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RUNWAY FRICTION MEASUREMENTS AND PAVEMENT CONDITION
SURVEY, NPTC EL CENTRO, CALIFORNIA, by

author:

R. B. BROWNIE,

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Port Hueneme, California 93043

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Runway Friction Measurements and Pavement Condition Survey,
NPTR El Centro, California

Technical Memorandum TM 76-53-6

by

R. B. Brownie

ABSTRACT

The results of friction tests and condition surveys on the active runways at the National Parachute Test Range, El Centro, California are presented. The survey established statistically-based condition numbers (weighted defect densities) which were direct indicators of the condition of the individual pavement facilities. The runway friction measurements showed the aircraft hydroplaning/skidding potential of the field. The results of the survey showed that in June 1976 the asphaltic concrete of Runways 8L-26R and 8R-26L had deteriorated since the 1969 condition survey. Portland cement concrete portions of Runway 8L-26R had slightly fewer defects where maintenance had been performed. Runway 12L-30R showed a substantial reduction in the number of defects due to the recent completion of a repair project. Runway friction measurements showed a high or some potential for aircraft to hydroplane. This was attributed to lack of surface texture. All asphaltic concrete pavement areas gave satisfactory friction coefficients.

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INTRODUCTION

In October 1969, the Naval Facilities Engineering Command authorized a series of periodic pavement condition surveys to be conducted at Naval and Marine Corps air stations. The purpose of this condition survey task is to quantitatively survey pavement defects, conduct runway friction measurements, supply information to the station for generation of repair projects, and establish a uniform basis for maintenance and repair efforts. A condition survey was made at the National Parachute Test Range (then the Naval Air Facility), El Centro, California by NCEL* in December 1969 (Reference 1).

A new survey of pavement condition and of runway friction measurements was completed by CEL in June 1976. For this new survey, only the active runways were evaluated. The survey consisted of a sophisticated, statistically-based procedure of pavement defect measurement which permitted the establishment of condition numbers (weighted defect densities) that are direct indicators of the condition of airfield pavement facilities. Runway friction measurements were made using a Mu-Meter, a small friction-measuring trailer. Additional survey efforts included photographic coverage of pavement defect types, preparation of a construction history of the airfield, compilation of current aircraft traffic data, summarization of climatological data, and delineation of requirements for further pavement evaluation efforts at the station.

SCOPE AND UTILIZATION

This report discloses the quantities of defects observed and assigns numbers (severity weights) to these defect measurements that reflect the importance of the defects to operational safety and anticipated maintenance effort. These numbers can be used by station forces for input to determine priorities and scheduling of maintenance and repair efforts; the higher the total weighted defect density, the more severe the pavement defects. Other inputs to the decision-making process - - operational requirements, funding levels, and specific repair procedures - - are beyond the scope of this study.

STATION BACKGROUND

The National Parachute Test Range, El Centro, is located in Imperial County, five miles west of El Centro, California, at an elevation of 43 feet below sea level. The airfield has three active runways, and two inactive runways (03-21 and 12 R-30L). The latter are used occasionally for taxiing and parking aircraft. Of the active runways, 8L-26R is 9,600 feet long, 8R-26L is 5,000 feet long, and 12L-30R is 6,900 feet long. The major portion of aircraft traffic (approximately 85 percent) is carried

*On 1 January 1974, redesignated the Civil Engineering Laboratory (CEL) of the Naval Construction Battalion Center, Port Hueneme, California

on Runway 8L-26R. Runway 12L-30R is used for crosswind conditions and Runway 8R-26L is rarely used. The principle missions of NPTR El Centro are to provide a base of operations for parachute and aerospace recovery testing, to provide gunnery and bombing training, to provide simulated carrier landing practice, and to provide a winter training facility for the Navy Flight Demonstration Team, the Blue Angels.

CONSTRUCTION HISTORY

Runways 12R-30L, 3-21, and a portion of Parking Apron 1 were constructed in 1943. Runways 8L-26R, 8R-26L, and 12L-30R were constructed in 1945. Also, in 1945, Runways 12R-30L and 3-21 were overlaid. During the ensuing years since original construction, extension and strengthening of the runways and taxiways has been accomplished, along with the addition of taxiways and parking aprons. A complete history of construction and recorded maintenance is provided in Appendix A.

CURRENT AIRCRAFT TRAFFIC

A tabulation of the number of aircraft operations for a 12 month period is shown in Table 1. Table 2 lists the aircraft normally based at the station and transient aircraft observed using the station.

CLIMATOLOGICAL DATA

A summary of climatological data for NPTR El Centro is presented in Appendix B.

PAVEMENT CONDITION SURVEY

Condition Survey Procedure

The condition procedure used at NPTR El Centro was developed by CEL in 1968. This procedure permits the establishment of condition numbers (weighted defect densities) which are direct indicators of the pavement surface condition. A complete description of the pavement condition survey procedure is presented in Appendix C. It should be noted that Appendix C describes procedures for both asphaltic concrete (AC) and portland cement concrete (PCC) pavements, and includes other pavement facilities in addition to runways. At NPTR El Centro, only the runways were surveyed. Discrete areas were selected after a preliminary inspection of the runways. The locations of the discrete areas are shown in Figure 1. Defect severity weights as used at NPTR El Centro are given in Table 3.

Results of Condition Survey

The results of the survey of each discrete area are shown in the

Discrete Area Defect Summary sheets, pages 29 through 34 of this report. Each Discrete Area Defect Summary includes a narrative description of the pavement defects encountered. In addition, photographs of typical pavement conditions noted during the survey can be seen in Figures 2 through 5. Facility Defect Summaries are shown on pages 35 through 36. Total weighted defect densities for asphaltic concrete pavements range from 20.36A for discrete area R8L-2 to 29.44A for discrete area R8R-1. For portland cement concrete area, total weighted defect densities ranged from 0.14C for discrete area R12L-2 to 4.87C for discrete area R8L-3.

RUNWAY FRICTION MEASUREMENTS

The skid resistance/hydroplaning characteristics of the runway surfaces were evaluated with a Mu-Meter friction measuring device. The test program consisted of field measurements of skid resistance/hydroplaning potential under standardized, artificially-wet conditions. In addition, both transverse and longitudinal pavement slopes were measured at intervals along each runway centerline to evaluate surface drainage characteristics.

Test Locations

Test sections on each runway were selected to provide a representative sample of the skid resistance properties of each runway. The test section layout is shown in Figure 6. The test sections were selected to provide pavement friction data in: (a) the aircraft touchdown areas, and (b) the runway interior where maximum braking is normally developed. No friction tests were made on Runway 8R-26L as it is rarely used.

Test Equipment

The principal items of test equipment used were the Mu-Meter, a tank truck for water application, and a device for measuring pavement slopes.

The Mu-Meter is a small trailer, designed and manufactured by M. L. Aviation of Maidenhead, England. It measures the side-force friction coefficient generated between the pavement surface and the pneumatic tires on the two wheels which are set at a fixed tow-out (yaw angle) to the line of drag. The Mu-Meter is a continuous recording device that graphically records the coefficient of friction, μ^* , versus the distance traveled along the pavement.

The water truck provided by the station was a runway foamer with a spray nozzle and pumping system calibrated to place 0.1-inch of water on the skid test strip with each pass.

The slope measuring device consisted of a rectangular aluminum section (10 feet long, 1 inch thick, and 4 inches high) with machinists' levels attached to define slope from 0 to 2.5 percent.

* The symbol μ or μ designates the coefficient of friction which is a constant used to represent the ratio of frictional force to force normal to the pavement surface.

Test Procedures

The field test procedures utilized at NPTR El Centro are those outlined in NAVFAC INSTRUCTION 11132.14B. The methods were:

(1) A preliminary reconnaissance of the pavement surfaces was made and representative test areas (each 1000 feet long) were selected for skid testing.

(2) Transverse and longitudinal slope measurements were made at 500-foot intervals along the runway centerline. Transverse measurements were made at two places on each side of the centerline covering a distance of approximately 20 feet. Longitudinal measurements were made on the centerline at the same stations where the transverse measurements were made.

(3) The water truck, which had been calibrated to apply 0.1-inch of water each time it passed over a test strip, made two passes over the test strip.

(4) Mu-Meter runs at 40 miles per hour, 1.2 times the theoretical hydroplaning speed for this vehicle, were initiated immediately after completion of the second water truck pass. Mu-Meter runs were made in alternate directions at convenient time intervals until a dry pavement condition was reached or 30 minutes had elapsed.

(5) All water truck and Mu-Meter operations were measured to the nearest second using a stop watch.

Runway Friction Test Results

The pavement skid resistance results are reported in terms of μ , coefficient of friction, as measured by the Mu-Meter. The actual friction coefficient versus distance traces as recorded by the Mu-Meter during the first run after wetting for each test section are shown in Figures 7 through 10. The traces show the variation of friction coefficient within each test section. Appendix D contains all test results for each Mu-Meter test section.

Figures 11 through 14 show changes in surface friction coefficient versus time after wetting for each pavement section tested. (Note that the time intervals after wetting at which skid tests were made often differed from one test to another, due to small variations in water truck speed and Mu-Meter adjustments.) These graphs demonstrate the natural drainage characteristics of the runway surface and the time required to return to an essentially dry condition or a consistently high friction coefficient.

A summary of test data and an associated Mu-Meter aircraft pavement rating guide are presented in Tables 4 and 5. The rating guide was developed from the results of an Air Force Weapons Laboratory research program and a joint NASA/AF/FAA test program using actual aircraft correlated with Mu-Meter skid coefficient results. While the current state-of-the-art does not allow a more precise delineation of exact aircraft responses,

the rating guide provides a good rule-of-thumb for interpretation of test data.

Table 4 presents the average skid resistance values for each skid test section. From the curves presented in Figures 11 through 14, values of μ were determined for time periods of 3, 15 and 30 minutes after water was applied. The coefficient determined at 3 minutes after water application corresponds to a wet runway condition, and the coefficient determined at 15 minutes after water application corresponds to a damp runway condition. At 30 minutes after wetting, the friction coefficient can be considered a dry pavement condition. The curves in Figures 11 through 14 were extrapolated, if necessary, to obtain friction coefficients at those time intervals. These data indicate the rate at which the pavement skid resistance properties were recovered after the test sections were wetted. By comparing the actual values of μ shown in Table 4 with the expected aircraft response in the associated rating guide, Table 5, it is possible to evaluate aircraft hydroplaning potential.

Measured pavement slopes are shown in Table 6. Positive transverse slopes indicate water drains to the runway edge without crossing the centerline, while negative transverse slopes indicate drainage crosses the runway centerline before draining to the edge. Positive longitudinal slopes indicate rising pavement grades in the direction of increasing runway stations while negative longitudinal slopes indicate falling grades in the direction of increasing stations.

DISCUSSION OF RESULTS

Condition Survey Results

Quantitative changes in each defect type for each discrete area are summarized in Table 7. Locations of discrete areas are shown in Figure 1 and the numbering of discrete areas is described in Appendix C. Each discrete area and possible causes of changes in defect quantities are discussed in the following paragraphs.

Runway 8R-26L.

R8R-1: The substantial increase in pattern cracking is attributed to continued aging of the pavement surface. Many of the cracks tallied as longitudinal cracks in 1969 are now included in pattern cracking.

Runway 8L-26R.

R8L-1: The largest change in defect quantities since 1969 was defective joint seal. This is typical of deterioration and oxidation of joint seal which is 17 years old.

R8L-2: This area was overlaid with 2 inches of asphaltic concrete in 1970, shortly after the 1969 condition survey. Substantially the same amount of cracking was tallied in 1976 as in 1969 in spite of this overlay. In addition, the overlay had a large amount of raveling tallied in 1976. The raveling is probably caused by insufficient asphalt or poor compaction of the overlay.

R8L-3: Spall repairs and selective joint sealing in 1973 reduced

the numbers of spalls and joint seal defects. The large number of slabs (38 percent) with transverse cracks is unchanged since 1969.

Runway 12L-30R.

R12L-1: A repair project was completed on this section just before this condition survey. This project accounts for the drastic reduction in spalls and defective joint seal. As in discrete area R8L-3, the large number of transverse cracks is essentially unchanged confirming that these cracks occurred shortly after construction as a result of defective load transfer devices (Reference 3).

R12L-2: During this survey, a few defects were observed on this small area as compared to no defects in 1969. The pavement was constructed in 1969, accounting for the zero defects at that time.

Runway Friction Test Results

The three-minute μ values given in Table 4 show that all test sections located on portland cement concrete demonstrated high or some potential for aircraft to hydroplane. The primary reason for the low friction values is lack of surface texture. Test Section 2 on Runway 12L-30R in the runway interior had a lower friction coefficient than the heavily rubber-coated end of Runway 8L-26R. Texture measurements made using procedures developed by NASA and described in Reference 2 gave surface texture depths of 0.003 to 0.007 inches. A surface texture depth of 0.050 inches or greater is recommended in Reference 2.

Asphaltic concrete areas gave satisfactory friction coefficients in all cases.

RECOMMENDATIONS

It is recommended that consideration be given to correcting the lack of surface texture in the portland cement concrete areas by grooving. The cost of grooving must be weighed against the infrequent occurrence of rainfall at NPTR El Centro. It is unlikely that removing rubber from Runway 8L-26R will give that runway satisfactory frictional resistance due the lack of surface texture on the underlying pavement.

Extensive repairs planned for completion on Runway 8L-26R in summer 1976, and repairs completed in June 1976 on Runway 12L-30R preclude the necessity for repair recommendations for these facilities at this time.

RECOMMENDATION FOR FURTHER EVALUATION EFFORTS

A complete evaluation of all pavements at NPTR El Centro was made by CEL in 1966 (Reference 3). Since that evaluation many pavement repairs have been made. However, no repairs that would substantially alter the pavement load ratings reported in Reference 3 have been performed. Therefore, no further load-type evaluation is recommended at this time.

REFERENCES

1. Naval Civil Engineering Laboratory. Technical Note N-1103, "Airfield Pavement Condition Survey, USNAF El Centro, California", by D. J. Lambiotte and L. J. Woloszynski. Port Hueneme, California, May 1970.
2. Federal Aviation Administration. Advisory Circular AC No. 150/5320-12, "Methods for the Design, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces." Washington, D.C.. June 1975.
3. Naval Civil Engineering Laboratory. Technical Note N-867, "Airfield Pavement Evaluation, USNAF El Centro, California", by R. J. Lowe and W. H. Chamberlin. Port Hueneme, California, December 1966.

TABLE 1. AIRCRAFT OPERATIONS DATA
NPTR EL CENTRO, CALIFORNIA

DATE	LANDINGS AND TAKEOFFS
May 1975	13,862
June	11,826
July	9,262
August	5,009
September	6,205
October	7,176
November	12,627
December	5,192
January 1976	17,563
February	8,667
March	13,426
April	10,368
Total operations for above 1-year period	121,183
Average monthly operations	10,099

TABLE 2. AIRCRAFT USING NPTR
EL CENTRO, CALIFORNIA

Aircraft based at NPTR El Centro	A3, A4, F4, C1, C47, T28
Other aircraft using NPTR El Centro	A6, A7, F8, F14, C9, C5, C130, C131, C141, T39, E1, E2, OV10, S2, S3, P-2, P-3

Note: Most operations at NPTR El Centro are by
aircraft attached to squadrons on temporary
duty for gunnery and bombing practice

TABLE 3. DEFECT SEVERITY WEIGHTS
AIRFIELD: NPTR EL CENTRO, CALIFORNIA

Asphaltic Concrete		Portland Cement Concrete	
<u>Defect</u>	<u>Weight</u>	<u>Defect</u>	<u>Weight</u>
Depression	9.0	Depression	9.0
Rutting	9.0	Shattered Slab	9.0
Broken-up Area	9.0	Faulting	8.5
Faulting	8.5	Spalling	7.5
Raveling	7.0	Scaling	7.0
Erosion-Jet Blast	7.5	"D-Line" Cracking	7.0
Longitudinal, Transverse, or Longitudinal Construction Joint Crack	3.5	Pumping	4.0
Pattern Cracking	3.5	Poor Joint Seal	3.5
Patching	3.5	Corner Break	3.5
Reflection Crack	2.0	Intersecting Crack	3.5
Oil Spillage	1.5	Longitudinal or Transverse Crack	3.5

TABLE 4. RUNWAY FRICTION MEASUREMENT SUMMARY
NPTR EL CENTRO, CALIFORNIA

Test Location	Average Friction Coefficients		
	3 min (Mu)	15 min (Mu)	30 min (Mu)
Runway 8L-26R			
Test Section 1			
Portland Cement Concrete	0.42	0.65	0.72
Asphaltic Concrete	0.66	0.78	0.78
Test Section 2	0.75	0.77	0.78
Test Section 3	0.45	0.83	0.85
Test Section 4	0.35	>0.85	>0.85
Runway 12L-30R			
Test Section 1	0.38	0.73	0.80
Test Section 2	0.31	0.57	0.65
Test Section 3	0.41	0.68	0.75

TABLE 5. MU-METER AIRCRAFT
PAVEMENT RATING*

3 Minute Friction Coefficient	Hydroplaning Potential
Greater than 0.50	No hydroplaning problems are expected
0.40 to 0.50	Hydroplaning potential for some aircraft
Less than 0.40	High hydroplaning potential

* Source: Air Force Civil Engineering Center, AF CEC-TR-75-3, Analysis of the Standard USAF Runway Skid Resistance Tests, by John H. Williams, May 1975.

TABLE 6. RUNWAY PAVEMENT SLOPES
NPTR EL CENTRO, CA

Location	Transverse Slopes				Longitudinal Slopes
	Left		Right		Percent
	Percent	Percent	Percent	Percent	
Runway 8L-26R					
0+00	1.0	0.9	0.7	0.8	0.2
5+00	1.0	0.6	0.7	1.6	0.2
10+00	0.7	0.8	0.8	1.1	0.1
15+00	0.8	0.9	0.4	1.2	-0.1
20+00	0.7	1.2	1.1	0.9	-0.2
25+00	0.9	1.0	0.6	1.2	0.1
30+00	1.1	0.7	0.7	0.7	0.0
35+00	1.0	0.7	0.5	1.2	0.2
40+00	0.9	0.6	0.4	1.2	-0.1
45+00	Intersection with Runway 12L-30 R				
50+00	0.2	0.0	-0.2	0.3	-0.2
55+00	0.1	0.2	0.0	0.1	-0.1
60+00	0.2	0.7	0.7	0.7	0.0
65+00	0.4	0.9	0.6	0.5	0.0
70+00	0.6	0.3	0.6	0.6	0.0
75+00	0.2	1.1	1.3	0.6	0.2
80+00	0.6	0.0	1.0	0.9	0.0
85+00	0.3	0.3	0.4	1.0	-0.1
90+00	0.6	0.7	1.1	0.8	-0.3
95+00	0.9	1.2	1.1	1.0	0.2
Runway 12L-30R					
0+00	0.9	0.0	1.0	1.0	0.0
5+00	0.8	1.0	0.8	0.9	0.0
10+00	1.2	0.8	1.0	1.0	-0.1
15+00	1.4	0.4	0.7	0.4	0.0
20+00	1.0	0.5	1.0	1.0	-0.3
25+00	0.0	0.0	0.4	0.3	-0.2
30+00	0.4	-0.2	-0.2	0.3	-0.5
35+00	0.4	0.7	0.9	1.2	-0.3
40+00	1.3	1.0	0.6	1.1	0.1
45+00	1.3	0.4	0.8	1.2	0.0
50+00	1.7	0.5	0.6	1.0	0.3
55+00	0.5	0.4	-0.3	-0.2	0.3
60+00	-0.3	0.0	0.5	0.5	0.0
65+00	Intersection with Runway 8L-26 R				
67+50	-0.3	0.3	1.2	0.2	0.0

Note: Positive transverse slopes indicate water drains to the runway edge without crossing the centerline, while negative transverse slopes indicate drainage across the centerline. Positive longitudinal slopes indicate rising grades in the direction of increasing runway stationing, while negative longitudinal slopes indicate falling grades.

TABLE 7. CHANGE IN DEFECT DENSITIES
NPTR EL CENTRO, CALIFORNIA

Facility and Discrete Area	Defect Type	Defect Density and Survey Date	
		Dec 1969	May 1976
Runway 8R-26L R8R-1	Pattern Cracking	2.799	7.723
	T.C., L.C., L.C.J.	1.697	0.666
	Raveling	0.011	0.012
Runway 8L-26R R8L-1	Corner Break	0.022	0.022
	L.C. or T.C.	0.015	0.015
	Spalling	0.164	0.142
	Joint Seal	0.328	0.940
R8L-2	T.C., L.C., L.C.J.	0.959	1.319
	Patching	0.034	0.0
	Pattern Cracking	2.725	2.497
	Rutting	0.005	0.00
	Raveling	0.102	1.00
R8L-3	Corner Break	0.044	0.044
	L.C. or T.C.	0.379	0.380
	I.C.	0.022	0.062
	Spalling	0.472	0.392
	Shattered Slab	0.000	0.006
	Joint Seal	0.088	0.050
Runway 12L-30R R12L-1	Corner Break	0.045	0.040
	L.C. or T.C.	0.429	0.432
	I.C.	0.084	0.108
	Spalling	0.563	0.051
	Scaling	0.017	0.00
	Shattered Slab	0.000	0.006
	Joint Seal	1.000	0.074
R12L-2	Corner Break	0.00	0.008
	L.C. or T.C.	0.00	0.016
	Spalling	0.00	0.008

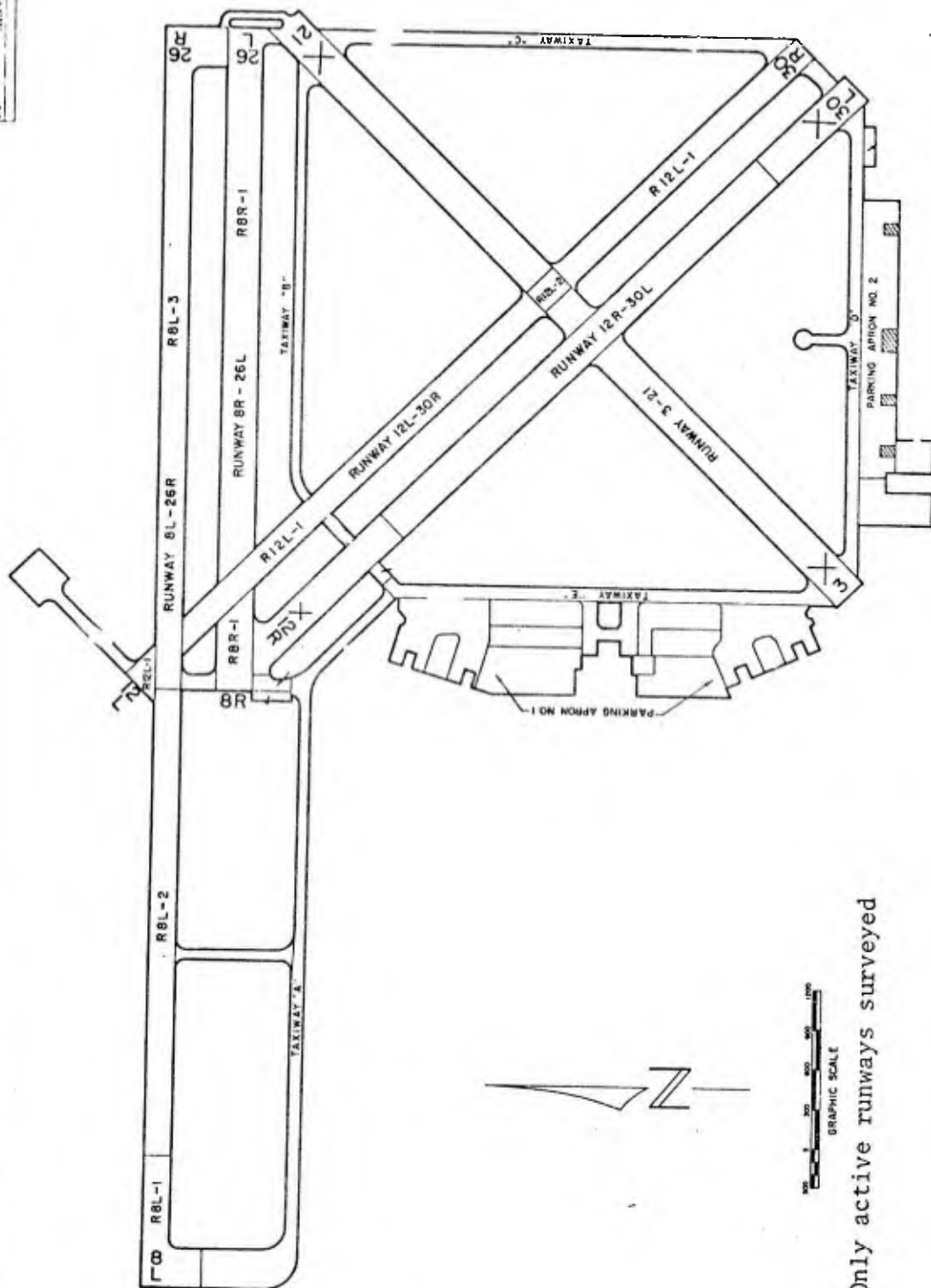


FIGURE 1



Figure 2. Severe pattern cracking and raveling,
Discrete Area R8R-1.

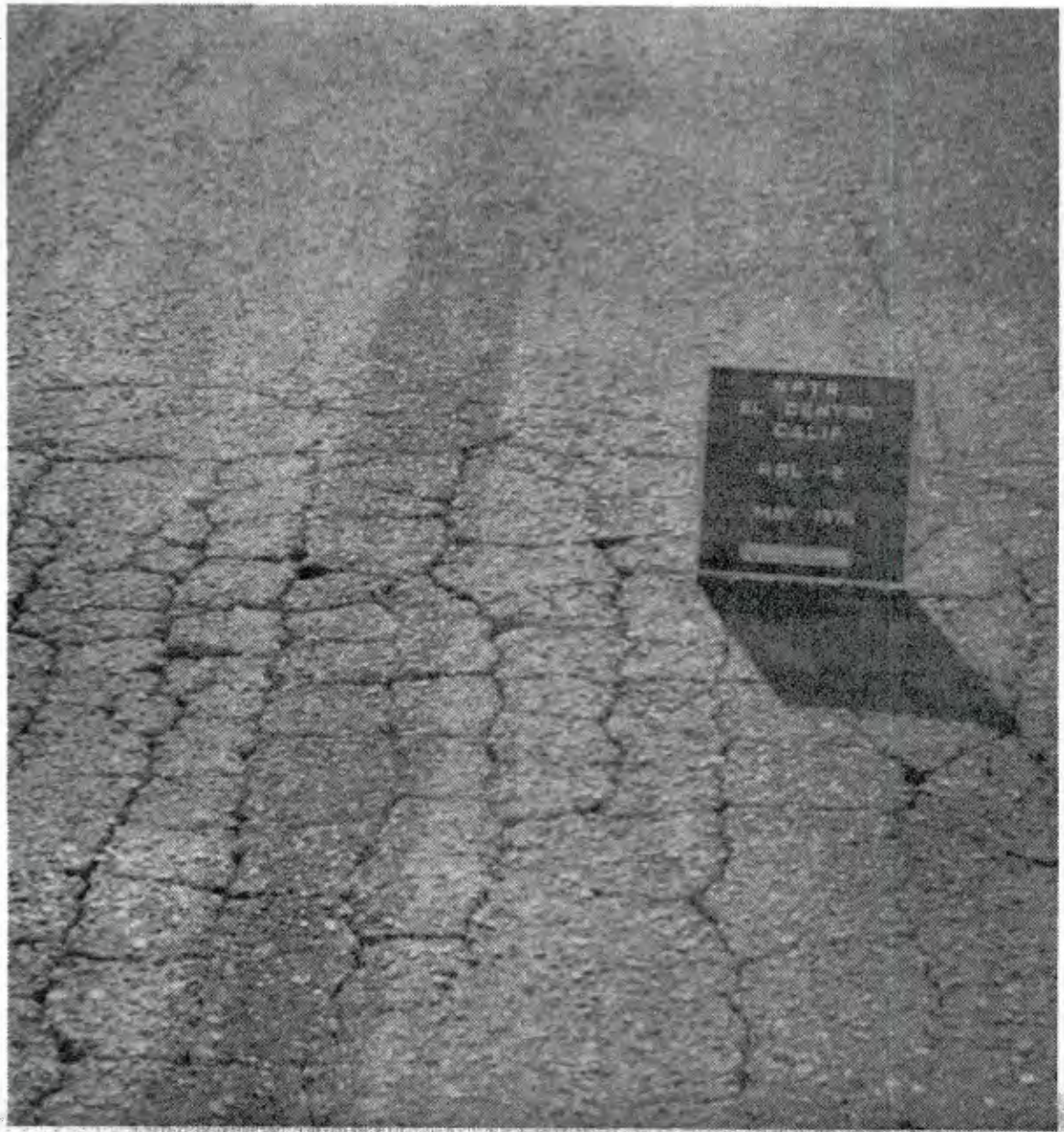


Figure 3. Pattern cracking and raveling,
Discrete Area R8L-2.

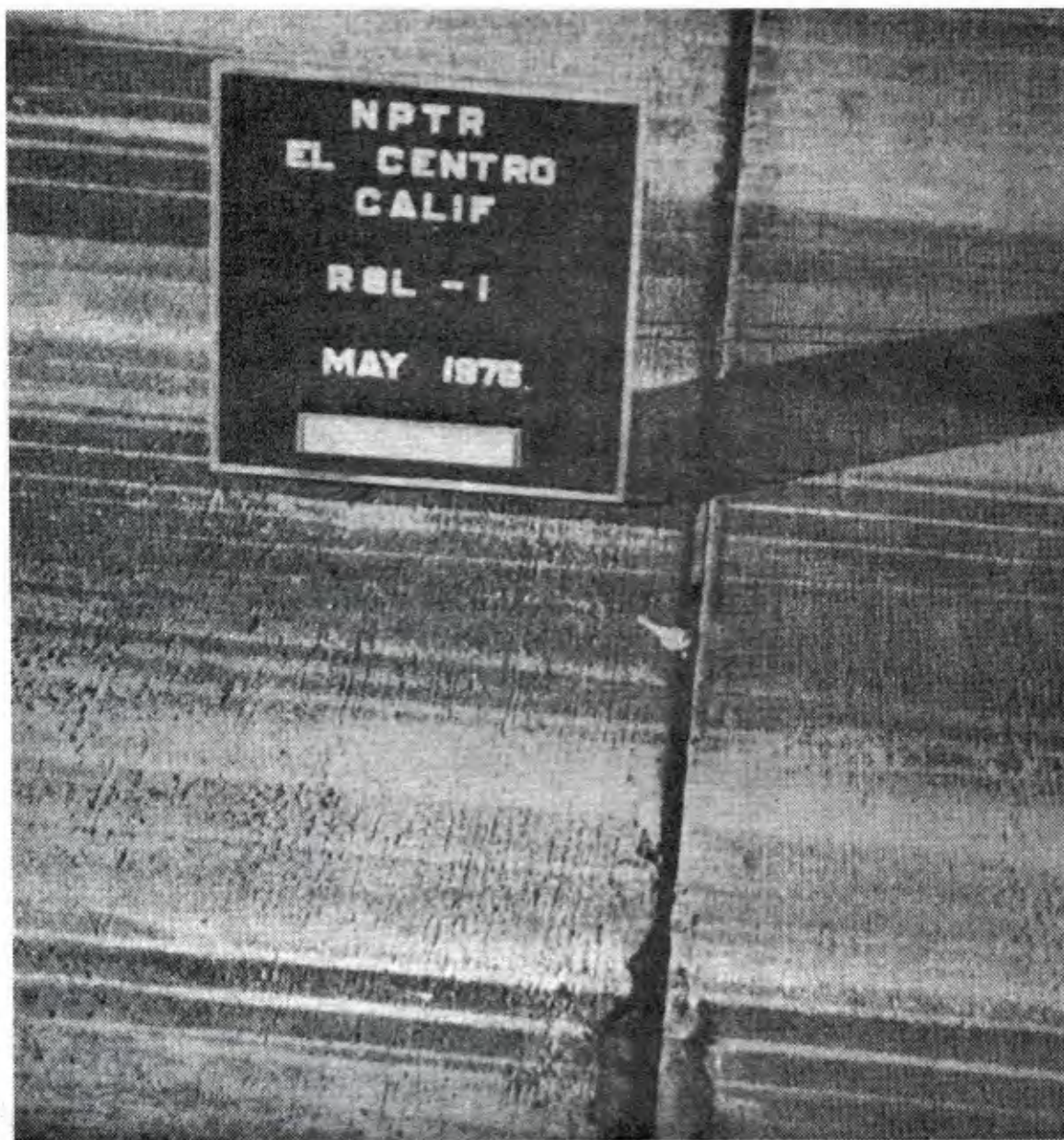
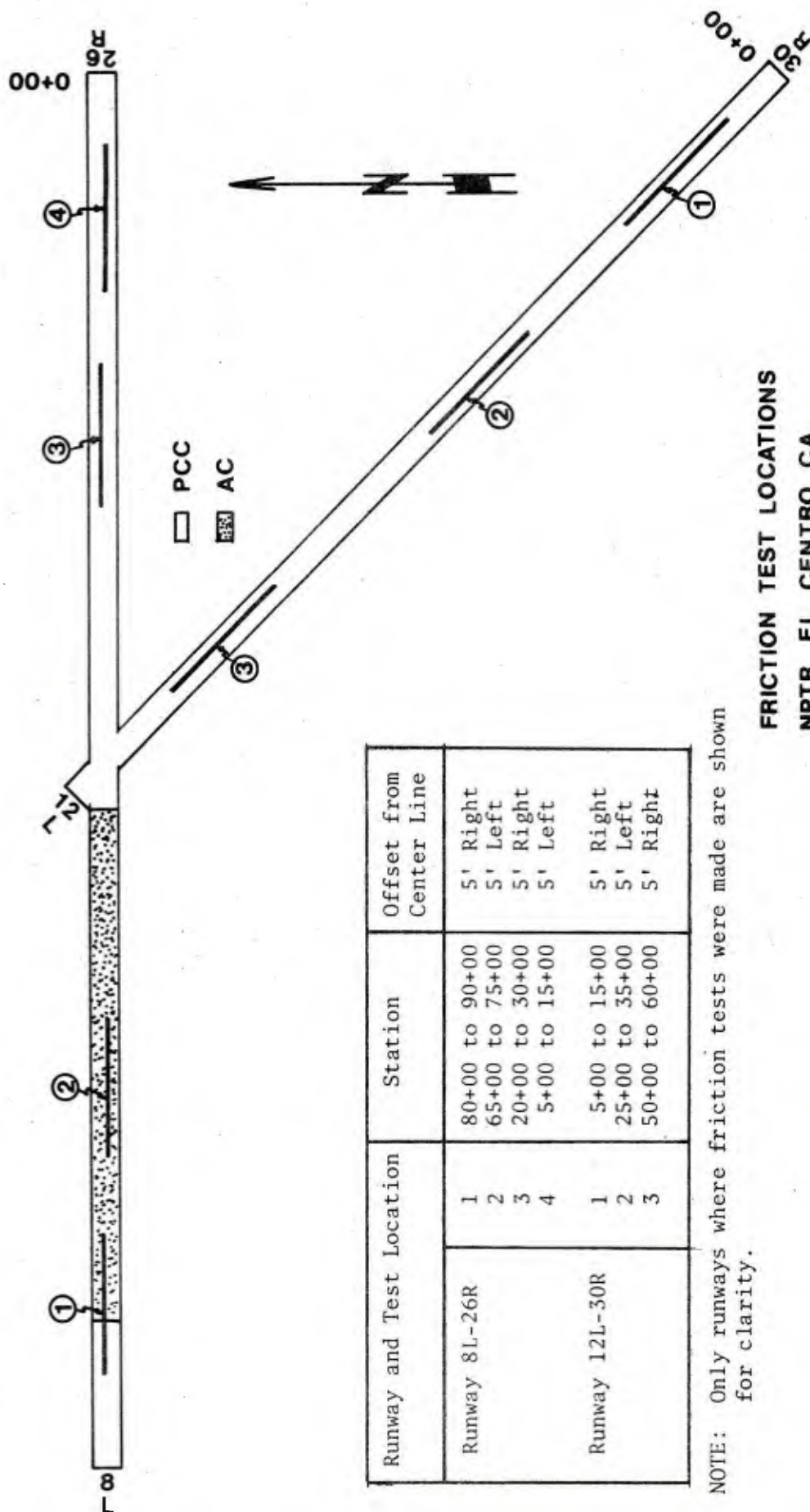


Figure 4. Missing joint seal, Discrete Area R8L-1.



Figure 5. Shattered slab, Discrete Area R12L-1.



No Scale

FIGURE 6

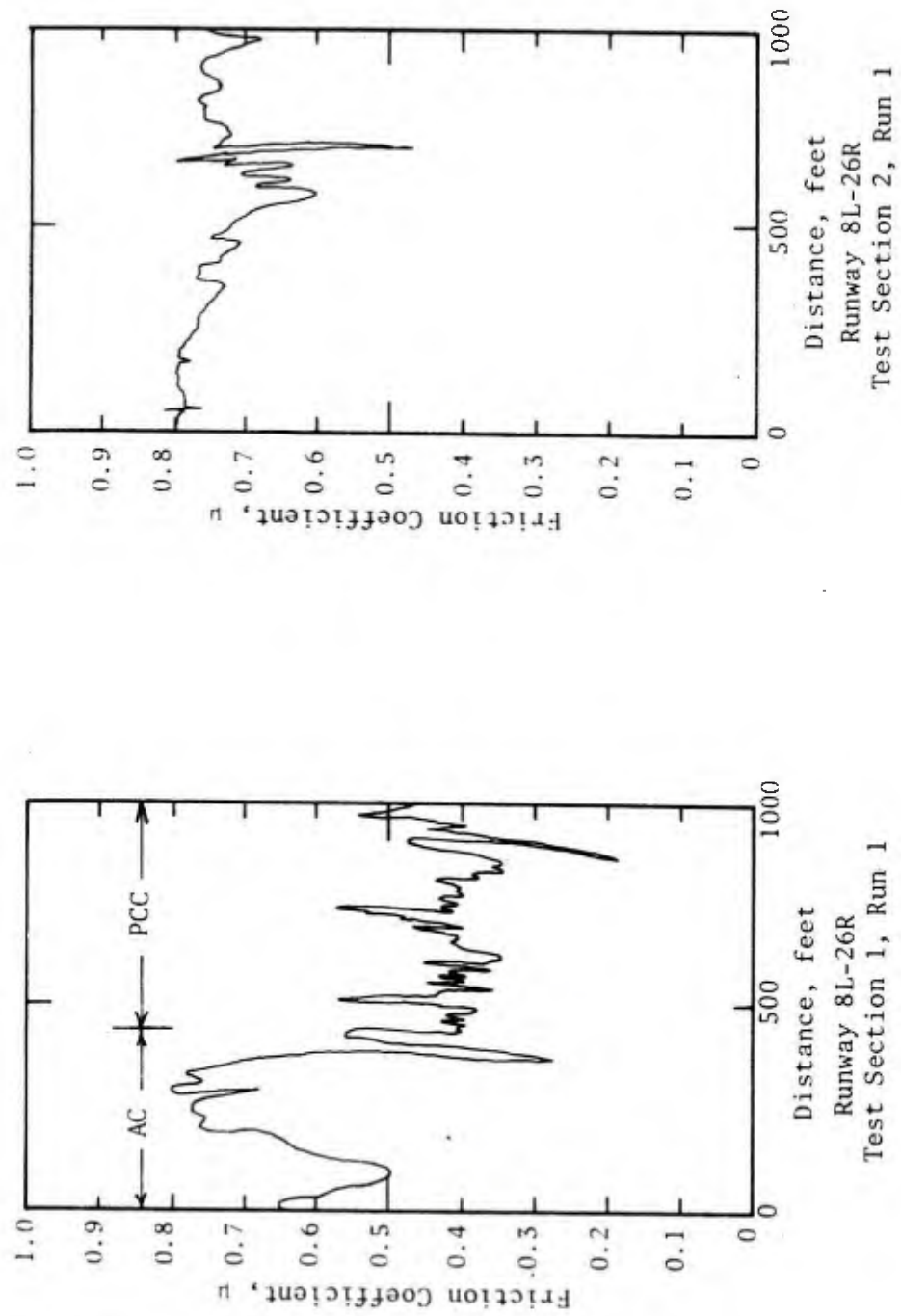


Figure 7. Friction Coefficient versus Distance,
NPTR El Centro, California

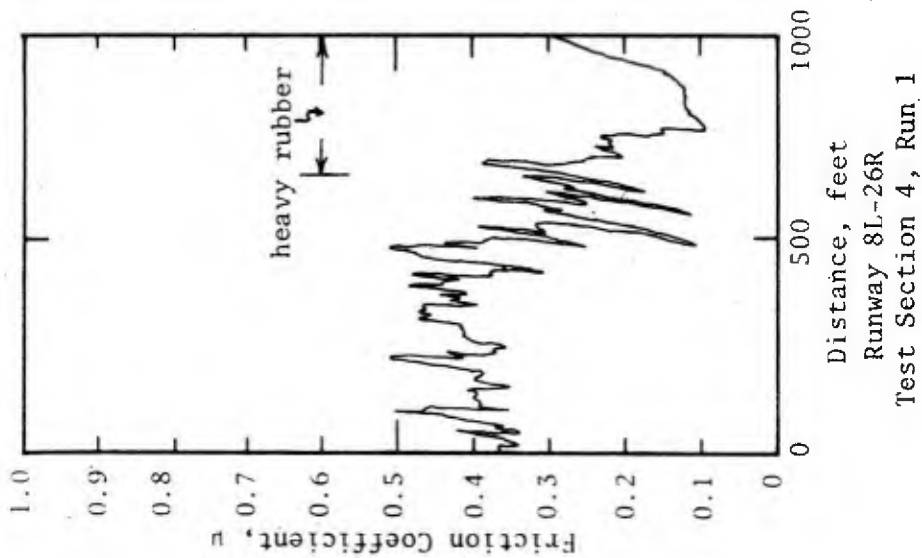
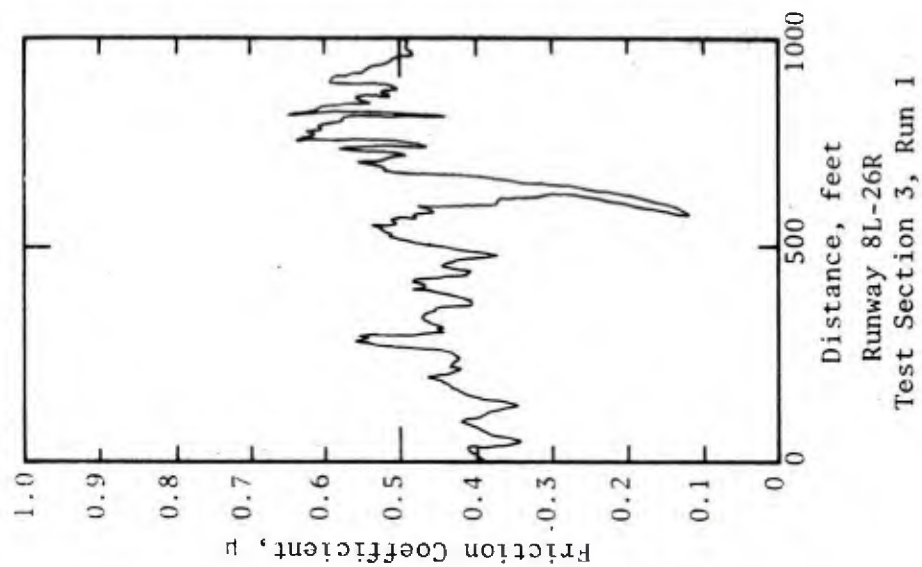


Figure 8. Friction Coefficient versus Distance,
NPTR EI Centro, California

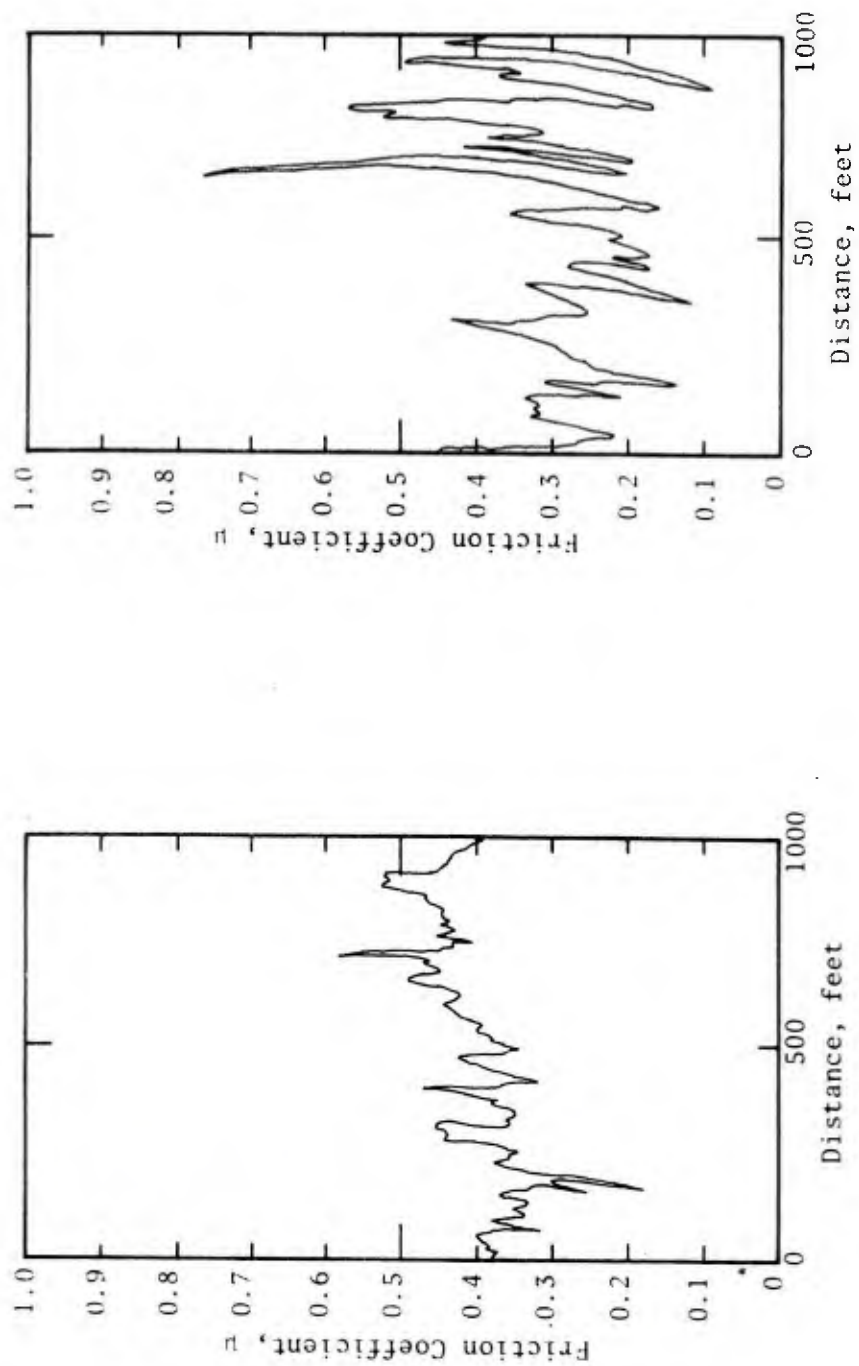


Figure 9. Friction Coefficient versus Distance,
NPTR El Centro, California

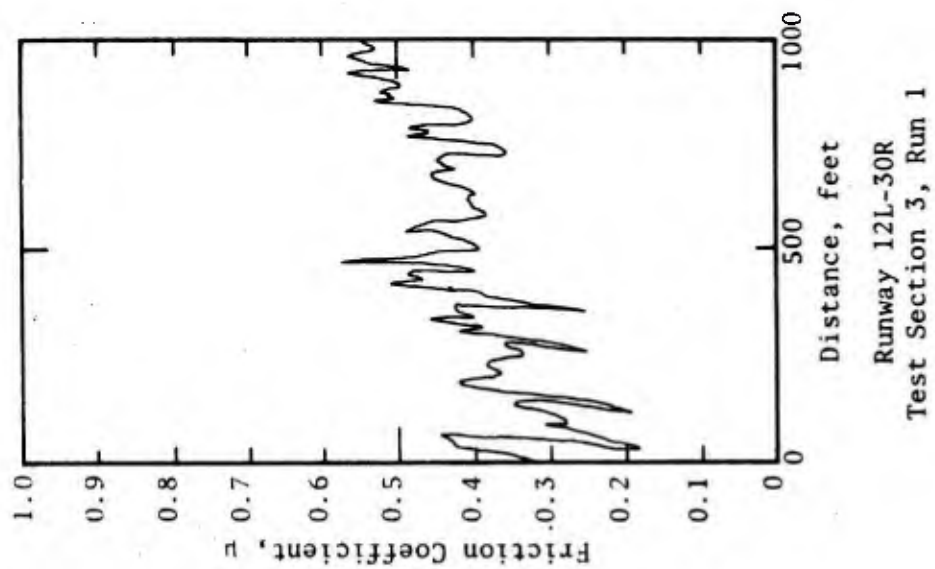


Figure 10. Friction Coefficient versus Distance,
NPTR El Centro, California

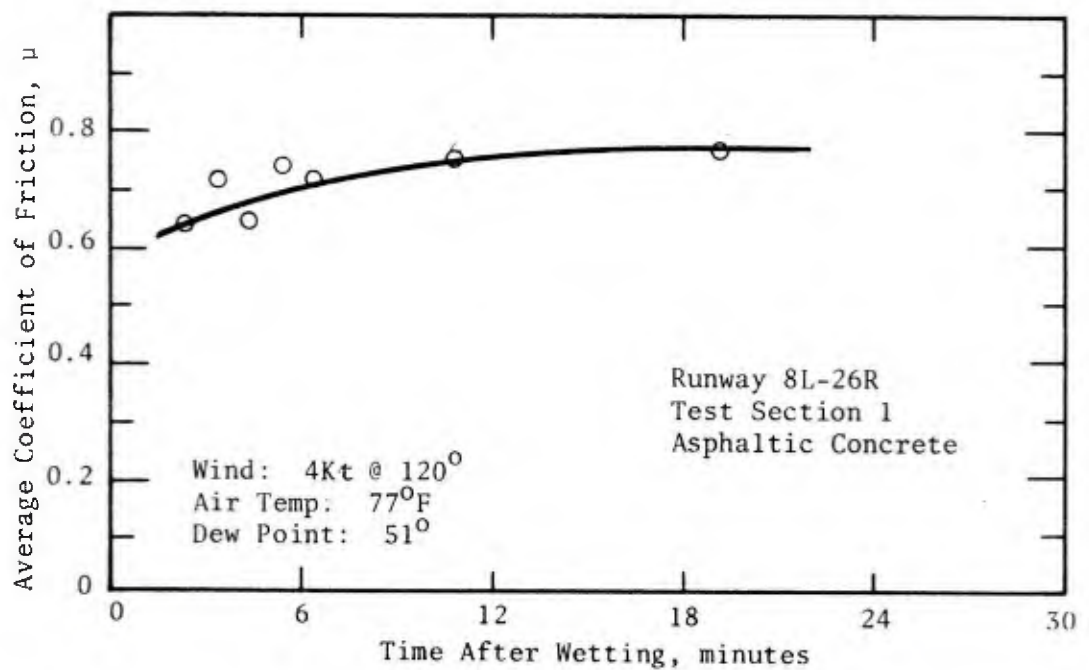
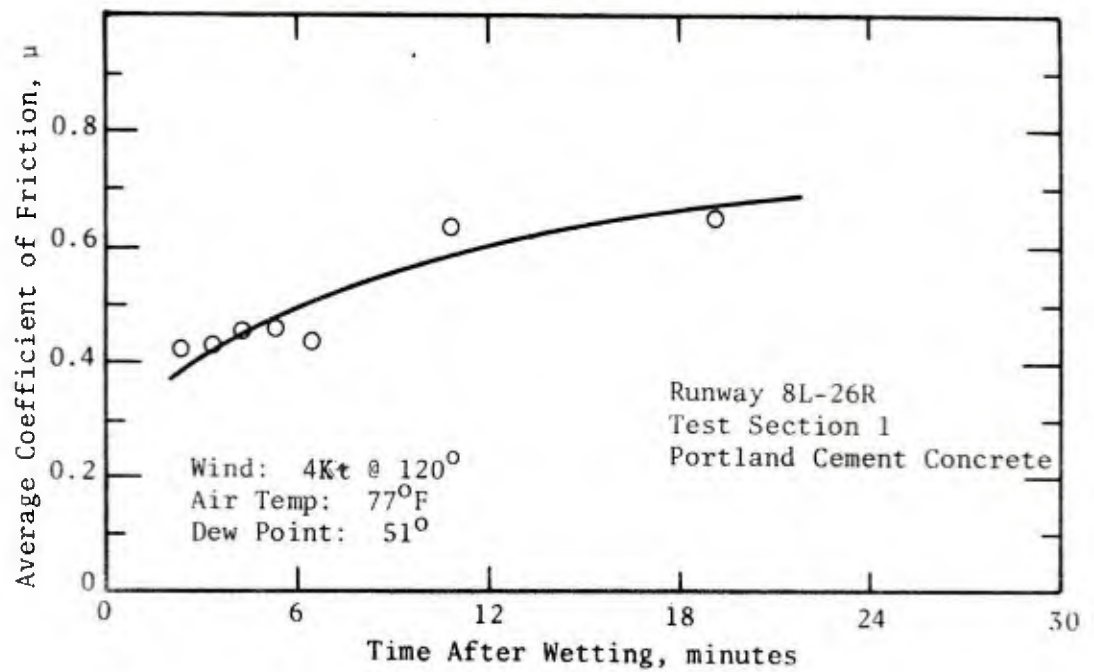


Figure 11. Average Friction Coefficient versus Time, NPTR El Centro, California

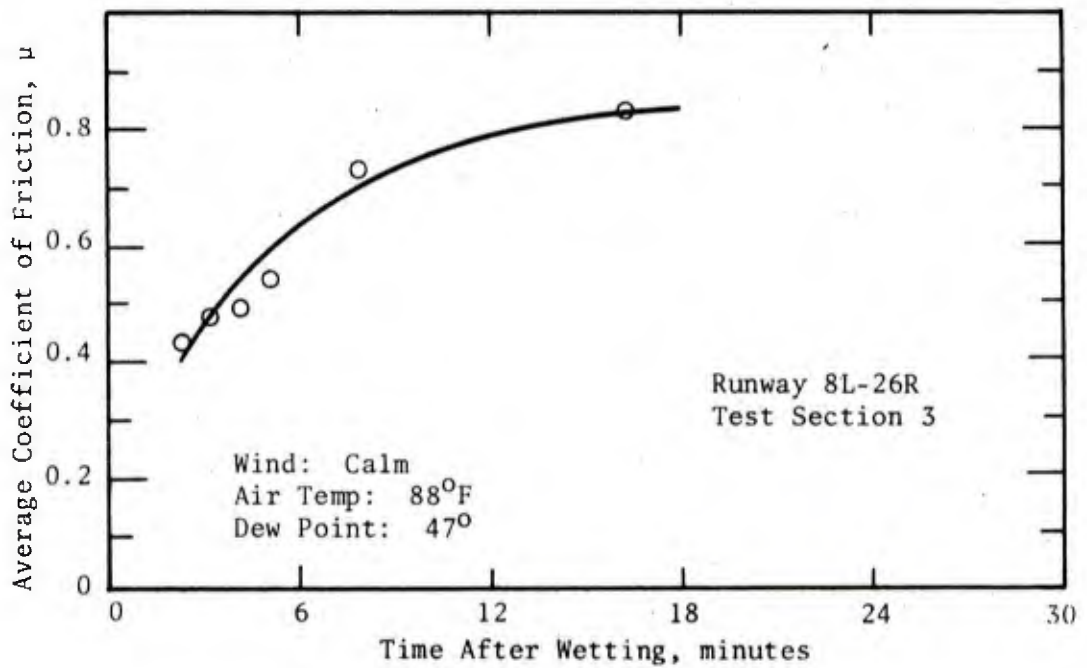
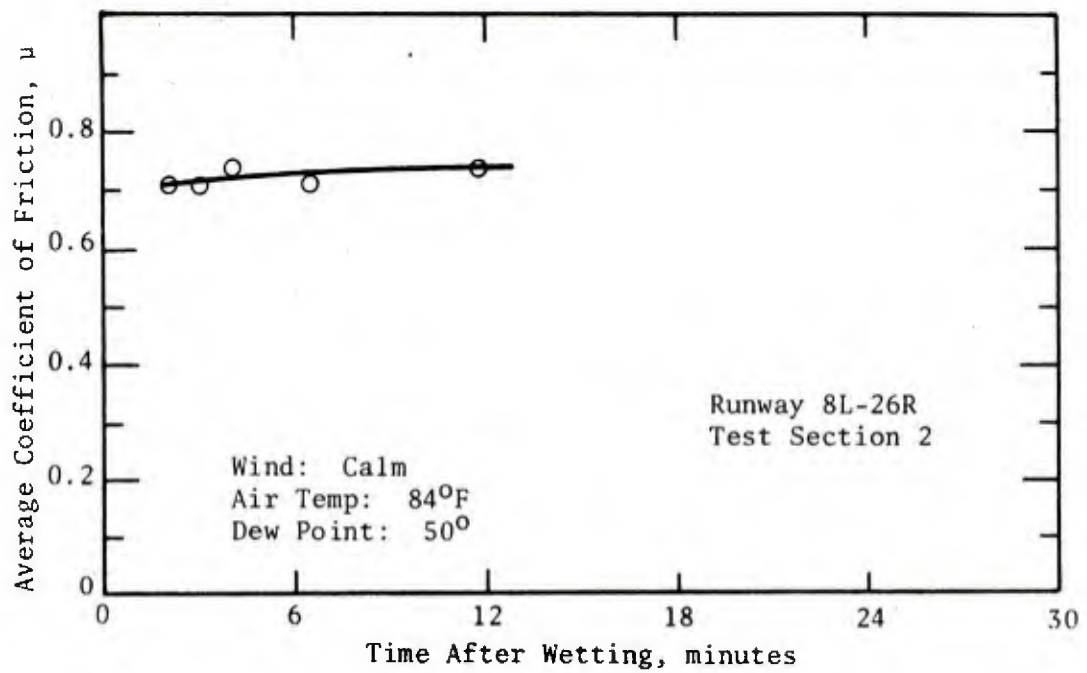


Figure 12. Average Friction Coefficient versus Time, NPTR El Centro, California

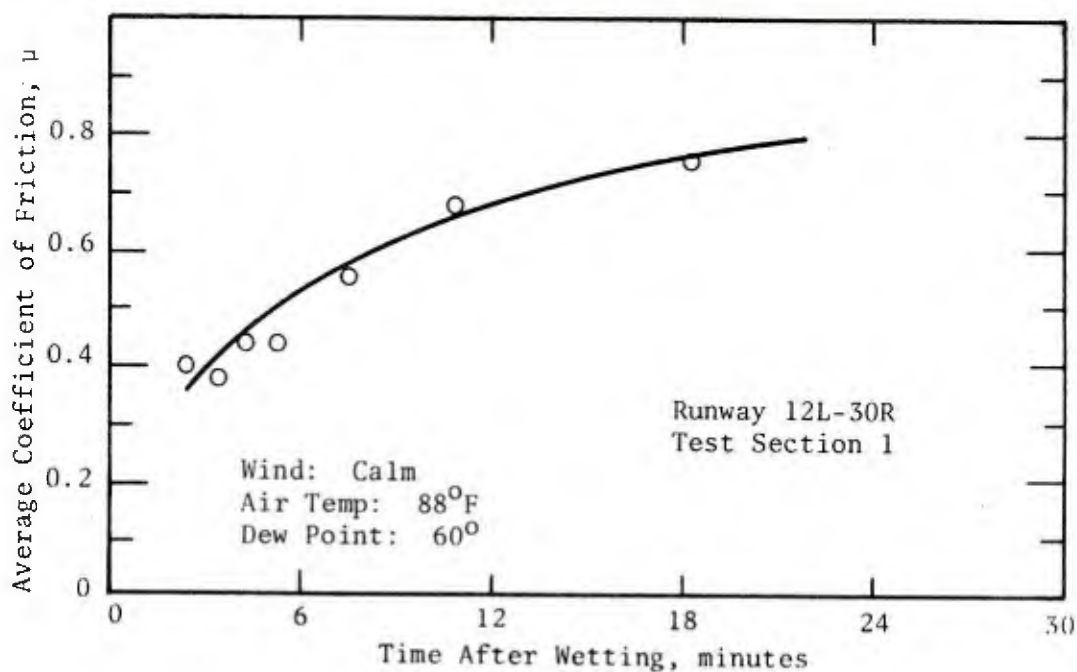
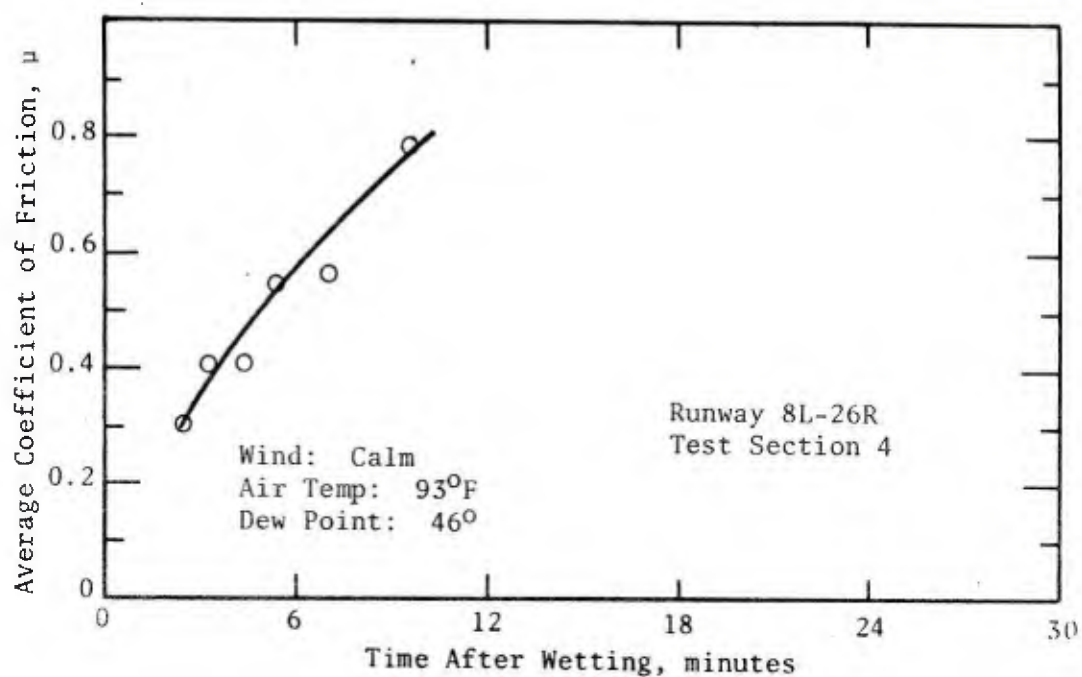


Figure 13. Average Friction Coefficient versus Time, NPTR, El Centro, California

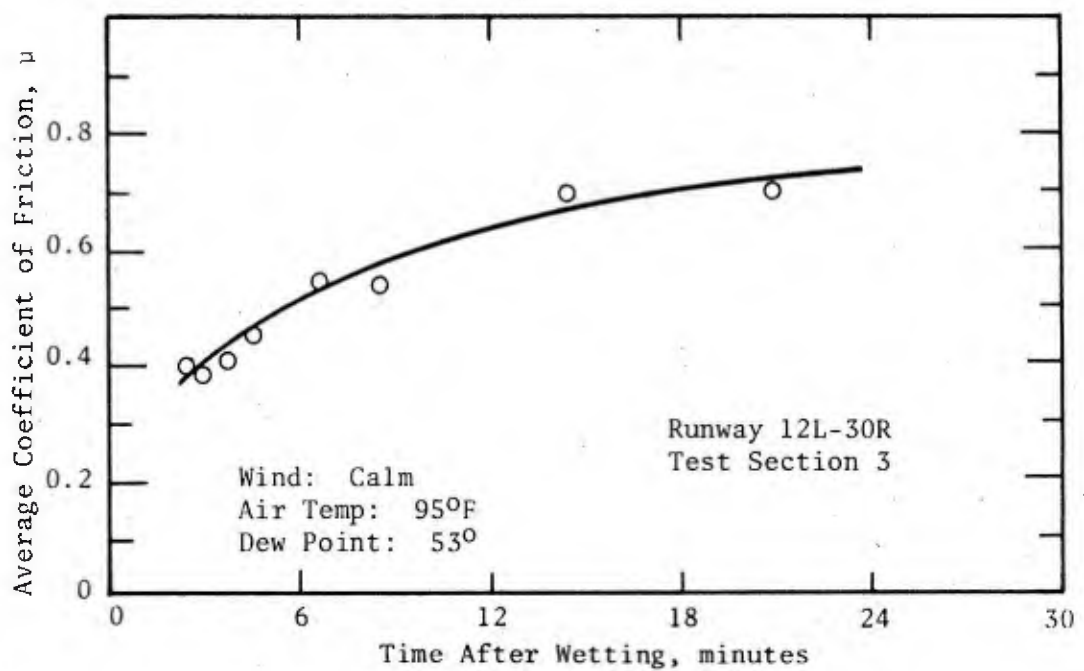
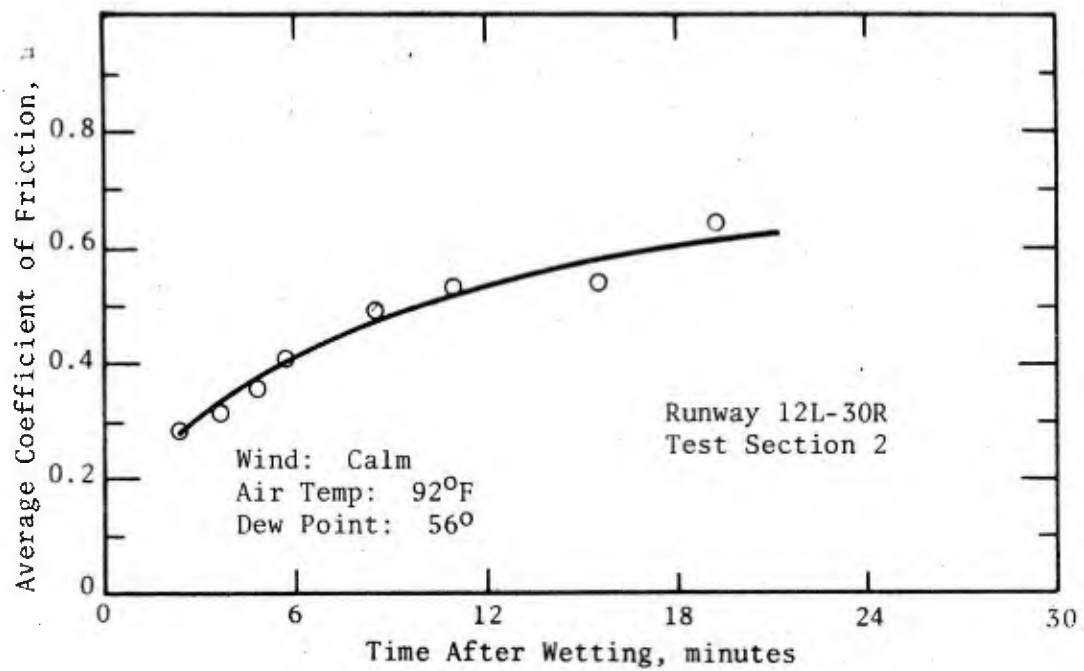


Figure 14. Average Friction Coefficient versus Time, NPTR El Centro, California

ASPHALTIC CONCRETE DISCRETE AREA DEFECT SUMMARY

Airfield NPTR, El Centro, California Facility Runway 8R-26L
 Discrete Area R8R-1 Area of Discrete Area (a) 401,700 ft²
 No. of Sample Areas (b) 16 Ratio: (a/2500b) 10.0

Defect Type	Length or Area of Sampled Defects	Total Length or Area of All Defects: (c) x Ratio	Defect Density (per 10 sq. ft.) 10 d/a	Defect Severity Weight	Weighted Defect Density: (e) x (f)
	(c)	(d)	(e)	(f)	(g)
T.C., L.C. or LCJ*	2,675 ft	26,750 ft	0.666	3.5	2.33
Reflection Crack					
Faulting					
Patching					
Settlement or Depression					
Pattern Cracking	31,025 ft ²	310,250 ft ²	7.723	3.5	27.03
Rutting					
Raveling	49 ft ²	490 ft ²	0.012	7.0	0.08
Erosion-Jet Blast					
Oil Spillage					
Broken-up Area					
Total					29.44A

Remarks on Pavement Condition

This seldom-used runway shows the effects of aging and little maintenance. The pattern cracking is mainly caused by shrinkage and hardening of the asphalt binder. Raveling is occurring along the cracks. See Figure 2.

* Transverse crack, longitudinal crack or longitudinal construction joint crack.
 ** Letter suffix "A" indicates asphaltic pavement.

ASPHALTIC CONCRETE DISCRETE AREA DEFECT SUMMARY

Airfield NPTR, El Centro, California Facility Runway 8L-26R
 Discrete Area R8L-2 Area of Discrete Area (a) 349,400 ft²
 No. of Sample Areas (b) 14 Ratio: (a/2500b) 10.0

Defect Type	Length or Area of Sampled Defects	Total Length or Area of All Defects: (c) x Ratio	Defect Density (per 10 sq. ft.) 10 d/a	Defect Severity Weight	Weighted Defect Density: (e) x (f)
	(c)	(d)	(e)	(f)	(g)
T.C., L.C. or LCJ*	4,610 ft	46,100 ft	1.319	3.5	4.617
Reflection Crack					
Faulting					
Patching					
Settlement or Depression					
Pattern Cracking	8,725 ft ²	87,250 ft ²	2.497	3.5	8.740
Rutting					
Raveling	3,500 ft ²	35,000 ft ²	1.000	7.0	7.000
Erosion-Jet Blast					
Oil Spillage					
Broken-up Area					
Total					20.36 A

Remarks on Pavement Condition

The overlay placed in 1970 was raveling and had lost most of the surface fines. Pattern cracking has progressed to small polygons with some pieces coming loose from the surface. See Figure 3.

* Transverse crack, longitudinal crack or longitudinal construction joint crack.

** Letter suffix "A" indicates asphaltic pavement.

PORTLAND CEMENT CONCRETE DISCRETE AREA DEFECT SUMMARY

Airfield NPTR, El Centro, California Facility Runway 8L-26R

Discrete Area R8L-1 Total Slabs in Discrete Area (a) 536

No. of Slabs Sampled (b) 134 Ratio a/b = 4.0

Defect Type	No. of Sample Slabs w/Defect	Total Slabs w/Defect: c x a/b	Defect Density (per slab) d/a	Defect Severity Weight	Weighted Defect Density e x f
	(c)	(d)	(e)	(f)	(g)
Faulting					
Corner Break	3	12	0.022	3.5	0.077
L.C. or T.C.*	2	8	0.015	3.5	0.052
I.C.**					
Depression					
Spalling	19	76	0.142	7.5	1.06
Scaling					
Shattered Slab					
Joint Seal	126	504	0.940	3.5	3.29
Pumping					
"D-line" cracking					
Remarks on Pavement Condition					Total
Joint seal was hardened and often had missing sections. See Figure 4. Spalls were generally small with one or two exceptions.					4.47 C ***

* Longitudinal crack or Transverse crack

** Intersecting crack

*** Letter suffix "C" represents PCC pavement

PORTLAND CEMENT CONCRETE DISCRETE AREA DEFECT SUMMARY

Airfield NPTR, El Centro, California Facility Runway 8L-26R

Discrete Area R8L-3 Total Slabs in Discrete Area (a) 2730

No. of Slabs Sampled (b) 160 Ratio a/b = 17.0

Defect Type	No. of Sample Slabs w/Defect	Total Slabs w/Defect: c x a/b	Defect Density (per slab) d/a	Defect Severity Weight	Weighted Defect Density e x f
	(c)	(d)	(e)	(f)	(g)
Faulting					
Corner Break	7	119	0.044	3.5	0.154
L.C. or T.C.*	61	1037	0.380	3.5	1.330
I.C.**	10	170	0.062	3.5	0.217
Depression					
Spalling	63	1071	0.392	7.5	2.940
Scaling					
Shattered Slab	1	17	0.006	9.0	0.054
Joint Seal	8	136	0.050	3.5	0.175
Pumping					
"D-line" cracking					

Remarks on Pavement Condition Total 4.87 C ***

Many spalls were defective prior to spall repairs. Many spalls were 2' to 3' long. Most of the transverse cracks were sealed.

* Longitudinal crack or Transverse crack

** Intersecting crack

*** Letter suffix "C" represents PCC pavement

PORTLAND CEMENT CONCRETE DISCRETE AREA DEFECT SUMMARY

Airfield NPTR, El Centro, California Facility Runway 12L-30R

Discrete Area R12L-1 Total Slabs in Discrete Area (a) 3408

No. of Slabs Sampled (b) 176 Ratio a/b = 19.4

Defect Type	No. of Sample Slabs w/Defect	Total Slabs w/Defect: c x a/b	Defect Density (per slab) d/a	Defect Severity Weight	Weighted Defect Density e x f
	(c)	(d)	(e)	(f)	(g)
Faulting					
Corner Break	7	136	0.040	3.5	0.14
L.C. or T.C.*	76	1474	0.432	3.5	1.51
I.C.**	19	369	0.108	3.5	0.38
Depression					
Spalling	9	175	0.051	7.5	0.38
Scaling					
Shattered Slab	1	19	0.006	9.0	0.05
Joint Seal	13	252	0.074	3.5	0.26
Pumping					
"D-line" cracking					
Remarks on Pavement Condition					Total
					2.72 C ***
The few spalls remaining after the recent repair project were relatively minor. Station forces plan to repair these as funds become available. Generally, the cracks were sealed. See Figure 5.					

* Longitudinal crack or Transverse crack

** Intersecting crack

*** Letter suffix "C" represents PCC pavement

PORTLAND CEMENT CONCRETE DISCRETE AREA DEFECT SUMMARY

Airfield NPTR, El Centro, California Facility Runway 12L-30R

Discrete Area R12L-2 Total Slabs in Discrete Area (a) 125

No. of Slabs Sampled (b) 125 Ratio a/b = 1.0

Defect Type	No. of Sample Slabs w/Defect	Total Slabs w/Defect: c x a/b	Defect Density (per slab) d/a	Defect Severity Weight	Weighted Defect Density e x f
	(c)	(d)	(e)	(f)	(g)
Faulting					
Corner Break	1	1	0.008	3.5	0.028
L.C. or T.C.*	2	2	0.016	3.5	0.056
I.C.**					
Depression					
Spalling	1	1	0.008	7.5	0.060
Scaling					
Shattered Slab					
Joint Seal					
Pumping					
"D-line" cracking					
Remarks on Pavement Condition					Total
					0.14 C ***
The one spall noted was small and the cracks were less than 1/8-inch wide.					

* Longitudinal crack or Transverse crack

** Intersecting crack

*** Letter suffix "C" represents PCC pavement

ASPHALTIC CONCRETE FACILITY DEFECT SUMMARY Airfield <u>NPTR, El Centro, California</u> Date Surveyed <u>June 1976</u>			
Facility (or portion)	Weighted Defect Density Total	Ratio: <u>Discrete Area</u> Total Facility Area*	Average Weighted Defect Density (a) x (b)
	(a)**	(b)	(c)**
<u>1976 Survey</u>			
Runway 8R-26L R-8R-1	29.44 A	1.00	29.44 A
Runway 8L-26R R-8L-2	20.36 A	1.00	20.36 A
<u>1969 Survey</u>			
Runway 8R-26L R-8R-1	15.81 A	1.00	15.81 A
Runway 8L-26R R-8L-2	13.14 A	1.00	13.14 A

* If facility entirely constructed of AC, indicates total facility area. If facility only partly constructed of AC, indicates total area of AC portion of facility.

** Letter suffix "A" on weighted defect densities indicates asphaltic concrete pavements.

PORTLAND CEMENT CONCRETE FACILITY DEFECT SUMMARY Airfield <u>NPTR El Centro, California</u> Date Surveyed <u>June 1976</u>			
Facility (or portion)	Weighted Defect Density Total	Ratio: <u>Discrete Area</u> Total Facility Area*	Average Weighted Defect Density (a) x (b)
	(a)**	(b)	(c)**
<u>1976 Survey</u>			
Runway 8L-26R			
R-8L-1	4.47 C	0.16	0.72
R-8L-3	4.87 C	0.84	4.09
			<u>4.81C(total)</u>
Runway 12L-30R			
R-12L-1	2.72 C	0.97	2.64
R-12L-2	0.14 C	0.03	0.01
			<u>2.65C(total)</u>
<u>1969 Survey</u>			
Runway 8L-26R			
R-8L-1	2.50 C	0.16	0.40
R-8L-3	5.40 C	0.84	4.54
			<u>4.94C(total)</u>
Runway 12L-30R			
R-12L-1	9.79 C	0.97	9.50
R-12L-2	0.00 C	0.03	0.00
			<u>9.50C(total)</u>

* If facility entirely constructed of PCC, indicates total facility area. If facility only partly constructed of PCC, indicates total area of PCC portion of facility.

** Letter suffix "C" on weighted defect densities indicates Portland cement concrete pavements.

Appendix A
CONSTRUCTION HISTORY

CONSTRUCTION HISTORY FOR NPTR, EL CENTRO, CALIFORNIA

39

Item No.	Section From Surface to Subgrade	Date Constructed	Date Strengthened or Sealed
	Shoulders: (Items 1A and 1B)		
	Asphalt penetration	1951	
	6" Base	1951	
2	<u>Runway 8R-26L</u>		
	Sand seal coat		1962
	Seal coat		1956
	1½" Asphaltic concrete		1956
	1" Asphaltic concrete binder		1956
	Tack coat		1956
	3" Asphaltic concrete	1945	
	6" Base	1945	
	¾" Asphalt penetration	1945	
	12" Base	1945	
	Shoulders:		
	Seal coat		1956
	2" Asphaltic concrete	1945	
	12" Crushed rock base	1945	
3	<u>Portion of Runway 12L-30R</u>		
	Spall repairs and joints sealed. Spall repairs made with the following mix:		1976
	6 parts fine aggregate		
	1 part coarse aggregate		
	6 parts aggregate mix to 1 part epoxy		
	Longitudinal, transverse expansion and selected transverse contraction joints were resealed with 1614 sealant		
	Clean and seal pavement joints		1959
	8" Portland cement concrete	1945	
	6" Crushed rock base	1945	
	6" Base	1945	
3A	<u>Portion of Runway 12L-30R</u>		
	Intersection 3-21/30R		1969
	Removal of all pavement and compaction of 6" base to 100% CBR and replacement of 9" PCC		1969
	Shoulders:		
	Seal coat	1945	
	2" Asphaltic concrete	1945	
	12" Crushed rock base	1945	

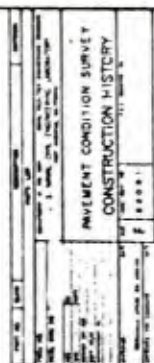
Item No.	Section From Surface to Subgrade	Date Constructed	Date Strengthened or Sealed
4	<u>Portion of Runway 12R-30L (closed)</u>		
	Seal coat		1956
	3" Asphaltic concrete		1953
	2-1/2" Asphaltic concrete		1945
	8" Crushed rock base		1945
	3" Asphaltic concrete	1943	
	12" Select base	1943	
4A	<u>Portion of Runway 12R-30L (closed)</u>		
	3" Asphaltic concrete	1953	
	12" Base	1953	
4B	<u>Portion of Runway 12R-30L (closed)</u>		
	3" Asphaltic concrete		1953
	2-1/2" Asphaltic concrete	1945	
	12" Crushed rock base	1945	
	Shoulders:		
	Seal coat	1945	
	2" Asphaltic concrete	1945	
	12" Crushed rock base	1945	
5	<u>Portion of Runway 3-21 (closed)</u>		
	Seal coat (widened 25' each side over existing shoulders)		1955
	3" Asphaltic concrete		1955
	Tack coat		1955
	2-1/2" Asphaltic concrete		1945
	8" Crushed rock base		1945
	3" Asphaltic concrete	1943	
	12" Select base	1943	

Item No.	Section From Surface to Subgrade	Date Constructed	Date Strengthened or Sealed
5A	<u>Portion of Runway 3-21 (closed)</u>		
	Seal coat	1955	
	3" Asphaltic concrete	1955	
	Tack coat	1955	
	15" Pulverized base	1955	
	6" Sand	1955	
	6" Compacted native material	1955	
	Shoulders:		
	Seal coat	1945	
	2" Asphaltic concrete	1945	
	12" Crushed rock base	1945	
6	<u>Portion of Parallel Taxiway A</u>		
	Rubber-asphalt seal coat		1975
	Slurry seal coat		1970
	Slurry seal coat		1966
	Seal coat		1966
	3" Asphaltic concrete	1951	
	12" Base	1951	
	9" Subbase	1951	
6A	<u>Portion of Parallel Taxiway A</u>		
	Rubber-asphalt seal coat		1975
	Slurry seal coat		1970
	Slurry seal coat		1966
	Seal coat		1956
	3" Asphaltic concrete	1953	
	12" Base	1953	
6B	<u>Portion of Parallel Taxiway A</u>		
	Rubber-asphalt seal coat		1975
	Slurry seal coat		1970
	Slurry seal coat		1966
	Seal coat		1956
	3" Asphaltic concrete	1951	
	12" Base course	1951	
	13" Subbase 95% compacted	1951	
	5" Subbase 90% compacted	1951	

Item No.	Section From Surface to Subgrade	Date Constructed	Date Strengthened of Sealed
7	<u>Connecting Taxiway 1</u>		
	Slurry seal coat		1966
	Seal coat		1956
	3" Asphaltic concrete	1951	
	12" Base course	1951	
8	<u>Connecting Taxiway 2</u>		
	Slurry seal coat		1966
	Seal coat		1956
	3" Asphaltic concrete	1953	
	12" Base	1953	
9	<u>Inbound Taxiway B</u>		
	Rubber-asphalt seal coat		1974
	Slurry seal coat		1970
	Slurry seal coat		1966
	3" Asphaltic concrete		1955
	5" Asphaltic concrete	1943	
	12" Select base	1943	
10	<u>East Taxiway C</u>		
	Slurry seal coat		1966
	3" Asphaltic concrete		1955
	3" Asphaltic concrete	1945	
	9" Base	1945	
	12" Subbase	1945	
11	<u>South Taxiway D</u>		
	Rubber-asphalt seal coat		1975
	Slurry seal coat		1970
	Slurry seal coat		1966
	3" Asphaltic concrete	1953	
	12" Base	1953	
12	<u>West Taxiway E</u>		
	Rubber-asphalt seal coat		1975
	Slurry seal coat		1970
	Slurry seal coat		1966
	Seal coat		1956
	3" Asphaltic concrete	1953	
	12" Base	1953	

Item No.	Section From Surface to Subgrade	Date Constructed	Date Strengthened or Sealed
13	<u>Parking Apron 1</u> 8" Portland cement concrete 6" Crushed rock base 12" Select base	1944 1944 1944	
14	<u>Parking Apron 1</u> Spall repairs and joints re-sealed (selected areas) (Superseal 777) 6" Portland cement concrete 6" Select base	 1943 1943	1975
15	<u>Parking Apron 1</u> 6" Portland cement concrete 6" Crushed rock base	1945 1945	
16	<u>Parking Apron 1</u> 10" Portland cement concrete 12" Subbase Parking Apron was repaired and resealed as in Item 1	 1951 1951 	1959
17	<u>Turn-up Apron 1</u> 8" Portland cement concrete 8" Subbase	1953 1953	

Item No.	Section From Surface to Subgrade	Date Constructed	Date Strengthened or Sealed
18	<u>Turn-up Apron 2</u>		
	8" Portland cement concrete	1953	
	8" Subbase	1953	
19	<u>Compass Rose</u>		
	6" Portland cement concrete	1945	
	6" Crushed rock base	1945	
	6" Select base	1945	
20	<u>Loading Range and Access Taxiway</u>		
	10" Portland cement concrete	1956	
	10" Subbase	1956	
	Shoulders:		
	Seal coat	1956	
	2" Plant mix	1956	
	Prime coat	1956	
	6" Subbase	1956	
21	<u>Parking Apron 2</u>		
	8" Portland cement concrete	1945	
	6" Crushed rock base	1945	
	6" Select base	1945	
21A	<u>Parking Apron Extension</u>		
	10" Portland cement concrete	1969	
	6" Cement-treated base	1969	
	1" - 6" imported fill compacted to 95%	1969	
	Compact top 6" of existing base material to 90%	1969	



APPENDIX A, FIGURE A-1

Appendix B
CLIMATOLOGICAL DATA

Appendix B

CLIMATOLOGICAL DATA FOR NPTR EL CENTRO, CALIFORNIA

Average Temperatures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	An'l.
1956	56.0	53.0	63.5	68.5	79.4	88.8	91.6	88.7	90.0	M	59.7	54.2	---
1957	52.9	63.1	65.0	70.0	74.2	88.1	92.0	89.3	84.8	71.2	59.2	56.1	72.2
1958	55.9	61.3	59.8	68.5	80.8	85.3	89.7	92.8	87.7	77.9	62.0	58.5	73.4
1959	56.6	55.5	65.2	72.8	74.1	87.6	93.3	89.4	81.9	73.3	61.4	52.5	71.9
1960	48.7	54.7	65.8	70.9	76.1	87.5	90.9	89.6	86.9	72.6	59.3	50.9	71.2
1961	55.9	59.4	63.2	70.2	74.4	85.9	90.2	89.7	79.7	70.7	56.9	50.7	70.6
1962	54.0	57.7	57.9	72.7	71.7	83.0	89.3	92.5	86.6	75.4	65.2	56.6	71.9
1963	51.4	64.4	60.8	64.5	76.9	81.1	89.9	89.9	86.3	75.8	62.7	53.2	71.4
1964	50.3	54.4	59.8	67.2	75.0	83.1	91.3	90.3	83.0	78.7	58.7	55.4	70.6
1965	55.1	57.0	60.0	68.0	74.3	78.6	89.6	90.3	80.7	76.6	64.5	53.8	70.7
10-YR													
AVG.	53.7	58.1	62.1	69.3	75.7	85.0	90.8	90.3	84.8	74.7	61.0	54.2	71.5
MAX.	70.8	74.3	76.3	84.3	92.9	97.7	107.5	107.3	98.2	96.8	78.7	67.4	---
MIN.	39.4	39.6	43.7	51.7	55.6	59.5	71.6	73.2	63.1	56.4	50.3	40.2	---

Total Precipitation

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	An'l.
1956	0.20	T	0.00	0.00	T	T	0.01	0.00	0.04	0.00	0.00	0.00	0.25
1957	0.70	0.09	0.02	T	0.00	0.00	0.00	0.74	0.00	2.09	T	0.05	3.69
1958	0.07	1.25	0.44	0.60	0.12	0.00	0.12	0.00	0.00	0.00	0.30	0.00	2.90
1959	0.16	0.23	0.00	0.00	0.00	0.00	0.00	0.23	0.10	0.49	0.00	0.69	1.90
1960	0.32	0.14	0.02	T	T	0.00	0.06	0.22	0.01	0.00	0.03	0.07	0.87
1961	0.15	0.00	T	0.00	T	0.00	0.02	0.75	0.00	T	0.05	0.81	1.78
1962	0.92	0.15	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	1.99
1963	0.00	0.07	0.15	0.00	0.00	0.00	0.00	0.13	1.02	0.37	0.48	0.00	2.22
1964	T	0.21	0.00	0.00	T	0.00	0.00	T	0.00	0.22	0.24	0.02	0.69
1965	T	0.16	0.20	0.61	0.00	0.00	T	0.00	0.00	0.00	0.24	1.88	3.09
10-YR													
AVG.	0.25	0.23	0.09	0.12	0.01	0.00	0.02	0.21	0.12	0.32	0.13	0.44	1.94

APPENDIX C
CONDITION SURVEY PROCEDURES

Appendix C

CONDITION SURVEY PROCEDURES

Step 1. Preliminary Survey

In the preliminary survey the evaluators make a general and personal inspection of all airfield pavement areas, during which they note the type and distribution of defects in each facility (runway, taxiway, etc.). In addition, a previously-prepared construction history is consulted and areas of different construction and different pavement type (AC or PCC) within a facility are noted. As a result of these efforts, each pavement facility is then divided into "discrete areas" of reasonably similar failure modes for performance of the subsequent sampling and tally or measurement of defects. Thus, if the type and/or number of defects found in one portion of a facility are distinctly different from those found in another portion of that facility, discrete areas are selected on this basis. If, however, the pavement facility contains few defects or if the defects found are similar in type and distribution throughout the facility, each facility is individually divided for survey according to the construction history. Under either criterion, a discrete area may vary, for example, from a 500 foot length of runway or taxiway to the entire length of the facility. All discrete areas are numbered with a system that relates the discrete area to the runway, taxiway, etc., of which it is a part. For example, discrete areas comprising Runway 11-29 are designated R 11-1 and R 11-2, etc.; discrete areas for Taxiway 2 are T 2-1 and T 2-2, etc.

A special survey of singular occurrences of serious defects is made during the preliminary survey. This is necessary because the statistical sampling techniques utilized in the subsequent survey are effective in spotting defects only when such defects are numerous and/or relatively well distributed. This abbreviated special survey provides information on those infrequent defects, if any, which may present a problem to safe aircraft operation.

Step 2. Statistical Sampling and Defect Survey

After discrete areas are selected, a number of small "sample areas" are chosen within each discrete area. The total number of sample areas is determined by statistical theory as a function of the relative size of the discrete area. Actual locations of the sample areas are selected at random from the discrete area.

Sample areas in PCC pavements basically consist of individual slabs, usually $12\frac{1}{2}$ x 15 feet in size. For the convenience of the evaluators, either a single slab or a number of adjacent slabs can be considered as a sample area. Both types of sampling area are shown schematically in Figure C-1. Note from Figure C-1 that individual sample slabs and/or sample strips are selected within the center 100 feet (laterally) of runways and within the center 50 feet (laterally) of taxiways by a random selection process. For parking aprons, mats, etc., similar sample areas are selected at random over the entire pavement area.

For AC pavements, sample areas are fifty-foot-square areas located as shown in Figure C-2. For parking aprons, mats, etc. (not shown in Figure C-2) sample areas are fifty-foot square, as for other traffic areas, and randomly located over the entire pavement area.

All defects or defected slabs in each of the selected sample areas are noted on appropriate data sheets. For PCC pavement slabs or sample strips, either single or multiple occurrences of a given defect type within the slab qualify the slab as a defected slab. For example, one or more spalls qualifies a slab as a spalled slab. A crack in the same slab requires that it be counted again, this time as a cracked slab. No measurement of length, area, etc. is recorded for PCC pavement defects. When a sample slab strip is chosen for test, the above mentioned tally method (slab by slab) is still utilized.

The defects found in AC sample areas are measured and tallied, rather than merely tallied as are those for PCC pavements. Depending on the type of defect, the total length in feet (for cracks, etc.) or total area in square feet (for pattern cracking, raveling, etc.) is recorded.

The above survey of defects found in sample areas (in each discrete area) are shown in column (c) of the Discrete Area Defect Summary sheets, Figures C-3 and C-4. Separate summary sheets are provided for portland cement concrete (PCC) and asphaltic concrete (AC) pavements. Total defect counts for the entire discrete area are calculated by a linear extrapolation of the defect data in column (c), and are shown in column (d) of the Discrete Area Defect Summary sheets. To remove the influence of the size of the discrete area on the total defect count, the count is divided by either the number of slabs in the discrete area (for PCC pavements) or by the area (in 10-square-foot increments) of the discrete area (for AC pavements). This gives a defect density (per slab or per 10 square feet) which is listed in column (e).

Step 3. Defect Severity Weighting System

A weighting system, providing a numerical weight for each type defect in proportion to the relative severity of that defect, is applied in the following manner to each of the defect counts in the discrete area;

$$\text{given defect density} \times \frac{\text{weight for that type defect}}{\text{type defect}} = \text{weighted defect density}$$

This is accomplished in columns (f) and (g) of the Discrete Area Defect Summary sheets. Next, a total weighted defect density is obtained for each discrete area by summing column (g) of these sheets. Note that a letter suffix is added to each total weighted defect density for the purpose of further distinguishing between asphaltic concrete defect densities (suffix "A") and portland cement concrete defect densities (suffix "C").

The defect weighting guide developed by NCEL assigns greater weights to defects that (1) presently affect the safe operation of aircraft or the cost of aircraft operation; (2) will lead to increased airfield pavement maintenance costs; or (3) will result in significant deterioration of load-carrying capacity of the pavements. The resultant numerical weights are further modified to reflect variations in pavement environment from station to station. For example, higher (more severe) weights are assigned to defects which are affected by factors such as freezing weather, heavy rainfall, or blow sand for surveys of airfields located in areas where these undesirable environmental effects occur. Thus, it can be seen that the higher the numerical weighted defect density, the poorer the condition of the surveyed pavement.

Remarks concerning the general pavement condition and the defects identified are given in narrative form on each Discrete Area Summary sheet. In addition, photographs of typical pavement conditions noted during the survey are used to further illustrate typical pavement defects.

Step 4. Facility Summary-- Weighted Defect Densities

A final step in providing a numerical condition rating for each facility (runway, taxiway, etc.) is accomplished in the Facility Defect Summary sheets, Figures C-5 and C-6. Again note that separate sheets have been provided for AC and PCC pavements. In these sheets the individual weighted defect densities for all discrete areas comprising the entire AC or PCC portion of a facility (runway, taxiway, etc.) are summarized in column (a). When an AC or PCC facility (or portion) has been divided into more than one discrete area for the condition survey, the proportional contribution of each discrete area to the entire AC or PCC facility area is determined in column (b). In column (c) these proportions are applied to the individual discrete area weighted defect densities listed in column (a) and added to obtain an overall average weighted defect density for the entire AC or PCC portion of the facility (marked "total" in column (c)). When an entire AC or PCC

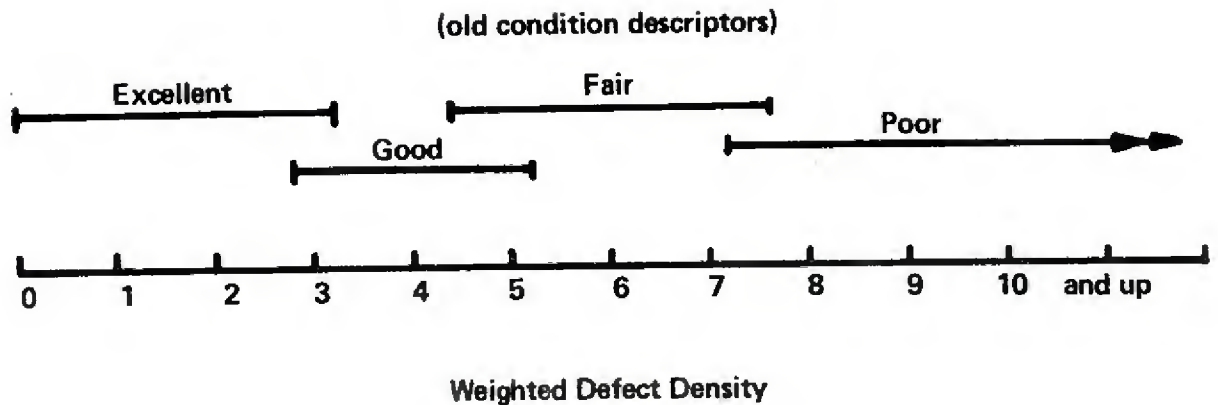
facility (or portion) has been designated a single discrete area (as often occurs), the proportionality factor in column (b) is obviously 1.00 and the discrete area weighted defect density from column (a) becomes the average weighted defect density for the entire facility (or portion) in column (c).

GENERAL COMMENTS ON CONDITION SURVEY PROGRAM

The weighted defect densities, listed in column (a) of the Facility Defect Summary for individual discrete pavement areas and in column (c) as averaged weighted defect densities for entire AC or PCC runways, taxiways, etc. (or portions thereof) represent, numerically, the surface condition of the airfield pavements at the station. As previously stated, the larger defect density numbers indicated basically a greater number and/or severity of defects per unit area of pavement, i.e., a poorer pavement. Thus, they represent the final product of the pavement condition survey. It should be noted specifically, however, that AC and PCC pavement defect densities, although often numerically similar, are obtained by two different condition survey techniques and, as such, are not numerically compatible and must not be combined. (It is largely because of this fact that the letter suffixes "A" and "C" have been affixed to defect densities for AC and PCC pavements respectively.) As an example, consider the common case of an AC runway with PCC ends. The condition survey system presented herein provides individual discrete are weighted defect densities for discrete areas selected on both AC and PCC pavements, but provides a separate average weighted defect density for the entire AC portion and a separate average weighted defect density for the combined PCC end pavements. It is not possible to combine these defect densities to obtain an average AC/PCC defect density for the entire runway. Thus the defect densities for AC and PCC are reported separately, given different letter suffixes, and should include the letter suffix when reference is made to them.

Individual numerical defect densities, however accurately they indicate pavement condition, may mean little to the reader of an individual airfield condition survey report, for he has no basis upon which to judge the relative severity of pavement condition associated with the numbers obtained for his pavements. The primary value of a numerical condition survey program will be the accumulation of uniformly-obtained, comparative condition data for many airfields which can best be correlated, studied, and used in the decision-making processes at headquarters levels.

For the benefit of the individual reader, however, an effort was made during the first year of pavement condition surveys (FY-70) to relate the numerical condition (defect densities) to the basic subjective condition descriptors (excellent, good, fair, poor, etc.) used in all previous Navy pavement evaluation procedures. Although the subjective condition-descriptor approach is poorly regarded as a means of comparing pavement condition from one airfield to another, the following diagram may serve temporarily as a rudimentary bridge between the old subjective system and the new (numerical) condition approach:



The system of numerical defect densities was developed to aid in determining the suitability of airfield pavement surfaces for satisfying aircraft operational requirements and to establish an unbiased, uniform basis for initiating maintenance and repair efforts. As such, defect densities are simply visually-determined indicators of the condition of the pavement and do not represent true "condition ratings" in that they do not include factors relating to pavement strength, traffic usage, etc. It is possible that additional measurements or modifications may be considered necessary or desirable in future condition survey programs.

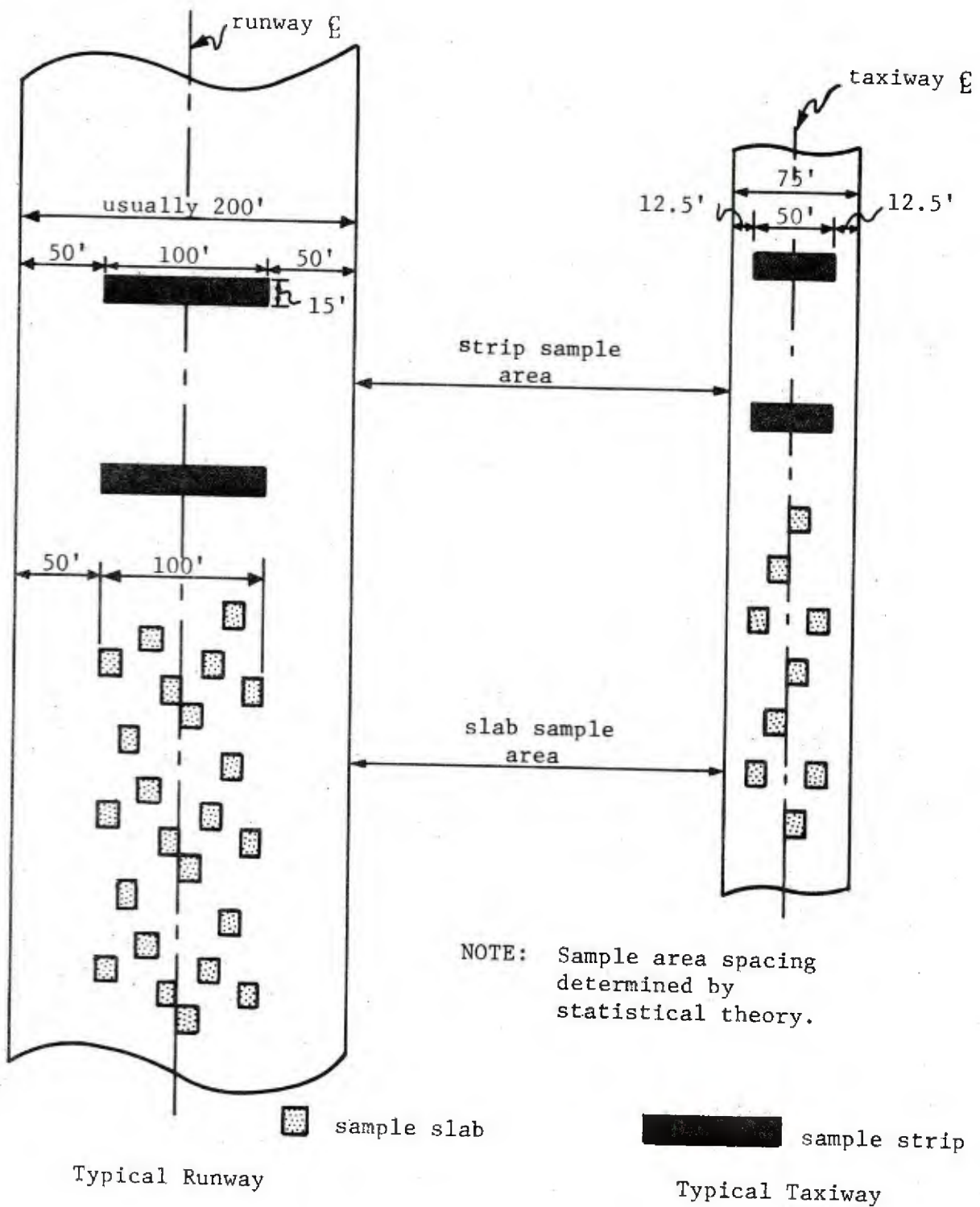


Figure C-1. Portland cement concrete sample areas.

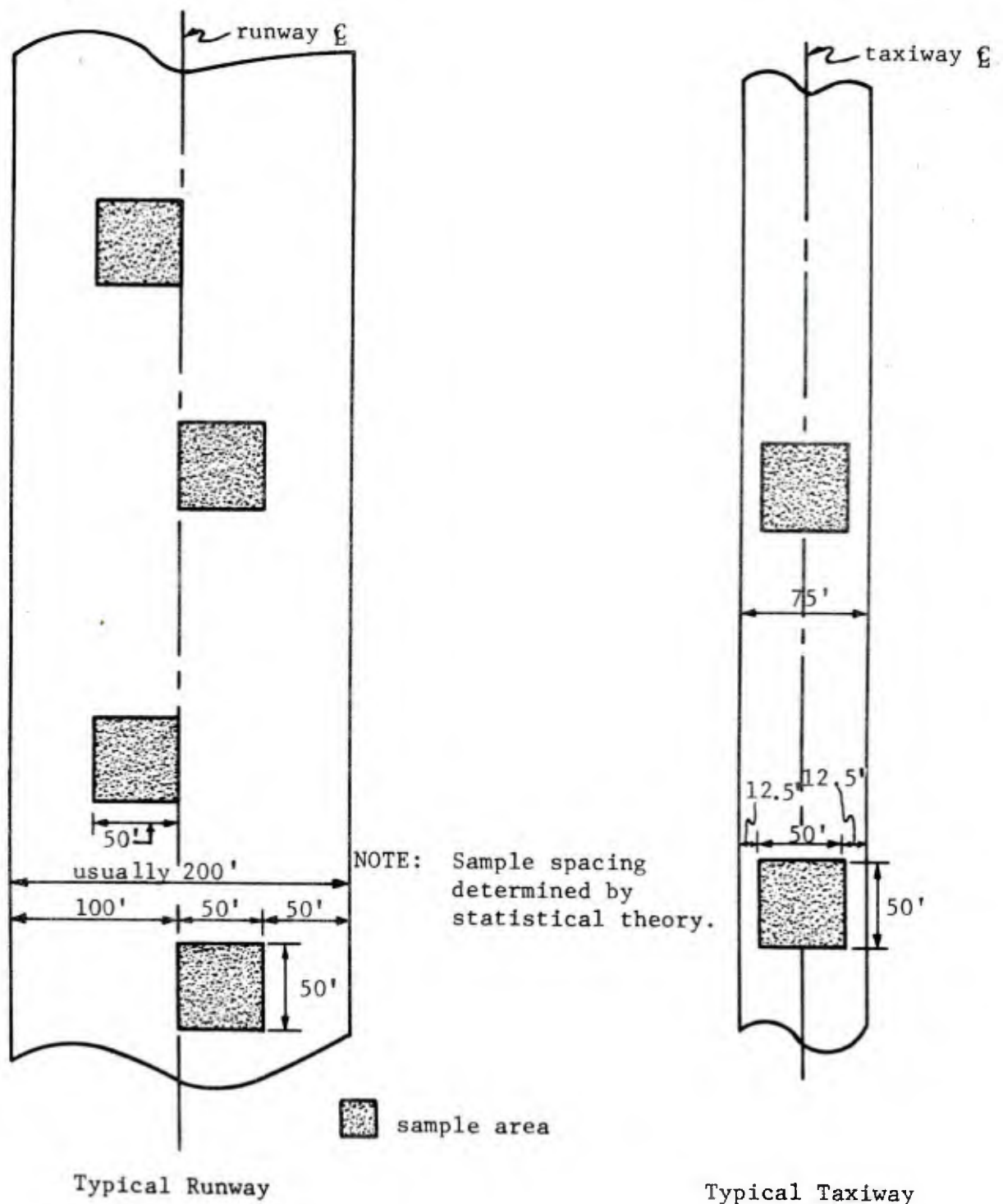


Figure C-2. Asphaltic concrete sample areas.

ASPHALTIC CONCRETE DISCRETE AREA DEFECT SUMMARY

Airfield E X A M P L E Facility Taxiway 2
 Discrete Area T2-1 Area of Discrete Area (a) 97,700 ft²
 No. of Sample Areas (b) 10 Ratio: (a/2500b) 3.9

Defect Type	Length or Area of Sampled Defects	Total Length or Area of All Defects: (c) x Ratio	Defect Density (per 10 sq. ft.) 10 d/s	Defect Severity Weight	Weighted Defect Density: (e) x (f)
	(c)	(d)	(e)	(f)	(g)
T.C., L.C. or LCJ*	80 ft	312 ft	0.0319	2.5	0.0798
Reflection Crack					
Faulting					
Patching					
Settlement or Depression	530 ft ²	2,067 ft ²	0.2116	9.0	1.9041
Pattern Cracking	126 ft ²	491.4 ft ²	0.0503	2.5	0.1257
Rutting					
Ravelling					
Erosion—Jet Blast					
Oil Spillage					
Broken-up Area					
Total					2.11 A**
Remarks on Pavement Condition The depressions were generally 1/2" deep. Pattern cracking formed 6" to 12" polygons and was associated with the depressions. Longitudinal cracks were unsealed and 1/8" wide. (See Figure 5.)					

* Transverse crack, longitudinal crack, and longitudinal construction joint

** Letter suffix "A" indicates asphaltic concrete pavement

Figure C-3. Typical Asphaltic Concrete Discrete Area Defect Summary

PORTLAND CEMENT CONCRETE DISCRETE AREA DEFECT SUMMARY

Airfield E X A M P L E Facility Taxiway 2
 Discrete Area T2-2 Total Slabs in Discrete Area (a) 1,542
 No. of Slabs Sampled (b) 193 Ratio a/b = 8.0

Defect Type	No. of Sample Slabs w/Defect	Total Slabs w/Defect: c x a/b	Defect Density (per slab) d/a	Defect Severity Weight	Weighted Defect Density e x f
	(c)	(d)	(e)	(f)	(g)
Faulting					
Corner Break	1	8	0.0052	2.5	0.013
L.C. or T.C. *	19	152	0.0985	1.0	0.098
I.C. **	1	8	0.0052	2.5	0.013
Depression		2***	0.0013	9.0	0.012
Spalling	59	472	0.3060	7.5	2.295
Scaling					
Disintegrated Slab					
Joint Seal	10	80	0.0518	2.5	0.130
Pumping					
Remarks on Pavement Condition					Total
					2.57 C****
Spalls were generally 1" wide by 3" long with some spalls up to 4" wide and 12" long. The longitudinal cracks found were mostly sealed. The depressions noted as singular defects consisted of two depressed and cracked slabs. The depression was approximately 1/2" deep. An attempt had been made to repair these slabs with portland cement concrete. Joint seal was missing in strips 4" to 12" long. (See Figures 25 and 26.)					

- * Longitudinal crack or transverse crack
- ** Intersecting crack
- *** Counted as singular defects during the preliminary survey
- **** Letter suffix "C" indicates portland runway concrete pavement

Figure C-4. Typical Portland Cement Concrete Discrete Area Defect Summary

ASPHALTIC CONCRETE FACILITY DEFECT SUMMARY Airfield <u>E X A M P L E</u> Date Surveyed _____			
Facility (or portion)	Weighted Defect Density Total	Ratio: <u>Discrete Area</u> Total Facility Area*	Average Weighted Defect Density (a) x (b)
	(a)**	(b)	(c)**
Taxiway 2 T2-1	2.11 A	1.00	2.11 A
Taxiway 10 T10-2	0.004 A	1.00	0.004 A
Towway 1 TOW-1	3.77 A	1.00	3.77 A
Parking Apron 2 PA2-1	7.29 A	1.00	7.29 A
Parking Apron 6 PA6-1	7.44 A	1.00	7.44 A
Parking Apron 7 PA7-1	4.97 A	0.79	3.93
PA7-2	23.18 A	0.21	4.87
			<u>8.80 A (Total)</u>
Parking Apron 8 PA8-1	2.76 A	1.00	2.76 A
Central Mat CM-1	2.89 A	1.00	2.89 A

* If facility entirely constructed of AC, indicates total facility area. If facility only partly constructed of AC, indicates total area of AC portion of facility.

** Letter suffix "A" on weighted defect densities indicates asphaltic concrete pavements.

Figure C-5. Typical Asphaltic Concrete Facility Defect Summary

PORTLAND CEMENT CONCRETE FACILITY DEFECT SUMMARY Airfield <u>E X A M P L E</u> Date Surveyed _____			
Facility (or portion)	Weighted Defect Density Total	Ratio: $\frac{\text{Discrete Area}}{\text{Total Facility Area}^*}$	Average Weighted Defect Density (a) x (b)
	(a)**	(b)	(c)**
Runway 11-29			
R11-1	0.80 C	0.25	0.02
R11-2	4.43 C	0.75	3.33
			<u>3.35 C (Total)</u>
Runway 18-36			
R18-1	1.25 C	0.68	0.85
R18-2	0.76 C	0.32	0.28
			<u>1.13 C (Total)</u>
Taxiway 1			
T1-1	2.82 C	0.12	0.34
T1-2	0.98 C	0.88	0.86
			<u>1.20 C (Total)</u>
Taxiway 2			
T2-2	2.57 C	1.00	2.57 C
Taxiway 3			
T3-1	1.82 C	1.00	1.82 C
Taxiway 4			
T4-1	3.02 C	1.00	3.02 C
Taxiway 5			
T5-1	0.98 C	1.00	0.98 C
Taxiway 6 and Taxiway 7			
T6-1 and T7-1	0.06 C	1.00	0.06 C

* If facility entirely constructed of PCC, indicates total facility area. If facility only partly constructed of PCC, indicates total area of PCC portion of facility.

** Letter suffix "C" on weighted defect densities indicates Portland cement concrete pavements.

Figure C-6. Typical Portland Cement Concrete Facility Defect Summary

Appendix D
MU-METER TEST RESULTS

Appendix D
MU-METER TEST RESULTS
NPTR EL CENTRO, CALIFORNIA

Test Location Run. No.	Runway Heading	Average Time After Wetting (Min)	Average Coefficient of Friction (Mu)	Maximum Coefficient of Friction (Mu)	Minimum Coefficient of Friction (Mu)
Runway 8L-26R					
Test Section 1					
Portland Cement Concrete					
1	8	2.30	0.43	0.58	0.34
2	26	3.32	0.44	0.64	0.29
3	8	4.29	0.46	0.57	0.30
4	26	5.32	0.46	0.62	0.31
5	8	6.45	0.44	0.62	0.32
6	26	10.90	0.64	0.66	0.35
7	8	19.12	0.65	0.74	0.49
Asphaltic Concrete					
1	8	2.30	0.64	0.80	0.28
2	26	3.32	0.72	0.83	0.51
3	8	4.29	0.64	0.76	0.22
4	26	5.32	0.74	0.78	0.30
5	8	6.45	0.72	0.82	0.37
6	26	10.90	0.75	0.81	0.50
7	8	19.12	0.76	0.78	0.60
Test Section 2					
1	8	2.23	0.72	0.80	0.61
2	26	3.07	0.72	0.80	0.62
3	8	4.03	0.74	0.81	0.64
4	26	6.68	0.72	0.80	0.60
5	8	11.98	0.74	0.82	0.68
Test Section 3					
1	26	2.27	0.43	0.64	0.12
2	8	3.13	0.47	0.74	0.15
3	26	4.02	0.49	0.74	0.08
4	8	4.95	0.54	0.78	0.20
5	26	7.88	0.73	0.88	0.20
6	8	16.13	0.84	0.95	0.42
Test Section 4					
1	26	2.23	0.30	0.52	0.10
2	8	3.17	0.42	0.65	0.24
3	26	4.12	0.42	0.70	0.19
4	8	5.05	0.55	0.76	0.30
5	26	7.05	0.57	0.77	0.33
6	8	13.73	0.79	0.94	0.46

Appendix D
MU-METER TEST RESULTS
NPTR EL CENTRO, CALIFORNIA
(continued)

Test Location Run No.	Runway Heading	Average Time After Wetting (Min)	Average Coefficient of Friction (Mu)	Average Coefficient of Friction (Mu)	Average Coefficient of Friction (Mu)
Runway 12L-30R					
Test Section 1					
1	30	2.34	0.39	0.59	0.16
2	12	3.31	0.38	0.67	0.13
3	30	4.34	0.45	0.67	0.13
4	12	5.38	0.44	0.64	0.12
5	30	7.53	0.56	0.73	0.21
6	12	11.01	0.68	0.84	0.18
7	30	18.31	0.76	0.90	0.54
Test Section 2					
1	30	2.47	0.28	0.77	0.09
2	12	3.75	0.31	0.67	0.09
3	30	4.85	0.35	0.78	0.10
4	12	5.88	0.41	0.73	0.09
5	30	8.68	0.49	0.90	0.12
6	12	15.72	0.53	0.87	0.18
7	30	19.47	0.64	0.92	0.13
Test Section 3					
1	30	2.26	0.40	0.56	0.20
2	12	2.98	0.39	0.75	0.08
3	30	3.91	0.41	0.72	0.15
4	12	4.66	0.46	0.81	0.18
5	30	6.81	0.54	0.86	0.14
6	12	8.68	0.54	0.80	0.11
7	30	14.41	0.70	0.91	0.21
8	12	21.04	0.70	0.91	0.10

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