USE OF A DIGITAL SURVEY VEHICLE FOR PAVEMENT CONDITION SURVEYS AT AIRPORTS

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ABSTRACT

Pavement Management Systems (PMS's) are used extensively as a tool to manage airfield pavements. The pavement surface condition survey is a primary component of all PMS's. Traditionally, pavement condition surveys at airports have been conducted using a foot-on-ground (FOG) approach where inspectors walk the pavement area and collect detailed distress data. In contrast, most highway pavement condition surveys are conducted by driving over the paved area; many of these driving surveys are now completed using a digital survey vehicle (DSV). The DSV collects downward facing pavement video, photographs, and other data while traveling at speeds up to 60 miles per hour (100 kilometers per hour).

The DSV offers several advantages over the FOG approach. One of the main advantages for airports is the speed of field data collection which minimizes the disruption to airfield operations. Some have been reluctant to use the DSV for airport condition surveys because of real or perceived limitations of the DSV approach. Airport pavements, especially runways, are significantly wider than roadway lanes thus requiring multiple passes of a DSV to collect data over the full pavement width which can pose challenges in referencing the relative position of each run. Other concerns include detection of pavement defects that pose a risk of foreign object damage (FOD) to aircraft and detection of slight rutting that may not be visible from DSV images.

This paper describes the advantages and disadvantages of DSV and FOG approaches to airport condition surveys as well as special considerations for mitigation of potential problems while using the DSV approach.

INTRODUCTION

Many airports use a Pavement Management System (PMS) to help manage their airfield pavements. Pavement managers use objective pavement condition data to assess the current state of their pavements and to proactively program maintenance and rehabilitation in such a way that benefit is maximized for the limited funds available. The primary input to the PMS is surface condition data. Although the method to be used for condition surveys is not mandated by the Federal Aviation Administration (FAA), their advisory circular AC 150/5380-6B *(1)* recommends that the procedures documented in ASTM D 5340 *(2)* be followed. Essentially, the procedure involves a determination of the type, quantity and severity of surface distresses in the pavement. It is common practice to obtain the pavement condition data by way of a foot-on-ground (FOG) condition survey.

Digital survey vehicles (DSV's) are commonly used by highway agencies to collect pavement condition data, especially for expressways that warrant a high degree of accuracy and speed of data collection (3). However, the use of DSV's and similar technology have not seen widespread use for airport pavement condition surveys due to perceived limitations of the DSV. This paper compares the use of FOG and DSV survey methods, provides advantages and disadvantages of each approach and provides recommendations for appropriate application of the DSV to airport pavements.

DESCRIPTION OF SURVEY METHODS

Conventional Foot on Ground Method

In foot on ground condition surveys, an inspector or team of inspectors walks over the area of pavement to be surveyed and records the type, quantity and severity of distresses in accordance with ASTM D5340*(2)* or a similar procedure. In some cases, measurements may to taken to assist the inspector in differentiating between distress severity levels (for example- a measurement of the width of a crack or the difference in elevation across a faulted concrete pavement joint). In practice, once an inspector gains adequate experience, very few measurements are taken to distinguish between distress severity levels since their subjective ratings are typically accurate. One exception is for depressions that are measured with the aid of a 10-foot (3- meter) straight edge and tape measure since it is not possible to reliably determine the depth of depressions with the human eye (see Figure 1). The quantity, or extent, of distress (length or area) is measured by inspectors with a measuring wheel.

In accordance with ASTM D 5340 *(2)* procedures, the condition evaluation is performed on randomly selected sampled units of pavement to obtain a statistically adequate estimate (95% confidence) of the pavement condition index (PCI). In the FOG approach, the units of pavement to be inspected are determined in advance and only those sample units are inspected (although there is provision for use of "additional sample units" to incorporate areas exhibiting unusual distress). The percent of paved areas inspected depends upon the number of sample units in the pavement management section, but can be as low as 10 percent. A typical survey covers approximately 30 percent of sample units.

Traditionally, the data collected in the field has been recorded on paper forms and subsequently entered into the PMS software in the office. In recent years, hand-held tablets have been used by some inspectors to enter the data in the field which is later electronically uploaded to the PMS software.

FIGURE 1 Measurement of Pavement Depression with 10-Foot Straight Edge.

Semi-Automated Condition Surveys with a Digital Survey Vehicle

In semi-automated surveys, a digital survey vehicle (DSV) is driven over the area to be surveyed and digital data is collected for one-hundred percent of the area of pavement traversed. The digital data usually includes downward facing pavement images, forward and side facing images, and geometric data such as rutting, longitudinal profile (roughness) and cross- slope collected through the use of lasers mounted on the DSV. The pavement images are of sufficient resolution that 1 mm defects are readily visible. The images are geo-referenced using a combination of GPS and inertial navigation systems and linearly referenced with a distance measuring instrument. The width of the images obtained from a DSV is typically 12 to 14 feet. A photograph of a typical DSV depicting its survey systems is shown in Figure 2.

The pavement images collected by the DSV are viewed by trained technicians in the office and a pavement condition assessment is performed in a manner similar to that accomplished with a foot-on-ground approach. The types and severity of each pavement distress are rated by the technician using the same rating system that would be used in the FOG survey. The quantity of each distress may be estimated or the technician may use specialized software to measure the quantity of each distress. If the measuring approach is used, the technician digitizes the limits of each distress visible on the computer screen and the software calculates the quantity (length or area) and stores it as digital data for each pavement management section or sample unit. The distress ratings are then uploaded to the pavement management software for calculation of a pavement condition index (PCI) for each segment and for other analyses done as part of the pavement management process. Figure 3 shows an example of a pavement image.

DSV Survey Systems

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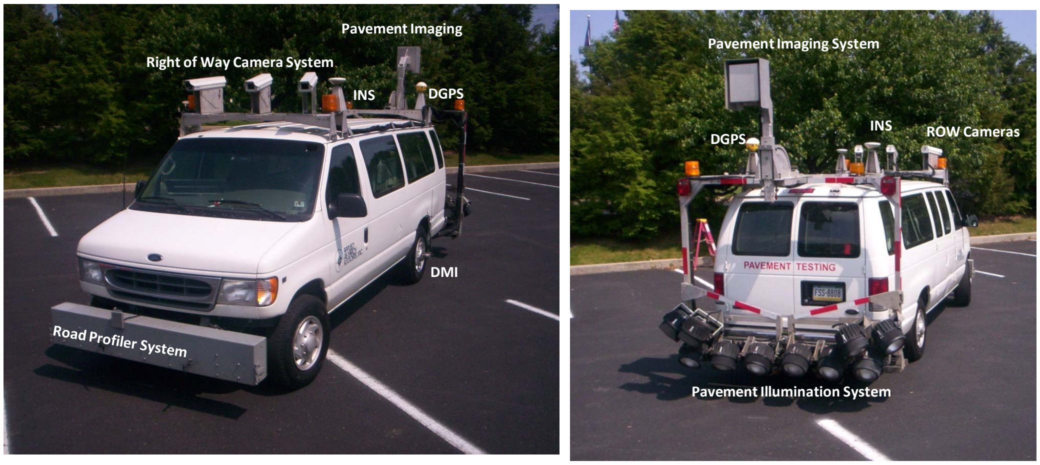

FIGURE 2 Digital Survey Vehicle.

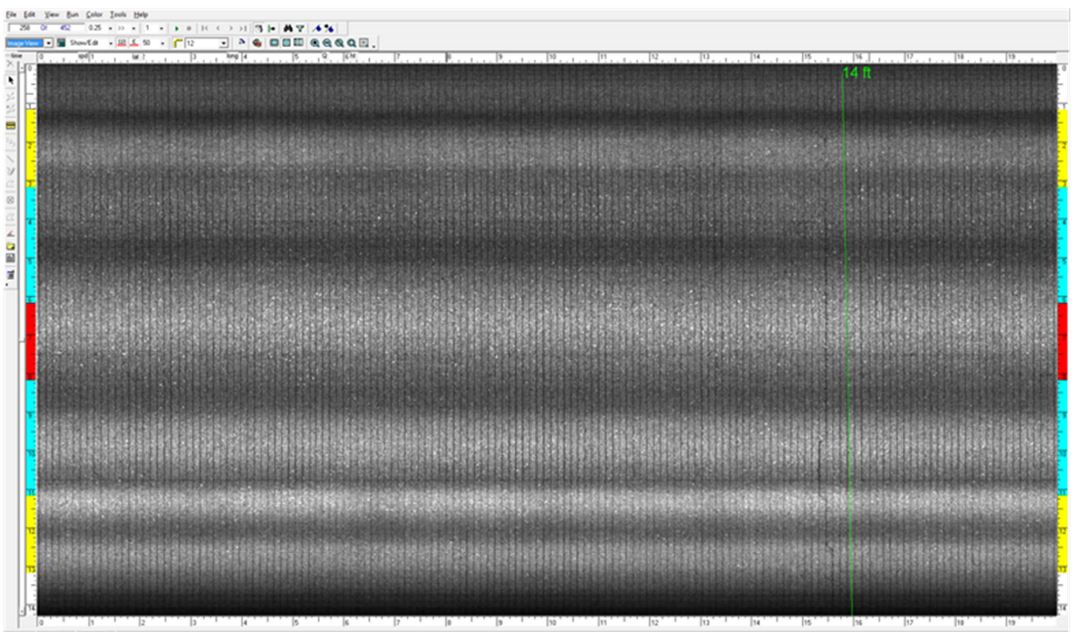

FIGURE 3 Example Digital Pavement Image Depicting Low-Severity Transverse Crack.

ADVANTAGES AND DISADVANTAGES OF FOOT ON GROUND APPROACH

The advantage of the FOG approach is that an inspector can view the pavement surface from close range and may be able to see detail that would not be discernible in a photograph. The inspector also has the option to make measurements if deemed necessary to help determine the severity of distress or to probe the distressed area (for example, a pocket knife or screwdriver could be used to determine if a piece of cracked pavement is loose or not).

The main disadvantage of the FOG approach is the speed at which the survey is conducted. A large airfield may take several days or weeks to survey using the FOG approach. This has a significant effect on airfield operations since the condition survey crew needs to work in an area that is free of aircraft traffic. Another disadvantage of the FOG approach is the limited quality control possible after the survey has been completed. There are typically only the inspector's notes and some limited photographs available for use in checking any questionable results.

ADVANTAGES OF SEMI-AUTOMATED APPROACH

There are several advantages to the DSV approach for airport pavement condition surveys. The first advantage of the DSV, compared to the FOG approach, is the speed at which the survey is conducted. The DSV can collect data at speeds up to 60 miles per hour (100 kilometers per hour). For example, a survey covering 100 percent of the paved area of a typical 5200 foot (1585-meter) long, 150 feet (45-meter) wide runway may be surveyed in as little as two to three hours. A runway at a large commercial airport that may be 200 feet (61 meters) wide and 10,000 feet (3,048 meters) long could be surveyed in 3 to 4 hours, depending upon the data being collected. Additionally, the DSV survey may be done at night since the equipment has on-board lighting. The speed of survey, combined with the option of performing the work at night, significantly reduces the disruption to airfield operations by the survey.

Another advantage of the DSV approach is that pavement images and other geometric data is collected on 100 percent of the pavement area even if only a fraction of the images are rated to obtain the 95 percent confidence level prescribed in ASTM D 5340*(2)*. In the event that questions arise after the survey is complete, images of areas not rated may be retrieved and viewed or rated. If all pavement images are provided in an image viewer module, a "virtual drive through" of any pavement may be done from the office.

If the distresses are digitized on the pavement images, detailed distress maps may be produced from the digital data. Detailed distress maps are not typically required for network level pavement management surveys but are often useful for more detailed project level evaluations of pavement areas that are planned for repair or rehabilitation. These detailed distressed maps are very useful for evaluating crack patterns as part of forensic evaluations and/or to delineate areas for repair that are then depicted on contract drawings.

DISADVANTAGES OF SEMI-AUTOMATED APPROACH

There are some disadvantages to using a DSV compared to a FOG approach, although some of these are perceived problems that may be overcome with proper techniques. The fundamental difference between the DSV and FOG approaches is that the DSV approach relies on visual observation of high resolution images which do not always provide the same degree of clarity as would an inspector standing on the pavement. The majority of pavement surface defects may be rated with acceptable accuracy using digital images from a DSV. However, in the case of asphaltic concrete pavements, raveling of the pavement surface and distortions such as depressions or rutting are more difficult to discern from digital images than from a FOG survey.

Raveling is defined in ASTM D 5340 *(2)* as wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. The severity level of this distress is estimated by the degree to which the pavement surface appears to be rough or pitted. Although the determination of severity by an inspector performing a FOG survey is subjective, it is not reliably detected by an inspector viewing a digital image of the pavement. Medium and high severity raveling is a concern on airports due to its potential to produce foreign object damage (FOD) to aircraft engines that could ingest loose particles from the raveled pavement.

Rutting and depressions in the pavement surface are evaluated in FOG surveys by a combination of visual perception of the distress being present and physical measurements made with a 10-foot (3-meter) straight edge to determine the depth of the distortion. One perceived disadvantage of the DSV approach is that rutting and depressions are not all captured using the conventional longitudinal runs of a DSV with a 5- sensor rut bar. As noted above, longitudinal depressions are captured using the DSV's laser system. However, rutting requires more detailed data in the transverse direction than the 5- sensor rut bar provides.

In addition to the concerns relating to the ability to detect the distress types noted above, there are two practical concerns that must be addressed if a DSV approach is used on an airfield. First, airfield pavements are much wider than highway lanes and more than one pass of the DSV is required to cover the surface of a runway, taxiway or apron. Consequently, an inspector must view pavement images from more than one run of the DSV to cover the width of a typical sample unit which may create challenges if the images locations are not referenced carefully. Finally, a DSV survey is not able to produce pavement images beneath aircraft parked on aprons, whereas an inspector performing a FOG survey is usually able to see beneath such aircraft and can complete an inspection of these areas.

RECOMMENDED PROCEDURE TO MITIGATE POTENTIAL LIMITATIONS OR DISADVANTAGES OF DSV APPROACH

Assessment of Pavement Raveling and FOD Potential

Use of a DSV's laser profiling system can actually improve the assessment of pavement raveling and FOD potential. A DSV is equipped with a series of bumper mounted lasers that measure the distance between the vehicle bumper and the pavement surface. The bounce of the vehicle's bumper is measured by accelerometers and this movement is removed from the distance measurements resulting in a detailed profile of the pavement surface directly beneath the laser. One of the outputs provided by the laser system is a "mean pavement texture depth" which is an average of the distance between high and low points on the pavement surface as measured by the laser system. This parameter provides an excellent quantitative measurement of raveling for most asphaltic concrete pavement surface courses. The mean texture depth may be equated to low, medium, and high severity levels as defined in ASTM D 5340*(2)*. It should be noted that this technique is not well suited to open graded surface courses, however such surface courses are not common on airports.

Assessment of Pavement Distortions

Although it is difficult to detect low and medium-severity rutting and depressions from DSV generated images, it is possible to use the laser systems on the DSV to provide a measurement of these distresses. As noted above, most DSV's are equipped with a laser profiling system that provides a profile of the pavement surface. One common profiling system uses a 5 sensor rut bar. Ruts and depressions may or may not be detected with such a profiler. Ruts and depressions outside of the path of the DSV's five lasers would not be detected. However, DSV's equipped with a laser rut measuring system (LRMS) utilize two line lasers that produce a continuous transverse profile each time the laser pulses are activated. Typically, the DSV can maintain its 60 mile per hour (100 kilometers per hour) survey speed while obtaining such transverse profiles at 50-foot (15-meter) intervals. These transverse profiles may be processed to identify pavement rutting in each sample unit.

Surveying Around Parked Aircraft on Aprons

The DSV can be used to survey apron areas if the survey is not a 100 percent area survey. The DSV can maneuver around parked aircraft and the DSV's GPS data can be used to keep track of the area covered. However, if the clear space available to the DSV is not adequate to allow coverage of the required percentage of sample units, some additional FOG survey may be needed to achieve the required coverage.

Referencing Multiple DSV Runs

As noted previously, the ASTM D5340 *(2)* procedure involves quantifying pavement distresses within selected sample units. For runways comprised of asphaltic concrete (AC) pavement, sample units are typically 50 feet wide. For taxiways, sample units are typically up to 75 feet (23 meters) wide. Since the width of images obtained from a single pass of the DSV are approximately 12 to 14 feet (3.6 to 4.3 meters), it is necessary to fit together images from four or more different runs in order to perform the condition assessment. For Portland cement concrete (PCC) pavements, distresses are quantified within each individual slab then accumulated over the area of the sample unit. Depending on the thickness of the PCC pavement, slab widths are typically 20 to 25 feet (6.0 to 7.6 meters) wide. Two passes of a DSV would be required to cover the width of these slabs.

Custom software is used by the technician to view and rate the downward pavement images and the pavement distresses contained therein. Multiple pavement images can be opened simultaneously to allow the technician to view the images from multiple passes. It is important to synchronize the linear referencing between all the passes made over the runway or taxiway so the technician knows where the images being rated are located. This can be accomplished by resetting the survey referencing system at a known location and/or through use of the vehicle's GPS data which is linked to each image and the sensor data.

SUMMARY AND CONCLUSIONS

Foot on ground (FOG) surveys have been traditionally used to collect pavement distress data required for airport pavement management systems. Digital Survey Vehicles (DSV's) have been used routinely for roadway pavement condition surveys. The DSV approach provides several benefits compared to the FOG approach including the speed of the survey (up to 100 km/hour) that greatly limits the disruption of airport operations during the survey. Some engineers have been reluctant to use the DSV for airport pavement condition surveys due to real and/or perceived limitations. Techniques have been presented that address these limitations.

Raveling of the pavement surface that can lead to FOD may be quantified using the DSV's laser system to determine mean texture depth which can then be converted to a raveling severity for use in the calculation of a pavement condition index. This approach provides a more accurate, quantitative assessment of raveling compared to the FOG approach which is more subjective.

Rutting and depressions may be rated using a DSV. A basic 5-sensor rut bar may miss distortions in the pavement outside of the wheel paths of the DSV, however, use of a laser rut measurement system (LRMS) provides a means to capture distortions and to quantify the severity and extent of such distresses.

Condition ratings for 50-foot wide sample units may be accomplished by viewing 12.5-foot (3.8 meter) wide DSV generated images from successive passes of the DSV. It is important that the starting point for each DSV run is precisely referenced in order for the image locations from adjacent runs to properly identified.

Engineers responsible for pavement condition surveys at busy commercial airports are encouraged to use the DSV approach in order to obtain quantitative data on pavement distresses and to limit disruption to airport operations. The techniques described in this paper have been successfully used at large hub airports, such as LaGuardia Airport in New York City, and at regional and general aviation airports such as those in Knoxville, Tennessee.

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