AN ABSTRACT OF THE THESIS OF

Krey D. Younger for the degree of Master of Science in Civil Engineering presented on November 8, 1994. Title: Evaluation of Porous Pavements Used in Oregon

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Abstract approved: ______________________________
R. Gary Hicks

Porous pavements or open-graded asphalt mixtures have been in use in Oregon since the late 1960's. The use of this pavement type has increased over the years because the pores in the mat provide an efficient way for water to drain from the pavement surface. This greatly increases safety in the areas of skid resistance and splash and spray. An added benefit from these pavements is that tire noise is partly absorbed by the voids of the pavement.

The purpose of this study was to evaluate porous pavements, especially the F-mix, as they are used in Oregon. The input from inside (i.e., contractors, ODOT personnel, asphalt experts) and outside (i.e., literature published over the years from agencies in the U.S. and abroad) Oregon was to study open-graded uses. This information was then used for improving porous pavements in Oregon.

Laboratory and field studies were performed on Oregon's open-graded mixtures. These tests were designed to understand how the mixture types performed with Oregon's conditions and mixture types. These tests included texture depth, permeability, accident analysis, friction testing, rutting, splash and spray, noise, core gradation, asphalt properties, and tack coat shear testing.

A number of findings resulted from this study. Porous pavements provide a 1-2 dB A-weighted roadside noise improvement when compared to B-mix pavements, a 2-4 dB(A) improvement in the 500 - 4000 Hz range, splash and spray visibility is improved, and safety on the roadway is improved. Potential problems with porous pavements include post-construction skid resistance, construction difficulties, and clogging of the pavement mat. Suggestions have been made in this study on solving these problems and increasing the benefits.

Evaluation of Porous Pavements Used In Oregon

by

Krey D. Younger

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Krey D. Younger, Author

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EVALUATION OF POROUS PAVEMENTS USED IN OREGON

1.0 INTRODUCTION

1.1 Background

Oregon began experimenting with an open-graded-type asphalt concrete in the 1930's. Early tests showed high skid resistance and decreased glare from headlights. Due to the noticed advantages, this pavement type developed into the plant-mix seal coat that saw substantial use by Western states in the late 1940's and 1950's (Copas et al., 1978). The late 1970's saw the change in open-graded mixtures that started Oregon toward the designation of their E- and F-mixes (Huddleston et al., 1993).

These mixtures were originally developed as a friction coarse, but they have also proven to reduce noise, splash and spray, and rutting. These benefits, along with some problems such as reduced durability and increased winter maintenance, have made it necessary to improve the quality of the mixes used in porous pavements. To facilitate this improvement, there is a need to quantify the improved safety as well as monitor the change in mixture properties (e.g. permeability, voids, etc.) over time. Finally, there is a need to evaluate the feasibility of placing porous pavements on both old and new portland cement concrete.

1.2 Project Objectives

The overall objective of this study is to develop improved guidelines for use of porous pavements in Oregon. Specific objectives are as follows:

1) Documentation of the advantages and disadvantages of porous pavements in the areas of safety, environmental, and performance;
2) Evaluation of mix properties over time (e.g. permeability/voids, surface friction, splash and spray, noise);
3) Recommendation of modifications to existing specifications as needed (e.g. moisture content, IRS, ECS, etc.); and
4) Development of guidelines for considering environment, pavement type and traffic, as well as for long-term maintenance of porous pavements.

1.3 Organization of Report

The study consisted of the following six tasks:

Task 1: Literature Review/Questionnaire Survey

The results of the literature review and the questionnaire survey are given in a separate report (Younger et al., 1994). Chapter 2 of this report summarizes those findings, plus new findings since January 1994.

Task 2: Field Evaluation of Porous Pavements Used in Oregon

The field evaluation portion of this project is discussed in Chapter 3 of this report. The field evaluation covered topics such as texture depth, permeability, splash and spray, accident surveys, and friction testing.

Additional testing included an evaluation of the noise properties of porous pavements as compared to dense-graded pavement types and portland cement concrete (PCC) pavements. These are presented in Chapter 5.

Task 3: Laboratory Evaluation

The laboratory evaluation for this project was performed on field cores taken from the field evaluation sites. The cores were tested for permeability, moisture sensitivity using the Environment Conditioning System (ECS), gradation, and asphalt properties. Chapter 4 discusses these results.

Task 4: Analysis of Data

Data analysis is discussed throughout the report. A summary of all findings is presented in Chapter 6.

Task 5: Field Study

An F-mix pavement was placed over a PCC pavement on Interstate 5 just north of Grants Pass, Oregon, under the Oregon Department of Transportation (ODOT) project name of Azalea to Jumpoff Joe. This portion of the Azalea to Jumpoff Joe project was completed in September of 1994. The overlay was completed without major problems, but long term study of the project is impossible for this paper. Teh tack coat shear study and Appendix D have sections pertaining to this task.

Task 6: Reports

The literature review/questionnaire survey contained in the interim report (Younger et al., 1994) and this report complete this task. This report is the culmination of all of the research completed in this project.

2.0 LITERATURE REVIEW AND QUESTIONNAIRE SURVEY

A literature review and questionnaire survey were completed as a separate report (Younger et al., 1994). The literature review consisted of an evaluation of information in both the United States and abroad.

The questionnaire was a survey of the porous pavement users in Oregon. The three survey groups were the ODOT project managers, the ODOT district maintenance managers, and asphalt contractors in Oregon.

2.1 History of Use

2.1.1 Oregon

Oregon began serious use of F-mix pavements in the late 1970's (Huddleston et. al., 1993). The success of these projects has made this pavement type popular with ODOT. Currently, Oregon has placed approximately 1820 (2930 km) center-line miles of F-mix along its highway system. F-mixes are a popular pavement surface along Oregon's Interstate system. (Appendix A provides a complete listing of all Oregon F-mix jobs.)

Table 2.1 compares the broadband limit gradation for the Oregon F-mix with a number of open-graded pavement types used elsewhere. These are also compared to Oregon's dense-graded B-mix gradation and the Oregon open-graded emulsion mix (OGEM) gradation. The table shows the higher percent of larger aggregate used for open graded mixtures.

The Oregon F-mix void contents and placement depth seem to match most closely those techniques used in European countries (Smith, 1992). The 15 to 20% void content

Table 2.1. Broadband limit gradations

Oregon Mixtures

Sieve Size	ODOT B-mix (ODOT, 1991)	ODOT E-mix (ODOT, 1991)	ODOT F-mix (ODOT, 1991)	ODOT OGEM (ODOT, 1991)
1 in (25 mm)	99-100	–	99-100	–
3/4 in (19 mm)	92-100	99-100	85-96	95-100
1/2 in (13 mm)	75-91	90-98	55-71	70-90
1/4 in (6 mm)	50-70	25-40	15-30	15-43
No. 10 (2 mm)	21-41	2-12	5-15	–
No. 40 (1 mm)	6-24	–	–	0-7
No. 200 (0.075 mm)	2-6	1-5	1-6	0-2

Open-Graded Asphalt Mixtures Used Elsewhere

Sieve Size	FHWA (Proposed)	United Kingdom (1993)	Australia (Booth et al., 1991)	France (1991)	Spain (Ruiz et al., 1990)
1 in (25 mm)	100	–	–	–	–
3/4 in (19 mm)	86-96	100	–	–	100
1/2 in (13 mm)	60-70	55-75	100	100	75-100
1/4 in (6 mm)	10-20	20-30	29	10	32-50
No. 10 (2 mm)	4-10	7-13	10	10	10-22
No. 40 (1 mm)	–	–	–	–	5-12
No. 200 (0.075 mm)	0-4	3.5-5.5	0-4	0-5	3-6

and 2 in (50 cm) placement depth seem to provide the best characteristics for splash and spray and noise reduction, while still maintaining strength and usefulness.

ODOT's F and B-mixes cost about $3.30 and $2.38 respectively for a 2 in (50 mm) thick square yard section. F-mixes are more expensive to produce, but considering that B-mixes are normally placed in thicknesses exceeding 3 in (76mm), F-mixes are less expensive on a per square yard basis.

2.1.2 Other States

Porous pavements evolved from the early efforts to improve pavement friction through the application of uniformly graded aggregate of about one-half inch nominal size, over a layer of asphalt concrete (Smith, 1992). This treatment first became known as the plant mix seal coat. These mixes posed a problem due to the aggregate coming loose from the pavement surface. Agencies then began developing a pavement to reduce the problems by increasing the asphalt content and changing the gradation to include some smaller sized aggregate. Through trial and error methods, the present open-graded friction course (OGFC) was developed, and there are still many different mixture design methods.

A 1991 study in Arizona (Hossain et al, 1991) was performed to analyze the use of a full-depth open graded pavement. This pavement was not the normal partial-depth design, where the water drains laterally through the voids, but a pavement designed for the water to drain vertically down through the pavement structure. The pavement was designed in such a manner as to allow the water to drain for a 10 year 24 hour storm.

2.1.3 Overseas (Europe, S. Africa)

European countries including Belgium, France, Italy, Netherlands, Spain, Switzerland, and United Kingdom frequently use porous pavements as a surface course (Smith, 1990). Usage of this mixture type has even ranged as far away as South Africa. These countries normally use a mix of more than 20 percent air voids and 40mm to 50mm (1.5 to 2 in). These mixes are generally of a void content and thickness greater than used in most US states, excepting Oregon. Reports of use in these countries are favorable, and use is continues. A main reason for this is the noise-reducing properties of porous pavements.

2.2 Advantages

A summary of the porous pavement mixture benefits, which have resulted in widespread use in Oregon, is presented in Table 2.2. Open-graded mixes seem to have a number of advantages that make it a viable mixture option. One of the main advantages of open-graded mixtures is improved safety. This improvement comes in a number of areas: decreased highway glare, improved skid resistance, reduced noise, reduced splash and spray, and reduced hydroplaning potential (Smith, 1992).

Skid resistance on open-graded mixes is most beneficial under rainy conditions. Porous mixes seem to maintain their friction properties during wet conditions and at higher speeds better than other mix types. An interesting example of improved skid resistance on Oregon highways is shown in Figure 2.1 (Huddleston et al., 1993). The only disconcerting thing about the skid resistance of porous pavements is that problems have been reported for newly constructed pavements (Booth, 1991). A good example of this

Table 2.2. Advantages of porous pavements

Advantage	Benefits	Sources of Information
Skid Resistance	In rainy pavement situations, high speed skid resistance is retained more than dense mixes.	Huddleston et al., 1993; Booth, 1992; Isenring et al., 1993
Splash and Spray	Reduced visibility reduction from tire spray.	Nelson et al., 1990
Noise Reduction	Reduced pavement noise.	Copas et al., 1978; Horak et al., 1994; Polcak, 1990; Nelson et. al., 1990
Hydroplaning	Chance of hydroplaning is reduced because water does not stay on surface.	Copas et al., 1978; Isenring et al., 1990
Rutting	High aggregate interlock reduces rutting potential.	Smith, 1992
Glare Reduction	Night time pavement glare is reduced for improved safety.	Huddleston et al., 1993; Colwill et al., 1993

phenomena is presented in Figure 2.2 (ODOT, 1993). This study, by ODOT, seems to show that the friction numbers for F-mixes, are lower than B-mixes of the same age. This phenomena was also studied in the Netherlands, due to a fatal accident (Deuss, 1994). The results of this latter study presented a 25 to 30% decrease in skid resistance on new porous mixes as compared to new dense mixes.

A study performed in the United Kingdom (UK) by the Transportation Road Research Laboratory (TRRL) quantified the splash and spray characteristics of porous pavements (Nelson, 1990). TRRL developed an electronic device which measures light backscatter from a laser source in which spray was measured as a voltage received from the detector. Open-graded friction course (OGFC) was shown to provide a significant reduction in water spray.

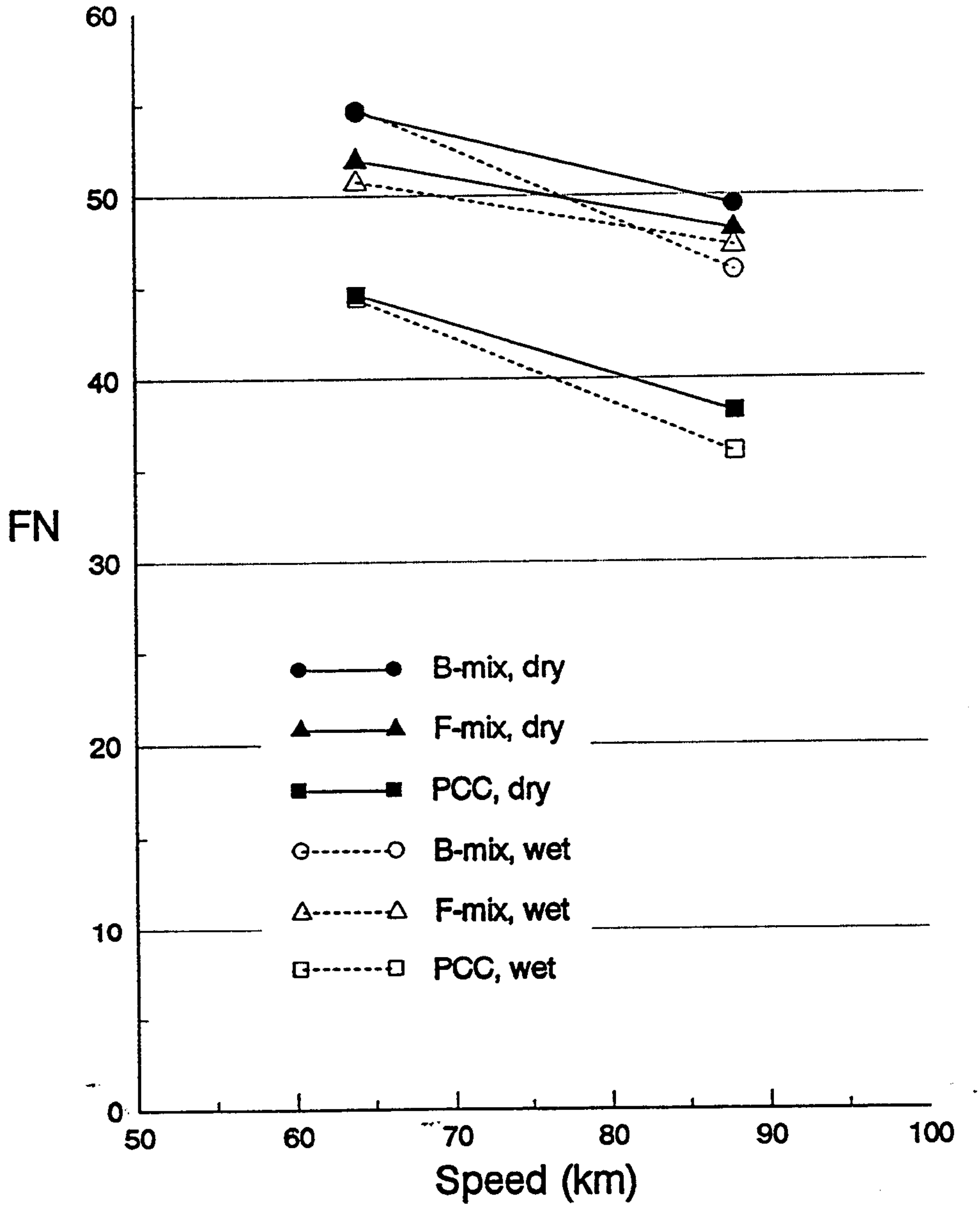


Figure 2.1. Effect of speed on frictional values (after Huddleston, 1993)

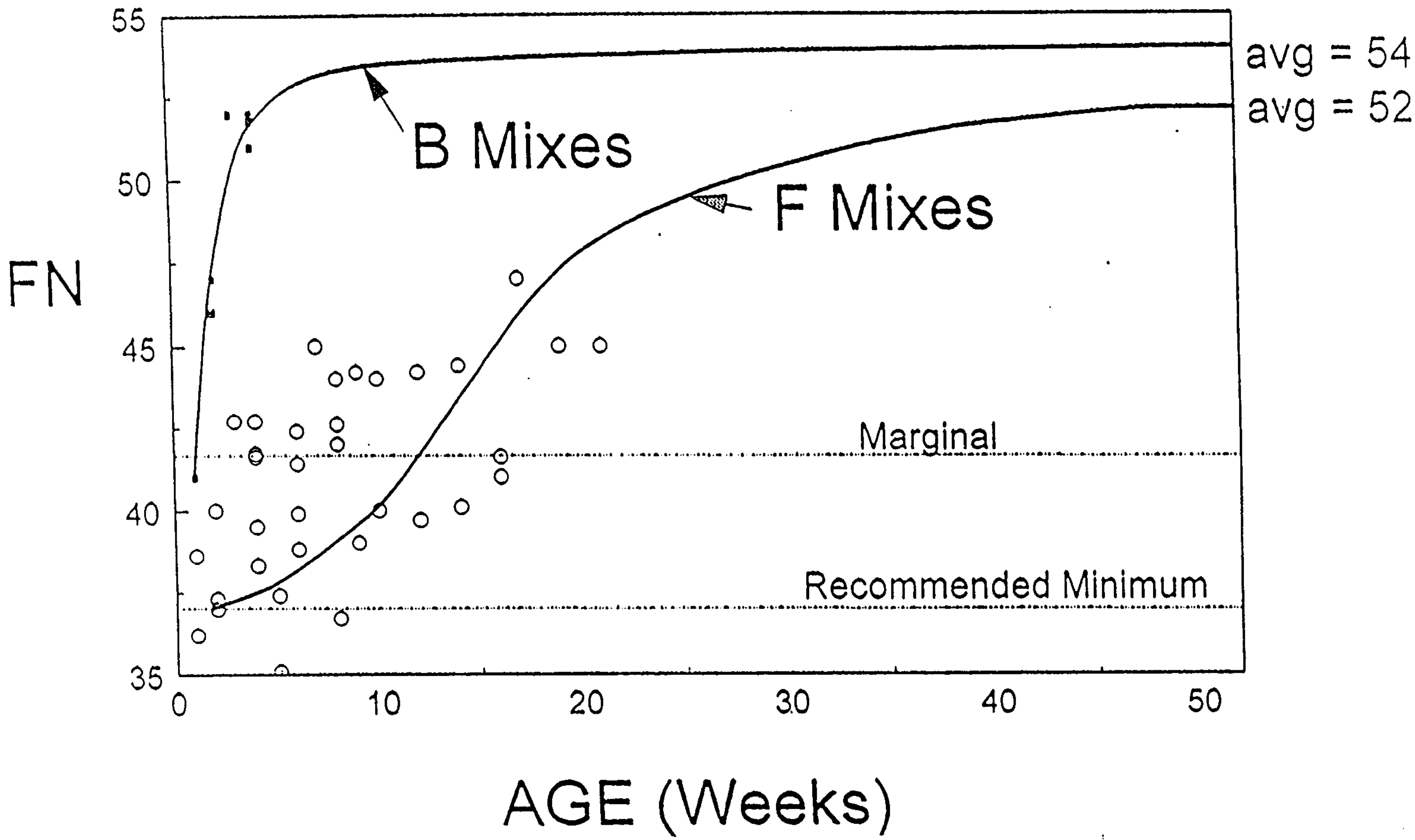


Figure 2.2 Frictional testing of newly constructed mixes (after ODOT, 1993)

The other safety benefits, reduced hydroplaning and potential glare reduction, have also been factors in the increased usage of OGFC. A glare reduction example was illustrated in the NCHRP Synthesis 180 (Smith, 1992). A photo demonstrated how glare reduction changes at a juncture of porous to dense-graded mixtures. As for hydroplaning benefits, porous mixtures work better because the excess water is allowed to drain through the pores, and not run across the pavement surface (Copas et al., 1978).

Another important advantage of porous pavements is from an environmental view. Noise levels of porous pavements have been reported to be somewhat lower than that of dense-graded pavements or PCC. Rolling tire noise on pavements is generated when the individual elements of the tire tread come into contact with the road surface. When the tire leaves the pavement surface, a "pumping" effect causes the noise (Jorgan, 1994). The porous structure of open-graded mixtures allows some of this air to be pumped into the voids, instead of off of the pavement surface, and thus decreases noise. The actual A-weighted sound levels seem to be lowered by around 0 to 6 dB(A) (Smith, 1991). The public have voiced an opinion that porous pavements seem to provide a quieter ride both inside and outside the vehicle, but sound experts say that the human ear can only detect a 3 dB(A) change in sound levels (Huddleston et al., 1992). A study by the Maryland State Highway Administration also looked into this difference by checking the 1/3 octave levels of the sound spectrum (Polcak, 1990). Figure 2.3 displays how the upper range frequencies improve with the use of porous pavements. As the upper range of frequencies are considered "harsher" to the human ear, this graph shows a significant improvement.

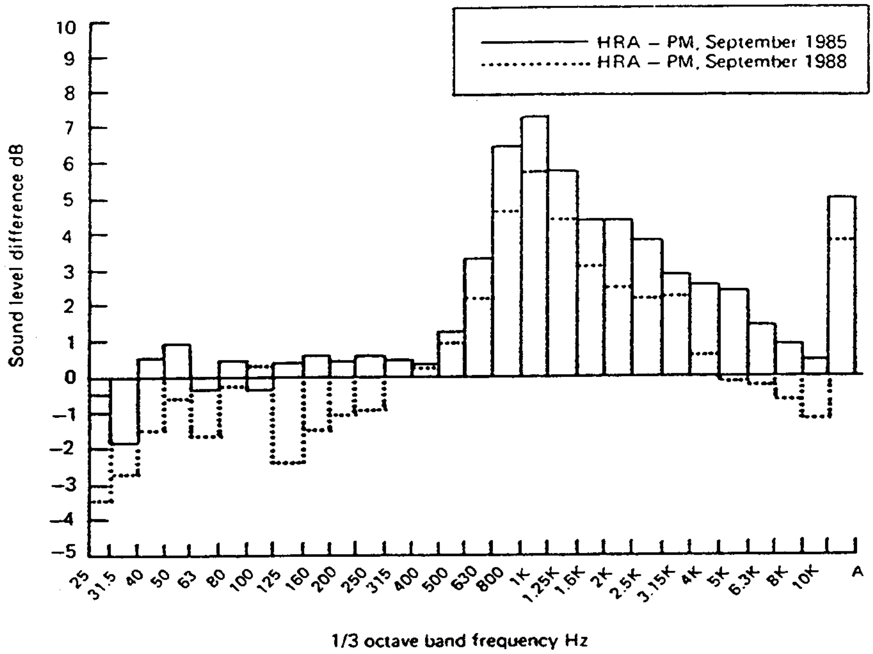


Figure 2.3. Comparison of the 1/3 octave band for porous asphalt and concrete (after Polcak, 1990)

Table 2.3. Limitations/disadvantages of porous pavements

Limitations	Sources of Problems	Sources of Information
Construction	Hand work, draindown, feathering	Younger et al., 1993
Winter Performance	Loss of de-icer in pores, snowplow damage, sand clogging pores	Camomilla et al., 1990; Smith, 1992; Huddleston et al., 1993
Oxidation	Oxidation of binder results in raveling	Smith, 1992
Patching	Small quantities of F-mix rarely made, so patches of dense mix restrict flow (unless an open graded cold mix is used)	Smith, 1992

One other benefit of porous pavements are their rutting resistance. The high aggregate interlock of porous mixes allow this pavement type to resist deformation for longer periods of time (Huddleston et al., 1992).

2.3 Limitations

Based on the literature review and the questionnaire survey, several limitations (or disadvantages) of porous pavements were also identified. They are summarized in Table 2.3 and each are discussed in detail below.

Limitations for F-mixes were identified during the survey of contractors and ODOT project managers (Younger et al., 1994). Problems have been experienced with porous mix construction, particularly in the area of placement. The lack of fine particles in the mix make it difficult to feather a mix to meet the adjacent pavement grade. Any handwork provides challenges, as porous mixtures do not rake very well. Hauling of porous mixtures can sometimes be a problem, as the high asphalt contents will often drain down to the bottom of the mixture, causing fat spots in the pavement mat.

Another reported problem with porous mixtures is that of winter performance. The rough macrotexture of porous pavements can result in aggregate pickout by snowplows (Huddleston et al., 1993). The increased voids have also been shown to cause problems with deicing chemicals, as they flow through the pores of the pavement faster, and sometimes require as much as three times the amount of chemicals to be effective (Camomilla et al., 1990). This is not a general consensus, as the survey conducted by Smith (1992) found that 12 agencies indicated no difference, eight indicated that it was less effective, and two even said that de-icing chemicals on porous pavements were more effective. The use of winter sand for increasing friction on porous mixtures has been shown to clog the pavement and decrease the effectiveness of the void structure.

There are other reported problems with using porous mixtures. One is that porous mixtures have increased problems with oxidation (Smith, 1992). The open nature of this mix type causes the asphalt cement to oxidize more rapidly than normal, resulting in raveling. This is not a great problem today, due to the thicker asphalt film obtained in porous mixes with modified binders.

Another limitation is in patching of open-graded mixtures. Since porous mixes drain laterally, it is not viable to patch large portions of problem open-graded areas with a dense graded mix. Open-graded mixes are not normally mixed at the plant in small, patching sized batches, since the mixing and compacting temperatures are different from a dense mix. If batching plants would agree to make small batches of open-graded hot mix patching would be a lesser problem. An option would be to use an open-graded emulsion mixture for patching.

2.4 Summary

The questionnaire survey results suggest several problems that can exist during the construction of F-mix pavements (Younger et al., 1994). However, there are a number of techniques presently being used to work around these problems. Through the sharing of these techniques, the qualities of the F-mix pavements throughout Oregon are improving every year.

The significant advantages of porous pavements still seem to outweigh the disadvantages, and until it is proved otherwise, ODOT continues to place F-mix pavements throughout Oregon.

3.0 FIELD EVALUATION

The field evaluation study was designed to provide insight into how porous pavements perform under road conditions. Tests were conducted to measure texture depth, permeability, noise levels, and the splash and spray characteristics of the pavement surface. Also, accident records were analyzed to determine whether or not porous pavements have any effect on increasing the safety at a new location.

3.1 Projects Evaluated

A selection of projects around Oregon were chosen as a part of our study of porous pavements. These are shown in Table 3.1 and in Figure 3.1.

These sites were chosen to provide a mixture of environmental regions with varying traffic and pavement age. Time effects could be quantified over a shorter period of time with a range of pavement ages. Of course, the pavement sites differ in weather/traffic/layout which affects the analysis. But with the number of sites evaluated, a general idea of how F-mixes perform under varying circumstances could be developed.

3.2 Evaluation Methods

Various test methods were employed in the field evaluation effort. Each is described below.

3.2.1 Texture Depth

Texture depth was measured using the sand patch method (Texas DOT, 1972). The sand patch method consists of spreading a known quantity of sand in a circle on the

Table 3.1. Porous pavement projects

Map No.	Project Name (F-mix unless stated otherwise)	Mile Points	ADT (1992)	Construc tion Date
1	Marquam Bridge to N. Tigard Interchange (I-5)	291.8 - 300.4	90983	1991
2	Hayesville to BattleCreek (I-5)	249.5 - 259.1	53750	1990
3	Azalea to Jump Off Joe (I-5)	67.0 - 90.2	15506	1994
4	Jump Off Joe to N. Grants Pass (I-5)	67.1 - 58.2	22500	1992
5	Murphy Road to Lava Butte (U.S. 97)	141.5 - 150.8	21750	1989
6	E. Pendleton to Emigrant Hill (I-84)	213.0 - 217.7	8550	1993
7	Oregon 138 near Diamond Lake (OGEM)	N/A	N/A	1976

pavement surface. The texture depth is a function of the sand circle radius placed on the pavement (see Figure 3.2).

Use of this method proved to be a problem at some of the newer sites because the sand dropped into the pores of the pavement. When this happens, the only statistically viable data from the measurement is that the pavement pores are highly open as this caused the texture depth to appear deeper than actual.

Another limitation of this test is that the pavement surface must be dry in order to perform the test. Because of this the I-84 (E. Pendleton - Emigrant Hill) site was not tested in 1993. This site could easily be tested at a future time, when the pavement surface is dry.

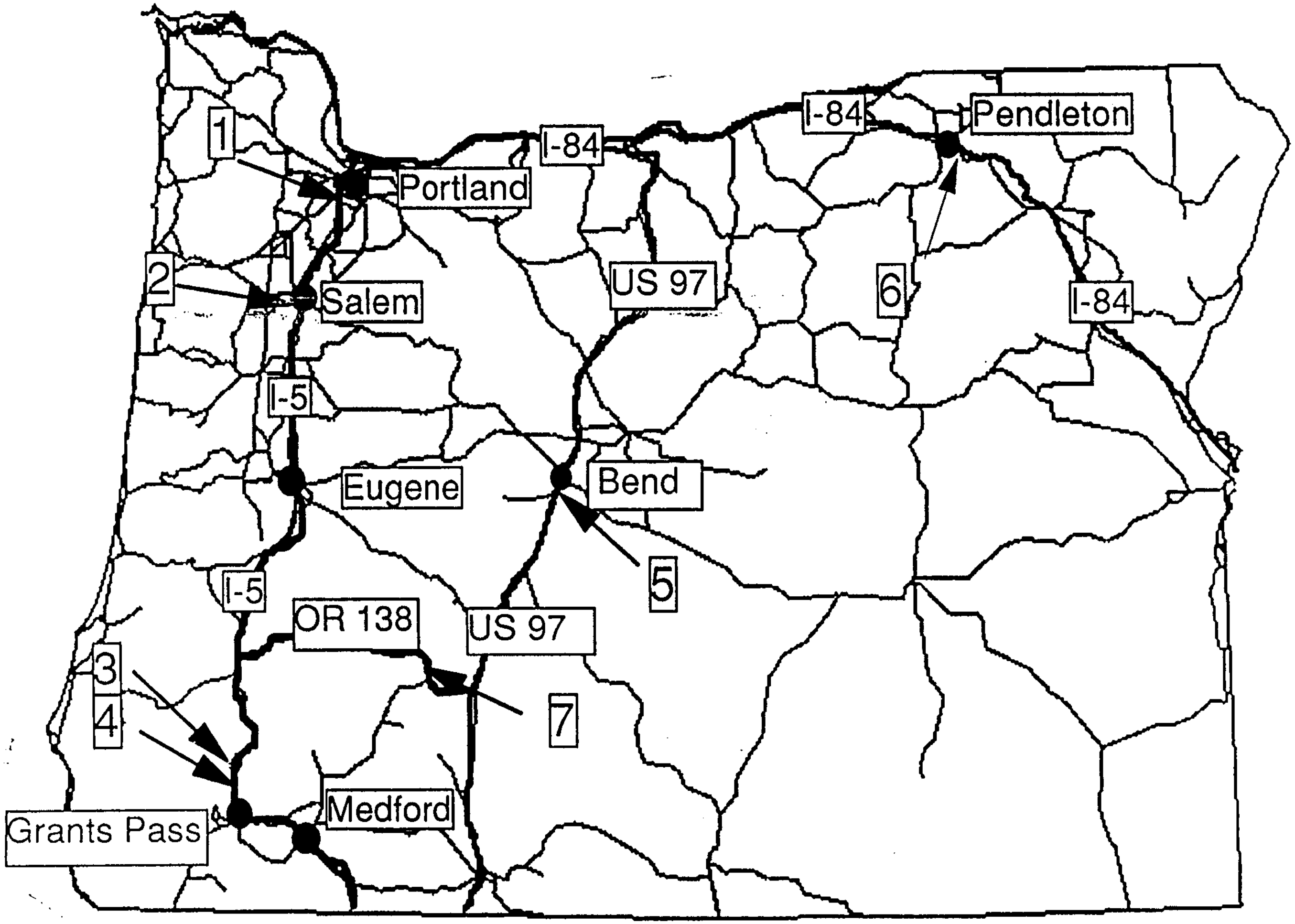


Figure 3.1. Oregon project site locations

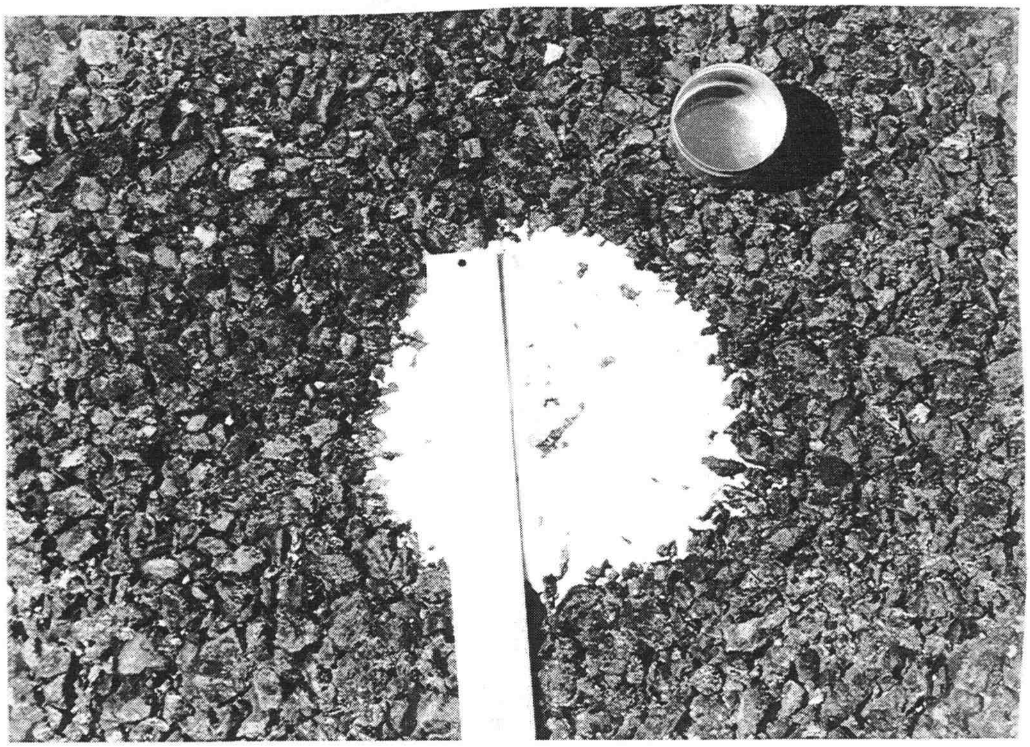


Figure 3.2. Texture depth measurement device

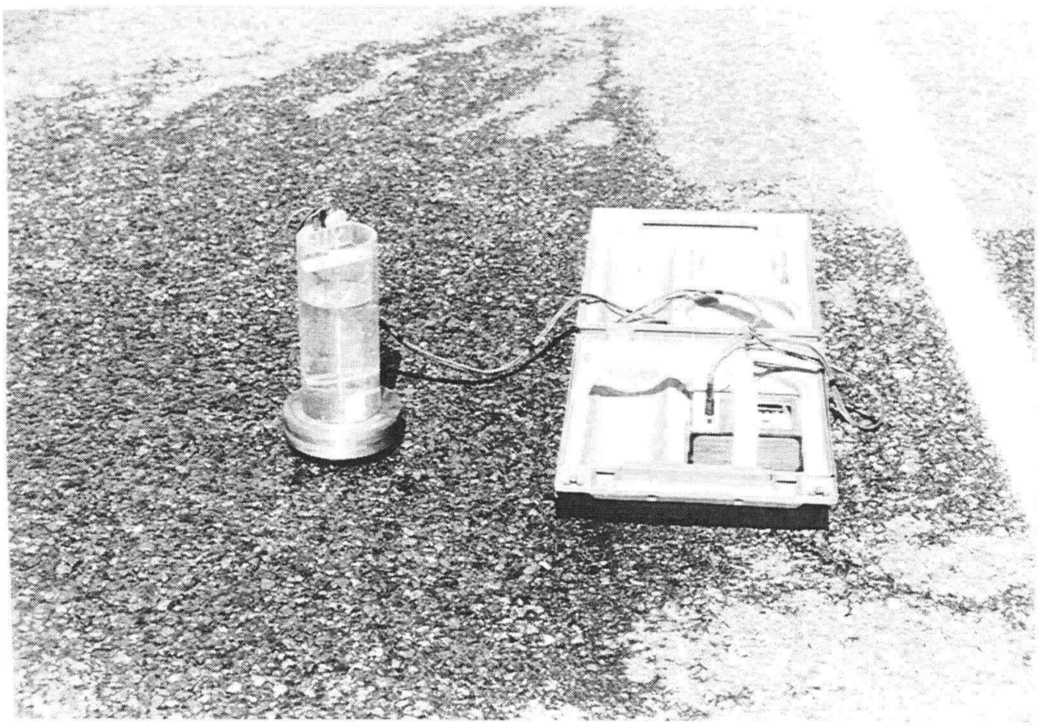


Figure 3.3. Permeability measuring device

3.2.2 Water Permeability

All test sections were evaluated for water permeability using the device shown in Figures 3.3 and 3.4. The test uses a hard plastic standpipe 13 in (330 cm) long. Initially,the water is 11.3 in (287 cm) from the pavement surface. The time requirement for the water to drain out of the pipe from a height of 9.5 to 7.5 in (241 to 190 cm) is recorded. A rubber ring connects the permeameter to the pavement surface. The inside diameter of this ring is 2.3 in (58.2 cm) (where water drains into the pavement). Two 2.5 in (63.2 cm) metal rings are placed on the outside of the pipe to hold the rubber ring onto the pavement surface.

It was noted that moving the permeameter only short distances could change the readings from the test. This was due to variations in the pavement surface allowing more or less water to flow. This was very evident at the U.S. 97 project as parts of the mat had large stone particles picked out as a result of winter snowplow damage and/or raveling problems. Placement of the permeameter was very important, because if the device were placed near or on a pavement defect, the values would change drastically. In addition, if the permeameter was placed on a section that had bleeding problems, the permeability values would decrease rapidly because the surface was relatively impermeable. Care had to be taken to place the permeameter away from these areas. The permeameter was placed at three different places for each measurement location, but because of higher pavement variability than expected, even more placements could have been useful.

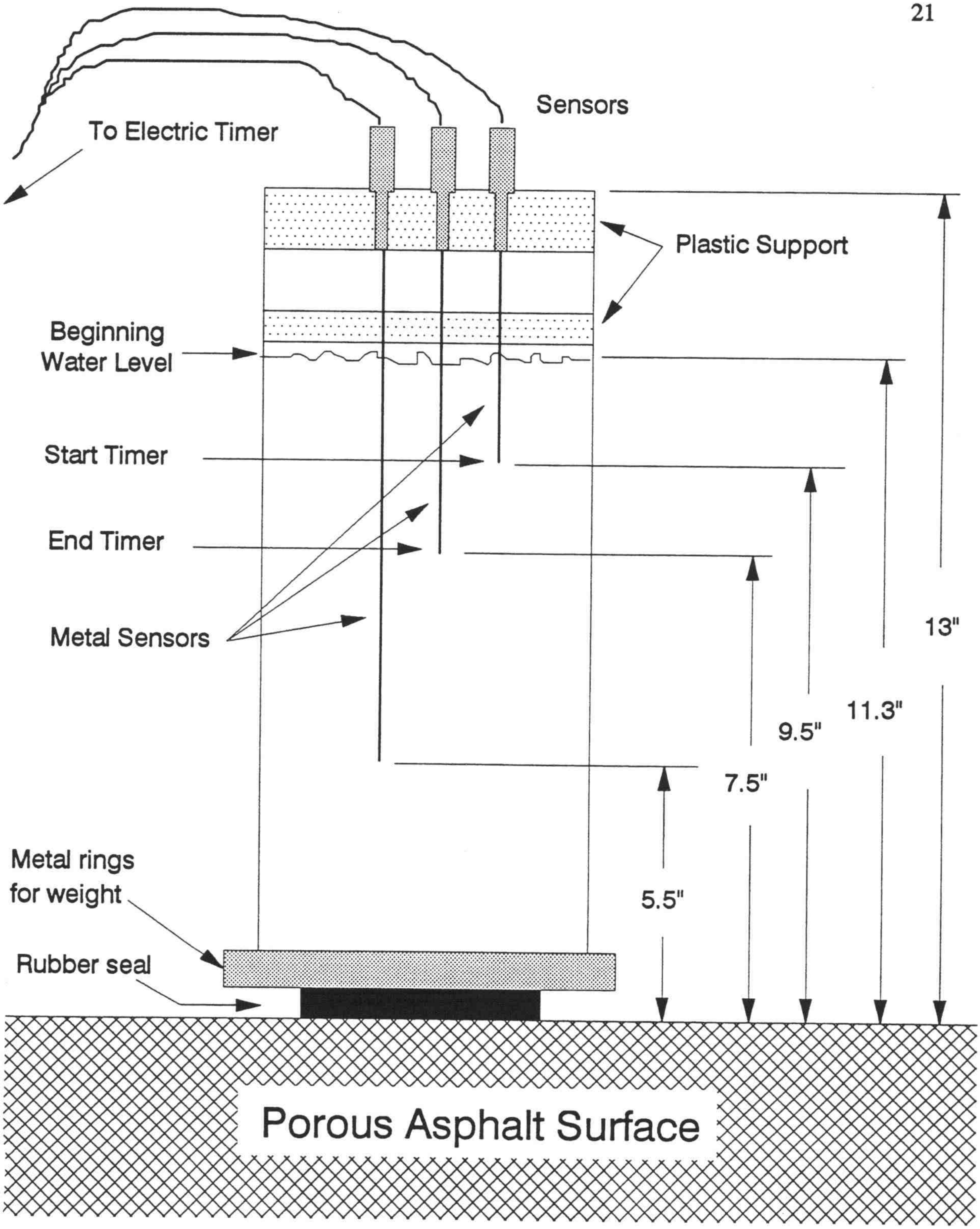


Figure 3.4. Drawing of permeability device

3.2.3 Rutting

Rutting measurements were taken during the field surveys in August 1993 and September of 1994. Two measurements were taken and averaged at each site for both inside and outside wheel tracks. Rutting was measured by placing a straight 6 ft (1.8 m) long rut depth across the wheel tracks, and then measuring the deflection of the gauge. Figure 3.5 shows how the rut depth gauge is used to measure the rutting in the wheel path. The rut depth data were compared from 1993 and 1994 in an attempt to evaluate the change in road deformation for the test site.

3.2.4 Friction Testing

Friction testing was performed on all the sites, except I-5 (Marquam Bridge - North Tigard) site, to quantify how Oregon's pavements perform under wet and dry conditions. Testing was performed using a K.J. Law Model 1290 Computer Controlled Pavement Friction Tester. Figure 3.6 shows a picture of this device. Tests were performed at speeds from 30 to 60 mph (48 to 96 km/h) in both wet conditions and dry conditions.

Dry conditions for this testing were based on ASTM E 274 testing procedure. Water is applied at a calibrated rate at 40 mph (65 km/h) to deliver 4.0 gal ± 10 %/min·in (600 ML/min·mm) of wetted width. The water layer has to be at least 1 in (25 mm) wider than the test tire tread and applied centrally between the edges. Wet conditions were actually same as dry conditions, only that there was additional water from heavy rainfall on the roadway. Heavy rainfall was measured in a subjective manner by ODOT's pavement friction testing crew.

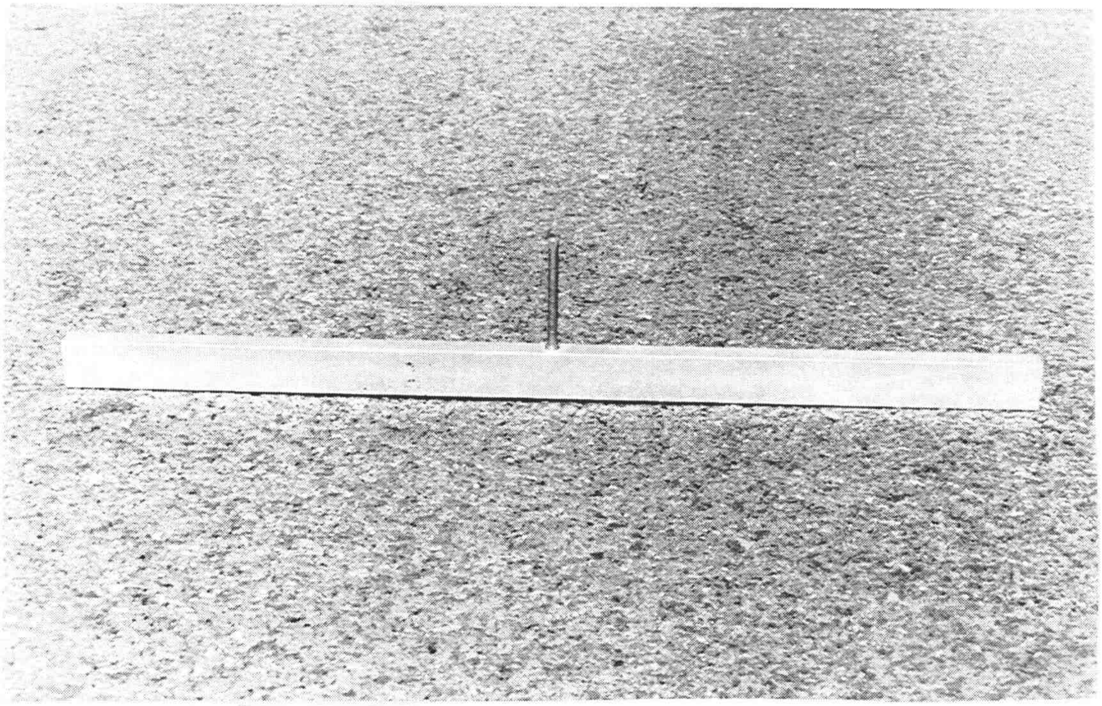


Figure 3.5. Rut depth measuring device

Figure 3.6. H.J. Law pavement friction tester

The speed gradient under wet conditions was the main focus of this testing plan. Reports such as Huddleston et al., 1990, have shown that porous pavements retain wet condition friction numbers better at higher speeds than other pavement types. The friction gradient is actually just the slope of the line for testing points acquired at various speeds. Speeds chosen for this test were 30, 40, 50, and 60 mph (48, 64, 86, and 96 km/h). Someareas, however, were in a 55 mph (89 km/h) speed zone and were not tested at 60 mph (96 km/h).

3.2.5 Accident Data

ODOT compiles accident information gathered yearly (ODOT, 1994). These data were used in an attempt to quantify the safety benefits of F-mix pavements. Data were evaluated from 1986 to 1993. The data used for the analysis are for both intersectional and nonintersectional accidents. An intersectional accident on an Interstate are defined as accidents which occur as a result of a conflict at an on/off ramp. Tables B.11 through B.15 in Appendix B present the raw data used in this analysis. These tables show that there were relatively few accidents involving intersectional conflicts as compared to nonintersectional. Since there were not enough accidents in the intersectional category to analyze, it was decided to analyze only the nonintersectional data.

Additional data presented in Appendix B (Table B.10) display the traffic ADT volumes for the test sections from 1986 to 1992. At the time of this report (September 1994) ODOT did not have the 1993 traffic volume information available.

Table 3.2. Location of projects evaluated

Highway	Date Evaluated	Speed (mph) (km/h)	Surface Type	Date of Construction
U.S. 34 – Tangent	October 1994	55 (88)	F-mix	1992
U.S. 34 – Tangent	October 1994	55 (88)	PCC	1992
U.S. 99W – S. Corvallis	October 1994	55 (88)	F-mix	1987
U.S. 99W – S. Corvallis	October 1994	55 (88)	B-mix	1987
U.S. 99W – N. Corvallis	October 1994	55 (88)	F-mix	1983
U.S. 99W – N. Corvallis	October 1994	55 (88)	B-mix	1976

3.2.6 Splash and Spray

Splash and spray testing was to be performed on selected pavement surfaces throughout Oregon. The surfaces examined were PCC, B-mix, and F-mix pavements (Table 3.2). Tests were conducted so that measurements were taken once for every 10 ft (3 m) of pavement length. Since measurements were conducted behind a car traveling 55 mph (87 km/h), a measurement was recorded every 0.124 seconds. The spray device, designed and constructed at Oregon State University, was mounted behind the rear wheel of the test vehicle directly in the spray path.

The schematic of the device is shown in Figure 3.7. Water from the roadway is "kicked back" by the tire and goes through the 1 in × 6 in (2.54 cm × 15 cm) opening. The water that flows through the opening blocks the light from the LED array, and changes the amount of voltage registered from the circuit. This voltage is shown as the change in water intensity flowing from the tire. The lower the voltage readout, the more spray coming off the roadway. The data are recorded by the program written for this

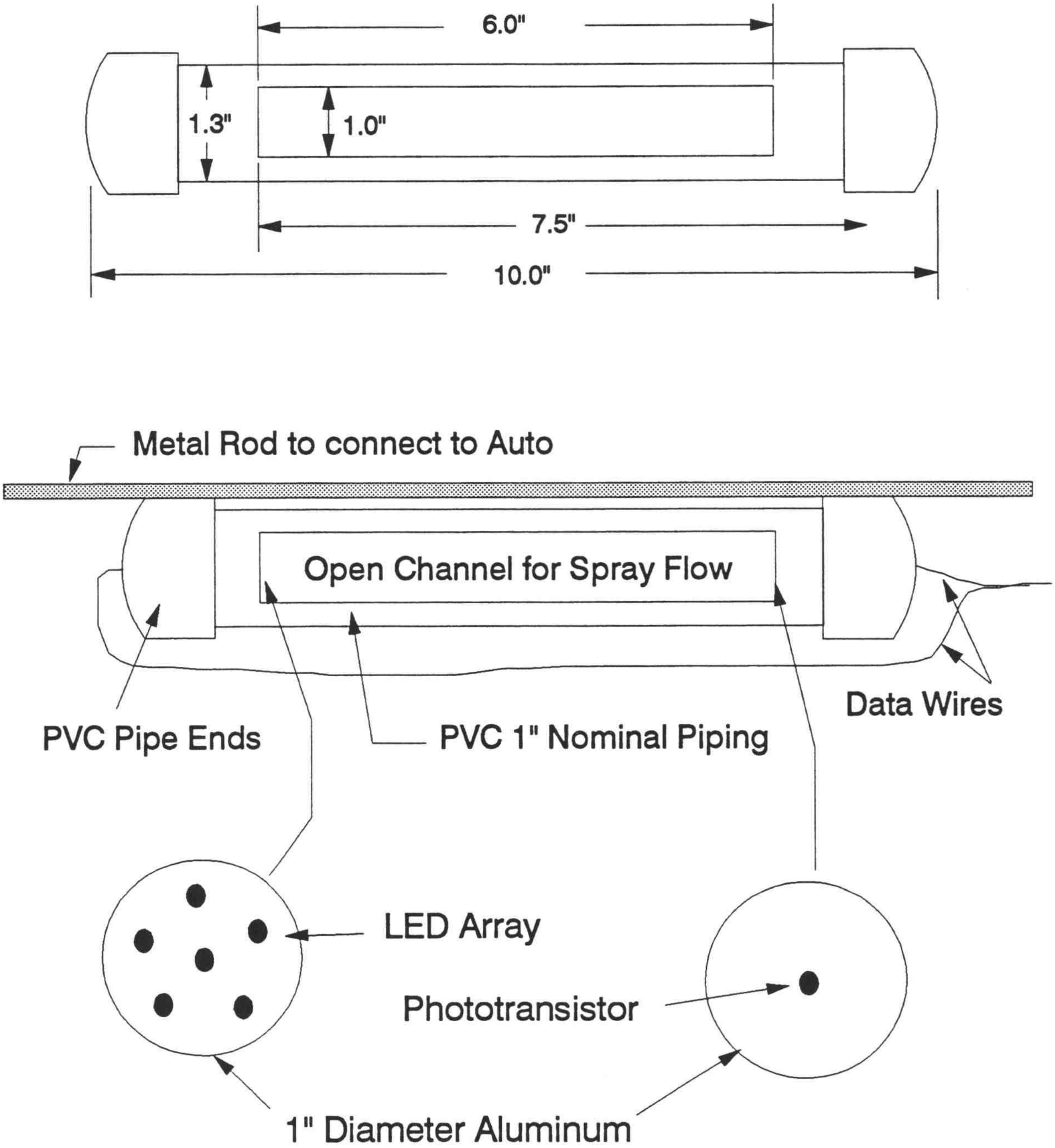


Figure 3.7. Diagram of splash and spray device (1" = 25.4 mm)

purpose. The data are recorded at the set in 0.124 seconds/measurement, although the measurement rate can easily be changed in the program. The program records measurements over a distance specified by the user. The voltage data are saved during the program run, and easily taken off the hard disk for analysis on a spreadsheet.

Tests were conducted to try to discern a difference in spray qualities for the F-mix pavement, B-mix pavement, and PCC pavement. As tests were all conducted at a 55 mph (87 km/h) standard speed, the spray intensity charge (measured as voltage) should be directly comparable across pavement types.

3.3 Test Results

3.3.1 Texture Depth/Water Permeability

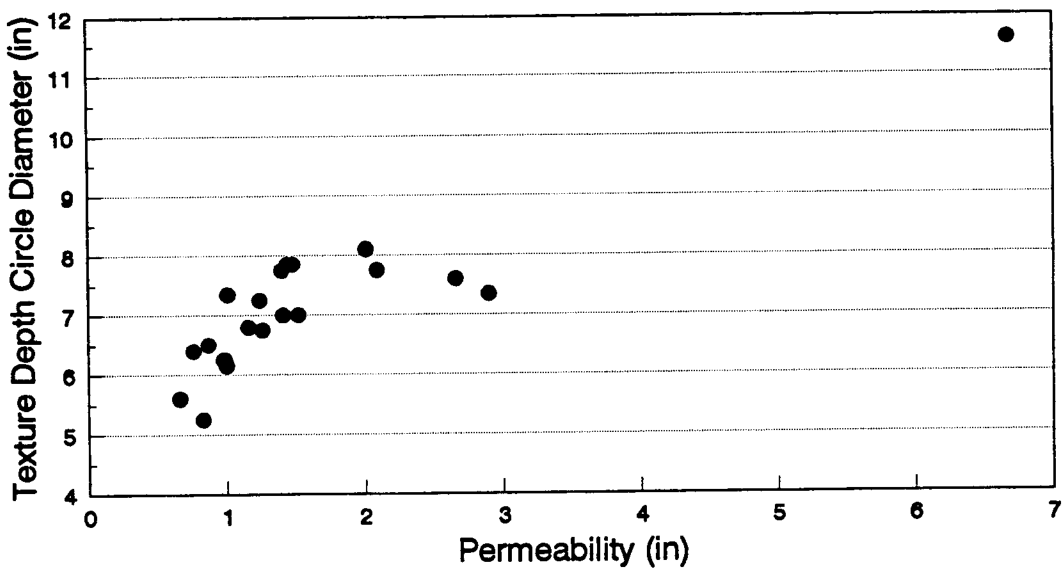
Data for texture depth and water permeability were collected in August 1993 and repeated in September 1994. Table 3.3 summarizes the data.

In an attempt to better use the texture depth data, a correlation between permeability and texture depth was hypothesized. Figure 3.8 shows that there is a fair correlation between the two data sets. Field experience might show that readings for a certain texture depth may vary a small amount with pavement changes, but this data shows a reasonable correlation.

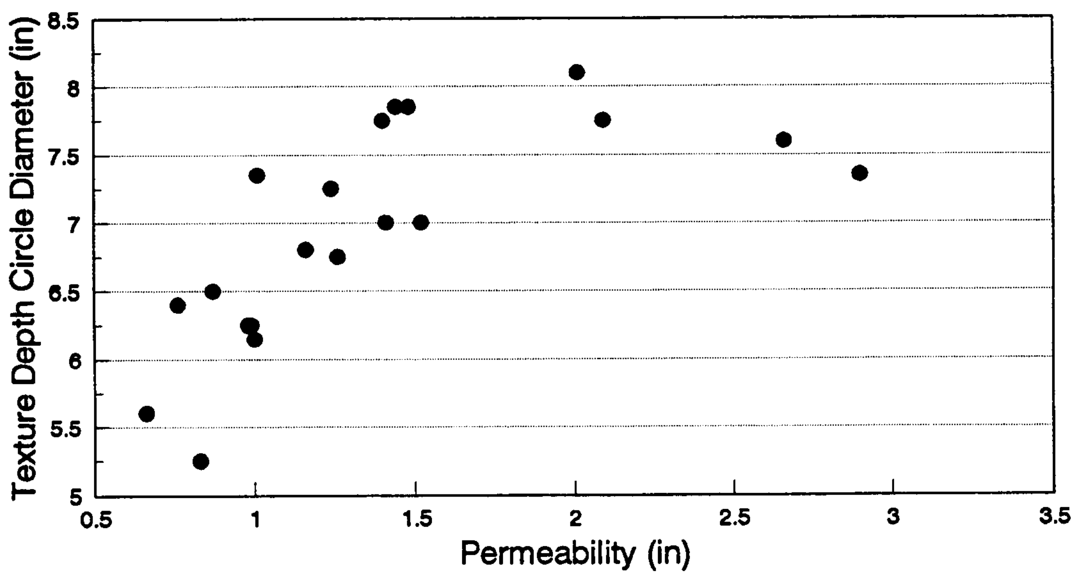
An area of interest was to see whether or not the permeability and/or texture depth changed over the period of the study, but the one year's change in permeability that could be recorded during the study time does not provide any definite conclusions. This is especially so because a limited number of sites were retested the following year due to construction at one site and problems with traffic control safety concerns on the busy

Table 3.3. Permeability and texture depth test results

Site	Mix Type	Location	Texture Depth (in)[f] 8/93	Texture Depth (in)[f] 9/94	Permeability (s) 8/93	Permeability (s) 9/94
a) Open Mixes						
I-5 Terwilliger	F	Shoulder	0.055	[b]	1.40	[b]
		IWP	0.063		1.24	
		BWP	0.072		1.16	
		OWP	0.079		0.87	
I-5 Salem	F	Shoulder	0.068	[b]	1.52	[b]
		IWP	0.088		1.00	
		BWP	0.085		0.99	
		OWP	0.081		0.76	
I-5 Grants Pass	F	Shoulder	0.121	[c]	0.83	0.91
		IWP	0.106		0.66	0.93
		BWP	0.085		0.98	0.93
		OWP	0.073		1.26	1.20
I-84 Pendleton	F	Shoulder	[a]	0.092	1.18	1.43
		IWP		0.100	0.84	0.84
		BWP		0.099	1.32	0.97
		OWP		0.098	0.92	0.89
U.S. 97 Bend	F	Shoulder	0.055	0.082	2.09	1.65
		IWP	0.062	0.90	1.01	1.35
		BWP	0.054	0.076	1.44	1.74
		OWP	0.068	0.088	1.41	1.53
Oregon 138 Diamond Lake	OGEM	Shoulder	0.058	[d]	2.66	[d]
		IWP	0.062		2.90	
		BWP	0.051		2.01	
		OWP	0.054		1.48	



a) All projects



b) Only F-mixes

Figure 3.8. Correlation between permeability and texture depth (1" = 25.4mm)

Interstate 5 thoroughfare. From the data shown in Table 3.3, it would appear that the permeability values for Grants Pass-Jumpoff Joe increased during the year's time. Sand patch measurements were not recorded at this site, as the sand drained into the pores of the pavement during these tests and caused the texture depth measurements to be flawed.

3.3.2 Rutting

Rut depths were recorded from the sites in August 1993 and September 1994 at the same time as the permeability and sand patch tests. Table 3.4 displays the data for each test section over the two year period, and Figure 3.9 provides a graphical view of the rut changes. It is easily noticed that the depth of the ruts change little over the oneyear period. This is a trademark of F-mix pavements, as rutting is not normally a problem.

3.3.3 Friction Data

Friction data were also collected twice during this study. The first set of data collection for this portion of the study was completed by February 1994 (Table 3.5). Figure 3.10 shows the first data collected during this experiment. The wet and dry data were collected under the same procedures as discussed earlier, where a "dry" test is actually a test performed using only the ASTM standard amount of water from the friction tester, and the "wet" test with both tester water and high intensity rainfall. As this data shows, for all data points the friction numbers for the "wet" condition were found to be higher than those recorded for the "dry" condition.

Additional tests were taken during the summer of 1994 to try to discover what anomalies in the data could be weeded out. Table 3.5 displays this data as well. From

Table 3.3. Permeability and texture depth test results (continued)

Site	Mix Type	Location	Texture Depth (in)[f]		Permeability (s)	
			8/93	9/94	8/93	9/94
b) Other Mixes[e]						
I-5 Salem	B	Shoulder	0.025		6.67	
Tyler St.-Corvallis	New PCC	Shoulder		N/A		∞
Harrison St.-Corvallis	Slurry Seal	Shoulder		0.033		5.43
Circle Blvd.-Corvallis	New C-mix	Shoulder		0.010		18.32
14th St.-Corvallis	Old C-mix	Shoulder		0.018		14.21
15th St.-Corvallis	Old PCC	Shoulder		0.029		6.87

Notes:
[a]Pavement wet during Pendleton survey, so no texture depth readings were taken.
[b]Measurements not taken due to traffic control restrictions.
[c]Grants Pass site not measured as sand ran into pores too fast.
[d]Site not reachable due to construction.
[e]Other mix types only taken one time for comparison purposes.
[f]1 in = 25.4 mm

Table 3.4. Rut depth levels by year

Project	Date Constructed	Location	8/93 Rut Depth (in)	9/94 Rut Depth (in)
Marquam to N. Tigard (I-5)	1991	OWT IWT	none 1/4 - 1/8	*
Hayesville - BattleCreek (I-5)	1990	OWT IWT	1/8 1/4	*
Jumpoff Joe - N. Grants Pass (I-5)	1993	OWT IWT	none 0 - 1/8	1/8 - 1/4 1/8 - 1/4
Murphy Road - Lava Butte (U.S. 97)	1989	OWT IWT	1/8 - 1/4 1/4	1/4 1/4
E. Pendleton - Emigrant Hill (I-84)	1993	OWT IWT	none none	1/8 - 1/4 0 - 1/8
Diamond Lake (OR 138)	1976	OWT IWT	1/4 - 1/2 1/8 - 3/8	**

NOTES:
*Measurements not taken due to traffic control restrictions.
**Site not reachable due to construction.
***1" = 25.4 mm

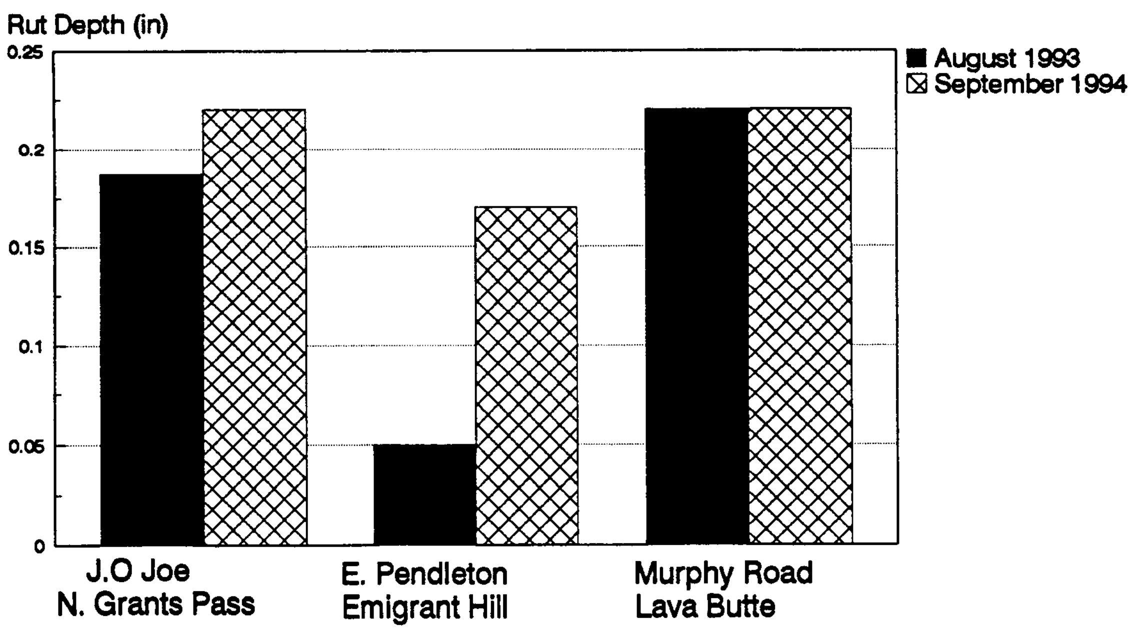


Figure 3.9. Rut depth changes by year

Table 3.5. Frictional test results

Project	Condition	Date	Nominal Speed (mph) (km/h)	FN	Actual Speed (mph) (km/h)
Murphy Road-Lava Butte	Wet		30 (48)		
			40 (64)	47.2	40 (64)
			50 (80)	44.7	50 (80)
			55 (88)	43.6	55 (88)
Hayesville-BattleCreek	Wet	11/17/93	30 (48)	45.8	32 (50)
			40 (64)	43.1	41 (66)
			50 (80)	40.6	50 (80)
			55 (88)	39.3	55 (88)
		11/18/93	30 (48)	45.8	30 (48)
			40 (64)	43.1	40 (64)
			50 (80)	40.9	50 (80)
			55 (88)	39.8	55 (88)
		12/8/93	30 (48)	59.7	30 (48)
			40 (64)	54.5	40 (64)
			50 (80)	52.3	49 (79)
			55 (88)	50.1	55 (88)
		2/23/94	30 (48)	60.1	31 (50)
			40 (64)	55.8	41 (66)
			50 (80)	50.4	50 (80)
			55 (88)	51.1	55 (88)
	Dry	1/18/94	30 (48)	53.3	31 (50)
			40 (64)	49.9	41 (66)
			50 (80)	47.8	50 (80)
			55 (88)	46.5	55 (88)
		6/14/94	30 (48)	49.5	32 (52)
			40 (64)	46.6	40 (64)
			50 (80)	44.2	50 (80)
			55 (88)	43.9	55 (88)
N. Grants Pass	Wet	12/7/93	30 (48)	52.6	31 (50)
			40 (64)	48.9	41 (66)
			50 (80)	45.6	50 (80)
			55 (88)	43.6	56 (88)
			60 (97)	41.9	59 (100)

Table 3.5. Frictional test results (continued)

Project	Condition	Date	Nominal Speed (mph) (km/h)	FN	Actual Speed (mph) (km/h)
Jumpoff Joe	Wet	11/15/93	30 (48)	45.1	31 (50)
			40 (64)	44.0	40 (64)
			50 (80)	42.5	50 (80)
			60 (97)	41.2	60 (97)
I-5 Marquam Interchange	Wet	11/8/93	30 (48)	38.2	31 (50)
			40 (64)	36.4	40 (64)
			50 (80)	34.5	50 (80)
			60 (97)	34.1	59 (95)
		12/1/93	30 (48)	56.8	30 (48)
			40 (64)	52.4	40 (64)
			50 (80)	48.6	50 (80)
			60 (97)	46.4	58 (88)
		2/24/94	30 (48)	57.4	31 (50)
			40 (64)	43.8	40 (64)
			50 (80)	49.2	50 (80)
			55 (88)	48.4	55 (88)
	Dry	1/18/94	30 (48)	48.3	31 (50)
			40 (64)	45.3	40 (64)
			50 (80)	43.5	50 (80)
			55 (88)	43.2	52 (84)
		7/19/94	30 (48)	41.0	32 (52)
			40 (64)	38.0	40 (64)
			50 (80)	37.1	49 (79)
			55 (88)	35.5	54 (87)
I-5 PCC	Wet	2/23/94	30 (48)	55.7	30 (48)
			40 (64)	47.8	40 (64)
			50 (80)	42.5	50 (80)
			55 (88)	39.8	55 (88)
	Dry	1/18/94	30 (48)	49.6	30 (48)
			40 (64)	43.8	41 (66)
			50 (80)	39.3	51 (82)
			55 (88)	37.5	56 (90)
		6/14/94	30 (48)	45.5	31 (50)
			40 (64)	40.1	41 (66)
			50 (80)	35.3	51 (82)
			55 (88)	34.1	56 (90)

Table 3.5. Frictional test results (continued)

Project	Condition	Date	Nominal Speed (mph) (km/h)	FN	Actual Speed (mph) (km/h)
I-5 B-Mix	Wet	2/23/94	30 (48) 40 (64) 50 (80) 55 (88) 60 (97)	61.7 55.1 48.6 45.8	31 (50) 40 (64) 50 (80) 55 (88)
	Dry	1/18/94	30 (48) 40 (64) 50 (80) 55 (88)	56.5 51.2 45.7 44.9	31 (50) 40 (64) 50 (80) 55 (88)
		6/14/94	30 (48) 40 (64) 50 (80) 55 (88)	54.4 49.8 45.5 44.8	31 (50) 41 (66) 50 (80) 55 (88)

looking at the June and July testing for the I-5 test sites for B-mix, PCC, F-mix at BattleCreek to N. Jefferson, and F-mix at Marquam Interchange, yield "dry" pavement friction numbers that are even lower than those from earlier tests. No "wet" friction tests were possible during the summer months due to lack of rain. Even without the "wet" measurements, the low friction numbers collected in June and July show that these data would not help explain why friction numbers were lower for "dry" than those for "wet" conditions.

3.3.4 Accident Data

Nonintersectional accident data are shown in tabular form for each project (see Tables 3.6 through 3.10). The total accident numbers for the year were divided by the

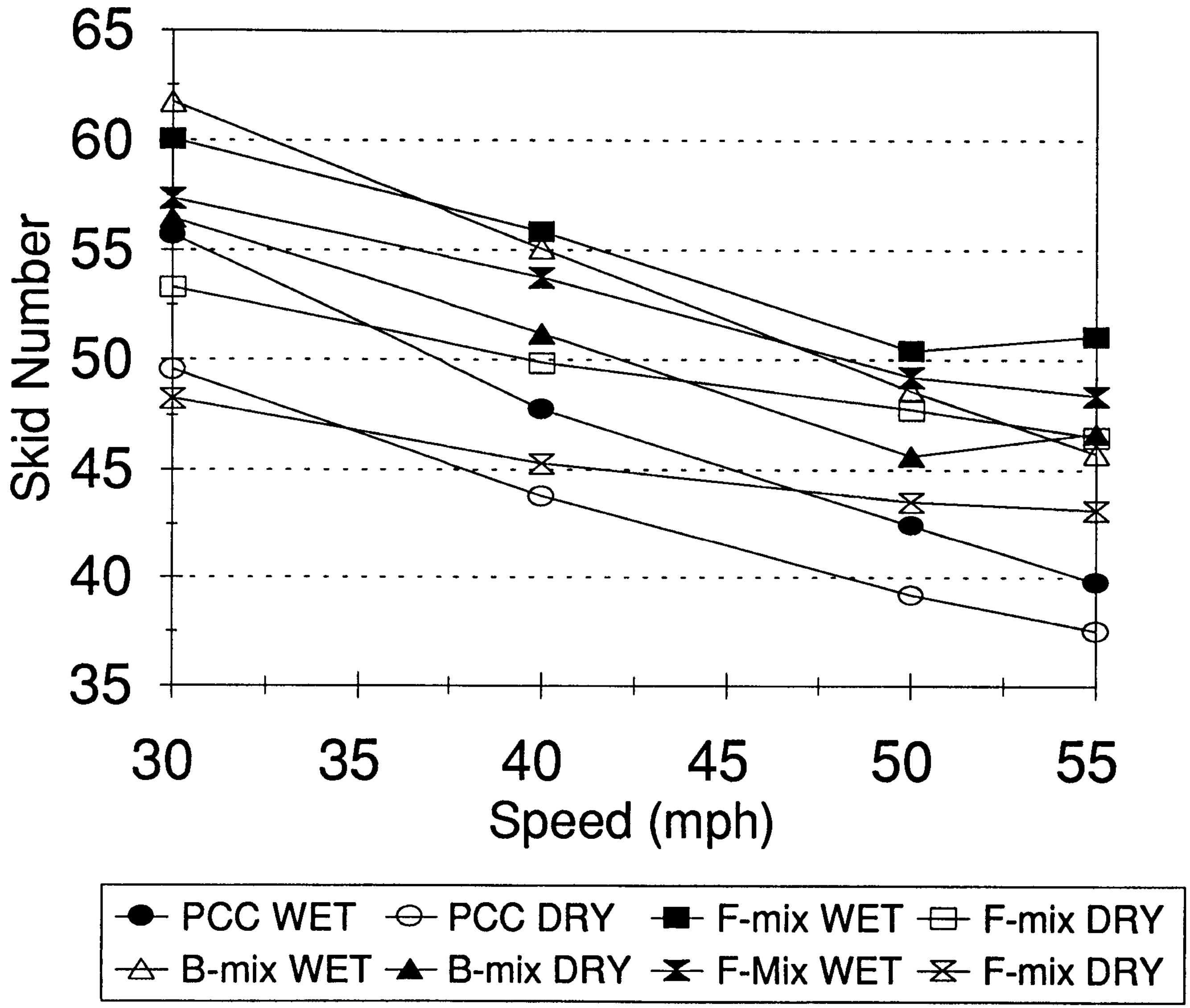


Figure 3.10 Frictional testing results (1994)

average daily traffic (ADT) for each road section and year. The yearly accidents/ADT values were then plotted for each year (see Figures 3.11 through 3.15).

The two sites that provide the most information are the I-5 (Marquam to N. Tigard) and I-5 (Hayesville to BattleCreek) projects. Porous pavements on those projects were placed in 1990 for the Marquam to N. Tigard project, and 1989 for the Hayesville to BattleCreek project. A change in the accidents/ADT would indicate whether or not the placement of the pavement affected the safety of the roadway. Figure 3.11 seems to show a significant reduction in the total number of accidents as a result of the change in pavement type in 1990. Figure 3.12, however, would seem to suggest that there was a significant decrease in fatal accidents, yet a rise in total accidents after the 1989 porous pavement. The rather low number of fatal accidents shown in Tables 3.6 through 3.10 would seem to suggest that there is not enough data in this area to make a significant conclusion.

3.3.5 Splash and Spray Results

Splash and spray results were unattainable during the late spring to early summer of 1994 because of a lack of rain. The results for the splash and spray portion of this thesis are not shown for this reason. The splash and spray results will be available soon after the completion of this thesis, and will be published in the ODOT report that was a part of this project.

Table 3.6. Marquam Bridge to N. Tigard Interchange accident data

Year	Avg. ADT	Fatal	Fatal/ ADT	Nonfatal	Nonfa- tal/ ADT	Property	Proper- ty/ ADT	Total	Total/ ADT
1986	79708	1	0.125	14	1.756	14	1.756	29	3.638
1987	85175	1	0.117	11	1.291	14	1.644	26	3.053
1988	91742	0	0.000	9	0.981	15	1.635	24	2.616
1989	91575	0	0.000	18	1.966	19	2.075	37	4.040
1990	85671	0	0.000	15	1.751	20	2.335	35	4.085
1991	93975	0	0.000	18	1.915	17	1.809	35	3.724
1992	90983	0	0.000	12	1.319	11	1.209	23	2.528
1993	**	0		4		9		13	

Table 3.7. Hayesville to BattleCreek accident data

Year	Avg. ADT	Fatal	Fatal/ ADT	Nonfa- tal	Nonfatal/ ADT	Prop- erty	Property/ ADT	Total	Total/ ADT
1986	39233	2	0.510	23	5.862	19	4.843	15	3.823
1987	41700	0	0.000	27	6.235	27	6.475	14	3.357
1988	50133	1	0.199	17	3.391	30	3.989	17	3.391
1989	50188	0	0.000	32	6.376	24	4.782	29	5.778
1990	50888	1	0.197	30	5.895	38	7.467	23	4.520
1991	51950	3	0.577	23	4.427	22	4.235	19	3.657
1992	53750	1	0.186	29	5.395	32	5.953	16	2.977
1993	**	2		25		30		9	

Table 3.8. Jumpoff Joe to N. Grants Pass accident data

Year	Avg. ADT	Fatal	Fatal/ ADT	Nonfatal	Nonfatal/ ADT	Prop-erty	Property/ ADT	Total	Total/ ADT
1986	13350	0	0.000	9	6.742	6	4.494	15	11.236
1987	13750	1	0.727	6	4.364	7	5.091	14	10.182
1988	14494	1	0.690	7	4.830	9	6.210	17	11.729
1989	15194	1	0.658	10	6.582	18	11.847	29	19.087
1990	15550	1	0.643	7	4.502	15	9.646	23	14.791
1991	15506	0	0.000	7	4.514	12	7.739	19	12.253
1992	16000	0	0.000	9	5.625	7	4.375	16	10.000
1993	**	0		5		4		9	

Table 3.9. E. Pendleton to Emigrant Hill accident data

Year	Avg. ADT	Fatal	Fatal/ ADT	Nonfatal	Nonfatal/ ADT	Prop-erty	Property/ ADT	Total	Total/ ADT
1986	5675	0	0.000	1	1.762	5	8.811	6	10.573
1987	6060	1	1.653	1	1.653	3	4.959	5	8.264
1988	25576	0	0.000	1	0.391	0	0.000	1	0.391
1989	6400	0	0.000	0	0.000	1	1.563	1	1.563
1990	6975	0	0.000	2	2.867	1	1.434	3	4.301
1991	7025	2	2.847	1	1.423	2	2.847	5	7.117
1992	8550	0	0.000	2	2.339	3	3.509	5	5.848
1993	**	0		0		1		1	

Table 3.10. Murphy Road to Lava Butte accident data

Year	Avg. ADT	Fatal	Fatal/ ADT	Nonfatal	Nonfatal/ ADT	Prop- erty	Property/ ADT	Total	Total/ ADT
1986	12825	**	0.000	**	0.000	**	0.000	**	0.000
1987	13325	**	0.000	**	0.000	**	0.000	**	0.000
1988	15275	0	0.000	11	7.201	11	7.201	22	14.403
1989	15900	3	1.887	10	6.289	14	8.805	27	16.981
1990	20375	2	0.982	8	3.926	9	4.417	19	9.325
1991	21850	0	0.000	5	2.288	14	6.407	19	8.696
1992	21750	1	0.460	8	3.678	13	5.977	22	10.115
1993	**	1		7		11		19	

3.4 Summary of Results

The data collected during the field study portion of this project were very useful in determining the characteristics of the field performance of porous pavement. The rutting and permeability measurments provide information about the change in properties of porous pavement for a one-year time period. The friction and accident data provide mixed insight into the safety properties of porous pavements. However, to have these data make more sense, it is necessary to record the pavement properties over a longer period of time.

Good data could be collected over an extended period of time, but first some of the test deficiencies would have to be addressed. One deficiency occurs when measuring the pavement permeability. For example, the measurements of "permeability" on some dense asphalt and PCC pavements is suspect. Currently, the permeameter is connected to the pavement surface by a hard rubber disk. This allows the water to not only flow through the voids of the pavement, but through the uneven texture of the surface, thus

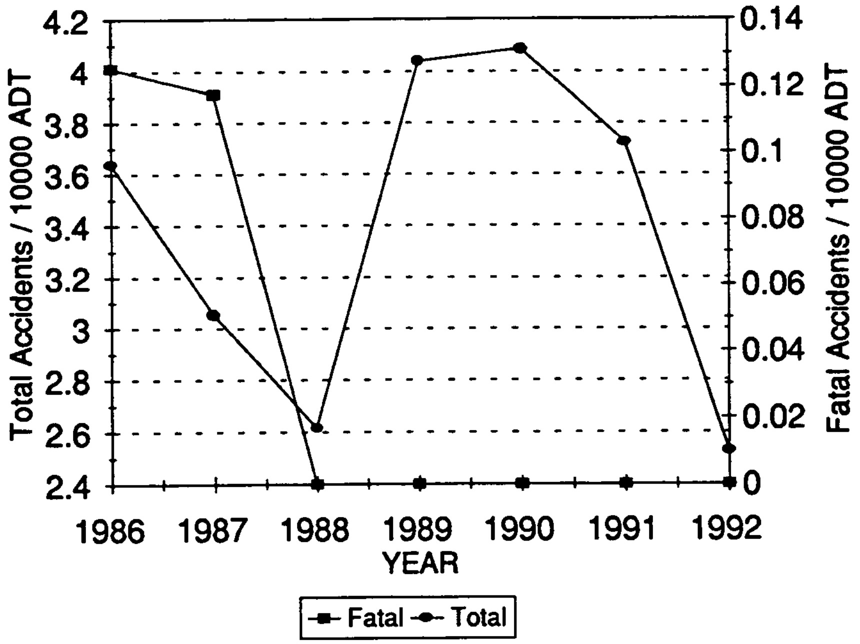


Figure 3.11. Marquam to N. Tigard accident information

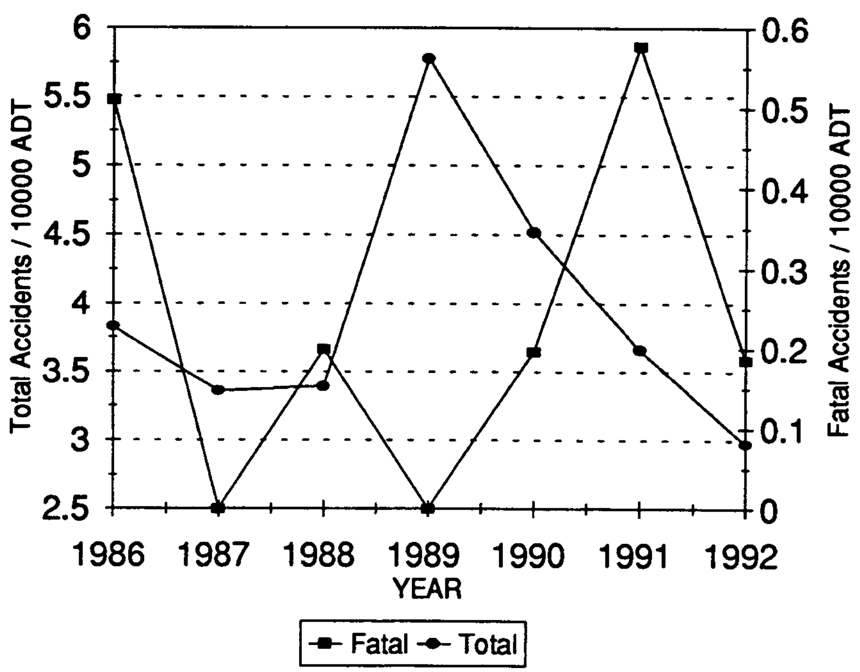


Figure 3.12. Hayesville to BattleCreek accident information

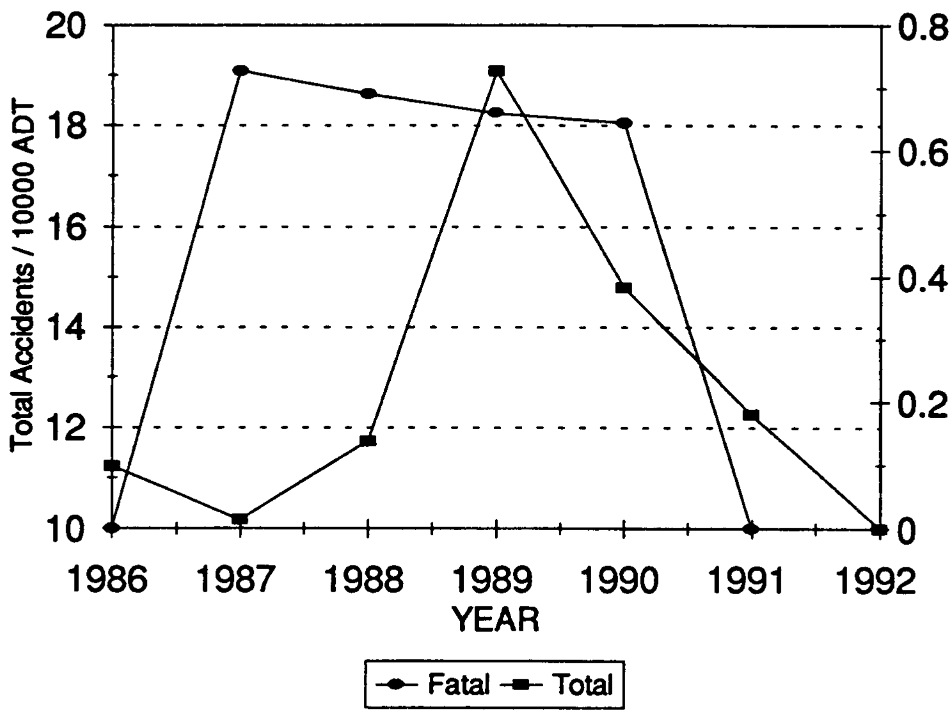


Figure 3.13. Jumpoff Joe to N. Grants Pass accident information

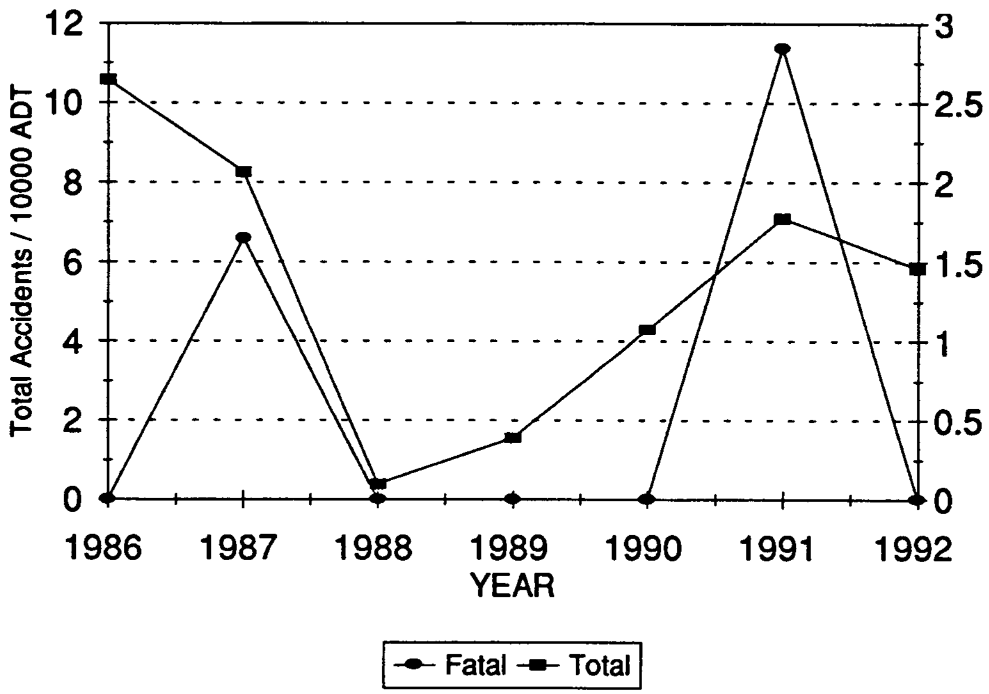


Figure 3.14. E. Pendleton to Emigrant Hill accident information

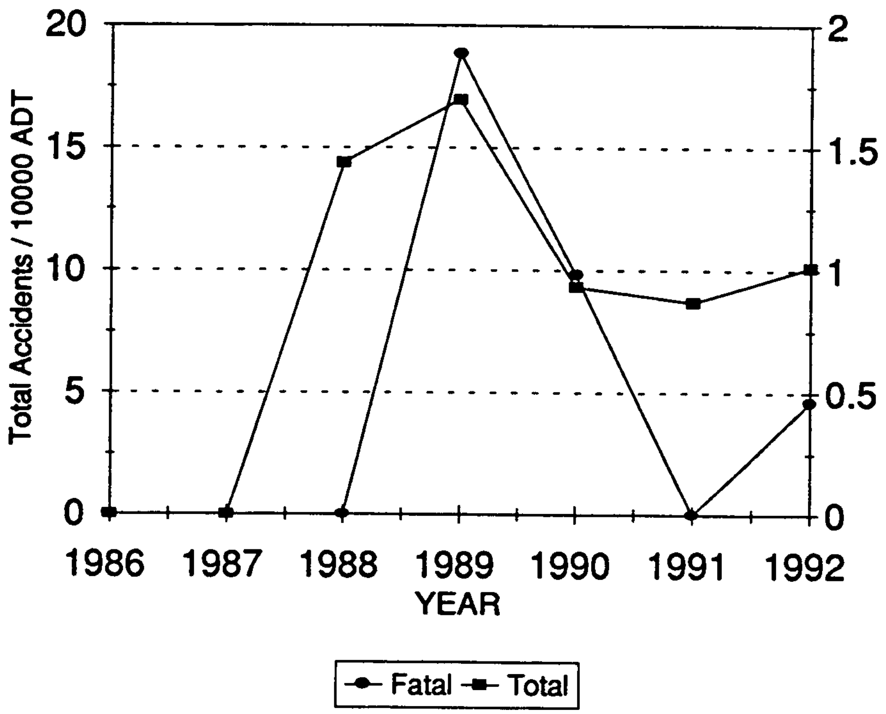


Figure 3.15. Murphy Road to Lava Butte accident information

making the permeameter more of a texture meter than an actual permeability measurement device. The connecting mechanism to the pavement should, in actuality, be a soft rubber or some material that can mold into the pavement texture. Another idea is to increase the frequency of measurements for each project site so the overall permeability average will be more representable.

Another area which should be studied is the anomalies in the data from the friction measurements. There is no obvious explanation as to why the data came out with the "dry" measurements showing a lower friction number than those for the "wet" conditions. A hypothesis for this problem is that the water from the sprayer on the friction tester actually loosens any dirt on the road surface, but does not provide enough water or time to wash it away completely. This would then mix with the road oils and cause a slicker pavement surface.

4.0 LABORATORY STUDY

This chapter presents the results of a laboratory study used to evaluate some porous pavement parameters in a controlled environment. This chapter summarizes the procedures used, the data, acquired, and discusses the significance of the data.

4.1 Core Sampling Plan

The sampling plan used for the projects described in Chapter 3 is summarized in Figure 4.1. Since the Environmental Condition System (ECS) test requires asphalt concrete cores to be of 4 ± 0.16 in (102 ± 4 mm) height, only two projects could be evaluated for these properties, the Pendleton and the N. Grants pass sites. These two sites contained two 2 in (51 mm) thick layers of F-mix, while all other sites were made of only one layer of F-mix. All other sites followed the non-ECS core sampling plan shown in Figure 4.1. All site samples were tested for mix permeability, aggregate gradation, asphalt content and properties, and voids.

4.2 Test Procedures - ODOT

All tests for aggregate gradation, asphalt properties, and asphalt content were performed by ODOT, using their standard test procedures.

4.2.1 Asphalt Recovery

The extraction of asphalt from asphaltic mixtures is covered under Oregon State Highway Division (OSHD, 1989) Test Method 314-86 (TM 34-86). This method is a modified version of AASHTO T164 and T170 designations (AASHTO, 1990). The

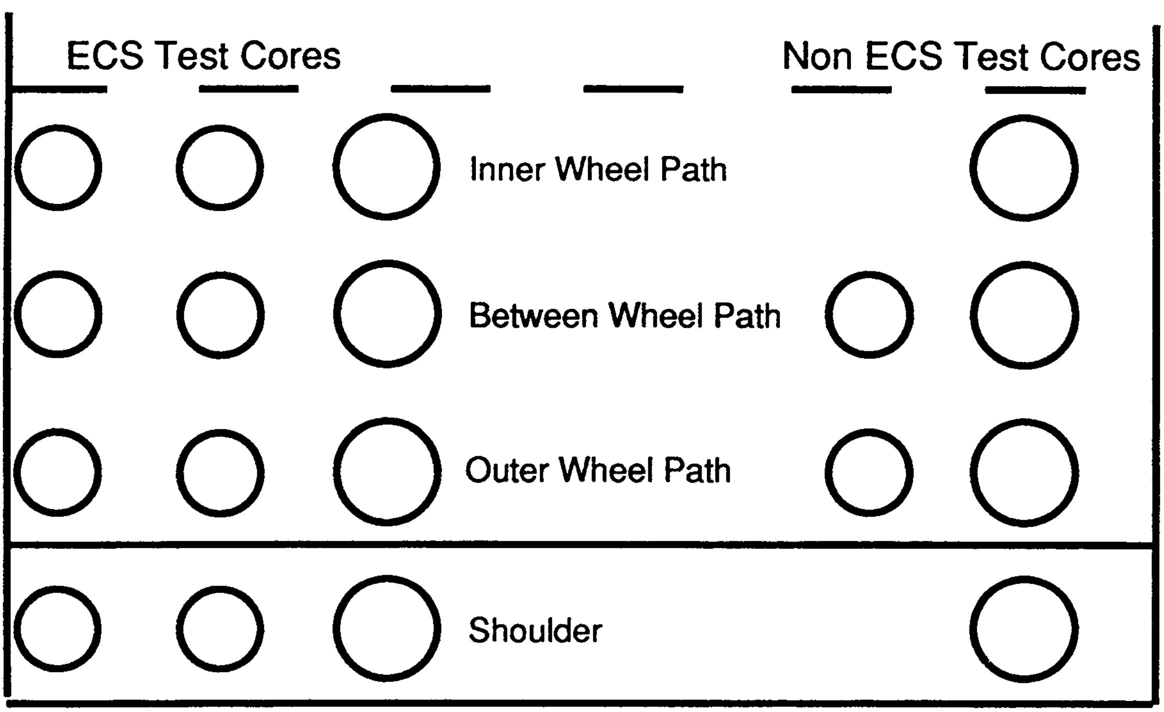


Figure 4.1. Core sampling plan

extraction technique uses a benzene solution conforming to the ASTM D835 Standard Specification of Nitration Grade Benzene for the reagent in the extraction process.

4.2.2 Asphalt Properties

Three asphalt property tests were performed on the recovered asphalt. These are penetration (TM 401), kinematic viscosity (TM 402), and absolute viscosity (TM 417). The penetration test (Oregon TM 401) is the same method as defined in ASTM D 5-73. All tests were performed at the 25 °C (77°F) test temperature. The absolute viscosity of asphalt (Oregon TM 417) is the same method as defined in ASTM D 2171-78 while the kinematic viscosity of asphalt (TM 402) is the same test method as defined in ASTM D 2170-76 (ASTM, 1993).

4.3 Test procedures – OSU

OSU performed laboratory tests on the cores for moisture sensitivity and permeability (using the ECS), and for tack coat shear. The ECS test was developed by OSU as part of a research project under the Strategic Highway Research Project (Allen, 1993).

4.3.1 ECS

The Environmental Conditioning System (ECS) was designed to simulate actual water conditioning within the specimen. The ECS test protocol follow the outline shown in Table 4.1. The ECS is made up of three subsystems as shown in Figure 4.2: the fluid conditioning apparatus, environmental conditioning cabinet, and loading system.

Table 4.1. Summary of the ECS test procedure (after Allen, 1993)

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 specimens 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.

The fluid conditioning system was designed to measure air and water permeability and provide water conditioning. This system was designed as a constant head permeameter with pressure gradient measured by three separate gauges. One is connected before the system, the second after the system, and the third is a differential pressure gauge across the system. The fluid conditioning system also includes a thermocouple with

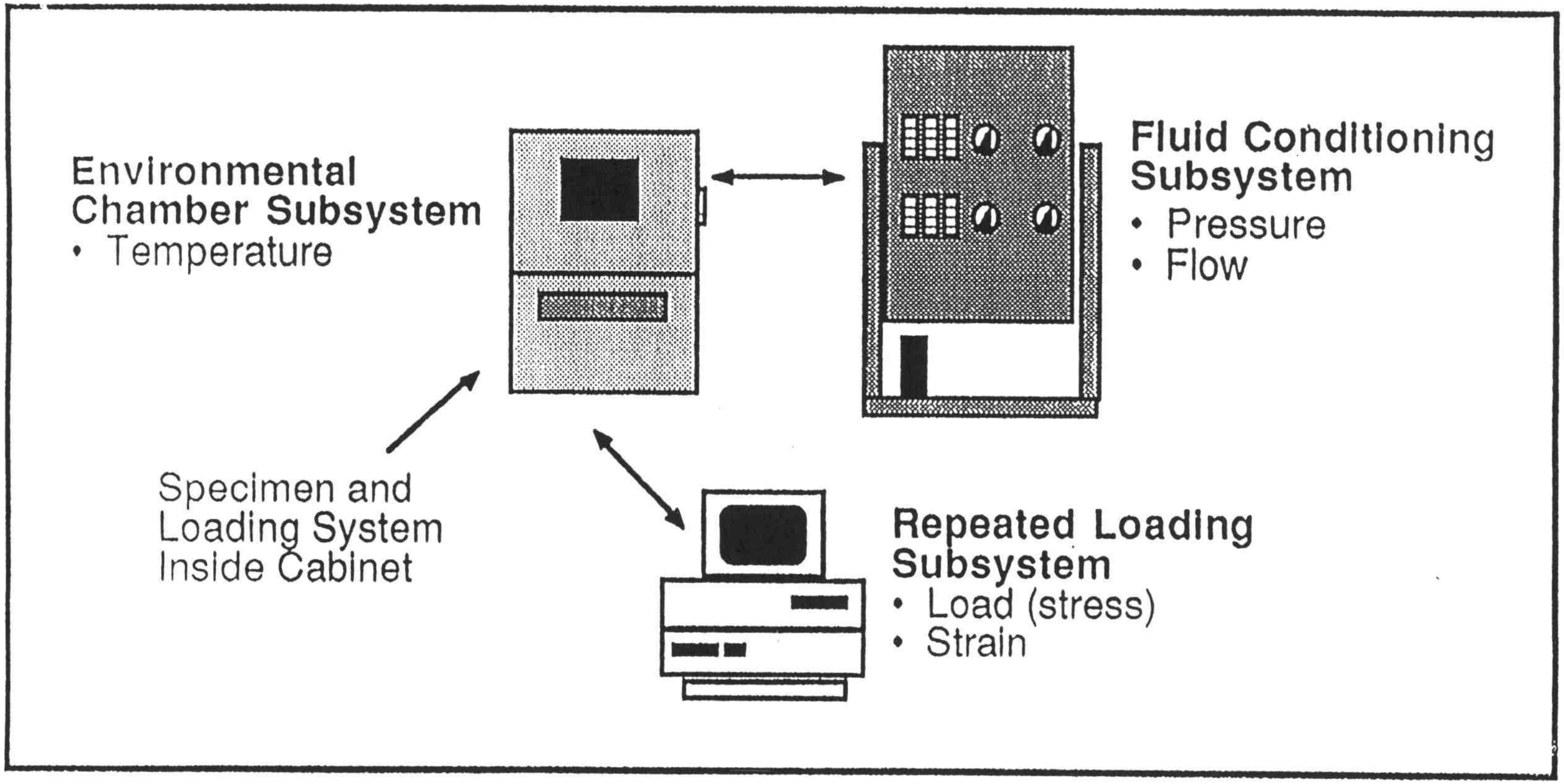


Figure 4.2. Overview of the Environmental Conditioning System (After Allen, 1993)

four channels that can be used to monitor the water flow temperature before and after flow through the specimen, the temperature of a dummy specimen in the chamber, and the temperature of the water reservoir. The three water flow meters are connected to the water conditioning system to provide a sufficient flow range from 1 to 3000 cm^3/min, and three air flow meters that can read a range of 100 to 70000 cm^3/min for measuring specimen air permeability.

Figure 4.3 shows a schematic of the loading system used with the ECS. This system is connected to a personal computer that controls the test through a controller card. The servovalve drives the system by controlling the pressure of the compressed air. Loads are delivered to the system through a load ram and load cell system that rests on top of the specimen. The deflections are monitored by linearly variable differential transducers (LVDTs), mounted on the specimen, and allowing calculation of the resilient modulus of the specimen. The tests are conducted using a haversine pulse load of duration 0.1 s and frequency of 1 Hz.

The testing protocol for the ECS requires that an environmental conditioning cabinet be used that is capable of heating to 100 °C and cooling to -20 ° C within a tolerance of ± 1 °C. Temperature changes and time limits are specified in the protocol as well.

4.3.2 Shear Testing

4.3.2.1 Specimen Preparation. The laboratory shear test was performed to measure the shear strength of a tack coat placed between a portland cement concrete (PCC) pavement and a F-mix layer. The test specimens were constructed using the

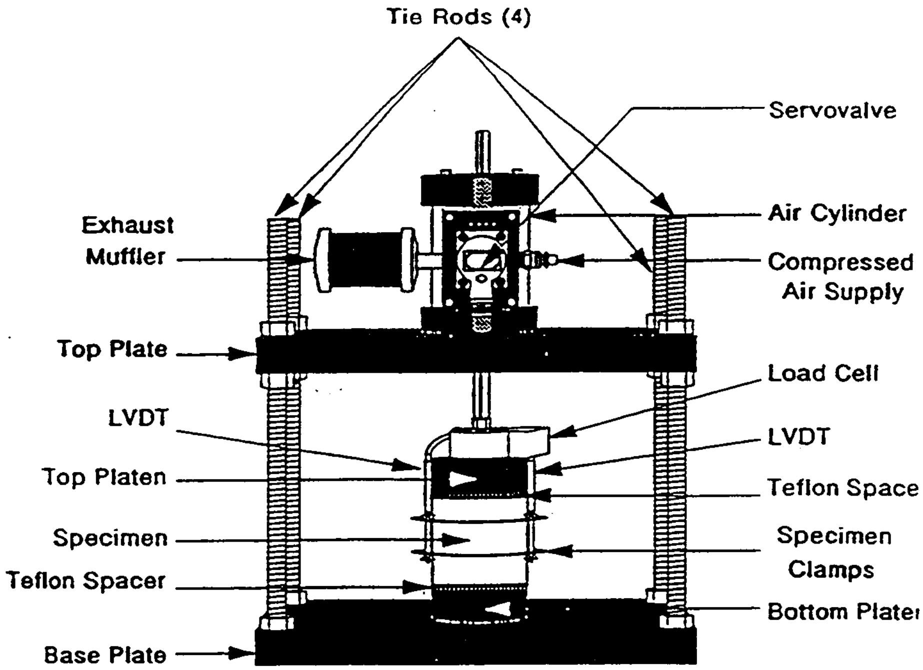


Figure 4.3. Schematic of ECS load frame (after Allen, 1993)

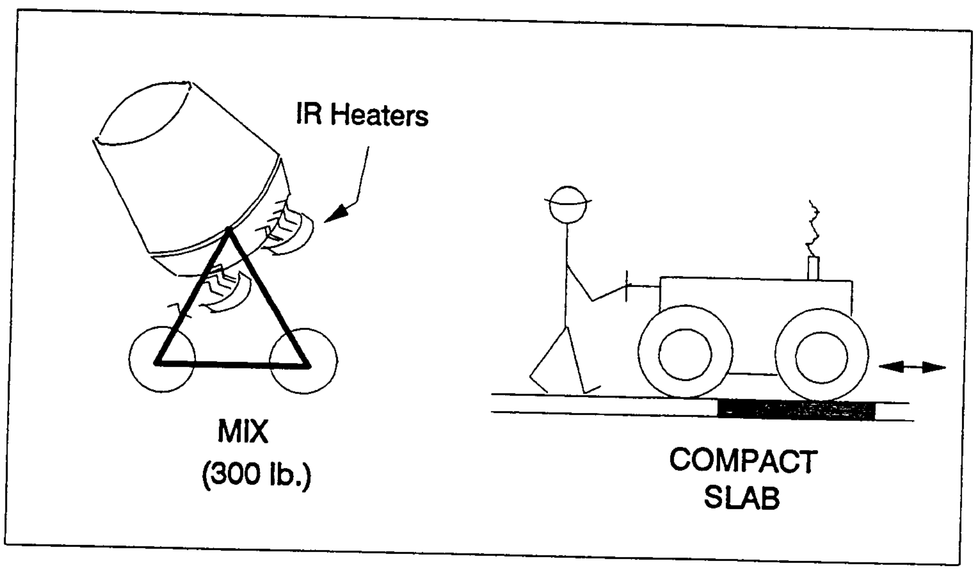


Figure 4.4. Rolling wheel compaction setup

rolling wheel compactor developed at OSU through the Strategic Highway Research Program (SHRP) (Terrel et al., 1993). Figure 4.4 illustrates the rolling wheel compaction procedure used. The procedure is briefly summarized below.

A concrete section measuring 28 × 28 in (71 × 71 cm) and 3 in (7.6 cm) in height was poured in a mold. This concrete slab was extracted after curing for 10 days and placed in the 5 in(13 cm) rolling wheel device. A tack coat of CSS-1 emulsion was then placed on the concrete layer following ODOT specification section 00730 (ODOT, 1991). Application rates used were 0.05, 0.10, 0.15, and 0.20 gal/yd^2 (0.23, 0.45, 0.68, and 0.91 l/m^2). The tack coat was then allowed cure until the water "broke" from the asphalt but still retained its tackiness, as defined in the ODOT specification. The F-mix asphalt layer placed on the tack coat surface in accordance to the rolling wheel compaction method.

Specimens were extracted from the 5 in(13 cm) slab of F-mix over PCC with a 4 in(10 cm) core barrel. From each section of emulsion spray rates, 5 samples were extracted. These samples were then set aside for testing. Two samples from each group were subject to some long term aging for 48 days at 85 °C in a force draft oven. This was performed to simulate the conditions the samples would go through while aging in the field. Two other samples were set aside for normal testing. The fifth sample was produced as a backup in case there were testing problems with the samples, and more tests had to be performed.

4.3.2.2 Testing Methods. The samples were tested in a tensile shear mode using the schematic of the device shown in Figures 4.5 and 4.6 and the photo shown in Figure 4.7. The specimens were subject to a shear force at a rate of 10 lb/s (4.5 N/s) along the

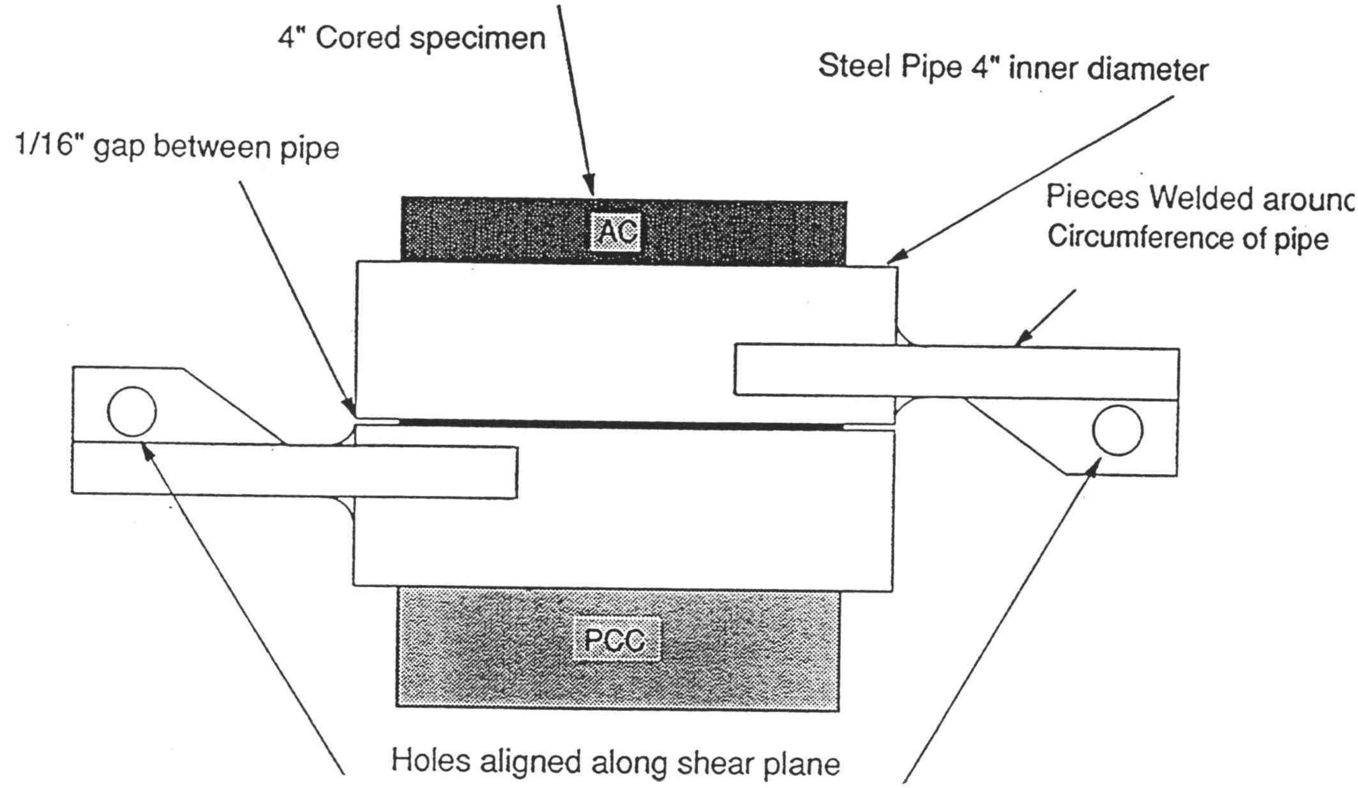


Figure 4.5. Shear testing device – front view (1" = 25.4mm)

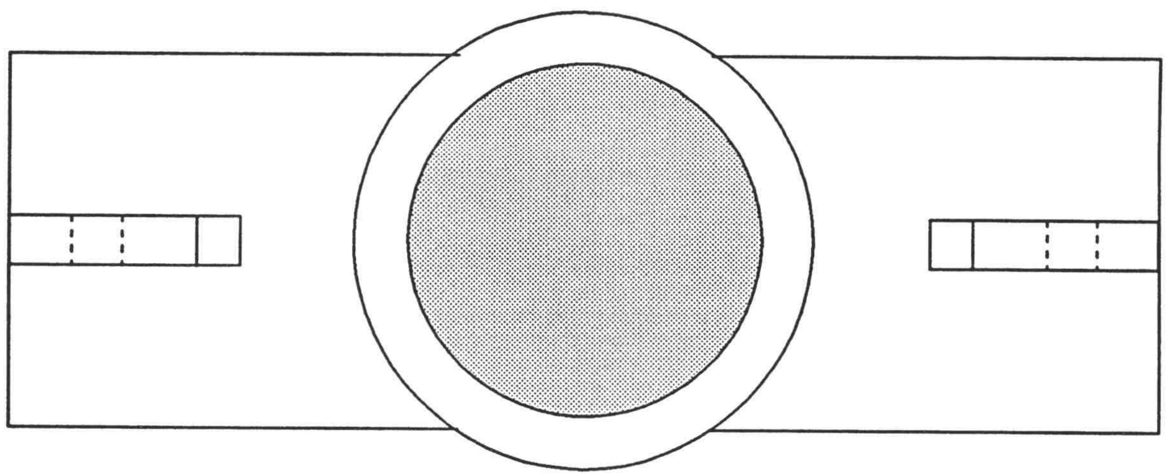


Figure 4.6. Shear testing device – top view

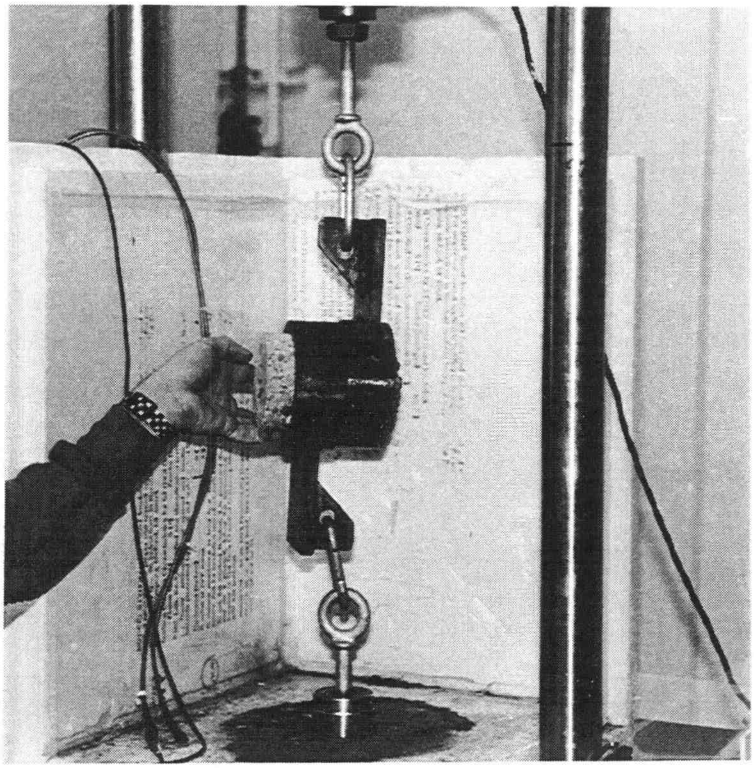


Figure 4.7. Photo of shear test setup

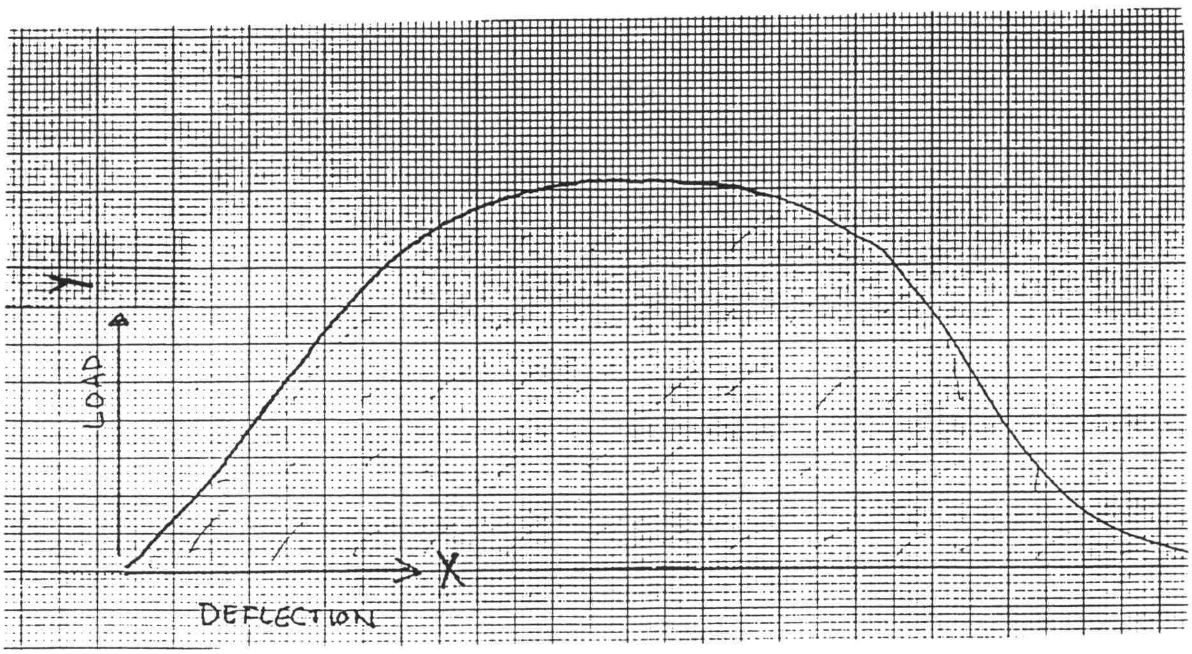


Figure 4.8. X-Y plot of test results

tack coat bond until failure. The test results were recorded using an X-Y plotter on a graph sheet. An example of the graphical results are shown in Figure 4.8.

4.4 Test Results – Field Cores

4.4.1 Aggregate Gradation/Asphalt Content/Voids

Tables 4.2 through 4.6 summarize the results from this portion of the project: the core results along with the initial job mix formula (JMF) were produced in ODOT's labs for each project. Figures 4.9 through 4.12 provide a graphical representation of how the gradation between the job mix formula (JMF) and the field cores differ. There seems to be little or no change in the gradations. The small gradation change is not sufficient to suggest any excess pore filling during the life of the project. It would seem to make sense, however, that the gradations for the No. 10 minus sizes would increase in percent passing for the field cores, due to particle infiltration into the pores of the pavement. The pumping effect of tires sucking out the small particles has kept the voids clean. If this were the case, one could hypothesize that the gradations for the BWT and shoulder cores would actually have a higher number of fines, as these pavement areas are not subject to the fines being pumped as readily as inside the wheel tracks.

4.4.2 ECS

The results of the ECS testing are shown in Tables 4.7 and 4.8. The five areas of data reported are ECS MR modulus, ECS MR ratio, visual stripping, coefficient of permeability for water, and coefficient of permeability for air.

Table 4.2. Core data for Murphy Road to Lava Butte

Milepost	141.79	141.79	141.79	141.79	Job Mix Formula
Core Location	OWT	IWT	BWT	Shoulder	
Gradation					
1" (25.4 mm)	100		100		100
3/4" (19.0 mm)	98		100		98
1/2" (12.5 mm)	81	Combined	81	Combined	75
3/8" (9.5 mm)	59	with OWT	59	with BWT	56
1/4" (6.35 mm)	30	for test	32	for test	25
#4 (4.75 mm)	21		22		–
#10 (2.00 mm)	12		14		9
#40 (0.41 mm)	6		7		4
#200 (0.075 mm)	1.3		1.1		2.7
Bulk Specific Gravity	2.13	1.93	2.04	1.93	2.36
Rice Specific Gravity (JMF)	2.535	2.535	2.535	2.535	2.535
Air Voids (%)	16.0	23.9	19.5	23.9	6.9
Asphalt Cement Information					
Asphalt Content (%)	4.2	Combined	4.2	Combined	5.0
Penetration, 25°C (dmm)	50	with OWT	30	with OWT	Chevron
Kinematic Viscosity, 135°C (cS)	806	for test	1179	for test	MAC-45
Absolute Viscosity, 60°C (P)	6710		15450		Lime Treat

Table 4.3. Core data for Jumpoff Joe to N. Grants Pass

Milepost	61.38	61.38	61.38	61.38	Job Mix Formula
Core Location	BWP	OWP	IWT	Shoulder	
Gradation					
1" (25.4 mm)	100	100	100	100	100
3/4" (19.0 mm)	93	93	94	92	94
1/2" (12.5 mm)	65	68	66	67	66
3/8" (9.5 mm)	47	48	45	47	39
1/4" (6.35 mm)	27	28	26	27	24
#4 (4.75 mm)	20	22	21	22	-
#10 (2.00 mm)	13	15	14	14	12
#40 (0.41 mm)	8	9	8	8	7
#200 (0.075 mm)	4	4.3	4.3	4.1	3.9
Bulk Specific Gravity	2.2	2.21	2.24	2.15	2.46
Rice Specific Gravity (JMF)	2.635	2.635	2.635	2.635	2.635
Rice Specific Gravity (ECS Cores)	2.616	2.616	2.616	2.616	NA
Air Voids (%)	16.5	16.1	15.0	18.4	6.6
Air Voids (%)	15.9	15.5	14.4	17.8	6.6
Asphalt Cement Information					
Asphalt Content (%)	4.3	5.1	4.8	5	5
Penetration, 25°C (dmm)	32	37	41	39	Chevron PBA-5
Kinematic Viscosity, 135°C (cS)	740	736	696	715	0.5% PaveBond
Absolute Viscosity, 60°C (P)	7330	7410	7030	6850	Lime Treat

Table 4.4. Core data for E. Pendleton to Emigrant Hill

Milepost	215	215	215	215	Job Mix Formula
Core Location	OWT	Shoulder	IWT	BWT	
Gradation					
1" (25.4 mm)	100		100		100
3/4" (19.0 mm)	100		96		95
1/2" (12.5 mm)	70	Combined	64	Combined	65
3/8" (9.5 mm)	51	with OWT	46	with IWT	43
1/4" (6.35 mm)	32	for test	28	for test	26
#4 (4.75 mm)	24		22		–
#10 (2.00 mm)	13		12		12
#40 (0.41 mm)	5		5		6
#200 (0.075 mm)	1.7		2.5		3.2
Bulk Specific Gravity	2.07	1.98	2.13	2.04	2.153
Rice Specific Gravity (JMF)	2.493	2.493	2.493	2.493	2.493
Rice Specific Gravity (ECS Core)	2.500	2.500	2.500	2.500	
Air Voids (%) (JMF)	17.0	20.6	14.6	18.2	13.6
Air Voids (%) (ECS Core)	17.2	20.8	14.8	18.4	6.9
Asphalt Cement Information					
Asphalt Content (%)	4.2	Combined	3.2	Combined	6.0
Penetration, 25°C (dmm)	47	with OWT	59	with IWT	Columbia
Kinematic Viscosity, 135°C (cS)	1141	for test	938	for test	PBA-6
Absolute Viscosity, 60°C (P)	8070		5270		Lime Treat

Table 4.5. Core data for Hayesville to BattleCreek

Milepost	150.73	150.73	150.73	150.73	Job Mix Formula
Core Location	OWT	Shoulder	IWT	BWT	
Gradation					
1" (25.4 mm)	100	Combined with OWT for test	100	Combined with IWT for test	100
3/4" (19.0 mm)	97		96		93
1/2" (12.5 mm)	68		66		67
3/8" (9.5 mm)	45		44		43
1/4" (6.35 mm)	28		27		23
#4 (4.75 mm)	24		23		–
#10 (2.00 mm)	17		17		10
#40 (0.41 mm)	10		11		5
#200 (0.075 mm)	5.2		6		2.4
Bulk Specific Gravity	1.91	2.17	2.11	1.65	2.28
Rice Specific Gravity (JMF)	2.469	2.469	2.469	2.469	2.469
Air Voids (%)	22.6	12.1	14.5	33.2	7.6
Asphalt Cement Information					
Asphalt Content (%)	4.1	Combined with OWT for test	4.1	Combined with IWT for test	5.5
Penetration, 25°C (dmm)	34		48		Chevron AC-30
Kinematic Viscosity, 135°C (cS)	1260		994		Lime Treat
Absolute Viscosity, 60°C (P)	32000		21400		

Table 4.6. Core data for Crater Lake Highway

Milepost	83.1	83.1	83.1	83.1	Job Mix Formula
Core Location	IWT	BWT	Shoulder	OWT	
Gradation					
1" (25.4 mm)	100	100	100	100	
3/4" (19.0 mm)	100	95	95	95	Specifications not known
1/2" (12.5 mm)	83	81	75	79	
3/8" (9.5 mm)	63	62	60	62	
1/4" (6.35 mm)	38	38	37	38	
#4 (4.75 mm)	24	25	24	24	
#10 (2.00 mm)	14	14	13	14	
#40 (0.41 mm)	11	10	9	10	
#200 (0.075 mm)	5.8	5.2	5	5.4	
Bulk Specific Gravity	1.84	1.9	1.88	1.91	
Rice Specific Gravity (JMF)					
Air Voids (%)					
Asphalt Cement Information					
Asphalt Content (%)	2.5	2.8	2.7	2.6	
Penetration, 25°C (dmm)	23	Not enough for test	15	19	
Kinematic Viscosity, 135°C (cS)	1080		7403	1430	
Absolute Viscosity, 60°C (P)	18300		39800	29800	

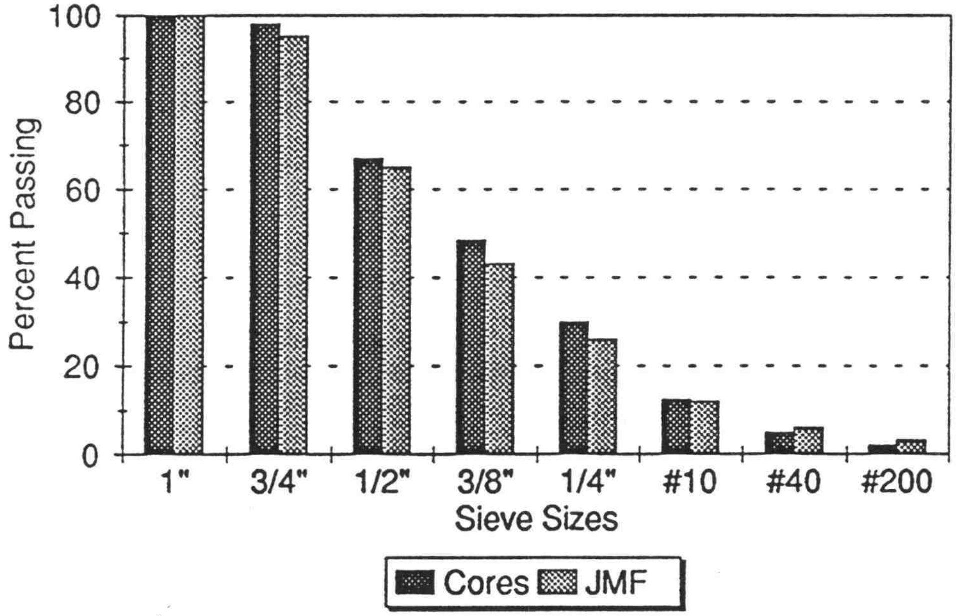


Figure 4.9. Murphy Road to Lava Butte gradation changes (1" = 25.4mm)

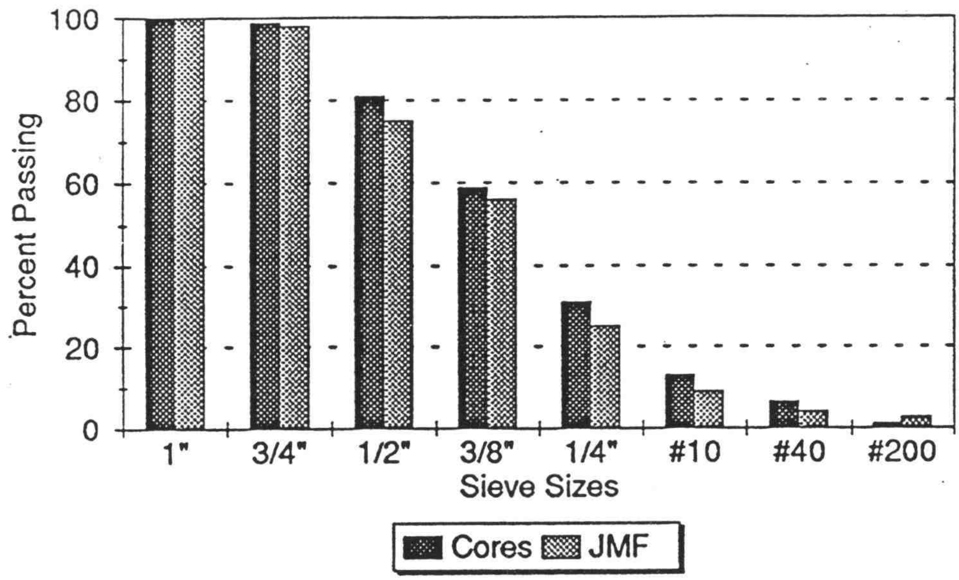


Figure 4.10. Jumpoff Joe to N. Grants Pass gradation changes (1" = 25.4mm)

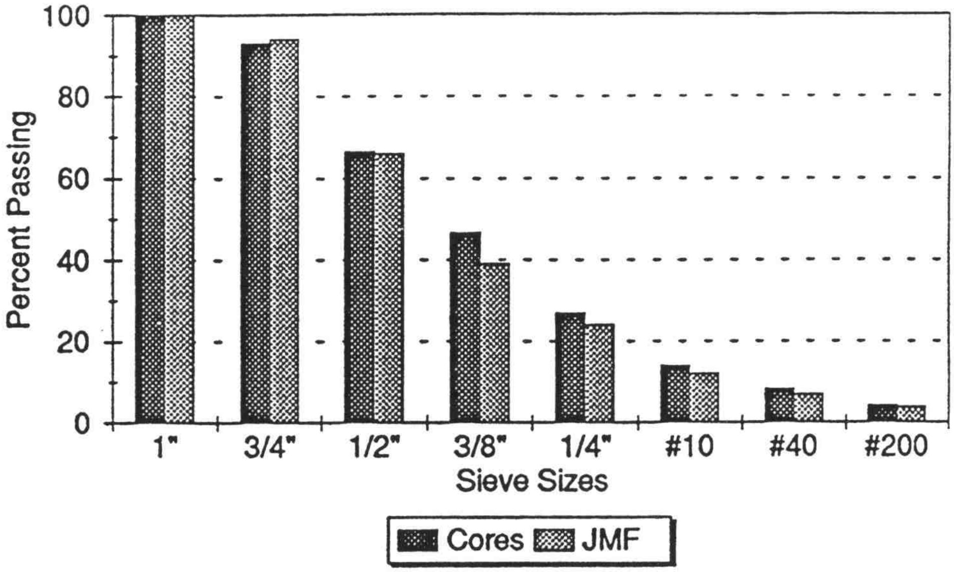


Figure 4.11. E. Pendleton to Marquam Hill gradation changes (1" = 25.4mm)

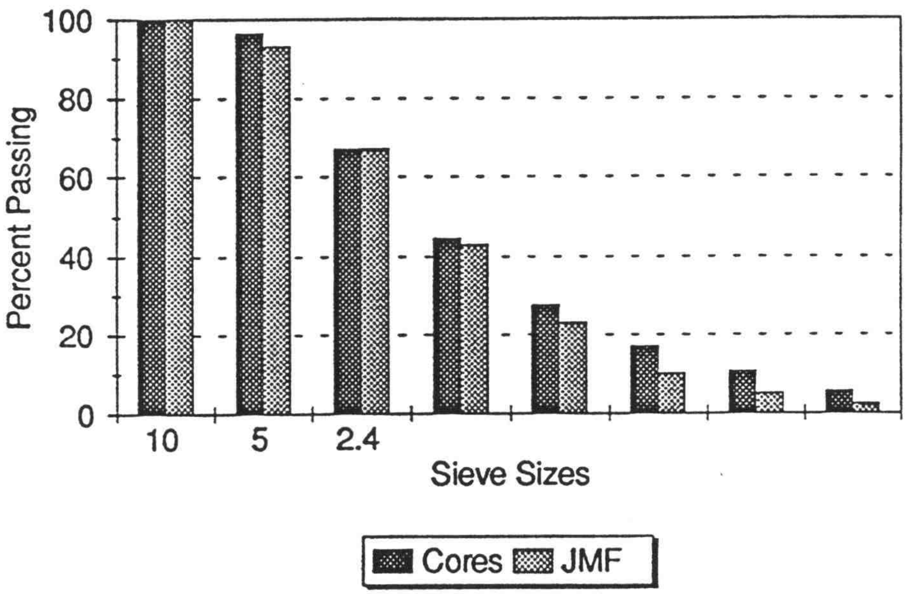


Figure 4.12. Hayesville to BattleCreek gradation changes (1" = 25.4mm)

Table 4.7. ECS results: I-5 (Jumpoff Joe to N. Grants Pass)

ECS Cycle	Sample ID	ECS Modulus (ksi) (MPa)	ECS MR	Stripping (%)	Coefficient of Permeability K (cm/s) (water)	Coefficient of Permeability K (cm/s) (air)
Initial	J1PP	229.2 (1580)	1.00	0 - 5	1.03E-03	3.8E-05
First		226.0 (1558)	0.99		7.66E-04	
Second		222.1 (1531)	0.97		1.08E-03	
Third		271.1 (1869)	1.18		9.58E-04	
Initial	J2PP	370.7 (2556)	1.00	0 - 5	5.80E-04	Impermeable
First		304.1 (2097	0.82		6.31E-04	
Second		294.3 (2029)	0.79		7.84E-04	
Third		291.3 (2008)	0.79		4.48E-04	
Initial	J3PP	720.7 (4969)	1.00	5 - 10	1.05E-03	Impermeable
First		414.2 (2856)	0.57		5.21E-04	
Second		412.0 (2840)	0.57		1.19E-03	
Third		413.4 (2850)	0.57		9.01E-04	
Initial	J4PP	212.3 (1464)	1.00	5 - 10	2.05E-03	2.3E-05
First		181.1 (1249)	0.85		2.41E-03	
Second		171.5 (1182)	0.81		2.21E-03	
Third		173.5 (1196)	0.82		2.73E-03	

Table 4.7. ECS results: I-5 (Jumpoff Joe to N. Grants Pass) (continued)

ECS Cycle	Sample ID	ECS Modulus (ksi) (MPa)	ECS MR	Stripping (%)	Coefficient of Permeability K (cm/s) (water)	Coefficient of Permeability K (cm/s) (air)
Initial	J5PP	489.0 (3372)	1.00	0 - 5	3.40E-05	Impermeable
First		347.1 (2393)	0.71		4.37E-03	
Second		369.1 (2545)	0.75		3.08E-03	
Third		370.0 (2551)	0.76		4.64E-03	
Initial	J6PP	492.7 (3397)	1.00	0 - 5	4.44E-03	5.9E-05
First		316.5 (2182)	0.64		6.06E-03	
Second		292.7 (2018)	0.89		1.49E-03	
Third		305.2 (2104)	0.62		5.72E-03	
Initial	J7PP	307.1 (2117)	1.00	5 - 10	1.38E-03	5.6E-05
First		263.1 (1814)	0.86		1.22E-03	
Second		260.1 (1793)	0.85		1.22E-03	
Third		254.4 (1754)	0.83		8.88E-04	
Initial	J8PP	405.5 (2796)	1.00	5 - 10	2.96E-03	5.7E-05
First		350.0 (2413)	0.86		1.88E-03	
Second		334.0 (2303)	0.82		2.42E-03	
Third		336.7 (2321)	0.83		4.29E-03	

Table 4.8. ECS results: I-84 (E. Pendleton to Emigrant Hill)

ECS Cycle	Sample ID	ECS Modulus (ksi) (MPa)	ECS MR	Visible Stripping (%)	Coefficient of Permeability K (cm/s) (water)	Coefficient of Permeability K (cm/s) (air)
Initial	P1PP	522.8 (3605)	1.00	0 - 5	1.04E-03	5.5E-05
First		272.3 (1877)	0.52		1.42E-03	
Second		288.7 (1991)	0.55		1.45E-03	
Third		245.5 (1693)	0.47		1.32E-03	
Initial	P2PP	305.3 (2105)	1.00	5 - 10	2.86E-03	6.0E-05
First		185.1 (1276)	0.61		2.56E-03	
Second		203.7 (1404)	0.67		2.90E-03	
Third		172.6 (1190)	0.57		1.76E-03	
Initial	P4PP	280.3 (1933)	1.00	0 - 5	7.88E-04	4.8E-05
First		153.4 (1058)	0.55		1.10E-03	
Second		197.2 (1360)	0.70		9.14E-04	
Third		183.9 (1268)	0.66		1.15E-03	
Initial	P5PP	325.5 (2244)	1.00	5 - 10	1.47E-03	6.7E-05
First		265.0 (1827)	0.81		1.47E-03	
Second		208.0 (1434)	0.64		1.25E-03	
Third		216.5 (1493)	0.67		1.99E-03	

Table 4.8. ECS results: I-84 (E. Pendleton to Emigrant Hill) (continued)

ECS Cycle	Sample ID	ECS Modulus (ksi) (MPa)	ECS MR	Visible Stripping (%)	Coefficient of Permeability K (cm/s) (water)	Coefficient of Permeability K (cm/s) (air)
Initial	P6PP	226.0 (1558)	1.00	0 - 5	1.17E-03	4.3E-05
First		180.0 (1241)	0.81		1.64E-03	
Second		155.0 (1069)	0.64		1.82E-03	
Third		172.5 (1189)	0.67		1.90E-03	
Initial	P7PP	269.1 (1855)	1.00	0 - 5	2.31E-03	6.9E-05
First		213.5 (1472)	0.80		2.04E-03	
Second		199.4 (1375)	0.69		2.95E-03	
Third		206.4 (1423)	0.76		2.35E-03	
Initial	P8PP	196.6 (1356)	1.00	5 - 10	3.44E-03	5.7E-05
First		146.7 (1011)	0.79		2.66E-03	
Second		147.2 (1015)	0.74		1.94E-03	
Third		157.0 (1082)	0.77		2.34E-04	

The ECS MR modulus and ratio are the main focus of the pass/fail criteria for the ECS test procedure. For ECS testing of porous pavements the failure criteria of a sample is defined as a ratio of less than 0.75 (Terrel et al., 1993). The ratio is the ECS modulus for the cycle divided by the ECS modulus for the initial conditions. Figures 4.13 and 4.14 provide a graphical representation of the ECS modulus ratio for each cycle. If the 0.75 ratio failure criteria is used, it would appear that the samples P1PP, P2PP, P4PP, P5PP, P6PP, J3PP, and J5PP all failed the test. There would appear to be some possible water sensitivity problems for the Pendleton project, since 5 out of 7 of the core samples exhibited water sensitivity after being in the field a short while (project ended in spring of 1993, and samples taken in summer of 1993).

The I-5 (Jumpoff Joe - N. Grants Pass) project exhibited potential water sensitivity on only 2 out of 8 samples for a pavement that was a year older than the Pendleton project. The pavement at the I-84 (E. Pendleton- Emigrant Hill) project may have problems with stripping in the future.

Degree of Visual Stripping was also measured from the ECS cores. After a sample had been subject to all four cycles of the ECS test procedure, it was split open diametrally and the stripping of the asphalt from the aggregate was checked visually using the degree of stripping guidelines shown in Figure 4.15. The visual stripping is measured in quantities of severeness where 0-5 means that there was zero to five percent stripping noticeable upon examination. The results for the visual stripping are shown alongside the rest of the ECS data in Tables 4.7 and 4.8. It would make sense that a sample which has shown some problem due to water sensitivity from the ECS test would have more bond loss between the asphalt and aggregate and thus more stripping. Surprisingly, this does

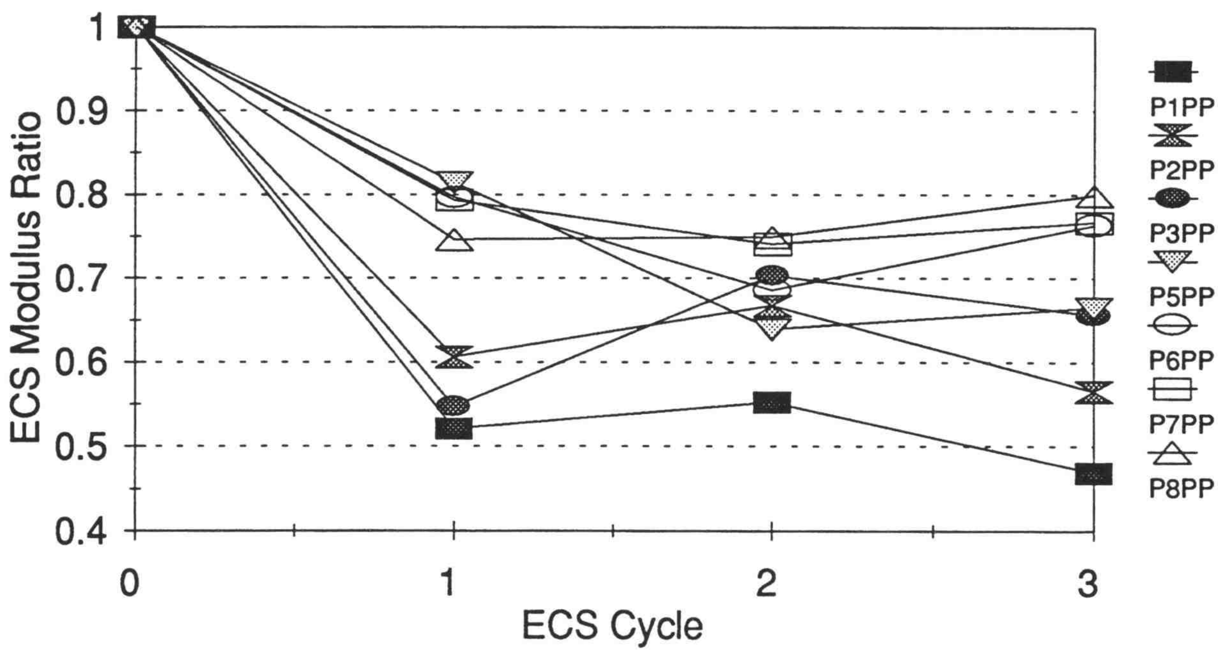


Figure 4.13. Pendleton ECS modulus changes

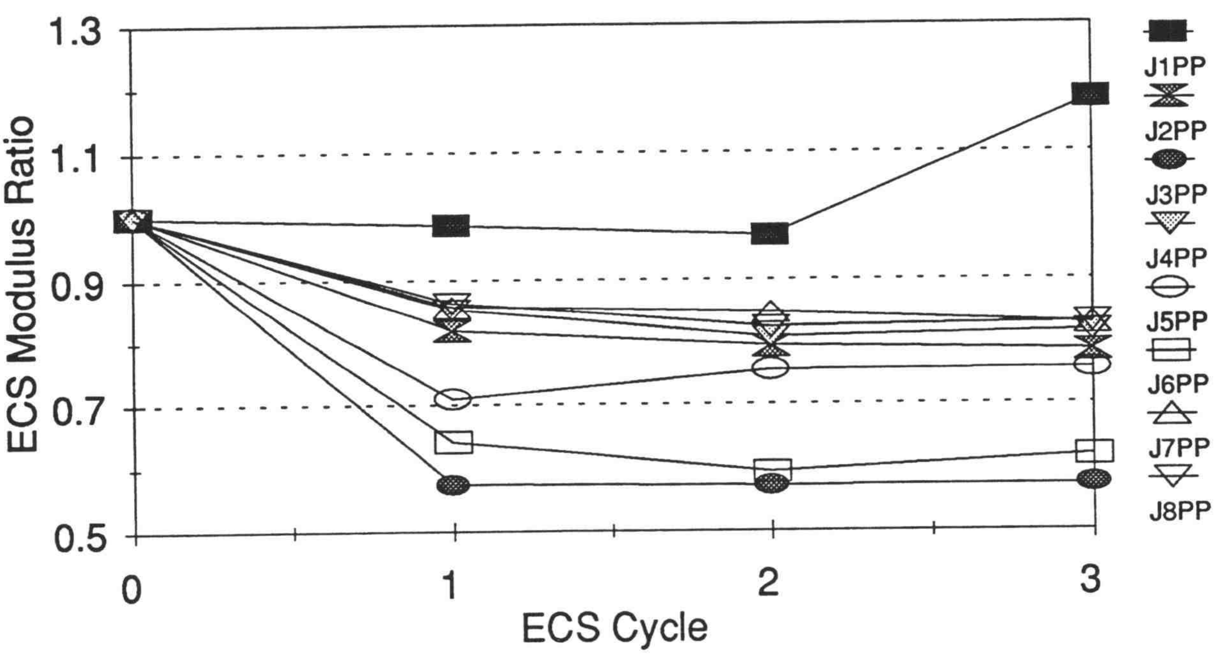


Figure 4.14. Jumpoff Joe ECS modulus changes

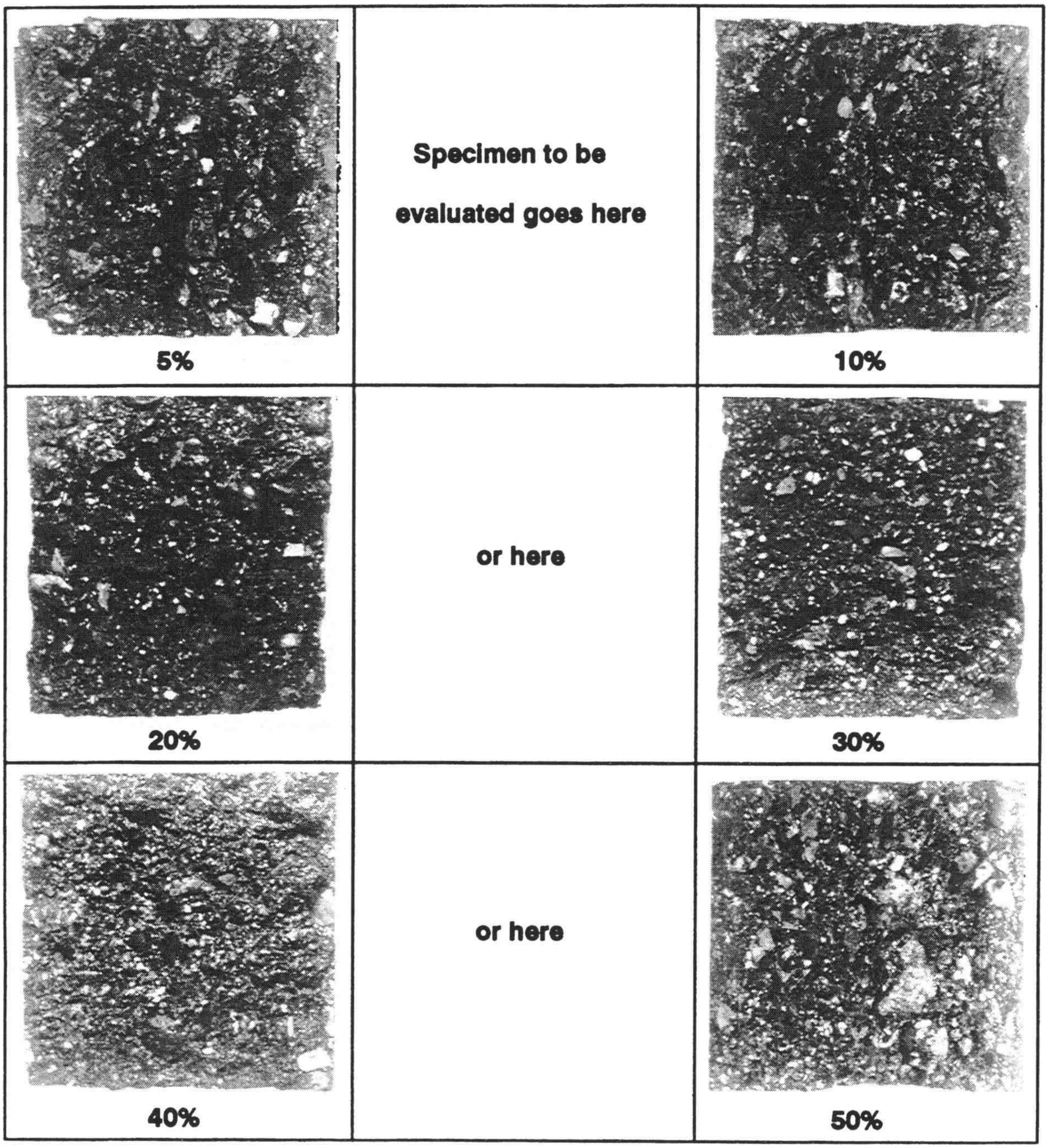


Figure 4.15. Visual stripping guidelines (after Allen, 1993)

not seem to be so when looking at the data. The Jumpoff Joe - N. Grants pass project displayed more water sensitive samples, yet had 4 out of 8 samples showing stripping in the 5-10 percent range. The E. Pendleton - Emigrant Hill project had 5 out of 7 samples exhibit water sensitivity as a result of the ECS modulus, yet had only 3 out of 7 samples with stripping in the 5-10 percent range.

Figures 4.16 and 4.17 provide a graphical representation of the water permeability tests performed on the ECS specimen. The calculation method suggested by Allen (1993) was used to calculate the coefficient of permeability k in cm/s. The figures display the results for the specimen and any changes per cycle can easily be noted by watching the trends on the graphs. The graphs show how sporadic the k values are for these data. As stated by Allen (1993), the piping of the ECS permeameter does not provide true permeability values. Due to this information and the results shown, there would seem to be little confidence in the results. The value of k could be of use in understanding whether or not the water permeability of a sample would change as the water sensivity of the sample.

4.4.3 Laboratory Shear Test

Data from the shear test were analyzed for three factors: 1) load failure; 2) amount of shear until failure; and 3) the total energy required for failure. Table 4.9 presents the summary for this data. For each tack coat rate, two tests were performed on the unaged and two on the aged specimens. Figures 4.18 and 4.19 present this data in a graphical mode, where the values from the repeated tests were averaged. These graphs display how the unaged and aged specimens reacted during the test. The increased

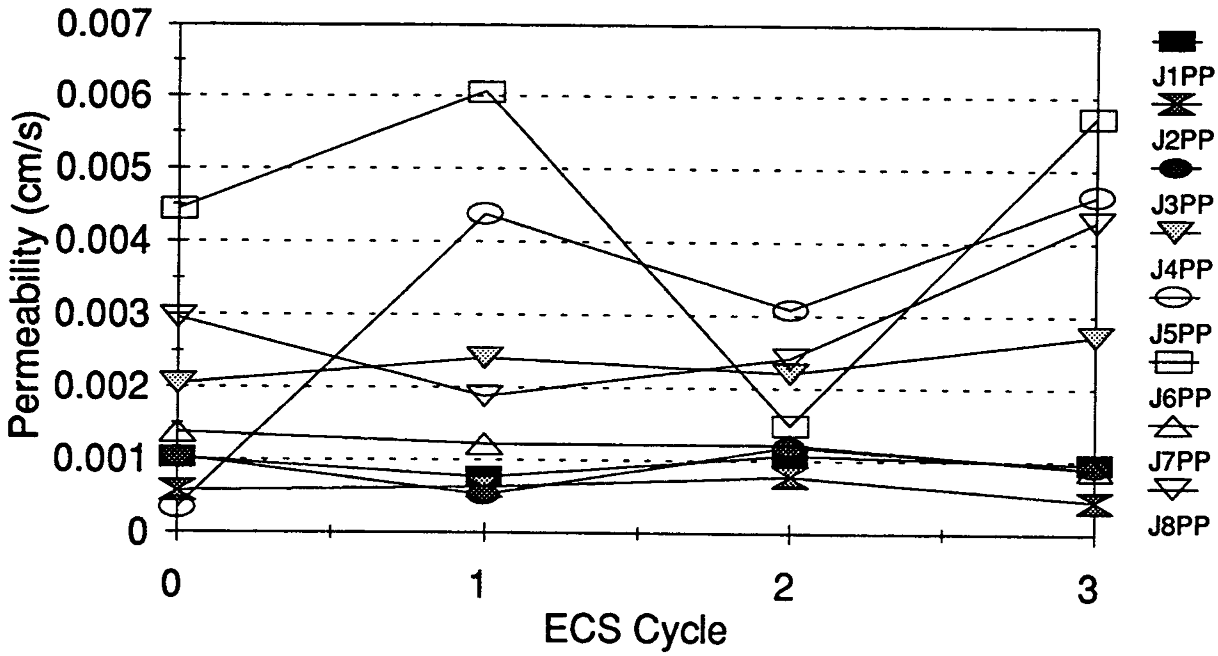


Figure 4.16. Water permeability changes - Jumpoff Joe

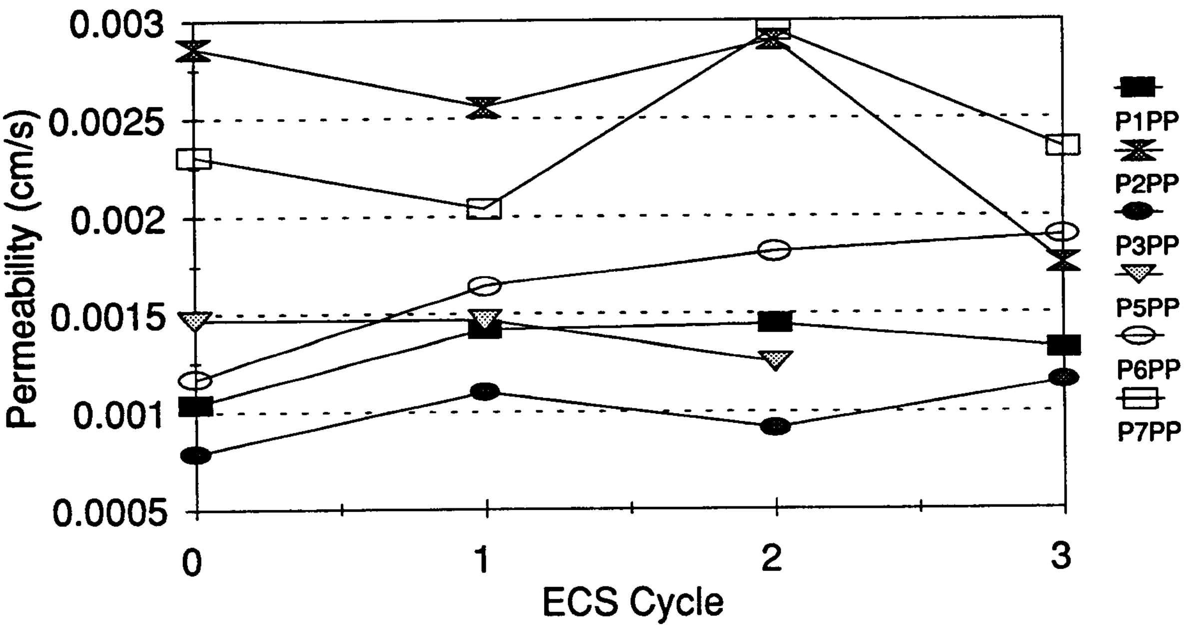


Figure 4.17. Water permeability changes - Pendleton

Table 4.9. Results of shear testing experiment

Tack Coat Rate		Condition Aged (Y or N)	Failure Load		Max Shear @ Max Load		Total Energy	
(gal/yd²)	(ℓ/m²)		(lb)	(kN)	(in)	(cm)	(lb·in)	(kN·n)
0.05	0.23	N	108	400	0.95	2.4	2300	403
0.05	0.23	N	106	470	0.75	1.9	1500	266
0.1	0.45	N	125	560	0.95	2.4	2500	432
0.1	0.45	N	123	550	0.95	2.4	2400	424
0.15	0.68	N	83	370	0.70	1.8	1100	194
0.15	0.68	N	64	280	0.44	1.1	330	58
0.2	0.91	N	62	270	0.70	1.8	460	81
0.2	0.91	N						
0.05	0.23	Y	172	760	0.92	2.3	3400	602
0.05	0.23	Y	180	800	0.72	1.8	2400	421
0.1	0.45	Y	161	710	0.82	2.1	2800	492
0.1	0.45	Y	176	780	0.92	2.3	3600	638
0.15	0.68	Y	150	670	0.91	2.3	3300	575
0.15	0.68	Y	110	490	0.73	1.9	1500	259
0.2	0.91	Y	99	440	0.94	2.4	2200	391
0.2	0.91	Y	154	680	0.88	2.2	3000	526

Some useful information came out as a result of the tack coat shear testing experiment. The results show that for the normal CSS-1 tack coat emulsion, a 0.10 gal/yd² (0.45 l/m²) spray rate is optimum for a PCC to F-mix bond.

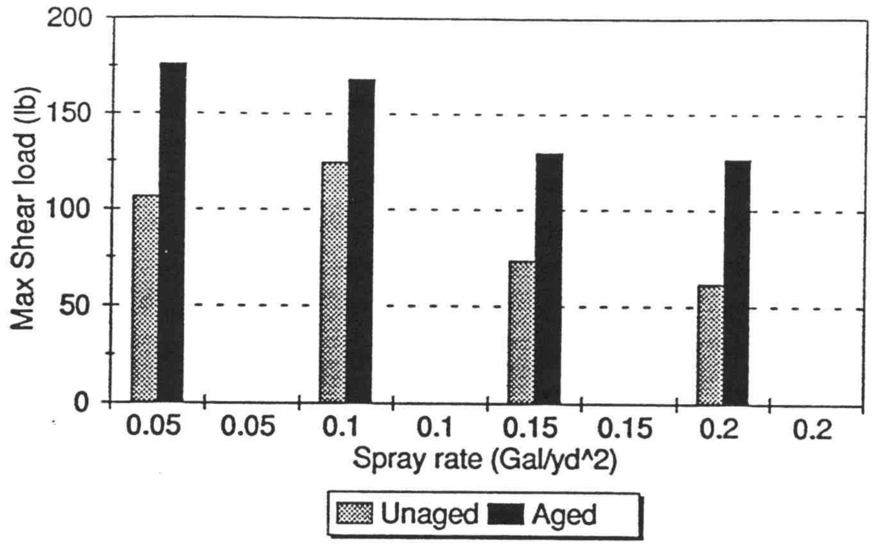


Figure 4.18. Shear load vs. spray rate

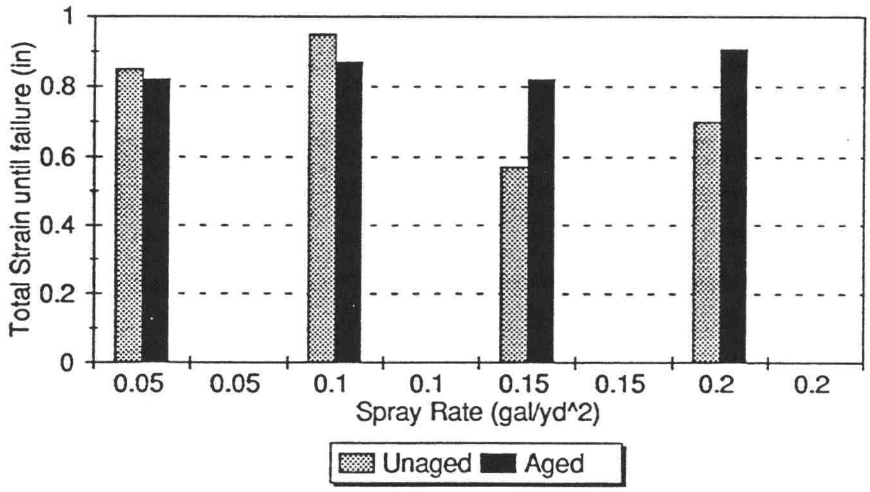


Figure 4.19. Shear strain to failure vs. spray rate

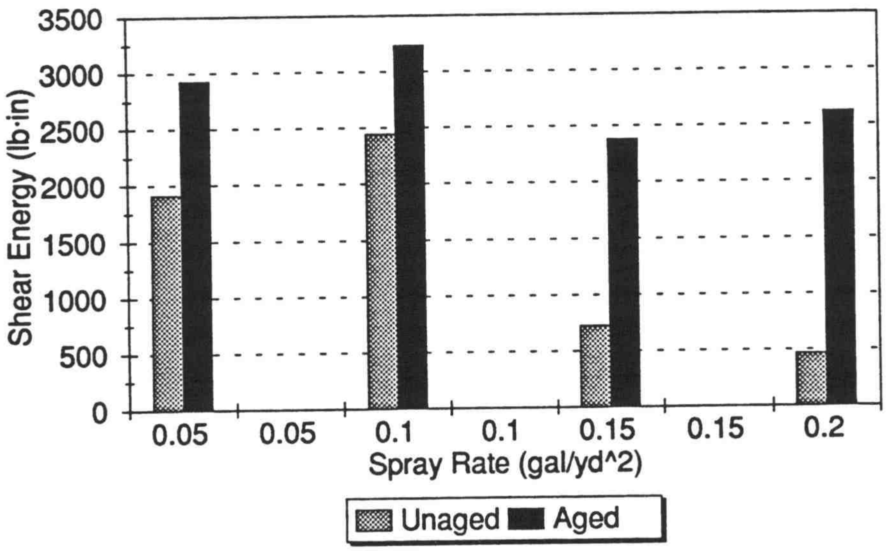


Figure 4.20. Average shear energy vs. spray rate

stiffness of the binder tack coat on the aged specimen is easily shown here, through the increased energy required to shear the specimen, and the higher shear force. It would appear from both the aged and unaged specimen that the 0.10 gal/yd^2 (0.45 l/m^2) spray rate provided the most shear resistance in all tests except for the maximum shear load for the aged specimen. The total failure strain for the aged spray rates are surprisingly equal, around 0.8 in(20 cm). Figure 4.20 shows how the small amount of energy required to shear the unaged 0.15 and 0.20 gal/yd^2 (0.68 and 0.91 l/m^2) specimens shows how high traffic areas with lots of load energy could fail quicker at spray rates other than 0.10 gal/yd^2 (0.45 l/m^2).

4.5 Summary of Results

The results from the laboratory data provide insight into the properties of porous mixes. Significant fingings from ECS testing, core gradation, asphalt properties, and tack coat shear testing are discussed below.

The ECS tests show that the pavements for the E. Pendleton - Emigrant Hill project might have some future water sensitivity problems. This would seem to agree with the JMF design, as the Pendleton project showed low Index of Retained Strength (IRS) values. The JMF IRS data for the Jumpoff Joe project provided an IRS above the 70% line which concurs with the ECS results.

The results from the core testing for porous mixes showed surprisingly few changes in the gradation curves from the JMF. This would indicate that the infiltration of fines into the porous pavement is not significant. Also, the asphalt properties do not show problems with aging and embrittlement.

5.0 NOISE STUDY

This chapter covers the information gathered during the noise study portion of the porous pavements project. Three sections were evaluated for noise properties along Oregon's Interstate-5 freeway. Because the sound measurements had to follow a certain format that allowed comparisons of various pavement types, special sections were studied in this section of the project. Table 5.1 provides information on these sites.

5.1 Test Methods

Two types of noise measurements were taken. The first was roadside noise and the second was interior vehicle noise. Noise measurement testing for roadside noise can often be a difficult task because varying geometric configurations can cause severe changes in the acoustic characteristics from site to site. In order to remove any geometric variables, test sites were chosen where fairly new pavement types existed, and overlays of F-mix were planned in the near future. Tests were then performed before and after overlay at identical locations.

Noise measurements for the roadside study were taken in four 1-hr test periods in an attempt to filter out any anomalies in the data and to make appropriate traffic count matches. These measurements were taken to determine both an A-weighted dB(A) level, and a 1/3 octave band spectrum. Traffic counts were taken during each hour period for large trucks, medium trucks, and autos. Figure 5.1 gives an example of the normal setup for the microphone in relation to the roadway. For all sites in this study the noise measurements were taken 50 feet from the centerline of the closest directional travel lanes. Measurements were performed with a Brüle and Kjær 2221 sound level meter (Figure 5.2) to determine the A-weighted Leq, and a Rion SA-27 1/3 octave band analyzer (Figure 5.3)

Table 5.1. Noise study site locations

Project Name	Limits	Mix Types	ADT (1992)
Halsey to Lane County Line	203.6 - 216.6	F-mix over 1993 B-mix	25500
BattleCreek to N. Jefferson	244-4 - 249.9	F-mix over 1993 B-mix	39800
Seven Oaks to Jackson	28.9 - 35.8	F-mix over 1994 B-mix over old PCC	33200

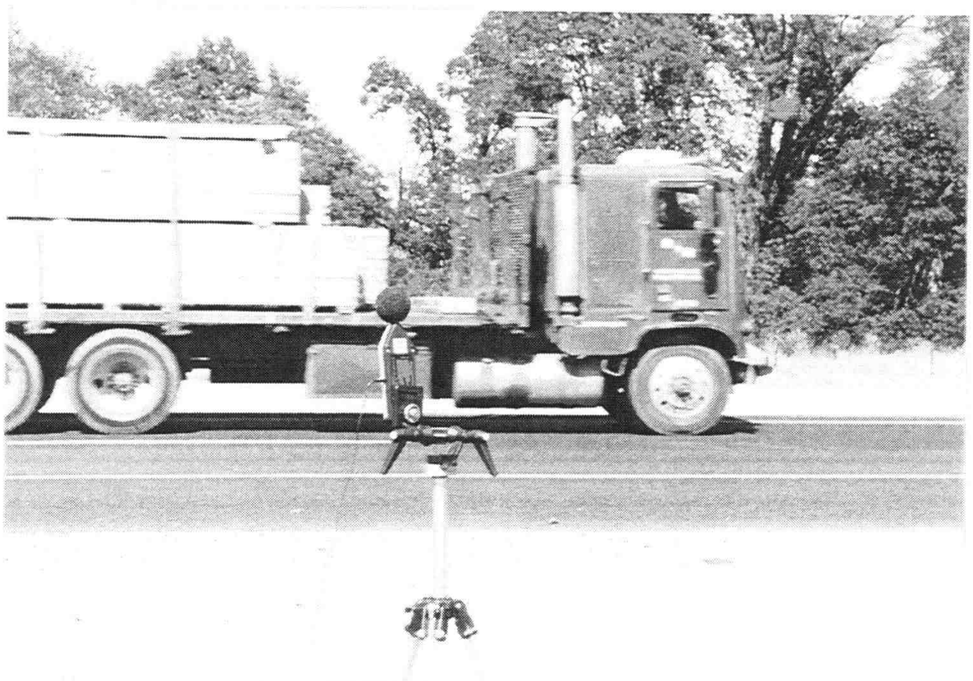


Figure 5.1. Typical setup for noise study

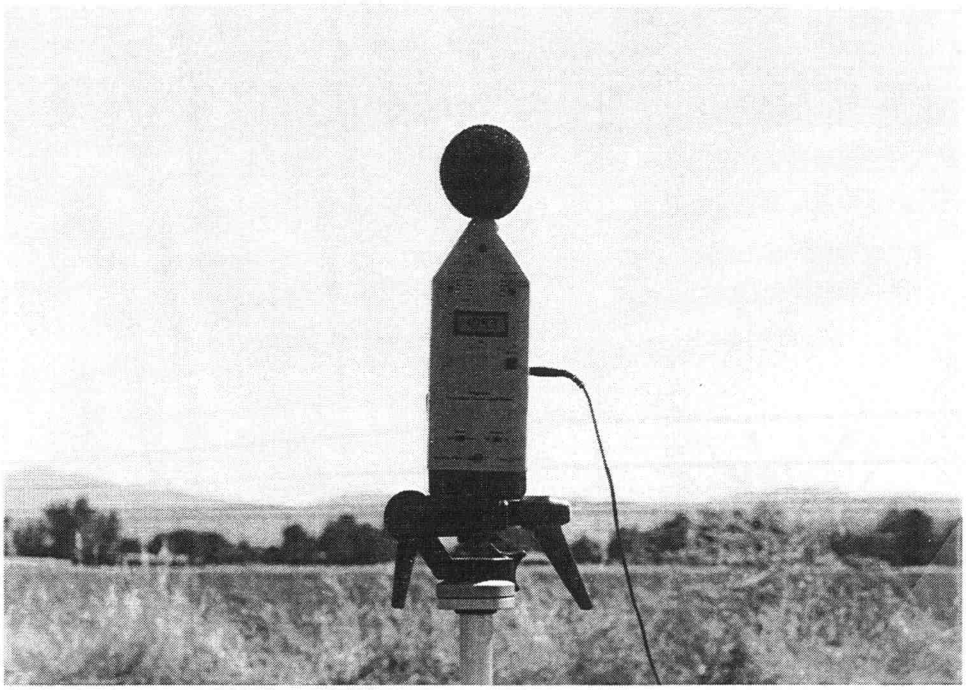


Figure 5.2. Photo of Brüle and Kjær 221 sound level meter

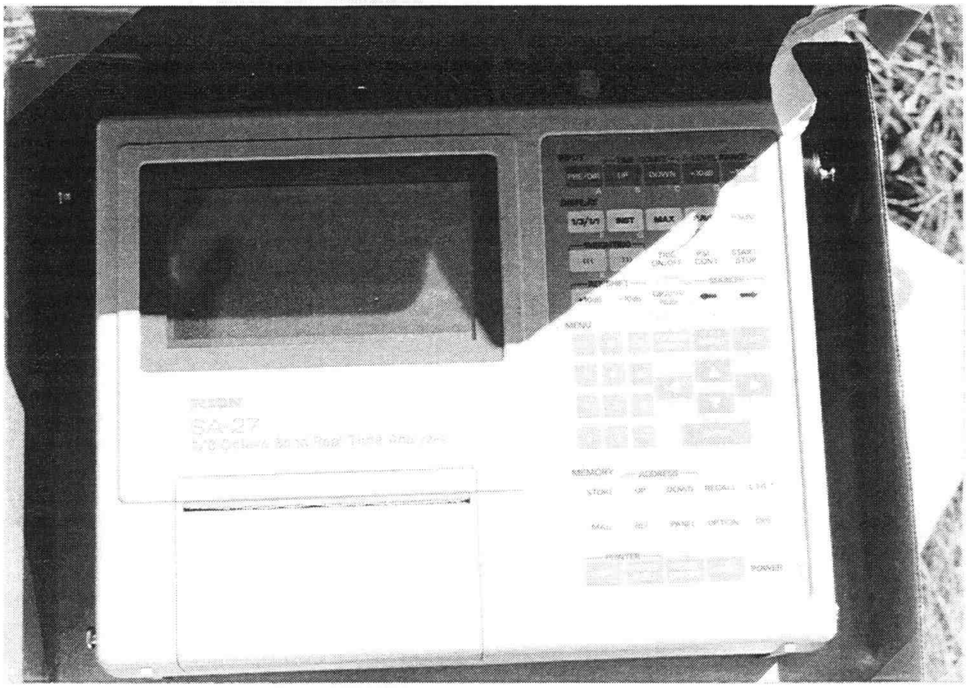


Figure 5.3. Photo of Rion SA-27 1/3 octave band analyzer

for the noise spectrum. All equipment was calibrated with a 1000 Hz calibrator at 93.8 dB(A) prior to measurements.

The interior noise measurements were taken inside a 1993 Dodge Caravan. The microphone was placed in the middle seat of the vehicle, at an approximate height of ear. Tests were performed at 65 mph (100 km/h). Care was taken that there were no heavy trucks travelling alongfside the van during measurements. Noise levels both for an A weighted decibel level and a 1/3 octave frequency spectrum were taken for this format as well. Length of measurement was approximately 2 minutes for each site. There were approximately 3 measurements taken at each site, and these measurements were then calculated into an Leq hourly equivalent.

5.2 Results

The results from the noise study were analyzed for changes in the A-weighted sound levels for both an Leq reading and 1/3 octave band analysis. Analysis for the roadside noise was performed to try to find traffic volumes that were comparable for a single hour, or a combination of hours across the road surface types. The model used for comparison was the FHWA Traffic Noise Prediction Model, Stamina 2.0 (FHWA, 1982). The prediction model computed traffic noise levels by using the highway traffic volumes and speeds that were observed during the measurements, distance to the roadway centerline, and the physical characteristics of the area. The input variables for this program include geometric characteristics of the site and traffic volumes for near and far lanes. The output is a dB(A) Leq level based on the program's built-in prediction model. The Stamina 2.0 Traffic Noise prediction model was used to compare the theoretical noise levels of two comparative traffic characteristics. The difference in the predicted noise levels provided an estimate of the accuracy (in dB(A)) that would result from comparing noise levels with varying traffic situations. The level of accuracy criteria set for this analysis was 0.5 dB(A).

The roadside data was analyzed for traffic "matches" and these matches were then compared. Decibel addition is addition using the logarithmic decibel scale. Graphical results are shown for each traffic match in Appendix B. The possible combinations were sought out for comparisons of old PCC, new B-mix and new F-mix (Seven Oaks to Jackson); year-old B-mix to year-old F-mix (Halsey Interchange to Lane County Line); and a comparison between year-old B-mix and new F-mix (BattleCreek to N. Jefferson). Matches were possible for combinations of hourly traffic columns, and these sets were decibel averaged into the appropriate hourly Leq level (i.e. Leq (2-hr), Leq (3-hr), or Leq (4-hr)). Tables 5.2 to 5.4 show the traffic characteristics and Stamina 2.0 results from each traffic match used.

Tables 5.5 to 5.8 show the results of the A-weighted Leq results for the roadside analysis. In all instances the noise levels are lower for F-mix than either B-mix or the older PCC pavement. As stated in an earlier chapter, the normal range of human hearing can detect a 3 dB(A) change in sound pressure. This means that the change in sound levels for PCC to F-mix pavement is significant for the Seven Oaks to Jackson project, but this same project shows a change in noise level in a range or only about 1 - 2 dB(A) between the new B-mix pavement and the F-mix pavement. Though this does imply an improvement, it is not significant if the 3 dB(A) criteria is used. The results from the BattleCreek to N. Jefferson and Halsey to Lane County Line projects show a reduction

Table 5.2. MP 34 Seven Oaks to Jackson Street (Medford), Stamina traffic matches

	Study Side	NorthBound auto	NorthBound med	NorthBound heavy	SouthBound auto	SouthBound med	SouthBound heavy	Stamina dB(A) diff
OLD PCC hour 1	South	773	72	116	701	44	110	
New B-mix hour 3	South	996	42	93	676	44	108	0.1
OLD PCC hour 1,3	South	1720	129	250	1376	72	212	
New B-mix 2,3	South	1898	80	221	1258	81	211	0.1
OLD PCC hour 1,3,4	South	2650	179	345	1924	95	302	
New B-mix hour 1,3,4	South	2692	124	314	1976	117	302	0.0
OLD PCC 2,3,4	South	2761	173	372	1845	90	307	
New B-mix 2,3,4	South	2892	122	314	1958	83	304	0.1
OLD PCC 1,4	South	1703	122	211	1249	67	200	
New B-mix 3,4	South	1958	77	187	1376	83	201	0.1
OLD PCC 3	North	660	72	122	747	24	91	
New B-mix 1	North	496	54	120	676	29	83	0.4
New B-mix 2	South	934	45	127	582	37	103	
New F-mix 3	South	1033	48	105	790	63	103	0.4
New B-mix 2,3	South	1896	80	221	1258	81	211	
New F-mix 3,4	South	2117	93	210	1414	98	215	0.2
New B-mix 1	North	496	54	120	676	29	83	
New F-mix 2	North	617	58	122	737	44	121	0.3
New B-mix 1,3	North	1075	115	234	1412	84	184	
New F-mix 1,3	North	1208	110	235	1509	116	242	0.1
New B-mix 1,2,3,4	North	2258	209	463	2813	184	374	
New F-mix 1,2,3,4	North	2553	225	469	2989	222	465	0.3
New B-mix 1,2,4	North	1676	148	349	2077	129	273	
New F-mix 1,3,4	North	1936	167	347	2252	178	344	0.3

Table 5.3. Halsey Interchange to Lane County Line, Stamina traffic matches

	Study Side	NorthBound autos	NorthBound med	NorthBound heavy	SouthBound autos	SouthBound med	SouthBound heavy	Stamina dB(A) diff
New B-mix 2	North	903	62	140	1013	28	115	
New F-mix 1	North	1059	73	135	1055	81	145	0.3
New B-mix 4	North	540	26	134	567	13	101	
New F-mix 1	North	1059	73	135	1055	81	145	0.8
Year old B-mix 2	North	903	62	140	1013	28	115	
Year old F-mix 1	South	817	89	205	795	46	143	0.1
Year old B-mix 3	North	737	45	165	851	18	98	
Year old F-mix 2	South	841	87	173	757	42	164	0.1
Year old B-mix 1	North	919	81	151	911	48	133	
Year old F-mix 4	South	880	71	178	806	41	148	0.3

Table 5.4. MP 248 BattleCreek to N. Jefferson, Stamina traffic matches

	Study Side	NorthBoun autos	NorthBoun med	NorthBoun heavy	SouthBound autos	SouthBound med	SouthBound heavy	Stamina dB(A) diff
New B-mix 1	South	1195	65	166	1058	76	132	
New F-mix 1	South	1150	76	208	1090	99	143	0.6
New B-mix 2	South	1506	86	189	1086	74	188	
New F-mix 2	South	1198	95	248	990	130	197	0.5
New B-mix 2,4	South	2962	178	388	2301	134	366	
New F-mix 1,3	South	2341	168	459	2202	243	259	0.3

Table 5.5. Seven Oaks to Jackson (South Bound) – exterior noise data

PCC to B-Mix Leq Levels				
Matches	Leq Time (hrs)	PCC Leq dB(A)	B-Mix Leq dB(A)	Difference dB(A)
1 to 3	1	76.4	69.8	6.6
1,3 to 2,3	2	76.3	70.0	6.3
1,4 to 3,4	2	75.7	70.0	5.7
1,3,4 to 1,3,4	3	75.9	69.7	6.2
2,3,4 to 2,3,4	3	75.9	70.0	5.9
PCC to F-Mix Leq Levels				
Matches	Leq Time (hrs)	PCC Leq dB(A)	F-Mix Leq dB(A)	Difference dB(A)
2,3 to 3,4	2	76.4	68.9	7.5
1 to 4	1	76.4	68.6	7.8
B-Mix to F-Mix Leq Levels				
Matches	Leq Time (hrs)	B-Mix Leq dB(A)	F-Mix Leq dB(A)	Difference dB(A)
2 to 3	1	70.1	69.2	0.9
2,3 to 3,4	2	70.0	68.9	1.1

Table 5.6. Seven Oaks to Jackson (North) - exterior noise data

PCC to B-Mix Leq Levels				
Matches	Leq Time (hrs)	PCC Leq dB(A)	B-Mix Leq dB(A)	Difference dB(A)
3 to 1	1	76.5	70.7	5.9
PCC to F-Mix Leq Levels				
Matches	Leq Time (hrs)	PCC Leq dB(A)	F-Mix Leq dB(A)	Difference dB(A)
1 to 4	1	76.8	69.2	7.5
1,3 to 3,4	2	76.7	69.2	7.4
B-Mix to F-Mix Leq Levels				
Matches	Leq Time (hrs)	B-Mix Leq dB(A)	F-Mix Leq dB(A)	Difference dB(A)
1 to 2	1	70.7	68.9	1.8
1,3 to 1,3	2	70.5	69.1	1.4
1,2,3,4 to 1,2,3,4	4	70.4	69.1	1.4
1,2,4 to 1,3,4	3	70.5	69.2	1.3

Table 5.7. Halsey to Lane County Line – exterior noise data

B-Mix to F-Mix Leq Levels				
Matches	Leq Time (hrs)	B-Mix Leq dB(A)	F-Mix Leq dB(A)	Difference dB(A)
2 to 1	1	73.3	68.8	4.4
4 to 1	1	72.1	68.8	3.3
2,4 to 1,3	2	76.8	72.6	4.2
1-year-old B-mix to 1-year-old F-mix Leq Levels				
Matches	Leq Time (hrs)	B-mix Leq dB(A)	F-mix Leq dB(A)	Difference dB(A)
2 to 1	1	73.3	71.3	2.0
3 to 2	1	73.4	71.9	1.5
1 to 4		73.3	71.4	1.9

Table 5.8. BattleCreek to North Jefferson – exterior noise data

B-Mix to F-Mix Leq Levels				
Matches	Leq Time (hrs)	B-Mix Leq dB(A)	F-Mix Leq dB(A)	Difference dB(A)
2,4 to 1,3	2	76.8	72.6	4.2
1 to 1	1	76.2	72.2	4.0
2 to 2	1	76.9	72.2	4.2

from 4 to 4.5 dB(A) when the one-year-old pavements were overlaid with a new F-mix. A comparison was made with the one-year-old B-mix (northbound) and the one-year-old F-mix (southbound) at the Halsey to Lane County Line project. This comparison was deemed possible as the geometric configurations were fairly close, and the median between lanes was 77 ft (23 m). An average difference of about 1.8 dB(A) was found in this instance.

The 1/3 octave band analysis was used as a method of better understanding the effect of pavement change on the user. It is generally believed that the most sensitive range of human hearing is in the 200 to 6000 Hz range. Although this range varies between individuals, the higher frequencies are usually considered more annoying than the lower levels. The purpose of the 1/3 octave band analysis was to show that this range of frequency sound levels would show an improvement when F-mix pavement was placed as opposed to another pavement type. As the comparison for new F-mix and new B-mix pavements on the north and southbound lanes of the Seven Oaks to Jackson and the comparison of year-old F-mix and B-mix pavements at the Halsey to Lane County Line projects were deemed the most useful projects by the direct pavement to pavement comparison, the frequency study is most useful when these projects are considered.

Figures 5.4 through 5.6 display a frequency spectrum dB(A) difference as a comparison across pavement types. A positive value shows at which frequencies the F-mix pavement is quieter and a negative value represents a lower dB(A) level for the B-mix pavement. Figures 5.4 and 5.5, which are from the Seven Oaks to Jackson project, show a 4 dB(A) to 1 dB(A) improvement for F-mix pavement in the 500 to 6000 Hz range, with all other ranges showing an improvement for B-mix pavement from 9 dB(A) to 1 dB(A).

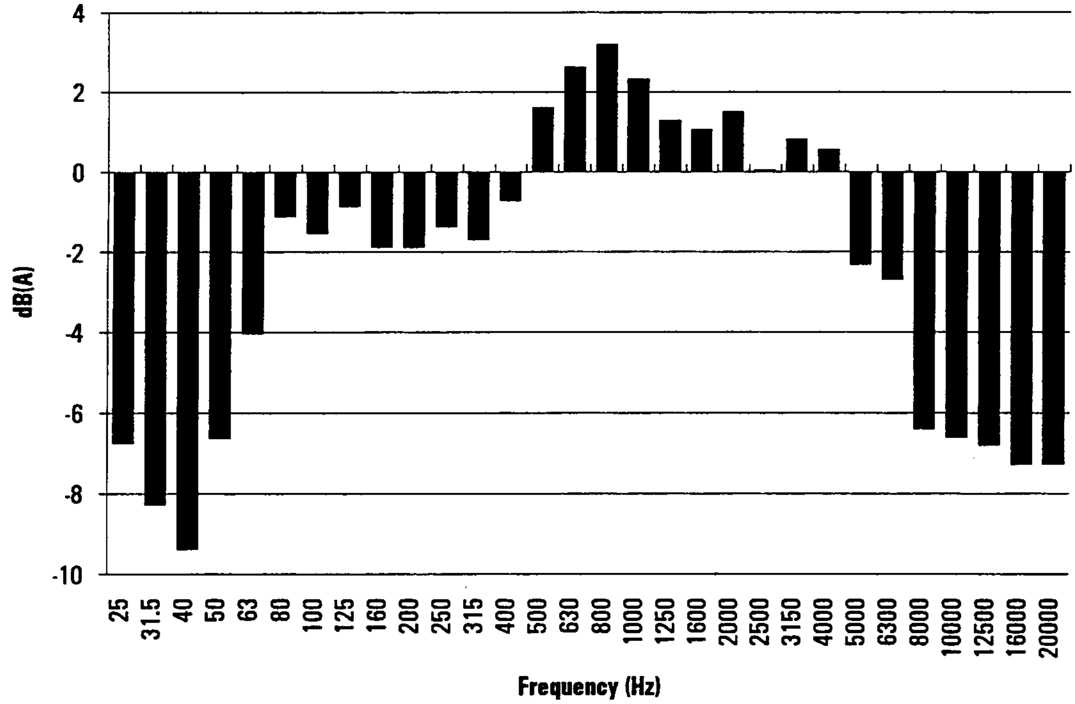


Figure 5.4. Seven Oaks to Jackson (South) new B-mix to new F-mix

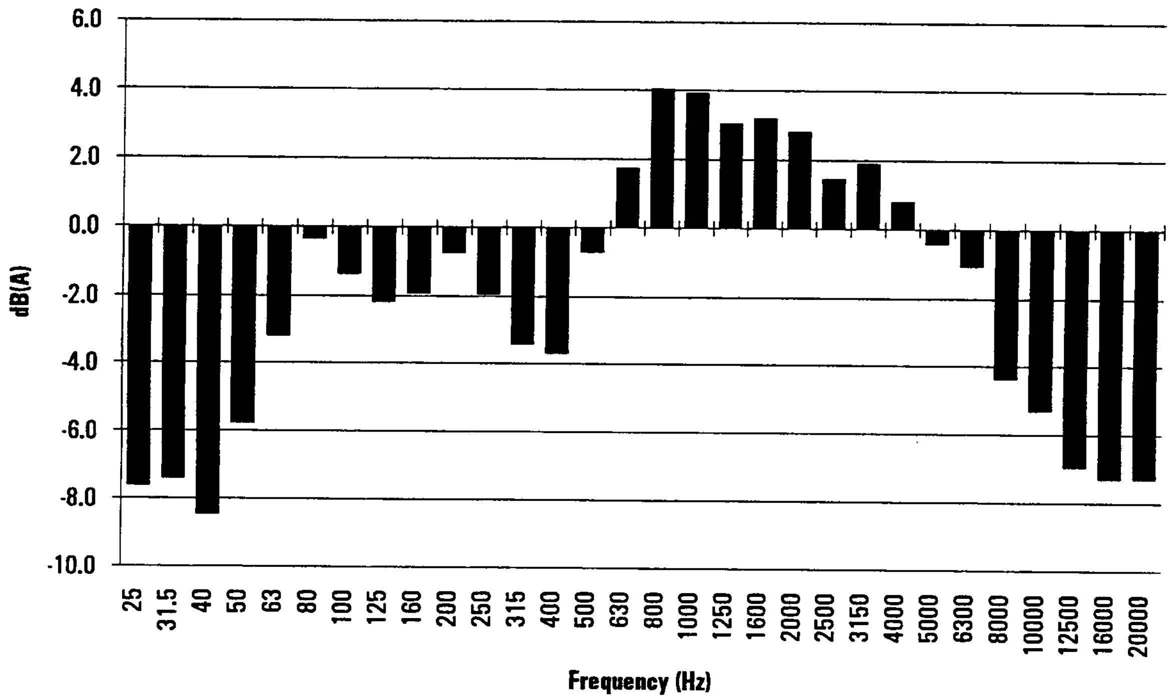


Figure 5.5. Seven Oaks to Jackson (North) new B-mix to new F-mix

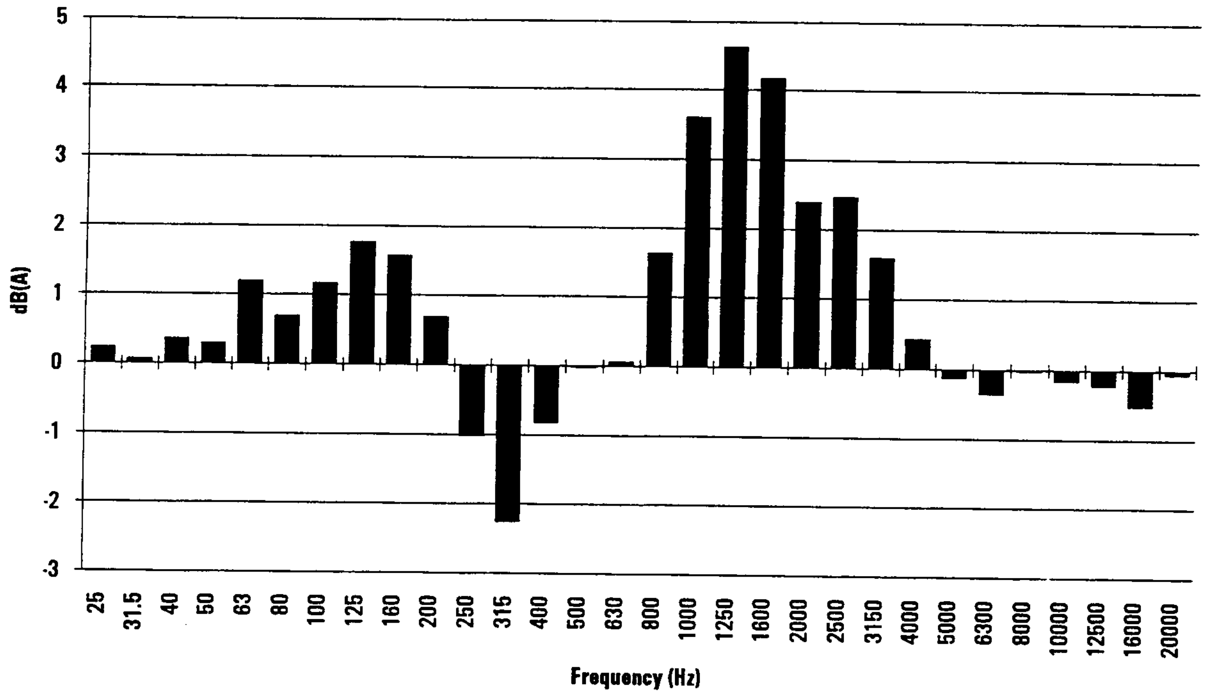


Figure 5.6. Halsey Interchange to Lane County Line 1-year-old B-mix to 1-year-old F-mix

Figure 5.6, which is from the Halsey Interchange to Lane County Line project, displays a curve that is much different from the new B-mix to new F-mix comparison. This curve shows F-mix improvements from 1 dB(A) to 4.5 dB(A) in the range of 500 to 4000 hz, and an improvement from 0 dB(A) to 1.5 dB(A) in the 25 to 200 Hz range. All other ranges show an improvement for B-mix in the range of 0 dB(A) to 2.5 dB(A).

Data for the interior noise levels were directly averaged for various 2-minute sample times using the decibel addition method. These numbers were compared for pavement types. Table 5.9 displays the Leq data computed for the noise measurements taken. These data seem more sporadic than the data for the roadside noise measurements, and even show a near significant to significant (2 - 2.9) dB(A) change in the favor of the B-mix pavement at the Seven Oaks to Jackson project. Data for the BattleCreek to N. Jefferson and the Halsey to Lane County Line show little to no change (0 to 1.5) dB(A) in the Leq levels.

Frequency sweeps for the interior noise levels, like those for the roadside were displayed for the same location sites. Figures 5.7 to 5.9 display how sporadic the interior measurements came out. The only site that displayed a curve that even remotely compared to those for the roadside measurements was the northbound lane for the Seven Oaks to Jackson project, where there is a 1 to 2.5 dB(A) improvement for the F-mix pavement in the 800 to 10,000 Hz range, and a 0 to 5.5 dB(A) improvement for B-mix at all other frequencies.

Table 5.9. Interior A weighted sound levels

Seven Oaks to Jackson Interior			
Matches	Leq dB(A)	Leq dB(A)	Difference dB(A)
PCC - B-mix South	75.1	68.5	6.6
PCC - B-mix North	73.5	70.5	3.0
PCC - F-mix South	75.1	71.4	3.7
PCC - F-mix North	73.5	72.5	1.0
B-mix - F-mix South	68.5	71.4	-2.9
B-mix - F-mix North	70.5	72.5	-2.0
BattleCreek to N. Jefferson Interior			
Matches	Leq dB(A)	Leq dB(A)	Difference dB(A)
B-mix - F-mix	72.7	72.0	0.7
Halsey to Lane County Line Interior			
Matches	Leq dB(A)	Leq dB(A)	Difference dB(A)
B-mix - F-mix	72.0	72.0	0.0

5.3 Summary of Findings

The results of the noise analysis confirm the data found in the literature search which indicate porous pavements reduce the noise in the higher frequency zones. This conclusion is supported mostly from the roadside measurements, and not from those taken in the interior of the vehicle. A possible explanation for this is that the higher frequencies are dampened by the vehicle shell. As high frequency noises have a shorter wavelength, they would be more apt to be reflected off the vehicle's thin shell, and would hide some of the data and make F-mix pavements appear a little more noisy inside than outside.

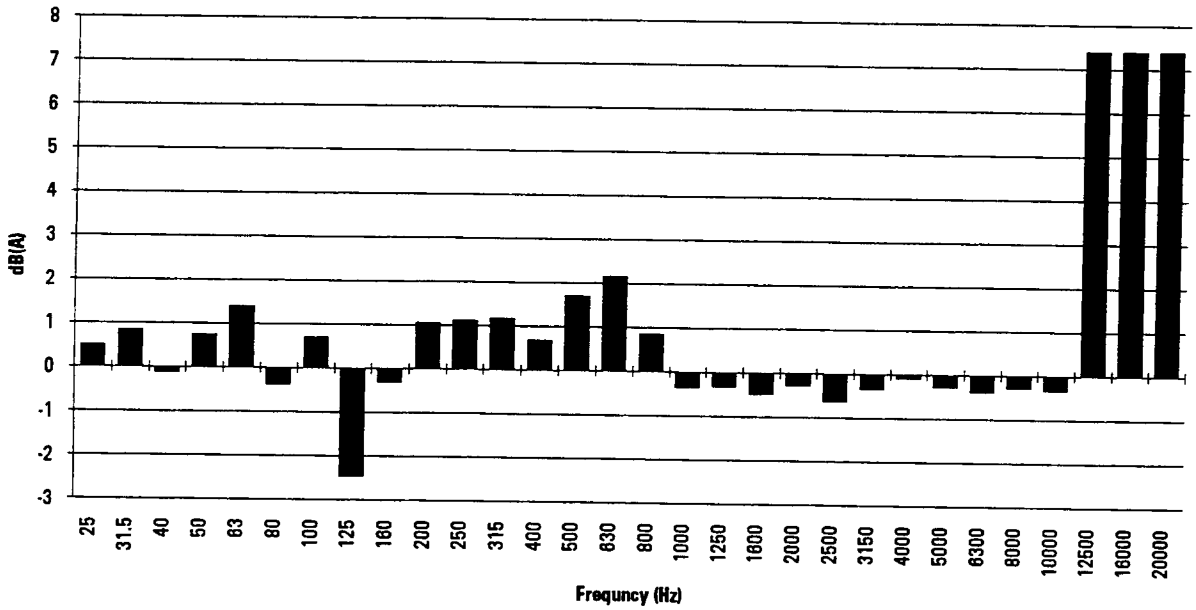


Figure 5.7. Seven Oaks to Jackson (South Interior) new B-mix to new F-mix

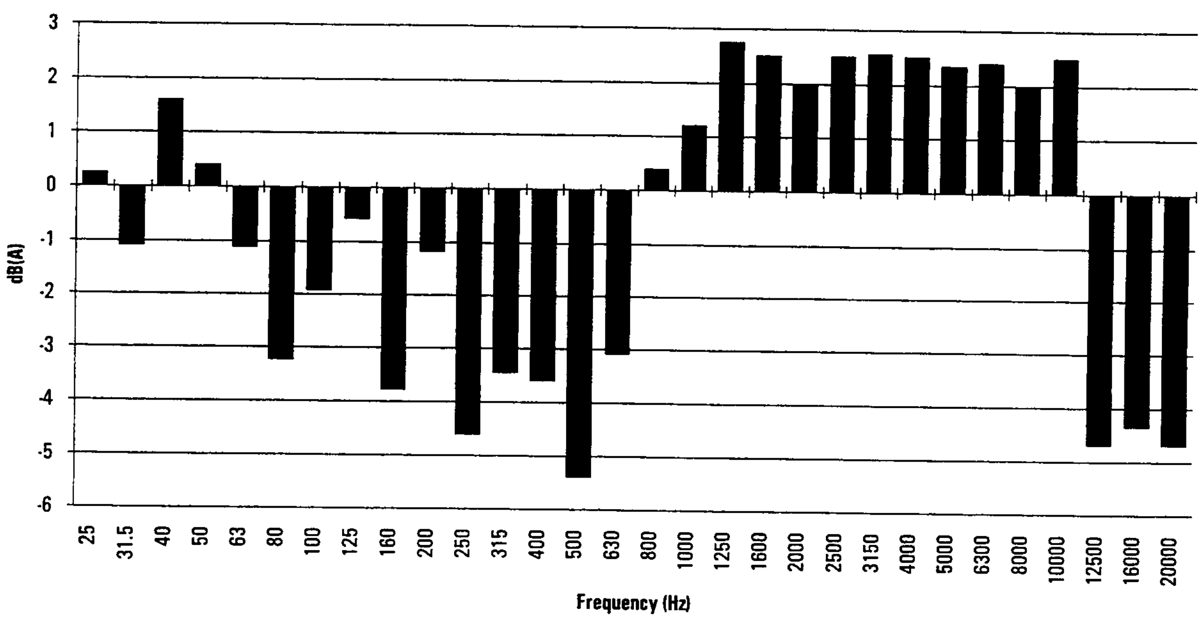


Figure 5.8. Seven Oaks to Jackson (North Interior) new B-mix to new F-mix

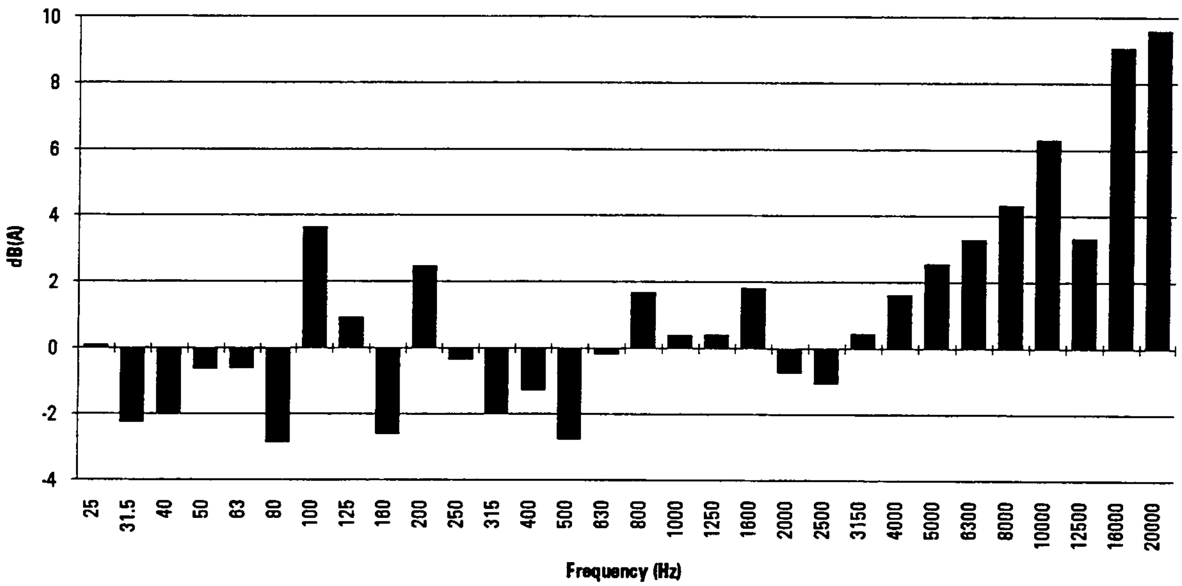


Figure 5.9. Halsey to Lane County Line (Interior) 1-year-old B-mix to 1-year-old F-mix

6.0 EVALUATION OF PROJECT DATA

The evaluation of the data for this report encompasses all that was discovered during the study. The significant findings include changes in properties over time, specification change suggestions, and new porous pavement guidelines.

6.1 Significant Findings

6.1.1 Field Studies

The friction data collected as a part of this study provided interesting results. It was never expected that the "wet" friction numbers would be higher (more skid resistant) than those for the "dry" condition. Even though the dry condition is not a true dry condition, there is still quite a lot more rain on the road during a rainstorm. These data are unexplainable, as data were taken at various times in the year, and the data came out to show the anomaly. Again, the hypothesis for this problem is that the water from the sprayer on the friction tester actually loosens any detritus on the road surface, but does not provide enough water or time to wash it away completely.

Data were also collected from the project for pavement permeability, texture depth, and rutting. The data are inconclusive as to whether or not the permeability is truly decreasing over time, as the length of the study was too short and the equipment used wasn't sufficient for F-mix pavements. Texture depth of the pavement is somewhat correlated to the pavement permeability. As for rut depth measurements for the sites, there is no truly noticeable change over the course of a year in the rutting potential of the pavement mat. This is an expected attribute of a good F-mix overlay.

The accident data that were collected as a part of the field study on F-mix pavements were disappointingly inconclusive. The amount of data available, and the relatively short time period available made it difficult to come up with any conclusive evidence that accident rates are lowered after placement of open-graded pavements.

6.1.2 Laboratory Studies

The laboratory data provided interesting insights into the behavior of porous pavements. The ECS results for the two tested projects suggest some differing performance characteristics. The Pendleton project may start to show some water sensitivity problems in the near future based on the results of the ECS test. Whether or not the ECS test is a valid test for F-mixes remains to be seen, and watching this project site should be useful in this determination.

From the results of the field core tests performed at the ODOT labs, it would appear as if the pavements surveyed in this project are holding up fairly well. It would also appear as if there is only a small amount of fines getting down into the pores of the pavement, and that there is little clogging of the pavement.

The shear test data provided some good numbers and information about placing a tack coat on a PCC surface before covering it with an open-graded friction course. Test data suggests that if the normal CSS-1 tack coat emulsion is used, that the 0.10 gal/yd^2 (0.45 l/m^2) spray rate would provide the best tack. These same results would be expected to be seen over time based on the results of artificially aging the sample.

6.1.3 Noise Study

The noise study portion of the project provided useful information on the differences in noise levels for conventional pavements and porous mixtures. The data clearly showed that porous mixtures used in Oregon provide a significant reduction in roadside noise over B-mix and PCC pavements with a reduction as high as 4 dB(A) in the higher frequencies. The main area of reduction is in the upper range frequencies, where the human ear is most sensitive. This was not the case for the interior noise study, however, as the data were somewhat inconclusive.

6.1.4 Stress Distributions in Porous Asphalt Mixes

Appendix D is a report completed as a part of this study. The study employed finite element analysis methods to discern the confinsing pressures in F-mixes, and the effecxt of F-mix over PCC overlays. The analysis provided a 100-300 psi (690 - 2100 kPa) confining pressure in F-mixes. For the F-mix over PCC, the F-mix doesn't significantly reduce stress in the PCC layer yet this pavement situation does not seem be invalid.

6.2 Changes in Mix Properties Over Time

An important aspect of any pavement surfacing is how it may react to time. ODOT realized that it is lacking some information in this area for porous pavements, and that is part of the reason for this project.

Many aspects of this reports findings should be monitored over time to get a better representation as to what is happening in the in use pavements through wear and age. Major areas of interest here are field permeability, rutting, noise, and friction properties.

Information gathered in these areas would help ODOT improve the porous pavements used in Oregon.

6.3 Suggested Modifications to Specifications

One of the reasons for this study was to try to come up with some valid changes in the asphalt specifications for porous pavements found in the *Oregon Standard Specifications for Highway Construction* (ODOT, 1991). Listed below are some suggested changes to the specifications.

In order to make sure water does not infiltrate the base course layers, the following is to be added:

Section - 00745.42 Preparation of Underlying Surfaces

Add the following section under part (b) <u>All Projects</u>

> For Open-graded pavements type E and F mix, make sure underlying layer is properly sealed with an appropriate dense material that fills in all depressed surface areas.

Because mixture transport distances from batch plant to project site are critical to reduce draindown and chunking of porous pavements, the following is to be added:

Section - 00745.48 Hauling, Depositing, and Placing

Add the following under part (a) <u>Hauling</u>

> For open-graded pavement haul times greater than 30 minutes, mixes should be tested for draindown according to F-mix design procedures. Those mixes showing draindown in excess of 60% should be adjusted for temperature and AC content as agreed by the engineer.

Add the following under part (b) Depositing section on windrows.

- Reduce any chunking in open-graded mixtures.

To facilitate proper compacting of F-mix pavements, the following changes are suggested:

Section - 00745.49 Compaction

Replace the following under part (d) Open-graded AC

Replace:

"Perform additional coverages, as directed and as necessary, to obtain thorough compaction and finish rolling of the AC."

With:

"Perform additional coverages, as directed and as necessary, to obtain thorough compaction resistance and finish rolling of the AC."

6.4 Suggested Guidelines for Use of Porous Mixtures

A number of interesting facts about porous pavements were discovered during the course of this project. The majority of this information was gathered through the literature search, and is thus gleaned from the experience of both ODOT and other agencies. Table 6.1 lists some limitations for porous pavements and the reason why.

Porous pavements are recommended for use in such areas as high volume trafficked areas with high rainfall levels, or in areas where noise reduction is required. The safety benefits of porous pavements make them an attractive paving alternative.

The problems noted in the frictional characteristics of porous pavements directly after placement require future investigation. For about a month after paving, the area should be posted with slick pavement warning signs, or the posted speed in the area be reduced.

Table 6.1. Limitations of porous pavements

Usage	Reasoning
City streets	Requires a lot of extra time and money to assure drainage occurs properly.
Heavy winter snow areas	Snow plows can damage the pavement surface and the pores can get clogged by sanding debris.
Paving that requires a lot of handwork	Porous pavements are not easy to handle by raking into position, and cost extra for such work.

Another point about porous pavements is that an environmental use zone for is needed. Due to the many difficulties in using porous pavements in mountainous regions porous pavements should be restricted from use in these areas.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This report is the culmination of two years of data gathering from porous pavements used throughout Oregon. The areas of skid, noise, water sensitivity, safety, properties over time, and tack coats were investigated and reported herein. The culmination of this study provides a fair amount of data dealing with porous pavements. Specific conclusions resulting from this study are given below:

1) Advantages documented in the litarature review are: increased wet weather skid resistance, reduces splash and spray, noise reduction, decreased hydroplaning, reduced rutting, and glare reduction.

2) Disadvantes documented in the literature review are: construction difficulties, poor winter performance, potential oxidation problems, and patching problems.

3) Porous pavements provide good rutting resistance.

4) ODOT's F-mix pavement significantly reduces roadside noise as compared to PCC pavements and new B-mixes.

5) After several years, F-mix pavements in Oregon do not seem to have a problem with filling of voids.

6) F-mixes are 1-2 dB(A) quieter than B-mixes for road side noise and 2-3 dB(A) louder for interior.

7) 1/3 octave band analysis show that F-mixes are 0-4.5 dB(A) quieter than B-mixes in the 500-4000 Hz range for exterior, and about the same for interior.

8) ECS testing shows a possible water sensitivity problem for the Pendleton - Emigrant Hill project, and none for the Jumpoff Joe project.

9) ODOT's F-mix shows little changes over time for rutting, permeability, and void levels.

10) Porous pavements should not be used in heavy winter snow areas.

11) Porous pavements should not be used in city streets or in areas that will require a lot of construction handwork

7.2 Recommendations for Implementation

The data presented in this report, along with the specification changes and guideline recommendations provide a good start for ODOT to build on the data base regarding the behavioral properties of porous pavements. Continuing this data collection process will provide ODOT will a data base of information to use for improvement of porous pavements. Specific recommendations for implementation include:

1) Use a 0.10 ga./yd^2 (0.45 l/m^2) spray rate for a CSS-1 emulsion tack coat between PCC and F-mix pavements.

2) Develop guidelines for climatic zones in Oregon.

3) Change specifications as suggested in Chapter 6.

4) Follow limitation guildlines stated in Table 6.1

7.3 Recommendations for Future Study

Though porous mixes seem to be performing well, future studies should possibly look at the following:

1) Continue testing of permeability, skid, and other properties of porous pavements over an extended period of time.

2) Monitor the water sensitivity of F-mixes using field cores for a few new projects over an extended period of time.

3) Document new construction procedures to improve construction methods, in cluding the development of pay incentive/disencentives for porous mixes.

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APPENDICES

APPENDIX A

List of Oregon F-mixes

Table A.1 F-mix Highway Log

CONTRACT #	JOB NAME	PLACED	NAME	NUMBER	COUNTY	MILES	M.P.	M.P.	COND	ADT
C 11037	DIST 5 OVERLAY PROJECT	1991	VARIOUS		LANE	2.10	5.23	3.13		
C 10751	DISTRICT 7 OVERLAY PROJECT	1989	VARIOUS		COOS	2.95	274.60	277.55		
C 10763	DIST. 3 PAVING PROJECT	1989	VARIOUS		MARION	6.67	23.36	30.03		
C 11037	DIST 5 OVERLAY PROJECT	1991	VARIOUS		LANE	5.28	20.31	22.59		
C 115-1557	ANTIOCH RD. CRATER LK. HWY.	1985	SAMS VALLEY	271	JACKSON	4.87	12.61	17.48	2	2100
C 10256	DISTRICT 5 PAVING PROJECTS	1986	VARIOUS		LANE	11.88				
C 09812	DAYS CREEK - TRUCK SCALES	1984	TILLER-TRAIL	230	DOUGLAS	2.00	10.80	12.80	2	500
C 09993	S. FRK. COQUILLE RV.- R.R. AVE.	1985	POWERS	242	JACKSON	4.89	12.61	17.48	4	640
C 09783	WILD PARK LANE - REEVES CR.	1984	REDWOOD	25	JOSEPHINE	2.57	22.00	24.57	3	6200
C 10006	DIST. 8 PAVING PROJECT	1985	REDWOOD	25	JOSEPHINE	5.20	6.90	12.10	4	7000
C 10761	DIST. 5 OVERLAY PROJECT	1989	VARIOUS		LANE	12.64				
C 09972	CLOVER LANE - NEIL CREEK RD.	1985	GREEN SPRINGS	21	JACKSON	2.90	1.50	4.40	3	3400
C 11065	JUMP OFF JOE-N.GRANTS PASS	1991	PACIFIC	001	JOSEPHINE	8.91	67.11	58.20	2	23900
C 10941	HAYSVILLE-BATTLE CR.INLAY SAL	1990	PACIFIC	001	MARION	9.59	259.09	249.50	2	39800
C 11038	SANTIIAM RV.(S.B.) BRIDGE	1992	PACIFIC	001	MARION,LINN	1.24	241.44	240.20	4	42500
C 11334	SANTIAM RV,N BOUND BR. SEC	1993	PACIFIC	001	MARION,LINN	1.38	240.60	241.07	4	42500
C 10980	N. JEFFERSN INTCH-N ALBNY INT(	1991	PACIFIC	001	LINN,MARION	9.80	234.23	244.49	2	42500
C 11294	HALSEY INTR. LANE CNTY LINE SE	1993	PACIFIC	001	LINN	12.59	216.14	203.55	9	25500
C 10989	WINCHESTER INT. N.B. RAMPS	1991	PACIFIC	001	DOUGLAS	0.62	129.43	129.21	2	21800
C 10963	SUTHERLIN INT.-GARDEN VLY BLV	1991	PACIFIC	001	DOUGLAS	11.76	124.80	136.27	2	29000
C 10952	W. MARQUAM INT.-N.TIGARD INT.	1990	PACIFIC	001	MULTNOMAH	5.29	294.00	299.50	2	87000
C 10749	SUVER- THOUSAND OAK DR SEC	1989	PACIFIC HWY WEST	01W	BENTN,POLK	7.01	70.50	77.51	3	5200
C 11300	PERRYDALE RD-CROWLEY RD	1993	PACIFIC WEST	01W	POLK,YAMHL	7.9	46.74	54.40	9	3150
C 11138	BELTLINE HWY-BARGER AV(EUGE	1992	PACIFIC HWY WEST	01W	LANE	1.28	118.24	119.52	1	11800
C 10961	BROOKMAN RD-GARLAND RD N.	1991	PACIFIC HWY W.	01W	WASHINGTO	2.0	17.42	19.42	2	20800
C 10939	CORBETT INTCHG.-MULTNOMH FL	1991	COLUMBIA RIVER	002	MULNOMAH	93.01	22.34	31.00	2	14700
C 11087	NE. 181ST AV-TROUTDALE OVERL	1991	COLUMBIA RIVER	002	MULTNOMAH	3.01	13.83	16.84	2	33900
C 11256	RUFUS-ARLINGTON (W.UNIT)	1993	COLUMBIA RIVER	002	GILM,SHRMN	15.54	128.76	129.30	1	7300
C 10949	RUFUS-ARLINGTON (E. UNIT)	1991	COLUMBIA RIVER	002	GILLIAM	12.7	125.5	138.2	1	7300
C 11245	UMATILLA - MCNARY	1993	COLUMBIA RIVER	002	UMATILLA	3.10	182.6	185.7	9	5000
C 10926	RAINIER- TIDE CREEK	1990	COLUMBIA RV. HWY(LOWER	02W	COLUMBIA	11.58	36.50	46.55	2	7300
C 11276	GREEN SPRNGS HWY-MDLND HW	1993	THE DALLES-CALIFORNIA	004	KLAMATH	2.71	277.79	280.50	9	6000
C 11351	KLAMATH FLS,MALIN,GREEN SPRI	1993	THE DALLES/CALIFORNIA	004	KLAMATH	5.47	272.35	277.37	4	6000
C 11351	" " " "	1993	" " " "	004	KLAMATH	11.20	280.50	291.70	9	3300
C 10743	CHEMULT- LENZ RD. SECT.	1990	THE DALLES- CALIFORNIA	004	KLAMATH	17.08	203.85	220.93	2	4350
C 11331	FREMONT JCT. - HACKETT DRIVE	1993	THE DALLES- CALIFORNIA	004	DESCHUTES	7.30	169.90	177.20	9	39000
C 10766	HACKETT DR.- GILCREST	1989	THE DALLES- CALIFORNIA	004	KLAMATH	6.20	177.00	183.20	2	39000
C 10462	MURPHY RD.- LAVA BUTTE	1989	THE DALLES CALIFORNIA	004	DESCHUTES	5.44	141.50	150.80	3	13800
C 11210	NORWOOD RD-PWRS RD(BEND)	1992	THE DALLES-CAL.,POWEL B	004	DESCHUTES	5.24	135.43	140.67	2	26000
C 10672	REDMOND BEND(SOUTH UNIT)	1989	THE DALLES- CALIFORNIA	004	DESCHUTES	2.09	132.66	134.75	2	12300
C 11104	REDMOND-BEND(N. UNIT)	1992	THE DALLES-CALIFORNIA	004	DESCHUTES	9.23	123.18	132.41	1	12300
C 11104	REDMOND-BEND (N.UNIT)	1992	THE DALLES-CALIFORNIA	004	DESCHUTES	9.23	123.18	132.41	1	12300
C 10850	O'NEIL JCT.-REDMOND COUPLET	1990	THE DALLES- CALIFORNIA	004	DESCHUTES	2.09	120.26	118.43	1	7500
C 11009	TERREBONNE-O'NEIL JCT	1991	THE DALLES CALIFORNIA	004	DESCHUTES	3.30	115.2	118.4	1	7500
C 11210	NORWOOD RD-PWRS RD(BEND)	1992	THE DALLES-CAL.,POWEL B	004	DESCHUTES	7.57	0.00	7.57	9	2900

Table A.1 F-mix Highway Log (Continued)

CONTRACT #	JOB NAME	PLACED	NAME	NUMBER	COUNTY	MILES	M.P.	M.P.	COND	ADT
C 09652	LENZ RD. - FORGE RD.	1984	THE DALLES/ CALIFORNIA	004	KLAMATH	18.30	222.90	241.20	2	3800
C 11015	WILLIAMSON RV.-MODOC PNT.	1991	THE DALLES-CALIFORNIA	004	KLAMATH	2.26	253.80	256.20	2	5300
C 10874	FORGE RD-LOBERT(S. UNIT)	1990	THE DALLES-CALIFORNIA	004	KLAMATH	2.70	247.70	251.60	2	3800
C 10972	FORGE RD-LOBERT(N. UNIT)	1991	THE DALLES-CALIFORNIA	004	KLAMATH	8.40	241.22	251.64	1	3800
C 10924	FAREWELL BEND-OLDS FERRY IN	1991	OLD OREGON TRAIL	006	MALHEUR	2.78	355.77	352.99	3	5700
C 11170	DURKEE INTERCHANGE	1993	OLD OREGON TRAIL	006	BAKER	14.97	327.15	342.12	9	5100
C 10930	BALDOCK SLOUGH-S BAKER INTC	1991	OLD OREGON TRAIL	006	BAKER	9.62	297.10	306.72	1	5510
C 11119	E. PENDLETON INTCH.-EMGRANT	1992	OLD OREGON TRAIL	006	UMATILLA	4.69	213.04	217.73	2	4500
C 09645	S. BAKER - DURKEE	1984	OLD OREGON TRAIL	006	BAKER	21.00	306.40	327.40	3	5100
C 10974	FARWELL BEND- OLD FERRY INT.	1990	OLD OREGON TRAIL	006	MALHEUR	2.78	253.30	356.08	3	5200
C 10425	POWLL BUTT JCT-ARNLD ICE CV		CENTRAL OREGON HWY	007	DESCHUTES	814	4.30	12.44	2	1950
C 11048	OCI ACCES RD-STANTON BLVD IN	1991	STANTON BLVD(COUNTY RD	007	MALHEUR	2.23				
C 11296	BROOTN RD-LITTLE NESTUCA RV	1993	OREGON COAST	009	TILLAMOOK	1.65	90.33	91.98	9	4000
C 11253	PLEASANT VLY-GREEN TIMBER R	1993	OREGON COAST	009	TILLAMOOK	1.03	75.08	76.11	9	4500
C 10681	SIMMONS CR.- PLEASANT VLY RD	1989	OREGON COAST	009	TILLAMOOK	1.42	71.57	72.99	1	4500
C 11305	NEDONNA BEACH RD-BARVIEW	1993	OREGON COAST	009	TILLAMOOK	5.40	48.60	54.00	9	6200
C 11205	ARCH CAPE TUNNL-SHORT SND (	1992	OREGON COAST	009	CLAT.,TILLM(	3.19	35.91	39.10	1	3100
C 10599	CAPE SABASTION- MYERS CR RD	1988	OREGON COAST	009	CURRY	1.75	334.75	336.50	2	4000
C 11298	DIST 7 OVERLAY PROJECT	1993	VARIOUS	009	COOS	0.28	280.82	280.10	2	4300
C 11298	DIST 7 OVERLAY PROJECT	1993	VARIOUS	009	COOS	2.60	224.40	227.00	2	8600
C 10673	LONGWOOD DR.- WINCHESTER W	1989	OREGON COAST	009	DOUGLAS	1.41	213.60	215.01	2	9600
C 11298	DIST 7 OVERLAY PROJECT	1993	VARIOUS	009	COOS	0.55	1.70	2.25	2	3500
C 11207	PASSMORE RD-BAYSHORE DR	1992	OREGON COAST	009	LINCOLN	7.37	147.38	154.75	1	10800
C 11333	DEPOE BAY RD-NE. 54TH ST	1993	OREGON	009	LINCOLN	9.92	127.60	137.53	9	8400
C 09781	GOLD BEACH - SEBASTION PK. RD	1984	OREGON COAST	009	CURRY	2.00	328.44	330.48	2	11300
C 11034	DIST. 7 PAVING PROJECT	1991	OREGON COAST	009	COOS,CURR	6.49	221.30	255.03	2	11400
C 10870	DOOLEY BR.- CANNON BEACH	1990	OREGON COAST	009	CLATSOP	1.58	22.50	24.50	3	7700
C 09987	EUCHRE CR.- OPHIR REST AREA	1985	OREGON COAST	009	CURRY	2.50	316.98	319.38	2	3400
C 10446	SUTTON LAKE - FLORENCE	1988	OREGON COAST	009	LANE	5.50	184.50	190.30	1	5800
C 10948	IMBLER-ELGIN (PASS LANE)	1992	WALLOWA LAKE	010	UNION	2.21	15.58	17.79	2	3200
C 11213	PACIFIC HWY-42ND ST.(SPRNGFIL	1993	EUGENE-SPRINGFIELD	015	LANE	3.50	4.00	7.50	2	15300
C 11243	MCKENZIE HWY PASSING BAYS	1993	MCKENZIE	015	LANE	1.43	21.98	38.49	3	3300
C 09776	Q ST. - A ST.(SPRINGFIELD)	1984		015	LANE	1.40	0.00	1.40	2	16300
C 10827	MCKENZIE HWY AT MP. 14.5	1990	MCKENZIE	015	LANE	0.45	14.20	14.63	2	4900
C 09978	SPRINGFIELD - LEABURG	1985	MCKENZIE	015	LANE	5.24	2.96	8.31	3	15200
C 11222	SISTERS- TUMALO	1993	MCKENZIE- BEND	017	DESCHUTES	12.6	0.0	12.6	9	6100
C 11270	DESCHUTES RIVER - US 97	1993	MCKENZIE-BEND	017	DESCHUTES	3.13	14.80	18.00	9	9500
C 11271	DESCHUTES RIVER-US 97	1993	MCKENZIE-BEND	017	DESCHUTES	3.13	14.91	18.04	9	8700
C 10770	PASSING LANES HWY 97	1990	MCKNZE-BND,THE DALLES-(	017	DSCHTS,KFA	6.1	112.80	122.30	9	9000
C 10465	LOWER SALT CR.- UPPER SALT C	1987	WILLAMETTE	018	LANE	4.91	36.76	41.70	2	4200
C 10881	RATTLESNAKE CR.- WHEELER RD	1990	WILLAMETTE	018	LANE	0.60	8.80	9.40	3	5600
C 10938	SALMON CR.(OAKRIDGE) BRIDGE	1991	WILLAMETTE	018	LANE	0.55	35.91	36.04	3	4500
C 11331	FREEMAN JCT-HACKETT DR.	1993	THE DALLES-CALIFORNIA	019	KLAMATH	7.23	169.87	177.10	2	1200
C 10704	EMIGRANT CREEK - M.P.4	1989	FAS-A346(DEAD INDIAN RD.)	020	JACKSON	3.1	0.90	4.00	4	22000
C 10760	HAYDEN MOUNTAIN PASS SECT.	1989	GREENSPRINGS	021	KLAMATH	10.30	32.97	43.27	3	460

Table A.1 F-mix Highway Log (Continued)

CONTRACT #	JOB NAME	PLACED	NAME	NUMBER	COUNTY	MILES	M.P.	M.P.	COND	ADT
C 11188	DIST. 8 OVERLAY	1992	GREEN SPRINGS, ROGUE VI	021	JACKSON	.95	20.92	21.87	3	460
C 10239	JENNY CR.- PARKER SUMMIT	1986	GREEN SPRINGS	021	JACKSON	5.30	23.41	28.71	3	460
C 10818	KERN SWAMP RD-WEYRHAUSR R	1990	GREEN SPRINGS	021	KLAMATH	3.00	53.60	56.60	2	3100
C 10433	DISTRICT 8 PAVING	1987	CRATER LK & GREENSPRIN	021	JACKSON\KL	2.30	45.50	47.80	3	750
C 15 MISC.	HWY 62- M.P. 40	1993	BUTTE FALLS RD	022	JACKSON	4.00	4.00	8.00	3	27800
C 10649	TRAIL-CASEY(EAST UNIT)	1989	CRATER LAKE	022	JACKSON	2.09	26.90	28.90	1	2900
C 15 MISC.	M.P. 40 CROWFOOT RD.	1992	BUTTE FALLS RD.	022	JACKSON	3.64	4.00	7.64	3	21500
C 11192	MINNIE CR.-BUTCHER KNIFE CR.	1992	REDWOOD	025	JOSEPHINE	5.24	9.08	14.32	1	7000
C 10726	CLACKAMS/BORNG HWY-362ND D	1989	MT. HOOT	026	CLACKAMAS	2.44	19.96	22.74	2	20100
C 10883	CORVALLIS E.C.L.-N.W. RONDO ST	1990	ALBANY-CORVALLIS	031	BENTON	6.10	1.38	7.48	2	9700
C 10833	CORVALLIS E.C.L. NW. RONDO ST	1990	ALBANY- CORVALLIS	031	BENTON	6.10	1.38	7.48	2	9700
C 10917	CORVALLIS BY-PASS (S.UNIT)	1990	CORVALLIS- NEWPORT	033	BENTON,LIN	1.04	56.79	55.75	1	10300
C 10598	GLEN AIKEN CR.- GREY CR.	1988	COOS BAY- ROSEBURG	035	COOS	1.40	15.15	16.55	2	7000
C 10653	CAMAS MT. WAYSIDE- MUNS CRE	1989	COOS BAY- ROSEBURG	035	DOUGLAS	3.54	58.53	62.07	2	3750
C 10846	CAMAS VLY-CAMAS MT WAYSIDE	1991	COOS BAY-ROSEBURG	035	DOUGLAS	4.83	54.23	59.06	2	3750
C 11291	REMOTE CAMPGROUND-SLATER	1994	COOS BAY-ROSEBURG	035	COOS,DUGL	6.12	38.25	46.00	9	3750
C 11110	MYRTLE POINT S.C.L. POWERS JC	1992	COOS BAY\ROSEBURG	035	COOS	1.5	21.83	23.33	2	5100
C 10719	N FORK COQUILLE RV. MYRTLE PO	1989	COOS BAY- ROSEBURG	035	COOS	0.84	19.61	20.45	2	7000
C 10866	GREY CREEK- N. FORK RD.	1990	COOS BAY- ROSEBURG	035	COOS	2.85	16.60	19.45	2	7000
C 11013	COQUILLE REROUTE	1993	COOS BAY-ROSEBURG	035	COOS	1.74	9.60	12.10	3	9300
C 10839	HOOVER HILL RD.-BROCKWAY RD	1990	COOS BAY- ROSEBURG	035	DESCHUTES	1.03	69.40	71.80	1	5300
C 11297	PACIFIC HWY WEST-GATEWAY ST	1993	BELTLINE	036	LANE	6.82	6.11	12.93	3	320
C 10843	SLICK ROCK CR.-SULPHUR CR.	1990	SALMON RIVER	039	LINCOLN	3.98	5.60	9.58	1	5700
C 11228	AIRPORT RD-PACIFIC HWY	1993	SALMON RIVER	039	YAMHILL	4.65	48.00	52.65	1	7700
C 10778	FORT HILL- WALLACE BRIDGE	1990	SALMON RIVER	039	POLK	2.63	24.23	26.86	2	10300
C 10788	ROSELODGE- POLK CNTY LINE	1990	SALMON RIVER	039	LINCN,TLMO	1.90	9.50	11.30	3	21500
C 10991	SALMON RV HWY, THREE RV HWY	1993	SALMON RIVER	039	POLK	.044	22.89	23.33	2	7900
C 10992	SAWTELL RD - M.P. 29	1992	SALMON RIVER	039	POLK	1.61	27.82	29.43	2	10300
C 11364	OCHOCO-SUMMIT-M.P.60.5	1993	OCHOCO	041	WHEELER	10.34	60.5	71.25	1	820
C 11189	MP 34.0 - MP 45.0	1992	OCHOCO	041	CROOK	11.35	34.05	45.40	1	790
C 10432	WEATHERLY CR.- GRAB CR. SEC.	1987	UMPQUA	045	DOUGLAS	2.38	22.75	25.13	2	3500
C 10852	ROCK CR. - ANLAUF SECTION	1990	UMPQUA	045	DOUGLAS	2.23	53.94	56.17	2	4000
C 11035	UMPQUA WAYSIDE-ELKTON	1991	UMPQUA	045	DOUGLAS	4.00	32.07	36.07	1	3500
C 11187	GOLDEN CR.-WEATHERLY CR.	1992	UMPQUA	045	DOUGLAS	2.58	20.10	22.68	2	3700
C 11087	GOLDE CR-WEATHERLY CR.	1991	UMPQUA	045	DOUGLAS	2.58	20.10	22.68	3	3500
C 10863	SCOTTBURG- WELLS CR. SEC.	1990	UMPQUA	045	DOUGLAS	3.0	16.5	19.5	2	3700
C 10923	HANCOCK HILL PASSING LANE	1991	UMPQUA	045	DOUGLAS	1.08	37.10	38.20	2	2800
C 11163	SADDIE MT. JCT.-COAST RANGE	1992	SUNSET	047	CLATSOP	4.2	9.8	14.0	1	3400
C 11302	CEDAR HILLS BLVD INT AUXILRY L	1993	SUNSET	047	WASHINGTO	1.37	68.11	68.67	3	92000
C 11342	MALLER RD-GLENCOE RD SEC.	1993	SUNSET	047	WASHINGTO	5.11	52.30	57.40	9	11800
C 11229	WOLF CR- W. FORK DAIRY CR.	1993	SUNSET	047	WASHINGTO	9.02	37.41	46.43	1	5300
C 10750	COAST RANGE SUMIT-JEWELL JC	1989	SUNSET	047	CLATSOP	7.62	14.05	21.67	2	3500
C 11341	KLAMATH FLS,MALN,LAKVEW,HAT	1993	KLAMATH FALLS-MALIN HWY	050	KLAMATH	1.49	3.78	2.29	9	4500
C 11220	EASIDE BYPASS(KLAMATH FALLS)	1993	KLAMATH FALLS-MALIN	050	KLAMATH	4.78	16.82	12.24	4	4500
C 10780	FROGLAKE- M.P. 83.0 SECT	1990	WARM SPRINGS	053	WASCO	16.98	71.00	83.00	2	3200

Table A.1 F-mix Highway Log (Continued)

CONTRACT #	JOB NAME	PLACED	NAME	NUMBER	COUNTY	MILES	M.P.	M.P.	COND	ADT
C 11269	M.P.66.9 JCT WAPINITA HWY	1993	WARM SPRINGS	053	WASCO	4.35	66.9	62.55	1	3200
C 11270	KAH-NEE-TA JCT-PELTON DAM RI	1993	WARM SPRINGS	053	JEFFERSON	5.91	105.29	111.20	9	4500
C 11360	KAH-NEE-TA JCT.PLTN DAM,W UN	1993	WARM SPRINGS	053	JEFFERSON	2.19	103.01	105.20	9	4250
C 11237	TRAIL-CASEY ST PARK (W.UNIT)	1994	CRATER LAKE	062	JACKSON	4.16	22.75	26.91	3	3550
C 10805	FOREST BOUNDARY- RIVER RD S	1990	FLORENCE- EUGENE	062	LANE	1.04	12.30	11.30	3	4850
C 10787	PENN RD.-COUGAR PASS SECT.	1990	FLORENCE - EUGENE	062	LANE	0.61	35.00	35.70	2	3600
C 11043	PHOENIS-VLY VIEW RD SEC	1991	ROGUE VALLEY	063	JACKSON	5.15	11.88	17.03	2	10100
C 10210	JACKSON COUNTY OVERLAY	1986	JACKSONVILLE	063	JACKSON	4.09	24.00	28.09	3	1000
C 10455	N.E. WASCO - S.E. DIVISION ST.		CASCADE HWY N.	068	MULTNOMAH	4.00	0.24	4.24	9	21900
C 11194	PACIFIC HWY W.-GATEWAY ST.	1993	BELTLINE	069	LANE	6.68	6.25	12.93	9	38000
C 10620	DISTRICT 6 OVERLAY	1988	NORTH UMPQUA	073	DOUGLAS	4.2	62.00	66.20	3	970
C 10754	FISH CR.- CHINQUAPIN CR.	1989	NORTH UMPQUA	073	DOUGLAS	6.45	56.00	62.45	2	970
C 11165	BOULDER FLAT-FISH CR. BR.	1993	NORTH UMPQUA	073	DOUGLAS	3.30	52.33	55.63	9	970
C 10899	SUSAN CR.- WRIGHT CR. RD.	1990	NORTH UMPQUA	073	DOUGLAS	6.32	27.88	34.20	9	1500
C 11278	SUSAN CR.-USFS BOUNDARY	1993	NORTH UMPQUA	073	DOUGLAS	2.12	28.67	30.79	9	1500
C 10979	STUMP LAKE-WINDIGO	1993	NORTH UMPQUA	073	DOUGLAS	6.70	67.18	73.88	1	970
C 11021	SPRING VLY CR-SALEM TOWNE	1991	SALEM-DAYTON	150	POLK	4.7	12.6	17.3	3	4200
C 10964	N.SANTIAM-ST. PARK-MILL CTY	1992	N. SANTIAM	162	MARION	4.09	24.62	28.71	1	4500
C 10905	SPANGLER HILL-MULINO	1991	CASCADE HWY.S.	160	CLACKAMAS	2.91	8.07	10.71	2	9000
C 11328	PACIFC HWY E.-CLACKMS CNTY L	1993	WOODBURN-ESTACADA	161	MARION	2.59	0.04	2.63	9	5400
C 11303	ECL GATES-LITTLE SWEEDEN SE	1993	NORTH SANTIAM	162	MARION	4.2	34.20	38.40	9	4000
C 11095	MILL CITY- GATES	1992	N. SANTIAM	162	MARION	3.58	30.03	33.61	1	5500
C 10777	LITTLE N. FORK RD.- M.P.25	1990	NORTH SANTIAM	162	MARION	1.80	23.20	25.00	2	4500
C 10951	FIR GROVE LANE-TOWERS ROAD	1991	NORTH SANTIAM	162	MARION	2.9	17.00	19.70	2	7300
C 10790	MILL CITY- GUN CR. SECT.	1990	NORTH SANTIAM	162	MARION	5.98	29.40	29.60	1	6200
C 10927	LAVA LK MEDOWS RD-SANTIAM S	1991	N. SANTIAM-SANTIAM	162	LINN	7.71	77.8	80.4	2	4200
C 11254	RIVERSIDE DR.-LAKE CREEK	1993	CORVALLIS-LEBANON	210	LINN	3.26	3.04	6.30	9	16300
C 11152	WILLAMETTE RV.-RIVERSIDE DR.	1992	CORVALLIS-LEBANON	210	LINN	3.33	0.28	3.61	1	21000
C 11304	E.COURTNEY CR. BRIDGE	1993	HALSEY-SWEET HOME	212	LINN	0.24	3.11	3.35	4	3900
C 10601	HENDRICKS RD.- PACIFIC HWY	1988	SPRINGFIELD- CRESWELL	222	LANE	2.96	11.63	14.59	2	2500
C 11285	42ND ST.-MCKENZIE HWY	1993	EUGENE-SPRINGFIELD	227	LANE	2.49	7.47	9.96	9	15000
C 11287	DIST 6 OVERLAY PROJECT	1993	UMPQUA & ELKTON-SUTHEI	231	DOUGLAS	3.75	0.00	3.75	9	1400
C 11324	SAMS VLY HWY JCT-SHADY CVR.N	1993	CRATER LAKE	234	JACKSON	2.94	18.56	15.62	3	21000
C 11265	CATCHING SLOUGH BRIDGE	1993	COOS RIVER	241	COOS	0.72	1.74	2.46	3	4000
C 10566	CRATER LAKE HWY- BROWNSBOI	1988	LAKE OF THE WOODS	270	JACKSON	8.22	0.00	8.22	1	3750
C 10607	SAMS VLY. HWY, TABLE ROCK	1988	SAMS VALLEY	271	JACKSON	0.14	10.68	10.82	2	2500
C 10600	JOHNSON CR.- CAMERON RD.	1988	JACKSONVILLE	272	JSPHN,JKSN	14.8	9.20	24.00	3	1900
C 10864	APPLEGATE RV. BRIDGE MP.9.2	1990	JACKSONVILLE	272	JOSEPHINE	3.02	6.18	9.20	3	3350
C 10867	NCL JACKSONVILLE-RIVERSIDE	1990	JACKSONVILLE	272	JACKSON	4.77	34.03	38.80	3	9200
C 10757	POORMANS CR. SECT.	1989	JACKSONVILLE	272	JACKSON	3.1	25.90	29.60	2	5000
C 11077	KIWA SPRINGS-MT. BACHELOR	1992	CENTURY DRIVE	372	DESCHUTES	10.47	21.62	11.15	2	730
C 11077	KIWA SPRING-MT BACHELOR	1992	CENTURY DRIVE	372	DESCHUTES	10.47	11.15	11.15	2	730
C 11351	• • • •	1993	&CHILOQUIN	422	WHEELER	5.34	0.00	5.34	9	5000
C 11197	DIST. 7 OVERLAY	1992	ORE COAST,COOS BAY-ROS	009, 035	COOS	0.52	234.50	235.02		
C 11197	DIST. 7 OVERLAY	1992	ORE COAST,COOS BAY-ROS	009,035	COOS	3.20	281.30	284.50		

Table A.1 F-mix Highway Log (Continued)

CONTRACT #	JOB NAME	PLACED	NAME	NUMBER	COUNTY	MILES	M.P.	M.P.	COND	ADT
C 11162	YOUNGS BAY BR-WARRENTON	1992	ORE COAST & LOWR COLUM	009 & 02W	CLATSOP	4.62	4.15	97.07		
C 10840	PLTN DAM,RIMRK RANCH,JEFRSN	1990	THE DALLES-CAL., WRM SPR	004, 053	JEFFERSON	23.8	91.90	115.70		
C 09799	S.P.R.R. O'XING SEC.	1984	SPRINGFIELD - CRESWELL	222	LANE	14.4	0.0	14.41		
C 11044	DIST 4 OVERLAY PROJECT	1991	PACIFC W.-CORVALLIS NWP	01W, 033	BENTON	5.31	79.75	82.60		
C 11044	DIST 4 OVERLAY PROJECT	1991	PACIFIC W.-CORVALLIS NWP	01W, 033	BENTON	2.36	53.49	51.03		

APPENDIX B

Field Survey Data

a) Field Survey

Table B.1. August 1993 field results for Marquam - N. Tigard

Section:	Marquam - N. Tigard		north
Milepost:	296.5		

RUTTING		
Outside	IWP	1/4" - 1/8"
	OWP	none

PERMEABILITY		MP 296.4		
Shoulder	2.23	1.93	1.67	1.79
IWP				
OWP	0.93	0.89		
BWP	0.81	0.84		
		MP 296.5		
Shoulder	1.38	1.42		
IWP	1.21	1.27		
OWP	1.06	0.79	0.76	
BWP	1.06	1.23	1.15	1.21

SAND PATCH		
Shoulder	7.7	7.8
IWP	7.5	7
BWP	6.8	6.8
OWP	6.5	6.5

Note: pavement in good condition, but bad spot was noticed in pavement a
see picture numbers 001 and 002

Table B.2. August 1993 field results for Hayesville - BattleCreek

SECTION:	Hayesville - Battlecreek		South
MILEPOST:	250.8		

RUTTING		
Outside	IWP	1/4"
	OWP	1/8"

PERMEABILITY		
Shoulder	1.50	1.54
IWP	0.98	1.02
OWP	0.77	0.74
BWP	1.00	0.97
B-mix taper	6.63	6.70

SAND PATCH		
Shoulder	7	7
IWP	6.1	6.2
BWP	6.2	6.3
OWP	6.5	6.3
B-mix taper	11.5	11.7

Table B.3. August 1993 field results for Jumpoff Joe - N. Grants Pass

SECTION: J.O. Joe - N. Grants Pass		North
MILEPOST: 64.7		

RUTTING		
Outside	IWP	0- 1/8"
	OWP	0

PERMEABILITY		
Shoulder	0.85	0.80
IWP	0.65	0.67
BWP	1.00	0.96
OWP	1.28	1.23

Note: Timer for permeameter did not work for this location. Manual stop watch had to be used.

SAND PATCH		
Shoulder	5.2	5.3
IWP	5.5	5.7
BWP	6.2	6.3
OWP	6.7	6.8

Note: For this site much of the sand escaped into the voids

Table B.4. August 1993 field results for E. Pendleton - Emigrant Hill

SECTION: E. Pendleton - Emigrant Hill		East
MILEPOST: 64.7		

RUTTING		
Outside	IWP	0
	OWP	0

PERMEABILITY			
Shoulder	1.12	1.25	1.18
IWP	0.96	0.77	0.80
BWP	1.30	1.34	1.33
OWP	0.96	0.97	0.84

SAND PATCH		
Shoulder		
IWP		
BWP		
OWP		

Note: Pavement was wet at this site so sand patch was unatainable

Table B.5. August 1993 field results for Murphy Road - Lava Butte

SECTION: Murphy Road - Lave Butte		South
MILEPOST: 146.7		

RUTTING		
Outside	IWP	1/4
	OWP	1/8 - 1/4

PERMEABILITY			
Shoulder	2.21	2.02	2.03
IWP	1.00	1.02	1.01
BWP	1.45	1.37	1.51
OWP 1	1.41	1.41	
OWP 2	0.80	0.96	0.96

SAND PATCH		
Shoulder	7.5	8.0
IWP	7.2	7.5
BWP	7.7	8.0
OWP	7.0	7.0

Note: Permeability for outside wheelpath conpleted twice, because the pavement had spots where aggregate had been picked out of the mat. This made a difference on the permeability as can be seen.

Table B.6. August 1993 field results for Oregon 138 project

SECTION: Oregon 138 Diamond Lk		North
MILEPOST: 82.3		

RUTTING		
Outside	IWP	1/8 - 3/8"
	OWP	1/4 - 1/2"

PERMEABILITY			
Shoulder	2.77	2.55	
IWP	2.87	2.92	
BWP	2.03	1.99	
OWP 2	1.51	1.44	

SAND PATCH		
Shoulder	7.7	7.5
IWP	7.2	7.5
BWP	8.2	8.0
OWP	8.0	7.7

Note: This section was badly deteriorated. Mumerous tranverse and fatigue cracks were evident. This made testing difficult.

Table B.7. September 1994 field results for Jumpoff Joe - N. Grants Pass

JumpOff Joe - N. Grants Pass		North	
MILEPOST: 64.7			

RUTTING		
Outside	IWP	1/8" -1/4"
	OWP	0-1/8"

PERMEABILITY			
Shoulder	0.75	0.74	7.10
IWP	0.83	0.97	0.96
OWP	1.61	1.45	1.49
BWP	0.71	0.71	0.77

SANDPATCH		
Shoulder		
IWP		
BWP		
OWP		

NOTE: Sandpatch measurements were not taken at this site
High pavement voids caused sand to run into pavement
and scew results

Table B.8. September 1994 field results for E. Pendleton - Emigrant Hill

E. Pendleton - Emigrant Hill		East	
MILEPOST: 214.2			

RUTTING		
Outside	IWP	1/8"
	OWP	0-1/8"

PERMEABILITY			
Shoulder	1.56	1.32	1.40
IWP	0.87	0.88	0.77
OWP	0.93	0.96	0.98
BWP	0.94	0.83	0.88

SANDPATCH		
Shoulder	7.0	6.7
IWP	6.5	6.2
BWP	6.5	6.3
OWP	6.7	6.2

Table B.9. September 1994 field results for Murphy Road - Lava Butte

Murphy Road - Lava Butte	South
MILEPOST: 146.8	

RUTTING		
Outside	IWP	1/8" - 1/4
	OWP	1/4"

PERMEABILITY			
Shoulder	1.68	1.50	1.20
IWP	1.32	1.37	1.35
OWP	1.08	1.06	1.02
BWP	1.67	1.73	1.83

SANDPATCH		
Shoulder	7.5	8.0
IWP	7.0	7.1
BWP	8.0	8.3
OWP	7.0	7.5

Table B.10. Interstate 5 traffic volume information

MP	1986	1987	1988	1989	1990	1991	1992
291.8	88400	94000	102400	103100	108800	109900	115000
293	58400	63900	69200	78200	70150	73900	79000
293.52	57800	63300	68500	67200	69200	73200	78000
294.74	72100	75800	82100	81900	83800	88200	93000
295.43	76800	81300	86900	86000	87850	90400	96000
296.24	75500	79600	85100	84100	85900	88200	94000
296.45	80700	84700	90600	89300	9100	94300	100000
297.08	87300	92100	99600	98900	100650	103600	10800
298.24	96000	101500	108300	108200	109900	113100	118000
299.13	93600	98800	106100	105000	106700	109600	114000
299.46	82800	87200	95100	92600	94100	95200	100000
300.37	87100	99900	107000	104400	101900	88100	94000
AVE	79708	85175	91742	91575	85671	93975	90983

MP	1986	1987	1988	1989	1990	1991	1992
251.03				36850	39600	40300	45000
253.48	32000	34000	39800	47050	48300	49800	52000
255.98	42800	45500	56200	59400	58750	59750	62000
258.26	42900	45600	54400	57450	56900	57950	56000
AVE	39233	41700	50133	50188	50888	51950	53750

MP	1986	1987	1988	1989	1990	1991	1992
71.29	13850	14300	15250	15800	16300	16250	17000
75.73	13350	13800	14750	14751	15900	15900	16000
76.5	12300	12700	13550	15300	14650	14650	15000
77.91	13350	13800	14700	15300	15600	15550	16000
80.3	13450	13900	14800	15400	15750	15700	16000
83.06	13600	14000	14450	15100	15600	15550	16000
85.84	13450	13600	14100	14800	15100	15050	16000
87.79	13450	13900	14350	15100	15500	15400	16000
AVE	13350	13750	14494	15194	15550	15506	16000

MP	1986	1987	1988	1989	1990	1991	1992
61.05	21150	21900	23950	24800	24650	24050	28000
64.2	14250	14800	15750	16300	16800	16800	17000
AVE	17700	18350	19850	20550	20725	20425	22500

U.S. 97 Traffic Volumes

MP	1986	1987	1988	1989	1990	1991	1992
141	15900	16500	19800	20600	23700	25400	25000
141.5	13700	14200	18300	19000	28500	30500	29000
142.27	11500	12000	13200	13800	15700	16900	18000
143.47	10200	10600	9800	10200	13600	14600	15000
AVE	12825	13325	15275	15900	20375	21850	21750

Interstate 84 Traffic Volumes

MP	1986	1987	1988	1989	1990	1991	1992
213.45	6000	6400	5151	6650	7300	7400	8800
216.44	5350	5700	46000	6150	6650	6650	8300
AVE	5675	6050	25576	6400	6975	7025	8550

Table B.11. Jumpoff Joe - N. Grants Pass accident data

	Accident Data					
	Fatal	Non-Fatal	Property Damage	Total	Killed	Injured
Intersection						
1986	0	0	0	0	0	0
1987	0	1	1	2	0	1
1988	0	0	1	1	0	0
1989	0	0	0	0	0	0
1990	0	0	1	1	0	0
1991	0	0	0	0	0	0
1992	0	1	1	2	0	1
1993	0	0	0	0	0	0
TOTAL	0	2	4	6	0	2
Non-Intersection						
1986	0	9	6	15	0	16
1987	1	6	7	14	2	10
1988	1	7	9	17	1	15
1989	1	10	18	29	1	15
1990	1	7	15	23	1	12
1991	0	7	12	19	0	10
1992	0	9	7	16	0	13
1993	0	5	4	9	0	9
TOTAL	4	60	78	142	5	100

Table B.12. Hayesville - BattleCreek accident data

	Accident Data					
	Fatal	Non-Fatal	Property Damage	Total	Killed	Injured
Intersection						
1986	0	6	4	10	0	8
1987	0	5	1	6	0	7
1988	0	4	1	5	0	5
1989	0	2	3	5	0	2
1990	0	5	3	8	0	5
1991	0	4	5	9	0	6
1992	0	3	4	7	0	5
1993	0	3	2	5	0	5
TOTAL	0	32	23	55	0	43
Non-Intersection						
1986	2	23	19	44	2	29
1987	0	26	27	53	0	43
1988	1	17	20	38	1	24
1989	0	32	24	56	0	62
1990	1	30	38	69	1	54
1991	3	23	22	48	4	42
1992	1	29	32	62	1	57
1993	2	25	30	57	2	36
TOTAL	10	205	212	427	11	347

Table B.13. Marquam Bridge - N. Tigard Interchange accident data

	Accident Data					
	Fatal	Non-Fatal	Property Damage	Total	Killed	Injured
Intersection						
1986	1	14	14	29	1	19
1987	1	11	14	26	1	21
1988	0	9	15	24	0	12
1989	0	18	19	37	0	27
1990	0	15	20	35	0	23
1991	0	18	17	35	0	25
1992	0	12	11	23	0	18
1993	0	4	9	13	0	12
TOTAL	2	101	119	222	2	157
Non-Intersection						
1986	1	14	14	29	1	19
1987	1	11	14	26	1	21
1988	0	9	15	24	0	12
1989	0	18	19	37	0	27
1990	0	15	20	35	0	23
1991	0	18	17	35	0	25
1992	0	12	11	23	0	18
1993	0	4	9	13	0	12
TOTAL	2	101	119	222	2	157

Table B.14. E. Pendleton - Emigrant Hill accident data

	Accident Data					
	Fatal	Non-Fatal	Property Damage	Total	Killed	Injured
Intersection						
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1992	0	0	0	0	0	0
1993	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0
Non-Intersection						
1986	0	1	5	6	0	1
1987	1	1	3	5	1	2
1988	0	1	0	1	0	2
1989	0	0	1	1	0	0
1990	0	2	1	3	0	3
1991	2	1	2	5	3	6
1992	0	2	3	5	0	5
1993	0	0	1	1	0	0
TOTAL	3	8	16	27	4	19

Table B.15. Murphy Road - Lava Butte accident data

	Accident Data					
	Fatal	Non-Fatal	Property Damage	Total	Killed	Injured
Intersection						
1986	**	**	**	**	**	**
1987	**	**	**	**	**	**
1988	0	3	6	9	0	4
1989	0	5	2	7	0	7
1990	0	8	5	13	0	16
1991	0	4	6	10	0	6
1992	0	17	10	27	0	43
1993	0	5	8	13	0	6
TOTAL	0	42	37	79	0	82
Non-Intersection						
1986	**	**	**	**	**	**
1987	**	**	**	**	**	**
1988	0	11	11	22	0	19
1989	3	10	14	27	4	32
1990	2	8	9	19	2	26
1991	0	5	14	19	0	9
1992	1	8	13	22	1	18
1993	1	7	11	19	1	11
TOTAL	7	49	72	128	8	115

** No data availiable for 1986 and 1987.

b) Noise Study Data

Table B.16. Traffic data for exterior noise study

			N	S	N	S	N	S	Pavement	Width
MP 34 S BND (I-	3/22/94	2:00 PM	773	701	72	44	116	110	PCC	76 Feet
		3:02 PM	884	622	66	39	143	115		
		4:04 PM	947	675	57	28	134	102		
		5:06 PM	930	548	50	23	95	90		
MP 34 N BND (I-	3/23/94	9:18 AM	531	691	65	34	140	102	PCC	76 Feet
		10:19 AM	606	772	78	44	140	94		
		11:20 AM	660	747	72	24	122	91		
		12:22 PM	740	723	55	29	143	94		
MP 208 S BND (	3/24/94	10:43 AM	817	795	89	46	205	143	B - North	77 Feet
		11:44 AM	841	757	87	42	173	164	F- South	
		12:45 AM	806	732	94	55	163	131		
		1:49 AM	880	806	71	41	178	148		
MP 208 N BND (	3/24/94	3:39 PM	919	911	81	48	151	133	B - North	77 Feet
		4:40 PM	903	1013	62	28	140	115	F- South	
		5:44 PM	737	851	45	18	165	98		
		6:46 PM	540	567	26	13	134	101		
MP 248 S BND (	3/25/94	8:28 AM	1195	1058	65	76	166	132	B	Barrier
		9:30 AM	1506	1086	86	74	189	188		
		10:34 AM	1519	1250	110	131	160	131		
		11:35 AM	1456	1215	92	60	199	178		
MAY TESTING										
Measurement Lo	Date	Time	Autos		Medium Trucks		Heavy Trucks		Existing	Median
			N	S	N	S	N	S	Pavement	Width
MP 34.52 S BN	05/11/94	01:45	734	600	47	34	127	101	B-mix	76 feet
		02:48	934	582	45	37	127	103		
		03:51	962	676	35	44	94	108		
		04:53	996	700	42	39	93	93		
MP 34 N BND	05/12/94	08:22	496	676	54	29	120	83	Bmix	76 feet
		09:26	537	717	56	44	109	97		
		10:31	579	736	61	55	114	101		
		11:33	646	684	38	56	120	93		
JULY TESTING										
Measurement Lo	Date	Time	Autos		Medium Trucks		Heavy Trucks		Existing	Median
			N	S	N	S	N	S	Pavement	Width
MP 34 N BND	07/27/94	08:10	536	754	57	51	118	108	F-mix	76 feet
		09:12	617	737	58	44	122	121		
		10:15	672	755	53	65	117	134		
		11:18	728	743	57	62	112	102		
MP 34.52 S BND	07/26/94	01:38	809	727	73	46	118	134	F-mix	76 feet
		02:45	916	736	54	62	114	134		
		03:47	1033	790	48	63	106	103		
		04:58	1084	624	45	35	105	112		
MP 208 N BND	07/22/94	12:59	1059	1055	76	81	135	145	F-mix	77 feet
		02:06	1175	1193	75	88	122	159		
		03:10	1267	1203	77	86	109	137		
		04:13	1208	1380	76	71	112	137		
MP 248 S BND	07/28/94	07:48	1150	1090	76	99	208	143	F-mix	Barrier
		08:52	1198	990	95	130	248	197		
		09:56	1191	1112	92	144	251	216		
		11:00	1226	1155	116	114	220	204		

Table B.17. BattleCreek - N. Jefferson 1-year-old B-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	111.7	SEL	112.4	SEL	111.9	SEL	112.1
Leq	76.1	Leq	76.8	Leq	76.3	Leq	76.5
SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25		25	39.6	25	40.0	25	40.0
31.5	39.2	31.5	39.3	31.5	39.4	31.5	39.3
40	39.8	40	40.8	40	41.3	40	41.2
50	41.6	50	42.3	50	42.8	50	42.6
63	47.2	63	47.5	63	47.6	63	48.2
80	52.4	80	53.7	80	53.2	80	54.0
100	53.0	100	54.5	100	54.4	100	55.5
125	53.3	125	54.3	125	54.5	125	54.1
160	54.8	160	56.7	160	55.9	160	56.7
200	56.8	200	58.1	200	57.3	200	58.1
250	57.3	250	59.3	250	58.2	250	58.8
315	59.1	315	60.8	315	60.2	315	60.6
400	61.4	400	62.7	400	62.2	400	62.5
500	64.8	500	65.8	500	65.0	500	65.4
630	67.3	630	67.9	630	67.3	630	67.6
800	69.4	800	69.9	800	69.4	800	69.5
1000	69.4	1000	69.9	1000	69.5	1000	69.6
1250	67.6	1250	68.1	1250	67.7	1250	67.8
1600	64.5	1600	65.0	1600	64.6	1600	64.6
2000	62.1	2000	62.7	2000	62.1	2000	62.5
2500	58.9	2500	59.7	2500	59.0	2500	59.5
3150	57.0	3150	57.4	3150	56.4	3150	57.4
4000	54.4	4000	54.9	4000	54.0	4000	55.3
5000	50.6	5000	51.3	5000	50.4	5000	51.8
6300	47.5	6300	48.3	6300	47.3	6300	47.8
8000	44.5	8000	45.1	8000	44.9	8000	44.9
10000	42.3	10000	42.1	10000	41.9	10000	42.0
12500	39.3	12500	39.3	12500	39.3	12500	39.2
16000	39.6	16000	39.4	16000	39.2	16000	39.3
20000	39.1	20000	39.1	20000	39.1	20000	39.1

Table B.18. BattleCreek - N. Jefferson new F-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	107.4	SEL	107.9	SEL	108.1	SEL	107.7
Leq	71.9	Leq	72.4	Leq	72.6	Leq	72.2
SEL-Leq	35.5	SEL-Leq	35.5	SEL-Leq	35.5	SEL-Leq	35.5
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	39.7	25	40.0	25	40.8	25	41.6
31.5	39.9	31.5	40.1	31.5	40.5	31.5	40.7
40	43.8	40	44.3	40	44.5	40	45.1
50	42.7	50	43.0	50	43.6	50	43.7
63	47.5	63	47.5	63	47.6	63	47.5
80	54.0	80	53.5	80	54.3	80	53.5
100	54.3	100	53.9	100	54.7	100	54.9
125	53.1	125	53.1	125	53.9	125	53.6
160	55.5	160	55.7	160	56.0	160	55.6
200	56.3	200	56.8	200	57.1	200	57.3
250	57.7	250	57.8	250	58.4	250	58.2
315	59.3	315	60.5	315	60.7	315	60.1
400	60.7	400	62.6	400	62.6	400	61.8
500	62.6	500	63.7	500	63.6	500	63.5
630	62.3	630	63.0	630	63.1	630	63.0
800	62.5	800	62.9	800	63.1	800	62.6
1000	62.9	1000	63.1	1000	63.3	1000	62.9
1250	62.6	1250	62.9	1250	63.0	1250	62.5
1600	60.5	1600	60.7	1600	61.0	1600	60.5
2000	59.1	2000	59.1	2000	59.5	2000	59.0
2500	57.4	2500	57.3	2500	57.8	2500	57.4
3150	55.2	3150	55.2	3150	55.6	3150	55.2
4000	53.6	4000	53.1	4000	53.8	4000	53.4
5000	51.5	5000	50.9	5000	51.6	5000	51.1
6300	47.6	6300	47.5	6300	48.1	6300	47.8
8000	45.7	8000	45.7	8000	46.1	8000	46.0
10000	42.4	10000	42.5	10000	42.9	10000	42.9
12500	39.7	12500	39.6	12500	39.7	12500	39.7
16000	39.5	16000	39.5	16000	39.5	16000	39.5
20000	39.5	20000	39.5	20000	39.5	20000	39.5

Table B.19. Halsey Interchange - Lane County Line (north) 1-year-old B-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	108.6	SEL	108.6	SEL	108.7	SEL	107.4
Leq	73	Leq	73	Leq	73.1	Leq	71.8
SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	39.9	25	39.9	25	39.8	25	39.4
31.5	39.4	31.5	39.3	31.5	39.3	31.5	39.3
40	41.4	40	40.8	40	40.7	40	40.3
50	42.5	50	42.1	50	42.2	50	41.3
63	46.0	63	46.5	63	46.7	63	45.3
80	53.2	80	52.7	80	53.1	80	52.6
100	53.5	100	53.7	100	53.7	100	52.6
125	53.0	125	53.5	125	54.6	125	51.7
160	54.7	160	54.4	160	54.8	160	52.8
200	55.1	200	55.8	200	55.5	200	54.4
250	53.9	250	53.9	250	54.1	250	52.8
315	55.1	315	54.9	315	56.5	315	53.7
400	57.2	400	57.3	400	57.5	400	55.9
500	62.0	500	62.0	500	62.2	500	61.3
630	63.7	630	63.6	630	63.8	630	62.5
800	65.9	800	65.9	800	65.9	800	64.7
1000	66.3	1000	66.5	1000	66.5	1000	65.2
1250	64.9	1250	64.8	1250	64.9	1250	63.5
1600	62.0	1600	61.8	1600	61.9	1600	60.6
2000	59.5	2000	59.3	2000	59.4	2000	58.3
2500	56.6	2500	56.4	2500	56.5	2500	55.3
3150	55.1	3150	54.9	3150	55.0	3150	54.1
4000	52.5	4000	52.3	4000	52.3	4000	51.7
5000	49.3	5000	49.1	5000	49.0	5000	49.1
6300	46.0	6300	46.1	6300	46.0	6300	45.8
8000	43.8	8000	43.8	8000	43.7	8000	43.5
10000	41.7	10000	41.8	10000	41.8	10000	41.6
12500	39.1	12500	39.2	12500	39.1	12500	39.2
16000	39.1	16000	39.1	16000	39.1	16000	39.1
20000	39.1	20000	39.1	20000	39.1	20000	39.1

Table B.20. Halsey Interchange - Lane County Line (north) new F-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	104.1	SEL	104	SEL	104.4	SEL	105
Leq	68.5	Leq	68.5	Leq	68.8	Leq	69.4
SEL-Leq	35.6	SEL-Leq	35.5	SEL-Leq	35.6	SEL-Leq	35.6
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	34.8	25	34.8	25	35.4	25	34.9
31.5	34.0	31.5	35.1	31.5	36.7	31.5	36.3
40	38.0	40	38.9	40	40.3	40	40.0
50	39.1	50	39.9	50	41.8	50	41.9
63	43.3	63	43.6	63	45.3	63	45.5
80	50.9	80	50.2	80	50.4	80	50.9
100	51.2	100	51.0	100	51.0	100	51.8
125	51.2	125	50.6	125	51.0	125	51.5
160	50.9	160	50.8	160	50.6	160	51.3
200	52.8	200	52.6	200	52.6	200	53.0
250	54.4	250	54.1	250	53.9	250	54.9
315	57.2	315	56.5	315	56.7	315	57.0
400	57.0	400	56.5	400	57.2	400	57.4
500	58.2	500	58.1	500	58.1	500	58.6
630	57.8	630	57.9	630	58.2	630	58.7
800	59.7	800	59.8	800	60.2	800	60.8
1000	60.4	1000	60.6	1000	61.1	1000	61.6
1250	59.1	1250	59.4	1250	59.8	1250	60.7
1600	56.5	1600	56.5	1600	57.0	1600	57.7
2000	55.0	2000	55.2	2000	55.5	2000	56.3
2500	54.7	2500	54.9	2500	55.1	2500	55.9
3150	52.7	3150	52.7	3150	52.5	3150	52.6
4000	50.5	4000	50.1	4000	50.6	4000	51.3
5000	48.1	5000	47.6	5000	47.5	5000	47.9
6300	43.9	6300	43.7	6300	43.9	6300	44.7
8000	40.8	8000	40.7	8000	40.8	8000	41.5
10000	36.8	10000	36.7	10000	37.0	10000	37.4
12500	31.0	12500	31.1	12500	31.2	12500	31.4
16000	30.0	16000	30.0	16000	30.1	16000	30.2
20000	29.5	20000	29.5	20000	29.5	20000	29.5

Table B.21. Halsey Interchange - Lane County Line (south) 1-year-old B-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	106.7	SEL	107.2	SEL		SEL	106.7
Leq	71.2	Leq	71.7	Leq	70.8	Leq	71.2
SEL-Leq	35.5	SEL-Leq	35.3	SEL-Leq		SEL-Leq	35.5
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	39.6	25	39.7	25	39.6	25	39.6
31.5	39.2	31.5	39.3	31.5	39.4	31.5	39.3
40	40.4	40	40.7	40	40.7	40	40.7
50	41.4	50	42.4	50	42.1	50	42.1
63	45.3	63	45.7	63	45.3	63	44.6
80	52.3	80	52.5	80	51.9	80	52.1
100	52.4	100	52.6	100	53.1	100	52.4
125	51.5	125	52.6	125	51.7	125	51.7
160	52.9	160	53.4	160	52.9	160	52.9
200	54.6	200	55.1	200	54.5	200	54.6
250	54.5	250	55.6	250	54.3	250	54.9
315	57.4	315	58.6	315	57.3	315	57.3
400	57.9	400	58.7	400	57.9	400	57.9
500	62.1	500	62.3	500	61.4	500	61.9
630	63.5	630	63.9	630	63.2	630	63.5
800	64.1	800	64.5	800	63.9	800	64.2
1000	62.7	1000	63.1	1000	62.3	1000	62.7
1250	59.9	1250	60.8	1250	59.6	1250	60.0
1600	57.4	1600	58.3	1600	57.4	1600	57.5
2000	56.5	2000	57.6	2000	57.0	2000	56.9
2500	52.2	2500	55.4	2500	54.1	2500	54.5
3150	52.9	3150	54.1	3150	53.1	3150	53.2
4000	51.5	4000	52.6	4000	51.7	4000	51.7
5000	48.6	5000	50.7	5000	48.3	5000	48.5
6300	45.5	6300	48.2	6300	45.3	6300	45.5
8000	43.5	8000	44.4	8000	43.4	8000	43.5
10000	41.5	10000	42.6	10000	41.8	10000	41.7
12500	39.2	12500	39.7	12500	39.3	12500	39.2
16000	39.4	16000	39.9	16000	39.6	16000	39.6
20000	39.1	20000	39.3	20000	39.1	20000	39.1

Table B.22. Seven Oaks - Jackson (south) old PCC exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	112	SEL	112.1	SEL	111.8	SEL	
Leq	76.4	Leq	76.5	Leq	76.2	Leq	74
SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	30.1	25	30.6	25	30.2	25	33.4
31.5	30.5	31.5	31.0	31.5	30.6	31.5	32.8
40	34.2	40	34.6	40	34.1	40	34.1
50	37.3	50	37.9	50	37.2	50	36.5
63	43.6	63	44.4	63	43.7	63	41.2
80	51.8	80	53.0	80	51.0	80	49.2
100	51.7	100	53.1	100	52.2	100	50.1
125	50.8	125	51.6	125	51.6	125	49.2
160	51.8	160	52.3	160	51.8	160	50.2
200	53.6	200	54.3	200	54.1	200	52.4
250	55.7	250	56.6	250	55.5	250	53.2
315	58.8	315	59.6	315	58.6	315	55.9
400	60.2	400	60.5	400	59.7	400	58.0
500	64.1	500	64.4	500	63.9	500	62.5
630	66.2	630	66.4	630	65.9	630	64.6
800	68.8	800	68.8	800	68.4	800	67.1
1000	69.7	1000	69.7	1000	69.4	1000	68.1
1250	68.6	1250	68.5	1250	68.4	1250	67.0
1600	66.6	1600	66.6	1600	66.6	1600	65.0
2000	64.5	2000	64.4	2000	64.4	2000	62.8
2500	61.1	2500	61.4	2500	61.2	2500	59.5
3150	58.4	3150	58.8	3150	58.4	3150	56.7
4000	55.3	4000	55.5	4000	55.3	4000	53.5
5000	51.6	5000	52.2	5000	51.7	5000	49.9
6300	46.9	6300	47.5	6300	47.1	6300	46.5
8000	42.1	8000	42.7	8000	42.3	8000	41.6
10000	37.1	10000	37.8	10000	37.3	10000	38.2
12500	30.5	12500	31.2	12500	30.5	12500	34.6
16000	29.1	16000	29.2	16000	29.1	16000	33.4
20000	29.1	20000	29.1	20000	29.1	20000	32.4

Table B.23. Seven Oaks - Jackson (south) new B-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	105.3	SEL	105	SEL	105.2	SEL	105.7
Leq	69.8	Leq	70	Leq	69.6	Leq	70.2
SEL-Leq	35.5	SEL-Leq	35	SEL-Leq	35.6	SEL-Leq	35.5
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	35.4	25	34.7	25	34.5	25	34.6
31.5	33.4	31.5	33.6	31.5	33.7	31.5	33.9
40	38.1	40	38.9	40	38.9	40	38.9
50	38.2	50	38.3	50	38.0	50	38.4
63	44.6	63	44.0	63	42.8	63	42.9
80	50.2	80	50.0	80	48.9	80	48.3
100	48.7	100	48.9	100	48.0	100	48.1
125	48.1	125	49.0	125	49.0	125	48.9
160	49.2	160	49.1	160	48.4	160	48.7
200	50.9	200	50.3	200	51.0	200	51.3
250	54.0	250	53.3	250	52.1	250	52.9
315	58.0	315	56.2	315	56.0	315	56.5
400	57.7	400	57.7	400	56.8	400	56.7
500	60.3	500	60.8	500	60.7	500	60.6
630	60.1	630	60.7	630	60.4	630	60.7
800	61.2	800	61.7	800	61.2	800	62.0
1000	61.7	1000	62.0	1000	61.8	1000	62.6
1250	60.4	1250	60.7	1250	60.6	1250	61.5
1600	58.6	1600	58.8	1600	58.4	1600	59.4
2000	57.3	2000	57.3	2000	57.1	2000	52.7
2500	54.6	2500	54.5	2500	54.6	2500	50.1
3150	52.9	3150	52.7	3150	52.4	3150	52.7
4000	50.6	4000	50.3	4000	50.0	4000	50.1
5000	47.0	5000	46.7	5000	46.5	5000	46.5
6300	43.5	6300	43.5	6300	43.1	6300	43.2
8000	40.2	8000	40.7	8000	40.3	8000	40.5
10000	36.8	10000	37.1	10000	36.9	10000	37.1
12500	32.6	12500	32.7	12500	32.6	12500	32.6
16000	32.2	16000	32.2	16000	32.2	16000	32.2
20000	32.2	20000	32.2	20000	32.2	20000	32.2

Table B.24. Seven Oaks - Jackson (south) new F-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	104.7	SEL	104.3	SEL	104.1	SEL	103.4
Leq	69.3	Leq	68.8	Leq	68.5	Leq	67.9
SEL-Leq	35.4	SEL-Leq	35.5	SEL-Leq	35.6	SEL-Leq	35.5
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	33.5	25	41.7	25	41.5	25	41.2
31.5	32.5	31.5	41.5	31.5	41.9	31.5	42.0
40	37.6	40	47.8	40	48.3	40	48.3
50	37.6	50	44.8	50	44.9	50	44.8
63	44.2	63	47.6	63	47.8	63	47.7
80	49.7	80	50.6	80	50.9	80	50.8
100	50.0	100	50.3	100	50.3	100	50.0
125	50.1	125	50.5	125	49.9	125	49.8
160	49.6	160	51.1	160	50.9	160	50.6
200	52.3	200	52.4	200	52.5	200	52.0
250	55.0	250	54.8	250	54.5	250	54.1
315	59.2	315	58.7	315	58.1	315	57.1
400	58.9	400	58.6	400	58.4	400	57.7
500	59.6	500	59.8	500	59.3	500	58.8
630	58.2	630	58.4	630	58.2	630	57.4
800	58.8	800	58.7	800	58.6	800	57.7
1000	60.4	1000	59.9	1000	59.7	1000	59.4
1250	60.2	1250	59.9	1250	59.5	1250	59.1
1600	58.1	1600	58.0	1600	57.8	1600	57.2
2000	56.4	2000	56.1	2000	56.0	2000	55.0
2500	54.9	2500	54.8	2500	54.7	2500	53.8
3150	52.8	3150	52.1	3150	52.0	3150	51.2
4000	51.0	4000	49.8	4000	49.9	4000	48.9
5000	47.3	5000	48.7	5000	49.0	5000	48.9
6300	42.9	6300	45.8	6300	46.1	6300	46.1
8000	39.1	8000	46.5	8000	47.0	8000	47.1
10000	35.6	10000	43.2	10000	43.6	10000	43.9
12500	30.3	12500	39.5	12500	39.5	12500	39.5
16000	29.5	16000	39.5	16000	39.5	16000	39.5
20000	29.5	20000	39.5	20000	39.5	20000	39.5

Table B.25. Seven Oaks - Jackson (north) old PCC exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	112.3	SEL	112.5	SEL	112.3	SEL	112.6
Leq	76.7	Leq	76.9	Leq	76.7	Leq	77.1
SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	36.5
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	30.4	25	32.1	25	33.0	25	32.7
31.5	30.7	31.5	33.3	31.5	34.2	31.5	33.4
40	33.4	40	36.4	40	37.1	40	36.5
50	37.2	50	39.6	50	40.1	50	39.5
63	44.1	63	45.1	63	44.9	63	44.9
80	51.9	80	51.2	80	51.6	80	51.7
100	52.2	100	52.0	100	52.2	100	52.5
125	52.4	125	52.6	125	52.7	125	53.1
160	54.1	160	54.5	160	53.9	160	54.5
200	57.1	200	57.2	200	56.8	200	57.4
250	58.3	250	58.2	250	58.0	250	58.8
315	60.4	315	60.0	315	59.8	315	60.5
400	60.8	400	60.4	400	60.1	400	60.6
500	63.7	500	63.9	500	53.6	500	64.1
630	65.6	630	65.8	630	65.5	630	66.0
800	68.3	800	68.7	800	68.4	800	68.8
1000	69.7	1000	70.2	1000	69.9	1000	70.2
1250	69.3	1250	69.5	1250	69.4	1250	69.6
1600	67.8	1600	67.8	1600	67.7	1600	68.0
2000	65.6	2000	65.4	2000	65.3	2000	65.7
2500	62.3	2500	61.8	2500	61.7	2500	62.0
3150	59.6	3150	58.9	3150	58.7	3150	58.9
4000	57.0	4000	56.3	4000	56.0	4000	56.3
5000	52.6	5000	51.7	5000	51.5	5000	51.8
6300	47.6	6300	46.9	6300	46.7	6300	47.1
8000	43.1	8000	42.7	8000	42.5	8000	43.0
10000	37.7	10000	37.3	10000	37.3	10000	37.5
12500	30.9	12500	30.7	12500	30.7	12500	30.8
16000	29.2	16000	29.1	16000	29.1	16000	29.1
20000	29.1	20000	29.1	20000	29.1	20000	29.1

Table B.26. Seven Oaks - Jackson (north) new B-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	106.2	SEL	105.9	SEL	105.8	SEL	105.6
Leq	70.6	Leq	70.3	Leq	70.2	Leq	70
SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	32.7	25	32.9	25	34.1	25	34.5
31.5	32.8	31.5	32.8	31.5	33.1	31.5	33.2
40	36.0	40	36.4	40	36.7	40	37.0
50	36.8	50	36.7	50	37.2	50	37.6
63	41.1	63	41.1	63	41.9	63	41.2
80	50.1	80	49.8	80	49.7	80	48.8
100	49.9	100	48.9	100	49.6	100	49.4
125	48.6	125	48.9	125	48.7	125	49.5
160	49.0	160	49.1	160	49.3	160	49.3
200	51.6	200	51.3	200	51.1	200	52.0
250	51.7	250	52.0	250	52.0	250	52.5
315	54.4	315	54.5	315	55.4	315	55.2
400	55.2	400	54.8	400	55.4	400	55.0
500	58.7	500	59.7	500	59.2	500	59.4
630	59.9	630	59.9	630	60.0	630	59.5
800	62.8	800	62.3	800	62.1	800	61.7
1000	63.5	1000	63.2	1000	62.8	1000	62.8
1250	62.4	1250	62.0	1250	61.9	1250	61.7
1600	60.5	1600	60.2	1600	60.0	1600	60.1
2000	58.7	2000	58.4	2000	58.3	2000	58.3
2500	56.2	2500	55.7	2500	55.9	2500	55.7
3150	54.6	3150	53.9	3150	53.8	3150	53.9
4000	51.5	4000	51.0	4000	50.9	4000	50.9
5000	48.4	5000	47.8	5000	47.7	5000	48.1
6300	44.0	6300	43.7	6300	43.7	6300	43.8
8000	40.4	8000	40.2	8000	40.5	8000	40.3
10000	36.8	10000	36.3	10000	36.5	10000	36.8
12500	32.6	12500	32.5	12500	32.5	12500	32.5
16000	32.2	16000	32.2	16000	32.2	16000	32.2
20000	32.2	20000	32.2	20000	32.2	20000	32.2

Table B.27. Seven Oaks - Jackson (north) new F-mix exterior noise data

First Hour		Second Hour		Third Hour		Fourth Hour	
SEL	104.1	SEL	103.9	SEL	104.1	SEL	104
Leq	68.5	Leq	68.3	Leq	68.5	Leq	68.4
SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6	SEL-Leq	35.6
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	39.7	25	40.0	25	42.1	25	42.3
31.5	39.8	31.5	39.8	31.5	40.8	31.5	41.4
40	43.1	40	44.0	40	45.6	40	47.1
50	41.8	50	42.1	50	43.5	50	44.2
63	43.3	63	43.5	63	45.3	63	46.5
80	50.4	80	49.9	80	50.3	80	50.2
100	51.2	100	50.9	100	50.9	100	51.2
125	51.0	125	50.8	125	50.9	125	51.5
160	50.3	160	51.0	160	51.3	160	52.0
200	51.7	200	52.4	200	52.3	200	53.1
250	53.7	250	53.6	250	54.2	250	54.2
315	58.2	315	58.0	315	58.4	315	58.2
400	58.8	400	58.9	400	59.0	400	58.7
500	59.4	500	59.6	500	59.6	500	61.0
630	57.9	630	58.0	630	58.3	630	58.4
800	58.4	800	58.2	800	58.6	800	58.5
1000	59.5	1000	59.0	1000	59.4	1000	59.4
1250	59.3	1250	58.9	1250	59.2	1250	58.9
1600	57.2	1600	56.9	1600	57.3	1600	57.0
2000	55.7	2000	55.4	2000	56.0	2000	55.8
2500	54.7	2500	54.2	2500	54.8	2500	54.5
3150	52.3	3150	52.2	3150	52.8	3150	51.9
4000	50.5	4000	50.5	4000	50.4	4000	50.2
5000	48.6	5000	48.5	5000	48.5	5000	48.8
6300	44.7	6300	44.6	6300	45.2	6300	45.7
8000	44.0	8000	44.2	8000	45.2	8000	46.2
10000	41.7	10000	41.5	10000	42.2	10000	43.1
12500	39.6	12500	39.5	12500	39.5	12500	39.5
16000	39.5	16000	39.5	16000	39.5	16000	39.5
20000	39.5	20000	39.5	20000	39.5	20000	39.5

Table B.28. Halsey Interchange - Lane County Line first run interior noise data

MP 216 - 214 SouthBound		MP 211 to 209 SouthBound		MP 208 - 205 SouthBound		MP 216 - 214 SouthBound		MP 216 - 214 SouthBound	
SEL	94	SEL	93.6	SEL	93	SEL	94.1	SEL	93.3
Leq	73.2	Leq	72.8	Leq	72.2	Leq	73.3	Leq	72.5
SEL-Leq	20.8	SEL-Leq	20.8	SEL-Leq	20.8	SEL-Leq	20.8	SEL-Leq	20.8
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	42.0	25	40.8	25	39.1	25	41.7	25	42.5
31.5	43.9	31.5	42.5	31.5	42.0	31.5	42.8	31.5	42.6
40	46.4	40	45.4	40	44.6	40	47.0	40	45.7
50	48.3	50	48.0	50	46.3	50	48.1	50	47.2
63	53.3	63	52.6	63	53.3	63	53.4	63	52.4
80	56.2	80	55.3	80	55.6	80	56.7	80	56.3
100	63.2	100	62.0	100	62.6	100	63.9	100	64.2
125	57.5	125	55.9	125	57.3	125	56.3	125	55.2
160	58.2	160	57.6	160	56.7	160	57.9	160	56.5
200	61.6	200	60.4	200	61.2	200	60.9	200	59.2
250	65.3	250	63.2	250	64.2	250	65.5	250	64.9
315	61.8	315	60.0	315	60.5	315	62.6	315	61.5
400	62.5	400	60.8	400	61.6	400	63.2	400	61.8
500	62.4	500	60.9	500	60.9	500	64.0	500	62.9
630	61.6	630	61.6	630	60.9	630	63.5	630	62.9
800	63.6	800	64.8	800	62.9	800	63.5	800	63.8
1000	60.9	1000	62.7	1000	59.6	1000	61.5	1000	60.0
1250	60.2	1250	62.9	1250	58.3	1250	59.5	1250	58.0
1600	57.4	1600	58.6	1600	55.7	1600	55.0	1600	53.2
2000	57.5	2000	56.9	2000	54.8	2000	52.8	2000	51.5
2500	55.6	2500	54.8	2500	53.2	2500	52.3	2500	50.4
3150	53.5	3150	52.8	3150	50.9	3150	51.5	3150	48.8
4000	50.6	4000	49.7	4000	48.1	4000	49.6	4000	46.6
5000	47.0	5000	46.3	5000	45.0	5000	48.2	5000	45.1
6300	42.5	6300	41.9	6300	40.6	6300	46.7	6300	42.5
8000	39.2	8000	38.7	8000	37.5	8000	44.7	8000	42.3
10000	35.9	10000	35.6	10000	34.6	10000	43.6	10000	41.1
12500	29.1	12500	29.3	12500	29.2	12500	41.8	12500	39.1
16000	29.1	16000	29.1	16000	29.6	16000	41.0	16000	39.4
20000	29.1	20000	29.1	20000	29.1	20000	40.3	20000	39.1

Table B.28. Halsey Interchange - Lane County Line first run interior noise data (continued)

MP 208 - 206 SouthBound		MP 206 - 204 SouthBound		MP 204 - 206 NorthBound		MP 207 - 209 NorthBound		MP 213 - 215 NorthBound	
SEL	92.8	SEL	92.7	SEL	92.7	SEL	93	SEL	91.6
Leq	72	Leq	72	Leq	72	Leq	72.2	Leq	70.8
SEL-Leq	20.8	SEL-Leq	20.7	SEL-Leq	20.7	SEL-Leq	20.8	SEL-Leq	20.8
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	42.8	25	43.3	25	42.1	25	42.3	25	42.1
31.5	43.3	31.5	43.2	31.5	42.5	31.5	42.7	31.5	42.7
40	46.1	40	46.0	40	44.4	40	44.3	40	45.4
50	47.7	50	47.6	50	47.2	50	47.1	50	46.0
63	52.5	63	52.1	63	51.5	63	51.6	63	52.1
80	56.2	80	55.9	80	53.8	80	53.6	80	53.9
100	63.7	100	63.2	100	62.9	100	63.0	100	62.8
125	55.5	125	55.1	125	56.1	125	56.5	125	54.7
160	56.5	160	56.1	160	56.1	160	55.9	160	55.7
200	59.3	200	59.0	200	61.7	200	61.5	200	60.2
250	64.8	250	64.2	250	63.4	250	63.8	250	61.6
315	61.4	315	61.0	315	59.3	315	59.7	315	57.9
400	61.7	400	61.3	400	61.0	400	61.5	400	60.0
500	62.9	500	62.0	500	60.2	500	60.7	500	58.8
630	64.0	630	62.6	630	61.1	630	61.8	630	59.9
800	64.7	800	63.4	800	63.5	800	63.9	800	61.9
1000	60.6	1000	59.8	1000	61.1	1000	61.3	1000	59.3
1250	58.7	1250	57.4	1250	59.5	1250	59.4	1250	58.2
1600	53.7	1600	53.3	1600	56.6	1600	56.2	1600	56.0
2000	51.7	2000	51.5	2000	53.4	2000	53.1	2000	53.0
2500	50.4	2500	50.3	2500	51.6	2500	51.3	2500	51.0
3150	48.7	3150	48.6	3150	50.3	3150	49.7	3150	49.6
4000	46.4	4000	46.2	4000	48.1	4000	47.5	4000	47.4
5000	44.5	5000	44.3	5000	46.1	5000	45.5	5000	45.5
6300	42.2	6300	42.1	6300	43.5	6300	42.9	6300	42.9
8000	42.1	8000	42.1	8000	42.3	8000	42.0	8000	42.0
10000	41.0	10000	40.9	10000	41.2	10000	41.1	10000	41.1
12500	39.1	12500	39.1	12500	39.1	12500	39.1	12500	39.1
16000	39.3	16000	39.3	16000	39.1	16000	39.1	16000	39.1
20000	39.1	20000	39.1	20000	39.1	20000	39.1	20000	39.1

Table B.29. Halsey Interchange - Lane County Line new F-mix, second run interior noise data

MP 249 SouthBound		MP 246 NorthBound		MP 248 - 250 SouthBound		MP 247 NorthBound	
SEL Leq SEL-Leq	72	SEL Leq SEL-Leq	71.5	SEL Leq SEL-Leq	71.9	SEL Leq SEL-Leq	72
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	41.8	25	42.4	25	42.0	25	41.6
31.5	45.0	31.5	44.6	31.5	45.1	31.5	45.8
40	47.0	40	46.6	40	46.7	40	46.7
50	47.7	50	47.2	50	47.5	50	48.8
63	53.0	63	52.2	63	51.9	63	52.5
80	57.3	80	55.0	80	57.3	80	56.9
100	60.9	100	60.7	100	51.2	100	61.0
125	55.3	125	54.3	125	55.1	125	55.9
160	58.5	160	58.4	160	58.7	160	57.7
200	59.0	200	58.4	200	58.7	200	59.1
250	63.9	250	63.2	250	63.1	250	63.4
315	61.3	315	60.6	315	61.1	315	60.3
400	62.7	400	61.9	400	61.9	400	62.2
500	63.4	500	62.5	500	62.3	500	62.5
630	61.3	630	60.9	630	61.4	630	61.3
800	61.1	800	61.4	800	62.0	800	61.9
1000	59.7	1000	60.1	1000	60.9	1000	60.8
1250	58.1	1250	58.4	1250	59.4	1250	59.1
1600	54.2	1600	53.9	1600	55.2	1600	55.1
2000	53.9	2000	53.2	2000	54.6	2000	54.6
2500	52.1	2500	51.3	2500	53.5	2500	52.7
3150	49.2	3150	48.5	3150	50.4	3150	50.0
4000	45.9	4000	45.2	4000	46.9	4000	47.7
5000	43.0	5000	42.7	5000	43.7	5000	45.0
6300	39.8	6300	39.3	6300	40.3	6300	41.0
8000	37.7	8000	37.5	8000	38.1	8000	38.5
10000	34.9	10000	34.5	10000	35.1	10000	35.2
12500	29.5	12500	39.8	12500	29.5	12500	29.8
16000	30.1	16000	30.0	16000	30.0	16000	30.0
20000	29.5	20000	29.5	20000	29.5	20000	29.5

Table B.30. Medford old PCC first run interior noise data

MP 35 - 33 SouthBound		MP 33.5 - 35 NorthBound	
SEL	94.2	SEL	94.2
Leq	74.9	Leq	73.4
SEL-Leq	19.3	SEL-Leq	20.8
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	45.5	25	41.6
31.5	46.2	31.5	43.5
40	48.5	40	46.3
50	52.4	50	50.4
63	55.4	63	54.1
80	60.2	80	59.1
100	67.6	100	66.8
125	58.9	125	56.4
160	60.2	160	58.1
200	61.7	200	60.3
250	65.0	250	62.9
315	62.2	315	59.6
400	61.3	400	59.1
500	61.3	500	59.3
630	63.1	630	61.2
800	65.8	800	64.8
1000	64.1	1000	62.3
1250	64.0	1250	62.2
1600	61.3	1600	60.5
2000	58.6	2000	54.6
2500	56.8	2500	51.5
3150	54.4	3150	50.4
4000	51.5	4000	48.0
5000	48.0	5000	45.7
6300	44.8	6300	43.0
8000	43.2	8000	41.5
10000	41.9	10000	41.5
12500	39.1	12500	39.1
16000	39.1	16000	39.1
20000	39.1	20000	39.1

Table B.31. Medford new B-mix second run interior noise data

MP 35.75 SouthBound		MP 32 NorthBound		MP 35.75 SouthBound		MP 32 NorthBound		MP 35.75 SouthBound	
SEL	88.4	SEL	91.2	SEL	87.4	SEL	90.8	SEL	84.7
Leq	68.8	Leq	70.4	Leq	68.8	Leq	70	Leq	66.9
SEL-Leq	19.6	SEL-Leq	20.8	SEL-Leq	18.6	SEL-Leq	20.8	SEL-Leq	17.8
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	39.0	25	42.0	25	39.3	25	41.9	25	38.4
31.5	39.6	31.5	42.5	31.5	40.8	31.5	42.6	31.5	41.6
40	43.1	40	45.0	40	44.2	40	45.9	40	43.3
50	45.5	50	48.0	50	45.4	50	48.3	50	44.5
63	48.9	63	50.1	63	48.0	63	49.5	63	47.0
80	52.2	80	53.1	80	52.1	80	52.7	80	52.2
100	60.0	100	59.2	100	59.5	100	59.7	100	52.9
125	52.1	125	54.1	125	51.8	125	54.9	125	56.6
160	56.9	160	57.3	160	55.7	160	57.4	160	51.9
200	55.9	200	57.3	200	58.7	200	58.1	200	55.7
250	58.5	250	59.7	250	58.6	250	59.3	250	58.8
315	56.1	315	58.2	315	56.2	315	57.9	315	54.8
400	57.2	400	59.0	400	57.3	400	58.7	400	55.5
500	57.3	500	58.7	500	57.2	500	58.3	500	56.7
630	58.5	630	60.2	630	58.1	630	59.5	630	56.4
800	59.1	800	61.0	800	58.9	800	60.4	800	56.7
1000	58.3	1000	60.2	1000	58.2	1000	59.5	1000	55.8
1250	58.0	1250	59.9	1250	57.7	1250	59.2	1250	55.3
1600	53.6	1600	56.8	1600	53.7	1600	56.1	1600	51.0
2000	52.1	2000	56.0	2000	52.2	2000	55.5	2000	48.1
2500	50.2	2500	54.6	2500	50.3	2500	53.8	2500	46.3
3150	48.1	3150	51.9	3150	48.1	3150	51.1	3150	44.3
4000	45.0	4000	49.0	4000	45.4	4000	48.3	4000	41.7
5000	42.3	5000	45.7	5000	42.8	5000	45.2	5000	40.0
6300	38.8	6300	42.0	6300	39.4	6300	41.5	6300	37.2
8000	37.1	8000	39.5	8000	37.7	8000	39.2	8000	37.0
10000	35.0	10000	37.0	10000	35.4	10000	36.8	10000	34.7
12500	32.2	12500	32.2	12500	32.2	12500	32.2	12500	32.2
16000	32.7	16000	32.6	16000	32.5	16000	32.5	16000	32.5
20000	32.2	20000	32.2	20000	32.2	20000	32.2	20000	32.2

Table B.32. Medford new F-mix third run interior noise data

MP 35.75 SouthBound		MP 33 - 35 NorthBound		MP 35.75 SouthBound		MP 33 - 35 NorthBound	
SEL Leq SEL-Leq	71.7	SEL Leq SEL-Leq	71.9	SEL Leq SEL-Leq	71.3	SEL Leq SEL-Leq	72.6
Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)	Freq. (Hz)	Sound Level db(A)
25	41.4	25	41.5	25	41.0	25	41.9
31.5	42.8	31.5	43.4	31.5	42.8	31.5	43.9
40	44.1	40	43.4	40	43.9	40	44.3
50	47.0	50	47.8	50	47.0	50	47.7
63	49.7	63	50.3	63	49.4	63	51.5
80	55.5	80	56.0	80	57.4	80	56.3
100	60.6	100	61.3	100	60.8	100	61.5
125	55.5	125	54.9	125	59.0	125	55.3
160	61.9	160	61.1	160	61.0	160	61.2
200	57.7	200	59.0	200	58.0	200	58.8
250	63.7	250	63.6	250	62.2	250	64.6
315	60.9	315	61.1	315	59.7	315	61.9
400	62.1	400	62.3	400	61.4	400	62.6
500	62.5	500	63.1	500	61.9	500	64.6
630	60.9	630	62.2	630	60.7	630	63.6
800	59.8	800	60.0	800	59.1	800	60.6
1000	59.4	1000	58.8	1000	58.6	1000	58.5
1250	57.4	1250	57.1	1250	56.9	1250	56.5
1600	54.3	1600	53.9	1600	54.6	1600	54.0
2000	54.1	2000	53.4	2000	54.0	2000	54.1
2500	52.4	2500	51.5	2500	52.3	2500	51.9
3150	49.5	3150	48.9	3150	49.1	3150	49.0
4000	46.3	4000	46.2	4000	46.2	4000	46.1
5000	43.4	5000	43.3	5000	43.4	5000	42.9
6300	39.8	6300	39.4	6300	39.7	6300	39.3
8000	37.6	8000	37.3	8000	37.7	8000	37.4
10000	34.7	10000	34.4	10000	34.8	10000	34.4
12500	29.5	12500	29.5	12500	29.5	12500	39.5
16000	29.5	16000	29.5	16000	29.5	16000	39.5
20000	29.5	20000	29.5	20000	29.5	20000	39.5

APPENDIX C

Laboratory Data

a) ECS Air Permeability Data

Table C.1. Air permeability calculations for samples P1PP to P8PP

P1PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97942	5.5	0	4.3E-05	4.5E-05	1.9E-05	0.0081	3.845	0.0977	8.1E-05	9.3E-05	1.3E-08
40	13533	94559	7.75	0	6.1E-05	6.5E-05	1.9E-05	0.0081	3.845	0.0977	6.3E-05	6.8E-05	9.9E-09
60	20299	91175	9.75	0	7.7E-05	8.5E-05	1.9E-05	0.0081	3.845	0.0977	5.6E-05	5.9E-05	8.8E-09
80	27066	87792	11.5	0	9E-05	0.0001	1.9E-05	0.0081	3.845	0.0977	5.2E-05	5.4E-05	8.2E-09
100	33832	84409	13	0	0.0001	0.0001	1.9E-05	0.0081	3.845	0.0977	4.9E-05	5.1E-05	7.8E-09
120	40599	81026	13.5	0	0.0001	0.0001	1.9E-05	0.0081	3.845	0.0977	4.5E-05	4.6E-05	7.1E-09
140	47365	77642	14.5	0	0.0001	0.0001	1.9E-05	0.0081	3.845	0.0977	4.3E-05	4.4E-05	6.8E-09
160	54132	74259		0	0	0	1.9E-05	0.0081	3.845	0.0977			0

Average K	5.5E-05	5.9E-05

P2PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97942	6	0	4.7E-05	4.9E-05	1.9E-05	0.0081	3.874	0.0984	8.9E-05	0.0001	1.4E-08
40	13533	94559	8.25	0	6.5E-05	7E-05	1.9E-05	0.0081	3.874	0.0984	6.7E-05	7.2E-05	1.1E-08
60	20299	91175	10.5	0	8.3E-05	9.2E-05	1.9E-05	0.0081	3.874	0.0984	6.1E-05	6.4E-05	9.6E-09
80	27066	87792	12	0	9.4E-05	0.0001	1.9E-05	0.0081	3.874	0.0984	5.5E-05	5.7E-05	8.6E-09
100	33832	84409	13.5	0	0.0001	0.0001	1.9E-05	0.0081	3.874	0.0984	5.2E-05	5.3E-05	8.2E-09
120	40599	81026	15	0	0.0001	0.0001	1.9E-05	0.0081	3.874	0.0984	5E-05	5.1E-05	7.9E-09
140	47365	77642	15.5	0	0.0001	0.0002	1.9E-05	0.0081	3.874	0.0984	4.6E-05	4.7E-05	7.3E-09
160	54132	74259		0	0	0	1.9E-05	0.0081	3.874	0.0984			0

Average K	6E-05	6.4E-05

P4PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97942	4.25	0	3.3E-05	3.5E-05	1.9E-05	0.0081	4.146	0.1053	6.7E-05	7.7E-05	1.1E-08
40	13533	94559	6.5	0	5.1E-05	5.5E-05	1.9E-05	0.0081	4.146	0.1053	5.7E-05	6.1E-05	9E-09
60	20299	91175	8.25	0	6.5E-05	7.2E-05	1.9E-05	0.0081	4.146	0.1053	5.1E-05	5.4E-05	8.1E-09
80	27066	87792	9.25	0	7.3E-05	8.4E-05	1.9E-05	0.0081	4.146	0.1053	4.5E-05	4.7E-05	7.1E-09
100	33832	84409	10.25	0	8.1E-05	9.7E-05	1.9E-05	0.0081	4.146	0.1053	4.2E-05	4.3E-05	6.6E-09
120	40599	81026	10.75	0	8.5E-05	0.0001	1.9E-05	0.0081	4.146	0.1053	3.8E-05	3.9E-05	6.1E-09
140	47365	77642	11	0	8.7E-05	0.0001	1.9E-05	0.0081	4.146	0.1053	3.5E-05	3.6E-05	5.6E-09
160	54132	74259		0	0	0	1.9E-05	0.0081	4.146	0.1053			0

Average K	4.8E-05	5.1E-05

P5PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97942	6.25	0	4.9E-05	5.1E-05	1.9E-05	0.0081	3.98	0.1011	9.5E-05	0.0001	1.5E-08
40	13533	94559	9	0	7.1E-05	7.6E-05	1.9E-05	0.0081	3.98	0.1011	7.6E-05	8.1E-05	1.2E-08
60	20299	91175	12	0	9.4E-05	0.0001	1.9E-05	0.0081	3.98	0.1011	7.1E-05	7.5E-05	1.1E-08
80	27066	87792	13.5	0	0.0001	0.0001	1.9E-05	0.0081	3.98	0.1011	6.3E-05	6.6E-05	1E-08
100	33832	84409	15	0	0.0001	0.0001	1.9E-05	0.0081	3.98	0.1011	5.9E-05	6.1E-05	9.3E-09
120	40599	81026	16	0	0.0001	0.0002	1.9E-05	0.0081	3.98	0.1011	5.5E-05	5.6E-05	8.7E-09
140	47365	77642	16.5	0	0.0001	0.0002	1.9E-05	0.0081	3.98	0.1011	5.1E-05	5.2E-05	8E-09
160	54132	74259		0	0	0	1.9E-05	0.0081	3.98	0.1011			0

Average K	6.7E-05	7.1E-05

Table C.1. Air permeability calculations for samples P1PP to P8PP (continued)

P6PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97942	4.25	0	3.3E-05	3.5E-05	1.9E-05	0.0081	4.09	0.1039	6.6E-05	7.6E-05	1E-08
40	13533	94559	5.75	0	4.5E-05	4.8E-05	1.9E-05	0.0081	4.09	0.1039	5E-05	5.3E-05	7.8E-09
60	20299	91175	7	0	5.5E-05	6.1E-05	1.9E-05	0.0081	4.09	0.1039	4.3E-05	4.5E-05	6.8E-09
80	27066	87792	8.25	0	6.5E-05	7.5E-05	1.9E-05	0.0081	4.09	0.1039	4E-05	4.1E-05	6.3E-09
100	33832	84409	9.25	0	7.3E-05	8.7E-05	1.9E-05	0.0081	4.09	0.1039	3.7E-05	3.8E-05	5.9E-09
120	40599	81026	9.75	0	7.7E-05	9.6E-05	1.9E-05	0.0081	4.09	0.1039	3.4E-05	3.5E-05	5.4E-09
140	47365	77642	10.5	0	8.3E-05	0.0001	1.9E-05	0.0081	4.09	0.1039	3.3E-05	3.4E-05	5.2E-09
160	54132	74259		0	0	0	1.9E-05	0.0081	4.09	0.1039			0

Average K	4.3E-05	4.6E-05

P7PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97942	6.25	0	4.9E-05	5.1E-05	1.9E-05	0.0081	4.052	0.1029	9.6E-05	0.0001	1.5E-08
40	13533	94559	9	0	7.1E-05	7.6E-05	1.9E-05	0.0081	4.052	0.1029	7.7E-05	8.3E-05	1.2E-08
60	20299	91175	12	0	9.4E-05	0.0001	1.9E-05	0.0081	4.052	0.1029	7.3E-05	7.6E-05	1.1E-08
80	27066	87792	13.5	0	0.0001	0.0001	1.9E-05	0.0081	4.052	0.1029	6.4E-05	6.7E-05	1E-08
100	33832	84409	15.5	0	0.0001	0.0001	1.9E-05	0.0081	4.052	0.1029	6.2E-05	6.4E-05	9.8E-09
120	40599	81026	16.5	0	0.0001	0.0002	1.9E-05	0.0081	4.052	0.1029	5.7E-05	5.9E-05	9.1E-09
140	47365	77642	17.5	0	0.0001	0.0002	1.9E-05	0.0081	4.052	0.1029	5.5E-05	5.6E-05	8.7E-09
160	54132	74259		0	0	0	1.9E-05	0.0081	4.052	0.1029			0

Average K	6.9E-05	7.4E-05

P8PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97942	5.75	0	4.5E-05	4.7E-05	1.9E-05	0.0081	3.738	0.0949	8.2E-05	9.4E-05	1.3E-08
40	13533	94559	8.25	0	6.5E-05	7E-05	1.9E-05	0.0081	3.738	0.0949	6.5E-05	7E-05	1E-08
60	20299	91175	10.25	0	8.1E-05	9E-05	1.9E-05	0.0081	3.738	0.0949	5.7E-05	6E-05	9E-09
80	27066	87792	12.25	0	9.6E-05	0.0001	1.9E-05	0.0081	3.738	0.0949	5.4E-05	5.6E-05	8.5E-09
100	33832	84409	13.5	0	0.0001	0.0001	1.9E-05	0.0081	3.738	0.0949	5E-05	5.1E-05	7.9E-09
120	40599	81026	15	0	0.0001	0.0001	1.9E-05	0.0081	3.738	0.0949	4.8E-05	4.9E-05	7.6E-09
140	47365	77642	15.5	0	0.0001	0.0002	1.9E-05	0.0081	3.738	0.0949	4.5E-05	4.6E-05	7.1E-09
160	54132	74259		0	0	0	1.9E-05	0.0081	3.738	0.0949			0

Average K	5.7E-05	6.1E-05

Table C.2. Air permeability calculations for samples J1PP to J8PP

J1PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97941.8	3.75	0	2.9E-05	3.1E-05	1.9E-05	0.00811	3.902	0.09911	5.6E-05	6.4E-05	8.8E-09
40	13533	94558.5	5	0	3.9E-05	4.2E-05	1.9E-05	0.00811	3.902	0.09911	4.1E-05	4.4E-05	6.5E-09
60	20299.5	91175.3	6.25	0	4.9E-05	5.5E-05	1.9E-05	0.00811	3.902	0.09911	3.6E-05	3.8E-05	5.8E-09
80	27066	87792	7.5	0	5.9E-05	6.8E-05	1.9E-05	0.00811	3.902	0.09911	3.4E-05	3.6E-05	5.4E-09
100	33832.5	84408.8	8.75	0	6.9E-05	8.3E-05	1.9E-05	0.00811	3.902	0.09911	3.4E-05	3.5E-05	5.3E-09
120	40599	81025.5	9.75	0	7.7E-05	9.6E-05	1.9E-05	0.00811	3.902	0.09911	3.3E-05	3.4E-05	5.2E-09
140	47365.5	77642.3	10.5	0	8.3E-05	0.00011	1.9E-05	0.00811	3.902	0.09911	3.2E-05	3.2E-05	5E-09
160	54132	74259		0	0	0	1.9E-05	0.00811	3.902	0.09911			0

Average K	3.8E-05	4E-05

J2PP impermeable

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97941.8		0	0	0	1.9E-05	0.00811	3.965	0.10071	0	0	0
40	13533	94558.5		0	0	0	1.9E-05	0.00811	3.965	0.10071	0	0	0
60	20299.5	91175.3		0	0	0	1.9E-05	0.00811	3.965	0.10071	0	0	0
80	27066	87792		0	0	0	1.9E-05	0.00811	3.965	0.10071	0	0	0
100	33832.5	84408.8		0	0	0	1.9E-05	0.00811	3.965	0.10071	0	0	0
120	40599	81025.5		0	0	0	1.9E-05	0.00811	3.965	0.10071	0	0	0
140	47365.5	77642.3		0	0	0	1.9E-05	0.00811	3.965	0.10071	0	0	0
160	54132	74259		0	0	0	1.9E-05	0.00811	3.965	0.10071			0

Average K	0	0

J3PP IMPERMEABLE

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97941.8		0	0	0	1.9E-05	0.00811	3.744	0.0951	0	0	0
40	13533	94558.5		0	0	0	1.9E-05	0.00811	3.744	0.0951	0	0	0
60	20299.5	91175.3		0	0	0	1.9E-05	0.00811	3.744	0.0951	0	0	0
80	27066	87792		0	0	0	1.9E-05	0.00811	3.744	0.0951	0	0	0
100	33832.5	84408.8		0	0	0	1.9E-05	0.00811	3.744	0.0951	0	0	0
120	40599	81025.5		0	0	0	1.9E-05	0.00811	3.744	0.0951	0	0	0
140	47365.5	77642.3		0	0	0	1.9E-05	0.00811	3.744	0.0951	0	0	0
160	54132	74259		0	0	0	1.9E-05	0.00811	3.744	0.0951			0

Average K	0	0

J4PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97941.8	2.5	0	2E-05	2E-05	1.9E-05	0.00811	3.634	0.0923	3.5E-05	4E-05	5.5E-09
40	13533	94558.5	3.25	0	2.6E-05	2.7E-05	1.9E-05	0.00811	3.634	0.0923	2.5E-05	2.7E-05	3.9E-09
60	20299.5	91175.3	4.25	0	3.3E-05	3.7E-05	1.9E-05	0.00811	3.634	0.0923	2.3E-05	2.4E-05	3.6E-09
80	27066	87792	5	0	3.9E-05	4.5E-05	1.9E-05	0.00811	3.634	0.0923	2.1E-05	2.2E-05	3.4E-09
100	33832.5	84408.8	5.5	0	4.3E-05	5.2E-05	1.9E-05	0.00811	3.634	0.0923	2E-05	2E-05	3.1E-09
120	40599	81025.5	5.75	0	4.5E-05	5.7E-05	1.9E-05	0.00811	3.634	0.0923	1.8E-05	1.8E-05	2.8E-09
140	47365.5	77642.3	6	0	4.7E-05	6.2E-05	1.9E-05	0.00811	3.634	0.0923	1.7E-05	1.7E-05	2.7E-09
160	54132	74259		0	0	0	1.9E-05	0.00811	3.634	0.0923			0

Average K	2.3E-05	2.4E-05

Table C.2. Air permeability calculations for samples J1PP to J8PP (continued)

J5PP Impermeable

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97941.8		0	0	0	1.9E-05	0.00811	3.766	0.09566	0	0	0
40	13533	94558.5		0	0	0	1.9E-05	0.00811	3.766	0.09566	0	0	0
60	20299.5	91175.3		0	0	0	1.9E-05	0.00811	3.766	0.09566	0	0	0
80	27066	87792		0	0	0	1.9E-05	0.00811	3.766	0.09566	0	0	0
100	33832.5	84408.8		0	0	0	1.9E-05	0.00811	3.766	0.09566	0	0	0
120	40599	81025.5		0	0	0	1.9E-05	0.00811	3.766	0.09566	0	0	0
140	47365.5	77642.3		0	0	0	1.9E-05	0.00811	3.766	0.09566	0	0	0
160	54132	74259		0	0	0	1.9E-05	0.00811	3.766	0.09566			0

Average K		
	0	0

J6PP

CHANGE

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97941.8	5.75	0	4.5E-05	4.7E-05	1.9E-05	0.00811	3.975	0.10097	8.7E-05	0.0001	1.4E-08
40	13533	94558.5	8	0	6.3E-05	6.7E-05	1.9E-05	0.00811	3.975	0.10097	6.7E-05	7.2E-05	1.1E-08
60	20299.5	91175.3	9.75	0	7.7E-05	8.5E-05	1.9E-05	0.00811	3.975	0.10097	5.8E-05	6.1E-05	9.1E-09
80	27066	87792	11	0	8.7E-05	1E-04	1.9E-05	0.00811	3.975	0.10097	5.1E-05	5.3E-05	8.1E-09
100	33832.5	84408.8	13	0	0.0001	0.00012	1.9E-05	0.00811	3.975	0.10097	5.1E-05	5.3E-05	8.1E-09
120	40599	81025.5	14	0	0.00011	0.00014	1.9E-05	0.00811	3.975	0.10097	4.8E-05	4.9E-05	7.6E-09
140	47365.5	77642.3	15.5	0	0.00012	0.00016	1.9E-05	0.00811	3.975	0.10097	4.8E-05	4.9E-05	7.5E-09
160	54132	74259		0	0	0	1.9E-05	0.00811	3.975	0.10097			0

Average K		
	5.9E-05	6.2E-05

J7PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97941.8	5	0	3.9E-05	4.1E-05	1.9E-05	0.00811	3.946	0.10023	7.5E-05	8.6E-05	1.2E-08
40	13533	94558.5	8	0	6.3E-05	6.7E-05	1.9E-05	0.00811	3.946	0.10023	6.7E-05	7.2E-05	1.1E-08
60	20299.5	91175.3	9.75	0	7.7E-05	8.5E-05	1.9E-05	0.00811	3.946	0.10023	5.7E-05	6E-05	9.1E-09
80	27066	87792	11.5	0	9E-05	0.0001	1.9E-05	0.00811	3.946	0.10023	5.3E-05	5.5E-05	8.4E-09
100	33832.5	84408.8	13	0	0.0001	0.00012	1.9E-05	0.00811	3.946	0.10023	5.1E-05	5.2E-05	8E-09
120	40599	81025.5	13.75	0	0.00011	0.00014	1.9E-05	0.00811	3.946	0.10023	4.7E-05	4.8E-05	7.4E-09
140	47365.5	77642.3	15	0	0.00012	0.00015	1.9E-05	0.00811	3.946	0.10023	4.6E-05	4.7E-05	7.2E-09
160	54132	74259		0	0	0	1.9E-05	0.00811	3.946	0.10023			0

Average K		
	5.6E-05	6E-05

J8PP

Press In. Hg	Press N/m2	Ave P. N/m2	Flow SCFH	flow ccm	Flow m3/s	Flow a.p m3/s	Viscosity N-s/m2	Area m2	Height in.	hEIGHT M	K (CM/S		k (cm2)
20	6766.5	97941.8	5.75	0	4.5E-05	4.7E-05	1.9E-05	0.00811	3.884	0.09865	8.5E-05	9.8E-05	1.3E-08
40	13533	94558.5	8	0	6.3E-05	6.7E-05	1.9E-05	0.00811	3.884	0.09865	6.6E-05	7E-05	1E-08
60	20299.5	91175.3	9.5	0	7.5E-05	8.3E-05	1.9E-05	0.00811	3.884	0.09865	5.5E-05	5.8E-05	8.7E-09
80	27066	87792	11.5	0	9E-05	0.0001	1.9E-05	0.00811	3.884	0.09865	5.3E-05	5.5E-05	8.3E-09
100	33832.5	84408.8	12.5	0	9.8E-05	0.00012	1.9E-05	0.00811	3.884	0.09865	4.8E-05	4.9E-05	7.6E-09
120	40599	81025.5	13.5	0	0.00011	0.00013	1.9E-05	0.00811	3.884	0.09865	4.5E-05	4.6E-05	7.1E-09
140	47365.5	77642.3	15	0	0.00012	0.00015	1.9E-05	0.00811	3.884	0.09865	4.5E-05	4.6E-05	7.1E-09
160	54132	74259		0	0	0	1.9E-05	0.00811	3.884	0.09865			0

Average K		
	5.7E-05	6E-05

b) ECS Water Permeability Data

Table C.3. ECS water permeability for samples J1PP to J8PP

Sample: J1PP 22-Jul

Cycle # Initial

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	2.5	2.9083567
8	2.25	2.6587957
7	2	2.4092346
6	1.75	2.1596735
5	1.5	1.9101124
4	1.25	1.6605514
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.902

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	40598.096	2.90836	0	3.1E-06	0.00092
8	36140.52	2.6588	0	2.8E-06	0.00095
7	31682.944	2.40923	0	2.5E-06	0.00099
6	27225.368	2.15967	0	2.3E-06	0.00103
5	22767.792	1.91011	0	2E-06	0.0011
4	18310.216	1.66055	0	1.7E-06	0.0012
3	20508.596	0	0	0	0

ave K: 1.03E-03

Cycle # 1

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	1.75	2.15967
8	1.5	1.91011
7	1.5	1.91011
6	1.5	1.91011
5	1.25	1.66055
4	1	1.41099
3		0.41275

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratio
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.902

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	45590.1	2.15967	0	2.3E-06	0.00061
8	41132.5	1.91011	0	2E-06	0.0006
7	35010.9	1.91011	0	2E-06	0.00071
6	28889.4	1.91011	0	2E-06	0.00086
5	24431.8	1.66055	0	1.7E-06	0.00089
4	19974.2	1.41099	0	1.5E-06	0.00093
3	20508.6	0	0	0	0

ave K: 0.000766

Cycle # 2

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	2.75	3.1579178
8	2.25	2.6587957
7	2.25	2.6587957
6	1.75	2.1596735
5	1.5	1.9101124
4	1.25	1.6605514
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.902

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	38934.107	3.15792	0	3.3E-06	0.00105
8	36140.52	2.6588	0	2.8E-06	0.00095
7	30018.955	2.6588	0	2.8E-06	0.00115
6	27225.368	2.15967	0	2.3E-06	0.00103
5	22767.792	1.91011	0	2E-06	0.0011
4	18310.216	1.66055	0	1.7E-06	0.0012
3	20508.596	0	0	0	0

ave K: 1.08E-03

Cycle # 3

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	2.25	2.6588
8	2	2.40923
7	1.75	2.15967
6	1.5	1.91011
5	1.5	1.91011
4	1.25	1.66055
3	0	1.66055

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratio
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.902

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	42262.1	2.6588	0	2.8E-06	0.00081
8	37804.5	2.40923	0	2.5E-06	0.00082
7	33346.9	2.15967	0	2.3E-06	0.00084
6	28889.4	1.91011	0	2E-06	0.00086
5	22767.8	1.91011	0	2E-06	0.0011
4	18310.2	1.66055	0	1.7E-06	0.0012
3	20508.6	1.66055	0	1.7E-06	0.00107

ave K: 9.58E-04

Table C.3. ECS water permeability for samples J1PP to J8PP (continued)

Sample: J2PP 22-Jul

Cycle # Initial

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.013256

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	-0.175982
8	2.25	2.103843
7	2	1.850529
6	2	1.850529
5	1.75	1.597215
4	1.75	1.597215
3	0	-0.175982

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.902

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.14	0	0	0	0
8	56663.73	2.10384	0	2.2E-06	0.00048
7	49639.59	1.85053	0	1.9E-06	0.00048
6	41703.72	1.85053	0	1.9E-06	0.00057
5	34679.59	1.59722	0	1.7E-06	0.0006
4	26743.72	1.59722	0	1.7E-06	0.00078
3	25189.95	0	0	0	0

ave K: 5.80E-04

Cycle # 1

Regression Output for System B (gph)
Constant -0.176
X Coefficient(s) 1.01326

Regression Output for System B (cc/min
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibrati
9	0	-0.176
8	2.5	2.35716
7	2.25	2.10384
6	2	1.85053
5	2	1.85053
4	1.75	1.59722
3		-0.176

Pressure	Reading	Calibratio
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.902

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.1	0	0	0	0
8	55752	2.35716	0	2.5E-06	0.00054
7	48727.9	2.10384	0	2.2E-06	0.00055
6	41703.7	1.85053	0	1.9E-06	0.00057
5	33767.9	1.85053	0	1.9E-06	0.00071
4	26743.7	1.59722	0	1.7E-06	0.00078
3	25190	0	0	0	0

ave K: 0.000631

Cycle # 2

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.013256

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	-0.175982
8	3	2.863785
7	2.75	2.610471
6	2.5	2.357157
5	2.25	2.103843
4	2	1.850529
3	0	-0.175982

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.902

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.14	0	0	0	0
8	53928.54	2.86378	0	3E-06	0.00068
7	46904.41	2.61047	0	2.7E-06	0.00071
6	39880.27	2.35716	0	2.5E-06	0.00076
5	32856.13	2.10384	0	2.2E-06	0.00083
4	25831.99	1.85053	0	1.9E-06	0.00094
3	25189.95	0	0	0	0

ave K: 7.84E-04

Cycle # 3

Regression Output for System B (gph)
Constant -0.176
X Coefficient(s) 1.01326

Regression Output for System B (cc/min
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibrati
9	0	-0.176
8	2	1.85053
7	1.75	1.59722
6	1.75	1.59722
5	1.5	1.3439
4	1.5	1.3439
3	0	-0.176

Pressure	Reading	Calibratio
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.902

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	72805.1	0	0	0	0
8	57575.5	1.85053	0	1.9E-06	0.00041
7	50551.3	1.59722	0	1.7E-06	0.00041
6	42615.5	1.59722	0	1.7E-06	0.00048
5	35591.3	1.3439	0	1.4E-06	0.00049
4	27655.4	1.3439	0	1.4E-06	0.00063
3	25190	0	0	0	0

ave K: 4.84E-04

Table C.3. ECS water permeability for samples J1PP to J8PP (continued)

Sample: J3PP 22-Jul

Cycle # Initial

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	3	3.4074789
8	2.5	2.9083567
7	2	2.4092346
6	1.75	2.1596735
5	1.5	1.9101124
4	1.25	1.6605514
3	0	0.412746

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.744

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	37270.118	3.40748	0	3.6E-06	0.00113
8	34476.531	2.90836	0	3.1E-06	0.00105
7	31682.944	2.40923	0	2.5E-06	0.00095
6	27225.368	2.15967	0	2.3E-06	0.00099
5	22767.792	1.91011	0	2E-06	0.00106
4	18310.216	1.66055	0	1.7E-06	0.00115
3	20508.596	0	0	0	0

ave K: 1.05E-03

Cycle # 1

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratio
9	1.25	1.66055
8	1.25	1.66055
7	1.1	1.51081
6	1	1.41099
5	0.8	1.21134
4	0.7	1.11152
3		0.41275

Pressure	Reading	Calibratior
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.744

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	48918	1.66055	0	1.7E-06	0.00042
8	42796.5	1.66055	0	1.7E-06	0.00048
7	37673.3	1.51081	0	1.6E-06	0.0005
6	32217.3	1.41099	0	1.5E-06	0.00054
5	27427	1.21134	0	1.3E-06	0.00055
4	21971	1.11152	0	1.2E-06	0.00064
3	20508.6	0	0	0	0

ave K: 0.000521

Cycle # 2

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	3.25	3.65704
8	2.75	3.1579178
7	2.5	2.9083567
6	2	2.4092346
5	1.5	1.9101124
4	1.25	1.6605514
3	0	0.412746

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.744

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	35606.129	3.65704	0	3.8E-06	0.00127
8	32812.542	3.15792	0	3.3E-06	0.0012
7	28354.966	2.90836	0	3.1E-06	0.00128
6	25561.379	2.40923	0	2.5E-06	0.00118
5	22767.792	1.91011	0	2E-06	0.00106
4	18310.216	1.66055	0	1.7E-06	0.00115
3	20508.596	0	0	0	0

ave K: 1.19E-03

Cycle # 3

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratic
9	2.75	3.15792
8	2.25	2.6588
7	1.9	2.30941
6	1.6	2.00994
5	1.25	1.66055
4	1	1.41099
3	0	1.41099

Pressure	Reading	Calibratior
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.744

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	38934.1	3.15792	0	3.3E-06	0.001
8	36140.5	2.6588	0	2.8E-06	0.00091
7	32348.5	2.30941	0	2.4E-06	0.00089
6	28223.8	2.00994	0	2.1E-06	0.00089
5	24431.8	1.66055	0	1.7E-06	0.00085
4	19974.2	1.41099	0	1.5E-06	0.00089
3	20508.6	1.41099	0	1.5E-06	0.00087

ave K: 9.01E-04

Table C.3. ECS water permeability for samples J1PP to J8PP (continued)

Sample: J4PP 22-Jul

Cycle # Initial

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	6	5.9035519
6	5	4.8902963
5	4.25	4.1303545
4	3.75	3.6237267
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.634

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	35051.947	5.90355	0	6.2E-06	0.00202
6	30762.992	4.8903	0	5.1E-06	0.00192
5	25562.31	4.13035	0	4.3E-06	0.00196
4	19449.9	3.62373	0	3.8E-06	0.00229
3	25189.95	0	0	0	0

ave K: 2.05E-03

Cycle # 1

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratio
9	0	-0.17598
8	0	-0.17598
7	6	5.90355
6	5.75	5.65024
5	5	4.8903
4	4	3.87704
3		-0.17598

Regression Output for System B (cc/min
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratio
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.634

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	35051.9	5.90355	0	6.2E-06	0.00202
6	28027.8	5.65024	0	5.9E-06	0.00244
5	22827.1	4.8903	0	5.1E-06	0.00261
4	18538.2	3.87704	0	4.1E-06	0.00257
3	25190	0	0	0	0

ave K: 0.002413

Cycle # 2

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	6	5.9035519
6	5.25	5.1436102
5	4.5	4.3836684
4	4	3.8770406
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.634

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	35051.947	5.90355	0	6.2E-06	0.00202
6	29851.265	5.14361	0	5.4E-06	0.00208
5	24650.583	4.38367	0	4.6E-06	0.00216
4	18538.173	3.87704	0	4.1E-06	0.00257
3	25189.95	0	0	0	0

ave K: 2.21E-03

Cycle # 3

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratio
9	0	-0.17598
8	0	-0.17598
7	6.5	6.41018
6	6.25	6.15687
5	5.25	5.14361
4	4.25	4.13035
3	0	-0.17598

Regression Output for System B (cc/min
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratio
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.634

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	33228.5	6.41018	0	6.7E-06	0.00232
6	26204.4	6.15687	0	6.5E-06	0.00285
5	21915.4	5.14361	0	5.4E-06	0.00287
4	17626.4	4.13035	0	4.3E-06	0.00289
3	25190	0	0	0	0

ave K: 2.73E-03

Table C.3. ECS water permeability for samples J1PP to J8PP (continued)

Sample: J5PP 22-Jul

Cycle # Initial

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	0	0.412746
8	0	0.412746
7	0	0.412746
6	0	0.412746
5	0	0.412746
4	0	0.412746
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	12	11.843663
7	8	8.2161487
6	7	7.3092701
5	4	4.5886343
4	2	2.7748772
3	0	0.96112

Height 3.766

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	57237.987	0	0	0	0
8	49850.63	0	11.8437	2E-07	4.7E-05
7	44150.996	0	8.21615	1.4E-07	3.7E-05
6	38134.913	0	7.30927	1.2E-07	3.8E-05
5	32329.796	0	4.58863	7.6E-08	2.8E-05
4	26419.196	0	2.77488	4.6E-08	2.1E-05
3	20508.596	0	0	0	0

ave K: 3.40E-05

Cycle # 1

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	0	0.41275
8	4.75	5.15441
7	4.5	4.90485
6	4	4.40572
5	3.25	3.65704
4	2.75	3.15792
3		0.41275

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratior
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.766

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	57238	0	0	0	0
8	19500.6	5.15441	0	5.4E-06	0.00337
7	15043.1	4.90485	0	5.2E-06	0.00422
6	12249.5	4.40572	0	4.6E-06	0.00473
5	11119.9	3.65704	0	3.8E-06	0.00436
4	8326.28	3.15792	0	3.3E-06	0.00519
3	20508.6	0	0	0	0

ave K: 0.004372

Cycle # 2

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	0	0.412746
8	4.25	4.6552843
7	4	4.4057232
6	3.5	3.906601
5	3	3.4074789
4	2.25	2.6587957
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.766

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	57237.987	0	0	0	0
8	22828.608	4.65528	0	4.9E-06	0.00258
7	18371.032	4.40572	0	4.6E-06	0.00307
6	15577.445	3.9066	0	4.1E-06	0.00324
5	12783.858	3.40748	0	3.6E-06	0.00349
4	11654.26	2.6588	0	2.8E-06	0.00301
3	20508.596	0	0	0	0

ave K: 3.08E-03

Cycle # 3

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	0	0.41275
8	5	5.40397
7	4.25	4.65528
6	3.75	4.15616
5	3.25	3.65704
4	2.25	2.6588
3	0	2.6588

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratior
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.766

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	57238	0	0	0	0
8	51116.4	5.40397	0	5.7E-06	0.00131
7	11715.1	4.65528	0	4.9E-06	0.00524
6	10585.5	4.15616	0	4.4E-06	0.00523
5	7791.89	3.65704	0	3.8E-06	0.00647
4	4998.3	2.6588	0	2.8E-06	0.00794
3	20508.6	2.6588	0	2.8E-06	0.00165

ave K: 4.64E-03

Table C.3. ECS water permeability for samples J1PP to J8PP (continued)

Sample: J6PP 22-Jul

Cycle # Initial

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	0	-0.175982
6	7.25	7.1701215
5	6.25	6.1568658
4	5	4.8902963
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.975

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	56933.412	0	0	0	0
6	22557.443	7.17012	0	7.5E-06	0.00426
5	18268.489	6.15687	0	6.5E-06	0.00456
4	14891.262	4.8903	0	5.1E-06	0.00451
3	25189.95	0	0	0	0

ave K: 4.44E-03

Cycle # 1

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratio
9	0	-0.17598
8	0	-0.17598
7	0	-0.17598
6	8.5	8.43669
5	7	6.91681
4	5.5	5.39692
3		-0.17598

Regression Output for System B (cc/min
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratio
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.975

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	56933.4	0	0	0	0
6	17998.8	8.43669	0	8.9E-06	0.00635
5	15533.3	6.91681	0	7.3E-06	0.00609
4	13067.8	5.39692	0	5.7E-06	0.00572
3	25190	0	0	0	0

ave K: 0.006056

Cycle # 2

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	0	-0.175982
6	10	9.9565745
5	8.75	8.6900049
4	7.5	7.4234354
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.975

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	56933.412	0	0	0	0
6	12528.439	9.95657	0	1E-05	0.01105
5	9151.2117	8.69	0	9.1E-06	0.01364
4	5773.9849	7.42344	0	7.8E-06	0.01987
3	25189.95	0	0	0	0

ave K: 1.49E-02

Cycle # 3

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratio
9	0	-0.17598
8	0	-0.17598
7	9.5	9.44995
6	8	7.93006
5	7	6.91681
4	5.5	5.39692
3	0	-0.17598

Regression Output for System B (cc/min
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratio
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.975

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	22287.8	9.44995	0	9.9E-06	0.00568
6	19822.3	7.93006	0	8.3E-06	0.00539
5	15533.3	6.91681	0	7.3E-06	0.00609
4	13067.8	5.39692	0	5.7E-06	0.00572
3	25190	0	0	0	0

ave K: 5.72E-03

Table C.3. ECS water permeability for samples J1PP to J8PP (continued)

Sample: J7PP   22-Jul

Cycle # Initial

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	3.5	3.906601
8	3.25	3.65704
7	2.75	3.1579178
6	2.25	2.6587957
5	1.75	2.1596735
4	0.75	1.1614292
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.946

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	33942.14	3.9066	0	4.1E-06	0.00151
8	29484.564	3.65704	0	3.8E-06	0.00163
7	26690.977	3.15792	0	3.3E-06	0.00156
6	23897.39	2.6588	0	2.8E-06	0.00148
5	21103.803	2.15967	0	2.3E-06	0.00136
4	21638.194	1.16143	0	1.2E-06	0.00071
3	20508.596	0	0	0	0

ave K: 1.38E-03

Cycle # 1

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	3	3.40748
8	2.5	2.90836
7	2.25	2.6588
6	2	2.40923
5	1.75	2.15967
4	1.25	1.66055
3		0.41275

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratior
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.946

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	37270.1	3.40748	0	3.6E-06	0.00119
8	34476.5	2.90836	0	3.1E-06	0.0011
7	30019	2.6588	0	2.8E-06	0.00116
6	25561.4	2.40923	0	2.5E-06	0.00125
5	21103.8	2.15967	0	2.3E-06	0.00136
4	18310.2	1.66055	0	1.7E-06	0.00122
3	20508.6	0	0	0	0

ave K: 0.001215

Cycle # 2

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	0.6	1.0116926
8	3	3.4074789
7	2.75	3.1579178
6	2.25	2.6587957
5	1.75	2.1596735
4	1.25	1.6605514
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.946

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	53244.414	1.01169	0	1.1E-06	0.00025
8	31148.553	3.40748	0	3.6E-06	0.00144
7	26690.977	3.15792	0	3.3E-06	0.00156
6	23897.39	2.6588	0	2.8E-06	0.00148
5	21103.803	2.15967	0	2.3E-06	0.00136
4	18310.216	1.66055	0	1.7E-06	0.00122
3	20508.596	0	0	0	0

ave K: 1.22E-03

Cycle # 3

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	2.25	2.6588
8	2	2.40923
7	1.75	2.15967
6	1.5	1.91011
5	1.25	1.66055
4	1	1.41099
3	0	1.41099

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratior
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.946

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	57238	2.6588	0	2.8E-06	0.0006
8	36140.5	2.40923	0	2.5E-06	0.00087
7	31682.9	2.15967	0	2.3E-06	0.00089
6	27225.4	1.91011	0	2E-06	0.00093
5	22767.8	1.66055	0	1.7E-06	0.00097
4	18310.2	1.41099	0	1.5E-06	0.00104
3	20508.6	1.41099	0	1.5E-06	0.00092

ave K: 8.88E-04

Table C.3. ECS water permeability for samples J1 to J8PP (continued)

Sample: J8PP 22-Jul

Cycle # Initial

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	7.75	7.6767493
6	6	5.9035519
5	5	4.8902963
4	4	3.8770406
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.884

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	28669.853	7.67675	0	8.1E-06	0.00347
6	27116.082	5.90355	0	6.2E-06	0.00283
5	22827.127	4.8903	0	5.1E-06	0.0028
4	18538.173	3.87704	0	4.1E-06	0.00276
3	25189.95	0	0	0	0

ave K: 2.96E-03

Cycle # 1

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratic
9	0	-0.17598
8	0	-0.17598
7	5.5	5.39692
6	5	4.8903
5	4	3.87704
4	3	2.86378
3		-0.17598

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratior
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.884

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	36875.4	5.39692	0	5.7E-06	0.00188
6	30763	4.8903	0	5.1E-06	0.00205
5	26474	3.87704	0	4.1E-06	0.0019
4	22185.1	2.86378	0	3E-06	0.00169
3	25190	0	0	0	0

ave K: 0.001882

Cycle # 2

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	6.5	6.4101797
6	5.5	5.3969241
5	4.5	4.3836684
4	3.75	3.6237267
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.884

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	33228.492	6.41018	0	6.7E-06	0.00249
6	28939.537	5.39692	0	5.7E-06	0.00241
5	24650.583	4.38367	0	4.6E-06	0.00232
4	19449.9	3.62373	0	3.8E-06	0.00245
3	25189.95	0	0	0	0

ave K: 2.42E-03

Cycle # 3

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratic
9	0	-0.17598
8	0	-0.17598
7	8.5	8.43669
6	7.5	7.42344
5	6	5.90355
4	5	4.8903
3	0	-0.17598

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratior
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.884

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	25934.7	8.43669	0	8.9E-06	0.00423
6	21645.7	7.42344	0	7.8E-06	0.00449
5	19180.2	5.90355	0	6.2E-06	0.00406
4	14891.3	4.8903	0	5.1E-06	0.0044
3	25190	0	0	0	0

ave K: 4.29E-03

Table C.4. ECS water permeability for samples P1PP to P8PP

Sample: P1PP   22-Jul

Cycle # Initial

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	3	3.4074789
8	2.5	2.9083567
7	2	2.4092346
6	1.75	2.1596735
5	1.5	1.9101124
4	1	1.4109903
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.845

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	37270.118	3.40748	0	3.6E-06	0.00116
8	34476.531	2.90836	0	3.1E-06	0.00108
7	31682.944	2.40923	0	2.5E-06	0.00097
6	27225.368	2.15967	0	2.3E-06	0.00102
5	22767.792	1.91011	0	2E-06	0.00109
4	19974.205	1.41099	0	1.5E-06	0.00092
3	20508.596	0	0	0	0

ave K: 1.04E-03

Cycle # 1

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	3.5	3.9066
8	3.25	3.65704
7	2.75	3.15792
6	2.25	2.6588
5	1.75	2.15967
4	1.25	1.66055
3		0.41275

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.845

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	33942.1	3.9066	0	4.1E-06	0.00147
8	29484.6	3.65704	0	3.8E-06	0.00159
7	26691	3.15792	0	3.3E-06	0.00152
6	23897.4	2.6588	0	2.8E-06	0.00144
5	21103.8	2.15967	0	2.3E-06	0.00133
4	18310.2	1.66055	0	1.7E-06	0.00119
3	20508.6	0	0	0	0

ave K: 0.001421

Cycle # 2

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	3.75	4.1561621
8	3.25	3.65704
7	2.75	3.1579178
6	2.25	2.6587957
5	1.75	2.1596735
4	1.25	1.6605514
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	1	1.8679986
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.845

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	32278.151	4.15616	0	4.4E-06	0.00164
8	29484.564	3.65704	0	3.8E-06	0.00159
7	26690.977	3.15792	0	3.3E-06	0.00152
6	23897.39	2.6588	1.868	2.8E-06	0.00144
5	21103.803	2.15967	0	2.3E-06	0.00133
4	18310.216	1.66055	0	1.7E-06	0.00119
3	20508.596	0	0	0	0

ave K: 1.45E-03

Cycle # 3

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	3.5	3.9066
8	3	3.40748
7	2.5	2.90836
6	2	2.40923
5	1.75	2.15967
4	1.25	1.66055
3	0	0.41275

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.845

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	33942.1	3.9066	0	4.1E-06	0.00147
8	31148.6	3.40748	0	3.6E-06	0.0014
7	28355	2.90836	0	3.1E-06	0.00132
6	25561.4	2.40923	0	2.5E-06	0.00121
5	21103.8	2.15967	0	2.3E-06	0.00133
4	18310.2	1.66055	0	1.7E-06	0.00119
3	20508.6	0	0	0	0

ave K: 1.32E-03

Table C.4. ECS water permeability for samples P1PP to P8PP (continued)

Sample: P2PP 22-Jul

Cycle # Initial

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	0	-0.175982
6	6.25	6.1568658
5	5	4.8902963
4	4	3.8770406
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.874

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	56933.412	0	0	0	0
6	26204.354	6.15687	0	6.5E-06	0.00305
5	22827.127	4.8903	0	5.1E-06	0.00279
4	18538.173	3.87704	0	4.1E-06	0.00275
3	25189.95	0	0	0	0

ave K: 2.86E-03

Cycle # 1

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratio
9	0	-0.17598
8	0	-0.17598
7	7	6.91681
6	5.5	5.39692
5	4.75	4.63698
4	3.75	3.62373
3		-0.17598

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratior
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.874

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	31405	6.91681	0	7.3E-06	0.00284
6	28939.5	5.39692	0	5.7E-06	0.00241
5	23738.9	4.63698	0	4.9E-06	0.00254
4	19449.9	3.62373	0	3.8E-06	0.00245
3	25190	0	0	0	0

ave K: 0.002558

Cycle # 2

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	7.5	7.4234354
6	6	5.9035519
5	5	4.8902963
4	4	3.8770406
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.874

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	29581.581	7.42344	0	7.8E-06	0.00324
6	27116.082	5.90355	0	6.2E-06	0.00282
5	22827.127	4.8903	0	5.1E-06	0.00279
4	18538.173	3.87704	0	4.1E-06	0.00275
3	25189.95	0	0	0	0

ave K: 2.90E-03

Cycle # 3

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratio
9	0	-0.17598
8	0	-0.17598
7	5.5	5.39692
6	4.25	4.13035
5	4	3.87704
4	3	2.86378
3	0	-0.17598

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratior
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 3.874

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	36875.4	5.39692	0	5.7E-06	0.00188
6	33498.2	4.13035	0	4.3E-06	0.00158
5	26474	3.87704	0	4.1E-06	0.0019
4	22185.1	2.86378	0	3E-06	0.00168
3	25190	0	0	0	0

ave K: 1.76E-03

Table C.4. ECS water permeability for samples P1PP to P8PP (continued)

Sample: P4PP 22-Jul

Cycle # Initial

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	2.25	2.6587957
8	2	2.4092346
7	0.01333	0.4260559
6	1.5	1.9101124
5	1.25	1.6605514
4	1	1.4109903
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 4.146

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	42262.086	2.6588	0	2.8E-06	0.00086
8	37804.51	2.40923	0	2.5E-06	0.00088
7	44906.111	0.42606	0	4.5E-07	0.00013
6	28889.357	1.91011	0	2E-06	0.00092
5	24431.781	1.66055	0	1.7E-06	0.00095
4	19974.205	1.41099	0	1.5E-06	0.001
3	20508.596	0	0	0	0

ave K: 7.88E-04

Cycle # 1

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	2.5	2.90836
8	2.25	2.6588
7	2	2.40923
6	1.75	2.15967
5	1.5	1.91011
4	1.25	1.66055
3		0.41275

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratio
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 4.146

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	40598.1	2.90836	0	3.1E-06	0.00098
8	36140.5	2.6588	0	2.8E-06	0.00101
7	31682.9	2.40923	0	2.5E-06	0.00105
6	27225.4	2.15967	0	2.3E-06	0.0011
5	22767.8	1.91011	0	2E-06	0.00117
4	18310.2	1.66055	0	1.7E-06	0.00128
3	20508.6	0	0	0	0

ave K: 0.001101

Cycle # 2

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	2.25	2.6587957
8	2	2.4092346
7	1.75	2.1596735
6	1.5	1.9101124
5	1.25	1.6605514
4	1	1.4109903
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	1	1.8679986
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 4.146

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	42262.086	2.6588	0	2.8E-06	0.00086
8	37804.51	2.40923	0	2.5E-06	0.00088
7	33346.933	2.15967	0	2.3E-06	0.00089
6	28889.357	1.91011	1.868	2E-06	0.00092
5	24431.781	1.66055	0	1.7E-06	0.00095
4	19974.205	1.41099	0	1.5E-06	0.001
3	20508.596	0	0	0	0

ave K: 9.15E-04

Cycle # 3

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratio
9	2.75	3.15792
8	2.5	2.90836
7	2	2.40923
6	1.75	2.15967
5	1.5	1.91011
4	1.25	1.66055
3	0	0.41275

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratio
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 4.146

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	38934.1	3.15792	0	3.3E-06	0.00111
8	34476.5	2.90836	0	3.1E-06	0.00116
7	31682.9	2.40923	0	2.5E-06	0.00105
6	27225.4	2.15967	0	2.3E-06	0.0011
5	22767.8	1.91011	0	2E-06	0.00117
4	18310.2	1.66055	0	1.7E-06	0.00128
3	20508.6	0	0	0	0

ave K: 1.15E-03

Table C.4. ECS water permeability for samples P1PP to P8PP (continued)

Sample: P5PP 22-Jul

Cycle # Initial

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	3.5	3.906601
8	3.25	3.65704
7	2.75	3.1579178
6	2.25	2.6587957
5	1.75	2.1596735
4	1.25	1.6605514
3	0	0.412746

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.980

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	33942.14	3.9066	0	4.1E-06	0.00152
8	29484.564	3.65704	0	3.8E-06	0.00165
7	26690.977	3.15792	0	3.3E-06	0.00158
6	23897.39	2.6588	0	2.8E-06	0.00149
5	21103.803	2.15967	0	2.3E-06	0.00138
4	18310.216	1.66055	0	1.7E-06	0.00123
3	20508.596	0	0	0	0

ave K: 1.47E-03

Cycle # 1

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratio
9	3.5	3.9066
8	3.25	3.65704
7	2.75	3.15792
6	2.25	2.6588
5	1.75	2.15967
4	1.25	1.66055
3		0.41275

Pressure	Reading	Calibratio
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.980

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	33942.1	3.9066	0	4.1E-06	0.00152
8	29484.6	3.65704	0	3.8E-06	0.00165
7	26691	3.15792	0	3.3E-06	0.00158
6	23897.4	2.6588	0	2.8E-06	0.00149
5	21103.8	2.15967	0	2.3E-06	0.00138
4	18310.2	1.66055	0	1.7E-06	0.00123
3	20508.6	0	0	0	0

ave K: 0.001473

Cycle # 2

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	3.25	3.65704
8	3	3.4074789
7	2.5	2.9083567
6	2	2.4092346
5	1.5	1.9101124
4	1	1.4109903
3	0	0.412746

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.980

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	35606.129	3.65704	0	3.8E-06	0.00135
8	31148.553	3.40748	0	3.6E-06	0.00145
7	28354.966	2.90836	0	3.1E-06	0.00136
6	25561.379	2.40923	0	2.5E-06	0.00126
5	22767.792	1.91011	0	2E-06	0.00112
4	19974.205	1.41099	0	1.5E-06	0.00095
3	20508.596	0	0	0	0

ave K: 1.25E-03

Cycle # 3

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratio
9	4	4.40572
8	3.5	3.9066
7	3.25	3.65704
6	2.75	3.15792
5	2.25	2.6588
4	1.75	2.15967
3	0	0.41275

Pressure	Reading	Calibratio
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 3.980

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	30614.2	4.40572	0	4.6E-06	0.00191
8	27820.6	3.9066	0	4.1E-06	0.00187
7	23363	3.65704	0	3.8E-06	0.0021
6	20569.4	3.15792	0	3.3E-06	0.00207
5	17775.8	2.6588	0	2.8E-06	0.00203
4	14982.2	2.15967	0	2.3E-06	0.00198
3	20508.6	0	0	0	0

ave K: 1.99E-03

Table C.4. ECS water permeability for samples P1PP to P8PP (continued)

Sample: P6PP 22-Jul

Cycle # Initial

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	4	3.8770406
6	3.25	3.1170989
5	2.75	2.610471
4	2.25	2.1038432
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 4.090

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	42345.769	3.87704	0	4.1E-06	0.00124
6	37145.086	3.1171	0	3.3E-06	0.00114
5	31032.676	2.61047	0	2.7E-06	0.00115
4	24920.266	2.10384	0	2.2E-06	0.00116
3	25189.95	0	0	0	0

ave K: 1.17E-03

Cycle # 1

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratic
9	0	-0.17598
8	0	-0.17598
7	5	4.8903
6	4.25	4.13035
5	3.5	3.37041
4	2.75	2.61047
3		-0.17598

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratio
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 4.090

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	38698.9	4.8903	0	5.1E-06	0.00171
6	33498.2	4.13035	0	4.3E-06	0.00168
5	28297.5	3.37041	0	3.5E-06	0.00163
4	23096.8	2.61047	0	2.7E-06	0.00156
3	25190	0	0	0	0

ave K: 0.001643

Cycle # 2

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	5.25	5.1436102
6	4.5	4.3836684
5	3.75	3.6237267
4	3	2.863785
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 4.090

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	37787.13	5.14361	0	5.4E-06	0.00184
6	32586.448	4.38367	0	4.6E-06	0.00183
5	27385.766	3.62373	0	3.8E-06	0.00181
4	22185.083	2.86378	0	3E-06	0.00178
3	25189.95	0	0	0	0

ave K: 1.82E-03

Cycle # 3

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratic
9	0	-0.17598
8	0	-0.17598
7	5.5	5.39692
6	4.5	4.38367
5	4	3.87704
4	3	2.86378
3	0	-0.17598

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibratio
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 4.090

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	36875.4	5.39692	0	5.7E-06	0.00198
6	32586.4	4.38367	0	4.6E-06	0.00183
5	26474	3.87704	0	4.1E-06	0.00201
4	22185.1	2.86378	0	3E-06	0.00178
3	25190	0	0	0	0

ave K: 1.90E-03

Table C.4. ECS water permeability for samples P1PP to P8PP (continued)

Sample: P7PP 22-Jul

Cycle # Initial

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	4	4.4057232
8	4	4.4057232
7	3.5	3.906601
6	3	3.4074789
5	2.5	2.9083567
4	1.75	2.1596735
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 4.052

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	30614.162	4.40572	0	4.6E-06	0.00194
8	24492.597	4.40572	0	4.6E-06	0.00245
7	21699.01	3.9066	0	4.1E-06	0.00247
6	18905.423	3.40748	0	3.6E-06	0.00249
5	16111.836	2.90836	0	3.1E-06	0.00251
4	14982.238	2.15967	0	2.3E-06	0.00202
3	20508.596	0	0	0	0

ave K: 2.31E-03

Cycle # 1

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratic
9	4.25	4.65528
8	3.75	4.15616
7	3.25	3.65704
6	2.75	3.15792
5	2.25	2.6588
4	1.5	1.91011
3		0.41275

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratior
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 4.052

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	28950.2	4.65528	0	4.9E-06	0.00218
8	26156.6	4.15616	0	4.4E-06	0.00216
7	23363	3.65704	0	3.8E-06	0.00214
6	20569.4	3.15792	0	3.3E-06	0.00211
5	17775.8	2.6588	0	2.8E-06	0.00207
4	16646.2	1.91011	0	2E-06	0.00159
3	20508.6	0	0	0	0

ave K: 0.00204

Cycle # 2

Regression Output for System A (gph)
Constant 0.412746
X Coefficient(s) 0.9982443

Pressure	Reading	Calibration
9	5.25	5.6535286
8	4.25	4.6552843
7	3.75	4.1561621
6	3.25	3.65704
5	2.75	3.1579178
4	2	2.4092346
3	0	0.412746

Regression Output for System A (cc/min)
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibration
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 4.052

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	22294.217	5.65353	0	5.9E-06	0.00347
8	22828.608	4.65528	0	4.9E-06	0.00279
7	20035.021	4.15616	0	4.4E-06	0.00285
6	17241.434	3.65704	0	3.8E-06	0.00294
5	14447.847	3.15792	0	3.3E-06	0.00307
4	13318.249	2.40923	0	2.5E-06	0.00256
3	20508.596	0	0	0	0

ave K: 2.95E-03

Cycle # 3

Regression Output for System A (gph)
Constant 0.41275
X Coefficient(s) 0.99824

Pressure	Reading	Calibratic
9	4.75	5.15441
8	4.25	4.65528
7	3.5	3.9066
6	3	3.40748
5	2.5	2.90836
4	1.75	2.15967
3	0	2.15967

Regression Output for System A (cc/min
Constant 0.96112
X Coefficient(s) 0.90688

Pressure	Reading	Calibratior
9	0	0.96112
8	0	0.96112
7	0	0.96112
6	0	0.96112
5	0	0.96112
4	0	0.96112
3	0	0.96112

Height 4.052

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	25622.2	5.15441	0	5.4E-06	0.00273
8	22828.6	4.65528	0	4.9E-06	0.00279
7	21699	3.9066	0	4.1E-06	0.00247
6	18905.4	3.40748	0	3.6E-06	0.00249
5	16111.8	2.90836	0	3.1E-06	0.00251
4	14982.2	2.15967	0	2.3E-06	0.00202
3	20508.6	2.15967	0	2.3E-06	0.00145

ave K: 2.35E-03

Table C.4. ECS water permeability for samples P1PP to P8PP (continued)

Sample: P8PP   22-Jul

Cycle # Initial

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	7.5	7.4234354
6	6.5	6.4101797
5	5.5	5.3969241
4	4.25	4.1303545
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 4.090

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	29581.581	7.42344	0	7.8E-06	0.00343
6	25292.626	6.41018	0	6.7E-06	0.00348
5	21003.672	5.39692	0	5.7E-06	0.00356
4	17626.445	4.13035	0	4.3E-06	0.00328
3	25189.95	0	0	0	0

ave K: 3.44E-03

Cycle # 1

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratio
9	0	-0.17598
8	0	-0.17598
7	6.75	6.66349
6	5.5	5.39692
5	4.75	4.63698
4	3.75	3.62373
3		-0.17598

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 4.090

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	32316.8	6.66349	0	7E-06	0.00281
6	28939.5	5.39692	0	5.7E-06	0.00255
5	23738.9	4.63698	0	4.9E-06	0.00269
4	19449.9	3.62373	0	3.8E-06	0.00259
3	25190	0	0	0	0

ave K: 0.002659

Cycle # 2

Regression Output for System B (gph)
Constant -0.175982
X Coefficient(s) 1.0132557

Pressure	Reading	Calibration
9	0	-0.175982
8	0	-0.175982
7	5.5	5.3969241
6	4.75	4.6369823
5	4	3.8770406
4	3	2.863785
3	0	-0.175982

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 4.090

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m3/s	K cm/sec
9	72805.142	0	0	0	0
8	64869.277	0	0	0	0
7	36875.402	5.39692	0	5.7E-06	0.00198
6	31674.72	4.63698	0	4.9E-06	0.00199
5	26474.038	3.87704	0	4.1E-06	0.00201
4	22185.083	2.86378	0	3E-06	0.00178
3	25189.95	0	0	0	0

ave K: 1.94E-03

Cycle # 3

Regression Output for System B (gph)
Constant -0.17598
X Coefficient(s) 1.01326

Pressure	Reading	Calibratio
9	0	-0.17598
8	0	-0.17598
7	6	5.90355
6	5.25	5.14361
5	4.5	4.38367
4	3.5	3.37041
3	0	-0.17598

Regression Output for System B (cc/min)
Constant 2.17333
X Coefficient(s) 0.74461

Pressure	Reading	Calibration
9	0	2.173328
8	0	2.173328
7	0	2.173328
6	0	2.173328
5	0	2.173328
4	0	2.173328
3	0	2.173328

Height 4.090

Pressure psi	Pressure N/m2	Q gph	Q ccm	Q m2/s	K cm/sec
9	72805.1	0	0	0	0
8	64869.3	0	0	0	0
7	35051.9	5.90355	0	6.2E-06	0.00229
6	29851.3	5.14361	0	5.4E-06	0.00235
5	24650.6	4.38367	0	4.6E-06	0.00244
4	20361.6	3.37041	0	3.5E-06	0.0023
3	25190	0	0	0	0

ave K: 2.34E-03

APPENDIX D

STRESS DISTRIBUTIONS IN POROUS ASPHALT MIXES

by

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June 1994

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1.0 INTRODUCTION

1.1 Background

Porous pavements are currently used in Oregon (Class F-mix) as overlays on dense-graded asphalt mixes to increase safety. F-mixes are also being proposed for use on portland cement concrete pavements. The effect of porous mixes on pavement structural performance has yet to be evaluated. This is because most laboratory tests and analytical methods are not capable of evaluating the affects of these mix types.

Using a finite element method can allow one to estimate the stresses in a multi-layered system. A finite element program (ANSYS) was used in this study to evaluate the performance characterics of porous mix overlay on both an asphalt concrete and a portland cement concrete pavement (1-4).

1.2 Purpose

The purpose of this appendix is twofold:

1) To evaluate the stresses porous mixes are subjected to in actual pavements. This will permit development of appropriate stress conditions for evaluating the laboratory performance of such mixes.

2) To evaluate the effect of varying thicknesses of porous mixes on the critical stresses in portland cement concrete mixes.

2.0 APPROACH USED

The approach used in this study is summarized in Figure D.1. The following sections describe the selected process in detail.

2.1 Stresses in Porous Mix

To determine the stresses in a porous mix placed over an asphalt concrete layer, a finite element program (ANSYS) was employed (1-4). Figure D.2 illustrates the cross sections employed while Figure D.3 identifies the finite element configuration. A tire pressure of 80 psi was employed for the analysis.

The material properties assumed for each layer were as follows:

1) Porous mix: 500,000 psi (3,400 MPa)
2) Existing ACP: 150,000 psi (1,000 MPa)
3) Aggregate base: 20,000 psi (140 MPa)
4) Subgrade: 3,000, 10,000 and 20,000 psi (21, 69, and 140 MPa)

Stresses in the porous mix were calculated along the left and right sides of the finite elements shown in Figure D.3b. Each of these elements is calculated as directly under the prospective wheel loads shown in the element diagram, Figure D.3a. Specification DLT, for example, stands for element beneath wheel load D, and on the top left corner. As it was necessary to try to determine what in field confining pressure exists, the pressure was determined by an average of the top, middle, and bottom corner stresses.

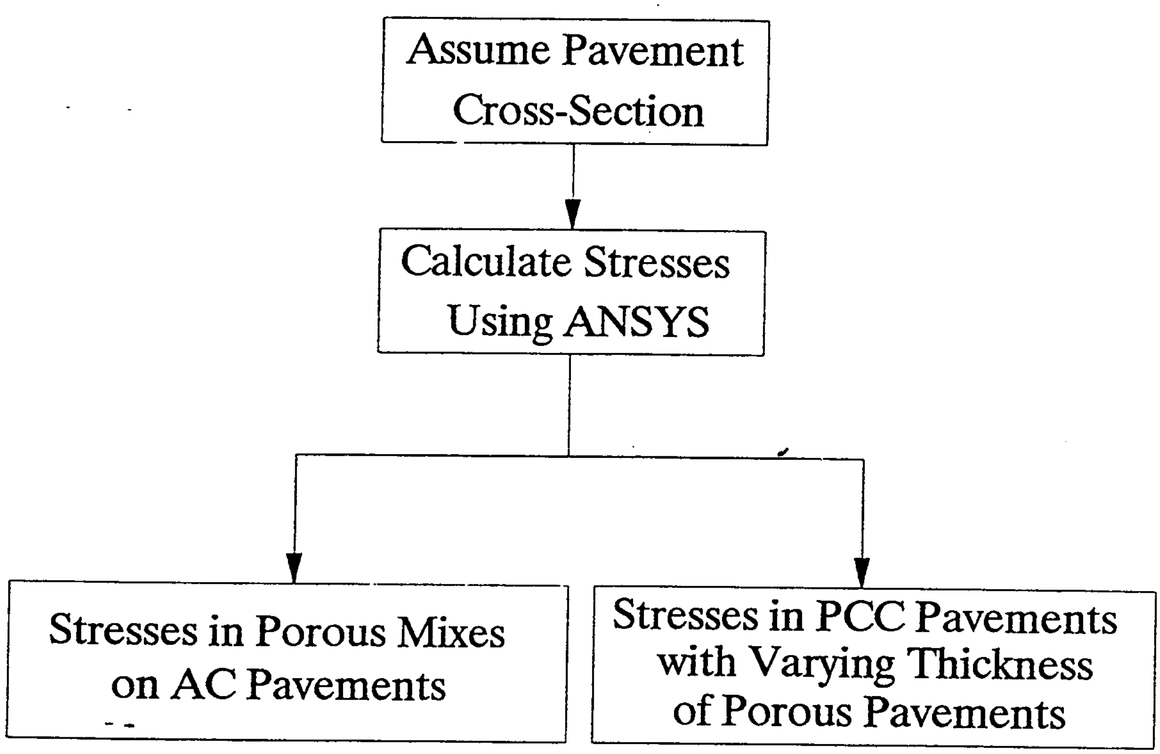


Figure D.1. Approach used

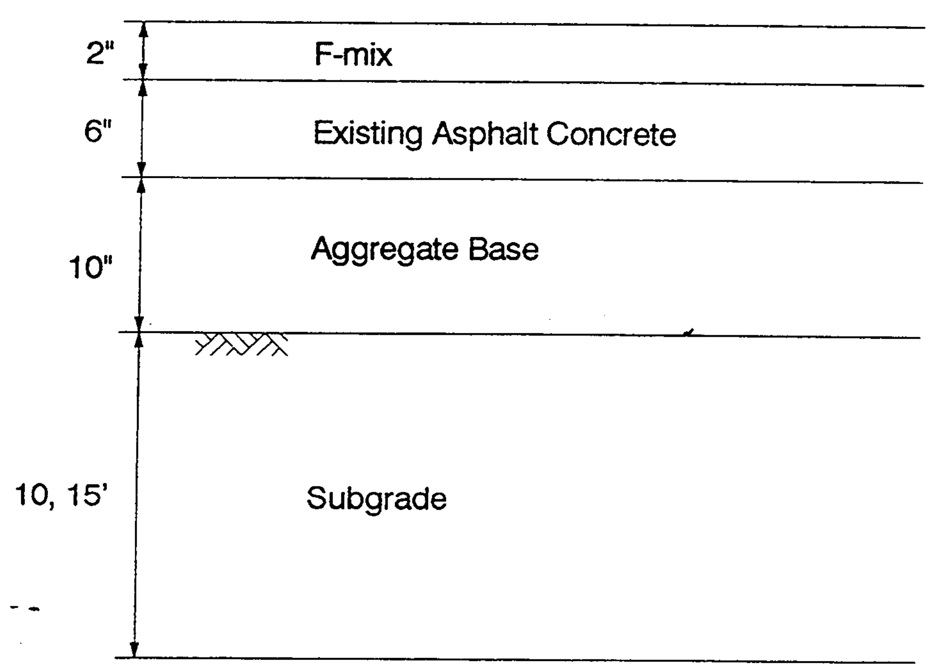
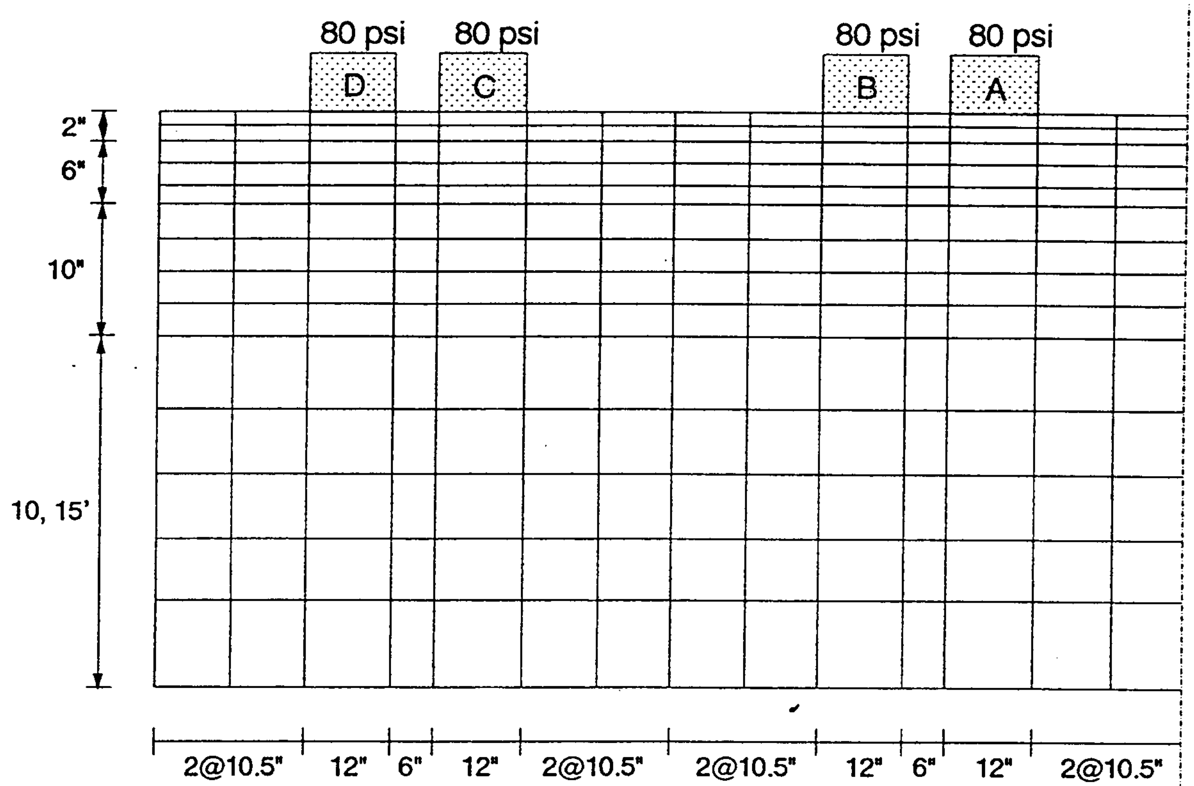
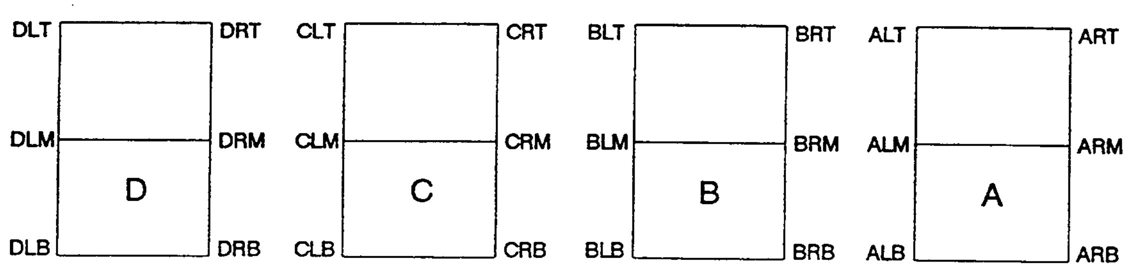


Figure D.2. Cross section used for calculating stresses in porous mixes



a) Grid used



b) Nodal locations under load

Figure D.3. Finite element grid for porous mix over dense mix

2.2 Stresses in PCC Pavements

A similar approach was used to calculate the critical stress reduction in portland cement concrete from the use of a porous overlay. The cross section employed is shown in Figure D.4. A tire pressure of 80 psi was employed for the analysis. The critical stress was the maximum flexural stress at the bottom of the PCC.

Figure D.5a describes how the elements were set up to handle this particular problem. As the critical stress at the bottom of the PCC was desired, the elements abutting this layer were used. The maximum critical stress would then be along the bottom of the elements shown in Figure D.5b.

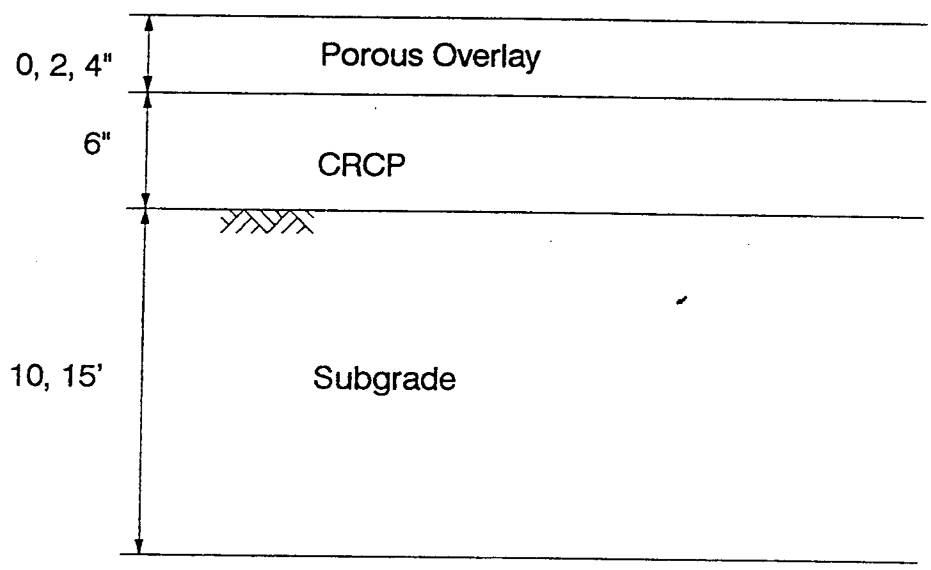
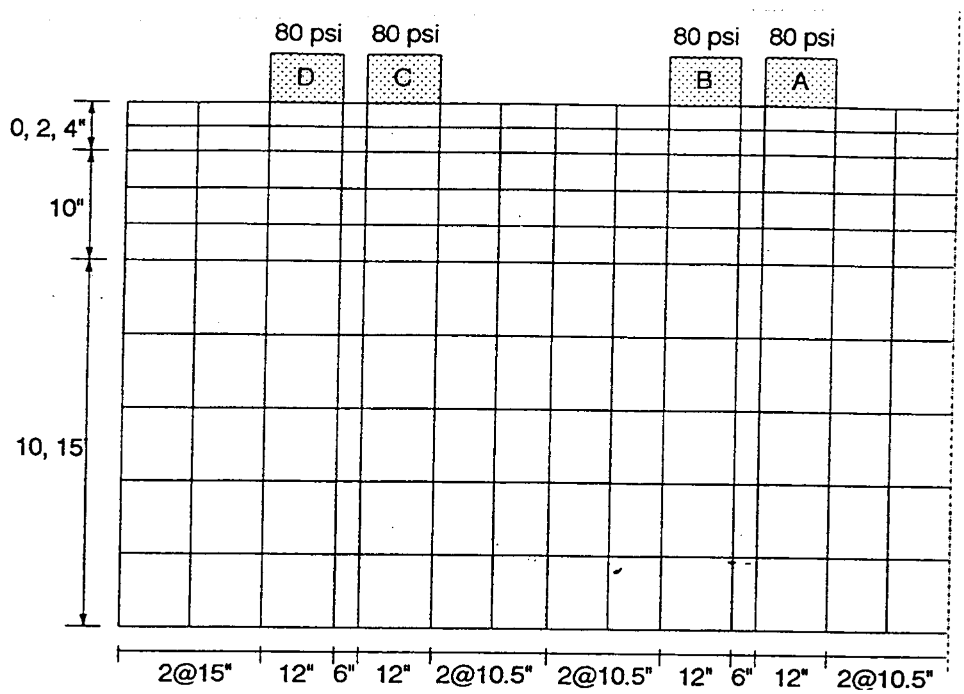
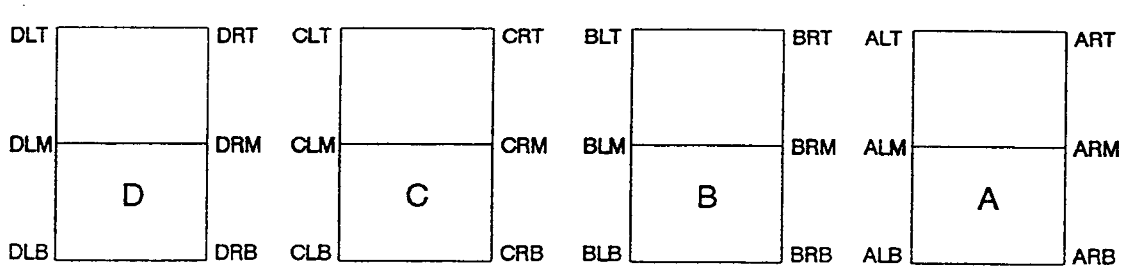


Figure D.4. Cross section used to calculate stresses in PCC pavement



a) Grid used



b) Nodal locations under load

Figure D.5. Finite element grid for calculating stresses in PCC pavement

3.0 RESULTS

3.1 Stresses in Porous Mixes

As discussed earlier, the horizontal stresses in the porous mix were calculated just outside the wheel loads and are summarized below.

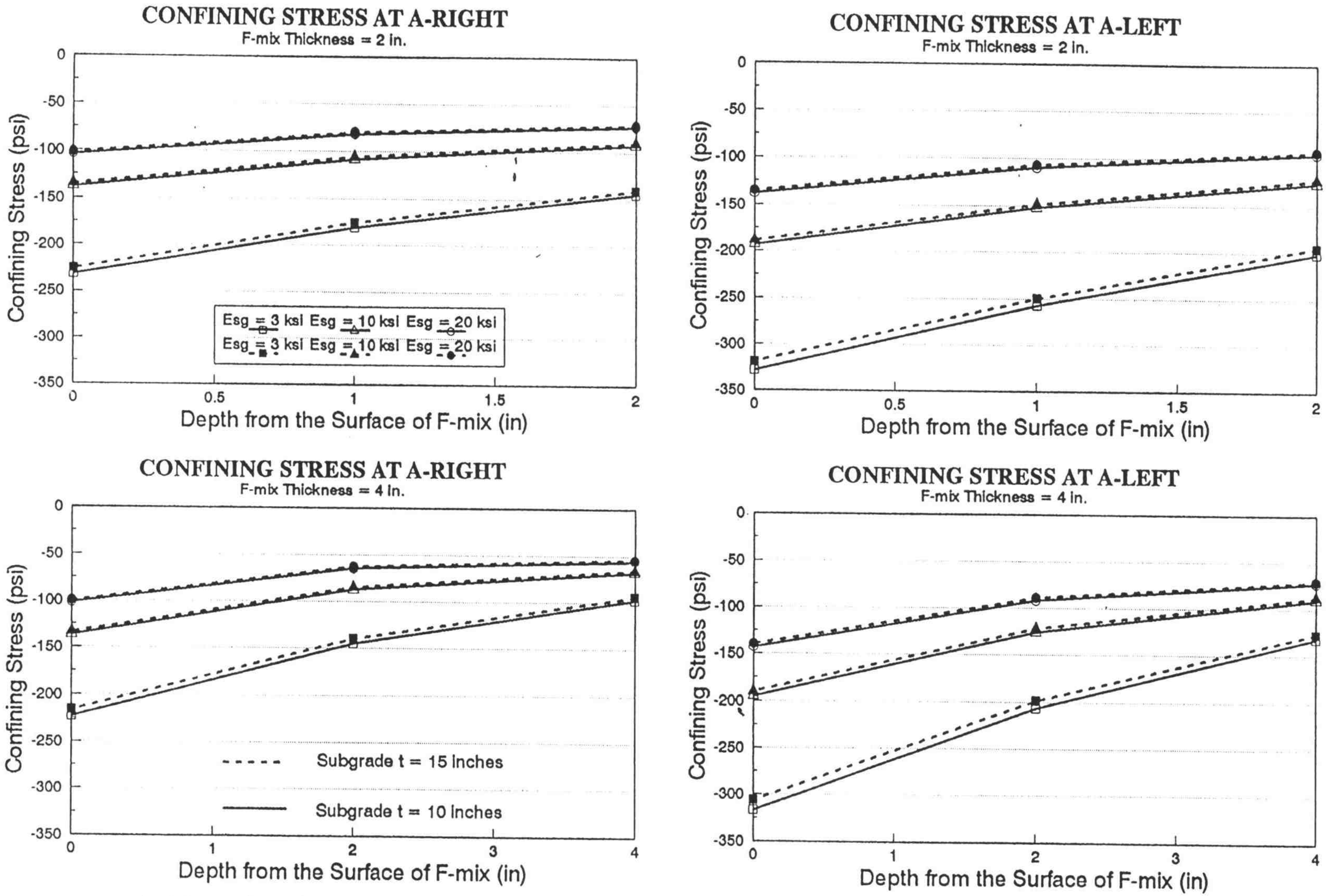
3.1.1 Under Wheel Loads A and B

As indicated in Figures D.6 and D.7, stresses were maximum at the surface of the F-mix overlay and decreased with depth. The maximum stresses for inner sides (left side of wheel load A and right side of wheel load B) were greater than those for outer sides. The maximum stresses for outer sides ranged from 100 to 230 psi and from 130 to 330 psi for inner sides for both 2 in and 4 in F-mixes.

No significant differences in horizontal stresses were found with varrying thickness of F-mix overlay were found. The stresses also tended to increase as the subgrade modulus decreased. The horizontal stresses were not significantly affected by the thickness of subgrade. Stresses for thicker subgrade were slightly lower than those for thinner subgrade.

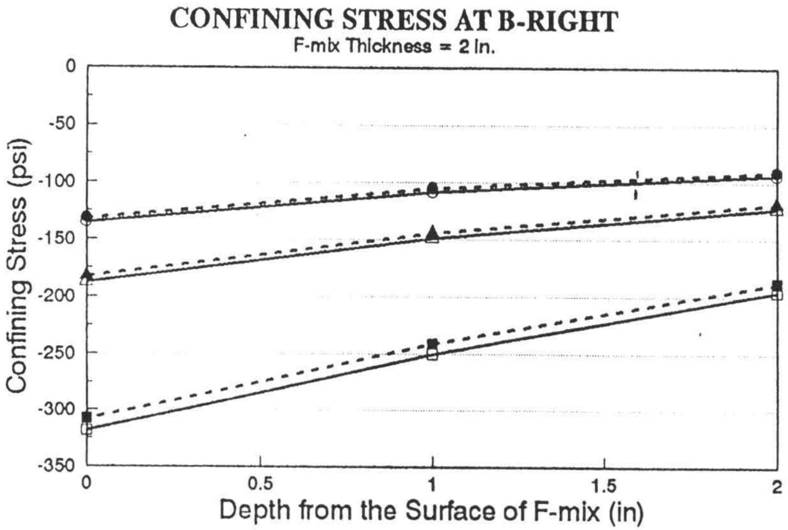
3.1.2 Under Wheel Loads C and D

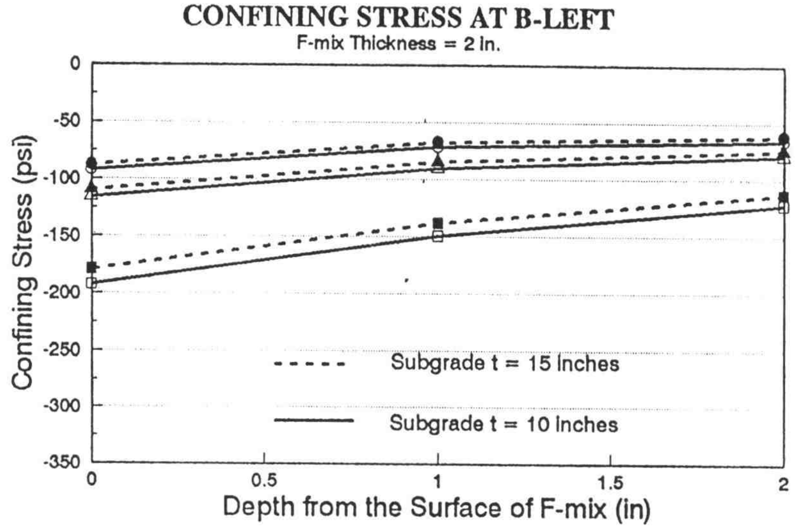
As shown in Figure D.8, the maximum stresses were at the surface of the porous mix overlay and decreased with depth. Maximum stresses for inner sides (left side of wheel load C and right side of wheel load D) were greater than those for outer sides.

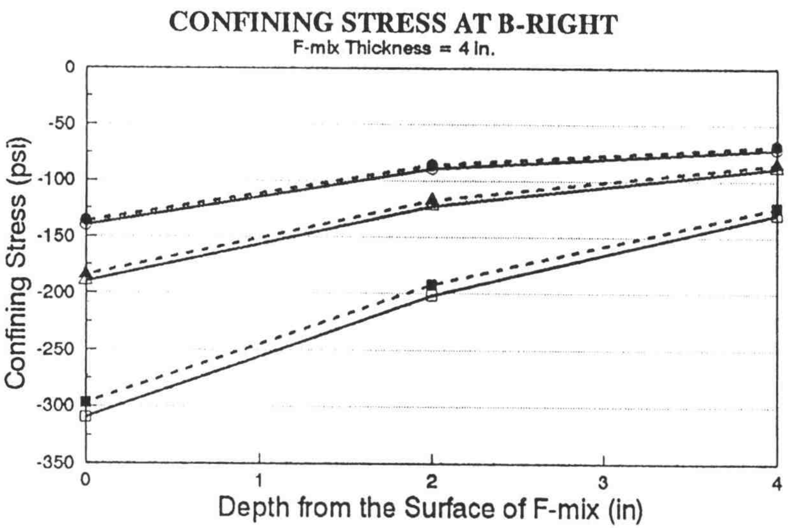


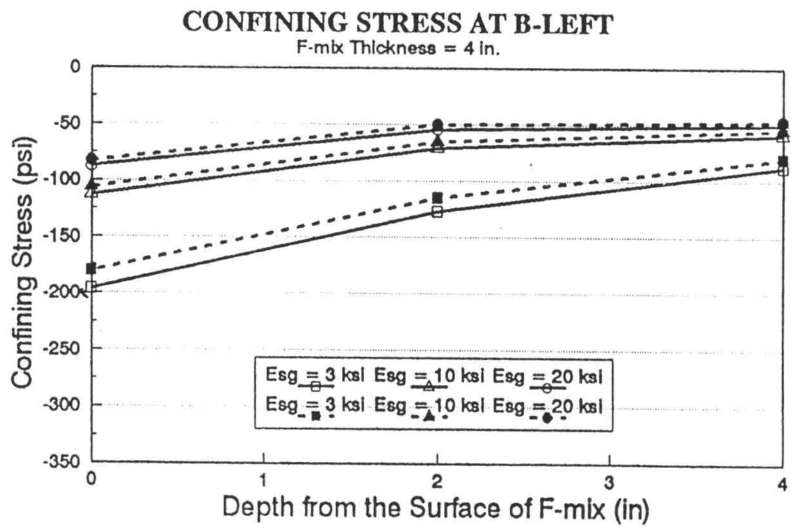
a) Right side of wheel load A **b) Left side of wheel load A**

Figure D.6 Stresses under wheel load A in porous mix





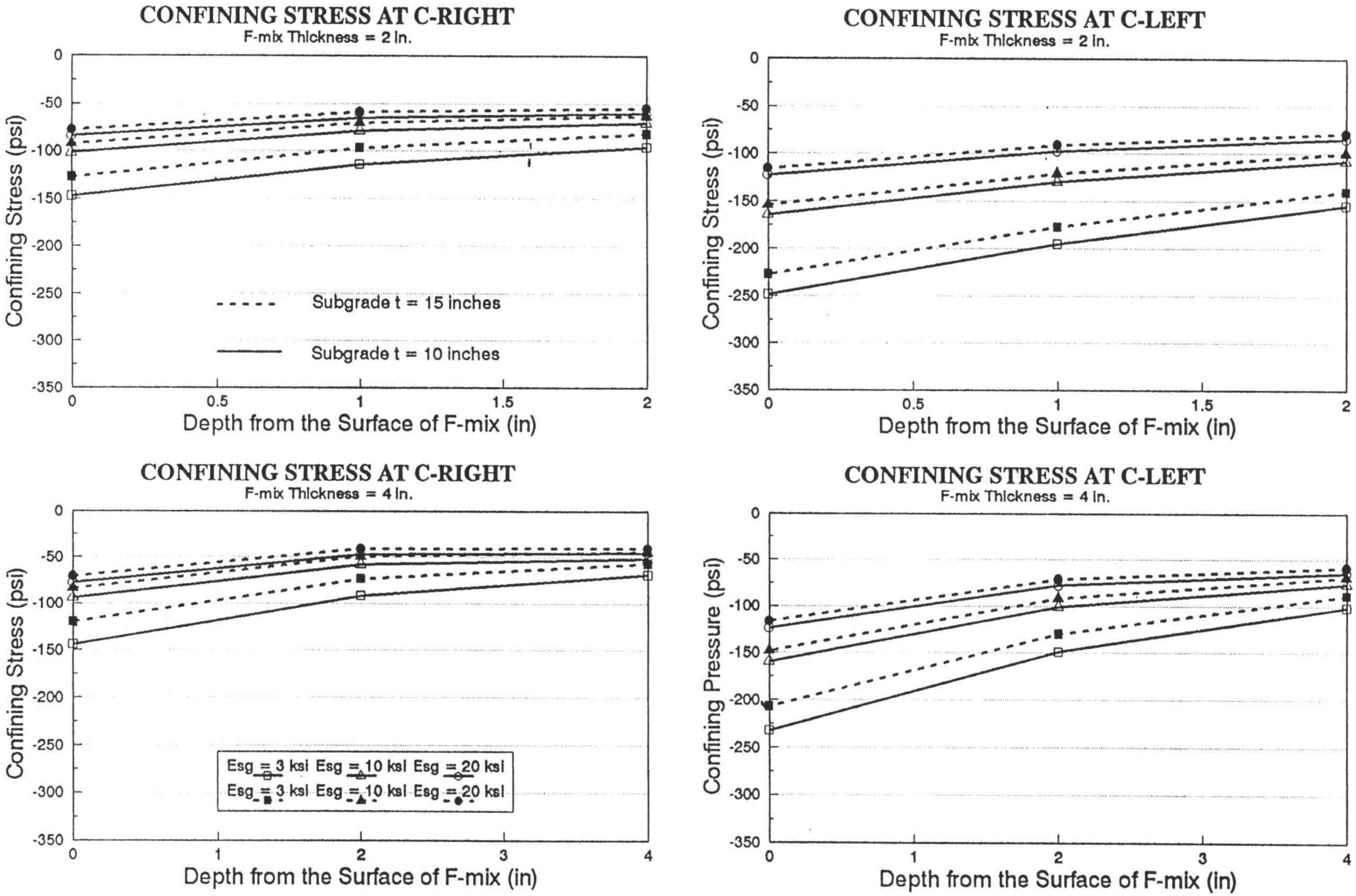




a) Right side of wheel load B

b) Left side of wheel load B

Figure D.7 Stresses under wheel load B in porous mix



a) Right side of wheel load C

b) Left side of wheel load C

Figure D.8 Stresses under wheel load C in porous mix

The maximum confining stresses under wheel loads C and D were lower than those under wheel loads A and B. It is considered that these are due to the effect of fixed boundary along the left edge. As shown in Figure D.9, wheel loads C and D are closer to the fixed boundary.

The effect of changing the thickness of subgrade was not significant for the confining stresses in the porous mixes. The confining stresses in thicker porous mixes were slightly lower.

3.2 Stresses in PCC Pavement

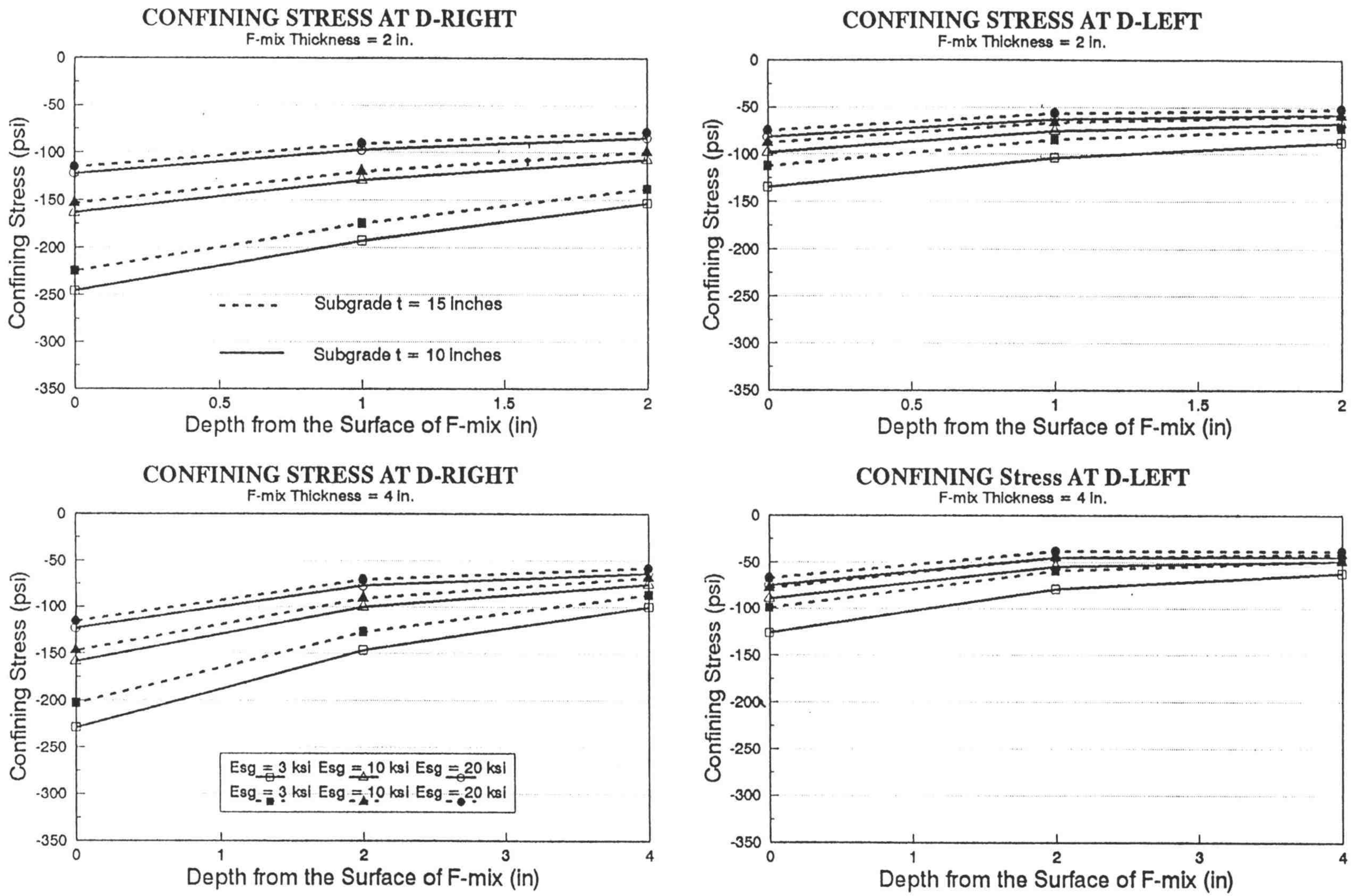
Figures D.10 and D.11 summarize the results of calculations for porous mixes over portland cement concrete. The results indicate the following:

1) Stresses in the PCC are not greatly reduced by the porous mix overlay.

2) Subgrade stiffness greatly reduces the critical stress in the PCC.

Figure D.10 exhibits relationships between the maximum tensile stresses at the bottom of PCC and the subgrade modulus for varying the thickness of porous mix overlay. The effect of increasing thickness of porous mix overlay on reducing tensile stresses at the bottom of PCC was not significant. The maximum tensile stresses at the bottom of PCC decreased slightly with increasing thickness of porous mix overlay.

The tensile stresses at the bottom of PCC were greatly reduced by increasing the subgrade modulus. The tensile stresses were reduced by half by increasing the subgrade modulus from 3,000 to 30,000 psi.



a) Right side of wheel load D

b) Left side of wheel load D

Figure D.9 Stresses under wheel load D in porous mix

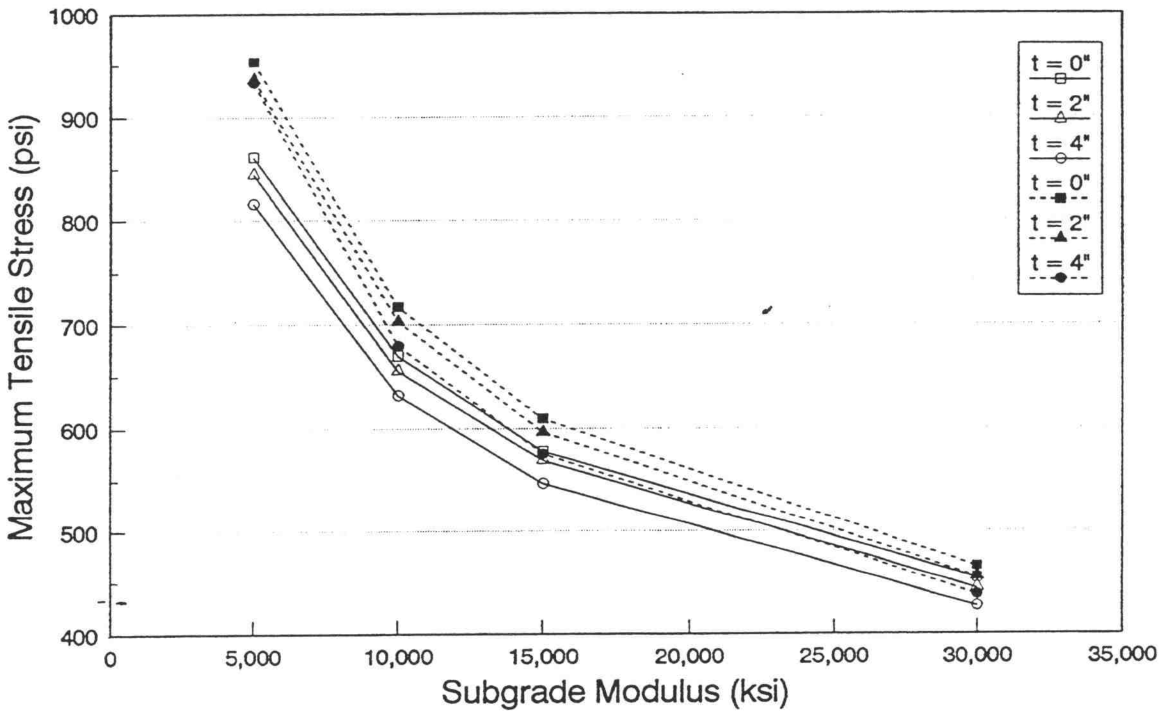


Figure D.10 Maximum tensile stresses under PCC vs. subgrade modulus

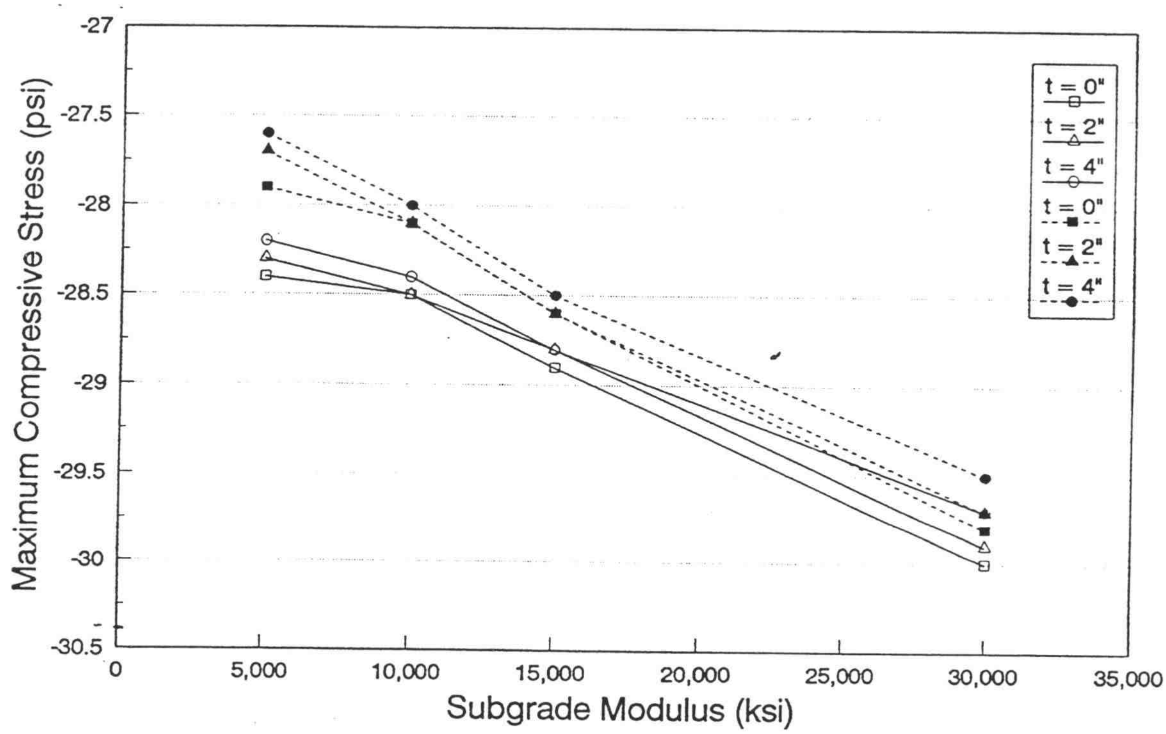


Figure D.11 Max. compressive stresses at the top of subgrade vs. subgrade modulus

The effect of increasing the thickness of subgrade was significant for a lower subgrade modulus. The reduction in tensile stresses was about 100 psi for the subgrade modulus of 3,000 psi, but the amount of reduction was minor for the subgrade modulus of 30,000 psi.

Figure D.11 exhibits relationships between the maximum compressive stresses at the top of subgrade and the strength of the subgrade, for varying thickness of porous mix overlay. These following relationships were found:

1) Increasing the thickness of porous mix overlay did not greatly reduce the compressive stresses at the top of subgrade.

2) Increasing the subgrade modulus tends to reduce compressive stresses at the top of subgrade but the amount of reduction was not considered significant.

3) The effect of increasing the thickness of subgrade on reducing compressive stresses was minor.

3.3 Discussion of Results

The data acquired from the study of the confining stress of open-graded mixes show that a confining stress between 100 to 300 psi can be found. This information can be used for the testing of open-graded mixes in many aspects. The fact that the subgrade has an effect on the stresses in the stresses on open-graded layer suggests that open-graded mixes can differ with respect to layers other than the normal dense graded AC subbase layer.

The information gleaned from the study into the compressive stress changes from open-graded mix overlays on PCC pavements only proves a long standing suspicion. It has been believed for some time that the addition of a porous AC layer does not contribute any significant stress reduction in the overlaid layers. The fact that no significant reduction was discovered does not mean that porous pavements are not useful, just that they do not assist in alleviating the stresses in the overlaid pavements.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions appear warranted:

1) The confining stresses in the porous mix over the B-mix were affected by the subgrade modulus. The confining stresses increased as the subgrade modulus decreased.

2) The confining stresses in the porous mix over the asphalt cement concrete pavement were not significantly influenced by the thickness of subgrade.

3) The confining stresses in the porous mix were greater for inner sides between two wheel loads.

4) The critical tensile stresses were greatly reduced by increasing the subgrade modulus.

5) The critical tensile stresses at the bottom of PCC was not significantly influenced by the thickness of porous mix overlay.

6) The critical compressive stresses at the top of subgrade were not significantly reduced by increasing the thickness of porous mix overlay or increasing the subgrade modulus.

4.2 Recommendations

The following recommendations are a result of this study:

1) The confining stress in tests like the sharp shear tester for open-graded pavements should be in the range of 100 to 300 psi depending on the severity of the sublayer changes for any specific project.

2) F-mixes, while not a stress relieving layer, have not been proven by this paper to be an invalid overly type for PCC pavements.

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