Asphalt Transport and Placement: Mixture Compactability

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Introduction

Warm mix asphalt (WMA) is defined by Bonaquist et al. [1] as asphalt concrete produced at temperatures approximately 50°F or more below temperatures typically used to produce hot mix asphalt (HMA). As of 2012, there were over twenty warm mix technologies in the US which could be classified into three general categories: chemical additives, wax additives, and foaming.

A 2011 project, funded by the Department of Homeland Security (DHS) through the Southeast Region Research Initiative (SERRI) at the Department of Energy's Oak Ridge National Laboratory [2,3], evaluated chemical and foam WMA technologies for potential use in disaster response. In this project mixture was produced by APAC-Mississippi Inc's Columbus, MS facility at HMA temperatures and placed at a variety of temperatures. Twelve test strips were placed on a parking lot at the APAC-Mississippi production facility. Figure 1 shows an aerial view of the parking lot at the conclusion of paving with test strips numbered 1 to 12. Strips 1 to 4 were *HMA*, strips 5 to 8 were *Foam*, and strips 9 to 12 were *Additive* (Evotherm 3G).

FIG. 1, Paved tests sections. [3]

This paper presents data and discussion of laboratory results from compactability testing, on the standard HMA binder and the chemically modified binder with Evotherm 3G chemistry, in accordance with AASHTO R35-12 [4].

Materials and Design

A PG67-22 from Ergon Asphalt & Emulsions Vicksburg, MS was used as the base binder for all mixtures evaluated. Evotherm 3G WMA additive, M-1, was supplied by Mead WestVaco (MWV) of Charleston, SC and used in some mixtures.

APAC Columbus, MS provided a 12.5 mm mix design currently approved for use by the Mississippi Department of Transportation (MDOT). Figure 2 provides the mix design information. Mixing and

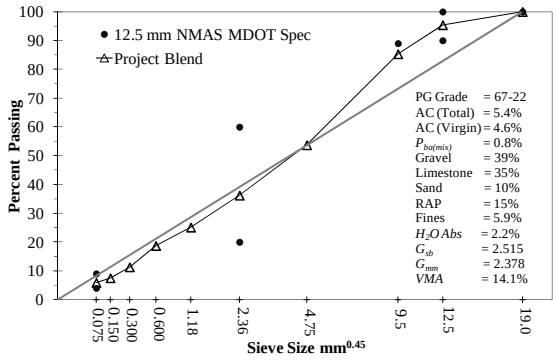

FIG. 2, Properties of asphalt mixture. [3]

compaction temperatures for the HMA were 320°F and 295°F respectively. In comparison, standard mixing and compaction temperatures for the Evotherm 3G WMA binders are in Table 1.

Table 1, Mixing and Compaction Temperatures for Evotherm

Mixing	
HMA	**M-1**
320°F	320°F
320°F	265°F
Compaction	
HMA	**M-1**
295°F	255°F

Based upon evaluation of the supplied materials and experience, Paragon Technical Services, Inc. (PTSI) and MWV recommend that 0.5% of the M-1 Evotherm 3G chemistry be used in the PG67-22 asphalt. The 0.5% M-1 Evotherm 3G loading is the equivalent of 0.42% M-1 based on the total asphalt. This additive amount allows for mixing and compaction temperatures previously presented.

The provided mix design gradations were used for sample batching. The materials were split on individual sieves to avoid segregation of the individual samples. The sieve screens used were as follows: ½", 3/8", No. 4, No. 8 and the Pan. Since the HMA design was already conducted and passed all requirements, a standard drop in design was conducted where the asphalt content was kept the same and properties evaluated with the new binder. The Evotherm 3G WMA chemistry was treated as an additive to the asphalt and accounted for in the liquid asphalt. A total asphalt content of 5.4% was required for the hot mix, of which 4.56% was added virgin asphalt. The virgin asphalt content of 4.56% was added to the Evotherm 3G WMA mixes, with different types of chemistry, all of which were based upon the asphalt content. Prepared samples were short term conditioned for a period of 2 hours at the compaction temperature before compaction.

Methodology

A product of National Highway Research Project 09-43, [1] was developing WMA criteria for AASHTO R35-12 (Appendix). Special mixture design considerations and practices to be used in conjunction with the standard practice for volumetric design of WMA are set forth in this appendix (X2) [4]. Section X2.8.3 refers specifically to "Compactability." Recommended compactability criterion is defined as a gyration ratio less than or equal to 1.25.

The procedure described in [4] for preparation and evaluation of gyratory specimens for compactability analysis calls for production of enough mixture to produce four gyratory specimens and perform one maximum specific gravity measurement using the appropriate WMA fabrication procedure described in Section X2.7 of [4]. Duplicate specimens are compacted at the design compaction temperature to N_{design} gyrations according to AASHTO T 312 on which the bulk specific gravity (G_{mb}) is determined in accordance with AASHTO T 166. This procedure is repeated on duplicate specimens prepared from mixture that has been allowed to cool 30°C (55°F) below the design compaction temperature. Corrected specimen relative densities are determined for each gyration using Equation (1):

$$\%Gmm_N = 100(G_{mb}h_d/G_{mm}h_N) \qquad (1)$$

Where:

$\%Gmm_N$ = relative density at N gyrations;
G_{mb} = bulk specific gravity of the specimen compacted to N_{design} gyrations;
h_d = height of the specimen after N_{design} gyrations, from the Superpave gyratory compactor, mm; and
h_N = height of the specimen after N gyrations, from the Superpave gyratory compactor, mm.

From this the number of gyrations needed to reach 92 percent relative density is determined at both the design compaction temperature and at 30°C (55°F) below the design compaction temperature. Using this data the gyration ratio is determined using Equation (2):

$$Ratio = (N_{92})_{T\text{-}30}/(N_{92})_T \qquad (2)$$

Where:

Ratio = gyration ratio;
$(N_{92})_{T\text{-}30}$ = gyrations needed to reach 92 percent relative density at 30°C below the design compaction temperature; and
$(N_{92})_T$ = gyrations needed to reach 92 percent relative density at the design compaction temperature.

Results and Discussion

An important note from [4] is that the compactability criterion limits the temperature sensitivity of WMA to that for typical HMA mixture based on limited research conducted in NCHRP 9-43. Therefore, the work described herein makes slight modifications in the recommendations of [4] with respect to number of specimens and test temperature.

Triplicate specimens were prepared for all testing conditions which consisted of HMA tested at the design compaction temperature and 55°F (30°C) below the design compaction temperature and WMA tested at the recommended WMA temperature of 255°F and at reduced temperatures in 15°F (10°C) intervals down to 195°F for a total of five WMA test

temperatures. Compaction ratios were calculated for the HMA in relationship to the design compaction temperature and for the WMA in relationship to the recommended WMA compaction temperature and the HMA design compaction temperature. In summary HMA was tested at two temperatures; 295°F and 240°F and WMA was tested at five temperatures; 255°F, 240°F, 225°F, 210°F and 195°F. Compacted mixture data for these materials and temperatures are presented in Table 3.

Table 3, Compacted Mixture Data

Compact Temp and Mix Type	Height at N_{design}	Weight in Air	SSD Weight	Weight in Water	Volume	Gmb	Height at 92%	Gyrations at 92%	Average
295°F									
HMA 1-1	122.0	4859.0	4865.1	2760.6	2104.5	2.309	128.8	17	
HMA 1-2	121.9	4927.3	4929.8	2817.2	2112.6	2.332	130.0	12	
HMA 1-3	121.7	4887.6	4891.3	2792.9	2098.4	2.329	129.6	13	
240°F									14.0
HMA 2-1	118.4	4749.7	4756.3	2704.9	2051.4	2.315	125.3	13	
HMA 2-2	119.4	4749.0	4756.0	2700.0	2056.0	2.310	126.1	17	
HMA 2-3	119.8	4751.0	4758.4	2686.3	2072.1	2.293	125.6	18	
255°F									16.0
WMA 1-1	122.2	4879.0	4884.2	2770.8	2113.4	2.309	128.9	16	
WMA 1-2	121.3	4847.4	4851.8	2758.6	2093.2	2.316	128.4	16	
WMA 1-3	120.6	4800.8	4804.5	2717.8	2086.7	2.301	126.8	17	
240°F									16.3
WMA 2-1	119.3	4783.8	4787.0	2723.9	2063.1	2.319	126.4	14	
WMA 2-2	119.7	4804.8	4808.3	2731.5	2076.8	2.314	126.6	13	
WMA 2-3	120.0	4777.4	4783.0	2710.6	2072.4	2.305	126.4	17	
225°F									14.7
WMA 3-1	119.1	4751.6	4755.3	2697.0	2058.3	2.309	125.7	16	
WMA 3-2	118.6	4749.1	4752.3	2695.5	2056.8	2.309	125.2	15	
WMA 3-3	119.5	4748.9	4753.1	2689.9	2063.2	2.302	125.7	18	
210°F									16.3
WMA 4-1	118.9	4749.3	4753.3	2698.7	2054.6	2.312	125.6	15	
WMA 4-2	119.6	4750.3	4756.4	2692.9	2063.5	2.302	125.8	17	
WMA 4-3	119.3	4751.0	4755.1	2692.4	2062.7	2.303	125.6	17	
195°F									16.3
WMA 5-1	120.1	4747.3	4755.2	2683.4	2071.8	2.291	125.8	20	
WMA 5-2	119.8	4748.8	4754.9	2683.5	2071.4	2.293	125.5	19	
WMA 5-3	120.1	4749.1	4755.5	2678.5	2077.0	2.287	125.5	19	
	Gmm = 2.378			Diameter = 150 mm					19.3

Equation (1) was solved for h_N, Equation (3), to yield the height of the specimen after N gyrations, from the Superpave gyratory compactor, mm, in this case the height of the specimen at 92% relative density.

$$h_N = (G_{mb}h_d)/(G_{mm}(\%Gmm_N/100) \qquad (3)$$

Column 8 of Table 3, "**Height at 92%**," presents the height data for each specimen. This data was compared to the compaction data of each specimen to determine the number of gyrations, N, required to achieve the calculated specimen height. Gyration data each specimen is presented in column 9, "**Gyrations at 92%**," of Table 3 with averages in column 10, "**Average**."

Using average gyration data from Table 3, compaction ratios were calculated using Equation (2). Compaction ratios included comparison of HMA at design and reduced temperatures as described by [1] and comparison of WMA at design and reduced temperature, and finally comparison of WMA to HMA. These data are presented in Table 4.

Table 4, Compaction Ratio

Mixture Type/ Compaction Temp °F	Average Gyrations at 92% Relative Density	Ratio	Ratio
		Hot/Hot	Hot/Hot
HMA/295	14.0	1.00	1.00
HMA/240	16.0	1.14	1.14
		Warm/Warm	Warm/Hot
WMA/255	16.3	1.00	1.16
WMA/240	14.7	0.90	1.05
WMA/225	16.3	1.00	1.16
WMA/210	16.3	1.00	1.16
WMA/195	19.3	1.18	1.38

From Table 4, in consideration of the criterion of [4], indications are that, with this binder, the HMA could be produced at reduced temperatures without the use of additives; this was affirmed by the work presented in [3]. It is assumed that this is possible due to the inherent lubricating character of the asphalt binder [5] and that if complete coating is achieved compaction temperatures may be reduced, the limit of which is determined by the asphalt binder source. Using the criterion of [4] the WMA compaction ratio data indicates that the WMA mixture may be compactable at temperatures as low as 50°F less than the WMA design compaction temperature of 255°F which is 90°F below the design HMA temperature. This has also been affirmed by the work presented in [3].

Conclusion

Reduced temperatures provide economical and environmentally conscious methods for production of both HMA and WMA. Adequate compaction is important to performance and longevity of asphalt pavements. The work in this study has evaluated applicability of the criterion established by NCHRP 9-43, presented in AASHTO R 35-12 to HMA and WMA production. While there is no single asphalt binder test to indicate minimum compaction temperatures for either HMA or WMA the mixture compaction ratio evaluated may be a valuable tool in determining minimum compaction temperatures for specific aggregate binder combinations.

References

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