Review of Hot Bituminous Surface Treatments in Washington State

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16. ABSTRACT

This report reviews the construction and performance review of 11 hot bituminous surface treatment (HBST) projects installed between 2014 and 2017. The HBST used AC-15P binders and either 3/8" to No. 8 or 3/8" to No. 4 aggregates pre-coated with PG binder. The pre-coated chips are dropped onto the hot binder and rolled with a series of pneumatic rollers which are followed by a steel wheel roller to further embed the aggregate into the binder. The HBST is open to normal speed traffic when the binder has taken a set.

The performance of the HBST's has been good on all of the projects with the exception of two, one built in 2015 and the other in 2017. The poor performance on these projects is attributed to poor chip seal placement practices.

Recommendations are provided for the successful construction of HBST projects.

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Executive Summary

This report reviews the construction and performance of eleven hot bituminous surface treatment (HBST) projects built between 2014 and 2017. The purpose of the review is to provide a baseline of information that can be used to compare the HBST process against conventional BST construction with respect to service life and life cycle costs.

The evolution of the specifications for HBST construction are reviewed as they are refined based on field experience. The biggest change was to soften the binder for the 2015 projects, but this was reversed based on poor results on the initial project with the softer specification. Minor changes also occurred on the application rates for the binder and aggregate, the temperature requirements for the binder in the distributor, the minimum air temperature for paving, the allowable maximum temperature for the binder when the aggregate can be applied, and the roller and the aggregate coating requirements.

Information is provided on each project beginning with a description of the project followed by a review of the specification details, information from the inspector's daily reports on the paving and photos of the operation. Information and photos from a 2017 review of each project are then presented. On some projects a review was conducted in 2016 and this information and photos are captured. Comments from a 2018 review are included along with photos from a project experiencing performance failures.

Nine of the eleven projects are performing well. The two poor performers are Contract 8766 on SR-14 which had large sections rebuilt due to flushing and delamination and Contract 9047 on SR-903 and SR-410 which are raveling to the extent that only the AC-15P remains in some areas.

Aggregate embedment, estimated during the 2017 review, ranged from 30-90% with a majority in the 60-80% range. Eight of the eleven projects had areas of 100% embedment, usually in the wheel paths. However, none of the eight projects had friction resistance numbers in the category requiring attention due to safety concerns.

The 11 projects built to date provide a good base line for the performance evaluation of HBST since they are on a variety of routes with varying amounts of traffic and climatic conditions. The average annual daily traffic (AADT) ranges from 570 to 12,000. Truck percentage ranged from 4-22%. The climates at the locations vary from dry to wet and temperatures from hot-mild in the summer and mild-cold with lots of snow in the winter.

The cost of the HBST on each project was calculated from the bid tabulations and if the project also included construction of conventional BST its cost was also calculated. The average cost of the HBST was $14,137 and the BST $11,770. This cost differential between the BST and HBST may be influenced by differences in the quantities of each item. One project where the quantities of the BST and HBST were almost equal resulted in the HBST costing $1,515 per lane mile more than the conventional BST.

It is too early in the evaluation process to draw conclusions on the long-term performance of the projects. With the exception of Contract 8766 and portions of Contact 9047, all of the projects are showing good performance. The presence of 100% embedment of the aggregates in the wheel paths of many of the projects is a concern; however, the annual statewide friction surveys have not found any significant problems with the friction resistance on any of the projects. The presence of only 50% embedment of the aggregates on the US-2 portion of Contract 9006 and 30% embedment on some of the sections on 9047 are a concern as evidenced by the raveling problems on SR-903 and SR-410.

Recommendations for future projects include: (1) Construct hot seals early in the construction season to allow time for traffic to embed the pre-coasted aggregates. Hot seals placed in shady or mountainous areas should be placed prior to August 1st to take advantage of warmer temperatures and traffic to embed the aggregates. (2) Aggregate application rates and binder shot rates should be monitored continuously on all projects. (3) Require a minimum of three pneumatic and one steel wheel roller on all projects. (4) Apply more compactive effort (rolling) on lower volume roadways to seat the aggregate. (5) Fog seal HMA patches prior to the application of HBST.

Introduction

In 2014, WSDOT began a new process for chip sealing using a hot applied asphalt binder AC-15P in place of CRS-2P, an asphalt emulsion binder. The process is called a hot chip seal (HBST). The AC-15P is modified with a polymer and applied to the roadway at temperatures between 275 and 370 ºF. In contrast, CRS-2P is applied to the roadway at 140 to 160 ºF. The aggregate for the HBST is pre-coated with a PG graded binder in an asphalt plant and is dropped onto the AC-15P directly behind the distributor, the same process used for a conventional chip seal. The big difference between the two processes is that the HBST can be opened to traffic operating at posted speed limits as soon as the aggregate is rolled and the binder has cooled. The conventional chip seal using the CRS-2P must cure (harden) for 8-12 hours before it can be broomed and traffic can be allowed to operate at the posted speed limit. During this curing period the roadway is posted with a 35 MPH speed limit. The HBST is thus a faster process than conventional BST construction.

The first HBST project was constructed in the summer of 2014 in the North Central Region on SR-97A between Entiat and Chelan. This project was followed by four addition projects in 2015, one each in the North Central, Eastern, South Central and Southwest Regions. Three projects were constructed in both 2016 and 2017.

This report is intended to document the construction and performance of the projects and compare that performance with conventional BST projects to determine which has the longer service life and is most cost effective.

Specification History

The specifications for the HBST have evolved over the years since the first project was built in 2014. These changes are discussed in the following section of the report and summarized in for 2014-2015, 2016, and 2017 projects in Tables 1, 2 and 3 respectively.

AC-15P

The contract plans for the second year projects contained a modified version of the AC-15P specification used on the 2014 project. The modification softened the binder by changes to the absolute and kinematic viscosities, penetration and elastic recovery properties. Contract 8721 on SR-12 in the South Central Region was the first to use this modified binder. Flushing problems were immediately encountered triggering a change order back to the original specification used in 2014. The other 2015 projects also issued change order to return to the harder binder. The harder binder was used on all the projects in 2016 and 2017.

AC-15P Application Rate

The application rate of the AC-15P was initially set at 0.35 to 0.45 gal/square yard in 2014 and remained at that level for all of the 2015 projects. In 2016 the NCR changed the application rate

to 0.35 to 0.40 while the ER and SWR remained at higher application rate. For 2017 all of the projects changed to the lower 0.35 to 0.40 application rate.

Aggregate Size

The aggregate size has been either 3/8" to No 4 or 3/8" to No. 8 and the choke, if used, is generally No. 4 to 0. One of the three 2016 projects did not specify a choke and none of the 2017 projects included a choke in the specifications or bid sheets.

Aggregate Application Rate

Most of the 2014 and 2015 projects used an application rate of 10-20 pounds per square yard with the exception of Contract 8728 which specified 15-18 pounds per square yard. In 2016 and 2017 the application rates have fluctuated from 14-18 to 14-22 pounds per square yard.

AC-15P Temperature in Distributor

The temperature of the AC-15P in the distributor was set at 325-350°F for the 2014 and 2015 projects, but increased to 350-370°F for the 2016 and 2017 or manufacturer's recommended temperature.

Road and Air Temperature

The air temperature must be at least 65°F and rising and the road temperature must be a minimum of 70°F for the 2014 and 2015 projects. The road temperature requirements were revised for the 2016 and 2017 project to a minimum of 70°F up to 150°F or lower.

Surface Temperature at Application of Aggregate

The temperature of the AC-15P on the roadway at the time of application of the aggregate was set at 120-180°F for the 2014 and 2015 projects. A revision was made for the 2016 and 2017 projects to 130-150°F and up to 180°F with approval of the Engineer.

Roller Requirements

All of the projects required three pneumatic rollers making a minimum of 2 passes. A steel wheel roller operating in static mode is often added to the compliment of pneumatic rollers.

Aggregate Coating Requirements

The aggregate coating requirements were set at 90% coating of all aggregates retained on the No. 4 sieve for the 2014 and 2015 projects. The 2016 and 2017 specifications was changed to read "The asphalt content of the aggregate for hot seal and asphalt mixture shall be between 0.5 - 0.8 percent by weight."

Wait Period after Repairs and Fog Seals

Many of the projects required repairs such as crack sealing or a fog seal prior to the HBST process. A wait period is often specified and it has ranged from no wait period to 7 days.

Aggregate Embedment

The contract specifications do not call out the aggregate embedment requirements, however, the WSDOT Construction Manual calls for 50-70% embedment of the aggregate chips in the binder.

Table 1. Summary of information on 2014 and 2015 HBST contracts.

Cont.	Title	SR	MP Limits	AC-15P Specification	AC-15P Appl. Rate (gal/SY)	Aggregate		Temp. of AC-15P in Distributor (°F)	Road and Air Temp. for Appl.	Surface Temp. Requirements
						Size	Appl. Rate (lbs/SY)			
2014 Projects										
8566	NCR Seal 2014	Alt 97	223.72–232.08	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.45	3/8"–No.4 Choke No.4-0	10-20	325-350	Road 70°F Air 65°F and rising	120-180°F
2015 Projects										
8711	NCR Chip Seal 2015	207	0.00-4.38	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.45	3/8"–No.8	10-20	325-350	Road 70°F Air 65°F and rising	120-180°F
		281	2.65-4.34							
8721	US 2 ET AL South Central Region Chip Seal	12	177.43-189.38	AV–1500/3500 KV–1200 Pen–100/150 ER 70 changed back to 2014 spec. mid-way	0.35-0.45	3/8"–No.4	10-20	325-350	Road 70°F Air 65°F and rising	120-180°F
8728	US 2 ET AL 2015 Easter Region Chip Seal	2	314.94-321.83	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.45	3/8"–No.8 parts of each section choked	15-18	325-350	Road 70°F Air 65°F and rising	120-180°F
		206	2.44-13.00							
8766	6th St. to Bingen City	14	27.87-67.11	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.45	3/8"–No.4 Choke No.4-0	10-20	325-350	Road 70°F Air 65°F and rising	120-180°F

Table 1. (Continued for 2014 and 2015 contracts).							
Contract No.	**Rollers**	**Aggregate Coating Spec.**	**Wait Period After Repairs and Fog Seals**	**Bid Prices**			
				AC-15P ($/Ton)	**3/8-No.8 ($/SY)**	**3/8-No.4 ($/SY)**	**No. 4-0 ($/SY)**
2014 Projects							
8566	3 pneumatic min. 2 passes	90% of aggregate. retained on the No. 4 sieve	None stated	500	1.02	-	0.10
2015 Projects							
8711	3 pneumatic min. 2 passes	90% of aggregate. retained on the No. 4 sieve	None stated	550	-	0.85	
8721	No special requirement stated for rollers	90% of aggregate. retained on the No. 4 sieve	None stated	698	-	66.05/ton	-
8728	3 pneumatic min. 2 passes, 1 static steel wheel 1 pass	90% of aggregate. retained on the No. 4 sieve	7 days	575	0.75	0.75	0.12
8766	3 pneumatic min. 2 passes, 1 static steel wheel 1 pass	90% of aggregate. retained on the No. 4 sieve	None stated	900	-	0.79	-

Table 2. Summary of information on 2016 HBST contracts.

Cont.	Title	SR	MP Limits	AC-15P Specification	AC-15P Appl. Rate (gal/SY)	Aggregate		Temp. Of AC-15P in Distributor (°F)	Road and Air Temp. for Appl.	Surface Temp. Requirements
						Size	Appl. Rate (lbs/SY)			
2016 Projects										
8864	US 2 ET AL 2016 ER Chip Seal	2	322.77-328.60	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.45	3/8"–No.8 Cover with CSS-1 and No.4-0 one pass of pneumatic roller	14-22	350-370	Road 70-150°F Air 65°F and rising	130-150°F up to 180°F with Engr. approval
8890	NCR Seal 2016	97	226-234.77 235-235.18	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.40	3/8"–No.8 Choke No. #4-0	14-18	350-370	Road 70-150°F Air 65°F and rising	130-150°F up to 180°F with Engr. approval
		Alt 97	201.57-203.67 203.82-204.67 206.70-214.22							
8901	SR- 500 and SR-505 Pavement Rehabilitation	500	8.5-17.26	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.45	3/8"–No.8	14-20	350-370	Road 70-150°F Air 65°F and rising	130-150°F up to 180°F with Engr. approval

Table 2. (Continued for 2016 projects).							
Contract No.	**Rollers**	**Aggregate Coating Spec.**	**Wait Period After Repairs and Fog Seals**	**Bid Prices**			
				AC-15P ($/Ton)	**3/8-No.8 ($/SY)**	**3/8-No.4 ($/SY)**	**No. 4-0 ($/SY)**
2016 Projects							
8864	3 pneumatic min. 2 passes, 1 static steel wheel 1 pass	AC content of pre-coated aggregate and asphalt mixture 0.4 to 0.8% by weight	24 hours	475	0.65	-	0.10
8890	3 pneumatic min. 2 passes, 1 static steel wheel 1 pass	AC content of pre-coated aggregate and asphalt mixture 0.5 to 0.8% by weight	1 day	500	0.70	0.40	0.12
8901	3 pneumatic min. 2 passes, 1 static steel wheel 1 pass	AC content of pre-coated aggregate and asphalt mixture 0.5 to 0.8% by weight	3 days	650	1.50		0.15

Table 3. Summary of information on 2017 HBST contracts.

Cont.	Title	SR	MP Limits	AC-15P Specification	AC-15P Appl. Rate (gal/SY)	Aggregate		Temp. of AC-15P in Distributor (°F)	Road and Air Temp. for Appl.	Surface Temp. Requirements
						Size	Appl. Rate (lbs/SY)			
2017 Projects										
8989	Sedro Wooley to Concrete	20	67.10-90.52	AV–1500 KV–2000 Pen–80/150 ER 55	0.35–0.40	3/8"–No.8 Choke No. #4-0 Fog Seal	14-18		Road 70-150°F Air 65°F and rising	130-150°F up to 180°F with Engr. approval
9006	NCR 2017 Pavement Rehabilitation and Seal	2	90.72-99.04	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.40	3/8"–No. 8 No Choke	14-18		Road 70-150°F Air 65°F and rising	130-150°F up to 180°F with Engr. approval
		28	10.17-19.12							
		173	0.00-11.98							
		281	0.00-10.54							
		283	0.05-14.86							
		City of Brewster Streets								
9047	SCR Region Wide Chip Seal	410	69.21-74.50	AV–1500 KV–2000 Pen–80/150 ER 55	0.35-0.40	3/8"–No. 8 No Choke	14-18		Road 70-150°F Air 65°F and rising	130-150°F up to 180°F with Engr. approval
			93.63-107.40							
			108.61-116.37							
		903	2.10-4.75							
			6.10-10.06							
		City of Walla Walla Streets								

Table 3. (Continued for 2017 contracts).							
Contract No.	Rollers	Aggregate Coating Spec.	Wait Period After Repairs and Fog Seals	Bid Prices			
				AC-15P ($/Ton)	3/8-No.8 ($/SY)	3/8-No.4 ($/SY)	No. 4-0 ($/SY)
2017 Projects							
8989	3 pneumatic min. 2 passes, 1 static steel wheel min.1 pass	AC content of pre-coated aggregate and asphalt mixture 0.5 to 0.8% by weight	7 days	700	0.85	-	0.14
9006	3 pneumatic min. 2 passes, 1 static steel wheel min.1 pass	AC content of pre-coated aggregate and asphalt mixture 0.5 to 0.8% by weight	3 days	550	0.90	-	-
9047	3 pneumatic min. 2 passes, 1 static steel wheel min.1 pass	AC content of pre-coated aggregate and asphalt mixture 0.5 to 0.8% by weight	7 days	625	0.80	-	-

2014 Project

Contract 8566, NCR Seal 2014

The first HBST was constructed on SR-97A between Entiat and Chelan (97A runs on the west side of the Columbia River between Wenatchee and Chelan). A total of 16.72 lane miles of roadway were sealed between MP 223.72 and 232.08. The project was built by Central Washington Asphalt using binder supplied by Western States Asphalt. Chad Simonson was the WSDOT Project Engineer.

The paving took place on July 30 and 31, 2014 using two Bearcat distributors, two Bearcat CRC chip spreaders, three Volvo PT125 pneumatic rollers, one Ingersoll Rand steel wheel roller, two RoadTec MB-85 brooms and one Broce RCT 350 broom.

Specification Details

The specifications called for the AC-15P to be applied at a rate of 0.35-0.45 gal/square yard and 3/8" to No. 4 chips at a rate of 10-20 lbs/square yard. The aggregates were pre-coated with PG64-22 asphalt binder using methods that resulted in a minimum of 90% coating of the rocks retained on the No. 4 sieve. The coated aggregates were stored in multiple stockpiles in order to accelerate the cooling and to increase the uniformity of the coating. The stockpiles were turned until they cooled and no additional coated aggregate could be added until their temperature was less than 120°F.

Inspector Daily Report (IDR) Information

Repaired or pre-leveled areas of the existing HMA received a fog seal prior to the construction of the HBST. The temperature of the AC-15P binder in the distributor ranged from of 325-350°F. The AC-15P binder was covered with the coated aggregates when the temperature of the binder decreased to between 120 and 180°F.

Initial compaction of the HBST began immediately behind the chip spreader using three pneumatic rollers making a minimum of two complete coverages. One pass of a steel wheel roller was used to seat the aggregate. Brooming followed the rolling with four power brooms making two passes in both directions. A choke of No. 4-0 aggregate was applied to areas that were flushing, bleeding, or picking after the initial brooming of the HBST.

Picking became a problem in the afternoons when temperatures increased into the high 90's and low 100's. A water truck was used to cool the pavement to decrease the picking during the rolling. On the second day of paving the fog seal and choke were stopped because the choke was sand colored and it did not look ascetically pleasing on the very black colored HBST. The IDR's do not indicate if they changed the choke stone and began again or if some of the project did not receive a choke. The IDR's indicated road surface temperatures reached as high as 146°F.

2017 Review

Photos were taken on August 17, 2017 during a statewide review of HBST projects. Conducting the tour were Jeff Uhlmeyer, Keith Anderson, Casey Fraisure, HQ Pavements, Kim Willoughby, HQ Maintenance, Tim Moomaw, North Central Region and Joe Mahoney, UW professor of civil engineering.

This project is one of the best looking HBST of all the ones visited on the review (Figures 1-10). Embedment was observed to be 80-90% and there was very little loose aggregate on the shoulders (evidence of little raveling). The underlying pavement was in very good condition prior to the application which may have added to the good performance of the HBST. Snowplow damage was noted at the centerline, Figures 7 and 8, which may have been in the portion of the project where the steel wheel roller was omitted. Some of the longitudinal cracks that were not sealed prior to the HBST are reflecting through the HBST. The HBST gives the appearance of flushing in the wheel paths due to the 100% embedment; however, the statewide friction inventory did not find any problems with low friction on this section.

Figure 1. Looking north from the start of the HBST at MP 223.76. (August 2017)

Figure 2. Looking south at the beginning of the HBST at MP 223.76. (August 2017)

Figure 3. Closer view at MP 223.76. (August 2017)

Figure 4. Longitudinal crack extending from crack that was sealed prior to the HBST at MP 223.76. (August 2017)

Figure 5. Looking north from MP 226.30. (August 2017)

Figure 6. Closer view at MP 226.30. (August 2017)

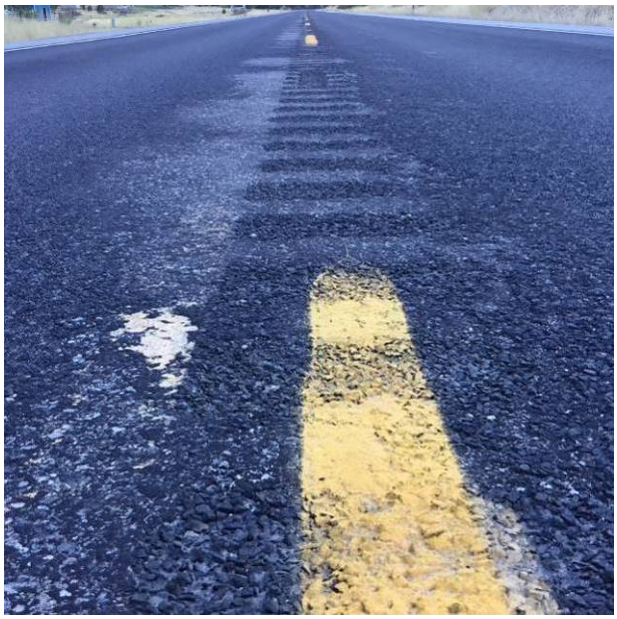

Figure 7. Snowplow damage at MP 227.50. (August 2017)

Figure 8. Snowplow damage at MP 227.50. (August 2017)

Figure 9. HBST with 100% embedment in the wheel paths at MP 230.20. (August 2017)

Figure 10. HBST with 100% embedment in the wheel paths at MP 230.20. (August 2017)

2015 Projects

Contract 8711, NCR Chip Seal 2015

The North Central Region (NCR) followed up the first project with an additional project in 2015. The entire lengths of SR-207 and SR-281 Spur were paved, a total of 8.76 and 3.38 lane miles, respectively. Central Washington Asphalt was the contractor and Kevin Waligorski was the WSDOT Project Engineer.

Specification Details

The chip size specification was changed from 3/8" to No. 4 to 3/8" to No. 8 for this project. The AC-15P binder was applied at the rate of 0.35 to 0.45 gal/square yard. The specification for the binder was changed for the 2015 projects, but due to excessive flushing on its first use on Contract 8721 in the South Central Region, all of the projects changed back to the 2014 specification. The chip application rate, chip coating requirements, roller requirements, roadway and air temperature requirements and surface temperature requirements were unchanged from the 2014 specifications. A steel wheel roller was added on the SR-281 Spur portion of the project. The steel wheel roller was used to set the chips in the binder.

IDR Information on SR-281 Spur Section

The SR-281 Spur section was chip sealed on July 6 and 7, 2015. A test section was built at the beginning of the section. Three pneumatic rollers made 3 passes and the steel wheel roller one pass. The oil yield ranged from 0.34 to 0.40 gal/square yard and the rock yield ranged from 15-18 lbs/square yard. Inspectors indicate the chips were embedded 70%. Chip trucks were picking up the chips and oil at one point in the operation with roller operators having to fix the seal before they made their passes. The temperature of the oil on the road was at 95°F when the rock was applied and the rollers were 15-20 minutes behind the chip spreader. Figures 11-23 show the paving operation on SR-281 Spur.

Figure 11. SR-281 Spur prior to the HBST. (July 2015)

Figure 12. SR-281 Spur prior to the HBST. (July 2015)

Figure 13. Distributor and chip spreader. (July 2015)

Figure 14. Truck dumping pre-coated chips into the spreader. (July 2015)

Figure 15. Pneumatic roller. (July 2015)

Figure 16. Pre-coated chips. (July 2015)

Figure 17. Aggregate and binder sticking to pneumatic roller tire. (July 2015)

Figure 18. Sweepers. (July 2015)

Figure 19. Steel wheel roller. (July 2015)

Figure 20. One lane completed. (July 2015)

Figure 21. Closer view of HBST. (July 2015)

Figure 22. Close-up of HBST. (July 2015)

Figure 23. Both lanes of the completed HBST on SR 281 Spur showing 100% embedment in the wheel paths. (July 2015)

2017 Review

The 2017 review tour took place on August 18 (Figures 24-27). The embedment ranged from 70-80% except in the wheel paths where it was 100% and thus the rich appearance. The 2016 friction survey found one value below a FN of 30, but a retest did not confirm that there was a problem with friction. The North Central Region indicated that this section should last a long time since there is no snow plowing on this roadway.

Figure 24. Looking north from MP 3.35 showing 100% embedment in the wheel paths. (August 2017)

Figure 25. Looking south from MP 3.35 showing the 100% embedment in the wheel paths. (August 2017)

Figure 26. Close-up of wheel path 100% embedment at MP 3.35. (August 2017)

Figure 27. Close-up of the wheel path with 100% embedment at MP 3.35. (August 2017)

IDR Information on SR-207 Section

Construction on SR-207 occurred on July 7, 8 and 9, 2015. Air temperatures ranged from 67-78°F and surface temperatures from 70-72°F. The oil temperature was 220°F when applied to the roadway and 78-190°F at the time of rock application. The rock application rate remained at 15 lbs/square yard and embedment estimated at 50%. Only problem was a gore area at MP 4.35 at the entrance to the state park, where a double shot of oil was applied by mistake. Extra chips were spread and rolled in with a pneumatic roller. Figures 28-31 show problems on the SR-207 section from July of 2015.

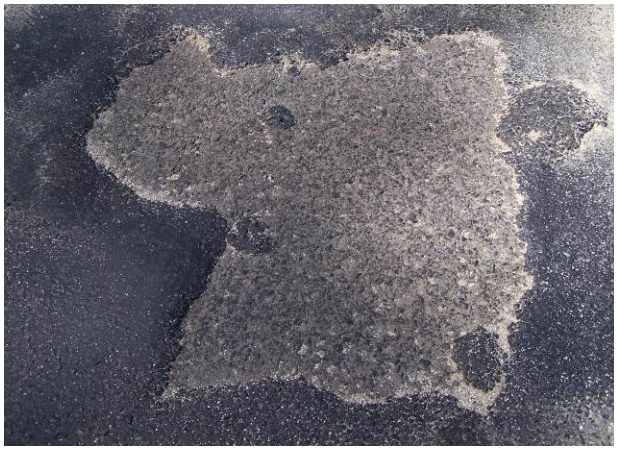

Figure 28. Delamination of HBST. (July 2015)

Figure 29. Delamination of HBST. (July 2015)

Figure 30. Delamination and flushing of the HBST. (July 2015)

Figure 31. Fog seal applied to HBST after repairs were made. (July 2015)

2017 Review

This section was reviewed on August 16, 2017 (Figures 32-37). The HBST has a somewhat streaky appearance due to the 100% embedment in the wheel paths. The North Central Region indicated that the oil shot was too heavy on this section. A slurry seal applied to the shoulder overlaps the HBST unevenly added to the negative ascetics of the project.

Figure 32. Looking north from MP 4.00. (August 2017)

Figure 33. HBST and slurry seal contact at MP 4.00. (August 2017)

Figure 34. Close-up at MP 4.00 showing 60% embedment. (August 2017)

Figure 35. Close-up at MP 4.00 showing 100% embedment. (August 2017)

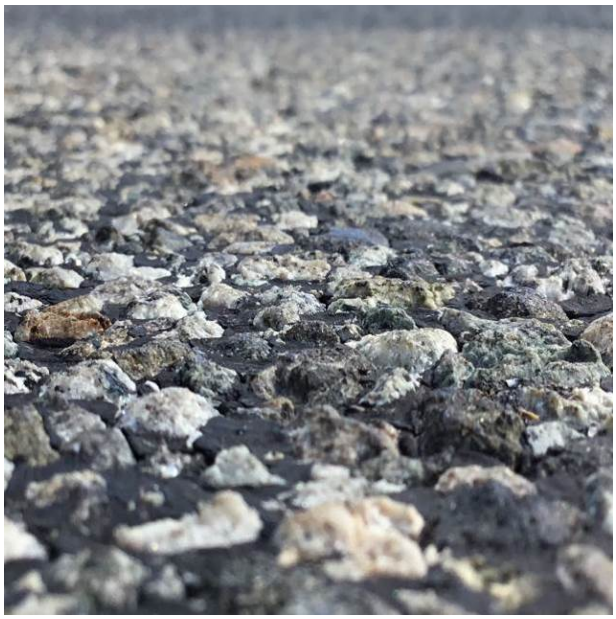

Figure 36. Low level view at MP 4.00 showing 60% embedment. (August 2017)

Figure 37. Longitudinal crack reflecting through the HBST at MP 4.00. (August 2017)

Contract 8721, US-12 ET AL South Central Region Chip Seal

HBST was installed under Contract 8721 on US-12 in the South Central Region. The contract also included the construction of conventional BSTs on US-12, SR-14 and SR-124. The contractor was Poe Asphalt Paving and Moe Davari was the WSDOT Project Engineer.

Specification Details

The aggregate used was 3/8" to No. 4 with an application rate of 10-20 lbs/square yard. The pneumatic rollers were complimented by the addition of a steel wheel roller.

IDR Information

Construction was completed between June 5 and June 25, 2015. Granite Construction produced the coated chips at their plant; Poe Asphalt Paving did the paving. The coated chips had to be rescreened prior to the first day of construction due to oversized chips. Five miles of the seal were placed on June 5 and 19, 2015 using the softer AC-15P 2015 specification. The remainder was placed on June 24 and 25 switching back to the 2014 specification for the binder. The coated rock was run back through the asphalt plant on June 19, 24 and 25 to burn off some of the asphalt coating (personal communication from the project engineer). The temperatures were moderate on the first two days, air temperature at 60°F and road temperature at 65°F. Air temperatures on June 25 ranged from 68-93°F with road temperatures from 70-135°F for the paving between MP 183.67 and 189.83. Water trucks were required to cool the pavement so traffic could be allowed on the road. Bleeding and picking of rocks were observed on this day. Rock yield was 22 lbs/square yard and oil yield 0.35 to 0.38 gal/square yard with the higher yield on June 25 (chips were noted to be very glossy black indicating that perhaps Granite may have increased the coating). In summary, the softer asphalt binder (2015 specification) was used from MP 177.43 to MP 179.52 on both lanes. The harder binder (2014 specification) was used from MP 179.52 to 189.38 in both directions. The construction process is shown in Figures 38-47.

Figure 38. AC-15P binder applied to roadway. (June 2015)

Figure 39. Spreader. (June 2015)

Figure 40. Curtain of chips falling onto binder. (June 2015)

Figure 41. Truck delivering pre-coated chips. (June 2015)

Figure 42. Three pneumatic rollers seating chips. (June 2015)

Figure 43. Steel wheel roller doing final rolling. (June 2015)

Figure 44. HBST prior to sweeping. (June 2015)

Figure 45. Close-up of finished HBST. (June 2015)

Figure 46. Finished HBST. (June 2015)

Figure 47. Finished HBST. (June 2015)

2016 Review

The project was inspected on December 11, 2016, six months after installation (Figures 48-59). The HBST was in generally good condition with some streaking and rich appearing wheel paths and transverse cracking.

Figure 48. HBST at the age of six months. (Dec. 2015)

Figure 49. HBST at the age of six months. (Dec. 2015)

Figure 50. Close-up view at the age of six months. (Dec. 2015)

Figure 51. HBST with 100% embedment at the age of six months. (Dec. 2015)

Figure 52. HBST with 100% embedment at the age of six months. (Dec. 2015)

Figure 53. Steaks from underlying crack sealant in HBST at the age of six months. (Dec. 2015)

Figure 54. Rich areas in the wheel paths at the age of six months. (Dec. 2015)

Figure 55. Transverse cracking at the age of six months. (Dec. 2015)

Figure 56. Transverse cracking at the age of six months. (Dec. 2015)

Figure 57. Streaking at the age of six months. (Dec. 2015)

Figure 58. Rich appearing wheel paths at the age of six months. (Dec. 2015)

Figure 59. Rich appearing wheel paths at the age of six months. (Dec. 2015)

Contract 8728, US-2 ET AL 2015 Eastern Region Chip Seal

Contract 8728 paved HBST on sections of US-2 and SR-206 in 2015. The US-2 section ran from MP 314.94 to 321.83, a total of 27.56 lane miles and the SR-206 from MP 2.44 to 13.00, a total of 21.12 lane miles. Central Washington Asphalt was the contractor and Chad Simonson was the WSDOT Project Engineer.

Specification Details

The specifications called for 3/8" to No. 8 chips applied at the rate of 15-18 lbs/square yard. Coating requirements, rollers, placement temperatures, and surface temperatures for placement remain the same as previous contracts. A choke was used on portions of both the US-2 and SR-206 with the remainder of these sections not receiving a choke.

IDR Information

The SR-206 section was paved on July 27 and 28, 2015 with daily air temperatures ranging from 71-96°F. The only problems encountered were clogged nozzles on the distributor. There was no information provided in the IDR's regarding the rock or oil yield.

The US-2 section was paved on August 3, 4, and 20, 2015. Air temperatures ranged from 84-87°F, oil yield ranged from 0.42 to 0.43 gal/square yard and rock yield from 16-19 lbs/square yard. Figures 60-62 show choked and un-choked pavement, trays containing aggregate sweepings and pre-coated aggregate, and finally a photo of the finished pavement.

Figure 60. Choked (left) and un-choked (right) HBST. (Sept. 2015)

Figure 61. Aggregate sweepings from US-2 (left tray), HBST pre-coated chips (center tray) aggregate sweepings from SR-206 (right tray). (Sept. 2015)

Figure 62. Finished HBST on US-2. (Sept. 2015)

2017 Review of US-2

The 2017 review occurred on August 17 (Figures 63-66). Embedment ranges from 60-100% which accounts for the rich appearance of the HBST in the wheel paths.

Figure 63. Looking east from MP 319.70. (August 2017)

Figure 64. Looking west from MP 319.70. (August 2017)

Figure 65. HBST at MP 319.70 with 100% embedment. (August 2017)

Figure 66. HBST at MP 319.70 with 100% embedment. (August 2017)

2017 Review of SR-206

The 2017 review occurred on August 17 (Figures 67-72). Embedment ranged from 60-100% which accounts for the rich appearance of the HBST in the wheel paths. Raveling and snowplow damage was noted. The first two miles of the project look better than the roadway where the photos were obtained.

Figure 67. HBST at MP 5.39 on with 100% embedment in the wheel paths. (August 2017).

Figure 68. Centerline snowplow damage on HBST at MP 5.39. (August 2017).

Figure 69. Transverse crack at MP 5.39. (August 2017)

Figure 70. Transverse streaking at MP 5.39. (August 2017)

Figure 71. Rich appearance of HBST at MP 5.39 with 100% embedment in the wheel paths. (August 2017)

Figure 72. Snowplow damage at MP 5.39. (August 2017)

Contract 8766, 6th Street to Bingen City

Contract 8766 installed HBST on 39 miles (78 lane miles) of SR-14 between MP 27.87 and MP 67.11. Granite Construction Company was the contractor and Susan Fell was the WSDOT Project Engineer.

Specification Details

The specifications called for 3/8" to No. 4 applied at the rate of 10-20 lbs/square yard. Other requirements remain the same as previous contracts.

IDR Information

The project was paved during daylight hours except through the towns of Bingen and Stevenson where paving occurred at night due to high traffic volumes. The result was rapid cooling of the binder which did not allow the oil to flow causing streaking. Streaks along the longitudinal joints was attributed to an overlap of the oil shot due to the distributor operator not being able to see the area that had been already paved. The rock loss problems were so extensive that portions of the project through Stevenson and Bingen were repaved in 2016 with HMA. The IDR's indicate that the paving started on August 24 and was completed on September 11, 2015. The IDR's contained no information on rock and oil yield.

Figures 73-76 are post-construction photos from October of 2015 following the paving in August.

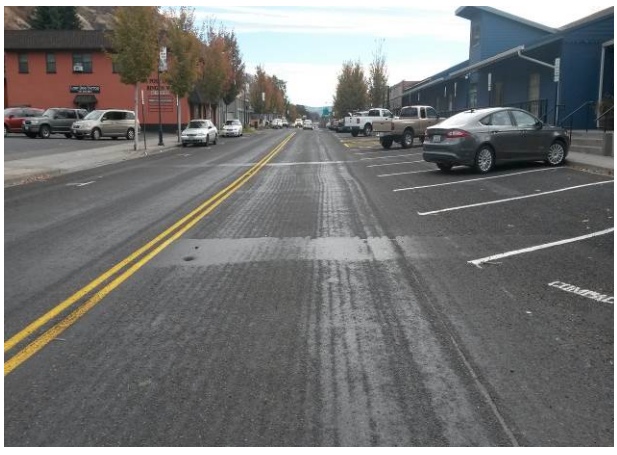

Figure 73. HBST through Bingen. (October 2015).

Figure 74. HBST through Bingen. (October 2015).

Figure 75. HBST through Bingen. (October 2015).

Figure 76. HBST through Bingen. (October 2015).

Photos from January of 2016 show the streaking and areas where the chips were lost (Figures 77-82).

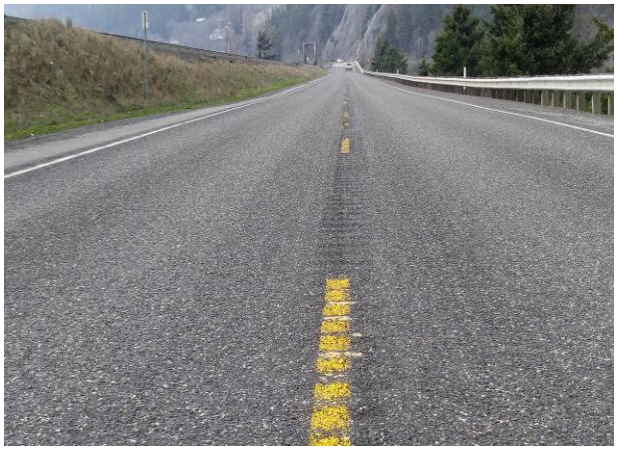

Figure 77. HBST showing one of the better areas. (Jan. 2016)

Figure 78. HBST showing aggregate loss. (Jan. 2016)

Figure 79. HBST showing aggregate loss. (Jan. 2016)

Figure 80. HBST showing cornrows. (Jan. 2016)

Figure 81. HBST showing aggregate loss. (Jan. 2016)

Figure 82. HBST showing aggregate loss. (Jan. 2016)

Figures 83-85 show the condition of the HBST in June of 2016, almost one year after paving.

Figure 83. Delamination of HBST. (June 2016)

Figure 84. Delamination of HBST. (June 2016)

Figure 85. Delamination of HBST. (June 2016)

Change Order

A change order was issued in 2016 to repair portions of the project with a grind and inlay due to potholes developing in the HBST. The limits of the repairs were from MP 44.07 to 44.60 in Stevenson and MP 62.57 to 67.10 in Bingen. The change order stated that the chip seal through Stevenson and Bingen was conducted at night and that the seal did not achieve the expected results. The chip seal in these towns were characterized as showing oil/asphalt bleeding and streaking. On the section beyond Bingen the initial performance was excellent, but over time the pavement began to lose aggregate especially along the tree-shaded segments. The shedding of aggregate was exacerbated by snowplows during the winter. During very hot summer temperatures oil came to the surface of the seal and was so soft that a boot would leave an imprint. Citizens complained that flying aggregate was causing windshield damage and oil was collecting on the undercarriages of their vehicles. Also, on June 3, 2016 a train derailment in Mosier, OR shut down I-84 in Oregon and traffic was detoured onto SR-14. As a result of hot weather, long delays and extra traffic, sections of the HBST delaminated.

2017 Review

No review of this project was performed in 2017; however, a review of the 2016 WSPMS video showed that the portions of the HBST not milled and filled with HMA had generally poor performance with flushing in the wheel paths, streaking, dig outs, and patching scattered throughout. Several reasons for the failures on this project include chip sealing at night; placing chip seal after the end of WSDOT's recommended chip seal window of August 31st and not monitoring asphalt binder applications and aggregate application rates. Successful chip seal projects required that for lower volume roadways chips seals be placed early enough in the chip seal season that traffic can knead and embed further the freshly placed surface. When chip seals are placed at night or the cutoff date is pushed or exceeded ambient temperatures limit the kneading

action that can occur in the new chip seal. The combination of correct binder and aggregate application rates combined with ambient temperatures over time contribute to the success of a chip seal project. The earlier in the construction season a chip seal is placed for a given project the more successful the chip seal project will likely be provided the required air and ground temperatures are within specifications.

2016 Projects

Contract 8864, US-2 ET AL 2016 ER Chip Seal

The 2016 Eastern Region Chip Seal included one section of HBST on US-2 between MP 322.77 and 328.60, a total of 11.66 lane miles. Central Washington Asphalt, Inc. paved the HBST and Chad Simonson was the WSDOT project engineer.

Specification Details

The specifications called for 3/8" to No. 8 chips applied at the rate of 14-22 lbs/square yard. Aggregate coating requirements were changed from 90% coating of the aggregate retained on the No. 4 sieve to 0.4 to 0.8 percent by weight. Rollers used were three pneumatics and one steel wheel. The surface temperature of the AC-15P prior to the application of the aggregate was changed from 120-180°F to 130-150°F up to 180°F with Engineer's approval.

IDR Information

The HBST was installed on August 11 and 12 and fog sealed on August 16, 2016. The IDRs indicate that the rock yield ranged from 23-24 lbs/square yard. The road temperatures ranged from 67-72°F at the beginning of each day of work. The only problems encountered were occasional plugged nozzles on the distributor. The fog sealing operation started to pick the aggregate out of the completed seal, so brooming was delayed until next day. The IDR's contained no information on oil yield or embedment. Figures 86-93 show the construction process.

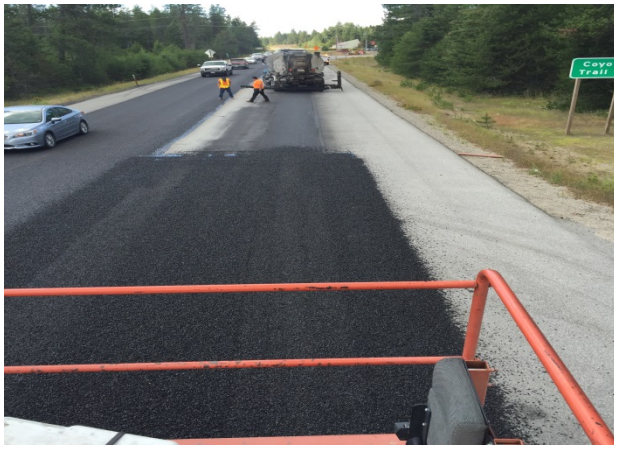

Figure 86. View from chip spreader of distributor. (August 2016)

Figure 87. Another view from chip spreader of the distributor. (August 2016)

Figure 88. AC-15P binder on the roadway. (August 2016)

Figure 89. Chips prior to rolling. (August 2016)

Figure 90. Choke stone on the HBST. (August 2016)

Figure 91. Choke stone on the HBST. (August 2016)

Figure 92. Chose-up of choke stone. (August 2016)

Figure 93. Choke stone on the HBST. (August 2016)

2017 Review

The 2017 review took place on August 17 (Figures 94-97). The aggregate embedment was about 60% over most of the lane and 100% in the wheel paths.

Figure 94. Looking west from MP 321.85. (August 2017).

Figure 95. Looking east from MP 321.85. (August 2017)

Figure 96. Closer view of HBST at MP 321.85 showing 100% embedment in the wheel paths and 60% between wheel paths. (August 2017

Figure 97. HBST at the top and conventional BST at the bottom at MP 321.85. (August 2017)

Contract 8890, NCR Seal 2016

This NCR project paved sections of HBST on SR-97 and SR-97A. SR-97 was sealed between MP 226.23 and 235.18, a total of 17.90 lane miles. SR-97A was sealed between MP 201.57 and 214.22, a total of 25.3 lane miles. Central Washington Asphalt did the paving and Dan Lewis was the WSDOT Project Engineer.

Specification Details

The specification called for 3/8" to No. 8 chips applied at a rate of 14-18 lbs/square yard. A choke of No. 4 to 0 was applied to finish the HBST. The aggregate pre-coating rate was changed from 0.4 to 0.8 percent, to 0.5 to 0.8 percent by weight.

IDR Information for SR-97

Construction on the SR-97 section occurred on August 18, 2016. The oil yield ranged from 0.33 to 0.41 with an average of 0.37 gal/square yard during the 12 hour construction day. The IDR's contain no information on the rock yield or embedment percentage. The equipment list includes two distributors, one chip spreader, three pneumatic rollers and one steel wheel roller.

2017 Review

The SR-97 portion of the project was inspected on August 17 at MP 234.00 (Figures 98-101). The rich appearance of the HBST in the wheel paths was due to 100% embedment of the chips. Snowplow damage at the centerline was noted.

Figure 98. Looking north from MP 234.00 showing snowplow damage at the centerline and 100% embedment in the wheel paths. (August 2017)

Figure 99. Looking north from MP 234.00. (August 2017)

Figure 100. Closer view of the HBST at MP 234. (Aug. 2017)

Figure 101. Snowplow damage at the centerline at MP 234.00. (August 2017)

IDR Information for SR-97A

Construction on SR-97A occurred on August 23 and 24, 2016. The only temperature information is from August 24 where the air temperature was 65°F at the beginning of the day and 78°F at 11:00 am when the construction was completed. The road temperature ranged from 62 to 77°F and oil temperature on the road ranged from 110 to 130°F during the paving. The equipment list includes two distributors, one chip spreader, eight pneumatic rollers, two steel wheel rollers, four side-cast brooms, and one pick-up broom. The IDR's contain no information on oil yield, rock yield or embedment.

2017 Review

The SR-97A portion of the project was inspected on August 17 at MP 205.09 (Figures 102-105). There is an appearance of flushing in the wheel paths due to the 100% embedment. The North Central indicated that there were problems with the oil setting too quickly and that is the cause of the chips not sticking to the centerline portion. Longitudinal cracks that were sealed prior to the paving are visible through the HBST.

Figure 102. Looking south from MP 205.09. (August 2017)

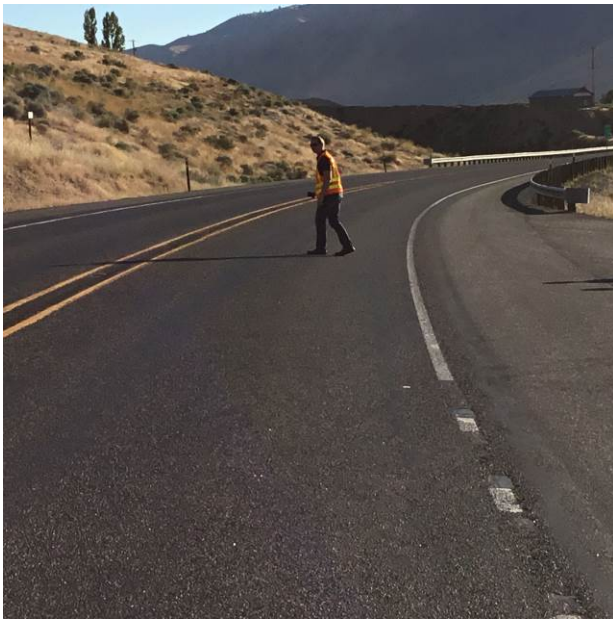

Figure 103. Looking north from MP 205.09. (August 2017).

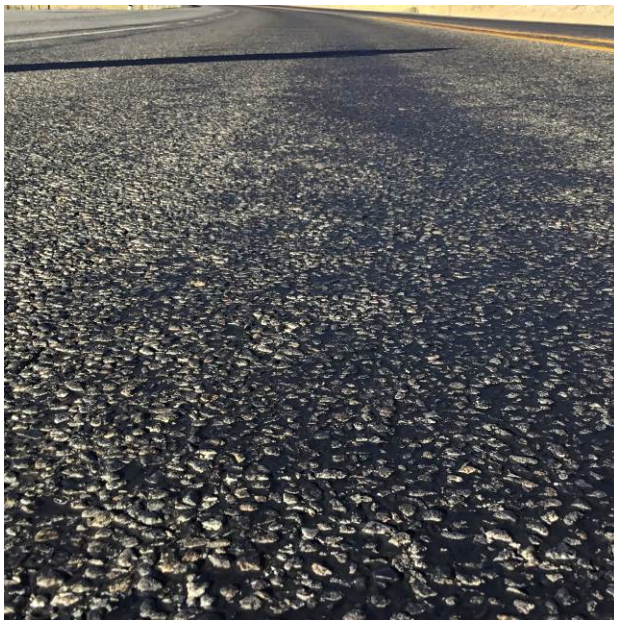

Figure 104. HBST at MP 205.09 showing 100% embedment in the wheel paths. (August 2017)

Figure 105. HBST with 100% embedment at MP 205.09. (August 2017)

US-2 Conventional BST

A conventional BST was installed on US-2 from MP 167.35 to MP 189.18 using a cushion course in certain areas to prevent transverse cracking in the underlying BST from reflecting through the

new overlay. Other areas of the section were rut filled or pre-leveled and one area, west of the million dollar cut, received a 0.15' mill and fill with HMA Class ½ Inch PG64-28. The million dollar cut is located between MP 172.50 and 173.10.

Before and after ride measurements documented the improvements provided by the cushion course and other treatments (see Table 4). The cushion course sections improved 65% as compared to the pre-leveled section which improved 44% and the rut filled section 38%. As expected the mill and fill section showed the most improvement at 69%. This section will be monitored to determine the success of the various treatments in reducing reflection cracking from the underlying pavement. Detailed ride data is provided in Appendix B, Table 14.

Table 4. US-2 before and after IRI data.

Treatment	Before IRI (inches/mile)	After IRI (inches/mile)	Percent Improvement
BST Over Cushion Course	194	69	65
BST Over Pre-Level	159	89	44
BST Over Rut Fill	194	69	38
HMA Mill and Fill	214	66	69

Figures 106-109 show the transverse cracking and the paving and compaction of the cushion course. Pre-level paving shown in Figures 110-111 and mill and fill in 112-113.

Figure 106. Transverse crack in US-2. (August 2016)

Figure 107. Spreading and compacting cushion course on US-2. (August 2016)

Figure 108. Rolling of cushion course on US-2 over transverse crack. (August 2016)

Figure 109. Rolling of cushion course on US-2 over transverse crack. (August 2016)

Figure 110. Pre-level paving over the cushion course. (August 2016)

Figure 111. Pre-level paving over the cushion course. (August 2016)

Figure 112. Pre-level on US-2. (August 2016)

Figure 113. Pre-level on US-2 with over sealed transverse crack. (August 2016)

Contract 8901, SR-500 and SR-504 Pavement Rehabilitation

The Southwest Region installed an HBST on SR-500 between MP 8.50 and 17.26, a total of 17.52 lane miles. Doolittle Construction, LLC was the contractor and Susan Fell was the WSDOT Project Engineer.

Specification Details

The specifications called for an application rate of 0.35 to 0.40 gal/square yard for the AC-15P and covered with 3/8" to No. 8 pre-coated chips at the rate of 14-20 lbs/square yard.

IDR Information

SR-500 was chip sealed from MP 8.50 to 17.26 on July 25, 26, 27 and 28, 2016. The sealing began at the SR-14 end of the project and proceeded west. The first day was a half day with construction started at 12:30 and ending at 5:00 pm. The road surface temperature ranged from 120-136°F in full sunshine and 112-120°F in the shade. The temperature of the oil in the distributor was 350-360°F. The temperature of the oil on the roadway when the chips were applied ranged from 140-150°F. The rock yield was 18 lbs/square yard and bumped up to 20 lbs/square yard halfway through the afternoon. The embedment after rolling was 40-50% and after one hour of traffic 50-60%.

On July 26 the sealing began again at the SR-14 end of the project at 9:05 am and finished at 5:11 pm. The oil yield was 0.385 gal/square yard, rock yield 16.4 lbs/square yard, embedment 40-50% before traffic and 50-60% after traffic. The air temperature ranged from 70-85°F, road temperature from 70-125°F, and oil on the road temperature from 100-190°F (115-155°F in the shade) at the time of the application of the chips. The contractor added more sand between MP 9.75 to 12.00 in both lanes because the mat was hot and he did not want it sticking to tires.

Construction on July 27 began at 8:00 am and finished at 4:35 pm. The air temperatures ranged from 66-86°F, the road temperature from 75-130°F, and the oil on the road temperatures from 130-185°F in the sun and 130°F in the shaded areas when the chips were applied. The oil yield was 0.40 gal/ square yard, embedment 50-60%, air temperature 80°F, and distributor temperature 350°F at 12:06 pm.

Construction on July 28 began at 8:00 am and finished at 12:30 pm. The air temperatures ranged from 68-74°F, the road temperatures from 71-109°F, and the oil on the road temperatures from 145-155°F at the application of chips. No measurements of oil, rock yield or embedment percentage were included in the IDR's. Table 5 summarizes the paving information and Figures 114-125 show the paving of the required test strip.

Table 5. Detailed information for each day's production on Contract 8901.						
Date	Air Temp. (°F)	Surface Temp. (°F)	Oil In Distributor Temp. (°F)	Oil on the Road Temp. (°F)	Oil Yield (gal/SY)	Rock Yield (lbs/SY)
7/25	-	120-136	350-360	140-150	-	18-20
7/26	70-85	70-125	-	100-190	0.39	16.4
7/27	66-86	75-130	350	130-185	0.40	-
7/28	68-74	71-109	-	145-155	-	-

Figure 114. SR-500 prior to HBST. (July 2016)

Figure 115. SR-500 prior to HBST. (July 2016)

Figure 116. Pre-coated chips. (July 2016)

Figure 117. Pre-coated chip stockpile. (July 2016)

Figure 118. Distributor. (July 2016)

Figure 119. Chip spreader. (July 2016)

Figure 120. Truck delivering chips. (July 2016)

Figure 121. Pneumatic rollers. (July 2016)

Figure 122. Steel wheel roller. (July 2016)

Figure 123. Vacuum truck. (July 2016)

Figure 124. Close-up of HBST test. (July 2016)

Figure 125. HBST test strip. (July 2016)

Additional photos of the finished HBST were during a review of the project in August of 2016 (Figures 126–132).

Figure 126. HBST one month after paving. (August 2016)

Figure 127. HBST one month after paving. (August 2016)

Figure 128. Shadows of crack sealant one month after paving. (August 2016)

Figure 129. Shadows of crack sealant one month after paving. (August 2016)

Figure 130. HBST one month after paving. (August 2016)

Figure 131. Close-up at one month after paving. (August 2016)

Figure 132. HBST one month after paving. (August 2016)

2017 Projects

8989, Sedro Wooley to Concrete

This NWR project applied an HBST on SR-20 from MP 67.10 to 90.52, a total of 46.84 lane miles, between Sedro-Wooley and Concrete. Granite Construction Company was the contractor and Dave Chrisman the WSDOT Project Engineer.

Specification Details

The specifications cited a binder application rate of 0.35 to 0.40 gal/ square yard, an aggregate application rate of 14-18 lbs/ square yard of 3/8" to No. 8 chips. Choke stone of No. 4 to 0 and a fog seal were also specified.

IDR Information

Work began on July 10, 2017 at the Concrete (east end of the project). Jim Weston and Kim Willoughby were on site at the beginning of paving and discussed the temperature of the oil when the chips are applied with the inspector. The inspector contended that the maximum was 150°F. After checking with his project engineer, he agreed that the temperature could go as high as 180°F with the permission of the Engineer. The temperature in the distributor ranged from 330-375°F. Rock was applied at 16 lbs/ square yard according to the spreader operator. The temperature of the oil when the chips were appled ranged from 120-194°F. The measured oil yield ranged from 0.35 to o.40 gal/square yard. Table 6 summarizes the temperature and oil yield information.

Table 6. Detailed information for each day's production on Contract 8989.

Date	Surface Temp. (°F)	Oil In Distributor Temp. (°F)	Oil Temp. Prior to Chips (°F)	Oil Yield (gal/SY)	Milepost Limits of Sealing
7/11	73-116	345	140-155	0.40	89.25 to 87.47
7/12	73-116	345	140-155	0.40	87.47 to 84.40
7/13	75-111	330-340	120-160	0.37	84.00 to 80.73
7/14	110-115	335-350	148-172	0.38-0.41	80.73 to 79.15
7/15	86-123	330-350	130-194	0.38	67.10 to 70.68
7/18	88-113	335-350	130-160	0.35	70.30 to 72.47
7/19	91-109	345-360	136-162	No data	72.47 to 74.53
7/25	76-124	335-375	139-163	0.39	74.54 to 79.15

Following completion of the HBST on July 26 they spread the choke stone and fog seal which extended through August 1, 2017. Figures 133-148 show the construction process.

Figure 133. Distributor applying AC-15P. (July 2017)

Figure 134. Truck delivering aggregate to spreader. (July 2017)

Figure 135. Chip spreader dropping 3/8" to No. 8 aggregate onto the AC-15P. (July 2017)

Figure 136. Three pneumatic rollers setting the chips. (July 2017)

Figure 137. Steel wheel roller which followed the three pneumatic rollers setting the chips. (July 2017)

Figure 138. Sweepers removing excess aggregate from the HBST. (July 2017)

Figure 139. Finished HBST. (July 2017)

Figure 140. Finished HBST. (July 2017)

Figure 141. Finished HBST. (July 2017)

Figure 142. Finished HBST. (July 2017)

Figure 143. Fog sealing HBST. (July 2017)

Figure 144. Fog sealed HBST. (July 2017)

Figure 145. Choked HBST. (July 2017)

Figure 146. Fog sealed choke. (July 2017)

Figure 147. Completed HBST with choke. (July 2017)

Figure 148. Paint striper. (July 2017)

2017 Review

A project review was attempted on February 1, 2018. Unfortunately the rain was so heavy that photos would not show anything of value. The project looked very good for its entire length and the embedment was estimated to be 70-80%.

9006, NCR 2017 Pavement Rehabilitation and Seal

The North Central Region chip sealed five sections of HBST on US-2, SR-28, SR-173, SR-281S, SR-283 and some of the city streets in Brewster on Contract 9006. Granite Construction Company was the contractor and Dan Lewis the WSDOT Project Engineer.

Specification Details

The AC-15P was applied at a rate of 0.35 to 0.40 gal/ square yard covered with 3/8" to No. 8 chips at 14-18 lbs/ square yard.

IDR Project Information

A summary of the temperatures and oil yield information for each of the sections on the project is contained in Table 7. Information from the IDR's for each section follows.

Table 7. Detailed information for each day's production on Contract 9006.

Date	Route	Air Temp. (°F)	Surface Temp. (°F)	Oil In Distributor Temp. (°F)	Oil Yield (gal/SY)	Milepost Limits of Sealing
7/26	SR-283	-	-	-	0.38	14.86 - 9.20
7/27	SR-283	75	72-141	153-160	-	9.20 – 0.05
7/31	SR-173	74	73-138	125-167	0.35	0.00 – 4.82
8/1	SR-173	78	70-120	140-150	0.36	4.82 - 10.49
8/2	SR-173	76	77-115	150-160	-	11.98 - 10.49
8/3	SR-281S	79	75-128	130-160	0.38	10.54 - ?*
8/7	SR-281S	82	75-130	154-170	0.36	?* - ?*
8/8	US-2	81	80-100	130-160	0.37	90.72 - 96.38
8/9	US-2	76	73-115	120-160	-	96.38 – 99.04
8/10	SR-28	78	76-134	140-175	0.37	10.17 - 19.12
8/14	SR-28	85	86-103	140-160	-	19.12 - 10.17
8/14	SR-281S	73	71-127	133-162	0.35	?* to 0.00

* Information missing from IDR.

IDR Information SR-283

Paving on SR-283 began at the north end of the section and worked south beginning on July 26, 2017. It appears that they ended the day at MP 9.20. Oil yield was 0.375 gal/square yard. The section was finished on July 27, 2017. The pavement temperatures on the 27th ranged from 72 to 141°F, the air temperature was 75°F and the temperature of the AC prior to the application of chips ranged from 153 to 160°F.

2017 Review

The 2017 review took place on August 18 (Figures 149-152). The HBST looked very good with 70-80% embedment outside of the wheel paths which were at 100% embedment. The North Central Region indicated that a steel wheel roller was used to embed the chips. Snow plows are rarely used on this section of SR-283 which should increase the chip seal life.

Figure 149. View at MP 4.41 with 70-80% embedment (100% in the wheel paths). (August 2017)

Figure 150. Another view at MP 4.41 with 70-80% embedment (100% in the wheel paths). (August 2017)

Figure 151. HBST at MP 4.41 with 70-80% embedment (100% in the wheel paths). (August 2017)

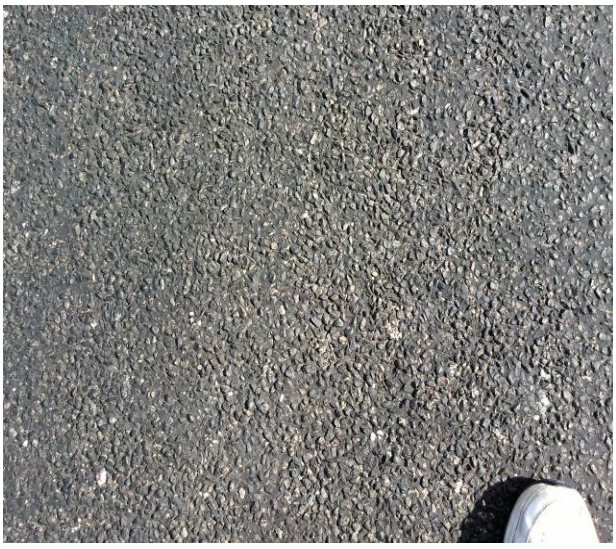

Figure 152. HBST at MP 4.41 with 70-80% embedment (100% in the wheel paths). (August 2017)

SR-283 Cushion Course

Some portions of the SR-283 section received a cushion course to address a poor ride and prevent reflection cracking from the underlying pavement. Pre-leveling was placed on top of the cushion course before the HBST was paved. Other sections of the roadway received pre-leveling prior to the HBST and some sections just the HBST was applied. The section from MP 0.00 to 3.66 was paved with 0.25' of Class 3/8 Inch PG64-28 HMA over the cushion course.

Before and after ride measurements were performed to determine the percent improvement provided by the various treatments (see Table 8). The HMA over cushion course improved the most at 62.3% with the HBST over cushion course a close second at 53.0%. The HBST over pre-leveling improved only 6.2% and the HBST over the existing pavement saw a decrease of 3.1% in ride. Detailed ride data is provided in Appendix B, Table 15.

Table 8. SR-283 before and after ride data.

Treatment	Direction	2015 IRI (inches/mile	2017 IRI (inches/mile)	Percent Improvement	Average % Improvement
HBST Over Cushion Course	NB	160	76	52.6	53.0
	SB	173	81	53.4	
HBST Over Pre-Level	NB	121	110	8.7	6.2
	SB	123	119	3.7	
HBST Only	NB	111	117	-5.4	-3.1
	SB	111	112	-0.8	
HMA Over Cushion Course	NB	173	71	59.0	62.3
	SB	195	67	65.6	

IDR Information SR-173

Paving started at MP 0.00 on SR-173 working from Bridgeport north toward Brewster on July 31, 2017. The pavement temperatures ranged from 73-138°F, air temperature at 74°F, and temperature of the AC prior to chips being applied ranged from 125-167°F. The calculated oil yield was 0.352 gal/ square yard. The second day of the SR-173 section completed the NB lane and portions of the SB lane. The pavement temperatures ranged from 70 to 120°F, air temperature at 78°F, and temperature of the AC prior to chip application from 140-150°F. The oil application rate was calculated at 0.358 gal/square yard. The remainder of the SB lane was chipped on August 2. The surface temperatures ranged from 77-115°F, the air temperature was 76°F, and the chips were applied to the oil on the roadway when it was between 150 and 160°F. No oil yield information was included in the IDR for August 2.

2017 Review

The 2017 review took place on August 17 (Figures 153-158). This section of Contract 9006 looks very good with 60-90% embedment. Each distributor shot had a different appearance. The North Central Region indicated that there has been very little traffic on this section since it was paved. A double shot of HBST was applied from the SR-97 junction to the bridge, MP 10.95 to 11.98.

Figure 153. Looking north from MP 11.74. (August 2017)

Figure 154. Looking south from MP 11.74. (August 2017)

Figure 155. Close-up view at MP 11.74 with 40-50% embedment. (August 2017)

Figure 156. Looking north from MP 8.00. (August 2017)

Figure 157. Looking south from MP 8.00. (August 2017)

Figure 158. Close-up view at MP 8.00 with 60-90% embedment. (Aug. 2017)

IDR Information for SR-281 Spur

The SR-281 Spur section was started on August 3 in Quincy and worked south towards George. The air temperature was 79°F, the surface temperature ranged from 75-128°F, and the temperature of the oil prior to the application of the chips ranged from 130-160°F. Oil yield was calculated at 0.380 gal/square yard. August 7 was the final day of paving on the SR-281 Spur section. The air temperature was 82°F, the surface temperatures ranged from 75-130°F, and the oil temperature on the ground prior to chips ranged from 154-170°F. The oil yield was 0.361 gal/square yard.

2017 Review

The 2017 review took place on August 18 (Figures 159-162). Streaking was noted due to an uneven application of the binder. The embedment ranged from 70-80%.

Figure 159. Looking north from MP 3.55. (August 2017)

Figure 160. Looking south from MP 3.55. (August 2017)

Figure 161. Looking south from MP 3.55 showing streaky appearance (cornrows). Embedment is 70-80%. (August 2017)

Figure 162. Close view at MP 3.55 with 70-80% embedment. (August 2017)

IDR Information for US-2

The US-2 section from MP 90.72 to 99.04 was started on August 8 at MP 90.72 working east towards Leavenworth. The air temperature was 81°F, the surface temperature ranged from 80-100°F, and the oil temperature prior to the application of chips ranged from 130-160°F. The calculated oil yield was 0.365 gal/square yard. The milepost at the end of the day was 96.38 and both lanes had been completed. The section was finished on August 9 starting at MP 96.38 and finishing at MP 99.04. The air temperature was 76°F, the surface temperature ranged from 73-115°F, and the oil temperature prior to the application of chips ranged from 120-160°F.

2017 Review

Figures 163-166 are from the 2017 review which took place on August 16. The chips were 50% embedded and there were lots of chips on the shoulder.

Figure 163. Looking west from MP 91.38. (August 2017)

Figure 164. HBST at MP 91.38. (August 2017)

Figure 165. HBST at MP 91.38. (August 2017)

Figure 166. Close-up view of the 50% chip embedment at MP 91.38. (August 2017)

IDR Information for SR-28

The SR-28 section was paved on August 10 starting at MP 10.17 and working east toward Quincy. The air temperature was 78°F, the surface temperatures ranged from 76-134°F, and the oil temperature prior to the application of chips ranged from 140-157°F. The oil yield was 0.367 gal/square yard. There were accidents on both ends of the job during paving that caused delays during the day. One of the inspectors noted that there was dirty oil and chips on the first run of the day. Apparently the loader operator dug too deep in the pit and dug up some dirt along with the chips. The chipper was sent away to clear out the load. On August 14 the operation started at MP 19.12 working west towards Wenatchee. The air temperature was 85°F, the surface temperature ranged from 86-103°F, and the oil temperature prior to chip application ranged from 140-160°F.

2017 Review

The 2017 review took place on August 18 (Figures 167-170). The HBST had 50-60% embedment of the chips in the oil. The North Central Region indicated that it appeared that the oil was too cool when the chips were applied causing the corn rows.

Figure 167. Looking east from MP 18.30. (August 2017)

Figure 168. Looking west from MP 18.30. (August 2017)

Figure 169. Streaky appearance at MP 18.30. (August 2017)

Figure 170. Close-up of the cornrows at MP 18.30. (August 2017)

9047, SCR Region Wide Chip Seal

Contract 9047 applied HBST on SR-410, SR-903, and some of the city streets in Walla Walla. Central Washington Asphalt was the contractor and Alex Sanguino the WSDOT Project Engineer.

Specification Details

The specifications called for a binder application rate of 0.35 to 0.40 gal/square yard, and an aggregate application rate of 0.14 to 0.20 lbs/square yard using 3/8" to No. 8 chips. Choke stone was not specified.

IDR Project Information

Table 9 is a summary of the temperatures, oil yield and chip application rate on the paving process for Contract 9047.

Table 9. Detailed information for each day's production on Contract 9047.

Date	Route	Air Temp. (°F)	Surface Temp. (°F)	Oil In Distributor Temp. (°F)	Oil Temp. when Chips Applied (°F)	Oil Rate (gal/SY)	Agg. Rate (lbs/SY)	Milepost Limits
8/4	903	-	-	-	-	0.35	20*	10.06 – 6.10
8/7	903	2 steel wheel rollers used to get more embedment				0.39	-	6.10 – 7.00
								4.75 – 2.10
8/9	410	-	-	-	-	0.39	-	69.21 – 72.1
8/10	410	Oversized rocks found in chips				-	-	72.1 – 74.5
8/10	410	-	-	-	-	-	-	93.63 – 98.13
8/11	410	68	70	-	-	-	-	93.63 – 107.40
8/14	410	70-75	88-114	355	150-170	0.39	14-20*	116.37 - 111.87
8/15	410	62-71	60-100	275-350	135-142	0.40	-	108.45 - 111.81

*** Estimate, not measured.**

IDR Information for SR-903 MP 2.10 to MP 10.06

The SR-903 section, MP 2.10 to MP 4.75 and MP 6.10 to MP 10.06, was paved on August 4 and 7, 2017. The measurements of temperatures and yields are listed in Table 7, above. During the HBST placement an additional steel wheel roller was added on the SR-903 section.

2017 Review

The 2017 review occurred on August 16 (Figures 171-175). Only 50% embedment of the chips was noted on this section. The HBST had a uniform appearance that was devoid of rich areas in the wheel paths.

Figure 171. Looking south from MP 7.30. (August 2017)

Figure 172. Looking north from MP 7.30. (August 2017)

Figure 173. Close-up view at MP 7.30 showing 50% embedment. (Aug. 2017)

Figure 174. Close-up view at MP 7.30. (August 2017)

Figure 175. Chip taken from the HBST at MP 7.30 showing 50% embedment. (Aug. 2017)

February 2018 Review by the South Central Region

The Cle Elum to Roslyn section, MP 2.10 to MP 4.75 showed minor raveling where snowplows have scraped the high spots, but overall the surface was in good condition. From Roslyn to Ronald, MP 6.10 to MP 7.10, the wheelpaths have raveled (see Figures 176 and 177). In Ronald (MP 7.10 to MP 7.50) the HBST looks good with only minor raveling. From Ronald to the Forest Service Boundary (MP 7.5 to MMP 10.06) the HBST is in poor condition with complete raveling in the wheel paths or across the entire lane (Figures 178 and 179). Figure 180 shows covered chips on the snow berm on the side of the road.

Figure 176. Raveling on the section between Roslyn and Ronald.

Figure 177. Raveling at MP 6.10 on the section between Roslyn and Ronald.

Figure 178. Raveling at MP 8.00 on the section between Ronald and National Forest Boundary.

Figure 179. Raveling at MP 9.00 on the section between Ronald and National Forest Boundary.

Figure 180. Aggregate chips on the snow berm, milepost unknown.

IDR Information SR-410 MP 69.21 to 74.50

The SR-410 paving was done in three sections. The western most section, near Chinook Pass, was paved on August 9 and 10, 2017. The only information was that the oil yield was 0.39 for August 9 and no calculation on the August 10. For some unknown reason the inspector began to measure temperatures on the last two days of the paving, August 14 and 15. The oil yield information is from calculations, the rock yields are estimates by the inspector.

2017 Review

The 2017 review took place on August 16 (Figures 181-186). The HBST looked very good from a distance, but upon closer examination the chips were only embedded about 30% in the oil. The evaluation team felt chip loss due to low aggregate embedment may be an issue due to snowplow action. Pre-coated chips that had shed to the shoulder were well coated.

Figure 181. Looking west from MP 69.44. (August 2017)

Figure 182. Looking east from MP 69.44. (August 2017)

Figure 183. Close-up at MP 69.44 showing 30% embedment. (Aug. 2017)

Figure 184. Close-up at MP 69.44 showing spots where the embedment is 60-70%. (August 2017)

Figure 185. Road level view at MP 69.44 showing lack of embedment. (August 2017)

Figure 186. Chips from the shoulder at MP 69.44 with 100% coating. (August 2017)

IDR Information SR-410 MP 93.63 to 107.40

This section was paved on August 10 and 11, 2017. Oversized rocks in the chips were found, some coated, others not coated. Oil and rock yield were not reported.

2017 Review

The 2017 review also took place on August 16 (Figures 187-191). This section showed better embedment possible due to higher temperatures at this lower elevation and more traffic. Embedment was 90% in the wheel paths and 30% outside of the wheel paths. There were bubbles of air under the chip seal at the centerline (may lead to delamination in the future).

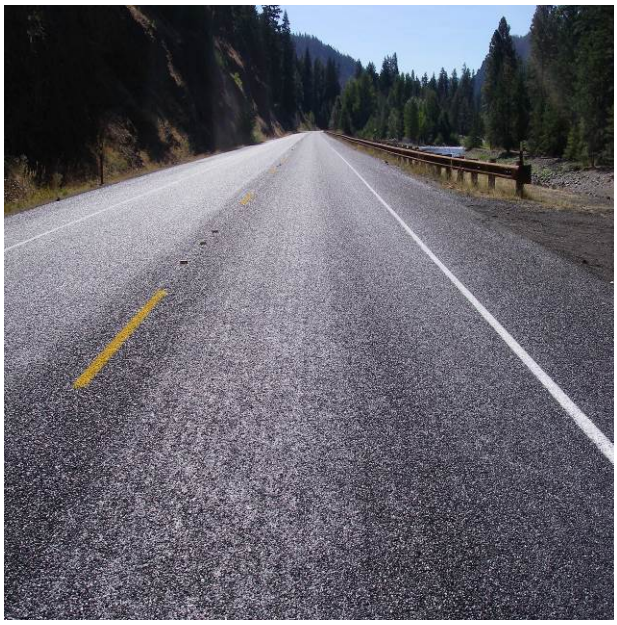

Figure 187. Looking east from MP 94.30. (August 2017)

Figure 188. Looking west from MP 94.30. (August 2017)

Figure 189. Close-up at MP 94.30 showing uniform texture across the lane.

Figure 190. Closer-up at MP 94.30. (August 2017).

Figure 191. Road level view at MP 94.30 showing 30% embedment. (Aug. 2017)

IDR Information SR-410 MP 108.61 to 116.37

This section was paved on August 14 and 15, 2017. Binder and aggregate yield information are recorded in Table 7 on page 60 along with temperature data.

2017 Review

This section looked very good with not a lot of loose rock on the shoulder. Higher temperatures and more traffic may have contributed to the better appearance. No photos were obtained from this section.

2018 Review by the South Central Region

The SR-410 section was reviewed in February of 2018 by the South Central Region Figures 192-199 show the condition of the HBST which had raveled, sometimes at the centerline, sometimes in the wheel paths and sometimes over the entire lane. The centerline raveling as shown in photos 192 to 195 is the result of placing the HBST on HMA patches. The patches were placed on substantial portions of the project to repair centerline rumble strips that had failed. Unfortunately, during the construction of the HBST HMA patches were not fog sealed to prevent excess AC-15P binder from being absorbed into the new asphalt leaving less asphalt to embed the pre-coated aggregate applied with the HBST. Applying a fog seal to the asphalt repair areas prior to the HBST would have prevented the raveling that occurred. The photos were taken on the two sections from MP 93.63 to 107.40 and MP 108.61 to 116.37. The third section is closed to traffic for the winter.

Figure 192. Raveling at MP 116.36. (February 2018)

Figure 193. Raveling on SR-410. (February 2018)

Figure 194. Raveling on SR-410. (February 2018)

Figure 195. Raveling on SR-410. (February 2018)

Figure 196. Raveling on SR-410. (February 2018)

Figure 197. Raveling on SR-410. (February 2018)

Figure 198. Raveling on SR-410. (February 2018)

Figure 199. Raveling on SR-410. (February 2018)

Figure 200. Centerline patch on SR-410. (April 2018)

Figure 201. Typical distress on SR-410 (streaks or show plow damage). (April 2018)

Figure 202. Typical good embedment on SR-410. (April 2018)

Figure 203. Isolated area of complete aggregate shedding. (April 2018). .

HBST Summary (2014 to 2018)

Performance

Nine of the eleven projects are performing well. The two poor performers are Contract 8766 on SR-14 which had large sections rebuilt due to flushing and delamination, Contract 9047 on SR-903 and SR-410 which are raveling to the extent that only the AC-15P remains in some areas. The problems on Contract 8766 can be traced to night paving where the AC-15P set too rapidly resulting in the loss of chips and failure to bond to the underlying pavement. The problem on Contact 9047 appears to be a lack of embedment of the aggregate in the binder. Table 10 summarizes the performance of the projects.

Table 10. Performance summary based on the 2017 review.					
Contract	Title	SR	Embedment		Comments
			Lane (%)	Wheel Paths (%)	
8566	NCR Seal 2014	97A	70-80	100	No chip loss, some shadowing of underlying sealed cracks, some longitudinal cracking, wheel paths have appearance of flushing due to 100% embedment, centerline snowplow damage
8711	NCR Chip Seal 2015	281S	70-80	100	Very rich appearance in wheel paths due to 100% embedment, no loose aggregate on shoulders.
		207	60	100	Mottled appearance due to light colored chips, wheel paths have 100% embedment, slurry seal on shoulders overlaps HBST giving a ragged appearance to roadway.
8721	US 2 ET AL South Central Chip Seal	12	60-80	100	Wheel paths have rich appearance due to 100% embedment, transverse cracking, shadowing of sealed underlying cracks.
8728	US 2 ET Al Eastern Region Chip Seal	2	60	100	Wheel paths have rich appearance due to 100% embedment, mottled appearance due to light colored chips and sand seal.
		206	60	100	Wheel paths have rich appearance, transverse cracking, and centerline snowplow damage.
8766	6th St. to Bingen City	14	No Info.	No Info.	Large areas of 100% loss of chips, other areas streaky due to aggregate not adhering to binder, delaminations, areas paved at night failed and were replaced with HMA.
8864	US 2 ET AL 2016 Eastern Region Chip Seal	2	60	100	Good appearance with normal rich appearance in wheel paths with 100% embedment.
8890	NCR Seal 2016	97	60-80	100	Ragged appearance due to longitudinal streaking, centerline snowplow damage.
		97A	70-80	100	Wheel paths have rich appearance due to 100% embedment, shadowing of the underlying sealed cracks, and no accumulation of chips on the shoulder.

Table 10. (Performance summary, continued).					
Contract	Title	SR	Embedment		Comments
			Lane (%)	Wheel Paths (%)	
8901	SR 500 and SR 504 Pavement Rehabilitation	500	50-60	50-60	Uniform appearance, no rich areas in the wheel paths.
8989	Sedro Wooley to Concrete	20	70-80	70-80	Entire project looked good for its entire length.
9006	NCR 2017 Pavement Rehabilitation and Seal	2	50	50	Uniform appearance, no rich areas in the wheel paths, very new application, so not much traffic to date, lots of chips on the shoulder.
		28	50-60	50-60	Very new application, corn row streaking across entire lane.
		173	60	90	Streaky appearance otherwise looks good.
		281S	70-80	70-80	Streaky appearance, across entire lane.
		283	70-80	100	Wheel paths had rich appearance due to 100% embedment.
9047	SCR Region Wide Chip Seal	410 MP 69.21-74.50	30	30	Higher elevation section had minimal embedment; lower sections had higher embedment due to higher temperatures and more traffic. The lower two sections are raveling at the centerline and across the entire lane in places. Blame was placed on patching of centerline RRPM slots prior to the HBST and the August paving which did not allow sufficient time for traffic to finish embedding the aggregate in the binder.
		410 MP 93.63-107.40	30	90	
		410 MP 108.61-116.37	-	-	
		903	50	50	Chip loss is extensive. Some areas are missing all the aggregate on 80-90% of the lane.

Embedment

There were 19 individual sections of road treated on the 11 projects. Aggregate embedment estimated during the 2017 review ranged from 30-90% with a majority in the 60-80% range during the 2017 review. Eleven of the 19 sections (58%) had areas of 100% embedment, usually in the wheel paths. The US-2 and SR-28 sections on Contracts 9006 and sections on SR-410 and SR-903 on Contract 9047 had low embedment 30-50%, which is a concern for their long-term performance and the possible cause of the raveling on the SR-903 and SR-410 sections noted in 2018.

Friction

Friction resistance is normally a concern when the aggregates approach 100% embedment. The 2016 friction inventory lists two sections in the low friction number category which are numbers below SN 30. The first was the section on SR-281 Spur, Contract 8711, which had one test of SN 29.1 in July of 2016 at MP 1.48. The section was retested in October of 2016 between MP 0.96 and 1.58. The retest average was 44.5 with a range from 33.1 to 58.5, indicating there was no problem with this roadway with respect to friction. The improvement in friction resistance may be due to the wearing away of the binder on the aggregates.

The second problem section was on SR-14, Contract 8766. The average for this section of HBST was 26.4 with a range from 19.3 to 29.6 in June of 2016. The tests were taken between MP 27.7 to 65.0, which encompasses most of the project. This section was not retested due to the mill and fill that took place later in 2016 to fix the delamination and flushing problems in Stevenson and Bingen.

Traffic and Climate

The eleven projects built to date provide a good base line for the performance evaluation of HBST since they are on a variety of routes with varying amounts of traffic and climatic conditions (see Table 11). The average annual daily traffic (AADT) ranges from 570 to 12,000 (2016 data). Truck percentage ranged from four to 22%. The climates at the locations vary from dry to wet and temperatures from hot-mild in the summer and mild-cold with lots of snow in the winter.

Table 11. Traffic and climatic conditions.					
Cont. No.	Title	Route	AADT	% Trucks	Climatic Zone
8566	NCR Seal 2014	97A	4,700	9	Dry, hot summers, cold winters
8711	NCR Chip Seal 2015	207	1,750	10	Dry, hot summers, cold winters
		281S	3,700	20	Dry, hot summers, cold winters some snow
8721	US 2 Et Al South Central Chip Seal	12	4,200	9	Wet to dry, warm summers, cold winters w/snow
8728	US 2 ET AL 2015 Eastern Region Chip Seal	2	6,700	10	Moderately dry, warm summers, cold winters w/snow
		206	1,300	5	Moderately dry, warm summers, cold winters w/snow
8766	6th St. to Bingen City	14	4,800	20	Wet, moderate summers and winters
8864	US 2 ET AL ER Chip Seal	2	4,700	10	Moderately dry, warm summers/cold winters w/ snow
8890	NCR Seal 2016	97	5,400	18	Dry, hot summers, cold winters w/snow
		97A	7,050	9	Dry, hot summers/cold winters w/snow
8901	SR 500 and SR 504 Pavement Rehabilitation	500	4,400-12,000	14	Moderately dry, mild summers and winters, little snow
8989	Sedro Wooley to Concrete	20	3,000-10,000	14	Wet, mild summers/cold winters w/snow
9006	NCR 2017 Pavement Rehabilitation and Seal	2	6,400	8	Dry, moderate summers, cold winters w/snow
		28	8,600	19	Dry, hot summers/cold winters, little snow
		173	3,150	4	Dry, hot summers and cold winters with snow
		281	6,300	22	Dry, hot summers/cold winters with little snow
		283	2,300	18	Dry, hot summers/cold winters with little snow
9047	SCR Region Wide Chip Seal	410	570-2,080	6-15	Wet to Dry, mild summers, cold winters with much snow at higher elevations
		903	4,100	13	Dry, mild summers/cold winters w/snow

Cost

Table 12 lists the cost of HBST and conventional BST for each contract. The bid tabulation costs listed in Appendix A were used to arrive at the cost per square yard for both the BST and HBST on each project. The costs per square yard was then multiplied by 7040, the number of square yards in a 12 foot lane of roadway to get a cost per lane mile. A 12 foot lane mile was used in place of calculating the lane miles from the contract plans. Using the lane miles in the plans does not take into account the variations in the width of pavement chip sealed which can range from 28 to 50 feet depending on the width of the shoulders and other paving included such as turn lanes, pull off areas, etc. Contract 8721 required one additional step because the crushed surfacing quantities were bid in tons. The Design Manual conversion factor of 30 pounds per square yard was used to convert tons to square yards on this contract. Appendix A contains details on the costs for each contract.

The cost calculations did not include items such as mobilization, traffic control and other costs necessary to the construction of chip seals. If the project included a choke it was not included in the calculations since the aggregate and fog seal are listed separately in the bid tabulations. Asphalt cost price adjustments for the CRS-2P or AC-15P binders and additional brooming were also not included in the calculations.

The average cost of the conventional BST ranged from $9,392.40 to $14,447.68 with an average of $11,770.49 per lane mile. The cost of the HBST was slightly higher and ranged from $10,170.82 to $21,055.17 with an average of $14,137.42 per lane mile. The average cost of the HBST was 20.1 percent higher than the average cost of the conventional BST. If the average pavement life of a BST is 6.0 years (72 months) then the HBST must last 7.21 years (86.5 months) to be cost effective.

The cost differential between the BST and HBST may be influenced by differences in the quantities of each item. It is assumed that bidders will increase the cost for items with small quantities or items for which they have no previous experience such as HBST. This is the case for most of these contracts with large quantities of conventional BST and much smaller quantities of HBST used on each contract. Contract 8890 is the one project where the quantities of the BST and HBST were almost equal and as a result the BST and HBST costs were close with only a difference of $1,515 per lane mile.

Table 12. Cost comparison between BST and HBST.				
Contact No.	Construction Year	Project Title	BST Cost (per lane mile)	HBST Cost (per lane mile)
8566	2014	NCR Seal 2014	$13,014	$14,226
8711	2015	NCR Chip Seal 2015	$12,320	$12,440
8721	2015	US 2 ET AL South Central Chip Seal	$13,374	$21,055
8728	2015	US 2 ET AL 2015 Eastern Region Chip Seal	$10,831	$12,887
8766	2015	6th St. to Bingen City	-	$15,584
8864	2016	US 2 ET AL ER Chip Seal	$9,901	$10,171
8890	2016	NCR Seal 2016	$9,392	$10,908
8901	2016	SR 500 and SR 504 Pavement Rehabilitation	$14,448	$18,987
8989	2017	Sedro Wooley to Concrete	-	$14,225
9006	2017	NCR 2017 Pavement Rehabilitation and Seal	-	$13,015
9047	2017	SCR Region Wide Chip Seal	$10,884	$11,983
		Average	$11,770	$14,135

Conclusions

It is too early in the evaluation process to draw conclusions on the long-term performance of the projects. With the exception of Contract 8766 on SR-14, the construction of the HBSTs was accomplished without significant problems. Again, with the exception of Contracts 8766 (SR 14) and portions of Contact 9047 (SR 903 and SR 410), all of the projects are showing good performance. The presence of 100 % embedment of the aggregates in the wheel paths of many of the projects is a concern; however, the annual statewide friction surveys have not found any significant problems with the friction resistance on any of the projects. The presence of only 50% embedment of the aggregates on the US-2 portion of Contract 9006 and 30% embedment on some of the sections on 9047 are a concern as evidenced by the raveling problems on SR-903 and SR-410.

Recommendations

All of the projects built to date and any new projects built in subsequent years should be monitored to determine the long-term performance and cost effectiveness of HBST pavements. Construction recommendations are as follows:

1. Place HBST early in the construction season to allow time for traffic to embed the pre-coated aggregates. Early placement allows traffic embedment during July and August when pavement surfaces are the warmest. Hot seals placed in shady or mountainous areas should be placed no later than August 1st.
2. Require at a minimum of three pneumatic and at least one steel wheel rollers. Pneumatic rollers should make a minimum of two passes, steel wheel at least one and coverage should be the full roadway section for both. Steel wheel rollers should weigh at least 12 to 15 tons pay special attention to the shoulders, turn lanes, quarter crown and centerline of the roadway.
3. Aggregate application rates and binder shot rates should be monitored continuously on all projects. Binder application rates require adjustment according to the condition of the roadway. Individual asphalt binder distributor trucks need separate calibrations.
4. Roadways with lower ADT require more compactive effort (rolling) to properly seat the aggregate in the binder.
5. Fog seal HMA patches prior to the application of HBST.

Appendix A

Cost Comparison

Table 13. Cost comparison data for all projects.

Cont. No.	Item	Aggregate (S.Y.)	Cost (per S.Y.)	Aggregate Cost	CRS-2P (Tons)	Cost (per Ton)	Binder Cost	Total Cost	Cost (per S.Y.)	Cost (per 12 foot lane mile)
8566	BST	3,033,785.00	$0.85	$2,578,717.25	7,574.00	$400.00	$3,029,600.00	$5,608,317.25	$1.85	$13,014.29
	HBST	152,390.00	$1.02	$155,437.80	305.00	$500.00	$152,500.00	$307,937.80	$2.02	$14,225.88
8711	BST	513,239.00	$0.80	$436,253.15	1,026.48	$450.00	$461,916.00	$898,169.15	$1.75	$12,320.01
	HBST	120,370.00	$0.85	$102,569.50	201.20	$550.00	$110,660.00	$213,229.50	$1.77	$12,441.01
8721	BST	502,946.67	$0.82	$413,667.99	1,105.67	$490.00	$541,778.30	$955,446.29	$1.90	$13,373.87
	HBST	146,866.67	$0.99	$145,508.15	420.83	$698.00	$293,739.34	$439,247.45	$2.99	$21,055.17
8728	BST	1,590,963.00	$0.75	$1,193,222.25	3,136.00	$400.00	$1,124,400.00	$2,447,622.25	$1.54	$10,830.71
	HBST	362,375.00	$0.75	$271,781.25	681.00	$575.00	$391,575.00	$663,356.25	$1.83	$12,887.28
8766	BST	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
	HBST	619,170.00	$0.79	$489,144.30	979.40	$900.00	$881,460.00	$1,370,604.30	$2.21	$15,583.85
8864	BST	419,950.00	$0.65	$272,967.50	847.00	$375.00	$317,625.00	$590,592.50	$1.41	$9.901.63
	HBST	135,677.00	$0.65	$88,190.05	227.00	$475.00	$107,825.00	$196,015.05	$1.44	$10,170.82
8890	BST	348,510.00	$0.40	$139,404.00	813.90	$400.00	$325,560.00	$464,964.00	$1.33	$9,392.40
	HBST	327,060.00	$0.70	$228,942.00	555.60	$500.00	$277,800.00	$506,742.00	$1.55	$10,907.67
8901	BST	514,200.00	$0.70	$359,940.00	1,178.50	$590.00	$695,315.00	$1,055,255.00	$2.05	$14,447.68
	HBST	123,380.00	$1.50	$185,070.00	227.20	$650.00	$147,680.00	$332,750.00	$2.70	$18,986.55
8989	BST	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
	HBST	362,960.00	$0.85	$308,516.00	607.00	$700.00	$424,900.00	$733,416.00	$2.02	$14,225.39
9006	BST	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
	HBST	797,950.00	$0.80	$638,360.00	1,339.00	$625.00	$836,875.00	$1,475,235.00	$1.85	$13,015.42
9047	BST	1,133,198.80	$0.75	$849,899.10	2,122.59	$425.00	$902,100.75	$1,751,999.85	$1.55	$10,884.30
	HBST	627,161.60	$0.90	$564,445.44	914.60	$550.00	$503,030.00	$1,067,475.44	$1.70	$11,982.60

Appendix B

Before and After HBST Construction
Ride Data

Table 14. US-2 before and after HBST construction ride data.				
Treatment	Milepost	2015 Average IRI (inches/mile)	2017 Average IRI (inches/mile)	Percent Improvement
Pre-Level	167.35 – 169.85	184	88	51
Rut Fill	169.85 – 169.95	132	72	46
Pre-Level	169.95 – 170.13	233	106	54
Cushion Course	170.13 – 171.17	235	74	67
Mill and Fill	171.17 – 173.16	214	66	66
Cushion Course	173.16 – 173.96	239	72	64
Rut Fill	173.96 – 174.21	140	102	28
Pre-Level	174.21 – 174.31	192	96	50
Rut Fill	174.31 – 174.41	122	72	41
Pre-Level	174.41 – 175.01	149	75	49
Rut Fill	175.01 – 175.21	150	72	52
Pre-Level	175.21 – 175.31	174	80	54
Rut Fill	175.31 – 175.71	125	67	46
Pre-Level	175.71 – 175.81	170	68	60
Rut Fill	175.81 – 176.21	135	77	42
Pre-Level	176.21 – 176.31	180	76	58
Rut Fill	176.31 – 176.41	132	87	34
Pre-Level	176.41 – 176.51	138	91	34
Rut Fill	176.51 – 176.81	119	80	32
Pre-Level	176.81 – 177.25	133	75	43
Rut Fill	177.25 – 177.75	153	92	40
Cushion Course	177.75 – 178.55	177	60	66
Rut Fill	178.55 – 179.05	148	86	40
Pre-Level	179.05 – 179.75	145	88	38
Rut Fill	179.75 – 180.08	158	115	27
Cushion Course	180.08 -180.58	162	68	58
Rut Fill	180.58 – 181.28	151	110	26
Pre-Level	181.28 – 181.58	132	86	33
Rut Fill	181.58 – 181.98	153	109	25
Cushion Course	181.98 – 182.48	154	69	54
Pre-Level	182.48 – 182.78	149	88	41
Rut Fill	182.78 – 183.08	157	103	34
Pre-Level	183.08 – 183.48	125	77	37
Rut Fill	183.48 – 183.68	157	100	37
Pre-Level	183.68 – 184.18	108	86	17
Rut Fill	184.18 – 185.28	126	82	33
Pre-Level	185.28 – 185.48	152	94	35
Rut Fill	185.48 – 185.68	169	100	39
Pre-Level	185.68 – 185.88	214	109	49
Rut Fill	185.88 – 185.98	133	89	32
Pre-Level	185.98 – 186.19	165	98	35
Rut Fill	186.19 – 186.49	179	92	45
Cushion Course	186.49 – 187.35	201	69	65
Pre-Level	187.35 – 187.44	128	119	7
Rut Fill	187.44 – 189.18	123	78	34
Cushion Course AVE IRI and % IMP		194	69	65
Pre-Level AVE IRI and % IMP		159	89	44
Rut Fill AVE IRI and % IMP		142	89	38
Mill and Fill AVE IRI and % IMP		214	66	69

Table 15. NB SR-283 before and after HBST construction ride data.				
Treatment	Milepost	2017 Average IRI (inches/mile)	2017 Average IRI (inches/mile)	Percent Improvement
Cushion Course	0.0 – 3.70	173	71	71
HBST Only	3.70 – 4.30	118	112	0
Cushion Course	4.30 – 5.60	173	67	59
HBST Only	5.6 – 7.00	116	113	1
Cushion Course	7.00 – 7.90	180	68	61
Pre-Level	7.90 – 8.40	97	96	1
HBST Only	8.40 – 9.10	125	124	1
Pre-Level	9.10 – 9.20	151	134	11
HBST Only	9.20 – 9.40	138	137	-1
Cushion Course	9.40 – 9.90	204	83	57
HBST Only	9.90 – 10.20	122	117	4
Pre-Level	10.20 – 10.30	163	131	20
HBST Only	10.30 – 10.40	99	100	-1
Pre-Level	10.40 – 10.50	96	88	8
HBST Only	10.50 – 10.70	101	104	-3
Pre-Level	10.70 – 10.80	147	143	3
HBST Only	10.80 – 11.00	100	108	-9
Cushion Course	11.00 – 11.40	146	84	37
HBST Only	11.40 – 11.50	102	136	-34
Pre-Level	11.50 – 11.60	129	127	1
HBST Only	11.60 – 11.70	120	133	-11
Pre-Level	11.70 – 11.80	115	118	-3
HBST Only	11.80 – 12.00	106	113	-6
Pre-Level	12.00 – 12.20	107	107	0
HBST Only	12.20 – 12.70	139	148	-7
Pre-Level	12.70 – 12.80	113	121	-7
HBST Only	12.80 – 12.90	84	90	-6
Pre-Level	12.90 – 13.00	89	71	20
Cushion Course	13.00 – 14.10	83	82	-1
HBST Only	14.10 – 14.81	86	101	-10
Cushion Course AVE IRI and % IMP		160	76	53
Pre-Level AVE IRI and % IMP		121	110	9
HBST Only AVE IRI and % IMP		111	117	-5

Table 15. (Continued) SB SR-283 before and after HBST construction ride data.				
Treatment	Milepost	2017 Average IRI (inches/mile)	2017 Average IRI (inches/mile)	Percent Improvement
HBST Only	14.76 – 14.16	105	93	11
Cushion Course	14.16 – 13.06	90	95	-7
Pre-Level	13.06 – 12.96	127	132	-4
HBST Only	12.96 – 12.76	95	93	2
Pre-Level	12.76 – 12.66	124	131	-6
HBST Only	12.66 – 12.26	143	137	4
Pre-Level	12.26 – 12.06	102	107	-5
HBST Only	12.06 – 11.86	113	108	4
Pre-Level	11.86 – 11.76	98	102	-3
HBST Only	11.76 – 11.66	87	88	-1
Pre-Level	11.66 – 11.56	124	107	14
HBST Only	11.56 – 11.46	104	123	-19
Cushion Course	11.46 – 11.06	180	98	37
HBST Only	11.06 – 10.86	100	92	5
Pre-Level	10.86 – 10.76	142	143	-1
HBST Only	10.76 – 10.56	107	114	-7
Pre-Level	10.56 – 10.46	88	81	9
HBST Only	10.46 – 10.36	115	124	-7
Pre-Level	10.36 – 10.26	148	114	23
HBST Only	10.26 – 9.96	104	114	-9
Cushion Course	9.96 – 9.46	196	80	55
HBST Only	9.46 – 9.26	122	116	3
Pre-Level	9.26 – 9.16	189	180	5
HBST Only	9.16 – 8.36	131	126	4
Pre-Level	8.36 – 7.96	92	91	1
Cushion Course	7.96 – 7.06	198	72	62
HBST Only	7.06 – 5.66	112	107	4
Cushion Course	5.66 – 4.26	181	72	60
HBST Only	4.26 – 3.66	115	129	-15
Cushion Course	3.66 – 0.06	195	67	63
Cushion Course AVE IRI and % IMP		173	81	53
Pre-Level AVE IRI and % IMP		123	119	4
HBST Only AVE IRI and % IMP		111	112	-1

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