POLYMER MODIFIED CHIP SEAL TEST ON OREGON ROUTE #22

North Santiam Highway (HWY #162, OR Route #22) Marion County, Oregon

Final Report

State Research Project #526

by

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16. Abstract

In 1987 ten chip seal sections were constructed on Oregon Route #22 near Stayton in Marion County. CRS-2 emulsion with conventional asphalt was used in the control sections. Two other emulsions in the 1987 ODOT specifications were used in the test sections: HFE-90 with conventional asphalt, and HFE-100S with polymer modified asphalt. Several emulsions rarely or never used in Oregon were also tried: CRS-2P, CRS-2R, CRS-2D, LMCRS-2H, CRS-2(P1) and CRS-2K. All used polymer modified asphalt.

In 1992, after five years of use, the seals were visually inspected and their friction numbers were measured. The condition of the chip seals were as follows: 1) CRS-2(P1): excellent condition, functional. 2) CRS-2 Calibration Section: excellent condition, functional. The calibration section's rating, however, was based on the amount of exposed surface asphalt, chip retention, and aggregate embedment only. The seal's resistance to raveling and ability to seal cracks was not known. 3) HFE 100S, CRS-2D, and CRS-2K: fair condition, functional. 4) CRS-2 Control Sections: poor condition, functional. 5) CRS-2R: poor condition, failed after five years due to poor crack sealing ability. 6) CRS-2P, HFE-90 and LMCRS-2H: failed after four years due to poor crack sealing ability.

All seals had similar and adequate friction numbers. In addition, all seals that were still functional at the end of five years were considered successful, according to local maintenance personnel. A double application of aggregate prior to the release of traffic onto the seals helped the performance of several test sections.

The comparative performance of these seals was influenced by other factors in addition to emulsion properties. As a result, the performance of some of the emulsions in this study may not represent their behavior.

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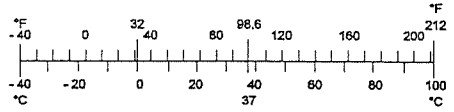
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

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DISCLAIMER

POLYMER MODIFIED CHIP SEAL TEST ON OREGON ROUTE #22

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1.0 INTRODUCTION

The Oregon Department of Transportation (ODOT) constructed ten chip seal test sections on the North Santiam Highway near Stayton in 1987[1,2]. The purpose of this project was to see if several polymer modified emulsions available in Oregon could provide superior chip seals. A commonly used emulsion in the 1987 OSHD Specifications for Asphalt Materials was used as a standard for comparison. It was:

- CRS-2 cationic emulsion with a conventional asphalt.

Two other emulsions in the 1987 OSHD Specifications were tried. They were:

- HFE-90 anionic high-float emulsion with a conventional asphalt;
- HFE-100S anionic high-float emulsion with Styrelf polymerized asphalt by Elf Aquitane.

Several emulsions not typically used in Oregon were also tested. They were:

- CRS-2P cationic emulsion with latex rubber by Polysar;
- CRS-2R cationic emulsion with AC-20R polymerized asphalt by Asphalt Supply and Service;
- CRS-2D cationic emulsion with Ductilad polymerized asphalt by LBD;
- LMCRS-2H cationic "hard residue" emulsion with polymerized asphalt containing Neoprene by DuPont;
- CRS-2(P1) cationic emulsion with Chevron's CA(P)-1 polymerized asphalt containing Elvax EVA by DuPont; and
- CRS-2K cationic emulsion with Chevron's CA(P)-2 polymerized asphalt containing Kraton by Shell.

This report presents the chip seals' condition in October 1992 and surface friction in May 1992. Comparisons between the various sections are presented. Conclusions and recommendations are included, and the current ODOT specifications for chip seal emulsions and chip seals are in the report appendices.

2.0 CHIP SEAL RATING CRITERIA

The condition of the chip seals was rated using a system developed for this study[1]. The rating criteria are:

1. **Exposed Surface Asphalt (in wheeltrack)**
   5 = Excellent: 0 to 10% exposed surface asphalt
   4 = Good: 11 to 30% exposed surface asphalt
   3 = Fair: 31 to 60% exposed surface asphalt
   2 = Poor: 61 to 90% exposed surface asphalt
   1 = Unsatisfactory: 91 to 100% exposed asphalt

2. **Chip Retention - ¼ inch to ⅜ (6 to 10mm) inch chips in wheeltrack**
   5 = Excellent: 81 to 100% chip retention
   4 = Good: 61 to 80% chip retention
   3 = Fair: 41 to 60% chip retention
   2 = Poor: 21 to 40% chip retention
   1 = Unsatisfactory: 0 to 20% chip retention

3. **Aggregate Embedment (in wheeltrack)**
   5 = Excellent: 50 to 60% of average aggregate height is embedded
   4 = Good: 61 to 70% of average aggregate height is embedded
   3 = Fair: 71 to 80% of average aggregate height is embedded
   2 = Poor: 81 to 90% of average aggregate height is embedded
   1 = Unsatisfactory: 91 to 100% of average aggregate height is embedded

4. **Resistance to Raveling (comparison among sections)**
   5 = Excellent
   4 = Good
   3 = Fair
   2 = Poor
   1 = Unsatisfactory

5. **Effectiveness of Crack Sealing (comparison among sections)**
   5 = Excellent
   4 = Good
   3 = Fair
   2 = Poor
   1 = Unsatisfactory

6. Overall Seal Condition Rating (Average of ratings 1 through 5)

Excellent =	from 4.5 to 5
Good =	from 3.5 to 4.4
Fair =	from 2.5 to 3.4
Poor =	from 1.5 to 2.4
Unsatisfactory =	from 0 to 1.4

7. Serviceability

The chip seals were considered "functional" if they:

1) Were sealing the majority of the alligator cracking in the evaluation section's wheeltracks. Before the chip seals there was alligator cracking throughout both wheeltracks in each of the ten evaluation sections. The extent of the alligatoring in the CRS-2 calibration section was not known.

2) Were not paved over by maintenance forces.

3) Had a friction number of 37 or higher.

If the seals did not meet any of the above criteria, they were considered to have "failed".

3.0 PERFORMANCE COMPARISON

This chapter includes a summary of the performance of the seals at the end of the five-year study, a detailed narrative description of each section's condition, comments on the frictional properties of the sections, and photographs of the seals.

3.1 SUMMARY

This section provides a summary of the performance of each test section at the end of the five year study. In addition, it is noted which ODOT chip seal specification includes the emulsion. ODOT allows use of all of these emulsions in one of their three chip seal specifications: Emulsified Asphalt Chip Seals, Polymer Modified Emulsified Asphalt Chip Seals (Standard Duty), and Polymer Modified Emulsified Asphalt Chip Seal (Heavy Duty). The current ODOT specifications for chip seal emulsions and chip seals are included in the Appendices. The comparative performance of the sections is shown in Table 1.

CRS-2 - Overall, this conventional emulsion performed well. It was a good crack sealer on the control sections and it had excellent chip retention on the calibration section. In the control sections, this product may have been a top performer if it had been covered with sand and rolled before it was exposed to traffic. This was done on the calibration section. CRS-2 emulsion is included in the ODOT specifications for standard duty chip seals with conventional emulsions.

CRS-2P - This emulsion performed the worst. However, its poor ranking in this test may be due to specific characteristics of the emulsion used on this job, and it may perform better on other projects. This was the only emulsion where the latex was blended with the emulsion in the tanker at the job site, and this on site blending may have compromised the product's performance. This emulsion can be blended at the refinery like the other products, and refinery blending may improve its performance.

Unlike the other seals, this emulsion's test section required a maintenance patch earlier than the other sections because it was not sealing the pavement's cracks. This patch did not cover only this product's test section. Rather, it extended a short distance into the adjacent test sections. In addition, the patch covered a section of the road that traversed a swampy area. The size and location of this distressed and patched area may indicate the pavement was overly flexible due to poor support from the roadway's base and/or sub-base materials. As a consequence, this section's early failure may be due to causes other than emulsion performance. CRS-2P emulsion is included in the ODOT specifications for standard duty chip seals with polymer modified emulsions.

Table 1: 1992 Performance Comparison of Chip Seal Sections

Section	Exposed[1] Surface Asphalt	Chip Retention[1]	Aggregate Embedment[1]	Resistance to Raveling[2]	Effectiveness of Crack Sealing[2]	Average	Overall Seal Condition Rating	Serviceability
CRS-2 East	2	1	2	3	3	2.2	Poor	Functional
CRS-2P[3]	-	-	-	-	-	-	-	Failed 1991
CRS-2R	3	3	3	1	1	2.2	Poor	Failed 1992
HFE-100S	3	5	4	2	3	3.4	Fair	Functional
HFE-90	3	1	3	1	1	1.8	Poor	Failed 1991
CRS-2D	3	5	4	1	2	3.0	Fair	Functional
LMCRS-2H	2	4	2	1	1	2.0	Poor	Failed 1991
CRS-2(P1)	4	5	5	5	5	4.8	Excellent	Functional
CRS-2K	3	5	2	3	4	3.4	Fair	Functional
CRS-2 West	2	1	2	2	3	2.0	Poor	Functional
CRS-2 Calibration	3	5	5	5[4]	5[4]	4.6	Excellent	Functional

[1] The performance ratings for Exposed Surface Asphalt, Chip Retention, and Aggregate Embedment are for pavement in the wheeltracks.

[2] The performance ratings for Resistance to Raveling and Effectiveness of Crack Sealing are comparisons among the sections.

[3] No data is available, as section was covered by an asphalt-concrete maintenance patch in 1991.

[4] The Resistance to Raveling and Effectiveness of Crack Sealing ratings for the CRS-2 Calibration section should not be compared to the other sections. The condition of the pavement under the Calibration section is not known. It may have had less distress than the other sections at the time it was sealed.

CRS-2R - This emulsion's section failed after five years of use due to poor crack sealing ability. Problems with the blending of this test section's emulsion resulted in a polymer content of 1.5% binder weight, rather than the desired 2%. This low polymer content may have reduced the ability of the binder to seal cracks and retain aggregate around crack edges. As a result, the poor performance may be due to unique characteristics of the emulsion used on this project, rather than the properties of typical CRS-2R emulsions. CRS-2R emulsion is included in the ODOT specifications for standard duty chip seals with polymer modified emulsions.

HFE-100S - This emulsion's section performed better than the other five seals placed on June 17, 1987 - the CRS-2 East and West, CRS-2P, CRS-2R, HFE-100S, and HFE-90 sections. These sections were constructed by similar methods and under similar conditions. As a result, the good performance of this seal may be due to superior properties of the emulsion. An equivalent of this emulsion, HFRS-P2, is in the ODOT specifications for heavy duty chip seals.

HFE-90 - This emulsion was a poor performer when compared to the CRS-2 control sections that were placed on the same day. It was especially poor at sealing cracks and retaining aggregate around crack edges. This may be linked to emulsion characteristics because there are no other known factors that could have hurt its performance. An equivalent of this emulsion, HFRS-2, is in the ODOT specifications for standard duty chip seals using conventional emulsions.

CRS-2D - The CRS-2D section was an adequate performer because its section was in fair condition and functional after the five year test period. CRS-2D emulsion is currently in the ODOT specifications for heavy duty chip seals.

LMCRS-2H - This emulsion did not resist raveling or seal cracks as well as the other three emulsions placed on the same day - CRS-2D, CRS-2(P1), and CRS-2K. Unlike the other three emulsions, its test section failed before the end of the five-year test period. The section's poor performance may be due to characteristics of the emulsion because there are no other known factors that could have hurt its performance. The underlying pavement appeared to be in similar condition to the other sections before sealing, and the construction techniques and environment during placement were similar to the other sections placed the same day. LMCRS-2H emulsion is in the ODOT specifications for standard duty chip seals using polymer modified emulsions.

CRS-2(P1) - This was the best performing emulsion. The test section was in excellent condition after five years and would likely have been functional for several more years. CRS-2(P1) emulsion is currently in the ODOT specifications for heavy duty chip seals.

CRS-2K - Overall, this emulsion performed well. The test section probably has several more years of functional life. Throughout most of the test period this section had "Fair" to "Poor" ratings for Exposed Surface Asphalt and Aggregate Embedment. These lower ratings were mainly due to the relatively high emulsion spread rate used on this section. CRS-2(K) emulsion is currently in the ODOT specifications for heavy duty chip seals.

3.2 NARRATIVE DESCRIPTION OF SEAL CONDITION

This section provides a detailed narrative description of the seals' performance.

The chip retention percentages in this chapter mention "original" aggregate. The original aggregate was spread during the initial application of rock onto the hot emulsion, and the stone grading varied from ⅜" to ¼" (10 to 6mm) on some sections to ⅜" (10mm) to #10 on others. After application it was rolled. All seals received a single application of original aggregate.

The chip retention percentages also refer to "choke" aggregate. This finer material was applied and rolled into the seal after the original aggregate was rolled, and the rock gradation was ⅜" (10mm) to #10. All seals had at least one application of choke aggregate.

On the CRS-2 Calibration, CRS-2D, LMCRS-2H, CRS-2(P1), and CRS-2K sections the choke material was rolled onto the seal immediately after the original aggregate was rolled. Traffic was kept off of the seals until the rolling of the choke aggregate was finished. These seals retained almost all of their original coarser cover stone throughout the study period, and as a consequence, they tended to have better ratings in the categories of Exposed Surface Asphalt, Aggregate Embedment, and Chip Retention.

On the CRS-2 Control, CRS-2P, CRS-2R, HFE-100S, and HFE-90 sections, traffic was allowed onto the seals during the evening after the original aggregate was rolled. The vehicles traveled on the seals during the night and they stripped significant amounts of the original aggregate from the wheeltracks of the CRS-2 Control, CRS-2P, CRS-2R, and HFE-90 sections. The HFE-100S section was the only seal that did not lose significant amounts of aggregate.

The next day one or more applications of choke stone were rolled onto all of the sections mentioned in the preceding paragraph and traffic was released onto the seals a second time. The exposed binder on many of the section's wheeltracks had hardened overnight and the bare areas would not retain a complete coverage of choke aggregate. In addition, the finer choke stone that was retained tended to embed deeply into the layer of chip seal binder. The binder layer was too thick for this finer aggregate because it was applied at a thickness suitable to properly imbed the coarser original aggregate. As a result, all of these sections except the HFE-100S seal tended to have average or poorer than average ratings for Exposed Surface Asphalt, Aggregate Embedment, and Chip Retention. The HFE-100S seal was average or above average in these categories.

"Ghosting" is mentioned in the discussion of Resistance to Raveling. Ghosting describes a loss of aggregate over sealed crack in the underlying pavement. The depressions due to lost aggregate in areas with ghosting revealed the pattern of the cracks in the sealed pavement - hence the term "ghosting".

All seals were in excellent condition outside of the wheeltracks. Out of the wheeltracks, they had 0 to 10% exposed surface asphalt, about 50% aggregate embedment, and almost complete retention of the original 1/4 to 3/8 inch (6 to 10 mm) cover stone. There was little ghosting,

raveling, or cracking on any section outside of the wheeltracks.

Almost all distress was in the wheeltracks. Consequently, in the narrative descriptions that follow, the comments on Exposed Surface Asphalt, Aggregate Embedment, and Chip Retention are for the seals in the wheeltracks. The rating and failure criteria are described in the previous chapter.

CRS-2 East - Exposed Surface Asphalt: 80%
Aggregate Embedment: 90%
Chip Retention: 10% original
90% choke

Resistance to Raveling: There was slight ghosting around seals underlying cracks and spalling around edges of wider open cracks. In comparison to other seals, Fair.

Effectiveness of Crack Sealing: Cracks were 1/16 to 1/2 inch (2 to 13 mm) wide, and one-fourth to one-third the length of each wheeltrack had open alligator cracking. In comparison to other seals, Fair.

This seal was functional.

CRS-2P - This seal failed in 1991 due to excessive cracking in the wheeltracks. It was paved over in 1991 with an asphalt-concrete maintenance patch.

CRS-2R - Exposed Surface Asphalt: 60%
Aggregate Embedment: 75%
Chip Retention: 50% original
50% choke

Resistance to Raveling: There was ghosting around 1/16 to 1/8 inch (2 to 3 mm) wide cracks in the inner wheeltrack and extensive spalling around other cracks in alligatored areas. Compared to other seals, Unsatisfactory.

This seal had failed in 1992 due to poor crack sealing ability.

HFE-100S - Exposed Surface Asphalt: 50%
Aggregate Embedment: 65%
Chip Retention: 90% original
10% choke

Resistance to Raveling: There was ghosting around sealed alligator cracks and spalling throughout the wheeltracks around open transverse alligator cracks. There was little spalling around open longitudinal cracks. Compared to other seals, Poor.

Effectiveness of Crack Sealing: About half the outer wheeltrack length and a quarter of the inner wheeltrack length had open alligatoring. Compared to other seals, Fair.

This seal was still functional.

HFE-90 - Exposed Surface Asphalt: 60%
Aggregate Embedment: 80%
Chip Retention: 20% original
80% choke

Resistance to Raveling: In the wheeltracks there was ghosting around sealed cracks and spalling around open cracks. Compared to other seals, Unsatisfactory.

Effectiveness of Crack Sealing: The alligator cracking was open throughout both wheeltracks. The severity of open cracking with many sections resembled the condition of the pavement before it was sealed. Compared to other seals, Unsatisfactory.

The seal failed in 1991 due to poor crack sealing ability.

CRS-2D - Exposed Surface Asphalt: 50%
Aggregate Embedment: 70%
Chip Retention: 90% original
10% choke

Resistance to Raveling: In the wheeltracks there was ghosting around sealed cracks and spalling around open cracks. Compared to other seals, Unsatisfactory.

Effectiveness of Crack Sealing: There was open alligator cracking throughout most of the outer wheeltrack and about a quarter of the inner wheeltrack length. Compared to other seals, Poor.

This seal bordered between being functional and having failed.

LMCRS-2H - Exposed Surface Asphalt: 70%
Aggregate Embedment: 85%
Chip Retention: 70% original
30% choke

Resistance to Raveling: In the wheeltracks, there was ghosting over sealed cracking and open alligator cracking. There was severe spalling around the cracks in some alligatored areas. Compared to other seals, Unsatisfactory.

Effectiveness of Crack Sealing: There was open alligatoring throughout the outer wheeltrack and most of the inner wheeltrack. The severity of the open cracking resembled the pavement condition before it was sealed. In comparison to the other seals, Unsatisfactory.

The seal failed in 1991 due to its poor crack sealing ability.

CRS-2(P1) - Exposed Surface Asphalt: 25%
Aggregate Embedment: 60%
Chip Retention: 100% original
0% choke

Resistance to Raveling: There was slight ghosting in sections of the wheeltracks and very little spalling around open cracks. Compared to other seals, Excellent.

Effectiveness of Crack Sealing: The only open cracks in the entire section were a very small number of narrow open alligator cracks in the outer wheeltrack. Compared to other seals, Excellent.

This seal was functional.

CRS-2K - Exposed Surface Asphalt: 50%
Aggregate Embedment: 85%
Chip Retention: 90% original
10% choke

Resistance to Raveling: There was ghosting over sealed alligator cracks in isolated sections of the wheeltracks, and spalling around open alligator cracks. Compared to other seals, Fair.

Effectiveness of Crack Sealing: Isolated sections of the outer wheeltracks had open alligator cracking. Compared to other seals, Good.

This seal was functional.

CRS-2 West - Exposed Surface Asphalt: 80%
Aggregate Embedment: 90%
Chip Retention: 10% original
90% choke

Resistance to Raveling: There was very little ghosting over underlying sealed cracks. In some sections of the wheeltrack there was severe spalling around open alligator cracking. Compared to other seals, Fair.

Effectiveness of Crack Sealing: There was open alligator cracking in sections of both wheeltracks. Compared to other seals, Fair.

This seal was functional.

CRS-2 Calibration
(Westbound Lanes) - Exposed Surface Asphalt: 50%
Aggregate Embedment: 60%
Chip Retention: 100% original
0% choke

Resistance to Raveling and Effectiveness of Crack Sealing: There was no ghosting and no open cracking. Although this seal is in extremely good condition, it is not known if the pavement that this chip seal covers was as badly distressed as the road under the other seals. As a result, information about the resistance to raveling or effectiveness of crack sealing ratings should not be used to directly compare this CRS-2 pavement to the other sections.

This seal was functional.

3.3 FRICTION TESTING

The friction of sections in the westbound lane was measured on May 20 and 26, 1992. All testing was done at speeds near 65 km/h (40 mph) in the left wheeltrack of the outer lane. The test data were adjusted to standard 65 km/h (40 mph) friction numbers (FN_{40}) using correlation equations. The test methods, calibration techniques, and equipment conformed to AASHTO T 242-90. All of the test sections' seals had similar friction values, and all friction numbers were adequate.

3.4 PHOTOS

This section includes photos of each seal.

Figure 1: CRS-2 East at Station 2+25 facing east.

This was one of the sections with open alligator cracking in the outer wheeltrack. The glare is sunlight reflecting off of the wet seal.

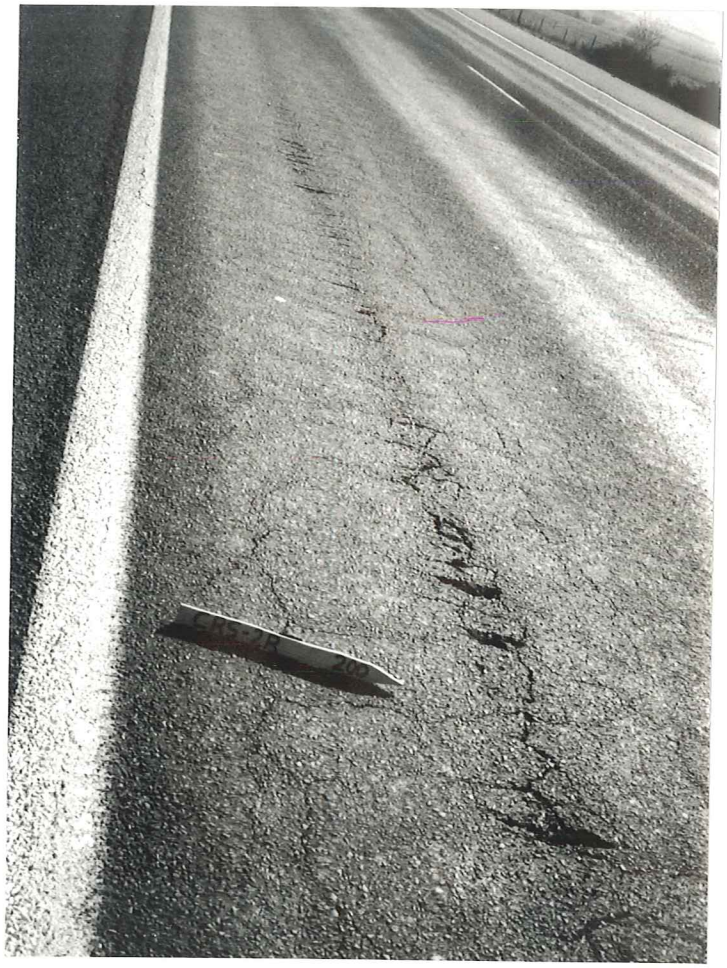

Figure 2: CRS-2R at Station 2+00 facing east.

This was the most distressed area of the outer wheeltrack. It had extensive open alligator cracking, ghosting, and severe spalling around the crack edges.

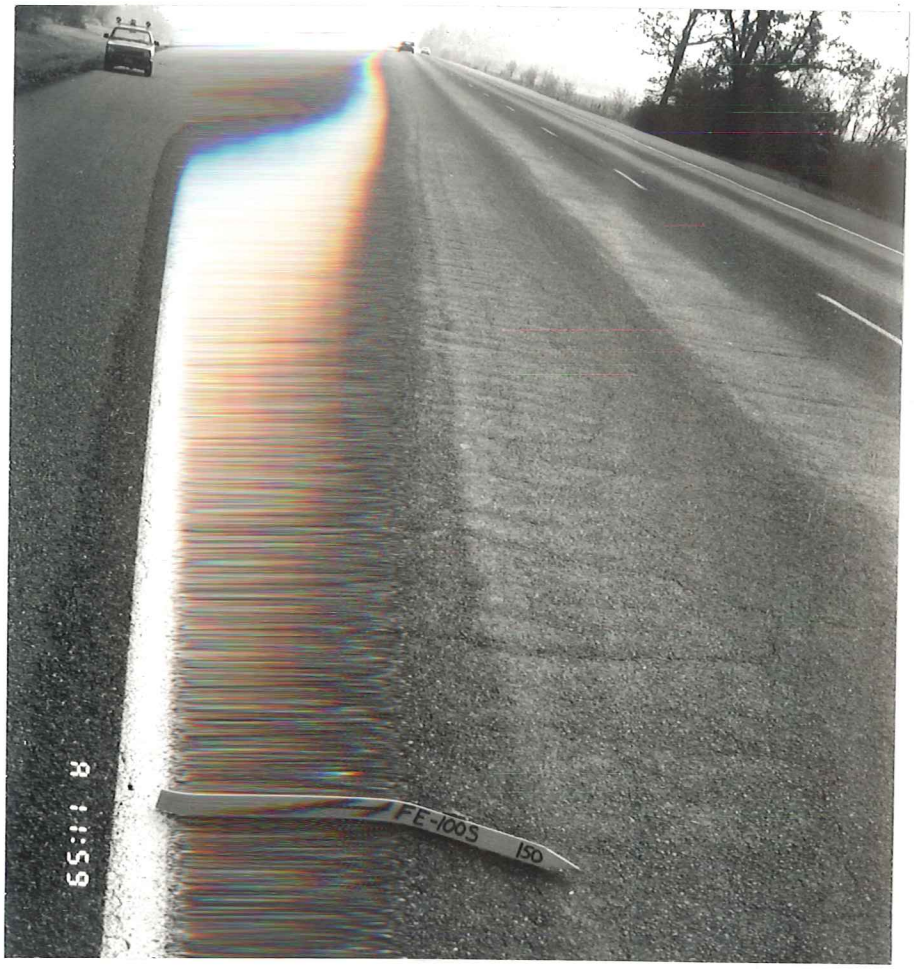

Figure 3: FE-100S at Station 1+50 facing east.

This was a typical section of the outer wheeltrack. Although there was extensive ghosting, most of the alligator cracks were sealed.

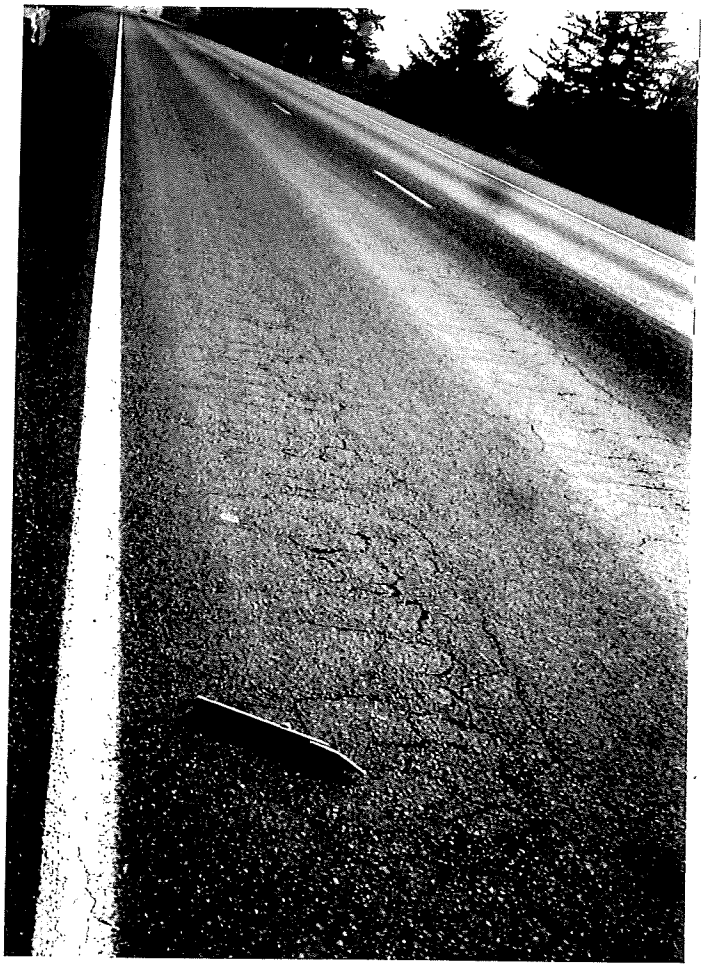

Figure 4: HFE-90 at Station 1+50 facing south.

This was typical of the distress found throughout both wheeltracks.

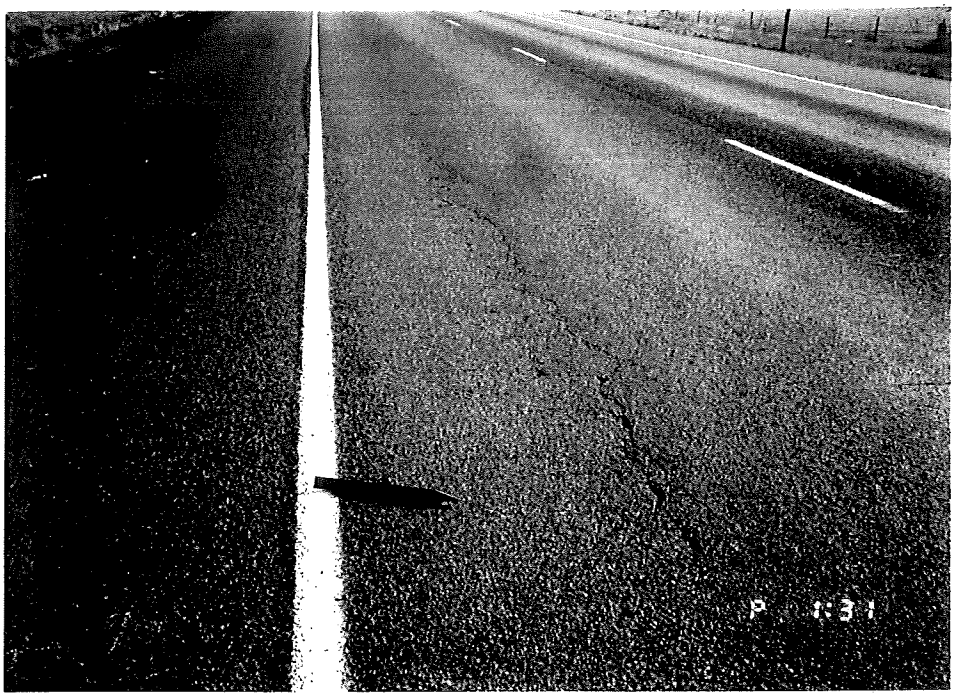

Figure 5: CRS-2D at Station 1+50 facing east.

Typical open alligatoring found throughout most of the outer wheeltrack and ¼ of the inner wheeltrack.

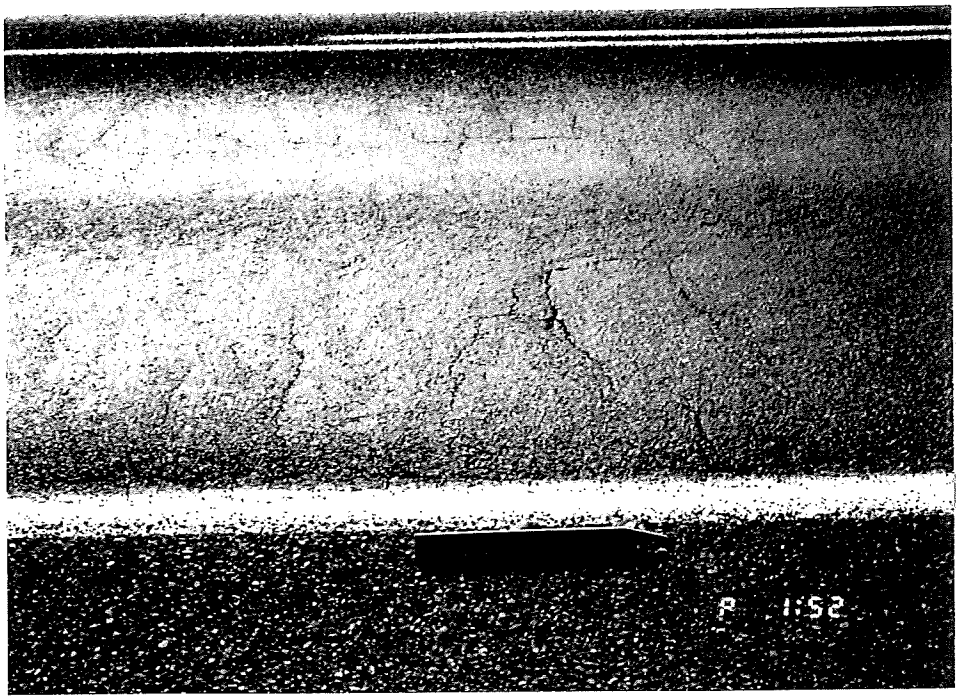

Figure 6: LMCRS-2H at Station 2+50 facing east.

Typical open alligator cracking.

Figure 7: CRS-2(P1) at Station 0+50 facing south.

This is a photo of one of the few cracked areas of the outer wheeltracks. The cracks were so fine, and there was so little spalling, that the cracks are not visible in the photo.

Figure 8: CRS-2K at Station 2+00 facing south.

This was one of the few areas that had open alligator cracking. Cracks were open and the edges were spalled.

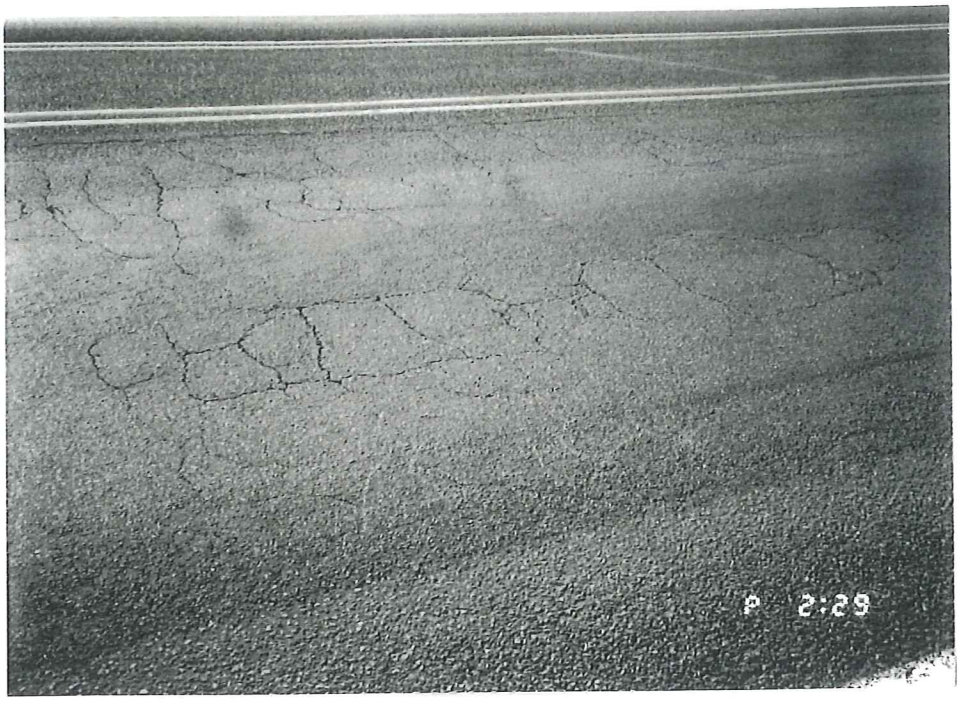

Figure 9: CRS-2 West at Station 0+75 facing south.

This was one of the areas with open alligator cracking. Most of the section had no open cracking.

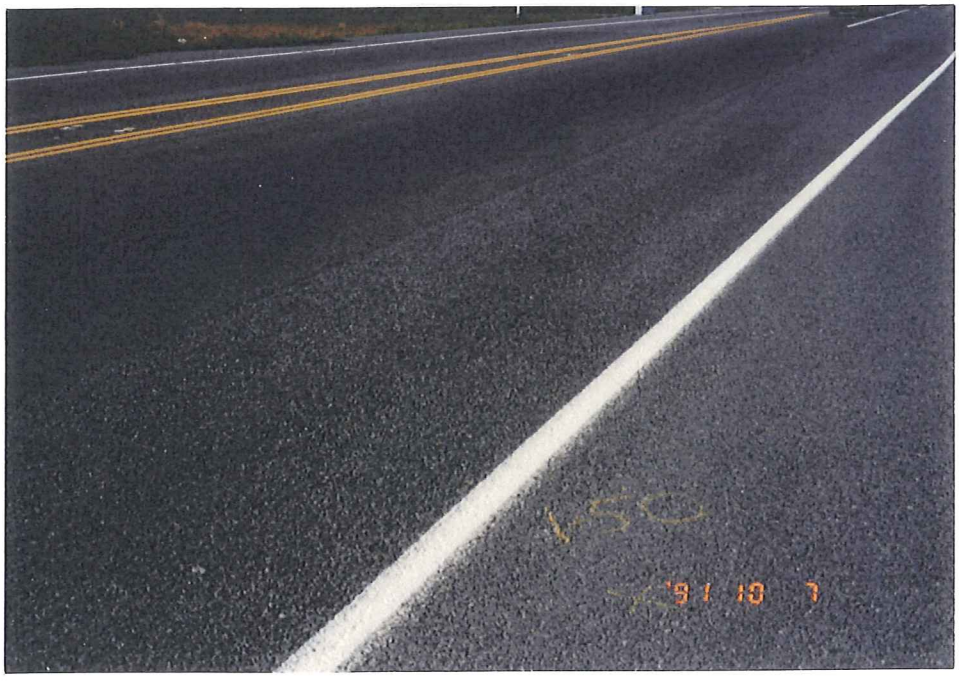

Figure 10: CRS-2 Calibration.

This section had no open cracking or raveling. Although this is a 1991 photo, this is what the section looked like in 1992.

4.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter gives conclusions on the emulsion performance and recommendations on their use and construction practices.

4.1 CONCLUSIONS

1. The seal performance observed in this study was influenced by the construction practices used on the various sections as well as the emulsion properties. As construction practices can vary considerably from job to job, the results of this study alone may not represent the performance of these emulsions in widespread use.

2. Excellent chip seals can be produced with conventional asphalt emulsions. Examples are the Calibration Sections in this study which used CRS-2 emulsion, and numerous other seals constructed statewide with conventional emulsions.

3. Excellent seals can also be produced with polymer modified emulsions. Examples are several seals placed during this study and many other high performing polymerized seals placed throughout the state. Experience during this study and statewide indicates that seals with polymerized asphalts may be better at retaining aggregate when the seal is opened to traffic while it is still curing. Statewide experience suggests that polymer modified emulsions may also be superior to conventional asphalts for sealing in cooler and damper conditions.

4. The ability of both types of emulsions to perform adequately is reflected by the current ODOT specifications. There is a specification for standard duty chip seals using either conventional or polymerized emulsions. The added benefits of polymerized emulsions are also recognized. The ODOT specifications for heavy duty chip seals require polymer modified emulsions.

4.2 RECOMMENDATIONS

1. To get a better comparison of the performance of the emulsions tested in this study, data from this study should be analyzed along with the results of other experiences with the use of these products.

2. Continued use of CRS-2, HFE-100S, CRS-2D, CRS-2(P1), and CRS-2K emulsion in the ODOT specifications is advisable.

3. Additional experimental applications of CRS-2P and CRS-2R emulsions are recommended before conclusions are made about their performance. Refinery blending is recommended on some of the CRS-2P test sections because field mixing may be inadequate for good performance.

4. Seals placed in the future with HFE-90 or LMCRS-2H emulsions should be monitored. If they tend to perform poorly, these emulsions should be removed from the ODOT specifications.

5. Many of the seals in this study with superior chip retention had two applications of aggregate before traffic was allowed onto them. This is recommended for seals subject to heavy traffic. The benefits of applying and rolling two applications of sand onto a fresh seal are recognized in the ODOT specifications for heavy duty chip seals. A typical chip seal specification requires single application of aggregate. For example, the standard ODOT coarse chip seal requires a ½" to ¼" (12 to 6mm) chip gradation. In contrast, the ODOT heavy chip seal requires one application of ½" to ¼" (12 to 6mm) aggregate followed by another application of ¼"-#10 (6mm -#10) aggregate.

6. Most of the lightly cracked areas of the test sections remained sealed after five years, regardless of the emulsion used. If a chip seal is intended to seal a pavement for a significant length of time, it is recommended that the pavement to be sealed is not severely cracked. Based on experience during this study, cracks of 1/32-inch (0.8mm) or less in width tended to remain sealed throughout the study and larger cracks were harder to seal.

5.0 REFERENCES

1. Bo Miller, Ronald L. Terrel, and James E. Wilson, Polymer Modified Chip Seal Test: Oregon Route 22, Interim Report OR-RD-92-06 (Salem, Oregon: Oregon Department of Transportation, November 1991).

2. Polymer Modified Emulsions for Chip Seals, Research Note 91-10 (Salem, Oregon: Oregon Department of Transportation, December 1991).

APPENDIX A

ODOT SPECIFICATIONS FOR CHIP SEAL EMULSIONS

CATIONIC EMULSIFIED ASPHALT

General Requirement: The cationic emulsified asphalt furnished under this specification shall be an emulsion of asphalt cement, water and emulsifying agent. The emulsified asphalt shall be homogeneous. It shall show no separation of asphalt after thorough mixing within 30 days after delivery. It shall meet the following requirements when tested within 30 days of sampling according to AASHTO Method T 59.

GRADE	RAPID SETTING				MEDIUM SETTING						SLOW SETTING			
	CRS-1[4]		CRS-2[4]		CMS-2S		CMS-2		CMS-2h		CSS-1		CSS-1h	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
TESTS ON EMULSION:														
Saybolt Viscosity @ 77°F, SFS											20	100	20	100
Saybolt Viscosity @ 122°F, SFS	20	100	150*	400	50	450	50	450	50	450				
Settlement, % (5 days) [1]		5		5		5		5		5		5		5
Storage Stability, % (1 day) [2]		1		1		1		1		1		1		1
Demulsibility 35 ml. 0.8% sodium dioctyl sulfosuccinate, %[3]	40		40											
Coating ability & water resistance:														
Coating, dry aggregate					Good		Good		Good					
Coating, after spraying					Fair		Fair		Fair					
Coating, wet aggregate					Fair		Fair		Fair					
Coating, after spraying					Fair		Fair		Fair					
Particle charge test	Positive		Positive		Positive		Positive		Positive		Positive[5]		Positive[5]	
Sieve test, %		0.10		0.10		0.10		0.10		0.10		0.10		0.10
Cement mixing test, %												2.0		2.0
Classification test	Passes		Passes											
Distillation (to 500°F):														
Oil distillate, % (by volume of emulsion)		3		3		12[6]		8[6]		8[6]		3[6]		3[6]
Residue, % (by weight)	60		65		60		65		65		57		57	
TESTS ON RESIDUE FROM DISTILLATION:														
Penetration @ 77°F, 100g, 5s, dmm	100[4]	250[4]	100[4]	250[4]	100	250	100	250	40	90	100	250	40	90
Ductility @ 77°F, cm	40		40		40		40		40		40		40	
Solubility in Trichloroethylene, %	97.5		97.5		97.5		97.5		97.5		97.5		97.5	

* Modification of AASHTO M 208

(1) The test requirement for settlement may be waived when the emulsified asphalt is used in less than 5 days time; or the purchaser may require that the settlement test be run from the time the sample is received until it is used, if the elapsed time is less than 5 days.

(2) The 24-hour (1 day) storage stability test may be used instead of the 5-day settlement test.

(3) The demulsibility test shall be made within 30 days from date of shipment.

(4) When CRS-1h or CRS-2h is specified, the penetration range is changed from 100-250 dmm to 40-90 dmm.

(5) Must meet a pH requirement of 6.7 maximum (AASHTO T 200 pH of Aqueous Solutions with the Glass Electrode) if the Particle Charge Test result is inconclusive.

(6) As required under Oregon Administrative Rules, Chapter 340, Division 22 - Department of Environmental Quality.

ANIONIC EMULSIFIED ASPHALT

General Requirement: The anionic emulsified asphalt furnished under this specification shall be an emulsion of asphalt cement, water and emulsifying agent. The emulsified asphalt shall be homogeneous. It shall show no separation of asphalt after thorough mixing within 30 days after delivery. It shall meet the following requirements when tested within 30 days of sampling according to AASHTO Method T 59 as modified.

GRADE	HFRS-2[1]		HFMS-2[2]		HFMS-2S[3]	
	Min	Max	Min	Max	Min	Max
TESTS ON EMULSION:						
Saybolt Viscosity @ 77°F, SFS			100		50	
Saybolt Viscosity @ 122°F, SFS	50*	400				
Sieve Test, %		0.10		0.10		0.10
Storage Stability, % (1 day)		1		1		1
Demulsibility, 0.02N/50 $CaCl_2$	30*					
Distillation (to 500°F): Oil Distillate, % (by volume of emulsion) Residue, % (by weight)	 63	7*	 65	7*	 1 65	7
TESTS ON RESIDUE FROM DISTILLATION:						
Penetration @ 77°F, 100g, 5s, dmm	90*	200	100	300*	200	
Ductility @ 77°F, cm	40		40			
Float Test @ 140°F, seconds	1200		1200		1200	

* Modification of AASHTO M 140

(1) Formerly HFE-90
(2) Formerly HFE-150
(3) Formerly HFE-300

STANDARD DUTY POLYMER-MODIFIED EMULSIFIED ASPHALT FOR CHIP SEALS

General Requirements: This specification has been designed to yield a set of distinguishing characteristics for a polymer-modified emulsion. It is for use in experimental chip seal projects and normal chip seal projects where early chip retention and resistance to chip loss is an important objective. The binder is not a conventional asphalt cement. The asphalt must be polymerized before shipment. It shall show no separation of asphalt after thorough mixing within 14 days after delivery. It shall meet the following requirements when tested within 14 days of sampling according to AASHTO Method T 59 as modified.

GRADE	HFRS-P1[9]		CRS-2P		CRS-2R		LMCRS-2H		PMCRS-2	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
TESTS ON EMULSION:										
Saybolt Viscosity @ 122°F, SFS	50		100	400	75	300	75	400	75	300
Sieve Test, %		0.10		0.10		0.10		0.30		0.30
Storage Stability, % (1 day) After thorough mixing shall be smooth and homogeneous throughout and shall show no material separation after setting undisturbed for 24 hours.		1.0		1.0		1.0		1.0		1.0
Demulsibility, %	30		40		40		40		40	
Distillation: Oil distillate, % (by volume of emulsion) Residue, % (by weight)	65[1]	3.0	65[2]	3.0	65[2]		65[1]		65[1]	
TESTS ON RESIDUE FROM DISTILLATION:										
Penetration @ 77°F, 100g, 5s, dmm	90	150	90	150	90	150	40	90	100	200
Float Test @ 140°F, seconds [3]	1200									
Solubility in Trichloroethylene, % [4]	97.5		97.5		97.5		97.5		97.5	
Elastic Recovery, % [5]	30									
Torsional Recovery,			18[6]		18[6]		18[7]		18[6]	
Ductility @ 77°F, cm [8]					40		40		40	

(1) AASHTO T 59 with modifications to include a 400° ± 10°F maximum temperature to be held for 15 minutes.
(2) AASHTO T 59 with modifications to include 300 grams emulsion and a 350° ± 10°F maximum temperature to be held for 15 minutes.
(3) AASHTO T 50 Float Test for Bituminous Materials.
(4) AASHTO T 44 Solubility of Bituminous Materials. May be waived if polymer modification interferes with test accuracy.
(5) ODOT TM 429 Method of testing on file at ODOT Materials Laboratory in Salem, Oregon.
(6) ODOT TM 428 Method A - Method of testing on file at ODOT Materials Laboratory in Salem, Oregon.
(7) ODOT TM 428 Method B - Method of testing on file at ODOT Materials Laboratory in Salem, Oregon.
(8) AASHTO T 51 Ductility of Bituminous Materials.
(9) Formerly HFE-90-1S

HIGH PERFORMANCE POLYMER-MODIFIED EMULSIFIED ASPHALT FOR CHIP SEALS

General Requirements: This specification has been designed to yield a set of distinguishing characteristics for a high performance polymer-modified emulsion. It is for use in experimental chip seal projects and normal chip seal projects where early chip retention and high resistance to chip loss is an important objective. The binder is not a conventional asphalt cement. The asphalt must be polymerized before shipment. It shall show no separation of asphalt after thorough mixing within 14 days after delivery. It shall meet the following requirements when tested within 14 days of sampling according to AASHTO Method T 59 as modified.

GRADE	HFRS-P2[6]		CRS-2(P1)		CRS-2K		CRS-2D	
	Min	Max	Min	Max	Min	Max	Min	Max
TESTS ON EMULSION:								
Saybolt Viscosity @ 122°F, SFS	50		100	400	100	400	150	400
Sieve Test, %		0.10		0.10		0.10		0.10
Storage Stability, % (1 day)		1		1		1		
Demulsibility, %	40		40		40		40	
Particle Charge Test	Negative		Positive		Positive		Positive	
Distillation (to 400°F): [1] Oil distillate, % (by volume of emulsion) Residue, % (by weight)	65	2	65	3	65	3	65	3
TESTS ON RESIDUE FROM DISTILLATION:								
Absolute Viscosity @ 140°F, poise [2]			750		1000			
Penetration @ 77°F, 100g, 5s, dmm	90	140	150		120		150	250
Float Test @ 140°F, sec	1200							
Ductility @ 39.2°F, cm			40		100			
Ductility @ 77°F, cm	75						100	
Solubility in Trichloroethylene, %	97.5						97.5	
Elastic Recovery, % [3]	58							
Force Ductility [4]	0.3							
TEST ON RESIDUE FROM EVAPORATION:								
Vialit Test @ -22°C, % [5]	40		40		40		40	

(1) AASHTO T 59 with modifications to include a 400° ± 10°F maximum distillation temperature held for 15 minutes.
(2) AASHTO T 202.
(3) ODOT TM 429 Method of testing on file at ODOT Materials Laboratory in Salem, Oregon.
(4) ODOT TM 427 Method of testing on file at ODOT Materials Laboratory in Salem, Oregon.
(5) ODOT TM 426 "French Chip" Method of testing on file at ODOT Materials Laboratory in Salem, Oregon.
(6) Formerly HFE-100S

APPENDIX B

ODOT SPECIFICATIONS FOR EMULSIFIED ASPHALT CHIP SEAL

SECTION 00710 - EMULSIFIED ASPHALT CHIP SEAL

Section 00710, which is not in the Standard Specifications, is included for this project by special provisions.

Description

00710.00 Scope - This work shall consist of an application or applications of emulsified asphalt and graded aggregates.

The type of chip seal (fine, medium, coarse) to be applied will be as designated on the plans or specified herein.

The emulsified asphalt chip seal shall be constructed in accordance with these specifications and in reasonably close conformity to the lines, grades, thicknesses, and cross sections shown on the plans or established by the Engineer.

00710.03 Variation of Quantities and Operations - The rates of spreads and quantities of materials are subject to variation as directed by the Engineer to adjust for variable conditions encountered or experienced during the construction. Recognize that the nature of the work calls for equipment in varying number and versatility and modification of procedures to some extent. Generally, the ratio of asphalt to aggregate shall be held closely constant to that specified.

Materials

00710.10 Aggregates - The size of aggregate for the chip seal shall conform to the following:

Chip Aggregate Type	Size of Screenings
Fine	1/4"-No. 10
Medium	3/8"-No. 10
Coarse	1/2"-1/4"

Aggregates shall consist of broken stone, crushed gravel, or a combination of both. At least 90 percent by weight of the total aggregate retained on the No. 10 and larger sieves shall be fractured on two faces, as determined visually by the Engineer.

Elongated pieces in the coarse aggregate (aggregate larger than 1/4 inch) shall be determined as described in OSHD Test Method 229N with the proportional caliper device set at a ratio of 5:1 and shall not exceed 10 percent by weight of the material retained on the 1/4-inch sieve.

Aggregates shall conform to the quality requirements of 02680.10(c), (d), and (f).

The percentage composition by weight of aggregates shall conform to one of the following gradings:

Sieve Sizes	Percentage Passing Coarse 1/2"-1/4"	Medium 3/8"-No. 10	Fine 1/4"-No. 10
1/2"	85-100	100	100
3/8"	-	85-100	-
1/4"	0-15	-	80-100
No. 10	0-4	0-10	0-10
No. 40	0-2	0-2	0-2
No. 200	0-2	-	0-2

(a) Taking Aggregates from Division Stockpiles - When it is specified that aggregates are to be taken from Division-controlled stockpiles, take the material in an orderly manner and to the full depth of the pile as far as needed. Care shall be exercised to not contaminate the materials, yet salvage all material possible from the area from which the materials are taken. Unused portions of a stockpile shall be shaped to neat lines. The Contractor will be charged for materials wasted through negligence or used without authority of the specifications or the Engineer.

(b) Stockpiling Contractor-Furnished Aggregates on Division Property - Aggregates can be temporarily stockpiled at approved sites on Division property provided the areas used are as small as practicable and are cleaned up and made sightly after the materials thereon are removed. Any contamination during storage or from reloading operations will be cause for rejection.

00710.11 Bituminous Materials - The bituminous materials to be used in the emulsified asphalt chip seal shall be CRS-1, CRS-2, or HFRS-2 emulsified asphalt as elected. The emulsified asphalt shall conform to the requirements of Section 02710 of the Standard Specifications.

The materials may be conditionally accepted based on certification at the source or point of loading for transport to the project. Excessive delay in the use of the emulsified asphalt or excessive pumping of the emulsified asphalt may significantly reduce the viscosity and may make the material unsuitable for chip seal use. For this reason, pumping which occurs between the bulk storage tank, hauling transportation, field storage tanks, and distributor shall be kept to an absolute minimum. Final acceptance of emulsified asphalt will be at the point of application.

Samples taken at the time of application will be tested at the Division's Materials Laboratory within 30 calendar days.

(Use the following 00710.15 and 00710.16 for Region 4 projects, any project with process control of other surfacing aggregates, or any other projects, when requested by the other regions.)

00710.15 Process Control - Be responsible for quality control, as required by 00165.10 of the Standard Specifications, and perform process control sampling and testing as follows:

(a) Aggregate - Sample aggregate during production and test as follows:

(a-1) Required Tests - Perform each of the following tests at the sampling frequency indicated:

Test	Test Method OSHD	Test Method AASHTO	Start of Production	One Per 5 Shifts*	One Per Shift*
Fracture of Gravel	TM 213		X	X	-
Wood Particles	TM 225		X	X***	-
Elongated Pieces	TM 229N		X	X***	-
Friable Particles		T 112	X	X***	-
Sieve Analysis		T 11/T 27	X	-	X**

*A shift means a production shift or 500 cubic yards, whichever results in the greatest sampling frequency.
**Perform at least three tests per project.
***May be waived after first five shifts, if allowed by the Engineer of Materials and Research.

(a-2) Split Samples - Provide split samples of all required samples to the Engineer.

(a-3) Engineer Testing - The Engineer may perform any of the tests required in 00710.15(a-1) and any additional tests, such as lightweight pieces, and qualifying tests for soundness, degradation, abrasion, and organic impurities.

(a-4) Removal of Failing Material - Make appropriate operational adjustments and conduct a second test immediately whenever a process control test result, other than sieve analysis and cleanness value, does not meet specifications. Remove all failing material from the stockpile if the second test result does not meet specifications. See 00710.16(a-2) relative to nonspecification aggregate gradation and cleanness value.

(a-5) Preproduced Aggregate - Compliance of aggregates produced and stockpiled before the award of this contract will be determined by either:

a. Continuing production records meeting the requirements of 00710.15(a-1), (a-3), and (a-4).

b. Sampling and testing the entire stockpile according to AASHTO T2 at the following minimum frequency schedule:

- Start of production (one set of tests per stockpile).
- One per 5 shifts (one set of tests per 2,500 cubic yards).
- One per shift (one set of tests per 500 cubic yards). At least one set per shift or three per project, whichever produces the greater number of tests).

00710.16 Acceptance Sampling and Testing - Acceptance sampling and testing will be performed as required by 00165.40 of the Standard Specifications and the following:

(a) Aggregate - Compliance of material will be based on the process control testing as required in 00165.10, 00710.10, 00710.15(a), and 00710.16(a) as verified by qualifying and check tests performed by the Engineer.

(a-1) Aggregate Gradation - A stockpile contains specification aggregate when the Quality Level (QL) for each sieve analysis calculated according to 00165.30 is equal to or greater than the QL indicated in Table 00165-2 for a Pay Factor of 1.00. Each required sample represents a sublot.

When the QL indicated in Table 00165-2 yields a Pay Factor of less than 1.00 for any constituent, the material is nonspecification.

(a-2) Nonspecification Aggregate Gradation - The Engineer will reject any stockpile of aggregate containing material not conforming to the gradation and specifications, unless the nonspecification material is removed from the stockpile. Additional material shall not be added to such a stockpile until enough nonspecifi-cation material is removed so that the QL for each constituent is equal to or greater than the QL in Table 00165-2 for a 1.00 Pay Factor.

(a-3) Engineer's Check Testing - If check tests are not within the allowable tolerances given in the Division's Standard Procedures, work with the Engineer immediately to resolve the difference in an attempt to avoid having this material rejected for not meeting specifications. Material not meeting qualifying and other tests performed by the Engineer will be rejected.

(a-4) Materials on Hand - Payment for stockpiled materials on hand may be allowed as described in 00195.60 subject to meeting 00710.10, 00710.15(a), and 00710.16(a).

Payment for preproduced and nonspecification materials will not be allowed.

Equipment

00710.20 Equipment - The equipment to be used shall include pressure distributor, hauling vehicles, chip spreader, compactors, power brooms, and such other necessary equipment to insure efficient operation and construction to meet specified results. Equipment shall be provided in such number and capacities as will provide coordinated and uniform progress of the work.

Provide two-way radio communication between the asphalt distributor and chip spreader.

(a) Asphalt Distributor - The asphalt distributor shall be so designed, equipped, maintained, and operated that emulsified asphalt material at even heat may be applied uniformly on variable widths of surface up to 15 feet at readily determinable and controlled rates from 0.05 gallon to 2.0 gallons per square yard with uniform pressure and with an allowable variation from any specified rate not to exceed 0.02 gallon per square yard. Distributor equipment shall include a tachometer, pressure gages, accurate volume measuring devices or a calibrated tank, and a thermometer for measuring temperature of tank contents. Distributors shall have a power unit for the pump and full circulation spray bars adjustable laterally and vertically.

Provide manufacturer's specifications showing proper nozzle size for desired viscosity, rate of travel, and rate of emulsified asphalt application. Pump pressure shall be in the middle or lower end of the acceptable range. Nozzle angle shall be set accurately to the angle stated in the manufacturer's specifications. Bar height shall be set for triple lap coverage.

(b) Chip Spreaders - The chip spreaders shall be self-propelled and shall be equipped with a mechanical device that will spread the aggregate at a uniform rate across the full width of the chip spreaders. Spreaders shall be equipped with an aggregate segregator assembly. Chip spreaders shall be capable of providing coverage without overlaps or joints within the wheel paths.

00710.24 Compactors - Rollers shall be self-propelled pneumatic-tired or steel-wheeled with a minimum of one pneumatic-tired roller and one steel-wheeled roller required. They shall be in good condition and capable of operating at speeds compatible with the chip seal operation.

(a) Pneumatic-tired Rollers - The pneumatic-tired rollers shall be self-propelled, tandem or multiple axle, multiple wheel type with smooth-tread pneumatic tires of equal size staggered on the axles at such spacings and overlaps as will provide uniform compacting pressure for the full compacting width of the roller and shall be capable of exerting ground pressures of 80 pounds per square inch of tire contact area. Tire inflation pressure shall be 45 psi to 60 psi.

(b) Steel-wheeled Rollers - The steel-wheeled roller shall provide a weight of not less than 200 pounds per inch of width of the compression roll or rolls.

00710.25 Power Brooms - Power brooms shall be pickup and/or nonpickup type and shall have a positive means to control vertical pressure.

Construction

(In Regions 1, 2, and 3, change 70°F to 65°F in the second line below.)

00710.40 Season and Weather Limitations - Emulsified asphalt shall not be applied when the pavement temperature is below 70°F nor if the humidity is higher than 75 percent. The application of the emulsified asphalt and the aggregate chips shall be completed 2 hours before sunset. Chip seals damaged by rain during the first 24 hours after application shall be removed by milling, or other methods approved by the Engineer, and replaced at the Contractor's expense. The placing of emulsified asphalt chip seal will not be allowed before July 1 or after August 31.

(Replace the last sentence in the above paragraph with the following sentence when Region 3 Projects are involved.)

The placing of emulsified asphalt chip seal will not be allowed before June 15 or after August 31.

00710.42 Rate of Progress and Scheduling - The amount of chip seal applied in any one day shall not exceed the amount that can be broomed the following morning unless approved by the Engineer. Provide a traffic control plan for approval by the Engineer if operations exceed 3 centerline miles or 6 lane-miles per day.

00710.43 Preparation of Underlying Surfaces - Immediately before applying the emulsified asphalt, the surface to be sealed shall be clean and dry. Cleaning shall be performed by sweeping, flushing, or other means necessary to remove all loose particles of paving, dirt, and other extraneous material.

00710.45 Applying Emulsified Asphalt - The exact rate of application will be determined by the Engineer. Normally, the rate of application will be the following:

Chip Seal Types	Gallons/Sq.Yd.	
	Region 4	Region 5
Fine	0.30 (± 0.05)	0.45 (± 0.10)
Medium	0.35 (± 0.05)	0.50 (± 0.10)
Coarse	0.40 (± 0.05)	0.55 (± 0.10)

Apply the emulsified asphalt working toward the aggregate stockpile at all times.

A minimum of 200 gallons of emulsified asphalt shall remain in the distributor tank at all times except for the last shot on the project.

The emulsified asphalt shall not be applied to more than one-half the width of the travel way at one time and the remaining width shall remain open to traffic. The open lane shall not be closed until traffic controlled by pilot car is operating on the new chip seal. The chip seal shall, weather permitting, be applied to both sides of the travel way so that by 2 hours before sunset the end of the work is squared up.

Emulsified asphalt shall not be applied a greater distance than can be immediately covered by aggregates before the emulsion breaks.

Building paper shall be placed over the treated surface at the beginning of each spread to insure that the nozzles are operating properly before the uncovered surface is reached. Building paper shall be removed and disposed of in a manner satisfactory to the Engineer.

If requested by the Engineer, demonstrate that the distribution of the emulsified asphalt does not vary between the individual nozzles by more than 15 percent transversely from the average and no more than 10 percent longitudinally from the specified rate of application.

The application temperature of the emulsified asphalt shall be between 140°F and 165°F.

00710.47 Hauling and Spreading Aggregates - The exact spread rate of aggregate for seal will be determined by the Engineer. Normally, the rate of spread will be the following:

Chip Seal Types	Cu.Yd./Sq.Yd.
Fine	0.004 (± 0.002)
Medium	0.009 (± 0.003)
Coarse	0.012 (± 0.003)

Hauling and spreading equipment shall not be operated on uncovered emulsified asphalt. During the first hour after application of the emulsified asphalt and aggregate, speeds shall be no more than 10 MPH and after the first hour, speeds shall not be in excess of 15 MPH until otherwise permitted by the Engineer. At all times, hauling equipment shall be operated in a prudent manner and at moderate speeds that will not damage the new chip seal or create a hazard to the traveling public.

The chip spreaders shall be accurately calibrated for the various sizes of aggregate to be used in regard to gate opening, gear selection and engine RPM. Following calibration, the rate of application shall be verified by truck measure and area covered.

Immediately following the application of the emulsified asphalt, the surface shall be covered with aggregate unless otherwise authorized by the Engineer. The rate of spread of this aggregate shall be maintained within 10 percent of specified rate. Emulsified asphalt that has set or "broke" before being covered with aggregate shall be removed or repaired by methods approved by the Engineer and shall be at the Contractor's expense.

Operating the chip spreader at speeds which cause the chips to roll over after striking the emulsion covered surface will not be permitted.

Provide coverage without overlaps or joints within the wheel paths.

The transverse cut off of aggregates shall be neat and any excess aggregates shall be removed from the surface prior to resuming operations.

Aggregates shall be surface damp at the time of application, but excess free water (water not adhering to the aggregate surface) on the aggregate will not be permitted.

00710.48 Shaping and Compacting - After the aggregates have been spread upon the emulsified asphalt, any piles, ridges, or uneven distribution shall be spread and/or removed by hand tools or mechanical means, as elected, to ensure against rough spots in the final surface.

In the event aggregates begin to pick under traffic or from the rolling operation, that area shall be immediately covered with additional quantities of fine aggregate and rolled.

Rolling shall consist of two coverages. The first coverage shall be performed with a pneumatic-tired roller that remains immediately behind the spreader, the second coverage shall be performed with a steel-wheeled roller, unless otherwise directed by the Engineer.

Rolling speeds shall be kept to a minimum, usually around 5 MPH, so that the rollers do not pick up aggregates from the emulsified asphalt surface.

00710.49 Power Brooming - Between the hours of 11:00 p.m. and 7:00 a.m. of the day following the application of the chip seal, the entire surface shall be carefully broomed, unless brooming damages the chip seal, to remove loose aggregate that could damage vehicles. A minimum of two power brooms shall be used.

Subsequent brooming the following 2 days may be directed by the Engineer to ensure that the surface is free of loose aggregate that could cause vehicle damage.

In curbed areas, use a pickup type power broom. On bridges, sidewalks, and other areas off the roadway, all extraneous aggregates shall be removed to the satisfaction of the Engineer.

00710.51 Provisions for Traffic - In addition to other required traffic provisions, control traffic according to the applicable provisions of 00220.40 of the special provisions.

Measurement

00710.80 General - The quantity of aggregate to be paid for will be the number of cubic yards measured in the hauling vehicles, as set forth in Section 00190 and incorporated in the completed course of emulsified asphalt chip seal.

The quantities of emulsified asphalt to be paid for will be the number of tons of emulsified asphalt, measured as set forth in Section 00190, and incorporated in the completed emulsified asphalt chip seal.

When indicated by the appropriate pay item listed in the Bid Schedule, separate measurement and additional payment is to be made per each location for the additional labor and other additional costs involved in constructing emulsified asphalt chip seal on connections to public roads and streets and on approaches to private properties.

(Use the following paragraph when the number and location of approaches are to be listed.)

There are approximately ____ approaches located within the limits of the project as follows:

Payment

00710.90 General - The accepted quantities will be paid for at the contract price per unit of measurement for each of the pay items listed below that appear in the Bid Schedule.

Item Reference	Pay Item	Unit of Measurement
(a)	Aggregate in Emulsified Asphalt Chip Seal	Cu.Yd.
(b)	Emulsified Asphalt in Chip Seal	Ton
(c)	Extra for Emulsified Asphalt Chip Seal Approaches	Each

Pay item (a) above is applicable to aggregates which are furnished, hauled, and placed in the work as specified.

Pay item (b) above is applicable to the emulsified asphalt furnished, hauled to, and placed in the work as specified.

Pay item (c) above is applicable to the extra costs of placing the aggregates and asphalt in emulsified asphalt chip seal on connections and approaches, which payment will be in addition to payment made for the materials used in the work.

No extra payment will be made for any additional costs of placing emulsified asphalt chip seal in connections, approaches, and guard rail flares.

The applicable contract prices and payment as above provided and as set forth in the Bid Schedule will be full compensation for preparing the roadway surface, providing all materials in final position, and brooming, including all labor, equipment, tools, and incidentals necessary to complete the work as specified.

APPENDIX C

SPECIFICATIONS FOR POLYMER MODIFIED ASPHALT CHIP SEALS
(Standard Duty)

SECTION 00711 - POLYMER MODIFIED EMULSIFIED ASPHALT CHIP SEAL (STANDARD DUTY)

Section 00711, which is not in the Standard Specifications, is included for this project by special provisions.

Description

00711.00 Scope - This work shall consist of an application of polymer modified emulsified asphalt and graded aggregates as directed by the Engineer.

The type of chips to be applied are (fine, medium, coarse).

The polymer modified emulsified asphalt chip seal shall be constructed in accordance with these specifications and in reasonably close conformity to the lines, grades, thicknesses, and cross sections shown on the plans or established by the Engineer.

00711.03 Variation of Quantities and Operations - The rates of spreads and quantities of materials are subject to variation as directed by the Engineer to adjust for variable conditions encountered or experienced during the construction. Recognize that the nature of the work calls for equipment in varying number and versatility and modification of procedures to some extent. Generally, the ratio of asphalt to aggregate shall be held closely constant to that specified.

Materials

00711.10 Aggregates - The size of aggregate for the chip seal shall conform to the following:

Chip Aggregate Type	Size of Screenings
Fine	1/4"-No. 10
Medium	3/8"-No. 10
Coarse	1/2"-1/4"

Aggregates shall consist of broken stone, crushed gravel, or a combination of both. At least 90 percent by weight of the total aggregate retained on the No. 10 and larger sieves shall be fractured on two faces, as determined visually by the Engineer.

Elongated pieces in the coarse aggregate (aggregate larger than 1/4 inch) shall be determined as described in OSHD Test Method 229N with the proportional caliper device set at a ratio of 5:1 and shall not exceed 10 percent by weight of the material retained on the 1/4-inch sieve.

Aggregates shall conform to the quality requirements of 02680.10(c), (d), and (f).

The percentage composition by weight of aggregates shall conform to one of the following gradings:

Sieve Sizes	Percentage Passing Coarse 1/2"-1/4"	Medium 3/8"-No. 10	Fine 1/4"-No. 10
1/2"	85-100	100	100
3/8"	-	85-100	-
1/4"	0-15	-	80-100
No. 10	0-4	0-10	0-10
No. 40	0-2	0-2	0-2
No. 200	0-2	-	0-2

(a) Taking Aggregates from Division Stockpiles - When it is specified that aggregates are to be taken from Division-controlled stockpiles, remove the material in an orderly manner and to the full depth of the pile as far as needed. Care shall be exercised to not contaminate the materials, yet salvage all material possible from the area from which the materials are taken. Unused portions of a stockpile shall be shaped to neat lines. The Contractor will be charged for materials wasted through negligence or used without authority of the specifications or the Engineer.

(b) Stockpiling Contractor-Furnished Aggregates on Division Property - Aggregates can be temporarily stockpiled at approved sites on Division property provided the areas used are as small as practicable and are cleaned up and made sightly after the materials thereon are removed. Any contamination during storage or from reloading operations will be cause for rejection.

00711.11 Bituminous Materials - The bituminous materials to be used in the polymer modified emulsified asphalt chip seal shall be HFRS-P1, CRS-2P, CRS-2R, LMCRS-2H, or PMCRS-2 emulsified asphalt as elected. The polymer modified emulsified asphalt shall conform to the requirements of Section 02710 of the Standard Specifications.

The materials may be conditionally accepted based on certification at the source or point of loading for transport to the project. Excessive delay in the use of the polymer modified emulsified asphalt or excessive pumping of the polymer modified emulsified asphalt may significantly reduce the viscosity and may make the material unsuitable for chip seal use. For this reason, pumping which occurs between the bulk storage tank, hauling transportation, field storage tanks, and distributor shall be kept to an absolute minimum. Final acceptance of polymer modified emulsified asphalt will be at the point of application.

Samples taken at the time of application will be tested at the Division's Materials Laboratory within 14 calendar days.

(Use the following 00712.15 and 00712.16 for Region 4 projects, any project with process control of other surfacing aggregates, or any other projects, when requested by the other regions.)

00711.15 Process Control - Be responsible for quality control, as required by 00165.10 of the Standard Specifications, and perform process control sampling and testing as follows:

(a) Aggregate - Sample aggregate during production and test as follows:

(a-1) Required Tests - Perform each of the following tests at the sampling frequency indicated:

Test	Test Method OSHD	Test Method AASHTO	Start of Production	One Per 5 Shifts*	One Per Shift*
Fracture of Gravel	TM 213		X	X	-
Wood Particles	TM 225		X	X***	-
Elongated Pieces	TM 229N		X	X***	-
Friable Particles		T 112	X	X***	-
Sieve Analysis		T 11/T 27	X	-	X**

*A shift means a production shift or 500 tons, whichever results in the greatest sampling frequency.
**Perform at least three tests per project.
***May be waived after first five shifts, if allowed by the Engineer of Materials and Research.

(a-2) Split Samples - Provide split samples of all required samples to the Engineer.

(a-3) Engineer Testing - The Engineer may perform any of the tests required in 00711.15(a-1) and any additional tests, such as lightweight pieces, and qualifying tests for soundness, degradation, abrasion, and organic impurities.

(a-4) Removal of Failing Material - Make appropriate operational adjustments and conduct a second test immediately whenever a process control test result, other than sieve analysis and cleanness value, does not meet specifications. Remove all failing material from the stockpile if the second test result does not meet specifications. See 00711.16(a-2) relative to nonspecification aggregate gradation and cleanness value.

(a-5) Preproduced Aggregate - Compliance of aggregates produced and stockpiled before the award of this contract will be determined by either:

a. Continuing production records meeting the requirements of 00711.15(a-1), (a-3), and (a-4).

b. Sampling and testing the entire stockpile according to AASHTO T2 at the following minimum frequency schedule:

- Start of production (one set of tests per stockpile).
- One per 5 shifts (one set of tests per 2,500 tons).
- One per shift (one set of tests per 500 tons. At least one set per shift or three per project, whichever produces the greater number of tests).

00711.16 Acceptance Sampling and Testing - Acceptance sampling and testing will be performed as required by 00165.40 of the Standard Specifications and the following:

(a) Aggregate - Compliance of material will be based on the process control testing as required in 00165.10, 00711.10, 00711.15(a), and 00711.16(a) as verified by qualifying and check tests performed by the Engineer.

(a-1) Aggregate Gradation - A stockpile contains specification aggregate when the Quality Level (QL) for each sieve analysis calculated according to 00165.30 is equal to or greater than the QL indicated in Table 00165-2 for a Pay Factor of 1.00. Each required sample represents a sublot.

When the QL indicated in Table 00165-2 yields a Pay Factor of less than 1.00 for any constituent, the material is nonspecification.

(a-2) Nonspecification Aggregate Gradation - The Engineer will reject any stockpile of aggregate containing material not conforming to the gradation specifications, unless the nonspecification material is removed from the stockpile. Additional material shall not be added to such a stockpile until enough nonspecification material is removed so that the QL for each constituent is equal to or greater than the QL in Table 00165-2 for a 1.00 Pay Factor.

(a-3) Engineer's Check Testing - If check tests are not within the allowable tolerances given in the Division's Standard Procedures, work with the Engineer immediately to resolve the difference in an attempt to avoid having this material rejected for not meeting specifications. Material not meeting qualifying and other tests performed by the Engineer will be rejected.

(a-4) Materials on Hand - Payment for stockpiled materials on hand may be allowed as described in 00195.60 subject to meeting 00711.10, 00711.15(a), and 00711.16(a).

Payment for preproduced and nonspecification materials will not be allowed.

Equipment

00711.20 Equipment - The equipment to be used shall include pressure distributor, hauling vehicles, chip spreader, compactors, power brooms, and such other necessary equipment to insure efficient operation and construction to meet specified results. Equipment shall be provided in such number and capacities as will provide coordinated and uniform progress of the work.

Provide two-way radio communication between the asphalt distributor and chip spreader.

(a) Asphalt Distributor - The asphalt distributor shall be so designed, equipped, maintained, and operated that polymer modified emulsified asphalt material at even heat may be applied uniformly on variable widths of surface up to 15 feet at readily determinable and controlled rates from 0.05 gallon to 2.0 gallons per square yard with uniform pressure and with an allowable variation from any specified rate not to exceed 0.02 gallon per square yard. Distributor equipment shall include a tachometer, pressure gages, accurate volume measuring devices or a calibrated tank, and a thermometer for measuring temperature of tank contents. Distributors shall have a power unit for the pump and full circulation spray bars adjustable laterally and vertically.

Provide manufacturer's specifications showing proper nozzle size for desired viscosity, rate of travel, and rate of polymer modified emulsified asphalt application. Pump pressure shall be in the middle or lower end of the acceptable range. Nozzle angle shall be set accurately to the angle stated in the manufacturer's specifications. Bar height shall be set for triple lap coverage.

(b) Chip Spreaders - The chip spreaders shall be self-propelled and shall be equipped with a mechanical device that will spread the aggregate at a uniform rate across the full width of the chip spreaders. Spreaders shall be equipped with an aggregate segregator assembly. Chip spreaders shall be capable of providing coverage without overlaps or joints within the wheel paths.

00711.24 Compactors - Rollers shall be self-propelled pneumatic-tired or steel-wheeled with a minimum of one pneumatic-tired roller and one steel-wheeled roller required. They shall be in good condition and capable of operating at speeds compatible with the chip seal operation.

(a) Pneumatic-tired Rollers - The pneumatic-tired rollers shall be self-propelled, tandem or multiple axle, multiple wheel type with smooth-tread pneumatic tires of equal size staggered on the axles at such spacings and overlaps as will provide uniform compacting pressure for the full compacting width of the roller and shall be capable of exerting ground pressures of 80 pounds per square inch of tire contact area. Tire inflation pressures shall be 45 to 60 psi.

(b) Steel-wheeled Rollers - The steel-wheeled roller shall provide a weight of not less than 200 pounds per inch of width of the compression roll or rolls.

00711.25 Power Brooms - Power brooms shall be pickup and/or nonpickup type and shall have a positive means to control vertical pressure.

Construction

(In Regions 1, 2, and 3, change 70°F to 65°F in the second line below.)

00711.40 Season and Weather Limitations - Polymer modified emulsified asphalt shall not be applied when the pavement temperature is below 70°F nor if the humidity is higher than 75 percent. The application of the polymer modified emulsified asphalt and the aggregate chips shall be completed 2 hours before sunset. Chip seals damaged by rain during the first 24 hours after application shall be removed by milling, or other methods approved by the Engineer, and replaced at the Contractor's expense. The placing of polymer modified emulsified asphalt chip seals will not be allowed before July 1 or after August 31.

(Replace the last sentence in the above paragraph with the following sentence when Region 3 Projects are involved.)

The placing of polymer modified emulsified asphalt chip seal will not be allowed before June 15 or after August 31.

00711.42 Rate of Progress and Scheduling - The amount of chip seal applied in any one day shall not exceed the amount that can be broomed the following morning unless approved by the Engineer. Provide a traffic control plan for approval by the Engineer if operations exceed 3 centerline miles or 6 lane-miles per day.

00711.43 Preparation of Underlying Surfaces - Immediately before applying the polymer modified emulsified asphalt, the surface to be sealed shall be clean and dry. Cleaning shall be performed by sweeping, flushing, or other means necessary to remove all loose particles of paving, dirt, and other extraneous material. When the underlying surface is open-graded, a pre-fog seal or equivalent treatment shall be constructed, as directed by the Engineer.

00711.45 Applying Polymer Modified Emulsified Asphalt - The exact application rate of polymer modified emulsified asphalt for the chip seal will be determined by the Engineer. Normally, the rate of application will be the following:

Chip Seal Types	Gallons/Sq.Yd.
Fine	0.45 (± 0.10)
Medium	0.50 (± 0.10)
Coarse	0.55 (± 0.10)

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Apply the polymer modified emulsified asphalt working toward the aggregate stockpile at all times.

A minimum of 200 gallons of polymer modified emulsified asphalt shall remain in the distributor tank at all times except for the last shot on the project.

The polymer modified emulsified asphalt shall not be applied to more than one-half the width of the travel way at one time and the remaining width shall remain open to traffic. The open lane shall not be closed until traffic controlled by pilot car is operating on the new chip seal. The chip seal shall, weather permitting, be applied to both sides of the travel way so that by 2 hours before sunset the end of the work is squared up.

Polymer modified emulsified asphalt shall not be applied a greater distance than can be immediately covered by aggregates before the emulsion breaks.

Building paper shall be placed over the treated surface at the beginning of each spread to insure that the nozzles are operating properly before the uncovered surface is reached. Building paper shall be removed and disposed of in a manner satisfactory to the Engineer.

If requested by the Engineer, demonstrate that the distribution of the emulsified asphalt does not vary between the individual nozzles by more than 15 percent transversely from the average and no more than 10 percent longitudinally from the specified rate of application.

The application temperature of the polymer modified emulsified asphalt shall be between 160°F and 185°F.

00711.47 Hauling and Spreading Aggregates - The exact spread rate of aggregate for seal will be determined by the Engineer. Normally, the rate of spread will be the following:

Chip Aggregate Types	Cu.Yd./Sq.Yd.
Fine	0.004 (± 0.002)
Medium	0.009 (± 0.003)
Coarse	0.012 (± 0.003)

Hauling and spreading equipment shall not be operated on uncovered polymer modified emulsified asphalt. During the first hour after application of the polymer modified emulsified asphalt and aggregate, speeds shall be no more than 10 MPH and after the first hour, speeds shall not be in excess of 15 MPH until otherwise permitted by the Engineer. At all times, hauling equipment shall be operated in a prudent manner and at moderate speeds that will not damage the new chip seal or create a hazard to the traveling public.

The chip spreaders shall be accurately calibrated for the various sizes of aggregate to be used in regard to gate opening, gear selection and engine RPM. Following calibration, the rate of application shall be verified by truck measure and area covered.

Immediately following the application of the polymer modified emulsified asphalt, the surface shall be covered with aggregate unless otherwise authorized by the Engineer. The rate of spread of this aggregate shall be maintained within 10 percent of specified rate. Polymer modified emulsified asphalt that has set or "broke" before being covered with aggregate shall be removed or repaired by methods approved by the Engineer and shall be at the Contractor's expense.

Operating the chip spreader at speeds which cause the chips to roll over after striking the emulsion covered surface will not be permitted.

Provide coverage without overlaps or joints within the wheel paths.

The transverse cut off of aggregates shall be neat and any excess aggregates shall be removed from the surface prior to resuming operations.

Aggregates shall be surface damp at the time of application, but excess free water (water not adhering to the aggregate surface) on the aggregate will not be permitted.

00711.48 Shaping and Compacting - After the aggregates have been spread upon the polymer modified emulsified asphalt, any piles, ridges, or uneven distribution shall be spread and/or removed by hand tools or mechanical means, as elected, to ensure against rough spots in the final surface.

In the event aggregates are picked up by traffic or by the rolling operation, that area shall be immediately covered with additional quantities of fine aggregate and rolled.

Rolling shall consist of two coverages. The first coverage shall be performed with a pneumatic-tired roller that remains immediately behind the spreader, the second coverage shall be performed with a steel-wheeled roller, unless otherwise directed by the Engineer.

Rolling speeds shall be kept to a minimum, usually around 5 MPH, so that the rollers do not pick up aggregates from the emulsified asphalt surface.

00711.49 Power Brooming - Between the hours of 11:00 p.m. and 7:00 a.m. of the day following the application of the chip seal, the entire surface shall be carefully broomed, unless brooming damages the chip seal, to remove loose aggregate that could damage vehicles. A minimum of two power brooms shall be used.

Subsequent brooming the following 2 days may be directed by the Engineer to ensure that the surface is free of loose aggregate that could cause vehicle damage.

In curbed areas, use a pickup type power broom. On bridges, sidewalks, and other areas off the roadway, all extraneous aggregates shall be removed to the satisfaction of the Engineer.

00711.51 Provisions for Traffic - In addition to other required traffic provisions, control traffic according to the applicable provisions of 00220.40 of the special provisions.

Measurement

00711.80 General - The quantity of aggregate to be paid for will be the number of cubic yards measured in the hauling vehicles, as set forth in Section 00190 and incorporated in the completed course of polymer modified emulsified asphalt chip seal.

The quantities of polymer modified emulsified asphalt to be paid for will be the number of tons of polymer modified emulsified asphalt, measured as set forth in 00190, and incorporated in the completed polymer modified emulsified asphalt chip seal.

When indicated by the appropriate pay item listed in the Bid Schedule, separate measurement and additional payment is to be made per each location for the additional labor and other additional costs involved in constructing polymer modified emulsified asphalt chip seal on connections to public roads and streets and on approaches to private properties.

(Use the following paragraph when the number and location of approaches are to be listed.)

There are approximately ____ approaches located within the limits of the project as follows:

Payment

00711.90 General - The accepted quantities will be paid for at the contract price per unit of measurement for each of the pay items listed below that appear in the Bid Schedule.

Item Reference	Pay Item	Unit of Measurement
(a)	Aggregate in Polymer Modified Emulsified Asphalt Chip Seal	Cu.Yd.
(b)	Asphalt in Polymer Modified Emulsified Asphalt Chip Seal	Ton
(c)	Extra for Polymer Modified Emulsified Asphalt Chip Seal Approaches	Each

Pay item (a) above is applicable to aggregates which are furnished, hauled, and placed in the work as specified.

Pay item (b) above is applicable to the polymer modified emulsified asphalt furnished, hauled to, and placed in the work as specified.

Pay item (c) above is applicable to the extra costs of placing the aggregates and asphalt in polymer modified emulsified asphalt chip seal on connections and approaches, which payment will be in addition to payment made for the materials used in the work.

No extra payment will be made for any additional costs of placing polymer modified emulsified asphalt chip seal in connections, approaches, and guard rail flares.

The applicable contract prices and payment as above provided and as set forth in the Bid Schedule will be full compensation for preparing the roadway surface, providing all materials in final position, and brooming, including all labor, equipment, tools, and incidentals necessary to complete the work as specified.

APPENDIX D

SPECIFICATIONS FOR POLYMER MODIFIED ASPHALT CHIP SEALS
(Heavy Duty)

SECTION 00712 - POLYMER MODIFIED EMULSIFIED ASPHALT CHIP SEAL (HEAVY DUTY)

Section 00712, which is not in the Standard Specifications, is included for this project by special provisions.

Description

00712.00 Scope - This work consists of an application of polymer modified emulsified asphalt and two applications of graded aggregates as directed by the Engineer.

The types of chips to be applied are coarse and fine, in that order.

The polymer modified emulsified asphalt chip seal (heavy duty) shall be constructed in accordance with these specifications and in reasonably close conformity to the lines, grades, thicknesses, and cross sections shown on the plans or established by the Engineer.

00712.03 Variation of Quantities and Operations - The rates of spreads and quantities of materials are subject to variation as directed by the Engineer to adjust for variable conditions encountered or experienced during the construction. Recognize that the nature of the work calls for equipment in varying number and versatility and modification of procedures to some extent. Generally, the ratio of asphalt to aggregate shall be held closely constant to that specified.

Materials

00712.10 Aggregates - The size of aggregate for the chip seal shall conform to the following:

Chip Aggregate Type	Size of Screenings
Fine	1/4"-No. 10
Coarse	1/2"-1/4"

Aggregates shall consist of broken stone, crushed gravel, or a combination of both. At least 90 percent by weight of the total aggregate retained on the No. 10 and larger sieves shall be fractured on two faces, as determined visually by the Engineer.

Elongated pieces in the coarse aggregate (aggregate larger than 1/4 inch) shall be determined as described in OSHD Test Method 229N with the proportional caliper device set at a ratio of 5:1 and shall not exceed 10 percent by weight of the material retained on the 1/4-inch sieve.

Aggregates shall conform to the quality requirements of 02680.10(c), (d), and (f).

The percentage composition by weight of aggregates shall conform to the following gradings:

Sieve Sizes	Percentage Passing Coarse 1/2"-1/4"	Fine 1/4"-No. 10
1/2"	85-100	-
3/8"	0-30	100
1/4"	0-15	80-100
No. 10	0-3	5-30
No. 40	-	0-6
No. 200	0-2	0-2
No. 200 (For Gravel Sources)	0-1	-

(a) Taking Aggregates from Division Stockpiles - When it is specified that aggregates are to be taken from Division-controlled stockpiles, remove the material in an orderly manner and to the full depth of the pile as far as needed. Care shall be exercised to not contaminate the materials, yet salvage all material possible from the area from which the materials are taken. Unused portions of a stockpile shall be shaped to neat lines. The Contractor will be charged for materials wasted through negligence or used without authority of the specifications or the Engineer.

(b) Stockpiling Contractor-Furnished Aggregates on Division Property - Aggregates can be temporarily stockpiled at approved sites on Division property provided the areas used are as small as practicable and are cleaned up and made sightly after the materials thereon are removed. Any contamination during storage or from reloading operations will be cause for rejection.

00712.11 Bituminous Materials - The bituminous materials to be used in the polymer modified emulsified asphalt chip seal shall be HFRS-P2, CRS-2(P1), CRS-2K, or CRS-2D emulsified asphalt as elected. The polymer modified emulsified asphalt shall conform to the requirements of Section 02710 of the Standard Specifications.

The materials may be conditionally accepted based on certification at the source or point of loading for transport to the project. Excessive delay in the use of the polymer modified emulsified asphalt or excessive pumping of the polymer modified emulsified asphalt may significantly reduce the viscosity and may make the material unsuitable for chip seal use. For this reason, pumping which occurs between the bulk storage tank, hauling transportation, field storage tanks, and distributor shall be kept to an absolute minimum. Final acceptance of polymer modified emulsified asphalt will be at the point of application.

Samples taken at the time of application will be tested at the Division's Materials Laboratory within 14 calendar days.

(Use the following 00712.15 and 00712.16 for Region 4 projects, any project with process control of other surfacing aggregates, or any other projects, when requested by the other regions.)

00712.15 Process Control - Be responsible for quality control, as required by 00165.10 of the Standard Specifications, and perform process control sampling and testing as follows:

(a) Aggregate - Sample aggregate during production and test as follows:

(a-1) Required Tests - Perform each of the following tests at the sampling frequency indicated:

Test	Test Method OSHD	Test Method AASHTO	Start of Production	One Per 5 Shifts*	One Per Shift*
Fracture of Gravel	TM 213		X	X	-
Wood Particles	TM 225		X	X***	-
Elongated Pieces	TM 229N		X	X***	-
Friable Particles		T 112	X	X***	-
Sieve Analysis		T 11/T 27	X	-	X**

*A shift means a production shift or 500 tons, whichever results in the greatest sampling frequency.
**Perform at least three tests per project.
***May be waived after first five shifts, if allowed by the Engineer of Materials and Research.

(a-2) Split Samples - Provide split samples of all required samples to the Engineer.

(a-3) Engineer Testing - The Engineer may perform any of the tests required in 00712.15(a-1) and any additional tests, such as lightweight pieces, and qualifying tests for soundness, degradation, abrasion, and organic impurities.

(a-4) Removal of Failing Material - Make appropriate operational adjustments and conduct a second test immediately whenever a process control test result, other than sieve analysis does not meet specifications. Remove all failing material from the stockpile if the second test result does not meet specifications. See 00712.16(a-2) relative to nonspecification aggregate gradation and cleanness value.

(a-5) Preproduced Aggregate - Compliance of aggregates produced and stockpiled before the award of this contract will be determined by either:

a. Continuing production records meeting the requirements of 00712.15(a-1), (a-3), and (a-4).

b. Sampling and testing the entire stockpile according to AASHTO T2 at the following minimum frequency schedule:

- Start of production (one set of tests per stockpile).
- One per 5 shifts (one set of tests per 2,500 tons).
- One per shift (one set of tests per 500 tons. At least one set per shift or three per project, whichever produces the greater number of tests).

00712.16 Acceptance Sampling and Testing - Acceptance sampling and testing will be performed as required by 00165.40 of the Standard Specifications and the following:

(a) Aggregate - Compliance of material will be based on the process control testing as required in 00165.10, 00712.10, 00712.15(a), and 00712.16(a) as verified by qualifying and check tests performed by the Engineer.

(a-1) Aggregate Gradation - A stockpile contains specification aggregate when the Quality Level (QL) for each sieve analysis calculated according to 00165.30 is equal to or greater than the QL indicated in Table 00165-2 for a Pay Factor of 1.00. Each required sample represents a sublot.

When the QL indicated in Table 00165-2 yields a Pay Factor of less than 1.00 for any constituent, the material is nonspecification.

(a-2) Nonspecification Aggregate Gradation - The Engineer will reject any stockpile of aggregate containing material not conforming to the gradation specifications, unless the nonspecification material is removed from the stockpile. Additional material shall not be added to such a stockpile until enough nonspecification material is removed so that the QL for each constituent is equal to or greater than the QL in Table 00165-2 for a 1.00 Pay Factor.

(a-3) Engineer's Check Testing - If check tests are not within the allowable tolerances given in the Division's Standard Procedures, work with the Engineer immediately to resolve the difference in an attempt to avoid having this material rejected for not meeting specifications. Material not meeting qualifying and other tests performed by the Engineer will be rejected.

(a-4) Materials on Hand - Payment for stockpiled materials on hand may be allowed as described in 00195.60 subject to meeting 00712.10, 00712.15(a), and 00712.16(a).

Payment for preproduced and nonspecification materials will not be allowed.

Equipment

00712.20 Equipment - The equipment to be used shall include pressure distributor, hauling vehicles, chip spreaders, compactors, power brooms, and such other necessary equipment to insure efficient operation and construction to meet specified results. Equipment shall be provided in such number and capacities as will provide coordinated and uniform progress of the work.

Provide two-way radio communication between the asphalt distributor and chip spreader.

(a) Asphalt Distributor - The asphalt distributor shall be so designed, equipped, maintained, and operated that polymer modified emulsified asphalt material at even heat may be applied uniformly on variable widths of surface up to 15 feet at readily determinable and controlled rates from 0.05 gallon to 2.0 gallons per square yard with uniform pressure and with an allowable variation from any specified rate not to exceed 0.02 gallon per square yard. Distributor equipment shall include a tachometer, pressure gages, accurate volume measuring devices or a calibrated tank, and a thermometer for measuring temperature of tank contents. Distributors shall have a power unit for the pump and full circulation spray bars adjustable laterally and vertically.

Provide manufacturer's specifications showing proper nozzle size for desired viscosity, rate of travel, and rate of polymer modified emulsified asphalt application. Pump pressure shall be in the middle or lower end of the acceptable range. Nozzle angle shall be set accurately to the angle stated in the manufacturer's specifications. Bar height shall be set for triple lap coverage.

(b) Chip Spreaders - The chip spreaders shall be self-propelled and shall be equipped with a mechanical device that will spread the aggregate at a uniform rate across the full width of the chip spreaders. Spreaders shall be equipped with an aggregate segregator assembly. Chip spreaders shall be capable of providing coverage without overlaps or joints within the wheel paths.

00712.24 Compactors - Rollers shall be self-propelled pneumatic-tired or steel-wheeled with a minimum of one pneumatic-tired roller and one steel-wheeled roller required. They shall be in good condition and capable of operating at speeds compatible with the chip seal operation.

(a) Pneumatic-tired Rollers - The pneumatic-tired rollers shall be self-propelled, tandem or multiple axle, multiple wheel type with smooth-tread pneumatic tires of equal size staggered on the axles at such spacings and overlaps as will provide uniform compacting pressure for the full compacting width of the roller and shall be capable of exerting ground pressures of 80 pounds per square inch of tire contact area. Tire inflation pressures shall be 45 psi to 60 psi.

(b) Steel-wheeled Rollers - The steel-wheeled roller shall provide a weight of not less than 200 pounds per inch of width of the compression roll or rolls.

00712.25 Power Brooms - Power brooms shall be pickup and/or nonpickup type and shall have a positive means to control vertical pressure.

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00712.40 Season and Weather Limitations - Polymer modified emulsified asphalt shall not be applied when the pavement temperature is below 70°F nor if the humidity is higher than 75 percent. The application of the polymer modified emulsified asphalt and the aggregate chips shall be completed 2 hours before sunset. Chip seals damaged by rain during the first 24 hours after application shall be removed by milling, or other methods approved by the Engineer, and replaced at the Contractor's expense. The placing of polymer modified emulsified asphalt chip seals will not be allowed before July 1 or after August 31.

(Replace the last sentence in the above paragraph with the following sentence when Region 3 Projects are involved.)

The placing of polymer modified emulsified asphalt chip seal will not be allowed before June 15 or after August 31.

00712.42 Rate of Progress and Scheduling - The amount of chip seal applied in any one day shall not exceed the amount that can be broomed the following morning unless approved by the Engineer. Provide a traffic control plan for approval by the Engineer if operations exceed 3 centerline miles or 6 lane-miles per day.

00712.43 Preparation of Underlying Surfaces - Immediately before applying the polymer modified emulsified asphalt, the surface to be sealed shall be clean and dry. Cleaning shall be performed by sweeping, flushing, or other means necessary to remove all loose particles of paving, dirt, and other extraneous material. When the underlying surface is open-graded, a pre-fog seal or equivalent treatment shall be constructed, as directed by the Engineer.

00712.45 Applying Polymer Modified Emulsified Asphalt - The exact application rate of polymer modified emulsified asphalt for chip seal (heavy duty) will be determined by the Engineer. Normally, the rate of application will be the following:

Gallons/Sq.Yd.
0.50 (± 0.10)

Apply the polymer modified emulsified asphalt working toward the aggregate stockpile at all times.

A minimum of 200 gallons of polymer modified emulsified asphalt shall remain in the distributor tank at all times except for the last shot on the project.

The polymer modified emulsified asphalt shall not be applied to more than one-half the width of the travel way at one time and the remaining width shall remain open to traffic. The open lane shall not be closed until traffic controlled by pilot car is operating on the new chip seal. The chip seal shall, weather permitting, be applied to both sides of the travel way so that by 2 hours before sunset the end of the work is squared up.

Polymer modified emulsified asphalt shall not be applied a greater distance than can be immediately covered by aggregates before the emulsion breaks.

Building paper shall be placed over the treated surface at the beginning of each spread to insure that the nozzles are operating properly before the uncovered surface is reached. Building paper shall be removed and disposed of in a manner satisfactory to the Engineer.

If requested by the Engineer, demonstrate that the distribution of the emulsified asphalt does not vary between the individual nozzles by more than 15 percent transversely from the average and no more than 10 percent longitudinally from the specified rate of application.

The application temperature of the polymer modified emulsified asphalt shall be between 160°F and 185°F.

00712.47 Hauling and Spreading Aggregates - The exact spread rate of aggregate for seal will be determined by the Engineer. Normally, the rate of spread will be the following:

Chip Aggregate Types	Cu.Yd./Sq.Yd.
Fine	0.004 (± 0.002)
Coarse	0.012 (± 0.003)

Hauling and spreading equipment shall not be operated on uncovered polymer modified emulsified asphalt. During the first hour after both applications of the polymer modified emulsified asphalt and aggregate, speeds shall be no more than 10 MPH and after the first hour, speeds shall not be in excess of 15 MPH until otherwise permitted by the Engineer. At all times, hauling equipment shall be operated in a prudent manner and at moderate speeds that will not damage the new chip seal or create a hazard to the traveling public.

The chip spreaders shall be accurately calibrated for the various sizes of aggregate to be used in regard to gate opening, gear selection and engine RPM. Following calibration, the rate of application shall be verified by truck measure and area covered.

Immediately following the application of polymer modified emulsified asphalt, the surface shall be covered with coarse aggregate. Fine aggregate shall be placed as soon as practical after the placement of the coarse aggregate. The number of trucks between the spreaders shall be limited to four. The rate of spread of aggregates shall be maintained within 10 percent of specified rate.

Polymer modified emulsified asphalt that has set or "broke" before being covered with aggregate shall be removed or repaired by methods approved by the Engineer and shall be at the Contractor's expense.

Operating the chip spreader at speeds which cause the chips to roll over after striking the emulsion covered surface will not be permitted.

Provide coverage without overlaps or joints within the wheel paths.

The transverse cut off of aggregates shall be neat and any excess aggregates shall be removed from the surface prior to resuming operations.

Aggregates shall be surface damp at the time of application, but excess free water (water not adhering to the aggregate surface) on the aggregate will not be permitted.

00712.48 Shaping and Compacting - After the aggregates have been spread upon the polymer modified emulsified asphalt, any piles, ridges, or uneven distribution shall be spread and/or removed by hand tools or mechanical means, as elected, to ensure against rough spots in the final surface.

In the event aggregates are picked up by traffic or by the rolling operation, that area shall be immediately covered with additional quantities of fine aggregate and rolled.

Rolling shall consist of two coverages. The first coverage shall be performed with a pneumatic-tired roller that remains immediately behind the spreader. The second coverage shall be performed with a steel-wheeled roller, unless otherwise directed by the Engineer.

Rolling speeds shall be kept to a minimum, usually around 5 MPH, so that the rollers do not pick up aggregates from the emulsified asphalt surface.

00712.49 Power Brooming - Between the hours of 11:00 p.m. and 7:00 a.m. of the day following the application of the chip seal, the entire surface shall be carefully broomed, unless brooming damages the chip seal, to remove loose aggregate that could damage vehicles. A minimum of two power brooms shall be used.

Subsequent brooming the following 2 days may be directed by the Engineer to ensure that the surface is free of loose aggregate that could cause vehicle damage.

In curbed areas, use a pickup type power broom. On bridges, sidewalks, and other areas off the roadway, all extraneous aggregates shall be removed to the satisfaction of the Engineer.

00712.51 Provisions for Traffic - In addition to other required traffic provisions, control traffic according to the applicable provisions of 00220.40 of the special provisions.

Measurement

00712.80 General - The quantity of aggregate to be paid for will be the number of cubic yards measured in the hauling vehicles, as set forth in Section 00190 and incorporated in the completed course of polymer modified emulsified asphalt chip seal (heavy duty).

The quantities of polymer modified emulsified asphalt to be paid for will be the number of tons of polymer modified emulsified asphalt, measured as set forth in 00190, and incorporated in the completed polymer modified emulsified asphalt chip seal (heavy duty).

When indicated by the appropriate pay item listed in the Bid Schedule, separate measurement and additional payment is to be made per each location for the additional labor and other additional costs involved in constructing polymer modified emulsified asphalt chip seal on connections to public roads and streets and on approaches to private properties.

(Use the following paragraph when the number and location of approaches are to be listed.)

There are approximately ____ approaches located within the limits of the project as follows:

Payment

00712.90 General - The accepted quantities will be paid for at the contract price per unit of measurement for each of the pay items listed below that appear in the Bid Schedule.

Item Reference	Pay Item	Unit of Measurement
(a)	Aggregate in Polymer Modified Emulsified Asphalt Chip Seal (Heavy Duty)	Cu.Yd.
(b)	Asphalt in Polymer Modified Emulsified Asphalt Chip Seal (Heavy Duty)	Ton
(c)	Extra for Polymer Modified Emulsified Asphalt Chip Seal Approaches	Each

Pay item (a) above is applicable to aggregates which are furnished, hauled, and placed in the work as specified.

Pay item (b) above is applicable to the polymer modified emulsified asphalt furnished, hauled to, and placed in the work as specified.

Pay item (c) above is applicable to the extra costs of placing the aggregates and asphalt in polymer modified emulsified asphalt chip seal on connections and approaches, which payment will be in addition to payment made for the materials used in the work.

No extra payment will be made for any additional costs of placing polymer modified emulsified asphalt chip seal in connections, approaches, and guard rail flares.

The applicable contract prices and payment as above provided and as set forth in the Bid Schedule will be full compensation for preparing the roadway surface, providing all materials in final position, and brooming, including all labor, equipment, tools, and incidentals necessary to complete the work as specified.