King County

Geotechnical Evaluation

SE 416TH STREET OVERLAY: SHINGLES IN PAVING DEMONSTRATION

POST-CONSTRUCTION PAVEMENT CONDITIONS FINAL REPORT

KING COUNTY, WASHINGTON
OCTOBER 2013

Prepared By:

King County

Department of Transportation
Traffic and Engineering Services Section
Materials Laboratory
155 Monroe Avenue NE, Bldg. D
Renton, WA 98056-4199

King County
Road Services Division
Materials Laboratory
Department of Transportation
RSD-TR-0100
155 Monroe Avenue Northeast, Building D
Renton, WA 98056-4199
www.metrokc.gov/roads

October 1, 2013

TO: Rick Brater, P.E., County Road Engineer and Section Manager,
Traffic and Engineering Services Section, Road Services Division, KCDOT

VIA: Alan D. Corwin, P.E., Materials Engineer, Materials Laboratory,
Traffic and Engineering Services Section, Road Services Division, KCDOT

FM: Kevin L. Kelsey, Senior Engineer, Materials Laboratory,
Traffic and Engineering Services Section, Road Services Division, KCDOT

SE 416th Street Overlay: Shingles in Paving Demonstration – Final Report

As requested, we have completed the third and final year of post-construction pavement monitoring for the SE 416th Street Overlay: Shingles in Paving Demonstration project. The purpose of our study was to document the structural performance of using post-consumer recycled asphalt shingles (RAS) in paving.

Organizations substantially contributing to the completion of this project included the King County Solid Waste Division LinkUp program, Washington State Department of Transportation Materials Laboratory, King County Sheriff's Office, and Foth Infrastructure and Environmental LLC.

The following report summarizes our findings, and provides conclusions and recommendations for the continued use of recycled asphalt shingles (RAS) on public roadways in King County. Our evaluation has concluded there is no significant effect when incorporating 3 percent RAS in Hot Mix Asphalt and recommend adopting special provisions for future use.

Upon your review of the report, we ask to meet with you to further discuss implementing the adoption of special provisions for the use of RAS on county-wide paving projects. We are available to provide additional support toward developing the special provisions. Please call me at 296-7712 or Alan Corwin at 296-7711, should you have any questions, require clarification, or would like further information.

Cc: Brenda Bauer, Road Services Director, Road Services Division, KCDOT

Chris Wierzbicki, Road Services Deputy Director, Road Services Division, KCDOT

Jay Osborne, Manager, Strategic Planning, Programming, and Reporting Office, Road Services Division, KCDOT

Debbie Arima, Roads Maintenance Operations Manager, Traffic and Engineering Services Section, Road Services Division, KCDOT

Jon Cassidy, Maintenance Engineering Manager, Traffic and Engineering Services Section, Road Services Division, KCDOT

Lydia Reynolds-Jones, Managing Engineer, Project Support Services, Traffic and Engineering Services Section, Road Services Division, KCDOT

Frank Overton, Supervising Engineer, Environmental Unit, Traffic and Engineering Services Section, Road Services Division, KCDOT

Victor Daggs, Supervising Construction Engineer, Construction Services, Traffic and Engineering Services Section, Road Services Division, KCDOT

Paul Moore, Senior Engineer, Construction Services, Traffic and Engineering Services Section, Road Services Division, KCDOT

Pat McLaughlin, Division Director, Solid Waste Division, Department of Natural Resources and Parks

Jeff Gaisford, Recycling and Environmental Services Manager, Recycling and Environmental Services, SWD/DNRP

Lauren Cole, Project/Program Manager IV, Recycling and Environmental Services, SWD/DNRP

Kris Beatty, Project/Program Manager, Recycling and Environmental Services, SWD/DNRP

David Wells, Detective, Major Accident Response and Reconstruction Unit, King County Sheriff's Office

Joe DeVol, Bituminous Materials Engineer, Washington State Department of Transportation

Dan Krivit, Senior Project Manager, Foth Infrastructure & Environment, LLC

ACKNOWLEDGEMENTS

This document was prepared by Kevin L. Kelsey, Senior Engineer, under the general supervision of Alan D. Corwin, Materials Engineer, King County Materials Laboratory. The information contained herein was compiled through a coordinated effort by the Road Services Division of the King County Department of Transportation, the Solid Waste Division of the King County Department of Natural Resources, The King County Sheriff's Office, the Washington State Department of Transportation (WSDOT) Materials Laboratory, and Foth Environmental & Infrastructure LLC.

The author wishes to specifically acknowledge Kris Beatty, Program Manager of the King County Solid Waste LinkUp program. The Shingles in Paving Demonstration project was the initiative of the LinkUp program. LinkUp continues to collaborate with government agencies and private industry to promote the use of shingles in paving.

We would also like to thank David Wells from the King County Sherriff's Office for coordinating and conducting skid resistance testing, and Joe Devol of the WSDOT Materials Laboratory for contributing expert advice on bituminous materials and for significantly contributing to the implementation of WSDOT Special Provisions for the use of asphalt shingles in paving. In addition, we thank Dan Krivits of Foth Environmental and Infrastructure LLC for literature research, consultation, compilation of the WSDOT Special Provisions specifically for the use of shingles, and for providing research and analysis to estimate potential cost benefits.

The King County Materials Laboratory relied on the support, sponsorship, and leadership of several King County Road Services Division Managers, past and present, and would like to give special thanks to Director Brenda Bauer, past Director Linda Dougherty, County Road Engineer Rick Brater, and Project Support Section Manager Lydia Reynolds-Jones.

EXECUTIVE SUMMARY

This report summarizes the evaluation of recycled asphalt shingles (RAS) as a partial asphalt binder component of Hot Mix Asphalt (HMA) and provides recommendations for future use of RAS in HMA on county-wide paving projects. The King County Department of Transportation Road Services Division, in collaboration with several King County agencies and the Washington State Department of Transportation, conducted a demonstration paving project on SE 416th Street near the City of Enumclaw in 2009 using RAS in HMA. The project represents the first use of RAS on public roadways in Washington State.

The potential benefits for incorporating RAS in HMA include reusing the significant amount of asphalt binder found in asphalt shingles. The cost of virgin asphalt binder used in HMA has soared over three fold in the last 10 years. Incorporating RAS as a portion of the asphalt binder can potentially reduce the cost of paving roadways in King County. In addition, recycling asphalt shingles can substantially reduce the amount of landfill waste. An estimated 29,000 tons of asphalt shingles are disposed of in King County, excluding Seattle, each year. King County is committed to reducing waste and recycling usable materials.

Asphalt binder found in shingles is typically stiffer than traditional pavement asphalt binders. The increased stiffness could potentially reduce rutting and increase the longevity of the pavement. However, increased stiffness could also lead to premature fatigue and thermal cracking, reducing the life of the pavement. The purpose of the study was to determine what impacts, good or bad, would occur to the pavement structure when incorporating 3 percent RAS by total weight to HMA.

Following completion of the paving project, the roadway was monitored for three years to evaluate structural performance under traffic. The roadway was monitored for cracking, rutting, and surface roughness. In addition, the King County Sheriff's Office conducted skid testing in wet and dry conditions. After three years of use, our evaluation concluded there is no significant effect, favorable or detrimental, on pavement performance when incorporating a maximum of 3 percent RAS by total weight to HMA.

Since 2009, the use of RAS in HMA has significantly increased across the country and locally. In 2008, only 10 States allowed the use of RAS. Today 27 States, including Washington, allow the use of RAS on either a standard or provisional basis. The Washington State Department of Transportation has recently published General Special Provisions for the use of RAS in HMA.

Several local agencies within the Puget Sound region have used or are considering to use RAS. RAS is now accepted on all King County Solid Waste projects. The access roads and parking areas at the newly completed Bow Lake Transfer Station were paved using over 9,000 tons of RAS in HMA. The city of Bellevue has included the use of RAS in their overlay program and the City of Tacoma has purchased equipment for its asphalt plant in order to incorporate RAS in HMA.

There is still concern, however, about the long-term effect of using stiffer asphalt found in asphalt shingles. Testing and analysis from transportation agencies and educational institutions, including Washington State University, are ongoing to determine the long-term outcome of using RAS in HMA.

On the basis of our evaluation of the demonstration project, and review of related documents, we recommend adopting provisions for the continued use of RAS, proceeding with appropriate caution until outstanding engineering issues are better understood. Detailed recommendations for adopting provisions are presented in Section 11.0 of this report.

TABLE OF CONTENTS

List of Tables Included in Text

Appendices

SE 416th Street Overlay: Shingles in Paving Demonstration

Post-Construction Pavement Conditions
Final Report
King County Materials Laboratory

October 2013

1.0 INTRODUCTION

The Road Services Division (RSD) of the King County Department of Transportation, in partnership with the Solid Waste Division (SWD) of the King County Department of Natural Resources and Parks, and the Washington State Department of Transportation (WSDOT) Materials Laboratory conducted a pavement demonstration project in September 2009 using recycled asphalt roofing shingles in hot mix asphalt. The demonstration project was initiated by the SWD LinkUp Program. The LinkUp Program coordinates, facilitates, and collaborates with both public and private sectors to promote the use of recycled materials.

The purpose of the demonstration project was to evaluate the performance of post-consumer Recycled Asphalt Shingles (RAS) in combination with Reclaimed Asphalt Pavement (RAP) in Hot Mix Asphalt (HMA) under actual field conditions over a 3-year time period. The demonstration project provides the first documented use of RAS on a public roadway within Washington State.

This final report summarizes recorded pavement conditions observed and measured following three years of post-construction traffic, and includes conclusions and recommendations for future use of RAS in HMA on county-wide paving projects.

1.1 BACKGROUND

A King County roadway was overlaid with a 2-inch thick layer of Hot Mix Asphalt (HMA) incorporating both RAS and RAP in designated test sections. The demonstration project allowed the use of 3 percent RAS and 15 percent RAP by weight in the total HMA job mix for a combined total of 18 percent recycled materials.

Based on preliminary mix design tests completed in 2008 by the WSDOT Laboratory, the RAS binder content from three different shingle recyclers ranged from 16.3 percent to 22.8 percent. The asphalt binder content for RAS produced by Woodworth & Company (now Miles Resources) and used for this demonstration project was measured at 22.8 percent. A trial mix design was developed by the paving contractor (Woodworth & Company) and verified by the WSDOT Laboratory. Based on testing and analysis, the optimum asphalt binder content was determined by WSDOT to be 5.6 percent by total weight of which 4.3 percent consisted of virgin asphalt binder, 0.7 percent from RAS and 0.6 percent from RAP. This equates to an overall asphalt binder contribution of 23.2 percent derived from recycled resources.

The incorporation of RAS in HMA potentially provides three major benefits. First, since RAS contains a substantial amount of asphalt binder that can be substituted for a portion of the virgin asphalt binder, the overall cost of HMA could be reduced, lowering the cost of future paving projects. Since 2002, according to the WSDOT Construction Office, the average cost of virgin asphalt binder per ton has risen from approximately $100 per ton to a current cost of about $350 per ton.

Secondly, recycling RAS could substantially reduce the amount of landfill waste. According to the LinkUp Program, an estimated 29,000 tons of asphalt shingles are generated in King County, excluding Seattle, each year. The use of RAS provides a significant opportunity to divert a valuable material resource for use in pavements and save landfill space.

Thirdly, asphalt binder used in roofing materials is typically stiffer than asphalt pavement binders. The stiffer asphalt binder found in RAS may aid in reducing rutting over the long-term performance of the roadway. Conversely, a significantly stiffer and potentially brittle asphalt binder may contribute to premature fatigue and thermal cracking of the roadway.

Following completion of the overlay in 2009, the King County Materials Laboratory (KCML) performed pavement condition surveys through 2012 on a yearly basis by walking the site and documenting distressed areas. Pavement condition surveys, including pavement rutting and surface roughness, were also conducted by WSDOT using a distress data collection van. In addition, roadway skid testing in wet and dry conditions was performed by the King County Sherriff's office in 2012 to compare with skid test results conducted in 2009.

1.2 RELATED DOCUMENTATION

Past reports relevant to this demonstration project include the following:

- King County Materials Laboratory, *Technical Support Document for SE 416th Street Overlay: Shingles in Paving Demonstration*, dated January 2010
- King County Materials Laboratory, *SE 416th Street Overlay: Shingles in Demonstration, Post-Construction Pavement Condition*, dated September 2010
- King County Materials Laboratory, *SE 416th Street Overlay: Shingles in Demonstration, Post-Construction Pavement Condition – Interim Report*, dated January 2012

The above listed reports can be found on the following King County Materials Laboratory website in their entirety:

http://www.kingcounty.gov/transportation/kcdot/Roads/EngineeringServices/GeotechnicalMaterialsTesting/MaterialsLabServices.aspx

Additional related documentation, including national and local information, is available on the Linkup Program website below:

http://your.kingcounty.gov/solidwaste/linkup/shingles/resources.asp

2.0 TEST SECTION

SE 416th Street, within the project limits, is located in south King County, near the City of Enumclaw. The roadway runs east-west and serves as a 2-lane paved rural arterial with 2-foot wide paved shoulders. The project limits extend approximately 2 miles, beginning at the intersection of 212th Avenue SE (Station 10+20) and ending at 244th Avenue SE (Station 116+00). The general location of the project is shown on the Vicinity Map, Figure 1, included in Appendix A.

The roadway was divided into four separate test sections, each approximately ½ mile in length. Each test section required about 1000 tons of HMA to provide a 2-inch thick overlay. The test section layout for this project is shown in Table 1 below:

TABLE 1
SE 416TH Street Overlay
Test Section Layout

Lane Description	Test Section #1	Test Section #2	Test Section #3	Test Section #4
Stationing Limits	10+20 to 36+50	36+50 to 63+10	63+10 to 89+66	89+66 to 116+00
Lane 1 (eastbound)	HMA Mix with 15% RAP	HMA Mix with 3% RAS and 15% RAP	HMA Mix with 3% RAS and 15% RAP	HMA Mix with 15% RAP
Lane 2 (westbound)	HMA Mix with 15% RAP	HMA Mix with 3% RAS and 15% RAP	HMA Mix with 3% RAS and 15% RAP	HMA Mix with 15% RAP

A graphical depiction of the test section layout is shown in Figure 2, Appendix A.

The demonstration mix design (Test Sections 2 and 3) was selected to represent a conservative mix ratio of RAS usage at 3 percent together with 15 percent RAP. The control mix design (Test Sections 1 and 4) was 15 percent RAP and 0 percent RAS. The project research team elected to use RAS plus RAP to demonstrate and test the impacts of anticipated commercial HMA mixes if the use of RAS was found to be feasible through this demonstration project and other research. This RAS/RAP mix design was expected to be the more likely preference of HMA producers and paving contractors compared to the use of RAS alone.

Ultimately, the decision to limit the quantity of RAS to 3 percent of the mix was based on efforts to stay below 30 percent recycled asphalt binder by total weight of the mix (including a share of recycled binder contributed from RAP) and thereby minimize impacts to the mixture volumetric properties.

3.0 SUMMARY OF CONSTRUCTION ACTIVITIES

The Contractor began construction operations on 9-21-09 and proceeded through 9-25-09. The work was accomplished in warm dry weather throughout the week. Work performed during each day of paving is summarized below.

On 9-22-09, the Contractor began overlay operations at the east end of the project (244th Avenue SE), paving Test Section 4 with the RAP only HMA mix. KCML performed all required testing to verify the quality and placement of the job mix. These tests included asphalt binder content, gradation, maximum theoretical specific gravity, volumetric tests, and in-place density tests.

Prior to paving Test Section 3 with the RAP/RAS mix the following day, the Contractor requested an adjustment of the virgin asphalt binder. Based on their experience utilizing recycled shingles in previous projects placed on private property, the Contractor assumed the RAS binder would not be 100 percent effective as an asphalt binder when incorporated into the mix. The effective percent of contributed asphalt binder from RAS into the final HMA job mix is dependent on many factors, including the grind size of the RAS, mixing temperatures, and the amount of time spent mixing the final blended HMA product.

To compensate for the anticipated partial utilization of the RAS binder, the Contractor recommended an increase in the virgin asphalt binder of 0.2 percent, for a total of 4.5 percent virgin asphalt binder, while still maintaining 15.0 percent RAP and 3.0 percent RAS. It was the consensus of all parties to allow the mix modification per the Contractor's request.

On 9-23-09, the Contractor paved Test Section 3 with the RAP/RAS added HMA mix. Test results revealed a high total asphalt binder content ranging above 6 percent compared to the mix design target optimum total asphalt binder content of 5.6 percent. In addition, the fines content (aggregate materials passing the U.S. #200 sieve) was at or slightly above the maximum amount allowed. The air void content of the mix was also much lower than anticipated. In-place density tests were above 96 percent of the maximum theoretical specific gravity, confirming low air void content. Actual plant HMA mix test results indicated that RAS contributed a greater amount of asphalt binder to the final HMA product than anticipated.

The high asphalt binder content of the final HMA product and increase in fines were not visually apparent on the pavement surface. The surface appeared similar to Test Section 4 (RAP only HMA mix), placed the previous day. In addition, recycled shingle fragments were not obviously noted. However, upon careful examination some very small pieces of shingle fragments could be found.

All parties met and agreed the RAP/RAS HMA mix needed to be adjusted prior to paving Test Section 2. It was decided the Contractor would proceed by paving Test Section 1 on 9-24-09 using the RAP only HMA mix.

To prepare for paving Test Section 2 with the RAP/RAS HMA mix the following day, the Contractor lowered the virgin asphalt binder content back to the original level proposed in the mix design (4.3 percent). In addition, the Contractor attempted to reduce the fines content in the overall mix by cleaning out the baghouse.
On 9-25-09, the Contractor completed overlay operations by paving Test Section 2 with the adjusted RAP/RAS HMA mix. Testing indicated the quality of the job mix was now in compliance. The measured asphalt binder ranged from 5.5 to 5.8 percent. However, the fines content of the aggregate still ranged within the upper limits of the specification. Compaction testing indicated the average relative density of the new overlay to be slightly over the minimum requirement of 92 percent of the maximum theoretical specific gravity.

The appearance of the pavement surface in Test Section 2 was typical of a well-placed and compacted conventional HMA roadway. A few intermittent shingle fragments and extraneous materials including wood, rubber, glass, and wire could be found and pulled from the compacted surface. The diameter of these materials was generally less than 1/2-inch in thickness. However, some RAS fragments, in the shape of strands, measured nearly 4 inches in length.

Further details regarding construction of the roadway can be found in the previously referenced King County Materials Laboratory Technical Support Document for SE 416th Street Overlay: Shingles in Paving Demonstration, dated January 2010.

4.0 PAVEMENT CONDITION SURVEYS

4.1 PAVEMENT CONDITION SURVEY METHODS

Post-construction pavement condition surveys were conducted by both KCML and WSDOT. For this project, KCML performed walking surveys using methodologies generally prescribed by The American Society for Testing and Materials (ASTM) test method D-6433-03 and the Northwest Pavement Management Association. WSDOT conducted drive-through surveys using laser and other sensing devices mounted to a distress data collection van.

Pavement distress observed during the respective surveys was categorized and quantified for the purpose of developing a Pavement Condition Index (PCI) for each test section. KCML recorded five distress categories for the PCI rating including alligator cracking, longitudinal cracking, transverse cracking, rutting, and patching for flexible pavements.

PCI is a numerical indicator that rates the present condition of the pavement surface based upon the type, quantity, and distress levels observed. A newly constructed pavement would have a PCI of 100 and a roadway that has failed would have a rating near 0. ASTM suggests using terminology shown in Table 2 to describe the condition of pavements based upon various PCI rating ranges.

TABLE 2 SE 416TH Street Overlay PCI Rating Ranges	
PCI Rating	**Condition Description**
85 to 100	Excellent
70 to 85	Very Good
55 to 70	Good
40 to 55	Fair
25 to 40	Poor
10 to 25	Very Poor
0 to 10	Failed

WSDOT designates a Pavement Condition Index (PCI) as a Pavement Structural Condition (PSC). The PSC is a scoring of the pavement structure based on a compilation of visible surface distresses. This score ranges from 100 being a new surface absent of any distress to 0 representing total pavement failure. The ratings are similar to those presented in Table

2 (PCI Rating Ranges).

The WSDOT Materials Laboratory conducted PSC surveys using laser equipment mounted to a distress data collection van. For calculation of the PSC, the van is driven along the test section collecting laser images while travelling near the posted speed limit. The images are evaluated with other pertinent roadway information, such as length and area. An operator then views the recorded images in a frame by frame progression back in the laboratory and documents pavement distresses as they appear.

4.2 POST-CONSTRUCTION PAVEMENT RATING COMPARISONS

In December 2009, the WSDOT Materials Laboratory conducted a post-construction pavement condition survey using the distress data collection van. In 2010 and 2011, both WSDOT and KCML conducted separate surveys. Post-construction pavement condition surveys are summarized below in Table 3. Test Sections 1 and 4 contain 15 percent RAP only. Test Sections 2 and 3 contain 3 percent RAS and 15 percent RAS.

TABLE 3
SE 416th Street Overlay
Post Construction Pavement Condition Surveys

Test Section	WSDOT 2009	WSDOT 2010	KCML 2010	WSDOT 2011	KCML 2011	WSDOT 2012	KCML 2012
Test Section 1	100	100	100	100	100	99	100
Test Section 2	100	100	100	99	100	99	100
Test Section 3	100	100	100	99	99	100	99
Test Section 4	100	100	100	99	100	99	99
Overall Rating	100	100	100	99	100	99	99

Note: Test results are rounded to whole numbers. Ratings are based on the combined average of both lanes in each test section.

The roadway surface in all test sections continues to appear in excellent condition following three years of post-construction service. There was no observed or measured significant difference between the test sections with RAS and the control sections without RAS.
In 2011, KCML found a 15-foot long low severity longitudinal crack in the westbound lane of Test Section 3. The hairline crack appears to follow along the edge of a roller mark and is most likely related to poor construction techniques. Preconstruction records indicate a low severity longitudinal crack existed at this location, prior to paving.

In 2012, about 90 feet of intermittent low severity longitudinal cracking was also observed along an apparent joint near the centerline of the roadway in Test Section 4, approximately from Station 111+00 to 111+90.

4.3 PAVEMENT RUTTING CONDITION (PRC)

The WSDOT distress data collection van documented the pavement rutting condition (PRC) using a Laser Rut Measurement System (LRMS) mounted on the distress data collection van. Two of these collection devices are mounted on the back of the collection van, one for each half of the lane width. The devices collect laser images every 5 feet through the length of the site.

PRC is a score representing the extent of rutting present in the rated lane. The PRC rating scale ranges from 100 (no rutting) to 0 (deep rutting dependent on the length). Typically, a roadway would be considered in need of rehabilitation when the PRC rating is 50 or below. Post-construction PRC test results from the WSDOT pavement condition surveys are summarized in Table 4.

Table 4 SE 416^{th} Street Overlay WSDOT Pavement Rutting Condition Surveys (PRC) – Post Construction								
	December 2009		August 2010		November 2011		January 2013	
Test Section	PRC	Average Depth (inches)	PRC	Average Depth (inches)	PRC	Average Depth (inches)	PRC	Average Depth (inches)
1	96	.05	95	.06	96	.07	95	.07
2	98	.04	96	.06	96	.06	96	.07
3	95	.06	95	.07	96	.07	96	.07
4	96	.06	94	.08	94	.09	94	.08
Average	96	.05	95	.07	96	.07	95	.07

Note: Ratings are based on the combined average of both lanes in each test section.

All roadway test sections continue to exhibit only minimal rutting following three years of service.

4.4 INTERNATIONAL ROUGHNESS INDEX (IRI)

WSDOT also recorded surface roughness based on the International Roughness Index (IRI). The collection van is outfitted with two accelerometers, one for each wheel path. As the van travels over the test site the accelerometers measure the axle movement of the van, recording surface irregularities.

For this rating, the scoring ranges from low to high and is measured in inches per mile. The higher the score, the rougher the roadway section, with zero considered equivalent to a smooth glass surface. WSDOT uses the following rankings, shown in Table 5, when rating the IRI:

TABLE 5 SE 416^{th} Street Overlay International Roughness Index Scale	
IRI (inches/mile)	**Pavement Rating**
Below 95	Very Good
95-170	Good
170-220	Fair
220-320	Poor
Above 320	Very Poor

Post-construction IRI test results from the WSDOT pavement condition surveys are summarized in Table 6:

TABLE 6 SE 416th Street Overlay WSDOT International Roughness Index Surveys (IRI) Post Construction				
Test Section	**December 2009**	**August 2010**	**November 2011**	**January 2013**
Test Section 1	68	60	67	62
Test Section 2	60	64	60	62
Test Section 3	88	91	92	92
Test Section 4	78	82	88	80
Overall Rating	74	74	77	74

Note: Test results are rounded to whole numbers. Ratings are based on the combined average of both lanes in each test section.

The roughness (IRI) of the roadway continues to be measured below a rating of 95 in all test sections indicating a relatively smooth surface since placement of the overlay.

5.0 SKID RESISTANCE TESTING

Roadway skid resistance testing was initially conducted by the Major Accident Response and Reconstruction Unit (MARR) of the King County Sheriff's Office following completion of paving in 2009. Additional testing was completed after 3 years of service in 2012. Within each test section, skid resistance testing was performed during both dry and wet pavement conditions.

The tests were conducted using both Vericom VC 2000 and VC 3000 Braking Computer Systems. The braking computer system calculates a drag factor which is used throughout the accident reconstruction industry as an indicator of skid resistance, and has been used by the MARR Unit for over 15 years involving thousands of test skids. The drag factor is a unitless value and is used to calculate the resistance of an object in motion. According to Vericom's website, the normal range for drag factors of various vehicles is presented in Table 7.

TABLE 7 SE 416th Street Overlay Normal Range for Drag Factor (F)	
Passenger Vehicles with Standard Brakes	0.75 ± 5%
Passenger Vehicles with ABS Brakes	0.85 ± 5%
Motorcycles	0.9 ± 10%
Commercial Vehicles	0.62 ± 10%

Note: Pickup trucks are 5 percent less than a passenger vehicle.

Tests were conducted using passenger vehicles with both conventional braking and anti-lock braking (ABS) systems. A comparison of dry surface skid tests conducted in 2009 and in 2012 is summarized in Table 8.

TABLE 8 SE 416th Street Overlay Drag Factor Test Results in Dry Roadway Surface Conditions				
Test Section	Conventional Braking		Anti-Lock Braking	
	Initial Test Results	2012 Test Results	Initial Test Results	2012 Test Results
Test Section 1	0.71	0.74	0.83	0.81
Test Section 2	0.70	0.75	0.86	0.83
Test Section 3	0.67	0.73	0.81	0.80
Test Section 4	0.72	0.74	0.87	0.83
Overall Rating	0.70	0.74	0.84	0.81

A comparison of wet surface skid tests conducted in 2009 and in 2012 is summarized in Table 9:

TABLE 9 SE 416th Street Overlay Drag Factor Test Results in Wet Roadway Surface Conditions				
Test Section	Conventional Braking		Anti-Lock Braking	
	Initial Test Results	2012 Test Results	Initial Test Results	2012 Test Results
Test Section 1	0.66	0.65	0.79	0.71
Test Section 2	0.68	0.68	0.82	0.78
Test Section 3	0.66	0.67	0.80	0.76
Test Section 4	0.73	0.69	0.83	0.79
Overall Rating	0.68	0.67	0.81	0.76

Test results continue to indicate overall skid resistance for both dry and wet conditions in all test sections remain comparable to those found on similar King County roadways.

6.0 EXTRANEOUS MATERIALS AND POP-OUTS

Preliminary test results prior to construction indicated the final RAS product was substantially free of extraneous waste materials and entirely free of whole, intact nails. The special provisions for the demonstration project required lighter extraneous materials such as paper, wood and plastic could not exceed 1.5 percent by mass as determined on material retained on the No. 4 sieve. Total extraneous materials including metals, glass, rubber, nails, soil, brick, tars, paper, wood and plastic could not exceed 3.0 percent by mass as determined on material retained on the No. 4 sieve. Preliminary test results revealed both the lighter extraneous materials and total extraneous materials were no greater than 0.06 percent by mass of the total sample.

During our initial post-construction pavement condition survey in 2010, we observed intermittent extraneous materials embedded in the surface of the asphalt mat in all test sections; however, these materials were most noted in RAS/RAP Test Sections 2 and 3. Materials consisted mostly of mastic-like fragments (rubbery texture) and were likely byproducts from RAS processing. Small wood fragments were typically found in RAP only Test Sections 1 and 4.

In addition to extraneous materials, we observed periodic surface voids which were typically less than one inch in diameter and generally less than ¼ inch in depth. These shallow depressions are sometimes called "pop-outs", due to the belief that materials originally filling the voids were forced or "popped" out from repeated traffic loading.

The pop-outs are visible only during a careful walk-through inspection of the pavement surface. The amount of materials and pop-outs as compared to the overall surface area of the pavement is considered minimal and sporadic.

A cursory survey of these imperfections was conducted in 2010. In 2011 and 2012, more carefully observed surveys were performed. A summary of the number of extraneous materials and pop-outs noted in 2011 and 2012 are listed in Table 10.

Table 10
SE 416th Street Overlay
Extraneous Materials and Pop-Outs Summary
Number Counts

Test Section	Extraneous Materials		Pop-Outs	
	2011	2012	2011	2012
1	6	11	7	20
2	28	32	21	33
3	15	15	12	15
4	10	20	14	15

Although observed in all test sections, the combined number of extraneous materials and pop-outs found in Test Sections 2 and 3 were slightly higher than Test Sections 1 and 4, and appear to be mostly related to byproducts of RAS processing.

7.0 SUMMARY OF SURVEY FINDINGS

7.1 PAVEMENT CONDITION SURVEYS

Both KCML and WSDOT post construction surveys revealed a PCI or PSC rating of or nearly 100 for each test section, following three years of service life. The entire roadway in all test sections is considered to be in excellent condition.

7.2 PAVEMENT RUTTING CONDITION (PRC)

PRC survey test results revealed relatively no change in the degree of rutting in any of the test sections. Rutting values were similar in all test sections. Minimal but expected rutting within the roadway has occurred in all test sections.

7.3 INTERNATIONAL ROUGHNESS INDEX (IRI)

The roughness (IRI) of the roadway continues to be measured below 95 in all test sections indicating a relatively smooth surface since placement of the overlay. Test Sections 3 and 4 have consistently rated about 20 points higher than Test Sections 1 and 2. This may be due to traveling over the existing Newaukum Creek Bridge located in Test Section 3 and/or accelerating or decelerating near intersections during testing. Overall, the severity of roughness has marginally increased since construction.

7.4 SKID RESISTANCE TESTING

Test results continue to indicate overall favorable skid resistance for both dry and wet conditions in all test sections. According to the King County MARR Unit, the test values obtained during both the initial testing conducted in 2009 and final testing in 2012 and 2013 remain comparable to those found on varying roadways throughout King County when investigating crashes and conducting skid tests.

7.5 EXTRANEOUS MATERIALS AND POP-OUTS

Minimal extraneous materials and periodic surface voids were observed on the pavement surface in all test sections; however, the combined amount was slightly higher in RAS/RAP Test Sections 2 and 3 than were found in RAP only Test Sections 1 and 4.

8.0 CHANGES TO PERFORMANCE GRADE (PG) ASPHALT BINDER

Asphalt binders are thermoplastic materials. As temperatures rise, the material begins to soften and when cooled it begins to harden. Currently, asphalt binders used in HMA are graded to meet a Performance Grade (PG) system developed by the Strategic Highway Research Program. The system designates an asphalt binder temperature range for specific regional climates.

The typical asphalt binder grade used on King County Roadways within the lowlands of Puget Sound is PG 64-22. The first number in the notation represents the predicted average 7-day maximum pavement temperature in Celsius expected in the region. Therefore, the maximum pavement temperature expected in the Puget Sound region is 64 degrees Celsius or 147 degrees Fahrenheit. The second number represents a minimum expected pavement temperature of -22°C or -7.6°F.

Studies have shown that asphalt binders found in RAS, as well as RAP, are stiffer than virgin asphalt binders. One combined asphalt binder sample from the demonstration project was tested by WSDOT during production in 2009. The recovered sample of asphalt binder consisting of RAS, RAP, and conventional HMA was graded at PG 76-16.

This grading indicates that at higher pavement temperatures, the pavement is less likely to rut. However, due to the increased stiffness, fatigue cracking may occur at an accelerated rate. During colder temperatures, this binder may become more brittle and susceptible to thermal cracking when compared to HMA mixes containing an asphalt binder graded at PG 64-22.

WSDOT has recently issued General Special Provisions (GSP) allowing the use of RAS in HMA. The specifications require the addition of an asphalt rejuvenator and/or the use of a softer virgin asphalt PG grade, when needed, to adjust the binder to the regional performance grade. Further discussion of the GSP is presented in Section 9.1.2 (Regional Use Summary).

9.0 DEVELOPMENTS SINCE 2009

9.1 NATIONAL AND REGIONAL USE OF RAS IN HMA

9.1.1 National Use Summary

In 2008, only 10 States allowed the use of RAS in HMA, including 4 that allowed tear-off (post-consumer) RAS. Since 2008, the use of shingles in HMA has grown substantially. According to the LinkUp Program, in 2013, 27 States have standard specifications allowing the use of RAS in HMA. 20 States allowed tear-off RAS as part of their standard specifications and 7 States have standard specifications allowing the use of RAS from manufacturing (post-industrial) scrap. In addition, California and Washington now allow the use of RAS on a provisional basis.

9.1.2 Regional Use Summary

SE 416th Street was the first documented public roadway within Washington State to utilize RAS in HMA. Since 2009, several local agencies have implemented or are considering using RAS. RAS is now accepted for use on all King County SWD projects. In addition, King County Metro Transit has installed an 800-foot test section of RAS on the E3 busway in Seattle to determine performance under heavy bus loading conditions. The City of Bellevue has also used RAS in its 2012 overlay program. The City of Tacoma has purchased new equipment for its HMA plant in order to incorporate RAS into HMA.

RAS in HMA was utilized during Phase 1 reconstruction of the King County SWD's Bow Lake Recycling and Transfer Station. Paving operations took place in 2011 and 2012. Phase 1 included paving the access road to the transfer building and fueling facility, and surrounding parking. The transfer building has been open since July 2012 and has endured heavy traffic loading.

A recent site reconnaissance this spring revealed no significant deterioration to the pavement from the associated heavy traffic loads. Additional paving will be completed on the transfer trailer yard, south processing area, and scale facility during the summer of 2013. Over 9,000 tons of RAS in HMA will be placed at the site when paving is completed.

At the State level, WSDOT has published General Special Provisions for the use of RAS in HMA. The specifications consist of a series of modified excerpts to Section 5-04 of the WSDOT 2012 Standard Specifications for Road, Bridge, and Municipal Construction. The use of RAS is currently accepted for use in any State of Washington contract, provided specific requirements are met.

The specifications allow up to 5 percent RAS by total weight of the HMA, provided the final performance grade of asphalt binder meets the performance grade required in each specific Contract. This may require adding an asphalt binder rejuvenator to adjust the final asphalt binder performance grade and/or adjusting the PG grade of the virgin binder to a softer grade to accommodate the stiffer binder in RAS.

The composite of excerpts and General Special Provisions pertaining to the use of RAS, including WSDOT web links, are included in Appendix B.

9.2 RECYCLED ASPHALT SHINGLES (RAS) SPECIFICATION GUIDELINES

In 2010, the LinkUp Program developed specification guidelines for the use of RAS in HMA based on specifications used and experience gained from the 2009 Demonstration project. The document provides guidelines for the safe handling and processing of RAS, as well as recommendations for quality control testing. The guidelines were last updated in January, 2012 and can be found on the LinkUp Program website (King County 2012 RAS Specifications Guidelines).

9.3 WSU AND WSDOT LONG-TERM PERFORMANCE TESTING

Washington State University and WSDOT are conducting additional long-term performance testing on asphalt cores recently obtained from the demonstration pavement at SE 416th Street. A total of 34 cores were cut and retrieved by KCML in February 2013. The LinkUp Program substantially funded the expense of retrieving the cores.

WSU is currently conducting indirect tensile testing to determine overall stiffness, as well as predicting the long-term performance of rutting, resistance to fatigue, and thermal cracking. WSDOT has conducted Hamburg wheel-tracking device testing to determine rutting and moisture susceptibility. Final test results from the study are expected to be completed by the end of 2013.

10.0 CONCLUSION

Pavement condition surveys verified the entire surface of the roadway is in excellent condition and performing as well as, if not better than, other typically overlaid roadways in King County following three years of service life. Slight rutting has occurred within the roadway and is relatively uniform across all test sections. The road surface is considered to be smooth with minimal measured roughness. Minor imperfections include intermittent pop-outs and extraneous materials imbedded in the surface of the finished paved roadway.

Current observations and test results continue to indicate there is no significant effect, favorable or detrimental, on pavement performance when incorporating a maximum of 3 percent RAS by total weight to HMA.

A well prepared and asphalt paved roadway in King County will generally not develop significantly noticeable deterioration, such as cracking and rutting, until roughly 8 to 12 years following construction. Additional observations over time are needed to assess the long-term performance of the SE 416th Street Overlay: Shingles in Paving Demonstration. Laboratory testing of the material properties of RAS in HMA is currently being conducted by WSU and WSDOT to further predict long-term performance, which may accelerate the time frame required for a more comprehensive assessment of the long-term performance of the demonstration project.

There are ongoing concerns regarding the performance grade change in the final asphalt binder when using RAS in HMA under the specification used in this demonstration project. This issue has been addressed in the WSDOT General Special Provisions by requiring the binder performance grade meet specifications through the use of an asphalt rejuvenator and/or virgin binder with a softer performance grade.

Since completion of the pavement demonstration, an increased number of states, including Washington, as well as local governmental agencies have incorporated or are considering allowing RAS in HMA as part of standard asphalt pavement specifications.

Industry interest in using RAS, bolstered by the SE 416th Street Overlay: Shingles in Paving Demonstration and the new WSDOT GSP, is increasing. There are currently four known asphalt shingle recycling facilities in Western Washington. In addition, 4 HMA plants are using RAS on a regular basis in their commercial mixes.

11.0 RECOMMENDATIONS

11.1 ADOPT PROVISIONS FOR USE OF RAS IN HMA ON COUNTY ROADWAYS

We recommend adopting provisions for the use of RAS in HMA on County roadways, proceeding with appropriate caution until outstanding engineering issues, especially related to changes in the performance grade of the final asphalt binder when incorporating RAS, are better understood.

For this reason, we recommend two alternatives for the use of RAS on County roadways:

- Allow the unlimited use of RAS in HMA, provided the pavement contractor meets all specifications as required in the current WSDOT GSP and supplemental provisions required by the County. Additional discussion of application of the WSDOT GSP on County roadways is presented in Section 11.1.1.

- Allow the use of RAS in HMA for a portion of annual County paving using a modified and improved version of the King County Special Provisions for the use of RAS in public roadways. Recommendations for using this alternative are further discussed in Section 11.1.2.

11.1.1 Adopting WSDOT General Special Provisions for the use of RAS in HMA

We recommend allowing the unlimited use of RAS in HMA on County roadways, provided the pavement contractor meets all specifications as required in the current WSDOT GSP and supplemental provisions required by the County.

The WSDOT GSP addresses the concerns regarding changes in asphalt binder performance grade by requiring the HMA supplier to meet the PG grade specified in the contract documents for each individual project. This will most likely require the asphalt supplier to incorporate an asphalt rejuvenator into the job mix or use a softer virgin binder PG grade to adjust the final HMA binder to the required performance grade.

The WSDOT GSP includes rigorous requirements for materials testing and QA/QC when using RAS in HMA, and utilization of the WSDOT GSP will enable additional testing and evaluation of RAS to occur. In addition to allowing the use of the WSDOT GSP on County Roadways, the RSD can track projects using the WSDOT GSP for the purposes of further evaluating the use of RAS in HMA in our region.

11.1.2 Adopting King County RAS in HMA Special Provisions

Concurrently, we recommend the use of RAS in HMA on overlays, new road construction, and maintenance projects, under a set of King County Special Provisions with the maximum amount of RAS being no greater than 3 percent and RAP no greater than 15 percent by total weight of the HMA job mix. We recommend limiting the use of RAS in HMA when utilizing this alternative until the impact from changes in the performance grade of the final asphalt binder, and other outstanding issues, are better understood.

The 3-year demonstration project has shown that incorporating 3 percent RAS into HMA does not adversely impact the short term performance of the asphalt mix on low traffic volume roadways. Research is on-going by others to evaluate the long term performance of RAS. Evaluation of additional roadway sections will provide further confidence of structural long-term performance.

As a continuing effort toward evaluating and incorporating RAS in HMA on King County projects, we recommend considering this alternate RAS provision for selected road projects each year. Selection of the trial projects should be considered based on design team consensus and such factors as HMA tonnage, road condition, and traffic volume for continued evaluation of RAS performance in HMA.

11.2 MODIFICATIONS TO THE KING COUNTY SPECIAL PROVISIONS

The current King County Special Provisions for the use of RAS in public roadways need to be modified and improved prior to further use. Recommended changes to the Special Provisions include modifications to gradation requirements, more rigorous requirements regulating the amount of extraneous materials, and specifications to improve blending methods.

11.2.1 Gradation Requirements

The King County Special Provision grading specifications for processing RAS during the demonstration project required the final RAS product be processed so that 100 percent of the material passes the 1/2-inch sieve and 95 percent pass the 3/8-inch sieve.

A few intermittent shingle fragments and extraneous materials including wood, rubber, glass, and wire were observed and pulled from the compacted surface during paving. The diameter of these materials was generally less than 1/2-inch in thickness. However, some RAS fragments, in the shape of strands, measured nearly 4 inches in length. During post-construction pavement survey monitoring, trace fragments of extraneous materials and periodic pop-outs were observed on the pavement surface.

We recommend grinding the final RAS product to a finer grade to further reduce the amount of extraneous materials and the formation of pop-outs. Finer grading may also aid in releasing the asphalt binder in a more predictable manner during the mixing and heating process for the final production of the HMA job mix.

Therefore, we recommend for future projects the final RAS product be processed so that 100 percent of the material passes the 3/8-inch sieve and 95 percent pass the 1/4-inch sieve.

11.2.2 Extraneous Waste Materials

Extraneous waste materials that may be found as a byproduct in RAS include nails and other metals, glass, rubber, soil, brick fragments, tars, paper, wood, and plastic. For the demonstration project, Special Provisions required the final RAS product to be substantially free of extraneous wastes materials and entirely free of whole, intact nails. Lighter materials such as paper wood and plastic could not exceed 1.5 percent by mass. Total extraneous materials could not exceed 3.0 percent by mass.

We do not anticipate the amount of extraneous materials found during and post-construction will significantly impact the long-term performance of the pavement. However, to improve the appearance and smoothness of the roadway surface, we recommend further restricting the maximum amount of extraneous materials when RAS is used on future projects.

We recommend adopting the Minnesota State Department of Transportation current specifications for the amount of allowable extraneous waste materials. Their specification requires the total amount of all extraneous waste materials shall not exceed 0.5 percent by mass.

11.2.3 Improving Blending Methods

The method used for blending RAS into the final HMA job mix for the 2009 demonstration project began by first blending together RAS and RAP materials using separate metered cold feed bins. The blended material was then stockpiled until paving operations began. During paving, the combined RAP/RAS was then placed in a metered bin and blended into the virgin asphalt binder and raw aggregates to produce the final HMA job mix.

Blending of RAS and RAP for the Bow Lake Transfer Station was accomplished by first weighing each material separately on a scale and placed in a combined pile. A bucket loader then blended the combined pile to a visually uniform mixture. During paving operations, the combined and mixed pile was placed in a metered bin and added to the virgin asphalt binder and raw aggregates.

We recommend requiring a separate cold feed bin for each product to improve blending methods. This will further ensure that separate proportions of RAP and RAS will be accurately proportioned, weighed, and incorporated into the final job mix. Further discussions are needed with local asphalt suppliers to verify the feasibility to provide a separate bin for each recycled product or other methods and procedures to ensure improved blending.

11.3 BENEFIT AND COST CONSIDERATIONS

King County is committed to minimizing operational resource use, maximizing reuse and recycling, and choosing products and services that have low environmental impacts (King County, 2012 Strategic Climate Action Plan: County Operations Goal O.4). We understand the environmental benefits associated with the use of shingles in paving are important incentives for incorporating RAS in HMA. Replacing virgin asphalt with recycled asphalt conserves nonrenewable resources and takes advantage of local supplies of materials that would otherwise go to waste.

An estimated 29,000 tons of asphalt shingles are generated in King County, excluding Seattle, each year. Potentially, thousands of these tons could be diverted from landfills and reprocessed to provide an important partial substitute for virgin asphalt binder. In addition, a cost savings of four to six dollars a ton of HMA could be foreseen, if widespread use of RAS is implemented and the price of virgin asphalt binder continues to increase.

In our opinion, the benefits of reducing waste and recycling asphalt shingles should provide an additional strong and positive incentive to help offset initial startup costs. We expect financial costs to incorporate RAS into the HMA job mix will be nearly equivalent to or less than the cost of placing conventional HMA, if RAS is expanded and incorporated in HMA on a more regular basis. According to the LinkUp program, this situation has been achieved in other states (including Missouri, Indiana, Minnesota, and Wisconsin) following adoption of a state transportation agency specification allowing RAS, which establishes reliable market demand and incentivizes local recyclers and HMA producers to invest in equipment and facilities to process and use RAS in HMA.

This balance between demand development and supply development will be important for realizing the cost-saving potential of RAS use in King County. By adopting provisions that allow for the use of RAS on County roadways, RSD can play an important role in this process.

11.4 CONTINUING POST-CONSTRUCTION MONITORING

Our study of SE 416th Street was concluded following 3 years of post-construction service life. Newly paved asphalt roadways in King County do not generally begin to develop significant observable deterioration until about eight to twelve years post-construction. Therefore, we recommend revisiting the study area in 3 years (2015) to conduct a pavement condition survey. Additional pavement surveys should be conducted after 9 and 12 years of use.

11.5 DOCUMENTATION OF RAS IN HMA IN THE PUGET SOUND REGION

The LinkUp program provides an informative and detailed summary of current activities regarding the use of RAS in HMA within the Puget Sound regional area as well as nationwide progress. King County Roads Division should follow up on the progress and continue to communicate and collaborate with King County Agencies, other local government agencies, and WSDOT on the progress of utilizing RAS in HMA.

Respectfully Submitted,

King County Materials Laboratory

ALAN D. CORWIN
STATE OF WASHINGTON
30703
REGISTERED
PROFESSIONAL ENGINEER

10/1/13

Alan D. Corwin, P.E.
Materials Engineer

Kevin L. Kelsey
Senior Engineer

12.0 REFERENCES

AASHTO MP015 09 UL: *Standard Specification for Use of Reclaimed Asphalt Shingles as an additive in Hot Mix Asphalt (HMA)*, 2009.

AASHTO PP 53-09, *Design Considerations When Using Reclaimed Asphalt Shingles (RAS) in New Hot Mix Asphalt (HMA)*, 2009.

ASTM Standards, Volume 04.03, *ASTM D 6433-07 Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*, 2009.

Dan Krivit (Foth Infrastructure & Environment, LLC) memo to Kris Beatty, King County, *"Value of Recycled Asphalt Shingles in the Puget Sound Area: An Economic Assessment"*, May 31, 2012.

Dan Krivit (Foth Infrastructure & Environment, LLC) memo to Kris Beatty, King County, *"RAS Market Development: "A Discussion of Two Options for Affirmative Purchasing Policies*, May 31, 2012.

King County Executive Services, *Strategic Climate Action Plan*, December 2012.

King County Department of Transportation, Road Services Division, *SE 416th Street Overlay: Shingles in Paving Demonstration, Special Provisions*, June 2009.

King County Department of Natural Resources and Parks, Solid Waste Division, LinkUp website - http://your.kingcounty.gov/solidwaste/linkup/shingles/paving-project.asp

King County Materials Laboratory, *Technical Support Document for SE 416th Street Overlay: Shingles in Paving Demonstration*, January 2010.

Northwest Pavement Management Association, *Pavement Surface Condition Field Rating Manual for Asphalt Pavement, Second Edition*, undated.

WSDOT Materials Manual website:
http://www.wsdot.wa.gov/publications/manuals/fulltext/M46-01/Materials.pdf, 2009 Edition

WSDOT: *"Selected Sections of the WSDOT Construction General Special provisions (GSPs): Excerpt Pertaining to Reclaimed Asphalt Shingles (RAS)"* as prepared for King County Linkup program by Dan Krivit, Foth Infrastructure & Environment, LLC (March 13, 2013).

APPENDIX A

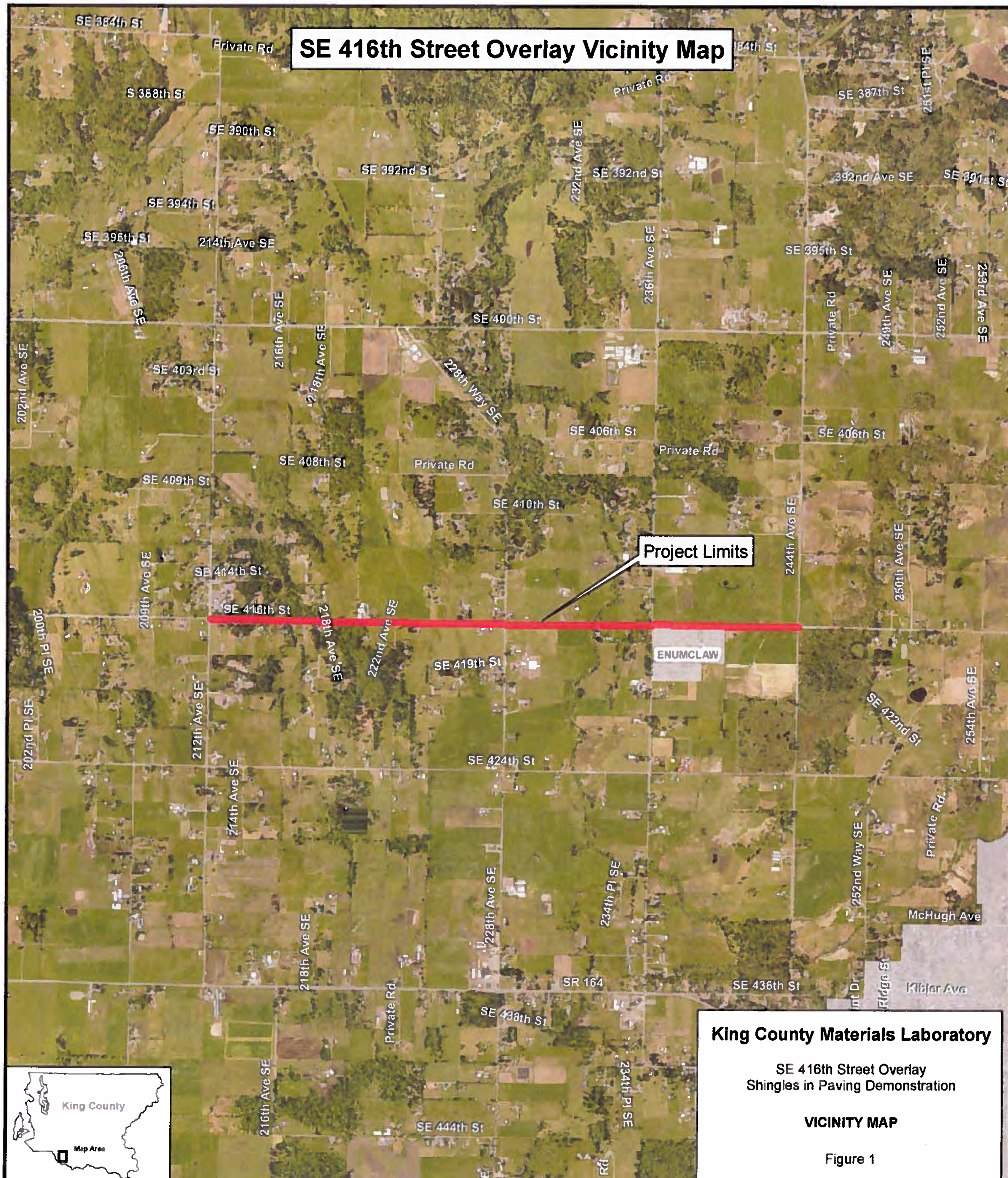
SE 416th Street Overlay: Shingles in Paving Demonstration

Post-Construction Pavement Conditions
Final Report
King County Materials Laboratory

Vicinity Map, Figure 1

Test Section Layout, Figure 2

SE 416th Street Overlay Vicinity Map



King County Materials Laboratory

SE 416th Street Overlay
Shingles in Paving Demonstration

VICINITY MAP

Figure 1

Project Limits

City

2009 King County natural color orthophoto - 0.5 GSD

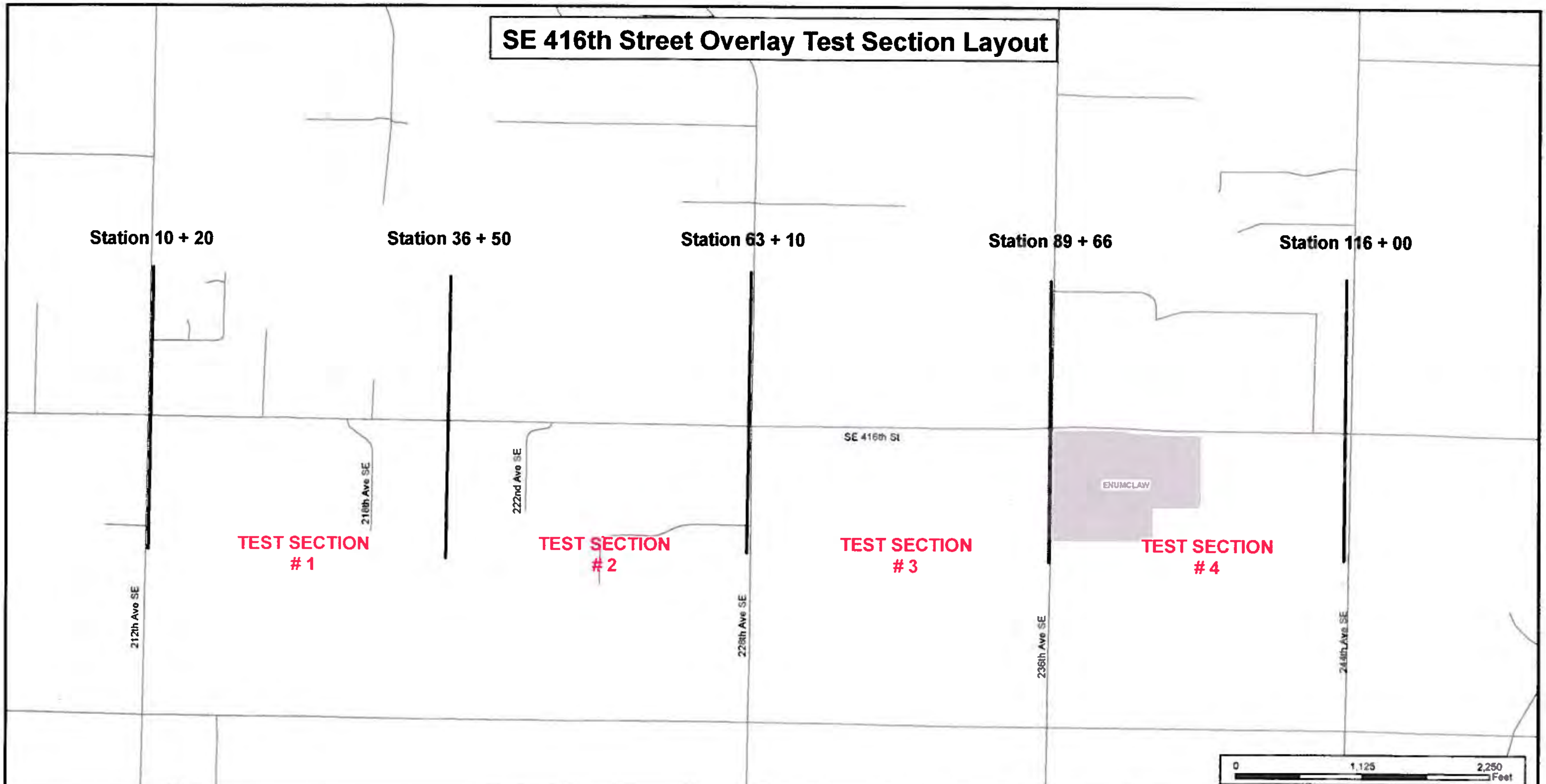
N

January 7, 2010

0 0.25 0.5 Miles

File Name:
KG TUdevelopment\ArcMap\ArcMapProjects\SE_416th_St_vicinity_map.mxd
Data Sources:
Standard King County datasets used include: trans_network,
2009 King County natural color orthophoto - 0.5 and 1.0 ft GSD
Roads Datasets include SE314thSt

King County
Department of Transportation
Road Services Division
Technology Unit



King County Materials Laboratory

SE 416th Street Overlay
Shingles in Paving Demonstration

TEST SECTION LAYOUT

Figure 2

Station Line
Street Network

N

January 7, 2010

File Name:
KC TUdevelopment\ArcMap\ArcMapProjects\SE_416th_St_test_section_map.mxd
Data Sources.
Standard King County datasets used include trans_network
Roads Datasets include SE416thSt_stationing

King County
Department of Transportation
Road Services Division
Technology Unit

APPENDIX B

SE 416th Street Overlay: Shingles in Paving Demonstration

Post-Construction Pavement Conditions
Final Report
King County Materials Laboratory

WSDOT General Special Provisions
Pertaining to the use of RAS
(Composite of Excerpts)

DISCLAIMER

The following information consists of a composite of excerpts from Division 5 Surface Treatments and Pavements of the WSDOT General Special Provisions pertaining to the use of RAS in HMA and is current to March 14, 2013. We expect the Special Provisions for the use of RAS will be frequently updated. Therefore, the composite of excerpts included in this appendix should be utilized as reference materials only. The latest changes and updates to the WSDOT Special Provisions can be found at the following website:

http://www.wsdot.wa.gov/Business/Construction/GSPs.htm

WSDOT GSP Web Links

[Selected Sections of the WSDOT
Construction General Special Provisions (GSPs)]
http://www.wsdot.wa.gov/Business/Construction/GSPs.html
Division 5 - Surface Treatments and Pavements:
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/egsp5.pdf
Section 5-04. GR5 Hot Mix Asphalt:
Subsection 5-04.2. GR5 Materials

Pertaining to Reclaimed Asphalt Shingles (RAS)

The new GSP on the WSDOT web pages (with latest posting date of January 7, 2013), but they are contained in several sections of WSDOT specs in the following PDF documents. "Section 5-04.2 is revised to read: ..... "each subsection contains the preface:

> "(Utilizes recycled asphalt pavement (RAP) or reclaimed asphalt shingles (RAS) in production HMA) ..... "
>
> "Use in all HMA paving projects. Headquarters Construction Office approval required to not use. This provision allows the use of recycled asphalt pavement (RAP) or reclaimed asphalt shingles (RAS) in the production of HMA ......"

[A – Introduction]
(January 7, 2013) **[REVISED]**
5-04.2.0PT8.GR5
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.2.OPT8.GR5.PDF

[B] Asphalt Material, General
5-04.2(9-02.1).OPT1.GR5
(August 2, 2012) **[UNCHANGED]**
[Specifications for the recycling agent used to rejuvenate the recovered asphalt.]
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.2(9-02.1).OPT1.GR5.pdf

[C] HMA Test Requirements
5-04.2(9-03.8(2)).0PT1.GR5
(November 12, 2012) **[REVISED]**
[Specifications for: voids in mineral aggregate (VMA); voids filled with asphalt (VFA); final HMA mix gradations; other mix design requirements; etc..]
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.2(9-03.8(2)).OPT1.GR5.pdf

[D] Gradation - Recycled Asphalt Pavement and Mineral Aggregate
(August 2, 2012) **[UNCHANGED]**
5-04.2(9-03 .8(3)B).OPT1.GR5
[RAP and RAS gradation requirements; Extraneous materials limits.]
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.2(9-03.8(3)B).OPT1.GR5.pdf

[E] General Requirements
5-04.2(9-03.21 (l)).OPT1 .GR5
(August 2, 2012) **[UNCHANGED]**
[Asbestos fibers limits.]
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.2(9-03.21(1)).OPT1.GR5.pdf

[F] HMA Mixing Plant
(November 12, 2012) **[REVISED]**
5-04.3(1). OPT1.GR5
[Requirement for screens or lump breaker.]
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.3(1).OPT1.GR5.pdf

[G] Preparation of Aggregates
5-04.3(7).0PT1.GR5
(August 6, 2012)) **[UNCHANGED]**
[Requirement for: stockpiling storage; blending of RAP with RAS; minimizing segregation; etc.]
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.3(7).OPT1.GR5.pdf

[H] Mix Design - General
5-04.3(7)Al.OPT1.GR5
(August 6, 2012) **[UNCHANGED]**
[Mix designing requirements; total recycled (RAP+RAS) binder limits shall not exceed a maximum of 40 percent of total binder; testing of RAP and RAS stockpiles to determine percent of recycling agent and/or grade of new asphalt binder; testing requirements; etc.]
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.3(7)A1.OPT1.GR5.pdf

[I] Statistical or Nonstatistical Evaluation
5-04.3(7)A2.0PT1.GR5
(November 12, 2012) **[REVISED]**
[Statistical evaluation requirements including sampling of RAP, RAS and recovered asphalt residue from RAP and RAS, Contracting Agency determination of anti-strip requirements, in any; Mix design/anti-strip evaluation report; Verification or rejection of mix design based on verification testing; etc.]
http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.3(7)A2.OPT1.GR5.pdf

[J] Mixing
5-04.3(8). OPT1.GR5
(August 6, 2012) **[UNCHANGED]**
[Requirements for HMA mixing to ensure complete and uniform coating of particles and thorough distribution of the asphalt binder; Optimum mixing temperature limits; Storage limits of finished HMA; Sizing of RAP and RAS to ensure uniform mixing and production of HMA etc.]

http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.3(8).OPT1.GR5.pdf

[K] Test Section-HMA Mixtures
5-04.3(8)A 7.0PTl.GR5
(August 6, 2012) **[UNCHANGED]**
[Test section requirements; Quantity of HMA shall be 600 to 1,000 tons; Mixture in the test section evaluated as a lot with a minimum of three sub lots required; Pay factor requirements shall be 0.95 or greater for each constituent; QA price adjustments; etc.]

http://www.wsdot.wa.gov/publications/fulltext/projectdev/gspspdf/5-04.3(8)A7.OPT1.GR5.pdf

A

Introduction

5-04.2.0PT8.GR5

(January 7, 2013)
Materials shall meet the requirements of the following sections:

Asphalt Binder	9-02.1(4)
Cationic Emulsified Asphalt	9-02.1(6)
Anti-Stripping Additive	9-02.4
Warm Mix Asphalt Additive	9-02.5
Aggregates	9-03.8
Recycled Asphalt Pavement	9-03.8(3)B
Blending Sand	9-03.8(4)
Mineral Filler	9-03.8(5)
Recycled Material	9-03.21

The Contract documents may establish that the various mineral materials required for the manufacture of HMA will be furnished in whole or in part by the Contracting Agency. If the documents do not establish the furnishing of any of these mineral materials by the Contracting Agency, the Contractor shall be required to furnish such materials in the amounts required for the designated mix. Mineral materials include coarse and fine aggregates, blending sand, and mineral filler.

The Contractor may choose to utilize recycled asphalt pavement (RAP) or reclaimed asphalt shingles (RAS) in the production of HMA. The RAP may be from pavements removed under the Contract, if any, or pavement material from an existing stockpile. The RAS may be from reclaimed shingles.

If greater than 20 percent of the total weight of HMA is RAP or any amount of RAS is utilized in the production of HMA, the Contractor shall sample and test the RAP and RAS during stockpile construction in accordance with WSDOT FOP for AASHTO T 308 for the determination of the asphalt binder content and WSDOT FOP for WAQTC/AASHTO T 27/T 11 for the gradation of the aggregates. The RAP shall be sampled and tested at a frequency of one sample for every 1,000 tons produced and not less than ten samples per project. The RAS shall be sampled and tested at a frequency of one sample for every 100 tons produced and not less than ten samples per project. The asphalt content and gradation test data shall be reported to the Contracting Agency prior to or when submitting the mix design for verification testing. If utilized, the amount of RAS shall not exceed 5-percent of the total weight of the HMA. The Contractor shall include the RAP and RAS as part of the mix design as defined in these Specifications.

The grade of asphalt binder shall be as required by the Contract. Blending of asphalt binder from different sources is not permitted. For HMA with either a RAP percentage greater than 20 percent of the total weight or any amount of RAS the final blended asphalt binder (after inclusion of RAP, RAS, new asphalt binder and recycling agent) shall be the grade as required by the Contract and comply with the requirements of Section 9-02.1(4).

The Contractor may use warm mix asphalt (WMA) processes in the production of HMA with a RAP percentage of 20 percent of the total weight or less. WMA processes shall not be used in the production of HMA with a RAP percentage greater than 20 percent of the total weight or any amount of RAS. The Contractor shall submit to the Engineer for approval the process that is proposed and how it will be used in the manufacture of HMA.

When the Contracting Agency provides aggregates or provides a source for the production of aggregates, the Contract Provisions will establish the approximate percentage of asphalt binder required in the mixture for each class of HMA.

Production of aggregates shall comply with the requirements of Section 3-01.

Preparation of stockpile site, the stockpiling of aggregates, and the removal of aggregates from stockpiles shall comply with the requirements of Section 3-02.

B

Asphalt Material, General

5-04.2(9-02.I).OPT1.GR5

(August 2, 2012)

The recycling agent used to rejuvenate the recovered asphalt from recycled asphalt pavement (RAP) and reclaimed asphalt shingles (RAS) shall meet the specifications in Table 1:

Table 1		**RA 1**		**RA 5**		**RA 25**	
Test	**ASTM Test Method**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Viscosity @ 140°F cSt	D2170 or D2171	50	150	200	800	1000	4000
Flashpoint COC, °F	D92	400		400		400	
Saturates, Wt. %	D2007		30		30		30
Specific Gravity	D70 or D2198	Report		Report		Report	
Tests on Residue from RTFC	D2872						
Viscosity Ratio[1]			3		3		3
Mass Change ± %			4		4		4

[1]Viscosity Ratio = $\frac{\text{RTFC Viscosity @ 140°F, cSt}}{\text{Original Viscosity @ 140°F, cSt}}$

C

HMA Test Requirements

5-04.2(9-03.8(2)).0PT1.GR5

(November 12, 2012)
The mix design shall produce HMA mixtures when combined with RAP, RAS, coarse and fine aggregate within the limits set forth in Section 9-03.8(6) and mixed in the laboratory with the designated grade of asphalt binder, using the Superpave gyratory compactor in accordance with WSDOT FOP for AASHTO T 312, and at the required gyrations for N initial, N design, and N maximum with the following properties:

	HMA Class							
	⅜ inch		**½ inch**		**¾ inch**		**1 inch**	
Mix Criteria	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Voids in Mineral Aggregate (VMA), %	15.0		14.0		13.0		12.0	
Voids Filled With Asphalt (VFA), %								
ESAL's (millions)	VFA							
< 0.3	70	80	70	80	70	80	67	80
0.3 to < 3	65	78	65	78	65	78	65	78
3 to < 10	73	76	65	75	65	75	65	75
10 to < 30	73	76	65	75	65	75	65	75
≥ 30	73	76	65	75	65	75	65	75
Dust/Asphalt Ratio	0.6	1.6	0.6	1.6	0.6	1.6	0.6	1.6
Stripping Evaluation, WSDOT Test Method T 718	Pass		Pass		Pass		Pass	
[1]Hamburg Wheel-Track Testing, AASHTO T 324 Rut Depth (mm) @ 20,000 Passes		12.5		12.5		12.5		12.5
[1]Texas Department of Transportation Indirect Tensile Strength Test, Tex-226 -F(psi)		150		150		150		150

	ESAL's (millions)	**N initial**	**N design**	**N Max.**
% Gmm	< 0.3	≤ 91.5	96.0	≤ 98.0
	0.3 to < 3	≤ 90.5	96.0	≤ 98.0
	≥ 3	≤ 89.0	96.0	≤ 98.0
Gyratory Compaction(number of gyrations)	< 0.3	6	50	75
	0.3 to < 3	7	75	115
	3 to < 30	8	100	160
	≥ 30	9	125	205

[1]This test applies only to mix designs with greater than 20 percent of the total weight RAP or any amount of RAS.

D

Gradation

Recycled Asphalt Pavement and Mineral Aggregate

5-04.2(9-03 .8(3)B).OPT1.GR5

(August 6, 2012)
For HMA with a RAP percentage greater than 20 percent of the total weight the RAP shall be processed to ensure that 100 percent of the material passes a sieve twice the size of the maximum aggregate size for the class of mix to be produced.

When RAS is used in the production of HMA the RAS shall be milled, crushed or processed to ensure that 100 percent of the material passes the ½ inch sieve. Extraneous materials in RAS such as metals, glass, rubber, soil, brick, tars, paper, wood and plastic shall not exceed 2.0 percent by mass as determined on material retained on the No. 4 sieve.

E

General Requirements

5-04.2(9-03.21 (l)).OPT1 .GR5

(August 2, 2012)
Reclaimed asphalt shingles samples shall contain less than the maximum percentage of asbestos fibers based on testing procedures and frequencies established in conjunction with the specifying jurisdiction and state or federal environmental regulatory agencies.

F

HMA Mixing Plant

5-04.3(1). OPT1.GR5

(November 12, 2012)

6. **Equipment for Processing RAP and RAS.** When producing HMA for mix designs with greater than 20 percent of the total weight RAP or any amount of RAS the HMA plant shall be equipped with screens or a lump breaker to eliminate oversize RAP/RAS particles from entering the pug mill or drum mixer.

G
Preparation of Aggregates
5-04.3(7).0PT1.GR5

(August 6, 2012)
The aggregates, RAP and RAS shall be stockpiled according to the requirements of Section 3-02. Sufficient storage space shall be provided for each size of aggregate, RAP and RAS. The Contractor may uniformly blend fine aggregate or RAP with the RAS as a method of preventing the agglomeration of RAS particles. The aggregates, RAP and RAS shall be removed from stockpile(s) in a manner to ensure a minimum of segregation when being moved to the HMA plant for processing into the final mixture. Different aggregate sizes shall be kept separated until they have been delivered to the HMA plant.

H
Mix Design - General
5-04.3(7)AI.OPT1.GR5

(August 6, 2012)

For mix designs with greater than 20 percent of the total weight RAP or any amount of RAS the Contractor shall develop a mix design including RAP, RAS, recycling agent and new asphalt binder. The mix design aggregate structure, RAP, RAS, recycling agent and new asphalt binder content shall be determined in accordance with Materials Manual WSDOT Standard Operating Procedure No. 732 and meet the requirements of Sections 9-03.8(2) and 9-03.8(6). The total quantity of asphalt binder contributed from the RAP and RAS shall not exceed 40 percent of the total asphalt binder content of the HMA. Once the RAP and RAS stockpiles have been constructed the Contractor shall extract, recover and test the asphalt residue from the RAP and RAS stockpiles to determine the percent of recycling agent and/or grade of new asphalt binder needed to meet the grade of asphalt binder required by the contract. The asphalt extraction testing shall be performed in accordance with AASHTO T 164 or ASTM D 2172 using reagent grade trichloroethylene. The asphalt recovery shall be performed in accordance with AASHTO T 170, ASTM D 1856. The recovered asphalt residue shall be tested in accordance with AASHTO R 29 to determine the asphalt binder grade in accordance with Section 9-02.1(4). Once the recovered asphalt binder grade is determined the percent of recycling agent and/or grade of new asphalt binder shall be determined in accordance with ASTM D 4887. The final blend of recycling agent, recovered and new asphalt shall be tested in accordance with AASHTO R 29 to confirm that it meets the grade of asphalt binder required by the contract in accordance with Section 9-02.1(4). All recovered and blended asphalt binder test data shall be reported to the Contracting Agency prior to or when submitting the mix design for verification testing.

I

Statistical or Nonstatistical Evaluation

5-04.3(7)A2.0PT1.GR5

(November 12, 2012)
Mix designs for HMA accepted by statistical and nonstatistical evaluation shall be submitted to the Project Engineer on WSDOT Form 350-042. For a mix design that was originally developed for another WSDOT contract, the Contractor shall also submit WSDOT Form 350-041 and include all changes to the job mix formula that have been approved on other contracts

For mix designs for HMA accepted by statistical and nonstatistical evaluation, which have 20 percent or less total weight RAP and no RAS, the Contractor shall submit representative samples of the mineral materials that are to be used in the HMA production. The Contracting Agency will use these samples to determine anti-strip requirements, if any, in accordance with WSDOT Test Method T 718. Anti-strip evaluation of HMA mix designs proposed by the Contractor that include 20 percent or less total weight RAP and no RAS will be completed without the inclusion of the RAP. Submittal of RAP samples is not required. A mix design/anti-strip evaluation report will be provided within 25 calendar days after a mix design submittal has been received in the State Materials Laboratory in Tumwater. No paving shall begin prior to issuance of the mix design/anti-strip evaluation report or reference mix design/anti-strip evaluation report for that year.

Mix designs for HMA accepted by statistical and nonstatistical evaluation, which have greater than 20 percent of the total weight RAP or any amount of RAS shall be submitted to the Project Engineer for verification testing. The Contractor shall submit representative samples of the mineral materials, RAP, RAS and 100 grams of recovered asphalt residue from the RAP and RAS that are to be used in the HMA production. The Contracting Agency will use the recovered asphalt residue samples to conduct verification testing of the final blended asphalt binder in accordance with Section 9-02.1(4). The Contracting Agency will use the mineral aggregate, RAP and RAS to conduct verification testing of the mix design in accordance with WSDOT Standard Operating Procedure 732 and to determine anti-strip requirements, if any, in accordance with WSDOT test method T 718. A mix design/anti-strip evaluation report will be provided within 25-calendar days after a mix design submittal has been received in the State Materials Laboratory in Tumwater. No paving shall begin prior to issuance of the mix design/anti-strip evaluation report for that year. If the results of the verification testing by the Contracting Agency of the final blended asphalt binder meets the requirements of Section 9-02.1(4) and the mix design including RAP and RAS is within the tolerances in Section 9-03.8(7) the mix design will be considered verified. If the results of the verification testing of the final blended asphalt binder fails to meet the requirements of Section 9-02.1(4) or the mix design including RAP and RAS is not within the tolerances in Section 9-03.8(7) the mix design will be rejected.

J

Mixing

5-04.3(8). OPT1.GR5

(August 6, 2012)
The following requirements shall apply to mix designs with greater than 20 percent of the total weight RAP or any amount of RAS:

After the required amounts of mineral materials, RAP, RAS, new asphalt binder and asphalt rejuvenator have been introduced into the mixer the HMA shall be mixed until a complete and uniform coating of the particles and a thorough distribution of the asphalt binder throughout the mineral materials, RAP and RAS is ensured.

When discharged, the temperature of the HMA shall not exceed the optimum mixing temperature by more than 25°F as shown on the mix design/anti-strip evaluation report or as approved by the Engineer. Storing or holding of the HMA in approved storage facilities will be permitted during the daily operation but in no event shall the HMA be held for more than 24 hours. HMA held for more than 24 hours after mixing shall be rejected. Rejected HMA shall be disposed of by the Contractor at no expense to the Contracting Agency. The storage facility shall have an accessible device located at the top of the cone or about the third point. The device shall indicate the amount of material in storage. No HMA shall be accepted from the storage facility when the HMA in storage is below the top of the cone of the storage facility, except as the storage facility is being emptied at the end of the working shift.

Recycled asphalt pavement (RAP) and reclaimed asphalt shingles (RAS) utilized in the production of HMA shall be sized prior to entering the mixer so that a uniform and thoroughly mixed HMA is produced. If there is evidence of the RAP or RAS not breaking down during the heating and mixing of the HMA, the Contractor shall immediately suspend production of HMA until changes have been approved by the Project Engineer.

K

Test Section-HMA Mixtures

5-04.3(8)A 7.0PTI.GR5

(August 6, 2012)
The following requirements shall apply to mix designs with greater than 20 percent RAP by weight or RAS:

For each class of HMA accepted by statistical evaluation, the Contractor shall construct a test section to determine whether the mixture meets the requirements of Sections 9-03.8(2) and 9-03.8(6). The test section shall be constructed at the beginning of paving and will be at least 600 tons and a maximum of 1,000 tons or as approved by the Project Engineer. No further wearing or leveling HMA will be paved the day of or the day following the construction of the test section. The mixture in the test section will be evaluated as a lot with a minimum of three sublots required. If more than one test section is required, each test section shall be a separate lot.

For a test section to be acceptable the pay factor (PF) for gradation, asphalt binder and Va shall be 0.95 or greater for each constituent and the remaining test requirements in Section 9-03.8(2) (dust/asphalt ration, sand equivalent, uncompacted void and fracture) shall conform to the requirements of that section.

For all HMA of the same class and PG asphalt binder grade, payment for the HMA test section(s) will be in accordance with the provisions of 5-04.5(1) Quality Assurance Price Adjustments.