Airfield Pavement Evaluation and Management at Dulles International Airport

STANLEY M. HERRIN, MICHAEL I. DARTER, ERNEST J. BARENBERG, and M. Y. SHAHIN

ABSTRACT

The pavements at Dulles International Airport were the subject of a comprehensive pavement management study. The study consisted of data collection, pavement evaluation, and long-term pavement rehabilitation development. Data collection included detailed visual surveys, nondestructive testing, and materials characterization. The existing condition of the pavements was evaluated to determine the cause of the deterioration and to predict future condition and end of service life. A cost-effective rehabilitation program was established to maintain the pavements in acceptable condition for safe aircraft operations.

All major airfield pavement elements at Dulles International Airport were the subject of a comprehensive evaluation study. The objectives of the study were to (a) update a previous 1978 pavement evaluation (1), (b) establish the rate of deterioration and predict the remaining service life of the airfield pavements, and (c) formulate a pavement rehabilitation and maintenance program including an estimated timetable and cost estimate.

The evaluation study was composed of two phases--a 1982 airfield pavement evaluation (2) and a 1984 airfield pavement evaluation (3). The overall evaluation study consisted of data collection, pavement evaluation, and long-term pavement management. The 1982 airfield pavement evaluation was the more thorough of the two evaluations. The purpose of the 1984 evaluation was to provide data to validate or adjust the 1982 evaluation. A previous evaluation of the Dulles International Airport pavements was performed in 1978. Data from that evaluation were incorporated into this evaluation study.

Essentially all of the pavements at Dulles International Airport were constructed at the same time by the same contractor with the same design detail and materials. Nevertheless, various pavements on the airfield have deteriorated at different rates. By establishing a comprehensive record of pavement conditions in 1978, and adding the data from the 1982 and 1984 evaluations, causes for these varying rates were uniquely determined. This paper presents the evaluation process, the conclusions of the evaluation, and how those conclusions were used to formulate the pavement rehabilitation program, and the long-term pavement management program.

SCOPE OF WORK

All the airfield pavements at Dulles Airport were surveyed. The most heavily trafficked pavements were subjected to a detailed survey consisting of detailed visual surveys and nondestructive testing (NDT) as shown in Figure 1. The remaining pavements were given a visual cursory survey to determine if major distress was observed. The pavements of the detailed survey are the subject of this paper.

The 1982 airfield pavement evaluation consisted of (a) a record review, (b) visual surveys using the Pavement Condition Index (PCI) over the entire pavement network, (c) NDT using the WES 16-kip vibrator (developed at the U.S. Army Corps of Engineers' Waterways Experiment Station) and the Falling Weight Deflectometer (FWD), (d) a detailed traffic analysis to determine traffic patterns as well as historic and future traffic volumes, and (e) pavement life predictions. From this evaluation, five rehabilita-

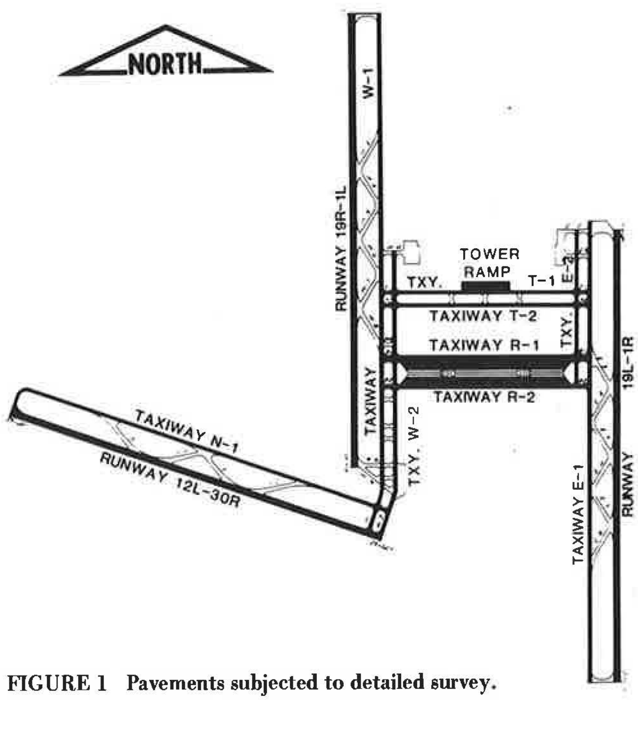

FIGURE 1 Pavements subjected to detailed survey.

S.M. Herrin, Crawford, Murphy, and Tilly, Inc., 2750 West Washington Street, Springfield, Ill. 62702. M.I. Darter and E.J. Barenberg, Department of Civil Engineering, University of Illinois, Champaign, Ill. 61801. Current address for M.I. Darter: ERES Consultants, Inc., Champaign, Ill. 61820. M.Y. Shahin, 37 Maple Court, Champaign, Ill. 61820.

tion programs were developed as feasible methods for future pavement management.

The 1984 airfield pavement evaluation was an abridged version of the 1982 evaluation. PCI visual surveys were only conducted on approximately one-third of the pavement; the amount of NDT, using the WES 16-kip vibrator only, was reduced by one-half, and traffic analysis was limited to revising future traffic projections. The pavement life predictions were examined to see the impact of the new data. One of the five rehabilitation alternatives was developed into a recommended program. The 1978 airfield pavement evaluation had consisted of cataloging of the pavement distress; NDT using the WES 16-kip vibrator and Dynaflect; a detailed traffic analysis; destructive testing consisting of coring, material sampling, and material testing; and pavement life predictions. An overall rehabilitation program was also proposed.

RECORD REVIEW

The first stage of data collection was to obtain all known information on the pavements. From as-built drawings, conversations with the airport engineering staff, and the 1978 pavement evaluation, information was obtained regarding typical pavement sections, thicknesses, panel sizes, subsurface information, material properties, pavement maintenance, and skid resistance.

Construction of Dulles International Airport was begun in 1958. The airport was opened to traffic in 1962. Since then, the only major improvement to the airfield pavement was expansion of the jet ramp in 1976. None of the pavements has been reconstructed. The pavements subjected to traffic consist of plain 15-in. portland cement concrete (PCC) on 9 in. of crushed stone with a typical panel size of 20 by 25 ft. The outer 50 ft of the runways taper to 12-in. PCC pavement. The runway joints are typical of airport construction. The first longitudinal construction joint from the edge of pavement is keyed with bars. All other longitudinal joints are keyed. Only the transverse contraction joints located within the first 600 ft of the runway have dowel bars. The taxiway joints consist of doweled transverse joints and keyed longitudinal joints with tie bars. The tower ramp consists of 9 in. of PCC pavement on 4 in. of crushed stone. Material properties were evaluated during the 1978 pavement evaluation. (Note that material properties are discussed elsewhere in this paper.)

Past maintenance activity has included full-depth slab replacement, slab jacking of settled pavement, shoulder repair, partial depth spall repair, and crack and joint sealing. Maintenance personnel at Dulles perform all maintenance that is not labor-intensive. This includes some full-depth pavement repair, all partial depth repair, and most crack sealing programs. (The annual number of man-hours spent working on maintenance is equivalent to the number of hours worked by two full-time employees.) The runways were grooved in 1979. The skid resistance of the runways has been tested since 1981 with the MU-Meter. Friction data have been used to monitor rubber build-up.

VISUAL SURVEYS

Visual surveys consisted of Pavement Condition Index (PCI) surveys, crack surveys, and cursory surveys.

PCI surveys consist of identifying the type, location, and severity of pavement distress in conformance with the procedure outlined in Federal Aviation Administration (FAA) Advisory Circular 150/5380-6 (4). The procedure assumes that new pavements have a PCI of 100. Deduct values are assigned to each observed distress, then added together and subtracted from 100 to determine the PCI value, indicating the condition of the pavement.

The amount of structural cracking in each feature was obtained by counting each slab that was cracked (longitudinal, diagonal, transverse, or shattered) or had previously been replaced. It was assumed that panels were replaced because of severe cracking. This information was recorded while conducting the PCI survey. If the sample unit was not subjected to a PCI survey, it was surveyed for cracked panels. In addition, sample units not subject to the PCI survey were cursorily examined to verify that they were representative of the pavement feature's PCI. Pavements not subjected to frequent aircraft loadings and heavy traffic were cursorily inspected to determine if any major problems existed.

The 1982 visual survey consisted of a 100 percent PCI survey of the heavily trafficked pavements and a cursory survey of all other pavements. All sample units were subject to a PCI survey. The detailed visual survey included a total of 1,073 sample units with PCI values that varied from a low of 0 to a high of 98.

The 1984 visual survey consisted of a statistical PCI survey, crack survey, and cursory survey. The PCI of the airfield pavement features was determined using the random sampling techniques outlined in FAA Advisory Circular 150/5380-6. Instead of surveying 100 percent of the sample units, only a portion of the sample units was surveyed. The number of sample units surveyed was based on the total number of sample units, standard deviation of 1982 PCI data, and allowable error. The detailed visual survey included a total of 350 sample units. The remaining sample units were subject to a crack survey as well as a cursory survey.

Observed Distress

Pavement distress types at Dulles include both traffic and nontraffic load-associated distress. Traffic load distress consists of longitudinal, transverse, and corner cracking in the center two panels of the runway and all three panels of the taxiway; pumping; and keyway failure. The major nontraffic distress consists of shrinkage and curling stress cracking, or both; settlement and cracking over utility trenches; crazing; and straining from water seepage.

Shrinkage and curling cracks are caused when the stress created by the fresh-shrinking concrete is greater than the concrete strength, or nonuniform expansion of the top and bottom of the concrete as a result of a difference in temperature or moisture. These cracks were found in the outer runway slabs (12 in. in thickness), in the center taxiway panel, and in panels with paint stripes as shown in Figure 2. (Note that in Figure 2, the cracks have been sealed by airport maintenance crews.) The paint stripes are the touchdown zone markers, located in the outer 37.5 ft of pavement where the panel sizes are 20 by 25 ft and pavement thickness is 12 in. Crazing may have been caused by overfinishing the concrete or improper curing. The crazing was not observed to deteriorate with time and, therefore, is not a major concern in the future. Pumping and staining were predominant sources of distress on the jet ramp. Except in the heavily trafficked areas, few signs of base material pumping through the cracks were observed. It was thus concluded that the water flowing out of the joints was due to natural springs or roof leakage and should be referred to as staining.

FIGURE 2 Paint stripe cracking caused by pavement curl.

Pavement Condition

The PCI sample units were combined into features based on PCI values; traffic; and use of the pavement (runway, taxiway, or ramp). The PCI features and their values are shown in Figure 3.

Based on the 1982 and 1984 visual surveys, the following conclusions were made:

1. Pavement deterioration is primarily aircraft load-associated (the concrete itself is sound).
2. Although significant amounts of nontraffic-associated distress were observed, these distresses did not significantly affect pavement deterioration.
3. Pavements used by departing traffic are in the worst condition.
4. There was no correlation between PCI and cut-fill of the subgrade, nor between PCI and elevation.
5. The ends of the runway have lower PCIs than the center.
6. Overall condition of the airfield pavements is good, although some severely deteriorated sections exist.

NONDESTRUCTIVE TESTING

NDT was used to determine the effective support of the pavement slabs, the efficiency of load transfer across a joint, and the presence of voids under a slab. The NDT equipment included the WES 16-kip vibrator and the FWD. The WES 16-kip vibrator was used in the 1978, 1982, and 1984 evaluations, and the FWD was used only in the 1982 evaluation.

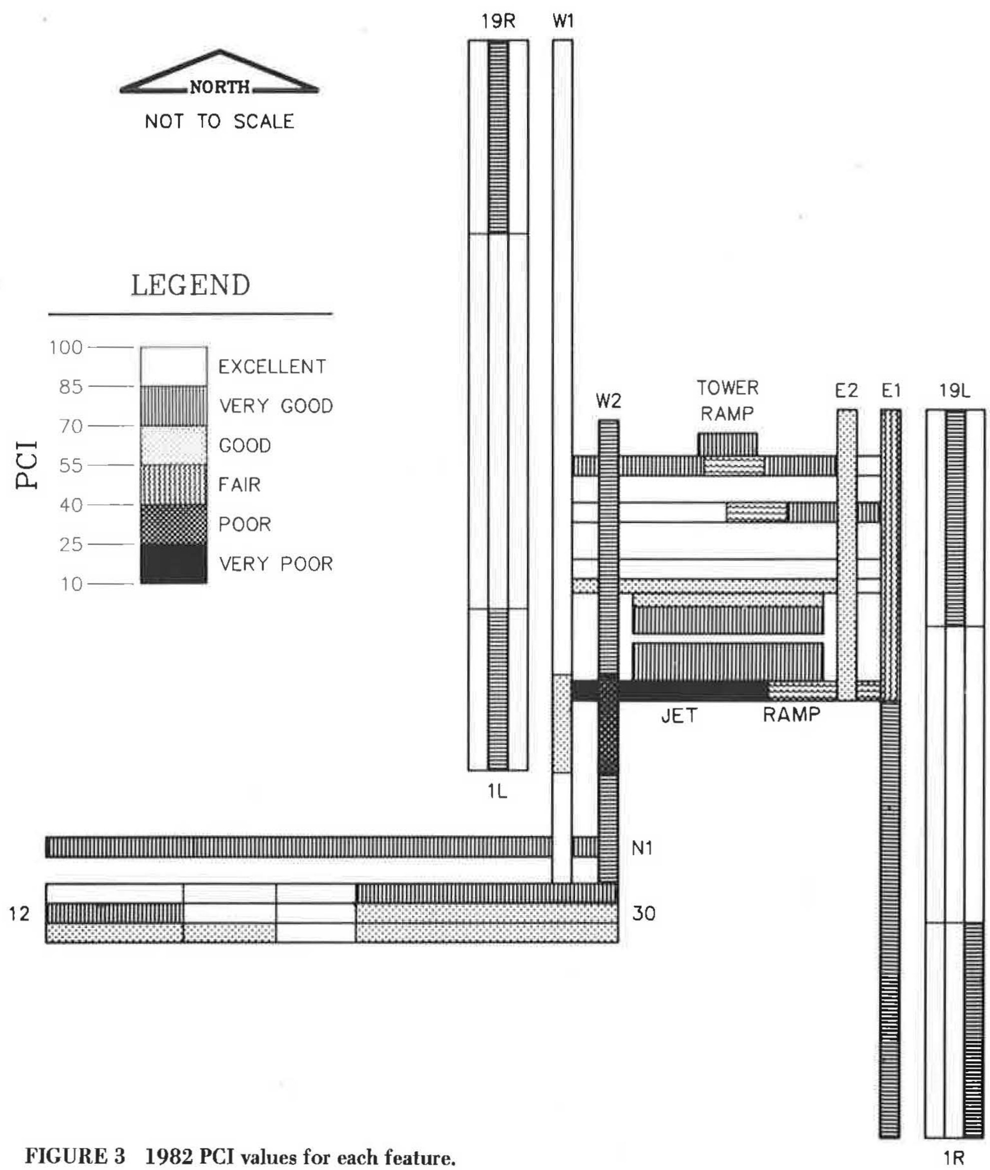

FIGURE 3 1982 PCI values for each feature.

All pavements subjected to the detailed visual surveys were tested with the NDT equipment. (Note that the NDT test locations were the same for all three evaluations.) Runways were tested in the center 50 ft of the runway. Panels were tested at the center of panel and transverse joint locations every 250 ft. Taxiways were tested in the center slab with a pattern of center of panel and transverse joint tests in one panel and corner and longitudinal joint tests in the panel 100 ft away. This pattern was repeated every 400 ft. In 1982, the FWD tested the same runway and taxiway slabs, but all four locations (center of panel, transverse joint, longitudinal joint, and corner) were tested. In 1984, the testing program was reduced to center of slab tests, and, following every fifth slab test, the transverse joint was tested.

The NDT data from each evaluation were tabulated and analyzed using the same procedures, and were compared to the other evaluations.

The WES vibrator deflection data from Sensor 1 was analyzed by dividing the pavement into similar sections according to criteria given in FAA Advisory Circular 150/5370-11 (5). These pavement sections have similar deflection values and are statistically different than adjacent pavement sections.

The average center-of-slab deflections for the sections have increased during the 6 years. The average deflection of all pavements increased 11 percent between 1982 and 1984 and 31 percent between 1978 and 1984. However, there were no significant changes in center-of-slab deflection between 1982 and 1984 for all three runways and heavily used taxiways. Changes in deflections indicated a reduction in subgrade support, possibly from increased moisture content.

The joints at Dulles Airport have joint-to-midspan ratio and load transfer values that are typical of pavements with good load transfer. In general, joint-to-midspan ratios are 1.4 or less and deflection load transfer values are in excess of 70 percent (unloaded side deflection/loaded side deflection x 100). No significant deterioration of the joint load transfer condition has occurred over the 6 years of testing.

The deflection sections of the three NDT programs delineate the same areas of pavement, although the boundary lines may shift slightly with each testing program. The center slab deflections section correlate well with cut-and-fill subsurface conditions. The average center-of-slab deflection was calculated for each PCI feature. Between 1982 and 1984, no relationship was found between change in center-of-slab deflection and change in PCI. This result is as expected because center-of-slab deflection does not change until after cracking has occurred. Deflection profiles, plotted from the three NDT testing periods, all show similar highs and lows. The 1984 deflections are typically the highest values of the three testing periods.

MATERIAL CHARACTERISTICS

Structural analysis of the pavement requires determination of several material properties. The modulus of elasticity of PCC slab, modulus of subgrade support (or k-value), modulus of rupture of the PCC slab, thickness of the PCC slab, and load transfer of the joints are required in the calculation of critical slab stresses from aircraft loads. These values were determined using core data from the 1978 study and the NDT deflection test results along with the ILLISLAB finite element computer program developed at the University of Illinois for the FAA (6).

The pavement can be accurately characterized by "backcalculating" the k-value of the foundation and the modulus of elasticity of the PCC from the measured deflection basin. From the NDT data, the area of the deflection basin was calculated. The plot shown in Figure 4 was then developed over a reasonable range of modulus of elasticity and k-values until the average area and maximum center of deflection of the pavement is bounded using the ILLISLAB program. The results showed the dynamic modulus of elasticity of the PCC slab to be close to the 5.4 million psi measured from the cores in 1978. Thus, 5.4 million psi was used for the PCC slab dynamic modulus of elasticity.

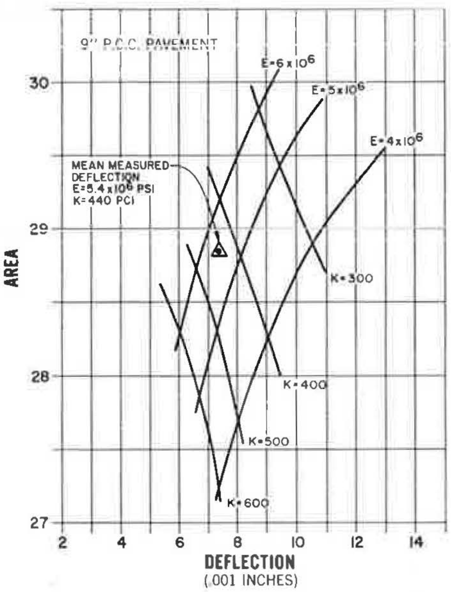

FIGURE 4 Illustration of determination of E_{PCC} and K-value for tower ramp.

The k-values for each feature were determined from deflections at the center of the slab. The largest k-values can be shown to be located at areas where the depth to bedrock was shallow (i.e., 2-5 ft.). These k-values are not the conventional static plate load k-values because they were computed using a dynamic load from the FWD and the WES 16-kip vibrator. The static value may be estimated by dividing these values by approximately 2 to 3.

The modulus of rupture can be approximated several different ways such as using the dynamic modulus of elasticity of the PCC, the indirect tensile strength of the cores, the compressive strength of the cores, or the measured modulus of elasticity of the concrete cores. ERES Consultants, Incorporated, of Champaign, Illinois, developed an approximate relationship between the dynamic (or sonic) modulus of elasticity (E) and the conventional third point modulus of rupture (MR) using data from the U.S. Army Corps of Engineers (7). The average modulus of rupture of the PCC is estimated as

$$MR = 209\ E^{0.736} \quad (1)$$

Thus, the average modulus of rupture for a modulus of elasticity of 5.4 million is 723 psi.

A similar estimate is obtained by using the results of the four compressive-strength (CS) tests and the conventional relationship between CS and modulus of rupture (MR). This can be expressed as

$MR = 9\ CS^{0.5}$

From 4-in. diameter cores, the average indirect tensile strength was found to be 614 psi, which is 0.85 of the 723 psi mean modulus of rupture. Thus, an estimate of the modulus of rupture for each feature where cores were taken can be obtained by dividing the indirect tensile strength by 0.85 to obtain an estimate of the modulus of rupture for that feature.

TRAFFIC

The last phase of data collection involved obtaining information on aircraft traffic. Several sources of data and existing traffic studies were reviewed to develop a projection of traffic volume, aircraft mix, and aircraft ground traffic patterns over the next 20 years for use in this study. Sources of information included the 1978 pavement evaluation; metropolitan Washington airport policy--aviation forecast; Peat, Marwick, Mitchell & Company forecasts; Jet ramp schedules for fall, 1982; a Civil Aeronautics Board report; and discussions with airport staff (1,8-11). (Note that traffic projections used for the 1978 study were based on the 1977 Peat, Marwick, Mitchell forecast. Projections used for this study are based on the 1983 Peat, Marwick, Mitchell forecast.) Pavement stress analysis indicated that an aircraft with a gross weight less than the DC-9/737 category would induce stresses well below a magnitude that would materially contribute to fatigue damage.

Airport ground traffic patterns were established by reviewing historic data and discussion with the airport operating staff. After determining runway and ramp patterns, traffic utilization was assigned to the connecting taxiway system. There were discernible differences in runway, taxiway, and ramp utilization for the various weight categories of aircraft. Aircraft were therefore grouped into the following weight categories for traffic distribution:

Weight	Category
Heavy	747, DC-10, L10-11, DC-8, 707, SST
Medium	727
Light	DC-9, HE-748, DASH-7, 737, CV-580

Past and future traffic volumes, by aircraft type, were calculated for each pavement feature for use in fatigue damage determinations. Fatigue damage predictions were developed by first correlating only historic traffic at the airport to existing pavement distress. It became apparent that observed distress density and location correlated best when only historical departures were considered. This was particularly true for the longitudinal center of runways where take-off and landing operations overlapped. Two factors contribute to the correlation of pavement deterioration and departing aircraft traffic patterns. They are as follows:

1. Departing aircraft are significantly heavier than arriving aircraft. The heavier wheel loads cause far more fatigue damage than the lighter wheel loads.
2. Most loading within the longitudinal center of the runway (where the path of landing and departing aircraft overlap) is a relatively high-speed dynamic load, which results in much less fatigue damage than the slow-moving departure aircraft at the runway ends.

PAVEMENT LIFE PREDICTIONS

The pavement evaluation phase consisted of evaluation of the collected data and prediction of remaining pavement service life. The collected data were analyzed to determine the cause of the deterioration. Various explanations were found including construction technique, design, environmental factors, and traffic loadings, with traffic pinpointed as the most significant cause for pavement condition deterioration.

The remaining life of the pavement features was estimated using three approaches. The first approach considered only the structural fatigue life of the slabs by predicting the amount of slab cracking. Repetitive loading will cause initial slab fatigue cracks. With additional loading, the cracks will continue to develop and deteriorate at an increased rate. The second approach involves the PCI, which includes all distress types--not just cracked slabs--using a straight-line prediction technique. The third approach related PCI to traffic and material characteristics using regression techniques. Graphic representation of the approaches is shown in Figure 5.

To determine the useful life of a pavement, criteria for pavement failure must be established. For this evaluation, failure criteria were based on structural cracking and minimum PCI values. Structural cracking refers to the percentage of slabs cracked as a result of loading. Failure criteria for structural cracking was defined as 50 percent cracked slabs, a value commonly considered as failure among engineers.

For failure criteria based on PCI value, two minimum PCI values were selected. The two levels represent the range of PCI values over which rehabilitation is normally required. The higher level, high pavement quality, is a condition where rehabilitation occurs before user complaints and heavy maintenance. The lower level, acceptable pavement quality, is the condition where rehabilitation occurs after or just as the pavement requires substantial maintenance effort and considerable user complaint.

The minimum PCI values for the end of service life as defined in this evaluation are shown in the following table:

Location	PCI Level to Maintain High Pavement Quality	PCI Level to Maintain Acceptable Pavement Quality
Runways	70	55
Taxiways	60	40
Ramps	50	40

These values were established from evaluating the existing airfield pavements.

PCI Life Prediction Analysis

Two pavement life predictions were developed from PCI data. The first procedure assumed that all pavements had a PCI of 100 at the completion of original construction. The current PCI of each pavement feature was calculated from distress data observed during the visual surveys. An average annual loss of PCI before the survey was calculated and the future annual loss of PCI was extrapolated at the same rate. However, straight-line extrapolation is a simplistic procedure and is valid only in the higher PCI ranges and for nontraffic load pavement features

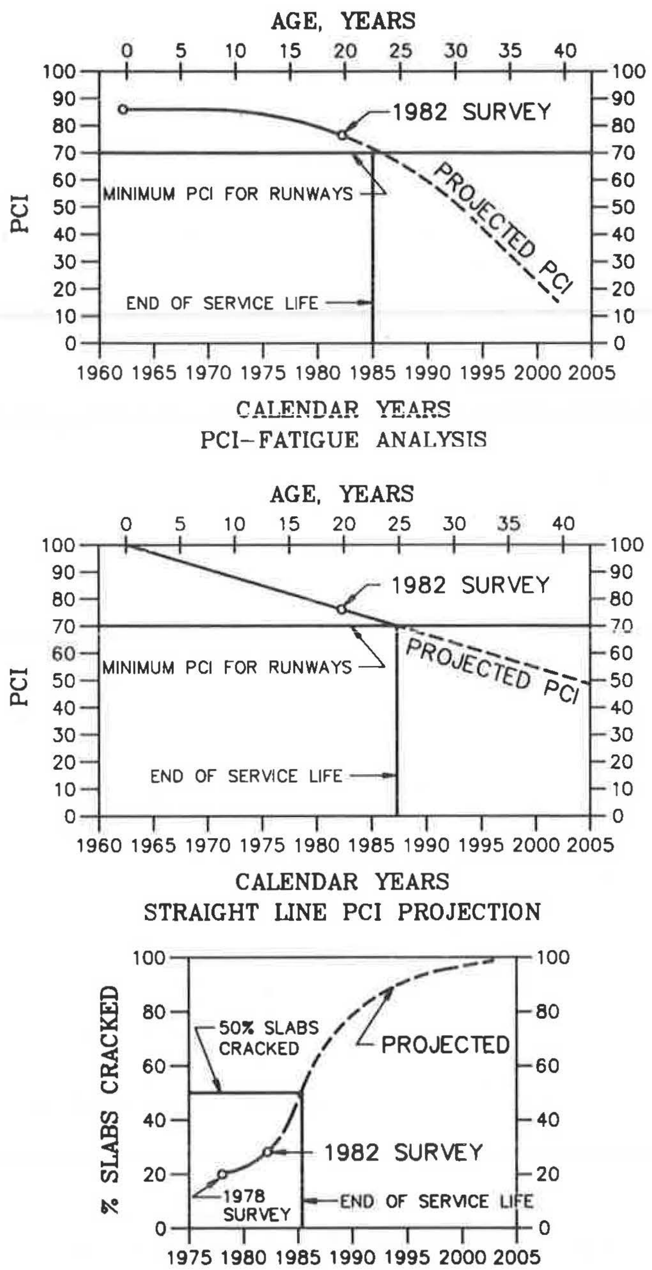

FIGURE 5 Three approaches to pavement life prediction.

where deterioration is normally a gradual, slow process.

The second life prediction procedure based on PCI relates the PCI to fatigue damage. As previously discussed, the varied traffic history and pavement distress for the individual pavement features can be used to relate pavement deterioration to traffic loadings. The current PCI and traffic history were determined for each pavement feature. Mathematical models were developed by regression techniques to closely approximate the historic rate of pavement deterioration. The procedure that best fits actual conditions included separate equations for runways, taxiways, and ramps. The models developed for pavement life prediction are as follows:

$$PCI = 83.567 - 0.00033\ [\sum(\sigma/MR)^{4.0} \cdot DEPARTURES]$$

$$PCI = 78.35 - 0.000436\ [\sum(\sigma/MR)^{2.5} \cdot DEPARTURES]$$

$$PCI = 6.531\ [\sum(\sigma/MR)^{4.0} \cdot DEPARTURES]^{-1.2847}$$

where

- σ = critical stress induced by each individual aircraft, in psi,
- MR = modulus of rupture of concrete of pavement feature, in psi, and
- DEPARTURES = total departures by each individual aircraft.

Fatigue Cracking Analysis

This procedure predicts the percentage of structurally cracked pavement panels over the analysis period based on the Miner's fatigue damage number. Laboratory and field pavement studies have shown that pavement panel cracking and the cumulative fatigue damage number can be represented by an S-shaped curve on a log-normal plot. The shape of the curve indicates that cracking begins slowly but then accumulates rapidly before slowing down after a large percentage of slabs are cracked. The shape of the S-curve was determined for the Dulles pavements by analyzing the wide range of past traffic and the corresponding observed cracking of the different pavement features.

Remaining Service Life

The remaining service life for a pavement was determined by summarizing the three approaches to pavement life. From the three approaches, an end-of-service-life date for the pavement was selected (by time phase) that best represents when rehabilitation will be required. The estimated time phases for rehabilitation were grouped into five categories as shown in the following table.

Category	Time Duration (yr)	Calendar Years
Immediate	2	1984 and 1985
Short term	3	1986 through 1988
Medium term	5	1989 through 1993
Long term	10	1994 through 2003
Future	--	Beyond 2003

The analysis period of 20 years was divided into four periods, each subsequent period having a longer time span. The reason for this distribution of time is that reliability of pavement life predictions decrease with further projections into the future. (A visual picture of the end-of-service-life time phases to maintain acceptable pavement quality is shown in Figure 6.)

PAVEMENT MANAGEMENT

The goal of pavement management is to develop an economical pavement rehabilitation program, including its priorities, that maintains or improves the overall pavement condition. The objective of pavement rehabilitation is to provide a pavement system that has adequate load-carrying capacity, that has good rideability, and that permits safe operation of aircraft under all weather conditions.

As part of the 1982 pavement evaluation, five different rehabilitation programs were developed for Dulles International Airport. In each program, the pavement rehabilitation involved one, two, or three

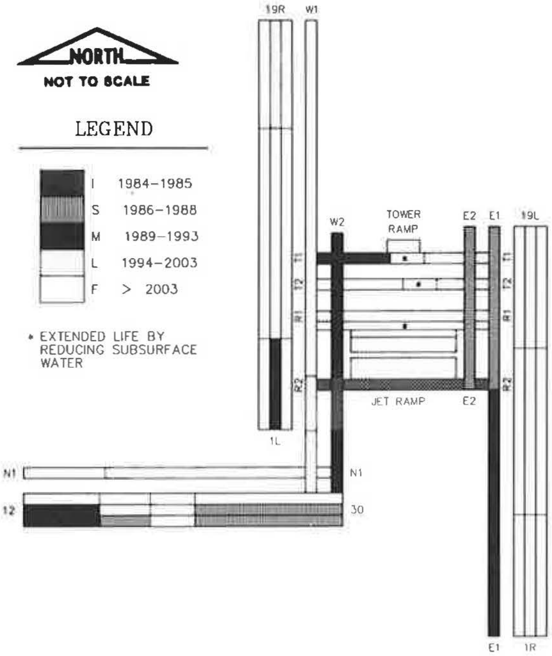

FIGURE 6 Time period for rehabilitation to maintain acceptable pavement quality.

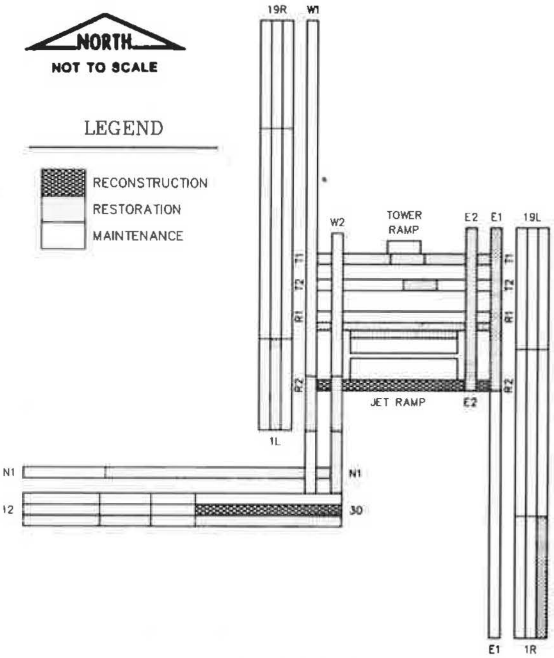

FIGURE 7 Alternative IV rehabilitation program.

rehabilitation techniques. These techniques are reconstruction, restoration, and maintenance. The specific rehabilitation technique for a feature was selected based on the existing and future pavement condition as depicted by visual distress surveys, NDT, and pavement service life projection. The five rehabilitation programs were evaluated by considering initial construction cost, annual maintenance cost, average PCI during the next 20 years, number of features closed to traffic (if no additional rehabilitation were to occur), disruption to traffic, traffic control flexibility, and other criteria.

The five rehabilitation programs were developed to meet a variety of funding levels and rehabilitation techniques. The following characteristics existed for each rehabilitation program: (a) specific rehabilitation techniques were selected for each feature; (b) the priority of the rehabilitation projects was determined based on projected end of service life; (c) the overall pavement quality was proportional to the program cost; and (d) the varying funding levels provided a range of possibilities.

SUMMARY

In summary, the five rehabilitation programs were as follows:

Alternative I: Overlaying of all airfield pavements during a 5-year period.

Alternative II: Reconstruction of all features that reached end of service life (high-quality pavement) during the next 10 years.

Alternative III: Restoration of all features that reach end of service life (high-quality pavement) during the next 20 years, and reconstruction of those features in which restoration was not projected to extend service life longer than 5 years.

Alternative IV: Restoration of all features that reach end of service life (acceptable quality pavement) during the next 20 years, and reconstruction of those features in which restoration was not projected to extend service life longer than 5 years (Figure 7).

Alternative V: Continued maintenance and slab replacement.

The cost of implementing each program was estimated by predicting the type and extent of work completed each year of the program, and by modifying construction costs to include engineering, inspection, administrative costs, and inflation.

Annual maintenance costs were estimated using the cost of present maintenance and increasing or decreasing cost based on rehabilitation, inflation cost, and pavement condition. The pavement condition was projected over the next 20 years. The average PCI projection reflects improvements to pavement condition and projected deterioration as a result of the environment and traffic after completion of the program (Figure 8). On completion of the 1984 evaluation, and following discussions with FAA and Dulles personnel, one of the rehabilitation programs was modified into a rehabilitation strategy to be followed at Dulles Airport.

The 1984 rehabilitation strategy was developed with the following guidelines:

1. Funding is not presently available to implement Alternatives I, II, and III.
2. Alternative V is not desirable because of high maintenance costs and possible future closure of features for maintenance.
3. As a minimum, Alternative IV should be implemented (except that the reconstruction would be delayed by initiating a restoration program now).
4. Restoration work would be contracted out as a result of the magnitude of work.

A detailed work program was developed for each of the next 10 years.

CONCLUSIONS

The following conclusions are made:

1. The pavement features at Dulles International Airport, all constructed at the same time by

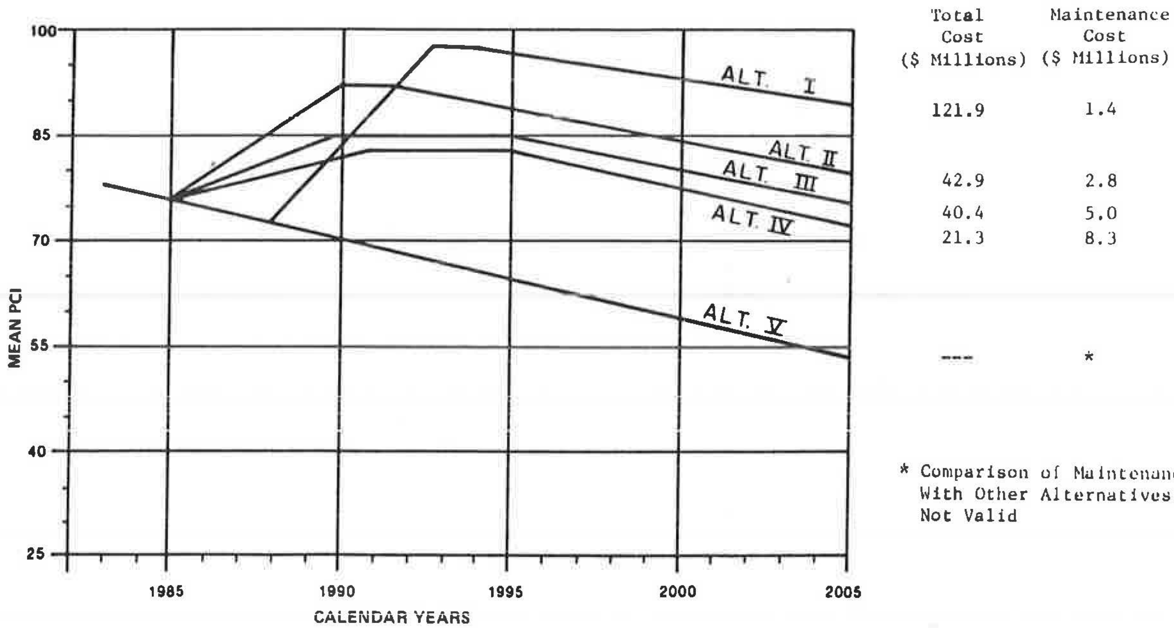

FIGURE 8 Projected mean PCI for all features for alternative rehabilitation programs I to V.

the same contractor and with the same design detail and materials, are deteriorating at different rates.

2. Both load-associated and nontraffic-associated distresses were identified. However, pavement condition deterioration is largely a result of load-associated distress.

3. Pavements used by departing aircraft are in the worst condition.

4. Pavements subjected to static traffic loading such as aprons, deteriorate at a faster rate than pavements subjected to the same amount of moving traffic, such as runways or taxiways.

5. The historic rate of pavement deterioration was closely correlated to fatigue damage, which was a function of stress induced by each individual aircraft, the modulus of rupture of concrete, and the volume of departing aircraft.

6. The PCI is a valuable tool for evaluating the existing condition of the pavement.

7. NDT is a valuable tool for rapidly characterizing properties of the pavement materials and determining joint load transfer.

8. Three separate methods were used to predict pavement service life. Although the exact year predicted at the end of the service life varied with each prediction method, the end of service life for each feature could be represented by a time phase for rehabilitation.

9. The three methods used to predict pavement service life all identified the same features with service lives of less than 10 years. Both PCI and cracking projections are useful in estimating remaining pavement functional and structural life.

10. Rehabilitation programs must be developed to meet various funding levels and maintenance commitments for overall pavement management.

11. Normal maintenance procedures at Dulles International Airport will not be capable of controlling future pavement deterioration.

12. To maintain the airport pavement network at its current average PCI condition over the next 20 years, an increase in funding of maintenance and rehabilitation activities must be obtained.

13. Pavement service life projections are dependent on traffic projections. Major changes in traffic will have significant impact on remaining pavement service life.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of David Jones of the Metropolitan Washington Airport Section of the FAA in Washington, D.C., and Frank Kirkbride and Rick Marinelli of the Engineering Section of Dulles International Airport.

REFERENCES

1. Evaluation of Airfield Pavements at Dulles International Airport. Howard, Needles, Tammen and Bergendoff, Alexandria, Virginia, 1979.
2. E.J. Barenberg and M.Y. Shahin. 1982 Report on Evaluation of Airfield Pavements at Dulles International Airport. ERES Consultants, Inc., Champaign, Illinois, 1985.
3. E.J. Barenberg and M.Y. Shahin. 1984 Report on Evaluation of Airfield Pavements at Dulles International Airport. ERES Consultants, Inc., Champaign, Illinois, 1985.
4. Guidelines and Procedures for Maintenance of Airport Pavements. Advisory Circular 150/5380-06. Federal Aviation Administration, U.S. Department of Transportation, Dec. 1982.
5. Use of Nondestructive Testing Devices in the Evaluation of Airport Pavements. Advisory Circular 150/5370-11. Federal Aviation Administration, U.S. Department of Transportation, June 1976.
6. A.M. Tabatabie and E.J. Barenberg. Longitudinal Joint System in Slip-Formed Rigid Pavements, Vol. III--Users Manual. Report FAA-RD-79-4. Federal Aviation Administration, U.S. Department of Transportation, 1979.
7. Nondestructive Structural Evaluation of Airfield Pavements. ERES Consultants, Inc., Champaign, Illinois, 1982.

8. Metropolitan Washington Airport Policy--Aviation Forecast, Final Report. Federal Aviation Administration, U.S. Department of Transportation, Aug. 1980.
9. Draft Final Master Plan Report, Dulles International Airport. Peat, Marwick, Mitchell & Company, Washington, D.C., Sept. 1977.
10. Aircraft Activity Update, Dulles International Airport. Peat, Marwick, Mitchell & Co., Washington, D.C., June 1983.
11. Airport Activity Statistics of Certified Route Air Carriers. Civil Aeronautics Board, Washington, D.C., 1985.

Publication of this paper sponsored by Committee on Pavement Management Systems.

Comparing Different Strategies for Selecting Pavement Sections for Major Repair

D. R. UZARSKI and M. I. DARTER

ABSTRACT

The U.S. Navy Public Works Center (PWC), which is located in Great Lakes, Illinois, successfully completed implementation of the PAVER Pavement Maintenance Management System in September 1982. As part of the implementation, a priority scheme for the selection of pavement sections needing major repair was created. The scheme developed was a "worst-first" priority strategy based on pavement condition and rank. A shortcoming to this scheme, however, is that cost and benefit of repair are not considered as criteria. Accordingly, the effects of incorporating cost and benefit criteria as additional parameters to be used in the selection of pavement sections for major repair are studied in this paper. Six strategies are compared--(a) do nothing, (b) use the existing priority scheme, (c) use a revised priority scheme that takes cost into account, (d) repair when needed, (e) use section benefit-cost optimization with variable utility, and (f) use section benefit-cost optimization with constant utility. The results concluded that by revising the priority strategy or by using benefit-cost optimization techniques, an improved network condition can result at a lower overall cost.

The PAVER Pavement Maintenance Management System (1,2), which was developed by the U.S. Army Corps of Engineers at the Construction Engineering Research Laboratory in Champaign, Illinois, is gaining widespread acceptance throughout all branches of the military service and in civilian communities as well. Where implemented, public works managers have found PAVER to be a valuable tool in managing their pavement network.

Pavement management is accomplished at two distinct levels--network and project--and each involves many specific tasks. A major task at the network level is the selection or programming of candidate pavement sections for major maintenance repair and rehabilitation. Because repair needs almost always exceed available funds, the engineer is tasked with deciding which sections will be repaired in a given year and which sections will be deferred to future years. Studied in this paper are the effects of employing different selection strategies on both overall network condition and the overall cost for repairs.

D.R. Uzarski, U.S. Army Construction Engineering Laboratory, P.O. Box 4005, Champaign, Ill. 61820. M.I. Darter, Department of Civil Engineering, University of Illinois, Urbana, Ill. 61801. Current Address: Eres Consultants, Inc., Champaign, Ill. 61801.

BACKGROUND

The U.S. Navy Public Works Center (PWC), which is located in Great Lakes, Illinois, successfully completed implementation of the PAVER Pavement Maintenance Management System for the Naval Training Center (NTC) (also located in Great Lakes) in September 1982. The implementation was accomplished via an architect-and-engineer (A&E) contract with the contractor and the Navy working in close harmony. One of the implementation tasks was the development of a priority scheme for selecting pavement sections needing major repair. The scheme ultimately adopted is shown in Figure 1a and the reverse of this scheme