Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-14/5-5598-03-1		

4. Title and Subtitle	5. Report Date
STATEWIDE IMPLEMENTATION OF VERY THIN OVERLAYS	Published: October 2014
	6. Performing Organization Code
7. Author(s) Tom Scullion, Cindy Estakhri, and Bryan Wilson	8. Performing Organization Report No. Report 5-5598-03-1
9. Performing Organization Name and Address Texas A&M Transportation Institute College Station, Texas 77843-3135	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. Project 5-5598-03
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office 125 E. 11th Street Austin, Texas 78701-2483	13. Type of Report and Period Covered Technical Report: September 2012–August 2013
	14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Statewide Implementation of Very Thin Overlays in Maintenance Operations
URL: http://tti.tamu.edu/documents/5-5598-03-1.pdf

16. Abstract

Very thin overlays are defined as overlays where the final lift thickness is 1 inch or less. These are designed to be high performance overlays in that they have to pass both a rutting (Hamburg Wheel tracking Test) and reflection cracking (Overlay Test) requirements. In this study three different types of thin overlay were designed and placed in the field; these being the open graded (fine Permeable Friction Course), gap graded (fine Stone matrix Asphalt) and fine dense graded mix. To meet the performance requirements, only high quality aggregates are recommended for these mixes, and for most applications the use of a PG 76-22 binder is recommended. Consequently these mixes cost approximately 30% more per ton than traditional Item 341 dense graded mixes. However, because of the thin placement temperatures a substantial savings per square yard has been reported when using these mixes.

In this study, test sections were built in several districts around the state, and the performance to date has been excellent. Specifications were written, and many of the recommendations have been incorporated into the Construction Division's current statewide specifications.

17. Key Words	18. Distribution Statement
Thin Overlays, Performance Tests, Rutting, Reflection Cracking, Specifications	No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia 22312 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	72	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorize**

STATEWIDE IMPLEMENTATION OF VERY THIN OVERLAYS

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented here. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear here solely because they are considered essential to the object of this report. The engineer in charge was Tom Scullion, P.E. (Texas No. 62683).

ACKNOWLEDGMENTS

This project was conducted for TxDOT, and the authors thank TxDOT and FHWA for their support in funding this research project. In particular, the guidance and technical assistance provided by the Project Director Tammy Sims, P.E., of the Paris District proved invaluable. Special thanks are also extended to Lee Gustavus and Tony Barbosa from the Texas A&M Transportation Institute (TTI) for their help in laboratory and field testing.

The following project advisors also provided valuable input throughout the course of the project, and their technical assistance is acknowledged: Darlene Goehl, P.E., Bryan District; Mike Arellano, P.E. and Tommy Blackmore, Austin District; and Magdy Mikhail, P.E., Maintenance Division, Austin.

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CHAPTER 1. INTRODUCTION

The objective of this project was to identify and assist multiple districts to develop a thin overlay mix design process with potential field applications. The following types of thin overlays mixtures were included as part of this task:

- Dense Graded Mixes (CAM or Crack Attenuating Mix).
- Gap-Graded Mixes (Fine SMA or Stone Matrix Asphalt).
- Fine PFC (Permeable Friction Course).

This project has assisted with the development of statewide specifications for thin overlays:

- Special Specification 3228.
- Standard Specification Item 347 (for new 2013 Spec Book).

The mix design details and lessons learned from the construction of the test sections in 5-5598-03 have permitted TxDOT's Construction Division to incorporate with confidence many features of these specifications into the standard statewide specification book for 2013. In the Appendix to this report an updated set of specifications is provided for these thin overlays.

Researchers contacted multiple districts to get test section candidates and to obtain materials for mixture designs. Researchers also evaluated the different maintenance applications, including treatment of severely bleeding surfaces, minimizing reflection cracking and restoration of skid resistance at intersections. In each case, samples of local materials were obtained and mix designs tested in TTI's lab. The researchers worked with the participating districts and local contractors through all phases of mix design, production, and placement.

In Chapter 2 of this report a description is given of the two performance tests that these high performance thin overlays must meet as well as a comparison of the test results with those obtained from existing maintenance operations. A description is also given of the reported cost savings from moving to these thin overlay materials.

The Project Director, Tammy Sims, coordinated efforts through the Maintenance Division to set aside funds to construct the test sections. A description of four of the test sections built during this study is given in Chapter 3. If funds were needed, each district willing to place a test section could use $10,000–$15,000 from these Maintenance Division funds to go toward the purchase and placement of a test section. This was to allow for optimizing the different applications prior to full-scale implementation and was a key factor in achieving statewide implementation of thin overlays.

Researchers contacted districts to obtain locally available materials with potential for thin overlay mix designs. Table 1 shows the mix designs that were completed in TTI's laboratory using aggregates from various suppliers and the candidate districts that could potentially obtain those materials from a local supplier. The remarks on the right-hand column of the tables denote the mixtures that were actually placed as test sections or full-scale projects in the field.

Table 1. Summary of Mix Designs Completed for Candidate Districts.

Candidate Districts	Material Sources	Mixture Type	Combined Gradation	Optimum AC Content, %	Density, %	Overlay Test, Cycles	Hamburg, mm	Remarks
ODA BWD ABL	Vulcan Eastland	CAM	38% Gr 6 + 33% Man Sand + 28% scrng +1% lime	7.0	96.5	1000+	3.3@20,0000	
		CAM	30% Gr 5 + 70% Man Sand	8.1	96.5	667	10.6@20,000	- Two Test Sections placed at Pecos
		PFC	100% Gr 5 + 0.3% fibers	6.5	77.8	300+	6.3@10,000	-Two Test Sections placed at Pecos - Full-Scale Project placed on US 183 Brownwood
		PFC	100% Gr 6 + 0.3% fibers	6.5	76.6	667	10.5@10,000	
		SMA	60% Gr 5 + 40% Man Sand + 0.3% fibers	7.2	93% SGC		6.6@20,000	-Two Test Sections placed at Pecos
ODA BWD SJT	Capital Aggregates Hoban	CAM	60% Gr 6 + 40% Rankin Scrng	8.2% ok for Ham and OT but 8.8% required for Volumetrics	93.7 @ 8.0 95.5 @ 8.5 SGC	- 1000+	- 3.2@20,000	
		CAM	30%Gr 6 + 70% man sand	9.0%	Samples from Dist Lab	189	3.1@20,000	
		CAM	65% Gr 6 + 35% Turner Scrng	7.8	93.8	513	2.5@20,000	-Two Test Sections placed at Pecos
		PFC	100% Gr 6 + 0.3% Fibers	6.5	73.5	450+	8.1@10,000	-Two Test Sections placed at Pecos
		SMA	60% Gr 5 + 40% Turner Scrn + 0.3% Fibers	7.0	98.0 TGC 96.7 SGC	300	2.7@20,000	-Two Test Sections placed at Pecos
AMA	Milligan	CAM	54% F + 45% Scrn +1% lime	7.5% PG 70-22	97.1	960	4.2@20,000	-Test section placed as rut-filler on US hwy in Amarillo District
WFS BWD	Zack Burk	CAM	30% F + 69% Scrn + 1% lime	No optimum AC could be determined since mix failed both Hamburg and OT at 4 different AC contents.				

LBB	Duinick	CAM	50% F + 24% DBI Man sand + 25% Thrasher Scrn + 1% lime	No optimum AC content could be determined due to poor Hamburg results.				
		CAM	52% F + 47% Kiewit #7-16 + 1% lime	7.2%	93%	1000+	16.1@15,000	
SJT	Turner	CAM	15% D + 20% F + 64% Scrn + 1% lime	No optimum AC could be determined due to poor OT results.				
ELP	Padre Canyon and Vado	CAM	No combination of aggregates could meet gradation requirements for CAM.					
LFK SAT BRY AUS	Delta Sandstone	PFC	99% Gr 5 + 1% lime + 0.3% fibers	6.5	74%	450	12.5@ 11,700	- Test Section placed on US 59 Cloverleaf in Lufkin - Test Section placed on Intersection of Loop in Lufkin - Test Section placed on SH 6 exit Ramp for district office
HOU DAL PAR FTW BMT	Mill Creek	TOM	45% D + 35% F + 19% Beckman Scrng + 1% lime	6.7	97.5%	1000+	4.0@20,000	-Scheduled for full-scale project in Houston this summer -Scheduled for full-scale project in Beaumont this summer
HOU ATL BMT	Jones Mill	TOM	48%D + 34%F + 17% Dry Beckman Scrng + 1% lime	6.7	97.5%	1000+	5.5@20,000	
BRY	Delta SS	SMA				508	3.8@20,000	-Full-scale project placed on SH FR in Bryan District -Full-scale project placed on SH 158 in Bryan District through curb and gutter downtown section
ATL	Little River	UT	55% F + 29% Scrng + 15% Byrd Pit Scrng + 1% lime	6.6	96.5	785	4.0@20,000	-Scheduled for test section construction in ATL in June 2013
AUS	Delta Sandstone	UT	100% Grade 2 micro aggregate					-Test section constructed in Austin District at Ramming plant entrance
SAT	Vulcan Knippa	PFC	99% F Gr 5 + 1% lime	7.0% PG	71.5	1000+	7.7@10,000 11.6@20,000	-Test section scheduled for construction in San Antonio District summer of 2013

CHAPTER 2. COMPARISON WITH TRADITIONAL MAINTENANCE MIXES

The maintenance mixes used in Texas for paving overlays are typically dense grade mixes designed under the Item 340 or 341 specifications. These are usually the lowest cost mixes available and typically contain between 4.4 and 4.8 percent asphalt. Performance mixes are substantially more expensive per ton, approximately 30 percent greater as they use higher quality aggregates and substantially more asphalt (minimum 6 percent).

The performance mixes are designed to have balanced properties with regard to resistance to rutting and reflection cracking. Conventional maintenance mixes may have to pass a rutting test so the most noticeable difference between the two is often in terms of their resistance to reflection cracking. In terms of the overlay tester results, maintenance mixes normally last less than 50 cycles to failure whereas the performance mixes range from 300 to 750 cycles. A major consideration is that maintenance mixes (typically Item 341 Type C) are always placed in 2 inch lifts whereas the performance mixes are designed to be placed in a lift of 1 inch or less. This thickness difference ensures that performance mixes are up to 25 percent cheaper per sq. yard.

The latest generation of performance mixes is new and most have been in service less than 4 years. However, very few performance problems have been encountered even under very heavy traffic such as on IH 35. Performance modeling estimates that these mixes will last twice as long as typical maintenance mixes in terms of the time until reflection crack recurs.

PERFORMANCE TESTS

In study 0-5598, specifications were developed for thin overlays that meet both TxDOT's existing rutting requirements and also have substantially improved reflection cracking resistance. In Task 2 of this project it was proposed to compare the engineering properties of these high performance thin overlays with those of traditional maintenance mixes. This includes a cost effectiveness evaluation of these mixes. It must be recalled that the high performance mixes are more expensive per ton than the traditional mixes but the fact that they are placed in lifts of 1 inch or less make them very cost competitive with the traditional mixes, which are normally placed in 2-inch thick mats.

For the thin overlays in Texas the engineering properties are measured by the Hamburg Wheel Tracking test (HWTT) and the Overlay Tester (OT) as described below.

RUT RESISTANCE AND MOISTURE SUSCEPTIBILITY (HAMBURG TEST)

The Hamburg test (Tex Method 242 F) is the approved test for measuring the moisture susceptibility and rutting potential of HMA layers in Texas. During the test two 2.5-inch high by 6-inch diameter HMA specimens compacted to 7 percent air voids were loaded at 122°F to characterize their rutting properties. The samples were submerged in a water bath and loaded with steel wheels. Figure 1 shows the Hamburg test device.

Figure 1. The Hamburg Test Device.

The test loading parameters for the Hamburg test were as follows:

- Load: 705 N (158-lb force).
- Number of passes: 20,000.
- Test condition/temperature: Under water at 50°C (122°F).
- Terminal rutting failure criterion: 0.5 inch (12.5 mm).
- HMAC specimen size: 6-inch diameter by 2.5-inch high.

REFLECTION CRACK RESISTANCE (OVERLAY TESTER)

Figure 2 shows the upgraded Overlay Tester, which is the standard test for measuring the reflection cracking potential of HMA mixes in Texas (Tex Method 248-F). This device has been implemented within TxDOT's construction division (Cedar Park) and in two TxDOT districts' labs (Childress and Houston).

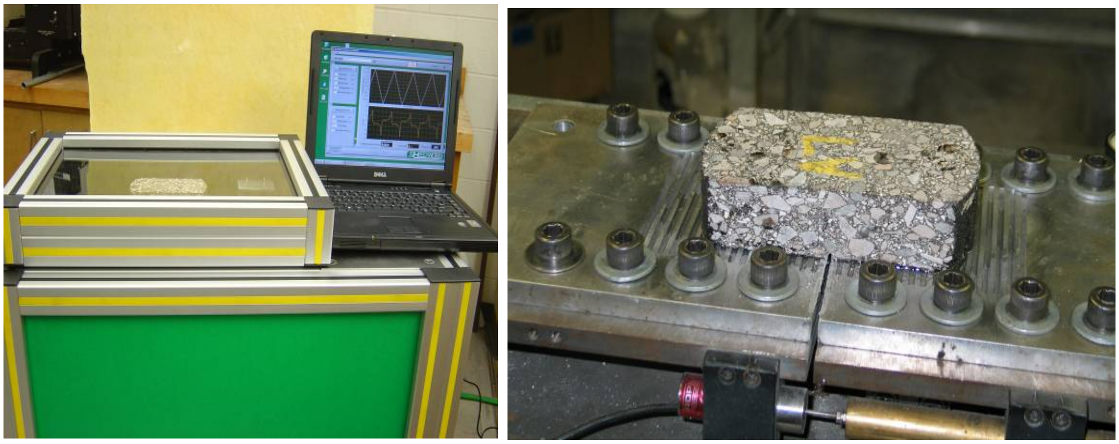

Figure 2. Overlay Tester Equipment and Sample.

The test loading parameters for the Overlay Tester are as follows:

- Loading: cyclic triangular displacement-controlled waveform at 0.025 in (0.63 mm).
- Loading rate: 10 seconds per cycle.
- Test temperature: 25°C (77°F).
- Specimen size: 6-inch length by 3-inch width by 1.5 inch.

The Overlay Tester was developed to evaluate a mixture's resistance to thermally induced reflection cracking. However, mixes that pass this test will also have good fatigue resistance.

The CAM specification SS 3109 was developed as an outcome of the initial research project. The asphalt content for these mixes is that which achieves 98 percent density after 50 gyrations in the Superpave Gyratory compactor. The main design requirement of this specification is that the mix must pass the HWTT requirement but it must also last more than 750 cycles in the Overlay Tester.

The Thin Overlay specification SS 3228 proposed three thin overlay mixes namely the fine graded PFC, SMA, and dense graded mix. In all cases these mixes must pass the Hamburg and Overlay test requirements. A minimum of 300 cycles was specified in the Overlay Tester.

The final mix that has recently become popular in Texas is the Thin Overlay Mix (TOM) designed according to SS 3239. This is essentially a fine SMA mix without the fibers. This mix has an overlay requirement of a minimum of 500 cycles.

In summary, traditional maintenance mixes do not have an Overlay test requirement and they may or may not be required to pass the Hamburg. The performance mixes proposed by TxDOT all must pass the Hamburg Wheel Tracking test (Tex Method 242-F) with a criteria based on the PG grade of the binder used, for PG 76-22 that would require 20,000 passes for a PG 70-22, (15,000 passes), PG 64-22 (10,000 passes) with less than a 12.5 mm rut. The required Overlay Tester criteria are shown below in Table 2.

Table 2. Overlay Tester Requirements for the Different Performance Mixes.

Mix Type	Overlay Tester Number of Cycles
Fine SMA (SS 3228)	300
Fine PFC (SS 3228)	300
Fine DGM (SS 3228)	300
TOM (SS 3239)	500
CAM (SS 3109)	750

COMPARISON ON CAM WITH LUFKIN'S TRADITIONAL MAINTENANCE MIX

A comparative study was conducted in the Lufkin District. Working closely with the district lab and the local hot mix plant two aggregates were selected for evaluation, Jones Mill 3/8-inch granite rock and Granite Mountain screenings. The mix design was developed according to SS 3109, and the proposed design is shown below in Figure 3. This mix with an asphalt content of 8.3 percent and a PG 76-22S binder type with granite aggregates passed both the HWTT and OT criteria.

	BIN FRACTIONS																						
	Bin No.1		Bin No.2		Bin No.3		Bin No.4		Bin No.5		Bin No.6		Bin No.7		Combined Gradation								
Aggregate Source:	Martin Marietta		Granite Mountain		Texas hydraded																		
Aggregate Number:	Jones Mill 3/8's		Hotmix Scr.		Lime																		
Sample ID:	Malvern, Ar.		Sweethome, Ar.		Cleburne, Tx.																		
Rap?, Asphalt%:															Total Bin								
Individual Bin (%):	30.0	Percent	69.0	Percent	1.0	Percent		Percent		Percent		Percent		Percent	100.0%	Lower & Upper Specification Limits							
Sieve Size:	Cum.% Passing	Wtd Cum. %	Cum.% Passing	Wtd Cum. %	Cum.% Passing	Wtd Cum. %	Cum.% Passing	Wtd Cum. %	Cum.% Passing	Wtd Cum. %	Cum.% Passing	Wtd Cum. %	Cum.% Passing	Wtd Cum. %	Cum. % Passing			Within Spec's	Restricted Zone	Within Spec's	Individual % Retained	Cumulative % Retained	Sieve Size
1"	100.0	30.0	100.0	69.0	100.0	1.0		0.0		0.0		0.0		0.0	100.0	100.0	100.0	Yes			0.0	0.0	1"
3/4"	100.0	30.0	100.0	69.0	100.0	1.0		0.0		0.0		0.0		0.0	100.0	100.0	100.0	Yes			0.0	0.0	3/4"
1/2"	100.0	30.0	100.0	69.0	100.0	1.0		0.0		0.0		0.0		0.0	100.0	100.0	100.0	Yes			0.0	0.0	1/2"
3/8"	100.0	30.0	100.0	69.0	100.0	1.0		0.0		0.0		0.0		0.0	100.0	98.0	100.0	Yes			0.0	0.0	3/8"
No. 4	56.7	17.0	88.9	61.3	100.0	1.0		0.0		0.0		0.0		0.0	79.4	70.0	90.0	Yes			20.6	20.6	No. 4
No. 8	16.7	5.0	60.3	41.6	100.0	1.0		0.0		0.0		0.0		0.0	47.6	40.0	65.0	Yes			31.7	52.4	No. 8
No. 16	7.6	2.3	40.2	27.7	100.0	1.0		0.0		0.0		0.0		0.0	31.0	20.0	45.0	Yes			16.6	69.0	No. 16
No. 30	4.9	1.5	25.6	17.7	100.0	1.0		0.0		0.0		0.0		0.0	20.1	10.0	30.0	Yes			10.9	79.9	No. 30
No. 50	3.7	1.1	14.6	10.1	100.0	1.0		0.0		0.0		0.0		0.0	12.2	10.0	20.0	Yes			8.0	87.8	No. 50
No. 200	2.4	0.7	3.6	2.5	100.0	1.0		0.0		0.0		0.0		0.0	4.2	2.0	10.0	Yes			8.0	95.8	No. 200

Not within specifications # Not cumulative

Asphalt Source & Grade:	PG 70-22 Or PG76-22	Binder Percent, (%):	7.5	Asphalt Spec. Grav.:	1.025
Antistripping Agent:	Texas Hydraded Lime	Percent, (%):	1		

Figure 3. Lufkin's CAM Mix.

As part of this project, samples of the maintenance mix currently being used to patch deteriorated sections of BUS 59 were obtained for comparative testing. Figure 4 shows the existing limestone maintenance mix and the proposed CAM Mix prior to overlay testing.

Figure 4. Lufkin's Traditional Maintenance Type D Mix (Left) CAM Mix (Right).

In both cases the samples were molded to 7 percent air voids for the performance tests. The results are shown below in Table 3. Both Hamburg and Overlay Tester results for the CAM mix are markedly superior to traditional Type D material.

Table 3. Comparison of CAM with Lufkin's Type D Mix.

Mix Type	Binder	Hamburg	Overlay Tester
Limestone Type D	4.4% PG 64-22	12.5 mm after 5,800 passes	38 cycles
Granite CAM	8.3% PG 76-22	7.8 mm after 20,000 passes	1510 cycles

The test results shown in Table 3 are thought to be representative of most maintenance mixes used in Texas, which are normally designed under Item 340 or 341 and are dense graded mixes with less than 5 percent asphalt. However substantial variations occur around the state, and this has become more complex recently with the introduction of both recycled asphalt and roofing shingles into the Item 341 mixes. Table 4 below shows the results from testing other mixes that are commonly used for maintenance operations in several districts.

Table 4. Performance Results from Other Mixes Used in Maintenance Applications.

District	Mix Type	Binder	% RAP	% RAS	HWTT	OT
Austin	C	PG 70-22	0	0	5.8	41
Austin	C	PG 64-22	15	3	8.4	6
Fort Worth	D	PG 64-22	0	0	Failed at 4,766	228
Fort Worth	D	PG 64-22	15	3	7.8	62

One obvious difference between the traditional and performance mixes is the widely different performance in the overlay tester. With many traditional dense graded mixes the OT results are typically less than 50 cycles to failure, when RAP and RAS are added this number often drops to less than 20 cycles to failure. The implications of this will be discussed in the following sections. The performance of the traditional mixes in the Hamburg is very variable. Most of the PG 64-22 unmodified mixes fail the Hamburg in less than 5000 passes; whereas, the mixes containing RAP/RAS often do not have problems passing the Hamburg test.

COST IMPLICATIONS (TRADITIONAL VERSUS PERFORMANCE MIXES)

The performance mixes, because of their use of modified binders and with a minimum asphalt content of 6 percent, will always be more expensive than conventional maintenance mixes. The typical cost differential is shown below in Figure 5. These data were provided by

TxDOT's Construction Division as statewide average cost values for 2012. In summary the cost of the traditional mixes on average is around $70 per ton whereas the performance mixes are around $100 per ton.

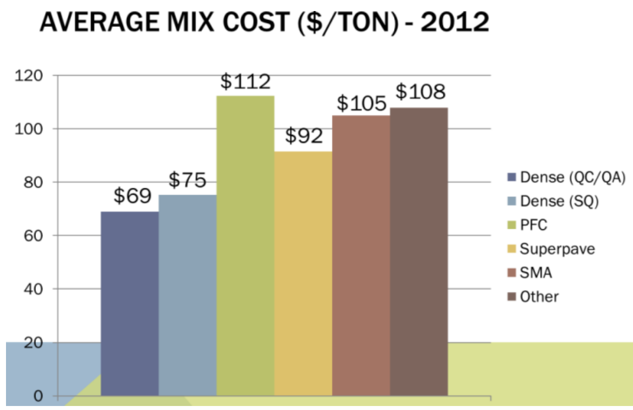

Figure 5. Statewide Cost Average (TxDOT Construction Div. 2013).

Performance mixes will only be cost effective if both of the following are met:

- They are placed in thin lifts so that the cost per sq. yard is less than the traditional mixes which are typically placed in 2-inch lifts.
- They have equal or better performance than the traditional mixes.

The cost comparison based on reduced layer thickness is shown below in Figure 6. This analysis was performed by Mike Arellano the lab engineer in the Austin District.

MIX THICKNESS – EFFECT ON MIX COST

Mix Type	2" Dense Graded Type D	1.5" PFC PFC-C	1.0" PFC PFC-F	2" SMA SMA-D	1" SMA SMA-F
Cost/Ton	$69	$112	$112	$105	$105
Cost/SY	$7.58	$7.56	$5.04	$11.55	$5.77
Cost/Mile	$53,363	$53,222	$35,482	$81,312	$40,621

Figure 6. Comparison of Cost against Layer Thickness for the Different Mix Types (Arellano 2013).

Clearly, when 1 inch of performance mix is compared with 2 inches of Type D, for example, the cost savings from the thickness differential will be around 25 percent.

PERFORMANCE OF TRADITIONAL VERSUS PERFORMANCE MIXES

The one unknown in the cost effectiveness evaluation of the thin lift mixes in comparison to the thicker dense graded mixes is their field performance. This will only be confirmed when long-term field performance data is available. The recent generation of performance mixes has only been around for the past 4 to 5 years. But the initial results are positive. Figure 7 shows a thin CAM mix in the Fort Worth District on a Jointed Concrete Pavement which is performing well after 4 years. Figure 8 shows one of the first TOM mixes placed on IH 35 in the Austin District in 2010, and it is also performing very well. Many more sections are being built and performance monitoring is underway. No major failures have been reported with the new performance mixes but many districts have raised concerns about the durability of the latest generation of maintenance mixes, which now contain both RAP and RAS.

Figure 7. CAM Mix in Fort Worth (Placed 2009).

Figure 8. TOM Mix on IH 35 Austin (Placed 2010).

CRACK PRO PREDICTIONS

Dr. Fujie Zhou from TTI developed a computational program called Crack Pro to let TxDOT districts predict the life until reflection cracking occurs for different overlays on pavement structures in the different districts in Texas. This program is still under development and more work is needed to model the benefits of thin overlays. But the program predictions show the benefits of going to mixes with higher overlay tester cycles with regard to their service life until reflection cracking occurs. Figure 9 and Figure 10 are examples of putting three different overlay types on a pavement with a stabilized base and moderate levels of existing cracking in both the Amarillo and Pharr Districts of Texas. Three different mixes were compared to a traditional maintenance mix with 50 cycles to failure in the OT as compared to performance mixes with 200 and 500 cycles to failure. From the results of the analysis the following are concluded:

- As the number of cycles to failure increases, the life until reflection cracks re-appear also increases.
- The percentage of increase moving from 50 cycles to 200 cycles in the OT approximately doubles the service life of the overlay.
- The results as expected are temperature dependent. The overlay lives are all much shorter in the colder district.

At this moment, efforts are underway to validate the predictions of this program as it will be a useful tool to let districts evaluate the cost effectiveness of moving to more expensive mixes. There is not a substantial increase in service life in all instances. In a pavement with low levels of cracking with solid support in mild climates, the improvements in overlay life may not be substantial.

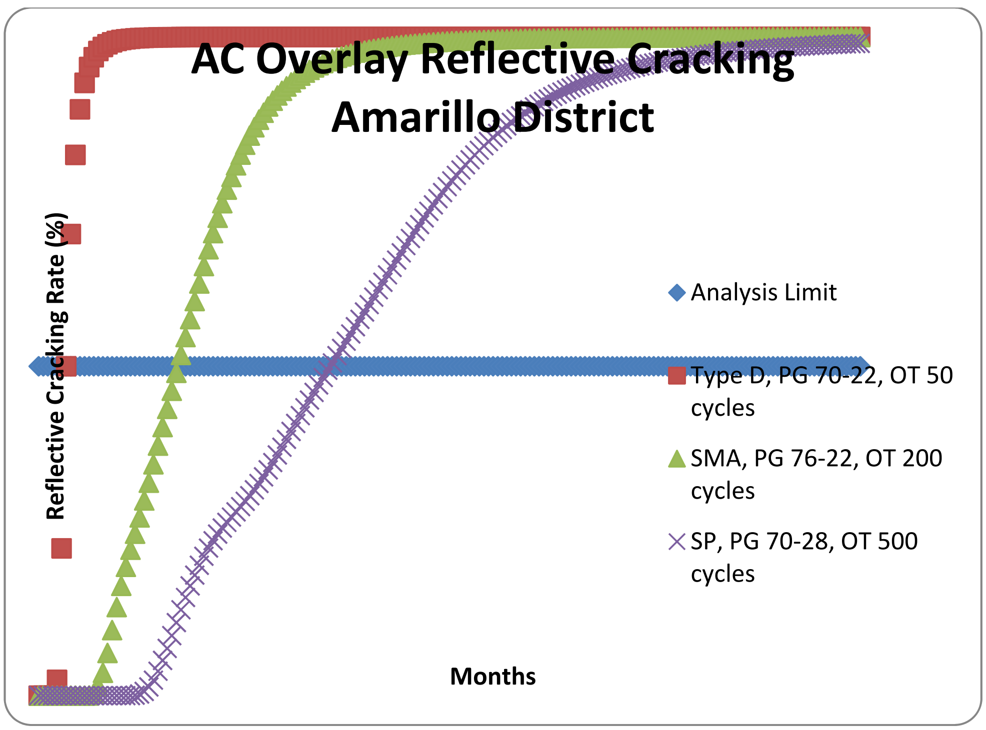

Figure 9. Overlay Life Predictions for Amarillo.

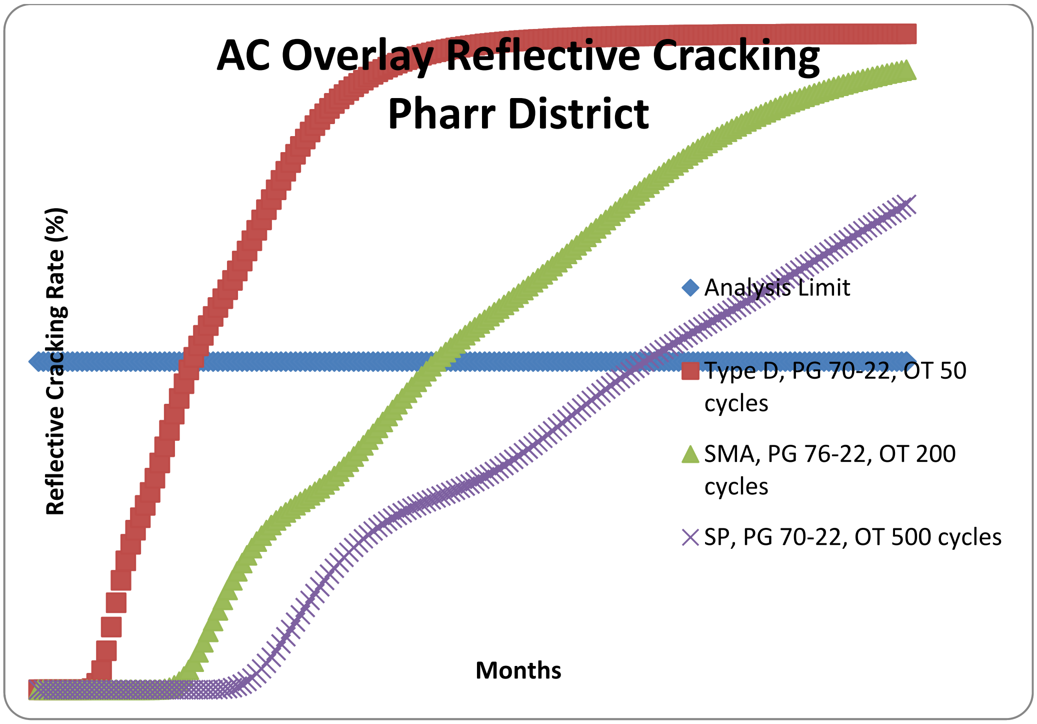

Figure 10. Overlay Life Predictions for Pharr.

CHAPTER 3. CONSTRUCTION OF TEST SECTIONS

One of the main objectives of this project was to assist districts and contractors to both design and construct thin overlay test sections. This chapter describes the construction of the following four test sections.

- Section 1 the Bryan District Fine SMA.
- Section 2 the Lufkin District Fine PFC.
- Section 3 the Bryan District Fine PFC.
- Section 4 the Brownwood District Fine PFC.

SECTION 1. BRYAN-FINE SMA

The Bryan-Fine SMA project was constructed in 2012. This mix was designed by Knife River, and this project is the first using the new specifications for fine SMA. The design process presented some difficulties with passing the overlay test, and compaction in the field required some trial and error with rolling patterns.

Site Description

This fine SMA project is located on the frontage roads on either side of SR 6 in north Bryan, as shown in Figure 11. The project runs between the Tabor Rd and Woodville Rd interchanges for 0.8 miles in each direction.

The traffic condition on this short section is unknown, but expected to be low severity. The climate condition in the area is moderately wet with relatively moderate summers and mild winters. The average annual rainfall is 40 inches. The average summer high is 94°F with 11 days on average reaching above 100°F. The average winter low is 44°F with an average of 17 days dropping below freezing.

The existing pavement was an old brittle HMA layer with multiple crack seals, as seen in Figure 12. Surface distress includes transverse cracking and longitudinal cracking in and out of the wheel paths. The pavement structure was not evaluated. The Bryan District has made widespread use of CAMs, but wanted to try this new mix for its superior surface texture and potentially better skid resistance.

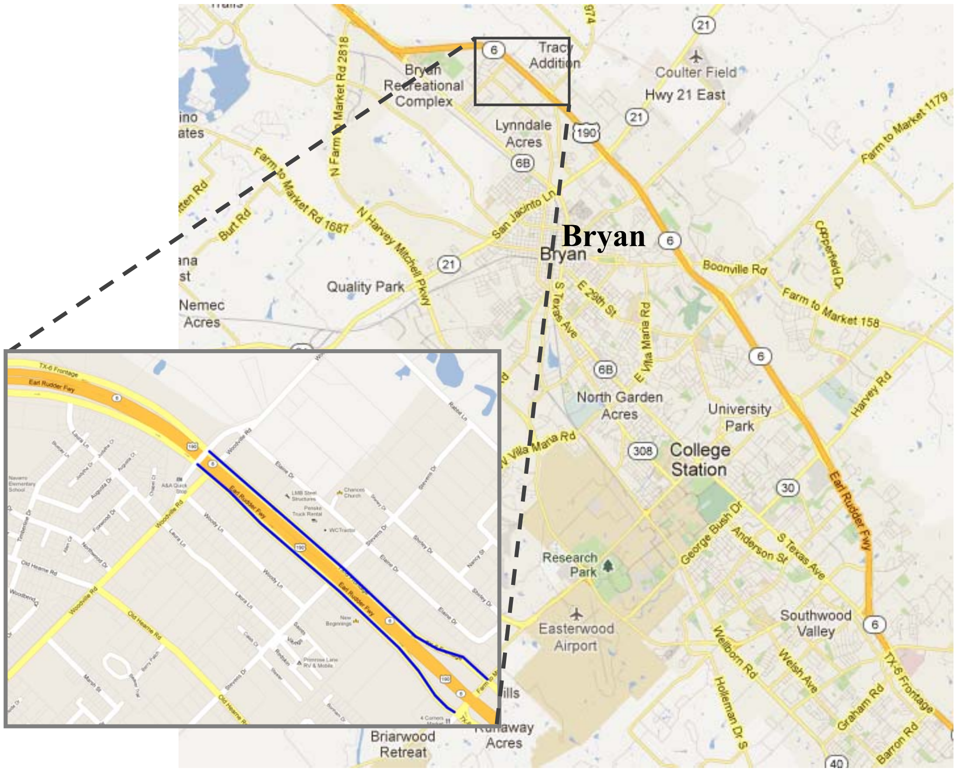

Figure 11. Project Location on SR 6 Frontage Road (Bryan-Fine SMA).

Figure 12. Existing Pavement Surface (Bryan-Fine SMA).

Overlay Design and Construction

This mix was designed by Knife River in consultation with TTI, following a district special specification. Mix compaction in the lab and overlay tester performance were issues during the design process. This mix was comprised of a Class A and B blend of coarse aggregates (Brownlee sandstone and Marble Falls dolomitic-limestone) as 75 percent of the mix with 24 percent dolomitic-limestone "dirty screenings," and 1 percent lime. At first, Knife River attempted to design the mix with washed screenings but later opted for dirty screenings. The final gradation is shown in Figure 13. OAC was originally determined as 6.5 percent at 96.5 percent density in the TGC. This was later adjusted to 6.7 percent to help pass the overlay test. The mix passed the HWTT test with 3.8 mm rutting after 20,000 cycles and the overlay test with 508 cycles.

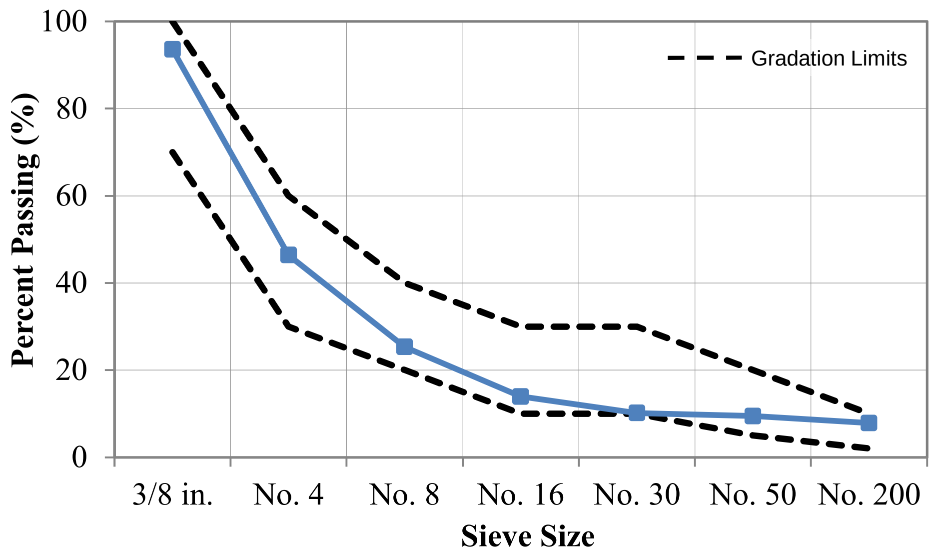

Figure 13. Mix Gradation (Bryan-Fine SMA).

The fine SMA was constructed in summer 2012. Particular interest was made to establish the correct rolling pattern. The initial sequence of two passes on each side of the mat (one pass defined as "down," not "down and back") was not sufficient as the initial void contents, as measured with a nuclear density gauge, were about 11 percent. A short section of tandem rolling was also attempted, as shown in Figure 14 to compact both sides of the mat before excessive cooling occurred. The final recommendation, however, was for three passes on each side of the mat with one roller. One of the rollers was also instrumented with intelligent compaction equipment, and the data from this equipment is still being analyzed. Construction was further complicated by long construction delays, resulting in hot mix trucks waiting several hours before distributing their loads.

Figure 14. Tandem Roller Compaction (Bryan-Fine SMA).

Overlay Performance

Shortly after construction, the project was tested for skid resistance and impermeability. The portable CTM and DFT devices were used to calculate the IFI. The IFI (F60) ranged between 0.40 and 0.43. These readings were taken before trafficking had removed the thin film of asphalt from the aggregate. The final surface texture seemed very similar to an open-graded texture, as shown in Figure 15; therefore, the water flow test was used to assess impermeability. All measurements were greater than 60 seconds, suggesting that the mix will not have problems of water ingress.

Figure 15. Project Surface Texture (Bryan-Fine SMA).

The Bryan District is pleased with the new fine SMA. It is the first mix of its kind using the new specifications. The design process presented some difficulties with passing the overlay test, and compaction in the field required some trial and error with rolling patterns. In the end, however, the project is tough and impermeable.

SECTION 2. LUFKIN-FINE PFC

The Lufkin-Fine PFC project was constructed in May 2011 on a highly trafficked cloverleaf exit ramp. The location has been a trouble spot for the district as vehicles would frequently lose control on the sharp turn during rainstorms. The fine PFC mix was the first constructed in Texas, thanks to funds dedicated to experimenting with the new thin overlay. To date, the district is very happy with the mix performance.

Site Description

This project is located on the cloverleaf exit from US 59 onto TX Loop 287 around Lufkin, as shown in Figure 16.

The traffic conditions on this short section are high severity. The single-lane loop services traffic along the busiest north-south route east of Houston. The curve radius of the loop is relatively small, resulting in severe turning movements and a low speed limit of 20 mph. The estimated AADT on the single lane is 6,000 with 24 percent truck traffic as estimated from adjacent freeway sections.

The climate condition in the area is wet with relatively moderate summers and mild winters. The average annual rainfall is 47 inches. The average summer high is 93°F with 6 days on average reaching above 100°F. The average winter low is 39°F with an average of 28 days dropping below freezing.

The pavement thickness was highly variable and possibly has interlayer debonding and/or stripping in several locations, as shown in Figure 17. The surface was a seal coat with some rutting in the outside wheel path.

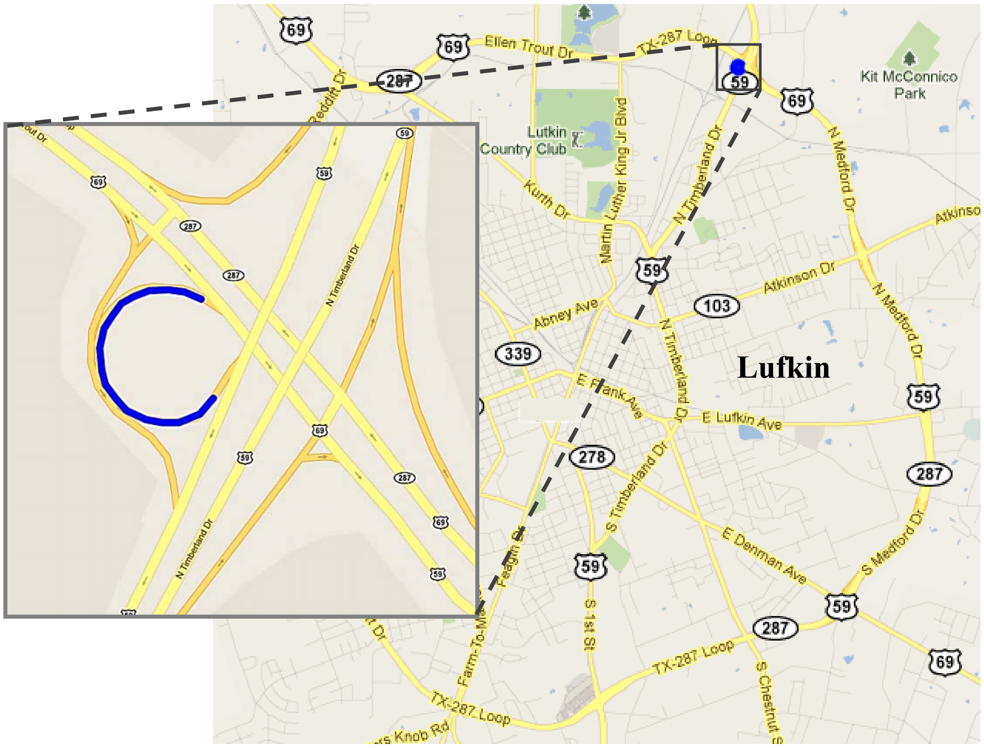

Figure 16. Project Location on US 59 Clover Leaf Exit (Lufkin-Fine PFC).

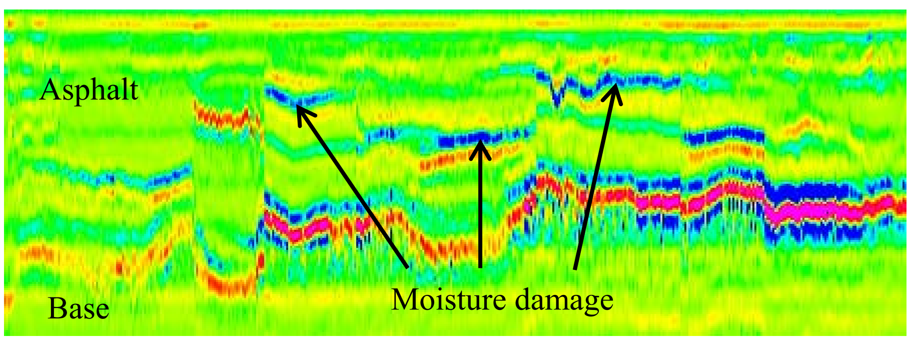

Figure 17. GPR Profile (Lufkin-Fine PFC).

Overlay Design and Construction

The fine PFC mix was designed by TTI as a modification of TxDOT Item 342. A volumetric design approach was applied. The gradation and gradation limits are illustrated in Figure 18. The aggregate was a Class A sandstone. The asphalt content was 6.5 percent with a PG 76-22 binder and was designed with 72 percent maximum density. An additional 0.3 percent fibers were also included in the mix. The mix passed the overlay test with 462 cycles. No data was available for the HWTT or for the densities at different asphalt contents.

The Atlanta TxDOT District was given funding to experiment with the new fine PFC mix. Because of the skid problems mentioned, this site was selected as a trial project for the new thin overlay. Construction took place in May 2011. The asphalt content during construction was 6.1 percent, lower than the original design. Other than this, no problems were noted in the process.

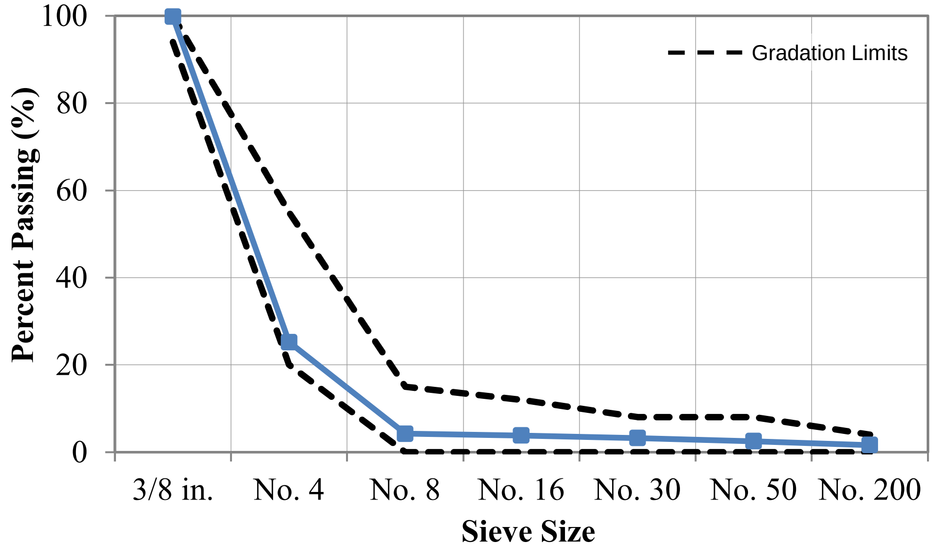

Figure 18. Mix Gradation (Lufkin-Fine PFC).

Overlay Performance

In July and August 2011, the overlay condition was evaluated with a visual assessment and GPR. At the time, the PFC was less than one year old. The day of construction, the water flow value of the new mix was measured with an average of 19.5 seconds. Due to speed limit restrictions and a tight turning radius on the cloverleaf, skid and noise measurements were not made.

This overlay was in exceptional condition as shown in Figure 19. There was no sign of cracking, rutting, or flushing here. Usually this would be expected for a pavement less than one year old, but it is impressive for an overlay subject to the extreme traffic conditions on this clover leaf ramp. As already described, this ramp carries anywhere from 1,400 to 2,500 slow turning semi-trucks every day, making this a worse-case scenario for trafficking.

Figure 19. Project and Surface Texture (Lufkin-Fine PFC).

This project is the first fine-PFC designed and placed in Texas and is very successful thus far. Even under extreme traffic conditions and extreme heat, the overlay is still performing well. The subsurface condition is not ideal and may cause problems in the future. This project should be carefully monitored over time.

SECTION 3. BRYAN-FINE PFC

The Bryan-Fine PFC project was constructed in July 2011 to surface a newly constructed exit ramp in Bryan. It is the same mix design as was used in the Lufkin-Fine PFC project. The project was paid for by funds dedicated to experimenting with the new thin overlays. Construction went well and the overlay performance is good to date.

Site Description

This project is located on the exit ramp from SR 6 in north Bryan onto the feeder road by the local DPS, as shown in Figure 20.

The traffic condition on this short section is unknown, but expected to be low severity. The climate condition in the area is moderately wet with relatively moderate summers and mild winters. The average annual rainfall is 40 inches. The average summer high is 94°F with 11 days on average reaching above 100°F. The average winter low is 44°F with an average of 17 days dropping below freezing. The ramp is new construction and the pavement thickness was not determined.

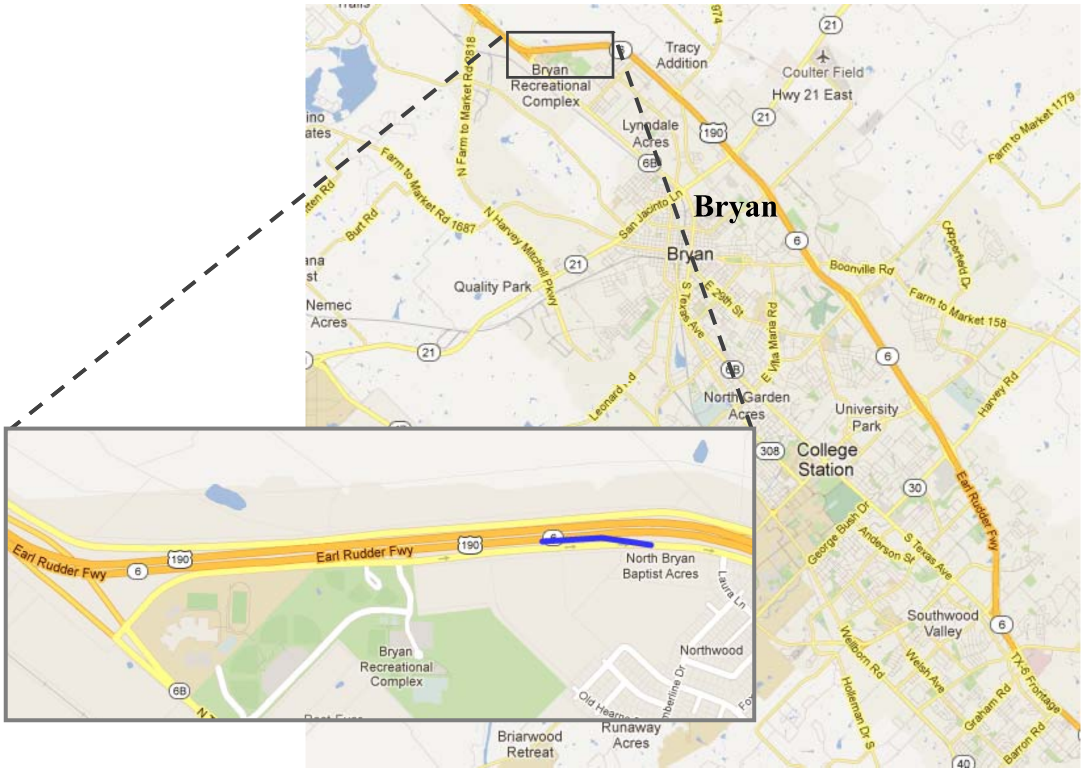

Figure 20. Project Location on SR 6 (Bryan-Fine PFC).

Overlay Design and Construction

The fine PFC mix was designed by TTI as a modification of TxDOT Item 342. A volumetric design approach was applied. The gradation and gradation limits are illustrated in Figure 21. The aggregate was a Class A sandstone. The asphalt content was 6.5 percent with a PG 76-22 binder and was designed with 72 percent maximum density. An additional 0.3 percent fibers were also included in the mix. The mix passed the overlay test with 462 cycles. No data were available for the HWTT or for the densities at different asphalt contents.

The Bryan District was given funding to experiment with the new fine PFC mix. They placed it to surface a newly constructed off ramp. The main freeway lanes were conventional PFC. Construction took place in late summer 2011 without any issues.

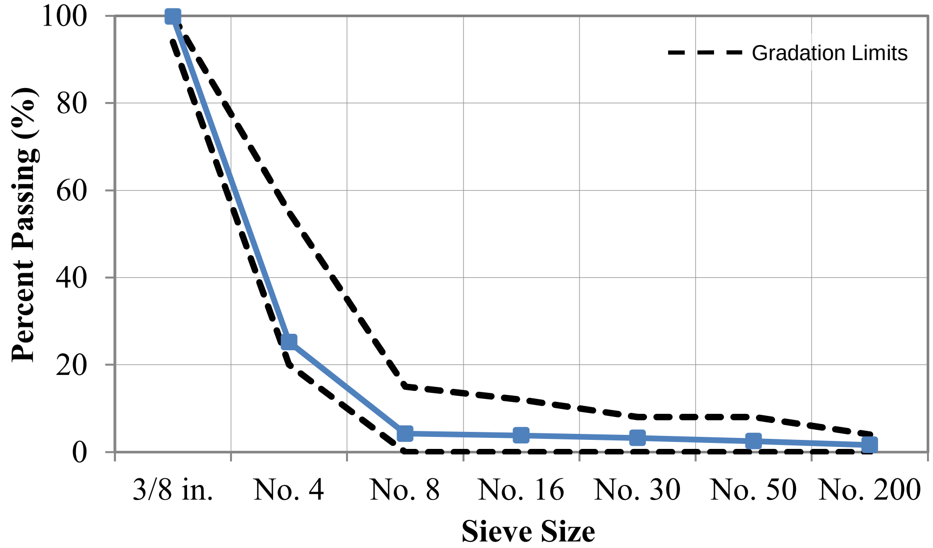

Figure 21. Mix Gradation (Bryan-Fine PFC).

Overlay Performance

The overlay was assessed shortly after construction. The project was in very good condition as shown in Figure 22. Skid number measurements taken at 50 mph ranged from 54 to 68, with an average of 61. This is considerably higher than the SN values for any of the other overlays tested. In this case, the reading was taken after some trafficking rather than immediately after construction. Skid resistance is often lower just after construction until the thin asphalt layer covering the aggregate wears away. The only performance issue noted was that surface water draining towards the shoulder from the main lanes would pond at the conventional PFC-fine PFC construction joint. Possibly, due to compaction practices, the mixes were not as permeable at the edges.

This fine PFC project used the same mix design as the Lufkin-Fine PFC project. The project was paid for by funds dedicated to experimenting with the new thin overlays. Construction went well and the overlay performance is good to date. Permeability at the edges of the overlays, however, may be less than ideal.

Figure 22. Project and Surface Texture (Bryan-Fine PFC).

SECTION 4. BROWNWOOD-FINE PFC

The Brownwood-Fine PFC project was constructed in 2012 as a corrective mix on a bleeding and peeling surface treatment near Breckenridge (Brownwood District). This was the first full-scale fine PFC project in Texas. Construction went well enough and the project is in good shape.

Site Description

This project is located just south of Breckenridge on US 183. The project runs just under 10 miles long from FM 2231 to FM 1032 as shown in Figure 23.

The climate condition in the area is moderately wet with both hot summers and a fair amount of winter freezing. The average annual rainfall is 30 in. The average summer high is 95°F with 25 days on average reaching above 100°F. The average winter low is 34°F with an average of 57 days dropping below freezing.

The surface treatment, shown in Figure 24, was in fair to poor condition. This was designed with a winter-grade emulsion and was flushing and peeling away after one year. Several large limestone rock asphalt patches were placed over problem areas, but these patches had an extra heavy tack coat application, increasing the amount of free binder and the severity of flushing. Tack rates for the seal coat and patches were 0.07 and 0.14 gsy, respectively. Using a PFC, with high air voids, to surface this road should provide room for the excess tack to move.

Figure 23. Project Location on US 183 (Brownwood-Fine PFC).

Figure 24. Flushing Surface Treatment (Brownwood-Fine PFC).

Overlay Design and Construction

The fine PFC mix was designed by TTI according to TxDOT's updated Item 342. The gradation and gradation limits are illustrated in Figure 25. The aggregates were two Class B limestones from the Zack Burkett and Eastland quarries. The asphalt content was 6.5 percent with a PG 76-22 binder and had a density of 79 percent. An additional 0.2 percent fibers and 0.8 percent liquid anti-stripping agent were also included in the mix. The density was higher than recommended and could cause permeability problems. The mix passed the HWTT with 9.3 mm rutting at 20,000 cycles and the overlay test with 395 cycles.

The Brownwood TxDOT District was given funding to offset the cost of construction to encourage experimentation with the new fine PFC mix. Construction started at the end of July 2012. Initially, the contractor put four passes with a steel-wheel breakdown roller and then three passes of a finishing roller (one pass is "down," not "down and back."). Fortunately, there were no signs of the mix moving under the rollers or aggregate crushing. The pattern was then relaxed to two breakdown and two finishing passes. The mat thickness was around 3/4 in. and yield was 63 lb/yd^2.

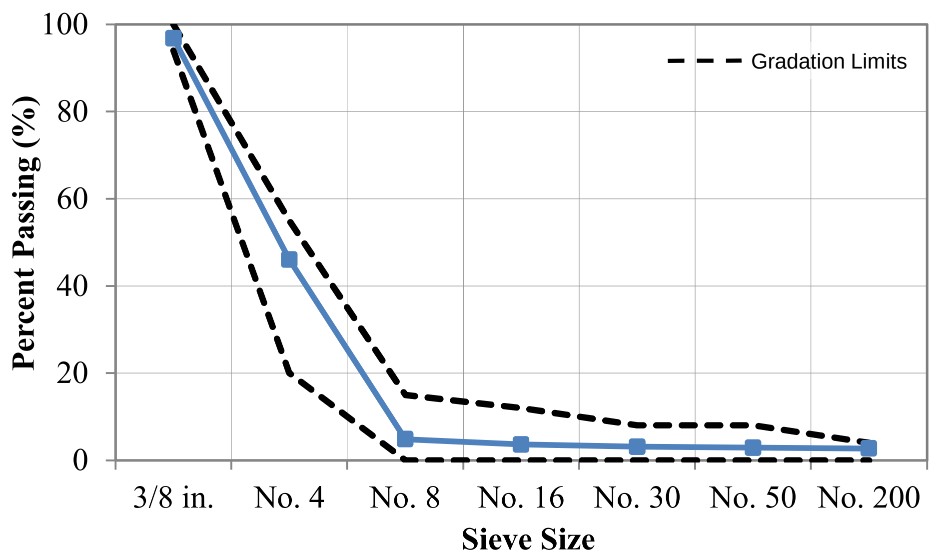

Figure 25. Mix Gradation (Brownwood-Fine PFC).

Overlay Performance

One lane after construction is shown in Figure 26. For the first section constructed with the original rolling pattern, the average WFV was 21 seconds. Water flow data were available after the pattern was adjusted. Laboratory densities were just under 80 percent. Other than the slightly high WFVs, no performance problems were noted. The site should be revisited to assess performance after service.

This project was the first full-scale fine PFC designed and placed in Texas. The mix was used to correct a flushed surface treatment. Construction went well enough and the project is in good shape.

Figure 26. Project and Lift Thickness (Brownwood-Fine PFC).

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

Very thin overlays have become very popular in Texas in large part because of the work conducted in Project 5598. The performance tests proposed in this study have initiated a new set of parallel development and implementation efforts in Texas districts. The Austin District has taken the lead in developing their version of a thin overlay mix. This is known as the TOM mix, and it is designed and constructed under SS 3239. Austin's TOM mix is similar to the Fine SMA mix mentioned below but does not include the use of fibers. Due to the high asphalt content and quality materials used in the thin mixes, the cost per ton is higher than that of conventional dense-graded mixtures. However, due to the thickness reduction, a 30 percent up-front cost savings is realized. Superior performance of these mixes also will result in less maintenance costs over the life.

This project has resulted in the successful implementation of three types of thin overlay mixtures:

- Dense-Graded Mixes (CAM or Crack Attenuating Mix).
- Gap-Graded Mixes (Fine SMA or Stone Matrix Asphalt).
- Fine PFC (Permeable Friction Course).

These mixtures are different from TxDOT's conventional dense-graded (Item 340/341) mixtures as follows:

- May be placed at a thickness of 1 inch or less due to the use of very fine aggregates.
- Must pass both a rutting (HWTT) and cracking (OT) performance test.
- No RAP or RAS is allowed.
- PG 76-22 asphalt is required.
- Minimum of 6.0 percent asphalt is required.

TTI researchers worked with many districts and contractors to develop successful mix designs of the three mixture types using their locally available materials. Construction of small scale test sections was facilitated with the support of the TxDOT Project Director, Tammy Sims (now Greenville Area Engineer of the Paris District), and funding through the Maintenance

Division. The overwhelming success of test section performance led to the construction of full-scale projects for all three mixture types in several districts.

A draft specification for these mixes was developed as presented in Appendix A. At this time, this specification is in the process of being in TxDOT's standard specification book due to be published in early 2014.

Thin overlays should only be used on structurally sound pavements to address a surface requirement. Pavements needing extensive rehabilitation or requiring structural improvement should be avoided. Similar to conventional overlays, spot base repair (mill and fill), level-up, and crack sealing in isolated areas should be done prior to placing a thin surface mix.

APPENDIX

TENTATIVE DRAFT SPECIAL SPECIFICATION FOR THE FINE GRADED MIXES

SPECIAL SPECIFICATION

XXXX
Fine Surface Mixes

Description. Construct a fine graded surface mix composed of a compacted mixture of aggregate and asphalt binder mixed hot in a mixing plant and placed at a lift thickness of 1 inch or less. Fine surface mixtures are defined as either:

Type I fine permeable friction course (F-PFC).

Type II fine-stone matrix asphalt (F-SMA).

Type III fine-dense graded mix (F-DGM).

Materials. Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications.

Notify the Engineer of all material sources. Notify the Engineer before changing any material source or formulation. When the Contractor makes a source or formulation change, the Engineer will verify that the specification requirements are met and may require a new laboratory mixture design, trial batch, or both. The Engineer may sample and test project materials at any time during the project to verify specification compliance.

Aggregate. Furnish aggregates from sources that conform to the requirements shown in Table 1, and as specified in this Section, unless otherwise shown on the plans. Provide aggregate stockpiles that meet the definition in this Section for either a coarse aggregate or fine aggregate. Do not use reclaimed asphalt pavement (RAP) in the Fine Graded Surface mixes. Supply mechanically crushed gravel or stone aggregates that meet the definitions in Tex-100-E. The Engineer will designate the plant or the quarry as the sampling location. Samples must be from materials produced for the project. The Engineer will establish the surface aggregate classification (SAC) and perform Los Angeles abrasion, magnesium sulfate soundness, and Micro-Deval tests. Perform all other aggregate quality tests listed in Table 1. Document all test results on the mixture design report. The Engineer may perform tests on independent or split samples to verify Contractor test results. Stockpile aggregates for each source and type separately. Determine aggregate gradations for mixture design in accordance with Tex-200-F, Part II. Do not add material to an approved stockpile from sources that do not meet the aggregate quality requirements of the Department's *Bituminous Rated Source Quality Catalog* (BRSQC) unless otherwise approved.

Coarse Aggregate. Coarse aggregate stockpiles must have no more than 20% material passing the No. 8 sieve. Provide aggregates from sources listed in the BRSQC. Provide aggregate from non-listed sources only when the Engineer tests and approves before use. Allow 30 calendar days for the Engineer to sample, test, and report results for non-listed sources.

Provide coarse aggregate with at least the minimum SAC as shown on the plans. SAC requirements apply only to aggregates used on the surface of travel lanes. When shown on the plans, SAC requirements apply to aggregates used on surfaces other than travel lanes. The SAC for sources on the Department's Aggregate Quality Monitoring Program (AQMP) is listed in the BRSQC.

When shown on the plans, Class B aggregate meeting all other requirements in Table 1 may be blended with a Class A aggregate in order to meet requirements for Class A materials. When blending Class A and B aggregates to meet a Class A requirement, ensure that at least 50% by weight of material retained on the No. 8 sieve comes from the Class A aggregate source. Blend by volume if the bulk specific gravities of the Class A and B aggregates differ by more than 0.300. When blending, do not use Class C or D aggregates.

Table 1
Aggregate Quality Requirements

Property	Test Method	Requirement
Coarse Aggregate		
SAC	AQMP	As shown on plans
Deleterious material, %, max	Tex-217-F, Part I	1.0
Decantation, %, max	Tex-217-F, Part II	1.5
Micro-Deval abrasion, %, max	Tex-461-A	Note 1
Los Angeles abrasion, %, max	Tex-410-A	30
Magnesium sulfate soundness, 5 cycles, %, max	Tex-411-A	20
Coarse aggregate angularity, 2 crushed faces, %, min	Tex 460-A, Part I	95[2]
Flat and elongated particles @ 5:1, %, max	Tex-280-F	10
Fine Aggregate		
Linear shrinkage, %, max	Tex-107-E	3
Combined Aggregate[3]		
Sand equivalent, %, min	Tex-203-F	45

1. Not used for acceptance purposes. Used by the Engineer as an indicator of the need for further investigation.
2. Only applies to crushed gravel.
3. Aggregates, without mineral filler, or additives, combined as used in the job-mix formula (JMF).

Intermediate Aggregate. Aggregates not meeting the definition of coarse or fine aggregate will be defined as intermediate aggregate. When used, supply intermediate aggregates that are free from organic impurities. The Engineer may test the intermediate aggregate in accordance with Tex-408-A to verify the material is free from organic impurities. When used, supply intermediate aggregate from coarse aggregate sources that meet the requirements shown in Table 1 unless otherwise approved.

Fine Aggregate. Fine aggregates that consist of manufactured sands and/ or screenings should be used in all Type II and Type III mixtures. Fine Aggregate are not allowed in Type I mixtures. Natural sands are not allowed in any mixture. Fine aggregate stockpiles must meet the gradation requirements in Table 2. Supply fine aggregates that are free from organic impurities. The Engineer may test the fine aggregate in accordance with Tex-408-A to verify that the material is free from organic impurities. Use fine aggregate from coarse aggregate sources that meet the requirements in Table 1, unless otherwise approved.

If 10% or more of the stockpile is retained on the No. 4 sieve, test the stockpile and verify that it meets the requirements in Table 1 for coarse aggregate angularity (Tex-460-A) and flat and elongated particles (Tex-280-F).

Table 2
Gradation Requirements for Fine Aggregate

Sieve Size	% Passing by Weight or Volume
3/8"	98 - 100
#8	70 – 100
#200	0 – 30

4. **RAP**. Do not use RAP in Fine Graded Surface Mixes.

Mineral Filler. Mineral filler consists of finely divided mineral matter such as agricultural lime, crusher fines, hydrated lime, cement, or fly ash. Mineral filler is allowed in Type II and Type III mixtures unless otherwise shown on the plans. Do not use more than 1% by weight of the total dry aggregate in accordance with Item 301, "Asphalt Antistripping Agents," unless otherwise shown on the plans. Do not add lime or cement directly into the mixing drum of any plant where they are removed through the exhaust stream, unless the plant has a baghouse or dust collection system that reintroduces them back into the drum.

When used, provide mineral filler that:

- is sufficiently dry, free-flowing, and free from clumping and foreign matter;
- does not exceed 3% linear shrinkage when tested in accordance with Tex-107-E; and
- meets the gradation requirements in Table 3.

Table 3
Gradation Requirements for Mineral Filler

Sieve Size	% Passing by Weight or Volume
#8	100
#200	55–100

Baghouse Fines. Fines collected by the baghouse or other dust-collecting equipment may be reintroduced into the mixing drum.

Asphalt Binder. Provide an asphalt binder with a high-temperature grade of PG 76 and low-temperature grade as shown on the plans, in accordance with Section 300.2.J, "Performance-Graded Binders."

Tack Coat. Unless otherwise shown on the plans or approved, furnish CSS-1H, SS-1H, or a PG binder with a minimum high-temperature grade of PG 58 for tack coat binder, in accordance with Item 300, "Asphalts, Oils, and Emulsions." Do not dilute emulsion asphalts at the terminal, in the field, or at any other location before use.

The Engineer will obtain at least one sample of the tack coat binder per project and test it to verify compliance with Item 300. The Engineer will obtain the sample from the asphalt distributor immediately before use.

Additives. When shown on the plans, use the type and rate of additive specified. Other additives that facilitate mixing or improve the quality of the mixture may be allowed, when approved.

Fibers. Provide cellulose or mineral fibers in Type I and Type II mixtures. Submit written certification to the Engineer that the fibers proposed for use meet the requirements of DMS-9204, "Fiber Additives for Bituminous Mixtures."

Warm mix asphalt (WMA) is defined as additives or processes that allow a reduction in the temperature at which asphalt mixtures are produced and placed. WMA is allowed for use at the Contractor's option, unless otherwise shown on the plans. The use of WMA is required when shown on plans. Unless otherwise directed, use only WMA additives or processes listed on the Department's Material Producer List maintained by the Construction Division (http://www.dot.state.tx.us/business/producer_list.htm).

If lime or liquid antistripping agent is used, add in accordance with Item 301, "Asphalt Antistripping Agents." When the plans require lime to be added as an antistripping agent, hydrated lime added as mineral filler will count towards the total quantity of hydrated lime specified. No more than 1% hydrated lime will be added to any mixture.

Equipment. Provide required or necessary equipment in accordance with Item 320, "Equipment for Hot-Mix Asphalt Materials."

Construction. Produce, haul, place, and compact the specified paving mixture. Schedule and participate in a prepaving meeting with the Engineer as required in the Quality Control Plan (QCP).

Certification. Personnel certified by the Department-approved hot-mix asphalt certification program must conduct all mixture designs, sampling, and testing in accordance with Table 4. In addition to meeting the certification requirements in Table 4, all Level II certified specialists must successfully complete an approved Superpave training course. Supply the Engineer with a list of certified personnel and copies of their current certificates before beginning production and when personnel changes are made. Provide a mixture design developed and signed by a Level II certified specialist. Provide a Level IA certified specialist at the plant during production operations. Provide a Level IB certified specialist to conduct placement tests.

Table 4
Test Methods, Test Responsibility, and Minimum Certification Levels

1. Aggregate Testing	**Test Method**	**Contractor**	**Engineer**	**Level**
Sampling	Tex-400-A	✓	✓	IA
Dry sieve	Tex-200-F, Part I	✓	✓	IA
Washed sieve	Tex-200-F, Part II	✓	✓	IA
Deleterious material	Tex-217-F, Part I	✓	✓	II
Decantation	Tex-217-F, Part II	✓	✓	II
Los Angeles abrasion	Tex-410-A		✓	
Magnesium sulfate soundness	Tex-411-A		✓	
Micro-Deval abrasion	Tex-461-A		✓	
Coarse aggregate angularity	Tex-460-A	✓	✓	II
Flat and elongated particles	Tex-280-F	✓	✓	II
Linear shrinkage	Tex-107-E	✓	✓	II
Sand equivalent	Tex-203-F	✓	✓	II
Organic impurities	Tex-408-A	✓	✓	II
2. Mix Design & Verification	**Test Method**	**Contractor**	**Engineer**	**Level**
Design and JMF changes	Tex-204-F	✓	✓	II
Mixing	Tex-205-F	✓	✓	II
Molding (SGC)	Tex-241-F	✓	✓	IA
Laboratory-molded density	Tex-207-F	✓	✓	IA
VMA	Tex-207-F	✓	✓	II
Rice gravity	Tex-227-F	✓	✓	IA
Ignition oven calibration[1]	Tex-236-F	✓	✓	II
Indirect tensile strength	Tex-226-F	✓	✓	II
Overlay Test	Tex-248-F		✓	
Hamburg Wheel test	Tex-242-F	✓	✓	II
Boil test	Tex-530-C	✓	✓	IA
3. Production Testing	**Test Method**	**Contractor**	**Engineer**	**Level**
Random sampling	Tex-225-F		✓	IA
Mixture sampling	Tex-222-F	✓	✓	IA
Molding (SGC)	Tex-241-F	✓	✓	IA
Laboratory-molded density	Tex-207-F	✓	✓	IA
VMA (calculation only)	Tex-207-F	✓	✓	IA
Rice gravity	Tex-227-F	✓	✓	IA
Gradation & asphalt content[1]	Tex-236-F	✓	✓	IA
Control charts	Tex-233-F	✓	✓	IA
Moisture content	Tex-212-F	✓	✓	IA
Overlay Test	Tex-248-F		✓	
Hamburg Wheel Test	Tex-242-F	✓	✓	II
Overlay Test	Tex-248-F		✓	
Micro-Deval abrasion	Tex-461-A		✓	
Boil Test	Tex-530-C	✓	✓	IA
Aging Ratio	Tex-211-F		✓	
4. Placement Testing	**Test Method**	**Contractor**	**Engineer**	**Level**
Random sampling	Tex-225-F		✓	IA
Establish rolling pattern	Tex-207-F	✓		IB
In-Place air voids	Tex-207-F	✓	✓	IA
Control charts	Tex-233-F	✓	✓	IA
Ride quality measurement	Tex-1001-S	✓	✓	IB
Segregation (density profile)	Tex-207-F, Part V	✓	✓	IB
Longitudinal Joint Density	Tex-207-F, Part VII	✓	✓	IB
Thermal profile	Tex-244-F	✓	✓	IB
Tack coat adhesion	Tex-243-F		✓	IB

1. Refer to Section 4.I.2.c for exceptions to using an ignition oven.

Reporting. Use Department-provided software to record and calculate all test data. The Engineer and the Contractor must provide any available test results to the other party when requested. The Engineer and the Contractor must immediately report to the other party any test result that requires production to be suspended or fails to meet the specification requirements. Use the approved communication method (e.g., email, diskette, hard copy) to submit test results to the Engineer.

Use the procedures described in Tex-233-F to plot the results of all quality control (QC) and quality assurance (QA) testing. Update the control charts as soon as test results for each sublot become available. Make the control charts readily accessible at the field laboratory. The Engineer may suspend production for failure to update control charts.

QCP. Develop and follow the QCP in detail. Obtain approval from the Engineer for changes to the QCP made during the project. The Engineer may suspend operations if the Contractor fails to comply with the QCP.

Submit a written QCP to the Engineer before the mandatory prepaving meeting. Receive the Engineer’s approval of the QCP before beginning production. Include the following items in the QCP:

Project Personnel. For project personnel, include:

a list of individuals responsible for QC with authority to take corrective action; and

contact information for each individual listed.

Material Delivery and Storage. For material delivery and storage, include:

the sequence of material processing, delivery, and minimum quantities to assure continuous plant operations;

aggregate stockpiling procedures to avoid contamination and segregation;

frequency, type, and timing of aggregate stockpile testing to assure conformance of material requirements before mixture production; and

procedure for monitoring the quality and variability of asphalt binder.

Production. For production, include:

loader operation procedures to avoid contamination in cold bins;

procedures for calibrating and controlling cold feeds;

procedures to eliminate debris or oversized material;

procedures for adding and verifying rates of each applicable mixture component (e.g., aggregate, asphalt binder, lime, liquid antistrip);

procedures for reporting job control test results; and

procedures to avoid segregation and drain-down in the silo.

Loading and Transporting. For loading and transporting, include:

type and application method for release agents; and

truck loading procedures to avoid segregation.

Placement and Compaction. For placement and compaction, include:

proposed agenda for mandatory prepaving meeting, including date and location;

type and application method for release agents in the paver and on rollers, shovels, lutes, and other utensils;

procedures for the transfer of mixture into the paver, while avoiding segregation and preventing material spillage;

process to balance production, delivery, paving, and compaction to achieve continuous placement operations;

paver operations (e.g., operation of wings, height of mixture in auger chamber) to avoid physical and thermal segregation and other surface irregularities; and

procedures to construct quality longitudinal and transverse joints.

Mixture Design.

Design Requirements. The Department will use the mixture design procedure given in Table 5 to design a mixture meeting the requirements listed in Tables 1, 2, 3, 5, and 6 unless otherwise shown on the plans. For Type I (F-PFC) and Type III (F-DGM) design for a target laboratory-molded density as shown in Table 6 with Ndes = 50 as the design number of gyrations. For Type II (FG SMA) use the Texas Gyratory Compactor (TGC) to design the mix unless otherwise shown on plans. For Type II and III mixes unless approved by the engineer, conduct the Hamburg Wheel Test and the Overlay Test at the OAC and at OAC+0.5%.

Use an approved laboratory to perform the Hamburg Wheel test and provide results with the mixture design, or provide the laboratory mixture and request that the Department perform the Hamburg Wheel test. The Construction Division maintains a list of approved laboratories. Provide the laboratory mixture and request that the Department perform the Overlay test. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel test and Overlay test results on the laboratory mixture design.

The Contractor may submit a new mixture design at any time during the project. The Engineer will approve all mixture designs before the Contractor can begin production. When shown on the plans, the Engineer will provide the mixture design. Provide the Engineer with a mixture design report using Department-provided software. Include the following items in the report:

the combined aggregate gradation, source, specific gravity, and percent of each material used;

results of all applicable tests;

the mixing and molding temperatures;

the signature of the Level II person or persons that performed the design;

the date the mixture design was performed; and

a unique identification number for the mixture design.

Table 5
Fine Surface Mix Master Gradation Bands
% Passing by Weight or Volume and Volumetric Properties

Sieve Size	**Percent Passing**		
	I **Fine-** **PFC**	**II** **Fine** **SMA**	**III** **Fine DGM**
3/8 in.	95 - 100	95 - 100	95 - 100
# 4	20 - 55	50 - 70	70 - 90
# 8	0 - 15	20 - 40	40 - 65
# 16	0 - 12	10 - 25	20 - 45
# 30	0 - 8	10 - 20	10 - 30
# 50	0 - 8	8 - 15	10 - 20
# 200	0 - 4	6 - 12	2 – 7
Mixture Design Method	Tex-204-F, Part V	Tex-204-F, Part I	Tex-204-F, Part IV
Property	**Requirement**		
	I	**II**	**III**
Minimum AC%	6.0%	6.0%	5.5%
Design VMA, % Min	NA	16.0	16.5
Plant Produced VMA, % Min	NA	15.5	16.0

Table 6
Laboratory Mixture Design Properties

Property	**Requirement**		
	I Fine- PFC	**II Fine- SMA**	**III Fine- DGM**
Design Gyrations (Tex-241-F)	50	Texas Gyratory Compactor	50[1]
Lab Molded Density Tex 207 F	72[2] – 76	96.5	96.5
Hamburg Wheel Tracking Test[3] Tex 242-F	Min 10,000 passes	Min 20,000 passes	Min 20,000 passes
Overlay Tester (Min. # Cycles) Tex 248-F[3]	300	300	300
Tensile Strength (dry), psi Tex-226-F	NA	85-200[6]	85-200[6]
Fiber Content %[5] (min – max)	0.2 – 0.5	0.2 - 0.5	NA[4]
Lime Content % (max)	1.0	1.0	1.0
Drain Down test % Tex 235 - F	Max 0.20%	Max 0.20%	NA
Cantabro Loss % Tex 245 - F	Max 20%	NA	NA

1. May be adjusted in the range of 50 to 100 gyrations when shown on the plans or allowed by the Engineer
2. Suggested test limit. Test and report for informational purposes only
3. For Performance testing Type I mixes compacted to lab molded density used to select Optimum Asphalt Content from Tex 207 F (in range 72 – 76%), Type II and III molded to 93%+/- 1% as per Tex 242-F and 248-F.
4. Not applicable.
5. Calculated by weight of total mixture.
6. May exceed 200 psi when approved and may be waived when approved.

2. **Job-Mix Formula Approval.** The job-mix formula (JMF) is the combined aggregate gradation and target asphalt percentage used to establish target values for hot mix production. JMF1 is the original laboratory mixture design used to produce the trial batch. The Engineer and the Contractor will verify JMF1 based on a plant-produced mixture from the trial batch, unless otherwise approved.

Contractor's Responsibilities.

Providing Superpave Gyratory Compactor. Furnish a Superpave gyratory compactor (SGC), calibrated in accordance with Tex-241-F, for molding production samples. Locate the SGC at the Engineer's field laboratory and make the SGC available to the Engineer for use in molding production samples.

Gyratory Compactor Correlation Factors. Use Tex-206-F, Part II, to perform a gyratory compactor correlation when the Engineer uses a different SGC. Apply the correlation factor to all subsequent production test results.

Submitting JMF1. When shown on plans, furnish the Engineer a mix design report (JMF1), and request approval to produce the trial batch. If opting to have the Department perform the Hamburg Wheel test on the laboratory mixture, provide the Engineer with approximately 10,000 g of the design mixture and request that the Department perform the Hamburg Wheel test. Provide the Engineer with approximately 25,000 g of the design mixture and request that the Department perform the Overlay test.

Supplying Aggregate. Provide the Engineer with approximately 40 lb. of each aggregate stockpile, unless otherwise directed.

Supplying Asphalt. Provide the Engineer at least 1 gal. of the asphalt material and sufficient quantities of any additives proposed for use.

Ignition Oven Correction Factors. Determine the aggregate and asphalt correction factors from the ignition oven in accordance with Tex-236-F. Provide the Engineer with split samples of the mixtures, including all additives (except water), and blank samples used to determine the correction factors. Correction factors established from a previously approved mixture design may be used for the current mixture design, if the mixture design and ignition oven are the same as previously used, unless otherwise directed.

Boil Test. Perform the test and retain the tested sample from Tex-530-C. Use this sample for comparison purposes during production. The Engineer may waive the requirement for the boil test.

Trial Batch Approval. Upon receiving conditional approval of JMF1 from the Engineer, provide a plant-produced trial batch, including the WMA additive or process, if applicable, for verification testing of JMF1 and development of JMF2.

Trial Batch Production Equipment. To produce the trial batch, use only equipment and materials proposed for use on the project.

Trial Batch Quantity. Produce enough quantity of the trial batch to ensure that the mixture is representative of JMF1.

Number of Trial Batches. Produce trial batches as necessary to obtain a mixture that meets the requirements in Table 7.

Trial Batch Sampling. Obtain a representative sample of the trial batch and split it into three equal portions, in accordance with Tex-222-F. Label these portions as "Contractor," "Engineer," and "Referee." Deliver samples to the appropriate laboratory as directed.

Trial Batch Testing. Test the trial batch to ensure that the mixture produced using the proposed JMF1 meets the verification testing requirements for gradation, asphalt content, laboratory-molded density, and VMA listed in Table 8 and is in compliance with the Hamburg Wheel and Overlay test requirements in Tables 6 and 7. Use an approved laboratory to perform the Hamburg Wheel test on the trial batch mixture or request that the Department perform the Hamburg Wheel test. The Department will perform the Overlay test. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel and Overlay test results on the trial batch. Provide the Engineer with a copy of the trial batch test results.

Development of JMF2. After the Engineer grants full approval of JMF1 based on results from the trial batch, evaluate the trial batch test results, determine the optimum mixture proportions, and submit as JMF2.

Mixture Production. After receiving approval for JMF2 and receiving a passing result from the Department's or a Department-approved laboratory's Hamburg Wheel test and the Department's Overlay test on the trial batch, use JMF2 to produce Lot 1. As an option, once JMF2 is approved, proceed to Lot 1 production at the Contractor's risk without receiving the results from either the Department's Hamburg Wheel test or Overlay test on the trial batch. If electing to proceed without either the Hamburg Wheel test or Overlay test results from the trial batch, notify the Engineer. Note that the Engineer may require that up to the entire sublot of any mixture failing either the Hamburg Wheel test or Overlay test be removed and replaced at the Contractor's expense.

Development of JMF3. Evaluate the test results from Lot 1, determine the optimum mixture proportions, and submit as JMF3 for use in Lot 2.

JMF Adjustments. If necessary, adjust the JMF before beginning a new lot. The adjusted JMF must:

be provided to the Engineer in writing before the start on a new lot;

be numbered in sequence to the previous JMF;

meet the master gradation limits shown in Table 5; and

be within the operational tolerances of JMF2 listed in Table 7.

Requesting Referee Testing. If needed, use referee testing in accordance with Section 4.I.1, "Referee Testing," to resolve testing differences with the Engineer.

Table 7
Operational Tolerances

Description	Test Method	Allowable Difference from Current JMF Target	Allowable Difference between Contractor and Engineer[1]
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	±3.0[2]	±3.0
Individual % retained for sieves smaller than #8 and larger than #200		±3.0[2]	±3.0
% passing the #200 sieve		±2.0[2]	±1.6
Asphalt content, %[5]	Tex-236-F	±0.3[3]	±0.3
Laboratory-molded density, %	Tex-207-F	±1.0[6]	±0.5
In-Place air voids, %		N/A	±1.0
Laboratory-molded bulk specific gravity		N/A	±0.020
VMA, % min		Note [4]	N/A
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	± 0.020

1. Contractor may request referee testing only when values exceed these tolerances.
2. When within these tolerances, mixture production gradations may fall outside the master grading limits; however, the % passing the #200 sieve will be considered out of tolerance when outside the master grading limits.
3. Tolerance between trial batch test results and JMF1 (lab produced mix) is not allowed to exceed 0.5%, unless otherwise directed. Tolerance between JMF1 (lab produced mix) and JMF2 is allowed to exceed ±0.3%.
4. Test and verify that Table 5 requirements are met.
5. May be obtained from asphalt meter readouts for Type I
6 For Type II and III mixes only, for Type I be within the range shown in Table 6

Engineer's Responsibilities.

Gyratory Compactor. The Engineer will use a Department SGC, calibrated in accordance with Tex-241-F, to mold samples for laboratory mixture design verification. For molding trial batch and production specimens, the Engineer will use the Contractor-provided SGC at the field laboratory or will provide and use a Department SGC at an alternate location. The Engineer will make the Contractor-provided SGC in the Department field laboratory available to the Contractor for molding verification samples.

Conditional Approval of JMF1. When the Contractor is required to perform the mixture design as shown on plans, within 10 working days of receiving the mixture design report (JMF1) and all required materials and Contractor-provided Hamburg Wheel test results, the Engineer will review the Contractor's mix design report and verify conformance with all aggregates, asphalt, additives, and mixture specifications. The Engineer may perform tests to verify that the aggregates meet the requirements listed in Table 1. The Engineer will grant the Contractor conditional approval of JMF1, if the information provided on the paper copy of JMF1 indicates that the Contractor's mixture design meets the specifications. When the Contractor does not provide Hamburg Wheel test results with laboratory mixture design, allow the Engineer 10 working days for conditional approval of JMF 1. The Engineer will base full approval of JMF1 on test results on mixture from the trial batch.

Hamburg Wheel and Overlay Testing of JMF1. If the Contractor requests the option to have the Department perform the Hamburg Wheel test on the laboratory mixture, the Engineer will mold samples in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 6. The Engineer will perform the Overlay test. The Engineer will mold samples in accordance with Tex-248-F to verify compliance with the Overlay test requirements in Table 6.

Authorizing Trial Batch. After conditionally approving JMF1, including either Contractor- or Department-supplied Hamburg Wheel test and Overlay Test results, the Engineer will authorize the Contractor to produce a trial batch.

Ignition Oven Correction Factors. The Engineer will use the split samples provided by the Contractor to determine the aggregate and asphalt correction factors for the ignition oven in accordance with Tex-236-F.

Testing the Trial Batch. Within 1 full working day, the Engineer will sample and test the trial batch to ensure that the gradation, asphalt content, laboratory-molded density, and VMA meet the requirements listed in Table 7. If the Contractor requests the option to have the Department perform the Hamburg Wheel test on the trial batch mixture, the Engineer will mold samples in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 6. The Engineer will perform the Overlay test and mold specimens in accordance with Tex-248-F to verify compliance with the Overlay test requirements in Table 6.

The Engineer will have the option to perform the following tests on the trial batch:

Tex-226-F, to verify that the indirect tensile strength meets the requirement shown in Table 6;

Tex-461-A, to determine the need for additional magnesium sulfate soundness testing; and

Tex-530-C, to retain and use for comparison purposes during production.

Full Approval of JMF1. The Engineer will grant full approval of JMF1 and authorize the Contractor to proceed with developing JMF2 if the Engineer's results for gradation, asphalt content, laboratory-molded density, and VMA confirm that the trial batch meets the requirements in Table 7.

The Engineer will notify the Contractor that an additional trial batch is required if the trial batch does not meet the requirements in Table 5.

Approval of JMF2. The Engineer will approve JMF2 within 1 working day if it meets the master grading limits shown in Table 5 and is within the operational tolerances of JMF1 listed in Table 7.

Approval of Lot 1 Production. The Engineer will authorize the Contractor to proceed with Lot 1 production as soon as a passing result is achieved from the Department's or an approved laboratory's Hamburg Wheel test and from the Department's Overlay test. As an option, the Contractor may, at their own risk, proceed with Lot 1 production without results from the Hamburg Wheel test and Overlay test on the trial batch.

If the Department's or approved laboratory's sample from the trial batch fails the Hamburg Wheel or Overlay test, the Engineer will suspend production until further Hamburg Wheel or Overlay tests meet the specified values. The Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel or Overlay test to be removed and replaced at the Contractor's expense.

Approval of JMF3. The Engineer will approve JMF3 within 1 working day if it meets the master grading limits shown in Table 5 and is within the operational tolerances of JMF2 listed in Table 7.

Production Operations. Perform a new trial batch when the plant or plant location is changed. Take corrective action and receive approval to proceed after any production suspension for noncompliance to the specification.

Storage and Heating of Materials. Do not heat the asphalt binder above the temperatures specified in Item 300, "Asphalts, Oils, and Emulsions," or outside the manufacturer's recommended values. On a daily basis, provide the Engineer with the records of asphalt binder and hot-mix asphalt discharge temperatures in accordance with Item 320, "Equipment for Hot-Mix Asphalt Materials." Unless otherwise approved, do not store mixture for a period long enough to affect the quality of the mixture, nor in any case longer than 12 hr.

Mixing and Discharge of Materials. Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. If requested, determine the moisture content by oven drying in accordance with Tex-212-F, Part II, and verify that the mixture contains no more than 0.2% of moisture by weight. Obtain the sample immediately after discharging the mixture into the truck, and perform the test promptly.

Hauling Operations. Before use, clean all truck beds to ensure that mixture is not contaminated. When a release agent is necessary, use a release agent on the approved list maintained by the Construction Division to coat the inside bed of the truck.

Placement Operations. Collect haul tickets from each load of mixture delivered to the project and provide the Department's copy to the Engineer approximately every hour, or as directed by the Engineer. Measure and record the temperature of the mixture as discharged from the truck or material transfer device prior to entering the paver and an approximate station number on each ticket. Unless otherwise directed, calculate and report the yield and cumulative yield following the production of every 250 tons or following every 2 hours of production, whichever occurs first for the specified lift and provide to the Engineer. The Engineer may suspend production if the Contractor fails to produce and provide haul tickets and yield calculations.

Prepare the surface by removing raised pavement markers and objectionable material such as moisture, dirt, sand, leaves, and other loose impediments from the surface before placing mixture. Remove vegetation from pavement edges. Place the mixture to meet the typical section requirements and produce a smooth, finished surface with a uniform appearance and texture. Offset longitudinal joints of successive courses of hot mix by at least 6 in. Place mixture so that longitudinal joints on the surface course coincide with lane lines, or as directed. Ensure that all finished surfaces will drain properly. Place mixture within the compacted lift thickness shown in Table 8, unless otherwise shown on the plans or allowed.

Table 8
Compacted Lift Thickness and Required Core Height

Mixture Type	Compacted Lift Thickness		Minimum Untrimmed Core Height (in.) Eligible for Testing
	Minimum (in.)	Maximum (in.)	
Type II and Type III	0.75	1.00	NA

1. Weather Conditions. Place Type I mixtures when the roadway surface temperature is 70ºF or higher unless otherwise approved. Place Type II and III mixtures when the roadway surface temperature is equal to or higher than 60ºF, unless otherwise approved or shown on the plans. Measure the roadway surface temperature with a handheld infrared thermometer. The Engineer may allow mixture placement to begin prior to the roadway surface reaching the required temperature requirements, if conditions are such that the roadway surface will reach the required temperature within 2 hr of beginning placement operations. Unless otherwise shown on the plans, place mixture only when weather conditions and moisture conditions of the roadway surface are suitable in the opinion of the Engineer.

Contractors may pave Type II and III mixtures at temperatures as low as 50°F when utilizing a paving process or equipment that eliminates thermal segregation. In such cases, the contractor must use either an infrared bar attached to the paver, a handheld thermal camera, or a hand held infrared thermometer operated in accordance with Tex-244-F to demonstrate to the satisfaction of the Engineer that the uncompacted mat has no more than 10°F of thermal segregation.

2. Tack Coat. Clean the surface before placing the tack coat. Unless otherwise approved, apply tack coat uniformly at the rate directed by the Engineer. The Engineer will set the rate between 0.04 and 0.10 gal. of residual asphalt per square yard of surface area. Apply a thin, uniform tack coat to all contact surfaces of curbs, structures, and all joints. Allow adequate time for emulsion to break completely prior to placing any material. Prevent splattering of tack coat when placed adjacent to curb, gutter, and structures. Roll the tack coat with a pneumatic-tire roller when directed. The Engineer may use Tex-243-F to verify that the tack coat has adequate adhesive properties. The Engineer may suspend paving operations until there is adequate adhesion.

3. Lay-Down Operations. Measure the temperature of the mixture delivered to the paver and take corrective action if needed to ensure the temperature does not drop below 280°F.

a. Thermal Profile. Use an infrared thermometer or thermal camera to obtain a thermal profile on each sublot in accordance with Tex-244-F. The Engineer may allow the Contractor to reduce the testing frequency based on a satisfactory test history. The Engineer may also obtain as many thermal profiles as deemed necessary. Thermal profiles are not applicable in miscellaneous paving areas subject to hand work such as driveways, crossovers, turnouts, gores, tapers, and other similar areas.

(1) Moderate Thermal Segregation. Any areas that have a maximum temperature differential greater than 25°F but not exceeding 50°F are deemed as having moderate thermal segregation. Take immediate corrective action to eliminate the moderate thermal segregation. Evaluate areas with moderate thermal segregation by performing a density profile in accordance with Section 4.I.3.c(2), "Segregation (Density Profile)."

(2) Severe Thermal Segregation. Any areas that have a maximum temperature differential greater than 50°F are deemed as having severe thermal segregation. When the Pave-IR system is not used, no production or placement bonus will be paid for any sublot that contains severe thermal segregation. Unless otherwise directed, suspend operations and take immediate corrective action to eliminate severe thermal segregation. Resume operations when the Engineer determines that subsequent production will meet the requirements of this Item. Evaluate areas with severe thermal segregation by performing a density profile in accordance with Section 4.I.3.c(2), "Segregation (Density Profile)." Unless otherwise directed, remove and replace the material in any areas that have both severe thermal segregation and a failing result for Segregation (Density Profile). The sublot in question may receive a production and placement bonus if applicable when the defective material is successfully removed and replaced.

(3) Use of the Pave-IR System. In lieu of obtaining thermal profiles on each sublot using an infrared thermometer or thermal camera, the Contractor may use the Pave-IR system (paver mounted infrared bar) to obtain a continuous thermal profile in accordance with Tex-244-F. When using the Pave-IR system, review the output results on a daily basis and, unless otherwise directed, provide the output results to the Engineer for review. Modify the paving process as necessary to eliminate any (moderate or severe) thermal segregation identified by the Pave-IR system. The Engineer may suspend paving operations if the Contractor cannot successfully modify the paving process to eliminate thermal segregation. Density profiles in accordance with Section 4.I.3.c(2), "Segregation (Density Profile)," are not required and are not applicable when using the Pave-IR system.

Record the information on Department QC/QA forms and submit the forms to the Engineer

b. Windrow Operations. When hot mix is placed in windrows, operate windrow pickup equipment so that substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

Compaction.

Type I Mixtures. Roll the freshly placed mixture with a steel-wheeled roller, operate in static mode, to seat the mixture without excessive breakage of the aggregate and to provide a smooth surface and uniform texture. Do not use pneumatic-tire rollers. Thoroughly moisten the roller drums with a soap-and-water solution to prevent adhesion. Unless otherwise directed, use only water or an approved release agent on rollers, tamps, and other compaction equipment.

The Engineer may use or require the Contractor to use Tex-246-F to test and verify that the compacted mixture has adequate permeability especially if the placed mix is allowed to cool below 275°F before compaction occurs and WMA is not used. The water flow rate should be less than 20 seconds. If the water flow rate is greater than 20 seconds, adjust the mixture design or construction methods if the compacted mixture does not exhibit adequate permeability.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic, unless otherwise directed. When directed, sprinkle the finished mat with water or limewater to expedite opening the roadway to traffic.

Type II Mixtures. Roll with two steel-wheel rollers working in tandem without excessive breakage of the aggregate and to provide a smooth surface and uniform texture, keeping the rollers as close as possible to the lay-down machine. If the steel-wheel rollers are used in vibratory mode, operate at low amplitude and high frequency. Do not use pneumatic-tire rollers. Use the control strip method given in Tex-207-F, Part IV, to establish the rolling pattern. Thoroughly moisten the roller drums with soap and water solution to prevent adhesion. Unless otherwise directed, use only water or an approved release agent on rollers, tamps, and other compaction equipment.

Use tamps to thoroughly compact the edges of the pavement along curbs, headers, and similar structures and in locations that will not allow thorough compaction with rollers. The Engineer may require rolling with a trench roller on widened areas, in trenches, and in other limited areas.

The Engineer may require the Contractor to use Tex-246-F to test and verify that the compacted mixture is not permeable, especially if the placed mix is allowed to cool below 275°F before compaction occurs and WMA is not used. The water flow rate should be greater than 60 seconds. If the water flow rate is lower than 60 seconds, the mix design or construction methods may need to be adjusted. Permeability test should be conducted at least on the first sublot of a day's or night's production.

The Engineer may require cores be taken to verify thickness and bond strength. Maintain thickness within ± ¼ inch of the target thickness. If the thickness exceeds this tolerance, it may be subject to removal, as directed by the Engineer. Adjust application rates of the tack coat or underseal if the thin overlay mixture is not bonded to the underlying pavement.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic, unless otherwise directed. When directed, sprinkle the finished mat with water or limewater to expedite opening the roadway to traffic.

Type III Mixtures. Roll the freshly placed mixture with a steel-wheeled roller to seat the mixture without excessive breakage of the aggregate and to provide a smooth surface and uniform texture. If the steel-wheel rollers are used in vibratory mode, operate at low amplitude and high frequency. Do not use pneumatic-tire rollers. Thoroughly moisten the roller drums with a soap-and-water solution to prevent adhesion. Unless otherwise directed, use only water or an approved release agent on rollers, tamps, and other compaction equipment.

The Engineer may use or require the Contractor to use Tex-246-F to test and verify that the compacted mixture is not permeable especially if the placed mix is allowed to cool below 275°F before compaction occurs and WMA is not used. The water flow rate should be greater than 120 seconds. If the water flow rate is less than 120 seconds, adjust the mixture design or construction methods if the compacted mixture does not exhibit adequate permeability.

The Engineer may require cores be taken to verify thickness and bond strength. Maintain thickness within ± ¼ inch of the target thickness. If the thickness exceeds this tolerance, it may be subject to removal, as directed by the Engineer. Adjust application rates of the tack coat or underseal if the thin overlay mixture is not bonded to the underlying pavement.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic, unless otherwise directed. When directed, sprinkle the finished mat with water or limewater to expedite opening the roadway to traffic.

Acceptance Plan. Sample and test the hot mix on a lot and sublot basis at the frequency shown in Table 9. A production lot consists of four equal sublots. Lot 1 will be 1,000 tons. The Engineer will select subsequent lot sizes based on the anticipated daily production. The lot size will be between 1,000 tons and 4,000 tons. The Engineer may change the lot size before the Contractor begins any lot. If production or placement test results are not within the acceptable tolerances listed in Table 7, suspend production until test results or other information indicate to the satisfaction of the Engineer that the next material produced or placed will meet the specified values.

Table 9
Production and Placement Testing Frequency

Description	Test Method	Minimum Contractor Testing Frequency	Minimum Engineer Testing Frequency
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	1 per sublot	1 per 12 sublots
Individual % retained for sieves smaller than #8 and larger than #200			
% passing the #200 sieve			
Laboratory-molded density	Tex-207-F	N/A	1 per sublot
VMA			
Laboratory-molded bulk specific gravity			
In-Place air voids			
Segregation (density profile)	Tex-207-F, Part V	1 per sublot	1 per project
Longitudinal joint density	Tex-207-F, Part VII		
Moisture content	Tex-212-F, Part II	When directed	
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	1 per sublot
Asphalt content	Tex-236-F	1 per sublot	1 per lot
Hamburg Wheel test	Tex-242-F	N/A	1 per project
Thermal profile	Tex-244-F	1 per sublot	
Asphalt binder sampling and testing[1]	Tex-500-C	1 per sublot (sample only)	
Boil test[1]	Tex-530-C	1 per lot	

1. The Engineer may reduce or waive the sampling and testing requirements based on a satisfactory test history.

Referee Testing. The Construction Division is the referee laboratory. The Contractor may request referee testing if the differences between Contractor and Engineer test results exceed the operational tolerance shown in Table 7 and the differences cannot be resolved. Make the request within 5 working days after receiving test results and cores from the Engineer. Referee tests will be performed only on the sublot in question and only for the particular test in question. Allow 10 working days from the time the referee laboratory receives the samples for reporting of test results. The Department may require the Contractor to reimburse the Department for referee tests, if more than three referee tests per project are required, and the Engineer's test results are closer than the Contractor's test results to the referee test results.

The Construction Division will determine the laboratory-molded density based on the molded specific gravity and the maximum theoretical specific gravity of the referee sample. The in-place air voids will be determined based on the bulk specific gravity of the cores, as determined by the referee laboratory, and the Engineer's average maximum theoretical specific gravity for the lot.

Production Acceptance.

Production Lot. A production lot consists of four equal sublots. Lot 1 will be 1,000 tons. The Engineer will select subsequent lot sizes based on the anticipated daily production. The lot size will be between 1,000 tons and 4,000 tons. The Engineer may change the lot size before the Contractor begins any lot.

Small-Quantity Production. When the anticipated daily production is less than 500 tons, the Engineer may waive all production and placement testing; however, the Engineer will retain the right to perform random acceptance tests for production and placement and may reject objectionable materials and workmanship.

When the Engineer waives all production and placement sampling and testing requirements:

produce, haul, place, and compact the mixture as directed by the Engineer;

control mixture production to yield a laboratory-molded density as indicated in Table 6 for the mixture type being produced to ± 1.0% as tested by the Engineer; and

Compact the mixture to yield In-Place air voids that are greater than or equal to 2.7% and less than or equal to 8.0% for Type II mixtures and 2.0% to 6.0% for Type III mixtures, as tested by the Engineer. Not applicable to Type I mixtures.

Incomplete Production Lots. If a lot is begun but cannot be completed, such as on the last day of production or in other circumstances deemed appropriate, the Engineer may close the lot.

Production Sampling.

Mixture Sampling. At the beginning of the project, the Engineer will select random numbers for all production sublots. Determine sample locations in accordance with Tex-225-F.

Obtain hot mix samples from trucks at the plant in accordance with Tex-222-F. For each sublot, take one sample at the location randomly selected. For each lot, the Engineer will randomly select and test a “blind” sample from at least one sublot. The location of the Engineer’s “blind” sample will not be disclosed to the Contractor. The Engineer will use the Contractor’s split sample for sublots not sampled by the Engineer.

The sampler will split each sample into three equal portions in accordance with Tex-200-F and label these portions as “Contractor,” “Engineer,” and “Referee.” Deliver the samples to the appropriate party’s laboratory. Deliver referee samples to the Engineer. Discard unused samples after the Engineer has accepted the material for payment.

Asphalt Binder Sampling. Obtain a 1-qt. sample of the asphalt binder for each sublot of mixture produced. Obtain the sample at approximately the same time the mixture random is obtained. Sample from a port located immediately upstream from the mixing drum or pug mill. Take the sample in accordance with Tex-500-C, Part II. Label the can with the corresponding lot and sublot numbers, and deliver the sample to the Engineer.

The Engineer may also obtain independent samples. If the Engineer chooses to obtain an independent asphalt binder sample, the Engineer will split a sample of the asphalt binder with the Contractor. The Engineer will test at least one asphalt binder sample per project to verify compliance with Item 300, "Asphalts, Oils, and Emulsions."

Production Testing. The Contractor and Engineer must perform production tests in accordance with Table 10. The Contractor has the option to verify the Engineer's test results on split samples provided by the Engineer. Determine compliance with operational tolerances listed in Table 8 for all sublots.

Control mixture production to yield a laboratory-molded density as indicated in Table 6 for the mixture type being produced to ± 1.0% as tested by the Engineer. Suspend production if two consecutive sublots fail to meet this requirement, unless otherwise approved. Resume production after the Engineer approves changes to production methods.

Referee testing is required for any sublot with a laboratory-molded density greater than 97.5% or less than 95.5% for Type II and Type III mixtures. For Type II and Type III mixtures, if the new laboratory-molded density is within the range of 95.5% to 97.5%, the material will receive full payment in accordance with Sections 5.A and 5.B provided that the material also meets the in-place air void requirements. If the new laboratory-molded density is not within the range of 95.5% to 97.5%, for Ty II and Type III mixtures, the Engineer may require removal and replacement or may allow the sublot to be left in place without payment or at a reduced payment. Replacement material meeting the requirements of this Item will be paid for in accordance with this Article.

If the aggregate mineralogy is such that Tex-236-F does not yield reliable results, the Engineer may allow alternate methods for determining the asphalt content and aggregate gradation. Unless otherwise allowed, the Engineer will require the Contractor to provide evidence that results from Tex-236-F are not reliable before permitting an alternate method. If an alternate test method is allowed, use the applicable test procedure as directed.

Operational Tolerances. Control the production process within the operational tolerances listed in Table 7. When production is suspended, the Engineer will allow production to resume when test results or other information indicates that the next mixture produced will be within the operational tolerances.

Gradation. Unless otherwise directed, suspend production when either the Contractor's or the Engineer's test results for gradation exceed the operational tolerances for three consecutive sublots on the same sieve or four consecutive sublots on any sieve. The consecutive sublots may be from more than one lot.

Asphalt Content. Unless otherwise directed, suspend production when two or more sublots within a lot are out of operational tolerance for asphalt content based on either the Contractor's or the Engineer's test results. Suspend production and shipment of mixture if the asphalt content deviates from the current JMF by more than 0.5% for any sublot.

Hamburg Wheel Test. The Engineer may perform a Hamburg Wheel test at any time during production, including when the boil test indicates a change in quality from the materials submitted for JMF1. In addition to testing production samples, the Engineer may obtain cores and perform the Hamburg Wheel test on any area of the roadway where rutting is observed. When the production or core samples fail the Hamburg Wheel test criteria in Table 6, suspend production until further tests meet the specified values. Core samples, if taken, will be obtained from the center of the finished mat or other areas excluding the vehicle wheel path. The Engineer may require up to the entire sublot of any mixture failing the test to be removed and replaced at the Contractor's expense.

If the Department's or Department-approved laboratory's Hamburg Wheel test results do not meet the minimum number of passes specified in Table 6, the Contractor may request that the Department confirm the results by retesting the failing material. The Construction Division will perform the Hamburg Wheel tests and determine the final disposition of the material in question based on the Department's test results.

Individual Loads of Mix. The Engineer can reject individual truckloads of mix. When a load of mix is rejected for reasons other than temperature, the Contractor may request that the rejected load be tested. Make this request within 4 hr of rejection. The Engineer will sample and test the mixture. If test results are within the operational tolerances shown in Table 7, payment will be made for the load. If test results are not within operational tolerances, no payment will be made for the load, and the Engineer may require removal.

Placement Acceptance for Type II and II mixtures.

Placement Lot. This section does not pertain to Type I mixtures. A placement lot consists of four placement sublots. A placement sublot consists of the area placed during a production sublot.

Incomplete Placement Lots. An incomplete placement lot consists of the area placed as described in Section 4.I.2.a.(2), "Incomplete Production Lots," excluding miscellaneous areas as defined in Section 4.I.3.a(3), "Miscellaneous Areas." Placement sampling is required if the random sample plan for production resulted in a sample being obtained from an incomplete production sublot.

Shoulders and Ramps. Shoulders and ramps are subject to in-place air void determination, unless otherwise shown on the plans.

Miscellaneous Areas. Miscellaneous areas include areas that are not generally subject to primary traffic, such as driveways, mailbox turnouts, crossovers, gores, spot level-up areas, and other similar areas. Miscellaneous areas also include level-ups and thin overlays, if the layer thickness designated on the plans is less than the compacted lift thickness shown in Table 8. Miscellaneous areas are not eligible for random placement sampling locations. Compact areas that are not subject to in-place air void determination in accordance with Section 4.H, "Compaction."

Placement Sampling. At the beginning of the project, the Engineer will select random numbers for all placement sublots. The Engineer will provide the Contractor with the placement random numbers immediately after the sublot is completed. Mark the roadway location at the completion of each sublot and record the station number. Determine one random sample location for each placement sublot in accordance with Tex-225-F. If the randomly generated sample location is within 2 ft. of a joint or pavement edge, adjust the location by no more than necessary to achieve a 2-ft. clearance.

Shoulders and ramps are always eligible for selection as a random sample location; however, if a random sample location falls on a shoulder or ramp designated on the plans as not subject to in-place air void testing, cores will not be taken for the sublot.

Unless otherwise determined, the Engineer will witness the coring operation and measurement of the core thickness. Unless otherwise approved, obtain the cores within 1 working day of the time the placement sublot is completed. Obtain two 6-in. diameter cores side-by-side from within 1 ft. of the random location provided for the placement sublot. Mark the cores for identification. Visually inspect each core and verify that the current paving layer is bonded to the underlying layer. If an adequate bond does not exist between the current and underlying layer, take corrective action to ensure that an adequate bond will be achieved during subsequent placement operations.

Immediately after obtaining the cores, dry the core holes and tack the sides and bottom. Fill the hole with the same type of mixture and properly compact the mixture. Repair core holes with other methods when approved.

If the core heights exceed the minimum untrimmed values listed in Table 8, trim the bottom or top of the core only when necessary to provide a flat and suitable surface for testing. Remove no more than 1/2 in. from the bottom of the core to remove any material from an underlying layer or surface treatment. Remove no more than 1/2 in. from the top of the core only when hot mix asphalt or a surface treatment has been placed on top of the material subject to testing. Deliver the cores to the Engineer within 1 working day following placement operations, unless otherwise approved.

If the core height before trimming is less than the minimum untrimmed value shown in Table 8, decide whether to include the pair of cores in the air void determination for that sublot. If the cores are to be included in air void determination, trim the bottom or top of the core only when necessary to remove any foreign matter and to provide a level and smooth surface for testing. Foreign matter is another paving layer, such as hot mix, surface treatment, subgrade, or base material. Trim the minimum amount necessary with a limit of 1/2 in. Do not trim the core if the surface is level and there is no foreign matter bonded to the surface of the core. Trim the cores as noted above before delivering to the Engineer. If the cores will not be included in air void determination, deliver untrimmed cores to the Engineer.

Placement Testing. Perform placement tests in accordance with Table 9. After the Engineer returns the cores, the Contractor has the option to test the cores to verify the Engineer’s test results for in-place air voids. The allowable differences between the Contractor’s and Engineer’s test results are listed in Table 7.

In-Place Air Voids. The Engineer will measure in-place air voids in accordance with Tex-207-F and Tex-227-F. Before drying to a constant weight, cores may be pre-dried using a Corelok or similar vacuum device to remove excess moisture. The Engineer will average the values obtained for all sublots in the production lot to determine the theoretical maximum specific gravity. The Engineer will use the average air void content for in-place air voids.

The Engineer will use paraffin coating or vacuum methods to seal the core, if required by Tex-207-F. The Engineer will use the test results from the unsealed core to determine in-place air voids if the sealed core yields a higher specific gravity than the unsealed core. After determining the in-place air void content, the Engineer will return the cores and provide test results to the Contractor.

Segregation (Density Profile). Test for segregation using density profiles in accordance with Tex-207-F, Part V. Provide the Engineer with the results of the density profiles as they are completed. Areas defined in Section 4.IH.3.a.(3), “Miscellaneous Areas,” are not subject to density profile testing.

Unless otherwise approved, perform a density profile every time the screed stops, on areas identified by either the Contractor or the Engineer as having thermal segregation, and on any visibly segregated areas. If the screed does not stop, and there are no visibly segregated areas or areas identified as having thermal segregation, perform a minimum of one profile per sublot. Reduce the test frequency to a minimum of one profile per lot if four consecutive profiles are within established tolerances. Continue testing at a minimum frequency of one per lot unless a profile fails, at which point resume testing at a minimum frequency of one per sublot. The Engineer may further reduce the testing frequency based on a consistent pattern of satisfactory results.

The density profile is considered failing if it exceeds the tolerances in Table 10. The Engineer may make as many independent density profile verifications as deemed necessary. The Engineer's density profile results will be used when available.

Investigate density profile failures and take corrective actions during production and placement to eliminate the segregation. Suspend production if two consecutive density profiles fail, unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

Table 10
Segregation (Density Profile) Acceptance Criteria

Maximum Allowable Density Range (Highest to Lowest)	Maximum Allowable Density Range (Average to Lowest)
6.0 pcf	3.0 pcf

Longitudinal Joint Density.

Informational Tests. While establishing the rolling pattern, perform joint density evaluations, and verify that the joint density is no more than 3.0 pcf below the density taken at or near the center of the mat for mixture Types II and III. Adjust the rolling pattern, if needed, to achieve the desired joint density. Perform additional joint density evaluations at least once per sublot, unless otherwise directed

Record Tests. For each sublot, perform a joint density evaluation at each pavement edge that is or will become a longitudinal joint. Determine the joint density in accordance with Tex-207-F, Part VII. Record the joint density information and submit results on Department forms to the Engineer. The evaluation is considered failing if the joint density is more than 3.0 pcf below the density taken at the core random sample location, and the correlated joint density is less than 94.0%. The Engineer may make independent joint density verifications at the random sample locations. The Engineer's joint density test results will be used when available.

Investigate joint density failures and take corrective actions during production and placement to improve the joint density. Suspend production if two consecutive evaluations fail, unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

Recovered Asphalt Dynamic Shear Rheometer (DSR). The Engineer may take production samples or cores from suspect areas of the project to determine recovered asphalt properties. Asphalt binders with an aging ratio greater than 3.5 do not meet the requirements for recovered asphalt properties and may be deemed defective when tested and evaluated by the Construction Division. The aging ratio is the dynamic shear rheometer (DSR) value of the extracted binder divided by the DSR value of the original unaged binder. DSR values are obtained according to AASHTO T 315 at the specified high temperature performance grade of the asphalt. The Engineer may require removal and replacement of the defective material at the Contractor's expense. The asphalt binder will be recovered for testing from production samples or cores in accordance with Tex-211-F.

Irregularities. Immediately take corrective action if surface irregularities, including but not limited to segregation, rutting, raveling, flushing, fat spots, mat slippage, color, texture, roller marks, tears, gouges, streaks, or uncoated aggregate particles, are detected.

The Engineer may allow placement to continue for at most 1 day of production, while taking appropriate action. If the problem still exists after that day, suspend paving until the problem is corrected to the satisfaction of the Engineer.

At the expense of the Contractor and to the satisfaction of the Engineer, remove and replace any mixture that does not bond to the existing pavement or that has other surface irregularities identified above.

Ride Quality. Unless otherwise shown on the plans, measure ride quality in accordance with Item 585, "Ride Quality for Pavement Surfaces."

Measurement. The hot mix will be measured by the ton of composite mixture. The composite mixture is defined as the asphalt, aggregate, and additives. The weight of asphalt and aggregate will be calculated based on the measured weight of mixtures and the target percentage of asphalt and aggregate. Measure the weight on scales in accordance with Item 520, "Weighing and Measuring Equipment."

Asphalt. The asphalt weight in tons will be determined from the total weight of the mixture. Measured asphalt percentage will be obtained using Tex-236-F or asphalt flow meter readings, as determined by the Engineer,

Target Percentage. The JMF target asphalt percentage will be used to calculate the weight of asphalt binder for the lot, unless the measured asphalt percentage for any sublot is more than 0.3 percentage points below the JMF target asphalt. Volumetric meter readings will be adjusted to 140°F and converted to weight.

Measured Percentage. The averaged measured asphalt percentage from each sublot will be used for payment for that lot's production when the measured percentage for any sublot is more than 0.3 percentage points below the JMF target asphalt percentage.

Aggregate. The aggregate weight in tons will be determined from the total weight of the mixture, less the weight of the asphalt.

Payment. The work performed and materials furnished in accordance with this Item and measured as provided under Section 5, "Measurement," will be paid for at the unit price bid for "Fine Graded Surface Mixes" (Asphalt) of the Type and binder specified and for "Fine Graded Surface Mixes" (Aggregate) for the type and surface aggregate classification specified. These prices are full compensation for surface preparation; materials, including tack coat; placement; equipment, labor; tools; and incidentals.

Trial batches will not be paid for unless they are included in pavement work approved by the Department.

Pay adjustment for ride quality will be determined in accordance with Item 585, "Ride Quality for Pavement Surfaces."