Preventive Maintenance Study - Final Report

WA-RD 871.2

Keith W. Anderson
Jim Weston
Mark Russell
Dave Luhr
Jeff S. Uhlmeyer
Kim Willoughby
Casey Fraisure

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WSDOT Research Report

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Special Project Report

Final Report
Special Project

Preventive Maintenance Study

Washington State – Statewide Locations


Crack Seal


Chip Seal


Dig Out


Blade Patch

Washington State Department of Transportation

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16. ABSTRACT

This final report details the performance of 69 test sites treated with various preventive maintenance treatments. The maintenance treatments applied included crack sealing, full lane chip sealing, wheel path chip sealing, dig outs (mill and fill), blade patching, and combinations of dig outs plus crack sealing and dig outs plus full lane chip sealing. The test sites are visited yearly to assess the condition of both the maintenance treatment and the pavements in which they were installed. The cost of the treatments ranged from $1.14 to $19.57 for application on a one foot length of a 12 foot lane.

All of the treatments were found to be effective in stabilizing the condition of pavements a minimum of three years and as much as five years, with some of the test sections still in good condition. The stabilization of the pavement's condition has allowed WSDOT to lengthen the time before rehabilitation and extend pavement life.

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DISCLAIMER

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Executive Summary

Hot mix asphalt (HMA) preventive maintenance techniques such as crack sealing, chip sealing, dig outs and blade patching are well-established maintenance practices. The goal of the study was to determine the effectiveness of each of the preventive maintenance treatments at extending pavement life and, using cost data, define which treatments are the most cost effective.

Sixty-nine test sites were evaluated on a yearly basis since initiation of the study in 2012. The evaluations were terminated in the fall of 2017; therefore, the oldest sites are approximately at the age of five years. Additional sites were added in 2013, 2014, 2015 and 2016; therefore, the youngest sites are only a year old. The test sites are located in all of the Regions with the exception of the Northwest Region, with the majority located in the Eastern and Olympic Regions. The preventive maintenance techniques applied are crack sealing (12 sites), chip sealing (4 sites), wheel path chip seal patching (2 sites), wheel path chip seal rut filling (5 sites), chip seal plus crack seal (2 sites), dig outs (22 sites), dig outs plus crack sealing (4 sites), dig outs plus chip sealing (6 sites), blade patching (8 sites), and control (4 sites) that received no treatment.

At the initiation of this study, it was assumed that the performance of the various preventive maintenance treatments would be differentiated by the failure of some treatments as contrasted with others that performed well. This has not been the case as virtually all of the treatments are performing well and preserving the pavements for extended periods of time. In fact, there is very little change in the condition of any of the preventive maintenance treatments over the four-year evaluation period. The one exception is the pavements that received the combination treatment of dig outs plus chip sealing. Flushing of the chip seal over the dig out locations is common to all of these sites.

The costs of the various treatments were compared by calculating the cost to treat a strip of pavement one foot in length and one lane wide (12 feet). This allows treatments that do not cover an entire lane, such as wheel path chip sealing, to be compared side by side with treatments that do cover the full lane. The costs ranged from the cheapest treatment, crack sealing, to the most expensive, dig outs plus chip sealing. The costs of the treatments, in order, were crack sealing ($1.14), wheel path chip seal rut filling ($2.76), wheel path chip seal patching ($4.44), full lane chip sealing ($7.08), blade patching ($10.00), dig outs ($12.49) dig out plus crack sealing ($13.63) and dig outs plus chip sealing ($19.57).

All of the maintenance treatments were effective in extending the life of the pavement in which they were installed. The primary treatment of crack sealing, chip sealing and dig outs are capable of extending pavement life for five years or more. The data on wheel path chip seal patching and rut filling indicated only four years, but the performance of full lane chip seal lasted for five years and there is no reason to believe that the same process used to fill wheel paths would have a different outcome. Only three years of data was available for blade patching; however, it appears that the duration of blade patches is one to two years before additional fixes are applied either in the form of full lane chip seals or HMA grind/inlays.

The primary recommendation is that preventive maintenance techniques should be applied when distress is first observed. In general, the least expensive techniques of crack sealing and wheel path chip sealing are very effective treatments when the distress is confined to the wheel paths. Full lane chip sealing could be used more frequently than currently utilized because it can mitigate a number of pavement distress conditions, but must be constructed correctly. Dig outs are recommended when the distress is severe but generally confined to small areas. The use of dig outs plus chip sealing is not recommended due to the problems with flushing or chip loss and higher cost. Blade patching is a necessary practice to address specific types of distress such as settlement or severe distress.

Background

Pavement preventive maintenance is defined as a "planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without increasing the structural capacity)" (Hicks et al, 2000). Thus, preventive maintenance differs from traditional maintenance in that it addresses pavement distress at an earlier point in the life of the pavement. This maintenance is designed to be performed before the pavement shows significant distress and to forestall the need for emergency maintenance. For example, the sealing of cracks when they first reach 1/4 inch in width will likely forestall the need for dig outs of complete sections of pavement at a later date. The result is cost savings because pavements last longer before needing complete rehabilitation.

Pavement Policy Considerations

WSDOT has historically had a fix it early fix it thin policy with regard to pavements. Under this policy, HMA pavements were milled (usually 0.15' or 1.8 inches) and filled with an equal amount of HMA when alligator cracking first appeared. This policy applied primarily to Interstates and other primary routes with high traffic volumes. On secondary and lower volumes roadways rehabilitation was delayed until alligator cracking was more widespread and severe. The result was pavements being maintained at a very high level of service, but also at a high system cost. This strategy was very effective until funding for pavement rehabilitation decreased drastically.

Several strategies were employed to address the funding shortfall. One of these was to convert lower volume roadways from hot-mix asphalt (HMA) to bituminous surface treatment (BST). Another strategy was to use preventive maintenance techniques to extend the useful life of pavements until funding was available for rehabilitation. The pavement preventive maintenance program was initiated in 2010, two years prior to the initiation of this study. Additional funding was expressly earmarked for preventive maintenance. The initial goal of this program was to extend pavement life by two years.

Study Purpose

HMA preventive maintenance techniques such as crack sealing, chip sealing, dig outs and blade patching are well-established practices. The purpose of this study is to determine the effectiveness of these preventive maintenance treatments at extending pavement life. In addition, the study will use cost data to determine which treatments are the most cost effective in addressing the existing conditions of a section of pavement.

Study Design

The study mimics the real world of pavement maintenance so that the data collected is valid. WSDOT Regions were requested to provide the research team with locations that were scheduled for preventive maintenance in the upcoming year. Many of the locations submitted in the initial years of the study were pavements that had reached their due year as defined by the Washington State Pavement Management System (WSPMS). The due year is the point at which the pavement should be scheduled for rehabilitation (a mill and fill for HMA pavements or a chip seal for BST pavements). These sites had reached or were below a pavement structural condition (PSC) of 45, but funding was not available for complete rehabilitation.

Site visits were made by the research team to document the existing condition of the pavements with photos and written comments. The Region Maintenance crews applied the preventive maintenance technique they determined was the best choice for the condition of the pavement at each location. Next, the research team made a second visit to each location and document the type of treatment applied and its condition. This process was repeated for each year of the study for new test sites as well as the older sites. The process provided documented evidence of the condition of the treatments at each test site as well as the condition of the untreated pavement that surrounds the area that was treated. It is important to note that the research team did not dictate the locations or types of treatments used by the maintenance crews.

Pavement Condition Rating

The test sites were placed into three categories, Good, Fair, and Poor based on the pavement's structural condition at the time of treatment as defined by the WSPMS. Test sites with structural conditions between a PSC of 60 and 100 were placed in the Good category. Pavements with structural conditions between a PSC of 40 and 59 were placed in the Fair category. The pavements with structural conditions below a PSC of 40 were in the Poor category. The goal of preventive maintenance is to apply less costly maintenance techniques when the pavement are in the Good category before it becomes necessary to apply more costly fixes when the pavement deteriorates into the Fair and Poor categories.

Test Sites

A total of 69 test sites were monitored using photographs and visual inspections (see Appendix A for complete test site descriptions). The preventive maintenance techniques used included crack sealing, chip sealing, dig outs, blade patching and various combinations of more than one technique. The test sites vary in length from 0.10 miles to over 11 miles with an average of 1.74 miles. The most common test site length is 0.50 miles.

The first test sites were initiated in 2012 with additional sites added in 2013, 2014, 2015 and 2016. Field reviews and photos were taken annually through the fall of 2017. The following bullets summarize the year of treatment, the WSDOT Region where the treatment was applied, the type of treatment, the pavement type and the preservation category of the treatments. Figure 2 shows test site locations on a map that also delineates the WSDOT Regions and rainfall averages.

Year of Treatment

- 16 treated in 2012
- 15 treated in 2013
- 9 treated in 2014
- 20 treated in 2015
- 9 treated in 2016

Region

- 30 Olympic Region
- 29 Eastern Region
- 3 South Central Region
- 4 Southwest Region
- 3 North Central Region

Treatment Type

- 12 - Crack Seal
- 4 - Chip Seal
- 2 - Wheel Path Chip Seal Patching
- 5 - Wheel Path Chip Seal Rut Filling
- 2 - Crack Seal + Chip Seal
- 22 - Dig Outs
- 4 - Dig Outs + Crack Seal
- 6 - Dig Outs + Chip Seal
- 8 - Blade Patch
- 4 - Control (no treatment)

Pavement Type

- 53 HMA
- 16 BST

WSPMS Condition Category

- 47 - Good (PSC 60-100)
- 8 - Fair (PSC 40-59)
- 14 - Poor (PSC <40)

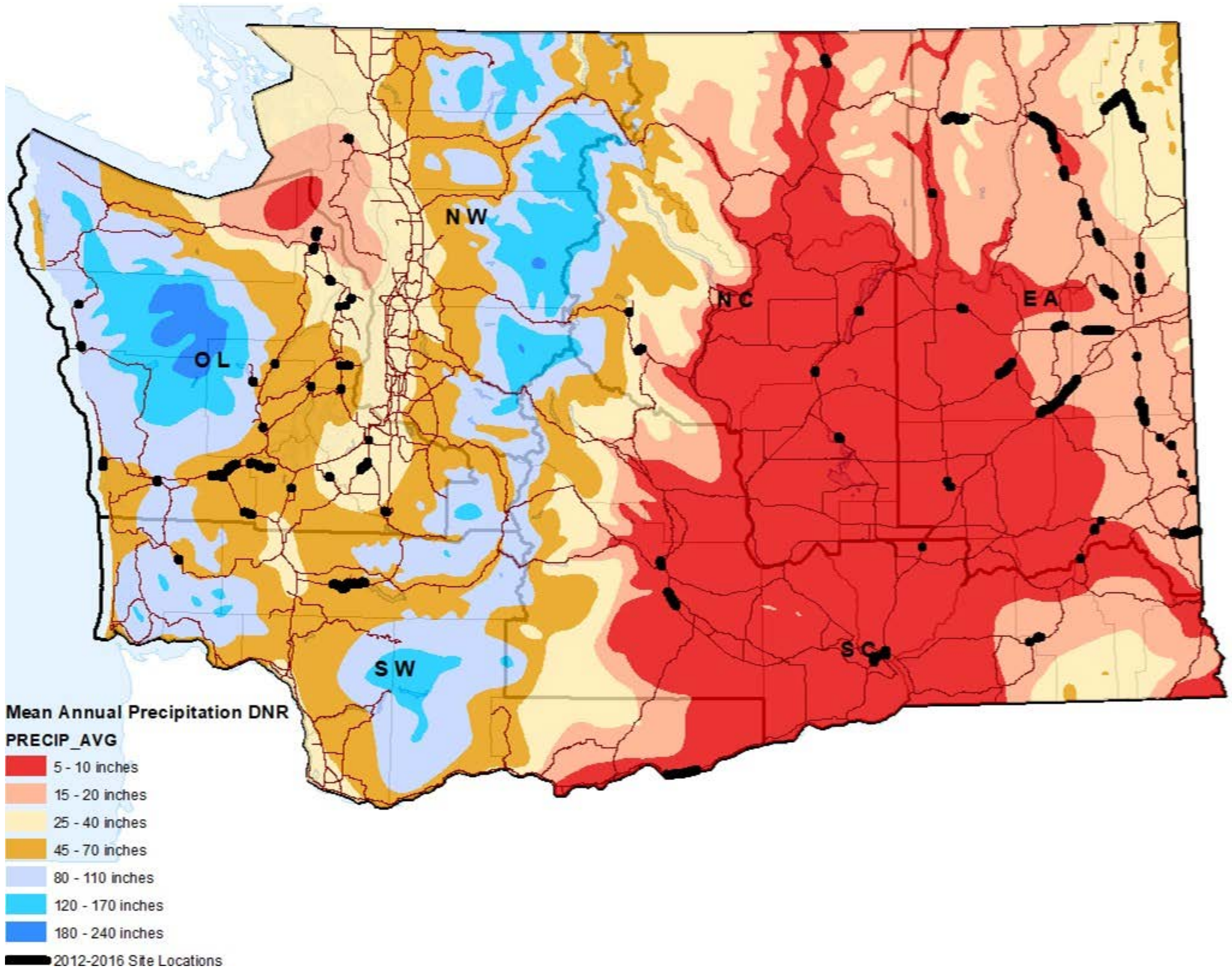

Figure 1. Map of WSDOT Regions, rainfall averages, and test site locations.

Performance Review of Treatments

The following section included a photo from each test site that illustrates the current condition of each of the 69 test sites. The sites are organized by the type of treatment applied to the pavement and in order from the oldest to the youngest. The caption on each photo identifies the Region and site number, followed by the State Route (SR) and the PSC category. An example of a given site would be (OR1, SR101, Poor) which would be a site in the Olympic Region on State Route 101 with an average PSC of 13. The ages noted on the photos are the time in months between installation and the last physical review which is the fall of 2017 except for those sites terminated by an overlay. If the site has received a HMA grind/inlay or chip seal, the contract number is provided.

A second series of photos illustrate the condition of the maintenance treatments over time for a representative test site in each category. Yearly photos at approximately the same location in these test sites show the change or lack of change in the condition of the treatments over the length of the study.

Crack Sealing

The twelve crack sealing test sites ranged in age from 14 to 62 months at the 2017 inspection. The crack sealing sites are performing well with only one of the oldest sites, OR1, showing hairline cracking of the sealant material. Some traffic wear is present on the over banded sealant on the more heavily trafficked sites. OR6, installed in 2013, received an HMA grind/inlay in 2017. Cracking continues to increase in extent and severity in areas of the test sites that were not crack sealed. Crack sealing has an excellent performance rating in spite of its use where chip sealing or dig outs may have been the better choice. Figures 2-13 show the condition of the 12 test sites at the most recent inspection. The photos illustrate that the crack sealant is preventing further deterioration of the pavement with no spalling or potholing present.

Figure 2. OR1, SR101, Poor, age 62 months.

Figure 3. OR6, SR8, Good, age 50 months. HMA grind/inlay in 2017, C9001.

Figure 4. OR8, SR8, Ramp, Poor, age 51 months.

Figure 5. OR9, SR105, Good, 50 months.

Figure 6. NC2, US2, Good, age 38 months. No spalling or potholes.

Figure 7. SC1, SR97, Good, age 25 months. No spalling or potholes.

Figure 8. ER41, SR395, Good, age 15 months.

Figure 9. OR20, SR12, Good, age 15 months.

Figure 10. OR21, SR12, Good, age 15 months.

Figure 11. OR31, SR115, Good, age 14 months.

Figure 12. OR32, SR160, Good, age 15 months.

Figure 13. OR34, SR302, Good, age 15 months.

One of the older crack sealing sites, OR1, on SR101 in the Olympic Region is a good example of the effectiveness of crack sealing as a preventive maintenance technique. The photos (Figures 14 through 19) show the same location, at different angles, in the area that was sealed. This was a Poor category pavement prior to treatment. The age of the site was 62 months at the 2017 inspection.


Figure 14. OR1, SR101, prior to treatment. Cracks exceed 1/4 inch in width in places.


Figure 15. OR1, SR101, one year after installation. Slight wear of sealant over banding.

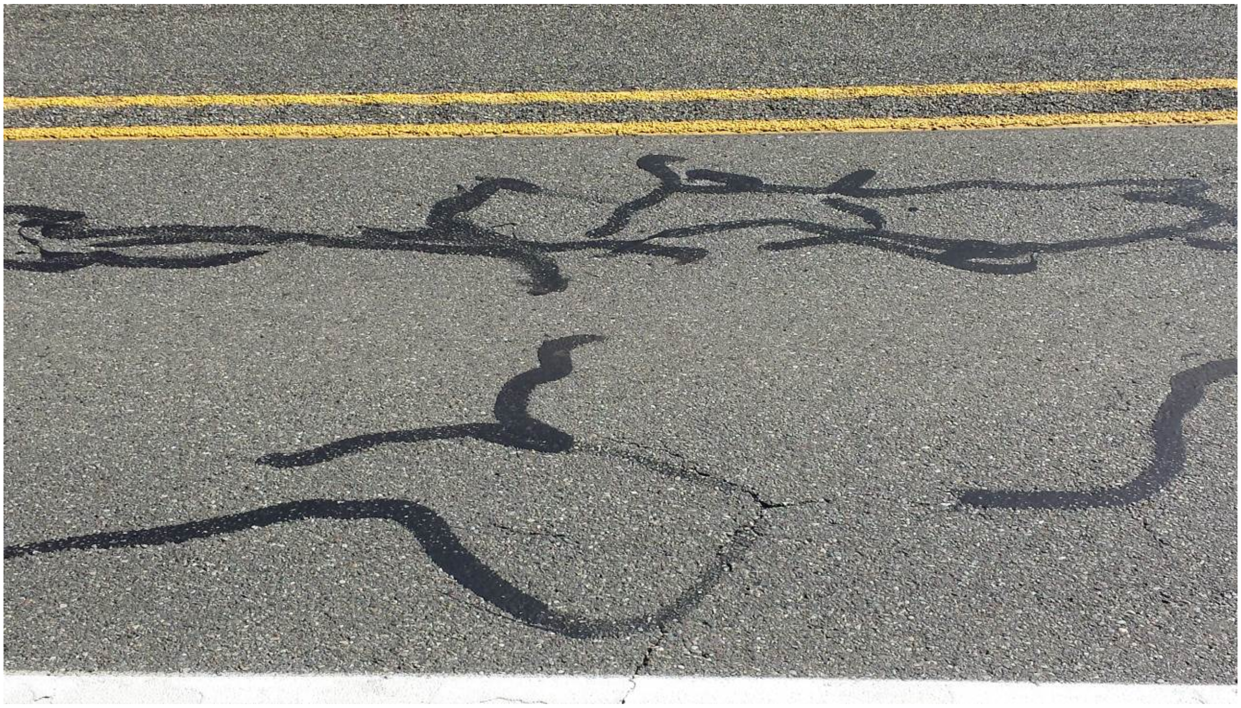

Figure 16. OR1, SR101, two years after installation. There is not much change from year one.

Figure 17. OR1, SR101, three years after installation. There is not much change from year one.

Figure 18. OR1, SR101, four years after installation. There has not been much change in the condition of the crack sealant since year one.

Figure 19. OR1, SR101, five years after installation. The cracks are beginning to appear through the sealant where the original sealant was minimal.

Test site OR1 is in excellent condition with no spalling of the cracks or potholes forming after 62 months of traffic and environmental exposure. The over banding of the crack sealant is wearing in the wheel paths; however, this is typical of the older crack sealing sites. At the age of five years the cracks are beginning to crack through the sealant. Additional cracks have formed and unsealed cracks have become longer. It might be argued, based on the relatively unchanged condition of the cracks that were not sealed, that the pavement would have performed equally as well if maintenance had not been performed. It might also be argued that the width and depth of all of the cracks would have increased if the sealant had not been present. Also, the addition of moisture entering the pavement structure through unsealed cracks may have increased the rate of deterioration of the pavement.

Full Lane Chip Sealing

The four full lane chip seal test sites ranged in age from 26 to 62 months at the 2017 inspection. The performance of the full lane chip sealing sites has been disappointing with two of the four sites either flushing in the wheel paths or raveling across the entire lane. Longitudinal cracks that were not sealed prior to the chip seal are reflecting through the chip seals on three of the four sites. Alligator cracking with pumping of fines is present on the fourth site. Most of the chip seals constructed under region wide contracts over many numbers of years have had excellent performance, indicating that the problems on these test sites may be due to materials or workmanship issues. It may also be that the chip seal was placed on a surface with distress not compatible with a chip seal such as delamination (see Figure 21). Figures 20-23 show the condition of the chip seals at the four test sites.

Figure 20. OR1b, SR101, Poor, age 62 months. Longitudinal cracking noted at 21 months. Slight flushing in the wheel paths.

Figure 21. OR3b, SR101, Poor, age 62 months. Delamination and spalling noted.

Figure 22. OR16, SR16, Good, age 49 months. Longitudinal cracking and pumping of fines noted at 14 months. Alligator cracking noted at 49 months.

Figure 23. OR22, SR101, Good, age 26 months. Loss of aggregate at bottom of super elevation.

One of the older full lane chip sealing test sites, OR1b on SR101 in the Olympic Region, provides visual evidence of the effectiveness of chip sealing as a preventive maintenance technique. Figures 24 through 29 show the same relative location in the test site over a 62-month period. Note that the traffic volumes on this section are low.

Figure 24. OR1b, SR101, prior to treatment. Alligator cracking was noted over the entire lane, but especially severe in the wheel paths.

Figure 25. OR1b, SR101, one year after installation. Slight flushing in the wheel paths, one longitudinal crack in the left wheel path.

Figure 26. OR1b, SR101, two years after installation. Longitudinal crack appears to have "healed". Slight flushing in the wheel paths.

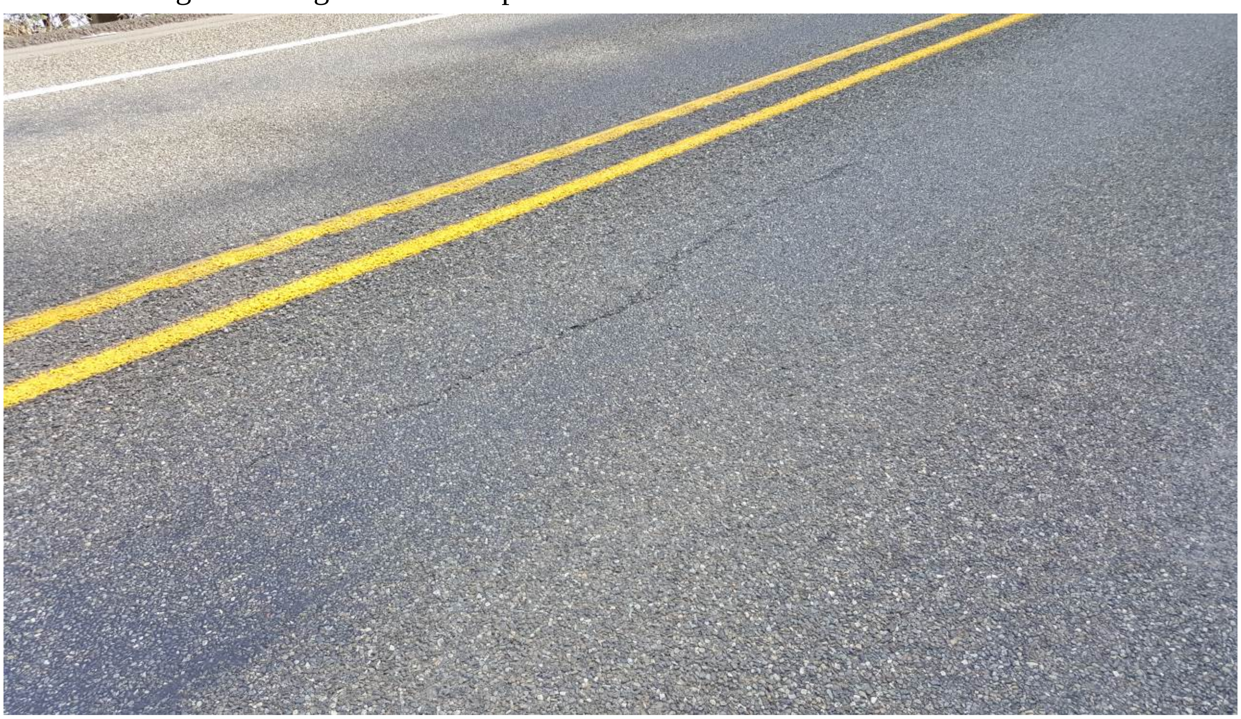

Figure 27. OR1b, SR101, three years after installation. Longitudinal crack is getting longer and wider. Flushing in the wheel paths is about the same.

Figure 28. OR1b, SR101, four years after installation. Longitudinal crack condition is about the same, slight rutting and flushing in the wheel paths.

Figure 29. OR1b, SR101, five years after installation. Longitudinal crack condition is about the same, slight rutting and flushing in the wheel paths.

The wheel paths show some flushing and rutting after 62 months of service. The single longitudinal reflection crack became more evident with age, but did not affect the overall performance of the pavement. The quality of the chip seal on all four of the test sites was not the best; however, each is performing the essential function of extending pavement life.

Wheel Path Chip Seal Patching

The two wheel path chip seal patching test sites ranged in age from 25 to 49 months at the 2017 inspection. Both are located in the Olympic Region where wheel path chip sealing is done primarily to address alligator or longitudinal cracking. The OR12 site is in fair condition due to longitudinal and transverse cracking showing through the chip seal. OR23 is also in fair condition with loss of aggregate and reflection cracking. In general, the performance was disappointing although the seals did hold the pavement together and did not allow pot holes to form. Figures 30 and 31 show the condition of the two test sites at the 2017 site visit.

Figure 30. OR12, SR20, Good, age 49 months. Longitudinal reflection crack and flushing noted at 10 months.

Figure 31. OR23, SR104, Good, age 25 months.

OR12 on SR 20 was selected as an example of wheel path chip seal patching. The pavement prior to treatment was in the Good category. Figures 32 through 37 show the same location in the test site that was installed in 2013.

Figure 32. OR12, SR20, prior to treatment. Longitudinal and alligator cracking present in the wheel paths.

Figure 33. OR12, SR20, immediately after installation. Wheel path chip seal patching was well constructed.

Figure 34. OR12, SR20, one year after installation. No change in the condition of the wheel path chip sealing.

Figure 35. OR12, SR20, two years after installation. Some loss of aggregate but no reflection cracking.

Figure 36. OR12, SR20, three years after installation. Some loss of aggregate but no reflection cracking.

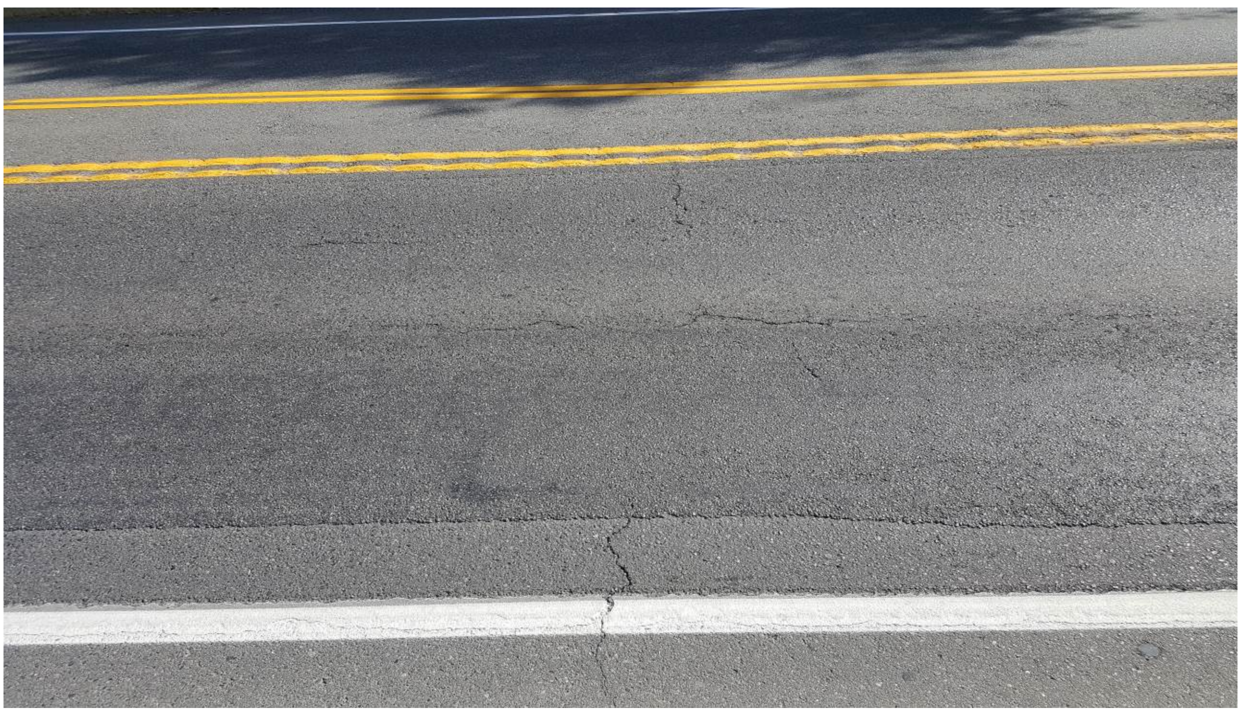

Figure 37. OR12, SR20, four years after installation. Some loss of aggregate and lots of reflection cracking through the wheel path chip seal.

OR12 represents the typical performance of the wheel path chip seal patching sites. The wheel path chip seals are in fair condition after four years due to the presence of longitudinal reflection cracking and raveling, however, each is performing its function of extending pavement life.

Wheel Path Chip Seal Rut Filling

The five wheel path chip seal rut filling sites ranged in age from 26 to 37 months at the 2017 inspection. The wheel path chip seal rutting filling sites are located primarily in the Eastern Region. These are single shot seals using aggregate from existing stockpiles. A finer choke aggregate is usually applied after the initial application of larger chips. The five rut fill sites had mixed results. ER7 received a full lane chip seal in 2015 and ER18 receiving the same in 2017. The Eastern Region is using the wheel path chip seals to fill the ruts and follows with a full lane chip seal in one to two years. Transverse reflection cracking was noted at 12 months on one site and 24 months on another. Figures 38-42 show the condition of the five test sites at the 2017 inspection.

Figure 38. ER7, SR20, Good, age 37 months. BST in 2015, C9728, at the age of 37 months.

Figure 39. ER10, US2, Good, age 36 months. Cracking noted at 12 months. Loss of aggregate in both wheel paths.

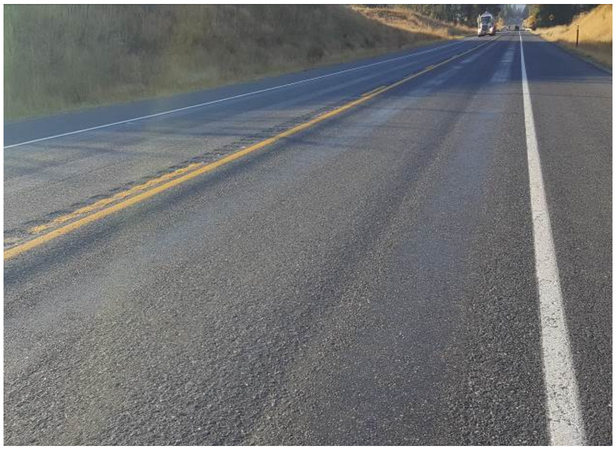

Figure 40. ER15, SR395, Good, age 24 months. Flushing noted in 2017. Transverse reflection cracking noted.

Figure 41. ER18, SR31, Good, age 26 months. BST in 2017, C9031. Photo is from 2016.

Figure 42. ER40, US270, Good, age 26 months. Loss of chips in both wheel paths.

ER7 was selected to demonstrate the performance of a wheel path chip seal rut fill site. The chip seal on ER7 was placed in 2013 on SR20 and is the oldest of all of the rutting wheel path sites. The Eastern Region overlaid the site with a full lane chip seal in 2015, thus ending further evaluation of this site. Figures 43-47 show the condition of the wheel path chip seals for the two years following installation and the site after the full lane chip seal was applied. The full lane chip seal applied in 2015 showed no signs of rutting, which was the reason for the initial wheel path chip seals.

Figure 43. ER7, SR20, prior to treatment. Rutting is visible in the wheel paths.

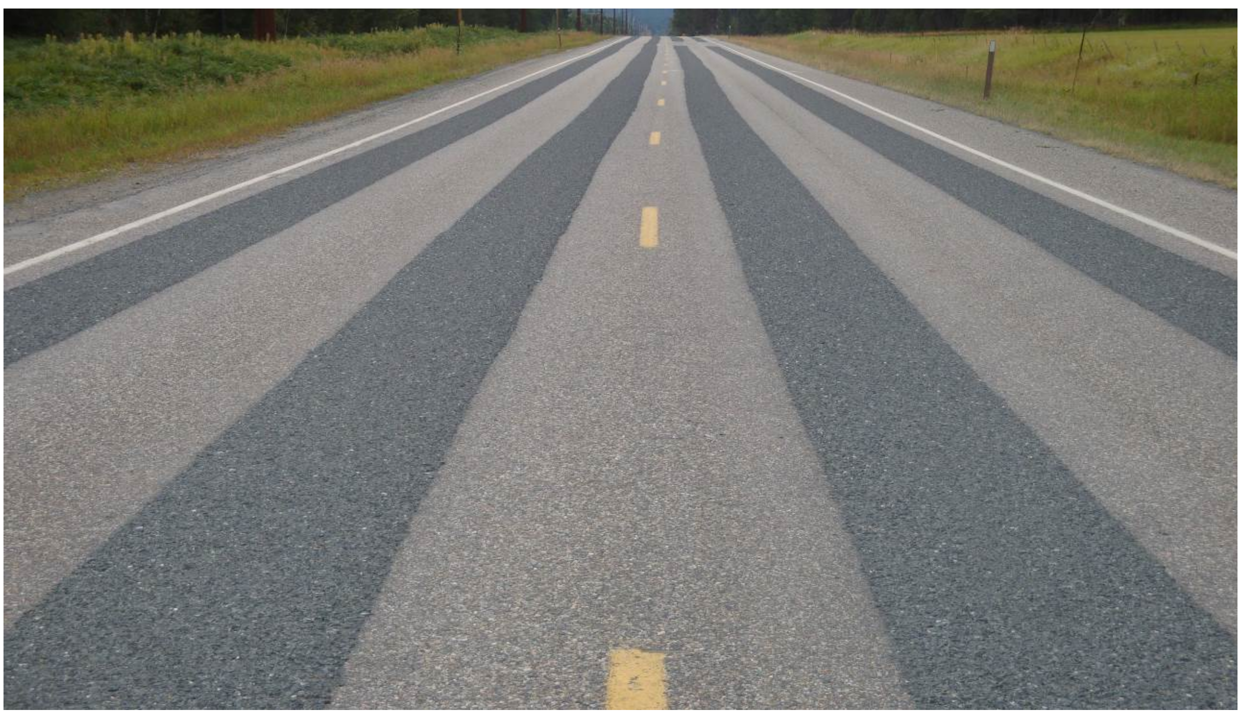

Figure 44. ER7, SR20, a few months after installation. Excellent looking wheel path chip seal rut filling.

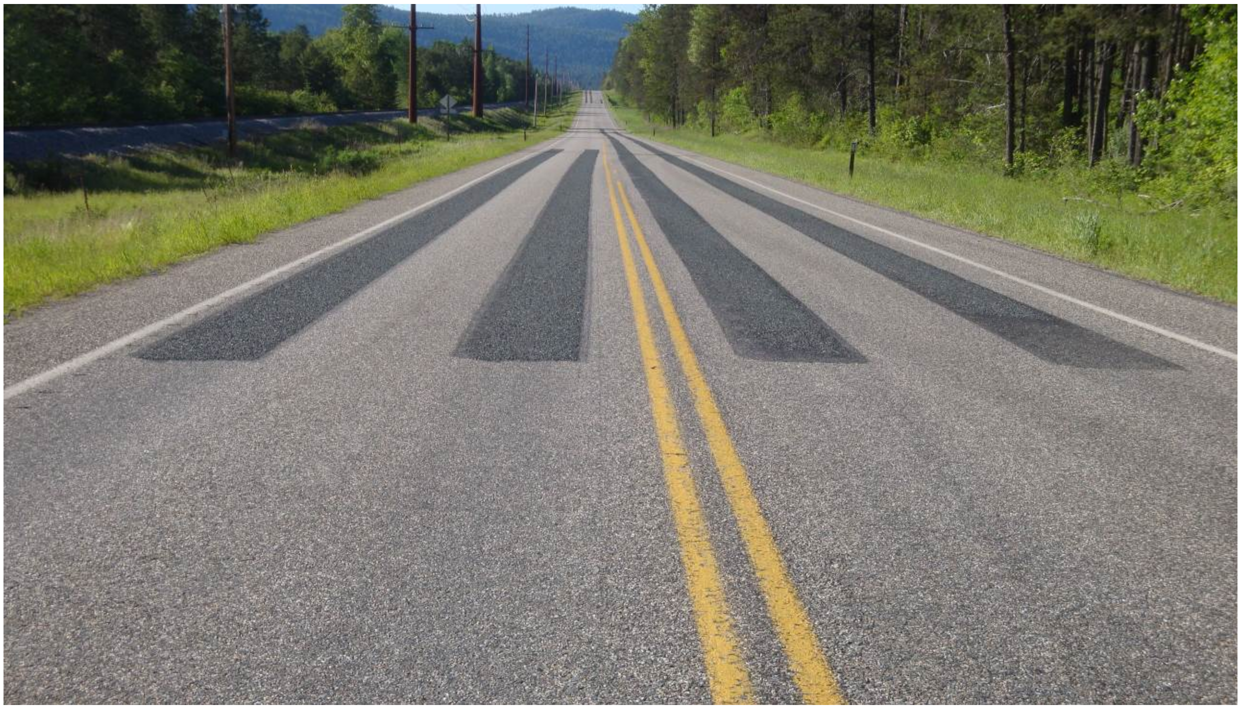

Figure 45. ER7, SR20, one year after installation. Wheel path chip seal rut fills are in excellent condition.

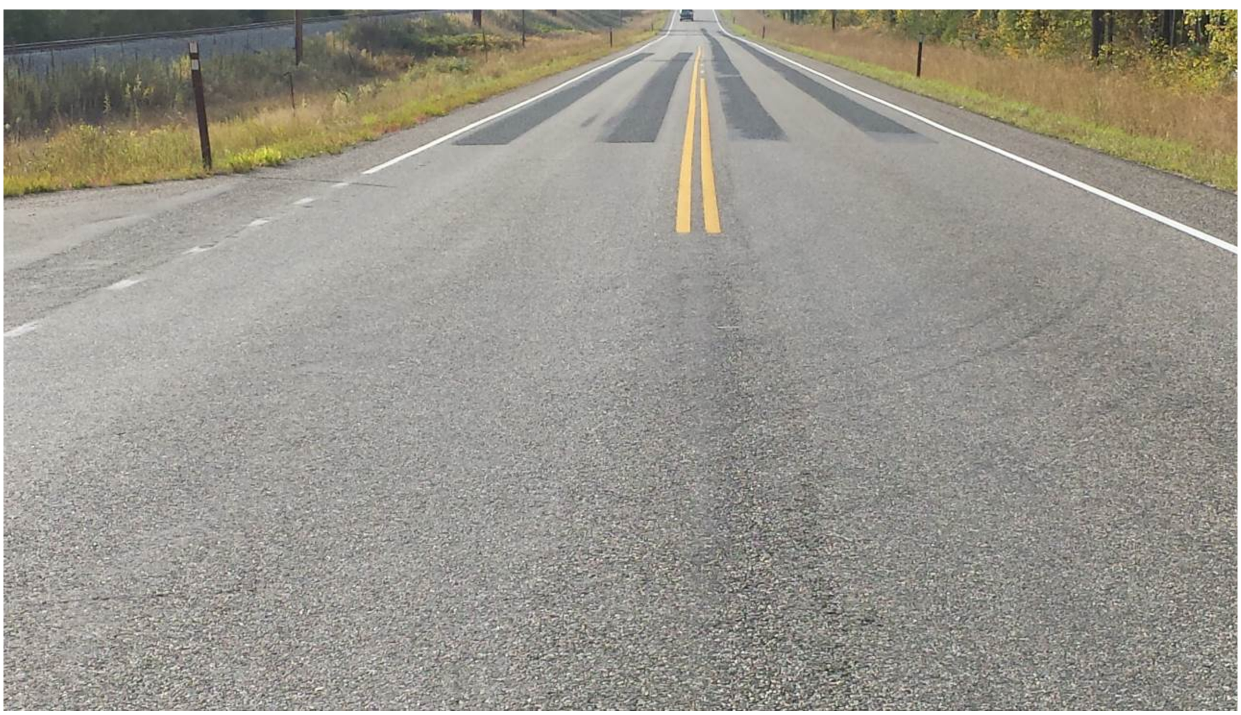

Figure 46. ER7, SR20, two years after installation. No change in chip seal.

Figure 47. ER7, SR20, three years after installation. Full lane chip seal installed under Contract 8728, US 2 ET AL 2015 Eastern Region Chip Seal.

These photos represent the typical good performance that was noted for the wheel path chip seals rut fill sites. The ruts have been filled and the chip seals show no signs of flushing or excessive chip loss.

Crack Sealing Plus Chip Sealing

The two test sites that combined crack sealing with chip sealing ranged in age from 38 to 62 months at the 2017 inspection. The cracks on the SR101 project were wide block cracks. The sealed cracks can be seen as shadowing under the seal, but none have reflected through the seal. The cracks on SR155 were very wide and deep transverse thermal cracks. The cracks were sealed with a special sealant called Nuvo Gap. The chip seal was applied one year after the Nuvo Gap was installed. In both cases crack sealing prior to a chip seal prevented reflection cracking although on the SR155 project there are very thin cracks visible in the depressions of the Nuvo Gap filler. Figures 48 and 49 show the condition of the two test sites in 2017.

Figure 48. OR1a, SR101, Poor, age 62 months. Underlying crack sealant can be seen as shadowing.

Figure 49. NC1, SR155, Good, age 38 months. Transverse crack locations are depressed and very thin cracks are present.

OR1a on SR101 was selected to provide visual evidence of the effectiveness of this combination of preventive maintenance techniques. Figures 50 through 55 show the same location in the test site. This is a Poor category test site.

Figure 50. OR1a, SR101, prior to treatment. Alligator and longitudinal cracking noted.

Figure 51. OR1a, SR101, one year after installation. Chip seal looks excellent.

Figure 52. OR1a, SR101, two years after installation. Shadowing of the sealed cracks visible.

Figure 53. OR1a, SR101, three years after installation. Very slight flushing and shadowing of the sealed cracks.

Figure 54. OR1a, SR101, four years after installation. Slight amount of rutting beginning to appear. Flushing does not seem to be a big issue.

Figure 55. OR1a, SR101, five years after installation. Slight amount of rutting beginning to appear. Flushing not an issue. Shadowing of underlying crack sealant.

Performance of the chip seal placed over the crack sealed pavement is excellent. The appearance of the chip seal changes over time to show a shadowing of the underlying crack sealing, but this has not been detrimental to the performance of the chip seal in extending pavement life.

Dig Outs

The 22 dig out test sites ranged in age from 14 to 62 months at the 2017 inspection. Six of the test sites have been overlaid, four with HMA and two with BST and two sites are scheduled for HMA grind/inlays in 2018. The patches have performed very well on all of the projects. Reflection of transverse cracks was noted on four of the seven sites underlain by PCCP, one at age 10 months after installation, another at 12 months, a third at 26 months, and the fourth at 37 months. ER2, ER3 and ER4 required the installation of additional dig out patches adjacent to the existing patches due to continued deterioration of the surrounding pavement. The patches themselves vary in workmanship with some well compacted, others with segregated areas around the edges or throughout and some with high and low areas that collect water; however, despite these inconsistencies the patches themselves have performed very well. A deterioration of ride quality was noted on roadways with dig outs. Figures 56-77 show the condition of the 22 test sites at the 2017 inspection.

Figure 56. OR2, SR8, Fair, age 62 months. HMA grind/inlay in 2017, C9001.

Figure 57. ER2, US2, Fair, age 62 months. HMA grind/inlay in 2017, C9063.

Figure 58. ER3, SR291, Fair, age 62 months. Additional dig outs added in 2015. Transverse reflection crack noted at 10 months after treatment. More dig outs are scheduled for installation in 2017 and a HMA grind/inlay in 2018, C9223.

Figure 59. ER4, US2, Fair, age 62 months. Additional dig outs installed in 2013 and 2015. Note different colors of dig out patches done in different years. HMA grind/inlay scheduled in 2018, C9187

Figure 60. ER5, US2, Poor, age 49 months. Transverse reflection crack at the age of 10 months.

Figure 61. OR5, SR7, Good, age 51 months.

Figure 62. OR8a, SR101, Poor, age 51 months.

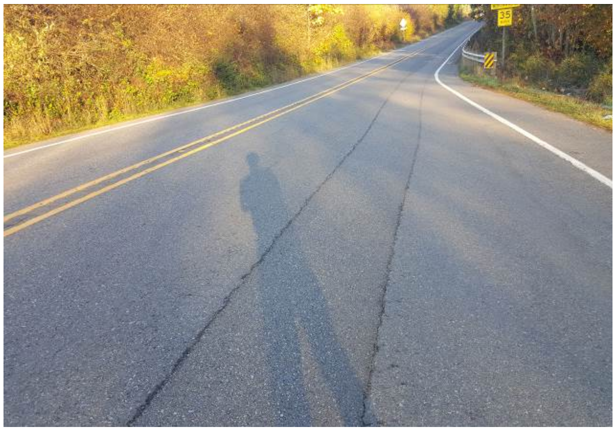

Figure 63. OR10, SR510, Good, age 51 months.

Figure 64. OR11, SR20, Good, age 49 months. Raveling of patch edges noted at 25 months.

Figure 65. OR15, SR12, Fair, age 49 months. BST in 2016, C8870.

Figure 66. ER9, SR395, Good, age 37 months. Additional dig outs installed in 2015. Transverse reflection cracking noted in 2017.

Figure 67. ER11, SR270, Fair, age 37 months. HMA grind/inlay in 2017, C9062.

Figure 68. SW5, SR6, Good, are 38 months. More dig outs added in 2015. HMA grind/inlay in 2017, C9087.

Figure 69. ER17, SR395, Good, age 26 months. Transverse reflection cracking in 2017.

Figure 70. ER24, SR127, Good, age 25 months. Excellent performance.

Figure 71. ER29, SR27, Good, age 26 months. Excellent performance.

Figure 72. OR24, SR119, Good, age 14 months. BST in 2017, C9077.

Figure 73. OR28, SR507, Good, age 28 months. Excellent performance.

Figure 74. SC5, SR12, Good, age 28 months. Excellent performance.

Figure 75. SW6, SR6, Good, age 27 months. Excellent performance.

Figure 76. ER42, SR20, Good, age 14 months. Excellent performance.

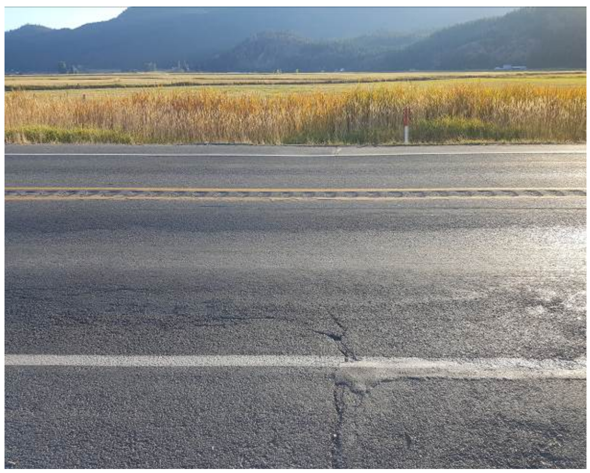

Figure 77. ER43, SR395, Good, age 14 months. Excellent performance.

OR2 located on SR8, one of the oldest sites, is shown in the following series of yearly photos. Figures 78 through 83 show the same location over a four plus year span of time. OR 2 was a Fair category site prior to treatment.

Figure 78. OR2, SR8, prior to treatment. Alligator cracking in the left wheel path. This is not the same location as the following photos which had alligator cracking in both wheel paths.

Figure 79. OR2, SR8, one year after installation.   Dig out patch looks excellent.

Figure 80. OR2, SR8, two years after installation.   No change in condition of patch.

Figure 81. OR2, SR8 three years after installation. Slight rutting in the patch.

Figure 82. OR2, SR8 four years after installation. No change in past year.

Figure 83. OR2, SR8 five years after installation. HMA grind/inlay in 2017 under Contract 9001.

The dig out patch shown in the photos has not changed in appearance for 62-months except for some slight rutting. The section received an HMA grind/inlay in 2017.

Another example was selected due to the large number of dig out test sites. Figures 84-89 show the condition of the dig outs on test site OR5 located on SR7. OR5 was a Good category pavement prior to treatment.

Figure 84. OR5, SR7, prior to treatment. Not at same location as following photos.

Figure 85. OR5, SR7, immediately after installation in 2013. Dig out patches look good. They appear to be related to utility cuts in original pavement.

Figure 86. OR5, SR7, one year after installation. No change in the dig out patches.

Figure 87. OR5, SR7, two years after installation. No change in the dig out patches.

Figure 88. OR5, SR7, three years after installation.   No change in the dig out patches.

Figure 89. OR5, SR7, four years after installation.   No change in the dig out patches. Different location in the same test site.

The appearance of the dig out patch does not change as it ages. Rutting in the wheel paths is the only visible change in the patch after 51 months. The dig outs extended pavement life five years on OR2, which received an HMA grind/inlay in 2017, and four years on OR5, which has not been rehabilitated. The two examples that were shown are typical of the dig out test sites, each with excellent performance.

Dig Outs Plus Crack Sealing

A total of four test sites used a combination of dig outs and crack sealing. The age of the sites ranged from 26 to 62 months at the 2017 inspection. Two of the sites received an HMA grind/inlay in 2017. Both the crack sealing and dig out patches are performing very well at all test sites. Reflection cracking through the patches on one site was noted 38 months after installation. It does not appear to be reflecting from the underlying PCCP. The oldest site, ER1 is a Poor category pavement that required additional dig outs and crack sealing to keep the pavement in a serviceable condition until a grind/inlay in 2017. Figures 90-93 show the condition of the five test sites at the last inspection.

Figure 90. ER1, US2, Poor, 62 months. Additional dig outs and crack sealing done in 2015. HMA grind/inlay in 2017, C9124.

Figure 91. OR4, SR3, Good, age 50 months. Dig out patches and crack sealing in excellent condition.

Figure 92. OR27, SR307, Good, age 26 months. Dig out patches and crack sealing in excellent condition.

Figure 93. SC4, SR395, Good to Poor, age 26 months. HMA grind/inlay in 2017, C9052.

The site selected to represent dig outs plus crack sealing was OR4 located on SR3 installed in 2013. Figures 94 through 99 show the same location in the test site over a span of three years. OR4 was a Good category pavement prior to treatment.

Figure 94. OR4, SR3, prior to treatment. Longitudinal, transverse and alligator cracking.

Figure 95. OR4, SR3, a few months after installation. Crack sealing looks good, dig out patches appear under filled in spots.

Figure 96. OR4, SR3, one year after installation. Dig out patch and crack sealing look unchanged.

Figure 97. OR4, SR3, two years after installation. No change in dig out patch or crack sealing.

Figure 98. OR4, SR3, three years after installation. No change in dig out patch or crack sealing.

Figure 99. OR4, SR3, four years after installation. No change in dig out patch or crack sealing.

The appearance of the dig out patch and the sealed cracks did not change over the 50 months on this test site. The excellent performance is typical for both types of treatments.

Dig Outs Plus Chip Sealing

There are six test sites with a combination of dig outs and chip sealing. They ranged in age from 38 to 62 months at the 2017 inspection. One of the sites, OR2a, was overlaid in 2017. Reflection cracking was noted on two of the sites, one at 9 months after installation and the other at 12 months. The dig outs on SW1 and SW1a addressed excessive wheel path cracking in these BST pavements. Transverse cracking was also present throughout both sites. There are potholes forming in one these BST sites. Flushing over the underlying dig out patches is present on five of the six test sites. It is possible that no dig out patches were installed on OR3 and that the site only received a full lane chip seal. Figures 100-105 show the condition of the six test sites at the 2017 inspection.

Figure 100. OR2a, SR8, Good, age 62 months. Flushing over the dig out patches. HMA grind/inlay in 2017, C9001.

Figure 101. OR3, SR101, Poor, age 62 months. Excellent performance.

Figure 102. SW1, SR14, Poor, age 62 months. Transverse reflection cracking and flushing noted at 9 months after installation.

Figure 103. SW1a, SR14, Poor, age 62 months. Transverse and longitudinal reflection cracking and flushing noted at 12 months after installation. Potholes developed at 50 months.

Figure 104. OR14, SR7, Good, age 51 months. Dig out patches flushing through the chip seal at 27 months.

Figure 105. NC3, SR207, Good, age 38 months. Dig out patches flushing through the chip seal after 12 months. This is actually a HBST with 100% embedment in the wheel paths.

OR2a on SR8 was selected as representative of the dig outs plus chip seal sites. Figures 106-111 show the same location in the test site over a span of four years. OR2a was a Good category pavement prior to treatment.

Figure 106. OR2a, SR8, prior to treatment.

Figure 107. OR2a, SR8, one year after installation. Slight flushing in the wheel paths over the dig out patches.

Figure 108. OR2a, SR8, two years after installation. Increased flushing in the wheel paths over the dig out patches.

Figure 109. OR2a, SR8, three years after installation. Flushing in the left wheel path throughout the length of the chip seal.

Figure 110. OR2a, SR8, four years after installation. Flushing has remained about the same as in 2015.

Figure 111. OR2a, SR8, the site received an HMA grind/inlay in 2017, C9001, five years after installation.

The type of flushing observed on this site was typical of five of the six sites. The flushing was caused by an excess of asphalt binder that results from a combination of the binder from the patch and the new binder used for the chip seal process. The common practice used to prevent this type of flushing is to wait for a period of time before applying the chip seal. One year is advisable, but shorter periods of time may also work. If there is not sufficient time between the patch and the chip seal, it is recommended to apply a fog seal over the patch prior to the chip seal.

Blade Patch

The eight test sites with blade patches ranged in age from 24 to 39 months at the 2017 inspection. Most of the patches are only one to two years old so are in good condition although surface roughness and raveling along the ends is common. ER9a, a 2014 site, was placed as a thin overlay with a paving machine had cracking reflecting through the patch after only 13 months. Two of the sites, ER20 and ER37 were overlaid with HMA and ER34 received a BST all in 2017.

ER8 and ER32 continue to receive additional blade patches. A pot hole formed in ER26 in 2016. Figures 112-120 show the condition of the eight test sites at the 2017 inspection.

Figure 112. ER8, SR195, Good, are 39 months. Blade patch used to fill wheel path ruts. Additional patches placed in 2017.

Figure 113. ER9a, SR395, Good, age 37 months. Transverse and longitudinal cracking reflecting through the patch at 13 months.

Figure 114. ER20, SR272, Good, age 24 months. Transverse crack reflecting through the patch. HMA grind/inlay in 2017, 9031.

Figure 115. ER26, SR127, Good, age 26 months. Pot hole formed in 2016. Flushing in wheel paths noted in 2017.

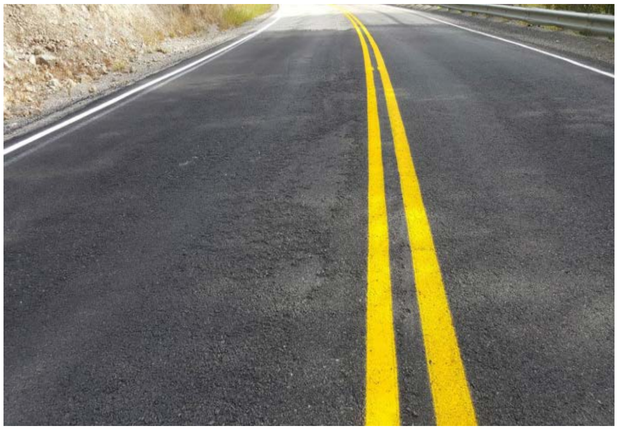

Figure 116. ER32, SR20, Good, age 12 months. Additional patches in 2017.

Figure 117. ER33, SR270, Good, age 24 months.

Figure 118. ER34, SR271, Good, age 24 months. Good performance. BST in 2017, C9031.

Figure 119. ER37, SR395, Fair, age 25 months. Excellent performance. HMA grind/inlay in 2017, C9105.

One of the older blade patch sites in the Eastern Region ER9a on SR395, a Good category pavement, provides visual evidence of the performance of this preventive maintenance technique. Figures 120 through 124 show the same location over a span of two years.

Figure 120. ER9a, SR395, prior to treatment. Longitudinal, transverse and alligator cracking.

Figure 121. ER9a, SR395, a few months after installation.   Blade patch looks excellent.

Figure 122. ER9a, SR395, one year after installation in 2014. Some wear of the blade patch at each end. Transverse cracks reflected through the blade patch after only one year.

Figure 123. ER9a, SR395, two years after installation. Longitudinal reflection cracking has been sealed. Note slight flushing in the left wheel path.

Figure 124. ER9a, SR395, three years after installation. Longitudinal reflection cracking has been sealed. Note slight flushing in the left wheel path.

Crack sealing was required between one the two years after installation to address a longitudinal reflection crack. The cracking is the result of the underlying cement treated base. Other common issues with blade patches are raveling at the ends where it is feathered into the existing pavement and raveling on the surface of the patch due to low density. The patches have preserved the pavement in a condition that allows safe travel and prevented further deterioration of the underlying pavement for a short period of time, but typically needs to be removed when performing rehabilitation. Blade patches are emergency fixes used to hold the pavement together until a chip seal or HMA rehabilitation can be scheduled and should always be removed prior to the permanent fix.

Control Sections

Four test sites that were set aside in 2012 as control sections, where no preventive maintenance treatments would be applied. The intent of the control sections was to provide an idea of what would happen to a pavement if preventive maintenance were withheld. All of the control sites continued to deteriorate with three of the four receiving emergency maintenance due to complaints from the public. One site received dig out patching in 2015 and again in 2017. As a result of the poor condition, two of the sites were overlaid in 2017 with HMA and another is scheduled in 2018. The only control site not receiving attention was OR3a where the cracking continues to increase in both extent and severity. Control sections were not included beyond year 2012 due to the rapid deterioration of the pavement that often required an emergency fix. Figures 125-128 show the condition of the four control sections at the 2017 inspection.

Figure 125. OR3a, SR101, Poor category, age 62 months. No maintenance as of the 2017 inspection.

Figure 126. ER1a, US2, Poor category, age 62 months. Dig outs, crack sealing and patching were necessary to preserve the roadway. HMA grind/inlay in 2017, C9124.

Figure 127. ER2a, US2, Poor category, age 62 months. Dig outs, crack sealing and patching were necessary to preserve the roadway. HMA grind/inlay in 2017, C9063.

Figure 128. ER3a, SR291, Fair category, 62 months. Dig outs, crack sealing and patching were necessary to preserve the roadway. HMA grind/inlay scheduled in 2018, C9223

The one site in the Olympic Region on SR101 that did not receive preventive maintenance during its life (OR3a) is shown over a span of five years (Figures 129-134). This was a Poor category pavement prior to treatment.

Figure 129. OR3a, SR101, condition in 2012, the year that the other sections were treated.

Figure 130. OR3a, SR101, one year after the other sections were treated. Cracking looks severe due to moisture in the cracks.

Figure 131. OR3a, SR101, two years after the other sections were treated. Vegetation growing in the wider cracks.

Figure 132. OR3a, SR101, three years after the other section were treated. Cracks are wide but not spalling.

Figure 133. OR3a, SR101, four years after the other sections were treated. Cracks are wide and beginning to spall.

Figure 134. OR3a, SR101, five years after the other sections were treated. Cracks are wide and beginning to spall.

There was no maintenance applied to this particular control section and, as a result, the cracks get wider and have become more extensive. Close examination of the last photo shows some spalling of the pavement on the sides of the wider crack. It should be noted that this is a very low traffic roadway and located where temperature is consistently moderate, when compared to the other control section test sites.

Side by Side Performance Comparisons

The study design did not allow for a comparison of the various treatments one against the other, except for three locations in the Olympic Region that place several treatments side by side on the same roadway. Below is a discussion of each of these locations.

OR1 – OR1a – OR1b

OR1, OR1a and OR1b were all located side by side on SR 101 along Hood Canal between Eldon and Lilliwaup. It is a two lane roadway (one lane in each direction) classified as a rural-principal arterial. OR1 was treated with crack sealing, OR1a was also crack sealed, but in addition received a chip seal, and OR1b received just a chip seal with no crack sealing (see Figure 136). The site with only crack sealing performed very well with no deterioration of the crack sealant except where traffic had worn down the over-banding. Additional cracking and growth of the existing cracks was noted in the section, but no additional work was required on the site during the five plus years of observation. The site with the crack seal followed by a chip seal was in very good condition with no flushing and no cracks reflecting through from the underlying pavement. As with the crack sealing only site, no additional work was required on the section for five plus years. The section with only the chip seal did not perform as well as the other two sections with rutting and flushing in the wheel paths and a longitudinal crack reflected through the chip seal. No additional work occurred on the chip seal only section for five plus years; however, the flushing, rutting, and reflection crack may have warranted some additional attention. It could be argued that crack sealing was the best treatment solution for this particular location knowing that the cost of crack sealing would be much less than the other two treatment choices. The correct choice depends on how long the pavement needed to be preserved before rehabilitation could be scheduled.

Figure 135. OR1, OR1a and OR1b on SR 101. OR1 has crack sealing, OR1a has crack sealing and chip sealing, and OR1b has a chip seal with no crack sealing. Photos from 2017.

OR2 – OR2a

The next location with multiple treatments was OR2 and OR2a, located on the westbound lanes of SR 8 approaching McCleary. It is a four lane divided roadway (two lanes in each direction) classified as a rural-principal arterial. OR2 received dig outs and OR2a received dig outs and a chip seal (Figure 137). The section with dig outs performed very well with no deterioration of the dig out patches and minor transverse reflection cracks. The dig out patching was only required in the inside wheel path. The outside wheel path had severe longitudinal and transverse cracking with some spalling where they intersected. The section that received the chip seal over the digs outs had flushing present in the wheel paths throughout the section with severe flushing over the dig out patches. Longitudinal cracks also reflected through the chip seal in the outside wheel path, the same longitudinal cracks not addressed in the section with only the dig outs. Dig outs without the chip seal performed much better than the section with the chip seal due to the flushing of the chip seal; however, both sites lasted five plus years without additional treatment. The application of the chip seal was apparently due to a misunderstanding between the Olympic Region Materials Engineer and Maintenance. The Materials Engineer indicated that the dig outs and chip sealing were alternatives for the treatment and were not meant to be applied in combination, but was a good comparison.

Figure 136. OR2 and OR2a on SR8. OR2 received dig outs and OR2a received dig outs and a chip seal. Photos are from 2016, both sections were milled and filled with HMA in 2017

OR3 – OR3a – OR3b

The final location is OR3, OR3a and OR3b located on SR 101 south of the Queets River Bridge. It is a two lane roadway (one lane in each direction) classified as a rural-principal arterial. OR3 received dig outs and a chip seal, OR3b a chip seal with no dig outs, and OR3a was a control section with no treatment (Figure 138). It is evident that the dig outs and chip seal section is performing much better than the section with only the chip seal; however, this may be due in part to the poor condition of the original pavement in the chip seal only section. The control section is also performing fairly well, although the cracks have grown in length and become wider with vegetation growing in the cracks. The best treatment solution for this location appears to be no treatment since the control section survived for five plus years without potholes or excessive spalling of the cracks; but now is the time to perform preventive maintenance before the cracks turn into potholes. The mild climate and low traffic volumes (ADDT of 870) were contributing factors to the slow deterioration of this section of pavement. In summary, the control section, OR3a, center photo, survived for five years without any treatment; however, in hindsight, crack sealing would have been the least costly and possibly best treatment for this roadway.

Figure 137. OR3, OR3a and OR3b on SR101. OR3 received dig outs and a chip seal, OR3a no treatment and OR3b a chip seal with no dig outs. Photos from 2017.

Performance Summary

The primary focus of the study is to document the performance of the preventive maintenance treatments. Table 1 summarizes the performance each preventive maintenance type for all of the test sites that used that treatment. The table includes the test site number, the year the treatment was installed, the PSC category (Good, Fair, or Poor) and the performance of the treatment including how long it lasted and if it had receive a chip seal or HMA grind/inlay. The test sites that received a chip seal or HMA grind/inlay are tinted yellow. The test sites that received additional preventive maintenance treatments are shaded purple. The additional treatments were normally the same as the original treatment, that is, additional blade patches for test sites in the Blade Patch category.

Table 1. Preventive maintenance treatment performance for each test site.

Site	Year	PSC Category	Treatment Performance
Crack Sealing (12 Test Sites)			
OR1	2012	Poor	Cracks remain sealed after 5+ years; some of the sealant cracks are beginning to open.
OR6	2013	Good	Cracks were still sealed after 4+ years before being HMA grind/inlay in 2017, C9001.
OR8	2013	Poor	Cracks remain sealed after 4+ years.
OR9	2013	Good	Cracks remain sealed after 4+ years.
NC2	2014	Good	Cracks remain sealed after 3+ years. Pavement has failed in some areas and required patching but not due to failure of the crack sealing.
SC1	2015	Good	Cracks remain sealed after 2+ years.
ER41	2016	Good	Cracks remain sealed after 1+ year.
OR20	2016	Good	Cracks remain sealed after 1+ year.
OR21	2016	Good	Cracks remain sealed after 1+ year.
OR31	2016	Good	Cracks remain sealed after 1+ year.
OR32	2016	Good	Cracks remain sealed after 1+ year.
OR34	2016	Good	Cracks remain sealed after 1+ year.
Full Lane Chip Sealing (4 Test Sites)			
OR1b	2012	Poor	Chip seal in good condition after 5+ years. Minor rutting and flushing and a one reflection crack.
OR3b	2012	Poor	Chip seal in fair condition after 5+ years due to delamination and spalling.
OR16	2013	Good	Chip seal in fair condition after 4+ years due to flushing and cracking and fines pumping.
OR22	2015	Good	Chip seal is fair condition after 2+ years. Lots of chip loss, reflection cracking with pumping fines.
Wheel Path Chip Seal Patching (2 Test Sites)			
OR12	2013	Good	WP seals in fair condition after 4+ years. Flushing and reflection cracking present.
OR23	2015	Good	WP seals in good condition after 2+ year. Some flushing and reflection cracking present.

Table 1. (Continued) Path Chip Seal Rut Filling (5 Test Sites)			
Site	**Year**	**PSC Category**	**Treatment Performance**
Wheel Path Chip Seal/Rutting (5 Test Sites)			
ER7	2013	Good	WP chip seals lasted two years before full lane chip seal in 2015.
ER10	2014	Good	WP seals in good condition after 3+ years. Some chip loss, transverse reflection cracking, and slight rutting.
ER15	2015	Good	WP seals in fair condition after 2+ years. Flushing and rutting full length of both wheel paths and transverse reflection cracking.
ER18	2015	Good	WP chip seal lasted two years before full lane chip seal in 2017.
ER40	2016	Good	WP chip seal in fair condition after 1+ years. Loss of aggregate in both wheel paths, flushing and rutting.
Crack Seal Plus Chip Seal (2 Test Sites)			
OR1a	2012	Poor	Chip seal in good condition after 5+ years with only no cracking reflecting through the chip seal.
NC1	2014	Good	Chip seal in good condition after 3+ years. Nuvo Gap sealant has hairline cracks.
Dig Outs (22 Test Sites)			
OR2	2012	Fair	Dig out patches lasted five years before HMA grind/inlay in 2017.
ER2	2012	Fair	Dig out patches lasted five years before HMA grind/inlay in 2017.
ER3	2012	Fair	Dig out patches in fair condition 5+ years. HMA grind/inlay scheduled in 2018.
ER4	2013	Fair	Dig out patches are in fair condition after 4+ years. Older patches are showing some raveling. HMA grind/inlay scheduled in 2018.
ER5	2013	Poor	Dig out patches are in fair condition after 4+ years.
OR5	2013	Good	Dig out patches in good condition after 4+ years.
OR8a	2013	Poor	Dig out patches in very good condition after 4+ years.
OR10	2013	Good	Dig out patches in very good condition after 4+ years.
OR11	2013	Good	Dig out patches in good condition after 4+ years. Minor reflection cracking and raveling.
OR15	2013	Fair	Dig out patches lasted 3+ years before full lane chip seal in 2016.
ER9	2014	Good	Dig out patches in good condition after 3+ years. Transverse reflection cracking present.

Table 1. (Continued).			
Site	Year	PSC Category	Treatment Performance
Dig Outs (Continued)			
ER11	2014	Fair	Dig out patches lasted 3+ years before HMA grind/inlay in 2017.
SW5	2014	Good	Dig out patches lasted 3+ years before full lane chip seal in 2017.
ER17	2015	Good	Dig out patches in very good condition after 2+ years.
ER24	2015	Good	Single dig out patch in fair condition after 2+ year. Alligator cracking in center of patch.
ER29	2015	Good	Dig out patches in fair condition after 2+ year. Patches have very open texture with some rutting.
OR24	2015	Good	Dig outs lasted 3+ years before HMA grind/inlay in 2017.
OR28	2015	Good	Dig out patches in fair condition after 2+ year.
SC5	2015	Good	Dig out patches in good condition after 2+ years. One bad area at the edge of one dig out.
SW6	2015	Good	Dig our patch in good condition after 2+ years.
ER42	2016	Good	Center line dig out patch in very good condition after 1+ year.
ER43	2016	Good	Dig out patch in good condition after 1+ year.
Dig Outs Plus Crack Sealing (4 Test Sites)			
ER1	2012	Poor	Dig out patches and crack sealing lasted 5+ years before HMA grind/inlay in 2017.
OR4	2013	Good	Dig out patches and crack sealing in good condition after 4+ years.
OR27	2015	Good	Dig out patches and crack sealing in fair condition after 2+ year.
SC4	2015	Good	Dig out patches lasted 3+ years before HMA grind/inlay in 2017.
Dig Outs Plus Chip Sealing (6 Test Sites)			
OR2a	2012	Good	Dig out patches plus chip seal lasted approximately 5 years before HMA grind/inlay in 2017.
OR3	2012	Poor	Chip seal in good condition after 5+ years. Minor loss of chips, but no flushing.
SW1	2012	Poor	Chip seal flushing in wheel paths and cracks reflecting through after 5+ years.
SW1a	2012	Poor	Chip seal flushing in the wheel paths and cracks reflecting through the seal after 5+ years.
OR14	2013	Good	Chip seal is flushing in the wheel paths at 4+ years but not as a result of dig out patches.

Table 1. (Continued). verse Blade Patching			
Site	**Year**	**PSC Category**	**Treatment Performance**
Dig Outs Plus Chip Sealing (continued)			
NC3	2014	Good	Chip seal is flushing in wheel paths over the dig out patches after 3+ years.
Blade Patching (8 Test Sites)			
ER8	2014	Good	Additional blade patches were placed in 2017.
ER9a	2014	Good	Patch is in fair condition after 3+ years. Longitudinal reflection cracks were sealed in the blade patch.
ER20	2015	Good	Blade patch lasted 2+ years before full lane chip seal in 2017.
ER26	2015	Good	Patch is in fair condition after 2+ year. Some raveling noted. Hole has developed due possibly to a collapsed culvert under the road.
ER32	2015	Good	Additional blade patches in 2017.
ER33	2015	Good	No additional treatment required, pavement life extended 2+ year.
ER34	2015	Good	Blade patch lasted approximately 2 years before full lane chip seal in 2017.
ER37	2015	Fair	Blade patch lasted approximately 2 years before HMA grind/inlay in 2017.
Control Sections (4 Test Sites)			
OR3a	2012	Poor	Block and alligator cracking has increased in severity after 5+ years. Vegetation growing in wider cracks.
ER1a	2012	Poor	Multiple installation of dig outs before HMA grind/inlay in 2017.
ER2a	2012	Poor	Multiple installation of dig outs before HMA grind/inlay in 2017.
ER3a	2012	Fair	Multiple installations of dig out patches throughout the 5+ years. HMA grind/inlay scheduled in 2018.

Note: Yellow shading sites received a chip seal or HMA grind/inlay. Purple shaded sites received additional treatment that was not a chip seal of HMA grind/inlay.

A summary of the performance of the individual preventive maintenance treatment categories follows.

Crack Sealing - The 12 crack sealing test sites range in age from one year to five years. The sealants are performing well with some wear showing in the wheel paths. The oldest site, installed in 2012, is showing hairline cracking in the sealant material; however, the sealant has not pulled away from the edges of the crack in this or any of other of the test sections. One site received an HMA grind/inlay in 2017.

Full Lane Chip Sealing - The four full lane chip seal test sites range in age from two to five years. The full lane chip seals are not performing up to expectations. Three of the four sites are flushing in the wheel paths and one has a small area that is delaminating due to an underlying patch that was not addressed (i.e. fog sealed) prior to the chip seal. The performance of the test sites in the study do not compare with the majority of chip seals placed in the state under contract which last from 6-8 years without the early flushing problems noted in the test sites. None of the test sites has received a HMA grind/inlay or BST overlay as of 2017.

Wheel Path Chip Seal Patching – The chip seals placed to fix cracking confined to the wheel paths are performing very well with only minor chip loss and no flushing. The sites range in age from two to four years. None of the sites have received a HMA grind/inlay or a BST overlay. Full lane chip sealing test sites have extended pavement life for five years; therefore, there is no reason to believe that wheel path chip seals will not perform very well beyond their current maximum age of four years.

Wheel Path Chip Seal Rut Filling – The two wheel path chip seal rut filling test sites range in age from one to four years. The sites have minor occurrences of chip loss, rutting, flushing, and reflection cracking. Two sites received full lane chip seals, one in 2015 and the other in 2017. The Eastern Region is using wheel path chip sealing followed by full lane chip sealing as a process to deal with wheel path rutting. There is no reason to believe that these sites will not perform well beyond their current maximum age of four years.

Crack Sealing Plus Chip Sealing – The two crack sealing plus chip sealing sites range in age from three to five years. The chip seals are performing very well. On one site, the crack sealing can be seen as shadowing in the surface of the chip seal, but no cracks have reflected through the chip seal after five years. On the other site, a special sealant (Nuvo Gap) was used to fill very wide transverse thermal cracks in a bituminous surface treatment (BST) pavement prior to the chip seal. Hairline cracking is visible in the sealant after three years; however, the sealant is not pulling away from the edges of the transverse cracks. None of the sites received a HMA grind/inlay or BST overlay.

Dig Outs – The 22 dig out test sites range in age from one to five years. The performance is outstanding with no flushing or significant distress noted in the patches. On a few of the test sites, the patches have transverse cracks from joints or cracks in the underlying concrete pavement. The compaction of the HMA in the dig outs varies from site to site from poor to good, which allows the accumulation of moisture; however, this has not resulted in distress detrimental to their performance. Four of the sites received HMA grind/inlays in 2017, two chip seals one in 2016 and one in 2017. Two sites are scheduled for HMA grind/inlays in 2018. In total, eight of the 22 sites will have a chip seal or HMA grind/inlay by the end of 2018.

Dig Outs Plus Crack Sealing – The four dig outs plus crack sealing sites range in age from two to five years. Their performance ranges from fair to good. One site required additional dig outs and crack sealing due to the very poor condition of the original pavement. Two sites received HMA grind/inlays in 2017.

Dig Outs Plus Chip Sealing – The six dig outs plus chip sealing sites range in age from three to five years. The dig outs plus chip seal were effective; however, flushing is a major problem on most of the sites. Some of the flushing is because the chip seal was placed over the dig out without either: (1) enough time between the dig out and chip seal (it is recommended to wait at least a few months) or (2) fog sealing the dig out prior to the chip seal. The fresh patch will absorb some of the chip seal binder and cause chip loss. SW1 and SW1a were BST roadways with significant structural deficiencies that resulted in widespread transverse cracking reflecting through the chip seal. One site received a HMA grind/inlay in 2017.

Blade Patch – The eight blade patch sites range in age from two to three years. They are, in general, performing poorly. Longitudinal cracks reflected through the blade patch were crack sealed on one site between one and two years after the initial blade patch was placed. Additional blade patches were applied to two sites in 2017. One site received a HMA grind/inlay in 2017 and two received full lane chip seals. Only two of the eight sites survived without additional treatment or a HMA grind/inlay or chip seal.

In summary, the observations indicate that the primary treatments, that is, crack sealing, chip sealing, and dig outs, are all performing very well with only minor problems. The yearly photos at the same location in the test sites show very little change in the condition of the treatments over time. The combination treatment of dig outs plus chip sealing and blade patching are two categories of treatment that are not exhibiting as good performance. Flushing problems on a majority of the dig out plus chip seal test sites would indicate that placing a chip seal over dig out patches in the same year is not a strategy that should be encouraged. The excellent performance of dig outs without a chip seal supports this observation. Blade patching is not a true preventive maintenance technique as evidenced by six of the eight sites receiving additional treatment or a

HMA grind/inlay or full lane chip seal after only one to three years of service. Blade patches are used to temporarily mitigate pavement failures until rehabilitation can be scheduled.

Maximum Treatment Life

The test sections show that the majority of the treatments held the pavement at an acceptable service level for three to five years as shown in Figure 138. The number above the column reflects how many sites reached the maximum possible age. The treatments with the longest monitoring histories include crack sealing, chip sealing, crack sealing and chip sealing, dig outs, dig outs plus crack sealing, and dig outs plus chip sealing with all having at least one test site that lasted five years without additional treatment or a chip seal or HMA grind/inlay. Some of the treatments like blade patching were only installed beginning in 2014; therefore, there was only three years of data for this treatment. Wheel path chip sealing for patching has only a four year history with the oldest site installed in 2013. Wheel path chip seal for rutting was initiated in 2013, however, the practice has been to chip seal these pavements one to two years after the rut filling; therefore, the oldest site, ER7, installed in 2013 received a full lane chip seal in 2015. The data shows that full lane chip seals can last for five years and there is no reason to believe that the same process used to fill wheel paths would have a different service life.

Crack sealing, chip sealing and dig outs can extend pavement life a minimum of five years. Blade patching is an emergency treatment used to temporarily preserve the serviceability of a pavement until rehabilitation is completed, and as such has a much shorter life.

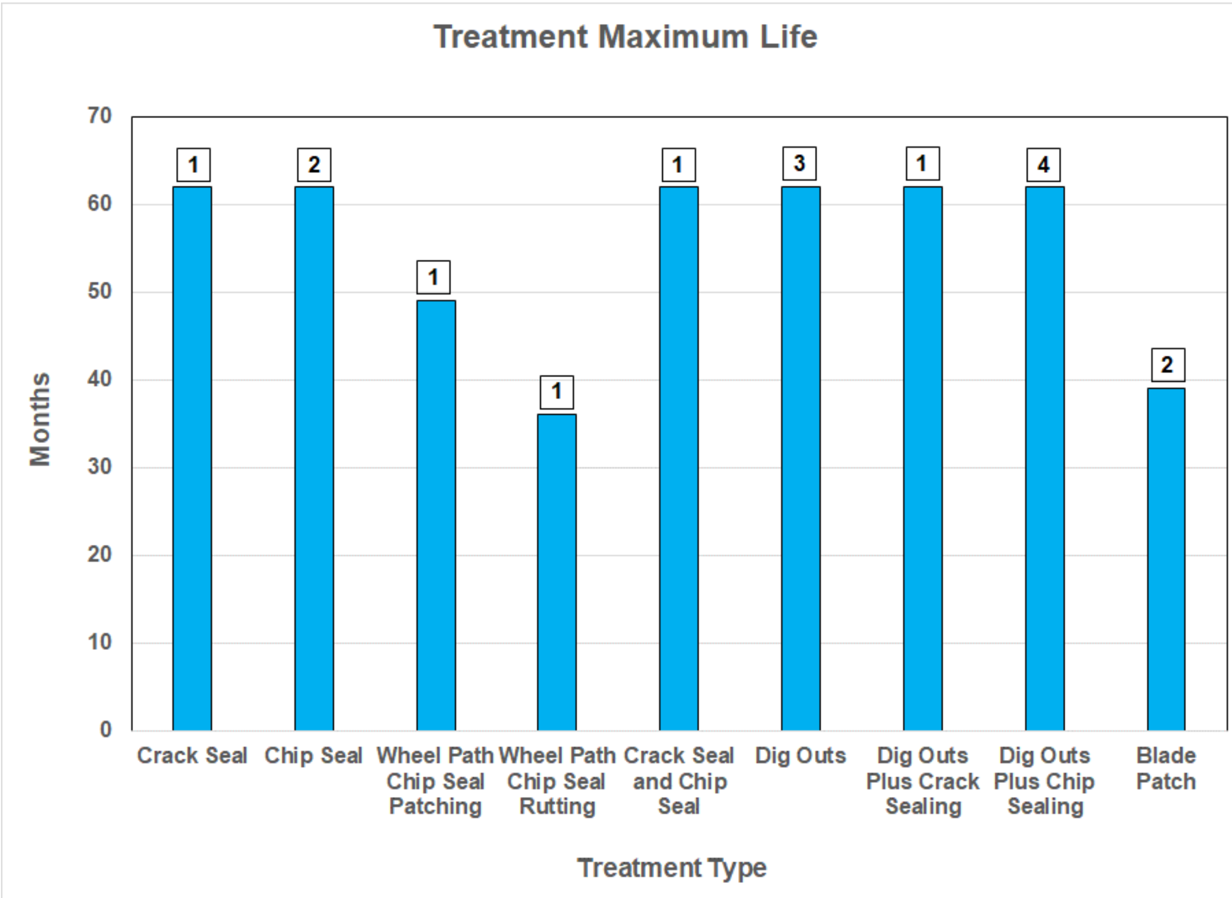

Figure 138. Treatment maximum life. Numbers above columns are the number of test sites that achieved the maximum life.

The maximums represent the end point of the evaluation period and not the point at which any of the treatments failed. The majority of the treatments lasted beyond the end point of the study. Only 17 of the 69 test sites were terminated by the application of a chip seal or HMA grind/inlay. As a side note, the performance of these 17 terminated test sites is examined in Appendix B.

Cost Data

Cost information on the treatment types is very difficult to gather from maintenance records. The data generally included the cost of labor, equipment and materials, the amount of materials used, and the length of the roadway treated. The available data and methods used to arrive at a cost for each treatment type are explained in the following paragraphs.

Crack Sealing

The data for crack sealing included costs for labor, equipment, materials, amount of crack sealant used in boxes or blocks, and the length of the roadway that was sealed in total miles. The length and width of the sealed cracks was not recorded. The process of calculating the cost involved measuring the crack lengths from WSPMS photo logs and using a Crafco table giving the amount of sealant required for cracks of different widths and lengths. The costs ranged from $0.42 to $1.34 per lineal foot of pavement treated. The mid-point of $0.88 per lineal foot was selected as an average cost for crack sealing. The average length of cracking in a one mile section for a large number of projects was 1.3 miles.

Chip Sealing

Chip sealing was the easiest cost to calculate because the data included the cost of labor, equipment, and materials for a stated square foot of area. The total costs ranged from $0.45 to $0.72 with an average of $0.59 per square foot.

Dig Outs

The data for dig outs included labor, equipment and materials cost, plus the tons of HMA, the length of the roadway treated, and the average depth of the dig outs. No information was provided on the number or size of the dig outs. The cost per ton of mix was calculated for 26 maintenance projects in the Eastern Region built in 2014 and 2015. The cost included labor, equipment and materials (HMA and tack coat). The average cost per ton for the 26 projects was $227.00. The average depth of the dig outs from a large number of projects was three inches.

Blade Patching

The cost for placing blade patches was the most difficult to calculate because there was no data provided on the square footage of the patch. The cost per ton of HMA including labor and equipment was the only data available. The cost per linear foot was calculated using an average depth of 1.5 inches and an average density of 145 pounds per cubic foot (pcf). The costs range from $5.00 to $15.00 per linear foot. The mid-point of $10.00 per lineal foot was chosen as an average cost.

Comparison of Treatment Costs

It was thought that it would be possible to calculate the cost of the various maintenance techniques on a unit basis such as square feet or square yards of treatment. This would work for crack sealing (using the average length of cracks sealed in a mile as 1.3 miles), chip sealing and blade patching, but not for dig outs and wheel path chip sealing which are only applied in strips. Another thought was to calculate the cost of one lane mile of each treatment. This would work for crack sealing, chip sealing and wheel path chip sealing, but not for dig outs or blade patching. In the case of dig outs, the amount of dig outs in a lane mile varies depending on roadway conditions. The same holds true for blade patches, the length of the patch is dependent on roadway conditions.

The solution was to calculate the cost of the treatment of one lineal foot of a 12-foot wide lane (Table 2). This size was chosen as a way to differentiate between a wheel path chip seal and a full lane chip seal. This approach allowed dig outs cost to be calculated as a dig out in one wheel path that was three feet wide by one foot in length. One dig out in one wheel path was chosen based on observation of the 21 dig out test sites, which generally had dig outs in only one wheel path.

Table 2. Cost comparison of the various treatments.	
Treatment	**Cost for treating 1 Foot of Pavement on a 12 Foot Wide Lane**
Crack Sealing	**$1.14**
Wheel Path Chip Seal Rut Filling	**$2.76**
Wheel Path Chip Seal Patching	**$4.44**
Full Lane Chip Sealing	**$7.08**
Crack Sealing + Chip Sealing	**$8.10**
Blade Patch	**$10.00**
Dig Outs	**$12.49**
Dig Outs + Crack Sealing	**$13.63**
Dig Outs + Chip Sealing	**$19.57**

The data and methods used to calculate the cost for each of the preventive maintenance treatment types are as follows:

- Crack Sealing – Maintenance data showed that the average length of crack sealing in a one-mile length of pavement was 1.3 miles. Using the average cost for crack sealing of $.88 per lineal foot and the average length of 1.3 feet, the cost was (1.3 X $0.88 = $1.14).
- WP Chip Seal Rut Filling – The average width of the wheel paths of the five projects in the WP chip sealing category were measured on the photos at 4.67 feet (measurements were taken of the width of the pavement as well as the width of the sealed wheel paths to determine the scaling factor). Cost was (4.67 X $0.59 = $2.76).
- WP Chip Seal Patching – using the same method as above, the average combined width of the wheel paths was 7.52 for the two test sites. Cost was (7.52 X $0.59 = $4.44).
- Chip Sealing – The cost for 12 square feet of chip sealing at $0.59 per square foot was (12 X $0.59 = $7.08).
- Crack Sealing + Chip Sealing – Combination of 1.3 feet for crack sealing and 12 square feet of chip sealing was ($1.14 + $7.08 = $8.22).
- Blade Patch – The cost for one linear foot of blade patch was $10.00.
- Dig Outs –The amount of HMA for a dig out that is 3 feet wide by one foot in length and 3 inches in depth was (3.0’ X 0.25’ X 1.0’ = 0.75 cu.ft.) Using a density of 145 pcf, it would require 109 lbs. of mix to fill the dig out which was 0.055 tons at $227/ton = $12.49
- Dig Outs + Crack Sealing – Cost was a combination of cost for dig outs and crack sealing ($12.49 + $1.14 = $13.63).

- Dig Outs + Chip Sealing – Cost was a combination of the costs for dig outs and chip sealing ($12.49 + $7.08 = $19.57).

PSC Category Repair Costs

The report by Hicks ET AL, 2000 states, "the concept of preventive maintenance is to place an economical treatment early in the life of the pavement to preserve the pavement condition and possibly extend the pavement life." Hicks also states, " . . . the longer maintenance is delayed the more it will cost to repair the pavement." Table 3-5 lists the average treatment cost for the test sites in each of the three PSC categories using the cost data from Table 2. The lowest average cost is for the Good category test sites at $8.53 per site followed by the Poor category at $11.08 and the Fair category at $12.13. The data indicates that early treatment for the tests sites considered in this study is more cost effective than delayed treatment. This conclusion would be much stronger if the actual cost of the treatment for each test site were known.

Table 3. Average treatment cost for Good category test sites.

Good Category			
Treatment	Treatment Cost (1 Foot of Pavement on a 12 Foot Wide Lane)	No. of Test Sites	Total Cost
Crack Sealing	$1.14	10	$11.40
WP Chip Seal Rut Filling	$2.76	5	$13.80
WP Chip Seal Patching	$4.44	2	$8.88
Full Lane Chip Sealing	$7.08	2	$14.16
Crack Seal + Chip Seal	$8.10	1	$8.10
Blade Patch	$10.00	7	$70.00
Dig Outs	$12.49	14	$174.86
Dig Outs + Crack Seal	$13.63	3	$40.89
Dig Outs+ Chip Seal	$19.57	3	$58.71
	Total	47	$400.80
		Average	$8.53

Table 4. Average treatment cost for Fair category test sites.

Fair Category			
Treatment	Treatment Cost (1 Foot of Pavement on a 12 Foot Wide Lane)	No. of Test Sites	Total Cost
Dig Outs	$12.49	6	$74.94
Blade Patch	$10.00	1	$10.00
	Total	7	$84.94
		Average	$12.13

Table 5. Average treatment cost for Poor category test sites.

Poor Category			
Treatment	Treatment Cost (1 Foot of Pavement on a 12 Foot Wide Lane)	No. of Test Sites	Total Cost
Crack Sealing	$1.14	2	$2.28
Full Lane Chip Sealing	$7.08	2	$14.16
Crack Seal + Chip Seal	$8.10	1	$8.10
Dig Outs	$12.49	2	$24.98
Dig Outs + Crack Seal	$13.63	1	$13.63
Dig Outs+ Chip Seal	$19.57	3	$58.71
	Total	11	$121.86
		Average	$11.08

Maintenance Treatment Selection Guidelines

The guiding principle in choosing a maintenance strategy to fix a particular pavement distress is to choose the option that will provide the lowest annual cost. The least expensive treatment may not be the most cost effective. Crack sealing a pavement with cracking over the entire lane may be the least expensive option, but a chip seal may be the most effective in sealing the entire surface of the lane. The design of the study does not lend itself to prescribing specific treatments for particular pavement distresses; however, general guidelines for choosing the most cost effective treatment are discussed in the following paragraphs.

Crack Sealing

Crack sealing could be the best choice for a pavement with longitudinal and transverse cracking or block cracking that exceeds 1/4 inch in width. It would not be the best choice for alligator cracking because it is impossible to fill all of the cracks and a massive use of sealant could result in a slippery pavement (Figure 139). Crack sealing was used effectively on some sites with alligator cracking because filling the larger cracks prevented spalling of the pavement and the formation of potholes.

Figure 139. Excessive crack sealant used on alligator cracking on SR 20. (November 2016)

Wheel Path Chip Sealing

Wheel path chip sealing is a good option when alligator cracking is confined to the wheel paths or when there is rutting in the wheel paths (Figure 140). The Eastern Region used wheel path chip sealing to fill ruts followed by a full lane chip seal in following years.

Figure 140. ER10, wheel path chip seal rut filling on US 2. (September 2016)

Full Lane Chip Sealing

Full lane chip sealing is one of the most effective treatments because it can cover a multitude of pavement distress (Figure 141). This would include alligator cracking, longitudinal cracking and transverse cracking (provided the cracks are less than ¼ inch in width), and patching. The experience in this study with three of the four test sites exhibited flushing would seem to indicate that this is a choice to be avoided, especially if the wheel paths are rutted; however, the very good experience when full lane chip seals placed under Region wide chip seal contracts would indicate just the opposite. As indicated previously, it may be that the materials used or the application techniques that may need to be given scrutiny in order to achieve the best results. Chip sealing is often described as an art due to the many factors that can contribute to either success or failure. A few of these factors include the condition of the application equipment, both chip spreader and distributor, the properties of the oil and aggregates, the application of the correct amounts of aggregate and oil, the uniformity of the application, the development of good adhesion between the chip seal and the existing pavement and the weather during application (Testa & Hossain, 2014). Because of the lack of control over these many variables, chip sealing has not been as successful as would be expected. As one of the lower cost options, it would seem to provide a good choice when the distress in the pavement is not too severe but distributed over the entire lane.

Figure 141. OR3b full lane chip seal on SR 101. (September 2016)

Crack Sealing + Chip Sealing

The crack sealing plus chip sealing is the next lowest cost option (Figure 142). It is best used where some of the cracks exceed 1/4 inch in width and some are very fine. Sealing these larger cracks prior to the application of the chip seal will likely prevent the cracks from reflecting through the chip seal. Its use was limited to two test sites, probably due to the higher costs involved. On the Olympic Region test site (OR1a), either crack sealing or chip sealing alone would probably have provided a solution that would have lasted five plus years. The adjacent sections, OR1 and OR1b, which received only crack sealing or chip sealing, respectively, have performed very well. On the North Central site NC1, a special crack sealant was used to seal very wide thermal cracks in the chip seal prior to the application of another chip seal. In this case, the crack sealing was a necessity due to the wide transverse cracks in the existing pavement. To minimize issues with chip seal flushing, it is best to wait at least one season after the crack sealant is placed before placing the chip seal.

Figure 142. OR1a crack sealing plus chip sealing on SR 101. (September 2016)

Blade Patch

Blade patching is the next least costly treatment (Figure 143). It has limited application for roadways that are out of shape or have large cracks due to movement of the pavement caused by unstable subgrades or other issues. It is generally applied as an emergency stopgap treatment until a more substantial solution such as a mill and fill or full lane chip seal can be applied. The experience has been generally satisfactory, and since other treatments are not an option, it will continue to be used for the previously described pavement issues.

Figure 143. ER20 blade patch on SR 395. (September 2016)

Dig Outs

Dig outs are one of the more expensive treatments due to the high cost of equipment, labor and materials required to prepare the holes, fill the holes, and compact the HMA (Figure 144). It is used when the cracks in the wheel path have become wide or alligator cracking has developed and potholes are forming.   It is very effective because it removes the entire area of the distressed pavement and replaces it with new HMA. The performance of the dig out patches has been excellent on all of the test sites.

Figure 144. OR2 dig outs on SR 8. (September 2016)

Dig Outs + Crack Sealing

Using a combination of dig outs and crack sealing is a very expensive fix, but may be necessary to fix a pavement with alligator cracking in the wheel paths and longitudinal and transverse cracking throughout (Figure 145). The dig outs plus crack sealing test sites were ones in which the pavement was in such poor condition that the dig outs could not encompass all of the distressed pavement, and as a result, crack sealing was necessary to fill the large cracks between the dig outs.

Figure 145. OR4 dig outs plus crack sealing on SR 3. (September 2016)

Dig Outs + Chip Sealing

Dig outs plus chip sealing is the most expensive option (Figure 146). Placing a chip seal over newly placed dig out patches is not a good practice due to the strong possibility that the chip seal will flush or could result in chip loss. A solution is to place the chip seal in the next construction season or applying sand to the patches before the chip seal. The flushing conditions on several of the sites could have been avoided by eliminating the chip seal; however, the chip seal serves an additional purpose of providing a better ride over the dig outs.

Figure 146. OR2a dig outs plus chip seal SR 8. (September 2016)

Discussion of Results

The primary preventive maintenance treatments of crack sealing, chip sealing and dig outs are capable of extending pavement life for five years or more. The data collection on wheel path chip seal patching and rut filling ended after only four years, but the full lane chip seal lasted for five years so there is no reason to believe that the same process used to fill wheel paths would have a different outcome. Only three years of data was available for blade patching; however, it appears that the duration of blade patches is one to two years before additional fixes are applied either in the form of full lane chip seals or HMA grind/inlays.

The use of multiple treatments on a site is expensive and often not warranted to extend the life of the pavement. Crack sealing prior to a chip seal will likely prevent reflection cracking of the larger cracks; however, the study shows that a chip seal with cracks reflecting through it will still extend the life of the pavement for five years or more. Applying a chip seal over newly placed dig out patches is also expensive and may result in flushing over the patches. The chip seal does help to smooth out the ride over the patches. It is advisable to wait a construction season or fog seal the dig out patches before applying the chip seal. Dig outs plus crack sealing is another expensive preventive maintenance treatment which was used when the test site had not only problems in the wheel paths, but cracking throughout the pavement. For these pavement conditions, a mill and fill with HMA or full lane chip seal would have been the optimum solution.

It is best to apply preventive maintenance treatments when cracking first begins to exceed 1/4 inch in width. Crack sealing in the wheel paths has been shown to be very effective in arresting further deterioration of the pavement into alligator cracking or potholing. The application of a full lane chip seal or wheel path chip seal is also a good choice when the cracking extends over the entire lane or for alligator cracked wheel paths. The Eastern Region has successfully used wheel path chip seals to fill ruts and often follows this treatment with a full lane chip seal in subsequent years. Dig outs are very effective because they remove the distressed pavement and replaces it with new HMA; however, at a much higher cost than crack sealing or chip sealing.

Recommendations

The primary recommendation is that preventive maintenance techniques are best applied when distress is first observed. In general, the least expensive techniques of crack sealing and wheel path chip sealing are very effective treatments when the distress is confined to the wheel paths. Full lane chip sealing could be used more frequently than currently utilized because it can mitigate a number of pavement distress conditions, but must be constructed correctly. Dig outs are recommended when the distress is severe but generally confined to small areas. The use of dig outs plus chip sealing is not recommended due to the problems with flushing or chip loss and higher cost. Blade patching is a necessary practice to address specific types of distress such as settlement or a rough ride.

References

Hicks, R. Gary, Stephen Seeds, and David G. Peshkin, "Selecting a Preventive Maintenance Treatment for Flexible Pavements", Foundation for Pavement Preservation, Washington, DC, June 2000.

Testa, Dean M., Mustague Hossain, "Kansas Department of Transportation 2014 Chip Seal Manual", Kansas Department of Transportation, Report No. K-TRAN:KSU-09-8, March 2014.

Appendix A

Test Site Data

Table 6. Test site descriptions.										
Test Site	Year	SR	DIR	Beg. SRMP	End SRMP	Length (miles)	Last Paved	Surface	Base	Age When Treated
Crack Sealing (12 sites)										
OR1	2012	101	I	321.90	322.10	0.20	2000	HMA	HMA	12
OR6	2013	8	D	17.55	17.75	0.20	1998	HMA	CTB	15
OR8	2013	101	I	344.90	345.30	0.40	2006	HMA	HMA	7
OR9	2013	105	B	47.88	47.98	0.10	1997	HMA	HMA	16
NC2	2014	2	B	98.87	100.81	1.94	2003	HMA	HMA	11
SC1	2015	97	I	69.20	74.20	5.00	2002	HMA	UTB	13
ER41	2016	395	B	202.79	207.82	5.03	2009	HMA	UTB	7
OR20	2016	12	I	17.80	20.96	3.16	2003	HMA	CTB	13
OR21	2016	12	B	21.30	22.20	0.90	2003	HMA	UTB	13
OR31	2016	115	B	0.00	2.28	2.28	2000	HMA	HMA	16
OR32	2016	160	B	0.70	1.03	0.33	1999	HMA	UTB	17
OR34	2016	302	B	1.00	1.25	0.25	2000	HMA	BST	16
Chip Sealing (4 sites)										
OR1b	2012	101	I	322.40	322.50	0.10	2000	HMA	HMA	12
OR3b	2012	101	I	152.22	152.45	0.23	1992	HMA	HMA	20
OR16	2013	12	B	37.35	37.55	0.20	1999	HMA	PCC	14
OR22	2015	101	B	167.00	167.50	0.50	1999	HMA	UTB	16
Wheel Path Chip Sealing/Cracking (2 sites)										
OR12	2013	20	B	7.90	10.20	2.30	2001	HMA	PCC	12
OR23	2015	104	B	9.00	10.10	1.10	2006	HMA	UTB	9
Wheel Path Chip Sealing/Rutting (5 sites)										
ER7	2013	20	B	390.43	402.00	11.57	2006	BST	BST	5
ER10	2014	2	B	253.55	256.75	3.20	1999	HMA	HMA	15
ER15	2015	395	B	219.00	221.00	2.00	2003	HMA	UTB	12
ER18	2015	31	B	0.00	1.00	1.00	2008	BST	UTB	7
ER40	2016	270	B	3.88	8.89	6.01	2007	HMA	UTB	9
Crack Seal Plus Chip Seal (2 sites)										
OR1a	2012	101	I	322.10	322.40	0.30	2000	HMA	HMA	12
NC1	2014	155	B	9.00	9.50	0.50	2006	BST	BST	8
Dig Outs (22 sites)										
OR2	2012	8	D	10.50	10.60	0.10	1995	HMA	CTB	17
ER2	2012	2	I	291.21	295.85	4.64	2005	HMA	PCC	8
ER3	2012	291	D	13.36	13.80	0.14	2004	HMA	HMA	8
ER4	2013	2	I	288.22	291.21	2.99	2005	HMA	PCC	8
ER5	2013	2	B	263.45	264.40	0.95	1998	HMA	PCC	15

Table 6. (Continued).

Test Site	Year	SR	DIR	Beg. SRMP	End SRMP	Length (miles)	Last Paved	Surface	Base	Age
Dig Outs (continued)										
OR5	2013	7	D	53.71	53.86	0.15	2004	HMA	PCC	9
OR8a	2013	101	I	344.90	345.30	0.40	2006	HMA	HMA	7
OR10	2013	510	B	7.08	7.23	0.15	2001	HMA	PCC	12
OR11	2013	20	B	3.90	4.00	0.10	2006	HMA	HMA	7
OR15	2013	12	B	35.20	35.40	0.20	1999	HMA	HMA	14
ER9	2014	395	B	193.67	196.78	3.11	2009	HMA	HMA	5
ER11	2014	270	B	0.78	2.25	1.47	2002	HMA	HMA	12
SW5	2014	6	B	6.30	6.80	0.50	2005	BST	BST	9
ER17	2015	395	D	65.30	65.50	0.20	2007	HMA	CTB	8
ER24	2015	127	B	10.50	10.80	0.30	2004	HMA	UTB	11
ER29	2015	27	B	34.80	36.10	1.30	2012	BST	UTB	3
OR24	2015	119	B	3.50	4.00	0.50	2006	BST	UTB	9
OR28	2015	207	B	39.90	43.50	3.60	2005	HMA	PCC	10
SC5	2015	12	B	356.97	358.20	1.23	2000	HMA	UTB	15
SW6	2015	6	D	32.10	32.30	0.20	2010	BST	PCC	5
ER42	2016	20	B	379.16	390.41	11.25	2011	BST	UTB	5
ER43	2016	395	B	230.90	241.73	10.83	2005	HMA	HMA	11
Dig Outs Plus Crack Sealing (4 sites)										
ER1	2012	2	I	299.30	299.60	0.30	2002	HMA	HMA	10
OR4	2013	3	I	53.36	53.47	0.11	1993	HMA	HMA	20
OR27	2015	307	B	5.00	5.25	0.25	1992	HMA	UTB	23
SC4	2-15	395	B	23.48	24.58	0.90	2007	HMA	UTB	8
Dig Outs Plus Chip Seal (6 sites)										
OR2a	2012	8	D	10.60	11.00	0.40	1995	HMA	CTB	17
OR3	2012	101	I	151.74	151.90	0.16	1992	HMA	HMA	20
SW1	2012	14	B	119.54	129.00	9.46	2000	BST	BST	12
SW1a	2012	14	B	129.00	129.25	0.25	2000	BST	BST	12
OR14	2013	7	B	28.50	28.65	0.15	1999	HMA	PCC	14
NC3	2014	207	B	0.44	0.57	0.13	2008	BST	BST	6
Blade Patch (8 sites)										
ER8	2014	195	B	62.15	69.94	7.79	2006	HMA	HMA	8
ER9a	2014	395	B	195.10	195.20	0.10	2009	HMA	HMA	5
ER20	2015	272	B	17.70	18.10	0.40	2008	BST	ATB	7
ER26	2015	127	B	22.00	23.00	1.00	2011	BST	UTB	4

Table 6. (Continued).Table 8. (Continued)										
Test Site	Year	SR	DIR	Beg. SRMP	End SRMP	Length (miles)	Last Paved	Surface	Base	Age
Blade Patch (continued)										
ER32	2015	20	B	310.00	318.60	8.60	2011	BST	BST	4
ER33	2015	270	B	5.50	6.50	1.00	2007	HMA	UTB	8
ER34	2015	271	B	2.00	2.10	0.10	2012	BST	BST	3
ER37	2015	395	B	227.90	228.50	0.60	2002	HMA	UTB	13
Control Sections (4 sites, no treatment)										
OR3a	2012	101	I	151.90	152.00	0.10	1992	HMA	HMA	20
ER1a	2012	2	I	299.60	299.72	0.12	2002	HMA	HMA	10
ER2a	2012	2	I	291.55	291.85	0.30	2005	HMA	PCC	7
ER3a	2012	291	B	13.50	13.80	0.30	2004	HMA	HMA	8

Appendix B

Test Site Pavement Performance

Introduction

The following information on pavement performance is included for those readers interested in what effect preventive maintenance treatments had on pavement performance. The first section addresses the test sites that were terminated by rehabilitation with a full lane chip seal or HMA grind/inlay. The second section shows how the treatments affected the structural condition of all of the test sites from the initial application to the 2016 survey.

Pavement Performance

The performance of the pavement in the 17 test sections that were terminated due to the application of a chip seal or HMA grind/inlay was examined beginning first with how pavements performed in each of the treatment categories. The test sites will then be examined to see if the initial structural condition had an influence on the performance of the pavements. Finally, the effect of traffic, climate and the use of traction devices will be accessed.

The treatment receiving rehabilitation with chip seals or HMA grind/inlays were dig out sites with eight followed by the blade patch sites with three (see Table 7). If the combination treatment sites of dig out sites with crack sealing and chip sealing are included in the dig out total, the results is 11 of the 17 sites or 65 percent of the dig outs sites receiving a chip seal or HMA grind/inlay. The blade patch treatment accounted for the next highest number with 3 sites. In total, 14 of the 17 sites were either dig out or blade patch sites, which is 82 percent of the total that received a chip seal or HMA, grind/inlay. Dig outs and blade patches are used on pavements with severe distress such as extensive alligator and longitudinal cracking or complete failures of the pavement in the case of blade patching. The severity of the distress in the original pavement appears to be one of the controlling factor in test sites receiving rehabilitation with a chip seal or HMA grind/inlay.

Table 7. Test sites receiving additional treatment for each treatment type.

Treatment Type	Sites with Additional Treatment	Percent of Total Sites Receiving Additional Treatment
Crack Sealing	1	6
Full Lane Chip Seal	0	0
Wheel Path Chip Seal for Cracking	0	0
Wheel Path Chip Seal for Rutting	2	12
Crack Seal Plus Chip Seal	0	0
Dig Outs	8	47
Dig Outs Plus Crack Seal	2	12
Dig Outs Plus Chip Seal	1	6
Blade Patch	3	17
Total	17	100%

It would be expected that test sites that were in the Poor structural condition category would receive rehabilitation sooner than sites that started as Good structural condition category. The Good category had the most sites rehabilitated with eight out of 17 sites (see Table 8). The Fair category had the least with seven sites and the Poor category two sites. It does not seem that the requirement for additional treatment correlates with the original structural condition of the pavement in the test site. An examination of the Good category test sites revealed that four were dig outs sites, three were blade patch sites, two were wheel path chip seal for rutting sites, and one was a crack seal site. The Fair category had six dig out sites and one blade patch site. It appears that the type of distress that required dig outs or a blade patch was the controlling factor and not the structural condition. This is probably the due to a few areas of alligator cracking in a one mile test section not be enough distress to lower the structural condition from Good to Fair.

Table 8. Test sites with additional treatment versus structural condition prior to treatment.

Test Site Structural Category	Additional Treatment Required	Percentage Requiring Additional Treatment
Good	8	47%
Fair	7	41%
Poor	2	12%
	17	100%

"Throughout the life-cycle of the pavement, the effects of truck traffic, climate, and traction devices will deteriorate the pavement condition" (from *Integrated Approach to Pavement Preservation*). One of a combination of these factors results in a pavement needing maintenance. The focus of this section is to determine what part each has played in the initial need for maintenance and eventually rehabilitation in the form of a chip seal or HMA grind/inlay. Table 9 lists the 17 sections that have reached the point where rehabilitation has occurred. The test sites are ordered from highest traffic to lowest traffic.

The data shows that three of the test sites with the highest traffic levels, ER1, ER2, and ER4, (all dig out sites) received additional dig outs and then an HMA grind/inlay. All three sites are on SR2 in Spokane. The Spokane urban area has the highest use of traction devices in the state. With the help of the preventive maintenance treatments the three sites managed to achieve the 12-15 years of service in Eastern Washington where the average for HMA pavement is 12.3 years. One additional test site with high AADT and a large truck percentage, SC4, received an HMA grind/inlay two years after the initial treatment which was dig outs and crack sealing. SC4 also managed to achieve the average service life of 12 years. ER4 and ER2 were Fair category sites and ER1 and SC4 were Poor category sites. The combination of Poor or Fair structural condition, high traffic levels, harsh climate and high use of traction devices resulted in an accelerated deterioration of the pavement condition that required additional treatment and eventually complete rehabilitation.

In contrast, OR6, OR2, and OR2a had high traffic levels, but managed, with the help of the preventive maintenance treatments, to not only achieve the average service life of 17.3 years but exceed it by two years for OR6 and by five years for OR2 and OR2a. OR6 and OR2a were in the Good structural category and OR2 in the Fair category. High traffic levels did not accelerate the deterioration of the pavement for these three sites. This is an example of the impact a milder climate and minimal use of traction devices has on extending pavement life.

It is interesting to note that of the remaining ten test sites that received a HMA grind/inlay or chip seal, eight are located in Eastern Washington where the climate is harsh and traction devices are utilized. It is also interesting to note that the majority are dig out or blade patch sites. As noted previously, the severe nature of the distress that results in the use of dig outs and blade patches indicates that the pavement is reaching the end of its service life. The service life of these ten pavements was extended from two to five years, with the majority being two years.

The severity of the distress in the test site was the controlling factor in a test site receiving rehabilitation in the form of a chip seal of HMA grind/inlay. The combination of severe distress, high traffic levels, harsh climate and the high use of traction devices was observed to accelerate the damage to the pavement in the test sites located in the Spokane urban area. Test sites in Eastern Washington with low traffic levels but severe distress (those requiring dig outs or blade patches) may require preventive maintenance treatment to achieve average pavement life due to the harsh climate.

Table 9. Traffic and pavement life data for the test sites terminated by a chip seal of HMA grind/inlay.

Test Site	Route	Pavt. Type	AADT	Percent Trucks	Treatment	Additional Treatment	Age At Treatment	Age At HMA grind/inlay or BST
ER4	2	HMA	40,100	2.9	Dig outs	Dig outs at 1 and 3 years, HMA grind/inlay at 5 years.	8	13
ER2	2	HMA	31,500	3.0	Dig outs	Dig outs at 1 and 3 years, HMA grind/inlay at 5 years.	7	12
ER1	2	HMA	21,400	4.8	Dig Outs + crack seal	Dig outs at 3 years, HMA grind/inlay at 5 years.	10	15
SC4	395	HMA	18,100	22.6	Dig outs + crack seal	HMA grind/inlay at 2 years.	8	10
OR6	8	HMA	17,100	9.3	Crack Seal	HMA grind/inlay at 4 years.	15	19
OR2a	8	HMA	15,900	9.3	Dig outs + chip seal	HMA grind/inlay at 5 years.	17	22
OR2	8	HMA	15,800	9.3	Dig outs	HMA grind/inlay at 5 years.	17	22
ER3	291	HMA	7,300	6.0	Dig outs	More dig outs at 3 years, chip seal at 5 years.	8	13
ER37	395	HMA	7,200	13.1	Blade patch	HMA grind/inlay at 2 years.	13	15
ER11	270	HMA	6,200	7.4	Dig outs	HMA grind/inlay at 3 years.	12	15
OR15	12	HMA	5,000	14.3	Dig outs	Chip seal at 3 years.	14	17
SW5	6	BST	2,800	12.1	Dig outs	Chip seal at 3 years.	9	12
OR24	119	BST	2,738	1.7	Dig outs	HMA grind/inlay at 2 years.	9	11
ER34	271	BST	2,000	15.1	Blade patch	Chip seal at 2 years.	3	5
ER18	31	BST	1,000	11.7	WP chip seal, rutting	Chip seal at 2 years.	7	9
ER20	272	BST	900	5.0	Blade patch	Chip seal at 2 years.	7	9
ER7	20	BST	850	19.0	WP chip seal, rutting	Chip seal at 2 years.	5	7

Note: Average service life for HMA is 12.3 years in Eastern WA and 17.3 in Western WA.
Average service life for chip seals is 7.1 in Eastern WA and 9.7 in Western WA. ER and SC are Eastern WA sites.
OR is Western WA.

Pavement Performance Over Time

The change in structural condition (PSC) prior to treatment and then each year after treatment is plotted for the test sites installed in 2012, 2013 and 2014. There are no plots for the sites installed in 2015 or 2016 due to the lack of sufficient data points to make them meaningful.

Figure 147 shows the yearly PSC data for the test sites that received preventive maintenance in 2012. The Good, Fair and Poor categories are delineated on the left side of the graph to show the initial condition of each test site. Patching and crack sealing reduce the PSC, but not as much as unsealed cracks or severe alligator cracking. When preventive maintenance treatments are applied such as crack sealing and dig outs the PSC value is increased for pavements in poor condition and stay at a relative constant rate for pavements in good condition. The PSC of pavements in the Poor category may increase into the Fair category after treatment and remain relatively constant year after year. Conversely, the PSC of a pavement in the Good category may decrease into the Fair category as the pavement continues to deteriorate, but preventive maintenance will maintain it at that level year after year.

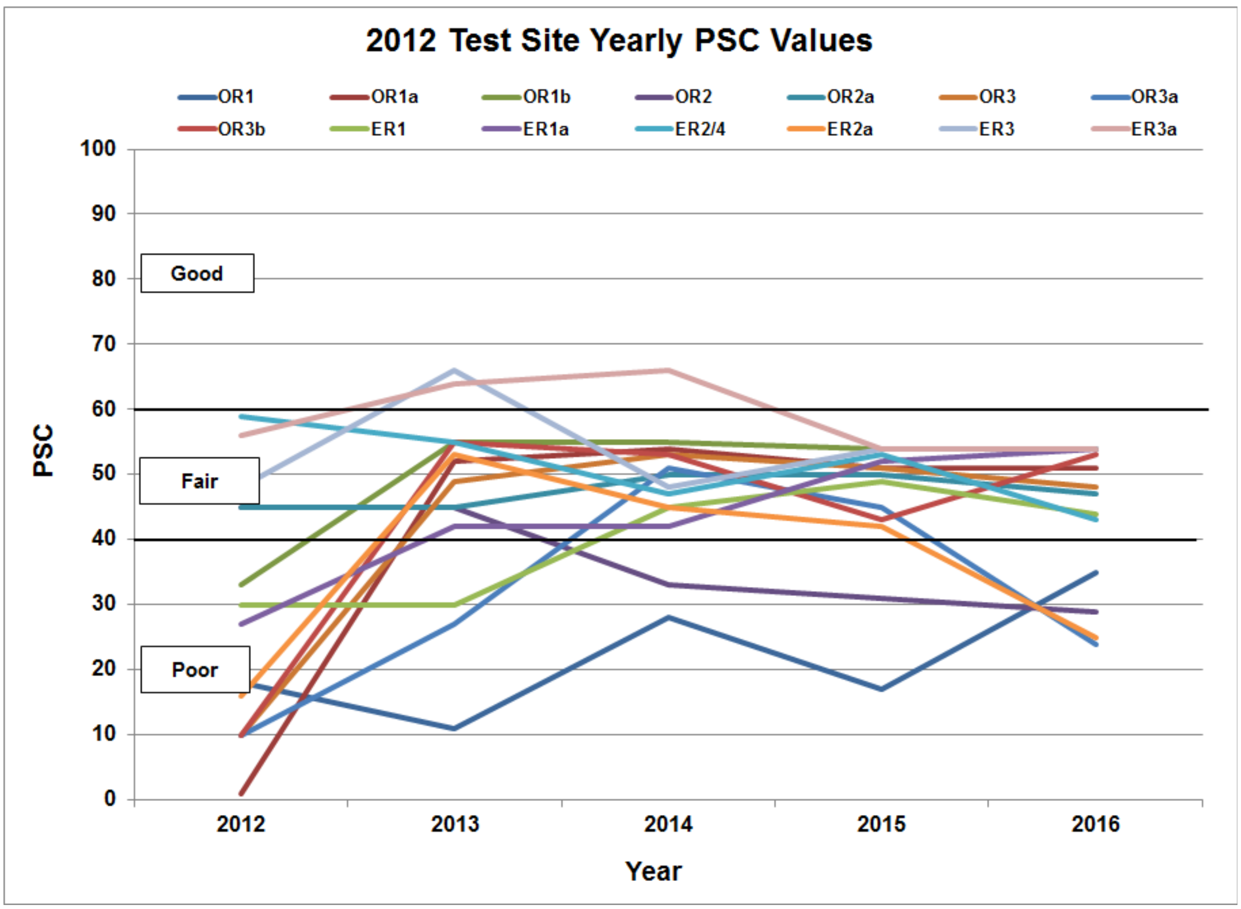

Figure 147. Yearly PSC values for the 2012 test sites.

The preventive maintenance for 2012 would have been installed after the 2012 ratings; therefore, the ratings for 2013, 2014 and 2015 reflect any changes resulting from the treatments. Ignoring the general up-trend from the 2012 to the 2013 ratings, the curves are generally flat for the ratings from 2013 to 2015. The up-trend from 2012 to 2013 can be attributed to the application of the preventive maintenance treatments. All of the 2012 pavements for the 2012 test sites were in the Poor or Fair categories, therefore; the improvements in PSC scores is much greater than if the pavements were in the Good category. The largest changes are for the test sites that were in the Poor category prior to treatment (OR1, OR1a, OR1b, ER1, ER1a, ER2a, ER3a, OR3, and OR3b). These test sites are indicted on the chart and have 2012 PSC values below 39. The sites in the Fair category (OR2a, ER3, ER2/4, and ER4) had relatively flat curves showing little improvement in PSC. These test sites are the lines that begin with 2012 PSCs between 40 and 60. This is also reasonable since preventive maintenance is not designed to improve structural condition, but rather preserve it. In summary, the preventive maintenance treatments applied in 2012, generally speaking, preserved Fair category pavements at the same level and improved Poor category pavements.

Figure 148 shows the yearly PSC data for test sites that received preventive maintenance in 2013.

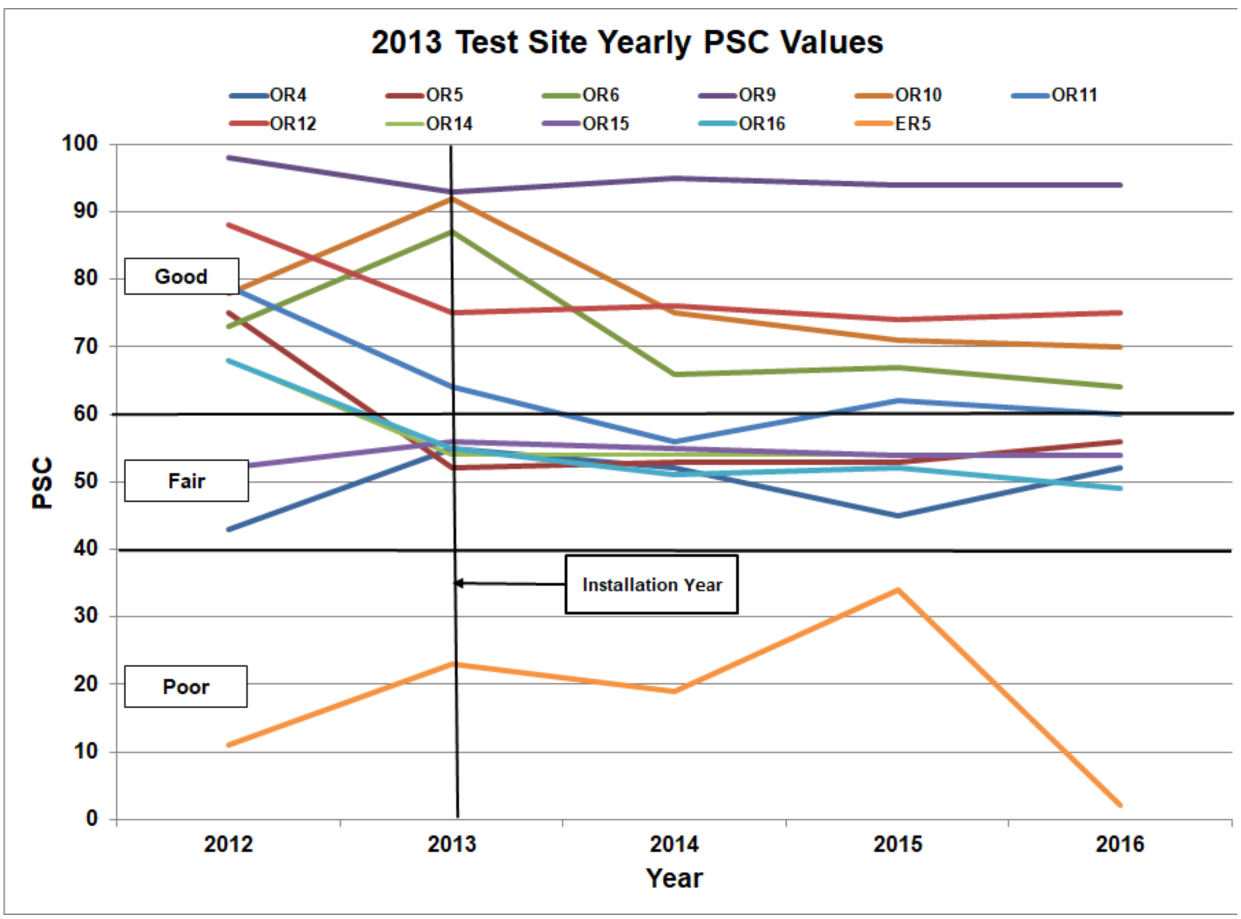

Figure 148. Yearly PSC values for the 2013 test sites.

The preventive maintenance treatments would have been applied after the 2013 ratings, therefore, the 2014 and 2015 values are the ones that reflect the changes due to preventive maintenance and these values are essentially flat. The PSC values for a majority of the test sites decreased slightly between 2014 and 2015. In summary, the preventive maintenance treatments did very little to change the structural condition of the pavement in the test sites, but did preserve the condition of the pavements at the pre-treatment levels.

Figure 149 shows the yearly PSC data for the sites that received preventive maintenance in 2014.

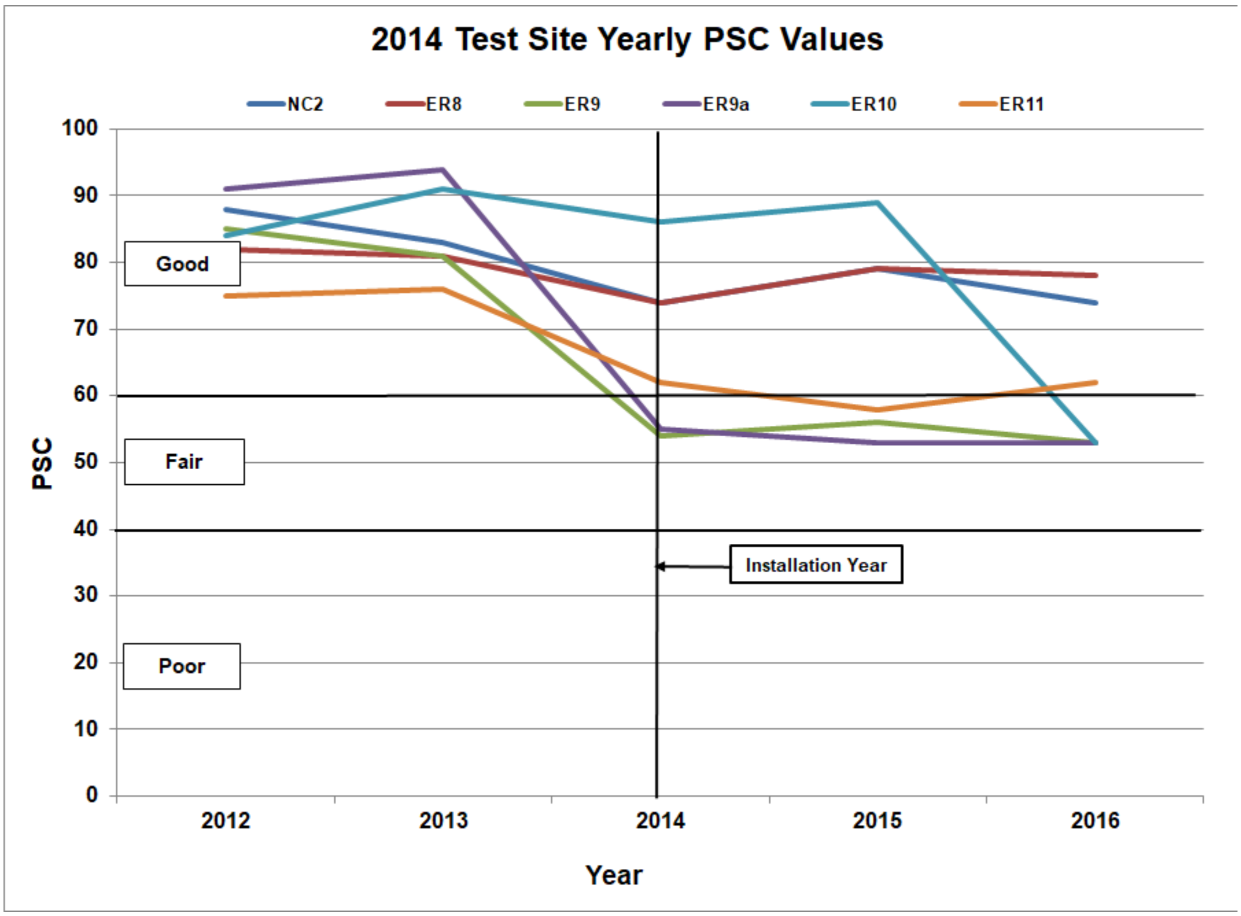

Figure 149. Yearly PSC values for the 2014 test sites.

The PSC ratings for the 2014 test sites were done in the spring of 2014 and the preventive maintenance treatments were applied in the summer of 2014, therefore only the 2015 and 2016 ratings reflect changes resulting from the treatments. The trend in PSC values is level for five of the six sites and down for the remaining site. The preventive maintenance treatments generally maintained the PSC values of the pavements prior to treatment.

In summary, the PSC values did not increase for the test site pavements after the treatments were applied except for those test sites with pavements in the Poor category. The PSC scores for test sites with pavements in the Fair and Good categories generally stay at the same level as they were prior to treatment, indicating that the structural condition of the pavements were stabilized by the maintenance treatment. The PSC data is compiled in Table 10.

Table 10. Yearly PSC data for each test site.

Test Site	PSC				
	2012	2013	2014	2015	2016
2012 Test Sites					
OR1	18	11	28	17	35
OR1a	1	52	54	51	51
OR1b	33	55	55	54	54
OR2	45	No Data	33	31	29
OR2a	No Data	No Data	50	50	47
OR3	No Data	49	53	51	48
OR3a	No Data	27	51	45	24
OR3b	10	55	53	43	53
ER1	30	45	No Data	49	44
ER1a	27	42	No Data	52	54
ER2/4	59	55	47	53	43
ER2a	16	53	45	42	25
ER3	48	66	48	54	54
ER3a	56	64	66	54	25
SW1	No Data	No Data	No Data	71	No Data
SW1a	No Data	No Data	No Data	64	No Data
2013 Test Sites					
OR4	43	55	52	45	52
OR5	75	52	53	53	56
OR6	73	87	66	67	64
OR8	Ramp No Data				
OR8a	Ramp No Data				
OR9	98	93	95	94	94
OR10	78	92	75	71	70
OR11	79	64	56	62	60
OR12	88	75	76	74	75
OR14	68	54	54	54	96
OR15	52	56	55	54	No Data
OR16	68	55	51	52	49
ER5	11	23	19	34	2
ER7	No Data	No Data	No Data	No Data	No Data

Table 8. (Continued)					
Test Site	PSC				
	2012	2013	2014	2015	2016
2014 Test Sites					
NC1	No Data	No Data	No Data	No Data	No Data
NC2	88	83	74	79	74
NC3	No Data	No Data	No Data	No Data	No Data
ER8	82	81	74	79	78
ER9	85	81	54	56	53
ER9a	91	94	55	53	No Data
ER10	84	91	86	89	53
ER11	75	56	62	58	62
SW5	No Data	No Data	No Data	54	53
2015 Test Sites					
OR22	87	85	93	96	99
OR23	94	95	96	83	75
OR24	No Data	No Data	79	64	No Data
OR27	60	63	66	58	61
OR28	94	94	85	80	76
ER15	95	97	95	54	54
ER17	50	84	68	47	52
ER18	No Data	No Data	91	82	No Data
ER20	No Data	No Data	87	78	No Data
ER24	99	96	99	96	99
ER26	No Data	No Data	No Data	No Data	No Data
ER29	No Data	No Data	No Data	97	92
ER32				No Data	No Data
ER33	100	99	100	100	55
ER34				No Data	No Data
ER37	69	91	58	50	70
SC1	68	62	57	45	51
SC4	89	92	68	32	30
SC5	80	65	65	65	64
SW6	No Data	No Data	No Data	82	59

Table 8. (Continued)					
Test Site	PSC				
	2012	2013	2014	2015	2016
2016 Test Sites					
OR20	89	83	91	87	86
OR21	97	93	No Data	91	74
OR31	87	85	93	96	95
OR32	52	62	64	78	58
OR34	89	95	87	93	80
ER40	99	98	99	97	54
ER41	98	99	98	97	96
ER42	No Data	No Data	No Data	No Data	No Data
ER43	82	83	86	86	88