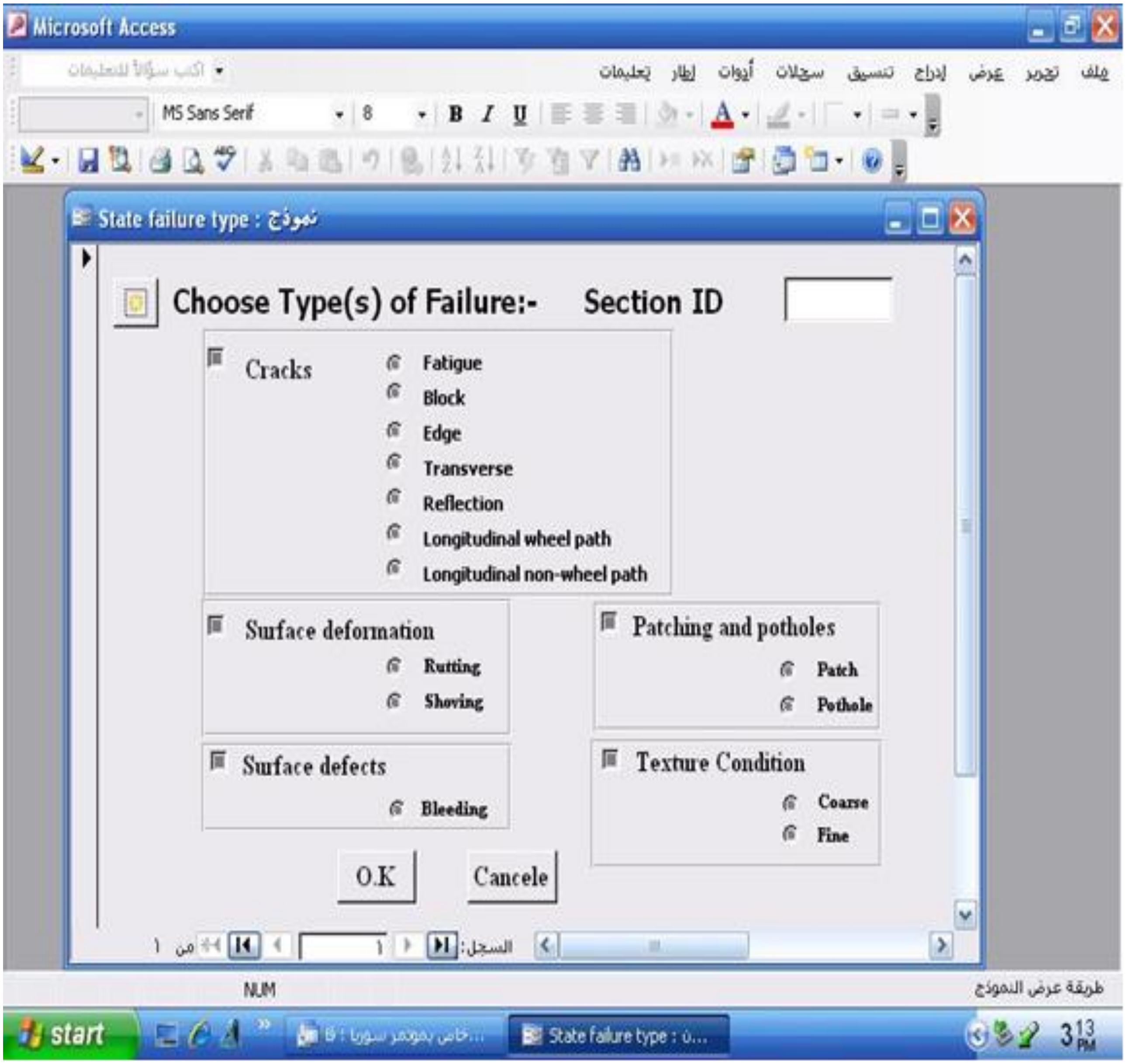

Plate 3. Type of pavement distress.

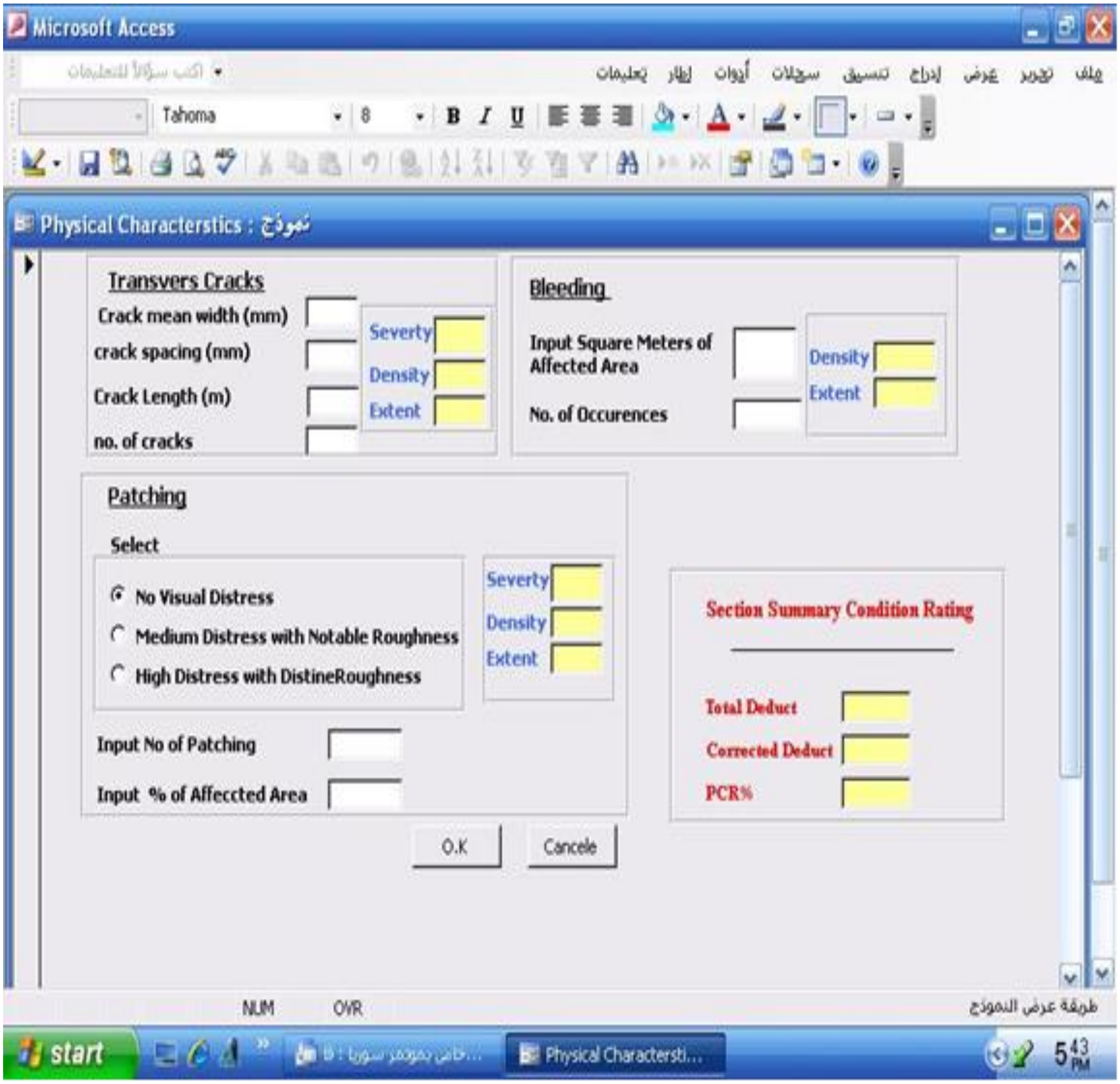

Plate 4 . Physical characteristics of the pavement.

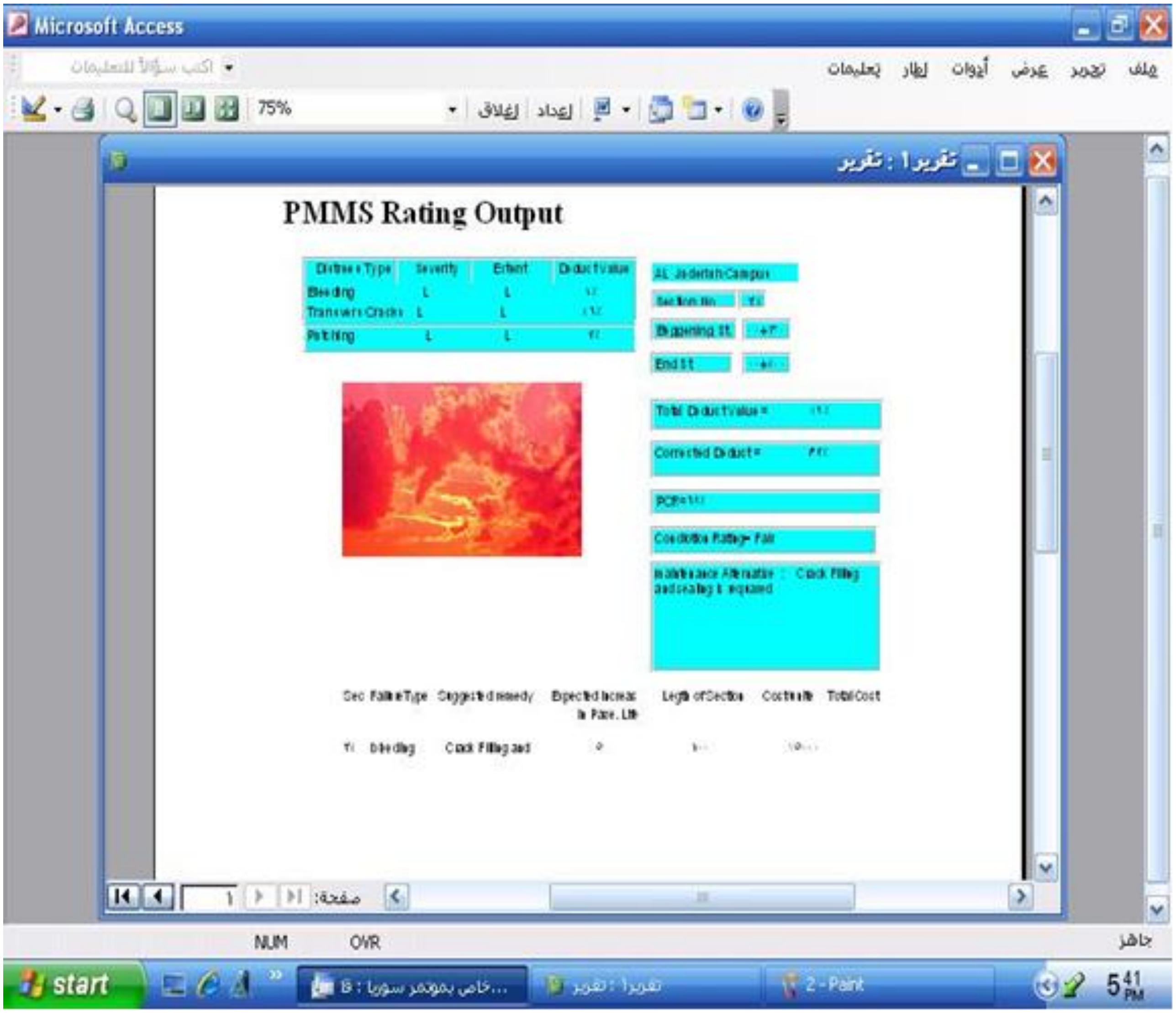

Plate 5. PMMS system output.

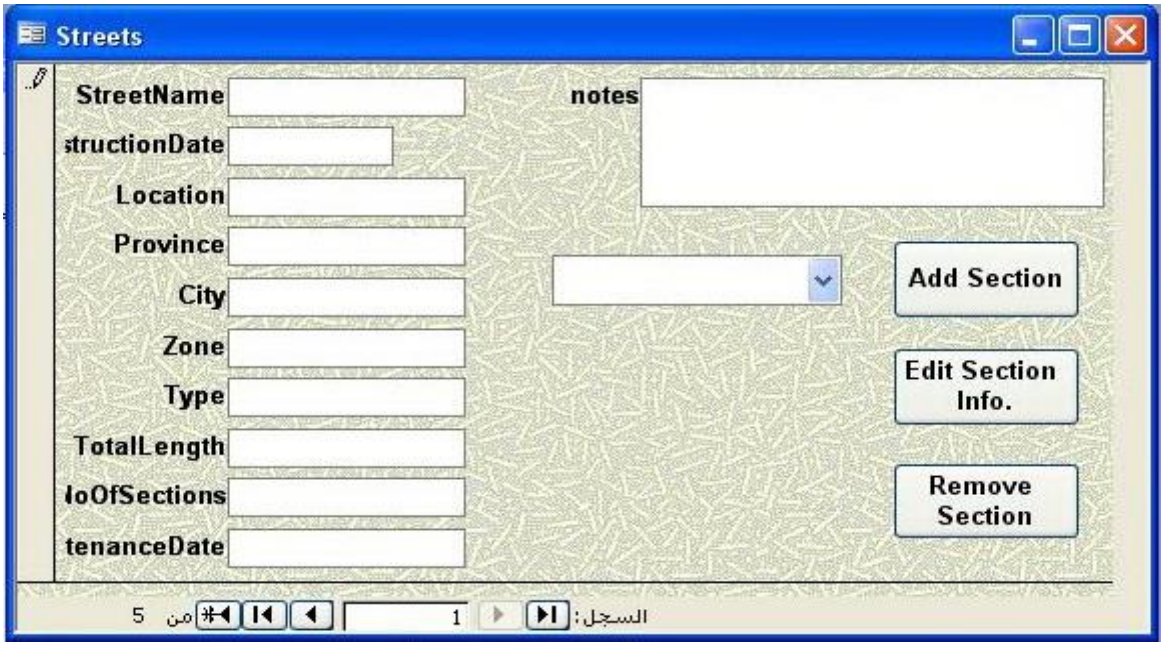

Plate 6. Sample of data entry form.