QC/QA TESTING DIFFERENCES BETWEEN HOT MIX ASPHALT (HMA) AND WARM MIX ASPHALT (WMA)

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Submitted to:

John Bowman, P.E.
Planning and Research Division Engineer
Oklahoma Department of Transportation
200 N.E. 21st Street
Oklahoma City, Oklahoma 73105

Submitted by:

Stephen A. Cross, Ph.D., P.E.
School of Civil & Environmental Engineering
Oklahoma State University
207 Engineering South
Stillwater, OK 74078

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I* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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QC/QA Testing Differences Between Hot Mix Asphalt (HMA) and Warm Mix Asphalt (WMA)

Introduction

The following report summarizes the work accomplished to date on a three-year (a 1-year extension to include laboratory compacted foam WMA was approved for FY 2012) study on QC/QA differences between warm mix asphalt (WMA) and conventional hot-mix asphalt (HMA). WMA represents a group of technologies which allow a reduction in the temperatures at which asphalt mixtures are produced and placed on the road. These technologies tend to reduce the viscosity of the asphalt cement allowing coating at lower temperatures. Reductions of 35 to 100^{o}F have been reported (1). Such drastic reductions have the obvious benefits of cutting fuel consumption and decreasing the production of greenhouse gases. In addition, potential engineering benefits include better compaction on the road, the ability to haul paving mix for longer distances, increased RAP percentages, and the ability to pave at lower temperatures (2).

Advances in WMA processes are progressing rapidly. When originally introduced in the US there were three WMA procedures. There currently are a multitude of procedures/technologies either available or proposed. WMA has advanced from demonstration projects to where many agencies, such as Texas DOT, allow the use of WMA technology.

ODOT Materials Division has conducted preliminary inquiries into QC/QA testing for WMA. Some respondents indicate that WMA can be tested exactly the same as hot mix asphalt (HMA) with the same results. Other data show that lab-molded and other volumetric properties are significantly different for WMA.

The objectives of this study are to develop testing protocols for the different WMA additives for mix design and QC/QA procedures. For mix design, testing protocols need to be developed for rut testing and moisture sensitivity testing. For QC/QA, protocols need to be developed for lab-molded void properties and asphalt content. To meet the objectives, equivalent compaction temperatures and/or compactive efforts need to be established for WMA additives. Originally, equivalent compaction temperatures and/or compactive efforts were those that will produce void results for WMA mixtures similar to conventional Superpave mixtures. Currently, the recommended compaction temperature is selected by the contractor or supplier and verified in accordance with draft procedures found in section 8.3 of the proposed Appendix to AASHTO R 35 (3). Once this temperature is established/verified, the effect of WMA additives on lab-molded volumetric results from Superpave Gyratory Compactor (SGC) samples (QC/QA properties) and mix design results (moisture sensitivity and rutting) can be determined. If properties/results differ significantly from those obtained from the same conventional HMA mix, standard testing protocol(s) using the SGC will be developed that will provide test results consistent with conventional HMA test results. Test protocols could be dependent upon the specific WMA technology. Because the test protocols will be highly dependent upon the accuracy and repeatability of the test results, sample preparation and testing is being performed by a commercial testing laboratory employing ODOT certified HMA technicians rather than graduate students.

Task 1 Literature Review

There is a wealth of literature on WMA technologies. The PI has participated in a recently completed study on moisture damage and performance issues of WMA for the Oklahoma Transportation Center, which contains a literature review that can serve as the background for this study. The literature review for this study will concentrate on QC/QA procedures for WMA.

WMA was originally classified based on the degree of temperature reduction. A mixture is considered WMA if the temperature at the plant exceeds 212^{o}F and half warm mix if the temperature at the plant is less than 212^{o}F. WMA is also classified by technology; those that use water, those that use organic additives or waxes, and those that use surfactants (1). A third classification will be those that use additives and those that are process driven. Process driven technologies tend to be foaming processes and could include Double Barrel Green plants and related technologies, Low Energy Asphalt and WAM-Foam. Bonaquist (4) reported that for mix design purposes WMA technologies are placed into four categories:

- WMA additives that are added to the asphalt binder,
- WMA additives that are added to the mixture during production,
- Sequential mixing processes, and
- Plant foaming processes.

There is a current NCHRP study, 9-43, on WMA mix design practices (3). When this study began there was a draft mix design method available; however, the procedure did not address mixing and compaction temperatures or QC/QA procedures. The mix design method is approaching finalization and is presented as an appendix to AASHTO R 35 and contains a commentary (3). NCHRP 9-43 recommends the contractor select his own WMA additive and mixing and compaction temperatures. The draft mix design procedure contains a method for evaluating mixing and compaction temperature based on coatability using AASHTO T 195 and compaction temperature based on compacting samples at the proposed roadway temperature and 30^{o}C less and evaluating the number of gyrations required to reach 92% Gmm. Data presented indicate compaction temperatures range from 270^{o}F to 220^{o}F (4).

Bonaquist (4) reported that, with the exception of Sasobit, WMA technologies perform poorer than equivalent HMA mixes in rutting tests and that WMA and equivalent HMA mixes can have similar TSRs from AASHTO T 283 but that both dry and conditioned indirect tensile strengths are lower for WMA. Reinke (5), in a study of outside aging of WMA samples, reported that initially WMA samples had less binder stiffness than HMA but that after a short period of time the binder properties approached similar levels.

There is a wealth of information available in the literature on constructability, material properties and environmental effects of the different WMA technologies. There was little literature found on the effect of WMA technologies on the effect of QC/QA properties, most notably laboratory compacted void properties. Some studies have indicated no difference in QC/QA procedures required for WMA technologies and other studies indicate significantly different void properties. The Ohio DOT reported the following reduced lab-molded air voids from their demonstration project on WMA technologies (6):

Table 1 Laboratory Molded Voids from Ohio Study

Mix Type:	Control	Aspha-min	Evotherm	Sasobit
Air Voids (%)				
@ 300°F	3.5	2.4	2.0	1.6
@240°F		3.8	3.2	3.0

Bistor (7) reported a 1.1% reduction in lab-molded air voids between HMA and Green WMA process (foam). Interestingly, Bistor also reported that the ignition furnace reported 0.3% more asphalt cement for the WMA mix compared to the control mix as well (7).

Cowsert (8) reported on the progress of *Task Force 09-01 State Agency WMA Specifications and Project Synthesis*. The research team is in the process of obtaining this report as it should provide valuable insight as to how other agencies are handling QC/QA procedures for WMA mixtures.

Task 2 Materials

Foam is the most common WMA procedure used in Oklahoma. When this study was originally proposed foam could not be evaluated in the laboratory; therefore, two local contractors were selected that could supply plant produced foam mixtures and aggregates. Mixtures that would be foamed in production were selected from these plants for control mixtures (no WMA). Two ODOT S-4 mixtures, one of which required an anti-strip to pass AASHTO T 283, were originally selected for sampling and testing. Neither mixture contained RAP. Production issues arose with the mix requiring anti-strip and a replacement mix was identified and sampled in November 2011. Approximately 1,000 pounds of aggregate, sampled off of the cold-feed belt, were obtained for the S-4 mixes. Mix 1, from Haskell-Lemon, is shown in table 2 and Mix 2, from Arkhola-Roberts, is shown in table 3. Mix design properties are shown in tables 2 and 3 as well. Using cold feed belt samples of aggregates precludes the need for mix designs.

Valero PG 64-22OK asphalt cement was obtained for Mix 1 and PG 64-22OK from Lion Oil Co., Muskogee was sampled for Mix 2.

Three WMA additives were obtained from suppliers. They are Sasobit, Evotherm M1 and Advera.

Table 2 Mix 1 Reported Mix Design

Number	Aggregate	Producer/Supplier	% Used
1	5/8" Chips	Martin-Marietta (Snyder,OK)	34
2	Stone Sand	Dolese Co., (Cyril, OK)	26
3	Man. Sand	Martin-Marietta (Davis,OK)	15
4	Scrns.	Martin-Marietta (Mill Creek,OK)	10
5	Sand	General Materials Inc., (OKC, OK)	15

Sieve	Material					Comb.	
Size	1	2	3	4	5	Agg.	JMF
	Percent Passing						
3/4 in.	100					100	100
1/2 in.	92					97	97
3/8 in.	71	100	100	100	100	90	90
No. 4	22	97	96	79	99	70	70
No. 8	5	64	60	52	99	47	47
No. 16	3	40	34	35	98	35	35
No. 30	2	27	20	24	92	27	27
No. 50	2	22	11	16	61	19	19
No. 100	2	14	6	11	15	9	9
No. 200	1.2	4.6	3.6	7.2	2	3.2	3.2
AC (%)							5.1

Reported Mix Properties at Optimum Asphalt Content	
Gse	2.663
Gsb	2.630
Gmm	2.458
Gmb	2.360
VTM	4.0
VMA	14.9
VFA	73.0
DP	0.7
Pba	0.5%
Pbe	4.7%

Table 3 Mix 2 Reported Mix Design

Number	Aggregate	Producer/Supplier	% Used
1	#67 Rock	Arkhola S & G (Okay, OK)	23
2	3/8" Chips	Arkhola S & G (Zeb, OK)	36
3	Washed Scrns.	Arkhola S & G (Zeb, OK)	24
4	Scrns.	Arkhola S & G (Okay, OK)	17
	Anti-Strip	Perma-Tac Plus Akzo Nobel (Waco, TX)	0.05%

Sieve	Material				Comb.	
Size	1	2	3	4	Agg.	JMF
	Percent Passing					
3/4 in.	100				100	100
1/2 in.	64	100			92	92
3/8 in.	25	99		100	82	82
No. 4	5	44	100	89	56	56
No. 8	3	7	88	57	34	34
No. 16	2	5	54	36	21	21
No. 30	2	4	34	24	14	14
No. 50	2	3	25	18	11	11
No. 100	2	3	17	15	8	8
No. 200	1.5	2	11.5	11.0	5.7	5.7
AC (%)						5.2

Reported Mix Properties at Optimum Asphalt Content

Gse	2.600
Gsb	2.550
Gmm	2.410
Gmb	2.314
VTM	4.0
VMA	14
VFA	71.3
DP	1.28
Pba	0.8%
Pbe	4.5%

Task 3a Control Samples

Control samples were made to the JMF gradation and asphalt content and compacted in the SGC to the N_{design} number of gyrations to determine baseline properties. Control samples were mixed at 325°F, oven aged for 2 hours at 300°F, and compacted immediately. At the same time, samples were prepared for Gmm testing (AASHTO T 209). The results are shown in Table 4.

Table 4 Laboratory Compacted Control Mix Properties

325 F Mix Temperature		
300 F 2-Hr Oven Aging		
300 F Compaction Temperature		
Mix	1	2
Gmm	2.454	2.402
Gmb	2.338	2.298
VTM (%)	4.7	4.3
VMA (%)	15.6	15.4
VFA (%)	69.8	71.9
Pba (%)	0.4	0.8
Pbe (%)	4.7	5
DP	0.7	1.15

Task 3b Equivalent Compaction Temperature

To determine the equivalent compaction temperature for mix 1, samples were prepared using each WMA additive. Additive rates were based on the supplier's recommendations. All binders were heated to 325°F. Aggregates were heated and mixed at 25°F above the selected compaction temperature; oven aged for two hours at the selected compaction temperature and compacted immediately after oven aging. Loose mix samples were prepared for Gmm testing (AASHTO T 209) using the same mixing and oven aging protocol. The results are shown in table 5. Figure 1 shows the selected equivalent compaction temperature for each additive.

Table 5 Mix 1 WMA Lab Molded Voids

Mixing Temp. (F)	Comp. Temp. (F)	Advera	Sasobit	Evotherm
		VTM (%)		
250	225	5.19	5.00	5.05
275	250	5.24	4.90	4.99
300	275	4.16	4.36	4.37

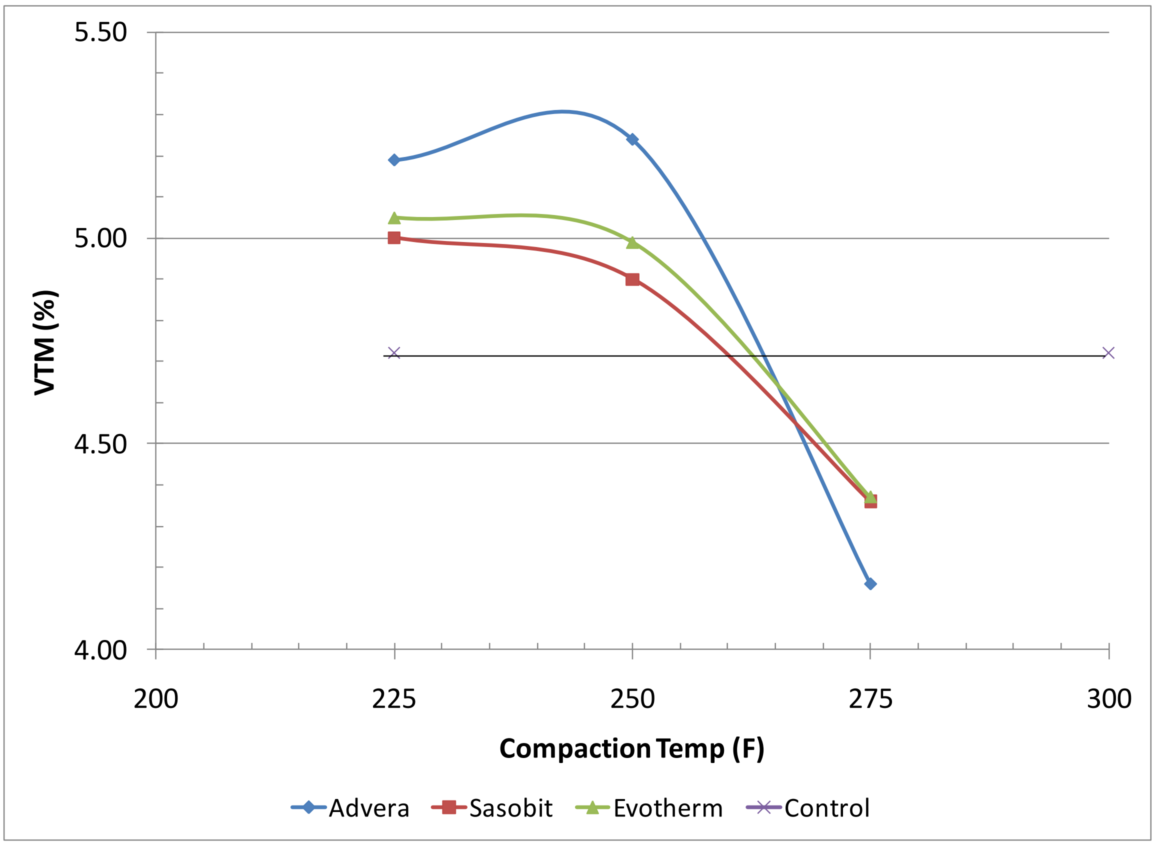

Figure 1 Mix 1 equivalent WMA compaction temperatures, based on VTM.

For Mix 2, a compaction temperature of 260°F was selected and verified by the procedures in sec. 8.3 of the proposed Appendix to AASHTO R 35 (3). All binders were heated to 325°F. Aggregates were heated and mixed at 25°F above the selected compaction temperature; oven aged for two hours at the selected compaction temperature and compacted immediately after oven aging. Loose mix samples were prepared for Gmm testing (AASHTO T 209) using the same mixing and oven aging protocol.

Task 4 Lab-Molded Voids, Task 5 Rut Depth Testing, Task 6 Moisture Sensitivity (AASHTO T 283)

Testing for tasks 4, 5 and 6 is complete. Tables 6-9 show the testing matrix for the laboratory mixed and compacted samples and for the simulated plant mix laboratory compacted samples. Data analysis is underway.

Table 6 Mix 1 Lab Molded (Mix Design) Test Matrix

	Mixing Temp.		Compaction	Oven-Age		Lab-Molded		
Mix	Asphalt	Aggregate	Temp.	Time	T 209 / L-26	Voids	T 283	Hamburg
Control Mix	325 F	325 F	300 F	2 hrs	3 samples	3 samples	1-set	4-pills
Sasobit	325 F	290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills
				2 hrs + 16			1-set	4-pills
				hrs @ 60C				
Advera	325 F	290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills
				2 hrs + 16			1-set	4-pills
				hrs @ 60C				
Evotherm	325 F	290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills
				2 hrs + 16			1-set	4-pills
				hrs @ 60C				

Table 7 Mix 2 Lab Molded (Mix Design) Test Matrix

	Mixing Temp.		Compaction	Oven-Age		Lab-Molded		
Mix	Asphalt	Aggregate	Temp.	Time	T 209 / L-26	Voids	T 283	Hamburg
Control Mix	325 F	325 F	300 F	2 hrs	3 samples	3 samples	1-set	4-pills
Sasobit	325 F	290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills
				2 hrs + 16			1-set	4-pills
				hrs @ 60C				
Advera	325 F	290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills
				2 hrs + 16			1-set	4-pills
				hrs @ 60C				
Evotherm	325 F	290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills
				2 hrs + 16			1-set	4-pills
				hrs @ 60C				

Table 8 Mix 1 Lab Molded (Field Simulated) Test Matrix

					Reheat below 100 F				Cool Overnight			
	Mixing Temp.		Compaction	Oven-Age	Lab-Molded				Lab-Molded			
Mix	Asphalt	Aggregate	Temp.	Time	T 209 / L-26	Voids	T 283	Hamburg	T 209 / L-26	Voids	T 283	Hamburg
Control Mix	325 F	325 F	300 F	2 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
Sasobit		290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				2 hrs + 16 hrs @ 60C	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
Advera		290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				2 hrs + 16 hrs @ 60C	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
Evotherm		290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				2 hrs + 16 hrs @ 60C	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills

Table 9 Mix 1 Lab Molded (Field Simulated) Test Matrix

					Reheat below 100 F				Cool Overnight			
	Mixing Temp.		Compaction	Oven-Age		Lab-Molded				Lab-Molded		
Mix	Asphalt	Aggregate	Temp.	Time	T 209 / L-26	Voids	T 283	Hamburg	T 209 / L-26	Voids	T 283	Hamburg
Control Mix	325 F	325 F	300 F	2 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
Sasobit		290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				2 hrs + 16 hrs @ 60C	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
Advera		290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				2 hrs + 16 hrs @ 60C	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
Evotherm		290 F	265 F	2 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				4 hrs	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills
				2 hrs + 16 hrs @ 60C	3 samples	3 samples	1-set	4-pills	3 samples	3 samples	1-set	4-pills

Work Planned for Year 3

Through a recent OTC grant, OSU was able to purchase a laboratory foaming device, *The Foamer*. The *Foamer* is designed and manufactured to provide a highly accurate and repeatable foamed asphalt sample that are use for Warm Mix Asphalt (WMA), cold mix asphalt and full depth reclamation (FDR) mix designs and performance testing in the Laboratory.

A one year extension was requested in FY 2011 to included laboratory evaluation of foamed WMA samples using the *Foamer*. The extension was approved for FY 2012. The Roberts-Arkhola mix was resampled and control properties will be restablished. The original Haskell-Lemon mix (mix 1) is no longer being produced. A foamed ODOT S-5 WMA mix from Haskell-Lemon's west plant was sampled in November 2011 to replace the original Mix 1. The work plan for year 3 is shown below. Task 1 is nearing completion and task 2 is complete.

Objectives

The objectives of this study are to evaluate laboratory produced foamed WMA and compare them to the QC/QA procedures developed from the SPR 2218 project and make recommended changes for foamed WMA if test results indicate.

Tasks

To meet the objectives of this study, the test plan from the SPR 2218 project will essentially be repeated, with slight modification. The following tasks will be accomplished.

Task 1 Literature Review: There is a wealth of literature on WMA technologies. The PI has participated in a recently completed a study on moisture damage and performance issues of WMA for the Oklahoma Transportation Center, which contains a literature review, and the SPR 2218 study. The literature review for this study will concentrate on laboratory foaming of WMA.

Task 2 Obtain Materials*:* Ideally, the same mixes from the SPR 2218 study would be used. However, materials change over time and one of the sources used in the Haskell-Lemon mix is no longer available. The Arkhola Roberts mix (Mix 2), used in the SPR 2218 study, was resampled. A second mix, an ODOT S-5 foamed mix from Haskell-Lemon's west plant, was selected to replace the original Mix 1. Cold feed belt samples of the aggregates were obtained, precluding the need for mix designs. Samples of the asphalt cement were obtained from these projects as well. A commercial laboratory will assist OSU with obtaining aggregates and asphalt cement.

Task 3 Determination of Mix Design Equivalent Laboratory Compaction Temperature: Control samples will be made to the JMF gradation and asphalt content for each mix. Samples will be compacted in the SGC to the N_{design} number of gyrations for the selected mixtures. Control samples will be mixed at 325°F, oven aged for 2 hours at 300°F, and compacted immediately. Loose mix samples will be prepared for Gmm testing (AASHTO T 209). A minimum of three replicates for each mix and aggregate will be evaluated. A complete voids analysis of the compacted samples will be performed including VTM, VMA, VFA, Pba, Pbe and DP. Sample preparation and testing will be performed by the commercial laboratory. Data analysis will be performed by the PI.

Next, samples will be prepared using foamed asphalt. Most foamed asphalt is produced by injecting 2% water, by mass of the binder. WMA mixes will be made using 2% water and 5% water. The mixing and compaction temperatures will be established using the *Draft Appendix to AASHTO R 35, Special Mixture Design Considerations and Methods for WMA*, proposed as a part of NCHRP 9-43 (3).

Once the mixing and compaction temperatures are established, three replicate samples will be mixed and compacted to the N_{design} number of gyrations in the SGC. Loose mix samples will be prepared for Gmm testing (AASHTO T 209). A complete voids analysis of the compacted samples will be performed including VTM, VMA, VFA, Pba, Pbe and DP. The data will be analyzed using ANOVA techniques and any additive showing different results from the control mix will be evaluated using the protocols recommended in SPR 2218.

Task 4 Lab-Molded Voids: One of the concerns with WMA samples is the effect reheating the samples might have on lab-molded void properties. To evaluate this, control samples will be mixed at 325°F and oven aged at 300°F. WMA samples will be mixed and oven aged at the temperatures determined in task 3. Samples will be allowed to cool as recommended in the proposed draft WMA specification. After cooling, the samples will be reheated to the appropriate compaction temperature determined in task 3 and compacted to the N_{design} number of gyrations. Loose mix samples will be prepared for Gmm testing (AASHTO T 209) using the same mixing and oven aging protocol. A minimum of three replicates for each mix and aggregate will be evaluated. Sample preparation and testing will be performed by the commercial laboratory.

A complete voids analysis of the compacted samples will be performed including VTM, VMA, VFA, Pba, Pbe and DP. The data will be analyzed using ANOVA techniques. If a significant difference is found, the samples will be evaluated using the SPR 2218 protocols. Data analysis and QC/QA testing protocol will be performed by the PI.

Task 5 Rut Depth Testing: Rut depth testing is a part of ODOT's mix design procedure and is being evaluated as a part of their QC/QA procedure (SPR 2226). Control and foamed WMA samples will be tested using the Hamburg Rut Tester (OHD L-55). Rut depths will be analyzed and if a significant difference exists between control mixes and foamed WMA, the protocols developed in SPR 2218 will be followed. A protocol for performing Hamburg testing of laboratory prepared foamed WMA mixtures will be developed. Sample preparation will be performed by the commercial laboratory. Hamburg rut testing and data analysis will be performed by OSU and the PI.

Task 6 Moisture Sensitivity (AASHTO T 283): AASHTO T 283 is a part of ODOT's mix design procedure. Control and foamed WMA samples will be tested using AASHTO T 283. OSU also has a MIST, Moisture Induced Stress Tester. The MIST is an alternative sample conditioning procedure, using a more realistic conditioning than a freeze cycle and vacuum saturation. In addition to AASHTO T 283, samples will be conditioned using the MIST. TSR's and tensile strengths will be analyzed and if a significant difference exists between control mixes and foamed WMA, the protocols developed in SPR 2218 will be followed. A protocol for performing moisture sensitivity testing of laboratory prepared foamed WMA mixtures will be developed. Sample preparation will be performed by the commercial laboratory. Testing and data analysis will be performed by OSU and the PI.

Task 7 Final Report A final report containing the findings and conclusions from the above tasks will be prepared. The report will contain the results from the analysis as well as a draft test method in AASHTO format, if applicable for foamed WMA additive, completing the SPR 2218 study. The final report will be the responsibility of the PI.

Time Schedule

The proposed work schedule, by work task, is shown in table 10.

Table 10 Proposed Year 3 Work Schedule

<table>
<tr><td></td><td colspan="12">Month</td></tr>
<tr><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr>
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</table>

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