DEVELOPMENT OF MAINTENANCE PRACTICES FOR OREGON F-MIX

Interim Report

SPR 371

DEVELOPMENT OF MAINTENANCE PRACTICES FOR OREGON F-MIX

INTERIM REPORT

SPR 371

by

Dave Rogge, P.E.
Associate Professor
Department of Civil Engineering
Oregon State University
Corvallis, OR 97331

and

Elizabeth A. Hunt, P.E.
Research Group
Oregon Department of Transportation
Salem, OR 97301-5192

for

Oregon Department of Transportation
Research Group
200 Hawthorne Avenue SE, Suite B-240
Salem, OR 97301-5192

August 1999

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-OR-RD-00-01		

4. Title and Subtitle	5. Report Date
Development of Maintenance Practices for Oregon F-Mix Interim Report	August 1999
	6. Performing Organization Code
7. Author(s) Dave Rogge, P.E., Associate Professor, Department of Civil Engineering, Oregon State University Elizabeth A. Hunt, P.E Research Coordinator, Research Group, Oregon Department of Transportation	8. Performing Organization Report No.
9. Performing Organization Name and Address Oregon Department of Transportation Research Group 200 Hawthorne SE, Suite B-240 Salem, Oregon 97301-5192	10. Work Unit No. (TRAIS) 11. Contract or Grant No. SPR 371
12. Sponsoring Agency Name and Address Oregon Department of Transportation Research Group 200 Hawthorne SE, Suite B-240 Salem, Oregon 97301-5192 and Federal Highway Administration Washington, D.C. 20590	13. Type of Report and Period Covered Interim April 1997-March 1999 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract:

The Oregon Department of Transportation (ODOT) produces an open-graded asphalt pavement (F-mix) unlike most open-graded pavements used in the United States. Its 25 mm maximum aggregate size and typical lift thickness of 50 mm is more like the porous asphalt pavements used in Europe. This type of pavement has been in use in Europe since the early 1980's and widely used in Oregon only since the late 1980's. Consequently, maintenance procedures for this type of pavement are still being developed and documented. This paper summarizes progress through March of 1999 on a study of F-mix maintenance needs and techniques being conducted by Oregon State University (OSU) and ODOT. The report includes information obtained from literature review, site investigations, and a survey of ODOT maintenance supervisors.

17. Key Words:	18. Distribution Statement
Open-graded asphalt pavement; porous pavement; pavement maintenance	Copies available from NTIS

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
unclassified	unclassified		

Technical Report Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

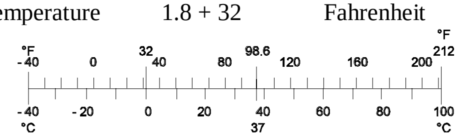
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	inches	25.4	Millimeters	mm
Ft	feet	0.305	Meters	m
Yd	yards	0.914	Meters	m
Mi	miles	1.61	Kilometers	km
		AREA		
In^2	square inches	645.2	Millimeters squared	mm^2
ft^2	square feet	0.093	Meters squared	m^2
Yd^2	square yards	0.836	Meters squared	m^2
Ac	acres	0.405	Hectares	ha
Mi^2	square miles	2.59	Kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	mL
Gal	gallons	3.785	Liters	L
ft^3	cubic feet	0.028	Meters cubed	m^3
Yd^3	cubic yards	0.765	Meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
Oz	ounces	28.35	Grams	g
Lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	Megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

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



* SI is the symbol for the International System of Measurement (4-7-94 jbp)

ACKNOWLEDGEMENTS

The authors are grateful for the assistance of the staff of the Oregon Department of Transportation. Particularly noteworthy were the contributions of Jeff Gower and Jerry Erickson. Gratitude is also expressed to all of the ODOT personnel who took the time to complete the F-mix maintenance questionnaire.

DISCLAIMER

This document is disseminated under the sponsorship of the Oregon Department of Transportation and the United States Department of Transportation in the interest of information exchange. The State of Oregon and the United States Government assume no liability of its contents or use thereof.

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official policies of the Oregon Department of Transportation or the United States Department of Transportation.

The State of Oregon and the United States Government do not endorse products of manufacturers. Trademarks or manufacturers' names appear herein only because they are considered essential to the object of this document.

This report does not constitute a standard, specification, or regulation.

DEVELOPMENT OF MAINTENANCE PRACTICES
FOR OREGON F-MIX

TABLE OF CONTENTS

APPENDICES

APPENDIX A: QUESTIONNAIRE SURVEY

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 BACKGROUND

The Oregon Department of Transportation (ODOT) began using open-graded F-mix (19 mm open) as a surface wearing course in the 1970's. In 1989, usage accelerated, and in recent years, these mixes have become the pavement of choice for rural high-traffic sites statewide. The F-mix is typically placed 50 mm thick. These pavements are performing well, but little is known about optimal methods for maintaining them. Fog seals have been used as a preventive maintenance procedure, but it is not known if current guidelines are optimal, or if better preventive maintenance procedures exist.

Emergency maintenance or corrective maintenance presents a challenge because ODOT's asphalt pavement maintenance procedures have been developed for dense-graded mixes, rather than open graded mixes. Use of traditional dense-graded maintenance procedures destroys the free-draining characteristics of F-mix, changes noise and ride characteristics, and increases the possibility of rutting problems.

Some of the older F-mixes are aging to the point where they are needing maintenance, but ODOT has not yet standardized maintenance practices. In addition, some maintenance managers resist further construction using F-mixes because of the maintenance challenge.

In general, field performance of F-mix has been excellent. However, as ODOT's inventory of F-mix pavements ages and wears under traffic, preservation through proper maintenance will take on increasing importance. Specific maintenance issues have been raised:

1. Fog-sealing applications have varied widely throughout the state. Although fog seals represent one of the most economical pavement maintenance procedures known, ODOT is uncertain of the benefit. Are fog seals the best preventive maintenance strategy, and if so, what is the optimum frequency and procedure?

2. Emergency and corrective maintenance procedures traditionally used for dense-graded pavements potentially destroy the spray-reduction, thermal stability, and the rut-resistance properties of the F-mix. Are better procedures available?

3. Excellent patches of F-mix using F-mix have been made – but they are difficult, and F-mix is difficult to obtain in small quantities.

4. Winter maintenance of F-mix presents a challenge because F-mix behaves differently than dense-graded pavements in freezing conditions.

It is important that economical, effective methods be developed for F-mix maintenance in order that the rut-resisting, thermal crack resisting, noise-reducing, and spray-reducing properties of

F-mix may be retained. Dissatisfaction with maintenance procedures could jeopardize ODOT's continued use of a successful paving procedure.

Unfortunately, little information is available regarding maintenance of open-graded friction courses, particularly as ODOT uses them. As one of the pioneer states in widespread usage of these pavements, Oregon must also be a leader in development of proper maintenance procedures.

1.2 RESEARCH OBJECTIVES

This study is being undertaken to provide a comprehensive study of preventive and corrective maintenance procedures for Oregon F-mix. Specific objectives include:

1. Evaluate the experiences of other public agencies with various maintenance procedures for open-graded pavements.
2. Evaluate the experiences of ODOT maintenance personnel with F-mix maintenance.
3. Propose and field-test recommended F-mix maintenance procedures.
4. Develop a plan for implementing the resulting recommendations.

1.3 SCOPE OF STUDY

This study consists of seven tasks:

- Task 1: Verification of performance problems
- Task 2: Literature review
- Task 3: Identification of promising materials and techniques
- Task 4: Field trials
- Task 5: Monitoring test sections
- Task 6: Evaluation
- Task 7: Report

This report summarizes the progress to date for Tasks 1-4.

2.0 RESEARCH METHODOLOGY

The three primary data collection efforts undertaken were a survey of ODOT maintenance supervisors, a literature review, and field visits to ODOT F-mix pavement sections experiencing distress. Each effort is discussed below.

2.1 SURVEY OF ODOT MAINTENANCE PERSONNEL – 1997

F-mix performance problems and maintenance challenges were summarized and verified through a survey of ODOT maintenance personnel conducted in the fall of 1997. The survey instrument is included in this report as Appendix A. It was intended that all of ODOT's first-line maintenance supervisors would have the opportunity to complete the questionnaire. In spite of concerted efforts to collect data, survey response was not good. Only 25 surveys were received. The results are summarized below.

2.1.1 F-Mix Distresses and Maintenance Challenges

Table 2.1 summarizes the results of the ODOT maintenance supervisor survey. The distresses rated as most common are clogging, icing problems, fat spots/bleeding becomes problem, and cracking due to inadequate structure (alligator cracking). Their numerical rating indicates a frequency of occurrence somewhere between "some" and "considerable." Although not a structural problem, clogging does represent a loss in pavement functionality. And while icing problems are generally limited to a few days a year, the safety and maintenance cost implications have the attention of the maintenance managers.

Table 2.1: Maintenance Supervisor Survey Results – Relative Severity of F-Mix Distress.

Distress Type	Number of Responses*				Total Responses	Average Score
	None	Some	Considerable	Extensive		
Clogging (no longer porous)	2	8	10	4	24	2.7
Icing problems	1	12	7	3	23	2.5
Fat spots/bleeding becomes problem	4	10	6	4	24	2.4
Cracking due to inadequate structure (alligator cracking)	5	8	4	5	22	2.4
Deformation rutting	5	8	7	3	23	2.3
Tire stud rutting	4	9	6	2	21	2.3
Gouging/scarring (snow-plow, etc.)	2	14	6	1	23	2.3
Noisy ride	6	9	5	3	23	2.2
Raveling	6	11	4	2	23	2.1
Rough ride	8	9	3	3	23	2.0
Stripping	7	8	5	1	21	2.0
Thermal cracking (transverse cracks)	9	8	3	2	22	1.9
Reflective cracking	8	6	3	1	18	1.8

*Note: Average Score Based On: None =1; Some =2; Considerable =3; Extensive =4

Review of the survey results with the research project Technical Advisory Committee (TAC) raised questions about the relatively high rating of "fat spots/bleeding becomes problem." Fat spots are not uncommon, but generally haven't presented serious maintenance problems. The summer of 1998 presented an exception. On a steep grade south of Amity on Highway 99W, several days with temperatures in excess of 38°C caused fat spots to flow and produce depressions.

"Cracking due to inadequate structure (alligator cracking)" indicates a problem with the total pavement section that is manifested by reflective cracks in the F-mix surface course. Some of these are present in maintenance overlays with F-mix that were done without benefit of pavement design. Regardless of the cause, they present a maintenance challenge.

The next most frequent distresses are "deformation rutting," "tire stud rutting," and "gouging/scarring (snow plow, etc.)". These distresses also rated between "some," and "considerable," but closer to "some." It was the opinion of the TAC that the "deformation rutting" item was unduly influenced by the relatively high-profile problem on I-5 in the outside southbound lane between Brownsville and Coburg interchanges. The rutting in this section is attributed to out of specification asphalt cement. Tire stud rutting is a challenge for all types of pavement. Gouging is generally more of an aesthetic problem than a functional or structural problem.

2.1.2 F-Mix Maintenance Tactics Employed and Considered

The survey requested feedback on maintenance techniques that had been attempted and that would be considered. The maintenance supervisors were also asked to rank, on a scale from 0 = "disaster" to 10 = "perfect," the relative success for F-mix maintenance of the techniques presented in Table 2.2.

Table 2.2: F-Mix Maintenance Techniques.

Maintenance Technique	Would Consider (Number)	Have Used (Number)	Success (0=disaster, 10=perfect)		
			Minimum	Mean	Maximum
Blade patch with dense-graded hot mix	1	15	4	8.0	10
Mill and inlay with dense-graded hot mix	6	10	3	7.4	10
Screed patch with dense-graded hot mix	4	10	3	6.7	9
Mill and inlay with F-mix	5	3	3	6.0	10
Mill and inlay with open-graded cold mix	2	0			
Blade patch with pre-mix	0	0			

Blade patching with dense-graded hot mix was the most widely used technique, and the most successful with a mean score of 8.0. Mill and inlay, and screed patch with dense-graded hot mix were also widely used and reasonably successful. All of these techniques are routinely used for maintenance of traditional dense-graded asphalt pavements. Only three respondents had milled and inlaid with F-mix, and their experiences varied widely. Only two respondents would even consider mill and inlay with open-graded cold mix, and no one would consider blade patching with pre-mix.

Maximum scores of nine and ten were noted by at least one respondent for the four highest-ranking techniques. The higher scores suggest that all four are viable techniques for F-mix maintenance. The wide range of success for these four techniques, however, suggests that maintenance procedures and methods may have a big impact on success experienced.

The maintenance supervisors listed other maintenance techniques that they have attempted. Full-width 50-mm thick overlays of B- and C-mix (19 mm and 12.5 mm dense mix, respectively) have been applied. The B-mix overlay resulted in success of only "2". The two C-mix overlays reported successes of "4" and "7". Surface grinding of F-mix to improve skid resistance was reported with a success of "2". Profiling of bulges resulted in success of "5". Pothole repairs with cold mix (success of "1"), with pre-mix (success of "4"), and with Percol (success of "7") were reported. One respondent reported hand patching with hot mix. Two respondents would consider using chip seals.

Only eight respondents reported using fog seals to preserve F-mix. The frequency of application reported ranged from every 3 years to every 7 years, with an average of every 5.5 years. Commonly expressed concerns about fog sealing were that it clogs the porous pavement, that traffic control for its application is disruptive, that skid resistance is reduced, and that benefits are unknown.

2.1.3 Perceptions Regarding F-Mix Maintenance

The best source of information regarding performance of Oregon F-mix is found in ODOT's Pavement Management System. Nonetheless, although perceptions of maintenance personnel are not as objective and not as comprehensive, they are still very real, and therefore important when determining optimum maintenance procedures.

Figures 2.1 - 2.4 show the survey results with respect to maintenance supervisor perceptions. Figures 2.1 and 2.2 compare perceptions of pavement distress for ODOT B-mix (dense-graded) and ODOT F-mix for 3-year old and 6-year old pavements. For both time frames, the largest percentage of survey respondents believes that F-mix is more likely to be distressed. Figures 2.3 and 2.4 compare perceptions of repair costs for B-mix and F-mix for a repair of 400 square yards and for potholes. For both types of repairs, the majority of survey respondents believe that F-mix is more expense to repair.

Clearly the perception of maintenance supervisors is that F-mix requires more maintenance than dense-graded asphalt pavements, and that the repairs for F-mix are more expensive than for dense-graded pavements. This perception exists even though in many cases the same blade-patching or screed-patching techniques are employed using the same materials on both dense-graded pavements and F-mix.

The survey results show that the majority of ODOT maintenance supervisors responding to the survey consider maintaining F-mix more difficult and more expensive than maintaining dense-graded mix. Because their maintenance budgets are limited, it is therefore the perception of the maintenance supervisors that F-mix is increasing their budget pressures.

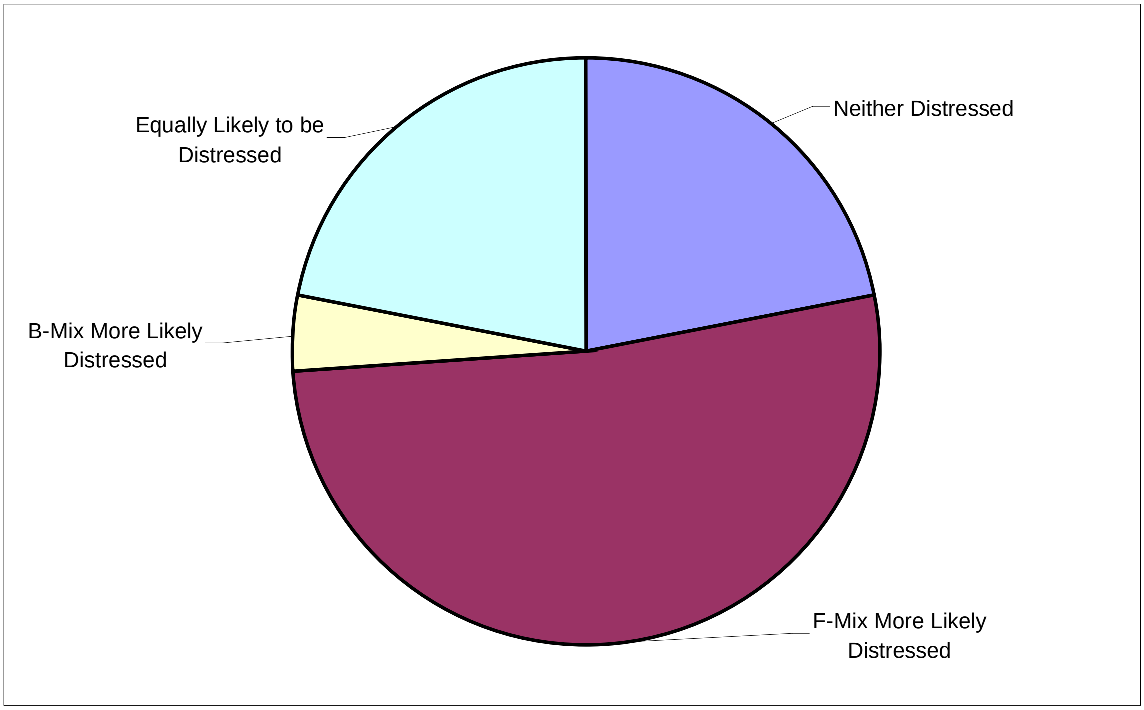


Figure 2.1: Maintenance Supervisor Perceptions of Three-Year-Old Pavement Distress.

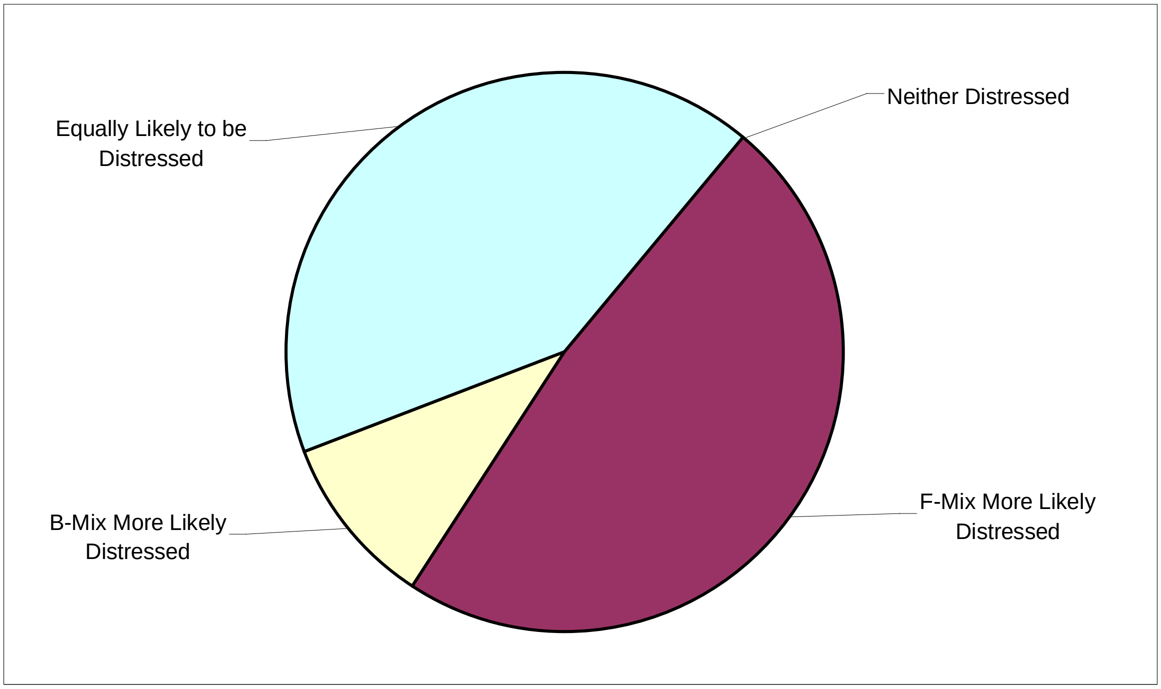


Figure 2.2: Maintenance Supervisor Perceptions of Six-Year-Old Pavement Distress.

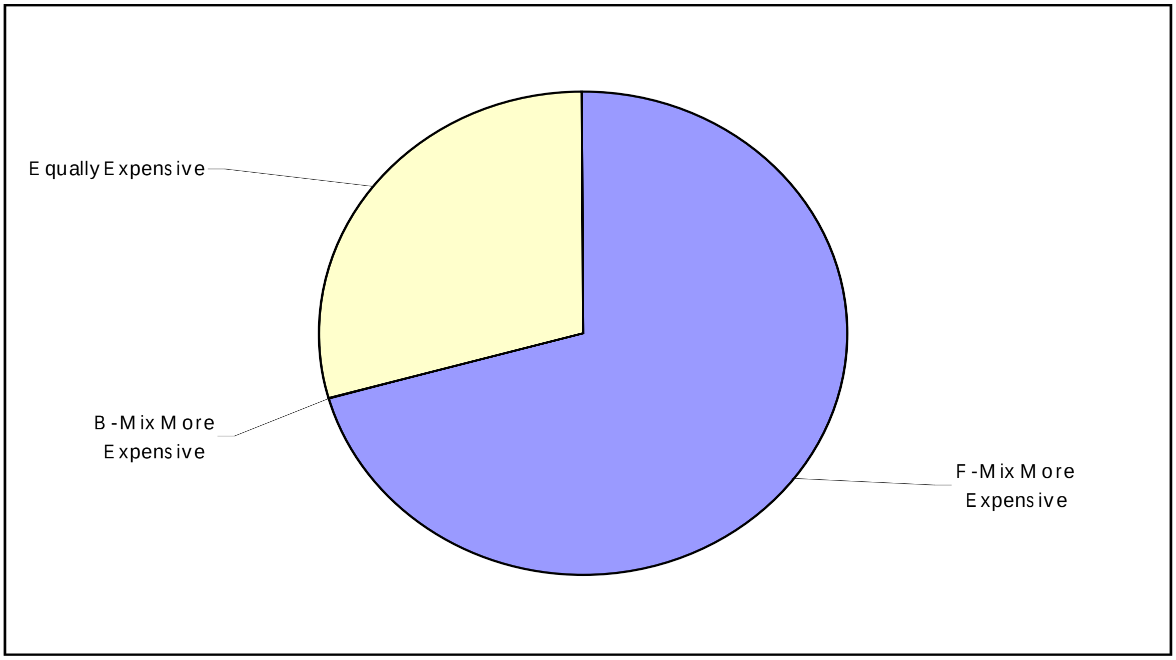


Figure 2.3: Maintenance Supervisor Perceptions of Cost of Repair of 400 m^2 Area.

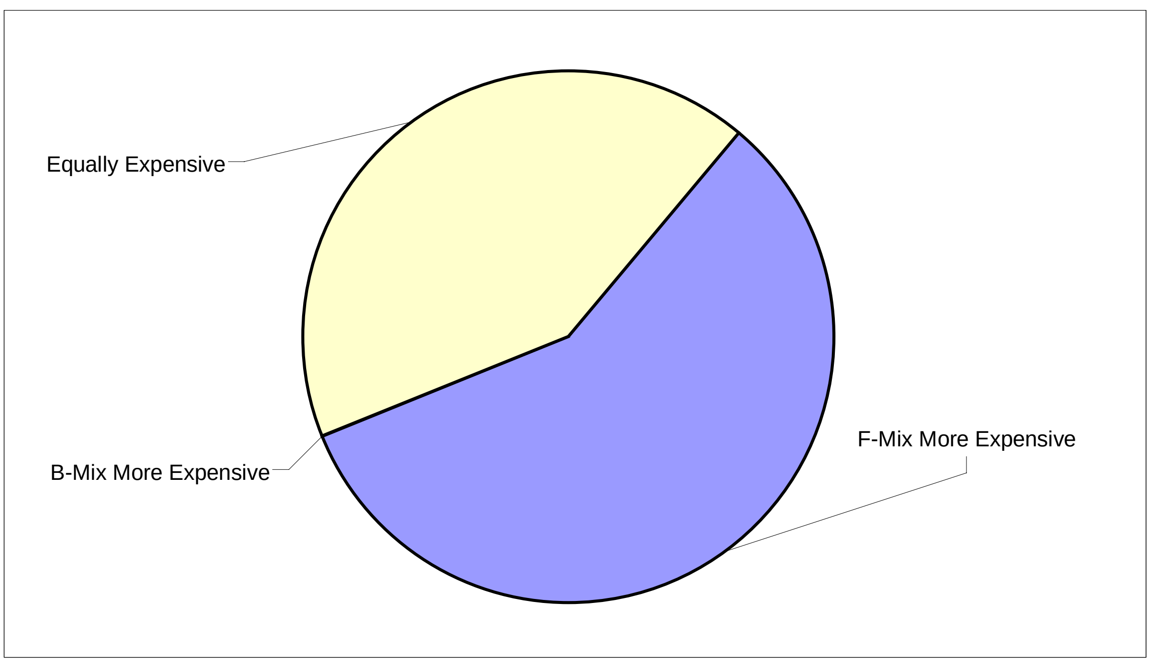


Figure 2.4: Maintenance Supervisor Perceptions of Expense for Pothole Repair.

2.2 LITERATURE REVIEW

The literature review is a continuing process. Porous pavements, as they are called in Europe, most closely resemble Oregon F-Mix. They are a relatively new phenomena, and only in recent years have the maintenance challenges that they present been addressed. Consequently, new problems and new studies are continually arising. Results from the literature review are discussed below, and in more detail in Chapters 3 and 4.

In the U.S., open-graded friction courses (OGFCs) have similar drainage characteristics to Oregon F-mix, but are very different in maximum aggregate size and layer thickness. They generally serve as a surface treatment rather than a structural element. OGFCs will be discussed first.

2.2.1 Literature Relating to Open Graded Friction Courses (OGFCs)

The states of Florida and Georgia have used OGFCs most extensively over the past 25 years. These states have the most experience with OGFCs. Unfortunately, little information regarding maintenance of OGFCs has been published. Telephone calls to Departments of Transportation in both states *(Musselman 1997; McGauhey 1997)* indicate the same trends emerging in both states. Both states plan to mill and inlay OGFCs at the end of their economic lives. Their emphasis has been on extending the economic life (time until mill and inlay is required) through use of modified binders and quality aggregates rather than on corrective or even preventive maintenance. Both states have essentially abandoned the use of fog seals because of lack of clear evidence of benefit, because of concerns about clogging the free-draining characteristics of the pavement, and because of concerns about traffic control during fog sealing and skid resistance immediately after fog sealing. These states undoubtedly have situations where they need to repair OGFCs, but nothing has been published on the subject, and no central state authority on the subject can be identified in either state.

2.2.2 Porous Pavement Literature

Porous pavements have been widely used in Europe since the early 1980's. PIARC has published the handbook, Pourous Asphalt *(PIARC 1993)*, which discusses all aspects of porous pavements, including maintenance. Major topics are construction costs, life, maintenance and repair, and winter maintenance. Maintenance of porous asphalt pavements is stated to be more expensive than conventional asphalt pavement. Winter maintenance is more expensive because more salt is needed.

The Transportation Research Board has devoted an entire publication to literature relating to design, management, and performance of porous pavements (TRB 1265, 1990). The performance of porous pavements was generally given favorable reviews, however, special maintenance needs of porous pavements were noted.

2.2.3 ODOT F-Mix Literature

ODOT has conducted studies on the performance of F-mix. The most comprehensive report is the "Evaluation of Porous Pavements Used in Oregon," by Younger, Hicks, and Gower *(1994)*. Results of laboratory and field tests of Oregon F-mix are reported. Results reported include accident analysis, asphalt properties, core gradation, noise, permeability, rutting, skid testing, splash and spray, tack coat shear testing, and texture depth. For the most part, the report confirmed the advantages and disadvantages reported in the European literature. Specifically relevant for the current research project, the report concluded that, "ODOT's F-mix shows little change over time for rutting, permeability, and void levels." The recommendation to "continue testing of splash and spray, and other properties of porous pavements over an extended period of time" was made.

Hunt and Boyle (*1995)* reported on the "Evaluation of PBA-6GR Binder for Open-Graded Asphalt Concrete 1993 and 1994 Projects." Because the study focused on design and construction of binder with ground recycled tire rubber, the material presented does not specifically relate to F-mix maintenance.

Huddleston, Zhou, and Hicks reported "Evaluation of Open-Graded Asphalt Concrete Mixtures Used in Oregon," to the Transportation Research Board *(1993)*. This paper focused on pavement condition and pavement friction. Comparisons of F-mix pavements to B- and C-mix (dense-graded) pavements showed better rutting resistance for the F-mix, and less load-related and thermal cracking for the F-mix. Friction testing results for F-mix and B/C- mix were compared. Although the mean friction numbers (FN's) for the F-mix projects were slightly higher than for the B/C-mix pavements, the differences were small. Problems for F-mix with road kill, draindown, and snowplow damage were noted, but specific maintenance needs and procedures were not addressed.

2.3 FIELD INVESTIGATIONS

Table 2.3 presents a summary of the field investigations conducted to develop a greater understanding of the maintenance challenges presented by Oregon F-mix. Surveillance of these locations continues.

Table 2.3: Field Investigations of F-Mix Distress and Maintenance Procedures.

DATE	Location	Distress or Treatment
6/97	US 101 north of Waldport	Utility construction scarring
6/97	SR 22, SW of Salem	Recent fog seal
6/97	SR 22, West of Salem	Catch basin drainage problem, French cross-drain settlement, grass growing through pavement shoulders and turn lane
6/97	I-5 Salem area	Rutting, cracking, blade patches, and screed patches at bridge approaches
6/97	I-5 Salem area	Water problem–pavement joints
7/97	I-5 outside southbound lane north of the Linn/Lane county line	Rutting – suspected off-spec asphalt used in construction
7/97	I-84 near Meacham exit	Fog seal
7/97	I-84 east of Pendleton, MP 213-218	Spalled areas – probably from stripping
7/97	I-84 near Corbett exit	Raveled, noisy pavement prior to fog seal
8/97	US 99W north of Corvallis	Newly placed screed patches over cracked pavements
7/98	U.S. 20 near Santiam Pass	Blade patches and screed patches over raveled areas
7/98	U.S. 26, MP 62-71	Alligator cracking and raveled spots
7/98	Oregon 126, MP 13-16	Screed and blade patches later covered with AC-15R (hot oil) chip seal
7/98	US 99W south of Amity	Fat spots raveled out after heat wave
10/98	US 99W south of Junction City	Minor surface repairs

3.0 MAINTENANCE CHALLENGES

This section presents a summary of the most significant Oregon F-mix maintenance challenges determined through the various data gathering activities.

3.1 CLOGGING

Both the survey of ODOT maintenance supervisors and the literature review indicate that reduction in drainage capacity due to clogging of pores with debris is a universal maintenance challenge presented by porous pavements. PIARC's Porous Asphalt, and papers from both Belgium *(Van Heystraeten and Moraux 1990)* and Spain *(Perez-Jimenez and Gordillo 1990)* note clogging of porous pavements over time, but generally, it is not considered a serious problem.

The Belgian study states that "It is well known that porous asphalt slowly silts up on places where traffic is not intense. This problem, therefore, does not occur in the traffic lanes of a highway or a motorway, and certainly not with an initial voids content of 22 percent and a 4-cm-thick layer." The study further notes that the real problem is with the shoulders used for emergency stops. Since they experience no traffic, they clog and impede drainage from the traffic lanes. Placement of an impermeable surface dressing on the shoulders is suggested as a solution.

The Spanish paper notes that the slight reduction in permeability, "has no appreciable effects on the efficiency of water drainage and the avoidance of its projection and splashing." And it is noted that the permeability, even when reduced, is higher than that of a "permeable sand." It is further stated that, "Rehabilitation has never been undertaken because the material closed up."

3.1.1 Permeability of Porous Pavements – Published Data

Isenring *(1990)* presents the most comprehensive summary of permeability measurements of porous pavements over time. Flow rates over time are reported for porous pavements of 10-mm maximum aggregate size and pavements of 16-mm maximum aggregate size. A falling head permeameter was used to obtain the measurements.

Because the 16 mm maximum aggregate size pavements are most like Oregon F-mix, the results for these pavements are considered most relevant. The most severe clogging resulted in reduction in flow rate from 1.7 liters/minute to 0.2 liters/minute over a five-year period. The best case measurements for 16 mm maximum aggregate porous pavement showed reduction in flow rate from 3.1 liters/minute to 1.8 liters/minute over a five year period. Measurements on dense-graded asphalt or concrete pavement would produce flow rates of 0.0 liters/minute. Clogging does occur, but the clogged porous pavement still allows drainage through the pavement, whereas dense-graded pavements do not.

3.1.2 Permeability Measurements of Oregon F-Mix

Younger's *(1994)* study of F-mix performance used a falling head permeameter as illustrated in Figure 3.1. The permeameter operates similarly to that used by Isenring *(1990)*, but because dimensions are not identical, flow rates may not be directly compared. In addition, Younger reports difficulty with obvious lateral leakage at the perimeter of the permeameter – pavement surface interface, and reports concerns about the accuracy of the measurements. His reporting of non-zero flow rates for dense-graded asphalt and portland cement concrete pavements when using the device substantiates this concern.

Permeability measurements at the same locations taken one year apart do not show evidence of clogging. However, the difference in time to drain the fixed volume of water varied only from 0.83 seconds to 2.09 seconds at three different locations where these measurements were made. With the limited number of permeability readings reported and the loss of water at the permeameter – pavement interface, it is not possible to determine degree of clogging.

The researchers for the current project were aware of the field permeameter leakage problems experienced and reported by Younger *(1994)*. To solve this problem, weather-stripping was applied around the field permeameter's rubber seal. This effectively solved the perimeter leakage problem experienced by Younger. Even though the current research project used the same field permeameter as Younger, it is the opinion of the authors that the application of the weather-stripping has produced a field permeameter that produces valid and useful readings.

The authors obtained permeability data from two newly constructed F-mix construction projects and a newly fog-sealed F-mix project. The fog-sealed pavement was eight years old. Time to drain a fixed quantity of water through the pavement varied from about two seconds at Stayton where the pavement was still warm from construction to a median value of 38.5 seconds on the eight-year-old pavement at Tiller Junction. The median value for fog sealed pavement at Tiller Junction was 38.5 seconds compared to 36.5 seconds without fog seal. These permeability readings were taken about 4 months after the fog seal. The more time required to drain the fixed quantity of water, the less permeable is the pavement. Low times mean high permeability and vice versa.

Permeability readings of the Grant's Pass – Applegate River F-mix project, constructed in summer of 1998, were taken about two months after construction and, for pavements without obvious clogging, had a median value of 5.3 seconds. Three locations with caked mud on the surface produced readings of 10, 10, and 17 seconds.

Permeability readings on dense-graded asphalt and concrete pavement with the same field permeameter (using the weather-stripping) produce essentially infinite time values. Readings using the permeameter with weather-stripping follow a logical and consistent pattern. The authors conclude that the field permeameter should be used with the weather-stripping for consistent, meaningful results.

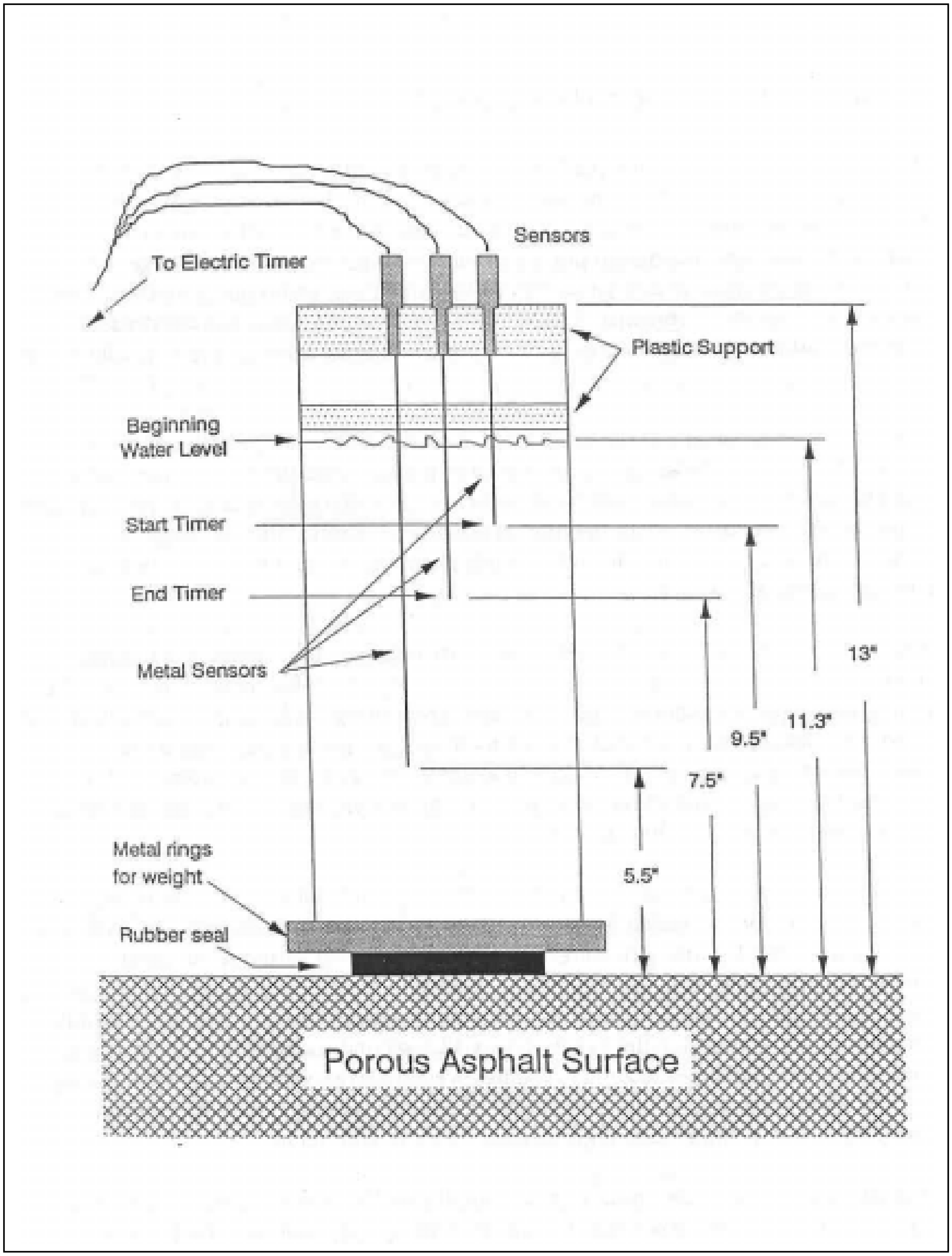


Figure 3.1: Falling-Head Permeameter *(Younger 1994)*.

3.2 WINTER MAINTENANCE

Consistent with the ODOT maintenance supervisor survey, winter icing of the porous pavement was the most frequently discussed maintenance challenge in Transportation Research Record (TRR) 1265. Papers from Italy, Belgium, Switzerland, Spain, and the Netherlands make note of differing winter maintenance for porous pavements. Five of eleven papers included in TRR 1265 note differing winter maintenance for porous pavements.

Winter maintenance of porous asphalts is different. This is because of different temperature behaviour for porous asphalt, and because of difficulty maintaining a sufficient salt level at the level of contact between tire and pavement. "Both in the laboratory as in actual practice it has been found that the behaviour of porous asphalt in winter conditions is sometimes better, sometimes worse than that of a dense mix" *(PIARC 1993: p 109)*.

In porous asphalt, the formation of ice occurs sooner than in a dense mix. "Both France and the Netherlands have proven a 1° to 2°C lower temperature in porous asphalt than in dense mixes. This means that more often and for a longer period this type of wearing course can be in critical temperature conditions." "Research in Austria led to the conclusion that porous asphalt within the temperature range of 0° to -5°C behaves differently. At lower temperatures there are no differences compared to dense mixes" *(PIARC 1993: p 109)*.

"Ice building, due to glazed frost or rain on a cold road surface, is very dangerous, because of the very rapidly changing road conditions. Here, preventive spreading is also less effective and during precipitation an increase of spreading is needed, because of the quick drainage of the salted meltwater. The brine will not be effective on the surface" *(PIARC 1993: p 109)*.

<u>Porous Asphalt</u> concludes its discussion of winter maintenance with the following positive statements. "In general the conclusion is that the noticed different behaviour of porous asphalt does not lead to unacceptable safety situations, certainly not if those responsible reckon with the different performance of porous asphalt. Some researchers (Belgium, Switzerland) conclude that, despite of the different behaviour of porous asphalt in general, no unsafe situations exist. Depending on the specific circumstances, porous asphalt is sometimes safer, sometimes less safe than a dense mix."

More recently, in a report on "Susceptibility to Icing on Different Road Pavements," Gustafson *(1994)* reports on investigations by the Swedish Road and Transport Research Institute aimed at "assessing the susceptibility to icing on various pavements in wintertime and the influence on deicing measure." He concludes that, "porous asphalt pavements are generally somewhat less skid-resistant and require more extensive de-icing measures than conventional dense asphalt concrete."

Schmitt *(1994)* provides a positive outlook on winter road maintenance of porous pavements. He reports results from three different winter road maintenance periods. Behaviour of conventional asphalt concrete pavements and porous asphalt "did not differ markedly from each other and certainly not to an extent that would suggest discontinuing the use of . . ." porous asphalt. "The disadvantages that porous asphalt was originally thought to have in winter road maintenance may have been well-founded in theory, but they were not confirmed in practice and appear to be controllable."

3.3 PHYSICAL/MECHANICAL DISTRESS

The published literature about porous pavements seldom discusses pavement deterioration. When mentioned, the distress is in the form of raveling. Ruiz, Alberola, Perez, and Sanchez *(1990)*, citing experience in Spain, note that "the main problems have come in the form of particle losses in localized or large areas. This process usually occurs very quickly once the flow of traffic begins. This problem usually originates from laying the mixture cold, from too low a level of compaction, or from segregation of the binder. The solution has always been to mill and substitute the withdrawn material for another porous asphalt. In one case, the repair was made by laying one porous asphalt over another; so far, no problems have arisen."

<u>Porous Asphalt</u> discusses porous asphalt pavement distress modes and specifics of maintenance. Structurally, "rutting or cracking hardly ever appears," except for reflection cracks. "Loss of material" is one of the major reasons for road maintenance.

Tolman *(1996)* reports that the most significant structural deterioration of porous asphalt pavements "is the loss of stones leading to raveling or eventually potholes." "After a rather long period of slow degradation (5-10 years) the speed of damaging increases.."

Van der Zwan, et.al. *(1990)*, citing Dutch experience, note that the "prevailing damage mechanism is the loss of material that results when stones become separated from the pavement surface." It is further noted that, "the deterioration process takes place relatively slowly and does not have any catastrophic effects." They further estimate a service life for porous asphalt wearing courses of 10 years versus 12 years for dense asphalt concrete.

4.0 PROMISING MATERIALS & TECHNIQUES

Van Heystraeten and Moraux *(1990)* refer to a joint Dutch and Belgian working group investigating maintenance challenges associated with porous asphalt pavement. They refer to fog seal sprays, in-place recycling, "overlays in porous asphalt," and "cold-laid porous asphalt mixes" for local repairs, including potholes, Unfortunately, it has not been possible to obtain detailed reports or updates on the progress of the Dutch/Belgian group.

Van der Zwan *(1990)* notes that, "experience has shown that minor repairs can be carried out to porous asphalt using conventional means, provided that care is taken to preserve the inherent drainage characteristics." He indicates that in-place repaving and remixing has been tested, but that more work is needed.

Maintenance materials and techniques for specific maintenance challenges are now discussed.

4.1 CLOGGING

Van Heystraeten and Moraux *(1990)* mention use of a suction sweeper with water jet for the cleaning of partially clogged pavement surfaces. According to Porous Asphalt, attempts to restore drainage capacity by flushing the pavement with high-pressure water cleaning or vacuum sweeping machines have not been encouraging. Improvements have been limited to the surface and have only been temporary. It is hoped that continuing developments in equipment technology may improve this situation.

4.2 WINTER MAINTENANCE

The use of CMA with porous pavements is not discussed in the literature. It is noted that porous asphalts require more salt per unit area than conventional pavements and that in general, brines are ineffective and should not be used. It is noted that in France and the Netherlands there has been a tendency for the use of electronic warning systems with porous pavements *(PIARC 1993)*.

A de-icing agent that will stay at the surface of porous pavements rather than disappear into the voids of the pavement is needed. One possibility is mixing CMA with another material that will stay at the surface. It is possible that cationic or anionic charges can be utilized in a manner analogous to their use in asphalt emulsions to form an attraction to the pavement surface. A new de-icing agent formulated from liquid residue from processing of corn, barley, and other agricultural products is becoming available *(APWA Reporter 1998)*. Its potential for use with F-mix pavements should be evaluated.

4.3 PREVENTIVE MAINTENANCE

Fog seal applications with porous pavements have been tested but evaluations of their success have not been reported in the literature. "An insufficient skid resistance has been measured in the Netherlands" *(PIARC 1993)*.

Fog seal applications present traffic control challenges. It is likely that pavement friction experiences a temporary reduction immediately after fog seal application. The authors could find no definitive studies weighing the advantages and disadvantages of fog seals for dense-graded or open-graded asphalt pavements. DOT's in Florida and Georgia, two states with extensive experience with open-graded friction courses, have concentrated on longer lives through better materials and construction techniques and down-played the use of fog seals for preventive maintenance.

4.4 MINOR MAINTENANCE

Ruiz, et.al. *(1990)* describe mill and inlay for poor performing porous asphalt, but the use they describe originates because of problems during construction rather than deterioration over time.

Porous Asphalt discusses maintenance for the most significant distress mode requiring minor maintenance – loss of material, or raveling. This distress ". . . can be repaired in the usual way without any trouble, by the application of hot or mastic asphalt. The repaired area introduces a discontinuity in the drainage of water, which is not serious, when dealing with a limited surface area." "Cold-applied porous mixture, with fluxed bitumen," has been tested, but long-term performance is unknown. It is known that any type of localized thermal treatment damages adjoining untreated porous pavement. Chip seals have been used to repair areas of reflective cracking. Longitudinal grooves resulting from mechanical damage to the pavement surface have been noted, but repair is not necessary because further degradation general does not occur.

4.5 MAJOR MAINTENANCE

Major maintenance includes rehabilitation and reconstruction techniques. Three methods considered appropriate for porous pavements are mill and inlay, in-place recycling or repaving, and overlays *(PIARC 1993: p102-105)*. Because of the relatively short time that porous pavements have been in use, long-term performance information is not available. It is stated that milling porous asphalt pavements is generally easier than milling dense-graded asphalt pavements. In-place recycling is still considered experimental. Both porous and conventional asphalt overlays have been used.

Van der Zwan, et. al. *(1990)* in discussing Dutch practice, project a service life of ten years for porous asphalt compared to 12 years for dense-graded, and note that the primary failure mode is expected to be relatively slow progression of raveling to a point where something must be done. At that time, mill and inlay is the preferred method for applying the new wearing course.

Van der Kooij and Verburg *(1996)* make the bold statement that, ". . . in years to come the motorway network in the Netherlands (approx. 80 sq. km) will be surfaced with porous asphalt." This increase in usage from the 20 percent utilization reported in 1994 *(Noort 1994)* is apparently based on favorable experience with porous asphalt and conclusions that advantages of spray and noise reduction outweigh maintenance challenges. Because of their planned high usage of porous asphalts, the Dutch are placing an emphasis on recycling of porous pavements, both in-plant and in-place.

5.0 FIELD TRIALS

Analysis of the literature and survey results combined with conversations with ODOT personnel indicate that the procedures presented in Table 5.1 should be considered for field trials. These field trials will document pavement distress, detail maintenance procedures employed, and monitor resulting performance.

Table 5.1: Procedures to be Considered for Field Trials.

Techniques likely to experience most widespread usage: • "C" mix (12.5 mm dense) blade patches • "D" mix (9.5 mm dense) screed patches • Partial mill and inlay, but with F-mix
Larger scale traditional repairs: • overlay F-mix with F-mix • overlay F-mix with C-mix • mill and inlay full width with F-mix
Winter maintenance: • application of a de-icing slurry, gel, or high-viscosity fluid that stays at the surface – perhaps a mix of organic wastes and CMA.
New and untried in Oregon: • application of cold-laid porous mixes using fluxed asphalt

With information currently available, it is virtually impossible to determine the cost-effectiveness of fog seals. A definitive study with adequate sample size using cores of fog-sealed and non-sealed sections of F-mix to predict the pavement life gained through fog-sealing is outside the scope of this research project. Fog seal projects on F-mix will be monitored, however, definitive results are not expected within the scope of this research.

6.0 CONCLUSIONS

The information presented in this report indicates that the following conclusions are justified:

1. ODOT concerns about clogging and winter maintenance are shared by European agencies experienced in porous pavements, however these concerns have not been significant enough to curtail the growth of its usage in Europe. A clogged porous pavement still drains better than dense-graded asphalt pavement.

2. Conventional repair techniques used for dense-graded pavements may be used on limited areas of F-mix provided that drainage implications are adequately addressed.

3. The greatest restraint for F-mix as a material for repair of F-mix is its limited availability in small quantities to maintenance crews.

4. In spite of evidence from ODOT's pavement management system to the contrary, ODOT maintenance personnel perceive that F-mix requires more maintenance than dense-graded asphalt pavements.

5. ODOT's maintenance personnel believe that maintenance of F-mix is more expensive than maintenance of dense-graded mix.

6. Optimum maintenance procedures for porous pavements have not yet been identified.

7.0 FUTURE RESEARCH ACTIVITIES AND RECOMMENDATIONS

7.1 FUTURE RESEARCH

Based on the information presented in this report, the following future research activities will be pursued:

1. A pricing schedule for small quantities of F-mix for maintenance purposes will be obtained from suppliers.

2. Successful maintenance practices including F-mix pavement screed patching and blade patching will be documented and distributed as *good maintenance practice*.

3. A facilitated brainstorming session will be investigated as a means to generate additional F-mix maintenance options. Visionaries from across the state would be included as well as representatives from ODOT Pavement Services and the Asphalt Pavement Association of Oregon.

4. The 1997 maintenance supervisor survey will be updated and redistributed with a goal of 80% response.

5. Additional information will be collected and distributed regarding the use of a de-icing agent that would remain on the surface of the porous pavement.

6. The procedures listed in Table 5.1 will be considered for field trials. The research will include documentation of pavement distress, detailed maintenance procedures employed, and resulting performance.

7. Fog seal construction on F-mix will be monitored and documented. If possible, control sections will be established on the fog sealed projects for long-term performance comparisons.

8. The results of the research will be documented in a final report in 2002.

7.2 RECOMMENDATIONS

1. An ODOT manager should make contact with her or his counterparts in Belgium and the Netherlands and arrange to visit those countries to examine porous pavement distresses and maintenance techniques.

2. A percentage of maintenance funds should be “held back” and released only for innovative F-mix maintenance projects.

8.0 REFERENCES

APWA Reporter, "New Weapon in Snow and Ice Fighting Arsenal that's Environmentally-Friendly and Effective," February 1998, p15.

Gustafson, "Susceptibility to Icing on Different Road Pavements," Ninth PIARC International Winter Road Congress, Technical Report, 1994 Volume 1, pp 258-265.

Huddleston, I. J., H. Zhou, and R.G. Hicks, 1993. "Evaluation of Open-Graded Asphalt Concrete Mixtures Used in Oregon," Transportation Research Record 1427, TRB, National Research Council, Washington D.C., pp 5-12.

Hunt, Liz, and Glenn E.Boyle, 1995. "Evaluation of PBA-6GR Binder for Open-Graded Asphalt Concrete 1993 and 1994 Projects," Oregon Department of Transportation, OR-RD-95-13, Salem.

Isenring, Thomas, Harald Koster, and Ivan Scazziga, "Experiences with Porous Asphalt in Switzerland," *Porous Asphalt Pavements: An International Perspective 1990*, Transportation Research Record No. 1265, 1990, pp. 41-53.

McGauhey, Harry, Georgia Department of Transportation, July 28, 1997 telephone conversation with Dr. Rogge, 404-363-7510.

Musselman, Jim, Florida Department of Transportation, November 3, 1997 conversation with Dr. Rogge.

Nicholls, "Review of UK Porous Asphalt Trials," Transport Research Laboratory Report 264, 1997.

Noort, "Winter Maintenance on Porous Asphalt," Ninth PIARC International Winter Road Congress, Technical Report, Volume 1, 1994, pp 224-231.

PIARC Technical Committee on Flexible Roads, Porous Asphalt, 1993.

Perez-Jimenez, F.E., and J. Gordillo, "Optimization of Porous Mixes Through the Use of Special Binders," Transportation Research Record 1265, TRB, National Research Council, Washington D. C., 1990, pp.59-68.

Ruiz, Aurelio, Roberto Alberola, Felix Perez, and Bartolome Sanchez, "Porous Asphalt Mixtures in Spain," Transportation Research Record 1265, TRB, National Research Council, Washington D. C., 1990, pp.87-94.

Schmitt, "Winter Road Maintenance on Porous Asphalt," Ninth PIARC International Winter Road Congress, Technical Report, Volume 1, 1994, pp 210-216.

Tolman, "Mechanical Durability of Porous Asphalt," Euroasphalt & Eurobitume Concress, Strasbourg, 7-10 May 1996, Volume 2.

Van der Kooij, and Verburg, "Mixing of High Penetration Bitumen with Aged Bitumen during Hot-Mix Recycling of Porous Asphalt," Eurasphalt & Eurobitume Congress, Strasbourg, 7-10 May 1996, Volume 3.

Van der Zwan, J., T. Goeman, H. Gruis, J. Swart, and R. Oldenburger, "Porous Asphalt Wearing Courses in the Netherlands: State of the Art Review," Transportation Research Record 1265, TRB, National Research Council, Washington D. C., 1990, pp.95-110.

Van Heystraeten, G., and C. Moraux, "Ten Years' Experience of Porous Asphalt in Belgium," Transportation Research Record 1265, TRB, National Research Council, Washington D. C., 1990, pp.34-40.

Younger, Krey, R.G. Hicks, and Jeff Gower, "Evaluation of Porous Pavements Used in Oregon, Volumes I and II," Oregon Department of Transportation, FHWA-OR-RD-95-13B, Salem, December, 1994.

APPENDIX A: QUESTIONNAIRE SURVEY

OREGON STATE UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
CORVALLIS, OR 97331-2302
541-737-4351 (VOICE)
541-737-3300 (FAX)
rogged@ccmail.orst.edu

December 1, 1999

Dear Maintenance Professional:

ODOT has contracted with Oregon State University to lead an effort to develop effective strategies for F-mix maintenance. Preventive, emergency, and corrective maintenance techniques are included in this study.

In many ways, we are plowing new ground. Most information about asphalt pavement maintenance deals with dense-graded pavements, such as B-mix. Documented information about maintaining open-graded pavements, such as F-mix is scarce. Because of this, your help in setting direction for the F-mix study is crucial. Please complete the attached questionnaire. Your honest and thoughtful responses will be vital to a successful research effort.

Don't feel restrained by the questionnaire. Please write any additional comments that you feel are useful, or call or e-mail me as indicated above.

Thank you for your assistance.

Sincerely,

Dave Rogge
Associate Professor

Attachment: F-mix maintenance questionnaire

F-mix Maintenance Questionnaire:

NAME:____

TELEPHONE CONTACT:______________________________

LOCATION:____

For how many years have you had responsibilities for asphalt pavement maintenance?

_________________ years

F-mix distress:

In general, what types of distress have you encountered with F-mix? (Please check one box on each line..)

	None	Some	Considerable	Extensive
1. Raveling				
2. Clogging (no longer porous)				
3. Gouging/scarring (snow-plow, etc.)				
4. Deformation rutting				
5. Tire stud rutting				
6. Thermal cracking (transverse cracks)				
7. Cracking due to inadequate structure (alligator cracking)				
8. Reflective cracking				
9. Stripping				
10.Fat spots/bleeding becomes problem				
11.Icing problems				
12.Noisy ride				
13.Rough ride				
Other:				

Preventive Maintenance:

Please indicate if you have used or plan to use any of the following preventive maintenance procedures on F-mix, and for those which you have used, indicate frequency in the past and planned frequency in the future:

a) Have you used fog seals on F-mix?

[ ] Yes

[ ] No. If no, skip to b) chip seals.

i) How frequently have you been fog sealing F-mix? Every ______ years.

ii) How frequently do you plan to fog seal F-mix in the future? Every _____ years.

iii) Comments:____

____

____

b) Have you used chip seals on F-mix?

[ ] Yes

[ ] No. If no, skip to c) below

i) How frequently in the past? Every _____ years.

ii) How frequently in the future? Every _____ years.

iii) Comments:____

____

____

c) What other preventive maintenance have you used on F-mix?

____

i) How frequently in the past? Every _____ years.

ii) How frequently in the future? Every _____ years.

iii) Comments:____

____

____

Corrective Maintenance:

Please indicate whether you have used or would consider using the following corrective maintenance techniques on F mix. Check boxes as appropriate. For treatments which you have used please indicate the success of the treatment using a scale of 0-10 (0=disaster; 10= perfect).

TREATMENT	NOT USED	HAVE USED	Success (0 to 10)	WOULD CONSIDER
Mill and inlay with F-mix				
Mill and inlay with dense-graded hot mix				
Mill and inlay with open-graded cold mix				
Screed patch with dense-graded hot mix				
Blade patch with dense-graded hot-mix				
Blade patch with pre-mix				
Other:				

Comments:____

Emergency Maintenance:

Please "write-in" any techniques that you have used or would consider using for emergency maintenance on F-mix. For treatments which you have used please indicate the success of the treatment using a scale of 0-10 (0=disaster; 10= perfect).

TREATMENT	HAVE DONE	Success (0 to 10)	WOULD CONSIDER
Other:			

Comments:____

General:

In your location, what is your most significant F-mix maintenance expense?

What topics do you think it is absolutely essential that this ODOT-OSU F-Mix Maintenance study address?

Please list any specific maintenance techniques that you'd like to see explored?

Perceptions of comparative Maintenance needs

Compare 3-year old F mix and B mix.

a) neither is likely to show disrtress.
b) F mix is more likely to show distress requiring patching
c) B mix is more likely to show distress requiring patching
d) They are equally likely to show distress requiring patching

Compare 6-year old F mix and B mix.

a) neither is likely to show disrtress.
b) F mix is more likely to show distress requiring patching
c) B mix is more likely to show distress requiring patching
d) They are equally likely to show distress requiring patching

Comments:____
____
____

Perceptions of comparative maintenance costs

Compare the cost of a pothole repair in F mix to a pot hole repair in B mix.

a) F mix is more expensive
b) B mix is more expensive
c) It is equally expensive

Compare the cost of a 400 square-yard (approx. 100-yard length of one lane width) repair in F mix to a similar repair in B mix.

a) F mix is more expensive
b) B mix is more expensive
c) It is equally expensive

Comments:____
____