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

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Introduction

The following report summarizes the work accomplished to date on a two-year 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 but now over 20 different technologies have been 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. Equivalent compaction temperatures and/or compactive efforts are those that would produce void results for WMA mixtures similar to conventional Superpave mixtures. Once this is established, 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) could be determined. If properties/results differ significantly from those obtained from the same conventional HMA mix, standard testing protocol(s) using the SGC would be developed that would provide test results consistent with conventional HMA test results. Test protocols could be dependent upon the specific WMA technology. Because the test protocols would 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 would 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 would 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 (3) 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 (4). 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 ranged from 270^{o}F to 220^{o}F (3).

Bonaquist (3) 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 for 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^{o}F	3.5	2.4	2.0	1.6
@240^{o}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 in Oklahoma but foam cannot be evaluated in the laboratory; however, two local contractors have agreed to supply foam mixtures and aggregates. Therefore, control mixtures were selected from these plants. 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 contains RAP. Production issues have arose with the mix requiring an anti-strip and a new mix will need to be identified and sampled. Approximately 1,000 pounds of aggregate, sampled off of the cold-feed belt, was obtained for the S-4 mix shown in Table 2. Using cold feed belt samples of the aggregates precludes the need for mix designs. Mix design properties are shown in Table 2 as well.

Approximately 50 gallons of OK PG 64-22 asphalt cement was obtained from Valero.

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

Table 2 Reported Mix Design, ODOT S-4 Insoluble Mix

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%

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 3.

Table 3 Laboratory Compacted Control Mix Properties

325 F Mix Temperature		
300 F 2-Hr Oven Aging		
300 F Compaction Temperature		
Gmm	2.454	
Gmb	2.338	
VTM (%)	4.7	
VMA (%)	15.6	
VFA (%)	69.8	
Pba (%)	0.4	
Pbe (%)	4.7	
DP	0.7	

Task 3b Equivalent Compaction Temperature

To determine the equivalent compaction temperature, samples were prepared using each WMA additive. Additive rates were based on the supplier's recommendations and are as follows:

- Sasobit,
- Advera,
- Evotherm M1,

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 4. Figure 1 shows the selected equivalent compaction temperature for each additive.

Table 4 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

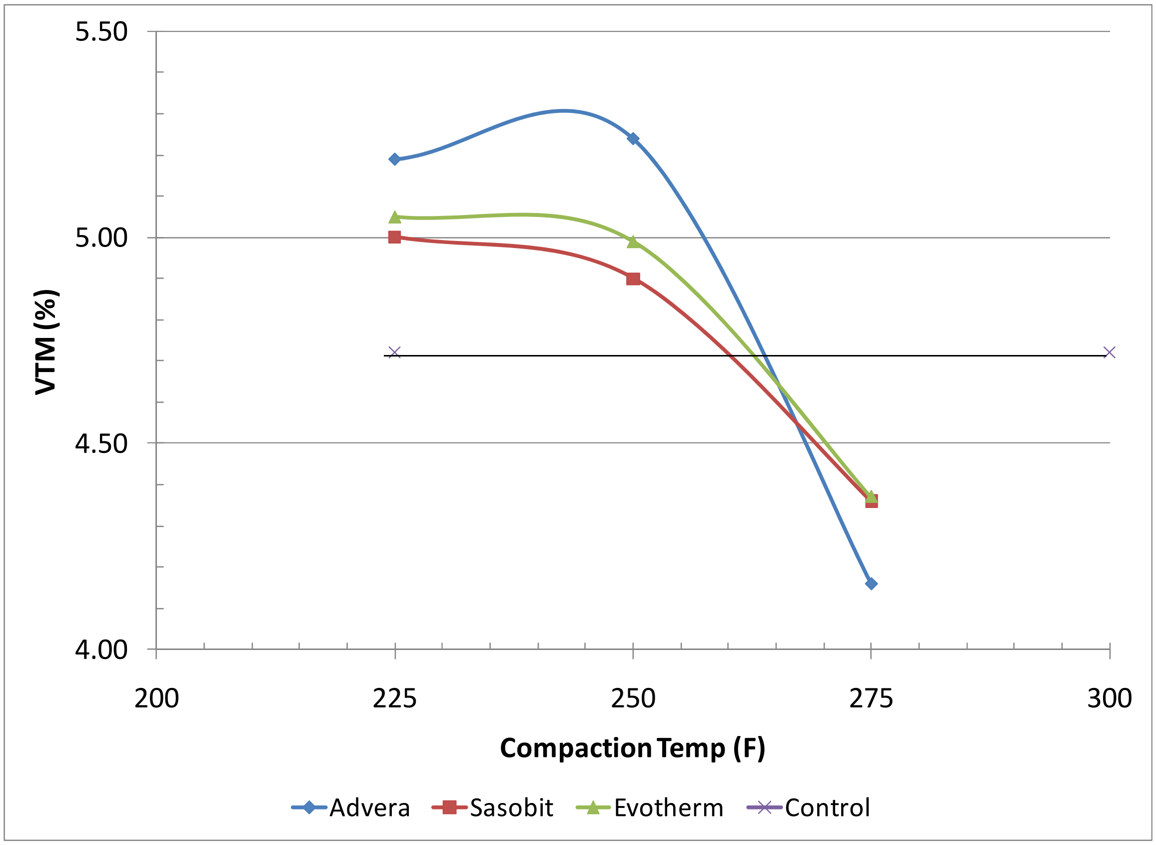

Figure 1 Equivalent WMA compaction temperatures based on VTM.

Task 4 Lab-Molded Voids:

This task is underway. A complete voids analysis of the compacted samples from Task 3b will be performed including VTM, VMA, VFA, Pba, Pbe and DP. The data will be analyzed using ANOVA techniques. Based on the results, a procedure for handling lab-molded samples for QC/QA testing will be recommended.

Task 5 Rut Depth Testing

This task is underway. Hamburg rut testing will be performed in accordance with OHD L-55. Rut depth testing will be completed in year two of this study.

Task 6 Moisture Sensitivity (AASHTO T 283)

AASHTO T 283 is a part of ODOT's mix design procedure. The proposed ODOT draft WMA specification recommends a 4-hour oven aging time rather than the 2-hour procedure used for HMA. The NCHRP study recommends a 2-hour cure (3). Samples will be compacted in year two to evaluate the effect of WMA additives on TSR testing.

Work Planned for Year 2

The following work is planned for the fall and winter months of year two:

- Sample a second S-4 mixture that requires an anti-strip from a producer that can produce foamed WMA,
- Determine control properties of the above mix,
- Determine equivalent compaction temperatures with the three laboratory WMA additives,
- Finish Hamburg rut testing of both mixes,
- Finish AASHTO T 283 testing.

The following work is planned for the spring of year two:

- **S**ample field produced foam WMA for both mixtures,
- Perform laboratory testing of field produced mix to evaluate equivalent compaction temperature for lab molded void properties,
- Perform Hamburg rut testing of field produced foam mixtures,
- Perform AASHTO T 283 on field produced foam mixtures,
- Evaluate effects of reheating field produced mix on mix properties.

Data analysis and the draft final report are scheduled for late summer of year two.

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