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Texas A&M Transportation Institute

Statewide Implementation of the Surface Performance Graded (SPG) Specification for Chip Seal Binders in Service: Implementation Report

Implementation Report 5-6616-01-R1

Cooperative Research Program

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16. Abstract
Over the past almost 20 years, a Surface Performance-Graded (SPG) specification for chip seal binders was developed and validated using laboratory measurements and visual field performance of 141 highway sections. This SPG specification was established in an effort to extend the service life of chip seals and save approximately $9 million per year by providing a binder grading system and associated selection guidelines that: (1) accounts for differences in climate and (2) uses existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction. This report documents a multi-year implementation effort that includes: (1) further validation and (2) industry interaction including outreach, state round robin testing programs, laboratory characterization efforts with private laboratories, and associated work with a national task force. The SPG specification now available as a special provision to Texas Department of Transportation (TxDOT) Item 300 (SP 300-011) will replace the TxDOT Chip Seal Binder Material Selection Table with the tiered system and conventional chip seal binder specifications for materials in service provided in TxDOT Item 300.

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STATEWIDE IMPLEMENTATION OF THE SURFACE PERFORMANCE GRADED (SPG) SPECIFICATION FOR CHIP SEAL BINDERS IN SERVICE: IMPLEMENTATION REPORT

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation. This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Amy Epps Martin, P. E TX#91053.

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER 1: INTRODUCTION

In Item 316 of the Texas Department of Transportation (TxDOT) specifications, chip seals are defined as a spray application of asphalt emulsion or hot-applied asphalt binder covered with aggregate (*1*). These maintenance treatments are known as chip seals or seal coats in Texas and cover approximately 40 percent of road surfaces in the state. TxDOT spends over $300 million every year in 25 districts on district-wide preventive maintenance programs to treat approximately 8 percent of the state highway system or 5000 miles. If the performance of these treatments can be improved to provide an additional year of service life on 20 percent of the treated sections, approximately $9 million could be saved every year.

Toward this goal of improving performance, a surface performance-graded (SPG) specification for chip seal binders in service (either hot-applied asphalt binder or emulsion residue) was developed and validated over almost 20 years as part of two TxDOT research projects and an implementation project for 141 highway sections (HSs) statewide to date (*2*, *3*, *4*, *5*, *6*, *7*, *8*, *9*, *10*, *11*). The specification was developed to provide a binder grading system and associated selection method that: 1) accounts for differences in climate, and 2) uses existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction.

This chapter first describes the motivation and evolution of the SPG specification, including the binder selection guidelines using this specification. The chapter concludes with the objectives and outline for this report on the 2013–18 implementation effort.

MOTIVATION

The Strategic Highway Research Program produced a performance-related specification for hot mix asphalt (HMA) binders known as the performance-graded (PG) system (*12*, *13*, *14*). In this system, binders are tested in three critical aging states using laboratory tests that measure performance-related properties. These new tests and the associated system addressed many shortcomings of the previous viscosity- or penetration-graded specification systems, including (*5*):

- The empirical nature of penetration and ductility tests.
- The inability to grade modified binders using viscosity tests at high temperatures.

- The absence of low-temperature characterization.
- The lack of consideration for long-term aging.

The resulting PG binder specification is applicable to both unmodified and modified binders and employs new equipment, including the Dynamic Shear Rheometer (DSR) and the Bending Beam Rheometer (BBR), to measure performance-related properties of the binder at temperature ranges for the climate in service (*13*). These properties preclude the binder's contribution to the three primary forms of distress in mixtures commonly encountered in the field: rutting caused by inadequate shear resistance under repeated load, repeated-load fatigue cracking, and low-temperature thermal cracking. The temperature range where these properties meet the specified thresholds is defined as the binder PG, and the required properties span the range from high temperatures the binder is exposed to during production and construction to low temperatures the binder is exposed to in service. Both short- and long-term aging are considered through the use of the Rolling Thin Film Oven (RTFO) and the Pressure Aging Vessel (PAV), respectively (*13*). Representative climate and traffic conditions for binders in HMA are considered in the associated binder selection guidelines.

Current specifications for chip seal binders (either hot-applied asphalt binders or asphalt emulsions and their residues) (including TxDOT Item 316) also consider properties of the material during construction and in service, but the same shortcomings highlighted previously remain and allow a wide range of materials to be used to meet the current specifications (*1*). As shown in Table 1 for modified binders, performance in service is only accounted for in current specifications by penetration and viscosity for emulsion residues or DSR and BBR PG properties at specific temperatures for hot-applied asphalt binders. Aging of emulsion residues is also not considered in current specifications.

To address the need for a new chip seal binder specification that addresses the same shortcomings but accounts for differences between chip seals and HMA in terms of distress and conditions during construction and in service, the SPG specification for chip seal binders in service (either hot-applied asphalt binder or emulsion residue recovered by American Association of State Highway and Transportation Officials [AASHTO] PP 72-11 Procedure B) was developed and validated over almost 20 years as part of two TxDOT research projects and an implementation project (*2–11*). The evolution of the SPG specification is described subsequently, but the most recent version now available as a special provision to TxDOT Item

300 (SP 300-011) and used in 2016 and 2017 is provided in Table 2 to illustrate that it is has the same framework as the PG specification and to facilitate comparison with current chip seal binder specifications and the PG specification for HMA binders (*15*). The original binder properties included for safety and sprayability in Table 2a are only required for hot-applied asphalt binders. Additional stability and composition properties for emulsions shown in Table 1 are included separately in Table 2b.

Table 1. Comparison of Current Specifications and the SPG Specification for Chip Seal Binders for: (a) Modified Hot-Applied Asphalt Binders and (b) Modified Emulsions.

(a) Grade	AC-15P	AC-10-2TR	AC-20-5TR	SPG
Composition				
Polymer Required?	X	X	X	
Minimum Polymer Content?	X	X	X	
Assurance of "Modified" Behavior				
Elastic Recovery @ 50°F	X	X	X	
Phase Angle @ T_{HIGH} threshold				X
Assurance of Sprayability				
Viscosity @ 275°F	X	X	X	X @ 205°C
Resistance to Bleeding @ High Pavement Temperatures (T_{high})				
DSR @ T_{HIGH}		X @ 58°C	X @ 64°C	X @ T_{HIGH}
Viscosity @ 140°F	X	X	X	
Other Consistency				
Penetration @ 77°F	X	X	X	
Softening Point	X	X	X	
Resistance to Aggregate Loss @ Low Pavement Temperatures (T_{low}) after Aging				
PAV Aging	X w/RTFO	X w/RTFO	X w/RTFO	X
BBR Stiffness @ T_{LOW}	X @ -18°C	X @ -18°C	X @ -18°C	X @ T_{low}
BBR m-value @ T_{LOW}	X @ -18°C	X @ -18°C	X @ -18°C	

(b) Grade	CRS-2P	HFRS-2P	SPG
Composition			
Polymer Required?	X	X	
Minimum Polymer Content?	X	X	
Minimum Asphalt Content?	X	X	X
Solubility?	X	X	X
Assurance of "Modified" Behavior			
Elastic Recovery @ 50°F / Ductility @ 39°F	X	X	
Phase Angle @ T_{HIGH} threshold			X
Float Test @ 140°F		X	X (for HF)
Assurance of Sprayability			
Saybolt Viscosity @ 122°F	X	X	X
Resistance to Bleeding @ High Pavement Temperatures (T_{high})			
DSR Parameter @ T_{HIGH}			X @ T_{high}
Viscosity @ 140°F	X	X	
Other Consistency			
Penetration @ 77°F	X	X	
Softening Point	X	X	
Resistance to Aggregate Loss @ Low Pavement Temperatures (T_{low}) after Aging			
PAV Aging			X
BBR Stiffness @ T_{LOW}			X @ T_{low}
Emulsion-Specific Stability Tests			
Demulsibility	X	X	X
Storage Stability	X	X	X
Sieve	**X**	**X**	**X**

Table 2. Special Provision to Item 300 (SP 300-011) SPG Specification for: (a) Hot-Applied Asphalt Binders and Emulsion Residues and (b) Emulsified Asphalt (*15*).

(a)

Surface Performance Grade	SPG 67				SPG 73				SPG 79			
	-13	-19	-25	-31	-13	-19	-25	-31	-13	-19	-25	-31
Average 7-day Max pavement surface design temperature, °C	<67				<73				<79			
Min pavement surface design temperature, °C	>-13	>-19	>-25	>-31	>-13	>-19	>-25	>-31	>-13	>-19	>-25	>-31
Original Binder												
Flash point temp, T 48, Min, °C	230											
Viscosity, T 316: Max 0.15 Pa*s, test temp., °C	205											
Original Performance Properties												
Dynamic Shear, T 315: G*/sin δ, Min 0.65 kPa, Test temp @ 10 rad/s, °C	67				73				79			
Phase angle (δ), Max, @ temp. where G*/sin δ = 0.65 kPa	–	80	80	80	80	80	80	80	80	80	80	80
Pressure Aging Vessel Residue (R 28)												
PAV aging temperature, °C	100				100				100			
Creep stiffness, T 313: S, Max 500 MPa, Test temp. @ 8 sec., °C	-13	-19	-25	-31	-13	-19	-25	-31	-13	-19	-25	-31

(b)

Grade	Test Procedure	HFRS-2(SPG xy[1])		CRS-2(SPG xy[1])		CHFRS-2(SPG xy[1])	
		Min	Max	Min	Max	Min	Max
Tests on emulsions:							
Viscosity, Saybolt Furol at 50°C, SFs[2]	T 72	150	400	150	400	150	400
Storage stability test, 24 h., %[2]	T 59		1		1		1
Demulsibility, 35 mL, 0.02 N $CaCl_2$, %	T 59	60					
Demulsibility, 35 mL, 0.8% dioctyl sodium sulfosuccinate, %	T 59			60		60	
Particle charge test	T 59			positive		positive	
Sieve test, %[2]	T 59		0.10		0.10		0.10
Residue recovery	PP 72, Procedure B						
Residue, %		65		65		65	
Tests on recovered residue:							
Residue properties		Meet the specified SPG grade[3], except the Max phase angle is 84					
Solubility in trichloroethylene, %	T 44	97.5		97.5			
Float test, 60°C, sec.[4]	T 50	1,200				1,200	

1. X is the average 7-day maximum pavement surface design temperature, and y is the minimum pavement surface design temperature used in SPG Specification.
2. This test requirement on representative samples is waived if successful application of the material has been achieved in the field.
3. Meet original performance properties and PAV residue requirements only
4. If Float test is less than 1,200 sec. using PP 72, Procedure B, for residue recovery, then use T 59 for residue recovery.

As shown in Table 1, the SPG specification for chip seal binders addresses the majority of the same issues as current specifications, including the following (*5*):

- Assurance of modified behavior.
- Assurance of sprayability during construction.
- Resistance to bleeding at high pavement temperature.
- Resistance to aggregate loss at low pavement temperature after aging.

Composition specific parameters are not included in the SPG specification due to inclusion of performance-related properties. Modification in the SPG specification is currently controlled by phase angle measured in the DSR during high temperature grading instead of a separate elastic recovery (ER) test. Sprayability parameters are the same except at a lower test temperature of 205°C for hot-applied asphalt binders. Viscosity is replaced by DSR parameters at a test temperature tied to the climate, and other consistency parameters are eliminated. Low temperature stiffness measured in the BBR after only PAV aging at a test temperature tied to the climate is also required by the SPG specification. Based on limited data from chip seals with uncoated aggregates that facilitate aging evaluation, PAV aging for 20 hr at 100°C simulates the critical first year of service for chip seals in Texas (*6*).

While the SPG specification uses the same framework and equipment as the PG specification to address the same shortcomings, to account for differences between chip seals and HMA in terms of distress and conditions during construction and service, the SPG is unique with the following differences highlighted in Figure 1 (*5*):

- Pavement temperatures (T_{pvmnt}) at the surface are used at both high temperatures (T_{high}) and low temperatures (T_{low}) for the chip seal surface treatments.
- The SPG temperatures at T_{high} and T_{low} are offset 3°C from those used for the PG specification to minimize confusion and accommodate the climate the SPG specification was developed for in Texas.
- The time-temperature shift at T_{low} is not used to capture aggregate loss at low temperatures due to traffic instead of non-load related thermal cracking.
- RTFO aging is not used since chip seal binders are not exposed to HMA plant temperatures, and there is currently not a performance-related property at intermediate temperatures (T_{int}).

- Only creep stiffness is determined from BBR testing, but this parameter is measured at 8 seconds to capture aggregate loss at low temperatures at the fastest reliable loading time to simulate this traffic load-related distress.
- A maximum phase angle at the T_{high} property threshold is required if the useful temperature interval (UTI), defined as the difference between the high-temperature and low-temperature SPG, is greater than or equal to 86.

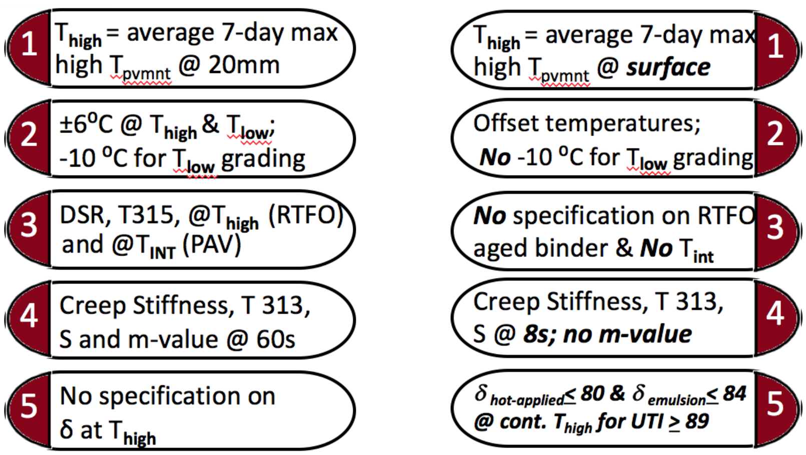


Figure 1. Comparison of PG and SPG Specifications (*5*).

EVOLUTION

The evolution of both the SPG specification and the associated SPG binder selection guidelines through two TxDOT research projects and an implementation project is summarized in this section.

SPG Specification

Table 3 presents the evolution of the SPG specification as documented in a series of reports and associated papers through the two TxDOT research projects with the 2012 revision used as a shadow specification in 2013 and 2014, the first published special provision to TxDOT Item 300 (SP 300-001) (*16*), and the most recent special provision to TxDOT Item 300 (SP 300-011) used in 2016 and 2017 and shown in Table 2 (*2–11,17*).

The minimum threshold value for G*/sin δ was first set at 0.75 kPa based on the theoretical threshold estimate given by the Upper Bound Theorem against aggregate loss and a qualitative field performance survey during the first TxDOT research project (*10*). Based on an analysis of quantitative field performance data, this threshold was revised to 0.65 kPa and subsequent field validation with 120 HSs confirmed this threshold. Several emulsion residue recovery processes were considered during the first TxDOT research project, and the Texas Oven Method that became Procedure B in AASHTO PP 72-11 was selected as the most efficient, representative, and repeatable method to recover the residue from both unmodified and modified emulsions while minimizing aging and ensuring removal of all water (*3, 6, 7*).

Table 3. Evolution of the SPG Specification (*5*).

Equipment Test Method Temperature Aging State	**Desired Performance**	**Performance Criteria**	**2001 (*6, 10*)**	**2005 (*7, 8*)**	**2010 (*9, 11*)**	**2012 (*3, 4*)**	**2015 SP 300-001 (16)**	**2016 SP300-011** Table 2 **(15)**
DSR AASHTO T 315 High Temperature Original/Unaged	**Resistance to Bleeding**	$\frac{G^*}{\sin\delta}$ (kPa), min	0.75	0.65	0.65	0.65	0.65	0.65
	Polymer Modification	δ, max @ $\frac{G^*}{\sin\delta}$ = 0.65 kPa	X	X	X	X	80 for UTI≥89	80 for UTI≥86 84 for emulsion residue
DSR AASHTO T 315 Intermediate Temperature Original/Unaged & PAV Aged	**Resistance to Aggregate Loss**	% strain, min @ 0.8$G_{initial}$* (Original/Unaged)	X	X	25	17.5	X	X
		$G_{initial}$*, max (PAV Aged)	X	X	2.5	2.5	X	X
BBR AASHTO T 313 Low Temperature PAV Aged	**Resistance to Aggregate Loss**	S (MPa), max @ 8 sec	500	500	500	500	500	500
	Stress Relaxation	m–value, min @ 8 sec	0.240	0.240	0.240	X	X	X

Shear strain sweep tests on both original unaged and PAV aged binders were introduced during the second TxDOT research project based on research by others to evaluate strain tolerance and preclude aggregate loss. Despite an adjustment to the threshold, these parameters were removed due to lack of correlation with field performance. More recently the phase angle parameter was added when the UTI of the binder is greater than or equal to 86 (e.g., SPG 67-19) to ensure polymer modification and obtain adequate field performance, especially in extreme hot or cold climates or under high traffic conditions. A maximum threshold of 80° was first chosen as it reasonably delineated the modified and unmodified binders for historically available phase angle data from TxDOT, but a higher threshold of 84° was selected for emulsion residues based on discussions with suppliers. The first maximum threshold for stiffness (S) of 500 MPa set using a qualitative field performance survey was confirmed with quantitative field performance data from 120 HSs in repeated validation efforts. An initial minimum threshold for m-value of 0.24 was also confirmed by field validation, but this parameter was removed from the specification in the second TxDOT research project due to a lack of relevance for chip seal performance.

SPG Binder Selection

To complement the SPG specification, the following steps and tools are offered to select the binder SPG to meet climate, traffic, and other project-specific demands (*5*):

1. Select a binder SPG using the revised climate-based requirement map that is color-coded by TxDOT district and county as shown in Figure 2c or the related and more specific TxDOT spreadsheet tool that uses the same data and the same worst-case temperatures for counties with multiple weather stations (*17*).
2. Consider adjusting the binder SPG for traffic or binder modification.
3. Select the final binder SPG.

The climate-based SPG map in Figure 2c or the associated TxDOT spreadsheet tool is used to establish the climate-based required SPG. As for the specification, this map also evolved with the first iteration developed based on worst-case surface pavement temperatures within each Texas county, starting from 95 percent confidence and rounding to the nearest 3°C increment. For practicality reasons, stricter grades (increased high temperature and/or decreased low temperature) were introduced to reduce the number of grades to 1–2 per TxDOT district as shown in Figure 2a. The map was further revised as shown in Figure 2b to 6°C increments based on results of round robin programs with the Texas A&M Transportation Institute (TTI), TxDOT, and binder suppliers as described subsequently in this report. The final revised map (Figure 2c) also used worst-case surface pavement temperatures within each Texas county, but 6°C increments were used based on the round robin programs described subsequently and this coarser delineation no longer required a practical reduction in the number of grades per TxDOT district.

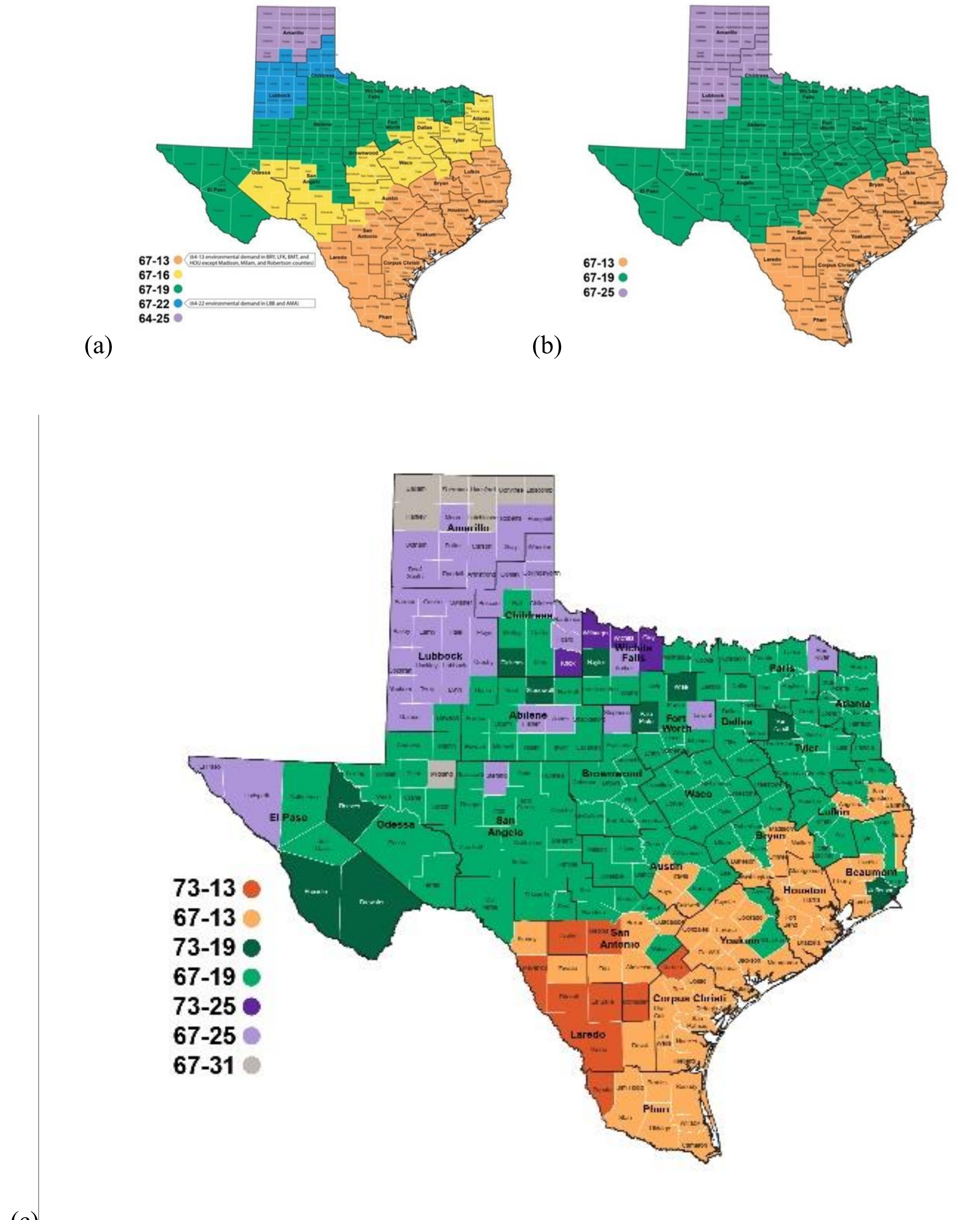


Figure 2. SPG Climate-Based Requirement Map for Texas Based on (a) Initial 3°C, (b) Initial 6°C Increments, and (c) Revised 6°C Increments.

The TxDOT spreadsheet tool uses location coordinates or county of interest and confidence intervals as inputs as shown in Figure 3a and generates the outputs shown in Figure 3b that include the recommended SPG and confidence interval and the locations and data for the weather stations used. The confidence interval is the reliability level desired for the climate-based SPG and represents the likelihood that the pavement temperature will exceed the UTI in a year. Common confidence intervals are 95 percent and 98 percent and can be interpreted as a temperature excursion outside the grade limits once every 20 years and once every 50 years, respectively. The recommended SPG is intended to encompass all the selected weather stations based on the 7-day high temperature converted to surface pavement temperature using the Superpave model (*12*). The binder SPG is calculated from the mean and standard deviation of the surface temperature, along with the confidence interval given as input, and rounded to the 6° incremental grade that will satisfy the requirement. Larger counties may have a large variation in SPG for various weather stations, and in that case a single station that is close to the project location may be selected.

After establishing the climate-based SPG, traffic and binder modification are considered. For facilities with high traffic volume or excessive truck traffic, the high-temperature SPG can be increased by one 6° increment. If binder modification is desired, a UTI of 86 or larger should be selected. After the climate and project-specific requirements have been taken into consideration, the final binder SPG is selected.

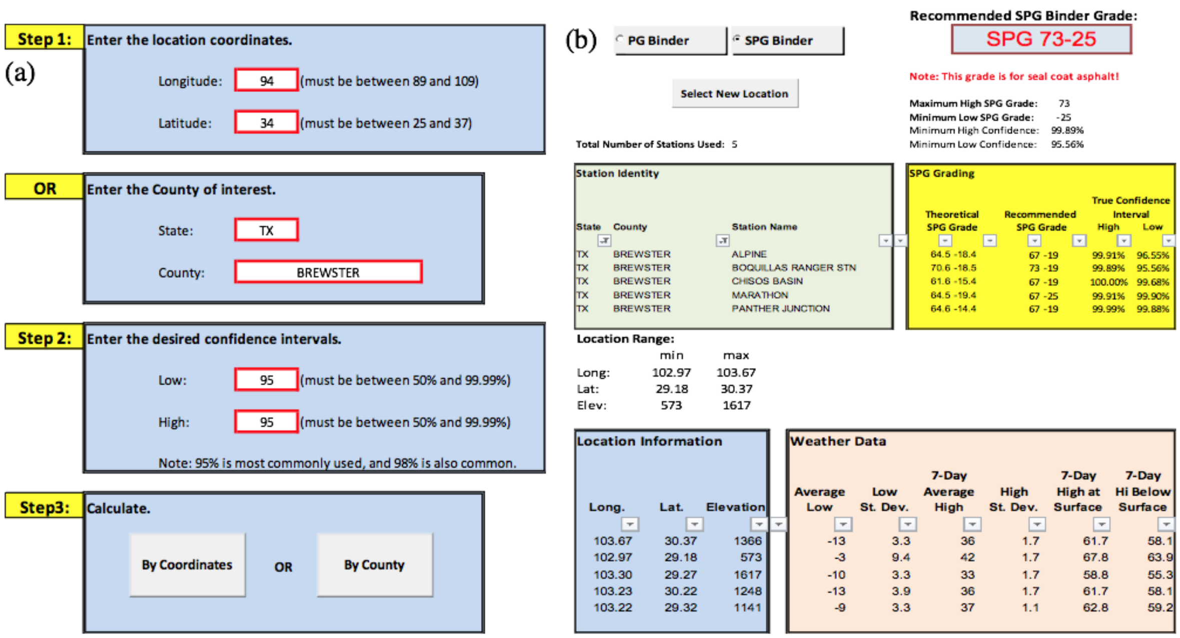


Figure 3. (a) Sample Inputs and (b) Output for the SPG Binder Grade Selection Tool Spreadsheet.

OBJECTIVES

Through two TxDOT research projects, the SPG specification for chip seal binders in service (either hot-applied asphalt binder or emulsion residue) was developed and validated through 2012 with field performance monitoring of 75 HSs statewide. The objective of this implementation project was to support and encourage statewide implementation of the SPG specification for chip seal binders in Texas by:

- Using the SPG specification as a shadow specification and with volunteer field demonstration HSs to provide additional field validation over multiple years and adjust the specification as needed, with a specific focus on:
    - Further validation that PAV aging represents the critical first year in service.
    - Continued evaluation of alternate testing methods to assess modification at T_{high} and to replace the BBR at T_{low}.
- Interacting with TxDOT and industry to address implementation concerns, including round robin testing programs.
- Participating nationally on the Federal Highway Administration (FHWA) Emulsion Task Force.

The SPG specification is intended to improve the field performance of chip seals (with either hot-applied asphalt binders or emulsions) by limiting aggregate loss and bleeding. This performance-related specification is meant to replace the current TxDOT Chip Seal Binder Material Selection Table (with the tiered system) and conventional chip seal binder specifications for materials in service provided in TxDOT Item 300 (*1*).

REPORT OUTLINE

This report documents the 2013–18 implementation effort of the SPG specification and is organized into four chapters. Chapter 1 provides the motivation and evolution of the SPG specification and associated binder selection guidelines along with the objectives and report outline. Chapter 2 describes the validation methodology, a small study on verification of PAV aging, and the results of the laboratory evaluation and field performance monitoring. Chapter 3 describes interaction with industry including outreach, state round robin testing programs, laboratory characterization efforts with private laboratories, and associated work with the national Emulsion Task Force of the Federal Highway Administration Pavement Preservation Expert Task Group. Chapter 4 concludes the report with a summary and recommendations for future improvements.

CHAPTER 2: VALIDATION

The primary objective of the 2013–2018 implementation effort was to validate the SPG specification and make adjustments as needed. This chapter first describes the validation methodology including the selected HSs constructed in 2013 and 2014 with the 2012 version as a shadow specification and those constructed in 2016 and 2017 using the SP 300-011 special provision. Next selected laboratory characterization protocols and tests are described, followed by the field performance monitoring methodology. Results from small studies to verify PAV aging and compare embedment depth (ED) measurement methods are also presented after the comparison of the laboratory results and field performance.

METHODOLOGY

The validation methodology shown in Figure 4 began with the selection of HSs in the TxDOT districts from district-wide chip seal programs. Subsequent steps included binder collection from the selected HSs; laboratory characterization of the collected binders; field performance monitoring pre-construction, post-construction, and after the first winter in service by visual distress surveys; and comparison of the laboratory results with field performance. For some HSs, performance monitoring was completed after two winters in service.

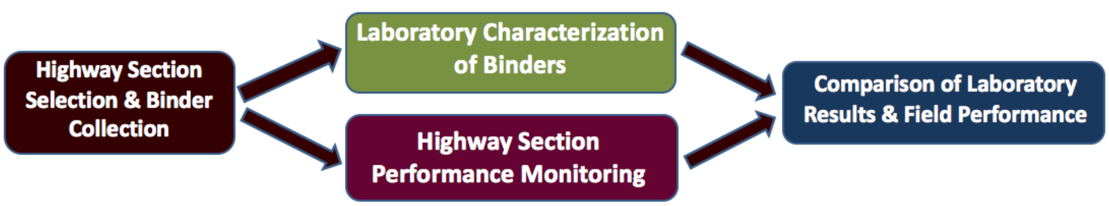


Figure 4. Validation Methodology for the SPG Specification.

HS Selection

For the implementation effort, 43 HSs (19 in six districts in 2013 in Table 4 and 24 in six districts in 2014 in Table 5) were constructed with the 2012 version of the SPG as a shadow specification (Table 3) to Item 300. Another 24 HSs (17 in seven districts in 2016 in Table 6 and 7 in two districts in 2017 in Table 7) were constructed with the SP 300-011 special provision and SPG grades. For each implementation year (with construction in 2013, 2014, 2016, and 2017), the HSs were labeled by year and with a three-letter TxDOT district abbreviation and a serial letter (i.e., 13-AMA-a) and ordered alphabetically by district.

Table 4. 2013 Highway Sections.

District	HS	County	Hwy	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	AADT 2013	% Trucks
Amarillo	13-AMA-a	Hartley	FM0767	AC10	0.44	PG GR 4	143	53
	13-AMA-b	Hutchinson	FM1551	AC10-2TR	0.37	PB GR 4	3180	4.3
	13-AMA-c	Gray	IH0040R	AC20-5TR	0.48	PB GR 4S	6182	45.9
	13-AMA-d	Hansford	SH0136	AC10-2TR	0.39	PB GR 4	398	33.1
	13-AMA-e	Armstrong	SH0207	AC10-2TR	0.34	PB GR 4	614	25.6
	13-AMA-f	Roberts	US0060	AC10-2TR	0.27	PB GR 4	2474	32.2
	13-AMA-g	Moore	US0287R	AC20-5TR	0.46	PB GR 4S	3236	42.4
Atlanta	13-ATL-a	Harrison	US0080	AC20-5TR	0.32	PB GR 4	4629	8.1
	13-ATL-b	Harrison	FM0134	AC20-5TR	0.29	PB GR 4	674	22.6
	13-ATL-c	Marion	FM3001	AC20-5TR	0.30	PB GR 4	463	28
Corpus Christi	13-CRP-a	Jim Wells	FM0665	AC15P	0.29	PC GR 3	10100	7.9
	13-CRP-c	San Patricio	PM2046	AC15P	0.31	PC GR 3S	335	11.6
	13-CRP-d	San Patricio	FM2512	AC15P	0.31	PC GR 3	530	11.5
San Antonio	13-SAT-a	Guadalupe	FM0621	AC15P	0.33	PB GR 4	3912	28.1
	13-SAT-b	Kendall	SH0046	AC15P	0.31	PB GR 4	8600	21.5
San Angelo	13-SJT-a	Runnels	FM1692	AC10-2TR	0.42	PB GR 3	470	5.8
	13-SJT-b	Sterling	SH0158	AC10-2TR	0.44	PB GR 3	726	22
	13-SJT-c	Coke	US0087L	AC20-5TR	0.43	PB GR 3	2315	17.1
Tyler	13-TYL-a	Rusk	US0259L	AC20-5TR	0.33	PD GR 4	6550	15.6

AADT = Average Annual Daily Traffic

Table 5. 2014 Highway Sections.

District	HS	County	Hwy	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	AADT 2014	% Trucks
Beaumont	14-BMT-a	Liberty	FM1725	CRS-2P	-	-	-	-
	14-BMT-b	Newton	SH87	CRS-2P	-	-	-	-
Bryan	14-BRY-a	Burleson	FM1362	AC20-5TR	0.37	PC GR 4	350	12.2
	14-BRY-b	Burleson	FM2000	AC20-5TR	0.38	PC GR 4	1050	15.4
	14-BRY-c	Leon	SH0007	AC20-5TR	0.37	PC GR 4	1950	46.7
Lubbock	14-LBB-a	Lamb	US84	AC20-5TR	-	-	-	-
Lufkin	14-LFK-a	Trinity	FM0357(A-D)	CRS-2P	-	PC GR 3	626	9.8
	14-LFK-b	Houston	FM0357(1-4)	CRS-2P	-	PC GR 3	365	12.7
	14-LFK-c	Trinity	FM0357(E-H)	CRS-2P	-	PC GR 3	224	11.7
	14-LFK-d	Trinity	FM0357(5-8)	CRS-2P	-	PC GR 3	412	11.7
	14-LFK-e	San Jacinto	FM2693(2)	CRS-2P	-	PC GR 3	295	6.6
San Antonio	14-SAT-a	Uvalde	FM2730	AC10	-	PC GR 4	250	19.3
	14-SAT-b	Kerr	SH0039	AC10	-	-	75	30.6
	14-SAT-c	Comal	FM3009	AC15P	0.3	PC GR 4	2500	9.2
	14-SAT-d	Kendall	RM0473	AC15P	0.31	PC GR 4	980	26.5
	14-SAT-e	Kendall	RM1376(1-4)	AC15P	0.32	PC GR 4	510	15.7
	14-SAT-f	Kendall	RM1376(5-8)	AC20-5TR	-	PC GR 4	1000	11.3
	14-SAT-g	Kendall	RM1376(A-D)	AC20-5TR	-	PC GR 4	4900	7.6
	14-SAT-h	Comal	RM2722	AC20-5TR	0.3	PC GR 4	4600	6.2
	14-SAT-i	Medina	SH0016	AC20-5TR	-	PC GR 4	2450	5.8
	14-SAT-j	Kerr	SH0039(1-4)	AC20-5TR	0.38	PC GR 3	3900	25.6
	14-SAT-k	Kerr	SH0039(5-8)	AC20-5TR	-	PC GR 4	1150	15.7
Waco	14-WAC-a	Bell	FM487	AC10-2TR	-	-	-	-
	14-WAC-b	Hill	FM67	AC10-2TR	-	-	-	-

Table 6. 2016 Highway Sections.

District	HS	County	Hwy	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	AADT 2016	% Trucks
Abilene	16-ABL-1	Howard	BI0020G	SPG73-19	0.36	PC GR 4	3700	45
	16-ABL-2	Jones	SH0092	SPG73-19	0.38	PB GR 4	2500	30
Amarillo	16-AMA-1	Ochiltree	US0083X	SPG64-25	0.45	PC GR ¾	3500	28
	16-AMA-2	Hartley	FM0281	SPG64-25	0.41	PC GR 4	2627	42.9
Austin	16-AUS-1	Mason	US0087	SPG 70-19	US0087-1| 0.31 US0087-2| 0.31 US0087-3| 0.31 US0087-4| 0:32	PC GR 4	2558	29.6
	16-AUS-2	Mason	SH0029(1-4)	SPG 70-19	0.32	PC GR 4	1148	15.9
	16-AUS-3	Llano	SH0029(5-6)	SPG 70-19	0.33	PC GR 4	4771	17.9
Brownwood	16-BWD-1	Coleman	US0084	CRS-2P	0.38	GR 4	3300	11.7
	16-BWD-2	Coleman	US0084	SPG67-22	0.42	Lime GR 4	3300	11.7
Corpus Christi	16-CRP-1	Jim Wells	FM3376	SPG70-19	0.35	PC GR 4	3000	10
	16-CRP-2	Nueces	FM0665	SPG70-19	0.35	PC GR 4S, B	3500	8
Paris	16-PAR-1	Hunt	FM0035	SPG70-22	0.32	PC GR 4	4147	9.1
	16-PAR-2	Fannin	US0069	SPG70-22	0.32	PC GR 4,B	3300	15.5
	16-PAR-3	Grayson	SH0289	SPG70-22	SH0289-1| 0.32 SH0289-2| 0.32 SH0289-3| 0.36 SH0289-4| 0.36	PC GR 4	2500	30
Pharr	16-PHR-1	Cameron	FM0506	SPG73-16	0.32	GR 4P, SAC B	696	40
	16-PHR-2	Cameron	FM1847	SPG73-16	0.32	GR 4P, SAC B	9940	2.9
	16-PHR-3	Starr	FM2098	SPG73-16	0.32	GR 4P, SAC B	600	4.2

Table 7. 2017 Highway Sections.

District	HS	County	Hwy	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	AADT 2017	% Trucks
Amarillo	17-AMA-1	Dallam	FM297(1-2)	SPG73-25	0.56	PC GR 3	1169	41.4
	17-AMA-2	Dallam	FM297(5-8)	SPG73-25	0.56	PC GR 3	674	41.4
	17-AMA-4	Gray	SH0070(1-2)	SPG73-25	0.47	PC GR 4	1879	54.5
	17-AMA-5	Gray	SH0070(5-8)	SPG73-25	0.47	PC GR 4	626	15.4
Pharr	17-PHR-1	Hidalgo	FM0088	SPG73-19	-	-	4126	32
	17-PHR-2	Hidalgo	FM2220	SPG73-19	-	-	5058	1.8

The factors considered in selecting these HSs from the district-wide chip seal programs were the binder type, traffic (AADT and % Trucks), and SPG environmental location (Figure 2c). Traffic was generally categorized in three tiers as shown in Table 8, but the threshold between tiers T2 and T3 was reduced from 1000 to 500 with SP 300-011 in 2016 and 2017.

Table 8. Traffic Tiers.

Traffic Tier	Thresholds
T1	AADT>5000
T2	500≤AADT≤5000
T3	AADT<500

Each TxDOT district selected a binder SPG based on the binder grade selection process described previously with additional information provided on the SPG of the binder they traditionally used. Each TxDOT district also selected the aggregate type and grade as defined by TxDOT Item 302 and shown in Table 9 and Table 10.

Table 9. Aggregate Types.

Type	Material
A	Gravel, crushed slag, crushed stone, or limestone rock asphalt (LRA)
B	Crushed gravel, crushed slag, crushed stone, or LRA
C	Gravel, crushed slag, or crushed stone
D	Crushed gravel, crushed slag, or crushed stone
E	Aggregate as shown on plans
L	Lightweight Aggregate
PA	Precoated gravel, crushed slag, crushed stone, or LRA
PB	Precoated crushed gravel, crushed slag, crushed stone, or LRA
PC	Precoated gravel, crushed slag, or crushed stone
PD	Precoated crushed gravel, crushed slag, crushed stone
PE	Precoated aggregate as shown on the plans
PL	Precoated lightweight aggregate

Table 10. Aggregate Grades (Cumulative Percent Retained[1]).

Sieve	Grade								
	1	2	3S[2]	3		4S[2]	4	5S[2]	5
				Non-lightweight	Lightweight				
1"	–	–	–	–	–	–	–	–	–
7/8"	0–2	0	–	–	–	–	–	–	–
3/4"	20–35	0–2	0	0	0	–	–	–	–
5/8"	85–100	20–40	0–5	0–2	0–2	0	0	–	–
1/2"	–	80–100	55–85	20–40	10–25	0–5	0–5	0	0
3/8"	95–100	95–100	95–100	80–100	60–80	60–85	20–40	0–5	0–5
1/4"	–	–	–	95–100	95–100	–	–	65–85	–
#4	–	–	–	–	–	95–100	95–100	95–100	50–80
#8	99–100	99–100	99–100	99–100	98–100	98–100	98–100	98–100	98–100

1. Round test results to the nearest whole number.
2. Single-size gradation.

In addition to pictures taken pre-construction, post-construction, and after the first winter in service to record the pavement surface condition; for the 2016 and 2017 HSs specified by SP 300-011 special provision; the following information was also collected and documented in construction summary reports presented as Appendix A:

- Material-related.
  - Binder type and application rate.
  - Aggregate type, grade, and application rate.
- Traffic-related.
  - AADT and % Truck.
- Construction-related.
  - Date of construction.
  - Weather and temperature during construction.
  - Time between binder and aggregate application.
  - Time between binder application and rolling.
- Pavement surface condition-related.
  - ED in and between wheel path (WP) post construction.
  - Other surface distresses if present.

Figure 5 shows an example of a TxDOT construction summary report.

Construction Summary Report

District – Abilene | County - Jones
Highway – SH0092 | Near - Hamlin

Site	Lane	BRM	ERM
SH0092-1	K1	394+0.1	394+0.2
SH0092-2	K6	394+0.2	394+0.1
SH0092-3	K1	396+0.0	396+0.1
SH0092-4	K6	396+0.1	396+0.0

Contractor Lipham, Aspermont, TX
Date 08/01/2016
Binder Type SPG 73-19 | Binder Source Saginaw
Agg Type PB Gr 4 | Agg Source Burkett, Graham, TX
Weather Windy, 95°
AADT 2500
2016 %Trk 30
2016 AADT Level M

Site	SH0092-1	SH0092-2	SH0092-3	SH0092-4
Binder rate	0.38 Gal/SY	0.38 Gal/SY	0.38 Gal/SY	0.38 Gal/SY
Aggregate rate	115 SY/CY	115 SY/CY	115 SY/CY	115 SY/CY
Binder Application Time	0:00	0:00	0:00	0:00
Time until Rock Added	3:55	8:34	8:42	3:33/6:04
Time to First Roll	6:07	11:57	12:55	10:12

Notes

The binder source changed during this project because the contractor was having difficulty in getting material. New source was Saginaw. On section #4, they stopped in the middle of the test section to remove huge clumps of grass from hopper.

Pre-Construction Distress Survey

Percent Embedment
SH0092-1 WP - 95 BWP - 50
SH0092-2 WP - 95 BWP - 90
SH0092-3 WP - 95 BWP - 95
SH0092-4 WP - 95 BWP - 95

Figure 5. Example TxDOT District Construction Summary Report.

For the same 2016 and 2017 HSs specified by SP 300-011 special provision, technical debriefings were conducted post-construction with TxDOT personnel to understand their overall experience with specifying SPG binders, any construction issues, and their plans for the future in terms of using SPG or traditional binder grades. Appendix B summarizes information gathered during the debriefings, laboratory results, and field performance of HSs in TxDOT district reports.

Laboratory Characterization

For the 2013 and 2014 HSs, the 2012 revision of the SPG was used as a shadow specification (Table 3) and included intermediate-temperature shear strain sweep testing. For the 2016 and 2017 HSs, SP 300-011 was used and included different phase angle thresholds for hot-applied asphalt binders and emulsion residues and did not include intermediate-temperature shear strain sweep testing. In addition to the current SPG tests shown in bold in Table 11 that were conducted for all binders in the implementation effort, alternate chemical and rheological tests to characterize the binders at low temperatures and evaluate polymer modification were also performed on some of the 2016 binders. Table 11 shows the tests included in the laboratory characterization effort that are briefly discussed following a description of the emulsion residue recovery method and the aging protocol.

Table 11. Binder Characterization Tests.

	Test	Conditions	Result Recorded
Original Binder	**DSR - Dynamic Shear, AASHTO T 315**	6°C increments at T_{high}; 10 rad/sec	G*/sin δ and Phase angle (δ) @ G*/sin δ = 0.65 MPa
	Fourier Transform Infrared (FTIR) Spectroscopy		Presence of polymer
	ER, AASHTO T 51 and Tex-539-C	10°C; 50 mm/ min strain rate for 4 minutes; specimen is held at 200 mm for 5 minutes and is cut at the center; allowed to recover for 1 hr	Elongation of the specimen in mm; calculate ER
	DSR - Multiple Stress and Creep Recovery (MSCR), AASHTO TP 70	55°C, 61°C, and 67°C; @ 0.1 kPa - 20 cycles of 1 sec loading and 9 sec unloading, @ 3.2 kPa (first 10 for conditioning) + 10 cycles of 1 sec loading and 9 sec unloading	J_{nr} and % R at test temperatures
	DSR – Shear Strain Sweep	25°C; 10 rad/sec linear loading from 1–50% strain, 1 sec delay time and 20–30 measurements	% strain @ 0.8 G_i*
PAV Residue after 20 hr @ 100°C	**BBR - Low-Temperature Creep Stiffness, AASHTO T 313**	6°C increments at T_{low}; 8 sec loading time	Stiffness, S
	FTIR Spectroscopy		Increase in carbonyl area
	DSR - Frequency Sweep with 4 mm Plate	−36°C, −30°C, −27°C, −24°C, −21°C, −18°C, −12°C, −6°C, and 0°C; 15 frequencies between 100 – 0.2 rad/s	G*, G', and G"
	DSR – Shear Strain	25°C; 10 rad/sec linear loading, 1% strain	G_i*

Emulsion Residue Recovery Method

Procedure B in AASHTO PP 72 was recommended for emulsion residue recovery in the second TxDOT research project (*3*) as the best method to simulate field conditions and procure a large quantity of residue in a short period of time. In this procedure, the emulsion is poured onto a silicone mat and in one continuous motion spread evenly with a wet film applicator to obtain a film thickness of 0.381 mm. The silicone mat is then placed in a 60°C forced draft oven for 6 hr.

The mat is allowed to cool for 15 minutes at room temperature prior to removal by peeling it off the mat using a uniform rolling motion with a metal rod. The recovered residue is then shaped appropriately for further chemical or rheological testing.

Aging Protocol

RTFO aging is not included in the SPG specification and was thus not performed on the binders because chip seal binders are not exposed to high production and construction temperature during application. Before determination of properties at T_{low}, both hot-applied asphalt binder and emulsion residues were aged in the PAV for 20 hr at 100°C by AASHTO R 28 to simulate approximately 1 year of environmental exposure for chip seals in Texas (*18*). This 1-year time period is critical to ensure adequate performance for chip seal binders (*19*).

Current SPG Binder Tests

According to the SPG specification, the high temperature SPG of a hot-applied asphalt binder or emulsion residue is the warmest test temperature at which $G^*/\sin\delta \geq 0.65$ kPa as measured in the DSR by AASHTO T 315 on the original unaged material. Using test results from one temperature at which $G^*/\sin\delta \geq 0.65$ kPa (passing the specification) and at another test temperature ((T+6) °C) at which $G^*/\sin\delta < 0.65$ kPa (failing the specification), the continuous SPG at T_{high} is determined by interpolation. In addition, the phase angle at this threshold ($G^*/\sin\delta = 0.65$ kPa) is also recorded to capture polymer modification.

The low temperature SPG of a hot-applied asphalt binder or emulsion residue is the coldest test temperature at which $S \leq 500$ MPa at 8 seconds as measured in the BBR by AASHTO T 313 on PAV aged material at the actual low temperature SPG (without a 10°C shift). Using test results from one temperature at which $S \leq 500$ MPa (passing the specification) and at another test temperature ((T-6) °C) at which $S > 500$ MPa (failing the specification), the continuous SPG at T_{low} is determined by interpolation.

Alternate Binder Tests

The DSR shear strain sweep test at an intermediate temperature of 25°C was also performed to assess the strain susceptibility and resistance to aggregate loss of unaged chip seal binders. Strain sweep testing was conducted on the standard DSR with 8 mm plates and a 2 mm gap. A thermal equilibrium time of 10 min was allowed after mounting the sample and before the test began. The loading frequency used in the test was 10 rad/sec (1.59 Hz), as specified by the Superpave system. Twenty measurements were recorded at various strain levels ranging from 1 to 50 percent. This range was selected to capture the full range of strain levels that most binders tested in this project can resist. A delay time of 1 sec was applied after the application of each strain level, but before the measurement was recorded, to allow the sample to attain equilibrium at the strain level. In cases where the DSR was incapable of reaching a 50 percent strain level (due to insufficient torque when testing stiffer materials), all measurements after the maximum stress was reached were recorded at or very near that maximum stress point.

The DSR shear strain test was also performed on PAV-aged binders to assess the strain susceptibility and resistance to aggregate loss by using standard DSR with 8 mm plates and a 2 mm gap. The PAV aging is designed to simulate 1-year aging of chip seal binders in service, which is considered the most critical time for adequate field performance. The PAV-aged binder was tested at 1 percent strain with 10 rad/sec frequency at an intermediate temperature of 25°C. Also, a 10-min thermal equilibrium time was applied after mounting the sample and before the test began.

FTIR spectroscopy was performed on the original binder to qualitatively identify the presence of polymers in the binders. The test is performed by first cleaning the surface of the FTIR prism using a mild solvent followed by acetone. The binder is locally heated and a small amount is mounted on the prism surface using a spatula. The FTIR spectra is then analyzed to evaluate if the peak near the 967 cm^{-1} frequency is present (*20*, *21*, *22*).

To further explore the possibility of capturing polymer modification, the traditional ER test was performed on the original binders according to AASHTO T 51 and Tex-539-C at 10°C. The binder is poured into the ER molds in between clips and is conditioned as required by AASHTO T 51. The sample clips are then attached to the ductilometer and are pulled at 50 mm/min till the sample reaches 200 mm. The sample is held at 200 mm for five minutes and is cut at its approximate center to let it relax for one hour. The clips are moved together so that the sample's cut ends meet and the elongation (E_f) is measured and recorded in mm. The %ER is then calculated using Equation 1:

$$\mathbf{\%ER = \frac{200 - E_f}{200}\ X100} \qquad \text{Equation 1}$$

The state-of-the-art MSCR test was also performed on the original binders to further explore the possibility of capturing polymer modification by percent recovery (% R) and to evaluate an alternate bleeding resistance parameter by the non-recoverable creep compliance (J_{nr}). In this test, these two parameters are determined at two stress levels (0.1 kPa and 3.2 kPa) and at three temperatures (55°C, 61°C, and 67°C) according to AASHTO TP 70. Twenty 1 s creep and 9 s recovery cycles are conducted at the lower creep stress of 0.1 kPa, with the first 10 for conditioning, followed by 10 creep and recovery cycles at the higher creep stress of 3.2 kPa. The strain accumulated at the end of the creep and recovery cycles is recorded and used to estimate the average % R, and J_{nr} is defined as the ratio of the maximum accumulated strain at the end of the test to the maximum stress level applied to the binder and calculated based on Equation 2 and Equation 3 for N=1 to 10 cycles:

$$\varepsilon_r(100, N) = \frac{\varepsilon_{10} - \varepsilon_1}{\varepsilon_1} X100 \qquad \text{Equation 2}$$

where ε_{10} is the adjusted strain value at the end of the recovery portion of each cycle, and ε_1 is the adjusted strain value at the end of the creep portion of each cycle:

$$J_{nr}(\sigma, N) = \frac{\varepsilon_{10}}{\sigma} \qquad \text{Equation 3}$$

where ε_{10} is the adjusted strain value at the end of the recovery portion of each cycle, and σ is the applied stress.

As presented subsequently, 4-mm DSR frequency sweeps at low temperatures were performed to develop master curves and to further investigate the resulting parameters to possibly replace the use of creep stiffness from the BBR test.

Field Performance Monitoring

Field performance monitoring data were collected pre-construction, post-construction, and after the first winter in service. Collected data included aggregate loss, bleeding, and ED. Multiple test sections for each HS were monitored using a visual survey technique from the long-term pavement performance (LTPP) distress identification manual and analyzed to determine surface condition index (SCI) scores as defined in the first research project, revised during the implementation project, and briefly described as follows (*2, 7, 8, 23*).

Test Section Definition

Consistent with the previous research projects and the implementation project, a test section was defined as a representative subsection of a HS with an area of approximately 5,000 to 7,000 ft^2 for which performance monitoring was conducted. Characteristics of a test section were as follows:

- Each test section was 500 ft long and 10 to 14 ft wide (equivalent highway lane width).
- Two to four test sections were established, depending on the length of the chip seal construction project. Overall performance of the HS was taken as the average of the performance of the individual test sections.
- Multiple test sections were used for each HS to avoid the possibility of overrating or underrating performance due to the absence or presence of localized distresses or geometric features such as turns or changes in surface elevation.
- Data were collected from the outside lane only to increase safety. The survey was conducted from the shoulder or edge of the pavement to eliminate the need for traffic control.
- Intersections, access road junctions, grades, and curves were avoided to minimize the effects of extremely slow and turning traffic, which could exaggerate distress, as well as for safety reasons.
- Test sections were marked using existing reference points or objects such as road mile marker signs. New test sections were marked using reference spikes (cotton gin spindle) driven into the pavement at the start and stop of the HS, along with spray-painted markings. Global positioning system coordinates and Texas reference markers were also gathered and tabulated for each HS.

Visual Surveys

Each test section was monitored for ED, aggregate loss, and bleeding by visual survey prior to construction, post construction (ED only), and after the first winter in service. Embedment of the aggregates into the binder layer was determined prior to construction and post construction as a percentage of the aggregate height in the WP and between the wheel path (BWP).

Aggregate loss or raveling is one of the primary distresses associated with chip seals and controlled by the SPG specification. This distress results as aggregates are dislodged from the surface of the pavement by traffic. During each visual survey, aggregate loss in terms of square feet of affected surface area at each severity level defined in Table 12 by LTPP was recorded on a field performance monitoring survey sheet as shown in the example in Figure 6 (*23*).

Table 12. Severity Levels for Aggregate Loss (*23*).

#	**Level**	**Description**
1	Low	Aggregate has begun to ravel off but has not significantly progressed. Evidence of loss of some fine aggregate.
2	Moderate	Surface texture is becoming rough and pitted; loose particles generally exist; loss of fine and some coarse aggregates.
3	High	Surface texture is very rough and pitted; loss of coarse aggregates.

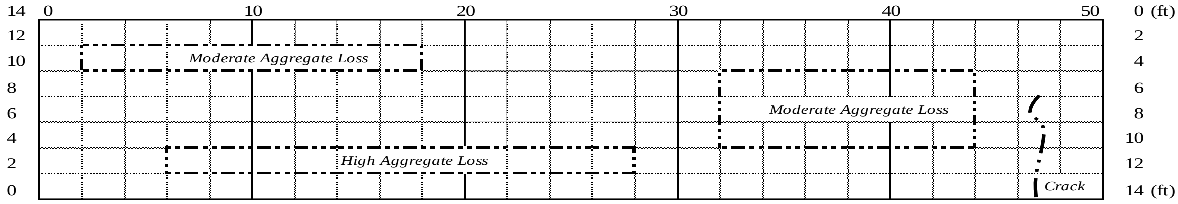
COMPLETED FIELD PERFORMANCE MONITORING SURVEY

VISUAL DISTRESS SURVEY SHEET

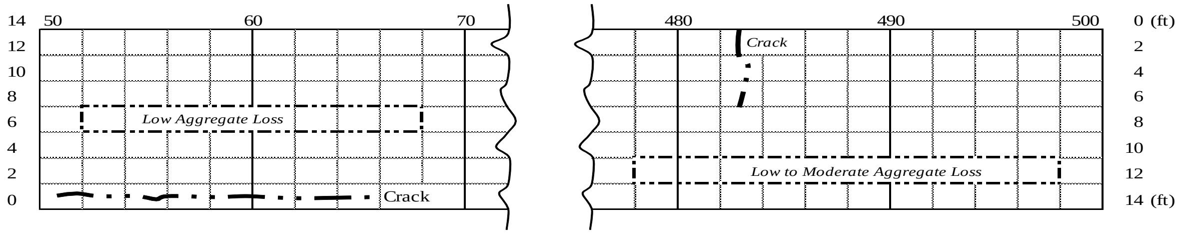
Hwy Section: *HS P3* Inspection No. *3*

Date: *9/5/2002* Time: *1.00PM* Weather: *Sunny*

Test Sction No. 1 Start: *196 K6* End: *196 K6 + 500 miles*



Comment: *Aggregate embedment = approximately 65% in wheel path, and about 30 to 40 % between wheel path*



Comment: *Evidence of aggregate loss. Some transverse cracks from underlying structure. Generally - inadequate performance (aggregate loss)*

Surveyed by: *Tom Freeman*

Example of Distress Observations:
Consider for example, the following field survey observations on a particular highway section:

Aggregate Loss

Area coverage on 4 test sections:	***20%, 5%, 10%, and 3%***
Mean area coverage on 4 test sections:	***9.5%***
SCI score for distress area coverage (DAC):	***72%***
Severity levels for 4 test sections:	***Low to moderate, low to moderate, low, & low***
Percent severity on each test section is thus:	***10% 10%, 5%, & 5%***
Mean percent severity:	***7.5%***
SCI score for degree of severity of aggregate loss (DSD):	***80%***

Cracking: ***Transverse cracking observed on some parts of the highway section***

Bleeding

Area coverage on 4 test sections:	***15%, 5%, 10%, & 10%***
Mean area coverage on 4 test sections:	***10%***
SCI score for distress area coverage (DAC):	***70%***
Severity levels for 4 test sections:	***High, low, moderate to high, & moderate to high***
Percent severity on each test section is thus:	***95%, 5%, 50%, & 50%***
Mean percent severity:	***50%***
SCI score for degree of severity of bleeding (DS	***300%***

Aggregate Embedment: ***60-90 % in wheel path***
30-50 % between wheel path

Figure 6. Example Field Performance Monitoring Survey Sheet.

Bleeding is the second primary distress in chip seals addressed by the SPG specification. This distress occurs as a shiny, black, or glasslike reflective surface caused by liquid binder migrating to the pavement surface, often in the WPs. It can also be defined as a film of excess binder occurring on the pavement surface. The result can be a dangerous, slippery pavement due to decreased frictional characteristics between the tire and pavement surface. Often, bleeding occurs at high pavement temperatures due to high binder content (associated with design and construction), low binder viscosity, use of small aggregates and excessive embedment, inadequate and/or loss of aggregates, excessive compaction during construction, and high traffic. This distress was also recorded in square feet of affected surface area at each of three severity levels defined in Table 13 by LTPP (*23*).

Table 13. Severity Levels for Bleeding (*23*).

#	**Level**	**Description**
1	Low	An area of pavement surface discolored (black) relative to the remainder of the pavement.
2	Moderate	Distinctive black appearance and loss of surface texture due to free excess binder.
3	High	Wet-black shiny appearance on the pavement surface due to excess binder; excess binder may obscure aggregates; tire marks may be evident in warm weather.

Performance Evaluation and Rating Criteria

The SCI methodology and criterion were consistent for both previous research projects and the implementation project. This performance index is based on calculated SCI scores, which range from 0.0 percent (poor performance) to 100 percent (perfect performance). For each distress (aggregate loss and bleeding), the SCI score was calculated as an equal weighted function of the distress area coverage (DAC) and the degree of severity of distress (DSD), expressed as percentages, as shown in Equation 4:

$$SCI_{Distress}=0.5(P_{DAC}+P_{DSD}) \qquad \text{Equation 4}$$

Where:

$SCI_{Distress}$ = SCI score as a percentage for a given distress.
P_{DAC} = distress area coverage as a percentage.
P_{DSD} = degree of severity of a distress in percentage.

In the two research projects, the values for P_{DAC} and P_{DSD} were determined by a severity level scale, as shown in Figure 7 and Figure 8. However, the % Area and % Severity in those scales were determined subjectively. Thus, a more quantitative approach to determine the % Area and % Severity for each distress (aggregate loss and bleeding) based on the field performance monitoring data was developed during the implementation effort, as shown in

Equation 5 and Equation 6. This approach enabled the evaluation of field performance to be more objective and consistent.

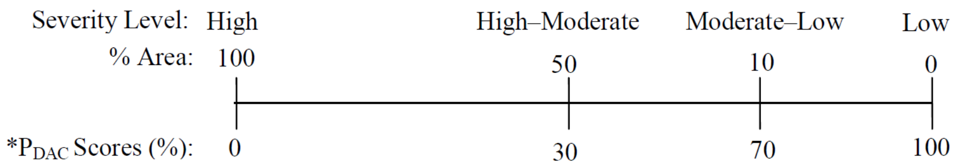


Figure 7. SCI Distress Evaluation and Scores—DAC.

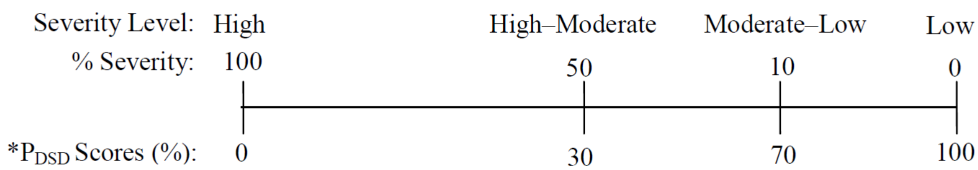


Figure 8. SCI Distress Evaluation and Scores—DSD.

$$\%Area = \frac{Area_{Low} + Area_{Medium} + Area_{High}}{Area_{Total}} \qquad \text{Equation 5}$$

$$\%Severity = \frac{Area_{Low}}{Area_{Dis}} \times \left(\frac{Area_{Low}}{Area_{Total}} \times 10 + 0\right) + \frac{Area_{Medium}}{Area_{Dis}} \times \left(\frac{Area_{Medium}}{Area_{Total}} \times 40 + 10\right) + \frac{Area_{High}}{Area_{Dis}} \times \left(\frac{Area_{High}}{Area_{Total}} \times 50 + 50\right)$$
Equation 6

where:

%Area = the percentage of area for a given distress in evaluation section.

%Severity = the percentage of severity for a given distress in evaluation section.

$Area_{Low}$ = the area of low severity for a given distress in evaluation section.

$Area_{Medium}$ = the area of medium severity for a given distress in evaluation section.

$Area_{High}$ = the area of high severity for a given distress in evaluation section.

$Area_{Dis}$ = the total area for a given distress in evaluation section.

$Area_{Total}$ = the total area in evaluation section.

As shown in Figure 9 and Equation 7 and Equation 8, the $SCI_{overall}$ score is a weighted average of the individual SCI scores for aggregate loss and bleeding, SCI_{AL} and SCI_{BL}, respectively, with relative weights of 80 percent for aggregate loss and 20 percent for bleeding, based on a survey of TxDOT districts conducted during the first research project (*6*). Cracking and other distresses were not considered as principal distresses for chip seals in this project:

$$\mathrm{SCI} = [\alpha_{\mathrm{AL}}\mathrm{SCI}_{\mathrm{AL}}] + [\alpha_{\mathrm{BL}}\mathrm{SCI}_{\mathrm{BL}}] + \cdots + [\alpha_{\mathrm{distress}}\mathrm{SCI}_{\mathrm{distress}}] \qquad \text{Equation 7}$$

$$\alpha_{\mathrm{AL}} + \alpha_{\mathrm{BL}} + \cdots + \alpha_{\mathrm{Distress}} = 1.00 \qquad \text{Equation 8}$$

Where:

SCI = Overall field section SCI score as a percentage.

SCI_{AL} = SCI score for aggregate loss as a percentage.

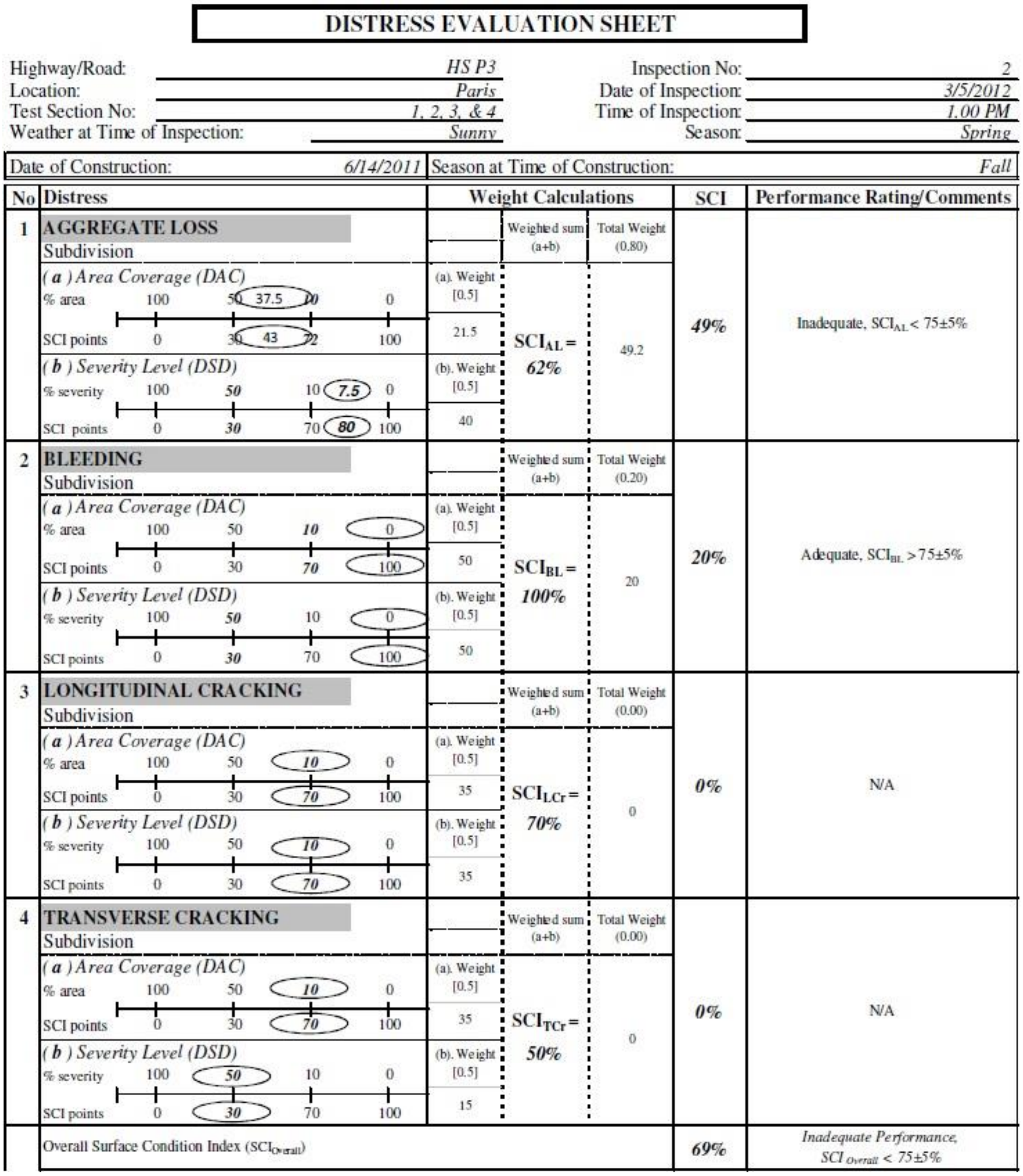
SCI_{BL} = SCI score for bleeding as a percentage.

$SCI_{Distress}$ = SCI score for other distresses as a percentage.

α_{AL} = Distress weighting factor for aggregate loss (~0.80).

α_{BL} = Distress weighting factor for bleeding (~0.20).

$\alpha_{Distress}$ = Distress weighting factors for other distresses (~0.00).



DISTRESS EVALUATION SHEET

Highway/Road: HS P3 — Inspection No: 2
Location: Paris — Date of Inspection: 3/5/2012
Test Section No: 1, 2, 3, & 4 — Time of Inspection: 1.00 PM
Weather at Time of Inspection: Sunny — Season: Spring

Date of Construction: 6/14/2011 — Season at Time of Construction: Fall

No	Distress	Weight Calculations			SCI	Performance Rating/Comments
1	AGGREGATE LOSS Subdivision (a) Area Coverage (DAC) % area: 100, 50, 37.5, 20, 0 SCI points: 0, 30, 43, 72, 100 (b) Severity Level (DSD) % severity: 100, 50, 10, 7.5, 0 SCI points: 0, 30, 70, 80, 100	(a). Weight [0.5]: 21.5 (b). Weight [0.5]: 40	Weighted sum (a+b) SCI_{AL} = 62%	Total Weight (0.80) 49.2	49%	Inadequate, $SCI_{AL} < 75 \pm 5\%$
2	BLEEDING Subdivision (a) Area Coverage (DAC) % area: 100, 50, 10, 0 SCI points: 0, 30, 70, 100 (b) Severity Level (DSD) % severity: 100, 50, 10, 0 SCI points: 0, 30, 70, 100	(a). Weight [0.5]: 50 (b). Weight [0.5]: 50	Weighted sum (a+b) SCI_{BL} = 100%	Total Weight (0.20) 20	20%	Adequate, $SCI_{BL} > 75 \pm 5\%$
3	LONGITUDINAL CRACKING Subdivision (a) Area Coverage (DAC) % area: 100, 50, 10, 0 SCI points: 0, 30, 70, 100 (b) Severity Level (DSD) % severity: 100, 50, 10, 0 SCI points: 0, 30, 70, 100	(a). Weight [0.5]: 35 (b). Weight [0.5]: 35	Weighted sum (a+b) SCI_{LCr} = 70%	Total Weight (0.00) 0	0%	N/A
4	TRANSVERSE CRACKING Subdivision (a) Area Coverage (DAC) % area: 100, 50, 10, 0 SCI points: 0, 30, 70, 100 (b) Severity Level (DSD) % severity: 100, 50, 10, 0 SCI points: 0, 30, 70, 100	(a). Weight [0.5]: 35 (b). Weight [0.5]: 15	Weighted sum (a+b) SCI_{TCr} = 50%	Total Weight (0.00) 0	0%	N/A
	Overall Surface Condition Index ($SCI_{Overall}$)				69%	Inadequate Performance, $SCI_{Overall} < 75 \pm 5\%$

Figure 9. Example Distress Evaluation Sheet (*8*).

As shown in Table 14, field performance results including SCI_{AL}, SCI_{BL}, and $SCI_{overall}$ were categorized with a threshold of 70 percent ($SCI_i \geq 70$ percent for adequate overall performance [$Pass_{Field}$] and $SCI_i < 70$ percent for inadequate overall performance [$Fail_{Field}$]). Due to variability in field performance monitoring based on available data from three test sections per HS, some HSs with SCI scores between 70 percent and 75 percent were tentatively classified as pass to indicate marginal performance.

Table 14. SCI_i Threshold Values and Overall Performance Rating Criteria.

SCI_i Threshold Value	SPG Validation
$SCI_i \geq 75\%$	$Pass_{Field}$ (Adequate Performance)
$70\% \leq SCI_i < 75\%$	Tentatively $Pass_{Field}$ (Adequate Performance)
$SCI_i < 70\%$	$Fail_{Field}$ (Inadequate Performance)

Comparison of Laboratory Results and Field Performance

The predicted field performance from the laboratory results and the observed field performance after the first winter in service were compared to validate the SPG parameter thresholds. For the 2013 and 2014 HSs, the 2012 revision of the SPG was used as a shadow specification (Table 3), so the binder was expected to fail in the field if it did not meet the climate-based SPG requirement. For the 2016 and 2017 HSs, SP 300-011 was used, so the binder was expected to fail if it did not meet the SPG specified for a given chip seal project. For instance, if the binder grade specified for a HS was SPG 67-19 and the binder was characterized as SPG 64-19 or SPG 70-16 or if the phase angle requirement was not met, and thus fails in the laboratory ($Fail_{Lab}$), the binder is expected to fail in the field (SCI < 70). If the same binder was graded as SPG 70-19 or SPG 67-22 or SPG 73-22, the binder is said to have passed in the laboratory ($Pass_{Lab}$) and is expected to pass in the field (SCI ≥ 70).

Thus, Table 15 was used to check the correlation between the predicted performance from laboratory results and the observed field performance. In addition, the SPG parameter thresholds are validated using these same relationships.

Table 15. Laboratory versus Field Performance Correlation.

Laboratory Results	Field Performance	Correlation
$Pass_{Lab}$	$Pass_{Field}$	Yes
$Pass_{Lab}$	$Fail_{Field}$	No
$Fail_{Lab}$	$Pass_{Field}$	No
$Fail_{Lab}$	$Fail_{Field}$	Yes

The SPG laboratory results (G*/sin δ from the DSR and S from the BBR) were correlated with $SCI_{overall}$ in both previous research projects (*3, 8*). However, in the implementation project, the more appropriate correlation of each binder property with the specific distress it is intended to control was considered. Thus G*/sin δ from the DSR at T_{high} was correlated with SCI_{BL}, and S from the BBR at T_{low} was correlated with SCI_{AL}.

Example of Adequate Laboratory and Field Performance Correlation (PassLab-PassField)

An example of adequate field performance is shown in Figure 10 for 16-AMA-1 after the first winter in service. This section is located on US83 in Ochiltree County in the AMA district. The SPG climatic requirement in that county is 64-25, and the binder specified for construction was a SPG 64-25. The binder used for construction was graded as a SPG 64-34 with the continuous phase angle meeting the SPG requirement of less than 80°. The 2016 AADT was approximately 3500 on this section with 28 percent trucks. This HS exhibited adequate performance in terms of aggregate loss (SCI_{AL} = 100) and bleeding (SCI_{BL} = 96) as shown Figure 10.

Figure 10. Example of Adequate Performance on 16-AMA-1 after the First Winter.

Example of Inadequate Laboratory and Field Performance Correlation (FailLab-FailField)

Figure 11 shows an example of inadequate performance for 16-CRP-2 after the first winter. This section is located on FM0665 in Nueces County in the CRP district. The SPG climatic requirement in that location is 67-13, and the binder specified for construction was a SPG 70-19. The binder used for construction was graded as a SPG 73-22, but the continuous phase angle failed to meet the SPG requirement of less than 80°. The 2016 AADT on this section was recorded at approximately 3500 with 8 percent trucks. The inadequate performance in terms of aggregate loss (SCI_{AL} = 57) is reflected in Figure 11.

Figure 11. Example of Inadequate Performance on 16-CRP-2 after the First Winter.

SHADOW SPECIFICATION RESULTS (2013, 2014)

The laboratory evaluation of the binders collected from the 19 chip seal HSs constructed in 2013 and their field performance after the first winter in service (and some after two winters in service) are presented in Table 16, and the data for the binders from the 24 chip seal HSs constructed in 2014 are shown in Table 17. Only the laboratory results, field performance, and construction factors relevant to the correlation of these results are discussed. The alternate binder test results are included in the next chapter.

Table 16. Laboratory versus Field Results for Chip Seal Binders for Highway Sections Built in 2013.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	% strain @ $0.8G_i^*$	G_i^*@ 25°C (MPa)	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
								WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
13-AMA-a	AC10	64-25	61-19	88.84	26.71	1.56	500	18	10	72	89	75	51	100	61
13-AMA-b	AC10-2TR	64-25	67-22	80.98	43.76	1.67	2500	35	30	95	99	95	69	80	71
13-AMA-c	AC20-5TR	64-25	73-19	77.52	38.38	1.54	6065	25	10	88	100	90	100	100	100
13-AMA-d	AC10-2TR	64-25	67-22	80.98	43.76	1.67	590	47	20	90	92	91	77	69	75
13-AMA-e	AC10-2TR	64-25	67-22	80.98	43.76	1.67	630	28	13	77	100	81	59	95	66
13-AMA-f	AC10-2TR	64-25	67-22	80.98	43.76	1.67	2300	28	20	71	100	77	34	96	44
13-AMA-g	AC20-5TR	64-25	73-19	75.76	36.71	1.31	3100	75	60	80	94	83	43	76	50
13-ATL-a	AC20-5TR	67-16	70-25	74.53	21.44	1.06	4000	57	33	93	96	94			
13-ATL-b	AC20-5TR	67-16	70-25	74.53	21.44	1.06	770	20	13	70	92	74			
13-ATL-c	AC20-5TR	67-16	70-25	74.53	21.44	1.06	490	13	10	68	100	75			
13-CRP-a	AC15P	67-13	73-28	71.39	23.46	0.76	2800	53	48	72	86	75			
13-CRP-c	AC15P	67-13	73-28	71.39	23.46	0.76	270	10	10	34	100	47			
13-CRP-d	AC15P	67-13	73-28	71.39	23.46	0.76	470	22	18	54	100	63			
13-SAT-a	AC15P	67-13	70-28	75.82	21.92	0.75	1050	55	38	88	91	89			
13-SAT-b	AC15P	67-13	70-28	75.82	21.92	0.75	6500	57	30	86	75	84			
13-SJT-a	AC10-2TR	67-19	67-19	83.11	29.88	2.60	490	58	32	57	96	65			
13-SJT-b	AC10-2TR	67-19	67-19	83.11	29.88	2.60	820	53	23	99	94	98			
13-SJT-c	AC20-5TR	67-19	76-19	63.25	27.57	1.65	2450	88	40	100	60	92			
13-TYL-a	AC20-5TR	67-16	70-22	75.05	18.58	1.08	5800	38	25	91	100	92			

Table 17. Laboratory versus Field Results for Chip Seal Binders for Highway Sections Built in 2014.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	% strain @ $0.8G_i^*$	G_i^*@ 25°C (MPa)	Traffic (AADT)	Post Constr ED		Performance after First Winter		
								WP	BWP	SCI_{AL}	SCI_{BL}	SCI
14-BMT-a	CRS-2P	64-13	70-22	76.37	10.5	0.61	-	43	25	77	100	82
14-BMT-b	CRS-2P	64-13	73-22	75.74	11.4	1.25	-	83	33	79	81	79
14-BRY-a	AC20-5TR	64-13	67-22	74.67	19.8	1.31	350	95	79	100	94	99
14-BRY-b	AC20-5TR	64-13	67-22	74.67	19.8	1.31	1050	79	35	94	90	93
14-BRY-c	AC20-5TR	64-13	67-22	74.67	19.8	1.31	1950	-	-	100	100	100
14-LBB-a	AC20-5TR	64-22	70-19	63.80	34.4	1.32	-	64	26	69	81	71
14-LFK-a	CRS-2P	64-13	71-19	77.32	13.0	2.00	626	94	61	86	76	84
14-LFK-b	CRS-2P	64-13	71-19	77.32	13.0	2.00	365	88	58	86	93	87
14-LFK-c	CRS-2P	64-13	71-19	77.32	13.0	2.00	224	49	18	85	92	87
14-LFK-d	CRS-2P	64-13	71-19	77.32	13.0	2.00	412	95	95	100	100	100
14-LFK-e	CRS-2P	64-13	71-19	77.32	13.0	2.00	295	98	98	35	100	48
14-SAT-a	AC10	67-13	64-25	85.59	23.8	1.46	250	59	51	95	95	95
14-SAT-b	AC10	67-13	64-25	85.59	23.8	1.46	75	51	21	61	100	69
14-SAT-c	AC15P	67-13	73-31	73.43	17.8	0.70	2500	98	64	90	54	83
14-SAT-d	AC15P	67-13	73-31	73.43	17.8	0.70	980	85	35	77	80	77
14-SAT-e	AC15P	67-13	73-31	73.43	17.8	0.70	510	85	39	76	54	71
14-SAT-f	AC20-5TR	67-13	76-28	75.09	18.6	1.34	1000	68	24	71	79	72
14-SAT-g	AC20-5TR	67-13	76-28	75.09	18.6	1.34	4900	85	61	100	58	92
14-SAT-h	AC20-5TR	67-13	76-28	75.09	18.6	1.34	4600	96	90	99	47	89
14-SAT-i	AC20-5TR	67-13	76-28	75.09	18.6	1.34	2450	83	30	68	91	73
14-SAT-j	AC20-5TR	67-13	76-28	75.09	18.6	1.34	3900	80	74	69	92	74
14-SAT-k	AC20-5TR	67-13	76-28	75.09	18.6	1.34	1150	82	72	100	68	94
14-WAC-a	AC10-2TR	67-16	67-22	78.20	36.0	0.89	-	30	15	35	100	48
14-WAC-b	AC10-2TR	67-16	67-22	78.88	35.9	1.53	-	61	26	62	81	66

SPG Results

The SPG grading results of the chip seal binders from the 2013 HSs are summarized in Table 16 with failure to meet specified thresholds highlighted in gray. Binders that meet the climate-based SPG requirement are expected to exhibit adequate performance in the field with respect to aggregate loss and bleeding, while those that fail in the laboratory are expected to demonstrate inadequate performance in the field. All of the 2013 binders met the required climate-based SPG and the specified SPG at T_{high} except the unmodified 13-AMA-a, but all seven AMA binders failed to meet the specified SPG at T_{low} and thus may be expected to perform poorly in terms of aggregate loss. In addition, five of these seven AMA binders and two SJT binders failed to meet the phase angle requirement (< 80°) that may indicate inadequate polymer modification and 13-SJT-a failed to meet the aged intermediate-temperature property that is no longer included in the SPG specification.

The SPG grading results of the chip seal binders from the 2014 HSs are summarized in Table 17 with failure to meet specified thresholds highlighted in gray. Binders that meet the climate-based SPG requirement are expected to exhibit adequate performance in the field with respect to aggregate loss and bleeding, while those that fail in the laboratory are expected to demonstrate inadequate performance in the field. All of the 2014 binders met the required climate-based SPG and the specified SPG at T_{low} except 14-LBB-a and thus may be expected to perform poorly in terms of aggregate loss. All of the 2014 binders met the required climate-based SPG and the specified SPG at T_{low} except 14-SAT-a and 14-SAT-b and thus may be expected to perform poorly in terms of bleeding. In addition, these same two SAT binders failed to meet the phase angle requirement (< 80°) that may indicate inadequate polymer modification and all five LFK binders and both BMT binders failed to meet the unaged intermediate-temperature property that is no longer included in the SPG specification.

Field Performance Results

Table 16 also provides the field performance results for the 2013 HSs after the critical first winter with failure in the laboratory by SPG requirements and in the field by SCI < 70 highlighted in gray. The AMA HSs were also monitored after two winters due to the low traffic levels on the majority of HSs and the lack of correlation after the first winter. Only one HS (13-SJT-c) showed inadequate field performance in terms of bleeding (SCI_{BL} < 70), but this performance can likely be attributed to construction factors such as excessive aggregate embedment post construction (ED > 80). Four HSs (13-ATL-c, 13-CRP-c, 13-CRP-d, and 13-SJT-a) exhibited poor performance in terms of aggregate loss, and this performance can likely be attributed to inadequate aggregate embedment post construction (ED < 30) for the ATL and CRP HSs or possibly the inadequate intermediate-temperature property for 13-SJT-a. After two winters, five of the seven AMA HSs exhibited inadequate field performance in terms of aggregate loss as predicted by SPG and one of the seven AMA HSs exhibited inadequate field performance in terms of bleeding for one of the HSs that failed to meet the phase angle requirement.

Table 17 also provides the field performance results for the 2014 HSs after the critical first winter with failure in the laboratory by SPG requirements and in the field by SCI < 70 highlighted in gray. Five SAT HSs (14-SAT-c, 14-SAT-e, 14-SAT-g, 14-SAT-h, 14-SAT-k) showed inadequate field performance in terms of bleeding (SCI_{BL} < 70), but this performance can likely be attributed to construction factors such as excessive aggregate embedment post construction (ED > 80). Seven HSs (14-LBB-a, 14-LFK-e, 14-SAT-b, 14-SAT-i, 14-SAT-j, 14-WAC-a, and 14-WAC-b) exhibited poor performance in terms of aggregate loss. This performance was predicted by SPG for 14-LBB-a and possibly 14-LFK-e with the intermediate-temperature property and 14-SAT-b with that failed to meet the phase angle requirement. Other poor performance can likely be attributed to construction factors such as inadequate embedment post construction (ED < 30) for 14-SAT-b, 14-SAT-i, and 14-WAC-a and relatively high traffic levels for 14-SAT-j.

Correlation and Other Factors

Figure 12 and Table 18 combine the correlation results from 2013 and 2014 when the 2012 version was used as a shadow specification. As shown in Figure 12 and Table 18, 79 percent and 72 percent of the HSs exhibited a correlation between measured SPG parameters $G^*/\sin\delta$ and S when compared to their respective thresholds, and appropriate field performance (bleeding or aggregate loss). Thus, each individual SPG parameter, in the majority of HSs constructed in 2013 and 2014, was validated as a good indicator of field performance in terms of aggregate loss or bleeding over the critical first-year period in service.

Seven of the emulsion-based chip seal residues listed in Table 17 exhibited %strains less than 17.5 percent but six of the seven corresponding HSs performed adequately in the field in terms of aggregate loss. This discrepancy may have resulted from the incomplete water removal or damage to the emulsion residue during recovery. This among other reasons including poor correlation to field performance led to removal of this parameter in the special provision to Item 300 (SP 300-011) now available to implement the SPG specification.

Traffic volume and construction practices as indicated by ED also affected field performance, which likely contributed to the discrepancies of a small number of HSs with uncorrelated laboratory and field performance. Excessive ED (ED >80) and inadequate ED (ED <30) in the WP or BWP, caused by improper construction practices, may cause bleeding or aggregate loss, respectively. In addition, HSs with extremely low traffic (AADT<1000) may temporarily exhibit adequate field performance and fail in the near future with the cumulative effects of traffic loads.

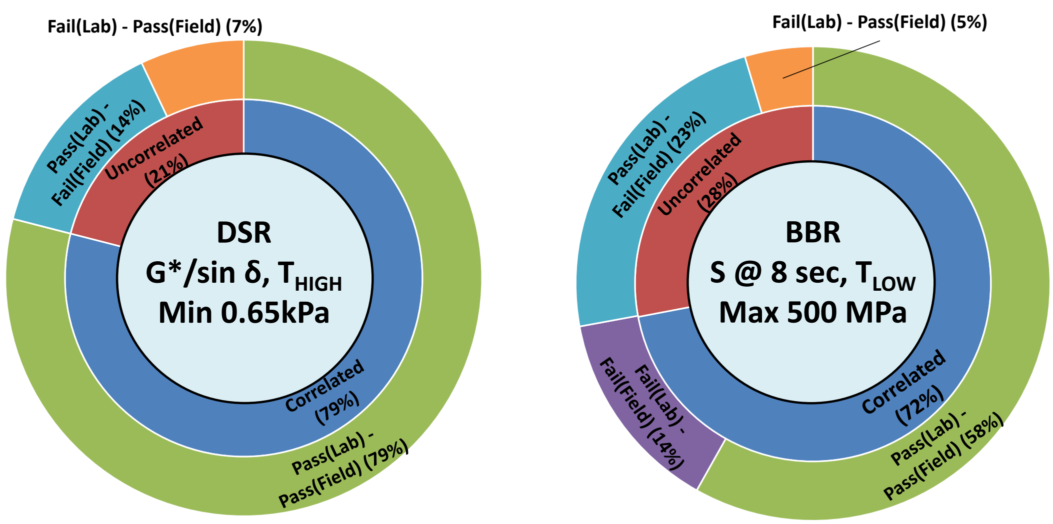


Figure 12. Shadow Specification (2013, 2014) Laboratory vs. Field Correlation.

Table 18. Shadow Specification (2013, 2014) Correlation.

SPG Parameter	Corresponding Performance	SPG Threshold	2013 & 2014 Laboratory[1] vs. Field[2] Results		Comments on Uncorrelated HSs
DSR G*/sin δ @ T_{HIGH}	Bleeding	Min 0.65 kPa	Correlated Pass$_{Lab}$–Pass$_{Field}$: 34 Fail$_{Lab}$–Fail$_{Field}$: 0	79%	**Pass$_{Lab}$–Fail$_{Field}$:** **Excessive ED:** 13-SJT-c, 14-SAT-c, 14-SAT-e, 14-SAT-g, 14-SAT-h, and 14-SAT-k
			Uncorrelated Pass$_{Lab}$–Fail$_{Field}$: 6 Fail$_{Lab}$–Pass$_{Field}$: 3	21%	**Fail$_{Lab}$–Pass$_{Field}$:** **Low traffic volume:** 13-AMA-a, 14-SAT-a and 14-SAT-b
BBR S @ 8 sec @ T_{LOW}	Aggregate Loss	Max 500 MPa	Correlated Pass$_{Lab}$–Pass$_{Field}$: 25 Fail$_{Lab}$–Fail$_{Field}$: 6	72%	**Pass$_{Lab}$–Fail$_{Field}$:** **Inadequate ED:** 13-ATL-c, 13-CRP-c, 13-CRP-d, 14-SAT-b, 14-SAT-i, 14-WAC-a, and 14-WAC-b **Failed @ intermediate-temperature**: 13- SJT-a, 14-LFK-e **Moderately high traffic volume:** 14-SAT-j **Fail$_{Lab}$–Pass$_{Field}$:** **Pass phase angle:** 13-AMA-c **Low traffic volume:** 13-AMA-d
			Uncorrelated Pass$_{Lab}$–Fail$_{Field}$: 10 Fail$_{Lab}$–Pass$_{Field}$: 2	28%	

[1]Pass$_{Lab}$/Fail$_{Lab}$ = Binder met/failed to meet specified SPG for HS in terms of the SPG threshold values
[2]Pass$_{Field}$ = Adequate field performance of HS with overall SCI score ≥ 70%;
Fail$_{Field}$ = Inadequate field performance of HS with overall SCI score < 70%

SPECIAL PROVISION RESULTS (2016, 2017)

The laboratory evaluation of the binders collected from the 17 chip seal HSs constructed in 2016 and their field performance after the first winter in service (and some after two winters in service) are presented in Table 19, and the data for the binders from the 7 chip seal HSs constructed in 2017 are shown in Table 20. Only the laboratory results, field performance, and construction factors relevant to the correlation of these results are discussed. The alternate binder test results are included in the next chapter.

Table 19. Laboratory versus Field Results for Chip Seal Binders for Highway Sections Built in 2016.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
16-ABL-1	SPG73-19	67-13	76-22	70.3	3700	95	80	100	60	92	100	61	92
16-ABL-2	SPG73-19	67-13	79-22	76.4	2500	48	24	98	90	96	89	86	88
16-AMA-1	SPG64-25	64-25	64-34	78.0	3500	21	10	92	100	93	92	100	94
16-AMA-2	SPG64-25	64-25	64-31	73.7	2627	21	14	93	94	93	79	73	77
16-AUS-1	SPG70-19	67-16	73-22	52.0	2558	21	11	64	89	69	72	82	74
16-AUS-2	SPG70-19	67-16	67-22	76.4	1148	65	11	82	77	81	100	77	95
16-AUS-3	SPG70-19	67-16	67-22	77.9	4771	95	20	100	62	92	100	51	90
16-BWD-1	CRS-2P	67-19	70-22	79.6	3300	44	29	67	88	71			
16-BWD-2	SPG67-22	67-19	67-25	81.1	3300	20	10	75	77	75			
16-CRP-1	SPG70-19	67-13	73-22	82.1	3000	15	13	58	100	66	69	100	75
16-CRP-2	SPG70-19	67-13	73-22	80.3	3500	26	11	57	100	66	84	82	84
16-PAR-1	SPG70-22	67-19	70-22	79.3	4147	75	25	100	66	93	94	80	91
16-PAR-2	SPG70-22	67-19	70-25	78.6	3300	78	55	82	88	84	75	85	77
16-PAR-3	SPG70-22	67-19	76-22	72.7	2500	20	10	95	100	96	57	100	66
16-PHR-1	SPG73-16	67-13	G*/sinδ @73°C =0.36kPa S(8sec)@ -16°C =179MPa	δ @73°C =77.8	696	73	40	97	66	91	100	78	96
16-PHR-2	SPG73-16	67-13			9940	35	20	78	91	80	100	82	96
16-PHR-3	SPG73-16	67-13			600	50	20	99	78	95	100	80	96

Table 20. Laboratory versus Field Results for Chip Seal Binders for Highway Sections Built in 2017.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	After First Winter ED		Performance after First Winter		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI
17-AMA-1	SPG73-25	67-31	85-25	74.3	1169	20	10	61	100	69
17-AMA-2	SPG73-25	67-31	91-25	38.0	674	30	15	59	100	67
17-AMA-4	SPG73-25	67-25	67-25	64.2	1879	40	20	80	100	84
17-AMA-5	SPG73-25	67-25	73-25	66.8	626	25	15	70	100	76
17-PHR-1	SPG73-19	67-13	79-25	48.0	4126	60	40	100	83	97
17-PHR-2	SPG73-19	67-13	79-25	48.0	5058	85	75	100	70	94

SPG Results

The SPG grading results of the chip seal binders from the 2016 HSs are summarized in Table 19 with failure to meet specified thresholds highlighted in gray. Binders that meet the specified SPG are expected to exhibit adequate performance in the field with respect to aggregate loss and bleeding, while those that fail in the laboratory are expected to demonstrate inadequate performance in the field. PHR binders were not collected at construction, so laboratory-measured SPG grades were not available. Verification data at the specified high and low SPG temperatures were available from TxDOT and noted in Table 20. Excluding the PHR binder, all of the other 14 binders met the required climate-based SPG and the specified SPG at T_{low}, but two AUS binders (16-AUS-2 and 16-AUS-3) and the PHR binder failed to meet the specified SPG at T_{high} and thus may be expected to perform poorly in terms of bleeding.

The 16-BWD-2 binder, both CRP binders (16-CRP-1 and 16-CRP-2), and the PHR binder (expected) failed to meet the phase angle requirement (< 80°) at T_{high} that may indicate inadequate polymer modification. However, all of the 2016 binders were found to be polymer modified by FTIR spectroscopy results presented subsequently. Therefore, the phase angle threshold did not capture polymer modification in these three binders. Possibly the modification was insufficient or compatibility between the base binder and the additives was poor. Depending on the type of modifier (plastomer/elastomer), this could adversely affect the field performance either in terms of bleeding (plastomer) or both bleeding and aggregate loss (elastomer).

The SPG grading results of the chip seal binders from the 2017 HSs are summarized in Table 20 with failure to meet specified thresholds highlighted in gray with light gray shading indicating failure to meet the climate-based SPG. Binders that meet the specified and climate-based SPG are expected to exhibit adequate performance in the field with respect to aggregate loss and bleeding, while those that fail in the laboratory are expected to demonstrate inadequate performance in the field. All of the 2017 binders met the climate-based requirement and the specified SPG at T_{low} except 17-AMA-1 and 17-AMA-2 that were used in far northeastern Texas where a colder SPG grade is needed and thus may be expected to perform poorly in terms of aggregate loss. All of the 2017 binders met the specified SPG at T_{high} except 17-AMA-4 and thus may be expected to perform poorly in terms of bleeding.

Field Performance Results

Table 19 also provides the field performance results for the 2016 HSs after the critical first winter with failure in the laboratory by SPG requirements and in the field by SCI < 70 highlighted in gray. All of the 2016 HSs except the two BWD HSs were also monitored after two winters.

Four HSs (16-ABL-1, 16-AUS-3, 16-PAR-1, and 16-PHR-1) showed inadequate field performance in terms of bleeding ($SCI_{BL} < 70$) after the first winter, but this performance was only predicted for 16-AUS-3 and 16-PHR-1 based on the SPG. Thus other factors are likely controlling the behavior. For 16-ABL-1, this poor performance can likely be attributed to construction factors such as excessive aggregate embedment post construction (ED > 80) due to very high temperatures at construction or opening the HS to traffic prematurely. For 16-PAR-1, poor performance in terms of bleeding can likely be attributed to a moderately high traffic level (4147 AADT) or the thin binder noted during construction as indicated in the TxDOT district report in Appendix B. Due to variability in field performance monitoring despite the use of multiple test sections per HS, only two HSs (16-ABL-1 and 16-AUS-3) continued to exhibit inadequate field performance in terms of bleeding after two winters.

Four HSs (16-AUS-1, 16-BWD-1, 16-CRP-1, and 16-CRP-2) exhibited poor performance in terms of aggregate loss ($SCI_{AL} < 70$) after the first winter, and this performance may have been predicted based on insufficient polymer modification captured by high phase angle ($\delta > 80°$) for both 16-CRP HSs and 16-BWD-1. This poor performance can also likely be attributed to inadequate aggregate embedment (ED < 30) immediately after construction for three of these HSs. Dusty aggregate and poor construction practices were also noted by BWD district personnel (Appendix B). Due to variability in field performance monitoring despite the use of multiple test sections per HS, only the 16-CRP-1 continued to exhibit inadequate field performance in terms of aggregate loss and another HS (16-PAR-3) with inadequate aggregate embedment also showed poor performance after two winters.

Table 20 also provides the field performance results for the 2017 HSs after the critical first winter with failure in the laboratory by SPG requirements and in the field by SCI < 70 highlighted in gray. All of the 2017 HSs exhibited adequate field performance in terms of bleeding, but 17-AMA-1 and 17-AMA-2 showed inadequate field performance in terms of aggregate loss as expected based on SPG and the extreme climate.

Correlation and Other Factors

Figure 13 and Table 21 combine the correlation results from 2016 and 2017 when the SP 300-011 was used as a special provision. As shown in Figure 13 and Table 21, 80 percent of the HSs exhibited a correlation between both measured SPG parameters G*/sin δ and S when compared to their respective thresholds, and appropriate field performance (bleeding or aggregate loss). Thus, each individual SPG parameter, in the majority of HSs constructed in 2016 and 2017, was validated as a good indicator of field performance in terms of aggregate loss or bleeding over the critical first-year period in service.

The 2016 PHR HSs were not included in the correlation because only TxDOT verification SPG data were available, but possible comparisons were made separately. Based on Table 21, eight binders and the 16-PHR binder produced failing laboratory results ($Fail_{Lab}$) and are expected to exhibit inadequate field performance on corresponding HSs based on failing the threshold at T_{high} for the specified SPG (16-AUS-2, 16-AUS-3, 17-AMA-4), failing the climate-based requirements at T_{low} (17-AMA-1, 17-AMA-2), or failing the phase angle requirement (16-BWD-2, 16-CRP-1, and 16-CRP-2).

Table 21 also indicates that 10 HSs included in the comparison and 16-PHR-1 produced failing field performance results ($Fail_{Field}$) based on inadequate resistance to bleeding ($SCI_{BL} < 70$) [16-ABL-1, 16-AUS-3, 16-PAR-1, and 16-PHR-1] or aggregate loss ($SCI_{AL} < 70$) [16-AUS-1, 16-BWD-1, 16-CRP-1, 16-CRP-2, 16-PAR-3, 17-AMA-1, and 17-AMA-2]. As shown in

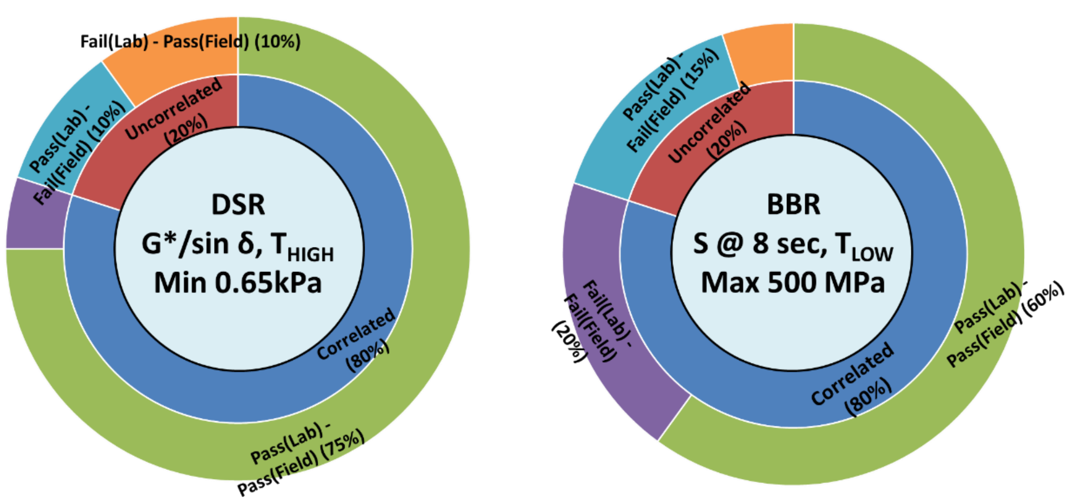


Figure 13. Special Provision (2016, 2017) Laboratory vs. Field Correlation.

Table 21, five of these $Fail_{Field}$ results are correlated ($Fail_{Lab}$–$Field_{Field}$) for four HSs for aggregate loss (16-CRP-1, 16-CRP-2, 17-AMA-1, and 17-AMA-2) and for bleeding on 16-AUS-3 and 16-PHR-1 along with another 15 correlated $Pass_{Lab}$-$Pass_{Field}$ results for bleeding and 12 for aggregate loss. Without consideration of other factors including construction and the interplay between high temperature properties, there were only uncorrelated $Fail_{Lab}$-$Pass_{Field}$ results for two HSs for only bleeding (16-AUS-2, 17-AMA-4) and one HS for only aggregate loss (16-BWD-2). There were also five of the most concerning uncorrelated $Pass_{Lab}$-$Fail_{Field}$ results for two HSs for bleeding (16-ABL-1, 16-PAR-1) and three HSs for aggregate loss (16-AUS-1, 16-BWD-2, and 16-PAR-3).

As discussed previously, 16-ABL-1, 16-AUS-1, 16-PAR-1, and 16-PAR-3 may have failed in the field due to construction issues or high traffic levels. 16-AUS-2 and 17-AMA-4 exhibited unexpected resistance to bleeding, but the corresponding binders passed the phase angle requirement (< 80°), which may indicate sufficient polymer modification that contributed to marginal field performance.

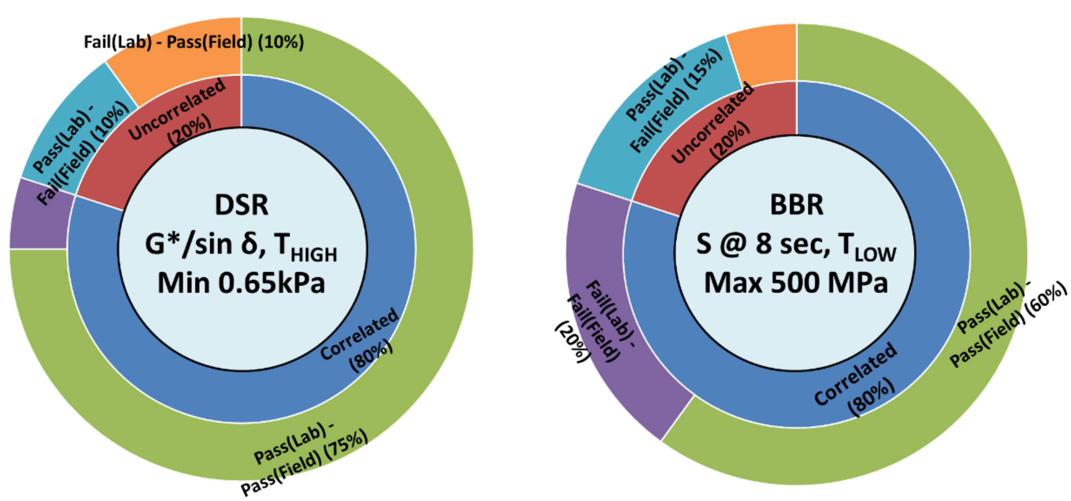


Figure 13. Special Provision (2016, 2017) Laboratory vs. Field Correlation.

Table 21. 2016 and 2017 Correlation between Laboratory and Field Performance Results (excluding 16-PHR).

Parameter	SPG Threshold	Laboratory[1] vs. Field[2] Results[3]		Comments on Uncorrelated HSs and PHR
DSR $G^*/\sin\delta$ @ T_{HIGH}	Min 0.65 kPa	Correlated Pass$_{Lab}$–Pass$_{Field}$: 15 Fail$_{Lab}$–Fail$_{Field}$: 1	80%	**Pass$_{Lab}$–Fail$_{Field}$:** **Excessive ED:**16-ABL-1 **Moderately high traffic volume or thin binder:** 16-PAR-1 **Fail$_{Lab}$–Pass$_{Field}$:** **Pass phase angle:** 16-AUS-2, 17-AMA-4 16-PHR-1 Correlated as Fail$_{Lab}$–Fail$_{Field}$, but 16-PHR-2 and 16-PHR-3 Uncorrelated as Fail$_{Lab}$–Pass$_{Field}$.
		Uncorrelated Pass$_{Lab}$–Fail$_{Field}$: 2 Fail$_{Lab}$–Pass$_{Field}$: 2	20%	
BBR S @ 8 sec @ T_{LOW}	Max 500 MPa	Correlated Pass$_{Lab}$–Pass$_{Field}$: 12 Fail$_{Lab}$–Fail$_{Field}$: 4	80%	**Pass$_{Lab}$–Fail$_{Field}$:** **Inadequate ED:** 16-AUS-1, 16-PAR-3 **Possibly dusty aggregate or poor construction practices:** 16-BWD-1 **Fail$_{Lab}$–Pass$_{Field}$:** **Polymer indicated by FTIR:** 16-BWD-2 16-PHR-1, 16-PHR-2, and 16-PHR-3 Uncorrelated as Fail$_{Lab}$–Pass$_{Field}$ based on TxDOT data for δ.
		Uncorrelated Pass$_{Lab}$–Fail$_{Field}$: 3 Fail$_{Lab}$–Pass$_{Field}$: 1	20%	

[1]Pass$_{Lab}$/Fail$_{Lab}$ = Binder met/failed to meet specified SPG for HS in terms of the SPG threshold values
[2]Pass$_{Field}$ = Adequate field performance of HS with overall SCI score ≥ 70%; Fail$_{Field}$ = Inadequate field performance of HS with overall SCI score < 70%
[3]Does not include PHR results since no measured SPG data were available

VERIFICATION OF PAV AGING

During the development of the SPG specification, FTIR spectroscopy analysis was performed on both laboratory and field binder samples to conclude that PAV aging simulates approximately one year of environmental exposure for surface treatments in Texas (*8*). Accordingly, the threshold for the low temperature parameter, stiffness (S) at 8 sec, obtained from BBR testing was developed and validated with PAV aged binders. However, additional aging research is needed to tie laboratory and field aging in different climates for chip seals since others such as Islam et al. (*24*) reported simulation of 3–4 years of field aging for hot-applied asphalt binders and less than 3 years for emulsions and Kim et al. (*25*) do not include aging in a related Emulsion Performance Grade (EPG) specification for emulsion residue. Other literature by Moraes and Bahia (*26*), Gransberg and James (*27*), and Bahia et al. (*28*) suggests that aging is important with respect to aggregate loss, and Moraes and Bahia (*26*) indicate that early aggregate loss in chip seals is due to improper construction and poor material selection or initial traffic while long-term aggregate loss is due to the brittleness of the binder caused by aging. Considering the consistent good correlation obtained with the current SPG low temperature threshold for PAV aged binders to simulate the critical first year in service, PAV aging is likely a reasonable laboratory tool to include in the SPG specification. In this separate study, field aging and PAV aging were compared for chip seal binders from HSs constructed in 2011 and 2016.

As shown in Table 22, four HSs in BWD were identified as in-service with uncoated aggregates and were selected for use in this study. Other HSs from the implementation project were not selected due to the use of precoated aggregates that confound the separation of the chip seal binder from that used to precoat the aggregates. Field samples of the chip seals were collected, and the binders were extracted using centrifuge (ASTM D2172) and rotary evaporation (ASTM D5404). DSR frequency sweeps from 0.1 to 100 rad/sec were performed at 5°C, 15°C, and 25°C on these field-aged binders and corresponding PAV-aged binders to determine Glover-Rowe (G-R) parameters at 0.005 rad/sec and 15°C as defined in Equation 9.

Table 22. HSs with Uncoated Aggregates to Verify PAV Aging.

Year	Code	TxDOT District	County	HS
2011	B-1 (CRS-2)	BWD	Stephens	FM3418
2011	B-2 (CRS-2)	BWD	Brown	FM0590
2016	16-BWD-1 (CRS 2P)	BWD	Coleman	US0084
2016	16-BWD-2 (SPG 67-22)	BWD	Coleman	US0084

$$\mathrm{G-R\ Parameter} = \frac{G^{*}(\cos\delta)^{2}}{\sin\delta} \qquad \text{Equation 9}$$

Using G-R parameter values, aging in binders can be tracked in black space as shown in Figure 14 with thresholds of 180 kPa and 600 kPa separating the three zones from the lower left to the upper right of no cracking, damage, and cracking based on age-associated block cracking in asphalt concrete mixtures (*29*). With aging, the binders march from the lower right to the upper left in black space. PAV aging simulated more than one year of field aging but less than 6 years of field aging in the BWD district. For this environment in Texas, PAV aging may be closer to the 3–4 years of field aging proposed by Islam et al. (*24*).

Based on this small study, laboratory aging is important to capture the condition of chip seal binders when they are most susceptible to aggregate loss, but further evaluation for additional materials and climates is needed to quantify the tie between laboratory and field aging and capture the individual binder response to aging.

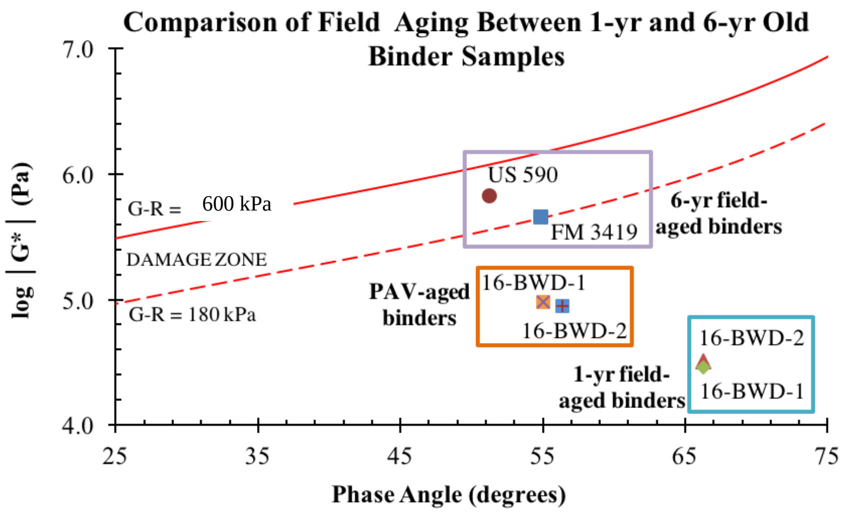


Figure 14. Black Space Comparing PAV-Aged and Field-Aged Chip Seal Binders.

COMPARISON OF ED MEASUREMENT METHODS

In previous TxDOT research projects and this implementation project to develop and implement the SPG specification, ED was evaluated in the field by experienced TTI personnel through visual observation to assess this construction factor that may confound validation of binder selection by SPG (*2, 3, 8*). However, concerns were raised about the empiricism involved with visual distress survey and data collection. Suggestions were received to use more mechanistic, quantitative, and automated field distress evaluation methods. To address this concern, a small study was conducted to compare the ED collected by visual inspection and ED calculated from the Mean Profile Depth (MPD) surface texture measurement (*30*). This section describes this small study and its outcomes.

One of TxDOT's recent developments is the high-speed 3D texture measurement device, which is capable of capturing the pavement's longitudinal profile through MPD surface texture measurements (*1*). By using a representative aggregate size in the chip seal, ED can be calculated. To explore this possibility, TxDOT provided MPD data acquired with the 3D texture measurement device from two HSs located in the BRY (FM 2000) and WAC (FM 0487) districts that are part of the implementation project. Since the aggregates used in these HSs were not collected at construction, certain assumptions had to be made.

The 3D texture measurement device collects the MPD data at three different locations (outside wheel path [OWP], center wheel path [CWP], and inside wheel path [IWP]), while the visual inspection is done at two locations (WP and BWP) along each lane. Figure 15 shows the data collection locations for both methods.

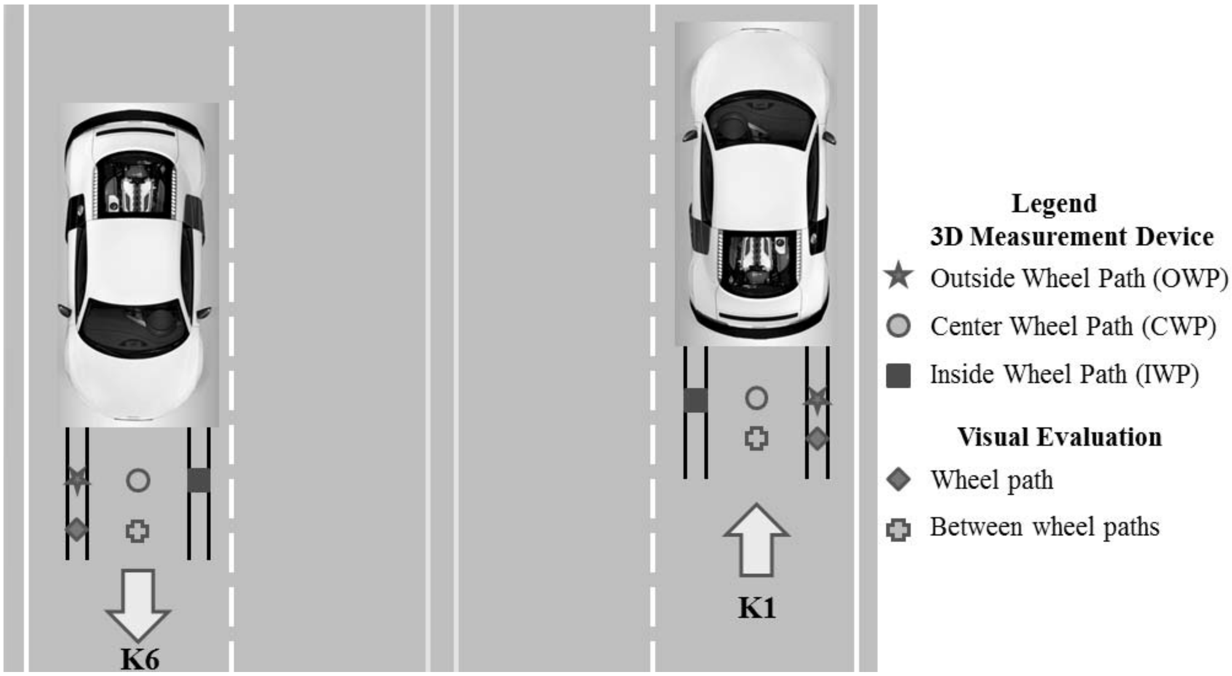


Figure 15. ED Locations.

MPD data are collected over 550 ft of the HS, and visual inspection is typically done along a 5 ft strip near the beginning of the HS. Due to these differences, all three measurement locations for the automated method were considered for the analysis; however, only two measurement locations (OWP and CWP) in the first 5 ft were considered for comparison with the visual inspection.

MPD data are a collection of distinct peaks and troughs reported every 0.2 ft (61 mm). Typical MPD data are as shown in Figure 16 where the MPD data for FM 2000 (BRY) for the three measurement locations along the K1 lane is presented. For the calculation of ED, only the peaks of the MPD data were considered, assuming they represented the largest aggregate particles above the surface of the pavement. Also, to eliminate outliers, peak points above the 98^{th} percentile of the MPD data were not considered.

The aggregates used in the FM 2000 and FM 0487 field sections were both Grade 4, which according to TxDOT specifications has 95–100 percent passing the #4 (4.75 mm) sieve (*2*). This aggregate size was selected as representative to compare against the MPD peaks. The ED was then calculated (using MATLAB) by subtracting the representative aggregate size (4.75 mm) from the peak points, and then dividing by the predominant aggregate size.

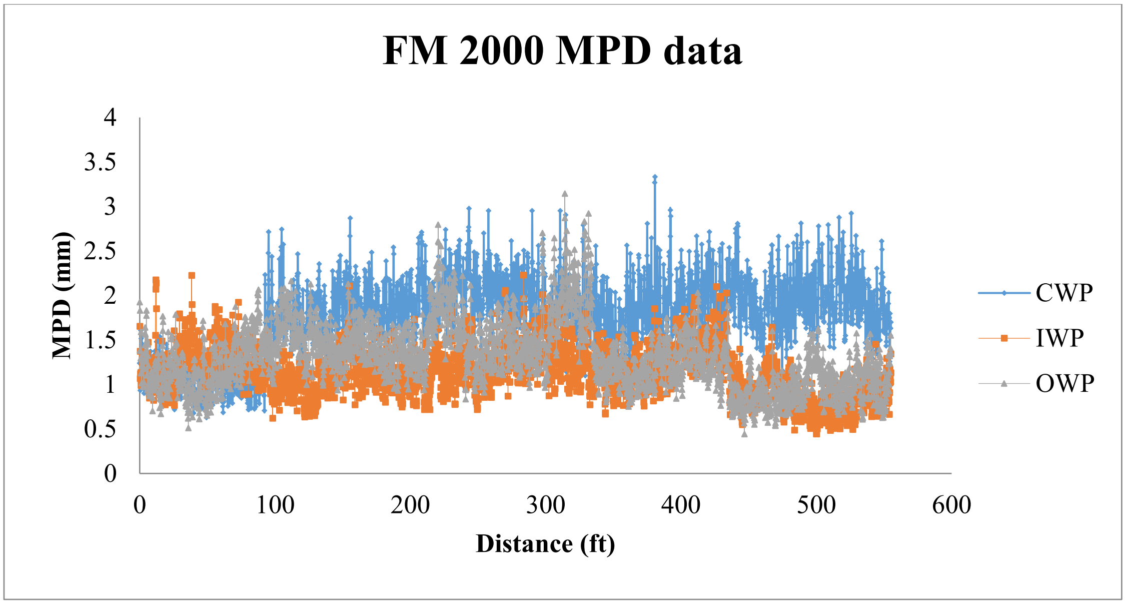


Figure 16. MPD Data for Different Locations on FM 2000 in the K1 Lane.

The EDs calculated using the MPD data for all locations along the FM 2000 and FM 0487 HSs are shown in Table 23 and are compared against the visual observation estimates in Figure 17. For the measurement locations, OWP for the automated procedure was compared to WP for the visual observation and CWP for the automated procedure was compared to BWP for the visual observation.

Table 23. Variation in ED at Different Locations along the Highway Sections.

Highway Section	Lane	Region of measurement	Manual ED (%)	Overall Automated ED (%)	Embedment Depth (ED, %) 0-5 ft	100-105 ft	200-205 ft	500-505 ft
FM 2000	K1	CWP (BWP)	10	59.2	69.9	57.0	59.4	53.2
		IWP	-	73.9	74.0	77.3	72.8	83.8
		OWP (WP)	58	70.5	69.5	63.1	69.1	71.2
	K6	CWP (BWP)	10	56.9	49.8	54.0	47.8	58.4
		IWP	-	79.6	83.7	78.3	72.8	75.4
		OWP (WP)	70	79.5	86.6	-	71.3	72.5
FM 0487	K1	CWP (BWP)	20	45.9	77.3	37.2	45.4	42.6
		IWP	-	60.9	52.8	58.8	64.2	63.6
		OWP (WP)	40	58.8	46.3	59.6	58.1	62.6
	K6	CWP (BWP)	10	43.1	42.6	44.5	45.2	43.0
		IWP	-	60.6	62.7	58.5	63.6	62.4
		OWP (WP)	20	60.6	62.7	58.5	63.6	62.4

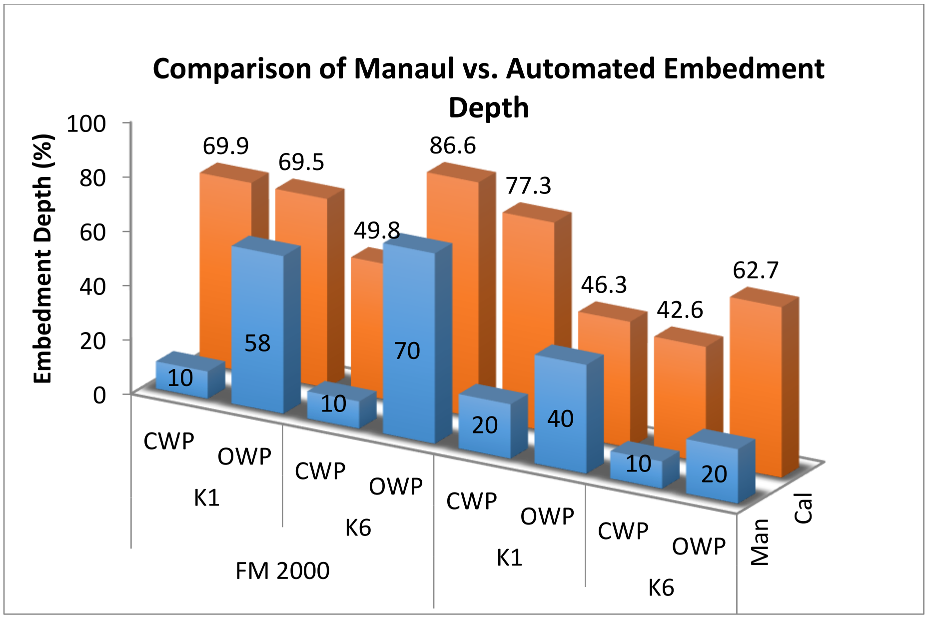


Figure 17. Comparison of Automated versus Manual ED.

In the CWP location, the ED estimated from the MPD data was remarkably higher than the ED obtained via visual observation for unknown reasons. However, in the OWP location, the automated and visual EDs were comparable. Based on this small study, the manual observation of ED is sufficient to identify if there is a construction issue and/or provide a reason for uncorrelated field performance expected based on the SPG of the chip seal binder. The automated method will provide objective and continuous data along the length of the section that may be useful in a forensic evaluation.

CHAPTER 3: INTERACTION WITH INDUSTRY

In addition to multiyear efforts to further validate and improvement the SPG specification, the following initiatives were completed as part of the implementation project to interact with industry:

- Outreach to the potential users of the specification including TxDOT personnel, binder suppliers, and asphalt user-producer groups in the form of technical presentations, publications in journals, revised special provisions to TxDOT Item 300 and accompanying chip seal binder selection guidelines, and a marketing infographic.
- Multiple round robin testing programs at the state level to achieve a certain level of comfort among the suppliers using the specification.
- Collaboration with private materials testing laboratories to evaluate alternate binder tests for possible inclusion in future SPG specification development to identify polymer modification and characterize binders at low temperatures with the DSR.
- Work associated with the Emulsion Task Force of the FHWA Pavement Preservation Expert Task Group.

Each of these initiatives are discussed in this chapter.

OUTREACH – PRESENTATIONS AND PUBLICATIONS

During the 2013–18 implementation effort for the SPG specification, the following presentations were given to various TxDOT personnel, binder suppliers, and asphalt user-producer groups or at national meetings:

1. "Statewide Implementation of the SPG Specification for Chip Seal Binders in Service," D. Hazlett presented to Emulsion Task Force, FHWA Pavement Preservation Expert Task Group, Warwick, Rhode Island, July 11, 2013.
2. "Seal Coat Binder Performance Specification Development, Field Validation, & Implementation," Presented at Texas Department of Transportation (TxDOT) / Texas Asphalt Pavement Association (TxAPA) Seal Coat Workshop, Waco, Texas, September 17, 2013.
3. "Seal Coat Binder Performance Specifications," Presented at the 87th Annual Transportation Short Course, College Station, Texas, October 15, 2013.
4. "Seal Coat Binder Performance Specifications," Presented at Texas Asphalt Pavement Association (TxAPA) Meeting of Seal Coat Binder User-Producers, Buda, Texas, December 2, 2013.

5. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” D. Hazlett presented to Emulsion Task Force, FHWA Pavement Preservation Expert Task Group, Arlington, Virginia, May 7, 2014.
6. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” Presented at State Pavement Technology Consortium Meeting, College Station, Texas, May 20, 2014.
7. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” Presented at Texas Asphalt Pavement Association (TxAPA) Meeting of Seal Coat Binder User-Producers, Buda, Texas, May 23, 2014.
8. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” Presented to Wright Asphalt, College Station, Texas, July 21, 2014.
9. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” Presented at Associated General Contractors (AGC) of Texas Seal Coat Committee Meeting, Austin, Texas, August 6, 2014.
10. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” D. Hazlett presented to TxDOT Rural and Urban District Engineers, Austin, Texas, August, 2014.
11. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” D. Hazlett presented at Texas Department of Transportation (TxDOT) / Texas Asphalt Pavement Association (TxAPA) Seal Coat Seminar, San Antonio, Texas, September 3, 2014.
12. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” D. Hazlett presented at the Texas Asphalt Pavement Association 40th Annual Meeting, Horseshoe Bay, Texas, September 18, 2014.
13. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” D. Hazlett presented at the 88th Annual Transportation Short Course, College Station, Texas, October 14, 2014.
14. “Surface Performance Grade Binders for Chip Seal Applications,” Presented at the AFK20 Committee Meeting, 94th Annual Meeting of the Transportation Research Board, Washington, D. C., January 12, 2015.
15. “Surface Performance Grade Binders for Chip Seal Applications,” Presented to Associated General Contractors (AGC) of Texas SPG Asphalt for Seal Coat Task Force, Austin, Texas, January 16, 2015.
16. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” Presented at the Western Association of State Highway and Transportation Officials (WASHTO) Subcommittee on Materials and Construction, San Antonio, Texas, March 24, 2015.
17. “Statewide Implementation of the SPG Specification for Chip Seal Binders in Service,” Presented to Emulsion Task Force, FHWA Pavement Preservation Expert Task Group, Lakewood, Colorado, June 22, 2015.
18. “Status of the SPG Binder Specification Implementation,” Presented at the 99th Annual Transportation Short Course, College Station, Texas, October 13, 2015.
19. “Seal Coat Binder SPG Specification Round Robin Program,” Presented at Texas Asphalt Pavement Association (TxAPA) Meeting of Seal Coat Binder Producers and Contractors, Buda, Texas, October 28, 2015.
20. “Implementation of the Surface Performance-Graded (PG) Specification for Chip Seal Binders,” Presented at the Rocky Mountain Asphalt User/Producer Group 24th Annual Conference, Phoenix, Arizona, November 4, 2015.

21. “Towards Implementation of the Surface Performance-Graded (SPG) Specification for Chip Seal Binders,” Presented in Poster Session with S. Chang* at the 95th Annual Meeting of the Transportation Research Board, Washington, D.C., January 12, 2016.
22. “Implementation of the Surface Performance-Graded (PG) Specification for Chip Seal Binders,” Presented at the Asphalt Emulsion Manufacturers Association (AEMA)-Asphalt Recycling and Reclaiming Association (ARRA)-International Slurry Seal Association (ISSA) 2016 Annual Meeting, Bonita Springs, Florida, February 26, 2016.
23. Implementation of the Surface Performance-Grade (SPG) Specification in Texas,” Presented to Emulsion Task Force, FHWA Pavement Preservation Expert Task Group (ETG), Lakewood, Colorado, May 6, 2016.
24. “Implementation of the Surface Performance-Grade (SPG) Specification in Texas,” Presented at Texas Asphalt Pavement Association (TxAPA) Meeting of Seal Coat Binder Producers and Contractors, Buda, Texas, May 25, 2016.
25. “Best Practice: Seal Coat – TxDOT Project 5-6616-01: SPG Spec for Seal Coat Binders,” Video Summary Report, Texas A&M Transportation Institute, https://www.youtube.com/watch?v=_2d7_9cqoEk&feature=youtu.be, July 1, 2016.
26. “Implementation of the Surface Performance-Grade (SPG) Specification in Texas,” Presented at the Asphalt Emulsion Manufacturers Association (AEMA) International Symposium on Asphalt Emulsion Technology (ISAET), Washington, D.C., November 4, 2016.
27. “Implementation of the Surface Performance-Grade (SPG) Specification for Chip Seal Binders in Texas,” Presented at the Southeast Asphalt User Producer Group (SEAUPG) Annual Meeting and Exhibits, Corpus Christi, Texas, November 17, 2016.
28. “Evolution of Field Performance Validation for SPG Binder Specification,” Presented to Emulsion Task Force, FHWA Pavement Preservation Expert Task Group (ETG), Tampa, Florida, December 13, 2016.
29. “Evolution of the Surface Performance-Graded (SPG) Specification for Chip Seal Binders,” Presented in Poster Session with S. Theeda* at the 96th Annual Meeting of the Transportation Research Board, Washington, D.C., January 10, 2017.

These presentations were aimed at educating the potential users of the specification about the need for the specification, how the specification evolved with time, validation and implementation efforts, how the specification changes the classification of the traditional binders used for chip seal applications, and the industry interaction initiatives. In addition to these presentations, a corresponding papers was published in Transportation Research Record in 2017 and also received the Transportation Research Board Design and Construction Group Practice-Ready Paper Award.

The SPG specification was also made available as a special provision to TxDOT Item 300 (SP300-001 and SP300-011) for use in both the 2016 and 2017 construction seasons, respectively, shown in Appendix C. Accompanying revised binder selection guidelines as shown in Figure 18 were also produced (*17*). In addition, the hot-applied asphalt binder SPG specification is under review by AASHTO for acceptance as a national standard. Finally, an infographic as shown in Figure 19 was developed for use in marketing the use of the SPG specification.

1) Look at climate-based SPG for low traffic using map or Excel spreadsheet ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/forms/docs/pg-spg-binder-climatic-grade-selection.xlsm

2) Review your application for changes to this base SPG.
   - Reasons to increase the high temperature SPG are: high traffic, high truck traffic, starting and stopping.
   - Reason to decrease the low temperature SPG is: compensation for weak pavement structure.
3) Review SPG grades of traditional materials for reference.

Traditional Materials	Typical SPG Grade
AC-10	SPG 61-19
AC-15P in Northern Texas	SPG 67-25
AC-20-5TR in Northern Texas	SPG 73-19
CHFRS-2 in Northern Texas	CHFRS-2 (SPG 67-25)
AC-15P in Central Texas	SPG 73-19
AC-20-5TR in Central Texas	SPG 79-13
AC-15P in Southern Texas	SPG 79-13
AR anywhere in Texas	AR anywhere in Texas

4) Select to use: 1) hot applied binder, 2) emulsion, or 3) either.

The SPG could be different for various roadways.

Figure 18. SPG Binder Selection Guidelines.

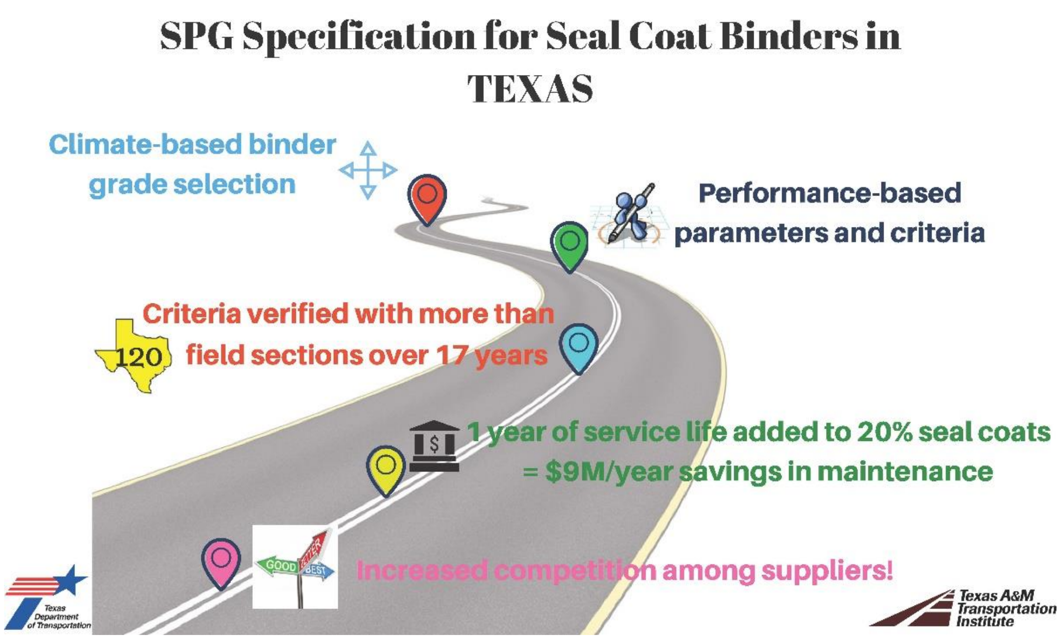


Figure 19. SPG Infographic.

STATE - ROUND ROBIN TESTING PROGRAMS

Toward statewide implementation of the SPG specification, two round robin testing programs were conducted with the help of TxDOT. The first round robin was aimed at improving consistency in test methods for the chip seal binder SPG specification. The second round robin was aimed at further exploring parameters other than phase angle at the high temperature threshold to ensure polymer modification in addition to achieving consistency in the specification's test methods.

For each of the round robin testing programs, a commonly used hot-applied asphalt binder and a typical emulsion were supplied to each of the participating laboratories by TxDOT. Testing and reporting guidelines were also provided for both round robin programs as shown in Appendix D. The participants were required to recover the emulsion by AASHTO PP 72 Method B prior to performing any SPG tests or any other tests prescribed in the guidelines. The results were reported to TTI by all the participants which were then further compiled and analyzed statistically. This section describes both round robin testing programs, the results of the analyses, and the conclusions.

Round Robin 1

TxDOT distributed samples of a typical emulsion (CRS-2P) and a commonly used hot-applied asphalt binder (AC-15P) to each participating laboratory that included five suppliers, TxDOT, and TTI. Testing guidelines included an evaluation of the effects of reheating emulsion residue prior to DSR testing. Each participant was required to recover the emulsion by AASHTO PP 72 Method B and use SPG tests to characterize the chip seal binders based on the SPG specification labeled as 2015 in Table 3.

Figure 20 summarizes results reported by the seven participants. The values in the parenthesis below each participant's name indicate the SPG of the sample. The bars in the graphs represent continuous SPG defined as the temperature in 1°C increments where the parameter meets the threshold (i.e., where $G^*/\sin\delta = 0.65$ kPa and $S = 500$ MPa).

For the AC-15P, five out of seven participants reported a T_{high} of 67°C showing good repeatability with only two participants reporting 70°C and 73°C (Figure 20a). However, all participants were within 3°C of each other's continuous T_{high} (i.e., 67°C to 70°C) except

Participants G and D, who reported high temperature grades 2°C higher than 70°C. All the participants reported a low temperature grade of −25°C, showing very good agreement.

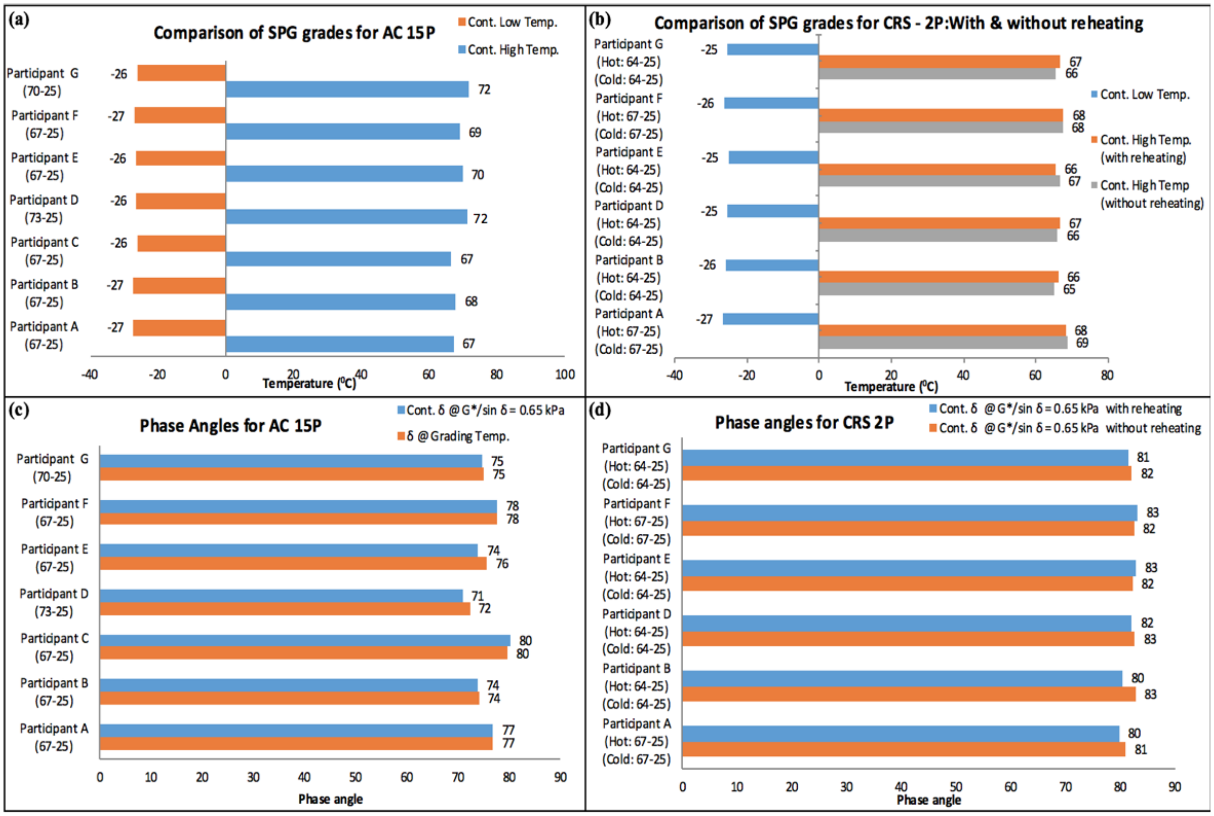


Figure 20. Round Robin 1 Results: (a) SPG for AC-15P, (b) SPG for CRS-2P with and without Reheating, (c) Phase Angle for AC-15P, and (d) Phase Angle for CRS-2P with and without Reheating.

For the CRS-2P, the high temperature grades were within 1°C of each other irrespective of reheating prior to DSR testing (Figure 20b). Four out of six participants (with one supplier not participating) reported a T_{high} of 67°C while two other participants reported 64°C. Again, all the participants reported a low temperature grade of −25°C, showing very good agreement.

The phase angles at G*/sinδ = 0.65 kPa reported for the AC-15P varied from about 71° to 80°, which is below the phase angle threshold of 80° (Figure 20c). For the CRS-2P, the phase angles at G*/sinδ = 0.65 kPa were within 3° of each other irrespective of reheating prior to DSR testing but were higher than the threshold of 80° (Figure 20d).

One supplier suggested that it is more practical to have the phase angle requirement at the grading temperature to reduce interpolation errors. Thus the phase angles for both conditions were compared (Figure 20c). For five out of seven participants, there was no change in phase angle. Only participants D and E showed 1° and 2° higher phase angles at the grading temperature.

A statistical analysis was also performed on the round robin results using the precision and bias estimates provided in AASHTO T 315 and T 313 for DSR and BBR tests, respectively (*31*, *32*). For multilaboratory precision, results from two different laboratories can be expected to differ by the acceptable range of test results (%d2s value) calculated as follows:

$$\%\text{d2s} = \frac{\text{Difference in two test results}}{\text{Mean of the two test results}} * 100 \qquad \text{Equation 10}$$

The multilaboratory precision %d2s value for DSR and BBR test results is 17.0 and 17.8, respectively. The following three temperatures where data were available for all participants were used in this analysis: 70°C for AC-15P, 67°C for CRS-2P, and −25°C for both materials. The %d2s values were then calculated for each pair of participants and compared to the allowable %d2s. Then the difference in the continuous SPG grades was determined.

Based on the statistical analysis, a difference of 2–3°C between the continuous high temperature grades was found to be reasonable between two different laboratories resulting in the conclusion that the 3°C SPG increment is too tight. At low temperatures, the 3°C SPG increment is acceptable.

Based on the first round robin testing program, 6°C increments at both high and low temperatures but offset to capture the statewide 67-19 climate in Texas and avoid confusion with PG grades was proposed for practicality. This makes SPG values unique and fewer in number and possibly decreases the adjustments needed from the climate-based requirement due to high traffic or modification.

Round Robin 2

Following the success of the first round robin testing program, a second round robin testing program was completed. Initially, TxDOT distributed samples of a typical emulsion and a commonly used hot-applied asphalt binder, both specified by SPG, to each participating laboratory that included 10 suppliers, TxDOT, and TTI. However, due to inconsistent results at the high temperature, three different hot-applied asphalt binder samples were distributed to the participants.

Testing and reporting guidelines shown in Appendix D were also provided wherein each participant was required to recover the emulsion by AASHTO PP 72 Method B and use SPG tests to characterize the chip seal binders using the revised SPG specification that uses 6°C increments offset by 3°C from those used in the PG specification (Table 2). For high temperature grading, two measurements (replicates) on the same sample without additional conditioning time before changing the test temperature for subsequent measurements were requested.

In addition to the SPG tests required by specification, the participants were requested to perform the ER test by Tex-539-C and the MSCR by AASHTO TP 70 on the original material for both binder samples for information only to provide additional data toward selection of an appropriate parameter to ensure polymer modification. The m-value was also requested for each cold temperature for information only.

Figure 21 summarizes the SPG results of the three hot-applied asphalt binder samples: hot-applied asphalt binder 1 (HAA 1), hot-applied asphalt binder 2 (HAA 2), and hot-applied asphalt binder 3 (HAA 3). The values in the parenthesis below each participant's name indicate the SPG grade of the sample whereas the bars represent continuous SPG grades defined as the temperature in 1°C increments where the parameter meets the threshold. Four different SPG grades were reported for HAA 1– four out of 11 participants reported a T_{high} of 73°C, two reported 79°C, three reported 85°C, and two reported 91°C. However, on the low temperature end, all the participants were within 4°C of each other's continuous low temperature grade (i.e., −21°C to −25°C) with a reported low temperature grade of −19°C, showing good agreement. Although most participants reported phase angles in the range 41° to 47°, participants F, I, and one replicate each of B and G reported phase angles ≥ 55°. Clearly, these results of HAA 1 were highly variable and thus necessitated that another sample be provided and characterized.

In the case of HAA 2, two out of seven participants reported a continuous T_{high} of 73°C, three reported 85°C, and two reported 91°C—a total of three different SPG grades. At low temperatures, all the participants reported −19°C with their continuous low temperature grade ranging from −19° C to −21°C (with one exception at −23°C). Similar to HAA 1, most participants reported phase angles in the range 41° to 47°, but participants A and F reported phase angles ≥ 60°. Three different SPG grades for the same binder were still unacceptably inconsistent; therefore, a third hot-applied asphalt binder was again distributed to the participants. In addition, for most participants, the two replicates of HAA 1 and HAA 2 were very different from each other.

For HAA 3, all six participants were in very good agreement with each other with respect to both the continuous high and low temperature grades and phase angles. All the participants reported one grade (SPG 79-19) and were within 1°C of each other's high and low temperature grades. Possible reasons for the inconsistency at high temperatures for HAA 1 and 2 include:

- Improper blending of the base binder and the polymers/ rubbers/other additives in the binder.
- Poor compatibility between the base binder and the additives present in the binder.

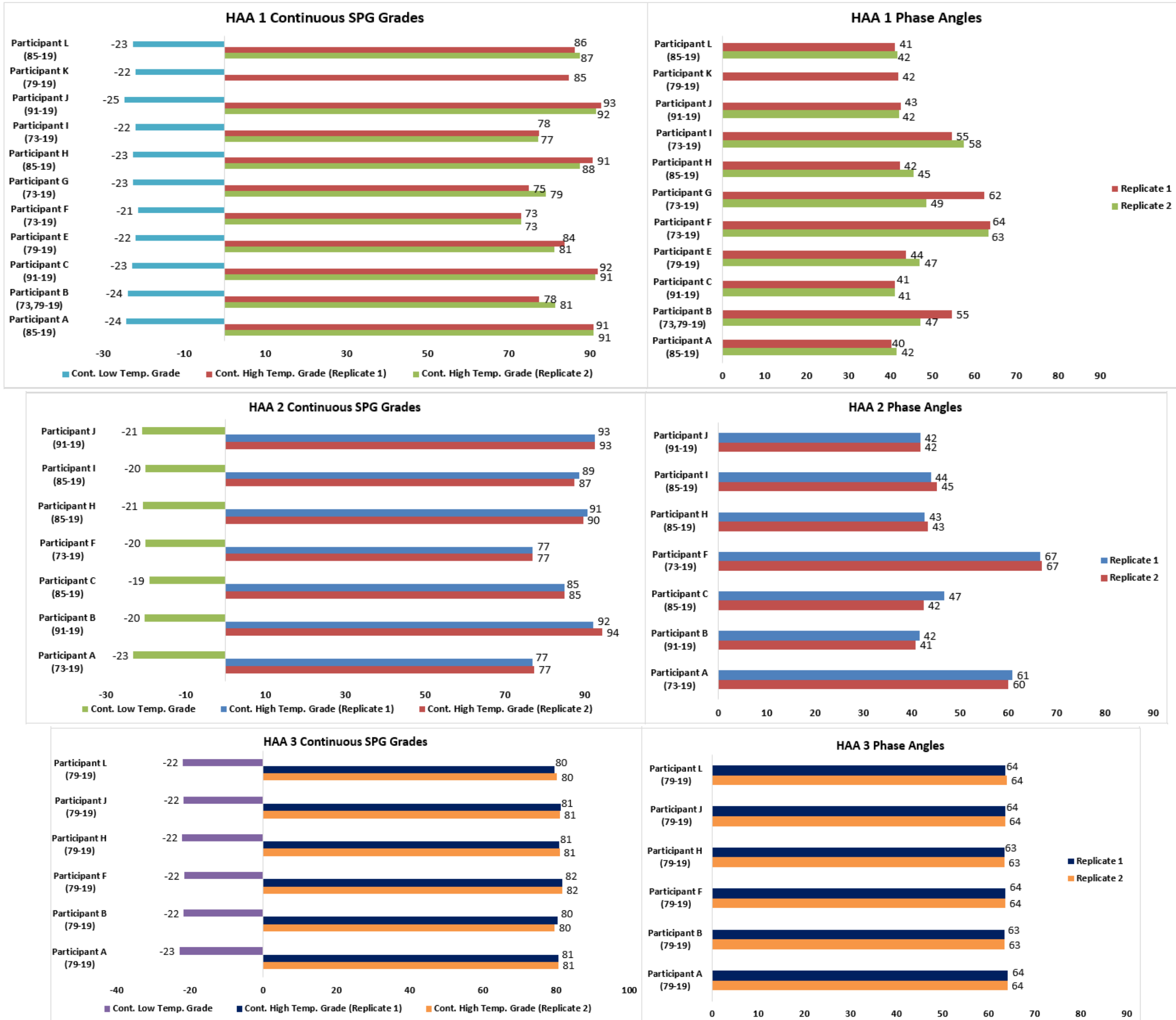


Figure 21. Round Robin 2 Results for Hot-Applied Asphalt Binders, HAA 1, HAA 2, and HAA 3.

Figure 22 shows the SPG results for the emulsion sample. Four out of eight participants reported a T_{high} of 67°C, and the remaining four reported 73°C. However, except participant G, all the participants' continuous high temperature grades were within 5°C ranging from 71°C to 76°C. In addition, the continuous low temperature grades (−22°C to −24°C) and the phase angles (79° to 82°) were in very good agreement with each other.

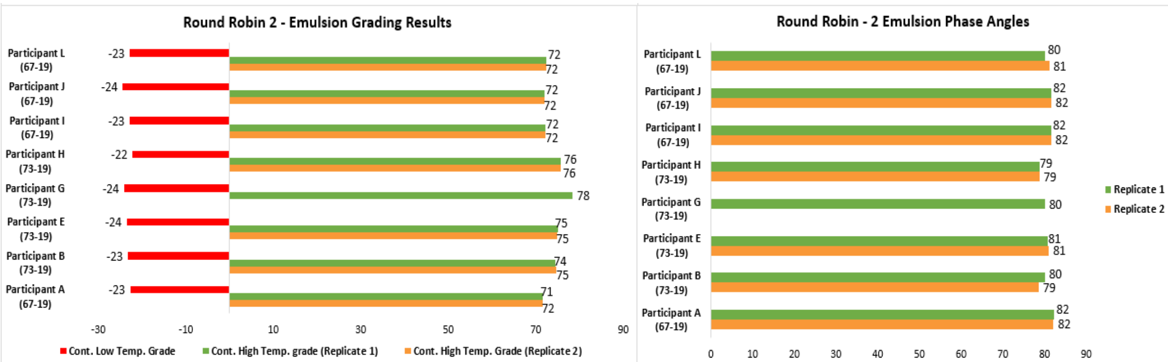


Figure 22. Round Robin 2 Results for Emulsion.

A statistical analysis was also performed on the round robin results using the precision and bias estimates provided in AASHTO T 315 and T 313 for DSR and BBR tests (*33*), respectively. For multilaboratory precision, results from two different laboratories can be expected to differ by the acceptable range of test results (%d2s value) calculated by Equation 13.

The multilaboratory precision %d2s value for DSR and BBR test results is 17.0 and 17.8, respectively. The following three temperatures where data were available for all participants were used in this analysis: 79°C (both replicates) for HAA 3, 73°C (both replicates) for emulsion, and −19°C for both materials. The %d2s values were then calculated for each pair of participants and compared to the allowable %d2s.

The %d2s values for HAA 3 indicate that the results of all the participants were equivalent. In the case of the emulsion, the %d2s values at high temperatures indicated that two sets of participants are equivalent—participants A, I, J, and L (SPG 67-19) and participants B, E, and H (SPG 73-19); participant G was an outlier. At low temperatures, all the participants were equivalent except B and J, and B and L; participant G was again an outlier. Similarly, ANOVA on replicates 1 and 2 of HAA 3 showed that at 99 percent confidence, the mean of $G^*/\sin\delta$ at 79°C of all six participants were equal. ANOVA on replicates 1 and 2 of the emulsion showed that at 99 percent confidence, A and I were equal and at 95 percent confidence, A and J; B and E;

I and J; I and L; and J and L were not significantly different from each other. Overall, the %d2s and ANOVA analyses agree with each other in terms of pairing the equivalent results.

Table 24 shows ER results reported for HAA 3 and the emulsion. In general, the %ER reported for the HAA 3, as observed from SPG results, is less variable when compared to that of the emulsion. Also, as indicated by the lower phase angle of the HAA 3, its %ER is very high (82.8); the emulsion, whose phase angle ranged from 79° to 82° exhibited a relatively low %ER of 52.8.

Table 24. ER Results for HAA 3 and the Emulsion.

	No. of reported results	%ER		Without Outliers	
		Average	Std. Dev.	Average	Std. Dev.
HAA 3	5	84.3	3.8	82.8	2.4
Emulsion	7	59.1	13	52.8	5.3

Figure 23 shows the MSCR %R values for HAA 3 and the emulsion at 55°C and 61°C. Similar to the SPG and %ER results, HAA 3 exhibited very consistent results whereas the emulsion %R values were variable. The %d2s analysis performed (using thresholds from a SEAUPG Inter Laboratory Study) on the %R values showed that for HAA 3, the %R values @ 0.1 kPa and 3.2 kPa at 55°C and @ 3.2 kPa at 61°C are equivalent whereas the corresponding values @ 0.1 kPa at 61°C are not (*34*). For the emulsion, none of the %R values were statistically equivalent.

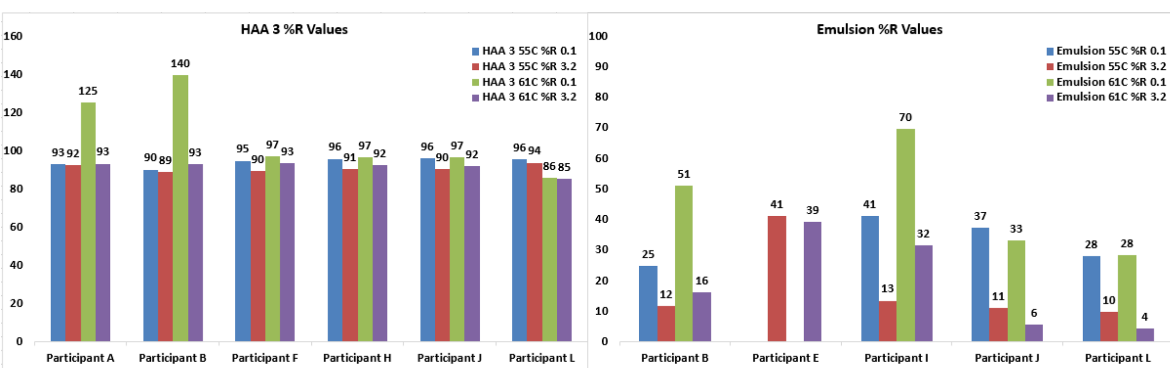


Figure 23. MSCR %R and J_{nr} Results at 0.1 and 3.3 kPa and 55°C and 61°C for HAA 3 and the Emulsion.

Based on the second round robin testing program:

- The third hot-applied asphalt binder (HAA 3) gave highly consistent results across all the participants for T_{HIGH} and T_{LOW}, phase angles, %ER, and %R values. The emulsion exhibited reasonably consistent results for T_{HIGH} and T_{LOW}, phase angles, and %ER, but the %R values were variable.
- The first and the second hot-applied asphalt binders (HAA 1 and 2) exhibited high variability at high temperatures, possibly due to improper blending or poor compatibility between the base binder and the polymers/rubbers/other additives. Parameters and corresponding threshold values to separate these types of binders should be explored.

PRIVATE MATERIALS LABORATORIES – ALTERNATE BINDER TESTS

Toward improvement of the SPG specification, collaboration with private materials testing laboratories was used to evaluate alternate binder tests for possible inclusion in future SPG specification development to identify polymer modification and characterize binders at low temperatures with the DSR.

Evaluation of Polymer Modification Tests

Currently the SPG specification includes a maximum phase angle threshold of 80° at the continuous high temperature SPG for UTI values greater than 86°C to ensure adequate polymer modification. However, concerns remain about the ability of this parameter and the corresponding threshold to capture polymer modification that provides adequate field performance. This section includes a review of the current phase angle parameter determined by DSR testing and an evaluation of alternate rheological parameters by the traditional elastic recovery (ER) test and by the state-of-the-art MSCR test also conducted in the DSR.

Prior to the evaluation of current and alternate polymer modification tests, FTIR spectroscopy was performed on 2016 binders to determine the presence of polymers since these binders were specified by SPG which is performance-based and does not indicate amount or type of polymer modification. The presence of a peak near a frequency of 967 cm^{-1} was used as a qualitative indication of polymer, and the FTIR results in Figure 24 for the original 2016 binders showed that all of the binders are polymer-modified.

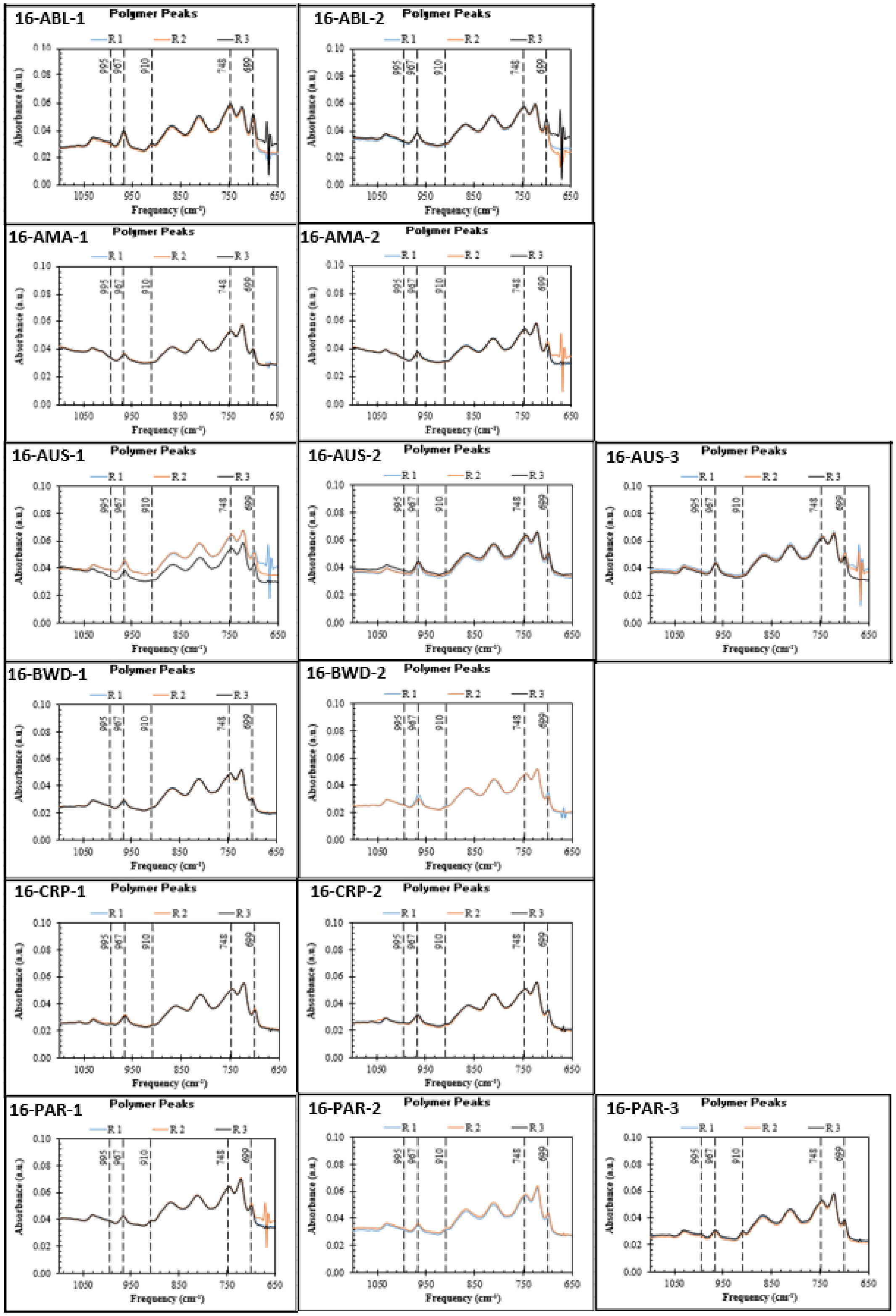


Figure 24. FTIR Spectroscopy Results on Original 2016 Binders.

Review of Phase Angle

At the request of a TX binder supplier and associated private testing laboratory that provides emulsions modified with latex that consistently fail the existing phase angle threshold of 80° but provide adequate field performance, the threshold was reviewed based on the following two sets of data shown in Figure 25:

- Historically available phase angle data from 2004 supplied by TxDOT.
- Phase angle data of the binders used during the first two years of the implementation project in 2013 and 2014 (*2*).

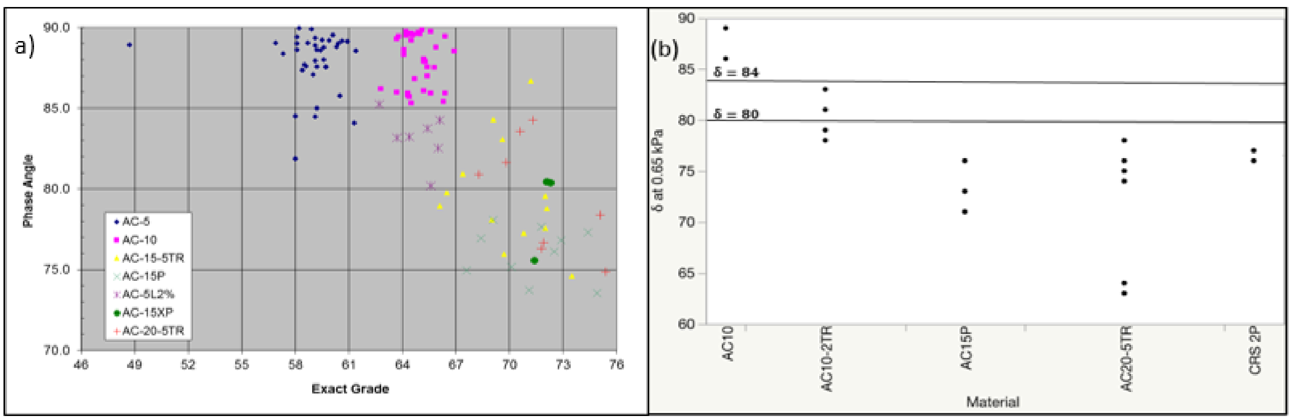


Figure 25. Phase Angle Data: (a) Historically Available from TxDOT for 2004 and (b) for 2013 and 2014 Binders from TxDOT Implementation Project.

Figure 25a shows that unmodified binders AC-5 and AC-10 exhibited phase angles above 80°, with the majority above 85°. Currently specified modified binder AC-15P exhibited phase angles less than 80°, and currently specified modified binder AC-20-5TR exhibited phase angles between 75° and 84°. However, the latex-modified AC-5L2% consistently exhibited phase angles between 80° and 84°. Figure 25b shows the range of phase angles for commonly used binders in 2013 and 2014 and indicates that the usage of unmodified binders declined considerably from 2004 to 2013. The only unmodified binder AC-10 still exhibited phase angles above 80°, and the more heavily-modified AC-15P and AC-20-5TR binders exhibited phase angles less than 80°. The less-modified AC-10-2TR binder exhibited a maximum phase angle of 84°. Thus, both datasets in Figure 25 are comparable and suggest that a threshold of between 80°, and 84° appears reasonable.

Another issue that was explored was the possibility of pre-aging a binder to meet the phase angle requirement in the current SPG specification. To check this possibility preliminarily, TxDOT phase angle data for original and corresponding RTFO aged binders as shown in Figure 26 was examined. The highlighted box shows that the majority of the RTFO aged binders with phase angles close to the current 80° threshold had phase angles between 80° and 84° in their original state. Excluding one outlier, the change in phase angle from original to RTFO-aged ranged from 0.7° to 5.6° for the same sample. Thus, binders that are unmodified or poorly modified may pass the phase angle threshold if pre-aged.

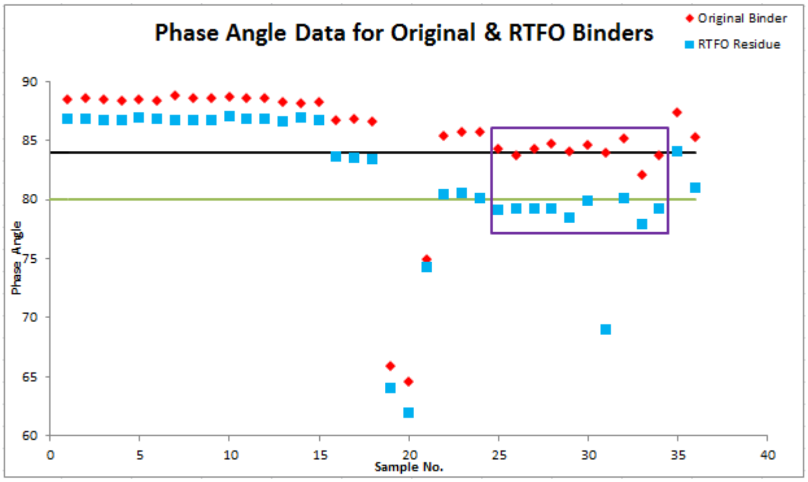


Figure 26. Phase Angle Data for Original and Corresponding RTFO Aged Binders from TxDOT.

To further explore this issue and the ability of the low temperature SPG threshold to preclude pre-aged binders, a small study was conducted with two unmodified AC-10 binders from 2013 and 2014 (13-AMA and 14-SAT). Both binders were tested in the DSR in three different aging states: original, RTFO aged, and RTFO+PAV aged. Figure 27 shows the change in phase angles with aging for both unmodified binders. Phase angles measured on both the binders in their original state when initially received (in 2013 and 2014) are also included. Laboratory aging reduced the phase angle exhibited by both binders, but there was no difference between the original results and the initial test results with the binders stored at cold temperature.

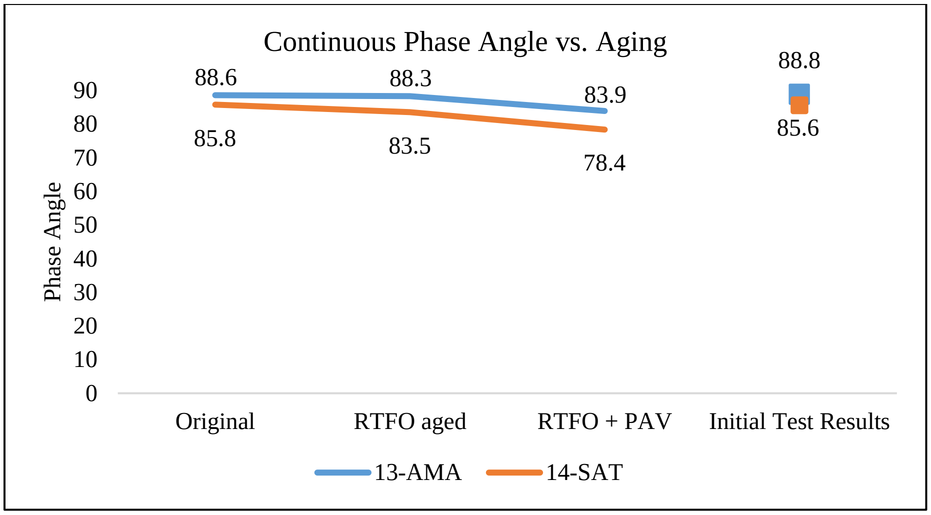


Figure 27. Change in Continuous Phase Angle (δ at 0.65 kPa) with Aging.

Both original binders exhibited phase angles greater than 84°, and their corresponding RTFO-aged phase angles did not go below the existing threshold of 80°. One of the binders (14-SAT) had a phase angle less than 80° after RTFO+PAV aging. This may indicate that unmodified or poorly modified binders with original phase angles close to 84° may pass the phase angle threshold with prolonged pre-aging prior to grading.

SPG continuous and 6°C grades for these binders in three aging states are shown in Table 25 to simulate a supplier providing a pre-aged unmodified binder. These data confirm the scenario where unmodified or poorly modified binders might be pre-aged to meet the phase angle requirement and yet have no change in low temperature grade. Thus, the low temperature SPG cannot prevent this issue.

Table 25. SPG Continuous and 6°C Grades for Unmodified Binders in Three Aging States.

Aging State (+PAV for SPG_{low})	13-AMA	14-SAT
Original	63-21 (SPG 61-19)	64-29 (SPG 61-25)
RTFO	68-20 (SPG 67-19)	72-28 (SPG 67-25)
RTFO+PAV	75-20 (SPG 73-19)	80-29 (SPG 73-25)

Phase angles of PAV-aged 2016 binders were also measured at the passing T_{high} of the original binders, and the results are presented in Figure 28. As expected, the phase angles of the PAV-aged binders were lower than those of their corresponding original binders with one exception. However, there was no clear delineation between the original binders with phase angles between 80° and 84° and those with phase angles less than 80° after PAV aging, possibly due to the fact that all of the 2016 binders are modified and that each binder can have a different rheological response to aging.

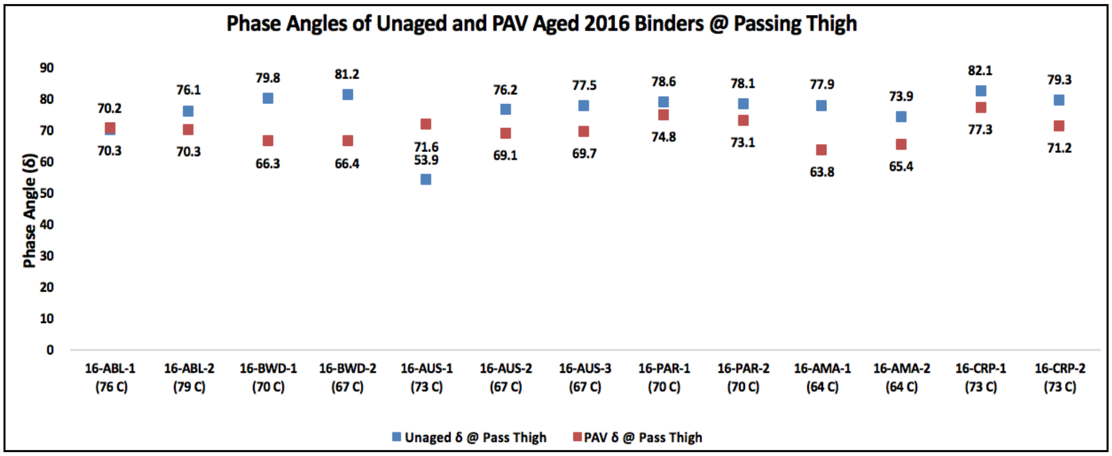


Figure 28. Phase Angles of Original (Unaged) and PAV-Aged 2016 Binders @ Passing T_{high} of the Unaged Binders.

Based on this small study to review the current phase angle parameter to capture polymer modification:

- The phase angle threshold for emulsion residues was increased to 84° for the revised SPG specification for use starting in 2017.
- The need for an alternate parameter that is blind to modifier type and that can preclude the use of aged unmodified or poorly modified binders was identified.

Evaluation of ER

Elastic recovery (ER) is one of the PG Plus tests currently utilized by a number of state highway agencies to ensure polymer modification. The ER test was performed on the original 2016 binders, and the results are shown in Figure 29 and Table 26. In addition to %ER, Table 26 also provides the peak force and a qualitative description of the post peak behavior based on a comparison of F_{200mm} (i.e., magnitude of force at maximum displacement of 200 mm) and $F_{min, post peak}$ (i.e., minimum force exhibited by the binder post peak). Post peak behavior was delineated as recovering for $F_{200mm} > F_{min, post peak}$ or declining for $F_{200mm} < F_{min, post peak}$.

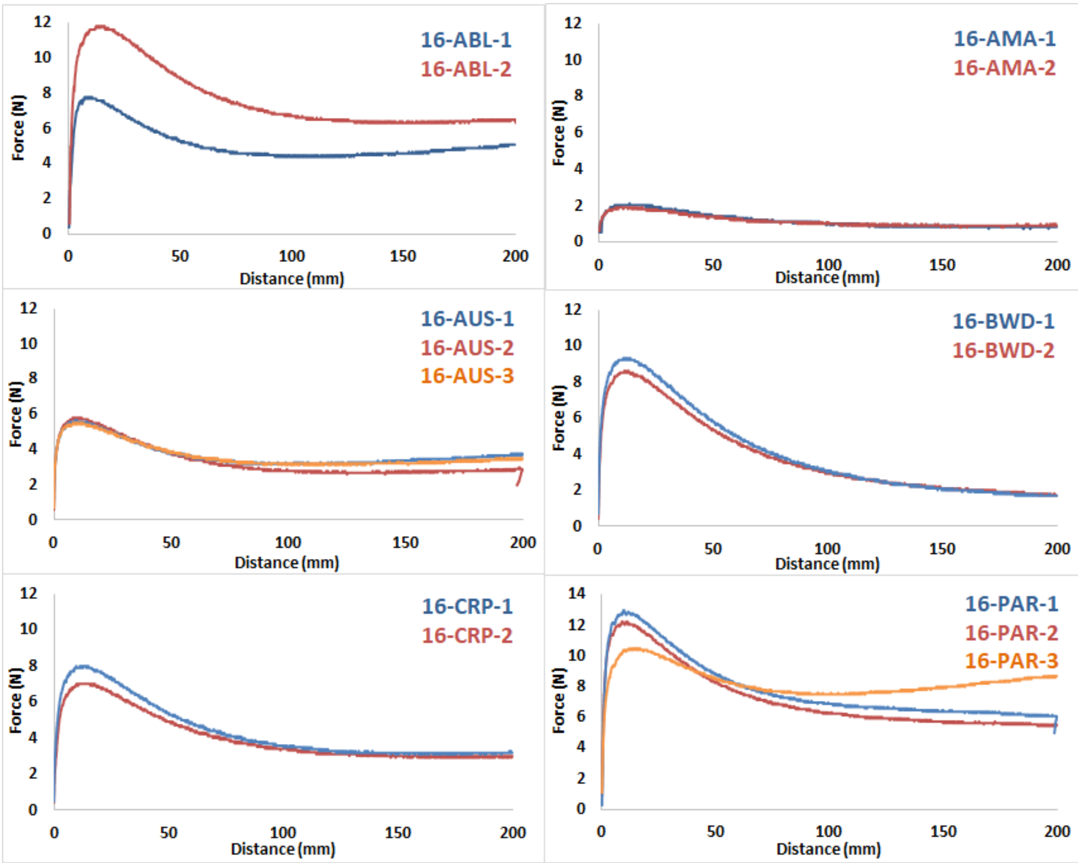


Figure 29. ER Plots for 2016 Binders.

Table 26. ER Results for 2016 Binders.

	% ER @ 10°C	Peak Force (N)	$F_{200mm} > F_{min,\ post\ peak}$?
16-ABL-1	88	7.8	Yes
16-ABL-2	56	11.8	Yes
16-AMA-1	59	2.1	No
16-AMA-2	71	1.9	No
16-AUS-1	73	5.7	Yes
16-AUS-2	72	5.8	Yes
16-AUS-3	72	5.5	Yes
16-BWD-1	55	9.3	No
16-BWD-2	52	8.6	No
16-CRP-1	81	8	Constant
16-CRP-2	83	7	Constant
16-PAR-1	60	13	No
16-PAR-2	40	12.2	No
16-PAR-3	73	10.5	Yes

In general, similar binders were supplied to each TxDOT district except for ABL and PAR based on the similar %ER plots in Figure 29. Binders exhibited varying peak forces from about 2 N to 12 N with a range of post peak behaviors. Generally %ER was correlated with binder recovery behavior, with a minimum threshold around 60 %ER separating the majority of binders that recovered. The %ER values were not indicative of the peak forces, for example a peak load of 1.9 N for 16-AMA-2 with declining post peak behavior ($F_{200mm} < F_{min, post peak}$) and an almost equivalent %ER value to that of 16-AUS-1 with a peak load of 5.7 N and recovering post peak behavior ($F_{200mm} > F_{min, post peak}$).

Based on this small study, the ER test was not pursued further as an alternate parameter to capture polymer modification due to:

- Inconsistent results among the parameters evaluated.
- The relatively low test temperature (10°C) that may not be representative of field conditions.
- The large sample size for one replicate (20 g).
- The long total test time for each sample (5 hours).

Evaluation of MSCR

The MSCR test is the most recent advancement for characterizing polymer modification and was performed on the 2016 binders at 55°C, 61°C, and 67°C. Since the MSCR test measures permanent deformation, it was first used to explore a possible correlation with bleeding (i.e., SCI_{BL}), as shown in Figure 30. The results show that there was an increase in the magnitude of J_{nr} and a decrease in MSCR %R values with increasing temperature that indicated an increase in the viscous component for all binders at higher temperatures. Unfortunately, the MSCR parameters did not discriminate between good and bad field performance at any of the three test temperatures. For example, 16-ABL-1 performed well in the laboratory with the smallest J_{nr} and the largest MSCR %R at the three test temperatures, but it had the lowest SCI_{BL}. Similarly, although 16-PAR-1 and 16-AUS-3 exhibited reasonably good MSCR results, the binders exhibited inadequate or marginal resistance to bleeding, respectively.

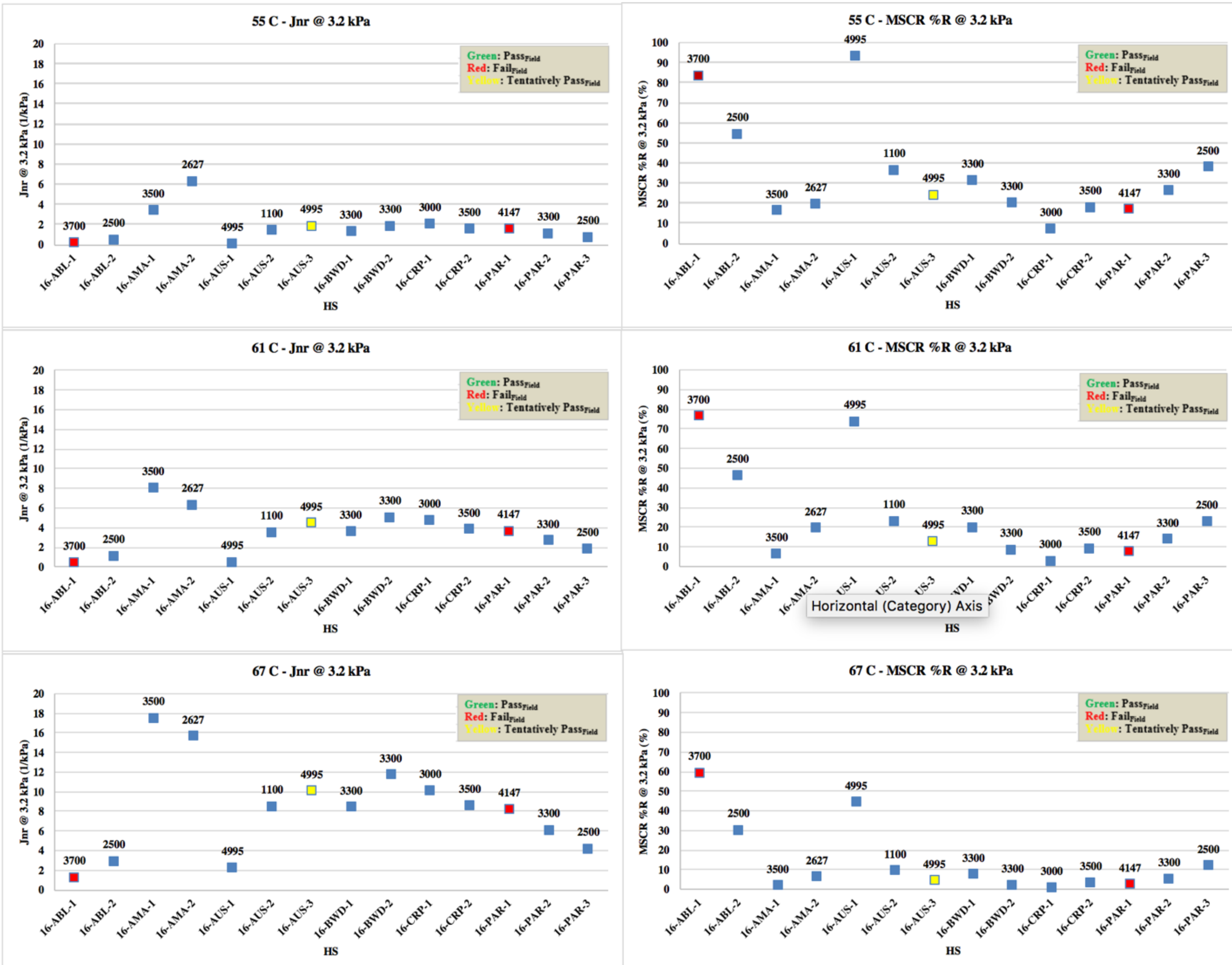


Figure 30. MSCR Test Results versus SCI$_{BL}$ for the 2016 Binders at 55°C, 61°C, and 67°C.

Although the MSCR parameters did not correlate with bleeding in the field, they may be useful to capture polymer modification. Thus the MSCR results were also analyzed based on the Asphalt Institute (AI) polymer curve method with a plot of MSCR % R and Jnr at 3.2 kPa at the three test temperatures as presented in Figure 31. For each binder, the highest point indicates the test results at 55°C, the middle point shows behavior at 61°C, and the lowest point was measured at 67°C. Binders that lie above the polymer curve (indicated in red) are expected to have sufficient polymer modification with good delayed elastic response. For a given stress level, as the temperature increases, the viscous component of the binder dominates its response with more permanent deformation. Therefore, with an increase in temperature, the magnitude of the binder's delayed elastic response is reduced, causing it to move toward the lower side of the polymer curve. This implies that the sufficiency of polymer modification can only be relatively defined based on the temperature and stress level at which the binder is expected to perform.

Except for the ABL binders and one AUS binder, none of the binders exhibited sufficient delayed elastic response at any of the three temperatures. Although the FTIR results indicated that all of the binders were modified, most binders were below the polymer curve, even at 55°C. Thus according to this analysis that was developed for HMA binders, only the binders from ABL and one from AUS are satisfactory in terms of the sufficiency of polymer modification and delayed elastic response. These results agree somewhat with phase angle values with the 16-ABL-1, 16-ABL-2, and 16-AUS-1 binders having three of the lowest six phase angles that are all less than 76°.

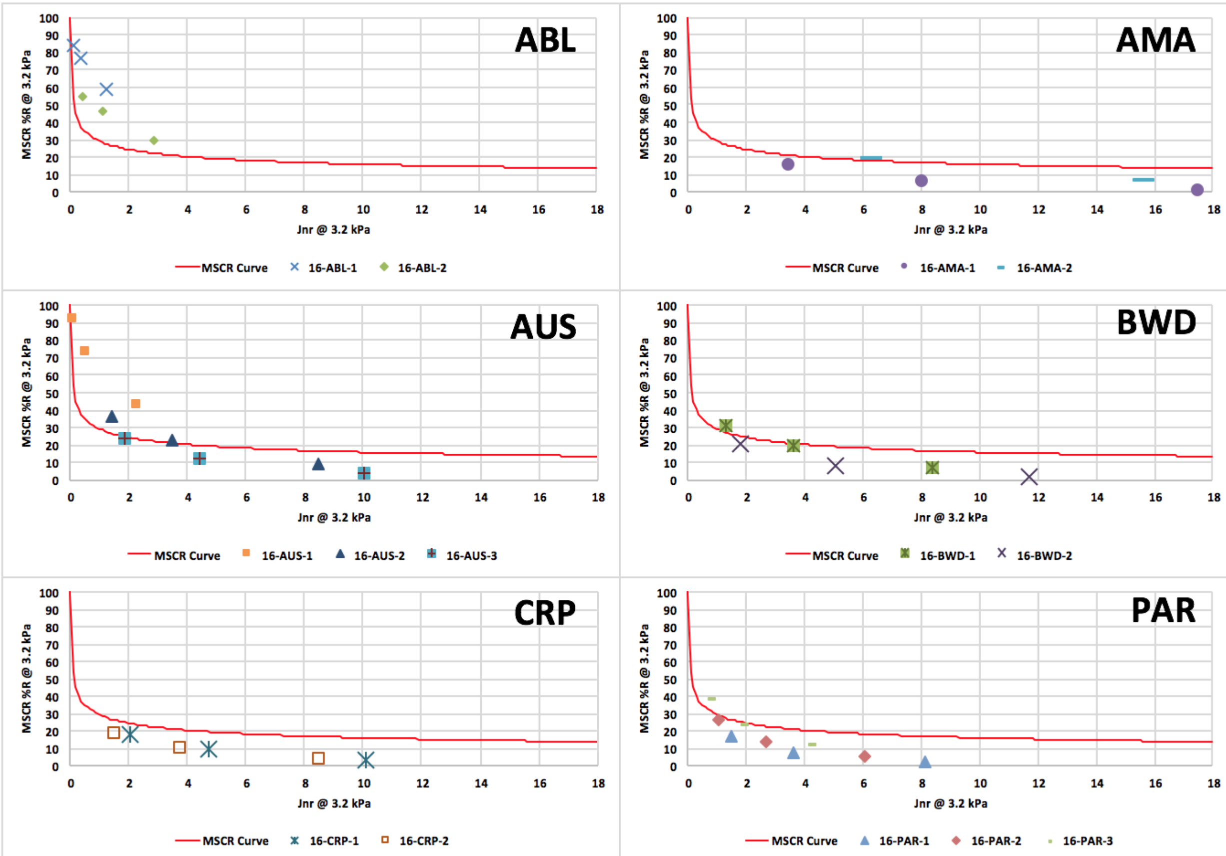


Figure 31. MSCR Test Results of 2016 Binders at 55°C, 61°C, and 67°C Analyzed by the AI Polymer Method.

The MSCR results were also analyzed using a quadrant method suggested by Hossain et al. as shown in Figure 32a using a typical existing %ER threshold for polymer-modified binders as specified by TxDOT (*35*). To make the supplier risk equal to the user risk for this analysis, the MSCR %R threshold was set as 55 percent. An ideally modified binder would lie in quadrant I where the binder meets both the MSCR %R and %ER thresholds. A binder in quadrant II puts the user at risk as it does not meet the %ER threshold, while a binder in quadrant IV puts the supplier at risk as it does not meet the MSCR %R. A binder in quadrant III indicates the failure to meet both %ER and MSCR %R thresholds.

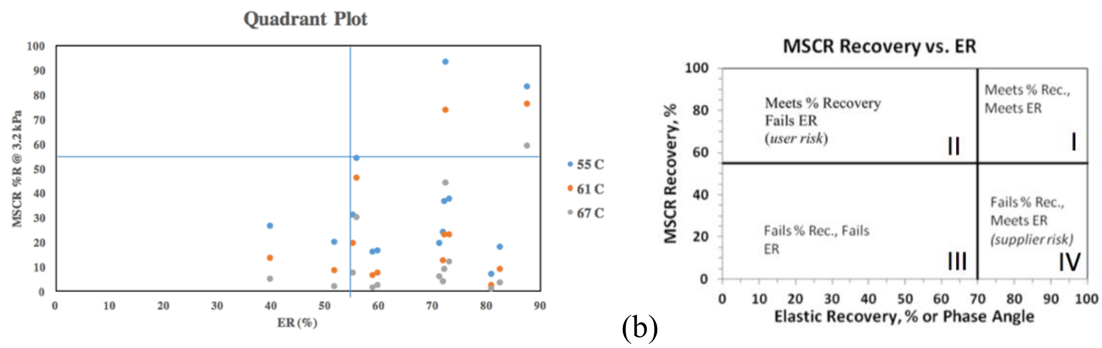


Figure 32. Quadrant Plot Analysis with: (a) MSCR Test Results of 2016 Binders at 55°C, 61°C, and 67°C and (b) Definition of Quadrant Plot.

Based on this analysis, none of the binders put the users at risk at any of the three test temperatures. However, the majority of the binders would put the suppliers at risk by not meeting the selected MSCR %R threshold, indicating insufficient or poor modification. These results agree with the conclusions from the polymer curve method where the majority of the binders were shown to have insufficient polymer modification. In terms of phase angle, the majority of the binders exhibited values greater than or equal to 78° (close to the existing threshold of 80°).

Based on this small study, the MSCR test is promising as an alternate to phase angle to capture polymer modification with further exploration of the following MSCR test parameters and modification of the test protocol to represent the conditions and failure mechanisms (aggregate loss and bleeding) for chip seals with consideration of a wide range of materials:

- ***Test Geometry:*** Test geometry becomes crucial to avoiding negative MSCR %R values due to tertiary flow. Although Golalipur et al. suggest the utilization of a cone and plate geometry at 0.275 mm, this is not practical given current equipment in most laboratories (*36*). For the stress levels and number of loading cycles chosen for chip seal binders (final protocol), if binder flow is observed, using a lower plate gap could be a possible alternative although particle size distribution of the binders could make this unfeasible (especially with crumb tire rubber).
- ***Loading and Rest Periods:*** The current loading period of 1 sec seems to be reasonable. However, if a higher stress level is chosen for the test protocol, the capacity of the rheometer to attain that higher stress level in 1 sec must be checked. In addition, the rest period should be long enough to sufficiently characterize the delayed elastic response of

the binders. Different loading and rest periods could be chosen for different stress levels, and the proposed loading to rest period ratio could be the same as the existing MSCR protocol (i.e., 1:9 or higher).

- ***Number of cycles:*** This parameter should be fixed based on the requirements to: (a) achieve steady state in the binder, (b) avoid unstable permanent strains, and (c) preclude tertiary flow at a given stress level. The methodology employed by Golalipur et al. to determine the optimum number of cycles could be used (*36*). Perhaps the number of cycles could be different for each stress level as the number of cycles to reach steady state could be higher for higher stress levels.
- ***Binder Aging States:*** The aging state of the binder depends on the worst-case age – distress scenario. For instance, aggregate loss is predominant with aged binders. Therefore, it is suggested to perform the test protocol corresponding to aggregate loss on PAV aged binders. Similarly, bleeding is greater with softer binders. Hence, the test protocol for bleeding is more relevant for unaged binders. In addition, testing binders before and after aging may help in identifying the deterioration in polymer networks induced by aging.
- ***Stress Levels:*** The stress levels used are extremely important because binders that exhibit similar properties in the linear viscoelastic (LVE) range (i.e., in terms of $G^*/ \sin \delta$) could exhibit completely different properties once outside of this range due to their inherent stress sensitivities (*37*, *38*, *39*). However, choosing the stress levels requires consideration of two important factors: (a) the stress levels should fall in the region where the binders exhibit stress sensitivity (i.e., beyond the LVE regime), and (b) the stress levels must be representative of the stresses that cause cohesive and adhesive failures in the binder. The typical ranges of LVE regime for binders can be obtained from the literature or, to specifically determine this range for chip seal binders, simple linear amplitude sweeps could be performed to determine the binder yield stress (*40*). It is important to consider that the stress levels causing failure in the field are temperature dependent (*39*). Mechanistic modeling is a crucial step in determining the stresses corresponding to field failure. Gerber and Jenkins developed a finite element model for chip seals with the major failure mechanisms taking into consideration the binder properties at 25°C and the standard 80 kN wheel load at 80 km/hr (*41*). They reported the

shear stresses at failure from the model along with those from literature in Figure 33. Based on further exploration of the validity of the models presented in Figure 33, the stress levels reported could be used as the starting point for the exploring the parameters for a modified MSCR test protocol.

	Adhesive zone	Bitumen	
Previous works[a]	Shear stress	Shear stress	95 Percentile von Mises
Henderson et al. (2006)	–	–	320 kPa
Milne (2004)		10–300 kPa	–
Huurman (2010)	120–330 kPa	–	–
Current paper	80–160 kPa	50–120 kPa	200–250 kPa

[a]Bitumen: 70–100 or 80–100 penetration grades; 25°C; 80 kN axle loads at 80 km/h.

Figure 33. Shear Stresses in the Binders for Adhesive and Cohesive Failures (*41*).

- ***Test Temperatures:*** The test temperatures should be representative of the critical temperatures at which the binders fail in the field. For instance, climate-based T_{high} for bleeding. However, it is important to consider that stress levels and the test temperatures are inter-related as high stress levels cannot be applied at high temperatures due to the higher viscous component in the binder at such temperatures.

Characterization of Low Temperature Properties Using the DSR

Previous research studies demonstrate it is possible to use the 4-mm DSR test to obtain BBR low temperature PG and/or extended binder characterization from low to intermediate temperatures in forensic studies (*42*, *43*, *44*, *45*, *46*). Common practices recommend conducting isothermal frequency sweeps in a temperature range from −40 to 0°C (or even up to 40°C if the binder is sufficiently stiff to hold its shape at such temperatures), and frequency range from 0.1 (or 0.2) to 100 rad/s. A mastercurve for dynamic modulus ($|G^*|$) can be obtained by applying time-temperature superposition principles and assuming a thermorheologically simple material. Relaxation modulus [G(t)] and slope [$m^G(t)$] at 60 s can be estimated by applying linear-viscoelastic interconversions from frequency to time domain; values that have been subsequently correlated through empirical regressions to creep stiffness [S(t)] and slope [$m^S(t)$] from the BBR test with extensive data sets from Western Research Institute (WRI) and MTE. While researchers acknowledge the 4-mm DSR technique may not offer a complete replacement to the BBR test method due to experimental limitations discussed subsequently, to date, this 4-mm DSR method is a powerful forensic tool requiring a minimum amount of material to obtain reliable low temperature characterization and performance grading.

As part of the 2016–17 implementation effort, collaboration with another private materials testing laboratory was undertaken to use 4-mm DSR testing to explore the possibility of obtaining low temperature properties for use in the SPG specification. Although previous work on the second research project and the implementation project toward this goal, the DSR equipment used had poor temperature control below 0°C, so these efforts were not successful (*3*, *47*, *48*). With the purchase of a research grade DSR with advanced temperature control Peltier technology, this possibility was explored once again in this small study. This section reports the recent efforts in the development of a 4-mm DSR SPG threshold that corresponds to the threshold for S(t) at 8 sec with BBR testing in the current SPG specification.

Experimental Procedure and Calibrations

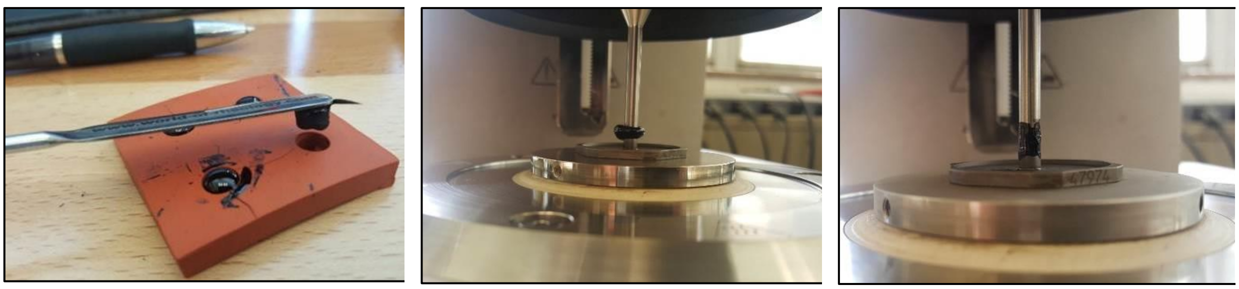
Additional considerations and calibration procedures are required when conducting 4-mm DSR low temperature measurements as reported in previous literature (*43, 46, 49*). The technique is an ongoing topic of discussion among researchers, and experimental difficulties continue to arise as more researchers pursue implementation of the method using different equipment configurations as compared to that at WRI and MTE where the original methods and correlations were developed. In this study, an Anton Paar Modular Compact Rheometer (MCR) 302 with H-PTD 200 Peltier hood and plate configuration, as shown in Figure 34, was used to perform the 4-mm DSR testing. The pipelines connecting the counter cooling system to the Peltier were insulated to provide more stable counter cooling. The selected Peltier plate/hood configuration includes top and bottom active heating and cooling plus air circulation, and it is capable of maintaining stable temperatures from −40 to 200°C provided that the appropriate counter cooling is supplied to the Peltier.

Figure 34. Anton Paar MCR 302.

The use of 4-mm DSR low temperature characterization of asphalt binders for PG grading involves rigorous experimental processes such as additional calibration procedures, additional experimental steps, extra care in sample preparation, and advanced analysis methodologies. It is imperative to verify and adjust temperature calibration and compliance factors related to equipment and geometry (*49*, *50*). Sample preparation, mounting, trimming, and sequence for lowering the temperature (which can include application of a normal force) should be carefully adjusted to prevent/minimize potential for slippage and/or debonding during testing. In this study the drafted recommendation for 4-mm DSR testing prepared from experiences at MTE and WRI was considered (*51*). The ice method for compliance verification was conducted rendering results highly comparable to the compliance factors provided by the equipment manufacturer, thus the latter were used. Other factors, including temperature calibration and equilibrium, were explored more extensively as discussed subsequently.

Sample Preparation and Mounting

Sample fabrication was conducted using an oversized rubber mold (Figure 35a), and the samples were prepared and tested within a few hours. Prior to mounting the sample at 30°C, the gap between the plates was zeroed at 0°C. To extract the sample from the rubber mold, the spatula was heated locally and attached to the sample (Figure 35a). To properly attach the sample to the bottom plate, the sample was heated locally for three to five seconds using an air-flow controlling heat gun at 400°C at the lowest speed (as recommended by WRI) and attached to the plate. Then the spatula was heated again to detach it from the sample, and the upper plate was lowered into the softened sample to promote bonding (Figure 35b). An initial trim was performed at the loading temperature (30°C) to a sample thickness of 2.35 mm (Figure 35c), and a final trim was performed at 0°C (after 600 s equilibrium) at a sample thickness of 2.15 mm so that a bulge was formed when lowered to a testing thickness of 2.00 mm. The temperature was then reduced to the lowest test temperature (i.e., −31°C in this study) while holding a constant normal force of 1 N to ensure contact with the sample was maintained as the sample contracts as the temperature decreases.



a) Sample Preparation **b) Sample Mounting** **c) Sample Trimming**

Figure 35. 4-mm DSR Sample Preparation, Loading, and Trimming.

Temperature Standardization, Equilibrium Time, and Testing Window

Asphalts are highly susceptible to temperature, thus accuracy in temperature calibration and selection of an appropriate time to allow the sample to achieve temperature equilibrium are extremely important aspects for any rheological measurement. DSR temperature control systems should be standardized (verified and adjusted) regularly to ensure accuracy. Temperature wafers (commonly 25 mm) for DSR temperature standardization for asphalt applications are meticulously adjusted to temperature standards based on AASHTO requirements in a range from 4 to 88°C, while no verification or adjustment is required by AASHTO outside that range. Such wafers are not reliable for conducting temperature standardization for 4-mm DSR testing below 4°C. In this study, the temperature verification and adjustment of the DSR at subzero temperature was performed using a 25 mm temperature wafer previously calibrated and adjusted to a temperature standard in a range between −40 to 0°C at 10°C intervals (ISO/IEC 17025).

Definition of temperature equilibrium time for DSR measurements of asphalt binders is not always a straight forward procedure. Molecular rearrangements can occur in asphalt binders at isothermal conditions and affect binder rheological properties with time through steric hardening (intermediate temperatures) and physical hardening (around the glass transition) (*52*, *53*, *54*). Physical hardening is a major concern in 4-mm DSR testing as the testing temperatures are around the glass transition. If the equilibrium time is not sufficient, the entire binder sample may not achieve the desired testing temperature. Conversely, if an excessive time is selected, the binder may continue to change (increase $|G^*|$) due to physical hardening; therefore it is important to define a reasonable time window for rheological characterization of asphalt binders.

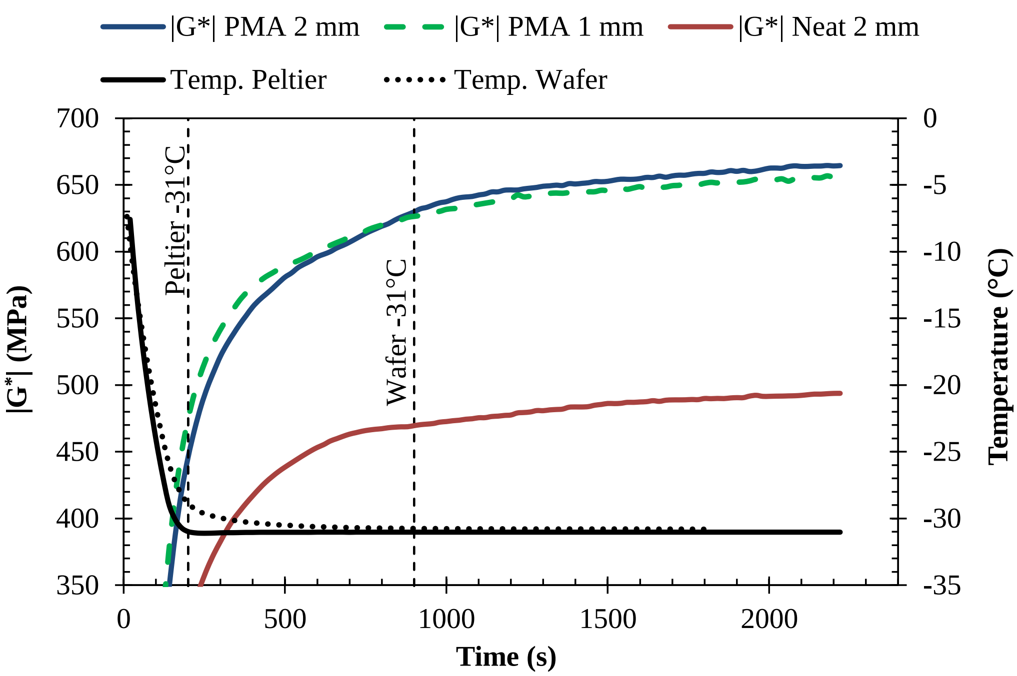
In this study three major factors were considered in selection of a testing time window: 1) the minimum time needed for the sample space to be at temperature, 2) the time at which the sample reaches a constant temperature throughout its entire thickness, and 3) minimization of physical hardening that will continue to occur during the testing time for an isothermal frequency sweep collecting six points per decade in the range of 0.2 to 100 rad/s (around 540 s with the equipment and configuration used in this study).

As an approximation to the minimum time for the sample space to be at temperature, readings from the 25 mm temperature wafer were recorded as the Peltier system executed the predefined temperature sequence for the 4-mm DSR low temperature testing. Change in binder modulus with temperature was addressed through separate experiments in which two different binders, a polymer modified asphalt (labeled PMA) and an unmodified binder (labeled neat), were continuously sheared at 10 rad/s while subjected to the same temperature sequences. In addition, the polymer modified asphalt was evaluated at two different gap thicknesses of 1 mm and 2 mm to provide insight on temperature uniformity across the sample thickness. Results from these experiments are summarized and discussed separately for the initial temperature drop from 0 to −31°C (Figure 36), and for the subsequent steps elevating the temperature for each isotherm measurement (Figure 37 and Table 27).

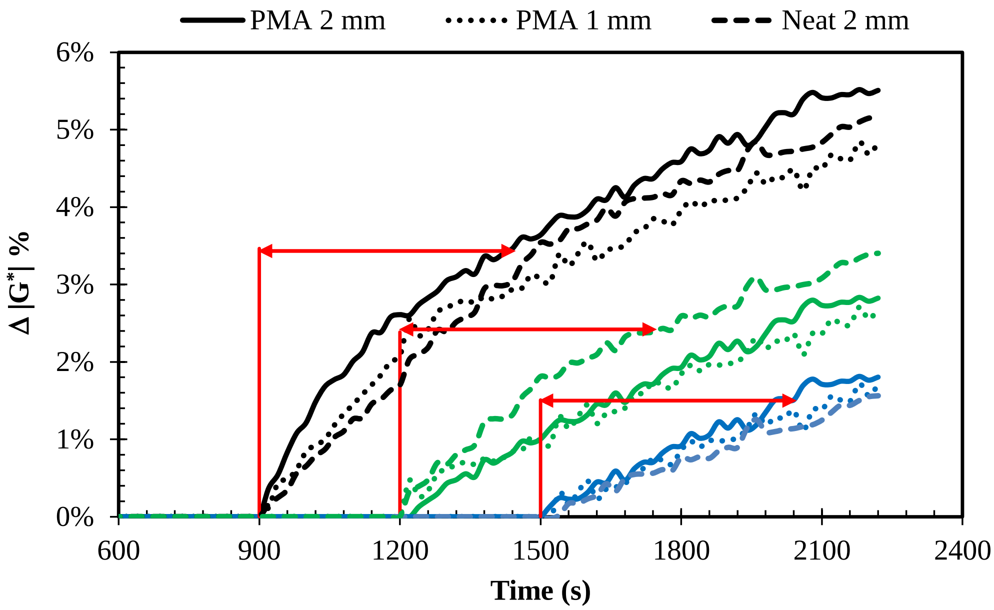
Figure 36a demonstrates how the Peltier system required about 200 s to reach a stable temperature at −31°C, while the wafer recorded stable readings after 900 s suggesting a minimum time for the samples space to be at temperature. Considering the modulus measurements in Figure 36a, the largest $|G^*|$ increase occurs prior to 900 s for all samples, yet a clearly increasing modulus trend is observed beyond this time. At this point there is likely a combined effect of temperature equilibration plus physical hardening contributing to the samples change in modulus, which cannot be deconvoluted numerically or experimentally. It is important to consider not only the initial point for assumed sample temperature equilibrium (900 s [Figure

36a]) but the change in |G*| up to the time needed to conduct a frequency sweep (540 s based on conditions in this study).

The |G*| measurements presented in Figure 36a were normalized to the % change in |G*| (Δ|G*|) and are presented in Figure 36b assuming three different starting points for temperature equilibrium: 900, 1200, and 1500 s. The double end arrow lines in Figure 36b represent the time window for testing, and the vertical red lines represent the largest % Δ|G*| of the three samples. If temperature equilibrium were selected at 900 s, the 2 mm gap (standard condition) samples could see around 3.5 percent Δ|G*| between the 1st and last point of a frequency sweep. In addition, the different test results between polymer modified asphalt at 1 mm and 2 mm gaps suggest that the temperature may not be uniform across the gap after 900 s. After 1200 s, the differences across the sample gap are no longer of concern, but different % Δ|G*| are clear for the two binder types. Finally, considering 1500 s for temperature equilibrium resulted in 1.7 percent Δ|G*| or less during the time period of interest and similar trends for all three samples. If physical hardening cannot be avoided during the testing sequence, at least it can be minimized and kept consistent across samples by appropriate selection of testing conditions. Therefore, 1500 s was selected.

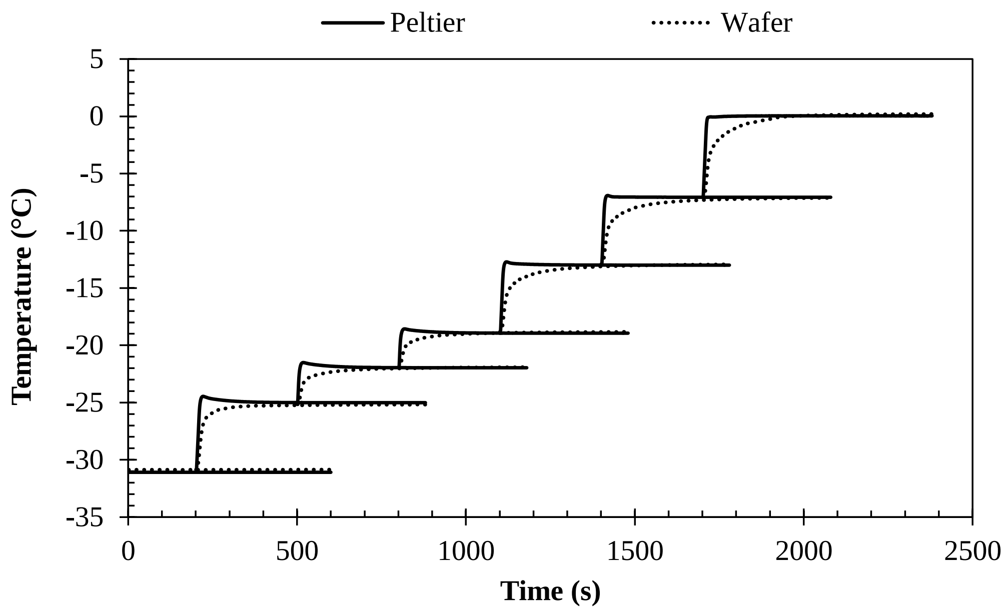


a) Temperature and |G*| during Temperature Drop

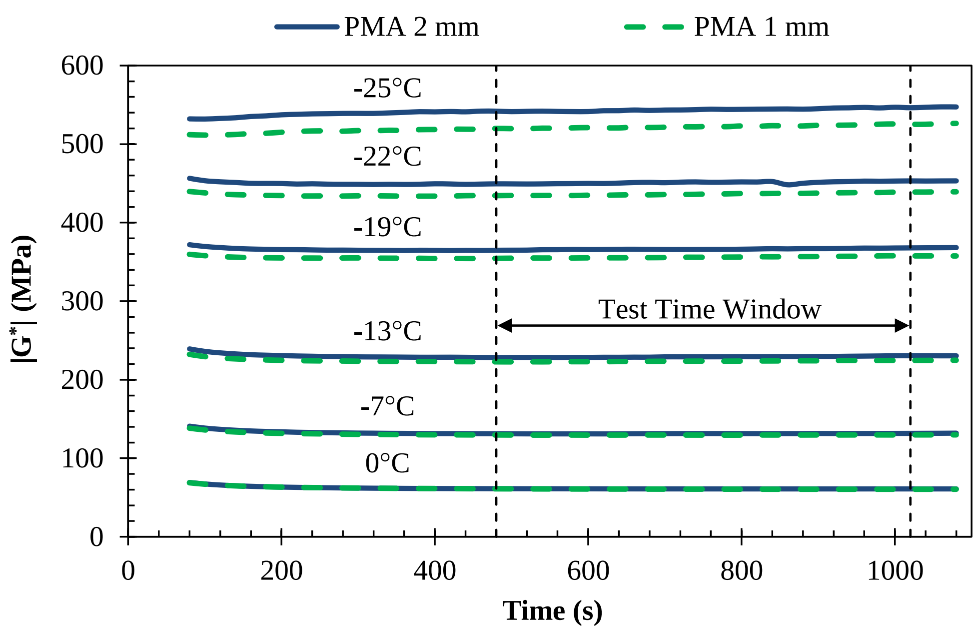


b) Δ|G*|: Temperature Equilibrium versus Physical Hardening
Figure 36. Selection of Equilibrium Time for Initial Temperature Step 0 to −31°C.

After the measurements at −31°C, the testing sequence continues with a series of increasing temperature steps during which the temperature signals from Peltier and wafer were recorded and |G*| was measured. Figure 37 shows these results overlapped on the time scale for illustration purposes. For every temperature step, the Peltier reached and exceeded the commanded temperature after 10 s, while stable readings were registered after 100 to 150 s (Figure 37a). The wafer, however, needed between 200 to 300 s to register stable readings. A time of 480 s for thermal equilibrium was recommended based on evaluation of |G*| and Δ|G*| throughout the 540 s testing window (Figure 37b and Table 27).



a) Temperature Peltier and Wafer during Subsequent Temperature Steps



b) |G*| and Test Time Window

Figure 37. Selection of Equilibrium Time for Subsequent Temperature Steps.

Table 27. $\Delta|G^*|$ During Testing Time Window for Subsequent Temperature Steps.

Test Temperature (°C)	$\Delta|G^*|$ Equilibrium Time 300 s			$\Delta|G^*|$ Equilibrium Time 480 s		
	PMA 2 mm	PMA 1 mm	Neat	PMA 2 mm	PMA 1 mm	Neat
−25	1.0%	1.2%	1.2%	0.8%	1.0%	1.4%
−22	0.8%	0.7%	0.8%	0.8%	1.1%	1.0%
−19	0.5%	0.4%	0.1%	0.8%	0.9%	0.3%
−13	0.1%	0.2%	−0.6%	1.0%	0.8%	0.4%
−7	−0.5%	−0.7%	−1.0%	0.3%	0.1%	0.2%
0	−1.7%	−2.4%	−2.4%	−0.5%	−0.9%	−1.0%

Final Testing Protocol

The experiments described previously provided information on temperature equilibrium, temperature uniformity across the binder thickness, and sample physical hardening during the entire 4-mm DSR test. The test temperatures were selected based on SPG. Strain levels were selected based on MTE's extensive experience and considering that the binders in this study were not overly aged. Table 28 details the final testing protocol used in testing five of the 2016 binders.

Table 28. Experimental Protocol 4-mm DSR.

Test Temperature (°C)	Temperature Change Step		Measuring Step	
	Time (s)	Normal Force (N)	ω (rad/s)	γ%
−31	1500	1	100 – 0.2	0.005
−25	480	1	100 – 0.2	0.01
−22	480	1	100 – 0.2	0.025
−19	480	0.8	100 – 0.2	0.05
−13	480	0.6	100 – 0.2	0.05
−7	480	0.4	100 – 0.2	0.1
0	480	0.2	100 – 0.2	0.5

Linear Viscoelastic Interconversions and Development of SPG Thresholds

The resulting isotherms were then analyzed using the software Rhea™, and the data were consolidated into a mastercurve in the frequency domain and fitted to relaxation and retardation models, which provide a simple means of data interconversion from the frequency to the time domain. The shear creep compliance J (t) is described in Equation 11 in terms of the Prony series constants (j_i and λ_i), instantaneous compliance (J_g), and the steady flow viscosity (η), which are given by Rhea. J (t) is then converted to creep compliance, D(t), using Equation 12 with the assumption of constant Poisson's ratio (ν). Finally, the creep stiffness, S(t), is estimated using Equation 13:

$$J(t) = J_g + \frac{t}{\eta} + \sum_1^{n-1} j_i \left[1 - \exp\left(-\frac{t}{\lambda_i}\right)\right] \quad \text{Equation 11}$$

$$D(t) = \frac{J(t)}{2(1+\nu)} \quad \text{Equation 12}$$

$$S(t) = \frac{1}{D(t)} \quad \text{Equation 13}$$

The 4-mm DSR frequency sweep test was performed on five randomly selected PAV-aged 2016 binders (16-ABL-1, 16-AUS-2, 16-CRP-2, 16-PAR-1, and 16-BWD-1). Figure 38 shows the comparison between the S (t) calculated from DSR mastercurves and the S (t) measured by BBR over a 240 s range for one example binder (16- PAR-1) at −25°C. Poisson's ratio of asphalt binders in a liquid state is typically assumed to be 0.5, while a binder at or below glass transition temperatures cannot be considered incompressible (with Poisson's ratio 0.5). It has been suggested that at low temperatures asphalt binder Poisson's ratio may vary from 0.5 to 0.35 (*55*), thus both of these values were considered. Figure 38 shows the BBR measurement renders significantly lower stiffness than the interconverted DSR data regardless of the assumption of Poisson's ratio. Considering the way both tests are conducted, possible differences may arise from differences in sample physical hardening based on geometry and heat transfer, assumption of linear viscoelasticity in BBR testing, and the assumption of a constant Poisson's ratio. These conclusions were consistent with all other measurements conducted in this study with BBR measurements at −19 and −25°C. Due to the experimental complexities to quantify the effect of physical hardening, direct mechanical conversions are prohibitive at this time, thus empirical regressions for SPG threshold development are recommended at this time.

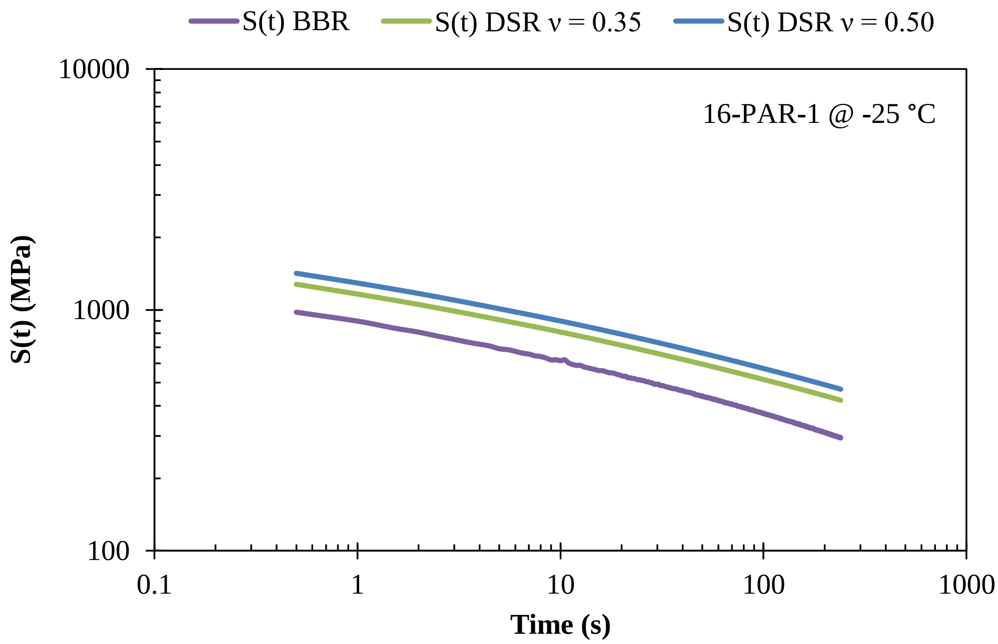


Figure 38. Example S(t) DSR versus S(t) BBR and Assumption of Poisson's Ratio.

To develop the SPG thresholds, the 4-mm DSR experiment G(t) DSR and S(t) BBR were correlated (Figure 39). Good correlations were obtained considering times of 8 s (SPG) and 60 s (PG). The SPG threshold equivalent to S (8) = 500 MPa was found at G (8) = 242 MPa, while the PG threshold equivalent to S (60) = 300 MPa was found at G (60) = 145 MPa. Previous research recommend a PG threshold G(60) = 143 MPa, which is in agreement with that obtained in this study considering the different equipment used and the fact that only polymer modified asphalts were evaluated in this study.

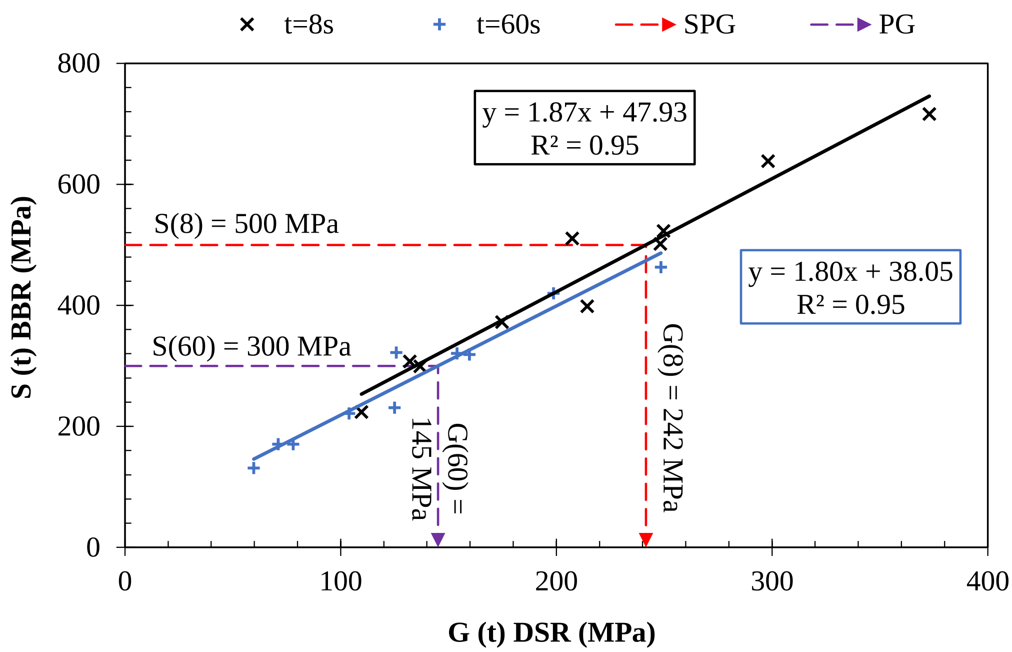


Figure 39. 4-mm DSR G(t) Threshold Development for SPG.

Practical Recommendations toward Simplifying 4-mm DSR Testing for SPG

In this study the experimental protocol and preliminary thresholds for low temperature grading using 4-mm DSR testing for SPG were developed. A series of experimental constraints were investigated, and practical solutions were proposed under the initial consideration that mastercurve data were required for a more complete characterization and insightful mechanical comparison to the BBR test. Experimental complexities resulted in differences that could not be reconciled by mechanistic interconversions between BBR and DSR data, presumably attributed to physical hardening and different testing geometries and conditioning times, so empirical correlations were preferred for SPG threshold development.

To reduce the post-testing analysis and conversion of the test output to obtain G(t), the possibility of proposing a threshold for $|G^*|(\omega)$ obtained directly from DSR measurements could be considered. The SPG 8 s time corresponds to approximately $\omega = 0.125$ rad/s, which was outside of the experimental range for each isotherm individually measured in this study. For practicality purposes $\omega = 0.125$ rad/s would not be recommended for 4-mm DSR testing that would require several point measurements at a single frequency (and reporting of the average) similar to AASHTO T315 for high temperature grading. The 8 s time for BBR low temperature SPG was selected because it is the shortest experimental time at which a reliable measurement can be obtained using the BBR test, but in fact for 4-mm DSR testing other frequencies could be considered. An example correlating S(8) to direct 4-mm DSR measurement at the standard 10 rad/s is presented in Figure 40 demonstrating the feasibility of such an approach with good correlation and a threshold of $|G^*|$ (10) = 570 MPa. Considering an experimental protocol at ω=10 rad/s, 20 point measurements could be collected rapidly in considerably less time than the 540 s testing time required for frequency sweeps.

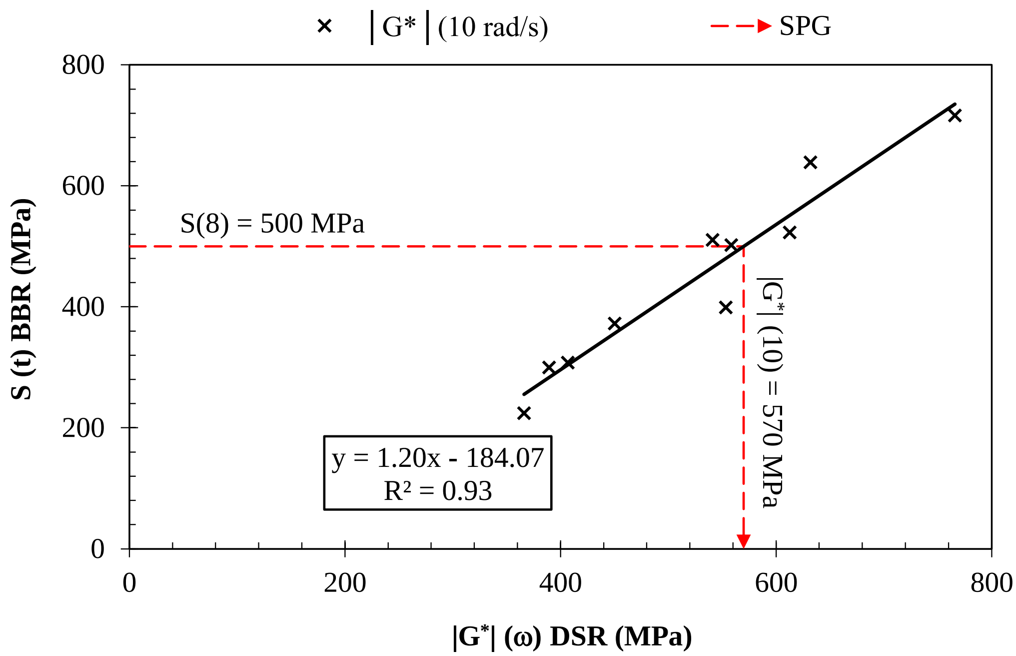


Figure 40. 4-mm DSR $|G^*|$ (ω) Threshold Development for SPG.

Toward implementation of the most practical SPG specification, 4-mm DSR testing for low temperature SPG should be developed considering temperature standardization procedures for different DSR equipment and careful evaluation of temperature equilibrium and corresponding selection of an appropriate testing time window. By grading based on direct measurements, the possibility of data manipulation is minimized. One additional consideration not explored in this study would be sample slippage and sample break, which could potentially be addressed by waveform analysis and controlled by a waveform quality index in the final grading procedure.

NATIONAL – EMULSION TASK FORCE

Work associated with the Emulsion Task Force (ETF) of the FHWA Pavement Preservation Expert Task Group (ETG) spanned throughout this implementation project, as researchers and TxDOT personnel from both TxDOT research projects were invited to participate from its inception in 2008. This group includes about 30 members from industry, academia, state departments of transportation, FHWA, and Federal Lands and meets approximately twice per year at different locations to:

- Review ongoing research and integrate work on emulsions on a national basis.
- Recommend, propose, and evaluate research needs on emulsions.
- Advance development of performance-based test methods and specifications for emulsions.
- Facilitate implementation and adoption of standards for emulsions through AASHTO and ASTM.
- Share information on emulsions with other FHWA ETGs.

During the course of the implementation project, TxDOT and TTI personnel have participated and given presentations at the following ETF in-person meetings, in addition to multiple web conference calls:

- New Orleans, LA, May 15, 2009.
- Scottsdale, AZ, December 14, 2009.
- Boston, MA, July 26, 2010.
- Warwick, RI, July 11, 2013.
- Arlington, VA, May 7, 2014.
- Lakewood, CO, June 22, 2015.
- Lakewood, CO, May 6, 2016.
- Tampa, FL, December 13, 2016.

The primary ETF task associated with chip seal binders is the forthcoming merge of the SPG specification developed through TxDOT research projects and this implementation project and the EPG specification developed in National Cooperative Highway Research Program (NCHRP) Project 9-50. In addition the ETF is responsible for the forthcoming RFP for NCHRP Project 9-63 for development and field validation of a combined national performance-related specification for emulsified asphalt for use with chip seals.

CHAPTER 4: SUMMARY AND RECOMMENDATIONS

This report documents the 2013–18 implementation effort for the SPG specification for chip seal binders in Texas. In this chapter, the validation and industry interaction efforts are summarized, the two primary products are presented, the economic impact of SPG implementation is estimated, and future improvements are recommended.

VALIDATION AND INDUSTRY INTERACTION

The first part of the work involved continuing the performance correlation of the current parameters in the specification, $G^*/\sin\delta$ and phase angle δ at high temperature and the stiffness S at low temperatures. The performance correlation was 79 percent for $G^*/\sin\delta$ and 75 percent for S with a review of construction factors for those HSs that did not correlate that highlighted the need for the combined use of good construction practices and material-related specifications to achieve adequate field performance. Two small studies to verify PAV aging and compare ED measurement methods were also completed. Industry interaction to support implementation of the SPG specification that included outreach presentations and publications, two successful round robin testing programs at the state level, collaboration with private materials testing laboratories to evaluate alternate tests to capture polymer modification, and characterization of low temperature properties using the DSR were also described. These validation and industry interaction efforts resulted in the following:

- Adoption of 6°C increments for both high and low temperature grades in the SPG specification.
- Recognition of the need for laboratory aging.
- Acknowledgement that visual examination of ED is sufficient to assess construction factors in validating SPG thresholds.
- Understanding that the MSCR holds promise as an alternate test to capture polymer modification, but revisions are needed for chip seal applications (no RTFO).
- Development of proposed thresholds of G (t=60 s) = 145 MPa or G (ω=10 rad/s) = 570 MPa for 4-mm DSR testing to characterize binders at low temperature and replace BBR testing.

QUICK REFERENCE GUIDES

Overall, these efforts produced two quick reference guides for specifying a chip seal binder by performance-based SPG and for selecting a chip seal binder based on climate and traffic considerations and other factors such as polymer modification. These two guides advanced the SPG specification to the next level toward statewide implementation and improved chip seal performance. Changes in materials are expected with implementation, but specifications such as the SPG with a strong foundation tied to field performance will continue to stand and move the industry forward as the PG specification has for HMA binders.

ECONOMIC IMPACT

Chip seals are the most widely used and cost effective preventive maintenance tool used in Texas. Relatively small improvements in the performance of these maintenance treatments will result in considerable cost savings to TxDOT maintenance and/or construction budgets. Over $300 million is expended by TxDOT on chip seals annually, covering about 10 percent of the pavement surfaces (20,000 to 25,000 lane miles). It is estimated that this funding is used to place about 450 projects under construction contracts, maintenance contracts, and by maintenance forces on an annual basis.

These common maintenance treatments have been successful and cost effective in Texas in part due to considerable associated research, development, and implementation efforts, including training, conducted by TxDOT over the last 50 plus years. These efforts have resulted in improved project selection practices, material selection, design methods, construction, and inspection methods. Typical costs of these efforts and other TxDOT activities associated with improving the performance of chip seals are estimated to be in the range of $100,000 to $200,000 annually. More specifically, a multiyear research and implementation effort was initiated in 1999 to improve chip seal binders through the following three projects with total funding of $1,626,415 and average annual expenditures of $153,000:

- Superpave Binder Tests for Surface Treatment Binders (TxDOT 0-1710).
- Validate Surface Performance Graded (SPG) Specification for Surface Treatment Binders (TxDOT 0-6616).
- Statewide Implementation of the Surface Performance Graded (SPG) Specification for Seal Coat Binders in Service (TxDOT 5-6616).

The benefit/cost ratio associated with these chip seal binder research and implementation efforts identified above is estimated based on details contained in Appendix E.

The SPG specification and binder selection system developed and validated in two TxDOT research projects and this implementation project provides improved chip seal performance by selecting binders that are more suitable for use under individual project climate and traffic conditions. The specification better defines binders that have improved properties at hot temperatures and in cold temperatures, better adhesion during construction, more elasticity over a wide temperature range, and reduced age hardening. Asphalt binders that are selected with this specification for use with a chip seal on a particular project are more uniform in their properties. Thus the performance benefits of this improved binder specification include the following:

- Improved binder adhesion during construction.
- Reduced short-term (first winter) aggregate loss.
- Reduced short-term bleeding (first summer).
- Reduced reflection cracking (three or more years after construction).

Economic savings associated with the improvement of chip seal performance are defined in Appendix E where the information presented can be used to estimate economic benefits making a number of different assumptions others than those used to develop the conclusions presented in this section.

Premature distress occurs on a number of chip seal projects on an annual basis. This distress must be addressed by activities funded in maintenance and/or construction budgets. If 3 percent of all chip seal pavement surfaces placed on an annual basis needed some form of maintenance, a cost of approximately $12–15 million would be incurred. If 1 percent or 5 percent of the surfaces were in need of repair, an expenditure of the order of $5–6 million or $20–25 million, respectively, would be needed.

It is not unreasonable to assume that the use of an improved binder selection process for individual projects would prevent the need for routine maintenance on about 1 percent of the surfaces chip sealed annually. This would result in a saving of about $5 million annually. The benefit/cost ratio of this group of research and implementation projects at a cost of approximately $150,000 per year will provide a benefit/cost ratio of $5,000,000/$150,000 or about 30:1. If the benefit was overestimated by 50 percent, the benefit/cost ratio is still substantial at 15:1.

Economic benefits of research, development, and implementation programs can also be estimated by considering life extension of the maintenance treatment. An increase in life extension of one year on 5 percent of the chip seal surfaces placed on annual basis results in a cost savings of about $2 million. If 10 or 20 percent of the pavements have a life extension of one year, the cost savings on an annual basis will be $4 and $8 million, respectively.

Assume that about 10 percent of the chip seal pavements placed in any given year have an increased life of one year as a result of the use of an improved binder. The benefit/cost ratio associated with this research and implementation is then $4,000,000/$150,000 or about 25:1. If the benefit was overestimated by 50 percent, the benefit cost ratio is still substantial at 12:1.

The information presented in this section and in Appendix E indicates that expenditures for research, development, and implementation efforts aimed at improving chip seal performance are cost effective.

FUTURE IMPROVEMENTS

Based on the conclusions of the current implementation effort, the following are some topics that could potentially be explored in the future to further improve the SPG specification:

- At high temperatures, modification of the MSCR test protocol and thresholds for chip seal binders.
- At low temperatures, consideration of DTc based on BBR testing and development of an associated threshold, where this parameter is defined as the critical temperature when S equals 500 MPa minus the critical temperature when m-value equals 0.24 or the difference between the S-controlled and m-controlled continuous low temperature SPG.
- At low temperatures, field validation of selected low temperature 4-mm DSR property and threshold to replace BBR testing.
- Merger of the SPG specification developed through TxDOT research projects and this implementation project and the EPG specification developed in NCHRP Project 9-50.

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APPENDIX A: CONTRUCTION AND PERFORMANCE REPORTS

APPENDIX A: CONSTRUCTION AND PERFORMANCE REPORTS

HS: 16-ABL-1

District – Abilene
County – Howard County
Highway – BI0020G
Near – Big Spring

Table A-1. Abilene BI0020G Test Sections.

Test Section	Lane	BRM	ERM
BI0020G-1	K1	308+0.5	308+0.6
BI0020G-2	K6	308+0.6	308+0.5

Table A-2. Abilene BI0020G Construction Details.

Contractor	Lipham, Aspermont, TX		
Date	05/09/2016		
Binder Type	SPG 73-19	Binder Source	Alon, Big Spring
Agg. Type	PB Gr 4	Agg. Source	Burkett, Graham, TX
Weather	Hot, 100°F		
AADT	3,700		
2016 %Trk	45		
2016 AADT Level	M		

Table A-3. Abilene BI0020G Binder and Aggregate Application Details.

Test Section	BI0020G-1	BI0020G-2
Binder rate	0.36 Gal/SY	0.36 Gal/SY
Aggregate application rate	115 SY/CY	115 SY/CY
Binder Application Time	-	-
Time until Rock Added	-	-
Time to First Roll	-	-

Construction Notes

Work had started when the field engineer arrived for the pre-construction survey, so there was only time to set up one test section. Construction started on inside lanes. The chip spreader stayed relatively close to the distributor and the rollers were close to the spreader.

Pre- and Post-Construction Distress Surveys

The test section was relatively flat and out on the east edge of town. While there are several driveways, there was little traffic entering the highway. There was a church and some closed businesses in the area.

Distresses are expressed in area for bleeding (BL), raveling (Rav), and patching (patch) and their severity noted as low (L), medium (M), or high (H). The percent embedment (EMB) is reported for both the wheel path (WP) and between the wheel paths (BWP).

Table A-4. Abilene BI0020G Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
BI0020G-1	K1	5/9/2016	Pre	2640	0	0	0	0	0	0	95	80
BI0020G-1	K1	10/5/2016	POST	450	2868	0	0	0	0	0	95	80
BI0020G-1	K1	3/29/2017	POST	2240	600	0	0	0	0	0	75	30
BI0020G-1	K1	4/23/2018	POST	3568	0	0	0	0	0	0	95	75
BI0020G-2	K6	5/9/2016	Pre	3696	0	0	0	0	0	0	95	80
BI0020G-2	K6	10/5/2016	POST	1368	1700	0	0	0	0	0	95	80
BI0020G-2	K6	3/29/2017	POST	2740	0	0	0	0	0	0	50	30
BI0020G-2	K6	4/23/2018	POST	2112	0	0	0	0	0	0	95	75

Pre-Construction Pictures (2016)

Figure A-1. BI0020G-1, Overall.

Figure A-2. BI0020G-1, Outside WP.

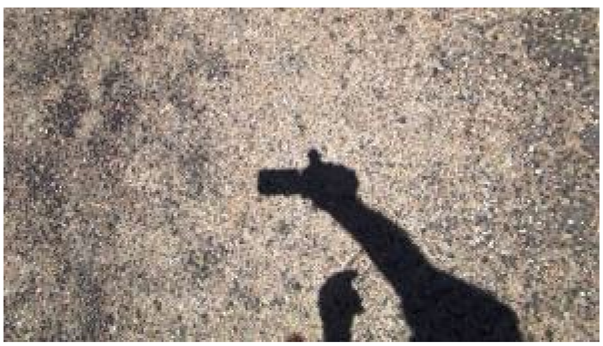

Figure A-3. BI0020G-1, BWP.

Figure A-4. BI0020G-1, Inside WP.

Figure A-5. BI0020G-2, Overall.

Figure A-6. BI0020G-2, Outside WP.


Figure A-7. BI0020G-2, BWP.


Figure A-8. BI0020G-2, Inside WP.

Post-Construction Pictures (2016)


Figure A-9. BI0020G-1, Overall.


Figure A-10. BI0020G-1, Outside WP.


Figure A-11. BI0020G-1, BWP.


Figure A-12. BI0020G-1, Inside WP.


Figure A-13. BI0020G-2, Overall.


Figure A-14. BI0020G-2, Outside WP.


Figure A-15. BI0020G-2, BWP. **Figure A-16. BI0020G-2, Inside WP.**

Post-Construction Pictures (2017)


Figure A-17. BI0020G-1, Overall. **Figure A-18. BI0020G-1, Outside WP.**


Figure A-19. BI0020G-1, BWP. **Figure A-20. BI0020G-1, Inside WP.**


Figure A-21. BI0020G-2, Overall. **Figure A-22. BI0020G-2, Outside WP.**

Figure A-23. BI0020G-2, BWP.

Figure A-24. BI0020G-2, Inside WP.

Post-Construction Pictures (2018)

Figure A-25. BI0020G-1, Overall.

Figure A-26. BI0020G-1, Outside WP.

Figure A-27. BI0020G-1, BWP.

Figure A-28. BI0020G-1, Inside WP.

Figure A-29. BI0020G-2, Overall.

Figure A-30. BI0020G-2, Outside WP.


Figure A-31. BI0020G-2, BWP.


Figure A-32. BI0020G-2, Inside WP.

HS: 16-ABL-2

District – Abilene
County – Jones
Highway – SH0092
Near – Hamlin

Table A-5. Abilene SH0092 Test Sections.

Test Section	Lane	BRM	ERM
SH0092-1	K1	394+0.1	394+0.2
SH0092-2	K6	394+0.2	394+0.1
SH0092-3	K1	396+0.0	396+0.1
SH0092-4	K6	396+0.1	396+0.0

Table A-6. Abilene SH0092 Construction Details.

Contractor	Lipham, Aspermont, TX		
Date	08/01/2016		
Binder Type	SPG 73-19	Binder Source	Saginaw
Agg. Type	PB Gr 4	Agg. Source	Burkett, Graham, TX
Weather	Windy, 95°F		
AADT	2500		
2016 %Trk	30		
2016 AADT Level	M		

Table A-7. Abilene SH0092 Binder and Aggregate Application Details.

Test Section	SH0092-1	SH0092-2	SH0092-3	SH0092-4
Binder rate	0.38 Gal/SY	0.38 Gal/SY	0.38 Gal/SY	0.38 Gal/SY
Aggregate application rate	115 SY/CY	115 SY/CY	115 SY/CY	115 SY/CY
Binder Application Time	0:00	0:00	0:00	0:00
Time until Rock Added	3:55	8:34	8:42	3:33/6:04
Time to First Roll	6:07	11:57	12:55	10:12

Construction Notes

Good, consistent test sections. Sections 1 and 2 had low severity bleeding and some sealed longitudinal cracking. Sections 3 and 4 had more sealed cracks, but no flushing. All sections were in straightaways. The binder source changed during this project because the contractor was having difficulty getting material. The new source was Saginaw. On section 4, they stopped in the middle of the test section to remove huge clumps of grass from hopper. Apparent raveling but most likely low aggregate application rate during construction.

__Pre- and Post-Construction Distress Surveys__

Table A-8. Abilene SH0092 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
SH0092-1	K1	5/8/2016	Pre	5808	0	0	0	0	0	0	95	50
SH0092-1	K1	10/5/2016	POST	200	0	0	1456	0	0	0	75	40
SH0092-1	K1	3/29/2017	POST	1156	0	0	0	0	0	0	60	10
SH0092-1	K1	4/24/2018	POST	1056	0	0	850	0	0	0	40	20
SH0092-2	K6	5/8/2016	Pre	6864	0	0	0	0	0	0	95	90
SH0092-2	K6	10/5/2016	POST	0	0	0	1400	0	0	0	50	30
SH0092-2	K6	3/29/2017	POST	728	0	0	0	0	0	0	40	20
SH0092-2	K6	4/24/2018	POST	650	0	0	0	0	0	0	80	50
SH0092-3	K1	5/8/2016	Pre	0	0	0	0	0	0	0	95	95
SH0092-3	K1	10/5/2016	POST	0	0	0	200	0	0	0	35	15
SH0092-3	K1	3/29/2017	POST	0	0	0	150	50	0	0	20	10
SH0092-3	K1	4/24/2018	POST	0	0	0	1350	150	0	0	20	10
SH0092-4	K6	5/8/2016	Pre	0	0	0	0	0	0	0	95	95
SH0092-4	K6	10/5/2016	POST	0	0	0	0	0	0	0	30	10
SH0092-4	K6	3/29/2017	POST	0	0	0	0	0	0	0	50	10
SH0092-4	K6	4/24/2018	POST	728	0	0	0	0	0	0	20	10

Pre-Construction Pictures (2016)

Figure A-33. SH0092-1, Overall.

Figure A-34. SH0092-1, Outside WP.

Figure A-35. SH0092-1, BWP.

Figure A-36. SH0092-1, Inside WP.


Figure A-37. SH0092-2, Overall.


Figure A-38. SH0092-2, Outside WP.


Figure A-39. SH0092-2, BWP.


Figure A-40. SH0092-2, Inside WP.


Figure A-41. SH0092-3, Overall.


Figure A-42. SH0092-3, Outside WP.


Figure A-43. SH0092-3, BWP.


Figure A-44. SH0092-3, Inside WP.

Figure A-45. SH0092-4, Overall

Figure A-46. SH0092-4, Outside WP

Figure A-47. SH0092-4, BWP

Figure A-48. SH0092-4, Inside WP

Post-Construction Pictures (2016)

Figure A-49. SH0092-1, Overall.

Figure A-50. SH0092-1, Outside WP.

Figure A-51. SH0092-1, BWP.

Figure A-52. SH0092-1, Inside WP.

Figure A-53. SH0092-2, Overall.

Figure A-54. SH0092-2, Outside WP.

Figure A-55. SH0092-2, BWP.

Figure A-56. SH0092-2, Inside WP.

Figure A-57. SH0092-3, Overall.

Figure A-58. SH0092-3, Outside WP.

Figure A-59. SH0092-3, BWP.

Figure A-60. SH0092-3, Inside WP.

Figure A-61. SH0092-4, Overall.

Figure A-62. SH0092-4, Outside WP.

Figure A-63. SH0092-4, BWP.

Figure A-64. SH0092-4, Inside WP.

Post-Construction Pictures (2017)

Figure A-65. SH0092-1, Overall.

Figure A-66. SH0092-1, Outside WP.

Figure A-67. SH0092-1, BWP.

Figure A-68. SH0092-1, Inside WP.

Figure A-69. SH0092-2, Overall.

Figure A-70. SH0092-2, Outside WP.

Figure A-71. SH0092-2, BWP.

Figure A-72. SH0092-2, Inside WP.

Figure A-73. SH0092-3, Overall.

Figure A-74. SH0092-3, Outside WP.

Figure A-75. SH0092-3, BWP.

Figure A-76. SH0092-3, Inside WP.

Figure A-77. SH0092-4, Overall.

Figure A-78. SH0092-4, Outside WP.

Figure A-79. SH0092-4, BWP.

Figure A-80. SH0092-4, Inside WP.

Post-Construction Pictures (2018)

Figure A-81. SH0092-1, Overall.

Figure A-82. SH0092-1, Outside WP.

Figure A-83. SH0092-1, BWP.

Figure A-84. SH0092-1, Inside WP.

Figure A-85. SH0092-2, Overall.

Figure A-86. SH0092-2, Outside WP.

Figure A-87. SH0092-2, BWP.

Figure A-88. SH0092-2, Inside WP.

Figure A-89. SH0092-3, Overall.

Figure A-90. SH0092-3, Outside WP.

Figure A-91. SH0092-3, BWP.

Figure A-92. SH0092-3, Inside WP.

Figure A-93. SH0092-4, Overall.

Figure A-94. SH0092-4, Outside WP.

Figure A-95. SH0092-4, BWP.

Figure A-96. SH0092-4, Inside WP.

HS: 16-AMA-1

District – Amarillo | County – Ochiltree
Highway – US0083 | Near – Perryton

Table A-9. Amarillo US0083 Test Sections.

Test Section	Lane	BRM	ERM
US0083-1	K1	012+0.0	012+0.1
US0083-2	K6	012+0.1	012+0.0
US0083-3	K1	014+0.0	014+0.1
US0083-4	K6	014+0.1	014+0.0

Table A-10. Amarillo US0083 Construction Details.

Contractor	Missouri Petroleum, Dallas		
Date	08/01/2016		
Binder Type	SPG64-25	Binder Source	Missouri Petroleum, Dallas
Agg. Type	PC, Gr 3	Agg. Source	Big Creek, Borger, TX
Weather	Hot, 100°F		
AADT	3500		
2016 %Trk	28		
2016 AADT Level	M		

Table A-11. Amarillo US0083 Binder and Aggregate Application Details.

Test Section	US0083-1	US0083-2	US0083-3	US0083-4
Binder rate	0.45 Gal/SY	0.45 Gal/SY	0.45 Gal/SY	0.45 Gal/SY
Aggregate application rate	100 SY/CY	100 SY/CY	100 SY/CY	100 SY/CY
Binder Application Time	-	-	-	-
Time until Rock Added	-	-	-	-
Time to First Roll	-	-	-	-

Construction Notes

The sections were very consistent and straight. Some cracking was observed next to the edge stripe. The test section was sealed one day earlier than scheduled, so the field engineer was not present during construction. The samples were acquired the next morning on SH0305.

Lower aggregate application rate lead to excessive daylight (area around each aggregate). Some crack seal was reflecting through, but was not classified as bleeding during inspection.

Pre- and Post-Construction Distress Surveys

Table A-12. Amarillo US0083 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
US0083-1	K1	5/17/2016	Pre	0	0	0	0	0	0	0	75	75
US0083-1	K1	8/15/2016	POST	0	0	0	0	0	0	0	25	10
US0083-1	K1	3/28/2017	POST	0	0	0	500	0	0	0	50	15
US0083-1	K1	4/25/2018	POST	0	0	0	0	0	0	0	40	20
US0083-2	K6	5/17/2016	Pre	0	0	0	0	0	0	0	75	75
US0083-2	K6	8/15/2016	POST	0	0	0	0	0	0	0	20	10
US0083-2	K6	3/28/2017	POST	0	0	0	0	0	0	0	40	10
US0083-2	K6	4/25/2018	POST	0	0	0	400	0	0	0	40	20
US0083-3	K1	5/17/2016	Pre	0	0	0	0	0	0	0	75	75
US0083-3	K1	8/15/2016	POST	0	0	0	0	0	0	0	20	10
US0083-3	K1	3/28/2017	POST	0	0	0	0	0	0	0	20	20
US0083-3	K1	4/25/2018	POST	0	0	0	0	0	0	0	60	20
US0083-4	K6	5/17/2016	Pre	0	0	0	0	0	0	0	75	75
US0083-4	K6	8/15/2016	POST	0	0	0	0	0	0	0	20	10
US0083-4	K6	3/28/2017	POST	0	0	0	1056	0	0	0	30	10
US0083-4	K6	4/25/2018	POST	0	0	0	1084	0	0	0	60	20

Pre-Construction Pictures (2016)

Figure A-97. US0083-1, Overall.

Figure A-98. US0083-1, Outside WP.

Figure A-99. US0083-1, BWP.

Figure A-100. US0083-1, Inside WP.

Figure A-101. US0083-2, Overall.

Figure A-102. US0083-2, Outside WP.

Figure A-103. US0083-2, BWP.

Figure A-104. US0083-2, Inside WP.

Figure A-105. US0083-3, Overall.

Figure A-106. US0083-3, Outside WP.

Figure A-107. US0083-3, BWP.

Figure A-108. US0083-3, Inside WP.

Figure A-109. US0083-4, Overall.

Figure A-110. US0083-4, Outside WP.

Figure A-111. US0083-4, BWP.

Figure A-112. US0083-4, Inside WP.

Post-Construction Pictures (2016)

Figure A-113. US0083-1, Overall.

Figure A-114. US0083-1, Outside WP.

Figure A-115. US0083-1, BWP.

Figure A-116. US0083-1, Inside WP.

Figure A-117. US0083-2, Overall.

Figure A-118. US0083-2, Outside WP.

Figure A-119. US0083-2, BWP.

Figure A-120. US0083-2, Inside WP.

Figure A-121. US0083-3, Overall.

Figure A-122. US0083-3, Outside WP.

Figure A-123. US0083-3, BWP.

Figure A-124. US0083-3, Inside WP.


Figure A-125. US0083-4, Overall.


Figure A-126. US0083-4, Outside WP.


Figure A-127. US0083-4, BWP.


Figure A-128. US0083-4, Inside WP.

Post-Construction Pictures (2017)


Figure A-129. US0083-1, Overall.


Figure A-130. US0083-1, Outside WP.


Figure A-131. US0083-1, BWP.


Figure A-132. US0083-1, Inside WP.

Figure A-133. US0083-2, Overall.

Figure A-134. US0083-2, Outside WP.

Figure A-135. US0083-2, BWP.

Figure A-136. US0083-2, Inside WP.

Figure A-137. US0083-3, Overall.

Figure A-138. US0083-3, Outside WP.

Figure A-139. US0083-3, BWP.

Figure A-140. US0083-3, Inside WP.


Figure A-141. US0083-4, Overall.


Figure A-142. US0083-4, Outside WP.


Figure A-143. US0083-4, BWP.


Figure A-144. US0083-4, Inside WP.

Post-Construction Pictures-2018


Figure A-145. US0083-1, Overall.


Figure A-146. US0083-1, Outside WP.


Figure A-147. US0083-1, BWP.


Figure A-148. US0083-1, Inside WP.

Figure A-149. US0083-2, Overall.

Figure A-150. US0083-2, Outside WP.

Figure A-151. US0083-2, BWP.

Figure A-152. US0083-2, Inside WP.

Figure A-153. US0083-3, Overall.

Figure A-154. US0083-3, Outside WP.

Figure A-155. US0083-3, BWP.

Figure A-156. US0083-3, Inside WP.

Figure A-157. US0083-4, Overall.

Figure A-158. US0083-4, Outside WP.

Figure A-159. US0083-4, BWP.

Figure A-160. US0083-4, Inside WP.

HS: 16-AMA-2

District – Amarillo	County – Hartley
Highway – FM0281	Near – Dalhart

Table A-13. Amarillo FM0281 Test Sections.

Test Section	Lane	BRM	ERM
FM0281-1	K1	266+0.0	266+0.1
FM0281-2	K6	266+0.1	266+0.0
FM0281-3	K1	268+0.0	268+0.1
FM0281-4	K6	268+0.1	266+0.0

Table A-14. Amarillo FM0281 Construction Details.

Contractor	Missouri Petroleum, Dallas		
Date	08/15/2016		
Binder Type	SPG64-25	Binder Source	Missouri Petroleum, Dallas
Agg. Type	PC, Gr 4S	Agg. Source	Big Creek, Borger, TX
Weather	85°F, Windy		
AADT	2627		
2016 % Trk	42.9		
2016 AADT Level	M		

Table A-15. Amarillo FM0281 Binder and Aggregate Application Details.

Test Section	FM0281-1	FM0281-2	FM0281-3	FM0281-4
Binder rate	0.41 Gal/SY	0.41 Gal/SY	0.41 Gal/SY	0.41 Gal/SY
Aggregate application rate	110 SY/CY	110 SY/CY	110 SY/CY	110 SY/CY
Binder Application Time	0:00	0:00	0:00	0:00
Time until Rock Added	5:53	5:04	3:34	4:12
Time to First Roll	7:03	7:50	5:04	8:46

Construction Notes

Sections had strip seal patching in both WPs, which extended for miles. Good, consistent, sections in straightaways. Field engineer had to wait for pavement temperature to raise to 60°F, but this was several miles from the test section.

Lower aggregate application rate along fog stripe lead to excessive daylight (area around each aggregate), which was classified as raveling during inspection.

Pre- and Post-Construction Distress Surveys

Table A-16. Amarillo FM0281 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM0281-1	K1	5/17/2016	Pre	0	0	0	0	0	0	4224	75	75
FM0281-1	K1	10/6/2016	POST	0	0	0	606	0	0	0		
FM0281-1	K1	3/28/2017	POST	0	0	0	528	0	0	0	50	10
FM0281-1	K1	4/24/2018	POST	384	0	0	3212	0	0	0	90	60
FM0281-2	K6	5/17/2016	Pre	0	0	0	0	0	0	5280	75	85
FM0281-2	K6	10/6/2016	POST	328	0	0	0	0	0	0	25	15
FM0281-2	K6	3/28/2017	POST	456	0	0	0	0	0	0	30	10
FM0281-2	K6	4/24/2018	POST	1484	1156	0	0	0	0	0	90	50
FM0281-3	K1	5/17/2016	Pre	0	0	0	0	0	0	4224	75	85
FM0281-3	K1	10/6/2016	POST	x	x	x	x	x	x	x	x	x
FM0281-3	K1	3/28/2017	POST	x	x	x	x	x	x	x	x	x
FM0281-3	K1	4/24/2018	POST	x	x	x	x	x	x	x	x	x
FM0281-4	K6	5/17/2016	Pre	0	0	0	0	0	0	5280	x	x
FM0281-4	K6	10/6/2016	POST	x	x	x	x	x	x	x	x	x
FM0281-4	K6	3/28/2017	POST	x	x	x	x	x	x	x	x	x
FM0281-4	K1	4/24/2018	POST	x	x	x	x	x	x	x	x	x

Pre-Construction Pictures (2016)

Figure A-161. FM0281-1, Overall.

Figure A-162. FM0281-1, Outside WP.

Figure A-163. FM0281-1, BWP.

Figure A-164. FM0281-1, Inside WP.

Figure A-165. FM0281-2, Overall. **Figure A-166. FM0281-2, Outside WP.**

Figure A-167. FM0281-2, BWP. **Figure A-168. FM0281-2, Inside WP.**

Figure A-169. FM0281-3, Overall. **Figure A-170. FM0281-3, Outside WP.**

Figure A-171. FM0281-3, BWP. **Figure A-172. FM0281-3, Inside WP.**

Figure A-173. FM0281-4, Overall. **Figure A-174. FM0281-4, Outside WP.**

Figure A-175. FM0281-4, BWP. **Figure A-176. FM0281-4, Inside WP.**

Post-Construction Pictures (2016)

Figure A-177. FM0281-1, Overall. **Figure A-178. FM0281-1, Outside WP.**

Figure A-179. FM0281-1, BWP. **Figure A-180. FM0281-1, Inside WP.**

Figure A-181. FM0281-2, Overall. **Figure A-182. FM0281-2, Outside WP.**

Figure A-183. FM0281-2, BWP. **Figure A-184. FM0281-2, Inside WP.**

Figure A-185. FM0281-3, Overall. **Figure A-186. FM0281-3, Outside WP.**

Figure A-187. FM0281-3, BWP. **Figure A-188. FM0281-3, Inside WP.**

Figure A-189. FM0281-4, Farm Equipment.

Figure A-190. FM0281-4, Farm Equipment.

Post-Construction Pictures (2017)

Figure A-191. FM0281-1, Overall.

Figure A-192. FM0281-1, Outside WP.

Figure A-193. FM0281-1, BWP.

Figure A-194. FM0281-1, Inside WP.

Figure A-195. FM0281-2, Overall.

Figure A-196. FM0281-2, Outside WP.

Figure A-197. FM0281-2, BWP. **Figure A-198. FM0281-2, Inside WP.**

Sections FM0281-3 and FM0281-4 were scarred by farm equipment.

Post-Construction Pictures (2018)

Figure A-199. FM0281-1, Overall. **Figure A-200. FM0281-1, Outside WP.**

Figure A-201. FM0281-1, BWP. **Figure A-202. FM0281-1, Inside WP.**

Figure A-203. FM0281-2, Overall. **Figure A-204. FM0281-2, Outside WP.**

Figure A-205. FM0281-2, BWP.

Figure A-206. FM0281-2, Inside WP.

Sections FM0281-3 and FM0281-4 were scarred by farm equipment.

HS: 16-AMA-3 (no binder collected or received)

District – Amarillo
County – Randall
Highway – FM1541
Near – Amarillo

Table A-17. Amarillo FM1541 Test Sections.

Test Section	Lane	BRM	ERM
FM1541-1	K1	110+0.0	110+0.1
FM1541-2	K6	110+0.1	110+0.0
FM1541-3	K1	112+0.0	112+0.1
FM1541-4	K6	112+0.1	112+0.0

Table A-18. Amarillo FM1541 Construction Details.

Contractor	Missouri Petroleum, Dallas		
Date	09/12/2016		
Binder Type	SPG 64-25	Binder Source	Wright Heartland, Saginaw
Agg. Type	PC, Gr 4S	Agg. Source	Big Creek, Borger, TX
Weather	85°F+, windy		
AADT	3400		
2016 %Trk	3.7		
2016 AADT Level	M		

Table A-19. Amarillo FM1541 Binder and Aggregate Application Details.

Test Section	FM1541-1	FM1541-2	FM1541-3	FM1541-4
Binder rate	Approx. 0.5 Gal/SY			
Aggregate application rate	110 SY/CY			
Binder Application Time	NA	NA	NA	NA
Time until Rock Added	NA	NA	NA	NA
Time to First Roll	NA	NA	NA	NA

Construction Notes

Sections 1, 2 had significant amount of sealed block cracks, in straightaway. Halfway through, bleeding changes from medium to low (1), or vice versa (2). Sections 3, 4 have less cracking, still sealed. Bleeding changes from medium to low as in other sections. Other than changes in bleeding, sections are very consistent. The field engineer was not present during construction.

Pre- and Post-Construction Distress Surveys

Table A-20. Amarillo FM1541 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM1541-1	K1	5/16/2016	Pre	2224	3250	0	0	0	0	0	100	100
FM1541-1	K1	10/6/2016	POST	650	0	0	0	0	0	0	50	10
FM1541-1	K1	3/28/2017	POST	728	0	0	1912	600	0	0	50	20
FM1541-1	K1	4/24/2018	POST	0	3168	0	1684	0	0	0	95	75
FM1541-2	K6	5/16/2016	Pre	5586	0	0	0	0	0	0	100	95
FM1541-2	K6	10/6/2016	POST	1456	0	0	0	0	0	0	50	15
FM1541-2	K6	3/28/2017	POST	1056	0	0	1868	200	0	0	50	20
FM1541-2	K6	4/24/2018	POST	300	2868	0	0	300	0	0	95	40
FM1541-3	K1	5/16/2016	Pre	984	2584	0	0	0	0	0	100	80
FM1541-3	K1	10/6/2016	POST	100	0	0	2206	100	0	0	50	10
FM1541-3	K1	3/28/2017	POST	1056	0	0	3696	0	0	0	50	10
FM1541-3	K1	4/24/2018	POST	984	2584	0	956	0	0	0	85	25
FM1541-4	K6	5/16/2016	Pre	1056	1584	0	0	0	0	0	90	40
FM1541-4	K6	10/6/2016	POST	100	0	0	0	0	0	0	40	10
FM1541-4	K6	3/28/2017	POST	0	0	0	4468	0	0	0	65	10
FM1541-4	K6	4/24/2018	POST	1112	1500	0	0	300	0	0	90	25

Pre-Construction Pictures (2016)

Figure A-207. FM1541-1, Overall.

Figure A-208. FM1541-1, Outside WP.

Figure A-209. FM1541-1, BWP.

Figure A-210. FM1541-1, Inside WP.

Figure A-211. FM1541-2, Overall.

Figure A-212. FM1541-2, Outside WP.

Figure A-213. FM1541-2, Inside WP.

Figure A-214. FM1541-3, Overall.

Figure A-215. FM1541-3, Outside WP.

Figure A-216. FM1541-3, BWP.

Figure A-217. FM1541-3, Inside WP.


Figure A-218. FM1541-4, Overall.


Figure A-219. FM1541-4, Outside WP.


Figure A-220. FM1541-4, BWP.


Figure A-221. FM1541-4, Inside WP.

Post-Construction Pictures (2016)


Figure A-222. FM1541-1, Overall.


Figure A-223. FM1541-1, Outside WP.


Figure A-224. FM1541-1, BWP.


Figure A-225. FM1541-1, Inside WP.


Figure A-226. FM1541-2, Overall.


Figure A-227. FM1541-2, Outside WP.


Figure A-228. FM1541-2, BWP.


Figure A-229. FM1541-2, Inside WP.


Figure A-230. FM1541-3, Overall.


Figure A-231. FM1541-3, Outside WP.


Figure A-232. FM1541-3, BWP.


Figure A-233. FM1541-3, Inside WP.

Figure A-234. FM1541-4, Overall.

Figure A-235. FM1541-4, Outside WP.

Figure A-236. FM1541-4, BWP.

Figure A-237. FM1541-4, Inside WP.

Post-Construction Pictures (2017)

Figure A-238. FM1541-1, Overall.

Figure A-239. FM1541-1, Outside WP.

Figure A-240. FM1541-1, BWP.

Figure A-241. FM1541-1, Inside WP.

Figure A-242. FM1541-2, Overall.

Figure A-243. FM1541-2, Outside WP.

Figure A-244. FM1541-2, BWP.

Figure A-245. FM1541-2, Inside WP.

Figure A-246. FM1541-3, Overall.

Figure A-247. FM1541-3, Outside WP.

Figure A-248. FM1541-3, BWP.

Figure A-249. FM1541-3, Inside WP.

Figure A-250. FM1541-4, Overall.

Figure A-251. FM1541-4, Outside WP.

Figure A-252. FM1541-4, BWP.

Figure A-253. FM1541-4, Inside WP.

Post-Construction Pictures (2018)

Figure A-254. FM1541-1, Overall.

Figure A-255. FM1541-1, Outside WP.

Figure A-256. FM1541-1, BWP.

Figure A-257. FM1541-1, Inside WP.


Figure A-258. FM1541-2, Overall.


Figure A-259. FM1541-2, Outside WP.


Figure A-260. FM1541-2, BWP.


Figure A-261. FM1541-2, Inside WP.


Figure A-262. FM1541-3, Overall.


Figure A-263. FM1541-3, Outside WP.


Figure A-264. FM1541-3, BWP.


Figure A-265. FM1541-3, Inside WP.

Figure A-266. FM1541-4, Overall.

Figure A-267. FM1541-4, Outside WP.

Figure A-268. FM1541-4, BWP.

Figure A-269. FM1541-4, Inside WP.

HS: 17-AMA-1

District – Amarillo | County – Hartley
Highway – FM0297 | Near – Dalhart

Table A-21. Amarillo FM0297A Test Sections.

Test Section	Lane	BRM	ERM
FM0297-1	K1	264+0.0	264+0.1
FM0297-2	K6	264+0.1	264+0.0

Table A-22. Amarillo FM0297A Construction Details.

Contractor	Lipham, Aspermont, TX		
Date	09/02/2017		
Binder Type	SPG 73-25	Binder Source	Alon, Big Spring
Agg Type	Gr3, PC	Agg Source	Boys Ranch
Weather	82°		
AADT	1169		
2016 %Trk	41.4		
2016 AADT Level	M		

Table A-23. Amarillo FM0297A Binder and Aggregate Application Details.

Test Section	FM0297-1	FM0297-2
Binder rate	0.56 Gal/SY	0.56 Gal/SY
Aggregate rate	110 SY/CY	110 SY/CY
Binder Application Time	-	-
Time until Rock Added	-	-
Time to First Roll	-	-

Pre- and Post-Construction Distress Surveys

Table A-24. Amarillo FM0297A Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM0297-1	K1	9/1/2017	Pre	3696	2640	0	0	0	0	0	90	80
FM0297-1	K1	4/24/2018	POST	0	0	0	1484	0	0	0	20	10
FM0297-2	K6	9/1/2017	Pre	1584	3168	0	0	0	0	0	95	75
FM0297-2	K6	4/24/2018	POST	0	0	0	4680	0	0	0	20	10

Pre-Construction Pictures (2017)

Figure A-270. FM0297-1, Overall.

Figure A-271. FM0297-1, Outside WP.

Figure A-272. FM0297-1, BWP.

Figure A-273. FM0297-1, Inside WP.

Figure A-274. FM0297-2, Overall.

Figure A-275. FM0297-2, Outside WP.

Figure A-276. FM0297-2, BWP.

Figure A-277. FM0297-2, Inside WP.

Post-Construction Pictures (2018)

Figure A-278. FM0297-1, Overall.

Figure A-279. FM0297-1, Outside WP.

Figure A-280. FM0297-1, BWP.

Figure A-281. FM0297-1, Inside WP.

Figure A-282. FM0297-2, Overall.

Figure A-283. FM0297-2, Outside WP.

Figure A-284. FM0297-2, BWP.

Figure A-285. FM0297-2, Inside WP.

HS: 17-AMA-2

District – Amarillo
County – Hartley
Highway – FM0297
Near – Dalhart

Table A-25. Amarillo FM0297B Test Sections.

Test Section	Lane	BRM	ERM
FM0297-5	K1	270+0.0	270+0.1
FM0297-6	K6	270+0.1	270+0.0
FM0297-7	K1	274+0.0	274+0.1
FM0297-8	K6	274+0.1	274+0.0

Table A-26. Amarillo FM0297B Construction Details.

Contractor	Lipham, Aspermont, TX		
Date	08/31/2017		
Binder Type	SPG 73-25	Binder Source	Alon, Big Spring
Agg. Type	Gr3, PC	Agg. Source	Boys Ranch
Weather	82º		
AADT	674		
2016 %Trk	41.4		
2016 AADT Level	M		

Table A-27. Amarillo FM0297B Binder and Aggregate Application Details.

Test Section	FM0297-5	FM0297-6	FM0297-7	FM0297-8
Binder rate	0.56 Gal/SY	0.56 Gal/SY	0.56 Gal/SY	0.56 Gal/SY
Aggregate rate	110 SY/CY	110 SY/CY	110 SY/CY	110 SY/CY
Binder Application Time	0:00			
Time until Rock Added				
Time to First Roll				

Pre- and Post-Construction Distress Surveys

Table A-28. Amarillo FM0297B Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM0297-5	K1	8/31/2017	Pre	3168	2640	0	0	0	0	0	100	95
FM0297-5	K1	4/24/2018	POST	0	0	0	1856	0	0	0	20	10
FM0297-6	K6	8/31/2017	Pre	1056	3696	0	0	0	0	0	100	90
FM0297-6	K6	4/24/2018	POST	0	0	0	2412	0	0	0	20	10
FM0297-7	K1	8/31/2017	Pre	1056	4224	0	0	0	0	0	100	95
FM0297-7	K1	4/24/2018	POST	0	0	0	3968	0	656	0	20	10
FM0297-8	K6	8/31/2017	Pre	0	0	0	0	0	0	5280	X	X
FM0297-8	K6	4/24/2018	POST	0	0	0	3168	0	0	0	60	25

Pre-Construction Pictures (2017)

Figure A-286. FM0297-5, Overall.

Figure A-287. FM0297-5, Outside WP.

Figure A-288. FM0297-5, BWP.

Figure A-289. FM0297-5, Inside WP.

Figure A-290. FM0297-6, Overall.

Figure A-291. FM0297-6, Outside WP.

Figure A-292. FM0297-6, BWP.

Figure A-293. FM0297-6, Inside WP.

Figure A-294. FM0297-7, Overall.

Figure A-295. FM0297-7, Outside WP.

Figure A-296. FM0297-7, BWP.

Figure A-297. FM0297-7, Inside WP.

Figure A-298. FM0297-8, Overall.

Figure A-299. FM0297-8, Outside WP.

Figure A-300. FM0297-8, BWP.

Figure A-301. FM0297-8, Inside WP.

Post-Construction Pictures (2018)


Figure A-302. FM0297-5, Overall.


Figure A-303. FM0297-5, Outside WP.


Figure A-304. FM0297-5, BWP.


Figure A-305. FM0297-5, Inside WP.


Figure A-306. M0297-6, Overall.


Figure A-307. FM0297-6, Outside WP.


Figure A-308. FM0297-6, BWP.


Figure A-309. FM0297-6, Inside WP.

Figure A-310. FM0297-7, Overall.

Figure A-311. FM0297-7, Outside WP.

Figure A-312. FM0297-7, BWP.

Figure A-313. FM0297-7, Inside WP.

Figure A-314. FM0297-8, Overall.

Figure A-315. FM0297-8, Outside WP.

Figure A-316. FM0297-8, BWP.

Figure A-317. FM0297-8, Inside WP.

HS: 17-AMA-3

District – Amarillo County – Potter
Highway – FM1719 Near – Amarillo

Table A-29. Amarillo FM1719 Test Sections.

Test Section	Lane	BRM	ERM
FM1719-1	K1	102+0.0	102+0.1
FM1719-2	K6	102+0.1	102+0.0

Construction Notes

The field engineer was not present during construction. A sample of the SPG binder was collected and sent for analysis.

Post-Construction Distress Survey

Table A-30. Amarillo FM1719 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM1719-1	K1	4/24/2018	POST	0	0	0	0	0	528	0	35	30
FM1719-2	K6	4/24/2018	POST	0	0	0	0	0	0	0	20	10

Post-Construction Pictures (2018)

Figure A-318. FM1719-1, Overall.

Figure A-319. FM1719-1, Outside WP.

Figure A-320. FM1719-1, BWP.

Figure A-321. FM1719-1, Inside WP.


Figure A-322. FM1719-2, Overall.


Figure A-323. FM1719-2, Outside WP.


Figure A-324. FM1719-2, BWP.


Figure A-325. FM1719-2, Inside WP.

HS: 17-AMA-4

District – Amarillo | County – Gray
Highway – SH0070 | Near – Pampa

Table A-31. Amarillo SH0070A Test Sections.

Test Section	Lane	BRM	ERM
SH0070-1	K1	80+0.0	80+0.1
SH0070-2	K6	80+0.1	80+0.0

Table A-32. Amarillo SH0070A Construction Details.

Contractor	Lipham, Aspermont, TX		
Date	09/07/2017		
Binder Type	SPG 73-25	Binder Source	Alon, Big Spring
Agg Type	Gr4, PC	Agg Source	Boys Ranch
Weather			
AADT	1879		
2016 %Trk	45.5		
2016 AADT Level	M		

Table A-33. Amarillo SH0070A Binder and Aggregate Application Details.

Test Section	SH0070-1	SH0070-2
Binder rate	0.47 Gal/SY	0.47 Gal/SY
Aggregate rate	110 SY/CY	110 SY/CY
Binder Application Time	-	-
Time until Rock Added	-	-
Time to First Roll	-	-

Construction Notes

The field engineer was not present during construction.

Pre- and Post-Construction Distress Surveys

Table A-34. Amarillo SH0070A Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
SH0070-1	K1	8/8/2017	Pre	0	0	0	0	0	0	0	X	X
SH0070-1	K1	4/25/2018	POST	0	0	0	400	400	0	0	60	25
SH0070-2	K6	8/8/2017	Pre	0	0	0	0	0	0	0	X	X
SH0070-2	K6	4/25/2018	POST	0	0	0	100	100	0	0	20	10

Pre-Construction Pictures (2017)

Figure A-326. SH0070-1, Overall.

Figure A-327. SH0070-1, Outside WP.

Figure A-328. SH0070-1, BWP.

Figure A-329. SH0070-1, Inside WP.

Figure A-330. SH0070-2, Overall.

Figure A-331. SH0070-2, Outside WP.

Figure A-332. SH0070-2, BWP.

Figure A-333. SH0070-2, Inside WP.

Post-Construction Pictures-2018

Figure A-334. SH0070-1, Overall.

Figure A-335. SH0070-1, Outside WP.

Figure A-336. SH0070-1, BWP.

Figure A-337. SH0070-1, Inside WP.

Figure A-338. SH0070-2, Overall.

Figure A-339. SH0070-2, Outside WP.

Figure A-340. SH0070-2, BWP.

Figure A-341. SH0070-2, Inside WP.

HS: 17-AMA-5

District – Amarillo
County – Hartley
Highway – SH0070
Near – Dalhart

Table A-35. Amarillo SH0070B Test Sections.

Test Section	Lane	BRM	ERM
SH0070-5	K1	104+0.0	104+0.1
SH0070-6	K6	104+0.1	104+0.0
SH0070-7	K1	102+0.0	102+0.1
SH0070-8	K6	102+0.1	102+0.0

Table A-36. Amarillo SH0070B Construction Details.

Contractor	Lipham, Aspermont, TX		
Date	08/08/2017		
Binder Type	SPG 73-25	Binder Source	Alon, Big Spring
Agg Type	Gr4, PC	Agg Source	Boys Ranch
Weather	70º		
AADT	626		
2016 %Trk	15.4		
2016 AADT Level	M		

Table A-37. Amarillo SH0070B Binder and Aggregate Application Details.

Test Section	SH0070-5	SH0070-6	SH0070-7	SH0070-8
Binder rate	0.47 Gal/SY	0.47 Gal/SY	0.47 Gal/SY	0.47 Gal/SY
Aggregate rate	110 SY/CY	110 SY/CY	110 SY/CY	110 SY/CY
Binder Application Time	0:00			
Time until Rock Added				
Time to First Roll				

Construction Notes

The field engineer was not present during construction.

Pre- and Post-Construction Distress Surveys

Table A-38. Amarillo SH0070B Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
SH0070-5	K1	8/8/2017	Pre	0	0	0	0	0	0	0	X	X
SH0070-5	K1	4/25/2018	POST	0	0	0	4424	256	0	0	20	10
SH0070-6	K6	8/8/2017	Pre	0	0	0	0	0	0	0	X	X
SH0070-6	K6	4/25/2018	POST	0	0	0	1712	0	700	0	30	20
SH0070-7	K1	8/8/2017	Pre	0	0	0	0	0	0	0	X	X
SH0070-7	K1	4/25/2018	POST	0	0	0	428	0	0	0	30	15
SH0070-8	K6	8/8/2017	Pre	0	0	0	0	0	0	0	X	X
SH0070-8	K6	4/25/2018	POST	0	0	0	328	0	0	0	25	10

Post-Construction Pictures (2017)

Figure A-342. SH0070-5, Overall.

Figure A-343. SH0070-5, Outside WP.

Figure A-344. SH0070-5, BWP.

Figure A-345. SH0070-5, Inside WP.

Figure A-346. SH0070-6, Overall.

Figure A-347. SH0070-6, Outside WP.

Figure A-348. SH0070-6, BWP.

Figure A-349. SH0070-6, Inside WP.

Figure A-350. SH0070-7, Overall.

Figure A-351. SH0070-7, Outside WP.

Figure A-352. SH0070-7, BWP.

Figure A-353. SH0070-7, Inside WP.


Figure A-354. SH0070-8, Overall.


Figure A-355. SH0070-8, Outside WP.


Figure A-356. SH0070-8, BWP.


Figure A-357. SH0070-8, Inside WP.

Post-Construction Pictures (2018)


Figure A-358. SH0070-5, Overall.


Figure A-359. SH0070-5, Outside WP.


Figure A-360. SH0070-5, BWP.


Figure A-361. SH0070-5, Inside WP.

Figure A-362. SH0070-6, Overall.

Figure A-363. SH0070-6, Outside WP.

Figure A-364. SH0070-6, BWP.

Figure A-365. SH0070-6, Inside WP.

Figure A-366. SH0070-7, Overall.

Figure A-367. SH0070-7, Outside WP.

Figure A-368. SH0070-7, BWP.

Figure A-369. SH0070-7, Inside WP.

Figure A-370. SH0070-8, Overall.

Figure A-371. SH0070-8, Outside WP.

Figure A-372. SH0070-8, BWP.

Figure A-373. SH0070-8, Inside WP.

HS: 17-AMA-6

District – Amarillo | County – Potter
Highway – SL0335 | Near – Amarillo

Table A-39. Amarillo SL0335 Test Sections.

Test Section	Lane	BRM	ERM
SL0335-1	K1	312+0.0	312+0.1
SL0335-2	K6	312+0.1	312+0.0

Table A-40. Amarillo SL0335 Construction Details.

Contractor	Lipham, Aspermont		
Date	8/5/2017		
Binder Type	AR Type 3	Binder Source	Alon?
Agg Type	4S, PC	Agg Source	Milligan
Weather			
AADT	4488		
2016 %Trk	13		
2016 AADT Level	M		

Table A-41. Amarillo SL0335 Binder and Aggregate Application Details.

Test Section	SL0335-1	SL0335-2
Binder rate	0.60 Gal/SY	0.60 Gal/SY
Aggregate rate	115 SY/CY	115 SY/CY
Binder Application Time	0:00	
Time until Rock Added		
Time to First Roll		

Construction Notes

The field engineer was not present during construction. Binder was base 64-19 + 19 percent rubber. Rain delayed the construction several days.

Pre- and Post-Construction Distress Surveys

Table A-42. Amarillo SL0335 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
SL0335-1	K1	4/24/2018	POST	2640	0	0	0	0	0	0	60	20
SL0335-1	K1	8/7/2017	Pre	0	0	0	0	0	0	0	50	40
SL0335-2	K6	4/24/2018	POST	1256	0	0	0	0	0	0	25	20
SL0335-2	K6	8/7/2017	Pre	0	0	0	0	0	0	0	80	40

Post-Construction Pictures (2017)


Figure A-374. SL0335-1, Overall.

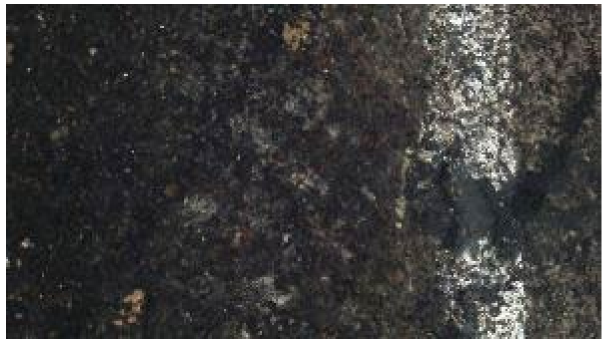
Figure A-375. SL0335-1, Outside WP.


Figure A-376. SL0335-1, BWP.


Figure A-377. SL0335-1, Inside WP.


Figure A-378. SL0335-2, Overall.


Figure A-379. SL0335-2, Outside WP.


Figure A-380. SL0335-2, BWP.


Figure A-381. SL0335-2, Inside WP.

Post-Construction Pictures (2018)

Figure A-382. SL0335-1, Overall.

Figure A-383. SL0335-1, Outside WP.

Figure A-384. SL0335-1, BWP.

Figure A-385. SL0335-1, Inside WP.

Figure A-386. SL0335-2, Overall.

Figure A-387. SL0335-2, Outside WP.

Figure A-388. SL0335-2, BWP.

Figure A-389. SL0335-2, Inside WP.

HS: 16-AUS-1

District – Austin | County – Mason
Highway – US0087 | Near – Mason

Table A-43. Austin US0087 Test Sections.

Test Section	Lane	BRM	ERM
US0087-1	K1	564+0.0	564+0.1
US0087-2	K6	564+0.1	564+0.0
US0087-3	K1	566+0.0	566+0.1
US0087-4	K6	566+0.1	566+0.0

Table A-44. Austin US0087 Construction Details.

Contractor:	FN Ploch, New Braunfels		
Date:	07/19/2016		
Binder Type	SPG70-19	Binder Source	Martin-Houston
Agg. Type	PC Gr 4 Sandstone	Agg. Source	Delta/Capital Agg., Marble Falls
Weather	95°F, hot, windy		
AADT	4995		
2016 %Trk	17.7		
2016 AADT Level	M		

Table A-45. Austin US0087 Binder and Aggregate Application Details.

Test Section	US0087-1	US0087-2	US0087-3	US0087-4
Binder rate	0.31 Gal/SY	0.31 Gal/SY	0.31 Gal/SY	0.32 Gal/SY
Aggregate application rate	110 SY/CY	110 SY/CY	110 SY/CY	120 SY/CY
Binder Application Time	0:00	0:00	0:00	0:00
Time until Rock Added	2:23	2:15	2:45	3:10
Time to First Roll	7:01	7:03	3:47	3:46

Construction Notes

Straight section with some raveling along the centerline, and some patchy bleeding spots. During construction, the operation was of good quality and smooth.

Pre- and Post-Construction Distress Surveys

Table A-46. Austin US0087 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
US0087-1	K1	5/6/2016	Pre	0	0	0	0	0	528	0	25	25
US0087-1	K1	7/28/2016	POST	0	0	0	3146	0	0	0	20	10
US0087-1	K1	3/30/2017	POST	1462	0	0	950	0	0	0	40	20
US0087-1	K1	4/23/2018	POST	1056	0	0	600	0	0	0	20	10
US0087-2	K6	5/6/2016	Pre	0	0	0	0	0	528	0	35	25
US0087-2	K6	7/28/2016	POST	0	0	0	4702	0	0	0	20	10
US0087-2	K6	3/30/2017	POST	0	0	0	3168	0	0	0	30	10
US0087-2	K6	4/23/2018	POST	1584	0	0	1584	0	0	0	40	25
US0087-3	K1	5/6/2016	Pre	1000	0	0	0	0	300	0	85	50
US0087-3	K1	7/28/2016	POST	0	450	0	3046	0	0	0	25	15
US0087-3	K1	3/30/2017	POST	934	0	0	2490	0	0	0	40	10
US0087-3	K1	4/23/2018	POST	450	330	0	1300	0	0	0	40	20
US0087-4	K6	5/6/2016	Pre	428	0	0	0	300	0	0	90	80
US0087-4	K6	7/28/2016	POST	0	0	0	4102	0	0	0		
US0087-4	K6	3/30/2017	POST	0	0	0	3418	0	0	0	10	10
US0087-4	K6	4/23/2018	POST	0	0	0	3852	0	0	0	25	10

Pre-Construction Pictures (2016)

Figure A-390. US0087-1, Overall.

Figure A-391. US0087-1, Outside WP.

Figure A-392. US0087-1, BWP.

Figure A-393. US0087-1, Inside WP.

Figure A-394. US0087-2, Overall. **Figure A-395. US0087-2, Outside WP.**

Figure A-396. US0087-2, BWP. **Figure A-397. US0087-2, Inside WP.**

Figure A-398. US0087-3, Overall. **Figure A-399. US0087-3, Outside WP.**

Figure A-400. US0087-3, BWP. **Figure A-401. US0087-3, Inside WP.**

Figure A-402. US0087-4, Overall.

Figure A-403. US0087-4, Outside WP.

Figure A-404. US0087-4, BWP.

Figure A-405. US0087-4, Inside WP.

Post-Construction Pictures (2016)

Figure A-406. US0087-1, Overall.

Figure A-407. US0087-1, Outside WP.

Figure A-408. US0087-1, BWP.

Figure A-409. US0087-1, Inside WP.

Figure A-410. US0087-2, Overall.

Figure A-411. US0087-2, Outside WP.

Figure A-412. US0087-2, BWP.

Figure A-413. US0087-2, Inside WP.

Figure A-414. US0087-3, Overall.

Figure A-415. US0087-3, Outside WP.

Figure A-416. US0087-3, BWP.

Figure A-417. US0087-3, Inside WP.

Figure A-418. US0087-4, Overall.

Figure A-419. US0087-4, Outside WP.

Figure A-420. US0087-4, BWP.

Figure A-421. US0087-4, Inside WP.

Post-Construction Pictures (2017)

Figure A-422. US0087-1, Overall.

Figure A-423. US0087-1, Outside WP.

Figure A-424. US0087-1, BWP.

Figure A-425. US0087-1, Inside WP.


Figure A-426. US0087-2, Overall.


Figure A-427. US0087-2, Outside WP.


Figure A-428. US0087-2, BWP.


Figure A-429. US0087-2, Inside WP.


Figure A-430. US0087-3, Overall.


Figure A-431. US0087-3, Outside WP.


Figure A-432. US0087-3, BWP.


Figure A-433. US0087-3, Inside WP.

Figure A-434. US0087-4, Overall.

Figure A-435. US0087-4, Outside WP.

Figure A-436. US0087-4, BWP.

Figure A-437. US0087-4, Inside WP.

Post-Construction Pictures (2018)

Figure A-438. US0087-1, Overall.

Figure A-439. US0087-1, Outside WP.

Figure A-440. US0087-1, BWP.

Figure A-441. US0087-1, Inside WP.

Figure A-442. US0087-2, Overall.

Figure A-443. US0087-2, Outside WP.

Figure A-444. US0087-2, BWP.

Figure A-445. US0087-2, Inside WP.

Figure A-446. US0087-3, Overall.

Figure A-447. US0087-3, Outside WP.

Figure A-448. US0087-3, BWP.

Figure A-449. US0087-3, Inside WP.

Figure A-450. US0087-4, Overall.

Figure A-451. US0087-4, Outside WP.

Figure A-452. US0087-4, BWP.

Figure A-453. US0087-4, Inside WP.

HS: 16-AUS-2

District – Austin | County – Mason
Highway – SH0029 | Near – Mason

Table A-47. Austin SH0029 Mason Test Sections.

Test Section	Lane	BRM	ERM
SH0029-1	K1	462+0.0	462+0.1
SH0029-2	K6	462+0.1	462+0.0
SH0029-3	K1	466+0.0	466+0.1
SH0029-4	K6	466+0.1	466+0.0

Table A-48. Austin SH0029 Mason Construction Details.

Contractor:	FN Ploch, New Braunfels		
Date:	07/19/2016		
Binder Type	SPG 70-19	Binder Source	Martin-Houston
Agg. Type	PC Gr 4	Agg. Source	Delta/Capital Agg., Marble Falls
Weather	90°F, light wind		
AADT	1100		
2016 %Trk	16.6		
2016 AADT Level	M		

Table A-49. Austin SH0029 Mason Binder and Aggregate Application Details.

Test Section	SH0029-1	SH0029-2	SH0029-3	SH0029-4
Binder rate	0.32 Gal/SY	0.32 Gal/SY	0.32 Gal/SY	0.32 Gal/SY
Aggregate application rate	120 SY/CY	120 SY/CY	120 SY/CY	120 SY/CY
Binder Application Time	0:00	0:00	0:00	0:00
Time until Rock Added	3:08	0:41	3:05	0:33
Time to First Roll	6:47	2:29	5:31	1:25

Construction Notes

As part of the surface preparation, this test section was overlaid with 1 inch hot mix asphalt concrete along the edge and 2 inches at the centerline. The surface was visually pleasant and consistent. The contractor did a quality job during construction. The aggregate was usually applied close to the time when the binder was applied.

Pre- and Post-Construction Distress Surveys

Table A-50. Austin SH0029 Mason Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
SH0029-1	K1	5/6/2016	Pre	0	0	0	0	0	0	0	95	95
SH0029-1	K1	9/28/2016	POST	528	0	0	1912	0	0	0	40	10
SH0029-1	K1	3/30/2017	POST	528	0	0	2568	0	0	0	60	10
SH0029-1	K1	4/23/2018	POST	528	0	0	0	0	0	0	60	20
SH0029-2	K6	5/6/2016	Pre	0	0	0	0	0	0	0	95	95
SH0029-2	K6	9/28/2016	POST	2212	0	0	0	0	0	0	80	15
SH0029-2	K6	3/30/2017	POST	2112	0	0	0	0	0	0	80	10
SH0029-2	K6	4/23/2018	POST	2112	0	0	0	0	0	0	90	20
SH0029-3	K1	5/6/2016	Pre	0	0	0	0	0	0	0	95	95
SH0029-3	K1	9/28/2016	POST	2550	0	0	0	0	0	0	60	10
SH0029-3	K1	3/30/2017	POST	2012	0	0	956	0	0	0	50	10
SH0029-3	K1	4/23/2018	POST	1112	0	0	0	0	0	0	50	25
SH0029-4	K6	5/6/2016	Pre	0	0	0	0	0	0	0	95	95
SH0029-4	K6	9/28/2016	POST	1106	0	0	400	0	0	0	80	10
SH0029-4	K6	3/30/2017	POST	756	0	0	656	0	0	0	60	10
SH0029-4	K6	4/23/2018	POST	1356	0	0	0	0	0	0	75	25

Pre-Construction Pictures (2016)

Figure A-454. SH0029-1, Overall.

Figure A-455. SH0029-1, Outside WP.

Figure A-456. SH0029-1, BWP.

Figure A-457. SH0029-1, Inside WP.


Figure A-458. SH0029-2, Overall.


Figure A-459. SH0029-2, Outside WP.


Figure A-460. SH0029-2, BWP.


Figure A-461. SH0029-2, Inside WP.


Figure A-462. SH0029-3, Overall.


Figure A-463. SH0029-3, Outside WP.


Figure A-464. SH0029-3, BWP.


Figure A-465. SH0029-3, Inside WP.

Figure A-466. SH0029-4, Overall.

Figure A-467. SH0029-4, Outside WP.

Figure A-468. SH0029-4, BWP.

Figure A-469. SH0029-4, Inside WP.

Post-Construction Pictures (2016)

Figure A-470. SH0029-1, Overall.

Figure A-471. SH0029-1, Outside WP.

Figure A-472. SH0029-1, BWP.

Figure A-473. SH0029-1, Inside WP.


Figure A-474. SH0029-2, Overall.


Figure A-475. SH0029-2, Outside WP.


Figure A-476. SH0029-2, BWP.


Figure A-477. SH0029-2, Inside WP.


Figure A-478. SH0029-3, Overall.


Figure A-479. SH0029-3, Outside WP.


Figure A-480. SH0029-3, BWP.


Figure A-481. SH0029-3, Inside WP.

Figure A-482. SH0029-4, Overall.

Figure A-483. SH0029-4, Outside WP.

Figure A-484. SH0029-4, BWP.

Figure A-485. SH0029-4, Inside WP.

Post-Construction Pictures (2017)

Figure A-486. SH0029-1, Overall.

Figure A-487. SH0029-1, Outside WP.

Figure A-488. SH0029-1, BWP.

Figure A-489. SH0029-1, Inside WP.


Figure A-490. SH0029-2, Overall.


Figure A-491. SH0029-2, Outside WP.


Figure A-492. SH0029-2, BWP.


Figure A-493. SH0029-2, Inside WP.


Figure A-494. SH0029-3, Overall.


Figure A-495. SH0029-3, Outside WP.


Figure A-496. SH0029-3, BWP.


Figure A-497. SH0029-3, Inside WP.

Figure A-498. SH0029-4, Overall.

Figure A-499. SH0029-4, Outside WP.

Figure A-500. SH0029-4, BWP.

Figure A-501. SH0029-4, Inside WP.

Post-Construction Pictures (2018)

Figure A-502. SH0029-1, Overall.

Figure A-503. SH0029-1, Outside WP.

Figure A-504. SH0029-1, BWP.

Figure A-505. SH0029-1, Inside WP.

Figure A-506. SH0029-2, Overall.

Figure A-507. SH0029-2, Outside WP.

Figure A-508. SH0029-2, BWP.

Figure A-509. SH0029-2, Inside WP.

Figure A-510. SH0029-3, Overall.

Figure A-511. SH0029-3, Outside WP.

Figure A-512. SH0029-3, BWP.

Figure A-513. SH0029-3, Inside WP.


Figure A-514. SH0029-4, Overall.


Figure A-515. SH0029-4, Outside WP.


Figure A-516. SH0029-4, BWP.


Figure A-517. SH0029-4, Inside WP.

HS: 16-AUS-3

District – Austin | County – Llano
Highway – SH0029 | Near – Llano

Table A-51. Austin SH0029 Llano Test Sections.

Test Section	Lane	BRM	ERM
SH0029-5	K1	496+0.0	496+0.1
SH0029-6	K6	496+0.1	496+0.0

Table A-52. Austin SH0029 Llano Construction Details.

Contractor:	FN Ploch, New Braunfels		
Date:	07/19/2016		
Binder Type	SPG70-19	Binder Source	Martin-Houston
Agg. Type	PC Gr 4	Agg. Source	Delta/Capital Agg., Marble Falls
Weather	100°F, hot, windy		
AADT	4995		
2016 %Trk	17.7		
2016 AADT Level	M		

Table A-53. Austin SH0029 Llano Binder and Aggregate Application Details.

Test Section	SH0029-5	SH0029-6
Binder rate	0.33 Gal/SY	0.33 Gal/SY
Aggregate application rate	121 SY/CY	120 SY/CY
Binder Application Time	0:00	0:00
Time until Rock Added	3:08	0:41
Time to First Roll	6:47	2:29

Construction Notes

As part of the surface preparation, this test section was overlaid with 1-inch hot mix asphalt concrete along the edge and 2 inches at the centerline. The surface was visually pleasant and consistent. The contractor did a quality job during construction. The aggregate was usually applied close to the time when the binder was applied.

Pre- and Post-Construction Distress Surveys

Table A-54. Austin SH0029 Llano Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
SH0029-5	K1	5/6/2016	POST	0	0	0	0	0	0	0	95	95
SH0029-5	K1	9/20/2016	POST	1584	1056	0	0	0	0	0	20	95
SH0029-5	K1	3/30/2017	POST	1356	756	0	0	0	0	0	95	20
SH0029-5	K1	4/23/2018	POST	900	1450	0	0	0	0	0	95	65
SH0029-6	K6	5/6/2016	POST	0	0	0	0	0	0	0	95	95
SH0029-6	K6	9/20/2016	POST	750	1890	0	0	0	0	0	95	20
SH0029-6	K6	3/30/2017	POST	2040	600	0	0	0	0	0	95	20
SH0029-6	K6	4/23/2018	POST	684	2284	0	0	0	0	0	95	35

Pre-Construction Pictures (2016)

Figure A-518. SH0029-5, Overall.

Figure A-519. SH0029-5, Outside WP.

Figure A-520. SH0029-5, BWP.

Figure A-521. SH0029-5, Inside WP.


Figure A-522. SH0029-6, Overall.


Figure A-523. SH0029-6, Outside WP.


Figure A-524. SH0029-6, BWP.


Figure A-525. SH0029-6, Inside WP.

Post-Construction Pictures (2016)


Figure A-526. SH0029-5, Overall.


Figure A-527. SH0029-5, Outside WP.


Figure A-528. SH0029-5, BWP.


Figure A-529. SH0029-5, Inside WP.

Figure A-530. SH0029-6, Overall.

Figure A-531. SH0029-6, Outside WP.

Figure A-532. SH0029-6, BWP.

Figure A-533. SH0029-6, Inside WP.

Post-Construction Pictures (2017)

Figure A-534. SH0029-5, Overall.

Figure A-535. SH0029-5, Outside WP.

Figure A-536. SH0029-5, BWP.

Figure A-537. SH0029-5, Inside WP.

Figure A-538. SH0029-6, Overall.

Figure A-539. SH0029-6, Outside WP.

Figure A-540. SH0029-6, BWP.

Figure A-541. SH0029-6, Inside WP.

Post-Construction Pictures (2018)

Figure A-542. SH0029-5, Overall.

Figure A-543. SH0029-5, Outside WP.

Figure A-544. SH0029-5, BWP.

Figure A-545. SH0029-5, Inside WP.

Figure A-546. SH0029-6, Overall.

Figure A-547. SH0029-6, Outside WP.

Figure A-548. SH0029-6, BWP.

Figure A-549. SH0029-6, Inside WP.

HS: 16-BWD-1

District – Brownwood   County – Coleman
Highway – US0084   Near – Goldsboro

Table A-55. Brownwood US0084B Test Sections.

Test Section	Lane	BRM	ERM
US0084-5	K1	526+0.0	526+0.1
US0084-6	K6	526+0.1	526+0.0
US0084-7	K1	530+0.0	530+0.1
US0084-8	K6	530+0.1	530+0.0

Table A-56. Brownwood US0084B Construction Details.

Contractor	Northeast Pavers, Granbury, TX		
Date:	07/12/2016		
Binder Type:	CRS-2P	Binder Source:	Wright, Brownwood
Agg. Type	Limestone, Gr 4	Agg. Source:	Vulcan, Brownwood, TX
Weather	RM526, light wind, 85°F. RM 530 Light wind, 96°F.		
AADT	3300		
2016 %Trk	11.7		
2016 AADT Level	M		

Table A-57. Brownwood US0084B Binder and Aggregate Application Details.

Test Section	US0084-5	US0084-6	US0084-7	US0084-8
Binder rate	0.42 Gal/SY	0.42 Gal/SY	0.42 Gal/SY	0.42 Gal/SY
Aggregate application rate	120 SY/CY	120 SY/CY	120 SY/CY	120 SY/CY
Binder Application Time	0:00	0:00	0:00	0:00
Time until Rock Added	12:56	7:29	11:10	8:01
Time to First Roll	15:57	12:32	13:18	10:38

<u>Construction Notes</u>

The aggregate was a little dusty on all test sections. During construction, the wind was blowing from K1 to K6, so there was aggregate dust on lane after the binder was placed and before the aggregate was added. In section K1, there was no apparent aggregate dusting. RM 530 was 80 feet from where they squared up the lanes from the previous shots. The base asphalt used was a PEN 92.

Pre- and Post-Construction Distress Surveys

Table A-58. Brownwood US0084B Pre- and Post-Construction Distress.

Test Section	Lane	Type	EMB-WP	EMB-BWP	Description
US0084-5	K1	Pre	95	90	Bleeding in both WPs
US0084-6	K6	Pre	90	90	Bleeding in both WPs
US0084-7	K1	Pre	95	95	Bleeding in both WPs
US0084-8	K6	Pre	80	100	Intermittent bleeding in both WPs
US0084-5	K1	Post	40	15	Flushing inside WP, Flushing/raveling outside WP
US0084-6, K6	K6	Post	50	75	Flushing Inside WP, raveling outside WP
US0084-7	K1	Post	35	15	Mixed raveling/flushing
US0084-8	K6	Post	50	10	Mixed raveling/flushing

Pre-Construction Pictures (2016)

Pictures were deleted when the decision to switch from SPG to CRS was made. These pictures were from construction.

Figure A-550. US0084-6, Dust.

Figure A-551. US0084-6, Dust.

Figure A-552. US0084-6, K6, Dust, Close.

Post-Construction Pictures (2016)

Figure A-553. US0084-5, K1, Overall.

Figure A-554. US0084-5, K1, Outside WP.

Figure A-555. US0084-5, K1, BWP.

Figure A-556. US0084-5, K1, Inside WP.

Figure A-557. US0084-6, K6, Overall.

Figure A-558. US0084-6, K6, Outside WP.

Figure A-559. US0084-6, K6, BWP.

Figure A-560. US0084-6, K6, Inside WP.

Figure A-561. US0084-7, K1, Overall.

Figure A-562. US0084-7, K1, Outside WP.

Figure A-563. US0084-7, K1, BWP.

Figure A-564. US0084-7, K1, Inside WP.

Figure A-565. US0084-8, K6, Overall.

Figure A-566. US0084-8, K6, Outside WP.

Figure A-567. US0084-8, K6, BWP.

Figure A-568. US0084-8, K6, Inside WP.

HS: 16-BWD-2

District – Brownwood   County – Coleman
Highway – US0084   Near – Goldsboro

Table A-59. Brownwood US0084A Test Sections.

Test Section	Lane	BRM	ERM
US0084-1	K1	510+0.5	510+0.6

Table A-60. Brownwood US0084A Construction Details.

Contractor	Northeast Pavers, Granbury, TX		
Date	07/15/2016		
Binder Type	SPG 67-22	Binder Source	Wright, Brownwood
Agg. Type	Limestone, Gr 4	Agg. Source	Vulcan, Brownwood, TX
Weather	Light wind, 96°F		
AADT	3300		
2016 %Trk	11.7		
2016 AADT Level	M		

Table A-61. Brownwood US0084A Binder and Aggregate Application Details.

Test Section	US0084-1
Binder rate	0.38 Gal/SY
Aggregate application rate	120 SY/CY
Binder Application Time	0:00
Time until Rock Added	9:50
Time to First Roll	16:40

Construction Notes

There was only one test section in this highway because the contractor switched from CRS-2P emulsion to SPG 67-22 to use the SPG binder. The section is in straightaway.

Pre- and Post-Construction Distress Surveys

Table A-62. Brownwood US0084A Pre- and Post-Construction Distress.

Test Section	Lane	Type	EMB-WP	EMB-BWP	Description
US0084-1	K1	Pre	50	40	WP bleeding in first 150 feet
US0084-1	K1	Post	20	10	Raveling both WPs

Pre-Construction Pictures (2016)

Figure A-569. US0084-1, Overall.

Figure A-570. US0084-1, Outside WP.

Figure A-571. US0084-1, BWP.

Figure A-572. US0084-1, Inside WP.

Post-Construction Pictures (2016)

Figure A-573. US0084-1, Overall.

Figure A-574. US0084-1, Outside WP.

Figure A-575. US0084-1, BWP.

Figure A-576. US0084-1, Inside WP.

HS: 16-CRP-1

District – Corpus Christi   County – Jim Wells
Highway - FM3376   Near - Alice

Table A-63. Corpus Christi FM3376 Test Sections.

Test Section	Lane	BRM	ERM
FM3376-1	K1	510+0.1	510+0.2
FM3376-2	K6	510+0.1	510+0.1
FM3376-3	K1	512+0.0	512+0.1
FM3376-4	K6	512+0.1	512+0.0

Table A-64. Corpus Christi FM3376 Construction Details.

Contractor	Wagner, Kendalia, TX		
Date	09/17/2016		
Binder Type	SPG70-19	Binder Source	Valero, Corpus Christi
Agg. Type	PC 4S, SAC B	Agg. Source	Vulcan, Uvalde
Weather	99°F, hot, humid		
AADT	3000		
2016 %Trk	10		
2016 AADT Level	M		

Table A-65. Corpus Christi FM3376 Binder and Aggregate Application Details.

Test Section	FM3376-1	FM3376-2	FM3376-3	FM3376-4
Binder rate	0.35 Gal/SY	0.35 Gal/SY	0.35 Gal/SY	0.35 Gal/SY
Aggregate application rate	110 SY/CY	110 SY/CY	110 SY/CY	110 SY/CY
Binder Application Time	0:00	0:00	Missed	Missed
Time until Rock Added	2:22	2:59	Missed	Missed
Time to First Roll	3:02	6:45	Missed	Missed

Construction Notes

This section was straight and showed minimal cracking. Construction occurred on a Saturday afternoon/evening. During construction, the chip spreader was moving fast, but the contractor had enough equipment and was able to work efficiently.

Pre- and Post-Construction Distress Surveys

Table A-66. Corpus Christi FM3376 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM3376-1	K1	5/4/2016	Pre	0	0	0	0	0	0	0	90	90
FM3376-1	K1	10/21/2016	POST	0	0	0	4752	0	0	0	20	10
FM3376-1	K1	3/17/2017	POST	0	0	0	3696	0	0	0	30	10
FM3376-1	K1	3/29/2018	POST	0	0	0	2310	0	0	0	70	20
FM3376-2	K6	5/4/2016	Pre	0	0	0	0	0	0	0	95	95
FM3376-2	K6	10/21/2016	POST	0	0	0	3596	0	0	0	20	10
FM3376-2	K6	3/17/2017	POST	0	0	0	3796	0	0	0	30	20
FM3376-2	K6	3/29/2018	POST	0	0	0	1434	0	0	0	40	20
FM3376-3	K1	5/4/2016	Pre	0	0	0	0	0	0	0	75	75
FM3376-3	K1	10/21/2016	POST	0	0	0	3576	0	0	0	10	10
FM3376-3	K1	3/17/2017	POST	0	0	0	2540	0	0	0	20	10
FM3376-3	K1	3/29/2018	POST	0	0	0	1800	0	0	0	25	20
FM3376-4	K6	5/4/2016	Pre	0	0	0	0	0	0	0	75	75
FM3376-4	K6	10/21/2016	POST	0	0	0	4638	0	0	0	10	20
FM3376-4	K6	3/17/2017	POST	0	0	0	2946	0	0	0	20	10
FM3376-4	K6	3/29/2018	POST	0	0	0	2498	0	0	0	50	20

Pre-Construction Pictures

Figure A-577. FM3376-1, Overall.

Figure A-578. FM3376-1, Outside WP.

Figure A-579. FM3376-1, BWP.

Figure A-580. FM3376-1, Inside WP.


Figure A-581. FM3376-2, Overall.


Figure A-582. FM3376-2, Outside WP.


Figure A-583. FM3376-2, BWP.


Figure A-584. FM3376-2, Inside WP.


Figure A-585. FM3376-3, Overall.


Figure A-586. FM3376-3, Outside WP.


Figure A-587. FM3376-3, BWP.


Figure A-588. FM3376-3, Inside WP.

Figure A-589. FM3376-4, Overall. **Figure A-590. FM3376-4, Outside WP.**

Figure A-591. FM3376-4, BWP. **Figure A-592. FM3376-4, Inside WP.**

Post-Construction Pictures (2016)

Figure A-593. FM3376-1, Overall. **Figure A-594. FM3376-1, Outside WP.**

Figure A-595. FM3376-1, BWP. **Figure A-596. FM3376-1, Inside WP.**

Figure A-597. FM3376-2, Overall.

Figure A-598. FM3376-2, Outside WP.

Figure A-599. FM3376-2, BWP.

Figure A-600. FM3376-2, Inside WP.

Figure A-601. FM3376-3, Overall.

Figure A-602. FM3376-3, Outside WP.

Figure A-603. FM3376-3, BWP.

Figure A-604. FM3376-3, Inside WP.

Figure A-605. FM3376-4, Overall.

Figure A-606. FM3376-4, Outside WP.

Figure A-607. FM3376-4, BWP.

Figure A-608. FM3376-4, Inside WP.

Post-Construction Pictures (2017)

Figure A-609. FM3376-1, Overall.

Figure A-610. FM3376-1, Outside WP.

Figure A-611. FM3376-1, BWP.

Figure A-612. FM3376-1, Inside WP.

Figure A-613. FM3376-2, Overall.

Figure A-614. FM3376-2, Outside WP.

Figure A-615. FM3376-2, BWP.

Figure A-616. FM3376-2, Inside WP.

Figure A-617. FM3376-3, Overall.

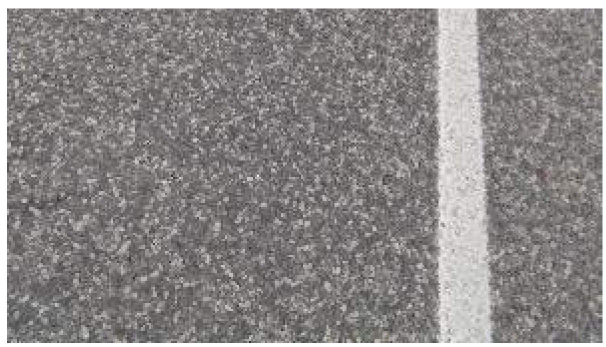

Figure A-618. FM3376-3, Outside WP.

Figure A-619. FM3376-3, BWP.

Figure A-620. FM3376-3, Inside WP.

Figure A-621. FM3376-4, Overall.

Figure A-622. FM3376-4, Outside WP.

Figure A-623. FM3376-4, BWP.

Figure A-624. FM3376-4, Inside WP.

Post-Construction Pictures (2018)

Figure A-625. FM3376-1, Overall.

Figure A-626. FM3376-1, Outside WP.

Figure A-627. FM3376-1, BWP.

Figure A-628. FM3376-1, Inside WP.


Figure A-629. FM3376-2, Overall.


Figure A-630. FM3376-2, Outside WP.


Figure A-631. FM3376-2, BWP.


Figure A-632. FM3376-2, Inside WP.


Figure A-633. FM3376-3, Overall.


Figure A-634. FM3376-3, Outside WP.


Figure A-635. FM3376-3, BWP.


Figure A-636. FM3376-3, Inside WP.

Figure A-637. FM3376-4, Overall.

Figure A-638. FM3376-4, Outside WP.

Figure A-639. FM3376-4, BWP.

Figure A-640. FM3376-4, Inside WP.

HS: 16-CRP-2

District – Corpus Christi County – Nueces
Highway – FM0665 Near – Corpus

Table A-67. Corpus Christi FM0665 Test Sections.

Test Section	Lane	BRM	ERM
FM0665-1	K1	556+0.0	556+0.1
FM0665-2	K6	556+0.1	556+0.0
FM0665-3	K1	558+0.2	558+0.3
FM0665-4	K6	558+0.3	558+0.2

Table A-68. Corpus Christi FM0665 Construction Details.

Contractor	Wagner, Kendalia, TX		
Date	09/19/2016 (1,3,4), 09/20/2016 (2)		
Binder Type	SPG 70-19	Binder Source	Valero, Corpus Christi
Agg. Type	PC 4S, B	Agg. Source	Vulcan, Uvalde
Weather	1-98°F, light wind; 2-74°F, still; 3-96°F, steady wind; 4-92°F, steady wind		
AADT	3500		
2016 %Trk	8		
2016 AADT Level	M		

Table A-69. Corpus Christi FM0665 Binder and Aggregate Application Details.

Test Section	FM0665-1	FM0665-2	FM0665-3	FM0665-4
Binder rate	0.35 Gal/SY	0.35 Gal/SY	0.35 Gal/SY	0.35 Gal/SY
Aggregate application rate	110 SY/CY	110 SY/CY	110 SY/CY	110 SY/CY
Time	2:02PM	8:02AM	3:45PM	6:00PM
Binder Application Time	0:00	0:00	0:00	0:00
Time until Rock Added	2:04	1:59	4:41	4:35
Time to First Roll	9:22	6:24	8:03	6:35

Notes

The selected sections were placed in straightaways locations and avoiding patches. The sections had some sealed longitudinal cracking. The contractor focused on production; therefore, plenty of equipment was present during construction (5 rollers, 2 brooms, 3–5 distributors). In addition, the chip spreader moved very quickly.

Pre- and Post-Construction Distress Surveys

Table A-70. Corpus Christi FM0665 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM0665-1	K1	5/4/2016	Pre	0	0	0	0	0	0	1536	80	75
FM0665-1	K1	10/21/2016	POST	0	0	0	3156	160	0	0	20	10
FM0665-1	K1	3/17/2017	POST	0	0	0	2590	0	0	0	50	10
FM0665-1	K1	3/29/2018	POST	0	0	0	2296	0	0	0	85	20
FM0665-2	K6	5/4/2016	Pre	0	0	0	0	0	0	0	75	75
FM0665-2	K6	10/21/2016	POST	0	0	0	4246	0	0	0	25	10
FM0665-2	K6	3/17/2017	POST	0	0	0	2662	200	0	0	40	10
FM0665-2	K6	3/29/2018	POST	0	0	0	1946	0	0	0	40	85
FM0665-3	K1	5/4/2016	Pre	0	0	0	0	0	0	0	80	80
FM0665-3	K1	10/21/2016	POST	0	0	0	3096	0	0	0	30	15
FM0665-3	K1	3/17/2017	POST	0	0	0	2384	0	0	0	35	10
FM0665-3	K1	3/29/2018	POST	2768	0	0	0	0	0	0	90	25
FM0665-4	K6	5/4/2016	Pre	0	0	0	0	0	0	0	75	75
FM0665-4	K6	10/21/2016	POST	0	0	0	5458	0	0	0	30	10
FM0665-4	K6	3/17/2017	POST	0	0	0	5236	520	0	0	20	10
FM0665-4	K6	3/29/2018	POST	2112	0	0	0	0	0	0	75	20

Pre-Construction Pictures (2016)

Figure A-641. FM0665-1, Overall.

Figure A-642. FM0665-1, Outside WP.

Figure A-643. FM0665-1, BWP.

Figure A-644. FM0665-1, Inside WP.

Figure A-645. FM0665-2, Overall.

Figure A-646. FM0665-2, Outside WP.

Figure A-647. FM0665-2, BWP.

Figure A-648. FM0665-2, Inside WP.

Figure A-649. FM0665-3, Overall.

Figure A-650. FM0665-3, Outside WP.

Figure A-651. FM0665-3, BWP.

Figure A-652. FM0665-3, Inside WP.

Figure A-653. FM0665-4, Overall. **Figure A-654. FM0665-4, Outside WP.**

Figure A-655. **FM0665-4, BWP** **Figure A-656**. **FM0665-4, Inside WP**

Post-Construction Pictures (2016)

Figure A-657. FM0665-1, Overall. **Figure A-658. FM0665-1, Outside WP.**

Figure A-659. FM0665-1, BWP. **Figure A-660. FM0665-1, Inside WP.**

Figure A-661. FM0665-2, Overall.

Figure A-662. FM0665-2, Outside WP.

Figure A-663. FM0665-2, BWP.

Figure A-664. FM0665-2, Inside WP.

Figure A-665. FM0665-3, Overall.

Figure A-666. FM0665-3, Outside WP.

Figure A-667. FM0665-3, BWP.

Figure A-668. FM0665-3, Inside WP.

Figure A-669. FM0665-4, Overall.

Figure A-670. FM0665-4, Outside WP.

Figure A-671. FM0665-4, BWP.

Figure A-672. FM0665-4, Inside WP.

Post-Construction Pictures (2017)

Figure A-673. FM0665-1, Overall.

Figure A-674. FM0665-1, Outside WP.

Figure A-675. FM0665-1, BWP.

Figure A-676. FM0665-1, Inside WP.


Figure A-677. FM0665-2, Overall.


Figure A-678. FM0665-2, Outside WP.


Figure A-679. FM0665-2, BWP.


Figure A-680. FM0665-2, Inside WP.


Figure A-681. FM0665-3, Overall.


Figure A-682. FM0665-3, Outside WP.


Figure A-683. FM0665-3, BWP.


Figure A-684. FM0665-3, Inside WP.


Figure A-685. FM0665-4, Overall.


Figure A-686. FM0665-4, Outside WP.


Figure A-687. FM0665-4, BWP.


Figure A-688. FM0665-4, Inside WP.

Post-Construction Pictures (2018)


Figure A-689. FM0665-1, Overall.


Figure A-690. FM0665-1, Outside WP.


Figure A-691. FM0665-1, BWP.


Figure A-692. FM0665-1, Inside WP.


Figure A-693. FM0665-2, Overall.


Figure A-694. FM0665-2, Outside WP.


Figure A-695. FM0665-2, BWP.


Figure A-696. FM0665-2, Inside WP.


Figure A-697. FM0665-3, Overall.


Figure A-698. FM0665-3, Outside WP.


Figure A-699. FM0665-3, BWP.


Figure A-700. FM0665-3, Inside WP.

Figure A-701. FM0665-4, Overall.

Figure A-702. FM0665-4, Outside WP.

Figure A-703. FM0665-4, BWP.

Figure A-704. FM0665-4, Inside WP.

HS: 16-CRP-3 (no binder collected or received)

District – Corpus Christi　　　County – Bee
Highway – FM0351　　　Near – Beeville

Table A-71. Corpus Christi FM0351 Test Sections.

Test Section	Lane	BRM	ERM
FM0351-1	K1	574+0.0	574+0.1
FM0351-2	K6	574+0.1	574+0.0

Table A-72. Corpus Christi FM0351 Construction Details.

Contractor	Wagner, Kendalia, TX		
Date	09/28/2016		
Binder Type	SPG 70-19	Binder Source	Valero, Corpus Christi
Agg. Type	PC 4S, B	Agg. Source	Vulcan, Uvalde
Weather	-		
AADT	4000		
2016 %Trk	18.0		
2016 AADT Level	M		

Table A-73. Corpus Christi FM0351 Binder and Aggregate Application Details.

Test Section	FM0351-1	FM0351-2
Binder rate	0.37Gal/SY	0.37Gal/SY
Aggregate application rate	110 SY/CY	110 SY/CY
Binder Application Time	Not present	Not present
Time until Rock Added	Not present	Not present
Time to First Roll	Not present	Not present

Construction Notes

The section was located in a curve. The entire section was skin patched. Not a lot of surface texture was apparent. The field engineer was not present during construction.

Pre- and Post-Construction Distress Surveys

Table A-74. Corpus Christi FM0351 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM0351-1	K1	5/4/2016	Pre	0	0	0	0	0	0	6864	99	99
FM0351-1	K1	10/21/2016	POST	0	0	0	3312	0	0	0	20	10
FM0351-1	K1	3/17/2017	POST	0	0	0	2228	0	0	0	20	10
FM0351-1	K1	3/29/2018	POST	0	0	0	2612	0	0	0	80	20
FM0351-2	K6	5/4/2016	Pre	0	0	0	0	0	0	6864	99	99
FM0351-2	K6	10/21/2016	POST	0	0	0	2202	0	0	0	20	10
FM0351-2	K6	3/17/2017	POST	0	0	0	3384	0	0	0	25	10
FM0351-2	K6	3/29/2018	POST	0	0	0	3512	0	0	0	80	20

Pre-Construction Pictures (2016)

Figure A-705. FM0351-1, Overall.

Figure A-706. FM0351-1, Outside WP.

Figure A-707. FM0351-1, BWP.

Figure A-708. FM0351-1, Inside WP.

Figure A-709. FM0351-2, Overall. **Figure A-710. FM0351-2, Outside WP.**

Figure A-711. FM0351-2, BWP. **Figure A-712.FM0351-2, Inside WP.**

Post-Construction Pictures (2016)

Figure A-713. FM0351-1, Overall. **Figure A-714. FM0351-1, Outside WP.**

Figure A-715. FM0351-1, BWP. **Figure A-716. FM0351-1, Inside WP.**

Figure A-717. FM0351-2, Overall.

Figure A-718. FM0351-2, Outside WP.

Figure A-719. FM0351-2, BWP.

Figure A-720. FM0351-2, Inside WP.

Post-Construction Pictures (2017)

Figure A-721. FM0351-1, Overall.

Figure A-722. FM0351-1, Outside WP.

Figure A-723. FM0351-1, BWP.

Figure A-724. FM0351-1, Inside WP.

Figure A-725. FM0351-2, Overall. **Figure A-726. FM0351-2, Outside WP.**

Figure A-727. FM0351-2, BWP. **Figure A-728. FM0351-2, Inside WP.**

Post-Construction Pictures (2018)

Figure A-729. FM0351-1, Overall. **Figure A-730. FM0351-1, Outside WP.**

Figure A-731. FM0351-1, BWP. **Figure A-732. FM0351-1, Inside WP.**

Figure A-733. FM0351-2, Overall.

Figure A-734. FM0351-2, Outside WP.

Figure A-735. FM0351-2, BWP.

Figure A-736. FM0351-2, Inside WP.

HS: 16-PAR-1

District - Paris | County - Hunt

Highway - FM0035 | Near – Royse City

Table A-75. Paris FM0035 Test Sections.

Test Section	Lane	BRM	ERM
FM0035-1	K1	618+0.2	618+0.3
FM0035-2	K6	618+0.3	618+0.2
FM0035-3	K1	620-0.1	620+0.0
FM0035-4	K6	620+0.0	620-0.1

Table A-76. Paris FM0035 Construction Details.

Contractor	NE Tex, New Boston, TX		
Date	07/07/2016		
Binder Type	SPG 70-22	Binder Source	Lion, Henderson
Agg. Type	PC Gr 4 Limestone/Sandstone	Agg. Source	Martin Marietta
Weather	Hot, 95°F		
AADT	4147		
2016 %Trk	9.1		
2016 AADT Level	M		

Table A-77. Paris FM0035 Binder and Aggregate Application Details.

Test Section	FM0035-1	FM0035-2	FM0035-3	FM0035-4
Binder rate	0.32 Gal/SY	0.32 Gal/SY	0.32 Gal/SY	0.32 Gal/SY
Aggregate application rate	130 SY/CY	130 SY/CY	130 SY/CY	130 SY/CY
Binder Application Time	-	-	0:00	0:00
Time until Rock Added	-	-	4:50	2:40
Time to First Roll	-	-	5:46	7:27

Construction Notes

All test sections were in straightaway and showed bleeding in both WPs. During construction, the contractor waited between binder applications so that the traffic that was waiting on the pilot car did not ride immediately on the fresh chip seal.

Pre- and Post-Construction Distress Surveys

Table A-78. Paris FM0035 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM0035-1	K1	5/18/2016	Pre	3168	0	0	0	0	0	0	75	40
FM0035-1	K1	10/20/2016	POST	2640	0	0	0	0	0	0	80	30
FM0035-1	K1	3/27/2017	POST	1216	0	0	0	0	0	0	40	20
FM0035-1	K1	4/26/2018	POST	456	0	0	1145	0	0	0	40	10
FM0035-2	K6	5/18/2016	Pre	3168	0	0	0	0	0	0	90	40
FM0035-2	K6	10/20/2016	POST	2112	0	0	0	0	0	0	80	20
FM0035-2	K6	3/27/2017	POST	2112	0	0	0	0	0	0	85	30
FM0035-2	K6	4/26/2018	POST	112	0	0	100	0	0	0	80	10
FM0035-3	K1	5/18/2016	Pre	3168	0	0	0	0	0	0	90	40
FM0035-3	K1	10/20/2016	POST	1356	1284	0	0	0	0	0	75	30
FM0035-3	K1	3/27/2017	POST	2718	300	0	0	0	0	0	90	55
FM0035-3	K1	4/26/2018	POST	428	1000	0	0	0	0	0	30	10
FM0035-4	K6	5/18/2016	Pre	0	3168	0	0	0	0	0	95	40
FM0035-4	K6	10/20/2016	POST	2640	0	0	0	0	0	0	65	20
FM0035-4	K6	3/27/2017	POST	1706	884	0	0	0	0	0	85	20
FM0035-4	K6	4/26/2018	POST	1784	0	0	0	0	0	0	65	10

Pre-Construction Pictures (2016)

Figure A-737. FM0035-1, Overall.

Figure A-738. FM0035-1, Outside WP.

Figure A-739. FM0035-1, BWP.

Figure A-740. FM0035-1, Inside WP.

Figure A-741. FM0035-2, Overall.

Figure A-742. FM0035-2, Outside WP.

Figure A-743. FM0035-2, BWP.

Figure A-744. FM0035-2, Inside WP.

Figure A-745. FM0035-3, Overall.

Figure A-746. FM0035-3, Outside WP.

Figure A-747. FM0035-3, BWP.

Figure A-748. FM0035-3, Inside WP.

Figure A-749. FM0035-4, Overall.

Figure A-750. FM0035-4, Outside WP.

Figure A-751. FM0035-4, BWP.

Figure A-752. FM0035-4, Inside WP.

Post-Construction Pictures (2016)

Figure A-753. FM0035-1, Overall.

Figure A-754. FM0035-1, Outside WP.

Figure A-755. FM0035-1, BWP.

Figure A-756. FM0035-1, Inside WP.


Figure A-757. FM0035-2, Overall.


Figure A-758. FM0035-2, Outside WP.


Figure A-759. FM0035-2, BWP.


Figure A-760. FM0035-2, Inside WP.


Figure A-761. FM0035-3, Overall.


Figure A-762. FM0035-3, Outside WP.


Figure A-763. FM0035-3, BWP.


Figure A-764. FM0035-3, Inside WP.

Figure A-765. FM0035-4, Overall.

Figure A-766. FM0035-4, Outside WP.

Figure A-767. FM0035-4, BWP.

Figure A-768. FM0035-4, Inside WP.

Post-Construction Pictures (2017)

Figure A-769. FM0035-1, Overall.

Figure A-770. FM0035-1, Outside WP.

Figure A-771. FM0035-1, BWP.

Figure A-772. FM0035-1, Inside WP.

Figure A-773. FM0035-2, Overall. **Figure A-774. FM0035-2, Outside WP.**

Figure A-775. FM0035-2, BWP. **Figure A-776. FM0035-2, Inside WP.**

Figure A-777. FM0035-3, Overall. **Figure A-778. FM0035-3, Outside WP.**

Figure A-779. FM0035-3, BWP. **Figure A-780. FM0035-3, Inside WP.**

Figure A-781. FM0035-4, Overall.

Figure A-782. FM0035-4, Outside WP.

Figure A-783. FM0035-4, BWP.

Figure A-784. FM0035-4, Inside WP.

Post-Construction Pictures (2018)

Figure A-785. FM0035-1, Overall.

Figure A-786. FM0035-1, Outside WP.

Figure A-787. FM0035-1, BWP.

Figure A-788. FM0035-1, Inside WP.

Figure A-789. FM0035-2, Overall. **Figure A-790. FM0035-2, Outside WP.**

Figure A-791. FM0035-2, BWP. **Figure A-792. FM0035-2, Inside WP.**

Figure A-793. FM0035-3, Overall. **Figure A-794. FM0035-3, Outside WP.**

Figure A-795. FM0035-3, BWP. **Figure A-796. FM0035-3, Inside WP.**

Figure A-797. FM0035-4, Overall.

Figure A-798. FM0035-4, Outside WP.

Figure A-799. FM0035-4, BWP.

Figure A-800. FM0035-4, Inside WP.

HS: 16-PAR-2

District - Paris County - Fannin

Highway - US0069 Near - Trenton

Table A-79. Paris US0069 Test Sections.

Test Section	Lane	BRM	ERM
US0069-1	K1	222+0.0	222+0.1
US0069-2	K6	222+0.1	222+0.0
US0069-3	K1	224+0.0	224+0.1
US0069-4	K6	224+0.1	224+0.0

Table A-80. Paris US0069 Construction Details.

Contractor	NE Tex, New Boston, TX		
Date	08/26/2016		
Binder Type	SPG70-22	Binder Source	Lion, Henderson
Agg. Type	PC Gr 4 Limestone/Sandstone	Agg. Source	Martin Marietta
Weather	Cloudy, 84		
AADT	3300		
2016 %Trk	15.5		
2016 AADT Level	M		

Table A-81. Paris US0069 Binder and Aggregate Application Details.

Test Section	US0069-1	US0069-2	US0069-3	US0069-4
Binder rate	0.32 Gal/SY	0.32 Gal/SY	0.32 Gal/SY	0.32 Gal/SY
Aggregate application rate	140 SY/CY	140 SY/CY	140 SY/CY	140 SY/CY
Binder Application Time	0:00	0:00	-	-
Time until Rock Added	4:02	1:29	-	-
Time to First Roll	6:40	4:30	-	-

Construction Notes

The test sections were hilly, with excessive amount of apparent raveling. There were no issues observed during construction.

Pre- and Post-Construction Distress Surveys

Table A-82. Paris US0069 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
US0069-1	K1	5/18/2016	Pre	0	0	0	734	2668	16	0	80	60
US0069-1	K1	10/20/2016	POST	0	0	0	1784	0	0	0	75	60
US0069-1	K1	3/27/2017	POST	0	0	0	600	0	0	0	40	25
US0069-1	K1	4/26/2018	POST	378	0	0	1334	0	0	0	60	30
US0069-2	K6	5/18/2016	Pre	0	0	0	3524	0	300	600	75	40
US0069-2	K6	10/20/2016	POST	1056	0	0	1812	0	0	0	90	60
US0069-2	K6	3/27/2017	POST	728	0	0	1584	0	0	0	65	20
US0069-2	K6	4/26/2018	POST	1056	0	0	1584	0	0	0	75	25
US0069-3	K1	5/18/2016	Pre	0	0	0	4224	0	0	0	75	40
US0069-3	K1	10/20/2016	POST	200	0	0	1584	0	0	0	75	60
US0069-3	K1	3/27/2017	POST	100	0	0	1784	0	0	0	40	20
US0069-3	K1	4/26/2018	POST	628	0	0	1684	0	0	0	40	20
US0069-4	K6	5/18/2016	Pre	0	0	0	3696	0	0	0	75	40
US0069-4	K6	10/20/2016	POST	1056	0	0	0	0	0	0	70	40
US0069-4	K6	3/27/2017	POST	1584	0	0	0	0	0	0	60	30
US0069-4	K6	4/26/2018	POST	528	0	0	1056	0	0	0	75	20

Pre-Construction Pictures (2016)

Figure A-801. US0069-1, Overall.

Figure A-802. US0069-1, Outside WP.

Figure A-803. US0069-1, BWP.

Figure A-804. US0069-1, Inside WP.

Figure A-805. US0069-2, Overall.

Figure A-806. US0069-2, Outside WP.

Figure A-807. US0069-2, BWP.

Figure A-808. US0069-2, Inside WP.

Figure A-809. US0069-3, Overall.

Figure A-810. US0069-3, Outside WP.

Figure A-811. US0069-3, BWP.

Figure A-812. US0069-3, Inside WP.

Figure A-813. US0069-4, Overall.

Figure A-814. US0069-4, Outside WP.

Figure A-815. US0069-4, BWP.

Figure A-816. US0069-4, Inside WP.

Post-Construction Pictures (2016)

Figure A-817. US0069-1, Overall.

Figure A-818. US0069-1, Outside WP.

Figure A-819. US0069-1, BWP.

Figure A-820. US0069-1, Inside WP.

Figure A-821. US0069-2, Overall.

Figure A-822. US0069-2, Outside WP.

Figure A-823. US0069-2, BWP.

Figure A-824. US0069-2, Inside WP.

Figure A-825. US0069-3, Overall.

Figure A-826. US0069-3, Outside WP.

Figure A-827. US0069-3, BWP.

Figure A-828. US0069-3, Inside WP.


Figure A-829. US0069-4, Overall.


Figure A-830. US0069-4, Outside WP.


Figure A-831. US0069-4, BWP.


Figure A-832. US0069-4, Inside WP.

Post-Construction Pictures (2017)


Figure A-833. US0069-1, Overall.


Figure A-834. US0069-1, Outside WP.


Figure A-835. US0069-1, BWP.


Figure A-836. US0069-1, Inside WP.

Figure A-837. US0069-2, Overall.

Figure A-838. US0069-2, Outside WP.

Figure A-839. US0069-2, BWP.

Figure A-840. US0069-2, Inside WP.

Figure A-841. US0069-3, Overall.

Figure A-842. US0069-3, Outside WP.

Figure A-843. US0069-3, BWP.

Figure A-844. US0069-3, Inside WP.

Figure A-845. US0069-4, Overall. **Figure A-846. US0069-4, Outside WP.**

Figure A-847. US0069-4, BWP. **Figure A-848. US0069-4, Inside WP.**

Post-Construction Pictures (2018)

Figure A-849. US0069-1, Overall. **Figure A-850. US0069-1, Outside WP.**

Figure A-851. US0069-1, BWP. **Figure A-852. US0069-1, Inside WP.**


Figure A-853. US0069-2, Overall.


Figure A-854. US0069-2, Outside WP.


Figure A-855. US0069-2, BWP.


Figure A-856. US0069-2, Inside WP.


Figure A-857. US0069-3, Overall.


Figure A-858. US0069-3, Outside WP.


Figure A-859. US0069-3, BWP.


Figure A-860. US0069-3, Inside WP.

Figure A-861. US0069-4, Overall. **Figure A-862. US0069-4, Outside WP.**

Figure A-863. US0069-4, BWP. **Figure A-864. US0069-4, Inside WP.**

HS: 16-PAR-3

District - Paris | County - Grayson
Highway - SH0289 | Near - Pottsboro

Table A-83. Paris SH0289 Test Sections.

Test Section	Lane	BRM	ERM
SH0289-1	K1	200+0.0	200+0.1
SH0289-2	K6	200+0.1	200+0.0
SH0289-3	K1	202+1.0	202+1.1
SH0289-4	K6	202+1.1	202+1.0

Table A-84. Paris SH0289 Construction Details.

Contractor	NE Tex, New Boston, TX		
Date	09/09/2016		
Binder Type	SPG 70-22	Binder Source	Lion, Henderson
Agg. Type	PC Gr 4 Limestone/Sandstone	Agg. Source	Martin Marietta
Weather	Windy, 1-84°F, 2-82°F, 3-84°F, 4-85°F		
AADT	2500		
2016 %Trk	30		
2016 AADT Level	M		

Table A-85. Paris SH0289 Binder and Aggregate Application Details.

Test Section	SH0289-1	SH0289-2	SH0289-3	SH0289-4
Binder rate	0.32 Gal/SY	0.32 Gal/SY	0.36 Gal/SY	0.36 Gal/SY
Aggregate application rate	140 SY/CY	140 SY/CY	140 SY/CY	140 SY/CY
Time	8:30	9:15	11:25	11:54
Binder Application Time	0:00	0:00	0:00	0:00
Time until Rock Added	0:45	2:02	1:02	2:28
Time to First Roll	2:29	3:31	1:45	6:03

Construction Notes

All test sections were in straightaways with apparent bleeding in both WPs. During construction, the contractor waited between binder applications so that the traffic that was waiting on the pilot car did not ride immediately on the fresh chip seal.

Pre- and Post-Construction Distress Surveys

Table A-86. Paris SH0289 Pre- and Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
SH0289-1	K1	5/18/2016	Pre	0	0	0	0	0	0	0	80	80
SH0289-1	K1	10/6/2016	POST	0	0	0	1918	0	0	0	20	10
SH0289-1	K1	3/27/2017	POST	0	0	0	0	0	0	0	20	20
SH0289-1	K1	4/26/2018	POST	0	0	0	4224	0	0	192	30	30
SH0289-2	K6	5/18/2016	Pre	0	0	0	0	0	0	0	80	80
SH0289-2	K6	10/6/2016	POST	0	0	0	2112	0	0	0	20	10
SH0289-2	K6	3/27/2017	POST	0	0	0	1056	0	0	0	20	20
SH0289-2	K6	4/26/2018	POST	0	0	0	5240	0	0	96	40	30
SH0289-3	K1	5/18/2016	Pre	0	0	0	0	0	0	0	90	90
SH0289-3	K1	10/6/2016	POST	150	0	0	0	0	0	0	30	10
SH0289-3	K1	3/27/2017	POST	0	0	0	0	0	0	0	25	10
SH0289-3	K1	4/26/2018	POST	0	0	0	2212	0	0	0	30	30
SH0289-4	K6	5/18/2016	Pre	0	0	0	0	0	0	0	90	90
SH0289-4	K6	10/6/2016	POST	0	0	0	2368	0	0	0	10	10
SH0289-4	K6	3/27/2017	POST	0	0	0	0	0	0	0	15	10
SH0289-4	K6	4/26/2018	POST	0	0	0	2112	0	0	0	60	40

Pre-Construction Pictures (2016)

Figure A-865. SH0289-1, Overall.

Figure A-866. SH0289-1, Outside WP.

Figure A-867. SH0289-1, BWP.

Figure A-868. SH0289-1, Inside WP.

Figure A-869. SH0289-2, Overall.

Figure A-870. SH0289-2, Outside WP.

Figure A-871. SH0289-2, BWP.

Figure A-872. SH0289-2, Inside WP.

Figure A-873. SH0289-3, Overall.

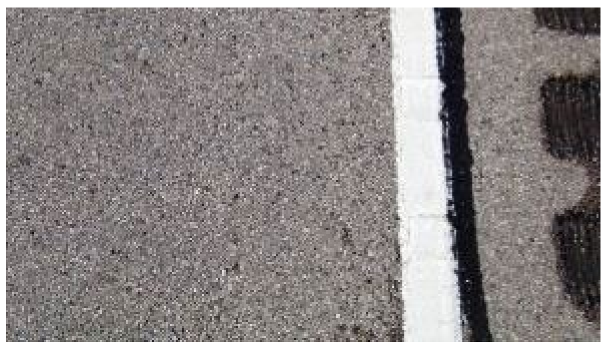

Figure A-874. SH0289-3, Outside WP.

Figure A-875. SH0289-3, BWP.

Figure A-876. SH0289-3, Inside WP.

Figure A-877. SH0289-4, Overall.

Figure A-878. SH0289-4, Outside WP.

Figure A-879. SH0289-4, BWP.

Figure A-880. SH0289-4, Inside WP.

Post-Construction Pictures (2016)

Figure A-881. SH0289-1, Overall.

Figure A-882. SH0289-1, Outside WP.

Figure A-883. SH0289-1, BWP.

Figure A-884. SH0289-1, Inside WP.

Figure A-885. SH0289-2, Overall.

Figure A-886. SH0289-2, Outside WP.

Figure A-887. SH0289-2, BWP.

Figure A-888. SH0289-2, Inside WP.

Figure A-889. SH0289-3, Overall.

Figure A-890. SH0289-3, Outside WP.

Figure A-891. SH0289-3, BWP.

Figure A-892. SH0289-3, Inside WP.

Figure A-893. SH0289-4, Overall. Figure A-894. SH0289-4, Outside WP.

Figure A-895. SH0289-4, BWP. Figure A-896. SH0289-4, Inside WP.

Post-Construction Pictures (2017)

Figure A-897. SH0289-1, Overall. Figure A-898. SH0289-1, Outside WP.

Figure A-899. SH0289-1, BWP. Figure A-900. SH0289-1, Inside WP.


Figure A-901. SH0289-2, Overall.


Figure A-902. SH0289-2, Inside WP.


Figure A-903. SH0289-3, Overall.


Figure A-904. SH0289-3, Outside WP.


Figure A-905. SH0289-3, BWP.


Figure A-906. SH0289-3, Inside WP.


Figure A-907. SH0289-4, Overall.


Figure A-908. SH0289-4, Outside WP.

Figure A-909. SH0289-4, BWP.

Figure A-910. SH0289-4, Inside WP.

Post-Construction Pictures-2018

Figure A-911. SH0289-1, Overall.

Figure A-912. SH0289-1, Outside WP.

Figure A-913. SH0289-1, BWP.

Figure A-914. SH0289-1, Inside WP.

Figure A-915. SH0289-2, Overall.

Figure A-916. SH0289-2, Outside WP.


Figure A-917. SH0289-2, BWP.


Figure A-918. SH0289-2, Inside WP.


Figure A-919. SH0289-3, Overall.


Figure A-920. SH0289-3, Outside WP.

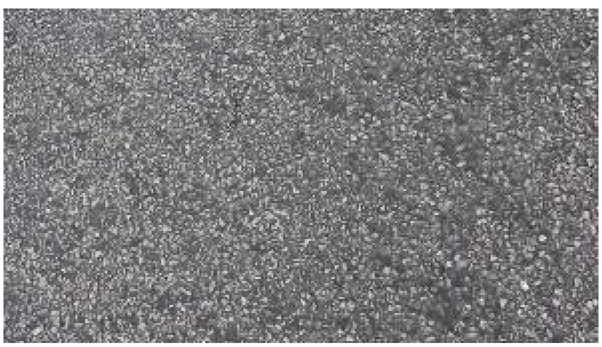
Figure A-921. SH0289-3, BWP.


Figure A-922. SH0289-3, Inside WP.


Figure A-923. SH0289-4, Overall.

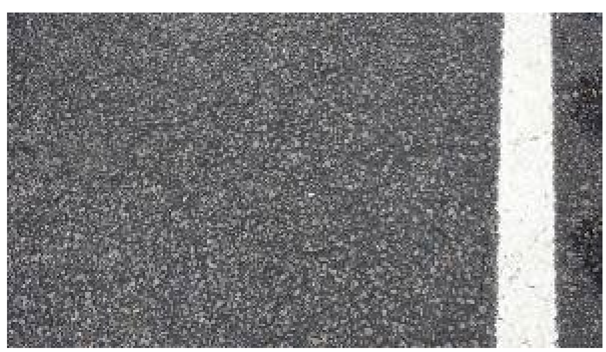
Figure A-924. SH0289-4, Outside WP.


Figure A-925. SH0289-4, BWP.


Figure A-926. SH0289-4, Inside WP.

HS: 17-PAR-1 (no binder collected or received)

District – Paris
Highway – FM1497

Table A-87. Paris FM1497 Test Sections.

Test Section	Lane	BRM	ERM
FM1497-1	K1	208+0.0	208+0.1
FM1497-4	K6	208+0.1	208+0.0

Construction Notes

The field engineer was not present during construction.

Post-Construction Distress Survey

Table A-88. Paris 1497 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM1497-1	K1	4/26/2018	POST	2840	0	0	0	0	0	0	95	50
FM1497-2	K6	4/26/2018	POST	0	0	0	1500	0	0	0	80	35

Post-Construction Pictures (2018)

Figure A-927. FM1497-1, Overall.

Figure A-928. FM1497-1, Outside WP.

Figure A-929. FM1497-1, BWP.

Figure A-930. FM1497-1, Inside WP.

Figure A-931. FM1497-2, Overall.

Figure A-932. FM1497-2, Outside WP.

Figure A-933. FM1497-2, BWP.

Figure A-934. FM1497-2, Inside WP.

HS: 17-PAR-2 (no binder collected or received)

District – Paris County – Red River
Highway – US0082 Near – Detroit

Table A-89. Paris US0082 Test Sections.

Test Section	Lane	BRM	ERM
US0082-1	K6	722+1.9	724+0.0
US0082-2	K1	724+0.0	722+1.9

Construction Notes

The field engineer was not present during construction.

Post-Construction Distress Survey

Table A-90. Paris US0082 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
US0082-1	K6	4/26/2018	POST	2418	750	0	0	0	0	0	90	20
US0082-2	K1	4/26/2018	POST	2640	0	0	0	0	0	0	90	50

Post-Construction Pictures (2018)

Figure A-935. US0082-1, Overall.

Figure A-936. US0082-1, Outside WP.

Figure A-937. US0082-1, BWP.

Figure A-938. US0082-1, Inside WP.

Figure A-939. US0082-2, Overall.

Figure A-940. US0082-2, Outside WP.

Figure A-941. US0082-2, BWP.

Figure A-942. US0082-2, Inside WP.

HS: 17-PAR-3 (no binder collected or received)

District – Paris
County – Red River
Highway – US0271
Near – Detroit

Table A-91. Paris US0271 Test Sections.

Test Section	Lane	BRM	ERM
US0271-1	K6	722+1.9	724+0.0
US0271-2	K1	724+0.0	722+1.9

Construction Notes

The field engineer was not present during construction.

Post-Construction Distress Survey

Table A-92. Paris US0271 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
US0271-1	K1	4/26/2018	POST	0	2912	0	0	0	0	0	95	60
US0271-2	K6	4/26/2018	POST	984	0	0	0	0	0	0	75	20

Post-Construction Pictures (2018)

Figure A-943. US0271-1, Overall.

Figure A-944. US0271-1, Outside WP.

Figure A-945. US0271-1, BWP.

Figure A-946. US0271-1, Inside WP.

Figure A-947. US0271-2, Overall.

Figure A-948. US0271-2, Outside WP.

Figure A-949. US0271-2, BWP.

Figure A-950. US0271-2, Inside WP.

HS: 16-PHR-1

District – Pharr
County – Willacy
Highway – FM0506
Near – Sebastian

Table A-93. Pharr FM0506 Test Sections.

Test Section	Lane	BRM	ERM
FM0506-1	K1	716+0.0	716+0.1
FM0506-2	K6	716+0.1	716+0.0
FM0506-3	K1	718+0.0	718+0.1
FM0506-4	K6	718+0.1	718+0.0

Construction Notes

The field engineer was not present during construction.

Post-Construction Distress Survey

Table A-94. Pharr FM0506 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM0506-1	K1	7/1/2016	POST	0	2112	0	0	0	0	0	85	50
FM0506-1	K1	3/16/2017	POST	0	2112	0	0	0	0	0	75	15
FM0506-1	K1	3/30/2018	POST	2112	0	0	0	0	0	0	90	70
FM0506-2	K6	7/1/2016	POST	0	1584	0	0	0	0	0	60	40
FM0506-2	K6	3/16/2017	POST	0	600	0	400	0	0	0	20	40
FM0506-2	K6	3/30/2018	POST	0	0	0	0	0	0	0	75	60
FM0506-3	K1	7/1/2016	POST	0	2640	0	0	0	0	0	85	40
FM0506-3	K1	3/16/2017	POST	2112	0	0	0	0	0	0	80	25
FM0506-3	K1	3/30/2018	POST	2718	0	0	0	0	0	0	75	50
FM0506-4	K6	7/1/2016	POST	0	1056	0	0	0	0	0	60	30
FM0506-4	K6	3/16/2017	POST	1584	0	0	0	0	0	0	75	20
FM0506-4	K6	3/30/2018	POST	856	0	0	0	0	0	0	75	40

Post-Construction Pictures (2016)

Figure A-951. FM0506-1, Overall.

Figure A-952. FM0506-1, Outside WP.

Figure A-953. FM0506-1, BWP.

Figure A-954. FM0506-1, Inside WP.

Figure A-955. FM0506-2, Overall.

Figure A-956. FM0506-2, Outside WP.

Figure A-957. FM0506-2, BWP.

Figure A-958. FM0506-2, Inside WP.

Figure A-959. FM0506-3, Overall. **Figure A-960. FM0506-3, Outside WP.**

Figure A-961. FM0506-3, BWP. **Figure A-962. FM0506-3, Inside WP.**

Figure A-963. FM0506-4, Overall. **Figure A-964. FM0506-4, Outside WP.**

Figure A-965. FM0506-4, BWP. **Figure A-966. FM0506-4, Inside WP.**

Post-Construction Pictures (2017)

Figure A-967. FM0506-1, Overall.

Figure A-968. FM0506-1, Outside WP.

Figure A-969. FM0506-1, BWP.

Figure A-970. FM0506-1, Inside WP.

Figure A-971. FM0506-2, Overall.

Figure A-972. FM0506-2, Outside WP.

Figure A-973. FM0506-2, BWP.

Figure A-974. FM0506-2, Inside WP.

Figure A-975. FM0506-3, Overall.

Figure A-976. FM0506-3, Outside WP.

Figure A-977. FM0506-3, BWP.

Figure A-978. FM0506-3, Inside WP.

Figure A-979. FM0506-4, Overall.

Figure A-980. FM0506-4, Outside WP.

Figure A-981. FM0506-4, BWP.

Figure A-982. FM0506-4, Inside WP.

Post-Construction Pictures (2018)

Figure A-983. FM0506-1, Overall.

Figure A-984. FM0506-1, Outside WP.

Figure A-985. FM0506-1, BWP.

Figure A-986. FM0506-1, Inside WP.

Figure A-987. FM0506-2, Overall.

Figure A-988. FM0506-2, Outside WP.

Figure A-989. FM0506-2, BWP.

Figure A-990. FM0506-2, Inside WP.


Figure A-991. FM0506-3, Overall.


Figure A-992. FM0506-3, Outside WP.


Figure A-993. FM0506-3, BWP.


Figure A-994. FM0506-3, Inside WP.


Figure A-995. FM0506-4, Overall.


Figure A-996. FM0506-4, Outside WP.


Figure A-997. FM0506-4, BWP.


Figure A-998. FM0506-4, Inside WP.

HS: 16-PHR-2

District – Pharr
County – Cameron
Highway – FM1847
Near – Los Fresnos

Table A-95. Pharr FM1847 Test Sections.

Test Section	Lane	BRM	ERM
FM1847-1	K1	732+0.0	732+0.1
FM1847-2	K6	732+0.1	732+0.0
FM1847-3	K1	734+0.0	734+0.1
FM1847-4	K6	734+0.1	734+0.0

Construction Notes

The field engineer was not present during construction.

Post-Construction Distress Survey

Table A-96. Pharr FM1847 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM1847-1	K1	7/1/2016	POST	0	390	0	0	0	0	0	50	30
FM1847-1	K1	3/16/2017	POST	728	0	0	650	0	0	0	95	50
FM1847-1	K1	3/30/2018	POST	2640	0	0	0	0	0	0	90	40
FM1847-2	K6	7/1/2016	POST	0	0	0	3168	0	0	0	40	20
FM1847-2	K6	3/16/2017	POST	0	0	0	3808	1100	0	0	50	20
FM1847-2	K6	3/30/2018	POST	1140	0	0	0	0	0	0	50	20
FM1847-3	K1	7/1/2016	POST	0	0	0	4224	0	0	0	25	20
FM1847-3	K1	3/16/2017	POST	956	0	0	0	0	0	0	25	10
FM1847-3	K1	3/30/2018	POST	0	0	0	0	0	0	0	50	35
FM1847-4	K6	7/1/2016	POST	0	0	0	4752	0	0	0	25	10
FM1847-4	K6	3/16/2017	POST	0	0	0	600	0	0	0		
FM1847-4	K6	3/30/2018	POST	456	0	0	0	0	0	0	50	25

Post-Construction Pictures (2016)

Figure A-999. FM1847-1, Overall.

Figure A-1000. FM1847-1, Outside WP.

Figure A-1001. FM1847-1, BWP.

Figure A-1002. FM1847-1, Inside WP.

Figure A-1003. FM1847-2, Overall.

Figure A-1004. FM1847-2, Outside WP.

Figure A-1005. FM1847-2, BWP.

Figure A-1006. FM1847-2, Inside WP.

Figure A-1007. FM1847-3, Overall. **Figure A-1008. FM1847-3, Outside WP.**

Figure A-1009. FM1847-3, BWP. **Figure A-1010. FM1847-3, Inside WP.**

Post-Construction Pictures (2017)

Figure A-1011. FM1847-1, Overall. **Figure A-1012. FM1847-1, Outside WP.**

Figure A-1013. FM1847-1, BWP. **Figure A-1014. FM1847-1, Inside WP.**


Figure A-1015. FM1847-2, Overall.


Figure A-1016. FM1847-2, Outside WP.


Figure A-1017. FM1847-2, BWP.


Figure A-1018. FM1847-2, Inside WP.


Figure A-1019. FM1847-3, Overall.


Figure A-1020. FM1847-3, Outside WP.


Figure A-1021. FM1847-3, BWP.


Figure A-1022. FM1847-3, Inside WP.

Figure A-1023. FM1847-4, Overall.

Figure A-1024. FM1847-4, Outside WP.

Figure A-1025. FM1847-4, BWP.

Figure A-1026. FM1847-4, Inside WP.

Post-Construction Pictures (2018)

Figure A-1027. FM1847-1, Overall.

Figure A-1028. FM1847-1, Outside WP.

Figure A-1029. FM1847-1, BWP.

Figure A-1030. FM1847-1, Inside WP.


Figure A-1031. FM1847-2, Overall.


Figure A-1032. FM1847-2, Outside WP.


Figure A-1033. FM1847-2, BWP.


Figure A-1034. FM1847-2, Inside WP.


Figure A-1035. FM1847-3, Overall.


Figure A-1036. FM1847-3, Outside WP.


Figure A-1037. FM1847-3, BWP.


Figure A-1038. FM1847-3, Inside WP.

Figure A-1039. FM1847-4, Overall.

Figure A-1040. FM1847-4, Outside WP.

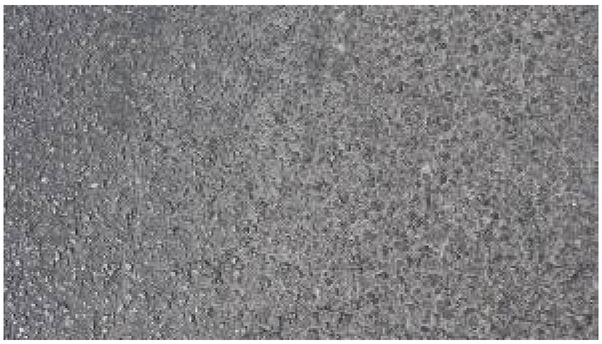

Figure A-1041. FM1847-4, BWP.

Figure A-1042. FM1847-4, Inside WP.

HS: 16-PHR-3

District – Pharr County – Starr
Highway – FM2098 Near – Falcon Heights

Table A-97. Pharr FM2098 Test Sections.

Test Section	Lane	BRM	ERM
FM2098-1	K1	698+0.0	698+0.1
FM2098-2	K6	698+0.1	698+0.0
FM2098-3	K1	700+0.0	700+0.1
FM2098-4	K6	700+0.1	700+0.0

Construction Notes

The field engineer was not present during construction.

Post-Construction Distress Survey

Table A-98. Pharr FM2098 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM2098-1	K1	7/1/2016	POST	0	0	0	0	0	0	0	30	10
FM2098-1	K1	3/16/2017	POST	784	0	0	0	0	0	0	35	20
FM2098-1	K1	3/30/2018	POST	274	0	0	0	0	0	0	40	15
FM2098-2	K6	7/1/2016	POST	1056	0	0	0	0	0	0	30	10
FM2098-2	K6	3/16/2017	POST	736	0	0	200	0	0	0	75	35
FM2098-2	K6	3/30/2018	POST	1066	0	0	0	0	0	0	35	20
FM2098-3	K1	7/1/2016	POST	756	0	0	0	0	0	0	50	30
FM2098-3	K1	3/16/2017	POST	350	534	0	0	0	0	0	70	25
FM2098-3	K1	3/30/2018	POST	1256	0	0	0	0	0	0	65	20
FM2098-4	K6	7/1/2016	POST	2640	0	0	0	0	0	0	90	30
FM2098-4	K6	3/16/2017	POST	1134	0	0	0	0	0	0	80	30
FM2098-4	K6	3/30/2018	POST	1456	234	0	0	0	0	0	50	20

Post-Construction Pictures (2016)

Figure A-1043. FM2098-1, Overall.

Figure A-1044. FM2098-1, Outside WP.

Figure A-1045. FM2098-1, BWP.

Figure A-1046. FM2098-1, Outside WP.

Figure A-1047. FM2098-2, Overall.

Figure A-1048. FM2098-2, Outside WP.

Figure A-1049. FM2098-2, BWP.

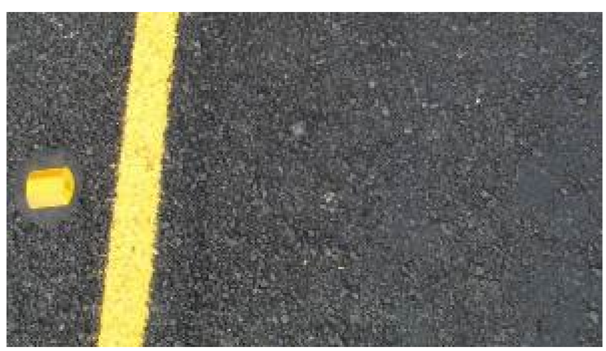

Figure A-1050. FM2098-2, Outside WP.

Figure A-1051. FM2098-3, Overall. Figure A-1052. FM2098-3, Outside WP.

Figure A-1053. FM2098-3, BWP. Figure A-1054. FM2098-3, Outside WP.

Figure A-1055. FM2098-4, Overall. Figure A-1056. FM2098-4, Outside WP.

Figure A-1057. FM2098-4, BWP. Figure A-1058. FM2098-4, Outside WP.

Post-Construction Pictures (2017)

Figure A-1059. FM2098-1, Overall.

Figure A-1060. FM2098-1, Outside WP.

Figure A-1061. FM2098-1, BWP.

Figure A-1062. FM2098-1, Outside WP.

Figure A-1063. FM2098-2, Overall.

Figure A-1064. FM2098-2, Outside WP.

Figure A-1065. FM2098-2, BWP.

Figure A-1066. FM2098-2, Outside WP.


Figure A-1067. FM2098-3, Overall.


Figure A-1068. FM2098-3, Outside WP.


Figure A-1069. FM2098-3, BWP.


Figure A-1070. FM2098-3, Outside WP.


Figure A-1071. FM2098-4, Overall.


Figure A-1072. FM2098-4, Outside WP.


Figure A-1073. FM2098-4, BWP.


Figure A-1074. FM2098-4, Outside WP.

Post-Construction Pictures (2018)

Figure A-1075. FM2098-1, Overall.

Figure A-1076. FM2098-1, Outside WP.

Figure A-1077. FM2098-1, BWP.

Figure A-1078. FM2098-1, Outside WP.

Figure A-1079. FM2098-2, Overall.

Figure A-1080. FM2098-2, Outside WP.

Figure A-1081. FM2098-2, BWP.

Figure A-1082. FM2098-2, Outside WP.


Figure A-1083. FM2098-3, Overall.


Figure A-1084. FM2098-3, Outside WP.


Figure A-1085. FM2098-3, BWP.


Figure A-1086. FM2098-3, Outside WP.


Figure A-1087. FM2098-4, Overall.


Figure A-1088. FM2098-4, Outside WP.


Figure A-1089. FM2098-4, BWP.


Figure A-1090. FM2098-4, Outside WP.

HS: 17-PHR-1

District – Pharr　　County – Hidalgo
Highway – FM0088　　Near – Edinburg

Table A-99. Pharr FM0088 Test Sections.

Test Section	Lane	BRM	ERM
FM0088-1	K1	714+0.0	714+0.1
FM0088-2	K6	714+0.1	714+0.0
FM0088-3	K1	716+0.0	716+0.1
FM0088-4	K6	716+0.1	716+0.0

Construction Notes

The field engineer was not present during construction.

Post-Construction Distress Survey

Table A-100. Pharr FM0088 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM0088-1	K1	3/30/2018	POST	0	0	0	0	0	0	0	35	10
FM0088-2	K6	3/30/2018	POST	0	0	0	0	0	0	0	35	60
FM0088-3	K1	3/30/2018	POST	2640	0	0	0	0	0	0	95	50
FM0088-4	K6	3/30/2018	POST	1816	150	0	0	0	0	0	75	30

Post-Construction Pictures (2018)

Figure A-1091. FM0088-1, Overall.

Figure A-1092. FM0088-1, Outside WP.


Figure A-1093. FM0088-1, BWP.


Figure A-1094. FM0088-1, Inside WP.


Figure A-1095. FM0088-2, Overall.


Figure A-1096. FM0088-2, Outside WP.


Figure A-1097. FM0088-2, BWP.


Figure A-1098. FM0088-2, Inside WP.


Figure A-1099. FM0088-3, Overall.


Figure A-1100. FM0088-3, Outside WP.

Figure A-1101. FM0088-3, BWP.

Figure A-1102. FM0088-3, Inside WP.

Figure A-1103. FM0088-4, Overall.

Figure A-1104. FM0088-4, Outside WP.

Figure A-1105. FM0088-4, BWP.

Figure A-1106. FM0088-4, Inside WP.

HS: 17-PHR-2

District – Pharr
County – Hidalgo
Highway – FM2220
Near – Edinburg

Table A-101. Pharr FM2220 Test Sections.

Test Section	Lane	BRM	ERM
FM2220-1	K1	718+0.0	718+0.1
FM2220-2	K6	718+0.1	718+0.0

Construction Notes

The field engineer was not present during construction.

Post-Construction Distress Survey

Table A-102. Pharr FM2220 Post-Construction Distress.

Test Section	Lane	Date	Type	BL-L	BL-M	BL-H	Rav-L	Rav-M	Rav-H	Patch-L	EMB-WP	EMB-BWP
FM2220-1	K1	3/30/2018	POST	2340	0	0	0	0	0	0	95	75
FM2220-2	K6	3/30/2018	POST	1584	0	0	0	0	0	0	75	75

Post-Construction Pictures (2018)

Figure A-1107. FM2220-1, Overall.

Figure A-1108. FM2220-1, Outside WP.

Figure A-1109. FM2220-1, BWP.

Figure A-1110. FM2220-2, Overall.

Figure A-1111. FM2220-2, Outside WP.

Figure A-1112. FM2220-2, BWP.

Figure A-1113. FM2220-2, Inside WP.

APPENDIX B: SUMMARY OF SPG IMPLEMENTATION

SUMMARY OF 2016 SPG IMPLEMENTATION IN ABL DISTRICT

Over the past 15 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 135 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the third year of SPG implementation, 17 HSs were established from many available in the district-wide chip seal programs, including two in the ABL district with location and construction information provided in Table B1.

Post-Construction Technical Debriefing for District-Wide Program (10/14/2016)

Construction at the beginning of the 2016 summer was smooth with no problems related to aggregate loss, including one section that experienced rain soon after spraying the binder and prior to aggregate application. Some sections constructed later in the summer experienced more than normal aggregate loss, including one that had to be redone likely due to a sudden drop in temperature and heavy rain (3-4 in.) during construction. To address the aggregate loss issue, the binder application rate was increased which although improved the performance, overran the construction costs. District personnel also remarked that the surface should be very clean for better adhesion. Although the binder looked different at application (more strung out), the contractor found the SPG binder satisfactory as it performed well even at higher temperatures late in the summer. Based on their experience, district personnel planned to use the traditional AC-20-5TR in 2017 and consider SPG binders again in 2018 after the field performance of the 2016 sections can be evaluated in 2017.

Laboratory and Field Performance

For the two ABL HSs, Table B2 provides the laboratory-measured SPG grade of the chip seal binders collected at construction and field performance after the first winter and after two winters in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B1 shows the HSs in 2017 after the first winter. Both binders were expected to perform adequately since they met the specified SPG 73-19 and passed the phase angle requirement ($< 80^0$), and adequate field performance in terms of aggregate loss ($SCI_{AL} > 70$) was exhibited for the first two years of service. However, 16-ABL-1 showed inadequate field performance in terms of bleeding ($SCI_{BL} < 70$) for the first two years of service that can likely be attributed to construction factors such as excessive aggregate embedment (ED > 80) due to very high temperatures at construction or opening the HS to traffic prematurely.

Table B1. 2016 ABL HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Abilene	16-ABL-1	Howard	BI0020G	5/9/2016	Hot, 100° F	SPG73-19	0.36	PC GR 4	115	-	-	3700	45
	16-ABL-2	Jones	SH0092	8/1/2016	Windy, 95° F		0.38	PB GR 4	115	SH0092-1| 3:55 SH0092-2| 8:34 SH0092-3| 8:42 SH0092-4| 3:33/6:04	SH0092-1| 6:07 SH0092-2| 11:57 SH0092-3| 12:55 SH0092-4| 10:12	2500	30

Table B2. Laboratory and Field Performance for 2016 ABL HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
16-ABL-1	SPG73-19	67-13	76-22	70.3	3700	95	80	100	60	92	100	61	92
16-ABL-2	SPG73-19	67-13	79-22	76.4	2500	48	24	98	90	96	89	86	88

Figure B1. 16-ABL-1 and 16-ABL-2 in 2017.

SUMMARY OF 2016 SPG IMPLEMENTATION IN AMA DISTRICT

Over the past 15 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 135 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the third year of SPG implementation, 17 HSs were established from many available in the district-wide chip seal programs, including two in the AMA district with location and construction information provided in Table B3.

Post-Construction Technical Debriefing for District-Wide Program (10/17/2016)

The 2016 construction experience was positive with nothing particularly different noted with application of SPG binders. There was some concern regarding less than normal bleeding that may lead to aggregate loss during winter. District personnel were encouraged to reduce binder application rates by suppliers citing bleeding issues, but TxDOT CST personnel encouraged them to keep high binder application rates to preclude aggregate loss. Therefore, binder application rates were not adjusted. District personnel also cited the challenge in getting supplier support toward successful implementation. Based on their experience, district personnel planned to continue to use the SPG specification in 2017 but with a SPG 73-25 required grade due to the change to 6^0 C increments.

Laboratory and Field Performance

For the two AMA HSs, Table B4 provides the laboratory-measured SPG grade of the chip seal binders collected at construction and field performance after the first winter and after two winters in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B2 shows the HSs in 2017 after the first winter. Both binders were expected to perform adequately since they met the specified SPG 64-25 and passed the phase angle requirement ($< 80^0$), and adequate field performance in terms of both bleeding ($SCI_{BL} > 70$) and aggregate loss ($SCI_{AL} > 70$) was exhibited for the first two years in service.

Table B3. 2016 AMA HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Amarillo	16-AMA-1	Ochiltree	US0083X	8/1/2016	Hot, 100° F	SPG64-25	0.45	PC GR 3/4	100	-	-	3500	28
	16-AMA-2	Hartley	FM0281	8/15/2016	Windy, 85° F		0.41	PC GR 4	110	FM0281-1| 5:53 FM0281-2| 5:04 FM0281-3| 3:34 FM0281-4| 4:12	FM0281-1| 7:03 FM0281-2| 7:50 FM0281-3| 5:04 FM0281-4| 8:46	2627	42.9

Table B4. Laboratory and Field Performance for 2016 AMA HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
16-AMA-1	SPG64-25	64-25	64-34	78	3500	21	10	92	100	93	92	100	94
16-AMA-2	SPG64-25	64-25	64-31	73.7	2627	21	14	93	94	93	79	73	77

Figure B2. 16-AMA-1 and 16-AMA-2 (with rain) in 2017.

SUMMARY OF 2016 SPG IMPLEMENTATION IN AUS DISTRICT

Over the past 15 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 135 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the third year of SPG implementation, 17 HSs were established from many available in the district-wide chip seal programs, including three in the AUS district with location and construction information provided in Table B5.

Post-Construction Technical Debriefing for District-Wide Program (10/24/2016)

The construction of chip seals with SPG binders was uneventful. In general, the experience was better with more continuous traffic, with some bleeding noted at an intersection with high truck traffic, very high temperatures, and application without variable rate nozzles for flushed surfaces. The SPG binder was applied at the same rate as the conventional AC-15P binder, and the contractor did not particularly notice any difference between these binders during construction. Based on their experience, district personnel did not know if SPG would be utilized again in 2017.

Laboratory and Field Performance

For the three AUS HSs, Table B6 provides the laboratory-measured SPG grade of the chip seal binders collected at construction and field performance after the first winter and after two winters in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B3 shows the HSs in 2017 after the first winter. The binder utilized in 16-AUS-1 was expected to perform adequately since it met the specified SPG 70-19 and passed the phase angle requirement ($< 80^0$), and adequate field performance in terms of bleeding ($SCI_{BL} > 70$) was exhibited for the first two years of service. However, 16-AUS-1 exhibited inadequate field performance in terms of aggregate loss ($SCI_{AL} < 70$) after the first winter that may be due to inadequate aggregate embedment (ED < 30) but this did not persist after two winters possibly due to variability in field performance monitoring despite the use of multiple test sections per HS. The binders utilized in 16-AUS-2 and 16-AUS-3 did not meet the specified SPG 70-19 at high temperatures, so they were not expected to perform adequately in terms of bleeding although passing the phase angle requirement ($< 80^0$) may have provided some resistance to bleeding with marginal field performance ($SCI_{BL} > 70$) for 16-AUS-2. As expected based on laboratory SPG results, 16-AUS-3 exhibited bleeding and both 16-AUS-2 and 16-AUS-3 provided adequate field performance in terms of aggregate loss (SCI_{AL} > 70) for the first two years of service.

Table B5. 2016 AUS HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Austin	16-AUS-1	Mason	US0087	7/19/2016	Hot, windy, 95° F	SPG70-19	US0087-1| 0.31 US0087-2| 0.31 US0087-3| 0.31 US0087-4| 0:32	PC GR 4	US0087-1| 110 US0087-2| 110 US0087-3| 110 US0087-4| 120	US0087-1| 2:23 US0087-2| 2:15 US0087-3| 2:45 US0087-4| 3:10	US0087-1| 7:01 US0087-2| 7:03 US0087-3| 3:47 US0087-4| 3:46	2558	29.6
	16-AUS-2	Mason	SH0029 (1-4)	7/19/2016	Light wind, 90° F		0.32	PC GR 4	120	SH0029-1| 3:08 SH0029-2| 0:41 SH0029-3| 3:05 SH0029-4| 0:33	SH0029-1| 6:47 SH0029-2| 2:29 SH0029-3| 5:31 SH0029-4| 1:25	1148	15.9
	16-AUS-3	Llano	SH0029 (5-6)	7/19/2016	Hot, windy, 100° F		0.33	PC GR 4	121	SH0029-5| 3:08 SH0029-6| 0:41	SH0029-5| 6:47 SH0029-6| 2:29	4771	17.9

Table B6. Laboratory and Field Performance for 2016 AUS HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
16-AUS-1	SPG70-19	67-16	73-22	52	2558	21	11	64	89	69	72	82	74
16-AUS-2	SPG70-19	67-16	67-22	76.4	1148	65	11	82	77	81	100	77	95
16-AUS-3	SPG70-19	67-16	67-22	77.9	4771	95	20	100	62	92	100	51	90

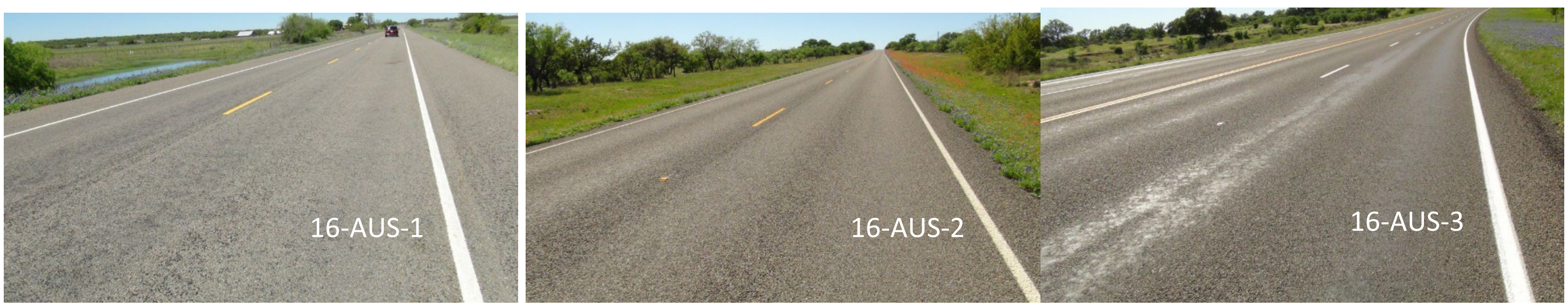

Figure B3. 16-AUS-1, 16-AUS-2, and 16-AUS-3 in 2017.

SUMMARY OF 2016 SPG IMPLEMENTATION IN BWD DISTRICT

Over the past 15 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 135 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the third year of SPG implementation, 17 HSs were established from many available in the district-wide chip seal programs, including two in the BWD district with location and construction information provided in Table B7.

Post-Construction Technical Debriefing for District-Wide Program (10/3/2016)

At first the SPG binder utilized on 16-BWD-2 looked equivalent to CRS-2P, but very high construction temperatures caused some expected tracking in the afternoon. On subsequent afternoons, the SPG binder continued to be soft and thus the binder was changed to a CRS-2P based on input from the supplier. Dusty aggregates were utilized, but the material did meet specifications and wet stockpiles were utilized to address this issue. District personnel also indicated that better construction practices could have been used. Based on their experience, district personnel planned to use the traditional CRS-2P in 2017 and consider SPG binders again in 2018 after the field performance of the 2016 sections can be evaluated in 2017.

Laboratory and Field Performance

For the two BWD HSs, Table B8 provides the laboratory-measured SPG grade of the chip seal binders collected at construction and field performance after the first winter in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B4 shows the HSs in 2017 after the first winter. The SPG binder utilized in 16-BWD-2 was not expected to perform adequately even though it met the specified SPG 67-22 because it failed the phase angle requirement (with $\delta > 80^0$), but marginal field performance in terms of both aggregate loss and bleeding were exhibited after the first winter. The CRS-2P binder utilized in 16-BWD-1 was expected to perform adequately since it met the specified SPG 67-22 and marginally passed the phase angle requirement ($< 80^0$), but inadequate field performance in terms of aggregate loss ($SCI_{AL} < 70$) was exhibited. The CRS-2P was stiffer than the SPG binder based on measured high temperature SPG and did pass the phase angle requirement ($< 80^0$), so if an SPG binder was considered in the future, an SPG 73-22 is recommended.

Table B7. 2016 BWD HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Brownwood	16-BWD-1	Coleman	US0084	7/15/2016	Light wind, 96° F	CRS-2P	0.38	GR 4	120	9:50	16:40	3300	11.7
	16-BWD-2		US0084	7/12/2016	Light wind 85° & 96° F	SPG67-22	0.42	Lime Gr 4	120	US0084-1| 12:56 US0084-2| 7:29 US0084-3| 11:10 US0084-4| 8:01	US0084-1| 15:57 US0084-2| 12:32 US0084-3| 13:18 US0084-4| 10:38	3300	11.7

Table B8. Laboratory and Field Performance for 2016 BWD HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
16-BWD-1	CRS-2P	67-19	70-22	79.6	3300	44	29	67	88	71			
16-BWD-2	SPG67-22	67-19	67-25	81.1	3300	20	10	75	77	75			

Figure B4. 16-BWD-1 and 16-BWD-2 in 2017.

SUMMARY OF 2016 SPG IMPLEMENTATION IN CRP DISTRICT

Over the past 15 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 135 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the third year of SPG implementation, 17 HSs were established from many available in the district-wide chip seal programs, including two in the CRP district with location and construction information provided in Table B9.

Post-Construction Technical Debriefing for District-Wide Program (10/24/2016)

Construction of chip seals with SPG binders did not present any problems, and district personnel suspect that they were provided with traditional AC-15P used in previous years that met the specified SPG 70-19. They raised concern that the SPG specification could not ensure the presence of tire rubber or delineate between AC-20-5TR and AC-15P binders. Thus, district personnel planned to use the traditional AC-20-5TR for Tier I and AC-15P for Tier II in 2017 based on their historic record of good performance, especially in terms of bleeding resistance.

Laboratory and Field Performance

For the two CRP HSs, Table B10 provides the laboratory-measured SPG grade of the chip seal binders collected at construction and field performance after the first winter and after two winters in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B5 shows the HSs in 2017 after the first winter. Both binders are not expected to perform adequately even though they meet the specified SPG 70-19 because they failed the phase angle requirement (with $\delta > 80^0$), and inadequate field performance in terms of aggregate loss ($SCI_{AL} < 70$) was exhibited after the first winter that can likely be attributed to inadequate aggregate embedment (ED < 30) or insufficient polymer modification captured by the high phase angle. Only one of the two HSs maintained inadequate field performance in terms of aggregate loss after two winters due to variability in field performance monitoring despite the use of multiple test sections per HS.

Table B9. 2016 CRP HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Corpus Christi	16-CRP-1	Jim Wells	FM3376	9/17/2016	Hot, humid, 99° F	SPG70-19	0.35	PC GR 4	110	FM3376-1| 2:22 FM3376-2| 2:59 FM3376-3| - FM3376-4| -	FM3376-1| 3:02 FM3376-2| 6:45 FM3376-3| - FM3376-4| -	3000	10
	16-CRP-2	Nueces	FM0665	FM0665-1| 9/19/16 FM0665-2| 9/19/16 FM0665-3| 9/19/16 FM0665-4| 9/20/16	FM0665-1| Light wind, 98°F FM0665-2| Still, 74° F FM0665-3| Steady wind, 96° F FM0665-4| Steady wind, 92° F		0.35	PC GR 4S, B	110	FM0665-1| 2:04 FM0665-2| 1:59 FM0665-3| 4:41 FM0665-4| 4:35	FM0665-1| 9:22 FM0665-2| 6:24 FM0665-3| 8:03 FM0665-4| 6:35	3500	8

Table B10. Laboratory and Field Performance for 2016 CRP HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
16-CRP-1	SPG70-19	67-13	73-22	82.1	3000	15	13	58	100	66	69	100	75
16-CRP-2	SPG70-19	67-13	73-22	80.3	3500	26	11	57	100	66	84	82	84

Figure B5. 16-CRP-1 and 16-CRP-2 in 2017.

SUMMARY OF 2016 SPG IMPLEMENTATION IN PAR DISTRICT

Over the past 15 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 135 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the third year of SPG implementation, 17 HSs were established from many available in the district-wide chip seal programs, including three in the PAR district with location and construction information provided in Table B11.

Post-Construction Technical Debriefing for District-Wide Program (10/7/2016)

Very high temperatures were noted during construction with hot-applied SPG binders, and at these temperatures the SPG binders were very thin such that the underlying crack seals and paint marks were still visible after binder application. In addition, high levels of bleeding were reported even at low binder application rates. These issues may be attributable to the presence of a cutback based on a peculiar smell noted by district personnel. District personnel did note good initial performance comparable to CRS-2P and lack of any construction issues after reducing the binder application rate for SPG 67-22 used on low volume roads but not included in this SPG field validation effort. Based on this experience, district personnel planned to use the traditional AC-20-5TR (and CRS-2P) in 2017 and consider SPG binders again in 2018 after further investigation of existing surface conditions and their contribution to the construction issues.

Laboratory and Field Performance

For the three PAR HSs, Table B12 provides the laboratory-measured SPG grade of the chip seal binders collected at construction and field performance after the first winter and after two winters in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B6 shows the HSs in 2017 after the first winter. All three binders were expected to perform adequately since they met the specified SPG 70-22 and passed the phase angle requirement (> 80^0), and all three HSs exhibited adequate field performance in terms of aggregate loss (SCI_{AL} > 70) after the first winter. After two winters, 16-PAR-3 failed in terms of aggregate loss possibly due to inadequate embedment depth (ED < 30). 16-PAR-2 and 16-PAR-3 also exhibited adequate field performance in terms of bleeding (SCI_{BL} > 70) for the first two years of service, but 16-PAR-1 failed in terms of bleeding (SCI_{BL} < 70) after the first winter that can maybe attributed to moderate traffic level (4147 AADT) or the thin binder noted during construction. This poor performance did not persist after two winters due to variability in field performance monitoring despite the use of multiple test sections per HS.

Table B11. 2016 PAR HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Paris	16-PAR-1	Hunt	FM0035	7/7/2016	Hot, 95° F	SPG70-22	0.32	PC GR 4	130	FM0035-1| - FM0035-2| - FM0035-3| 4:50 FM0035-4| 2:40	FM0035-1| - FM0035-2| - FM0035-3| 5:46 FM0035-4| 7:27	4147	9.1
	16-PAR-2	Fannin	US0069	8/26/2016	Cloudy, 84° F		0.32	PC GR 4, B	140	US0069-1| 4:02 US0069-2| 1:29 US0069-3| - US0069-4| -	US0069-1| 6:40 US0069-2| 4:30 US0069-3| - US0069-4| -	3300	15.5
	16-PAR-3	Grayson	SH0289	9/9/2016	SH0289-1| Windy, 84° F SH0289-2| Windy, 82° F SH0289-3| Windy, 84° F SH0289-4| Windy, 85° F		SH0289-1| 0.32 SH0289-2| 0.32 SH0289-3| 0.36 SH0289-4| 0.36	PC GR 4	140	SH0289-1| 0:45 SH0289-2| 2:02 SH0289-3| 1:02 SH0289-4| 2:28	SH0289-1| 2:29 SH0289-2| 3:31 SH0289-3| 1:45 SH0289-4| 6:03	2500	30

Table B12. Laboratory and Field Performance for 2016 PAR HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
16-PAR-1	SPG70-22	67-19	70-22	79.3	4147	75	25	100	66	93	94	80	91
16-PAR-2	SPG70-22	67-19	70-25	78.6	3300	78	55	82	88	84	75	85	77
16-PAR-3	SPG70-22	67-19	76-22	72.7	2500	20	10	95	100	96	57	100	66

Figure B6. 16-PAR-1, 16-PAR-2, and 16-PAR-3 in 2017.

SUMMARY OF 2016 SPG IMPLEMENTATION IN PHR DISTRICT

Over the past 15 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 135 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the third year of SPG implementation, 17 HSs were established from many available in the district-wide chip seal programs, including three in the PHR district with location information provided in Table B13. Construction information was not available.

Post-Construction Technical Debriefing for District-Wide Program (10/14/2016)

The district-wide chip seal program was bid with AC-15P, even though an SPG 73-16 was specified by change order. Based on TxDOT verification results, the chip seal binder did not meet the AC-15P for penetration and elastic recovery and the SPG 73-16 at the high temperature. No construction issues were noted, but bleeding was experienced at multiple locations. Based on their experience, district personnel planned to continue to use the SPG specification in 2017 but with a SPG 73-19 required grade due to the change to 6^0 C increments and to ensure adequate resistance to bleeding at very high temperatures with the phase angle requirement for useful temperature interval (UTI) > 89^0 C.

Laboratory and Field Performance

For the three PHR HSs, Table B14 provides the field performance after the first winter and after two winters in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B7 shows the HSs in 2017 after the first winter. Chip seal binders were not collected at construction and thus laboratory-measured SPG grades were not available. Verification data at the specified high and low SPG temperatures was available from TxDOT and noted in Table 2. The PHR binder was not expected to perform adequately in terms of bleeding because it failed to meet the specified SPG 73-16 and is expected to fail the phase angle requirement (with $\delta > 80^0$) at the continuous high SPG temperature (< 73^0 C), and inadequate field performance in terms of bleeding ($SCI_{BL} < 70$) was exhibited on 16-PHR-1 after the first winter. This poor performance did not persist after two winters due to variability in field performance monitoring despite the use of multiple test sections per HS. 16-PHR-2 and 16-PHR-3 exhibited adequate performance in terms of both bleeding ($SCI_{BL} > 70$) and aggregate loss ($SCI_{AL} > 70$), but the lack of corresponding binders and associated construction information from these HSs precluded correlation of laboratory and field performance.

Table B13. 2016 PHR HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Pharr	16-PHR-1	Cameron	FM0506	5/?/2016	-	SPG73-16	0.32	GR 4P, SAC B	120	-	-	696	40
	16-PHR-2		FM1847		-							9940	2.9
	16-PHR-3	Starr	FM2098		-							600	4.2

Table B14. Laboratory and Field Performance for 2016 PHR HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	Post Constr ED		Performance after First Winter			Performance after Two Winters		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI	SCI_{AL}	SCI_{BL}	SCI
16-PHR-1	SPG73-16	67-13	G*/sinδ @73°C =0.36kPa S(8sec)@ -16°C =179MPa	δ @73°C=77.8	696	73	40	97	66	91	100	78	96
16-PHR-2	SPG73-16	67-13			9940	35	20	78	91	80	100	82	96
16-PHR-3	SPG73-16	67-13			600	50	20	99	78	95	100	80	96

Figure B7. 16-PHR-1, 16-PHR-2, and 16-PHR-3 in 2017.

SUMMARY OF 2017 SPG IMPLEMENTATION IN AMA DISTRICT

Over the past almost 20 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 141 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the fourth year of SPG implementation, 6 HSs were established from many available in the district-wide chip seal programs, including four in the AMA district with location and construction information provided in Table B15.

Post-Construction Technical Debriefing for District-Wide Program (5/16/2018)

Utilization of the SPG specification in 2017 was not as successful as in 2016 with a disappointing estimated 15% aggregate loss overall that started after the extreme cold temperatures in early December. There is concern regarding this aggregate loss that may lead to bleeding this summer. There is additional concern that there is some carry over from 2017 with the same supplier, and the district lacks confidence in the performance in terms of aggregate loss. Based on their experience, district personnel planned to continue to use the SPG specification in 2018, but they are considering specifying SPG 73-31 based on the revised climate-based map and limiting REOB to 5%. There will be a new binder supplier this year, and they also plan to keep a closer eye on the variability of the binder test results through the Austin laboratory, embedment depths, material application rates, and dirty aggregates.

Laboratory and Field Performance

For the four AMA HSs, Table B16 provides the laboratory-measured SPG grade of the chip seal binders collected at construction and field performance after the first winter in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B8 shows the HSs in 2018 after the first winter. The 17-AMA-1 and 17-AMA-2 binders were not expected to perform adequately in terms of aggregate loss since they met the specified low temperature SPG but did not reach the extreme temperatures in that location, and inadequate field performance was indicated by $SCI_{AL} < 70$ after the first winter. The 17-AMA-4 binder was not expected to perform adequately in terms of bleeding since it did not meet the specified high temperature SPG, but adequate field performance was exhibited. Finally, the 17-AMA-5 binder was expected to perform adequately based on SPG results, and good field performance was noted after the first winter.

Table B15. 2017 AMA HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Amarillo	17-AMA-1	Dallam	FM297(1-2)	9/2/2017	82° F	SPG73-25	0.56	PC GR 3	110	-	-	1169	41.4
	17-AMA-2	Dallam	FM297(5-8)	8/31/2017	82° F		0.56	PC GR 3	110	-	-	674	41.4
	17-AMA-4	Gray	SH0070(1-2)	9/7/2017	-		0.47	PC GR 4	110	-	-	1879	54.5
	17-AMA-5	Gray	SH0070(5-8)	8/8/2017	70° F		0.47	PC GR 4	110	-	-	626	15.4

Table B16. Laboratory and Field Performance for 2017 AMA HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	After First Winter ED		Performance after First Winter		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI
17-AMA-1	SPG73-25	67-31	85-25	74.3	1169	20	10	61	100	69
17-AMA-2	SPG73-25	67-31	91-25	38	674	30	15	59	100	67
17-AMA-4	SPG73-25	67-25	67-25	64.2	1879	40	20	80	100	84
17-AMA-5	SPG73-25	67-25	73-25	66.8	626	25	15	70	100	76

Figure B8. 17-AMA-1, 17-AMA-2, 17-AMA-4, and 17-AMA-5 in 2018.

SUMMARY OF 2017 SPG IMPLEMENTATION IN PHR DISTRICT

Over the past almost 20 years, the Surface Performance-Graded (SPG) specification for chip seal binders in service was developed for TxDOT and validated using laboratory measurements and visual field performance of 141 highway sections (HSs). This SPG specification available as a Special Provision to Item 300 (SP300-011) was created to extend the service life of chip seals by providing a binder grading system and associated selection method that:

(1) accounts for differences in climate,
(2) utilizes existing equipment and performance-based properties that preclude bleeding and aggregate loss in the critical first year of service after construction, and
(3) replaces the current TxDOT Seal Coat Material Selection Table (with the tiered system) and specifications provided in TxDOT Item 300.

As part of the fourth year of SPG implementation, 6 HSs were established from many available in the district-wide chip seal programs, including two in the PHR district with location and construction information provided in Table B17.

Post-Construction Technical Debriefing for District-Wide Program (5/16/2018)

District personnel are pleased with the performance of the 2017 HSs, and no issues were noted during construction with application rates approximately the same as for AC15P. They have also received positive comments from visitors to the district that their chip seals look like hot mix asphalt. They indicated that the most important factor is the contractor, and they had a good one in 2017. They did note some aggregate loss due to extreme cold temperatures. Based on their experience, district personnel planned to continue to use the SPG specification in 2018, but they plan to specify SPG 79-13 based on the revised climate-based map and polymer modification requirement.

Laboratory and Field Performance

For the two PHR HSs, Table B18 provides the laboratory-measured SPG grade of the chip seal binders collected at construction and field performance after the first winter in terms of surface condition indices (SCI) for bleeding (BL) and aggregate loss (AL) based on visual distress surveys. Figure B9 shows the HSs in 2018 after the first winter. Both binders were expected to perform adequately since they met the climate-based requirements and the specified SPG 73-19 and passed the phase angle requirement ($< 80^0$), and adequate field performance in terms of both bleeding ($SCI_{BL} > 70$) and aggregate loss ($SCI_{AL} > 70$) was exhibited.

Table B17. 2017 PHR HSs.

District	HS	County	Hwy	Construction Date	Weather During Construction	Specified Binder Type	Binder Rate (gal/SY)	Agg Type	Agg Rate (SY/CY)	Time Between Binder and Rock Application (min)	Time to First Roll from Binder Application (min)	AADT 2016	% Trucks
Pharr	17-PHR-1	Hidalgo	FM0088	-	-	SPG73-19	-	-	-	-	-	4126	32
	17-PHR-2	Hidalgo	FM2220	-	-		-	-	-	-	-	5058	1.8

Table B18. Laboratory and Field Performance for 2017 PHR HSs.

HS	Specified Binder Type	Climate SPG	Lab SPG	δ @ T_{HIGH}	Traffic (AADT)	After First Winter ED		Performance after First Winter		
						WP	BWP	SCI_{AL}	SCI_{BL}	SCI
17-PHR-1	SPG73-19	67-13	79-25	48	4126	60	40	100	83	97
17-PHR-2	SPG73-19	67-13	79-25	48	5058	85	75	100	70	94

Figure B9. 17-PHR-1 and 17-PHR-2 in 2018.

APPENDIX C: SPECIAL PROVISIONS SP 300-001 AND SP 300-011

Special Provision to Item 300
Asphalts, Oils, and Emulsions

For this project, Item 300, "Asphalts, Oils, and Emulsions," of the Standard Specifications, is hereby amended with respect to the clauses cited below, and no other clauses or requirements of this Item are waived or changed hereby.

Section 300.2.4., "Emulsified Asphalt" is supplemented by the following.

Table 7A
Surface Performance-Grade Emulsified Asphalt

Grade	Test Procedure	HFRS-2(SPG xy[1])		CRS-2(SPG xy[1])		CHFRS-2(SPG xy[1])	
		Min	Max	Min	Max	Min	Max
Tests on emulsions:							
Viscosity, Saybolt Furol at 50°C, SFs[2]	T 72	150	400	150	400	150	400
Storage stability test, 24 h., %[2]	T 59		1		1		1
Demulsibility, 35 mL, 0.02 N $CaCl_2$, %	T 59	60					
Demulsibility, 35 mL, 0.8% dioctyl sodium sulfosuccinate, %	T 59			60		60	
Particle charge test	T 59			positive		positive	
Sieve test, %[2]	T 59		0.10		0.10		0.10
Residue recovery	PP 72, Procedure B						
Residue, %		65		65		65	
Tests on recovered residue:							
Residue properties		Meet the specified SPG in Table 17A[3]					
Solubility in trichloroethylene, %	T 44	97.5		97.5			
Float test, 60°C, sec.[4]	T 50	1,200				1,200	

1. X is the average 7-day maximum pavement surface design temperature, and y is the minimum pavement surface design temperature used in Table 17A.
2. This test requirement on representative samples is waived if successful application of the material has been achieved in the field.
3. Meet original performance properties and PAV residue requirements only
4. If Float test is less than 1,200 sec. using PP 72, Procedure B, for residue recovery, then use T 59 for residue recovery.

Section 300.2.10., "Performance-Graded Binders," is supplemented by the following.

Table 17A
Surface Performance Grade (SPG) Specification

Surface Performance Grade	**SPG 64**	**SPG 67**					**SPG 70**					**SPG 73**			
	-25	-13	-16	-19	-22	-25	-13	-16	-19	-22	-25	-16	-19	-22	-25
Average 7-day Max pavement surface design temperature[1], °C	<64	<67					<70					<73			
Min pavement surface design temperature[1], °C	>-25	>-13	>-16	>-19	>-22	>-25	>-13	>-16	>-19	>-22	>-25	>-16	>-19	>-22	>-25
Original Binder															
Flash point temp, T 48, Min, °C	230														
Viscosity, T 316[2]: Max 0.15 Pa*s, test temp., °C	205														
Original Performance Properties															
Dynamic Shear, T 315: G*/sinδ, Min 0.65 kPa, Test temp @ 10 rad/s, °C	64	67					70					73			
Phase angle[3] (δ), Max, @ temp. where G*/sinδ = 0.65 kPa	80	–	–	–	80	80	–	–	80	80	80	80	80	80	80
Pressure Aging Vessel (PAV) Residue (R 28)															
PAV aging temperature, °C	100	100					100					100			
Creep stiffness, T 313: S, Max 500 MPa, Test temp. @ 8 sec., °C	-25	-13	-16	-19	-22	-25	-13	-16	-19	-22	-25	-16	-19	-22	-25

1. Temperatures are at the surface of the pavement structure. These may be determined from experience or may be estimated using equations developed by SHRP or LTPP, but modified to represent surface temperatures. Surface-grade high temperatures are generally 3°C to 4°C greater than those determined for Superpave PG binders.
2. The referee method will be AASHTO T 316 using a #21 spindle at 50 r/min, however alternate methods may be used for routine testing and quality assurance.
3. Phase angle is determined at the temperature where G*/sin δ =0.65 kPa. For routine testing and quality assurance, the phase angle can be interpolated from testing at two temperatures, one above and one below where G*/sin δ=0.65 kPa.

Special Provision to Item 300
Asphalts, Oils, and Emulsions

Item 300, "Asphalts, Oils, and Emulsions," of the Standard Specifications, is amended with respect to the clauses cited below. No other clauses or requirements of this Item are waived or changed.
Section 300.2.4., "Emulsified Asphalt," is supplemented by the following.

Table 7A
Surface Performance-Grade Emulsified Asphalt

Grade	Test Procedure	HFRS-2(SPG xy[1])		CRS-2(SPG xy[1])		CHFRS-2(SPG xy[1])	
		Min	Max	Min	Max	Min	Max
Tests on emulsions:							
Viscosity, Saybolt Furol at 50°C, SFs[2]	T 72	150	400	150	400	150	400
Storage stability test, 24 h., %[2]	T 59		1		1		1
Demulsibility, 35 mL, 0.02 N $CaCl_2$, %	T 59	60					
Demulsibility, 35 mL, 0.8% dioctyl sodium sulfosuccinate, %	T 59			60		60	
Particle charge test	T 59			positive		positive	
Sieve test, %[2]	T 59		0.10		0.10		0.10
Residue recovery	PP 72, Procedure B						
Residue, %		65		65		65	
Tests on recovered residue:							
Residue properties		Meet the SPG in Table 17A, except the Max phase angle is 84[3]					
Solubility in trichloroethylene, %	T 44	97.5		97.5			
Float test, 60°C, sec.[4]	T 50	1,200				1,200	

5. X is the average 7-day maximum pavement surface design temperature, and y is the minimum pavement surface design temperature used in Table 17A.
6. This test requirement on representative samples is waived if successful application of the material has been achieved in the field.
7. Meet original performance properties and PAV residue requirements only
8. If float test is less than 1,200 sec. using PP 72, Procedure B, for residue recovery, then use T 59 for residue recovery.

Section 300.2.10., "Performance-Graded Binders," is supplemented by the following.

Table 17A
Surface Performance Grade (SPG) Specification

Surface Performance Grade	**SPG 67**				**SPG 73**				**SPG 79**			
	-13	-19	-25	-31	-13	-19	-25	-31	-13	-19	-25	-31
Average 7-day Max pavement surface design temperature[1], °C	< 67				< 73				< 79			
Min pavement surface design temperature[1], °C	> -13	> -19	> -25	> -31	> -13	> -19	> -25	> -31	> -13	> -19	> -25	> -31
Original Binder												
Flash point temp, T 48, Min, °C	230											
Viscosity, T 316[2]: Max 0.15 Pa*s, test temp., °C	205											
Original Performance Properties												
Dynamic Shear, T 315: G*/sinδ, Min 0.65 kPa, Test temp @ 10 rad/s, °C	67				73				79			
Phase angle[3] (δ), Max, @ temp. where G*/sinδ = 0.65 kPa	–	80	80	80	80	80	80	80	80	80	80	80
Pressure Aging Vessel (PAV) Residue (R 28)												
PAV aging temperature, °C	100				100				100			
Creep stiffness, T 313: S, Max 500 MPa, Test temp. @ 8 sec., °C	-13	-19	-25	-31	-13	-19	-25	-31	-13	-19	-25	-31

4. Temperatures are at the surface of the pavement structure. These may be determined from experience or may be estimated using equations developed by SHRP or LTPP, but modified to represent surface temperatures. Surface-grade high temperatures are generally 3°C to 4°C greater than those determined for Superpave PG binders.
5. The referee method will be AASHTO T 316 using a #21 spindle at 50 r/min, however alternate methods may be used for routine testing and quality assurance.
6. Phase angle is determined at the temperature where G*/sin δ =0.65 kPa. For routine testing and quality assurance, the phase angle can be interpolated from testing at two temperatures, one above and one below where G*/sin δ=0.65 kPa.

APPENDIX D: ROUND ROBIN GUIDELINES

SEAL COAT BINDER SPG SPECIFICATION ROUND ROBIN GUIDELINES AND RESULTS

Thank you for your participation in a round-robin program as part of the Texas Department of Transportation (TxDOT) implementation of the seal coat binder SPG specification. This program requires the participants to **grade** a hot-applied asphalt binder sample and an emulsion distributed by TxDOT, i.e., report the high and low temperature SPG grades of the samples using the current SPG specification (TxDOT Special Provision 300-001 attached). Each SPG grade requires a temperature at which the measured property Passes the specification threshold and a temperature at which the measured property Fails the threshold for both low and high temperatures.

The SPG specification is applicable to both hot-applied asphalt binders and emulsion residues, with emulsion residues recovered by AASHTO PP 72-11 Procedure B prior to performing the tests included in Table D1. For consistency, all participating laboratories are required to store the hot-applied asphalt binder and emulsion residue in approximately 20 g batches and test them per the guidelines provided subsequently.

High Temperature Grading

According to the SPG specification (TxDOT Special Provision 300-001 attached), the high temperature SPG grade of a hot-applied asphalt binder or emulsion residue is the highest temperature at which $G^*/\sin\delta > 0.65$ kPa as measured in the DSR by AASHTO T315 on the original unaged material. Therefore, to report the high temperature SPG grade, the participants must provide a temperature (T°C) at which $G^*/\sin\delta > 0.65$ kPa (Pass) and another temperature ((T+3)°C) at which $G^*/\sin\delta < 0.65$ kPa (Fail). With one Pass and one Fail temperature, the high temperature SPG grade is reported as T°C.

Figure D1 gives the general procedure to be followed for high temperature SPG grading of a hot-applied asphalt binder or emulsion residue.

In addition, the continuous phase angle at the high temperature where $G^*/\sin\delta =$ 0.65 kPa is interpolated and reported. For example, for the data given in Table D1, the interpolated phase angle at $G^*/\sin\delta = 0.65$ kPa is 74.67.

Table D1. Example Data for Determination of Continuous Phase Angle at G*/sin δ = 0.65 kPa.

G*/sinδ (kPa)	δ
0.853	74.0
0.64	74.7

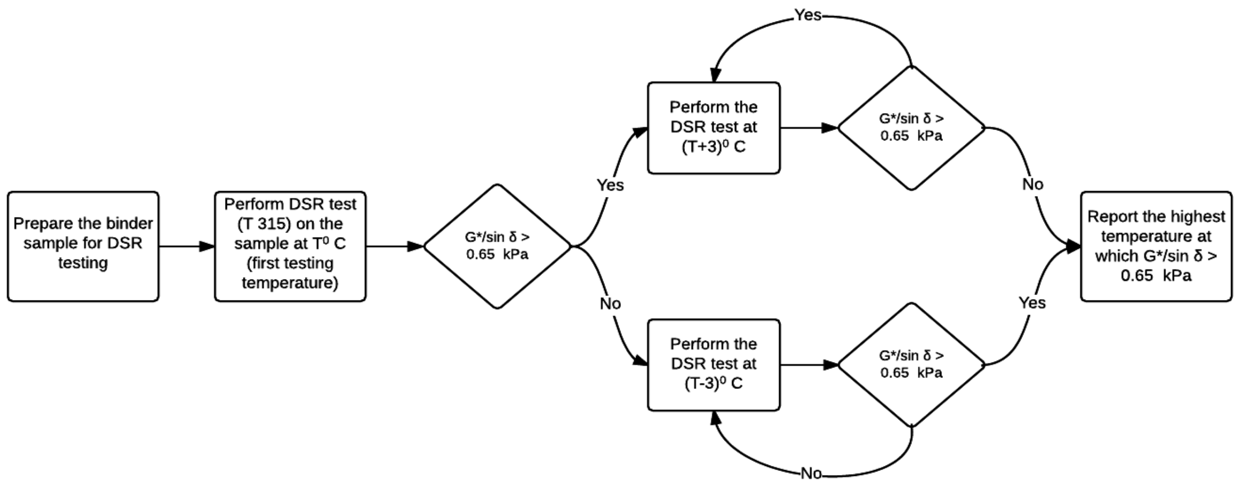

Figure D1. SPG High Temperature Grading of Hot-Applied Asphalt Binders and Emulsion Residues.

The SPG specification (TxDOT Special Provision 300-001 attached) was developed for high temperature grading after reheating the binder to pour in the DSR mold. However, for the Round Robin test program, two procedures for sample preparation for DSR testing have been suggested for emulsion residues – with reheating and without reheating. Only the procedure with reheating is used for hot-applied asphalt binders. The guidelines for these procedures are described subsequently.

With reheating

1. Recover emulsion residue in accordance with AASHTO PP72 Method B.
2. Place 20 g of residue in a 6oz metal tin[1] (approx. 3 in. diameter).
3. Place the sample tin in an oven heated at 160°C (320°F) for 10 minutes.[2]
4. Stir the sample with a spatula after the tin has been in the oven for 5 minutes.
5. After 10 minutes, pour the sample to be tested in the 25 mm DSR silicone mold.

[1] http://www.globalgilson.com/tinned-sample-container-6oz.
[2] Some residues may require additional time and/or higher temperature to become fluid enough for pouring into the DSR mold. If additional time or higher temperature is needed, please record the conditions used for reheating.

Without reheating (only for emulsion residue)

1. Recover emulsion residue in accordance with AASHTO PP72 Method B.
2. Place the ball of residue on wax release paper and fold the release paper so that it encloses the residue.
3. Place the residue covered by the release paper into a sample container.
4. When taking samples for DSR testing, pull enough asphalt for the test or cut a sample large enough to test. Gloves can be used to place the sample in the 25mm DSR silicone mold.

Low Temperature Grading

According to the SPG specification (TxDOT Special Provision 300-001 attached), the low temperature SPG grade of a hot-applied asphalt binder or emulsion residue is the lowest temperature at which S < 500 MPa at 8 seconds as measured in the BBR by AASHTO T313 on the PAV aged material at the actual low temperature SPG grade (without a 10°C shift). Therefore, to report the low temperature SPG grade, the participants must provide a temperature (T°C) at which S < 500 MPa (Pass) and another temperature ((T-3)°C) at which S > 500 MPa (Fail). With one Pass and one Fail temperature, the low temperature SPG grade is reported as T°C.

Figure D2 gives the general procedure to be followed for low temperature SPG grading of a hot-applied asphalt binder or emulsion residue.

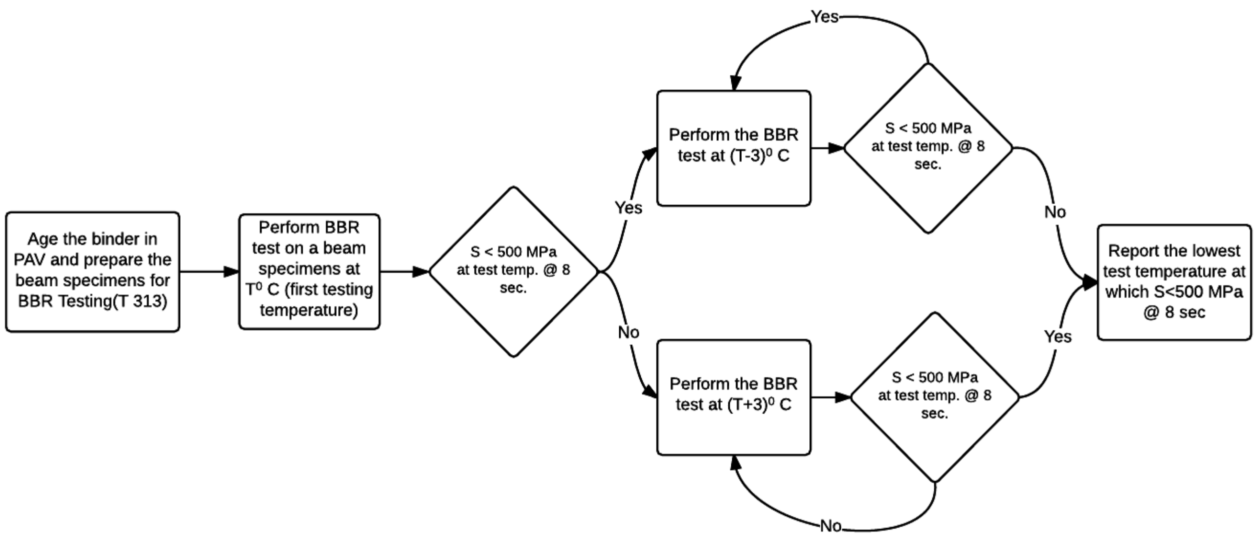

Figure D2. SPG Low Temperature Grading of Hot-Applied Asphalt Binders and Emulsion Residues.

Results to Report

In summary, the following results are to be reported by the participants for each material tested using the data sheet attached.

Original Unaged Binder – High Temperature Grading

Criteria: $G^*/\sin\delta < 0.65$ kPa

Report:

- Highest temperature at which $G^*/\sin\delta < 0.65$ kPa
- Phase angle at the temperature where $G^*/\sin\delta = 0.65$ kPa

PAV Aged Binder – Low Temperature Grading

Criteria: S < 500 MPa at 8sec

Report: Lowest temperature at which S < 500 MPa at 8sec

Seal Coat Binder SPG Specification Round Robin Results

Testing facility:

Date of testing:

Sample tested:

Sample ID:

Operator:

High Temperature Grading (please report one Pass temperature and one Fail temperature)

Temperature (°C)	$\frac{G*}{sin\ \delta}$ (kPa)	Phase angle, δ	Result
			PASS
			FAIL

δ
interpolated at $\frac{G*}{sin\ \delta}$ = 0.65 kPa =

Low Temperature Grading (please report one Pass temperature and one Fail temperature)

Temperature (°C)	S (MPa) at 8sec	Result
		PASS
		FAIL

SPG grade of the sample: ***SPG -***
Phase angle criterion: <80 OR >80
Notes: (Report any deviations from suggested testing procedures)

1.
2.
3.

Seal Coat Binder SPG Specification Round Robin II Revised Guidelines (10/13/16)

Thank you for your participation in the second round-robin as part of the Texas Department of Transportation (TxDOT) implementation of the seal coat binder SPG specification. This program requires the participants to **grade** a hot-applied asphalt binder sample and an emulsion residue using the revised SPG specification for Round Robin II (Table D2) that utilizes 6°C increments offset from those used in the PG specification.

The SPG specification is applicable to both hot-applied asphalt binders and emulsion residues, with emulsion residues recovered by AASHTO PP 72-11 Method B prior to performing the tests included in Table D2. For consistency, all participating laboratories are required to store the hot-applied asphalt binder and emulsion residue in approximately 20 g batches and test them per these guidelines.

Each SPG grade requires a temperature at which the measured property passes the specification threshold and a temperature at which the measured property fails the threshold for both low and high temperatures. The interpolated phase angle at the high temperature threshold ($G^*/\sin\delta = 0.65$ kPa) is also required.

Table D2. Revised SPG Specification for Round Robin II.

Surface Performance Grade	SPG 61					SPG 67					SPG 73			
	-7	-13	-19	-25	-31	-7	-13	-19	-25	-31	-13	-19	-25	-31
Average 7-day Max pavement surface design temperature, °C	<61					<67					<73			
Min pavement surface design temperature, °C	>-7	>-13	>-19	>-25	>-31	>-7	>-13	>-19	>-25	>-31	>-13	>-19	>-25	>-31
Original Binder														
Flash point temp, T 48, Min, °C	230													
Viscosity, T 316: Max 0.15 Pa*s, test temp., °C	205													
Original Performance Properties														
Dynamic Shear, T 315: G*/sin δ, Min 0.65 kPa, Test temp @ 10 rad/s, °C	61					67					73			
Phase angle (δ), Max, @ temp. where G*/sin δ = 0.65 kPa	–	–	–	80	80	–	–	80	80	80	80	80	80	80
Pressure Aging Vessel Residue (R 28)														
PAV aging temperature, °C	100					100					100			
Creep stiffness, T 313: S, Max 500 MPa, Test temp. @ 8 sec., °C	-7	-13	-19	-25	-31	-7	-13	-19	-25	-31	-13	-19	-25	-31

In addition to the SPG tests required by specification in Table D2, the participants are requested to perform the elastic recovery test by Tex-539-C and the multiple stress creep recovery test (MSCR) by AASHTO TP 70 on the original unaged material on both binder samples for information only to provide additional data toward selection of an appropriate parameter to ensure polymer modification. The m-value is also requested for each cold temperature for information only.

High Temperature Grading

To prepare the sample prior to DSR testing:

1. Place 20 g of sample in a 6 oz metal tin[3] (approx. 3 in. diameter).
2. Place the sample tin in an oven heated at 160°C (320°F) for 10 minutes.[4]
3. Stir the sample with a spatula after the tin has been in the oven for 5 minutes.
4. After 10 minutes, pour the sample to be tested in the 25 mm DSR silicone mold.

According to the SPG specification (Table D2), the high temperature SPG grade of a hot-applied asphalt binder or emulsion residue is the warmest test temperature at which $G^*/\sin\delta > 0.65$ kPa as measured in the DSR by AASHTO T315 on the original unaged material. Therefore, to report the high temperature SPG grade, the participants must provide a test temperature (T°C) at which $G^*/\sin\delta > 0.65$ kPa (Pass) and another test temperature ((T+6)°C) at which $G^*/\sin\delta < 0.65$ kPa (Fail). With one pass and one fail test temperature, the high temperature SPG grade is reported as T°C. Figure D3 provides the procedure to be followed for high temperature SPG grading of a hot-applied asphalt binder or emulsion residue. For each test temperature, please conduct **two** measurements on the same sample without additional conditioning time before changing the test temperature for subsequent measurements.

[3] http://www.globalgilson.com/tinned-sample-container-6oz.

[4] Some residues may require additional time and/or higher temperature to become fluid enough for pouring into the DSR mold. If additional time or higher temperature is needed, please record the conditions used for reheating.

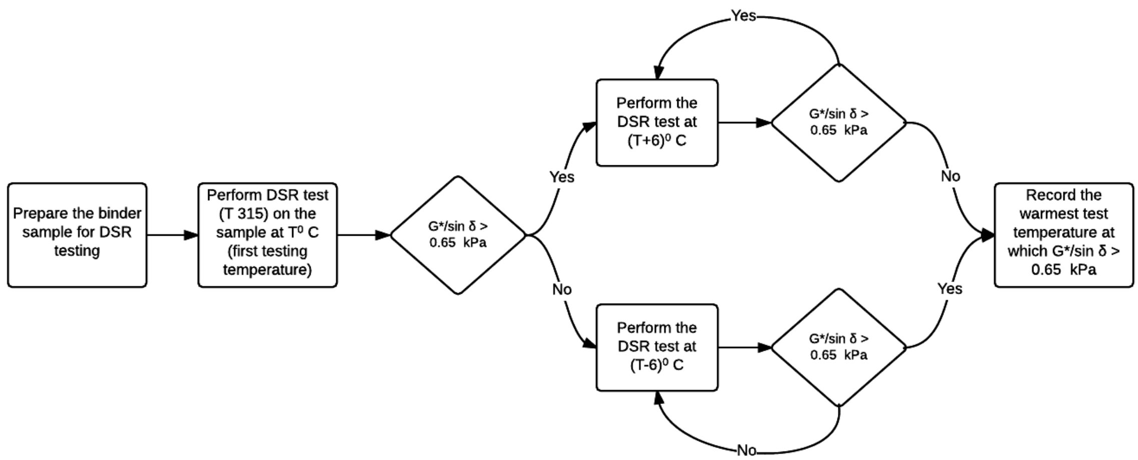

Figure D3. SPG High Temperature Grading of Hot-Applied Asphalt Binders and Emulsion Residues.

Low Temperature Grading

According to the SPG specification in Table D2, the low temperature SPG grade of a hot-applied asphalt binder or emulsion residue is the coldest test temperature at which S < 500 MPa at 8 seconds as measured in the BBR by AASHTO T313 on the PAV aged material at the actual low temperature SPG grade (without a 10°C shift). Therefore, to report the low temperature SPG grade, the participants must provide a test temperature (T°C) at which S < 500 MPa (Pass) and another test temperature ((T-6)°C) at which S > 500 MPa (Fail). With one pass and one fail test temperature, the low temperature SPG grade is reported as T°C. Figure D4 provides the procedure to be followed for low temperature SPG grading of a hot-applied asphalt binder or emulsion residue.

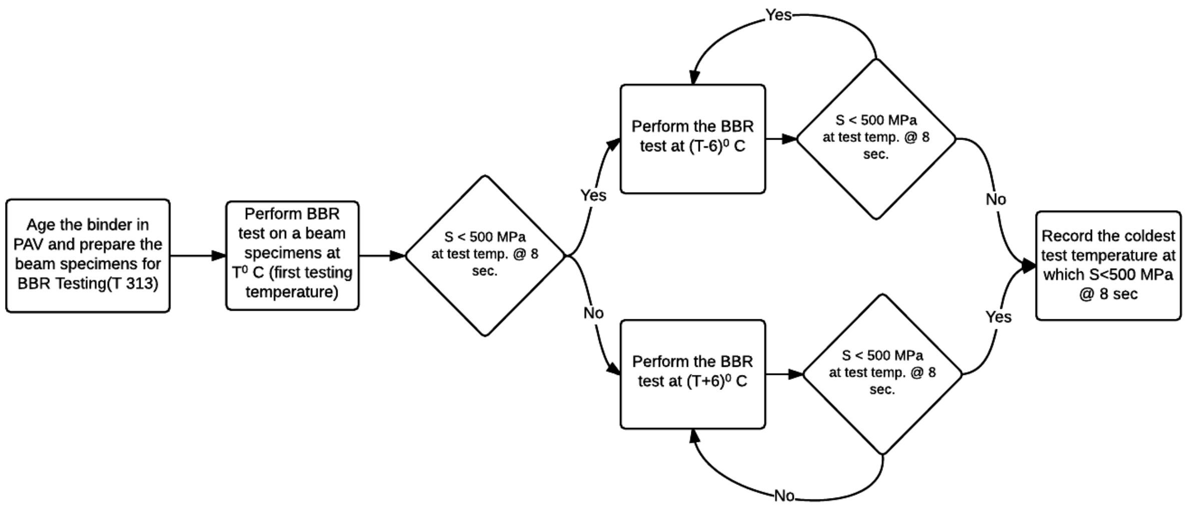

Figure D4. SPG Low Temperature Grading of Hot-Applied Asphalt Binders and Emulsion Residues.

Additional Testing

To further explore parameters other than phase angle at the high temperature threshold to ensure polymer modification, participants are requested to perform the elastic recovery test at 50°F (10°C) by Tex-539-C to report ER (%) and the MSCR test with original unaged binder at 61°C and 55°C by AASHTO TP 70 to report J_{nr} (kPa^{-1}) and minimum recovery (MR, %) values for information only. The m-value is also requested for each cold temperature for information only to further explore the use of this parameter or the corresponding T_c (determined from the difference in the temperatures where the m-value and S thresholds are met) to ensure adequate stress relaxation or flexibility.

Results to Report

A sample data sheet for reporting the following results for each binder sample is attached.

Original Unaged Binder – High Temperature Grading

Criteria: $G^*/\sin\delta > 0.65$ kPa

Report:

- Warmest test temperature at which $G^*/\sin\delta > 0.65$ kPa and phase angle for replicates 1 and 2
- Coldest test temperature at which $G^*/\sin\delta < 0.65$ kPa and phase angle for replicates 1 and 2
- Interpolated phase angle at the temperature where $G^*/\sin\delta = 0.65$ kPa

PAV Aged Binder – Low Temperature Grading

Criteria: S < 500 MPa at 8sec

Report:

- Coldest test temperature at which S < 500 MPa at 8 sec (and m-value at 8 sec for information only)
- Warmest test temperature at which S > 500 MPa at 8 sec (and m-value at 8 sec for information only)

Additional Results for information only

- ER (%) at 50°F (10°C) on residue recovered by AASHTO PP 72-11 Method B
- J_{nr} (kPa^{-1}) and MR (%) values @ 0.1 and 3.2 kPa for original unaged binder at 61°C and 55°C

Seal Coat Binder SPG Specification Round Robin II

Testing facility:

Date of testing:

Sample tested:

Sample ID:

Operator:

High Temperature Grading (please report one Pass temperature and one Fail temperature)

Temperature (°C)	G*/sinδ (kPa)		Phase angle, δ		Result
	Replicate 1	**Replicate 2**	**Replicate 1**	**Replicate 2**	
					PASS
					FAIL

Interpolated δ for Replicate 1 = ___ ☐ < 80 OR ☐ > 80

Interpolated δ for Replicate 2 = ___ ☐ < 80 OR ☐ > 80

Low Temperature Grading (please report one Pass temperature and one Fail temperature)

Temperature (°C)	S (MPa) at 8sec	m – value at 8 sec for information only	Result
			PASS
			FAIL

SPG grade:

Additional Results for information only

% ER @ 55 F (10 C)	Jnr (1/kPa) @						MR (%) @					
	55 C			61 C			55 C			61 C		
	0.1 kPa	3.2 kPa	Jnr Diff (%)	0.1 kPa	3.2 kPa	Jnr Diff (%)	0.1 kPa	3.2 kPa	MR Diff (%)	0.1 kPa	3.2 kPa	MR Diff (%)

Notes: (Report any deviations from suggested testing procedures)

1.
2.

APPENDIX E: SEAL COAT ECONOMICS

INTRODUCTION

Seal coats (1) or *chip seals* are used by TxDOT as a preventive maintenance tool as well as to provide friction, color demarcation and sound/noise differences on pavement surfaces. As a preventive maintenance tool, seal coats "seal" pavements and reduce the amount of water and air that enters the asphalt bound layers positioned below the seal coat. This sealing effect helps reduce the damage caused by water to the asphalt mixtures, the granular base course and the subgrade and hence maintains the load carrying ability of the pavement in wet weather. Thus, rutting and fatigue cracking of the pavement structure are reduced over time. In addition, reducing the entrance of air into the pavement will help reduce hardening of the asphalt binder that can cause premature cracking of the pavement.

Seal coats are also used to provide a surface layer to unbound or granular base course materials. In this application, seal coats are typically referred to as "surface treatments". Surface treatments; either one, two or three course (layer) treatments, continue to be used by TxDOT as all-weather surfaces on roadways.

Over the years, TxDOT has proven that seal coats are a very cost effective preventive maintenance tool and that they provide good inexpensive surfaces to low and moderate traffic volume roadways. Due to increased traffic volumes in Texas, TxDOT is utilizing seal coats on higher traffic volume routes than in the past. In addition, due to funding constraints, seal coats have been placeD successively as pavement surfacing layers on the same roadway. The successive use of seal coats often leads to bleeding and reduced friction on these surfaces.

This document illustrates the benefit/cost ratio associated with conducting various activities that will reduce the amount of premature distress and increase the life of seal coats. The information presented below has a number of assumptions associated with the data presented.

BACKGROUND

Seal coats and surface treatments are relatively low cost pavement surfacing materials and are used by a number of public agencies throughout the world. TxDOT annually applies a large number of miles of seal coat surfaces. TxDOT expenditures for seal coats constructed under contract for the period of May 1, 2017 to April 30, 2018 are shown below (2-5).

- Construction Contracts $241,095,750
- Maintenance Contracts $56,260,897
- Total Contracts $297,356,647

The number of construction contracts was 240, and the number of maintenance contracts was 80 (4). This implies an average cost of the contracts to be of the order of $500,000 to $650,000. Unfortunately, the number of contracts does not equal the number of individual seal coat projects as some of the contracts were District wide seal coat program contracts with multiple projects. In addition to seal coats placed under contract to third parties, TxDOT maintenance forces also place a substantial amount of seal coats. It is likely that $300 plus million is expended on about 450 plus or minus individual seal coat projects on an annual basis.

TxDOT spends over $300 million on seal coats annually on its 195,000 lane-mile system. Using typical unit prices for seal coats and expenditures at the $300 million plus level, approximately 10 to 12 percent (20,000 to 25,000 lane miles) of the pavements in the TxDOT system are surfaced with seal coats on an annual basis.

As a result of the extensive use of seal coats in Texas considerable research, development and implementation work efforts have resulted over the years. These efforts provided better materials selection, design methods, construction methods and performance in the field. This document looks at the benefit/costs associated with research, development and implementation efforts.

Specifications of interest, price information and performance will be discussed to provide background for the economic analysis.

SPECIFICATIONS

A number of standard and special specification items are of importance to this document. These are specifications associated with the design, materials and construction of the seal coat as well as those activities that are used for the repair of seal coats that experience distress. Table E1 shows TxDOT specifications of interest.

Item 300 specifies the asphalt binders used for seal coats while Item 302 is used to specify the aggregates that are used for seal coats. Item 316 is the seal coat specification that describes the materials selection and construction process as well as measurement and payment. Repair or replacement materials for seal coats include fog seals, various types of hot mix asphalt, microsurfacing and cold milling. Hot in-place recycling can be used.

Table E1. Specification Items of Interest (1).

Items No.	Description
300	Asphalts, Oils and Emulsions
302	Aggregates for Surface Treatments
315	Fog Seal
316	Seal Coat
340	Dense Graded Hot Mix Asphalt Concrete Pavement (small quantities)
341	Dense Graded Hot Mix Asphalt
342	Permeable Friction Course
344	Superpave Mixtures
346	Stone Matrix Asphalt
347	Thin Overlay Mixture
348	Thin Bonded Friction Courses
350	Microsurfacing
354	Planing and Texturing Pavement
358	Hot In-Place Recycling of Asphalt Concrete Surfaces

PRICE INFORMATION

Prices of various specification items identified above were obtained from TxDOT bid tabulations (2-5). Table E2 shows a summary based on this information.

Prices for seal coats vary with asphalt binder type and grade as well as aggregate type and gradation. Hot mix asphalt prices vary with type of hot mix, asphalt binder grade and aggregate gradation among other factors.

Table E2. Typical Bid Item Unit Prices (2).

Item No.	Description	Unit	Avg. Bid, $ Per unit bid	Usage
315	Fog Seal-CSS-1H	Gal	3.21	10
316	Seal Coat-Asph multi-option	Gal	2.78	49
	Seal Coat-Asph-Tier I	Gal	2.06	23
	Seal Coat-Asph-Tier II	Gal	1.98	20
	Seal Coat-Asph-AC-20-5TR	Gal	2.27	37
	Seal Coat-Aggr-Ty PB-Gr 3, SAC A	CY	91.59	11
	Seal Coat-Aggr-Ty PB-Gr 4, SAC A	CY	77.57	23
	Seal Coat-Aggr-Ty PB-Gr 5, SAC A	CY	95.56	2
	Seal Coat-Aggr-Ty B-Gr 3, SAC B	CY	80.14	6
	Seal Coat-Aggr-Ty B-Gr 4, SAC B	CY	84.33	17
	Seal Coat-Aggr-Ty B-Gr 5, SAC B	CY	62.09	12
	Seal Coat-Aggr-Ty PB-Gr 3, SAC B	CY	74.10	23
	Seal Coat-Aggr-Ty PB-Gr 4, SAC B	CY	80.17	71
	Seal Coat-Aggr-Ty PB-Gr 5, SAC B	CY	92.91	9
	Seal Coat-Asph-AC-15P, AC-10-5TR	CY	2.57	43
340	HMA-Ty D, PG64-22	Ton	108.34	32
	HMA-Ty D, SAC A, PG 70-22	Ton	93.76	5
	HMA-Ty D, SAC B, PG 70-22	Ton	85.33	11
341	HMA-Ty D, PG 64-22	Ton	76.48	14
	HMA-Ty D, PG 70-22	Ton	70.57	14
	HMA-Ty D, PG 70-22, SAC A	Ton	79.60	5
	HMA-Ty D, PG 70-22, SAC B	Ton	61.66	34
	HMA-Ty D, PG 76-22, SAC A	Ton	71.38	7
	HMA-Ty D, PG 76-22, SAC B	Ton	72.08	6
	HMA-Ty D, PG 76-28, SAC A	Ton	88.16	9
342	PFC-PG 76-22	Ton	118.95	21
	PFC-PG 76 Mix, SAC A	Ton	107.64	15
344	Super-SP-C, PG 64-22	Ton	95.36	9
	Super-SP-C, PG 70-22, SAC A	Ton	77.00	25
	Super-SP-C, PG 70-22, SAC B	Ton	70.20	15
	Super-SP-C, PG 76-22, SAC A	Ton	84.88	15
	Super-SP-C, PG 76-22	Ton	103.17	8
	Super-SP-D, PG 64-22, SAC B	Ton	74.26	18
	Super-SP-D, PG 64-22	Ton	71.59	10
	Super-SP-D, PG 70-22, SAC A	Ton	84.15	11
	Super-SP-D, PG 70-22, SAC B	Ton	72.12	14
	Super-SP-D, PG 76-22, SAC A	Ton	74.20	11
346	SMA-D, PG 76-22, SAC A	Ton	96.37	20
	SMA-D, PG 76-28, SAC A	Ton	114.47	4
	SMA-D, PG 70-28, SAC A	Ton	116.81	5
347	TOM-C, SAC A	Ton	84.82	28
	TOM-C, SAC B	Ton	93.32	11
348	Thin Bonded-PG 76-22	Ton	118.41	3
	Thin Bonded-Ty C	Ton	140.73	3
354	Plane & Text 0-1 inch	SY	0.54	3
	Plane & Text 0-2 inch	SY	1.48	37
	Plane 0-1 inch	SY	0.95	18
	Plane 0-2 inch	SY	1.28	79
	Plane 1.5 inch	SY	1.15	32
	Plane 2 inch	SY	1.31	80
	Plane 3 inch	SY	1.51	23

	Plane 0-1.5 inch	SY	1.34	29
358	Hot In-Place Recycling 2 inch	SY	4.41	3
	Hot In-Place Recycling 2 inch	SY	4.43	1

Representative Prices

The bid price information was converted to prices for a unit of area assuming various materials properties and design parameters. Table E3 contains representative values and ranges for specification items identified in Table E2. Note that a non-specification item of high-pressure water jet removal of excess asphalt binder on a seal coat was included based on information from a research project (6).

Table E3. Representative Prices.

Item		Unit	Price	
No.	Description		Representative*	Typical Range
315	Fog Seal	$/sq. yd.	0.18	0.15-0.20
316	Seal Coat	$/sq. yd.	1.65	1.25-2.00
340	HMA-small quantities	$/sq. yd.-in.	5.00	4.50-6.00
341	HMA-larger quantities	$/sq. yd.-in	3.75	3.25-4.75
342	Permeable Friction Course	$/sq. yd.-in	6.00	5.50-6.50
344	Superpave HMA	$/sq. yd.-in	4.00	3.75-5.50
346	Stone Matrix Asphalt	$/sq. yd.-in	5.25	5.00-6.25
347	Thin Overlay Mixture	$/sq. yd.-in	4.75	4.50-5.25
348	Thin Bonded Friction Course	$/sq. yd.-in	6.50	6.25-7.50
350	Microsurfacing	$/sq. yd.	2.25	
354	Planing and Texturing	$/sq. yd.-in	0.90	0.55-1.15
358	Hot In-Place Recycling	$/sq. yd.-in	2.25	1.75-2.50
	Water Jet Removal	$/sq. yd.	1.50	1.40-1.65

Typical routine maintenance costs for operations used to repair seal coats are shown on Table E4. These costs are from a 2010 database (6).

Table E4. Typical Maintenance Cost*.

Item		Cost, $/sq. yd.	
Code	Description	Representative	Typical Range
212	Level-up patch with maintainer	4.51	3.91-6.61
214	Level-up patch with drag-box	2.60	1.71-6.23
232	Strip or spot seal coat	2.58	2.19-3.14
252	Mill or plane	2.05	1.37-11.46
253	Spot milling or plane	6.65	3.19-19.81

*obtained from TxDOT Maintenance Management Information System 2010 (6)

PERFORMANCE

Seal coats are typically used on roadways with low to moderate traffic volumes. The performance life of seal coats is typically in the 6 to 8 year range. At the end of the 6 to 8 year performance period another seal coat is placed, a hot mix asphalt layer is placed or the pavement can be scheduled for different types of rehabilitation or reconstruction.

Seal coat performance is impacted by a number of variables including; asphalt binder type and grade, aggregate type and grade, quantities of asphalt binder and aggregate, construction operations and weather conditions. Successful placement and long-term performance of a seal coat is dependent on project selection as well as the factors identified above.

Premature distress in seal coats may occur early in the life of the seal coat. Distress such as bleeding in the wheel path and rock loss between the wheel path and at the centerline and edge of the pavement are not unusual. Long-term performance is typically impacted by bleeding in the wheel paths, rock loss and reflection cracking. If the proper aggregate for the traffic volume is not selected, friction can become a problem. Loss of friction due to bleeding can also result.

ECONOMICS

Two primary scenarios will be considered to establish economic parameters. Treatment of short-term, premature distress in seal coats and extending the performance life of seal coats.

Premature Distress

Premature distress occurs on a number of seal projects on an annual basis. When bleeding of the seal coat appears within the first few months of construction, typical causes are due to the use of a soft asphalt binder or excessive or insufficient asphalt binder application. Other factors are excessive or inadequate aggregate application, traffic turning movements and bleed through from the underlying pavement. The repair of bleeding is difficult with the application of an additional seal coat layer. Removal of the bleeding seal coat or overlaying with a hot mix asphalt or asphalt bound patching materials are also used to repair bleeding pavements.

Rock or aggregate loss is also a common form of premature distress that typically occurs the first cool or cold weather during the first of second winter. Typically, the rock loss is between the wheel paths and at the centerline and edge of pavement where wheel contacts with the pavement surface are at a minimum. The most common form of repair for this premature distress is the application of a strip seal coat or the application of a hot mix asphalt overlay or asphalt bound patching material.

Common forms of seal coat distress after several years of service include bleeding, rock loss and reflection cracking. Loss of friction and surface texture can also be issues that need to be addressed. Typical repair strategies, depending on the type, extend and severity of distress, include the application of another seal coat or thin hot mix asphalt overlay.

Table E5 and Table E6 contain information on costs associated with repair of premature distress assuming various values for lane miles of roadway seal coated annually, percent of the seal coated surfaces needing repair and the repair costs. Table 5 assumes that the various amounts of pavement surfaces are treated with selected types of repair strategies (cold milling-$1.00/ sq. yd., high-pressure water jet removal of excess asphalt binder-$1.50/ sq. yd., strip seal-$2.50/ sq. yd. and one inch of asphalt bound overlay material-$4.50/ sq. yd.-in.). Table 6 shows economic impacts of using various types of repair strategies.

Assume that 20,000 lane miles of pavement surfaces are seal coated on an annual basis in Texas. If about 5 percent of the surfaces seal coated need to be repaired with either a strip seal or asphalt bound mix overlay; the approximate cost impact to the annual maintenance budget would be of the order of $17 to $20 million. If the amount of surfacing needing repaired were 1 or 3 percent of the surfaces treated with a seal coat, the annual maintenance budget impact would be of the order of $5 to $12 million, respectively.

Assume that 25,000 lane miles of pavement surfaces were seal coated on an annual basis in Texas. The impacts for 1, 3 and 5 percent of the surfaces needing treatment with maintenance operations would be of the order of $6, $15 and $25 million, respectively.

Table E5 and Table E6 can be used to investigate various scenarios associated with seal coat economic impacts as well as looking at the sensitivity of various assumptions.

Table E5. Typical Repair Premature Distress.

Lane Miles Constructed/year	Percent of Surface Needing Repair	Sq. Yds. of Surface Needing Repair, millions	Repair Costs, $/Sq. Yds.*	Total Costs, $ millions
20,000	10	14.1	1.00	14.1
			1.50	21.2
			2.50	36.0
			4.50	63.5
	7	9.86	1.00	9.86
			1.50	14.8
			2.50	24.7
			4.50	44.4
	5	7.05	1.00	7.05
			1.50	10.6
			2.50	17.6
			4.50	31.7
	3	4.22	1.00	4.22
			1.50	6.33
			2.50	10.6
			4.50	19.0
	1	1.4	1.00	1.4
			1.50	2.1
			2.50	3.5
			4.50	6.3
25,000	10	17.6	1.00	17.6
			1.50	26.4
			2.50	44.0
			4.50	79.2
	7	12.3	1.00	12.3
			1.50	18.5
			2.50	30.8
			4.50	55.4
	5	8.8	1.00	8.8

			1.50	13.2
			2.50	22.0
			4.50	39.6
	3	5.28	1.00	5.28
			1.50	7.92
			2.50	13.2
			4.50	23.8
	1	1.76	1.00	1.76
			1.50	2.64
			2.50	4.40
			4.50	7.92

*representative costs-$1.00 cold milling, $1.50 high pressure water jet removal, $2.50 strip seal, $4.50 one-inch hot mix asphalt overlay

Table E6. Representative Repair Scenarios.

Lane Miles Constructed/year	Percent of Surface Needing Repair	Sq. Yds. of Surface Needing Repair, millions	Sq. Yds. of Surface Repaired by Method, millions	Repair Costs, $/Sq. Yds.*	Total Costs, $ millions
20,000	10	14.1	4.7	0.20 (fog seal)	0.940
			4.7	2.50 (seal coat)	11.7
			4.7	4.50 (HMA)	21.2
				Total	33.8
	5	7.05	2.35	0.20	0.470
			2.35	2.50	5.88
			2.35	4.50	10.6
				Total	17.0
	1	1.4	0.47		0.094
			0.47		1.17
			0.47		2.12
				Total	3.38
25,000	10	17.6	5.87	0.20	1.17
			5.87	2.50	14.7
			5.87	4.50	26.4
				Total	42.3
	5	8.8	2.93	0.20	0.586
			2.93	2.50	7.33
			2.93	4.50	13.2
				Total	21.1
	1	1.76	0.587	0.20	0.117
			0.587	2.50	1.47
			0.587	4.50	2.64

				Total	4.23

*representative costs-$1.00 cold milling, $1.50 high pressure water jet removal, $2.50 strip seal, $4.50 one-inch hot mix asphalt overlay

Extending the Performance Life

Another approach for determining the impact of seal coats not performing as desired can be accomplished by assuming that the life of the seal coat can be extended one year from say 6 to 7 years or 7 to 8 years. The economic savings associated with extending the life of seal coats one year are of the order of $30 to $50 million annually when TxDOT has a $300 million annual seal coat program. Table E7 shows the economic impact of extending the life of a seal coat when from 1 to 20 percent of the pavements are impacted by the life extension. For example, if the annual savings associated with extending the life of the seal coats placed in Texas was of the order of $40 million and if 20 percent of the surfaces actually had a life extension of 1 year, the economic savings on an annual basis would be about $8 million dollars. If the percent of surfaces impacted by the life extension of one year were reduced to 5 or 10 percent, the economic impact would be of the order of $2 to $4 million annually.

Table E7. Cost Savings Associated with Increasing the Life of a Seal Coat One Year-Life Cycle Cost Basis.

Annual Saving Resulting by Increasing Life of Seal Coat by One Year, $, millions	Percent of Chip Seals that are Impacted by Research Findings	Estimated Annual Savings, Millions
30	20	6.0
	10	3.0
	5	1.5
	1	0.3
40	20	8.0
	10	4.0
	5	2.0
	1	0.4
50	20	10.0
	10	5.0
	5	2.5
	1	0.50

SUMMARY

Seal coats are the most widely used preventive maintenance “tool” used in Texas. Seal coats are a very cost effective preventive maintenance alternative for Texas highway. Relatively small improvements in the performance of seal coats will result in considerable cost savings to TxDOT maintenance and/or construction budgets.

Over $300 million is expended by TxDOT on seal coats annually. On an annual basis, about 10-12 percent of the pavement surfaces (20,000 to 25,000 lane miles) are covered with seal coats. It is estimated that about 450 projects are placed under construction contracts, maintenance contracts and by maintenance forces on an annual basis.

Considerable research, development and implementation efforts including training have been conducted over the last 50 plus years under the sponsorship of TxDOT. Typical costs of these activities are of the order of $100,000 to $200,000 annually. These efforts have resulted in improved project selection practices, material selection, design methods, construction and inspection methods. Additional improvements are needed to fully capture the economic benefits associated with the use of seal coats as a preventive maintenance alternative.

Economic savings associated with the improvement of seal coat performance are defined in this document. The reader can use the information presented to determine economic benefit making a number of different assumptions others than those used to develop the conclusions in this document.

Premature distress occurs on a number of seal coat projects on an annual basis. This distress must be addressed by activities funded in maintenance and/or construction budgets. If 3 percent of all seal coated pavement surfaces placed on an annual basis needed some form of maintenance, a cost of approximately $12 to 15 million would be incurred. If one percent or five percent of the surfaces were in need of repair, an expenditure of the order of $5-6 million and $20-25 million would be needed. Research, development and implementation efforts, which include training and improved specification and inspection, can partially avoid these costs. A $1 million annual effort to improve the performance of seal coats through research, development and implementation efforts will produce benefit/cost ratios of the order of 5:1 to 25:1.

Economic benefits of an active research, development and implementation program can also be estimated by considering life extension of the treatment. An increase in life extension of one year on 5 percent of the pavement surfaces placed on an annual basis results in a cost savings of $2 million. If 10 or 20 percent of the pavements can have a life extension of one year, the cost savings on an annual basis will be $4 and $8 million, respectively. A $1 million annual effort to improve the performance of seal coats through research, development and implementation efforts will produce benefit/cost rations of the order of 2:1 to 8:1.

Improvements in seal coats performance resulting from research, development, implementation, training efforts will reduce premature distress as well as provide an overall life extension of seal coats. Therefore, benefit cost ratios associated with these types of activities will likely have benefit/cost ratios of the order of 10:1 to 20:1 with a $1 million annual expenditure.

Investments in improving seal coat performance will be extremely cost effective. The savings identified are on an annual basis.

REFERENCES

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