Performance Measure of Warm Mix Asphalt with Three Organic Additives

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ABSTRACT: Warm mix asphalt (WMA) technology allows asphalt to flow at a lower temperature for mixing, placing and compaction. The advantages of WMA include reduced fuel consumption, less carbon dioxide emission, longer paving season, longer hauling distance, reduced oxidation of asphalt, early opening to traffic and a better working environment in the field. Recently, WMA mixtures with organic additives have been implemented rapidly in the U. S. However, there is no study done to compare organic WMA additives against HMA mixtures. In this study, WMA mixtures with organic additives of Cecabase RT®, Sasobit® and KW-1, along with the control hot mix asphalt (HMA) mixture, were evaluated with respect to their indirect tensile strength, dynamic modulus and flow number. Based on the limited test results, organic additives were found effective in producing WMA mixtures in the laboratory that is comparable to HMA mixtures.

KEY WORDS: Warm mix asphalt, organic additive, indirect tensile strength, dynamic modulus, flow number.

1 INTRODUCTION

Since 1901, hot mix asphalt (HMA) has been typically produced at around 160°C. It is not until 1997 when efforts to lower production temperature of HMA by between 25°C and 55°C were presented at the German Bitumen Forum, which was founded in 1996 to provide a focused and objective scientific approach to research on asphalt fume (Ruhl 2004). Since WMA is mixed and placed at a lower temperature, the amount of green house gas emission from the asphalt plant is reduced while conserving the energy. Due to the cooler temperature of WMA mixture, the working environment is better for construction workers with lesser amount of asphalt fumes. NAPA started an investigation of WMA technologies from Europe in 2002 leading to the first WMA public demonstration project in the U.S. in 2004 (NAPA 2007). In less than five years since the first demonstration project, WMA projects have been constructed in forty states (NAPA 2008). Particularly, WMA technology with organic additives has been implemented quickly because of easy application in the plant with minor modification. However, none of them evaluated WMA mixtures with organic WMA additives and compared them against the control HMA mixtures. In this paper, a comprehensive evaluation result of WMA mixtures with three organic additives is presented with regards to their fundamental engineering properties and performance-related characteristics such as air void, indirect tensile strength, dynamic modulus and flow number.

2 ORGANIC WMA ADDITIVES

Typically, organic WMA additives, that have melting points below a normal HMA production temperature, can be added to asphalt to reduce its viscosity. With organic additives, the viscosity of asphalt is reduced at the temperature above the melting point in order to produce asphalt mixtures at lower temperatures. Below the melting point, organic additives tend to increase the stiffness of asphalt (Anderson et al. 2008).

Three organic additives were selected to prepare WMA test specimens in the laboratory. As shown in Figure 1 (a), Cecabase RT®, which is liquid at room temperature, can be mixed into the asphalt (wet process) before the asphalt mix production. The liquid Cecabase RT® additive should be added to asphalt at an application rate of 0.2% to 0.5% by weight of asphalt. As shown in Figure 1 (b) Sasobit®, which is a Fischer-Tropsch wax produced from the coal gasification process, is typically added at the rate of 1.5% to 2.0% by weight of asphalt. Sasobit® additive can be added to the asphalt (wet process) or the asphalt mixture (dry process). As shown in Figure 1 (c), KW-1 is a wax-based composition, which includes crystal controller and artificial additives. KW-1 additive is typically added at the rate of 1.5% to 3.0% by weight of asphalt and it can be added to the asphalt mixture (dry process). It is being modified to improve resistance of both rutting and thermal cracking.

(a) Cecabase RT® (b) Sasobit® (c) KW-1

Figure 1: Three warm mix asphalt organic additives for evaluation

3 MIX DESIGN PARAMETERS

To produce consistent mixtures for laboratory testing, the identical mix design parameters and testing conditions were adopted for all WMA additives. Five stockpiles of aggregates (3/4" crushed, 3/8" chip, crushed limestone, manufactured sand, and natural sand) were blended to produce the SuperPave design gradation of nominal maximum aggregate size of 19.0mm. Following the Iowa DOT specification, the 86-gyration level was selected for the surface mix under a traffic volume of 3 Million ESAL with 5.5% of PG 64-34 asphalt (Iowa 2005). Following the manufacturers' recommendations, as summarized in Table 1, The WMA specimens were prepared by a wet process for Cecabse RT® (0.4% of AC) and Sasobit® (1.5% of AC) and by a dry process for Sasobit® (1.5% AC) and KW-1 (1.5% of AC).

Table 1: Mixing process and quantity of organic additives

Additive	Mixing Process	Dosage
Cecabase RT®	Wet	0.4% of asphalt weight
Sasobit®	Both Dry and Wet	1.5% of asphalt weight
KW-1	Dry	1.5% of asphalt weight

First, the aggregates were heated at temperature of 125°C for 6 hours and the PG 64-34 asphalt was heated at 149°C for 1.5 hours in the oven. To produce WMA mixtures by the dry process, the WMA additive was added to the heated aggregate and manually stirred in the bucket mixer and then asphalt was added. To produce WMA mixtures by the wet process, the WMA additive was added to the heated asphalt and then added to the heated aggregate. Second, the aggregates, asphalt and WMA additives were mixed for 60 seconds. Third, the WMA mixtures were heated at 125°C for 30 minutes in the oven. Finally, the WMA mixtures heated at 125°C were added into the gyratory mold preheated at 125°C and compacted for 86 gyrations.

To prepare a control HMA mixture, the aggregate was heated at temperature of 165°C for 6 hours and PG 64-34 asphalt was heated at 149°C for 1.5 hours in the oven. Next, the heated asphalt was added into the heated aggregates in the bucket mixer. Aggregates and asphalt were mixed for 60 seconds and the HMA mixtures were then heated at 135°C for 30 minutes in the oven. The HMA mixtures heated at 135°C were added into a gyratory mold preheated at 135°C and compacted for 86 gyrations.

4 LABORATORY TEST RESULTS

Basic characteristics of laboratory WMA specimens were measured: 1) mixing and compaction temperature; 2) bulk specific gravity; and 3) air void. To evaluate fundamental engineering properties and performance-related characteristics of laboratory WMA specimens, the following three laboratory tests were conducted: 1) indirect tensile strength test; 2) dynamic modulus test; and 3) repeated load test.

4.1 Mixing and Compaction Temperatures

The asphalt temperature was kept constant at 149˚C. The temperatures of mixing and compaction were measured throughout the sample preparation process for each specimen. Overall, WMA mixtures were produced at temperatures between 119˚C and 124˚C whereas the control HMA mixtures were prepared at around 150˚C. WMA mixtures were compacted at temperatures between 116˚C and 123˚C whereas the control HMA mixtures were compacted at temperatures between 133˚C and 134˚C.

4.2 Volumetric Characteristics

The theoretical maximum specific gravity was measured twice for each mixture using a CoreLok device and they ranged between 2.444 and 2.454. The bulk specific gravities of each specimen were also determined using CoreLok device. Given the compaction level of 86 gyrations, the average bulk specific gravities of WMA specimens ranged between 2.326 and 2.349 whereas the bulk specific gravity of control HMA specimens was 2.352. Consequently, the air void of WMA specimens ranged between 4.1% and 5.1% whereas the air void of the control HMA specimens was 4.2%. Overall, average air void of WMA specimens with

Cecabase RT® was the lowest followed by Sasobit® and KW-1.

4.3 Indirect Tensile Strength Test Result

Three test specimens for each WMA additive were prepared and cured in the oven at 25˚C for 2 hours before testing. Figure 2 shows the average indirect tensile strengths of three WMA mixtures, the control HMA mixture along with their standard deviations. As shown in Figure 2, the average indirect tensile strengths of WMA specimens ranged between 376kPa and 676kPa where WMA mixtures with KW-1 exhibited the highest strength followed by Sasobit® (wet process), Cecabase RT®, and Sasobit® (dry process).

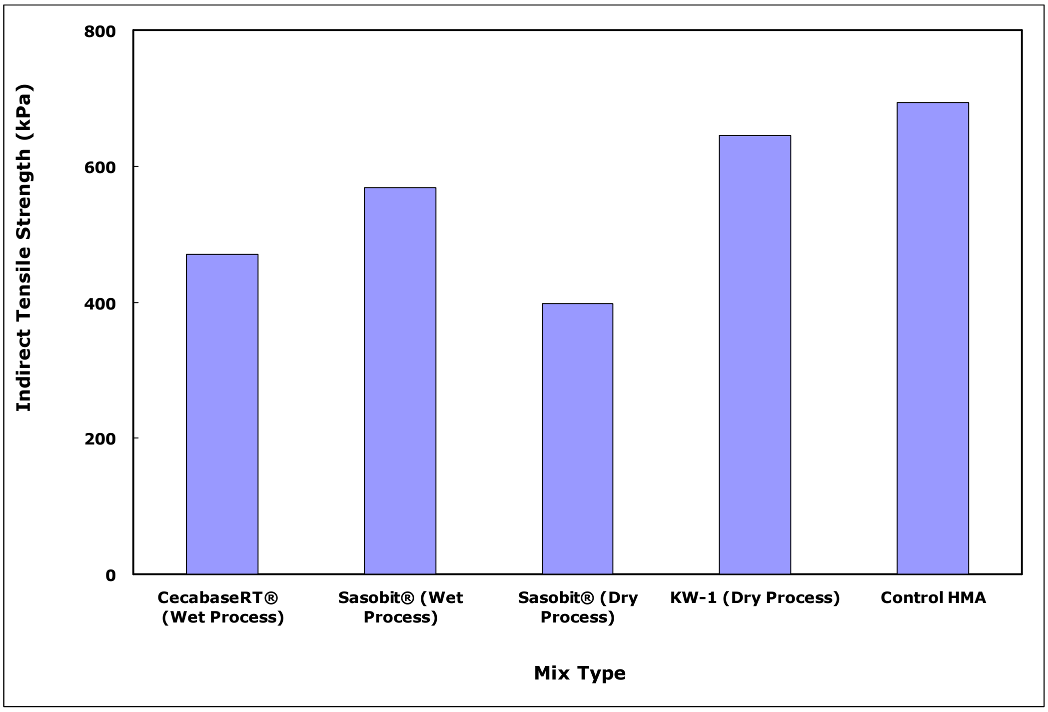

Figure 2: Average indirect tensile strengths of WMA and HMA mixtures

4.4 Dynamic Modulus Test Result

For each mixture type, two test specimens with 100-mm diameter and 150-mm height were prepared by gyratory compactor at 86 gyrations. The dynamic modulus test was performed at three different temperatures of 4.4°C, 21.1°C, and 37.8°C and six frequencies of 25Hz, 10Hz, 5Hz, 1Hz, 0.5Hz, and 0.1Hz.

By shifting dynamic modulus test results to a reference temperature of 21.1˚C, as shown in Figure 3, master curves were constructed for three WMA mixtures, the control WMA mixture and the control HMA mixture. Master curves of all WMA mixtures, except the one with LEADCAP-c, are quite similar to the control HMA mixture, which confirms that their viscoelastic responses are similar to that of HMA mixture.

4.5 Repeated Load Test Result

For each mixture type, two specimens with 100-mm diameter and 150-mm height were prepared by gyratory compactor at 86 gyrations. The uniaxial compression load without confinement was applied to obtain a loading stress level of 600kPa at 45˚C. The loading stress was applied in the form of a haversine curve with a loading time of 0.1 second with a rest period of 0.9 second in one cycle. The test was conducted up to 10,000 cycles or until reaching 5.0% cumulative stain.

Figure 4 shows plots of the cumulative strain values against the number of loading cycles for WMA mixtures with three organic additives, the control HMA mixture. It should be noted that the control HMA specimen and WMA specimens with Sasobit® passed the requirement of 10,000 cycles whereas WMA mixtures with Cecabase RT® and KW-1 did not.

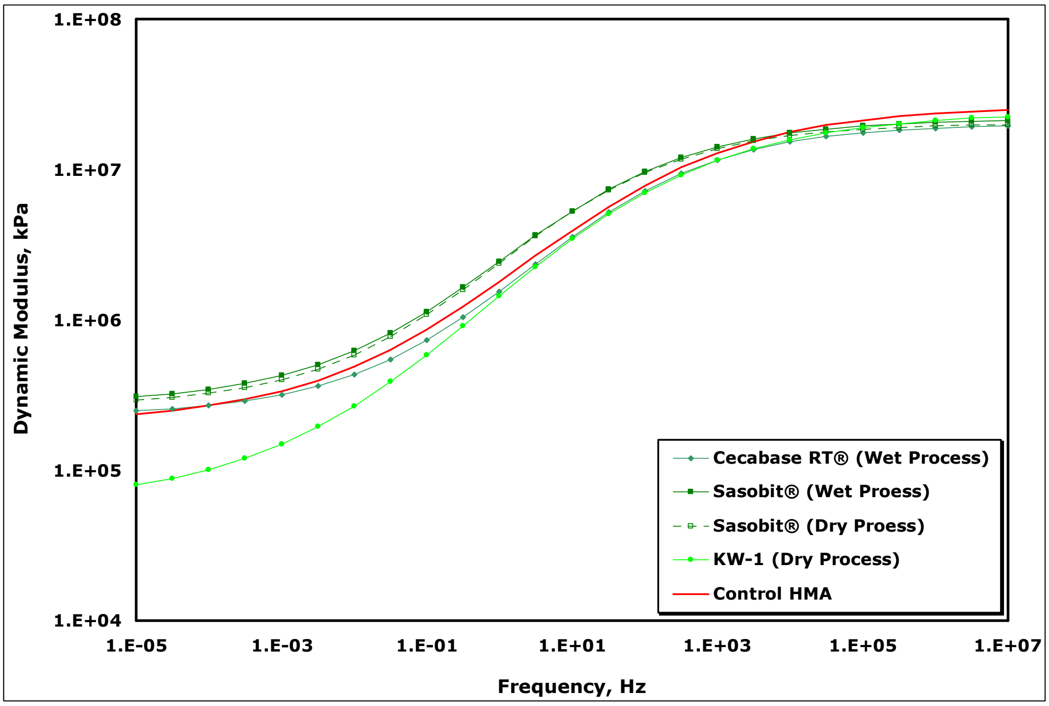

Figure 3: Mater curves of WMA and HMA mixtures

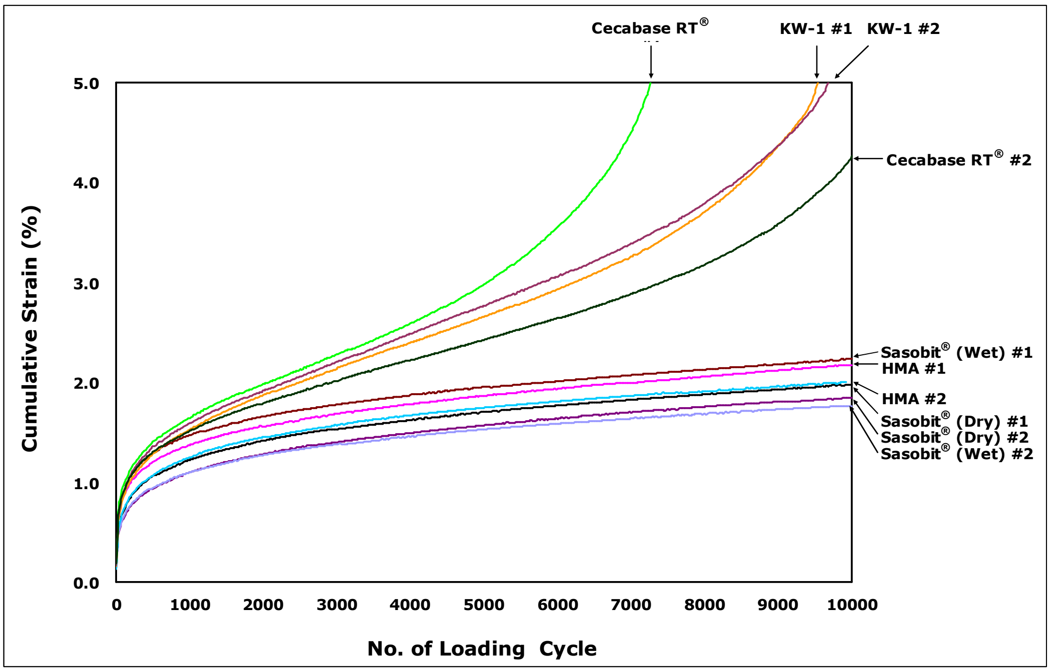

Figure 4: Plots of cumulative strain against loading cycle of WMA and HMA mixtures

5. SUMMARY AND CONCLUSIONS

The warm mix asphalt (WMA) mixtures with three organic additives of Cecabase RT®, Sasobit® and KW-1, and the control HMA mixture were evaluated for their fundamental characteristics such as indirect tensile strength, dynamic modulus and flow number.

Overall, the WMA mixtures exhibited similar air voids as HMA mixture which indicates these WMA additives are effective in compacting asphalt mixtures at a lower temperature. The indirect tensile strength of WMA mixtures with KW-1 exhibited the highest strength followed by Sasobit® (wet process), Cecabase RT®, and Sasobit® (dry process). Master curves of all WMA mixtures, except KW-1, were quite similar to the control HMA mixture, which confirms that their viscoelastic responses are similar to that of HMA mixture. Particularly, the WMA mixture with Sasobit® exhibited the least amount of cumulative strain followed by the control HMA mixtures, KW-1 and Cecabase RT®. Based on the limited test results, it can be concluded that organic additives are effective in producing WMA mixtures in the laboratory that is comparable to HMA mixture.

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