Performance of Modified Class D HMA Pavements in Washington State

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16. ABSTRACT

Modified Class D HMA, a ¾ inch nominal maximum aggregate size open graded friction course used by the Washington State Department of Transportation (WSDOT), is evaluated as an alternative to dense graded HMA. Modified Class D HMA was found to perform better than dense graded HMA at resisting fatigue cracking but is susceptible to failure by raveling or stripping. When compared to dense graded HMA in eastern Washington Modified Class D HMA was found to have a shorter service life. Much of the reduction in service life was due to two early failing Modified Class D HMA projects on I-90. Modified Class D HMA was not recommended as an alternative to dense graded HMA because of a shorter service life, the risk of early failure and higher cost.

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Table of Contents

List of Figures

List of Tables

Introduction

The Washington State Department of Transportation (WSDOT) began using Modified Class D hot mix asphalt (HMA) in the early 1990's in response to the success of a similar open graded friction course (OGFC) used in Oregon. WSDOT expected Modified Class D HMA to exhibit superior rutting and studded tire resistance while providing the wet weather benefits of an OGFC (WSDOT, 1995). Despite its early potential, Modified Class D HMA never saw widespread use. Early failures of Modified Class D HMA led pavement designers to prefer dense graded mixes despite its wet weather benefits. However, no studies were ever conducted to validate the preference. If Modified Class D HMA was found to perform comparable to dense graded HMA, its increased use could provide the benefits of an OGFC without sacrificing performance. This report investigates the performance of Modified Class D HMA in Washington State to evaluate its suitability as an overlay alternative to dense graded HMA.

Background

OGFC's incorporate an open aggregate structure which makes them highly permeable and allows water to drain through the OGFC instead of staying on the surface. Less surface water means better contact between tires and the road leading to reduced hydroplaning and improved braking. The reduction in surface water also improves wet weather visibility by decreasing splash and spray. The disadvantages of OGFC's are that they do not generally last as long as dense graded pavement and are subject to clogging which can reduce the effectiveness of rainwater drainage (NCHRP, 2000).

Two OGFC's have had limited use on Washington highways. Both mixes are designated "Class D" with "modified" added to indicate the larger nominal maximum aggregate size (NMAS) mix. Class D HMA is a 3/8 inch NMAS mix primarily used for thin overlays of one inch or less. Class D HMA is highly susceptible to studded tire wear (WSDOT, 1995) and further discussion of its performance is beyond the scope of this report. Modified Class D HMA differs in its larger, 3/4 inch NMAS, and is used as a structural layer usually 0.15 feet or more in depth.

The successful use of this wearing surface by the Oregon Department of Transportation (ODOT) influenced the use of Modified Class D HMA in Washington State. ODOT began using open graded HMA in the late 1970's and today has over 1,800 centerline miles in service. ODOT uses this open graded HMA on arterials and interstates throughout the state under the designation of Class F mix. The primary reasons ODOT chose to use Class F were to improve skid resistance, to decrease road noise, and to reduce splash and spray (Moore et al, 2001).

Use of Modified Class D HMA in Washington State

Despite its potential to quickly remove surface water, Modified Class D HMA has seen limited use on highways in Washington. Of the over 4,000 highway centerline miles of HMA managed by WSDOT, less than 410 lane miles of Modified Class D have been placed since 1990.

Almost all Modified Class D HMA use has been in eastern Washington[1] in WSDOT's Eastern and South Central Regions. Interstate 90 between Ellensburg and Spokane accounts for about two thirds of the lane miles paved. The only use in western Washington was on Interstate 5 between Olympia and Centralia. Placement of Modified Class D HMA began 1993 and the most recent placement was an overlay in the Eastern Region in 2005. Tables 1 through 3 list the Modified Class D HMA projects constructed in Washington State.

Table 1. Eastern Region Modified Class D HMA projects.

Contract No.	State Route	Project Title	Milepost	Year Paved	ADT (2006 Data)	Depth (ft)
4158	90	Adams County Line to Spokane County Line	239.15 to 256.04	1993	8,300[1]	0.15
4254	90	Grant County Line to Vicinity SR 21	191.89 to 208.16	1994	4,800[1]	0.15
4277	90	Lincoln County Line to Vic. Salnave Rd	256.04 to 265.84	1995	8,300[1]	0.15
5544	211	Vicinity Four Lanes to SR 20	0.17 to 15.10	1999	2,100	0.20
5635	904	Vicinity Betz Road to I-90	12.68 to 16.82	1999	13,300	0.15
6708	90 Outside Lanes[2]	Adams County Line to Spokane County Line	239.12 to 255.29	2004	8,300[1]	0.15
6907	90 Outside Lanes[2]	Lincoln County Line to Salnave Road	255.29 to 265.84	2005	8,300[1]	0.15

[1]Directional ADT
[2]Portions of the inside lane were also included (see appendix C)

[1]The Cascade Crest is usually considered the dividing line between eastern and western Washington. The west is generally wetter and more temperate while the east is dryer and experiences greater temperature extremes. The distinction is important when discussing pavements because performance differs significantly between the two areas.

Table 2. South Central Region Modified Class D HMA projects.						
Contract No.	State Route	Project Title	Milepost	Year Paved	ADT (2006 Data)	Depth (ft)
4187	12	E. C/L Naches to PP&L Spillway	190.65 to 193.04	1993	4,800	0.15
4249	90	West Ellensburg I/C to Ryegrass Rest Area	121.97 to 126.18	1994	7,100[1]	0.15
4279	395	Columbia River Bridge to Court St I/C - Southbound	19.15 to 20.13	1993	22,700[1]	0.20
4359	97	Vicinity Bridge 97/106 to Dry Creek	46.46 to 50.70	1995	3,200	0.15
4376	17	Adams County Line to MP 12.70	12.80 to 21.80	1994	4,200	0.30
4591	97	SR 22 to Indian Church Rd and SR 22 to Rocky Ford Rd	59.29 to 61.27	1995	5,100	0.15
4591	223	SR 22 to Indian Church Rd and SR 22 to Rocky Ford Rd	0.01 to 2.10	1995	4,300	0.15
4795	90	Ryegrass to Vantage – Stage 2	126.18 to 137.20	1996	7,100[1]	0.15
4888	24	Taylor Ranch to Vicinity SR 241	23.05 to 31.45	1997	3,200	0.20
5126	90	Yakima River to West Ellensburg I/C – Stage 2	102.61 to 106.34	1997	12,500[1]	0.15

[1]Directional ADT

Table 3. Olympic Region (Western Washington) Modified Class D HMA project.						
Contract No.	State Route	Project Title	Milepost	Year Paved	ADT (2006 Data)	Depth (ft)
4036	5 NB	Lewis County Line to SR 12	85.51 to 88.03	1993	30,100[1]	0.15

[1]Directional ADT

Modified Class D Background/WSDOT Experience

Materials

Modified Class D HMA obtains its open structure by using a large percentage of coarse aggregate without the significant proportion of fines common to dense graded mixes. Figure 1 shows the broadband limits for Modified D HMA compared to ½ inch dense graded HMA.

Recent Modified Class D HMA overlays have incorporated PG70-28 or PG76-28 binders. Prior to the use of performance graded binders, PBA-6 was the preferred asphalt binder type. Typical asphalt contents observed during construction have ranged from 4.9 to 5.5 percent. Drain down of the binder is a concern with OGFC mixes making the drain down test (AASHTO T-305) critical to ensure that the Modified Class D HMA does not excessively flush.

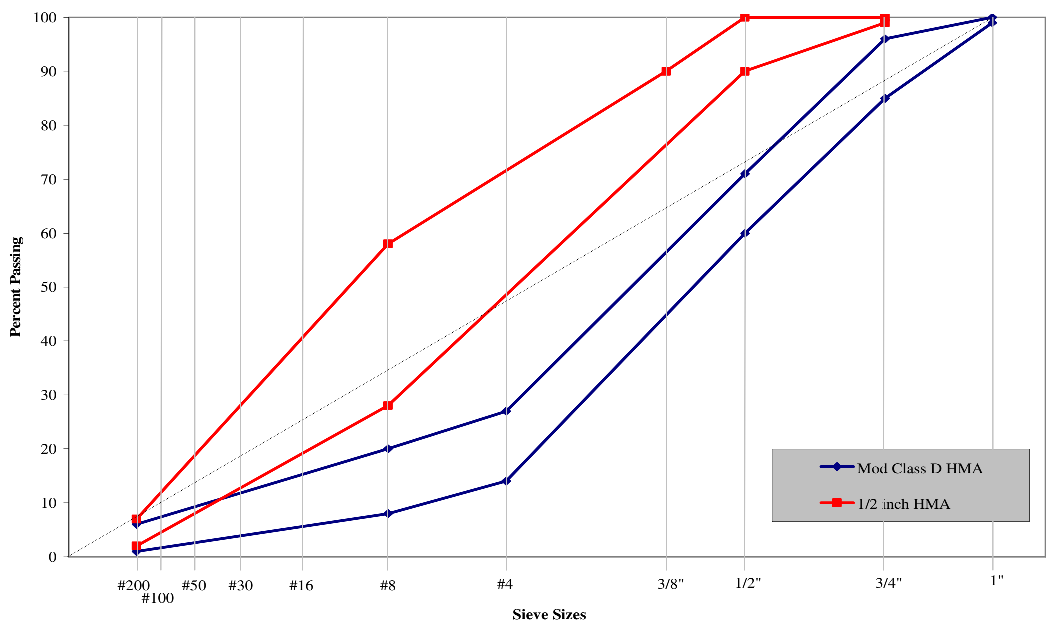


Figure 1. Modified Class D and 1/2 inch HMA specification bands.

Pavement Design

WSDOT uses Everpave[2], a mechanistic-empirical based software program, to determine thicknesses for both Modified Class D and dense-graded HMA overlays. Modified Class D HMA overlays are designed to be at least 1.8 inches (0.15 feet) in depth. It is felt that 1.8 inches gives the aggregate enough space to reorient and become properly seated during compaction. Design requirements include preleveling or milling to correct rutting greater than 3/8 inch and repairing both alligator and longitudinal cracking prior to paving. Modified Class D HMA, because of its high air void content, is designed as a sacrificial layer implying that complete removal is required prior to any future overlay. If left in place, Modified D HMA will trap moisture, which can and has accelerated stripping. WSDOT typically uses Modified Class D HMA for roadways with an average daily traffic (ADT) of 10,000 or less per lane; however, it could be used on higher ADT routes.

Construction

Modified Class D HMA is produced with standard batch or drum plants and placed with conventional paving equipment. Drain down is the primary concern during paving operations and can be effectively controlled by using PG binders, fibers and proper construction techniques. Cyclic density is overcome by the use of a materials transfer vehicle or materials transfer device. Changes to the Modified D mixes are typically adjusted in the field by experienced field personnel.

WSDOT did not allow vibratory rollers for initial compaction on its earlier projects due to concerns with aggregate crushing. Current practice is to allow vibrations on the initial breakdown pass only. WSDOT recommends a minimum of four passes with an eight to 10 ton steel wheel roller and that rolling operations cease once the internal mix temperature reaches 175°F. There is no minimum density requirement. A nuclear density gauge is used to determine the optimum number of roller passes needed to achieve maximum density. ODOT recommends that lay down temperature not exceed 265°F or fall below 205°F (Moore et al, 2001). The lower maximum temperature, as compared to the 275°F to 320°F for breakdown rolling of traditional dense graded mixes, helps to promote a thicker film coating during hauling and lay down.

Modified Class D HMA pavements may be fog sealed during construction and again every four years depending on the Region's practices. Modified Class D pavements in Eastern Region are fog sealed every four years after initial placement while no fog sealing takes place in South Central Region. It is felt that the fog seals helps replace some of the binder lost due to drain down and prevents raveling by enhancing the asphalt holding the aggregate in place. The effectiveness of fog sealing within Washington has not been established. The Eastern Region

[2] http://www.wsdot.wa.gov/biz/mats/Apps/EPG.htm

will be investigating the effectiveness of fog seals during the 2008 construction season. A listing of fog seal projects and dates is shown in Appendix A.

Performance – Eastern Washington

WSDOT collects and evaluates approximately 8,600 lane miles of pavement condition data annually as part of the Washington State Pavement Management System (WSPMS). The pavement condition data is used to evaluate pavements based on pavement structural condition (PSC), rutting and roughness. Threshold values for PSC, rutting and roughness are used in the determination of when to apply pavement rehabilitation. The following will discuss each condition criteria.

The PSC is a combined score that considers the primary distresses of longitudinal cracking, transverse cracking, alligator cracking and patching. The PSC ranges between a high of 100 for the best possible condition to a low of 0 corresponding to the worst possible condition. WSDOT has determined that a pavement can be rehabilitated at its lowest life cycle cost when the PSC score reaches 50.

Rutting data includes both load induced deformation of the pavement layers and wear caused by studded tires. WSDOT prefers to rehabilitate pavements before the rut depth reaches 0.4 inches.

WSDOT uses the International Roughness Index (IRI) to evaluate pavement roughness. A roadway with an IRI higher than 220 inches/mile is considered due for rehabilitation.

Eastern Washington WSPMS Condition Data

Figure 2 displays the average PSC for each year after construction for Modified Class D HMA projects in Eastern and South Central Regions. The Eastern Region data is from ten projects consisting of 255 lane miles of Modified Class D HMA placed from 1993 through 2005. A total of 137 lane miles in nine projects placed from 1993 though 1997 make up the South Central Region data.

The figure shows an average PSC of over 80 after eight years indicating good structural performance of the Modified Class D HMA used in both Eastern and South Central Region. The low value in the second year for the Eastern Region data is due to the early failure of one project, contract 6708, which is discussed later. These results are project averages and the actual distress can vary considerably within a project requiring repair or rehabilitation even though the average PSC is still good.

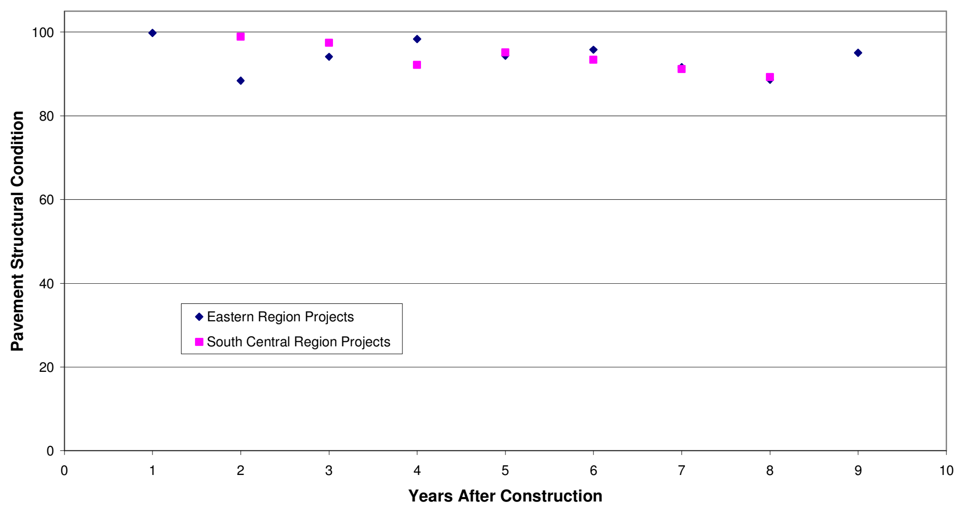


Figure 2. Average PSC of Modified Class D HMA for each year after construction in Eastern and South Central Region.

Figure 3 shows a divergence in rutting performance between the two Regions. The trend line predicts that the average rutting in Eastern Region will reach 0.4 inches in about 8 years and about 16 years for South Central Region. The cause of the difference in rutting performance between the two Regions is unclear, however Eastern Region does experience a higher use of studded tires which may contribute to the rutting in that Region.

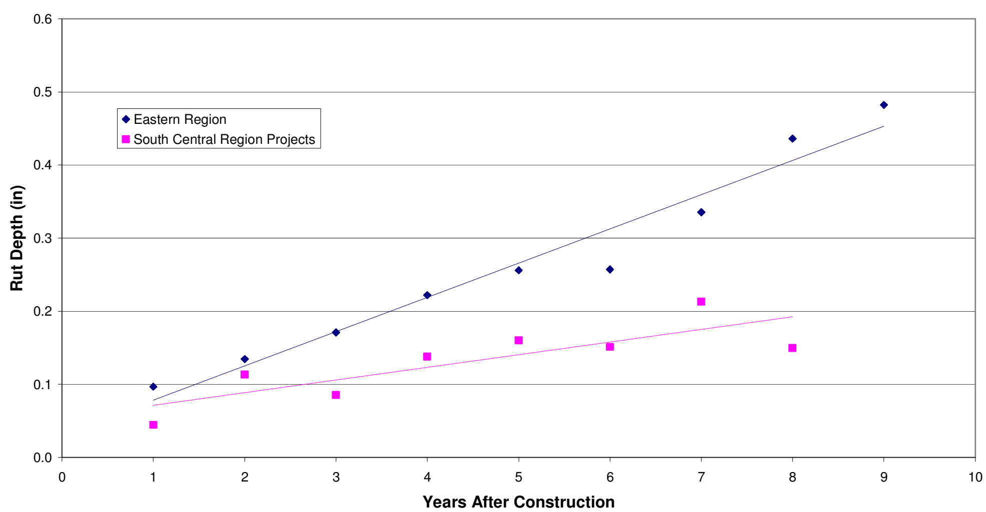


Figure 3. Average rut depth for Modified Class D HMA in Eastern and South Central Regions.

Figure 4 shows that Modified Class D HMA projects performed well with respect to ride in both Regions. The trend of the IRI indicates that it will not reach 220 in/mi, the level at which rehabilitation is due, until long after Modified Class D HMA pavements have reached the PSC or rutting thresholds for rehabilitation. IRI is therefore not a factor leading to rehabilitation of Modified Class D HMA pavements and further evaluation of the performance of Modified Class D HMA in this report will be limited to PSC and rutting.

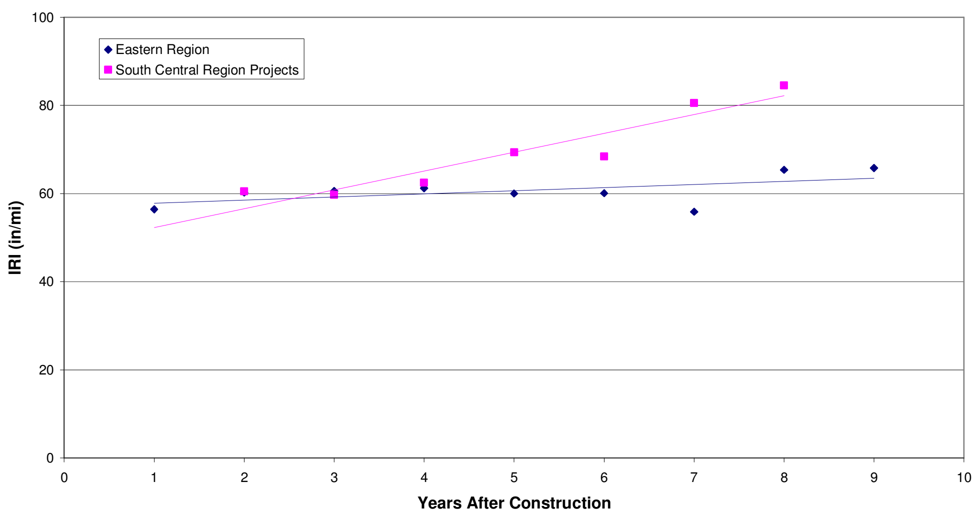


Figure 4. Average IRI for Modified Class D HMA in Eastern and South Central Regions.

Comparison of Service Life of Eastern Washington Projects

The best measure of a pavements performance is its life in actual service. Tables 4 and 5 show the service life of Modified Class D HMA projects in Eastern and South Central Regions. Both the actual service life of Modified Class D HMA projects which have already been rehabilitated and the estimated service life of projects not yet rehabilitated are shown. The tables use the year of rehabilitation to compute the age of projects that have been repaved. If a project had a major section repaired, the year of the repair is used to compute age. Several of the sections have not been rehabilitated or undergone major repair but have been scheduled for rehabilitation. Although rehabilitation has not yet occurred on these projects the date that the rehabilitation is scheduled is a reliable estimate of service life since it has already been determined when the rehabilitation will occur. The remaining projects rely on WSPMS due dates to compute the service life. WSPMS creates regression equations based on pavement condition ratings from previous years. The regression equations are then used to predict when the rating will reach 50 and the pavement will be due for rehabilitation. The table uses these due dates to compute the service lives of projects where more accurate due dates based on actual rehabilitation, repair or scheduled rehabilitation are not available.

Table 4. Service life of Eastern Region Modified Class D HMA projects.

Contract No.	State Route	Milepost Limits	Year Paved	Service Life (yrs)	Basis for Service Life
4158 EB	90	239.15 to 256.04	1993	11	Rehabilitated in 2004
4158 WB	90	239.15 to 256.04	1993	11	Rehabilitated in 2004
4254 EB	90	191.89 to 208.16	1994	5	Sections Repaired in 1999
4254 WB	90	191.89 to 208.16	1994	5	Sections Repaired in 1999
4277 EB	90	256.04 to 265.84	1995	10	Rehabilitated in 2005
4277 WB	90	256.04 to 265.84	1995	10	Rehabilitated in 2005
5544	211	0.17 to 15.10	1999	18	WSPMS Due 2017
5635	904	12.68 to 16.82	1999	19	WSPMS Due 2018
6708 EB	90	239.12 to 255.29	2004	4	Sections Repaired in 2008
6708 WB	90	239.12 to 255.29	2004	4	Sections Repaired in 2008
6907 EB	90	255.29 to 265.84	2005	12	WSPMS Due 2017
6907 WB	90	255.29 to 265.84	2005	11	WSPMS Due 2016

Table 5. Service life of South Central Region Modified Class D HMA projects.					
Contract No.	**State Route**	**Milepost Limits**	**Year Paved**	**Service Life (yrs)**	**Basis of Service Life**
4187 EB	12	190.65 to 193.04	1993	17	Rehabilitation Scheduled in 2010
4187 WB	12	190.65 to 193.04	1993	17	Rehabilitation Scheduled in 2010
4249 EB	90	121.97 to 126.18	1994	12	Rehabilitated in 2006
4249 WB	90	121.97 to 126.18	1994	10	Rehabilitated in 2004
4279	395	19.15 to 20.13	1993	7	Rehabilitated in 2000
4359	97	46.46 to 50.70	1995	8	Rehabilitated in 2003
4376	17	12.80 to 21.80	1994	16	WSPMS Due 2010
4591	97	59.29 to 61.27	1995	8	Rehabilitated in 2003
4591	223	0.01 to 2.10	1995	9	Rehabilitated in 2004
4795 EB	90	126.18 to 137.20	1996	11	WSPMS Due 2007
4795 WB	90	126.18 to 137.20	1996	na	Replaced due to new construction
4888	24	23.05 to 31.45	1997	7	Rehabilitated in 2004
5126 EB	90	102.61 to 106.34	1997	12	Rehabilitation Scheduled in 2009
5126 WB	90	102.61 to 106.34	1997	12	Rehabilitation Scheduled in 2009

When all projects are included the average service life of Modified Class D HMA is 10.0 years for Eastern Region projects and 11.2 years for South Central Region projects. However, when each of the methods for estimating average service life is compared (Table 6) there is a large discrepancy. If WSPMS due dates are accurately predicting the service life of Modified Class D HMA, they would be expected to be close to the service life of projects that have already been rehabilitated. The table shows that WSPMS due dates are predicting a service life of 14.5 years while projects are actually being rehabilitated after 10.9 years. This implies that WSPMS due dates might not be an accurate predictor of the service life of Modified Class D HMA.

Table 6. Average service life according to basis of rehabilitation for both Regions.	
Basis of Service Life	**Average Service Life (yrs)**
Rehabilitated or Rehabilitation Scheduled	10.9
Sections Repaired (Early Failure)	4.5
WSPMS Due Date	14.5

The discrepancy between the service lives predicted by WSPMS due dates and the actual service lives of projects that have been rehabilitated arises because the PSC is relatively high when the Modified Class D HMA projects are rehabilitated. Tables 7 and 8 display the PSC and rut depths of rehabilitated Modified Class D HMA projects one year prior to rehabilitation. The tables show that most of the Modified Class D HMA projects had a PSC in the 80's or 90's the year before rehabilitation. These projects were clearly rehabilitated when the PSC indicated that they were still in good structural condition.

Table 7. PSC and rut depth one year prior to rehabilitating Modified Class D HMA projects in Eastern Region.

Contract No.	State Route	Milepost	PSC	Rut Depth (in)
4158 EB	90	239.15 to 256.04	87.5	0.50
4158 WB	90	239.15 to 256.04	97.8	0.50
4254 EB	90	191.89 to 208.16	86.6	0.19
4254 WB	90	191.89 to 208.16	93.3	0.17
4277 EB	90	256.04 to 265.84	96.2	0.39
4277 WB	90	256.04 to 265.84	94.1	0.43
6708 EB	90	239.12 to 255.29	54.8	0.06
6708 WB	90	239.12 to 255.29	94.0	0.04

Table 8. PSC and rut depth one year prior to construction of Modified Class D HMA projects in South Central Region.

Contract No.	State Route	Milepost	PSC	Rut Depth (in)
4249 EB	90	121.97 to 126.18	73.6	0.15
4249 WB	90	121.97 to 126.18	85.8[1]	0.27[1]
4279	395	19.15 to 20.13	93.3	0.14
4359	97	46.46 to 50.70	99.7	0.32
4591	97	59.29 to 61.27	94.7	0.26
4591	223	0.01 to 2.10	98.6	0.17
4795 EB	90	126.18 to 137.20	74.5	0.24[1]
4888	24	23.05 to 31.45	99.0	0.14

[1]Linear estimate based on pre 2003 data

When the WSPMS predicts a due date it indicates which measure of pavement performance (PSC, rutting or IRI) is critical in determining when rehabilitation is due. All of the due dates estimated by WSPMS in Tables 4 and 5 used the PSC as the critical factor. Since the PSC is relatively high when Modified Class D HMA projects are rehabilitated, this caused WSPMS to predict a longer service life for these projects than what is actually occurring. WSPMS would predict that a project with a PSC in the 80's or 90's has several years until the PSC reaches 50 requiring rehabilitation. A Modified Class D HMA project which had a PSC in the 80's or 90's the year before rehabilitation would therefore have several years of service life left according to WSPMS even though it was rehabilitated the next year. Either the PSC deteriorates in the last year before rehabilitation much faster than WSPMS predicts or some other factor not measured by PSC is causing these projects to be rehabilitated.

The overestimation of the service life leads to the conclusion that WSPMS due dates should not be used to estimate the service life of Modified Class D HMA. When projects with WSPMS due dates are not included, the average service life is 7.5 years in Eastern Region, 10.8 years in South Central Region and 9.4 years in both Regions combined.

Table 9 shows the average service life of all HMA pavements in Washington State. The average service life of 10.8 years for Modified Class D HMA in South Central Region is nearly the same as the 11.0 year average for all HMA projects in eastern Washington but the 7.5 year average service life of Modified Class D HMA in Eastern Region is significantly lower. Overall the 9.4 year average service life of Modified Class D HMA in both Regions is 1.6 years less than the Eastern Washington average for all HMA projects. Without the two early failing projects the Eastern Region average service life would be 10.5 years and the average for both Regions would be 10.7 years. By eliminating the two failing projects the average service life of Modified Class D HMA and all HMA projects in Eastern Washington would be nearly the same. This leads to the conclusion that early failure of some projects is the main reason the Modified Class D HMA does not last as long as dense graded HMA in Eastern Washington.

Table 9. Average service life of HMA pavement in Washington State.

Year	Eastern Washington	Western Washington	Entire State
1997	10.7	14.6	12.9
2000	10.8	15.8	14.1
2003	11.3	16.5	14.7
2005	11.2	16.8	14.9
Average	**11.0**	**15.9**	**14.2**

WSDOT uses a combination of WSPMS due dates and visual inspection to determine when a project needs to be rehabilitated. Tables 7 and 8 make it clear that WSPMS due dates based on PSC do not lead to rehabilitation of Modified Class D HMA. Some distress other than fatigue cracking, which is measured by PSC, must be causing these projects to be rehabilitated. Rutting is one possibility being relatively high in both Regions the year before rehabilitation. However, only two projects are above the 0.4 inch rut depth that would trigger rehabilitation indicating rutting is not the only cause of rehabilitation of Modified Class D projects.

WSDOT Regions prepare Pavement Rehabilitation Reports for all HMA rehabilitation projects documenting existing conditions pertaining to the design. Part of the report includes a description of the pavement distress exhibited by the pavement to be rehabilitated. Tables 10 and 11 list the distress described in the Pavement Rehabilitation Report for each of the Modified Class D HMA projects that have been overlaid with HMA.

Table 10. Distresses in Eastern Region Modified Class D HMA Pavement Rehabilitation Reports.

Contract No.	State Route	Milepost	Distress
4158	90	239.15 to 256.04	Medium to high severity rutting, low to medium severity raveling and longitudinal cracking with areas of high severity longitudinal cracking and raveling
4254	90	191.89 to 208.16	Flushing, rutting and potholes attributed to stripping, many patched areas
4277	90	256.04 to 265.84	Medium to high severity rutting, low to medium severity flushing and areas of high severity longitudinal and alligator cracking
6708	90	239.12 to 255.29	Flushing, rutting and potholes attributed to stripping, many patched areas

Table 11. Distresses listed in South Central Region Modified Class D HMA Pavement Rehabilitation Reports.

Contract No.	State Route	Milepost	Distress
4249	90	121.97 to 126.18	Raveling resulting in rutting, Low level transverse cracking
4279	395	19.15 to 20.13	Heavy raveling, flushing and stripping in the underlying layers
4359	97	46.46 to 50.70	Raveling in wheel paths, Areas of flushing and stripping in underlying layer, No apparent fatigue cracking
4591	97	59.29 to 61.27	Raveling in wheel paths, rutting
4795 EB	90	126.18 to 137.20	Raveling leading rutting and flushing, Low level transverse cracking
5126	90	102.61 to 106.34	Raveling[1]

[1]From email correspondence proceeding Pavement Rehabilitation Report

Raveling was the most often listed distress closely followed by rutting and flushing. Rutting was attributed to raveling by several of the reports and flushing and stripping were related in some of the reports. Overall fatigue cracking did not seem to be a major source of distress.

The distress descriptions in the Pavement Rehabilitation Reports indicate two failure modes for Modified Class D HMA pavements in eastern Washington. Raveling in the wheel paths leading to unacceptable rutting seems to be the more common of the two. Flushing followed by stripping in the underlying layer seems less common but possibly more serious because it may have led to the early failures of contracts 4254 and 6708. These types of failures explain why the WSPMS has difficulty predicting the service life of Modified Class D HMA. Neither raveling nor flushing is included in the calculation of the PSC. Since fatigue cracking is minimal when the pavements are replaced the PSC was still relatively high even though rehabilitation is necessitated by the level of raveling, rutting, flushing and/or stripping. Flushing and stripping eventually lead to potholes and patches lowering the PSC since they are included in the calculation. However, potholes and patching due to stripping on Modified Class D HMA pavements tend to be localized which does not reduce the PSC as much as longitudinal or alligator cracking which tend to be spread over a larger percentage of the pavement surface.

Comparison with Dense Graded Pavements on Interstate 90

Another measurement of the performance of Modified Class D HMA in eastern Washington is to compare it with other pavements placed during the same time period on a roadway with the same traffic and environmental conditions. The Modified Class D HMA placed on Interstate 90 allows this comparison. Between mileposts 102.61 and 265.84 Interstate 90 is a divided highway with two lanes in each direction having a directional ADT ranging between 4,700 and 12,500 (2006 traffic counts). WSDOT placed over 300 lane miles of Modified Class D HMA on this section of Interstate 90 between 1993 and 2005. About the same time period (1989 through 2004) WSDOT placed over 560 lane miles of dense graded HMA between the same mileposts.

Structural performance of both Modified Class D HMA and dense graded mixes on Interstate 90 is shown in the plot of average PSC versus project age in Figure 5. The Figure illustrates that the PSC of Modified Class D HMA was consistently higher than dense graded mixes meaning that Modified Class D HMA exhibits less cracking and patching than dense graded mixes. As discussed earlier the failure modes of Modified Class D HMA (raveling, rutting, flushing and stripping) do not show up in the PSC score so this does not necessarily indicate superior performance of Modified Class D HMA.

The rutting performance of dense graded pavement on Interstate 90 is somewhat better than Modified Class D HMA (Figure 6). This is not surprising given Modified Class D HMA tendency to ravel in the wheel paths. Neither mix type has performed well at preventing rutting on Interstate 90. The trend lines show average rut depth of Modified Class D HMA exceeding 0.4 inches after about 10 years and dense graded mixes exceed 0.4 inches at about 12 years. The short time needed for ruts to reach 0.4 inches may lead the pavement to require rehabilitation even though the pavement still has structural life.

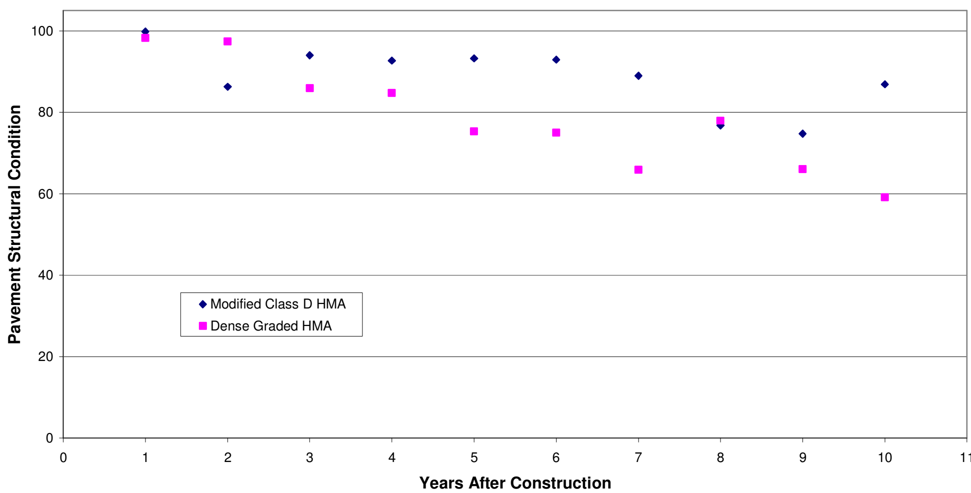


Figure 5. Comparison of average PSC each year after construction on Interstate 90.

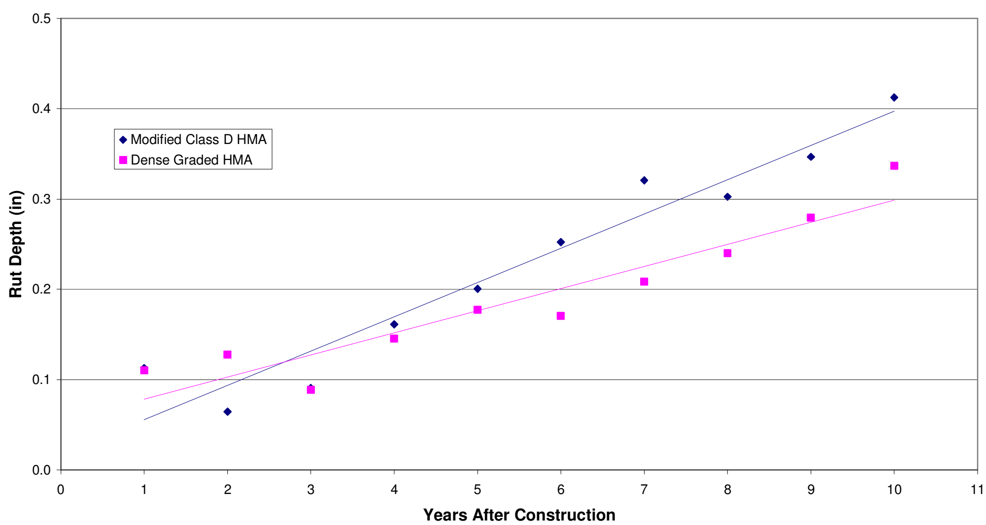


Figure 6. Comparison of average rut depth each year after construction on Interstate 90.

The actual service lives of Modified Class D HMA and dense graded HMA on Interstate 90 are listed in Tables 12 through 16. If we once again eliminate the projects with WSPMS due dates, the average service life of Modified Class D on Interstate 90 in Eastern Region was 7.5 years and 12.0 years in South Central Region. The average service life of dense graded HMA on Interstate 90 was 11.8 years in Eastern Region, 10.5 years in North Central Region[3] and 9.7 years in South Central Region. When all projects are combined into a single average for each pavement type the average service life for Modified Class D HMA on Interstate 90 is 9.0 years and 10.8 years for dense graded HMA. The reduced service life indicates that Modified Class D HMA does not perform as well as dense graded HMA. As was the case when all Modified Class D HMA projects were considered the two early failing projects are a large part of the reduced service life. If the early failures are not included the average service life of Modified Class D HMA on Interstate 90 is 11.3 years, 0.5 years longer than dense graded HMA. So it is the risk of early failure that ultimately controls whether Modified Class D HMA performs as well as dense graded mixes.

Table 12. Service life of Eastern Region Modified Class D HMA projects on Interstate 90.

Contract No.	State Route	Milepost Limits	Year Paved	Service Life (yrs)	Basis for Service Life
4158 EB	90	239.15 to 256.04	1993	11	Rehabilitated in 2004
4158 WB	90	239.15 to 256.04	1993	11	Rehabilitated in 2004
4254 EB	90	191.89 to 208.16	1994	5	Sections Repaired in 1999
4254 WB	90	191.89 to 208.16	1994	5	Sections Repaired in 1999
4277 EB	90	256.04 to 265.84	1995	10	Rehabilitated in 2005
4277 WB	90	256.04 to 265.84	1995	10	Rehabilitated in 2005
6708 EB	90	239.12 to 255.29	2004	4	Sections Repaired in 2008
6708 WB	90	239.12 to 255.29	2004	4	Sections Repaired in 2008
6907 EB	90	255.29 to 265.84	2005	12	WSPMS Due 2017
6907 WB	90	255.29 to 265.84	2005	11	WSPMS Due 2016

[3] A portion of North Central Region lies between Eastern and South Central Region on Interstate 90; however Modified Class D HMA has not been placed in the North Central Region section. Dense graded HMA placed by North Central Region are included since they are within the section of Interstate 90 that is being compared to Modified Class D HMA.

Table 13. Service life of South Central Region Modified Class D HMA projects on Interstate 90.					
Contract No.	**State Route**	**Milepost Limits**	**Year Paved**	**Service Life (yrs)**	**Basis of Service Life**
4249 EB	90	121.97 to 126.18	1994	12	Rehabilitated in 2006
4249 WB	90	121.97 to 126.18	1994	12	Rehabilitated in 2006
4795 EB	90	126.18 to 137.20	1996	11	WSPMS Due 2007
4795 WB	90	126.18 to 137.20	1996	na	Replaced due to new construction
5126 EB	90	102.61 to 106.34	1997	12	Rehabilitation Scheduled in 2009
5126 WB	90	102.61 to 106.34	1997	12	Rehabilitation Scheduled in 2009

Table 14. Service life of Eastern Region dense graded HMA projects on Interstate 90.					
Contract No.	**State Route**	**Milepost Limits**	**Year Paved**	**Service Life (yrs)**	**Basis of Service Life**
3658 EB	90	208.16 to 218.60	1989	13	Rehabilitated in 2002
3658 WB	90	208.16 to 218.60	1989	13	Rehabilitated in 2002
3503 EB	90	218.60 to 231.47	1989	13	Rehabilitated in 2002
3503 WB	90	218.60 to 231.47	1989	13	Rehabilitated in 2002
6136 EB	90	218.60 to 231.75	2002	9	Rehabilitation Scheduled in 2011
6136 WB	90	218.60 to 231.75	2002	9	Rehabilitation Scheduled in 2011
4157 EB	90	231.75 to 239.15	1993	11	Rehabilitated in 2004
4157 WB	90	231.75 to 239.15	1993	11	Rehabilitated in 2004
4018 EB	90	265.84 to 270.28	1992	13	Rehabilitated in 2005
4018 WB	90	265.84 to 270.28	1992	13	Rehabilitated in 2005

Table 15. Service life of Eastern Region dense graded HMA projects on Interstate 90.					
Contract No.	**State Route**	**Milepost Limits**	**Year Paved**	**Service Life (yrs)**	**Basis of Service Life**
5779 EB	90	137.67 to 148.44	2000	8	Rehabilitated in 2008
5779 WB	90	137.67 to 148.44	2000	9	WSPMS Due 2009
4435 EB	90	148.44 to 164.21	1995	10	Rehabilitated in 2005
4435 WB	90	148.44 to 164.21	1995	10	Rehabilitated in 2005
4181 EB	90	164.21 to 175.62	1993	11	Rehabilitated in 2004
5051EB	90	175.62 to 179.35	1997	13	Rehabilitation Scheduled in 2010
5051WB	90	175.62 to 179.35	1997	13	Rehabilitation Scheduled in 2010
3919 EB	90	181.77 to 191.89	1991	11	Rehabilitated in 2002
3919 WB	90	181.77 to 191.89	1991	11	Rehabilitated in 2002
6238 EB	90	181.77 to 191.89	2002	10	Rehabilitation Scheduled in 2012
6238 WB	90	181.77 to 191.89	2002	10	Rehabilitation Scheduled in 2012

Table 16. Service life of Eastern Region dense graded HMA projects on Interstate 90.					
Contract No.	**State Route**	**Milepost Limits**	**Year Paved**	**Service Life (yrs)**	**Basis of Service Life**
4249 EB	90	106.34 to 110.00	1994	8	Rehabilitated in 2002
4249 WB	90	106.34 to 110.00	1994	8	Rehabilitated in 2002
6061 EB	90	106.34 to 110.00	2002	9	WSPMS Due 2011
6061 WB	90	106.34 to 110.00	2002	9	WSPMS Due 2011
5675 EB	90	110.00 to 121.96	1999	12	WSPMS Due 2011
5675 WB	90	110.00 to 121.96	1999	12	WSPMS Due 2011

Documented Failures of Modified Class D HMA

WSDOT documented two failures of Modified Class D on Interstate 90. The first was Contract 4254 which placed 0.15 feet of Modified Class D HMA between MP 191.89 and MP 208.16. Two years after placing the Modified Class D HMA the section exhibited areas of potholing, flushing, rutting and shoving. An investigation revealed that stripping was occurring primarily in the underlying layer of HMA leading to the distress. The report concluded that traffic consolidated the Modified Class D HMA in the left wheel path of the truck lane making it impermeable. The roadway cross slope ran from the left shoulder downward to the right shoulder, so surface water would flow through the Modified Class D HMA from left to right until it reached the right edge and flow out of the pavement. However the "dam" created by the impermeable pavement in the left wheel path of the truck lane prevented the flow of water through the pavement. The trapped water induced stripping in the underlying HMA leading to the distress (Gibson and Uhlmeyer, 1996).

An additional segment on this project placed the Modified Class D HMA over an aged WSDOT Class D HMA OGFC which was described earlier, lead to stripping on this section of Interstate 90. The complete investigation for SR 90, MP 191.89 to 208.16 can be found in Appendix B.

The second failure involves Contract 6708 placed in 2004 between MP 239.12 and 255.29. This project removed 0.15 feet of the existing Modified Class D HMA from the entire right lane and sections of the left lane and replaced it with 0.15 feet of new Modified Class D HMA. An additional 0.15 or 0.20 feet was removed from selected locations and replaced with the same amount of ½ inch dense graded HMA. Within a year of placement, the pavement exhibited flushing, rutting, cracking and potholing. Flushing occurred first followed by rutting and cracking. Finally a pothole would form which would require patching by maintenance crews. As with Contract 4254, most of the distress occurred in the left wheel track of the outside lane. It is believed that the distress was being caused by stripping in the underlying HMA by a mechanism similar to the one seen on Contract 4254. Essentially, the milled surface allows pooling of water in the pavement structure. The hydraulic action of trucks and vehicles promotes the stripping of the underlying HMA. A complete progression of the distress is displayed in Figures 7 through 10. A Project Change Request Form detailing the scope of the repair, vicinity maps showing repair locations and a schematic of the repairs are included in Appendix C.

Figure 7. Fat spots and rutting in wheel path resulting from stripping.

Figure 8. Area with fat spots beginning to crack.

Figure 9. New pothole developing ahead of a previously patched area.

Figure 10. String of patches typical to distressed areas.

Performance – Western Washington

The limited amount of Modified Class D HMA placed in western Washington makes evaluating performance difficult. A total of five lane miles were placed in 1994 under one project on northbound Interstate 5 between Olympia and Centralia. The directional ADT of 30,100 in 2006 on two northbound lanes was the highest of any Modified Class D HMA overlay in the state. Anecdotal evidence indicates that this section performed poorly. The pavement was reported to have quickly rutted requiring repair and early replacement in 2004. This rutting is believed to be tied to difficulties experienced during mix production. Records indicate the PBA-6GR asphalt content for the mix approached 6.6 percent which was far above the 5.4 percent recommended in the mix design. Figures 11 and 12 display the average PSC and rutting for each year after the Modified Class D HMA overlay on Interstate 5.

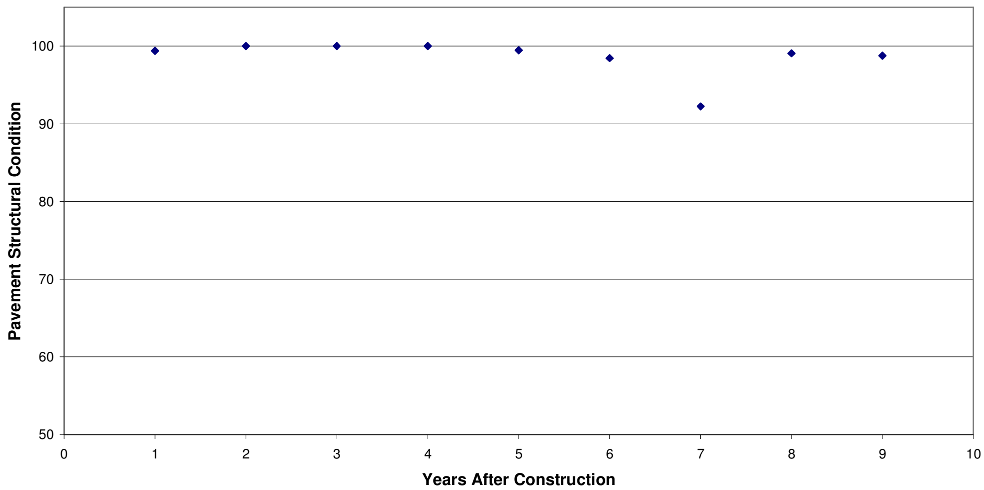


Figure 11. PSC each year after construction for Modified Class D HMA on Interstate 5.

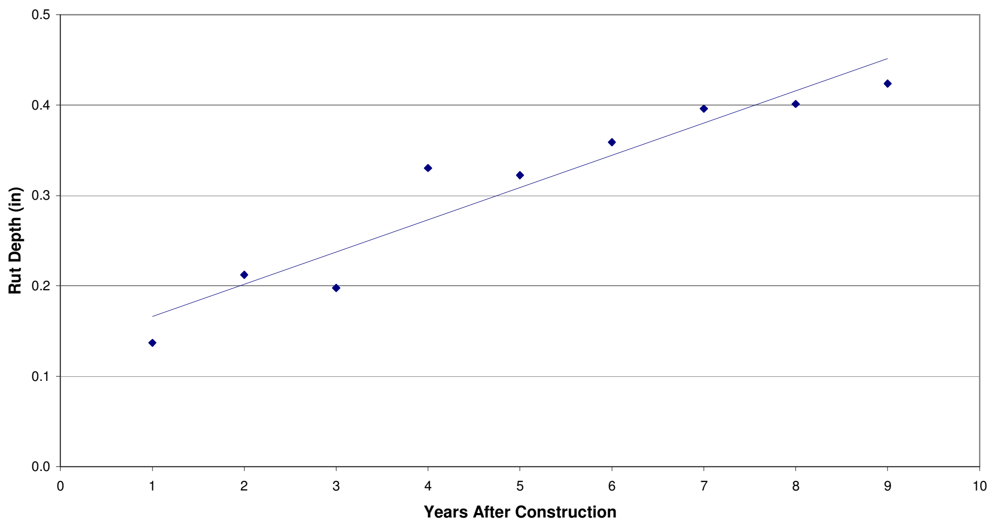


Figure 12. Rut depth each year after construction for Modified Class D HMA on Interstate 5.

The PSC for this section was near 100 nine years after construction indicating the pavement was in good condition structurally. The dip that occurred at age seven is due to longitudinal cracking recorded on the 1999 pavement condition survey. The 1999 survey data also showed longitudinal cracking in the pavement sections before and after the Modified Class D HMA section, suggesting that the rater had difficulty interpreting what they saw during the pavement evaluation. Subsequent surveys did not record any longitudinal cracking resulting in the PSC raising back to near 100 in the next year and indicating that the longitudinal cracking was not due to poor structural performance of the Modified Class D HMA. If the longitudinal cracking is disregarded at year seven, the PSC for the pavement would be close to 100 for that year.

Figure 12 illustrates the poor rutting performance of the one Modified Class D HMA on Interstate 5. By 2001, seven years after placement, the ruts reached the 0.4 inch average depth at which WSDOT considers pavement due for rehabilitation. Subsequent pavement condition surveys recorded rut depths up to 0.55 inches. With only one project it is difficult to say that Modified Class D HMA is inappropriate for overlays in western Washington, however, its performance on this project on Interstate 5 was less than desirable.

Cost Comparison

Comparing the cost of Modified Class D HMA placed in the 1990's to current dense graded HMA prices is difficult. Recent increases in HMA cost and the change to Superpave mix designs for dense graded HMA make a direct comparison impossible. WSDOT keeps a cost index of bid prices for various construction materials including dense graded HMA. Table 17 shows cost per ton for Modified Class D HMA and dense graded HMA (placed 2004 through 2007) adjusted to 2007 prices using WSDOT's cost index.

Table 17. HMA cost comparison.

Mix Class	Cost ($/ton)
Modified Class D HMA Eastern Region	50.77
½ Inch HMA Eastern Region	51.50
Modified Class D HMA South Central Region	63.42
½ Inch HMA South Central Region	52.47
Modified Class D HMA Both Regions	58.38
½ Inch HMA Both Regions	51.87

The cost data shows that Modified Class D HMA is about $6.50 per ton more costly than dense graded HMA. The lower density of Modified Class D HMA partially offsets its higher cost. The high air voids makes a square yard of Modified Class D HMA weigh less than a square yard of the same depth of dense graded HMA. The result is that a ton of Modified Class D HMA will cover more surface area than a ton of dense graded HMA requiring fewer tons of Modified Class D HMA to pave the same area reducing overall project cost. The cost index reflects the increase in price of dense graded HMA when WSDOT switched over to Superpave mix designs.

Modified Class D HMA designs have remained essentially the same making the cost index slightly overestimate the cost of Modified Class D HMA relative to dense graded Superpave. The result is that Modified Class D HMA likely costs slightly more than dense graded HMA.

There is a large difference between the average cost of Modified Class D HMA placed in Eastern Region and South Central Region. The cost difference arises primarily from a variation in project quantities between the regions. The four smallest projects, all with quantities of less than 10,000 tons, have the highest cost per ton. All four of these projects are in South Central Region and are responsible for most of the difference in cost between the regions. Furthermore the average project size in Eastern Region is 46,700 tons versus 17,900 tons for South Central Region. The larger quantities allow contractors to distribute their overhead over more tons thus resulting in lower price per ton in Eastern Region. For equal project sizes the cost between the Regions should be about the same.

Conclusions

Modified Class D HMA does not perform as well as dense graded mixes in Eastern Washington. The overall service life for Modified Class D HMA in Eastern Washington averaged 9.7 years while the average service life for all HMA pavement in Eastern Washington averages 11.0 years.

Modified Class D pavements tend to be in relatively good structural condition as measured by the PSC rating at the time of rehabilitation. This causes WSPMS to overestimate the due date of Modified Class D HMA pavements. WSPMS schedules rehabilitation when a projects PSC rating reaches 50. Modified Class D HMA projects usually fail due to raveling or due to flushing, stripping and potholing. Raveling and flushing are not part of the PSC rating leading to the PSC being relatively high at rehabilitation.

Two failure modes were identified for Modified Class D HMA. The first was raveling in the wheel path that eventually leads to rutting severe enough to require rehabilitation. The second is stripping in the underlying layer leading to flushing and rutting and eventually potholes. WSPMS PSC ratings do not reflect the severity of these distresses.

Modified Class D HMA on Interstate 90 performed somewhat better than dense graded HMA at preventing cracking and somewhat worse at resisting rutting.

The average service life of Modified Class D HMA pavement on Interstate 90 was less than dense graded mixes. When the two early failing Modified Class D HMA projects are not included in the average the service life of Modified Class D HMA was longer than dense graded HMA. This makes the risk of early failure the determining factor when deciding to use Modified Class D HMA over dense graded HMA.

Two early failures of Modified Class D HMA on Interstate 90 were documented. Both failures were attributed to water trapped in the Modified Class D HMA and causing the underlying layer to strip. The failures first manifested themselves by flushing, rutting and cracking in the wheel paths. Eventually a pothole would form requiring repair by maintenance and rehabilitation.

The one trial of Modified Class D HMA is Western Washington performed poorly. The pavement quickly rutted requiring early rehabilitation. The rutting was attributed to excess binder in the mix.

Cost comparison shows that Modified Class D HMA would likely cost slightly more than dense graded mixes.

Recommendations

The conclusion of this report show that Modified Class D HMA has a shorter service life and higher cost than dense graded HMA. Furthermore, Modified Class D HMA is prone to early failures. The shorter service life and higher cost would result in higher initial and life cycle costs. Early failures would require emergency repairs by state maintenance forces and lead to unplanned expenditures. Based on the conclusions of this report, the use of Modified Class D HMA as an alternative to dense graded HMA is not recommended.

References

1. Gibson, G., Uhlmeyer, J. (1996). Summary of Deteriorating Modified Class D Asphalt: WSDOT internal memorandum. Washington State Department of Transportation.

2. Moore, L.M., Hicks, R.G. and Rogge, D.F. (2001). Design, Construction, and Maintenance Guidelines for Porous Asphalt Pavements. *Transportation Research Record No. 1778*, Transportation Research Board, p. 91 to 99.

3. Transportation Research Board (TRB) (2000). NCHRP Synthesis 283: Performance Survey on Open Graded Friction Course Mixes. Transportation Research Board, National Research Council, Washington D.C.

4. Washington State Department of Transportation (WSDOT). (1995). WSDOT Pavement Guide, Vol. 2. Washington State Department of Transportation.

Appendix A - Eastern Region Modified Class D Fog Sealing History

Table B–1. Fog seal dates for Eastern Region Modified Class D HMA projects					
Contract No.	**State Route**	**Project Title**	**Milepost**	**Year Paved**	**Years Fog Sealed**
4158	90	Adams County Line to Spokane County Line	239.15 to 256.04	1993	1998
4254	90	Grant County Line to Vicinity SR 21	191.89 to 208.16	1994	1998,2002[1],2004[2]
4277	90	Lincoln County Line to Vic. Salnave Rd	256.04 to 265.84	1995	2005[2]
5544	211	Vicinity Four Lanes to SR 20	0.17 to 15.10	1999	2002,2006
5635	904	Vicinity Betz Road to I-90	12.68 to 16.82	1999	2002,2006
6708	90 Outside Lanes[2]	Adams County Line to Spokane County Line	239.12 to 255.29	2004	None
6907	90 Outside Lanes[2]	Lincoln County Line to Salnave Road	255.29 to 265.84	2005	None

[1]Pavement between mileposts 194.85 to 198.65, 202.20 to 204.99, 205.50 to 208.16 westbound and 194.85 to 204.99 eastbound were not fog sealed in 2002.
[2]Only the left lane was fog sealed.

Appendix B - Investigation of Deteriorating Modified Class D

SR 90

MP 191.89 to 208.16

Washington State
Department of Transportation

Memorandum

Date: July 22, 1996

From: Gion Gibson/ Jeff Uhlmeyer
Phone: 324-6175

Subject: I-90
Grant County Line Schrag
MP 191.89 to MP 200.35
Schrag to Vicinity SR 21
MP 200.35 to MP 208.16
Summary of Deteriorating Modified Class D Asphalt

To: **Mike Frucci**
Gary Janousek
Keith Metcalf

This memorandum summarizes our investigation on I-90 for the deteriorating Modified Class D (MCD) pavement that was placed during 1993 under Contract 4254. Distress in this overlay is severe and extensive rehabilitation will eventually be required.

This investigation provides brief histories of the two roadway sections, describes and analyzes the distress that is occurring, provides both short term and long term rehabilitation measures, and provides recommendations for future projects utilizing MCD asphalt.

HISTORY

__Grant County Line to Schrag (MP 191.89 to MP 200.35)__

The resurfacing history for this section is summarized as followings:

Year	Contract	Depth (ft)	Asphalt Class
1993	4254	0.15	Modified D
1982	2279	0.06	D
1982	2279	0.15	B
1982	2279	0.15	Planing ACP
1972	9221	0.35	B
1972	9221	0.50	E
1972	9221	0.25	CSTC
1972	9221	0.40	Ballast

1.71 ft Total Surfacing

The materials source for the 1972 construction came from QS-AD-147 located just south of MP 196.7. The remaining contracts came from QS-AD-121 which are located north of MP 203.8.

Distress in this section prior to the last contract (1994) was minimal. Distress included 1/4 inch rutting in the wheel paths, some transverse or thermal cracking, and almost no longitudinal cracking.

Schrag to Vicinity SR 21 (MP 200.35 to MP 208.16)

The surfacing for this section is summarized as follows:

Year	Contract	Depth (ft)	Asphalt Class
1993	4254	0.15	Modified D
1993	4254	0.15	Planing ACP
1984	2730	0.17	B
1972	9232	0.35	B
1972	9232	0.50	E
1972	9232	0.25	CSTC
1972	9232	0.40	Ballast

1.67 ft Total Surfacing

The materials source for each of these contracts was QS-AD-121.

The resurfacing recommendation for the 1993 project noted the truck lane in both eastbound and westbound directions exhibited 1/4 to 1 inch rutting and potholes in the left wheel paths of the truck lane.

The potholes were described as 5 ft to 20 ft in length and 3 ft to 5 ft in width occurring approximately 135 ft apart. The greatest concentration of potholes occurred between MP 200.35 and MP 207.00. The cause of the potholes is unknown but one theory is that during the 1972 project diesel or hydraulic fluid leaked from either the trucks hauling ACP or the Blaw Knox paving machine. Whatever the cause, maintenance forces have performed extensive patching by removing the distressed ACP and patching with cold mix asphalt.

The 1993 contract specified in addition to planing 0.15 ft removing an additional 0.15 ft to 0.45 ft depth in the distressed areas. A total of 3,930 sy of "Roadway Repair" was set up in the contract. A review of the contract pay notes showed only 28 percent or 1,114 sy were done (683 sy westbound, 431 sy eastbound).

CURRENT DISTRESS AND ANALYSIS

After two summers the 1993 overlay already exhibits areas of potholes, flushing, rutting and shoving. The ride quality of I-90 has been adversely affected. The major cause of the distress, although not limited to, appears to be stripping of the MCD and mostly the underlying Class B asphalt. The section furthest east will be discussed first.

MP 200.35 to MP 208.16

This section was planed 0.15 ft shoulder to shoulder and then inlayed with MCD asphalt during 1993. A CRS-2 seal was placed prior to the overlay.

Potholes, flushing, rutting and shoving

The progression to potholes as reported by maintenance begins with the wheelpaths appearing fat with asphalt (photos 1 to 4). Before long, and especially during wet weather, the asphalt pushes, shoves and breaks up (photo 5). With continual traffic the pothole enlarges until finally a patch is required (photo 6).

A possible reason for this stripping has been outlined in Transportation Research Board No. 1454, Materials and Construction. In a 1994 article entitled "Field and Laboratory Investigation of Stripping in Asphalt Pavements: State of the Art" author P. S. Kandhal states:

> . . . several states in the southeastern United States experienced stripping in the hot mix asphalt course underlying open graded asphalt friction course (OGFC) during the late 1970's. It has been hypothesized that the OGFC retains moisture for a longer time and does not dry out after rain as fast as a conventional, dense-graded hot mix asphalt surface. The water in OGFC is also pressed into the underlying course by the truck tires initiating the stripping action, which can also cause flushing, rutting, or shoving at the surface.

Kandhal noted several states in the southeastern United States have suspended the use of open graded asphalts since the 1980's. **To minimize stripping, it is recommended to have an impervious dense graded asphalt below the open graded asphalt.** The recommended air-void content should not exceed 4 to 5 percent.

The conditions Kandhal writes about are identical to those on I-90, MP 200.35 to MP 208.16. The underlying asphalt below the MCD as verified by cores is indeed stripping. Photos 7 to 11 are examples where cores were taken in wheelpaths that exhibited a fat surface. Seen in the photos is the stripped layer beneath the MCD that has little or no asphalt as binder. Essentially, the asphalt has migrated to the surface. The end result is the surface becomes rich, the MCD asphalt consolidates, and rutting, pushing, or shoving appears. It is unknown whether the stripping of the underlying layers or the consolidation of the asphalt occurs first. But the end result is that the asphalt potholes and a patch is required.

For comparison photos 12 to 14 show cores taken from the center of the lane. Stripping is not seen in the underlying layers. Where there is no traffic there is no hydraulic action to initiate and progress stripping.

It is interesting that the majority of distress occurs in the left wheelpath of the truck lane. The reason for this is likely because this section of I-90 is built with a shed section and the water drains away from the medium. Photos 15 and 16 show how moisture becomes dammed or trapped within the left wheelpath of the truck lane. The water cannot drain because of the consolidation of the MCD. The trapped water is pressed into and strips the underlying asphalt as a result of the pressure from the truck tires.

The majority of the distress occurs in the westbound truck lane, particularly from MP 206.35 to MP 208.16. The remainder of the westbound lanes and most of the eastbound lanes suffer from occasional potholes and a flushed or "fat" surface. The Materials Lab and Maintenance feels the underlying stripping and surface flushing will eventually lead to failure of this entire section.

Pavement Cores

Extensive coring was performed and a summary of the core depths and extent of the distress is attached. Cores were obtained in the wheel paths and in the center of the truck lane.

The depth of stripping ranged from 0.26 to 0.56 ft beneath the pavement surface. The deeper depths were in patched areas. In most cases the MCD asphalt, especially in the wheelpaths, showed minimal voids and appears as a dense graded asphalt. The CRS-2 seal that was placed prior to the MCD overlay was not visible in most cores. The Class B asphalt beneath the stripped layers was aged but generally appeared sound.

The stiffness of the MCD asphalt as seen in the cores was soft to gooey immediately as it was obtained. But, as the cores were left to dry at room temperature the asphalt stiffened considerably. Several cores were soaked in water and checked several days later. The stiffness of the MCD was slightly softer which indicates the asphalt is very moisture sensitive and explains why Maintenance reports an increase in potholes with wet weather.

Previous Pavement Repairs

Prior to the placement of the MCD asphalt approximately 175 locations in the eastbound and westbound truck lanes received "roadway repair'. The "roadway repair" consisted of removing distressed asphalt 3 to 6 ft wide by 10 to 40 ft long at a depth of 0.15 to 0.45 ft. This repair was needed to eliminate the potholes that may have occurred from equipment leaking diesel or hydraulic fluid during the 1972 contract.

There has been concern that repairs to correct the potholes for some locations were not made (considering only 28 percent of the pavement repair was done). This concern can be discounted as a review of construction records showed that the majority of the locations specified for repair in the PS & E were indeed repaired.

Of the 54 locations in the westbound lanes that were not repaired only 10 of these have potholed and have required a patch. Of 26 locations in the eastbound lanes that were not repaired no potholes have formed. In addition, the flushed or consolidated surface is present in areas of "roadway repair" and areas that were not repaired alike. More potholes have developed in areas where pavement repair was not even specified.

Maintenance Requirements

Davenport Maintenance currently invests considerable time maintaining the roadway. Maintenance reports increased potholes in the fall with increased moisture from inclement weather. When the pavement stays damp or freezes and thaws maintenance reports daily spending three to four hours placing cold mix. As the road completely freezes the maintenance effort decreases. From February through April considerable maintenance effort is again expended.

MP 191.89 to MP 200.35

This section was overlaid shoulder to shoulder with 0.15 ft MCD asphalt placed over an existing Class D pavement. The major distinction between this section and the last is that the underlying stripping is not present as the distress appears to be restricted to the MCD and Class D asphalt. The distress, although not as severe as the previous section, includes potholes, flushing, rutting and shoving.

Potholes - Westbound Lanes

The westbound lanes are in good condition with the MCD pavement appearing open graded and stable (photo 17). The only distress showing is isolated potholes in the truck lane and the depth is limited to the MCD and Class D lifts.

Potholes, Flushing, Rutting and Shoving - Eastbound Lanes

The majority of the eastbound lanes appear in good condition and the distress that shows is primarily isolated to MP 195.12 to MP 196.87. The distress that dominates is flushing (photo 18). Some of the flushed areas, as discussed previously, have rutted, shoved, and potholed (photos 19 to 22). Some of the failures look like they could be attributed to "bad" loads of asphalt.

Pavement Cores

A summary of the core depths and extent of the distress is attached. Cores were obtained in the wheel paths and in the center of the truck lane.

The distress seen in this section is likely being driven by stripping of the MCD and Class D lifts. The depth of stripping, with the exception of a few major potholes, is no more than 0.25 to 0.30 ft beneath the pavement surface (photo 23). In the areas of distress the MCD asphalt appears as a dense graded asphalt. The MCD asphalt, especially in the wheelpaths, showed minimal voids. The CRS-2 seal that was placed prior to the MCD overlay was not visible in many of the cores.

When coring this section the core typically broke in the middle of the Class D layer. The appearance of the Class D seemed low in asphalt content and was stripped. The Class B asphalt beneath the MCD and Class D layers was aged but generally appeared sound.

Three locations showed major potholes. A couple of these area were cored and the depth of stripping was 0.60 to 0.70 ft. below the pavement surface (photos 24 and 25). The asphalt beneath the stripped layer appeared aged but was intact.

The stiffness of the MCD asphalt as seen in the cores was soft to gooey immediately as cores were obtained. But, as the cores were left to dry at room temperature the asphalt stiffened considerably. Several cores were soaked in water and checked several days later. The stiffness of the MCD was again soft which indicates the asphalt is moisture sensitive and explains why maintenance reports an increase in potholes with wet weather.

Maintenance Requirements

Except for isolated potholes maintenance in this section is minimal at this time.

REHABILITATION MEASURES

Short Term

To eliminate the bulk of the maintenance patching and in order to stretch the life of this project the following short term rehabilitation measures are recommended:

MP 191.89 to MP 200.35 Eastbound

- Provide pavement repair per Section 5-04.3(5)E of the Standard Specifications at the following locations:

Mile Post	Square Yards
195.680	9
195.718	80
195.773	140
195.784	9
196.364	91
196.744	3

- Monitor and repair as needed additional distressed areas.

MP 206.35 to MP 208.16 Westbound

- Plane shoulder to shoulder 0.15 ft.
- Plane an additional 0.25 ft within the traveled lanes and inlay with 0.25 ft Asphalt Class E or A. Isolated areas may required additional planing depth.
- Overlay shoulder to shoulder with 0.15 ft Asphalt Class A.

Long Term

The eventual recommendation for this project will include:

MP 191.89 to MP 200.35

- Provide 500 sy of pavement repair per Section 5-04.3(5)E of the Standard Specifications.

- Plane shoulder to shoulder 0.25 to 0.30 ft and overlay shoulder to shoulder with 0.25 to 0.30 ft. Asphalt Class A. Additional coring is necessary to determine the thickness of isolated distressed areas.

MP 200.35 to MP 208.16

- Plane shoulder to shoulder 0.15 ft.

- Plane an additional 0.25 ft within the traveled lanes and inlay with 0.25 ft Asphalt Class E or A. Isolated areas determined by further pavement investigation may required additional planing depth.

- Overlay shoulder to shoulder with 0.15 ft Asphalt Class A.

RECOMMENDATIONS FOR FUTURE MODIFIED CLASS D PROJECTS

WSDOT should consider the following when rehabilitating with MCD asphalt:

- Provide a dense graded asphalt base prior to placement of a MCD pavement. This may required planing and inlaying with an Asphalt Class A or B if the existing asphalt is aged or subject to stripping. Investigation on other sections of I-90 show good performance where dense graded asphalt was placed prior to the MCD. Two MCD projects placed during 1993 and 1994 respectively include:

  Adams County Line to Spokane County Line - MP 239.15 to MP 256.04

  Lincoln County Line to Vicinity Salnave - MP 256.04 to MP 265.84

  These projects show minor rutting, but this appears to be the result of consolidation (possibly inadequate compaction) rather than stripping of underlying asphalt layers.

- Refrain from overlaying open graded pavements as stripping may occur in the lower layer. The existing open graded layer appears to be aged and subject to stripping.

- Correct if at all possible all underlying pavement distress prior to placement of MCD.

- Continue monitoring for rutting on the MCD roadways within the Eastern Region. (The materials lab takes rut measurements in the fall and spring when studded tires are allowed and removed. To date, no significant increase in rutting has been noted. A summary of rutting occurring on these projects is attached. The summary includes a comparison with an Asphalt Class A project that was paved at the same time.)

- Apply fog seals as preventive maintenance or if raveling appears.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 1, MP 208.09, Westbound Lanes
Failing Modified Class D (MCD) surface. The wheel paths first appear fat, second push and shove, and finally potholes develop. This location shows several areas have almost progressed to potholes.

Photo 2, MP 202.49, Westbound Truck Lane
Left wheel path where the MCD surface has become fat.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 3, MP 208.01, Westbound Lanes
Wheelpaths in the truck lane where the MCD has turned fat.

Photo 4, MP 208.09, Westbound Lanes
Wheelpaths in the truck lane where the MCD has turned fat.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 5, MP 207.90, Westbound Truck Lane
Typical infancy stage of potholing of the MCD surface.

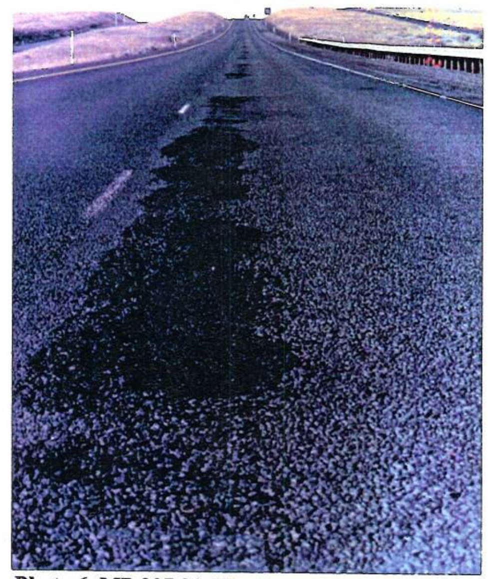


Photo 6, MP 207.91, Westbound Truck Lane
Potholes that have required maintenance patching.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 7, MP 207.87, Westbound Truck Lane
Stripped Asphalt Class B beneath the MCD surface in the left wheelpath. The MCD surface appears fat and the core appears very dense.

Photo 8, MP 202.49, Westbound Truck Lane
Stripped Asphalt Class B beneath the MCD surface in the left wheelpath. The MCD surface appears fat and the core appears very dense.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 9, MP 205.73, Westbound Truck Lane
Stripped Asphalt Class B beneath the MCD surface in the left wheelpath. The MCD surface appears fat and the core appears very dense.

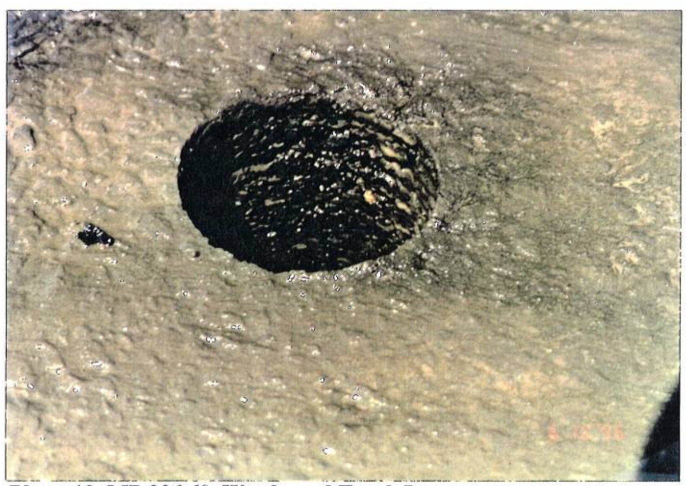


Photo 10, MP 206.69, Westbound Truck Lane
Stripped Asphalt Class B beneath the MCD surface in the left wheelpath. The MCD surface appears fat and the core appears very dense.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 11, MP 206.62, Westbound Truck Lane
Stripped Asphalt Class B beneath the MCD surface in the left wheelpath. The MCD surface appears fat and the core appears very dense.

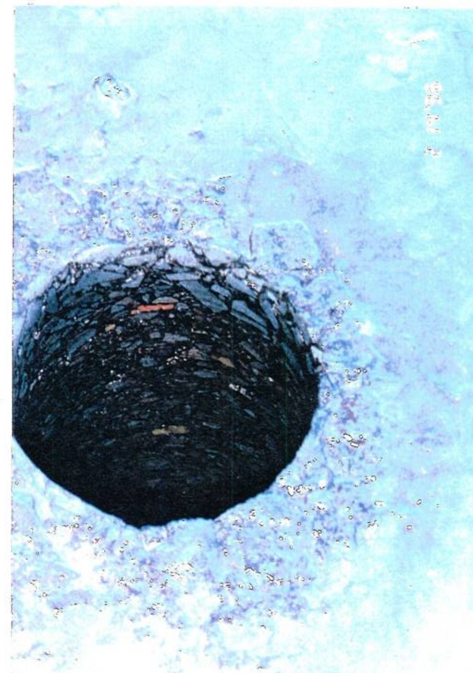


Photo 12, MP 207.87, Westbound Truck Lane
Core taken in the center of lane. The underlying asphalt Class B looks good.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 13, MP 202.37, Westbound Truck Lane
Core taken in the center of lane. The underlying asphalt Class B looks good.

Photo 14, MP 205.73, Westbound Truck Lane
Core taken in the center of lane. The underlying Asphalt Class B looks good.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 15, MP 207.19, Westbound Truck Lane
This section of I-90 is built with a shed section that drains to the outside shoulder. Water is "dammed" left of the left wheelpath for westbound traffic.

Photo 16, MP 208.84, Westbound Truck Lane
Water "dammed" by compressed MCD on the high side of the wheel rut.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

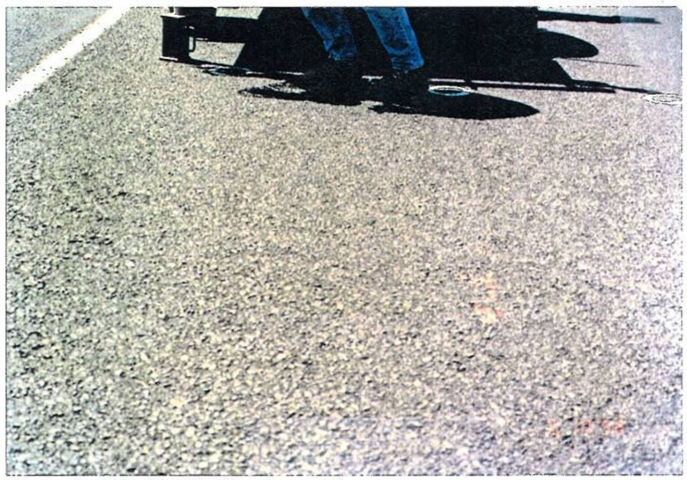


Photo 17, MP 195.00, Westbound Lanes
This MCD was overlaid over an existing Asphalt Class D. The pavement looks good.

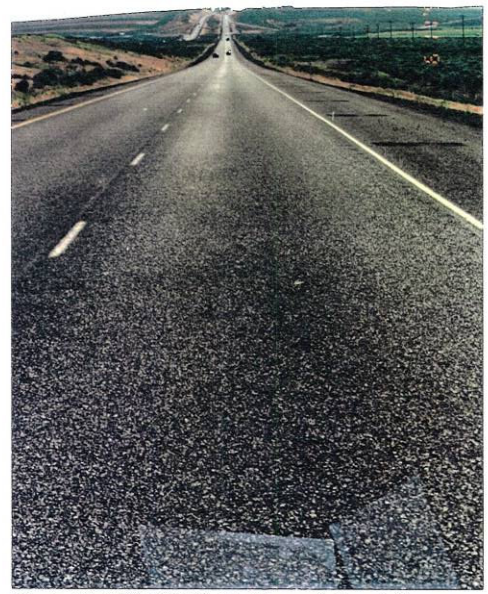


Photo 18, MP 195.00, Eastbound Truck Lane
Flushing appearing in the eastbound truck lane.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 19, MP 195.85, Eastbound Truck Lane
Isolated area of pushing and shoving.

Photo 20, MP 195.75, Eastbound Truck Lane
Isolated pothole. Stripping occurs almost full thickness.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 21, MP 195.90, Eastbound Truck Lane
Isolated pothole. Stripping occurs almost full thickness.

Photo 22, MP 195.68, Eastbound Truck Lane
Isolated pothole. Stripping occurs almost full thickness

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

Photo 23, MP 194.88, Eastbound Truck Lane
Stripping occurring within the top 0.25 to 0.30 ft of MCD and Class D.

Photo 24, MP 195.68, Eastbound Truck Lane
Core taken within a pothole. Stripping is deep seated.

Modified Class D Investigation
I 90, Grant County Line to Vicinity SR 21

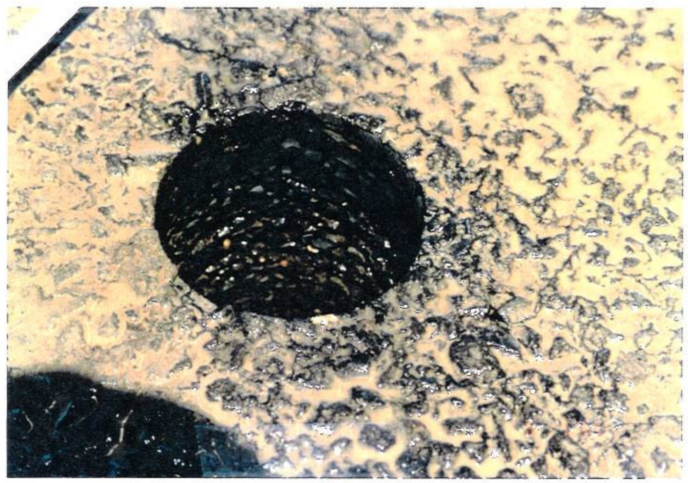


Photo 25, MP 195.79, Eastbound Truck Lane
Core taken within a pothole. Stripping is deep seated.

Appendix C - Interstate 90 Modified Class D HMA Emergency Repairs

MP 208.5 to 254.4

Special Report

Date Submitted: _3/20/08______ **Region/Office Submitting:** Eastern___ **Date:** _3/19/08______

Project Page Title (if appropriate):
CPMS Project Title: I-90/SR 21 TO FISHTRAP – PAVEMENT REPAIR
Location: Sprague Vicinity
Program Item No.: 609024F

Work Item No: F09024F

Subprogram: P1

1. Statement of Needs:

- Primary
  Numerous locations on Interstate 90 are exhibiting premature failure of the asphalt concrete pavement surface. The failing areas are concentrated around the SR 21 interchange which was paved in 2002, under contract 004254 and within the Sprague to Fishtrap stretch which was paved in 2004, under contract 006708. The majority of the failing areas are attributed to the open graded asphalt class D mix, previously placed for the wearing course. Water is collecting or ponding within the wearing course which is stripping the underlying pavement course. The result is a roadway characterized by numerous potholes and maintenance patches with the continued propagation of localized pavement failures.
- Other needs being addressed
  This project will only address the locations with failing pavement. The patched locations shall be striped upon completion of the pavement repair.

2. Purpose:
Rehabilitate the existing pavement in failing areas to extend the service of the adjacent pavement.

3. Summary of Project Functional Intent:

- Scope of work
  Remove the existing pavement in isolated areas and replace with hot mix asphalt. The exact locations of work are dependent upon funding with the intent of rehabilitating the worst locations first. Areas identified to date include:
  MP 245.8 to MP 247.2 EB Outside lane
  MP 250.8 to MP 253.8 EB Outside lane
  MP 249.8 to MP 254.4 WB Outside lane
  MP 208.0 to MP 208.7 EB Outside lane
  MP 211.2 to MP 211.5 EB Outside lane
  MP 208.5 to MP 210.4 WB Outside lane

This limits and locations are subject to change based on updated information and funding constraints.

- Are there deviations from the Design Matrix? If yes, what are they? No
- Are there any environmental mitigation requirements? If yes, what are they? No

4. Summary of Proposed Schedule:

	Project Milestones					
Project Timeline	**Project Definition Complete**	**Preliminary Engineering (Start)**	**Environmental (Prior to Ad)**	**Right of Way Certification**	**Project Advertised**	**Operationally Complete**
Proposed Milestones	4/7/08	4/7/08	4/30/08		5/12/08	10/13/08

5. Summary of Proposed Budget ($):

Proposed Expenditure Plan

Phase	Cost	Prior	05-07	07-09	09-11	11-13	13-15	Future	Total
Prel. Engineering	Proposed	0	0	110					110
Right of Way	Proposed	0	0						0
Construction	Proposed	0	0	1,289					1,289
Total	Proposed	0	0	1,399	0	0	0	0	1,399

6. Proposed program adjustments to accommodate new project. Please select from the following and explain where indicated:

- ❑ Can be accommodated within Region Program Budget for similar work. Explain how or why not:
  This project will be funded using reserves from 600223C, US 2/Creston to Rocklyn Road – Paving. The construction phase of 600223C is currently programmed at $5.114 million but due to favorable bids there over $1.4 million available on that PIN to use on this project. The current unauthorized funds will be reduced from PIN 600223C construction phase to pay for this project.

7. Address any lessons learned that might provide similar positive outcomes or preclude similar

negative outcomes in future projects:

Select the lesson learned categories that apply: N/A These are emergent failures

(**Select from the following categories:** Access, Agreements, Architectural, Cost Risk assessment, Environmental, Estimates & Schedules, Geotechnical, Hearings, Hydraulics, Managing Project Delivery, Materials, Plans, Project
Data (As-Built, survey), Project Summary, Public Agency Involvement, Railroad, Reports, Right of Way, Roadside Restoration, Roadway, Safety, Structures, Traffic, Utilities)

Lesson – *Describe what knowledge was gained from this experience.* *N/A*

Recommendation – *Describe how the knowledge gained from the lesson can be used.* *N/A*

8. Proposal Concurrence:

	Name	Date
Region/Office Program Manager	Mike Gribner	3/20/08
Region Administrator/Director	______________________	_____
HQ Program Manager	______________________	_____
❑ HQ ASDE	______________________	_____
❑ Priority Manager	______________________	_____
❑ Materials Lab	______________________	_____
❑ Project Control Engineer	______________________	_____
❑ Other: ______________	______________________	_____
Manager, System Analysis & Program Development	______________________	_____

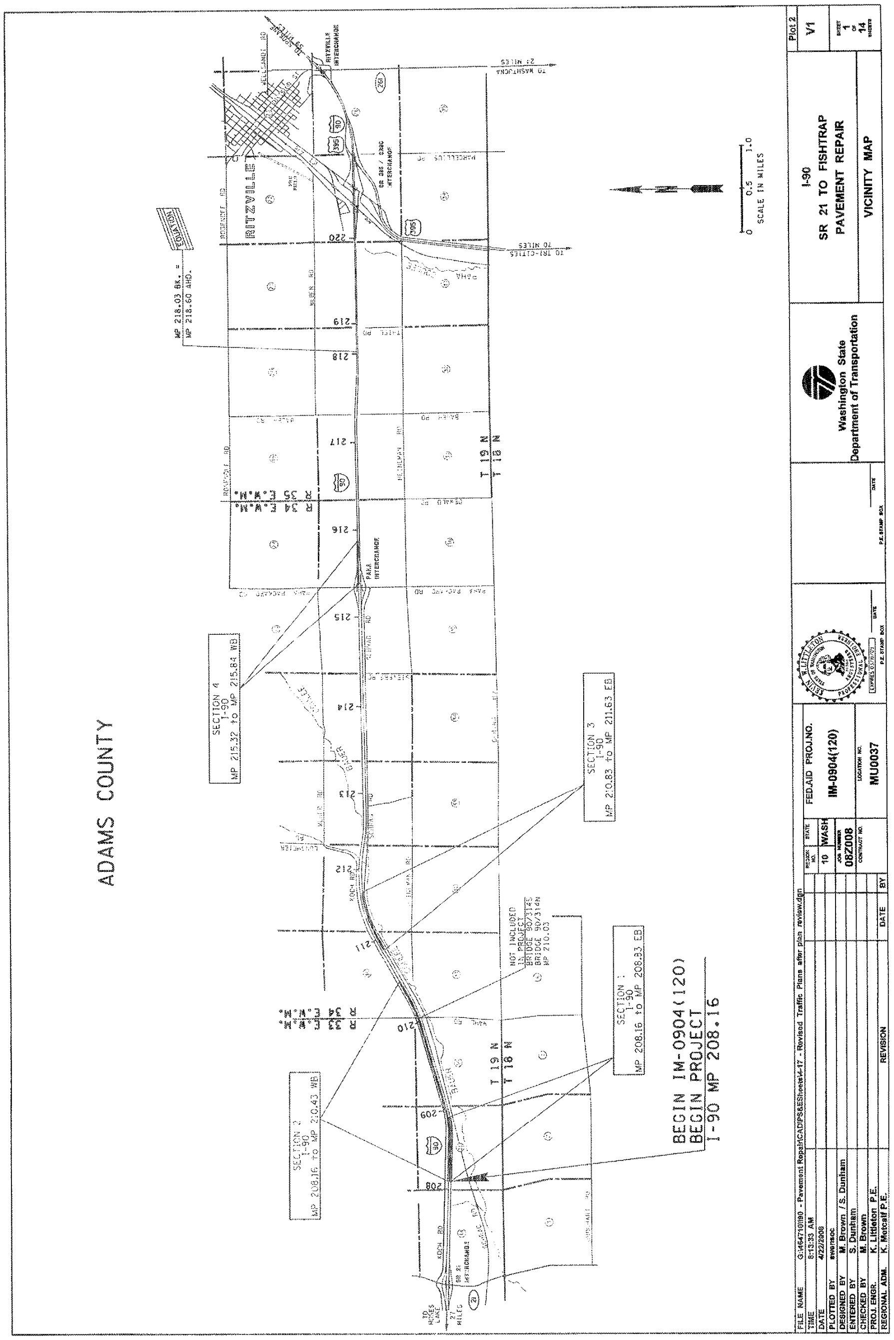
9. Concurrence Comments:

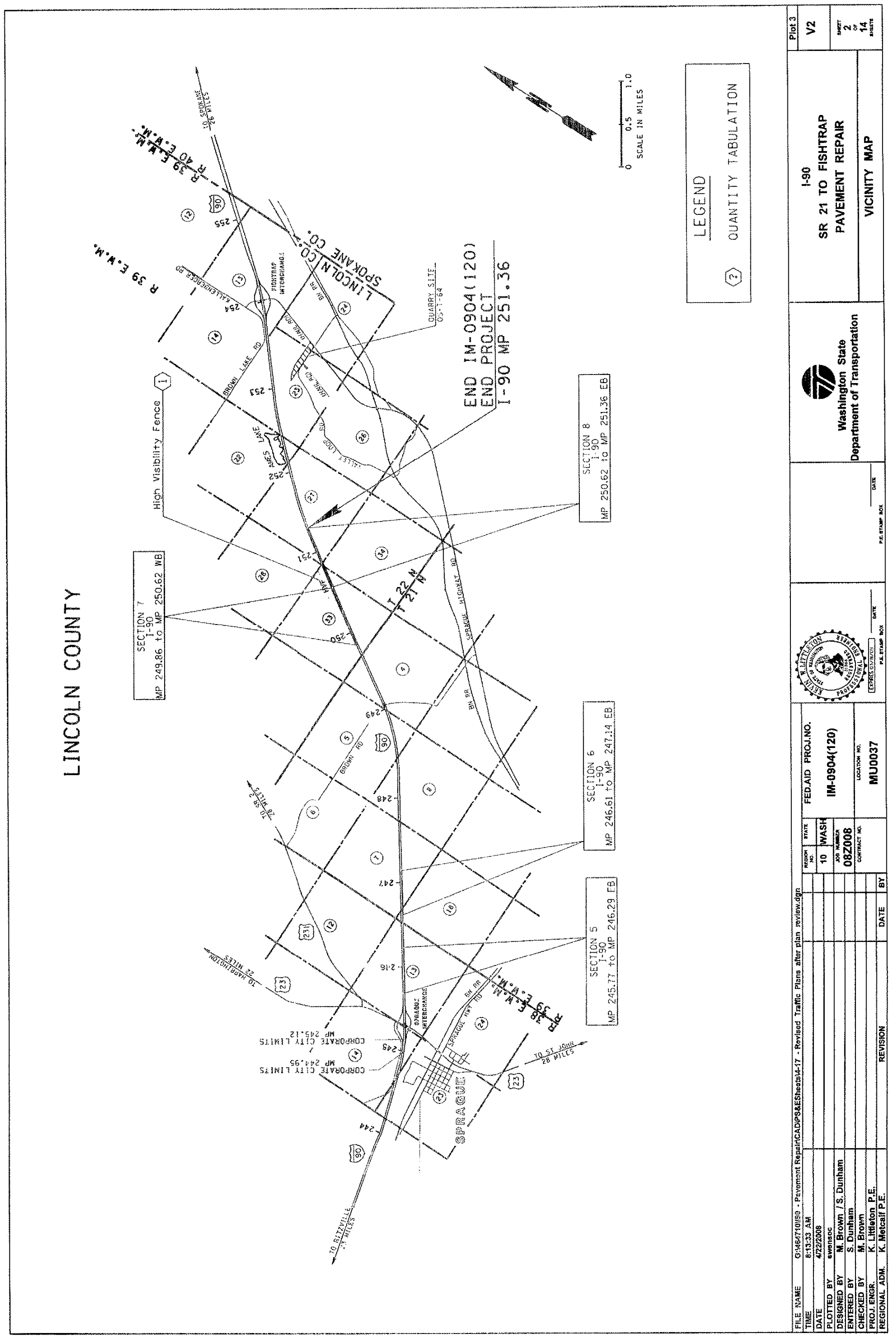
10. Approving Authority's Response:

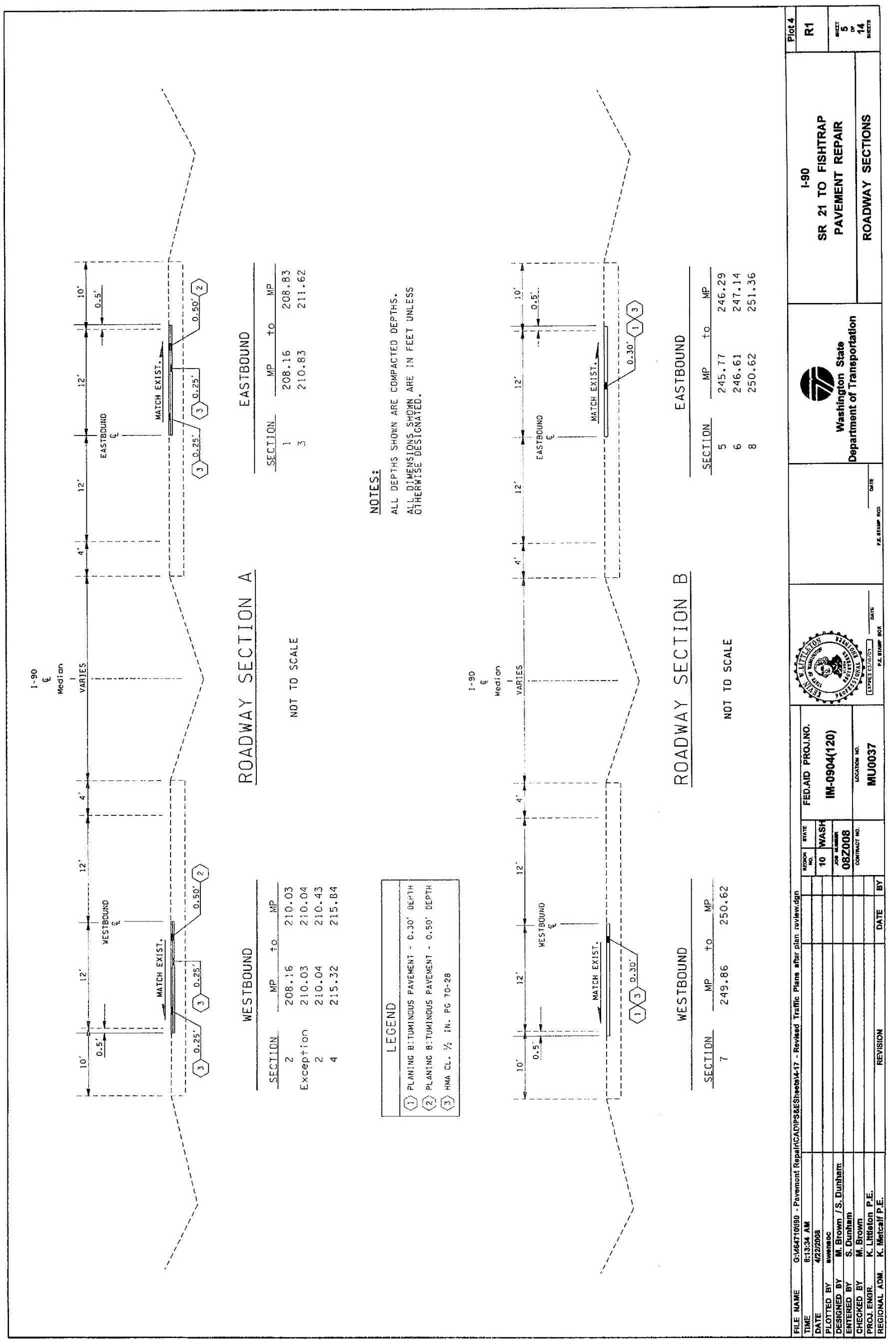
- ❑ Approved
- ❑ Approved with conditions (see Comments)
- ❑ Needs additional evaluation or information (see Comments)
- ❑ Not Approved

Name: ___________________________________ **Date:** ______________

Approving Authority's Comments:


ADAMS COUNTY
RITZVILLE
BEGIN IM-0904(120)
BEGIN PROJECT
I-90 MP 208.16
SECTION 1
I-90
MP 208.16 to MP 208.83 EB
SECTION 2
I-90
MP 208.16 to MP 210.43 WB
SECTION 3
I-90
MP 210.83 to MP 211.63 EB
SECTION 4
I-90
MP 215.32 to MP 215.84 WB
T 19 N
T 18 N
R 34 E.W.M.
R 35 E.W.M.
SCALE IN MILES
I-90
SR 21 TO FISHTRAP
PAVEMENT REPAIR
VICINITY MAP
Washington State
Department of Transportation
FED.AID PROJ.NO.
IM-0904(120)
MU0037
08Z008
WASH
V1


LINCOLN COUNTY
SECTION 5 I-90 MP 245.77 to MP 246.29 EB
SECTION 6 I-90 MP 246.61 to MP 247.14 EB
SECTION 7 I-90 MP 249.86 to MP 250.62 WB
SECTION 8 I-90 MP 250.62 to MP 251.36 EB
END IM-0904(120)
END PROJECT
I-90 MP 251.36
High Visibility Fence
QUARRY SITE
LINCOLN CO.
SPOKANE CO.
SPRAGUE
CORPORATE CITY LIMITS MP 244.95
CORPORATE CITY LIMITS MP 245.12
T 22 N
T 21 N
R 39 E.W.M.
R 40 E.W.M.
LEGEND
QUANTITY TABULATION
SCALE IN MILES
I-90
SR 21 TO FISHTRAP
PAVEMENT REPAIR
VICINITY MAP
Washington State Department of Transportation
FED.AID PROJ.NO.
IM-0904(120)
08Z008
MU0037
V2
Plot 3


ROADWAY SECTION A
NOT TO SCALE
ROADWAY SECTION B
NOT TO SCALE
EASTBOUND
WESTBOUND
MATCH EXIST.
NOTES:
ALL DEPTHS SHOWN ARE COMPACTED DEPTHS.
ALL DIMENSIONS SHOWN ARE IN FEET UNLESS OTHERWISE DESIGNATED.
LEGEND
PLANING BITUMINOUS PAVEMENT - 0.30' DEPTH
PLANING BITUMINOUS PAVEMENT - 0.50' DEPTH
HMA CL. ½ IN. PG 70-28
I-90
SR 21 TO FISHTRAP
PAVEMENT REPAIR
ROADWAY SECTIONS
Washington State Department of Transportation
IM-0904(120)
08Z008
MU0037