Adapting an Automated Data Collection Device for Use at an Airport

MARGARET BROTEN, GEORGE SCHWANDT, AND RUDY BLANCO

O'Hare International Airport, in Chicago, Illinois, is one of the busiest and largest airports in the world. It is critically important to maintain all the O'Hare airside and landside pavements in operational and safe condition. Accurate and current distress data are needed to document the present condition of the pavement, to determine maintenance and rehabilitation needs, and to form the basis of a pavement management system. However, it is very difficult to collect pavement condition information safely and accurately in this extremely congested environment. A demonstration project was conducted on one runway and one parallel taxiway to determine the feasibility of using automated data collection equipment for distress data collection. The demonstration project was successful, and a full-scale data collection effort was undertaken to film the remaining runways and parallel taxiways. This approach allowed the data to be collected between 11:00 p.m. and 5:00 a.m. In addition, data collection was fast and efficient. Modifications to the procedures and equipment used to collect distress information on roads had to be made to use this equipment successfully on airfield pavements. A method for maintaining a straight pass down the runway had to be devised. A lighting system had to be developed because the data collection occurred during the nighttime hours. Finally, data interpretation was modified to obtain an acceptable estimate of a pavement condition index.

O'Hare International Airport is one of the busiest facilities in the world, and it provides a critical link in the United States' air transportation system. Figure 1 shows the layout of the airside pavements at O'Hare. It is very important to keep the pavements at this airport in safe and operational condition. In addition, because any pavement closure is extremely costly, it is important to apply timely maintenance and rehabilitation to the pavements to reduce any required closures.

Accurate and current distress information is needed to effectively manage the pavements at O'Hare International Airport. Distress data are used to document current condition, to identify maintenance and rehabilitation needs, to estimate repair quantities, and to provide the basis for a pavement management system (PMS). However, it is difficult to collect pavement distress data safely and efficiently, without disrupting operations, at a facility like O'Hare.

Because of heavy traffic conditions during the daytime hours at O'Hare, the only available time for distress data collection on the runways and taxiways is between 11:00 p.m. and 5:00 a.m. It was estimated that it would take several months to manually collect distress data on all the runways and taxiways under these conditions, which would be a hardship on the operations staff at O'Hare and would be a difficult task for a survey crew.

This situation led to the conduct of the demonstration project and full-scale implementation project discussed in this paper. The city of Chicago contracted with ERES Consultants, Inc. (ERES), to conduct a pavement evaluation of all airside and landside pavements at O'Hare and to implement a PMS for O'Hare. An automated data collection device was evaluated for its feasibility to collect distress data on runways and taxiways at O'Hare during a demonstration project. The successful completion of this demonstration project led to the evaluation of all runways and parallel taxiways at O'Hare using this equipment.

M. Broten, ERES Consultants, Inc., 439 Edgewood Drive, Ambler, Pa. 19002. G. Schwandt, City of Chicago, 20 North Clark, Suite 2900, Chicago, Ill. 60602. R. Blanco, PaveTech, Inc., P.O. Box 639, Norman, Okla. 73070.

DEMONSTRATION PROJECT

A PaveTech video inspection vehicle (VIV) was used to collect distress data on a runway and its parallel taxiway for the purpose of evaluating the feasibility of using this type of equipment at O'Hare. There are several other automated data collection devices on the market today. However, it was determined that this equipment best fit O'Hare's requirements when the contract was signed.

Pavement Condition Index Procedure

Pavement management decisions are dependent on some method of evaluating pavement condition to document current pavement condition, predict future performance, priority rank needs, and determine required repair levels. The pavement condition index (PCI) procedure, outlined in the FAA's advisory circular (AC) 150/5380-6, entitled *Guidelines and Procedures for Maintenance of Airport Pavements*, is the standard used by the aviation industry to assess current pavement condition (*1*). The PCI, developed by the U.S. Army Corps of Engineers, is a numerical rating ranging from 0 to 100, with 100 being a pavement in new condition. The PCI provides an objective and repeatable indication of the condition of the pavement. A manual is used to identify individual distress types in asphalt and concrete pavements and to guide the determination of severity level and quantity of each distress present.

The first step in the procedure is to divide the airport pavements into branches, features (sections), and sample units. A branch is defined as an entity that serves a single function, such as a runway, a taxiway, or an apron. Sections are a portion of the branch with consistent characteristics throughout their entire area or length. The area within a section should have been constructed at the same time, should receive approximately the same type and level of traffic, should have received the same type of rehabilitation and maintenance throughout the years since original construction, and should be a size that can be economically managed as a single entity. An example of a runway at O'Hare, which has been broken into sections, is shown in Figure 2.

Sections are further subdivided into sample units for the purpose of inspection. Guidelines have been established for determining the appropriate size of sample units. As defined in FAA AC 150/5380-6, sample units for asphalt-surfaced pavements are approximately 5,000 ft^2 (1,524 m^2), and sample units for concrete pavements are approximately 20 slabs. Figure 3 illustrates runway sections that have been subdivided into sample units.

Once the network definition has been completed, the PCI inspection can be conducted. The measured data for distress type, severity, and quantity are used to calculate a composite index, the PCI. The procedure to perform this calculation is outlined in the FAA AC and is shown in Figure 4.

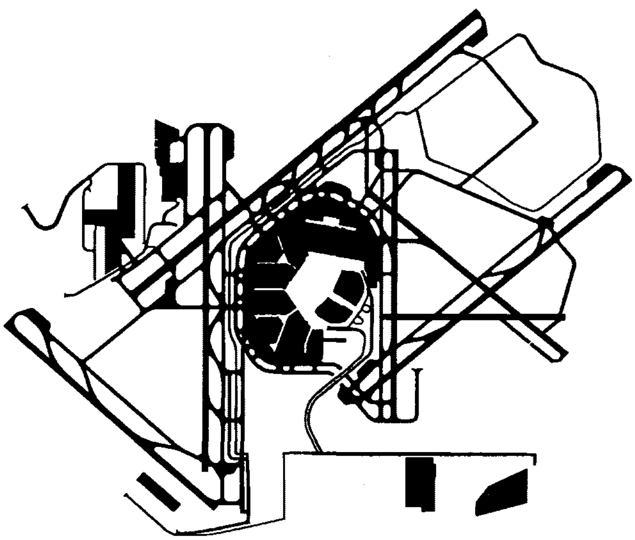


FIGURE 1 O'Hare International Airport layout map.

Equipment Description

The VIV uses video cameras to collect super-VHS video images of 100 percent of the pavement surface. The high-detail resolution video distress images were used for distress identification. Pavement profile, roughness, rutting, faulting, and texture information are collected automatically by the equipment.

The pavement profile is collected using a South Dakota–type profiler that operates using the inertial reference concept. As the vehicle travels along the pavement, an accelerometer mounted on the vehicle senses acceleration forces and generates an electrical signal proportional to the vehicle's vertical accelerations. The signal is filtered, digitized numerically, and doubly integrated to calculate the vehicle's up-and-down movement and to establish the position of the vehicle as a function of time. A distance-measuring sensor, in this case an ultrasonic transducer, measures the distance between the accelerometer and the pavement surface by emitting a short burst of high-frequency sound toward the pavement surface. The sound waves strike the roadway, reflect upward,

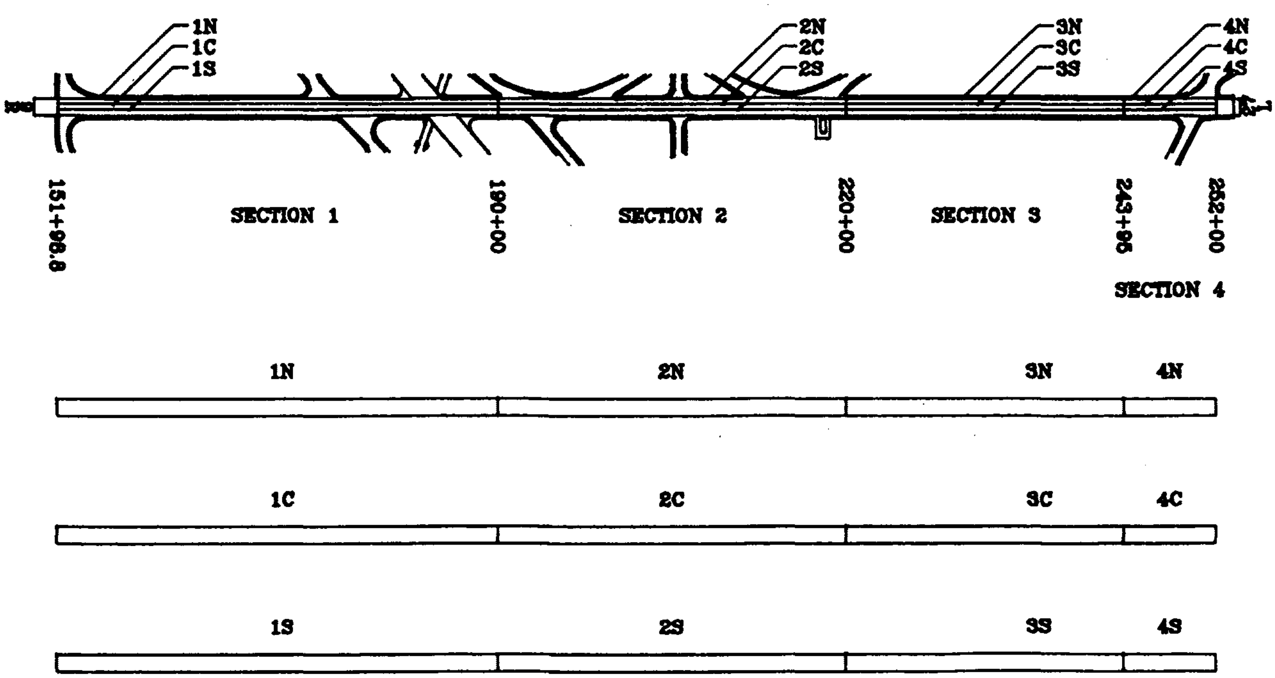


FIGURE 2 Example of section identification map.

and are detected by the same transducer. The time between the sound generation and echo detection is proportional to the distance to the roadway surface. The roadway profile is then computed as the difference between displacement and the distance between the vehicle and the road surface.

Rutting is measured using the results from five ultrasonic transducers mounted in the vehicle bumper. They are collinear and equidistant from each other. At every foot these sensors measure the distance to the pavement surface.

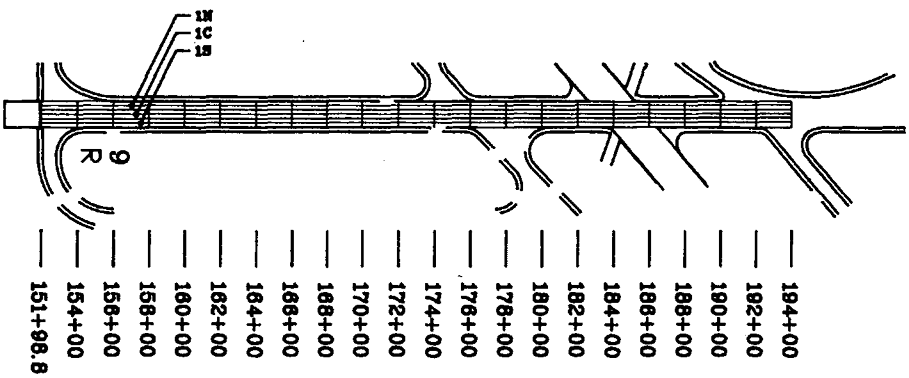
The automatic faulting measurement device uses two sensors that measure the distance from the moving vehicle to the ground. The sensors are triggered simultaneously to eliminate any negative impact on the readings as a result of the up-and-down movement of the vehicle. The sensors are located one behind the other close to the center of the vehicle to minimize any impact of the pitch movement of the vehicle. Once the sensors are simultaneously triggered, a computer reads the distance from the vehicle to the ground for each sensor. The computer compares these readings and calculates the difference between each sensor. The differences are then stored in the computer. The differences in height along the pavement become the raw data used to calculate faulting measurements at concrete slab joints.

Preparation and Conduct of Demonstration Project

The automated equipment was originally developed to collect road condition data. It was designed to collect information during daylight, and a single pass of the equipment videotapes a width up to 13.8 ft (4.2 m). For use on the airside pavements at O'Hare, the equipment had to be adapted to operate under nighttime conditions on facilities that were up to 200 ft (61 m) wide.

A lighting system was added to allow data collection during nighttime for this airport application. The lighting system consisted of a modified trailer that rides behind the VIV and provided the lighting needed for the back distress cameras. The trailer contained a gasoline-powered generator, the lights, and an extendible and retractable modified "goose neck tongue." The goose neck was modified to prevent it from being videotaped.

Because of the width limitations of the filming equipment, the sample unit layouts were different from what they would have been for a manual inspection. Using conventional methods, a section that was 50 ft (15 m) wide would have sample units with dimensions of 50 ft (15 m) wide by 100 ft (30 m) long. However, because the equipment was set to videotape



1N

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42

1C

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42

1S

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42

FIGURE 3 Example of sample unit identification map.

passes 12.5 ft (3.8 m) wide, this type of layout would have been inconvenient. Instead, sample units on asphalt-surfaced pavements were 12.5 ft (3.8 m) wide by 400 ft (122 m) long, which allowed a single video pass to be viewed to inspect a sample unit. Sample units for concrete pavements were 1 slab wide by 20 slabs long. Two filming passes had to be combined to inspect a concrete sample unit.

There was concern that at night it would be difficult to maintain a straight pass down the length of the runway. It is important to maintain a straight pass, because 7 to 12 (depending on the width of the facility) longitudinal passes are needed to provide complete coverage. The runway and parallel taxiway that O'Hare Operations identified as the most convenient for the demonstration project were painted at 200-ft (60-m) intervals. Each filming lane was marked, and the paint marks were staggered so that the effective spacing was 100 ft (30 m). These paint marks were to be used by the vehicle driver to maintain a straight line as each lane was filmed.

In addition, sample units were identified; these were to be inspected manually for the purposes of comparing the manual results with the videotape results. Unfortunately, because of the unforeseen scheduling of a rubber removal project on the demonstration runway, the marked runway and taxiway were not available to the crews during the scheduled demonstration period. The operations staff was able to obtain closure for the crews on a different runway and parallel taxiway. However, these facilities were not premarked in any way.

Because of the change in schedule, the first night of filming was a test run. The driver attempted to maintain straight passes visually. The parallel taxiway was filmed, and a few passes on the runway were made. A review of this film revealed that not all the passes were straight, and in addition, light rainfall had resulted in glare occurring on the film.

The crew was adaptable and devised an alternative way of maintaining straight passes. They set up traffic cones before filming to aid the driver. Orange cones with reflective tape were used to mark the lanes. One cone approximately every 200 ft (60 m) proved to be sufficient to guide the driver. This approach worked so well that is was adapted for the full-scale implementation later.

The use of cones was much more cost-effective than prepainting the facilities. Painting the originally identified demonstration runway and taxiway took a crew of three people

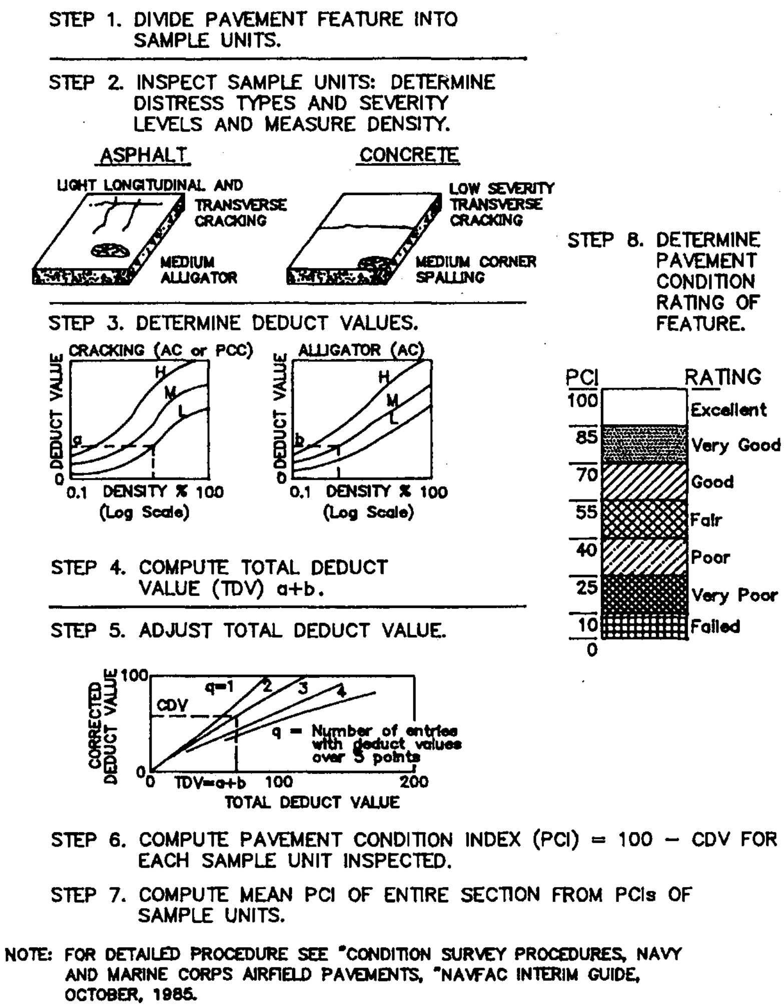


FIGURE 4 PCI procedure.

four nights (6 hr available per night) to complete. Setting up the cones took less than 1 hr each night, and picking up the cones took about ¼ hr. In one night, the parallel taxiway was refilmed, and the runway was filmed.

While one crew was filming the runway and taxiway, another crew was manually inspecting selected sample units for later comparison with film inspections. Unfortunately, there was some difficulty with the lighting equipment, and because of the last-minute change in the available runway and taxiway, the sample units were not premarked on the pavement. This made later comparisons difficult and not as reliable as planned.

Interpretation of Demonstration Project Film

The distress data were collected automatically using videotape; however, the distress identification process was conducted manually. This approach was selected because complete control of the data evaluation process was desired. The videotape was reviewed manually, with the aid of a computerized workstation.

The runway and taxiway films were reviewed by the same person who manually inspected the sample units during the demonstration project. The use of the same person allowed a direct comparison to be made between the automated and manual condition evaluation results because a subjective element exists in the rating of distress severity levels.

The operation of the workstation used to review the videotapes is not difficult. It is harder to review videotapes collected during the night because the cameras that normally collect perspective information are not operational. It is not possible to provide sufficient lighting to these cameras. Thus, other than the distance measurement that is provided for each frame of film, there is no other easy way to determine exactly where the pavement is located that the technician is reviewing, which can be disorienting for the inspector. Under daylight conditions, the technician would use the perspective views to locate landmarks such as intersections and signs.

For the results to be useful for an airport application, it was determined that some alterations had to be made to the method in which the videotape is reviewed for road projects. Changes had to be made to accommodate concrete slabs 25 ft (7.6 m) wide. Also, incorporation of the automatic faulting and rutting measurements had to be made. Finally, recommendations for future videotaping were made on the basis of the film reduction process. Each of these items is discussed below.

Portland Cement Concrete Slab Review

The PCI procedure for portland cement concrete slabs requires that approximately 20 slabs per sample unit be inspected. The slabs on the runway and taxiway evaluated during the demonstration project have dimensions of 25 × 25 ft (7.6 × 7.6 m). However, the automated equipment provides a width coverage of 12.5 ft (3.8 m), which results in only one-half of a slab being filmed in one pass. To perform a PCI in accordance with the FAA guidelines, it is necessary to evaluate an entire slab, not just a portion of a slab. A procedure was developed for merging the distress data identified by the technician on the two consecutive film passes. The distress data are then filtered to eliminate any duplicate distress calls created by merging the results of two film passes.

Incorporation of Faulting and Rutting Measurements into Distress Review

Faulting and rutting measurements are gathered automatically by the VIV. This information must be merged with the distress data at the sample unit level. A method is used whereby the faulting and rutting can be identified at the sample unit level through the use of the distance measurements collected on each pass. The distress data and rutting and faulting measurements are then manually combined for each sample unit.

Recommendations for Full-Scale Implementation

A review of the film showed that in some situations the slab joints were not captured on film. This has serious ramifications on the PCI calculations because slab edges often are where the majority of distress occurs. For the full-scale implementation to be successful, corrections needed to be made in the data collection process to ensure that full slab coverage was achieved during videotaping.

The determination of distress severity was not difficult in most situations. However, it was felt that it would be beneficial to incorporate a way to determine actual crack width. A template was developed for the full-scale implementation that was spray painted onto each of the facilities evaluated. This template showed lines of ¼, ½, ¾, and 1 in. (0.64, 1.27, 1.91, and 2.54 cm) thick. In that way, the person evaluating the film can "calibrate" his or her eye with respect to crack thickness.

Because of the filming width constraint of 12.5 ft (3.8 m), it was determined that the videotaping process was not efficient for collecting distress data on parking lots, aprons, or short connectors with significant fillets. In these situations, it is difficult to accurately track the exact location of each piece of film and to merge the results of the film reduction later into a condition index. A manual survey was recommended and utilized for these sections.

Comparison of Manual Inspections with Video Inspections

As discussed previously, an attempt was made to inspect selected sample units during the demonstration project both manually and through video interpretation. The purpose of this evaluation was to determine the feasibility of using automated data collection, followed by manual distress identification using the videotape, to obtain a reasonable estimate of a PCI. Because of the unforeseen change in the project runway and taxiway, the locations of the sample units were not premarked. In some cases, the filming of an area took place after the crew had manually marked and inspected a sample unit. The locations of these sample units showed up on the film, and a comparison was relatively simple. However, some areas were filmed before the manual survey crew conducted their inspection, and it was not always possible to locate the exact area on film that was manually surveyed.

The problems encountered during this test limit the statistical significance of the results. However, it was possible to draw some general conclusions from the data. Overall, the major disadvantage of performing a PCI survey by reviewing videotapes is the lack of three-dimensional depth perception provided by the tapes. During a manual survey, the depth perception helps an inspector identify the severity of several distresses, including joint seal damage and weathering and raveling. The automated data collection procedure was more time consuming in the data interpretation steps but required far less field time. The major disadvantage of using manual inspection is the fact that distresses can be missed, particularly when conducted under inadequate lighting conditions or during distracting aircraft activity. In addition, no permanent record of pavement condition is collected during a manual survey, as it is with the automated equipment.

Success of Demonstration Project

The results of the demonstration project were presented to the city of Chicago. In addition, city officials were shown the collected film from the demonstration project. City officials were very satisfied with the data collected and believed that the data more than met their needs. The alternative, which involved manually collecting the distress data, was not considered to be viable because of the conditions under which the inspection would have to be conducted. It was felt that although the measurement of certain distress types, such as low-severity weathering and raveling, was difficult using videotape, the benefits of the system offset the disadvantages. Members of the maintenance department were extremely pleased that they could obtain accurate measurements of total crack length, rather than having to rely on the extrapolation of inspected sample unit distresses to the section level. In addition, a permanent record of the pavement surface has the potential to provide more useful information than just distress data. For example, the maintenance department staff expressed an interest in using the film to calculate the area of paint striping on each facility. The engineering staff anticipates that the videotapes will be useful during communications with consultants, upper management, and maintenance personnel. The videotapes will make it much easier to locate distresses and effectively demonstrate the need for maintenance and rehabilitation work.

FULL-SCALE IMPLEMENTATION

A full-scale implementation was conducted at O'Hare International Airport June 22 through June 30, 1992. The automated equipment was used to videotape the remaining runways and parallel taxiways. Manual field crews collected distress information on the aprons, short connector taxiways, and the parking lots.

Conduct of Project

On nights when there were no traffic delays or equipment malfunctions, on the average the crew videotaped one runway and one parallel taxiway. The coning system devised during the demonstration project continued to work very well, and the lighting system developed for this nighttime application operated perfectly. The weather was excellent throughout the project and did not create any delays. However, because a film of water on the pavement surface results in a glare from the lights on the videotape, if rain had occurred, videotaping would have been halted.

Coordination with the operation's personnel worked smoothly. If a facility to be filmed was closed and did not cross any other active facilities, the crew was escorted to one end of that facility. The crew was then allowed to conduct the filming passes, while keeping alert for any unexpected traffic. In situations in which the crew was required to cross active facilities, an airport escort in a vehicle obtained clearance for the crew when needed. The filming was completed without incident.

Interpretation of Film

A computerized workstation for analyzing the videotapes was installed in the ERES office, and PaveTech personnel provided a training course in its use. The engineering technicians and project engineers who have the responsibility of conducting manual PCI surveys for the firm were assigned to the workstation. A high level of quality control was desired throughout the data reduction process, and a quality-assurance plan was implemented for the data interpretation process. Sample units that had already been processed were selected at random for reinspection. In addition, no technician was required to spend more than 3 consecutive hr at the workstation because it was found that fatigue is a factor if more time than that is spent reviewing the film.

USES OF COLLECTED DATA

The collected pavement condition data are being used to document current pavement conditions; identify maintenance and rehabilitation needs; estimate repair quantities and costs; and form the basis of a state-of-the-art PMS. Each of these items is discussed briefly in the following sections.

Documentation of Current Conditions

Distress data were evaluated using the videotapes in accordance with FAA AC 150/5380-6. The distress types and severities were identified by the engineering technician reviewing the film. A computer system was used to determine the starting and end point of each distress, length, area, and the location of each distress on the filming pass. The system was also used to record the pavement distress data at the sample unit level.

The distress data were then loaded into a computerized PMS. The program automatically determines the sample unit and section PCIs for each facility. These data then form the heart of the computerized PMS.

Estimation of Repair Quantities and Costs

The city of Chicago now possesses videotapes that cover 100 percent of the runways and parallel taxiways at O'Hare. The videotapes can be analyzed to obtain accurate crack counts or any other maintenance measurement that may be required. Combined with cost information, these data can then be used to develop cost estimates.

Basis for PMS

The distress data collected were entered into a PMS developed by ERES. This system has been linked to a computerized map of O'Hare to facilitate data retrieval. The implemented PMS allows the city of Chicago to manage the pavements at O'Hare International easily and rapidly. It contains advanced budgeting and planning software that the city has found to be extremely useful.

CONCLUSION

The objective of this paper was to discuss the adaptation of an automated distress data collection device to the airport environment. A demonstration project, followed by a full-scale implementation, at O'Hare International Airport was presented. The automated data collection approach was selected by the city of Chicago to minimize interference with aircraft operations at the airport while pavement management data were obtained. The videotaping was conducted at night so that peak traffic flow interruption at this extremely busy airport was eliminated.

Several modifications to the equipment and procedures normally used for roadway data collection had to be made. During a typical road condition inventory, the equipment is operated during the day, and the coverage of 13.8 ft (4.2 m) wide is more than sufficient to film a lane. The data collection at O'Hare International Airport was performed at night on facilities that are up to 200 ft (61 m) wide. The modifications necessary for an airport application were made and then tested during a successful demonstration project.

The videotapes were interpreted manually to estimate PCI values, which were entered into a customized PMS. The distress data were determined to be acceptable by the city. Certain distress types, such as joint sealant damage and low-severity weathering and raveling, were difficult to identify because of the two-dimensional nature of the videotape. However, it was felt that adequate interpretation of the data was possible and that the advantages outweighed any disadvantages. The videotapes provide the city with physical documentation of pavement conditions to supplement their PMS, and the information has already proven very useful for the city.

REFERENCE

1. *Guidelines and Procedures for Maintenance of Airport Pavements.* Advisory Circular 150/5390-6. FAA, U.S. Department of Transportation, 1982.

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