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16. Abstract

Thin HMA overlays, laid at 1.0 inch or thinner, are cost-effective surface maintenance options. The primary focus of this research was to develop specifications for three such mixes: fine dense-graded mix (fine DGM), fine-graded stone matrix asphalt (fine SMA), and fine-graded permeable friction course (fine PFC). A number of slurry overlay systems were also evaluated, but to a lesser extent.

Draft specifications for the three mix types were first developed based on the results of a literature/information search and a field investigation of 11 existing projects. The specifications included minimum material quality levels, laboratory performance criteria, and construction recommendations. To evaluate the design recommendations, extensive laboratory testing was performed on each of the three thin overlay mixes with five different aggregates. Of the 15 mixes attempted, 12 had acceptable designs in terms of the specified performance tests. For the most part, the draft specifications appeared to function well with minor alterations recommended. Testing also included two supplementary studies on the effects of screening type in fine SMA and the effects of recycled materials on both the fine SMA and fine PFC. Compaction of the fine SMAs was highly influenced by packing characteristics of the coarse and fine aggregates. Screening quality did not affect fine SMA rutting resistance, but did affect cracking resistance. Using recycled aggregates reduced rutting problems but increased cracking susceptibility; however, most mixes performed well suggesting that quality, well-engineered mixes can still have good performance when recycled materials are used in limited amounts.

Concerning laboratory testing of slurry overlays, the applicability of the overlay tester/procedures and the three-wheel polishing device in testing should be further studied. In particular, a tie-in with actual field performance should be identified, perhaps with the Accelerated Pavement Test program.

Six thin overlay projects, comprising 10 unique mix designs, were constructed and evaluated. Most projects were constructed without problems, though some encountered issues with over- and under-compaction. Initial performance has been very good, although, since all the sections are less than two years old, the long-term performance is still undetermined.

The researchers recommend adapting the specifications accompanying this report, which require using high quality materials and passing strict laboratory performance tests on both the lab design and trial batch materials. They do not recommend incorporating recycled materials in these mixes, though preliminary results are promising. Guidelines for pavement evaluation and mix selection were also prepared, which recommend the use of certain thin overlay or slurry overlay options given the pavement, traffic, and climate conditions.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation. It is not intended for construction, bidding, or permit purposes. The researcher in charge of the project was Tom Scullion, P.E. (Texas, #62683). The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
ASTM	American Society for Testing and Materials
CAM	Crack Attenuating Mixture
CMHB-F	Coarse-Matrix High-Binder, Type F
CTM	Circular Track Meter
DFT	Dynamic Friction Tester
DGM	Dense-Graded Mix
ERNL	Estimated Road Noisiness Level
FHWA	Federal Highway Administration
F60	Estimated Friction at 60 km/h
GPR	Ground Penetrating Radar
HWTT	Hamburg Wheel Tracking Test
IFI	International Friction Index
NM OGFC	New Mexico Open-Graded Friction Course
OAC	Optimum Asphalt Content
OAC_D	Design OAC
OAC_R	Recommended OAC
OBSI	On-Board Sound Intensity
PFC	Permeable Friction Course
RAP	Reclaimed Asphalt Pavement
RAS	Reclaimed Asphalt Shingles
SAC	Surface Aggregate Classification
SGC	Superpave Gyratory Compactor
SMA	Stone Matrix Asphalt
$SN_{(X)}$	Skid Number (at X mph)
TCS	Texas Crushed Stone
TGC	Texas Gyratory Compactor
TFCO	Thin Friction Course Overlay
TOM	Thin Overlay Mix
TTI	Texas A&M Transportation Institute
TWPD	Three-Wheel Polishing Device
TxDOT	Texas Department of Transportation
WFV	Water Flow Value

CHAPTER 1
INTRODUCTION

PROBLEM STATEMENT

The Texas Department of Transportation (TxDOT) is interested in cost-effective surface maintenance mixes for both urban and rural pavements. Traditional HMA overlays, with lift thicknesses from 1.25 to 2.0 inches, have a long history of successful implementation. Under good circumstances, they can have a service life of 8 to 10 years and extend the overall pavement life. However, with limitations of available funds there is always a need to explore more economical resurfacing options. Surface treatments, the longstanding economical option, are often discouraged within cities because of problems with chip loss and resulting property damages. They can also be very noisy, which is undesirable when people live and work near freeways.

One solution may be thin HMA overlays. These overlay mixes can be laid 1.0 inch or thinner because they use a small nominal maximum aggregate size (No. 4 or 3/8 inch) and use high quality materials to ensure adequate performance (*1*). They are more economical than traditional overlays and, as an added benefit, mitigate problems with curb/gutter height restrictions. Though still more expensive than surface treatments, these mixes should not have chip-loss problems, are relatively quiet, and where properly designed and constructed will hopefully provide the same service life as traditional mixes.

At the time this project was proposed, TxDOT did not have adequate thin overlay options that could be easily and cost effectively implemented throughout the state. Of the options available, these either were not intended for surface applications (crack attenuating mixture [CAM]), or required specialized construction equipment unfamiliar to many districts (spray pavers for thin bonded friction course and ultra-thin bonded hot mix wearing course). Thin overlay mixes have been developed at the national level and in other states (*1, 2, 3*), and though proprietary thin overlays were used several years ago with the Type F dense graded mixes, their use has decreased substantially in the past 10 years.

Another option for thin urban-area pavement maintenance is slurry overlay systems. These emulsion- or cement-based materials are spread or sprayed onto the pavement surface at ambient temperatures, do not require compaction, and can be opened to traffic after a short time (*4, 5, 6*). Because of these properties, they are often promoted as the more eco-friendly option.

The purpose of this research, therefore, is (1) to develop new thin overlay options that TxDOT districts can easily and cost-effectively implement, and (2) to evaluate various slurry overlay systems in similar applications. These options could be attractive alternatives to traditional HMA overlays and surface treatments.

SCOPE

This primary focus of this project is the development and field evaluation of the following thin overlay mix types:

- Fine dense-graded mix (fine DGM).
- Fine-graded stone matrix asphalt (fine SMA).
- Fine-graded permeable friction course (fine PFC).

These mixes cover the three main gradations types: dense-, gap-, and open-graded, respectively. Mixes from each gradation type have unique performance characteristics (ease of compaction and handwork, rutting resistance, splash and spray reduction, etc.). In addition to ongoing development of the mix specifications, the scope of the research included:

- A literature and information search.
- A field evaluation of eight existing thin overlay projects.
- Extensive laboratory testing
    - Trial run of the draft mix design specifications for three mix types (fine DGM, fine SMA, and fine PFC) with five aggregates types.
    - Focused study on the effects of screening type in fine SMA.
    - Focused study on the effects of RAP and RAS on fine SMA and fine PFC.
- Development of pavement evaluation and mix selection guidelines.
- A field evaluation of six new thin overlay projects (10 unique mix designs).

To a lesser extent, this project will also address the following slurry overlay systems:

- MicroTekk™ (conventional microsurfacing).
- MicroTekk™ Flex (flexible microsurfacing).
- E-Krete® (cement-based slurry).
- Tuffseal (cement-based slurry).
- Experimental high-skid slurries.

These were reviewed in the literature and evaluated in existing field projects. Existing slurry overlay designs were tested in the lab.

DELIVERABLES

This project provides the following implementable products:

- Draft specifications for three thin overlays mix types (fine DGM, fine SMA, and fine PFC) including minimum material quality levels, laboratory performance criteria, and construction recommendations (Appendix A).
- Workshop materials including instructor and student guides (Submitted as 0-6615-P2).
- Proposed pavement evaluation and mix selection guidelines (Tables 6.1 and 6.2).

OUTLINE

This report contains eight chapters. Chapter 1 describes the problem statement, project scope, and deliverables, while Chapter 2 gives background information for thin HMA overlays and slurry overlays. Chapter 3 describes the field evaluation of existing thin overlay and slurry overlay projects. Chapters 4 and 5 present the laboratory evaluation of the thin overlay and slurry overlays, respectively. Chapter 6 presents the proposed pavement and evaluation guidelines for these mixes. Chapter 7 describes the field evaluation of new thin overlay projects, and finally Chapter 8 summarizes the research and offers recommendations based on the findings. The report also contains information in the appendices, most notably the proposed mix design specifications for fine DGM, fine SMA, and fine PFC.

CHAPTER 2
LITERATURE AND INFORMATION SEARCH

OVERVIEW

This chapter reports the findings of Task #1, *Literature and Information Search*. This task involved compiling and synthesizing details of various thin overlays and the experience of different agencies and contractors with these mixes. Researchers conducted surveys of the literature, TxDOT personnel, and other DOT/agency personnel. The types of overlays studied are as follows:

Thin HMA Overlays

- CAM
- Dense-Graded Type F
- Ohio Smooth Seal (Type B)
- Fine SMA
- Coarse Matrix High Binder, Type F (CMHB-F)
- TTI Fine PFC
- New Mexico Open-Graded Friction Course (NM OGFC)

Slurry Overlay Systems

- MicroTekk (conventional microsurfacing)
- MicroTekk Flex (flexible microsurfacing)
- E-Krete (cement-based slurry)

While some of these mixes do not meet the thin overlay thickness requirement (1.0 inch and less), with minor alterations the mixes could be used in thinner lifts. The findings, therefore, provide a framework for the development of new thin overlay specifications. As a side note, the design specifications referenced in this chapter were those available at the beginning of this project; since then, many of the specifications have been updated or replaced.

This chapter is divided into the following sections: *Thin HMA Overlays*, *Slurry Overlay Systems*, and *Summary*.

THIN HMA OVERLAYS

This section discusses the following topics for each mix: function and project selection; materials and mix design; and construction.

Function and Project Selection

The HMA overlays are presented in this order: dense-graded, gap-graded, and then open-graded. The general description, function, and appropriate candidate pavement application for each mix is discussed.

The CAM is described in TxDOT special specification (SS) 3615. It was originally designed as a stress-relieving interlayer to mitigate crack propagation. This dense-graded mix uses high quality aggregate and a high amount of quality binder. When the CAM is placed on the surface, the design density is often lowered, thus reducing the asphalt content, though the official specification does not reflect this alteration. When used as a surface layer, the CAM is recommended over structurally sound pavements with minor to moderate cracking and little rutting. It can correct raveling, minor roughness, and produce very smooth and quiet surfaces. It is not recommended for high-speed roads, however, since the surface texture is minimal and could lead to skid problems in wet weather (*7*).

The Dense-Graded Type F mix is described in TxDOT Item 341. This mix has the finest gradation of all mixes in the dense-graded HMA specification. It is similar to the CAM, but is generally coarser, and the aggregate and laboratory performance requirements are much less stringent. Because the material qualities do not need to be as high, many dense-graded Type F designs are not expected to perform as well as CAM designs. It is typically used as a thin, surface-wearing course, and applied to the same candidate sections as the CAM. With crumb rubber or SBR latex additives, performance in terms of cracking rutting and skid resistance has been good (*8*).

Ohio Smoothseal (Type B) is a dense fine-graded polymer modified HMA, designed in Ohio and described under ODOT Item 424 (*9*), and has been used for about 25 years. It is ideally suited for thin pavement maintenance applications and as a long-lasting surface in rehabilitation. This type of HMA restores skid resistance, rejuvenates weathered surfaces, and seals extensive surface cracking (*10*). Candidate pavements will have no unrepaired structural damage, no appreciable rutting (< 1/4 inch), and sufficient remaining structural capacity to last the life of the treatment. The surface may be dry-looking, raveling, and 'bony' (porous or permeable). Pavement surfaces with significant irregularity will require a leveling course or milling prior to placement of Smoothseal.

TxDOT's fine SMA is a gap-graded mix defined by Item 346, Type F. Developed in Germany in the 1960s as Splittmastixasphalt, SMA mixtures are more durable than traditional dense-graded mixes due to the high binder content and a strong coarse aggregate skeleton or matrix. The space created within the matrix is filled with asphalt-rich mastic. SMA mixes are, therefore, rut-resistant yet still flexible and impermeable. The surfaces also have more texture than dense-graded mixes, and therefore provide adequate skid resistance for high-speed roads. Lastly, since this is a fine-graded mix, the tire-pavement noise should be lower than for coarser SMA options (*2, 11*). This type of mix can be used to correct low- to moderate-severity cracking, low- to moderate-severity raveling, and low-severity rutting. The current specification does not allow this mix to be laid less than 1.25 inches thick.

CMHB-F (Item 344) is another fine gap-graded mix, very similar to fine SMA and the mix should be applied in similar situations. The main difference between these mixes is that material qualities and laboratory performance is less strict with CMHB-F; therefore, some CMHB-F designs are not expected to perform as well as most fine SMA designs. At the time of this final project report, this mix has been retired and replaced by SS 3226 (Thin Friction Course Overlay [TFCO]), and this new specification may also be replaced by Thin Overlay Mix (TOM), a design widely used in the Austin District. The requirements of these later mixes are tighter and should result in better-performing mixes.

The Texas A&M Transportation Institute's (TTI's) fine PFC is an open-graded mix that, at the beginning of this project, was not part of any official specification. Like standard PFC, this mix uses a uniformly graded aggregate (usually Grade 5 or Type F gradation), binder, fibers to prevent draindown, and lime to prevent stripping. The result is a stone-on-stone contact mix with an open surface texture. Fine PFCs have good surface drainage, greatly reducing splash-and-spray and the risk of hydroplaning. The mix also provides good nighttime visibility. If not designed correctly, these may be vulnerable to raveling. Fine PFCs can correct poor skid, bleeding, and low-severity cracking and rutting.

The New Mexico OGFC is very similar to TTI's fine PFC, and is described in NMDOT Item 404 (*12*). It functions in the same way but has slightly different gradation requirements and less detailed material and laboratory performance constraints.

Materials and Mix Design

Requirements for materials, gradation, and mix design are summarized in Tables 2.1 through 2.3, respectively. Figures 2.1 through 2.3 show the gradation plots.

Many of the mix designs require high quality materials, but dense-graded Type F, Ohio Smoothseal, and NM OGFC mixes do not. The Type F mix specifications are lenient on the *Deleterious materials, LA Abrasion, Fractured Faces, Asphalt grade,* and *Recycled aggregate* requirements. Smoothseal and NM OGFC specifications, on the other hand, do not recommend any values for most of these properties. The NM OGFC, however, does require an Aggregate Index of 20 or less. This is a composite index from LA Abrasion, soundness loss, and absorption test results. The CAM and TTI fine PFC have the highest material requirements and do not allow any recycled materials.

Of the dense-graded mix gradations, the CAM is the broadest, permitting a wide spectrum of gradations. The Type-F mix is on the coarser side of this band, and the Smoothseal on the finer side; Smoothseal should be easiest to compact in a thin lift less than 1.0 inch, while the Type F will have problems this thin. The two gap-graded mixes are nearly identical with the CMHB-F producing a slightly finer mix. The current fine SMA gradation is too coarse for paving at 1.0 inches and less; the nominal maximum aggregate size needs to be lowered to accomplish this. The CMHB-F gradation bands could also produce mixes too coarse to compact at or below 1.0 inches. Of the open-graded mixes, the TTI fine PFC gradation band is broadest and the NM OGFC gradation is on the coarser side. Both mixes should compact to 1.0 inch and possibly thinner.

The current mix design requirements specify compaction with a Superpave gyratory compactor (SGC) for all but the Smoothseal mix. From the perspective of mix design procedures, CAM and dense-graded Type-F mixes are very similar expect CAMs are more dense and have an overlay requirement of 750 cycles. The high density requirement in CAMs may

Table 2.1. Material Requirements.

	Mix Type						
Property	CAM	Dense-Graded Type-F	Ohio Smooth-seal (Type B)	Fine SMA	CMHB-F	TTI Fine PFC	NM OGFC
Coarse Aggregate							
SAC	See plans[1]	See plans[1]	-	See plans[1]	See plans[1]	See plans[1]	Note 2
Deleterious materials, %, max	1	1.5	-	1	1	1	-
Decantation, %, max	1.5	1.5	-	1.5	1.5	1.5	-
LA Abrasion, % loss, max	30	40	-	30	35	30	-
Mag. Sulfate Soundness, %, max	20	30	-	20	25	20	-
2 Fractured Faces, %, min	95[3]	85[3]	-	95[3]	95[3]	95[3]	75
Flat Elongated, %, max	10	10	-	10	10	10	-
Fine Aggregate							
Linear Shrinkage, %, max	3	3	-	3	3	NA	-
Combined Aggregate[4]							
Sand Equivalent, %, min	45	45	-	45	45	NA	-
Other Materials							
Asphalt grade	See plans	-	PG 76-22[5]	PG 76	See plans	PG 76	See Plans
Recycled agg., %, max	0	20	10	20	20	0	-
Fibers, %, max	-	Allowed	-	0.2-0.5	-	0.2-0.5	0.2 - 0.5
Lime, %, max	1.0	Allowed	-	1.0	2.0	1.0	2.0
Other	WMA allowed	Allowed	10% Silica, no antistrip	-	Note 6	WMA allowed	-

1. Class B aggregate meeting all other aggregate requirements may be blended with Class A. Ensure at least 50% of material retained on No. 4 is Class A.
2. Aggregate should have Aggregate Index of 20 or less (NM Specification, Section 910)
3. Only applies to crushed gravel
4. Aggregates, without mineral filler, RAP, or additives
5. Minimum asphalt grade.
6. Additives to facilitate mixing or quality of mix allowed when approved.

'-' Not specified

Table 2.2. Gradation Requirements.

	Mix Type						
	CAM	Dense-Graded Type-F	Ohio Smooth-seal (Type B)	Fine SMA	CMHB-F	TTI Fine PFC	NM OGFC
Sieve Size	Percent Passing (%)						
1/2 in.	100	100	100	100	100	100	100
3/8 in.	98-100	98-100	95-100	70-90	85-100	95-100	90-100
No. 4	70-90	80-86	85-95	30-50	40-60	20-55	25-55
No. 8	40-65	38-48	53-63	20-30	17-27	0-15	0-12[1]
No. 16	20-45	-	37-47	8-30	5-27	0-12	-
No. 30	10-30	12-27	25-35	8-30	5-27	0-8	0-8[1]
No. 50	10-20	6-19	9-19	8-30	5-27	0-8	-
No. 200	2-10	2-7	3-8	8-14	5-9	0-4	0-4

1. For sieves No. 10 and No. 40

'-' Not specified

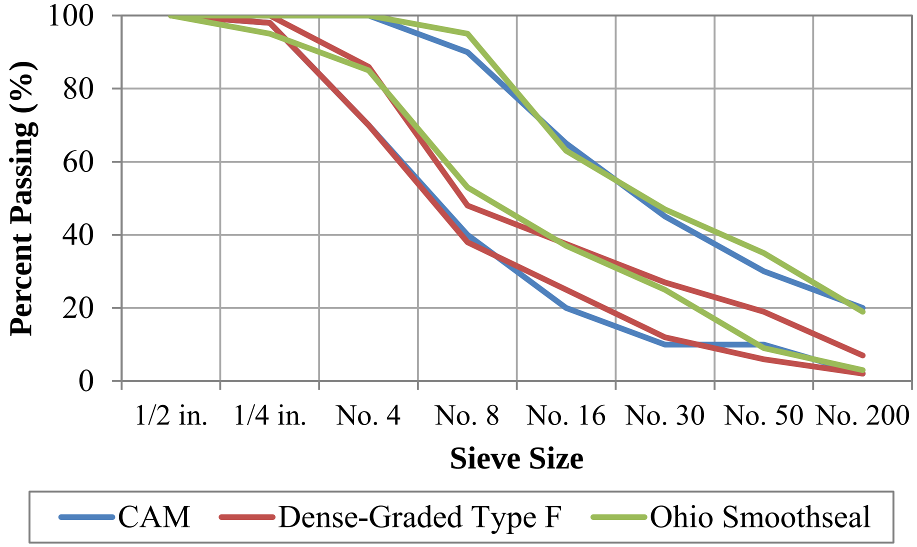


Figure 2.1. Gradation Curves of Dense-Graded Mixes.

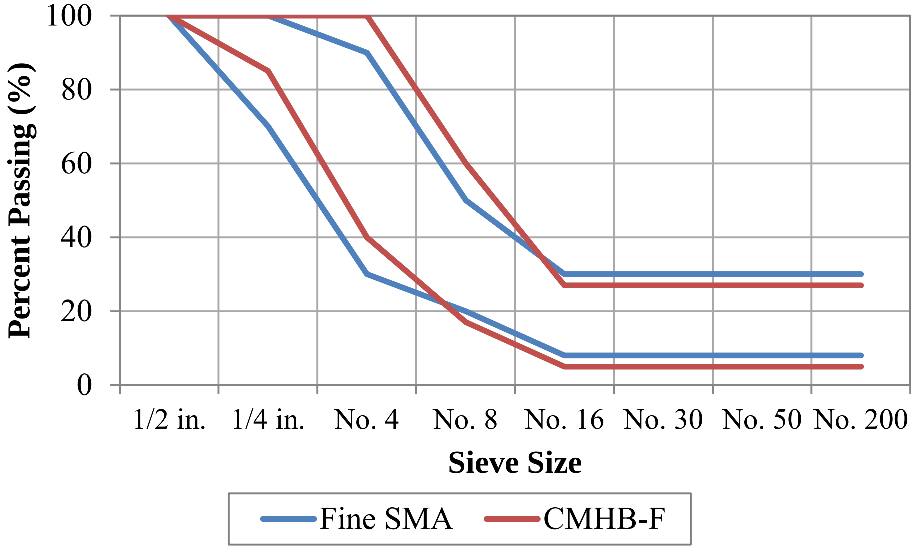


Figure 2.2. Gradation Curves of Gap-Graded Mixes.

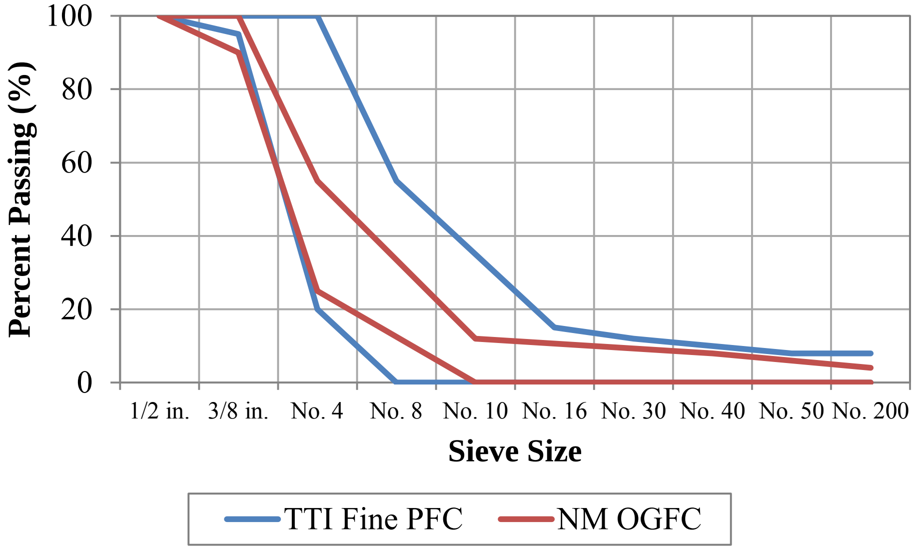


Figure 2.3. Gradation Curves of Open-Graded Mixes.

Table 2.3. Mix Design Requirements.

	Mix Type						
Property	CAM	Dense-Graded Type-F	Ohio Smooth-seal (Type B)	Fine SMA	CMHB-F	TTI Fine PFC	NM OGFC
Compaction and Volumetrics							
Lab Modled Density, %	98	96	-	96	96	72-76	78-82
Compaction Method	SGC	SGC	Marshall	SGC	SGC	SGC	SGC
Gyrations	50	50	NA	75-100	See plans	50	50
Asphalt Content, %, min	7.0	-	6.4	6.0	-	6.0	-
Dust/Asphalt Ratio, max	1.4	-	-	-	0.6-1.6	NA	NA
Min Design VMA, %, min	17.0	16.0	-	17.5	15.0	NA	NA
Laboratory Performance							
Depth in HWTT, mm, max	12.5	12.5	-	12.5	12.5	12.5	-
Passes in HWTT, max	Note 1	Note 1	-	20k	Note 1	10k	-
OT Cycles, min	750	-	-	-	-	300	-
IDT, psi	85-200[2]	85-200[2]	-	85-200[2]	85-200[2]	NA	-
Draindown, %, max	-	-	-	0.2	-	0.2	0.2
Cantabro, % loss, max	NA	NA	-	NA	-	20	20

1. 10k cycles for PG 64 or lower, 15k for PG 70, and 20k for PG 76 and higher
2. May exceed 200 psi or waived when approved.

'-' Not specified
NA - Not Applicable

Table 2.4. Construction Requirements.

	Mix Type						
Property	CAM	Dense-Graded Type-F	Ohio Smooth-seal (Type B)	Fine SMA	CMHB-F	TTI Fine PFC	NM OGFC
Mat Thickness, in.	1.00-2.00	1.25-2.50	0.75-1.50	1.25-2.50	1.50-3.00	0.75-1.00	0.50 min
Asphalt Temp, F, min	-	Varies with PG	210 (compaction)	280 (in paver)	Varies with PG	280 (in paver)	See plans
Pneumatic Roller Allowed	No	Yes	No	Yes	Yes	No	No
In-Field Density QC	Yes	Yes	No	Yes	Yes	No	No

'-' Not specified

produce a mix with too high an asphalt content for a surface mix. Of gap-graded mixes, these are also nearly the same except that the CMHB-F mix may have different HWTT requirements depending on the binder grade used. The design VMA requirements are also quite different. Concerning the open-graded mixes, the density requirement for the TTI fine PFC is much lower than the NM OGFC. This is likely because the NM OGFC is coarser, which tends to produce higher density mixes. (From TTI's experience, the fine PFCs produce mixes with lower densities.) The TTI fine PFC also has more laboratory performance requirements.

Construction

A summary of the construction requirements is given in Table 2.4. Of the mixes discussed, the CAM, Smoothseal, TTI Fine PFC, and NM OGFC are recommended to be laid at 1.0 inch thick. None of the current TxDOT specified mixes are allowed for paving less than 1.0 in. The asphalt temperature for TxDOT mixes is only monitored going into the paver and is based on the specified binder grade. There is no minimum temperature requirement required before compaction begins. The thicker layers (Type-F, fine SMA, and CMHB-F) permit the use of pneumatic rollers. If these mixes are redesigned for thinner lifts, pneumatic rollers could cause surface irregularities difficult to remove. Finally, the in-field density quality control is not required on the Smoothseal mix or PFCs. When layers are so thin, density measurements can be very difficult to run, especially for open-graded mixes

SLURRY OVERLAY SYSTEMS

This section discusses the following topics for each slurry overlay mix: function and project selection; materials and mix design; and construction. Since most of these slurry overlay systems are proprietary, detailed material and mix design information is often unavailable.

Function and Project Selection

Microsurfacing specifications are given in TxDOT Item 350. It is a durable and stable slurry, composed of fine and coarse aggregate, mineral filler, polymer-modified emulsion, water, and chemical additives (*4, 13*). As with other slurry systems, it is spread, rather than laid and compacted. It protects against water ingress, retards oxidation of asphalt, increases skid, corrects raveling and bleedings, restores skid resistance, and improves pavement aesthetics. Microsurfacing also resists shear deformation and can therefore be used to fill ruts up to 1 inch deep, even in high-traffic, urban environments (*4, 14, 15*). Generally, microsurfacing should be used as a preventative maintenance product for use on low-severity cracked pavements only. MicroTekk™ is a branded version of microsurfacing offered by Road Science LLC. Another branded microsurfacing, the brand which was first introduced to the United States, is called Ralumac™ (*4*).

MicroTekk™ Flex is another Road Science product, marketed as "flexible microsurfacing." Overall, it uses the same materials as microsurfacing but also includes a performance additive to enhance its crack resistant properties. The benefits of MicroTekk Flex™ are the same as microsurfacing but with increased cracking resistance and a tougher surface. Whether it can be applied successfully to moderately cracked pavement is still unknown.

A few proprietary cement-slurry products are available, including E-Krete, Tuffseal, Endurablend, and Emerald Cities. This discussion will focus on E-Krete, manufactured by PolyCon USA. The company website describes E-Krete as a "Polymer Composite Micro-Overlay (PCMO®) that contains specially sized aggregates, Portland cement, and acrylic modifiers" (*6*). It improves skid resistance, seals the existing surface from oxidation, water intrusion, and UV degradation, it reduces UV reflectance, and improves surface aesthetics. It is marketed as an environmentally friendly product with exceptional wear resistance. It can be applied over new asphalt, oxidized asphalt, spalled concrete, and prepared metal surfaces (*6*). It cannot correct cracking. The results of testing, however, are mixed; some agree that E-Krete delivers as promised (good performance on airport pads except for a few problems (*16*); skid resistance similar to control sample (*17*); good reflectance (*18*)), while others question the long-term durability of the product (delamination, rutting, wearing away (*19*)).

Materials and Mix Design

As previously stated, microsurfacing is a thin, bituminous treatment comprised of fine and coarse aggregate, mineral filler, polymer-modified emulsion, water, and chemical additives. Table 2.5 shows the fine gradation requirements in Item 350. Aggregate should have a surface aggregate classification (SAC) A or B, have no more than 30 percent mass loss from the magnesium sulfate soundness test, and a minimum sand equivalent value of 70 percent. The emulsion used should be a CSS-1P and the residual asphalt content is between 6 and 9 percent. The mineral filler (cement or hydrated lime) content is between 0.5 and 3.0 percent. The mixture must pass the standard wet-track abrasion test and a mix-time test before acceptance for TxDOT use.

MicroTekk Flex is designed according to the same requirements as MicroTekk with the inclusion of a small amount of performance additive, and an additional overlay tester criterion, self-mandated by Road Science. The mixture must last 100 cycles in the overlay tester at 5°C,

Table 2.5. Microsurfacing Gradation Requirements.

Sieve Size	Percent Passing (%)
1/2 in.	100
3/8 in.	99-100
No. 4	86-94
No. 8	45-65
No. 16	25-46
No. 30	15-45
No. 50	10-25
No. 200	5-15

gap opening of 0.05 inch, and total cycle time of 60 sec, to a failure criterion of 90 percent, the initial maximum load. (These conditions are much more severe than the current TxDOT test methods.) Given these criteria, an alternative emulsion with improved low-temperature flexibility is often prescribed.

E-Krete is a three-part system of Portland cement, fine aggregate, and an acrylic modifier (*6*). No mix design process is necessary since E-Krete is a predetermined recipe. In some cases, sand can also be embedded into the surface to increase skid resistance, and dye can be used to add color to the treatment.

Construction

In the construction of microsurfacing, all the materials are brought on site separately, then mixed and spread with specialized equipment. For MicroTekk Flex, the performance additive is introduced at the time of mixing. Microsurfacing can be laid up to two stones thick. A rut box can be added in place of the conventional spreader to channel the mixture into narrower courses for rut filling. After an initial rut-filling application, a second application is usually applied over the full pavement width to provide a uniform surface. The overall process, from the entry of materials into the mixer to the application of the mixture onto the road, should be no more than 2 minutes (*14*). Longer mixing times may result in premature hardening, or breaking of the emulsion. A minimum of just 1 hour is normally required for the treatment to adequately harden before traffic can be reintroduced, making it an ideal pavement treatment for high-traffic, urban environments. More details of the construction procedure are found in the literature (*4, 20*).

Cement slurries are constructed in either a spreader or paver fashion. E-Krete uses hand spreaders or a truck-mounted spreader. The surface should be prepared by sweeping off dust and debris and recommended ambient temperature is 95°F. After construction, the road can be reopened to traffic in about 1 hour. The product thickness is between 1/16 and 1/8 inch thick.

SUMMARY

Researchers first completed a comprehensive literature and information search, compiling and synthesizing details of various overlays, and the experience of different agencies and contractors with these mixes. The findings, therefore, provide a framework for the development of new thin overlay specifications. The findings are summarized as follows:

- Of TxDOT's current dense-graded options, the CAM is too rich in binder and thus susceptible to rutting and low skid resistance. The Type-F mix, on the other hand, is too coarse for thin applications, and has lenient material quality and performance requirements that could lead to poor performance in rutting and cracking.
- The Ohio Smoothseal (Type B) mix seems to work well, though for TxDOT's purposes the specifications would need to ensure the use of quality aggregates and allow the use of the SGC in design.

- TxDOT’s gap-graded mixes both provide high performance, but the current gradations are slightly too coarse for lifts 1.0 inch and thinner. Also, the CMHB-F specification should have tighter tolerances all around. (Note: The newer SS 3226 and Austin’s TOM design have replaced CMHB-F).
- TTI’s fine PFC design appears to produce an acceptable thin overlay mix. The gradation is similar to the NM OGFC gradation, but permits a slightly finer design.
- The NM OGFC has a higher density requirement that, in the experience of the researchers, could cause problems with in-field permeability.
- During the construction of thin overlays, pneumatic rollers should not be permitted and consideration should be given to omitting in-field density requirements on open-graded mixes.
- The slurry overlay findings are mostly informational. Conventional microsurfacing (MicroTekk) is well documented by numerous agencies, while MicroTekk Flex is largely unstudied. The performance of E-Krete is not well documented in the field; the research mostly pertains to controlled laboratory studies and airport pavements, and not to highway applications.

CHAPTER 3
FIELD EVALUATION OF EXISTING PROJECTS

OVERVIEW

This chapter reports the findings from Task #3, *Performance Evaluations on Existing TxDOT Projects*. The researchers evaluated 11 existing thin overlay and slurry overlay projects. The types of HMA overlays studied include CAMs, fine SMAs, fine PFCs, a CMHB-F, and a PFC based on the New Mexico OGFC. The slurry overlays studied were MicroTekk, MicroTekk Flex and E-Krete. A thorough assessment of these projects will help TxDOT identify good and poor practices for project selection, overlay selection, mix design, and construction. The findings, therefore, are an input in the on-going development of the proposed thin overlay specifications.

This chapter is divided into the following sections: *Procedures*, *Results*, and *Summary*. The *Results* section provides just a summary of the findings, while Appendix B presents the detailed case studies.

PROCEDURES

This section outlines the procedures involved in completing the research task. It first gives general information about the overlay projects, then briefly describes how background information was gathered, and finally details the procedures used in the performance evaluations.

Project Overview

The projects studied are shown in Table 3.1 and in the map in Figure 3.1. Eleven thin-overlay projects from eight districts were studied. The majority of the mixes were CAMs. The other

Table 3.1. General Project Information.

	Project Location				
Project Name	Route	District	City	**Mix Type**	**Year Constructed**
Texarkana-CAM	US 82	Atlanta	Texarkana	CAM	2004
Lufkin-CAM	BS 59	Lufkin	Lufkin	CAM	2008
Uvalde-CAM	US 90	San Antonio	Near Uvalde	CAM	2008
Mt Pleasant-CAM	US 49	Atlanta	Near Mt. Pleasant	CAM	2009
College St-CAM	FM 2154	Bryan	College Station	CAM	2010
Atlanta-Fine SMA	IH 20	Atlanta	Near Longview and Marshall	Fine SMA	2010
Austin-CHMB-F	IH 35 Frontage Rd	Austin	Austin	CHMB-F	2009
Lubbock-NM OGFC	US 62/82	Lubbock	Lubbock	New Mexico OGFC Type I	2007
Del Rio-MicroTekk	US 90	Laredo	Del Rio	MicroTekk and MicroTekk Flex	2010
Atlanta-E-Krete	US 80 and IH 20	Atlanta	Near Marshall	E-Krete	2009

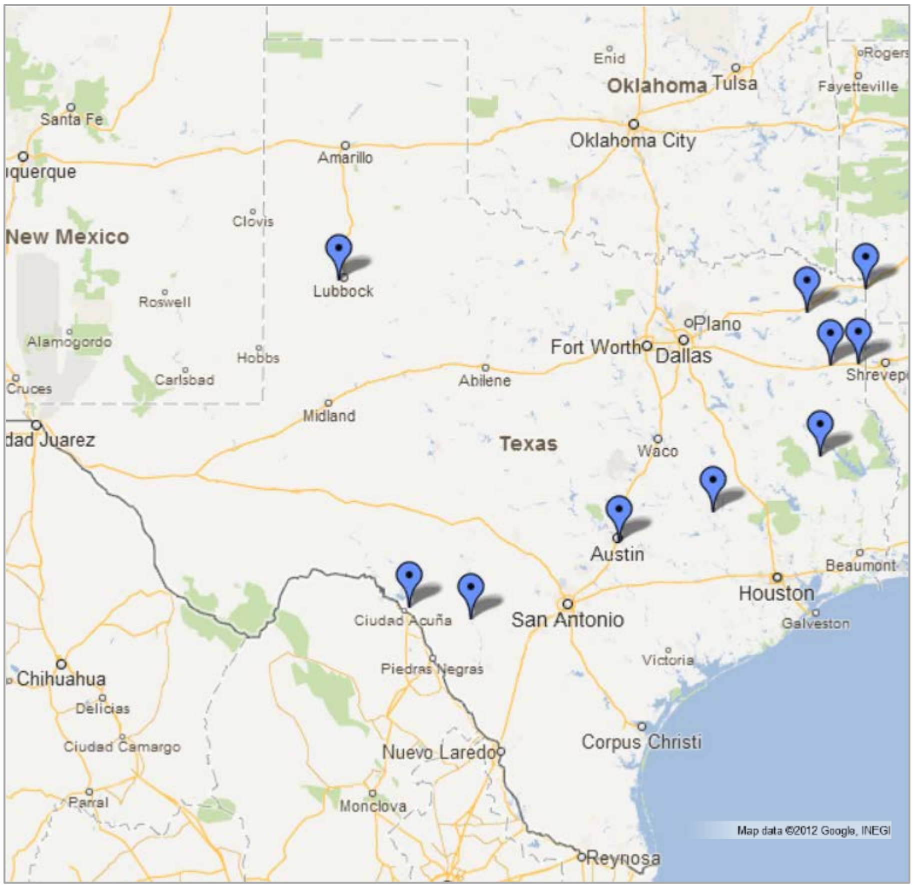


Figure 3.1. Thin Overlay Project Locations.

mixes were fine SMAs, fine PFCs, a CMHB-F, a NM OGFC, MicroTekk and MicroTekk Flex (side by side in the same project), and E-Krete. The oldest project here is a 7-yr old CAM, and all other projects are 4-years old or newer.

Background Data Collection

The performance of an overlay is dependent on several factors like site conditions, mix design properties, and construction procedures. Therefore, in order to appreciate the effectiveness of a given mix, performance measurements must be viewed in light of these other factors.

The condition of the site was characterized by the traffic condition, climate condition, and the existing pavement structure and condition. Traffic conditions were accounted for with the annual average daily traffic (AADT) per travel lane and percent truck traffic. The research team collected these data from TxDOT traffic maps (*21*) and, in some instances, from researcher observations. The climate conditions were accounted for with average annual precipitation, and high/low temperature averages and extremes. Moisture will weaken the pavement subsurface, high temperatures will facilitate rutting, flushing, and oxidation, and cold temperatures stiffen the pavement, facilitating cracking. The pavement structure and condition was estimated using ground penetrating radar (GPR), field cores, and/or discussions with district engineers. For a description of the GPR technology, refer to the following *Performance Evaluation* subsection. Information on subgrade materials were obtained from the U.S. Geological Survey database (*22*).

The mix design information included aggregate properties, aggregate gradations, binder contents and grades, other mix additives, and laboratory performance results. These data were obtained from the detailed mix design spreadsheets used for most projects. The laboratory performance data were plotted to help assess the effectiveness of current and proposed mix design procedures (simple volumetric design vs. balanced performance design).

The construction procedures were assumed to follow TxDOT specifications unless otherwise stated. Complications reported by the district engineer or observed by researchers were also noted.

Performance Evaluation

The overlays were assessed with four performance indicators: visual condition, subsurface condition, and skid resistance. This subsection reviews these indicators and describes how the assessments were conducted.

Surface Distress

The most apparent indicator of overlay performance is its visual condition. Surface distresses can be an indication of poor mix design properties, construction issues, harsh traffic/climate conditions, etc. Common overlay distress types include rutting, flushing, fatigue cracking, longitudinal cracking, transverse cracking, and raveling.

The surface distress of the overlays was assessed by visiting each site, documenting the outside lanes of the full project on video, and noting the observed existing distresses. Photos were taken of the distresses, the general roadway, and surface texture condition.

Subsurface Condition

While not a direct measure of the performance of the new overlay, the condition of underlying layers can indicate future problems. If the subsurface pavement has non-uniform layers, trapped moisture, or existing cracks, the overlay may exhibit problems like fatigue cracking, stripping, or reflective cracking. Generally, these issues are present before overlay construction, though overlay construction may worsen some issues like trapped moisture.

The subsurface condition was assessed with GPR using the radar-equipped vehicle (see Figure 3.2). GPR technology is used to detect pavement layer interfaces and anomalies by estimating the dielectric value of the structure at various depths. The dielectric value is largely dependent on moisture content and density, which often changes between pavement layers. Though dielectric values are not a direct measure of layer quality, assumptions about layer quality and uniformity can still be inferred from the findings. GPR data was collected for the whole project extent in the outside wheel paths.

Figure 3.2. GPR Van.

Skid Resistance

Skid resistance is the force developed when a fixed tire slides along the pavement surface. On this project, the wet skid number (SN) was measured at either 50 or 40 mph using a skid trailer with a smooth tire (see Figure 3.3). Readings were taken every 0.1 mi then averaged together. The following sites were not tested due to speed limit restrictions: Texarkana-CAM, Austin-CMHB-F, Lufkin-Fine PFC, and Del Rio-MicroTekk. Also, the Mt. Pleasant-CAM project was not tested because the original CAM surface was covered with a surface treatment.

Figure 3.3. Skid Trailer.

RESULTS

This section summarizes the findings of the existing overlay project evaluations. Detailed case scenarios for each project are contained in Appendix B.

Site Description

Table 3.2 summarizes the traffic and climate conditions at each project, and indicates the relatively severe conditions with bolded values. Projects with severe traffic conditions (Atlanta-Fine SMA and one of the Atlanta-E-Krete sections) were both on IH 20 and had AADT of about 8,000 and 30 percent trucks. Projects with high precipitation averages were all in East Texas (Texarkana, Lufkin, Mt. Pleasant, and Atlanta.) Projects with severe high temperatures were in South-Central Texas (Uvalde, Austin, and Del Rio.) Finally, projects with more severe freezing conditions were in the northern half of Texas (Texarkana, Mt. Pleasant, Atlanta, and Lubbock). All these data represent averages, which, in the case of climate, might not reflect conditions in recent years. The summer highs these past few years, for example, have been well above average, pushing most of these overlays beyond their design thresholds.

The pavement structures on these projects greatly vary. Table 3.3 summarizes the primary pavement layers and general condition. The projects are well distributed among overlays on good, fair, and poor pavements. Pavements in good condition (Uvalde-CAM, Lubbock-NM OGFC, and one Atlanta-E-Krete section) had good structural support, no signs of internal moisture damage, and little to no surface cracking. The Mt. Pleasant-CAM pavement was rated *Poor* because of a very weak support structure. The GPR and cores on the Atlanta-Fine SMA

Table 3.2. Traffic and Climate Conditions.

	Traffic Condition		**Climate Condition**		
Project Name	AADT / lane	Percent Trucks (%)	Ave. Annual Precip. (in.)	Ave. # Days ≥ 100°F	Ave. # Days < 32°F
Texarkana-CAM	5,250*	-	**51**	8	**45**
Lufkin-CAM	4,080	-	**47**	6	28
Uvalde-CAM	1,800	17	23	**31**	18
Mt Pleasant-CAM	1,460	14	**48**	12	**62**
College St-CAM	5,250	-	40	11	17
Atlanta-Fine SMA	**7,750**	**30**	**49**	7	**40**
Austin-CMHB-F	-	-	34	**20**	11
Lubbock-NM OGFC	5,400	8*	19	9	**78**
Del Rio-MicroTekk					
North-South	7,250	10	19	**29**	10
East-West	5,500	6			
Atlanta-E-Krete					
US 80	1,850	9*	**51**	6	**40**
Overpass	1,850*	9*			
IH 20	**8,000**	**30**			

* Approximated from adjoining section
'-' Data not available
Bolded values indicate high severities

Table 3.3. Pavement Structure and Condition.

Project Name	Pavement Structure (excluding base and subgrade)	General Condition	Specific Issues
Texarkana-CAM	3-4 in. asphalt on 10-11 in. jointed concrete	Fair	Severe raveling but structurally sound
Lufkin-CAM	3-5 in. asphalt on 8-10 in. jointed concrete	Fair	Internal moisture damage
Uvalde-CAM	6-7 in. asphalt & 11 in. asphalt	Good	NA
Mt Pleasant-CAM	Two 3/8 in. surface treatments	Poor	Very flexible base
College St-CAM	10-12 in. asphalt	Fair	Some rutting and cracking
Atlanta-Fine SMA	5 in. asphalt on 8 in. continually reinforced contrete	Poor	Lower asphalt badly damaged by moisture
Austin-CMHB-F	Highly variable asphalt (5 - 18 in.)	Poor	Surface cracking
Lubbock-NM OGFC	12 in. asphalt	Good	NA
Del Rio-MicroTekk			
North-South	4-5.5 in. asphalt & 5-7 in. asphalt	Poor	Surface cracking
East-West	13-14 in. asphalt & 3-4.5 in. asphalt	Poor	Surface cracking
Atlanta-E-Krete			
US 80	3.5 in. asphalt on 10 in. jointed concrete	-	-
Overpass	Concrete bridge deck	Good	NA
IH 20	5 in. asphalt on 8 in. continually reinforced contrete	-	-

NA - Not applicable
'-' Data not available

Overlay Design and Construction

The overlay designs consist of aggregate properties, material quantities, gradations, and lab performance results. Table 3.4 presents the aggregate properties. Most of the aggregates were SAC A. The overlay mix designs, comprising binder content and grade, aggregate composition, admixtures, and the overall gradation, are shown in Table 3.5. The laboratory properties for the selected mix designs are summarized in Table 3.6. The optimum asphalt content (OAC) for the mixes were determined either volumetrically as in the TxDOT specifications, or according to the balanced mix design approach developed at TTI.

Table 3.4. Aggregate Properties.

		Source		Properties			
Project Name	**Type**	Producer	Quarry	SAC	RSLA	RSSM	RSMD
Texarkana-CAM	Sandstone	Martin Marietta	Sawyer	A	30	14	10
Lufkin-CAM	Granite	Martin Marietta	Snyder	A	25	2	4
Uvalde-CAM	Trap rock	Vulcan Materials	Knippa	A	14	8	14
	Siliceous and Limestone Gravel	E E Hood & Sons	Davenport	B	29	18	21
Mt. Pleasant-CAM	Sandstone	Smith Buster	Sawyer	A	35	19	12
	Sandstone	Martin Marietta	Sawyer	A	30	14	10
College St-CAM	Sandstone	Capitol Aggregate	Delta	A	20	7	12
	Dolomite	Capitol Aggregate	Marble Falls	B	30	7	11
Atlanta-Fine SMA	Quartzite	Martin Marietta	Jones Mill	A	17	5	8
	Granite	Donna Fill	Little Rock	-	-	-	-
Austin-CMHB-F	Sandstone	Capitol Aggregate	Delta	A	20	19	12
	-	RTI Hot Mix	Yearwood	B	27	21	-
Lubbock-NM OGFC	Rhyolite	Hanson	Davis	A	16	9	12
	Limestone	Vulcan	Brownwood	B	24	7	13
Del Rio-MicroTekk	Limestone	Capitol Aggregate	Delta	-	-	-	-
Atlanta-E-Krete	Quartz	-	-	-	-	-	-

SAC - Surface Aggregate Classification

RSLA - Rated Source Los Angeles Abrasion

RSSM - Rated Source Soundness Magn

RSMD - Rated Source MicroDeval

'-' Data not available

Table 3.5. Overlay Mix Designs.

					Percent Passing (%)								
	Binder	Aggregate			Sieve Size								
Project Name	Content (Grade)	Composition	(Quarry)	Other	3/8 in.	No. 4	No. 8	No. 10	No. 16	No. 30	No. 40	No. 50	No. 200
Texarkana-CAM	7.8% (70-22S)	60% F-rock 40% Screenings	(Sawyer- Marietta)		100.0	78.8	39.5	-	25.5	19.9	-	17.3	8.1
Lufkin-CAM	8.3% (76-22)	30% 3/8" C.A. 69% Screenings	(Snyder)	1% lime	100.0	79.4	47.6	-	31.0	20.1	-	12.2	4.2
Uvalde-CAM	6.8% (76-22S)	38% Gr 5 42% Man. sand 19% Screenings	(Knippa) (Davenport)	1% lime	98.9	71.9	53.8	-	31.6	19.1	-	12.3	6.6
Mt Pleasant-CAM	8.2% (70-22)	29% "CAM rock" 21% Man. sand 29% Type F C.A. 21% Screenings	(Sawyer- Smith Buster) (Sawyer- Marietta)	1% Akzo anti-stripping agent	99.6	74.8	42.1	-	28.8	23.1	-	19.6	6.4
College St-CAM	7.1% (76-22)	21% Gr 5 18% D-rock 60% Screenings	(Delta) (Marble Falls)	1% lime	98.7	73.6	55.3	-	37.5	22.2	-	10.7	4.4
Atlanta-Fine SMA	6.4% (70-22)	43% LA 2 C.A 35% 3/8" C.A. 10% Screenings 12% "Donna fill"	(Jones Mill) (Little Rock)	1% lime 0.2% fibers	77.5	37.0	24.0	-	19.3	16.9	-	14.4	8.9
Austin-CMHB-F	6.7% (76-22)	77% Dirty F-rock 23% Screenings	(Delta) (Yearwood)		100.0	56.3	24.1	-	17.3	13.0	-	10.2	6.6
Lubbock-NM OGFC	6.4% (76-28)	65% 1/2" C.A. 33.7% Gr 5	(Davis) (Brownwood)	1% lime 0.3% fibers	93.6	34.8	-	4.6	-	-	3.2	-	2.8
Del Rio-MicroTekk	13.5% CSS-1P	100% Screenings	(Delta)	0.15% fibers	100.0	91.2	45.5	-	25.9	16.4	-	11.3	6.6
Atlanta-E Krete	Port. Cement	100% Sand	-	Latex	-	-	-	100.0	-	-	-	-	-

'-' No data available

Table 3.6. Overlay Laboratory Properties.

Project Name	Asphalt Content (%)	Rice Specific Gravity[1] (g/cm3)	Relative Density[1] (%)	VMA[1] (%)	HWTT[2]		Overlay[2]
					Rut Depth (mm)	# Cycles	# Cycles
Texarkana-CAM	7.8	2.289	-	18.8	6.8	15,000	>900
Lufkin-CAM	8.3	2.302*	98.0*	20.5*	7.8	20,000	1,510
Uvalde-CAM	6.8	6.640*	95.8*	20.9*	6.4	15,000	>1,000
Mt. Pleasant-CAM	8.2	2.305*	98.0*	20.2*	12.4	15,000	>1,000
College St.-CAM	7.1	2.479*	98.0*	18.7	6.1	20,000	-
Atlanta-Fine SMA	6.4	2.430*	96.0*	18.6*	6.9	20,000	>1,000
Austin-CMHB-F[3]	6.7	2.384*	97.5*	17.6*	5.8	20,000	-
Lubbock-NM OGFC	6.4	2.414*	80.0*	32.0*	-	-	-
Del Rio-MicroTekk	NA	NA	NA	NA	-	-	105
Atlanta-E Krete	NA	NA	NA	NA	-	-	-

1. Specimens molded at 50 gyrations
2. Specimens molded to 93±0.5% density
3. Specimens molded with Texas Gyratory

NA - Not applicable
'-' Data not available
* Interpolated value

The important mix design issues are as follows:

- All but the Uvalde-CAM project used the balanced performance mix design approach. In this case, the final OAC was associated with a relative density just under 96 percent. Other CAM mixes were designed at 98 percent density. Had this mix been designed at the higher content, it likely would not have passed the HWTT.
- If the balanced mix design approach were applied to other CAMs, the resulting designs would likely have lower asphalt contents at lower densities.
- No warm-mix additive was used in the Atlanta-Fine SMA mix design, even though the additive was used during construction.
- The Mt. Pleasant-CAM design narrowly passed the HWTT with 12.4 mm rutting after 15,000 cycles.
- Two designs were made for the Del Rio-MicroTekk project: one was MicroTekk and the other MicroTekk Flex. The project was intended to promote MicroTekk Flex as a more crack-resistant mix.

Important construction issues are as follows:

- The Atlanta-Fine SMA project used PG 70-22 binder (rather than 76-22) in construction and used a warm-mix additive without reducing the compaction temperature.
- A small test section of Atlanta-Fine SMA used PG 76-22 and no warm mix additive.
- In an effort to increase skid resistance, a surface treatment was placed directly over the new Mt. Pleasant-CAM. The CAM itself was laid thick between 1 3/8 and 2.25 inches.
- The MicroTekk and MicroTekk Flex designs were placed side by side in the same project for a direct performance comparison.

Overlay Performance

Overlay performance was evaluated according to surface distress, subsurface condition, and skid resistance. Table 3.7 summarizes these results for all the projects. When analyzing the surface distress results, the age of the pavement must also be considered. The Texarkana-CAM project, for example, may be transversely cracked, but it is the oldest project in the study and overall still performing well. On the other hand, the Del Rio-MicroTekk project is already cracking after 1 year. Many of these projects show no signs of distress but are still very new and should be monitored to better assess long-term performance. The subsurface conditions may not reflect the present overlay condition, but may indicate future problems. In the case of the Atlanta-Fine SMA project, the subsurface moisture damage may be connected to moisture damage in the new overlay. Skid measurements were available on most of the projects and noise on only a few. Most projects had acceptable skid, though the CAM mixes generally had the lowest values.

Table 3.7. Overlay Performance.

				Skid Resistance		
Project Name	**Age (yr)**	**Surface Distress**	**Subsurface Condition**	**SN**	**St. Dev.**	**Speed (mph)**
Texarkana-CAM	7	Transverse reflective cracking	Uniform, some cracking	-	-	-
Lufkin-CAM	3	Shoving at stop sign	Variable, some moisture damage	17	2.5	40
Uvalde-CAM	3	Almost none, slight rippling and cracking	Uniform, some layer dedonding	30	10.9	50
Mt Pleasant-CAM	2	Flushing through surface treatment	Uniform, some moisture damage	NA	NA	NA
College St-CAM	<1	Cracking in wheel path, shoving/ rutting at stop light	Uniform, some moisture damage, some cracking	25	4.6	50
Atlanta-Fine SMA	1.5	Very severe flushing, some rutting	Uniform, extensive moisture damage in SMA and asphalt	11* (37)	1.7* (4.1)	50
Austin-CMHB-F	2	Almost none, one crack noted	Highly variable, some moisture damage	-	-	-
Lubbock-NM OGFC	4	None	Very good	35	6.6	50
Del Rio-MicroTekk						
North-South	1	Developing transverse cracks in MicroTekk	Variable, extensive cracking, moisture damage	36** (36)	97** (7.9)	40
East-West	1	Fatigue cracking in conventional microsurfacing	Variable, some moisture damage	37** (32)	6.7** (6.3)	40
Atlanta-E-Krete						
US 80	1.5	Reflective transverse cracking, worn surface texture	Uniform, cracking	32	-	50
Overpass	1.5	Longitudinal cracks, fine fatigue cracking	NA	25***	-	40
IH 20	1.5	Pothole (not from E-Krete), smooth surface texture	Uniform, moisture damage	26	-	50

* Value in parenthesis from the short PG 76-22 section

** Value in parenthesis from conventional microsurfacing

*** Value from measurement 1 year before

NA - Not applicable

'-' Data not available

A brief summary of the performance of each project is shown as follows:

Texarkana-CAM (7 yrs.)

- The oldest project studied.
- Overall looks good. At this age, reflective cracking is expected.
- This CAM mix is suitable for implementation.

Lufkin-CAM (3 yrs.)

- Generally looks good (no cracking).
- Localized shoving by a stop sign.
- Poor skid resistance (SN_{40} = 17).
- This CAM mix may have some stability issues, despite passing the Hamburg test, and is not suited for high speeds for safety reasons.

Uvalde-CAM (3 yrs.)

- Generally looks good.
- One area with rippled surface and minor cracking.
- This CAM is suitable for implementation if distresses were construction related.

Mt. Pleasant-CAM (2 yrs.)

- No cracking
- Flushing problems where the surface treatment was pushed down into the CAM.
- The mix narrowly passed the Hamburg test (rutting = 12.4 mm) and may have been designed too soft.
- This pavement combination (surface treatment on soft CAM) should be avoided.

College St.-CAM (<1 yr.)

- Some wheel path cracking (moderate to severe fatigue in existing pavement).
- Rutting/shoving at signalized intersection.
- Fair skid resistance (SN_{50} = 25).
- Given site conditions, mix is well-balanced against cracking and rutting.

Atlanta-Fine SMA (1.5 yrs.)

- Major flushing problems caused by high temperatures, mix design, and construction issues.
- Very poor skid resistance (SN50 = 11), though the small section constructed with a higher grade binder and without the warm mix additive had much better skid resistance (SN50 = 37).
- Parts of the SMA were stripped.
- Mix alterations in the field should first be tested in the lab.
- Mix design process should be further evaluated with warm mix additives.

Austin-CMHB-F (2 yrs.)

- Looks good and appears suitable for implementation

Lubbock-NM OGFC (4 yrs.)

- Looks great and appears suitable for implementation.

Del Rio-MicroTekk (1 yr.)

- Transverse cracking coming through one MicroTekk Flex section and fatigue cracking in a MicroTekk section.
- A comparison of MicroTekk and MicroTekk Flex is inconclusive

Atlanta-E-Krete (1.5 yrs.)

- Several signs of cracking and surface wear after a very short time.
- Skid resistance acceptable (SN_{50} around 25 to 35.)
- E-Krete has acceptable skid but is not as durable as other mixes in this report.

The following list touches on the important trends observed.

- All the mixes studied, except College St.-CAM, MicroTekk, MicroTekk Flex, and E-Krete, had good cracking resistance.
- Rutting, shoving, and flushing were observed on some CAMs and may have been avoided with a lower asphalt content. This could have been achieved using a lower design density or by applying the balanced performance design approach.
- The skid resistance of CAMs is generally lower than for other mix types; however, some CAMs had acceptable skid resistance even for high speeds. It may be possible to design this property into CAMs.
- When constructed correctly, the skid resistances of fine SMA, fine PFC, CMHB-F, NM OGFC, MicroTekk, MicroTekk Flex, and E-Krete are good.
- The behavior of thin overlays with warm mix additives is not well understood.

SUMMARY

The purpose of this chapter was to report the findings from Task #3, *Performance Evaluations on Existing TxDOT Projects*. In this task, the research team evaluated 11 existing fine-graded overlay projects. The types of overlays studied included CAMs, fine SMAs, fine PFCs, a CMHB-F, MicroTekk, MicroTekk Flex, and E-Krete. Information was gathered on traffic and climate conditions, the surface conditions prior to construction, mix design specifics, construction issues, and the in-service overlay performance.

The key findings made during this evaluation are as follows:

- Several CAM projects with rutting, flushing, or shoving problems were likely over-asphalted for a surface application. By lowering the design density or applying the balanced performance design approach, the CAM designs would have lower asphalt contents.

- All the projects studied, except one CAM, MicroTekk, MicroTekk Flex, and E-Krete, had good cracking resistance.
- The skid resistance of CAMs is generally lower than for other mix types, however, some CAMs had acceptable skid resistance even for high speeds.
- When constructed correctly, the skid resistance of fine SMA, fine PFC, CMHB-F, NM OGFC, MicroTekk, MicroTekk Flex, and E-Krete are good.

CHAPTER 4
LABORATORY EVALUATION OF THIN HMA OVERLAYS

OVERVIEW

This chapter presents the findings from Task #4, *Laboratory Evaluation of Thin Hot Mix Layers*. The first part of this task was a trial run of the proposed draft specifications for thin overlay mix designs. (The first draft of the specifications was developed based on findings from the literature and information search and evaluations of existing projects, and was submitted previously as 0-6615-P1 (*23*).) Five aggregate materials of variable quality were each used to design three types of thin overlay mixes (fine DGM, fine SMA, and fine PFC). The resulting mixes were then subjected to rutting, cracking, raveling, and permeability performance tests at OAC and at OAC+0.5 percent. Additional tests were performed to characterize skid and noise properties of slab specimens. In the end, the findings will be used to modify the draft specifications, and successful designs can be implemented in later experimental sections.

In the second part of this task, two supplementary studies were conducted to address specific questions about thin overlay mix design. The first evaluated the effects of using screenings of varying quality and gradation in fine SMA. One of the main issues in the design of fine SMA is finding a good match between the coarse and fine aggregates to achieve compaction both in the lab and in the field. The researchers and others in the industry have had difficulty designing these mixes because these tend to be very stiff. The second study evaluated the effects of substituting reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS) into fine SMA and fine PFC mixes. TxDOT and the industry are always looking for ways to reduce material costs, and substituting in recycled aggregate is currently a very popular option for thicker dense-graded layers. At this point, however, districts have been hesitant to introduce these lower quality materials into high performance-critical overlays.

This chapter is divided into the following sections: *Trial Run of Proposed Mix Design Specification*, *Effect of Screenings in Fine SMA, Effect of RAP and RAS Substitution,* and *Summary*.

TRIAL RUN OF PROPOSED MIX DESIGN SPECIFCATIONS

This section presents the procedures used in the trial run of the proposed specifications for thin overlay mix design. This involved using five materials to design three thin-overlay mix types each, and running various tests on the designs. The section then presents the results.

Procedures

This sub-section presents materials information, and details mix design and testing procedures.

Materials

The five primary aggregate materials used for testing are described in Table 4.1 with the respective aggregate properties obtained from TxDOT's Bituminous Rated Source Quality Catalog. The materials include igneous aggregate (Hoban and Jones Mill), limestone aggregate (Eastland and Texas Crushed Stone [TCS]), and a sandstone aggregate (Delta). All the materials, except TCS met the minimum aggregate quality requirements in the specification. These materials were sampled from stockpiles of Grade 5, Grade 6, F-Rock, and screenings, and then processed in the lab.

The aggregates were combined in the amounts given in Table 4.2 to meet the gradations for fine DGM, fine SMA, and fine PFC. On average, the fine DGMs had 45 and 55 percent coarse and fine aggregate, respectively; the fine SMAs had 65 and 35 percent coarse and fine aggregate, respectively; and the fine PFCs had 100 percent coarse aggregate. All mixes used PG 76-22 binder from either the Alon or Lion refineries. The only exception is the Jones Mill fine DGM, which used a modified PG 76-22S binder from Wright. The fine SMAs, fine FPCs, and one fine DGM also incorporated lime and/or fibers.

The mix gradations are shown in Table 4.3 and the associated percent passing graphs are shown in Figures 4.1 through 4.3. The fine DGM gradations for the Delta, Jones Mill, and TCS mixes were very similar. The Hoban fine DGM retained more material on the No. 8 sieve than the other fine DGMs, and the Eastland fine DGM retained more materials on the No. 16 and No. 30 sieves but had less material passing the No. 200 sieve. The fine SMA gradations were most variable on the No. 4 and No. 8 sieves and below the No. 200 sieve. The Hoban and Delta fine SMAs had more aggregate on the No. 4 sieve than other fine SMAs; the Eastland and Jones Mill mixes had more on the No. 8 sieve; and the Eastland and Delta mixes had very little material passing the No. 200 sieve. These last two mixes actually are out of specification and do not have inadequate amounts of fines. The fine PFCs are composed of aggregate on the No. 4 and No. 8 sieves. The Hoban, Delta, and TCS mixes have most aggregate retained on the No. 4 sieve. The Eastland and Jones Mill mixes had nearly equal amounts of aggregate retained on both sieves.

Table 4.1. Aggregate Properties.

Material Name	**Aggregate Type**	**Source**		**Properties**			
		Producer	Quarry	SAC	RSLA	RSSM	RSMD
Hoban	Rhyolite Gravel	Capitol Aggregate	Hoban	A	20	10	8
Eastland	Limestone	Vulcan	Eastland	B	25	13	16
Delta	Sandstone	Capitol Aggregate	Delta	A	20	7	12
Jones Mill	Quartzite	Martin Marietta	Jones Mill	A	17	5	8
TCS	Limestone	Texas Crushed Stone	Feld	B	33	21	24

SAC - Surface Aggregate Classification

RSLA - Rated Source Los Angeles Abrasion

RSSM - Rated Source Soundness Magnesium

RSMD - Rated Source MicroDeval

Table 4.2. Mix Composition.

Mix Type	Mix Name	Aggregate Composition	 Quarry	Asphalt	Other
Fine DGM	Hoban	65% Gr 6 35% Scrn	Hoban Turner	Alon 76-22	-
	Eastland	30% Gr 5 70% Man. sand	Eastland	Alon 76-22	-
	Delta	35% Gr 5 64% Scrn	Delta	Lion 76-22	1% lime
	Jones Mill	45% F-Rock 55% Scrn	Jones Mill	Wright 76-22S	-
	TCS	45% F-Rock 25% Scrn 30% Scrn	TCS Servtex	Alon 76-22	-
Fine SMA	Hoban	60% Gr 6 40% Scrn	Hoban Turner	Alon 76-22	0.3% fibers
	Eastland	60% Gr 6 40% Man. sand	Eastland	Alon 76-22	0.3% fibers
	Delta	65% Gr 5 34% Scrn	Delta	Lion 76-22	1% lime 0.3% fibers
	Jones Mill	68% F-Rock 23% Scrn 8% Fines	Jones Mill	Alon 76-22	1% lime
	TCS	70% F-Rock 29% Scrn	TCS	Alon 76-22	1% lime 0.3% fibers
Fine PFC	Hoban	100% Gr 5	Hoban	Alon 76-22	0.3% fibers
	Eastland	100% Gr 5	Eastland	Alon 76-22	0.3% fibers
	Delta	99% Gr 5	Delta	Lion 76-22	1% lime 0.3% fibers
	Jones Mill	99% F-Rock	Jones Mill	Alon 76-22	1% lime 0.3% fibers
	TCS	100% F-Rock	TCS	Alon 76-22	0.3% fibers

Table 4.3. Mix Gradations.

		Percent Passing (%)						
		Sieve Size						
Mix Type	**Mix Name**	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Fine DGM	Hoban	99.9	80.8	40.4	24.0	17.2	13.1	8.2
	Eastland	99.3	83.9	60.0	33.8	19.2	10.5	3.1
	Delta	99.7	74.3	52.9	36.8	26.3	17.3	4.2
	Jones Mill	98.0	73.7	51.6	34.3	23.2	16.5	8.4
	TCS	100.0	73.8	49.5	37.1	27.6	19.7	9.6
Fine SMA	Hoban	99.7	53.4	34.2	22.7	17.3	13.4	7.6
	Eastland	98.7	67.8	35.6	20.1	11.6	6.5	2.3
	Delta	99.4	52.4	29.7	20.7	15.1	10.3	3.2
	Jones Mill	100.0	65.7	34.1	23.7	16.8	12.3	7.6
	TCS	100.0	59.4	29.1	21.4	16.6	13.4	9.2
Fine PFC	Hoban	94.5	30.2	4.8	1.0	0.4	0.3	0.2
	Eastland	97.8	46.4	3.4	1.9	1.6	1.5	1.3
	Delta	99.8	25.2	4.2	3.8	3.2	2.5	1.6
	Jones Mill	99.8	54.4	10.7	5.2	4.2	3.8	3.2
	TCS	100.0	42.0	2.6	2.0	1.9	1.8	1.7

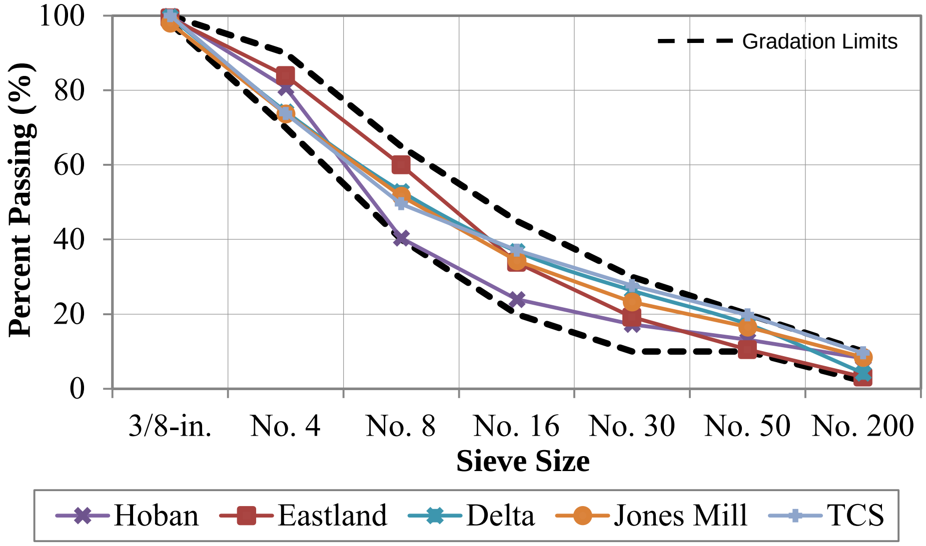


Figure 4.1. Fine DGM Gradation Curves.

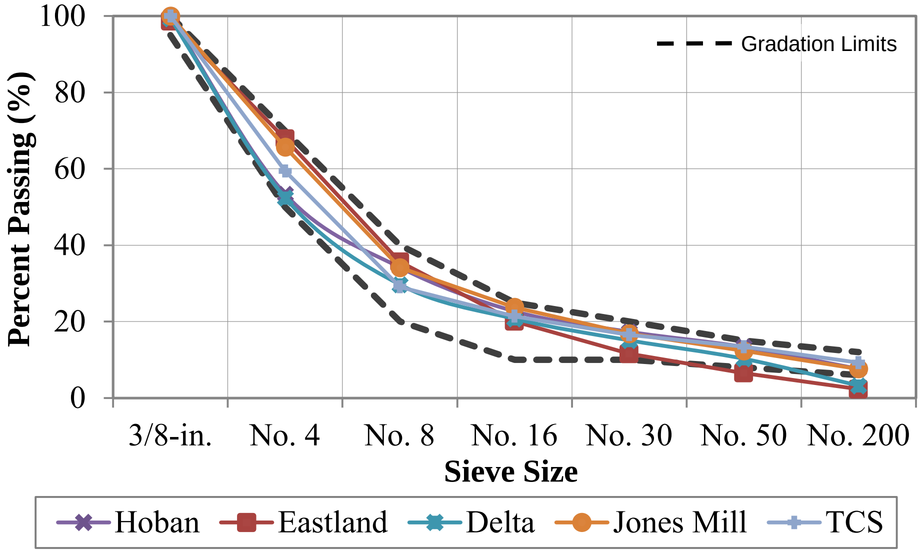


Figure 4.2. Fine SMA Gradation Curves.

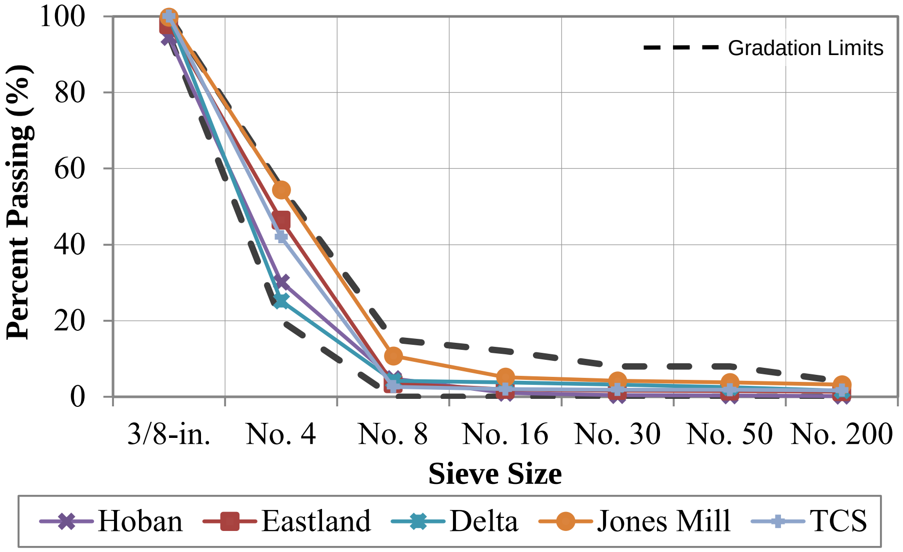


Figure 4.3. Fine PFC Gradation Curves.

Mix Design

As recommended in the proposed specifications, Tex-204-F was followed to determine the OAC of each mixture composition. This involved compacting each mixture in a gyratory compactor at various asphalt contents and selecting the OAC based on the sample density relative to a theoretical maximum density. For this task, the fine DGMs were compacted with 50 gyrations in the SGC and the OAC was chosen from a design density of 96.5 percent. The fine SMAs were compacted in the Texas gyratory compactor (TGC) and the design density was 96.5 percent. The fine PFCs were compacted with 50 gyrations in a SGC and the acceptable design density range was 72 to 76 percent. The density for the fine PFC samples was calculated dimensionally based on the compaction height in the SGC. In this task, the OAC determined by the design density is termed "OAC_D." This is different than the final recommended OAC, termed "OAC_R," which was determined following performance testing.

Performance Testing

The mix designs were assessed with the following performance tests and analyses:

- Hamburg wheel-tracking test (HWTT).
- Overlay test.
- Cantabro test (fine PFCs only).
- Permeability test (fine PFCs only).
- Skid and polishing resistance test.
- Tire-pavement noise characteristics analysis.

The results of the first four tests were used to determine the recommended asphalt content, OAC_R.

Hamburg Wheel Tracking Test. The HWTT is a mandatory test for all TxDOT HMA mix designs. It evaluates both rutting and moisture susceptibility by rolling a steel wheel over the surface of asphalt samples submerged in hot water. Duplicate specimens were molded and tested in general accordance with Tex-248-F. The fine DGM and fine SMAs were subjected to 20,000 passes and the fine PFCs to 10,000 passes. Failure was defined as 12.5 mm (0.5 inch) rutting. In most cases, the mixes were molded at OAC_D and OAC_D+0.5 percent, but in some cases the tests were performed over a wider range of asphalt contents and the results at OAC_D and OAC_D+0.5 percent were interpolated.

Overlay Test. The overlay test is recommended to assess the reflective cracking resistance of the mix. It involves fixing the bottom of a small 38-mm (1.5-inch)-thick asphalt specimen to two loading plates, which apply a cycling tensile strain. This represents the strain induced on a new HMA layer placed over an existing crack during temperature cycling. The specimen is tested until it has substantially cracked (a 93 percent loss of original tensile load capacity) up to a maximum of 1,000 cycles. Above 1,000 cycles, the number of cycles to failure can be predicted by advanced polynomial extrapolation. All mixes were required to last a minimum of 300 cycles. As in the HWTT, samples for this test were run most often at OAC_D and OAC_D+0.5 percent, but in some cases other asphalt contents were chosen and the results interpolated.

For fine DGMs and fine SMAs, the testing results at OAC_D and OAC_D+0.5 percent were then evaluated and OAC_R was determined.

Cantabro Test. The Cantabro test was conducted on fine PFC samples as described in Tex-245-F. The test is a surrogate measure of raveling potential. A 115-mm (4.5-nch) SGC sample is placed in an empty Los Angeles abrasion machine for 10 minutes and the mass loss is recorded. Samples with greater than 20 percent mass loss may exhibit durability problems. All mixes but the Eastland fine PFC were tested at OAC_D.

Permeability Test. The permeability of the fine PFCs was assessed using the Florida falling-head permeameter (Figure 4.4). Testing was accomplished in general accordance with FM 5-513 (Florida Method of Test for Coefficient of Permeability – Falling Head Method). A prepared 4.5-inch SGC sample is placed in a cylindrical tube, and voids between the sample and the tube are carefully sealed with petroleum jelly and a pressurized rubber membrane. Water is allowed to flow through the top of the sample and out the bottom. The time it takes a column of water to drain through the sample is used to compute the coefficient of permeability, which is reported in cm/s × 10^{-5}.

At this point, the testing results for fine PFCs at OAC_D and OAC_D+0.5 percent were evaluated and OAC_R was determined.

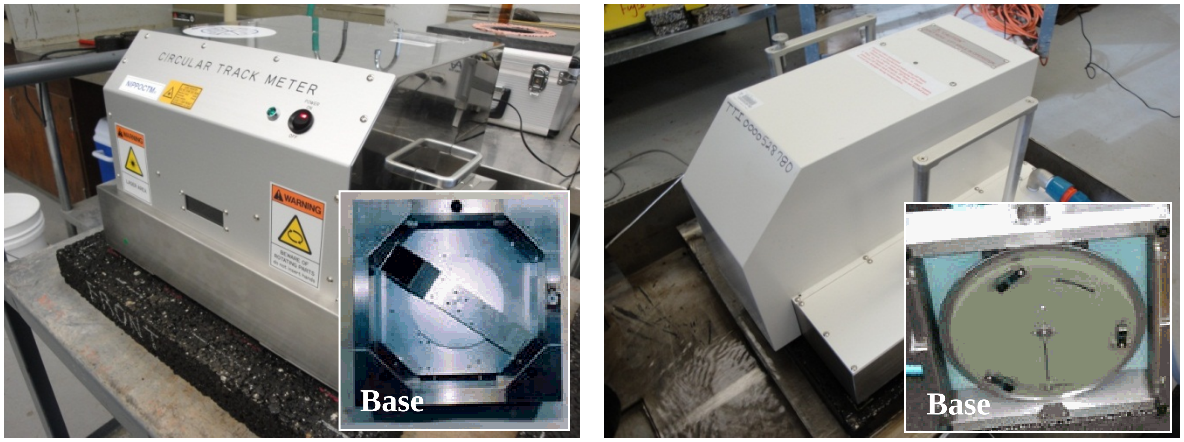
Figure 4.4. Florida Falling-Head Permeameter.

Skid and Polishing Resistance Test. The skid and polishing resistance tests were performed on large slab specimens at OAC_R or, in cases where no design was recommended, at the "next best" asphalt content as selected by the researcher. The slab was molded with a PMW Linear Compactor as shown in Figure 4.5, with 7 percent air voids for fine DGMs and fine SMAs. For fine PFCs, the air voids were the same as for samples at OAC_D under 50 SGC gyrations. The tests are described as follows.

Skid resistance can be evaluated in terms of the international friction index (IFI), which is calculated from a combination of texture depth and friction measurements (ASTM E1960). Texture depth can be measured by a circular track meter (CTM) shown in Figure 4.6a. The portable device uses a laser scanner to measure the texture depth along a 280-mm (11-inch)-diameter circular track. The measurements are then used to calculate the mean-profile depth. The wet coefficient of friction can be measured by a dynamic friction tester (DFT), shown in Figure 4.6b. A circular disk equipped with three calibrated skid pads is freely rotated up to 90 km/h (55 mph), and is then lowered onto a wet surface and allowed to slow to a stopped position. During deceleration, the resistance force is measured and used to calculate the friction coefficient at different speeds. Equations 1 and 2 show the IFI calculations.

After initial testing, the slabs are placed in a three-wheel polisher, shown in Figure 4.7, to simulate traffic wear. The device runs three load-bearing tires over a slab in a constant turning

Figure 4.5. PMW Linear Compactor for Molding Slabs.



(a) Circular Track Meter **(b) Dynamic Friction Tester**

Figure 4.6. Testing Equipment.

(a) Three-Wheel Polisher **(b) Polished Slab**

Figure 4.7. Slab Polishing.

motion. Water is applied to the surface to simulate wet conditions and to wash away abraded particles. Each slab was polished a total of 100,000 cycles and tested after 5,000; 10,000; 20,000; 50,000; and 100,000 cycles.

$$S_p = 14.2 + 89.7 * MPD \tag{1}$$

Where:

S_p = Speed constant of wet pavement friction
MPD = Mean profile depth, mm (output of CTM)

$$F60 = A + B * FRS * e^{[(S-60)/S_p]} \tag{2}$$

Where:

$F60$ = Wet friction at 60 km/h
A and B = Calibration constants for friction testing device
(A = 0.081 and B = 0.732 for the DFT)
FRS = Friction measured by the device (DFT) at slip speed S
S = Slip speed of the equipment, km/h

Tire-Pavement Noise Characteristics Analysis. The tire-pavement noise analyses were performed on the same slab specimens just discussed, but prior to polishing. Tire-pavement noise generation and amplification can be partially predicted from pavement surface texture and porosity. Noise potential was therefore assessed with the CTM and slab void content. From the raw CTM data, the texture spectrum was calculated through the procedures described in International Standards Organization (ISO) 13473-4 (Characterization of Pavement Texture by Use of Surface Profiles: Spectral Analysis of Surface Profiles). The texture levels at a long and short wavelength (63 and 4 mm, respectively) were calculated. High texture levels at long wavelengths tend to generate low frequency noise while low texture levels at high wavelengths generate high frequency noise.

The Estimated Road Noisiness Level (ERNL), similar to the peak noise level for a coast-by passenger car at 7.7 m (25 ft), was calculated using Equation 3.

$$ENRL = 0.50 * L_{63} - 0.25 * L_4 - q \ln(\Omega d) + 67 \qquad (3)$$

Where:

$ENRL$ = Estimated road noisiness level (approximately dBa)
L_{63} = Texture level in octave band centered at 63 mm wavelength, ref. level of 10_{-6} m rms
L_4 = Texture level in octave band centered at 63 mm wavelength, ref. level of 10_{-6} m rms
q = Constant, which is
0 for $\Omega d \leq 4.5$
4.7 for $4.5 < \Omega d < 20$
7 for $\Omega d \geq 20$
Ω = Design air void content, %
d = Thickness of layer, mm

This equation is a slightly modified version of a noise prediction model developed in Europe (*24*). Please note that the model is not intended to predict actual noise values, but should rather be used to compare noise potential between surfaces. In this study, the ENRL values for the fine DGMs (supposedly the smoothest non-porous mixes in the study) were averaged together, and the difference in ENRL from this average was calculated for every mix.

The impedance tube, shown in Figure 4.8, was used to measure the acoustic absorption properties of the fine PFCs directly. White noise is transmitted through the tube and reflected off the material surface. Two microphones measure the sound intensity from 400 to 1,600 Hz before and after the reflection and are used to compute the percentage decrease in sound intensity, or absorption. A plate attachment and putty were used to seal the tube-pavement interface. Five readings at different locations of the slab were made and averaged together and each reading was the average of three measurements. A few of the fine DGM and fine SMA slabs were also measured for comparison purposes.

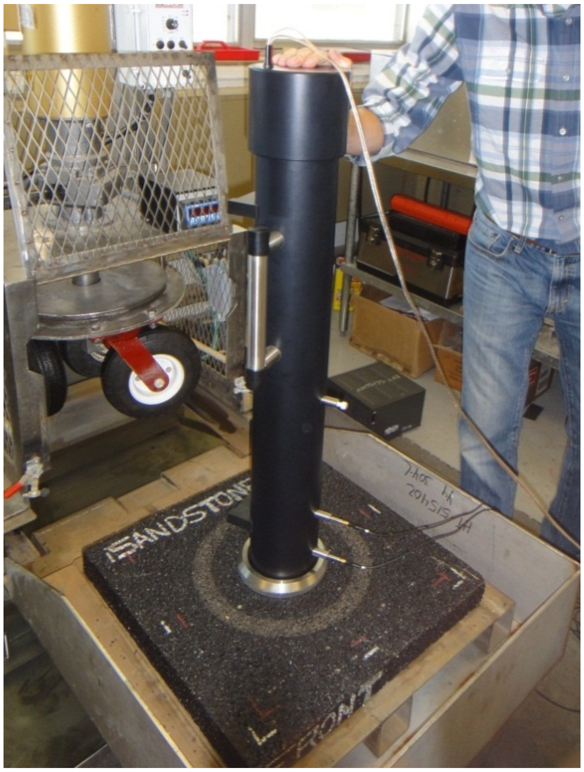


Figure 4.8. Acoustic Impedance Tube.

Results

This sub-section presents the mix design results. The discussion is first organized by mix type (fine DGMs, fine SMAs, and fine PFCs) and reports the results for the HWTT, OT, Cantabro (fine PFC), and permeability tests (fine PFC). The skid and polishing results, and the tire-pavement noise and noise absorption results are then presented. Finally, a summary of the key findings is given.

Fine DGMs

Table 4.4 shows the OAC_D percentages for the fine DGMs, as determined by Tex-204-F, along with relative density and theoretical maximum density. Three of the mixes had an OAC of

Table 4.4. Optimum Asphalt Contents from Design Density for Fine DGMs.

Mix Name	OAC_D* (%)	Relative Density (%)	Theoretical Maximum Density (%)
Hoban	8.8	96.5	2.260
Eastland	8.1	96.5	2.390
Delta	6.8	96.5	2.462
Jones Mill	6.8	96.5	2.432
TCS	6.8	96.5	2.379

* Based on density from 50 SGC gyrations

6.8 percent, while the other two were greater than 8.0 percent. OAC is highly dependent on aggregate gradation, angularity, hardness, and absorption characteristics. In this case, the Delta, Jones Mill, and TCS materials had similar gradations while the Hoban material was coarser and the Eastland material was finer. Eastland and TCS are limestone aggregates and are more absorptive than the other aggregates.

The fine DGM performance results in the HWTT and overlay test are shown in Figures 4.9 and 4.10. Results for the Hoban and Eastland materials at OAC+0.5 percent are not available. At OAC, all but the TCS mix rutted less than 12.5 mm in the HWTT. The Eastland and Delta mixes passed the test but were near failure. At OAC+0.5 percent, both Delta and TCS mixes

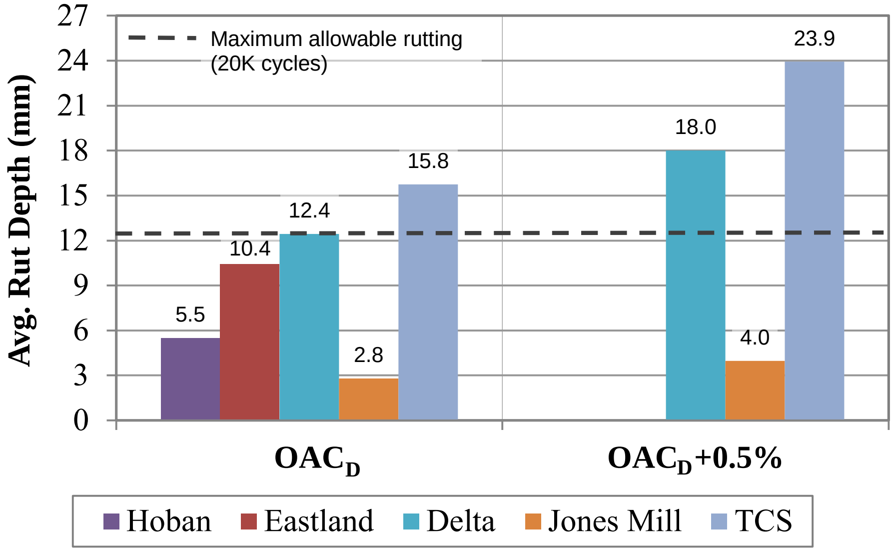


Figure 4.9. Rutting Resistance Results for Fine DGMs.

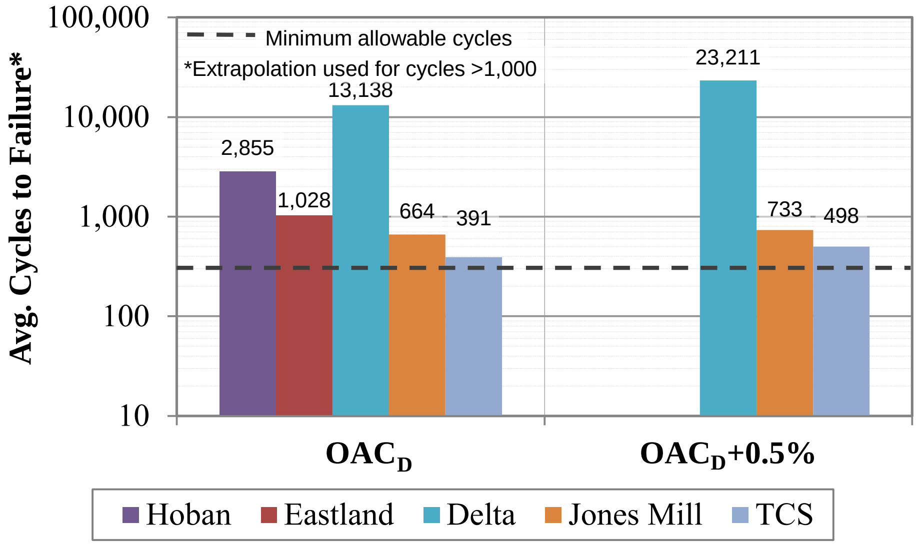


Figure 4.10. Cracking Resistance Results for Fine DGMs.

failed. The Eastland mix would likely have failed at OAC+0.5 percent. In the overlay test, all mixes at OAC_D met the 300 cycle requirement. The Delta mix has exceptional performance at both asphalt contents.

In light of the performance results, the OAC_R percentages are shown in Table 4.5. The Hoban mix easily passed both tests at OAC_D; therefore, OAC_R is slightly lower to mitigate the risks of bleeding and decrease mix costs. At this content, the mix is still expected to pass the OT. The Eastland mix easily passed the overlay test, but could have rutting problems. The final OAC_R therefore was slightly lower than OAC_D. The Delta mix passed has no problems in cracking, but is susceptible to rutting at both OAC and OAC+0.5 percent; therefore, the recommended OAC is lower to guard against these rutting problems. The Jones Mill mix had no problems in rutting or cracking. The TCS mix did not perform satisfactorily in rutting for any of the asphalt contents tested, and was very near cracking failure at OAC_D; therefore, no acceptable design was recommended.

Table 4.5. Recommended Optimum Asphalt Contents for Fine DGMs.

Mix Name	**OAC_D (%)**	**OAC_R (%)**	**Performance Problems**
Hoban	8.8	**8.5**	None
Eastland	8.1	**7.9**	Possible rutting > 8.1%
Delta	6.8	**6.5**	Rutting at 6.8%
Jones Mill	6.8	**6.8**	None
TCS	6.8	**NA**	Rutting at 6.8%, probably cracking < 6.8%

NA - No acceptable design recommended

Fine SMAs

The OAC percentages and densities for the Fine SMA mixes, as determined by Tex-204-F, are shown in Table 4.6. Four of the mixes had an OAC between 5.9 and 6.3 percent, while the last one, TCS, was 7.5 percent. The reason for the higher OAC may be that the weaker TCS aggregate experienced crushing during compaction.

Table 4.6. Optimum Asphalt Contents from Design Density for Fine SMAs.

Mix Name	**OAC_D* (%)**	**Relative Density (%)**	**Theoretical Maximum Density (%)**
Hoban	6	96.8	-
Eastland	6	96.8	2.428
Delta	6.3	96.8	2.430
Jones Mill	5.9	96.5	2.489
TCS	7.5	96.5	2.345

* Based on density from TGC

The fine SMA performance results in the HWTT and overlay test are shown in Figures 4.11 and 4.12. Results for the Hoban materials at OAC are not available. All the fine SMAs passed the HWTT with no problems. This is characteristic of mixes with a strong coarse aggregate skeleton. In the overlay test, the Delta, Jones Mill, and TCS mixes passed the 300-cycle requirement, with the former two mixes performing exceptionally well. The Eastland mix failed the overlay test at both asphalt contents and the Hoban mix failed at OAC_D+0.5 percent.

In light of the performance results, the OACR percentages are shown in Table 4.7. The Hoban mix had cracking problems at OAC_D+0.5 percent (6.5 percent); therefore, OAC_R is 7.0 percent. Subsequent testing of the mix at this asphalt content had an average of 300 cycles. The Eastland mix, like Hoban, did not pass the overlay test at OAC_D (6.0 percent) or OAC_D+0.5 percent (6.5 percent).

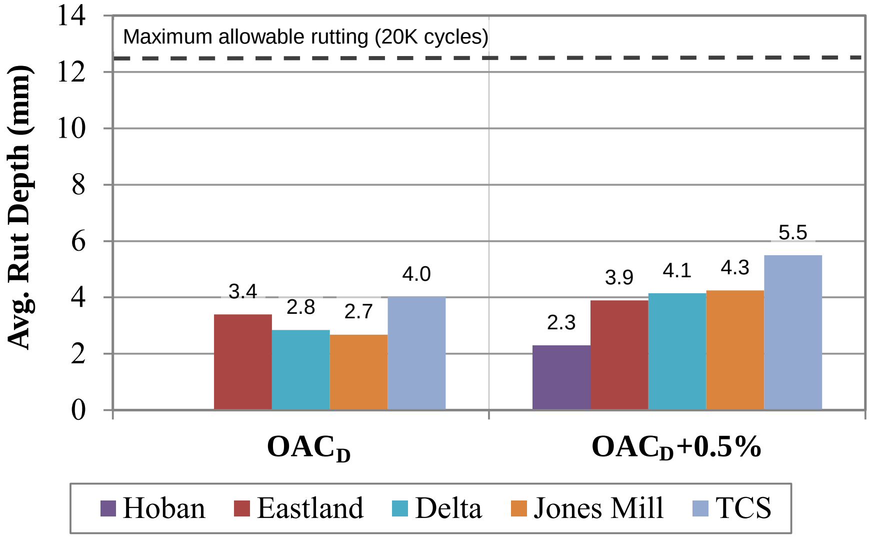


Figure 4.11. Rutting Resistance Results for Fine SMAs.

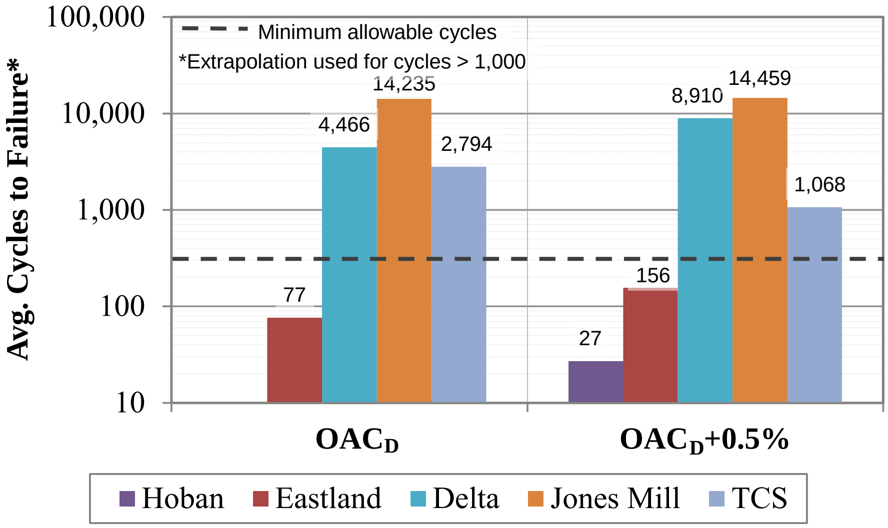


Figure 4.12. Cracking Resistance Results for Fine SMAs.

Table 4.7. Recommended Optimum Asphalt Contents for Fine SMAs.

Mix Name	OAC_D (%)	OAC_R (%)	Performance Problems
Hoban	6.0	**7.0**	Cracking at 6.5%
Eastland	6.0	**7.2**	Cracking at 6.0% and 6.5%
Delta	6.3	**6.3**	None
Jones Mill	5.9	**6.0**	None
TCS	7.5	**7.5**	None

Subsequent testing at 7.0 percent had an average of 260 cycles; therefore, a slightly higher asphalt content of 7.2 percent was recommended. The Hoban and Eastland mixes also passed the HWTT at these higher contents. All other mix designs passed the performance tests, therefore no change to the OAC is recommended.

Fine PFCs

The OAC_D percentages and densities for the fine PFCs, as determined by Tex-204-F, are shown in Table 4.8. For these mixes, OAC_D was selected as any asphalt content resulting in a density between 72 and 76 percent. The exception, however, was the Eastland mix, which was designed at the same time as the Hoban mix. Both used 6.5 percent asphalt to evaluate the effect of aggregate type, alone, on mix performance.

The fine PFC performance results in the HWTT and overlay test are shown in Figures 4.13 and 4.15. All mixes had less than 12.5 mm rutting after 10,000 HWTT cycles at OAC_D, and all but the Hoban and Jones Mill mixes passed at OAC_D+0.5 percent. These results, however, do not fully characterize the mix behavior as shown by this Jones Mill mix at OAC_D in Figure 4.14. Though the mix did not rut according to the HWTT definition, it did have excessive shoving, coming up and out of the mold as much as 1 inch. Many of the fine PFC mixes exhibited this behavior and may result in problems if placed in the field. All mixes passed the overlay test and the Jones Mill mixes had exceptional cracking resistance performance.

The Cantabro and Florida falling-head permeability results are shown in Figures 4.16 and 4.17. The Eastland mix was not tested for Cantabro mass loss and the Hoban mix was not tested

Table 4.8. Optimum Asphalt Contents from Design Density for Fine PFCs.

Mix Name	OAC_D* (%)	Relative Density (%)	Theoretical Maximum Density (%)
Hoban	6.5	74.0	2.292
Eastland	6.5	77.8	2.431
Delta	6.5	74.0	2.373
Jones Mill	6.1	75.1	2.440
TCS	6.3	74.0	2.395

* Based on density from 50 SGC gyrations

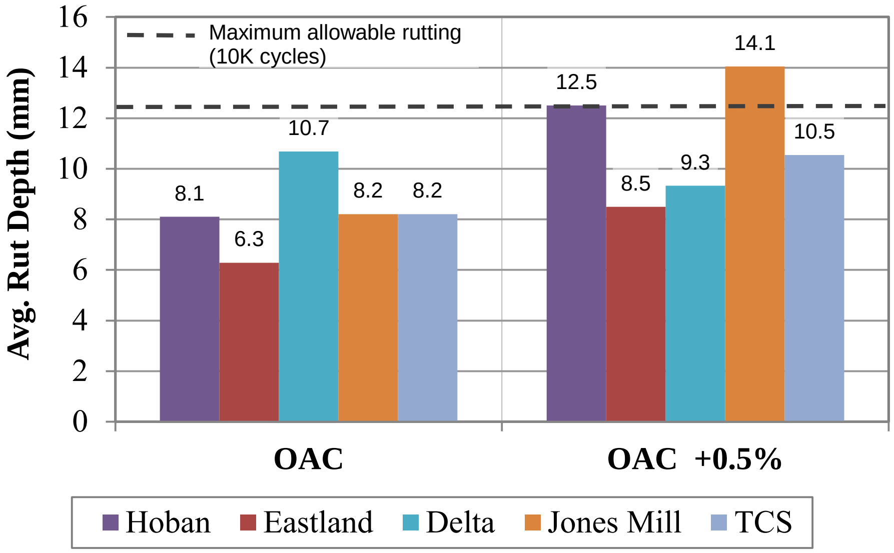


Figure 4.13. Rutting Resistance Results for Fine PFCs.

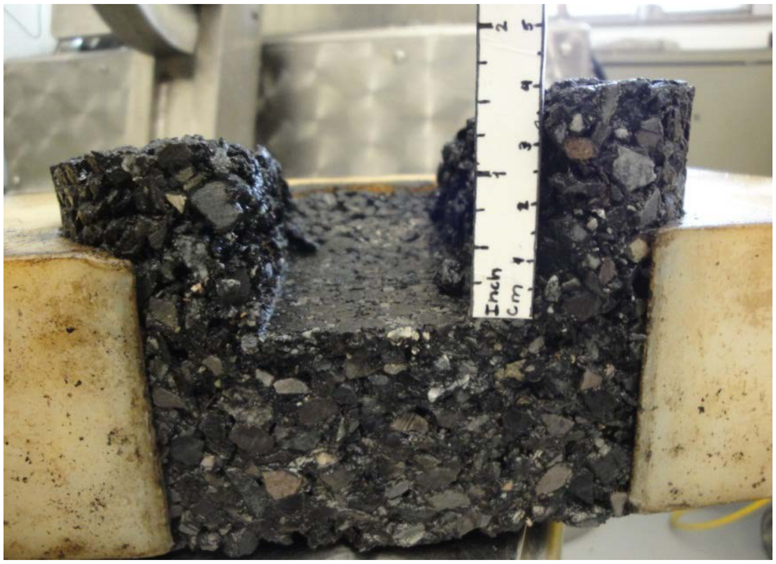


Figure 4.14. Example of Shoving in Jones Mill Fine PFC.
(*Note: This particular picture was taken after 15,000 cycles, but this behavior was also noted after 10,000 cycles.*)

for permeability. Based on the Cantabro results, the Hoban and TCS mixes at OAC_D are potentially susceptible to raveling. However, the Hoban aggregates have been used widely in PFCs in the Odessa District for many years with little or no reported raveling, raising questions about the validity of this test. The Delta and Jones Mill mixes, on the other hand, did pass the test. The permeability of the tested samples was very high. The Jones Mill mix had the lowest permeability, likely because of the slightly higher density. Though the Eastland mix had an even higher density, testing procedures were slightly different for this mix, omitting the step of cutting off the sample ends. This step is thought to close up some of the voids on the ends.

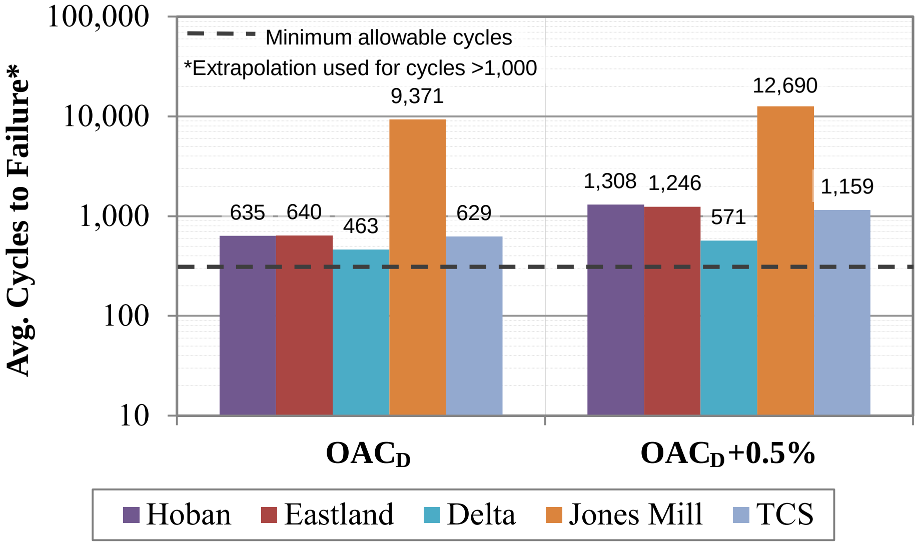


Figure 4.15. Cracking Resistance Results for Fine PFCs.

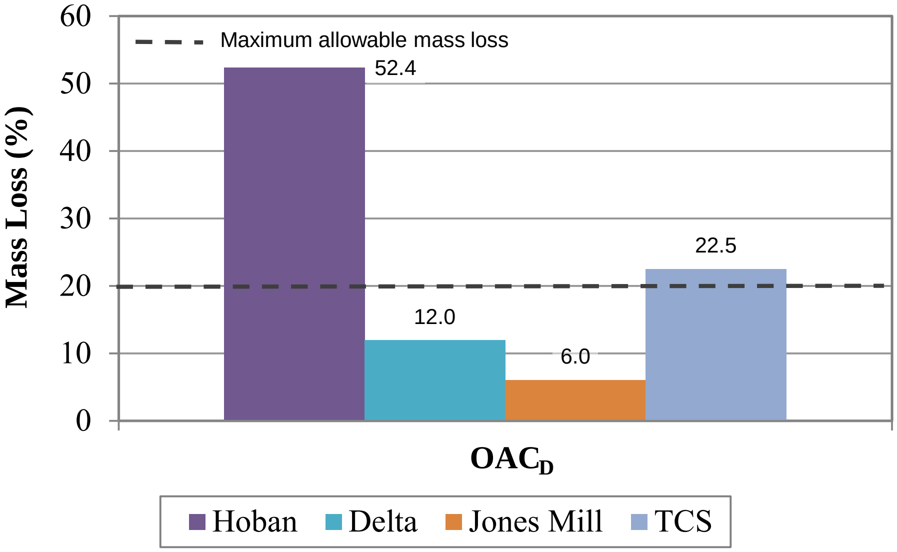


Figure 4.16. Raveling Resistance Results for Fine PFCs.

In light of the performance results, the OAC_R percentages are shown in Table 4.9. Based on the Cantabro test, the Hoban mix exhibited potentially severe raveling problems and rutting; therefore, no acceptable design is recommended. The Eastland mix performed well in rutting and cracking but the raveling properties are still unknown; OAC_R is the same as OAC_D. The Delta mix performed well in all the tests; therefore, no change in OAC is recommended. This mix showed signs of shoving, but not rutting, in the HWTT. The Jones Mill mix also passed all the tests. It had exceptional cracking resistance and had signs of potential shoving from the Hamburg test. The recommended OAC is 6.0 percent, the minimum allowable asphalt content and slightly lower than the original OAC. The TCS mix had potential raveling problems at OAC_D, but is

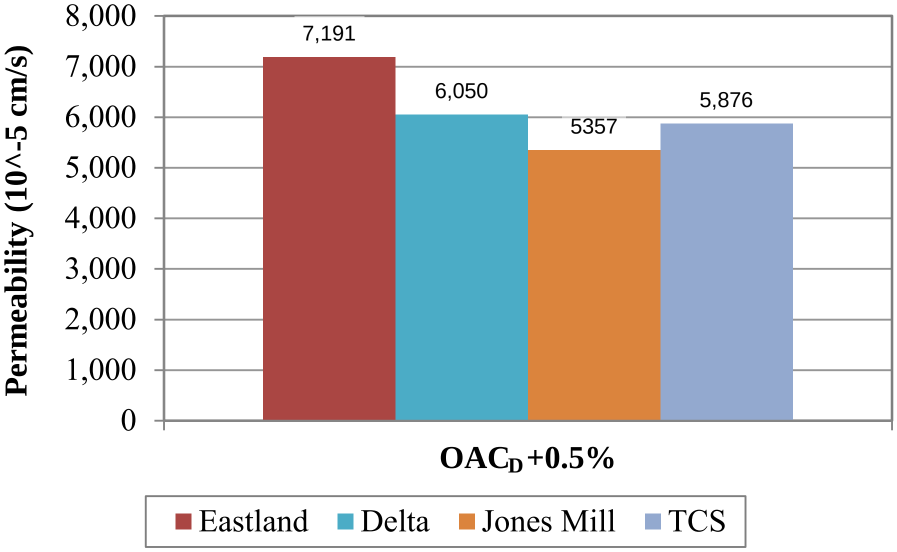


Figure 4.17. Permeability Results for Fine PFCs.

Table 4.9. Recommended Optimum Asphalt Contents for Fine PFCs.

Mix Name	OAC$_D$ (%)	OAC$_R$ (%)	Performance Problems
Hoban	6.5	**NA**	Raveling at 6.5% and rutting at 7.0%
Eastland	6.5	**6.5**	Unknown raveling properties
Delta	6.5	**6.5**	Possible shoving
Jones Mill	6.1	**6.0**	Possible shoving, possibly too dense
TCS	6.3	**NA**	Raveling, possible shoving, aggregate crushing

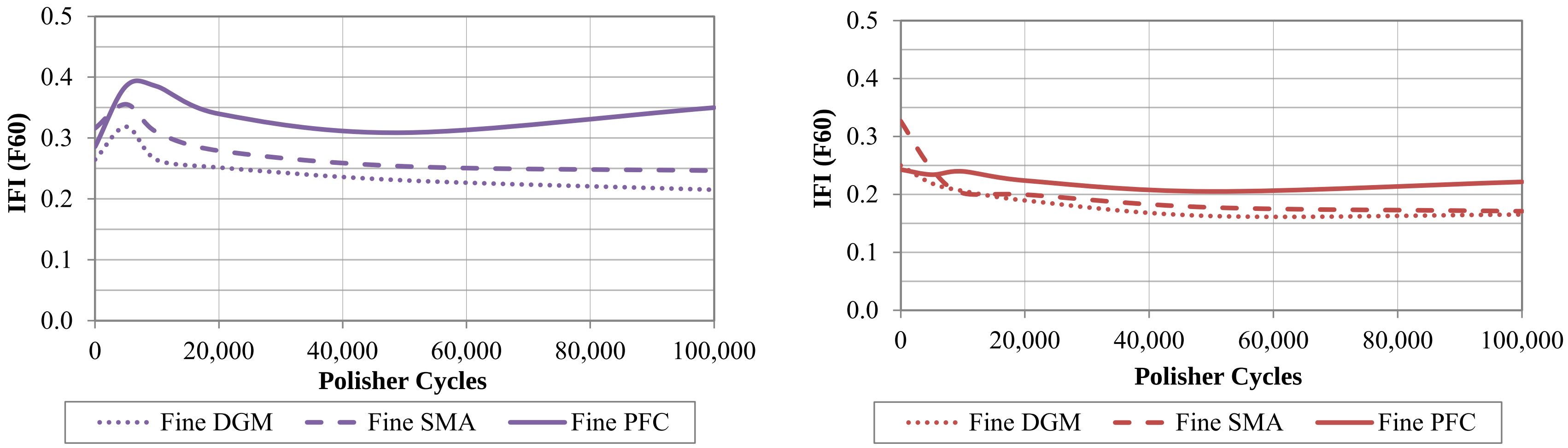
NA - No acceptable design recommended

shoving problems. In addition, the TCS aggregate showed signs of crushing after compaction. Though a TCS design passing the tests may be possible to find, the mix would likely have marginal performance; therefore, no design is recommended.

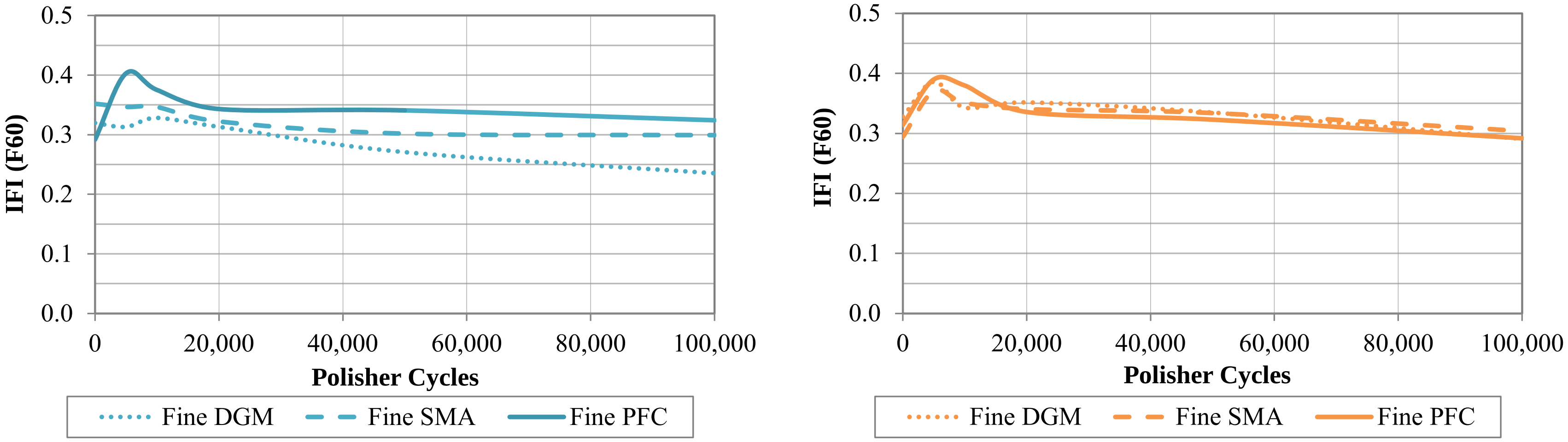
Skid and Polishing Resistance

Figure 4.18 shows the skid resistance and polishing resistance results. Each graph represents one aggregate type and each line in the graph represents the mix type for that aggregate. Figure 4.19 compares the average results for each aggregate type. The skid resistance is reported as the F60 component of IFI, which is the estimated friction value at 60 km/h.

Before any polishing occurs, the skid resistance is highly influenced by the presence of the thin film of asphalt covering the aggregate. After 5,000 cycles, the film is removed and the results then reflect the aggregate properties. This discussion addresses the results following 5,000 polisher cycles. For the Hoban (a), Delta (c), and Jones Mill (d) mixes, the aggregate has a base IFI of 0.3 to 0.4. After 100,000 cycles, the long-term IFI is anywhere between 0.2 and 0.35. For

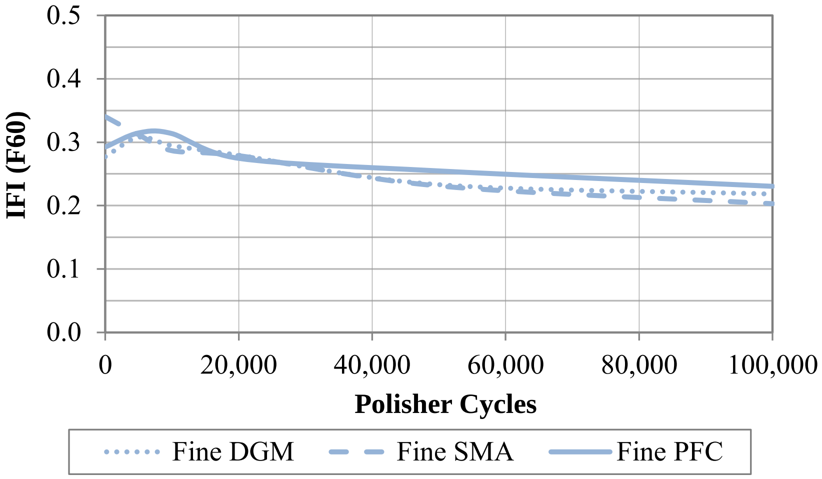


(a) Hoban **(b) Eastland**



(c) Delta **(d) Jones Mill**

Figure 4.18. Skid Resistance of Mix Designs with Polishing.



(e) TCS

Figure 4.18. Skid Resistance of Mix Designs with Polishing (cont.)

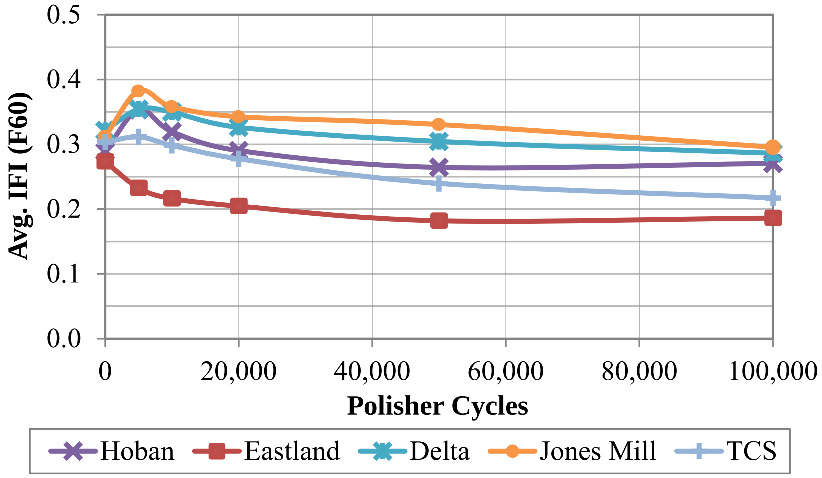


Figure 4.19. Comparison of Average Skid Resistance by Aggregate Type with Polishing.

the TCS (e) mix, the aggregate has a base IFI around 0.3 and a polished IFI less than of 0.25. For the Eastland (b) mixes, the aggregate has a base IFI below 0.25 and a polished IFI around 0.15. There does not seem to be a given mix type (fine DGM, fine SMA, fine PFC) that consistently performs better than the others. For the Hoban mix, the find PFC has much better performance; however, in the Jones Mill mixes, the fine PFC is the poorest performer. Similarly, the Delta-fine DGM mix performs worse than the other Delta mixes, however, this trend is not observed for the other aggregate types. Most often, it seems mix type makes little difference to skid and polishing resistance.

The ranking of best to worst performing aggregates is first, Jones Mill; second, Delta; third, Hoban; fourth, TCS; and fifth, Eastland. This generally corresponds with the aggregate properties reported in Table 4.1 and with field performance. The Abilene District has reported skid concerns on IH 20 with mixes where the Eastland rock was used. These results confirm the importance of the current surface aggregate classification system in predicting skid resistance. The SAC A aggregates are the three best performers and the SAC B did substantially worse. However, the researchers are aware that some SAC B aggregates, like dolomitic limestone, can also have acceptable performance.

Finally, Figure 4.20 gives the skid results for each mix type, averaging results of all aggregate types together. Based on these results, there is little difference in skid resistance, except after 100,000 cycles, among fine DGMs, fine SMAs, and a fine PFCs. This finding goes contrary to the popular belief that fine PFCs have superior performance than the other mix types. Field results may or may not follow this same trend.

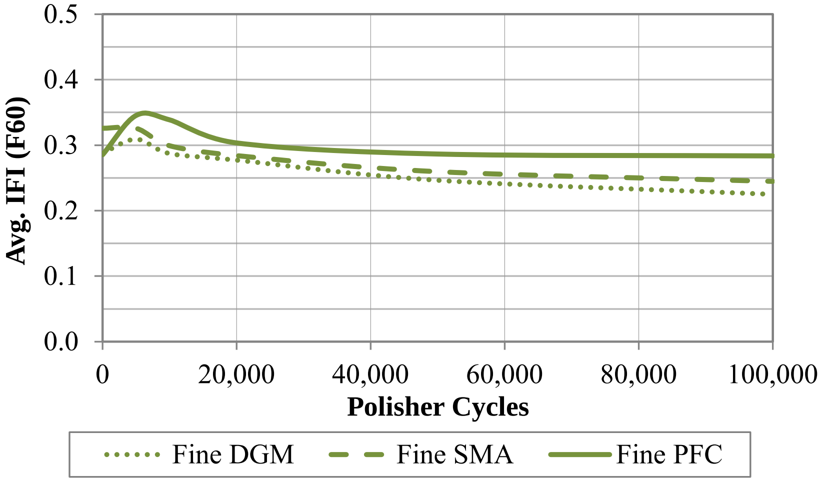


Figure 4.20. Comparison of Average Skid Resistance by Mix Type with Polishing.

Tire-Pavement Noise Characteristics

Tire pavement noise is a function of both the surface texture and the noise absorption of the surface layer. Figure 4.21 shows the results of the tire-pavement noise analysis. This graph shows the predicted difference in noisiness from a baseline average. The average was taken from the five fine DGMs, as these would normally be the smoothest dense-graded mixes in the study. All the fine SMAs are expected to be slightly noisier than the fine DGMs, by as much as 2.6 dBA. This is because the fine SMAs have more coarse aggregate and result in higher texture levels at longer wavelengths. The fine PFCs, on the other hand, are all expected to be quieter than the fine DGMs, by as much as 6.7 dBA. Though these surfaces are coarser than the other mix types, the permeable surface is expected to absorb much of the noise. Without this effect, the fine PFCs would be nearly 7 dBA noisier.

Figure 4.22 shows the noise absorption properties for the fine PFCs and a few impermeable mixes. The fine PFCs have average absorption values around 60 percent, which is much higher than the values for the fine DGMs and fine SMAs tested. While these values were

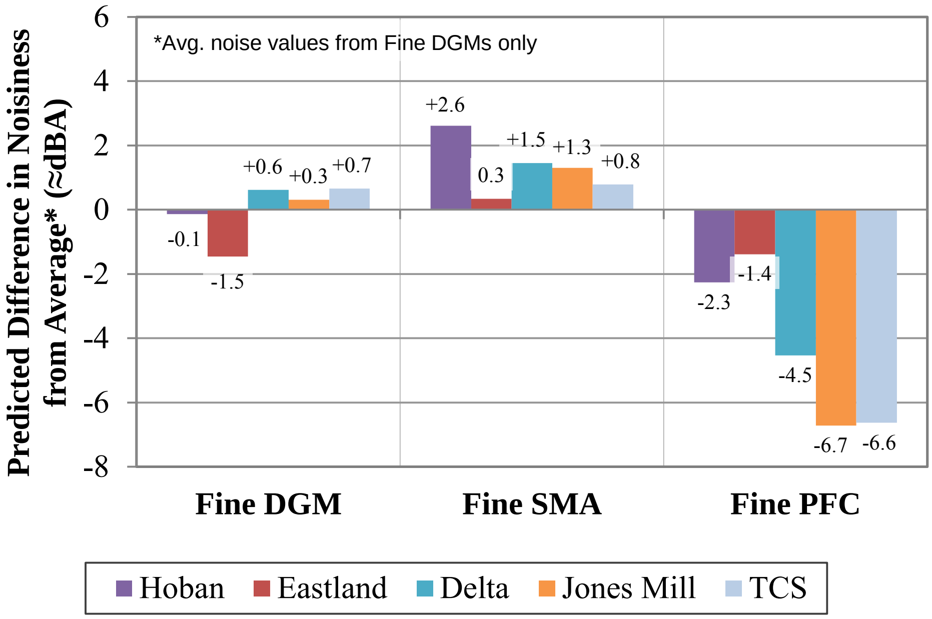


Figure 4.21. Comparative Predicted Pavement Noisiness.

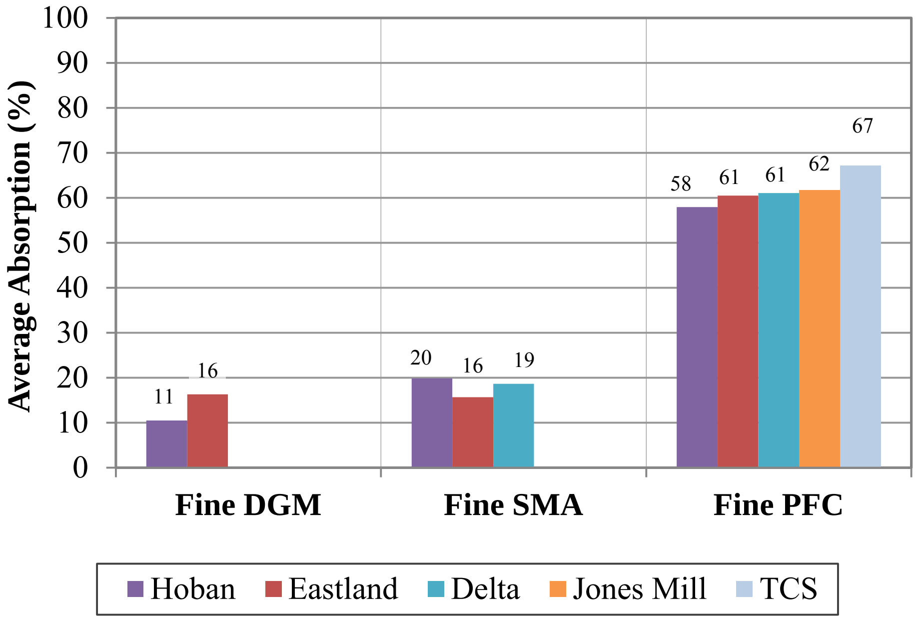


Figure 4.22. Acoustic Absorption Results.

the average absorption levels across all frequencies tested (400 to 1,600 Hz), the peak absorption levels were as high as 93 percent for a given frequency. The resonant frequency, the frequency with the greatest absorption, for all mixes was slightly above 600 Hz. Absorption values were between 30 and 50 percent around 400, 1,400, and 1,600 Hz.

Results Summary

Table 4.10 summarizes the results. The table indicates whether an acceptable design was determined for each mix, identifies the performance problems when no design was recommended or possible problems with the proposed designs, and reports the skid and noise properties. Of the 15 mixes, 12 were successfully designed, suggesting that the proposed specifications provide good guidelines for materials selection, design, and testing. The one material that did not meet the materials specification to begin with (TCS) had failed mixes for both fine DGM and fine PFC. On the other hand, the two mixes below the percent passing No. 200 specification for fine SMA (Delta and Eastland) did not have any indication of unacceptable compactability or performance. This may suggest that the fines requirement on the fine SMA could be relaxed.

The failed fine DGM design had cracking and rutting issues, and the two failed fine PFC designs had raveling and rutting/shoving problems. Based on observations in the laboratory, many of the fine PFCs had possible shoving problems, where the mix passed the HWTT but exhibited excessive displacement of the mix up and out of the testing molds. Other research projects are under way to address the appropriateness of the HWTT in predicting shear failure. The fine SMAs were all successfully designed and have very good rut-resistant properties, though the Hoban and Eastland mixes were designed near the cracking failure threshold. Overall, many mixes had excellent cracking resistance with overlay test cycles > 1,000.

The specifications have screened out three unacceptable mixes; however, it is not possible to say whether these mixes actually have unacceptable performance without some sort of field implementation. The same should be said about acceptable mixes. Will all these have acceptable field performance? Since the results in this study are similar to results obtained by TxDOT districts for successfully designed and constructed mixes, it appears the proposed specifications are functioning well.

Regarding the skid and polishing resistance results, skid resistance was highly influenced by aggregate type and not by mix type. Concerning the noise analysis, the predicted noise properties seem reasonable, where mixes with slightly coarser gradations are predicted louder and the permeable mixes are predicted quieter.

Recommendations for modifying the draft specifications are presented at the end of this chapter.

Table 4.10. Results Summary of the Proposed Mix Design Specification Trial Run.

Mix Type	Mix Name	Design Recommended?	Performance Problems	Long-Term Skid Resistance (IFI (F60))	Noisiness Relative to Fine DGM Avg. (dBA)
Fine DGM	Hoban	Y	None	0.22	-0.1
	Eastland	Y	Possible rutting	0.17	-1.5
	Delta	Y	None	0.24	0.6
	Jones Mill	Y	None	0.29	0.3
	TCS	N	Rutting and cracking	0.22	0.7
Fine SMA	Hoban	Y	Possible cracking	0.25	2.6
	Eastland	Y	Possible cracking	0.17	0.3
	Delta	Y	None	0.30	1.5
	Jones Mill	Y	None	0.30	1.3
	TCS	Y	None	0.20	0.8
Fine PFC	Hoban	N	Raveling and rutting	0.35	-2.3
	Eastland	Y	Raveling unknown	0.22	-1.4
	Delta	Y	Possible shoving	0.32	-4.5
	Jones Mill	Y	Possible shoving	0.29	-6.7
	TCS	N	Raveling, possible shoving, aggregate crushing	0.23	-6.6

EFFECT OF SCREENINGS IN FINE SMA

This section presents the procedures and results for the study of the effect of screenings with varying quality and gradation on fine SMA laboratory performance.

Procedures

Fine SMA mixes were designed with a quality coarse aggregate and one of four different screenings. The coarse aggregate was a Class A sandstone from the *Capitol Aggregate* Delta quarry and had a Grade 5 gradation. Each of the screenings had unique aggregate properties (see Table 4.11). The Delta screening is derived from the same parent rock as the coarse aggregate and is described as a low-fines, quality screening; Servtex is a high-fines, lower quality screening; Turner is a high-fines, lower quality screening; and Lampasas is a coarse and high-fines, quality screening.

The mix composition for all designs was 65 and 34 percent coarse and fine aggregate, respectively, 1 percent lime, 0.3 percent fibers, and used Lion PG 76-22 binder; therefore, the only difference among the mix designs was the screenings. Table 4.12 and Figure 4.23 show the mix gradations. The gradations are very similar except that the Lampasas screening mix is coarser on the No. 8 sieve, and the Delta and Turner screening mixes had low amounts passing the No. 200 sieve, falling just out of specification.

Table 4.11. Aggregate Properties.
(Screenings in Fine SMA)

Material Name	Aggregate Type	Aggregate Properties				Fines Content
		SAC	RSLA	RSSM	RSMD	
Delta Scrn.	Sandstone	A	20	10	8	Low
Servtex Scrn.	Limestone	B	27	14	19	Low
Turner Scrn.	Limestone	B	31	20	24	High
Lampasas Scrn.	Limestone	B	25	7	9	High

SAC - Surface Aggregate Classification
RSSM - Rated Source Soundness Magnesium
RSLA - Rated Source Los Angeles Abrasion
RSMD - Rated Source MicroDeval

Table 4.12. Mix Gradations.
(Screenings in Fine SMA)

	Percent Passing (%)						
	Sieve Size						
Mix Name	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Delta Scrn.	99.4	52.4	29.7	20.7	15.1	10.3	3.2
Servtex Scrn.	99.4	52.3	31.7	24.5	18.3	12.3	4.8
Turner Scrn.	99.4	51.5	30.8	21.0	16.3	12.9	8.0
Lampasas Scrn.	99.4	50.5	23.2	16.2	12.6	10.0	6.1

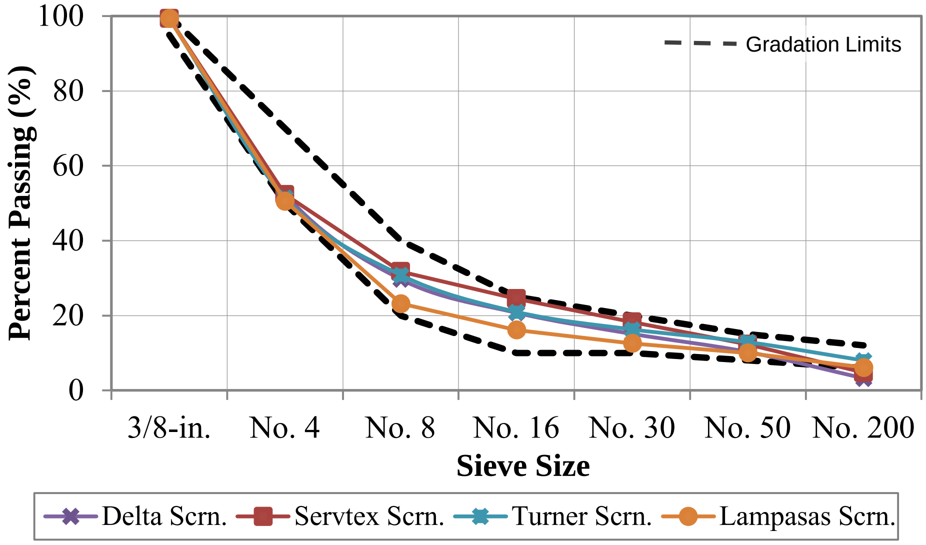


Figure 4.23. Mix Gradation Curves.
(Screenings in Fine SMA)

The OAC for each mix was determined in general accordance with Tex-204-F. Compaction was first attempted with the SGC at 75 gyrations and then with the TGC. The design density was 96.5 percent in each case. Each mix was then subjected to the HWTT and overlay test at OAC and OAC+0.5 percent.

One final aspect of this supplementary study was to evaluate the effect of slightly modifying the gradation on fine SMA compactability. Two fine SMA designs were attempted using the same Jones Mill aggregate, Alon PG 76-22 binder, and lime. The first gradation was created using 75 percent F-rock and 24 percent screenings, while the second used 68 percent F-rock and 23 percent screenings with an additional 8 percent engineered fines. The engineered fines were a blend derived from the Jones Mill screenings and mostly consisted of material passing the No. 50 sieve. The gradations, as shown in Table 4.13 and Figure 4.24, indicate the modified gradation was only slightly finer than the original gradation. Compaction at various asphalt contents was performed in the TGC, and the density curves of the two mixes were compared.

Table 4.13. Original and Modified Mix Gradations.
(Screenings in Fine SMA)

	Percent Passing (%)						
	Sieve Size						
Mix Name	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Original Gradation	100.0	67.3	29.9	18.9	13.5	10.2	6.6
Modified Gradation	100.0	65.7	34.1	23.7	16.8	12.3	7.6

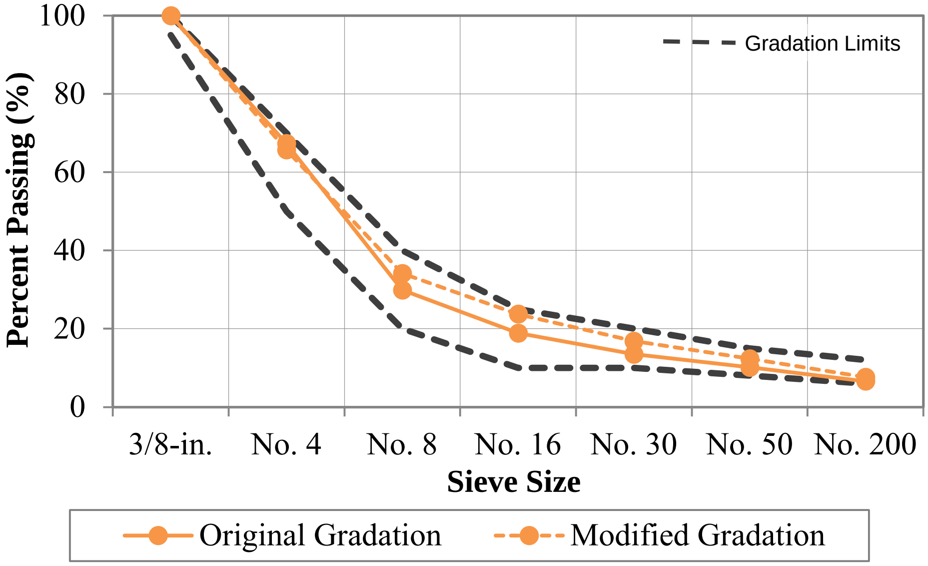


Figure 4.24. Original and Modified Mix Gradation Curves. (Screenings in Fine SMA)

Results

The gradation curves for the mixes in the SGC and TGC are shown in Figures 4.25 and 4.26, respectively. Only the Turner screening mix reached density in the SGC for the asphalt contents tested. The Lampasas screening mix, which had the coarsest gradation, was furthest from the target density. After moving to the TGC, the first three mixes had nearly identical compaction curves and had OAC values between 6.2 and 6.3 percent. Fine SMAs can be stiff and basing results off the SGC may lead to excessively high asphalt contents. The Lampasas mix was still unable to meet compaction within this range and was omitted from further testing.

The issue here is in the packing characteristics of SMA. These mixes are gap-graded, meaning they have a large portion of material on the upper sieves, a significant amount of material on the finer sieves, and little in between. When compacted, the coarse aggregate has stone-on-stone contact, forming a rigid aggregate skeleton, while the fine aggregate and binder should fill the voids left by the coarse aggregate, increasing the mix density and ensuring an impermeable layer. In the case of the Lampasas mix, the screenings were likely too coarse, leading to premature aggregate interlock, which left large voids that could only be filled by adding more asphalt. Note that this mix fit the specified gradation, even the passing 200 requirement. Careful consideration of aggregate packing characteristics is not a new concept, but is often overlooked in the mix design process.

The remaining three mixes at both tested asphalt contents performed very well in the HWTT, as shown in Figure 4.27. The differences in performance here are very small, suggesting that screening quality seems to have a negligible effect on fine SMA rutting. Concerning the overlay test results (see Figure 4.28), all but the Delta-Turner mix at OAC passed with more than 300 cycles. The best performing mix was Delta-Delta. As noted in previous research on variables

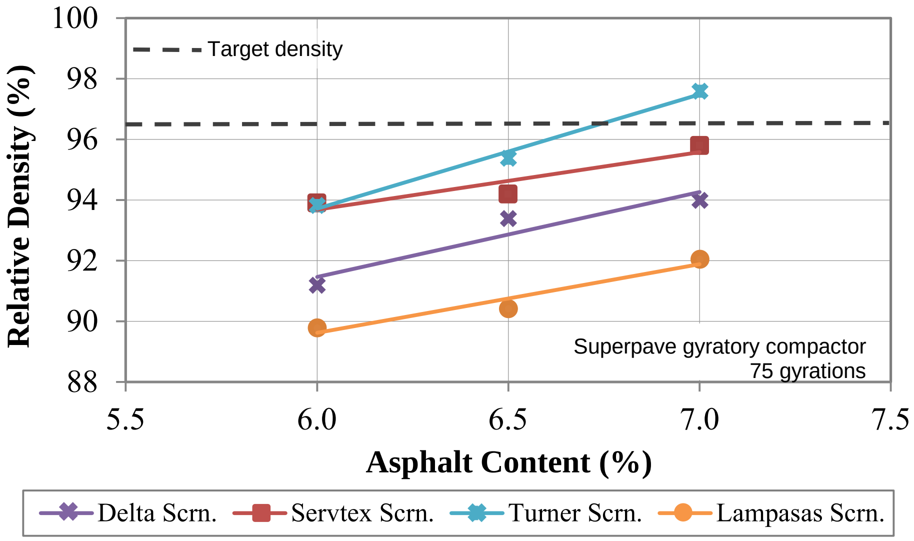


Figure 4.25. Density Curves in SGC.
(Screenings in Fine SMA)

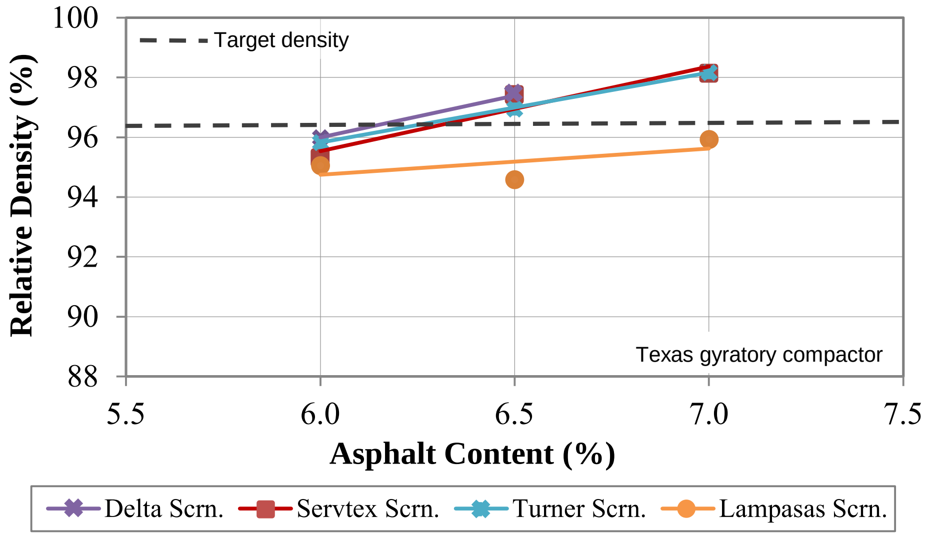


Figure 4.26. Density Curves in TGC.
(Screenings in Fine SMA)

in the overlay tester (*25*), the poorer quality aggregates absorb a portion of the binder and thus decrease the effective binder, which is required for increased flexibility. It seems screening quality does have an effect on cracking resistance, though for these mixes, most designs are still acceptable.

Most likely, the Lampasas mix would also have passed these tests. The issue is that the mix would be very difficult to compact in the field and then have permeability problems.

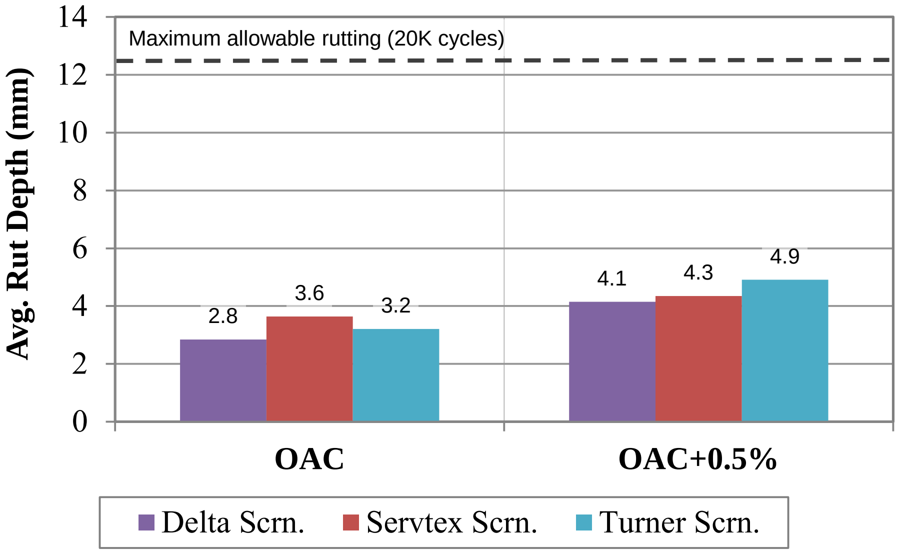


Figure 4.27. Rutting Resistance Results for Fine SMA.
(Screenings in Fine SMA)

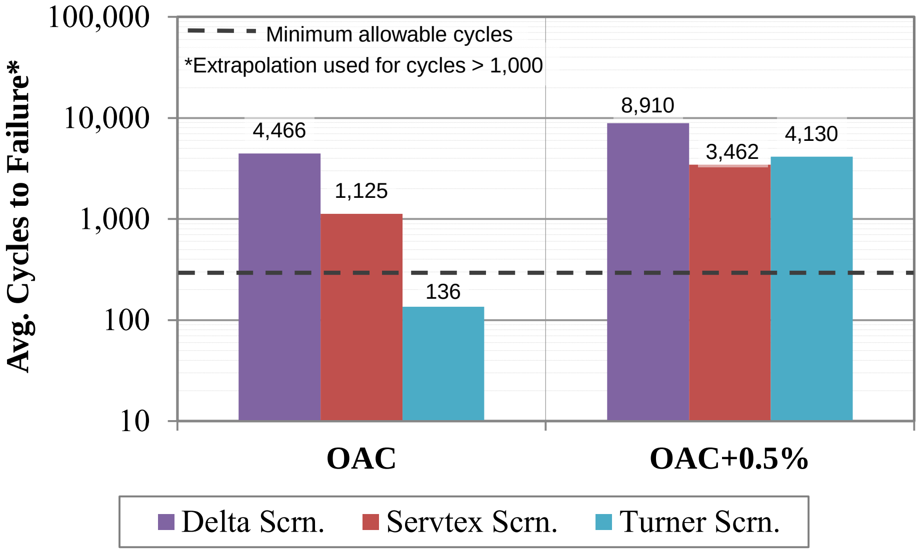


Figure 4.28. Cracking Resistance Results for Fine SMA.
(Screenings in Fine SMA)

Increasing the asphalt content would help, but would result in a more expensive mix and raise concerns of bleeding.

The last part of this study was to evaluate the effect of slightly altering the screening gradation while holding all other material properties constant. Figure 4.29 shows the density curves of the mix with the original gradation and then with a slightly modified gradation. Compactability increased dramatically from a state of refusal to near over-densification. This change occurred by reducing the material on the No. 8 sieve and increasing the materials below

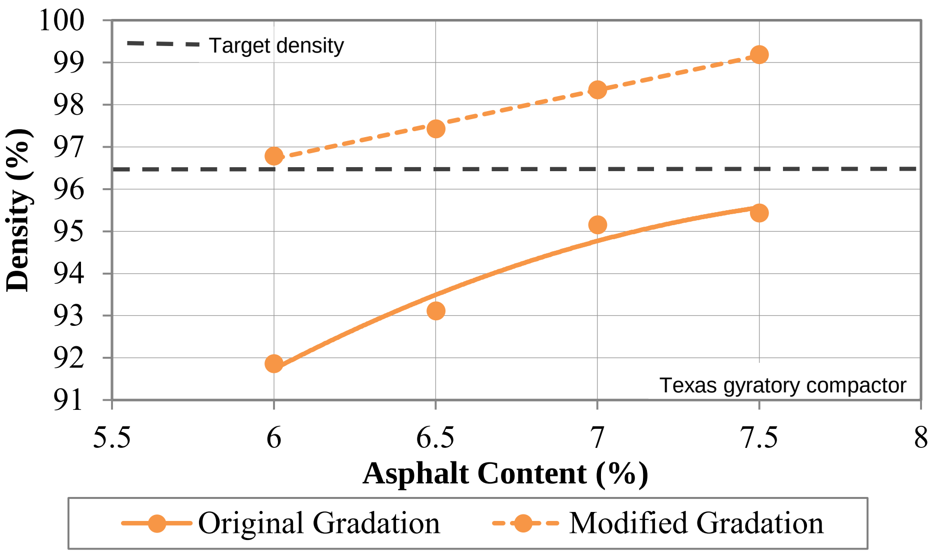


Figure 4.29. Design Density Curves for the Original and Modified Gradations. (Screenings in Fine SMA)

the No. 30 sieve. The result, once again, emphasizes the importance of packing characteristics in the design of fine SMA. The modified mix here is the same mix presented before as the Jones Mill fine SMA, which had exceptional performance, and will be further discussed in the next study.

The conclusions from this supplementary study are given later at the end of this chapter.

EFFECT OF RAP AND RAS SUBSTITUTION

This section presents the procedures and results of the evaluation of substituting RAP and RAS into fine SMAs and fine PFCs.

Procedures

Fine SMA and fine PFC mixes were first designed with no recycled aggregate, then with RAP, and then with RAS. Table 4.14 summarizes the mix compositions, and Table 4.15 shows the RAP and RAS properties. All the designs used the Class A Jones Mill aggregate and Alon PG 76-22 binder. Fine SMAs also used lime and the fine PFCs used both lime and fibers. In the SMA mixes, the "Fines" were an engineered blend derived from the Jones Mill screenings mostly consisting of material passing the No. 50 sieve, and were necessary to achieve density by filling voids in the coarse aggregate skeleton. Slightly different ratios of coarse and fine aggregate were used in the other fine SMA mixes to maintain the same overall gradation after the RAP and RAS were introduced. Maximum amounts of RAP and RAS were used based on either bulk percentages of recycled materials or percent of recycled binder, according to the new TxDOT specifications for thin overlay mixes.

The OAC was determined in general accordance with Tex-204-F. The fine SMAs were compacted in the TGC and the design density was 96.5 percent. The fine PFC with no recycled

Table 4.14. Mix Composition.
(Effect of RAP and RAS)

Mix Type	Mix Name	Aggregate			OAC (%)	Recycled Binder (%)
		Virgin Agg.	Recycled Agg.	Other		
Fine SMA	Jones Mill	68% F-Rock 23% Scrn 8% Fines	-	1% lime	5.9	0
	Jones Mill+RAP	63.7% F-Rock 15.6% Scrn 4.4% Fines	15% RAP	1% lime	5.7	11
	Jones Mill+RAS	68% F-Rock 20% Scrn 7% Fines	5% RAS	1% lime	6	15
Fine PFC	Jones Mill	99% F-Rock	-	1% lime 0.3% fibers	6.1	0
	Jones Mill+RAP	90% F-Rock	9.4% RAP	1% lime 0.3% fibers	6.1	6.5
	Jones Mill+RAS	95% F-Rock	4.3% RAS	1% lime 0.3% fibers	6.1	15

Table 4.15. Recycled Materials.
(Effect of RAP and RAS)

Material	Origin	Asphalt content (%)
RAP	Waco SH-31	4.4
RAS	Waco SH-31	19.2

aggregate was compacted in the SGC with 50 gyrations and the design density was 75 percent. The resulting OAC from this design was used for the other fine PFCs.

Each mix was subjected to the HWTT and overlay test at OAC and OAC+0.5 percent. Fine PFCs were also subjected to the Cantabro test.

Results

This sub-section gives the results for the fine SMA and then fine PFC mixes.

Fine SMA Mixes

The density curves for the fine SMAs are shown in Figure 4.30. The mixes compacted at or above the 96.5 percent density target at 6 percent asphalt. Table 4.16 presents the OAC percentages and densities. In the current specification, mixtures with asphalt contents below 6.0 percent are not allowed, but these were allowed for the purpose of this sub-study.

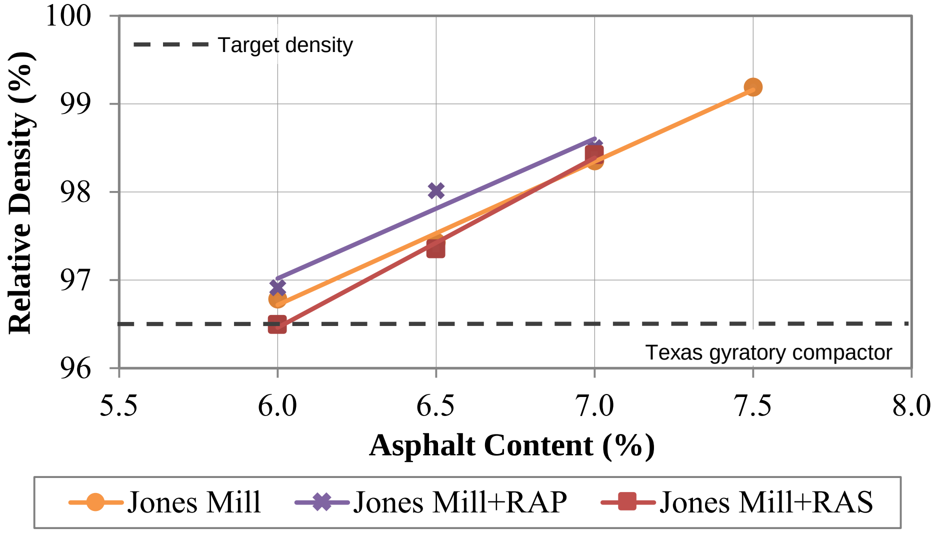


Figure 4.30. Gradation Curves of Fine SMA. (Effect of RAP and RAS)

Table 4.16. Optimum Asphalt Contents. (Effect of RAP and RAS)

Mix Name	OAC* (%)	Relative Density (%)	Theoretical Maximum Density (%)
Jones Mill	5.9	96.5	2.489
Jones Mill+RAP	5.7	96.5	2.468
Jones Mill+RAS	6	96.5	2.481

* Based on density from TGC

The HWTT and overlay test results are shown in Figures 4.31 and 4.32. All mixes at OAC and OAC+0.5 percent easily passed the HWTT with no more than 5.1mm rutting after 20,000 cycles. The Jones Mill mix and Jones Mill+RAS mix rutted slightly more than the Jones Mill+RAP mix, probably because these mixes had more virgin binder in them. All mixes passed the overlay test with a minimum of about 800 cycles up to over 10,000 predicted cycles, and should have adequate reflection cracking resistance. There is a notable decrease in overlay test performance when substituting RAP and RAS, but it is still within acceptable limits.

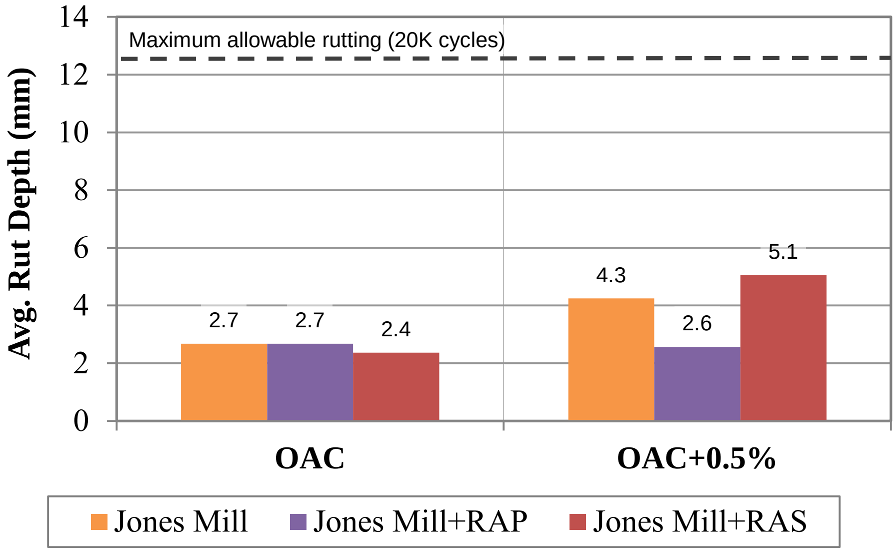


Figure 4.31. Rutting Resistance Results for Fine SMA. (Effect of RAP and RAS)

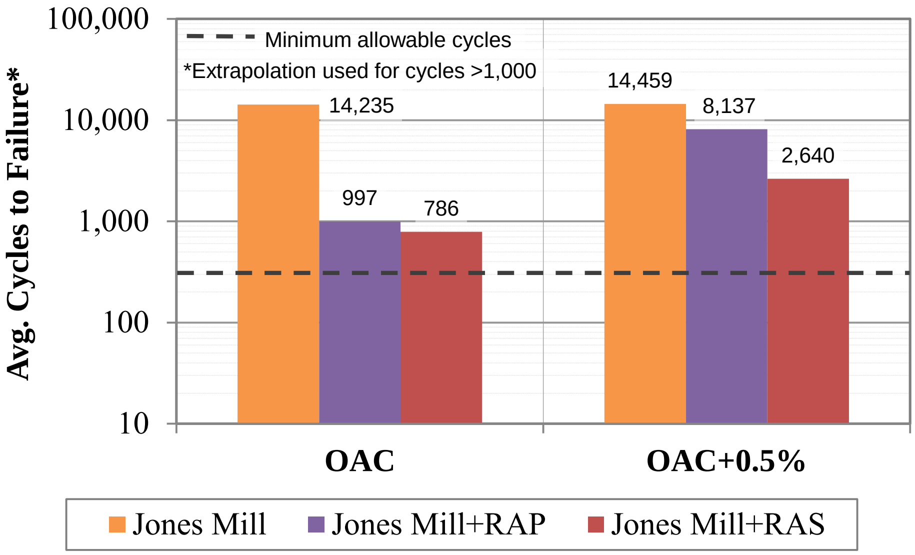


Figure 4.32 Cracking Resistance Results for Fine SMA. (Effect of RAP and RAS)

Fine PFC Mixes

Figure 4.33 shows the density curves for the fine PFC mixes. The mix gradation is on the dense-side, and only the plain Jones Mill mix had a design within the recommended density range. To correspond to previous fine PFC designs, the OAC for all mixes was selected as 6.1 percent.

The HWTT and overlay test results are shown in Figures 4.34 and 4.35. All designs but Jones Mill at OAC+0.5 percent passed the HWTT. At both OAC and OAC+0.5 percent, this mix

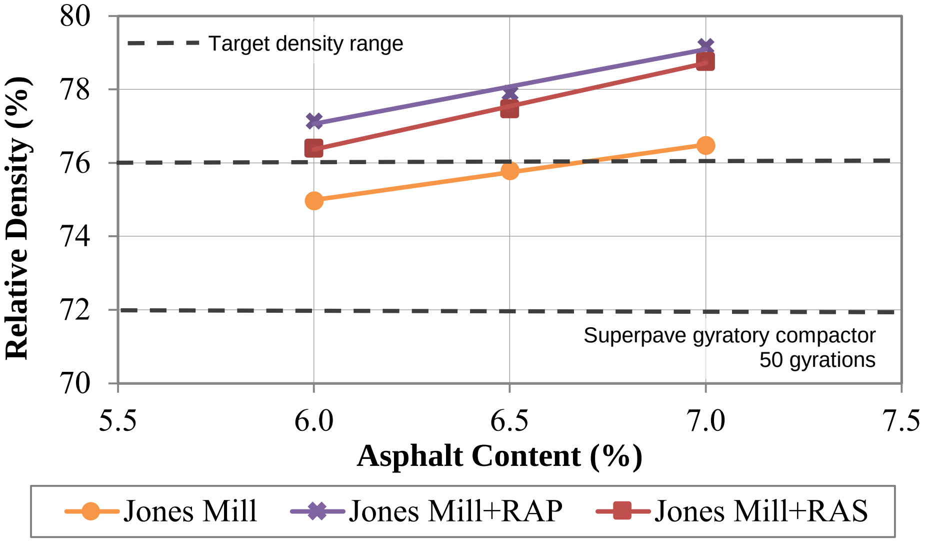


Figure 4.33. Density Curves for Fine FPC. (Effect of RAP and RAS)

showed signs of shoving. Substituting in the recycled materials clearly decreases the risks of rutting and shoving here, because of the decreased virgin binder content. Also, the recycled aggregates add material from smaller sieves that help stabilize the larger aggregate. As with the fine SMA mixes, there is a notable decrease in overlay test performance when substituting RAP and RAS, but performance is still above the minimum recommended amount. All mixes had adequate resistance to raveling (see Figure 4.36).

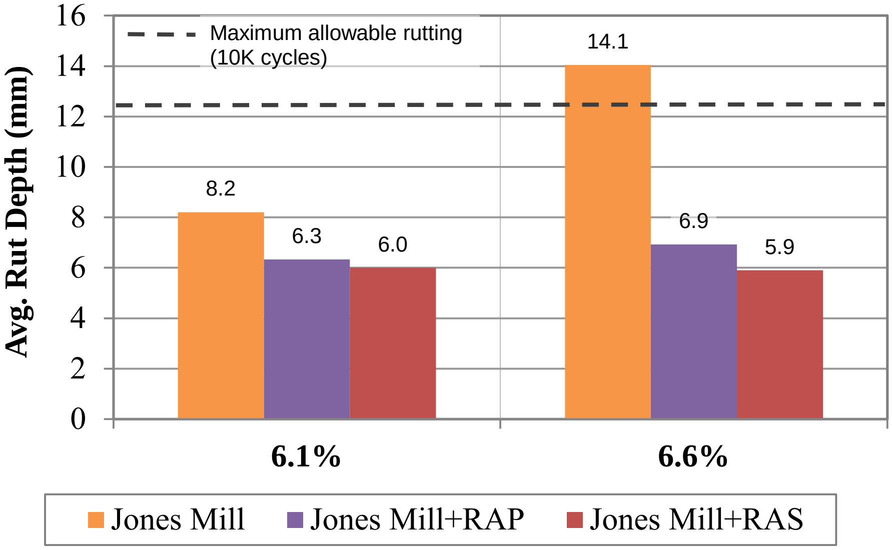


Figure 4.34. Rutting Resistance Results for Fine PFC. (Effect of RAP and RAS)

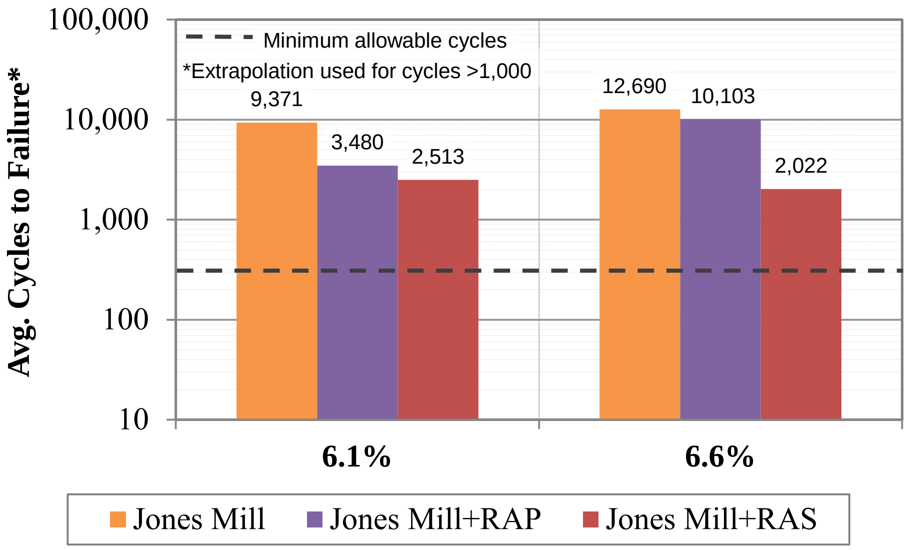


Figure 4.35. Cracking Resistance Results for Fine PFC. (Effect of RAP and RAS)

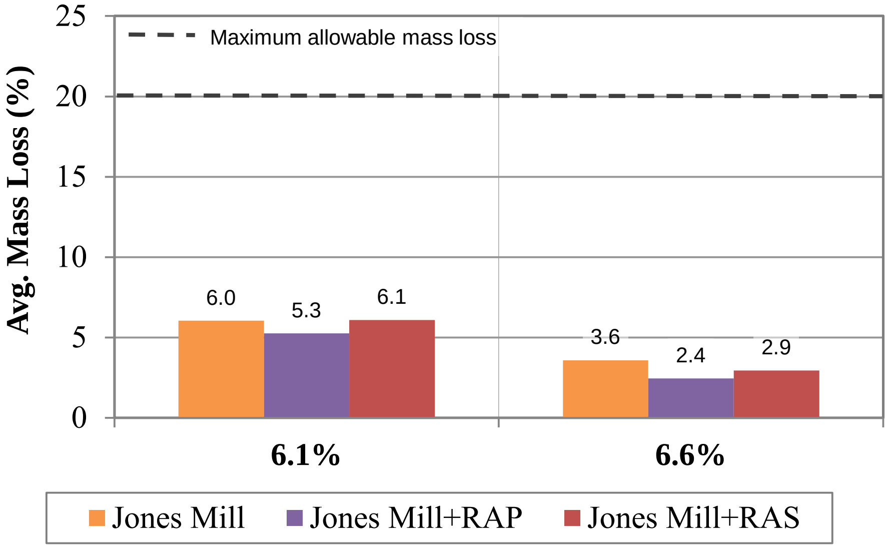


Figure 4.36. Raveling Resistance Results for Fine PFC. (Effect of RAP and RAS)

SUMMARY

The purpose of this chapter was to report the findings from Task #4, *Laboratory Evaluation of Thin Hot Mix Layers*. The first part of this task was a trial run of the proposed specifications for thin overlay mix design. In the second part of this task, two smaller supplementary studies were conducted to address specific questions about thin overlay mix design. The first evaluated the effects of using screenings of varying quality and gradation in fine SMA. The second evaluated the effects of substituting RAP and RAS into fine SMA and fine PFC mixes.

The scope of the specifications trial run involved using five materials to design three thin-overlay mix types each: fine DGM, fine SMA, and fine PFC. The OAC was first determined for each mix based on the target design density and termed "OAC_D". Rutting and cracking resistance tests were conducted for nearly all designs at OAC_D and OAC_D+0.5 percent. Fine PFC mixes were also evaluated with raveling resistance and permeability tests. The OAC of each mix was then reevaluated based on the performance results and a new recommended OAC given, termed "OAC_R". Slab samples were also created for each mix at OAC_R or, in cases where no design was recommended, at the next best asphalt content as selected by the researcher. Skid and polishing resistance tests and a tire-pavement noise analysis were conducted on each slab.

The scope of the study of screenings in fine SMA involved designing fine SMA mixes with a quality coarse aggregate and one of four screenings. Each screening had unique aggregate properties and gradations. Compaction curves were made in the SGC and TGC. Rutting and cracking resistance tests were then run at OAC and OAC+0.5 percent. Another aspect of this study evaluated the effect of slightly modifying the gradation on fine SMA compactability. Compaction curves of two designs using the same quality aggregate were done in the TGC and compared. One design was slightly finer than the other.

The scope of the RAP and RAS substitution study involved designing fine SMA and fine PFC mixes first with no recycled aggregate, then with RAP, and then with RAS. RAP contents were as high as 15 percent and RAS contents as high as 9.4 percent. Each mix was then subjected to rutting and cracking resistance tests at OAC and OAC+0.5 percent.

The findings from the thin overlay specification trial run are as follows:

- Of the 15 mixes attempted, 12 had acceptable designs.
- The one aggregate material that did not meet the minimum quality specifications had failed mixes for both fine DGM and fine PFC.
- Three of the four accepted fine DMG designs had recommended OAC values below the asphalt content as the current target density of 96.5 percent, suggesting that the design density could be lowered.
- Two fine SMAs that were below the percent passing No. 200 specification did not have compaction or performance issues, suggesting the gradation band could be lowered.
- All fine SMAs were successfully designed and none had rutting issues, though the recommended asphalt content of two mixes was much higher than the OAC+0.5 percent recommendation.
- All fine PFC mixes were compacted above 74 percent and one was above 76 percent, suggesting the design density range could be adjusted.
- Many of the fine PFC designs had possible shoving problems, where the mix passed the HWTT but exhibited excessive displacement of the mix up and out of the testing molds.

- Since the lab results in this study are similar to or better than the results obtained by TxDOT Districts for successfully designed and constructed mixes, it appears the proposed specifications, for the most part, are functioning well.
- Skid resistance was highly influenced by aggregate type and not by mix type
- The predicted noise properties seem reasonable, where mixes with coarser gradations are louder and the permeable mixes are quieter.

The findings from the study of the effect of screenings in fine SMA are as follows:

- Fine SMA mixes are very tough mixes, and are difficult to compact with the SGC. Only one mix could was successfully designed in the SGC while four were designed with the TGC.
- Small changes in the screening gradations can greatly affect the packing characteristics of fine SMA. Screenings used should not be too coarse and should have enough fine sand and fines to fill voids in the coarse aggregate skeleton. The gradation band for these mixes needs further study.
- Screening quality did not affect the rutting resistance of fine SMA.
- Screening quality did affect the cracking resistance where lower quality screenings increased crack susceptibility mix.

The findings from the study of RAP and RAS in fine SMA and fine PFC are as follows:

- Adding RAP and RAS helped reduce rutting and shoving problems in the particular fine PFC studied.
- Adding RAP and RAS increased cracking susceptibility of these particular fine SMA and fine PFC mixes.
- These mixes performed very well in most cases, suggesting that quality, well-engineered mixes can have good rutting and crack-resistant properties even when recycled materials are used in limited amounts.

Based on these findings, the following modifications to the draft specifications are proposed:

- For fine DGM, reduce the target lab molded density to 96.0 percent.
- Change the range of allowable fines for fine SMA from 6–12 percent to 4–10 percent. While the recommending fines content could be even lower, this decision could be premature.
- Add a note that fine SMA mixes may need to be evaluated at more asphalt contents than OAC and OAC+0.5 percent.
- For fine PFC, change the current range of target densities from 72–76 percent to 74-78 percent.
- Though good performance with RAP and RAS was noted, the researchers still do not recommend including recycled materials until further testing has been done.

CHAPTER 5
LABORATORY EVALUATION OF SLURRY OVERLAY SYSTEMS

OVERVIEW

This chapter reports the findings from Task #5, *Laboratory Evaluation of Micro-Overlay Systems*. Unlike the previous task, which focused on the development of new designs, in this task the researchers evaluated existing designs. They tested four types of slurry overlays in the lab for cracking resistance, skid/polishing resistance, abrasion resistance, and bond strength. The overlay types included MicroTekk, MicroTekk Flex, Tuffseal, and an experimental skid slurry product. Since these products have core differences in composition and structure than HMA, the results should not be compared with the thin overlays from Chapter 4. This chapter is divided into the following sections: *Procedures*, *Results,* and *Summary*.

PROCEDURES

This section describes the materials used and then the testing procedures.

Materials

The materials information for the tested slurry overlays is summarized in Table 5.1, which describes the composition and gives a brief description. As shown, the difference between

Table 5.1. Slurry Overlays.

Material Name	Composition	Description
MicroTekk	Microsurfacing rock (Sandstone) 3.8% Type I cement 8% Water 13% Emulsion A (CSS-1P)	• Conventional mcirosurfacing (TxDOT Item 350) • A durable and stable asphalt slurry
MicroTekk Flex	Microsurfacing rock (Sandstone) 3.8% Type I cement 9.5% Water 13.5% Emulsion B (CSS-1P) 0.2% Performance additive	• "Flexible microsurfacing" • Performance additive provide enhanced flexibility and durability
Tuffseal	Polymer-modified cement slurry Silica sand (various types and gradations)	• Spray-applied cement slurry with sand spread on surface • Promoted as environmentally friendly • Comparable to E-Krete
Skid slurry (sand)	Asphalt emulsion* Trap rock sand	• Asphalt slurry with sand
Skid slurry (glass)	Asphalt emulsion* Crushed glass	• Asphalt slurry with glass

* Unknown emulsion formulation

MicroTekk and MicroTekk Flex is the presence of a performance additive and a different emulsion formulation, described as Emulsions A and B. The microsurfacing mixes are generally laid 1/2 –-inch-thick while the Tuffseal and skid slurries are approximately 1/8-inch-thick. For a more detailed description of the slurries, refer to Chapter 2.

Two additional microsurfacing mixes, modifications of MicroTekk and MicroTekk Flex, were made to better identify the effects of the performance additive in MicroTekk Flex. These mixes, given in Table 5.2, are called MicroTekk *with* Additive and a MicroTekk Flex *without* Additive. When compared to conventional MicroTekk, the first mix would assess the effects of the additive alone and the second the difference in using Emulsion B vs. Emulsion A.

Table 5.2. Modified Microsurfacing Overlays.

Material Name	Composition
MicroTekk with Additive	Microsurfacing rock (Sandstone) 3.8% Type I cement 9.0% Water 13.2% Emulsion A (CSS-1P) 0.2% Performance additive
MicroTekk Flex without Additive	Microsurfacing rock (Sandstone) 3.8% Type I cement 8.0% Water 13.2% Emulsion B (CSS-1P)

Performance Testing

Slurry overlay performance was characterized with the following tests:

- Overlay test.
- Wet-track abrasion test.
- Skid and polishing resistance test.
- Pull-off test.

The research team used these tests to assess cracking resistance, abrasion resistance, skid and polishing resistance and abrasion resistance, and bond strength, respectively. Table 5.3 shows which tests were performed for each material. The overlay test was not appropriate for the very thin Tuffseal and skid slurry materials, and skid slurry samples were not available for the wet-track abrasion test. The procedures followed during testing are described in the following subsections.

Table 5.3. Testing Matrix.

	Laboratory Test			
Material Name	Overlay Test	Wet-Track Abrasion Test	Skid and Polishing Resistance Test	Pull-Off Test
MicroTekk	X	X	X	X
MicroTekk Flex	X	X	X	X
MicroTekk with Additive	X		X*	
MicroTekk Flex without Additive	X		X*	
Tuffseal		X	X	X
Skid slurry (sand)			X*	X
Skid slurry (glass)			X	X

* Limited study

Overlay Test

Cracking resistance of the original and modified microsurfacing designs was evaluated with the overlay test, which simulates crack propagation during thermal contraction/expansion cycles. Tex-248-F (Test Procedure for Overlay Test) specifies testing of a 1.5-inch thick asphalt specimen, but this was modified to accommodate the thin nature of microsurfacing. Samples were formed by pouring the wet mix into 3-inch- × 6-inch molds, 0.5-inch thick, and striking off the excess material. The samples were placed in a 60°C hot room for 48 hours and then glued to the loading plates. Figure 5.1 shows various steps of sample preparation.

Note that the emulsions for the original and modified designs were batched at different times. The original design samples were made between two and five weeks after batching the emulsion, and the modified design samples were made within two weeks of batching. Over a few weeks the suspended binder starts to separate from the rest of the emulsion, and this may have occurred, to some extent, for the original design samples.

Two testing methods were employed: the standard TxDOT method (Tex-248-F) and a modified method developed by Road Science specifically for testing microsurfacing. Table 5.4 summarizes these test methods. The modified method is intended to test the mix at expected field conditions when reflection cracking most often occurs.

(a) Mold **(b) Wet Sample** **(c) Complete Sample**

Figure 5.1. Sample Preparation for Overlay Test.

Table 5.4. Overlay Testing Parameters.

Property	TxDOT Method	Modified Method
Temperature (C)	25	5
Max. gap opening (in.)	0.025	0.05
Complete cycle length (s)	10	60
Failure criteria (% drop from max. load)	93	90

Results were assessed according to the number of cycles to the failure criteria, assessment of the loading curves, and visual observations. Each measurement was the average of at least three samples.

Wet-Track Abrasion Test

Abrasion resistance was evaluated with the wet-track abrasion test ASTM D3910 (Standard Practices for Design, Testing and Construction of Slurry Seal) (see Figure 5.2). This test is intended to replicate raveling field performance of slurry seals and moisture susceptibility. The researchers prepared microsurfacing samples by spreading the mix in a 1/4-inch-thick, 11-inches-diameter template over 30-lb roofing felt. They made Tuffseal samples by spraying the slurry over circular pieces of roofing felt then applying the sand on top. Both sample types were cured at 60°C for 48 hours, and then soaked in water for either 1 hour or 6 days. The sample was then fixed in a Hobart mixer equipped with a free-hanging rubber hose attachment, which abraded the sample surface for about 5 min. Performance was described as the percentage of mass loss and each measurement was the average of two tests.

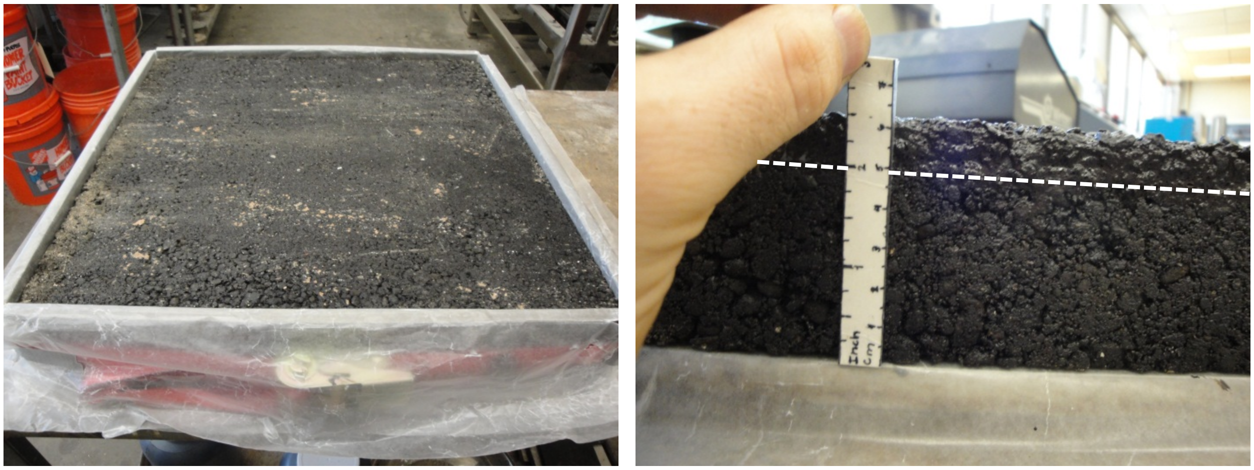
(a) Testing Equipment **(b) Sample**

Figure 5.2. Wet Track Abrasion Test.

Skid and Polishing Resistance Test

Skid and polishing resistance were characterized by calculating the IFI before and after slab polishing under the three-wheel polishing device (TWPD) developed by the National Center for Asphalt Technology (NCAT). Aside from a few modifications, the same testing process described in Chapter 4 was employed in this task. The TWPD was also used to assess abrasion resistance since the turning tires wear away the slurry material over time.

Samples were prepared by applying the slurries to existing 2-inch-thick HMA slabs (see Figure 5.3). The original and modified microsurfacing mixes were poured into a ½-inch deep mold constructed around the slabs, then the excess material was struck off. The Tuffseal slurry was sprayed onto the surface in two lifts with sand hand-applied between the lifts and on top. Three Tuffseal slabs were made, each with a unique sand configuration as follows:
coarse sand + fine white sand (C+W), fine sand + fine white sand (F+W), and two coatings of



(a) MicroTekk/MicroTekk Flex

(b) Tuffseal

Figure 5.3. Slab Sample Preparation.

fine white sand (W+W). The skid slurry samples were prepared by the product developers and not by TTI researchers.

In most cases, the IFI for each slab was determined before polishing and after 1,000; 2,000; 5,000; 10,000; 20,000; 50,000; and 100,000 cycles, or until the slurry was worn away under the polishing action. In some cases, polishing was terminated early to minimize damage the equipment if the sample was wearing unevenly. Measurements were not performed once the underlying slab was exposed.

Regarding abrasion resistance, the research team took pictures to document slurry wear over time and noted once the overlay was completely worn through. The modified microsurfacing samples were subjected to 10,000 cycles only at one time and visually assessed. These samples were not used to measure IFI.

Pull-Off Test

Bond strength was evaluated in the pull-off test according to ASTM D4541 (Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers), to measure the quality of slurry overlay adhesion. Some treatments have exhibited delaminating failures, which this test may have been able to detect. Figure 5.4 shows the device in testing. A small steel disk is attached to the test surface with epoxy, and then anchored into the pulling device, which applies a tension force until failure. The maximum load just prior to failure is automatically recorded and used to compute the tensile strength in psi. The failure plane can be examined to determine if the failure occurred within the overlay, at the overlay-slab interface, or in the slab. When testing the thicker microsurfacing and Tuffseal samples, a 2-inches-diameter core barrel was first used to cut through the sample and into the slab. Three tests in the center of the skid and polishing resistance slabs, after polishing was completed, were conducted and averaged together.

Figure 5.4. Pull-Off Test Device.

RESULTS

This section presents the results of the performance tests.

Overlay Test

The cracking resistance results from the overlay tester (average number of cycles until failure) are shown in Figure 5.5. The graph is first divided into the standard TxDOT method results and then the modified method results. The biggest differences between these methods is temperature (25°C vs. 5°C), maximum opening (0.025 inch vs. 0.05 inch), and failure criteria (90 percent vs. 93 percent drop from maximum load). Under each method, the two solid columns are the original microsurfacing designs (MicroTekk and MicroTekk Flex) and the two striped columns are the modified designs, where the performance additive was taken from MicroTekk Flex and put into the regular MicroTekk.

Concerning the TxDOT method, cracking resistance results from the original designs are nearly identical (96 and 88 cycles), and the modified design results are also very close, about 3,000 and 5,000 cycles (note the use of a logarithmic scale). It seems then that the MicroTekk Flex has similar cracking-resistant properties as regular MicroTekk. However, the significant discrepancy between the original samples and modified designs is not understood. This could indicate that significantly better cracking resistance is obtained when combining Emulsion A with the performance additive, or using Emulsion B alone. More likely, though, this suggests that the emulsion batches used in the original and modified design samples were not the same, or that the emulsion for the original samples was at rest too long and separated before sample preparation.

Concerning the modified testing method, samples without the performance additive (MicroTekk and MicroTekk Flex without additive) both failed the test with an average of three

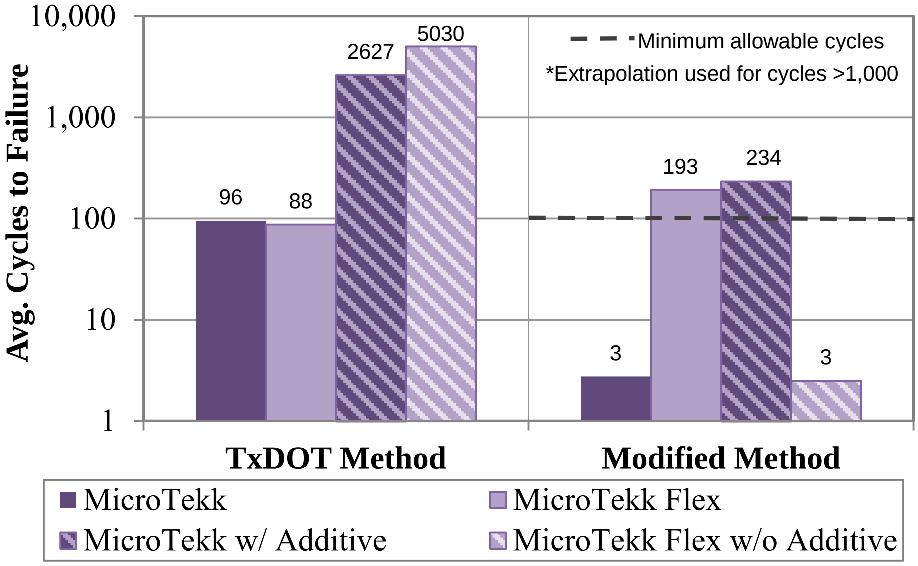


Figure 5.5. Cracking Resistance Results.

cycles each. This suggests that there was little difference between Emulsions A and B, and that Emulsion B alone does not increase the cracking resistance under these conditions. Both samples with the additive (MicroTekk Flex and MicroTekk with additive) performed significantly better than the other samples, with around 200 cycles to failure, passing Road Science's minimum 100 cycle requirement. This suggests that the performance additive does improve the cracking resistance under the modified conditions.

Overlay test data can also be analyzed by the shape of the loading curves over the first few cycles. The overlay cycles from the TxDOT and modified testing methods are shown in Figures 5.6 and 5.7, respectively. When testing at 25°C, the maximum load on the first cycle for MicroTekk samples was higher than for MicroTekk Flex samples. This suggests that the emulsion type influences the maximum tensile strength and not the performance additive, where samples with Emulsion B are softer. Interestingly, the number of cycles to failure was not affected by this difference as shown in the previous figure. Judging by the shape of the loading curve in the second cycle, these samples continue to carry a load at the maximum opening, indicating that the sample is not completely cracked. This was confirmed visually and at the end of the test, none of the samples were visibly cracked on top. Since none were visibly cracked, the TxDOT failure criteria may not apply to microsurfacing samples. Note that all loads here are very low (<50 lb) and the overlay test has not been formally assessed at such low loads.

When testing with the modified method, the maximum loads are much higher because the emulsion is stiffer at the low temperatures. MicroTekk Flex is again softer than MicroTekk (lower load), but the load from the MicroTekk Flex without additive design is nearly identical to the MicroTekk with additive design. Because the plates open much farther than in the TxDOT method, a larger crack is formed as noted by the dramatic decrease in load through the first half of the first cycle. The subsequent cycle carries very little load (<50 lb), suggesting that material is now mostly cracked. However, samples with the additive carry a small load at the end of the

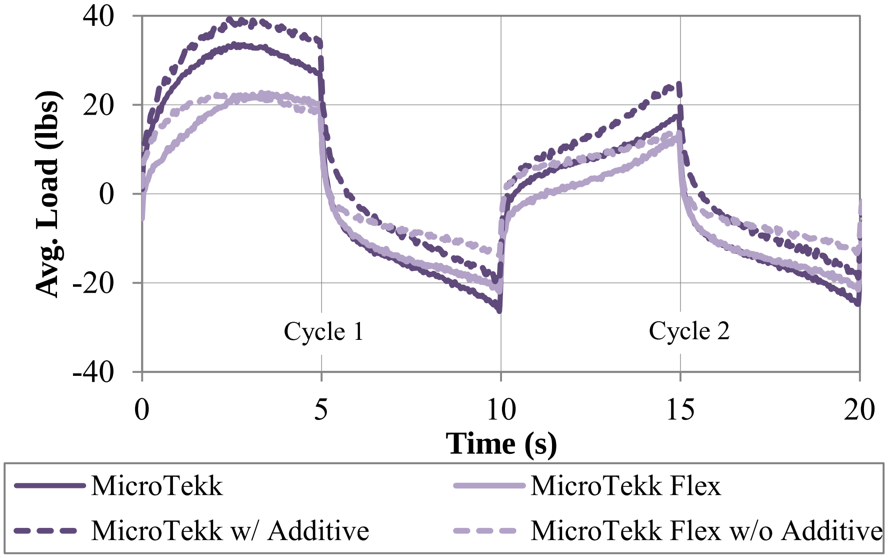


Figure 5.6. First Two Overlay Cycles with the TxDOT Testing Method.

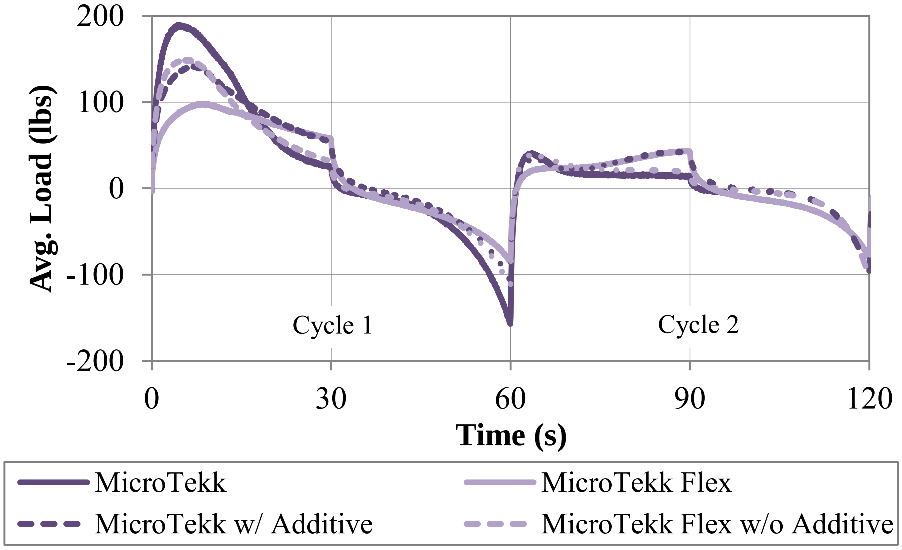


Figure 5.7. First Two Overlay Cycles with the Modified Testing Method.

second cycle while samples without the additive have nearly flat load curves. It is this small fact that allows samples with the additive to perform better in the overlay tester under the modified test configuration. Even though these samples do not fail according to the failure criteria (a 90 percent decrease from the maximum load) the researchers noted that all samples were visibly cracked before the end of testing. The test failure criteria, therefore, may be inappropriate for microsurfacing under these conditions.

As mentioned before, the loads while testing microsurfacing according to both the TxDOT and modified methods can be very low. This easily pushes the limits of the overlay tester equipment (see Figure 5.8). Below 10 lb, the accuracy of the load cell or the vibration

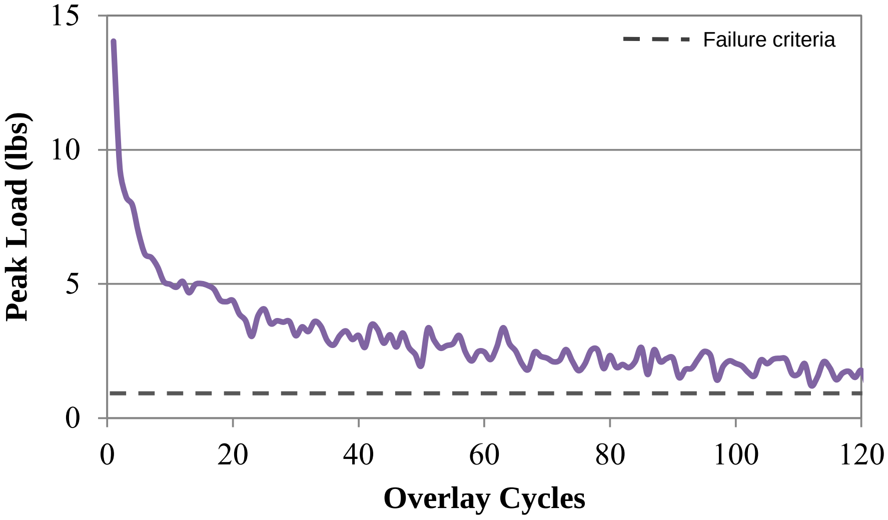


Figure 5.8. Peak Loads in TxDOT Method.

inherent in the machine causes significant noise in the results. This can cause the test to end prematurely if the technician does not take steps to guard against this possibility. It also means that when the maximum load is low, the load at failure will be *very* low, perhaps lower than is practically significant. For these reasons, and those already stated, the overlay tester might not be appropriate for testing microsurfacing. To continue work in this area, it will be necessary to change the load cell range, currently 0–2000 lb, to a 0–400 lb load cell when testing microsurfacing.

Wet-Track Abrasion Test

Figure 5.9 shows the abrasion resistance results. All samples tested performed very well after both a 1-hr and 6-day soak. This test was originally designed for testing slurry seals and fog seals, and might not be severe enough to differentiate among high performance slurry mixes. Abrasions resistance was also assessed qualitatively with the TWPD as described in the following section.

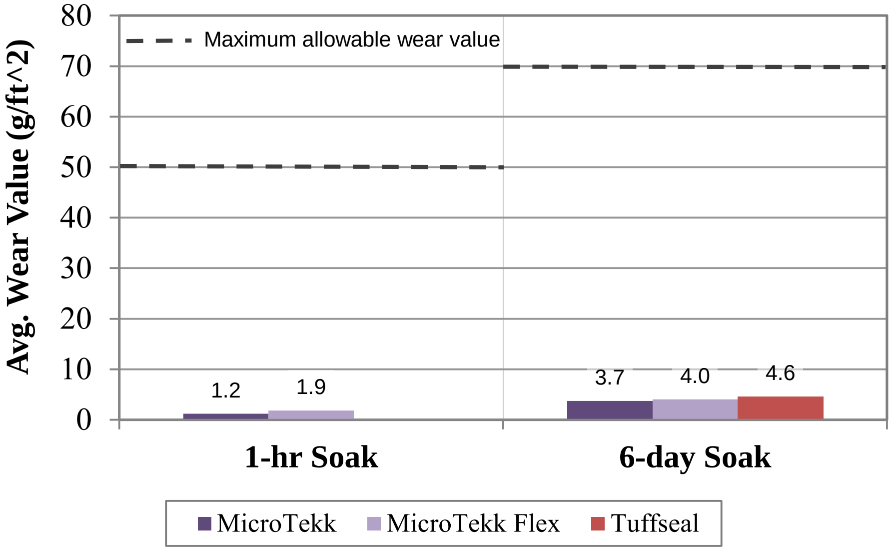
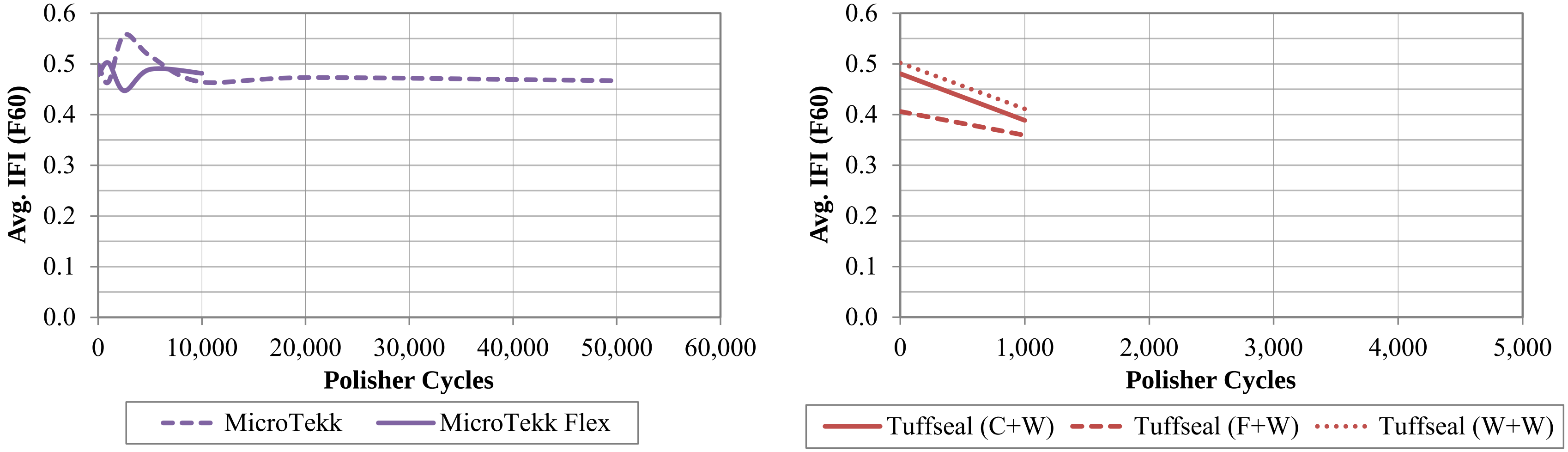


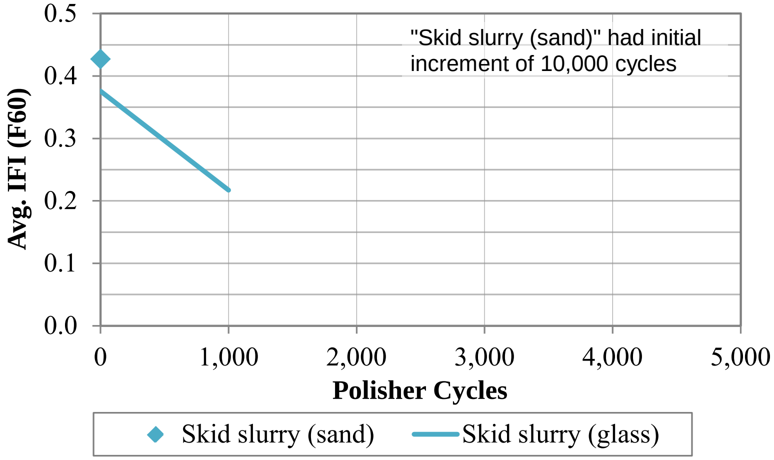
Figure 5.9. Abrasion Resistance Results.

Skid and Polishing Resistance Test

Figure 5.10 show the results of the skid resistance tests over various stages of polishing for each sample. These graphs report the IFI parameter for wet pavement friction at 60 km/h, F60. The results may also be indicative of slurry abrasion resistance or durability since the test was terminated once the material was worn away. Pictures of a few of these slabs at termination are shown in Figures 5.11 through 5.13, and a complete set of pictures of slab polishing is contained in Appendix C.



(a) Microsurfacing **(b) Tuffseal**



(c) Skid Slurries

Figure 5.10. Skid Resistance of Slurry Overlays with Polishing.

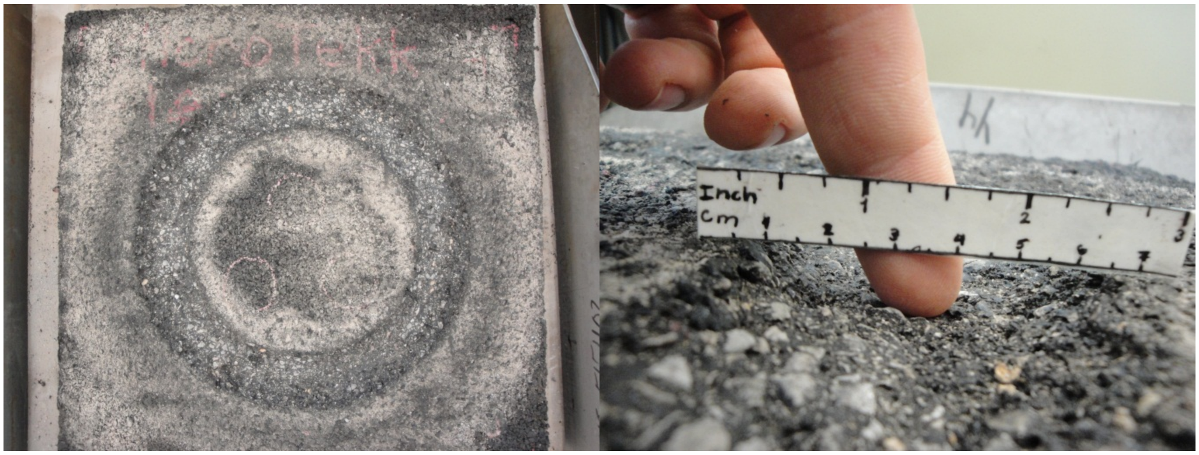


Figure 5.11. MicroTekk Flex Slab (10,000 Cycles).

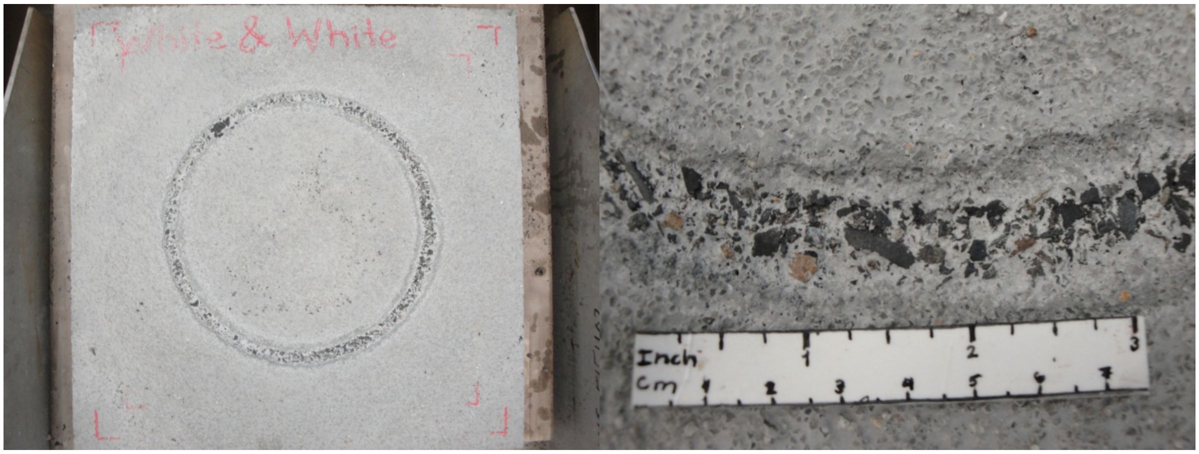


Figure 5.12. Tuffseal (W+W) Slab (2,000 Cycles).

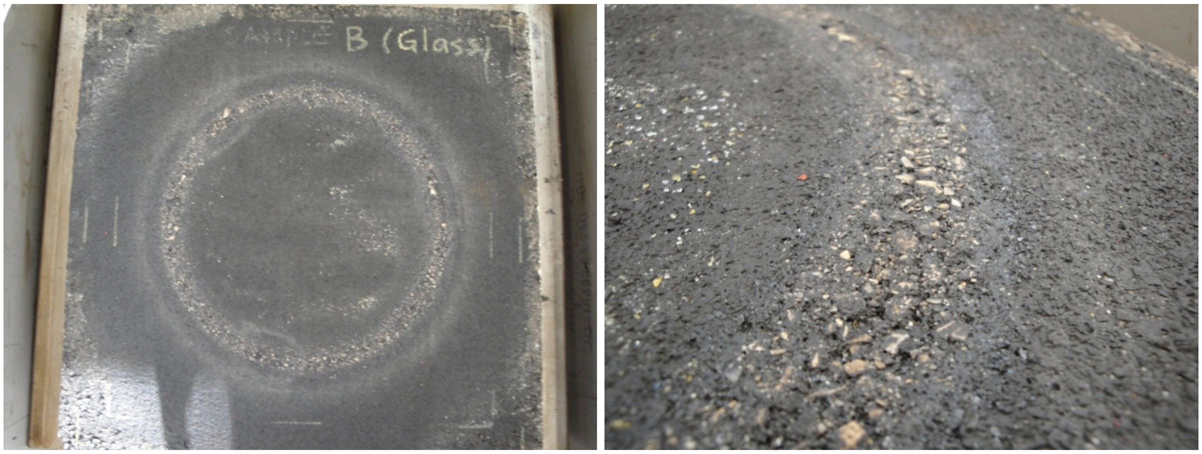


Figure 5.13. Skid Slurry (Glass) Slab (2,000 Cycles).

The IFI (F60) of both MicroTekk and MicroTekk Flex was around 0.5 for most of the test. Aggregate polishing throughout the test was probably minimal since the surface was constantly being abraded away. The MicroTekk and MicroTekk Flex slabs lasted through 50,000 and 10,000 cycles, respectively. By the end of 100,000 cycles, MicroTekk was completely worn through. Polishing of the MicroTekk Flex was terminated early because the slab was wearing unevenly to the point that the TWPD was at risk of being damaged. After 10,000 cycles, however, it was considerably more worn than the MicroTekk slab at the same point. This fact was surprising since the performance additive is said to increase the surface toughness.

Two alternative microsurfacing slabs (MicroTekk with additive and MicroTekk Flex without additive) were also run through the TWPD to identify the effects of the performance additive alone and the difference between Emulsion A and B. After 10,000 cycles, the MicroTekk with additive slab was worn through in several places and the MicroTekk Flex without additive slab was worn through more than halfway. Again, the slab with the additive wore away faster than the slab without, which is contrary to the claim that additive increases surface toughness. The researchers, however, do not suspect that the additive caused the decreased abrasion resistance, but recommends further study on this topic.

The three Tuffseal slabs, each using different sand configurations, had initial IFI values between 0.4 and 0.5, and terminal IFI values between 0.35 and 0.45. The slab with the fine sand and fine white sand (F+W) had the lowest IFI, though this slab also seemed to have a higher slurry-to-sand ratio, resulting in a smoother texture. The other two slabs had nearly identical IFI values. The decrease in IFI is likely not a result of polishing, but rather related to the loss of sand from the slurry matrix. Tuffseal lasted through 1,000 cycles, but after 2,500 cycles, the underlying slab was showing through.

The sand and glass skid slurries had initial IFI values of 0.43 and 0.38, respectively. The glass skid slurry lasted through 1,000 cycles, and the terminal IFI value was 0.22. Again, the decrease in skid was caused by aggregate loss and not aggregate polishing. The sand slurry, on the other hand, was initially polished to 10,000 cycles and the time of slurry loss is unknown.

Figure 5.14 summarizes the skid and polishing resistance results, where results for each slurry type were averaged together. Microsurfacing lasts longer than the other products and maintains high skid resistance. This is expected since the sample is much thicker (1/2 inch vs. 1/8 inch). Tuffseal maintains skid better than the skid slurry, suggesting that once the high friction aggregate is lost, the base cement slurry has higher friction properties than the base emulsion.

After conducting these tests, the researchers question the applicability of the TWPD for testing slurry overlays. The test is very severe and might not have a tie-in to field performance. Other testing configurations with the TWPD (lighter load, lower tire pressure, fewer cycles, etc.) may yield better results when testing these types of products.

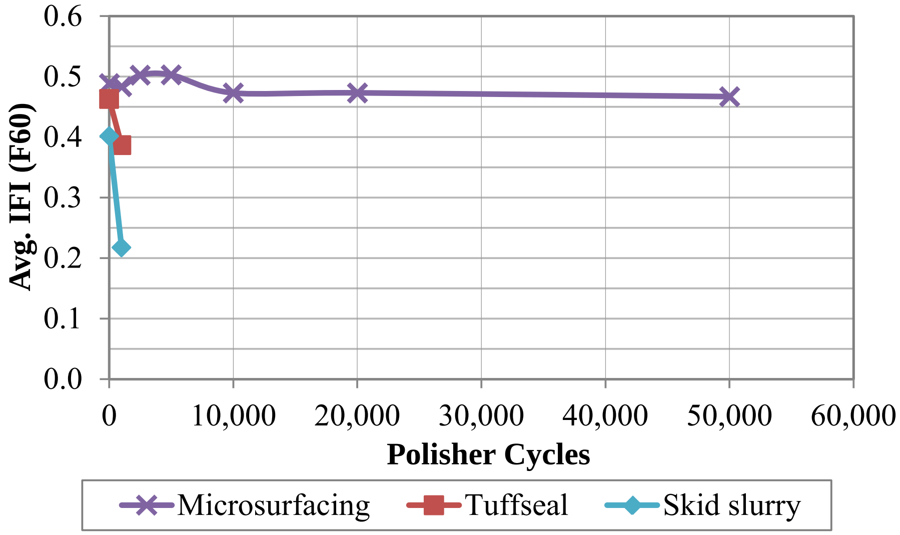


Figure 5.14. Skid Resistance of Slurry Systems with Polishing.

Pull-Off Test

The pull-off test results are shown in Figure 5.15. The average tensile strength of microsurfacing was 27 psi (failure occurred within the layer); the tensile strengths of Tuffseal-pavement bond was 172 psi (failure occurred at the bond); and the average tensile strength of the skid slurry-pavement bond was 245 psi (failure occurred at the bond). Compared to typical bond strengths of chip seals to cement-treated base, the Tuffseal and skid slurry values are very high. These products should not have delaminating issues. The bond strength of the microsurfacing could not be determined as the failure occurred within the sample and not at the interface. It is unknown at this moment what impact the low tensile strength of the material will have on the eventual field performance.

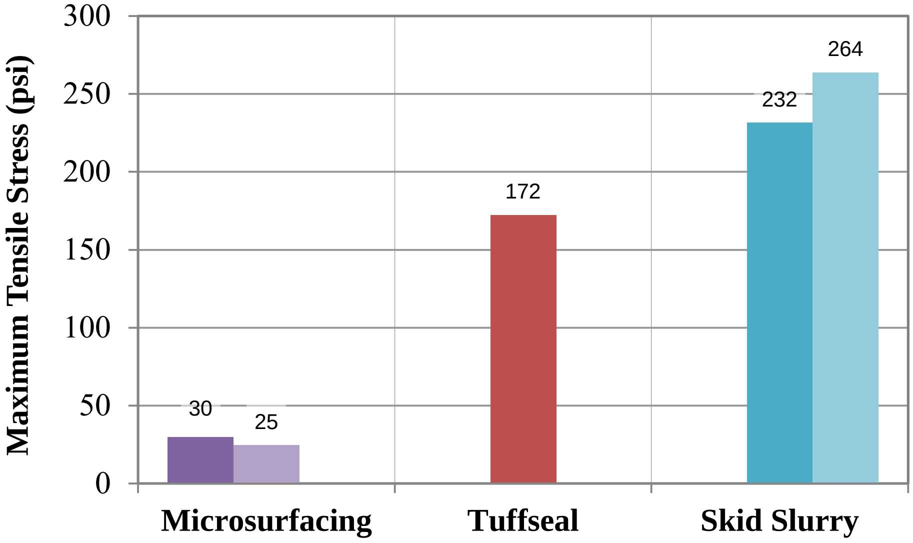
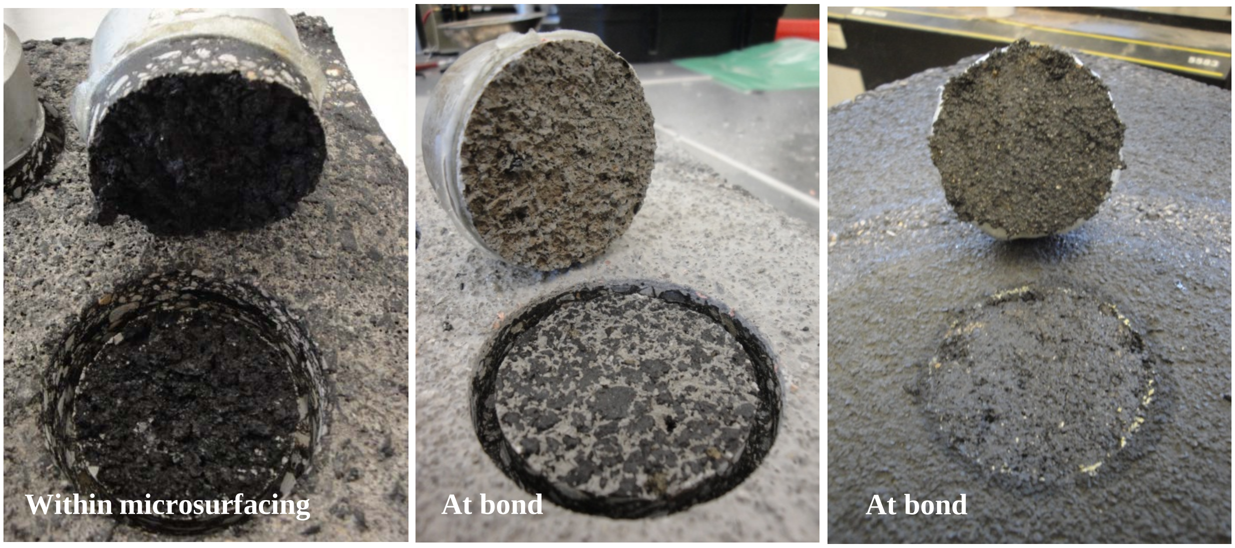


Figure 5.15. Bond Strength Results.



(a) Microsurfacing **(b) Tuffseal** **(c) Skid Slurry**

Figure 5.16. Location of Tensile Failure.

SUMMARY

The purpose of this chapter was to report the findings from Task #4, *Laboratory Evaluation of Micro-Overlay Systems*. In this task, existing slurry overlays designs were tested in the lab with the overlay tester (cracking resistance), wet-track abrasion test (abrasion resistance), skid and polishing resistance test (skid/polishing resistance and abrasion resistance), and the pull-off test (bond strength). The overlay types include MicroTekk, MicroTekk Flex, two modified microsurfacing designs, Tuffseal, and an experimental high-skid slurry product.

Findings

The findings made during this evaluation are summarized below.

Overlay Test

- Microsurfacing behaves very differently in the overlay tester when tested with the TxDOT method and with the modified method.
- At 25°C and crack displacement of 0.025 inch, MicroTekk and MicroTekk Flex have the same cracking resistance (by the test definition). The effect of the performance additive alone and the emulsion type is still undetermined.
- At 5°C and crack displacement of 0.05 inch, the inclusion of the performance additive in microsurfacing significantly increases cracking resistance (by the test definition). There was no difference in performance between the emulsion types.
- More work is required to determine the appropriate cracking test for these materials, especially to find a tie-in to field performance. The cracking definitions in the overlay test (for both the TxDOT and modified methods) do not correctly identify cracking.

Wet-Track Abrasion Test

- All the slurry overlays studied had good performance in the wet-track abrasion test, but the test is not severe enough to differentiate between the overlays.

Polishing and Skid Resistance Test

- No noticeable difference in skid resistance exists between MicroTekk and MicroTekk Flex, and between different sand configurations in Tuffseal.
- Microsurfacing maintains skid resistance longer than Tuffseal and the skid slurries.
- The skid resistance of Tuffseal and the skid slurries decreases if the high skid aggregate is lost. This decrease in skid resistance is very significant for the skid slurries.
- Microsurfacing has superior abrasion resistance than the other overlays tested, most notably because it is significantly thicker and contains coarser aggregate.
- Polishing in the TWPD with the current setup may be too severe for slurry overlays.

Pull-Off Test

- The skid slurries and Tuffseal have very good bond strength, whereas the internal microsurfacing tensile strength is low.

More work is required to develop defensible performance-related tests for Microsurfacing products. None of the materials failed the current specification based on the wet track abrasion test, which does not seem to be severe enough. Problems were encountered with the interpretation of all the tests results reported above.

Additional studies should be initiated, which may involve placing short test sections in the field so that actual performance of competing products can be monitored and ranked. This could be on actual highways or as part of the Accelerated Pavement Test program about to get started at the University of Texas, Arlington. In an Accelerated Pavement Test program, short sections of microsurfacing could be applied at the ends of the test strip where the loaded wheels are accelerating or slowing. The same materials tested in the field can then be evaluated in the laboratory to determine the critical performance related properties of abrasions resistance, crack resistance, and bond strength. Running both controlled field and lab tests will allow researchers to define the most appropriate test arrangements, and lab test conditions to match the observed field performance.

CHAPTER 6
PROPOSED PAVEMENT EVALUATION AND MIX SELECTION GUIDELINES

OVERVIEW

This chapter reports on Task #6, *Pavement Evaluation and Mix Selection Guidelines*. In this task, the researchers created tools to assist TxDOT Districts regarding maintenance options using thin overlays for flexible pavements. The tools recommend or discourage the use of certain thin overlay and slurry overlay options given the pavement, traffic, and climate conditions. They further summarize the performance characteristics of each material type. This document is simply one tool to be used with sound engineering judgment and local experience in the development of plans, specifications, and estimates for future lettings.

This chapter is divided into the following sections: *Guidelines* and *Summary*.

GUIDELINES

Based on experience and discussions with TxDOT personnel, recommendations are given for the use of thin overlays in pavement maintenance. This guide provides information for the three proposed thin HMA overlay types and three slurry overlay types, as follows:

Thin HMA Overlays
- Fine DGM
- Fine SMA
- Fine PFC

Slurry Overlays
- MicroTekk
- MicroTekk Flex
- E-Krete

As mentioned before, the fine DGM is essentially a CAM mix designed at a target density of 96.5 percent with an overlay tester requirement of 300 cycles. The CAM specification remains unchanged at 750 cycles but the CAM is not currently recommended as a surface mix. It is recommended as a crack-resistant level up mix where a surfacing mix will be placed on top. The fine DGM is intended as the surface mix.

Table 6.1 is a tool that provides strategies to mitigate pavement distresses at the surface with the previously mentioned overlays. The table should be used with sound engineering judgment and local experience. Effectiveness of the selected strategy is highly dependent on adequate field investigation to determine the exact cause and origin of the existing distress, and selection of the proper overlay type that address the site-specific traffic loading and environment. General steps in selecting a suitable rehabilitation strategy are as follows:

- Determine the type of distress and evaluate its extent and severity. The PMIS distress survey information can provide the basic condition information, but it has only limited details on distress severity. For example, site visits are required to note the severity of alligator cracking. District personnel can obtain objective distress measurements by following guidelines in the Long-Term Pavement Performance Program's *Distress Identification Manual for the Long-Term Pavement Performance Program* (*26*) available as a pdf on the FHWA website.

- Evaluate the typical thin-overlay treatments and compare against district standard operating procedure/experience and preferences.
- Ensure the thin overlay option is suitable for the given traffic and climate conditions.

Note: The evaluation process presented here has been simplified in the following ways: 1) the discussion focuses only on the distress type and not the distress source; and 2) maintenance options only include thin overlays and no rehabilitation options are discussed. Therefore, remember, when applying thin overlays to cracked or rutted pavements, even of low severity, the overlay generally will not mitigate the source of the problem, but will only "buy" short-term performance. If wanting to take more extensive corrective measures, consult Selecting Rehabilitation Strategies for Flexible Pavements CD-ROM [research product 5-1712-01-P4] and Chapters 4 and 7 of the online Pavement Design Guide (27).

Table 6.2 ranks the thin overlays according to various performance properties. The rankings are subjective and assume the mix was well-designed and constructed. The table addresses the following parameters:

Resistance to

- Rutting
- Cracking
- Segregation
- Raveling
- High shear forces
- Moisture damage
- Freeze-thaw damage

Functionality

- Impermeability
- Long-term durability
- Wet weather traction
- Wet weather visibility
- Noise reduction
- Ease of compaction
- Ability to hand work

Economy

- Initial cost

Table 6.1. Pavement Evaluation and Mix Selection Guidelines.

Distress		**Thin HMA Overlay Options**			**Slurry Overlay Options**			
Type	Severity	Fine DGM[2]	Fine SMA	Fine PFC[3]	MicroTekk	MicroTekk Flex	E-Krete	**Treatment Plan[4]**
Alligator Cracking[1]	Low	**R**	**R**	**R**	**?**	**R**	▨	• Mill (optional), overlay
	Moderate	**R**	**R**	**?**	**?**	**?**	▨	• Mill, overlay • Surface treatment, overlay
	High	▨	▨	▨	▨	▨	▨	(Structural evaluation needed)
Rutting[1]	< 0.5"	**R**	**R**	▨	**R**	**R**	▨	• Level-up overlay (1.25 - 1.5 in.) • Rut-filling with slurry overlay
	0.5 to 1.0"	▨	▨	▨	**R**	**R**	▨	• Mill, overlay • Rut-filling with slurry overlay
	>1.0"	▨	▨	▨	**?**	**?**	▨	• Full-depth reconstruction • Rut-filling?
Block Cracking[1]	Low	**R**	**R**	**R**	**?**	**R**	▨	• Standard/rubberized seal, HMA overlay • Slurry overlay
	Moderate	**R**	**R**	**?**	**?**	**?**	▨	• Mill (optional), rubberized seal, HMA overlay
	High	▨	▨	▨	▨	▨	▨	(Structural evaluation needed, perhaps a CAM plus thin overlay)
Longitudinal Cracking[1] (in & out of wheel path)	Low	**R**	**R**	**R**	**?**	**R**	▨	• Crack seal, overlay
	Moderate	**R**	**R**	**?**	**?**	**?**	▨	• Mill, crack seal/CAM, overlay
	High	▨	▨	▨	▨	▨	▨	-
Transverse Cracking[1]	Low	**R**	**R**	**R**	**?**	**R**	▨	• Mill, crack seal, thin overlay
	Moderate	**R**	**R**	**?**	**?**	**?**	▨	• Mill, CAM and/or thin overlay
	High	▨	▨	▨	▨	▨	▨	- Thick overlay required
Potholing	Localized or Extensive	▨	▨	▨	▨	▨	▨	-
Raveling	Low	**R**	**R**	**R**	**R**	**R**	**R**	• Seal coat, HMA overlay • HMA overlay • Slurry overlay
	Moderate	**R**	**R**	**?**	**R**	**R**	**?**	
	High	**?**	**?**	**?**	**R**	**R**	▨	
Flushing	-	▨	▨	**R**	**?**	**?**	▨	• Mill (optional), overlay
Polished Aggregate	-	**R**	**R**	**R**	**R**	**R**	**R**	• Overlay

R - Recommended **?** - May be recommended ▨ - Not recommended

1 - Applying treatments even to low severity cracking and rutting distresses will only "buy" short-term performance
2 - Due to skid resistance issues, fine DGM should not be used as a surface layer on sections with speeds > 45 mph.
3 - Due to freeze-thaw damage issues, fine PFC should not be used in the following districts: Amarillo, Childress, and Lubbock.
4 - When surface preparation requires milling, consider micro-milling so surface irregularities do not impose on thin overlay.

Table 6.2. Rankings of Thin Overlay Performance for Various Properties.

	Mix Characteristics														
	Resistance to							Functionality							Economy
Thin Overlay Type	Rutting[4]	Cracking[5]	Segregation	Raveling	High Shear Forces[4] (braking and turning)	Moisture Damage	Freeze-Thaw Damage[5]	Impermeability	Long-Term Durability	Wet Weather Traction	Wet Weather Visibility	Noise Reduction	Ease of Compaction	Ability to Hand Work	Initial Cost
HMA															
Fine DGM[1]	4	5	5	5	2	5	5	5	4	2	1	4	5	4	2
Fine SMA[2]	5	5	4	5	5	4	5	4	5	4	1	4	3	3	3
Fine PFC[3]	5	4	5	4	3	5	1	NA	4	4	5	5	5	2	4
Slurry															
MicroTekk	5	2	3	5	4	4	-	4	2	4	3	2	NA	2	1
MicroTekk Flex	4	3	3	5	4	4	-	4	3	4	3	2	NA	1	1
E-Krete	NA	1	NA	NA	2	5	-	4	-	3	2	2	NA	4	5

1 to 5 - Subjective ranking of performance (5 being best)

' -' Unknown

NA - Not applicable

1 - Due to skid resistance issues, fine DGM should not be used as a surface layer on sections with speeds > 45 mph.

2 - Fine SMA is a highly impermeable mix and generally can be used without an underseal, provided that the underlying pavement is not exposed to moisture intrusion for extended periods of time.

3 - Alternative thin open-graded mixes include thin bonded PFC and ultra-thin bonded hot mix wearing course. These alternatives have superior bonding properties with the pavement but require specialized construction equipment.

4 - Better rutting and shear resistance may be obtained by increasing the high temperature grade of the binder.

5 - Better cracking and freeze/thaw damage resistance may be obtained by decreasing the low temperature grade of the binder.

SUMMARY

The latest generation of thin overlays proposed in this study includes high performance mixes meeting strict materials and testing requirements. These thin overlay types (fine DGM, fine SMA, and fine PFC) have numerous applications, but the one major requirement is that the mixes are placed on structurally sound highways.

The guidelines presented in Tables 6.1 and 6.2 will help Districts select the most appropriate mix type based on current pavement conditions.

This generation of mixes is so new that long-term performance data is not yet available. Though all mixes should be durable with good cracking and rutting resistance, at this moment it is recommended that the mixes be used in the following general applications:

Fine DGM

- Low- and moderate-severity rutting up to 0.5 inch.
- Over chip seals with large variations in transverse texture.
- Low-speed city applications.
- Need for very thin layer (some districts propose this to be placed at 0.5 inch thick).
- Need for easy hand work.

Fine SMA

- Moderately cracked sections.
- Areas of stop and go traffic.
- High-speed sections.

Fine PFC

- Wet weather accident locations.
- Areas where tire noise is a concern.
- Over flushed pavements, seal coats or surface treatments.

Concerning slurry overlays, the mixes are recommended in the following applications:

MicroTekk

- Moderate- and high-severity rutting up to 1.0 inch.
- Raveled or polished surfaces

MicroTekk Flex

- Moderate- and high-severity rutting up to 1.0 inch.
- Low-severity cracked pavements
- Raveled or polished surfaces

E-Krete

- Slightly raveled or polished surfaces

CHAPTER 7
FIELD EVALUATION OF NEW THIN OVERLAY PROJECTS

OVERVIEW

This chapter reports the findings from Task #8, *Evaluation of Experimental Sections Built during the Course of this Study*. In this task, six thin overlay projects, comprising 10 unique mix designs, were evaluated. The types of overlays studied include fine DGMs, fine SMAs, a thin overlay mix (TOM) (similar to fine SMA), and fine PFCs. Detailed data of the site condition, mix design, construction, and initial performance were collected for each project and are presented in this chapter. This information provides TxDOT with good examples of how to implement these types of mixes in their own Districts.

This chapter is divided into the following sections: *Purpose*, *Procedures*, *Results,* and *Summary*. The *Results* section provides a summary of the findings, while Appendix D contains detailed case studies.

PROCEDURES

This section first gives general information about the overlay projects, then briefly describes how background information was gathered, and finally details various testing procedures used in the performance evaluations.

Project Overview

The projects studied are shown in Table 7.1 and a map of the section locations is shown in Figure 7.1. Six thin-overlay projects from five districts comprising 10 unique mix designs were evaluated. Two were fine DGMs, three were fine SMAs, one was a TOM, and four were fine PFCs. (The same fine PFC design was used for both the Lufkin- and Bryan-Fine PFC projects.) The TOM is a mix similar to a fine SMA, but is actually a direct modification of a

Table 7.1. General Project Information.

	Project Location			
Project Name	Route	District	City	**Mix Type**
Pecos RTC (6 mixes)	Research & Testing Center (RTC)	Odessa	Near Pecos	2 Fine DGMs, 2 Fine SMAs, and 2 Fine PFCs
Georgetown-TOM	IH 35	Austin	Near Gerogetown	TOM
Bryan-Fine SMA	SR 6 Frontage Rd.	Bryan	Bryan	Fine SMA
Lufkin-Fine PFC	BS 59 (cloverleaf)	Lufkin	Lufkin	Fine PFC
Bryan-Fine PFC	SR 6	Bryan	Bryan	Fine PFC
Brownwood-Fine PFC	US 183	Brownwood	Near Breckenridge	Fine PFC

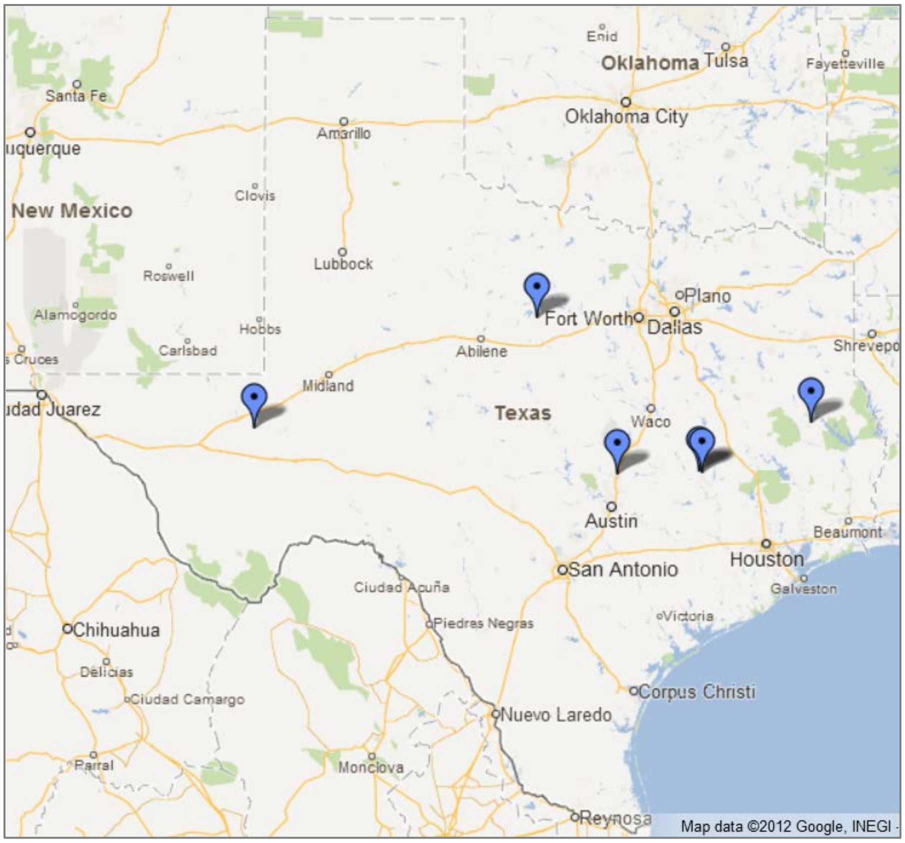


Figure 7.1. Location of Experimental Sections.

TFCO (SS 3226), including an overlay tester requirement, higher minimum binder content, etc. The TOM mix does not include fibers, which are mandatory for the fine SMA. All projects were constructed during the course of this research project.

Background Data Collection

The performance of an overlay depends on several factors like site conditions, mix design properties, and construction procedures. Therefore, the short- and long-term effectiveness of any treatment must be viewed in light of these factors. This subsection describes how these background data were collected.

Each site was characterized by the traffic condition, the climate condition, and the existing surface condition. Traffic conditions were accounted for with the AADT per travel lane and percent truck traffic. These data were collected from TxDOT traffic maps (*21*) and researcher observations. The climate conditions were accounted for with average annual precipitation and frequency of extreme temperatures. Moisture can decrease the substructure support; high temperatures will facilitate rutting, flushing, and oxidation; and cold temperatures stiffen the pavement, facilitating cracking. The surface condition was assessed through visual inspection and/or discussions with district engineers.

Three projects were further characterized according to the existing pavement structure condition with GPR and field cores. GPR technology is used to detect pavement layer interfaces and anomalies by estimating the dielectric value of the structure at various depths. The dielectric value is largely dependent on moisture content and density, which often changes between pavement layers. Though dielectric values are not a direct measure of layer quality, assumptions about layer quality and uniformity can still be inferred from the findings. GPR data was collected for the whole project extent in the outside wheel paths. For some sites, subgrade information was also collected from the U.S. Geological Survey database (*22*).

The mix design information included aggregate properties and gradations, binder contents, mix additives, and laboratory performance results. These data were obtained from the detailed mix design spreadsheets used for most projects.

The construction procedures were assumed to follow TxDOT specifications unless otherwise stated. Complications reported by the district engineer or observed by the researchers were also noted.

Performance Evaluation

Various pavement properties were collected to assess the initial condition of the overlays, including skid resistance, tire-pavement noise, and permeability. The tests employed were determined on a project-to-project basis as described below.

Skid Resistance

Skid resistance was measured on the Pecos RTC, Georgetown-TOM, and Bryan-Fine PFC projects with the TxDOT skid trailer at 50 mph equipped with a smooth tire. Readings were taken every 0.1 mi then averaged together. For the Bryan-Fine SMA project, skid resistance was assessed with the DFT and CTM. Measured values were used to calculate the IFI. Skid resistance testing with a skid trailer is further discussed in the *Procedures* section of Chapter 3, and DFT and CTM testing in the *Procedures* section of Chapter 4.

Tire-Pavement Noise

Tire-pavement noise was measured on the Pecos-RTC and Georgetown-TOMF projects using an on-board sound intensity (OBSI) system (see Figure 7.2). The OBSI system measures sound intensity at different frequencies, which can then be used to calculate an overall noise level. The perceived noisiness of a pavement is then based on both the overall noise level and the distribution of the noise at different frequencies. Overall noise determines the loudness, while sharp peaks in the frequency distribution may indicate the noise is unpleasant. All the measurements were made at 60 mph and were the average of three or four test sections in a 0.5-mile stretch with three runs on each section.

Figure 7.2. On-Board Sound Intensity System.

Permeability

The permeability of all fine PFC projects was evaluated with the TxDOT water flow test in accordance with Tex-246-F (Permeability or Water Flow of Hot Mix Asphalt) (see Figure 7.3). In this test, a given volume of water is discharged through the pavement surface through a 6-inches-diameter opening. The time is takes the water to discharge is the water flow value (WFV). For PFC, TxDOT recommends a WFV of less than 20 sec. The Bryan-Fine SMA was also assessed with the water flow test for *impermeability*, where the WFV should be at least 60 sec.

Figure 7.3. Water Flow Test.

RESULTS

This section summarizes the new thin overlay projects, including the pre-existing site conditions, overlay design and construction, and initial overlay performance. Appendix D has detailed case scenarios for each project.

Site Description

Table 7.2 summarizes the traffic and climate conditions at each project, and indicates with bolded values relatively severe conditions. Projects with high-severity traffic are the Georgetown-TOM (freeway traffic on IH-35), and the Lufkin-Fine PFC (very frequent turning truck traffic.) Pecos RTC and Brownwood-Fine PFC are in areas with high and low temperature extremes, and Lufkin-Fine PFC has a high amount of precipitation. The average climate data do not reflect the extreme summer temperatures from 2011. The projects that were constructed at that time were Pecos RTC, Georgetown-TOM, and Lufkin-Fine PFC.

The pavement structures and surface conditions for these projects are summarized in Table 7.3. This includes a description for the upper pavement structure, a rating of the surface condition, and distress description. Considering that the existing Pecos RTC pavement was severely cracked, it would normally not qualify for a thin overlay treatment; but this was an experimental project on a private test facility, and will be an interesting extreme scenario for testing the new designs for cracking resistance. The Georgetown-TOM pavement was in decent condition prior to the overlay, with noteworthy distresses being repaired prior to construction. The Lufkin-Fine PFC was placed on a cloverleaf with significant skid resistance problems. The Bryan-Fine PFC was used to surface new construction. Finally, the Brownwood-Fine PFC was placed over a flushing, intact pavement. In this case, a PFC mix was selected, rather than a fine DGM of fine SMA, to provide room for the flushing asphalt to go, if needed.

Table 7.2. Traffic and Climate Conditions.

	Traffic Condition		**Climate Condition**		
Project Name	AADT / lane	Percent Trucks (%)	Avg. Annual Precip. (in.)	Avg. # Days ≥ 100°F	Avg. # Days < 32°F
Pecos RTC					
Entry road	-	-	12	**45**	**60**
Test track	-	100**			
Georgetown-TOM	**9,670**	**24***	28	18	24
Bryan-Fine SMA	-	-	40	11	17
Lufkin-Fine PFC	**6,000***	**24****	**47**	6	28
Bryan-Fine PFC	-	-	40	11	17
Brownwood-Fine PFC	1,100	10	30	**25**	**57**

* Approximated from adjoining section
** Approximated by TTI observations
'-' Data not available
Bolded values indicate high severities

Table 7.3. Pavement Structure and Condition.

Project Name	Pavement Structure (excluding base and subgrade)	Surface Condition Rating	Surface Condition Description
Pecos RTC			
Entry road	1 in. asphalt, cracked	Poor	Surface cracking
Test track	5 in. asphalt, cracked	Poor	Surface cracking
Georgetown-TOM	9.5 in. asphalt & 20 in. asphalt, Generally in good condition	Fair	Surface cracking (worst spots were repaired)
Bryan-Fine SMA	-	Fair	-
Lufkin-Fine PFC	15-20 in. asphalt (highly variable), Moisture damage or debonding	Fair	Poor skid resistance
Bryan-Fine PFC	New construction	Good	No distress
Brownwood-Fine PFC	Uniform asphalt layer, likely in good condition, unknown thickness	Poor	Flushing and peeling surface treatment

'-' Data not available

Overlay Design and Construction

The overlay designs consist of aggregate properties, material quantities, gradations, and laboratory results. Table 7.4 presents the aggregate properties. Many of the projects used SAC A aggregates blended with some SAC B aggregate. The Brownwood-Fine PFC was designed specifically with two SAC B aggregates to avoid problems of aggregate crushing as noted in other PFC projects with blended aggregates. Note that the mix design for the Lufkin- and Bryan-Fine PFC projects was the same. These projects are grouped together in the following design tables.

The overlay mix designs, comprising aggregate composition, binder, and admixtures are shown in Table 7.5 along with the mix gradations. Table 7.6 summarizes the laboratory properties for the selected mix designs. The OAC was first determined volumetrically and then adjusted based on the laboratory performance results.

A few noteworthy mix design issues not addressed in the summary tables are as follows:

- The Pecos RTC Hoban-Fine PFC failed the Cantabro test and the Eastland-Fine PFC has unknown Cantabro performance.
- The Lufkin/Bryan-Fine PFC mixes passed the HWTT, but showed possible signs of shoving (see Figure 4.14).
- The OAC values for the Pecos RTC Fine SMAs and Bryan-Fine SMAs are the minimum to achieve acceptable cracking resistance

Table 7.4. Aggregate Properties.

		Source		**Properties**			
Project Name	**Type**	Producer	Quarry	SAC	RSLA	RSSM	RSMD
Pecos-RTC (6 mixes)	Rhyolite Gravel	Capitol Aggregate	Hoban	A	20	10	8
	Limestone	CSA Materials	Turner	B	31	20	24
	Limestone	Vulcan	Eastland	B	25	13	16
Georgetown-TOM	Sandstone	Capitol Aggregate	Delta	A	20	19	12
	-	RTI Hot Mix	Yearwood	B	27	21	-
Bryan-Fine SMA	Sandstone	Capitol Aggregate	Delta	A	20	19	12
	Dolomite	Capitol Aggregate	Marble Falls	B	30	6	11
	Limestone	Colorado Mtrls.	Hunter	B	32	23	24
Lufkin/Bryan-Fine PFC	Sandstone	Capitol Aggregate	Delta	A	20	7	12
Brownwood-Fine PFC	Limestone	Zack Burket Co.	Leach	B	28	17	19
	Limestone	Vulcan	Eastland	B	25	13	16

SAC - Surface Aggregate Classification
RSLA - Rated Source Los Angeles Abrasion
RSSM - Rated Source Soundness Magnesium
RSMD - Rated Source MicroDeval
'-' Data not available

Table 7.5. Overlay Mix Designs and Gradations.

	Aggregate		**Asphalt**			**Percent Passing (%)**						
						Sieve Size						
Project Name	Composition	Quarry	Content (%)	Source (PG)	**Other**	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Pecos RTC												
Hoban-Fine DGM	65% Gr 6	Hoban	8.8	Alon (76-22)		99.9	80.8	40.4	24.0	17.2	13.1	8.2
	35% Screenings	Turner										
Eastland-Fine DGM	30% Gr 5	Eastland	8.1	Alon (76-22)		99.3	83.9	60.0	33.8	19.2	10.5	3.1
	70% Man. sand	Eastland										
Hoban-Fine SMA	60% Gr 6	Hoban	7.0	Alon (76-22)	0.3% fibers	99.7	53.4	34.2	22.7	17.3	13.4	7.6
	40% Screenings	Turner										
Eastland-Fine SMA	60% Gr 6	Eastland	7.2	Alon (76-22)	0.3% fibers	98.7	67.8	35.6	20.1	11.6	6.5	2.3
	40% Man. sand	Eastland										
Hoban-Fine PFC	100% Gr 5	Hoban	6.5	Alon (76-22)	0.3% fibers	94.5	30.2	4.8	1.0	0.4	0.3	0.2
Eastland-Fine PFC	100% Gr 5	Eastland	6.5	Alon (76-22)	0.3% fibers	97.8	46.4	3.4	1.9	1.6	1.5	1.3
Georgetown-TOM	77% Dirty F-rock	Delta	6.7	(76-22)		100.0	56.3	24.1	17.3	13.0	10.2	6.6
	23% Screenings	Yearwood										
Bryan-Fine SMA	42% Gr 5	Delta	6.7	Jebro (76-22)	1% lime	93.6	46.4	25.3	13.9	10.2	9.5	7.9
	33% D-Rock	Marble Falls			0.3% fibers							
	24% Dirty Scrn	Hunter										
Lufkin/Bryan-Fine PFC	100% Gr 5	Delta	6.5	Lion (76-22)	1% lime	99.8	25.2	4.2	3.8	3.2	2.5	1.6
					0.3% fibers							
Brownwood-Fine PFC	40% D-Rock	Leach	6.5	Heartland	0.8% liquid	96.8	46.1	4.8	3.6	3.1	2.9	2.7
	40% F-Rock	Leach		(76-22)	anti-strip							
	20% Gr 5	Eastland			0.2% fibers							

Table 7.6. Overlay Laboratory Properties.

Project Name	Asphalt Content (%)	Rice Specific Gravity (g/cm^3)	Density (%)	HWTT Rut Depth (mm)	HWTT # Cycles	Overlay # Cycles	Cantabro Mass loss (%)
Pecos RTC							
Hoban-Fine DGM	8.8	2.270*	96.5*	9*	20,000	>1,000*	NA
Eastland-Fine DGM	8.1	2.385*	96.5*	10.5*	20,000	700*	NA
Hoban-Fine SMA	7.0	2.309	98.8	2.6	20,000	300	NA
Eastland-Fine SMA	7.2	2.390*	98.0*	6*	20,000	300*	NA
Hoban-Fine PFC	6.5	-	-	8.1	10,000	635	52
Eastland-Fine PFC	6.5	2.431	77.8	6.3	10,000	640	-
Georgetown-TOM	6.7	2.384*	97.5*	5.8	20,000	520	NA
Bryan-Fine SMA	6.7	2.442	96.7*	3.8	20,000	300*	NA
Lufkin/Bryan-Fine PFC	6.5	2.370	72.0	-	-	462	12
Brownwood-Fine PFC	6.5	2.420	79.1	7.8	10,000	395	6.4

NA - Not applicable * Interpolated value

'-' Data not available

Construction of the mixes was carried out in general accordance with the thin overlay specifications submitted in this project. Noteworthy construction issues are as follows:

- Several rolling patterns were attempted on the Bryan-Fine SMA project. Final recommended pattern was three or four breakdown passes and two finishing passes on each side of the mat.
- Many sections of the Bryan-Fine SMA project were cooler than 200°F when compaction started for half the project, and 3/4 of the whole project were below 250°F.
- Excessive rolling (four breakdown and three finish passes) during compaction of the Brownwood-Fine PFC project possibly decreased the air void a bit too much.

Overlay Performance

Overlay performance was evaluated according to skid resistance, tire-pavement noise, and permeability. These results are summarized in Table 7.7.

Skid measurements were available on nine of the different mix designs. SN_{50} values from the skid trailer were around 35 and 40 for the Pecos RTC and Georgetown-TOM projects. For Pecos RTC, the highest SN values were the fine SMAs. These readings were all done on newly constructed sections. The SN for the Bryan-Fine PFC was above 60. This measurement is high in comparison to the other projects, likely because the reading was taken after about a month of traffic, while other measurements were taken shortly after construction. Skid resistance is often lower just after construction until the thin asphalt layer covering the aggregate wears away.

Noise measurements were available on seven mixes from the Pecos RTC and Georgetown projects. The readings range from 98.5 dBA (Georgetown-TOM) to 101.6 and101.9 dBA (Pecos RTC-Fine SMAs). After the Georgetown mix, the next quietest sections

Table 7.7. Overlay Performance.

Project Name	Skid Resistance SN_{50}	Skid Resistance IFI (F60)	Overall Noise (dBA)	Water Flow Value (seconds)
Pecos RTC				
Hoban-Fine DGM	34	-	100.8	-
Eastland-Fine DGM	37	-	100.9	-
Hoban-Fine SMA	40	-	101.6	-
Eastland-Fine SMA	41	-	101.9	-
Hoban-Fine PFC	35	-	100.5	7
Eastland-Fine PFC	34	-	99.3	33, 23
Georgetown-TOM	37	-	98.5	-
Bryan-Fine SMA	-	0.41	-	> 60
Lufkin-Fine PFC	-	-	-	20
Bryan-Fine PFC	61	-	-	-
Brownwood-Fine PFC	-	-	-	21

'-' Data not available

were the Pecos RTC-Fine PFCs followed by the Pecos-Fine DGMs. For reference, 1 to 3 dB is often considered a "just noticeable" difference in noise level, about 5 dB is a significant difference, and 10 dB is perceived as doubling (or halving) the sound level (*28*). For these data, therefore, the difference between the loudest and quietest mix is just noticeable.

The permeability measurements on the fine PFCs ranged from 7 to 33 sec. For the first Eastland-Fine PFC reading and the Brownwood-Fine PFC, these measurements were made early in construction when the mat was being rolled excessively. The rolling pattern later adjusted to have fewer passes. For Eastland, this reduced the WFV to 32 sec. In the case of the Bryan-Fine SMA, the water-flow test was done to ensure the mix was impermeable. The Austin District has defined this as a WFV greater than 60 sec.

These projects were new and therefore had no surface distress. However, to understand the long-term performance of the new mixes, these sites should be monitored over several years.

SUMMARY

The purpose of this chapter was to report the findings from Task #8, *Evaluation of Experimental Sections Built during the Course of This Study*. In this task, the research team evaluated six thin overlay projects, comprising 10 unique mix designs. The types of overlays studied include two fine DGMs, three fine SMAs, one TOM, and four fine PFCs. Detailed data of the site condition, mix design, construction, and initial performance were collected for each project.

The findings are summarized as follows:

- Site conditions for the projects range from very poor (severely cracked surface or severe trafficking) to very good (new construction).
- The quality of the mixes designed also vary; some mixes used quality aggregate and performed very well in laboratory rutting and cracking resistance tests, while others used lower quality aggregate and marginally passed the same tests.
- Most mixes were constructed without problems, though some encountered issues with over- or under-compaction.
- The initial performance of all projects, from the perspective of skid resistance, tire-pavement noise, and permeability, was acceptable; therefore, the mix design and construction specifications for these mix types produce thin overlays with good initial performance. Long-term performance, on the other hand, is undetermined since these projects are all less than two years old, and several less than 3 months old.
- Even though the Hoban-Fine PFC mix failed the Cantabro test, it had good performance here and reportedly good performance in other Odessa District projects.

CHAPTER 8
CONCLUSION

REPORT SUMMARY

The primary focus of this research was to develop new thin HMA overlay options (1 inch thick or less) that TxDOT districts could easily implement. The developed mix types were fine DGM, fine SMA, and fine PFC. A number of slurry overlay systems, namely MicroTekk, MicroTekk Flex, E-Krete, Tuffseal, and an experimental high-skid slurry, were also evaluated but to a lesser extent. These thin overlay and slurry overlay options could be attractive alternatives to surface treatments and traditional HMA overlays, especially for maintenance of urban-area pavements.

Chapter 2: Literature and Information Search

A comprehensive literature and information search was first completed, compiling and synthesizing details of various overlays and the experience of different agencies and contractors with these mixes. The findings summarized below provide a framework for the development of new thin overlay specifications.

- Of TxDOT's current dense-graded options, the CAM is too rich in binder and thus susceptible to rutting and low skid resistance. The Type-F mix, on the other hand, is too coarse for thin applications, and has lenient material quality and performance requirements that could lead to poor performance.
- The Ohio Smoothseal (Type B) mix seems to work well, though for TxDOT's purposes the specifications would need to ensure the use of quality aggregates and allow the use of the SGC in design.
- TxDOT's gap-graded mixes both provide high performance, but the current gradations are slightly too coarse for lifts 1.0 inch and thinner. Also, the CMHB-F specification should have tighter tolerances all around. (Note: The newer SS 3226 and Austin's TOM design have replaced the CMHB-F specification.)
- TTI's fine PFC design and seems to provide what is needed in a thin overlay mix. The gradation is similar to the NM OGFC gradation, but permits a slightly finer design.
- The NM OGFC has a higher density requirement that, in the experience of the researchers, could cause problems with in-field permeability.
- During the construction of thin overlays, pneumatic rollers should not be permitted and consideration should be given to omitting in-field density requirements on open-graded mixes.
- The slurry overlay findings are mostly informational. Conventional microsurfacing (MicroTekk) is well documented by numerous agencies, while MicroTekk Flex is largely unstudied. The performance of E-Krete is not well-documented in the field; the research

mostly pertains to controlled laboratory studies and airport pavements, and not to highway applications.

Chapter 3: Field Evaluation of Existing Projects

The research team evaluated 11 existing thin overlay and slurry overlay projects by collecting background information (site condition, mix design properties, and construction procedures) and performance data (surface distress, subsurface condition, and skid resistance). The findings are summarized as follows:

- Several CAM projects with rutting, flushing, or shoving problems were likely over-asphalted for a surface application. By lowering the design density or applying the balanced performance design approach, the CAM designs would have lower asphalt contents.
- All the projects studied, except one CAM, MicroTekk, MicroTekk Flex, and E-Krete, had good cracking resistance.
- The skid resistance of CAMs is generally lower than for other mix types, however, some CAMs had acceptable skid resistance even for high speeds.
- When constructed correctly, the skid resistance of fine SMA, fine PFC, CMHB-F, NM OGFC, MicroTekk, MicroTekk Flex, and E-Krete are good.

Chapter 4: Laboratory Evaluation of Thin HMA Overlays

Extensive laboratory testing of the thin overlays was carried out. This first involved a trial run of the draft specifications for all three mix types (fine DGM, fine SMA, and fine PFC) with five unique aggregates. (The specifications were based on the findings from the literature and information search and the field evaluations. They provide minimum material quality levels, laboratory performance criteria, and construction recommendations.) The resulting mixes were subject to the HWTT (rutting resistance), overlay test (cracking resistance), Cantabro test (raveling resistance, fine PFC only), and permeability test (fine PFC only) at OAC and OAC+0.5 percent. Skid resistance and noise properties were also evaluated on slab specimens. The findings from the thin overlay specification trial run are summarized as follows:

- Of the 15 mixes attempted, 12 had acceptable designs.
- The one aggregate material that did not meet the minimum quality specifications had failed mixes for both fine DGM and fine PFC.
- Three of the four accepted fine DMG designs had recommended OAC values below the asphalt content as the current target density of 96.5 percent, suggesting that the design density could be lowered.
- Two fine SMAs that were below the percent passing No. 200 specification had no compaction or performance issues, suggesting the gradation band could be lowered.

- All fine SMAs were successfully designed and none had rutting issues, though the recommended asphalt content of two mixes was much higher than the OAC+0.5 percent recommendation.
- All fine PFC mixes were compacted above 74 percent and one was above 76 percent, suggesting the design density range could be adjusted.
- Many of the fine PFC designs had possible shoving problems, where the mix passed the HWTT but exhibited excessive displacement of the mix up and out of the testing molds.
- Since the lab results in this study were similar or better to results obtained by TxDOT districts for successfully designed and constructed mixes, the proposed specifications appear, for the most part, to function well.
- Skid resistance was highly influenced by aggregate type and not by mix type
- The predicted noise properties seem reasonable, where mixes with coarser gradations are louder and the permeable mixes are quieter.

Lab testing also included two supplementary studies on the effects of screening types in fine SMA and the effects of RAP and RAS substitution on fine SMA and fine PFC. The effects were evaluated with density curves, HWTT, overlay test, and Cantabro test (fine PFC only). The findings from the study of the effect of screenings in fine SMA are summarized as follows:

- Fine SMA mixes are very tough mixes, and are difficult to compact with the SGC. Only one mix was successfully designed in the SGC while four were designed with the TGC.
- Small changes in the screening gradations can greatly affect the packing characteristics of fine SMA. Screenings used should not be too coarse and should have enough fine sand and fines to fill voids in the coarse aggregate skeleton. The gradation band for these mixes needs further study.
- Screening quality did not affect the rutting resistance of fine SMA.
- Screening quality did affect the cracking resistance where lower quality screenings increased crack susceptibility mix.

The findings from the study of RAP and RAS in fine SMA and fine PFC are summarized as follows:

- Adding RAP and RAS helped reduce rutting and shoving problems in the fine PFC in this study.
- Adding RAP and RAS increased cracking susceptibility of the fine SMA and fine PFC mixes in this study.
- These mixes performed very well in most cases, suggesting that quality, well-engineered mixes can have good rutting and crack-resistant properties even when recycled materials are used in limited amounts.

Chapter 5: Laboratory Evaluation of Slurry Overlay Systems

Laboratory testing of existing slurry overlay designs (MicroTekk, MicroTekk Flex, Tuffseal, and experimental high-skid slurries) was conducted to evaluate slurry performance. Two additional modified microsurfacing designs were also tested. The cracking resistance of the original and modified microsurfacing designs was evaluated in the overlay tester with both TxDOT procedures and modified procedures (lower temperature, wider opening, and stricter failure criteria). The original microsurfacing designs and Tuffseal were subjected to wet-track abrasion testing to evaluate abrasion resistance. All slurry designs were tested for skid/polishing resistance and abrasion resistance with the TWPD. Lastly, the original microsurfacing designs, Tuffseal, and skid slurries were subject to the pull-off test to evaluate bond strength. The findings are summarized as follows:

- The cracking definitions in the overlay test (for both the TxDOT and modified methods) do not correctly identify cracking.
- Microsurfacing behaves very differently in the overlay tester with the TxDOT method than with the modified method.
- The slurry overlays studied had good performance in the wet-track abrasion test, but the test was not severe enough to differentiate between the overlays.
- No noticeable difference in skid resistance exists between MicroTekk and MicroTekk Flex, and between different sand configurations in Tuffseal.
- Microsurfacing maintains skid resistance longer than Tuffseal and the skid slurries.
- The skid resistance of Tuffseal and the skid slurries decreases dramatically if the high skid aggregate is lost from the slurry mastic.
- Polishing in the TWPD with the current setup is likely too severe for slurry overlays.
- The skid slurries and Tuffseal have very good bond strength whereas the internal microsurfacing tensile strength is low.

Chapter 6: Proposed Pavement Evaluation and Mix Selection Guidelines

Pavement evaluation and mix selection guidelines were created, which recommend or discourage the use of certain thin overlay and slurry overlay options given the pavement, traffic, and climate conditions. The guidelines are shown in Tables 6.1 and 6.2.

Chapter 7: Field Evaluation of New Thin Overlay Projects

Finally, a field evaluation of six thin HMA overlay projects, comprising 10 unique mix designs, was performed. The types of overlays studied included two fine DGMs, three fine SMAs, one TOM (similar to fine SMA), and four fine PFCs. Detailed data of the site condition, mix design, construction, and initial performance were collected for each project. The findings are summarized as follows:

- Site conditions for the projects range from very poor (severely cracked surface or severe trafficking) to very good (new construction).
- The quality of the mixes designed also varies. Some mixes used quality aggregate and performed very well in laboratory rutting and cracking resistance tests, while others used lower quality aggregate and marginally passed the same tests.
- Most mixes were constructed without problems, though some encountered issues with over- or under-compaction.
- The initial performance of all projects, from the perspective of skid resistance, tire-pavement noise, and permeability, was acceptable; therefore, the mix design and construction specifications for these mix types produce thin overlays with good initial performance. Long-term performance, on the other hand, is undetermined since these projects are all less than two years old, and several less than three months old.
- Even though the Hoban-Fine PFC mix failed the Cantabro test, it had good performance here and reportedly good performance in other Odessa District projects.

RECOMMENDATIONS

The recommendations for thin HMA overlays are as follows:

- Adopt the proposed specifications for fine DGM, fine SMA, and fine PFC for use in all TxDOT Districts. These specifications are provided in Appendix A of this report. The aspects that make these specifications ideal for designing and constructing quality thin overlays are summarized as follows:
    - High aggregate quality requirements (SAC A encouraged, LA Abrasion: 30 max, Sulfate soundness: 20 max, no RAP).
    - PG 76-22 (Given the recent set of very hot summer temperatures the PG 76-22 binder is strongly recommended for the first application of these thin overlays in any Texas district. Future studies should focus on the cost savings/risk of moving to other binders such as PG 70-22).
    - Gradations with nominal maximum aggregate size between 3/8 and No. 4.
    - Use a target lab molded density of 96 percent for the fine DGM in the SGC, use 96.5 percent for the fine SMA in the TGC, and within the range of 74–78 percent in the SGC for the fine PFC (the SGC does not always arrive at an acceptable design for fine SMA).
    - Run the performance tests at two asphalt contents: the OAC from the volumetric design and the OAC + 0.5 percent.
    - HWTT: 12.5 mm at 20,000 passes for fine DGM and fine SMA and 10,000 passes for fine PFC. Overlay tester: 300 cycles for all mixes.
    - Min. asphalt content of 5.5 for fine DGM and 6.0 for fine SMA and fine PFC.
    - For all mixes, pay for the asphalt as a separate bid item.

  - For the trial batch, in addition to binder content and density testing, also run the HWTT and overlay test to ensure the mix conforms with the specification.
  - Tandem rollers recommended during compact of fine SMA.
  - Water flow >120 sec on fine DGM and > 60 sec for the fine SMA to ensure impermeability.
  - Omit in-field density requirements for fine PFC and rather control its placement via the field water flow test. Water flows must be less than 20 sec, and ideally less than 10 sec. Back off rolling if the water flows are near or above these limits.
- Districts should incorporate these mixes into their maintenance and new construction operations, especially in urban environments (severe traffic, curb and gutter height restrictions, lower tire-pavement noise). They are encouraged to try smaller experimental sections first.
- Encourage pavement engineers to give special attention to coarse and fine aggregate packing characteristics when designing fine SMA. Achieving adequate compaction can be difficult and is very dependent on this.
- Refer to the pavement evaluation and mix selection guidelines in Chapter 6 when assessing the appropriateness of using any of these thin overlay options. The general recommendations are as follows:

  Fine DGM

  - Low- and moderate-severity rutting up to 0.5 inch.
  - Over chip seals with large variations in transverse texture.
  - Low-speed city applications.
  - Need for very thin layer (some districts propose placement at 0.5 inch thick).
  - Need for easy hand work.

  Fine SMA

  - Moderately cracked sections.
  - Areas of stop-and-go traffic.
  - High-speed sections.

  Fine PFC

  - Wet weather accident locations.
  - Areas where tire noise is a concern.
  - Over flushed pavements, seal coats, or surface treatments.

- For further study:
  - Design and construction of fine DGM test sections to evaluate the potential to achieve higher skid resistance.
  - Incorporation of recycled aggregates and warm-mix additives in thin overlays.

    - Continued evaluation of new thin overlay projects, in particular the Pecos RTC overlays (severely cracked pre-existing surface), Lufkin-Fine PFC and Georgetown-CMHB-F (severe traffic), and Brownwood-Fine PFC (flushed pre-existing surface).
    - Alternative test methods for rutting and shoving susceptibility in fine PFC.

The recommendations for slurry overlay systems are as follows:

- Refer to the guidelines in Chapter 6 when assessing the appropriateness of using a slurry overlay. The general recommendations are as follows:

  MicroTekk

    - Moderate- and high-severity rutting up to 1.0 inch.
    - Raveled or polished surfaces.

  MicroTekk Flex

    - Moderate- and high-severity rutting up to 1.0 inch.
    - Low-severity cracked pavements.
    - Raveled or polished surfaces.

  E-Krete

    - Slightly raveled or polished surfaces.

- For further study:
    - An objective cost-benefit analysis comparing slurry overlays to thin overlays.
    - Applicability of the overlay tester and testing procedures for cracking susceptibility in microsurfacing. Ensure a tie-in with actual performance.
    - Applicability of the TWPD with a different test setup (lighter load, lower tire pressure, fewer cycles, etc.) to assess both skid and polishing resistance and abrasion resistance.
    - The effect of low internal tensile strength in microsurfacing on actual performance.
    - Studies could include short test sections with the Accelerated Pavement Test at the University of Texas, Arlington.

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APPENDIX A
PROPOSED SPECIFICATION FOR THIN FINE GRADED OVERAYS

SPECIAL SPECIFICATION

XXXX

Fine Surface Mixes
(10/14/2012)

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 aggregates 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. **Recycled Aggregate**. Do not use RAP or RAS 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 anti-strip 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 pre-paving 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%. Type II mixes (F-SMA) may require evaluating additional asphalt contents.

    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	4 - 10	2 – 10
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	74[2] – 78	96.5	96.0
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 %[7] 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.
7. May be waived based on existing field performance

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 and Overlay tests on the trial batch mixture or request that the Department perform the Hamburg Wheel and 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

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

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.

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

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

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

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

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

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 120 seconds. If the water flow rate is less than 120 seconds, adjust the mixture design or construction methods if the compacted mixture does not exhibit adequate permeability.

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

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

I. 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 III 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.”

5. **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.

6. **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.”

APPENDIX B
CASE STUDIES OF EXISTING THIN OVERLAYS

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FOR APPENDIX B

Page

TEXARKANA-CAM

The Texarkana-CAM project was placed in 2004 and was the first mix of its kind in Texas. It was originally designed as a Type F Hybrid mix with a gradation similar to a 3/8-inch Superpave mix. This mix was a precursor to what is now called a CAM. The initial design and construction of this project has been reported in a previous TTI report (*7*). Good long-term performance is indicated by this case scenario.

Site Description

This project is located on US 82 near downtown Texarkana (see Figure B.1). The extents are the intersection with Loop 14 on the north and the intersection with 7th Street on the south, for a total length of 0.7 mi.

The traffic conditions on this section of road are low to moderately severe. The section is a four-lane principal arterial with a few traffic signals and a speed limit of 40 mph. The estimated AADT/lane is 5,250 with an unknown (likely low) percentage of truck traffic.

The climate condition in the area is wet with relatively moderate summers and a fair amount of winter freezing. The average annual rainfall is 51 inches. The average summer high is 92°F with eight days on average reaching above 100°F. The average winter low is 35°F with an average of 45 days dropping below freezing.

The existing pavement structure, as estimated from GPR readings, consisted of a thin seal coat on 3 to 4 inches of asphalt on 10 to 11 inches of concrete. The surface seal was severely raveling at the time. The subgrade is a low-plasticity gravelly and sandy loam at shallow depths and low- to moderate-plasticity sandy and clayey loam deeper down.

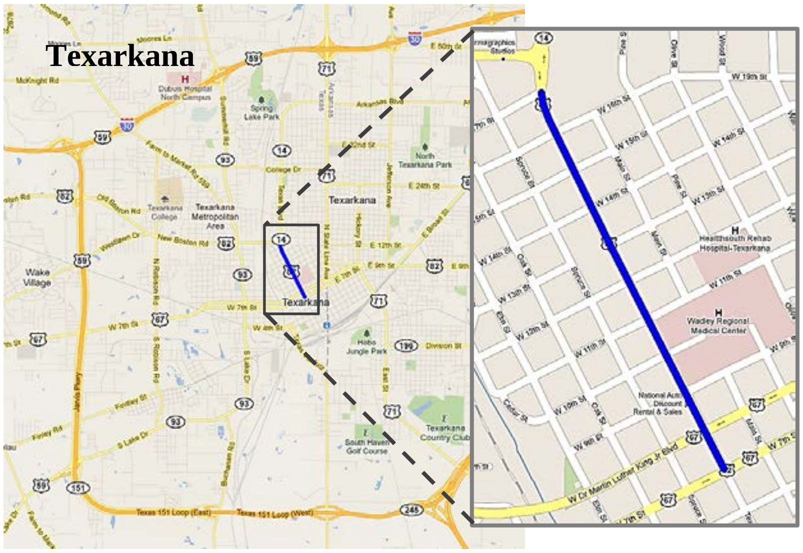


Figure B.1. Project Location on US 82 (Texarkana-CAM).

Overlay Design and Construction

The Texarkana-CAM mix was originally designed by TxDOT as a Type F Hybrid mix with a gradation similar to a 3/8-inch Superpave mix. Aside from a minimal violation on the No. 8 sieve, the mix fit what is now the CAM gradation as well. The combined gradation and the CAM gradation limits are shown in Table B.1. The aggregate for the CAM was a Class A sandstone.

The asphalt content was determined volumetrically at 98 percent density and was 7.8 percent with a PG 70-22S binder. The design passed the HWTT with 6.8 mm rutting after 15,000 cycles, and the overlay test with over 900 cycles without cracking. No density information is available.

The mix was used to fix the severely raveled surface of US 82 and was laid with a thickness around 1.0 inch. Construction took place in 2004 and no problems were encountered.

Table B.1. Mix Gradation (Texarkana-CAM).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	100.0	78.8	39.5	25.5	19.9	17.3	8.1
CAM Limits	98-100	70-90	40-65	20-45	10-30	10-20	2-10

Overlay Performance

In July 2011, the overlay condition was evaluated with a visual assessment and GPR. At the time, the CAM was 7 years old, making it the oldest mix of its kind in Texas. Skid and noise measurements were not performed on this pavement due to speed limit restrictions.

The most noticeable distress was low-severity reflective cracking as shown in Figure B.2. These cracks were spaced every 12 ft, corresponding with concrete joints in the curb and underlying pavement. The cracks extended full-width across the outside lane and intruded into the inner lane by as much as 3 ft. Other distresses included minor rutting and flushing at the signals. CAM is an asphalt-rich mix and relatively soft, so this low-level type of distress is common and does not indicate poor performance.

In all other locations along the road, the CAM was still in perfect condition. The ride was smooth and there was no sign of the previous raveling problem. Figure B.3 shows a close-up of the intact surface texture. The texture is not as dense as other CAM textures, probably because of loss of fines over time; the surface should have suitable macrotexture, but skid properties are unknown.

Figure B.4 shows the typical GPR profile on this project. The profile suggests the subsurface condition is fairly uniform, though there may be some issues with subsurface cracking in the asphalt layer associated with concrete joints. A jagged and broken pattern in the GPR layer interface may indicate cracking. The pattern is moderately developed here.

The Texarkana-CAM is in very good condition for its age. The overlay was placed on transverse-cracked HMA over jointed concrete. These joints have reflected through most areas of the CAM, though cracks are of low severity. Though no skid measurements were available, the surface texture seems coarse enough to provide good skid resistance.

(a) Along Road (b) At a Transverse Joint

Figure B.2. Reflective Cracking (Texarkana-CAM).

Figure B.3. Surface Texture (Texarkana-CAM).

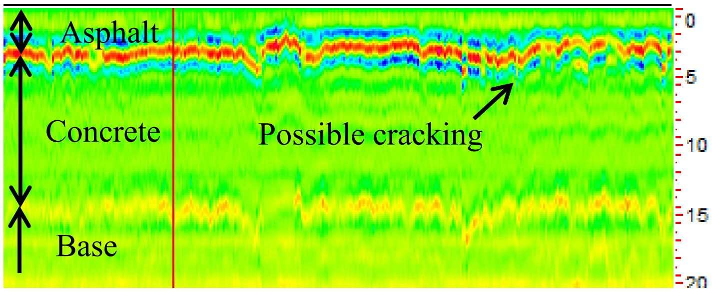


Figure B.4. GPR Profile (Texarkana-CAM).

LUFKIN-CAM

The Lufkin-CAM project was placed in 2008 and was the focus of other TTI studies on CAMs and the Pave-IR thermal segregation monitoring system (*7, 29*). This case scenario shows how the CAM may have problems under extreme stop-go traffic and with skid resistance.

Site Description

This CAM project is located on BS 59 (1st Street) in Lufkin (see Figure B.5). The project extents are the intersection with TX Loop 287 on the south and the intersection of 1st Street and Timberland Dr. on the north. The total length of the section is 1.0 mi.

The traffic conditions on this section are low to moderate severity. BS 59 is a four-lane principal arterial with a few traffic signals, one stop sign, and a speed limit of 45 mph. The estimated AADT/lane is 4,080 with an unknown (likely low) percentage of truck traffic.
The climate condition in the area is wet with relatively moderate summers and mild winters. The average annual rainfall is 47 inches. The average summer high is 93°F with 6 days on average above 100°F. The average winter low is 39°F with an average of 28 days below freezing.

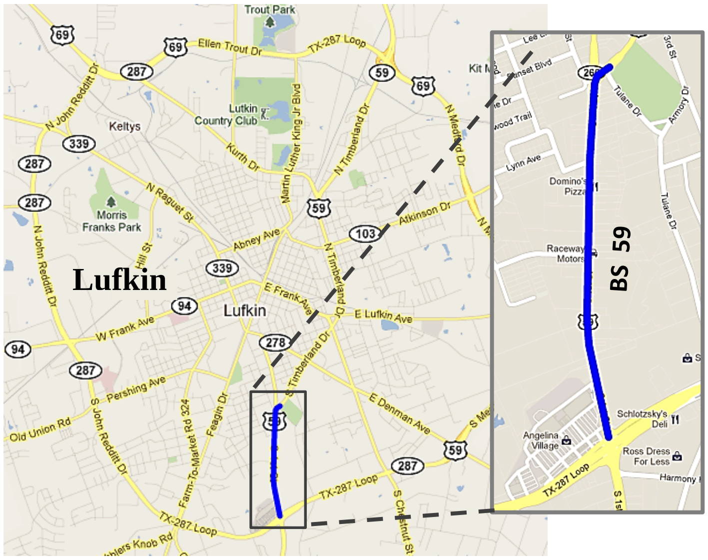


Figure B.5. Project Location on BS 59 (Lufkin-CAM).

The existing pavement structure, as estimated from GPR readings, consisted of between 3 and 5 inches of asphalt on 8 to 10 inches of jointed concrete. The subgrade is a non-plastic sandy loam at shallow depths and moderate- to high-plasticity clay loam deeper down. The surface condition was characterized by reflective transverse cracking and patching. A short 200-ft section to the north had joints with poor load transfer, as determined by rolling dynamic deflectometer testing. The joints in this area were repaired to mitigate future reflective cracking problems and crack seal was applied to other existing cracks.

Overlay Design and Construction

The Lufkin-CAM mix was designed according to TxDOT SS 3165. The combined gradation and the CAM gradation limits are illustrated in Table B.2. The aggregate was a Class A granite and 1 percent lime was added to the mix. The asphalt content was determined volumetrically at 98 percent density and was 8.3 percent with a PG 76-22 binder. The design passed the HWTT with 7.8 mm rutting after 20,000 cycles, and the overlay test with 1,510 cycles. The balance mix design approach would likely have resulted in a lower asphalt content with even lower HWTT rutting.

The CAM was constructed in August 2008. As this project was the focus of a few TTI studies, construction procedures were carefully monitored and documented. The contractor used belly-dump trucks to place the mix in windrows. A Lincoln 660 windrow elevator and a Blaw Knox PF-3200 paving machine then placed the CAM. The contractor’s primary compaction roller was a CAT CB-634D, and an Ingersoll Rand DD130 was used as the finish roller.

The TTI researchers made the following observations. Thermal profiles provided by the Pave-IR system showed good thermal uniformity within truckloads. Thermal segregation that did occur was associated with truck ends and variable truck arrival times. The densities of two core samples were 93.6 and 91.8 percent relative density.

A few issues were observed in construction. During paving, in some locations the CAM appeared to heave directly over existing transverse cracks that had been crack sealed. The next day, however, the researchers did not notice anything unusual in the appearance or ride of the pavement. The heaves observed probably resulted from a temporary swelling of the crack seal. Also, on the final day of paving, mechanical problems with the breakdown roller delayed compaction on a 1,000-foot section for more than 1 hour. This section was subsequently replaced.

Table B.2. Mix Gradation (Lufkin-CAM).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	100.0	79.4	47.6	31.0	20.1	12.2	4.2
CAM Limits	98-100	70-90	40-65	20-45	10-30	10-20	2-10

Overlay Performance

In July 2011, the overlay condition was evaluated with a visual assessment and GPR. At the time, the CAM was about three years old. The overlay skid performance was measured in November 2008 (three months after construction), in July 2009, and in August 2011. Noise measurements were not made due to speed limit restrictions.

This CAM is in good condition. Figure B.6a shows the site and close-up of the surface texture. The densely graded surface seems intact except for an occasional low-severity crack. One issue, however, was localized shoving and rutting by a stop sign on the north end of the project. The surface was pushed backwards nearly 2 ft at the stop bar (see Figure B.6b). Accelerating vehicles exert a shearing force on the overlay surface, causing the layer to either shear internally or at a layer interface. This issue was not observed at the stoplights, though these areas have lower concentrated stop-go traffic volumes. Every car traveling this road must stop and then accelerate at the stop sign, while vehicles are stopped at the lights only occasionally and only a few vehicles will accelerate at the signal stop bar itself. A stiffer mix with a lower asphalt content would have resisted these forces better.

Figure B.7 shows two example GPR profiles from this project. These indicate a variable asphalt and concrete structure. The thick red-blue patterns within the asphalt layer may indicate moisture damage like stripping. There are several problem areas like these along the project that may cause m problems in the future. Good, uniform subsurface sections exist as well.

(a) Site Overview and Texture (b) Severe Shoving

Figure B.6. Site Pictures (Lufkin-CAM).

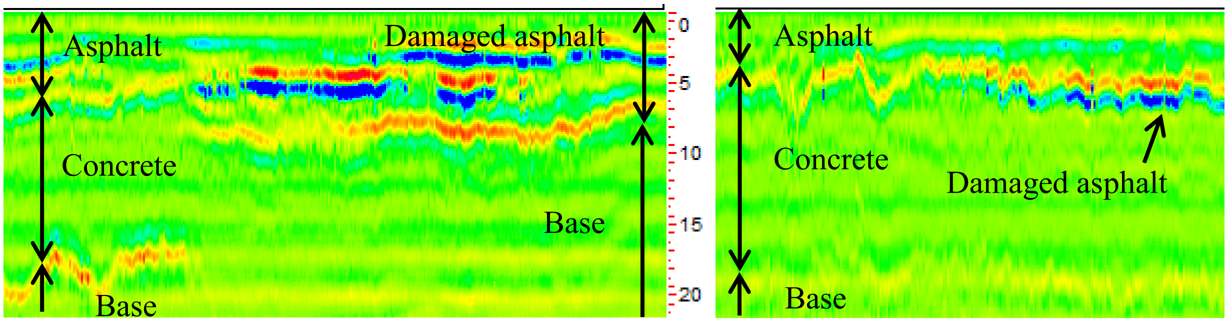


Figure B.7. GPR Profiles (Lufkin-CAM).

The skid was measured three times during the treatment life; Figure B.8 shows the results. Each value represents the average of 10 readings. In November 2008, a month after construction, the CAM had an average SN_{40} in the low 20s with standard deviations around 6.5. About eight months later the average SN_{40} dropped below 20 with standard deviations around 3.5. Three years after construction, the SN values hardly decreased, indicating the skid resistance had equilibrated. At this point, the average SN_{40} for the whole project was 17, with a standard deviation of 2.5. This value is low, likely due to the dense and smooth surface texture, and raises safety concerns. In this case, the CAM mix would likely not be recommended for higher speed roads.

After three years, the Lufkin-CAM project looks good overall, but may have some issues with shoving and skid resistance. There is almost no cracking on the surface, despite the existing transverse cracks in the old asphalt beneath. The CAM showed severe signs of shoving at a stop sign, where every passing vehicle must brake and accelerate. The CAM mix may not have been

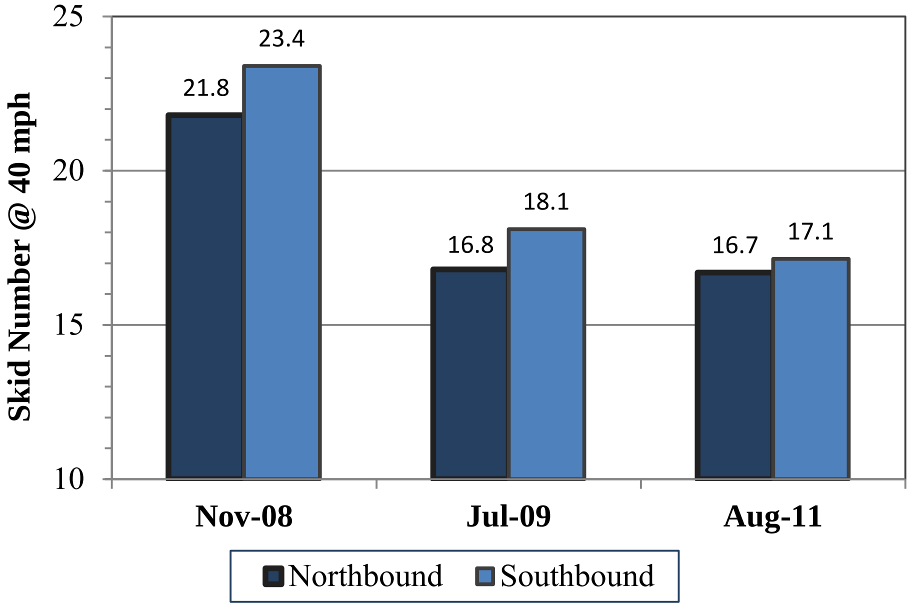


Figure B.8. Skid Results (Lufkin-CAM).

designed to resist such harsh shearing conditions, though a stiffer mix produced by the balanced mix design approach may have performed better. Finally, the average SNs are low and not suitable for a higher speed road.

UVALDE-CAM

The Uvalde-CAM project was constructed in 2008. This was used as an experimental project for the San Antonio District to monitor the design process, construction, and performance of CAM. It was also the focus of past TTI studies on the balanced mix design approach for thin overlays and the Pave-IR system (*7, 29*). This project shows generally good performance to date.

Site Description

This CAM project is located on US 90, 6.5 mi west of Uvalde (see Figure B.9). The project extents are reference marker (RM) 478 on the west and RM 482 on the east. The total length of the section is 2.3 mi.

The traffic conditions on this section are of low severity. The road is a four-lane undivided rural principal arterial with a speed limit of 70 mph. The estimated AADT/lane is 1,800 with 17 percent truck traffic.

The climate condition in the area is fairly dry with high summer temperatures and mild winters. The average annual rainfall is 23 inches. The average summer high is 96°F with 31 days on average reaching above 100°F. The average winter low is 41°F with an average of 18 days dropping below freezing.

This project has two distinct existing pavement structures. The section to the west end has 11 inches of asphalt over an unknown thickness of base or subgrade. The section on the east has 6 to 7 inches of asphalt, where the top 2 inches is poorly bonded in some locations. Most of the project rests on low-plasticity gravelly loam and cemented material, though the subgrade to the east is a thick gravelly clay layer with moderate- to high-plasticity. A field core should be used to verify the layer properties. The asphalt condition before CAM construction was not documented.

Figure B.9. Project Location on US 90 (Uvalde-CAM).

Overlay Design and Construction

The Uvalde-CAM mix was designed according to TxDOT SS 3165 but with the balanced mix design approach. Table B.3 illustrates the mix gradation and the CAM gradation limits. The primary aggregate was a Class A trap rock and 1 percent lime was added to the mix. The OAC selected, based on performance in both the HWTT and overlay tester, was 6.8 percent with a PG 76-22S binder. As shown in the laboratory results in Table B.4, the design passed the overlay test at all asphalt contents tested and passed the HWTT at all but 7.2 percent asphalt after 15,000 cycles. Though a lower asphalt content would seem to produce acceptable results, such a mix may result in excessively low densities. The resulting density was around 96 percent.

The balanced mix design approach here resulted in an OAC almost 1 percent lower than would have been obtained with the volumetric approach at 98 percent density. Furthermore, the mix would not have passed the HWTT at the higher asphalt content, and would have resulted in a failing mix. This trend has been noted on other CAM designs and it is a primary reason TTI researchers prefer the balanced mix design approach.

The CAM was constructed in September 2008. One construction issue noted was that the CAM was placed at a relatively normal temperature, between 250° and 275°F. Furthermore, several cold streaks in the mat, with temperatures around 200°F, were observed. These streaks are often associated with low densities and future surface raveling (see Figure B.10). These observations from TTI were made on the last day of paving and may or may not represent the rest of the project.

Table B.3. Mix Gradation (Uvalde-CAM).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	98.9	71.9	53.8	31.6	19.1	12.3	6.6
CAM Limits	98-100	70-90	40-65	20-45	10-30	10-20	2-10

Table B.4. Laboratory Results (Uvalde-CAM).

Asphalt	**TGC Relative**	**HWTT**		**Overlay**	
Content (%)	**Density (%)**	Rut Depth (mm)	Cycles	Cycles	Max Load (lb)
6.4	-	5.2	15,000	>1,000	657
6.5	94.6	-	-	-	-
6.8	-	6.4	15,000	>1,000	538
7.0	96.6	-	-	-	-
7.2	-	12.7	15,000	>1,000	553
7.5	97.7	-	-	-	-

Figure B.10. Low-Density Cold Streak with Potential for Raveling (Uvalde-CAM).

Overlay Performance

In July and August 2011, the overlay condition was evaluated with a visual assessment, GPR, skid measurements, and noise measurements. At the time, the CAM was about 3 years old.

For the most part, this CAM was in good condition. Most locations on the project looked like the section in Figure B.11. There was no cracking or raveling noted here. The surface was

Figure B.11. Project and Surface Texture (Uvalde-CAM).

densely graded so the macrotexture would be low, which could be detrimental to skid resistance.

Another section, however, had a subtle rippled pattern on the surface and some transverse and longitudinal cracking (see Figure B.12). The ride was also noted as being a little rough along the project. None of these distresses were associated with the cold spots documented during construction.

The typical GPR profiles, shown in Figure B.13, suggest the subsurface condition is generally good. The layers and layer interfaces are very uniform, though one section has issues with a weak interface 2 inches below the surface. Cores from the project confirm this.

The skid measurements in the eastbound and westbound directions were 26 and 31, respectively, with an average of 29. This value is not particularly high, but is acceptable for the traffic on this road.

Figure B.12. Subtle Pavement Roughness (Uvalde-CAM).

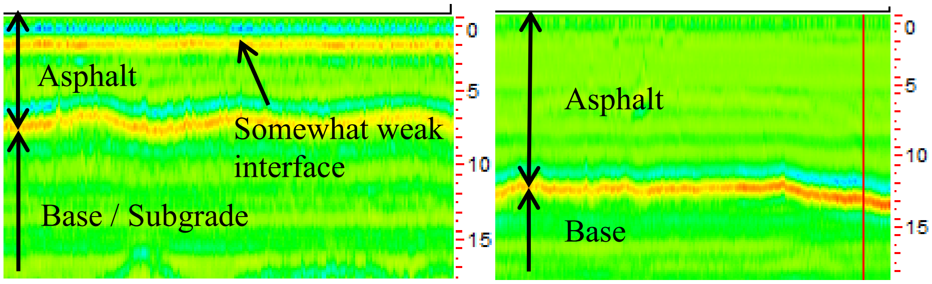


Figure B.13. GPR Profiles (Uvalde-CAM).

MT. PLEASANT-CAM

The Mt. Pleasant-CAM project was placed in 2009. Among the other projects in the report, this project is unique in that the thin overlay was finished with a surface treatment rather than leaving the treatment as the wearing surface. Also, the mix was designed with the traditional TxDOT specification, which, in this case, resulted in a high asphalt content. Because of these points and unusually hot summer temperatures, the project had flushing complications after one year.

Site Description

This CAM project is located on SH 49, 2.3 mi southeast of Mt. Pleasant (see Figure B.14). The project extents are the intersection with FM 1735 on the west and the Titus-Morris county line on the east. The total length of the project is just over 6 mi.

The traffic conditions on this road are of low severity. The road is a four-lane rural major collector with a speed limit of 65 mph. The estimated AADT/lane is 1,460 with 14 percent truck traffic.

The climate condition in the area is wet with relatively moderate summers and a fair amount of winter freezing. The average annual rainfall is 48 inches. The average summer high is 93°F with 12 days on average reaching above 100°F. The average winter low is 32°F with an average of 62 days dropping below freezing.

The existing pavement structure, consisted of an 8-inch lime-fly ash stabilized subgrade, 12 inches of Type A, Grade 4 iron-ore base, and two one-course surface treatments. Before the new overlay was applied, the surface ride was very rough. The subgrade is a low-plasticity gravelly and sandy loam at shallow depths, and low- to moderate-plasticity sandy and clayey loam deeper down.

The iron-ore base material in this pavement is commonly used in the district and is known for having a high fines content and relatively low strength. It traditionally has high deflection properties (around 20 mils) under the falling-weight deflectometer. For this reason, any overlying surface would need to have high flexibility properties to resist cracking.

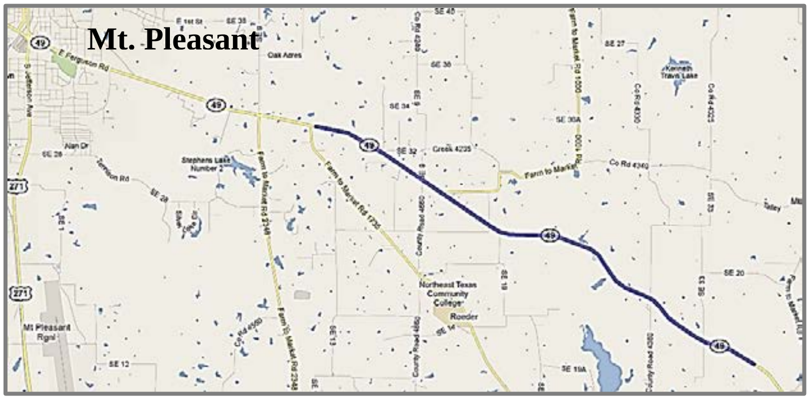


Figure B.14. Project Location on SH 49 (Mt. Pleasant-CAM).

Overlay Design and Construction

The Mt. Pleasant-CAM mix was designed according to TxDOT SS 3165. Table B.5 gives the combined gradation and the gradation limits. The aggregate was a Class A sandstone. An additional 1 percent of Akzo anti-stripping agent was added to the mix. The asphalt content was determined volumetrically at 8.2 percent with a PG 70-22 binder. The design narrowly passed the HWTT with 12.4 mm rutting after 15,000 cycles, and the overlay test with >1,000 cycles. Because the test so nearly failed in rutting, the project may be more susceptible to rutting and flushing problems. Had the balanced mix design approach been implemented, the mix would probably have required a lower asphalt content and been more resistant to rutting.

In July 2009, the pavement was first primed, then surfaced with a CAM. Fearing the dense and finely graded CAM would have poor skid resistance, the project was finished with a 3/8-inch asphalt-rubber surface treatment. The CAM was 2.25 inches thick at the centerline, tapered down to 1 3/8 inches at the lane line, and then 1 3/8 inches for the full width of the outside lane. The new CAM with one lane completed with the surface treatment is shown in Figure B.15. Though this treatment is thicker than the other projects evaluated report, the performance on this project provides useful insight into potential issues with CAM mixes.

Table B.5. Mix Gradation (Mt. Pleasant-CAM).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	99.6	74.8	42.1	28.8	23.1	19.6	6.4
CAM Limits	98-100	70-90	40-65	20-45	10-30	10-20	2-10

Figure B.15. Surface Treatment on Top of New CAM (Mt. Pleasant-CAM).

Overlay Performance

In June 2011, the overlay condition was evaluated with a visual assessment and GPR. At the time, the CAM was about three years old. Since the CAM was covered by a surface treatment, measurements of skid and noise would not represent the thin overlay properties; therefore, no skid or noise measurements were made.

The most noticeable distress was flushing (see Figure B.16a), and was most severe in the outside lane under heavy truck traffic. The flushing was a result of the surface treatment aggregate being pushed down into the CAM and the asphalt being displaced upwards. Unfortunately, the original purpose of the surface treatment, to increase the skid resistance, may be defeated by this flushing.

During the hot summer of 2010, the district engineer noticed localized swellings or blisters on the surface. The blistering was possibly an indication that the dense, asphalt-rich CAM had sealed moisture in the base, which was then steaming and expanding under the high temperatures. No residual blistering was seen in 2011 as the swellings had receded since their first occurrence. Whether they would recur is unknown.

In some locations, significant aggregate loss from the surface treatment was observed along the longitudinal construction joint (see Figure B.16a). This problem is not associated with the CAM, but rather a result of poor surface treatment construction.

Minor rutting was noted, no cracking was present, and the ride seemed adequate.

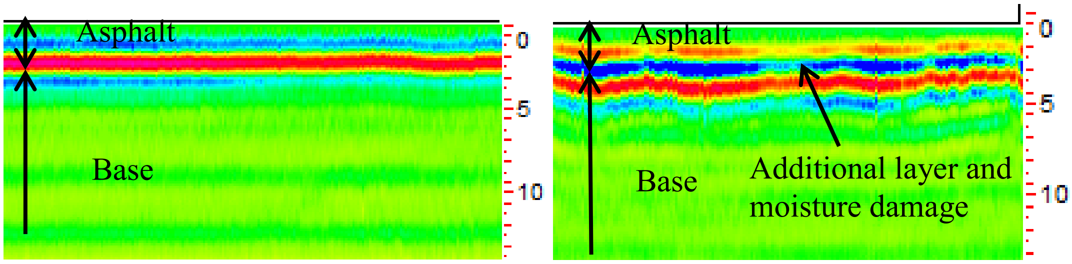
(a) Flushing through the Surface Treatment

(b) Surface Treatment Construction Joint

Figure B.16. Project Distresses (Mt. Pleasant-CAM).

Generally, the GPR profile showed pavement structures as in Figure B.17. The top structure was noted along most of the project. In some instances, the GPR indicated the moisture of the base was likely very high. This is understandable, considering the marginal base materials as described earlier. Other areas of the pavement had the profile shown on the bottom. These sections are a little thicker and have, what appears to be, an additional layer. There may be some debonding issues between these layers.

The Mt. Pleasant-CAM project is performing well in cracking resistance, but has problems associated with the soft and dense nature of the mix. The project is unique among these studies in that this CAM was finished with a surface treatment to provide better skid performance. This was not a bad idea considering the poor SNs from the Lufkin-CAM project. Unfortunately, under high temperatures and traffic loads, the surface treatment aggregate was pushed down into the soft CAM, resulting in a relatively smooth surface texture, negating the benefit of the treatment. Perhaps a CAM mix with less asphalt that did not narrowly pass the HWTT would have performed better. Such a mix could have been developed with the balanced mix design approach. One other unique issue from this project was the blistering observed. The CAM is so dense that steaming moisture beneath the pavement cannot escape, resulting in sporadic surface swellings. In the future, these issues should be considered when applying CAM designs.



(a) Typical **(b) Variant**

Figure B.17. GPR Profiles (Mt. Pleasant-CAM).

COLLEGE ST.-CAM

The College St.-CAM project was constructed in 2010. The local TxDOT district designed and placed it as part of routine maintenance. To date, this case study shows fairly good performance, though the mix is beginning to crack in the wheel paths and rutting/shoving slightly at a signalized intersection. Given the site conditions, the mix may have the best balanced performance possible.

Site Description

This CAM project is located on FM 2154 (Wellborn Rd) in College Station (see Figure B.18). The project runs from George Bush Drive on the north and between Southwest Pkwy and the interchange with FM 2818 on the south. The total length of the section is 1.0 mi long.

The traffic conditions on this road are of moderate severity. This section of FM 2154 is an urban principal arterial with two stoplights and a speed limit of 45 mph. The estimated AADT/lane is 5,250 with an unknown percentage of truck traffic.

The climate condition in the area is moderately wet with relatively moderate summers and mild winters. The average annual rainfall is 40 inches. The average summer high is 94°F with 11 days on average reaching above 100°F. The average winter low is 44°F with an average of 17 days dropping below freezing.

The existing pavement structure, as estimated from GPR readings, consisted of 10 to 12 inches of asphalt on 7 inches of base. The surface condition of an adjacent section was characterized by moderate rutting in the outside lanes and stopping areas, and moderate to severe fatigue cracking. Flushing was apparent but not detrimental to traffic safety. The subgrade is a non-plastic clay loam at shallow depths and moderate- to high-plasticity clay loam deeper down.

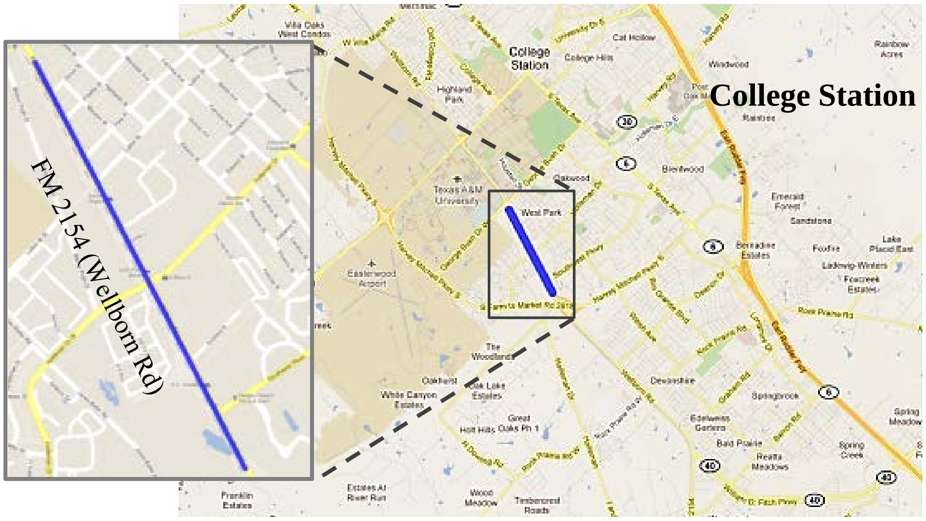


Figure B.18. Project Location on FM 2154 (College St.-CAM).

Overlay Design and Construction

The College St.-CAM mix was designed according to TxDOT SS 3165. Table B.6 gives the combined gradation and the CAM gradation limits. The aggregate was a Class A sandstone and 1 percent lime was added to the mix. The asphalt content was determined volumetrically at 98 percent density and was 7.1 percent with a PG 76-22 binder. The design passed the HWTT with 6.1 mm rutting after 20,000 cycles. The overlay test was not run on this mix.

This CAM was constructed in October 2010 and no problems were reported.

Table B.6. Mix Gradation (College St.-CAM).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	98.7	73.6	55.3	37.5	22.2	10.7	4.4
CAM Limits	98-100	70-90	40-65	20-45	10-30	10-20	2-10

Overlay Performance

In February 2011, the overlay condition was evaluated with GPR. A visual assessment and skid measurements were then made in August 2011. At the time, the CAM was just under one year old. Noise measurements were not made due to speed limit restrictions.

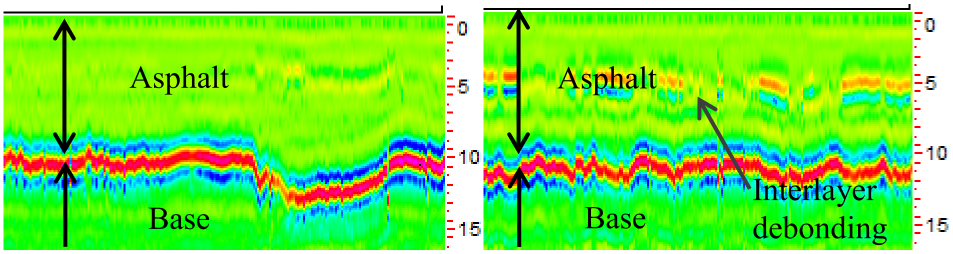
This CAM is in fairly good condition but is showing some signs of premature distress. Figure B.19 shows the project and surface texture. The densely graded surface seems mostly intact except for some longitudinal and fatigue cracking in the wheel paths in some locations. Figure B.20a shows an example of this cracking. The cracks all were of low severity and are probably reflection cracks from beneath. That the cracks appeared after less than one year is a sign that CAM may be slightly too stiff, especially given the underlying severe cracks. A more flexible mix would have resisted cracking a little better. Near the stoplight, the overlay was moderately rutting and shoving (see Figure B.20b). Similar to the distress on the Lufkin-CAM project, accelerating vehicles have pushed the surface backwards about 6 inches at the stop bar. As opposed to the cracking issue, a stiffer mix with a lower asphalt content would have mitigated this distress.

Most of the pavement had the uniform GPR profile as shown in Figure B.21a, suggesting the subsurface structure is in good condition. Toward the south end of the project, the profile begins to show signs of interlayer debonding or stripping (see Figure B.21b). This area may be susceptible to pavement deterioration. However, the GPR results do not show the moderate to severe fatigue cracking distress present in the previously existing surface.

Figure B.19. Project and Surface Texture (College St.-CAM).

(a) Fatigue Cracking **(b) Rutting and Shoving at the Stop Light**

Figure B.20. Pavement Distresses (College St.-CAM).



(a) Typical **(b) Damaged Sections**

Figure B.21. GPR Profiles (College St.-CAM).

The skid resistance was measured in one direction and the average SN_{50} was 24.5 with a standard deviation of 4.6. This may be lower than desired for this 45 mph section.

Overall, the project is performing fairly well, but the site conditions are pushing the limits of the mix. The underlying pavement was fatigued and these cracks are coming through the mix after less than one year. On the other hand, the mix is beginning to rut and shove at the signaled intersection. In this case, the mix may have well-balanced performance between cracking and rutting.

ATLANTA-FINE SMA

The Atlanta-Fine SMA project was constructed in 2010. Several complications were encountered including a mix design change, the use of warm-mix construction (without warm-mix design), and record breaking heat. The project suffered from severe flushing issues.

Site Description

This fine SMA project is located on IH 20 running 16.5 mi from Longview to Marshall (see Figure B.22). The project extents are RM 596.5 to 614 from west to east.

The traffic conditions on this road are of high severity. This section of IH 20 is a four-lane rural interstate with a speed limit of 70 mph, and is a major east-west trucking route. The estimated AADT/lane is 7,750 with 30 percent truck traffic.

The climate condition in the area is wet with relatively moderate summers and a fair amount of winter freezing. The average annual rainfall is 49 inches. The average summer high is 92°F with seven days on average reaching above 100°F. The average winter low is 40°F with an average of 40 days dropping below freezing.

The existing pavement structure consisted of about 5 inches of asphalt, on 8 inches of continually reinforced concrete, on stabilized base and subgrade. In several locations, the asphalt-concrete layer interface had moisture damage. The surface had reflected transverse and longitudinal cracking and a generally rough ride. The subgrade is a low-plasticity sandy loam at shallow depths and low- to moderate-plasticity silty and sandy clay loam deeper down. These thicknesses were confirmed with field coring.

Figure B.22. Project Location on IH 20 (Atlanta-Fine SMA).

Overlay Design and Construction

The Atlanta-Fine SMA mix was designed according to TxDOT Item 346-Type F. Table B.7 gives the combined gradation and the gradation limits. The aggregate was primarily a Class A quartzite. The asphalt content was determined volumetrically with PG 70-22 binder at 6.4 percent and an additional 0.2 percent fibers were used to stabilize the mix. The design passed the HWTT with 6.9 mm rutting after 20,000 cycles and the overlay test with >1,000 cycles.

In construction, the binder was modified with a warm-mix additive while the binder content and compaction effort remained unchanged. The effects of the additive are not captured in the lab tests.

Table B.7. Mix Gradation (Atlanta-Fine SMA).

	Percent Passing (%)							
Property	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	100	77.5	37.0	24.0	19.3	16.9	14.4	8.9
Fine SMA Limits	100	70-90	30-50	20-30	8-30	8-30	8-30	8-14

IH 20 was surfaced with a fine SMA in the spring of 2010. Unlike other thin-overlay projects in Texas, the contractor here used a warm mix additive in the SMA. Warm mix can help reduce overall costs by reducing the high temperature requirements of compaction. Unfortunately, several issues were encountered during construction. Because thin mats tend to cool very fast, the compaction temperature was not reduced, thus defeating the purpose of the warm mix additive. The mix was originally designed with a PG 76-22 binder, but was changed to a less-expensive PG 70-22 after learning the lower-grade mix passed laboratory rutting tests. After most of the construction was complete, severe flushing problems with this binder were observed, so a smaller 2-mile section was consequently constructed with the PG 76-22 and without the foaming additive. According to the quality control records, 25 percent of the sampled locations had air voids much lower than allowed, and several other locations also had asphalt contents greater than the target content, but still within the tolerance limit. Performance problems were likely a cumulative result of the issues described above.

Overlay Performance

Since the time of construction, serious flushing problems were noted. This issue was well-documented with photos and field cores in late 2010 and early 2011 in conjunction with emergency repairs after just a few months of service. In June 2011, the overlay was again evaluated with the GPR and skid measurements were made in August 2011 shortly before reconstruction. Because of the apparent performance issues, noise measurements on this project would not represent noise characteristics for traditional fine SMA mixes.

Shortly after construction, all lanes in all directions were severely flushed (see Figure B.23a). This occurred after record-high temperatures with over a week of air temperatures above 110°F and surface temperatures likely at 160°F. A small area constructed with PG 76-22 (rather than PG 70-22) and without the foaming additive was performing much better, but did have some flushing. Some rutting failures were also observed, as shown in Figure B.23b, but only for 2 mi in the outer lane in the westbound direction.

The field cores in Figure B.24 clearly illustrate the flushing problem and moisture damage concerns. The surface of the cores in the wheel path is smooth and completely closed up with asphalt. Some of the cores also show signs of stripping within the overlay and debonding from the existing asphalt.

The typical GPR profiles are shown in Figure B.25. The first profile shows a good, uniform HMA layer over concrete. This type of profile was observed along half of the westbound direction and two of the 16.5 mi in the eastbound direction. However, the profiles in Figure B.25b

(a) Severe Flushing **(b) Rutting**

Figure B.23. Pavement Distresses (Atlanta-Fine SMA).

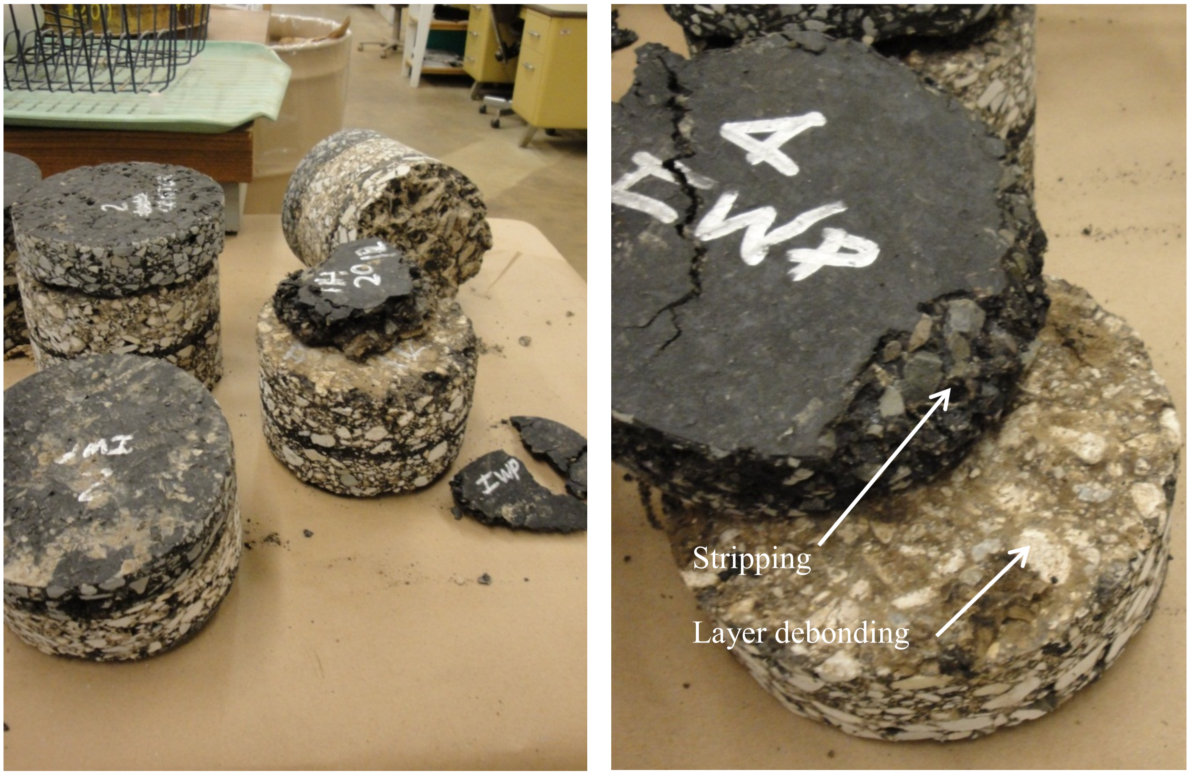
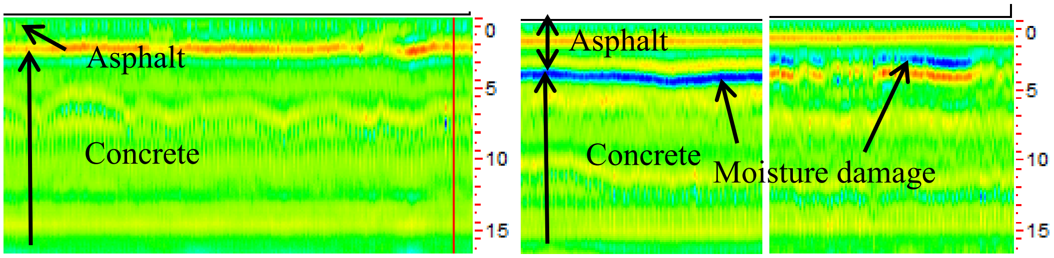


Figure B.24. Flushed and Moisture-Damaged Core Specimens (Atlanta-Fine SMA).

are typical for the majority of the project. These profiles suggest the lower part of the asphalt layer had moisture damage. As previously discussed, the field cores confirm this issue. One theory is that the moisture damage to the SMA occurred only in locations where moisture was trapped in the existing asphalt. Under the high temperatures, the moisture evaporated but was then trapped beneath the flushed surface, damaging the SMA.

As concerns skid resistance, the majority of the project, constructed with PG 70-22 binder, had very poor skid resistance where SN_{50} was about 11 with a standard deviation of 1.7. The SN_{50} of the PG 76-22 section was about 31 with a standard deviation of 4.1. This better performing section was visibly less flushed.

The severe flushing on this project is likely a compounded effect. The primary cause was the switch to PG 70-22 binder instead of PG 76-22. This is evident in the short PG 76-22 section, which is performing much better. The very hot weather was clearly significant. The number "70" in "PG 70-22" refers to 70°C (158°F) as the upper limit of desirable viscosity properties in the binder. This limit was almost certainly approached. Finally, the use of warm-mix technology without adjusting the compaction temperature could also have caused problems, though most of the tested air voids are within acceptable limits.



(a) Undamaged **(b) Damaged**

Figure B.25. GPR Profiles (Atlanta-Fine SMA).

AUSTIN-CMHB-F

When the Austin district discovered a waste pile of "dirty" F-rock with inherently good qualities, they decided to design a maintenance mix to take advantage of the inexpensive aggregates. This project was constructed in 2009 and was used to evaluate the resulting CHMB-F mix as a precursor to more widespread application. Usually a mix is evaluated for three years before adopting it, but the district engineers were so pleased with this project that they decided to incorporate the overlay into their maintenance schedule after only one year.

Site Description

This CMHB-F project is located on the northbound frontage road along IH 35 in Austin (see Figure B.26). It is a short test section to experiment with a CMHB-F mix, which involves stone-on-stone contact similar to an SMA mix. This test project runs between exits 232 A and B for 0.4 mi.

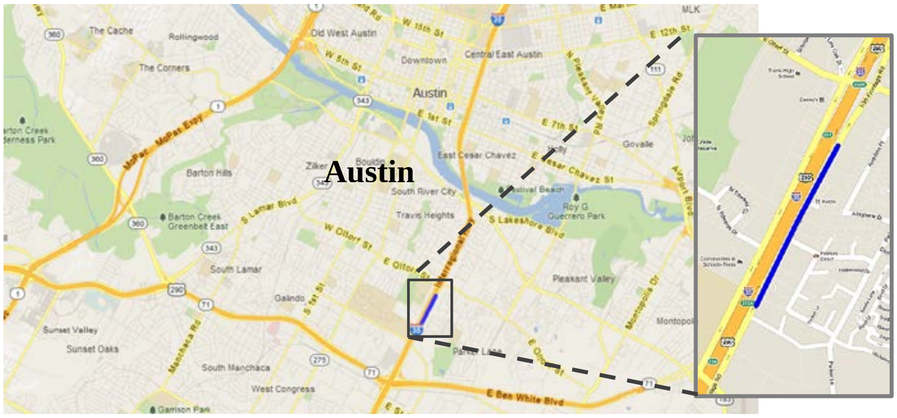


Figure B.26. Project Location on IH 35 Frontage Road (Austin-CMHB-F).

The traffic conditions on this road are unknown though estimated to be of low severity. The three-lane frontage road services traffic between the freeway and a small commercial area, a nearby mall, and a large residential neighborhood.

The climate condition in the area is moderately wet with fairly hot summers and mild winters. The average annual rainfall is 34 inches. The average summer high is 95°F with 20 days on average reaching above 100°F. The average winter low is 45°F with an average 11 days dropping below freezing.

The existing asphalt thickness is highly variable ranging from 5 to 17 inches, as shown in the GPR profile in Figure B.27. The thickness of the base is unknown and the subgrade is a high-plasticity clay. The existing surface condition had extensive fatigue and block cracking. The most damaged lane was repaired before construction.

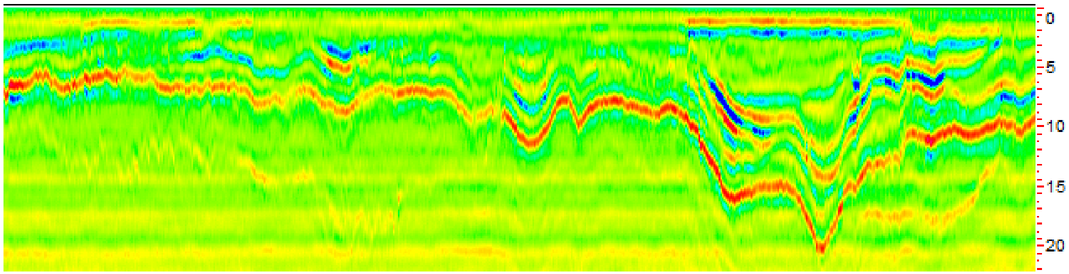


Figure B.27. Variable Asphalt Depth (Austin-CMHB-F).

Overlay Design and Construction

This CMHB-F was designed according to the TxDOT SS 3226. Table B.8 shows the gradation. The aggregate was a primarily a “dirty” F-rock from a Class A sandstone with some screenings. Though this aggregate was a waste product, the inherent aggregate properties were still good. The asphalt content was determined volumetrically at 6.7 percent with PG 76-22 binder. The mix passed the HWTT test with 5.8 mm rutting after 20,000 cycles. The mix was not tested for cracking resistance in the overlay tester.

Table B.8. Mix Gradation (Austin-CMHB-F).

	Percent Passing (%)							
Property	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	100	77.5	37.0	24.0	19.3	16.9	14.4	8.9
CMHB-F Limits	98-100	85-100	40-60	17-27	5-27	5-27	5-27	5-9

The project was constructed in the summer of 2009. The most damaged lane received an 8-inch-deep repair; the other lane, with some fatigue and block cracking, was left untouched. The CMHB-F was 1 inch thick and no construction problems were reported.

Overlay Performance

In June 2011, the overlay condition was evaluated with a visual assessment and GPR. At the time, the CMHB-F was about two years old. Noise and skid measurements were not made since more concentration was given to the full-scale construction of this mix described in the next project.

This overlay is in good condition as shown in Figure B.28. This is expected since the project is not old. The only distress is a small longitudinal edge crack in the outer lane. The GPR profile in Figure B.29 shows the variability of the asphalt layer thickness and indicates there are several small areas of potential stripping. This may manifest itself as surface distress later on. The section had good skid, ride, and noise properties that are not reported here.

Figure B.28. Project and Surface Texture (Austin-CMHB-F).

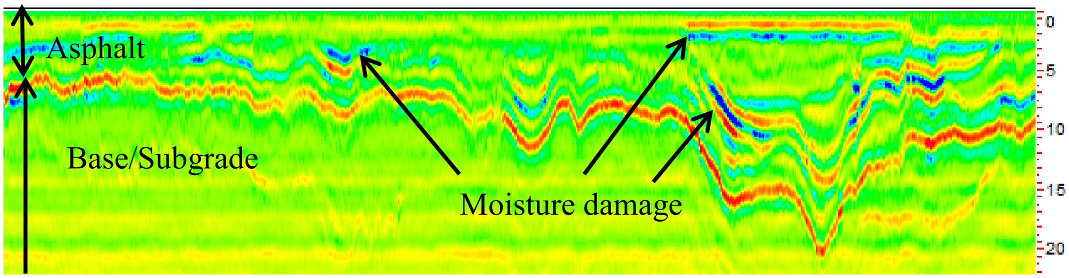


Figure B.29. GPR Profile (Austin-CMHB-F).

This project was used to evaluate the new thin overlay as a precursor to more widespread application. Usually a mix is evaluated for three years before adopting it. However, the district engineers were so pleased with this project that they decided to incorporate the overlay into their maintenance schedule after only one year.

LUBBOCK-NM OGFC

The Lubbock-NM OGFC project was constructed in 2007 as a trial run for a new thin overlay. The mix was designed to replicate a successful thin OGFC that the New Mexico DOT uses.

Site Description

The New Mexico OGFC project is located on US 62/82 (Martha Sharp Freeway) in Lubbock, leading up to an overpass at the interchange with TX Loop 289 (see Figure B.30). The east end of the overlay meets up with the concrete bridge deck, and the west end corresponds to where the concrete dividing the freeway from the frontage road on-ramp ends. The total length of the project is 1,700 ft.

The traffic conditions on this section of the urban principle arterial freeway are of low severity. The estimated AADT/lane is 4,050 with 8 percent truck traffic as estimated from an adjacent freeway section.

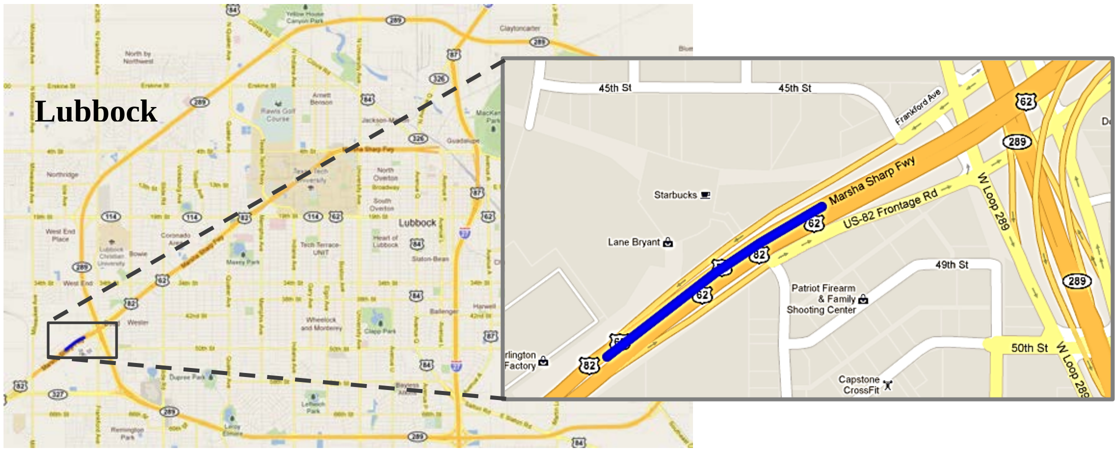


Figure B.30. Project Location on US 62/82 (Lubbock-NM OGFC).

The climate condition in the area is dry with relatively moderate summers and winter freezing. The average annual rainfall is 19 inches. The average summer high is 91°F with nine days on average reaching above 100°F. The average winter low is 30°F with an average of 78 days dropping below freezing.

The existing pavement structure was 12 inches of asphalt on an unknown thickness of base and engineered fill material.

Overlay Design and Construction

The Lubbock-NM OGFC mix was designed to replicate a successful mix that the New Mexico DOT had used. The specification design is documented in SS 3411 in the Lubbock District. The gradation and the gradation limits are shown in Table B.9. The aggregate was primarily a Class A rhyolite. The asphalt content was determined volumetrically with a target density of 80 percent. With a PG 76-28 binder, the OAC was found to be 6.4 percent, and an additional 0.3 percent fibers were used to stabilize the mix. The design was not checked for adequate laboratory performance in either the HWTT or overlay test. This project was construction in March 2007 and no problems were reported.

Table B.9. Mix Gradation (Lubbock-NM OGFC).

	Percent Passing (%)				
Property	3/8 in.	No. 4	No. 10	No. 40	No. 200
Mix Gradation	93.6	34.8	4.6	3.2	2.8
OGFC Limits	90-100	25-55	0-12	0-8	0-4

Overlay Performance

In May 2011, the overlay condition was evaluated with a visual assessment and GPR. At the time, the PFC was four years old. Skid and noise measurements were then made in August 2011.

The surface at this time was still in excellent condition. The picture in Figure B.31 was actually taken the year before, but the condition reportedly had not changed. The surface appears that it will provide adequate macrotexture for skid resistance. The GPR profile, shown in Figure B.32, indicates a very uniform subsurface condition. There are no concerns of moisture damage or cracking.

The results of the skid measurements on the westbound and eastbound lanes were 32.2 and 36.8, respectively. The overall average SN_{50} of the project was 35 with a standard deviation of 6.6. This is a good standard value for skid. Because of the excellent subsurface condition, this project is a best-case scenario for the performance of this thin overlay design.

Figure B.31. Project and Surface Texture (Lubbock-NM OGFC).

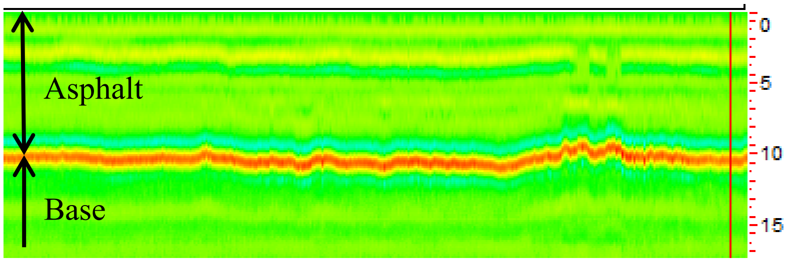


Figure B.32. GPR Profile (Lubbock-NM OGFC).

DEL RIO-MICROTEKK

The Del Rio-MicroTekk project was constructed in 2010. The project was used to promote MicroTekk Flex, a propriety surfacing from Road Science, which is advertised as a flexible microsurfacing that is more resistant to reflective cracking. To compare performance, MicroTekk Flex and MicroTekk (traditional microsurfacing) were constructed side by side over transverse cracked pavement. From the limited observations thus far, both treatments are in good condition, but may show signs of poor resistance to reflective cracking. Also, not enough data are available to conclude that one treatment is performing better than the other.

Site Description

The project is located on two sections of US 90 in Del Rio (see Figure B.33). The first section runs from 17th St on the south to Stricklen Ave. on the north. The other section runs from the bend in US 90 on the west to just past De La Rosa St. on the east. Both sections are about 1.25 mi long.

The traffic conditions on this road are low to moderate severity. These sections of US 90 are urban principle arterials with several signal-controlled intersections and speed limits from 30

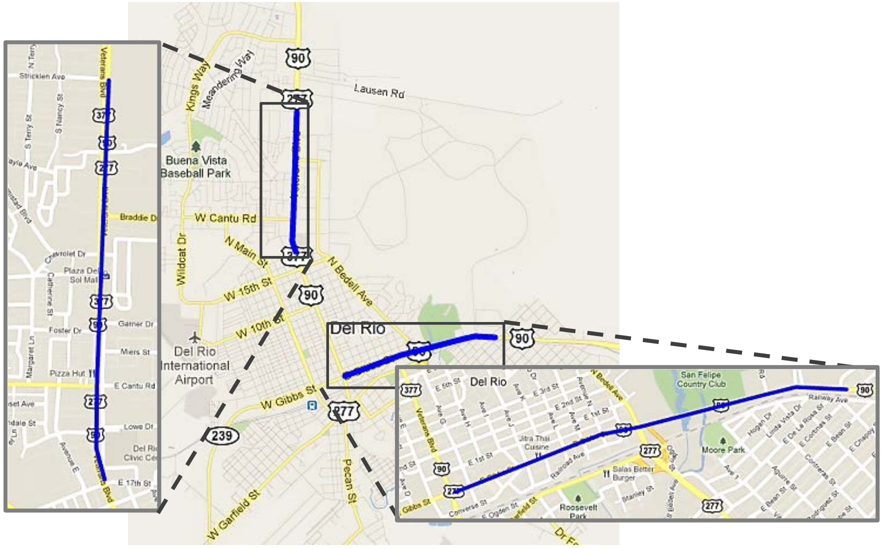


Figure B.33. Project Locations on US 90 (Del Rio-MicroTekk).

to 40 mph. On the north-south section, the estimated AADT/lane is 7,250 with 10 percent truck traffic. On the east-west section, the estimated AADT/lane is 5,500 with 6 percent truck traffic.

The climate condition in the area is arid with hot summers and mild winters. The average annual rainfall is 19 inches. The average summer high is 96°F with 29 days on average reaching above 100°F. The average winter low is 44°F with an average of 11 days dropping below freezing.

The pavement structures of these sections varied from location to location. A summary of the different structures, as estimated from GPR readings, is illustrated in Figure B.34. The asphalt in the north-south section was likely heavily distressed as indicated by the GPR data in Figure B.35. The east-west section was not so heavily distressed. The base thickness for all sections was unknown and the subgrade is a low- to moderate-plasticity silt loam and clay loam.

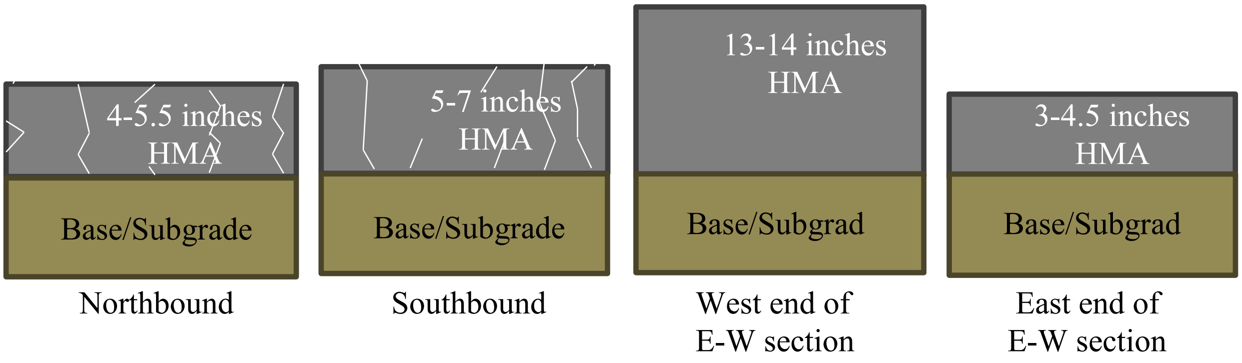


Figure B.34. Existing Pavement Structures on US 90 (Del Rio-MicroTekk).

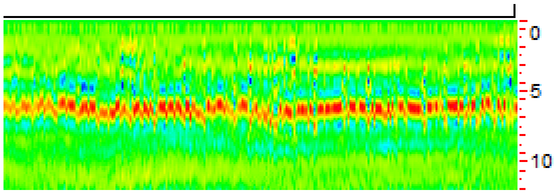


Figure B.35. Cracking Pattern in N-S US 90 Section (Del Rio-MicroTekk).

Overlay Design and Construction

The mix design for the MicroTekk Flex and MicroTekk adhered to TxDOT Item 350. The MicroTekk design deviated a little from the specification with the inclusion of a performance additive and an additional overlay tester requirement in the lab. Table B.10 gives the mix gradations. The aggregate was reportedly a limestone (properties unknown) from the Capitol Aggregates Delta pit. The emulsion content was 13.5 percent with CSS-1P, a slow-set latex modified emulsion. The residual emulsion content was 65 percent and the residual asphalt in the mix was 8.8 percent. The mix included 0.25 percent lime and 0.15 percent performance additive. The MicroTekk mix had nearly the same properties except no performance additive.

The performance tests for microsurfacing, established by the International Slurry Surfacing Association, and are different than hot-mix overlay tests. A comparison of most of these tests with hot-mix tests is not appropriate. MicroTekk Flex was subjected to and passed the wet cohesion test (20 kg-cm in 60 min), wet track test (74 g/ft^2 after a six-day soak), and loaded wheel track test (3 percent lateral and 12 percent vertical displacement). The mix was also subject to a slightly modified version of the overlay test and achieved 105 cycles. MicroTekk was only tested in the wet track test (74 g/ft^2 after a six-day soak).

To compare the performance of MicroTekk Flex and MicroTekk, the two mixes were placed side by side. In the north-south section, MicroTekk Flex was constructed in the outside lanes and MicroTekk in the inside lanes. On the east-west section, these were reversed. All sections were constructed around August 2010 with no reported issues.

Table B.10. Mix Gradations (Del Rio-MicroTekk).

	Percent Passing (%)							
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200
Mix Gradations	100.0	91.2	45.5	25.9	16.4	11.3	8.3	6.6
Microsurfacing Limits	99-100	86-94	45-65	25-46	15-35	10-25	7-18	5-15

Overlay Performance

In July and August 2011, about one year after construction, the overlay condition was evaluated with a visual assessment, GPR, and skid measurements. Noise measurements were not made due to speed limit restrictions. As described earlier, in the north-south direction, MicroTekk Flex was placed in the outside lanes and MicroTekk was placed in the inside lanes. The reverse was done in the east-west direction.

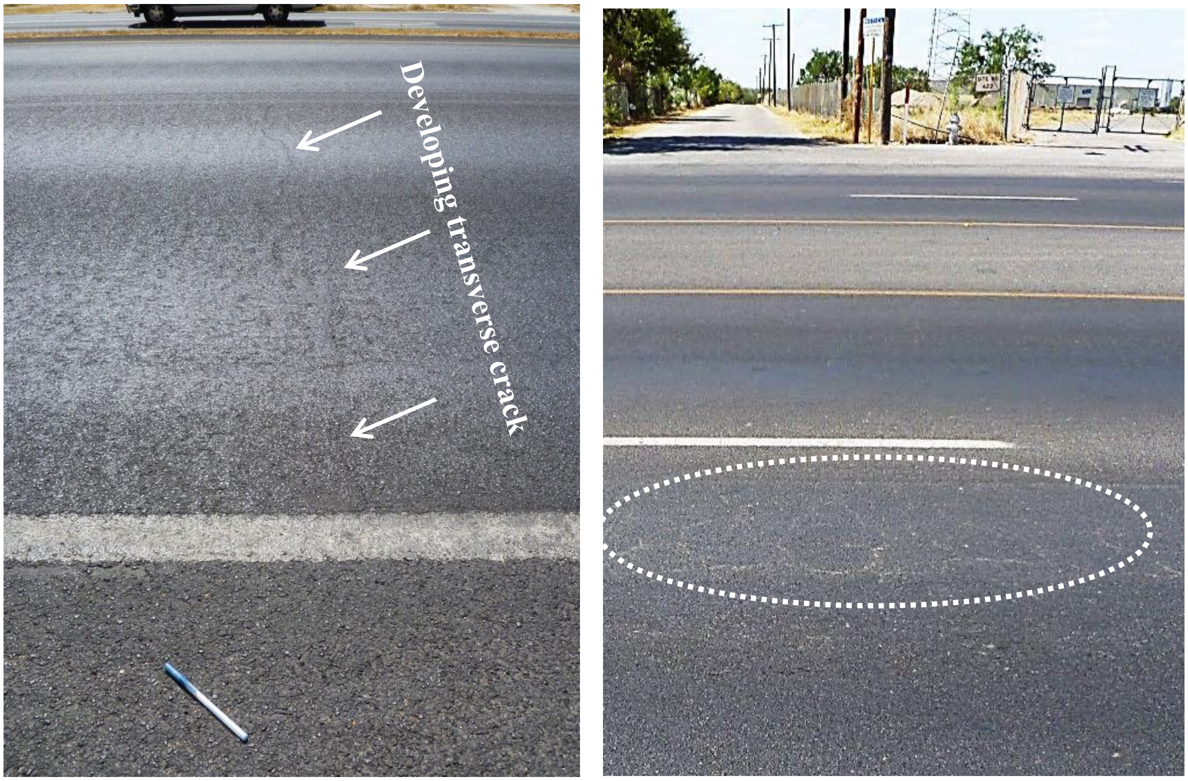
All the sections were in good condition, as shown in Figure B.36, though some distresses are reflecting through after one year. Figure B.37a shows the initial development of transverse cracking in the north-south direction (reflection cracking from full-width transverse cracks in the existing pavement.) The emerging cracks were only located in the shoulder and the MicroTekk Flex lane, and not in the MicroTekk. In the east-west direction, a few areas had fatigue cracking reflecting through MicroTekk, as shown in Figure B.37b. These distresses are just developing and so the other lanes may develop similar distresses in the near future.

The GPR data are shown in Figure B.38. The subsurface layers of the north-south section are in poor condition. A few sections likely have moisture damage in the middle and bottom of the asphalt layer, especially in the northbound lanes. The section is also characterized by clear subsurface cracking. The east-west section seems to have a less distressed asphalt layer. Portions of this section may have moisture damage at the asphalt-base interface.

The skid results for both MicroTekk and MicroTekk Flex sections are shown in Figure B.39. The average SN values were acceptable and even high in some areas. Since microsurfacing is a cold-laid slurry mixed on-site, the binder and fines contents tend to vary more than hot plant-mixed overlays. Often, the surface texture from one area to another is very different; therefore, the skid at high speeds would also vary. On average, MicroTekk Flex had a SN_{40} of 37 and standard deviation of 8.1. MicroTekk had a SN_{40} of 33.5 with a deviation of 7.3. Statistically, there is no significant difference in the skid resistance of these mixes.

(a) N-S **(b) E-W**

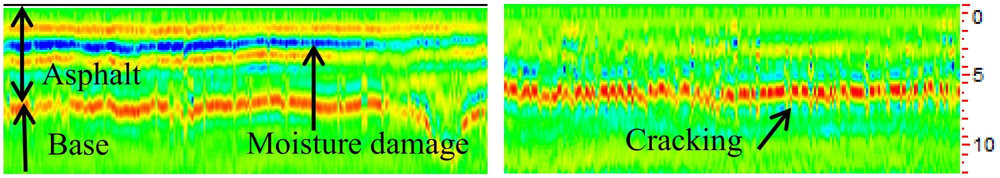
Figure B.36. Project and Surface Condition (Del Rio MicroTekk).



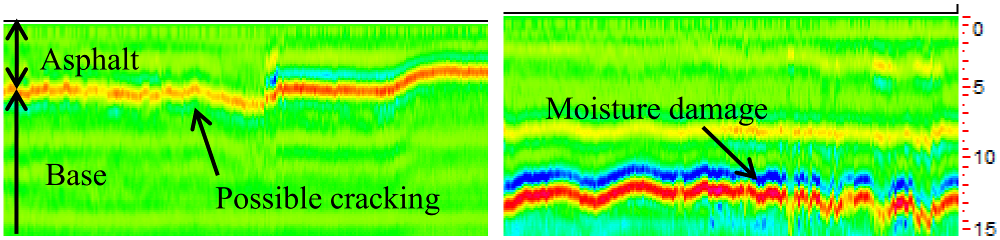
(a) Developing Transverse Crack in NB MicroTekk Flex

(b) Fatigue Cracking in EB MicroTekk

Figure B.37. Pavement Distress (Del Rio-MicroTekk).



(a) N-S Section



(b) E-W Section

Figure B.38. GPR Profiles (Del Rio-MicroTekk).

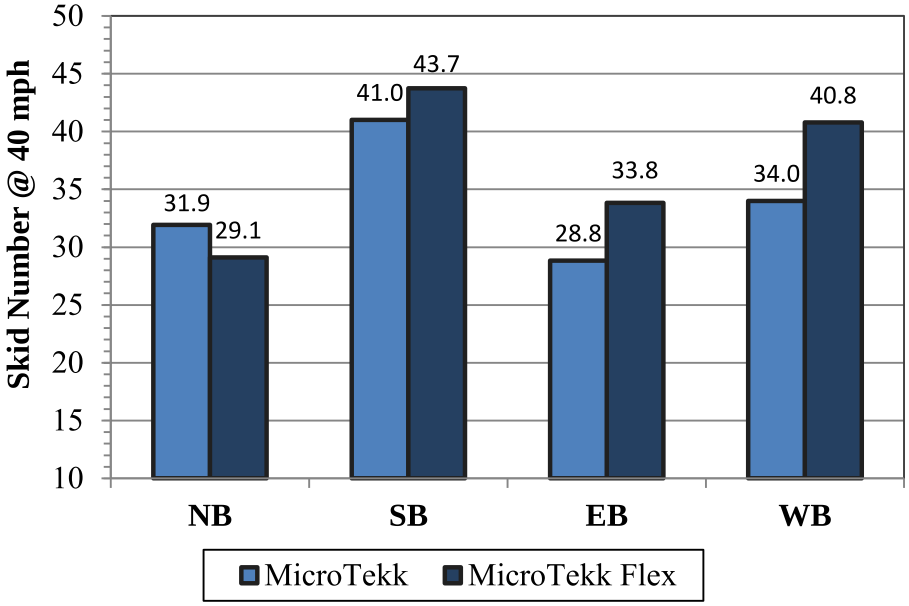


Figure B.39. Skid Resistance (Del Rio-MicroTekk).

From these limited observations, the microsurfacing project is in good condition, but might not resist reflective cracking as well as other mixes in the field evaluations. Evidence of low-severity distresses were appearing after one year. However, the existing pavement was more distressed on this project than in most other field studies and traffic conditions were moderately severe. As concerns MicroTekk Flex vs. MicroTekk, not enough data is available to conclude that one treatment is performing better than the other. The skid results were not significantly different, and the distresses require more time to develop before sound conclusions can be drawn.

ATLANTA-E-KRETE

The Atlanta-E-Krete project was constructed in 2009. It was used to promote E-Krete, a proprietary Portland cement-base composite micro-overlay, distributed by PolyCon Manufacturing. It is marketed as an eco-friendly maintenance skid surface with an exceptionally long service life. After 1.5 years, the surface has reflective, longitudinal, and fatigue cracking and the skid resistance has decreased from the low 30s to the low 20s. From this project, E-Krete does not appear to perform as well as other thin overlays in this report.

Site Description

This project is divided into three sections located on US 80 and IH 20 near Marshall (see Figure B.40). The 500-foot section on US 80 is in the westbound lane only, 0.4 mi from Exit 268 on the freeway. The section on the overpass at the exit is applied to the entire bridge deck for a

Figure B.40. Project Locations on US 82 and IH 20 (Atlanta-E-Krete).

length of 240 ft. The last 500-foot section is on the outside eastbound lane, 1.2 mi east of the interchange.

The traffic conditions on the US 80 and overpass sections are of low severity, and the IH 20 section is of high severity. US 80 here is a rural minor arterial, and IH 20 is an urban interstate and major trucking route. On US 80 and the overpass, the estimated AADT/lane is 1,850 with 9 percent truck traffic as estimated from an adjacent section. On IH 20, the estimated AADT/lane is 8,000 with 30 percent truck traffic.

The climate condition in the area is wet with relatively mild summers and a fair amount of winter freezing. The average annual rainfall is 51 inches. The average summer high is 91°F with six days on average reaching above 100°F. The average winter low is 39°F with an average of 40 days dropping below freezing.

The existing pavement structure was estimated from GPR readings. The US 80 section consisted of 3.5 inches of asphalt on 10 inches of jointed concrete, and the IH 20 section consisted of 5 inches of asphalt on 8 inches of continually reinforced concrete. The overpass was a concrete deck of unknown thickness with a surface treatment. The surface of the US 80 section had sealed transverse cracks about every 15 ft. The sections were too short to obtain reliable subgrade descriptions from the USGS soil database.

Overlay Design and Construction

Since E-Krete is a proprietary product, specific mix design information is unavailable. The general mixture, however, is quartz sand passing the No. 10 sieve or smaller, hydraulic cement, and latex. Construction of the test sections took place in March 2009 and no placement issues were encountered.

Overlay Performance

In June 2011, the overlay condition was evaluated with a visual assessment and GPR. At the time, the MicroTekk sections were about 1.5 years old. The skid was measured in March 2009 shortly after construction and in September 2009. Another skid measurement is scheduled for the near future and the data will be added to the final report. Noise measurements were not made because the noise properties of this treatment are not of concern to TxDOT personnel.

The E-Krete sections were applied in three locations: on US 80, on the overpass bridge deck at exit 628 off IH 20, and on IH 20 itself. The US 80 section, shown in Figures B.41 and B.42, had several reflective transverse cracks and signs of a developing longitudinal crack in the wheel path. The surface texture appeared smooth, worn, and in a small area had broken away from the pavement. The overpass section, shown in Figures B.43 and B.44, was also beginning to crack in the wheel path. Parts of the surface texture were filled with asphalt that may be from an underlying surface seal. If this is the case, then the E-Krete must be wearing away from the surface. The IH 20 section in Figure B.45 had some potholing problems and variable surface texture. The potholes were not associated with the E-Krete as they were much deeper than the thin treatment. The non-uniform surface textures were located in the wheel path and seemed smoother than other areas. Whether this was caused by trafficking or occurred during construction is unknown.

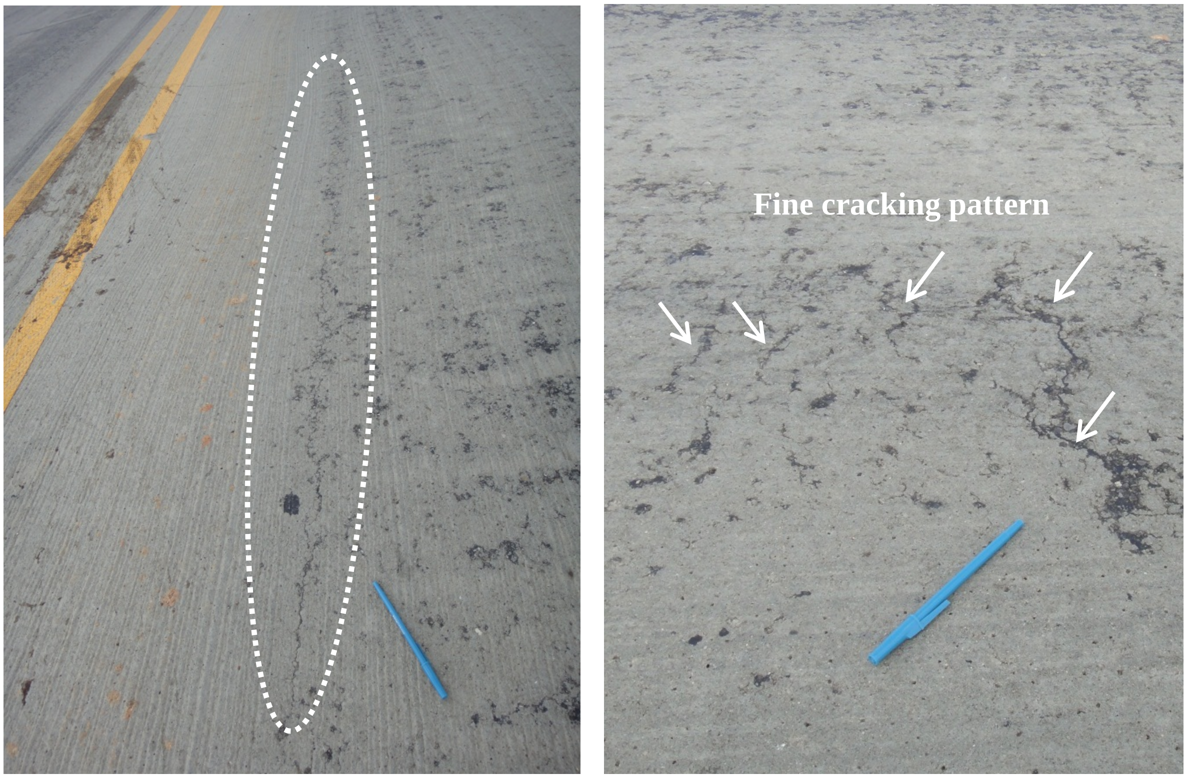
The GPR profiles for US 80 and IH 20 are shown in Figure B.46. The US 80 profile suggests the asphalt layer may be cracked corresponding to concrete joints. The IH 20 section suggests the HMA may have moisture damage. The profile for the overpass section is not shown because the concrete and rebar in the bridge deck confound the radar signal.

Figure B.41. Project and Surface Texture on US 80 (Atlanta-E-Krete).

(a) Transverse Cracking **(b) Longitudinal Cracking**

Figure B.42. Surface Distress on US 80 (Atlanta-E-Krete).

Figure B.43. Project and Surface Texture on Overpass (Atlanta-E-Krete).



(a) Longitudinal Cracking **(b) Fine Fatigue Cracking**

Figure B.44. Surface Distress on Overpass (Atlanta-E-Krete).

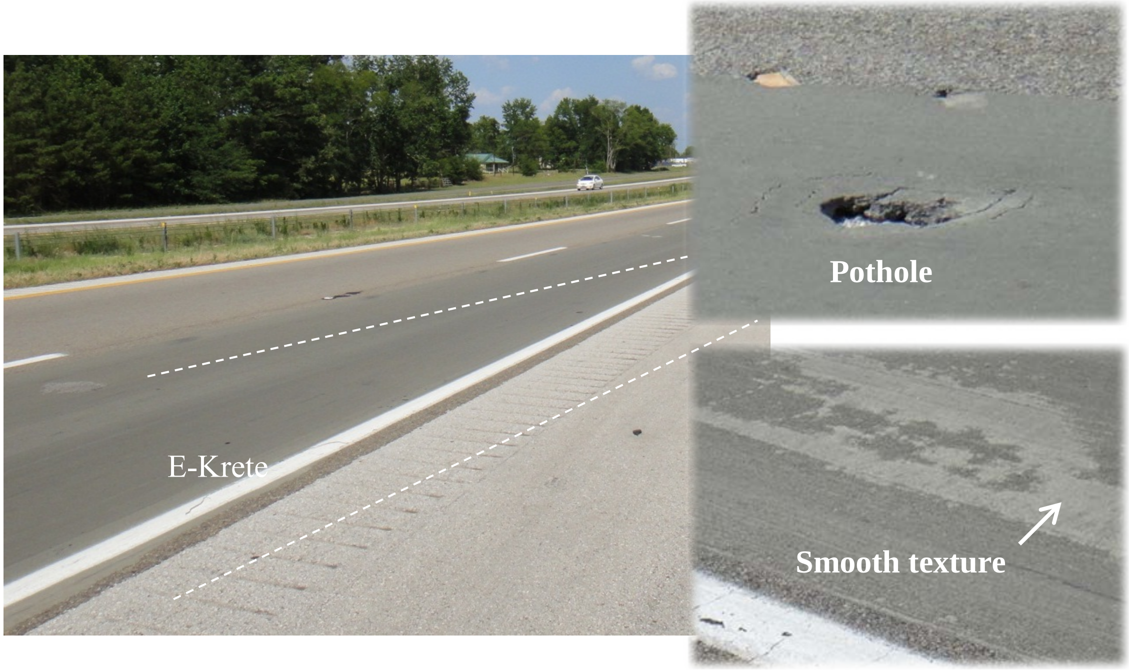
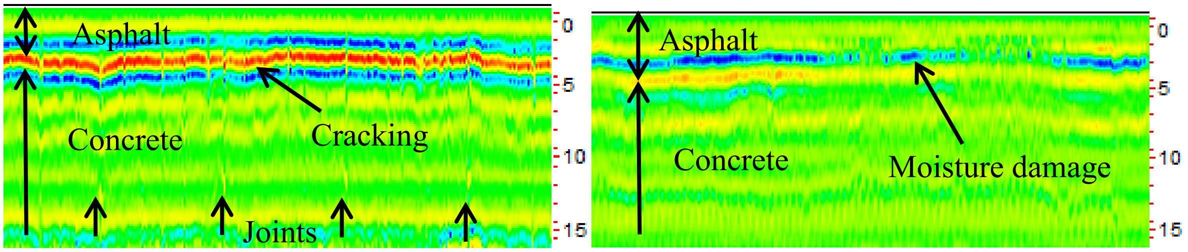


Figure B.45. Project and Distresses on IH 20 (Atlanta-E-Krete).



(a) US 80 **(b) IH 20**

Figure B.46. GPR Profiles (Atlanta-E-Krete).

The skid results are shown in Figure B.47. The US 80 and IH 20 sections were tested at 50 mph, and the overpass section at 40 mph. Just after construction, the sections had SN values between 30 and 34. After six months, the values dropped to between 22 and 25. These values are acceptable for skid resistance, though not particularly high. Whether the skid resistance continues to decrease will be determined after the scheduled skid measurements are complete.

E-Krete is marketed as an eco-friendly maintenance skid surface with an exceptionally long service life. The 1.5-year-old test sections show signs of reflective cracking, and longitudinal and fatigue cracking in the wheel path. The thin surface is too rigid to resist cracking under traffic deflections. The macrotexture appears worn in some areas, which could explain why the skid resistance decreased from the low 30s to the low 20s. From these test sections, E-Krete does not appear to perform as well as other thin overlays in this report.

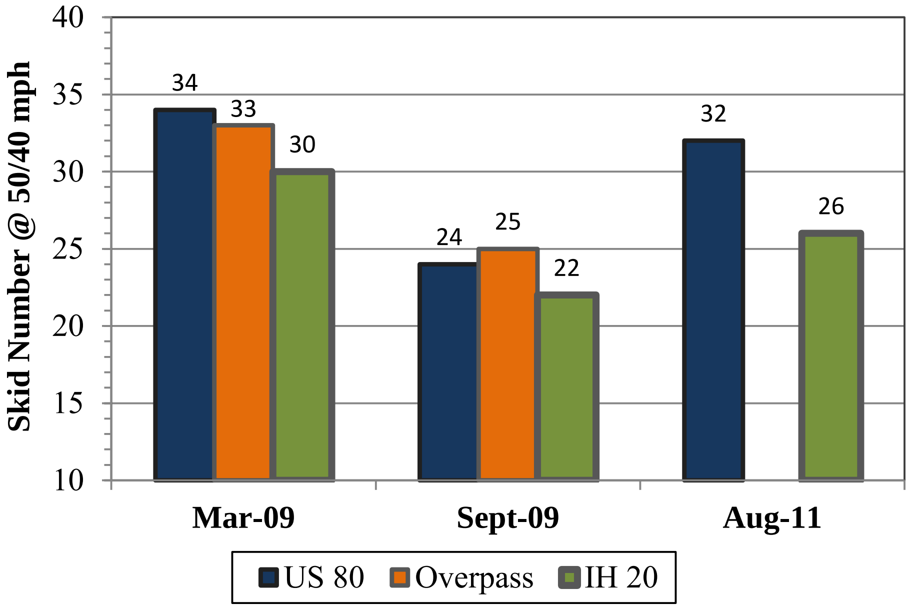


Figure B.47. Skid Results (Atlanta-E-Krete).

APPENDIX C
PHOTOGRAPHS OF SLURRY OVERLAY SLABS

Figure C.1. MicroTekk Slab (0 Cycles).

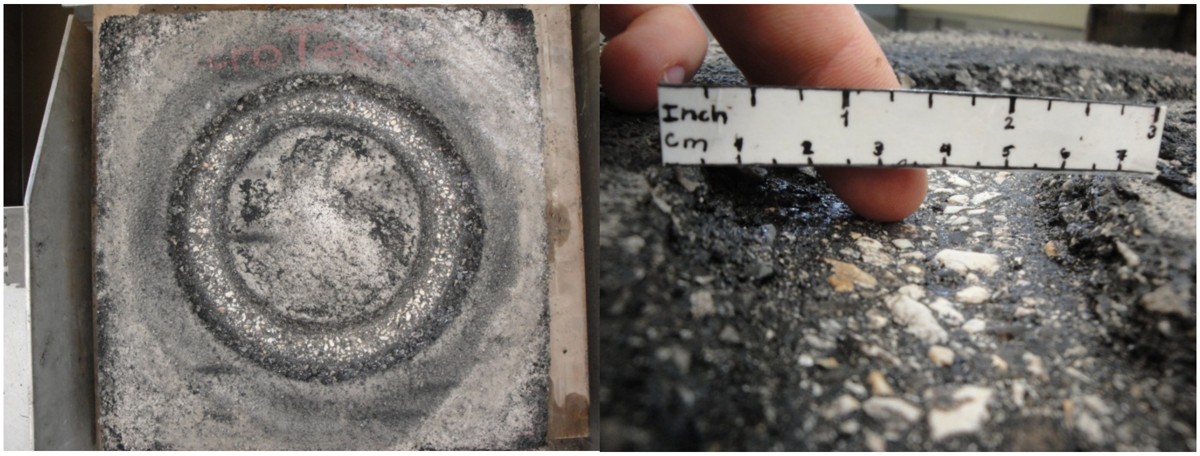


Figure C.2. MicroTekk Slab (100,000 Cycles).

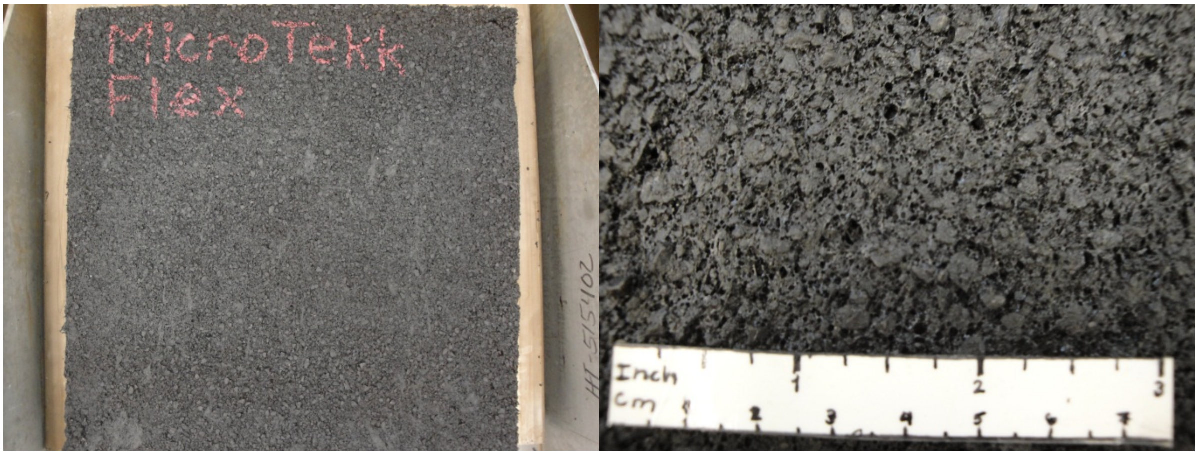


Figure C.3. MicroTekk Flex Slab (0 Cycles).

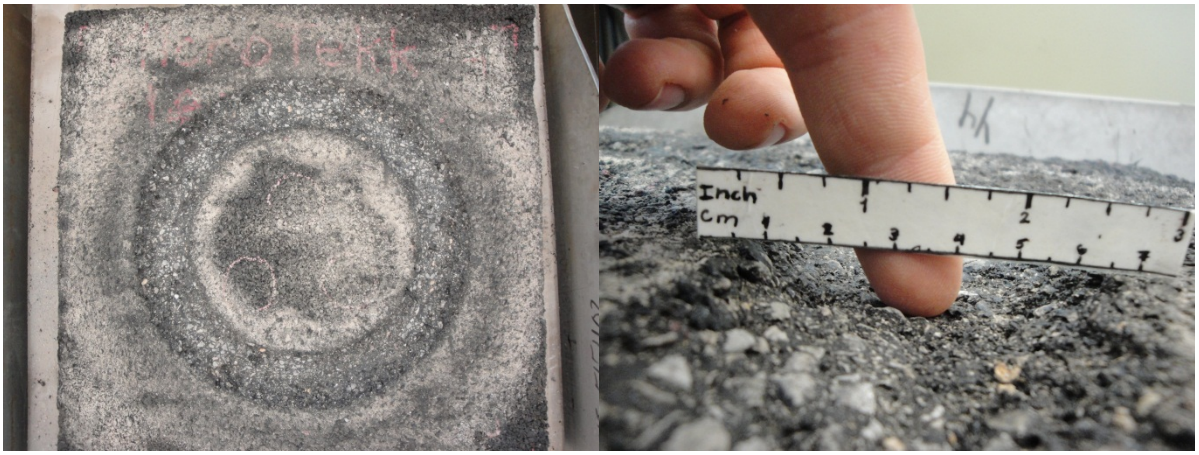


Figure C.4. MicroTekk Flex Slab (10,000 Cycles).

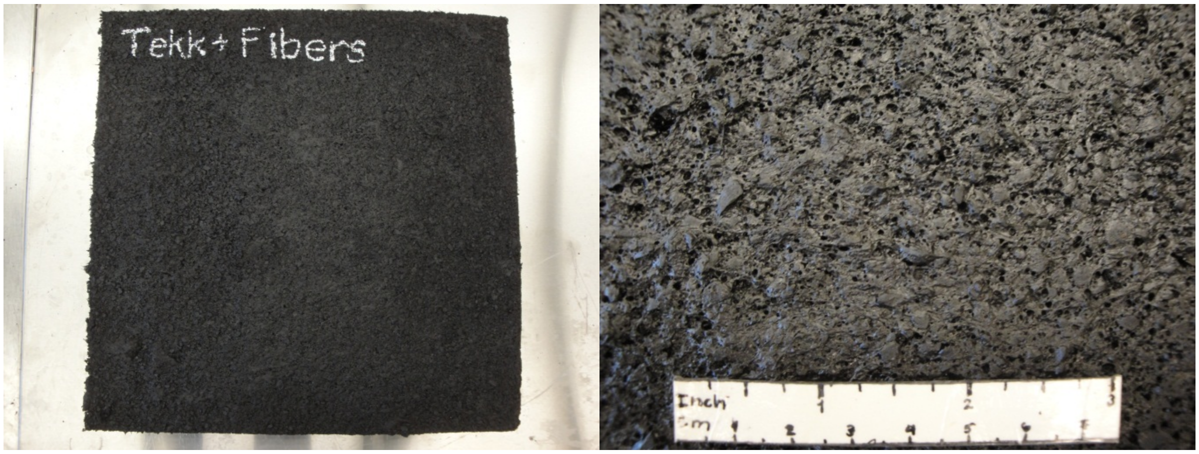


Figure C.5. MicroTekk with Additive Slab (0 Cycles).

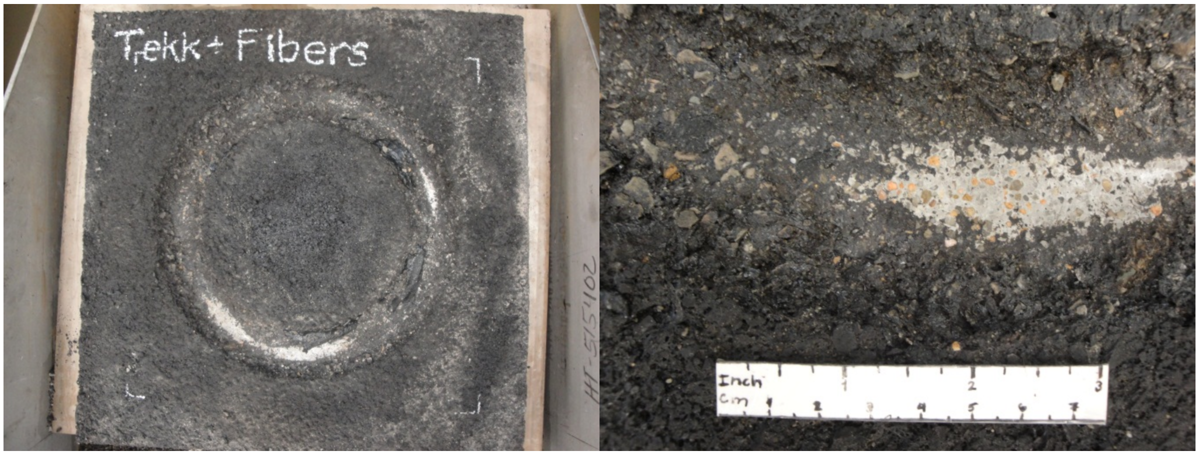


Figure C.6. MicroTekk with Additive Slab (10,000 Cycles).

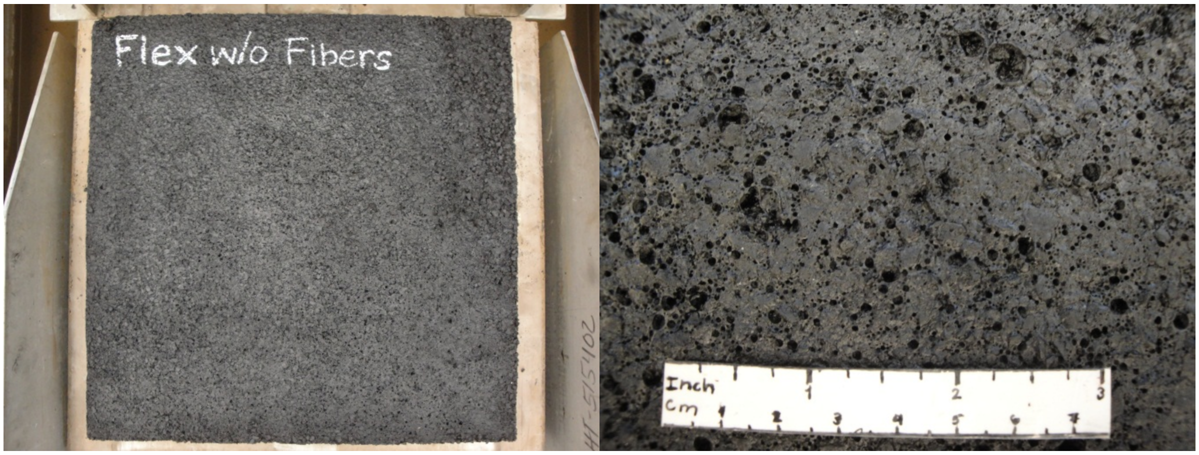


Figure C.7. MicroTekk Flex without Additive Slab (0 Cycles).

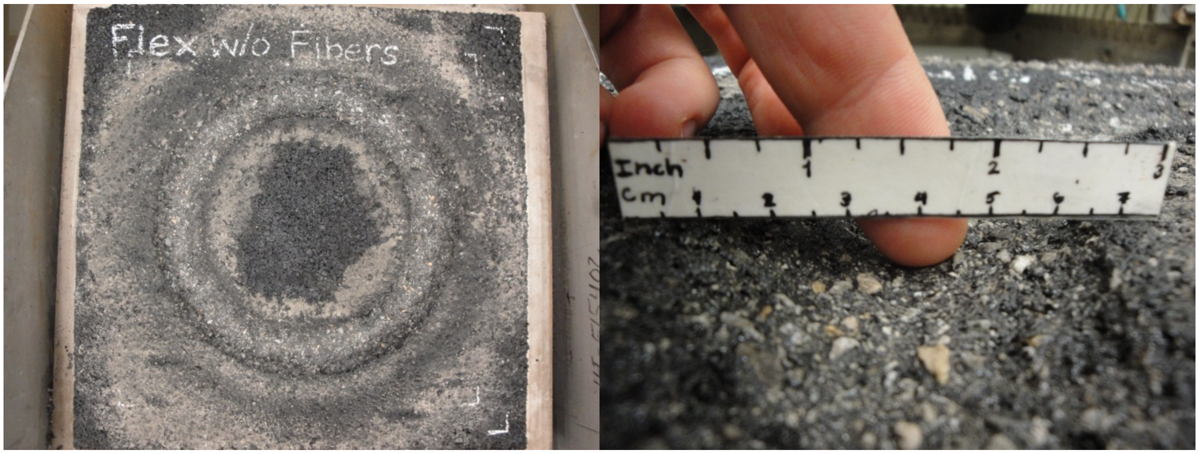


Figure C.8. MicroTekk Flex without Additive Slab (10,000 Cycles).

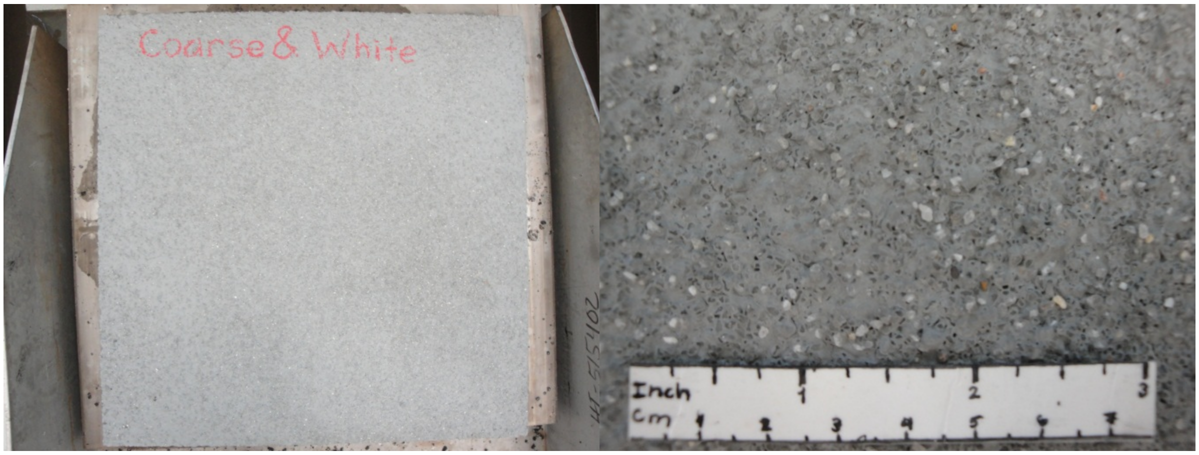


Figure C.9. Tuffseal (C+W) Slab (0 Cycles).

Figure C.10. Tuffseal (C+W) Slab (2,000 Cycles).

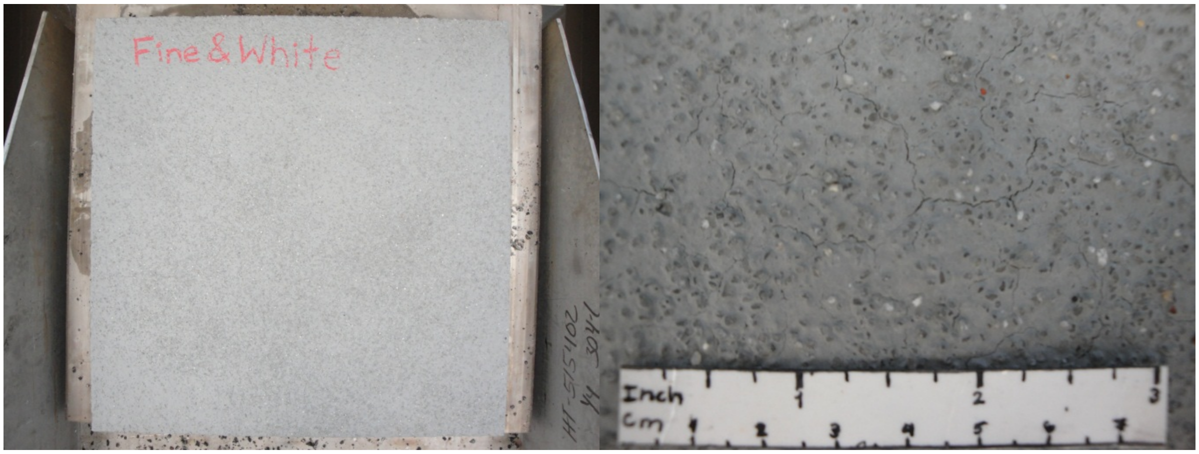


Figure C.11. Tuffseal (F+W) Slab (0 Cycles).

Figure C.12. Tuffseal (F+W) Slab (2,000 Cycles).

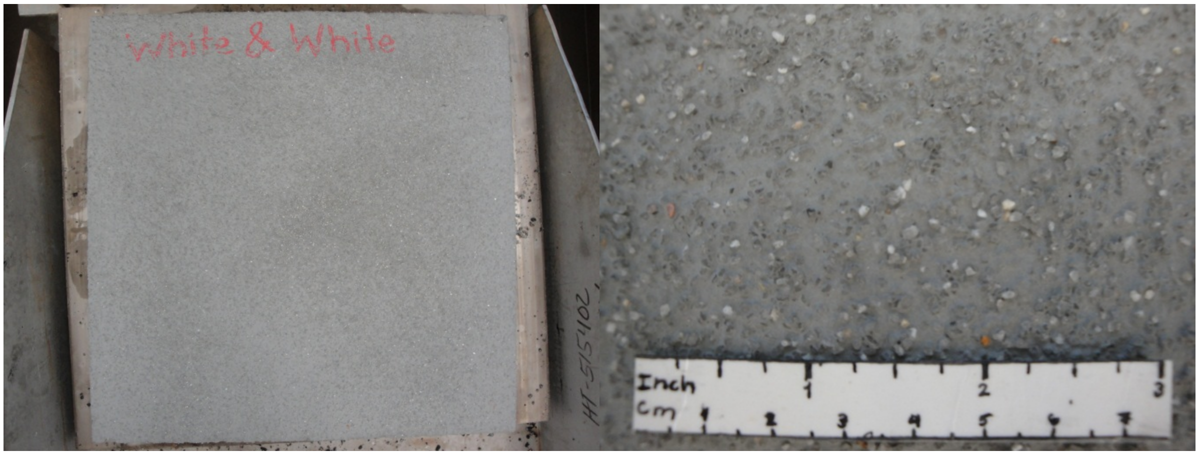


Figure C.13. Tuffseal (W+W) Slab (0 Cycles).

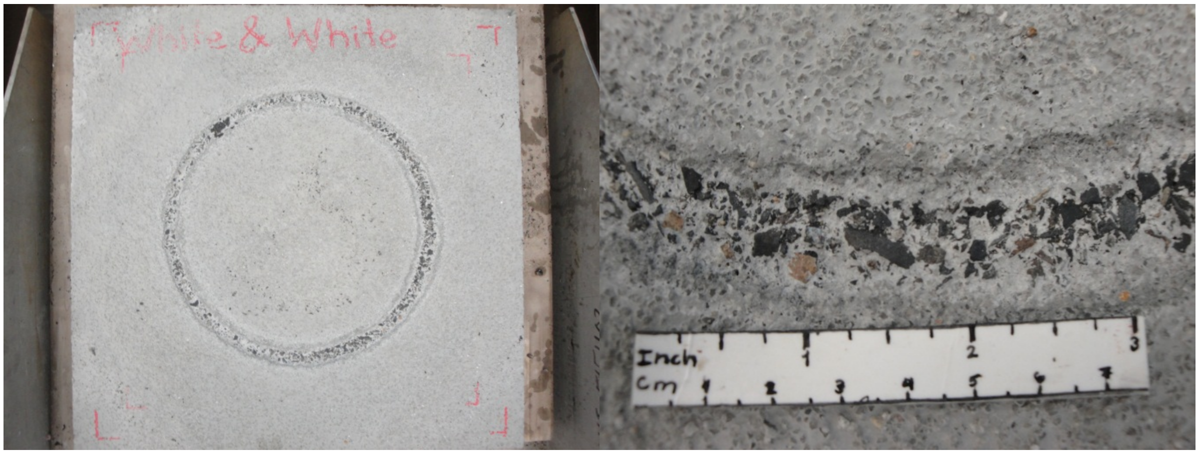


Figure C.14. Tuffseal (W+W) Slab (2,000 Cycles).

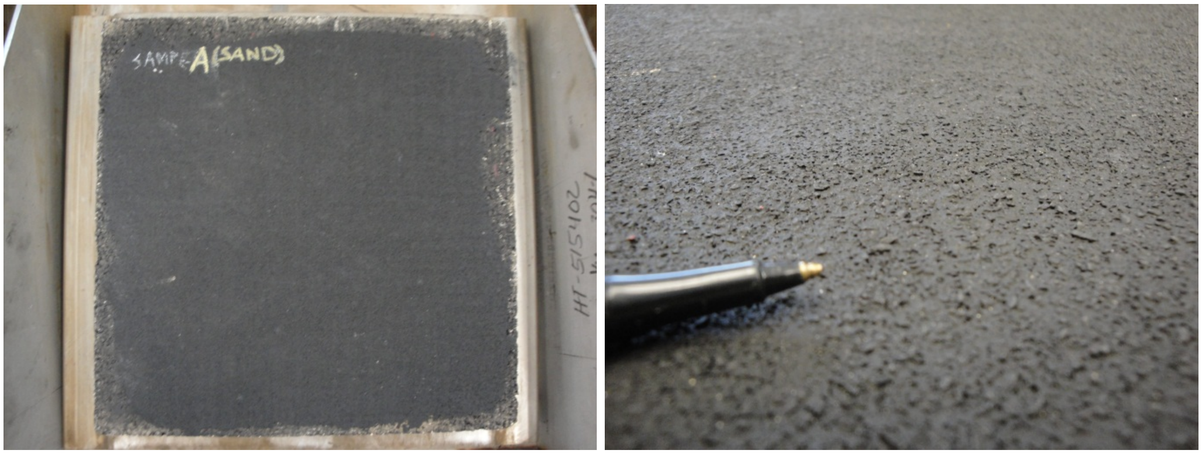


Figure C.15. Skid Slurry (Sand) Slab (0 Cycles).

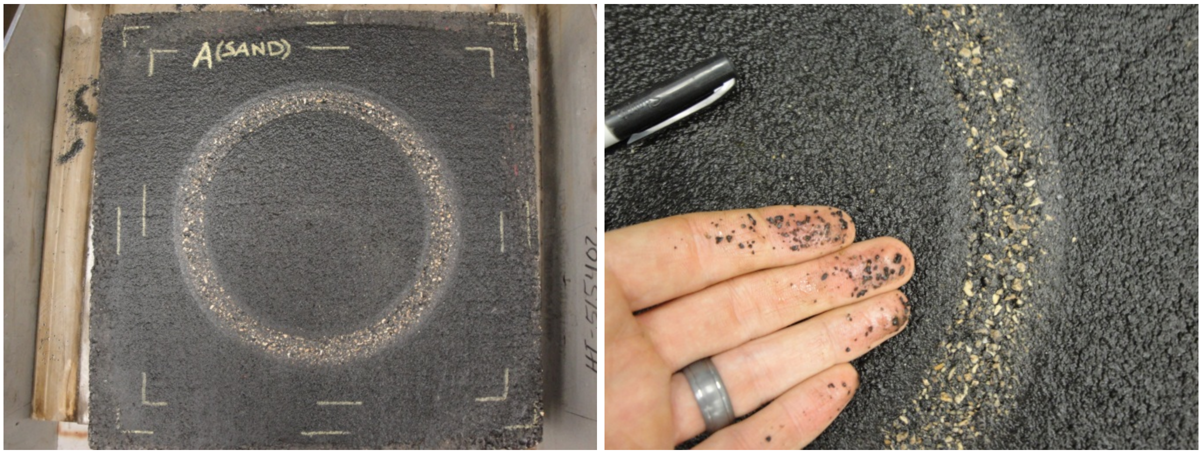


Figure C.16. Skid Slurry (Sand) Slab (10,000 Cycles).

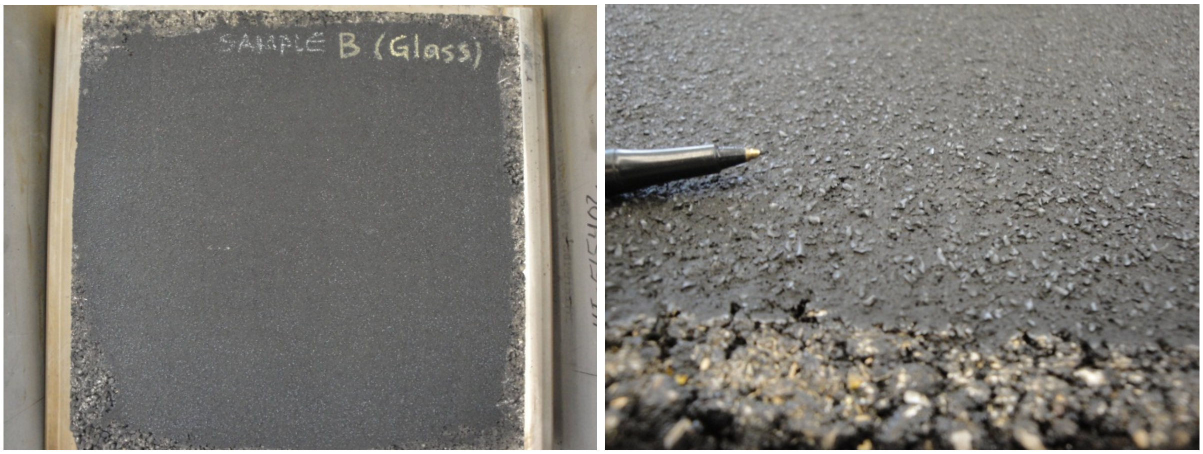


Figure C.17. Skid Slurry (Glass) Slab (0 Cycles).

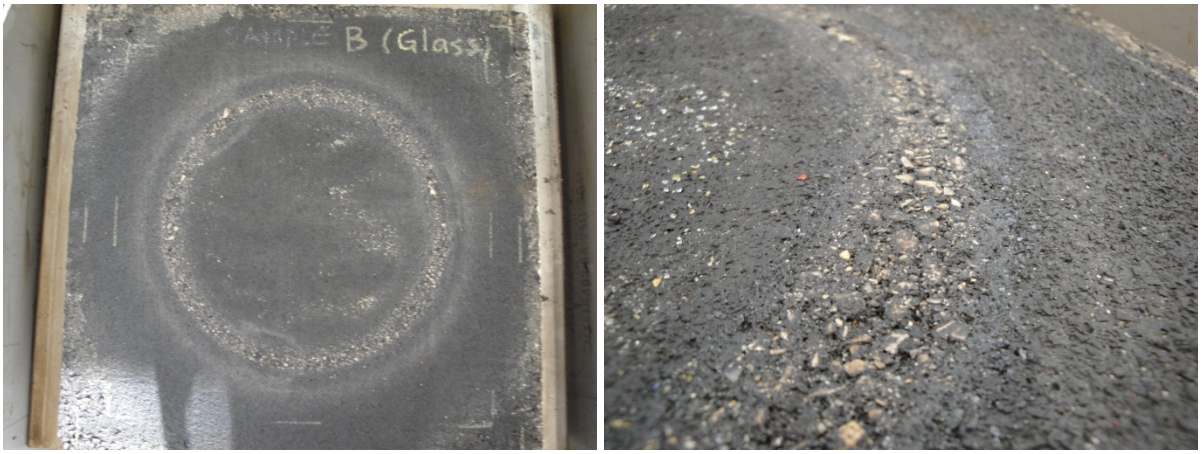


Figure C.18. Skid Slurry (Glass) Slab (2,000 Cycles).

APPENDIX D
CASE STUDIES OF NEW THIN OVERLAY SECTIONS

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FOR APPENDIX D

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PECOS RTC

The Pecos Research and Testing Center (RTC) project was constructed in 2011. The facilities, which include several miles of diverse testing tracks, can support a wide range of transportation-related research and testing. More information about these unique facilities is found at www.pecosrtc.org.

As part of a controlled field experiment, several thin overlays (two fine DGMs, two fine SMAs, and two fine PFCs) were designed then constructed side by side on the site. During design, the research team noted that the behavior of some of the mixes was not ideal, and may indicate poor long-term performance. As constructed, all mixes had good skid resistance, where the fine SMAs were highest. The quietest pavements constructed were the fine PFCs, followed by the fine DGMs and then the fine SMAs.

Site Description

This project is located 20 mi southeast of Pecos, TX. Figure D.1 gives an aerial view of the facilities and location of the thin asphalt overlays. Construction took place on the entry road and on a portion of a large 9-mile circular test track. These two roadways were divided into test sections for six different mix designs as shown in Figure D.2 shows. The inbound and outbound

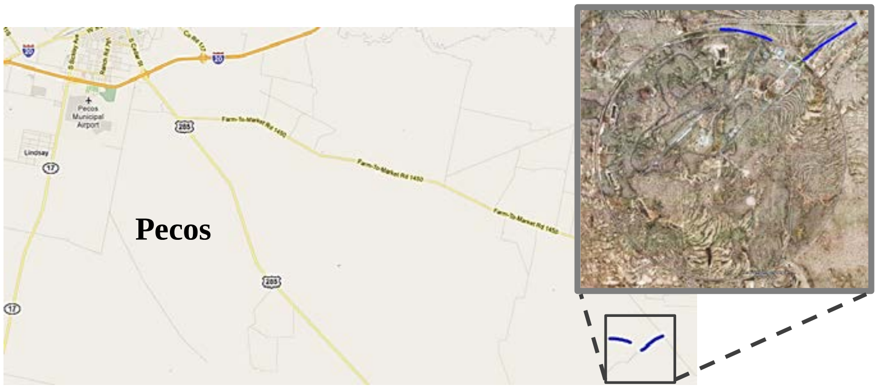


Figure D.1. Project Location on Testing Facilities (Pecos RTC).

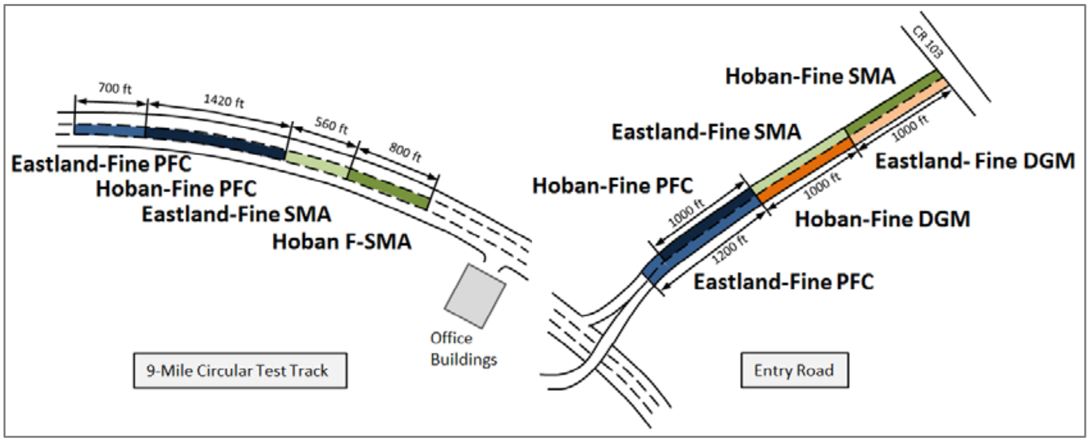


Figure D.2. Section Layout (Pecos RTC).

lanes of the entry road were surfaced for a total length of 3,200 ft, and the middle lane of the circular track was surfaced for a length of about 3,500 ft. As noted in the figure, several different overlay types were used in paving.

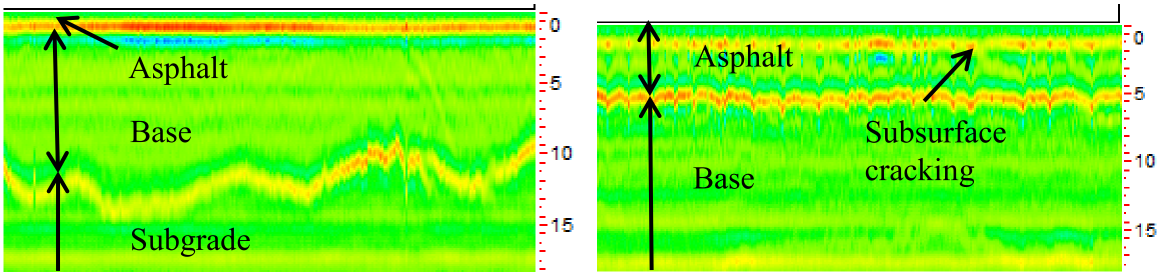
The entry road is subject to low severity traffic, including daily passenger car movements, and occasional delivery truck and test vehicle traffic. The circular track is currently subject to occasional heavy truck trafficking associated with tire testing. The estimated AADT is unknown, but likely very low.

The climate condition in the area is arid with both hot summers and a fair amount of winter freezing. The average annual rainfall is a mere 12 inches. The average summer high is 97°F with 45 days on average reaching above 100°F. The average winter low is 31°F with an average of 60 days dropping below freezing.

The existing pavement structure of the entry road, as estimated by GPR, consisted of a thin 1-inch overlay on 9 to 15 inches of base. The circular track structure is 5 inches of HMA on 12 inches of base. The HMA here may consist of an older 3-inch layer with 2 inches of newer asphalt on top. Both pavement surfaces are heavily distressed. The entry road has extensive fatigue cracking and the middle lane of the test track has block cracking and fatigue cracking around the construction joints as shown in Figure D.3 shows. The GPR data indicate that cracking extends to the bottom of the asphalt (see Figure D.4). The subgrade is a gravelly loam at shallow depths and caliche deeper down.

(a) Entry Road **(b) Test Track**

Figure D.3. Surface Distress (Pecos RTC).



(a) Entry Road **(b) Test Track**

Figure D.4. GPR Profiles (Pecos RTC).

Considering the severe distress, these pavements would normally not qualify for a thin overlay treatment. But these were small experimental sections on a private test facility, not large-scale maintenance surfaces on a public road. The poor pavement conditions will provide an interesting extreme scenario for testing the new mix designs for resistance to crack propagation.

Overlay Design and Construction

Six unique thin overlays were designed for the Pecos RTC project. These consisted of three overlay types (fine DGM, fine SMA, and fine PFC), each designed with two aggregate types, a Class A rhyolite gravel (Hoban) and a Class B limestone (Eastland). The design process followed an early draft of the thin overlay recommendations.

The general mix compositions are summarized in Table D.1. Fine DGM and fine SMA designs used a combination of coarse aggregate (Hoban or Eastland) and fine aggregate. The fine aggregate used was a limestone screening from Turner and a manufactured sand from Eastland. Fine PFCs were 100 percent coarse aggregate. All mixes used a PG 76-22 grade asphalt binder.

Table D.1. Mix Composition (Pecos RTC).

	Aggregate			
Mix Type	Composition	Quarry	**Asphalt**	**Other**
Fine DGM				
Hoban	65% Gr 6	Hoban	Alon (76-22)	-
	35% Screenings	Turner		
Eastland	30% Gr 5	Eastland	Alon (76-22)	-
	70% Man. sand	Eastland		
Fine SMA				
Hoban	60% Gr 6	Hoban	Alon (76-22)	0.3% fibers
	40% Screenings	Turner		
Eastland	60% Gr 6	Eastland	Alon (76-22)	0.3% fibers
	40% Man. sand	Eastland		
Fine PFC				
Hoban	100% Gr 5	Hoban	Alon (76-22)	0.3% fibers
Eastland	100% Gr 5	Eastland	Alon (76-22)	0.3% fibers

An additional 0.3 percent fibers were used in the PFC and SMA mixes. The combined gradations are given in Table D.2.

The final OAC for each mix design was selected based on either volumetric results or roughly on the balanced performance approach, as described in Table D.3. The fine DGM designs were strictly based on the volumetric approach, even though the Eastland design may be at risk of rutting. The fine SMA designs were based more on laboratory performance where the final OAC was just slightly lower than that determined by the balanced design approach. The critical design constraint for these mixes was cracking resistance. The Hoban-Fine PFC design

Table D.2. Mix Gradations (Pecos RTC).

	Percent Passing (%)						
Mix Type	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Fine DGM							
Hoban	99.9	80.8	40.4	24.0	17.2	13.1	8.2
Eastland	99.3	83.9	60.0	33.8	19.2	10.5	3.1
Limits	95-100	70-90	40-65	20-45	10-30	10-20	2-7
Fine SMA							
Hoban	99.7	53.4	34.2	22.7	17.3	13.4	7.6
Eastland	98.7	67.8	35.6	20.1	11.6	6.5	2.3
Limits	95-100	50-70	20-40	10-25	10-20	8-15	6-12
Fine PFC							
Hoban	94.5	30.2	4.8	1.0	0.4	0.3	0.2
Eastland	97.8	46.4	3.4	1.9	1.6	1.5	1.3
Limits	95-100	20-55	0-15	0-12	0-8	0-8	0-4

Table D.3 Mix Design (Pecos RTC)

	Volumetric		**Bal. Performance**			
Mix Type	**OAC (%)**	**Density (%)**	**OAC (%)**	**Density (%)**	**Final OAC (%)**	**Design Issues**
Fine DGM						
Hoban	8.8	96.5	8.5	95.5	8.8	None
Eastland	8.1	96.5	7.9	95.8	8.1	Possible rutting > 8.1%
Fine SMA						
Hoban	5.9	96.5*	7.1	98.8	7.0	Cracking below 7.0%
Eastland	5.8	96.5*	7.3	98+	7.2	Cracking below 7.2%
Fine PFC						
Hoban	6.5	74.0	None	-	6.5	Rutting at 6.0 and 7.0%, Failed Cantabro test
Eastland	6.0	76.0	6.5	77.8	6.5	Rutting increases at lower and higher asphalt contents

* Based on density from TGC

was based primarily on volumetrics. The design passed in rutting and cracking at 6.5 percent, but failed the Cantabro. This fact was discovered following project construction. The Eastland-Fine PFC was based on balanced performance, but was actually never tested for raveling. For both fine PFCs in the HWTT, rutting increased at both higher and lower asphalt contents.

The thin overlay sections were constructed at the end of April in 2011. The fatigued pavement was left unrepaired and unsealed. A tack coat was applied to the surface and then the fine DGM, fine SMA, and fine PFC mixes were constructed. Standard equipment for asphalt construction was used, including a material transfer vehicle, paver equipped with an infrared monitoring system, a 13.5-ton tandem steel wheel roller, and a one-ton tandem finish roller.

No significant complications occurred during construction. Limited measurements with a nuclear density gauge were made on the two fine SMA mixes but not on any of the other sections. The Hoban-Fine SMA section on the entry road was compacted to an average 92.7 percent maximum density. The same mix on the test track was at 88.5 percent density. The Eastland-Fine SMA section on the test track was at 94.3 percent density. In all cases, much lower densities were observed within the first 200 ft of paving.

Overlay Performance

In May 2011, shortly after construction, all six Pecos RTC overlay mixes were evaluated with a visual assessment, skid measurements, and noise measurements. The subsurface condition was evaluated with GPR prior to construction. The fine PFCs were also evaluated for permeability during construction with the water.

Aside from some issues near construction joints between the test sections, no distresses were present and the pavement was essentially perfect. Figures D.5 through D.10 show each of these sections with a close-up of the surface texture. The only note here is that the texture of the Eastland-Fine SMA mix appears very dense, almost like a fine DGM. In reference to the mix designs shown previously, the Eastland-Fine SMA has much more aggregate passing the No. 4 sieve than the Hoban-Fine SMA, but less aggregate passing the No. 30, No. 50, and No. 200 sieves. How this might affect the performance is uncertain. The gradations for both mixes were within the acceptable limits.

During construction, one water flow measurement was made on the Hoban-Fine PFC and was less than 9 sec. This easily passes the <20 second requirements. The Eastland-Fine PFC, on the other hand, initially had an average WFV of 33 sec. The roller pattern was then lowered to two passes and the average WFV was 23 sec. This problem is likely attributed to the high density of the mix.

Figure D.11 shows the skid results. Overall, the thin overlays had good skid performance. The lowest SN_{50} was 30 and was measured on the Eastland-Fine PFC mix on the test track. On the entry road, however, this same mix had a SN_{50} of 37. This may be a result of slightly different asphalt contents, gradations, or rolling effort during construction. The skid resistance of a given mix, therefore, depends on both the original mix design and variations encountered

Figure D.5. Hoban-Fine DGM, Entry Road (Pecos RTC).

Figure D.6. Eastland-Fine DGM, Entry Road (Pecos RTC).

(a) Entry Road (b) Circular Test Track

Figure D.7. Hoban-Fine SMA (Pecos RTC).

(a) Entry Road (b) Circular Test Track

Figure D.8. Eastland-Fine SMA (Pecos RTC).

(a) Entry Road (b) Circular Test Track

Figure D.9. Hoban-Fine PFC (Pecos RTC).

(a) Entry Road (b) Circular Test Track

Figure D.10. Eastland-Fine PFC (Pecos RTC).

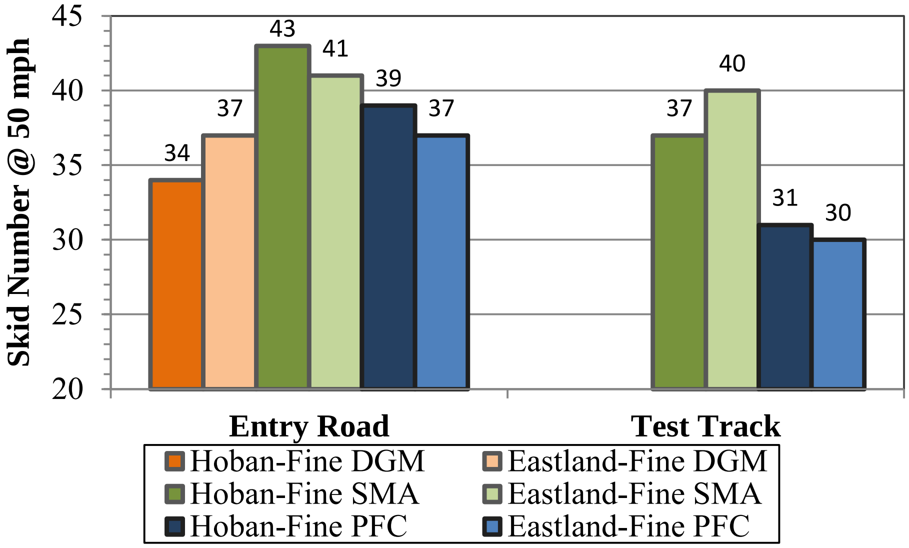


Figure D.11. Skid Resistance (Pecos RTC).

during placement. The highest SN_{50} measured were for the fine SMA mixes and were in the range of 37 and 43. The fine DGMs had the lowest skid values on the entry road and were not placed on the test track.

The overall tire-pavement noise levels for each section are shown in Figure D.12. The fine PFC mixes produced the lowest noise levels (98.7 to 100.8 dBA), followed by the fine DGMs (100.8 and 100.9 dBA) and then the SMAs (101.3 to 102.0 dBA). The quietness of a pavement is related to the surface texture, which is tied to the mix gradation. The gradation for the quietest mix, Eastland-Fine PFC, had more material passing the larger sieves than for the Hoban-Fine PFC mix, making the surface texture more uniform. The porosity of the fine PFCs

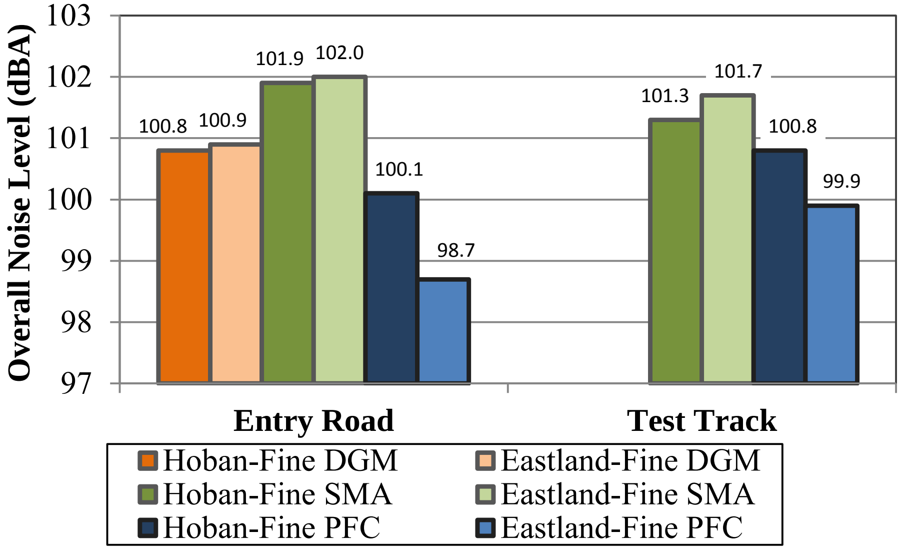


Figure D.12. Onboard Noise Levels (Pecos RTC).

further reduces the noise level. For reference, new standard HMA has a noise level around 104 dBA and a Grade 4 chip seal between 104 and 107 dBA (*30*). Furthermore, 1 to 3 dB is often considered a "just noticeable" difference in noise level, about 5 dB is a significant difference, and 10 dB is perceived as doubling (or halving) the sound level (*28*). For these data, therefore, the difference between the loudest and quietest mix is just noticeable.

The average frequency distributions are shown in Figure D.13. The PFC mixes had a more gentle distribution of frequencies and higher noise levels at frequencies below 1000 Hz. These lower frequencies would indicate the noise has an overall lower pitch. The SMA and fine DGM mixes had a more pronounce frequency peak at 1000 Hz and much higher noise levels at frequencies greater than 1600 Hz (higher pitch). As mentioned before, sharp peaks in the frequency distribution often indicate unpleasant noise. So, not only did the PFC mix have the lowest overall noise, but its noise is also the least unpleasant.

The various test sections on the Pecos RTC project look good just after construction. The average SN was highest for the SMA mixes and lowest for the PFC mixes on the test track. On the entry road, the fine DGMs had the lowest average SN. All the SN values were very acceptable. For noise, the quietest mixes were the PFCs, followed by the fine DGMs, then the SMAs. The different between the quietest and loudest pavements was just over 3 dBA, which is noticeable but not very significant. The frequency distributions indicated the PFCs might produce the most pleasant noise of the test mixes. The performance of these thin overlays should be monitored over time.

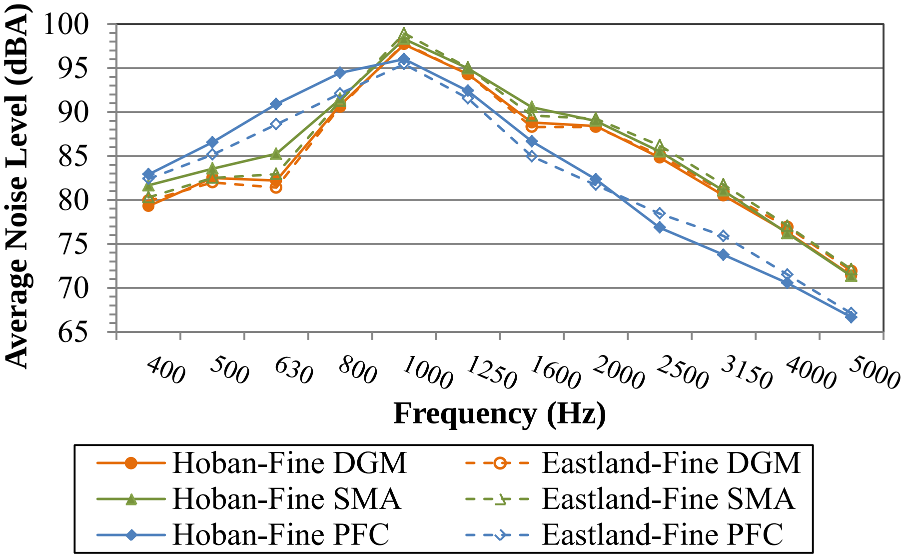


Figure D.13. Distribution of Noise Frequencies (Pecos RTC).

GEORGETOWN-TOM

When the Austin district discovered a waste pile of "dirty" F-rock with inherently good qualities, they decided to design a maintenance mix to take advantage of the inexpensive aggregates. The resulting mix has been used on numerous maintenance projects since then, including the Georgetown-TOM project was constructed in 2011. No problems have been identified on this project.

Site Description

This TOM project is located on IH 35 just north of Georgetown (see Figure D.14). The project runs from RM 266 to RM 277 for a total length of 11.0 mi long.

The traffic conditions on this road are of high severity. IH 35 services traffic between San Antonio, Austin, Waco, Dallas, and several other towns along the road. This section of IH 35 is an urban interstate with a speed limit of 70 mph. The estimated AADT/lane is 9,670 with 24 percent truck traffic as estimated from an adjacent freeway section.

The climate condition in the area is moderately wet with fairly hot summers and mild winters. The average annual rainfall is 28 inches. The average summer high is 94°F with 18 days on average reaching above 100°F. The average winter low is 40°F with an average 24 days dropping below freezing.

Two different pavement structures were identified from the GPR readings. The structure on a 2.3 mi. stretch on the south consisted of about 9.5 inches of old CMHB asphalt on and unknown thickness of base. On the rest of the project, the asphalt was about 20 inches thick, and was likely a series of at least six different overlays. In localized sections, the thickness was as shallow as 6 inches. The subgrade is moderate- to high-plasticity silty clay loam. A field core should be used to verify the layer properties.

The surface was in fair to poor condition. Figure D.15 shows the general condition and more distressed condition of the surface. Distresses include transverse cracking, joint cracking, longitudinal cracking in and out of the wheel path, fatigue cracking, and patching. Most of the cracking was sealed and some of these sections were repaired before construction. The GPR indicated that the subsurface condition was generally uniform, though some sections may have debonding issues. These areas were not apparently associated with increased surface distress.

Figure D.14. Project Location on IH 35 (Georgetown-TOM).

(a) Typical (b) More Distressed

Figure D.15. Existing Surface Condition (Georgetown-TOM).

Overlay Design and Construction

This mix is very similar to the Austin-CHMB-F project described in Appendix B. The TOM is a modified version of the CMHB-F and the TFCO. Table D.4 gives the gradation. The aggregate was a primarily a “dirty” F-rock from a Class A sandstone with some screenings. Though this aggregate is “waste,” the inherent properties are still optimal. The asphalt content was determined volumetrically with 6.7 percent PG 76-22 binder at 97.5 percent density in the TGC. The mix passed the HWTT test with 5.8 mm rutting after 20,000 cycles. The mix was not tested for cracking resistance in the overlay tester.

The TOM on a portion of the southbound lanes was constructed in 2010 and then the rest was constructed in July and August 2011. The heavily distressed areas were first repaired with a 2-inch mill and fill. A Grade 5 underseal was applied to help seal the existing surface and bond the overlay to the surface. Care was taken to keeping all vehicles but the paver off the seal. The TOM material was windrowed in the adjacent lane and transferred with a shuttle buggy into the paver. The TOM was 1 inch thick.

Table D.4. Mix Gradation (Georgetown-TOM).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	100.0	56.3	24.1	17.3	13.0	10.2	6.6
TOM Limits	85-100	40-60	17-27	5-27	5-27	5-27	5-9

Overlay Performance

In June 2011, the southbound overlay condition was evaluated with a visual assessment and GPR. At the time, the TOM was less than one year old. The overlay skid and noise performance was also measured in the southbound section shortly after construction in November 2010.

This overlay, in Figure D.16, was newly constructed and is in great condition. The surface texture is dense but not completely closed like a fine DGM mix. This should provide adequate skid resistance as long as no flushing occurs.

GPR profiles from this project are shown in Figure D.17. The first profile is from the south end and the second near the middle. In each profile, several old overlays are readily apparent. The blue areas within the asphalt may indicate weak interfaces that have experienced moisture damage, but overall the structure seems to be in pretty good condition. As mentioned before, the surface had some distresses, the worst of which were repaired prior to construction.

Figure D.16. Project and Surface Texture (Georgetown-TOM).

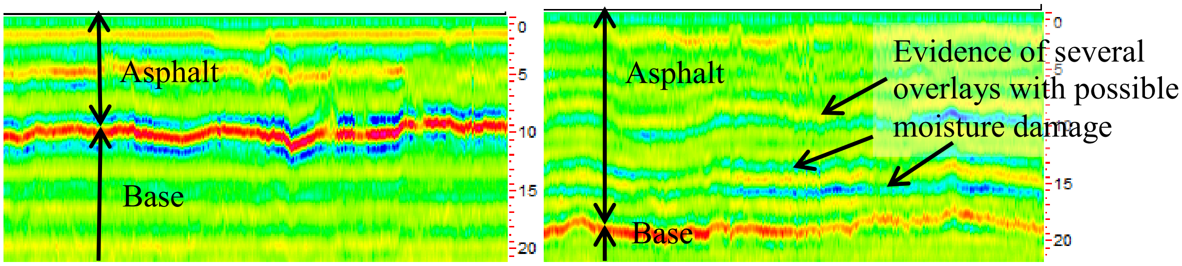


Figure D.17. GPR Profiles (Georgetown-TOM).

The skid on this overlay was very good with an average SN_{50} of 37 and a standard deviation of 2.5. Skid was measured every 0.1 mi for a total of 63 readings. The minimum and maximum recorded SN_{50} values were 32 and 42, respectively.

The overall OBSI noise level was fairly low at 98.5 dBA, and the frequency distribution of the noise is shown in Figure D.18. The highest frequencies are at 800 and 1,000 Hz. Statistical variations between different noise measurements were negligible.

The initial impressions of the District are very favorable for this TOM. The skid and noise were greatly improved, and the roughness was reportedly improved as well. Since the underlying pavement was not in the best condition, this project should be monitored to assess resistance to reflective cracking.

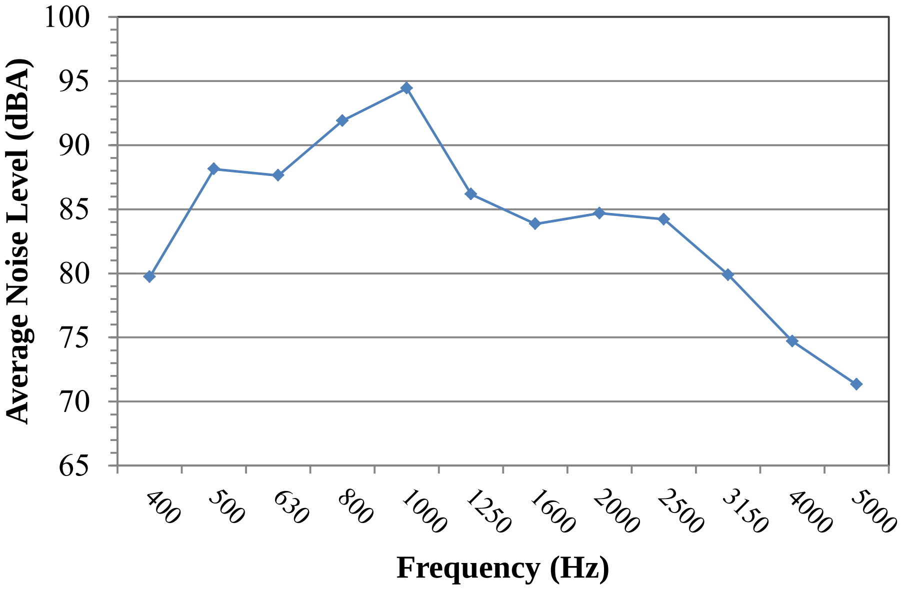


Figure D.18. Noise Level Distribution (Georgetown-TOM).

BRYAN-FINE SMA

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

Site Description

This fine SMA project is located on the frontage roads on either side of SR 6 in north Bryan (see Figure D.19). The project runs between the Tabor Rd. and Woodville Rd. interchanges for 0.8.mi in each direction.

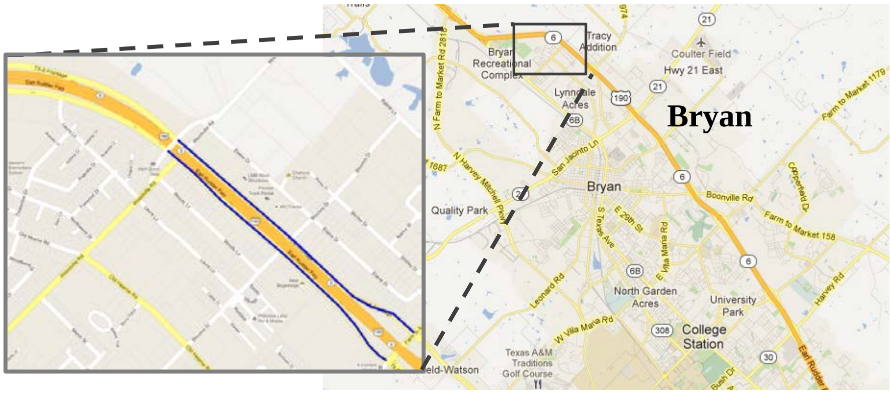


Figure D.19. Project Location on SR 6 Frontage Road (Bryan-Fine SMA).

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

The existing pavement was an old brittle HMA layer with multiple crack seals, as seen in Figure D.20. Surface distress includes transverse cracking and longitudinal cracking in and out of the wheel paths. The pavement structure was not evaluated. The Bryan District has made widespread use of CAMs, but wanted to try this new mix for its superior surface texture and potentially better skid resistance.

Figure D.20. Existing Pavement Surface (Bryan-Fine SMA).

Overlay Design and Construction

In consultation with TTI, Knife River designed this mix, following a District special specification. Mix compaction in the lab and overlay tester performance were issues encountered during the design process. This mix comprises a Class A and B blend of coarse aggregates (Brownlee sandstone and Marble Falls dolomitic-limestone) as 75 percent of the mix with 24 percent dolomitic-limestone 'dirty screenings,' and 1 percent lime. At first, Knife River attempted to design the mix with washed screenings but later opted for dirty screenings. Table D.5 gives the final gradation. OAC was originally determined as 6.5 percent at 96.5 percent density in the TGC. This was later adjusted to 6.7 percent to help pass the overlay test. The mix passed the HWTT test with 3.8 mm rutting after 20,000 cycles and the overlay test with 508 cycles.

The fine SMA was constructed in the summer of 2012. Particular interest was made to establish the correct rolling pattern. The initial sequence of two passes on each side of the mat (one pass defined as "down," not "down and back") was not sufficient as the initial void contents, as measured with a nuclear density gauge, were about 11 percent. Figure D.21 shows a short section of tandem rolling that attempted to compact both sides of the mat before excessive cooling occurred. The final rolling pattern was three to four breakdown passes and then two finishing passes on each side of the mat. Long construction delays complicated construction, resulting in hot mix trucks waiting several hours before distributing their loads. Many sections were cooler than 200F when compaction started, and about 3/4 of the project was below 250°F.

Table D.5. Mix Gradation (Bryan-Fine SMA).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	93.6	46.4	25.3	13.9	10.2	9.5	7.9
Fine SMA Limits	70-100	30-60	20-40	10-30	10-30	5-20	2-10

Figure D.21. Tandem Roller Compaction (Bryan-Fine SMA).

Overlay Performance

Shortly after construction, the project was tested for skid resistance and impermeability. The portable CTM and DFT devices were used to calculate the IFI. The IFI (F60) ranged between 0.40 and 0.43. These readings were taken before traffic had removed the thin film of asphalt from the aggregate. The final surface texture seemed very similar to an open-graded texture (see Figure D.22); therefore, the water flow test was used to assess impermeability. All measurements were greater than 60 sec, suggesting that the mix will not have problems of water ingress.

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

Figure D.22. Project Surface Texture (Bryan-Fine SMA).

LUFKIN-FINE PFC

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

Site Description

This project is located on the cloverleaf exit from US 59 onto TX Loop 287 around Lufkin (see Figure D.23).

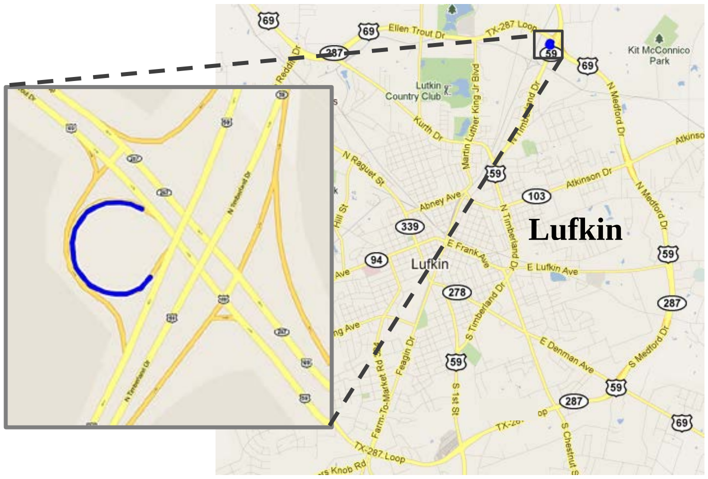


Figure D.23. Project Location on US 59 Cloverleaf Exit (Lufkin-Fine PFC).

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

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

The pavement thickness was highly variable and possibly has interlayer debonding and/or stripping in several locations (see Figure D.24). The surface was a seal coat with some rutting in the outside wheel path.

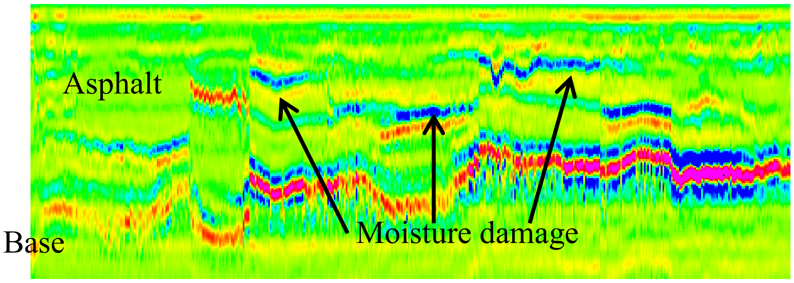


Figure D.24. GPR Profile (Lufkin-Fine PFC).

Overlay Design and Construction

The fine PFC mix was designed by TTI as a modification of TxDOT Item 342. A volumetric design approach was applied. The gradation and gradation limits are given in Table D.6. The aggregate was a Class A sandstone. The asphalt content was 6.5 percent with a PG 76-22 binder and was designed with 72 percent maximum density. Additional 0.3 percent fibers were also

Table D.6. Mix Gradation (Lufkin-Fine PFC).

Property	Percent Passing (%) 3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	99.8	25.2	4.2	3.8	3.2	2.5	1.6
Fine PFC Limits	95-100	20-55	0-15	0-12	0-8	0-8	0-4

included in the mix. The mix passed the overlay test with 462 cycles. No data were available for the HWTT or for the densities at different asphalt contents.

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

Overlay Performance

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

This overlay was in exceptional condition as shown in Figure D.25. There was no sign of cracking, rutting, or flushing here. Usually this would be expected for a pavement less than one year old, but it is impressive for an overlay subject to the extreme traffic conditions on this cloverleaf ramp. As previously described, this ramp carries anywhere from 1,400 to 2,500 slow turning semi-trucks every day, making this a worse-case scenario for trafficking.

Figure D.25. Project and Surface Texture (Lufkin-Fine PFC).

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

BRYAN-FINE PFC

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

Site Description

This project is located on the exit ramp from SR 6 in north Bryan onto the feeder road by the local DPS (see Figure D.26).

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

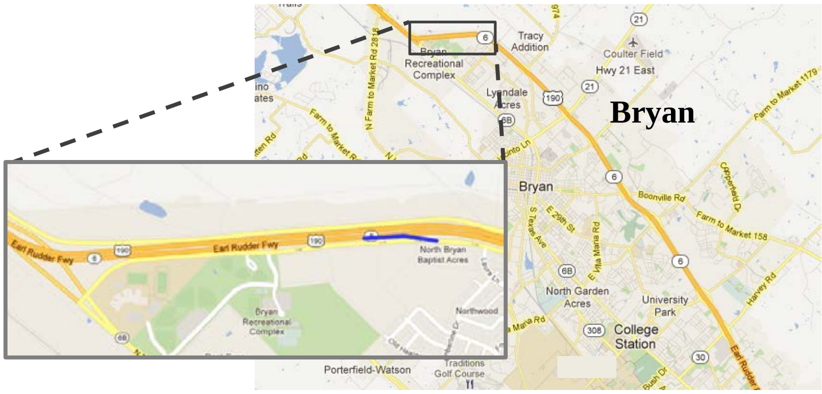


Figure D.26. Project Location on SR 6 (Bryan-Fine PFC).

Overlay Design and Construction

The fine PFC mix was designed by TTI as a modification of TxDOT Item 342. A volumetric design approach was applied. The gradation and gradation limits are given in Table D.7. The aggregate was a Class A sandstone. The asphalt content was 6.5 percent with a PG 76-22 binder and was designed with 72 percent maximum density. Additional 0.3 percent fibers were also included in the mix. The mix passed the overlay test with 462 cycles. No data were available for the HWTT or for the densities at different asphalt contents.

Table D.7. Mix Gradation (Bryan-Fine PFC).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	99.8	25.2	4.2	3.8	3.2	2.5	1.6
Fine PFC Limits	95-100	20-55	0-15	0-12	0-8	0-8	0-4

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

Overlay Performance

The overlay was assessed shortly after construction. The project was in very good condition as shown in Figure D.27. Skid measurements taken at 50 mph ranged from 54 to 68, with an average of 61. This is considerably higher than the SN values for any of the other overlays tested. In this case, the reading was taken after some trafficking rather than immediately after construction. Skid resistance is often lower just after construction until the thin asphalt layer covering the aggregate wears away. The only performance issue noted was that surface water draining towards the shoulder from the main lanes would pond at the conventional PFC-fine PFC construction joint. Possibly due to compaction practices, the mixes were not as permeable at the edges.

Figure D.27. Project and Surface Texture (Bryan-Fine PFC).

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

BROWNWOOD-FINE PFC

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

Site Description

This project is located just south of Breckenridge on US 183. The project runs just under 10 mi long from FM 2231 to FM 1032 (see Figure D.28).

The traffic conditions on this road are of high severity. IH 35 services traffic between San Antonio, Austin, Waco, Dallas, and several other towns along the road. This section of IH 35 is an urban interstate with a speed limit of 70 mph. The estimated AADT/lane is 9,670 with 24 percent truck traffic as estimated from an adjacent freeway section.

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

The surface treatment, shown in Figure D.29, was in fair to poor condition. This was designed with a winter-grade emulsion and was flushing and peeling away after one year. Several large limestone rock asphalt patches were placed over problem areas, but these patches had an extra heavy tack coat application, increasing the amount of free binder and the severity of flushing. Tack rates for the seal coat and patches were 0.07 and 0.14 gsy, respectively. Using a PFC, with high air voids, to surface this road should provide room for the excess tack to move.

Figure D.28. Project Location on US 183 (Brownwood-Fine PFC).

Figure D.29. Flushing Surface Treatment (Brownwood-Fine PFC).

The GPR indicated that the subsurface condition was generally uniform and likely in good condition (see Figure D.30). From the profile, however, the layer boundaries are not clear, though the asphalt is at least 7 inches thick.

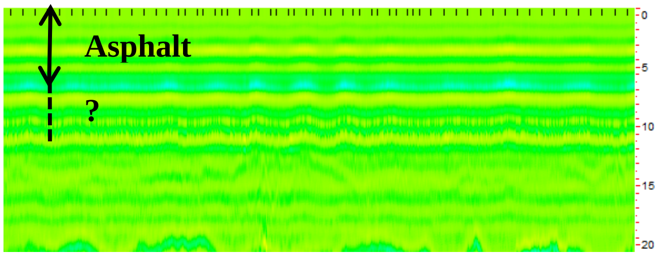


Figure D.30 GPR Profile (Brownwood-Fine PFC).

Overlay Design and Construction

The fine PFC mix was designed by TTI according to TxDOT's updated Item 342. Table D.8 gives the gradation and gradation limits. The aggregates were two Class B limestone aggregates from the Zack Burkett and Eastland quarries. The asphalt content was 6.5 percent with a PG 76-22 binder and had a density of 79 percent. An additional 0.2 percent fibers and 0.8 percent liquid anti-stripping agent were also included in the mix. The density was higher than recommended and

Table D.8. Mix Gradation (Brownwood-Fine PFC).

	Percent Passing (%)						
Property	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
Mix Gradation	96.8	46.1	4.8	3.6	3.1	2.9	2.7
Fine PFC Limits	95-100	20-55	0-15	0-12	0-8	0-8	0-4

could cause permeability problems. The mix passed the HWTT with 9.3 mm rutting at 20,000 cycles and the overlay test with 395 cycles.

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

Overlay Performance

One lane after construction is shown in Figure D.31. For the first section constructed with the original rolling pattern, the average WFV was 21 sec. Water flow data was available after the pattern was adjusted. Laboratory densities were just under 80 percent. Other than the slightly high WFVs, no performance problems were noted. The site should be revisited to assess performance after service.

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

Figure D.31. Project and Lift Thickness (Brownwood-Fine PFC).