Long-Term Performance of a Hot In-Place Recycling Project — Final Report

WA-RD 738.2

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Long-Term Performance of a Hot In-Place Recycling Project Final Report

Contract 7648
SR-542
Britton Road to Coal Creek Bridge Vicinity
MP 3.38 to MP 19.27




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16. ABSTRACT

This report documents the construction and long-term performance of a hot in-place recycled (HIPR) project on SR 542. HIPR project selection, mix design, construction and testing are described. It was shown that the HIPR process successfully rehabilitated the pavement using less new material than a traditional HMA mill and fill while reducing project costs and traffic disruptions as compared to conventional HMA construction. The roadway met the design criteria according to the Asphalt Recycling and Reclaiming Association.

Performance of the HIPR was monitored for 6 years using periodic photos of the pavement and data from the Washington State Pavement Management System (WSPMS). The HIPR pavement after construction was observed to have an open texture and dry appearance, possibly due to inadequate asphalt binder content. The pavement is currently characterized by a raveled surface with alligator and longitudinal cracking at various locations. The poor performance has been attributed to insufficient asphalt binder in the HIPR mix. The HIPR process may have been a contributing factor due to aging of the binder in the existing pavement, but was not the primary cause of the pavement's poor performance.

Due to the poor condition of the pavement a chip seal is programmed for 2018. A life cycle cost analysis showed the HIPR to have an annual per lane mile cost $3,700 more than a conventional 0.15' mill and fill HMA pavement.

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Introduction

Hot in-place recycling (HIPR) is a technology that promises to reduce energy consumption and lower the cost of hot mix asphalt (HMA) pavement rehabilitation. The traditional method of recycling HMA pavement in Washington State is to grind the top layer of the existing pavement, truck it back to the asphalt plant, stockpile it, and then incorporate it back into new HMA. HIPR eliminates the trucking and handling of the recycled HMA by performing the complete process in one pass. If successful, the HIPR process will provide the Washington State Department of Transportation (WSDOT) an additional rehabilitation technology that potentially saves money and conserves resources. This final report summarizes the construction of the project and the performance after five years of traffic, as required in the experimental feature work plan (Appendix A).

Definitions

During the HIPR process the bituminous mixture takes several different forms. These include the HMA pavement before it is recycled, the loose mix during the recycling process and the finished HIPR pavement. To avoid confusion, it is necessary to have a clear definition of the bituminous mixture during each stage. To that end this report uses the following definitions to describe the forms the bituminous mixture can take during the different stages of the HIPR process:

Existing HMA Pavement: The HMA pavement in the roadway to be rehabilitated before milling.

Hot Millings: The existing HMA after it has been milled from the roadway prior to being placed back on the roadway by the paver.

Admixture: Additional virgin asphalt and aggregate added to the hot millings during the HIPR process.

HIPR Pavement: Pavement recycled by the HIPR process after it has been placed by the paving machine.

HIPR Process

HIPR is a process by which rehabilitation of the existing HMA pavement occurs on site in one operation. The process begins by heating the existing HMA pavement to a temperature high enough to allow milling or scarifying equipment to easily remove the upper layer of existing HMA pavement from the roadway surface. After removal from the roadway, some HIPR processes improve the properties of the HIPR pavement by adding aggregate, asphalt and rejuvenator to the hot millings. Finally, conventional paving equipment is used to spread and compact the recycled mix. The Asphalt Recycling and Reclaiming Association (ARRA) identify three HIPR processes; (1) surface recycling, (2) remixing and (3) repaving (ARRA 2001):

Surface recycling is the oldest and simplest HIPR process. The existing HMA pavement is softened by heating before being milled or scarified from the surface. The hot millings are then mixed, spread and re-compacted without any further processing. Rejuvenating agent may be added to the hot millings if needed. Surface recycling can only rehabilitate the top inch of pavement and is often followed by an HMA or bituminous surface treatment (BST) overlay.

The remixing process is similar to surface recycling with the advantage that improvement of the mix properties is possible by adding virgin aggregate and binder, in the form of admixture, to the hot millings. Heating and scarifying can occur in one or multiple passes allowing recycling depths of two inches or more. The HIPR subcontractor on the SR 542 project, GreenRoads Recycling, used a two stage remixing process. Later sections of this report include a more in depth description of the process and equipment used on the SR 542 project.

Repaving combines the HIPR process with a new HMA overlay. The top layer of the existing HMA pavement is recycled and improved just as in the remixing process. A new layer of conventional HMA is immediately placed over the HIPR pavement that was just recycled. Both lifts are then compacted together with the same compaction equipment.

HIPR Benefits

HIPR has the following benefits (ARRA 2001, Button et al. 1999, Pierce 1996):

- HIPR recycles 100 percent of the existing pavement reducing the need for new aggregate and asphalt.
- Uses less energy than other rehabilitation methods.
- Heating and softening of the existing HMA pavement before planing reduces the amount of aggregate breakage when compared to cold planing.
- HIPR does not require transportation of large quantities of new material to the job site resulting in less traffic disruptions from trucks entering and leaving the work area.
- HIPR lay down temperatures are lower than conventional HMA and the paving train moves slower. Both of these factors reduce the length of lane closures as compared to conventional HMA. The shorter lane closures mean traffic can pass through the work area more quickly, reducing delays.
- The initial cost of HIPR pavement is less than traditional HMA.

HIPR Project Selection

Not all HMA rehabilitation projects are appropriate for HIPR. Careful evaluation of the existing HMA pavement and site conditions is necessary before selecting HIPR as a potential rehabilitation strategy. Pavement designers should consider the following factors when determining whether a project is a good candidate for HIPR.

Pavement Structure

As is the case with an HMA overlay or mill and fill, HIPR cannot correct deficiencies in the underlying pavement structure. HIPR does not add structure so roadways with insufficient structure are not good candidates. Depth of recycling is normally limited to two inches. Correction of cracks that extend below this depth is necessary before the HIPR or they may reflect through the new pavement. Correction of base failures is also necessary before HIPR paving. Verifying the depth of existing HMA is advised prior to choosing HIPR as a rehabilitation strategy. ARRA recommends that the existing HMA be at least three inches in depth to prevent pulling up the underlying HMA during HIPR paving (ARRA, 2001).

Material Deficiencies

Evaluation of the constituent materials and properties of the existing HMA pavement is essential to ensure that construction of an acceptable HIPR pavement is possible. Currently the remixing process only allows the addition of about 30 percent new material to the HIPR pavement. As a result, the properties of the existing HMA pavement will have the largest impact on the properties of the finished HIPR pavement. Investigation of problems like stripping and raveling are important because their cause is usually due to aggregate or binder properties which the HIPR process might not be able to correct. Mixes with too much asphalt or dry mixes are not good candidates unless enough material can be added to completely correct the problem. Mix consistency is also important in determining the suitability of existing HMA pavement for HIPR. Changes in the existing HMA pavement materials, gradation or asphalt content will change the properties of the finished HIPR pavement. If not accounted for during mix design these changes may affect mix quality.

The presence of surface treatments such as chip seals can affect HIPR paving. Surface treatments tend to insulate the underlying HMA making heating more difficult (Pierce, 2006). The gradation of a chip seal may also be undesirable. Removal of surface treatments should be considered before performing HIPR.

Geometric Elements

A HIPR paving train is not as maneuverable or flexible as conventional paving equipment. A HIPR paving train cannot be easily backed up to pave gore areas and turn lanes that were missed in the initial pass, making projects with many such areas costlier to pave using the HIPR process. Sharp curves can also pose a problem for HIPR. The longest piece of equipment used on SR 542 was 60 feet. Equipment this long needs to be able to maneuver around any sharp curves while keeping its heaters and milling heads properly oriented over the lane being rehabilitated. The width of the heaters and milling heads restrict the width of paving. Paving wide lanes or paving the lane and shoulder simultaneously is impossible. Paving narrow areas is also not possible due to the width of the grinding heads. The relatively small amount of additional mix (30 percent) limits the ability to correct defects in the roadway profile and cross slope. Roadways that require cross slope correction or correction of frequent dips are not good candidates for HIPR.

Constructability

The HIPR train moves slower than a conventional paving operation. The amount of time needed for the HIPR paving train to pass side roads and driveways may require detours or other accommodation to get traffic past the closure in a reasonable amount of time. HIPR can pave over utility covers but placement will be slower (Pierce, 1996). Evaluation of the effects of lower productivity and longer duration closures is advisable on roadways with many utility covers. Overnight storage of HIPR equipment is also a constructability concern. HIPR equipment requires more parking space than conventional paving equipment and takes considerably more time to pick up and mobilize to a different location. Pullouts or parking areas of sufficient size to accommodate the HIPR equipment spaced about one day's production (about 1 to 2 miles) apart should be available along the roadway.

The heaters have the potential to ignite flammable materials. Investigation of sources of flammable gases such as sewers and areas of increased fire danger is necessary before selecting HIPR as a rehabilitation strategy. The heaters also vent hot gas above the unit. Anything overhanging the roadway that may be affected by the hot gases must be addressed during HIPR placement.

Environmental Considerations

Unlike conventional paving, emissions from HIPR mix production occur on the project site instead of at an asphalt plant. When evaluating a project for HIPR designers must consider the affect that these emissions may have. HIPR equipment uses incinerators to remove pollutants but this may not be sufficient in areas that are sensitive to air quality changes. Rubberized crack sealing materials in the roadway can cause increased emissions during HIPR paving which could be a factor when evaluating the suitability of HIPR. WSDOT's current crack sealing procedure uses a sand slurry mixture made with emulsified asphalt. Since

WSDOT's process only uses asphalt and no rubber materials, cracks sealed using the WSDOT procedure should not cause increased emissions.

Project Background

Contract 7648, SR 542 Britton Road to Coal Creek Bridge Vicinity, is located in Whatcom County east of the city of Bellingham. The section of SR 542 rehabilitated with the HIPR process starts 3.38 miles east of the junction with Interstate 5 (Milepost 3.38) and ends 3.5 miles west of the junction with SR 547 (Milepost 19.27). This section of SR 542 is an undivided highway with one lane in each direction and is classified as a rural arterial. Channelization in the form of left and/or right turn lanes is provided at major intersections and there is a two way left turn lane through the town of Deming (MP 13.48 to 13.81). The terrain is rolling with many side roads and driveways. Figure 1 shows the project location.

Figure 1. Project location.

Traffic

Traffic volumes vary considerably within the project. The west end of the project is near the city of Bellingham resulting in AADT's as high as 12,000. The level of development decreases to the east and the AADT decreases correspondingly to a low of 4,900 at the eastern end of the project. Truck percentages are fairly consistent varying between 9.23 and 11.52 percent.

Contract Information

WSDOT awarded the contract for rehabilitating SR 542 to Granite Construction Inc. Along with managing the project, Granite Construction paved HMA in areas not designated for HIPR, designed the HIPR mix and produced the admixture for the HIPR in their asphalt plant. Granite selected GreenRoads Recycling out of Fernie, British Columbia to place the HIPR pavement. GreenRoads Recycling has considerable experience with HIPR having paved over 7,000 miles of roadway using the HIPR process (GreenRoads, 2009).

Existing HMA Pavement

As with any roadway that has been in service for a long period of time there are many variations in the roadway section. These variations are often short sections where a minor improvement was constructed (i.e. widening, intersection improvements, culvert replacements, local pavement failures, etc.). If the minor variations are ignored this section of SR 542 can be divided into three distinct roadway sections. The Northwest Region Pavement Rehabilitation Report in Appendix B includes the complete construction history for the roadway.

Milepost 3.38 to 9.43

The original pavement for this section of SR 542 was 0.50 feet of portland cement concrete pavement (PCCP) constructed in 1919. Projects in 1942, 1976 and 1993 placed a total depth of 0.29 feet of HMA over the PCCP. The most recent overlay was a 1/2 inch HMA placed in 1993 at a depth of 0.12 feet. In 1997 turn lanes were added to several intersections resulting in an additional 0.13 feet of HMA in these locations. The original PCCP driving lanes were only

16 feet wide. Prior to 1993 the driving lanes were widened to their present width of 22 feet using crushed rock and/or HMA to build up the existing shoulder to match the grade of the PCCP.

This section was experiencing low severity alligator cracking and maintenance patching mainly in the widened areas outside of the PCCP panels. Longitudinal and transverse cracking, mostly due to PCCP joints reflecting through the HMA, was also present. Rut depths averaged 0.27 inches with a minimum recorded depth of 0.17 inches and a maximum of 0.37 inches.

Milepost 9.43 to 9.94

Most of this section was reconstructed in 2001 as part of the project that replaced the Nooksack River Bridge. The roadway section consists of 0.40 feet of ½ inch HMA over 0.60 feet of untreated base. The only distress present on this section was some low severity longitudinal cracking. Average rut depth was 0.26 inches and varied between 0.23 and 0.30 inches.

Milepost 9.94 to 19.27

This section consists of 0.27 to 0.35 feet of ½ inch HMA placed over a BST roadway. Distress consisted of low to medium severity longitudinal, transverse and alligator cracking. Rutting on this section varied between 0.08 and 0.36 inches with a 0.22 inch average depth.

HIPR Mix Design Process

Many different methods have been used to design HIPR mixes but there is no nationally accepted method. The basic goal of any HIPR mix design method is to produce a recycled mix with properties as close to new HMA as possible (ARRA, 2001).

ARRA lists the following steps in developing a mix design for HIPR (ARRA, 2001):

- Evaluation of the existing HMA pavement
- Determination of recycling agent requirements
- Determination of admixture requirements
- Fabrication and testing of sample mixes
- Selection of optimum mix

The following summary of each step in the HIPR mix design process is based on information provided in the ARRA's Basic Asphalt Recycling Manual (ARRA, 2001).

Evaluation of the Existing HMA

Just as the gradation of the aggregate stockpiles and the properties of the asphalt binder need to be known to design a conventional HMA mix, the gradation and binder properties of the existing HMA pavement need to be known to design an HIPR mix. Determination of the gradation and binder properties of the existing HMA pavement requires testing of samples from the roadway. Samples can be in the form of cores, grindings or other methods. Regardless of the sampling method used, care should be exercised as to minimize cutting or breaking the aggregate as it will affect the gradation.

Determination of Rejuvenation Requirements

The asphalt binder in the existing HMA pavement will have aged as a result of exposure to air and water during its service life. Aging is a process by which oxygen reacts with molecules in the binder making it stiffer and less ductile. The loss of ductility makes the pavement more susceptible to cracking which can affect pavement life. Increased stiffness will make the recycled HMA more difficult to spread and compact during construction.

The purpose of rejuvenation is to restore the properties of the aged asphalt to those of new asphalt binder. Rejuvenation involves adding recycling agent or soft asphalt to the recycled mix. Recycling agents are a mixture of hydrocarbons that are mixed with aged asphalt binder to modify or improve its properties. Adding soft, new asphalt binder to aged asphalt binder will produce an "average" binder. Recycling agents and soft asphalt binders can be used together.

Determination of Admixture Requirements

The remix process allows the addition of virgin aggregate and asphalt binder to produce a final mix with the desired volumetric properties. The purpose of this step is to select the quantity, gradation and binder content of admixture.

Fabrication and Testing of Trial Mixes

In a conventional HMA mix design the aggregate gradation and asphalt binder grade are usually predetermined. The conventional HMA mix design process consists of testing several trial mixes prepared with varying amounts of asphalt to determine the asphalt content that yields the specified volumetric properties. Additional variables make the HIPR mix design process more complicated. The amount of recycling agent, the percentage of admixture, the admixture asphalt content and admixture gradation all need to be selected to produce a mix with the desired qualities. Properties of the existing HMA pavement can also change from location to location further complicating the process. There is no established procedure for HIPR mix design requiring the proportioning of trial mixes to depend on the experience of the mix designer.

Selection of Optimum Mix

The trial mixes are tested to determine if they meet the project requirements. If none of the trial mixes meets project requirements, more trial mixes with different proportions will need to be tested. Additional testing such as moisture susceptibility should be performed after the final mix design is selected.

SR 542 Mix Design

The contract specifications (Appendix B) required the Contractor to design the HIPR mix. The design was to use sufficient admixture to meet an air void specification of 2.5 to 5.5 percent when compacted to 75 gyrations in a Superpave gyratory compactor. Properties of the existing HMA pavement from roadway cores taken throughout the project were used to develop the mix design. The existing HMA pavement was placed under five separate projects between 1989 and 2001. Each project had a different mix design but all were ½ inch nominal maximum aggregate size dense graded mixes. The five mixes were similar enough to combine into one HIPR mix design for the entire project. The following outlines the mix design process used on this project based on information provided by Granite Construction during a meeting held on July 22, 2009.

Evaluation of the Existing HMA

Evaluation of the existing HMA included a combination of test results provided in the contract specifications and testing by Granite Construction as part of the mix design effort. Results of core testing are displayed in Tables 1 and 2. Appendix C includes the HIPR specifications for SR 542 which contains the complete results of the core testing performed by WSDOT before advertising the project.

Table 1. Gradation and asphalt content from core testing.

Sieve Size	WSDOT Avg. of 16 Core Locations	Standard Deviation	Granite Avg. of Cores from Locations 1 and 2	Granite Avg. of Cores from Locations 15 and 16
3/4 in	100	0.0	100	100
1/2 in	97	2.6	97.6	99.2
3/8 in	87	4.7	90.9	92.3
No. 4	61	4.6	64.4	66.2
No. 8	45	3.3	47.3	46.2
No. 16	33	2.5		
No. 30	23	1.9	24.8	21.6
No. 50	14	1.2		
No. 100	8	0.8		
No. 200	5.7	0.7	5.1	4.8
% Asphalt	5.9	0.5	5.8	5.7

Table 2. Binder properties obtained from cores.

Property	WSDOT		Granite	
	Core Location 1	Core Location 15	Core Location 1 and 2	Core Location 15 and 16
Viscosity @ 60C (Poise)	23,806	52,907	22,537	34,922
G* @ 60C (kPa)			18.89	26.85
G*/sinδ @ 64C (kPa)	9.99	21.86	10.37	27.6
Stiffness @ -12C (mPa)			378	157

Determination of Recycling Agent Requirements

Recycling agents improve the properties of the aged asphalt to a level adequate for use in the new HIPR pavement. The amount of recycling agent used on the SR 542 HIPR was determined by comparing the viscosity testing of the asphalt recovered from the existing HMA pavement to new asphalt binder typically used on WSDOT projects. The viscosity of the asphalt in the existing pavement was based on asphalt extracted from the cores (Table 2). Recommendations from the recycling agent supplier were also considered determining the amount of recycling agent needed.

Determination of Admixture Requirements

The gradation, asphalt content and amount of admixture were determined during the fabrication and testing of sample mixes on the SR 542 project. The contract specifications called for admixture to meet the gradation requirements for crushed screenings 5/8” - US No. 4; however, this gradation was not used. Granite Construction tested trial mixes using gradations for WSDOT’s Class D HMA and British Columbia’s Graded Aggregate Seal Class C. WSDOT Class D HMA is an open graded friction course that WSDOT stopped using in 2004. Graded Aggregate Seal Class C is normally used for surface treatments but it is also the gradation most often used as HIPR admixture in British Columbia. Based on recommendations from GreenRoads Recycling, the admixture selected for production was Graded Aggregate Seal Class C at 20 percent of the weight of the total mix. Table 3 displays gradation specifications for the various admixture options.

Table 3. Gradation specifications of admixture options.			
Sieve Size	Percent Passing		
	WSDOT Crushed Screenings 5/8" - US No. 4	WSDOT Class D HMA	B.C. Graded Aggregate Seal Class C
3/4 in.	100		
5/8 in.	95 - 100		100
1/2 in.		100	
3/8 in.		97 - 100	30 - 70
No. 4	0 - 10	30 - 50	25 - 45
No. 8		5 - 15	
No. 10	0 - 3		
No. 16			
No. 30			5 - 20
No. 50			
No. 100			
No. 200	0 – 1.5	2 - 5	0 - 3

Fabrication and Testing of Sample Mixes

Granite Construction began the mix design process by producing and testing three trial mixes. Only a limited amount of aggregate was available from the cores so the first three mixes were fabricated using virgin aggregate with a structure similar to that of the existing HMA pavement. The purpose of the first three mixes was to establish trial mix proportions while conserving the material from the cores for future testing.

Three additional trial mixes were developed using material from the cores. The first two used admixture meeting the gradation requirements of WSDOT Class D HMA. After testing the first two mixtures, Granite Construction used the Bailey Method (a method used to evaluate and select HMA aggregate proportions) to predict mix properties for various admixture options. The Bailey Method results and conversations with GreenRoads Recycling resulted in the fabrication of the third trial mix using British Columbia Graded Aggregate Seal Class C as the basis for the admixture gradation. Table 4 shows the results of gradation and volumetric testing of the three mixtures.

Table 4. Gradation and volumetric properties of trial blends.			
Sieve Size	Trial No. and Admixture (percent of mix and type)		
	Trial 1 20% Class D	Trial 2 5% Class D	Trial 3 20% Graded Agg. Seal Class C
	Percent Passing		
3/4 in.	100	100	100
1/2 in.	97.9	97.5	96.2
3/8 in.	88.0	87.2	85.1
No. 4	53.2	59.2	57.2
No. 8	37.6	42.9	42.0
No. 16	27.5	31.6	30.9
No. 30	19.4	22.2	21.4
No. 50	11.4	13.0	12.2
No. 100	6.6	7.4	6.9
No. 200	4.9	5.5	5.1
Volumetric Properties	Percent		
Pb of Admixture	1.65	1.65	4.5
Pb of total mix	5.0	5.6	5.5
Recycling Agent	0.25	0.25	0.25
VMA	13.9	13.4	13.6
Va	3.7	1.2	1.4

Selection of Optimum Mix

Although the specified air void content was not achieved, the final trial mixture using 20 percent British Columbia's Graded Aggregate Seal Class C was selected as the production mix. The reasons for this selection were:

- Graded Aggregate Seal Class C has a history of successful use on many HIPR projects in British Columbia.
- GreenRoads Recycling's experience is that material meeting the 5/8" - US No. 4 gradation specified by WSDOT would excessively cool the HIPR mix.
- It was felt that the 2.5 to 5.5 percent air void specification may not be achievable with the existing HMA pavement.

WSDOT had concerns about using a mix design with such low air voids due to the risk of rutting but allowed its use based on GreenRoads Recycling's stated success and experience. It was agreed that the asphalt content in the admixture would start at 4.5 percent. Samples would be taken at the start of paving to determine if any adjustments were needed.

SR 542 HIPR Construction

HIPR paving began on August 18, 2009 and ran through September 21. GreenRoads Recycling placed nearly 31 lane miles of HIPR in 25 working days. The average production was 1.3 lane miles per day with as much as 1.7 lane miles completed in one day. Most of the HIPR placement, a total of 16 days, occurred at night due to high daytime traffic. East of milepost 15, where traffic volumes were lower, nine days of HIPR placement occurred during the day. Weather was generally warm (50°F - 80°F) during daytime placement and cooler (30°F - 50°F) at night. Rainfall occurred on several nights but paving was either halted prior to the rain or the rain was short in duration and light enough to not affect the paving. Appendix D lists the daily HIPR production on SR 542.

Equipment

GreenRoads Recycling used HIPR equipment manufactured by Pyrotech Holdings Corporation consisting of two preheaters and two heater scarifiers. A third preheater was added to the paving train later in the project. A conventional asphalt paving machine spread the mixture and two double drum steel wheel rollers provided compaction. Solo end dumps delivered admixture to the second heater scarifier. The following describes the equipment and its function in the HIPR paving train based on field observations and information from the Pyrotech website (Pyrotech, 2009).

Preheaters

The purpose of the preheaters is to remove moisture from the pavement and begin the heating process. The preheaters consist of a five ton truck pulling a trailer equipped with propane burners housed in an insulated steel enclosure. A 1,500 gallon tank on the truck provides enough propane to operate the heater for an entire shift. Rubber tires on the rear of the trailer are removed and steel wheels support the trailer during operation.

Figure 2. Preheater unit consisting of a propane truck and trailer with propane fired heaters.

Figure 3. Removing rubber tires prior to paving.

Heater Scarifier (Unit A)

The two heater scarifiers do not perform identical operations. To differentiate between the two heater scarifiers, Pyrotech labels the first as Unit A and the second Unit B. Unit A uses propane-fired infrared heaters mounted on the front of the unit to heat the pavement to a depth of 1 to 1 ¼ inches. Two five-foot-wide milling heads then mill the outside five feet on both sides of the lane to a depth of one inch leaving a two-foot un-milled strip down the center. After milling, Unit A places the hot millings in a windrow and adds recycling agent to the windrowed hot millings. A trailer with propane-fired heaters pulled by Unit A provided additional heat to the pavement.

Figure 4. Front left side of Unit A.

Figure 5. Right rear of unit A and towed trailer with heater.

Figure 6. Milling head on left side of unit A.

Figure 7. Milled HMA behind unit A is windrowed into the center of the lane.

Heater Scarifier (Unit B)

The introduction of admixture occurs in Unit B. The front of this unit contains a hopper similar to a paving machine. End dumps back into the gap between Unit A and Unit B and place admixture into the hopper. Behind the hopper is a four-foot milling head which removes the one inch depth of existing HMA pavement from the center of the lane not removed by Unit A. The four foot milling head combines the new hot millings with the windrowed hot millings from Unit A and places them on a conveyer which transports them over a bank of propane-fired infrared heaters. Unit B combines the required amount of admixture from the hopper with the hot millings on the conveyer. The heaters on Unit B provide additional heat to allow a full width milling head to remove another inch of existing HMA pavement. The hot millings from the full width milling head and the hot millings and admixture from the conveyor are then combined into a new windrow allowing them to be picked up and placed in a pugmill. The pugmill thoroughly mixes the hot millings, admixture and recycling agent before transferring them to the paving machine hopper.

Figure 8. Left rear of unit B.

Figure 9. Right front of unit B showing hopper for admixture.

Figure 10. Truck dumping admixture into hopper of unit B.

Figure 11. Windrowing of millings from unit B with millings from conveyer.

Paving Machine

GreenRoads Recycling used a RoadTec RP 235 paving machine with a Carlson EZ III screed to place the HIPR pavement. In addition to spreading the mix the paving machine also pushed Unit B.

Figure 12. RoadTec RP 235 paving machine.

Figure 13. Rear view of RoadTec paving machine.

Rollers

Compaction equipment consisted of two double drum steel wheel rollers. The slow speed of the HIPR train meant that the rollers worked relatively close to the paving machine. Table 5 gives the type and capacity of the rollers.

Table 5. Roller descriptions.

Manufacturer	Model	Type	Weight (lb.)	Drum Width (in.)
Ingersoll-Rand	DD-110HF	Double Drum Vibratory	25,000	78
Bomag Hypac	C 784	Double Drum Vibratory	28,000	84

Mix Temperature

Lay down temperature for the HIPR pavement was lower and more uniform than with conventional HMA paving. Thermal images (Figure 14 and 15) showed a temperature range of 195°F to 240°F behind the screed. GreenRoads Recycling indicated that compaction temperatures on the SR 542 project were typical for HIPR paving. The recycling agent assists in making the mix more compactable allowing adequate compaction at temperatures lower than conventional HMA (Stothert, 2009).

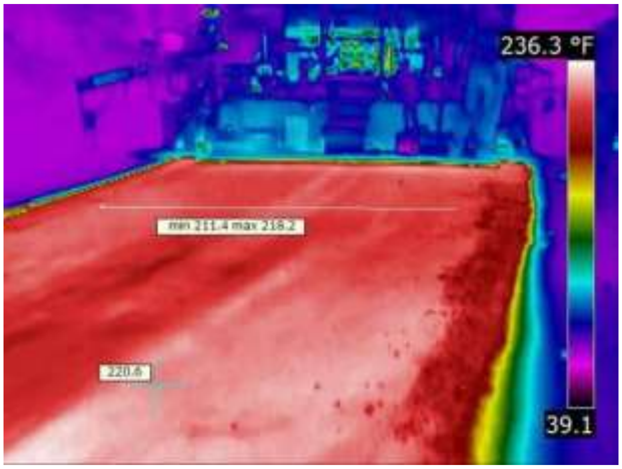

Figure 14. Thermal image showing uniform temperature across the mat.

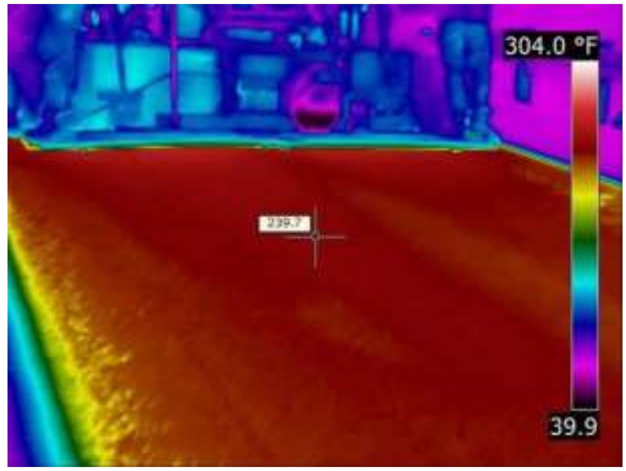

Figure 15. Maximum mat temperature was approximately 240°F.

Test Results

WSDOT tested the HIPR mix for in-place density, gradation, asphalt content and volumetric properties.

Density Test Results

WSDOT uses nuclear density gauges to accept in-place density of HMA. To use the nuclear density gauge to accurately test HMA density, correlation of the gauge to the specific mix is necessary. WSDOT's procedure for correlating a nuclear gauge is to determine the density of ten locations by using the nuclear density gauge and by testing cores using WSDOT test method T-166[1]. The ratio of the core density to the nuclear gauge density is determined for each location. The average of the ratios is the gauge correction factor used for density testing of that specific mix. If the mix changes significantly, the procedure has to be repeated to establish a new correction factor.

The HIPR pavement is made up of the recycled existing HMA pavement and the admixture. The admixture did not change significantly during HIPR paving so the only significant change to the mix requiring a new nuclear gauge correction factor were the changes

[1] WSDOT test method T-166 is based on AASHTO T-166-07 and is available at http://www.wsdot.wa.gov/publications/manuals/fulltext/M46-01/Materials.pdf

to the existing HMA pavement. There were five different paving projects, each with a unique mix design, which made up the recycled existing HMA pavement on SR 542 (Table 7). WSDOT's procedures require a different gauge correction factor for each mix design.

Table 6. Milepost limits of existing HMA recycled by HIPR.

Contract	Year Paved	Thickness (ft.)	Mix Type	Binder	Milepost Limits
5238	1997	0.13*	½ inch HMA	AR4000W	3.38 - 3.86 5.71 - 5.87 6.36 - 6.48
4213	1993	0.12*	½ inch HMA	AR4000W	3.86 - 5.71 5.87 - 6.36 6.48 - 9.43
5410	2001	0.55	½ inch HMA	AR4000W	9.43 - 10.11
4294	1993	0.20	½ inch HMA	AR4000W	10.11 - 14.09
3455	1989	0.15*	½ inch HMA	AR4000W	14.09 - 19.27

*The underlying lift also would need to be considered since these thicknesses are less than the two inch (0.17 ft.) recycling depth. Fortunately, the underlying layer for each of these projects did not vary within the project milepost limits allowing them to be left off for clarity. Complete details are in the surfacing report included in Appendix B.

Although WSDOT did informational density testing on the entire project, the only HIPR pavement correlated to the nuclear density gauge was the section of existing HMA pavement paved under contract 3455. Figure 16 shows a plot of the nuclear density gauge readings compared to the corresponding core density used to correlate the nuclear density gauge. The plot shows a fair correlation ($r^2 = 0.57$) between the two test methods indicating a linear relationship between the nuclear density gauge and core density.

Within the limits of contract 3455, milepost 14.09 to 19.27, the average density from the corrected nuclear density gauge was 93.5 percent of theoretical maximum with a standard deviation of 1.37. The percentage of tests below WSDOT's 91.0 percent minimum density requirement was 4.7 percent. Figure 17 shows the distribution of test results. Appendix E includes complete density testing results.

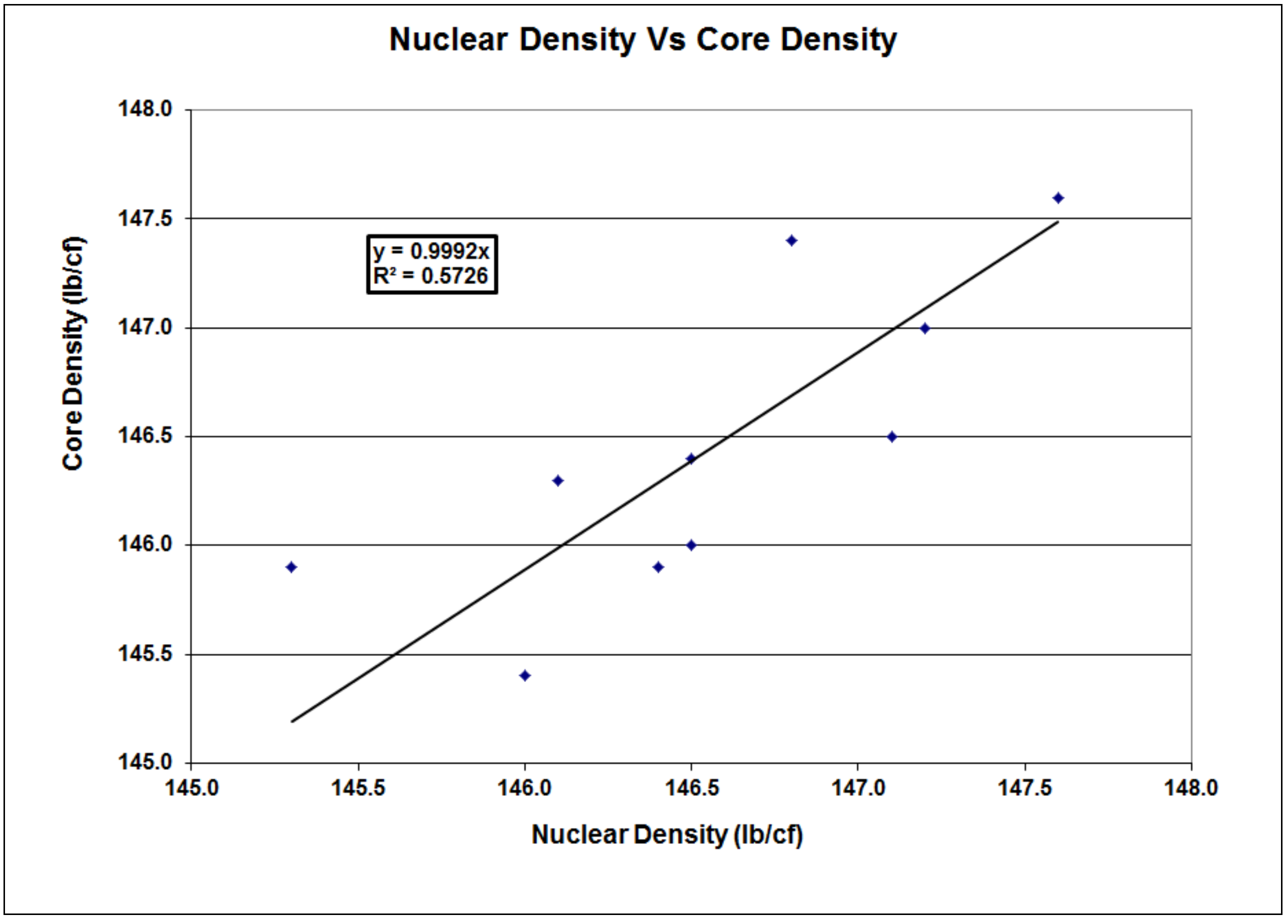

Figure 16. Plot of nuclear density gauge readings vs. core density results.

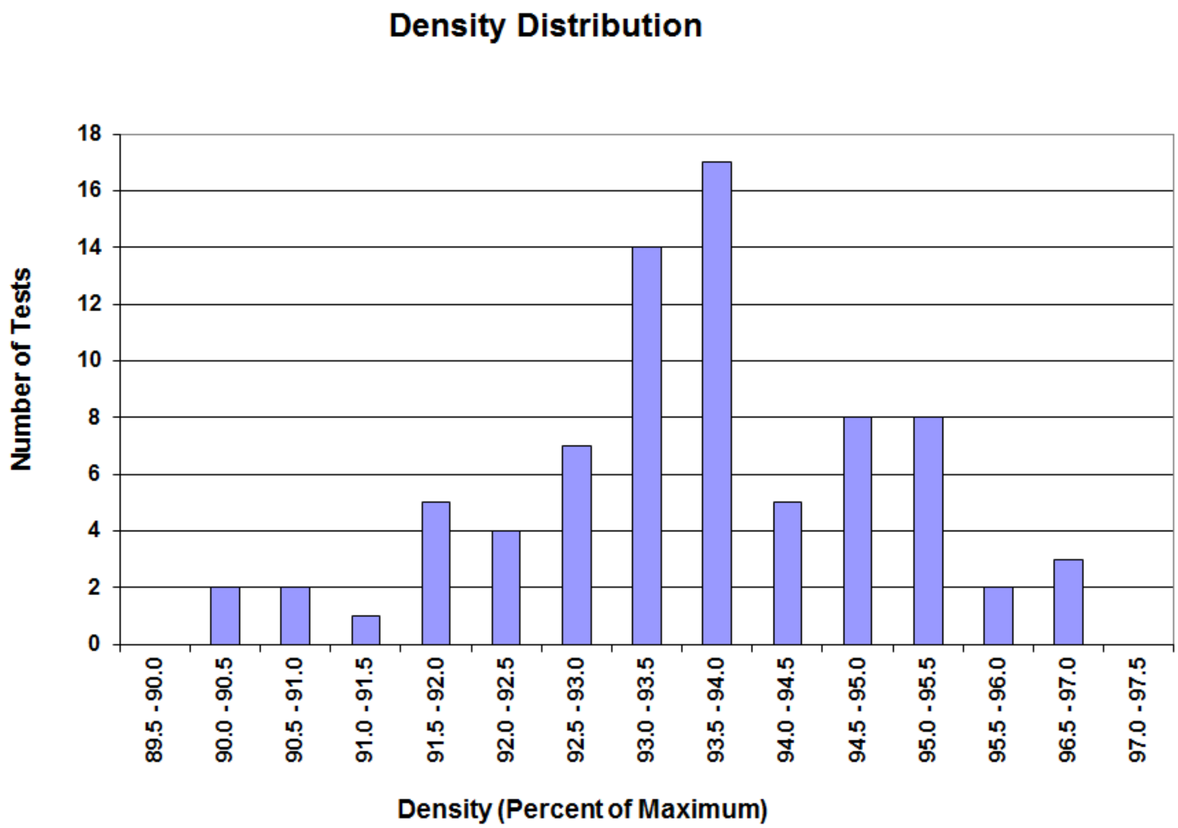

Figure 17. Distribution of corrected nuclear density test results for milepost 14.09 to 19.27.

Figure 18 compares the normal distribution of HIPR density tests between milepost 14.09 and 19.27 with that of WSDOT HMA density tests taken between 1990 and 2005. The similarity of the two distributions suggests that HIPR is capable of achieving in place densities comparable to HMA paved on WSDOT projects.

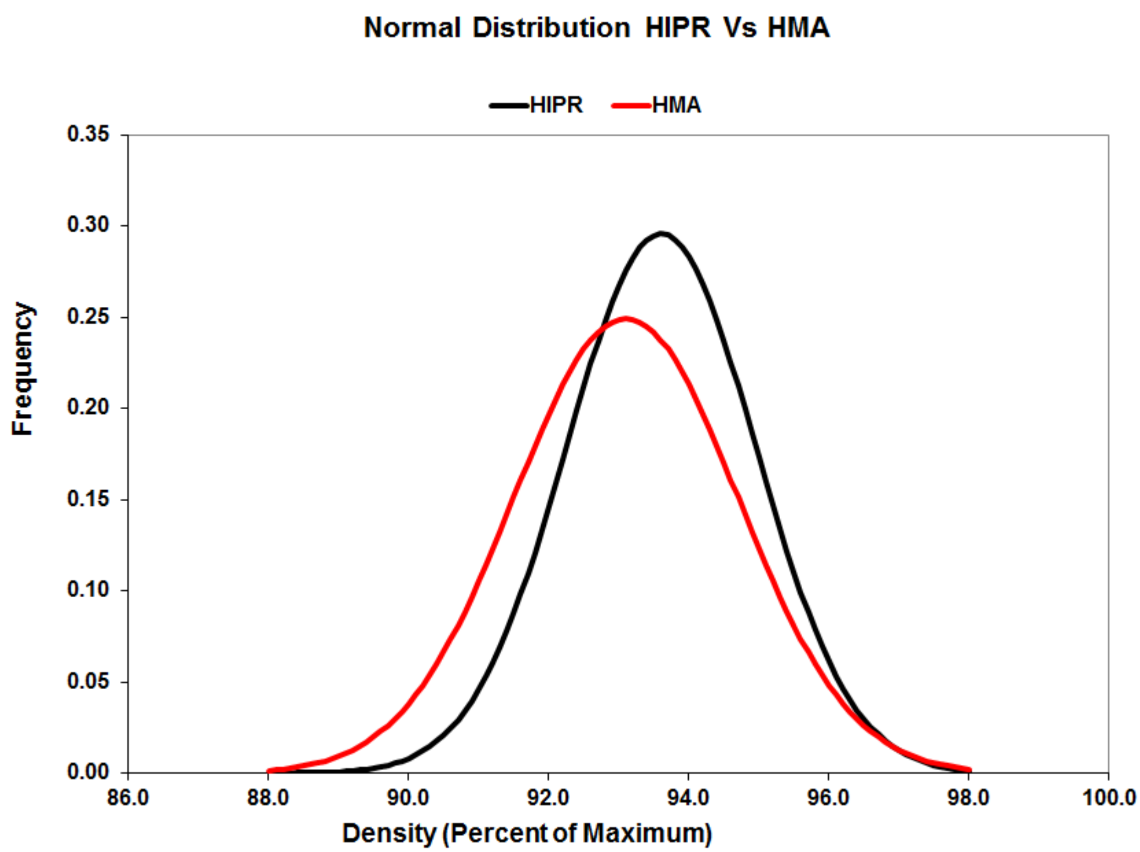

Figure 18. Normal distributions of HIPR density test results vs WSDOT HMA.

Mix Testing Results

WSDOT tested samples of the HIPR mix taken before they entered the paving machine for gradation, asphalt content and volumetric properties (Table 7). The test results revealed that the gradation of the HIPR pavement fell mostly within WSDOT's ½-inch HMA specification which was not surprising since the recycled existing HMA pavement was also ½-inch HMA. Only the No. 200 sieve did not meet WSDOT's specification for ½ inch HMA. Voids in mineral aggregate (VMA) test results were within WSDOT's specifications but air voids (Va) were lower and consequently the voids filled with asphalt (VFA) were higher. Typically, low Va and high VFA would indicate too much asphalt which would make the mix more susceptible to rutting. It is not clear how the low Va and high VFA will affect the HIPR pavement but it will be monitored to determine if it is susceptible to rutting. Appendix F includes the complete gradation, asphalt content and volumetric test results.

Table 7. WSDOT gradation, asphalt content and volumetric tests results.

Property	Existing HMA Pavement Contract										WSDOT 1/2" HMA Specs.
	3445		4213		4294		5410		5438		
	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	
3/4-in	100	0.0	100	0.0	100	0.0	100	0.0	100	na	100
1/2-in	96.6	1.5	96.3	0.5	96.6	0.5	96.0	1.4	97.0	na	90 - 100
3/8-in	87.4	2.8	87.2	2.5	88.4	1.5	88.0	2.8	90.0	na	90 max
No. 4	60.4	2.5	59.2	3.5	61.2	2.5	60.0	1.4	63.0	na	
No. 8	44.9	2.0	43.5	3.0	45.2	1.9	43.5	0.7	47.0	na	28 - 58
No. 16	33.9	1.7	32.8	2.3	33.8	0.8	32.0	0.0	35.0	na	
No. 30	24.3	1.4	24.0	1.7	24.0	1.0	23.0	0.0	26.0	na	
No. 50	15.4	1.0	15.0	0.9	15.0	1.0	15.0	0.0	16.0	na	
No. 100	9.9	0.7	9.5	0.5	9.6	0.5	9.5	0.7	10.0	na	
No. 200	7.3	0.5	6.8	0.3	6.8	0.4	7.0	0.1	7.2	na	2.0 - 7.0
Pb	5.6	0.3	5.4	0.2	5.6	0.2	5.9	0.2	5.8	na	
Va, %	1.4	1.0	2.3	0.4	2.0	0.6	1.9	0.5	1.1	na	2.5 - 5.5
VMA, %	14.3	0.4	14.4	0.3	14.8	0.2	14.9	0.4	14.6	na	14 min
VFA, %	90.3	6.6	84.1	2.8	86.6	4.1	87.2	3.3	92.5	na	65 - 78

Granite Construction tested the admixture for gradation and asphalt content (Table 8). The test results revealed that on average the material passing the ⅜ inch and the number 200 sieves were finer than WSDOT's ½ inch HMA specification. The admixture made up only 20 percent of the total mix so the finer admixture gradation only had a minor affect on the gradation of the overall mix. Appendix G contains the complete admixture gradation and asphalt content test results

Table 8. Granite Construction admixture test results.			
Property	Average	Std. Dev.	Agg. Seal Class C Spec.
3/4-in	100.0	0.0	
5/8-in			100
1/2-in	91.9	2.3	
3/8-in	78.8	3.2	30 - 70
No. 4	43.1	3.1	25 - 45
No. 8	32.1	2.6	
No. 16	23.5	2.1	
No. 30	15.9	1.9	5 - 20
No. 50	8.8	1.6	
No. 100	4.9	1.0	
No. 200	3.4	0.8	0 - 3
Pb	4.0	0.5	

Project Cost

The total project cost was $5,670,000 which includes design, administration, safety, HMA paving (portions of SR 542 and adjoining sections of SR 9 were paved with HMA as well as driveway approaches and turn lanes), pavement marking and incidental work required to complete the project. The total cost per lane mile was $169,000 based on a total of 33.48 lane miles rehabilitated including paving 1.7 lane miles of SR 9 and SR 542 with HMA. The cost of the HIPR items only was $1,860,000 (Table 9). A total of 31.79 lane miles were rehabilitated by HIPR resulting in a cost of $58,500 per lane mile.

Table 9. Contract 7648 HIPR costs.				
Item	Unit of Measure	Final Quantity	Unit Price	Total Cost
Hot In-Place Recycled HMA	S.Y.	227,863.2	$6.30	$1,435,538.16
Asphalt Binder	Ton	157.99	$521.00	$82,312.79
Recycling Agent	Ton	51.34	$1,800.00	$92,412.00
Aggregate For Hot In-Place Recycled HMA	Ton	3,823.5	$65.00	$248,527.50
Total Cost				$1,858,790.45

The total cost per lane mile for a conventional HMA rehabilitation on a highway in Washington State is $200,000. Using HIPR for most of the paving on SR 542 yielded an initial savings in total cost of 15 percent over the cost of using conventional HMA. Ultimately any life cycle cost savings achieved by HIPR will depend on the pavement life which will be evaluated in the final report.

Recap Meeting

A meeting was held between representatives of GreenRoads Recycling, Granite Construction and WSDOT on November 3, 2009. The purpose of the meeting was to share experience and knowledge in order to improve future HIPR projects. The following bullet points list some of the suggestions and observations brought up at the meeting:

Mix Design

- More cores should be provided on future HIPR projects. WSDOT provided 24 cores and Granite obtained about that many additional cores. Cores should be taken by WSDOT prior to awarding the project.
- More time for mix design development should be allotted between contract award and the start of paving.
- Volumetric properties should be included in the contract documents to help the bidders determine the mix design effort required.
- A meeting should be required early on in the project to discuss mix design sampling and testing requirements.
- Low air voids usually do not lead to a rutting problem with HIPR pavement.
- WSDOT should consider including a pay item to cover the cost of developing the HIPR mix design.

Specifications

- Definitions need to be clear in the specifications. Items that needed definitions include:
    - Existing HMA Pavement
    - Admixture

- Recycling Agent
- Hot millings
- Completed HIPR Pavement

Construction

- The completed HIPR pavement normally shows a slight amount of flushing and feels tacky when walked on. The SR 542 pavement appeared dryer than HIPR placed in British Columbia.

- The public liked the concept of HIPR. Using a "greener" process and reusing the pavement seemed to be supported by the public.

- Comments concerning excessive glare were received from the public. This may make the pavement markings less visible. On future projects we should try to get the pavement markings down quicker.

- Some advantages that HIPR has over a conventional grind and inlay were discussed. HIPR paving was quieter than cold milling and the project did not have any noise complaints. HIPR eliminates problems of leaving an abrupt lane edge during grinding and the hazard caused by the grinding areas filling with water. There are also no flying rocks.

- HIPR could not pave some of the turn lanes which had crowns in the center. The milling heads can only grind flush. To maintain the paving depth at the edge of the lane would require deeper recycling at the center of the lane than the HIPR process is capable of.

- Small areas including turn lanes and gore areas should be paved with HMA before the HIPR paving to avoid having joints in the lane.

- Sharp corners are difficult to pave with HIPR. The longest piece of equipment is 60 feet and needs to stay in the lane as it goes around a corner.

- HIPR reduced traffic disruptions. The paving is completed in one operation. A grind and inlay disrupts people twice and requires a butt joint at the end of each day's operation. Fewer trucks getting in and out of the work zone and not dumping trailers reduces traffic disruption.

- In British Columbia, joints between paving shifts are fog sealed to help seal pavement that tends to have an open texture at the start of each day's paving.

- The HIPR paving left a slight lip on the edge of the traveled lane which bicyclist brought up as a concern.

Long-Term Performance

The performance of the HIPR pavement was evaluated using 2014 measurements of friction, rutting/wear and ride. Photos taken in October 2015 show the current condition of the pavement.

Friction Resistance

The friction resistance measurements (see Table 10) were excellent right after construction with an average friction number of 64 and a range of 51 to 75. The 2014 measurements, taken in the eastbound direction, were also very good with an average of 51 and a range of 48 to 56. These results are well above 30 which is the level at which there is a safety concern. The friction properties of the HIPR pavement are excellent.

Table 10. Friction resistance results.

Year	Direction	Friction Number (FN)		
		Average	Minimum	Maximum
2009	EB & WB	64	51	75
2014	EB	51	48	56

Rutting

Rutting in an HMA pavement is the result of; (1) wear of the pavement surface, (2) additional compaction of the new pavement by traffic, (3) deformation of the pavement section caused by heavy truck traffic or some combination of all three. The average, maximum and minimum rutting/wear measurements for the HIPR pavement are listed in Table 11. The rutting/wear for the HIPR pavement is little less than 1 mm per year (0.82 mm). This is a normal amount of rutting/wear that can be expected for an HMA pavement.

Table 11. Rutting/wear measurements in millimeters for 2015.	
Year	2015
Average	4.9
Maximum	7.9
Minimum	2.5

Note: 2 mm = 5/64 in. 5 mm = 13/64 in.
3 mm = 7/64 in. 6 mm = 15/64 in.
4 mm = 10/64 in. 7 mm = 18/64

Ride

The ride measurements in International Roughness Index (IRI) units of inches per mile are listed in Table 12 and shown graphically in Figure 19. The average IRI of 93 is high for a new pavement and the spikes in roughness at various locations throughout the length of the project indicate that this particular HIPR process did not produce the smoothest profile.

Table 12. 2015 ride measurements in IRI (in/mile)	
Year	2015
Average	93
Maximum	335
Minimum	46

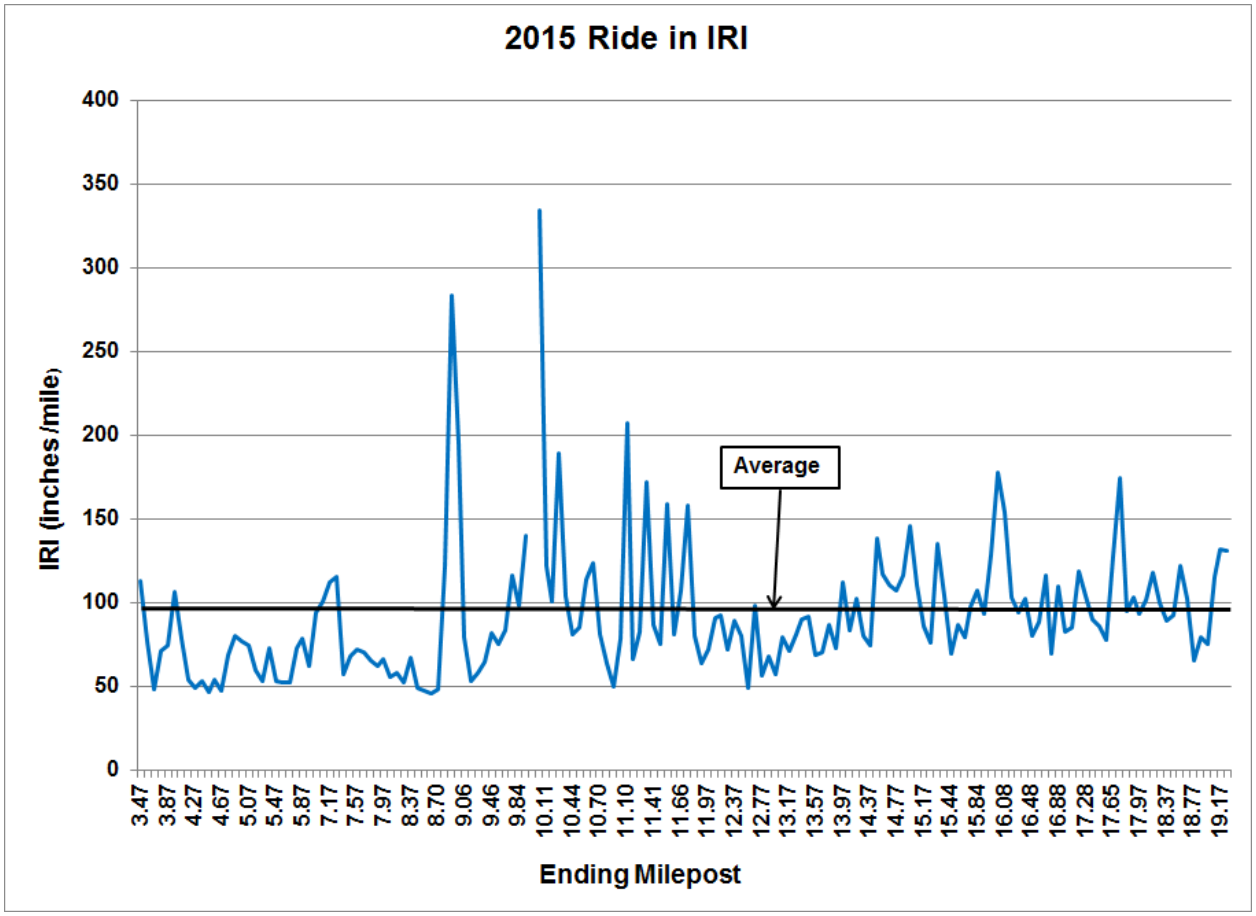

Figure 19. Ride measurements for 2015 showing average of 93 inches/mile.

Pavement Structural Condition

The Northwest Region recognized that there were problems in the structure of the existing pavement at various locations. They recommended in their Pavement Rehabilitation Report (Appendix B) that these areas of alligatored pavement be removed prior to the HIPR process. The repair recommended involved removal of the HMA and underlying base materials to a depth of 1.05 feet for a minimum width of 4.0 feet and the entire length of the damaged HMA. The excavated area was to be re-compacted and rebuilt with 0.35 feet of crushed surfacing base course (CSBC) followed by 0.70 feet of HMA Class ½" using PG58-22 binder. The report, however, did not delineate the areas of alligatored pavement that needed to be repaired.

The contract plans delineated three locations for repair in the vicinity of Mileposts 7, 14 and 17, see Table 13. The table lists the 2008 and 2015 pavement structural condition (PSC) values for the 1/10 mile segments at the three locations. The 2015 PSC's for the four segments ranged from 71 to 97 with an average of 79 indicating that the repairs probably did improve the structure of the pavement and prevented early distress in the HIPR pavement (PSC's range from 100 for a perfect pavement with no cracking to 0 for a pavement that has failed due to cracking and other forms of distress.

Table 13. 2008 and 2014 PSC data for locations repaired prior to HIPR.

Beg. MP	End. MP	Location	Segment Beg. MP	Segment End. MP	PSC	
					2008	2015
6.98	7.27	RWP in the right lane	7.07	7.17	42	74
			7.17	7.27	64	71
14.22	14.24	RWP in the right lane	14.17	14.27	54	74
17.69	17.71	Full width of both lanes	17.67	17.77	87	97

The underlying structure of the roadway appears to be the source of some of the cracking noted in the HIPR pavement at locations other then those repaired prior to the construction of the HIPR pavement. The WSPMS pavement structural condition (PSC) ratings for 2008 (black line) and 2015 (blue line) are compared in Figure 20. The repaired areas from Table 13 are noted. Areas noted with blue arrows have low PSC's (less than 70) in both 2008 and 2015 surveys indicating the possibility that the underlying pavement structure is having a negative effect on the performance of the HIPR pavement. Table 14 lists the segment locations and the 2008 and 2015 PSC's. The possibility exists that additional full depth repairs in these segments may have improved the cracking performance of the HIPR pavement.

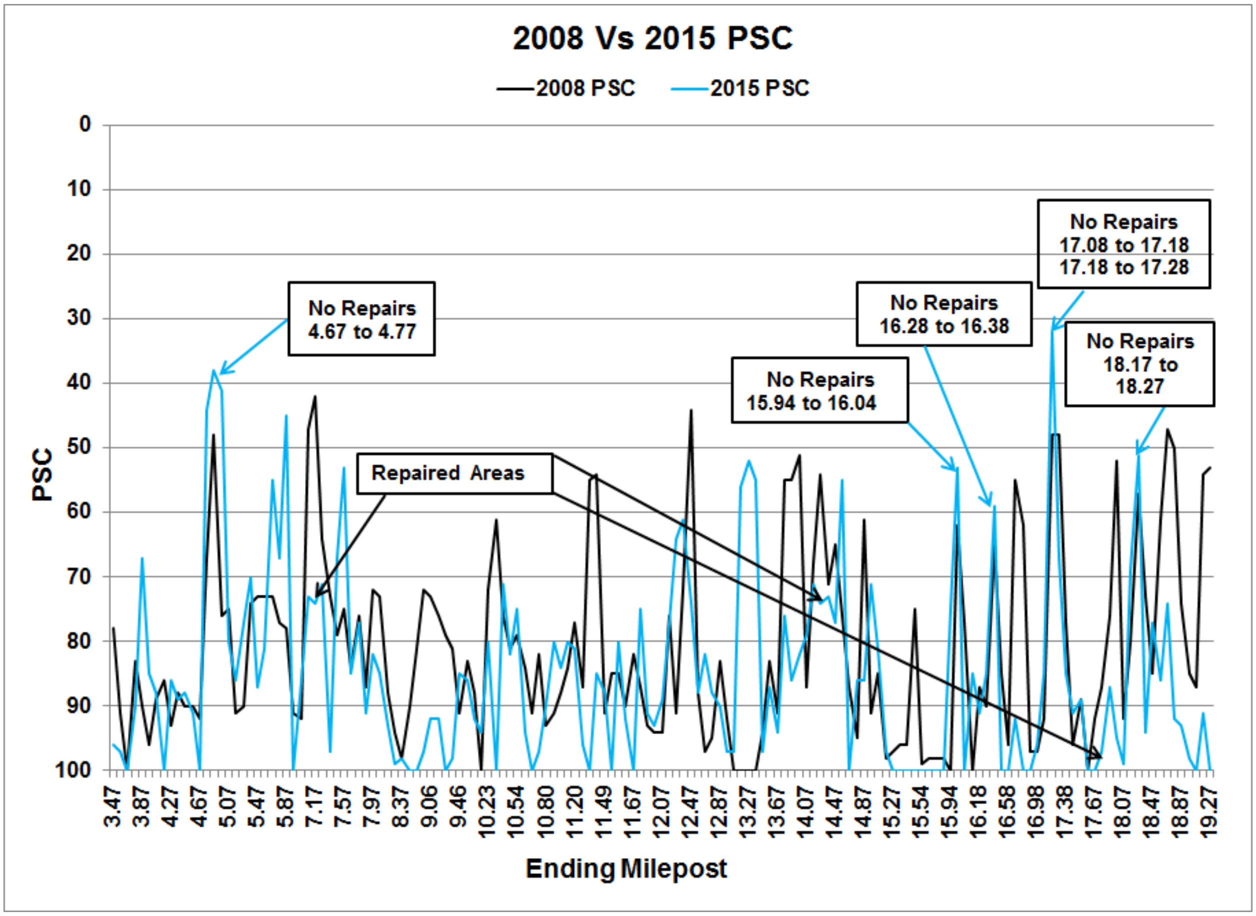

Figure 20. PSC readings from 2008 and 2014.

Table 14. Segments with low PSC values in both 2008 and 2015 surveys that did not receive repairs prior to the HIPR.				
Segment	Beginning Milepost	Ending Milepost	PSC	
			2008	2015
1	4.67	4.77	44	67
2	4.77	4.87	48	58
3	15.94	16.04	53	62
4	16.28	16.38	65	59
5	17.08	17.18	32	48
6	17.18	17.28	67	48
7	18.17	18.27	51	57

In summary, a limited number of distressed segments that received full depth repairs prior to the HIPR process are in general performing considerably better than a limited number of equally distressed segments that received no repairs.

There are other segments in the HIPR pavement that have low 2015 PSC's (less than 70) that are not linked to low PSC's in the original pavement indicating that the poor performance of the HIPR pavement is probably not because of the poor condition of the underlying pavement structure (see Table 15).

Table 15. Segments with low PSC values in 2015 not correspond with low values in 2008.

Segment	Beginning Milepost	Ending Milepost	PSC	
			2015	2008
1	3.77	3.87	67	90
2	4.87	4.97	41	76
3	5.57	5.67	55	73
4	5.67	5.77	67	77
5	5.77	5.87	45	78
6	7.37	7.47	67	79
7	7.47	7.57	53	75
8	12.17	12.27	64	91
9	12.27	12.37	61	72
10	13.07	13.17	56	100
11	13.17	13.27	52	100
12	13.27	13.37	55	100
13	14.47	14.57	55	76
		Average	57	84

Table 16 lists pavement segments with low 2008 PSC's (less than 70) that do not match with low 2015 PSC's (less than 70). The 2008 PSC's ranged from 42 to 64 with an average of 54. The matching 2015 PSC's ranged from 71 to 100 with an average of 86. The absence of matching low PSC values would indicate that the distress in the existing pavement was limited to the top portion of the pavement that was removed and recycled during the HIPR process and had no influence on the HIPR performance.

Table 16. PSC values for 2015 at locations with low values in 2008.				
Segment	Beginning Milepost	Ending Milepost	PSC	
			2008	2015
1	6.07	6.17	47	73
2	7.07	7.17	42	74
3	7.17	7.27	64	71
4	10.23	10.24	61	100
5	11.29	11.31	55	100
6	11.31	11.41	54	85
7	12.37	12.47	44	74
8	13.67	13.77	51	76
9	13.77	13.87	55	86
10	13.87	13.97	51	82
11	14.17	14.27	54	74
12	14.77	14.87	61	86
13	16.58	16.68	55	92
14	16.68	16.78	62	100
15	17.87	17.97	52	95
16	18.47	18.57	61	86
17	18.57	18.67	47	74
18	18.67	18.77	50	92
19	19.07	19.17	54	91
20	19.17	19.27	53	100
		Average	54	86
		Minimum	42	71
		Maximum	64	100

For the 112 segments that are not included in the above two categories 67 percent of the segments had a 2015 PSC higher than the 2008 PSC with an average PSC of 90, and 33 percent of the segments had a 2015 PSC that was lower than the 2008 PSC with an average of 87. Since the PSC values are based primarily on cracking, this indicates that from a fatigue standpoint the majority of the segments are not performing reasonably well for a six year old pavement. Fatigue cracking, however, is not the only issue affecting this roadway as will be seen later in this report.

The PSC data seems to indicate a number of factors. Some locations that received full depth repairs prior to the HIPR process resulted in better performance of the HIPR overlay and the extension of full depth repairs to a number of other areas may have resulted in better performance of the HIRP overlay in those specific locations. However, the poor condition of the underlying pavement did not always result in poor performance in the HIPR overlay and, in contrast, the poor performance of the HIPR did not always occur where the underlying pavement was in poor condition. In summary, the poor condition of the underlying pavement condition did have a negative effect on the performance of the HIPR overlay in some locations, but in other locations the poor performance of the HIPR overlay was due strictly to problems with the overlay itself.

Visual Pavement Condition History

The following sets of photos show the condition of the existing pavement prior to any work, the condition of the HIPR pavement at intervals of 22 months, 35 months, 46 months, and 75 months after construction. The most recent set of photos from October 2015 show the poor surface condition of the pavement after only six years of life.

Photos Prior to Construction in 2008

Figure 21. Pre-construction longitudinal cracking. (0776)

Figure 22. Pre-construction alligator cracking. (1363)

Figure 23. Pre-construction alligator cracking. (1364)

Figure 24. Pre-construction alligator and longitudinal cracking. (1365)

Figure 25. Pre-construction alligator and longitudinal cracking. (1366)

Figure 26. Pre-construction alligator and longitudinal cracking. (1367)

July 2011, Two Years (22 months) After Construction

Figure 27. Transverse crack at MP 14.10. (4826)

Figure 28. Alligator cracking at MP 14.5. (4818)

Figure 29. Alligator and longitudinal cracking at MP 17.2. (4807)

Figure 30. Close-up of alligator cracking at MP 17.2. (4870)

August 2012, Three Years (35 months) After Construction

Figure 31. Sealed alligator cracking at MP 17.24. (6593)

Figure 32. Alligator and long. cracking at unknown location. (6594)

Figure 33. Alligator cracking at unknown location. (6590)

May 2013, Four Years (46 months) After Construction

Figure 34. Alligator, longitudinal cracking and potholes in the westbound lane at MP 17.2 in May 2013. (1334)

Figure 35. Alligator, longitudinal cracking and potholes in the westbound lane at MP 17.2 in May 2013. (1335)

October 2015, Six Years (75 months) After Construction

Figure 36. Longitudinal and alligator cracking at MP 4.8. (85258)

Figure 37. Open-texture and raveling at MP 10.1. (90232)

Figure 38. Open-texture, raveling and longitudinal cracking at MP 11.8. (90910)

Figure 39. Open-texture, raveling and longitudinal cracking at MP 13.15 (90910)

Figure 40. Open-texture, raveling, alligator and longitudinal cracking at MP 14.1. (92525)

Figure 41. Open-texture, raveling, alligator and longitudinal cracking at MP 14.6. (93117)

Figure 42. Sealed cracks at MP 17.1. (93723)

Figure 43. Close-up view at MP 17.2. (94003)

Figure 44. Alligator and longitudinal cracking at MP 17.3. (94210)

Figure 45. Alligator cracking, raveling and pothole at MP 17.3. Note erosion of the binder surrounding the aggregate. (94527)

Figure 46. Alligator and transverse cracking and potholes at MP 17.3. (00562)

Figure 47. Close-up of raveled surface of pavement at MP 17.3. (00559)

The photos show that the deterioration of the pavement began almost immediately after construction. The most recent set of photos show the current poor condition of the HIPR pavement that is characterized by a dry surface appearance which is raveling and cracking and forming potholes at the intersection of the many cracks. The cause of the early distress may be attributable to problems with the underlying structure or a problem with the quality of the mix placed. Initial observations during and following completion of the paving were that the mix was dry and that the finished pavement had an open texture. It was reported that GreenRoads Recycling recommended increasing the asphalt content of the mix during paving. Laboratory testing of the mix indicated that the voids filled with asphalt were higher than allowed; therefore, the decision was made to not increase the asphalt content. A dry mix in combination with the aging of the asphalt binder due to the heating that takes place in the recycling process could result in a brittle binder that might be more prone to raveling and early cracking.

Discussion of Results

Hot in-place recycling has certain advantages such as the conservation of resources, materials and energy, lower costs due to the use of less new materials and less transportation costs associated with hauling those materials to the job site, and less disruptions to traffic due to shorter lane closures. Selection of a project for HIPR requires consideration of the pavement structure, any deficiencies in the existing pavement, geometric elements that may limit the use of a long paving train, constructability limitation from expected lower productivity and longer duration lane closures, and environment considerations due to possible emissions on the roadway as contrasted to a plant based recycling operation. This particular project met all of the criteria qualifying it as a good candidate for HIPR (ARRA, 2015).

The publication by the Asphalt Recycling and Reclamation Association (ARRA) recommends a thin lift of new HMA be placed over the recycled mix if the existing pavement has extensive longitudinal, transverse of alligator cracking (ARRA, 2015). The inclusion of a thin HMA overlay or bituminous surface treatment (BST) on top of HIPR pavement as part of the process may have improved the performance of the HIRP pavement, however at a much higher total project cost. However, WSDOT's has had repeated successes with 0.15' mill and fills on extensively alligatored pavements, provided full depth failures are addressed prior to the mill and fill. The poor results cannot be attributed to the use of the HIPR process, but to inadequate binder in the mix as noted previously.

Visually the HIPR pavement appears to lack sufficient asphalt binder and suffered from distresses that are typical of a high RAP mix with insufficient binder. If the project had been a conventional mill and fill and insufficient binder had been used in the mix the results may have looked similar to what happened with the HIPR pavement.

Life Cycle Cost Analysis

The Northwest Region has noted the performance issues with the project and has put the SR-542 section on the schedule for a chip seal in 2018. This would result in a 9 year life for the HIPR pavement. A per lane mile life-cycle cost analysis (LCCA) was performed using the expected life as shown in Table 17. The HMA mill and fill has a higher per lane mile cost, however, the shorter life of the HIPR results in an annual per lane mile cost that is $3,700 higher than the HMA mill and fill.

Table 17. Per lane mile life-cycle cost analysis results.

	HIPR	HMA Mill and Fill
Per Lane Mile Cost	$111,405.56	$125,419.96
Pavement Life	9 years	15 years
Discount Rate	4%	4%
Annual Cost	$14,983	$11,280
Annual Per Lane Mile Cost Difference	$3,703	

Conclusions

The following conclusion can be drawn regarding the HIPR project on SR-542:

- The poor performance of the pavement produced by the HIPR process was due to insufficient asphalt binder in the mix that resulted in premature aging, raveling, cracking and pot holing.
- The HIPR process may have been a contributing factor due to the aging of the binder of the existing pavement, but was not the primary cause of the pavement's poor performance.

References

Asphalt Recycling and Reclaiming Association (2015). "Basic Asphalt Recycling Manual", Annapolis, MD.

Button, J.W., Estakhri, C.K., Little, D.N. (1999). "Overview of Hot In-Place Recycling of Bituminous Pavements", Transportation Research Record 1684, TRB, National Research Council, Washington D.C.

GreenRoads Recycling website, www.greenroadsrecycling .com, accessed November 12, 2009.

Pierce, L.M. (1996). "Hot In-Place Recycling: SR 97 West Wapato Road to Lateral A Road (SB) Post Construction Report", Washington State Department of Transportation, Olympia, WA.

Pyrotech (2009). "Ecopave Systems Inc.", Accessed September 3rd, 2009.

Stothert, J. (2009). Personal communication, November 3, 2009.

Appendix A

Experimental Feature Work Plan

Washington State Department of Transportation

WORK PLAN

Hot In-Place Recycling

State Route 542
Britton Road to Coal Creek Bridge Vicinity
Milepost 2.98 to Milepost 19.27

Mark A. Russell
Pavement Research and New Technology Engineer
Washington State Department of Transportation

Introduction

Hot in-place recycling (HIPR) is a technology that promises to reduce energy consumption and lower the cost of hot mix asphalt (HMA) rehabilitation. The traditional method of recycling HMA pavement in Washington is to grind the top layer of existing pavement, truck it back to the asphalt plant, stockpile it, and then incorporate it back into new HMA. HIPR eliminates the trucking and handling of the recycled HMA by performing the complete process in one pass. If successful, the HIPR process will provide WSDOT an additional rehabilitation technology that potentially saves money and conserves resources. This experimental feature will document the construction and performance of HIPR rehabilitation of SR 542.

Scope

Both lanes of SR 542 will be rehabilitated between milepost 2.98 and 19.27 using the HIPR process. The existing pavement consists of multiple projects paved between 1989 and 2001 which are displaying low severity raveling of cyclic segregation areas, rutting, longitudinal cracking and transverse cracking. There are several areas of high severity alligator cracking and maintenance patching.

Staffing

This research project will be constructed as a Northwest Region programmed rehabilitation project (the entire project will be evaluated under this research study). Therefore, the Region Project office will coordinate and manage all construction aspects. Representatives from and WSDOT Materials Laboratory (1 – 3 people) and the Northwest Region Materials Laboratory (1-2 people) will also be involved with the process.

Contacts and Report Author

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Uhlmeyj@wsdot.wa.gov

Mark Russell
Pavement Research and New Technology Engineer
Washington State DOT
(360) 709-5479
russelm@wsdot.wa.gov

Testing

Testing during mix development and construction will include:

- Asphalt Binder Properties - Viscosity, DSR, BBR
- Mix Properties - Asphalt content, gradation and air voids
- Density - Nuclear densometer readings and density from cores

Pavement performance will be monitored by the following methods:

- Ride will be measured before and after construction
- Friction will be measured after construction
- The pavement condition (structure, rutting and ride) will be surveyed annually

Reporting

A "Post Construction Report" will be written following completion of the test section. This report will include construction details, construction test results, and other details concerning the overall process. Annual summaries will also be conducted over the next five years. At the end of the five-year period, a final report will be written which summarizes performance characteristics and future recommendations for use of this process.

Cost Estimate

Construction Costs

No additional construction costs are required. This project will be constructed as a Region pavement preservation (P1 program) project.

Testing Costs

Ride testing before and after construction and friction testing will be conducted as part of the Region overlay project. Condition surveys will be conducted as part of statewide annual survey. Additional mix testing is estimated to cost $10,000.

Report Writing Costs

Initial Report – 20 hours = $1,300

Annual Report – 5 hours (1 hour each) = $325

Final Report – 40 hours = $2,600

Total Cost = $14,225

Schedule

Construction: August – September 2009

Date	Condition Survey (Annual)	End of Construction Report	Annual Report	Final Report
Fall 2009	X			
Fall 2010	X	X		
Fall 2011	X		X	
Fall 2012	X		X	
Fall 2013	X		X	
Fall 2014	X		X	
Spring 2015				X

Appendix B

NW Region Pavement Rehabilitation Report

Washington State Department of Transportation

Memorandum

DATE: October 30, 2008

TO: Jeff S. Uhlmeyer — MS 47365

FROM: Chris J. Johnson/Nabil Dbaibo/Hon T. Hua — MS 29

SUBJECT: SR 542 — XL-2433
Britton Road to Coal Creek Bridge Vic.
Hot-In Place, MP 2.98 to MP 19.27
Pavement Rehabilitation Report

Transmitted for you review and concurrence is our Pavement Rehabilitation Report for this project.

Chris J. Johnson, P.E.

CHRISTOPHER JAY JOHNSON
STATE OF WASHINGTON
37891
REGISTERED PROFESSIONAL ENGINEER
10/30/08

NW Region Materials Engineer

EEP Materials Lab Concurrence:

11-11-08
Signature and Date

Copies to:

J. Marlega	MS 209
Plans	MS 111
Area 1 Maintenance	MS 41

File: SR-542, XL-2433
Serial File: 08-194

RECEIVED
NOV 03 2008
STATE MATS LAB

DOT Form 700-008 EF
Revised 5/99

Washington State Department of Transportation

Memorandum

DATE:	October 30, 2008	
TO:	Janice Marlega/Carl Vogt	MS 209
FROM:	Chris Johnson/Nabil Dbaibo/Hon Hua	MS 29
SUBJECT:	SR-542 Britton Road to Coal Creek Bridge Vic. Hot-In Place, MP 2.98 to MP 19.27 **Pavement Rehabilitation Report**	XL-2433

As requested by your office, the NW Region Materials Lab has completed the pavement rehabilitation report for the design and construction for the SR-542, Britton Road to Coal Creek Bridge Vic. Project. This project proposes to rehabilitate the roadway using a Hot In-Place Recycling (HIP) method of recycling the top surface of the existing roadway, and grind rumble strips on center line and both shoulders for SR 542 mainline from MP 2.98 to MP 19.27. This project also proposes to rehabilitate SR 9 mainline from MP 84.01 to MP 84.46. Other minor safety works will be also included in this project.

Traffic Data, Pavement Construction History and Condition

SR 542 Mainline *(MP 2.98 to MP 19.27)*
The Washington State Pavement Management System (WSPMS) indicates that the current two-way ADT for this section of SR 542 is varying between 12,500 and 5,400 vehicles of which 9.0% are trucks. The growth rate is projected at 3.0%. SR 542 corridor is a two-way lane, rural-minor arterial with rolling/level terrain and having a speed limit of 55mph. The overall roadway lane width varies between 11 and 14 feet with shoulder widths varying between 2 and 10 feet (see attached WSPMS analysis unit).

Previous contracts that constructed and resurfaced SR-542 mainline within the project limits as summarized in WSPMS, are shown in Table 1:

Table 1 - Corridor Pavement Profiles

Beginning MP	Ending MP	Year	Contract	Thickness and Surface Type
2.98	3.86	1997	5238	0.13' HMA Class B
		1993	4213	0.12' HMA Class B
		1976-1937	N/A	(0.40' HMA Class B over 1.25' UTB) or (0.58' PCCP over 0.67' UTB)
3.86	5.71	1993	4213	0.12' HMA Class B
		1976	0175	0.15' HMA Class B
		1942	N/A	0.12' HMA Class B
		1937-1919		0.58' PCCP over 0.67' UTB

DOT Form 700-008 EF
Revised 5/99

SR-542/Britton Road to Coal Creek Bridge Vic. XL-2433
October 30, 2008 Page 2 of 10

Beginning MP	Ending MP	Year	Contract	Thickness and Surface Type
5.71	5.87	1997	5238	0.13' HMA Class B
		1993	4213	0.12' HMA Class B
		1976-1919	N/A	(0.40' HMA Class B over 1.25' UTB) or (0.27' HMA Class B over 0.50' PCCP over 0.50' UTB)
5.87	6.36	1993	4213	0.12' HMA Class B
		1976	0175	0.15' HMA Class B
		1949-1919	N/A	(0.25' HMA Class B over 1.25' UTB) or (0.12' HMA Class B over 0.50' PCCP over 0.50' UTB)
6.36	6.48	1997	5238	0.13' HMA Class B
		1992	4213	0.12' HMA Class B
		1976-1942	N/A	0.27' HMA Class B
		1919		0.50' PCCP over 0.50' UTB
6.48	9.43	1993	4213	0.12' HMA Class B
		1976	0175	0.15' HMA Class B
		1949	N/A	(0.25' HMA Class B over 1.25' UTB) or (0.12' HMA Class B over 0.50' PCCP over 0.50' UTB)
9.43	9.66	2001	5410	0.15' HMA Class B
		1976	0175	0.15' HMA Class B
		1947	N/A	0.17' Mixed Bituminous over 0.83' UTB
9.66	9.95	2001	5410	Bridges # 542/010 & #542/011
9.95	10.11	2001	5410	0.15' HMA Class B
		1982	2302	0.15' HMA Class B
		1950	N/A	0.08' BST over unknown HMA thickness
10.11	14.09	1993	4294	0.20' HMA Class B
		1982	2302	0.15' HMA Class B
		1950	N/A	0.08' BST over unknown HMA thickness
14.09	19.27	1989	3445	0.15' HMA Class B
		1981	2066	0.06' HMA Class B
		1974	N/A	0.06' HMA Class B
		1950-1922		0.06' BST over unknown HMA thickness

The pavement throughout the SR-542 mainline within the project limits shows low severity raveling of cyclic segregation areas, rutting, longitudinal and transverse cracking. In some areas, the HMA over the PCCP has low to medium severity longitudinal and transverse reflective cracking. In addition, there are several areas that show medium to high severity alligator cracking, and maintenance patching areas (see Photos 2 to 10). Most of these alligator cracked areas extend outwards from the edge of the narrow underlying PCCP panels.

SR-542/Britton Road to Coal Creek Bridge Vic. XL-2433
October 30, 2008 Page 3 of 10

Fifteen (15) core samples were obtained within the project limits to verify the thickness of the last HMA overlay and total pavement thickness. The location and thickness of each overlay layer in each core sample are summarized in Table 2. Representative cores were sent to the HQ Lab for testing to determine the residual asphalt binder properties.

Table 2 - Location and Thickness of HMA Core Samples

Core No.	Contract	Location Mainline (Approximate MP)	Thickness (ft)
1	5238	~ MP 3.5	0.35' HMA (.13'+.08'+.14')*
2		~ MP 3.7	0.55' HMA (.14'+.06'+.25'+.06')*
3		~ MP 5.8	0.28' HMA (.12'+.09'+.070')*
4		~ MP 6.4	0.50' HMA (.13'+.11'+.05'+.10'+>.21')*
5	4213	~ MP 6.8	0.19' HMA (.10'+.09')*
6		~ MP 7.6	0.27' HMA (.12'+.15')*
7		~ MP 8.4	0.47' HMA (.12'+.14'+.09'+.12)*
8		~ MP 9.2	0.35' HMA (.15'+.20')*
9	4294	~ MP 10.3	0.42' HMA (.13'+.06'+.23')*
10		~ MP 11.5	0.55' HMA (.12'+.07'+.20'+>.16')*
11		~ MP 12.7	0.45' HMA (.12'+.07'+.25')*
12		~ MP 13.9	0.15' HMA (.15')*
13	3445	~ MP 14.6	0.31' HMA (.15'+.16')*
14		~ MP 16.0	0.40' HMA (.14'+.09'+.17')*
15		~ MP 17.5	0.30' HMA (.15'+.05'+.10')*
16		~ MP 19.0	0.44' HMA (.15'+.05'+.18'+>.06')*

* These were the actual measured HMA layer thicknesses of each core sample. HMA core locations were not cored to the full depth of pavement.

Twenty-three (23) core samples were obtained from the existing left and right shoulders within the project limits to verify the actual pavement thicknesses for shoulder rumble strips. The location and thickness of core samples are summarized in Table 3:

Table 3 - Location and Thickness of HMA Shoulder Core Samples

Core No.	Location (Vic. MP)	Thickness (ft)	Core No.	Location (Vic. MP)	Thickness (ft)
1	EB SR 542, ~ MP 3.0	0.27	13	WB SR 542, ~ MP 3.5	0.38
2	EB SR 542, ~ MP 4.0	0.29	14	WB SR 542, ~ MP 4.5	0.49
3	EB SR 542, ~ MP 5.0	0.35	15	WB SR 542, ~ MP 5.5	0.38
4	EB SR 542, ~ MP 6.0	0.47	16	WB SR 542, ~ MP 6.5	0.54
5	EB SR 542, ~ MP 7.0	0.28	17	WB SR 542, ~ MP 7.5	0.39
6	EB SR 542, ~ MP 8.0	0.36	18	WB SR 542, ~ MP 8.5	0.39
7	EB SR 542, ~ MP 9.0	0.43	19	WB SR 542, ~ MP 9.5	0.41
8	EB SR 542, ~ MP 10.0	0.41	20	WB SR 542, ~ MP 10.5	0.75
9	EB SR 542, ~ MP 11.0	0.75	21	WB SR 542, ~ MP 11.5	0.58
10	EB SR 542, ~ MP 12.0	0.76	22	WB SR 542, ~ MP 12.5	0.73
11	EB SR 542, ~ MP 13.0	0.53	23	WB SR 542, ~ MP 13.5	0.69

Core No.	Location (Vic. MP)	Thickness (ft)	Core No.	Location (Vic. MP)	Thickness (ft)
12	EB SR 542, ~ MP 14.0	0.48			

SR 9 Mainline *(MP 84.01 to MP 84.46)*
WSPMS indicates that the ADT for this section is 4,000 vehicles of which 18.81% are trucks. The growth rate is projected at 3.0%. The WSPMS shows previous contracts that constructed and resurfaced SR 9 mainline within the project limits as shown in Table 4.

Table 4 – Corridor Pavement Profiles

Beginning MP	Ending MP	Year	Contract	Thickness and Surface Type
84.01	84.03	1976	0208	0.15' HMA Class B
		1930		0.58' PCCP over 0.50' UTB
84.05	84.46	1998	5442	0.13' HMA Class B
		1985	2905	0.04 BST Class B
		1976	0208	0.15' HMA Class B
		1930		0.58' PCCP over 0.50' UTB

The HMA over the PCCP has low severity raveling, longitudinal and transverse reflective cracking, and medium to high severity alligator cracking (see Photos 9 & 10). Most of these alligator cracked areas extend outwards from edge of the narrow underlying PCCP panels.

Six (6) core samples were obtained within the project limits to verify the thickness of the last HMA overlay, and total pavement thickness. The location and thickness of each overlay layer in each core sample are summarized in Table 5.

Table 5 - Location and Thickness of HMA Core Samples

Core No.	Location (Approximate MP)	Thickness (ft)
1	Bridge No. 009/351 (Southbound)	0.12' HMA + Bridge Deck
2	Bridge No. 009/352 (Southbound)	0.13' HMA + Bridge Deck
3	NB SR 9, ~ MP 84.12 (Travel lane)	0.35' HMA (.09'+.11'+.15')* + PCCP
4	NB SR 9, ~ MP 84.38 (Travel lane)	0.53' HMA (.14'+.17'+.22')*
5	SB SR 9, ~ MP 84.15 (Travel lane)	0.43' HMA (.10'+.15'+.18')* + PCCP
6	SB SR 9, ~ MP 84.28 (Travel lane)	0.52' HMA (.12'+.17'+.14'+.09')*

* These were the actual measured HMA layer thicknesses of each core sample.

Pavement Design

SR-542 Mainline (MP 2.98 to MP 3.38)
The pavement section from MP 2.98 to MP 3.38 has a thin HMA (~0.10') overlay over the PCCP panels (see Photos 1 & 2). We recommend this area to be overlaid and rehabilitated in the following manner:

1. At the beginning and end of the paving limits, grind transverse butt joints. The transverse butt joints should taper from 0.08' to 0.00' in a minimum length of 15'.
2. Crack seal cracks greater than ¼" in accordance with Section 5-04.3(5)C of the *Standard Specifications for Road, Bridge, and Municipal Construction*
3. Overlay the roadway including the shoulders with 0.15' HMA Class ½", PG 58-22.

SR-542 Mainline (MP 3.38 to MP 19.27)
With HIP method, 100 percent recycling of the existing asphalt pavement is completed on site. Typical treatment depths range from ¾" to 2 inches although some equipment can treat up to 3 inches deep. The process consists of heating and scarification of the existing pavement, mixing the scarified material with additional aggregate, asphalt, and/or rejuvenating agent, as necessary, relaying the recycled mix and compacting with conventional HMA paving equipment. HIP can be used to address the pavement distresses such as rutting, corrugations, raveling, flushing, loss of friction, and minor thermal cracking. HIP method have several advantages including economic savings (between 20% and 30%) compared to a HMA mill and fill operation, it reduces traffic disruptions and user inconvenience, the roadway is opened to traffic at the end of the day, and minimal environmental impacts. Based on these advantages and early discussions between Chris Johnson, NW Region Material Lab, and Jeff Uhlmeyer, HQ Material Lab, and other members of Program Management Office, it was decided to use the Hot In-Place method in lieu of the conventional overlay techniques for this project. This project will allow the NW Region to observe the latest HIP process as well as to evaluate the short and long term performance of a HIP pavement. Due to budget constraint, this process will help balance the P-1 program funding while maintaining the pavement integrity.

1. Repair alligatored pavement by removing HMA and underlying base materials a minimum of 4.0 ft wide extending the length of the damaged HMA to a depth of 1.05'. Recompact the remaining material, and replace the excavated pavement section with 0.70' HMA Class ½", PG 58-22 over 0.35' CSBC.
2. Implement the Hot In-Place Recycling method over the entire mainline through the intersections, including the lane widen, turn lanes, and bus pullouts.

Bridges
The bridge condition report (see attached) obtained from WSDOT Bridge Division were reviewed and showed that the Bridges No. 542/13, 542/14, 542/16, 542/17, & 542/18 do not require an HMA overlay except to improve ride quality. We recommend using the Hot In-Place Recycling method over these bridges to improve the ride. The depth of the HIP operation over Bridge No. 542/21 should be limited to a depth of 0.05', but the HMA (recycled and/or virgin) replacing it shall be 0.15' thick. This will require some extra virgin HMA material to be added to the HIP train for this application. Provide the bridges with transverse joint seals at both ends of the bridge decks as shown in Detail 1 of the WSDOT Standard Plan Sheet A-40.20-00.

SR 542 Mainline (Rumble Strips)
It is our understanding that the existing EB and WB shoulders of SR 542 mainline will not be re-stripped, and will not be used as a travel lane after the shoulders rumble strips are installed. Based on the WSPMS data and thickness of HMA core samples, the existing left and right shoulders, and SR 542 mainline from MP 2.98 to MP 19.27 are adequate to support the grinding for centerline and shoulder rumble strips. The centerline rumble strip should be installed as shown in *Standard Plan* M-65.10-01, and the shoulder rumble strip plan sheet will be modified by the Design Office.

SR-9 Mainline *(MP 84.01 to MP 84.46)*

1. Grind the full width of the roadway including the shoulders to a depth of 0.15'.
2. Repair alligatored cracking by saw cutting at the edge of the concrete panels, and removing the existing HMA and underlying base materials in the travel lanes and shoulders with a minimum of 4.0 ft wide extending the length of the damaged HMA to a depth of 0.95'. Re-compact the remaining material, and replace the excavated pavement section with 0.60' HMA Class ½", PG 58-22 over 0.35' CSBC.
3. **Bridge #9/352**: Grind 0.12' of HMA off the bridge decks. Provide the bridge with transverse joint seals at both ends of the bridge deck as shown in Detail 1 of the WSDOT Standard Plan Sheet A-40.20-00.
4. Crack seal cracks greater than ¼" in accordance with Section 5-04.3(5)C of the *Standard Specifications for Roads, Bridge, and Municipal Construction.*
5. Inlay the roadway, including the bridge #9/352 and shoulders, with 0.15' HMA Class ½", PG 58-22.

HMA Test Requirements

The 15-year calculated design ESALs of 1.7 million should be used for HMA Test Requirements per Section 9-03.8(2) of the *Standard Specifications* and for the fill-in in GSP 03082.FR9.

Joe DeVol and Jeff Uhlmeyer of the Headquarters Materials Lab should be contacted to obtain the appropriate Hot In-Place Recycling Special Provisions. In addition, Joe DeVol can provide the design office with the residual asphalt properties and gradation information obtained from the roadway cores.

HMA Construction Requirements

Include GSP 0403130.FR5, "Surface Smoothness" use with the fill-in for "Pay Adjustment Schedule 3 in GSP 04053.FR5" in the special provisions for this project. Contact John Livingston at the Headquarters Materials Lab at (360) 709-5472 for the testing and latest reading of the International Roughness Index (IRI) Values.

SR-542/Britton Road to Coal Creek Bridge Vic.
October 30, 2008

XL-2433
Page 7 of 9

Other

In the special provisions for this project revise the first sentence of **Standard Specification 5-04.3(10)B Control** with the following:

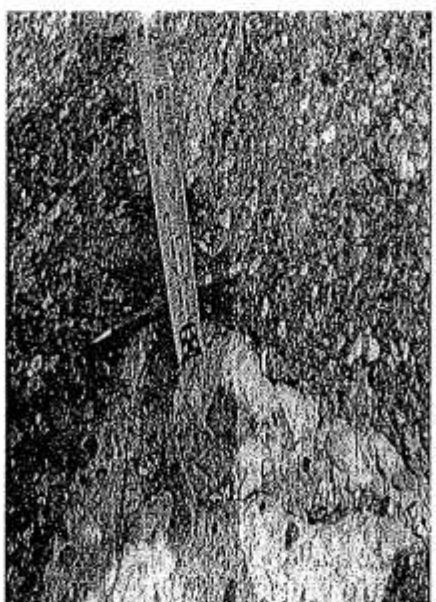
"HMA used in traffic lanes, including lanes for ramps, truck climbing, weaving, speed change, **and shoulders,** and having a specified compacted course thickness greater than 0.10 foot, shall be compacted to a specified level of relative density."

No state owned material source is being provided. The contractor will be required to supply sources of all material incorporated in the project.

We trust this information is sufficient at this time. If you have any questions regarding this Memorandum, please call Nabil Dbaibo at (206) 768-5905 or Hon Hua at (206) 768-5921.

CJJ/ NTD/HTH:hth

Job No: XL-2433
Serial File: 08-194



Photos 1 & 2 (~MP 3.10): ACP over the PCCP slabs has low to medium severity longitudinal and transverse cracking. The HMA layer thickness was measured ~.08'.

SR-542/Britton Road to Coal Creek Bridge Vic. XL-2433
October 30, 2008 Page 8 of 9

Photo 3 (~MP 4.8): Low to medium severity transverse & longitudinal reflective cracking.

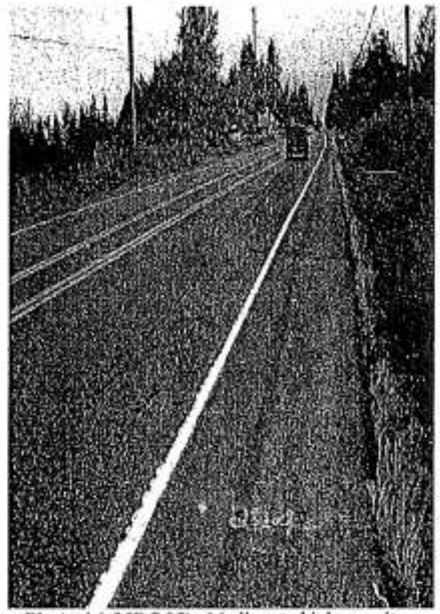


Photo 4 (~MP 7.05): Medium to high severity transverse and longitudinal cracking

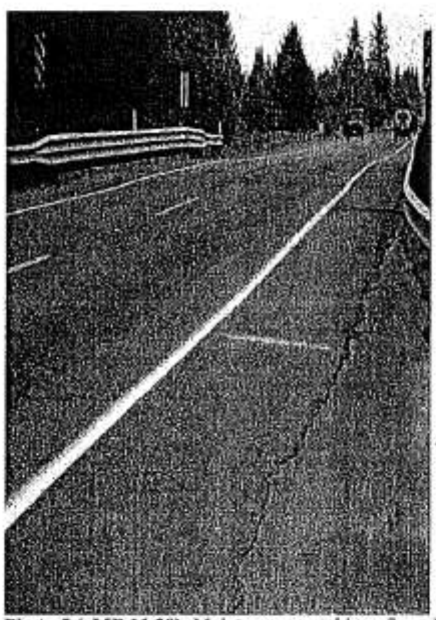


Photo 5 (~MP 11.29): Maintenance patching of HMA over the bridge deck # 542/016.

Photo 6 (~MP 14.27): Medium to high severity alligator cracking along the fog line and shoulder on WB lane.

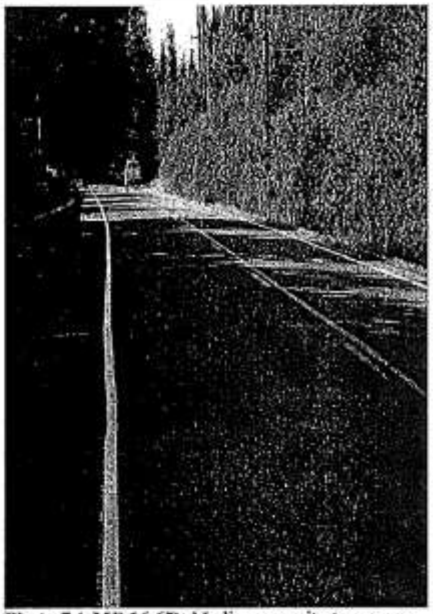
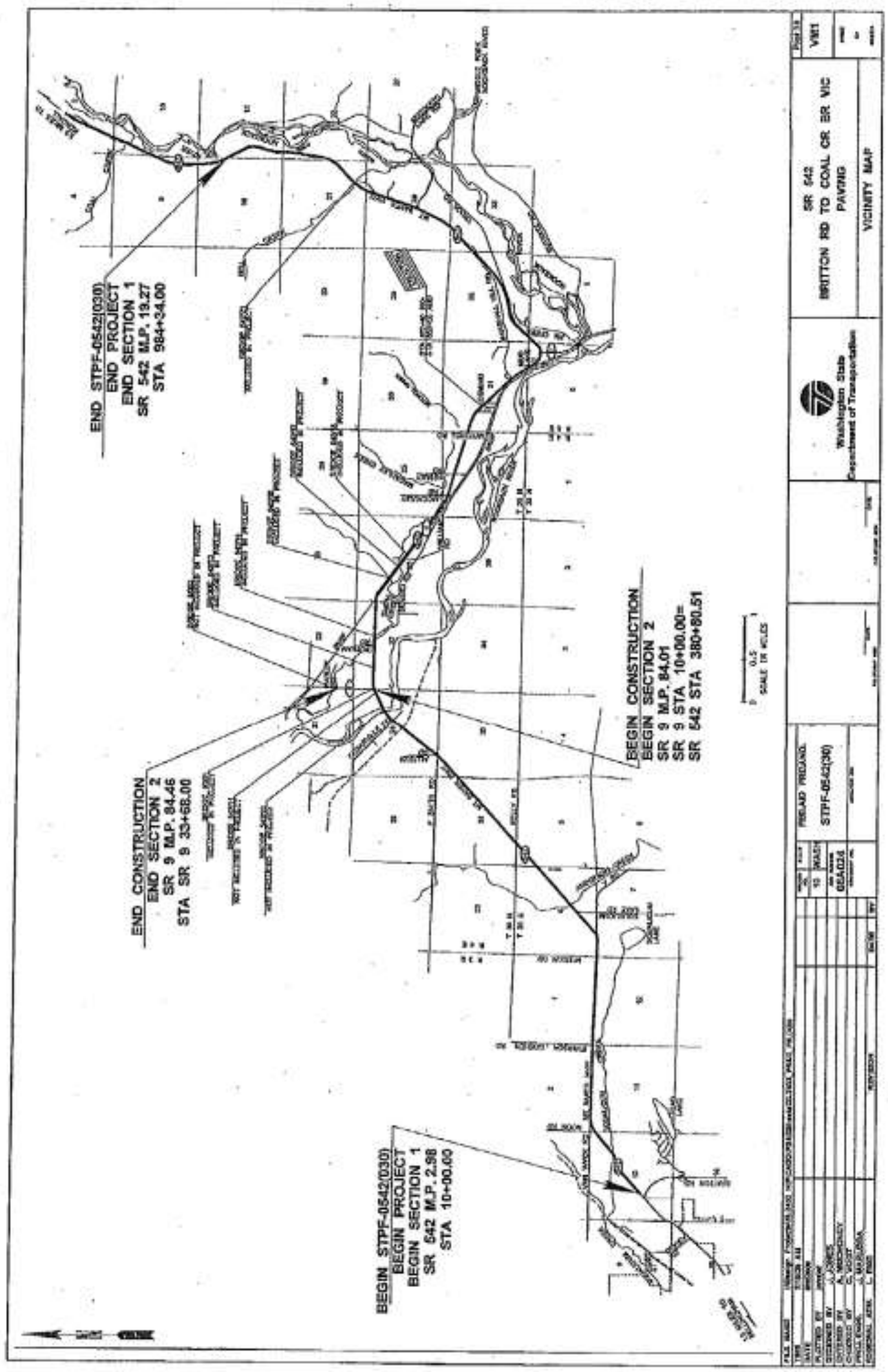


Photo 7 (~MP 16.65): Medium severity transverse and longitudinal cracking that was patched with HMA by maintenance crews.

Photo 8 (~MP 17.65): High severity alligator cracking and settlement that was patched with HMA by maintenance at both ends of the bridge #542/21.

Photos 9 & 10 (SR 9 at ~ MP 84.06): Medium to high severity alligator cracking occurring in the wheel path between the edge of the PCCP panels and HMA pavement.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SR 542 M.P. 19.27
STA 984+34.00
END CONSTRUCTION
END SECTION 2
SR 9 M.P. 84.46
STA SR 9 33+68.00
BEGIN CONSTRUCTION
BEGIN SECTION 2
SR 9 M.P. 84.01
SR 9 STA 10+00.00=
SR 542 STA 380+80.51
BEGIN STPF-0542(030)
BEGIN PROJECT
BEGIN SECTION 1
SR 542 M.P. 2.98
STA 10+00.00
SR 542
BRITTON RD TO COAL CR BR VIC
PAVING
VICINITY MAP
Washington State
Department of Transportation
STPF-0542(30)
VM1

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
WSDOT
6431 Corson Ave., So.
Seattle, WA 98108

Flexible Structural Design Module

SR 542 XL 2433
Britton Road to Coal Creek Bridge Vic.
MP 2.98 to MP 19.27
(Pavement Repair Section)

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	14,258,447
Initial Serviceability	4.5
Terminal Serviceability	3
Reliability Level	80 %
Overall Standard Deviation	0.5
Roadbed Soil Resilient Modulus	12,500 psi
Stage Construction	1
Calculated Design Structural Number	4.28 in

Simple ESAL Calculation

Performance Period (years)	50
Two-Way Traffic (ADT)	8,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	9 %
Average Initial Truck Factor (ESALs/truck)	1.25
Annual Truck Factor Growth Rate	0 %
Annual Truck Volume Growth Rate	3 %
Growth	Simple
Total Calculated Cumulative ESALs	14,258,447

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)		Width (ft)	Calculated SN (in)
1	HMA Class 1/2", PG 58-22	0.44	1	8.4	0.70	12	3.70
2	CSBC	0.14	1	4.2	.35	12	0.59
Total	-	-	-	12.60	1.05	-	4.29

Page 1

Layered Thickness Design

Thickness precision | Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	HMA	0.44	1	-	4.2	400,000	12	7.09	3.12
2	CSBC	0.14	1	-	4.2	28,000	12	8.30	1.16
Total	-	-	-	-	-	-	-	15.39	4.29

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
WSDOT
6431 Corson Ave., So.
Seattle, WA 98108

Flexible Structural Design Module

SR 542 XL 2433
Britton Road to Coal Creek Bridge Vic.
MP 2.98 to MP 19.27
(SR 9, MP 84.01 to MP 84.46 - Pavement Repair Section)

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	14,900,077
Initial Serviceability	4.5
Terminal Serviceability	3
Reliability Level	80 %
Overall Standard Deviation	0.5
Roadbed Soil Resilient Modulus	12,500 psi
Stage Construction	1
Calculated Design Structural Number	4.31 in

Simple ESAL Calculation

Performance Period (years)	50
Two-Way Traffic (ADT)	4,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	18.81 %
Average Initial Truck Factor (ESALs/truck)	1.25
Annual Truck Factor Growth Rate	0 %
Annual Truck Volume Growth Rate	3 %
Growth	Simple
Total Calculated Cumulative ESALs	14,900,077

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)		Width (ft)	Calculated SN (in)
1	HMA Class 1/2", PG 58-22	0.44	1	1.8	0.15'	12	0.79
2	HMA Class 1/2", PG 58-22	0.44	1	1.8	0.15'	12	0.79
3	HMA Class 1/2", PG 58-22	0.44	1	3.6	0.30'	12	1.58
4	CSBC	0.14	1	8.4	0.70'	12	1.18
Total	-	-	-	15.60	1.30'	-	4.33

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Layered Thickness Design

Thickness precision Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	HMA	0.44	1	-	4.2	400,000	12	7.14	3.14
2	CSBC	0.14	1	-	4.2	28,000	12	8.48	1.19
Total	-	-	-	-	-	-	-	15.63	4.33

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Appendix C

Contract HIPR Specifications

HOT IN-PLACE RECYCLED HMA

Description
This work shall consist of hot in-place recycled HMA in accordance with these Specifications and the lines, grades, thicknesses, and typical cross-sections shown in the Plans.

Materials
Materials shall meet the requirements of the following sections:

Asphalt Binder 9-02.1(4)
Anti-Stripping Additive 9-02.4
Aggregate for Bituminous Surface Treatment 9-03.4(2)

Recycling Agent
The recycling agent used to rejuvenate the existing pavement shall meet the specifications in Table 1.

Table 1			
Test	ASTM Test Method	Minimum	Maximum
Viscosity @ 140˚F cSt	D2170 or D2171	200	800
Flashpoint COC, ˚F	D92	400	
Saturates, Wt. %	D2007		30
Specific Gravity	D70 or D2198	Report	
Residue Test from RTFC	D2872		
Viscosity Ratio note 1			3
Mass Change ± %			4
Note 1 Viscosity Ratio = RTFC Viscosity @ 140˚F, cSt / Original Viscosity @ 140˚F, cSt			

Aggregate
The mineral aggregate for Hot in-Place Recycled HMA shall meet the grading and quality requirements as found in the table for Crushed Screening Percent Passing for 5/8" - US No. 4 in Section 9-03.4(2). The mineral aggregate shall be pre-coated with PG58-22 performance graded asphalt binder which contains 1% anti-strip additive by weight of asphalt binder.

Existing Pavement
The Contracting Agency has randomly sampled and tested the existing pavement along the hot in-place recycling limits. The gradation and Percent Binder (Pb) results of those core samples are as follows:

Roadway Core Gradation & Pb Test Results										
	Percent Passing									Percent Binder
Core Location	3/4"	1/2"	3/8"	US #4	US #8	US #16	US #30	US #50	US #100	US #200	Pb
MP 3.5	100	97	88	63	47	35	25	15	9	6.1	5.8
MP 3.7	100	96	86	58	43	33	23	14	8	5.8	5.6
MP 5.8	100	95	84	58	42	31	21	13	8	5.8	5.9
MP 6.4	100	91	82	56	40	29	20	12	8	5.5	6.0

MP 6.8	100	99	92	64	47	36	25	15	8	6.0	6.3
MP 7.6	100	99	90	62	45	34	24	14	8	5.9	7.2
MP 8.4	100	96	87	63	47	36	26	15	9	6.8	5.7
MP 9.2	100	98	91	67	50	38	26	15	9	6.4	5.6
MP 10.3	100	98	87	59	43	32	23	13	8	5.3	5.5
MP 11.5	100	98	88	60	44	33	23	13	8	5.4	5.4
MP 12.7	100	97	86	60	45	34	23	14	8	5.1	5.7
MP 13.9	100	99	94	65	46	34	22	12	7	4.8	6.2
MP 14.6	100	95	81	56	42	30	21	12	7	4.7	6.4
MP 16.0	100	92	80	53	40	30	21	12	8	5.4	5.8
MP 17.5	100	94	83	58	43	32	23	13	7	5.1	5.4
MP 19.0	100	100	97	71	51	36	25	15	10	7.4	6.2
Average	100	97	87	61	45	33	23	14	8	5.7	5.9

Construction Requirements

Project Experience

The Contractor shall demonstrate that personnel responsible for the hot in-place recycling have had experience with this method of paving for five or more similar projects totaling a minimum of 200 lane miles.

Resumes with information on personnel experience and a list of referenced projects shall be provided to the Engineer for approval at least 15 working days prior to the start of work on the hot in-place recycling. The list shall include a description of the work, location; inclusive dates when the work was performed, and a contact for each project. The contact shall include an individual's name, title, and current telephone number.

Project Pre-paving Meeting

A meeting shall be held a minimum of 10-working days before hot in-place recycling paving to discuss construction procedures, personnel, and equipment to be used. Those attending shall include:

1. (representing the Contractor) The superintendent and all foremen in charge of the hot in-place recycling paving

2. (representing the State) The Project Engineer, key inspection assistants, and the State Construction Office.

General

Heating and milling/scarifying the existing pavement, adding recycling agent and anti-stripping additive, mixing with pre-coated mineral aggregate, spreading, leveling, and compacting of the Hot in-Place Recycled HMA shall be accomplished by a single pass equipment train.

Equipment

The equipment used for the hot in-place recycling HMA on this project shall meet the air quality requirements of Section 1-07.5(4).

Heating Units

Heating units shall be clusters of indirect radiant heaters or infrared heaters capable of uniformly heating the existing pavement to a temperature sufficient to allow milling of the material to the specified depth without; fracturing aggregate, burning or charring the asphalt binder, or producing undesirable pollutants. The heating unit shall heat the existing surface a minimum of 4 inches beyond the width of the milling and shall not subject the surface to open flame. The heating unit shall be under an enclosed or shielded hood.

Milling/Scarifying Units

Two separate milling/scarifying machines shall be used, with each unit capable of removing 1/2 of the specified depth of the existing pavement surface. Each unit shall be capable of milling/scarifying as wide as 12 feet in one pass. These milling/scarifying units shall uniformly loosen and remove the heated pavement to the depth specified without fracturing aggregate. Automatic grade and cross slope controls shall be required on the final milling/scarifying unit in the equipment train. The milling/scarifying units shall be capable of height adjustments in order to clear manholes and other obstructions in the pavement surface.

Distribution and Blending Unit(s)

A controlled system shall be used for adding and uniformly blending the recycling agent, anti-strip additive and pre-coated mineral aggregate at a predetermined rate with the milled existing pavement during remixing and leveling operation. The recycling system shall be required to provide the following:

1 Application rate for the added materials synchronized with the speed on the recycling system.

2. Control of the quantity of recycling agent to ± 0.05 gallons per square yard of surface treated with an application range of 0.1 to 2.0 percent by weight of the milled existing pavement.

3. Heating the recycling agent to ± 25˚F of the temperature of the milled existing pavement.

4. Measurement of the recycling agent by a device capable of recording accumulated gallons to an accuracy of ± 2 percent.

5. Twin shaft pug mill capable of thoroughly mixing the recycling agent and anti-strip additive, pre-coated mineral aggregate and milled existing pavement to produce a uniform, consistent product.

Spreading and Leveling Unit(s)

The spreading and leveling unit shall be capable of spreading and leveling the blended, mixed, recycled hot mix asphalt (HMA) material uniformly over the width being processed to the finished grade and cross slope specified in the Plans. The unit shall meet the requirements of Section 5-04.3(3)

Compaction

Compaction equipment shall meet the requirements of Section 5-04.3(4) Rollers.

Preparation of Existing Surface

The existing pavement surface to be recycled shall be cleaned and all dirt, thermoplastic markers, rubberized materials, oils and other objectionable materials shall be removed before beginning the hot in-place recycling. Power brooms shall be used, supplemented when necessary by hand brooming and other tools as required to bring the surface to a clean, suitable condition free of deleterious material.

Heating and Milling/Scarifying

The existing pavement surface shall be uniformly heated, milled/scarified and reworked to the widths and depths shown in the Plans. The existing pavement surface shall be heated with continuously moving heaters to allow the pavement to be scarified to a minimum of 1/2 the specified depth and at least 4 inches beyond the width of milling in a single pass. The temperature of the milled material shall not exceed 325˚F when measured immediately behind the milling machine.

Blending, Mixing, Spreading and Leveling

The recycling agent shall be applied uniformly to the milled existing pavement at a rate of 0.14 gallons per square yard prior to remixing in the pug-mill. The mineral aggregate shall be 5/8”-US No. 4 Crushed, thoroughly pre-coated with PG58-22 asphalt binder treated with 1% anti-stripping additive prior to remixing in the pug-mill. The milled existing pavement treated with recycling agent and the pre-coated mineral aggregate shall be fed into a mixing unit and thoroughly mixed to produce a consistent recycled HMA. The recycled HMA shall be distributed and leveled by an activated screed assembly. The leveling unit shall be capable of screeding the full width of the recycled HMA being placed.

Joints

When a pass is made adjacent to a previously placed mat, the longitudinal joint shall extend 2 inches into the previously placed mat. When a pass is adjacent to a previously placed mat, the transverse joint shall extend 4 inches into the previously placed mat. All longitudinal joints in the completed pavement shall be located at a lane line or an edge line of the traveled way.

Mixture Design

Prior to production of Hot In-Place Recycled HMA, the Contractor shall determine the optimum quantity of pre-coated mineral aggregate needed to meet the end product Air Void (Va) specification of 2.5% - 5.5% when compacted to 75 N design gyrations using the Superpave Gyratory Compactor (SGC). The Contracting Agency will perform specification testing in accordance with WSDOT Standard Operating Procedure SOP 731.

A set of 16 core samples taken from the existing pavement surface will be provided by the Contracting Agency to the Contractor. The Contractor shall determine through testing the optimum quantity of pre-coated mineral aggregate to add to meet the end product specifications.

Testing and Acceptance

The basis for acceptance for compaction of hot in-place recycled HMA will be by a satisfactory rolling pattern. A rolling pattern shall be defined as the number of passes the Contractor's compaction equipment must make over the surface of hot in-place recycled HMA to achieve the maximum density. The number of passes shall be established by taking nuclear density tests after each roller pass to determine the number of passes needed to reach the maximum density. Nuclear density testing to establish a rolling pattern will be conducted by WSDOT. A new rolling pattern may be established any time the Engineer determines that compaction requirements have changed but not less than once per lane mile.

The Contracting Agency will perform informational sampling to test for Percent Air Voids (Va).

Smoothness

The smoothness shall meet the requirements of Section 5-04.3(13) Surface Smoothness.

Measurement

Hot In-Place Recycled HMA

Hot in-place recycled HMA will be measured by the square yard of surface area of completed and accepted work for the width and depth as specified in the Plans.

Recycling Agent

Recycling agent will be measured by the ton incorporated in the project.

Asphalt Binder

Asphalt binder will be measured by the ton incorporated in the project.

Anti-Stripping Additive

Anti-Stripping Additive will be measured as provided in Section 5-04.4.

Aggregate

Mineral aggregate for Hot in-Place Recycled HMA will be measured by the ton incorporated in the project.

Payment

Payment will be made in accordance with Section 1-04.1, for each of the following bid items that are included in the Proposal:

"Hot In-Place Recycled HMA", per square yard.
The unit contract price per square yard for "Hot In-Place Recycled HMA" shall be full payment for all costs of materials, labor, tools, and equipment to complete the work.

"Recycling Agent", per ton.
The unit contract price per ton for "Recycling Agent" of the type and grade specified shall be full payment for furnishing, hauling, dispersing, labor, tools, equipment and incidentals necessary to complete the work.

“Asphalt Binder”, per ton.

“Anti-Stripping Additive”, by calculation
Payment for “Anti-Stripping Additive” will be as provided in Section 5-04.5.

“Aggregate for Hot in-Place Recycled HMA”, per ton.
The unit contract price per ton for "Aggregate for Hot in-Place Recycled HMA " shall be full payment for producing, heating, pre-coating, blending, mixing, hauling, placement, labor, tools, equipment and incidentals necessary to complete the work.

“Asphalt Cost Price Adjustment”, by calculation.
“Asphalt Cost Price Adjustment” will be calculated and paid for as described in Section 5-04.5 as supplemented in these Special Provisions. For the purpose of providing a common proposal for all bidders, the Contracting Agency has entered an amount in the proposal to become a part of the total bid by the Contractor.

Appendix D

HIPR Daily Production

Table 18. Daily HIPR production.					
Date	Begin MP	End MP	Direction	Distance (lane/miles)	Shift
8/18/2009	14.57	15.82	EB	1.25	day
8/19/2009	15.82	17.20	EB	1.38	day
8/20/2009	17.20	18.59	EB	1.39	day
8/21/2009	18.59	19.29	EB	0.71	day
8/24/2009	19.29	18.05	WB	1.24	day
8/25/2009	18.05	16.66	WB	1.34	day
8/26/2009	16.66	15.23	WB	1.44	day
8/27/2009	15.23	13.49	WB	1.72	day
8/28/2009	13.49	12.68	WB	0.82	day
8/30/2009	12.68	11.29	WB	1.29	night
8/31/2009	11.29	9.84	WB	1.19	night
9/1/2009	9.66	8.17	WB	1.37	night
9/2/2009	8.17	6.62	WB	1.55	night
9/3/2009	6.62	4.99	WB	1.63	night
9/8/2009	4.99	3.83	WB	1.16	night
9/9/2009	3.83	2.98	WB	0.85	night
9/9/2009	3.38	3.91	EB	0.53	night
9/10/2009	3.91	5.03	EB	1.39	night
9/11/2009	5.03	6.75	EB	1.72	night
9/13/2009	6.75	8.40	EB	1.72	night
9/14/2009	8.40	8.76	EB	0.36	night
9/15/2009	8.76	9.42	EB	1.33	night
9/16/2009	9.42	10.94	EB	1.15	night
9/17/2009	10.95	12.54	EB	1.32	night
9/21/2009	12.54	14.57	EB	0.89	night

Appendix E

Density Test Results

Table 19. Density test results.

Date	Direction	Sta.	Offset (ft.)	Gauge Reading (pcf)	Correlation Factor	Rice Density (pcf)	Corrected Density (pcf)
8/18/2009	RT	739+52	5.2	143.7	0.9993	153.4	93.6
8/18/2009	RT	747+63	8.5	143.9	0.9993	153.4	93.7
8/18/2009	RT	748+86	8.8	145.4	0.9993	153.4	94.7
8/18/2009	RT	755+76	3.4	143.1	0.9993	153.4	93.2
8/18/2009	RT	761+77	7.4	143.8	0.9993	153.4	93.7
8/18/2009	RT	768+77	10.2	145.9	0.9993	153.4	95.0
8/18/2009	RT	773+35	5.3	147.7	0.9993	153.4	96.2
8/18/2009	RT	781+01	3.4	147.3	0.9993	153.4	96.0
8/18/2009	RT	789+05	10.4	146.2	0.9993	153.4	95.2
8/18/2009	RT	792+68	5.5	145.5	0.9993	153.4	94.8
8/19/2009	RT	804+43	2.3	144.3	0.9993	154.5	93.3
8/19/2009	RT	807+76	9.2	143.6	0.9993	154.5	92.9
8/19/2009	RT	816+47	4.9	144.8	0.9993	154.5	93.7
8/19/2009	RT	820+30	3.5	145.8	0.9993	154.5	94.3
8/19/2009	RT	826+94	6.1	144.8	0.9993	154.5	93.7
8/19/2009	RT	833+47	7.0	145.2	0.9993	154.5	93.9
8/19/2009	RT	837+96	8.3	143.7	0.9993	154.5	92.9
8/19/2009	RT	843+02	2.9	144.4	0.9993	154.5	93.4
8/19/2009	RT	852+22	1.7	146.2	0.9993	154.5	94.6
8/19/2009	RT	854+23	5.4	147.0	0.9993	154.5	95.1
8/20/2009	RT	875+53	4.0	144.1	0.9993	154.9	93.0
8/20/2009	RT	880+34	5.0	140.1	0.9993	154.9	90.4
8/20/2009	RT	889+21	3.8	140.4	0.9993	154.9	90.6
8/20/2009	RT	895+44	5.6	145.1	0.9993	154.9	93.6
8/20/2009	RT	901+60	4.7	146.1	0.9993	154.9	94.3
8/20/2009	RT	909+14	2.0	143.6	0.9993	154.9	92.6
8/20/2009	RT	913+25	1.7	146.9	0.9993	154.9	94.8
8/20/2009	RT	916+51	8.9	144.5	0.9993	154.9	93.2
8/20/2009	RT	927+21	10.3	142.0	0.9993	154.9	91.6
8/20/2009	RT	935+67	5.3	144.2	0.9993	154.9	93.0
8/21/2009	RT	948+43	5.3	145.1	0.9993	154.7	93.7
8/21/2009	RT	956+86	6.0	147.8	0.9993	154.7	95.5
8/21/2009	RT	962+15	9.4	145.1	0.9993	154.7	93.7
8/21/2009	RT	973+15	5.3	142.2	0.9993	154.7	91.9
8/21/2009	RT	982+79	4.3	146.2	0.9993	154.7	94.4
8/24/2009	LT	980+19	8.3	141.6	0.9993	154.4	91.6
8/24/2009	LT	973+79	3.2	145.3	0.9993	154.4	94.0
8/24/2009	LT	970+14	8.3	144.4	0.9993	154.4	93.5

Table 19. Density test results (continued).							
Date	Direction	Sta.	Offset (ft.)	Gauge Reading (pcf)	Correlation Factor	Rice Density (pcf)	Corrected Density (pcf)
8/24/2009	LT	962+24	2.4	146.6	0.9993	154.4	94.9
8/24/2009	LT	959+69	9.2	144.8	0.9993	154.4	93.7
8/24/2009	LT	954+96	6.0	146.8	0.9993	154.4	95.0
8/24/2009	LT	946+55	2.8	142.7	0.9993	154.4	92.4
8/24/2009	LT	941+27	10.2	146.5	0.9993	154.4	94.8
8/24/2009	LT	937+45	8.8	144.0	0.9993	154.4	93.2
8/24/2009	LT	930+07	4.0	147.0	0.9993	154.4	95.1
8/25/2009	LT	917+88	9.0	148.6	0.9993	155.7	95.4
8/25/2009	LT	914+92	6.0	145.5	0.9993	155.7	93.4
8/25/2009	LT	910+34	3.0	143.6	0.9993	155.7	92.2
8/25/2009	LT	901+65	10.0	143.1	0.9993	155.7	91.8
8/25/2009	LT	893+67	9.0	146.4	0.9993	155.7	94.0
8/25/2009	LT	891+14	8.0	147.4	0.9993	155.7	94.6
8/25/2009	LT	884+78	10.0	143.8	0.9993	155.7	92.3
8/25/2009	LT	880+10	2.0	140.5	0.9993	155.7	90.2
8/25/2009	LT	875+07	3.0	143.0	0.9993	155.7	91.8
8/25/2009	LT	868+41	6.0	144.2	0.9993	155.7	92.5
8/26/2009	LT	844+35	5.0	144.8	0.9993	155.2	93.2
8/26/2009	LT	839+06	2.0	145.5	0.9993	155.2	93.7
8/26/2009	LT	830+10	8.0	140.8	0.9993	155.2	90.7
8/26/2009	LT	823+14	5.0	145.5	0.9993	155.2	93.7
8/26/2009	LT	819+72	4.0	145.8	0.9993	155.2	93.9
8/26/2009	LT	814+23	7.0	141.7	0.9993	155.2	91.2
8/26/2009	LT	809+88	5.0	146.9	0.9993	155.2	94.6
8/26/2009	LT	805+35	6.0	145.1	0.9993	155.2	93.4
8/26/2009	LT	799+59	2.0	144.4	0.9993	155.2	93.0
8/26/2009	LT	791+89	5.0	145.0	0.9993	155.2	93.4
8/27/2009	LT	787+48	2.0	144.6	0.9993	154.1	93.8
8/27/2009	LT	779+68	5.0	143.6	0.9993	154.1	93.1
8/27/2009	LT	771+57	9.0	144.0	0.9993	154.1	93.4
8/27/2009	LT	770+34	9.0	142.9	0.9993	154.1	92.7
8/27/2009	LT	763+44	3.0	142.4	0.9993	154.1	92.3
8/27/2009	LT	757+43	8.0	144.3	0.9993	154.1	93.6
8/27/2009	LT	750+43	10.0	143.7	0.9993	154.1	93.2
8/27/2009	LT	745+85	5.0	145.7	0.9993	154.1	94.5
8/27/2009	LT	736+19	3.0	144.6	0.9993	154.1	93.8
8/27/2009	LT	730+15	10.0	147.7	0.9993	154.1	95.8
8/27/2009	LT	726+52	5.5	147.0	0.9993	154.1	95.3
8/27/2009	LT	720+77	3.0	148.2	0.9993	154.1	96.1

Table 19. Density test results (continued).							
Date	Direction	Sta.	Offset (ft.)	Gauge Reading (pcf)	Correlation Factor	Rice Density (pcf)	Corrected Density (pcf)
8/27/2009	LT	717+44	9.0	148.4	0.9993	154.1	96.2
8/27/2009	LT	708+73	5.0	145.4		154.1	
8/27/2009	LT	704+91	3.5	147.4		154.1	
8/28/2009	LT	565+26	6.0	146.6		154.9	
8/28/2009	LT	558+73	7.0	147.6		154.9	
8/28/2009	LT	554+24	8.0	144.4		154.9	
8/28/2009	LT	549+18	3.0	147.0		154.9	
8/28/2009	LT	539+98	2.0	144.3		154.9	
8/28/2009	LT	537+97	5.5	143.8		154.9	
8/28/2009	LT	528+44	5.5	146.8		154.9	
8/28/2009	LT	526+68	7.5	148.8		154.9	
8/30/2009	LT	519+58	7.8	144.7		155.7	
8/30/2009	LT	516+55	3.4	146.4		155.7	
8/30/2009	LT	510+39	10.4	145.5		155.7	
8/30/2009	LT	501+02	9.0	143.2		155.7	
8/30/2009	LT	499+62	7.2	146.9		155.7	
8/30/2009	LT	490+34	4.2	145.5		155.7	
8/30/2009	LT	485+30	2.0	147.2		155.7	
8/30/2009	LT	481+63	2.4	143.9		155.7	
8/30/2009	LT	476+31	10.0	144.8		155.7	
8/30/2009	LT	471+13	7.0	142.6		155.7	
8/30/2009	LT	460+25	3.8	146.9		155.7	
8/30/2009	LT	455+02	4.4	148.6		155.7	
8/31/2009	LT	447+48	5.2	144.9		154.4	
8/31/2009	LT	439+37	8.5	144.8		154.4	
8/31/2009	LT	438+14	8.8	146.6		154.4	
8/31/2009	LT	431+23	3.4	144.0		154.4	
8/31/2009	LT	425+23	7.4	146.0		154.4	
8/31/2009	LT	418+23	10.2	145.9		154.4	
8/31/2009	LT	413+65	5.3	143.3		154.4	
8/31/2009	LT	403+99	3.4	146.1		154.4	
8/31/2009	LT	397+95	10.4	145.5		154.4	
8/31/2009	LT	392+50	5.5	141.9		154.4	
8/31/2009	LT	388+57	2.3	142.0		154.4	
8/31/2009	LT	376+92	9.2	141.7		154.4	
9/1/2009	LT	358+32	4.0	144.4		154.9	
9/1/2009	LT	353+51	5.2	144.0		154.9	
9/1/2009	LT	344+37	3.8	147.2		154.9	
9/1/2009	LT	338+41	5.6	145.0		154.9	

Table 19. Density test results (continued).							
Date	Direction	Sta.	Offset (ft.)	Gauge Reading (pcf)	Correlation Factor	Rice Density (pcf)	Corrected Density (pcf)
9/1/2009	LT	332+25	4.7	144.1		154.9	
9/1/2009	LT	325+47	1.8	145.3		154.9	
9/1/2009	LT	321+86	1.7	146.4		154.9	
9/1/2009	LT	319+00	8.9	147.3		154.9	
9/1/2009	LT	309+59	10.3	145.9		154.9	
9/1/2009	LT	302+16	5.3	142.3		154.9	
9/1/2009	LT	300+10	6.0	141.8		154.9	
9/1/2009	LT	293+49	9.4	142.2		154.9	
9/1/2009	LT	289+34	5.3	141.9		154.9	
9/1/2009	LT	280+72	4.3	143.2		154.9	
9/1/2009	LT	273+17	8.5	144.0		154.9	
9/2/2009	LT	271+05	4.4	141.4		154.9	
9/2/2009	LT	265+38	9.4	142.8		154.9	
9/2/2009	LT	258+45	5.3	142.4		154.9	
9/2/2009	LT	253+59	2.4	143.5		154.9	
9/2/2009	LT	244+71	10.2	146.2		154.9	
9/2/2009	LT	239+87	2.0	143.6		154.9	
9/2/2009	LT	237+08	2.0	144.0		154.9	
9/2/2009	LT	226+74	8.3	142.9		154.9	
9/2/2009	LT	220+82	7.6	144.4		154.9	
9/2/2009	LT	215+41	5.3	140.1		154.9	
9/2/2009	LT	211+19	8.3	142.5		154.9	
9/2/2009	LT	204+79	3.2	143.1		154.9	
9/2/2009	LT	201+09	8.3	142.7		154.9	
9/2/2009	LT	193+25	2.4	144.0		154.9	
9/2/2009	LT	190+69	9.2	143.4		154.9	
9/3/2009	LT	185+96	6.0	142.0		155.8	
9/3/2009	LT	177+56	2.8	145.2		155.8	
9/3/2009	LT	172+27	10.2	143.6		155.8	
9/3/2009	LT	168+45	8.8	144.3		155.8	
9/3/2009	LT	161+07	4.0	143.8		155.8	
9/3/2009	LT	155+87	3.0	145.5		155.8	
9/3/2009	LT	145+77	4.4	142.7		155.8	
9/3/2009	LT	144+06	8.5	145.8		155.8	
9/3/2009	LT	139+31	8.9	144.3		155.8	
9/3/2009	LT	130+41	5.2	145.5		155.8	
9/3/2009	LT	127+00	10.4	145.2		155.8	
9/3/2009	LT	119+71	10.4	142.3		155.8	
9/3/2009	LT	112+32	2.3	143.1		155.8	

Table 19. Density test results (continued).							
Date	Direction	Sta.	Offset (ft.)	Gauge Reading (pcf)	Correlation Factor	Rice Density (pcf)	Corrected Density (pcf)
9/3/2009	LT	110+55	2.2	144.5		155.8	
9/3/2009	LT	101+60	2.2	144.5		155.8	
9/8/2009	LT	95+37	3.5	145.9		156.6	
9/8/2009	LT	92+36	7.4	144.0		156.6	
9/8/2009	LT	85+97	1.5	142.9		156.6	
9/8/2009	LT	81+28	4.8	144.2		156.6	
9/8/2009	LT	71+87	8.0	144.5		156.6	
9/8/2009	LT	65+58	7.8	140.8		156.6	
9/8/2009	LT	62+55	3.4	142.2		156.6	
9/8/2009	LT	56+39	10.4	145.2		156.6	
9/8/2009	LT	47+02	9.0	144.1		156.6	
9/8/2009	LT	45+62	7.2	145.6		156.6	
9/9/2009	LT	35+18	4.2	144.2		155.6	
9/9/2009	LT	29+97	2.0	143.1		155.6	
9/9/2009	LT	26+16	2.4	145.6		155.6	
9/9/2009	LT	20+66	10.0	145.3		155.6	
9/9/2009	LT	15+30	7.0	144.8		155.6	
9/9/2009	RT	36+57	3.8	145.1		155.6	
9/9/2009	RT	43+10	4.4	144.0		155.6	
9/9/2009	RT	46+64	7.9	143.5		155.6	
9/9/2009	RT	49+77	3.7	143.5		155.6	
9/9/2009	RT	56+97	4.7	141.8		155.6	
9/10/2009	RT	63+52	5.2	143.4		154.5	
9/10/2009	RT	71+63	8.5	144.7		154.5	
9/10/2009	RT	72+86	8.8	144.1		154.5	
9/10/2009	RT	79+76	3.4	142.7		154.5	
9/10/2009	RT	85+77	7.4	144.2		154.5	
9/10/2009	RT	92+77	10.2	143.5		154.5	
9/10/2009	RT	97+35	5.3	142.8		154.5	
9/10/2009	RT	197+01	3.4	142.5		154.5	
9/10/2009	RT	100+05	10.4	142.3		154.5	
9/10/2009	RT	103+68	5.5	142.8		154.5	
9/11/2009	RT	110+43	2.3	144.2		155.0	
9/11/2009	RT	113+76	9.2	142.9		155.0	
9/11/2009	RT	122+47	4.9	145.7		155.0	
9/11/2009	RT	126+30	3.5	145.3		155.0	
9/11/2009	RT	132+94	6.1	141.8		155.0	
9/11/2009	RT	139+47	7.0	144.7		155.0	
9/11/2009	RT	143+96	8.3	146.4		155.0	

Table 19. Density test results (continued)							
Date	Direction	Sta.	Offset (ft.)	Gauge Reading (pcf)	Correlation Factor	Rice Density (pcf)	Corrected Density (pcf)
9/11/2009	RT	144+02	2.9	144.1		155.0	
9/11/2009	RT	158+22	1.7	142.4		155.0	
9/11/2009	RT	160+23	5.4	143.7		155.0	
9/12/2009	RT	169+76	5.6	141.4		155.0	
9/12/2009	RT	171+52	7.4	140.8		155.0	
9/12/2009	RT	179+96	7.0	142.4		155.0	
9/12/2009	RT	182+61	2.9	141.8		155.0	
9/12/2009	RT	192+26	7.1	144.0		155.0	
9/12/2009	RT	195+68	3.8	142.1		155.0	
9/12/2009	RT	200+49	5.2	142.4		155.0	
9/12/2009	RT	209+36	3.8	143.7		155.0	
9/12/2009	RT	215+59	5.6	142.5		155.0	
9/12/2009	RT	221+75	4.7	145.3		155.0	
9/13/2009	RT	228+53	1.8	144.6		155.5	
9/13/2009	RT	232+14	1.7	144.4		155.5	
9/14/2009	RT	282+95	6.0	142.4		155.5	
9/14/2009	RT	286+80	9.4	141.1		155.5	
9/14/2009	RT	295+55	5.3	142.2		155.5	
9/14/2009	RT	300+41	4.3	145.7		155.5	
9/14/2009	RT	309+29	8.5	144.9		155.5	
9/14/2009	RT	314+13	2.0	143.4		155.5	
9/14/2009	RT	316+92	2.0	144.0		155.5	
9/14/2009	RT	327+26	8.3	144.6		155.5	
9/14/2009	RT	333+18	7.6	144.4		155.5	
9/14/2009	RT	338+59	5.3	142.4		155.5	
9/15/2009	RT	351+81	8.3	143.8		154.9	
9/15/2009	RT	358+21	2.9	142.3		154.9	
9/15/2009	RT	361+86	8.3	144.4		154.9	
9/15/2009	RT	378+62	2.0	143.0		154.9	
9/15/2009	RT	377+71	9.2	143.5		154.9	
9/15/2009	RT	387+03	6.0	143.2		154.9	
9/15/2009	RT	395+44	2.8	143.4		154.9	
9/15/2009	RT	400+73	10.2	144.7		154.9	
9/15/2009	RT	404+55	9.1	143.6		154.9	
9/15/2009	RT	411+93	4.0	145.4		154.9	
9/16/2009	RT	417+13	3.0	147.1		155.5	
9/16/2009	RT	427+23	4.4	145.0		155.5	
9/16/2009	RT	428+94	8.5	144.4		155.5	
9/16/2009	RT	433+69	8.9	143.9		155.5	

Date	Direction	Sta.	Offset (ft.)	Gauge Reading (pcf)	Correlation Factor	Rice Density (pcf)	Corrected Density (pcf)
9/16/2009	RT	442+59	5.2	143.3		155.5	
9/16/2009	RT	446+00	10.4	144.2		155.5	
9/16/2009	RT	453+29	10.4	141.9		155.5	
9/16/2009	RT	460+68	2.3	145.2		155.5	
9/16/2009	RT	462+45	2.2	144.1		155.5	
9/16/2009	RT	472+40	2.0	143.6		155.5	
9/17/2009	RT	477+63	3.5	141.9		155.7	
9/17/2009	RT	480+64	7.4	142.0		155.7	
9/17/2009	RT	487+03	1.5	143.4		155.7	
9/17/2009	RT	491+72	4.8	143.6		155.7	
9/17/2009	RT	501+13	7.9	145.8		155.7	
9/17/2009	RT	507+42	7.8	143.9		155.7	
9/17/2009	RT	510+45	3.4	147.6		155.7	
9/17/2009	RT	516+61	10.4	144.0		155.7	
9/17/2009	RT	525+98	9.0	144.2		155.7	
9/17/2009	RT	527+38	7.6	143.9		155.7	
9/17/2009	RT	536+66	4.2	142.9		155.7	
9/17/2009	RT	541+70	2.0	147.3		155.7	
9/17/2009	RT	545+37	2.4	144.6		155.7	
9/17/2009	RT	550+69	10.0	141.3		155.7	
9/17/2009	RT	555+87	7.0	147.3		155.7	
9/17/2009	RT	565+45	3.8	144.3		155.7	
9/17/2009	RT	571+98	4.4	143.5		155.7	
9/17/2009	RT	686+52	7.9	145.0		155.7	
9/17/2009	RT	689+65	3.7	144.3		155.7	
9/17/2009	RT	696+85	4.7	143.3		155.7	
9/20/2009	RT	691+68	4.0	141.2		156.0	
9/20/2009	RT	696+49	5.2	140.9		156.0	
9/20/2009	RT	705+63	3.8	143.1		156.0	
9/20/2009	RT	711+59	5.6	142.5		156.0	
9/20/2009	RT	717+75	4.7	143.4		156.0	
9/20/2009	RT	724+53	1.8	146.2		156.0	
9/20/2009	RT	728+14	1.7	145.0		156.0	
9/20/2009	RT	731+00	8.9	142.8		156.0	
9/20/2009	RT	740+01	10.3	144.1		156.0	
9/20/2009	RT	747+84	5.3	143.5		156.0	

Table 19. Density test results (continued).

Note: Gauge number 39469 was used on all tests on or before September 13th. From September 14th onward gauge number 39471 was used. Blanks indicate locations where the mix was not correlated to the gauge. Only gauge 39469 was correlated for HIPR pavement placed at station 711+59 and higher.

Appendix F

Gradation, Asphalt Content and Volumetric Test Results

Table 20. WSDOT gradation and asphalt content test results.											
Date	Station	3/4-in	1/2-in	3/8-in	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	Pb
8/18/09	14.5 EB	100.0	98.1	86.5	59.0	43.8	33.1	23.5	14.3	9.6	7.0	5.94
8/18/09	14.5 EB	100.0	96.0	86.0	61.0	46.0	35.0	25.0	16.0	10.0	7.1	5.90
8/19/09	16 EB	100.0	99.0	92.0	66.0	49.0	37.0	27.0	17.0	11.0	8.0	6.20
8/20/09	884-885 RT	100.0	96.0	86.0	61.0	46.0	35.0	25.0	16.0	11.0	8.1	5.70
8/21/09	958 RT	100.0	95.0	84.0	57.0	43.0	32.0	23.0	15.0	9.0	6.9	5.50
8/24/09	967 LT	100.0	97.0	86.0	62.0	46.0	35.0	25.0	16.0	10.0	7.6	5.70
8/25/09	859 LT	100.0	97.0	86.0	60.0	45.0	34.0	25.0	16.0	10.0	7.3	5.40
8/26/09	821 LT	100.0	95.0	87.0	59.0	44.0	33.0	24.0	15.0	10.0	7.4	5.30
8/27/09	724 LT	100.0	95.0	87.0	58.0	42.0	32.0	23.0	14.0	9.0	7.0	5.70
8/28/09		100.0	97.0	89.0	62.0	45.0	34.0	25.0	16.0	10.0	7.2	5.80
8/30/09	521 LT	100.0	96.0	86.0	59.0	43.0	33.0	23.0	14.0	9.0	6.6	5.40
8/31/09		100.0	97.0	89.0	61.0	46.0	34.0	24.0	15.0	10.0	6.8	5.70
9/1/09	~376 LT	100.0	95.0	86.0	59.0	43.0	32.0	23.0	15.0	10.0	7.1	6.00
9/2/09		100.0	97.0	88.0	61.0	45.0	34.0	25.0	16.0	10.0	7.2	5.50
9/3/09	196 LT	100.0	96.0	84.0	55.0	39.0	29.0	21.0	14.0	9.0	6.7	5.40
9/8/09	108 LT	100.0	96.0	88.0	59.0	44.0	33.0	24.0	15.0	9.0	6.7	5.30
9/9/09		100.0	97.0	90.0	63.0	47.0	35.0	26.0	16.0	10.0	7.2	5.80
9/10/09	83+50 RT	100.0	96.0	87.0	60.0	44.0	33.0	24.0	15.0	9.0	6.9	5.40
9/10/09		100.0	96.0	87.0	58.0	43.0	33.0	24.0	15.0	10.0	6.9	5.40
9/13/09	212 RT	100.0	96.0	85.0	57.0	42.0	32.0	24.0	14.0	9.0	6.4	5.20
9/14/09	301 RT	100.0	97.0	91.0	65.0	48.0	36.0	26.0	16.0	10.0	6.9	5.70
9/15/09	357 RT	100.0	97.0	90.0	61.0	44.0	32.0	23.0	15.0	9.0	6.9	5.70
9/16/09	433 RT	100.0	96.0	88.0	59.0	44.0	33.0	23.0	14.0	9.0	6.2	5.40
9/17/09		100.0	97.0	90.0	65.0	48.0	35.0	25.0	16.0	10.0	7.0	5.90
9/20/09	693 RT	100.0	99.0	93.0	60.0	43.0	32.0	22.0	14.0	9.0	6.7	5.30

Table 21. Granite Construction gradation and asphalt content test results.												
Date	Station	3/4-in	1/2-in	3/8-in	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	Pb
8/18/09	MP 14.5 EB	100.0	98.1	86.5	59.0	43.8	33.1	23.5	14.3	9.6	7.0	5.94
8/18/09	MP 14.5 EB	100.0	98.6	88.4	63.7	48.0	36.0	26.1	15.5	9.6	7.0	6.03
8/19/09	MP 16 EB	100.0	97.1	88.4	63.7	48.2	36.4	26.7	15.9	9.7	7.0	5.67
8/20/09	884-885 RT	100.0	96.8	87.7	61.5	46.6	34.4	25.3	15.5	9.5	6.9	5.66
8/20/09		100.0	96.2	85.2	57.3	43.1	32.4	23.8	14.2	8.4	6.1	5.39
8/21/09	958 RT	100.0	94.9	81.5	54.9	41.4	31.1	22.8	13.6	8.2	5.9	5.23
8/24/09	967 LT	100.0	95.7	85.8	62.0	46.2	35.0	25.8	15.6	9.6	7.0	5.66
8/25/09	859 LT	100.0	95.8	85.5	58.9	44.4	33.4	24.7	14.8	8.9	6.4	5.12
8/26/09	821 LT	100.0	96.3	88.3	60.3	45.2	33.7	24.7	15.0	9.3	6.9	5.36
8/27/09	724 LT	100.0	97.4	87.0	59.3	44.3	32.8	23.4	14.1	8.8	6.4	5.72
8/30/09	521 LT	100.0	96.0	86.2	57.9	43.2	32.5	23.3	13.7	8.2	5.8	5.19
8/31/09		100.0	96.0	88.2	61.8	45.0	34.4	24.0	14.9	9.2	6.7	5.52
9/1/09	~Sta. 376 LT	100.0	93.5	85.8	59.5	43.4	32.1	23.1	14.2	9.0	6.5	5.64
9/2/09		100.0	98.0	90.4	62.5	45.9	35.3	25.3	16.0	10.1	7.5	5.53
9/3/09	196 LT	100.0	96.0	84.3	54.3	38.8	29.1	20.6	13.7	9.2	6.9	5.13
9/8/09	108 LT	100.0	97.8	89.0	58.5	43.5	32.5	23.8	14.2	8.5	6.0	5.02
9/10/09	83+50 RT	100.0	96.2	88.4	59.4	45.0	34.3	25.1	15.0	9.2	6.5	5.33
9/13/09	212 RT	100.0	96.8	89.2	60.3	44.3	33.8	23.9	14.8	9.1	6.5	5.33
9/14/09	301 RT	100.0	96.5	91.0	64.3	47.5	36.2	26.6	16.1	10.0	7.3	5.72
9/15/09	357 RT	100.0	97.3	91.8	61.7	44.6	33.1	23.0	14.6	9.4	6.9	5.54
9/16/09	433 RT	100.0	97.1	87.9	60.0	44.1	33.5	23.4	14.3	8.7	6.2	5.33
9/20/09	693 RT	100.0	98.4	91.3	61.1	42.9	31.9	22.1	13.9	9.1	6.5	5.15
9/21/09	796 RT	100.0	97.2	89.5	63.6	51.6	34.6	25.8	15.1	9.4	6.1	5.80

Table 22. WSDOT volumetric test results.								
Date	Station	G_{sb}	G_{mm}	P_b	G_{mb}	V_a	VMA, %	VFA, %
8/18/09	14.5 EB	2.688	2.453	5.9	2.449	0.16	14.30	98.90
8/19/09	16 EB	2.688	2.459	6.2	2.438	0.85	14.90	94.30
8/20/09	884-885 RT	2.688	2.470	5.7	2.453	0.69	13.90	95.00
8/21/09	958 RT	2.688	2.484	5.5	2.445	1.57	14.00	88.80
8/24/09	967 LT	2.688	2.464	5.7	2.443	0.85	14.30	94.00
8/25/09	859 LT	2.688	2.496	5.4	2.431	2.60	14.40	81.90
8/26/09	821 LT	2.688	2.489	5.3	2.444	1.81	13.90	87.00
8/27/09	724 LT	2.688	2.469	5.7	2.452	0.69	14.00	95.10
8/28/09		2.688	2.470	5.8	2.439	1.26	14.50	91.30
8/30/09	521 LT	2.688	2.493	5.4	2.425	2.73	14.70	81.40
8/31/09		2.688	2.476	5.7	2.429	1.90	14.80	87.20
9/1/09	376 LT	2.688	2.480	6.0	2.442	1.53	14.60	89.50
9/2/09		2.688	2.488	5.5	2.436	2.09	14.40	85.50
9/3/09	196 LT	2.688	2.501	5.4	2.441	2.40	14.10	83.00
9/8/09	108 LT	2.688	2.495	5.3	2.433	2.48	14.30	82.60
9/9/09		2.688	2.465	5.8	2.438	1.10	14.60	92.50
9/10/09	83+50 RT	2.688	2.488	5.4	2.434	2.17	14.30	84.80
9/10/09		2.688	2.482	5.4	2.441	1.65	14.10	88.30
9/13/09	212 RT	2.688	2.496	5.2	2.421	3.00	14.60	79.40
9/14/09	301 RT	2.688	2.479	5.7	2.423	2.26	15.00	84.90
9/15/09	357 RT	2.688	2.477	5.7	2.420	2.30	15.10	84.80
9/16/09	433 RT	2.688	2.480	5.4	2.419	2.46	14.90	83.50
9/17/09		2.688	2.469	5.9	2.431	1.54	14.90	89.70
9/20/09	693 RT	2.688	2.498	5.3	2.415	3.32	14.90	77.70

Table 23. Granite Construction volumetric test results.								
Date	Station	G_{sb}	G_{mm}	P_b	G_{mb}	V_a	VMA, %	VFA, %
8/18/09	MP 14.5 EB	2.688	2.464	6.03	2.448	0.65	14.42	95.50
8/18/09	MP 14.5 EB	2.688	2.464	6.03	2.444	0.81	14.56	94.43
8/19/09	MP 16 EB	2.688	2.482	5.67	2.440	1.69	14.37	88.22
8/20/09	884-885 RT	2.688	2.493	5.66	2.461	1.28	13.63	90.58
8/20/09	919 RT	2.688	2.483	5.39	2.449	1.37	13.80	90.08
8/21/09	958 RT	2.688	2.486	5.23	2.451	1.41	13.59	89.64
8/24/09	967 LT	2.688	2.480	5.66	2.455	1.01	13.84	92.72
8/25/09	859 LT	2.688	2.501	5.12	2.438	2.52	13.94	81.93
8/26/09	821 LT	2.688	2.494	5.36	2.449	1.80	13.77	86.90
8/27/09	724 LT	2.688	2.476	5.72	2.453	0.93	13.96	93.35
8/30/09	521 LT	2.688	2.501	5.19	2.428	2.92	14.36	79.67
8/31/09		2.688	2.481	5.52	2.435	1.85	14.41	87.13
9/1/09	~Sta. 376 LT	2.688	2.488	5.64	2.452	1.45	13.92	89.61
9/2/09		2.688	2.488	5.53	2.442	1.85	14.18	86.96
9/3/09	196 LT	2.688	2.503	5.13	2.417	3.44	14.69	76.61
9/10/09	83+50 RT	2.688	2.483	5.33	2.433	2.01	14.31	85.93
9/13/09	212 RT	2.688	2.499	5.33	2.421	3.12	14.73	78.81
9/14/09	301 RT	2.688	2.499	5.72	2.422	3.08	15.05	79.53
9/15/09	357 RT	2.688	2.489	5.54	2.417	2.89	15.06	80.79
9/16/09	433 RT	2.688	2.499	5.33	2.410	3.56	15.12	76.45
9/20/09	693 RT	2.688	2.507	5.15	2.410	3.87	14.96	74.14
9/21/09	796 RT	2.688	2.477	5.80	2.468	0.36	13.51	97.31

Appendix G

Admixture Gradation and Asphalt Content Test Results

Table 24. Granite Construction admixture gradation and asphalt content test results.											
Date	3/4-in	1/2-in	3/8-in	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	P_b
8/18/09	100.0	95.6	83.6	47.6	34.3	24.8	16.6	8.6	5.1	3.6	5.02
8/18/09	100.0	92.0	76.8	43.3	32.4	23.3	15.7	8.1	4.6	3.3	4.85
8/18/09											5.63
8/18/09	100.0	93.9	77.9	43.3	32.3	23.3	15.7	8.0	4.3	2.9	4.53
8/19/09	100.0	89.8	71.8	37.7	28.1	20.8	14.6	7.8	4.3	4.1	3.98
8/20/09	100.0	89.4	75.4	41.2	30.2	22.3	15.5	8.0	4.2	2.8	4.12
8/20/09	100.0	88.8	74.9	41.4	29.5	20.5	13.6	6.9	3.9	2.7	4.11
8/21/09	100.0	90.2	74.5	40.6	30.3	22.0	15.2	8.0	4.5	3.2	3.84
8/24/09	100.0	97.6	86.8	52.2	39.9	30.5	22.5	13.8	9.0	6.4	4.43
8/24/09	100.0	91.6	79.0	43.5	32.3	23.6	16.4	8.9	5.1	3.7	4.02
8/25/09	100.0	93.4	79.9	43.4	31.8	23.3	16.3	8.7	4.7	3.2	4.14
8/25/09											4.09
8/26/09	100.0	91.3	77.3	42.9	31.7	23.2	16.2	8.7	4.7	3.2	3.83
8/27/09	100.0	89.7	78.1	45.3	34.6	25.7	17.7	9.4	4.9	3.5	3.10
8/27/09	100.0	89.8	78.0	38.8	29.4	22.0	15.5	8.5	5.0	3.8	3.54
8/28/09	100.0	94.8	82.3	47.4	36.4	26.8	18.4	9.4	4.9	3.4	3.42
8/30/09	100.0	93.8	80.7	45.2	33.2	23.6	15.6	8.0	4.4	3.1	3.38
8/31/09	100.0	94.6	81.3	45.9	34.6	24.7	16.8	8.7	4.8	3.3	3.46
9/1/09	100.0	90.0	79.1	41.6	30.3	22.1	15.5	8.9	5.7	4.3	3.89
9/2/09	100.0	93.4	80.2	44.1	32.7	22.5	14.1	6.3	4.4	2.7	4.75
9/3/09	100.0	94.0	82.1	43.5	32.4	24.2	16.1	12.2	4.5	2.6	4.20
9/13/09	100.0	90.1	78.5	41.4	30.9	22.5	14.7	8.0	4.4	3.1	3.85
9/14/09	100.0	90.2	78.6	42.0	30.3	23.0	15.1	9.2	5.4	3.6	3.77
9/15/09	100.0	89.7	76.2	40.7	31.1	23.2	15.7	8.8	5.1	3.6	3.92
9/16/09	100.0	92.9	81.1	40.1	30.7	21.7	13.1		5.3	2.1	3.92
9/20/09	100.0	93.8	82.8	45.1	34.3	25.5	16.7	9.2	5.2	3.7	4.28