ESTABLISHMENT OF QC/QA PROCEDURES FOR OPEN-GRADED MIXES

Final Report

SPR 5268

RESEARCH

Oregon Department of Transportation

ESTABLISHMENT OF QC/QA PROCEDURES FOR OPEN-GRADED MIXES

SPR 5268

by

Kimberly D. Dunn
Assistant Professor
and
Judith A. Gray
Graduate Research Assistant
Department of Industrial & Manufacturing Engineering

R.G. Hicks
Professor
and
Larry Ilg
Research Assistant
Department of Civil Engineering

Oregon State University
Corvallis, OR 97331

and

Jeff Gower
Pavements Engineer
Oregon Department of Transportation
Salem, OR 97310

for

Oregon Department of Transportation
Research Unit

September 1998

Technical Report Documentation Page

1. Report No. FHWA-OR-RD-99-12	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Establishment of QC/QA Procedures for Open-Graded Mixes	5. Report Date September 1998 6. Performing Organization Code
7. Author(s) Kimberly D. Dunn, Judith A. Gray, R.G. Hicks, Larry Ilg, and Jeff Gower	8. Performing Organization Report No. TRR 97-5
9. Performing Organization Name and Address Oregon State University Dept. of Civil Engineering Corvallis, OR 97331-2302 ODOT - Pavement Services 800 Airport Rd. SE Salem, OR 97310	10. Work Unit No. (TRAIS) 11. Contract or Grant No. SPR 5268
12. Sponsoring Agency Name and Address Oregon Dept of Transportation, Research Section 200 Hawthorne SE, Suite B-240 Salem, OR 97310 Federal Highway Administration Oregon Division 530 Center St., Suite 100 Salem, OR 97301	13. Type of Report and Period Covered Final Report (April 1, 1995 - July 5, 1996) 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The State of Oregon has employed the use of porous concrete surfaces (E- and F-mixes) since the 1970s. The use of porous mixes has increased substantially in the past five years. Previously, no work had been done to evaluate whether the quality control/quality assurance (QC/QA) procedures used for dense-graded mixes were appropriate for open-graded mixes. This study consisted of a literature review, expert survey, and field survey of selected projects to determine the relative importance of factors such as asphalt content, gradation, voids, and moisture content on the long-term performance of the pavement.

The overall objective achieved by this study was the development of a basis for an improved QC/QA specification for porous pavements in Oregon. Specific objectives achieved include: 1) evaluated experiences of others to control quality of open-graded mixes; 2) conducted a field survey of selected projects in Oregon to determine what factors most affect pavement performance; 3) recommended modifications to existing specifications which would include pay adjustments; and 4) developed a plan for implementing the resulting recommendations.

This study found that the factors to be controlled during the production of porous pavements include asphalt content, gradation, and moisture content. The recommended weights for computing the composite pay factor were selected to contribute to improving contractor performance. The 25 mm sieve was eliminated as a pay factor and adjustments were made to the weights of the remaining factors to reflect the findings of this study. An implementation plan was developed and includes involvement of the specification committee, contractor quality control, training, and field testing the new specification.

17. Key Words Pay factors, porous mixes, asphalt pavements, pavement performance, quality control	18. Distribution Statement No restrictions

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 107 + appendices	22. Price

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

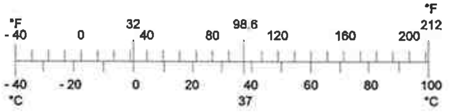
SI* (MODERN METRIC) CONVERSION FACTORS

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)

ACKNOWLEDGMENTS

The authors would like to thank the members of the Technical Advisory Committee (see list below) for their input regarding this project and their review of this report:

Rob Edgar, ODOT Research Unit
Jeff Gower, ODOT Pavements Engineer
Ivan Marrero, FHWA (Oregon Division)
Jim Huddleston, Asphalt Pavement Association of Oregon
Liz Hunt, ODOT Research Unit
Ken Karnosh, ODOT Contract Administration Engineer
Mike Remily, ODOT Pavement Quality Engineer
Gary Thompson, Asphalt Pavement Association of Oregon
Mike Wildish, Wildish Construction

DISCLAIMER

ESTABLISHMENT OF QC/QA PROCEDURES FOR OPEN-GRADED MIXES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The State of Oregon has employed the use of open-graded (porous) surfaces since the 1970s. The use of these mix types has increased substantially in the 1990s. The open-graded mixes have been found to possess numerous attributes including: reduced splash and spray, lower noise levels, and improved durability, to name a few.

As the use of porous mixes evolved, the quality control/quality assurance (QC/QA) procedures developed for dense-graded mixtures were used by Oregon Department of Transportation (ODOT) to control the construction of open-graded mixtures. The overall objective of this study was to develop improved QC/QA specifications for the porous mixes used in Oregon. Specific objectives included:

1) Evaluate experiences of other agencies in controlling the quality of open-graded mixes.
2) Survey selected projects in Oregon to determine which factors most affect pavement performance.
3) Develop recommendations for modifications to existing specifications which would include new weighting factors.
4) Create a plan for implementing the resulting recommendations.

The results of the literature review (and the associated survey) suggest that asphalt content and aggregate gradation are the most important factors related to the performance of porous pavement. Raveling tends to be the biggest problem, followed by fat spots. To a large degree, these are both related to variations in asphalt content. Potential for reduction of distress in porous mixes may lie in the alteration of asphalt properties through the use of modifiers, and through close control of the binder and mix temperatures.

Most agencies' control asphalt content and gradation for porous mixes, although mix temperature, moisture content, aggregate fracture, and other factors are also monitored. Some subset of the control factors, typically asphalt content and aggregate gradation, is used to determine pay adjustment factors to provide incentives to contractors who exceed construction specifications and disincentives to contractors who fail to meet specifications. Oregon uses these and moisture content to calculate pay adjustments.

The results of the field survey indicated that of the 19 projects surveyed, four projects were rated to be in fair condition, 11 projects were rated to be in good condition, three projects were found to be in very good condition, and one project was rated to be in excellent condition. Thus, overall performance of the open-graded projects in Oregon was found to be positive. Eight of the 19 projects exhibited measurable rut depths. The highest rut depths were from 9 to 13 mm. The remaining projects that exhibited rutting were all under 6 mm. This could be considered normal rutting in Oregon due to the high use of studded tires. In addition, two projects were noted to have raveling problems and six projects exhibited fat spots (two were localized). Some pushing and shoving was also noted on one project.

The results of the laboratory tests on cores taken from six of the 19 projects indicated that all of the mixes were generally finer than the mix design gradation. The asphalt content for the cores tested showed two projects had high asphalt content, two projects had low values, and two were within design specifications. The samples tested in the Environmental Conditioning Systems (ECS) indicated the water sensitivity of the two known problem mixes and another mix was also shown to potentially have a water sensitivity problem. In specific, the following emerged from the results of the laboratory study:

1) Sampling at the cold feed may not be adequate to control the gradation of the open-graded mixes because the gradation of the cores tend to be on the fine side of the broadband.

2) Segregation may be an issue with the open-graded mixes leading to isolated fat spots and raveled areas.

3) Water sensitivity of mixes (treated with lime) did not appear to be a major problem. However, there may be isolated areas where lime is not present due to poor mixing. Performing tests to determine whether or not lime is present in mixes would help to resolve this question.

4) Additional study projects may be required to link the exact causes of the problems observed to gradation, asphalt and moisture content.

An evaluation of all data resulted in specific suggestions for factors to control (aggregate gradation, asphalt content, mix moisture, mix temperature) and recommendations for new pay adjustment schedules. In general, more weight was given to asphalt content and gradation and less to moisture content. It was also recommended that mix temperature be considered in one of the pay schedules.

A plan for implementing the study findings was developed and includes field tests of the new pay factors as well as training of personnel in QC/QA techniques.

1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

The Oregon Department of Transportation (ODOT), as well as other highway agencies, has used porous asphalt concrete surfaces (E-mixes and F-mixes) since the 1970s. This is in part due to the success of open-graded emulsion mixes which were first used in Oregon in the late 1960s *(Hicks, et al. 1995)*. The use of porous mixes has increased substantially in the past five years. However, to date, no work has been done to evaluate whether the quality control/quality assurance (QC/QA) procedures used for dense-graded mixes are appropriate for open-graded mixes. If they are not, then appropriate procedures/measurements for the QC/QA need to be developed for open-graded mixes.

This study consists of a literature review and survey of selected projects to determine the relative importance of factors such as asphalt content, gradation, voids, and moisture content on the long-term performance of the pavement. The information developed in this study will be used to develop improved guidelines for the use of porous pavements in Oregon as well as suggestions for changes to ODOT specifications.

1.2 BACKGROUND

ODOT has placed over 950 centerline kilometers of E-mix and F-mix in the past six years (1990-1995). In general, the field performance has been excellent; however, there have been situations in which performance has been less than satisfactory. Typical problems include:

- draindown during construction resulting in some problem fat spots in the mixes;
- early rutting; and
- raveling of the asphalt pavement.

Although ODOT presently has pay adjustments for dense-graded mixes based on evaluation of asphalt content, gradation, compaction, and moisture content, there is no indication whether these factors are appropriate for open-graded mixes.

1.3 OBJECTIVES

The overall objective of this study was to develop improved QC/QA specifications for the use of porous pavements in Oregon. Specific objectives include:

1) Evaluate experiences of other agencies in controlling quality of open-graded mixes.

2) Survey selected projects in Oregon to determine what factors most affect pavement performance.

3) Develop recommendations for modifications to existing specifications which would include new weighing factors.

4) Create a plan for implementing the resulting recommendations.

Chapter 2 provides the results of the literature review. Chapter 3 describes the findings from the survey of selected projects. Chapter 4 presents the results of a laboratory evaluation on cores taken from projects experiencing early distress. Chapter 5 includes an evaluation of the data collected as well as the recommended modifications to the current specifications for F-mixes. Chapter 6 presents a plan for implementing the results of the study. Chapter 7 provides the conclusions and recommendations.

2.0 LITERATURE REVIEW

The purpose of this chapter is to draw from the body of experience and research with porous pavements in the U.S. and abroad. References reviewed pertain to: factors affecting the performance of porous mixes; factors designated by agencies for control and acceptance of porous mixes; and the development of pay adjustment factors for completed projects. Included also is a discussion of findings from the survey conducted as a part of this study (Appendix A).

2.1 FACTORS AFFECTING PERFORMANCE

Several agencies now have porous pavements that have been in use for five or more years, providing an opportunity for agencies and researchers to identify the most common problems encountered with porous pavements and the primary factors that relate to those problems. This section summarizes agency reports and survey data regarding these factors.

2.1.1 Asphalt Content

The high air void content that is characteristic of porous mixes increases the air and moisture contact with the surface of the binder film, compared to dense-graded mixes. This can result in loss of durability or premature aging, whereby the pavement becomes more brittle and raveling occurs *(Booth 1991, Smith 1992)*. An overview of the experience with porous mixes in Europe finds that the "main roots of distress are aging of binder, causing raveling," and loss of adhesion between binder and aggregate, due to moisture, leading to stripping *(van Gorkum 1991)*. The U.S. experience parallels that in Europe. Severe raveling was given as a primary factor in the decision to discontinue use of porous mixes in Louisiana, Maryland, and Arkansas *(Arkansas State Highway 1990, Smith 1992)*. In the survey conducted for this research, raveling is consistently given as the most common type of failure. Current research is addressing the use of asphalt modifiers (e.g., rubber, polymers) to reduce the deterioration related to the high surface/air contact, while maintaining the high air voids content.

Increasing the asphalt content can result in a mix that is more resistant to aging, but can also lead to draindown and subsequent fat spots *(Rebbechi 1986, Younger, Hicks and Gower 1994)*. Furthermore, higher asphalt content can increase the propensity to clog and deform *(Colwill et al. 1993)*. Survey results indicate that raveling and fat spots (due to draindown) are the most common problems found in porous mixes, leading many responders to simultaneously list "too little asphalt" and "too much asphalt" as the sources of problems with porous mixes. Table 2.1 provides a summary of these survey responses.

2.1.2 Asphalt Type (Properties)

Many researchers are looking for a solution to this problem by improving the rheological properties of the asphalt binder. What is needed is a thick binder film to increase durability, one that has good adhesion to aggregate, and a binder that is less susceptible to oxidation *(van Gorkum 1991, International Road Federation 1992, Page 1993)*. Improvements in the asphalt binder have been identified as having the "greatest potential for improvement" *(Page 1993)*. To that end, asphalt modifiers and tighter controls on mix temperatures have been applied by many agencies.

Table 2.1: Survey Responses: Asphalt Content Levels and Associated Performance Problems.

Agency	Asphalt Content	
	Too Much	**Too Little**
Arizona DOT	fat spots	raveling
CalTrans	fat spots and rutting	raveling
Florida DOT		raveling
Louisiana Transportation Research Center		raveling
Maryland State Highway Administration		raveling
Nevada DOT	fat spots	raveling
Texas DOT	fat spots	raveling
Washington State DOT	fat spots	
LCPC (France)		raveling
Delft University of Technology (The Netherlands)		raveling
Johannesburg Road Directorate (South Africa)	fat spots and rutting	raveling
Spain	rutting	raveling
EMPA (Switzerland)	fat spots	

Fiber additives can help maintain void content *(Huet et al. 1990)*, reduce drain own *(Colwill et al. 1993)*, and allow for a higher binder content, with good durability *(Decoene 1990)*. The use of polymer modifiers reduced clogging, raveling and rutting in South Australia and Spain *(Perez-Jiminez and Gordillo 1990, Booth 1991)*. Hydrated lime (at 1% by mass of mineral aggregate) improves durability *(Rebbechi 1986)* and reduces stripping *(van Heystraeten and Moraux 1990)*. Table 2.2 summarizes some of the research on asphalt modifiers and fillers, and the associated findings.

2.1.3 Aggregate Gradation

Experience in Florida with porous mixes has shown that aggregate gradation is a factor that has a high potential for improvement, second only to asphalt type. Tighter control on 2 mm (#10) and 0.075 mm (#200) sieves was used to address problems with fat spots *(Page 1993)*. In Connecticut, adjustments were made in the level of fines and coarse aggregate to remedy loss of permeability *(Smith 1992)*. Florida and the UK also show excess fines contributing to clogging *(Colwill et al. 1993, Page 1993)*. In Arizona, changes in aggregate gradation, combined with changes in asphalt content are found to have significant effects on air voids, density, resilient moduli and permeability *(Gemayel and Mamlouk 1993)*. Clogging has not yet been a significant problem in Oregon *(Younger, Hicks and Gower 1994)*. According to a survey response, research is underway in Georgia to evaluate the effects of gradation, polymer-modified asphalt, and various fibers on porous mix performance. Table 2.3 lists the broadband limits for aggregate gradation for Oregon and other agencies.

Table 2.2: Results from Using Asphalt Modifiers and Fillers in Porous Pavements.

State/Country	Modifier/Filler	Reference	Results
Georgia	anti-strip	Smith, 1992	Use of lime as an anti-strip alleviated stripping in the underlying AC layer.
	other modifiers/ fillers	Survey	Current research to evaluate the effect of gradation, polymer-modified asphalt and various fibers on performance.
Maryland	polymer additive	Smith, 1992	Severe raveling in 1989-91 halted use of open graded friction courses for further study. Use of polymer additive being tested in 1992.
Michigan	latex-rubber	Smith, 1992	Use of latex-rubber (3% rubber solids of the total placement weight) helped reduce premature raveling.
Oregon	rubber, (PBA-6GR)	Hunt, 1995	Blending of the asphalt cement with rubber is reported to improve engineering properties of the binder, including resistance to oxidation and aging.
Washington	rubber; polymer mixes	Anderson, correspondence	Research on rubber-asphalt, conventional mix, and polymer mix as yet reveals no apparent increase in pavement life.
Belgium	filler	van Heystraeten, 1990	Spreading of 50 g/m^2 of filler (fines < .08 mm) on the surface before opening to traffic avoids stripping of the aggregate while the pavement is new.
	cellulose fibers	Decoene, 1990	Tests showed significant reduction in draindown with the use of cellulose fiber (use of asbestos and mineral fibers is prohibited).
France	fiber based, SBS modified, and pure asphalt tested	Huet, 1990	Fiber-based asphalt helped maintain void content and had least rutting; pure asphalt had the most rutting.
The Netherlands	$Ca(OH)_2$	Survey	$Ca(OH)_2$ added to fines reduced raveling.
South Australia	EVA polymer	Booth, 1991	Use of EVA polymer-modified asphalt reduced raveling, clogging and rutting, but leaves pavement slick and glossy for longer.
Spain	polymer additive	Perez-Jiminez, 1990	Polymeric asphalt retained higher adhesiveness after immersion in water; reduced draindown; maintained void content.
		Ruiz, 1990	Hydrocarbonated binder provided thicker binder film.
UK	rubber, mineral or organic fiber	Colwill, 1993	Allows higher binder content (around 4.5%) without drainage and clogging.
Victoria, Australia	filler	Rebbechi, 1986	Use of hydrated lime filler reduces stripping and improves durability.

2.1.4 Aggregate Properties

Aggregate type is one factor that can minimize raveling, as well as affect skid resistance. In Florida, 90% of the open-graded friction course pavements use oolitic limestone, although crushed granite, gravel and slag have also been used. Florida evaluates other sources of aggregate based on in-place friction testing. Gravel was required to have 85% crushed faces (for aggregate retained on the No. 4), but the use of gravel has been discontinued due to problems with raveling *(Page 1993)*.

Table 2.3: Aggregate Gradation Broadband Limits.

U.S. AGENCIES

Percent Passing

Sieve Size	**Georgia**	**Florida**	**Louisiana**		**California**		**Washington**	**Oregon***	
	D mix	FC-2	A	B	1/2" max	3/8" max	Class D	E	F
1" (25 mm)							99-100		99-100
3/4" (19 mm)				100	100		85-96	99-100	85-96
1/2" (12.5 mm)	100	100	100	90-100	95-100	100	60-71	95-100	60-71
3/8" (9.5 mm)	85-100	85-100	90-100	50-80	78-89	90-100			
1/4" (6.25 mm)							17-31	52-72	17-31
No. 4 (4.75 mm)	20-40	10-40	20-50	10-30	28-37	29-36			
No. 8 (2.36 mm)	5-10	4-12	5-15	5-20	7-18	7-18			
No. 10 (2 mm)							7-19	5-15	7-19
No. 16 (1.18 mm)	–	–	–	–	0-10	0-10			
No. 200 (0.075 mm)	2-4	2-5	2-6	2-6	0-3	0-3	1-6	1-5	1-6

*Limits used during project study period. Revised limits are available at www.odot.state.or.us

INTERNATIONAL AGENCIES

Percent Passing

Sieve Size	**Spain**		**United Kingdom**	**Australia**	**Victoria, Australia**
	P12	PA12			
1.1" (28 mm)			100		
3/4" (19 mm)	100	100	95-100		100
1/2" (12.5 mm)	75-100	70-100	55-75	100	100
3/8" (9.5 mm)	60-80	50-80			95
1/4" (6.25 mm)			20-30	29	61
No. 4 (4.75 mm)	32-46	18-30			30
No. 6 (3.35 mm)			7-13		
No. 8 (2.36 mm)	10-18	10-22			12
No. 10 (2 mm)				10	10
No. 30 (0.6 mm)	6-12	6-13			8
No. 50 (0.3 mm)					6
No. 100 (0.15 mm)					4
No. 200 (0.075 mm)	3-6	3-6	3.5-5.5	0-4	4

One report on the experience with porous mixes in Spain gives the following aggregate properties to minimize raveling: abrasion loss value ≤ 20%; flakiness index < 25; polished stone value > 0.45 or 0.4, depending on traffic; two or more fractured faces on 100% or 75%, depending on traffic *(Ruiz et al. 1990)*.

Georgia aggregates have been prone to stripping in the presence of water, and problems with moisture-induced stripping in the underlying AC layer occurred. These were remedied by adding lime as an anti-strip agent *(Smith 1992)*.

In general, use of skid-resistant aggregate is suggested as a way to maintain surface friction *(Rebbechi 1986*). FHWA Technical Advisory T5040.31 recommends using 100% crushed aggregate, to enhance structural stability *(FHWA 1978)*.

2.1.5 Aggregate Moisture

Survey responses indicate that aggregate moisture is an important factor influencing pavement performance. Connecticut cites damp conditions at paving projects as a primary reason for discontinuing the use of porous mixes. No reports, however, were identified that deal specifically with aggregate moisture effects on porous pavements.

2.2 FACTORS USED TO CONTROL OPEN-GRADED MIXES

In establishing Quality Control (QC) guidelines, the contracting agency determines the production factors (control factors) that most influence pavement performance, and the desirable values (or range of values) for those factors. The contractor has the responsibility to perform process control tests according to agency guidelines and maintain specified values during manufacture and placement of the pavement. The agency is responsible for acceptance testing on a lot-to-lot basis, and the determination of pay adjustments, where applicable. Quality Assurance (QA) tests are conducted by the agency to verify that control factors are within acceptable ranges. Good QC/QA procedures must include consideration of the variability associated with sampling and testing methods, as well as the variability of the material. Failure to do so can result in inappropriate pay reductions to the contractor *(see Amirkhanian et al. 1994)*. Table 2.4 summarizes QC factors and the factors used to determine pay adjustment in Florida, Nevada, and Oregon for porous mixes. Table 2.5 gives the corresponding QC tolerances.

Table 2.4: Factors Used for Quality Control and Pay Adjustment.

Florida			**Nevada**			**Oregon**		
Factor	QC	Pay Factors	Factor	QC	Pay Factors	Factor	QC	Pay Factors
			Aggregate gradation except Nos. 4 & 16.	✓		1" (25 mm)	✓	✓
						3/4" (19 mm)	✓	✓
1/2" (12.5 mm)	✓					1/2" (12.5 mm)	✓	✓
3/8" (9.5 mm)	✓							
						1/4" (6.25 mm)	✓	✓
No. 4 (4.75 mm)	✓	✓	No. 4 (4.75 mm)	✓	✓			
No. 8 (2.36 mm)	✓	✓						
						No. 10 (2 mm)	✓	✓
			No. 16 (1.18 mm)	✓	✓			
No. 200 (0.075 mm)	✓	✓				No. 200 (0.075 mm)	✓	✓
Asphalt content	✓	✓	Asphalt content	✓	✓	Asphalt content	✓	✓
			Binder temp	✓				
			Mix temp	✓		Mix temp	✓	
			Moisture content	✓		Moisture content	✓	✓
			Liquid limit plastic index	✓				
			Fractured faces	✓				
			Absorption	✓				

Table 2.5: Quality Control Tolerances (n = 1).

Factor		Florida (Table 3331-3)	Nevada (Table 411.6)	Oregon* (SP00745.14)
25 mm	(1")			
19 mm	(3/4")			broadband limits
12.5 mm	(1/2")	±7	±7	broadband limits
9.5 mm	(3/8")	±7	±7	
6.25 mm	(1/4")			±5
4.75 mm	(No. 4)	±7	±7	
2.36 mm	(No. 8)			
2 mm	(No. 10)	±5.5		±2
1.18 mm	(No. 16)		±4	
.425 mm	(No. 40)			
.177 mm	(No. 80)			
0.075 mm	(No. 200)	±2	±2	±2
Asphalt content		±0.55% extraction ±0.15% printout	±0.4% nuclear	±0.5% nuclear ±0.2% meter method
Mix temperature			±20°F	±20°F
Moisture content			maximum 1%	maximum 0.7%
Absorption			maximum 4%	
Fractured faces			minimum 90% minimum 2 fracture	
Binder temperature at plant			AC-30P AC-20P 290-350°F	
			AC-30 AC-20 270-350°F	
Liquid limit plastic index			maximum 35, N.P. (0-3)	

*Limits used during project study period. Revised limits are available at www.odot.state.or.us.

2.2.1 Oregon

In Oregon, the contractor performs process control during aggregate production. Verification testing is performed by ODOT. Ranges are given within which the test results must be. If results fall outside the acceptable range, the contractor must work with the agency to resolve the difference or else the material is rejected.

ODOT specifications also provide testing frequency and method guidelines for process control during asphalt mix production. However, the frequency of testing for agency acceptance is higher than for process control, and the agency is required to provide a Composite Pay Factor (CPF) to the contractor for each day's production on the morning following production. Because their aim is to maximize the CPF, contractors often make adjustments to production methods based on the results of acceptance testing by the agency, rather than their own process control testing. A transition toward total contractor process control is now in progress, and is expected to be complete by 1998 *(Huddleston 1993)*. At the time of printing, contractors conduct process and product control testing.

2.2.1.1 Process Control

Table 2.6 shows the tests required of contractors for aggregate process control. Split samples must be provided to the project manager. The agency engineer may perform any of the tests. If a sample test fails to meet specifications, a second test is performed from the contractor's portion of the split sample. If the second test also fails to meet specification, the material is considered out-of-specification.

Table 2.6: Required Tests for Process Control During Aggregate Production.

Test	**Aggregates**	**Minimum Frequency Schedule**		
		Start of Production	One per 5 shifts*	One per shift*
Fracture of gravel	coarse/fine	X	X	
Wood particles	coarse	X	X**	
Dust or clay coating	coarse	X	X**	
Elongated pieces	coarse	X	X**	
Sieve analysis	coarse/fine	X		X***
Sand equivalent	fine	X		X**

* A shift means one per day or 1,000 tons, whichever results in the greatest sampling frequency.
** May be waived after first five shifts if allowed by the Materials Unit Engineer.
*** Perform a minimum of three tests.

For process control of asphalt mixture production, the contractor is responsible for testing asphalt content, aggregate gradation, and lime content. Test frequency for the asphalt mixture was based on a 450 Mg (500 ton) sublot size for jobs sampled. The current sublot size is 1000 Mg (1100 tons). The following test methods are prescribed:

Asphalt Content (one of the following):

- the plant's asphalt metering and weighing system
- extraction of bitumen by centrifuge or vacuum (ODOT TM 309)
- nuclear asphalt content gauge (ODOT TM 319)

Gradation (one of the following):

- cold feed sieve analysis (AASHTO[1] T 27)
- mechanical analysis of extracted aggregate (ODOT TM 309)

Anti-Strip Additives:

- the plant's metering and weighing system
- certification for amines

---

[1] American Association of State Highway and Transportation Officials

2.2.1.2 Acceptance

Acceptance of aggregate is based on the results of the process control tests listed in Table 2.6, as well as the verification tests. Material that fails to yield a Pay Factor of "1" for each size of aggregate is considered out-of-specification and is rejected or given reduced pay. Additional aggregate may be added only after the non-specification aggregate has been removed in an amount sufficient to provide a Pay Factor of "1".

Agency acceptance procedures for asphalt mixture during the study period are based on 450 Mg (500 ton) sublots with samples taken from the discharge at the paving plant. The current agency acceptance testing frequency is one tenth of the QC frequency. The following tests are used:

Gradation (one of the following):

- cold feed or hot bin samples (AASHTO T11/T27)
- solvent extraction (ODOT TM 309) may be requested by the contractor

Asphalt Content:

- nuclear method (ODOT TM 319)
- meter method (ODOT TM 321/TM 322)

Moisture:

- microwave method (ODOT TM 311)

2.2.1.3 Out-of-Specification Procedures

If the gradation or asphalt content acceptance test results vary by more than 1-1/2 times the tolerance values from the JMF, a second test is run from the backup sample. The test result which yields the highest CPF is used. Asphalt mix that yields a CPF of less than 1.0 is considered out-of-specification. A pay adjustment of up to 25% may be applied. Any material falling below the 0.75 CPF can be removed without payment at the agency's discretion.

2.2.2 Florida (FDOT Specifications: Sections 331, 336)

In Florida, the contractor provides personnel, certified by the state, to perform the QC tests. QC tests are performed for all sieve sizes and for asphalt content. The results of the tests are maintained on control charts.

The mix is accepted at the plant, with respect to gradation and asphalt content, on a lot to lot basis. These QA test results serve as the basis for determining pay adjustment factors. Furthermore, the engineer can also deem a lot unacceptable "for reason of being excessively segregated, aggregates improperly coated, or excessively high or low mix temperature."

2.2.2.1 Test Methods

Asphalt content can be measured by extraction analysis, or by printout for automatic batch plants. For the automatic printout, the tolerance range is only ±0.15%, compared to ±0.55% for extraction testing (sample size n = 1). Extraction analysis is required for aggregate gradation acceptance.

2.2.2.2 Lot Sizes, Test Frequency

A lot is defined as 3630 Mg (4000 tons) at the plant, divided into four equal sublots of 910 Mg (1000 tons). A minimum of one extraction gradation analysis must be conducted for each day's production, or following any change in the production process.

2.2.2.3 Out-of-Specification Procedures

The mix is out of specification if the asphalt content is outside of the target content by 0.55% (extraction test), or if the aggregate gradation falls outside of the given limits. If this happens on two consecutive tests, the process is stopped until the problem is corrected. A lot is considered out of control if any individual test falls within the 80% pay factor values for sample size n = 1.

2.2.3 Nevada (NDOT Specifications: Section 411)

In Nevada, the contractor performs the QC and QA tests. The QA tests are used to determine pay adjustments. Verification tests are performed by the contracting agency. Ranges are given within which the QC/QA test results must be in agreement with verification test results. If results fall outside of the acceptable range on two or more tests, referee tests may be conducted.

2.2.3.1 Test Methods

Solvent extraction is usually required for QC tests of aggregate gradation, although cold feed or hot bin samples can be used under certain conditions. A nuclear asphalt content gauge is used to determine asphalt content.

2.2.3.2 Lot Sizes, Test Frequency

A production lot is made up of four sublots. A sublot is either 230, 450, or 680 Mg (250, 500 or 750 tons), as determined by the contractor prior to the beginning of production. Each sublot is tested for gradation and asphalt content, with tests on other QC parameters conducted for every lot. Temperatures of the mix and the binder are continuously monitored.

2.2.3.3 Out-of-Specification Procedures

If QC tests reveal deviations from operational ranges (for gradation, moisture, asphalt temperature, or mix temperature) once, the contractor should evaluate the process. If it happens twice, consecutively, corrective action should be taken. After three consecutive tests outside of the acceptable range, the production process is stopped.

2.3 PAY ADJUSTMENT FACTORS

The use of pay adjustment factors for asphalt pavement is an integral part of the implementation of End Result Specifications (ERS). Method specifications require 100% compliance with specification targets and provide little or no guidance for work that is below target, but still of some value.

The ERS should take account of variability due to testing and sampling methods, as well as variability in materials. Incentives and disincentives in payment to contractors are provided relative to the degree of compliance with specifications. This section reviews current literature on the development of pay adjustment schedules, and the factors used by various agencies to determine pay adjustment factors for porous pavements.

2.3.1 Background

The State of Oregon began using statistical specifications for asphalt pavements with provisions for incentives and disincentives in 1985. A questionnaire distributed to ODOT project managers, region materials inspectors and region assurance specialists revealed that 76% were of the opinion that the bonus pay system improves cooperation with the contractors, and that 57% considered the bonus pay system effective. Though porous pavements are given some mention, the questionnaire and related report deal primarily with dense-graded mixes *(Scholl 1991)*.

By the end of 1994, ODOT bonuses for F-mix (porous pavement) totaled $973,002, while penalties were $203,447, for net bonus payments of $769,555. This amount corresponds to an average Composite Pay Factor per ton of 1.012[2]. Figure 2.1 tracks the history of bonus and penalty payments since 1985 both in total dollars and dollars per ton by region.

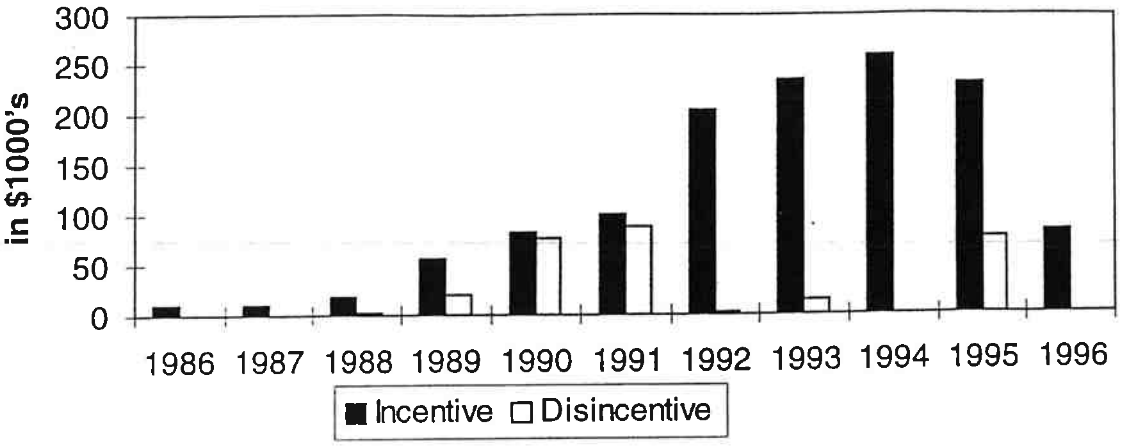
2.3.2 Development of Pay Factor Schedules

The National Cooperative Highway Research Program (NCHRP) Synthesis 212 describes two general types of pay adjustment systems: judgment plans and rational plans *(Chamberlain 1995)*. The intention of *judgment plans* is to "force contractual compliance by exacting a monetary penalty," while the *rational* approach seeks to link final compensation to the quality of the final product. Using a rational pay adjustment schedule, penalties charged to contractors should reflect anticipated costs associated with reduced performance life *(Weed 1984)*.

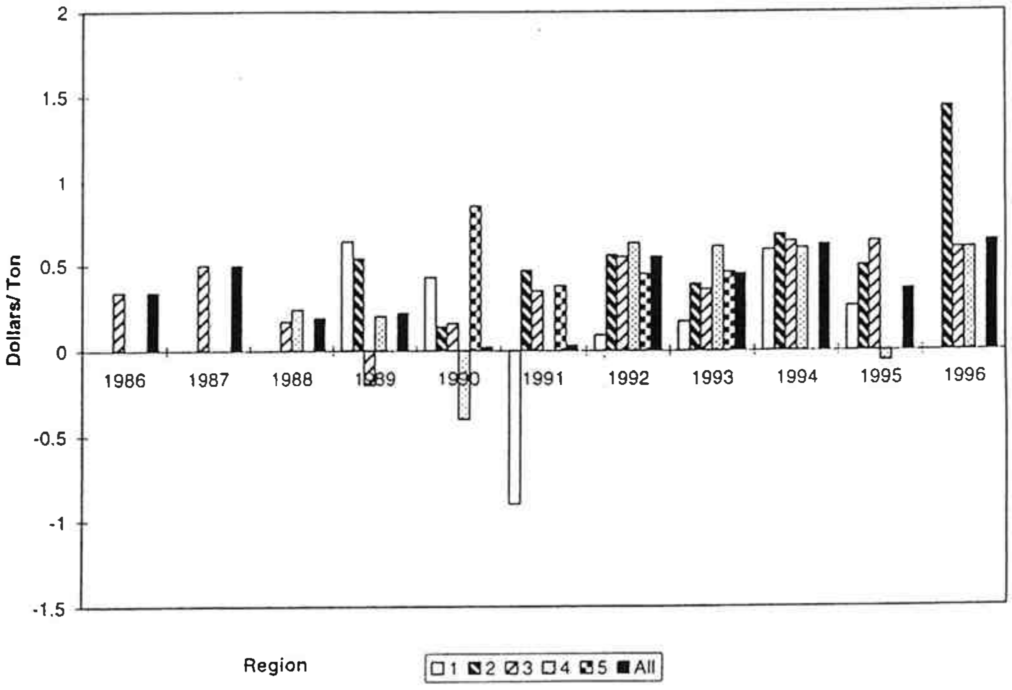
---

[2] 403 OR 0745 (Standard or Heavy Duty) Statistical Asphalt Concrete Mixture Summary for "F" mixtures, Revised 03-28-95

History of Pay Adjustments for Porous Pavements



a) In Dollars



b) In Dollars/Ton

Figure 2.1: History of Pay Adjustments for Porous Pavement.

Likewise, bonuses should reflect enhanced value of the pavement *(Chamberlin 1995)*. In brief, an agency determines an acceptable quality level (AQL) at which full pay is warranted, and a rejectable quality level (RQL) at which the pavement can be rejected. Final products with higher quality than the AQL receive a bonus. In theory, Oregon's 5% AQL should lead to an expected pay factor of 1.00 for work with 5% defects. However, due to rounding and sample size determination, the expected pay factor for 5% AQL work is greater than 1.00 *(Scholl 1991)*.

Oregon uses a schedule of pay factors, based on the schedule developed for the Federal Highway Administration (FHWA) in 1985 *(ODOT 1991)*. For each sublot of material, values are taken for each of the pay factor constituents. Then, for the entire lot, a pay factor is determined based on the standard deviations of each constituent. The schedule takes into account the wider confidence intervals associated with small sample sizes.

Other states, including New Jersey, use a pay factor equation. An example of a simple linear model might be:

$$\text{Pay Factor} = 105 - \text{Percent Defective}$$

This would provide a 5% bonus for material with no measurable defects and no bonus or penalty for material with 5% defective material. Percent defective values above 5 cost contractors a unitary penalty in pay.

Nevada bases pay adjustment on absolute deviation from target values *(Nevada DOT 1995)*. For each constituent, a pay factor value is provided for a given range of difference from target values.

2.3.3 Factors Used to Determine Pay Adjustment

Of interest for this research is the *absence* of literature addressing pay factors for porous pavements. Estimates of enhanced or diminished performance are derived using pavement factors deemed most influential, with respect to their values relative to specification targets and tolerances. With dense-graded mixes, the most important factor influencing performance is compaction, with lower air void content associated with improved pavement performance *(Puangchit et al. 1982)*. As a result, Oregon uses a 0.40 weight allocated to compaction in the determination of composite pay factors for asphalt concrete pavement – the highest weight for any individual factor. Current practice with porous pavements is to set the factor value equal to one, thereby "eliminating" the effect of the compaction term. The concern has been raised that this makes it too easy to get a high pay factor when gradation or asphalt content is outside specification *(Scholl 1991)*.

Asphalt content and aggregate gradation are the factors most commonly used by state highway agencies to determine pay adjustment for porous mixes. Nevada uses "ride quality" in addition to factors related to pavement failure. Before halting use of porous pavements, Louisiana had a 10% penalty for failure to use an anti-strip agent. Table 2.7 summarizes the factors used by agencies to determine pay factors for porous mixes.

Table 2.7: Factors Used to Determine Pay Adjustments for Porous Mixes (Survey).

Agency	Aggregate Gradation	Asphalt Content	Moisture
California	✓		
Florida	✓	✓	
Georgia	✓	✓	
Maryland		✓	
Nevada	✓	✓	
Oregon	✓	✓	✓
Washington	✓		

Oregon. Oregon uses individual factors for aggregate gradation, asphalt content, moisture, and compaction, combined with factor weights, to get the composite pay factor (CPF). Constituent factors are weighted as follows (see Section 00745.95 of the ODOT Specifications):

Constituent		Weight
25 mm	(1")	1
19 mm	(3/4")	1
12.5 mm	(1/2")	1
6.25 mm	(1/4")	5
2 mm	(No. 10)	5
0.425 mm	(No. 40)	3
0.075 mm	(No. 200)	10
Asphalt content		26
Moisture content		8
Compaction		40

For porous pavement, compaction and No. 40 aggregate have pay factors of one.

Washington. Like Oregon, Washington uses a system of weighted factors (but for aggregate gradation only) to determine a CPF for porous mixes. The weights are as follows:

Percent Passing		Factor Weight
25 mm	(1")	10
19 mm	(3/4")	10
12.5 mm	(1/2")	20
6.25 mm	(1/4")	25
2 mm	(No. 10)	15
0.075 mm	(No. 200)	20

These are the current weights which have changed since publication of the 1994 specification and are documented in a supplement.

Florida. Florida calculates pay adjustment based on asphalt content (both extraction and printout) and gradation (No. 4, No. 10, and No. 200). When two or more gradation factors fall below 1.00, in one lot of material, the greatest reduction in payment is used (Table 331-6, footnote). A lot is considered out of control if any individual test falls at or below the 80% pay factor values for sample size n = 1. The agency has the option of requiring removal and replacement at no cost for such work.

Nevada. In determining pay adjustment factors, Nevada has provisions for using a ride quality factor in addition to characteristics of the pavement mix. Individual pay factors from 0.70 to 1.05 are determined for gradation (No. 4 and No. 16) and asphalt content. If each of the factors is 1.0 or more, the highest factor is used. Otherwise, the lowest factor is used. If a lot falls below the 70% pay factor limit, the contractor is responsible for removal and replacement of the material.

2.3.4 Evaluation of Risk and OC Curves

Central to the implementation of QC/QA procedures is the sharing of responsibility between the agency and the contractor. Risks involved in statistical acceptance and pay adjustment methods are the owner's risk of accepting poor quality work, and the contractor's risk of rejecting good quality work. A recent study by Amirkhanian et al. *(1994)* found that most state agencies fail to accurately account for testing and sampling variability, thereby shifting a disproportionate share of risk to the contractor, resulting in a tendency toward underpayment. Oregon's pay factor tables were developed with the intention to maintain contractors' risk at 5%, while the risk to the state is in the range of 1% to 48%, depending on the sample size *(Scholl 1991)*.

Operating characteristic (OC) curves can be used to evaluate the risks to both owner and contractor, and the ability of a pay adjustment schedule to maintain them at acceptable levels. A conventional OC curve (Figure 2.2) plots the probability of acceptance on the vertical axis, against the quality level of the material. For use in evaluating pay factors, the vertical axis represents pay factor levels (Figure 2.3). The AQL level should exactly correspond to a pay factor of 1.00, and the lowest pay factor is represented at the horizontal axis. OC curves have been called the "only way" to know in advance whether the payment plan will work as intended *(Weed 1993, Chamberlin 1995)*. They can be constructed using special software, or with computer simulation. Oregon's current pay adjustment system is analyzed using the OC curves in Chapter 5 of this report.

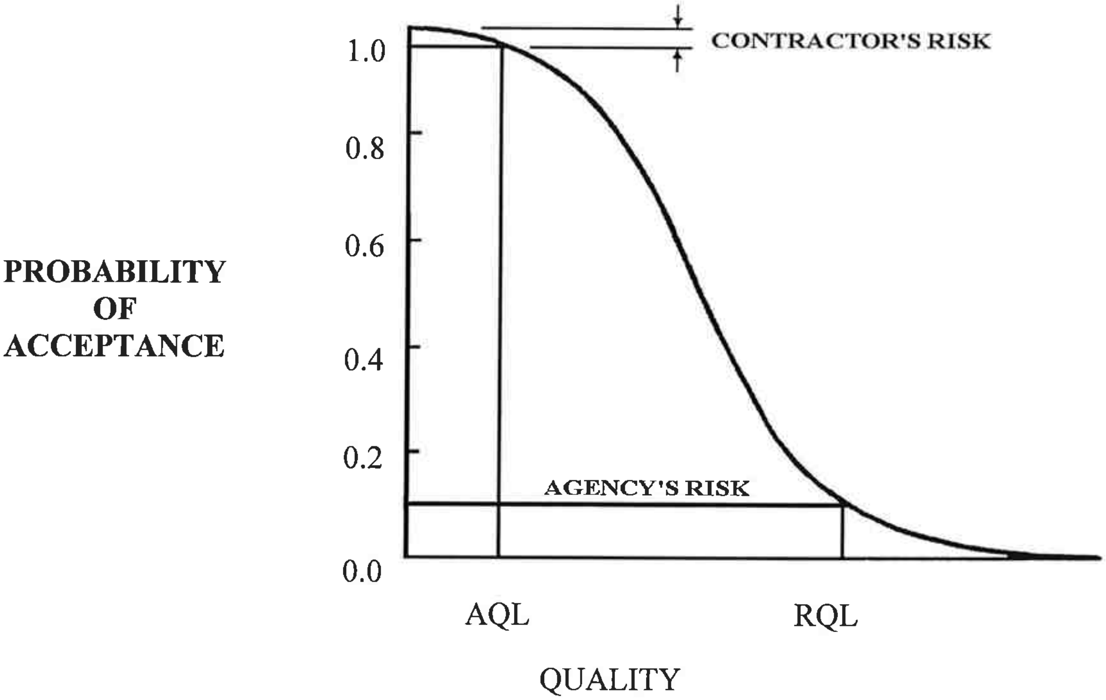


Figure 2.2: Conventional OC Curve

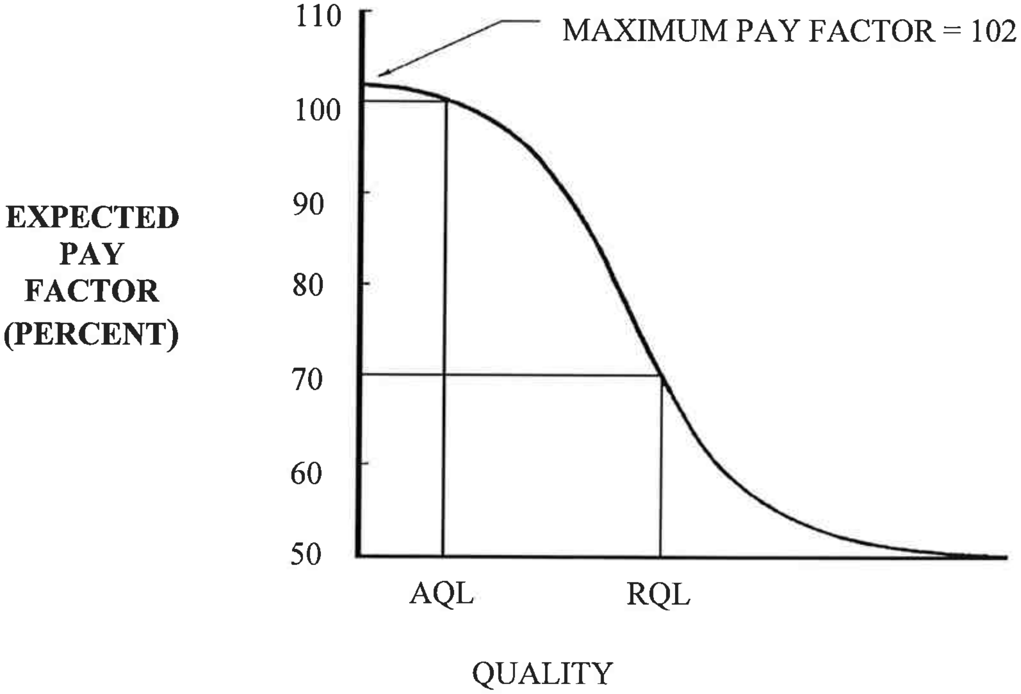


Figure 2.3: Pay Factor OC Curve

2.4 SUMMARY

The survey responses, as well as recent literature, suggest that asphalt content and aggregate gradation are the most important factors related to the performance of porous pavement. Raveling tends to be the biggest problem, followed by fat spots. To a large degree, these are both related to asphalt content. Potential for improvements may lie in the alteration of asphalt properties through the use of modifiers, and by close controls of binder and mix temperatures.

Most agencies' quality control methods for porous mixes emphasize asphalt content and gradation, although mix temperature, moisture content, aggregate fracture, and other factors are also monitored. Some subset of the control factors, typically asphalt content and aggregate gradation, is used to determine pay adjustment factors, providing incentives to contractors who exceed construction specifications, and disincentives to contractors who fail to meet specifications. Oregon uses these and moisture content to calculate pay adjustments.

Oregon's pay adjustment determination is based on a weighted average of individual pay factors for various factors. Developed for dense graded mixes, compaction carries a weight of 0.40, the highest given to any individual factor. Since compaction was considered not a suitable measure for porous mixes, a compaction pay factor of "1" is used. In developing pay adjustment schedules, the use of operating characteristics (OC) curves is critical to evaluating the distribution of risks to both the contractor and the contracting agency.

3.0 FIELD SURVEYS

This chapter describes the results of field surveys conducted in June 1994 and July 1995 on open-graded projects which either had no problems or had experienced some problem shortly after construction. Historical information on the projects was provided by ODOT. Both surveys were conducted by co-authors Gower and Hicks.

3.1 PROJECTS EVALUATED

The state project managers/district maintenance engineers were asked to suggest projects with good performance records and those with poor performance records to be included in the survey. The projects included in the surveys are given in Table 3.1.

Table 3.1: F-mix Projects Evaluated.

Hwy. No.	Project Name	Year Constructed	Mile Post		Treatment Type
			Begin	End	
001	Hayesville-Battle Creek	1990	250.0	259.0	grind/2" overlay
001	W. Marquam-N. Tigard	1990	194.2	299.5	grind/2" overlay
144	Sunset Hwy.-Pacific Hwy.	1994	0.000	7.5	grind/2" overlay
047	Wolf Cr.-W. Fork Dairy Cr.	1993	37.4	46.3	2" overlay
002	Corbett Intch.-Multnomah	1991	22.1	31.0	2" F/0-6" B
026	Mt. Hood-Long Prairie	1995	88.0	91.0	2" F-mix overlay
002	Rufus-Arlington (W. Unit)	1993	109.0	125.8	2" F/2" B
002	Rufus-Arlington (E. Unit)	1991	125.8	138.3	2" F/2" B
002	Umatilla-McNary	1993	182.6	185.7	2" F/2" B
006	E. Pendleton-Emigrant Hill	1992	213.0	218.0	grind/4" F-mix
006	Baldock Slough-S. Baker	1991	297.1	306.5	grind/2" F/2" B
041	Prine. Airport-Powell Butte	1995	6.8	16.4	2" F/2-4" B
004	Willowdale-Qualle Rd.	1995	75.0	81.0	2" F/3" B
004	Murphy Rd.-Lava Butte	1989	146.6	150.8	2" F/2" B
004	Forge Rd.-Lobert Rd.	1990	241.0	251.6	2" F/2" B
004	Williamson Riv.-Modoc Pt.	1991	253.9	256.1	2" F/ 2" B
001	Jumpoff Joe-N. Grants Pass	1991	67.1	58.2	grind/4" F
001	Azalea-Jumpoff Joe	1994	88 (south) 90 (north)	67.1	grind/2" F
001	Halsey Intch.-Lane Co. Line	1994	203.55	216.14	2" F/2-9" B

Note: 1" = 25 mm

3.2 HISTORICAL INFORMATION

Prior to conducting the survey, mix design and QC/QA data were obtained for each of the projects. Table 3.2 summarizes the mix design information provided by ODOT for each project and Table 3.3 provides the aggregate gradations for each of these projects.

Table 3.2: Mix Design Data.

Hwy. No.	Project Name	Year Completed	Asphalt Type	Asphalt Content (%)	Additive	Mix Temp.* (°F)	Placement Temp.* (°F)	Contractor
001	Hayesville-Battle Creek	1990	Chevron, AC-30	5.5	Aggregate treated with lime	249-254	232-240	J.C. Compton
001	W. Marquam-N. Tigard	1990	US Oil, AC-30	5.2	Aggregate treated with lime	252-259	236-244	Babler Bros.
144	Sunset Hwy.-Pacific Hwy.	1994	EOTT, PBA-6	5.6	Aggregate treated with lime	256-263	240-248	N.B. Hatch
047	Wolf Cr.-W. Fork Dairy Cr.	1993	McCall, PBA-5	6.0	None	247-255	231-240	Wildish Std. Paving Co.
002	Corbett Intch.-Multnomah	1991	Chevron, PBA-5	5.5	Aggregate treated with lime	250-258	234-242	Wildish Std. Paving Co.
026	Mt. Hood-Long Prairie	1995	Albina, PBA-6	6.0	Aggregate treated with lime	271-279	254-262	McCafferty-Whittle
002	Rufus-Arlington (W. Unit)	1993	Chevron, PBA-6	5.8	1% lime treatment	273-279	261-267	J.C. Compton
002	Rufus-Arlington (E. Unit)	1991	Albina, PBA-5	5.3	1.0% Unichem 8161 and aggregate treated with lime	250-257	234-242	Babler Bros.
002	Umatilla-McNary	1993	Koch, PBA-6	6.2	1% lime treatment	276-285	256-266	J.C. Compton
006	E. Pendleton-Emigrant Hill	1992						Kiewit
	Lot 1		Columbia, PBA-3	6.3	Aggregate treated with lime	244-254	228-238	
	Lot 2		Columbia, PBA-3	6.0	Aggregate treated with lime	261-270	243-252	
	Lot 3		Albina, PBA-6	6.0	Aggregate treated with lime	270-280	252-261	
006	Baldock Slough-S. Baker	1991	McCall, AC-20(R)	5.5	Aggregate treated with lime	278-287	257-267	Babler Bros.
041	Prine. Airport-Powell Butte	1995	Albina, PBA-6	5.2	None	268-275	252-259	R.L. Houck
004	Willowdale-Qualle Rd.	1995	Albina, PBA-6	5.5	None	266-275	250-257	J.C. Compton
004	Murphy Rd.-Lava Butte	1989						R.L. Coats
	Lot 3		Elf Asphalt (p), AC-20	5.5	Aggregate treated with lime	260-268	243-252	
	Lot 4		Chevron, AC-20	5.2	Aggregate treated with lime	250-257	238-243	
	Lot 5		Asphalt Supply & Serv. AC-20R	5.5	Aggregate treated with lime	263-272	243-258	
	Lot 6		Chevron, CA (p)-1	5.5	Aggregate treated with lime	258-267	242-250	
004	Forge Rd.-Lobert Rd.	1990	McCall, AC-20R	6.0	.5% PaveBond Special and aggregate treated with lime	268-278	250-259	J.C. Compton Contractor, Inc.
004	Williamson Riv.-Modoc Pt.	1991	Witco, AC-20R	5.2	Aggregate treated with lime	252-260	235-244	Klamath Pacific Corp.
001	Jumpoff Joe-N. Grants Pass	1991	Chevron, PBA-5	5.0	.5% PaveBond Special and hydrated lime	253-262	237-245	Hamilton
001	Azalea-Jumpoff Joe	1994	Chevron, PBA-6	5.6	Aggregate treated with lime	268-275	252-260	Kiewit
001	Halsey Intch-Lane Co. Line	1994						Wildish Std. Paving Co.
	Lot 3 (SB)		McCall, PBA-6	6.0	Aggregate treated with lime	266-272	252-259	
	Lot 4 (NB)		Chevron, PBA-6	5.8	Aggregate treated with lime	264-271	249-257	

*Recommended placement temperatures from the mix design, based on asphalt viscosity.

Table 3.3: **Aggregate Gradation of the Mix Design.**

Hwy. No.	Project Name	Year Completed	Sieve Size					
			25 mm (1")	19 mm (3/4")	12.5 mm (1/2")	6.25 mm (1/4")	2 mm (#10)	0.075 mm (#200)
001	Hayesville-Battle Creek	1990	100	93	67	24	13	4.6
001	W. Marquam - N. Tigard	1990	100	94	65	24	14	3.8
144	Sunset Hwy.-Pacific Hwy.	1994	100	90	63	23	11	3.0
047	Wolf Cr.-W. Fork Dairy Cr.	1993	100	90	65	24	12	3.0
002	Corbett Intch. - Multnomah	1991	100	95	67	26	11	2.8
026	Mt. Hood-Long Prairie	1995	100	93	64	24	9	3.0
002	Rufus-Arlington (W. Unit)	1991	100	95	65	25	12	3.0
002	Rufus-Arlington (E. Unit)	1993	100	93	65	25	11	3.0
002	Umatilla-McNary	1993	100	92	64	24	14	3.0
006	E. Pendleton-Emigrant Hill	1992	100	95	65	26	12	3.2
006	Baldock Slough - S. Baker	1991	100	93	64	26	11	2.6
041	Prine. Airport-Powell Butte	1995	100	93	63	23	10	2.9
004	Willowdale-Qualle Rd.	1995	100	95	63	23	9	3.1
004	Murphy Rd.-Lava Butte	1989	100	98	75	25	9	3.6
004	Forge Rd.-Lobert Rd.	1990	100	93	66	25	14	3.6
004	Williamson Riv.-Modoc Pt.	1991	100	92	66	25	12	4.0
001	Jumpoff Joe-N. Grants Pass	1991	100	94	66	24	12	3.9
001	Azalea-Jumpoff Joe	1994	100	93	65	23	12	3.0
001	Halsey Intch-Lane Co. Line	1994	100	93	66	24	12	4.0

As indicated, most projects used a PBA-6 asphalt and the design asphalt content varied from 5.0 to 6.3%. Mixing and placing temperatures reported in Table 3.2 were established using the procedures described in Appendix B. Differences in the mixing and compaction temperatures between Table 3.2 and the appendix are due to differences in techniques used to plot the temperature-viscosity curves.

Table 3.4 summarizes the QC data taken during the project. For all projects, information was collected to determine:

- aggregate gradation,
- asphalt content, and
- mix moisture content.

The methods used to measure moisture content of bituminous mixtures from 1986 to the present are given in Table 3.5. As noted, several changes have occurred; however, the purpose of each change was solely to reduce the drying time of the test.

The results from the QC data indicate that:

- Mix temperatures and laydown temperatures were determined from the mix design based on the asphalt viscosity. For example, the specified ranges for mix temperature varied from 111-116°C (231-240°F) to 137-142°C (278-287°F), while laydown temperature ranges varied from 111-116°C (232-240°F) to 138-142°C (280-288°F).

Table 3.4. QC Data for Projects Surveyed

Hwy. No.	Project Name	Year Completed	Value	Sieve Size						Asphalt Content %	Moisture Content %
				25 mm (1")	19 mm (3/4")	12.5 mm (1/2")	6.25 mm (1/4")	2 mm (#10)	.075 mm (#200)		
001	Hayesville-Battle Creek Lot 1 34,115 metric tons CPF = 0.989	1990	USL	100	96	71	29	17	6	5.9	0.5
			LSL	99	85	60	19	9	2	5.1	0
			Target	100	93	67	24	13	4.6	5.5	
			Mean	99.94	94.43	64.72	24.96	12.57	4.28	5.50	0.35
			St. Dev.	0.29	2.68	7.26	3.65	1.53	0.54	0.27	0.04
001	W. Marquam-N. Tigard Lot 1 29,945 metric tons CPF = 1.014	1990	USL	100	96	71	29	18	5.8	5.6	0.7
			LSL	99	85	60	19	10	1.8	4.8	0
			Target	100	94	65	24	14	3.8	5.2	
			Mean	99.90	92.08	65.14	23.43	12.30	4.49	5.26	0.43
			St. Dev.	0.35	2.27	3.83	2.68	1.95	0.83	0.22	0.11
144	Sunset Hwy.-Pacific Hwy. Lot 1 2,177 metric tons CPF = 1.018	1994	USL	100	96	71	28	15	5	5.4	0.7
			LSL	99	85	60	18	7	1	5	0
			Target	100	90	63	23	11	3	5.6	
			Mean	99.67	87.33	64	18.67	7.33	2.3	5.28	0.6
			St. Dev.	0.58	3.51	4.36	2.08	0.58	0.46	0.04	0.09
144	Sunset Hwy.-Pacific Hwy. Lot 2 4,058 metric tons CPF = 1.024	1994	USL	100	96	71	28	15	5	5.7	0.7
			LSL	99	85	60	18	7	1	5.3	0
			Target	100	90	63	23	11	3	5.6	
			Mean	99.5	89.33	68.17	23.33	9.33	3.15	5.49	0.60
			St. Dev.	0.548	1.86	4.26	3.93	1.75	0.50	0.02	0.05
144	Sunset Hwy.-Pacific Hwy. Lot 3 28,673 metric tons CPF = 1.022	1994	USL	100	96	71	28	15	5	5.4	0.7
			LSL	99	85	60	18	7	1	5	0
			Target	100	90	63	23	11	3.0	5.6	
			Mean	99.93	92.14	69.66	22.76	8.79	2.93	5.20	0.57
			St. Dev.	0.26	2.56	3.67	1.90	0.86	0.40	0.08	0.10
047	Wolf Cr.-W. Fork Dairy Cr. Lot 1 25,742 metric tons CPF = 0.989	1993	USL	100	96	71	30	17	5	6.5	0.8
			LSL	99	85	60	18	7	1	5.5	0
			Target	100	90	65	24	12	3.0	6.0	
			Mean	99.98	90.86	66.32	24.95	12.89	2.73	6.00	0.66
			St. Dev.	0.13	1.78	3.24	2.74	1.77	0.37	0.39	0.17
002	Corbett Intch-Multnomah Lot 1 34,022 metric tons CPF = 1.0	1991	USL	100	96	71	31	15	4.8	5.9	0.7
			LSL	99	85	60	21	7	0.8	5.1	0
			Target	100	95	67	26	11	2.8	5.5	
			Mean	100.00	95.03	67.72	24.03	9.93	2.31	5.42	0.89
			St. Dev.	0.00	1.47	3.14	2.14	1.23	0.46	0.24	0.12

Table 3.4: QC Data for Projects Surveyed. (continued)

Hwy. No.	Project Name	Year Completed	Value	Sieve Size						Asphalt Content %	Moisture Content %
				25 mm (1")	19 mm (3/4")	12.5 mm (1/2")	6.25 mm (1/4")	2 mm (#10)	.075 mm (#200)		
026	Mt. Hood-Long Prairie Lot 4 11,225 metric tons CPF = 0.9369	1995	USL	100	96	71	30	14	5	6.2	0.8
			LSL	99	85	60	18	4	1	5.8	0
			Target	100	93	64	24	9	3	6	
			Mean	100	92.55	62.27	28	11.45	2.55	5.97	1.17
			St. Dev.	0.00	1.81	2.1	3.38	1.37	0.88	0.10	0.28
002	Rufus-Arlington (W. Unit) Lot 1 68,241 metric tons CPF = 1.026	1993	USL	100	96	71	30	15	5	6	0.7
			LSL	99	85	60	20	7	1	5.6	0
			Target	100	93	65	25	11	3.0	5.8	
			Mean	99.97	91.67	64.83	24.53	10.59	2.21	5.78	0.52
			St. Dev.	0.18	1.87	3.55	2.39	1.50	0.45	0.05	0.11
002	Rufus-Arlington (E. Unit) Lot 1 39,845 metric tons CPF = 1.000	1991	USL	0	96	71	30	16	5	5.7	0.6
			LSL	99	85	60	20	8	1	4.9	0
			Target	100	95	65	25	12	3.0	5.3	
			Mean	100.00	94.69	66.99	25.87	12.64	3.04		0.39
			St. Dev.	0.00	2.20	4.39	3.19	2.24	0.55		0.19
002	Umatilla-McNary Lot 1 9,176 metric tons CPF = 1.025	1993	USL	100	96	71	30	19	5	6.7	0.8
			LSL	99	85	60	18	9	1	5.7	0
			Target	100	92	64	24	14	3.0	6.2	
			Mean	100.00	92.95	63.11	26.68	14.05	2.41	6.29	0.35
			St. Dev.	0.00	1.51	2.60	1.73	0.85	0.35	0.23	0.09
006	E. Pendleton-Emigrant Hill Lot 1 10,345 metric tons CPF = 1.024	1992	USL	100	96	71	31	16	5.2	6.8	0.8
			LSL	99	85	60	21	8	1.2	5.8	0
			Target	100	94	65	25	12	3.1	6	
			Mean	100	95.57	69.65	28.22	13.17	2.71	6.30	0.32
			St. Dev.	0.00	1.08	2.48	1.86	0.94	0.56	0.18	0.10
006	E. Pendleton-Emigrant Hill Lot 2A 5,128 metric tons CPF = 1.001	1992	USL	100	96	71	30	16	5.1	6.6	0.8
			LSL	99	85	60	20	8	1.1	5.6	0
			Target	100	94	65	25	12	3.1	6	
			Mean	100	96.5	67.33	28.17	12.33	2.34	6.46	0.39
			St. Dev.	0.00	1	3.82	1.95	0.65	0.27	0.23	0.10
006	E. Pendleton-Emigrant Hill Lot 2B 18,696 metric tons CPF = 1.015	1992	USL	100	96	71	30	16	5.1	6.6	0.8
			LSL	99	85	60	20	8	1.1	5.6	0
			Target	100	95	65	26	12	3.2	5.6	
			Mean	99.98	95.28	64.28	27.33	11.35	2.69	6.46	0.22
			St. Dev.	0.16	1.36	4.12	1.93	1.33	.60	0.24	0.07

Table 3.4: QC Data for Projects Surveyed. (continued)

Hwy. No.	Project Name	Year Completed	Value	Sieve Size						Asphalt Content %	Moisture Content %
				25 mm (1")	19 mm (3/4")	12.5 mm (1/2")	6.25 mm (1/4")	2 mm (#10)	.075 mm (#200)		
006	E. Pendleton-Emigrant Hill Lot 3 1,886 metric tons CPF = 1.028	1992	USL	100	96	71	30	16	5.1	6.8	0.8
			LSL	99	85	60	20	8	1.1	5.8	0.8
			Target	100	94	65	25	12	3.1	6	
			Mean	100	95	65	28	11	2.45	6.4	0.22
			St. Dev.	0.00	1.41	4.08	0.82	0	0.48	0.22	0.07
006	Baldock Slough-S. Baker Lot 1 41,356 metric tons CPF = 1.014	1991	USL	100	96	71	31	15	4.6	5.9	0.5
			LSL	99	85	60	21	7	0.6	5.1	0
			Target	100	93	64	26	11	2.6	5.5	
			Mean	99.98	92.76	66.86	29.21	12.22	2.75	5.45	0.26
			St. Dev.	0.15	2.27	3.07	2.01	0.93	0.19	0.20	0.05
006	Baldock Slough-S. Baker Lot 2 1,940 metric tons CPF = 1.027	1991	USL	100	96	71	31	15	4.6	5.9	0.5
			LSL	99	85	60	21	7	0.6	5.1	0
			Target	100	93	64	26	11	2.6	5.5	
			Mean	100	89.4	63.4	28.2	12.4	2.98	5.46	0.22
			St. Dev.	0.00	2.97	4.62	1.79	1.14	0.16	0.11	0.01
041	Prineville Airport-Powell Butte Lot 1 18,089 metric tons CPF = 1.010	1995	USL	1E+09	96	71	28	14	4.9	5.4	0.8
			LSL	99	85	55	18	6	1	5	0
			Target	100	93	63	23	10	2.9	5.2	
			Mean	100.00	92.60	63.55	23.05	10.50	2.17	5.20	0.76
			St. Dev.	0.00	1.23	2.50	0.76	0.83	0.27	0.03	0.13
004	Willowdale-Qualle Rd. Lot 1 12,559 metric tons CPF = 0.943	1995	USL	100	96	71	28	13	5.1	5.5	0.8
			LSL	99	85	55	17	5	1.1	5.1	0
			Target	100	95	63	23	9	3.1	5.5	
			Mean	100.00	93.93	64.50	25.71	10.21	3.54	5.22	0.86
			St. Dev.	0.00	1.07	3.50	1.64	0.89	0.38	0.04	0.08
004	Murphy Rd.-Lava Butte Lot 3 5,717 metric tons CPF = 1.020	1989	USL	100	100	80	30	14	5.6	6	0.6
			LSL	99	95	66	18	6	1.6	5	0
			Target	100	98	75	25	10	3.6	5.5	
			Mean	100	97.82	77.45	24.18	9	3.86	5.53	0.43
			St. Dev.	0.00	1.72	4.11	1.54	1.61	1.24	0.30	0.13
004	Murphy Rd.-Lava Butte Lot 4 6,602 metric tons CPF = 0.994	1989	USL	100	100	80	30	13	5.6	5.7	0.6
			LSL	99	95	66	18	5	1.6	4.7	0
			Target	100	98	75	25	9	3.6	5.2	
			Mean	100.00	97.83	74.58	22.42	8.08	3.24	5.36	0.46
			St. Dev.	0.00	1.03	3.06	3.06	1.24	0.62	0.43	0.12

Table 3.4: QC Data for Projects Surveyed. (continued)

Hwy. No.	Project Name	Year Completed	Value	Sieve Size						Asphalt Content %	Moisture Content %
				25 mm (1")	19 mm (3/4")	12.5 mm (1/2")	6.25 mm (1/4")	2 mm (#10)	.075 mm (#200)		
004	Murphy Rd.-Lava Butte Lot 5 5,076 metric tons CPF = 1.014	1989	USL	100	100	80	30	14	5.5	6	0.6
			LSL	99	95	66	18	6	1.5	5	0
			Target	100	98	75	25	10	3.5	5.5	
			Mean	99.91	97.91	75.09	21.73	8.18	3.21	5.31	0.39
			St. Dev.	0.30	1.22	2.43	1.90	0.60	0.49	0.32	0.11
004	Murphy Rd.-Lava Butte Lot 6 1,491 metric tons CPF = 1.025	1989	USL	100	100	80	30	14	5.5	6	0.6
			LSL	99	95	66	18	6	1.5	5	0
			Target	100	98	75	25	10	3.5	5.5	
			Mean	100	97	74	21	8.33	3.4	5.47	0.45
			St. Dev.	0.00	2	7.21	1	0.58	0.27	0.40	0.11
004	Forge Rd.-Lobert Rd. Lot 1 21,412 metric tons CPF = 1.001	1990	USL	100	96	71	30	18	5.6	6.5	0.6
			LSL	99	85	60	20	10	1.6	5.5	0
			Target	100	93	66	25	14	3.6	6.0	
			Mean	99.94	92.29	61.53	26.94	13.18	2.91	5.86	0.16
			St. Dev.	0.24	3.26	4.46	2.16	1.51	0.60	0.26	0.05
004	Williamson Riv.-Modoc Pt. Lot 1 4,965 metric tons CPF = 1.023	1991	USL	100	96	71	30	16	6	5.7	0.8
			LSL	99	85	60	20	8	2	4.7	0
			Target	100	92	66	25	12	4.0	5.2	
			Mean	100.00	93.91	68.91	26.00	11.36	2.60	5.11	0.36
			St. Dev.	0.00	1.14	5.17	0.63	0.67	0.53	0.12	0.05
011	Jumpoff Joe-N. Grants Pass Lot 1 14,874 metric tons CPF = 1.000	1991	USL	100	96	71	29	16	5.9	5.4	0.8
			LSL	99	85	60	19	8	1.9	4.6	0
			Target	100	94	66	24	12	3.9	5.0	
			Mean	100.00	93.12	65.41	24.77	11.47	3.35	4.95	0.25
			St. Dev.	0.00	1.69	3.61	3.20	1.68	0.52	0.16	0.05
011	Jumpoff Joe-N. Grants Pass Lot 2 46,808 metric tons CPF = 1.021	1991	USL	100	96	71	29	16	5.9	5.4	0.8
			LSL	99	85	60	19	8	1.9	4.6	0
			Target	100	94	66	24	12	3.9	5	
			Mean	100	93.12	65.41	24.77	11.47	3.35	4.95	0.25
			St. Dev.	0.00	1.69	3.61	3.20	1.68	0.52	0.16	0.05
001	Azalea-Jumpoff Joe Lot 1 6,141 metric tons CPF = 0.9413	1994	USL	100	96	71	25	15	5	5.2	0.7
			LSL	99	85	60	17	7	1	4.8	0
			Target	100	94	66	21	11	3	5	
			Mean	100	93.43	61.29	26.14	11.57	2.23	4.87	0.21
			St. Dev.	0.00	1.72	1.80	1.68	0.53	0.23	0.15	0.04

Table 3.4: QC Data for Projects Surveyed. (continued)

Hwy . No.	Project Name	Year Completed	Value	Sieve Size						Asphalt Content %	Moisture Content %
				25 mm (1")	19 mm (3/4")	12.5 mm (1/2")	6.25 mm (1/4")	2 mm (#10)	.075 mm (#200)		
001	Azalea-Jumpoff Joe Lot 2 72,291 metric tons CPF = 1.0191	1994	USL	100	96	71	28	16	5	5.8	0.7
			LSL	99	85	60	18	8	1	5.4	0
			Target	100	93	65	23	12	3.0	5.6	
			Mean	100	94.10	62.58	25.41	11.68	2.26	5.56	0.29
			St. Dev.	0.00	1.18	3.23	2.59	1.57	0.44	0.09	0.06
001	Halsey Intch-Lane Co. Line Lot 3 23,154 metric tons CPF = 1.0074	1994	USL	100	96	71	29	16	6	6.4	0.7
			LSL	99	85	60	19	8	2	5.6	0
			Target	100	93	66	24	12	4	6	
			Mean	100	91.08	64.75	25.46	11.63	4.10	—	0.4
			St. Dev.	0.00	2.21	4.28	3.5	1.86	0.72	—	0.13
001	Halsey Intch-Lane Co. Line Lot 4 34,524 metric tons CPF = 1.0087	1994	USL	100	96	71	29	16	6	6.2	0.7
			LSL	99	85	60	19	8	2	5.4	0
			Target	100	93	66	24	12	4	5.8	
			Mean	100	90.92	64.21	24.01	10.37	3.56	—	0.55
			St. Dev.	0.00	2.19	3.14	2.99	1.33	0.56	—	0.12

Table 3.5: Moisture Content Measurements – ODOT.

- ODOT has changed its method of measuring the moisture content of bituminous mixtures three times since 1986. Prior to 1986 it is believed that AASHTO T-255 test method was used. T-255 dries the samples in a conventional oven at 230°F until a constant weight is reached. A total of 15-20 hours was often needed to obtain a constant weight.
- In 1986 ODOT released its first lab manual. The manual listed two methods for determining the moisture content of bituminous mixtures. The first method, OSHD Test Method 311(O)-86 is just AASHTO T-255 with an ODOT test number. The second method, OSHD Test Method 311(M)-86, used a microwave oven to heat the bituminous mixture to drive out the moisture. Although the microwave method was included in the lab manual, the conventional oven method was used the majority of the time.
- In 1991 OSHD TM311(M)-91 was adapted into the field test manual. This procedure increased the temperature in the microwave from 205°F to 350°F. With the new microwave method, field personnel could get the moisture content in one or two hours, rather than the 15 to 20 hours needed for the conventional oven. The oven drying method was used as a check the first time a mix was tested using the microwave drying method.
- A revision of the field operating procedures for AASHTO T-255 was issued in 1993. This revision mainly consolidated the two protocols into one test protocol without any change to the procedures.
- The last change in AASHTO T-255 occurred in 1996. It added a 90-minute drying time in a forced air oven. Not only did this shorten the drying time of the sample but, unlike the microwave method, the technician is not required to monitor the drying of the sample. Although this procedure was not added to the procedure until 1996, it was actually implemented in spring 1994.

- The target aggregate gradation values and specification limits of the mix designs varied in the following manner:

	Target Value		Specification Range	
	Highest	Lowest	Highest	Lowest
1" (25 mm)	100	100	99-100	99-100
¾" (19 mm)	98	90	95-100	86-96
½" (12.5 mm)	75	63	66-80	55-71
¼" (6.25 mm)	26	23	21-31	17-28
#10 (2 mm)	14	9	10-18	5-13
#200 (0.075 mm)	4.6	2.6	2-6	.6-4.6

- In every case, the sample means of the QC data fell within the specification limits, except moisture content. However, this information can be misleading since many of the individual values were outside specification as discussed later in the report.

3.3 SURVEY PROCEDURES

The surveys were conducted on June 27-28, 1994, and July 24-25, 1995. All projects were evaluated for the following:

1) Overall condition. The type and extent of distress (if any) were noted. Photos were also taken of the pavements during the survey.

2) Rut depth. This was measured for each project using the standard 1.8 m (5 ft) rut bar furnished by ODOT.

The survey was also used to identify the projects which needed to be cored. Tests on the cores will be used to identify the cause of the observed distress (see Chapter 4 for tests performed and test results).

3.4 SURVEY RESULTS

Hayesville-Battle Creek. This project, constructed in 1990, consists of 50 mm (2 inches) of F-mix over an unstable C-mix. The condition after five years was rated as good. Rut depths up to 13 mm (1/2 inch) were recorded. Most of the rutting was attributed to the unstable C mix or to studded tires (Figure 3.1).

W. Marquam-N. Tigard. This project, constructed in 1990, is a 50 mm (2 inch) overlay over an existing unstable dense-graded mix that had been profiled. The condition after five years was rated as good (Figure 3.2).

Sunset Highway-Pacific Highway. This project, constructed in 1994, was a 50 mm (2 inch) overlay over an existing dense-graded mix that had been profiled. The 1995 survey indicated the pavement was in good condition, with no measurable rutting. There were some fat spots (Figure 3.3) and the pavement surface looked in need of a fog seal.

Wolf Creek-W. Fork Dairy Creek. This project, constructed in 1993, had fat spots immediately after construction. The worst areas were replaced, but fat spots still persist and the extent is growing (Figure 3.4). Rut depths of up to 9 mm (3/8 inch) were measured.

Corbett Interchange-Multnomah. This project, constructed in 1991, was in good condition (Figure 3.5) with no measurable rutting. This was despite high mix moisture content measured during construction (Table 3.4).

Mt. Hood-Long Prairie. This project, constructed in 1995, was in excellent condition (Figure 3.6). There were no obvious problems, despite reports of high mix moisture (Table 3.4).

Rufus-Arlington (West Unit). This project, constructed in 1992, was in good condition with no rutting (Figure 3.7).

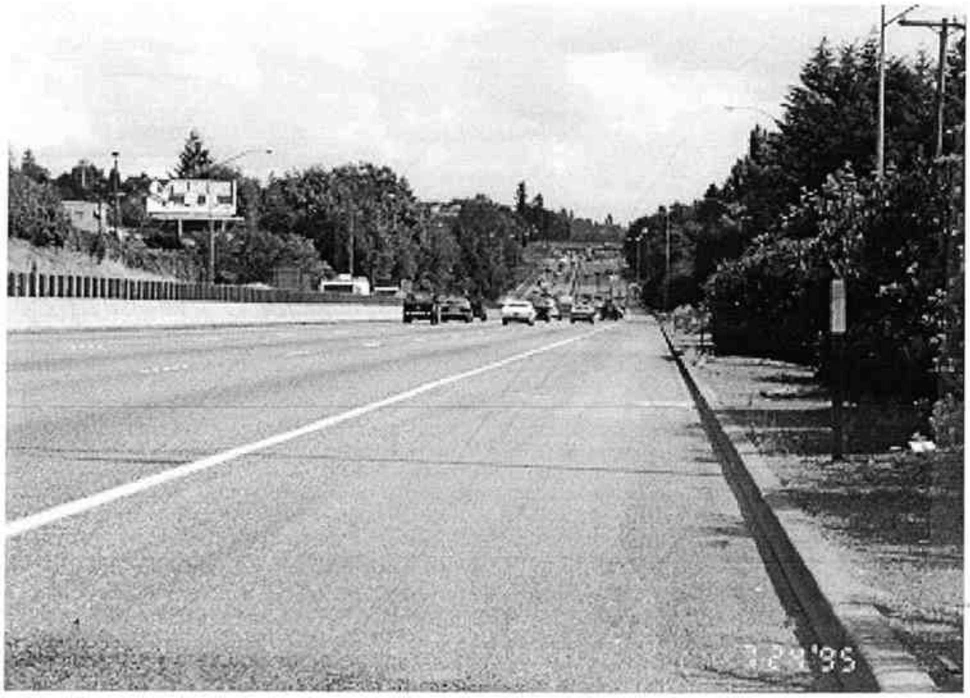
Rufus-Arlington (East Unit). This project, constructed in 1991, was also in good condition. Rut depths of 6 mm (1/4 inch) were measured in the truck lane. Also, there were some stains coming from the longitudinal joint in places along the project (Figure 3.8). High mix moisture was reported early on the project.

Umatilla-McNary. This project, constructed in 1993, consisted of 50 mm (2 inches) of F-mix over 50 mm (2 inches) of B-mix. Immediately after construction, it was reported to have fat spots with some rutting. Most of the fat spots are at the intersection of US 395. The remainder of the project is in good condition, with some fat spots showing (Figure 3.9). The rut depth was measured to be 3 to 6 mm (1/8 to 1/4 inch).

a) Overview

b) Closeup

Figure 3.1: Haysville-Battle Creek, MP 258



a) Overview

b) Closeup

Figure 3.2: W. Marquam-N. Tigard, MP 199.5

a) Overview

b) Closeup

Figure 3.3: Sunset Highway-Pacific Highway, 99W Interchange

a) Overview

b) Closeup

Figure 3.4: Wolf Creek-W. Fork Dairy, MP 38

a) Overview

b) Closeup

Figure 3.5: Corbett Interchange-Multnomah, MP 25

a) Overview

b) Closeup

Figure 3.6: Mt. Hood-Long Prairie at Miller Road

a) Overview

b) Closeup

Figure 3.7: Rufus-Arlington (West Unit), MP 120.5

a) Overview, MP 131

b) Staining at Joint, MP 134.5

Figure 3.8: Rufus-Arlington (East Unit)

a) Overview

b) Closeup of Fat Spots

Figure 3.9: Umatilla-McNary, MP 185

East Pendleton-Emigrant Hill. This project, constructed in 1992, was in very good condition (Figure 3.10). It consists of 100 mm (4 inches) of F-mix over an existing dense-graded mix that had been profiled. The measured rut depths were less than 6 mm (1/4 inch).

Baldock Slough-S. Baker. This project, constructed in 1991, was one of two which reportedly had moisture sensitivity problems. Localized fat spots/raveling were noted near MP 299. The measured rut depth was less than 6 mm (1/4 inch).

Prineville Airport-Powell Butte. This project, constructed in 1995, consists of 50 mm (2 inches) of F-mix over 100 mm (4 inches) of B-mix. It was in very good condition, with no measurable rutting or fat spots (Figure 3.12).

Willowdale-Qualle Rd. This project, constructed in 1995, consists of 50 mm (2 inches) of F-mix over 75 mm (3 inches) of B-mix. This project was in good condition. It was reported to have high mix moisture during construction (Table 3.4).

Murphy Rd.-Lava Butte. This project, constructed in 1989, was in good condition. There was some snow plow damage and rut depths were measured to be less than 6 mm (1/4 inch) (Figure 3.13). This was a test section with several different binder types.

Forge Rd.-Lobert Road. This project constructed in 1990, is experiencing spots of raveling. The raveling occurred in fat spots (Figure 3.14).

Williamson River-Modoc Pt. This project, constructed in 1991, was in good condition with some fat spots (Figure 3.15). The fat spots reportedly occurred during construction.

Jumpoff Joe-N. Grants Pass. This project, constructed in 1991, was in good condition with less than a 3 mm (1/8 inch) rut depth (Figure 3.16). It was raining during the survey, so the splash and spray benefits could be noted (Figure 3.17).

Azalea-Jumpoff Joe. This project, constructed in 1994, was in very good condition (Figure 3.18). Shortly after this field survey was conducted, this project exhibited low skid numbers (two years after construction). Sections on the curves were milled to correct the problem.

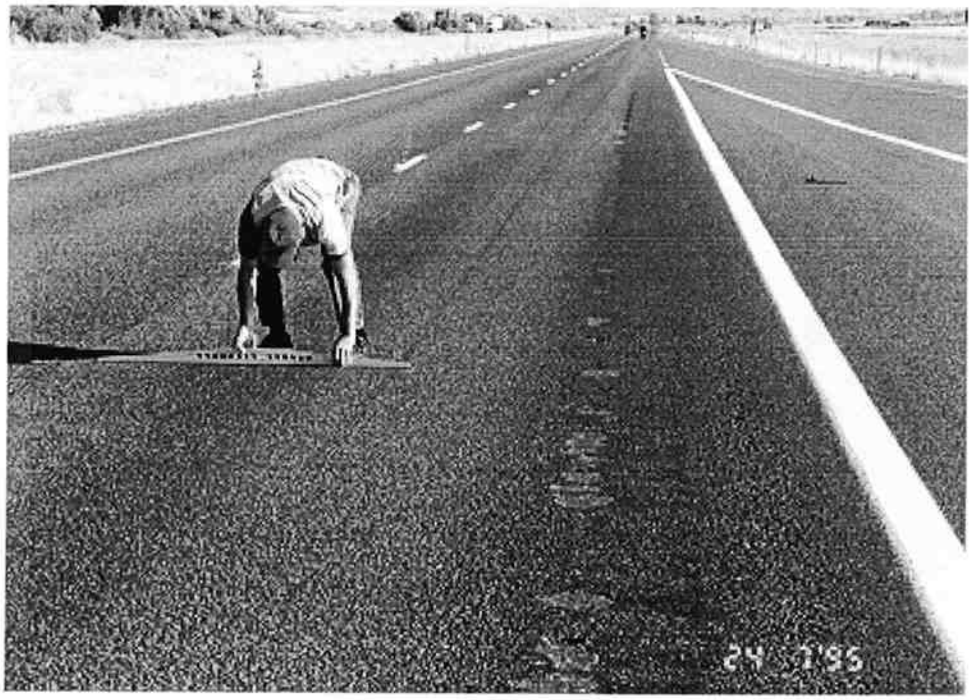
Halsey Interchange-Lane County Line. This project, constructed in 1994, consists of 50 mm (2 inches) of F-mix over 50-225 mm (2-9 inches) of B-mix. There are fat spots, and some pushing and shoving has occurred (Figure 3.19).

a) Overview

b) Closeup

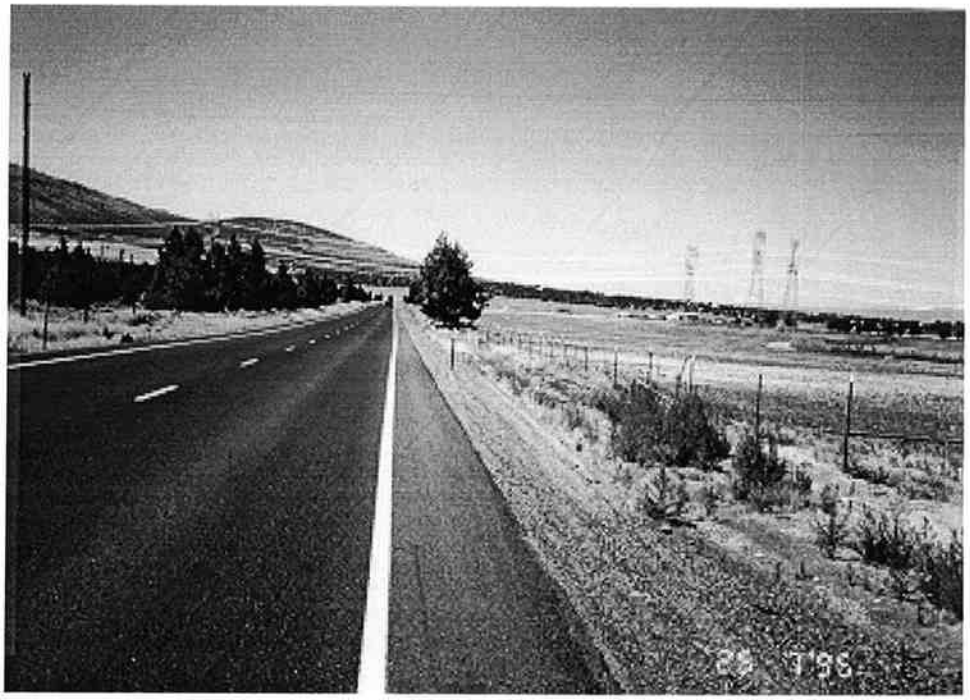
Figure 3.10: E. Pendleton-Emigrant Hill, MP 214.5

a) Overview

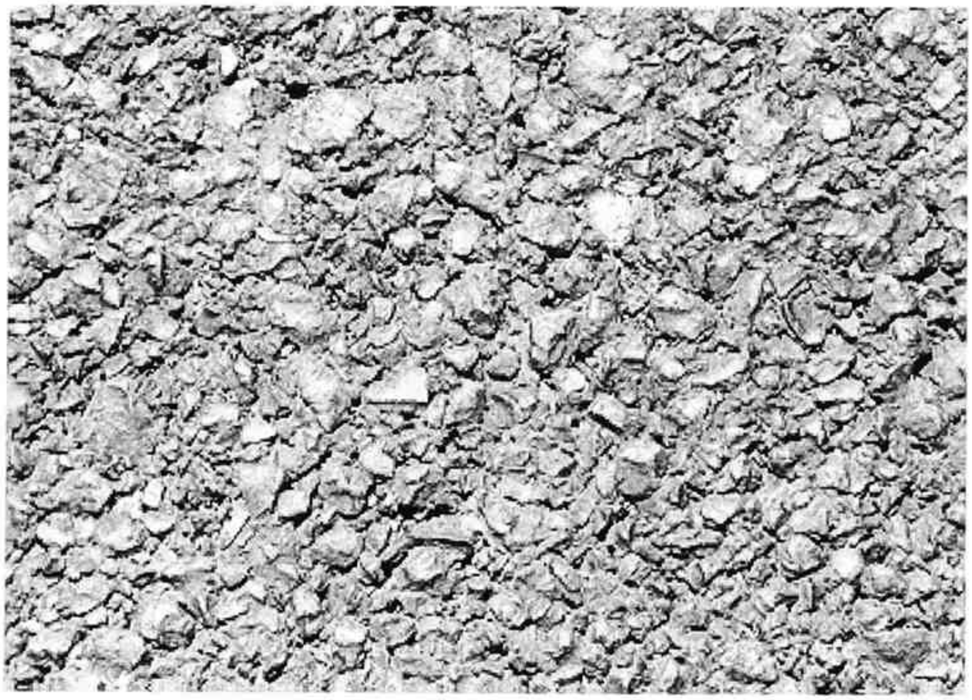


b) Localized Raveling

Figure 3.11: Baldock Slough-S. Baker, MP 299



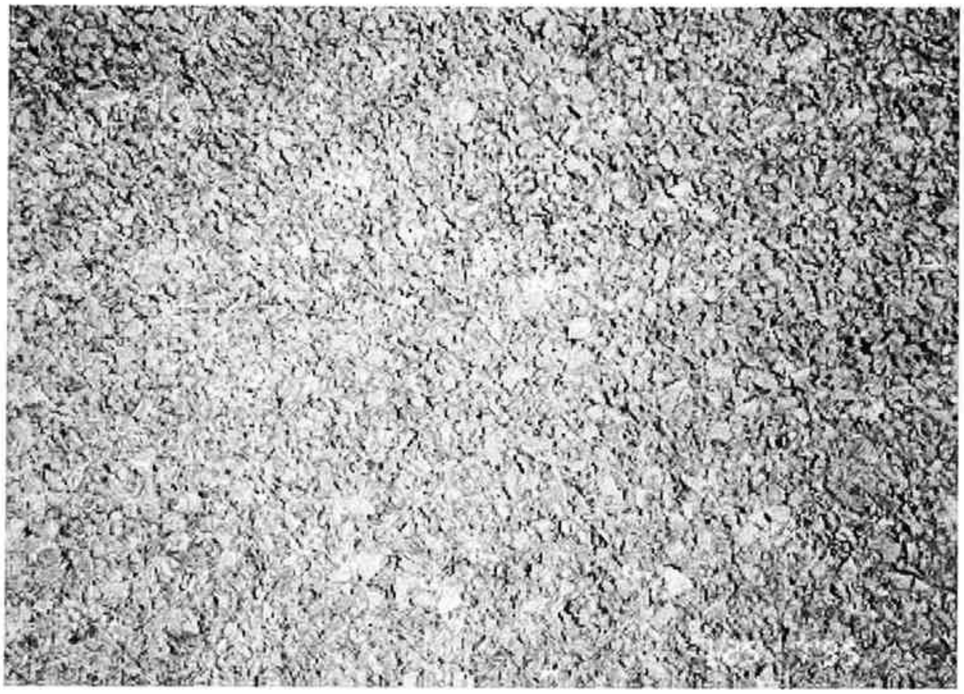
a) Overview



b) Closeup

Figure 3.12: Prineville Airport-Powell Butte Rd., MP 12.5

a) Overview



b) Closeup

Figure 3.13: Murphy Rd.-Lava Butte, MP 148.5

6 28 '94

a) Overview, 1994

b) Overview, 1996

Figure 3.14: Forge Rd.-Lobert Rd., MP 245

a) Overview

b) Closeup

Figure 3.15: Williamson River-Modoc Point, MP 256

a) Overview

b) Closeup

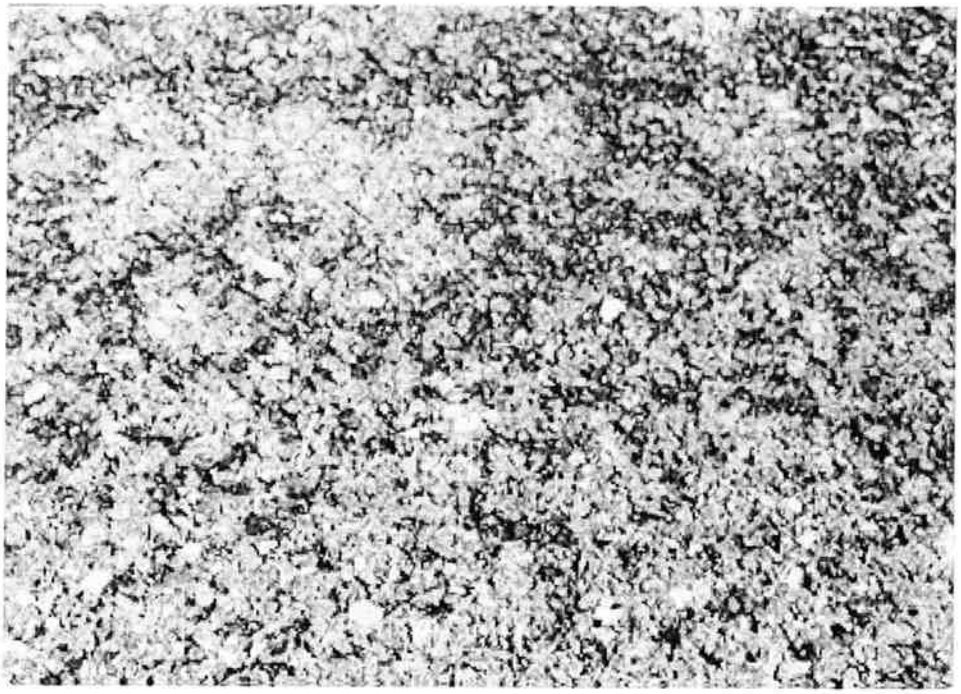
Figure 3.16: Jumpoff Joe-N. Grants Pass, MP 61

a) Overview

b) Closeup

Figure 3.17: Porous Mixes in Rainy Conditions

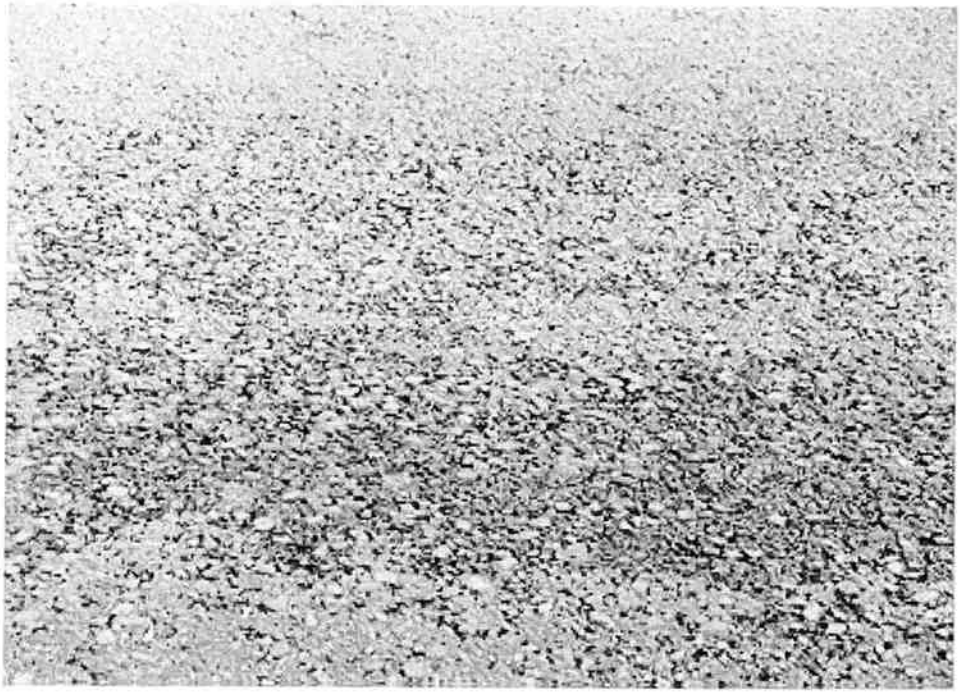
a) Overview



b) Closeup

Figure 3.18: Azalea-Jumpoff Joe, MP 79

a) Overview



b) Closeup

Figure 3.19: Halsey Interchange-Lane County Line, MP 202

3.5 SUMMARY

Table 3.6 summarizes project performance for the projects surveyed. Of the 19 projects surveyed, 4 projects were rated to be in fair condition, 11 projects were rated to be in good condition, 3 projects were found to be in very good condition, and 1 project was rated to be in excellent condition. Thus, overall performance of F-mix projects in Oregon was found to be positive.

Eight of the 19 projects exhibited measurable rut depths. The highest rut depths were found on the Hayesville-Battle Creek project at up to 13 mm, followed by the Wolf Creek-W. Fork Dairy Creek project at up to 9 mm. The remaining projects that exhibited rutting were all under 6 mm. This could be considered normal rutting in Oregon due to the high use of studded tires. In addition, two projects were noted to have raveling problems and six projects exhibited fat spots (two were localized). Some pushing and shoving was also noted on the Halsey Interchange-Lane County Line project.

Given these performance issues, a test plan was recommended by OSU to include the core requirements presented in Table 3.7. This test plan was approved by the project's Technical Advisory Committee on October 10, 1995, and is documented more thoroughly in the next chapter.

Table 3.6. Project Performance (1995).

Hwy. No.	Project Name	Year Constructed	Condition	Rut Depth	Comments
001	Hayesville-Battle Creek	1990	good	Up to 13 mm	
001	W. Marquam-N. Tigard	1990	good	—	
144	Sunset Hwy.-Pacific Hwy.	1994	Good	—	fat spots, needed fog seal
047	Wolf Cr.-W. Fork Dairy Cr.	1993	fair	Up to 9 mm	fat spots due to too much asphalt and high moisture content
002	Corbett Intch.-Multnomah	1991	good	—	despite high moisture
026	Mt. Hood-Long Prairie	1995	excellent	—	despite high moisture
002	Rufus-Arlington (W. Unit)	1993	good	—	
002	Rufus-Arlington (E. Unit)	1991	good	< 6 mm	stains
002	Umatilla-McNary	1993	good	3-6 mm	localized fat spots
006	E. Pendleton-Emigrant Hill	1992	very good	< 6 mm	
006	Baldock Slough-S. Baker	1991	fair to good	< 6 mm	localized fat spots/raveling
041	Prine. Airport-Powell Butte	1995	very good	—	
004	Willowdale-Qualle Rd.	1995	good	—	
004	Murphy Rd.-Lava Butte	1989	good	< 6 mm	some snow plow damage; test section – several binder types
004	Forge Rd.-Lobert Rd.	1990	fair to good		raveling
004	Williamson Riv.-Modoc Pt.	1991	good	—	some fat spots
001	Jumpoff Joe-N. Grants Pass	1991	good	< 3 mm	
001	Azalea-Jumpoff Joe	1994	very good	—	sections milled on curves
001	Halsey Intch.-Lane Co. Line	1994	fair	—	fat spots, pushing and shoving

Table 3.7. Core Requirements for Test Plan.

Project	Sampling Areas
Wolf Creek-W. Fork Dairy Cr.	in and out of fat spots
Rufus-Arlington (East Unit)	at longitudinal joint to determine cause of stains (stains could be from CIR)
Baldock Slough-S. Baker	in and out of raveled areas
Forge Road-Lobert Road	in and out of raveled areas
Azalea-Jumpoff Joe	splash and spray benefits were noted only in parts of the project
Halsey Interchange-Lane County Line	in and out of fat spots (pushing and shoving)

4.0 LABORATORY EVALUATIONS

The field survey results indicated that the problems in F-mixes include: 1) fat spots, 2) raveling, and 3) rutting. This chapter presents the test program work to evaluate the causes of pavement distress. The location of the cores from the six projects evaluated is given in Table 4.1.

Table 4.1: Projects Sampled

Project	Contractor	Sampling areas	Post Location	Location*
Wolf Creek - W. Fork Dairy Creek**	Wildish	in and out of fat spots	east bound M.P. 37.6	Rt. Ln., Rt. of SS 3.0 m (OWT) 3.25 m (OWT)
		surface fat spots	east bound M.P. 38.38	Rt. Ln., Rt. of SS 2.2 m (BWT) 2.6 m (OWT) 2.8 m (OWT)
			west bound M.P. 42.02	Rt. Ln., Rt. of SS 2.0 m (BWT) 2.1 m (BWT) 3.2 m (OWT) 3.4 m (OWT)
			west bound M.P. 45.2	Rt. Ln., Rt. of SS 1.6 m (BWT) 1.7 m (BWT) 2.5 m (OWT) 2.7 m (OWT)
Rufus - Arlington** (east unit)	Babler Bros.	at longitudinal point to determine cause of stress	east bound M.P. 126.5	Rt. Ln., Rt. of SS 3.2 m (OWT) 3.0 m (OWT)
			east bound M.P. 133	Left Ln., Left of SS 1.7 m (BWT) 1.9 m (BWT) Rt. Ln., Rt. of SS 2.5 m (OWT) 2.7 m (OWT)
			east bound M.P. 135.15	Left Ln., Left of SS 3.1 m (OWT) 3.2 m (OWT) Rt. Ln., Rt. of SS 2.8 m (OWT) 3.1 m (OWT)

*Between wheel track (BWT) is for 1.5 to 2.3 m from skip strip (SS) line. Outer wheel track (OWT) is for distances greater than 2.4 m from SS line.

**BWT and OWT determinations for Wolf Creek and Rufus Arlington are estimated from information provided.

Table 4.1: Projects Sampled (continued)

Project	Contractor	Sampling areas	Post Location	Location*
Baldock Slough - S. Baker	Babler Bros.	in and out of raveled areas	east bound M.P. 299.38	Outside Ln., Rt. of SS 2.9 m (BWT) 2.9 m (BWT) 3.3 m (OWT)
			east bound M.P. 299.22	Outside Ln., Rt. of SS 3.1 m (OWT) 3.0 m (OWT) 3.0 m (OWT) 3.1 m (OWT) 1.7 m (BWT) 1.9 m (BWT) 2.0 m (BWT)
Forge Rd. - Lobert Rd.	J.C. Compton	in and out of raveled areas	north bound M.P. 246.18	Rt. Ln., Rt. of SS 2.5 m (OWT) 2.8 m (OWT) 2.7 m (OWT) 2.7 m (OWT) 2.0 m (OWT) 2.0 m (OWT) 1.8 m (BWT) 1.8 m (BWT)
			south bound M.P. 244.14	Rt. Ln., Rt. of CL 5.9 m (OWT) 5.9 m (OWT) 5.9 m (OWT) 5.9 m (OWT)
Azalea - Jumpoff Joe (south end)	Kiewit	splash and spray benefits?	south bound M.P. 78.05	Rt. Ln., Rt. of SS 2.7 m (OWT) 2.8 m (OWT) 2.8 m (OWT) 2.9 m (OWT) 1.8 m (BWT) 1.8 m (BWT) 1.8 m (BWT) 1.8 m (BWT)
Halsey Interchg. - Lane Co. Line	Wildish	in and out of shoving areas	south bound M.P. 212.98	Rt. Ln., Rt. of SS 2.9 m (OWT) 2.9 m (OWT) 2.0 m (BWT) 2.0 m (BWT)

*Between wheel track (BWT) is for 1.5 to 2.3 m from skip strip (SS) line. Outer wheel track (OWT) is for distances greater than 2.4 m from SS line.

**BWT and OWT determinations for Wolf Creek and Rufus Arlington are estimated from information provided.

4.1 TEST PROGRAM

The test program is displayed in Figure 4.1. Depending on the type of distress, the testing plan varied as shown in Table 4.2. Oregon DOT obtained the cores in November/ March 1995. The testing took place during the spring of 1996.

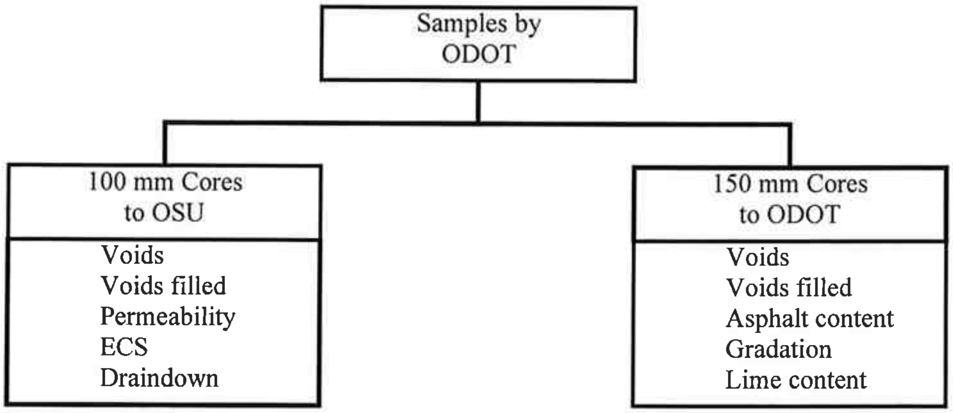


Figure 4.1: Laboratory Test Program

Table 4.2: Test Program

Type of Distress	Samples*	Type of Test
Fat Spots/Shoving	2–150 mm diameter/site (ODOT)	Asphalt content Gradation Voids Voids filled
	2–100 mm diameter/site (OSU)	ECS
Raveling	2–150 mm diameter/site	Asphalt content Gradation Voids Voids filled Lime content
	2–100 mm diameter/site	ECS Boiling water
Splash and Spray	4–150 mm diameter cores	Asphalt content Gradation Voids Voids filled
	4–100 mm diameter cores	Voids Permeability

*2 to 3 sites/project

4.1.1 ODOT Tests (150 mm cores)

The Operations Support Section of ODOT was responsible for performing the tests on the 150 mm (6-inch) diameter cores. The initial testing was done to investigate the volumetric properties of each core; it was followed by an extraction procedure to examine the compliance to the mix design. The following protocols were used:

1) Volumetric. The volumetric test accomplished by ODOT consisted of the maximum specific gravity by AASHTO T-209; the saturated surface dry bulk specific gravity by AASHTO T-166; the geometric bulk specific gravity by ODOT TM 307-95; and air void calculation by AASHTO test method T-269. Using the data from the job mix formula sheets and the extraction reports, OSU calculated the percentage of voids in the mineral aggregate (VMA) and the percentage of voids filled with asphalt (VFA).

2) Bituminous Extraction. The bituminous extraction method used followed the ODOT test method TM 309-95 to separate the binder and aggregate. The asphalt content was determined according to the procedures in ODOT TM 309-95. The aggregate gradation was measured using sieve analysis according to AASHTO test methods T-11 and T-27.

4.1.2 OSU Tests (100 mm cores)

The 100 mm diameter cores from each project were delivered to Oregon State University for testing. Initial testing was performed to evaluate the volumetric properties of the cores. Final testing was done on two samples from each project in the Environmental Conditioning System (ECS) to examine any moisture sensitivity in the mix. The protocols used included the following:

1) Volumetric. The volumetric testing accomplished at OSU consisted of the parafilm bulk specific gravity test method from Chevron Research Company *(Del Valle, 1985)*. The air void content calculation was performed according to ASTM test method D3203. The average maximum specific gravity was obtained from the extraction data from ODOT. At each core location, an average maximum specific gravity was calculated and used in the air void calculation for the 100 mm cores from the same milepost. Calculation of the VMA and VFA for the OSU cores used aggregate properties from the job mix formula sheet.

2) Environmental Conditioning System. One sample from each project was cycled through the ECS according to SHRP M-006. A slight modification was made to the procedure in that the samples did not receive any repeated loading. Previous studies *(Kliewer et al., 1995)* have shown that the open-graded mixes deform excessively under loading. The ECS testing procedure tracks the change in the modulus of the sample as it is cycled through the testing. If the modulus ratio of the sample falls below 75%, the sample is considered susceptible to moisture damage. The sample is split in half at the end of the ECS testing and a visual strip rating is assigned to the core.

4.2 TEST RESULTS

This section presents the results of the six projects used in the laboratory investigation of the porous pavements. The asphalt contents for the projects are summarized in Table 4.3. Results for each project are described, including results from both ODOT and OSU laboratory testing. For each project, the ODOT volumetric test results are reported followed by the bituminous extraction results. The OSU lab results include the volumetric data followed by the permeability, and then conclude with the ECS test results. The detailed results are presented in Appendix C.

When comparing the volumetrics of the cores tested in the ODOT lab with the volumetrics from the OSU lab, there are differences in the resulting values. These differences can be explained by the methods used to measure the volumetrics of the cores. The ODOT lab used a geometric method, while OSU used a parafilm method. Although both ODOT and OSU volumetric results are reported, **all references to volumetrics in later chapters are based upon OSU results only**.

It should be pointed out that the number of samples taken (and tested) varied from project to project. This was due primarily to differences in the performance found along any given project.

Table 4.3: Summary of Asphalt Contents for All Projects Sampled

Project	Target (%)	Upper Limit (%)	Lower Limit (%)	Average (%)	Median (%)	Minimum (%)	Maximum (%)	Met Spec/ Total
Wolf Cr.-W. Fork Dairy Cr.	6.0	6.5 *(5 over)*	5.5 *(2 under)*	6.9	6.1	5.1	13.1	5/12
Rufus-Arlington	5.3	5.7 *(6 over)*	4.9 *(1 under)*	5.5	5.8	4.3	6.3	2/9
Baldock Slough-S. Baker	5.5	5.9	5.1	5.6	5.7	5.4	5.8	3/3
Forge Rd.-Lobert Rd.	6.0	6.5	5.5 *(5 under)*	5.0	4.9	4.7	5.8	1/6
Azalea-Jumpoff Joe*	5.6	5.8	5.4 *(8 under)*	5.1	5.0	4.6	5.3	0/8
Halsey Intch.-Lane Co. Line	5.8	6.2	5.4 *(1 under)*	5.7	5.7	5.0	6.1	10/11

*Some areas on this project were replaced, other areas received a fog seal.

4.2.1 Wolf Creek-W. Fork Dairy Creek

4.2.1.1 ODOT Tests

Extraction results showed the individual gradation of the 12 samples all exceeded the upper broadband limit significantly at a minimum of one gradation control point (Figure 4.2). The average gradation (Figure 4.3) for the 12 samples tested exceeds the upper control limit at 12.5 mm sieve by 6.7%. It is also 3.7% above on the 6.25 mm (1/4 inch) control point, 0.8% above on the 2 mm (No. 10) control point, and 0.3% above on the 0.075 (No. 200) control point.

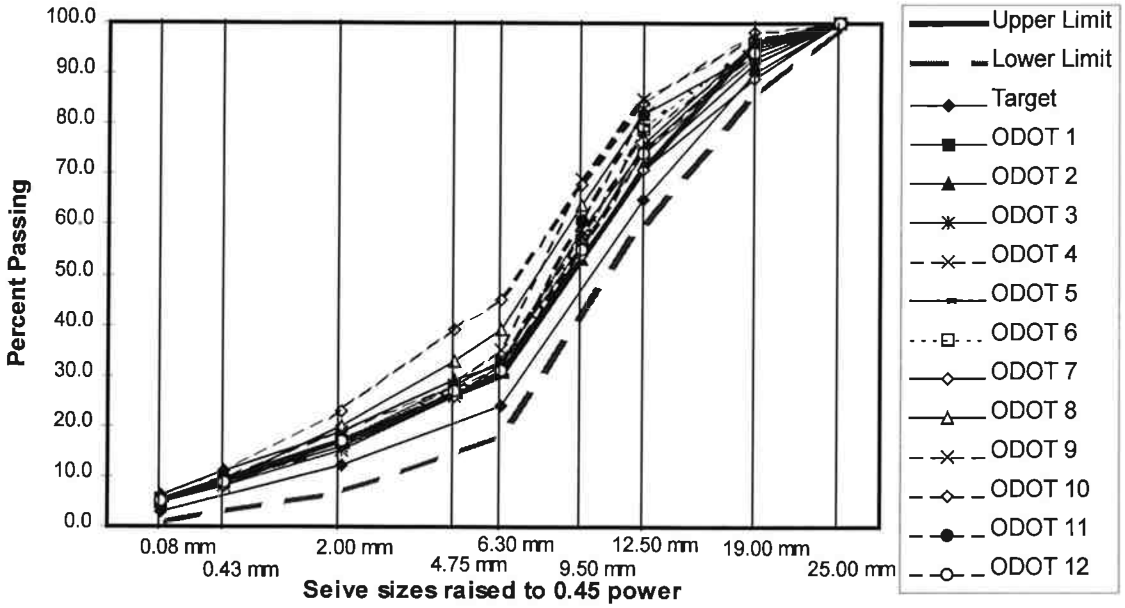


Figure 4.2: Extracted Gradation for Wolf Creek - W. Fork Dairy Creek

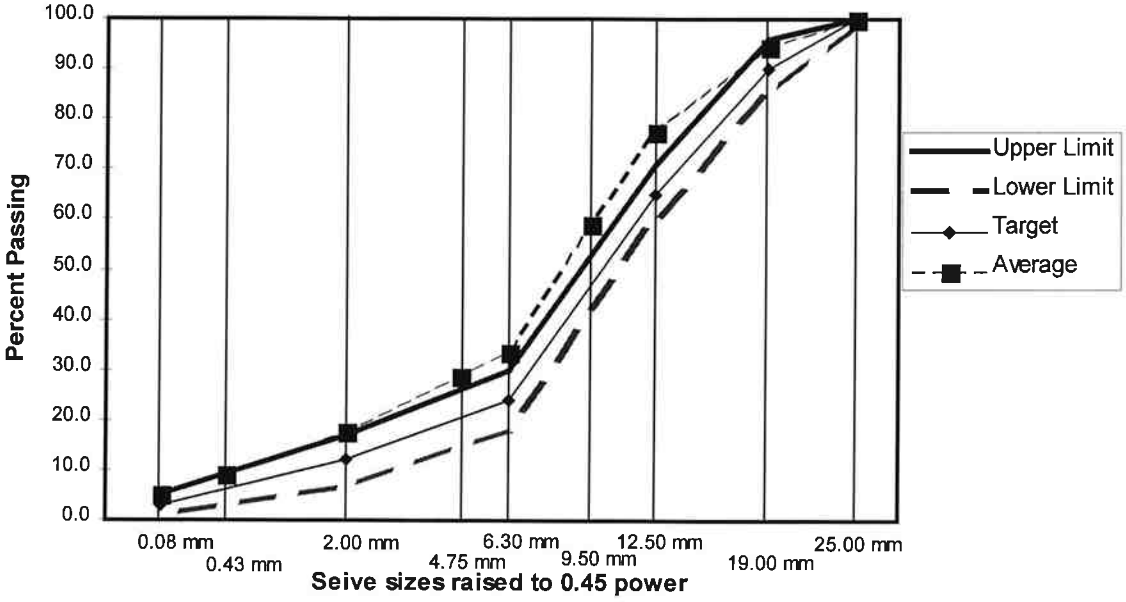


Figure 4.3: Average Extraction Gradation for Wolf Creek - W. Fork Dairy Creek

Asphalt content of the nine samples varied from 5.4 to 13.1% with an average of 6.9%. The average asphalt content exceeded the upper design limit by 0.4%. Only five of the tested samples met the design specification limits, while five exceeded the upper limit and two fell under the lower limit (Table 4.3). The void content for the cores tested by ODOT ranged from 5.3 to 14.6% with an average of 9.9% (Table 4.4).

Table 4.4. Summary Volumetrics for Wolf Creek-W. Fork Dairy Creek (ODOT)

	Geometric Bulk Specific Gravity	Maximum Specific Gravity	Percent Air Voids
Minimum	2.119	2.408	5.3
Maximum	2.309	2.482	14.6
Average	2.201	2.445	9.9
Standard deviation	0.07	0.02	3.2
Coefficient of variation (%)	3.0	0.9	31.7

4.2.1.2 OSU Tests

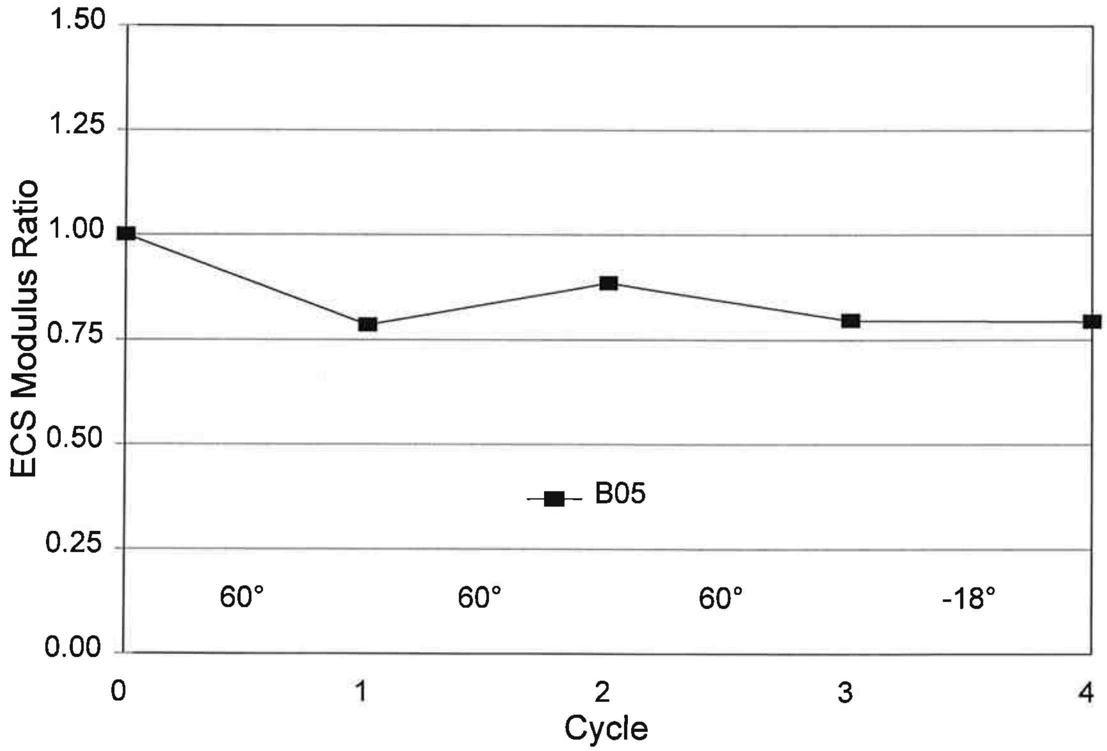
The void content for the cores tested by OSU ranged from 5.0 to 14.6% with an average of 9.6% (Table 4.5). The sample tested in the ECS remained at approximately 80% after the first cycle and had no significant stripping (Figure 4.4).

Table 4.5: Summary Volumetric Data for Wolf Creek-W. Fork Dairy Creek (OSU)

	Parafilm Bulk Specific Gravity	Percent Air Voids
Minimum	2.089	5.0
Maximum	2.308	14.6
Average	2.209	9.6
Standard deviation	0.07	3.0
Coefficient of variation (%)	3.0	31.0

Wolf Cr. - W. Fork Dairy Cr.
Additives: None
Asphalt: McCall PBA-5 (6.0%)

Specimen ID	ECS System	Air Voids (%)	Cond. Cycle	ECS Stress (psi)	ECS Strain (micro)	ECS MR (ksi)	ECS MR Ratio	Visual Stripping (%)
B05	C	5.2	0	17.5	100.9	174	1.00	0-5
			1	13.8	100.9	137	0.79	
			2	15.8	102.8	154	0.89	
			3	14.0	101.2	138	0.80	
			4	13.9	100.6	138	0.79	



ECS Modulus Test Results

Figure 4.4: ECS Results for Wolf Cr. - W. Fork Dairy Cr.

4.2.2 Rufus-Arlington

4.2.2.1 ODOT Tests

Extraction results showed the individual gradation of the nine samples all exceeded the upper broadband limit significantly at a minimum of one gradation control point (Figure 4.5). The average gradation (Figure 4.6) for the nine samples tested first exceeds the upper control point at 12.5 mm sieve by 4.0%. As the average gradation continues through the control points, it is 9.1% above the 6.25 mm (1/4 inch) control point; 4.7% above the 2 mm (No. 10) control point; and ends almost 1% above at the 0.075 mm (No. 200) control point.

Asphalt content of the nine samples varied from 4.3 to 6.3% with an average of 5.5%. Although the average asphalt content was within design specifications, only two of the nine samples tested met the design limits of 4.9 to 5.7%. Six of the samples were above the upper asphalt limit and one sample was below the lower limit resulting in a median of 5.8% (Table 4.3). The void content for the cores tested by ODOT ranged from 6.0 to 18.2% with an average of 12.2% (Table 4.6).

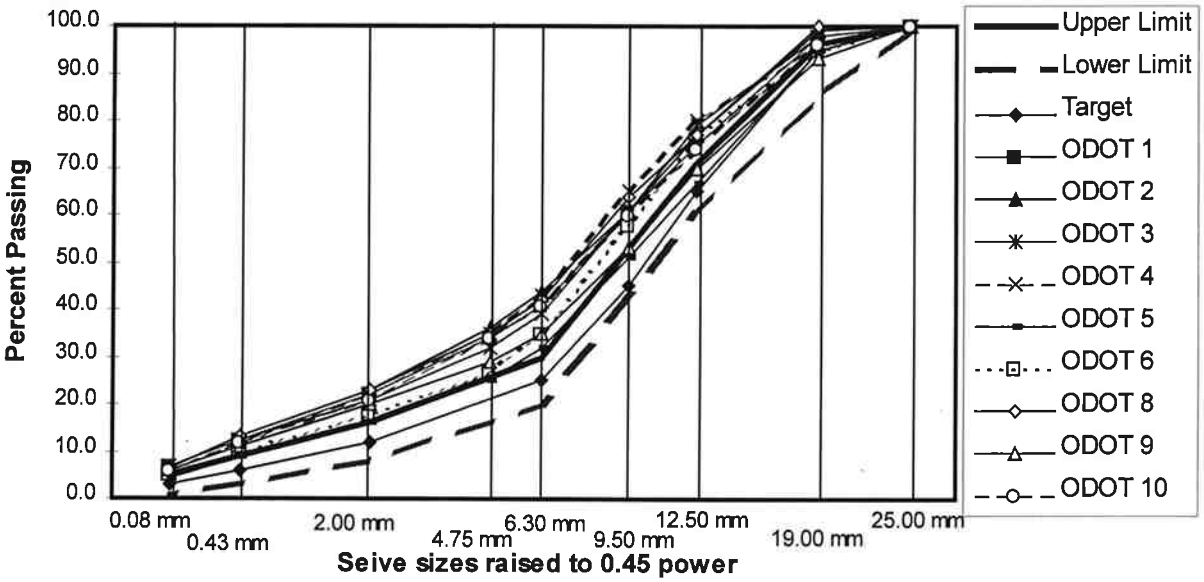


Figure 4.5: Extracted Gradation from Rufus-Arlington

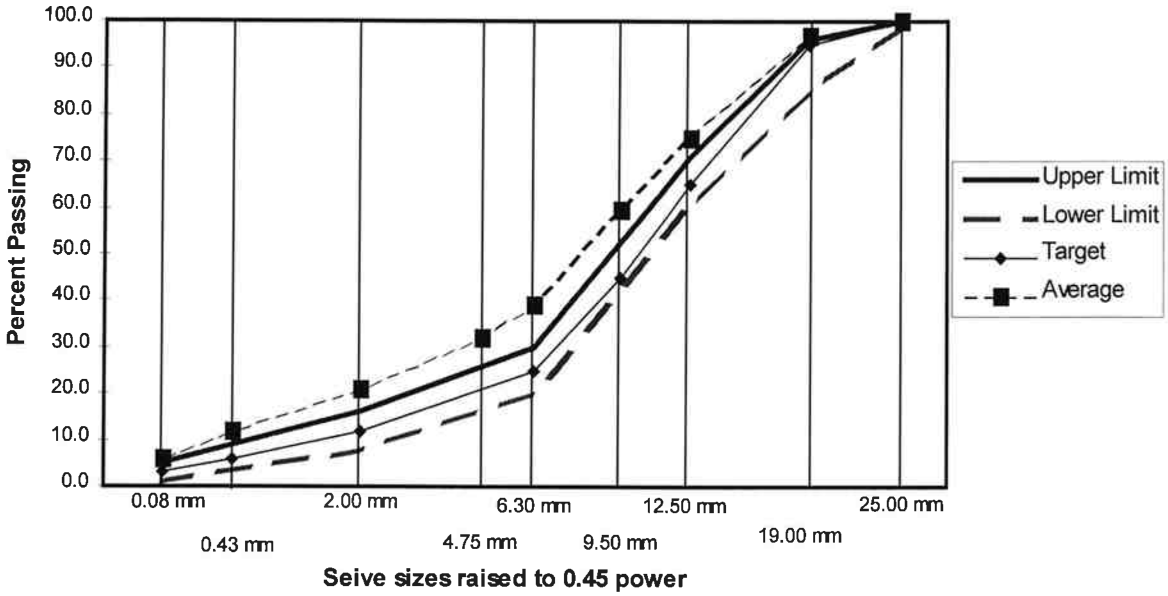


Figure 4.6: Average Extracted Gradation for Rufus-Arlington

Table 4.6: Summary Volumetrics for Rufus-Arlington (ODOT)

	Geometric Bulk Specific Gravity	Maximum Specific Gravity	Percent Air Voids
Minimum	2.138	2.536	6.0
Maximum	2.411	2.627	18.2
Average	2.259	2.574	12.2
Standard deviation	0.1	0.03	4.1
Coefficient of variation (%)	4.4	1.1	33.3

4.2.2.2 OSU Tests

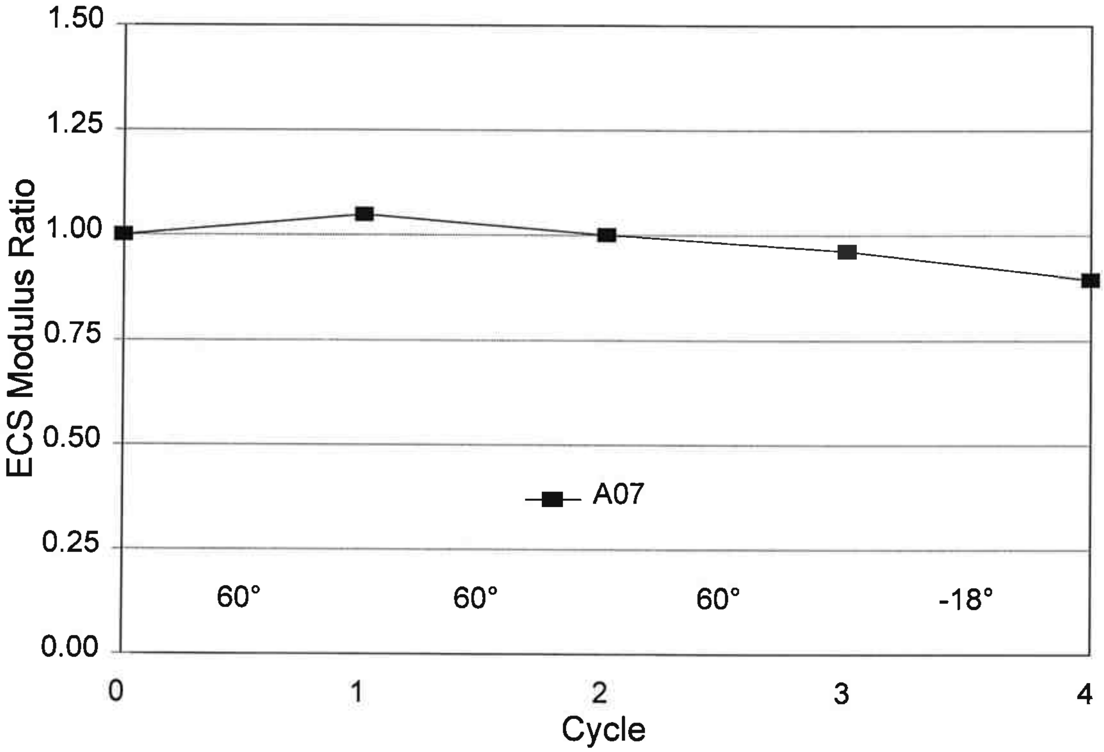
The void content for the cores tested by OSU range from 3.6 to 16.9% with an average of 9.9% (Table 4.7). The sample tested in the ECS lowest modulus ratio was 86% and had no significant stripping (Figure 4.7).

Table 4.7: Summary Volumetric Data for Rufus-Arlington (OSU)

	Parafilm Bulk Specific Gravity	Percent Air Voids
Minimum	2.154	3.6
Maximum	2.466	16.9
Average	2.307	9.9
Standard deviation	0.1	4.3
Coefficient of variation (%)	4.5	43.8

Rufus - Arlington
Additives: Lime
Asphalt: Albina PBA-5 (5.3%)

Specimen ID	ECS System	Air Voids (%)	Cond. Cycle	ECS Stress (psi)	ECS Strain (micro)	ECS MR (ksi)	ECS MR Ratio	Visual Stripping (%)
A07	C	12.2	0	21.5	99.8	216	1.00	0-5
			1	22.6	100.0	226	1.05	
			2	21.6	100.3	216	1.00	
			3	20.7	100.0	207	0.96	
			4	19.2	99.6	193	0.89	



ECS Modulus Test Results

Figure 4.7: ECS Results for Rufus - Arlington

4.2.3 Baldock Slough-S. Baker

4.2.3.1 ODOT Tests

Extraction results showed the individual gradation of the three samples all exceeded the upper broadband limit significantly at a minimum of one gradation control point (Figure 4.8). The average gradation for the three samples tested first exceeds the upper control point at 12.5 mm sieve by 5.3%. As the average gradation continues through the control points it is 7.7% above the 6.25 mm (1/4 inch) control point, 2.2% above the 2 mm (No. 10) control point, and ends slightly lower than the 0.075 mm (No. 200) upper control point (Figure 4.9).

Asphalt content of the three samples varied from 5.4 to 5.8% with an average of 5.6%. All of the samples were within the design target range of 5.1 to 5.9% (Table 4.3). The void content for the cores tested by ODOT ranged from 7.4 to 11.0% with an average of 9.0% (Table 4.8).

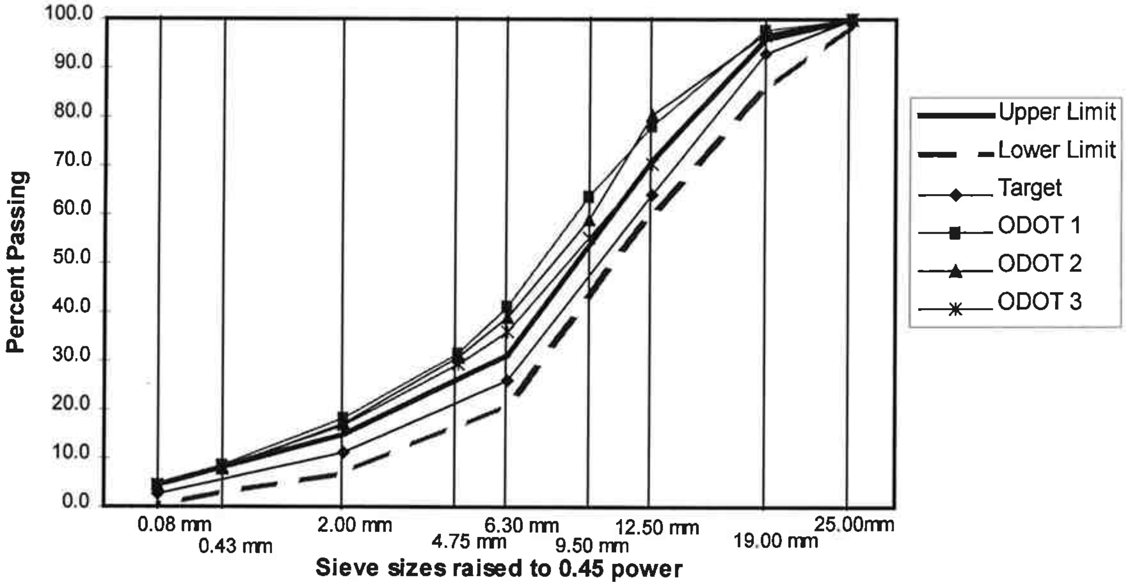


Figure 4.8: Extraction Results for Baldock Slough-S. Baker Interchange

4.2.3.2 OSU Tests

The void content for the cores tested by OSU ranged from 7.0 to 14.1% with an average of 10.8% (Table 4.9). The sample tested in the ECS lowest modulus value was 86% of its initial value after the fourth cycle and had 20-30% visual stripping (Figure 4.10). Although the sample did not have a significant reduction in modulus value, the visual stripping indicates the mix is sensitive to moisture.

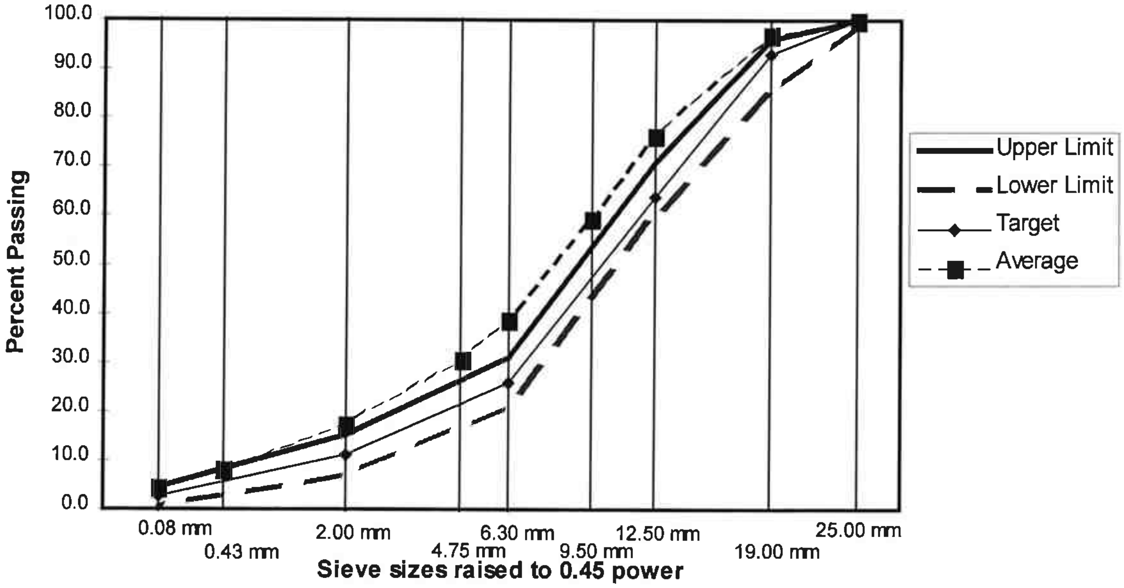


Figure 4.9: Average Extraction Results for Baldock Slough-S. Baker Interchange

Table 4.8: Volumetrics for Baldock Slough-S. Baker Interchange (ODOT)

	SSD Bulk Specific Gravity	Maximum Specific Gravity	Percent Air Voids
Minimum	2.170	2.431	7.4
Maximum	2.250	4.440	11.0
Average	2.217	2.436	9.0
Standard deviation	0.04	0.01	1.8
Coefficient of variation (%)	1.9	0.2	20.4

Table 4.9: Volumetric Data for Baldock Slough-S. Baker Interchange (OSU)

	Parafilm Bulk Specific Gravity	Percent Air Voids
Minimum	2.094	7.0
Maximum	2.262	14.1
Average	2.171	10.8
Standard deviation	0.04	1.9
Coefficient of variation (%)	2.0	17.1

Baldock Slough - S. Baker Interch.
Additives: Lime
Asphalt: Albina AC-20 (R) (5.5%)

Specimen ID	ECS System	Air Voids (%)	Cond. Cycle	ECS Stress (psi)	ECS Strain (micro)	ECS MR (ksi)	ECS MR Ratio	Visual Stripping (%)
F12	C	10.3	0	33.3	98.5	338	1.00	20-30%
			1	29.4	100.6	292	0.87	
			2	31.4	101.3	309	0.92	
			3	31.6	100.3	315	0.93	
			4	29.4	101.5	290	0.86	

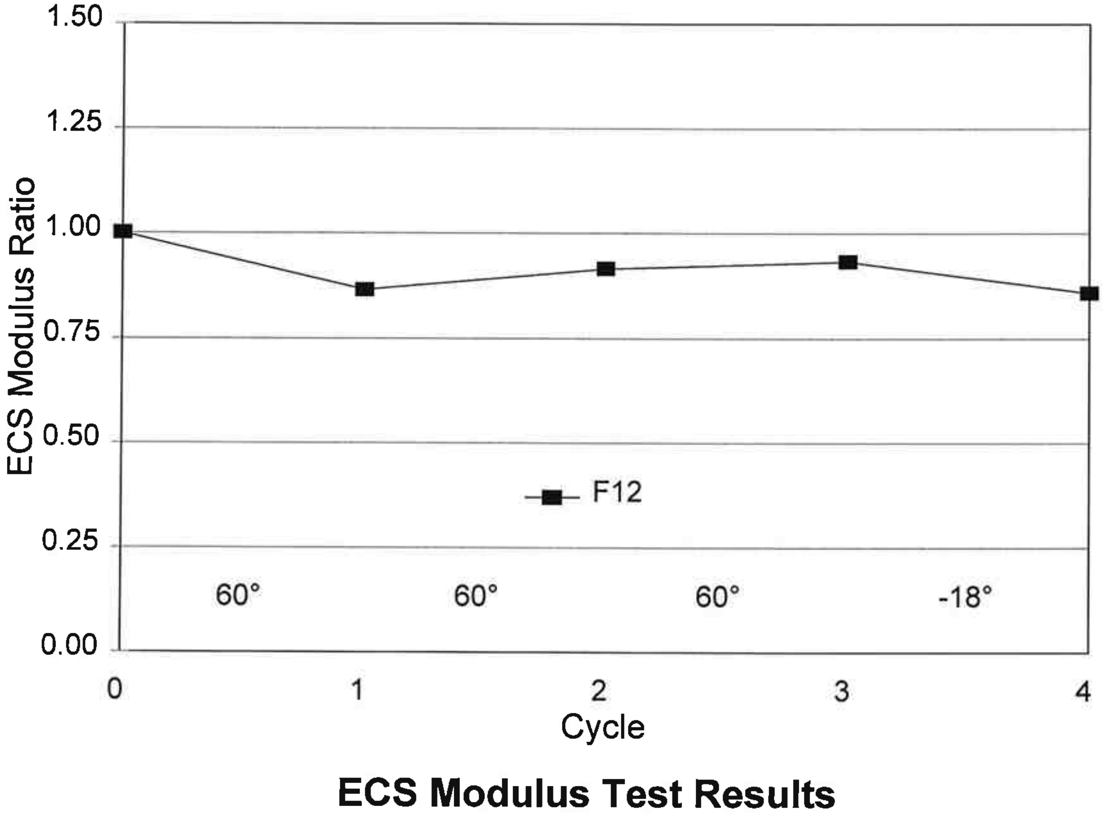


Figure 4.10: ECS Results for Baldock Slough - S. Baker Interchange

4.2.4 Forge Rd.-Lobert Rd.

4.2.4.1 ODOT Tests

Extraction results showed the individual gradation of the six samples all exceeded the upper broadband limit significantly at a minimum of one gradation control point (Figure 4.11). The average gradation for the six samples closely follows the upper limit of the mix design. Only at the 6.25 mm (1/4 inch) and 2 mm (No. 10) control points is the upper limit exceeded by 2.3% and 0.5%, respectively (Figure 4.12).

Asphalt content of the eight samples varied from 4.7 to 5.8% with an average of 5.0%. The average asphalt content fell below the lower design limit by 0.5%. Only one of the samples was within the design asphalt range while the remaining five fell below the minimum design asphalt (Table 4.3). The void content for the cores tested by ODOT ranged from 10.4 to 17.3% with an average of 14.1% (Table 4.10).

4.2.4.2 OSU Tests

The void content for the cores tested by OSU ranged from 10.3 to 15.5% with an average of 13.0% (Table 4.11). The sample tested in the ECS dropped to 70% of its original modulus after the second cycle and had 10-20% visual stripping on aggregate faces (Figure 4.13). This project should expect to exhibit stripping.

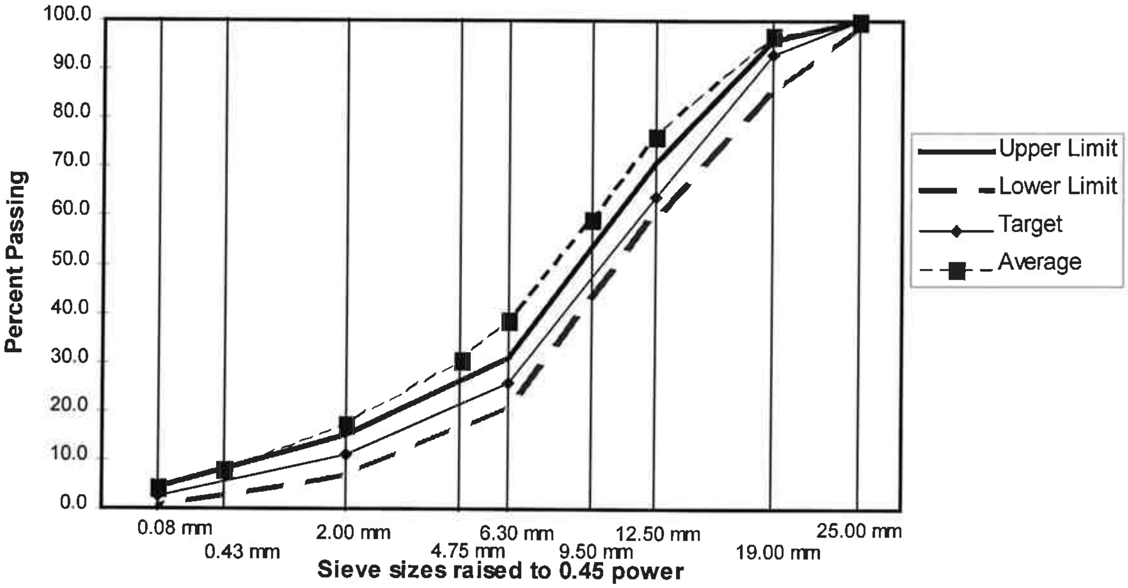


Figure 4.11: Extraction Results for Forge Rd.- Lobert Rd.

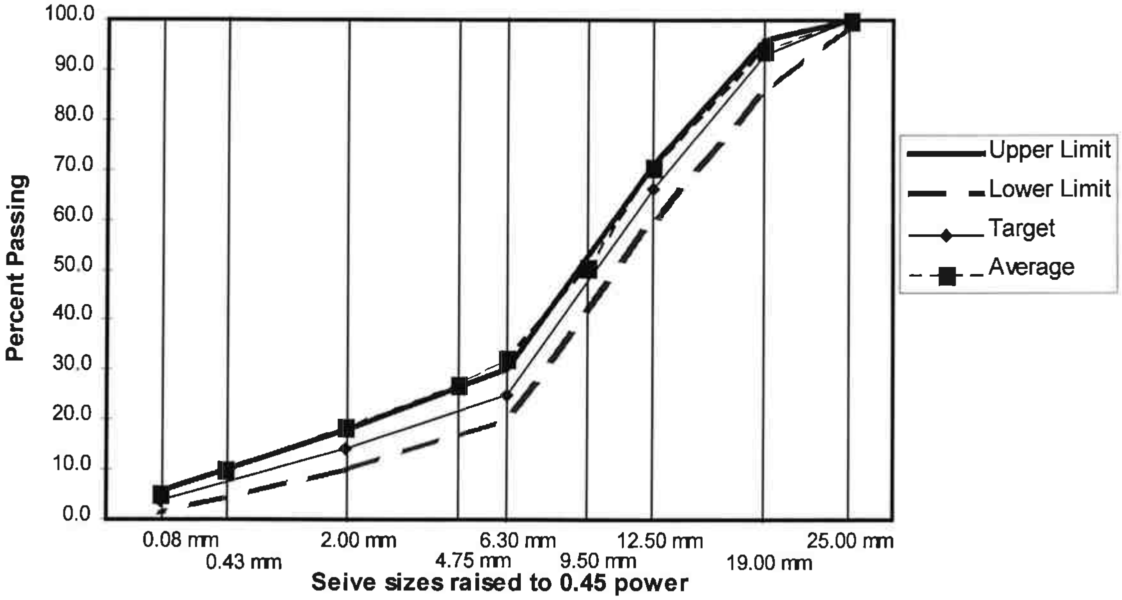


Figure 4.12: Average Extraction for Forge Rd.-Lobert Rd.

Table 4.10: Summary Volumetrics for Forge Rd.-Lobert Rd. (ODOT)

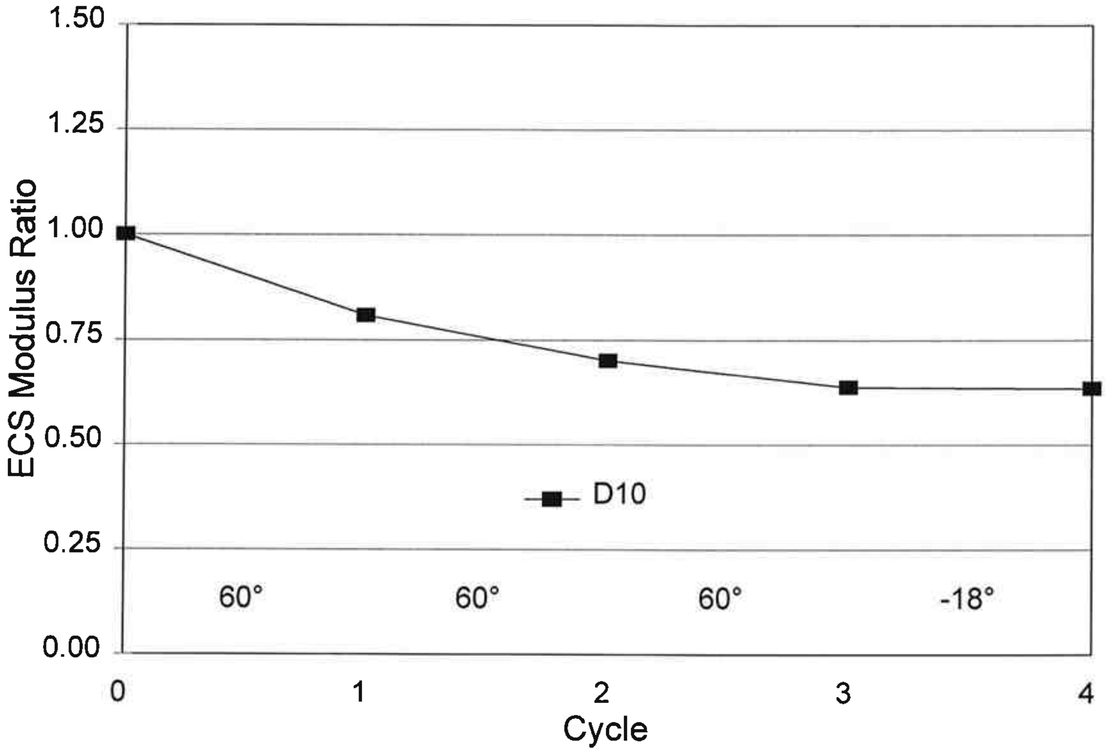
	Geometric Bulk Specific Gravity	**Maximum Specific Gravity**	**Percent Air Voids**
Minimum	2.079	2.471	10.4
Maximum	2.215	2.525	17.3
Average	2.156	2.511	14.1
Standard deviation	0.05	0.02	2.4
Coefficient of variation (%)	2.3	0.8	16.9

Table 4.11: Summary Volumetric Data for Forge Rd.-Lobert Rd. (OSU)

	Parafilm Bulk Specific Gravity	**Percent Air Voids**
Minimum	2.130	10.3
Maximum	2.237	15.5
Average	2.183	13.0
Standard deviation	0.03	1.5
Coefficient of variation (%)	1.5	11.9

Forge Rd. - Lobert Rd.
Additives: Lime (1.0%)
Asphalt: McCall AC-20 (R) (6.0%)

Specimen ID	ECS System	Air Voids (%)	Cond. Cycle	ECS Stress (psi)	ECS Strain (micro)	ECS MR (ksi)	ECS MR Ratio	Visual Stripping (%)
D10	C	14.1	0	30.0	101.1	297	1.00	10-20
			1	24.4	101.9	240	0.81	
			2	21.0	101.1	208	0.70	
			3	19.1	100.8	189	0.64	
			4	18.9	100.3	188	0.63	



ECS Modulus Test Results

Figure 4.13: ECS Results for Forge Rd. - Lobert Rd.

4.2.5 Azalea-Jumpoff Joe

4.2.5.1 ODOT Tests

Extraction results showed the individual gradation of the eight samples all exceeded the upper broadband limit significantly at a minimum of two gradation control points (Figure 4.14). The average gradation for the eight samples tested first exceeds the upper control point at 6.25 mm (1/4 inch) sieve by 3.6%. It is 3.6% above on the 2 mm (No. 10) upper limit, and is at the upper limit of the 0.075 mm (No. 200) control point (Figure 4.15).

Asphalt content of the eight samples varied from 4.6 to 5.3% with an average of 5.1%. The average asphalt content fell below the lower design limit by 0.3%. All of the samples were under the lower design limit of 5.4% (Table 4.3). The void content for the cores tested by ODOT ranged from 6.0 to 17.4% with an average of 12.9% (Table 4.12).

4.2.5.2 OSU Tests

The void content for the cores tested by OSU ranged from 8.7 to 12.5% with an average of 10.9% (Table 4.13). The sample tested in the ECS dropped to 75% of its original modulus after the first cycle and reduced to 50% after the second cycle. The visual stripping of the sample after the fourth cycle revealed 5-10% of the aggregate faces were stripped (Figure 4.16). This project may exhibit stripping in the distant future; however, because it is in western Oregon and does not experience severe freeze-thaw action, the stripping will be slow to develop.

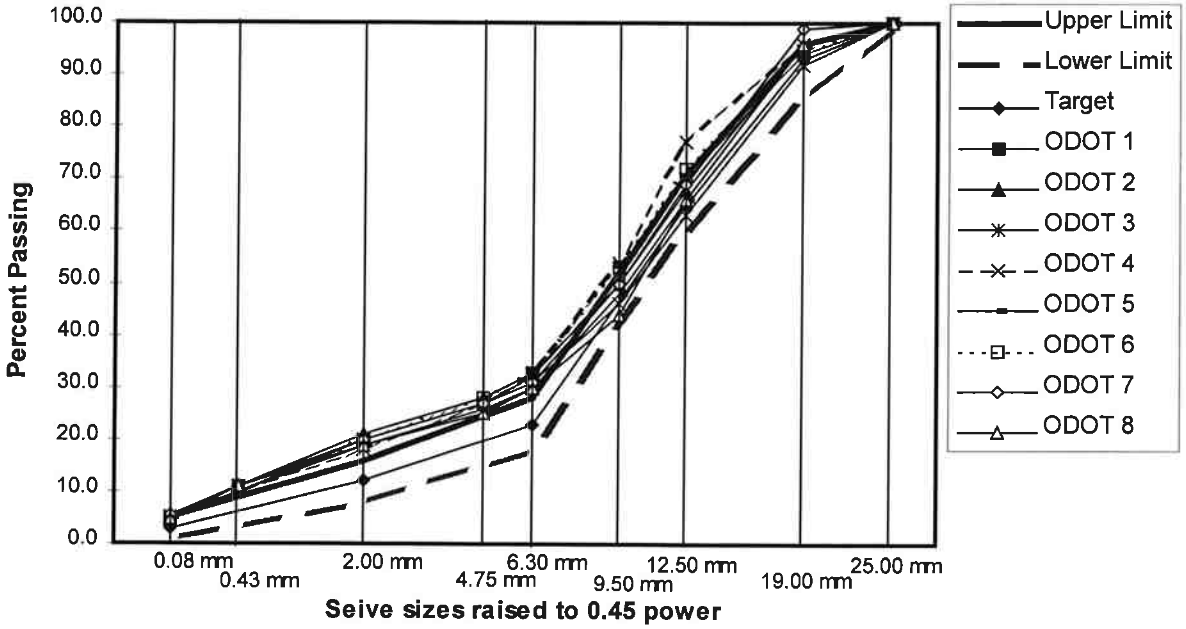


Figure 4.14: Extraction Results for Azalea-Jumpoff Joe

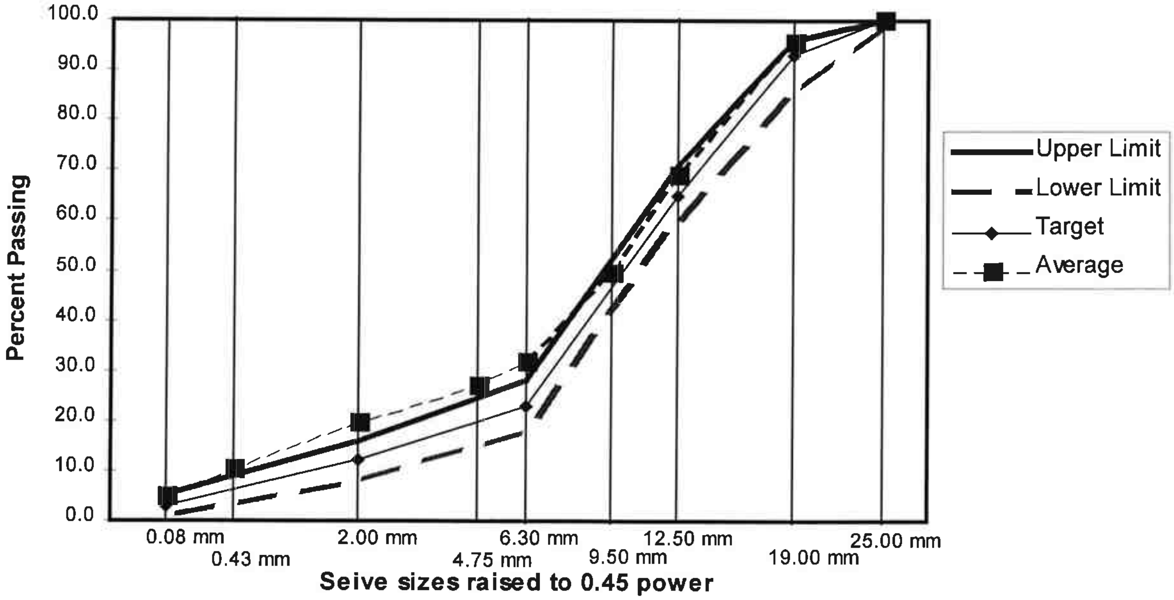


Figure 4.15: Average Extraction Results for Azalea-Jumpoff Joe

Table 4.12: Summary Volumetrics for Azalea-Jumpoff Joe (ODOT)

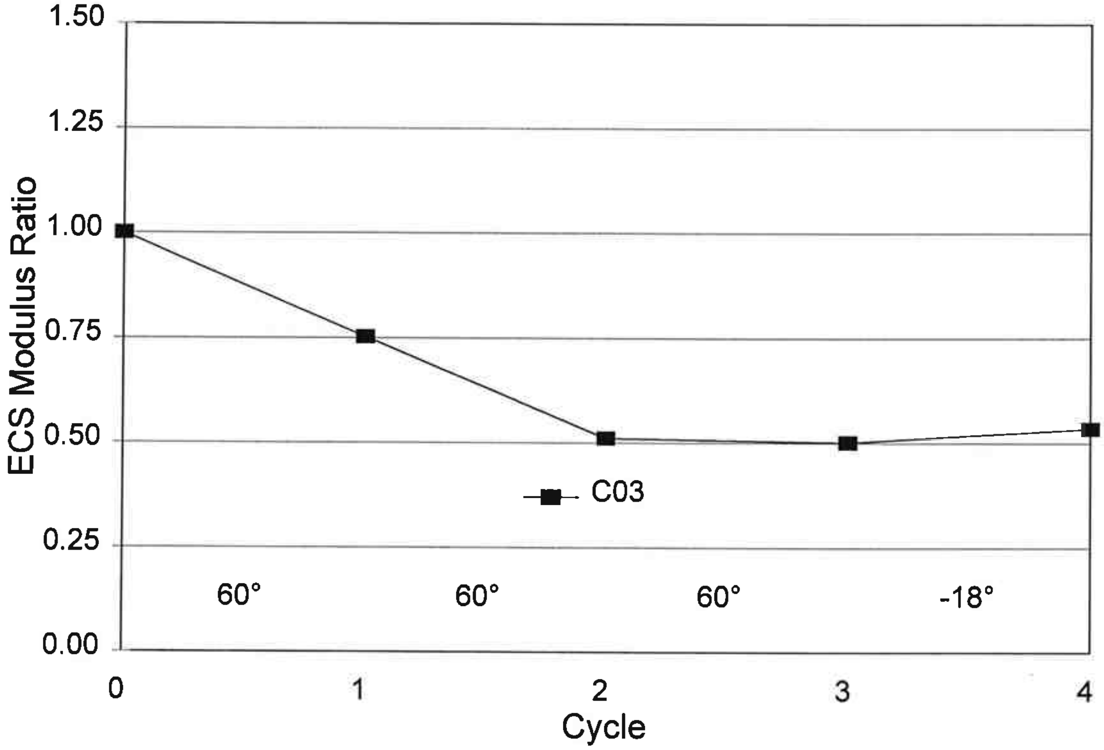
	Geometric Bulk Specific Gravity	Maximum Specific Gravity	Percent Air Voids
Minimum	2.214	2.447	6.0
Maximum	2.380	2.680	17.4
Average	2.269	2.610	12.9
Standard deviation	0.05	0.10	4.3
Coefficient of variation (%)	2.3	3.9	33.4

Table 4.13: Summary Volumetric Data for Azalea-Jumpoff Joe (OSU)

	Parafilm Bulk Specific Gravity	Percent Air Voids
Minimum	2.283	8.7
Maximum	2.382	12.5
Average	2.326	10.9
Standard deviation	0.03	1.1
Coefficient of variation (%)	1.2	9.9

Azalea - Jumpofff Joe
Additives: Lime
Asphalt: Chev PBA-6 (5.6%)

Specimen ID	ECS System	Air Voids (%)	Cond. Cycle	ECS Stress (psi)	ECS Strain (micro)	ECS MR (ksi)	ECS MR Ratio	Visual Stripping (%)
C03	C	10.6	0	15.6	99.1	158	1.00	5-10
			1	11.9	100.1	119	0.75	
			2	8.1	100.7	81	0.51	
			3	7.9	100.2	79	0.50	
			4	8.5	100.4	84	0.53	



ECS Modulus Test Results

Figure 4.16: ECS Results for Azalea - Jumpoff Joe

4.2.6 Halsey Interchange-Lane County Line

4.2.6.1 ODOT Tests

Extraction results showed the gradation of about half of the samples crossed the upper limit by more than 5% at the 8.3 mm (1/3 inch) and 6.25 mm (1/4 inch) control points (Figure 4.17). The average gradation for the 11 samples does not display this well because the other half of the samples were within the upper limit. The average gradation for the 11 samples tested first exceeds the upper control point at 12.5 mm sieve by 2.2%. As the average gradation continues through the control points, it is 4.1% above the 6.25 mm (1/4 inch) control point and falls back into the design limits by the No. 10 control point (Figure 4.18).

The asphalt content of the samples varied from 5.0 to 6.1% with an average of 5.7%. Only one of the samples fell below the lower limit of 5.4% while the remaining ten were within the design asphalt content limits (Table 4.3). The void content for the cores tested by ODOT ranged from 5.3 to 14.6% with an average of 10.6% (Table 4.14).

4.2.6.2 OSU Tests

The void content for the cores tested by OSU ranged from 8.5 to 16.0% with an average of 11.9% (Table 4.15). The sample tested in the ECS never fell below the initial modulus but did have 5-10% visual stripping (Figure 4.19).

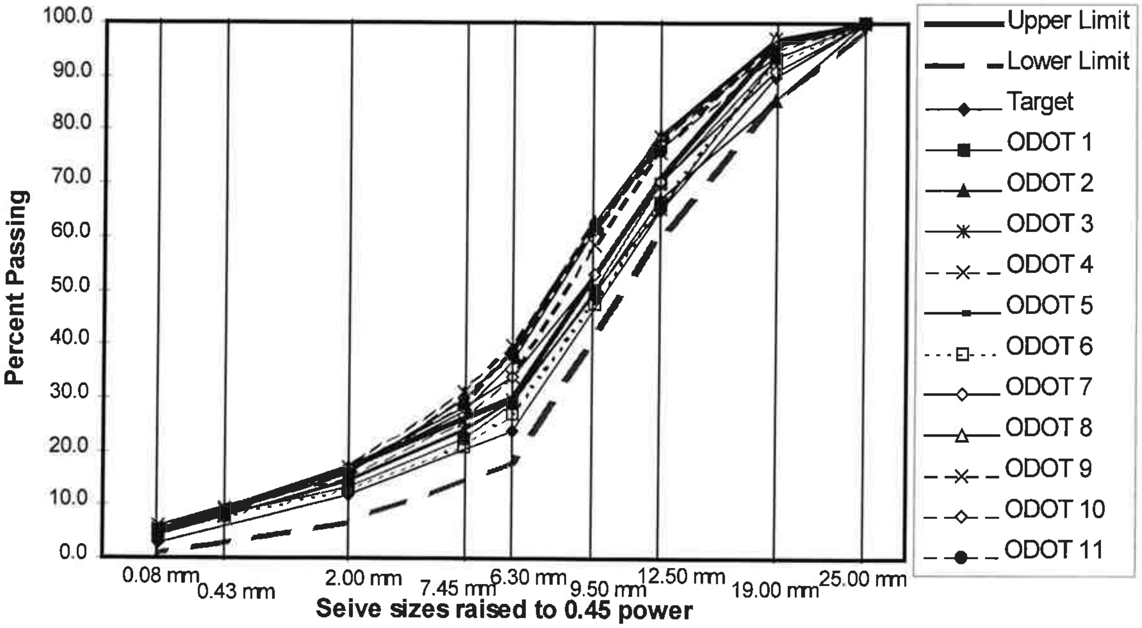


Figure 4.17: Extraction Results for Halsey Interchange-Lane County Line

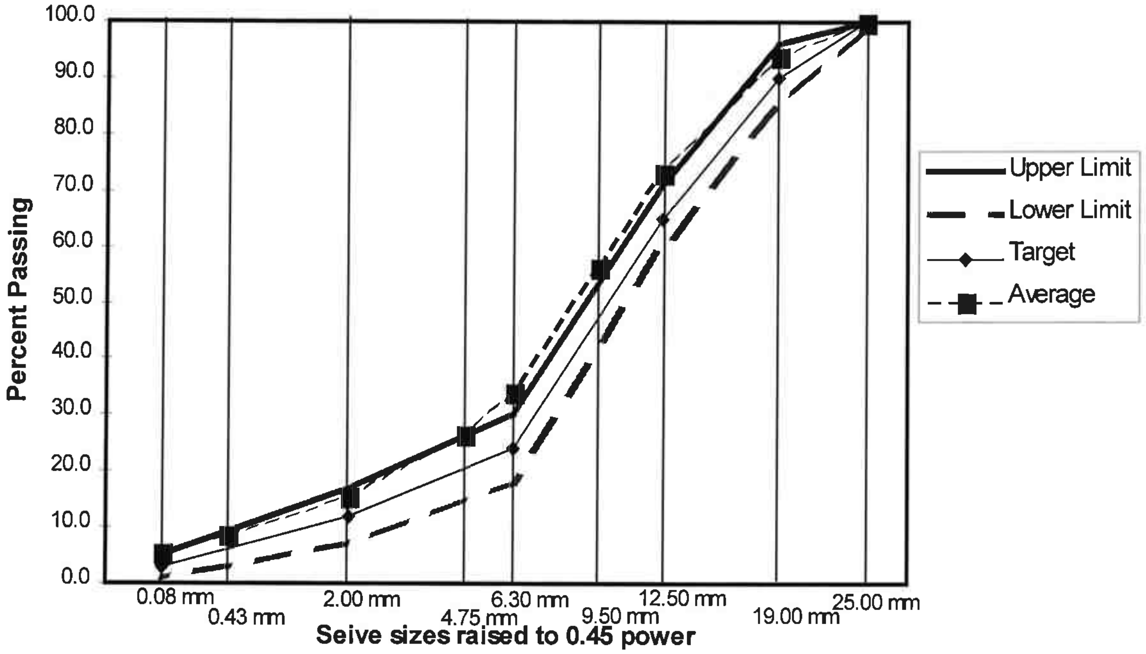


Figure 4.18: Average Extraction Results for Halsey Interchange-Lane County Line

Table 4.14: Summary Volumetrics for Halsey Interchange-Lane County Line (ODOT)

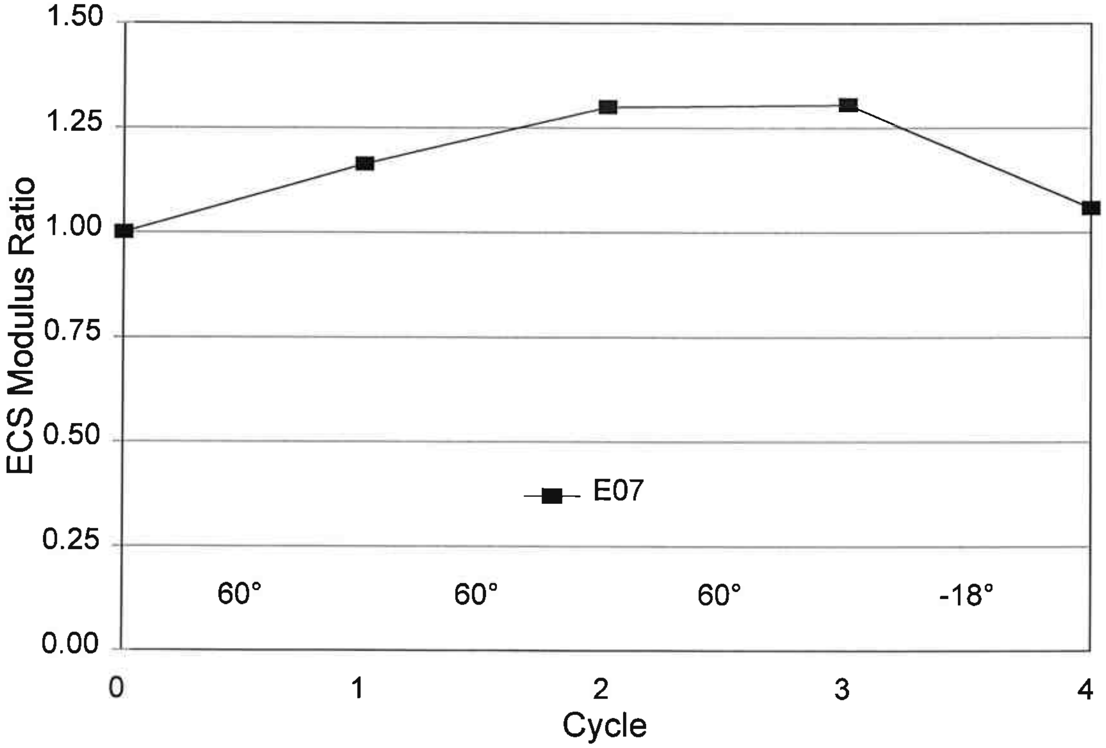
	Geometric Bulk Specific Gravity	Maximum Specific Gravity	Percent Air Voids
Minimum	2.119	2.420	5.3
Maximum	2.309	2.493	14.6
Average	2.192	2.453	10.6
Standard deviation	0.06	0.03	2.8
Coefficient of variation (%)	2.7	1.0	26.6

Table 4.15: Summary Volumetric Data for Halsey Interchange-Lane County Line (OSU)

	Parafilm Bulk Specific Gravity	Percent Air Voids
Minimum	2.034	8.5
Maximum	2.258	16.0
Average	2.148	11.9
Standard deviation	0.15	2.2
Coefficient of variation (%)	3.1	18.4

Halsey Inter. Lane County
Additives: Lime
Asphalt: Albina PBA-6 (5.8%)

Specimen ID	ECS System	Air Voids (%)	Cond. Cycle	ECS Stress (psi)	ECS Strain (micro)	ECS MR (ksi)	ECS MR Ratio	Visual Stripping (%)
E07	C	13.9	0	13.7	100.8	136	1.00	5-10
			1	15.9	100.6	158	1.16	
			2	17.7	100.4	177	1.30	
			3	17.8	100.5	177	1.31	
			4	14.4	100.2	144	1.06	



ECS Modulus Test Results

Figure 4.19: ECS Results for Halsey Interchange - Lane County

4.3 DISCUSSION

The following is an evaluation of the results from the lab study for each of the projects:

1) Wolf Creek-W. Fork Dairy Creek — This project had extensive fat spots. The aggregate gradation is finer and the asphalt content is higher than specified. The haul distance for this job was 90 km (56 miles), which may have contributed to the drain down and the fat spots. It does not explain the finer gradation, which contributed to the low voids. The ECS test results suggest that the fat spots are a drain down problem and not a stripping one.

2) Rufus-Arlington — Although this project was in relatively good condition, it did not conform to the F-mix gradation. This explains the relative low air voids found along the project length. The results of the ECS tests indicate the mix was resistant to stripping. There is no clear explanation for the stains along a portion of the project.

3) Baldock Slough-S. Baker Interchange — This project experienced some isolated stripping at select sites on the project. The average gradation for the mix was on the fine side of the gradation curve and the voids low. Although the mix did not have a significant reduction in its ECS modulus value, the visual stripping indicates the mix is sensitive to moisture.

4) Forge Rd.-Lobert Rd. — This project was one of the two experiencing stripping problems. It is a heavy traffic site in a severe climate. The mix contains hydrated lime as an anti-strip agent. Again the mix tends to be on the fine side and the asphalt content was lower than the target value. Although the void content averaged 15.5%, the ECS test shows a significant drop in ECS modulus and a high amount of visual stripping confirming a moisture sensitivity problem.

5) Azalea-Jumpoff Joe — This project was in fair condition; however, a portion of it did not seem to offer the splash and spray benefit. The gradation again was on the fine side of the F-mix bar and the void content was low. Also, a fog seal was applied to sections of this project which helps explain the poor splash and spray properties for this mix. The mix appears sensitive to moisture damage; however, at the time of this report (1996), there was no evidence of moisture damage in the field.

6) Halsey Interchange-Lane County Line — This project is experiencing the problem of shoving in the southbound truck lane. The northbound lanes, which contain a different asphalt and mix design, are not showing any problems. The extraction results show half of the samples meet the target gradation and half did not, suggesting a segregation problem. The ECS results showed that the mix is not moisture sensitive.

4.4 SUMMARY

In general, the laboratory study indicated all of the mixes were generally finer than the mix design gradation. The asphalt content for the cores tested showed two projects had high asphalt contents, two projects had low values, and two were within the design specifications. The samples tested in the ECS indicated the water sensitivity of the two known problem mixes and another mix was also shown to potentially have a water sensitivity problem.

In specific, the following emerged from the results of the laboratory study:

1) Sampling at the cold feed may not be adequate to control the gradation of the open-graded mixes because the gradation of the cores tend to be on the fine side of the broadband.

2) Segregation may be an issue with the open-graded mixes leading to isolated fat spots and raveled areas.

3) Water sensitivity of mixes (treated with lime) did not appear to be a major problem. However, there may be isolated areas (e.g., Forge Rd.-Lobert Rd.) where lime is not present due to poor mixing.

4) Additional study projects may be required to link the exact causes of the problems observed to gradation, asphalt and moisture content.

5.0 EVALUATION OF FINDINGS

The purpose of this chapter is to evaluate information from the literature review, the field survey, and the laboratory study, to recommend which factors affect performance, determine which factors should be controlled during production, and to develop improved F-mix pay factors. The sections detailed below present an evaluation of the data.

5.1 FACTORS AFFECTING PERFORMANCE

The factors affecting performance were first identified through the literature review and expert survey. These factors were then further explored by conducting a field survey and laboratory evaluation of projects in Oregon. Follow-up interviews with agencies and experts were made to further refine the recommendations, and QC/QA data were analyzed to see if the findings were consistent with previous work.

5.1.1 Literature Review and Expert Survey

Asphalt Content. This factor was found to be an important one, affecting the performance of porous pavements. Too much asphalt caused fat spots and rutting while too little asphalt led to raveling.

Asphalt Type. Many researchers are addressing the issues with asphalt type by improving the rheological properties of the asphalt binder.

Aggregate Gradation. This factor has contributed to a number of performance issues, including fat spots *(Page 1993)*; loss of permeability *(Smith 1992; Gemayel and Mamlouk 1993*); clogging *(Colwill et al. 1993; Page 1993; Younger, Hicks and Gower 1994)*; air voids *(Gemayel and Mamlouk 1993)*; and mix stiffness *(Gemayel and Mamlouk 1993*). According to the literature, aggregate type can contribute to minimizing raveling.

Aggregate Moisture. This was an important factor influencing pavement performance according to the survey responses. Generally speaking, too much moisture causes boiling of the asphalt and contributes to fat spots in the mixture.

In summary, the survey responses and recent literature suggest that asphalt content and aggregate gradation are the most important factors related to performance of porous pavement. Raveling tends to be the biggest problem followed by fat spots. To a large degree, these are both related to asphalt content. Potential for improvements may lie in the use of asphalt containing modifiers, close controls on the binder and mix temperatures, and development of improved mix design procedures.

5.1.2 Field Survey and Laboratory Evaluation

The results of the field survey and the laboratory test program suggest that asphalt content and aggregate gradation may affect the short-term and long-term performance of F-mixes. Higher asphalt contents may lead to fat spots and rutting. Lower asphalt may lead to raveling. Although the aggregate gradation for most of the projects sampled tended to be finer than the job mix formula, there is no conclusive evidence to suggest the finer mixes contributed to any of the problems.

The field survey and laboratory test program were also not clear with respect to importance of mix moisture on performance. Projects which reported high moisture content showed no visible problems in the field. ODOT has relaxed the current mix moisture requirement and this decision is generally consistent with the study's findings.

5.1.3 Follow-up Interviews

Follow-up interviews were conducted to explore further some of the initial findings from the literature review, field survey, and expert survey. The interviews allowed practitioners to react to initial findings so that their opinions could be further incorporated into the final recommendations. Follow-up interviews were conducted with ODOT maintenance personnel and with several state agencies having the most experience with porous pavements. In addition, feedback was solicited from contractors at a meeting of the Asphalt Pavement Association of Oregon (APAO) Board of Directors meeting in Newport, Oregon.

Maintenance personnel from Clackamas, Medford, and The Dalles were also interviewed in the follow-up study. General comments indicated that F-mixes were performing well in these areas. When questioned about performance problems with F-mixes, those interviewed commented on issues such as a lack of drainage due to the fog seals, or clogging (water can collect and freeze, causing cracking and black ice); fat spots (excess asphalt); raveling; and damage due to snow plows and studded tires. Comments concerning fat spots and raveling were consistent with the findings from the field survey.

At the Newport APAO meeting, the contractors were asked, "What are the most important short- and long-term performance problems in F-mixes?" Their opinions included:

1) Haul Temperature. In many instances, it is necessary to run the plant hotter than normal to deal with longer haul distances.

2) Fat Spots. Asphalt content is critical to this type of distress.

3) Mix Design Process. The current process needs to be improved since contractors will soon start doing mix design; the inherent variability in the process needs to be reduced.

4) Smoothness. Some concern was expressed over the need for a smoothness requirement.

5) Night Time Work. Problems are worse at night due to lower temperatures. Segregation is worse at night.

Many of these issues are actually production issues and are discussed in more detail in the next section.

5.2 FACTORS TO CONTROL DURING PRODUCTION

Like the factors affecting performance, factors that need to be controlled during production were first identified through the literature review and expert survey. These factors were subsequently further explored through a field survey and laboratory evaluation of projects in Oregon. Finally, follow-up interviews with agencies and experts were done to refine the recommendations, and QC/QA data was analyzed to see if findings were consistent with previous work.

5.2.1 Literature Review and Expert Survey

In reviewing the literature on factors that need to be controlled during production, it is important to remember that the primary concern is process control (quality control), not quality assurance. Process control is the responsibility of the contractors and is the means by which they insure that they are laying a high quality pavement. Quality assurance, on the other hand, is the means by which the agency (ODOT) verifies contractor process control testing and independently inspects the pavement to confirm that the contractor is laying a high quality pavement.

Table 2.4 presented the factors used for quality control as well as the pay factors for three states: Florida, Nevada, and Oregon. All three states specify that quality control should apply to aggregate gradation and asphalt content. However, these agencies do vary on which sieve sizes they believe to be important.

5.2.2 Field Survey and Laboratory Evaluation

Based on these studies, it was shown that several of the projects sampled were out of specification on both gradation and asphalt content. Unfortunately, with a sample size of only six projects, it is difficult to link clearly the relationship between gradation and asphalt content to performance. However, if the job mix formula is the desired target, then the observed variations about the target could have contributed to the observed performance problems. The out of specification jobs tended to result in lower air voids, isolated fat spots and rutting, and diminished splash and spray characteristics.

5.2.3 Follow-up Interviews and QC/QA Data

Initial findings concerning performance factors and production factors indicated that aggregate gradation and asphalt content are critical to the performance of porous pavements. However, there were several other issues identified for which there was not a clear consensus. These included ambient temperature, mix temperature, maximum haul distance or haul time, maximum storage time, and equipment used. It was important to conduct follow-up interviews to determine if the experts felt these factors were important. Table 5.1 summarizes the results of these follow-up interviews.

Table 5.1: Results from Follow-up Interviews with Selected Agencies

Factor	Florida (Gale Page)	Nevada (Rudy Edgington)	Texas (Maghsoud Tahmoressi)	Washington (Robyn Moore)
Ambient temperature	15.6°C and rising	15.6°C ambient 15.6°C surface	21.1°C and rising	15.6°C
Compliance notes	none	no night paving in northern region	restricted paving season	typically avoid night paving
Mix temperature	143.3°C with rubber 115.6°C w/out rubber	none provided	82.2-126.7°C in specs 121.5-132.2°C in practice	Max 126.7°C
Taken at plant?	yes	Yes	yes	yes
Taken at paving site?	yes	Yes	no	no
Compliance notes	removed if out of specification	none provided	no difficulties	no difficulties
Maximum haul distance or haul time	no restrictions	no restrictions	no restrictions, probably good idea	no restrictions
Maximum storage time	1 hour in silo	no restrictions	no restrictions	24 hours
Equipment requirements	No restrictions	no restrictions	Insulated trucks to maintain temperature	no restrictions

According to Texas DOT, excess mix moisture is the cause of many problems. However, it is not used as a pay factor because the measurements taken with the oven method are not reliable. Oregon uses both microwave and conventional ovens (see Table 3.5).

Other states seem to have strict enforcement of the ambient temperature restrictions (e.g., no night time paving where the temperature may be below 16°C (60°F)). At the June 1996 Technical Advisory Committee meeting, members suggested that in Oregon (due to increased layer thicknesses), this criteria is not as critical for Oregon F-mixes (e.g., lower ambient temperatures may be permitted).

The issues related to mix temperature and haul time/distance are closely related. Process control could be established by placing limits on haul time and/or haul distance, or by requiring mix temperature readings at both the production plant and at the paving site. Florida and Nevada handle it this way.

Follow-up interviews with other contractor and agency personnel who are familiar with the production of porous pavements in Oregon indicated that, while the appropriate testing is taking place, the contractors are not typically using control charts to make effective decisions based on data. Contractor process control data were not available for analysis, but ODOT quality assurance data were available. For all of the projects where there was a sufficient amount of QA test results, the researchers charted the data as though they were QC data to determine how often the data would have indicated a need to consider corrective action. Table 5.2 indicates the projects and factors for which charts were created.

The charts are provided in Appendix D. On the charts, an "X" indicates that a corrective action might be necessary. In reviewing these charts, the reader must realize that the charts use control limits and not specification limits to determine when corrective action might be necessary. It is desirable for the control limits to be within the specification limits. Table 5.3 indicates whether the control limits were within the specification limits for each of the projects and factors charted.

Table 5.2: Projects and Factors for which Control Charts were Made

Project	12.5 mm (1/2")	6.25 mm (1/4")	2 mm (#10)	0.075 mm (#200)	Asphalt Content	Moisture Content
Hayesville - Battle Creek	X	X	X	X	X	X
W. Marquam - N. Tigard	X	X	X	X	X	X
Wolf Cr. - W. Fork Dairy Cr.	X	X	X	X	X	X
Corbett Intch. – Multnomah	X	X	X	X	X	X
Rufus - Arlington (West Unit)	X	X	X	X	X	X
Rufus - Arlington (East Unit)	X	X	X	X		X
E. Pendleton - Emigrant Hill						
Lot 2B	X	X	X	X	X	X
Baldock Slough - S. Baker						
Lot 1	X	X	X	X	X	X
Forge Rd. - Lobert Rd.	X	X	X	X	X	X
Jumpoff Joe - N. Grants Pass						
Lot 1	X	X	X	X		X
Lot 2	X	X	X	X	X	X
Azalea - Jumpoff Joe	X	X	X	X	X	X
Halsey Intch. - Lane Co. Line						
Lot 3	X	X	X	X		X
Lot 4	X	X	X	X		X

As the table shows, control limits were outside the specification limits 93% of the time for the 12.5 mm (1/2 in.) sieve, 64% of the time for the 6.25 mm (1/4 in.) sieve, 7% of the time for the 2 mm (#10) sieve and the 0.75 mm (#200) sieve, 50% of the time for asphalt content, and 36% of the time for moisture content. If processes are effectively managed using statistical process control, control limits should <u>not</u> be outside specification limits.

Table 5.3: Were Control Limits within Specification Limits?

Project	12.5 mm (1/2")	6.25 mm (1/4")	2 mm (#10)	0.075 mm (#200)	Asphalt Content	Moisture Content
Hayesville - Battle Creek	No	No	Yes	Yes	No	Yes
W. Marquam - N. Tigard	No	Yes	Yes	No	No	Yes
Wolf Cr. - W. Fork Dairy Cr.	No	No	Yes	Yes	No	No
Corbett Intch. - Multnomah	No	No	Yes	Yes	Yes	No
Rufus - Arlington (West Unit)	No	Yes	Yes	Yes	Yes	Yes
Rufus - Arlington (East Unit)	No	Yes	Yes	Yes	—	No
E. Pendleton - Emigrant Hill						
Lot 2B	No	No	Yes	Yes	No	Yes
Baldock Slough - S. Baker						
Lot 1	No	No	Yes	Yes	Yes	Yes
Forge Rd. - Lobert Rd.	No	Yes	Yes	Yes	No	No
Jumpoff Joe - N. Grants Pass						
Lot 1	No	No	No	Yes	—	Yes
Lot 2	No	No	Yes	Yes	Yes	Yes
Azalea - Jumpoff Joe						
Lot 2	Yes	No	Yes	Yes	Yes	Yes
Halsey Intch. - Lane Co. Line						
Lot 3	No	No	Yes	Yes	—	Yes
Lot 4	No	Yes	Yes	Yes	—	No
Summary (No/Yes)	13/1	9/5	1/13	1/13	5/5	5/9

The purpose of process control is to collect information on the porous mixture to be able to make effective decisions based on data. Variations exist in everything: the aggregate, the asphalt, the equipment used, the mix temperature, the personnel running the equipment, the paving conditions, and even in the testing methods used. Given all of the sources of variation in a production process, the most effective way to make decisions based on data in this setting is through the use of control charts.

Control charts allow the contractor's personnel to diagnose patterns in the data consistently so that corrective actions can be taken in a timely fashion. Each point graphed on the control chart should be an average of at least two numbers (tests). This can best be accomplished by taking two samples from a sublot, testing both, and averaging the test results. If this is an unacceptable approach, an alternate would be to use a moving average and a moving range chart which will not increase the amount of testing required. By following these procedures, the control charts will be more sensitive to changes in the process and will identify potential problems more quickly.

5.3 COMPARISON OF QC AND CORE DATA

Tables 5.4 through 5.8 compare the QC data (in Chapter 3) with the core results (in Chapter 4). As was mentioned previously, it is possible for the overall mean to be within specification limits (99.7% of data) while still having problems with quality due to a high standard deviation. One way to check for this problem is to compare the specification limits with the mean plus or minus three standard deviations.

In the tables, the QC data analysis considered the specification limit that was relevant to core findings. Typically, in the cases analyzed in this study the primary interest is the upper specification limit. Therefore, the tables show the upper specification limit and the mean plus three standard deviations. The only exception is Table 5.8, which considers asphalt content. In this case, some core results were over the upper specification limit and some were under the lower specification limit. Therefore, both the mean plus and minus three times the standard deviation are shown in Table 5.8.

If the processes used to produce these pavements were in states of statistical control and centered within the specification limits, one would expect that the upper specification limit would be greater than the mean plus three standard deviations, and one would expect that the lower specification limit would be less than the mean minus three standard deviations. The QC data results column describes these comparisons. For example, if the mean plus three standard deviations is greater than the specification limit, this would be consistent with a core results finding that the core average could be at the upper specification limit or could exceed it. If the QC data and core findings are consistent, this would strengthen the expected results. In other words, consistency between QC and core results means that the quality control results indicate that the core results are not surprising. Inconsistency does not imply that either result (QC data or core data) is wrong.

Table 5.4: Comparison of QC Data and Core Results for 12.5 mm Sieve

Project	QC Data						Core Results	Are Results Consistent
	Target	Mean	Standard Deviation	Upper Spec. Limit	Mean +3 Standard Deviations	QC Results		
Wolf Creek – W. Fork Dairy Creek	65	66.32	3.24	71	76.04	Since 76.04 > 71, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 6.7%	Yes
Rufus – Arlington (east unit)	65	64.83	3.55	71	75.48	Since 75.48 > 71, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 4.0%	Yes
Baldock Slough - S. Baker	64	66.86	3.07	71	76.07	Since 76.07 > 71, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 5.3%	Yes
Forge Rd. - Lobert Rd.	66	61.53	4.46	71	74.91	Since 74.91 > 71, it is likely that cores could average at the upper spec. limit.	Average is at upper spec. limit	Yes
Azalea - Jumpoff Joe (south end) Lot 1 Lot 2	66 65	61.29 62.58	1.80 3.23	71 71	66.69 72.27	If cores were taken from Lot 1, since 66.69 < 71, it is likely that cores would be within the upper spec. limit. If cores were taken from Lot 2, since 72.27 is only slightly higher than 71, the cores could average within the spec. limit.	Average is within spec. limits	Yes No
Halsey Intch. - Lane Co. Line Lot 3 Lot 4	66 66	64.75 64.21	4.28 3.14	71 71	77.59 73.63	Since 77.59 > 71 and 73.63 > 71, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 2.2%	Yes Yes

Table 5.5: Comparison of QC Data and Core Results for 6.25 mm Sieve

Project	QC Data						Core Results	Are Results Consistent
	Target	Mean	Standard Deviation	Upper Spec. Limit	Mean + 3 Standard Deviations.	QC Results		
Wolf Creek - W. Fork Dairy Creek	24	24.95	2.74	30	33.17	Since 33.17 > 30, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 3.7%	Yes
Rufus – Arlington (east unit)	25	24.53	2.39	30	31.70	Since 31.70 > 30, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 9.1%	Yes
Baldock Slough – S. Baker	26	29.21	2.01	31	35.24	Since 35.24 > 31, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 7.7%	Yes
Forge Rd. – Lobert Rd.	25	26.94	2.16	30	33.42	Since 33.42 > 30, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 2.3	Yes
Azalea – Jumpoff Joe (south end)						Since 31.18 > 25 and 33.18 > 28, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 3.6%	
Lot 1	21	26.14	1.68	25	31.18			Yes
Lot 2	23	25.41	2.59	28	33.18			Yes
Halsey Intch. - Lane Co. Line						Since 53.96 > 29 and 32.98 > 29, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 4.1%	
Lot 3	24	25.46	3.5	29	35.96			Yes
Lot 4	24	24.01	2.99	29	32.98			Yes

Table 5.6: Comparison of QC Data and Core Results for 2 mm (#10) Sieve

Project	QC Data						Core Results	Are Results Consistent
	Target	Mean	Standard Deviation	Upper Spec. Limit	Mean + 3 Standard Deviations	QC Results		
Wolf Creek - W. Fork Dairy Creek	12	12.89	1.77	17	18.20	Since 18.20 > 17, it is likely that cores could exceed the upper spec. limit.	Average exceeds upper spec. limit by 0.8%	Yes
Rufus – Arlington (east unit)	11	10.59	1.50	16	15.09	Since 15.09 < 16, it is not likely that cores could average above the spec. limit.	Average exceeds upper spec. limit by 4.7%	No
Baldock Slough – S. Baker	11	12.22	0.93	15	15.01	Since 15.01 _ 15, it is not likely that cores could average at the spec. limit.	Average exceeds upper spec. limit by 2.2%	No
Forge Rd. – Lobert Rd.	14	13.18	1.51	18	17.71	Since 17.71 < 18, it is not likely that cores could average above the spec. limit.	Average exceeds upper spec. limit by 0.5%	No
Azalea – Jumpoff Joe (south end) Lot 1 Lot 2	11 12	11.75 11.68	0.53 1.57	15 16	13.34 16.39	Since 13.34 < 15 and 16.39 _ 16, it is not likely that cores could average above the spec. limit.	Average exceeds upper spec. limit by 3.6%	No Yes
Halsey Intch. - Lane Co. Line Lot 3 Lot 4	12 12	11.63 10.37	1.86 1.33	16 16	17.21 14.36	If cores were taken from Lot 1, since 17.21 > 16, it is likely that cores could exceed the upper spec. limit. If cores were taken from Lot 2, since 14.36 < 16, cores should average within the spec. limit.	Average is at the upper spec. limit	Yes No

Table 5.7: Comparison of QC Data and Core Results for 0.075 mm (#200) Sieve

Project	**QC Data**						**Core Results**	**Are Results Consistent**
	Target	Mean	Standard Deviation	Upper Spec. Limit	Mean + 3 Standard Deviations	QC Results		
Wolf Creek - W. Fork Dairy Creek	3.0	2.73	0.37	5.0	3.84	Since 3.84 < 5.0, it is not likely that cores could average above the spec. limit.	Average exceeds upper spec. limit by 0.3%	No
Rufus - Arlington (east unit)	3.0	2.21	0.45	5.0	3.56	Since 3.56 < 5.0, it is not likely that cores could average above the spec. limit.	Average exceeds upper spec. limit by 1.0%	No
Baldock Slough - S. Baker	2.6	2.75	0.19	4.6	3.32	Since 3.32 < 4.6, it is not likely that cores could average above the spec. limit.	Average is at upper spec. limit	No
Forge Rd. - Lobert Rd.	3.6	2.91	0.60	5.6	4.71	Since 4.71 < 5.6, it is not likely that cores could average above the spec. limit.	Average is at upper spec. limit	No
Azalea - Jumpoff Joe (south end)						Since 2.92 < 5.0 and 3.58 < 5.0, it is not likely that cores could average above the spec. limit.	Average is at upper spec. limit	
Lot 1	3.0	2.23	0.23	5.0	2.92			No
Lot 2	3.0	2.26	0.44	5.0	3.58			No
Halsey Intch. - Lane Co. Line						Since 6.26 > 6.0 and 5.24 < 6.0, it is not likely that cores could average above the spec. limit.	Average is at upper spec. limit	
Lot 3	4.0	4.10	0.72	6.0	6.26			No
Lot 4	4.0	3.56	0.56	6.0	5.24			No

Table 5.8: Comparison of QC Data and Core Results for Asphalt Content

Project	QC Data								Core Results*	Are Results Consistent
	Target	Mean	Standard Deviation	Upper Spec. Limit	Mean + 3 Standard Deviations	Lower Spec. Limit	Mean – 3 Standard Deviations	QC Results		
Wolf Creek - W. Fork Dairy Creek	6.0	6.00	0.39	6.5	7.17	5.5	4.83	Since 7.17 < 6.5, it is likely that cores could be above spec., and since 4.83 < 5.5, it is also likely that cores could be below spec.	5 of 12 within spec. (5 over, 2 under)	Over-Yes Under-Yes
Rufus - Arlington (east unit)	5.5	5.42	0.24	5.9	6.14	4.9	4.70	Since 6.14 > 5.19, it is possible that cores could be above spec., and since 4.70 < 4.90, it is also possible that cores could be below spec.	2 of 9 within spec. (6 over, 1 under)	Over-Yes Under-Yes
Baldock Slough - S. Baker	5.5	5.45	0.20	5.9	6.05	5.1	4.85	Even though the control limits are outside the spec. limits, it is possible that all selected cores are within spec. limits.	3 of 3 within spec.	Yes
Forge Rd. – Lobert Rd.	6.0	5.86	0.26	6.5	6.64	5.5	5.08	Since 5.08 < 5.5, it is likely that cores could be below spec.	1 of 6 met spec. (5 under)	Yes
Azalea - Jumpoff Joe (south end) Lot 1 Lot 2	5.0 5.6	4.87 5.56	0.15 0.09	5.2 5.8	5.32 5.83	4.8 5.4	4.42 5.29	Since 4.42 < 4.8 and 5.29 < 5.4, it is possible that cores could be below spec.	0 of 8 within spec. (8 under)	Yes Yes
Halsey Intch. - Lane Co. Line Lot 3 Lot 4	6.0 5.8	— —	— —	6.4 6.2	— —	5.6 5.4	— —	Data not available.	10 of 11 within spec. (1 under)	

*See Table 4.3 for more detail.

Tables 5.4 to 5.7 also provide a direct comparison between the gradations (12.5, 6.25, 2, and 0.075 mm) for each of the six projects. These data indicate the following for each of the projects:

1) Wolf Creek-W. Fork Dairy Creek. The gradations from the cores are consistently higher than the upper specification limit for all sieve sizes. This project experienced considerable fat spots throughout its length.

2) Rufus-Arlington (east unit). The gradations for the cores are consistently higher than the upper specification limit for all sieve sizes. This project did not have any major performance problems.

3) Baldock Slough-S. Baker. The gradations from the cores exceeded the upper specification limit on all sieves but the 0.075 mm. The project exhibited some isolated areas of raveling/fat spots.

4) Forge Rd.-Lobert Rd. The core gradations were at the upper specification limit except for the 6 mm sieve (which exceeded the limit). The project exhibited some isolated areas of raveling/fat spots.

5) Azalea-Jumpoff Joe. The core gradation exceeded the upper specification limit on the 6 and 2 mm sizes. This project was low in asphalt initially, then fog sealed. It was in good condition during the surveys.

6) Halsey Intch.-Lane Co. Line. The gradation of the cores exceeded the upper specification limit on the 12.5 and 6 m sieves. This project exhibited considerable shoving in the southbound lanes.

All cores were trimmed to remove cut surfaces before extracting the asphalt and performing a gradation test. In all cases, the gradation of the cores was finer than the QC data. However, the data indicates there is no direct correlation between gradation and performance. Since all of the cores were sampled in known problem areas, further investigation is necessary to determine if controlling the aggregate at the cold feed is not adequate to ensure a specification product.

Table 5.8 provides a similar comparison between the asphalt content based on QC data and extractions from cores. The results suggest the following for each of the projects:

1) Wolf Creek-W. Fork Dairy Creek. Five of the 12 extractions were within specification (five over and two under). This, combined with the finer gradation, may have contributed to some of the observed problems.

2) Rufus-Arlington (east unit). Only two of the nine core extractions were within specification (six over, one under). The higher asphalt content and finer gradation does not explain the good performance of this project.

3) Baldock Slough-S. Baker. All asphalt contents were within specification. This, together with the generally good gradation, could explain the good performance on the project, but does not explain the isolated areas of raveling/fat spots.

4) Forge Rd.-Lobert Rd. Only one of six core samples was within specification. All of the non-specification material was low in asphalt content. This could explain some of the isolated raveled areas, but not the fat spots.

5) Azalea-Jumpoff Joe. All core results were out of specification (low asphalt content). This was somewhat surprising since part of the project was fog sealed after construction to correct low asphalt contents during construction. This treatment was apparently sufficient to prevent early distress along the project, despite the low asphalt contents measured on the cores.

6) Halsey Intch.-Lane Co. Line. Ten of 11 cores were within specification on this project. The southbound lane (with the higher design a/c) has experienced considerable problems. The asphalt data alone does not explain the cause of the problem.

The project data, however, does show that the core results are often out of specification. This suggests the QC program needs to be reevaluated. Control of the aggregate at the cold feed and the asphalt using plant meters may not be adequate. Equally important, the limited data set show no correlation between gradation and asphalt content and field performance. This, however, does not mean these factors are not related to field performance. Other factors such as field moisture content, mix temperature, and haul distances may have contributed to some of the observed problems.

5.4 DEVELOPMENT OF IMPROVED F-MIX PAY FACTORS

F-mix pay factors were first identified through the literature review and expert survey. An operating characteristic (OC) curve analysis was then performed to help evaluate the distribution of risk between buyer and seller. This section presents the recommendations for new weighting factors for F-mixes.

5.4.1 Factors to Include

After collecting information from the literature, the expert survey, and follow-up interviews, findings indicate that asphalt content and aggregate gradation are critical pay factors. The key question with gradation, though, is which sieve sizes to include. Initially, a reduction in the number of sieve sizes used was considered, but feedback in the follow-up interviews suggested that this was not a good idea. Reducing the sieve sizes monitored would lead to increased variability in the final product. Next, adding 0.425 mm (#40) as a pay factor was considered. The QA data indicates that contractors are consistently meeting the specifications for 2 mm (#10) and 0.075 mm (#200) so it seems unnecessary to reintroduce the 0.425 mm sieve.

Moisture is important but commonly used methods of moisture content measurement are not reliable. The pay factor should also reflect the variability in the test method. Furthermore, the upper limit of 0.8% does not appear to relate to field performance (Note: the upper limit for moisture content is currently 1.10%). This issue may need further investigation.

Mix temperature is also very important. However, no state agency currently uses this as a pay item. Initial reaction to including mix temperature as a pay factor was negative, but this reaction seemed to be linked to the difficulty of administering the requirement rather than lack of agreement that it is important enough to include. It seems to make sense to include both mix and laydown temperatures, and to require the contractor to maintain process control charts for these factors, and to use their data to determine the pay factor for this component. It could be an additional step toward payment based on contractor process control data.

The most critical change that must be made is to eliminate compaction as a pay factor for open-graded mixes. This is because the contractor currently receives 100% pay for an item not controlled. As a result, it will be necessary to change the factor weightings for the remaining factors. This is discussed in a later section of this chapter.

5.4.2 OC Curve Analysis of Pay Factor Schedule

Some amount of uncertainty is always present in the calculation of pay adjustments. Not only is there inherent variability in the sampling process, but there will be some error in the measurement as well. Operating characteristic (OC) curves can be used to evaluate the distribution of risk between buyer and seller.

Weed has developed an interactive software package, OCPLOT, to assist in OC curve analysis of pay adjustment for road construction *(Weed 1995)*. Because OCPLOT requires a pay adjustment equation, an equation was estimated from Oregon's pay schedule. Three equations were estimated and analyzed using OCPLOT, for sample sizes 5, 10, and 70. Although the results of the analyses vary with sample size, for every sample size OCPLOT found ODOT's schedule to be unduly generous in providing bonuses. For example, with a sample of 70, the following expected pay factors were computed:

Percent Defective		Average Pay Factor
0		1.05
5	--- Acceptable Quality Level (AQL) ---	1.027
10		0.995
15		0.959
20		0.919
25		0.878
30		0.841
35	--- Rejectable Quality Level (RQL) ---	0.805
40		0.762

Notice that for material that is just at the AQL of 5% defective, an average pay factor of 1.027 can be expected. In other words, almost 3% bonus will be paid for work that should receive only the contract price. With smaller sample sizes, the discrepancy is greater. These three estimated pay equations and their calculated pay factors are provided along with the pay factors from ODOT's schedule in Appendix E. Also provided are the OCPLOT results.

These results are consistent with findings on analyzing the federal schedule of pay adjustment, which was the basis for Oregon's schedule *(Weed 1995)*. The FHWA (WFLD) revised its pay adjustment schedule for its 1992 specifications. Oregon DOT evaluated the new pay schedule, but decided not to adopt it. Other changes in the new schedule include the requirement for larger sample sizes for full bonus potential, the addition of category II pay factors for constituents with less impact on performance, and a lower AQL.

5.4.3 Factor Weights in Composite Pay Factor Calculation

In calculating the composite pay factor (CPF) for asphalt pavement, Oregon weighs the compaction value at 40%. For F-mixes, the practice has been to assign a value of PF = 1.0 for compaction. The effect is to narrow the range of pay factors from 0.85 to 1.03, instead of 0.75 to 1.05, as for dense-graded mixes with the same level of defects. This limits both the possible penalty and bonus.

ODOT's acceptance policy provides that the agency can require the contractor to remove, at the contractor's expense, material for which the CPF is lower than 0.75. Because the rejection criteria is based on CPF rather than percent within limits or percent defective, the error associated with setting the compaction PF equal to 1 could result in accepting material that falls below rejectable quality level. For instance, if all other constituents receive pay factors just below 0.75, the compaction pay factor could pull the CPF above rejection level.

Oregon should use individual factors for aggregate gradation, asphalt content, and moisture to calculate the composite pay factor. Reducing the number of sieves monitored could lead to increased variability in the final product. It is suggested that ODOT explore the possibility of including mix temperature as a factor in the near future. Three alternatives are given. Initially, the composite pay factor would not include temperatures, and the recommended weights for the constituent factors would be as listed in Table 5.9.

Table 5.9: Recommended Initial Pay Factors.

Constituent	Existing Weight	Recommended Weights		
		Alternative 1	Alternative 2	Alternative 3
1" (25 mm)	1	0	0	0
3/4" (19 mm)	1	9	12	5
1/2" (12.5 mm)	1	9	12	5
1/4" (6.25 mm)	5	15	12	15
#10 (2 mm)	5	15	12	15
#40 (0.425 mm)	3	0	0	0
#200 (0.075 mm)	10	15	12	20
Moisture content	8	9	9	10
Asphalt content	26	28	31	30
Compaction	40	0	0	0

5.4.3.1 Basis for Alternative 1

Asphalt content has been consistently shown to impact pavement performance. Survey results indicate that it was the most significant factor contributing to performance. Analysis of the QC data indicated mixed results in achieving specifications for asphalt content, and core results indicated difficulties with asphalt content. For these reasons, a significant weight of 28% is recommended for asphalt content.

The current pay factor weights include a 1% weight for the 25 mm (1 inch) sieve. Since the QC data indicates that there is virtually no variation on this sieve, its usefulness as a pay factor is very limited. Therefore, this sieve should be eliminated in calculating the composite pay factor. It was also reasoned that the 19 mm (3/4 inch) and the 12.5 mm (1/2 inch) sieves were of minor importance compared to the 6.25 mm (1/4 inch), 2 mm (#10) and 0.075 mm (#200) sieve sizes, which were more significant.

It is recommended that the weights be adjusted to encourage contractors to increase their process capability. The 19 mm (3/4 inch) and 12.5 mm (1/2 inch) factors should be increased to 9, while the more significant 6.25 mm, 2 mm and 0.075 mm sieve weights should be increased to 15. By placing a higher weight on these factors, contractors will be encouraged to monitor the processes more closely.

The 0.075 mm (#200) sieve was identified for emphasis by calculating a measure of process capability known as C_{pk}. C_{pk} is a performance index which reflects the current process mean's proximity to either the upper specification limit or lower specification limit. This statistic is calculated by the following equation:

$$C_{pk} = \min\left[\frac{\overline{X} - LSL}{3s}, \frac{USL - \overline{X}}{3s}\right] \tag{5-1}$$

where:

s = sample standard deviation
$\overline{X}$ = arithmetic mean
LSL = lower specification limit
USL = upper specification limit

A value of C_{pk} less than 1.0 indicates that one should expect more than a small percentage of the values for this factor would be outside the specification limits. Note that C_{pk} can be influenced by either changes in the numerator (shifts in the process mean) or changes in the denominator (shifts in the process standard deviation). ALL of the C_{pk} values for the 0.075 mm (#200) sieve were less than 1.0. This indicates a significant opportunity for improvement. Similarly, the 19 mm (3/4 inch) and 2 mm (#10) sieves showed some difficulties with process capabilities (some C_{pk} values less than 1.0) and, therefore, should not be removed from consideration. Details of the C_{pk} analysis are found in Appendix F.

Moisture content was listed by some survey respondents as a contributor to performance. However, commonly used methods of measuring moisture content are not reliable and there is no clear link between moisture content and performance. Therefore, a minor weight of 9% is recommended for moisture content.

In addition to making these changes in factor weights, ODOT should consider rewriting their specification to use a 5 mm (#4) sieve rather than the 6.25 mm (1/4 inch) sieve.

This change would be consistent with the practices of other states and would allow cross-state information sharing to be more effective.

5.4.3.2 Basis for Alternative 2

Alternative 1 assumes that the mix design is similar to a recipe where the quantities and combination of ingredients are critical to a quality product. There was some debate among the TAC members as to whether this was indeed the case. It was requested that a second alternative be considered that merely spread the weight that was previously assigned to compaction evenly across the other factors.

5.4.3.3 Basis for Alternative 3

This alternate places the same relative importance on gradation and asphalt content as the current pay schedule. Additional emphasis is placed on the 6.25 mm, 0.425 mm and 0.075 mm sieve as compared to Alternative 1. Alternative 3 places the most emphasis of all alternatives on the 0.075 mm sieve. Also, asphalt content and moisture content weights are increased. Intuitively, this alternate would best relate to the findings from the literature and the survey of users.

5.5 POTENTIAL IMPACT OF PROPOSED PAY FACTORS

The Technical Advisory Committee requested an analysis of prior projects with recommended weight changes. This analysis is found in Appendix G. However, please note that this analysis is for information purposes only and conclusions should NOT be drawn from this analysis. The intended purpose of using pay factors is to influence contractors to focus on improving performance on factors that impact pavement performance. Therefore, one cannot assess the impact of a pay factor change without the corresponding influence on contractor behavior.

Figure 5.1 shows the distributions of the composite pay factors for the 208 production lots available for this analysis. Figure 5.2 shows the same information, but focuses on narrower cell ranges between 0.90 and 1.05. Finally, Table 5.10 presents CPF comparisons for projects included in the field survey. Appendix G shows the same information for all 208 lots. As shown in both Table 5.10 and Appendix G, Alternatives 1 and 2 slightly decrease the average CPF while lowering the minimum CPF and raising the maximum CPF. Alternative 3 increases the average CPF while lowering the minimum and raising the maximum CPF.

Contractors should be strongly encouraged to monitor performance on these factors with statistical process control charts. In addition, during this first phase of implementation, contractors should be required to show documentation (control charts) of their actual mix temperature and laydown temperature data. These numbers would not be used to calculate pay factors but, rather, would verify use of temperature readings for process control. It is our understanding that contractors are currently collecting data on each of these factors, but that they are not currently using statistical control charts to help them identify situations where corrective action may be necessary. In the implementation plan discussed in the next chapter, it is recommended that training be made available to contractors on the use of statistical process control.

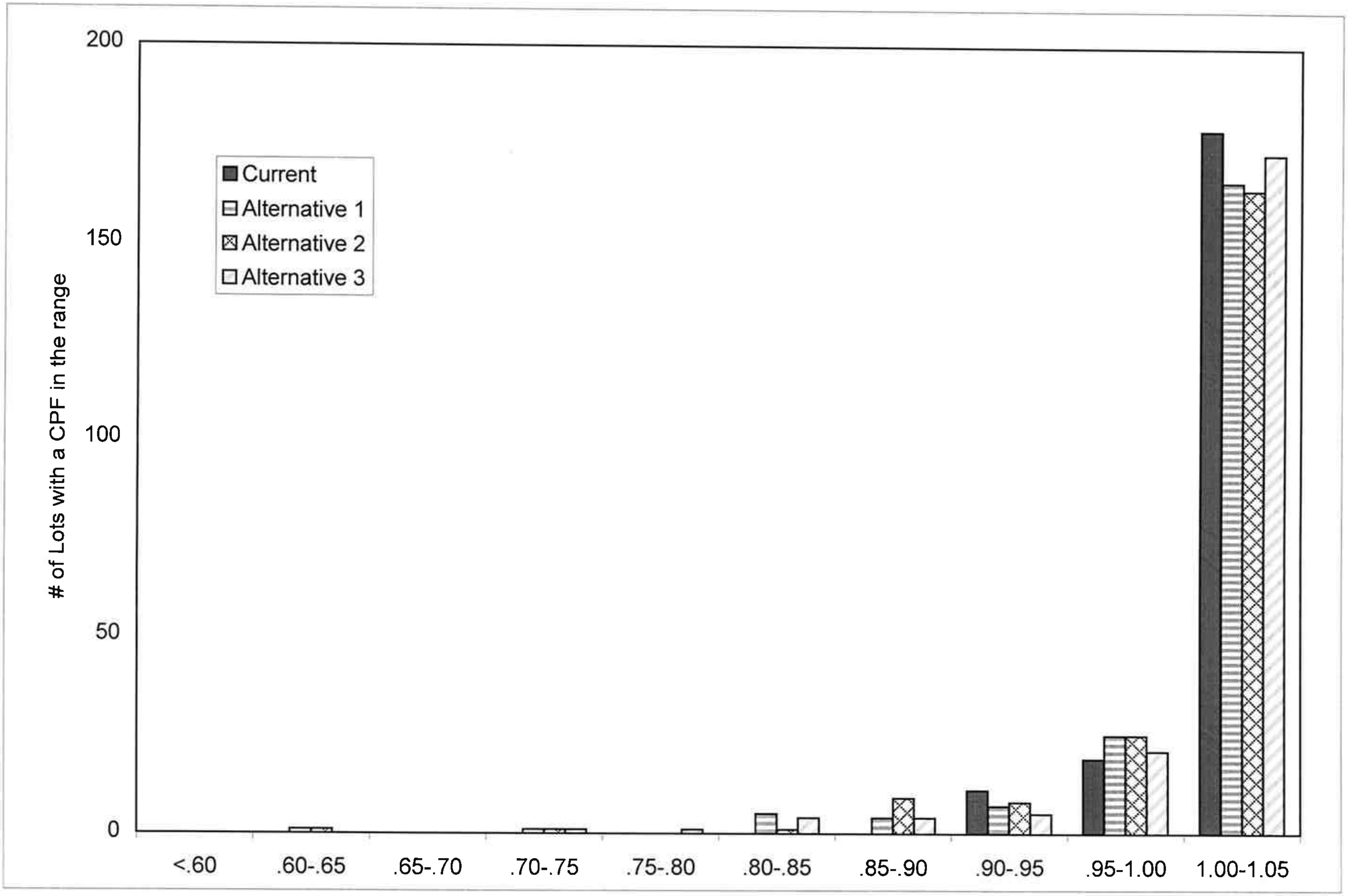


Figure 5.1 Comparison of CPF Values for Alternatives Considered

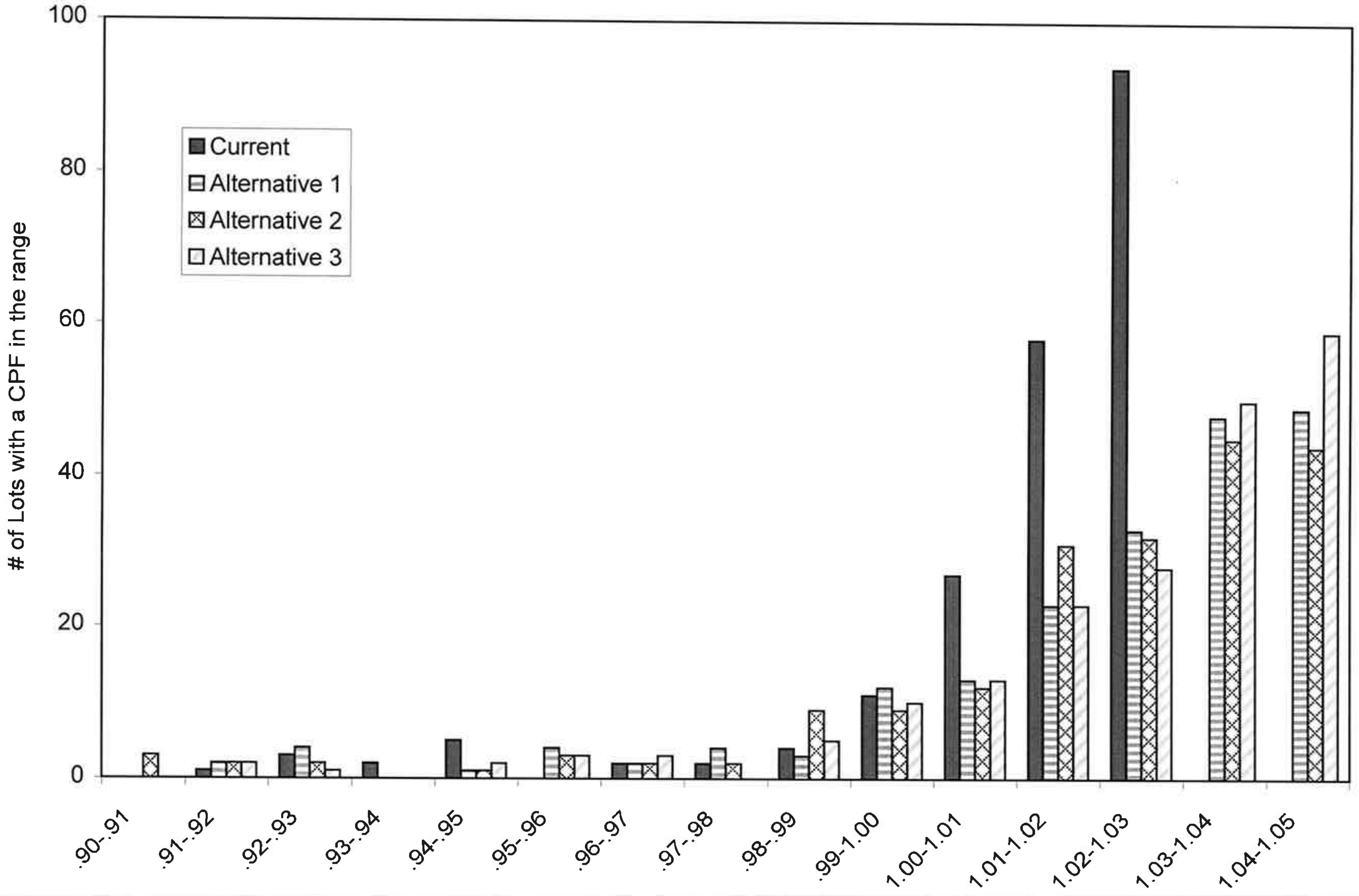


Figure 5.2: Detailed Comparison of CPF Values between CPF=.90 and CPF-1.05

Table 5.10: CPF Comparison for Field Study Projects

CONT		TONS	PRICE	LOT	# SUB	PAY FACTORS										Current	ALT 1	ALT 2	ALT 3
NO	SECTION	F MIX	ADJUST ($)	NO	LOTS	1	3/4	1/2	1/4	10	40	200	ASPH	MOIS	COMP	CPF	CPF	CPF	CPF
11344	Azalea Jumpoff Joe	6771	-12714	1	7	1.05	1.04	0.97	0.00	1.05	1.00	1.05	0.92	1.05	1.00	0.941	0.848	0.873	0.849
11344	Azalea Jumpoff Joe	79703	46148	2	80	1.05	1.02	0.90	0.95	1.05	1.00	1.05	1.04	1.05	1.00	1.019	1.016	1.013	1.023
10930	Baldock Slough - S Baker Intch	45596	16552	1	91	1.05	1.01	1.00	0.93	1.05	1.00	1.05	1.02	1.05	1.00	1.014	1.016	1.016	1.019
10930	Baldock Slough - S Baker Intch	2139	1202	2	5	1.05	1.04	0.99	1.04	1.05	1.00	1.05	1.05	1.05	1.00	1.027	1.042	1.040	1.045
10939	Corbett Intch - Multnomah Falls	37511	-62861	4	75	1.05	0.89	0.97	1.02	1.05	1.00	1.05	1.00	0.00	1.00	0.930	0.915	0.908	0.914
10874	Forge Rd - Lobert (S Unit)	8629	4459	1	17	1.05	1.01	0.82	1.03	1.04	1.00	1.05	1.02	1.05	1.00	1.017	1.013	1.005	1.023
11294	Halsey Int. - Lane Co. Line, Lot 3	25528	4325	3	52	1.05	1.04	0.93	0.94	1.04	1.00	1.05	1.00	1.04	1.00	1.007	1.005	1.004	1.010
11294	Halsey Int. - Lane Co. Line, Lot 4	38064	8140	4	75	1.05	1.05	0.99	1.00	1.04	1.00	1.05	1.00	1.01	1.00	1.009	1.018	1.017	1.019
10941	Hayesville - Battle Cr	37613	-7696	1	77	1.05	0.84	0.00	0.93	1.05	1.00	1.05	0.97	1.05	1.00	0.989	0.896	0.860	0.945
11065	Jumpoff Joe Cr - N Grants Pass	16399	0	1	33	1.05	0.91	0.85	0.84	1.01	1.00	1.05	1.00	1.05	1.00	1.000	0.968	0.964	0.981
11065	Jumpoff Joe Cr - N Grants Pass	51608	27961	2	101	1.05	1.03	0.98	0.98	1.04	1.00	1.05	1.04	1.05	1.00	1.021	1.027	1.027	1.031
10462	Murphy Rd - Lava Butte	6303	3372	3	13	1.05	1.04	0.93	1.05	1.04	1.00	1.03	1.04	1.03	1.00	1.020	1.029	1.026	1.033
10462	Murphy Rd - Lava Butte	7279	-1017	4	13	1.05	1.05	1.04	1.03	1.05	1.00	1.05	0.93	1.02	1.00	0.994	1.010	1.007	1.008
10462	Murphy Rd - Lava Butte	5596	2311	5	11	1.05	1.05	1.04	1.04	1.05	1.00	1.05	1.00	1.04	1.00	1.014	1.033	1.031	1.032
10462	Murphy Rd - Lava Butte	1644	1212	6	3	1.05	1.03	0.99	1.05	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.040	1.037	1.043
11573	Powell Butte - Prineville Airport	19944	5022	1	20	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	0.82	1.00	1.009	1.022	1.023	1.020
11256	Rufus - Arlington (W Unit)	75238	53795	3	150	1.05	1.05	0.98	1.04	1.05	1.00	1.05	1.05	1.03	1.00	1.026	1.040	1.039	1.043
10949	Rufus - Arlington (E Unit)	43931	0	1	87	1.05	0.85	0.89	0.98	1.01	1.00	1.05	1.00	0.97	1.00	1.000	0.980	0.971	0.993
11468	Sunset Highway - Pacific Hwy	2401	1566	1	3	1.04	1.00	1.03	0.95	0.99	1.00	1.05	1.05	1.03	1.00	1.018	1.018	1.021	1.021
11468	Sunset Highway - Pacific Hwy	4474	3872	2	6	1.01	1.05	0.97	1.01	1.03	1.00	1.05	1.05	1.05	1.00	1.024	1.034	1.033	1.037
11468	Sunset Highway - Pacific Hwy	31613	25414	3	29	1.05	1.03	0.82	1.05	1.04	1.00	1.05	1.05	1.01	1.00	1.022	1.022	1.015	1.032
11245	Umatilla - McNary	10117	7871	1	19	1.05	1.04	1.01	1.04	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.041	1.040	1.043
10952	W Marquam Intch - N Tigard Intch	33015	14208	1	65	1.05	1.03	0.97	1.03	0.99	1.00	1.03	1.02	1.05	1.00	1.014	1.018	1.017	1.020
11015	Williamson R - Modoc Pt	5474	4659	1	11	1.05	1.04	0.85	1.05	1.05	1.00	1.02	1.05	1.05	1.00	1.023	1.027	1.021	1.034
11572	Willowdale - Qualle Road	13847	-21137	1	14	1.05	1.04	1.04	1.03	1.05	1.00	1.05	1.05	0.00	1.00	0.943	0.951	0.951	0.941
11229	Wolf Cr - W Fork Dairy Cr	28381	-6824	6	56	1.05	1.05	1.01	1.04	1.05	1.00	1.05	0.94	0.93	1.00	0.989	1.003	0.999	1.002
														Average		1.005	1.001	0.998	1.006
														Minimum		0.930	0.848	0.860	0.849
														Maximum		1.027	1.042	1.040	1.045

After the contractors have demonstrated an ability to document their performance on maintaining mix and laydown temperatures within specifications, it is recommended that ODOT investigate the best method to incorporate temperatures in the quality control/quality asurance program. The process control data collected during the first phase of this implementation can be used to further assess the impact of mix and laydown temperature on pavement performance. Provided that this analysis indicates the expected relationship between mix and laydown temperatures and performance, the composite pay factor would include temperatures and the recommended weights (similar to alternate 3) for the constituent factors as listed in Table 5.11.

Table 5.11: Recommended Pay Factors Including Temperatures

Constituent	Weight
3/4" (19 mm)	5
1/2" (12.5 mm)	5
1/4" (6.25 mm)	15
#10 (2 mm)	15
#200 (0.075 mm)	20
Moisture content	10
Asphalt content	24
Mix temperature	6

5.6 SUMMARY

This chapter evaluated information from the literature review, the field survey, and the laboratory study, and recommended which factors affect performance, which factors should be controlled during production, and how weights should be improved for F-mix pay factors.

Specifically, the following emerged from the evaluation of findings:

1) Survey responses and recent literature suggest that asphalt content and aggregate gradation are the most important factors related to performance of porous pavement.

2) The results of the field survey and laboratory test program suggest that asphalt content and aggregate gradation may affect short-term and long-term performance of F-mixes. They were not clear with respect to the importance of mix moisture on performance.

3) If processes are effectively managed using statistical process control, control limits should not be outside specification limits. Control limits were found to be outside specification limits 93% of the time for 12.5 mm (1/2 in.) sieve, 64% of the time for the 6.25 mm (1/4 in.) sieve, 7% of the time for the 2 mm (#10) sieve and the 0.075 mm (#200) sieve, 50% of the time for asphalt content, and 36% of the time for moisture content.

4) QC data results were consistent with core results for the 12.5 mm sieve, the 6 mm sieve, and asphalt content. Results from the two sources were not consistent for the 2 mm sieve and the 0.075 mm sieve.

5) In all cases, the gradation of cores was finer than the QC data. All of the cores, however, were taken from known problem sites. Further investigation is necessary to determine if controlling aggregate at the cold feed is not adequate to ensure a specification product.

6) Three alternatives for pay factor weights were analyzed. It is recommended that Alternative 3 weights be used, since it most closely relates to the findings from the literature review and expert survey. As shown in Appendix G, applying these weights to the 208 production lots available resulted in shifting the average composite pay factor from 1.012 to 1.016.

6.0 IMPLEMENTATION PLAN

The findings from this study should be implemented in the following way:

1) Specification Committee. The results of this study should be turned over to the ODOT Specification Committee as soon as possible. This will allow decisions to be made relative to implementation of these recommendations at the fall meeting. Pilot implementation could then begin as early as the 1999 construction season.

2) Field Test of New Specification. The first phase of the control and pay factor recommendations could be included in pilot projects for the 1999 season. This includes implementing the pay factor changes documented in Table 5.9, as well as measuring mix temperature to see if it should be included as a pay factor. Use of these weights to calculate a composite pay factor for porous pavements will allow the pay factor to reflect the factors that most influence performance in porous pavements.

3) Training in QC/QA. Agency and contractor personnel should consider training in order to understand the value of using control charts for process control, in addition to training on the mechanics of using control charts. Both agency and contractor personnel should be trained (through the Certified Asphalt Technician Program of APAO) in the implications of the new QC/QA specifications prior to the full implementation.

4) Monitoring Projects. Projects constructed with the new specification should be carefully monitored to determine whether the pay incentives and disincentives are appropriate. If mix temperature proves to be an important factor to control, then adoption of the weighting factors given in Table 5.11 should be considered.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based on the findings in this study, the following conclusions appear warranted:

1) Experiences of others indicate the factors to be controlled should include asphalt content, gradation, and moisture. Most agencies do not control compaction (or voids) of porous mixes.

2) The survey of projects in Oregon indicate, for the most part, that F-mixes perform very well. Problems were noted on some projects which included fat spots, raveling, and rutting. Some of the older projects are now beginning to fatigue crack. The results of the laboratory study suggested that the fat spots and rutting generally occurred where there was excess asphalt and/or a fine mix.

3) An evaluation of all data resulted in specific suggestions for factors to control (aggregate gradation, asphalt content, mix moisture, etc.) and recommendations for new pay adjustment schedules. In general, more weight was given to the finer sieves and less weight given to moisture content and asphalt content.

4) A plan for implementing the study findings was developed. It includes both field trials as well as training of personnel.

7.2 RECOMMENDATIONS FOR FURTHER STUDY

Recommendations for further study include:

1) Modifications to the current mix design process are needed to improve repeatability.

2) Re-evaluation of the QC/QA practices for all mixes to ensure that the use of the process is consistent with normal practices.

3) Continuation of training of personnel in QC/QA technologies.

4) Development of methods for incorporating mix and laydown temperature in pay factor calculations.

5) Continuation of studies to determine whether moisture can be eliminated as a pay factor.

8.0 REFERENCES

Amirkhanian, Serji N., James L. Burati, Jr., and Harish C. Mirchandani. "Effect of Testing Variability on Contractor Payment for Asphalt Pavements." *Journal of Construction Engineering & Management,* 120. September 1994. pp. 579-592.

Anderson, Keith. "Asphalt-Rubber Open-Graded Friction Course; I-5: Vancouver Vicinity." WA-RD-131.1. Washington Department of Transportation. September 1987.

Anderson, Keith. Personal correspondence (e-mail). Washington Department of Transportation. July 23, 1995.

Arkansas State Highway and Transportation Department. "A Performance Evaluation Summary of Open Graded Friction Courses in Arkansas." 1990.

Bodine, Harry. "State Will Repave Rutted Oregon 217." *The Oregonian.* March 13, 1994. p. E1.

Booth, Edward. "Some Applications of Open Graded Asphalt in South Australia." *8th AAPA International Asphalt Conference.* Australian Asphalt Pavement Association. November 1991.

Bowers, David. "Performance of an Open-graded Bituminous Concrete Overlay." Connecticut Department of Transportation. 1978.

Centro de Investigation Elpidio Sanchez Marcos. "Technical Specifications on Porous Mixes." Madrid, Spain.

Chamberlain, William P. *NCHRP Synthesis of Highway Practice 212: Performance Related Specifications for Highway Construction and Rehabilitation.* Transportation Research Board, Washington, DC. 1995.

Colwill, Douglas, Graham J. Bowskill, J. Clifford Nicholls, and Maurice E. Daines. "Porous Asphalt Trials in the UK." *TRR 1427.* Transportation Research Board, Washington, DC. 1993. pp. 13-21.

Colwill, Doug. "The Story of Porous Asphalt." *TRL News*, Transportation Research Laboratory. February 1995.

Connecticut Department of Transportation. "Performance Observations on Open Graded Bituminous Concrete Overlays in Connecticut." Connecticut DOT. 1981.

Currie, D.T., and J.D. Bethune. "Design and Use of Open Graded Friction Course Asphalt for Road Surfacing." Country Roads Board, Victoria, Australia. 1976.

Decker, Dale. "Field Management of Hot Mix Asphalt." *Journal of the Association of Asphalt Paving Technologists,* vol. 61. 1994. pp. 636-643.

Decoene, Y. "Contribution of Cellulose Fibers to the Performance of Porous Asphalts." *TRR 1265.* Transportation Research Board, Washington, DC. 1990. pp. 82-86.

Del Valle, H.F. "Procedure — Bulk Specific Gravity of Compacted Bituminous Mixtures Using Parafilm-Coated Specimens." Chevron Research Company, Richmond, CA. 1985.

Eaton, Robert, and P.C. Marzbanian. "Structural Evaluation of Porous Pavement Test Sections at Walden Pond State Reservation." *Special Report 80-39.* U.S. Corps of Engineers. December 1980.

Elliott, Robert P., and Moreland Herrin. "Development of an Asphalt Construction Pay Schedule Based on the Value Concept." *TRR 1056.* Transportation Research Board, Washington, DC. 1986. pp. 10-20.

Elliott, Robert P., and Moreland Herrin. *Asphalt QA Specifications - Influence of Significant Material Factors & Development of a Rational Payment Schedule.* University of Illinois. 1983.

Emery, John. "Specifying End Results." *Civil Engineering Magazine.* August 1995. pp. 60-61.

Federal Highway Administration (FHWA). "Open Graded Friction Courses." Technical Advisory T5040.31. Federal Highway Administration, Washington, DC. 1978.

FHWA. "State-of-the-Art in Asphalt Pavement Specifications." FHWA-RD-84-075. Federal Highway Administration, Washington, DC, July 1984. pp. 25-82.

FHWA. "Quality Assurance in Highway Construction." FHWA-TS-89-038. Federal Highway Administration, Washington, DC. 1989. pp. 1-8.

FHWA. "Materials Control and Acceptance - Quality Assurance." FHWA-HI-93-047. Federal Highway Administration, Washington, DC. 1993.

Florida Department of Transportation. "Specifications: Sections 331, 336, and 337, Asphalt Concrete Friction Courses." Florida DOT. 1994.

Gemayel, Chaouki A., and Michael S. Mamlouk. "Characterization of Hot-Mixed Open-Graded Asphalt Mixtures." *TRR 1171.* Transportation Research Board, Washington, DC. 1988. pp. 184-192.

Georgia Department of Transportation. "Specifications: Section 828 - Hot Mix Asphalt Concrete Mixes." 1995.

Hicks, R.G., et al. "Open-Graded Emulsion Mixtures: 25 Years of Experience." *Proceedings, 6th International Conference on Low Volume Roads.* Transportation Research Board. June 1995.

Horak, E., B.M.J.A. Verhaeghe, F.C. Rust, and C. van Heerden. "The Use of Porous Asphalt on Major Roads in Johannesburg." *Proceedings 6th Conference on Asphalt Pavements for Southern Africa.* Johannesburg Roads Directorate. 1994.

Huddleston, I.J., H. Zhou, and R.G. Hicks. "Evaluation of Open-Graded Asphalt Concrete Mixtures Used in Oregon." *TRR 1427.* Transportation Research Board, Washington, DC. 1993. pp. 5-12.

Huet, M., A. de Boisoudy, J.-C. Gramsammer, A. Bauduin, and J. Samanos. "Experiments with Porous Asphalt on the Nantes Fatigue Test Track." *TRR 1265.* Transportation Research Board, Washington, DC. 1990. pp. 54-58.

Hughes, C.S. "Incentive and Disincentive Specifications for Asphalt Concrete Density." *TRR 986.* Transportation Research Board, Washington, DC. 1984. pp. 38-42.

Hunt, Liz. "Evaluation of PBA-6GR Binder for Open Graded Asphalt Concrete 1993 & 1994 Projects: Construction Report." Oregon Department of Transportation. 1995.

International Road Federation. *Contribution Towards Reductions of Traffic Noise.* Working Group on Interaction of Vehicles, Tyres and Pavement. 1992.

Irwin, Lynn. "What Are the Odds on Your Paving Project's Success?" *Roads & Bridges.* February 1994.

Kansas Department of Transportation. "Open Graded Asphalt Friction Courses, Final Report." December 1986.

Kliewer, J.E., L.D. Ilg, R.B. Leahy, and R. Dominick. "Evaluation of the Moisture Sensitivity of Open-Graded Mixes Using the Environmental Conditioning System." Transportation Research Record, paper no. 961116. 1995.

Louisiana Department of Transportation. "Specifications Section 502, Asphalt Concrete Friction Courses." 1992.

Maryland Department of Transportation. "Specifications, Section 504.04, Measurement and Payment." 1995.

Michigan Department of Transportation. "Michigan's Experience with Open Graded Asphalt Friction Courses." 1987.

National Asphalt Paving Association. "Quality Control for Hot Mix Asphalt Manufacturing Facilities and Paving Operations." *NAPA Quality Improvement Series 97/86.* NAPA. 1986.

National Cooperative Highway Research Program. *Open-Graded Friction Courses for Highways, Synthesis of Highway Practice 49.* Transportation Research Board, Washington, DC. 1978.

Nevada Department of Transportation. "Specifications: Section 411, Hot Mix Asphalt Pavement (Open-Graded)." 1995.

New York Department of Transportation. "Specifications, Item 15403.2005-2006." 1992.

Oregon Department of Transportation. "Standard Specifications for Highway Construction." 1991.

Oregon Department of Transportation. "Asphalt Concrete Mix Design." 1994.

Page, G.C. "Open-Graded Friction Courses: Florida's Experience." *TRR 1427*. Transportation Research Board, Washington, DC. 1993. pp. 1-4.

Parker, Frazier. "Alabama DOT Implementation of Hot Mix Asphalt QC/QA Procedures." *Proceedings of the Materials Engineering Conference*. October 1994. pp. 1026-1033.

Perez-Jiminez, F.E., and J. Gordillo. "Optimization of Porous Mixes Through the Use of Special Binders." *TRR 1265*. Transportation Research Board, Washington, DC. 1990. pp. 59-68.

Puangchit, Prachuab, R.G. Hicks, James E. Wilson, and C.A. Bell. "Development of Rational Pay Adjustment Factors for Asphalt Concrete." *TRR 911*. Transportation Research Board, Washington, DC. 1983. pp. 70-79.

Rebbechi, J.J. "Twelve Years History of Open Graded Asphalt Performance." *6th AAPA International Asphalt Conference*. Australian Asphalt Pavement Association. January 1986. pp. 41-45.

Ruiz, Aurelia, Roberto Alberola, Feliz Perez, and Bartolome Sanchez. "Porous Asphalt Mixtures in Spain." *TRR 1265*. Transportation Research Board, Washington, DC. 1990. pp. 87-94.

Scholl, Lewis. *Pay Adjustment System for AC Pavements: A 5-year Evaluation*. HP&R Study #5286. Oregon DOT. October1991.

The Shell Bitumen Handbook. Shell Bitumen U.K. 1990.

Smith, Harry. *"NCHRP Synthesis of Highway Practice 180: Performance Characteristics of Open Graded Friction Courses."* Transportation Research Board, Washington, DC. 1992.

"Task Force on Statistical Methods Advocates Quality Assurance Techniques." *TR News 169*. Transportation Research Board, Washington, DC. November/December 1993. pp. 20-21.

Transport Research Laboratory. "Specifications for Highway Work, Section 938." United Kingdom. 1993.

van Gorkum, F. *Synthesis: "Porous Asphalt Surfacing."* SPRINT Workshop, The Netherlands. 1991.

van Heystraeten, G., and C. Moraux. “Ten Years Experience of Porous Asphalt Pavement in Belgium.” *TRR 1265.* Transportation Research Board, Washington, DC. 1990. pp. 34-40.

Washington State Department of Transportation. “Specifications, Sec 106, Sec. 504.” WsDOT. 1994.

Weed, Richard. “Adjusted Pay Schedules: New Concepts & Provisions.” *TRR 986.* Transportation Research Board, Washington, DC. 1984. pp. 32-38.

Weed, Richard. “The Proof is in the Pavement.” *Civil Engineering.* August 1993. pp. 67-69.

Weed, Richard. “Composite Pay Equations: A General Approach.” *TRR 1465.* Transportation Research Board, Washington, DC. 1994. pp. 9-15.

Weed, Richard. “OCPLOT: PC Program to Generate Operating Characteristic Curves for Statistical Construction Specifications.” Preprint, 74th Annual Meeting. Transportation Research Board, Washington, DC. 1995.

Younger, Krey, R.G. Hicks, and Jeff Gower. “Evaluation of Porous Pavements used in Oregon.” Volume 1 and 2. FHWA-OR-RD-95-13B. Oregon Department of Transportation. 1994.

APPENDIX A

QUESTIONNAIRE SURVEY

INTRODUCTION

A survey was administered to various national and international agencies inquiring about their knowledge and experience of porous pavements, as part of a larger research effort to develop an improved specification for porous pavements which would contain pay incentives and disincentives. ODOT presently has pay adjustment factors for dense-graded mixes based on an evaluation of constituents including asphalt content, gradation, compaction, and moisture content. Since this study is to establish appropriate pay factors for open-graded mixtures, the survey was designed to learn about how other agencies were dealing with specifications and adjustment factors for porous pavements.

APPROACH USED

During June and July 1995, the survey presented in Figure A.1 was mailed to the individuals listed in Table A.1. Of the 28 individuals listed in the table, 24 responded for an 86% response rate. One of the respondents did not fill out the survey but provided a letter and copies of the appropriate specifications. Thus, for all practical purposes the data provided below is compiled from 23 survey responses. Table A.1 also indicates which agencies responded to the request and if they provided copies of specifications. The names and addresses of the respondents are provided in the final section of this appendix. The initial letter requesting information is provided in Figure A.2 and the reminder letter is included in Figure A.3. The following section details the information obtained from the survey.

POROUS MIX SURVEY FORM

Name: ____________________ Address: ____________________

Position: ____________________ ____________________

Phone No.: ____________________ ____________________

Fax No.: ____________________ ____________________

1. Have you been involved with the construction of an open-graded asphalt surface mix during the past five years?

   a. Yes

   b. No

   → Briefly explain why you have not used open-graded asphalt mixes, then return this questionnaire.

2. What factors most affect the performance of open-graded surface mixes placed in your state (circle one number for each)

	Very Important				Not Important
a) Asphalt content	5	4	3	2	1
b) Aggregate gradation	5	4	3	2	1
c) Compaction	5	4	3	2	1
d) Aggregate moisture content	5	4	3	2	1
e) Other ____________	5	4	3	2	1

____

____

Figure A.1: Survey

3. What are the most common types of failures in open-graded asphalt mixes?

	Very Important				Not Important
a) Rutting	5	4	3	2	1
b) Bleeding	5	4	3	2	1
c) Raveling	5	4	3	2	1
d) Other ____________	5	4	3	2	1

4. What factor is the primary cause of failures?

a) Rutting

☐ Too much asphalt

☐ Asphalt type selection

☐ Aggregate gradation

☐ Other ____________________

b) Bleeding

☐ Too much asphalt

☐ Draindown

☐ Other ____________________

c) Raveling

☐ No antistrip

☐ Too little asphalt

☐ Other ____________________

Figure A.1: Survey (continued)

5) Do your specifications contain provision for pay adjustment?

☐ Yes ☐ No

5a. What factors control the pay adjustment?

☐ asphalt content

☐ aggregate gradation

☐ aggregate moisture content

☐ compaction

☐ other ____________________

5b. Please provide the basis for the pay adjusment and a copy of your current specifications for open-graded asphalt mixes.

6) Do you use stone matrix asphalt (SMA) mixes in your state?

☐ Yes ☐ No

6a. Is there a pay incentive/disincentive provision for these mix types?

☐ Yes ☐ No

6b. Please provide the basis for the pay adjustment and a copy of your current specifications for SMA.

7) Do you have any current research dealing with open-graded asphalt surface courses?

☐ Yes ☐ No

7a. What is the title of the study and the scope of work?

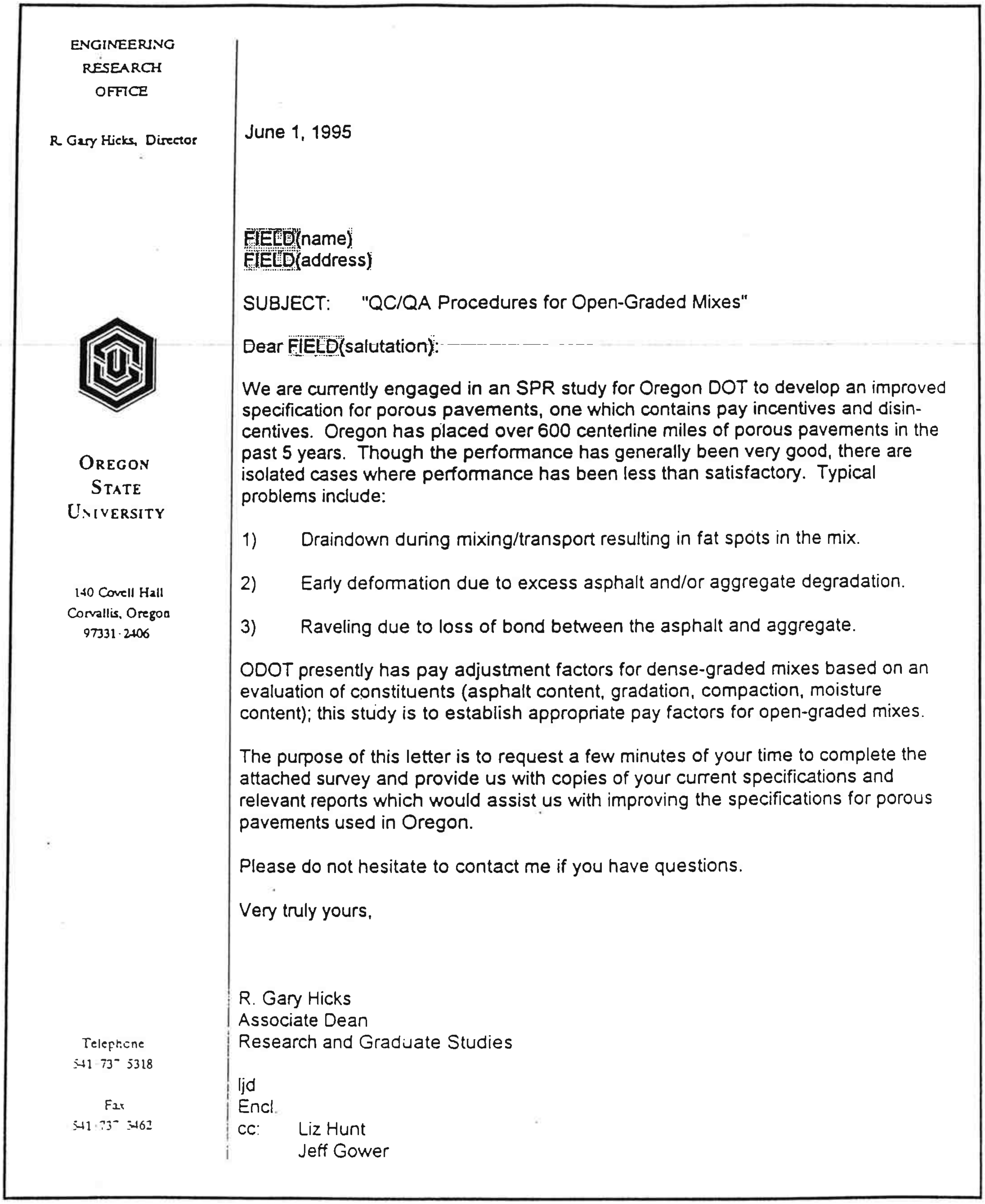
Please return the survey form to:

R. Gary Hicks
Associate Dean - Research & Graduate Studies
Oregon State University
Engineering Research Office
Covell Hall 140
Corvallis, OR 97331-2406
PH: 503-737-5318; FAX: 503-737-3462

Figure A.1: Survey (continued)

Table A.1: List of Survey Recipients

Agency	Survey Sent to	Survey Response	Response from	Spec. Included
Arizona Department of Transportation	Douglas A. Forstie	Yes	Douglas A. Forstie	No
Arkansas State Highway Department	Jim Gee	Yes	Jim Gee	No
California Department of Transportation	Roy Bushey	Yes	Jack Van Kirk	Yes
Connecticut Department of Transportation	Charles E. Dougan	Yes	Charles E. Dougan	No
Florida Department of Transportation	L.L. Smith	Yes	Gale C. Page	Yes
Georgia Department of Transportation	Ronald Collins	Yes	Ronald Collins	Yes
Kansas Department of Transportation	Lon S. Ingram	Yes	Rodney Maag	No
Louisiana Department of Transportation	Jarvis J. Poche	No		
Louisiana Transportation Research Center	Harold R. Paul	Yes	Harold R. Paul	Yes
Maryland State Highway Administration	Samuel R. Miller, jr.	Yes	Samuel R. Miller, jr.	Yes
Massachusetts Highway Department	Leo C. Stevens, jr.	Yes	Leo C. Stevens, jr.	No
Michigan Department of Transportation	James D. Culp	Yes	Douglas Coleman	No
Nevada Department of Transportation	Jack Montrose	Yes	Ledo Quilici	No
New York Department of Transportation	Paul J. Mack	Yes	Gary Frederick	Yes
Texas State Department of Highways and Public Transportation	Katherine Hargett	Yes	Maghsoud Tahmoressi	No
Vermont Agency of Transportation	Robert F. Cauley	Yes	Charles E. Jerd	No
Washington Department of Transportation	Rodney G. Finkle	Yes	Robyn Moore	Yes
Belgium	Bernard Eckmann	No		
France	Jacques Bonnot	Yes	Jacques Bonnot	No
Delft University of Technology, The Netherlands	Andre Molenaar	Yes	P.C. Hopman	No
Spain	Jaime Gordillo Gracia	Yes	Jaime Gordillo Gracia	Yes
Swiss Federal Laboratories, Switzerland	Manfred N. Partl	Yes	Manfred N. Partl	No
City of Johannesburg, RSA	Emile Horak	Yes	H. D'Amico	No
Transportation Research Laboratory, United Kingdom	D.M. Colwill	No	D.M. Colwill	Yes
Switzerland	K. Suter	Yes	Dieter Baer	No
Switzerland	D. Claivaz	No		
IVT Swiss Federal Institute of Technology, Switzerland	M. Caprez	Yes	Martin Horat	No
LAVOC Department of Civil Engineering, EPFL, Switzerland	A. G. Dumont	No		



ENGINEERING
RESEARCH
OFFICE

R. Gary Hicks, Director

OREGON
STATE
UNIVERSITY

140 Covell Hall
Corvallis, Oregon
97331-2406

Telephone
541-737-5318

Fax
541-737-3462

June 1, 1995

FIELD(name)
FIELD(address)

SUBJECT: "QC/QA Procedures for Open-Graded Mixes"

Dear FIELD(salutation):

We are currently engaged in an SPR study for Oregon DOT to develop an improved specification for porous pavements, one which contains pay incentives and disincentives. Oregon has placed over 600 centerline miles of porous pavements in the past 5 years. Though the performance has generally been very good, there are isolated cases where performance has been less than satisfactory. Typical problems include:

1) Draindown during mixing/transport resulting in fat spots in the mix.

2) Early deformation due to excess asphalt and/or aggregate degradation.

3) Raveling due to loss of bond between the asphalt and aggregate.

ODOT presently has pay adjustment factors for dense-graded mixes based on an evaluation of constituents (asphalt content, gradation, compaction, moisture content); this study is to establish appropriate pay factors for open-graded mixes.

The purpose of this letter is to request a few minutes of your time to complete the attached survey and provide us with copies of your current specifications and relevant reports which would assist us with improving the specifications for porous pavements used in Oregon.

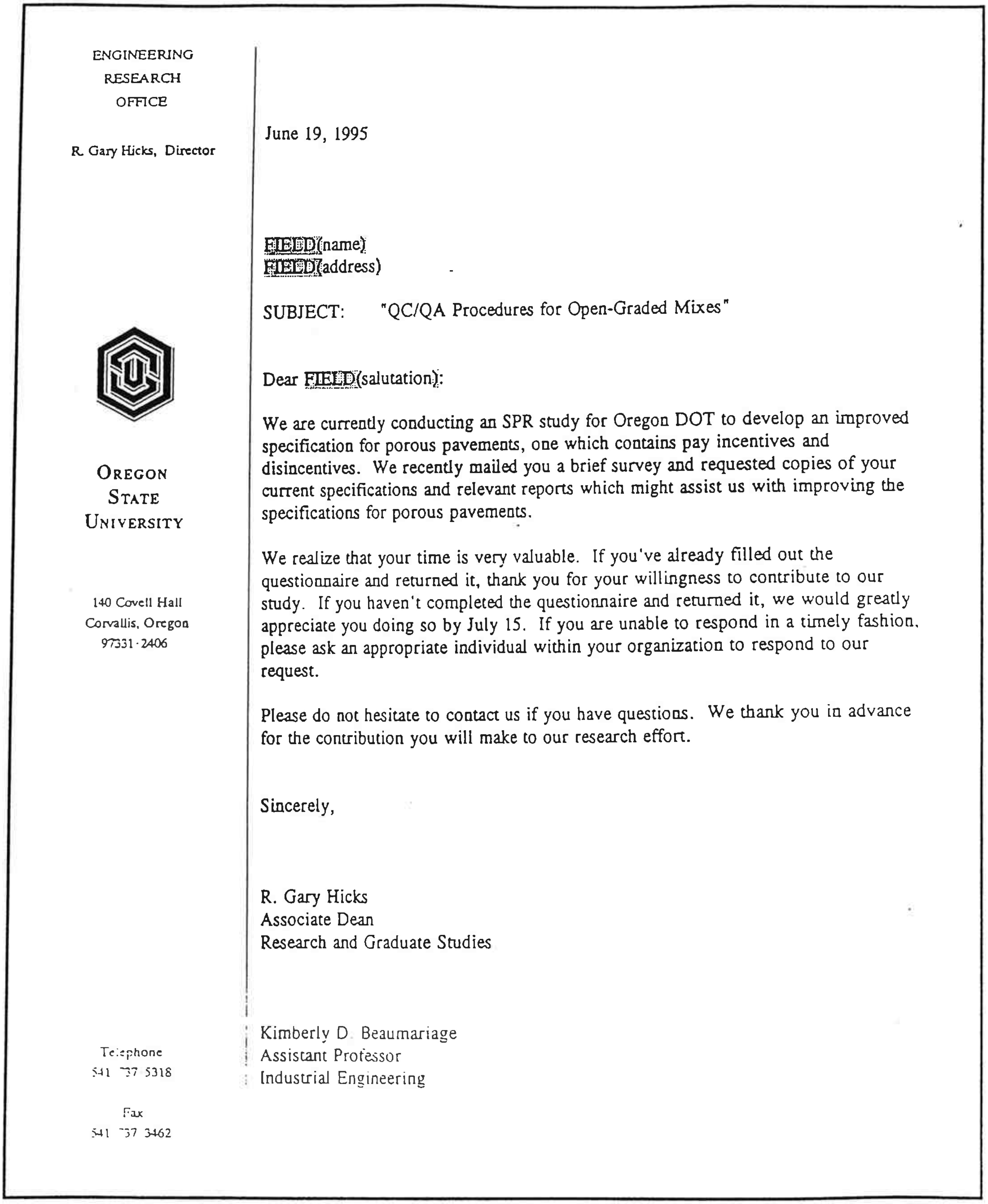
Please do not hesitate to contact me if you have questions.

Very truly yours,

R. Gary Hicks
Associate Dean
Research and Graduate Studies

ljd
Encl.
cc: Liz Hunt
Jeff Gower

Figure A.2: Letter Sent with Survey



ENGINEERING
RESEARCH
OFFICE

R. Gary Hicks, Director

OREGON
STATE
UNIVERSITY

140 Covell Hall
Corvallis, Oregon
97331-2406

Telephone
541 737 5318

Fax
541 737 3462

June 19, 1995

FIELD(name)
FIELD(address)

SUBJECT: "QC/QA Procedures for Open-Graded Mixes"

Dear FIELD(salutation):

We are currently conducting an SPR study for Oregon DOT to develop an improved specification for porous pavements, one which contains pay incentives and disincentives. We recently mailed you a brief survey and requested copies of your current specifications and relevant reports which might assist us with improving the specifications for porous pavements.

We realize that your time is very valuable. If you've already filled out the questionnaire and returned it, thank you for your willingness to contribute to our study. If you haven't completed the questionnaire and returned it, we would greatly appreciate you doing so by July 15. If you are unable to respond in a timely fashion, please ask an appropriate individual within your organization to respond to our request.

Please do not hesitate to contact us if you have questions. We thank you in advance for the contribution you will make to our research effort.

Sincerely,

R. Gary Hicks
Associate Dean
Research and Graduate Studies

Kimberly D. Beaumariage
Assistant Professor
Industrial Engineering

Figure A.3: Reminder Letter

RESULTS

The first question on the survey inquires if the respondent was involved in the construction of an open-graded asphalt surface mix during the past five years. Figure A.4 illustrates that 16 of 22 respondents (or 72.7%) had been involved in the construction of open-graded mixes in the past five years while the remaining 6 respondents had not. Table A.2 indicates which respondents were involved with open-graded mixes, and Table A.3 provides the reasoning for not using open-graded asphalt mixes from the individuals who indicated they had not been involved with them.

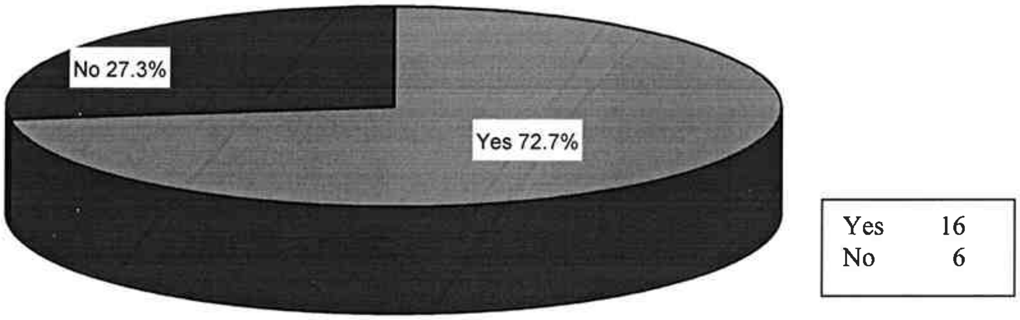


Figure A.4: Construction of Open-Graded Mixes in Past 5 Years

Table A.2: Respondents with Open-Graded Asphalt Experience

Agency	Response from
Arizona Department of Transportation	Douglas A. Forstie
California Department of Transportation	Jack Van Kirk
Florida Department of Transportation	Gale C. Page
Georgia Department of Transportation	Ronald Collins
Maryland State Highway Administration	Samuel R. Miller, jr.
Massachusetts Highway Department	Leo C. Stevens, jr.
Nevada Department of Transportation	Ledo Quilici
Texas State Department of Highways and Public Transportation	Maghsoud Tahmoressi
Vermont Agency of Transportation	Charles E. Jerd
Washington Department of Transportation	Robyn Moore
France	Jacques Bonnot
The Netherlands	P. C. Hopman
Spain	Jaime Gordillo Gracia
Switzerland	Dieter Baer
City of Johannesburg	H. D'Amico
United Kingdom	D. M. Colwill

Table A.3: Reasons for Not Using Open-Graded Asphalt Mixes

Respondent	Reason
Arkansas	Arkansas stopped using open-graded asphalt surface mix (friction course) approximately 5 years ago. After good, initial drainage performance, the voids would begin to fill, causing moisture retention, prolonged freezing, and snow and ice removal problems. Failure would be evidenced by underlying layers rutting (due to water penetration) or by raveling of the surface aggregate.
Connecticut	1) The time frame for proper placement is limited to May 15 through October 1 with a temperature requirement of 60°+ for air and base. 2) O.G.F.C. are very sensitive to temperature and moisture during production and placement. Much of our paving on interstate roadways is now done at night where dampness and temperature could be a problem.
Kansas	During winter snow and ice storms, the open-graded mix sometimes filled with water and froze solid. They developed an icy surface. It took two or three times the amount of salt and number of treatments to melt the ice from the surface and within the open-graded mix.
Louisiana	Moratorium was placed on ACFC construction in 1984 due to end of service life on older pavements (10+ years) and extensive raveling on newly constructed ACFCs.
Maryland	We discontinued the use of open-graded asphalt surface mixes in approximately 1993 due to severe raveling of the mix during periods of severe winter weather. We now use SMA for the surface of our flexible and composite interstates and similar highways.
Michigan	Open-graded mixtures placed in the late 70s failed to perform. After looking into failures, it would appear the open-graded mixture was okay. However, the leveling courses all failed because of stripping, caused by water pressure/pumping from the surface.
New York	Open-graded mixes are only used for prevention of hydro-planing/wet weather accident reduction. Accident history must show wet weather related accidents. Open-graded mixes only receive limited use.

The second survey question pertains to the factors that most affect the performance of open-graded surface mixes. A five-point Likert scale was used to express the importance of each factor with "5" indicating "very important" and "1" indicating "not important." The results for this question are shown in Figure A.5 and indicate the average level of importance of each factor. As shown in the graph, asphalt content and aggregate gradation were both indicated as important factors affecting performance. The respondents were also asked to list other factors if appropriate. Table A.4 presents the other factors listed and the corresponding respondent.

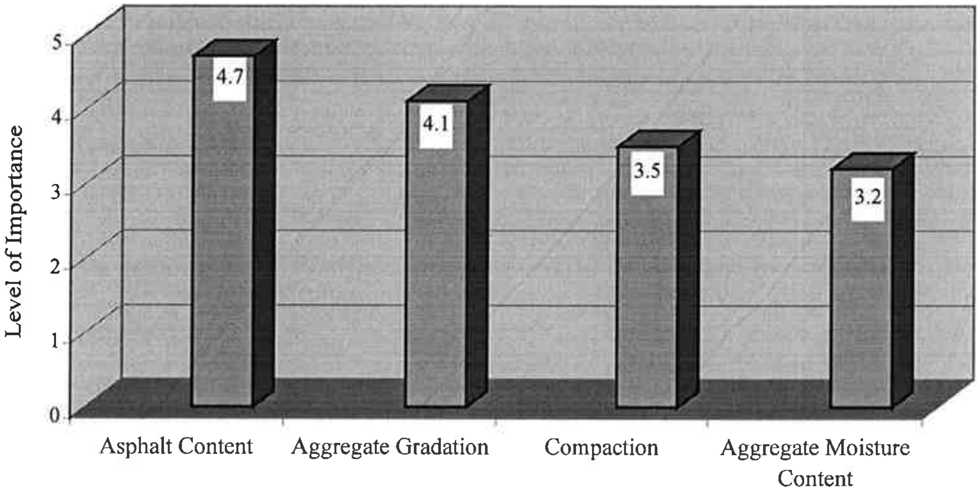


Figure A.5: Factors Affecting Performance

Table A.4: Factors that Most Affect Performance

Respondent	Factor
California	- mix placement temperature - ambient and pavement surface temperature
Florida	- aggregate type and friction
Georgia	- use of polymers and fibers
Maryland	- stripping - placement temperatures
Massachusetts	- ambient temperature
Nevada	- mixing - weather
Washington	- consistency of product
France	- asphalt binder grade
Spain	- asphalt grade
Switzerland	- quality of materials
Switzerland	- type of binder

The third question on the survey relates to the most common types of failures in open-graded asphalt mixes. Again, a five-point Likert scale was used to express the extent of each type of failure with "5" indicating "very important" and "1" indicating "not important." The results for this question are provided in Figure A.6 and indicate the average level of importance of each factor. According to the survey respondents, raveling is the most common failure type. The respondents were also asked to list other types of failures if appropriate. Table A.5 presents the other factors listed and the corresponding respondent.

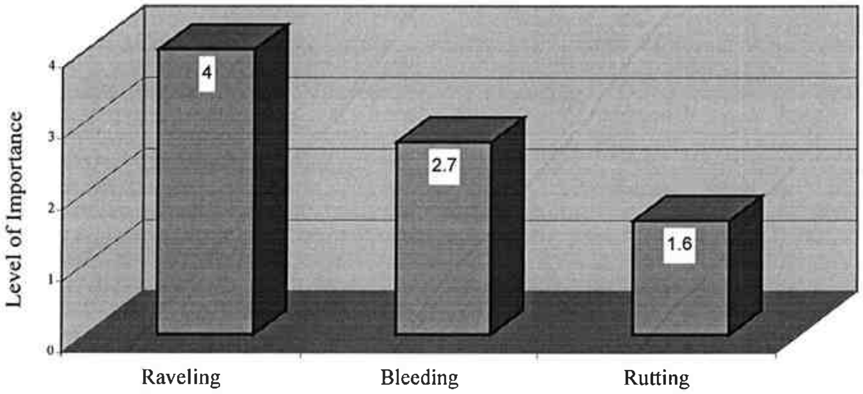


Figure A.6: Most Common Failure Types

Table A.5: Most Common Types of Failures

Respondent	Failure Type
Florida	- low FN_{40}
Georgia	- oxidation
Massachusetts	- delimination
The Netherlands	- stripping (bottom of open graded course)
Spain	- clogging
Switzerland	- clogging

The fourth survey question discussed the primary cause of failures of various types. The respondents were asked to check the causes that were relevant in each case, and to list other cause of failures if appropriate. The results for this question are provided in Figures A.7, A.8, and A.9. Figure A.7 provides information on rutting, Figure A.8 on fat spots, and Figure A.9 on raveling. With respect to rutting, too much asphalt and aggregate gradation were the most frequently cited cause of rutting failures. In regard to fat spots, draindown was the most frequently given cause of failure. The most frequently cited cause of raveling failures was too little asphalt. Tables A.6, A.7, and A.8 present the other causes of failures for rutting, fat spots, and raveling, respectively.

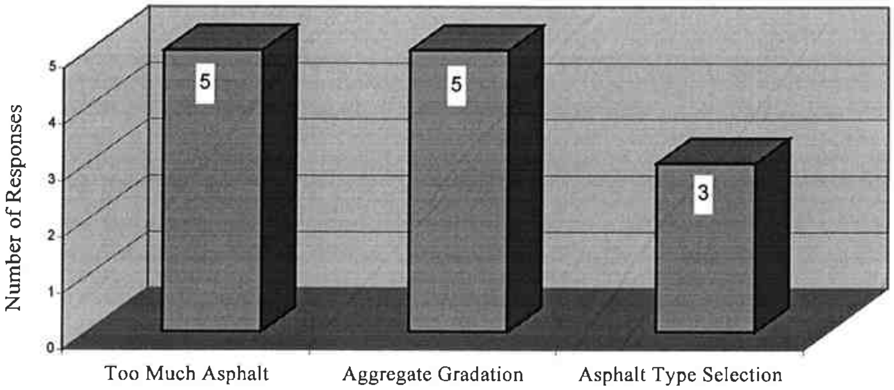


Figure A.7: Primary Factors Causing Rutting Failures

Table A.6: Primary Cause of Rutting Failures

Respondent	Cause
Massachusetts	• thickness of application
Washington	• underlying pavement (structural) • studded tire wear
City of Johannesburg	• compaction
Switzerland	• construction quality

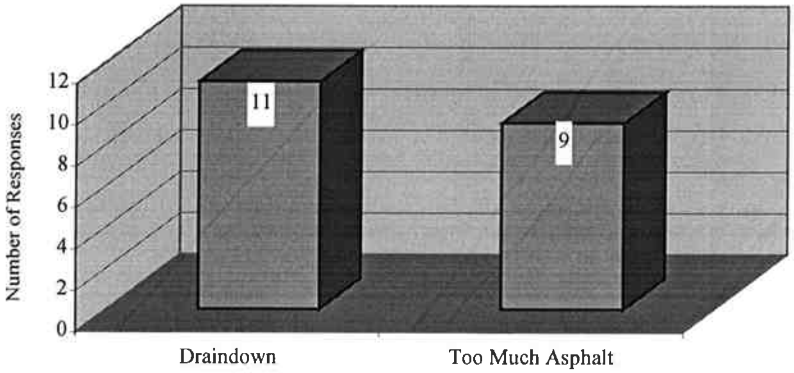


Figure A.8: Primary Factors Causing Fat Spots Failures

Table A.7: Primary Cause of Fat Spots Failures

Respondent	Cause
Arizona	- high P200

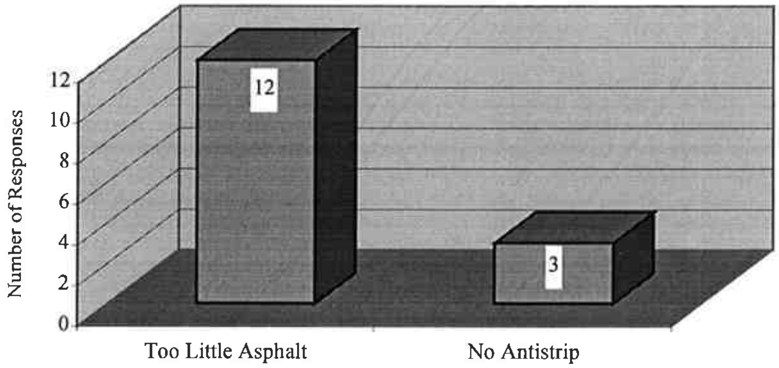


Figure A.9: Primary Factors Causing Raveling Failures

Table A.8: Primary Cause of Raveling Failures

Respondent	Cause
Arizona	- Placed when weather is cold. - Inadequate tack coat.
California	- Mix placement. - Ambient, and surface temperature.
Georgia	- Oxidized asphalt binder.
Maryland	- Poor construction practices. - Aging of the asphalt binder.
Massachusetts	- Lay down temperature.
Nevada	- Moisture sensitivity of the aggregate.
New York	- Lift thickness too thin. - Stripping of the asphalt mix.
Washington	- Late season paving or cold weather paving. - Trapping water in OGAP.
France	- Too high void content (28-30%) with very low sand content formula. - Too hard binder (or too susceptible to aging, or too high temperatures at the mixing plant).
The Netherlands	- Draindown leading to localized spots of low asphalt.
Spain	- Lack of compaction. - Mix applied at very low temperature.
Switzerland	- Mix and paving temperatures (e.g., overheating of binder).

The fifth question on the survey inquired about the use of specifications which contain provision for pay adjustment. Figure A.10 indicates that most agencies (11 agencies or 64.7%) did NOT have specifications for pay adjustment. Figure A.11 indicates the factors which were used to control pay adjustment by the six agencies that indicated they had specifications providing for it. All six agencies use some form of aggregate gradation and four of the six use asphalt content as a pay factor. Table A.9 lists other factors used for pay adjustment.

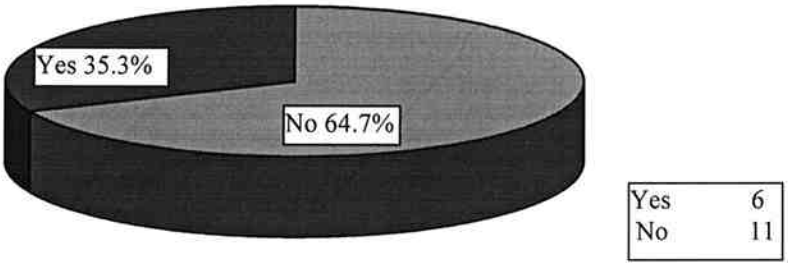


Figure A.10: Have Specifications For Pay Adjustment?

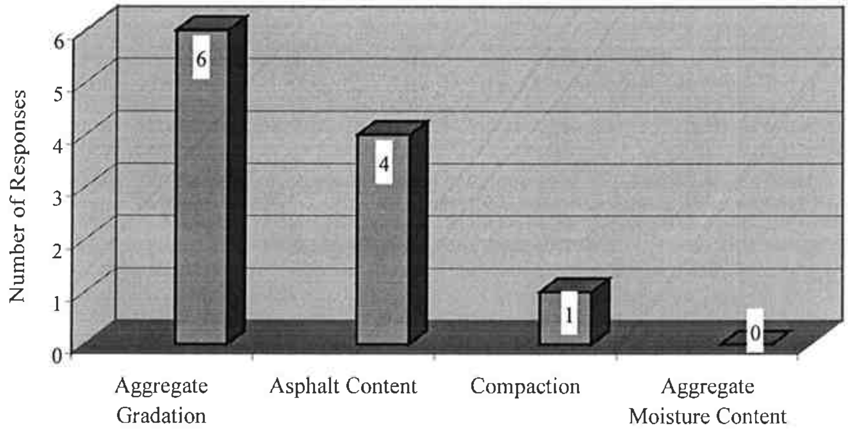


Figure A.11: What Factors Control Pay Adjustment?

Table A.9: Other Factors Used for Pay Adjustment

Respondent	Factor
Louisiana	• anti-strip - failure to add - 90%. • asphalt - deviations from specifications.
Washington	• weighting factor for each screen.

The sixth survey question dealt with the use of SMA mixes. Of the 21 respondents who answered this question, 11 indicated they had used SMA mixes, as illustrated in Figure A.12. Figure A.13 indicates that three agencies actually have pay provisions for SMA mixes. Table A.10 presents details provided in the survey responses concerning the use of SMA mixes.

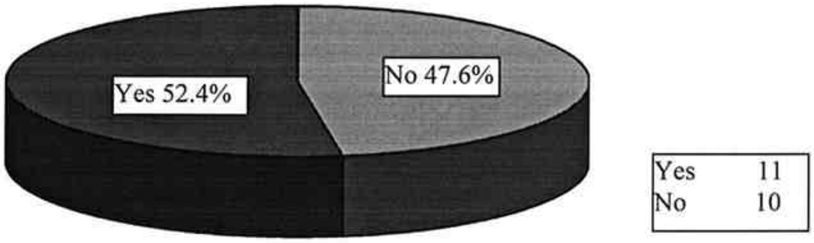


Figure A.12: Number of Respondents Using SMA Mixes

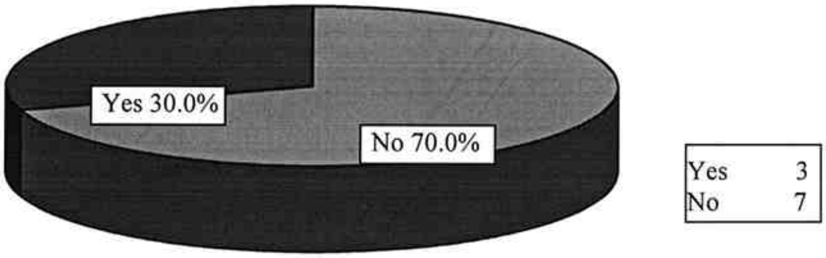


Figure A.13: Number of Respondents with Pay Provisions for SMA Mixes

Table A.10: SMA Mix Usage

Respondent	Type of Usage
Arizona	Arizona has built two test sections of SMA mixes, each one mile long.
Arkansas	Arkansas has placed SMA mixes an experimental project and is still evaluating results.
California	California has two experimental SMA projects.
Georgia	Georgia uses SMA mixes. Due to the importance of aggregate gradation in SMA mixes, the tolerances for dense graded mixes were reduced by 25%.
Louisiana	Louisiana is using SMA mixes experimentally. Four projects are complete and four more are to be let.

Finally, in question 7, respondents were asked if they were currently doing research on open-graded mixes. Figure A.14 indicates that 7 of 20 respondents to this question were doing research on open-graded mixes. These respondents included: Georgia, France, the Netherlands, Spain, and Switzerland.

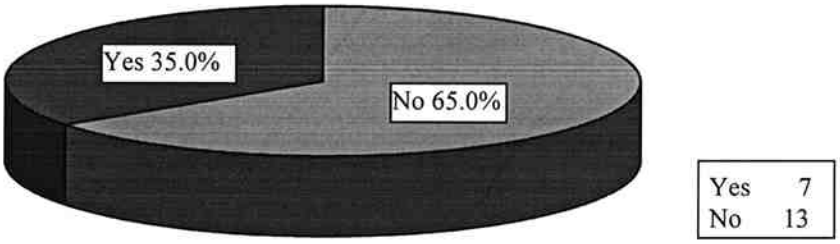


Figure A.14: Number of Respondents Doing Research on Open-Graded Mixes

Table A.11 provides the specific responses used to generate the graphs shown in this section of the appendix.

Table A.11: Raw Data from Survey Respondents

Agency	Contact	Constructed Open-Graded Mix in Past 5 Years?		Factors Most Affecting Performance			
		Yes	No	Asphalt Content	Aggregate Gradation	Compaction	Aggregate Moisture Content
Arizona DOT	Forstie	X		5	5	3	4
Arkansas DOT	Gee		X				
California DOT	Van Kirk	X		5	4	4	4
Connecticut DOT	Dougan		X				
Florida DOT	Page	X		5	5	3	3
Georgia DOT	Collins	X		5	5	3	4
Kansas DOT	Maag		X				
Louisiana DOT & Development	Paul		X	5	4	2	5
Maryland State Highway Administration	Miller	X		5	4	2	3
Massachusetts Highway Department	Stevens	X		4	4	4	5
Michigan DOT	Coleman		X				
Nevada DOT	Quilici	X		5	3	4	5
New York DOT	Frederick		X	4	5	5	5
Texas State Dept. of Highways & Transport.	Tahmoressi	X		5	4	4	3
Vermont Agency of Transportation	Jerd	X		5	4	4	2
Washington DOT	Moore	X		5	4	4	2
France	Bonnot	X		4	4	3	2
The Netherlands	Hopman	X		5	1	4	1
Spain	Gordillo	X		4	4	4	3
Switzerland	Partl	X		4	3	2	4
Switzerland	Baer			5	5	3	1
Switzerland	Horat		X	5	5	4	2
City of Johannesburg, RSA	Horak	X		5	4	4	3
United Kingdom	Colwill	X					
				4.7	4.1	3.5	3.2

Table A.11: Raw Data from Survey Respondents (continued)

Agency	Most Common Failure Types			Factor Primary Cause of Failures						
				Rutting			Fat Spots		Raveling	
	Rutting	Bleeding	Raveling	Too Much Asphalt	Asphalt Type Selection	Aggregate Gradation	Too Much Asphalt	Draindown	No Antistrip	Too Little Asphalt
Arizona DOT	1	5	5				X			X
Arkansas DOT										
California DOT	2	2	5	X		X	X	X		X
Connecticut DOT										
Florida DOT	1	3	3			X		X		X
Georgia DOT	2	2	5		X			X		
Kansas DOT										
Louisiana DOT & Dev.	1	1	5							X
Maryland SHA	1	3	5					X	X	X
Massachusetts Hwy. Dept.	2	1	4							
Michigan DOT										
Nevada DOT	1	3	4				X	X		X
New York DOT	1	1	5							
Texas DOT	3	4	5			X	X	X		X
Vermont Agy. of Trans.				X				X		
Washington DOT	2	3	5				X			
France	1	2	2					X		X
The Netherlands	1	1	4						X	X
Spain	1	2	5	X	X			X	X	X
Switzerland	2	4	4		X		X			
Switzerland	3	5	1	X		X	X	X		
Switzerland	1	3	2				X			X
City of Johannesburg, RSA	2	4	3	X		X	X	X		X
United Kingdom										
	1.6	2.7	4.0	5	3	5	9	11	3	12

Table A.11: Raw Data from Survey Respondents (continued)

Agency	Specification for Pay Adjustment			Factors Control Pay Adjustment			Use SMA Mixes		Pay Provisions for SMA Mixes		Current Research on Open-Graded Mixes	
	No	Yes	Asphalt Content	Aggregate Gradation	Aggregate Moisture Content	Compaction	No	Yes	No	Yes	No	Yes
Arizona DOT	X						X				X	
Arkansas DOT								X				
California DOT		X		X				X	X		X	
Connecticut DOT							X				X	
Florida DOT		X	X	X			X				X	
Georgia DOT		X	X	X				X		X		X
Kansas DOT												
Louisiana DOT & Dev.	X			X				X	X		X	
Maryland SHA		X	X					X		X	X	
Massachusetts Hwy. Dept.	X						X				X	
Michigan DOT												
Nevada DOT	X						X				X	
New York DOT	X						X				X	
Texas DOT	X							X	X		X	
Vermont Agy. of Trans.	X						X				X	
Washington DOT		X		X			X				X	
France	X						X					X
The Netherlands		X	X	X		X		X		X		X
Spain	X							X	X			X
Switzerland	X							X	X			X
Switzerland	X							X	X			X
Switzerland	X							X	X			X
City of Johannesburg, RSA	X						X				X	
United Kingdom												
	13	6	4	6	0	1	10	11	7	3	13	7

LIST OF SURVEY RESPONDENTS

Douglas Forstie
State Materials Engineer
1221 N. 21st Avenue
Phoenix, AZ 85009
Phone: 602-255-7286
FAX: 602-255-8138

Jim Gee
Materials Engineer
P.O. Box 2261
Little Rock, AR 72203
Phone: 501-569-2185
FAX: 501-569-2400

Jack Van Kirk
Senior M & R Engineer
CALTRANS
5900 Folsom Blvd.
Sacramento, CA 95819
Phone: 916-227-7300
FAX: 916-227-7242

Charles E. Dougan
Manager of Research and Materials
Connecticut Dept. of Transportation
Office of Research and Materials
280 West Street
Rocky Hill, CT 06067
Phone: 203-258-0372
FAX: 203-529-0323

Gale C. Page
State Bit Materials Engineer
Florida DOT/ State Materials Office
2006 NE Waldo Road
Gainesville, FL 32609
Phone: 904-372-5304
FAX: 904-334-1648

Ronald Collins
State Materials and Research Engineer
Georgia Department of Transportation
Office of Materials and Research
15 Kennedy Drive
Forest Park, GA 30050
Phone: 404-363-7510
FAX: 404-363-7684

Rodney Maag
Materials Field Engineer
Kansas Department of Transportation
Docking State Office Bldg., Room 1011N
Topeka, Kansas 66612-1568
Phone: 913-296-3711
FAX: 913-296-6665

Skip Paul
Materials Research Manager
LTRC
4101 Gourrier Avenue
Baton Rouge, LA 70808
Phone: 504-767-9124
FAX: 504-767-9108

Samuel R. Miller, Jr.
Deputy Chief Engineer
Office of Materials and Research
Maryland State Highway Administration
2323 W. Joppa Road
Brooklandville, MD 21022
Phone: 410-321-3538
FAX: 410-321-2208

Leo C. Stevens, Jr.
Research and Materials Engineer
400 D. Street
South Boston, MA 02210-1953
Phone: 617-526-8686
FAX: 617-526-8696

LIST OF SURVEY RESPONDENTS (continued)

Douglas Coleman
Bituminous Engineer
Michigan Dept. of Transportation
Materials and Technology Division
P.O. Box 30049
Lansing, MI 48909
Phone: 517-322-5672
FAX: 517-322-5664

Ledo Quilici
Principal Bituminous Engineer
Nevada Dept. of Transportation
1263 South Stewart
Carson City, NV 89712
Phone: 702-687-5520
FAX: 702-687-4846

Gary Frederick
CE II
New York State Dept. of Transportation
1220 Washington Avenue
Albany, NY 12232
Phone: 518-457-4582
FAX: 518-457-8171

Maghsoud Tahmoressi
Bituminous Engineer
Texas Dept. of Transportation/MAT
125 E. 11th Street
Austin, TX 78701
Phone: 512-465-7603
FAX: 512-302-2288

Charles E. Jerd
Bituminous Concrete Supervisor
Vermont Agency of Transportation
State Administration Building
c/o Materials and Research Division
Montpelier, VT 05633
Phone: 802-828-2561
FAX: 802-828- 2792

Robyn Moore
Pavement Engineer
WSDOT
Materials Lab
P.O. Box 167
Olympia, WA 98507-0167
Phone: 360-753-7110
FAX: 360-586-4611

J. Bonnot
Technical Director
LCPC
58 Boulevard Lefebvre
75732 Paris cedex 15
FRANCE
Phone: 33 (1) 40 43 54 23
FAX: 33 (1) 40 43 54 93

P. C. Hopman
Associate Professor
Road and Railroad Lab
Delft University of Technology
P.O. Box 5048
2600 GA Delft
THE NETHERLANDS
Phone: (1) 31 15 78 4246
FAX: (1) 31 15 78 3443

Jaime Gordillo
Carrera de San Jeronimo, 14
28014 Madrid
SPAIN
Phone: 34-1-522 64 90
FAX: 34-1-522 27 87

Manfred N. Partl
EMPA Dubendorf
Head of Section Road Engineering/
Sealing Components
Swiss Federal Laboratories
CH-8600 Dubendorf
Phone: +41-1-823 55 11
FAX: +41-1-821 62 44

LIST OF SURVEY RESPONDENTS (continued)

H. D'Amico
Research and Materials Manager
Laboratory Services
Roads Directorate
Johannesburg Administration
P.O. Box 32243
Braamfontein 2017 RSA
Phone: (011) 493 6386
FAX: (011) 493 0612

D.M. Colwill
Transport Research Laboratory
Old Wokingham Road, Crowthorne
Berkshire RG11 6AU
UNITED KINGDOM
Phone: 0344 773131
FAX: 0344 770356

Dieter Baer
Wissenschaftlicher Mitarbeiter
Bundesamt für Strassenbau
Monbijoustrasse 40
CH-3003 Bern
SWITZERLAND
Phone: 031/322 94 11
FAX: 031/371 90 63

Marlin Horat
Research Engineer
IVT
ETH-Hönggerberg
CH-8093 Zurich
SWITZERLAND
Phone: +41-1-633 31 99
FAX: +41-1-633 10 39

APPENDIX B

DEVELOPMENT OF MIXING AND COMPACTION TEMPERATURES FOR F-MIXES

DEVELOPMENT OF MIXING AND COMPACTION TEMPERATURES FOR F-MIXES

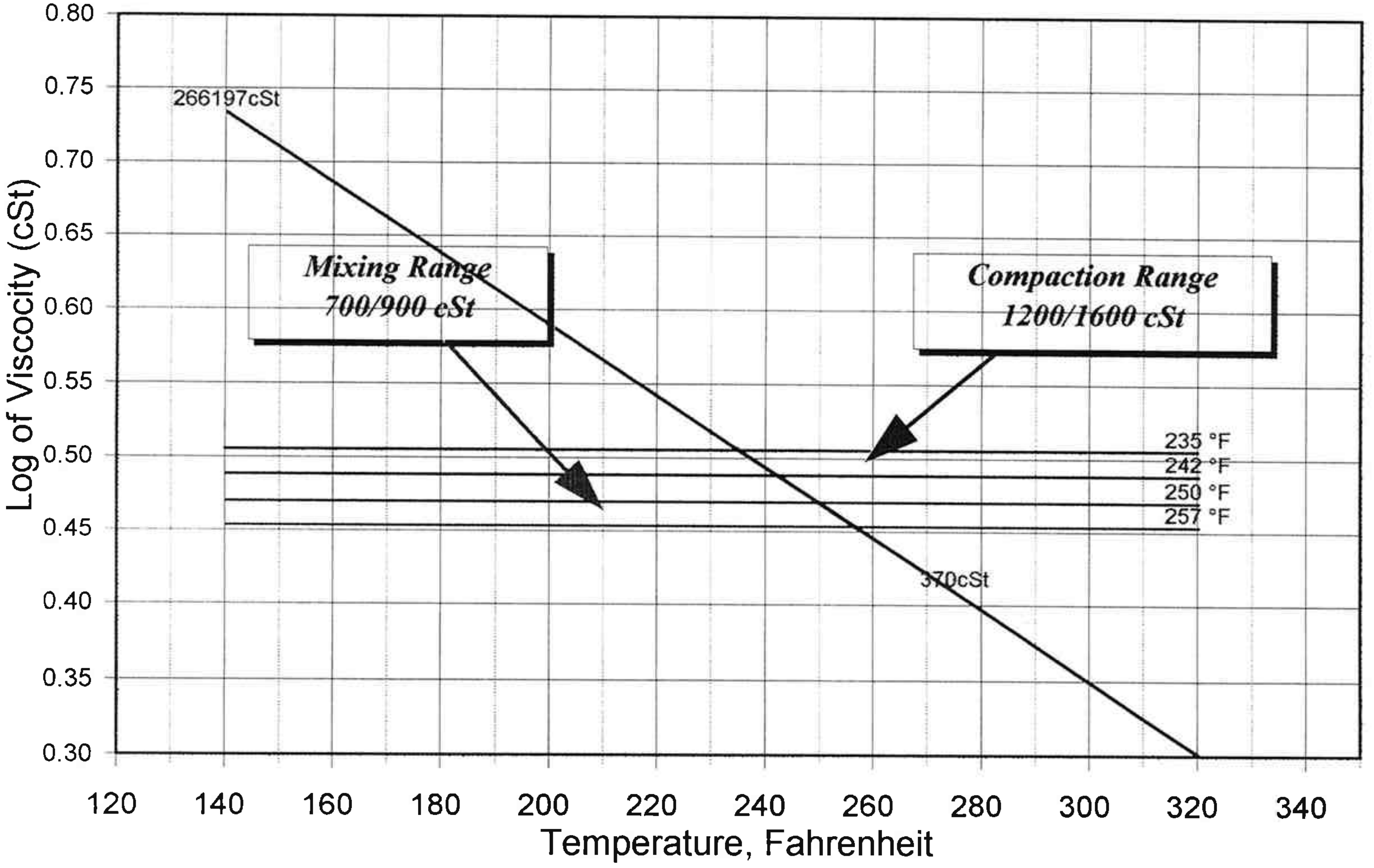
This appendix presents the temperature-viscosity curves for the asphalts used in the projects described in Chapter 3. Also included is a summary of the ODOT recommended mixing and compaction temperatures for the jobs. The temperatures are based on the following viscosity ranges for mixing and compaction (ODOT, 1994):

	Recommended Viscosity, cs	
Application	B-Mixes	F-Mixes
Mixing	150-190	700-900
Compaction	250-310	1200-1600

The importance of controlling these temperatures has been discussed in the body of the report. It directly affects the occurrence of draindown of the asphalt and fat spots in the mat.

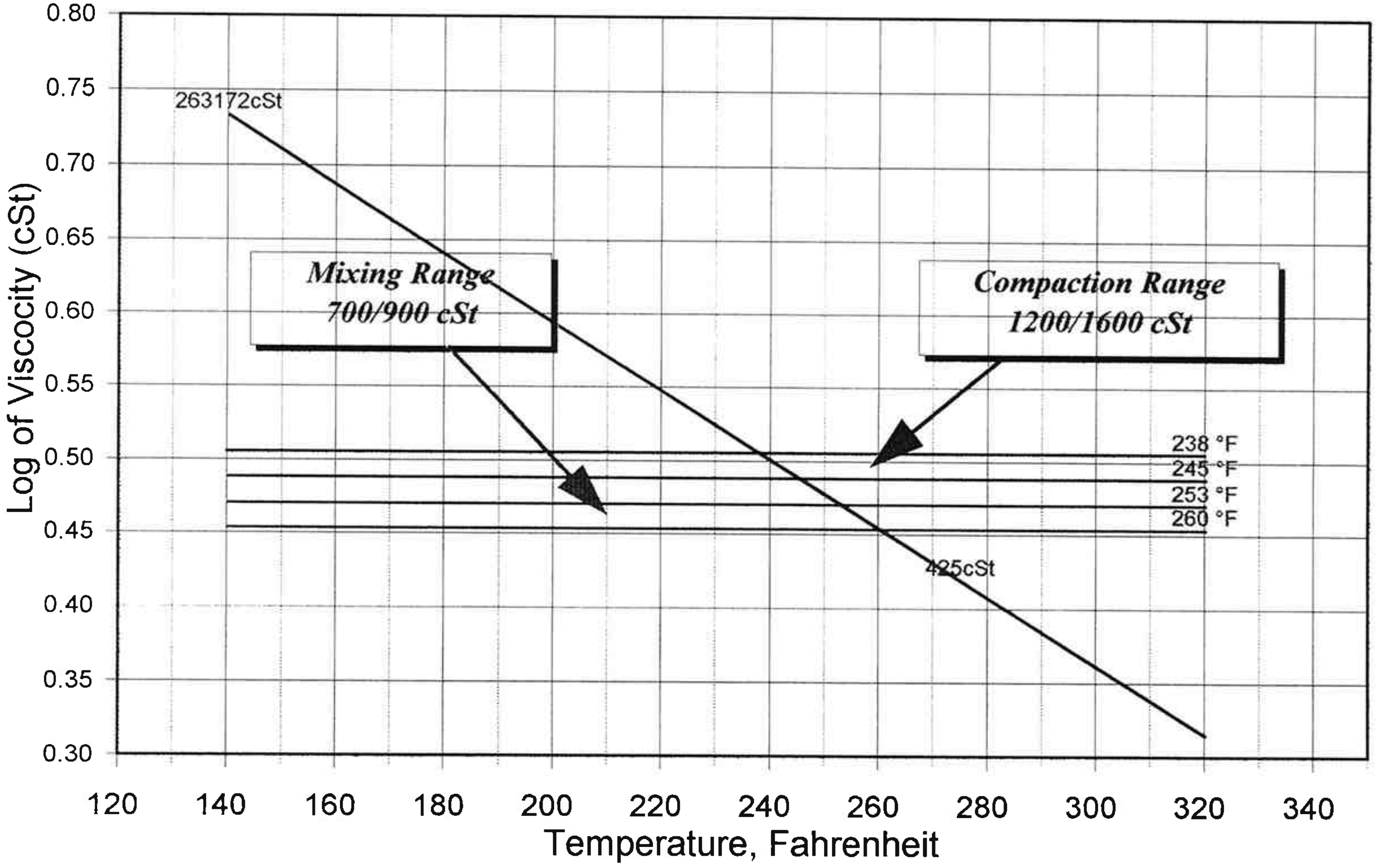
Hayesville - Battle Creek

Temperature / Viscosity Curve (for use with open graded mixes)



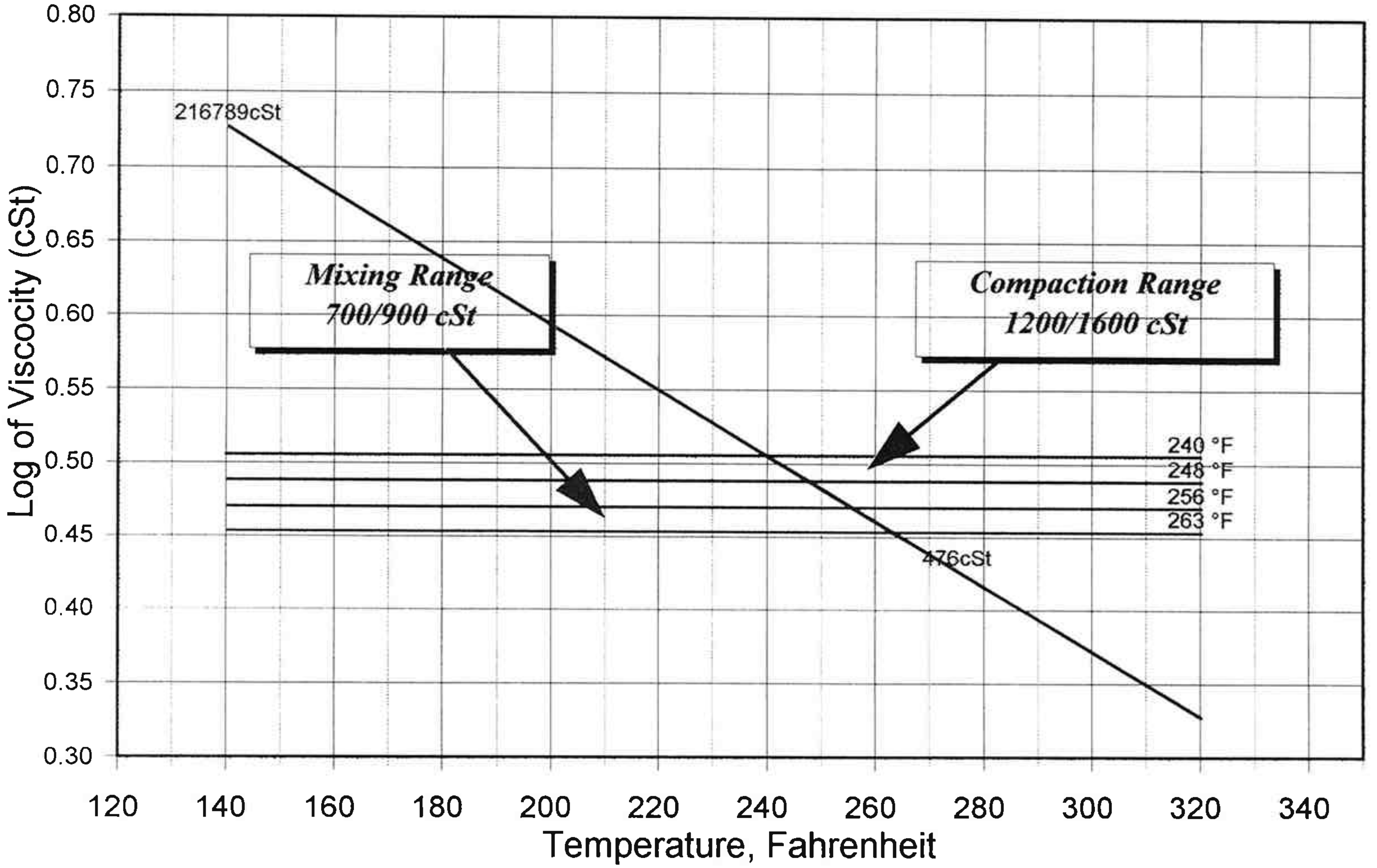
West Marquam - N. Tigard

Temperature / Viscosity Curve (for use with open graded mixes)



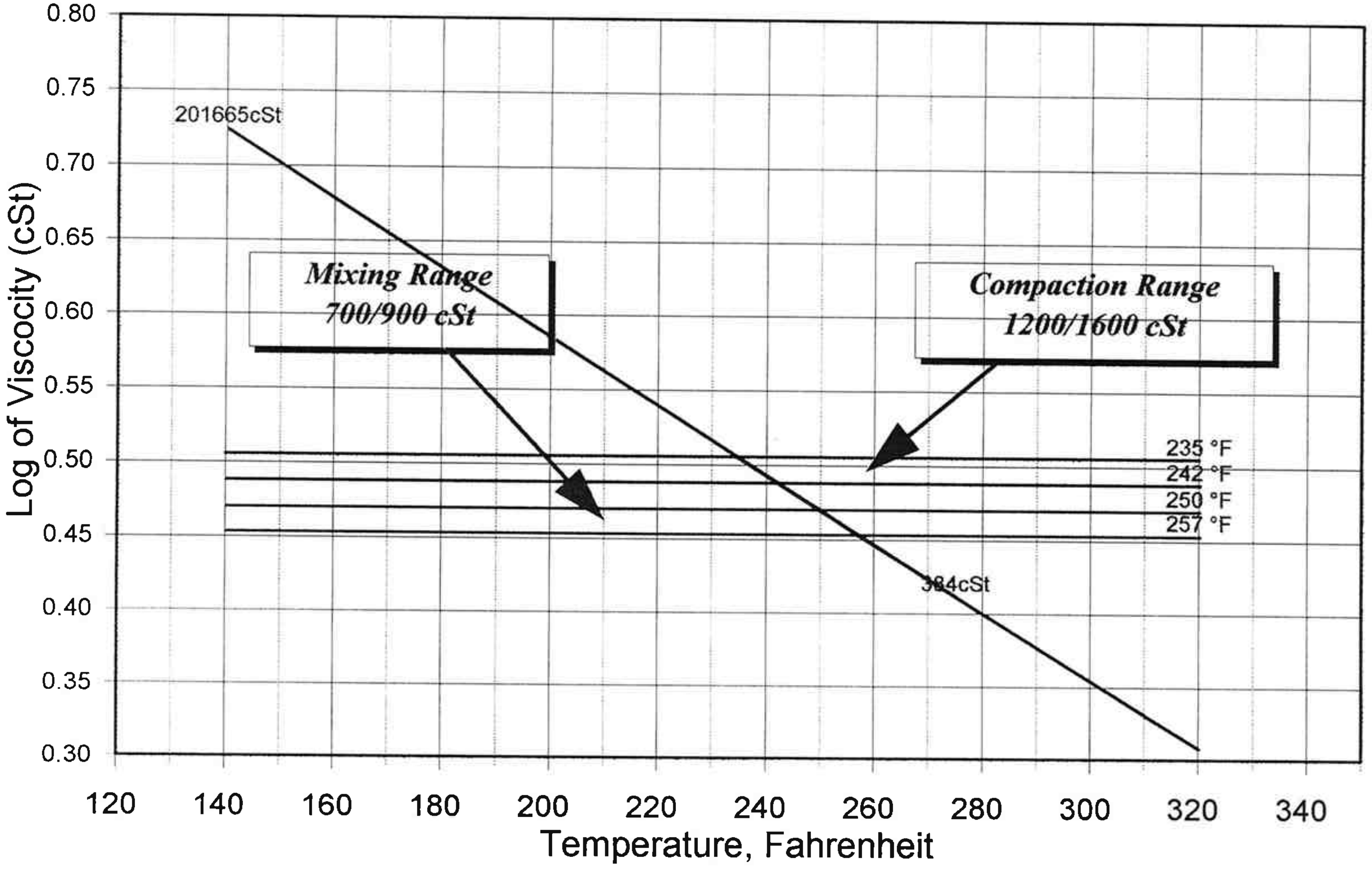
Sunset Hwy - Pacific Hwy

Temperature / Viscosity Curve (for use with open graded mixes)



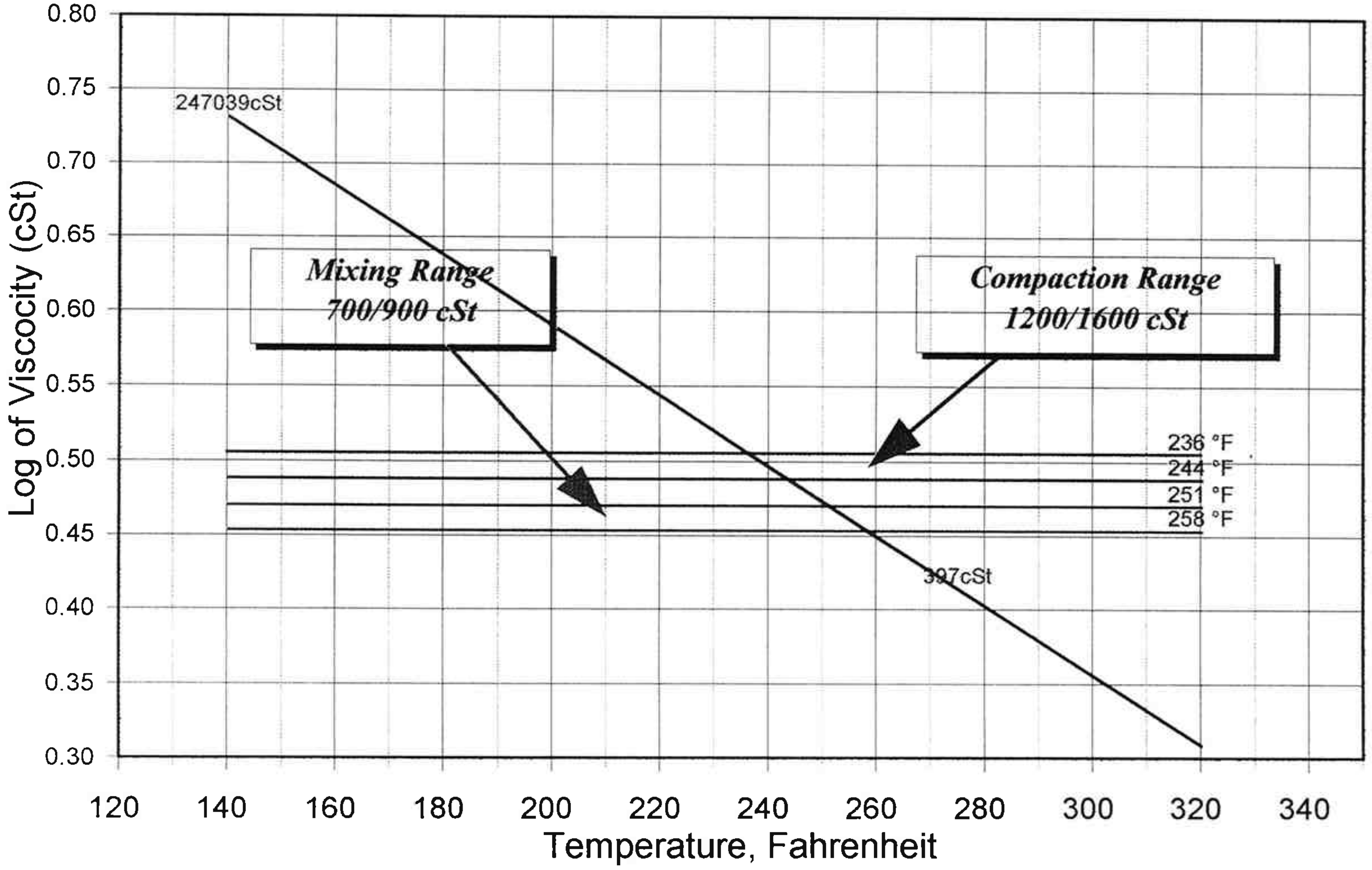
Wolf Creek - W. Fork Dairy Creek

Temperature / Viscosity Curve (for use with open graded mixes)



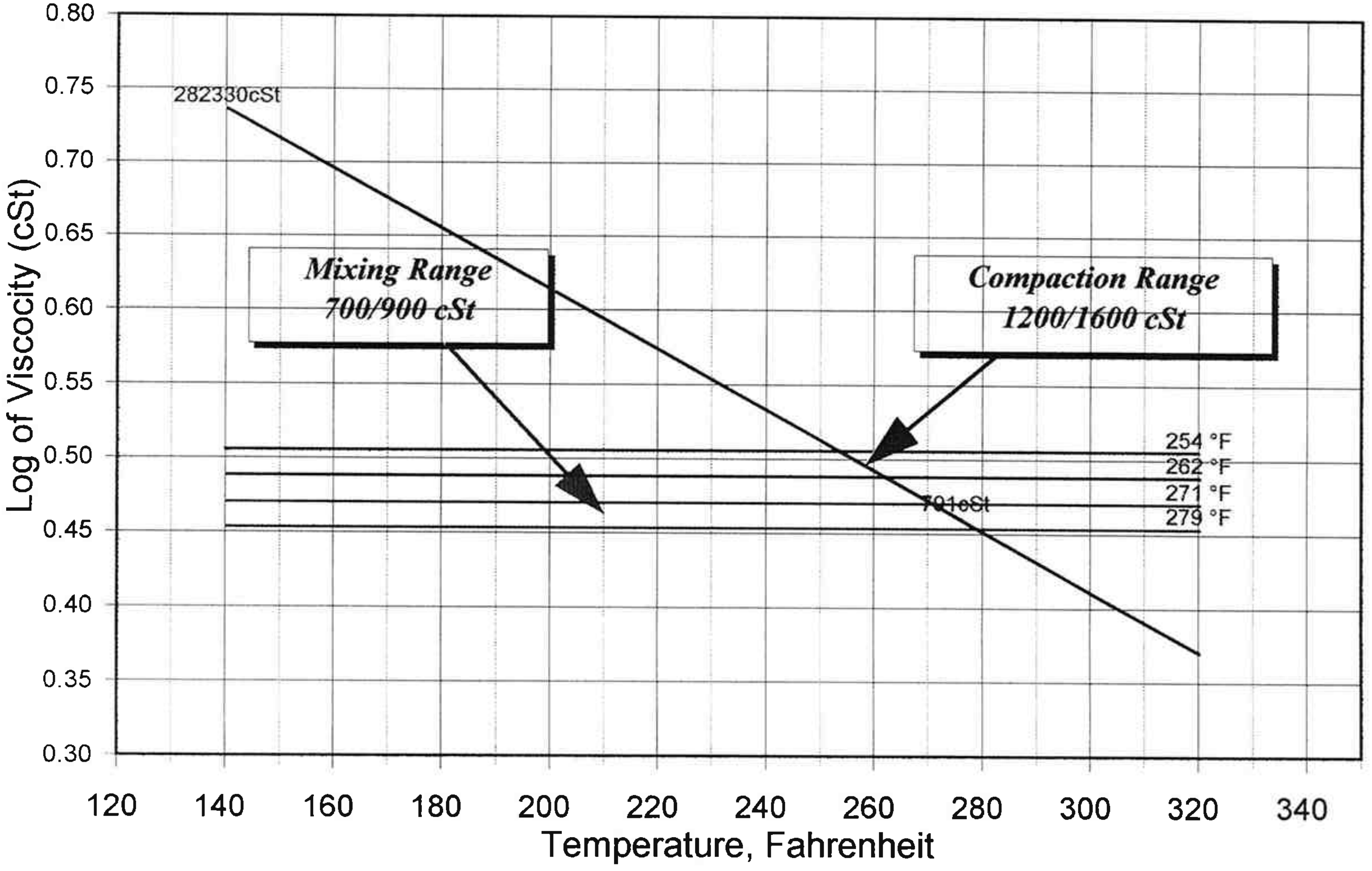
Corbett Interchange - Multnomah

Temperature / Viscosity Curve (for use with open graded mixes)



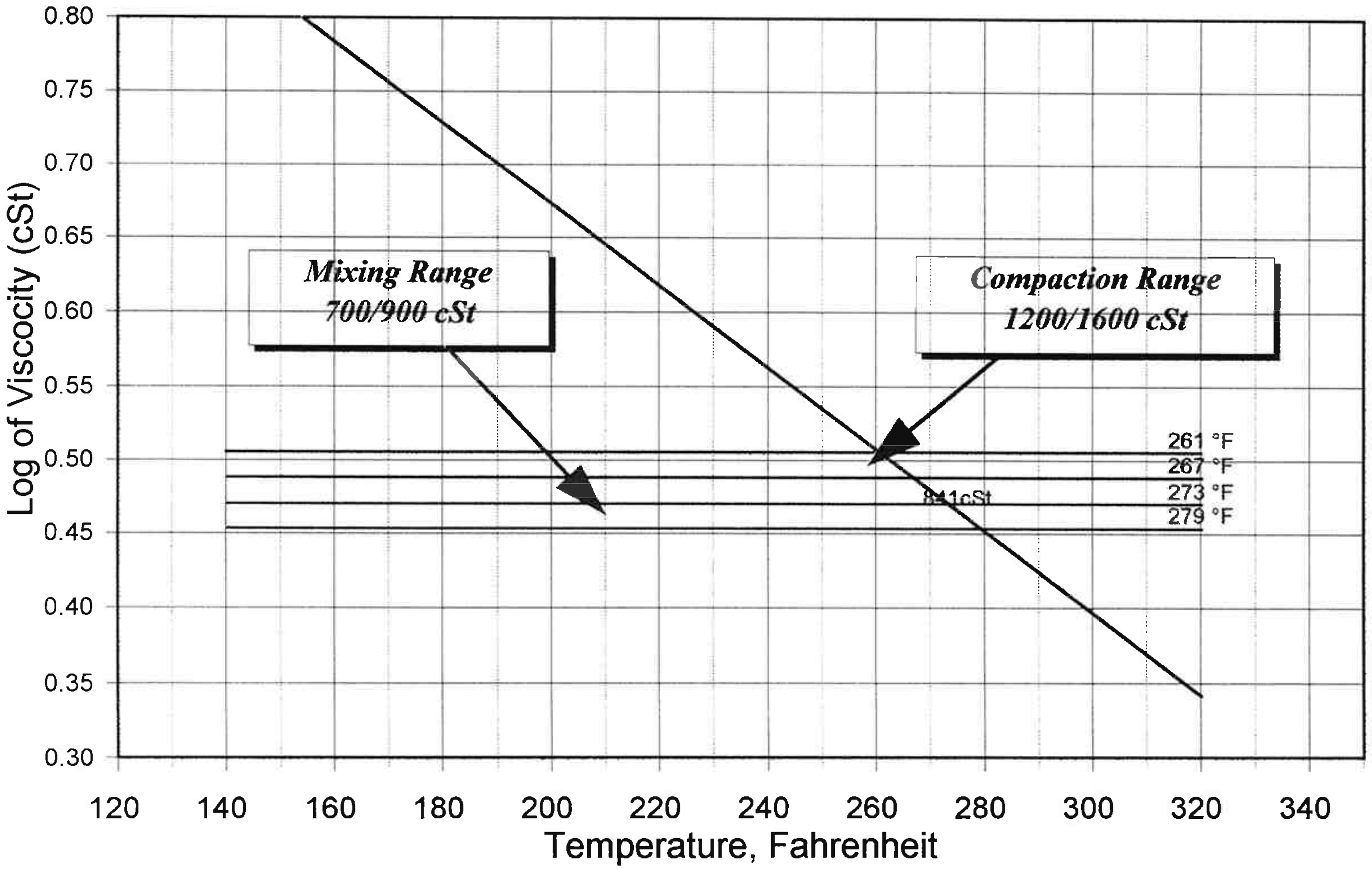
Mt. Hood - Long Prairie

Temperature / Viscosity Curve (for use with open graded mixes)



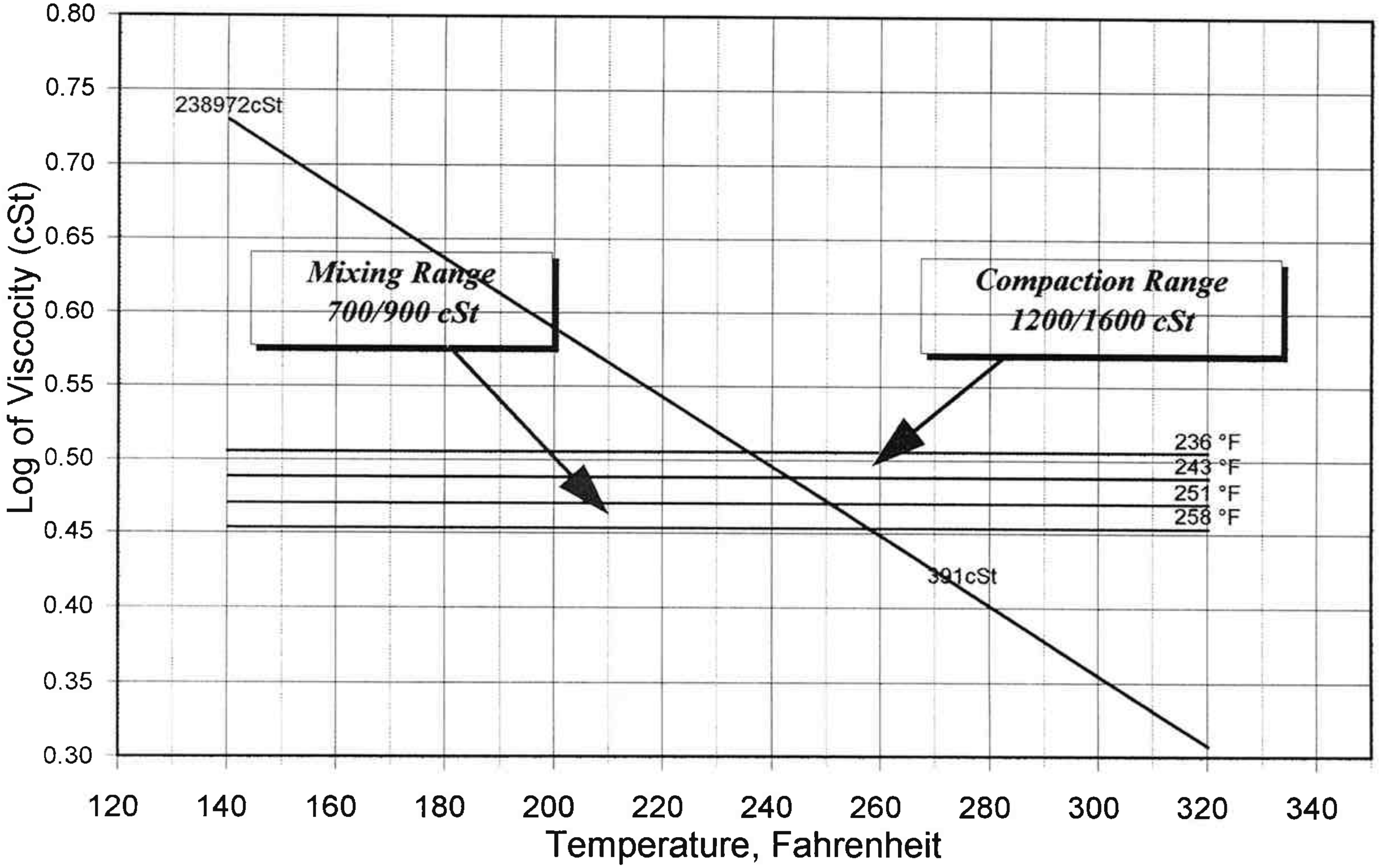
Rufus - Arlington (West Unit)

Temperature / Viscosity Curve (for use with open graded mixes)



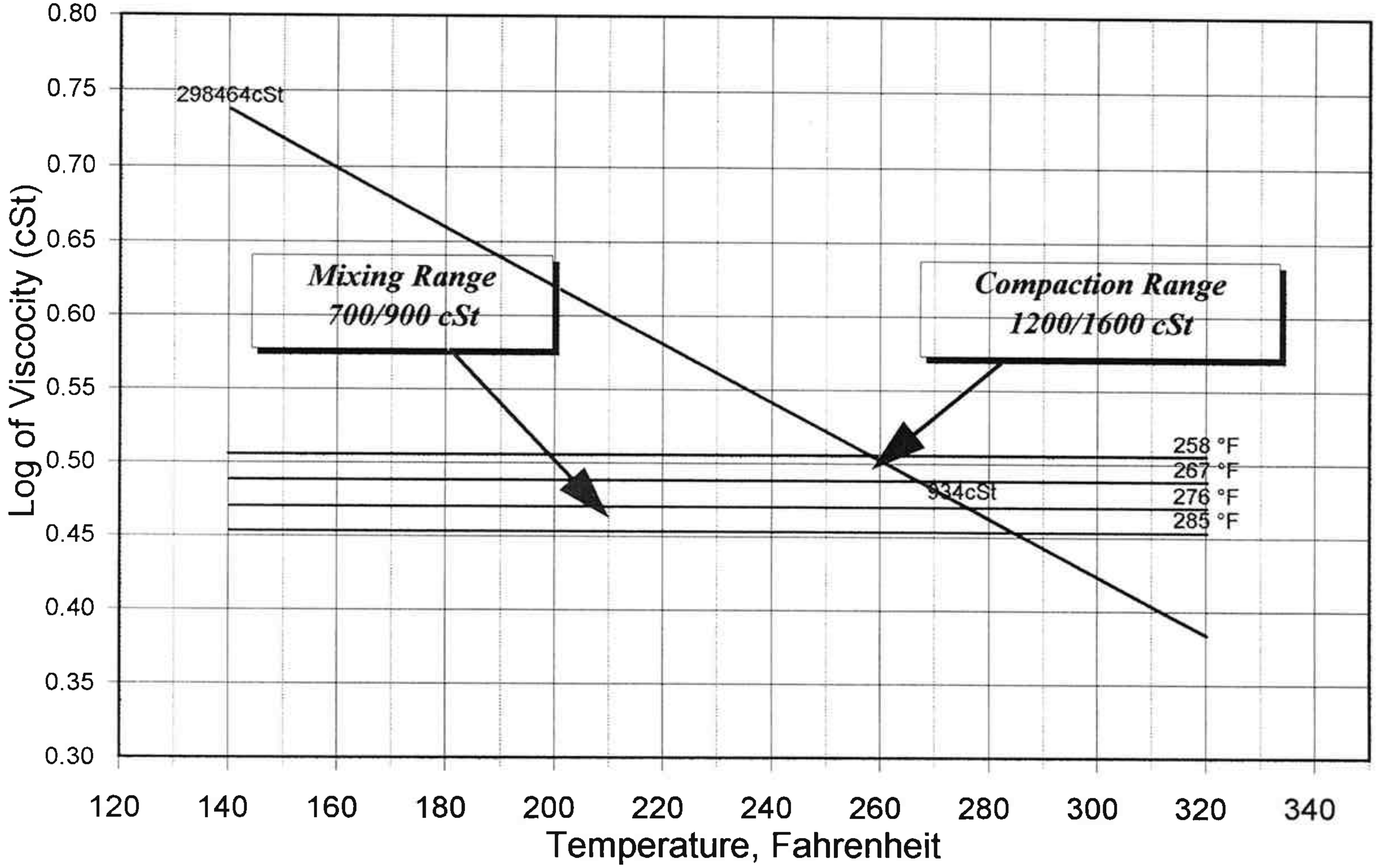
Rufus - Arlington (East Unit)

Temperature / Viscosity Curve (for use with open graded mixes)



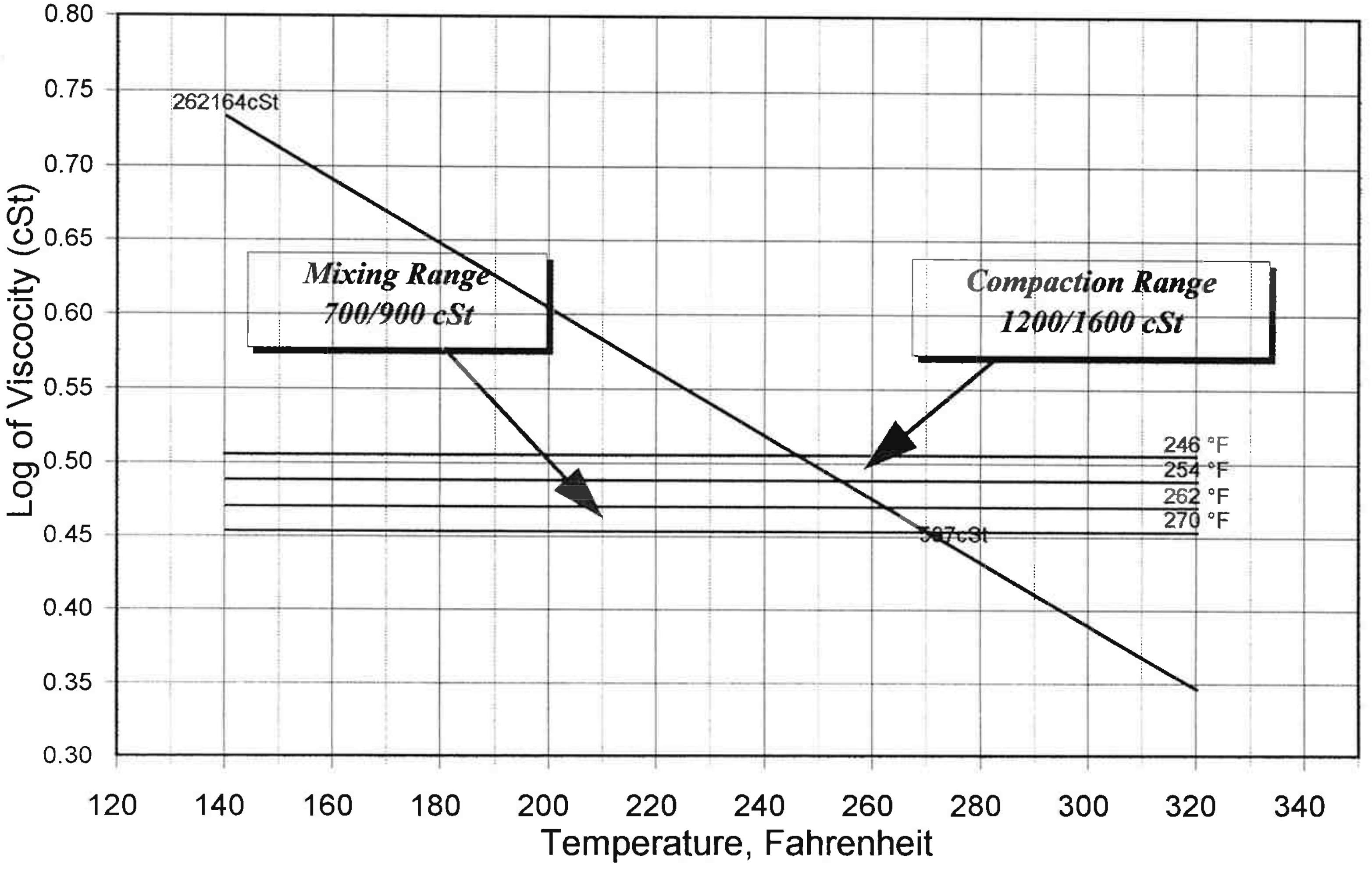
Umatilla - McNary

Temperature / Viscosity Curve (for use with open graded mixes)



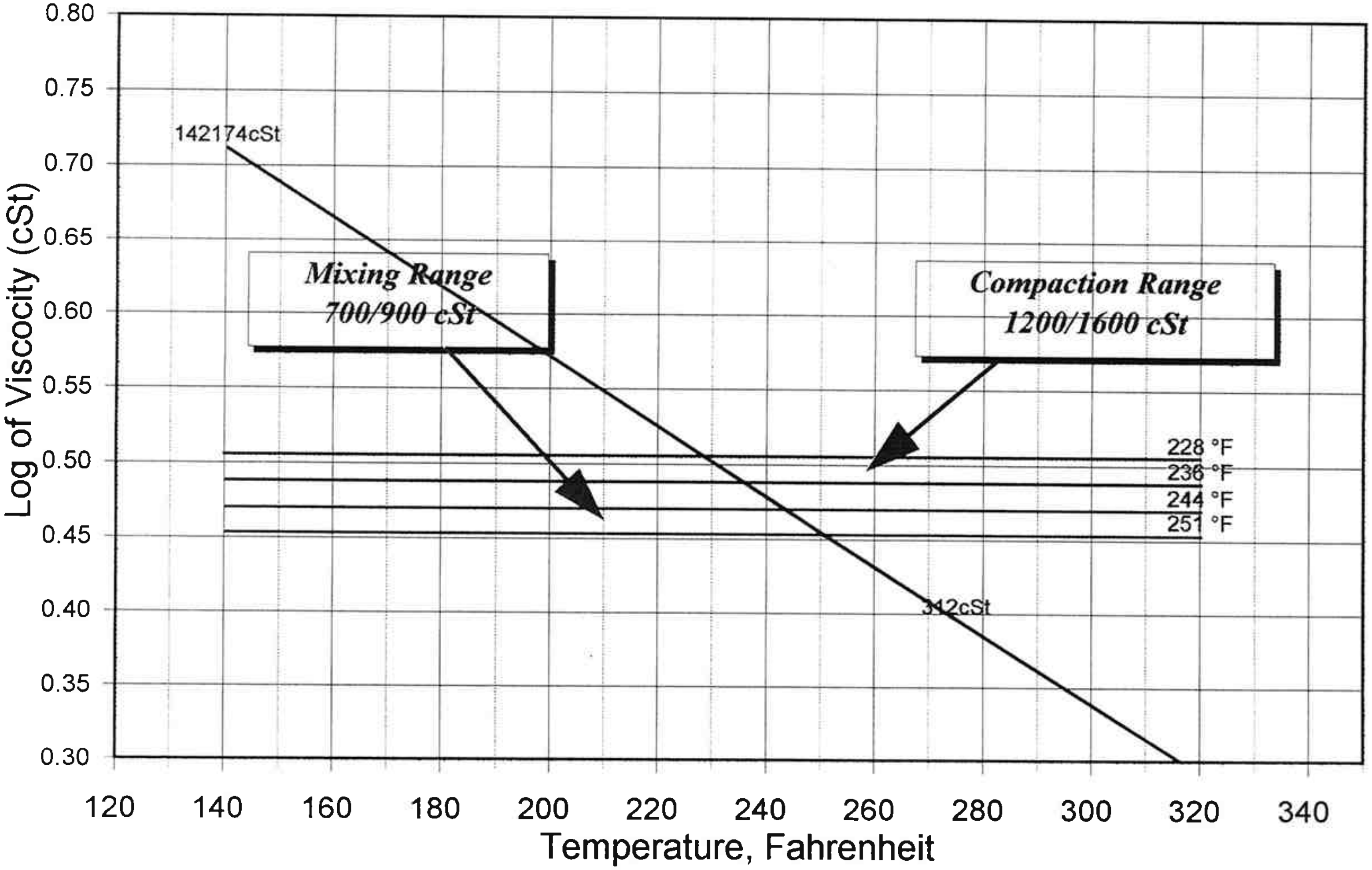
E. Pendleton - Emigrant Hill - I

Temperature / Viscosity Curve (for use with open graded mixes)



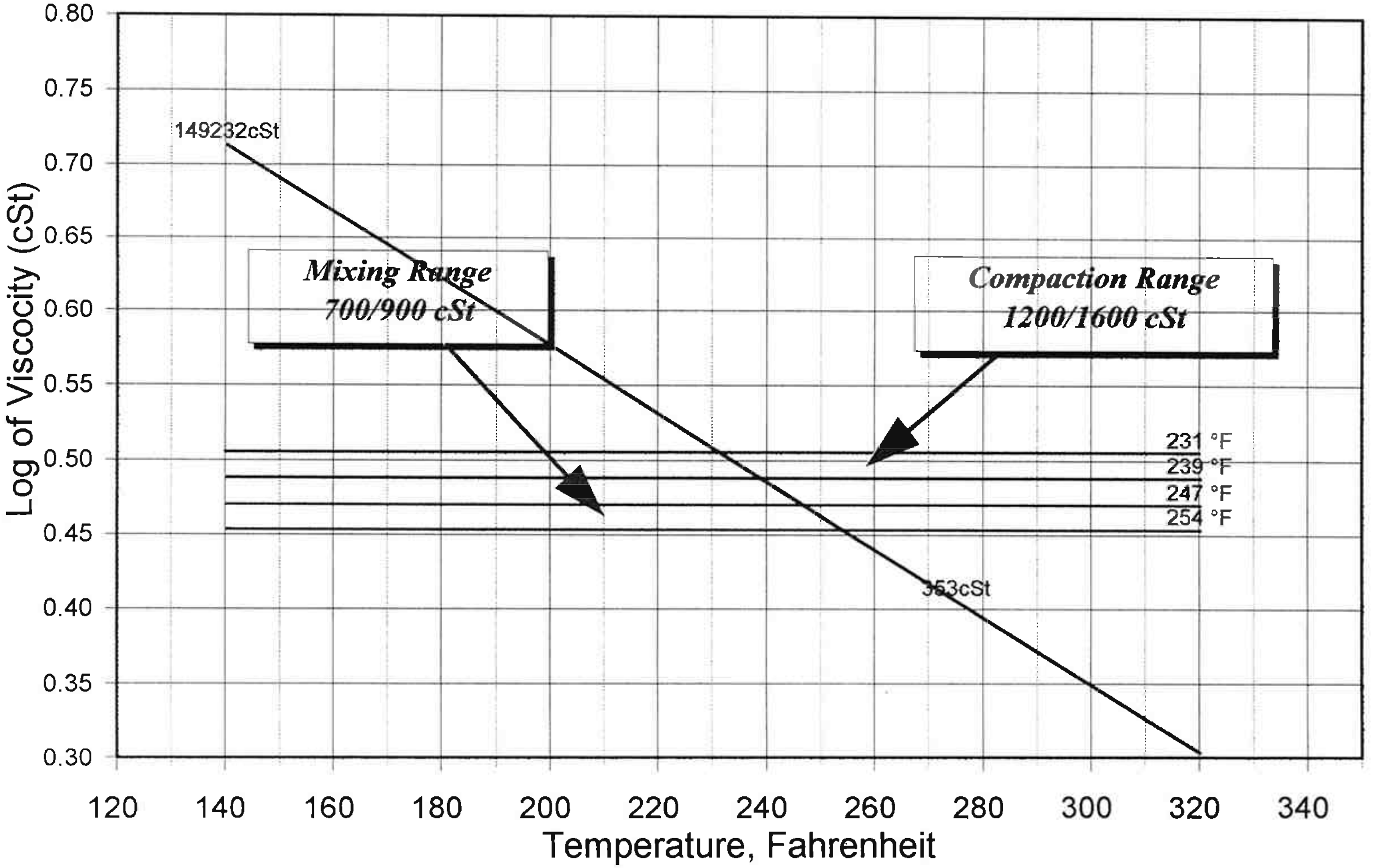
E. Pendleton - Emigrant Hill - II (Test 1)

Temperature / Viscosity Curve (for use with open graded mixes)



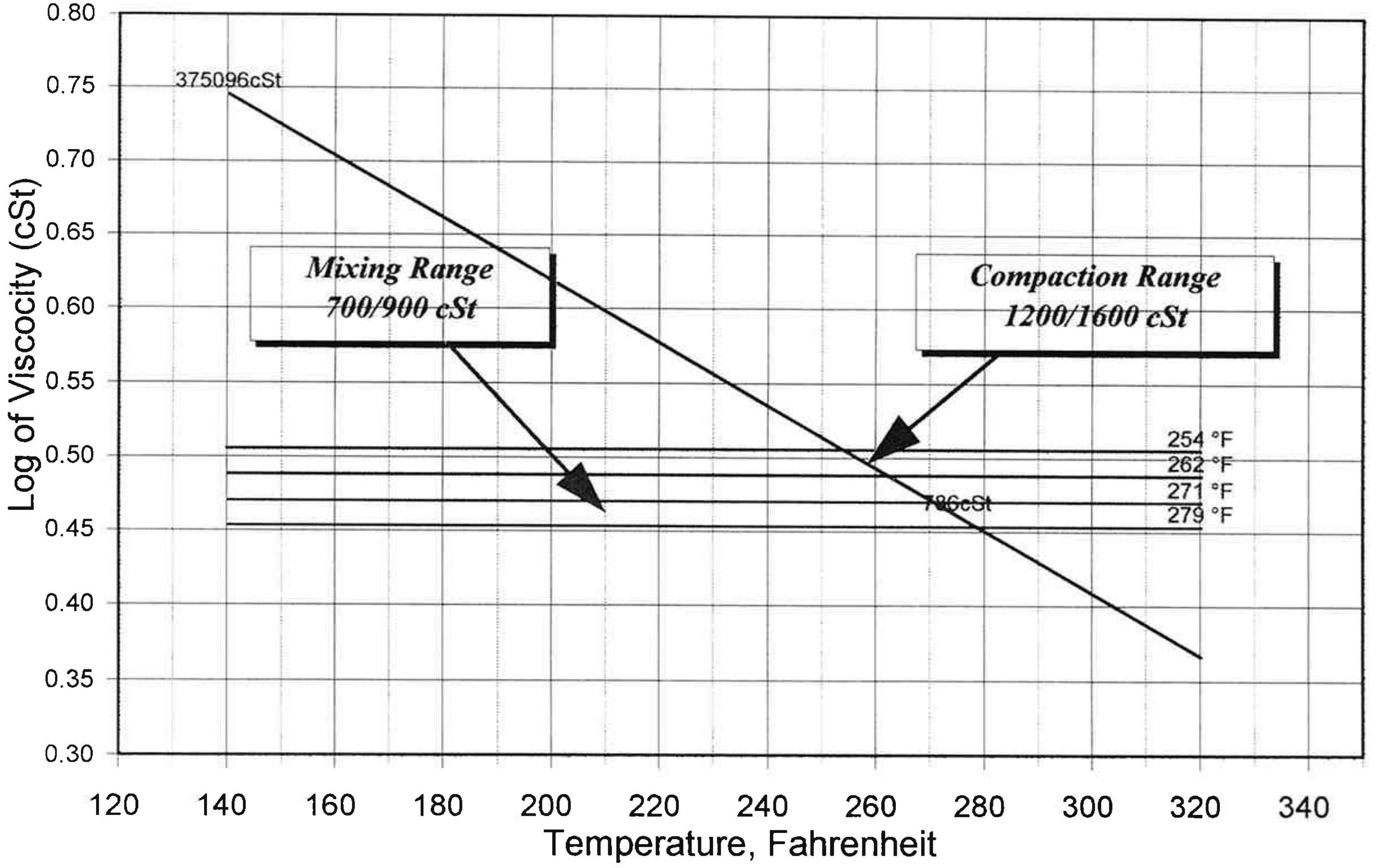
E. Pendleton - Emigrant Hill - II (Test 2)

Temperature / Viscosity Curve (for use with open graded mixes)



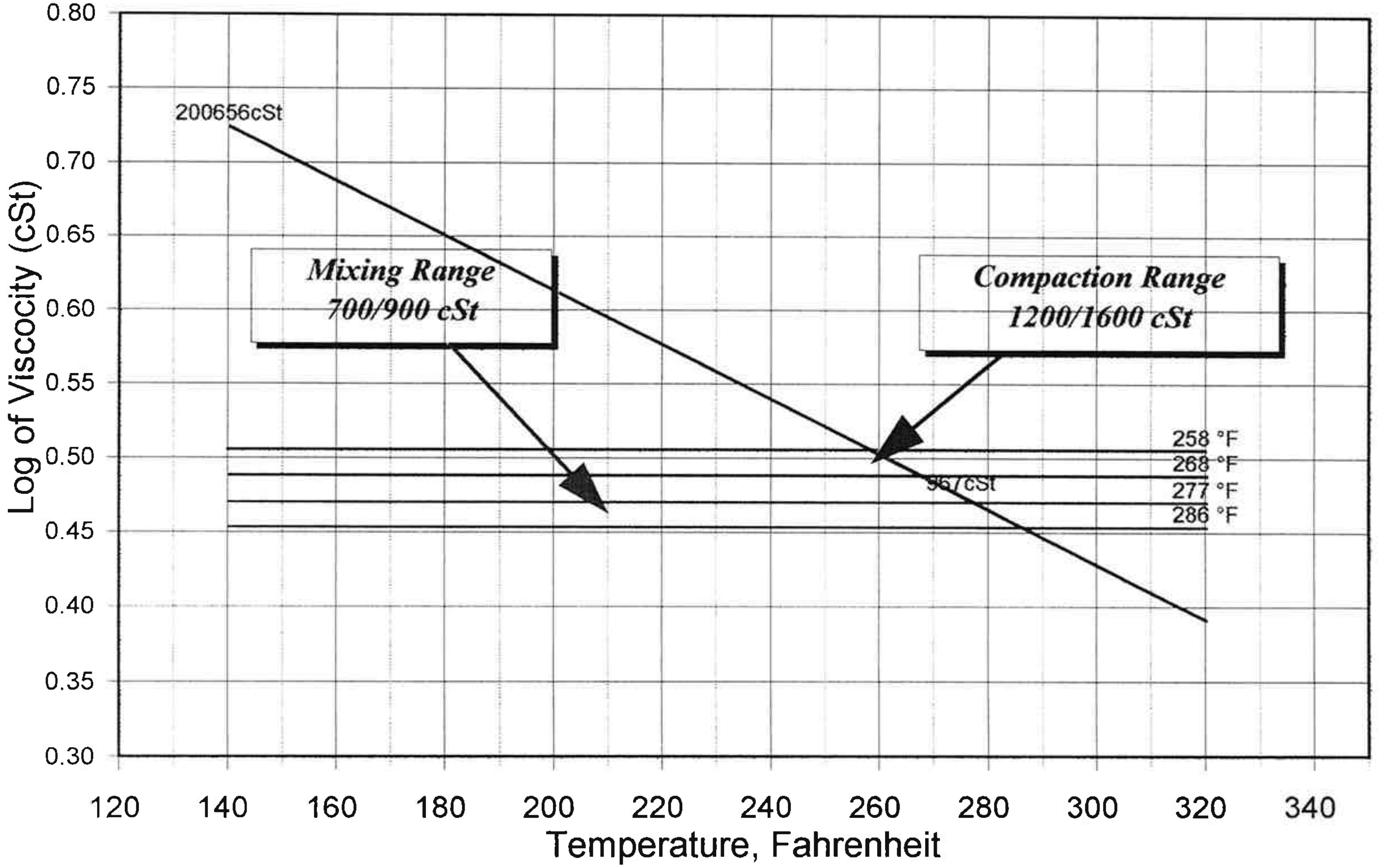
E. Pendleton - Emigrant Hill - III

Temperature / Viscosity Curve (for use with open graded mixes)



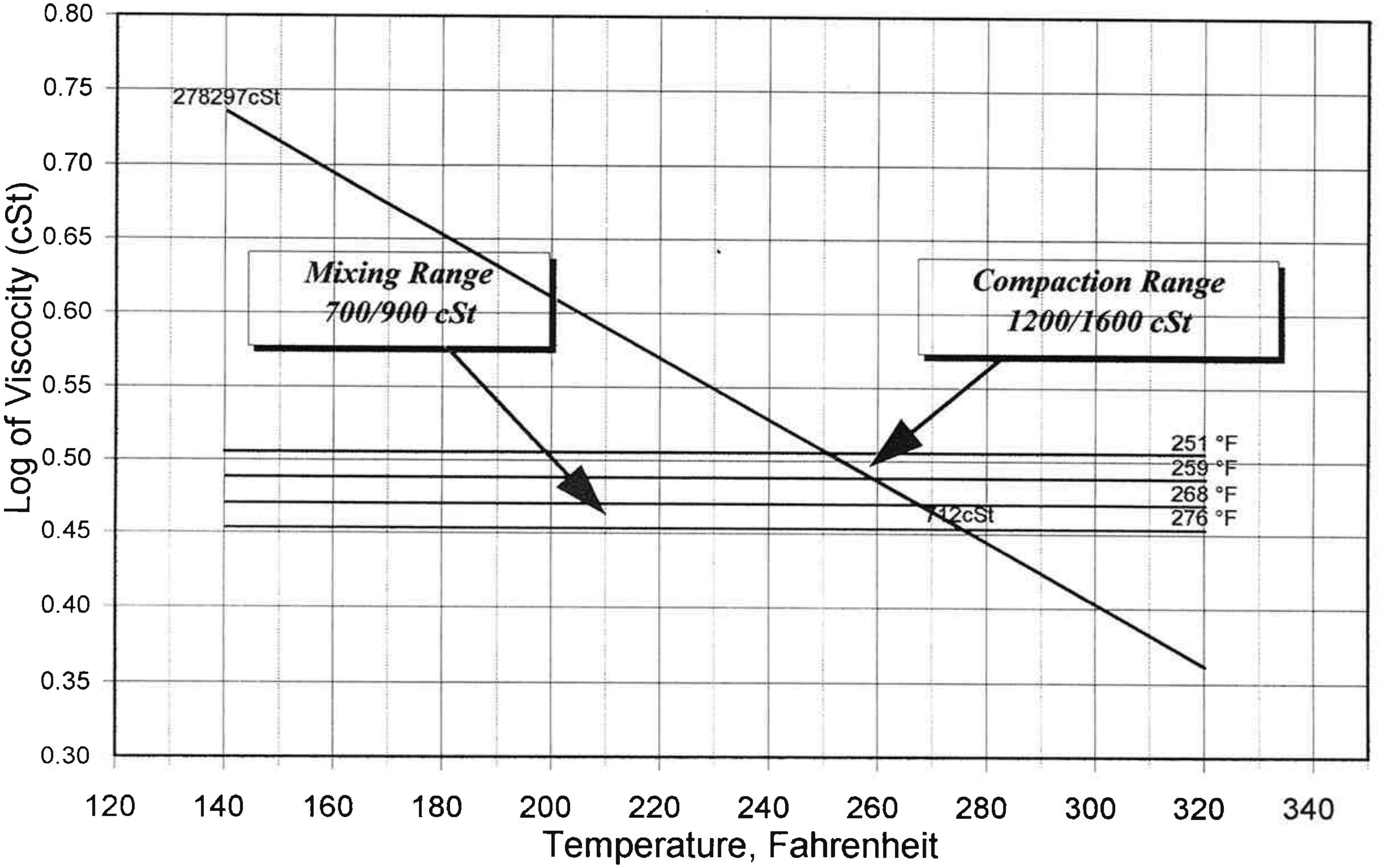
Baldock Slough - S. Baker

Temperature / Viscosity Curve (for use with open graded mixes)



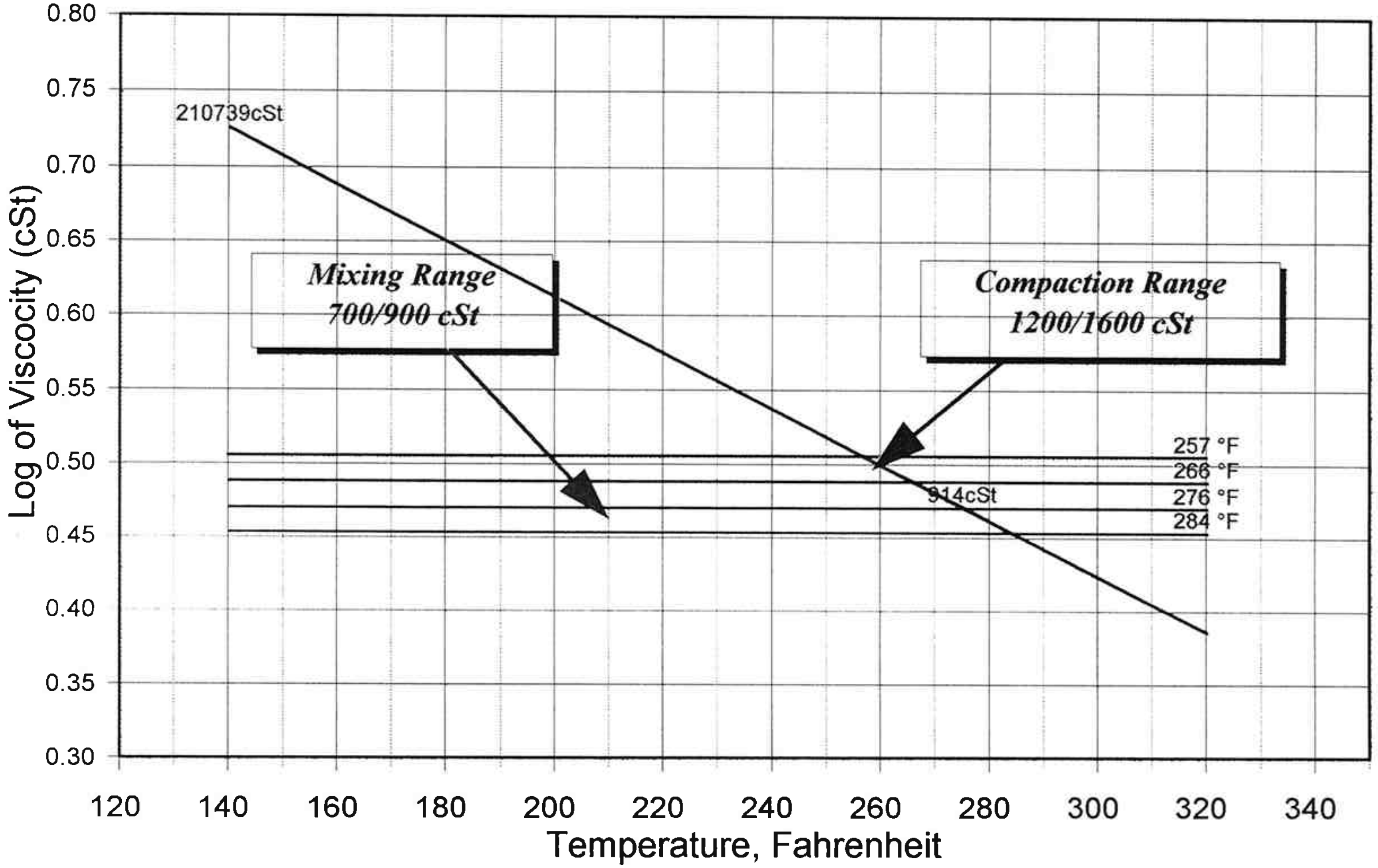
Prineville Airport - Powell Butte

Temperature / Viscosity Curve (for use with open graded mixes)



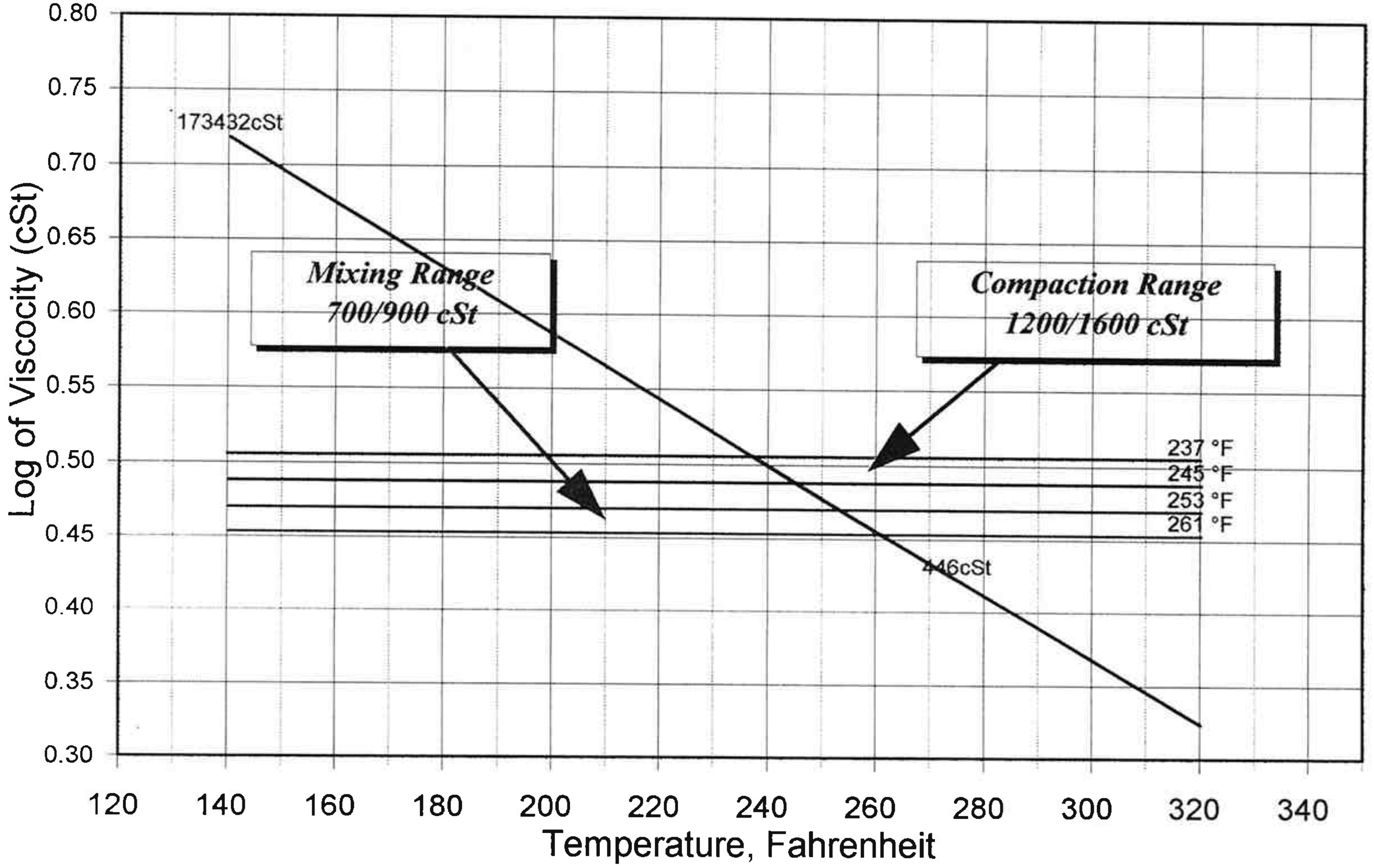
Forge Road - Lobert Road

Temperature / Viscosity Curve (for use with open graded mixes)



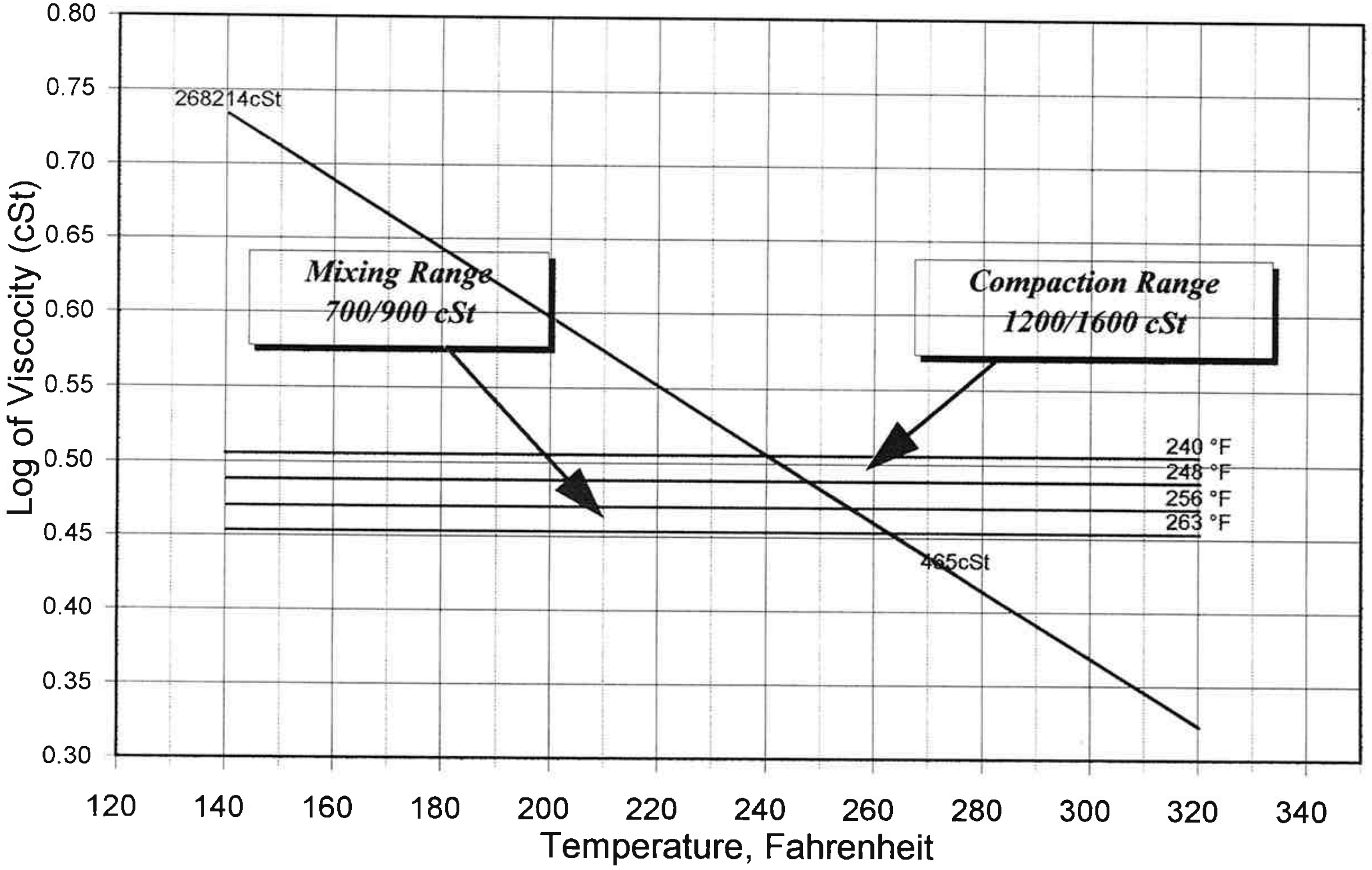
Williamson River - Modoc Point (Middle Unit)

Temperature / Viscosity Curve (for use with open graded mixes)



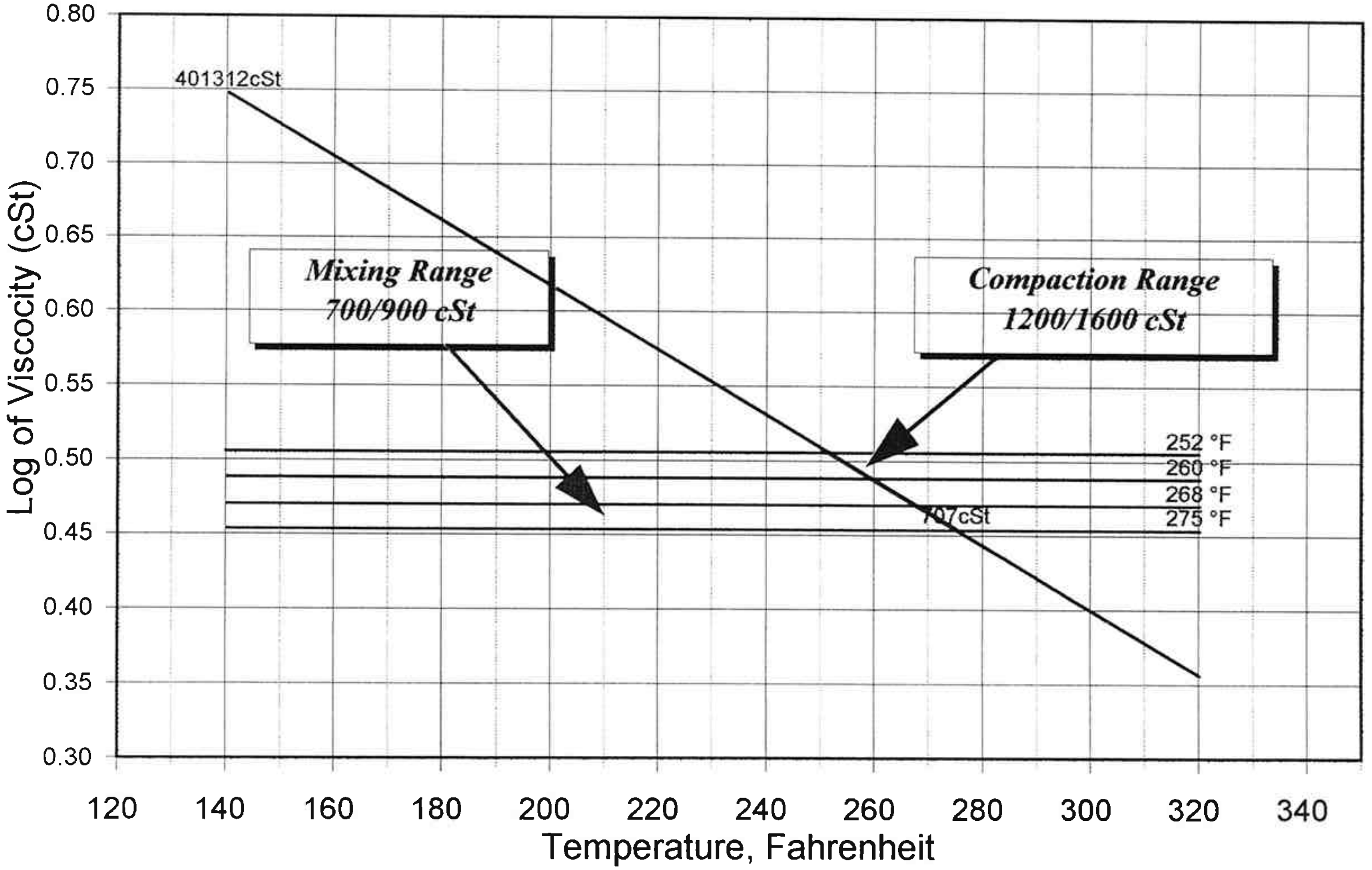
Jumpoff Joe - N. Grants Pass

Temperature / Viscosity Curve (for use with open graded mixes)



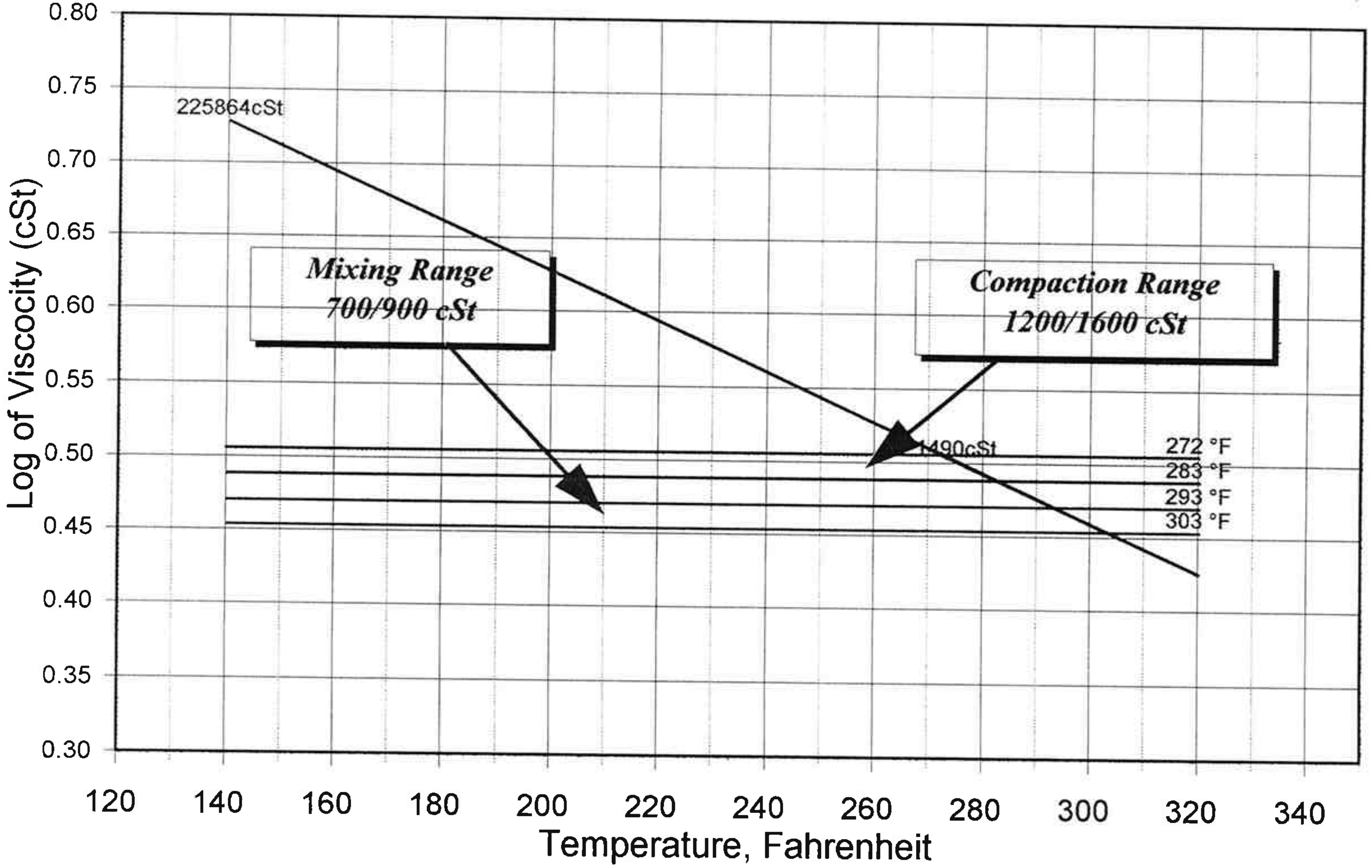
Azalea - Jumpoff Joe - I

Temperature / Viscosity Curve (for use with open graded mixes)



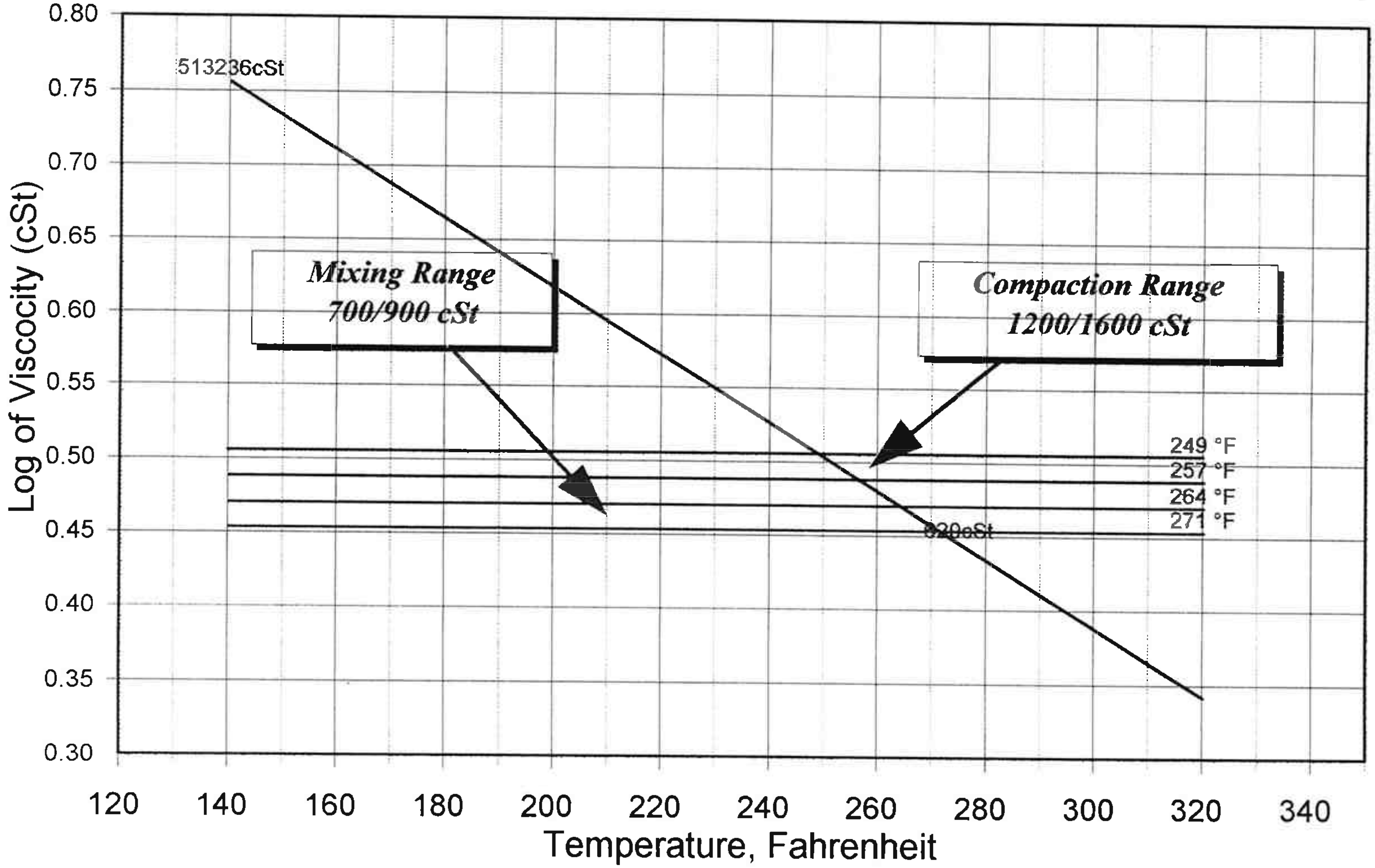
Azalea - Jumpoff Joe - II

Temperature / Viscosity Curve (for use with open graded mixes)



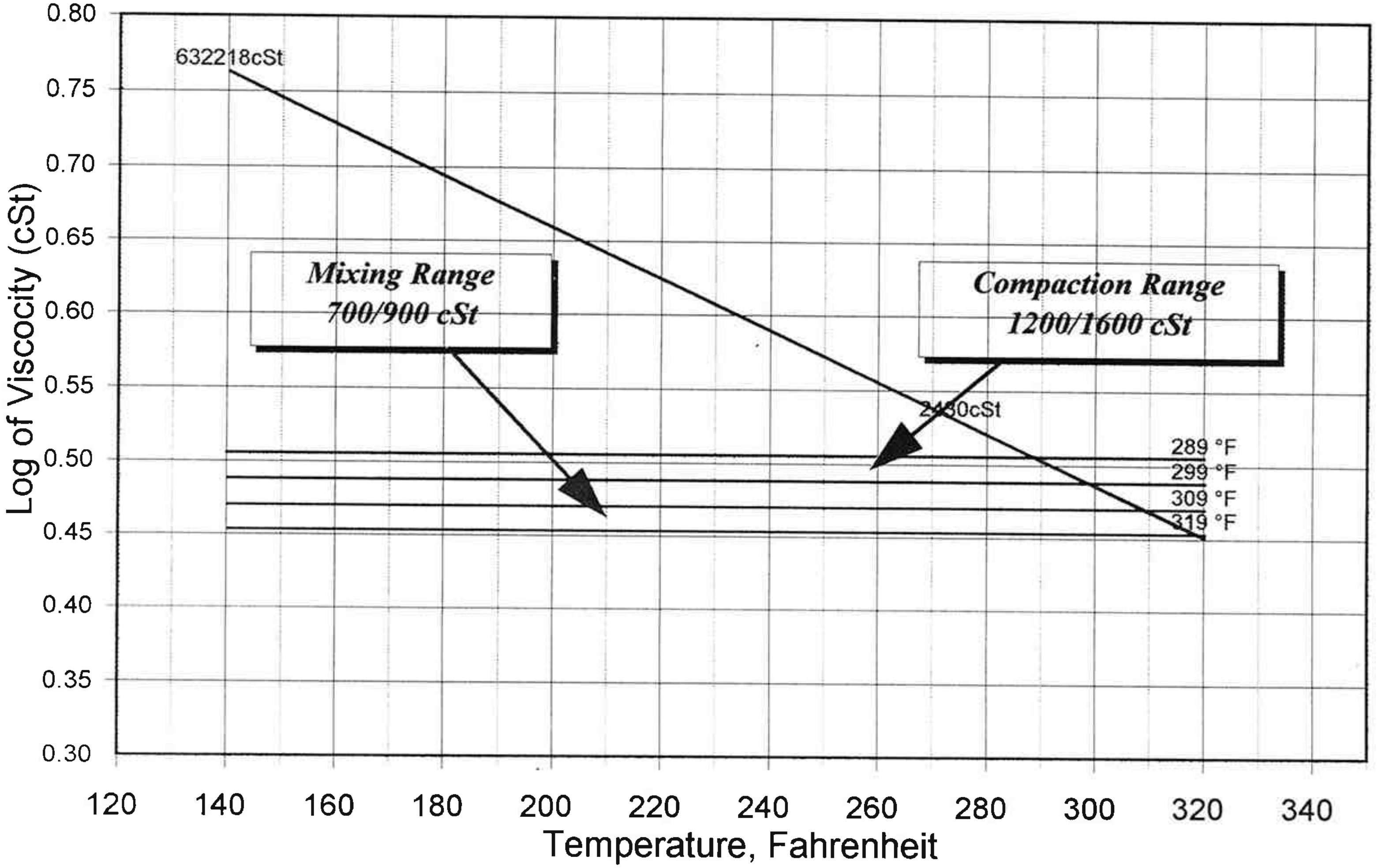
Halsey Interchange - Lane County Line

Temperature / Viscosity Curve (for use with open graded mixes)



Halsey Interchange - Lane County Line

Temperature / Viscosity Curve (for use with open graded mixes)



APPENDIX C

LABORATORY TEST DATA

LABORATORY TEST DATA

This appendix contains the detailed results for the laboratory tests done at both the ODOT and the OSU labs. All of the data from one project are presented before data from a different project is presented.

The first page of each data set lists the volumetric measurements of the cores sent to OSU. A summary table shows the minimum, maximum and average value, along with the standard deviation and coefficient of variation.

Tabulated on the second page are the results of the gradation testing done by ODOT. Included on the table is the minimum, maximum and average value, along with the standard deviation and coefficient of variation. The graph below the table provides a plot each core's gradation along with the project's specified gradation.

The final page of data for each project contains two tables. The first table shows the difference between the target gradation and the upper design limit or core. This table allows one to see how far from the target and the upper design limit each core is. The second table displays a summary of the ODOT volumetric measurements for each core. Included on the table is the minimum, maximum and average value, along with the standard deviation and coefficient of variation.

Laboratory Data for Following Projects — OSU Data

Open graded QC/QA project (OSU cores)

LOCATION: **Wolf Creek**
ASPHALT: PBA-5
ADDITIVES: None

BULK SPECIFIC GRAVITY-VOLUME AIR VOIDS DATA

ID	Core Milepost	Core Condition	Thickness (inches)	Gmb	Av (%)	VMA (%)	VFA (%)	NOTES
B01	37.600	Good	2.103	2.089	14.6	25.3	42.3	Gmm = 2.447
B02	37.600	Good	2.053	2.098	14.3	25.0	43.0	Gmm = 2.447
B03	38.380	Good	2.198	2.227	8.3	20.4	59.1	Gmm = 2.430
B04	38.380	Fat spot	2.402	2.308	5.0	17.5	71.3	Gmm = 2.430
B05	38.380	Fat spot	2.340	2.300	5.3	17.8	70.0	Gmm = 2.430
B07	42.020	Good	1.221	2.176	11.4	22.2	48.7	Gmm = 2.456
B08	42.020	Good	1.817	2.189	10.9	21.7	50.1	Gmm = 2.456
B13	42.020	Good	1.699	2.206	10.2	21.1	51.9	Gmm = 2.456
B09	45.200	Fat spot	1.880	2.244	8.1	19.8	59.4	Gmm = 2.440
B11	45.201	Good	1.912	2.231	8.6	20.3	57.7	Gmm = 2.440
B12	45.201	Good	2.028	2.225	8.8	20.5	57.0	Gmm = 2.440
		Average	1.979	2.199	10.0			

The average Gmm for each milepost is from tests perfomed by the Operations Support Section of ODOT.

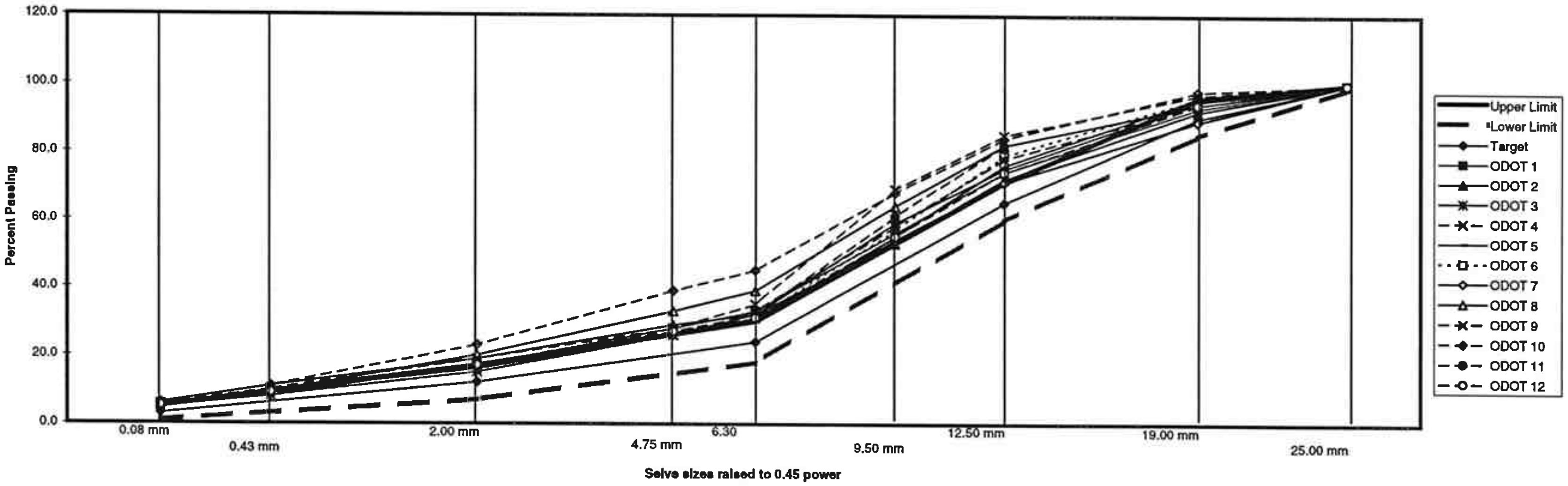
Summary

	Gmb	Va (%)	VMA (%)	VFA (%)
Minimum	2.089	5.0	17.5	42.3
Maximum	2.308	14.6	25.3	71.3
Average	2.209	9.6	21.1	55.5
Standard Dev.	0.07	3.0	2.4	9.1
Coefficient of Variation	3.0	31.0	11.3	16.4

Wolf Creek - W. Fork Dairy

Sieve size (inches)	Sieve size (mm)	Percent Passing																		
		Target	Upper	Lower	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	ODOT 7	ODOT 8	ODOT 9	ODOT 10	ODOT 11	ODOT 12	*Average*	*Min*	*Max*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	99.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	*100.0*	*100.0*	*100.0*	*0.0*	*0.0*
3/4	19.000	90.0	96.0	85.0	93.0	92.0	95.0	97.0	96.0	96.0	89.0	94.0	94.0	98.0	94.0	94.0	*94.3*	*89.0*	*98.0*	*2.4*	*2.5*
1/2	12.500	65.0	71.0	60.0	74.0	72.0	75.0	85.0	76.0	79.0	71.0	82.0	78.0	84.0	82.0	74.0	*77.7*	*71.0*	*85.0*	*4.7*	*6.1*
3/8	9.500	-	-	-	56.0	53.0	59.0	69.0	55.0	57.0	54.0	64.0	58.0	68.0	61.0	55.0	*59.1*	*53.0*	*69.0*	*5.4*	*9.1*
1/4	6.300	24.0	30.0	18.0	33.0	32.0	32.0	35.0	30.0	31.0	31.0	39.0	33.0	45.0	32.0	31.0	*33.7*	*30.0*	*45.0*	*4.3*	*12.7*
No. 4	4.750	-	-	-	28.0	29.0	26.0	28.0	26.0	27.0	26.0	33.0	28.0	39.0	27.0	27.0	*28.7*	*26.0*	*39.0*	*3.8*	*13.2*
No. 10	2.000	12.0	17.0	7.0	17.0	19.0	15.0	16.0	16.0	17.0	17.0	20.0	19.0	23.0	17.0	17.0	*17.8*	*15.0*	*23.0*	*2.2*	*12.3*
No. 40	0.425	5.0	-	-	9.0	11.0	8.0	9.0	9.0	9.0	8.0	9.0	10.0	11.0	9.0	9.0	*9.3*	*8.0*	*11.0*	*1.0*	*10.4*
No 200	0.075	3.0	5.0	1.0	4.9	6.1	4.9	5.4	5.3	4.9	4.8	5.4	5.6	6.1	4.8	5.2	*5.3*	*4.8*	*6.1*	*0.5*	*8.8*

Wolf Extraction Gradation



Wolf Creek - W. Fork Dairy

Sieve size (inches)	Sieve size (mm)	Percent Passing		Differences															
		Target	Upper	Upper	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	ODOT 7	ODOT 8	ODOT 9	ODOT 10	ODOT 11	ODOT 12	*Average*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3/4	19.000	95.0	96.0	-1.0	2.0	3.0	0.0	-2.0	-1.0	-1.0	6.0	1.0	1.0	-3.0	1.0	1.0	0.7	2.4	358.0
1/2	12.500	65.0	71.0	-6.0	-9.0	-7.0	-10.0	-20.0	-11.0	-14.0	-6.0	-17.0	-13.0	-19.0	-17.0	-9.0	-12.7	4.7	-37.4
1/4	6.300	25.0	30.0	-5.0	-8.0	-7.0	-7.0	-10.0	-5.0	-6.0	-6.0	-14.0	-8.0	-20.0	-7.0	-6.0	-8.7	4.3	-49.5
No. 10	2.000	12.0	16.0	-5.0	-5.0	-7.0	-3.0	-4.0	-4.0	-5.0	-5.0	-8.0	-7.0	-11.0	-5.0	-5.0	-5.8	2.2	-37.9
No 200	0.075	3.0	5.0	-2.0	-1.9	-3.1	-1.9	-2.4	-2.3	-1.9	-1.8	-2.4	-2.6	-3.1	-1.8	-2.2	-2.3	0.5	-20.4
		Air voids (%)			3.8	4.0	8.8	8.4	5.8	5.8	7.0	4.5	4.8	2.8	4.1	6.4	5.5	1.9	33.9
		Asphalt Content (%)			5.9	7.4	5.4	6.1	6.1	13.1	5.1	6.6	7.3	6.2	7.2	5.9	6.9	2.1	30.5
		P200 / %AC			0.8	0.8	0.9	0.9	0.9	0.4	0.9	0.8	0.8	1.0	0.7	0.9	0.8	0.2	19.8

Sample	Geo. Gmb	Gmm	Geo V_a (%)	VMA (%)	VFA (%)
ODOT 1	2.301	2.444	5.9	17.2	65.9
ODOT 2	2.242	2.408	6.9	20.6	66.5
ODOT 3	2.122	2.461	13.8	23.2	40.6
ODOT 4	2.14	2.432	12.0	23.1	48.1
ODOT 5	2.163	2.437	11.2	22.3	49.6
ODOT 6	2.182	2.467	11.6	27.5	57.9
ODOT 7	2.119	2.482	14.6	23.1	36.6
ODOT 8	2.197	2.42	9.2	21.5	57.1
ODOT 9	2.219	2.457	9.7	21.3	54.5
ODOT 10	2.257	2.421	6.8	19.0	64.4
ODOT 11	2.309	2.438	5.3	18.0	70.6
ODOT 12	2.163	2.469	12.4	22.1	44.0
Average	*2.201*	*2.445*	*9.9*	*21.6*	*54.7*
Min	*2.119*	*2.408*	*5.3*	*17.2*	*36.6*
Max	*2.309*	*2.482*	*14.6*	*27.5*	*70.6*
Std. Dev.	*0.1*	*0.0*	*3.2*	*2.7*	*11.0*
CV	*3.0*	*0.9*	*31.7*	*12.7*	*20.2*

Open graded QC/QA project (OSU cores)

LOCATION: **Rufus - Arlington**
ASPHALT: PBA-5
ADDITIVES: Lime

BULK SPECIFIC GRAVITY-VOLUME AIR VOIDS DATA

ID	Core Milepost	Core Condition	Thickness (inches)	Gmb	Va (%)	VMA (%)	VFA (%)	NOTES
A01	126.509	Good	2.253	2.466	3.6	10.6	66.0	Gmm = 2.558
A02	126.509	Good	1.740	2.446	4.4	11.3	61.3	Gmm = 2.558
A03	133.000	Good	2.063	2.363	8.9	14.3	38.0	Gmm = 2.593
A04	133.000	Good	1.576	2.304	11.1	16.4	32.3	Gmm = 2.593
A05	133.000	Good	2.460	2.154	16.9	21.9	22.6	Gmm = 2.593
A06	133.000	Good	2.686	2.169	16.3	21.3	23.4	Gmm = 2.593
A07	135.150	Good	2.873	2.242	11.5	18.7	38.3	Gmm = 2.534
A08	135.150	Good	2.257	2.239	11.6	18.8	38.1	Gmm = 2.534
A09	135.150	Good	2.093	2.394	5.5	13.2	58.1	Gmm = 2.534
A10	135.150	Good	1.308	2.295	9.4	16.8	43.7	Gmm = 2.534
		Average	2.131	2.307	9.9			

The average Gmm for each milepost is from tests perfomed by the Operations Support Section of ODOT.

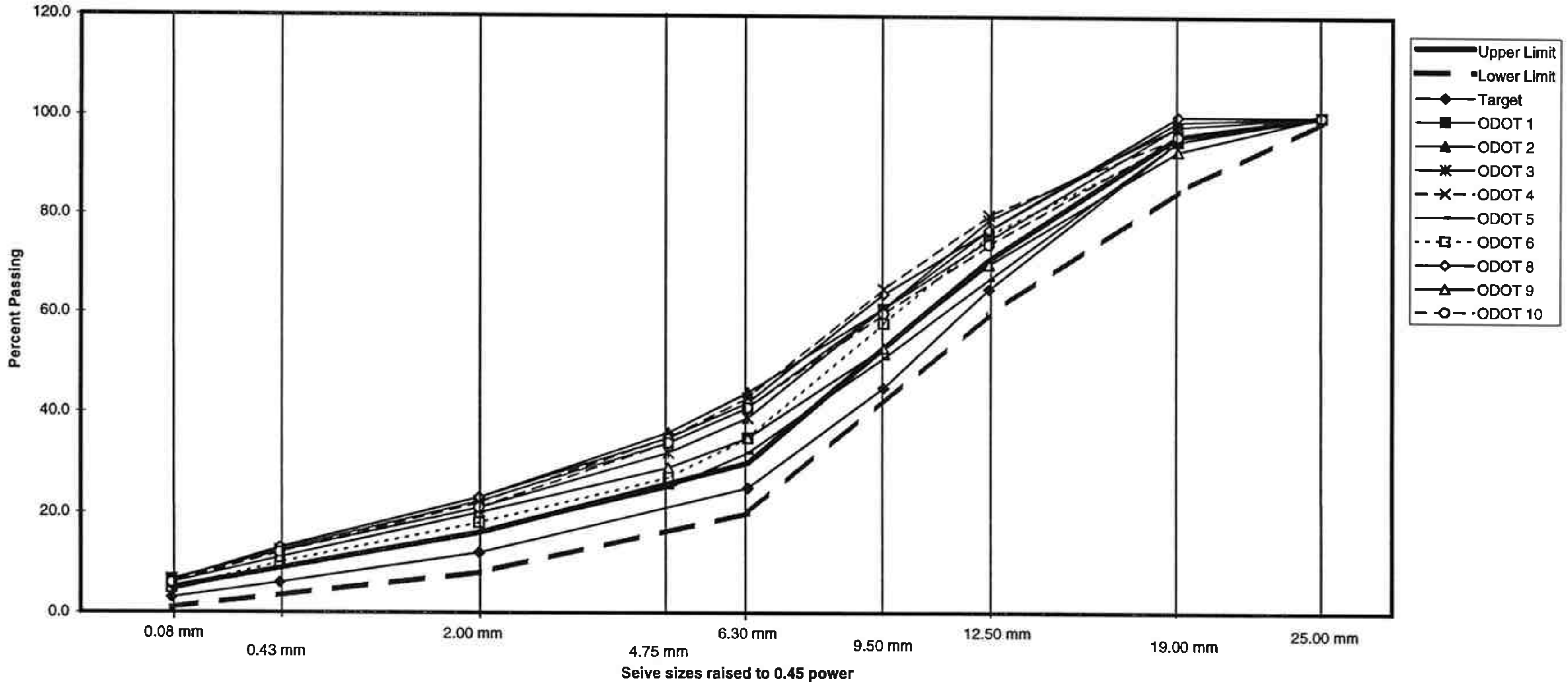
Summary

	Gmb	Va (%)	VMA (%)	VFA (%)
Minimum	2.154	3.6	10.6	22.6
Maximum	2.466	16.9	21.9	66.0
Average	2.307	9.9	16.3	42.2
Standard Dev.	0.10	4.3	3.7	14.4
Coefficient of Variation	4.5	43.8	23.0	34.1

Rufus - Arlington (East unit)

Sieve size (inches)	Sieve size (mm)	Percent Passing																
		Target	Upper	Lower	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	ODOT 8	ODOT 9	ODOT 10	*Average*	*Min*	*Max*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	99.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	*100.0*	*100.0*	*100.0*	*0.0*	*0.0*
3/4	19.000	95.0	96.0	85.0	98.0	99.0	98.0	96.0	95.0	95.0	100.0	93.0	96.0	*96.7*	*93.0*	*100.0*	*2.2*	*2.3*
1/2	12.500	65.0	71.0	60.0	75.0	77.0	79.0	80.0	67.0	76.0	77.0	70.0	74.0	*75.0*	*67.0*	*80.0*	*4.2*	*5.6*
3/8	9.500	45.0	-	-	61.0	61.0	61.0	65.0	51.0	58.0	64.0	53.0	60.0	*59.3*	*51.0*	*65.0*	*4.7*	*7.9*
1/4	6.300	25.0	30.0	20.0	41.0	44.0	39.0	43.0	32.0	35.0	42.0	35.0	41.0	*39.1*	*32.0*	*44.0*	*4.2*	*10.7*
No. 4	4.750	-	-	-	34.0	36.0	32.0	35.0	25.0	27.0	35.0	29.0	34.0	*31.9*	*25.0*	*36.0*	*4.0*	*12.4*
No. 10	2.000	12.0	16.0	8.0	22.3	23.0	21.0	22.0	16.0	18.0	23.0	20.0	21.0	*20.7*	*16.0*	*23.0*	*2.4*	*11.4*
No. 40	0.425	6.0	-	-	12.5	13.0	12.2	12.0	9.0	10.0	13.0	11.0	12.0	*11.6*	*9.0*	*13.0*	*1.4*	*11.8*
No 200	0.075	3.0	5.0	1.0	6.6	6.4	6.7	6.1	4.4	4.9	6.4	6.0	6.0	*5.9*	*4.4*	*6.7*	*0.8*	*13.2*

Rufus Extraction Gradation



Rufus - Arlington (East unit)

Sieve size (inches)	Sieve size (mm)	Percent Passing		Differences												
		Target	Upper	Upper	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	ODOT 8	ODOT 9	ODOT 10	*Average*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	*0.0*	
3/4	19.000	95.0	96.0	-1.0	-3.0	-4.0	-3.0	-1.0	0.0	0.0	-5.0	2.0	-1.0	*-1.7*	*2.2*	*-134.2*
1/2	12.500	65.0	71.0	-6.0	-10.0	-12.0	-14.0	-15.0	-2.0	-11.0	-12.0	-5.0	-9.0	*-10.0*	*4.2*	*-41.8*
1/4	6.300	25.0	30.0	-5.0	-16.0	-19.0	-14.0	-18.0	-7.0	-10.0	-17.0	-10.0	-16.0	*-14.1*	*4.2*	*-29.5*
No. 10	2.000	12.0	16.0	-4.0	-10.3	-11.0	-9.0	-10.0	-4.0	-6.0	-11.0	-8.0	-9.0	*-8.7*	*2.4*	*-27.2*
No 200	0.075	3.0	5.0	-2.0	-3.6	-3.4	-3.7	-3.1	-1.4	-1.9	-3.4	-3.0	-3.0	*-2.9*	*0.8*	*-26.6*
		Air voids (%)			3.2	3.5	4.9	5.0	11.5	10.3	7.0	6.6	3.4	*6.2*	*3.0*	*49.1*
		Asphalt Content (%)			5.8	6.0	6.3	5.8	4.3	4.9	5.8	5.2	5.8	*5.5*	*0.6*	*11.3*
		P200 / %AC			1.1	1.1	1.1	1.1	1.0	1.0	1.1	1.2	1.0	*1.1*	*0.1*	*4.8*

Sample	Geo. Gmb	Gmm	Geo. V_a (%)	VMA (%)	VFA (%)
ODOT 1	2.289	2.552	10.3	17.5	41.2
ODOT 2	2.411	2.564	6.0	13.3	55.1
ODOT 3	2.238	2.575	13.1	19.8	33.8
ODOT 4	2.341	2.576	9.1	15.6	41.7
ODOT 5	2.148	2.627	18.2	21.4	14.6
ODOT 6	2.152	2.593	17.0	21.7	21.7
ODOT 8	2.138	2.536	15.7	23.0	31.6
ODOT 9	2.35	2.592	9.3	14.8	36.8
ODOT 10	2.26	2.552	11.4	18.6	38.3
Average	*2.259*	*2.574*	*12.2*	*18.4*	*35.0*
Min	*2.138*	*2.536*	*6.0*	*13.3*	*14.6*
Max	*2.411*	*2.627*	*18.2*	*23.0*	*55.1*
Std. Dev.	*0.1*	*0.0*	*4.1*	*3.4*	*11.8*
CV	*4.4*	*1.1*	*33.3*	*18.2*	*33.6*

Open graded QC/QA project (OSU cores)

LOCATION: **Baldock Slough - S. Baker Inter.**
ASPHALT: AC-20
ADDITIVES: Lime

BULK SPECIFIC GRAVITY-VOLUME AIR VOIDS DATA

ID	Core Milepost	Core Condition	Thickness (inches)	Gmb	Av (%)	VMA (%)	VFA (%)	NOTES
F02	299.216	Chip seal	2.548	2.262	7.0	19.2	63.6	Gmm = 2.431
F03	299.216	Chip seal	2.062	2.240	7.8	19.9	60.6	Gmm = 2.431
F04	299.216	Chip seal	1.969	2.249	7.5	19.6	61.8	Gmm = 2.431
F05	299.216	Chip seal	1.991	2.197	9.6	21.5	55.2	Gmm = 2.431
F06	299.216	Chip seal	2.810	2.196	9.6	21.5	55.1	Gmm = 2.431
F07	299.216	Chip seal	2.619	2.186	10.1	21.9	53.9	Gmm = 2.431
F08	299.216	Chip seal	2.463	2.160	11.2	22.8	51.1	Gmm = 2.431
F09	299.216	Chip seal	1.800	2.166	10.9	22.6	51.7	Gmm = 2.431
F10	299.235	Chip seal	2.515	2.094	14.1	25.2	43.8	Gmm = 2.439
F11	299.235	Chip seal	2.493	2.168	11.1	22.5	50.6	Gmm = 2.439
F12	299.235	Chip seal	2.904	2.186	10.4	21.9	52.6	Gmm = 2.439
F13	299.235	Chip seal	2.583	2.248	7.8	19.7	60.2	Gmm = 2.439
F16	299.235	Chip seal	2.005	2.205	9.6	21.2	54.7	Gmm = 2.439
F17	299.235	Chip seal	2.348	2.208	9.5	21.1	55.1	Gmm = 2.439
F18	299.235	Chip seal	2.608	2.182	10.5	22.0	52.1	Gmm = 2.439
F19	299.235	Chip seal	2.163	2.155	11.7	23.0	49.3	Gmm = 2.439
F20	299.337	Good	1.629	2.158	11.4	22.9	50.1	Gmm = 2.436 for all
F21	299.338	Good	2.313	2.178	10.6	22.2	52.2	calculations. The Gmm is
F22	299.338	Good	2.357	2.166	11.1	22.6	50.9	average of three values from
F23	299.338	Good	2.025	2.140	12.2	23.5	48.3	cores taken at section
F24	299.338	Good	2.398	2.177	10.6	22.2	52.1	299.235.
F25	299.338	Good	1.743	2.109	13.4	24.6	45.4	
F26	299.338	Good	2.014	2.157	11.4	22.9	50.0	
F27	299.338	Good	2.418	2.175	10.7	22.2	51.9	
F28	299.378	Good	2.371	2.106	13.5	24.7	45.2	
F29	299.378	Good	1.941	2.113	13.2	24.5	45.9	
F30	299.378	Good	2.215	2.111	13.4	24.6	45.6	
F31	299.378	Good	1.955	2.121	12.9	24.2	46.6	

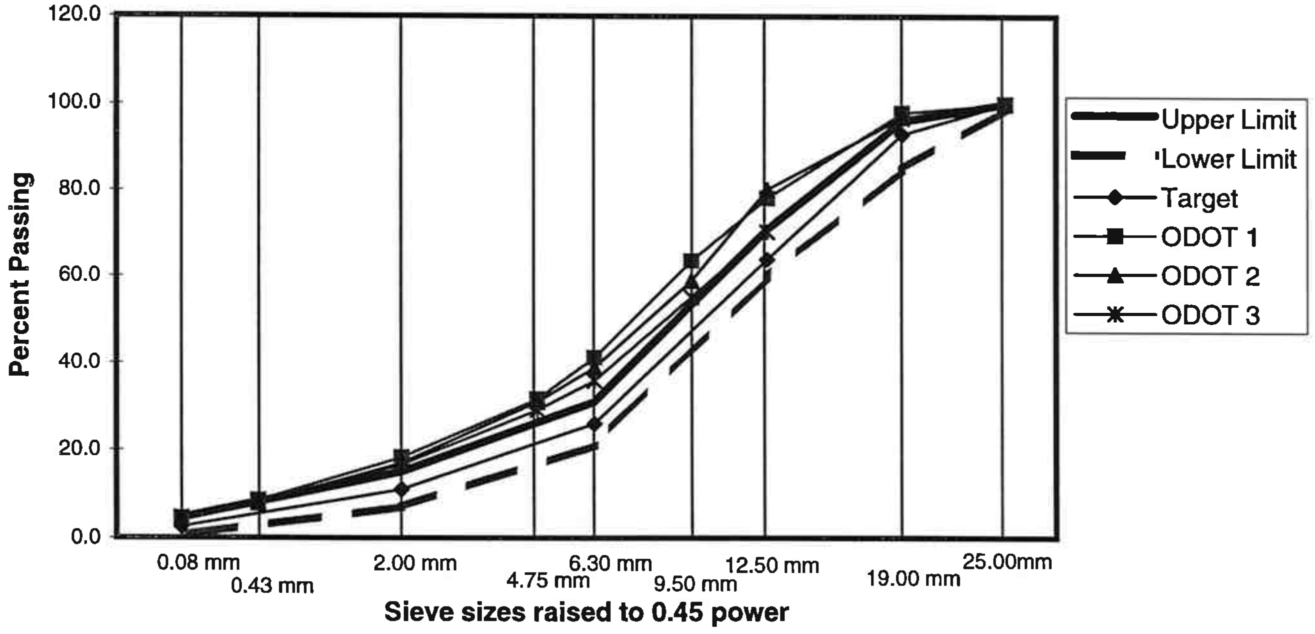
The average Gmm for each milepost is from tests perfomed by the Operations Support Section of ODOT.

	Gmb	Va (%)	VMA (%)	VFA (%)
Minimum	2.094	7.0	19.2	43.8
Maximum	2.262	14.1	25.2	63.6
Average	2.172	10.8	22.4	52.0
Standard Dev.	0.04	1.9	1.6	5.0
Coefficient of Variation	2.0	17.1	7.1	9.7

Baldock Slough - S. Baker Interch.

Sieve size (inches)	Sieve size (mm)	Percent Passing										
		Target	Upper	Lower	ODOT 1	ODOT 2	ODOT 3	Average	Min	Max	Std. Dev.	CV
1	25.000	100.0	100.0	99.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0
3/4	19.000	93.0	96.0	85.0	96.9	97.9	96.7	97.2	96.7	97.9	0.6	0.7
1/2	12.500	64.0	71.0	60.0	80.2	78.2	70.4	76.3	70.4	80.2	5.2	6.8
3/8	9.500	-	-	-	59.0	63.6	55.2	59.3	55.2	63.6	4.2	7.1
1/4	6.300	26.0	31.0	21.0	38.9	41.2	35.9	38.7	35.9	41.2	2.7	6.9
No. 4	4.750	-	-	-	30.9	31.6	29.1	30.5	29.1	31.6	1.3	4.2
No. 10	2.000	11.0	15.0	7.0	17.0	18.2	16.5	17.2	16.5	18.2	0.9	5.1
No. 40	0.425	-	-	-	7.9	8.5	8.1	8.2	7.9	8.5	0.3	3.7
No 200	0.075	2.6	4.6	0.6	4.5	4.4	4.6	4.5	4.4	4.6	0.1	2.2

Baldock Slough Extraction Gradation



Baldock Slough - S. Baker Interch.

Sieve size (inches)	Sieve size (mm)	Percent Passing		Differences						
		Target	Upper	Upper	ODOT 1	ODOT 2	ODOT 3	*Average*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	0.0	0.0	0.0	0.0	*0.0*	*0.0*	
3/4	19.000	95.0	96.0	-1.0	-2.9	-1.9	-1.7	*-2.2*	*0.6*	*-29.7*
1/2	12.500	65.0	71.0	-6.0	-13.2	-15.2	-5.4	*-11.3*	*5.2*	*-46.0*
1/4	6.300	25.0	30.0	-6.0	-16.2	-13.9	-10.9	*-13.7*	*2.7*	*-19.4*
No. 10	2.000	12.0	16.0	-3.0	-6.2	-5.0	-4.5	*-5.2*	*0.9*	*-16.7*
No 200	0.075	3.0	5.0	-1.6	-1.4	-1.5	-1.6	*-1.5*	*0.1*	*-6.7*
		Air voids (%)			8.6	7.4	11.0	*9.0*	*1.8*	*20.4*
		Asphalt Content (%)			5.8	5.7	5.4	*5.6*	*0.2*	*3.7*
		P200 / %AC			0.8	0.8	0.9	*0.8*	*0.0*	*5.9*

Sample	Geo. Gmb	Gmm	Geo V_a (%)	VMA (%)	VFA (%)
ODOT 1	2.23	2.44	8.6	25.6	66.5
ODOT 2	2.25	2.431	7.4	24.9	70.3
ODOT 3	2.17	2.437	11	27.3	59.8
Average	*2.217*	*2.436*	*9.0*	*26.0*	*65.5*
Min	*2.170*	*2.431*	*7.4*	*24.9*	*59.8*
Max	*2.250*	*2.440*	*11.0*	*27.3*	*70.3*
Std. Dev.	*0.042*	*0.005*	*1.833*	*1.250*	*5.3*
CV	*1.9*	*0.2*	*20.4*	*4.8*	*8.1*

Open graded QC/QA project (OSU cores)

LOCATION: **Forge Rd. - Lobert Rd.**
ASPHALT: AC-20
ADDITIVES: Lime

BULK SPECIFIC GRAVITY-VOLUME AIR VOIDS DATA

ID	Core Milepost	Core Condition	Thickness (inches)	Gmb	Av (%)	VMA (%)	VFA (%)	NOTES
D01	246.18	Good	2.048	2.130	15.5	30.6	49.4	Gmm = 2.52
D02	246.18	Good	1.853	2.194	12.9	28.5	54.7	Gmm = 2.52
D07	246.18	Good	1.960	2.196	12.8	28.4	54.8	Gmm = 2.52
D08	246.18	Good	2.110	2.171	13.9	29.3	52.6	Gmm = 2.52
D09	244.14	Good	2.239	2.237	10.3	27.1	62.2	Gmm = 2.492
D10	244.14	Good	2.213	2.169	13.0	29.3	55.8	Gmm = 2.492
		Average	2.071	2.183	13.0			

The average Gmm for each milepost is from tests perfomed by the Operations Support Section of ODOT.

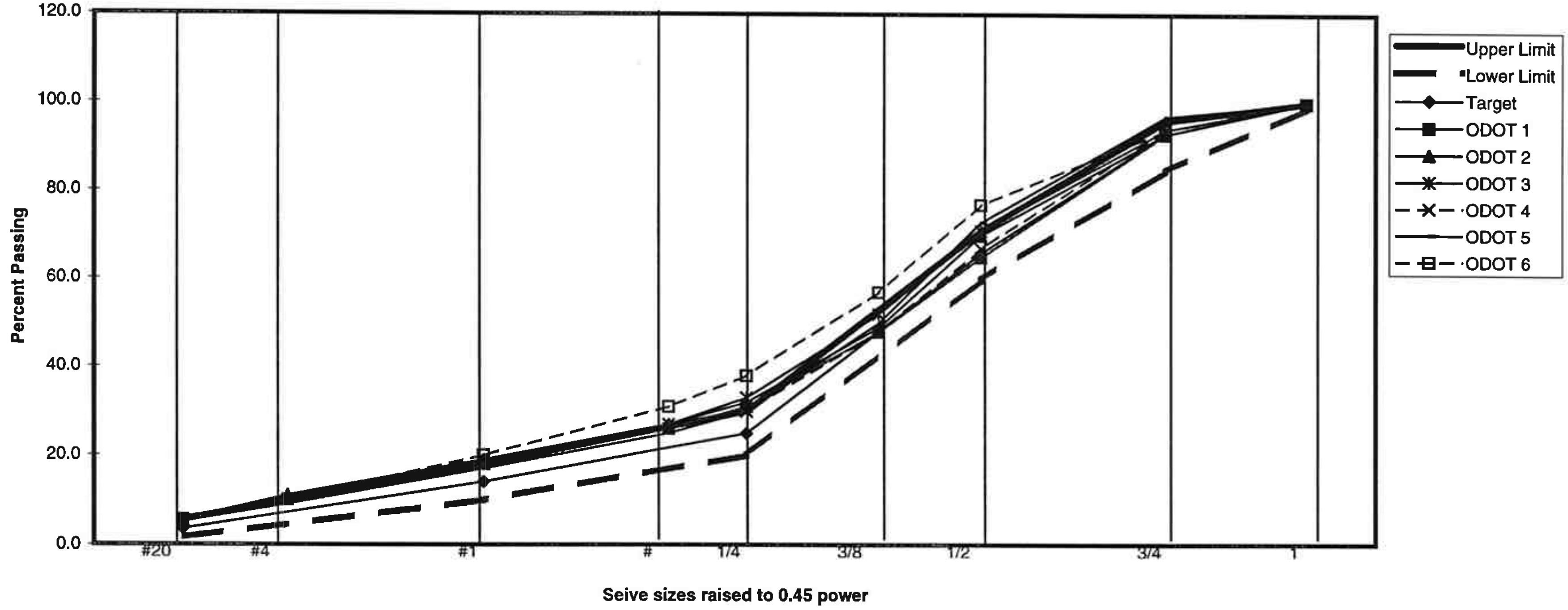
Summary

	Gmb	Va (%)	VMA (%)	VFA (%)
Minimum	2.130	10.3	27.1	49.4
Maximum	2.237	15.5	30.6	62.2
Average	2.183	13.0	28.9	54.9
Standard Dev.	0.03	1.5	1.1	3.9
Coefficient of Variation	1.5	11.9	3.7	7.0

Forge Rd. - Lobert Rd.

Sieve size (inches)	Sieve size (mm)	Percent Passing													
		Target	Upper	Lower	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	*Average*	*Min*	*Max*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	99.0	100.0	100.0	100.0	100.0	100.0	100.0	*100.0*	*100.0*	*100.0*	*0.0*	*0.0*
3/4	19.000	93.0	96.0	85.0	93.0	93.0	94.0	94.0	97.0	94.0	*94.2*	*93.0*	*97.0*	*1.5*	*1.6*
1/2	12.500	66.0	71.0	60.0	65.0	70.0	71.0	67.0	73.0	77.0	*70.5*	*65.0*	*77.0*	*4.3*	*6.1*
3/8	9.500	-	-	-	48.0	49.0	52.0	48.0	50.0	57.0	*50.7*	*48.0*	*57.0*	*3.4*	*6.8*
1/4	6.300	25.0	30.0	20.0	31.0	32.0	33.0	30.0	30.0	38.0	*32.3*	*30.0*	*38.0*	*3.0*	*9.3*
No. 4	4.750	-	-	-	26.0	27.0	27.0	26.0	25.0	31.0	*27.0*	*25.0*	*31.0*	*2.1*	*7.8*
No. 10	2.000	14.0	18.0	10.0	18.0	19.0	18.0	19.0	17.0	20.0	*18.5*	*17.0*	*20.0*	*1.0*	*5.7*
No. 40	0.425	-	-	-	10.0	11.0	10.0	10.0	9.0	10.0	*10.0*	*9.0*	*11.0*	*0.6*	*6.3*
No 200	0.075	3.6	5.6	1.6	5.1	5.6	5.4	5.1	5.2	5.6	*5.3*	*5.1*	*5.6*	*0.2*	*4.4*

Wolf Extraction Gradation



Forge Rd. - Lobert Rd.

Sieve size (inches)	Sieve size (mm)	Percent Passing		Differences									
		Target	Upper	Upper	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	*Average*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	*0.0*	
3/4	19.000	95.0	96.0	-1.0	2.0	2.0	1.0	1.0	-2.0	1.0	*0.8*	*1.5*	*176.6*
1/2	12.500	65.0	71.0	-6.0	0.0	-5.0	-6.0	-2.0	-8.0	-12.0	*-5.5*	*4.3*	*-77.8*
1/4	6.300	25.0	30.0	-5.0	-6.0	-7.0	-8.0	-5.0	-5.0	-13.0	*-7.3*	*3.0*	*-41.1*
No. 10	2.000	12.0	16.0	-6.0	-6.0	-7.0	-6.0	-7.0	-5.0	-8.0	*-6.5*	*1.0*	*-16.1*
No 200	0.075	3.0	5.0	-2.6	-2.1	-2.6	-2.4	-2.1	-2.2	-2.6	*-2.3*	*0.2*	*-10.0*
		Air voids (%)			9.0	9.0	9.0	10.3	9.7	6.0	*8.8*	*1.5*	*16.8*
		Asphalt Content (%)			4.8	4.7	4.9	4.9	5.0	5.8	*5.0*	*0.4*	*7.9*
		P200 / %AC			1.1	1.2	1.1	1.0	1.0	1.0	*1.1*	*0.1*	*7.1*

Sample	Geo. Gmb	Gmm	Geo V_a (%)	VMA (%)	VFA (%)
ODOT 1	2.201	2.522	12.7	22.5	43.4
ODOT 2	2.135	2.525	15.4	28.4	45.5
ODOT 3	2.143	2.521	15.0	28.2	46.9
ODOT 4	2.079	2.513	17.3	30.4	43.2
ODOT 5	2.164	2.513	13.9	27.6	49.7
ODOT 6	2.215	2.471	10.4	26.5	61.0
Average	*2.156*	*2.511*	*14.1*	*27.3*	*48.3*
Min	*2.079*	*2.471*	*10.4*	*22.5*	*43.2*
Max	*2.215*	*2.525*	*17.3*	*30.4*	*61.0*
Std. Dev.	*0.0*	*0.0*	*2.4*	*2.7*	*6.7*
CV	*2.3*	*0.8*	*16.9*	*9.7*	*13.8*

Open graded QC/QA project (OSU cores)

LOCATION: **Azalea - Jumpoff Joe**
ASPHALT: PBA-6
ADDITIVES: Lime

BULK SPECIFIC GRAVITY-VOLUME AIR VOIDS DATA

ID	Core Milepost	Core Condition	Thickness (inches)	Gmb	Av (%)	VMA (%)	VFA (%)	NOTES
C01	78.05	Good	2.154	2.334	10.6	24.0	56.0	Gmm = 2.610
C02	78.05	Good	2.278	2.382	8.7	22.5	61.1	Gmm = 2.610
C03	78.05	Good	2.145	2.332	10.6	24.1	55.8	Gmm = 2.610
C04	78.05	Good	2.213	2.311	11.5	24.8	53.7	Gmm = 2.610
C05	78.05	Good	2.226	2.347	10.1	23.6	57.3	Gmm = 2.610
C06	78.05	Good	2.149	2.317	11.2	24.6	54.3	Gmm = 2.610
C07	78.05	Good	2.384	2.283	12.5	25.7	51.2	Gmm = 2.610
C08	78.05	Good	2.097	2.303	11.8	25.0	53.0	Gmm = 2.610
		Average	2.206	2.326	10.9			

The average Gmm for each milepost is from tests perfomed by the Operations Support Section of ODOT.

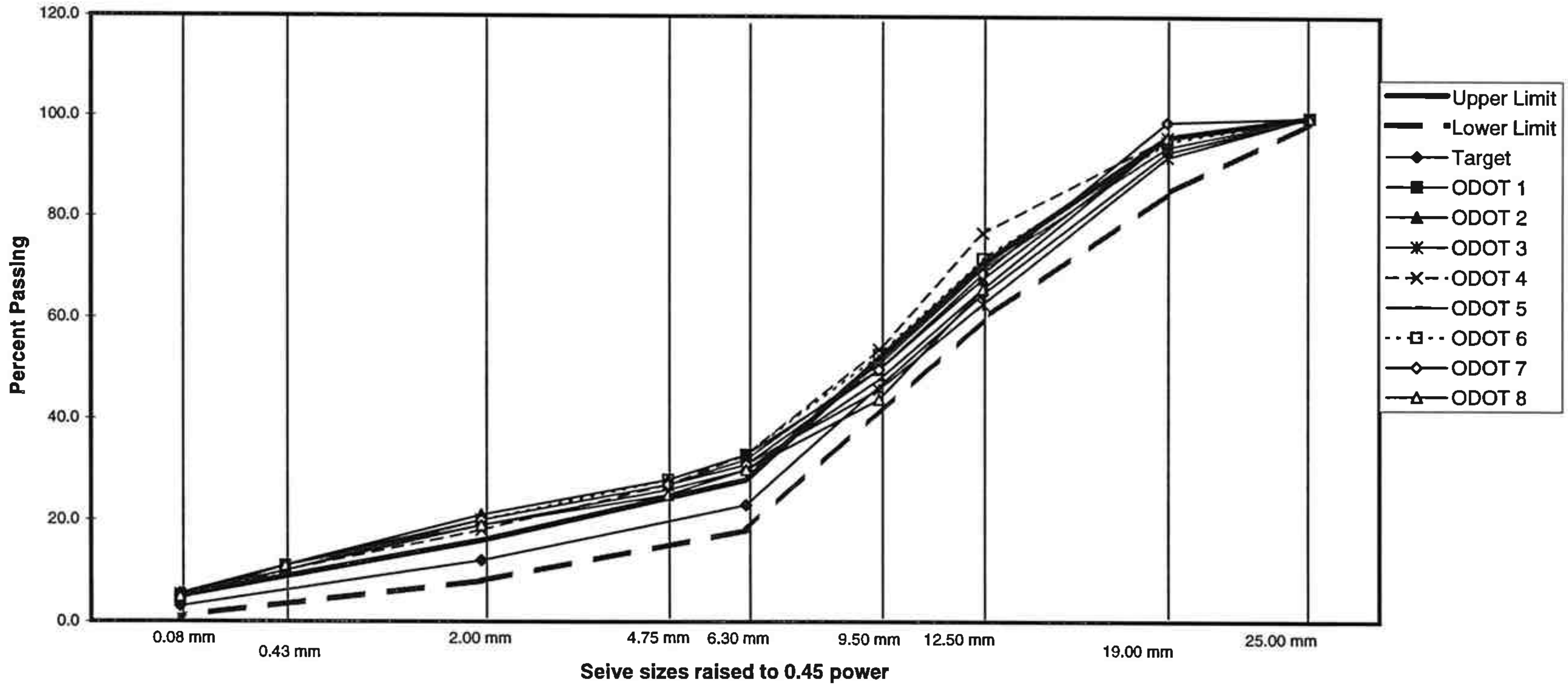
Summary

	Gmb	Va (%)	VMA (%)	VFA (%)
Minimum	2.283	8.7	22.5	51.2
Maximum	2.382	12.5	25.7	61.1
Average	2.326	10.9	24.3	55.3
Standard Dev.	0.03	1.1	0.9	2.8
Coefficient of Variation	1.2	9.9	3.8	5.1

Azalea - Jumpoff Joe

Sieve size (inches)	Sieve size (mm)	Percent Passing															
		Target	Upper	Lower	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	ODOT 7	ODOT 8	*Average*	*Min*	*Max*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	99.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	*100.0*	*100.0*	*100.0*	*0.0*	*0.0*
3/4	19.000	93.0	96.0	85.0	94.0	96.0	92.0	96.0	96.0	95.0	99.0	96.0	*95.5*	*92.0*	*99.0*	*2.0*	*2.1*
1/2	12.500	65.0	71.0	60.0	70.0	68.0	63.0	77.0	66.0	72.0	69.0	66.0	*68.9*	*63.0*	*77.0*	*4.3*	*6.2*
3/8	9.500	-	-	-	51.0	50.0	46.0	54.0	48.0	53.0	50.0	44.0	*49.5*	*44.0*	*54.0*	*3.4*	*6.8*
1/4	6.300	23.0	28.0	18.0	32.0	33.0	31.0	33.0	30.0	33.0	31.0	30.0	*31.6*	*30.0*	*33.0*	*1.3*	*4.1*
No. 4	4.750	-	-	-	27.0	28.0	27.0	27.0	26.0	28.0	27.0	25.0	*26.9*	*25.0*	*28.0*	*1.0*	*3.7*
No. 10	2.000	12.0	16.0	8.0	20.0	21.0	20.0	18.0	19.0	20.0	20.0	19.0	*19.6*	*18.0*	*21.0*	*0.9*	*4.7*
No. 40	0.425	-	-	-	11.0	11.0	10.0	10.0	10.0	10.0	11.0	11.0	*10.5*	*10.0*	*11.0*	*0.5*	*5.1*
No 200	0.075	3.0	5.0	1.0	4.3	5.2	4.8	5.3	5.2	4.5	5.5	4.9	*5.0*	*4.3*	*5.5*	*0.4*	*8.3*

Azalea Extraction Gradation



Azalea - Jumpoff Joe

Sieve size (inches)	Sieve size (mm)	Percent Passing		Differences											
		Target	Upper	Upper	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	ODOT 7	ODOT 8	*Average*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	*0.0*	
3/4	19.000	94.0	96.0	-2.0	0.0	-2.0	2.0	-2.0	-2.0	-1.0	-5.0	-2.0	*-1.5*	*2.0*	*-133.3*
1/2	12.500	66.0	71.0	-5.0	-4.0	-2.0	3.0	-11.0	0.0	-6.0	-3.0	0.0	*-2.9*	*4.3*	*-149.2*
1/4	6.300	24.0	30.0	-4.0	-8.0	-9.0	-7.0	-9.0	-6.0	-9.0	-7.0	-6.0	*-7.6*	*1.3*	*-17.1*
No. 10	2.000	12.0	16.0	-4.0	-8.0	-9.0	-8.0	-6.0	-7.0	-8.0	-8.0	-7.0	*-7.6*	*0.9*	*-12.0*
No 200	0.075	3.9	5.0	-1.1	-0.4	-1.3	-0.9	-1.4	-1.3	-0.6	-1.6	-1.0	*-1.1*	*0.4*	*-38.9*
		Air voids (%)			8.2	6.6	0.5	0.7	8.7	9.3	9.0	7.9	*6.4*	*3.7*	*57.4*
		Asphalt Content (%)			5.0	5.1	5.0	5.2	4.9	5.3	5.2	4.9	*5.1*	*0.1*	*2.9*
		P200 / %AC			0.9	1.0	1.0	1.0	1.1	0.8	1.1	1.0	*1.0*	*0.1*	*8.5*

Sample	Geo. Gmb	Gmm	Geo V_a (%)	VMA (%)	VFA (%)
ODOT 1	2.38	2.672	10.9	20.4	46.4
ODOT 2	2.269	2.656	14.6	24.2	39.7
ODOT 3	2.263	2.448	7.6	24.3	68.9
ODOT 4	2.301	2.447	6.0	23.2	74.3
ODOT 5	2.264	2.647	14.5	24.2	40.2
ODOT 6	2.247	2.656	15.4	25.1	38.6
ODOT 7	2.215	2.675	17.2	26.1	34.0
ODOT 8	2.214	2.68	17.4	25.9	32.8
Average	*2.269*	*2.610*	*12.9*	*24.2*	*46.9*
Min	*2.214*	*2.447*	*6.0*	*20.4*	*32.8*
Max	*2.380*	*2.680*	*17.4*	*26.1*	*74.3*
Std. Dev.	*0.1*	*0.1*	*4.3*	*1.8*	*15.9*
CV	*2.3*	*3.9*	*33.4*	*7.4*	*33.9*

Open graded QC/QA project (OSU cores)

LOCATION: **Halsey - Lane County**
ASPHALT: PBA - 6
ADDITIVES: Lime

BULK SPECIFIC GRAVITY-VOLUME AIR VOIDS DATA

ID	Core Milepost	Core Condition	Thickness (inches)	Gmb	Av (%)	VMA (%)	VFA (%)	NOTES
E02	212.980	Good	1.851	2.213	10.9	20.9	47.6	Gmm = 2.485
E01	212.984	Good	1.874	2.200	10.8	21.4	49.4	Gmm = 2.467
E03	212.984	Good	1.742	2.224	9.8	20.5	52.0	Gmm = 2.467
E04	212.984	Good	1.778	2.257	8.5	19.3	56.0	Gmm = 2.467
E07	213.200	Good	2.031	2.149	11.2	23.2	51.8	Gmm = 2.42
E06	213.200	Good	2.051	2.148	11.2	23.2	51.6	Gmm = 2.42
E08	213.200	Good	2.066	2.157	10.9	22.9	52.6	Gmm = 2.42
E11	213.200	Good	2.055	2.166	10.5	22.6	53.5	Gmm = 2.42
E05	213.250	Good	1.957	2.094	13.5	25.1	46.2	Gmm = 2.422
E09	213.250	Good	1.544	2.034	16.0	27.3	41.3	Gmm = 2.422
E10	213.250	Good	2.002	2.081	14.1	25.6	45.1	Gmm = 2.422
E12	213.250	Good	1.995	2.053	15.2	26.6	42.8	Gmm = 2.422
		Average	1.934	2.179	10.8			

The average Gmm for each milepost is from tests perfomed by the Operations Support Section of ODOT.

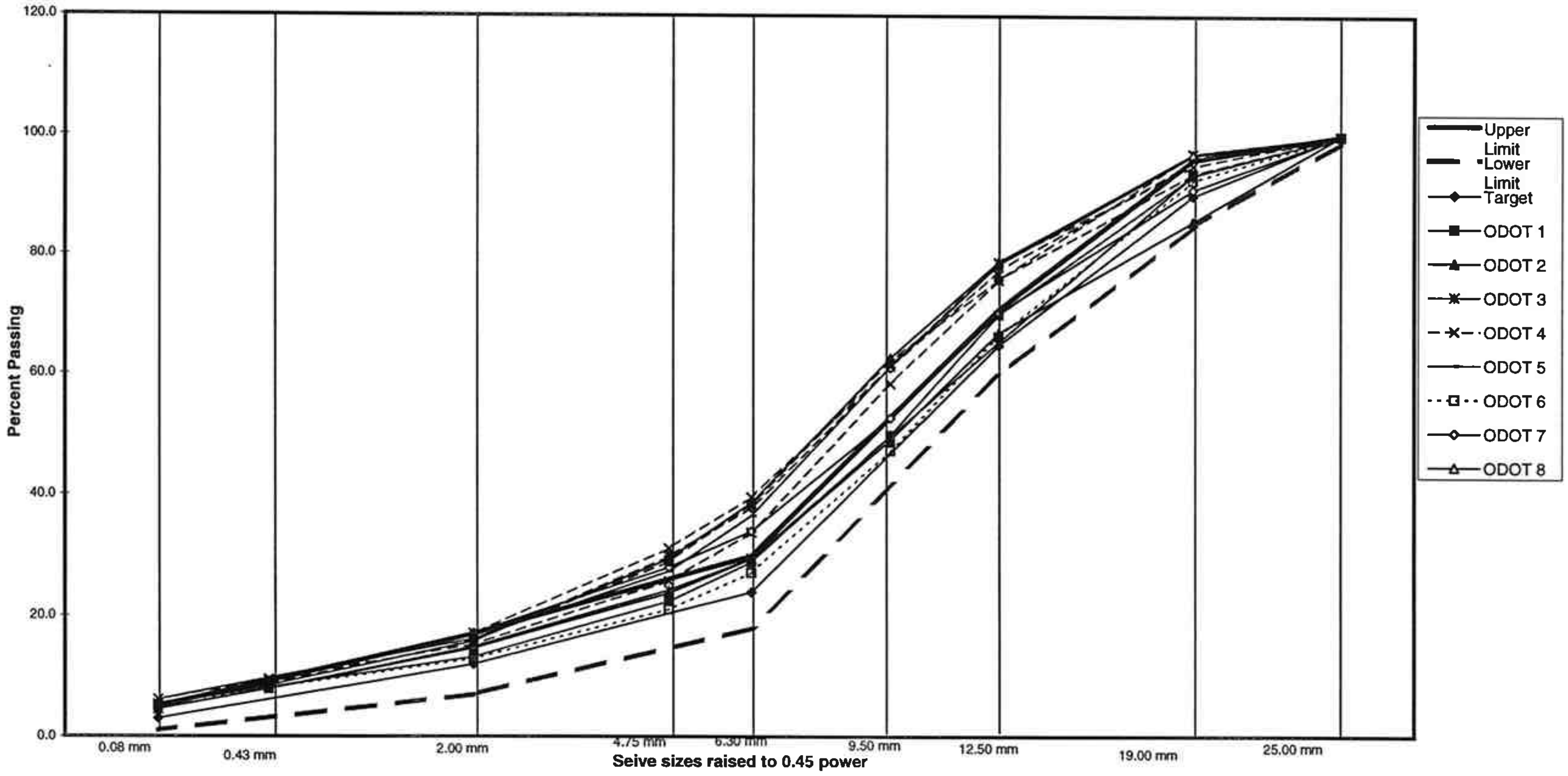
Summary

	Gmb	Va (%)	VMA (%)	VFA (%)
Minimum	2.034	8.5	19.3	41.3
Maximum	2.257	16.0	27.3	56.0
Average	2.148	11.9	23.2	49.2
Standard Dev.	0.1	2.2	2.4	4.4
Coefficient of Variation	3.1	18.4	10.4	8.9

Halsey Inter. - Lane County

Sieve size (inches)	Sieve size (mm)	Percent Passing																		
		Target	Upper	Lower	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	ODOT 7	ODOT 8	ODOT 9	ODOT 10	ODOT 11	*Average*	*Min*	*Max*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	99.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	*100.0*	*100.0*	*100.0*	*0.0*	*0.0*
3/4	19.000	90.0	96.0	85.0	85.7	93.4	93.5	97.1	96.8	92.6	91.0	97.0	95.0	95.7	93.7	*93.8*	*85.7*	*97.1*	*3.3*	*3.5*
1/2	12.500	65.0	71.0	60.0	67.1	70.1	65.5	75.9	78.5	66.5	70.4	78.9	78.8	77.5	76.0	*73.2*	*65.5*	*78.9*	*5.3*	*7.3*
3/8	9.500	-	-	-	49.3	50.1	49.9	58.6	61.4	47.5	52.9	62.9	61.5	61.2	62.4	*56.2*	*47.5*	*62.9*	*6.2*	*11.0*
1/4	6.300	24.0	30.0	18.0	29.5	29.0	29.6	33.9	36.7	27.2	34.1	38.8	39.7	38.0	38.6	*34.1*	*27.2*	*39.7*	*4.6*	*13.5*
No. 4	4.750	-	-	-	23.8	22.4	24.3	25.8	27.4	21.1	28.1	29.5	31.2	29.9	29.0	*26.6*	*21.1*	*31.2*	*3.3*	*12.5*
No. 10	2.000	12.0	17.0	7.0	14.6	13.2	14.9	15.3	16.2	12.9	17.1	15.8	17.1	15.8	15.9	*15.3*	*12.9*	*17.1*	*1.4*	*9.0*
No. 40	0.425	5.0	-	-	7.9	8.2	7.9	9.5	9.7	8.1	9.1	8.5	9.2	8.7	8.6	*8.7*	*7.9*	*9.7*	*0.6*	*7.3*
No 200	0.075	3.0	5.0	1.0	4.5	5.2	4.6	6.1	6.1	5.2	5.4	5.0	5.3	5.1	5.2	*5.2*	*4.5*	*6.1*	*0.5*	*9.6*

Halsey Extraction Gradation



Halsey Inter. - Lane County

Sieve size (inches)	Sieve size (mm)	Percent Passing		Differences														
		Target	Upper	Upper	ODOT 1	ODOT 2	ODOT 3	ODOT 4	ODOT 5	ODOT 6	ODOT 7	ODOT 8	ODOT 9	ODOT 10	ODOT 11	*Average*	*Std. Dev.*	*CV*
1	25.000	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	*0.0*	
3/4	19.000	95.0	96.0	-1.0	1.6	9.3	1.5	-2.1	-1.8	2.4	4.0	-2.0	0.0	-0.7	1.3	*1.2*	*3.3*	*270.6*
1/2	12.500	65.0	71.0	-6.0	-5.1	-2.1	-0.5	-10.9	-13.5	-1.5	-5.4	-13.9	-13.8	-12.5	-11.0	*-8.2*	*5.3*	*-65.0*
1/4	6.300	25.0	30.0	-5.0	-4.0	-4.5	-4.6	-8.9	-11.7	-2.2	-9.1	-13.8	-14.7	-13.0	-13.6	*-9.1*	*4.6*	*-50.4*
No. 10	2.000	12.0	16.0	-5.0	-1.2	-2.6	-2.9	-3.3	-4.2	-0.9	-5.1	-3.8	-5.1	-3.8	-3.9	*-3.3*	*1.4*	*-41.1*
No 200	0.075	3.0	5.0	-2.0	-2.2	-1.5	-1.6	-3.1	-3.1	-2.2	-2.4	-2.0	-2.3	-2.1	-2.2	*-2.2*	*0.5*	*-22.5*
		Air voids (%)			3.8	4.0	8.8	8.4	5.8	5.8	7.0	4.5	4.8	2.8	4.1	*5.4*	*1.9*	*35.7*
		Asphalt Content (%)			5.5	5.4	5.4	5.7	5.9	5.0	5.6	6.0	6.0	6.1	5.9	*5.7*	*0.3*	*5.9*
		P200 / %AC			0.9	0.8	0.9	1.1	1.0	1.0	1.0	0.8	0.9	0.8	0.9	*0.9*	*0.1*	*9.8*

Sample	Geo. Gmb	Gmm	Geo V_a (%)	VMA (%)	VFA (%)
ODOT 1	2.228	2.478	10.1	19.9	49.4
ODOT 2	2.174	2.493	12.8	21.8	41.3
ODOT 3	2.122	2.461	13.8	23.7	41.8
ODOT 4	2.14	2.432	12.0	23.3	48.4
ODOT 5	2.163	2.437	11.2	22.6	50.3
ODOT 6	2.182	2.467	11.6	21.2	45.5
ODOT 7	2.119	2.482	14.6	23.9	38.9
ODOT 8	2.197	2.42	9.2	21.5	57.1
ODOT 9	2.219	2.457	9.7	20.7	53.2
ODOT 10	2.257	2.421	6.8	19.4	65.1
ODOT 11	2.309	2.438	5.3	17.4	69.6
Average	*2.192*	*2.453*	*10.6*	*21.4*	*51.0*
Min	*2.119*	*2.420*	*5.3*	*17.4*	*38.9*
Max	*2.309*	*2.493*	*14.6*	*23.9*	*69.6*
Std. Dev.	*0.1*	*0.0*	*2.8*	*2.0*	*9.7*
CV	*2.7*	*1.0*	*26.6*	*9.3*	*19.1*

APPENDIX D

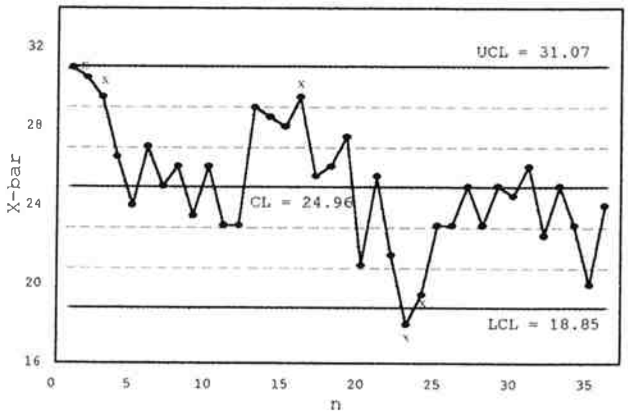
QA TEST DATA PLOTTED ON CONTROL CHARTS

QA TEST DATA PLOTTED ON CONTROL CHARTS

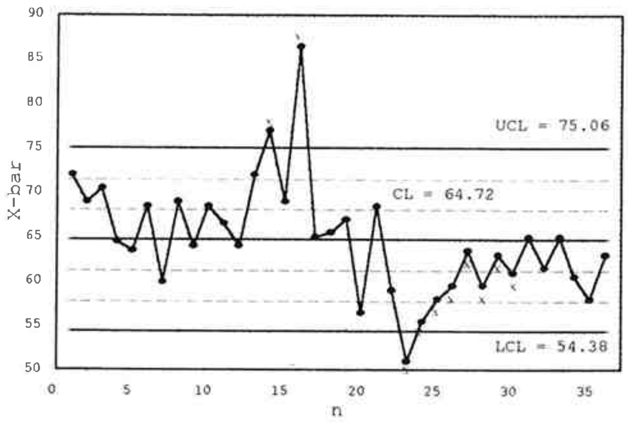
Contractor process control data were not available for analysis, but ODOT quality assurance data were available. For all of the projects where there was a sufficient amount of QA test results, the researchers charted the data as though they were QC data to determine how often the data would have indicated a need to consider corrective action. Table 5.2 indicates the projects and factors for which charts were created. These charts are provided on the following pages. On the charts, an "X" indicates that a corrective action might be necessary.

In reviewing these charts, the reader must realize that the charts use control limits and not specification limits to determine when corrective action might be necessary. It is desirable for the control limits to be within the specification limits. Table 5.3 indicates whether the control limits were within the specification limits for each of the projects and factors charted.

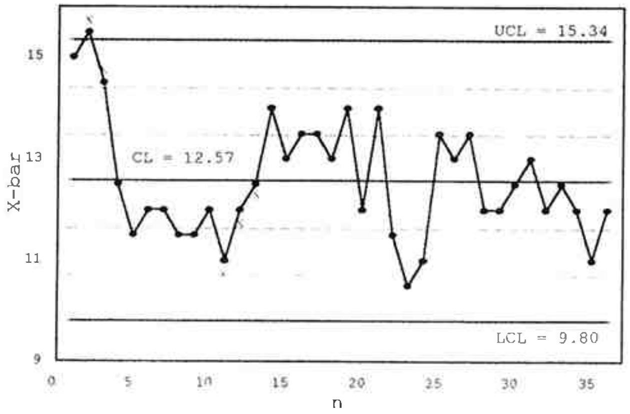
X-bar Chart for 1/4" Sieve
Hayesville-Battle Creek



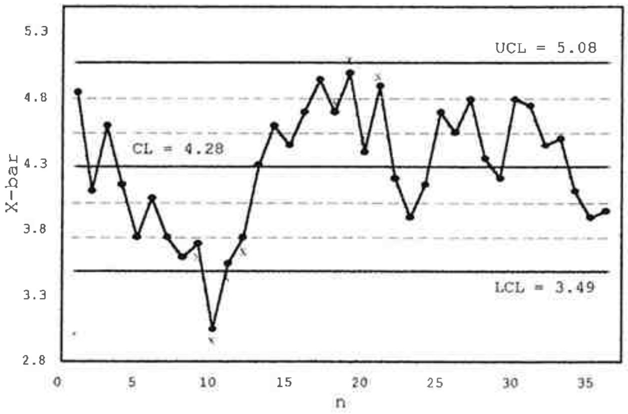
X-bar Chart for 1/2" Sieve
Hayesville-Battle Creek



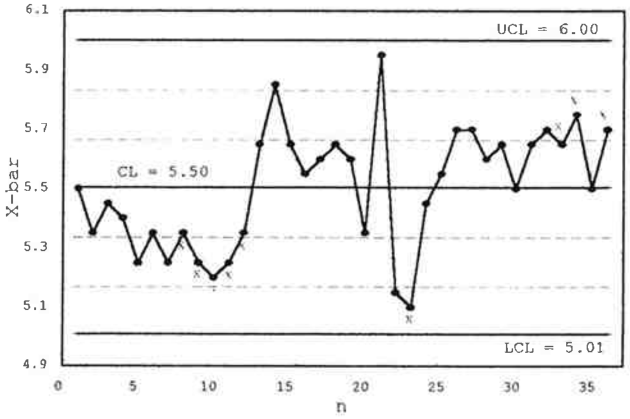
X-bar Chart for #10
Hayesville-Battle Creek



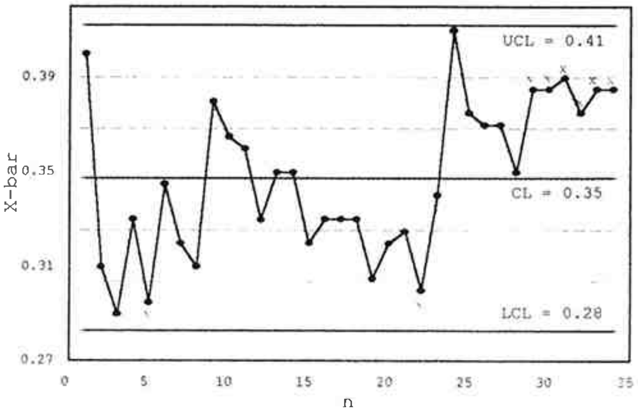
X-bar Chart for #200
Hayesville-Battle Creek



X-bar Chart for Asphalt
Hayesville-Battle Creek

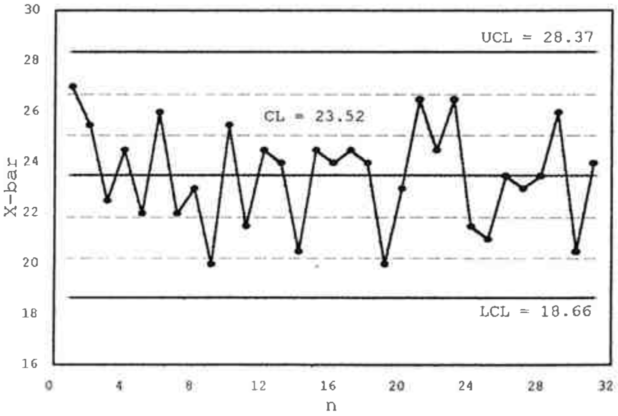


X-bar Chart for Moisture
Hayesville-Battle Creek



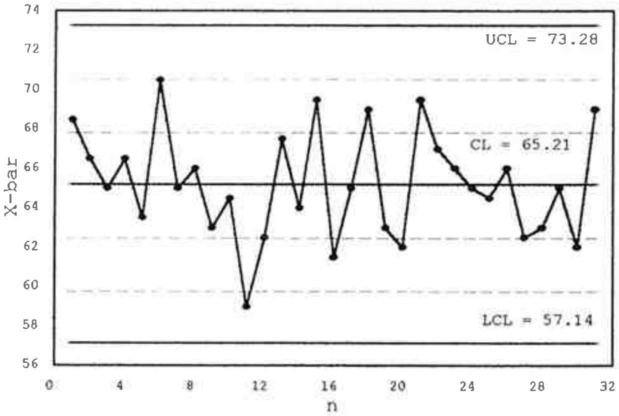
X-bar Chart for 1/4" Sieve

W. Marquam Int.-N. Tigard Int.



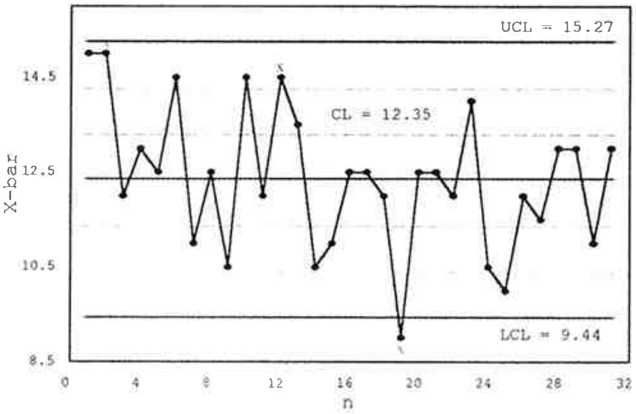
X-bar Chart for 1/2" Sieve

W. Marquam Int.-N. Tigard Int.



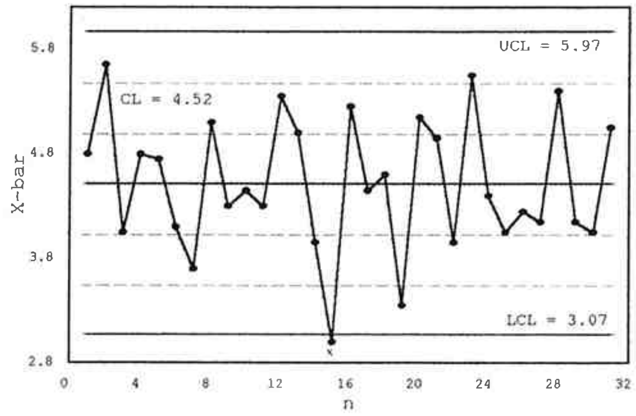
X-bar Chart for #10

W. Marquam Int.-N. Tigard Int.



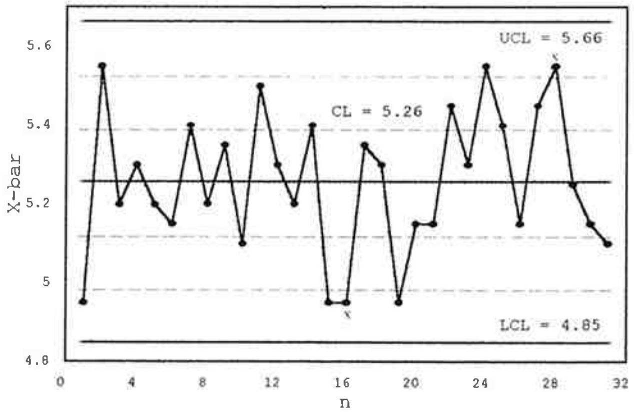
X-bar Chart for #200

W. Marquam Int.-N. Tigard Int.



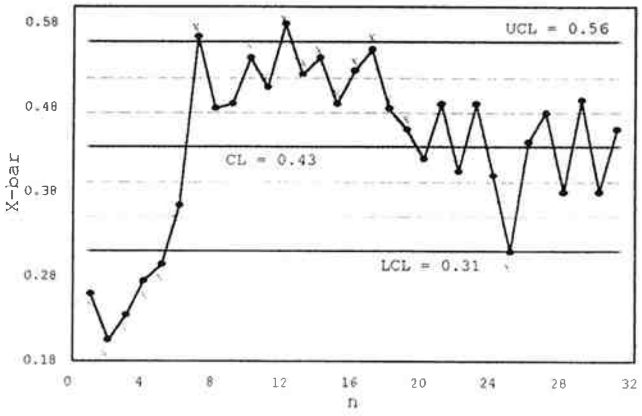
X-bar Chart for Asphalt

W. Marquam Int.-N. Tigard Int.



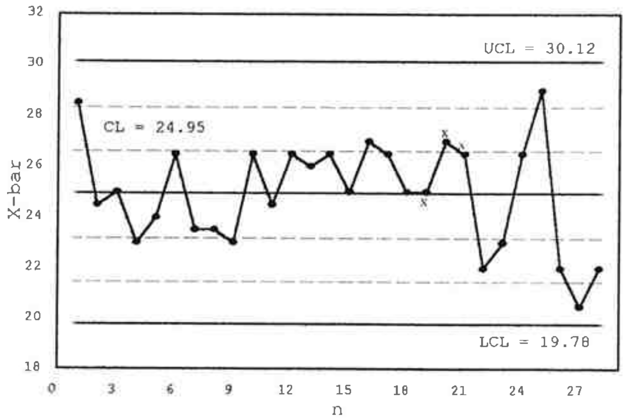
X-bar Chart for Moisture

W. Marquam Int.-N. Tigard Int.



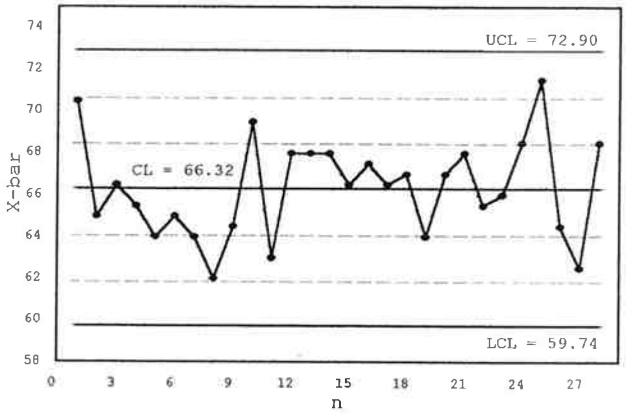
X-bar Chart for 1/4" Sieve

Wolf Cr - W Fork Dairy Cr



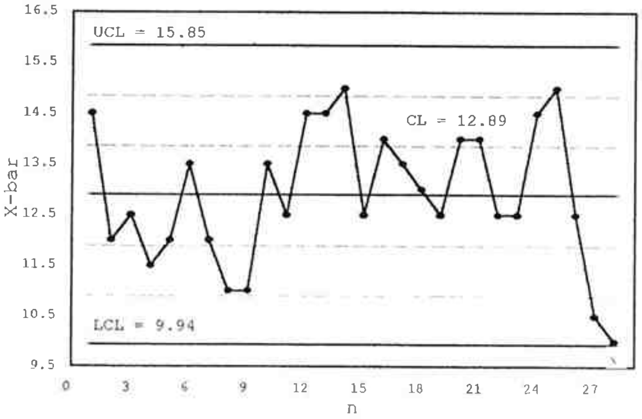
X-bar Chart for 1/2" Sieve

Wolf Cr - W Fork Dairy Cr

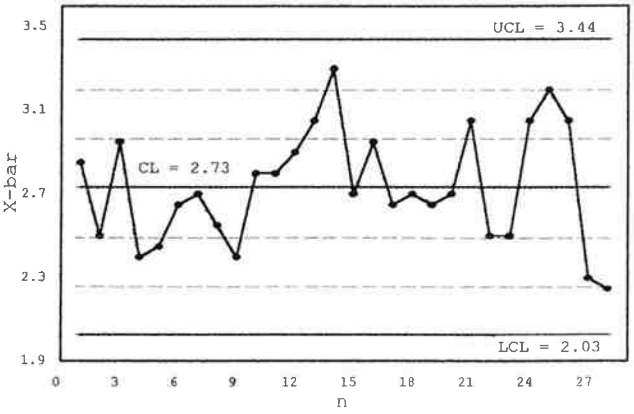


X-bar Chart for #10

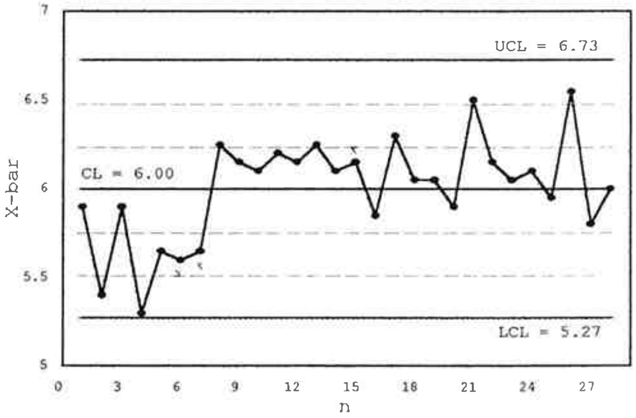
Wolf Cr - W Fork Dairy Cr



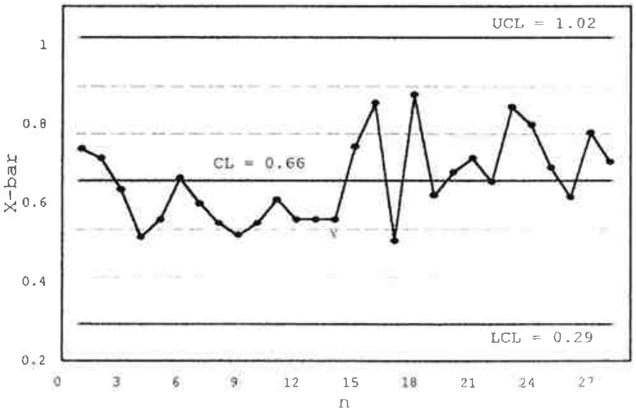
X-bar Chart for #200
Wolf Cr - W Fork Dairy Cr



X-bar Chart for Asphalt
Wolf Cr - W Fork Dairy Cr

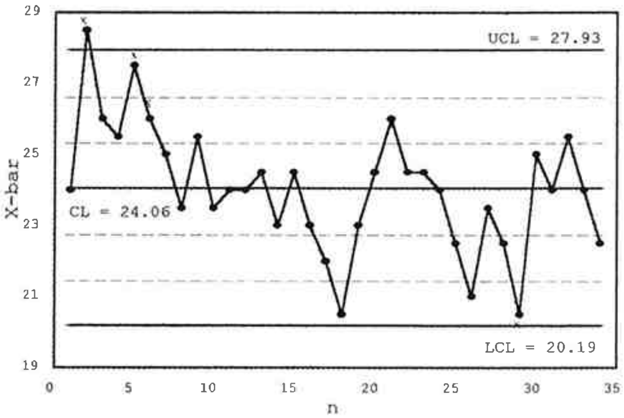


X-bar Chart for Moisture
Wolf Cr - W Fork Dairy Cr



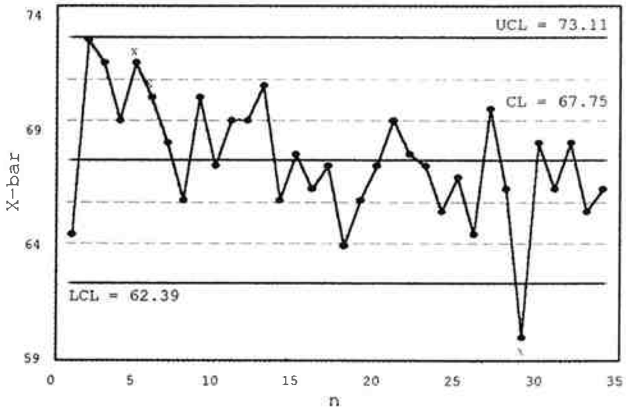
X-bar Chart for 1/4" Sieve

Corbett Int. - Multnomah Falls



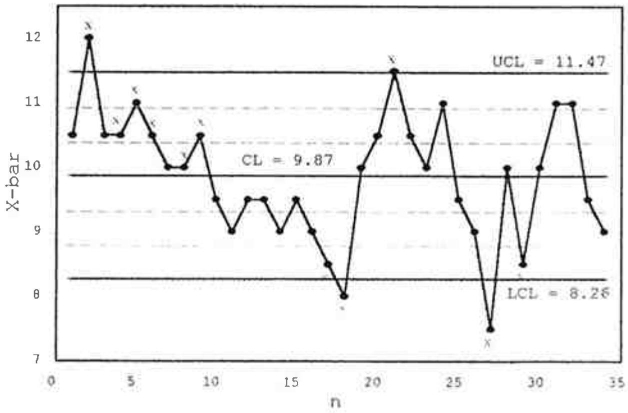
X-bar Chart for 1/2" Sieve

Corbett Int. - Multnomah Falls

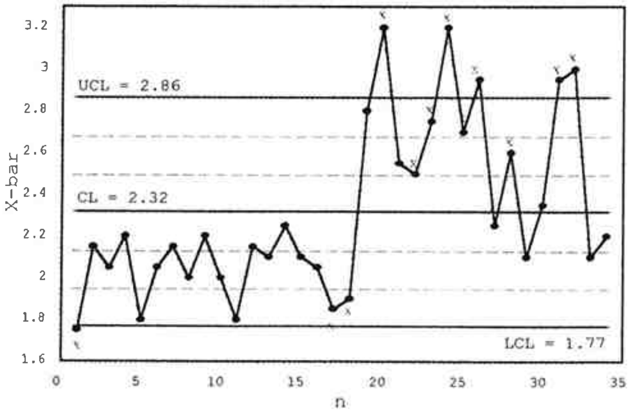


X-bar Chart for #10

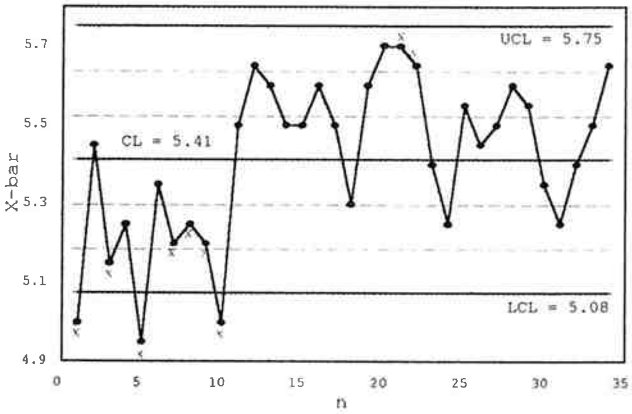
Corbett Int. - Multnomah Falls



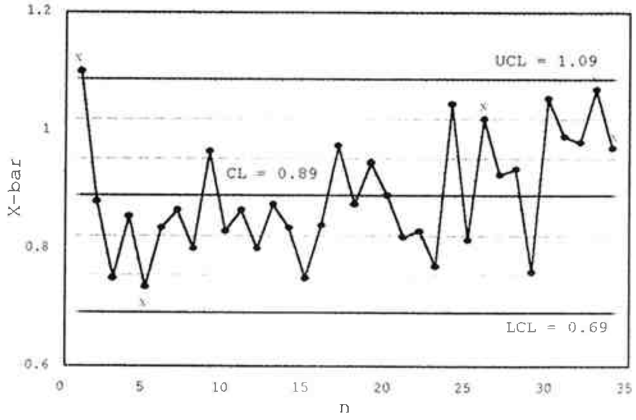
X-bar Chart for #200
Corbett Int. - Multnomah Falls



X-bar Chart for Asphalt
Corbett Int. - Multnomah Falls

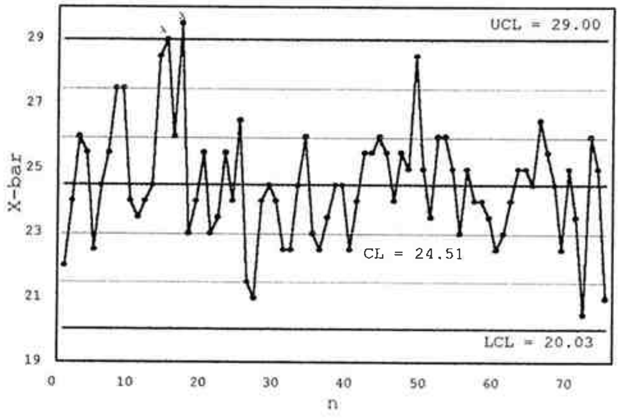


X-bar Chart for Moisture
Corbett Int. - Multnomah Falls



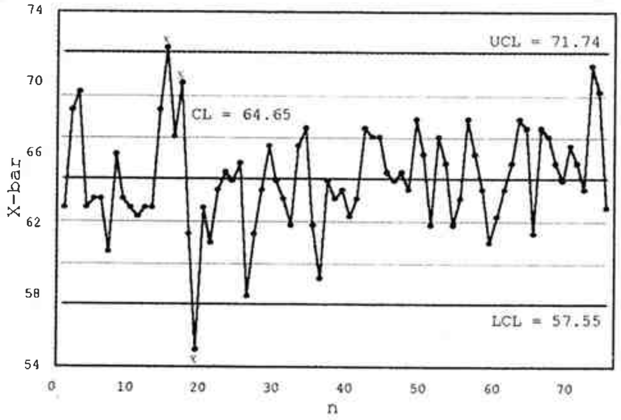
X-bar Chart for 1/4" Sieve

Rufus-Arlington (West Unit)



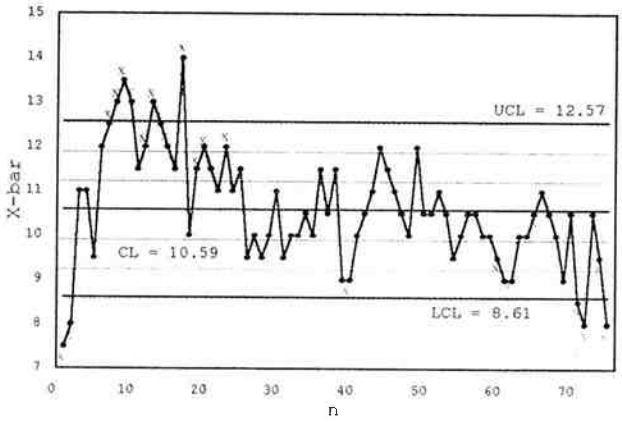
X-bar Chart for 1/2" Sieve

Rufus-Arlington (West Unit)



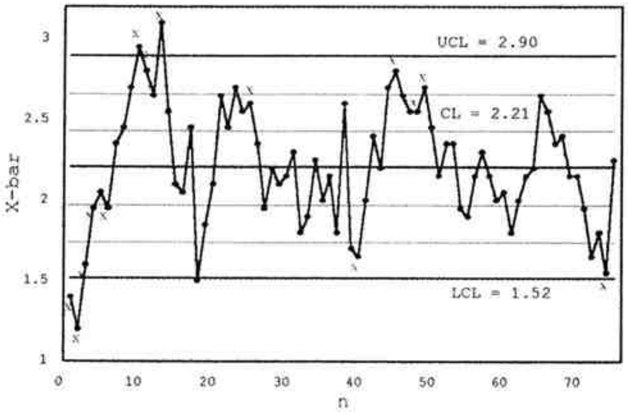
X-bar Chart for #10

Rufus-Arlington (West Unit)



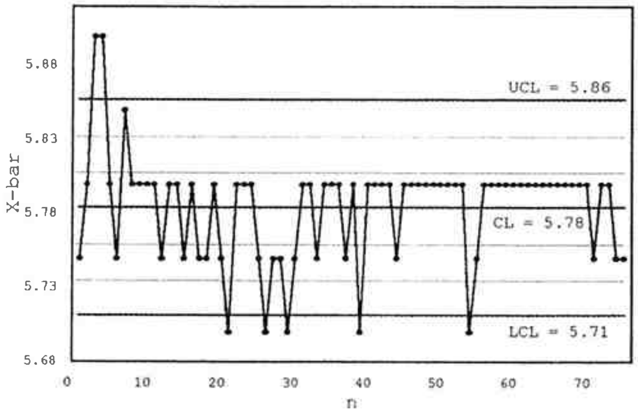
X-bar Chart for #200

Rufus-Arlington (West Unit)



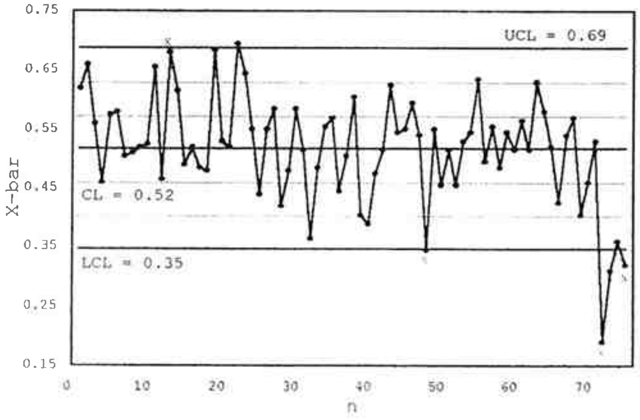
X-bar Chart for Asphalt

Rufus-Arlington (West Unit)

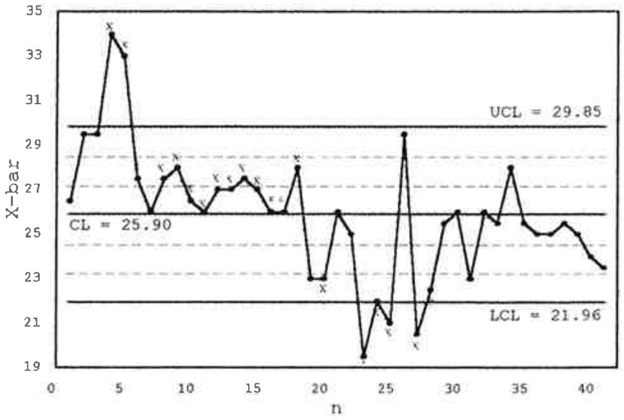


X-bar Chart for Moisture

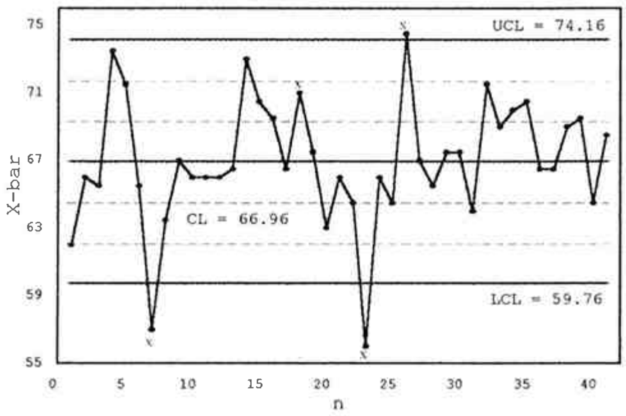
Rufus-Arlington (West Unit)



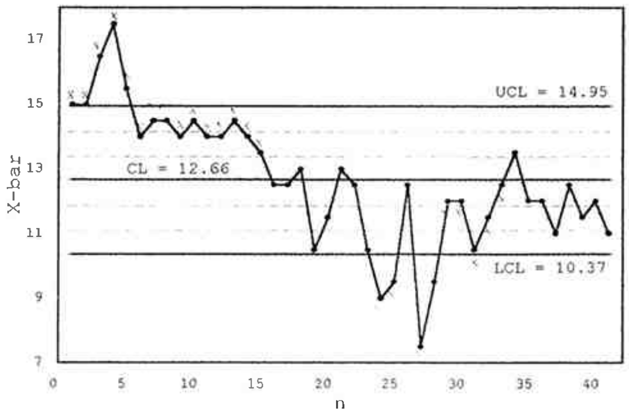
X-bar Chart for 1/4" Sieve
Rufus-Arlington (East Unit)



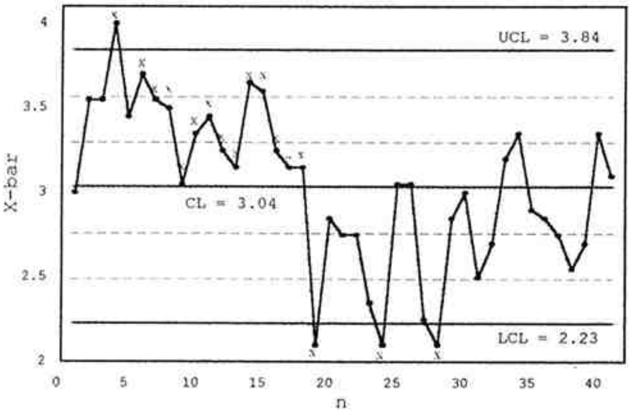
X-bar Chart for 1/2" Sieve
Rufus-Arlington (East Unit)



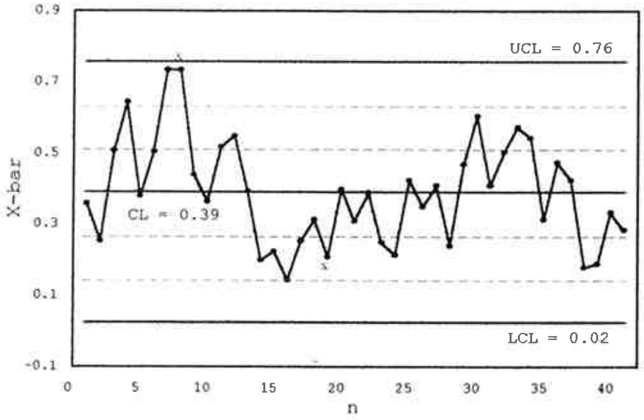
X-bar Chart for #10
Rufus-Arlington (East Unit)

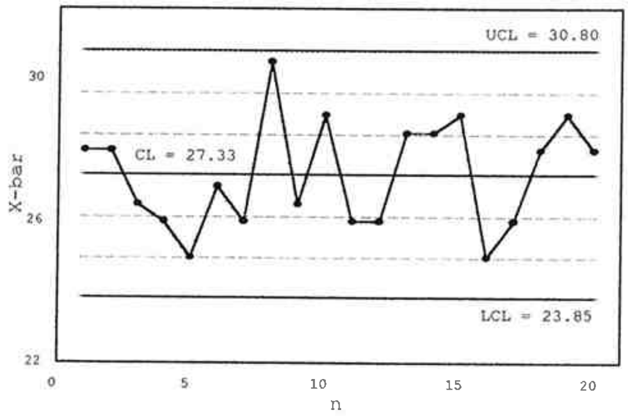


X-bar Chart for #200
Rufus-Arlington (East Unit)



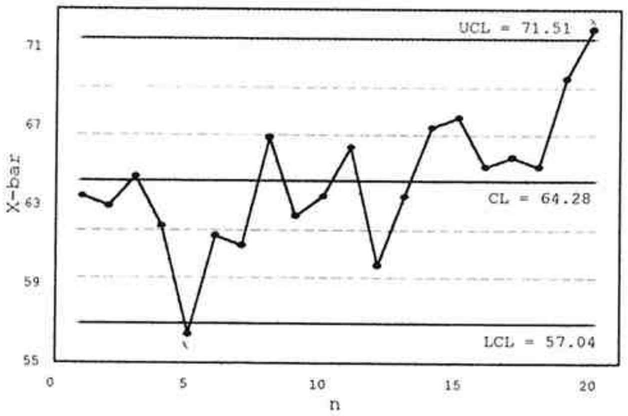
X-bar Chart for Moisture
Rufus-Arlington (East Unit)





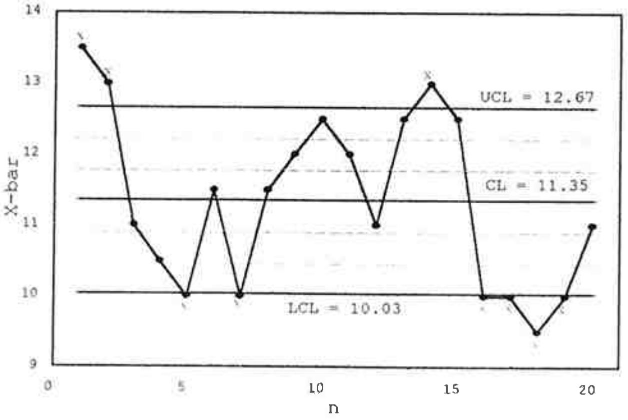
X-bar Chart for 1/4" Sieve

E. Pendleton - Emigrant Hill (Lot 2B)



X-bar Chart for 1/2" Sieve

E. Pendleton - Emigrant Hill (Lot 2B)

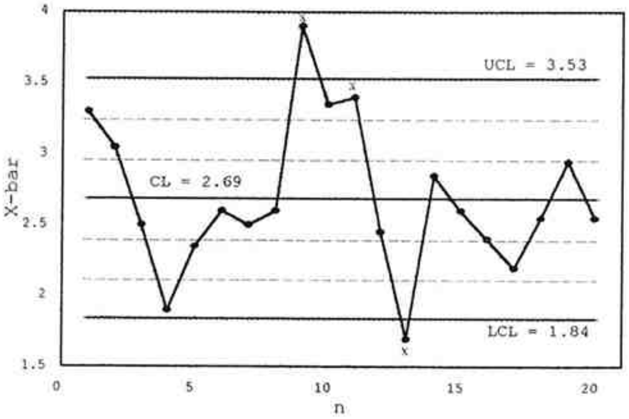


X-bar Chart for #10

E. Pendleton - Emigrant Hill (Lot 2B)

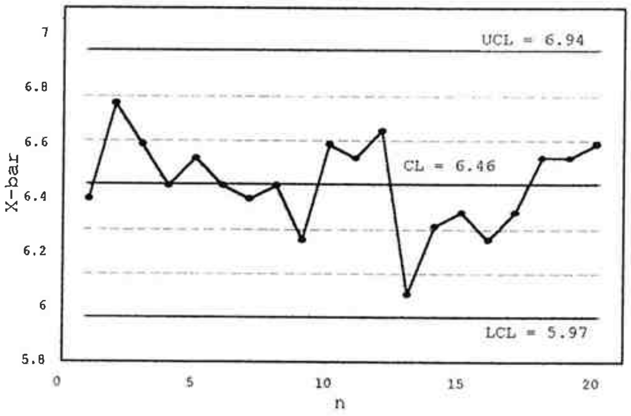
X-bar Chart for #200

E. Pendleton - Emigrant Hill (Lot 2B)



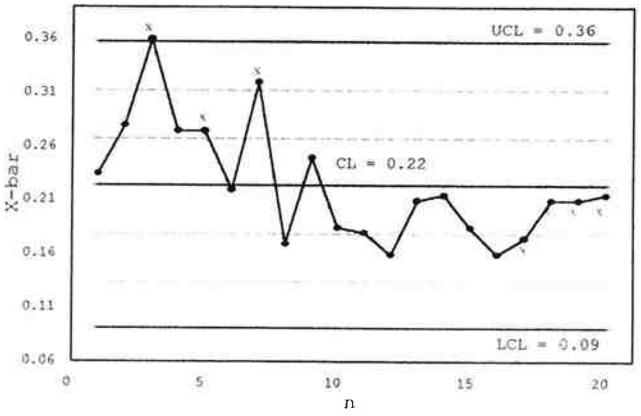
X-bar Chart for Asphalt

E. Pendleton - Emigrant Hill (Lot 2B)



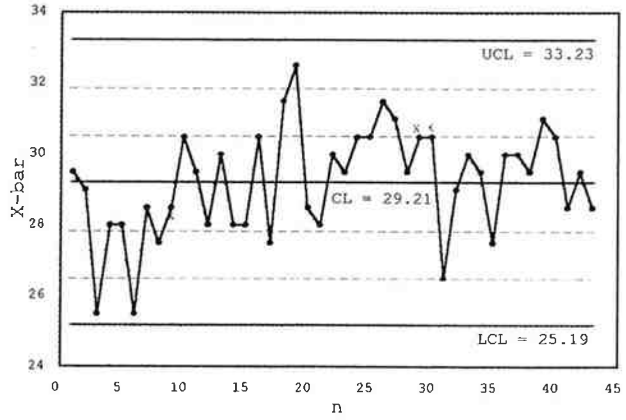
X-bar Chart for Moisture

E. Pendleton - Emigrant Hill (Lot 2B)



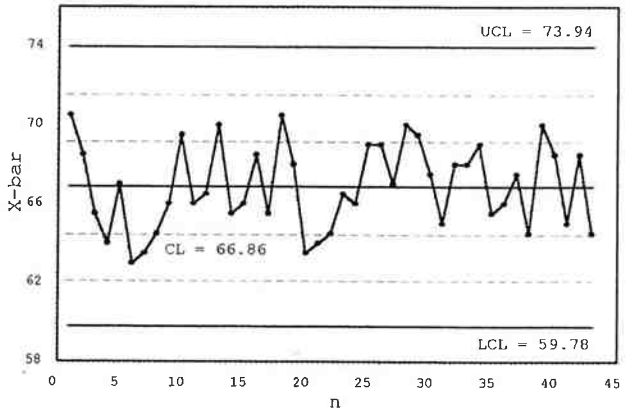
X-bar Chart for 1/4" Sieve

Baldock Slough - S. Baker (Lot 1)



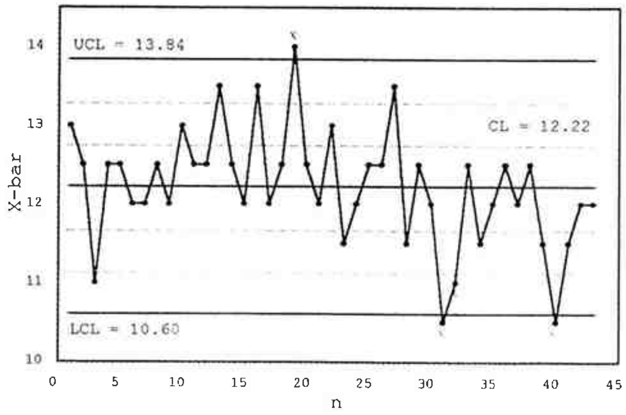
X-bar Chart for 1/2" Sieve

Baldock Slough - S. Baker (Lot 1)



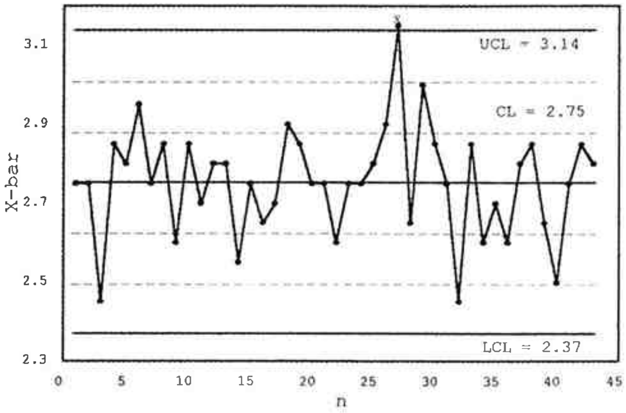
X-bar Chart for #10

Baldock Slough - S. Baker (Lot 1)



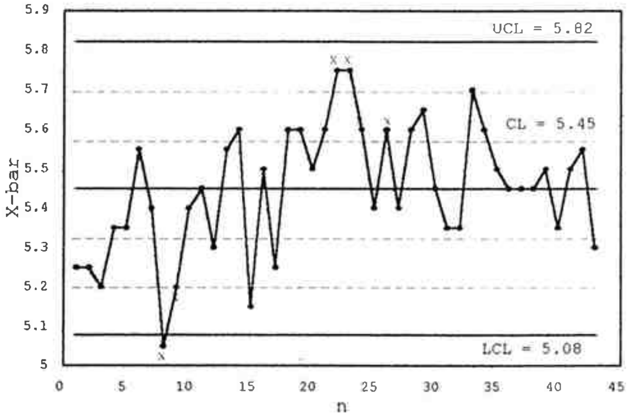
X-bar Chart for #200

Baldock Slough - S. Baker (Lot 1)



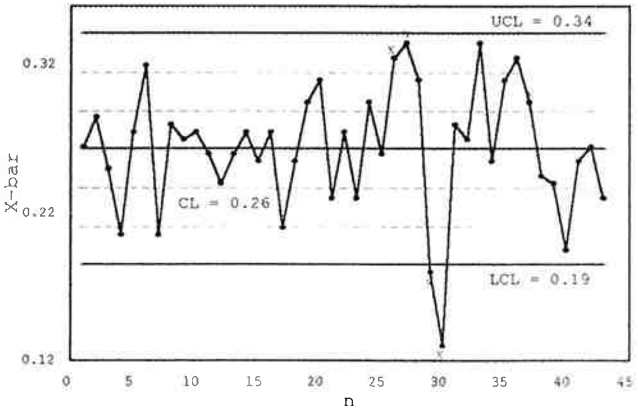
X-bar Chart for Asphalt

Baldock Slough - S. Baker (Lot 1)

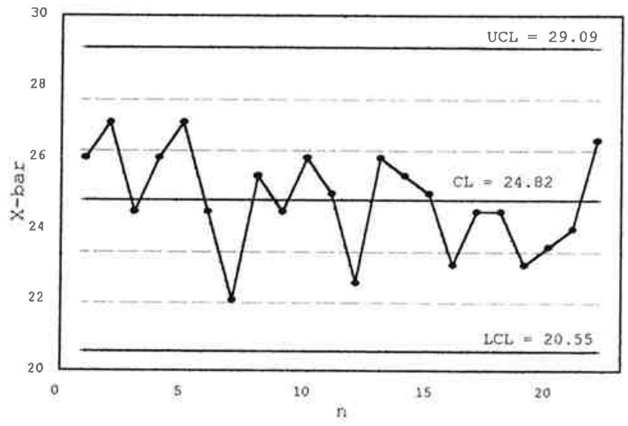


X-bar Chart for Moisture

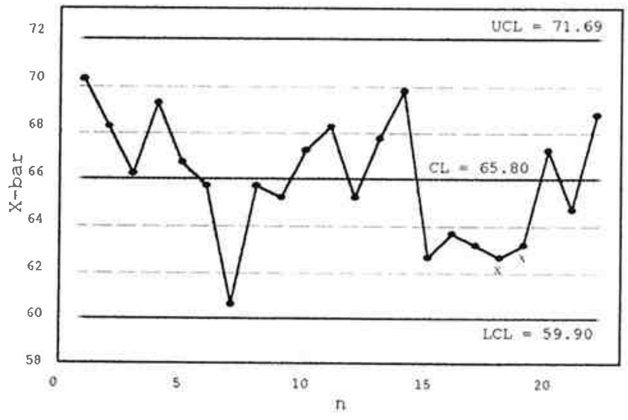
Baldock Slough - S. Baker (Lot 1)



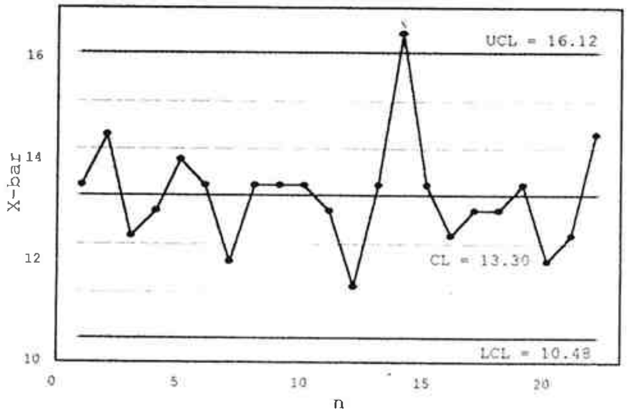
X-bar Chart for 1/4" Sieve
Forge Rd. - Lobert



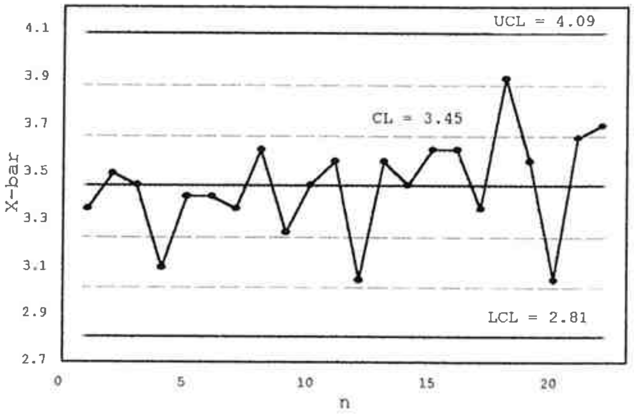
X-bar Chart for 1/2" Sieve
Forge Rd. - Lobert



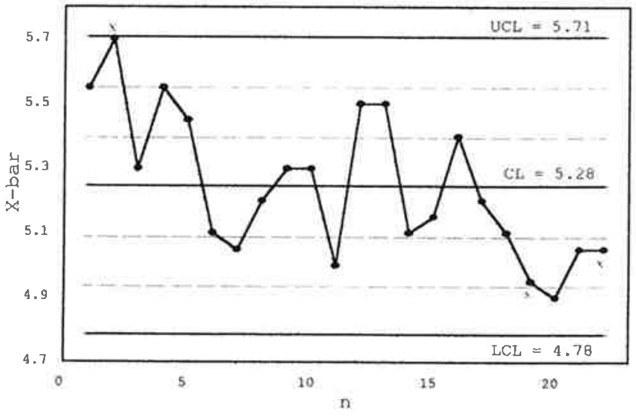
X-bar Chart for #10
Forge Rd. - Lobert



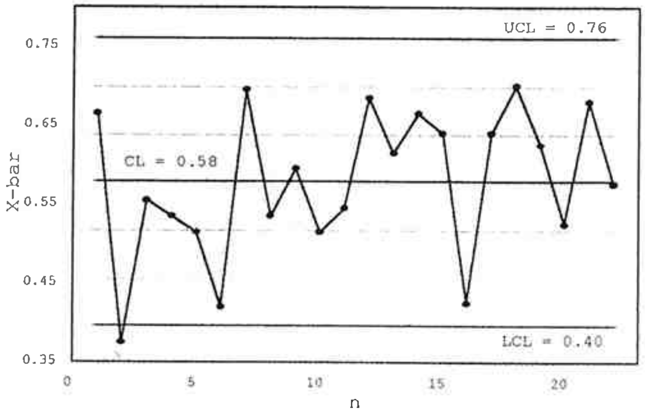
X-bar Chart for #200
Forge Rd. - Lobert



X-bar Chart for Asphalt
Forge Rd. - Lobert

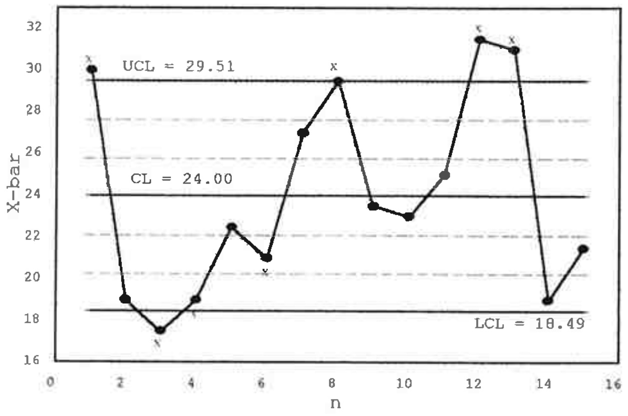


X-bar Chart for Moisture
Forge Rd. - Lobert



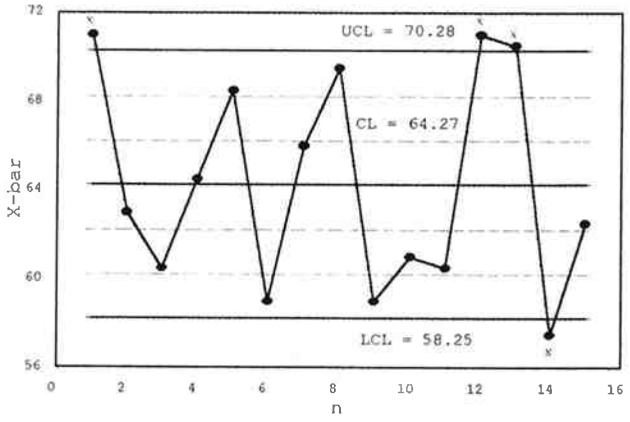
X-bar Chart for 1/4" Sieve

Jump Off Joe - North Grants Pass (Lot 1)



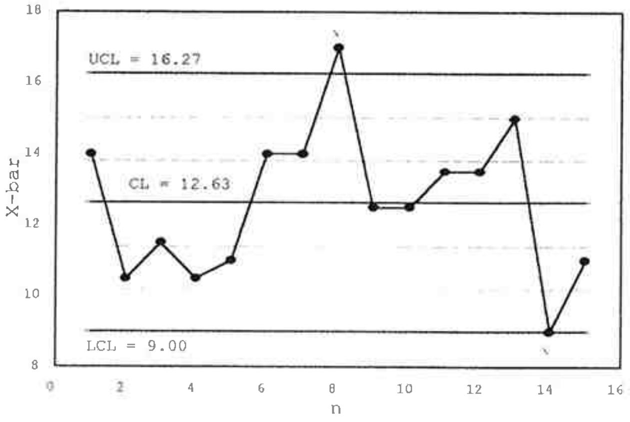
X-bar Chart for 1/2" Sieve

Jump Off Joe - North Grants Pass (Lot 1)



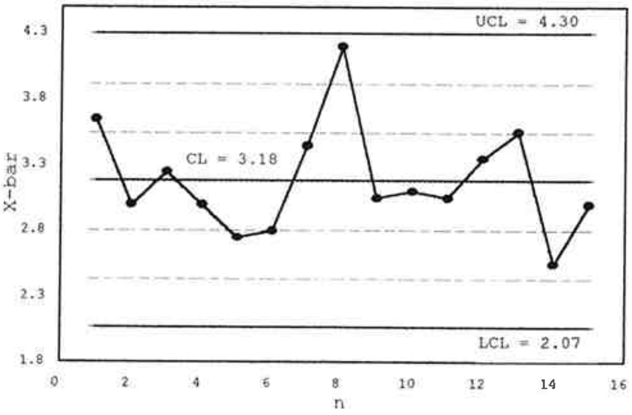
X-bar Chart for #10

Jump Off Joe - North Grants Pass (Lot 1)



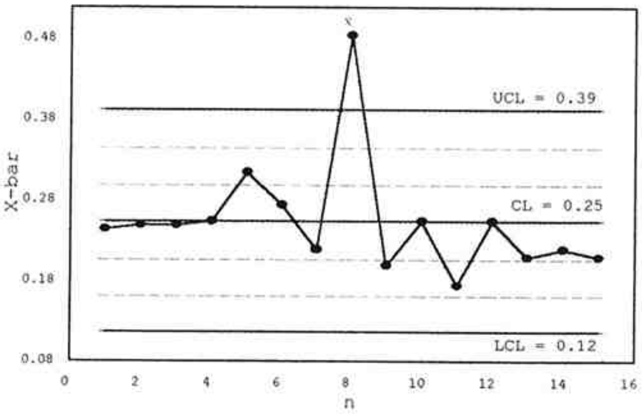
X-bar Chart for #200

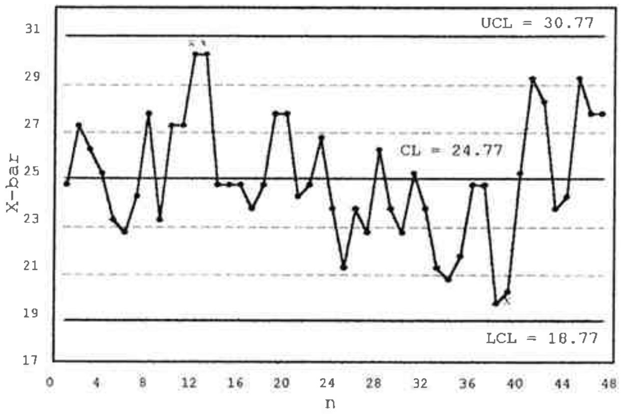
Jump Off Joe - North Grants Pass (Lot 1)



X-bar Chart for Moisture

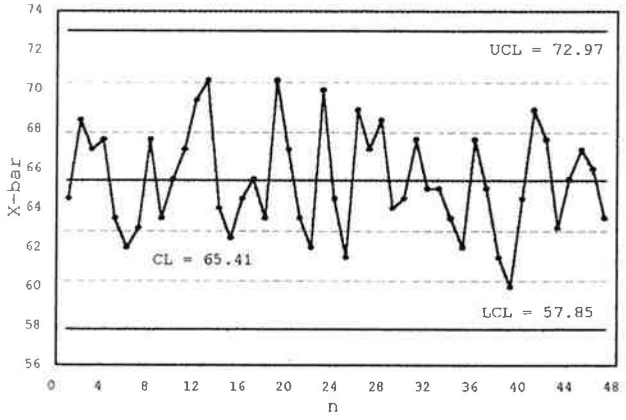
Jump Off Joe - North Grants Pass (Lot 1)





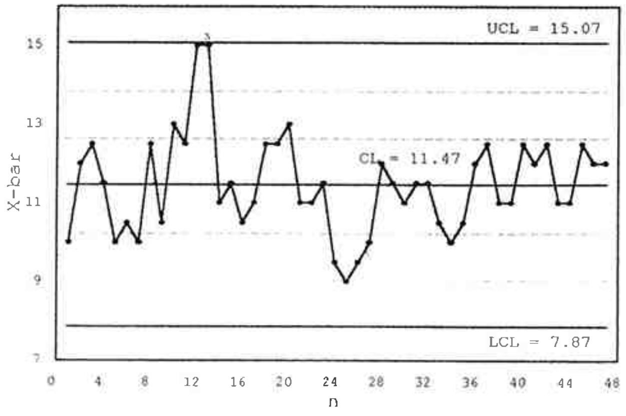
X-bar Chart for 1/4" Sieve

Jump Off Joe - North Grants Pass (Lot 2)



X-bar Chart for 1/2" Sieve

Jump Off Joe - North Grants Pass (Lot 2)

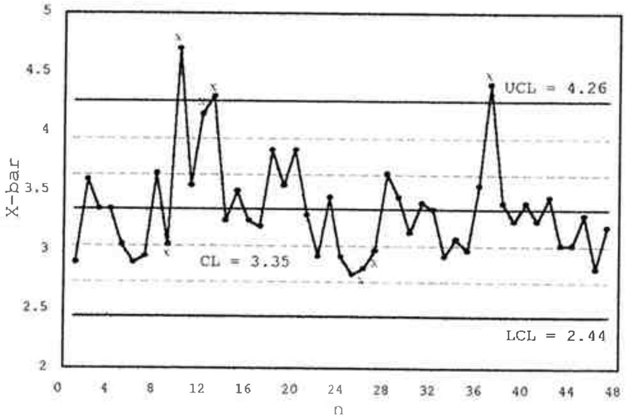


X-bar Chart for #10

Jump Off Joe - North Grants Pass (Lot 2)

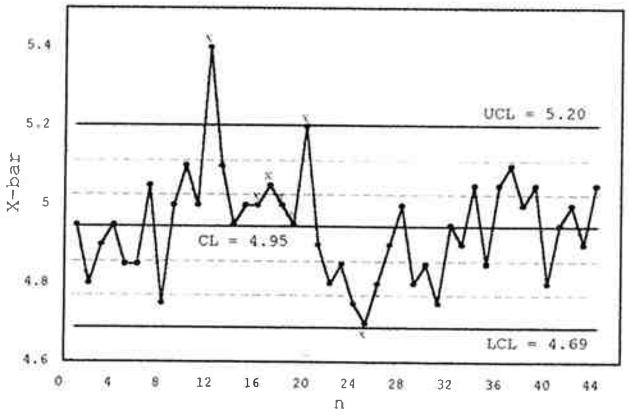
X-bar Chart for #200

Jump Off Joe - North Grants Pass (Lot 2)



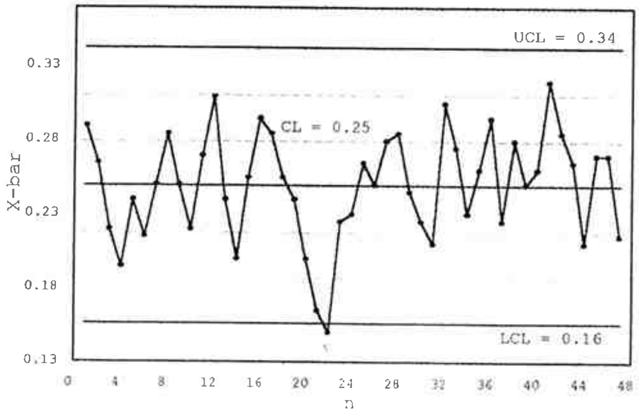
X-bar Chart for Asphalt

Jump Off Joe - North Grants Pass (Lot 2)



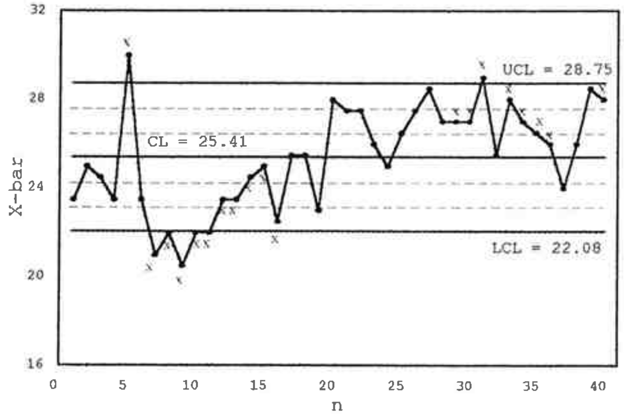
X-bar Chart for Moisture

Jump Off Joe - North Grants Pass (Lot 2)



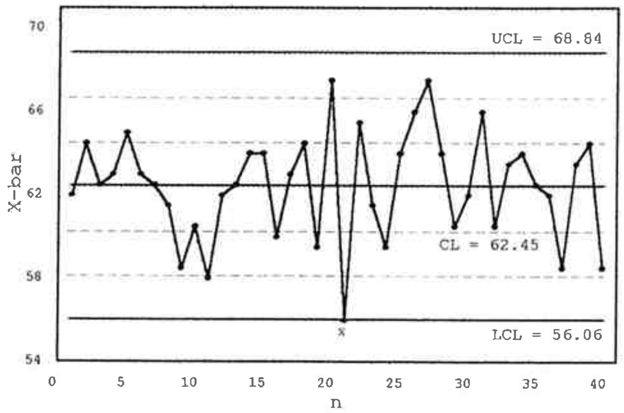
X-bar Chart for 1/4" Sieve

Azalea - Jumpoff Joe (Lot 2)



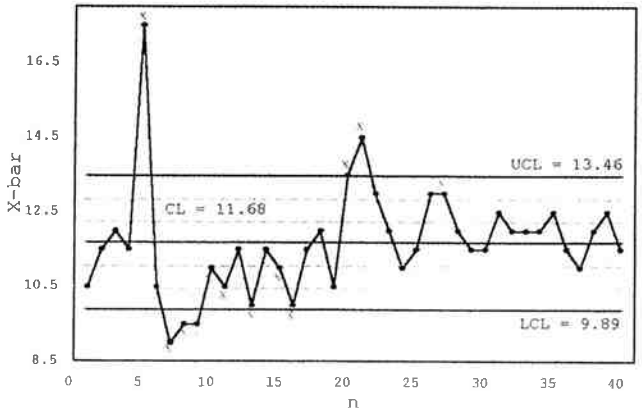
X-bar Chart for 1/2" Sieve

Azalea - Jumpoff Joe (Lot 2)



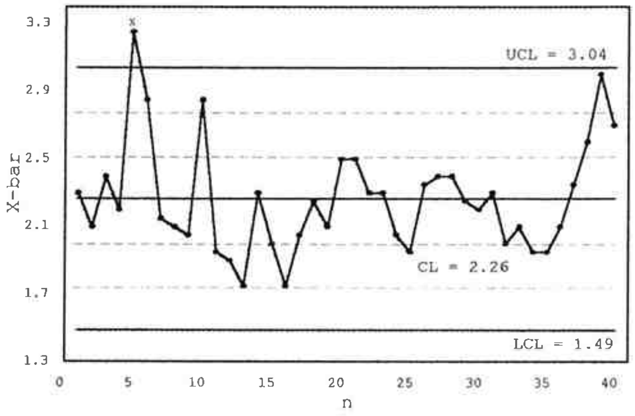
X-bar Chart for #10

Azalea - Jumpoff Joe (Lot 2)



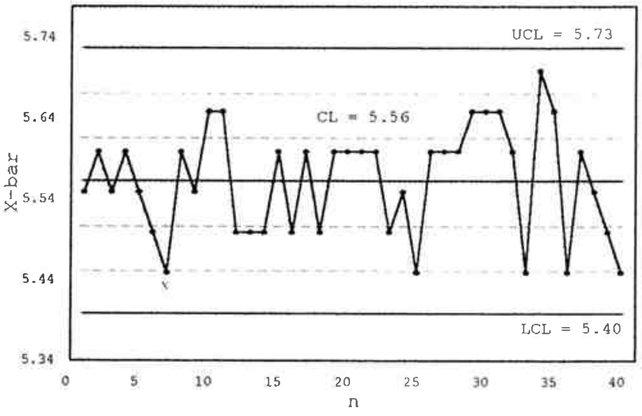
X-bar Chart for #200

Azalea - Jumpoff Joe (Lot 2)



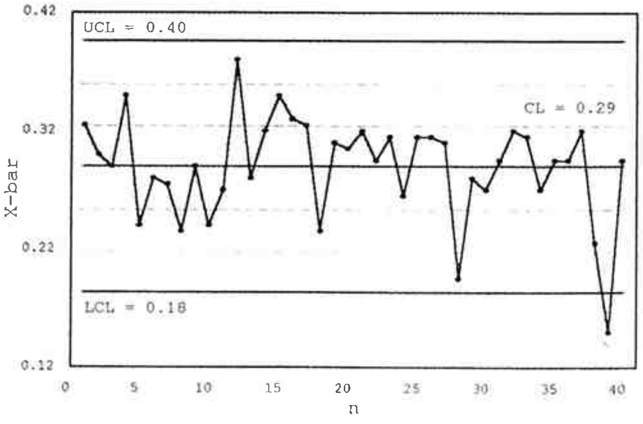
X-bar Chart for Asphalt

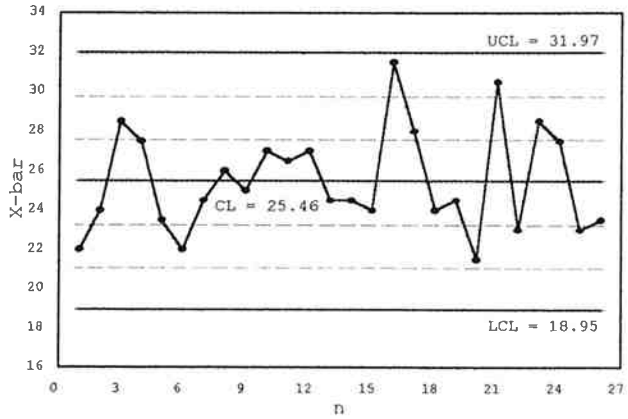
Azalea - Jumpoff Joe (Lot 2)



X-bar Chart for Moisture

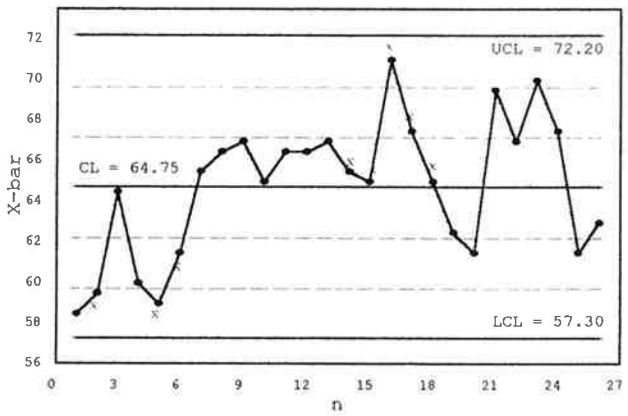
Azalea - Jumpoff Joe (Lot 2)





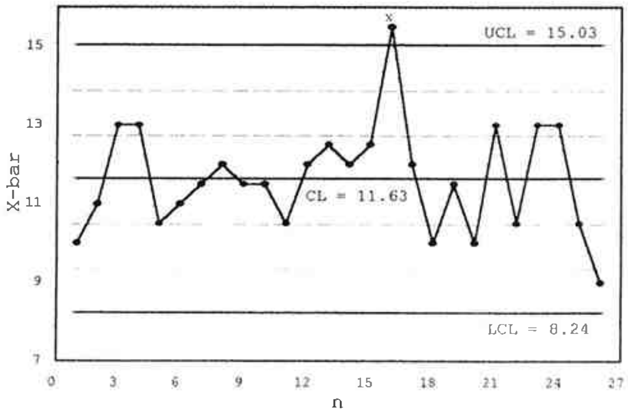
X-bar Chart for 1/4" Sieve

Halsey Int. - Lane Co. Line (Lot #3)



X-bar Chart for 1/2" Sieve

Halsey Int. - Lane Co. Line (Lot #3)

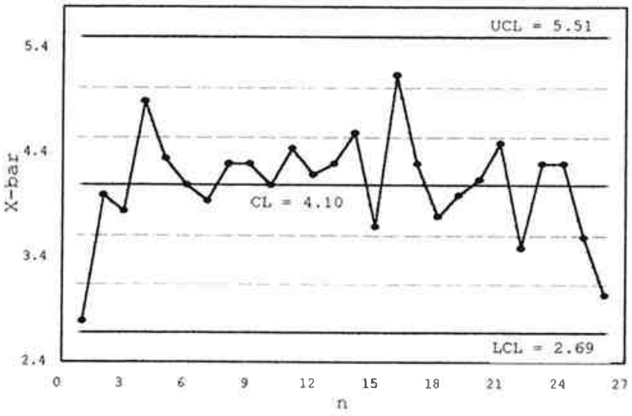


X-bar Chart for #10

Halsey Int. - Lane Co. Line (Lot #3)

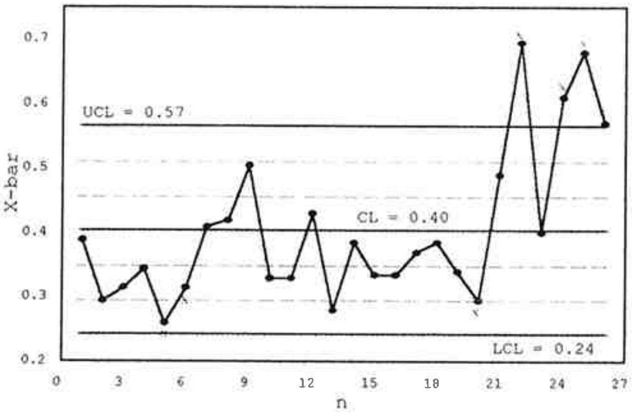
X-bar Chart for #200

Halsey Int. - Lane Co. Line (Lot #3)

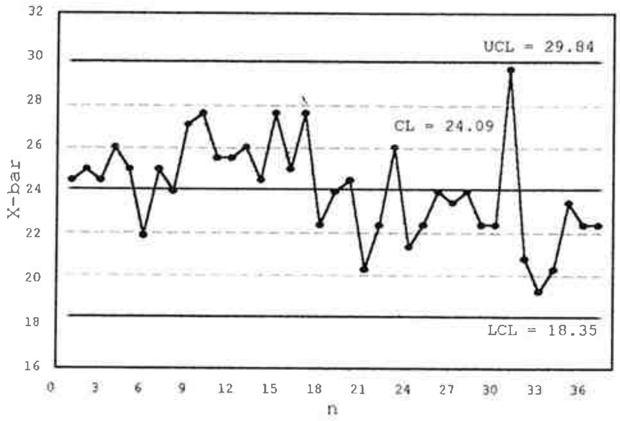


X-bar Chart for Moisture

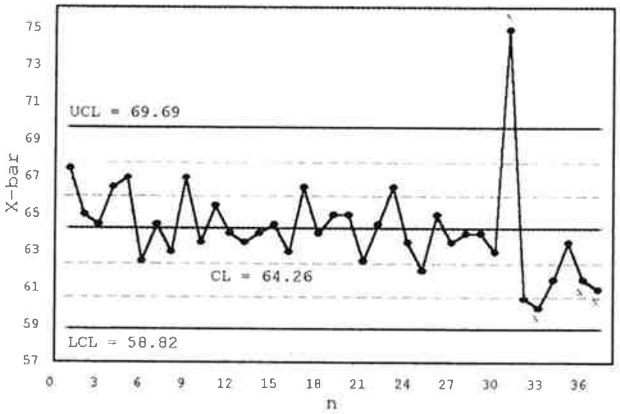
Halsey Int. - Lane Co. Line (Lot #3)



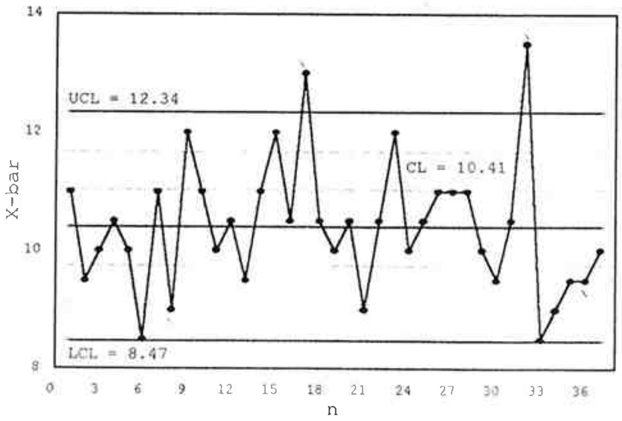
X-bar Chart for 1/4" Sieve
Halsey Int. - Lane Co. Line (Lot #4)

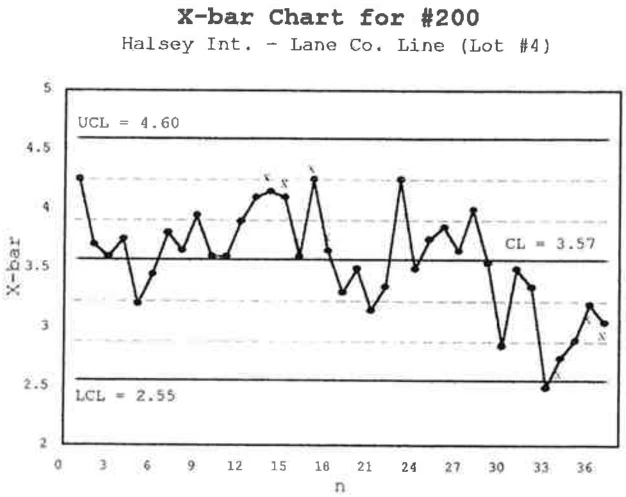


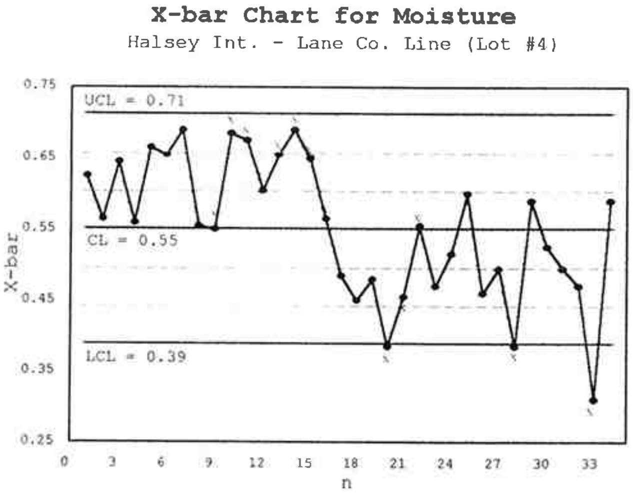
X-bar Chart for 1/2" Sieve
Halsey Int. - Lane Co. Line (Lot #4)



X-bar Chart for #10
Halsey Int. - Lane Co. Line (Lot #4)




X-bar Chart for #200
Halsey Int. - Lane Co. Line (Lot #4)
UCL = 4.60
CL = 3.57
LCL = 2.55
X-bar
5
4.5
4
3.5
3
2.5
2
0
3
6
9
12
15
18
21
24
27
30
33
36
n


X-bar Chart for Moisture
Halsey Int. - Lane Co. Line (Lot #4)
UCL = 0.71
CL = 0.55
LCL = 0.39
X-bar
0.75
0.65
0.55
0.45
0.35
0.25
0
3
6
9
12
15
18
21
24
27
30
33
n

APPENDIX E

PAY ADJUSTMENT SCHEDULES – ODOT

Table 00165 - 1

QUALITY LEVEL ANALYSIS BY THE STANDARD DEVIATION METHOD

P_U or P_L PERCENT WITHIN LIMITS FOR POSITIVE VALUES OF Q_U or Q_L	UPPER QUALITY INDEX Q_U OR LOWER QUALITY INDEX Q_L							
	n = 3	n = 4	n = 5	n = 6	n = 7	n = 8	n = 9	n = 10 to n = 11
100	1.16	1.50	1.79	2.03	2.23	2.39	2.53	2.65
99	-	1.47	1.67	1.80	1.89	1.95	2.00	2.04
97	1.15	1.44	1.60	1.70	1.76	1.81	1.84	1.86
97	-	1.41	1.54	1.62	1.67	1.70	1.72	1.74
96	1.14	1.38	1.49	1.55	1.59	1.61	1.63	1.65
95	-	1.35	1.44	1.49	1.52	1.54	1.55	1.56
94	1.13	1.32	1.39	1.43	1.46	1.47	1.48	1.49
93	-	1.29	1.35	1.38	1.40	1.41	1.42	1.43
92	1.12	1.26	1.31	1.33	1.35	1.36	1.36	1.37
91	1.11	1.23	1.27	1.29	1.30	1.30	1.31	1.31
90	1.10	1.20	1.23	1.24	1.25	1.25	1.26	1.26
89	1.09	1.17	1.19	1.20	1.20	1.21	1.21	1.21
88	1.07	1.14	1.15	1.16	1.16	1.16	1.16	1.17
87	1.06	1.11	1.12	1.12	1.12	1.12	1.12	1.12
86	1.04	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04	1.04	1.04	1.04	1.04
84	1.01	1.02	1.01	1.01	1.00	1.00	1.00	1.00
83	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.96
82	0.97	0.96	0.95	0.94	0.93	0.93	0.93	0.92
81	0.96	0.93	0.91	0.90	0.90	0.89	0.89	0.89
80	0.93	0.90	0.88	0.87	0.86	0.86	0.86	0.85
79	0.91	0.87	0.85	0.84	0.83	0.82	0.82	0.82
78	0.89	0.84	0.82	0.80	0.80	0.79	0.79	0.79
77	0.87	0.81	0.78	0.77	0.76	0.76	0.76	0.75
76	0.84	0.78	0.75	0.74	0.73	0.73	0.72	0.72
75	0.82	0.75	0.72	0.71	0.70	0.70	0.69	0.69
74	0.79	0.72	0.69	0.68	0.67	0.66	0.66	0.66
73	0.76	0.69	0.66	0.65	0.64	0.63	0.63	0.62
72	0.74	0.66	0.63	0.62	0.61	0.60	0.60	0.59
71	0.71	0.63	0.60	0.59	0.58	0.57	0.57	0.57
70	0.68	0.60	0.57	0.56	0.55	0.55	0.54	0.54
69	0.65	0.57	0.54	0.53	0.52	0.52	0.51	0.51
68	0.62	0.54	0.51	0.50	0.49	0.49	0.48	0.48
67	0.59	0.51	0.47	0.47	0.46	0.46	0.46	0.45
66	0.56	0.48	0.45	0.44	0.44	0.43	0.43	0.43
65	0.52	0.45	0.43	0.41	0.41	0.40	0.40	0.40
64	0.49	0.42	0.40	0.39	0.38	0.38	0.37	0.37
63	0.46	0.39	0.37	0.36	0.35	0.35	0.35	0.34
62	0.43	0.36	0.34	0.33	0.32	0.32	0.32	0.32
61	0.39	0.33	0.31	0.30	0.30	0.29	0.29	0.29
60	0.36	0.30	0.28	0.27	0.27	0.27	0.26	0.26
59	0.32	0.27	0.25	0.25	0.25	0.24	0.24	0.24
58	0.29	0.24	0.23	0.22	0.21	0.21	0.21	0.21
57	0.25	0.21	0.20	0.19	0.19	0.19	0.18	0.18
56	0.22	0.18	0.17	0.16	0.16	0.16	0.16	0.16
55	0.18	0.15	0.14	0.14	0.13	0.13	0.13	0.13
54	0.14	0.12	0.11	0.11	0.11	0.11	0.10	0.10
53	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.08
52	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05
51	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NOTE: For negative values of Q_U or Q_L, P_U or P_L is equal to 100 minus the table value for P_U or P_L. If the value of Q_U or Q_L does not correspond exactly to a figure in the table, use the next higher figure

Table 00165 - 1

QUALITY LEVEL ANALYSIS BY THE STANDARD DEVIATION METHOD

P_U or P_L PERCENT WITHIN LIMITS FOR POSITIVE VALUES OF Q_U or Q_L	UPPER QUALITY INDEX Q_U OR LOWER QUALITY INDEX Q_L						
	n = 12 to n = 14	n = 15 to n = 18	n = 19 to n = 25	n = 26 to n = 37	n = 38 to n = 69	n = 70 to n = 200	n = 201 to n = ∞
100	2.83	3.03	3.20	3.38	3.54	3.70	3.83
99	2.09	2.14	2.18	2.22	2.26	2.29	2.31
97	1.91	1.93	1.96	1.99	2.01	2.03	2.05
97	1.77	1.79	1.81	1.83	1.85	1.86	1.87
96	1.67	1.68	1.70	1.71	1.73	1.74	1.75
95	1.58	1.59	1.61	1.62	1.63	1.63	1.64
94	1.50	1.51	1.52	1.53	1.54	1.55	1.55
93	1.44	1.44	1.45	1.46	1.46	1.47	1.47
92	1.37	1.38	1.39	1.39	1.40	1.40	1.40
91	1.32	1.32	1.33	1.33	1.33	1.34	1.34
90	1.26	1.27	1.27	1.27	1.28	1.28	1.28
89	1.21	1.22	1.22	1.22	1.22	1.22	1.23
88	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.12	1.12	1.12	1.12	1.12	1.13	1.13
86	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.04	1.04	1.04	1.04	1.04	1.04	1.04
84	1.00	1.00	1.00	1.00	0.99	0.99	0.99
83	0.96	0.96	0.96	0.96	0.95	0.95	0.95
82	0.92	0.92	0.92	0.92	0.92	0.92	0.92
81	0.88	0.88	0.88	0.88	0.88	0.88	0.88
80	0.85	0.85	0.85	0.84	0.84	0.84	0.84
79	0.81	0.81	0.81	0.81	0.81	0.81	0.81
78	0.78	0.78	0.78	0.78	0.77	0.77	0.77
77	0.75	0.75	0.75	0.74	0.74	0.74	0.74
76	0.71	0.71	0.71	0.71	0.71	0.71	0.71
75	0.68	0.68	0.68	0.68	0.68	0.68	0.67
74	0.65	0.65	0.65	0.65	0.65	0.64	0.64
73	0.62	0.62	0.62	0.62	0.62	0.61	0.61
72	0.59	0.59	0.59	0.59	0.59	0.58	0.58
71	0.56	0.56	0.56	0.56	0.56	0.55	0.55
70	0.53	0.53	0.53	0.53	0.53	0.53	0.52
69	0.50	0.50	0.50	0.50	0.50	0.50	0.50
68	0.48	0.48	0.47	0.47	0.47	0.47	0.47
67	0.45	0.45	0.45	0.44	0.44	0.44	0.44
66	0.42	0.42	0.42	0.42	0.41	0.41	0.41
65	0.39	0.39	0.39	0.39	0.39	0.39	0.39
64	0.37	0.37	0.36	0.36	0.36	0.36	0.36
63	0.34	0.34	0.34	0.34	0.33	0.33	0.33
62	0.31	0.31	0.31	0.31	0.31	0.31	0.31
61	0.29	0.29	0.28	0.28	0.28	0.28	0.28
60	0.26	0.26	0.26	0.26	0.26	0.25	0.25
59	0.23	0.23	0.23	0.23	0.23	0.23	0.23
58	0.21	0.21	0.20	0.20	0.20	0.20	0.20
57	0.18	0.18	0.18	0.18	0.18	0.18	0.18
56	0.15	0.15	0.15	0.15	0.15	0.15	0.15
55	0.13	0.13	0.13	0.13	0.13	0.13	0.13
54	0.10	0.10	0.10	0.10	0.10	0.10	0.10
53	0.08	0.08	0.08	0.08	0.08	0.08	0.08
52	0.05	0.05	0.05	0.05	0.05	0.05	0.05
51	0.03	0.03	0.03	0.03	0.03	0.03	0.02
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NOTE: For negative values of Q_U or Q_L, P_U or P_L is equal to 100 minus the table value for P_U or P_L. If the value of Q_U or Q_L does not correspond exactly to a figure in the table, use the next higher figure.

Table 00165 - 2

PAY FACTOR	REQUIRED QUALITY LEVEL FOR A GIVEN SAMPLE SIZE (n) AND A GIVEN PAY FACTOR							
	n = 3	n = 4	n = 5	n = 6	n = 7	n = 8	n = 9	n = 10 to n = 11
1.05	100	100	100	100	100	100	100	100
1.04	90	91	92	93	93	93	94	94
1.03	80	85	87	88	89	90	91	91
1.02	75	80	83	85	86	87	88	88
1.01	71	77	80	82	84	85	85	86
1.00	68	74	78	80	81	82	83	84
.99	66	72	75	77	79	80	87	82
.98	64	70	73	75	77	78	79	80
.97	62	68	71	74	75	77	78	78
.96	60	66	69	72	73	75	76	77
.95	59	64	68	70	72	73	74	75
94	57	63	66	68	70	72	73	74
93	56	61	65	67	69	70	71	72
92	55	60	63	65	67	69	70	71
91	53	58	62	64	66	67	68	69
.90	52	57	60	63	64	66	67	68
.89	51	55	59	61	63	64	66	67
.88	50	54	57	60	62	63	64	65
87	48	53	56	58	60	62	63	64
86	47	51	55	57	59	60	62	63
85	46	50	53	56	58	59	60	61
.84	45	49	52	55	56	58	59	60
.83	44	48	51	53	55	57	58	59
.82	42	46	50	52	54	55	57	58
.81	41	45	48	51	53	54	56	57
.80	40	44	47	50	52	53	54	55
.79	38	43	46	48	50	52	53	54
.78	37	41	45	47	49	51	52	53
.77	36	40	43	46	48	50	51	52
.76	34	39	42	45	47	48	50	51
.75	33	38	41	44	46	47	49	50
REJECT	QUALITY LEVELS LESS THAN THOSE SPECIFIED FOR A 0.75							

NOTE: If the computed QUALITY LEVEL does not correspond exactly to a figure in the table, use the next lower value.

Table 00165 - 2

PAY FACTOR	REQUIRED QUALITY LEVEL FOR A GIVEN SAMPLE SIZE (n) AND A GIVEN PAY FACTOR						
	n = 12 to n = 14	n = 15 to n = 14	n = 19 to n = 25	n = 26 to n = 37	n = 38 to n = 69	n = 70 to n = 300	n = 201 to n = ∞
1.05	100	100	100	100	100	100	100
1.04	95	95	96	.96	97	97	99
1.03	92	93	93	94	95	95	97
1.02	89	90	91	92	93	94	95
1.01	87	88	89	90	91	93	94
1.00	85	86	87	89	90	91	93
.99	83	85	86	87	88	90	92
.98	81	83	84	85	87	88	90
.97	80	81	83	84	85	87	89
.96	78	80	81	83	84	86	88
.95	77	78	80	81	83	85	87
.94	75	77	78	80	81	83	86
.93	74	75	77	78	80	82	84
.92	72	74	75	77	79	81	83
.91	71	73	74	76	78	80	82
.90	70	71	73	75	76	79	81
.89	68	70	72	73	75	77	80
.88	67	69	70	72	74	76	79
.87	66	67	69	71	73	75	78
.86	64	66	68	70	72	74	77
.85	63	65	67	69	71	73	76
.84	62	64	65	67	69	72	75
.83	61	63	64	66	68	71	74
.82	60	61	63	65	67	70	72
.81	58	60	62	64	66	69	71
.80	57	59	61	63	65	67	70
.79	56	58	60	62	64	66	69
.78	55	57	59	61	63	65	68
.77	52	56	57	60	62	64	67
.76	51	55	56	58	61	63	66
.75	51	53	55	57	59	62	65
REJECT	QUALITY LEVELS LESS THAN THOSE SPECIFIED FOR A 0.75						

NOTE: If the computed QUALITY LEVEL does not correspond exactly to a figure in the table, use the next lower value.

ODOT's
Pay Adjustment Schedule
and Estimated Equation for Sample Size n=5

	Pay Schedule	Estimated Equation
PD	PF	PF
0	1.05	1.05
8	1.04	1.04
13	1.03	1.03
17	1.02	1.02
20	1.01	1.01
22	1.00	1.01
26	0.99	0.99
28	0.98	0.98
30	0.97	0.97
32	0.96	0.96
33	0.95	0.96
35	0.94	0.95
36	0.93	0.94
38	0.92	0.93
39	0.91	0.92
41	0.90	0.91
42	0.89	0.90
44	0.88	0.89
45	0.87	0.88
46	0.86	0.87
48	0.85	0.86
49	0.84	0.85
50	0.83	0.85
51	0.82	0.84
53	0.81	0.82
54	0.80	0.81
55	0.79	0.81
56	0.78	0.80
57	0.77	0.79
58	0.76	0.78
59	0.75	0.77

ESTIMATED PAY EQUATION

$PF = 105 - 0.032 * PD^{1.655}$

OCPLOT Results

PD		Ave. PF
0		1.05
5		1.041
10	AQL	1.029
15		1.018
20		1.004
25		0.985
30		0.957
35		0.922
40		0.887
45		0.854
50		0.823
55		0.796
60		0.78
65		0.765

ODOT's
Pay Adjustment Schedule
and Estimated Equation for Sample Size n=10 to 11

		Pay Schedule	**Estimated Equation**
PWL	PD	PF	PF
100	0	1.05	1.05
94	6	1.04	1.04
91	9	1.03	1.03
88	12	1.02	1.02
86	14	1.01	1.01
84	16	1.00	1.00
82	18	0.99	0.99
80	20	0.98	0.98
78	22	0.97	0.97
77	23	0.96	0.96
75	25	0.95	0.95
74	26	0.94	0.94
72	28	0.93	0.93
71	29	0.92	0.92
69	31	0.91	0.91
68	32	0.90	0.90
67	33	0.89	0.89
65	35	0.88	0.88
64	36	0.87	0.87
63	37	0.86	0.86
61	39	0.85	0.85
60	40	0.84	0.84
59	41	0.83	0.83
58	42	0.82	0.82
57	43	0.81	0.81
55	45	0.80	0.80
54	46	0.79	0.79
53	47	0.78	0.78
52	48	0.77	0.77
51	49	0.76	0.76
50	50	0.75	0.75

ESTIMATED PAY EQUATION
PF = 105 - 0.0638 * PD^1.573

OCPLOT Results

PD	Ave. PF
0	1.05
5	1.038
10	1.021
15	0.999
20	0.978
25	0.96
30	0.928
35	0.889
40	0.85
45	0.811
50	0.776
55	0.764

ODOT's
Pay Adjustment Schedule
and Estimated Equation for Sample Size n=70 to 200

		Pay Schedule	**Estimated Equation**
PWL	PD	PF	PF
100	0	1.05	1.05
97	3	1.04	1.04
95	5	1.03	1.03
94	6	1.02	1.02
93	7	1.01	1.01
91	9	1.00	1.00
90	10	0.99	0.99
88	12	0.98	0.98
87	13	0.97	0.97
86	14	0.96	0.96
85	15	0.95	0.96
83	17	0.94	0.94
82	18	0.93	0.93
81	19	0.92	0.92
80	20	0.91	0.92
79	21	0.90	0.91
77	23	0.89	0.89
76	24	0.88	0.88
75	25	0.87	0.87
74	26	0.86	0.86
73	27	0.85	0.85
72	28	0.84	0.85
71	29	0.83	0.84
70	30	0.82	0.83
69	31	0.82	0.82
67	33	0.80	0.80
66	34	0.79	0.79
65	35	0.78	0.78
64	36	0.77	0.77
63	37	0.76	0.76
62	38	0.75	0.75

ESTIMATED PAY EQUATION
PF = 105 - 0.3287 * PD^1.2389

OCPLOT Results

PD		Ave. PF
0		1.05
5	AQL	1.027
10		0.995
15		0.959
20		0.919
25		0.877
30		0.841
35		0.805
40		0.762

APPENDIX F

C_{pk} ANALYSIS

C_{pk} ANALYSIS

C_{pk} is a performance index which reflects the current process mean's proximity to either the upper specification limit or lower specification limit. In order to determine the greatest opportunities for contractor process capability improvement, C_{pk} values were calculated for the following sieves: .075 mm (#200), 2 mm (#10), 6.25 mm (1/4 inch), 12.5 mm (1/2 inch), 19 mm (3/4 inch), and 25 mm (1 inch).

C_{pk} is calculated by the following equation:

$$C_{pk} = \min\left[\frac{\overline{X} - LSL}{3s}, \frac{USL - \overline{X}}{3s}\right]$$

s = sample standard deviation
$\overline{X}$ = arithmetic mean
LSL = lower specification limit
USL = upper specification limit

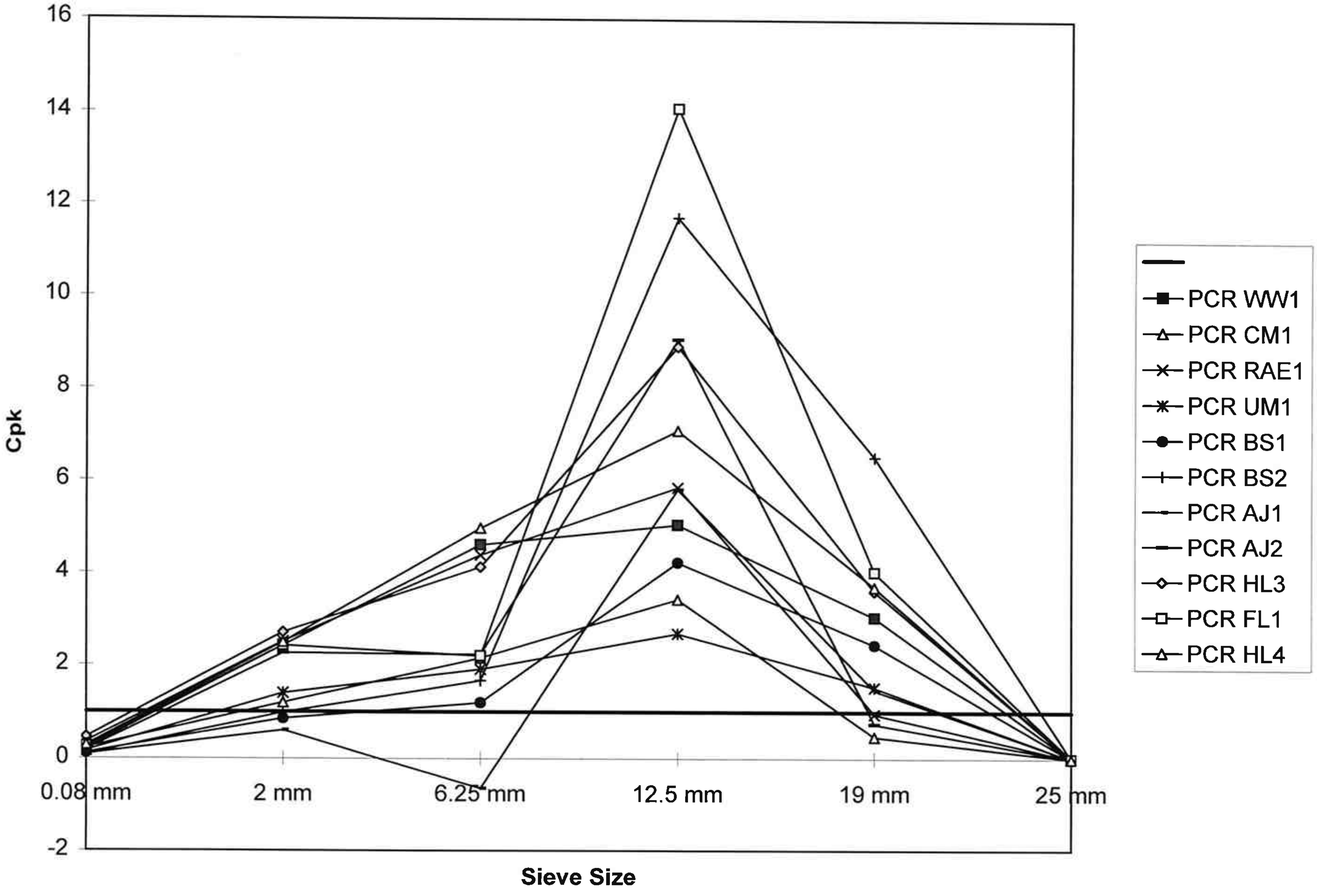
A value of C_{pk} less than 1.0 indicates that one should expect more than a small percentage of the values for this factor would be outside the specification limits.

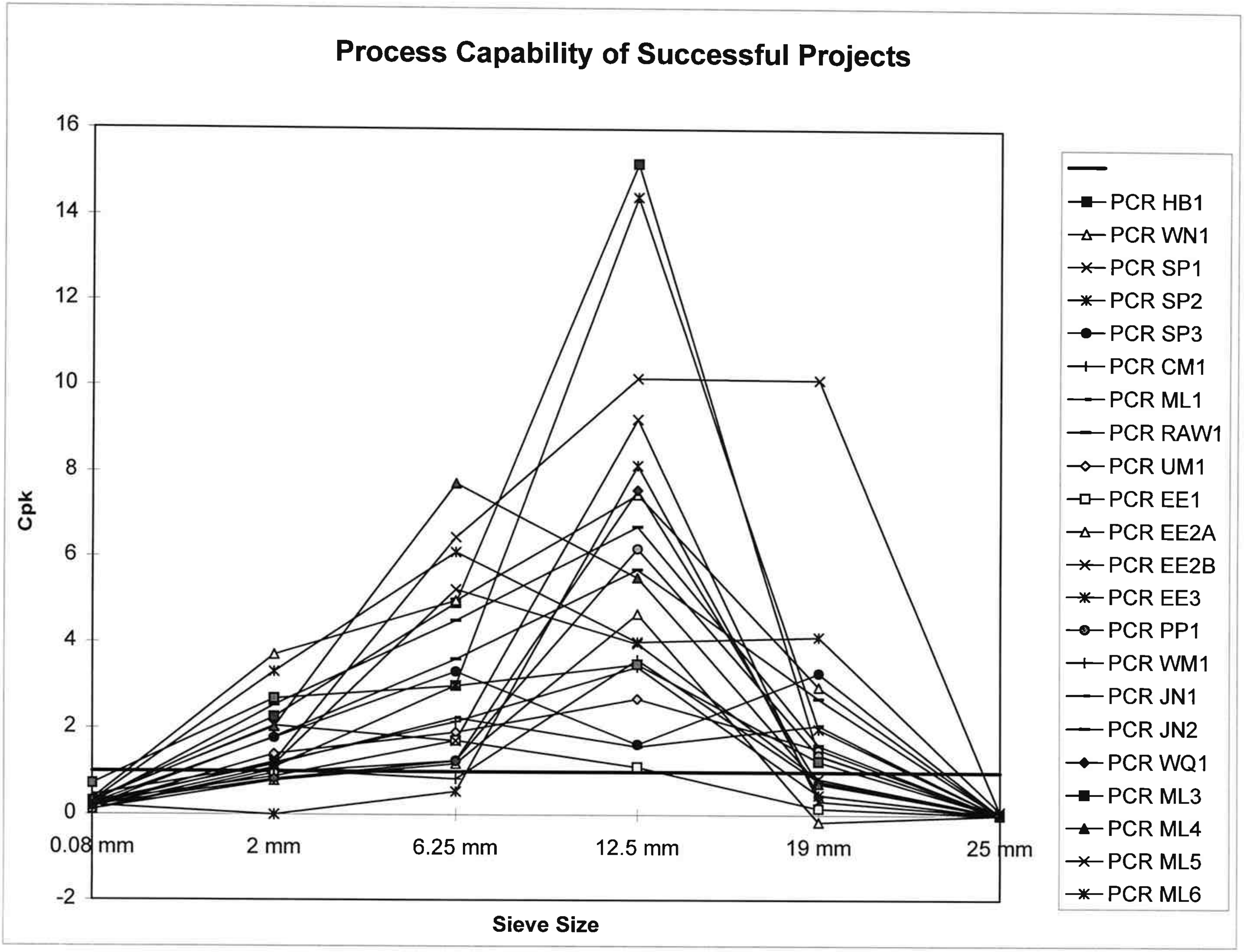
These C_{pk} values were graphed for both "successful" and "unsuccessful" projects. "Successful" projects were defined as projects which did not require core analysis and "unsuccessful" projects were defined as those requiring core analysis. The purpose in graphing the C_{pk} values was to look for patterns and to see if there were significant differences in the patterns of successful versus unsuccessful projects. As can be seen from the following charts, the patterns for successful and unsuccessful projects were very similar. Please note that the values of C_{pk} do NOT represent a continuous distribution. Rather, values are connected by lines to indicate a particular project.

As previously mentioned, values of C_{pk} less than 1.0 indicate an opportunity for improving process capability. However, C_{pk} values of 0 indicate that there is no problem with process capability as is the case with the 25 mm (1 inch) sieve.

ALL of the C_{pk} values for the 0.75 mm (#200) sieve were less than 1.0 and not equal to zero. This indicates a significant opportunity for improvement. Similarly, the 19 mm (3/4 inch) and 2 mm (#10) sieves showed some difficulties with process capabilities (some C_{pk} values less than 1.0) and, therefore, should not be removed from consideration.

Process Capability of Unsuccessful Projects




Process Capability of Successful Projects
Cpk
16
14
12
10
8
6
4
2
0
-2
0.08 mm
2 mm
6.25 mm
12.5 mm
19 mm
25 mm
Sieve Size
PCR HB1
PCR WN1
PCR SP1
PCR SP2
PCR SP3
PCR CM1
PCR ML1
PCR RAW1
PCR UM1
PCR EE1
PCR EE2A
PCR EE2B
PCR EE3
PCR PP1
PCR WM1
PCR JN1
PCR JN2
PCR WQ1
PCR ML3
PCR ML4
PCR ML5
PCR ML6

APPENDIX G

PAY FACTORS FOR PRIOR PROJECTS USING RECOMMENDED PAY FACTOR WEIGHTS

PAY FACTORS FOR PRIOR PROJECTS USING RECOMMENDED PAY FACTOR WEIGHTS

While the Technical Advisory Committee requested that this analysis be done, please note that conclusions can NOT be drawn from this analysis. The purpose of pay factors is to influence contractors to focus on improving performance on factors that impact pavement performance. Therefore, one can not assess the impact of a pay factor change without the corresponding influence on contractor behavior.

The following pages include detailed listing of the prior projects, the original composite pay factor, and the alternative composite pay factors.

IMPACT OF CHANGES TO PAY FACTOR WEIGHTS FOR "F" MIXTURE LOTS

CONT		TONS	PRICE	LOT	# SUB	PAY FACTORS										Current	ALT 1	ALT 2	ALT 3
NO	SECTION	OF MIX	ADJUST ($)	NO	LOTS	1	3/4	1/2	1/4	10	40	200	ASPH	MOIS	COMP	CPF	CPF	CPF	CPF
11285	42nd St - McKenzie Hwy	12483	1700	3	25	1.05	1.05	1.02	0.95	1.03	1.00	1.05	1.01	0.98	1.00	1.006	1.012	1.013	1.012
11228	Airport Rd - Pacific Hwy W	11115	6710	1	23	1.05	1.05	1.01	1.04	1.05	1.05	1.05	1.04	1.05	1.00	1.025	1.042	1.041	1.044
10864	Applegate R Br - MP 9.2	3543	-7529	1	7	1.05	0.00	0.00	0.00	0.84	1.00	1.05	0.94	1.05	1.00	0.916	0.641	0.613	0.723
11205	Arch Cape Tunnel - Short Sand Dr	7355	4766	1	15	1.05	1.05	0.98	1.03	1.04	1.00	1.05	1.04	1.05	1.00	1.024	1.036	1.035	1.039
11186	Arlington - Cedar Springs Rd	1491	-2198	1	3	1.05	0.82	1.05	1.03	1.02	1.00	1.05	1.04	0.00	1.00	0.937	0.925	0.919	0.923
11344	Azalea Jumpoff Joe	6771	-12714	1	7	1.05	1.04	0.97	0.00	1.05	1.00	1.05	0.92	1.05	1.00	0.941	0.848	0.873	0.849
11344	Azalea Jumpoff Joe	79703	46148	2	80	1.05	1.02	0.90	0.95	1.05	1.00	1.05	1.04	1.05	1.00	1.019	1.016	1.013	1.023
10930	Baldock Slough - S Baker Intch	45596	16552	1	91	1.05	1.01	1.00	0.93	1.05	1.00	1.05	1.02	1.05	1.00	1.014	1.016	1.016	1.019
10930	Baldock Slough - S Baker Intch	2139	1202	2	5	1.05	1.04	0.99	1.04	1.05	1.00	1.05	1.05	1.05	1.00	1.027	1.042	1.040	1.045
11365	Battle Cr Intch - N Jefferson Intch	19028	13218	1	38	1.05	1.05	1.05	1.03	1.05	1.00	1.05	1.03	1.03	1.00	1.021	1.040	1.040	1.039
11365	Battle Cr Intch - N Jefferson Intch	11867	10992	2	12	1.05	1.04	1.05	1.04	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.048	1.048	1.048
11365	Battle Cr Intch - N Jefferson Intch	1466	485	3	3	1.05	1.05	1.05	1.05	1.03	1.00	1.05	1.00	1.00	1.00	1.010	1.029	1.028	1.027
11449	Bear Cr Rd - Alder Cr	8329	6545	1	9	1.05	1.05	1.04	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.049	1.049	1.050
11138	Belt Line Hwy - Barger Ave (Eug)	5487	2682	1	11	1.05	1.04	1.04	0.99	1.04	1.00	1.05	1.05	1.01	1.00	1.022	1.034	1.036	1.035
11165	Boulder Flat - Fish Cr Br	5048	3347	1	10	1.05	1.03	0.96	1.05	1.05	1.00	1.05	1.04	1.03	1.00	1.023	1.036	1.032	1.040
10961	Brookman Rd - Garland Rd	4808	2123	1	10	1.05	1.04	0.89	1.02	1.05	1.00	1.05	1.03	1.04	1.00	1.019	1.024	1.019	1.030
11296	Brooten Rd - Little Nestucca R	3614	2485	1	7	1.05	1.01	0.95	1.03	1.05	1.00	1.05	1.04	1.05	1.00	1.024	1.032	1.028	1.037
10653	Camas Mt Wayside - Muns Cr	6310	3372	F1	13	1.05	0.00	1.03	1.03	1.05	1.00	1.05	1.05	1.05	1.00	1.017	0.951	0.919	0.994
10846	Camas Valley - Camas Mt Wayside	16266	10178	1	32	1.05	1.04	0.86	1.05	1.05	1.00	1.05	1.04	1.05	1.00	1.024	1.029	1.023	1.037
10599	Cape Sebastian - Myers Cr Rd	4029	1250	1	8	1.05	1.04	1.01	0.90	1.05	1.00	1.05	1.00	1.05	1.00	1.011	1.009	1.011	1.010
11302	Cedar Hills Blvd Intch Aux Lane	3895	1744	1	8	1.05	1.05	1.01	1.04	1.05	1.00	1.05	1.01	1.04	1.00	1.016	1.033	1.031	1.034
11427	Cent Ore Preservation Pro (1994)	35198	26343	1	35	1.05	1.04	1.02	1.03	1.05	1.00	1.05	1.05	1.05	1.00	1.027	1.043	1.043	1.045
10743	Chemult - Lenz Rd	17330	-1043	F1	37	1.05	1.05	0.96	0.99	1.04	1.00	0.96	0.98	1.05	1.00	0.997	0.998	0.998	0.996
10743	Chemult - Lenz Rd	10528	1242	F2	21	1.05	1.04	1.04	1.03	1.05	1.00	1.04	0.97	1.05	1.00	1.006	1.021	1.019	1.020
10743	Chemult - Lenz Rd	37725	-8873	F3	75	1.05	0.99	0.98	0.94	1.04	1.00	1.02	0.95	1.05	1.00	0.992	0.988	0.985	0.990
10726	Clackamas/Boring - 362nd Dr	7872	4920	2	16	1.05	1.05	1.03	1.05	1.05	1.00	1.04	1.04	1.05	1.00	1.025	1.044	1.043	1.044
10726	Clackamas/Boring - 362nd Dr	4483	3001	3	9	1.05	1.05	0.96	1.04	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.038	1.035	1.041
10750	Coast Range Summit - Jewell Jct	11758	6926	2	23	1.05	1.05	1.04	0.90	1.02	1.00	1.05	1.05	1.05	1.00	1.019	1.022	1.027	1.023
11013	Coquille Reroute	7258	7917	2	15	1.05	1.04	0.97	1.05	1.05	1.00	1.05	1.05	1.04	1.00	1.027	1.041	1.038	1.045
10939	Corbett Intch - Multnomah Falls	37511	-62861	4	75	1.05	0.89	0.97	1.02	1.05	1.00	1.05	1.00	0.00	1.00	0.930	0.915	0.908	0.914
10917	Corvallis By-Pass (S Unit)	1741	1207	1	3	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.050	1.050	1.050
10883	Corvallis ECL - NW Rondo St	13152	1538	1	27	1.05	1.03	0.84	0.90	1.04	1.00	1.05	1.00	1.05	1.00	1.005	0.991	0.988	1.000
10566	Crater Lake Hwy - Brownsboro	22774	804	F1	46	1.05	1.05	0.00	0.87	1.05	1.00	1.05	1.01	1.05	1.00	1.002	0.917	0.890	0.959
11333	Depoe Bay Br - NE 54th St	28284	15370	1	56	1.05	0.96	0.98	1.02	1.04	1.00	1.05	1.04	1.05	1.00	1.022	1.027	1.023	1.033
11271	Deschutes R - US 97	10745	6789	1	21	1.05	1.05	1.01	1.04	1.05	1.00	1.05	1.03	1.05	1.00	1.022	1.039	1.038	1.041
11044	Dist 4 Overlay Projects (1991)	7918	3665	1	15	1.05	1.05	1.05	1.02	1.05	1.00	1.05	1.05	0.98	1.00	1.021	1.039	1.040	1.039
10761	Dist 5 Overlay Project	3547	610	1	7	1.05	1.05	0.80	0.77	1.05	1.00	1.04	1.04	1.05	1.00	1.008	0.981	0.982	0.991

IMPACT OF CHANGES TO PAY FACTOR WEIGHTS FOR "F" MIXTURE LOTS

CONT NO	SECTION	TONS OF MIX	PRICE ADJUST ($)	LOT NO	# SUB LOTS	PAY FACTORS 1	3/4	1/2	1/4	10	40	200	ASPH	MOIS	COMP	Current CPF	ALT 1 CPF	ALT 2 CPF	ALT 3 CPF
10761	Dist 5 Overlay Project	13735	591	2	27	1.05	1.05	1.00	0.90	1.04	1.00	1.05	0.98	1.05	1.00	1.002	1.002	1.003	1.003
10763	Dist 5 Overlay Project	4778	1391	4	10	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	0.85	1.00	1.013	1.032	1.032	1.030
10872	Dist 5 Overlay Project (1990)	21416	9034	2	44	1.05	1.05	1.04	1.04	1.05	1.00	1.05	1.04	0.96	1.00	1.018	1.037	1.036	1.036
11037	Dist 5 Overlay Projects (1991)	11231	4525	1	22	1.05	1.05	0.87	0.97	0.94	1.00	1.05	1.05	1.05	1.00	1.017	1.005	1.006	1.013
10256	Dist 5 Paving Projects	16154	1541	2	32	1.05	1.05	1.01	1.03	1.04	1.05	1.04	0.97	1.02	1.00	1.004	1.015	1.013	1.015
10620	Dist 6 Overlay	4568	1455	1	9	1.05	1.05	1.02	1.04	0.92	1.00	1.05	1.01	1.05	1.00	1.011	1.015	1.017	1.016
10620	Dist 6 Overlay	4724	2598	2	9	1.05	1.05	1.05	1.04	1.03	1.00	1.05	1.02	1.05	1.00	1.019	1.037	1.037	1.037
11450	Dist 6 Overlay Proj	8327	6608	1	8	1.05	1.05	1.05	1.04	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.049	1.049	1.049
11287	Dist 6 Overlay Project	2444	2062	1	5	1.05	1.05	1.04	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.049	1.049	1.050
11287	Dist 6 Overlay Project	9641	6100	2	19	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	0.96	1.00	1.021	1.042	1.042	1.041
11034	Dist 7 Overlay Project (1991)	11645	8407	1	23	1.05	1.04	1.03	1.02	1.02	1.00	1.05	1.05	1.03	1.00	1.024	1.037	1.037	1.038
11298	Dist 7 Overlay Projects	4197	818	1	8	1.05	1.05	1.01	1.04	1.05	1.00	1.05	1.04	0.83	1.00	1.007	1.022	1.021	1.022
11197	Dist 7 Overlay Projects	13493	8786	2	27	1.05	1.04	0.92	1.04	1.05	1.00	1.05	1.04	1.05	1.00	1.024	1.033	1.029	1.039
11298	Dist 7 Overlay Projects	2267	63	3	5	1.05	1.04	0.90	1.05	1.05	1.00	1.05	0.97	0.99	1.00	1.001	1.008	1.001	1.012
10751	Dist 7 Paving	5795	-9154	F1	12	1.05	0.96	0.93	0.00	1.00	1.00	1.05	0.99	0.89	1.00	0.943	0.835	0.860	0.841
11188	Dist 8 Overlay Project	6633	2745	1	13	1.05	0.93	0.94	1.05	1.05	1.00	1.05	1.00	1.05	1.00	1.013	1.015	1.007	1.024
10433	Dist 8 Paving Projects	3124	1946	2	6	1.05	1.02	1.02	1.05	1.05	1.00	1.05	1.03	1.05	1.00	1.023	1.039	1.037	1.041
10433	Dist 8 Paving Projects	5613	756	3	12	1.05	0.86	0.98	1.02	1.05	1.00	0.98	1.00	1.05	1.00	1.005	0.998	0.991	1.004
10870	Dooley Br - Cannon Beach Jct	3011	2438	1	6	1.05	1.00	0.94	1.03	1.05	1.00	1.05	1.05	1.05	1.00	1.026	1.033	1.028	1.039
11170	Durkee Intch - Lime	91820	41911	1	183	1.05	1.02	0.98	0.85	1.05	1.00	1.05	1.05	1.04	1.00	1.017	1.010	1.013	1.014
11446	E End One Way Coup - Glen Aiken Cr	13903	10822	1	14	1.05	1.05	1.04	1.05	1.05	1.00	1.05	1.05	1.03	1.00	1.027	1.047	1.047	1.048
11119	E Pendleton Int - Emigrant Hill	11406	7139	1	23	1.05	0.84	0.88	1.03	1.05	1.00	1.05	1.05	1.05	1.00	1.024	1.013	1.002	1.028
11119	E Pendleton Int - Emigrant Hill	2079	1720	3	4	1.05	1.00	1.03	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.044	1.042	1.047
11119	E Pendleton Int - Emigrant Hill	5654	165	2A	12	1.05	0.00	0.98	0.99	1.05	1.00	1.05	1.00	1.05	1.00	1.001	0.926	0.893	0.970
11119	E Pendleton Int - Emigrant Hill	20613	9137	2B	41	1.05	0.84	0.93	1.01	1.05	1.00	1.05	1.02	1.05	1.00	1.015	1.006	0.996	1.019
11220	E Side Bypass (KF) Phase 1	1291	2060	1	3	1.05	1.02	0.88	1.05	1.05	1.05	1.05	1.05	1.05	1.00	1.028	1.032	1.026	1.040
11220	E Side Bypass (KF) Phase 1	1020	1802	1	3	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.00	1.030	1.050	1.050	1.050
11220	E Side Bypass (KF) Phase 1	8931	7551	1	17	1.05	1.02	0.98	1.05	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.038	1.035	1.042
11341	Eastside Bypass (Klamath Falls)	6385	3948	1	12	1.05	1.04	1.04	1.04	1.05	1.00	1.05	1.02	1.05	1.00	1.020	1.038	1.037	1.039
11303	ECL Gates - Little Sweden	8473	5680	1	17	1.05	1.05	1.00	1.03	1.04	1.00	1.05	1.05	1.05	1.00	1.027	1.041	1.040	1.043
11343	Elkhead Rd Int - Rice Hill Int	15541	7889	1	15	1.05	1.05	1.04	1.04	1.04	1.00	1.05	1.00	1.04	1.00	1.014	1.031	1.030	1.031
10704	Emigrant Cr - MP 4	4020	953	F1	8	1.05	1.05	0.97	0.88	1.05	1.00	1.05	1.02	1.05	1.00	1.011	1.009	1.011	1.012
11448	Emigrant Lake - Green Springs Hwy	6336	4273	1	6	1.03	1.05	1.03	1.05	1.05	1.00	1.05	1.04	1.05	1.00	1.026	1.045	1.045	1.046
11460	Enid Rd - Beltline Hwy	7631	139	2	16	1.05	1.05	0.82	1.03	1.05	1.00	1.05	0.97	1.01	1.00	1.001	1.000	0.992	1.008
10924	Farewell Bend - Olds Ferry Intch	12632	10762	1	25	1.04	1.01	0.97	1.01	1.00	1.05	1.05	1.04	1.05	1.00	1.024	1.023	1.022	1.028
10951	Fir Grove Ln - Tower Rd	8779	3378	1	17	1.05	0.96	0.95	1.04	1.04	1.00	1.05	1.02	1.05	1.00	1.018	1.022	1.016	1.029

IMPACT OF CHANGES TO PAY FACTOR WEIGHTS FOR "F" MIXTURE LOTS

CONT		TONS	PRICE	LOT	# SUB	PAY FACTORS										Current	ALT 1	ALT 2	ALT 3
NO	SECTION	OF MIX	ADJUST ($)	NO	LOTS	1	3/4	1/2	1/4	10	40	200	ASPH	MOIS	COMP	CPF	CPF	CPF	CPF
10754	Fish Cr - Chinguapin Cr	7635	-248	1	15	1.05	1.04	1.02	0.94	0.99	1.00	1.05	0.97	1.05	1.00	0.999	0.999	1.000	0.999
10805	Forest Boundary - Rice Hill	4912	2697	2	10	1.05	1.05	1.04	1.05	1.05	1.00	1.05	1.03	0.98	1.00	1.018	1.037	1.036	1.037
10972	Forge Rd - Lobert (N Unit)	23607	788	1	47	1.05	1.05	1.01	1.04	1.05	1.00	1.05	0.95	1.04	1.00	1.001	1.016	1.012	1.016
10874	Forge Rd - Lobert (S Unit)	8629	4459	1	17	1.05	1.01	0.82	1.03	1.04	1.00	1.05	1.02	1.05	1.00	1.017	1.013	1.005	1.023
10778	Fort Hill - Wallace Br	7812	4966	1	16	1.05	1.05	1.04	1.04	1.05	1.00	1.05	1.05	1.02	1.00	1.026	1.045	1.045	1.045
11331	Fremont Jct - Hackett Dr	14345	13183	1	29	1.05	1.04	1.04	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.048	1.048	1.049
10780	Frog Lake - MP 83.0	1426	-1214	4	3	1.05	1.00	1.05	0.00	1.05	1.00	1.05	1.02	1.05	1.00	0.968	0.880	0.909	0.881
10780	Frog Lake - MP 83.0	14172	-29177	5	29	1.05	0.96	0.88	0.00	1.04	1.00	1.05	0.92	1.05	1.00	0.939	0.831	0.851	0.839
10874	Froge Rd - Lobert (S Unit)	8629	4459	F1	18	1.05	1.01	0.82	1.03	1.04	1.00	1.05	1.02	1.05	1.00	1.017	1.013	1.005	1.023
10598	Glen Aiken Cr - Grey Cr	4634	-1828	1	9	1.05	1.03	1.03	0.00	0.89	1.00	1.05	1.04	1.05	1.00	0.986	0.862	0.897	0.864
11187	Golden Cr - Weatherly Cr	5890	3237	1	12	1.05	1.05	0.92	1.03	1.04	1.00	1.02	1.04	1.05	1.00	1.020	1.027	1.024	1.030
10766	Hackett Dr - Gilchrist	11819	5290	1	23	1.05	1.05	1.01	0.96	1.05	1.00	1.01	1.02	1.05	1.00	1.012	1.019	1.020	1.018
11294	Halsey Int. - Lane Co. Line, Lot 3	25528	4325	3	52	1.05	1.04	0.93	0.94	1.04	1.00	1.05	1.00	1.04	1.00	1.007	1.005	1.004	1.010
11294	Halsey Int. - Lane Co. Line, Lot 4	38064	8140	4	75	1.05	1.05	0.99	1.00	1.04	1.00	1.05	1.00	1.01	1.00	1.009	1.018	1.017	1.019
10923	Hancock Hill Passing Lane	2742	1596	1	6	1.05	1.05	0.78	1.05	1.04	1.00	1.05	1.04	1.05	1.00	1.023	1.021	1.013	1.032
10760	Hayden Mt Pass	10629	-8810	1	21	1.05	0.87	0.83	0.00	1.05	1.00	1.04	1.05	0.97	1.00	0.965	0.848	0.868	0.863
10941	Hayesville - Battle Cr	37613	-7696	1	77	1.05	0.84	0.00	0.93	1.05	1.00	1.05	0.97	1.05	1.00	0.989	0.896	0.860	0.945
10601	Hendricks Rd - Pacific Hwy	4493	-1043	1	9	1.05	1.03	0.88	0.83	0.95	1.00	1.02	0.96	1.05	1.00	0.989	0.955	0.957	0.960
10839	Hoover Hill Rd - Brockway Rd	5137	2460	F1	10	1.05	1.02	0.94	0.98	1.05	1.00	1.05	1.03	1.05	1.00	1.018	1.021	1.019	1.027
10948	Imbler - Elgin (Climbing Lane)	2076	290	1	4	1.05	0.85	0.90	0.89	1.00	1.00	1.05	1.01	1.05	1.00	1.004	0.976	0.970	0.989
10948	Imbler - Elgin (Climbing Lane)	1895	973	2	4	1.05	0.90	1.03	1.01	1.04	1.00	1.05	1.03	1.00	1.00	1.015	1.017	1.013	1.023
10948	Imbler - Elgin (Climbing Lane)	2341	1344	3	5	1.05	0.77	0.87	1.02	1.05	1.00	1.05	1.03	1.05	1.00	1.017	0.999	0.985	1.017
10210	Jackson Co Paving Project	5629	3307	1	11	1.05	1.05	0.88	1.04	1.05	1.05	1.05	1.04	1.05	1.00	1.025	1.030	1.025	1.037
10239	Jenny Ck - Parker Mt Summit	6235	4088	1	12	1.05	1.05	1.00	1.04	1.01	1.05	1.05	1.04	1.02	1.00	1.022	1.033	1.032	1.034
10600	Johnson Cr - Cameron Rd	10499	5021	1	21	1.05	0.90	1.02	0.94	1.04	1.00	1.05	1.04	1.05	1.00	1.020	1.013	1.011	1.020
11065	Jumpoff Joe Cr - N Grants Pass	16399	0	1	33	1.05	0.91	0.85	0.84	1.01	1.00	1.05	1.00	1.05	1.00	1.000	0.968	0.964	0.981
11065	Jumpoff Joe Cr - N Grants Pass	51608	27961	2	101	1.05	1.03	0.98	0.98	1.04	1.00	1.05	1.04	1.05	1.00	1.021	1.027	1.027	1.031
11423	Juniper Butte - Crooked R	9227	7480	1	10	1.05	1.05	1.00	1.00	1.05	1.00	1.05	1.05	1.05	1.00	1.026	1.038	1.038	1.040
11270	Kah-nee-ta Jct - Pelton Dam Rd	16183	10729	1	32	1.05	1.05	1.03	1.00	1.05	1.00	1.05	1.05	1.05	1.00	1.026	1.041	1.042	1.042
11360	Kah-nee-ta Jct - Pelton Dam Rd	5989	3847	1	11	1.05	1.05	1.04	0.88	1.04	1.00	1.05	1.05	1.05	1.00	1.019	1.022	1.027	1.023
10818	Kern Swamp Rd - Weyerhaeuser Rd	6418	-10484	F1	13	1.05	1.00	0.80	0.93	0.00	1.00	0.87	1.04	1.05	1.00	0.945	0.818	0.849	0.821
11077	Kiwa Springs - Mt Bachelor	29012	17366	1	57	1.05	1.04	0.99	0.95	1.04	1.00	1.05	1.04	1.05	1.00	1.020	1.024	1.025	1.027
11077	Kiwa Springs - Mt Bachelor	2109	65	2	4	1.05	1.05	0.79	0.86	1.01	1.00	1.05	1.00	1.05	1.00	1.001	0.978	0.976	0.988
11351	Klamath Falls/Malin - Green Springs	19411	17756	2	19	1.05	1.04	1.04	1.05	1.05	1.00	1.05	1.05	1.03	1.00	1.027	1.046	1.046	1.047
10927	Lava Lk Meadows - Santiam Summit	30098	18027	9	60	1.05	1.05	1.03	1.04	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.047	1.046	1.048
10777	Little N Fork Rd - MP 25	4057	3249	3	8	1.05	1.05	1.05	1.04	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.049	1.049	1.049

IMPACT OF CHANGES TO PAY FACTOR WEIGHTS FOR "F" MIXTURE LOTS

CONT NO	SECTION	TONS OF MIX	PRICE ADJUST ($)	LOT NO	# SUB LOTS	PAY FACTORS										Current CPF	ALT 1 CPF	ALT 2 CPF	ALT 3 CPF
						1	3/4	1/2	1/4	10	40	200	ASPH	MOIS	COMP				
10777	Little N Fork Rd - MP 25	1284	571	4	3	0.94	0.91	0.92	0.88	1.05	1.00	1.05	1.05	1.05	1.00	1.016	1.000	0.997	1.011
10673	Longwood Dr - Winchester Bay	3872	1751	F1	7	1.05	1.05	1.04	0.82	1.04	1.00	1.05	1.03	1.05	1.00	1.016	1.008	1.014	1.008
10465	Lower Salt Cr - Upper Salt Cr	7263	4306	1	15	1.05	1.05	1.04	1.05	1.03	1.00	1.04	1.04	1.05	1.00	1.024	1.042	1.042	1.042
11342	Maller Rd - Glencoe Rd	28241	15420	3	55	1.05	1.05	0.92	1.03	1.05	1.00	1.05	1.04	1.05	1.00	1.024	1.033	1.029	1.038
11243	McKenzie Hwy Passing Bays	4543	1262	3	9	1.05	1.05	1.01	0.98	1.05	1.00	1.05	1.05	0.85	1.00	1.009	1.018	1.019	1.018
11095	Mill City - Gates	4388	2873	1	8	1.05	1.03	1.05	1.05	1.05	1.00	1.05	1.04	1.05	1.00	1.026	1.045	1.045	1.046
10790	Mill City - Gun Cr	9590	4552	4	19	1.05	1.05	0.94	0.93	1.05	1.00	1.05	1.05	1.05	1.00	1.021	1.022	1.022	1.027
11192	Minnie Cr - Butcher Knife Cr	8358	3855	1	17	1.05	1.02	0.81	0.85	1.04	1.00	1.05	1.05	1.05	1.00	1.015	0.994	0.992	1.005
11189	MP 34.62 - MP 45.40	19695	8483	1	39	1.05	1.05	1.01	1.03	1.05	1.00	1.05	1.02	1.05	1.00	1.019	1.035	1.034	1.036
11269	MP 66.9 - Jct Wapinitia Hwy	14747	9075	3	28	1.05	1.01	1.02	1.04	1.05	1.00	1.05	1.02	1.05	1.00	1.020	1.034	1.031	1.036
11422	Multnomah Falls - Cascade Locks	9131	6660	2	9	1.05	1.05	1.05	1.04	1.05	1.00	1.05	1.05	1.03	1.00	1.026	1.047	1.047	1.047
11422	Multnomah Falls - Cascade Locks	67262	37734	3	67	1.05	1.05	1.03	0.97	1.05	1.00	1.05	1.05	0.99	1.00	1.020	1.031	1.033	1.031
10462	Murphy Rd - Lava Butte	6303	3372	3	13	1.05	1.04	0.93	1.05	1.04	1.00	1.03	1.04	1.03	1.00	1.020	1.029	1.026	1.033
10462	Murphy Rd - Lava Butte	7279	-1017	4	13	1.05	1.05	1.04	1.03	1.05	1.00	1.05	0.93	1.02	1.00	0.994	1.010	1.007	1.008
10462	Murphy Rd - Lava Butte	5596	2311	5	11	1.05	1.05	1.04	1.04	1.05	1.00	1.05	1.00	1.04	1.00	1.014	1.033	1.031	1.032
10462	Murphy Rd - Lava Butte	1644	1212	6	3	1.05	1.03	0.99	1.05	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.040	1.037	1.043
11001	Murray Blvd - Fanno Cr	10428	930	1	20	1.00	1.05	1.00	1.05	1.03	1.00	1.05	0.96	1.05	1.00	1.003	1.017	1.014	1.018
11110	Myrtle Pt SCL - Powers Jct	3496	2784	2	7	1.05	1.05	1.03	1.03	1.05	1.00	1.05	1.05	1.05	1.00	1.027	1.045	1.045	1.046
10719	N Fork Coquille R - Myrtle R	3688	-8206	F1	7	1.05	1.04	1.04	0.84	0.91	1.00	1.05	1.04	0.00	1.00	0.924	0.898	0.908	0.889
10980	N Jefferson Int - N Albany Int	20601	5420	1	42	1.05	1.05	1.01	1.04	1.04	1.00	1.05	1.00	1.00	1.00	1.010	1.025	1.023	1.025
10964	N Santiam State Park - Mill City	10687	3474	1	22	1.05	1.05	0.96	1.01	0.99	1.00	1.05	1.02	1.05	1.00	1.015	1.019	1.018	1.022
10867	NCL Jacksonville - Riverside	7346	3312	1	14	1.05	1.05	0.90	0.99	1.04	1.00	1.05	1.05	1.00	1.00	1.020	1.022	1.019	1.027
11087	NE 181st Ave - Troutdale Overlay	1872	1573	3	3	1.05	1.02	1.02	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.045	1.043	1.047
11087	NE 181st Ave - Troutdale Overlay	1731	3182	4	4	1.05	1.05	1.05	1.03	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.047	1.048	1.047
11305	Nedonna Beach Rd - Barview	11608	7689	1	12	1.05	1.05	0.96	1.03	1.00	1.00	1.05	1.05	1.05	1.00	1.024	1.031	1.031	1.035
11439	Nicholson Rd - Kanpp Rd	1777	1634	1	3	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.050	1.050	1.050
11210	Norwood Rd - Powers Rd (Bend)	16121	12090	1	32	1.05	1.04	0.99	1.04	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.039	1.037	1.042
11364	Ochoco Summit - MP 60.5	22134	1218	1	43	1.05	1.00	0.78	1.01	1.05	1.00	1.05	1.02	0.88	1.00	1.002	0.992	0.982	1.002
11048	OCI Access Rd - Stanton Blvd	5163	2237	1	10	1.05	1.05	1.04	1.05	1.04	1.00	1.05	1.00	1.05	1.00	1.015	1.034	1.032	1.033
10850	O'Neil Jct - Redmond Couplet	8384	-215	1	16	1.05	1.00	0.00	0.98	1.04	1.00	1.03	1.00	1.05	1.00	0.999	0.922	0.891	0.964
11213	Pac Hwy - 42nd St (Springfield)	17143	-2503	6	35	1.05	1.05	0.88	0.99	1.02	1.00	1.05	1.00	0.83	1.00	0.992	0.987	0.984	0.991
11000	Pac Hwy E - Clackamas Co Line	5223	2260	1	10	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.01	1.05	1.00	1.018	1.039	1.038	1.038
11297	Pacific Hwy W - Gateway St (EB)	7267	3442	1	15	1.05	1.04	1.02	1.01	1.05	1.00	1.05	1.04	1.00	1.00	1.020	1.033	1.033	1.034
10291	Page Rd - Hooker Ave	3989	1851	1	8	1.05	1.05	1.02	1.05	1.04	1.05	1.05	1.00	1.05	1.00	1.016	1.032	1.030	1.032
11405	Pamelia Rd - Twin Medows	9716	8254	1	19	1.05	1.04	1.04	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.028	1.048	1.048	1.049
10770	Passing Lanes	3270	2294	1	7	1.05	1.03	1.00	1.01	1.01	1.00	1.05	1.04	1.05	1.00	1.021	1.029	1.029	1.032

IMPACT OF CHANGES TO PAY FACTOR WEIGHTS FOR "F" MIXTURE LOTS

CONT NO	SECTION	TONS OF MIX	PRICE ADJUST ($)	LOT NO	# SUB LOTS	PAY FACTORS 1	3/4	1/2	1/4	10	40	200	ASPH	MOIS	COMP	Current CPF	ALT 1 CPF	ALT 2 CPF	ALT 3 CPF
11207	Passmore Rd - Bayshore Dr	17458	12155	2	35	1.05	0.93	0.96	1.03	1.05	1.00	1.05	1.05	1.05	1.00	1.025	1.028	1.022	1.037
10787	Penn Rd - Cougar Pass	1934	-1432	2	4	1.05	1.05	0.81	0.78	1.05	1.00	1.05	0.91	1.05	1.00	0.976	0.949	0.945	0.956
11300	Perrydale Rd - Crowley Rd	10199	740	1	21	1.05	1.02	0.81	1.02	1.05	1.00	1.05	1.04	0.82	1.00	1.003	0.998	0.990	1.006
11300	Perrydale Rd - Crowley Rd	8104	2533	2	15	1.05	1.05	1.02	1.05	1.05	1.00	1.05	1.05	0.86	1.00	1.013	1.030	1.029	1.030
11043	Phoenix - Valley View Rd	12827	-1866	1	26	1.05	1.02	0.96	1.05	1.05	1.00	1.05	1.00	0.79	1.00	0.994	1.002	0.997	1.003
11253	Pleasant Valley - Green Timber	3958	2779	1	8	1.05	0.98	0.97	1.04	1.05	1.00	1.05	1.04	1.05	1.00	1.024	1.032	1.028	1.038
10757	Poormans Cr	4818	1303	1	10	1.05	1.04	1.04	0.93	1.05	1.00	1.05	1.01	1.05	1.00	1.012	1.019	1.021	1.019
10425	Powell Bt Jct - Arnold Ice Cave	15637	3751	7	31	1.05	1.05	1.04	0.77	1.04	1.00	1.05	1.01	1.05	1.00	1.009	0.994	1.002	0.994
11573	Powell Butte - Prineville Airport	19944	5022	1	20	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	0.82	1.00	1.009	1.022	1.023	1.020
10926	Rainer - Tide Cr	4500	2128	3A	9	1.05	1.05	1.04	0.99	1.04	1.00	1.05	1.04	1.05	1.00	1.022	1.036	1.037	1.036
10926	Rainer - Tide Cr	14191	-610	3B	29	1.05	1.04	0.92	0.78	1.05	1.00	1.05	0.99	1.05	1.00	0.998	0.980	0.982	0.985
11104	Redmond - Bend (N Unit)	8921	6197	1	18	1.05	1.05	1.04	1.05	1.05	1.00	1.05	1.03	1.05	1.00	1.023	1.044	1.043	1.044
11104	Redmond - Bend (N Unit)	27406	18545	2	54	1.05	1.04	1.03	1.04	1.05	1.00	1.05	1.03	1.05	1.00	1.023	1.040	1.039	1.041
11104	Redmond - Bend (N Unit)	1459	1875	3	3	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.029	1.050	1.050	1.050
11104	Redmond - Bend (N Unit)	3417	2614	4	6	1.05	1.05	1.04	1.00	1.05	1.00	1.05	1.05	1.05	1.00	1.026	1.042	1.043	1.042
10672	Redmond - Bend (S Unit)	12104	-2000	4	24	1.05	1.05	0.89	1.03	1.05	1.00	1.05	0.92	1.05	1.00	0.993	0.996	0.988	1.000
11291	Remote Campground - Slater Cr	10250	8024	1	11	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.029	1.050	1.050	1.050
11291	Remote Campground - Slater Cr	2294	1844	2	3	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.029	1.050	1.050	1.050
11254	Riverside Dr - Lake Cr	12720	2091	1	25	1.05	1.05	0.92	0.94	1.04	1.00	1.05	1.00	1.04	1.00	1.007	1.005	1.004	1.010
10852	Rock Creek - Anlauf	4122	2905	5	9	1.05	1.02	0.95	1.04	1.05	1.00	1.05	1.05	1.05	1.00	1.027	1.037	1.033	1.042
10788	Rose Lodge - Polk Co Line	5647	3129	1	12	1.03	1.05	0.90	0.97	1.05	1.00	1.05	1.04	1.05	1.00	1.020	1.022	1.019	1.028
11467	Roseburg ECL - Dixonville	11580	6783	1	11	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.029	1.050	1.050	1.050
11411	Rosewood Dr - Willamette R	6810	4280	2	6	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.03	1.05	1.00	1.023	1.044	1.044	1.044
11393	Rowena - US 97 Intch, Phase 1	27905	9142	1	34	1.05	1.05	1.02	0.98	1.05	1.00	1.05	1.03	0.98	1.00	1.014	1.025	1.026	1.025
11393	Rowena - US 97 Intch, Phase 1	8716	6101	2	7	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.04	1.00	1.028	1.049	1.049	1.049
11393	Rowena - US 97 Intch, Phase 1	21706	12980	4	21	1.05	1.05	1.05	1.04	1.05	1.00	1.05	1.05	1.03	1.00	1.026	1.047	1.047	1.047
11393	Rowena - US 97 Intch, Phase 1	4814	3009	5	5	1.05	1.05	1.05	1.03	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.044	1.045	1.044
11393	Rowena - US 97 Intch, Phase 1	23590	6992	6	21	1.05	1.05	1.05	1.05	1.03	1.00	1.05	1.05	0.87	1.00	1.013	1.031	1.031	1.029
11256	Rufus - Arlington (W Unit)	75238	53795	3	150	1.05	1.05	0.98	1.04	1.05	1.00	1.05	1.05	1.03	1.00	1.026	1.040	1.039	1.043
10949	Rufus - Arlington (E Unit)	43931	0	1	87	1.05	0.85	0.89	0.98	1.01	1.00	1.05	1.00	0.97	1.00	1.000	0.980	0.971	0.993
11163	Saddle Mt Jct - Coast Range Smt	17585	10155	1	35	1.05	0.87	0.99	1.03	1.05	1.00	1.05	1.04	1.04	1.00	1.022	1.022	1.015	1.031
10991	Salmon R Hwy @ Three R Hwy	1752	-3986	1	3	1.05	1.02	1.00	1.00	1.05	1.00	1.05	1.00	0.00	1.00	0.928	0.927	0.924	0.919
11324	Sams Valley Hwy Jct - Shady Cove	6509	4181	1	7	1.05	1.05	1.01	0.98	1.05	1.00	1.05	1.05	1.05	1.00	1.025	1.036	1.037	1.038
11038	Santiam R (SB) Br	4354	1969	1	9	1.05	1.02	1.00	1.04	1.04	1.00	1.05	1.00	1.05	1.00	1.014	1.026	1.023	1.028
10992	Sawtell Rd - MP 29	3013	2665	1	5	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.029	1.050	1.050	1.050
10863	Scottsburg - Wells Cr	4323	2820	1	9	1.05	1.00	0.88	1.04	1.05	1.00	1.04	1.04	1.05	1.00	1.022	1.024	1.018	1.033

IMPACT OF CHANGES TO PAY FACTOR WEIGHTS FOR "F" MIXTURE LOTS

CONT NO	SECTION	TONS OF MIX	PRICE ADJUST ($)	LOT NO	# SUB LOTS	PAY FACTORS 1	3/4	1/2	1/4	10	40	200	ASPH	MOIS	COMP	Current CPF	ALT 1 CPF	ALT 2 CPF	ALT 3 CPF
10681	Simmons Cr - Pleasant Valley Rd	3695	2149	1	7	1.05	1.05	1.05	1.01	1.05	1.00	1.05	1.03	1.05	1.00	1.021	1.038	1.039	1.038
11222	Sisters - Tumalo	7331	742	1	15	1.05	1.04	1.02	1.05	1.05	1.00	1.05	0.96	1.04	1.00	1.004	1.020	1.016	1.020
11222	Sisters - Tumalo	14413	10583	2	28	1.05	1.04	1.04	1.05	1.05	1.00	1.05	1.05	1.03	1.00	1.027	1.046	1.046	1.047
11339	Siuslaw R - Douglas Co Line	18711	7395	1	19	1.05	1.04	1.02	1.05	1.04	1.00	1.05	1.00	1.04	1.00	1.014	1.030	1.028	1.031
10843	Slick Rock Cr - Sulphur Cr	6568	3603	1	13	1.05	1.05	1.05	1.04	1.05	1.00	1.05	1.02	1.05	1.00	1.020	1.040	1.040	1.040
10905	Spangler Hill - Mulino	10648	-13093	5	21	1.05	0.00	0.77	0.81	0.00	1.00	1.05	1.04	1.03	1.00	0.947	0.732	0.731	0.785
11021	Spring Valley Cr - Salemtowne	9112	5277	1	18	1.05	1.03	1.04	1.05	1.05	1.00	1.05	1.04	1.03	1.00	1.024	1.043	1.042	1.044
11468	Sunset Highway - Pacific Hwy	2401	1566	1	3	1.04	1.00	1.03	0.95	0.99	1.00	1.05	1.05	1.03	1.00	1.018	1.018	1.021	1.021
11468	Sunset Highway - Pacific Hwy	4474	3872	2	6	1.01	1.05	0.97	1.01	1.03	1.00	1.05	1.05	1.05	1.00	1.024	1.034	1.033	1.037
11468	Sunset Highway - Pacific Hwy	31613	25414	3	29	1.05	1.03	0.82	1.05	1.04	1.00	1.05	1.05	1.01	1.00	1.022	1.022	1.015	1.032
11278	Susan Cr - USFS Boundary	3238	2683	1	6	1.05	1.00	0.80	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.026	1.023	1.014	1.035
10899	Susan Cr - Wright Cr Rd	5843	3231	1	12	1.05	0.94	0.84	1.04	1.05	1.00	1.05	1.03	1.05	1.00	1.020	1.014	1.004	1.027
10446	Sutton Lake - Florence	9484	3138	10	19	1.05	1.05	1.02	0.94	1.05	1.00	1.05	1.00	1.05	1.00	1.012	1.017	1.018	1.017
10749	Suver - Thousand Oaks Dr	24280	12980	1	48	1.05	1.05	1.02	1.04	1.05	1.00	1.05	1.05	1.04	1.00	1.027	1.045	1.044	1.046
11009	Terrebonne - O'Nell Jct	11708	-9537	1	23	1.05	1.00	0.89	0.98	1.04	1.00	0.98	0.88	1.05	1.00	0.971	0.961	0.954	0.963
11009	Terrebonne - O'Nell Jct	456	247	2	3	1.05	1.05	1.05	1.05	1.05	1.00	1.00	1.05	1.05	1.00	1.024	1.043	1.044	1.040
10649	Trail - Casey (E Unit)	3641	2219	4	7	1.05	1.05	1.03	1.04	1.05	1.00	1.05	1.03	1.05	1.00	1.023	1.041	1.040	1.042
11410	Tripp Rd - Knappa	4321	3976	1	4	1.05	1.05	1.05	1.05	1.05	1.00	1.05	1.04	1.05	1.00	1.026	1.047	1.047	1.047
11245	Umatilla - McNary	10117	7871	1	19	1.05	1.04	1.01	1.04	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.041	1.040	1.043
11035	Umpqua Wayside - Elkton	6713	3651	1	13	1.05	1.03	0.00	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.018	0.954	0.922	0.997
10952	W Marquam Intch - N Tigard Intch	33015	14208	1	65	1.05	1.03	0.97	1.03	0.99	1.00	1.03	1.02	1.05	1.00	1.014	1.018	1.017	1.020
10432	Weatherly Cr - Grabb Cr	3813	2941	1	7	1.05	1.05	0.95	1.05	1.05	1.00	1.05	1.04	1.05	1.00	1.025	1.038	1.035	1.042
11152	Willamette R - Riverside Dr	18206	7220	6	37	1.05	1.04	1.04	1.05	1.05	1.00	1.05	1.04	0.98	1.00	1.020	1.039	1.038	1.039
11015	Williamson R - Modoc Pt	5474	4659	1	11	1.05	1.04	0.85	1.05	1.05	1.00	1.02	1.05	1.05	1.00	1.023	1.027	1.021	1.034
11572	Willowdale - Qualle Road	13847	-21137	1	14	1.05	1.04	1.04	1.03	1.05	1.00	1.05	1.05	0.00	1.00	0.943	0.951	0.951	0.941
10989	Winchester Intch NB Ramps	1802	1698	1	4	1.05	1.05	0.93	1.05	1.05	1.00	1.05	1.05	1.05	1.00	1.027	1.039	1.036	1.044
11229	Wolf Cr - W Fork Dairy Cr	28381	-6824	6	56	1.05	1.05	1.01	1.04	1.05	1.00	1.05	0.94	0.93	1.00	0.989	1.003	0.999	1.002
11162	Youngs Bay Br - Warr/Asto Hwy	6979	4785	1	13	1.05	1.04	1.04	1.05	1.03	1.00	1.04	1.04	1.05	1.00	1.024	1.041	1.041	1.041
			3755											AVERAGE		1.012	1.011	1.009	1.016
			-62861											MINIMUM		0.916	0.641	0.613	0.723
			46148											MAXIMUM		1.030	1.050	1.050	1.050