DETERMINING ASPHALT CONTENT FOR RECYCLED ASPHALT PAVEMENT (RAP) MATERIALS

Final Report

PROJECT 304-221

DETERMINING ASPHALT CONTENT FOR RECYCLED ASPHALT PAVEMENT (RAP) MATERIALS

Final Report

PROJECT 304-221

by

Gary Thompson
Asphalt Pavement Association of Oregon
5240 Gaffin Rd. SE
Salem, OR 97301

for

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

and

Federal Highway Administration
Washington, D.C.

July 2003

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-OR-DF-04-02		

4. Title and Subtitle
Determining Asphalt Content for Recycled Asphalt Pavement (RAP) Materials
Final Report

5. Report Date
July 2003

6. Performing Organization Code

7. Author(s)

Gary Thompson

8. Performing Organization Report No.

9. Performing Organization Name and Address

Asphalt Pavement Association of Oregon
Asphalt Research Program
5240 Gaffin Rd. SE
Salem, Oregon 97301

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

304-221

12. Sponsoring Agency Name and Address

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

and

Federal Highway Administration
Washington, D.C.

13. Type of Report and Period Covered

Final Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The State of Oregon uses significant amounts of Recycled Asphalt Pavement (RAP) in dense-graded mixes on State highways. The design process for these mixes relies on accurately knowing the amount of asphalt cement in the RAP materials being used. Beginning in 1997 ODOT began using ignition furnaces to determine RAP asphalt contents and gradations.

Asphalt contents are determined by measuring the change in mass between the original dry RAP sample and the mass of the final residue aggregate sample after the asphalt is burned off in the ignition furnace. One shortcoming of the process is that a small portion of the aggregate is usually lost in the burning process. The amount of aggregate lost is on the order of 0.5% which may be considered significant for most RAP mixtures.

This research attempted to use volumetric equations to solve for the RAP asphalt content by exploiting the constant nature of the Effective Specific Gravity of Aggregates, G_{se}. A solution is presented using a simplified equation which ignores the difference in Specific Gravity of Asphalt, G_b, between the RAP asphalt and the new added asphalt. This solution proved to be unstable and diverged significantly with only small changes in assumed G_b.

A second more exact equation was derived to better account for the difference in G_b between the RAP asphalt and the new added asphalt. However, it's analytic solution collapsed to zero due to the dependent nature of the volumetric equation being used. Attempts to derive a second linearly independent equation failed; however, future research may lead to a complete solution to this equation.

17. Key Words	18. Distribution Statement
Recycled asphalt pavement, asphalt content,	Copies available from NTIS, and online at http://www.odot.state.or.us/tddresearch

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	30	

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

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	(F-32)/1.8	Celsius	°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
m^2	meters squared	1.196	square yards	yd^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	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

ACKNOWLEDGEMENTS

The author thanks Mike Remily, ODOT Pavement Quality Engineer, and the ODOT Bituminous Crew for sampling and testing the various RAP materials used in this study.

DISCLAIMER

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

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

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

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

DETERMINING ASPHALT CONTENT FOR RECYCLED ASPHALT PAVEMENT (RAP) MATERIALS

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

The Oregon Department of Transportation (ODOT) eliminated solvent extractions for measuring asphalt cement content (P_b) of hot mixed asphalt concrete (HMAC) in 1997 due to worker health concerns. In lieu of chlorinated solvents, ODOT began using the Ignition Method (AASHTO T 308) to establish asphalt cement contents for HMAC and recycled asphalt pavement (RAP) materials *(AASHTO 2001)*.

The ignition method involves burning an asphalt mixture (or RAP) sample of known dry mass in an ignition furnace. The temperature in the ignition furnace is such that the flammable asphalt cement material is ignited and consumed leaving only the inert aggregate material as residue. The exact asphalt cement content can be calculated based on the before and after mass of this burning process if two conditions are met. The first condition is that all of the asphalt cement is consumed during the ignition process. The second condition is that all of the aggregate material remains as the unburned residue.

During the process, however, some small loss of aggregate material generally occurs during the burn. This results in a larger mass change during the process than just the mass of the asphalt cement that is consumed. To correctly calculate the asphalt cement content, a correction factor must be applied to account for this small aggregate loss.

For new materials, the correction factor may be determined by combining known masses of aggregate and asphalt cement. These known masses are then burned in the ignition furnace. The asphalt cement content determined from the final residue is compared to asphalt cement content from the initial known masses. The difference in these two asphalt cement contents becomes the correction factor.

RAP materials are problematic however, because we usually do not have their original asphalt cement and aggregate as separate constituents. Therefore, the correction factor development process described above cannot be performed for RAP materials. To overcome this problem ODOT has elected to assume a 0.50% aggregate correction factor for all RAP materials used in the state. This practice is consistent with most other states in the U.S.

Experience in Oregon shows that correction factors vary widely when using virgin materials. Therefore, it can be reasonably assumed that RAP produced from Oregon mixes would also exhibit a similar variation.

Accurate RAP asphalt cement contents are a critical element in the design and construction of HMAC mixtures. Asphalt cement content is also used as the basis for determining the quantity of asphalt cement for contract payment purposes. If the actual RAP asphalt cement content is substantially different than that determined using the standard 0.50% correction factor, then it may result in substantial over- or under-payment for RAP asphalt cement contents. This problem becomes more important as mix designs start to approach the specification limits of 30% RAP materials.

There is a need to develop a more accurate means of determining the asphalt cement contents of RAP materials for use in Oregon mixtures.

1.2 PROPOSED METHODOLOGY

Conventional means of measuring asphalt cement contents as a percentage involve physically determining the mass of the asphalt cement. An alternate strategy is to solve for the asphalt cement content using standard volumetric equations for HMAC.

The effective specific gravity of aggregate (G_{se}) for an HMAC mixture remains constant over a range of asphalt contents. The same should hold true for RAP materials. G_{se} is calculated as follows:

$$G_{se} = \left[\frac{100 - P_b}{\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)} \right] \quad \textbf{(1-1)}$$

where G_{mm} = maximum specific gravity of the mixture,
G_b = specific gravity of the asphalt cement, and
P_b = asphalt cement content as a percentage of total mixture.

Within the normal range of asphalt cement contents encountered in conventional mixtures, G_{se} should be constant. Mathematically this would be:

$$G_{se}m = G_{se}n \quad \textbf{(1-2)}$$

where $G_{se}m$ and $G_{se}n$ = effective specific aggregate gravity of aggregate at any two different asphalt contents P_bm and P_bn.

Substituting Equation 1-1 into Equation 1-2:

$$\left[\frac{100 - P_b m}{\left(\frac{100}{G_{mm} m}\right) - \left(\frac{P_b m}{G_b}\right)} \right] = \left[\frac{100 - P_b n}{\left(\frac{100}{G_{mm} n}\right) - \left(\frac{P_b n}{G_b}\right)} \right] \quad \textbf{(1-3)}$$

Note that Equation 1-3 uses the same specific gravity of asphalt (G_b) for both samples.

The proposed methodology for RAP materials is to artificially create RAP samples of different asphalt cement contents by mixing known amounts of new asphalt cement with the RAP. This would produce the following:

$$P_b m = P_{br} + \%m \qquad \textbf{(1-4a)}$$

$$P_b n = P_{br} + \%n \qquad \textbf{(1-4b)}$$

where P_{br} = unknown RAP asphalt content, and
$\%m$ and $\%n$ = different known percentages of new asphalt cement.

Substituting Equations 1-4a and 1-4b into Equation 1-3:

$$\left[\frac{100 - \left(P_{br} + \%m\right)}{\left(\dfrac{100}{G_{mm}m}\right) - \left(\dfrac{P_{br} + \%m}{G_b}\right)}\right] = \left[\frac{100 - \left(P_{br} + \%n\right)}{\left(\dfrac{100}{G_{mm}n}\right) - \left(\dfrac{P_{br} + \%n}{G_b}\right)}\right] \qquad \textbf{(1-5)}$$

The maximum specific gravities (G_{mm}) of these mixtures are then measured in the laboratory. Using a reasonable assumption for G_b the only remaining unknown P_{br} can then be solved.

2.0 SIMPLIFIED EQUATION

2.1 BACKGROUND

Equation 1-5 has two unknowns; the RAP asphalt content (P_{br}) and the specific gravity of the combined RAP and new added asphalt cements (G_b). It is not possible to solve Equation 1-5 with two unknowns, so a reasonable assumption must be made for G_b. Typical neat asphalt cements in Oregon have specific gravities ranging from 1.020 to 1.030. For this research a value of $G_b = 1.025$ will be used.

2.2 SIMPLIFIED EQUATION

Solving Equation 1-5 for P_{br} gives the following:

$$P_{br} = 100\% + \%m \left[\frac{G_{mm}m\left(G_{mm}n - G_b\right)}{G_b\left(G_{mm}m - G_{mm}n\right)} \right] - \%n \left[\frac{G_{mm}n\left(G_{mm}m - G_b\right)}{G_b\left(G_{mm}m - G_{mm}n\right)} \right] \qquad \textbf{(2-1)}$$

2.3 VALIDATION OF ANALYTIC SOLUTION

To validate the analytic solution given in Equation 2-1, a set of test data was taken from a virgin mix design. In the mix design process, samples are prepared over a range of known asphalt contents, P_b. The mix designer selected P_b's of 5.0%, 5.5%, 6.0% and 6.5%, with an asphalt cement of known specific gravity, $G_b = 1.028$.

To test the analytic solution, it was assumed that this was an equivalent RAP mixture with an unknown RAP asphalt content, $P_{br} = 3.0\%$. The remaining asphalt cement above 3.0% was considered the new added oil for each increment. Therefore, the corresponding added oil increments were 2.0%, 2.5%, 3.0% and 3.5% (i.e., a P_{br} of 3.0% plus added oil of 2.0% would equate to the original known mix design increment of 5.0%, etc.).

The G_{se} was calculated for the mix design and Rice gravities back-calculated to five decimal places for each known increment. The Rice gravities are given in Table 2.1:

Table 2.1: Known test inputs based on virgin mix design

% Added Oil	2.0%	2.5%	3.0%	3.5%
G_{mm}	2.48719	2.46874	2.45057	2.43266

If the analytic model is correct, then Equation 2-1 should correctly predict the asphalt content of the RAP as 3.0% across any two sets of asphalt contents given in Table 2.1. The results of

Equation 2-1 are provided in Appendix A for all combinations of new added oil listed above. The predicted RAP oil contents ranged from 2.99 to 3.03% depending on the two increments chosen as inputs. This would seem to indicate the solution is a reasonable predictor of the unknown increment of RAP asphalt.

In actual practice the specific gravity of the RAP asphalt would be unknown and therefore would need to be assumed. In most volumetric equations the solutions are relatively insensitive to the specific gravity of the asphalt, G_b. It was decided in the absence of a known value $G_b = 1.025$ would be assumed.

When the same analysis was ran on the inputs from Table 2.1 using $G_b = 1.025$, the results were less successful. The predicted RAP asphalt contents dropped significantly and ranged from 2.52 to 2.56%. The error from the true value of 3.0% is of the same magnitude as the assumed 0.50% correction factor currently in use.

It is apparent that the analytic solution is not insensitive to the specific gravity of asphalt as assumed. The solution would only be practical if the actual specific gravity of the combined RAP asphalt and new added asphalt is accurately known. In general, there is currently no easy way to determine this unknown specific gravity in the field.

3.0 EXACT EQUATION

3.1 BACKGROUND

The sensitivity of Equation 2-1 to the value of the specific gravity of the asphalt (G_b) demonstrates the need for a more exact equation for G_b in Equation 1-5. An equation will be derived which exactly accounts for the specific gravity of the RAP asphalt cement and the new added asphalt cement. The specific gravity of the new added asphalt will be known and only the RAP asphalt specific gravity will need to be assumed.

3.2 EXACT EQUATION

An exact representation of the G_{se} equation must recognize the separate contribution of the RAP asphalt and the new added asphalt. In all probability each will have its own unique specific gravity. By definition:

$$Total\ P_b = \left[\frac{\left(P_{br}/100 \right) Mass_{RAP} + Mass_{NEW\ OIL}}{Mass_{RAP} + Mass_{NEW\ OIL}} \right] x\ 100\% \qquad \textbf{(3-1)}$$

where $Mass_{RAP}$ = dry mass of RAP sample, and
$Mass_{NEW\ OIL}$ = mass of added new oil,

define the following:

$$A_m = \frac{Mass_{RAP}}{Mass_{RAP} + Mass_{NEW\ OIL}m} \qquad \textbf{(3-2a)}$$

$$B_m = \frac{100\ Mass_{NEW\ OIL}m}{Mass_{RAP} + Mass_{NEW\ OIL}m} \qquad \textbf{(3-2b)}$$

where $Mass_{NEW\ OIL}m$ = mass of added new oil to produce a %m increase.

Substituting Equations 3-2a and 3-2b into Equation 3-1 the total asphalt content for any added asphalt cement increment *m* is as follows:

$$Total\ P_{bm} = P_{br}\ A_m + B_m \qquad \textbf{(3-3)}$$

A more exact equation for the Specific Gravity of the Combined Asphalt Cements may now be written as follows:

$$\frac{Total\ P_{bm}}{Total\ G_b} = \frac{P_{br}\ A_m}{G_{br}} + \frac{B_m}{G_b} \tag{3-4}$$

where *Total* G_b = combined specific gravity of the RAP oil and new oil,
G_{br} = specific gravity of the RAP oil, and
G_b = specific gravity of the new oil

Substituting Equation 3-4 into Equation 1-3 and solving for P_{br} gives the following:

$$P_{br} = G_{br}\left\{\frac{\left(\frac{G_b}{G_{mm}n}\right)\left(100 - B_m\right) - \left(\frac{G_b}{G_{mm}m}\right)\left(100 - B_n\right) + \left(B_m - B_n\right)}{A_m\left[\left(\frac{B_n}{100}\right)\left(G_b - G_{br}\right) - G_b\right] + A_n\left[\left(\frac{B_m}{100}\right)\left(G_{br} - G_b\right) + G_b\right] + G_{br}\left[A_m\left(\frac{G_b}{G_{mm}n}\right) - A_n\left(\frac{G_b}{G_{mm}m}\right)\right]}\right\} \tag{3-5}$$

3.3 VALIDATION OF EXACT EQUATION

To validate the analytic solution given in Equation 3-5, a set of data was constructed based on 1000 g of RAP with an unknown P_{br} = 5.0% and an unknown G_{br} = 1.024. The effective specific gravity of the aggregate was arbitrarily chosen as 2.73361 and the resulting Rice gravities were back-calculated as shown in Table 3.1.

Table 3.1: Known test inputs using 1000 g of RAP

Mass of Added Oil	0.0g	10.0g	20.0g	30.0 g
G_{mm}	2.52300	2.48736	2.45338	2.42096

If the analytic model is correct, Equation 3-5 should correctly predict the asphalt content of the RAP as 5.0% across any two sets of added oil. However, when the inputs were entered into Equation 3-5, the solution across all sets of added oil came out to zero.

Upon closer examination it was determined that in every case it was the numerator of Equation 3-5 that was collapsing to zero, as Equation 3-6 shows.

$$\left(\frac{G_b}{G_{mm}n}\right)\left(100 - B_m\right) - \left(\frac{G_b}{G_{mm}m}\right)\left(100 - B_n\right) + \left(B_m - B_n\right) = 0 \tag{3-6}$$

4.0 LABORATORY TESTING

Representative RAP materials were gathered from ten different sources around the state. Samples of these materials were mixed with 1%, 2%, 3% and 4% increments of added new oil. Rice gravities were performed on the different increments per AASHTO T 209 *(2001)*. The results are contained in Appendix B.

This testing was performed concurrently with the development of the two equations used in this research effort. Had a successful solution been found to either equation, this data would have been used to test the validity of the equations. However, because a stable solution was not found for either equation, trials were not made. This data is presented as an archive for future research.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 SIMPLIFIED EQUATION

The simplified equation showed early promise and was tested with a set of known values including the actual Specific Gravity of the RAP asphalt (G_b = 1.028). Under these circumstances the equation did a reasonable job of predicting the RAP asphalt content.

However, when the Specific of Gravity of Asphalt was *assumed* to be G_b = 1.025, the solution diverged significantly from the true answer (i.e. – the known RAP asphalt content of 3.0% was predicted to be 2.52%). Hence, a relatively minor three thousandths error in assuming a specific gravity resulted in a 0.48% error in asphalt content. This is the same magnitude as the assumed standard ignition oven burn loss of 0.5%.

It was concluded that the simplified equation was not practical for field use.

5.2 EXACT EQUATION

In lieu of the simplified equation a more exact equation was attempted to try to reduce the sensitivity to G_b. The resulting equation was mathematically correct in its derivation, however, the numerator of the final equation collapses to zero when the test set of known values is entered into the equation.

The exact equation also now contains the unknown variable G_{br}. Attempts made to solve this equation numerically failed when the author was unable to find a second linearly independent equation to account for the additional unknown variable G_{br}.

Because the exact equation collapses to zero, it was concluded that it also was not practical for field use.

6.0 REFERENCES

American Association of State Highway and Transportation Officials (AASHTO). "Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part 2 – Tests". Washington, D.C. 2001.

Asphalt Institute. "Manual Series No. 2 (MS-2)", Sixth Edition. 1993.

APPENDIX A

VALIDATION OF SIMPLIFIED EQUATION

RAP Asphalt Content Study - 2002

RAP Source: Example

Simplified Linear Analytic Solution

Inputs:

Gb: 1.025

New Oil:

Pb1	Pb2	Pb3	Pb4
2.00	2.50	3.00	3.50

Gmm1	Gmm2	Gmm3	Gmm4
2.48719	2.46874	2.45057	2.43266

Coefficients A:

	Gmm2	Gmm3	Gmm4
Gmm1	6.140225	6.095033	6.050488
Gmm2		6.049820	6.005605
Gmm3			5.961404

Coefficients B & C:

Gmm1	Gmm2	Gmm3	Gmm4
2.549370	2.530459	2.511834	2.493477

Coefficients A-B:

	Pb2	Pb3	Pb4
Pb1	3.590856	3.545663	3.501118
Pb2		3.519362	3.475147
Pb3			3.449569

Coefficients A-C:

	Pb2	Pb3	Pb4
Pb1	3.609767	3.583199	3.557011
Pb2		3.537986	3.512129
Pb3			3.467927

Coefficients B-C:

	Pb2	Pb3	Pb4
Pb1	0.018911	0.037536	0.055893
Pb2		0.018624	0.036982
Pb3			0.018358

Calculated RAP Asphalt Content:

	Pb2	Pb3	Pb4
Pb1	2.560329	2.538398	2.540947
Pb2		2.516687	2.531406
Pb3			2.545965

RAP Asphalt Content Study - 2002

RAP Source: Example

Simplified Linear Analytic Solution

Inputs:

Gb: 1.028

New Oil:

Pb1	Pb2	Pb3	Pb4
2.00	2.50	3.00	3.50

Gmm1	Gmm2	Gmm3	Gmm4
2.48719	2.46874	2.45057	2.43266

Coefficients A:

	Gmm2	Gmm3	Gmm4
Gmm1	6.140225	6.095033	6.050488
Gmm2		6.049820	6.005605
Gmm3			5.961404

Coefficients B & C:

Gmm1	Gmm2	Gmm3	Gmm4
2.556831	2.537865	2.519186	2.500774

Coefficients A-B:

	Pb2	Pb3	Pb4
Pb1	3.583394	3.538202	3.493656
Pb2		3.511955	3.467740
Pb3			3.442218

Coefficients A-C:

	Pb2	Pb3	Pb4
Pb1	3.602361	3.575847	3.549713
Pb2		3.530634	3.504831
Pb3			3.460629

Coefficients B-C:

	Pb2	Pb3	Pb4
Pb1	0.018967	0.037645	0.056057
Pb2		0.018679	0.037090
Pb3			0.018411

Calculated RAP Asphalt Content:

	Pb2	Pb3	Pb4
Pb1	3.034094	3.012271	3.014808
Pb2		2.990669	3.005314
Pb3			3.019800

APPENDIX B

FIELD TEST RESULTS

Added Binder: Albina PF64-22 Gb(25/25) = 1.023

RAP Source		Mass Pyc+Lid +Mix	Mass Pyc+Lid	Dry Sample Mass	SSD Sample Mass	Mass Pyc+Lid+ Water	Mass Pyc+Lid +Water +Mix	Water Temp (F)		Gmm	Gmm ssd	Change in Gmm
Porter Yett	Pbr+1%	5156.7	2972.4	2184.3	2191.8	7370.4	8661.0	75.0		2.44411	2.42377	
Porter Yett	Pbr+2%	5158.6	2977.8	2180.8	2187.0	7375.8	8655.0	74.4		2.41881	2.40229	0.02530
Porter Yett	Pbr+3%	4992.3	2813.6	2178.7	2188.0	7217.6	8477.4	74.6		2.37099	2.34496	0.04782
Porter Yett	Pbr+4%	5131.9	2958.9	2172.0	2180.9	7357.9	8606.9	74.4		2.35320	2.33072	0.01779
MBI-Eugene	Pbr+1%	5150.5	2972.4	2178.1	2186.5	7370.4	8659.3	77.0		2.44951	2.42658	
MBI-Eugene	Pbr+2%	5155.5	2977.8	2177.7	2180.6	7375.8	8656.2	77.3		2.42695	2.41913	0.02256
MBI-Eugene	Pbr+3%	4984.0	2813.6	2170.4	2174.8	7217.6	8475.0	77.0		2.37722	2.36582	0.04973
MBI-Eugene	Pbr+4%	5123.5	2959.9	2163.6	2167.2	7357.9	8600.9	77.0		2.35021	2.34105	0.02701
Riverbend	Pbr+1%	5162.0	2972.4	2189.6	2195.3	7370.4	8668.0	78.4		2.45471	2.43912	
Riverbend	Pbr+2%	5162.4	2977.8	2184.6	2188.0	7375.8	8661.0	78.6		2.42895	2.41981	0.02576
Riverbend	Pbr+3%	4997.2	2813.6	2183.6	2186.9	7217.6	8488.6	78.6		2.39272	2.38410	0.03623
Riverbend	Pbr+4%	5137.1	2959.9	2177.2	2179.8	7357.9	8613.8	78.6		2.36318	2.35653	0.02954
MBI-Corvallis	Pbr+1%	5158.4	2972.4	2186.0	2191.7	7370.4	8654.1	77.3		2.42270	2.40749	
MBI-Corvallis	Pbr+2%	5156.3	2977.8	2178.5	2182.9	7375.8	8640.8	78.0		2.38478	2.37335	0.03791
MBI-Corvallis	Pbr+3%	4993.4	2813.6	2179.8	2189.9	7217.6	8468.6	77.5		2.34690	2.32165	0.03788
MBI-Corvallis	Pbr+4%	5126.4	2959.9	2166.5	2175.3	7357.9	8590.7	77.9		2.32034	2.29867	0.02656
Island City Strip	Pbr+1%	5149.7	2972.4	2177.3	2185.6	7370.4	8661.4	77.7		2.45662	2.43383	
Island City Strip	Pbr+2%	5144.8	2977.8	2167.0	2178.7	7375.8	8651.0	77.5		2.42992	2.39845	0.02670
Island City Strip	Pbr+3%	4981.8	2813.6	2168.2	2178.6	7217.6	8479.2	77.5		2.39157	2.36445	0.03834
Island City Strip	Pbr+4%	5122.7	2959.9	2162.8	2170.2	7357.9	8607.9	77.3		2.36941	2.35036	0.02216
Lakeside	Pbr+1%	5163.2	2972.4	2190.8	2191.1	7370.4	8690.4	76.8		2.51585	2.51498	
Lakeside	Pbr+2%	5162.9	2977.8	2185.1	2195.9	7375.8	8679.9	76.8		2.48025	2.45021	0.03560
Lakeside	Pbr+3%	5002.1	2813.6	2188.5	2194.3	7217.6	8508.5	76.2		2.43817	2.42251	0.04208
Lakeside	Pbr+4%	5134.9	2959.9	2175.0	2180.2	7357.9	8628.9	76.4		2.40597	2.39221	0.03219
Roseburg Paving	Pbr+1%	5166.9	2972.4	2194.5	2199.4	7370.4	8690.9	76.2		2.51087	2.49687	
Roseburg Paving	Pbr+2%	5172.2	2977.8	2194.4	2200.7	7375.8	8682.3	75.9		2.47145	2.45404	0.03942
Roseburg Paving	Pbr+3%	5005.0	2813.6	2191.4	2197	7217.6	8506.7	75.7		2.42868	2.4137	0.04277
Roseburg Paving	Pbr+4%	5149.7	2959.9	2189.8	2191.8	7357.9	8632.5	75.7		2.3927	2.38748	0.03598

Sand Creek (US 97)	Pbr+1%	5155.8	2972.4	2183.4	2186.6	7370.4	8641.0	76.2		2.39198	2.38362	
Sand Creek (US 97)	Pbr+2%	5135.5	2977.8	2157.7	2160.3	7375.8	8619.1	76.4		2.35969	2.35300	0.03229
Sand Creek (US 97)	Pbr+3%	4951.0	2813.6	2137.4	2139.3	7217.6	8435.0	76.6		2.32326	2.31847	0.03643
Sand Creek (US 97)	Pbr+4%	5143.2	2959.9	2183.3	2185.4	7357.9	8597.4	76.6		2.31331	2.30817	0.00995
Bowery Ln (US 97 Bend)	Pbr+1%	5162.9	2972.4	2190.5	2192.3	7370.4	8659.5	77.5		2.43011	2.42527	
Bowery Ln (US 97 Bend)	Pbr+2%	5163.9	2977.8	2186.1	2190.1	7375.8	8648.4	77.3		2.3931	2.38267	0.03701
Bowery Ln (US 97 Bend)	Pbr+3%	4991.2	2813.6	2177.6	2180.3	7217.6	8470.1	77.5		2.35391	2.34706	0.03920
Bowery Ln (US 97 Bend)	Pbr+4%	5129.9	2959.9	2170	2173.6	7357.9	8593.6	77.5		2.32259	2.31368	0.03131
Celilo-Rufus (I-84)	Pbr+1%	5152.7	2972.4	2180.3	2185.5	7370.4	8695.7	77.3		2.55006	2.53464	
Celilo-Rufus (I-84)	Pbr+2%	5208.8	2977.8	2230.2	2235.4	7375.8	8714.7	77.3		2.50219	2.48767	0.04784
Celilo-Rufus (I-84)	Pbr+3%	5062.6	2813.6	2249.0	2255.3	7217.6	8547.0	77.0		2.44563	2.42899	0.05656
Celilo-Rufus (I-84)	Pbr+4%	5046.4	2959.9	2086.5	2090.2	7357.9	8586.1	76.8		2.43097	2.42053	0.01466