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FIELD PERFORMANCE OF POROUS FRICTION SURFACE COURSE

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FINAL REPORT

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16. Abstract

This report presents the results of a field performance survey first described in Report No. FAA-RD-73-197. Additional prototype construction experience and validation of a design procedure including a desired mixing viscosity range are reported. Long-term porous friction course (PFC) performance is recorded and combined with laboratory test results that provide data for a new recommended PFC gradation, water permeability requirements, and initial voids total mix requirement.

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PREFACE

This project was conducted by the Soils and Pavements Laboratory, U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., for the Federal Aviation Administration as a part of Inter-Agency Agreement No. DOT FA71WAI-218.

The project was conducted under the general supervision of Mr. James P. Sale, Chief of the Soils and Pavements Laboratory. This report was written by Mr. Thomas D. White and covers work done from December 1971-June 1975.

COL G. H. Hilt, CE, was Director of WES during the preparation of this report. Technical Director was Mr. F. R. Brown.

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METRIC CONVERSION FACTORS

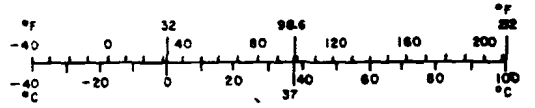
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in. = 2.54 (exactly). For other exact conversions and more detailed tables, see NBC Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



EXECUTIVE SUMMARY

The overall objectives of the porous friction surface course (PFC) study were to develop a PFC mix design method and construction specifications. To accomplish these objectives, a program was followed that included a review of pertinent literature, design methods, and construction specifications; observation of PFC construction; laboratory study of PFC mix design methods; and field inspection and evaluation of PFC performance.

The review of literature and current PFC construction experience indicated that PFC job-mix formulas have been adopted largely based on subjective evaluations of tests. The laboratory portion of the PFC study was therefore directed at identifying a physical property that would correlate with PFC field performance. Results of these tests indicated a lack of sensitivity of PFC mixes to physical test methods. Positive results of the laboratory work included development of a laboratory water permeability test and adaptation of the laboratory test equipment to field testing. A minimum water permeability of 1000 ml/min was recommended. A method for determining density of PFC and other open-graded mixtures was recommended as well as a procedure for preparing PFC samples comparable with actual in-place PFC pavement surfaces.

Observations of several PFC construction jobs provided information for preparing a standard specification for PFC. The PFC specification was written early in the project, but very few changes have been recommended.

Continued laboratory studies and evaluation testing of field samples provided data for analysis and development of a mix design concept. Correlation of laboratory test results and field performance indicated that an estimate of the asphalt content (EOA) could be made from the relation $EOA = 2K_c + 4.0$, where K_c is the coarse aggregate fraction surface area constant as determined by the California Centrifuge Kerosene Equivalency (CKE) test, Test Method California No. 303F. Construction experience indicated a need for selecting a rational mixing temperature to reduce asphalt drainage problems during construction. Job

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INTRODUCTION

BACKGROUND

This report presents the evaluation of performance of porous friction course (PFC) for airport pavements. Results of the initial literature and laboratory studies and preliminary field evaluation are presented in Report No. FAA-RD-73-197, "Porous Friction Surface Course."[1]

In the latter part of 1971 and in 1972, a number of airfield PFC's were constructed. These PFC's were located in different climatic areas of the United States. They were constructed using a range of binder materials, aggregate types, and gradations, and they were subjected to a wide range of traffic types and levels.

An extended performance evaluation was not originally planned for this project, but results of laboratory tests and preliminary field observations indicated a need for this type of study.

OBJECTIVE

The objective of this report is to present validation data on the design, construction, and performance of PFC pavements.

SCOPE

Additional data on design and construction were obtained from participation in the design and construction of a new PFC for a runway at the Greensboro--High Point--Winston-Salem Airport in North Carolina. The performance data on PFC pavements were collected through a series of condition surveys on 10 airports that have PFC pavements, including the pavements surveyed for the earlier report.[1] Table 1 lists the locations of the 10 pavements surveyed.

A safe viscosity (temperature) is considered to be one at which excess asphalt drainage in the PFC will not occur. At a given viscosity, an asphalt will coat a constant aggregate surface area with a certain film thickness. If there is a volume of asphalt in the mix in excess of that required for aggregate coating, asphalt drainage will occur. In addition, even though the optimum asphalt content is proportioned into the mix, an increase in mixing temperature will cause a corresponding decrease in viscosity, and the asphalt will become more fluid. As a result, a thinner film of asphalt will coat a constant aggregate surface area. The amount of asphalt in excess of that needed to form the aggregate coating will drain and cause rich spots in the pavement. Even though the optimum asphalt content is added at the desired viscosity, poor gradation control will cause the aggregate surface area to vary. If the aggregate surface area is too low, the resulting excess asphalt will also cause drainage.

Field analysis of stockpiles at Greensboro indicated a variance in gradations from those furnished for the laboratory mix design, particularly with respect to the coarse aggregate. Because of nonuniformity of the aggregate stockpiles, a new coarse aggregate with a gradation nearer that of the original coarse aggregate was obtained. With the new material, a field job-mix formula was established consisting of the following:

Gradation

Sieve Size	Percent Passing
1/2 in.	100
3/8 in.	97 ± 3
No. 4	38 ± 3
No. 8	15.7 ± 2
No. 30	6.1 ± 2
No. 200	2.0 ± 1

Binder content ..... 6.5 ± 0.25 percent by weight

Mixing temperature ... 280 ± 6°F

No change in asphalt content was recommended since the same aggregate type was being used and there were minimal differences in gradation. The gradation was recommended with consideration to the need to use the

FIELD SURVEYS

Condition surveys were conducted on PFC pavements at nine airports throughout the United States. These are the pavements described in the original PFC report.[1] Tables 1 and 2 present an updated summary of the dates and types of surveys conducted and the construction data. Results of surveys conducted in 1973, 1974, and 1975 are presented in Tables 3, 4, and 5. The results of laboratory tests on samples collected in 1973 are included later in this report

Skid resistance tests using the British Portable Skid Resistance Tester described in American Society for Testing and Materials Designation: E 303-69[2] and water permeability tests using procedures described in Appendix A were conducted on the in-place pavement. Samples (6-in.-diam cores) of the PFC were removed from the pavement both in and out of traffic areas for laboratory testing. Method 101 of Military Standard MIL-STD-620[3] was used to determine density and voids using values for the volume of the samples determined from physical measurements.

PEASE AFB

During the survey conducted in September 1974, reflective cracking that had been noted in previous visits was still evident (Figure 5). At this time, there was a series of reflected cracks approximately 7 ft to the south of the runway center line, intermittently along the length of the runway (Figure 6). Petroset was used to seal these reflected cracks. Some raveling was still occurring as well as some damage due to locked-wheel turns and jet blast (Figure 7). No significant snow removal equipment damage was noted. Urea is used in snow and ice removal operations at Pease AFB, and it was reported that more urea is required for the PFC surface. There has been some rubber buildup, but it is not considered a problem (Figure 8). Base personnel indicated that they were satisfied with the PFC's performance.

In March 1975, Pease AFB was visited again and a visual inspection of the PFC conducted. Also, 6-in.-diam cores were removed from the pavement for further laboratory analysis. No significant change in the

impermeable surface. Outside the traffic areas, the permeability of the PFC was adequate. Nashville Airport engineering personnel voiced dissatisfaction with the performance of the PFC at the time field inspections were conducted.

In March 1975, Nashville Metropolitan Airport was visited to visually inspect the PFC and obtain samples for laboratory testing. The problems of consolidation, rutting, and rubber buildup were continuing (Figures 13, 14, and 15). Continued dissatisfaction with the PFC was voiced by airport engineering personnel. Plans are being made to overlay the entire runway with portland cement concrete.

NAVAL AIR STATION, DALLAS

A field party visited the Naval Air Station, Dallas, in November 1973 and conducted field tests and collected samples for laboratory testing. At that time, Public Works Office personnel expressed their satisfaction with the PFC. The overall condition of the PFC was good, and good drainage was observed in the area where jet blast damage had occurred (Figure 16). Previously reported raveling problems seemed to be stabilized. However, a few areas near the south end of the runway were still raveling (Figure 17). Some gouging from aircraft arrester hooks was observed (Figure 18). Both transverse and longitudinal reflected cracks were observed (Figure 19). No significant increase had occurred in raveling at those reflected cracks that were observed in the previous survey.

In April 1975, Dallas was visited to visually inspect the condition of the PFC and remove 6-in.-diam samples from the pavement for laboratory testing. No change in the PFC's condition or performance was noted.

KIRTLAND AFB (KAFB)

As noted in the report of field observations in May 1973,[1] the PFC test sections at KAFB received only minor traffic. Therefore, as expected, the condition of the PFC test sections was relatively unchanged when a field party visited KAFB in October 1974 to conduct field tests and collect samples for laboratory tests. The only change observed was

reflected cracks that was performing satisfactory (Figures 23 and 24). No solution for effectively removing the rubber building up on the PFC (Figure 25) had been found.

Airport personnel expressed their satisfaction with the overall performance of the PFC. The maintenance problems caused by reflected cracks, raveling, and bonding of sections of PFC had been greatly reduced.

Stapleton International Airport was visited again in March 1975 to inspect the PFC and obtain 6-in.-diam samples for laboratory testing. There appeared to be more cracks and existing sealed cracks were opening wider. The weather at Denver was cold at the time of inspection, and some ice was observed on the PFC. Ice had formed where water was forced to the surface at sealed cracks (Figure 26). Sealing cracks effectively created a dam in the PFC, and water draining internally in the PFC was forced to the surface. Ice was also observed at longitudinal construction joints. Figure 27 shows a patch of ice on the surface of the PFC melting from the bottom. This condition occurs when air is warmed in the voids of the PFC.

BARTLESVILLE MUNICIPAL AIRPORT

Observations on a field inspection made in May 1973 at Bartlesville Municipal Airport are reported in Reference 1.

A party visited the airport again in November 1974 to conduct additional field tests and remove 6-in.-diam samples from the pavement for laboratory testing. At that time, the PFC was in good condition. Little change could be observed with the exception of some surface wear or stripping of asphalt and minor reflective cracking near the south end of the runway. No raveling at these cracks had occurred. Airport personnel expressed their satisfaction with the performance of the PFC pavement.

Bartlesville was visited again in March 1975 to inspect the PFC and collect samples for laboratory testing. At the time of this inspection, the area of the PFC that had been surface treated with Petroset was darker in color than the untreated area. The reflected cracks at the south end of the runway showed some minor raveling

LABORATORY EVALUATION OF FIELD SAMPLES

Laboratory evaluation of the field samples was conducted to determine the properties of the in-place PFC. This evaluation allowed a comparison of the laboratory designed mix and the as-constructed mix properties and the effects of time and environment on the binder. Six -in.-diam samples collected in the field inspections provided material for this laboratory testing. To obtain the samples, the pavement was cored through to at least one pavement layer interface below the PFC, and the core was separated at that interface by shearing with a hot knife. The resulting specimen consisted of a PFC layer on a dense core of the underlying pavement. Samples were obtained in and out of traffic areas where possible; however, restricted access on operational runways did not allow this procedure at all sites.

In 1973 and 1974, an acceptable density determination method had not been developed; therefore, the laboratory test results did not include voids and density values until 1975. In 1973 and 1974, the PFC sample was separated from its dense base with a hot knife after the sample was slightly warmed. Prior to testing PFC components, aggregate particles cut during the coring process were removed. The PFC specimen was then broken up and extractions conducted according to ASTM D 2172-72.[4] The gradation was determined according to ASTM C 136-71.[5] The recovered asphalt was tested for penetration and viscosity according to ASTM D 5-73[6] and ASTM D 2170-67,[7] respectively. The binder was recovered according to ASTM D 1856-69.[8]

Laboratory water permeability tests and density determinations in 1975 were conducted according to the procedures described in Reference 1. For these tests, the water permeability was determined prior to separating the PFC from the dense base. The samples were prepared for density determinations by sawing slightly above the PFC-dense base interface. Examination of the sawed faces during density measurements enabled a relative evaluation of densification and uniformity of the aggregate gradation. These sawed faces are shown in Figures 34-43. Where available, samples from in and out of the traffic area are shown.

$$A_0 + A_1(\% \text{ voids}) + A_2(\% \text{ passing No. } 8)$$

where A_0 , A_1 , and A_2 are constants determined by the least squares method.

An analysis of permeability, voids total mix, and gradation data from Table 5 indicates that an estimate of the permeability P can be made with the following equation:

$$P = 1982 + 40.9(\% \text{ voids}) - 82.0(\% \text{ passing No. } 8)$$

Substituting the minimum percent voids total mix and maximum percent passing the No. 8 sieve recommended above gives

$$P = 1469 \text{ ml/min}$$

The standard error of estimate would be 507 ml/min. Applying this standard error of estimate, the minimum permeability would be above 1000 ml/min at the 82 percent confidence level. Hence, setting the minimum percent voids total mix at 30 percent and the maximum percent passing the No. 8 sieve at 20 percent will insure that for these critical values there is a confidence level of 82 percent with respect to permeability.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are believed warranted based on the results of this study:

a. The poor PFC performance at Nashville could have been the combined result of several parameters. There are no definitive data to clarify the performance of limestone aggregate in PFC. However, by following the design method, quality control procedures, and good construction practices recommended as a result of this study, PFC pavements can be constructed with a much higher degree of confidence.

b. Based on evaluations of test results, a change in the aggregate gradation to limit the amount of material passing the No. 8 sieve to 20 percent maximum is recommended. The following table is a suggested gradation reflecting this limitation:

PFC Gradation

Sieve Size	Percent by Weight Passing Sieve
1/2 in.	100
3/8 in.	80-100
No. 4	25-40
No. 8	12-20
No. 200	3-5

c. The asphalt drainage test does not enhance the design procedure and should only be used to gain secondary background information.

d. Based upon the apparent good results obtained at Greensboro, it is recommended that the design procedure in Reference 1 be used, with the exception that the viscosity range be changed to 275 ± 25 centistokes.

e. The minimum permeability desired for PFC is 1000 ml/min. This requirement combined with a minimum initial voids total mix requirement of 30 percent and the new gradation band will result in good, long-term permeability performance.

f. The procedure for conducting the water permeability test and the recommended design procedure are presented in Appendixes A and B, respectively.

Table 1 (Concluded)

Site No.	Location	Date Constructed	Type of Survey	Date Conducted
7	Stapleton International Airport, Denver, Colo.	Sep-Oct 72	Field testing and sampling	May 73
			Field testing and sampling	Oct 74
			Visual inspection and sampling	Mar 75
8	Bartlesville Municipal Airport, Bartlesville, Okla.	Jul 72	Field testing	May 73
			Field testing and sampling	Nov 74
			Visual inspection and sampling	Mar 75
9	Salt Lake City International Airport, Salt Lake City, Utah	Aug-Sep 72	Observation of construction	Aug 72
			Field testing	May 73
			Field testing and sampling	Oct 74
			Visual inspection and sampling	Mar 75
10	Greensboro--High Point--Winston-Salem Regional Airport, Greensboro, N. C.	Sep 74	Design, quality control of construction	Sep 74
			Visual inspection and sampling	Mar 75

Table 3

1973 PFC Evaluation

Site No.	Location	Traffic Area	Asphalt: Viscosity, 10^2 cSt, at Cited Mixing Temperature 140°F	225°F	275°F	Penetration 1/10 mm	Content* Percent	Percent Aggregate Passing Cited Sieve Size: 3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 50	No. 200	Flow Rate for Falling Head Permeability ml/min: Field	Laboratory	Average Skid Resistance BPN**: Dry	Wet
4	NAS, Dallas	In	24,508	67.73	9.06	16	5.4	100	100.0	100.0	41.1	16.6	7.5	3.5	1.7	2662	Permeability data not collected.	94	56
		Out	--†	--†	--†	--†	--†	100	100.0	100.0	47.2	18.7	8.0	4.0	2.4	4288		92	68
5	Kirtland AFB††																		
	Test section 1	Out	2,507	18.64	3.56	49	4.8	100	81.6	57.0	30.8	25.4	18.7	11.2	7.1	861		96	83
	Test section 2	Out	11,437	41.69	6.21	24	5.4	100	92.1	76.1	48.5	27.7	19.0	11.6	8.3	1429		87	72
	Test section 3	Out	2,493	18.53	3.38	44	5.3	100	100.0	95.9	55.0	35.1	26.6	17.7	12.0	406		85	67
	Test section 4	Out	2,174	17.96	3.52	47	5.1	100	98.4	83.4	46.2	30.6	21.6	13.3	8.9	121		88	72
	Test section 5	Out	12,293	43.16	6.96	30	5.2	100	90.6	66.9	33.0	21.9	16.7	11.7	8.3	708		94	72
	Test section 6	Out	8,617	37.29	6.07	32	5.5	100	95.9	85.8	51.6	34.8	26.0	16.4	11.0	78		90	71
	Test section 7	Out	4,836	26.99	4.83	34	5.7	100	96.3	87.7	70.4	58.5	43.2	25.2	16.6	0		80	66
	Test section 8	Out	16,052	49.84	7.24	24	4.3	100	53.5	29.6	24.4	21.0	17.4	10.2	5.8	--‡		82	61
6	Great Falls	In	9,744	35.06	5.60	34	6.2	100	98.3	93.7	40.1	20.0	13.8	8.5	4.2	3710		99	80
		Out	--†	--†	--†	--†	--†	100	100.0	97.8	43.2	19.1	11.4	7.0	4.3	3574		100	76
7	Stapleton	In	6,185	40.07	7.00	42	6.3	100	100.0	99.4	46.4	22.1	16.0	9.8	5.8	602			
		Out	5,618	38.28	6.61	45	--†	100	100.0	98.2	40.4	20.7	15.7	9.1	5.1	2334		93‡‡	74‡‡
8	Bartlesville	In	56,443	111.56	13.97	29	5.9	100	100.0	99.3	46.0	25.8	16.4	9.2	6.1	1202		99	75
		Out	47,318	101.38	13.10	28	--†	100	100.0	98.6	44.3	21.6	13.5	7.2	4.4	2122		94	79
9	Salt Lake City	In	10,880	58.52	8.90	31	--†	100	84.6	63.1	25.1	12.1	7.5	3.1	1.5	3101		94	64
		Out	5,072	37.04	8.58	29	4.6	100	79.9	58.0	23.6	12.6	8.3	3.2	1.5	4039		100	73

Note: Pease AFB, Hot Springs Airport, and Nashville Metropolitan Airport were not included in the 1973 evaluation.

* Based on amount extracted from field core.

** The BPN (British Portable (Tester) Number) represents the frictional property of the PFC as determined using ASTM E 303-69.

† Not enough material was available to conduct this test both in and out of traffic area.

†† Due to the limited amount of traffic applied to the test sections, it was assumed that the results were indicative of an out of traffic area.

‡ Permeability was too high to measure.

‡‡ Value is average BPN for the test section at Stapleton; access to the runway itself was restricted.

Table 5

1975 PFC Evaluation

Site No.	Location	Traffic Area	Asphalt: Viscosity, 10^2 cSt, at Cited Mixing Temperature 140°F	225°F	275°F	Penetration 1/10 mm	Content* percent	Properties of Mix: Percent Voids Total Mix	Density pcf	Percent Aggregate Passing Cited Sieve Size: 3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 50	No. 200	Flow Rate for Falling Head Permeability ml/min: Field	Laboratory
1	Pease AFB	In	3,344	28.45	5.27	46	4.9	27.2	119.2	100**	100**	94.8**	40.2**	22.2**	14.4**	7.6**	4.5**	No flow	542
		Out	4,243	26.80	5.05	49	5.2	28.2	114.2										1591
2	Hot Springs	In	12,852	48.31	7.48	30	5.2	32.3	109.3	--	--	--	--	--	--	--	--		2490
		Out	20,765	66.85	9.48	25	5.0	39.3	96.7	--	--	--	--	--	--	--	--		3859
3	Nashville	In	7,775	35.97	6.02	31	6.3	17.1	128.0	--	--	--	--	--	--	--	--		--
		Out	18,213	59.75	8.04	24	5.4	31.0	108.0	--	--	--	--	--	--	--	--		1286†
4	NAS, Dallas	In	59.706	99.00	12.36	8	5.3	41.0	104.1	100	100	100	37.1	13.3	6.1	3.0	2.1		2412
		Out	71,979	110.02	13.02	9	5.0	42.9	101.2	100	100	100	47.7	19.6	7.9	3.5	1.9		3508
5	Kirtland AFB††																		
	Test section 1	Out*	8,330	32.08	5.37	31	5.0	24.3	121.5	100	91.3	68.9	40.6	34.0	26.9	15.0	8.4		1591
	Test section 2	Out*	8,237	37.50	6.09	21	4.6	26.0	119.2	100	90.6	75.8	46.8	25.8	18.1	11.8	8.2		853
	Test section 3	Out*	19,549	49.39	7.42	20	5.0	21.8	126.6	100	98.0	89.7	48.8	30.5	21.4	12.9	7.9		300
	Test section 4	Out*	5,742	21.06	3.90	36	4.6	27.5	118.3	100	98.6	90.2	51.9	33.5	25.1	16.6	10.1		19
	Test section 5	Out*	6,693	25.55	4.95	28	4.7	30.3	112.7	100	89.6	73.8	41.2	29.2	22.5	13.9	8.1		780
	Test section 6	Out*	5,616	24.77	4.58	28	5.0	24.6	123.6	100	99.3	88.9	50.9	34.2	23.8	14.6	10.0		111
6	Great Falls	In	2,944	30.22	5.13	34	6.7	17.7	123.4	100	100	95.1	39.4	18.9	12.6	8.0	4.2		776
		Out	16,872	48.81	7.03	25	5.8	28.6	108.6	100	100	95.9	45.2	20.5	12.5	7.5	4.4		3508
7	Stapleton	In	7,781	46.27	7.97	33	6.3	16.0	127.3	100	98.7	96.7	46.4	26.1	19.7	10.3	4.9		917
		Out	11,730	56.04	9.19	30	6.0	20.8	120.4	100	99.0	95.6	53.1	29.3	22.0	11.5	5.5		977
8	Bartlesville	In	217,062	235.37	24.44	21	5.6	24.3	113.6	100	100	99.2	44.8	24.1	14.9	8.4	5.6		1029
		Out	183,404	211.79	22.58	20	5.6	27.2	109.2	100	100	97.4	45.0	22.2	13.6	7.2	4.5		1575
9	Salt Lake City	In	34,674	121.14	16.12	15	4.6	24.1	145.4	100	87.7	69.7	32.9	16.5	10.5	5.5	3.1		1429
		Out	29,641	84.52	13.23	19	4.7	30.3	133.3	100	92.3	72.1	32.0	16.8	11.7	5.9	3.0		1354
10	Greensboro	In	5,549	39.08	7.30	49	6.0	28.9	112.9	100**	100**	98.1**	49.5**	19.0**	10.5**	4.8**	2.7**		2573
		Out	5,179	39.41	7.26	44	6.2	28.4	113.7										3508

* Based on amount extracted from field core.

** Due to limited amount of material available, combined gradation was run.

† Permeability decreased markedly on samples taken progressively toward runway center line.

†† Due to the limited amount of traffic applied to the test sections, it was assumed that the results were indicative of an out of traffic area.

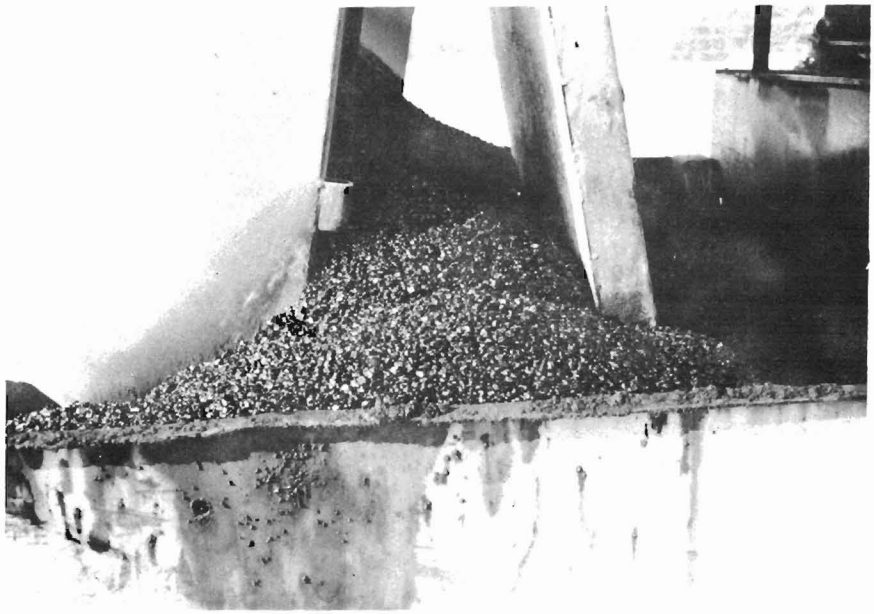


Figure 2. PFC mixture being placed in laydown machine hopper (Greensboro)

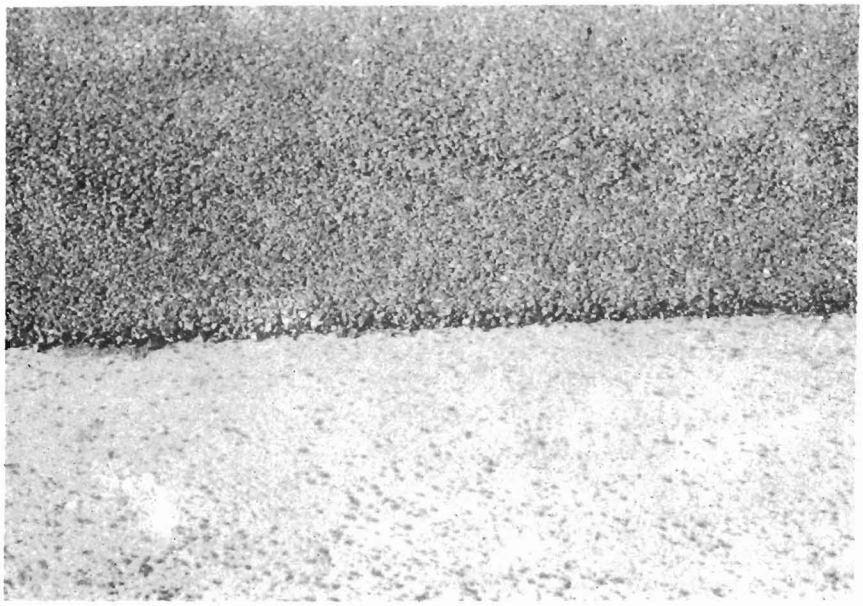


Figure 3. Closeup view of edge of compacted PFC and surface texture (Greensboro)

Figure 6. Longitudinal reflected cracks sealed with Petroset (Pease)

Figure 7. Jet blast damage (Pease)

Figure 10. Damage from locked-wheel turns (Hot Springs)

Figure 11. Water from coring operation running in rutted wheel path (Nashville)

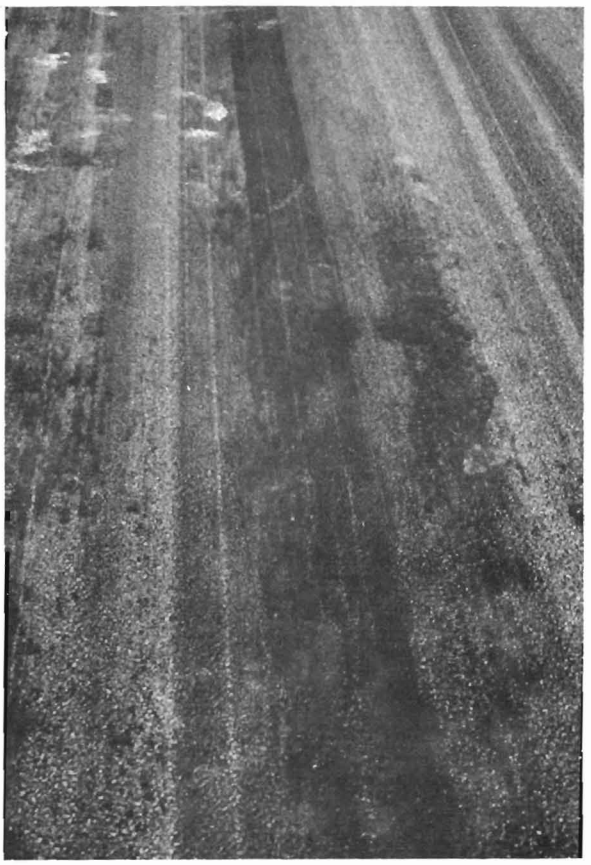


Figure 14. Surface texture and rubber buildup (Nashville)

Figure 15. General view of PFC condition (Nashville)

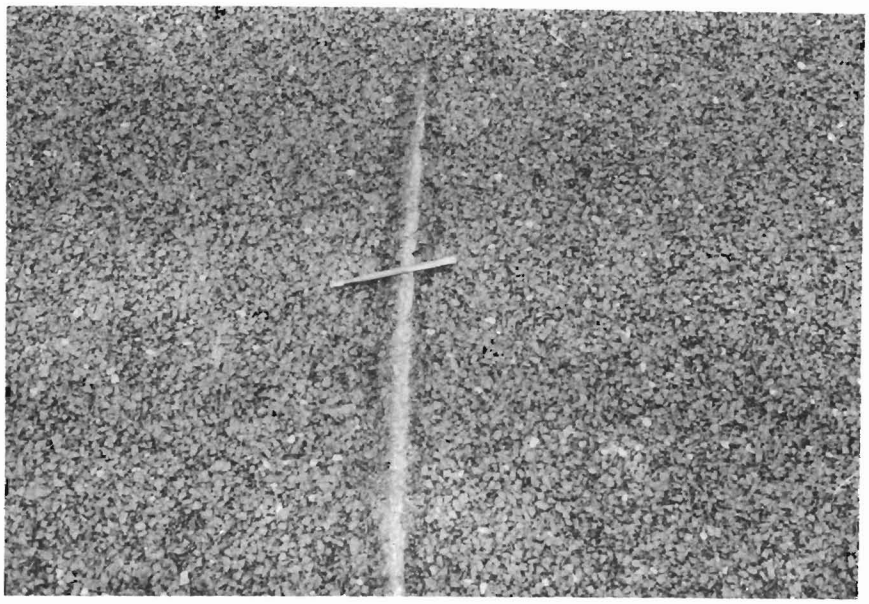
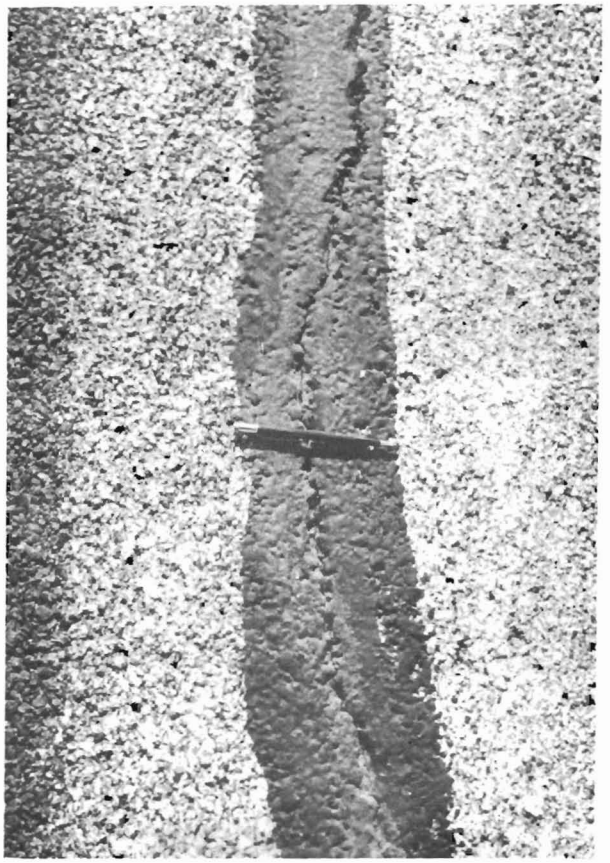


Figure 18. Arrester hook damage (Dallas)

Figure 19. Reflected crack (Dallas)



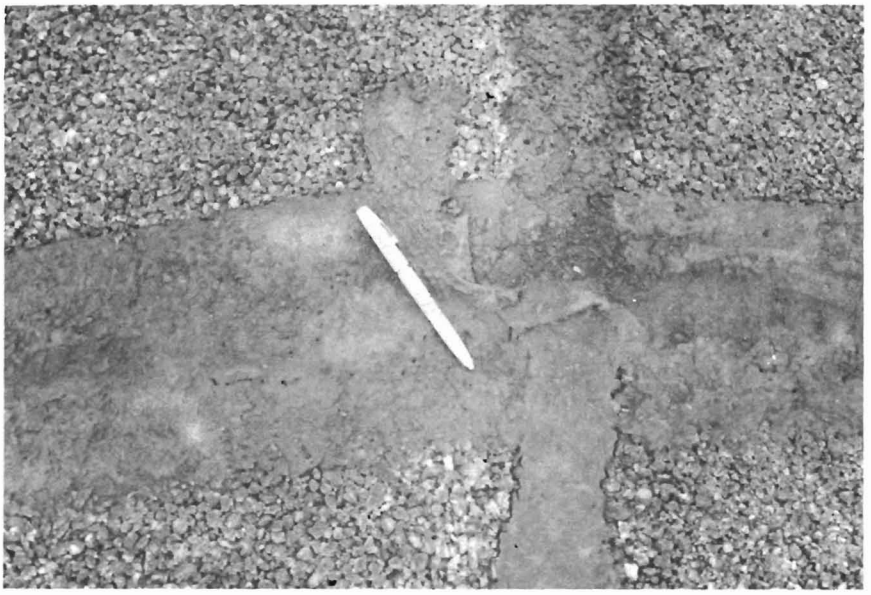


Figure 20. (sheet 2 of 2)

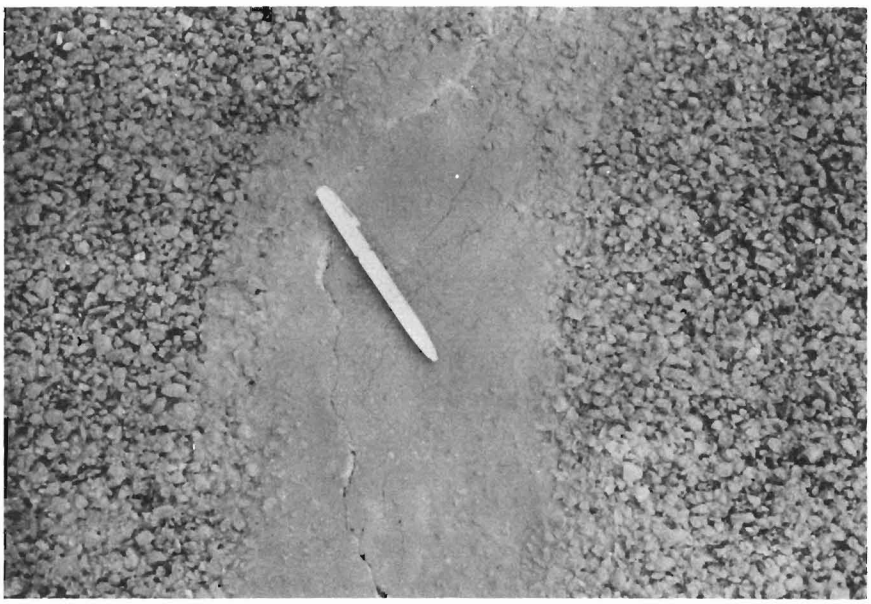


Figure 23. Sealed reflected crack (Stapleton)

Figure 24. Sealed reflected cracks (Stapleton)

Figure 27. Ice patch melting from bottom (Stapleton)

Figure 28. Closeup of reflected crack (Bartlesville)

Figure 31. Pop out (Bartlesville)

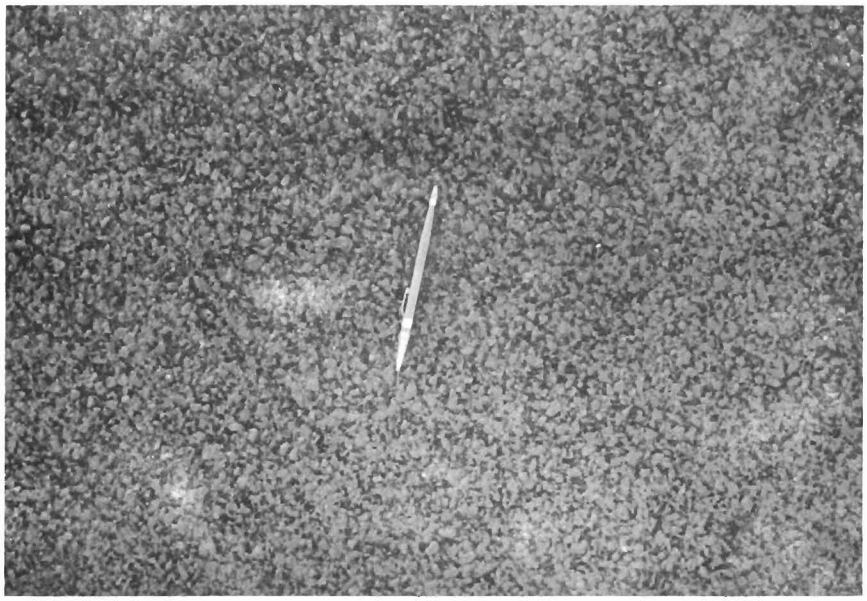
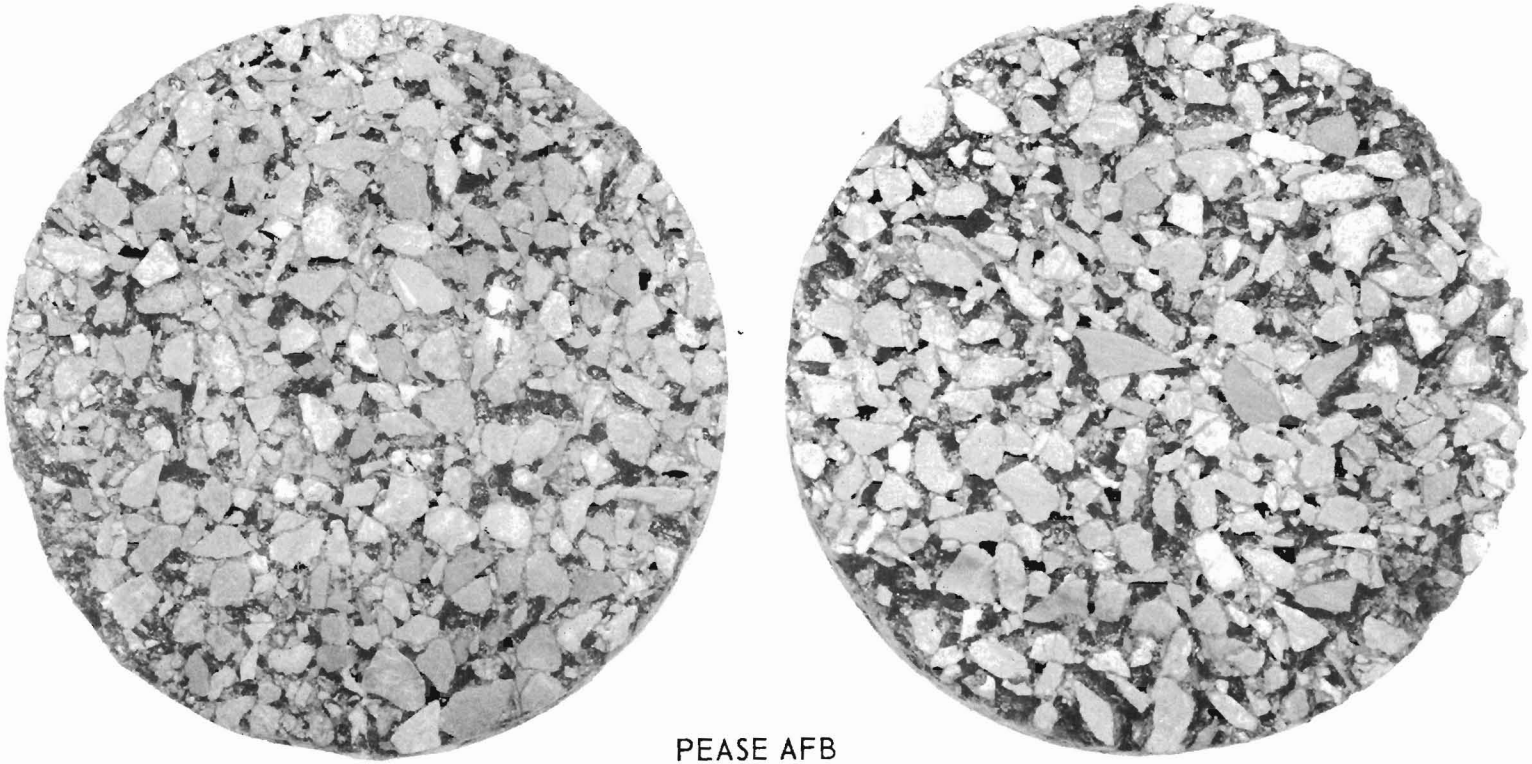


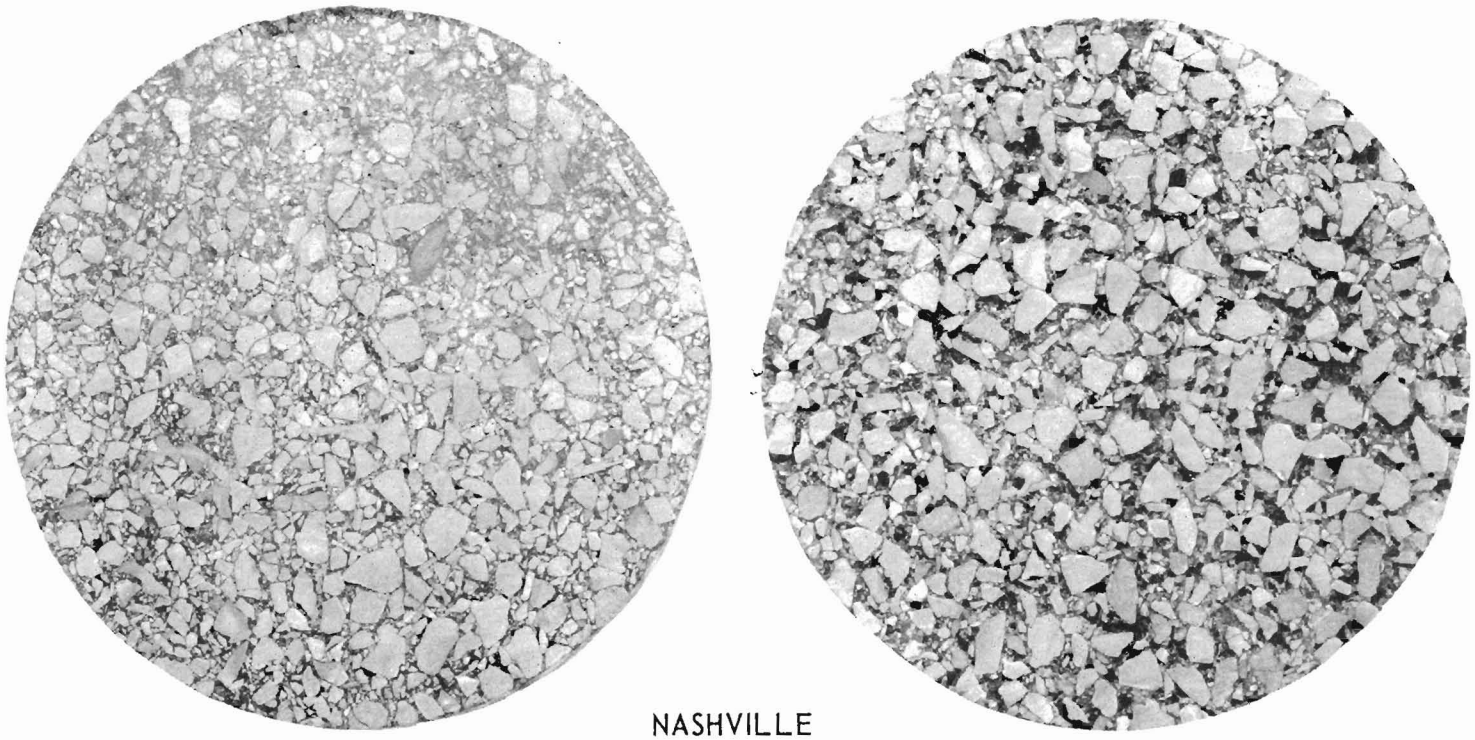
Figure 32. PFC surface texture (Greensboro)



PEASE AFB

IN OUT

Figure 34. Sawed faces of Pease PFC samples



NASHVILLE

IN OUT

Figure 36. Sawed faces of Nashville PFC samples

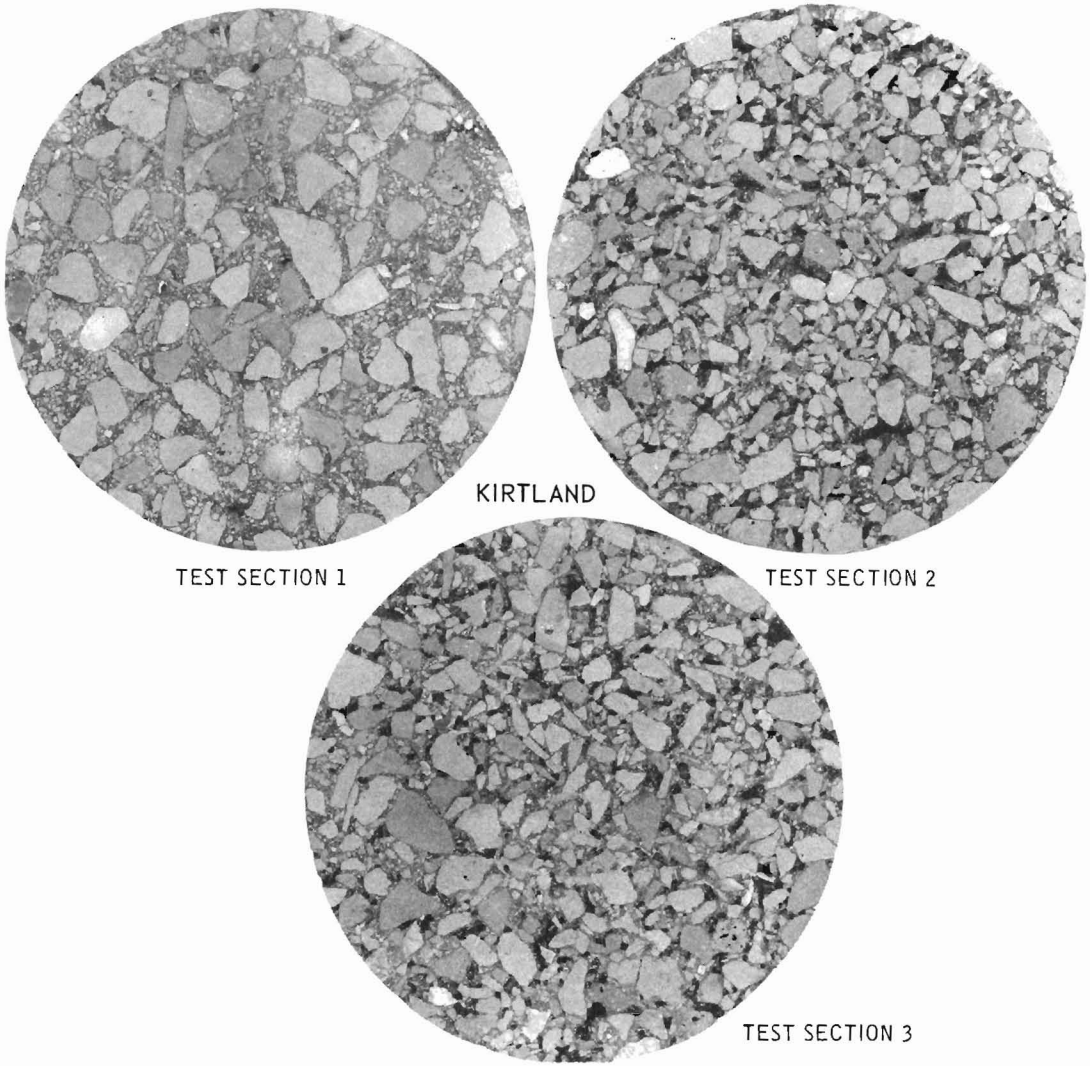


Figure 38. Sawed faces of KAFB PFC samples (sheet 1 of 2)

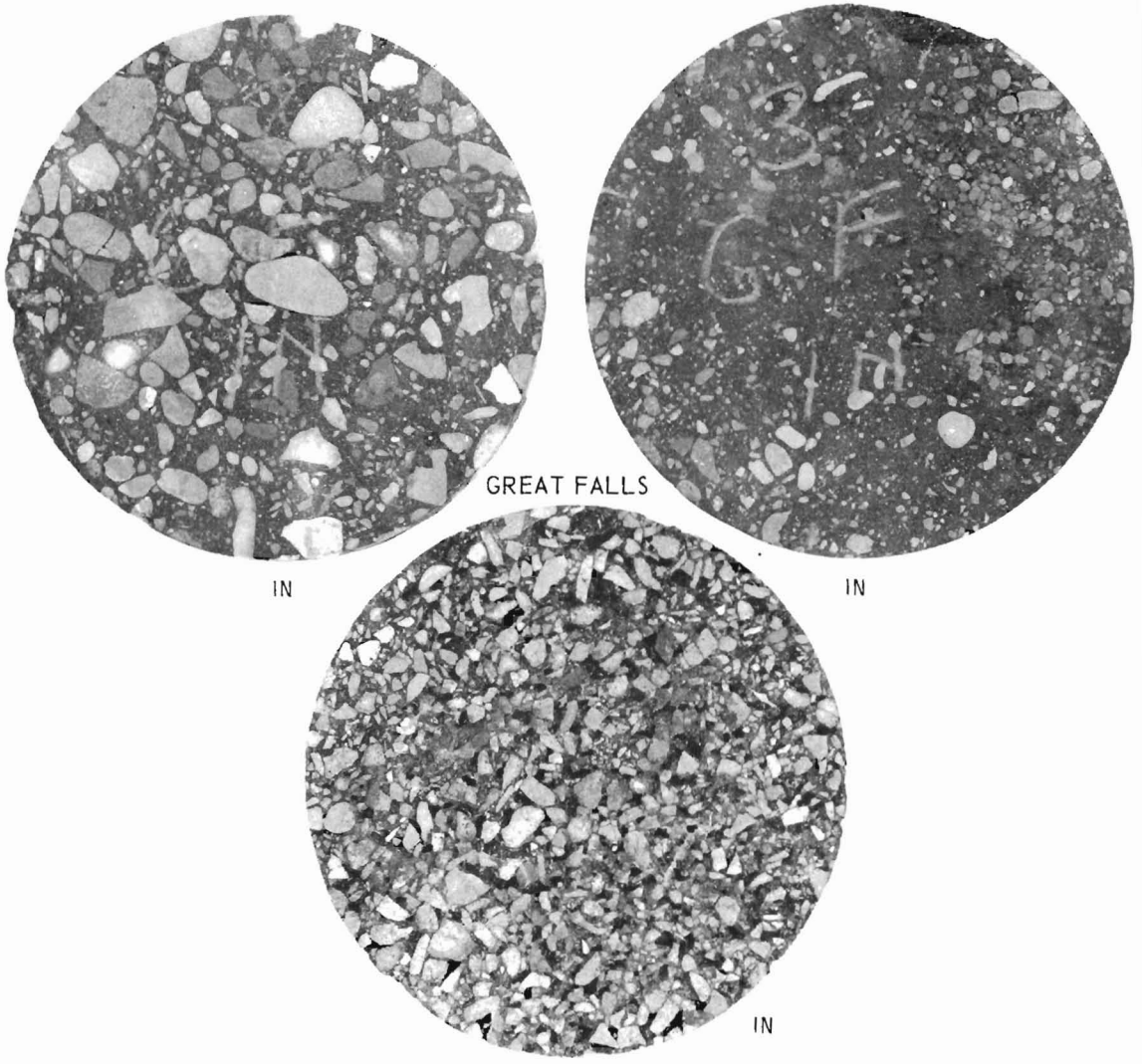
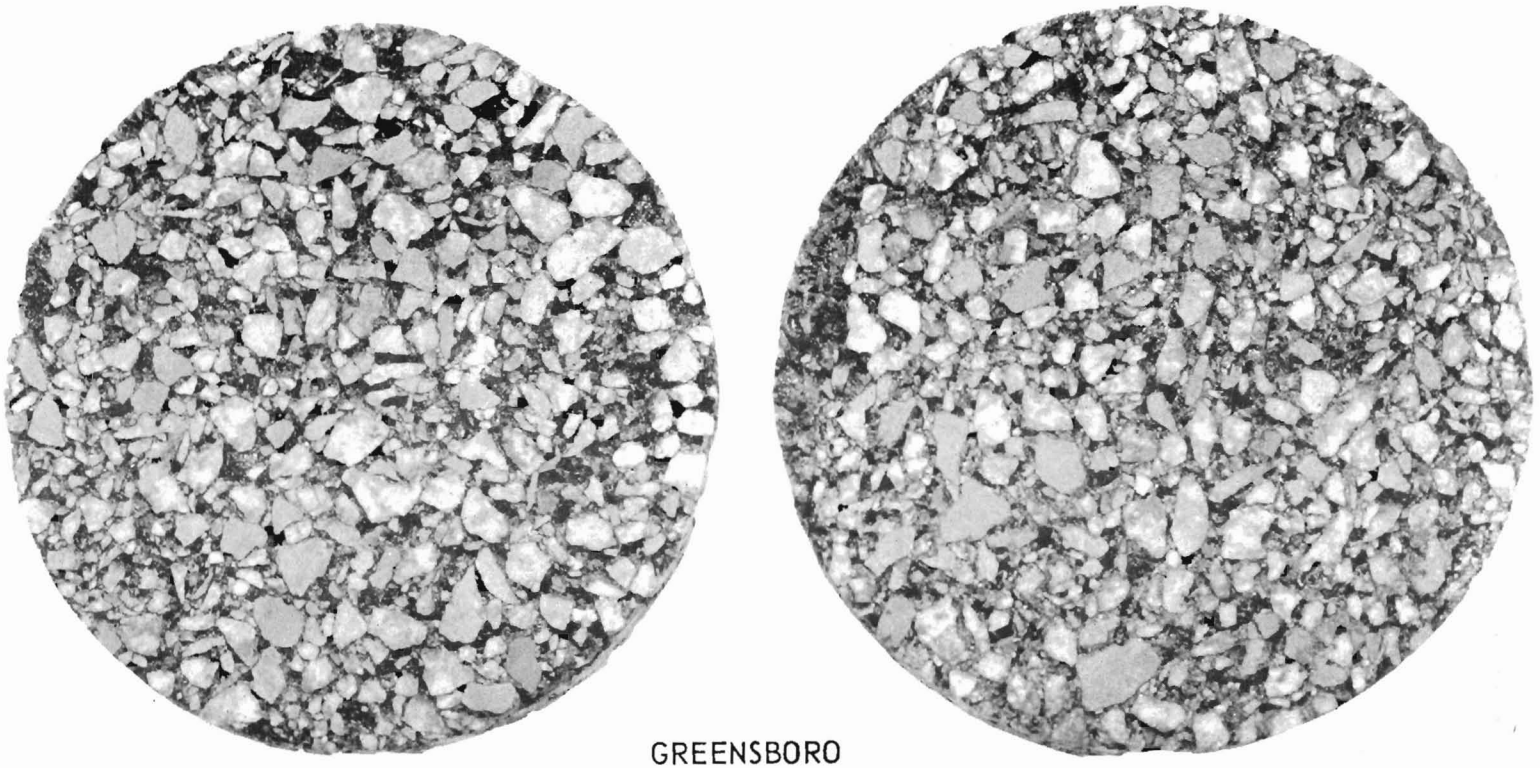


Figure 39. Sawed faces of Great Falls PFC samples

Figure 41. Sawed faces of Bartlesville PFC samples



GREENSBORO

IN OUT

Figure 43. Sawed faces of Greensboro PFC samples

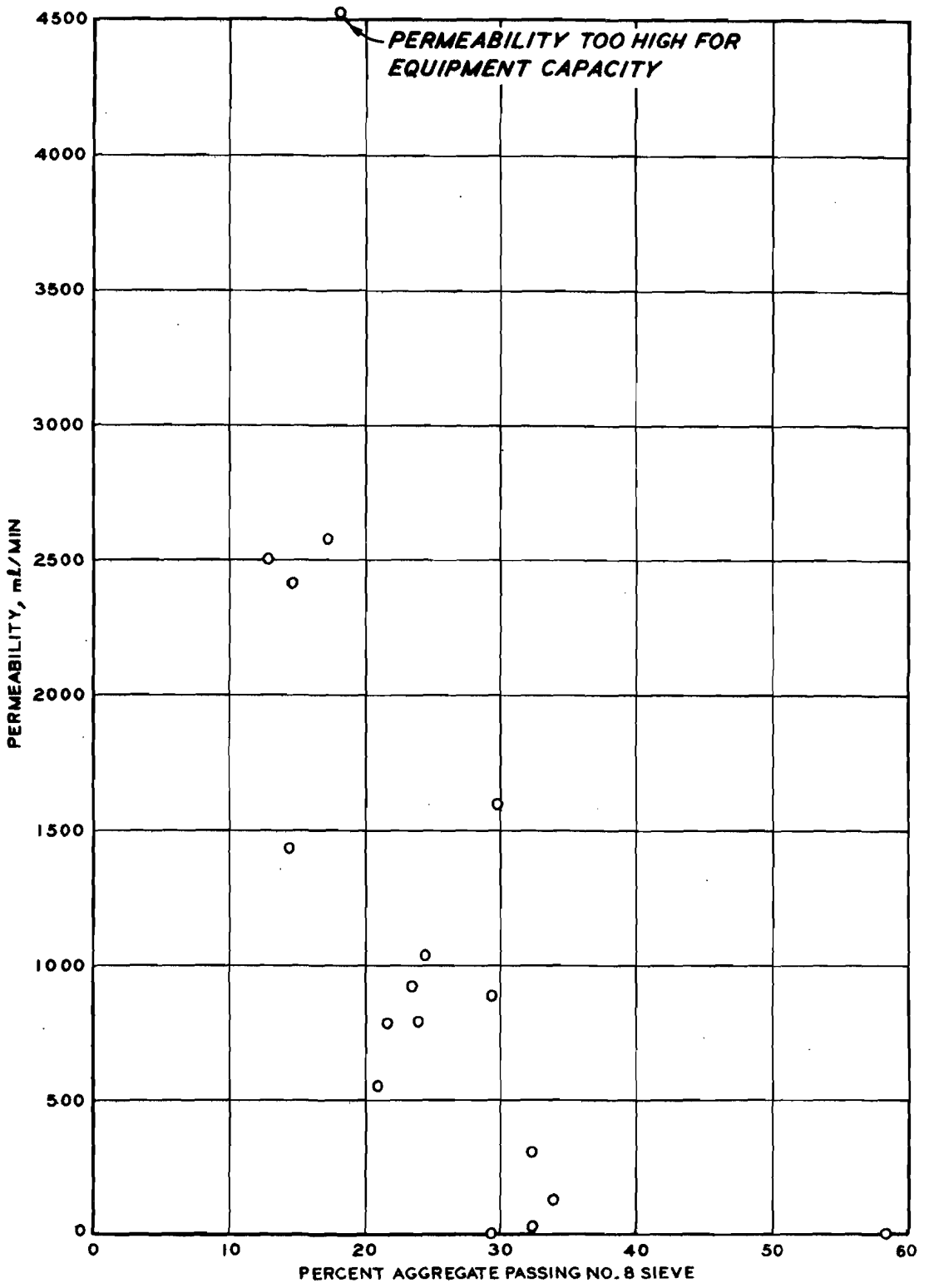


Figure 45. PFC permeability versus percent aggregate passing No. 8 sieve

APPENDIX A: PERMEABILITY TEST

The results of the permeability tests are affected by the surcharge load applied to insure contact of the standpipe and pavement surface. A surcharge load of 100 lb has been satisfactorily used to insure that the conditions of the tests are reasonably constant in this respect. In the field, an open truck door or bumper-mounted bracket can be used for the reaction weight and an extension screw can be used to apply the load. The loading system should include a ball bearing or universal mechanism for self-alignment. In the field where a truck is used to react against, the truck should not be parked broadside to the wind. Wind rocking the truck will cause the load to vary and affect the results.

In the laboratory, good results have been obtained by conducting the test on 6-in.-diam specimens consisting of a 3/4-in. PFC layer compacted by 10 blows of a Marshall hammer with a 6-in.-diam foot. The 3/4-in. layer is compacted on a 6-in.-diam dense bituminous base. A laboratory CBR mold is used to prepare the specimen. The 10-blow compaction effort has been correlated to give permeabilities equivalent to those obtained in the field.

When the standpipe has been positioned and loaded, water is introduced into the standpipe to a level above the 10-in. mark on the side of the standpipe. Addition of water is then stopped, and the time to fall from the 10- to 5-in. level is measured with a stopwatch. This test is repeated three times and the average of the values is computed. The flow rate is determined from the relation $Q = VA$. Thus, for a 5-in. falling head, Q in millilitres per minute is equal to 15,436.8 divided by the time to fall in seconds. A wide range in permeability can be expected to be measured, but a reasonable lower limit of permeability for newly constructed PFC pavements is 1000 ml/min.

APPENDIX B: PFC DESIGN PROCEDURE

The design procedure for PFC pavements consists of primary and validation procedures.

The primary procedure involves conducting the Centrifuge Kerosene Equivalency (CKE) tests on the proposed job aggregate using Test Method California No. 303-F.[9] The K_c value determination from this test is used in the relation $2K_c + 4.0$ to obtain an estimate of asphalt content (EOA). The amount of binder estimated from this relation has been evaluated in the laboratory and in the field and is reasonable. To insure that this amount of asphalt can be prepared in a PFC without excessive drainage, a proper mixing temperature must be selected. This is accomplished by choosing a mixing temperature that will give a viscosity of 275 + 25 centistokes. This can only be accomplished by evaluating the temperature-viscosity relation for the specific job asphalt.

These steps essentially provide the necessary information for selection of the binder content for a PFC mixture. However, only close uniform control of the aggregate gradation will insure that the PFC can be satisfactorily produced and constructed.

An evaluation or validation of the above mix design in the laboratory may include the asphalt drainage test and water permeability test.

The asphalt drainage test has not been proven to be sensitive for all types of aggregates; however, the test may be conducted for background information and to insure that detrimental drainage of asphalt does not occur. The test is conducted by preparing a 300-g sample of the mixture at the design binder content, placing the sample in a 6-in.-diam culture dish, and placing the dish in an oven preset at the mixing temperature selected from the temperature-viscosity relation. The sample is removed from the oven after 2 hr and allowed to cool. The amount of drainage to the bottom of the dish is observed. At this time, over 50 percent coverage is assumed to be excessive. If the binder drainage is excessive, either the mixing temperature or binder content can be reduced.

The water permeability test is conducted on specimens prepared as described in Appendix A. It is suggested that laboratory water permeability tests be used to evaluate gradations and binder contents and mixing temperature. A gradation different from the recommended gradation may greatly affect the permeability. The permeability is also affected by the binder film thickness, which is controlled by the binder volume and mixing temperature. Low permeability may also require an adjustment in the binder content or mixing temperature.

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2. American Society for Testing and Materials, "Standard Method of Test for Measuring Surface Frictional Properties Using the British Portable Tester," Designation: E 303-69, 1973 Annual Book of ASTM Standards, Part 11, 1973, Philadelphia, Pa.

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9. California Division of Highways, "Method of Test for Centrifuge Kerosene Equivalent Including K-Factor," Test Method No. Calif. 303-F, Oct 1974, Sacramento, Calif.