Use of a Double Chip Seal to Correct a Flushing Hot Mix Asphalt Pavement in Washington State — Final Report

WA-RD 760.2

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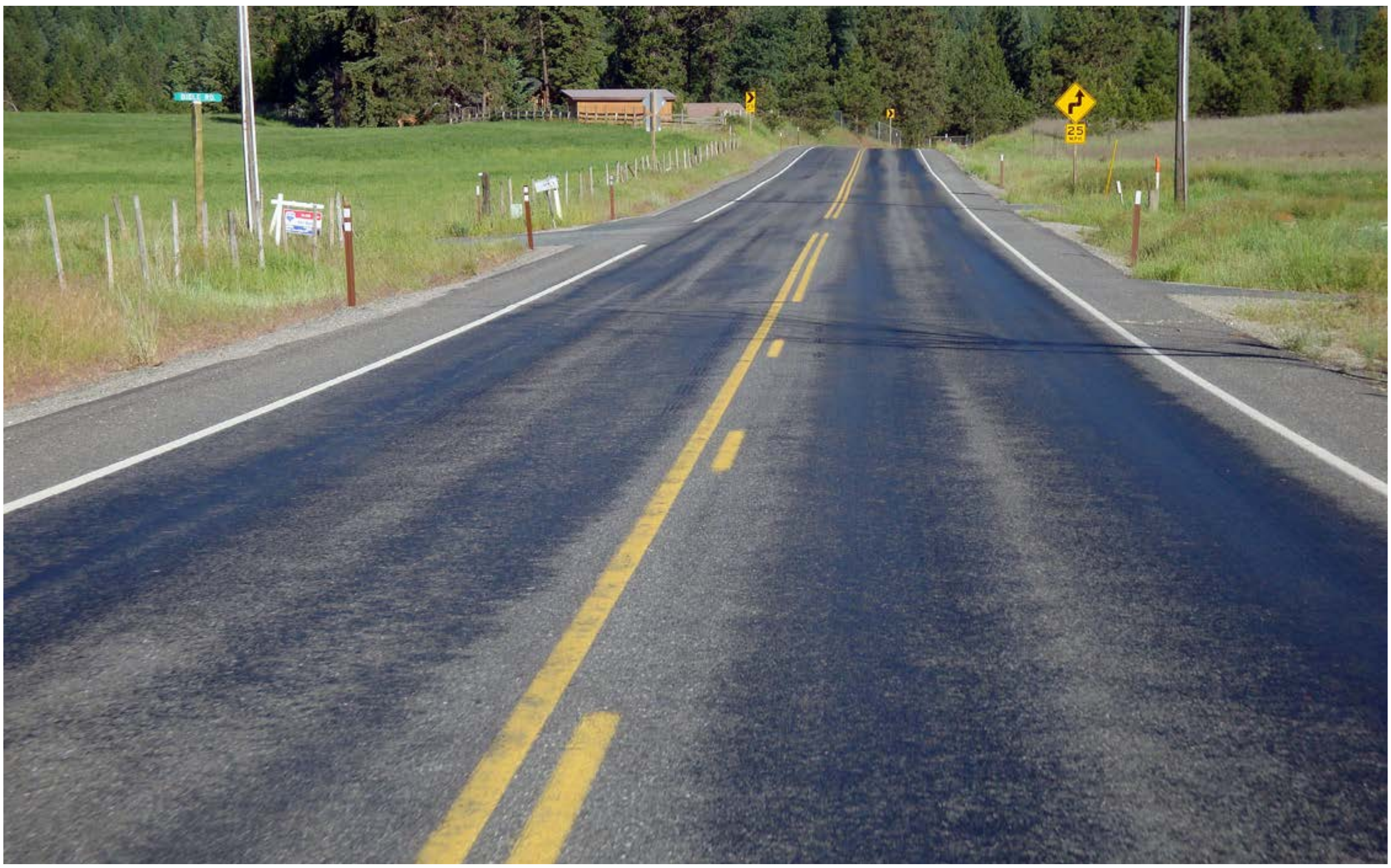
September 2016



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Experimental Feature Report

Final Report
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Use of a Double Chip Seal to Correct a Flushing Hot Mix Asphalt Pavement in Washington State - Final Report

Contract 7915
SR 20
Eastern Region Chip Seal 2010
MP 363.61 to MP 372.84

Washington State Department of Transportation

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16. ABSTRACT

A double chip seal was applied to an existing HMA pavement to mitigate severe flushing that existed throughout the project. Special care was taken to adjust the amount of binder used to account for the degree of flushing in the existing pavement. The double chip seal was effective for approximately two years before flushing began to appear through the seal. After five years the flushing extended throughout the project in the wheel paths of both lanes. The origin of the flushing in the double seal was judged to be from the underlying HMA and not the double seal. For this particular HMA pavement a double chip seal was not the long term solution. The double seal and underlying HMA pavement will be removed by grinding and replaced with a new HMA pavement.

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Introduction

In 1999 WSDOT overlaid a section of SR-20 with hot-mix asphalt (HMA) to provide additional pavement structure on the existing bituminous surface treatment (BST) roadway. Soon after construction, the new HMA began to flush excessively (Figures 1 and 2). Maintenance crews periodically rolled aggregate and sand into the flushed surface in order to improve friction but the flushing persisted. The roadway was in good condition structurally, but a surface treatment was needed to address the flushing, improve friction and preserve the roadway surface. Placing a single chip seal on this pavement would likely result in flushing of the newly placed chip seal due to the presence of the excess binder that would mitigate to the surface of the seal and fill the aggregate void space. Therefore, other repair strategies were investigated that would properly accounted for the excess binder during the design and construction of the seal.

Figure 1. Flushing HMA on SR 20 soon after placement.

Figure 2. Condition of flushing pavement before placement of the double chip seal.

Limited information was found regarding the construction of a chip seal on an existing flushed surface. A review of the literature indicated that both an inverted double chip seal and a sandwich seal were capable of correcting flushing in an existing pavement. The drawback to the information in the literature was that construction details and performance data for these types of chip seals were not included. Although the inverted double chip seal and sandwich seal reported in the literature are not conventional double chip seals, they both involve two applications of aggregate and one or two applications of binder. This led to the decision to construct a double chip seal as a method to address the section on SR 20.

A single chip seal consists of one application of aggregate over one application of asphalt binder. A double chip seal is essentially two single chip seals, one placed on top of the other. In a standard double chip seal the aggregate in the top layer usually has a finer gradation than the aggregate in the bottom layer. The inverted double chip seal is the opposite of a conventional double chip seal with the finer aggregate gradation placed in the bottom layer and the coarser aggregate in the top layer. Double chip seals are more durable and seal the roadway against water better than a single chip seal leading to their use in locations where there is high truck traffic or on steep grades (Gransberg and James, 2005). The disadvantage of a double chip seal is higher cost because of the two applications of binder and aggregate.

A double chip seal is a departure from the normal practice used by the Washington State Department of Transportation (WSDOT). WSDOT uses single chip seals almost exclusively to preserve low volume highways. If it can successfully address the flushing pavement on SR 20, a double chip seal will provide an economical method of addressing flushing on chip seal roadways in the future. In 2008 WSDOT constructed a half mile double chip seal test section on a portion of the flushed section of SR 20 to evaluate the double chip seal's effectiveness at mitigating the flushing. The performance of the test section was promising resulting in the decision to place the double chip seal on the remainder of the flushing pavement in 2010. This report documents the design and construction of the double chip seal and its performance over a 5-year period.

Location

The section of SR 20 that received the double chip seal was located approximately 15 miles east of Colville in Stevens County, between milepost 363.61 and 372.84. This section of SR 20 is a rural minor arterial in rolling terrain with many curves. Forest lines most of the roadside with interspersed open areas where farms or home sites are located along the route. Traffic is light with Average Annual Daily Traffic (AADT) varying between 600 and 1,400 vehicles per day of which between 20 and 25 percent are trucks. The average high temperature in July is 87°F and the average low in January is 18°F. Precipitation occurs throughout the year with December being the wettest month with 2.26 inches and August the driest with 0.74 inches. Annual precipitation is over 17 inches with an average of 42 inches of snowfall occurring during the winter season.

Methods for Correcting a Flushed Pavement with a Chip Seal

The available literature was reviewed to investigate methods that had the potential to correct a flushed pavement using a chip seal. The following briefly describes four methods that were identified and discusses their applicability to the flushed pavement on SR 20.

Adjust the Binder Application Rate

The simplest and most common method used to address a flushed existing pavement is to adjust the binder application rate based on the condition of the existing pavement. Both the McLeod and modified Kearby chip seal design methods use correction factors that reduce the application rate for flushed surfaces. The McLeod design method recommends reducing the binder application rate by up to 0.06 gal/yd^2 for a flushed or bleeding surface (McLeod 1969). The modified Kearby design method recommends the same reduction of 0.06 gal/yd^2 (Gransberg and James, 2005).

Reducing the binder application rate may be an effective way to construct a single chip seal over a flushed pavement as long as the flushing is not too excessive. It is unlikely that the binder application rate adjustments in the McLeod or modified Kearby methods were intended to address the severity of the flushing on SR 20. WSDOT chose to reduce the binder application rate as part of its strategy to correct the flushing pavement on SR 20, but it was believed that a single chip seal with a correction to the binder application alone would not be sufficient to correct the flushing.

Retexturing

Australia, New Zealand and the United Kingdom use retexturing to correct a flushing surface (Gransberg and James 2005, Gransberg, Pidwerbesky and James 2005). Retexturing is a process which uses high pressure water to remove flushed binder from the pavement surface and to restore surface texture prior to placing a new chip seal (Gransberg and James 2005). Retexturing can address flushing over the entire pavement surface by using full width water blasting equipment or on small areas using a water cutting machine (Gransberg, Pidwerbesky and James 2005).

Although retexturing appears promising, WSDOT does not have experience with this process and did not consider it as a viable solution for the flushing problem on SR 20.

Inverted Double Chip Seal

An inverted double chip seal includes two applications of binder and two applications of aggregate. Unlike a conventional double chip seal where the top layer of aggregate is finer than the bottom, the finer aggregate gradation is on the bottom of an inverted double chip seal. Inverted double chip seals have been used successfully on bleeding pavements with up to 30,000 Average Daily Traffic (ADT) in Australia (Gransberg and James 2005). Despite the reported success, the literature review did not include information describing the design or construction of projects where an inverted chip seal was used to correct flushed pavements.

Sandwich Seal

New Zealand uses sandwich seals to correct flushing pavements and Texas has used them on a limited basis as a remedy for flushed or bleeding pavements (Gunderson 2008, Lawson and Senadheera 2009). A sandwich seal consist of two layers of aggregate and one application of binder. The first layer consists of coarse aggregate placed directly on the existing pavement without a preceding application of binder. An application of binder followed by a second layer of finer gradation aggregate placed on top of the coarse aggregate layer completes the sandwich seal. It is essentially a double chip seal without the first application of binder. A sandwich seal requires about 20% less binder than a comparable double chip seal (Gunderson 2008).

It was felt that a sandwich seal would be more appropriate on a freshly placed bleeding chip seal as opposed to the 11 year old flushed HMA pavement on SR 20. The aged flushed asphalt on SR 20 may not hold the aggregate without at least some new binder applied to the existing pavement.

Instead of an inverted chip seal or sandwich seal, WSDOT elected to use a double chip seal using the same aggregate gradation in both the top and bottom layers. It was felt that this type of double chip seal should perform as well as an inverted chip seal at a lower cost.

Double Chip Seal Design

The successful use of a double chip seal to correct a flushing pavement in Thurston County Washington influenced WSDOT's design. The double chip seal used in Thurston County consisted of two applications of CRS-2P binder and two applications of 1/2 inch to U.S. No. 4 aggregate with a reduced application rate of the binder for the first layer (Doolittle, 2007). Test sections of double chip seal were placed on the SR 20 problem pavement in 2008 to test the performance of variable application rates for both the binder and the aggregate.

Test Section Results

The test sections built in July of 2008 were placed in both lanes of a one half mile section of SR 20 selected because of its relatively high rate of flushing and because its geometry was representative of most of the remainder of the flushed roadway (Figure 3). The plan was to use different application rates for both the aggregate and the CRS-2P binder. Actual binder application rates varied from the planned rates resulting in the first application for Test Section 1 having an application rates very similar to Test Section 2 and the first application for Test Sections 3 and 4 having the same binder application rates. Table 1 shows the actual application rates for the first and second application of binder and aggregate and the percent embedment. Complete details of the planned and actual application rates are included in Appendix A.

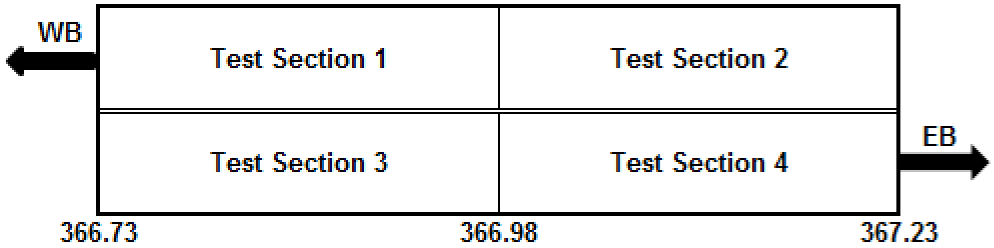

Figure 3. Location of test sections.

Table 1. Double chip seal test section binder and aggregate application rates and percent embedment of the aggregate.						
Test Section	**Location (milepost)**	**First Application**		**Second Application**[1]		**Percent Embedment**
		CRS-2P (gal/yd^2)	**3/8 inch – U.S. No 4 (lbs/yd^2)**	**CRS-2P (gal/yd^2)**	**3/8 inch – U.S. No 4 (lbs/yd^2)**	
1	366.73 to 366.98 WB	0.27	20	0.35	22	80
2	366.98 to 367.23 WB	0.28	20	0.36	20	80
3	366.73 to 366.98 EB	0.20	20	0.40	20	70
4	366.99 to 367.23 EB	0.20	20	0.40	20	70

[1] The second application also included 4 lbs/yd^2 of U.S No 4 – 0 choke on all sections.

Checking embedment after the first applications of aggregate gave an indication of the affect the flushing pavement would have on the chip seal (Table 1). Binder application rates should be adjusted so that embedment is between 50 and 70 percent (Jackson, Jackson and Mahoney). Higher embedment rates indicate too much binder and could result in flushing. As expected, the embedment measurements for the first application were higher than they would be if the existing pavement surface was not flushing. There were also some indications of bleeding during construction especially in the sections with higher binder application rates (Figures 4-5).

Figure 4. Chip seal placement on Test Section 1 (on right) with 0.27 gal/yd^2 showing slight flushing in the wheel path after the first application.

Figure 5. Test Section 1 (on left) with 0.27 gal/ yd^2 shows flushing in the wheel path after construction while no flushing was present in Test Section 3 (on right) at 0.20 gal/ yd^2.

Monitoring the test sections for two years after construction revealed wheel path flushing had occurred in many locations. Test Sections 1 and 2, which had higher binder application rates during the first application than Test Sections 3 and 4, appeared to have the more severe flushing (Figures 6 through 9). Despite the overall lower flushing severity, Test Sections 3 and 4 still had many severely flushed areas presumably where the flushing of the underlying pavement was more severe. By 2009 the embedment was 100 percent in the flushed areas of lanes 1 and 2 (Figure 8) but was reported to be in the 70 percent range in Test Sections 3 and 4 which had the lower binder application rates for the first application (Stephen Van De Bogert email, 2009). The test sections showed that the lower application rates for the first application of CRS-2P seal reduced the flushing and could produce an acceptable pavement. The test sections also showed that the application rates for the first application of CRS-2P would need to be varied depending on the flushing present on the existing surface.

Figure 6. West end of Test Section 1 (on left) with 0.27 gal/ yd^2 and Test Section 3 (on right) with 0.20 gal/ yd^2 for the first application one year after placement.

Figure 7. East end of Test Section 4 (on the left) with 0.20 gal/ yd^2 and Test Section 2 (on the right) with 0.28 gal/ yd^2 for the first application.

Figure 8. Test Section 4 (on left) with 0.20 gal/ yd^2 shows minimal flushing while Test Section 2 (on right) with 0.28 gal/ yd^2 shows flushing in wheel paths two years after construction.

Figure 9. Typical 100% embedment area in Test Sections 1 and 2, one year after construction.

Final Design

To simplify the design and use available materials, WSDOT selected a double chip seal similar to the Thurston County design consisting of two applications of CRS-2P binder and two applications of 3/8 inch to U.S. No. 4 aggregate (Table 2). An application of U.S. No. 4 to 0 choke (Table 2) placed after the second application of aggregate would fill surface voids and lock in the second application of 3/8 inch to U.S. No. 4 aggregate. The binder application rates used for Test Sections 3 and 4 were the basis for the final design included in the contract documents (Table 1). The goal was to achieve an initial embedment of about 50 percent. The CRS-2P target of 0.20 gal/yd^2 for the first layer was about one half of the application rate typically used by WSDOT on a single chip seal (Table 3). The remaining application rates for the CRS-2P and aggregate for the second layer were within the normal range for a WSDOT typical single chip seal. The complete double chip seal specification from the contract documents is included in Appendix B.

Table 2. Double chip seal aggregate gradations.		
Sieve	**3/8" – U.S. No. 4**	**U.S. No. 4 – 0**
1/2" Square	100	---
3/8" Square	70 – 90	100
U.S. No. 4	0 – 5	76 – 100
U.S. No. 8	0 – 3	---
U.S. No. 10	---	30 – 60
U.S. No. 200	0 – 1.5	0 – 10

Table 3. Application rates from the contract documents.			
Application	**Asphalt (CRS-2P) gal./yd²**	**Gradation**	**Aggregate lbs./yd²**
Bottom Layer	0.20	3/8 inch – U.S. No. 4	20
Top Layer	0.35 – 0.40	3/8 inch – U.S. No. 4	20 - 30
		U.S. No. 4 – 0	4 - 6

Double Chip Seal Construction

The double chip seal on SR 20 was part of a larger project to place over 300 lane miles of single chip seal. The bottom layer of aggregate and binder for the double chip seal occurred on July 27, 2010 and the top layer the day following. The weather was ideal for chip seal placement with clear skies and high temperatures in the upper 90's °F. The maximum surface temperature measured during placement was 116°F. The Contractor, Central Washington Asphalt (CWA) used conventional chip seal equipment and placement procedures. Overall the construction of the double chip seal went well. Two issues that may affect performance were that the aggregate gradations were outside of specifications limits and that the application rates of the No. 4 to 0 choke were inconsistent and lower than specified. The gradation testing results are covered further under Construction Test Results.

The intent was that the application rates in the contract documents would be a starting point and that field personnel would adjust the rates during placement to account for field conditions. Prior to placing the double chip seal, WSDOT field personnel gave each section of the roadway a 1 to 4 rating based on the extent of flushing visible with 1 being no flushing and 4 being severe flushing (Table 4 and Figures 10 and 11). Adjustments to the first application of CRS-2P and aggregate were based on the rating for each section. Sections with a rating of 1 did not have significant flushing and did not receive an application of binder or aggregate during the first application. Instead these areas received a single application of binder and aggregate using the top layer applications rates.

Table 4. Roadway flushing rating system.

Visual Rating	Roadway Condition
1	No flushing.
2	Intermittent flushing in the wheel paths.
3	Consistent flushing in the wheel paths and intermittent flushing in the remaining portion of the travel lane.
4	Severe flushing in the entire travel lane.

Figure 10. Upper left – Rating 1 (No Flushing), Bottom left – Rating 4 (Entire lane flushing) and Right – Rating 3 (Consistent wheel path flushing).

Figure 11. Left –Rating 1 (No flushing) and Right – Rating 2 (Intermittent flushing in wheel path).

Changes in application rate for the first application of CRS-2P were marked with lath placed at the beginning of each section. The application rate written on the lath was entered into the computerized application rate control system on the distributor truck to ensure the proper application of CRS-2P. WSDOT field personnel verified application rates by computing the yield based on the area chip sealed and the gallons of CRS-2P used.

Tables 6 and 7 show the actual application rates for each section along with the percent embedment. The embedment of most sections was around 50 percent but some were as low as 30 percent. The low embedment in some sections may have been due to minimal traffic allowed on the sections prior to checking the embedment.

Table 5. Flushing rating and application rates for first application of the double chip seal on west bound SR 20.

Beginning Milepost	Ending Milepost	Total Distance (miles)	Visual Rating	CRS-2P (gal/yd^2)	3/8 inch to U.S No. 4 (lbs/yd^2)	Percent Embedment
363.610	**364.195**	0.585	1	Bottom layer deleted		
364.195	**365.204**	1.009	3	0.18	21	45
365.204	**366.734**	1.530	4	0.17	21	35
366.734	**367.233**	0.499	2	0.16	21	50
367.233	**367.849**	0.616	4	0.15	21	30
367.849	**367.931**	0.082	1[1]	0.15	21	50
367.931	**370.202**	2.271	4	0.15	21	50
370.202	**371.305**	1.103	2	0.22	20	50
371.305	**372.063**	0.758	1	Bottom layer deleted		
372.063	**372.300**	0.237	2	0.23	22	50
372.300	**372.840**	0.540	1	Bottom layer deleted		

[1]This section was treated with a double chip seal as if it had a rating of 2.

Table 6. Flushing rating and application rates for first application of the double chip seal on east bound SR 20.						
Beginning Milepost	**Ending Milepost**	**Total Distance (miles)**	**Visual Rating**	**CRS-2P (gal/yd^2)**	**3/8 inch to U.S No. 4 (lbs/yd^2)**	**Percent Embedment**
363.610	**365.204**	1.594	3	0.15	21	50
365.204	**366.734**	1.530	4	0.16	21	35
366.734	**367.233**	0.499	1	Bottom layer deleted		
367.233	**367.594**	0.361	4	0.14	21	50
367.594	**371.340**	3.746	3	0.18	21	50
371.340	**372.063**	0.723	2	0.21	20	50
372.063	**372.300**	0.237	3	0.19	22	40
372.300	**372.840**	0.540	2	0.23	22	50

The top layer of the double chip seal occurred following the completion of the first application on the areas noted in Table 6 and 7. The top layer consisted of 0.34 to 0.39 gal/yd^2 of CRS-2P binder and 24 lbs/yd^2 of 3/8 inch to U.S. No. 4 aggregate with 2.3 lbs/yd^2 of U.S. No. 4 to 0 choke on all areas regardless of the condition rating. This means that the application rates for the areas that were deleted from the bottom layer were the same rates used on the top layer.

Construction Test Results

Testing of samples from the stockpiles revealed that the gradation of the 3/8 inch to U.S. No. 4 aggregate was outside specification requirements for the percentage passing the U.S. No. 4 sieve and that the gradation of the U.S. No. 4 to 0 choke was outside the specification for the percentage passing the U.S. No. 200 sieve. WSDOT uses a specification for statistical acceptance of aggregates on this project. Although the aggregate gradations were outside specification requirements for individual sieves, the overall quality level was such that the specification allowed the aggregate to remain in place with a price reduction. The percentages passing the remaining sieves were all within specification and the higher percentages passing the two sieves should not affect the performance of the double chip seal. Appendix C includes the results of the gradation testing.

Double Chip Seal Performance

After three months in service the double chip seal appeared to be performing well with only a few areas in the wheel paths where the embedment appeared to be near 100 percent (Figures 12 and 13).

Figure 12. Appearance of the double chip seal three months after construction.

Figure 13. Area with embedment near 100 percent three months after construction.

WSDOT tested the friction of the double chip seal after construction with a ribbed tire using a locked-wheel friction tester meeting ASTM E-274 requirements. As would be expected for a chip seal, the friction numbers were good with a range in values from 57.5 to 68.0 and an average of 62.1(Table 7).

Table 7. Friction numbers immediately after construction on September 16, 2010.		
Milepost	Direction	Friction Number (FN)
364.0	EB	63.5
365.0	EB	62.8
366.0	EB	63.1
367.0	EB	62.8
368.0	EB	62.8
369.0	EB	62.6
370.0	EB	62.0
371.0	EB	64.1
372.0	EB	61.9
372.5	WB	68.0
371.5	WB	64.1
370.5	WB	61.2
369.5	WB	57.5
368.5	WB	59.7
367.5	WB	60.9
366.5	WB	59.8
365.5	WB	59.4
364.5	WB	62.0
	Average	**62.1**
	Range	**57.5 - 68.0**

Long-Term Performance

The performance of the double chip seal was monitored for five years by collecting friction data and photos of the roadway. Beginning with the photos, the first two sets of photos below illustrate the condition of the chip seal at two locations at intervals of 3, 25, 37, 50 and 62 months after construction.

Condition at MP 368.50

Figure 14. Three months after construction.

Figure 15. Twenty-five months after construction.

Figure 16. Thirty-seven months after construction. Poor light conditions.

Figure 17. Fifty months after construction.

Figure 18. Sixty-two months after construction.

Condition at MP 368.00

Figure 19. MP 368.00 three months after construction.

Figure 20. Twenty-five months after construction.

Figure 21. Thirty-seven months after construction. Poor light conditions.

Figure 22. Fifty months after construction.

Figure 23. Sixty-two months after construction.

June 2015 photos (Figures 24-36) show the flushing condition of the pavement with the captions indicate the pre-construction flushing conditions ratings from Tables 5 and 6 and the ratings determined from the examination of these photos.

Figure 24. MP 372.5 vicinity, pre-construction rating 2 on the left EB lane, 1 on the right lane. The June 2015 ratings were 3 on the left, 2 on the right.

<u>Rating System</u>

1 = No flushing.
2 = Intermittent flushing in the wheel paths.
3 = Consistent flushing in the wheel paths and intermittent flushing in the remaining portion of the travel lane.
4 = Severe flushing in the entire travel lane.

Figure 25. MP 372.0 pre-construction rating 2 on the left EB lane. June 2015 rating was 3 on the left lane.

Figure 26. MP 371.5 pre-construction rating 2 on the left EB lane, 1 on the right WB lane. June 2015 ratings were 4 on the left lane, 2 on the right lane.

Figure 27. MP 371.25 pre-construction rating 2 on the left EB lane, 3 on the right WB lane. June 2015 ratings were 4 on both lanes. Severe raveling in the right lane.


Figure 28. MP 370.0 pre-construction rating 3 on the left EB lane, 4 on the right WB lane. June 2015 ratings were 4 on both lanes.

Figure 29. MP 369.0 pre-construction rating 4 on the right WB lane. June 2015 rating was 4 on the right lane. Left lane cannot be seen well enough to rate.

Figure 30. MP 368.0 pre-construction rating 3 on the left EB lane, 4 on the right WB lane. June 2015 rating was 4 on both lanes.

Figure 31. MP 367.0, pre-construction rating 1 on the left EB lane, 2 on the right WB lane. June 2015 rating was 4 on both lanes.

Figure 32. MP 366.7, pre-construction rating 1 on the left EB lane, 2 on the right WB lane. June 2015 rating was 4 on both lanes.

Figure 33. MP 366.0, pre-construction rating 4 on both left EB and right WB lanes pre-construction. June 2015 rating was 4 on both lanes.

Figure 34. MP 364.9, pre-construction rating 3 on both left EB and right WB lanes. June 2015 rating was 3 on both lanes.

Figure 35. MP 364.3, pre-construction rating 3 on both left EB and right WB lanes. June 2015 rating was 4 on both lanes.

Figure 36. MP 363.6, pre-construction rating 3 on the left EB lane, 1 on the right WB lane. June 2015 rating was 3 on the left lane 2 on the right lane.

Table 8 lists the pre-construction flushing ratings and the ratings as determine from the 2015 photos. The amount of flushing June of 2015 is either the same or in most cases higher than the amount noted prior to the application of the chip seal (Tables 5 and 6 on pages 11 and 12).

Table 8. Pre-construction versus June 2015 flushing ratings.

Milepost	Flushing Rating			
	Pre-Construction		June 2015	
372.5	2	1	3	2
372.0	2	-	3	-
371.5	2	1	4	2
371.3	2	3	4	4
370.0	3	4	4	4
369.0	-	4	-	4
368.0	3	4	4	4
367.0	1	2	4	4
366.7	1	2	4	4
366.0	4	4	4	4
364.9	3	3	3	3
364.3	3	3	4	4
363.6	3	1	3	2
Average	**2.4**	**2.7**	**3.7**	**3.4**

In summary, the amount of flushing is equal to the flushing observed on the existing pavement prior to the construction of the double chip seal

Friction Resistance

The friction resistance results are another indicator of the amount and severity of the flushing on the double chip seal. The range and average friction numbers from 2010 to 2015 are listed in Table 9.

Table 9. Historical friction results.					
Lane	Friction Number (FN)				
	2010	2011	2012	2014	2015
Average	62.1	59.2	58.7	49.2	34.1
Range	57.5 - 68.0	40.8 - 64.3	47.6 – 66.9	26.9 – 62.0	16.9 – 58.7

The most recent results from 2015 included 103 tests. Table 10 list the number and percentage of the 103 test below a friction number of 30. Roadways with values below 30 are of a concern and trigger further action to determine if the roadway is a hazard as required by the WSDOT Skid Accident Reduction Program (Appendix C). The low friction numbers indicate that flushing is a problem on both eastbound and westbound lanes throughout the entire length of the project. A tabulation of the 2015 friction numbers is found in Appendix D.

Table 10. 2015 friction numbers less than 30.			
Direction	Number of Tests	FNs Less Than 30	Percent Less Than 30
EB	41	13	32
WB	62	29	47
Totals	**103**	**42**	**41**

Discussion of Results

WSDOT designed and constructed a double chip seal to correct the extreme flushing of an HMA pavement on SR 20. Design of the double chip seal was straightforward and construction was accomplished using conventional chip seal equipment and methods. The application rates of the binder were adjusted to compensate for the amount of flushing of the existing HMA. Initially the double seal looked good with little evidence of flushing. Within a year after placement, flushing became evident but did not appear to be affecting performance. By four years after construction flushing had progressed to the point where low friction needed to be addressed. The photos and friction number data indicate that adjusting the amount of binder did not result in a decrease in the degree of flushing of the double chip seal.

Conclusion

The double chip seal was not successful in mitigating the extremely flushing conditions of this section of SR 20. The binder in the underlying HMA eventually bled through the chip seal resulting in flushing conditions that were equal to or worse than conditions prior to the application of the double chip seal.

The Easter Region has scheduled a project that will remove the double seal and underlying HMA pavement and replace them with a new HMA pavement.

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Appendix A

Test Section Application Rates

First Shot - 7/8/2008

(Started in westbound lane heading east, pulled back and shot the eastbound lane)

	MP 366.73			MP 366.92		MP 366.94			MP 367.23
Westbound		Section 1	Ordered 0.28 gal/yd^2 - Shot 0.27 (CRS-2P) 20 lbs/yd^2 (Agg - 3/8"-US No.4)		Ordered 0.28 Shot 0.28		Section 2	Ordered 0.24 gal/yd^2 - Shot 0.28 (CRS-2P) 20 lbs/yd^2 (Agg - 3/8"-US No.4)	
		Centerline							

	MP 366.73			MP 366.99			MP 367.23
Eastbound		Section 3	Ordered 0.20 gal/yd^2 - Shot 0.20 (CRS-2P) 20 lbs/yd^2 (Agg - 3/8"-US No.4)		Section 4	Ordered 0.24 gal/yd^2 - Shot 0.20 (CRS-2P) 20 lbs/yd^2 (Agg - 3/8"-US No.4)	

Embedment found on 7/9 after 7/8 application

Westbound	80%	50%
Centerline		
Eastbound	70%	70%

Second Shot - 7/9/2008

	MP 366.73			MP 366.98			MP 367.23
Westbound		Section 1-A	Ordered 0.35 gal/yd^2 - Shot 0.36 (CRS-2P) 22 lbs/yd^2 (Agg - 3/8"-US No.4) 4 lbs/yd^2 (Agg - US No.4-0)		Section 2-A	Ordered 0.35 gal/yd^2 - Shot 0.36 (CRS-2P) 20 lbs/yd^2 (Agg - 3/8"-US No.4) 4 lbs/yd^2 (Agg - US No.4-0)	
		Centerline					
Eastbound		Section 3-A	Ordered 0.40 gal/yd^2 - Shot 0.40 (CRS-2P) 20 lbs/yd^2 (Agg - 3/8"-US No.4) 4 lbs/yd^2 (Agg - US No.4-0)		Section 4-A	Ordered 0.40 gal/yd^2 - Shot 0.40 (CRS-2P 20 lbs/yd^2 (Agg - 3/8"-US No.4) 4 lbs/yd^2 (Agg - US No.4-0)	

Appendix B

Double Chip Seal Construction Specification

(******)
Double Seal
The Contractor shall apply a Double Seal to Section 8 (MP 363.61 to MP 372.84) at the following rates:

	Undiluted Asphalt Emulsion (gal. per sq. yd.) Applied	Aggregate Size	Aggregate (lbs.per sq. yd.) Applied
First Application:			
3/8 to No. 4	0.20	3/8 to No.4	20
Second Application:			
3/8 to No.4	0.35-0.40	3/8 to No.4	20 – 30
Choke Stone		No. 4 to 0	4 - 6

(Target application rates are subject to charge as directed by the Engineer)
The Contractor should anticipate changes to the asphalt emulsion and aggregate application rates throughout each day.

The first application will consist of CRS-2P emulsion covered by 3/8 to No.4 aggregate.

The second application will consist of CRS-2P emulsion covered by 3/8 to No.4 aggregate with an application rate of no. 4 to 0. The second application of bituminous surface treatment shall be applied as the first order of work the following morning when the brooming of the first bituminous surface treatment is completed.

Appendix C

Skid Accident Reduction Program

Washington State Department of Transportation

Policy Statement
Number: P 2035.00

Signature on file
J.C. Lenzi, P.E.
Assistant Secretary of Engineering and Regional Operations

May 18, 2011
Date

Skid Accident Reduction Program

I. Introduction

A. Purpose

This Policy Statement provided guidance for the use of pavement friction tests collected by the Pavement Branch of the State Materials Laboratory in Tumwater.

B. Supersession

This Policy Statement supersedes Interim Directive ID 55-77 Skid Accident Reduction Program dated September 29, 1994. All references to the superseded ID 55-77 now reference P 2035.00.

C. What Has Changed

Direction is reworded to be more concise and clear. Direction to employees remains the same.

D. Background

The October 5, 1992 amendment to the December 1991 federal aid Policy Guide Section 23 CFR 626.5 suggests that each state's skid collision reduction program should include,"…a systematic process to identify, analyze and correct hazardous skid locations."

In literature on pavement friction tests and skid collision location identification, there are limited studies that suggest correlation between wet weather collision rates and skid numbers below 26. No studies suggested a correlation between wet weather collision rates and skid numbers at or above 26. This information was considered in the current Skid Collision Reduction Program.

The literature maintains that collision histories are the best indicators of the cause of wet weather collisions. Wet weather collisions may be caused by complex interactions among roadway, vehicle, human, and environmental factors. Collisions may result from unpredictable factors and random variables.

II. Policy Statement

It is the policy of the Washington State Department of Transportation (WSDOT) to minimize the risk of wet weather skid collisions by using the Skid Collision Reduction Program as follows.

III. Information to Carry Out This Policy Statement

The following rules and responsibilities are established.

A. Test Pavement Friction Every Two Years

Pavement friction tests must be conducted on state routes every two years at one mile intervals to help identify potential skid collision locations.

1. Undivided roads are tested only in one direction.
2. Divided roads with fewer than three lanes are tested in both directions in the outer lane.
3. Divided roads with more than three lanes are tested in both directions in the second lance from the outside.

B. Identify and Rank Safety Needs

Use these two primary sources t identify and rank statewide safety needs.

1. Crash history analyses.
2. Roadway geometric/condition modeling that uses skid number assessment. Skid numbers are considered in the development of appropriate solutions to address both collision history and potential collision locations.

C. Locations with Skid Numbers at or Below 30

Locations with skid numbers at or below 30 must be retested promptly. These retests must be completed within the same calendar year and reported to regional authorities. Corrective actions may be required depending on analyses and site inspections.

D. State Materials Laboratory

The State Materials Laboratory is responsible for the following.

1. Test pavement friction on a systematic basis (ASTM E-274-Rib Tire) throughout the state highway system on a two year cycle.
2. Test newly constructed or overlaid pavement that is one lane mile or longer one month or more after completion and before the construction season ends, unless prevented by weather conditions.
3. Retest locations with skid number at or below 30 promptly.

a. Retests consist of at least five friction tests taken within one quarter mile of the point of the skid number at or below 30.

b. Retests report the original low number.

c. Retests report the average of the five retests.

4. Provide the pavement friction test results to the Regional Administrator.

E. Region Administrator

The Region Administrator is responsible for the following.

1. Manage the Skid Reduction Program within the region to endure compliance with this Policy Statement.
2. Provide the pavement friction test results to the Region Operations Engineer.
3. In the absence of a Region Operations Engineer designate a position to carry out those responsibilities, and inform the Assistant Secretary.

F. Region Operations Engineer or Designee

The Region Operations Engineer or designee is responsible for the following.

1. Review friction test results.
2. Compare prior pavement friction test results at or below 30 with current friction test results. Determine whether or not adverse collision history has developed at these locations. If so, check whether or not improvements have been scheduled or completed.
3. Review pavement friction test results with skid numbers at or below 30 with the Region Maintenance Engineer and Region Traffic Engineer.
4. When tests and reviews indicate if is needed coordinate construction improvements with the Region Maintenance Area Superintendent or with the Region Project Development Office.

G. Region Maintenance Area Superintendent

The Region Maintenance Area Superintendent is responsible for the following.

1. Conduct joint field reviews with the Region Traffic Engineer at each site that has skid numbers are or below 30.
2. Schedule construction of the appropriate surface treatment to improve skid resistance.
   a. Use state forces or contract.
   b. Inform the Region Operations Engineer or designee.
3. Remove any “Slippery When Wet” signs installed and inform the Region Traffic Engineer.

H. Region Traffic Engineer

The Region Traffic Engineer is responsible for the following.

1. Conduct joint field reviews with the Region Maintenance Area Superintendent at each site that has skid numbers at or below 30.
2. Analyze traffic data records to determine high or potentially high risk of wet weather collision rates in those areas with skid numbers at or below 30.
3. At locations where crash rates or roadway/roadside modeling indicates that a problem exists, recommend solutions wither to the Region Operations Engineer or the Region Maintenance Area Superintendent for correction.
4. Direct installation of "Slippery When Wet" signs, when needed, at sites with average skid numbers at or below 30.
5. Direct other immediate corrective action as needed.

I. Region Program Management

The Region Program Management Office is responsible to program suitable improvements at locations having a low skid number and a high collision rate, where maintenance has not yet made alterations.

IV. Contact for More Information

For more information about this Policy Statement please contact the Pavement Branch of the State Materials Laboratory at 360-709-5485

V. Executive Review and Update Requirements

When changes are necessary to update this Policy Statement please inform the Assistant Secretary of Engineering and Regional Operations.

The Assistant Secretary of Engineering and Regional Operations periodically reviews and updates this Policy Statement.

Americans with Disabilities Act (ADA) information
Materials can be provided in alternative formats by calling the ADA compliance Manager at 360-705-7097. Persons who are deaf or hard of hearing may contact that number via the Washington Relay Service at 7-1-1.

Appendix D

Gradation Test Results

Table 11. Construction quality control 3/8 inch to U.S No. 4 gradation test results.

Sieve	Percent Passing			
	Specifications	Test 1	Test 2	Test 3
½” Square	100	100	100	100
⅜” Square	70 – 90	84	87	82
U.S. No. 4	0 – 5	7	7	4
U.S. No. 8	0 – 3	2	2	2
U.S. No. 10	---			
U.S. No. 200	0 – 1.5	1.2	1.0	1.1
% Fracture	90	99	100	100

Table 12. Construction quality control U.S No. 4 to 0 gradation test results.

Sieve	Percent Passing		
	Specifications	Test 1	Test 2
½” Square	---		
⅜” Square	100	100	100
U.S. No. 4	76 – 100	88	86
U.S. No. 8	---		
U.S. No. 10	30 – 60	54	51
U.S. No. 200	0 – 10	10.9	10.5
% Fracture	90	100	100

Appendix E

2015 Friction Testing Results

Table 13. 2015 eastbound friction results.		
Milepost	Direction	Friction Number[1]
364.00	EB	33.5
364.29	EB	37.8
364.46	EB	52.3
364.50	EB	39.2
364.65	EB	25.5
364.71	EB	21.5
364.76	EB	25.2
364.95	EB	29.3
365.00	EB	32.3
365.21	EB	38.0
365.50	EB	55.3
365.81	EB	41.4
366.00	EB	39.3
366.35	EB	46.5
366.41	EB	49.2
366.50	EB	42.7
366.90	EB	18.0
366.96	EB	16.9
367.00	EB	24.3
367.05	EB	27.2
367.13	EB	37.3
367.24	EB	27.9
367.37	EB	46.5
367.49	EB	43.4
367.72	EB	30.9
368.00	EB	33.6
368.45	EB	58.0
368.50	EB	49.6
369.00	EB	57.7
369.43	EB	35.7
369.50	EB	57.3
370.00	EB	52.3
370.04	EB	22.9
370.18	EB	27.2
370.32	EB	24.8
370.50	EB	58.1
370.84	EB	31.1
371.00	EB	28.9
371.50	EB	44.4
372.00	EB	36.4
372.50	EB	58.7

[1]Based on a locked wheel friction tester with a ribbed tire meeting ASTM E-274 requirements.

Table 14. 2015 westbound friction results.		
Milepost	Direction	Friction Number[1]
372.48	WB	56.3
371.98	WB	47.0
371.49	WB	40.8
371.28	WB	35.5
371.14	WB	36.9
370.99	WB	36.8
370.88	WB	39.3
370.48	WB	54.4
370.17	WB	31.1
369.99	WB	33.3
369.82	WB	34.6
369.67	WB	35.1
369.63	WB	38.0
369.55	WB	34.5
369.49	WB	34.3
369.43	WB	17.3
369.37	WB	20.2
369.32	WB	35.5
369.24	WB	27.0
369.08	WB	45.3
369.03	WB	25.0
368.99	WB	21.9
368.88	WB	28.8
368.78	WB	24.4
368.68	WB	31.1
368.58	WB	33.7
368.49	WB	23.2
368.40	WB	31.0
368.35	WB	30.9
368.18	WB	26.7
368.05	WB	25.1
367.98	WB	34.5
367.81	WB	27.9
367.72	WB	35.3
367.49	WB	38.6
367.16	WB	27.8
367.10	WB	28.4
366.99	WB	42.6
366.91	WB	27.8
366.74	WB	34.0
366.55	WB	34.3
366.49	WB	25.4
366.41	WB	31.8
366.28	WB	21.1
366.14	WB	19.0
366.09	WB	26.9
366.01	WB	29.2

Table 16. (continued).		
Milepost	**Direction**	**Friction Number[1]**
365.90	WB	32.5
365.83	WB	29.4
365.76	WB	23.5
365.68	WB	19.7
365.64	WB	17.4
365.49	WB	40.6
365.50	WB	23.9
365.29	WB	26.7
365.12	WB	22.5
365.00	WB	40.1
364.48	WB	44.7
364.42	WB	20.1
364.29	WB	19.8
364.21	WB	17.4
363.99	WB	50.6

[1]Based on a locked wheel friction tester with a ribbed tire meeting ASTM E-274 requirements.

Appendix F

Experimental Feature Work Plan

Washington State Department of Transportation

WORK PLAN

Double Chip Seal Evaluation

State Route 20
Contract 7914
Eastern Region Chip Seal 2010
Milepost 363.61 to Milepost 372.84
(Section 8)

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Washington State Department of Transportation

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Introduction

The section of SR 20 between milepost 363.61 and 372.84 is a bituminous surface treatment route which was overlaid with HMA in 2000 to provide additional pavement structure. Soon after construction, the new HMA began to flush excessively. Despite the flushing the roadway is in good structural condition, but a surface treatment is needed to address the flushing and friction. Placing a single chip seal on this pavement would likely result in the flushed asphalt bleeding up through the new chip seal. In order to find a better solution WSDOT's Eastern Region constructed a half mile test section of double chip seal from MP 366.73 to 367.23 within this section of SR 20 in 2008 to evaluate its effectiveness at mitigating the flushing. The results of the test section are promising resulting in the decision to place a double chip seal on the rest of the flushing pavement. The application rates used will be those that showed the best performance over the last two years (Table 1). This experimental feature will evaluate the effectiveness of the double chip seal in mitigating a flushing section of HMA and preserving the pavement on SR 20.

Table 1. Double seal application rates

Application	Undiluted Asphalt Emulsion (gal/sy)	Aggregate Gradation (Std. Spec. 9-03.4)	Aggregate (lb/sy)
First (Bottom)	0.20	3/8 to No. 4	20
Second (Top)	0.35 – 0.40	3/8 to No. 4 No. 4 to 0	20 – 30 4 – 6

Scope

Both lanes of SR 20 will be rehabilitated between milepost 363.61 and 372.84 using a double chip seal. A single shot of BST will be placed over the 2008 test section to keep this section of the highway on a coordinated schedule for treatment from MP 366.73 to 367.23.

Staffing

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

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Testing

Pavement performance will be monitored by the following methods:

- The pavement condition (structure, rutting and ride) will be surveyed annually
- Friction testing will be conducted after construction then annually
- The effectiveness of the double chip seal at mitigating the flushing will be evaluated visually

Reporting

A "Post Construction Report" will be written following completion of the double chip seal. This report will include construction details, construction test results, actual oil and aggregate application rates used, 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 recommendations for any future 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

Condition surveys will be conducted as part of statewide annual survey so no additional cost will be incurred.

Friction Testing - $2,500 post construction + $2,500 / year for 5 years = $15,000

Report Writing Costs

Initial Report – 30 hours = $3,000

Annual Report – 4 hours (1 hour each) = $400

Final Report – 60 hours = $6,000

TOTAL COST = $24,400

Schedule

Construction: June - August 2010

Date	Condition Survey (Annual)	End of Construction Report	Annual Report	Final Report
Fall 2010	X			
Fall 2011	X	X		
Fall 2012	X		X	
Fall 2013	X		X	
Fall 2014	X		X	
Fall 2015	X		X	
Spring 2016				X