EVALUATION OF OPEN-GRADED "F" MIXTURES FOR WATER SENSITIVITY

Final Report

State Planning and Research
Project Number 5252

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16. Abstract

The Oregon Department of Transportation (ODOT) has increased their use of open-graded paving mixtures. During the last five years, ODOT has constructed several hundred miles of highways with open-graded "F" asphalt concrete mixtures. These pavements have performed well, with no known failures attributable to moisture damage.

In 1992, many "F" mixtures failed the Index of Retained Strength (IRS) test used by ODOT to evaluate the water damage potential of asphalt concrete mixtures. Although "F" mixtures had difficulty passing the IRS test, ODOT engineers felt that the problem was not with the "F" mixtures, but with the test itself.

This study investigated the suitability of implementing the Strategic Highway Research Program's (SHRP) Environmental Conditioning System (ECS) procedure for evaluating the water sensitivity of "F" mixtures. As a part of this study, test data was collected using the IRS test and the ECS test for several different "F" mixtures. The IRS procedure is more severe that the ECS, indicating potential pavement failure problems where they don't exist and that are not predicted by the ECS. The IRS test may not be suitable for "F" mixtures. The ECS procedure shows promise as a test method for evaluating water sensitivity of "F" mixtures, but further evaluation and correlation with field performance is required.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

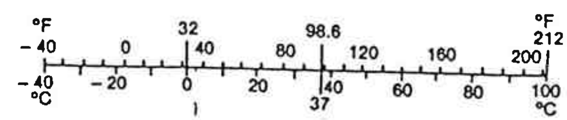
NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

* SI is the symbol for the International System of Measurement

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



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DISCLAIMER

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1.0 INTRODUCTION

The Oregon Department of Transportation (ODOT) has utilized open-graded paving mixtures for many years, both in surface and base courses. The use of these porous mixtures has increased markedly over the past few years. During the past five years, ODOT has constructed several hundred miles of highways with open-graded class "F" asphalt concrete mixtures. The performance of these pavements has in general been excellent, with no known failures attributable to moisture damage. In addition, these pavements have shown the advantage, over conventional dense-graded pavements, of reducing splash and spray during wet weather, resulting in improved safety. This report specifically addresses the issue of the evaluation of the potential for water damage in "F" mixtures; other issues related to porous pavements are being addressed in a separate ODOT research project entitled "Evaluation of Porous Pavements Used in Oregon."

Historically, stripping and water damage have been problems of dense graded mixtures, not porous mixtures like "F" mixes. In 1992, however, many "F" mixtures failed the Index of Retained Strength (IRS) test used by ODOT to evaluate the water damage potential of asphalt concrete mixtures. At the same time, dense graded mixtures using the same aggregate source and the same asphalt were passing the IRS test, although, based on past performance, these mixtures were more likely to experience water damage than the "F" mixtures that failed this same test. It is not certain why "F" mixtures began having problems passing the IRS test, however, some believe that it may be related to the change in asphalt that occurred when ODOT began to use Performance Based Asphalt (PBA) specifications. Although "F" mixtures have had difficulty passing the IRS test, it is the consensus of ODOT engineers that the problem is not with the "F" mixtures, but with the test itself.

As a part of the Strategic Highway Research Program (SHRP), the Environmental Conditioning System (ECS) was developed at Oregon State University (OSU) to assess the water sensitivity of asphalt concrete mixtures, and to provide an improved method for mixture acceptance, with respect to water sensitivity, during the mix design process. The ECS subjects asphalt concrete specimens to a series of conditioning cycles including water flow, elevated/or lowered temperatures, and repeated axial loading. The ECS procedure was developed and validated for dense graded mixtures, with only limited consideration of porous mixtures.

The objective of this study was to investigate the suitability of implementing the SHRP ECS procedure for use in assessing the water sensitivity of "F" mixtures. To accomplish this objective, mixtures that failed the conventional ODOT evaluation method (IRS test) were evaluated, ECS and IRS results were compared, and modifications to the ECS procedures were recommended.

2.0 PROJECTS EVALUATED

The projects evaluated were selected from the 1992 construction program. The mixtures met all design criteria except the majority of them failed the IRS test (minimum IRS 75%). Table 2.1 summarizes the projects that were evaluated for water sensitivity; two specimens were ECS tested from each project. The mixture designs for each project are included in Appendix A.

Table 2.1: Summary of ODOT "F" Mixtures Selected for Evaluation

Mixture	Job Name (Contract No.)	Aggregate Source	Asphalt Source	Additives
A	Myrtle Point SCL-Powers Jct. (11110)	Wahl's Pit (8-108-3)	McCall PBA-5	None
B	Pacific Hwy. West-Gateway St. (11194)	Eugene S&G (20-45-3)	Chevron PBA-5	Lime 1.0% PBS[1] 0.5%
C	Santiam River Bridge (11038)	Hilroy Pit (24-2-2)	Albina PBA-5	Lime 1.0% PBS 0.5%
D	Youngs Bay Br.-Warrenton (11162)	Naselle Rock (WA-02S-2)	McCall PBA-5	PBS 0.5%
E	Eastside Bypass (11220)	Stukel Pit/Horseridge Pit (18-36-4,9-21-4)	Albina PBA-6	Lime 1.0% Unichem 8161 0.75%
F	Butte Falls Rd. (15-misc)	140 Pit / Kirkland Pit (15-192-3, 9-21-4)	Witco PBA-5	None
G	Santiam River Bridge (11038)	Hilroy Pit (24-2-2)	Albina PBA-5	None
H	Umatilla-McNary (11245)	Powerline Pit (30-001-5)	Koch PBA-6	None

[1]PBS - PaveBond Special

3.0 TEST PROCEDURES

Cylindrical specimens measuring 4 in. (102 mm) in diameter by 4 in. (102 mm) height were fabricated by ODOT, using the procedures of AASHTO T 165 and T 167. The maximum specific gravity (Rice gravity) of each mixture was determined by ODOT using the AASHTO T 209 procedure. The density and air voids were determined by OSU by wrapping each specimen in parafilm and then weighing it in water. This procedure permits accurate determination of the air void content of very porous mixtures. The IRS test (performed by ODOT) and the ECS test (performed by OSU) were also conducted for each mixture. ODOT elected not to perform the Index of Retained Modulus (IRM) and Resistance of Compacted Bituminous Mixtures to Moisture-Induced Damage (AASHTO T 283) tests because they have not been found to be good indicators of the potential for moisture damage. The properties of the mixtures tested are summarized in Table 3.1.

3.1 INDEX OF RETAINED STRENGTH (IRS)

The IRS was determined by ODOT for each mixture using the procedure of AASHTO T 165, Effect of Water on Cohesion of Compacted Bituminous Mixtures. In this procedure, the compressive strength of 4 in. (102 mm) by 4 in. (102 mm) cylindrical specimens that have been immersed in a water bath at 140° F (60° C) for 24 hours (group 2 specimens) and the compressive strength of specimens that have not been immersed are measured (group 1 specimens). The IRS is calculated as the ratio (expressed as a percentage) of the group 2 compressive strength to the group 1 compressive strength. A mixture with an IRS less than 75% is considered water sensitive.

3.2 ENVIRONMENTAL CONDITIONING SYSTEM (ECS)

3.2.1 ECS TEST SYSTEM

The basic ECS was designed and fabricated to provide a means of simulating various condition within an asphalt pavement. Figure 3.1 shows the ECS and its subsystems:

1. Fluid conditioning,
2. Environmental chamber, and
3. Repeated loading.

Fluid Conditioning Subsystem

This subsystem was designed to measure air and water permeability and provide water, air, and temperature conditioning. Three gages are used to measure the pressure gradient across the specimen. This system is designed essentially as a constant head permeameter with vacuum. The specimen is placed in a load frame, as shown in Figure 3.2, and a vacuum regulator is used to control the desired pressure gradient across the specimen.

Table 3.1: Summary of Properties of "F" Mixtures Prepared by ODOT

MIX	ASPHALT GRADE	ASPHALT CONTENT (%)	ADDITIVE 1	ADDITIVE 2	RICE SP GR	AVE. DRY STRENGTH (LBS)	AVE. WET STRENGTH (LBS)	IRS AVERAGE (%)
A	PBA-5	6.2	NONE	NONE	2.44	2547	1503	59
B	PBA-5	5.7	LIME 1.0%	PBS 0.5%	2.47	2705	1580	58
C	PBA-5	6.0	LIME 1.0%	PBS 0.5%	2.46	2473	1773	72
D	PBA-5	6.5	PBS 0.5%	NONE	2.57	2620	2135	81
E	PBA-6	6.0	LIME 1%	UNICHEM 0.75	2.44	3143	2020	64
F	PBA-5	5.5	NONE	NONE	2.49	2540	1312	52
G	PBA-5	6.0	NONE	NONE	2.46	2653	1333	50
H	PBA-6	6.2	NONE	NONE	2.57	2273	1743	77

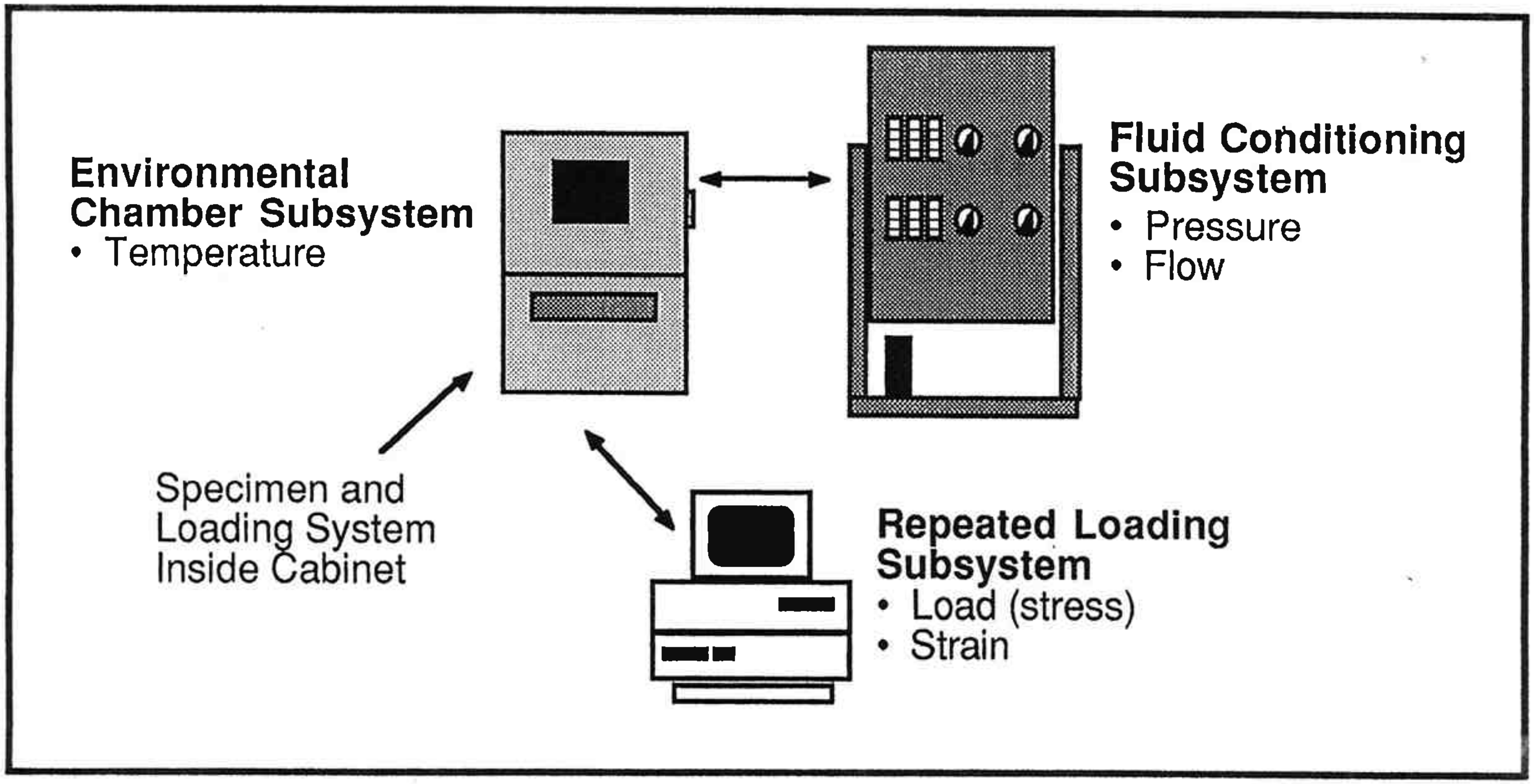

Figure 3.1: Overview of Environmental Conditioning System (ECS)

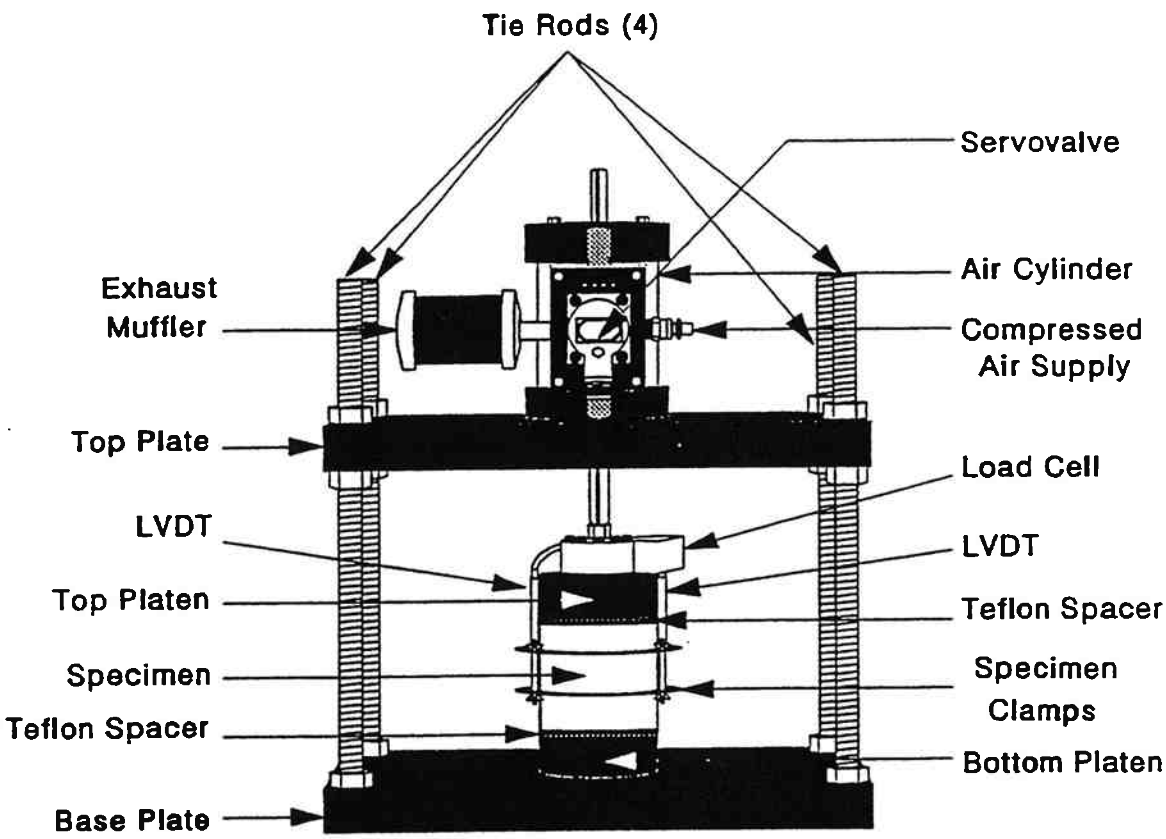

Figure 3.2: Load Frame Inside Environmental Cabinet.

An optional pH-meter may be connected directly after the specimen to monitor the change in the pH value during the conditioning process. A thermocouple controller with four channels is connected to this system, one channel to read flow temperature right before the specimen and a second channel to read flow temperature right after the specimen. The third channel is installed inside a dummy specimen to monitor the internal temperature of the specimen that is inside the environmental cabinet, and the fourth thermocouple is connected to the water reservoir to record water flow temperature, which is required to obtain actual water viscosity. Three water flow meters of different flow capacities are connected to a fluid water conditioning system to provide a sufficiently wide flow range, from 1 to 3000 cm^3/min. The coefficient of permeability, k, can be calculated using measurements from the ECS flow system according to Darcy's law, assuming that the flow is saturated, laminar, and non-inertial. The coefficient of permeability can be used to evaluate the performance of the specimen.

Environmental Chamber Subsystem

The environmental chamber has the capability of providing high and low temperatures. Specifications require a cabinet capable of heating to 100° C and cooling to -20° C within the time limits specified by the ECS protocol, and maintaining set conditioning and testing temperatures within ±1° C.

Repeated Loading Subsystem

The repeated loading subsystem is an electro-pneumatic closed-loop system consisting of a personal computer with software and an analog-to-digital/digital-to-analog interface card; a transducer signal conditioning unit; a servovalve amplifier and power supply; and a load frame. Figure 3.2 shows a schematic of the load frame that includes a double-acting pneumatic actuator (piston) and a servovalve. The servovalve, serviced by compressed air and controlled by the computer, drives the piston. Loads are delivered by the piston through a load ram to a load cell mounted on the specimen cap, which rests atop the test specimen. The signals from the load cell and linearly variable differential transducers (LVDTs), mounted on the specimen, are collected by the computer software program. These signals are converted to stress and strain allowing the calculation of the resilient modulus, designated the ECS modulus (ECS-M_R). ECS tests are conducted using a haversine pulse load with a duration of 0.1 s, and a frequency of 1 Hz.

The loading system can apply repeated axial loading during the ECS hot conditioning cycles, and runs the ECS resilient modulus test that allows for evaluation of the performance of the mixtures.

3.2.2 ECS TEST PROCEDURES

After specimens were received at OSU and the air voids were measured, they were stored at 15° C. This is necessary because at room temperature (25° C) the open graded specimens can easily deform, and the asphalt film can flow to the bottom of the specimens. Approximately two hours before testing, the specimens were allowed to warm to room temperature (25° C) in preparation for testing.

Prior to ECS testing, the diametral resilient modulus (M_R) of each specimen provided by ODOT was measured using a MTS electro-hydraulic testing machine. The specimens to be ECS tested from each mixture, were selected to have similar air voids and diametral M_R test results. Specimens that were in the extremes of the air voids and diametral M_R range for the group were not selected for further testing. This method was established to eliminate specimens that might have unusual properties that are not representative of the other specimens in the same group. In retrospect, it was probably not a good idea to conduct diametral M_R tests on these specimens because of the potential for excessive deformation. The screening procedure for selection of specimens to test has been modified for porous mixtures to be based only on air voids to eliminate this potential problem.

Table 3.2 summarizes the ECS test procedure as developed for dense graded mixtures; the detailed protocol is included in Appendix B. ODOT elected to prepare specimens using the procedures of AASHTO T 165 and T 167 instead of using the SHRP specimen preparation protocol (step 1). The ECS test protocol was also modified to eliminate repeated loading during the hot cycles (step 9) for the "F" mixtures tested in this project. This modification was necessary because the specimens were unstable without lateral support and they were susceptible to excessive deformation during hot cycle repeated loading.

Visual stripping ratings were made on split samples at the conclusion of ECS testing. The visual stripping evaluation is made by comparing the specimens to a stripping rating chart (Figure 3.3). The rating chart was developed for dense graded mixtures and is very subjective.

Table 3.2: Summary of the ECS Test Procedure [2].

Step	Description
1	Prepare test specimens according to SHRP specimen preparation protocol.
2	Determine the geometric and volumetric properties of the specimen.
3	Encapsulate specimen in silicon sealant and latex rubber membrane,
4	Place the specimen in the ECS load frame, and determine air permeability.
5	Determine unconditioned (dry) triaxial resilient modulus.
6	Vacuum condition specimen (subject to vacuum of 20 in. (508 mm) Hg for 10 minutes).
7	Wet specimen by pulling distilled water through specimen for 30 minutes using a 20 in. (508 mm) Hg vacuum.
8	Determine unconditioned water permeability.
9	Heat the specimen to 140° F (60° C) for six (6) hours under repeated loading. This is a hot cycle.
10	Cool the specimen to 77° F (25° C) for at least four (4) hours. Measure triaxial resilient modulus and water permeability.
11	Repeat steps 9 and 10 for two (2) more hot cycles.
12	Cool the specimen to 0° F (-18° C) for six (6) hours, without repeated loading. This is a freeze cycle.
13	Heat the specimen to 77° F (25° C) for at least four (4) hours and measure the triaxial resilient modulus and the water permeability.
14	Split the specimen and perform a visual evaluation of stripping and binder migration.
15	Plot the ECS resilient modulus ratio.

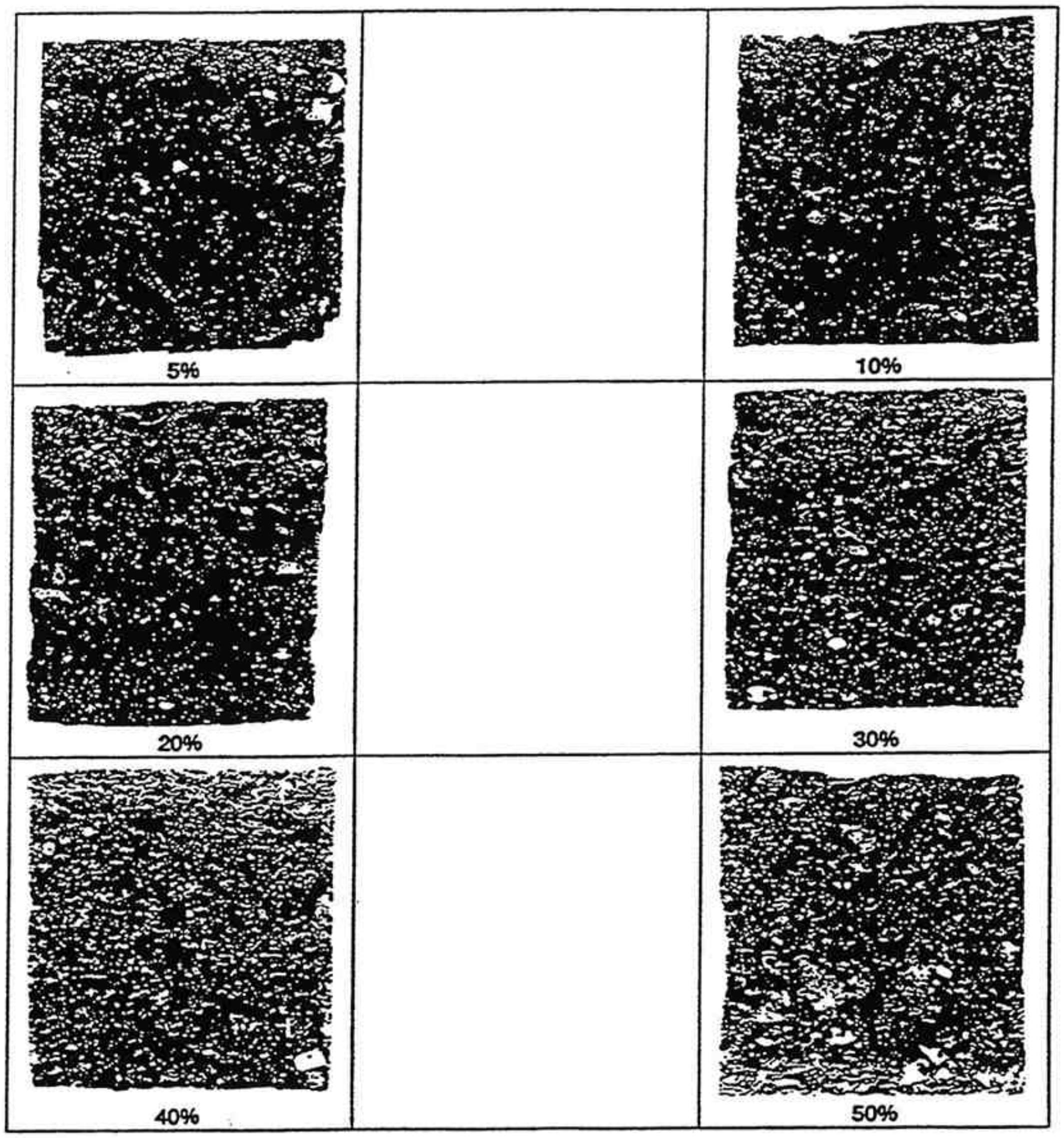

Figure 3.3: Visual Stripping Rating Chart.

4.0 RESULTS

The results of the ECS testing of the "F" mixtures conducted by OSU and of the IRS testing conducted by ODOT are shown in Table 4.1. Figures 4.1 to 4.8 show the results of ECS conditioning for each mixture. A reduction in stiffness (ECS-M_R ratio less than one) indicates that the mixture has experienced moisture damage. All of the mixtures tested exhibited moisture damage, except mixture A (Figure 4.1). The increase in stiffness exhibited by mixture A may be the result of densification of the mixture. Although all of the other mixtures have experienced moisture damage, only mixture B (Figure 4.2), mixture F (Figure 4.6), and mixture G (Figure 4.7) approach the failure criteria (ECS-M_R ratio less than 0.75). Mixtures that have ECS-M_R ratios less than 0.75 are considered moisture sensitive. In this case, mixture B, F, and G would be considered marginal mixtures with respect to moisture sensitivity. However, since they all exhibit relatively flat slopes after the first conditioning cycle, in these plots, they are considered acceptable.

Mixtures D and H (Figures 4.4 and 4.8) showed a significant increase in the ECS-M_R at the end of cycle 4 (freeze cycle). This increase was probably caused by not allowing sufficient time for the specimen to thoroughly warm to 25° C prior to measuring the ECS-M_R. Because of this possible problem with some of the cycle 4 data, results were analyzed using the cycle 3 data, except where specifically noted.

Figure 4.9 shows ECS results represented by visual stripping vs. IRS results. Figure 4.10 shows ECS-M_R ratios after three cycles vs. IRS results. Figure 4.11 shows ECS-M_R ratios vs. stripping after three cycles. The results shown for each mixture are the average of the two specimens. For an IRS failure criterion of 75 percent, all but two mixtures failed the IRS test. On the other hand, using an ECS failure criterion of 0.75, all of the mixtures would have passed the ECS test, with mixtures B, F, and G being only marginal. Also, stripping of the mixtures was somewhat consistent with IRS results, except mixture A. Generally, mixtures that showed higher stripping rates (or water damage) also had lower IRS values.

Figure 4.12 compares the results of testing both mixture C, which includes 1.0% lime and 0.5% PaveBond Special (PBS), and mixture G, which is the same mix as C but without the additives. The ECS test suggests that the mixture improved when the additives were used, and the ECS-M_R ratio increased from 0.80 to 0.85 after four cycles. In the IRS test performed by ODOT, mixture G failed (50%), and mixture C failed (72%).

The ODOT open-graded "F" mixtures performed reasonably well in the ECS with respect to water sensitivity. Six mixtures passed the ECS-M_R ratio criterion of .75, and three mixtures (B, F, and G) were only marginal, as shown in Figure 4.10. However, only two mixtures (D and H) passed the IRS criterion, while another mixture (C) only marginally failed. Based on past field performance of "F" mixtures (no known moisture sensitivity related failures), this implies that the IRS test is not correctly evaluating the water sensitivity of these mixtures, or that the IRS failure criterion (75%) is too high.

Table 4.1: Summary of Test Data for ODOT Open-graded Mixtures

Specimen ID	IRS (%)	Initial Air Permeability (E-5 cm/s)	Diametrial MR (ksi)	CYCLE No.	ECS-MR (ksi)	Retained ECS-MR Ratio	Water Permeability (E-3 cm/s)	STRIPPING (%)
A-03	56	Impermeable	145.5	0	162.0	1.00	0.68	5
				1	184.0	1.14	1.07	
				2	174.0	1.07	1.01	
				3	184.0	1.14	0.66	
				4	184.0	1.14	0.77	
A-02	56	1.29	142.0	0	209.0	1.00	0.33	5
				1	224.5	1.07	0.69	
				2	224.5	1.07	0.48	
				3	225.0	1.08	0.49	
				4	227.0	1.09	0.51	
B-02	59	Impermeable	169.0	0	188.0	1.00	0.00	20
				1	166.0	0.88	0.52	
				2	167.0	0.89	0.37	
				3	167.0	0.89	0.37	
				4	167.0	0.89	0.33	
B-08	59	Impermeable	174.0	0	240.0	1.00	0.00	20
				1	196.0	0.82	0.66	
				2	187.0	0.78	0.59	
				3	177.0	0.74	0.57	
				4	175.0	0.73	0.56	
C-01	72	Impermeable	188.0	0	217.8	1.00	0.00	20
				2	224.0	1.03	0.17	
				3	234.3	1.08	0.36	
				4	199.0	0.91	0.31	
C-03	72	Impermeable	173.0	0	306.6	1.00	0.00	20
				2	249.0	0.81	0.71	
				3	245.1	0.80	0.68	
				4	240.0	0.78	0.65	

Table 4.1: Summary of Test Data for ODOT Open-graded Mixtures (cont.)

Specimen ID	IRS (%)	Initial Air Permeability (E-5 cm/s)	Diametrial MR (ksi)	CYCLE No.	ECS-MR (ksi)	Retained ECS-MR Ratio	Water Permeability (E-3 cm/s)	STRIPPING (%)
D-01	81	Impermeable	207.0	0	328.5	1.00	0.00	10
				2	315.0	0.96	0.33	
				3	267.6	0.81	0.34	
				4	302.1	0.92	0.36	
D-03	81	Impermeable	187.0	0	279.1	1.00	0.00	10
				2	260.5	0.93	0.45	
				3	265.5	0.95	0.64	
				4	292.0	1.05	0.62	
E-03	64	Impermeable	63.5	0	120.9	1.00	0.00	20
				2	114.2	0.94	0.25	
				3	117.0	0.97	0.24	
				4	115.0	0.95	0.26	
E-04	64	Impermeable	69.0	0	72.3	1.00	0.00	20
				2	84.0	1.16	0.52	
				3	96.3	1.33	0.50	
				4	87.0	1.20	0.48	
F-02	52	5.1	228.5	0	432.2	1.00	1.20	20
				2	315.5	0.73	1.30	
				3	328.0	0.76	1.10	
				4	340.0	0.79	1.09	
F-06	52	2.6	230.5	0	334.0	1.00	0.70	20
				2	230.0	0.69	1.57	
				3	250.0	0.75	1.31	
				4	255.0	0.76	1.39	

Table 4.1: Summary of Test Data for ODOT Open-graded Mixtures (cont.)

Specimen ID	IRS (%)	Initial Air Permeability (E-5 cm/s)	Diametrial MR (ksi)	CYCLE No.	ECS-MR (ksi)	Retained ECS-MR Ratio	Water Permeability (E-3 cm/s)	STRIPPING (%)
G-01	50	Impermeable	186.5	0	220.3	1.00	0.00	10
				2	195.0	0.89	0.42	
				3	175.2	0.80	0.44	
				4	180.6	0.82	0.59	
G-02	50	Impermeable	192.0	0	229.3	1.00	0.00	10
				2	200.4	0.87	0.52	
				3	172.6	0.75	0.52	
				4	176.7	0.77	0.51	
H-01	77	Impermeable	N/A	0	111.3	1.00	0.00	10
				2	101.8	0.91	0.38	
				3	109.6	0.98	0.20	
				4	107.3	0.96	0.18	
H-03	77	Impermeable	N/A	0	70.5	1.00	0.00	10
				2	62.0	0.88	0.44	
				3	66.5	0.94	0.38	
				4	93.2	1.32	0.38	

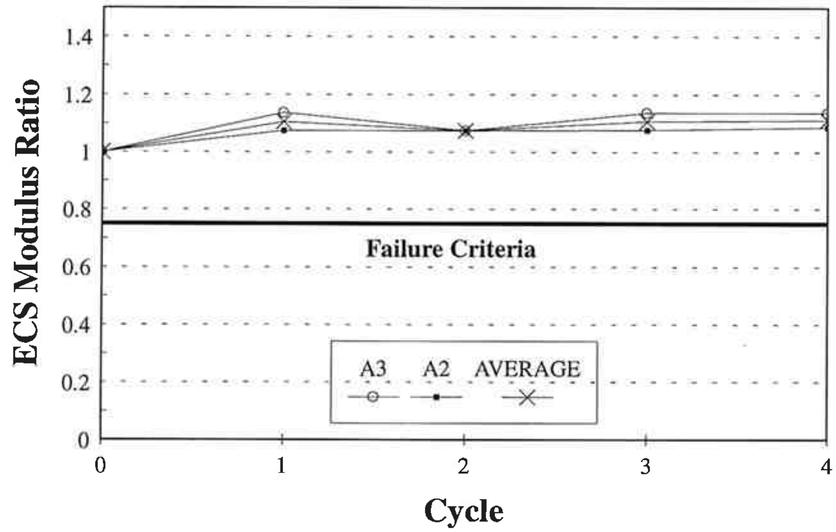

Figure 4.1: Results of ECS Test on ODOT Open-graded "F" Mixture A.

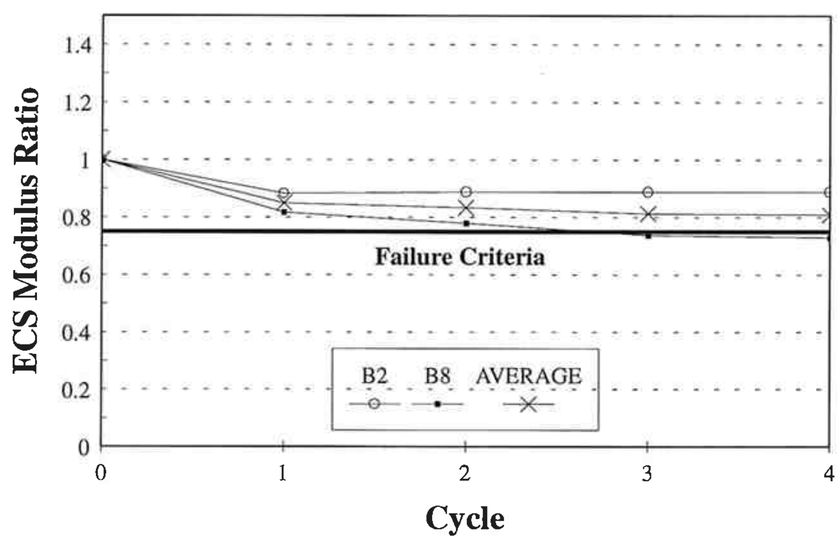

Figure 4.2: Results of ECS Test on ODOT Open-Graded "F" Mixture B

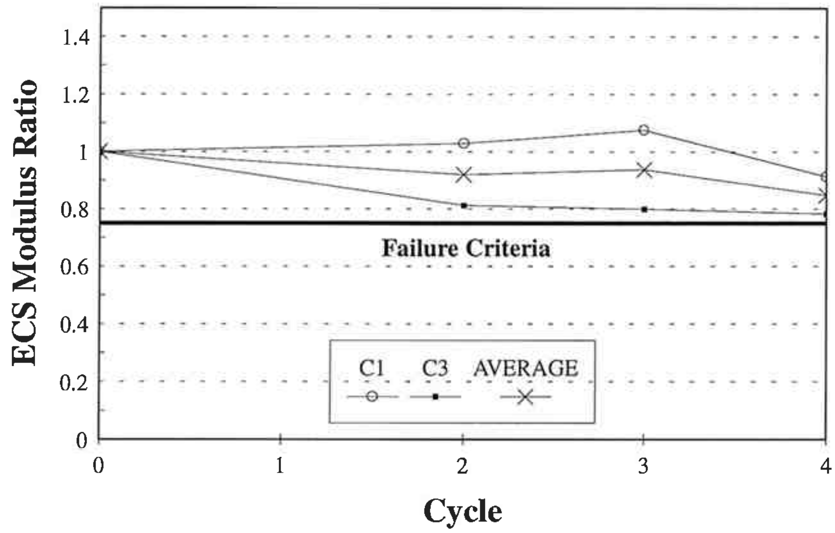

Figure 4.3: Results of ECS Test on ODOT Open-Graded "F"Mixture C

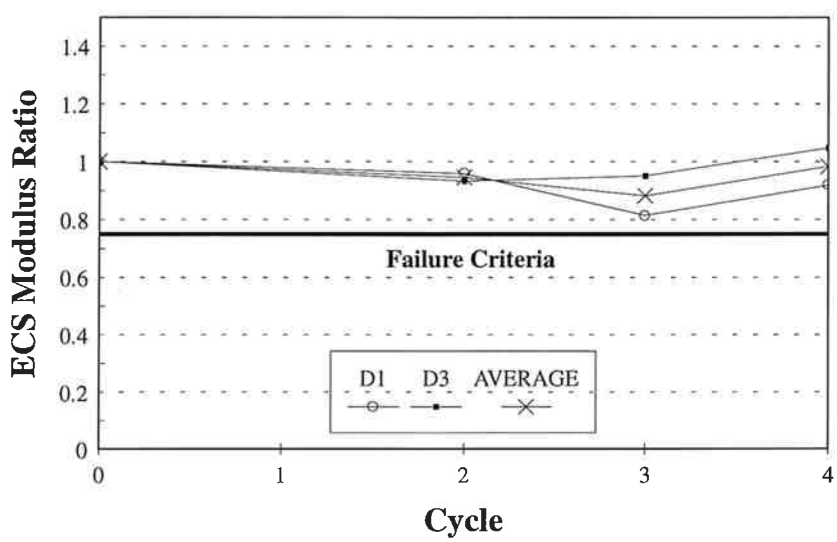

Figure 4.4: Results of ECS Test on ODOT Open-Graded "F" Mixture D

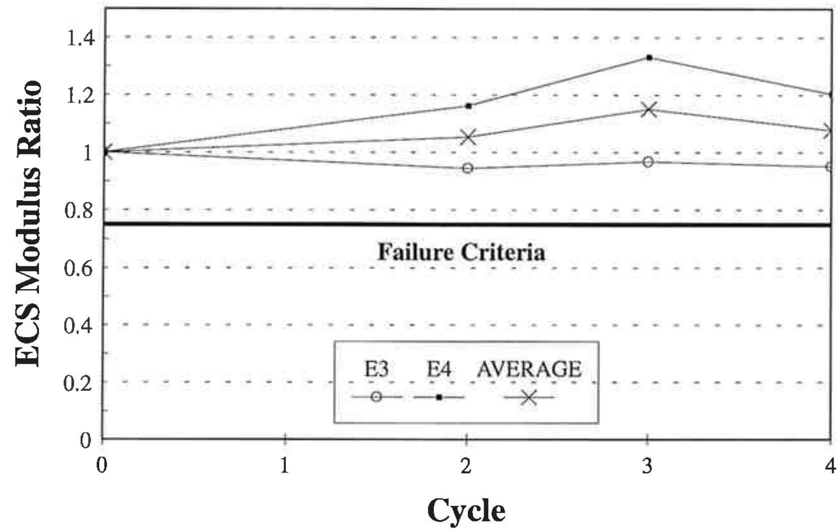

Figure 4.5: Results of ECS Test on ODOT Open-Graded "F" Mixture E

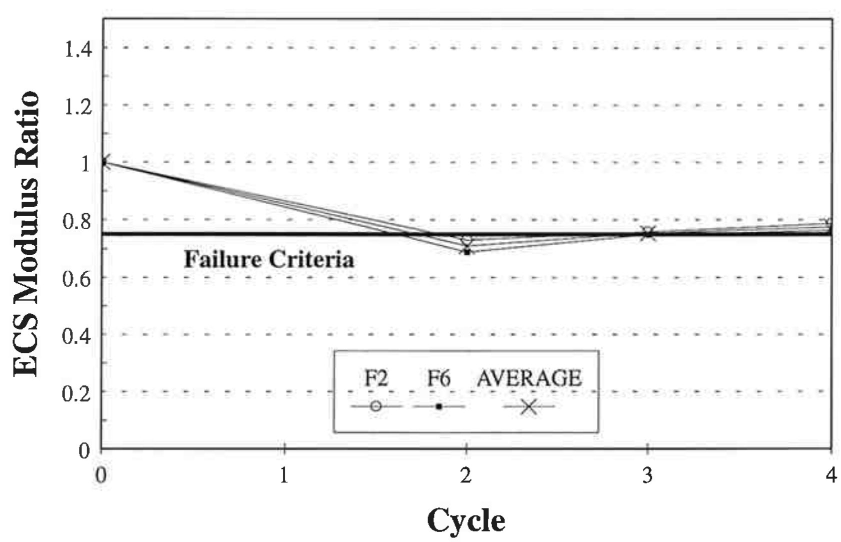

Figure 4.6: Results of ECS Test on ODOT Open-Graded "F" Mixture F

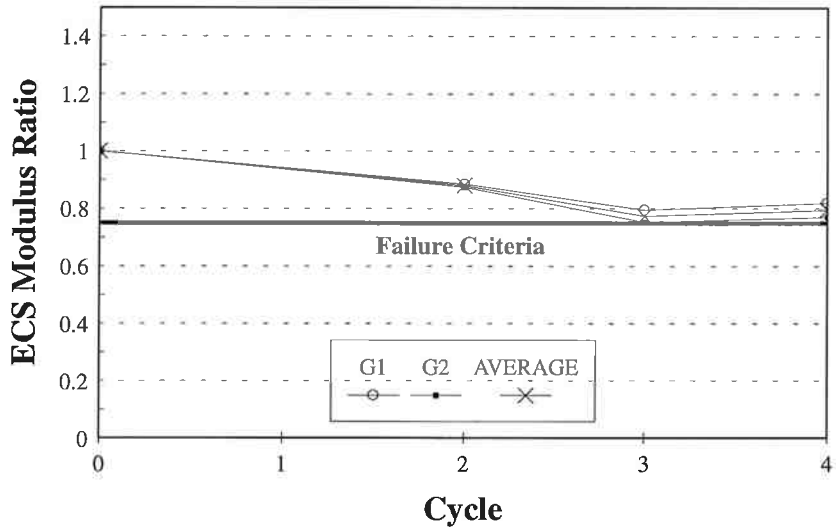

Figure 4.7: Results of ECS Test on ODOT Open-Graded "F" Mixture G

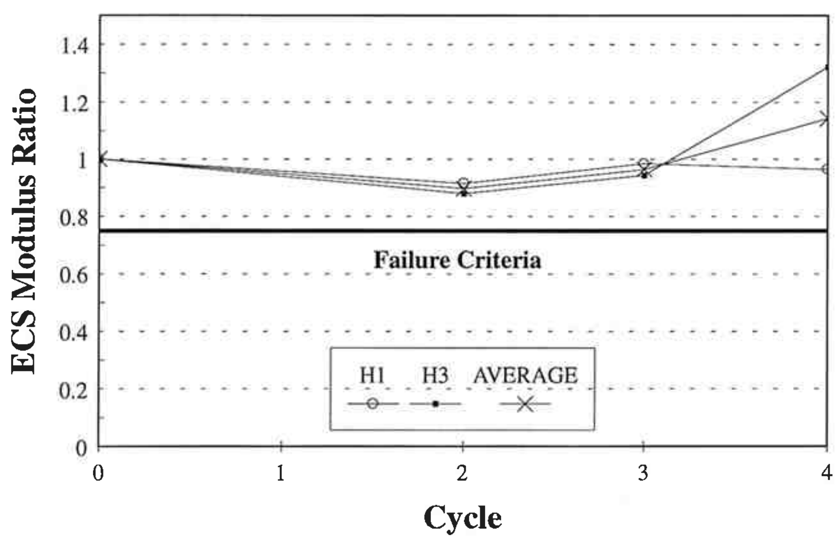

Figure 4.8: Results of ECS Test on ODOT Open-Graded "F" Mixture H

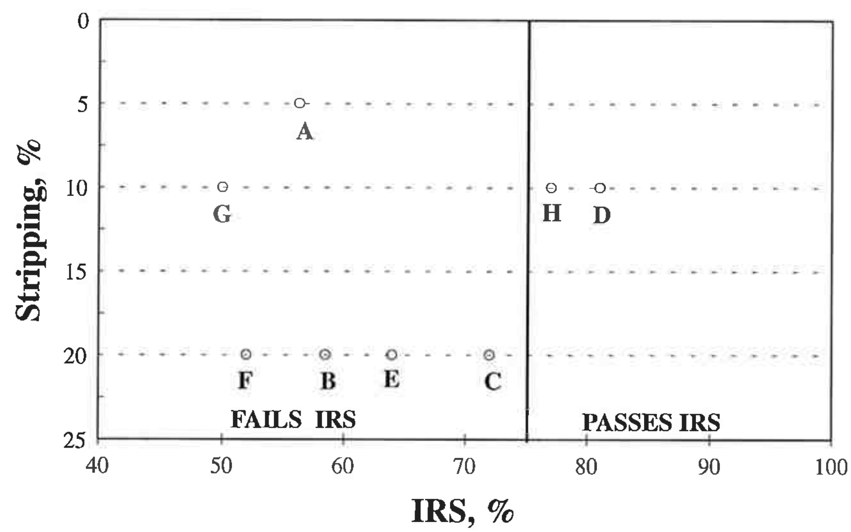

Figure 4.9: Visual Stripping After ECS Test vs. IRS for ODOT "F" Mixtures

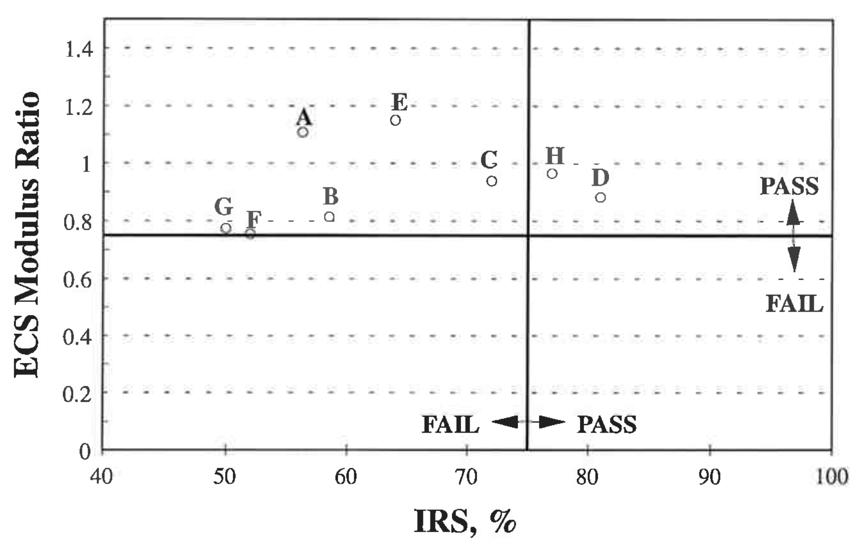

Figure 4.10: ECS-MR Ratio After 3 Hot Cycles vs. IRS

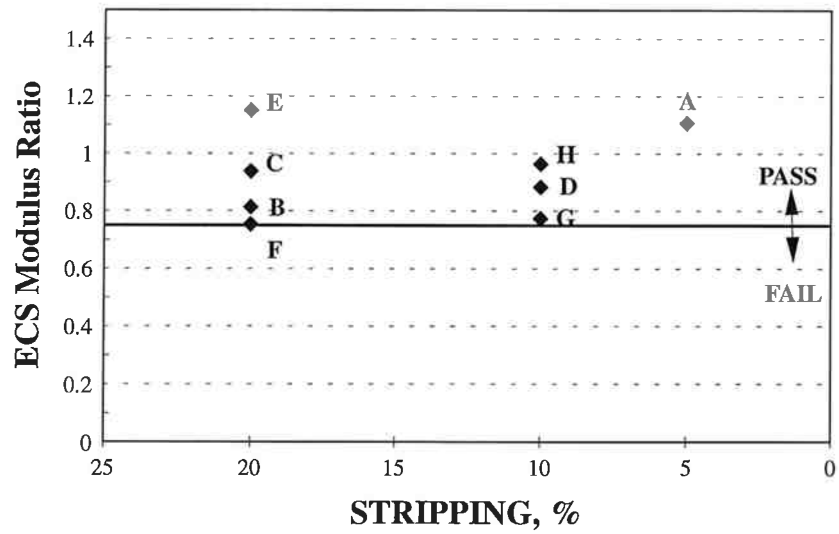

Figure 4.11: ECS-MR Ratio After 3 Hot Cycles vs. Stripping

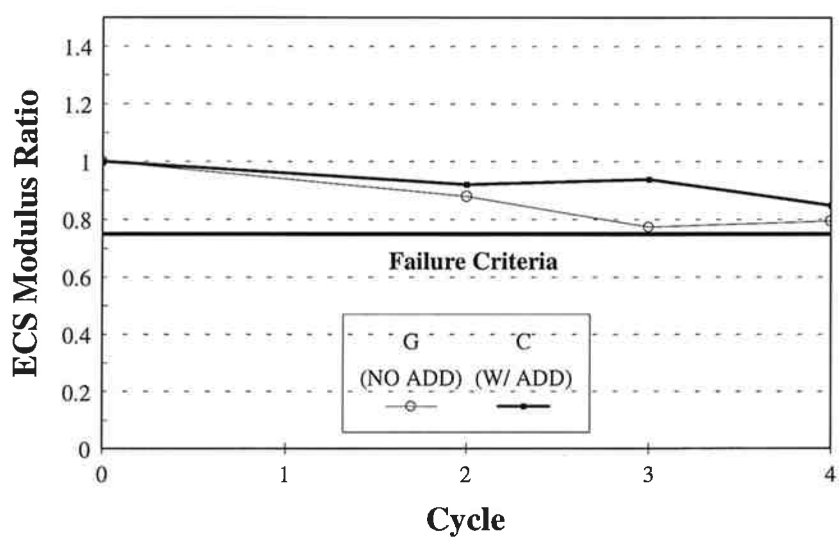

Figure 4.12: Effect of Additives

5.0 ANALYSIS AND DISCUSSION

A statistical analysis of the ECS test results was conducted using the General Linear Model (GLM) procedure to investigate the significance of the effect of all the different variables and their interactions on the ECS-M_R ratio (the dependent variable). The GLM procedure uses the method of least squares to fit general linear models, i.e., testing each variable in a given model reveals how significant the variable (or its interaction with other variables) is to the model. The GLM procedure can analyze classification variables that have discrete levels as well as continuous variables. Also, GLM can create output data of the dependent variable (ECS-M_R) based on the prescribed model, i.e., the original ECS-M_R data will be changed to show the effects of the different variables in the model.

The statistical analysis was unsuccessful in showing correlations between the different variables, and the only significant variable was the mixture type as shown in Table 5.1. The reason for the unsuccessful outcome was that the mixtures were very different from each other, and mix type alone explains the difference in the ECS results. Therefore, the following analysis is based on observation and engineering judgement.

Table 5.1: GLM Analysis of the "F" Mixtures Study

Class Variables	Levels	Values		
MIX	8	A, B, C, D, E, F, G, and H		
Cycle No. 3				
Model: R^2 = 0.70, CV = 13.74, ECS-M_R ratio mean = 0.92				
Source of Error	Degrees of Freedom	Type III Sum of Squares	Test Statistic (F_o)	Probability of $F_o > F_{critical}$
MIX	7	0.30	2.69	0.09
Cycle No. 4				
Model: R^2 = 0.72, CV = 13.40, ECS-M_R ratio mean = 0.94				
Source of Error	Degrees of Freedom	Type III Sum of Squares	Test Statistic (F_o)	Probability of $F_o > F_{critical}$
MIX	7	0.33	2.95	0.08

Earlier work with the ECS in the Strategic Highway Research Program (SHRP) [1,2] indicated that the performance of asphalt mixtures with respect to water sensitivity was largely dependent on the air voids. The concept of "pessimum" voids [3] suggested that mixtures designed with very low (<4%) or high (>14%) voids would perform better than those with moderate voids (4-14%), which include conventional dense-graded mixtures. The ODOT "F" mixtures tested are essentially outside the pessimum range, with air voids approximating 14 percent. Therefore, it would be expected that the performance, in the ECS, of the "F" mixtures would be better than for the same materials constructed in a dense configuration. The test results tend to bear this out and as a result, the failure criterion for ECS testing of "F" mixtures was raised to 0.75 from 0.70 the current failure criterion for dense mixtures.

Comparison of the data from the two test methods, ECS and IRS, would suggest that the IRS is more severe, resulting in relatively more damage than the ECS would impart to the mixture. This limited study primarily included mixtures that had previously failed the IRS test, and only two mixtures that had successfully passed the IRS, so it was biased or skewed. Additional comparison of the two procedures using "F" mixtures would be beneficial and a follow-on study is planned which may be helpful in establishing a better relationship.

The stripping evaluation following the ECS test and compared to IRS results (Figure 4.9) is somewhat limited because of the few mixtures, but also because the IRS results include gross effects, and not just stripping. It would be much better to be able to compare stripping in both tests, if the data were available. There is only a general trend to indicate that stripping increases inversely with IRS.

Comparing the net result of ECS and IRS tests, as in Figure 4.10, shows that there is a slight trend indicating that the ECS and IRS are proportional. When the suggested failure criteria are superimposed on Figure 4.10, it is readily apparent that the IRS is more severe than the ECS. In this limited analysis, it appears that the IRS procedure may be imparting damage to specimens that may not be experienced in the pavement. Early experience with these "F" mixtures has shown that actual performance in the pavement is better than the IRS procedure would predict. The ECS procedure tends to bear this out, but caution should be exercised because of the limited amount of data.

Additional comparisons of the test results are shown in several different ways. As indicated earlier, Figure 4.12 shows the effect of using an anti-strip additive, and in this case, the mixture was improved. However, it is uncertain what caused the improvement when one considers Figure 4.9; the additive improved the IRS (from 50 to 72 percent), but stripping following the ECS conditioning increased from 10 to 20 percent.

Figure 5.1 is an alternative method of comparing the data. The results are ranked by decreasing values of IRS, and the ECS-M_R Ratios are compared.

As a part of this study, it is appropriate to again consider the differences in the IRS and the ECS procedures and how they might affect the results and their interpretation. The IRS utilizes a 24-hr. heat soak that may permit more run-down or drainage of asphalt, thus altering the fabric

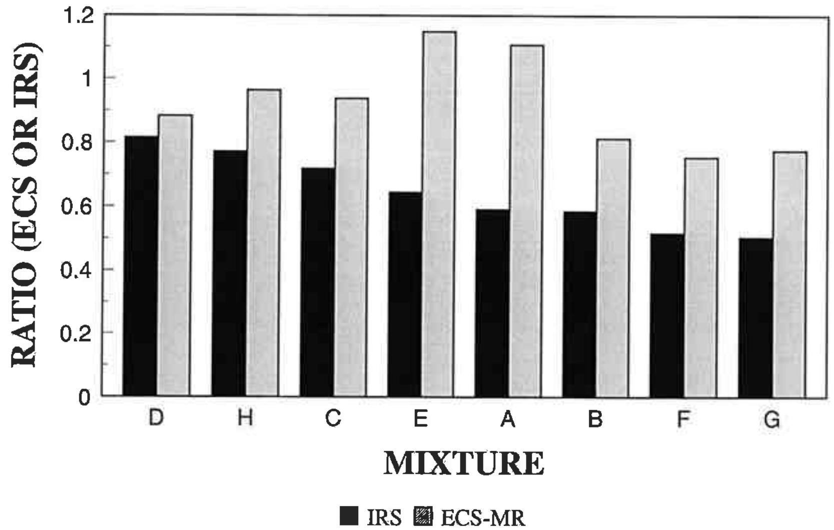

Figure 5.1: Comparison of ECS and IRS Test Results.

of the mixture. The shorter heating periods used in the ECS may reduce the drainage tendency. This difference would not be seen for conventional dense graded mixtures.

The method of test for the IRS (unconfined compressive strength) may not be appropriate for open graded mixtures that require lateral support in order to utilize the grain-to-grain strength benefit. The deformation and failure of "F" mixture specimens under unconfined loading are largely due to binder characteristics, rather than overall cohesiveness and shear resistance, as with dense graded mixtures. In the ECS, the specimen is partially confined by the rubber membrane and atmospheric pressure induced by a vacuum, and the loading is repeatedly applied for a very short duration, thus tending to measure more of the elastic (dynamic) response rather than the plastic (static) response exhibited in the unconfined compression test.

6.0 CONCLUSIONS AND RECOMMENDATIONS

ODOT prepared specimens of open-graded "F" asphalt mixtures for ECS testing at OSU. Most of those same mixtures had previously failed the IRS test. This project was intended to compare results using the two test methods and determine if the IRS was appropriate for evaluating these mixtures.

The results of this study are somewhat limited because very few mixtures were tested, but it would appear that the following conclusions are warranted:

1. The ECS procedure shows promise as a test method for evaluating the water sensitivity of "F" mixtures.

2. The IRS procedure is more severe than the ECS, indicating potential pavement failure problems where they don't exist and that are not predicted by the ECS.

3. Of the mixtures evaluated, all but two were failed by the IRS procedure (with one of the passing mixtures being only marginal), but the ECS procedure would predict satisfactory performance in all mixtures, with two of them marginally questionable.

4. The IRS test may not be suitable for "F" mixtures.

Recommendations

1. Additional testing over a wider range of materials and mixtures should be conducted in order to confirm the above preliminary conclusions. It is recommended that the ECS be used to test additional projects and that the results eventually be compared to field performance.

2. ECS and IRS failure criteria for porous pavements need to be further evaluated in conjunction with a validation study. Follow-up of the projects tested in this study should be made.

3. The process for evaluating visual stripping needs to be refined to reduce subjectivity. The visual stripping rating chart or other procedures need to be developed for porous pavements.

7.0 REFERENCES

1. Terrel, R.L. and S. Al-Swailmi, "Water Sensitivity of Asphalt-Aggregate Mixtures - Test Development", Final Report TM-OSU-A-003A-92-16, Strategic Highway Research Program, Washington, D.C., Nov. 1, 1992, 200 pp.

2. Allen, W.L., and R.L. Terrel, "Field Validation of Environmental Conditioning System (ECS)", Final Report TM-OSU-A-003A-92-12, Strategic Highway Research Program, Washington, D.C., Jan. 31, 1993, 239pp.

3. Terrel, R.L. and S. Al-Swailmi, "The Role of Pessimum Voids Concept in Understanding Moisture Damage to Asphalt Concrete Mixtures", *Transportation Research Record 1386*, Transportation Research Board, National Academy of Sciences, 1993.

APPENDIX A

MIXTURE DESIGNS

APPENDIX A

MIXTURE DESIGNS

PRELIMINARY BITUMINOUS MIXTURE DESIGN

MATERIALS SECTION

PROJECT	MYRTLE POINT S.C.L. - POWERS JCT.
PRIME CONTRACTOR	RACELIN-YEAGER EXCAVATING & TRUCKING INC.
PAVING CONTRACTOR	
MIX TYPE CLASS	"F" a/c
REGION ENGINEER	BOB ALDRICH
PROJECT MANAGER	F.D.MORRISON 8011
LAB NO.	92-05970
EA/SUB JOB/ACTIVITY	C11110
DATA SHEET NO.	AB 69194-96
FED. AID NO.	F-14 (40)
DATE RECEIVED	4-17-92
DATE REPORTED	7-9-92
TEST NO.	301
VAR.	V
LAB CHARGES	$ 950.00

AGGREGATE GRADATION: Source— Wahl's Pit #8-108-3 Type— Gravel

Aggregate Size	3/4 - 1/4	1/4 - 10	10 - 0				Combined ~~Dry Sieve~~ Wet sieve	Agg. Grad. Extracted
% Comb.	81	10	9					
1"	100						100	
3/4	91						93	
1/2	58						66	
3/8	35	100					47	
1/4	10	89	100				26	
10	3	8	92				11	
40	3	4	36				6	
200 (Dry)	--	--	--				--	
200 (Wet)	1.5	2.7	11.7				2.5	
No. Ave.								
Lime Treat (%)							P200/AC - 0.4	

NUCLEAR GAUGE DATA

Calibration Number: 5978
Mix ID: 1110 "F" PBA-5
Number of Samples: 4
Count Time per Sample: 16
Fit Coeff= 0.997
Calibration Date: 6/16/92
Background Count: 2471
Weight: 6599
Calibration Constants:
A1: -12.682818
A2: 6.093182
A3: -4.004573

JOB MIX FORMULA TEST DATA:

Percent Asphalt (total mix)	4.0	4.5	5.0	5.5	6.0	7.0
Asphalt Film	dry	dry-suf	suff.	suff-thk	thick	thick
Sp. Gr. @ 1st Comp. ~~(T-246)~~ geometric voids	2.070		2.107		2.129	2.134
Percent Voids @ 1st Comp.	16.7		14.1		12.4	
Stability @ 1st Comp. (T-247)						
Sp. Gr. @ 2nd Comp.						
Percent Voids @ 2nd Comp.						
Stability @ 2nd Comp.						
Max. Sp. Gr. (T-209)	2.486	2.467	2.453	2.434	2.431	
Index Ret. Str. (T-165)	72		67		68	77 **
Index Ret. Mr. (TM315)						
asphalt draindown *	0	0	10%	20%	50%	95%

JOB MIX FORMULA:

Aggregate Sieve Size	JMF Gradation	Paving Course	Asphalt Content % By Wt. of Total Mixture	Sp Gr @ 1st Comp	Sp Gr @ 2nd Comp	Max Sp Gr T-209	Design Voids 1st Comp	Design Voids 2nd Comp
1"	100	Wearing	6.2	2.130	--	2.429est.	12.3 est.	
3/4	93	Base						
1/2	66							
3/8	47	Shoulder						
1/4	26	Asphalt Lab No. 92-5326						
10	11	Brand— McCall						
40	6	Grade— PBA-5						
200	2.5	Additive—						

CALCULATED JOB MIX FORMULA PROPERTIES

Mix Placement Temp.— ~~288~~ 237 °F— ~~297~~ 245 °F

Mixing Temp.— ~~307~~ 253 °F— ~~316~~ 262 °F

AGGREGATE TEST DATA:

92-3335 CA: LAR = 17.2%; Na2SO4 = 1.4%; Degrade = 1.0", 18.4%; Friables = 0.1%; Dust=.12%
92-3336 FA: " = -- ; " = 2.5%; " = 0.8", 16.6%; " = 0.3%; SE = 72
92-3337 FA: " = -- ; " = 2.5%; " = 0.8", 16.6%; " = 1.0%; SE = 72

Const.
FHWA
Reg. Engr.
Res. Engr.

COMMENTS: * draindown @ 6.5% asphalt = 90%, target draindown is between 60 and 90%.

** IRS test @ 7.0% asphalt run with 0.5% Pavebond Spec.

Oregon Department of Transportation
HIGHWAY DIVISION

ASPHALT LABORATORY RECORD

OREGON STATE HIGHWAY DIVISION,
MATERIALS SECTION, 800 AIRPORT RD., SALEM OR 97310

MCCALL PBA-5
ASPHALT BRAND AND TYPE

LABORATORY REPORT NUMBER: 9205326

PROJECT: MYRTLE POINT S.C.L. - POWERS JCT.		DATA SHEET NO.: NONE
HIGHWAY: COOS BAY - ROSEBURG	COUNTY: COOS	EXP. ACCOUNT, SUB JOB: C11110
CONTRACTOR: BRACELIN - YEAGER	F.A. PROJECT NUMBER: F 14(40)	BID ITEM NUMBER:
PROJECT MANAGER: F.D.MORRISON 8011	AGENCY ORG. UNIT: 8011	DATE RECEIVED: 5-28-92 / DATE REPORTED: 6-2-92
SUBMITTED BY: MCCALL OIL CO.	AGENCY ORG. UNIT:	TEST NO.: 416A / VAR: / LAB CHARGE: 344.00
SOURCE OF MATERIAL: MCCALL OIL CO. PORTLAND, OR.	QUANTITY REPRESENTED: 8 qts.	
SAMPLED AT: PORTLAND / SAMPLED BY: UNK.	TO BE USED: "F" a/c	DATE SAMPLED: 5-27-92

SAMPLE NO. 92-12 COMPLETE — TEST RESULTS — DATE TESTED: 5-30-92

PAVING ASPHALT

T 73	Flash Point, closed cup		°F
T 44	Solubility in CHCL:CCL2	99.99	%
T 49	Penetration at 77F/39.2		cm/100
	Penetration ratio 39.2/77F		
T201	Viscosity, Kinematic 275 F	~~~~ 460	C.S.
T202	Viscosity, Absolute 140 F	2680	P.
T240	**Paving Asphalt RTF (c) Residue**		
T 47	Loss on heating	~~~~ .59	%
T201	Viscosity, Kinematic 275 F	746	C.S.
T202	Viscosity Absolute 140 F, 30cm Hg., Vac.	7270	P.
	Viscosity Ratio Res./Orig.	2.7	
T 49	Penetration at 77 F/39.2 F	37 / 18	cm/100
	% of orig. penetration		%
T 51	Ductility at 77 F	100+	cm
	Ductility at 45 F	12	cm

Liquid Asphalt

T 48	Flash point, open cup	575	°F
T201	Viscosity, Kinematic at 140 F		C.S.
T 78	Distillation (% of total distillate to 680 F)		
	To 374 F		%
	To 437 F		%
	To 500 F		%
	To 600 F		%
	Residue from distillation to 680 F Volume by difference		%
	Water		%

Liquid Asphalt Residue

T 49	Penetration at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm
T202	Viscosity ABS at 140 F		P.

Emulsified Asphalt

T 59	Viscosity, S.F. at ____ F		sec.
T 59	Sieve Test		%
T 59	Residue by distillation to 500 F		%
T 59	Oil distillate in		%
T 49	Penetration of Res. at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm

Modified Abson Recovery of Asphalt

T170	Modified Abson Recovery of Asphalt		
T201	Viscosity, Kinematic 275 F		C.S.
T202	Viscosity, Absolute 140 F, 30cm Hg. Vac.		P.
T 49	Penetration of Res. at 77 F		cm/100
	"C" value		

T49 PENETRATION of RESIDUE @ 39.2F
100 g. 5 sec. 5 cm/100

DISTRIBUTION ONLY
X FILES
X F.D. MORRISON
X RAS 3
X BRACELIN-YEAGER EXCAVATING & TRUCKING, INC.
X OPERATIONS
X MCCALL OIL CO.
X BIT
X FHWA

RECOMMENDATION:
Material as represented by this sample does, ~~does not~~ comply with specifications.

The Oregon Department of Transportation
Highway Division

PRELIMINARY BITUMINOUS MIXTURE DESIGN
MATERIAL SECTION

PROJECT: PACIFIC HIGHWAY WEST - GATEWAY ST.		EA / SUB JOB / ACTIVITY: C11194		DATA SHEET NO.: AB 53112,14,17
CONTRACTOR: EUGENE SAND & GRAVEL		FED AID NO.: STATE PRES 92		LABORATORY NO.: 92-13599
PAVING CONTRACTOR:	MIX TYPE CLASS: "F"	DATE RECEIVED: 7-11-92		DATE REPORTED: 10-30-92
REGION ENGINEER: BOB ALDRICH	PROJECT MANAGER: LARRY LINDLEY 8020	TEST NO.: 301	VAR.: X	LAB CHARGES: $1500.00 *

AGGREGATE GRADATION: SOURCE- EUGENE S & G #20-45-3 TYPE: GRAVEL

AGGREGATE SIZE	3/4 - 1/2	1/2 - 1/4	1/4 - 0		COMBINED WET SIEVE	AGG. GRAD. EXTRACTED
% COMB.	36	45	19			
1"	100				100	
3/4	77	100			92	
1/2	11	93			65	
3/8	4	60	100		47	
1/4	2	13	96		25	
4	2	4	83		18	
10	2	2	46		10	
40	2	2	20		5	
200(WET)	1	2	9		3	
NO. AVE.						
LIME TREAT % =					P200/AC =	

NONE REPORTED	
CALIBRATION NUMBER	
MIX ID	
NUMBER OF SAMPLES	
COUNT TIME PER SAMPLE	
FIT COEFF =	
CALIBRATION DATE	
BACKGROUND COUNT:	
BASE WEIGHT:	
CALIBRATION CONSTANTS - A1:	
A2:	
A3:	

VMA=

JOB MIX FORMULA TEST DATA:

PERCENT ASPHALT (TOTAL MIX)	4.5	5.0	5.5	6.0	6.5
ASPHALT FILM	DRY-SUFF	SUFF	SUFF-THICK	THICK	THK-THK
SPECIFIC GRAVITY @ 1ST COMP. (T-166)					
PERCENT VOIDS @ 1ST COMP.					
STABILITY @ 1ST COMP. (T-246)					
SPECIFIC GRAVITY @ 2ND COMP.					
PERCENT VOIDS @ 2ND COMP.					
STABILITY @ 2ND COMP					
MAXIMUM SPECIFIC GRAVITY (T-209)					
INDEX RET. STR. (T-165)	**	**	**	**	**
INDEX RET. Mr. (TM315)					
PERCENT DRAINDOWN	55	60	75	85	95

JOB MIX FORMULA: CALCULATED JOB MIX FORMULA PROPERTIES

AGGREGATE SIEVE SIZE	JMF GRADATION	PAVING COURSE	ASPHALT CONTENT % BY WT. OF TOTAL MIXTURE	Sp. Gr. @ 1ST COMP.	Sp. Gr. @ 2ND COMP.	MAX Sp. Gr.	DESIGN VOIDS 1ST COMP.	DESIGN VOIDS 2ND COMP.
1"		WEARING						
3/4		BASE						
1/2								
3/8		SHOULDER						
1/4		Asphalt LAB NO.						
10		BRAND-	CHEVRON		MIXING TEMP.-			
40		GRADE-	PBA-5		PLACEMENT TEMP.-			
200		ADDITIVE-						

AGGREGATE TEST DATA:

92-7619 & 07620 CA - LAR=15.1;DEG=0.6",14.1;SSL=5.1;DUST=0.26;SPG=2.61
92-07621 FA - SSL=6.6;DEG=0.4",8.4;SPG=2.55;SE=72

These are supplemental charges for extra IRS testing. [initials]

Distribution		COMMENTS
2X	Files	** DUE TO THE NUMBER OF TESTS CONDUCTED, I.R.S RESULTS ARE ON ATTACHED SHEET.
X	CONST.	* CHARGES REDUCED FORM THE NORMAL RATE
X	FHWA	
	Reg. Engr.	
X	Proj. Engr. LARRY LINDLEY	
X	Dist. Engr. RAS 3	
	Region Geo.	
X	Contractor EUGENE SAND & GRAVEL	

Oregon Department of Transportation
HIGHWAY DIVISION

ASPHALT LABORATORY RECORD

OREGON STATE HIGHWAY DIVISION,
MATERIALS SECTION, 800 AIRPORT RD., SALEM OR 97310

Page 1 of 2

ASPHALT BRAND AND TYPE: CHEVRON PBA-5	LABORATORY REPORT NUMBER: 9209354
PROJECT: PACIFIC HIGHWAY WEST-GATEWAY STREET	DATA SHEET NO.: NONE
HIGHWAY: BELTLINE	COUNTY: LANE	EXP. ACCOUNT, SUB JOB: C11194
CONTRACTOR: EUGENE SAND & GRAVEL	F.A. PROJECT NUMBER:	BID ITEM NUMBER:
PROJECT MANAGER: LARRY LINDLEY	AGENCY ORG. UNIT: 8020	DATE RECEIVED: 8-11-92	DATE REPORTED: 8-17-92
SUBMITTED BY: CHEVRON OIL CO.	AGENCY ORG. UNIT:	TEST NO.: 416A	VAR:	LAB CHARGE: 344.00
SOURCE OF MATERIAL: CHEVRON OIL CO.PORTLAND, OR.	QUANTITY REPRESENTED: 12 qts.
SAMPLED AT: PORTLAND	SAMPLED BY: UNK.	TO BE USED: "F"(SD)	DATE SAMPLED: 8-11-92

SAMPLE NO. COMPLETE — TEST RESULTS — DATE TESTED: 8-12-92

PAVING ASPHALT

T 73	Flash Point, closed cup		°F
T 44	Solubility in CHCL:CCL2	99.99	%
T 49	Penetration at 77F/39.2		cm/100
	Penetration ratio 39.2/77F		
T201	Viscosity, Kinematic 275 F	440	C.S.
T202	Viscosity, Absolute 140 F	2670	P.
T240	Paving Asphalt RTF (c) Residue		
T 47	Loss on heating	.72	%
T201	Viscosity, Kinematic 275 F	727	C.S.
T202	Viscosity Absolute 140 F, 30cm Hg., Vac.	6510	P.
	Viscosity Ratio Res./Orig.	2.4	
T 49	Penetration at 77 F/39.2 F	42/20	cm/100
	% of orig. penetration		%
T 51	Ductility at 77 F	105+	cm
	Ductility at 45 F	23+	cm

Liquid Asphalt

T 48	Flash point, open cup	590	°F
T201	Viscosity, Kinematic at 140 F		C.S.
T 78	Distillation (% of total distillate to 680 F)		
	To 374 F		%
	To 437 F		%
	To 500 F		%
	To 600 F		%
	Residue from distillation to 680 F Volume by difference		%
	Water		%

Liquid Asphalt Residue

T 49	Penetration at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm.
T202	Viscosity ABS at 140 F		P.

Emulsified Asphalt

T 59	Viscosity, S.F. at ___ F		sec.
T 59	Sieve Test		%
T 59	Residue by distillation to 500 F		%
T 59	Oil distillate in		%
T 49	Penetration of Res. at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm

T170 Modified Abson Recovery of Asphalt

T201	Viscosity, Kinematic 275 F		C.S.
T202	Viscosity, Absolute 140 F, 30cm Hg. Vac.		P.
T 49	Penetration of Res. at 77 F		cm/100
	"C" value		

T49 Penetration of Residue @ 39.2F 100 g. 5 sec. 7 cm/100

DISTRIBUTION ONLY
X FILES
X OPERATIONS
X FHWA
X LARRY LINDLEY
X RAS 3
X EUGENE SAND AND GRAVEL
X CHEVRON OIL CO.
X BIT

RECOMMENDATION:
Material as represented by this sample does [redacted] comply with specifications

PRELIMINARY BITUMINOUS MIXTURE DESIGN

MATERIALS SECTION

LAB NO.	9206813
PROJECT	YOUNGS BAY BR.-WARRENTON & HAMBURG AVE.
EA/SUB JOB/ACTIVITY	C11162
DATA SHEET NO.	AB 45467-69
PRIME CONTRACTOR	KIEWIT PACIFIC CO.
FED. AID NO.	NH-2-6(15) & F-1(49)
PAVING CONTRACTOR	
MIX TYPE CLASS	"F" (SD)
DATE RECEIVED	6-23-92
DATE REPORTED	8-14-92
REGION ENGINEER	KEN STONEMAN
PROJECT MANAGER	TOM FALLS 8034
TEST NO.	301M 319
VAR.	
LAB CHARGES	$1650.00 $ 367.00

AGGREGATE GRADATION: Source— Naselle #WA-025-2 Type— Quarry

Aggregate Size	3/4-1/2	1/2-1/4	1/4-0	Sand			Combined "Dry" Sieve	Agg. Grad. Extracted
% Comb.	29	44	22	5			Wet Sieve	
1"	100						100	
¾	63	100					89	
½	8.8	83					66	
⅜	4.4	27.6	100				40	
¼	2.4	4.0	82	100			26	
10	2.2	3.2	37	98			15	
40	2.0	2.4	16	32			7	
200 (Dry)	--	--	--	--			--	
200 (Wet)	1.6	1.8	9.0	1.9			3.3	
No. Ave.								
Lime Treat (%)							P200/AC =	

JOB MIX FORMULA TEST DATA:

Percent Asphalt (total mix)	5.0	5.5	6.0	6.5	7.0
Asphalt Film					
Sp. Gr. @ 1st Comp. T-166		2.267	2.291	2.305	
Percent Voids @ 1st Comp.					
Stability @ 1st Comp. (T-247)					
Sp. Gr. @ 2nd Comp.					
Percent Voids @ 2nd Comp.					
Stability @ 2nd Comp.					
Max. Sp. Gr. (T-209)					
Index Ret. Str. (T-165)		61	73	79	
Index Ret. Mr. (TM315)					
% DRAINDOWN	40	65	85	90	95

JOB MIX FORMULA:

Aggregate Sieve Size	JMF Gradation	Paving Course	Asphalt Content % By Wt. of Total Mixture	Sp Gr. @ 1st Comp	Sp Gr. @ 2nd Comp	Max Sp Gr T-209	Design Voids 1st Comp	Design Voids 2nd Comp
1"	100	Wearing	6.5	2.305				
¾	89	Base						
½	66							
⅜	40	Shoulder						
¼	26	Asphalt Lab No. 92-08547						
10	15	Brand— McCall		Mix Placement Temp.— 235 °F— 243 °F				
40	7	Grade— PBA-5		Mixing Temp.— 252 °F— 260 °F				
200	3.3	Additive— 0.5% PAVEBOND SPECIAL						

(CALCULATED JOB MIX FORMULA PROPERTIES)

AGGREGATE TEST DATA:

92-06270 & 06271 CA - LAR=12.8; NaSO4=4.9;DEG=0.4",10.0;SpG=2.80;Clay=0.28

92-06272 & 06273 FA - " =14.8;" =1.2",17.5; " =2.73; SE=46

Calibration Number: 6813
Mix ID: 11162
Number of Samples: 4
Count Time per Sample: 16
Fit Coeff= 0.999
Calibration Date: 7/28/92
Background Count: 2468
Weight: 6200
Calibration Constants:
A1: -14.781233
A2: 8.505826
A3: -7.478206

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Oregon Department of Transportation
HIGHWAY DIVISION

ASPHALT LABORATORY RECORD

OREGON STATE HIGHWAY DIVISION,
MATERIALS SECTION, 800 AIRPORT RD., SALEM OR 97310

PAGE 1 of 2

ASPHALT BRAND AND TYPE: McCALL PBA-5		LABORATORY REPORT NUMBER: 08547	
PROJECT: YOUNGS BAY BRIDGE – WARRENTON/ASTORIA HWY. SECTION		DATA SHEET NO.: NONE	
HIGHWAY: OREGON COAST & LOWER COLUMBIA RIVER	COUNTY: CLATSOP	EXP. ACCOUNT, SUB JOB: C1162	
CONTRACTOR: KIEWIT PACIFIC CO.	F.A. PROJECT NUMBER: NH-2-6(15) & F-1(49)	BID ITEM NUMBER:	
PROJECT MANAGER: TOM FALLS	AGENCY ORG. UNIT: 8034	DATE RECEIVED: 7-30-92	DATE REPORTED: 08-04-92
SUBMITTED BY: McCALL	AGENCY ORG. UNIT:	TEST NO.: 416A	VAR / LAB CHARGE: 344.00
SOURCE OF MATERIAL: McCALL CO.	QUANTITY REPRESENTED: 12 qts.		
SAMPLED AT: PORTLAND, OR. / SAMPLED BY: McCALL	TO BE USED: "A"C"F" a/c		DATE SAMPLED: 7-29-92

SAMPLE NO. COMPLETE — TEST RESULTS — DATE TESTED: 8-3-92

PAVING ASPHALT

T 73	Flash Point, closed cup		°F
T 44	Solubility in CHCL:CCL2	99.99	%
T 49	Penetration at 77F/39.2		cm/100
	Penetration ratio 39.2/77F		
T201	Viscosity, Kinematic 275 F	426	C.S.
T202	Viscosity, Absolute 140 F	2370	P.
T240	**Paving Asphalt RTF (c) Residue**		
T 47	Loss on heating	.57	%
T201	Viscosity, Kinematic 275 F	66	C.S.
T202	Viscosity Absolute 140 F, 30cm Hg., Vac.	6220	P.
	Viscosity Ratio Res./Orig.	2.6	
T 49	Penetration at 77 F/39.2 F	40/19	cm/100
	% of orig. penetration		%
T 51	Ductility at 77 F	100+	cm
	Ductility at 45 F	15	cm

Liquid Asphalt

T 48	Flash point, open cup	575	°F
T201	Viscosity, Kinematic at 140 F		C.S.
T 78	Distillation (% of total distillate to 680 F)		
	To 374 F		%
	To 437 F		%
	To 500 F		%
	To 600 F		%
	Residue from distillation to 680 F Volume by difference		%
	Water		%

Liquid Asphalt Residue

T 49	Penetration at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm
T202	Viscosity ABS at 140 F		P

Emulsified Asphalt

T 59	Viscosity, S.F. at ____ F		sec
T 59	Sieve Test		%
T 59	Residue by distillation to 500 F		%
T 59	Oil distillate in		%
T 49	Penetration of Res. at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm

Modified Abson Recovery of Asphalt

T170	**Modified Abson Recovery of Asphalt**		
T201	Viscosity, Kinematic 275 F		C.S
T202	Viscosity, Absolute 140 F, 30cm Hg. Vac.		P.
T 49	Penetration of Res. at 77 F		cm/100
	"C" value		

T49 Penetration of Residue @ 39.2F
100 g. 5 sec. [redacted] 4 cm/100

DISTRIBUTION ONLY
- X FILES
- X RAS 2
- X TOM FALLS
- X KIEWIT PACIFIC
- X McCALL OIL
- X OPERATIONS
- X FHWA
- X BIT

RECOMMENDATION:
Material as represented by this sample does, [redacted] comply with specifications

PRELIMINARY BITUMINOUS MIXTURE DESIGN

MATERIALS SECTION

PROJECT: M.P. 4.0-CROWFOOT ROAD			LAB NO. 9?05974
		EA/SUB JOB/ACTIVITY: 15 - MISC	DATA SHEET NO. AB 60427-29
PRIME CONTRACTOR: LTM		FED. AID NO. ------	
PAVING CONTRACTOR:	MIX TYPE CLASS: "F" a/c	DATE RECEIVED: 5-11-92	DATE REPORTED:
REGION ENGINEER: JIM GIX	PROJECT MANAGER: DALE PETRASEK (Jackson Co.)	TEST NO. 301M / 319	VAR. X / X; LAB CHARGES $ 50.00 / $ 67.00

AGGREGATE GRADATION: Source— LTM QUARRY COUNTY SOURCE Type— QUARRY

Aggregate Size	3/4-1/4	1/4-10	10-0				Combined Dry-Sieve	Agg. Grad. Extracted
% Comb.	83	7	10				WET SIEVE	
1"	100						100	
3/4	90						92	
1/2	57						64	
3/8	33	100					46	
1/4	9	82					26	
10	0.2	3	83				11	
40	0.2	1	30				4	
200 (Dry)	0.1	3.0	11.2				—	
200 (Wet)							2.1	
No. Ave.	11	11	11					
Lime Treat (%)							P200/AC = 0.4	

JOB MIX FORMULA TEST DATA:

Percent Asphalt (total mix)	5.0	5.5	6.0	6.5	7.0
Asphalt Film	Suf-Thk	Thick	Thick	Thk-Thk	Thk, Thk!!
Sp. Gr. @ 1st Comp. (T-246)					
Percent Voids @ 1st Comp.					
Stability @ 1st Comp. (T-247)					
Sp. Gr. @ 2nd Comp.					
Percent Voids @ 2nd Comp.					
Stability @ 2nd Comp.					
Max. Sp. Gr. (T-209)		2.486			
Index Ret. Str. (T-165)	67		89		79
Index Ret. Mr. (TM315)					
Geometrically measured gravitys	2.116	2.127	2.137		2.142

JOB MIX FORMULA:

CALCULATED JOB MIX FORMULA PROPERTIES

Aggregate Sieve Size	JMF Gradation	Paving Course	Asphalt Content % By Wt. of Total Mixture	Sp Gr @ 1st Comp	Sp Gr @ 2nd Comp	Max Sp Gr T-209	Design Voids 1st Comp	Design Voids 2nd Comp
1"	100	Wearing	5.5			2.486		
3/4	92	Base						
1/2	64							
3/8	46	Shoulder						
1/4	26	Asphalt Lab No. 92-04016						
10	11	Brand— Witco		Mix Placement Temp.— 230 °F— 238 °F				
40	4	Grade— PBA-5		Mixing Temp.— 245 °F— 253 °F				
200	2.1	Additive—						

AGGREGATE TEST DATA:

Calibration Number: 5974
Mix ID: 15.4
Number of Samples: 4
Count Time per Sample: 16
Fit Coeff= 0.999
Calibration Date: 6/19/92
Background Count: 2470
Weight: 6500
Calibration Constants:
A1: -28.112749
A2: 15.219207
A3: -16.169669

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Engineer of Materials

Oregon Department of Transportation
HIGHWAY DIVISION

ASPHALT LABORATORY RECORD

OREGON STATE HIGHWAY DIVISION,
MATERIALS SECTION, 800 AIRPORT RD., SALEM OR 97310

PAGE 1 of 2

ASPHALT BRAND AND TYPE: WITCO PBA-5	LABORATORY REPORT NUMBER: 92C4016
PROJECT: JACKSON CO. BUTTE FALLS RD.	DATA SHEET NO.: NONE
HIGHWAY: BUTTE FALLS RD. / COUNTY: JACKSON	EXP. ACCOUNT, SUB JOB: 15MISC. / CONTR.#238
CONTRACTOR: UNK. / F.A. PROJECT NUMBER:	BID ITEM NUMBER:
PROJECT MANAGER: UNK. / AGENCY ORG. UNIT: COUNTY	DATE RECEIVED: 5-4-92 / DATE REPORTED: 5-8-92
SUBMITTED BY: WITCO CORP. / AGENCY ORG. UNIT:	TEST NO.: 416A / VAR / LAB CHARGE: 344.00
SOURCE OF MATERIAL: WITCO CORP. OILDALE CA. / QUANTITY REPRESENTED: 8 qts.	
SAMPLED AT: OILDALE / SAMPLED BY: UNK. / TO BE USED: "F" a/c	DATE SAMPLED: 4-29-92

SAMPLE NO. 92-2 COMPLETE **TEST RESULTS** DATE TESTED: 5-7-92

PAVING ASPHALT

Test	Description	Result	Unit
T 73	Flash Point, closed cup		°F
T 44	Solubility in CHCL:CCL2	99.6E	%
T 49	Penetration at 77F/39.2		cm/100
	Penetration ratio 39.2/77F		
T201	Viscosity, Kinematic 275 F	335	C.S.
T202	Viscosity, Absolute 140 F	2610	P.
T240	**Paving Asphalt RTF (c) Residue**		
T 47	Loss on heating	.17	%
T201	Viscosity, Kinematic 275 F	443	C.S.
T202	Viscosity Absolute 140 F, 30cm Hg., Vac.	5040	P.
	Viscosity Ratio Res./Orig.	1.9	
T 49	Penetration at 77 F/39.2 F	34/17	cm/100
	% of orig. penetration		%
T 51	Ductility at 77 F	100+	cm
	Ductility at 45 F	16	cm

Liquid Asphalt

Test	Description	Result	Unit
T 48	Flash point, open cup	590	°F
T201	Viscosity, Kinematic at 140 F		C.S.
T 78	Distillation (% of total distillate to 680 F)		
	To 374 F		%
	To 437 F		%
	To 500 F		%
	To 600 F		%
	Residue from distillation to 680 F Volume by difference		%
	Water		%

Liquid Asphalt Residue

Test	Description	Result	Unit
T 49	Penetration at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm
T202	Viscosity ABS at 140 F		P

Emulsified Asphalt

Test	Description	Result	Unit
T 59	Viscosity, S.F. at ____ F		sec.
T 59	Sieve Test		%
T 59	Residue by distillation to 500 F		%
T 59	Oil distillate in		%
T 49	Penetration of Res. at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm

T170 Modified Abson Recovery of Asphalt

Test	Description	Result	Unit
T201	Viscosity, Kinematic 275 F		C.S.
T202	Viscosity, Absolute 140 F, 30cm Hg. Vac.		P
T 49	Penetration of Res. at 77 F		cm/100
	"C" value		

T49 PENETRATION of RESIDUE @ 39.2F
100 g. 5 sec. 4 cm/100

DISTRIBUTION ONLY
X FILES
2X JACKSON COUNTY PUBLIC WORKS
X WITCO CORP.

RECOMMENDATION:
Material as represented by this sample does, ~~does not~~ comply with specifications

gon Department of Transportation
ay Division

PRELIMINARY BITUMINOUS MIXTURE DESIGN

MATERIAL SECTION

LA – MCNARY		EA / SUB JOB / ACTIVITY: C11245		LABORATORY NO.: 93 – 01083; DATA SHEET NO.: AB 60602 – 4
CONTRACTOR: J.C.COMPTON		FED.AID NO.: NH–18(8)		
PAVING CONTRACTOR	MIX TYPE CLASS: "F"(SD)	DATE RECEIVED: 1/13/93		DATE REPORTED: 4-1-93
REGION ENGINEER: J.X.WILSON	PROJECT MANAGER: TOM PENNER 8067	TEST NO.: 301 / 319	VAR.: V	LAB CHARGES: $950.00 / $367.00

AGGREGATE GRADATION: SOURCE– 30 – 001 – 5 POWERLINE GRAVEL TYPE: GRAVEL & QUARRY

AGGREGATE SIZE	3/4" – 1/4"	#10 – 0	LIME		COMBINED WET SIEVE	AGG. GRAD. EXTRACTED
% COMB.	86%	13%	1%		100	
1"	100				100	
3/4	91				92	
1/2	58				64	
3/8	39				48	
1/4	12				24	
4	5	100			18	
10	2	89			14	
40	1	34			6	
200(WET)	0.5	11.2	100		2.9	
NO. AVE.	47	49				
LIME TREAT % = 1.0					P200/AC =	0.5

VMA= 21.2

CALIBRATION NUMBER	1083
MIX ID	11245
NUMBER OF SAMPLES	4
COUNT TIME PER SAMPLE	16
FIT COEFF =	0.999
CALIBRATION DATE	3/25/93
BACKGROUND COUNT:	2473
BASE WEIGHT:	6750
CALIBRATION CONSTANTS – A1:	–30.133099
A2:	15.948307
A3:	–16.468365

JOB MIX FORMULA TEST DATA:

PERCENT ASPHALT (TOTAL MIX)	5.0	5.5	6.0	6.5	7.0
ASPHALT FILM	SUFFICIENT	SUFF – THK	THICK	THK – THK	THICK +
SPECIFIC GRAVITY @ 1ST COMP. (T–166)	2.29		2.30		2.34
PE…ENT VOIDS @ 1ST COMP.			9.5		
…ITY @ 1ST COMP. (T–246)					
S…IFIC GRAVITY @ 2ND COMP.					
PERCENT VOIDS @ 2ND COMP.					
STABILITY @ 2ND COMP					
MAXIMUM SPECIFIC GRAVITY (T–209)			2.541		
INDEX RET. STR. (T–165)	88		79		103
INDEX RET. Mr. (TM315)					
PERCENT DRAINDOWN	30	50	65	85	98

JOB MIX FORMULA: / **CALCULATED JOB MIX FORMULA PROPERTIES**

AGGREGATE SIEVE SIZE	JMF GRADATION	PAVING COURSE	ASPHALT CONTENT % BY Wt. OF TOTAL MIXTURE	Sp. Gr. @ 1ST COMP.	Sp. Gr. @ 2ND COMP.	MAX Sp. Gr.	DESIGN VOIDS 1ST COMP.	DESIGN VOIDS 2ND COMP.
1"	100	WEARING	6.2	2.31	----	2.541	9.5	----
3/4	92	BASE						
1/2	64							
3/8	48	SHOULDER						
1/4	24	Asphalt LAB NO. 93 – 00255						
10	14	BRAND– KOCH		MIXING TEMP.– 276 ° – 285 ° F				
40	6	GRADE– PBA – 6		PLACEMENT TEMP.– 256 ° – 266 ° F				
200	3.0	ADDITIVE– 1% LIME TREATMENT OF THE AGGREGATE IS REQUIRED						

AGGREGATE TEST DATA:

CA: 92–14993; SP GRAV = 2.80; NA2SO4 = 0.6; DEG = 0.2",11.9%; LAR = 12.4%; FRIA = 0.2%; DUST = 0.08%

FA: 92–14994 & 5; SP GRAV = 2.64; NA2SO4 = 2.3; DEG = 0.4",8.0%; SE = 80; FRIA = 0.4%

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Res. Engr.
Dist. Engr.
Region Geo.
Contractor

COMMENTS:

Wayne Habine
ENGINEER OF MATERIALS

Oregon Department of Transportation

~~HIGHWAY~~ DIVISION

1-22-93 FW13-65

ASPHALT LABORATORY RECORD

OREGON STATE HIGHWAY DIVISION,
MATERIALS SECTION, 800 AIRPORT RD., SALEM OR 97310

LABORATORY REPORT NUMBER	9300255
ASPHALT BRAND AND TYPE	Koch PBA-6
PROJECT	Umatilla - McNary
DATA SHEET NO.	None
HIGHWAY	Columbia River
COUNTY	Umatilla
EXP. ACCOUNT. SUB JOB	C11245
CONTRACTOR	J.C. Compton
F.A. PROJECT NUMBER	NH-18(8)
BID ITEM NUMBER	
PROJECT MANAGER	Tom Penner
AGENCY ORG. UNIT	8067
DATE RECEIVED	1-13-93
DATE REPORTED	1-19-93
SUBMITTED BY	Koch Materials Co.
AGENCY ORG. UNIT	
TEST NO.	416A
VAR	
LAB CHARGE	344.00
SOURCE OF MATERIAL	Koch Materials Co., Mack, Co.
QUANTITY REPRESENTED	12 Qts.
SAMPLED AT	
SAMPLED BY	UNK.
TO BE USED	"B"(50) & "F"(50)
DATE SAMPLED	UNK.

SAMPLE NO. Complete   TEST RESULTS   DATE TESTED: 1-15-93

PAVING ASPHALT

Test	Description	Result	Unit
T 73	Flash Point, closed cup		°F
T 44	Solubility in CHCL:CCL2		%
T 49	Penetration at 77F/39.2		cm/100
	Penetration ratio 39.2/77F		
T201	Viscosity, Kinematic 275 F	934	C.S.
T202	Viscosity, Absolute 140 F	2960	P.

T240 Paving Asphalt RTF (c) Residue

Test	Description	Result	Unit
T 47	Loss on heating	.07	%
T201	Viscosity, Kinematic 275 F	1080	C.S.
T202	Viscosity Absolute 140 F, 30cm Hg., Vac.	6100	P.
	Viscosity Ratio Res./Orig.	2.1	
T 49	Penetration at 77 F/39.2 F	59/34	cm/100
	% of orig. penetration		%
T 51	Ductility at 77 F	150+	cm
	Ductility at 45 F	96	cm

Liquid Asphalt

Test	Description	Result	Unit
T 48	Flash point, open cup	310+C °F	
T201	Viscosity, Kinematic at 140 F		C.S
T 78	Distillation (% of total distillate to 680 F)		
	To 374 F		%
	To 437 F		%
	To 500 F		%
	To 600 F		%
	Residue from distillation to 680 F Volume by difference		%
	Water		%

Liquid Asphalt Residue

Test	Description	Result	Unit
T 49	Penetration at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm.
T202	Viscosity ABS at 140 F		P.

Emulsified Asphalt

Test	Description	Result	Unit
T 59	Viscosity, S.F. at ____ F		sec.
T 59	Sieve Test		%
T 59	Residue by distillation to 500 F		%
T 59	Oil distillate in		%
T 49	Penetration of Res. at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm

T170 Modified Abson Recovery of Asphalt

Test	Description	Result	Unit
T201	Viscosity, Kinematic 275 F		C.S.
T202	Viscosity, Absolute 140 F, 30cm Hg. Vac.		P.
T 49	Penetration of Res. at 77 F		cm/100
	"C" value		

T49 Penetration of Residue @ 39.2F
100 g. 5 sec. 11 cm/100

DISTRIBUTION ONLY

X FILES
X TOM PENNER
X RAS 5
X J.C. COMPTON CONTRACTOR
X KOCH MATERIALS CO.
X OPERATIONS
X FHWA
X BIT

RECOMMENDATION:
Material as represented by this sample does, ~~does not~~ comply with specifications

Wayne Hobie

ENGINEER OF MATERIALS

734-3054(5-91)

PRELIMINARY BITUMINOUS MIXTURE DESIGN

MATERIALS SECTION

PROJECT: EASTSIDE BYPASS (KLAMATH FALLS) PHASE 1		LAB NO. 9208725	
PRIME CONTRACTOR: KLAMATH PACIFIC CORP.		EA/SUB JOB/ACTIVITY: C11220	DATA SHEET NO.: AB 56718-16
PAVING CONTRACTOR:	MIX TYPE CLASS: "F"(SD)(LIME)	FED. AID NO.: STP-(48)9	
REGION ENGINEER: STEVE MCNAB	PROJECT MANAGER: RICHARD STEYSKAL 8033	DATE RECEIVED: 7-20-92	DATE REPORTED:
		TEST NO.: 301 / 319	VAR.: X
		LAB CHARGES: $2850.00 / $ 367.00	

AGGREGATE GRADATION: Source— Stukel #18-036-4 Type— Quarry

Aggregate Size	3/4-1/2	1/2-1/4	1/4-00	LIME			Combined ~~Dry~~ Sieve Wet Sieve	Agg. Grad. Extracted
% Comb.	36	40	23	1				
1"	100						100	
¾	74.3	100					91	
½	11.4	94.6					66	
⅜	4.3	53.8	100				47	
¼	3.0	10.3	91.2				27	
10	2.9	3.2	45.2				14	
40	2.7	3.0	19.3				8	
200 (Dry)	--	--	--				--	
200 (Wet)	1.6	1.7	9.0	100			4.3	
No. Ave.	11	7	12					
Lime Treat (%)				1			P200/AC = 0.7	

JOB MIX FORMULA TEST DATA:

Percent Asphalt (total mix)	5.0	5.5	6.0	6.5	7.0
Asphalt Film		Suf-Thk	Thick	Thk-Thk	
Sp. Gr. @ 1st Comp. ~~(TM205)~~ T-166		2.113	2.142	2.143	
Percent Voids @ 1st Comp.					
Stability @ 1st Comp. (T-247)					
Sp. Gr. @ 2nd Comp.					
Percent Voids @ 2nd Comp.					
Stability @ 2nd Comp.					
Max. Sp. Gr. (T-209)				2.375	
Index Ret. Str. (T-165)		65	75	65	
Index Ret. Mr. (TM315)					
PERCENT DRAINDOWN	45	65	75	90	99

JOB MIX FORMULA:

Aggregate Sieve Size	JMF Gradation	Paving Course	Asphalt Content % By Wt. of Total Mixture
1"	100	Wearing	6.0
¾	91	Base	
½	66		
⅜	47	Shoulder	
¼	27	Asphalt Lab No. 92-07514	
10	14	Brand— Albina	
40	8	Grade— PBA-6	
200	4.3	Additive— LIME TREATMENT OF THE AGGREGATE IS REQUIRED	

CALCULATED JOB MIX FORMULA PROPERTIES

Sp Gr. @ 1st Comp	Sp Gr. @ 2nd Comp	Max Sp Gr T-209	Design Voids 1st Comp	Design Voids 2nd Comp
		2.375		

Mix Placement Temp.— 247 °F— 257 °F

Mixing Temp.— 265 °F— 274 °F

AGGREGATE TEST DATA:

92-07925 & 07926 CA- LAR=18.0;SSL=1.9;DEG=0.2",6.2;SpG=2,51;ABS=2.51;Clay=0.28

92-07927 FA - " =2.8; " =0.5",7.6; " =2.55; " =3.63; SE=70

Const.
FHWA
Reg. Engr.
Res. Engr.
Dist. Engr.
Region Geo.
Files

Calibration Number: 8725
Mix ID: 11220 'F'
Number of Samples: 4
Count Time per Sample: 16
Fit Coeff= 0.997
Calibration Date: 8/05/92
Background Count: 2471
Weight: 6200
Calibration Constants:
A1: -35.760963
A2: 20.215575
A3: -23.515351

Engineer of Materials

10-14-92 FGC5-43

Oregon Department of Transportation

HIGHWAY DIVISION

ASPHALT LABORATORY RECORD

OREGON STATE HIGHWAY DIVISION,
MATERIALS SECTION, 800 AIRPORT RD., SALEM OR 97310

ALBINA PBA-6
ASPHALT BRAND AND TYPE

PROJECT: REDMOND - BEND (NORTH UNIT)		LABORATORY REPORT NUMBER: 9211726
		DATA SHEET NO.: NONE
HIGHWAY: THE DALLES - CALIFORNIA	COUNTY: DESCHUTES	EXP. ACCOUNT. SUB JOB: C11104
CONTRACTOR: R.L.COATS	F.A. PROJECT NUMBER: F-4-2(26)	BID ITEM NUMBER:
PROJECT MANAGER: TOM GARNER	AGENCY ORG. UNIT: 8027	DATE RECEIVED: 9-18-92 / DATE REPORTED: 9-28-92
SUBMITTED BY: ALBINA FUEL CO.	AGENCY ORG. UNIT:	TEST NO.: 416A / VAR: / LAB CHARGE: 344.00
SOURCE OF MATERIAL: ALBINA FUEL CO. PORTLAND, OR.	QUANTITY REPRESENTED: 12 qts.	
SAMPLED AT: PORTLAND / SAMPLED BY:	TO BE USED: "F"a/c	DATE SAMPLED:

SAMPLE NO. COMPLETE **TEST RESULTS** **DATE TESTED:** 9-25-92

PAVING ASPHALT

Test	Description	Result	Unit
T 73	Flash Point, closed cup		°F
T 44	Solubility in CHCL:CCL2		%
T 49	Penetration at 77F/39.2		cm/100
	Penetration ratio 39.2/77F		
T201	Viscosity, Kinematic 275 F	804	C.S.
T202	Viscosity, Absolute 140 F	4590	P.
T240	**Paving Asphalt RTF (c) Residue**		
T 47	Loss on heating	.05	%
T201	Viscosity, Kinematic 275 F	1230	C.S.
T202	Viscosity Absolute 140 F, 30cm Hg., Vac.	11600	P.
	Viscosity Ratio Res./Orig.	2.5	
T 49	Penetration at 77 F/39.2 F	72/40	cm/100
	% of orig. penetration		%
T 51	Ductility at 77 F	99+	cm
	Ductility at 45 F	25+	cm

Liquid Asphalt

Test	Description	Result	Unit
T 48	Flash point, open cup	580	°F
T201	Viscosity, Kinematic at 140 F		C.S.
T 78	Distillation (% of total distillate to 680 F)		
	To 374 F		%
	To 437 F		%
	To 500 F		%
	To 600 F		%
	Residue from distillation to 680 F Volume by difference		%
	Water		%

Liquid Asphalt Residue

Test	Description	Result	Unit
T 49	Penetration at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm
T202	Viscosity ABS at 140 F		P

Emulsified Asphalt

Test	Description	Result	Unit
T 59	Viscosity, S.F. at ______ F		sec
T 59	Sieve Test		%
T 59	Residue by distillation to 500 F		%
T 59	Oil distillate in		%
T 49	Penetration of Res. at 77 F		cm/100
T 44	Solubility in CHCL:CCL2		%
T 51	Ductility at 77 F		cm

Modified Abson Recovery of Asphalt

Test	Description	Result	Unit
T170	**Modified Abson Recovery of Asphalt**		
T201	Viscosity, Kinematic 275 F		C.S
T202	Viscosity, Absolute 140 F, 30cm Hg. Vac.		P
T 49	Penetration of Res. at 77 F		cm/100
	"C" value		

T49 Penetration of Residue @ 39.2F 100 g. 5 sec. 13 cm/100

DISTRIBUTION ONLY
X FILES
X TOM GARNER
X RAS 4
X R.L. COATS
X OPEATIONS
X FHWA
X BIT

RECOMMENDATION:
Material as represented by this sample does, [redacted] comply with specifications

ENGINEER OF MATERIALS

734-3054(5-91)

APPENDIX B

STANDARD TEST METHOD FOR THE ENVIRONMENTAL CONDITIONING SYSTEM (ECS)

Standard Method of Test for

Determining the Water Sensitivity Characteristics of Compacted Asphalt Concrete Mixtures Subjected to Hot and Cold Climatic Conditions

AASHTO DESIGNATION: T ###-YY
(ASTM DESIGNATION: D ####-YY)

This document is the draft of a test method being developed by researchers at Oregon State University for the Strategic Highway Research Program (SHRP). The information contained herein is considered interim in nature and future revisions are expected. It is also recognized that this document may lack details with respect to the test equipment (schematics, dimensions, etc.); more details will be provided after the test procedure is finalized. This version represents the state of the test procedure as of ***March 1, 1993****.*

The test method is in a format similar to the test methods contained in the American Association of State Highway and Transportation Officials' (AASHTO) standard specifications. At the conclusion of ***SHRP****, selected test methods will be submitted to AASHTO for adoption into its standard specifications.*

1. SCOPE

1.1 This method determines the water sensitivity or stripping characteristics of compacted asphalt concrete mixtures under warm and cold climatic conditions.

1.2 *This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Documents:*

M ###	Specification for Performance Graded Asphalt Binders
R 11	Practice for Indicating Which Places of Figures are to be Considered Significant in Specifying Limiting Values
T 2	Method for Sampling Aggregates
T 40	Method for Sampling Bituminous Materials
T 27	Method for Sieve Analysis of Fine and Coarse Aggregates
T 164	Method for Quantitative Extraction of Bitumen from Paving Mixtures
T 167	Method for Compressive Strength of Bituminous Mixtures
T 168	Method of Sampling Bituminous Paving Mixtures
T 247	Method for Preparation of Test Specimens of Bituminous Mixtures by Means of California Kneading Compactor
T ###	Practice for Preparation of Asphalt Concrete Specimens by Means of the Rolling Wheel Compactor
T ###	Practice for Short Term Aging of Asphalt Concrete Mixtures

2.2 *ASTM Documents:*

D 8	Standard Definitions of Terms Relating to Materials for Roads and Pavements
D 3549	Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens

3. TERMINOLOGY

3.1 Definitions for many terms common to asphalt are found in the following documents:

3.1.1 Standard Definitions D 8
3.1.2 Performance Graded Asphalt Binder M ###

4. SUMMARY OF PRACTICE

4.1 Compacted asphalt concrete test specimens are subjected to a water and temperature conditioning process. The water sensitivity characteristics of the compacted mixtures are determined based upon measurements of percent stripping, the ECS modulus, and the coefficients of permeability for air and water flow.

5. SIGNIFICANCE AND USE

5.1 The measured water sensitivity characteristics may be used to evaluate or characterize asphalt concrete mixtures.

5.2 The water sensitivity characteristics of asphalt concrete mixtures can be used to determine its suitability for use as a highway paving material. This information may also be used to compare and select various asphalt binders, asphalt modifiers, asphalt concrete mixtures, asphalt concrete additives and asphalt concrete aggregates.

6. APPARATUS

6.1 *Environmental Conditioning System (ECS)* - Any closed-loop computer controlled test system which meets the minimum requirements outlined in Table 1. The ECS must be capable of increasing the temperature within an asphalt concrete specimen to 100°C and decreasing it to -20°C within 2 hours. It must be capable of pulling air and distilled water through a specimen at specified vacuum levels. The ECS must be capable of applying axial load pulses (220 ± 5 N (50 ± 1 lbf) static and 6700 ± 25 N (1506 ± 5 lbf) dynamic) in a haversine wave form with a load duration of 0.1 s and a rest period of 0.9 s between load pulses. The system must also be capable of measuring axial deformations and be equipped with computer software which can compute axial compressive stress and recoverable axial strain at various load cycles. In addition, the ECS must be capable of applying stresses sufficient to obtain deformations between 50 to 100 μstrain in compacted asphalt concrete specimens. The ECS is illustrated in Figures 1, 2, and 3.

6.2 *Testing Machine* - a pneumatic or hydraulic testing machine that meets the requirements outlined in 4.3 of T 167.

6.3 *Specimen End Platens* - two aluminum end platens which are 102 ± 2 mm in diameter by 51 ± 2 mm thick. Each end platen will have a drainage hole at its center that is 4.8 ± 0.5 mm in diameter and one side of each end platen will be patterned with grooves as shown in Figure 4. In addition, the platen must have a groove around its perimeter at mid height which is of sufficient width and depth to hold the O-rings described in 6.6.2.

6.4 *Perforated Teflon Disks* - As shown in Figure 5. The perforations must coincide with the grooving pattern in the specimen end platens.

6.5 *Yoke and Spacer Assembly* - Used for mounting 2 vertical linear variable transducers (LVDTs) on the test specimen as shown in Figure 2. Spacers should not be more than 51 mm for a 102 mm specimen.

6.6 *Miscellaneous Apparatus:*

6.6.1 150 mm (6 in.) of 100 mm (4 in.) diameter rubber membrane
6.6.2 Two 102 mm (4 in.) O-Rings
6.6.3 Caulking gun for applying silicone sealant
6.6.4 Calipers capable of measuring 150 ± 1 mm
6.6.5 Steel Spatula
6.6.6 Vacuum Source
6.6.7 Distilled Water Source

7. MATERIALS

7.1 The following materials are required:

7.1.1 Clear silicone sealant
7.1.2 Compressed air

8. SAMPLING

8.1 Asphalt binder shall be sampled in accordance with T 40.

8.2 Aggregate shall be sampled in accordance with T 2.

8.3 Asphalt concrete mixtures shall be sampled in accordance with T 168.

8.4 Compacted roadway test specimens from a newly laid pavement may be sampled and tested if the cores meet the dimension requirements specified in 9.4, however, the top and bottom of the cores must not sustain cut surfaces.

9. SPECIMEN PREPARATION

9.1 Prepare an asphalt concrete mixture sample in accordance with T ###, Preparation of Test Specimens of Bituminous Mixtures by Means of Laboratory Kneading Compaction or T ###, Preparation of Test Specimens of Bituminous Mixtures by Means of Rolling Wheel Compactor.

Note 1: Plant mixed asphalt concrete samples are not to be subjected to short term aging as described in T ###.

Note 2: The top and bottom of a specimen cored from a slab must not sustain cut surfaces.

9.2 Determine the air void content of the specimen in accordance with T ### or T ###.

9.3 Measure the diameter and height of the specimen at three locations as described in D 3549. Record the average measurement as the diameter and height of the specimen within ± 1 mm.

9.4 Place the specimen inside the 150 mm long rubber membrane, centering the specimen within the membrane so that there is a 25 mm extension at each end. Inject a continuous line of silicone cement around the specimen at mid height between the membrane and the specimen. Inject sufficient silicone to ensure that the entire surface area of the specimen will be sealed. Use a spatula to smooth and spread the silicone to a thin uniform layer. Allow the specimen to stand at room temperature, overnight or longer, until the silicone is dry.

10. PROCEDURE

10.1 *Test Set-Up*

10.1.1 Place a perforated teflon disk on top of the grooved surface of the bottom end platen inside the load frame.

10.1.2 Place the specimen vertically on top of the teflon disk and bottom end platen.

Note 3: Field cores shall be positioned such that the top of the specimen corresponds with the top of the pavement.

10.1.3 Place a perforated teflon disk on top of the specimen and place the top end platen on top of the disk, with the grooved surface facing the disk and specimen.

10.1.4 Seal the rubber membrane around the specimen platen assembly by placing an O-ring in each groove of the end platens, over the rubber membrane.

10.1.5 To ensure that the system is airtight, close the system to the water and air supplies by selecting vacuum with the Water-Vacuum-Air valve. Open the vacuum valve and adjust the vacuum regulator until the specimen inlet and outlet pressures read 510 ± 25 mm Hg (20 ± 1 in. Hg). Close the vacuum valve. Close the bypass valve so that any air in the specimen is removed. Monitor the specimen inlet and outlet pressure gages for 5 min. If both gage readings remain constant throughout the 5 min, the system is airtight and testing may continue. If either gage reading decreases, the system is not airtight and adjustments must be made to the system prior to continuing testing.

10.1.6 Attach the yoke with the spacers and the LVDTs to the specimen.

10.2 *Coefficient of Permeability For Air Flow*

10.2.1 Set and establish the temperature of the environmental control chamber to 25 ± 0.5°C.

10.2.2 Open the vacuum valve and select air from the Water-Vacuum-Air valve. Turn the air valve on. Apply the lowest differential pressure possible (typically 6 to 7 kPa) by adjusting the vacuum regulator. Record the air flow through the test specimen. Record the pressure differential reading.

10.2.3 Repeat 10.2.2 for three additional differential pressures. The pressures selected will vary depending upon the void content of the specimen being tested. Specimens with low air voids will require higher pressures. A constant interval between the differential pressures must be selected (e.g. 20, 30, 40, and 50 kPa (3, 4.4, 5.8, and 7.3 psi)). Any range of pressures may be selected that provides measurable flows on the air flow meters and which results in a range of air flows which are within + 10% of the air flow for the 4 pressures selected.

10.2.4 Calculate the coefficient of permeability for air flow of the test specimen as described in 11.2.1 for each of the pressures applied in 10.2.2 and 10.2.3. Calculate and report the average of the four results.

10.2.5 Close the vacuum valve.

10.3 *ECS Modulus Test*

10.3.1 Maintain the temperature of the environmental chamber at 25 ± 0.5°C. Remove the spacers from the yoke.

10.3.2 Apply a static load of 130 ± 25 N (30 ± 5 lbf) and an axial compressive repeated load of approximately 2200 N (494 lbf) to the test specimen. The repeated load should be in a haversine wave form with a load duration of 0.1 s and a rest period of 0.9 s between load pulses.

10.3.3 Adjust the specimen and/or yoke assembly until the readings from the two LVDTs are within 15% of each other.

10.3.4 If the strain is less than 50 μstrain, increase the magnitude of the repeated load until a strain level between 50 and 100 μstrain is reached. If the strain is more than 100 μstrain, decrease the repeated load until a strain level between 50 and 100 μstrain is reached. Record the final loads applied and utilize the same loading levels ± 25 N for subsequent ECS modulus testing after conditioning is applied to the specimen as described in 10.7.

Note 4: Typically, a load of 4000 N (9000 lbf) may be required to achieve a strain level of 100 μstrain.

10.3.5 Measure the peak axial load and recoverable vertical deformations for the load interval from the last 5 cycles. Record the peak axial load and recoverable vertical deformations at each load cycle for the last five load cycles applied. Calculate the ECS moduli as outlined in 11.3.3 and 11.3.4.

Note 5: Do not exceed 250 load cycles when performing the ECS modulus test as this will damage the specimen.

10.3.6 Remove the load from the specimen after the last load cycle. Close the valves of the inlet and outlet gages.

10.4 *Vacuum Conditioning*

10.4.1 Open the bypass valve.

10.4.2 Open the vacuum valve and close the bypass valve. Apply a vacuum of 510 ± 25 mm Hg (20 ± 1 in. Hg) for 10 ± 1 min.

10.4.3 Open the bypass valve. Close the vacuum valve.

10.5 *Wetting*

10.5.1 Maintain the temperature of the environmental chamber at 25 ± 0.5°C. Establish the temperature of the distilled water source at 25 ± 3°C. Open the bypass valve.

10.5.2 Select water from the Vacuum-Water-Air valve. Turn on the vacuum valve and adjust the vacuum regulator until a level of 510 ± 25 mm Hg is measured at the specimen outlet gage.

10.5.3 Wait about 1 min or until the distilled water has been drawn into the tubing and the system. Close the bypass valve and allow the distilled water to be pulled through the test specimen for 30 ± 1 min.

10.6 *Coefficient of Permeability For Water Flow*

10.6.1 Set the vacuum level to approximately 40 kPa (5.8 psi) differential pressure by adjusting the vacuum regulator. Record the water flow through the test specimen. Record the pressure differential reading.

10.6.2 Repeat 10.6.1 for three additional pressures. The pressures selected will vary depending on the void content of the specimen being tested. Specimens with low air voids will require higher pressures. The pressures may range from 20 to 40 kPa (3 to 6 psi) differential pressure. A constant interval between the pressures must be selected (e.g. 20, 30, 40, and 50 kPa (3, 4.4, 5.8, and 7.3 psi)). Any range of pressures may be selected that provide measurable flow on the water flow meter and which results in a range of water flows which are within + 10% of the water flow for the 4 pressures selected.

10.6.3 Calculate the coefficient of permeability for water flow as described in 11.5.1 for each pressure. Calculate and report the average result.

10.7 *Water Conditioning*

10.7.1 Conduct water conditioning for either the warm or cold climate conditions as described in 10.7.2 or 10.7.3, respectively. Figure 6 summarizes the procedure described in 10.7.2 and 10.7.3.

10.7.2 *Warm Climate Conditioning*

10.7.2.1 Open the vacuum valve and set the vacuum pressure to 254 ± 25 mm Hg (10 ± 1 in. Hg) at the specimen outlet gage. Set the water flow to 4 ± 1 cm^3/min. Close the bypass valve.

10.7.2.2 Set the temperature of the environmental cabinet to 60 ± 0.5°C for 6 hr ± 5 min. followed by a temperature of 25 ± 0.5° C for at least 2 hours (but not more than 6 hours).

10.7.2.3 Apply an axial compressive load of 90 ± 5 N static (20 ± 1 lbf) and 900 ± 25 N (202 ± 5 lbf) dynamic to the test specimen, in a haversine wave form with a load duration of 0.1 s and a rest period of 0.9 s between load pulses. Continuous application of the load is to occur throughout the hot conditioning period (i.e., 6 hours at 60° C)

Note 6: For open-graded mixes, the loads may need to be reduced to avoid damage to specimen.

10.7.2.4 After 6 h, terminate the load applications.

10.7.2.5 After 8 h or more (no more than 12 hours), close the vacuum valve, open the bypass valve and open the system to atmospheric pressure. Continue to maintain the temperature setting of the environmental chamber at 25 ± 0.5°C. Determine the ECS moduli as described in 10.3.2 to 10.3.6.

10.7.2.6 If excessive deformation (>5%) of the specimen is experienced after a conditioning cycle, terminate further conditioning. Record all information collected as specified in 12.1. Conduct the stripping evaluation as described in 10.8. Note in data recorded that failure of the specimen was encountered during conditioning.

10.7.2.7 Continue to maintain temperature setting of the environmental chamber at 25 ± 0.5°C and determine the coefficient of permeability for water flow as described in 10.6.

10.7.2.8 Apply a second hot conditioning cycle by repeating 10.7.2.1 to 10.7.2.6.

10.7.2.9 Apply a third hot conditioning cycle by repeating 10.7.2.1 to 10.7.2.6.

10.7.3 *Cold Climate Conditioning*

10.7.3.1 Complete the three hot conditioning cycles as described in 10.7.2.

10.7.3.2 Turn the vacuum valve on and set the vacuum pressure to 250 ± 25 mm Hg (10 ± 1 in. Hg) at the outlet gage and set the water flow to 4 ± 1 cm^3/min. Terminate the loads applied. Check that the bypass valve is closed.

10.7.3.3 Set the temperature of the environmental chamber to -18 ± 0.5°C for 6 hours ± 5 min followed by a temperature of 25 ± 0.5°C for at least 2 h (no more than 6 hours).

10.7.3.4 After 8 h or more (not more than 12 hours), close the vacuum valve, open the bypass valve and open the system to atmospheric pressure. Continue to maintain the temperature setting of the environmental chamber at 25 ± 0.5°C. Determine the ECS modulus as described in 10.3.2 to 10.3.6.

10.7.3.5 Continue to maintain the temperature setting of the environmental chamber at 25 ± 0.5°C and determine the coefficient of permeability for water flow as described in 10.6.

10.8 *Stripping and Binder Migration Evaluation*

10.8.1 At the conclusion of the last conditioning cycle, remove the specimen from the environmental chamber. Remove the membrane from the specimen and place the specimen in a diametral position between two bearing plates of a loading jack on a mechanical or hydraulic testing machine.

10.8.2 Apply a load sufficient to induce a vertical crack in the specimen.

10.8.3 Remove the test specimen and pull the two halves apart.

10.8.4 Estimate the percentage of stripping which has occurred by making a relative comparison to the standard patterns of stripping shown in Figure 7.

10.8.5 Estimate the level of binder migration which has occurred by making a relative comparison to the standards shown in Figure 8.

11. CALCULATIONS

11.1 Calculate the following:

11.1.1 *Cross Sectional Area (m^2):*

$$A = \frac{\pi d^2}{40\,000} \qquad (1)$$

where:

d = Average diameter of the test specimen, in cm
π = 3.14159

11.2 After conducting the air permeability testing outlined in 10.2, calculate the following:

11.2.1 *Coefficient of Permeability for Air Flow (cm/s)*

$$k_a = \frac{Q\,H}{\Delta h\,A} \qquad (2)$$

where:

k_a	=	coefficient of permeability for air flow, cm/s
Q	=	flow rate of air at mean pressure across specimen, cm^3/s
H	=	average height of the test specimen, cm
Δh	=	difference in piezometric head across the specimen, cm
A	=	cross sectional area of the specimen, cm^2

Note 7: Equation 2 is only applicable for test specimens which are 102 ± 2 mm in diameter and for air supply testing temperatures which are 25 ± 30°C. It is also only applicable for the units above.

11.3 After applying each of the last five load cycles as specified in 10.3.5, calculate the following:

11.3.1 *Peak Stress (kPa) per load cycle:*

$$\sigma_{i-n} = \left(\frac{V_{i-n}}{A}\right) \qquad (3)$$

where:

V_{i-n} = peak load applied by the vertical actuator over a load cycle, in N
i = number of conditioning cycles applied (i.e. 0, 1,...4)
n = number of load cycles applied (i.e. 1, 2,...5)

11.3.2 *Recoverable Axial Strain (mm/mm) per load cycle:*

$$\epsilon_{i-n} = \frac{\sigma_{ri-n}}{h} \qquad (4)$$

where:

δ_{ri-n}	=	peak recoverable vertical deformation over a load cycle, in mm
h	=	gage length, the distance over which deformations are measured (i.e. distance between yoke rings), in mm

Note 8: The recoverable deformation is the portion of the total deformation that disappears (or is recovered) upon unloading the specimen as shown in Figure 9.

11.3.3 *ECS Modulus (kPa) per load cycle:*

$$M_{i-n} = \left(\frac{\sigma_{i-n}}{\epsilon_{i-n}}\right) \tag{5}$$

11.4 After calculating ECS modulus for the last five load cycles as described in 11.3.5, calculate the following:

11.4.1 *Average ECS Modulus (kPa) per conditioning cycle:*

$$M_{Ai} = \frac{\sum_{n=1}^{5} (M_{i-n})}{\Delta n} \tag{6}$$

where:

Δn = the number of load cycle included in M_{Ai} calculation (for last five load cycles, Δn = 5)

11.5 After conducting the water permeability testing outlined in 10.6, calculate the following:

11.5.1 *Coefficient of Permeability For Water Flow (cm/s):*

$$k_w = \frac{Q\,H}{\Delta h\,A} \tag{7}$$

where:

k_w	=	coefficient of permeability for water flow, cm/s
Q	=	flow rate of water at pressure across specimen, in cm^3/s
H	=	average height of the test specimen, cm
Δh	=	difference in piezometric head across the specimen, cm
A	=	cross sectional area of the specimen, cm^2

Note 9: Equation 7 is only applicable for test specimens which are 102 ± 2 mm in diameter and for water supply testing temperatures which are 25 ± 30°C. It is also only applicable for the units above.

11.6 After completing each conditioning cycle (i), compute the following:

11.6.1 *ECS Modulus Ratio:*

$$MR_i = \left(\frac{M_{Ai}}{M_{A0}}\right) \tag{8}$$

where: M_{A0} = initial ECS modulus, in kPa

12. REPORT

12.1. Report the following information:

12.1.1 *Asphalt Binder Grade*

12.1.2 *Asphalt Binder Content* - in % to the nearest 0.1%

12.1.3 *Aggregate Type and Gradation*

12.1.4 *Mixing and Compaction Conditions* - the following information as applicable:

12.1.4.1 *Plant Mixing Temperature* - in °C to the nearest 1°C
12.1.4.2 *Laboratory Mixing Temperature* - in °C to the nearest 1°C
12.1.4.3 *Laboratory Compaction Temperature* - in °C to the nearest 1°C
12.1.4.4 *Laboratory Compaction Method*
12.1.4.5 *Compacted Specimen Height* - in cm to the nearest 0.10 cm
12.1.4.6 *Compacted Specimen Diameter* - in cm to the nearest 0.10 cm
12.1.4.7 *Compacted Specimen Area* - in m^2 to the nearest 0.0002 m^2
12.1.4.8 *Compacted Specimen Density* - in kg/m^2 to the nearest 1 kg/m^2
12.1.4.9 *Compacted Specimen Air Voids* - in % to the nearest 0.1%

12.1.5 *Coefficient of Permeability for Air Flow* - a table listing of the following results for each differential pressure applied:

12.1.5.1 *Chamber Testing Temperature* - in °C to the nearest 0.5°C
12.1.5.2 *Differential Pressure* - kPa to the nearest 1 kPa
12.1.5.3 *Air Flow* - in cm^3/min to the nearest 2 cm^3/min
12.1.5.4 *Coefficient of Permeability For Air Flow* - in cm/s to the nearest 2 cm/s

12.1.6 *Average Coefficient of Permeability for Air Flow* - in cm/s to the nearest 2 cm/s

12.1.7 *ECS Modulus Results* - a table listing the following results for each load cycle (last five cycles) prior to any conditioning cycles and after each conditioning cycle:

12.1.7.1 *Chamber Testing Temperature* - in °C to the nearest 0.5°C
12.1.7.2 *Static Load Applied* - in N to the nearest 5 N
12.1.7.3 *Dynamic Load Applied* - in N to the nearest 5 N
12.1.7.4 *Peak Stress* - in kPa to the nearest 0.1 kPa
12.1.7.5 *Recoverable Axial Strain* - in mm/mm to the nearest 10^{-6} mm/mm
12.1.7.6 *ECS Modulus* - in kPa to the nearest 5 kPa

12.1.8 *Initial ECS Modulus* - in kPa to the nearest 5 kPa

12.1.9 *Coefficient of Permeability for Water Flow* - a table listing the following results for each differential pressure applied prior to applying any condition cycles and after each conditioning cycle is applied:

12.1.9.1 *Chamber Testing Temperature* - in °C to the nearest 0.5°C
12.1.9.1 *Water Temperature* - in °C to the nearest 0.5°C
12.1.9.2 *Differential Pressure* - in kPa to the nearest 1 kPa
12.1.9.3 *Water Flow* - in cm^3/min to the nearest 2 cm^3/min
12.1.9.4 *Coefficient of Permeability for Water Flow* - in cm/s to the nearest 10^{-4} cm/s

12.1.10 *Initial Average Coefficient of Permeability for Water Flow* - in cm/s to the nearest 10^{-4} cm/s

12.1.11 *Average Coefficient of Permeability for Water Flow after Each Conditioning Cycle Applied* - in cm/s to the nearest 10^{-4} cm/s

12.1.12 *Water Conditioning Results* - a table listing the following results for each conditioning cycle:

12.1.12.1 *Average ECS Modulus* - in kPa to the nearest 5 kPa
12.1.12.2 *ECS Modulus Ratio*

12.1.13 *Stripping Rate* - in percent to the nearest 5 percent
12.1.14 *Binder Migration* - single letter designation

13. PRECISION

13.1 Data to support a precision statement for this test method are not available.

13.2 Since there is no accepted reference value, the bias for this test method cannot be determined.

14. KEYWORDS

14.1 Asphalt concrete, bituminous paving mixtures, water sensitivity, stripping potential, ECS modulus, permeability.

Table 1. Minimum test system requirements

Measurement and Control Parameters	Range	Resolution	Accuracy
Load (compression)	0 to 4400 N	≤ 0.5%	± 1%
Axial Deformation	0 to 6.35 mm	≤ 0.0001 mm	± 0.0001 mm
Chamber Temperature	-20 to +100°C	≤ 0.5°C	± 0.5°C
Vacuum Pressure	0 to 635 mm Hg	≤ 25 mm Hg	± 25 mm Hg
Air Flow	20 to 20 000 cm^3/min	≤ 5%	± 3%
Water Flow	0 to 2525 cm^3/min	≤ 2 cm^3/min	± 1 cm^3/min
Water Reserve Temperature	25 ± 3°C	≤ 0.5°C	± 0.5°C

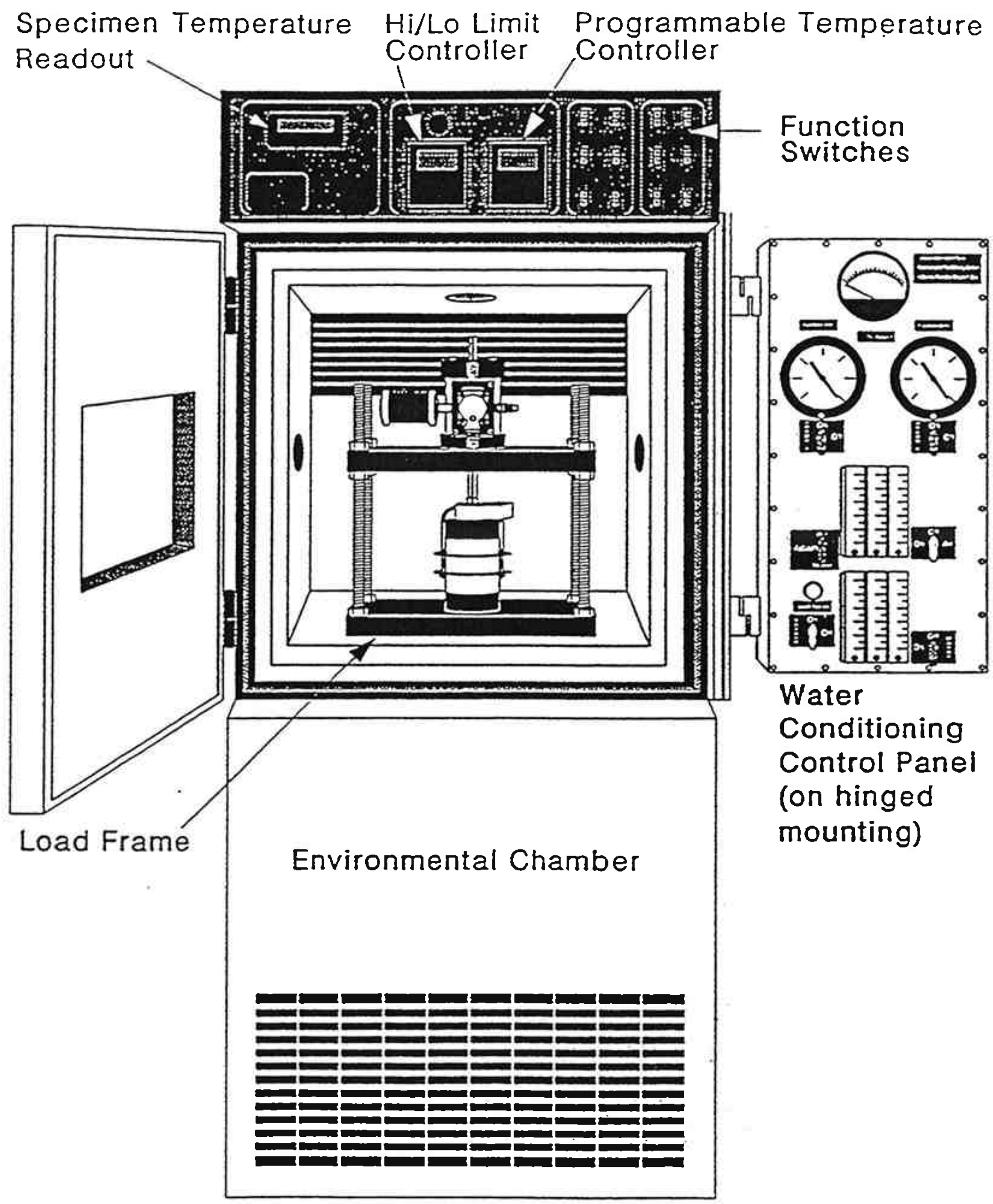

Figure 1. Environmental conditioning system (front view)

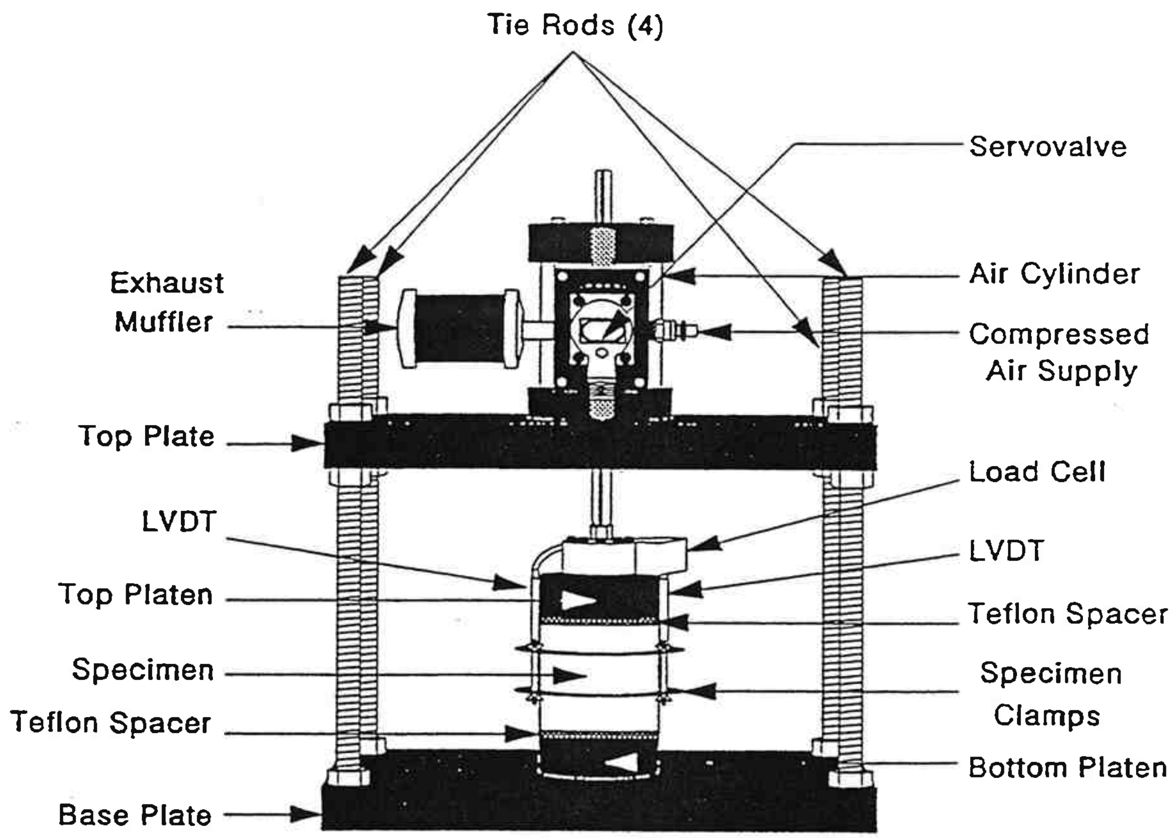

Figure 2. Load frame with specimen

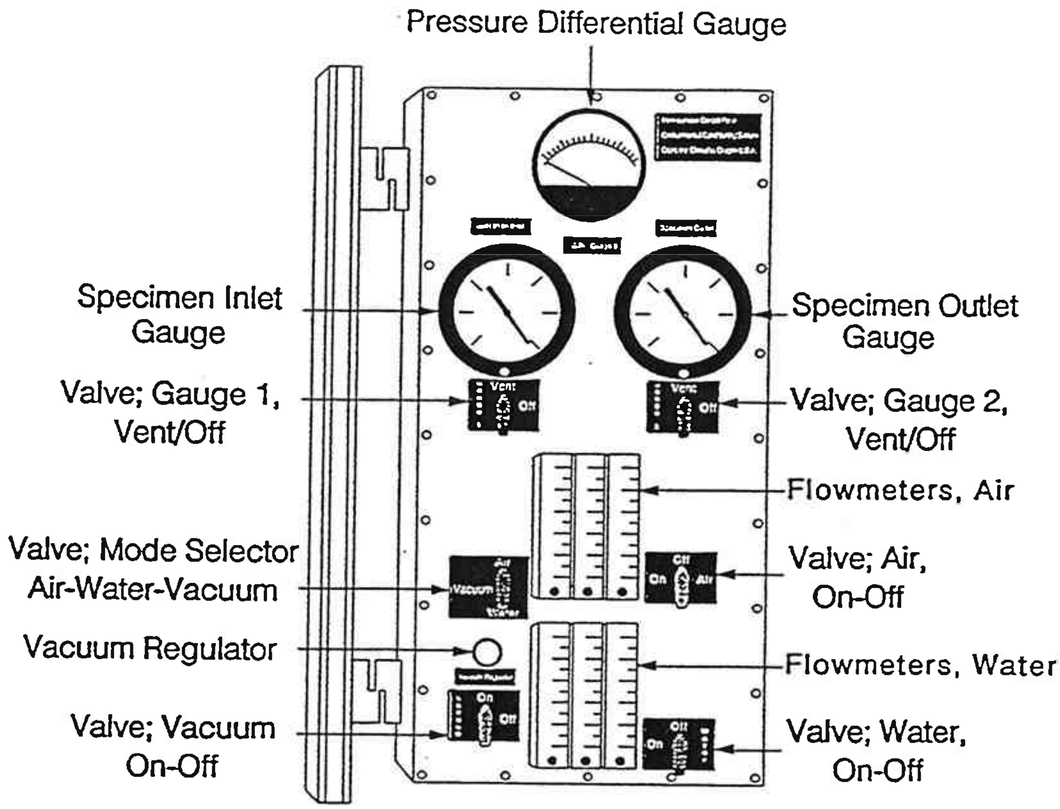

Figure 3. Control panel

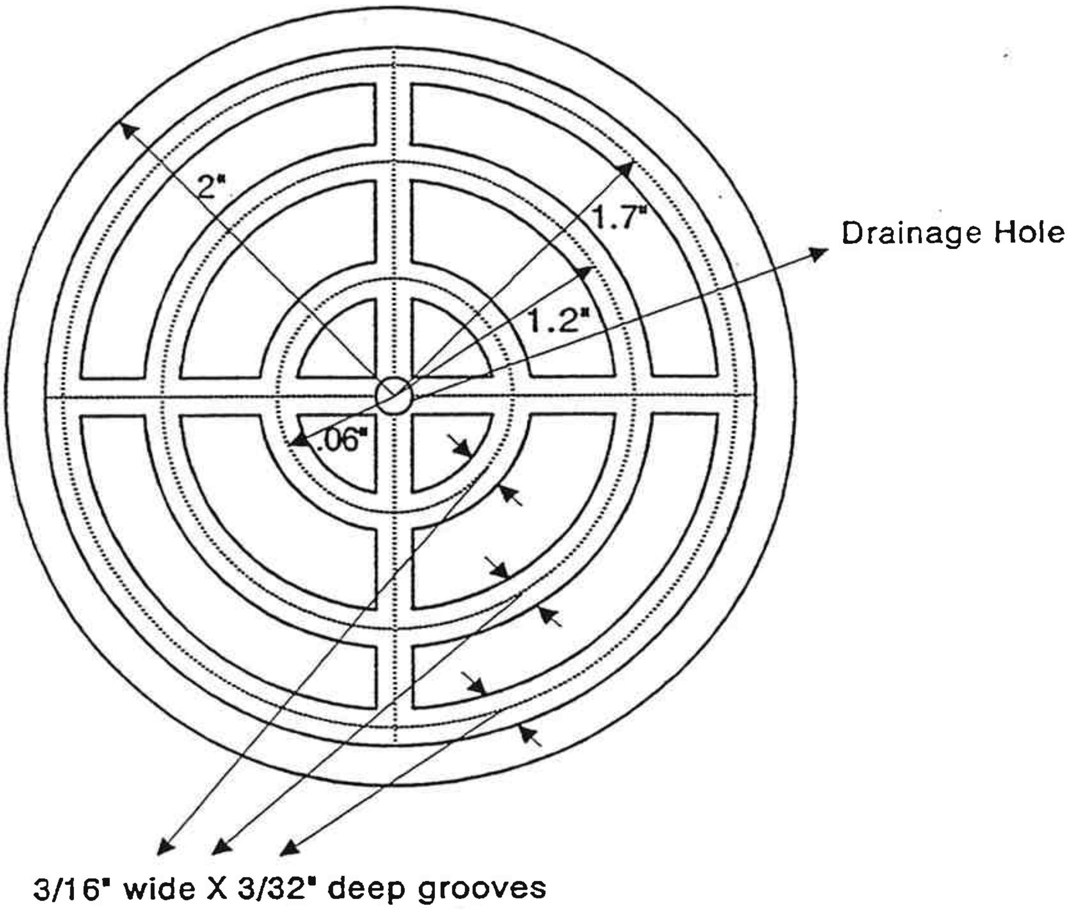

Figure 4. Groove pattern for end platens

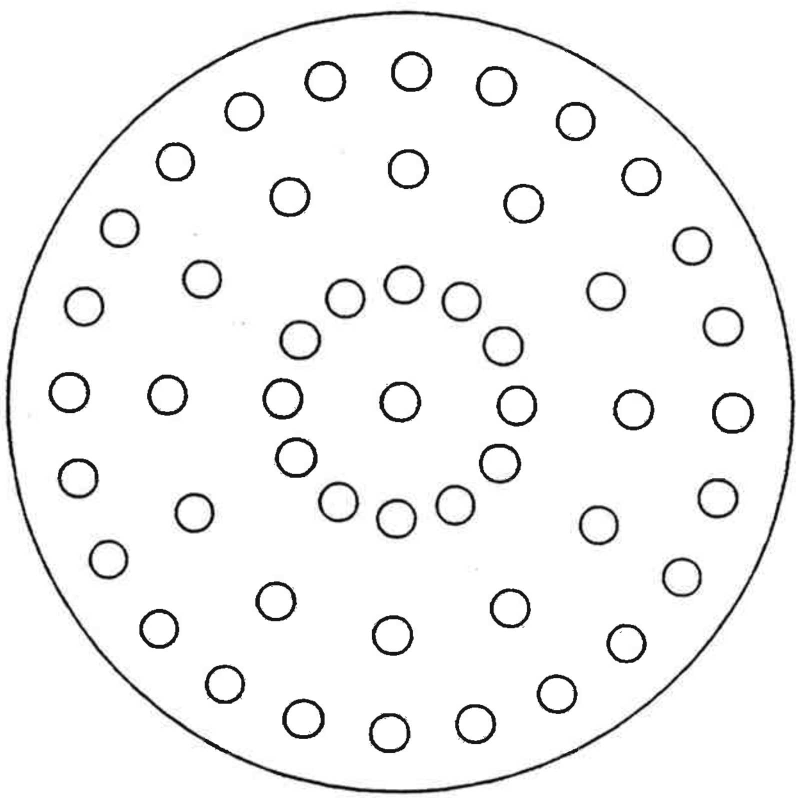

Figure 5. Perforated teflon spacers

CONDITIONING FACTOR	WETTING *	CONDITIONING STAGE			
		CYCLE-1	CYCLE-2	CYCLE-3	CYCLE-4
Vacuum Level (mm. Hg):	510	250	250	250	250
Repeated Loading	NO	YES	YES	YES	NO
Ambient Temp. (C) **	25	60	60	60	-18
Duration (hr.)	0.5	6	6	6	6

Conditioning Procedure for Warm Climate (Wetting through Cycle-3)

Conditioning Procedure for Cold Climate (Wetting through Cycle-4)

* WETTING: Wetting the specimen prior to the conditioning cycles

** Inside the Environmental Cabinet

Notes:

1. The conditioning procedure for a warm climate is wet then 3 hot cycles
2. The conditioning procedure for a cold climate is wet then 3 hot cycles plus one cold cycle

Figure 6. Conditioning cycles for warm and cold climates

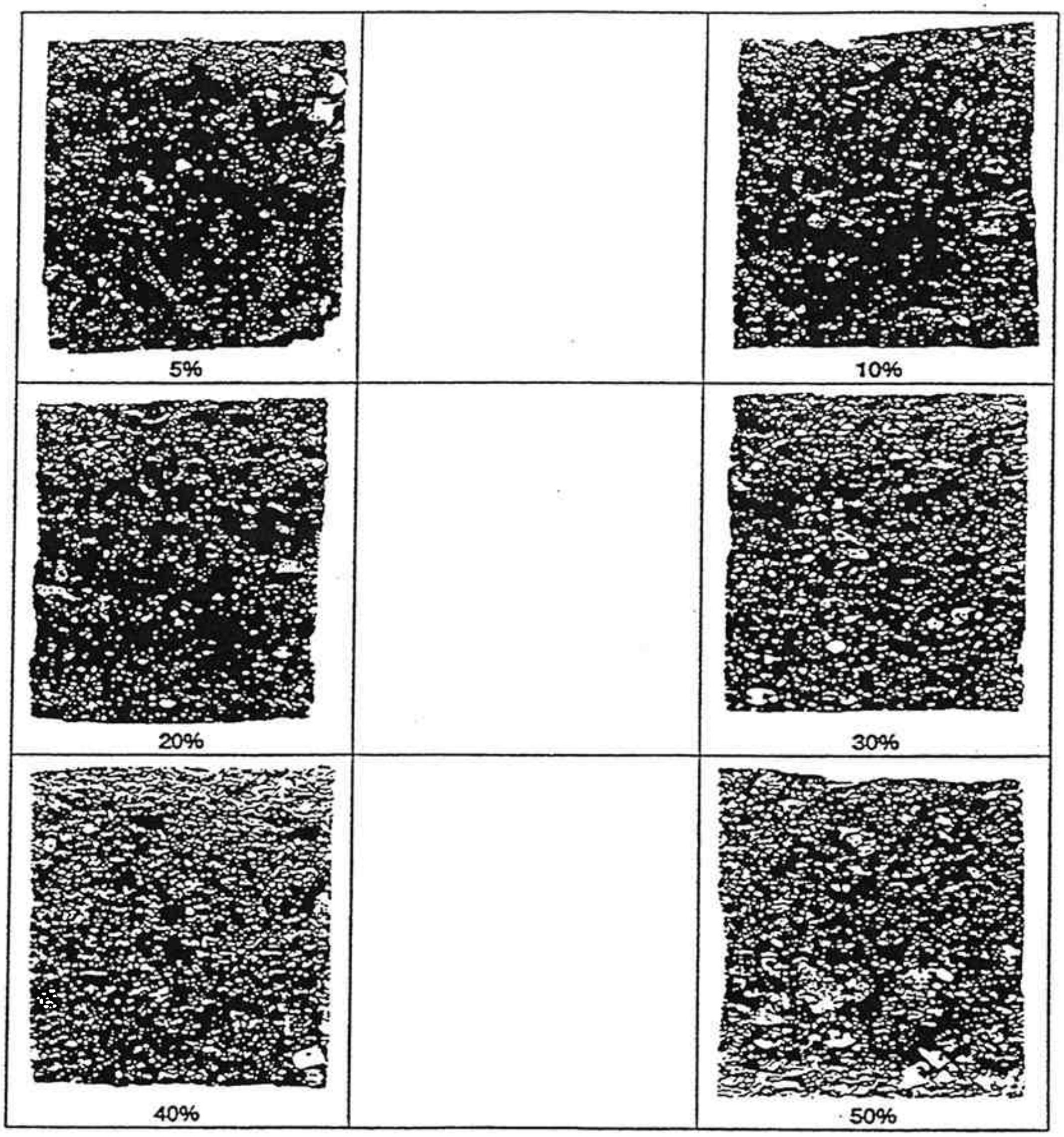

Figure 7. Stripping rate standards

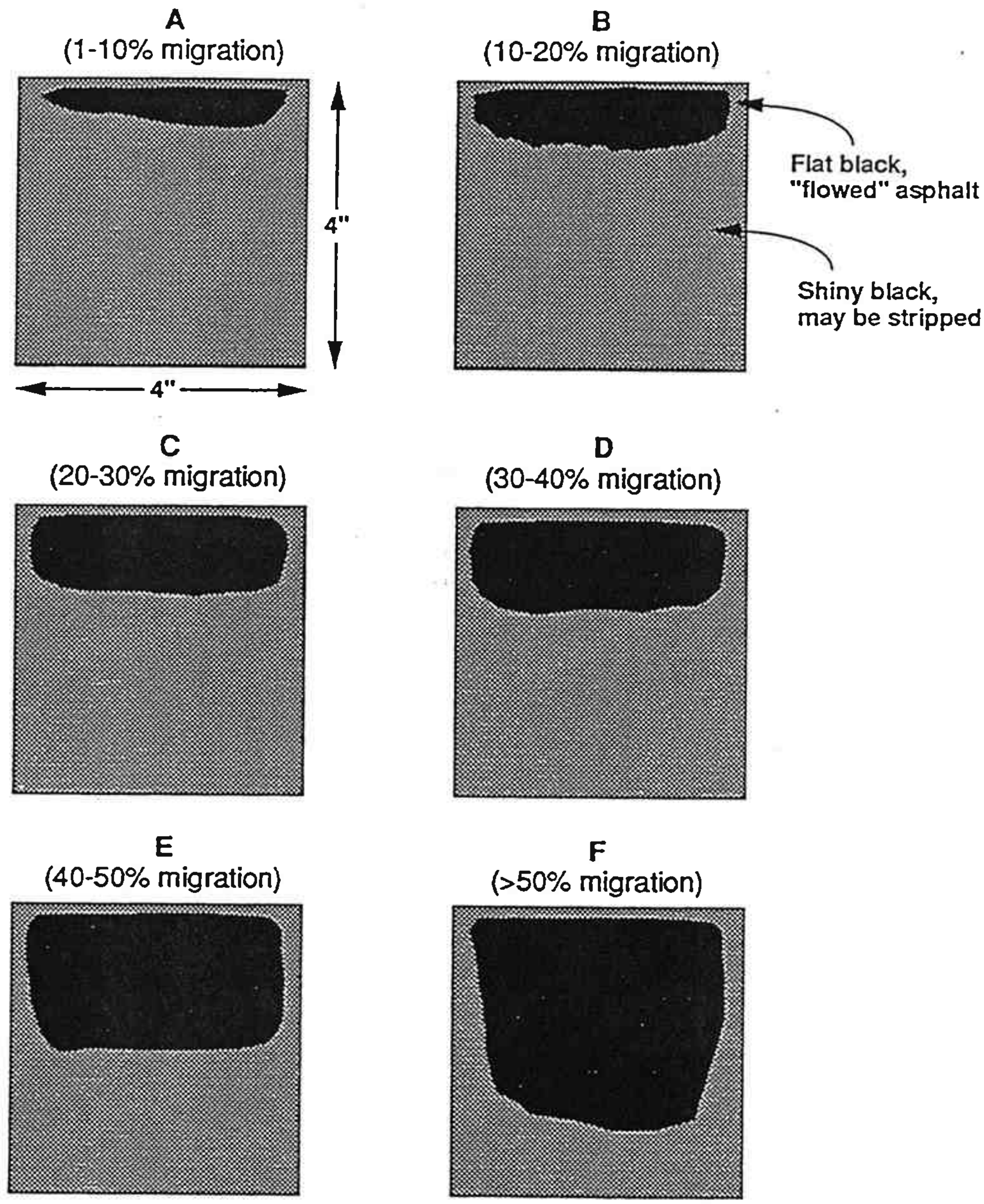

Figure 8. Binder migration standards

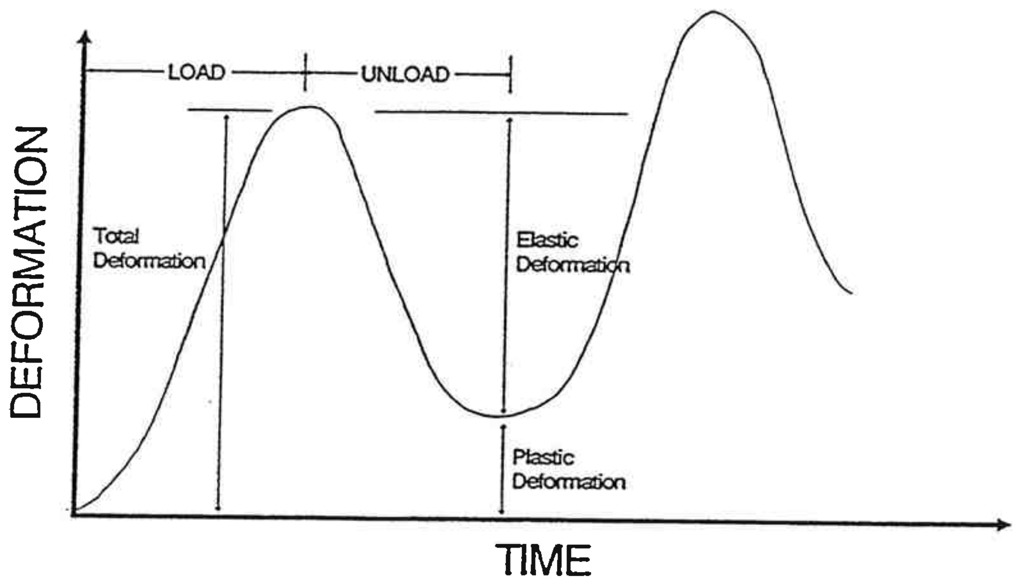

Figure 9. Illustration of specimen deformation resulting from application of load