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16. Abstract

A thin overlay 1-inch thick was placed as a surface layer on the jointed concrete pavement on Business 59 in the Lufkin District. This mix was designed in the laboratory to have a balance of good rut resistance as measured by TxDOT's Hamburg Wheel Tracking test (HWTT) and good reflection cracking resistance as measured by the Overlay Tester (OT). These Crack Attenuating Mixes (CAM) were designed and constructed based on TxDOT's special specification SS 3109. A top quality granite aggregate was used with 1 percent lime and an asphalt content of 8.3 percent with a PG76-22 binder.

This project was tested with both Ground Penetrating Radar (GPR) and the Rolling Dynamic Deflectometer (RDD). One area of poor load transfer efficiency (LTE) was noted. The overlay was placed in the summer of 2008. Performance to date has been good. After 1 year some low severity reflection cracks were found in the location where the RDD found poor LTE, and some additional low severity longitudinal cracks were found in one location where the longitudinal joint was directly in the wheel path. The one area of concern with this mix was the relatively low skid values, which averaged around a skid number of 20.

A subsequent laboratory evaluation was made of the mix design developed under SS 3109. Using the balanced mix design approach it was found that the HWTT and OT performance criteria were met at binder contents ranging from 7.0 to 8.5 percent. Future applications of this mix should consider reducing the binder content from 8.3 percent to 7.5 percent.

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DESIGN, CONSTRUCTION, AND PERFORMANCE MONITORING OF THE VERY THIN OVERLAY PLACED ON BUS 59 IN THE LUFKIN DISTRICT

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DISCLAIMER

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CHAPTER 1.
INTRODUCTION

Implementation study 5-5981-01 was set up to field test the new Crack Attenuating Mixes (CAM) developed as an outcome of TTI research project 0-5598 (*1*). The Lufkin District recommended a short section of BUS 59 in the middle of the City of Lufkin as a candidate for this evaluation. This section is a 4-lane heavily trafficked urban highway with existing jointed concrete and an existing thin Hot Mix Asphalt (HMA) surface. The existing HMA was badly cracked and in continuing need of maintenance.

In study 0-5598 the concept of the CAM mix was proposed as a very thin overlay mix that meets both TxDOT's existing rutting requirements and also has substantially improved reflection cracking resistance. For thin overlays these engineering properties are measured by the Hamburg Wheel Tracking test (HWTT) and the Overlay Tester (OT) as described below.

RUT RESISTANCE AND MOISTURE SUSCEPTIBILITY (HAMBURG TEST)

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

Figure 1. The Hamburg Test Device.

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

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

REFLECTION CRACK RESISTANCE (OVERLAY TESTER)

Figure 2 shows the upgraded Overlay Tester is the standard test for measuring the reflection cracking potential of HMA mixes in Texas (Tex Method 248-F). This new version of the device has been implemented within TxDOT's Construction Division (Cedar Park) and in three TxDOT Districts labs (Atlanta, Childress, and Houston).

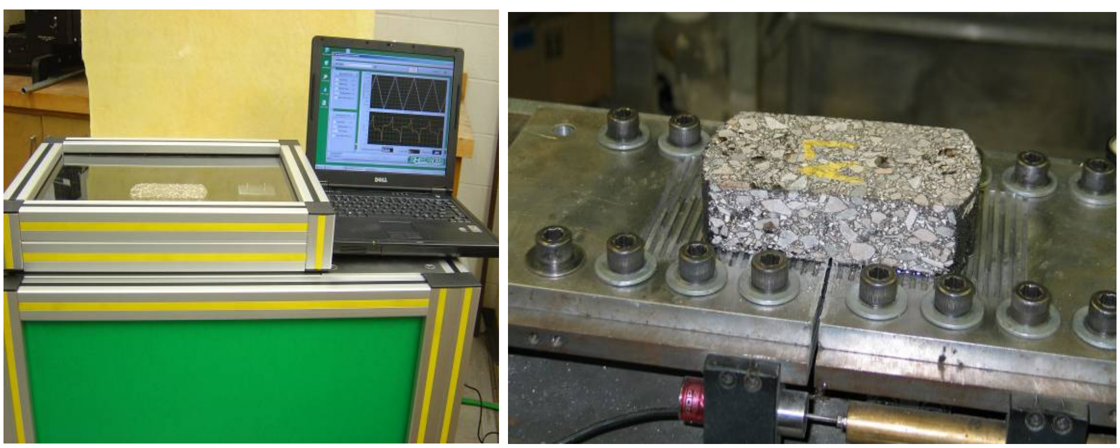

Figure 2. Overlay Tester Equipment and Sample.

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

- Loading: cyclic triangular displacement-controlled waveform at 0.025 in (0.63 mm)
- Loading rate: 10 seconds per cycle
- Test temperature: 25 °C (77 °F)

- Tentative cracking failure criterion: 750 load cycles for CAM mixes
- Specimen size: 6 inch length by 3 inch width by 1.5 inch

The Overlay Tester was developed to evaluate a mixes' resistance to thermally induced reflection cracking. However mixes that pass this test will also have good fatigue resistance. This was demonstrated by TTI with testing of the performance of mixes under accelerated pavement testing conditions (*2*).

The CAM specification SS 3109 (*3*) was developed as an outcome of the initial research projects. The asphalt content for these mixes is that which achieves 98 percent density after 50 gyrations in the Superpave Gyratory compactor. The main addition of this specification is that the designed mix must still pass the HWTT requirement but it must also last more than 750 cycles in the Overlay Tester. This specification was used to select the binder content for the BUS 59 CAM mix.

In addition to this volumetric design procedure the balanced mix design procedure was also run on the Lufkin materials (*4)*. In this procedure the performance tests are run first at a range of asphalt content on samples compacted to 7 percent air voids. The concept of the balanced mix design is shown in Figure 3. The green line represents the Hamburg rut depth for different binder contents; rut depths below 12.5 mm (0.5 inches) are acceptable. The red line shows the performance in the Overlay Tester. In this case samples which last over 300 cycles to failure are judged as acceptable. As the percent asphalt increases the rutting resistance decreases but the cracking resistance increases. The balanced design is the zone of asphalt contents that passes both rutting and cracking requirements. Studies at TTI (*3*) have shown that the window of acceptable asphalt contents is narrow for the lower PG grades. For PG64-22 binders, adding additional binder often get the mixes to rut excessively. The window for PG76-22 has been found to be substantially wider as these binders are not highly rut susceptible.

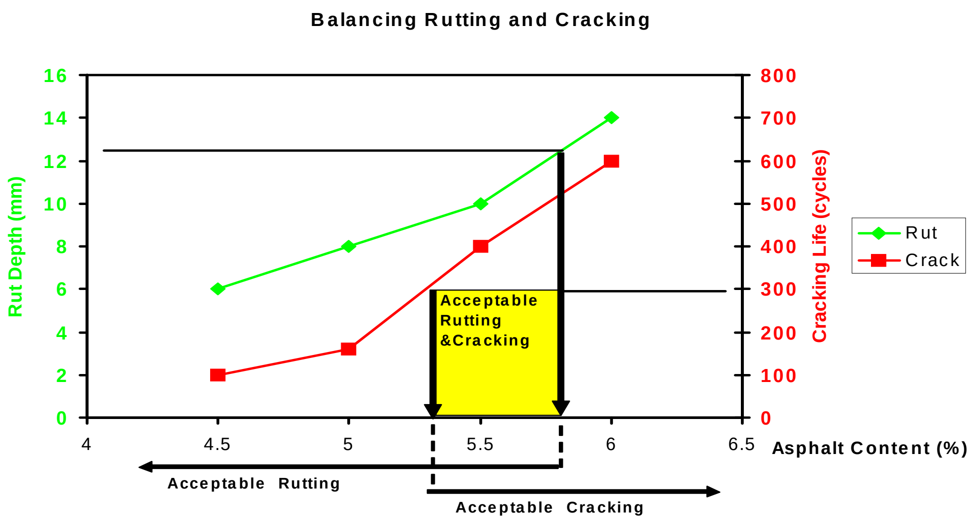

Figure 3. Determining the Binder Content to Meet Rutting and Cracking Requirements.

CHAPTER 2.

US 59 – LUFKIN: TXDOT CAM DESIGN

Working closely with the Lufkin District lab and the local Hot Mix plant two aggregates were selected for evaluation, Jones Mill 3/8-inch granite rock and Granite Mountain screenings. The mix design was developed according to SS 3109 and the proposed design is shown below in Figure 4. This mix with an asphalt content of 8.3 percent, with a PG76-22S binder type with granite aggregates passed both the HWTT and OT criteria.

	BIN FRACTIONS						
	Bin No.1	Bin No.2	Bin No.3	Bin No.4	Bin No.5	Bin No.6	Bin No.7
Aggregate Source:	Martin Marietta	Granite Mountain	Texas hydraded				
Aggregate Number:	Jones Mill 3/8's	Hotmix Scr.	Lime				
Sample ID:	Malvern, Ar.	Sweethome, Ar.	Cleburne, Tx.				
Rap?, Asphalt%:							
Individual Bin (%):	30.0 Percent	69.0 Percent	1.0 Percent	Percent	Percent	Percent	Percent

Total Bin: 100.0%

Sieve Size:	Bin No.1 Cum.% Passing	Bin No.1 Wtd Cum. %	Bin No.2 Cum.% Passing	Bin No.2 Wtd Cum. %	Bin No.3 Cum.% Passing	Bin No.3 Wtd Cum. %	Bin No.4 Cum.% Passing	Bin No.4 Wtd Cum. %	Bin No.5 Cum.% Passing	Bin No.5 Wtd Cum. %	Bin No.6 Cum.% Passing	Bin No.6 Wtd Cum. %	Bin No.7 Cum.% Passing	Bin No.7 Wtd Cum. %	Combined Gradation Cum. % Passing	Lower Specification Limit	Upper Specification Limit	Within Spec's	Restricted Zone		Within Spec's	Individual % Retained	Cumulative % Retained	Sieve Size
1"	100.0	30.0	100.0	69.0	100.0	1.0		0.0		0.0		0.0		0.0	100.0	100.0	100.0	Yes				0.0	0.0	1"
3/4"	100.0	30.0	100.0	69.0	100.0	1.0		0.0		0.0		0.0		0.0	100.0	100.0	100.0	Yes				0.0	0.0	3/4"
1/2"	100.0	30.0	100.0	69.0	100.0	1.0		0.0		0.0		0.0		0.0	100.0	100.0	100.0	Yes				0.0	0.0	1/2"
3/8"	100.0	30.0	100.0	69.0	100.0	1.0		0.0		0.0		0.0		0.0	100.0	98.0	100.0	Yes				0.0	0.0	3/8"
No. 4	56.7	17.0	88.9	61.3	100.0	1.0		0.0		0.0		0.0		0.0	79.4	70.0	90.0	Yes				20.6	20.6	No. 4
No. 8	16.7	5.0	60.3	41.6	100.0	1.0		0.0		0.0		0.0		0.0	47.6	40.0	65.0	Yes				31.7	52.4	No. 8
No. 16	7.6	2.3	40.2	27.7	100.0	1.0		0.0		0.0		0.0		0.0	31.0	20.0	45.0	Yes				16.6	69.0	No. 16
No. 30	4.9	1.5	25.6	17.7	100.0	1.0		0.0		0.0		0.0		0.0	20.1	10.0	30.0	Yes				10.9	79.9	No. 30
No. 50	3.7	1.1	14.6	10.1	100.0	1.0		0.0		0.0		0.0		0.0	12.2	10.0	20.0	Yes				8.0	87.8	No. 50
No. 200	2.4	0.7	3.6	2.5	100.0	1.0		0.0		0.0		0.0		0.0	4.2	2.0	10.0	Yes				8.0	95.8	No. 200

\# Not within specifications # Not cumulative

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

Figure 4. Lufkin's CAM Mix.

COMPARISON ON CAM WITH LUFKIN'S TRADITIONAL MAINTENANCE MIX

As part of this project TTI obtained samples of the maintenance mix currently being used to patch deteriorated sections of BUS 59. As will be described later this highway is continually receiving maintenance patches. This work was underway in a preliminary visit to the project and samples of the widely use maintenance mix were obtained for comparative testing at TTI.

Figure 5 shows the existing limestone maintenance mix and the proposed CAM Mix prior to overlay testing.

Figure 5. Lufkin's Traditional Maintenance Type D Mix (Left) CAM Mix (Right).

In both cases the samples were molded to 7 percent air voids for the performance tests. The results are shown below in Table 1. Both Hamburg and Overlay Tester results for the CAM mix are markedly superior to traditional Type D material.

Table 1. Comparison of CAM with Lufkin's Type D Mix.

Mix Type	Binder	Hamburg	Overlay Tester
Limestone Type D	4.4% PG64-22	12.5 mm after 5,800 passes	38 cycles
Granite CAM	8.3% PG76-22	7.8 mm after 20,000 passes	1510 cycles

CHAPTER 3.
SITE EVALUATION AND CONSTRUCTION DETAILS

The CAM mix was placed in the summer of 2008 as a 1-inch overlay to resurface an existing pavement. The existing underlying pavement structure was jointed concrete with approximately 2 to 3 inches of existing Hot Mix Asphalt (HMA). Rolling Dynamic Deflectometer (RDD) and Ground Penetrating Radar (GPR) data were collected along this project. The complete RDD for the entire project 4500 ft is shown in Figure 6. Complete details on RDD equipment and testing procedures can be found elsewhere (*5*).

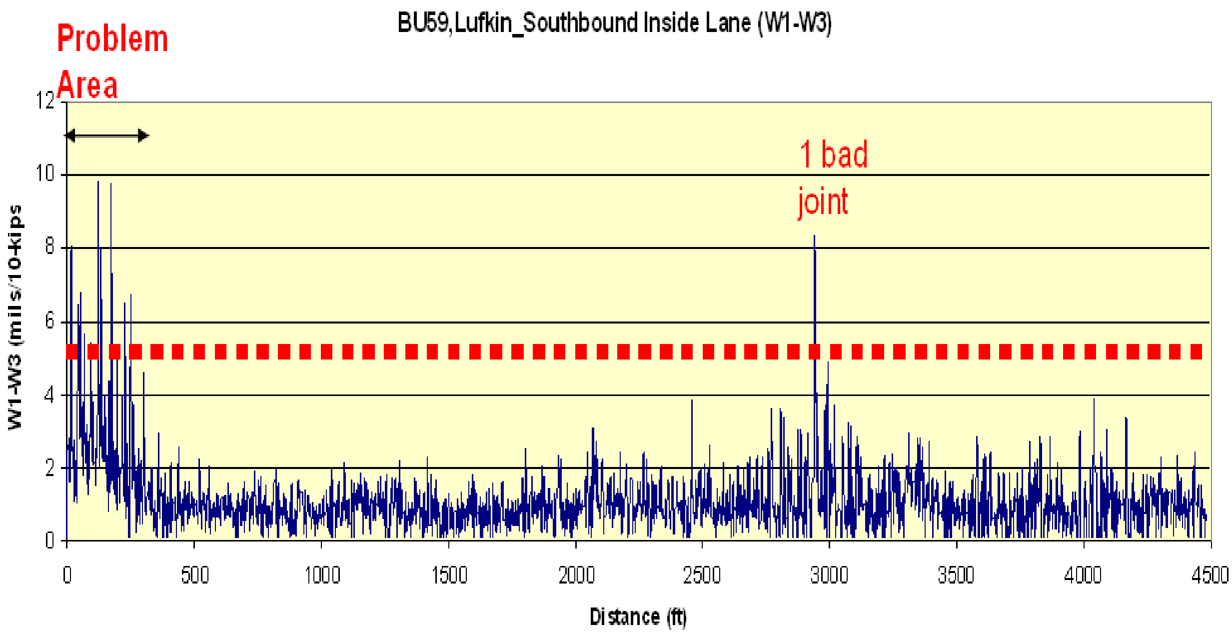

Figure 6. RDD Data (W1 – W3) for the CAM Project in Lufkin.

The data shown in Figure 5 are the difference in deflections between two sensors under the RDD. Sensor W1 is directly between the loading wheels and W3, which is 38 inches away. As the RDD rolls over a joint or crack the value of W1-W3 is an indication of the vertical movement or load transfer efficiency (LTE) of the joint. Studies have found that if this value is greater than 5 mils then there will be a potential for a reflection cracking problem with overlays placed over that joint (*5*). The red line in Figure 5 marks the 5 mils level. However, overall the load transfer efficiency for this highway looks good. There is one small area at the beginning of the project about 250 ft long where the deflections are high, and there is one bad joint near 3000 ft from the beginning. The remainder of the section looks very good. This indicates that the section is a very good candidate for a thin overlay and that the design should be based on cracking caused by thermal movements of the underlying slabs. This is exactly the failure mode that is modeled in the Overlay Tester.

The problem area at the start of this project is expanded below in Figure 7. The large peaks in these data are recorded when the RDD runs over joints with poor load transfer. This plot shows that the eight problem joints are located in the first 250 ft of the project. It is anticipated that overlays placed over these joints would be prone to reflection cracking because of the high vertical movement occurring at these joints.

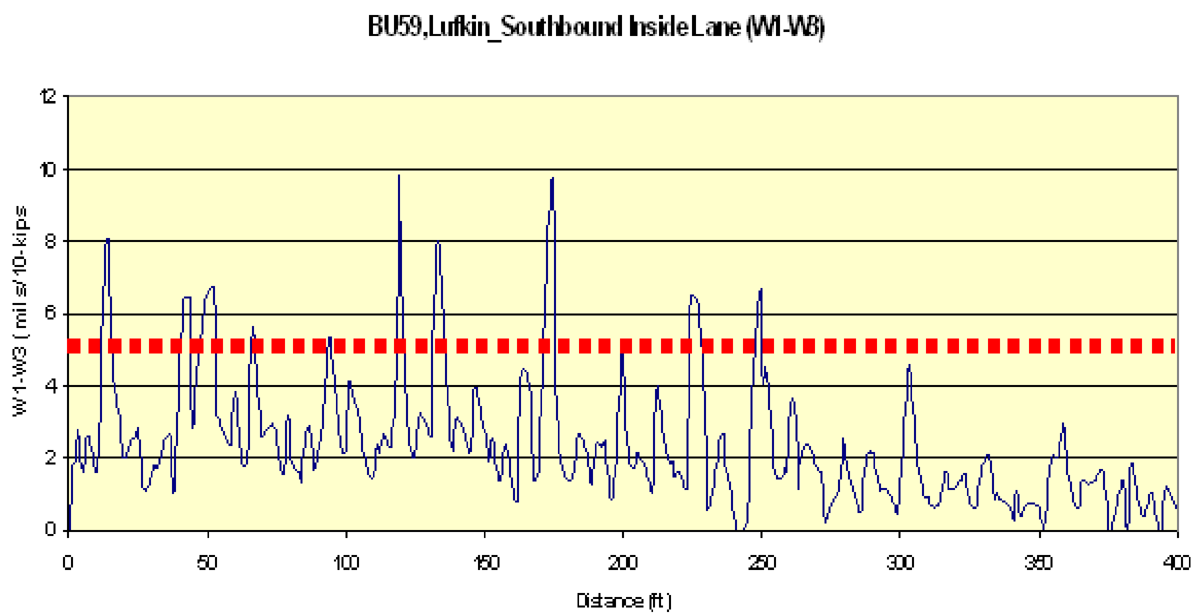

Figure 7. Problem Area Identified by the RDD on US 59.

The problem area is shown in Figure 8. At this location it was proposed that the contractor perform joint repair before the placement of the CAM mix. The areas requiring repair where identified before the project was let and incorporated into the plan sheets for this project. In subsequent discussions with TxDOT personnel not all of these joints were treated prior to placing the thin overlay.

Figure 8. Location of Poor LTE on US 59 Prior to CAM Placement.

PLACEMENT OF CAM MIX

Prior to placement trail batch samples were obtained from the plant and subjected to Hamburg and Overlay testing, the trial batch samples passed both tests 8.7 mm in Hamburg after 20,000 passes and over 1100 cycles in the Overlay Tester.

On July 31 and August 1, 2008, researchers from the Texas Transportation Institute (TTI) conducted an infra-red thermal survey and observed construction of the CAM placed at night on Business 59. The results showed the following:

- The thermal profiles show good uniformity within truckloads. The temperature anomalies that occur are due to truck ends, with thermal differentials between 30 and 60 °F, and changes in the arrival temperature of trucks, which tended to result in mean placement temperatures of individual truckloads varying between approximately 275 and 300 °F.

- Of the core results that were available at the time of TTI's visit, the contractor achieved between 91.8 and 93.6 percent density using a CAT CB-634D breakdown and IR DD130 finish roller.

- Some locations of transverse cracking in the existing pavement seemed to be visible in the CAM at the time of placement. However, the defects seemed to be only temporary, likely resulting from a temporary swelling of the crack seal in the existing transverse cracks. The swells were not found the day after placement.

Paving Conditions

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. Figure 9 shows the paving operation. The contractor's primary compaction roller was a CAT CB-634D shown in Figure 10. The contractor used an Ingersoll Rand DD130 for the finish roller.

Figure 9. CAM Paving Operation on Business 59.

Figure 10. CAT CB-634D on CAM.

Thermal Profile

To collect the thermal profile, TTI used a Pave-IR system attached to the paver footplate as Figure 11 shows. This system uses 10 infrared (IR) sensors spaced approximately 13 inches apart to profile the HMA placement temperatures. TTI used a sampling rate of 2 inches, i.e., a temperature scan was collected for every 2 inches of forward travel.

Figure 11. Pave-IR Collecting Thermal Profile on Business 59.

TTI performed two thermal surveys. The first survey collected the thermal profile of the turn lane that the contractor paved heading southbound. IR data were collected from approximately station 12+05 to 53+90. The second thermal profile was collected on the southbound inside lane, beginning at the northern project limit and continuing to station 45+09.

Thermal Profile Results from Turning Lane

Figure 12 shows excerpts from the thermal profile of the turning lane. The profiles show good uniformity within truckloads. The temperature anomalies that occur are due to truck ends, with thermal differentials between 30 and 60 °F, and changes in the arrival temperature of trucks, which tended to result in mean placement temperatures of individual truckloads varying between approximately 275 and 300 °F. The cold location shown by sensor 1 in the thermal profile resulted because that sensor was off the mat.

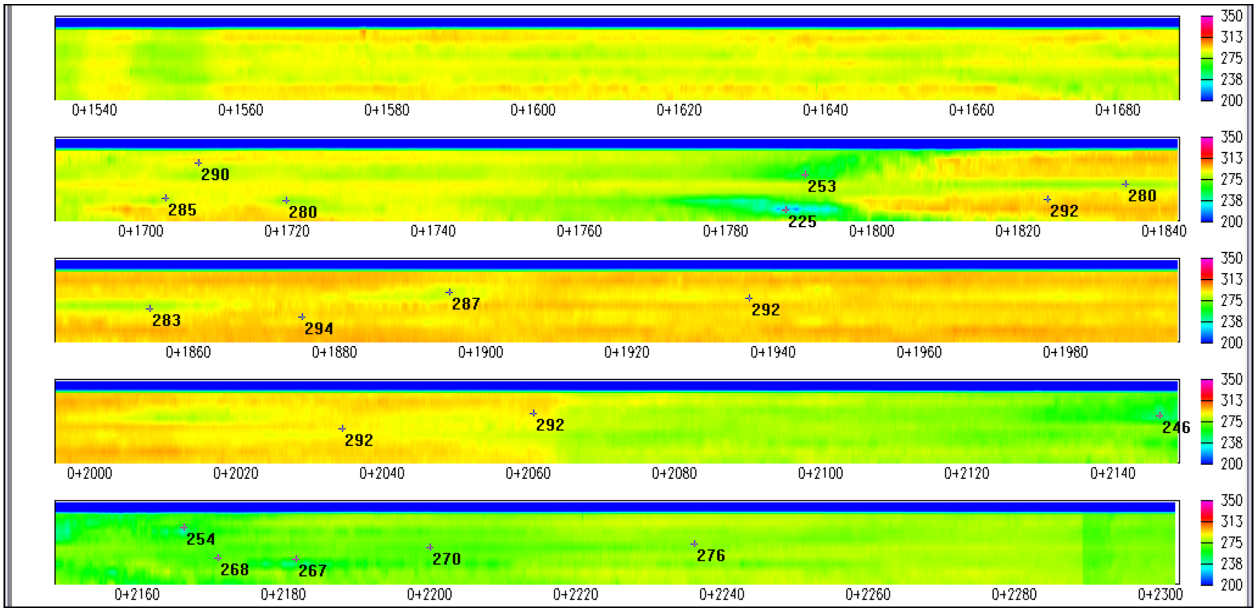

Figure 12. Thermal Profile at Start of US 75 Paving on 12-3-08.

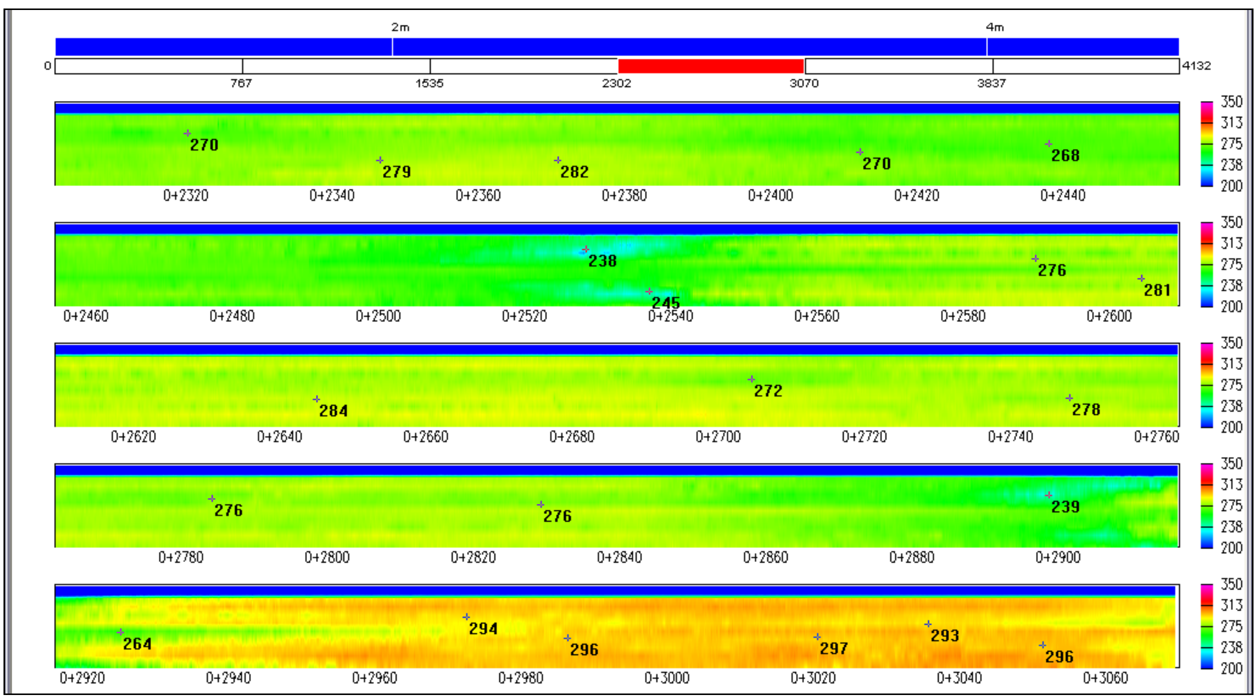

Figure 12. Thermal Profile at Start of US 75 Paving on 12-3-08 (Continued).

Figure 13 shows a histogram of the measured placement temperatures on the turning lane. The temperatures less than 200 °F resulted from sensor 1 being off the mat and should be ignored. The histogram shows approximately 97.5 percent of the placement temperatures fall within a 50 °F range from 260 to 310 °F.

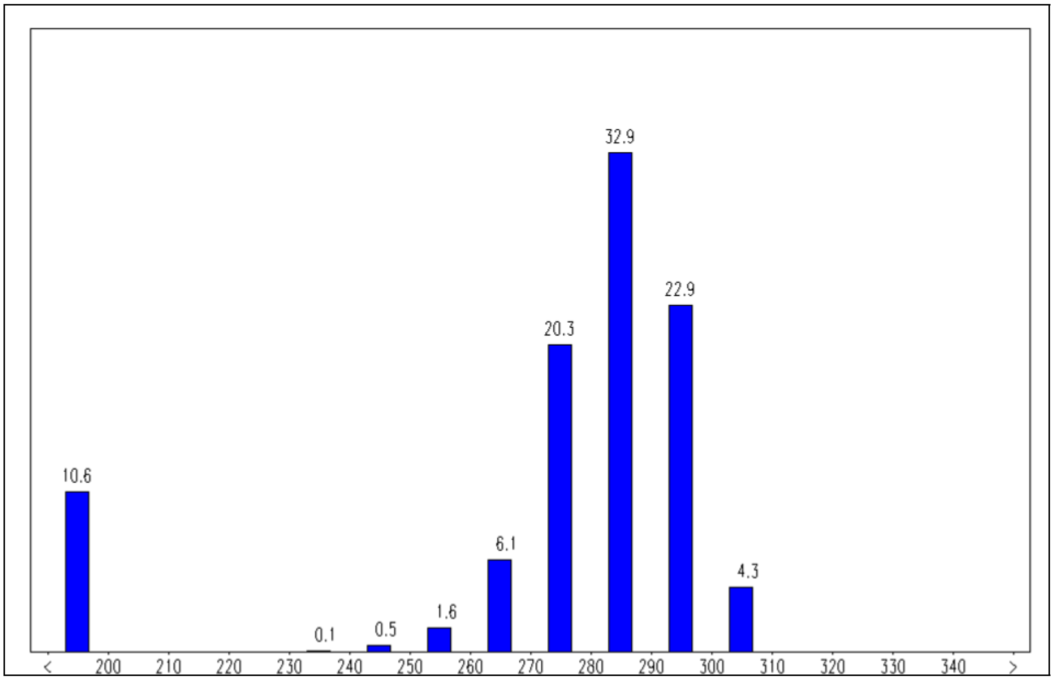

Figure 13. Temperature Histogram from CAM Turn Lane.

Thermal Profile Results from Southbound Inside Lane

Figure 14 shows excerpts from the thermal profile of the southbound inside lane. As before, the profile shows good uniformity within truckloads, some variations in the mean placement temperature from individual trucks, and some truck-end thermal differentials. The histogram from the temperatures recorded in the thermal profile, shown in Figure 15, reveals that approximately 95 percent of the placement temperatures fell within the 50 °F range from 260 to 310 °F.

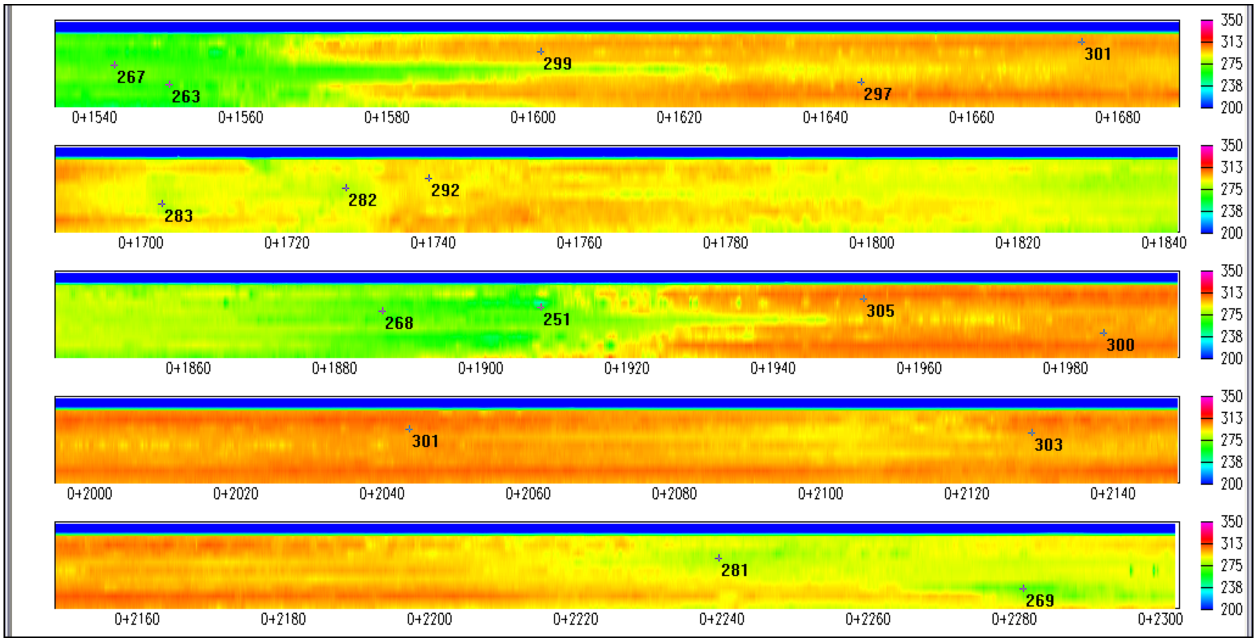

Figure 14. Thermal Profile of CAM Southbound Inside Lane.

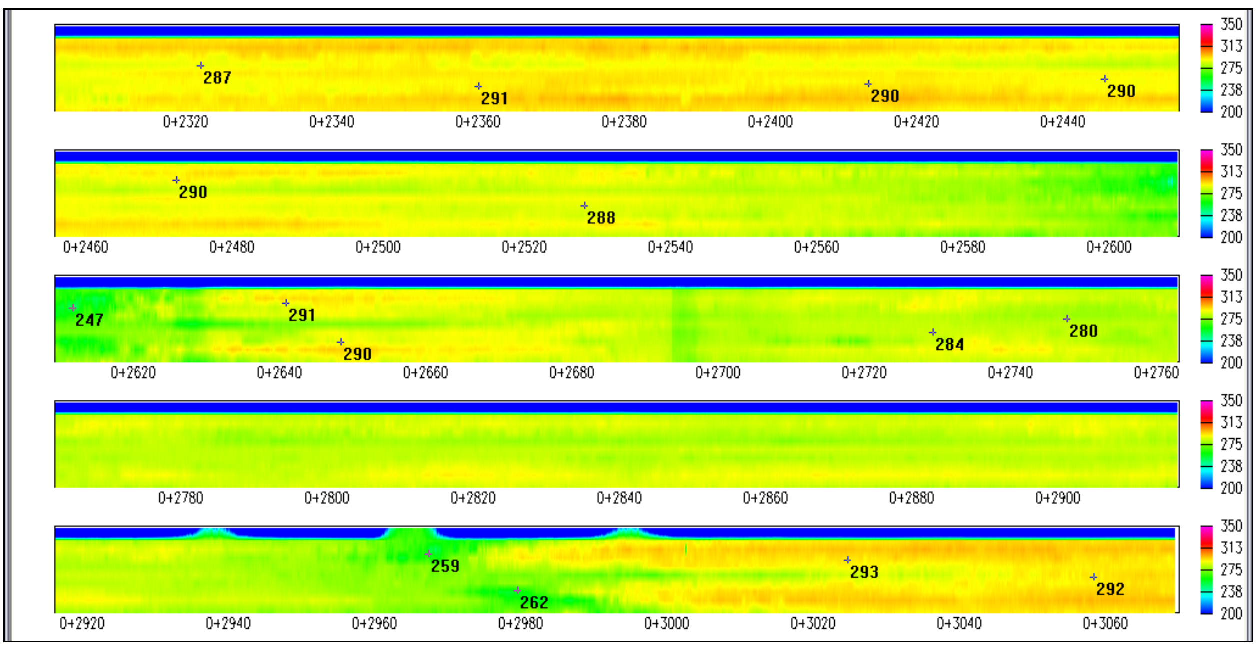

Figure 14. Thermal Profile of CAM Southbound Inside Lane (Continued).

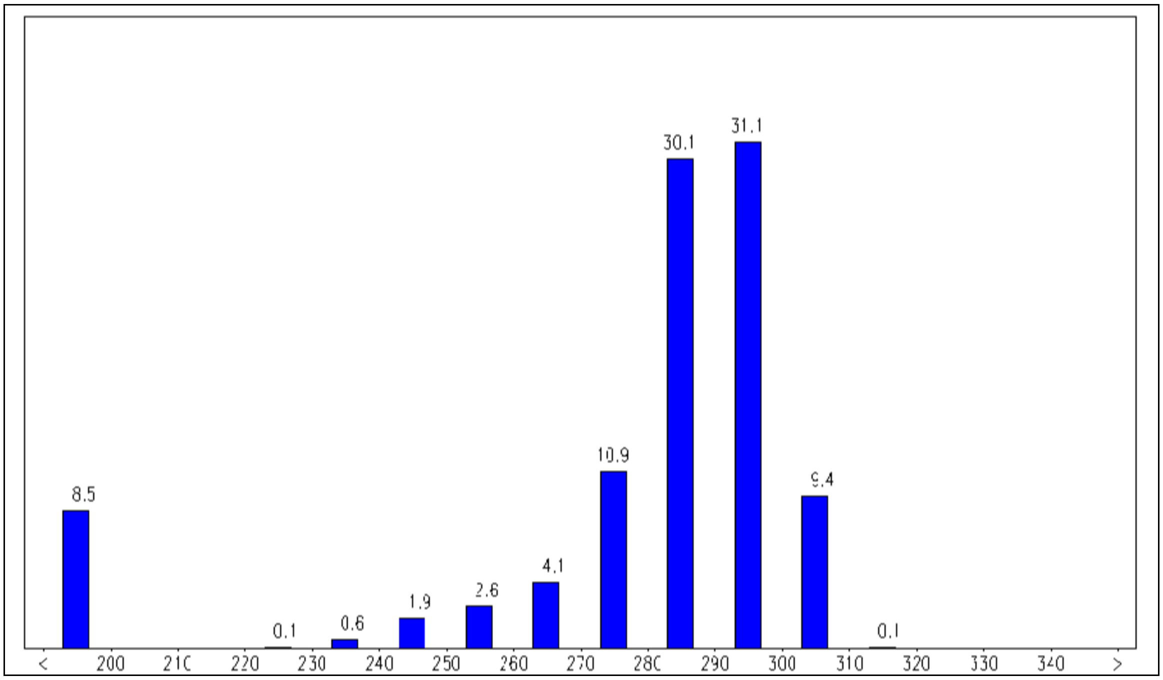

Figure 15. Temperature Histogram from CAM Southbound Inside Lane.

Core Density Results

During TTI's visit the contractor obtained density results for two cores. These core densities were 93.6 and 91.8 percent. Figure 16 shows the cores.

Figure 16. CAM Cores 1 (Left) and 2 (Right).

Other Construction Considerations

At the time of paving, some locations the CAM appeared to be heaved directly over existing transverse cracks that had been crack sealed. However, when driving the section the next day, nothing unusual was noticed in the appearance or ride of the pavement. This observation indicates the heaves observed the night of construction probably resulted from a temporary swelling of the crack seal in the existing transverse cracks.

TTI was not present during the final day of paving on this project. But temperature problems were reported by Mr. Kip Smith from the Lufkin lab. These were related to mechanical problems with the breakdown roller. The mix was placed at the correct temperature but no compaction was performed for more than 1 hour. This 1000-ft section was replaced.

CHAPTER 4.
PERFORMANCE TO DATE

Several inspections were made on this project; after three months in service a visual inspection and skid data were collected on this project. A photo of the CAM mix is shown in Figure 17.

Figure 17. CAM Mix on US 59 Three Months after Placement.

No performance problems were reported and no reflection cracks were found during this inspection. TxDOT also performed skid testing on this section, and the results are shown in Figure 18 as the blue line. This is with a bald tire locked wheel trailer traveling at 40 mph. The average value is reasonable at 23.5, but this section does have some low values with three values below 20. There are no standards for acceptable skid numbers but values for new pavements are normally above 20. These measurements were repeated after one year, and the results are shown as the pink line in Figure 18. The skid values continue to drop and the average value is now less than 20. The CAM mix is not flushing, the surface has a dense finish with very low macro-texture, and there is no explanation for these low skid numbers at this time.

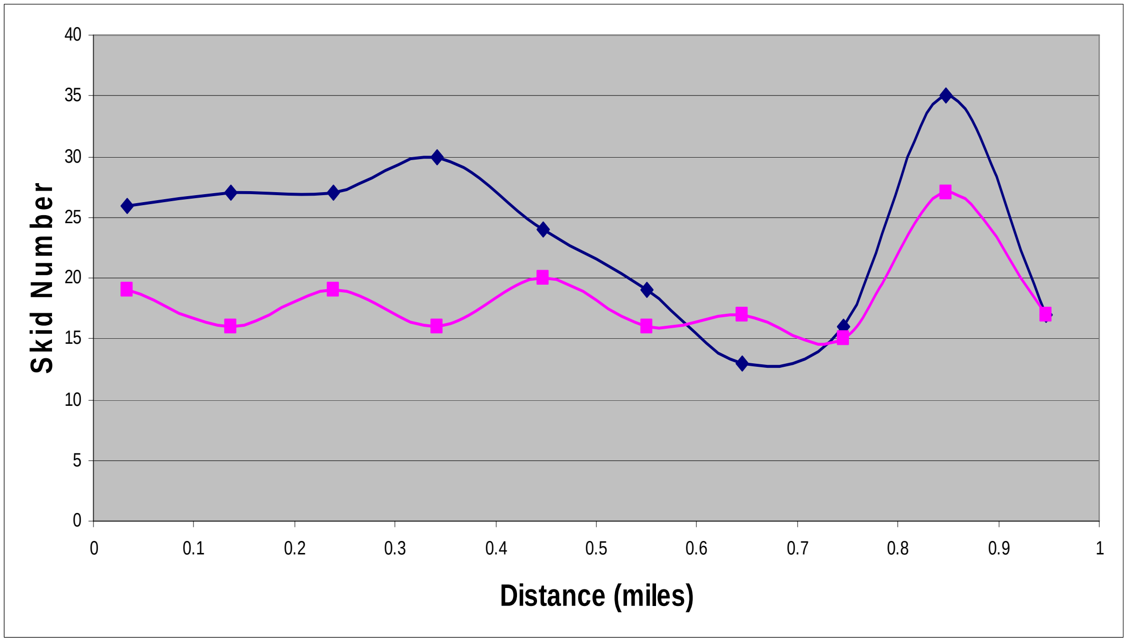

Figure 18. Skid Numbers from US 59 Three Months after Placement.

In a re-inspection a few very fine reflection cracks were found after one year in service. These are primarily at the beginning of the project where the RDD indicated load transfer problems. Figure 19 shows an example of these cracks.

Figure 19. Low Severity Reflection Cracking after 1 Year – Original Condition on Right.

A short section of low severity longitudinal cracking (about 60 ft long) is also apparent in the inside lane in the south bound direct. The before and after photos of this are shown below in Figure 20. At this location there is a longitudinal joint directly in the wheel path.

Figure 20. Before and After Photos of an Area Showing Fine Longitudinal Cracking.

No areas of mix instability reported except for the location shown in Figure 21. There are two major sets of lights on this project and one stop sign. In one lane there is evidence of pushing of the mix. In Figure 21 the outside lane is fine but the inside lane has problems. This was discussed with TxDOT inspectors and this was the very first placement of the CAM material. After this stop sign there is a major 90 degree turn to the left. The inspector said the turn was too tight for the paver and that this area was basically too cold to be adequately compacted.

Figure 21. Mix Instability at One Stop Sign Associated with Construction Problems.

CHAPTER 5.
BALANCE MIX DESIGN FOR LUFKIN CAM

As a final step in the evaluation of the CAM mix used in Lufkin it was proposed to do a laboratory redesign of the mix using the balanced mix design proposed by TTI (*4*) and to compare the optimal asphalt content with that recommended with the existing volumetric procedure. The concern is that the volumetric procedure arrives at a single asphalt content and there is no way to determine if this is the optimum. From earlier studies with the balanced design concept for most mixes it was found that there was a range of asphalt contents that meet both the HWTT and OT performance criteria. There was no way to tell that the optimum asphalt content selected with the SS 3109 volumetric procedure was within the acceptable window. It was suspected that the current procedures will give binder contents toward the upper end of the acceptable window. The concern here was that a) for CAM mixes the asphalt is paid for as a separate item so there is no incentive to take asphalt out of the mix and b) operational tolerances permit ±0.3 percent asphalt then there is a possibility that rich mixes could end up with too much asphalt and consequently stability problems in demanding locations (corners, stop signs, etc.).

In the balanced mix design approach the performance tests are run first at a range of asphalt contents. Once the asphalt content gets too high the mix will fail the HWTT and too low it will fail the OT criteria (750 cycles). An acceptable range of asphalt contents is therefore defined and the optimal is selected from within that range (normally the middle of the range). Once the new optimum is selected a volumetric check is performed in a Superpave Gyratory Compactor with 50 gyrations, the mix must achieve a minimum of the 96.5 percent of the maximum theoretical density to be acceptable.

In doing the redesign two PG graded binders were used, PG76-22 and PG70-22. The two balance mix designs for Lufkin CAM were carried out by TTI on July and August 2009, which was based on the original design combined gradation.

OBTAINING THE CORRECT MIX GRADATION

In performing the redesign a new set of materials was obtained from the Lufkin District. The first challenge was that the new materials were of a very different gradation of that presented in Figure 4. In order to match the gradation of the original design, TTI technicians sieved each rock to individual size particles and then batched them based on the original design combined gradation for mixing and molding. The current new materials and the original design gradation are shown in Table 2.

Table 2. Comparing the Gradation of Each Rock (the Percentage of Cumulative Passing).

Sieve Size	New materials		Original gradation from the designed spreadsheet	
	Jones Mill 3/8"	Screenings	Jones Mill 3/8"	Screenings
1"	100.0	100.0	100.0	100.0
3/4"	100.0	100.0	100.0	100.0
1/2"	100.0	100.0	100.0	100.0
3/8"	99.4	100.0	100.0	100.0
No. 4	39.9	78.4	56.7	88.9
No. 8	7.6	33.3	16.7	60.3
No. 16	3.6	14.9	7.6	40.2
No. 30	2.6	8.1	4.9	25.6
No. 50	2.3	4.5	3.7	14.6
No. 200	1.9	1.3	2.4	3.6

After re-sieving and combining, the TTI tests were performed on exactly the same gradation as that shown in Figure 4.

THE HAMBURG AND OVERLAY TESTING RESULTS

Three trial asphalt contents, i.e., 7.0 percent, 7.5 percent and 8.0 percent, were chosen to mold the Hamburg and Overlay samples for each asphalt binder (i.e., PG76-22 and PG70-22). The Hamburg and Overlay Testing results of those samples are shown in Table 3 and Table 4, respectively.

Table 3. Hamburg Testing Results.

Asphalt Binder	Sample's No.	Air Void	Rutting	Pass or Not
PG76-22	7.0% Asphalt	7.7 / 7.8	2.6 mm @ 20000	**yes**
	7.5% Asphalt	7.8 / 7.9	2.9 mm @ 20000	**yes**
	8.0% Asphalt	7.1 / 7.6	3.6 mm @ 20000	**yes**
PG70-22	7.0% Asphalt	7.7 / 7.6	5.2 mm @ 15000	**yes**
	7.5% Asphalt	7.8 / 7.8	11.7 mm @ 15000	**no**
	8.0% Asphalt	7.6 / 7.4	17.8 mm @ 15000	**no**

Table 4. Overlay Testing Results.

Asphalt Binder	Sample's No.	Max load at first cycle	Cycles of failure	Pass or Not
PG76-22	7.0% Asphalt_1	543.8	>1000	**yes**
	7.0% Asphalt_2	562.0	>1000	**yes**
	7.5% Asphalt_1	602.2	>1000	**yes**
	8.0% Asphalt_1	457.1	>1000	**yes**
PG70-22	7.0% Asphalt_1	448.4	>1000	**yes**
	7.0% Asphalt_2	445.8	>1000	**yes**
	7.5% Asphalt_1	393.3	>1000	**yes**

From Table 3 and Table 4, the following observations can be obtained:

1) For PG76-22:

- The resistance rutting as measured in the HWTT was no problem for the three trial asphalt contents; even at 8.0 percent the rutting level was only 3.6 mm.
- All three asphalt contents easily passed the OT criteria of 750 cycles.

2) For PG70-22:

- The 7.0 percent asphalt past the HWTT, the 7.5 percent was very close to failure (i.e., <12.5mm @ 15,000 cycles).
- For the three trial asphalt content, the mix had no problem meeting the OT criteria.

Volumetric Check

(1) PG76-22

For PG76-22, the 7.5 percent asphalt content was selected to run the volumetric check. The testing results were listed in Table 5. At this level at 50 gyrations the mix was easy to compact reaching a density of 97.5 percent of the maximum. From Table 6, if the target density was 98.0 percent, by interpolate, the minimum gyrations would be 62. Test results are also presented for the compaction achieved after 75 gyrations.

Table 5. Volumetric Check.

Volumetric Check @ 50 and 75 Gyrations							
Sample's No.	Gyrations	RICE	Sample Height /mm	Weight of Dry Sample	Sample Weight in Water	Weight of Dry Surface	Density
7.5%_50_1	50	2.3676	115.9	4639.4	2624.2	4642.8	97.5%
7.5%_50_2	50	2.3676	115.6	4641.5	2627.1	4644.4	
7.5%_75_1	75	2.3676	114.9	4684.1	2675.3	4685.3	98.8%

(2) PG70-22

For PG70-22, since the highest asphalt content was 7.5 percent for Hamburg (but all three trial asphalt content can match the Overlay criteria), 7.2 percent asphalt content was chosen for the volumetric check. The testing results were listed in Table 6.

Table 6. Volumetric Check for PG70-22 Asphalt.

Volumetric Check @ 50 and 75 Gyrations							
Sample's No.	Gyrations	RICE	Sample Height /mm	Weight of Dry Sample	Sample Weight in Water	Weight of Dry Surface	Density
7.2%_1	50	2.3752	119.5	4664.9	2600.2	4673.5	94.5%

From Table 6, it can be found that 7.2 percent asphalt content was too low and it was not possible to achieve the 96.5 percent target density. As the 7.5 percent was close to failing the HWTT it was concluded that it was not possible to arrive at a satisfactory design for the PG70-22 binder.

Based on the testing results, the following conclusions are drawn:

1) 7.5 percent asphalt content was the optimum if PG76-22 asphalt binder was used.
2) PG70-22 was not recommended to use for this CAM design.

This optimum binder content is well below the 8.3 percent binder, which was designed using SS 3109 and used in the field.

REFERENCES

1. L.F. Walubita, and Scullion, T. "Thin HMA Overlays in Texas: Mix Design and Laboratory Material Property Characterization," Technical Report. 0-5598-1. Texas Transportation Institute, College Station, Texas. January 2008.
2. F. Zhou, Hu, S., Scullion, T., Chen, D., Qi, X., and Claros, G. *Development and Verification of the Overlay Tester Based Fatigue Cracking Prediction Approach*. Journal of Association of Asphalt Paving Technologists, Vol. 76, 2007, pp. 627-662.
3. TxDOT Special Specification SS 3109, Crack Attenuating Mixes (CAM), Bryan District, CSJ 0057-04-022. August 2007.
4. F. Zhou, Hu, S., and Scullion T. "Integrated Asphalt (Overlay) Mixture Design, Balancing Rutting and Cracking Requirements," Research Report 0-5123-1. Texas Transportation Institute, College Station, Texas. December 2006.
5. Scullion, T., "Using Rolling Deflectometer and Ground Penetrating Radar Technologies for Full Coverage Testing of Jointed Concrete Pavements," TTI Report 0-4517-2, July 2005.