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Airfield Pavement Distress Measurement and Use in Pavement Management

M.Y. SHAHIN

This paper describes airfield pavement distress measurement and use procedures that were developed for the U.S. Air Force. The procedures have been implemented by the U.S. Air Force and published by the Federal Aviation Administration. Distress identification, distress data collection procedures, distress data processing, and distress data analysis and use in pavement management are discussed. The paper also describes the pavement condition index (PCI), which is computed based on distress type, severity, and amount. The PCI is measured on a scale from 0 to 100, with 100 being excellent. Both the distress data and PCI provide an invaluable tool for pavement evaluation, determination of maintenance and repair needs, and management at both the project and the network levels.

The majority of existing airfield pavements is approaching their economic design life, so a great need exists for pavement management. A primary component of pavement management is pavement condition evaluation. Figure 1 presents the major pavement condition indicators (PCIs) for airfield pavements. These indicators include roughness, skid resistance, structural integrity and capacity, and the potential for damage from foreign objects. Field experience has shown that most of these condition indicators can be measured through objective and accurate measurement of distress. Figure 1 also shows how the various distress types in asphalt pavements relate to the various pavement condition indicators. Many pavement engineers think that a distress survey should be performed before a direct measurement of the condition indicators (e.g., structural capacity) is recommended.

This paper describes airfield pavement distress measurement and use procedures that were developed for the U.S. Air Force. The procedures have been implemented by the U.S. Air Force and published by the Federal Aviation Administration (FAA).

DISTRESS IDENTIFICATION

An accurate distress characterization should include three parameters: distress type, severity, and quantity. The lack of any of these parameters will produce an unrepeatable and inconsistent distress characterization. A comprehensive distress manual, which identifies various distress types in both asphalt- and concrete-surfaced pavements, has been developed for the U.S. Air Force (1). FAA has also published the same manual in a technical report (2). Figure 2 (1,2) is an example distress definition for rutting. For each distress type a description is provided that includes the possible causes of distress. Three levels of severity are defined: low, medium, and high. Photographs of each level of severity are also provided. The use of the distress identification manual has provided accurate and consistent distress survey results.

DISTRESS DATA COLLECTION PROCEDURES

The first step in the distress data collection procedures is to divide the airfield pavements into uniform features based on construction, condition, and traffic. Figure 3 shows an airfield layout map with pavements divided into features. For the purpose of inspection each feature is divided into sample units. A sample unit is defined as approximately 5000 ft^2 for asphalt-surfaced pavements and approximately 20 slabs for jointed concrete-surfaced pavements. When the inspection is performed, each sample unit may be surveyed or inspection may be performed by sampling. For inspection by sampling, both the number of sample units to be surveyed and their locations should be determined. A procedure to do so has been developed and used successfully (1). The number of sample units to be inspected is a function of the level of reliability desired in the data collected. This in turn is a function of the objective of the survey (i.e., whether the survey is performed for developing a project for that pavement or only for the purpose of identifying the overall condition of the airfield pavement network). If the objective is the latter, then only a few sample units may suffice; however, if the objective is to use the distress information in developing a project, then more sample units should be surveyed.

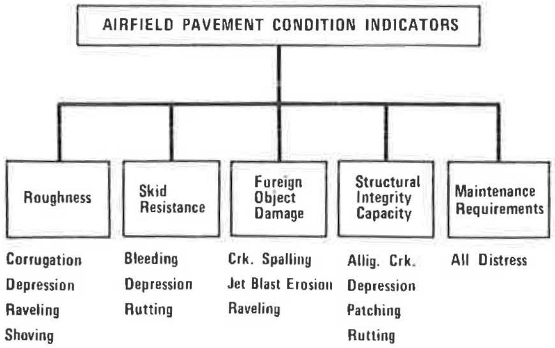
Figure 4 shows a field data sheet for asphalt pavements that is used when surveying a sample unit. The numbers shown in circles are the distress types. In this example they are distress types 1 (alligator cracking) and 3 (block cracking). Under each distress type the quantity of distress encountered is recorded, followed by the severity level. For example, 20L indicates that there were 20 ft^2 of low-severity alligator cracking. After the field survey, the data are then totaled.

The distress data can be collected manually or by using automated methods.

Manual Distress Collection

For manual distress collection the survey is performed by a crew that usually consists of two or three persons. The crew walks the pavement and, through the use of simple tools such as a measuring wheel, straight edge or rope, and a ruler, identifies the distress types and severities that exist in each sample unit. The rope or straight edge is used to determine depths of surface deformations such as rutting and depression.

Figure 1. Relation between pavement condition indicators and distress types for asphalt airfield pavements.



Automated Data Collection

The automated data collection procedures presented here have been used in Japan for the last 10 years. They have been developed by the Pacific Aero Survey Company, Ltd. (PASCO) (3). Two systems are presented here. The first is known as Road Recon-70. The Road Recon-70 is capable of photographing pavements at night while traveling at speeds of up to 45 mph. One advantage of using the system is that the condition of the pavement is recorded on film for future use and reference. The second system used by PASCO is the Rut Depth-75 (RDP-75). The RDP-75 [Figure 5 (3)] is used to measure rut depth at preselected intervals. It uses the same vehicle, power source unit, power control unit, and camera supporting unit as the Road Recon-70. The RDP-75, however, uses a pulse camera and a power source unit and hairline projector that are all mounted on the vehicle. The camera shutter intervals are correctly controlled through the pulse signal transmission device in accordance with the traveling speed of the vehicle. The RDP-75 system is patented in the United States and several other countries.

DISTRESS DATA PROCESSING

The distress type, severity, and amount collected for each sample unit are used to compute PCI. The PCI (Figure 6) is measured on a scale of 0-100, with

Figure 2. Example distress definition for rutting.

Name of Distress: Rutting

Description: A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut; however, in many instances ruts are noticeable only after a rainfall, when the wheel paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrade, usually caused by consolidation or lateral movement of the materials due to traffic loads. Significant rutting can lead to major structural failure of the pavement.

Severity Levels: Mean Rut Depth Criteria

Severity	All Pavement Sections
L	¼-½ inch (Figures A1-58, A1-59)
M	>½ 1 inch (Figure A1-60)
H	>1 inch (Figures A1-61, A1-62)

How to Measure: Rutting is measured in square feet of surface area, and its severity is determined by the mean depth of the rut. To determine the mean rut depth, a straightedge should be laid across the rut and the depth measured. The mean depth in inches should be computed from measurements taken along the length of the rut.

Figure 3. Airfield layout showing different pavement features.

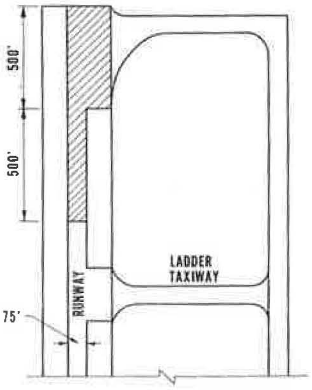


Figure 4. Sample field data sheet for asphalt pavements.

DISTRESS TYPES

1. Alligator Crack
2. Bleeding
3. Block Crack
10. Patching
11. Polished Agg
12. Raveling

	Existing Distress Types			
	①	③		
	20L	100L		
	30L	150M		
L	50	100		
M		150		
H				

100 being excellent. It is computed by using the concept of deduct values. A series of deduct values has been developed for each distress type, as shown in Figure 7. The deduct values for each distress existing in the pavement are determined from such

Figure 5. Rut depth measurement system RDP-75 used by PASCO.

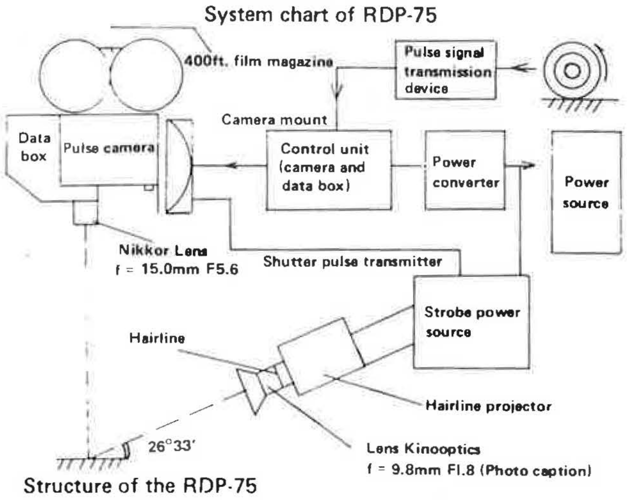


Figure 6. PCI rating system.

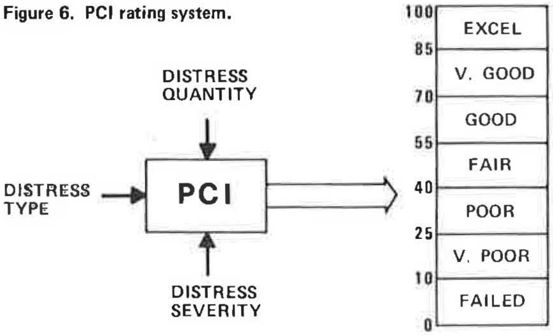


Figure 7. Example deduct values for one distress type.

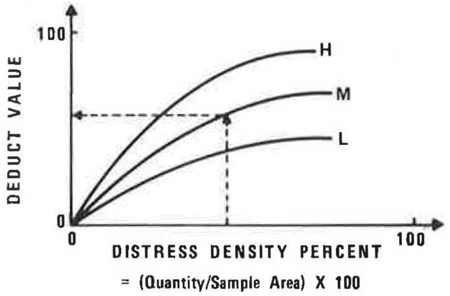
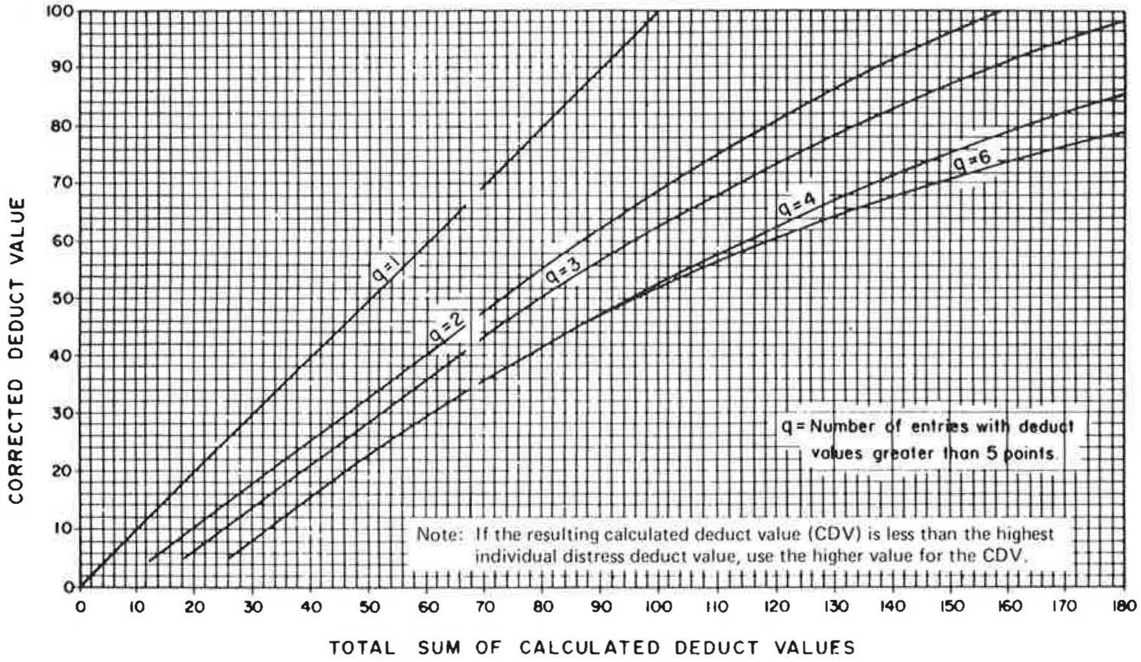


Figure 8. Corrected deduct values for asphalt- or tar-surfaced pavements.



q = Number of entries with deduct values greater than 5 points.

Note: If the resulting calculated deduct value (CDV) is less than the highest individual distress deduct value, use the higher value for the CDV.

Figure 9. PCI calculation for sample unit.

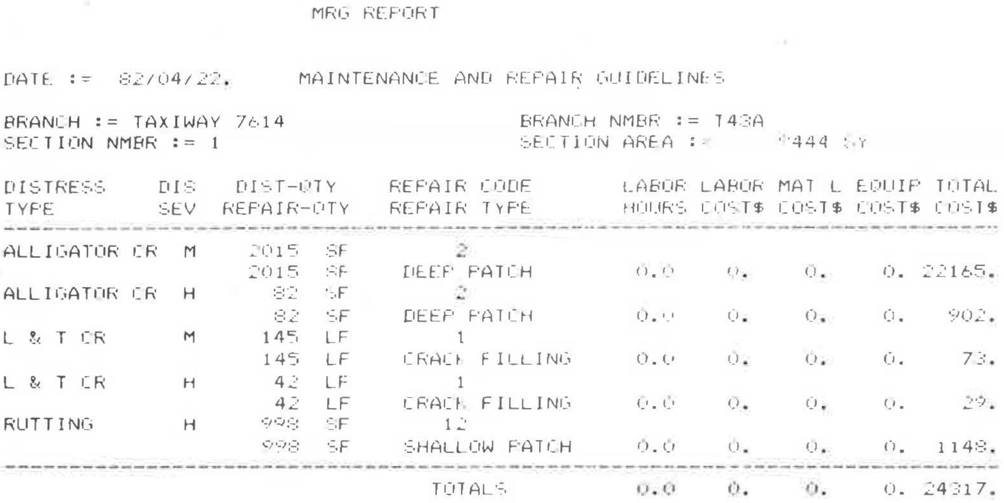
DIST TYPE	DENSITY %	SEVERITY	DEDUCT VALUE
Allig. Crack	1.0	L	21
Block Crack	2.0	L	10
Block Crack	3.0	M	16
		Total =	47
		Corrected =	26
		PCI = 100–26 =	74

Figure 10. Extrapolated distress data for pavement feature.

PCI: Average PCI of Sample Units
Extrapolated Distress Data

DIST.TYPE	SEV.	QUANTITY	DENSITY	DEDUCT VALUE
Allig. Crack	L	450	0.9	20
Block Crack	L		2	10
Block Crack	M	1500	6	20

Figure 11. Example of computer output showing estimated cost based on distress data.



```
                         MRG REPORT

DATE := 82/04/22.      MAINTENANCE AND REPAIR GUIDELINES

BRANCH := TAXIWAY 7614                    BRANCH NMBR := T43A
SECTION NMBR := 1                         SECTION AREA :=      9444 SY

DISTRESS      DIS   DIST-QTY    REPAIR CODE          LABOR LABOR MAT L EQUIP TOTAL
TYPE          SEV  REPAIR-QTY   REPAIR TYPE          HOURS COST$ COST$ COST$ COST$
-----------------------------------------------------------------------------------
ALLIGATOR CR   M     2015  SF         2
                     2015  SF     DEEP PATCH          0.0    0.    0.    0. 22165.
ALLIGATOR CR   H       82  SF         2
                       82  SF     DEEP PATCH          0.0    0.    0.    0.   902.
L & T CR       M      145  LF         1
                      145  LF     CRACK FILLING       0.0    0.    0.    0.    73.
L & T CR       H       42  LF         1
                       42  LF     CRACK FILLING       0.0    0.    0.    0.    29.
RUTTING        H      998  SF        12
                      998  SF     SHALLOW PATCH       0.0    0.    0.    0.  1148.
-----------------------------------------------------------------------------------
                                    TOTALS            0.0    0.    0.    0. 24317.
```

Figure 12. Sample computer output of PCI versus time plot.

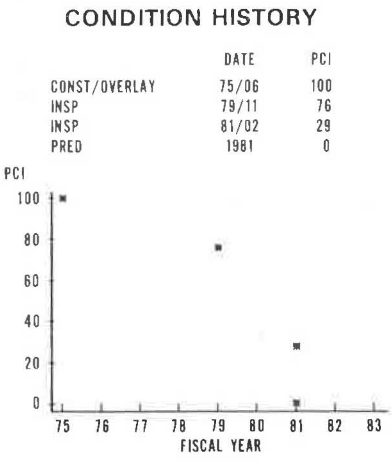


Figure 13. Sensitivity analysis of PCI prediction model, which is function of load, environment, and material thickness and properties.

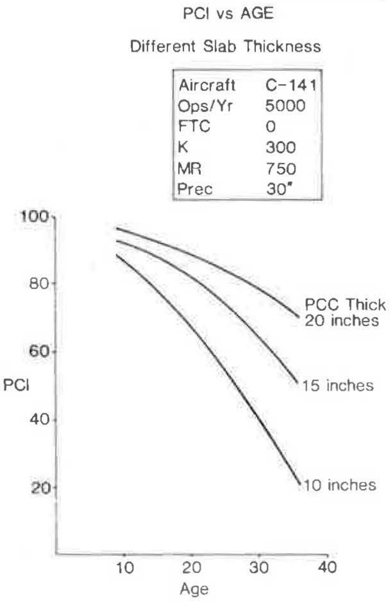
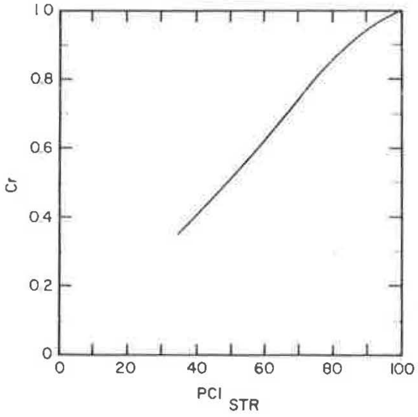


Figure 14. Relation between PCI, computed based on structural distress (PCI_{STR}), and C factor in U.S. Army Corps of Engineers design equation.



curves and totaled for the sample unit. The total deduct values are then corrected based on the number of deducts over 5 points and the total value of the deducts, as shown in Figure 8. Figure 9 is an example PCI calculation for a sample unit. The PCI for a feature is determined by averaging PCIs of the sample units inspected.

The distress for the feature is extrapolated based on the distresses determined for the sample units, as illustrated in Figure 10. To expedite the process of PCI calculations for a sample unit and a feature, a computer program has been prepared that performs these calculations in a batch or interactive mode. An important characteristic of PCI is that it agrees closely with the collective judgment of experienced pavement engineers. That was one of the objectives of its development. Another important characteristic is that it correlates closely with the needed level of maintenance and repair. This is particularly true because PCI is computed based on the distress.

ANALYSIS AND USE OF DISTRESS DATA

The distress data and PCI play an important role in pavement management at both the project level and the network level. At the project level the distress data can be used to determine the causes of failure. The calculations below show that the sum of deduct values due to alligator cracking (load caused) is 20 and due to block cracking (climate caused) is 30.

Percentage of deduct due to load = (20/50) x 100 = 40 percent

Percentage of deduct due to climate = (30/50) x 100 = 60 percent

The percentage of deduct value due to load and climate can be calculated as shown. The distress information can also be used to compute the cost of localized repair such as patching and crack filling, as shown in Figure 11. The figure shown is obtained from the PAVER pavement management system (4-6). The localized repair costs are computed based on user's identified maintenance policy and unit cost of repair. The program also computes the cost of overlay if requested.

Another important use at the project level is the determination of rate of deterioration, both for the short term and for the long term. This can be obtained by plotting the PCI versus time for the pavement, as shown in Figure 12. The consequence of various maintenance and repair alternatives is also achieved through PCI. Special mathematical models have been developed that correlate PCI deterioration with existing pavement structure, traffic, and climate. Figure 13 is a sensitivity analysis on the model for concrete pavement. The distress and PCI data also provide necessary information for overlay design. In the U.S. Army Corps of Engineers design Equation 1, C factor is computed that reflects the condition of existing pavement.

$$h_c = [h^p - C_r h_e^p]^{1/p} \qquad (1)$$

where

h_c = required concrete overlay thickness;
h = designed concrete thickness for a new pavement;
h_e = thickness of existing concrete pavement;
p = 2.0 for unbonded overlay, 1.4 for partly bonded overlay, or 1.0 for fully bonded overlay; and
C = 1.0 for existing pavement in good condition, 0.75 for existing pavement in fair condition, or 0.35 for existing pavement in poor condition.

Shahin and Darter (7) have developed a method with which the C factor can be more consistently determined by using the PCI information. The relation between PCI computed based on structural related distress only and the C factor is shown in Figure 14. Distress and PCI data are also very important at the network level. Various uses have been summarized by Shahin and Kohn (5). These include project prioritization, inspection scheduling, prediction of network condition, and budget planning.

SUMMARY AND CONCLUSIONS

A procedure for airfield pavement distress measurement and use in pavement management has been presented. The procedures are implemented by the U.S. Air Force and have been used by several states, including Illinois and Texas. In conclusion, distress provides invaluable information for management at both the project level and the network level. It is, however, important to emphasize that load-carrying capacity, roughness, and skid should also be considered, particularly at the project level.

ACKNOWLEDGMENT

The views expressed in this paper do not purport to reflect the position of the U.S. Department of the Army or the U.S. Department of Defense.

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