AUTOMATED IMAGING TECHNIQUE FOR RUNWAY CONDITION SURVEY

By:
Kelvin C.P. Wang and Zhiqiong Hou
University of Arkansas, AR 72701
Quintin B. Watkins
Hartsfield-Jackson Atlanta International Airport
Subash Reddy Kuchikulla
ACCURA Engineering & Consulting Services Inc.
USA
Phone: (479) 575-8425
kcw@uark.edu

PRESENTED FOR THE
2007 FAA WORLDWIDE AIRPORT TECHNOLOGY TRANSFER CONFERENCE
Atlantic City, New Jersey, USA

April 2007

ABSTRACT

Accurate data collection and interpretation of pavement data is critical for the decision-making process in pavement management. Collection and analysis of pavement surface distress is still a manual process for many highway and airport agencies, even though a substantial amount of resources were used in the past decades to devise automated approaches to collecting and analyzing pavement surface distress. In 2001, the Digital Highway Data Vehicle (DHDV) developed at the University of Arkansas was used to survey two runways of the Hartsfield Atlanta International Airport. In 2004, the second round of survey was conducted with a newer generation of technology of DHDV that provided 1-mm resolution for covering four runways. This paper introduces the automated system capable of collecting and analyzing pavement surface distresses, primarily cracks, in real-time through the use of high resolution digital camera, efficient image processing algorithms and multi-computer, multi-CPU based parallel computing. A comparison is shown between image data collected in 2001 and 2004, demonstrating deteriorating of concrete surfaces. The FAA guide for airport distress survey is used in the analysis. As the automated digital system was not designed for PCI rating, manual survey was used to collect distress information from the digital images of the runways. In addition, laser illumination technology is also introduced in the paper to illustrate the energy efficiency and image uniformity of the new image capturing system currently used in the DHDV vehicle.

INTRODUCTION

This paper describes a new imaging technique applied in the pavement distress survey on airport runways. The Digital Highway Data Vehicle (DHDV) developed at the University of Arkansas and WayLink Systems Co. was used to conduct the runway pavement distress survey for Hartsfield-Jackson Atlanta International Airport (H-JAIA) in October 2001 and September 2004. DHDV is a multi-function survey device designed to collect and analyze various data sets on highway and airport pavements. The pavement imaging sub-system in the DHDV successfully accomplished the survey tasks for the airport runways. It is faster, safer and more consistent than manual surveys. Analysis results between the two surveys in 2001 and 2004 are presented in the paper which shows the trend of the deterioration of the runway pavement in HAIA and the effectiveness of the higher resolution of the imaging system at 1-mm.

THE DIGITAL HIGHWAY DATA VEHICLE (DHDV)

Many accidents of airplanes happened in the airport. The quality of the runway becomes critically important to the air travel safety. Due to the busy schedule of the airport, the survey of the runway has to be accomplished in a limited short period of time to avoid interrupting the normal operation of the airport.

Traditionally, technicians are sent to the field to do the inspection by visual observation. This is hazardous, slow, and lacks consistency. Recent advances in technology for field data acquisition and storage improved the data acquisition process and data quality. Roadway data survey using digital imaging techniques is becoming increasingly popular due to many advantages [1].

System Overview

The Digital Highway Data Vehicle (DHDV) is a roadway survey system developed by the researchers at the University of Arkansas since the 1990s. Figure 1 shows the exterior appearance of the third and current generation DHDV. The DHDV is multi-functional and includes a sub-system for pavement surface imaging, a sub-system for Right-of-Way (ROW) imaging, and a sub-system for road roughness and rutting measurement. Other hardware includes GPS receiver, Distance Measurement Instrument (DMI), power supply, and Gyro sensor. The software system used in the on-board computers of the DHDV employs real-time relational database engine, inter-computer communication techniques, multi-computer and multi-CPU based parallel computing, real-time control of digital sensors, and the generation of multimedia databases. In the runway surveys in Atlanta, only the pavement imaging subsystem was used. It can capture pavement images with more than 13-ft width. The systems from the second and third generations of DHDV obtain a resolution of 1mm/pixel in both longitudinal and transverse directions at a speed over 100 KPH (about 60mph). The imaging system works day or night and it is invariant to different weather condition due to its use of laser based illumination in an invisible narrow spectrum.

Figure 1. DHDV Exterior Appearance.

Pavement Imaging Sub-System

Two types of digital cameras are normally used in the data acquisition system in pavement imaging: line scan cameras and area scan cameras. The first generation DHDV used area scan camera. The second generation DHDV used line scan camera. Both of them used traditional visible light sources for illumination. The third and also current generation DHDV uses Laser Road Imaging System (LRIS) which employs line scan cameras and laser illumination. The third generation DHDV also provides better image quality due to its uniformity of illumination, despite the fact that the second and the third generations of DHDV have the same optical resolution. Figure 2 shows the working principle for line scan camera.

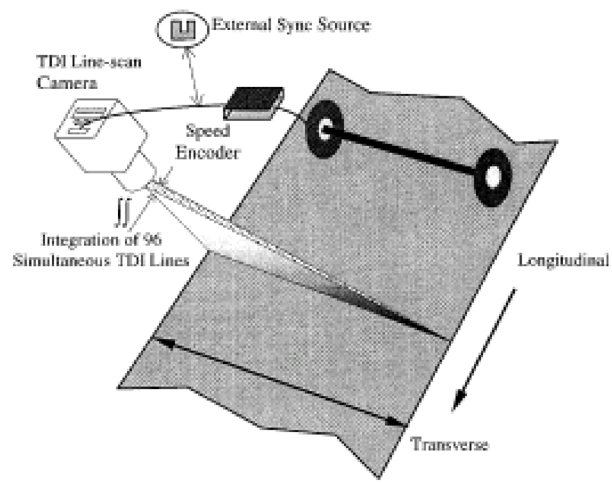

Figure 2. Line Scan Camera.

The image size obtained in LRIS is 4096 pixels/line and 28000 lines/second which allows 1mm resolution at 100km/h (about 60mph) collection speed. The LRIS system uses two high speed/high resolution line-scan cameras in conjunction with high power laser line projectors that are aligned in the same plane in a symmetrically crossed optical configuration (Figure 3). The laser used in LRIS has a wavelength of 800nm to 580nm which belongs to class IIIb. The line scan camera is triggered proportionally to the vehicle's driving speed to achieve the 1 mm resolution. This particular configuration offers several advantages as compared to more traditional imaging techniques. It is compact (20 kg total weight), power efficient (250W), and immune to shades, shadows, and change of ambient illumination.

ATLANTA AIRPORT SURVEY

Surveys were conducted on the runway at Hartsfield-Jackson Atlanta International Airport (H-JAIA) in November 2001 and September 2004. The runways in the airport were shut off for the survey around midnight for several hours. The DHDV did the image collection during the provided time period. The real-time processing result combined with the post processing are used to provide the runway condition report. As part of the post processing, screening and editing over all the images were conducted by WayLink staff for quality control purposes.

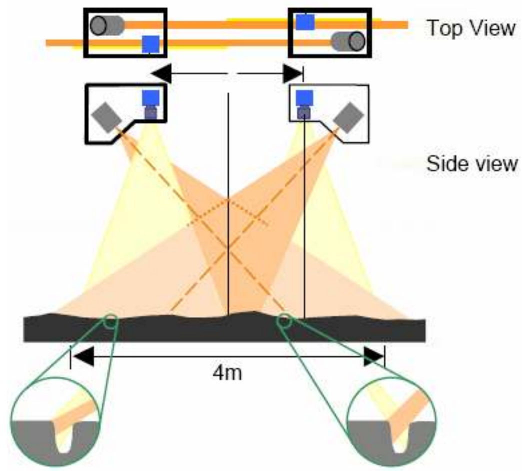

Figure 3. Configuration of the LRIS Sensors.

The runways in H-JAIA were constructed with jointed concrete pavement. There are 6 lanes on each runway, which are identified as A, B, C, D, E, and F, starting from the North edge to the South. There are 134 slabs in each lane for Runway 8R. The typical slab dimension is 75 ft long and 25 ft wide except the second slab in sample unit 8R-16-119, 8R-36-316 and 8R-56-516. These three slabs are 25 ft long and 25 ft wide. There are 185 slabs in each lane for Runway 9L. Slabs in this runway have three different dimensions. Some slabs are 25 ft long by 25 ft wide, some are 50 ft long by 25 ft wide, and some are 75 ft long by 25 ft wide. Since one image can only cover a little more than 13-ft width of a runway, two passes were made to capture all 25 ft wide of lane.

The scope of the 2001 survey includes two runways of H-JAIA, Runway 8R and Runway 9L. The same runways were surveyed during the 2004 survey. Pavement Condition Index (PCI) method was used in the analysis. Guidelines provided by FAA (Guidelines and Procedures for Maintenance of Airport Pavements [2]) and advices from the airport engineering staff are followed in the analysis and reporting.

According to the Guidelines [2], a project is divided into sections with similar pavement design, construction history or traffic area. Each section is further divided into sample units. The Guidelines recommend 20 slabs (with joint spacing not to exceed 25 feet) as a sample unit for airfield runway. However, H-JAIA has its own method in sectioning runway pavements. The runways have been delineated into predetermined sections and sample units for the initial implementation of MicroPaver. Each sample unit is inspected for distress type and its severity, and documented for every concrete slab (or 25 ft fraction thereof). For each distress type, severity level and density within a sample unit, a deduct value will be given according to the curves in Figures A-10 to A-24 in the Guidelines [2]. A total deduct value (TDV) will be obtained by summing all the deduct value for each distress. A corrected deduct value (CDV) will then be obtained from Figure A-25 in the Guidelines. PCI for each sample unit is calculated as

100 – CDV. The Pavement Condition Index (PCI) for the uniform section is the average of all sample units.

Calculation of the PCI for the section in this project uses weighted average method. For instance, there are two sample units, 130 and 131, in section 20. Sample unit 130 is 225 ft long with a PCI of 88. Sample unit 131 is 150 ft long with a PCI of 83. Weighted average PCI for section 20 is obtained as shown below:

$$Weighted\_Average\_PCI = \frac{(225 \times 88) + (150 \times 83)}{225 + 150} = 86$$

Back in 2001, the first generation of DHDV was used. The resolution then was about 3 mm per pixel. Area scan camera was used and the image size is 1300 by 1024 pixels. In 2004, the second generation of DHDV was used. The resolution improved to 1-mm per pixel and the line scan camera was used. The image resolution and quality were substantially improved.

The same section of the Runway 8R-39-333 was chosen to compare the result from the two surveys. The PCI value from 2001 survey is 66 (Good), the PCI value from 2004 is 50 (Fair). The following two images (Figure 4) are section 126C at 8R. The top images are from 2001 data and the pavement surface was stitched with frame images taken by area scan camera. Distortions from the lens and unevenly distributed lighting are obvious in the images. Stitching and overlapping of the images were also evident.

The bottom images are from 2004 survey where the pavement surface was formed with individual lines. The lens distortion is not visible and the resolution is increased by three times in each direction. Figures 5 and 6 show images of the same spot in the two surveys. The upper image in Figure 6 is from the 2001 survey, it has coarser resolution than the bottom one from the 2004 survey. The 2004 image also shows that the crack areas had deteriorated since 2001. Figure 6 illustrates the obvious improvement of image resolution and quality of the 2004 survey over the 2001 survey, and the distress deterioration.

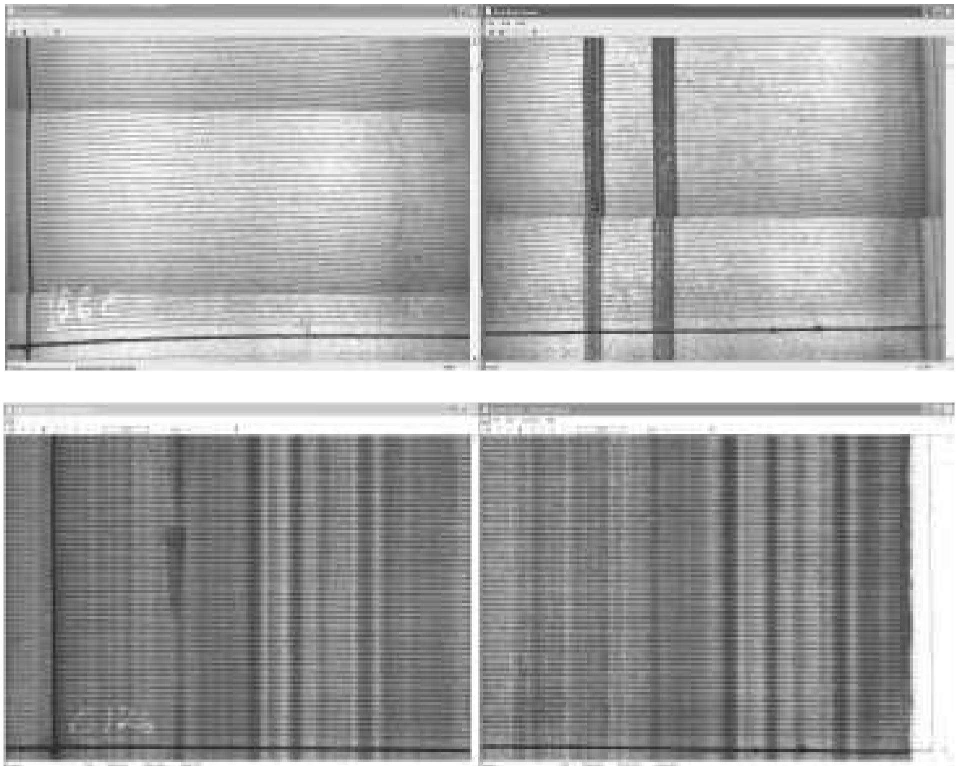

Figure 4. Images Comparison between 2001 (top) and 2004 (bottom) Surveys.

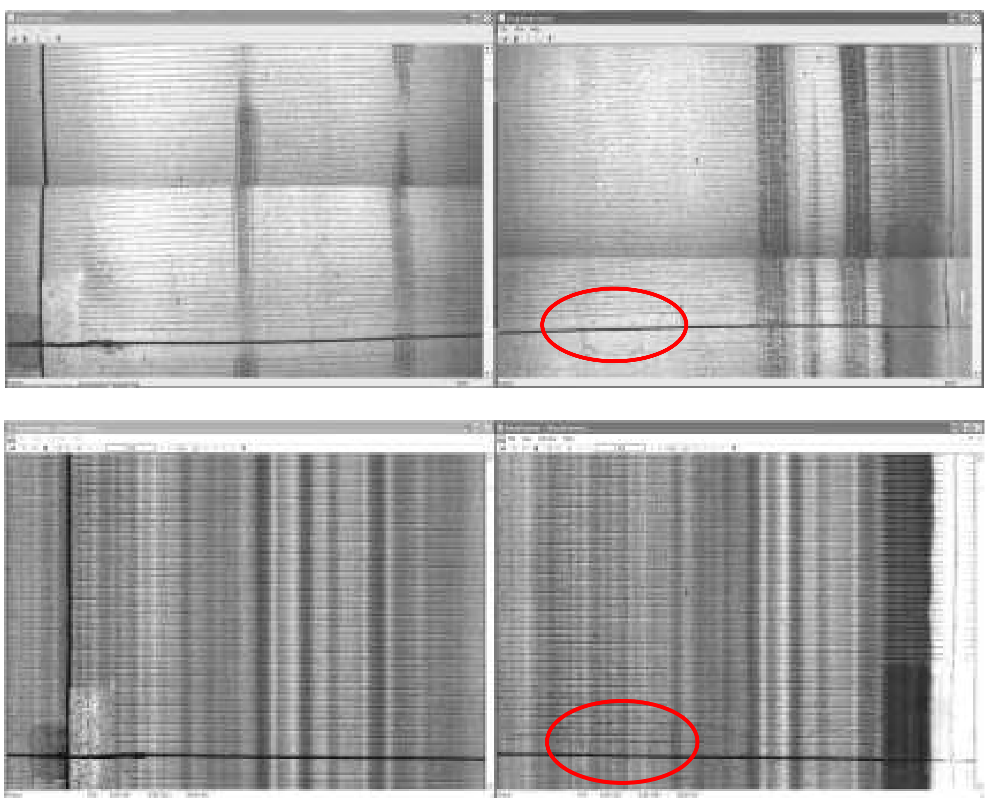

Figure 5. Comparison of the Same Distresses between 2001 (top) and 2004 (bottom) Surveys.

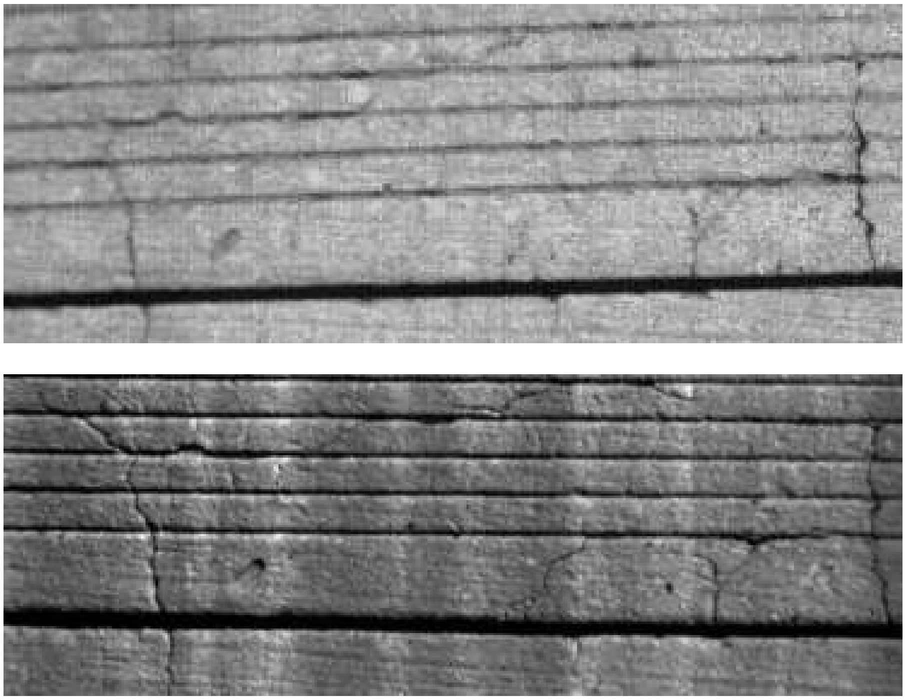

Figure 6. Distresses of Zoomed-in Area from Figure 5.

Figures 7, 8 and 9 demonstrate the difference between the 2004 and 2001 survey results for the Left Outboard, Keel and Right Outboard respectively for Runway 8R. Figure 10 demonstrates the absolute drop of PCI values during the three-year period due to continuing distresses suffered from loading and other factors.

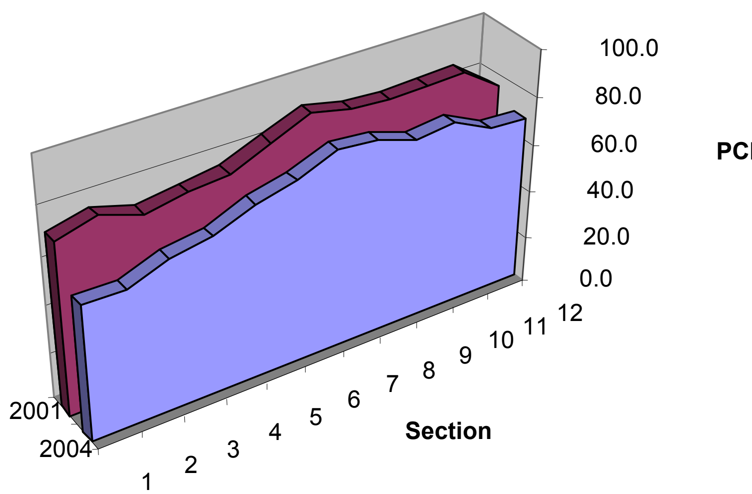

Figure 7. Comparison between 2001 and 2004 Survey Results (LeftOutBoard, Runway 8R).

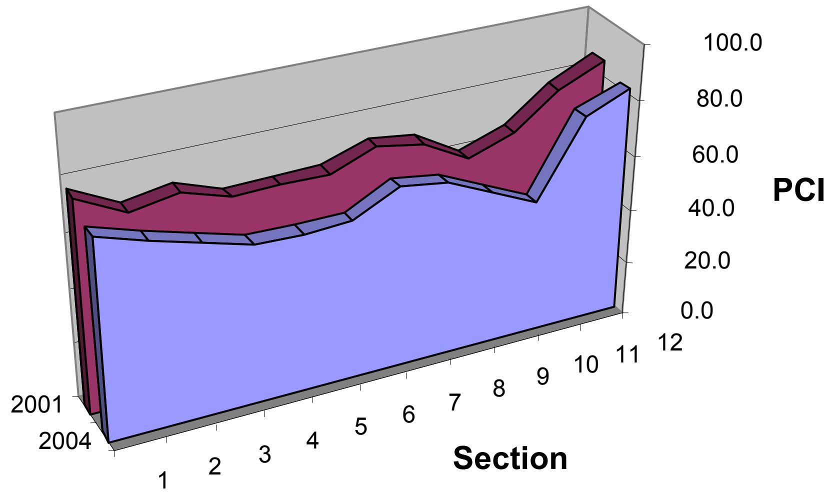

Figure 8. Comparison between 2001 and 2004 Survey Results (Keel, Runway 8R).

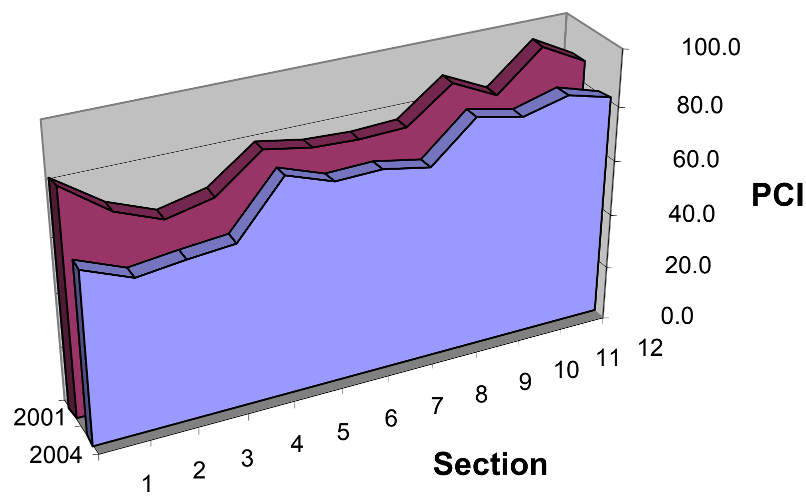

Figure 9. Comparison between 2004 and 2001 Survey Results (RightOutBoard, Runway 8R).

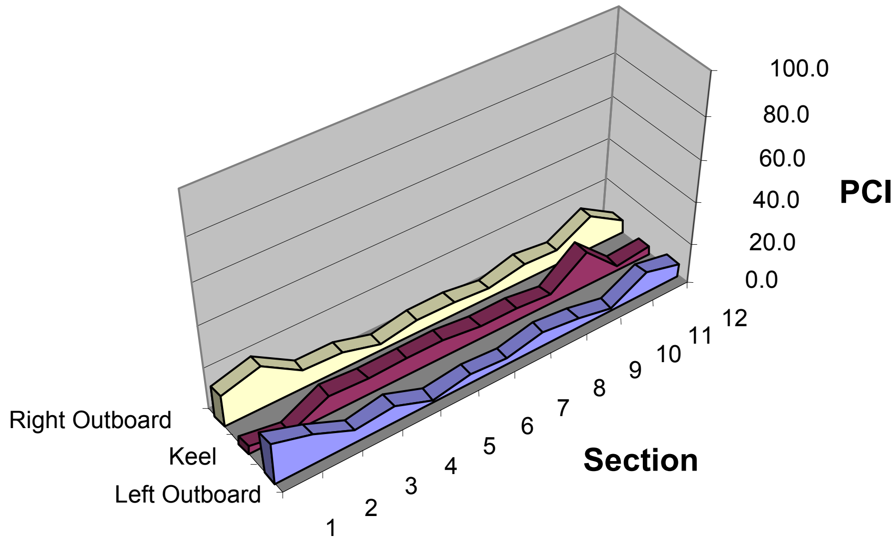

Figure 10. Dropped PCI Values during 2001-2004 for Runway 8R.

Figure 11. MHIS Deluxe Interface.

CONCLUSION

The images collected through the Digital Highway Data Vehicle (DHDV) have been demonstrated to be faithful representations of airport runway surface through two generations of collection technologies. DHDV is an effective platform to chronically keep tracking runway conditions. It is planned to use the third generation of DHDV for additional airport surveys in the near future. It should be particularly noted that the new software made for various distress surveys, i.e. the Multimedia based Highway Information System (MHIS) Deluxe, will be used for rating runways based on the PCI method. Coupled with cracking results from the Automated Distress Analyzer (ADA), MHIS Deluxe allows operators interactively to rate pavement conditions based on methodologies defined by the Long-Term Pavement Performance (LTPP) Distress Manual and the PCI approach. Figure 11 illustrates the user interface of MHIS Deluxe.

REFERENCES

1. Wang, K.C.P., "Design and Implementation of Automated Systems for Pavement Surface Distress Survey," ASCE Journal of Infrastructure Systems, Vol.6, No1, March, pp. 24-32, 2000.
2. Federal Aviation Administration, Office of Airport Safety and Standards, "Guidelines and Procedures for Maintenance of Airport Pavements," Advisory Circular AC 150/5380-6A, 2003.