Use of Fine Graded Mixes for Pavement Preservation: *Student Notes*

Tom Scullion, Cindy Estakhri, Bryan Wilson

Texas Transportation Institute for

Texas Department of Transportation

TxDOT Research Project 0-6615

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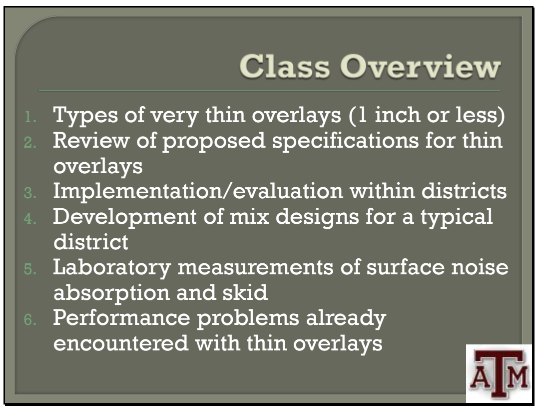

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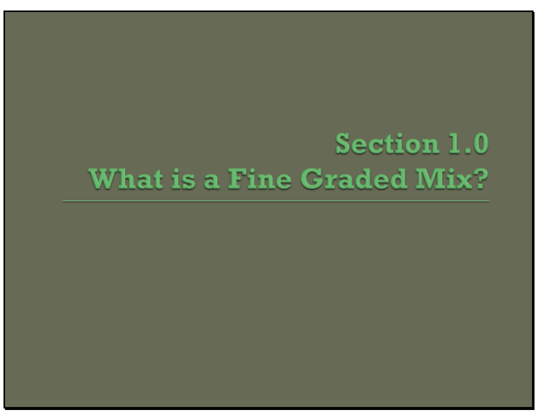

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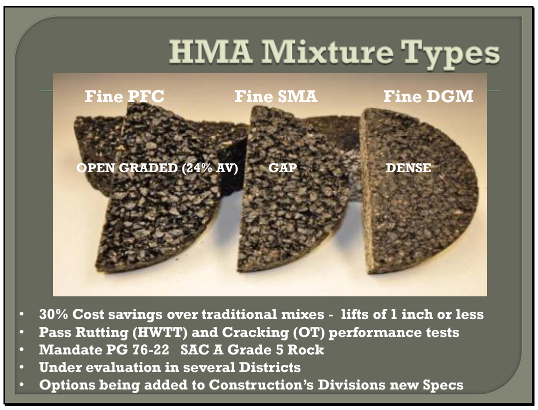

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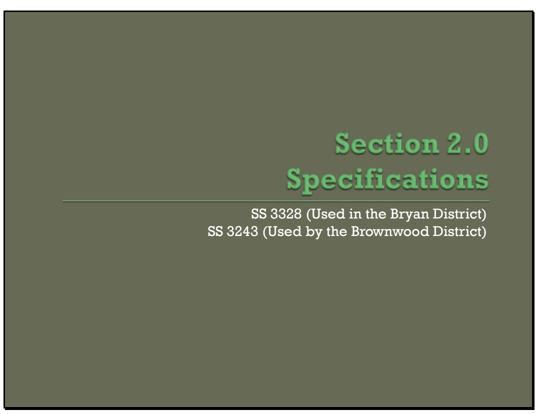

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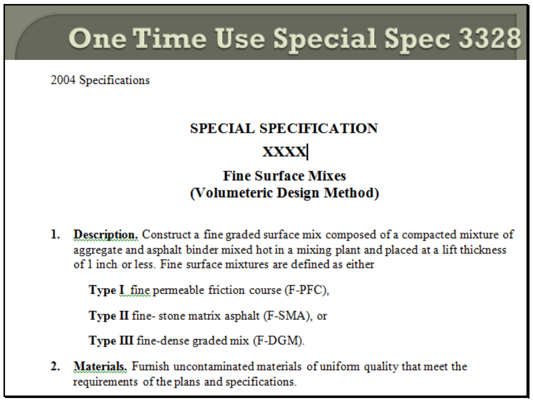

One Time Use Special Spec 3328

2004 Specifications

SPECIAL SPECIFICATION

XXXX

Fine Surface Mixes
(Volumeteric Design Method)

1. **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), or

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

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

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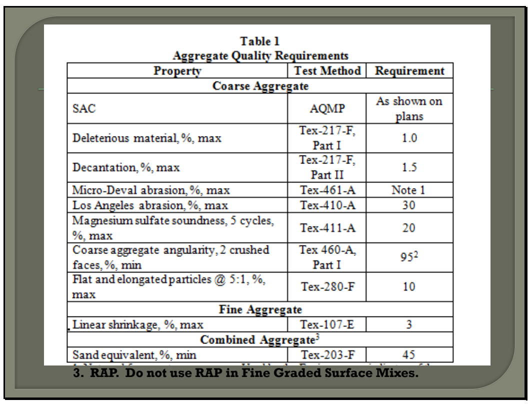

Table 1
Aggregate Quality Requirements

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

3. RAP. Do not use RAP in Fine Graded Surface Mixes.

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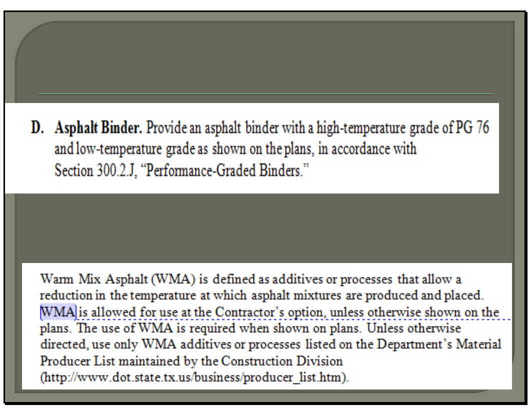

D. Asphalt Binder. Provide an asphalt binder with a high-temperature grade of PG 76 and low-temperature grade as shown on the plans, in accordance with Section 300.2.J, "Performance-Graded Binders."

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).

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D. Mixture Design.

1. **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. Evaluate each mixture using the Hamburg Wheel Test and the Overlay Test at the OAC and at OAC+0.5%.

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.

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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

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Table 6
Laboratory Mixture Design Properties

Property	Requirement		
	I Fine- PFC	II Fine- SMA	III Fine- DGM
Design Gyrations (Tex-241-F)	50	50[1]	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.

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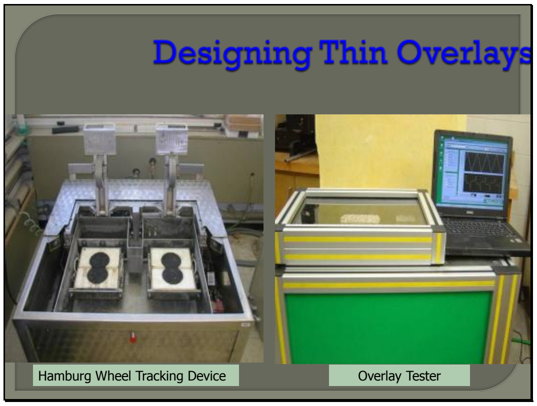

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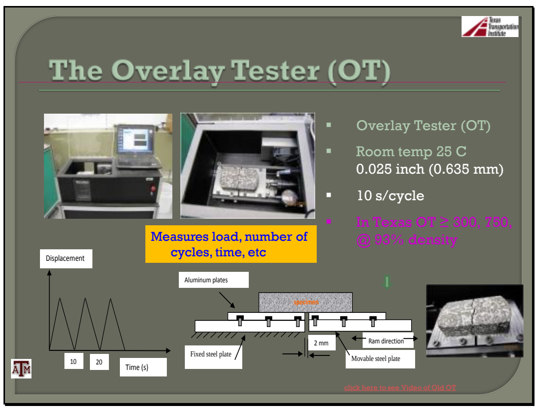

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Table 7
Operational Tolerances

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

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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 70°F or higher unless otherwise approved. Place Type II and III mixtures when the roadway surface temperature is equal to or higher than 60°F, 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 hrs. 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 hand held 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.

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H. Compaction.

1. **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.

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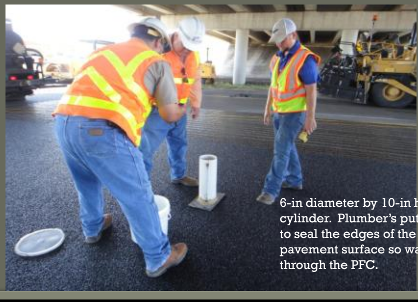
Water Flow Test – 6 seconds



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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 30 seconds. If the water flow rate is lower than 30 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.

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2. **Type III 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 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 less than 60 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.

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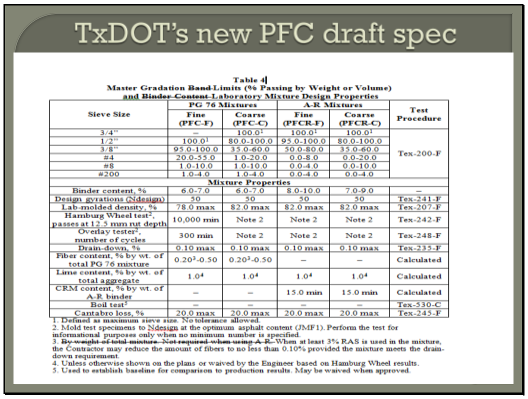

Table 4
Master Gradation ~~Band~~ Limits (% Passing by Weight or Volume) and ~~Binder Content~~ Laboratory Mixture Design Properties

Sieve Size	PG 76 Mixtures Fine (PFC-F)	PG 76 Mixtures Coarse (PFC-C)	A-R Mixtures Fine (PFCR-F)	A-R Mixtures Coarse (PFCR-C)	Test Procedure
3/4"	–	100.0[1]	100.0[1]	100.0[1]	Tex-200-F
1/2"	100.0[1]	80.0-100.0	95.0-100.0	80.0-100.0	
3/8"	95.0-100.0	35.0-60.0	50.0-80.0	35.0-60.0	
#4	20.0-55.0	1.0-20.0	0.0-8.0	0.0-20.0	
#8	1.0-10.0	1.0-10.0	0.0-4.0	0.0-10.0	
#200	1.0-4.0	1.0-4.0	0.0-4.0	0.0-4.0	
Mixture Properties					
Binder content, %	6.0-7.0	6.0-7.0	8.0-10.0	7.0-9.0	–
Design gyrations (Ndesign)	50	50	50	50	Tex-241-F
Lab-molded density, %	78.0 max	82.0 max	82.0 max	82.0 max	Tex-207-F
Hamburg Wheel test[2], passes at 12.5 mm rut depth	10,000 min	Note 2	Note 2	Note 2	Tex-242-F
Overlay tester[2], number of cycles	300 min	Note 2	Note 2	Note 2	Tex-248-F
Drain-down, %	0.10 max	0.10 max	0.10 max	0.10 max	Tex-235-F
Fiber content, % by wt. of total PG 76 mixture	0.20[3]-0.50	0.20[3]-0.50	–	–	Calculated
Lime content, % by wt. of total aggregate	1.0[4]	1.0[4]	1.0[4]	1.0[4]	Calculated
CRM content, % by wt. of A-R binder	–	–	15.0 min	15.0 min	Calculated
Boil test[5]	–	–	–	–	Tex-530-C
Cantabro loss, %	20.0 max	20.0 max	20.0 max	20.0 max	Tex-245-F

1. Defined as maximum sieve size. No tolerance allowed.
2. Mold test specimens to Ndesign at the optimum asphalt content (JMF1). Perform the test for informational purposes only when no minimum number is specified.
3. ~~By weight of total mixture. Not required when using A-R.~~ When at least 3% RAS is used in the mixture, the Contractor may reduce the amount of fibers to no less than 0.10% provided the mixture meets the drain-down requirement.
4. Unless otherwise shown on the plans or waived by the Engineer based on Hamburg Wheel results.
5. Used to establish baseline for comparison to production results. May be waived when approved.

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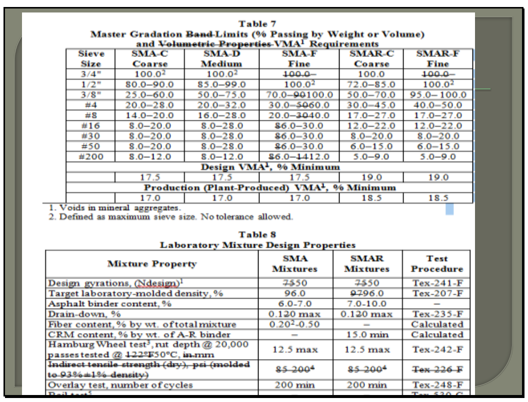

Table 7
Master Gradation ~~Band~~ Limits (% Passing by Weight or Volume) and ~~Volumetric Properties~~ VMA[1] Requirements

Sieve Size	SMA-C Coarse	SMA-D Medium	SMA-F Fine	SMAR-C Coarse	SMAR-F Fine
3/4"	100.0[2]	100.0[2]	~~100.0–~~	100.0	~~100.0–~~
1/2"	80.0–90.0	85.0–99.0	100.0[2]	72.0–85.0	100.0[2]
3/8"	25.0–60.0	50.0–75.0	70.0–~~90~~100.0	50.0–70.0	95.0–100.0
#4	20.0–28.0	20.0–32.0	30.0–~~50~~60.0	30.0–45.0	40.0–50.0
#8	14.0–20.0	16.0–28.0	20.0–~~30~~40.0	17.0–27.0	17.0–27.0
#16	8.0–20.0	8.0–28.0	~~8~~6.0–30.0	12.0–22.0	12.0–22.0
#30	8.0–20.0	8.0–28.0	~~8~~6.0–30.0	8.0–20.0	8.0–20.0
#50	8.0–20.0	8.0–28.0	~~8~~6.0–30.0	6.0–15.0	6.0–15.0
#200	8.0–12.0	8.0–12.0	~~8~~6.0–~~14~~12.0	5.0–9.0	5.0–9.0
Design VMA[1], % Minimum					
	17.5	17.5	17.5	19.0	19.0
Production (Plant-Produced) VMA[1], % Minimum					
	17.0	17.0	17.0	18.5	18.5

1. Voids in mineral aggregates.
2. Defined as maximum sieve size. No tolerance allowed.

Table 8
Laboratory Mixture Design Properties

Mixture Property	SMA Mixtures	SMAR Mixtures	Test Procedure
Design gyrations, (Ndesign)[1]	~~75~~50	~~75~~50	Tex-241-F
Target laboratory-molded density, %	96.0	~~97~~96.0	Tex-207-F
Asphalt binder content, %	6.0-7.0	7.0-10.0	–
Drain-down, %	0.1~~2~~0 max	0.1~~2~~0 max	Tex-235-F
Fiber content, % by wt. of total mixture	0.20[2]-0.50	–	Calculated
CRM content, % by wt. of A-R binder	–	15.0 min	Calculated
Hamburg Wheel test[3], rut depth @ 20,000 passes tested @ ~~122°F~~50°C, ~~in.~~mm	12.5 max	12.5 max	Tex-242-F
~~Indirect tensile strength (dry), psi (molded to 93%±1% density)~~	~~85-200~~[4]	~~85-200~~[4]	~~Tex-226-F~~
Overlay test, number of cycles	200 min	200 min	Tex-248-F

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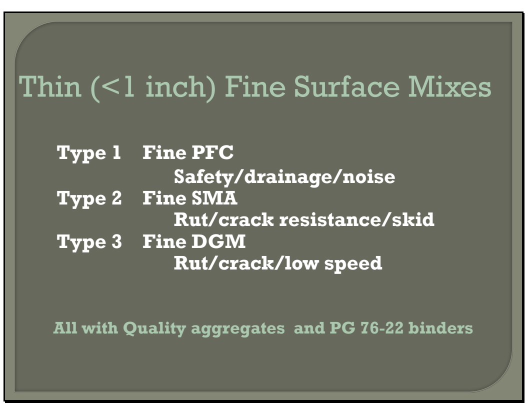

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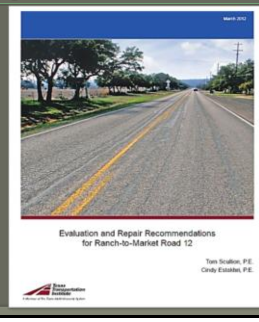
Anyone for Seal Coats?



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Section 3.0 TxDOT's Field Evaluation of Thin Overlays

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Thin Lift Construction at Pecos Test Track

All layers 1 inch thick
Fine mixes typically 95 to 100% passing 3/8 sieve
All mixes pass Hamburg and Overlay Tester requirements

- 2 fine Porous Friction Course designs
- 2 fine Stone Matrix Asphalt designs
- 2 Crack Attenuating Mixes designs

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Existing Conditions

Entry Road

Test Track

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Mix Designs

Mix Name	Binder (PG 76-22)	Aggregate Composition	Aggregate (Quarry)	Other
Hoban Fine PFC	6.5% (76-22)	100% Gr 5	(Hoban)	0.3% fibers
Eastland Fine PFC	6.5% (76-22)	100% Gr 5	(Eastland)	0.3% fibers
Hoban Fine SMA	7.0% (76-22)	60% Gr 5	(Hoban)	0.3% fibers
		40% Screenings	(Turner)	
Eastland Fine SMA	7.2% (76-22)	60% Gr 5	(Eastland)	0.3% fibers
		40% Man. Sand		
Hoban CAM	8.8% (76-22)	65% Gr 6	(Hoban)	-
		35% Screenings	(Turner)	
Eastland CAM	8.1% (76-22)	30% Gr 5	(Eastland)	-
		70% Man. sand		

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Mix Designs (cont.)

Mix Name	Design Density (%)	Design Gyrations	HWTT Rut Depth (mm)	HWTT # Cycles	Overlay # Cycles
Hoban Fine PFC	-	50	8.1	10,000	635
Eastland Fine PFC	77.8	50	6.3	10,000	640
Hoban Fine SMA*	98.8	-	2.6	20,000	300
Eastland Fine SMA*	98.0	-	6.0	20,000	300**
Hoban CAM	96.5	50	9.0	20,000	>1,000
Eastland CAM	96.5	50	10.5	20,000	950

*Texas Gyratory Compactor and Balanced Mix Design
**Predicted

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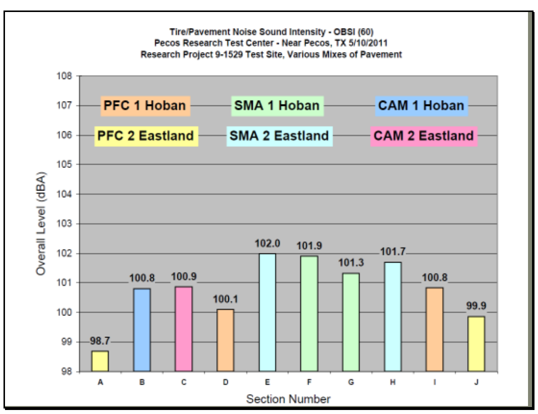

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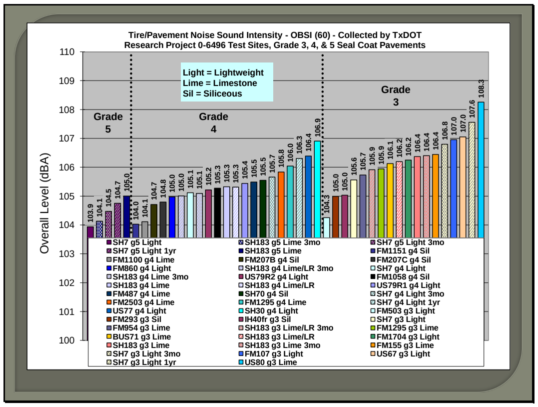

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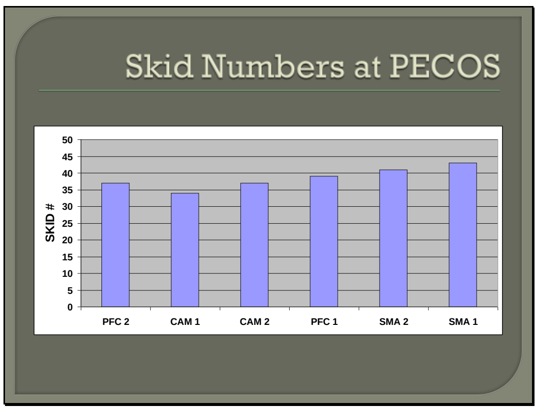

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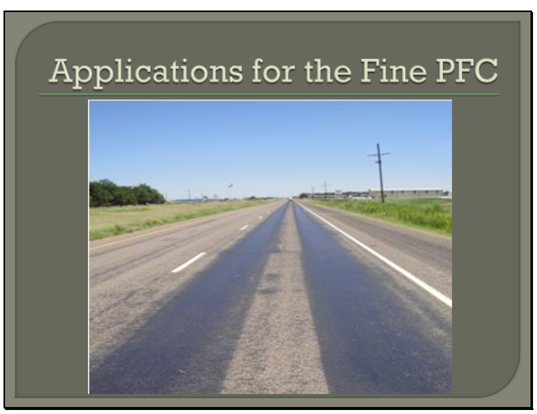

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New Rice Crispy PFC

New Fine PFC　　Current Item 342

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Proposed Criteria for Fine PFC

Property	Fine PFC Specification Requirement
Design Gyrations	50
Lab Molded Density	74 – 78%
Hamburg Wheel Tracking	Min 10,000 Passes to ½ inch rut
Overlay Test, Minimum # of Cycles	300
Cantabro Loss	20 %
Fiber content	0.2 – 0.5%
Lime Content, max	1%
Drain Down Test, max	0.20%

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Field Test – Lufkin District – May 2011

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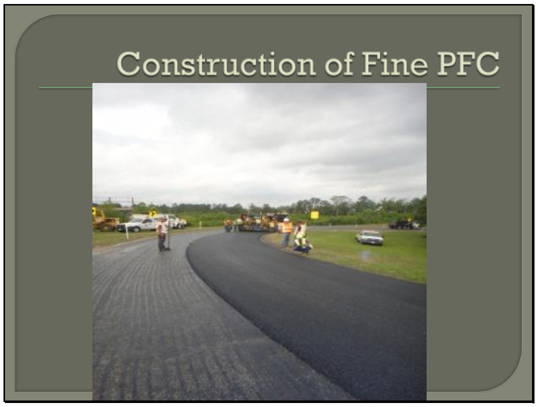

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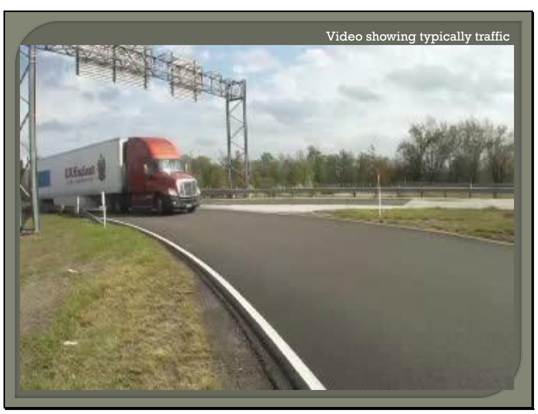

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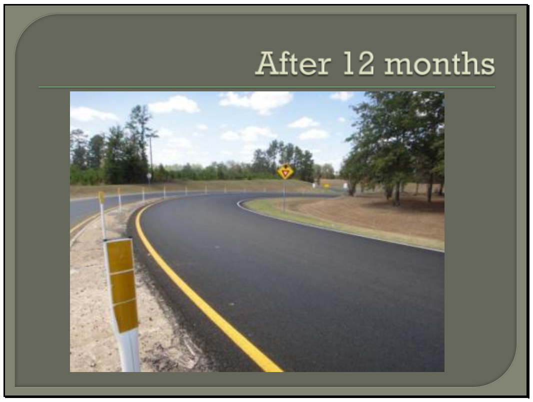

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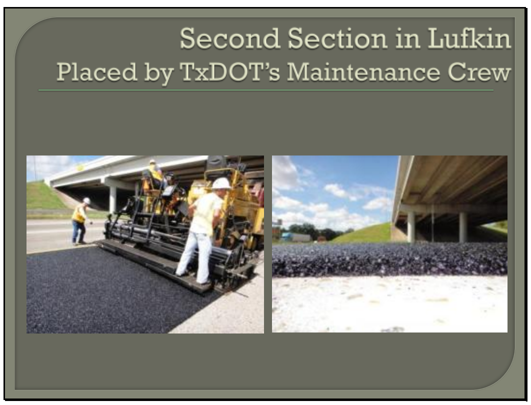

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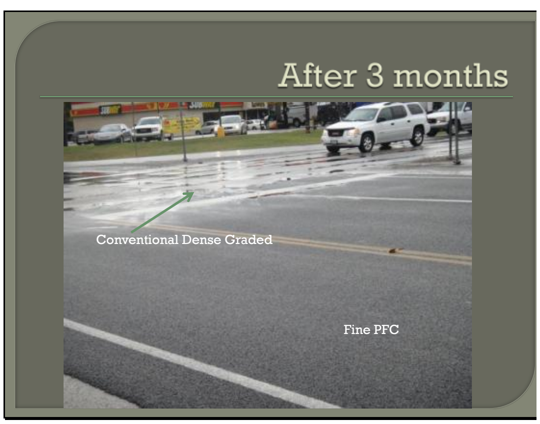

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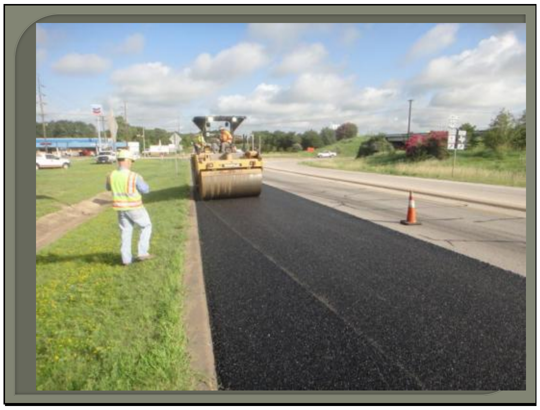

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Houston's US 59

- Plans under development for 1" CAM + 1"Thin Surfacing
- Based on early success with performance mixes on

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Slabs made at TTI for performance testing

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Statewide Summary

- **Specs for fine mixes developed**
- **TTI assisting with initial implementation**
- **MNT has funds available for demo sections**
- **No RAP or RAS in mixes**
- **Placement by both**
  - **Contractor (tied to on-going job)**
  - **District Maintenance Crews**
- **Trials completed under intense loading successful**
- **Districts moving to full-scale implementation (Austin/Brownwood/Bryan)**
- **Lots of interest statewide**

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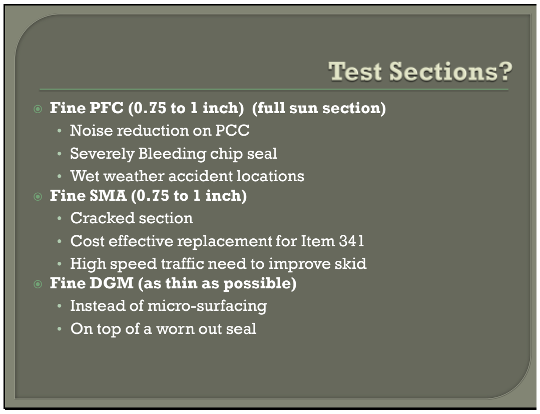

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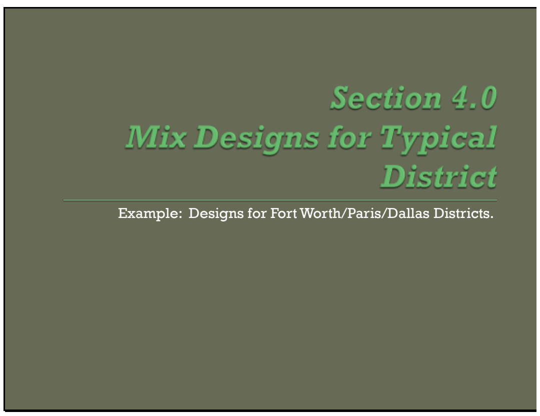

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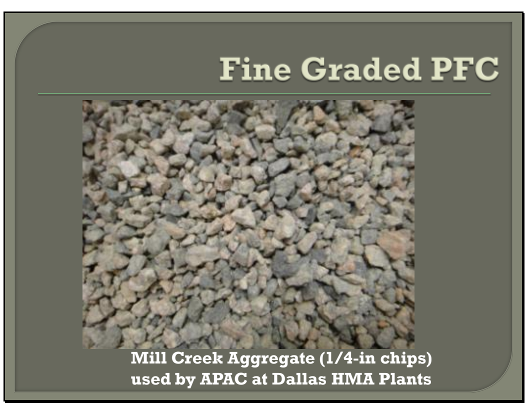

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Fine PFC

Best Lab Performance Test Results Seen to Date

Mix Design	Percent Passing
3/8 in.	99.5
# 4	47.0
# 8	7.0
# 16	3.0
# 30	2.0
# 50	1.5
# 200	1.1
1% Lime 6.5% PG 76-22	76.4% Density

Hamburg	Overlay Test	Permeability, Elapsed time	Cantabro Loss
7.1 mm @ 20000 cycles	1000 cycles	2.6 seconds Conventional PFC: 10.4 s	6.0% AC ,30.9% 6.5% AC, 16.2%

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Fine Graded SMA

65% MILL CREEK ¼ IN CHIPS

35% MILL CREEK DIRTY SCREENINGS

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Fine SMA

Mix Design	Percent Passing
3/8 in.	99.7
# 4	65.3
# 8	32.1
# 16	20.9
# 30	14.3
# 50	10.4
# 200	6.6
1% Lime 0.3% Fibers 6.6% PG 76-22	96.5 % Density

Hamburg	Overlay Test
2.66 mm @ 20,000 cycles	352 cycles

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Fine Dense-Graded Mix

50% MILL CREEK
¼ IN CHIPS

25% MILL CREEK
DIRTY SCREENINGS

25% Mill Creek Clean Screenings

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Fine DGM

Mix Design	Percent Passing
3/8 in.	99.8
# 4	73.2
# 8	43.6
# 16	28.3
# 30	17.9
# 50	10.8
# 200	5.4
1% Lime 7.2% PG 76-22	96.5 % Density

Hamburg	Overlay Test
5.4 mm at 20 K	**1000+**

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Section 5
Laboratory Testing of HMA Surface Properties

texture and skid resistance & noise absorption

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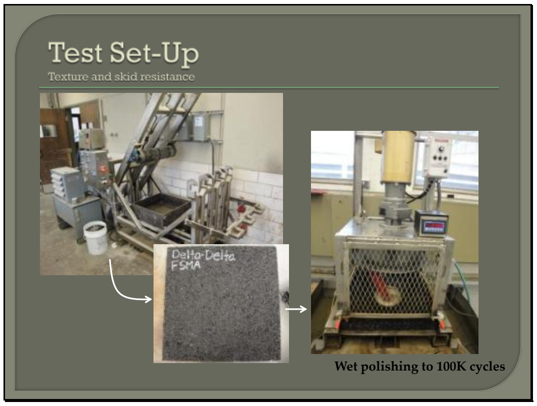

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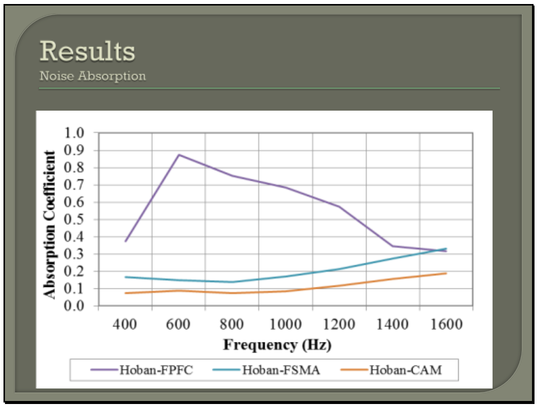

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Section 6.0
Field Performance Evaluations

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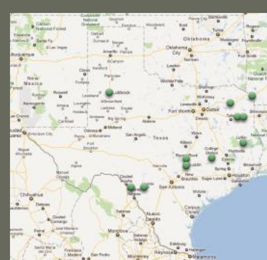
Performance Evaluations on Existing TxDOT Projects

- 5 CAMs
- 3 Fine CMHB/SMA Mixes
- 1 Fine PFC
- E-Krete
- MicroTekk/Microsurfacing

Data Collected
Mix Design & Construction Info.
Visual Condition
Subsurface Condition (GPR)
Skid Resistance
Tire-Pavement Noise



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Summary of Findings

- Several CAMs had shoving/flushing problems.
  - Lowering target density to 96.5% of mandating PG 76 would help.
- Don’t put seal coat on soft CAM.
- All mixes studied, except one CAM, MicroTekk, and E-Krete, had good cracking resistance.

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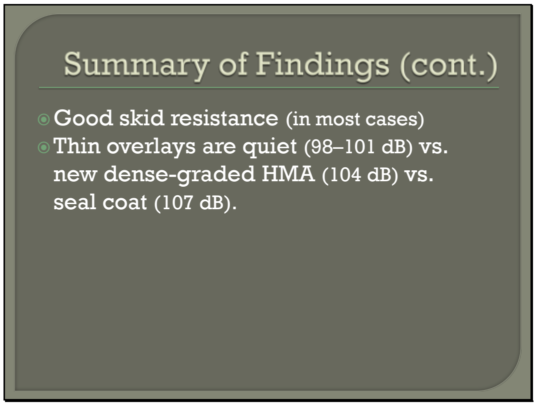

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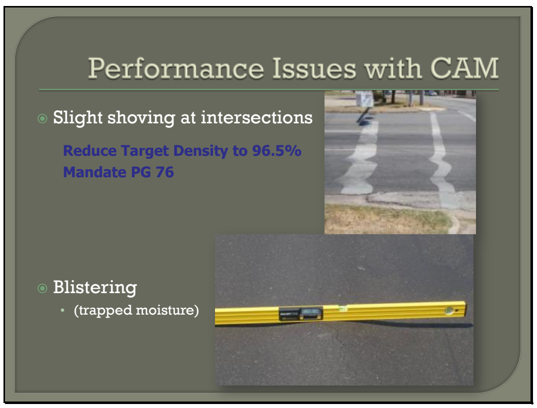

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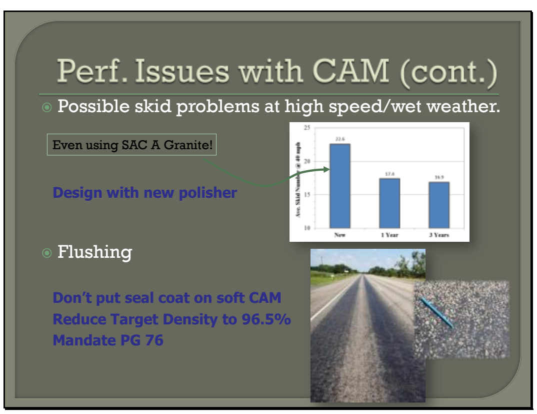

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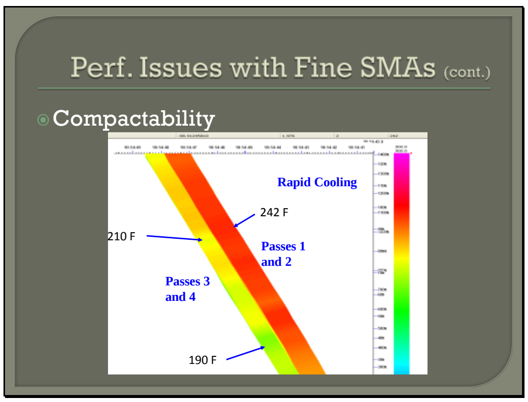

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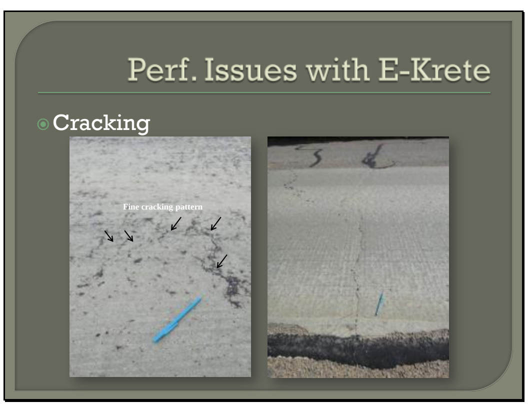

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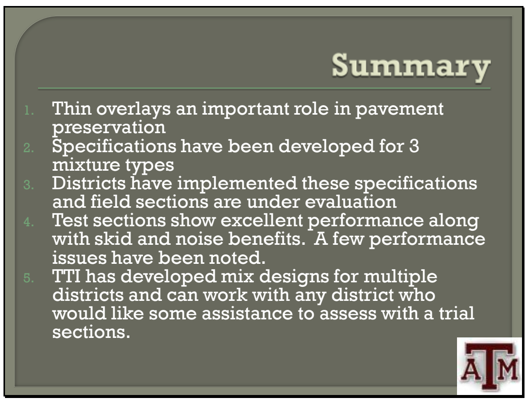

SPECIAL SPECIFICATION

XXXX

Fine Surface Mixes
(Volumeteric Design Method)

1. **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), or

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

2. **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.

   A. 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.

   1. **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).

2. **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

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

B. 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

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

D. 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.”

E. 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.

F. 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.

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

4. 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).

A. 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.

B. 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.

C. 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:

1. **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.
2. **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.
3. **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.
4. **Loading and Transporting.** For loading and transporting, include:
   - type and application method for release agents; and

- truck loading procedures to avoid segregation.

5. **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.

D. Mixture Design.

1. **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. Evaluate each mixture using 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.

   a. **Contractor's Responsibilities.**

      (1) **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.

(2) 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.

(3) 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.

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

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

(6) 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.

(7) 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.

(8) 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.

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

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

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

(12) **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.

(13) **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 an 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.

(14) **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.

(15) **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.

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

(17) **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.

(18) **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

b. Engineer's Responsibilities.

(1) 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.

(2) 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.

(3) 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.

(4) 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.

(5) 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.

(6) 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.

(7) 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.

(8) 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.

(9) 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.

(10) 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.

E. 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.

1. **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.

2. **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.

F. 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.

G. 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 hrs. 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 hand held 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 ºF.

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

ITEM 2**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.

A. Compaction.

1. 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 30 seconds. If the water flow rate is lower than 30 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.

2. **Type III 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 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 less than 60 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.

B. 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.

1. 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.

2. **Production Acceptance.**

a. **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.

(1) **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 Ty III mixtures, as tested by the Engineer. Not applicable to Type I mixtures.

(2) **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.

b. **Production Sampling.**

(1) **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.

(2) 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."

c. 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.

d. 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.

(1) **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.

(2) **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.

(3) **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.

e. 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.

3. Placement Acceptance for Type II and II mixtures.

a. 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.

(1) **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.

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

(3) 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."

b. 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 not 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.

c. 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.

(1) 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.

(2) 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

(3) Longitudinal Joint Density.

(a) 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

(b) 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.

(4) **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.

4. **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.

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

2. **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."

A. **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,

1. **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.

2. **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.

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

3. **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.”

DESIGN AND PERFORMANCE EVALUATION OF A FINE-GRADED PERMEABLE FRICTION COURSE

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by

Cindy Estakhri, P.E.
Research Engineer
Texas Transportation Institute
Texas A&M University System
3135 TAMU
College Station, TX 77843-3135
Phone: 979-845-9551; Email: c-estakhri@tamu.edu

Tom Scullion, P.E.
Senior Research Engineer
Texas Transportation Institute
Texas A&M University System
3135 TAMU
College Station, TX 77843-3135
Phone: 979-845-9913; Email: t-scullion@tamu.edu

Xiaodi Hu, Ph. D..
Transportation Research Center
Wuhan Institute of Technology
693 Xiongchu Avenue, Wuhan, Hubei, 430073, P. R. China
Email: huxiaodi625@hotmail.com

ABSTRACT

Permeable Friction courses (PFC's) are very popular in Texas where the current specification for PFC (Item 342) has a maximum aggregate size of ½ inch and is typically placed in layer thicknesses of 1.5 to 2 inches. The fine-graded PFCs discussed in this paper are proposed to be placed at a nominal thickness of one inch and are composed of a single aggregate fraction.

Initial laboratory testing found that the target air void content for volumetric design would be around 26% air voids, substantially higher than the current PFC designs which are between 18 to 22% air voids. In an attempt to minimize the likelihood of failure, substantial lab testing was performed to arrive at the proposed design. This included Hamburg wheel track testing, overlay tester cracking, Cantabro, drain down and water flow tests.

The proposed fine PFC mix was first placed on a test track in Pecos Texas. Two different designs were placed and subjected to limited traffic loadings, field water flow, noise and skid measurements. These test sections looked and performed very well. The next section was placed on a TxDOT project and subjected to extremely intense traffic loading conditions on an exit ramp on US 59 in Lufkin Texas in May 2011. This ramp was a location with a high frequency of wet weather accidents. In addition to extreme traffic loads the surface has experienced extreme heat (air temperatures approaching 105°F) and heavy localized rain (a 6-inch rain event within a 24 hour period). After 3 months the fine PFC is holding up well.

BACKGROUND

Permeable Friction courses (PFC's) are very popular in Texas where the current specification for PFC (Item 342) has a maximum aggregate size of ½ inch and is typically placed in layer thicknesses of 1.5 to 2 inches. A volumetric design approach is used with a target air void content of between 18 and 22 %, and the proposed mix must pass both a Cantabro test and a drain down requirement.

In this paper a laboratory and field test program is undertaken to develop and evaluate a new fine-graded PFC and to compare its performance with the current design. The overall goal is to design the next generation of thin permeable surfaces which will be a) less expensive, b) longer lasting and c) have better water flow characteristics than current designs. The challenges of developing any economical thin overlays of 1 inch of less revolve around developing a process to balance the following competing requirements;

a) providing adequate rut resistance;
b) providing adequate resistance to reflection cracking;
c) providing adequate skid resistance;
d) providing construction specifications for placement and compaction; and
e) providing a mix that is economical.

In addition to these properties for thin PFC-type mixes, the following additional properties are important:

f) good splash/spray properties;

g) resistance to raveling; and

h) resistance to aging.

The proposed fine-graded PFC is similar in gradation to a fine porous asphalt mix used in Denmark which is designed at 25.5 percent air voids and 6.3 percent asphalt and subjected to Hamburg wheel tracking tests for durability evaluation. (Danish Road Institute, 2005)

MATERIALS SELECTED FOR INITIAL MIX DESIGN AND EVALUATION

Aggregate

The aggregate gradation selected for development of a fine graded PFC mixture design is one that is sometimes used for chip seal construction in Texas (Spec Item 302, Grade 5) as shown in Table 1. This aggregate gradation is readily available in Texas and, at some quarries, may even be considered a by-product that is generated when crushing coarser fractions. For this preliminary design a good quality sandstone material widely available at an economical price in central Texas was selected. The parent rock is known for good friction, soundness, and durability properties. For comparison purposes, the gradation specification limits for TxDOT's conventional PFC (with PG 76 binder) is included in Table 1 together with the gradation proposed for the fine PFC.

Asphalt and Additives

TxDOT specifications currently allow two types of binder for PFCs: PG 76 at a binder content of between 5.5 and 7.0 percent or asphalt rubber at a content of 8.0 to 10.0 percent. For the fine-graded PFC, the PG 76-22 asphalt was selected. As is normal with traditional PFC's both lime and fibers (1.0% lime and 0.3% fibers) were included in the design.

Conventional PFC's produced according to TxDOT Specification Item 342 (Permeable Friction Course) are designed volumetrically at an air void content of 18 to 22 percent using 50 gyrations of the Superpave Gyratory Compactor. Bulk specific gravity of the specimens are determined using a dimensional analysis method. The initial fine-graded PFC's designed in this study could not be designed in the 18 to 22% air void range and averaged around 26%. Because of this higher air voids in the mix, researchers attempted to minimize the risk of poor performance incorporating a series of additional performance test criteria for the new fine PFC.

Table 1 Gradation Analysis for Fine Graded PFC.

Sieve Size	Sandstone Washed Sieve Analysis (Cumulative Passing %)	Fine Graded PFC Draft spec	Conventional PFC Specification Limits (Item 342 – for PG76 binder) (Cumulative Passing, %)
3/4 "	100.0	100	100
1/2 "	100.0	100	80.0-100.0
3/8 "	100.0	95 - 100	35.0-60.0
No. 4	51.9	20 - 55	1.0-20.0
No. 8	7.9	0 – 15	1.0-10.0
No. 200	2.1	0 - 4	1.0-4.0

LABORATORY MIXTURE DESIGN PROPERTIES FOR FINE GRADED PFC

The following laboratory tests were performed and the results obtained are shown below:

(1) Select an optimal asphalt content based on meeting both Hamburg Wheel tracking test (Tex Test Method 242-F) and Overlay Test (Tex Test Method 248-F) criteria. Test samples at the following 4 asphalt content of 5.5%, 6.0%, 6.5% and 7% with 0.3% fibers and 1% lime, select the lowest asphalt content that meets both the rutting and cracking

criteria; (This approach is under development in Texas for a range of other mixes; this is the first time it has been applied to PFC design).

(2) Binder drain-down and Cantabro testing for the mixture at optimum asphalt content.
(3) Permeability testing for the mixture at optimum asphalt content.

Proposed Comprehensive Mix Design Approach

The criteria shown in Table 2 were selected for this fine PFC design.

TABLE 2 Tentative Design Criteria for the Fine PFC Design.

Property	**Fine-Graded PFC Specification Requirement**
Design Gyrations (Tex-241-F)	50
Lab Molded Density Tex 207 F	70 – 74
Hamburg Wheel Tracking Test Tex 242-F	Min 10,000 passes to reach 12.5 mm rut depth
Overlay Tester (Min. # Cycles) Tex 248-F	300
Cantabro Loss % Tex 245 - F	Max 20%
Fiber Content %5 (min – max)	0.2 – 0.5
Lime Content % (max)	1.0
Drain Down test % Tex 235 - F	Max 0.20%

Hamburg and Overlay Test Results

The Hamburg testing results and photos are presented in Table 3 and the overlay testing results are presented in Table 4. The Hamburg testing results indicated all samples lasted longer than 11,000 passes thereby meeting the 10,000 pass criteria in Table 2. The Overlay Test was developed to judge a mixture's resistance to reflection cracking. It is performed on a specimen that is 6-inches in length, 1.5 inches wide, and 1 inch in height at a temperature of 25C, a controlled displacement of 0.025 inches, and loading of 10 seconds per cycle. For this design the Overlay Tester was the controlling test at an asphalt content of 6.5%, the cycles to failure exceeded 300 (average = 462 cycles). Therefore for this design 6.5% asphalt was selected as the optimum asphalt content.

TABLE 3 Hamburg Testing Results at Each Asphalt Content.

Sample	Air Voids	Rutting Depth / mm @ Cycles
5.5% Asphalt	26.0 / 26.5	**12.5 @ 13700**
6.0% Asphalt	25.0 / 25.4	**12.5 @ 11100**
6.5% Asphalt	25.9 / 25.8	**12.5 @ 11700**
7.0% Asphalt	25.5 / 25.5	**12.5 @ 13400**

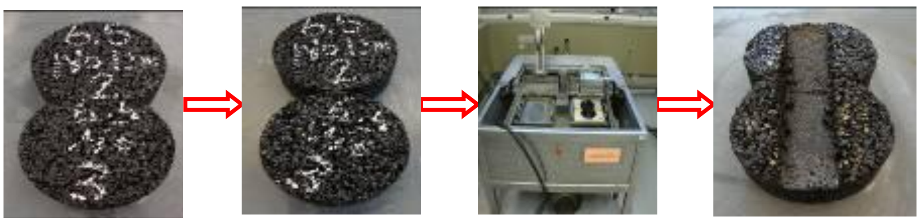
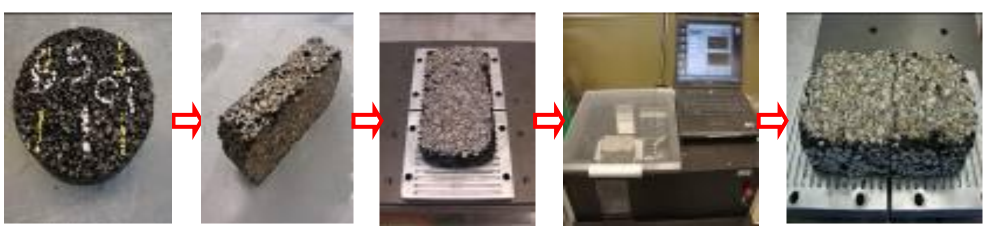


TABLE 4 Overlay Test Results at Each Asphalt Content.

Sample's No.	Air Void	Cycles to failure	Max load at first cycle / lbs
5.5% Asphalt_1	26.5	**139**	**375.6**
5.5% Asphalt_2	26.4	**107**	**379.1**
6.0% Asphalt_1	25.8	**136**	**329.7**
6.0% Asphalt_2	25.5	**83**	**378.0**
6.5% Asphalt_1	25.8	**616**	**323.3**
6.5% Asphalt_2	26.1	**309**	**344.0**



Drain-down Testing

According to Item 342, drain down susceptibility is evaluated after the specimen has been placed in the oven for one hour at 177 °C. However, in order to get more information regarding this PFC, the drain-down samples were kept in the oven for three hours, and, the mass of asphalt drained down for each hour was reported.

The testing results for the drain-down test and photos of the test samples are shown in Table 5. The binder drain-down was zero even for the mix which remained in the oven for 3 hours.

TABLE 5 Drain-down Test Results.

Mixture Type	Drain-down after ONE hour (%)	Drain-down after TWO hours (%)	Drain-down after THREE hours (%)
6.5% asphalt content with lime and fibers	**0**	**0**	**0**
	 **1 hour**	 **2 hours**	 **3 hours**

Cantabro Loss Testing

Samples produced at 6.5% asphalt were also molded for Cantabro testing. The results for the Cantabro test are listed in Table 6. Photos of the specimens after the test are also shown. All specimens met the Cantabro loss requirement of 20% maximum.

TABLE 6 Cantabro Test Results and Photos of the Samples Before and After Testing

Mixture Type	No. of Sample	AV (%)	Initial Weight of Test Sample	Final Weight of Test Sample	Cantabro Loss (%)
6.5% asphalt content with lime and fibers	A	**25.1**	3566.7	3156.4	**11.5**
	B	**25.3**	3565.3	3122.5	**12.4**

Permeability and Water Flow Testing

Permeability tests were conducted in the laboratory in accordance with American

Standard of Testing and Materials (ASTM) PS 129-01 (2001) for the samples at the following four asphalt contents, i.e., 6.0%, 6.5%, 7.0% and 7.5% (Figure 1a). The field water flow test (Tex-246-F) was also performed on the lab molded sample as shown in Figure 1b. For comparison purposes, a conventional PFC sample was also tested.

The test results are shown Table 7.

(a) Laboratory Permeability Test **(b) Simulated Field Water Flow Test**

FIGURE 1 Permeability and water flow testing.

The permeability, from both the elapsed time and coefficient of permeability, of the fine-graded PFC is much better than the conventional PFC, by a factor of three in the lab tests. This indicates that the fine-graded mix has the potential to improve the permeability characteristics of PFCs.

TABLE 7 Results of Permeability and Water Flow Tests.

	Permeability Test					Field Water Flow Test				
	6.0% AC	6.5% AC	7.0% AC	7.5% AC	Con. PFC[2]	6.0% AC	6.5% AC	7.0% AC	7.5% AC	Con. PFC[2]
Time_1[1], sec	2.50	2.78	3.50	3.47	10.47	19.09	25.41	35.12	31.94	55.78
Time_2[1], sec	2.47	2.75	3.53	3.41	10.43	19.10	25.31	35.18	31.85	56.16
Time_3[1], sec	2.47	2.75	3.40	3.37	10.47	19.28	25.19	35.28	31.97	56.66
Time_4[1], sec	2.50	2.72	3.31	3.44	10.44	--	--	--	--	--
Time_5[1], sec	2.44	2.75	3.31	3.34	10.25	--	--	--	--	--
Average Elapsed Time, sec	**2.48**	**2.75**	**3.41**	**3.41**	**10.41**	**19.16**	**25.30**	**35.19**	**31.92**	**56.20**
Coefficient of Permeability, cm/sec	**0.156**	**0.139**	**0.112**	**0.114**	**0.037**	--	--	--	--	--

[1]: Time_*i* (*i=1,2,3,4,5*) means the elapsed time of water, five test times for laboratory test and three test times for simulated field test.

[2]: Con. PFC means conventional PFC sample.

FIELD CONSTRUCTION

To evaluate the constructability and performance of the fine-graded PFC mixture, field trials were conducted in two locations and mixtures were designed for each location using materials local to the area:

- Entrance Road to the Pecos Test Track.
- Exit Ramp in the Lufkin District.

Pecos Test Track

The Pecos Research Testing Center is located 20 miles southeast of Pecos, TX and includes many miles of tracks which are used by TTI and others for research testing. For decades it was the primary testing facility for the B.F. Goodrich Company. Researchers developed specifications and let a contract to Reece Albert Construction of Midland to construct two fine-graded PFC mixtures on the entrance to the facility using a relatively good quality limestone from Vulcan Materials in Eastland and a rhyolite gravel from Capital Aggregates' Hoban Pit.

TTI designed the mixes using a single aggregate fraction from each source. The aggregate gradations for each mix are shown in Table 8. The minimum gradation specification requirement on the No. 3/8 was lowered from 95% (as originally proposed in Table 1) to 94% to allow the use of the Hoban material which could not meet the 95% specification. A minimum asphalt content of 6.5% was specified and was also selected as optimum for both mixtures and 0.3% fibers were used. Lime was not included in the mix design since the capability at the plant was not available. The mixtures also were required to meet the performance properties specified in Table 2. The mixtures were designed according to TxDOT procedure Tex 204-F, Part V.

TABLE 8 Mix Design Compositions for Field Testing at Pecos

	PFC Mix Design No. 1	PFC Mix Design No. 2	Draft Specification Lower and Upper Specification Limits	
	Capital Aggregates Hoban	Vulcan Materials Eastland Limestone		
Sieve Size	Cum. % Pass	Cum. % Pass		
No. 1/2	100.0	100.0	100	100
No. 3/8	94.5	97.8	94	100
No. 4	30.2	46.4	20	55
No. 8	4.8	3.4	0	15
No. 16	1.0	1.9	0	12
No. 30	0.4	1.6	0	8
No. 50	0.3	1.5	0	8
No. 200	0.2	1.3	0	4

Asphalt Type: PG 76-22 Binder Percent: 6.5% Lime: 0% Fibers: 0.3%

Selecting Optimum Asphalt Content

As discussed previously, since these mixes had higher air void contents than conventional PFC mixes, additional tests (Hamburg and Overlay) were added to ensure adequate field performance. These tests were also used to aid in selecting the asphalt content. The results are presented in Table 9. Samples were molded at 6.0, 6.5, and 7.0 percent asphalt and evaluated for density, Hamburg, and Overlay test characteristics. The Hoban Rhyolite mixture failed the Hamburg requirement of no more than 12.5 mm rut depth at 10,000 cycles but passed this criteria at 6.5% asphalt. Overlay test data exceeded the minimum of 300 cycles for all 3 asphalt contents. All 3 asphalt contents met the density requirements of between 70 and 74 percent. So based on the Hamburg criteria, the acceptable asphalt content was selected as 6.5%.

The Eastland mix had acceptable Hamburg and Overlay Test results at all 3 asphalt contents but the least rut depth was at 6.5 percent asphalt. The density results for all 3 asphalt contents exceeded the proposed specification values of between 70 and 74. This density value is controlled by the aggregate gradation and since the aggregate is from a single fraction (or stockpile) no change in the gradation could be made given this is what was available from this quarry. A goal of the research was to determine if the proposed specifications were acceptable based on field performance characteristics. So allowing a mix to be constructed which was outside of the density specifications provided additional information which may be used to validate and/or modify the specifications. An asphalt content of 6.5% was selected for the Eastland limestone mix.

While considered a good quality limestone, the Eastland material still did not meet TxDOT the polish value requirements for a Class A in the Surface Aggregate Classification System. A Class A aggregate must also have a Los Angeles Abrasion loss of less than 30 and a Magnesium Sulfate Soundness loss of less than 20 and both aggregates met these values. The final specification requirement for the fine-graded PFC will likely require 100% class A aggregates. Soundness values for the Eastland and Hoban materials were as follows:

Eastland: LAA = 25%, Soundness = 13%

Hoban: LAA = 20%, Soundness = 10%.

TABLE 9 Mix Design Performance Test Results at Different Asphalt Contents

Mixture Type	Asphalt Content, %	Density, %	Hamburg Results, Rut depth@ No of cycles	Overlay Test Results		Performance Testing Outcome
				Max Load, lbs	Number of Cycles to Failure	
PFC-1 Hoban Rhyolite	6.0	73.1	12.5 mm @ 4900	336.3	402	Fail
	6.5	73.5	8.1 mm @ 10000	367.0	450	Pass
	7.0	73.7	12.5 @ 7000	317.0	1000	Fail
PFC-2 Eastland Limestone	6.0	76.3	9.12 @ 10000	478.4	337	Pass
	6.5	77.8	6.29 @ 10000	419.0	300	Pass
	7.0	78.4	8.50 @ 10000	494.5	1000	Pass

Laboratory Test Results of Field Produced Mixtures

Both mixes were designed to have asphalt contents of 6.5 percent. The actual asphalt content from ignition oven testing of the plant produced field samples revealed the Hoban rhyolite mixture had an asphalt content of 6.4 percent but the limestone mixture had a low asphalt content of only 5.8 percent. Laboratory test results from the field produced mixtures are shown in Table 10. The limestone mixture failed to meet the minimum requirements for overlay test and Cantabro testing. This is very likely to be related to the low asphalt content. Correcting the asphalt content in the plant was difficult due to the small quantities of mix produced.

TABLE 10 Mixture Properties of Field Sampled Mixes and Specification Requirements

Property	PFC Mix 1 Hoban Rhyolite	PFC Mix 2 Eastland Limestone	Fine-Graded PFC Specification Requirement
Design Gyrations (Tex-241-F)	50	50	50
Lab Molded Density Tex 207 F	71.9%	77.9*	70 – 74
Hamburg Wheel Tracking Test Tex 242-F	6.1 mm @ 10,000 passes	5.2 mm @ 10,000 passes	Min 10,000 passes
Overlay Tester (Min. # Cycles) Tex 248-F	378	55*	300
Cantabro Loss % Tex 245 - F	24.1*	55.5*	Max 20%

*Outside of specification requirement

The mixtures were placed side-by-side on the entry road to the facility as shown in Figure 2. Standard equipment for asphalt concrete pavement construction was used, including a material transfer vehicle, paver equipped with an infrared monitoring system, and 3 passes with a 13.5-ton tandem steel wheel roller operated in static mode.

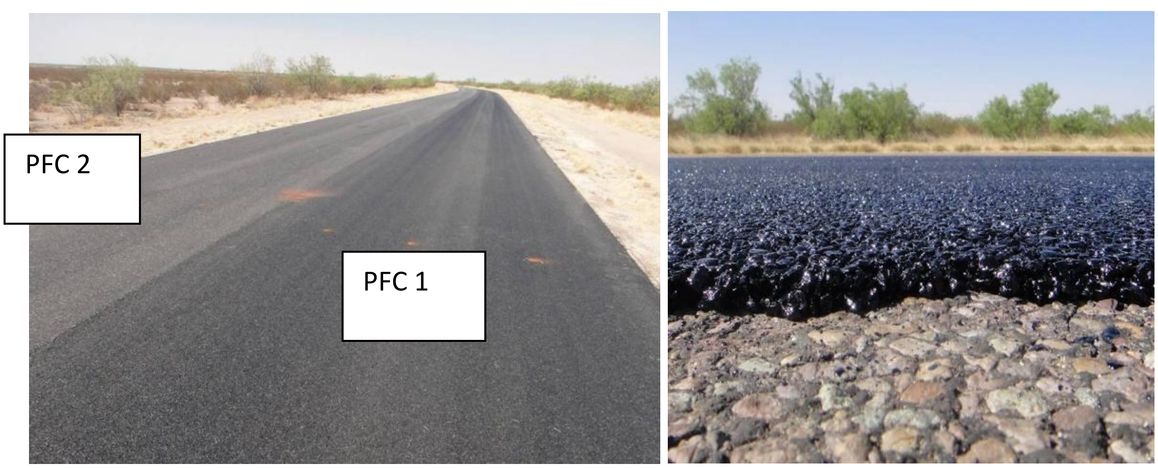


FIGURE 2 PFC Mix on Pecos facility entrance road.

Performance

The PFC mixtures were evaluated immediately after construction for drainage characteristics using a field water flow test shown in Figure 3 (Tex 246-F). The test evaluates the time required to discharge a given volume of water channeled onto the pavement surface through a six-inch diameter opening. The time corresponds to the water flow value (WFV) and is expressed in seconds.

FIGURE 3 Test Method Tex-246-F, Field Water Flow Test.

For conventional PFC mixtures, TxDOT recommends water flow values of less than 20 seconds. The Hoban PFC had an average water flow value of 9 seconds while the Eastland mix had a water flow value of about 27 seconds. This indicates that the higher than desired lab molded density of the Eastland PFC translated to poorer drainability in the field.

TxDOT measured skid resistance on the mixtures a few days after construction. The wet skid number (SN) was measured at 50 mph using a smooth tire. Values obtained were 39 for the Hoban mix and 31 for the Eastland mix. These values are expected to increase as the asphalt on the surface is eventually worn away by traffic and weathering.

The direct tire-pavement noise was measured on each section using an on-board sound intensity (OBSI) system. The OBSI measures sound intensity at different frequencies, which can then be used to calculate an overall noise level. The Hoban PFC mix had a noise level of 100.1 dBA and the Eastland PFC mix had a noise level of 98.7 dBA. Recent measurements made by TxDOT on eight of the conventional coarse graded PFCs using the PG 76 binder produced an average overall noise level of 102.2 dBA. The higher air voids and/or finer texture for the fine graded PFC should be contributing to the lower noise level.

Lufkin Construction Project

On May 19, 2011, researchers worked with the Maintenance Engineer of TxDOT's Lufkin district to place the experimental fine-graded PFC on an exit ramp of US 59 as shown in Figure 4. This ramp had an existing chip seal surface and a number of accidents had occurred when drivers exited too fast and skidded off the ramp while trying to make the sharp curve during wet weather. The district personnel said they were pulling vehicles out of the ditch every time it rained. And none of the surfaces Maintenance had tried could withstand these high shear forces exerted by traffic on the surface.

The mixture design for this project was the sandstone design as presented earlier in this paper. Traffic speeds on the exit ramp prohibit skid and noise testing.

Thus far, the mix has held up very well in one of the hottest summer’s Texas has seen (over 30 consecutive days of 100°F+ temperatures) and the district is happy to report no accidents even during a recent 6-inch rain event. An inspection conducted 6 weeks after placement found the section looked identical to the day it was placed, with no flushing or closing up of the open surface. Testing performed on the mix showed that it met the specification requirements (Table 12).

TABLE 12 Test Results on Lufkin Fine Graded PFC Plant Mix.

<table>
<tr><th rowspan="2"></th><th>Lufkin PFC Mix Plant Sampled Material</th><th colspan="2" rowspan="3">Lower and Upper Specification Limits</th><th>Additional Testing on Field Mix</th></tr>
<tr><th>Sandstone</th><td rowspan="10">Target Asphalt Content: 6.5 %
Actual Asphalt Content: 6.1%

Hamburg Test: 7.4 mm at 10,0000 cycles

Overlay Test: 356 cycles to failure

Cantabro loss: 5.4%

Field Water Flow: 19 seconds (Avg of 6 readings taken on pavement surface immediately after construction)</td></tr>
<tr><th>Sieve Size</th><th>Cum. % Pass (ignition oven sample)</th></tr>
<tr><td>No. 1/2</td><td>100.0</td><td>100</td><td>100</td></tr>
<tr><td>No. 3/8</td><td>99.2</td><td>94</td><td>100</td></tr>
<tr><td>No. 4</td><td>37.4</td><td>20</td><td>55</td></tr>
<tr><td>No. 8</td><td>8.7</td><td>0</td><td>15</td></tr>
<tr><td>No. 16</td><td>6.2</td><td>0</td><td>12</td></tr>
<tr><td>No. 30</td><td>5.3</td><td>0</td><td>8</td></tr>
<tr><td>No. 50</td><td>4.7</td><td>0</td><td>8</td></tr>
<tr><td>No. 200</td><td>3.2</td><td>0</td><td>4</td></tr>
</table>

Very Thin, Fine-Graded PFC Placed on Cloverleaf Exit Ramp of US 59 Near Lufkin District Office. Maintenance needed a mix to address the numerous wet weather accidents occurring on this ramp.

FIGURE 4 Cloverleaf exit ramp of US 59 of the TxDOT Lufkin district.

SUMMARY AND CONCLUSIONS

The paper describes the design, constructability and preliminary performance measurements on a fine graded PFC. This design has never been placed previously in Texas and it has the potential of being less expensive than current PFC's primarily because it uses aggregate sizes that are widely available and because the target thickness is 1 inch or less. The one aggregate requirement included in the draft specification for this material is that it meets TxDOT Surface Aggregate Classification (SAC) requirement for a Class A material and have a LA Abrasion of less than 30, and a Magnesium Soundness of less than 20. The proposed mix design requirements include the use of :

- TxDOT Grade 5 (1/4 inch) aggregate, with 1% lime, 0.3% fibers.
- SAC A aggregate
- PG 76-22 binder
- Target air void content of 26%, Ndes 50 gyrations.
- Hamburg results: less than 12.5 mm at 10,000 cycles.
- Overlay Test results: More than 300 cycles
- Cantabro Loss less than 20%.
- Drain-down: less than 0.2%

In the first phase of this evaluation a design was made with sandstone aggregates from central Texas. All the above test requirements were met. In addition water flow tests were conducted in the laboratory and it was determined that the flow was up to three times more than traditional PFCs.

Based on reasonable results in the laboratory two field trials were conducted in early 2011. In both cases no problems were found with constructability, and in both cases the design mat thickness was 1 inch. Noise measurements made on the test sections in Pecos showed the surface to be quieter than TxDOT's conventional coarse-graded PFC.

The most interesting site is the cloverleaf exit ramp off of US 59 in the Lufkin District. This is extremely brutal traffic loading with a very high percentage of trucks which are braking and turning. After three months in service and under extremely hot conditions, the fine PFC is performing exceptionally well. The hope of the researchers is that as the design incorporated both a rutting and cracking test (which is not done for traditional PFCs in Texas) and with a higher initial air void content that this fine PFC will have a longer effective service life (in terms of water flow characteristics) than current PFC designs. Continued monitoring is recommended to ensure these characteristics remain for the next 10 years.

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