NONDESTRUCTIVE TECHNIQUE FOR EVALUATING D-CRACKING IN AIRFIELD PAVEMENTS

Robert K. Kumapley, ERES Consultants, Inc.
Emmanuel B. Owusu-Antwi, Arizona State University
Department of Civil and Environmental Engineering
Leslie Titus-Glover, ERES Consultants, Inc.

ABSTRACT

D-cracking is a form of concrete deterioration associated with the use of nondurable coarse aggregates that disintegrate when saturated and subjected to repeated cycles of freezing and thawing. The distress usually originates along cracks, joints, and free edges in the lower portion of pavement slabs and progresses upward. The need for detailed investigation of D-cracking is most often triggered by the distress appearing on pavement surfaces when it has reached an advanced stage of deterioration. The early detection and tracking of D-cracking before signs are evident on an airfield pavement surface is critical to the management of resources for maintenance and rehabilitation. Currently, the investigation of D-cracking before it becomes visible at the surface is accomplished by examination of full-depth cores taken through the pavement. Coring operations to identify and track D-cracking can be expensive and time-consuming, particularly in situations where D-cracking is widespread but not visible at the surface.

This paper presents a simple, efficient, cost-effective, and nondestructive technique that can be used for the early detection and investigation of D-cracking in airfield pavements, even before it appears on the surface. The procedure involves the use of the ratio of deflections at slab edge to the deflections at the slab center, DEF_{ratio}. Data used in this study were obtained from concrete pavements at six major airfields in the United States. The procedure has been tested on pavements with D-cracking and has been found to be effective.

Keywords: D-cracking, concrete pavement, nondestructive testing, DEF_{ratio} .

INTRODUCTION

D-cracking is a form of concrete deterioration that has developed into a serious, widespread problem in the midwest, northern, and eastern United States and in Canada (1). A typical jointed plain concrete pavement (JPCP) with severe D-cracking is shown in figure 1. The occurrence of the distress is associated with the use of nondurable coarse aggregates that disintegrate when saturated and subjected to repeated cycles of freezing and thawing, causing cracking (1,2). The cracking propagates through the mortar mix surrounding the aggregate. This eventually appears on the pavement surface parallel to intersecting joints, cracks, and edges, eventually acquiring a pattern resembling the letter D and sometimes filled with a dark deposit at the pavement surface. The distress usually originates in the lower portion of pavement slabs and progresses upward. In some instances, however, it has been known to start at the top of the slab or in the interior. Even so, it always starts along cracks, joints, and free edges. Because it usually starts at the bottom of the slab and progresses upward, deterioration in the bottom of the slab can be fairly extensive before signs of D-cracking show on the pavement surface.

The detection and tracking of D-cracking before signs are evident on the pavement surface is critical to the management of resources for maintenance and rehabilitation. To date, the need for detailed investigation of

D-cracking is most often triggered by the distress appearing on pavement surfaces. Detection is usually accomplished by examination of full-depth cores taken through the pavement near joints and cracks. Coring operations to identify and track D-cracking can be expensive, time-consuming, and destructive, particularly in situations where D-cracking is widespread but not visible at the surface.

This paper presents a simple, efficient, economical, and nondestructive procedure that can be used for early detection, assessment, and monitoring of D-cracking in airfield pavements. The procedure involves the use of the ratio of normalized deflections at the slab edge to the deflections at the slab center, DEF_{ratio}. Based on the DEF_{ratio} for pavements with and without D-cracking, limiting criteria have been established for evaluation of portland cement concrete (PCC) pavement for early detection and assessment of the distress, as well as the monitoring of its progression before signs are evident on the pavement surface. Data were collected using a falling weight deflectometer (FWD) from concrete pavements at six major airfields in the United States. Cores were also taken from all the pavements in this study.

BACKGROUND

The study presented in this paper was inspired by the favorable results from a recent study conducted by Kumapley and Owusu-Antwi using DEF_{ratio} values to investigate D-cracking (3). The primary objective of that study was to assess the overall performance of two D-cracked pavement sections rehabilitated between 1986 and 1989. The original pavements, located at Forbes Field in Topeka, Kansas, consisted of 356- to 483-mm (14- to 19-in) thick JPCP placed directly on a clay subgrade. The JPCP had D-cracking in the top 102 mm (4 in). The D-cracking was completely removed by milling prior to the placement of a 229-mm (9-in) bonded JPCP overlay. One of the major concerns studied was the extent of D-cracking progression in the original JPCP, if any, years after rehabilitation, and the structural condition of the overlay and the original JPCP. These concerns were investigated using the DEF_{ratio} technique and inspection of cores taken from the rehabilitated pavement. The results of that study are summarized in table 1. It was found in that study that pavements with sound PCC with no obvious D-cracking or structural integrity problems typically have DEF_{ratio} values less than 2.5, irrespective of the load transfer efficiency (LTE) at the joints. Slabs with severe D-cracking typically had DEF_{ratio} values greater than 5.

Even though the findings from that study were based on very limited data from two airports, the potential use of the technique as a nondestructive tool for effectively detecting D-cracking was promising. With the availability of more data from six major airfields, the DEF_{ratio} technique was investigated further in this study. Deflection data from 568 slabs randomly selected from pavements at the six airports were used in this study.

DESCRIPTION OF PAVEMENT SECTIONS USED IN STUDY

Concrete pavement sections with D-cracking and sound concrete (without D-cracking) were selected from six major airfields in the United States. The PCC thickness for all pavement sections ranged from 356 to 559 mm (14 to 22 in). The size of PCC slabs in the pavement sections was 7.6 by 7.6 m (25 by 25 ft).

Sections with Sound Concrete

Pavement sections with sound PCC were selected from four airfields: O'Hare International Airport in Illinois, Dayton International Airport in Ohio, Raleigh-Durham International Airport in North Carolina, and Louisville International Airport in Kentucky. A total of 420 sound PCC slabs were selected from these airports. Details on the pavement sections, construction dates, and typical pavement structures are presented in table 2.

Sections with D-Cracking Problems

Pavement sections with D-cracking problems were available from two airfields: Forbes Field in Topeka, Kansas, and the McConnell Air Force Base (AFB) in Kansas. A total of 148 PCC slabs with D-cracking problems were selected from these airports. Details on the pavement sections, construction dates, test dates, and typical pavement structures are presented in table 3. The cores taken from these sections suggest that the D-cracking may have started at surface.

NONDESTRUCTIVE TESTING AND CORING

All the data used in this study were obtained from previous studies conducted by ERES Consultants, Inc. for the aforementioned airports (4, 5, 6, 7, 8, 9). The authors actively participated in most of these projects and are therefore familiar with the procedures used for data collection and the quality of data.

Pavement deflection data were collected at the joints (at midslab in the main gear path) and center of the PCC slabs using a heavy weight FWD, as shown in figures 1 and 2. The heavy weight FWD is an impulse loading device that exerts a force similar in magnitude and duration to that produced by a moving aircraft tire load. Three target load magnitudes of 133, 222, and 290 kN (30, 50, and 65 kips) were applied to the pavements at each test location. The target loads were selected to cover the range of single wheel loads of expected operational aircraft at the airfields. NDT was conducted when the pavement surface temperature was between 21 and 32 °C (70 and 90 °F).

Cores were taken for visual inspection to confirm the condition of the PCC (with and without D-cracking) in each pavement section . Because D-cracking begins at and is most severe along cracks, joints, and edges of pavements, where water infiltrates into the pavement, the cores were taken at these locations. In some cases, laboratory strength tests were performed on cores from midslab to confirm the soundness of the concrete in the pavement sections without D-cracking. Average flexural beam strength (ASTM C78) for the pavement sections without D-cracking ranged from 4,410 to 5,512 kPa (640 to 800 psi).

NDT DATA ANALYSIS

NDT data have been used in the past to assess the structural integrity of pavements. The objective of the data analysis in this study was to validate a procedure based on NDT data for early detection of D-cracking in concrete pavements. This involves the use of the ratio of the normalized deflection at the slab joint, edge, or crack to the deflection at the slab center. The ratio is designed to highlight the deterioration of the PCC due to D-cracking at the joints, cracks, and edges of slabs. Because D-cracking always starts at these locations, deflections obtained for PCC with D-cracking are expected to be higher than those for a similar concrete pavement with sound PCC. Also, because the deflections at the edges are theoretically higher than at the slab center, the DEF_{ratio} is expected to be greater than 1.

The DEF_{ratio} is computed as follows:

$$DEF_{ratio} = \frac{DEF_{joint}}{DEF_{center}} \quad (1)$$

where:

DEF_{ratio} = Ratio of deflections from slab edge and center of slab tests.

DEF_{joint} = Normalized maximum deflection under the FWD load plate from the slab edge (in the wheel path, at midslab).

DEF_{center} = Normalized maximum deflection under the FWD load plate from the slab center.

Using equation 1, the DEF_{ratio} values were computed for the 420 sound PCC slabs tested, as well as for the 148 PCC slabs with D-cracking. Due to the influence of load transfer on deflections at slab joints, LTE was computed for each DEF_{ratio} to assess the influence of LTE on DEF_{ratio}. The LTE was computed as the ratio of the unloaded slab's deflection to that of the loaded slab's deflection. In general, LTE greater than 75 percent is considered good for long-term performance, and LTE less than 50 percent translates to little reduction in free edge stress and is therefore considered poor (10). It is important to assess the in-situ load transfer for design purposes, as it is a key factor that influences the deflections obtained from the slab edge.

A plot of DEF_{ratio} versus LTE values for pavements with and without D-cracking is shown in figure 3. As can be seen in figure 3, there is a significant difference in DEF_{ratio} values for sound PCC and PCC with D-cracking. All the DEF_{ratio} values for sound PCC (with no D-cracking) are consistently less than 3, irrespective of other pavement properties and features such as PCC thickness, subgrade type, and load transfer. The figure also shows that 92 percent of the slabs (136 slabs) in the pavement sections with D-cracking have DEF_{ratio} values greater than 3. For the slabs with sound PCC, the DEF_{ratio} values approach 3 as LTE decreases, and there is a suggestion of a strong linear relationship between LTE and DEF_{ratio}.

STATISTICAL ANALYSIS

To further validate the initial results obtained from figure 3, statistical analyses were conducted to determine and establish a criterion for using the DEF_{ratio} to detect D-cracking in concrete pavement. This involved statistical comparative testing of DEF_{ratio} values to investigate whether a significant difference exists in the DEF_{ratio} values for slabs with sound PCC and slabs with D-cracking. Significant differences in DEF_{ratio} values are necessary to detect D-cracking effectively.

Using the statistical software SAS, a simple t-test and a multiple comparison of means test were used to compare the DEF_{ratio} values (11, 12). The software was also used to develop a regression model that defines the maximum DEF_{ratio} value for slabs with sound PCC.

Comparison of DEF_{ratio} Values

The t- and multiple comparison of means tests were used to compare DEF_{ratio} values, to investigate whether a significant difference exists between the DEF_{ratio} values for pavements with D-cracking and pavements with sound PCC. The primary considerations in the analysis were as follows:

- Perform a t-test to determine if there is a significant difference in DEF_{ratio} values for pavement with and without D-cracking.
- Conduct a multiple comparison of means test to investigate the magnitude of the difference between the mean DEF_{ratio} values for pavements with different design characteristics and site conditions.

The data used in the data analysis consisted of pavements with various design and material properties. These pavements are located in different airports in the United States with varying environmental conditions. The pavement sections with no D-cracking were designated as "N," and pavement sections with D-cracking were designated as "Y." In this experiment, differences are expected in DEF_{ratio} values for different pavement sections with varying design, materials, and environmental conditions, but the test of interest is to determine if there is a difference in the DEF_{ratio} values of pavement sections with or without D-cracking.

The t-test makes a precise comparison of the two different means in the presence of other possible sources of variability. The hypotheses tested in this study were as follows:

Null hypothesis H_0: $DEF_{ratio,y} - DEF_{ratio,n} = 0$

Alternate hypothesis H_A: $DEF_{ratio,y} - DEF_{ratio,n} \neq 0$

A significance level of 5 percent (Prob> |T| = 0.05) was used in the analysis. Therefore, the null hypothesis that $DEF_{ratio,y}$ and $DEF_{ratio,n}$ come from the same population and are not statistically different will be rejected if the t-test is significant at a level of less than 0.05.

Figure 4 presents a summary of the t-test results from SAS. Even though there is strong evidence that the variances for the two populations are not equal (an assumption necessary for a t-test), the results still show a level of significance less than 0.0001 (Prob> |T| = 0.0001) using Satterthwaite's approximation for a t-test of two populations with unequal variances (12). Based on the results in the figure, the null hypothesis is rejected, indicating that the DEF_{ratio} values for sound PCC slabs are significantly different from PCC slabs with D-cracking.

Scheffe's multiple comparison of means test was used to investigate further the magnitude of the difference between the DEF_{ratio} values for pavement sections with D-cracking and those without D-cracking, given that the pavements come from different airports with different pavement characteristics and site conditions (such as environmental conditions, design features, and material properties). A summary of Scheffe's multiple comparison of means test results is shown in figure 5. The results in the figure shows that, even with the different pavement characteristics and site conditions taken into account, DEF_{ratio} values can be used to distinguish sound PCC slabs from PCC slabs with D-cracking.

Critical Limit of DEF_{ratio} for Sound PCC

Figure 3 shows increasing DEF_{ratio} values with decreasing LTE. The LTE values for sound PCC range from 17 to 99 percent. Because the LTE values in the experiment did not cover the full range (i.e., 0 to 100 percent), a linear regression model was developed with DEF_{ratio} and LTE as the dependent and independent variables, respectively, to define the maximum DEF_{ratio} value for slabs with sound PCC. The model was developed for sound PCC using data from the 420 tested slabs. The model obtained with a coefficient of determination, R^2, of 63 percent is as follows:

$$DEF_{ratio} = 2.9565 - 0.0186 *(LTE) \quad (2)$$

From equation (2), an LTE of 0 percent results in a DEF_{ratio} estimate of approximately 3, and for LTE of 100 percent, DEF_{ratio} is approximately 1. This finding is consistent with the field data for sound PCC in figure 3. It can be concluded that for sound PCC, DEF_{ratio} values will always be less than 3, even for the worst LTE case of 0 percent. This indicates conclusively that DEF_{ratio} values greater than 3 indicate potential D-cracking problems.

EARLY DETECTION

The potential of the DEF_{ratio} technique to highlight D-cracking even before it appears on the surface is demonstrated using results from a network-level evaluation of D-cracking problems at Dayton International Airport. The results presented in this paper are for four JPCP—three runways (Runways 6L-24R, 6R-24L, and 18-36) and one apron (FEDEX Apron)—that have coring information for verification. The cores from these sections suggest that the D-cracking may have started from the bottom of the PCC layer. As can be seen in table 4, the pavement in the FEDEX Apron was divided into two sections, 04 and 05 to distinguish between doweled and keyed joints.

Average DEF_{ratio} values were computed for each section. A summary of the average DEF_{ratio} values, coring, and results of visual inspection of the pavement surface with respect to D-cracking is presented in table 4. Although the results from visual inspection for Section 05 of the FEDEX Apron indicate that no D-cracking is present, this is not consistent with the coring results for the joints. Moreover, the DEF_{ratio} value of 2.6 indicates that the PCC in this section is showing early signs of D-cracking and has potential durability problems. This demonstrates the need for DEF_{ratio} data to supplement D-cracking information from visual inspections.

The above findings indicate that the DEF_{ratio} technique has great potential for early detection of D-cracking even before it appears on pavement surfaces.

SUMMARY OF FINDINGS AND CONCLUSIONS

The nondestructive technique presented in this paper for evaluating D-cracking in concrete pavement has been shown to be simple, efficient, and economical. The technique involves the use of the ratio of the normalized deflection at the slab joint, edge, or crack (where D-cracking always starts) to the slab center, DEF_{ratio}. The DEF_{ratio} values have been found to highlight the deterioration in PCC due to D-cracking, distinguishing clearly between sound PCC and PCC with D-cracking. It is conclusive from the results in this paper that for sound PCC, DEF_{ratio} values will always be less than 3, even for the worst LTE case of 0 percent. DEF_{ratio} values substantially greater than 3 indicate potential D-cracking problems.

The DEF_{ratio} technique has the potential for early detection, assessment, and monitoring of D-cracking in airfield pavements with widespread D-cracking using routinely collected NDT data.

Tables

Table 1. Ratio of deflections results from previous study.
Table 2. Typical pavement structures for pavement sections with sound PCC.
Table 3. Typical pavement structures for pavement sections with D-cracking problem.
Table 4. Summary of results for network-level evaluation of D-cracking at Dayton.

Figures

Figure 1. A concrete pavement with severe D-cracking.
Figure 2. Typical nondestructive testing and coring locations on PCC slabs.
Figure 3. A plot of DEF_{ratio} versus LTE.
Figure 4. Summary of t-test results for comparing DEF_{ratio} values.
Figure 5. Summary of Scheffe's Multiple Range Test results for comparing DEF_{ratio} values.

Table 1. Ratio of deflection results from the previous study (2).

Site	N	DEF_{ratio}		LTE, %		
		Mean	COV, %	Mean	COV, %	Comments
Test Site A	8	1.59	16	72	14	Rehabilitated pavement
Test Site B	16	2.42	15	38	34	Rehabilitated pavement
Dayton	25	1.3	21	88	4	Section with sound PCC
Forbes Field	20	>5*	-	70	50	Section with D-cracking

Notes
COV denotes coefficient of variation.
N denotes number of slabs tested.
* Represents results for severe D-cracking sections only.

Table 2. Typical pavement structures for pavement sections with sound PCC.

Airfield	Number of slabs tested (facilities tested)	Typical structure	Year	
			Constructed	Tested
O'Hare International Airport	42 (TWs E and G)	533 mm JPCP 203 mm CTB 152 mm AS	1994	1994
Dayton International Airport	7 (RW 6L-24R)	406 mm JPCP 254 mm CTB 254 mm subbase	1989	1995
	4 (RW 18-36)	356 mm JPCP 254 mm CTB 229 mm subbase	1988	1995
	16 (TW W, section 01)	256 mm JPCP 203 mm CTB 152 mm subbase	1981	1995
	12 (TW W, section 02)	356 mm JPCP 254 mm CTB 152 mm subbase	1981	1995
Raleigh-Durham International Airport	181 (RW 5L-23R, TW E, TW B, and TWs B1 through B9)	406 mm JPCP 140 mm AC	1987	1994
	15 (TWs F1 and F2)		1990	1995
Louisville International Airport	143 (RW 17L-35R, TW D, TW E, TW E4, TWs D1 through D5)	432 mm JPCP 152 mm CTB 305 mm AS 610 mm CC	1994	1994

Notes
1. JPCP denotes jointed plain concrete pavement.
2. CTB denotes cement-treated base.
3. AS denotes aggregate subbase.
4. CC denotes crushed PCC.
5. RW denotes Runway.
6. TW(s) denotes Taxiway(s).

Table 3. Typical pavement structures for pavement sections with D-cracking problem.

Airfield	Number of slabs tested (facility tested)	Typical structure	Year	
			Constructed	Tested
Forbes Field	50 (RW 13-31)	76 mm AC 560 mm JPCP	1959	1992
McConnell AFB	143 (Northeast aircraft parking apron)	432 mm JPCP 229 mm Sand	1951	1984

Notes
1. JPCP denotes jointed plain concrete pavement.
2. AC denotes asphalt concrete.
3. RW denotes Runway.

Table 4. Summary of results for network-level evaluation of D-cracking at Dayton.

Facility	Section	Average DEF_{ratio}	Coring information		Is D-cracking present?	
			location	PCC condition	Cores	Pavement surface
Runway 6L-24R	01	1.2	Joint and Midslab	Excellent	No	No
Runway 6R-24L	02	1.1	Joint and Midslab	Excellent	No	No
Runway 18-36	03	1.1	Joint and Midslab	Excellent	No	No
FEDEX Apron	04 (Doweled joints)	3.2	Joint	Very poor	Yes	Yes
			Midslab	Excellent	No	No
	05 (Keyed joints)	2.6	Joint	Poor	Yes	No
			Midslab	Excellent	No	No

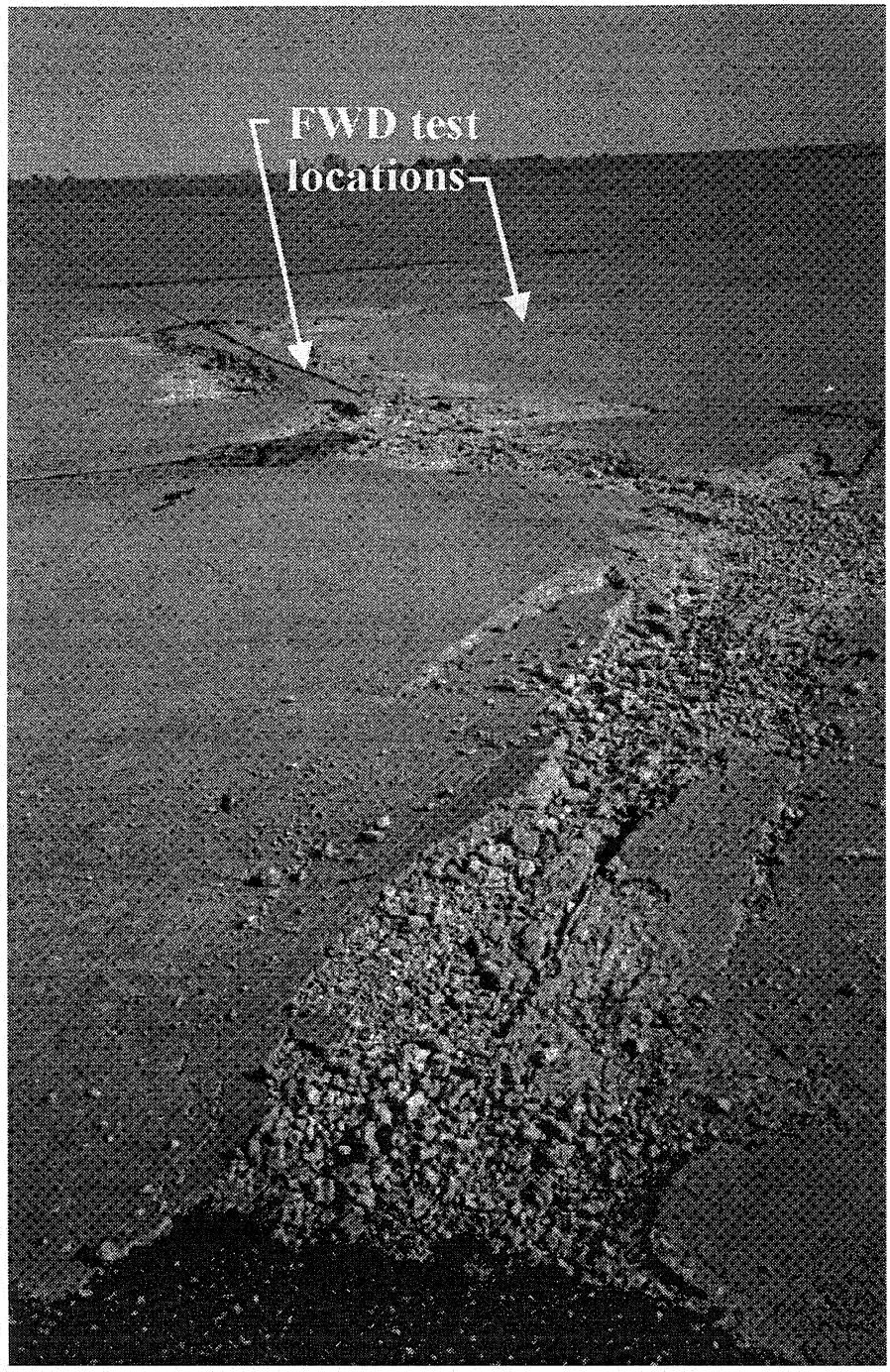


Figure 1. A concrete pavement with severe D-cracking.

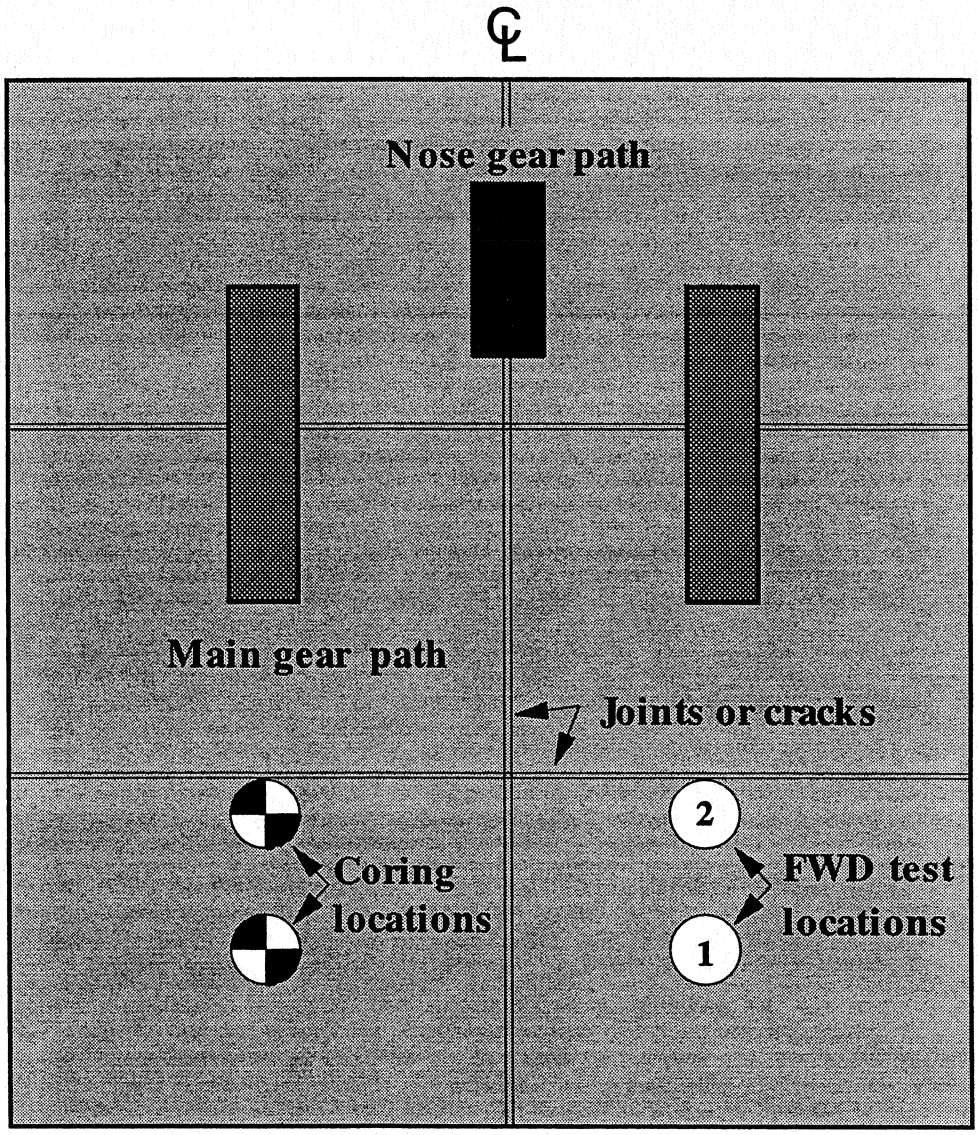


Figure 2. Typical FWD test and coring locations on PCC slabs.

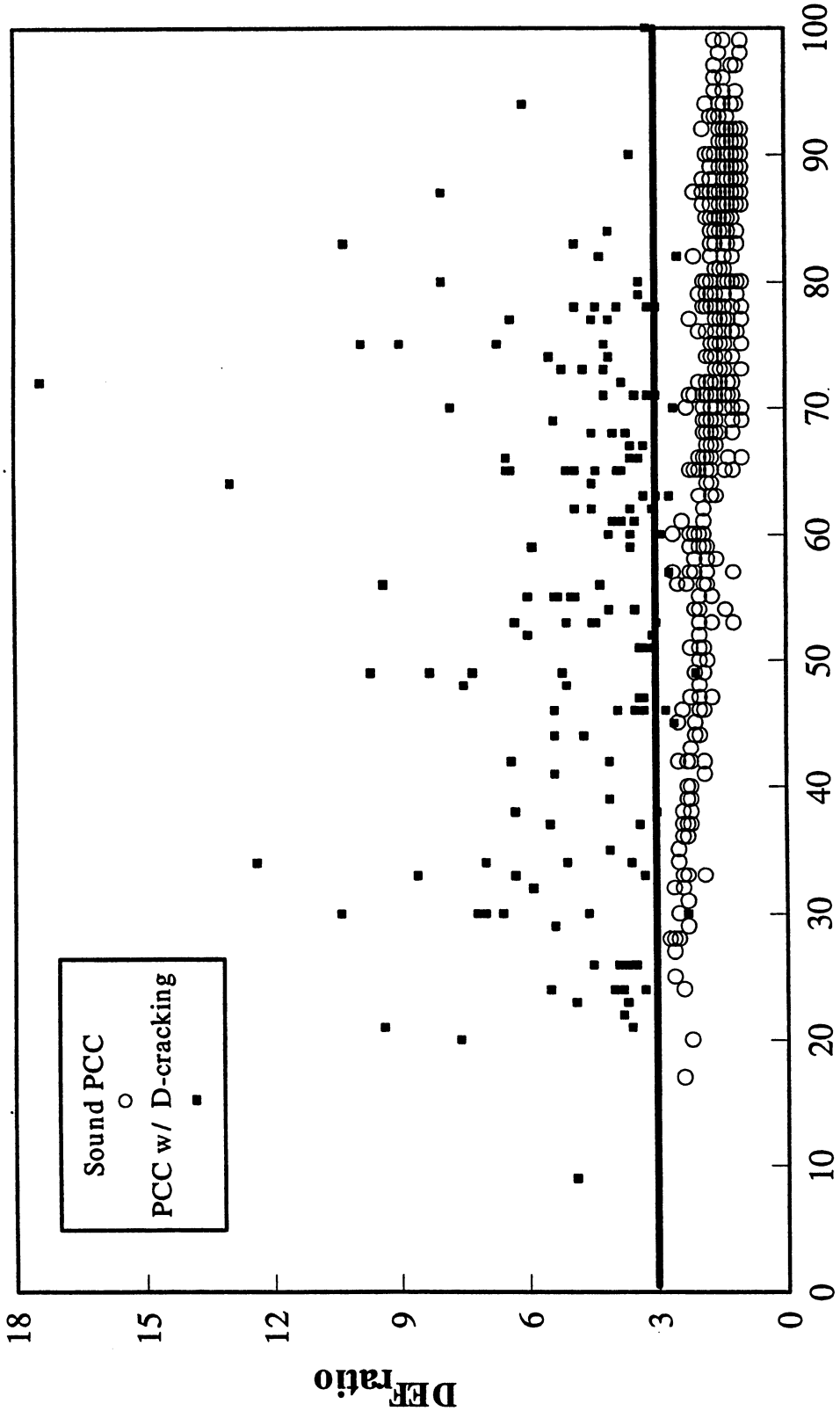


Figure 3. A plot of DEF_{ratio} versus LTE.

T-Test Procedure

Variable: DEF_{ratio}

D-cracking	N	Mean	Std Dev	Std Error	Variances	T	DF	Prob>|T|
No	420	1.62	0.41	0.0198	**Unequal**	**-18.1975**	**150.4**	**0.0001**
Yes	148	4.97	2.23	0.1831	Equal	-29.5204	566.0	0.00001

For H0: Variances are equal, F' = 30.16 DF = (147,419) Prob>F' = 0.00001

Figure 4. Summary of t-test results for comparing DEF_{ratio} values.

Analysis of variance procedure

Dependent Variable: DEF_{ratio}

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1247.17447684	249.43489537	179.89	0.0001
Error	562	779.26592809	1.38659418		
Corrected Total	567	2026.44040493			

R-Square	C.V.	Root MSE	DEF Mean
0.615451	47.23788	1.17753734	2.49278169

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Airport	5	1247.17447684	249.43489537	179.89	0.0001

Scheffe's test for variable: DEF_{ratio}

Alpha= 0.05 df= 562 MSE= 1.386594 Critical Value of F= 2.23006

Means with the same letter are not significantly different.

Scheffe Grouping	Mean	N	Airport
A	5.0720	50	Forbes Field
A	4.9184	98	McConnell AFB
B	1.8250	196	Raleigh-Durham
B	1.5905	42	O'Hare
B	1.4483	143	Louisville
B	1.2487	39	Dayton

Figure 5. Summary of Scheffe's Multiple Range Test results for comparing DEF_{ratio} values.

REFERENCES

1. Schwartz, R. D., "D-Cracking of Concrete Pavements". National Cooperative Highway Research Program Report 134. *Transportation Research Record,* National Research Council, Washington, D.C., October 1987.

2. McGhee, K. H., *NCHRP Synthesis 211: Design, Construction, and Maintenance of PCC Pavement Joints. Transportation Research Record,* National Research Council, Washington, D.C., 1995.

3. Kumapley, R.K. and E.B. Owusu-Antwi, "Performance of a Rehabilitated D-Cracked Jointed Plain Concrete Airfield Pavement," Paper No. 970750 accepted for publication in the *Transportation Research Record,* TRB, National Research Council, Washington, D.C., January 1997.

4. ERES Consultants, Inc., *Evaluation of New Portland Cement Concrete Pavement in Taxiways E and G at Chicago's O'Hare International Airport.* Final Report for Howard Needles Tammen and Bergendoff (HNTB), Chicago, Illinois, January 1995.

5. Kumapley, R.K. and W.J. Seiler, *Airport Pavement Evaluation and Management Study, Volume II. Project Level Pavement Evaluation Results.* Final Report submitted to the City of Dayton, Department of Aviation, Dayton International Airport, Vandalia, Ohio, ERES Consultants, Inc., May 1996.

6. ERES Consultants, Inc., *Evaluation of Airside Pavement at Raleigh-Durham International Airport, Morrisville, North Carolina.* Final Report for the Raleigh-Durham Airport Authority, RDU Airport, North Carolina, March 1995.

7. ERES Consultants, Inc., *Evaluation of New Portland Cement Concrete Pavement at Louisville International Airport.* Final Report for Howard Needles Tammen and Bergendoff (HNTB), Louisville, Kentucky, November 1994.

8. ERES Consultants, Inc., *Airport Pavement Evaluation, Runway 13-31, Forbes Field, Topeka, Kansas.* Final Report for Bartlett & West Engineers, Inc., Topeka, Kansas, February 1993.

9. ERES Consultants, Inc., *Pavement Systems Evaluation, Overlay Aircraft Parking Apron, McConnell AFB,Contract No. DACA 45-84-C-0151.* Wichita, Kansas, November 1984.

10. ERES Consultants, Inc., *AASHTO Design Procedures For New Pavements: Participant's Manual.* NHI Course No. 13128, FHWA-HI-94-023, National Highway Institute, Washington, D.C., February 1995.

11. SAS Institute Inc., SAS system version 6. SAS Institute, Cary, North Carolina, 1991.

12. SAS Institute Inc., *SAS User's Guide: Statistics Version 5 Edition.* SAS Institute, Cary, North Carolina, 1991.

ACKNOWLEDGMENT

The authors wish to express their appreciation to ERES Consultants, Inc. and the airport authorities at O'Hare International Airport, Dayton International Airport, Raleigh-Durham International Airport, Louisville International Airport, Forbes Fiel, and the McConnell Air Force Base for assisting with this study. The opinions and conclusions expressed in this paper are those of the authors and in no way reflect those of any of the aforementioned agencies.