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16. Abstract

Crack Attenuating Mix (CAM) designs are made according to the volumetric procedure defined in Special Specification 3109 (now 3165) where the optimal asphalt content (OAC) is computed as that which achieves 98 percent of the maximum density at 50 gyrations of Superpave Gyratory Compactor. Samples at the proposed OAC are then molded to 93 percent density and then subjected to performance testing in the Hamburg Wheel tracker and Overlay tester. A design was performed for the CAM mix to be placed on BUS 59 in Lufkin and using the specified procedure an optimum asphalt content of 8.3 percent PG76-22 was determined. This material was placed in the summer of 2008.

In this study an alternative mix design procedure was evaluated. In the balanced mix design procedure the performance tests are first run at several different asphalt contents, and an acceptable range of asphalt contents is identified where both the rutting and cracking criteria are met. An optimum asphalt content is then defined within the acceptable range, and volumetric checks are then made as the final step. Using this procedure the acceptable range of asphalt contents was defined to be between 7.0 and 8.0 percent (the upper limit tested in the balance mix design procedure). An optimum of 7.5 percent PG76-22 was proposed with the balanced mix design approach, substantially lower than that found with the current volumetric procedure. No acceptable design could be achieved with a PG70-22 binder.

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BALANCED MIX DESIGN REPORT FOR LUFKIN'S CRACK ATTENUATING MIX (CAM)

by

Tom Scullion
Senior Research Engineer
Texas Transportation Institute

Report 5-5598-01-1
Project 5-5598-01
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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

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BACKGROUND

Crack Attenuating Mix (CAM) designs are made according to the volumetric procedure defined in Special Specification 3109 (now 3165) where the optimal asphalt content (OAC) is computed as that which achieves 98 percent of the maximum density at 50 gyrations of Superpave Gyratory Compactor. Samples at the proposed OAC are then molded to 93 percent density and then subjected to performance testing in the Hamburg Wheel Tracker and Overlay Tester.

ORIGINAL MIX DESIGN USED IN LUFKIN

Working closely with the Lufkin District lab and a local hot mix plant, two aggregates were selected for evaluation for the CAM design proposed for BUS 59 in Lufkin, the Jones Mill 3/8-inch granite rock and Granite Mountain screenings. The mix design was developed according to TxDOT's Special Specification SS 3109, and the proposed design is shown below in Figure 1. This mix with Jones Mill granite aggregate and 8.3 percent asphalt (PG 76-22S) passed both TxDOT's performance criteria; namely the Hamburg Wheel Tracking Test (HWTT) and Overlay Test (OT). The mix passed the proposed performance criteria with the following lab results:

- HWTT – 7.8 mm after 20,000 passes (< 12.5 mm)
- Overlay Tester – 1510 cycles (> 750 cycles)

This mix was placed on BUS 59 in the summer of 2008.

LABORATORY EVALUATION OF ORIGINAL MIX DESIGN

As a final evaluation of the CAM used in Lufkin it was proposed to do a laboratory redesign of the mix using the balanced mix design 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.

HMACP MIXTURE DESIGN : COMBINED GRADATION

Refresh Workbook

File Version: 06/15/06 15:19:42

SAMPLE ID:	Special spec. CAM	SAMPLE DATE:	
LOT NUMBER:		LETTING DATE:	
STATUS:		CONTROLLING CSJ:	
COUNTY:	Angelina	SPEC YEAR:	2004
SAMPLED BY:		SPEC ITEM:	CAM
SAMPLE LOCATION:		SPECIAL PROVISION:	
MATERIAL:	CAM Hotmix	MIX TYPE:	Other
PRODUCER:	East Texas Asphalt		
AREA ENGINEER:		PROJECT MANAGER:	

COURSE\LIFT:		STATION:		DIST. FROM CL:		CONTRACTOR DESIGN # :	

Enter Specifications

	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, (%):	8.3	Asphalt Spec. Grav.:	1.025
Antistripping Agent:	Texas Hydraded Lime	Percent, (%):	1		

Figure 1. Original Mix Design Used on BUS 59 Project in Lufkin.

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) as 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, a PG76-22 and PG70-22. The two balance mix designs for Lufkin CAM were carried out by Texas Transportation Institute (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 were obtained from the Lufkin District. The first challenge was that the new materials were of a very different gradation of that presented in Figure 1. 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 1.

Table 1. 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 1.

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 2 and Table 3, respectively.

Table 2. 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 @ 20,000	**yes**
	7.5% Asphalt	7.8 / 7.9	2.9 mm @ 20,000	**yes**
	8.0% Asphalt	7.1 / 7.6	3.6 mm @ 20,000	**yes**
PG70-22	7.0% Asphalt	7.7 / 7.6	5.2 mm @ 15,000	**yes**
	7.5% Asphalt	7.8 / 7.8	11.7 mm @ 15,000	**yes**
	8.0% Asphalt	7.6 / 7.4	17.8 mm @ 15,000	**no**

Table 3. 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 2 and Table 3, 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 passed the HWTT; the 7.5 percent was very close to failure (i.e., <12.5 mm @ 15,000 cycles).
- For the three trial asphalt contents, 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 test results are listed in Table 4. At 50 gyrations the mix was easy to compact reaching a density of 97.5 percent of the maximum. From Table 4, 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 4. Volumetric Check.

<table>
<tr><td colspan="8">Volumetric Check @ 50 and 75 Gyrations</td></tr>
<tr><td>Sample's No.</td><td>Gyrations</td><td>RICE</td><td>Sample Height /mm</td><td>Weight of Dry Sample</td><td>Sample Weight in Water</td><td>Weight of Dry Surface</td><td>Density</td></tr>
<tr><td>7.5%_50_1</td><td>50</td><td>2.3676</td><td>115.9</td><td>4639.4</td><td>2624.2</td><td>4642.8</td><td rowspan="2">97.5%</td></tr>
<tr><td>7.5%_50_2</td><td>50</td><td>2.3676</td><td>115.6</td><td>4641.5</td><td>2627.1</td><td>4644.4</td></tr>
<tr><td>7.5%_75_1</td><td>75</td><td>2.3676</td><td>114.9</td><td>4684.1</td><td>2675.3</td><td>4685.3</td><td>98.8%</td></tr>
</table>

(2) PG70-22

For PG70-22, since the highest asphalt content passing the HWTT was 7.5 percent (but all three trial asphalt contents passed or exceeded the Overlay criteria), a 7.2 percent asphalt content was chosen for the volumetric check. The test results are listed in Table 5.

Table 5. 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 5, 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.

CONCLUSIONS

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.