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RECOMMENDATIONS AND GUIDELINES FOR THE USE OF WMA MIXTURES

Zelalem Arega
Amit Bhasin

TxDOT Project 0-6591: Developing a Fundamental Understanding of the Chemistry of Warm Mix Additives

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Performing Organization:	**Sponsoring Organization:**
Center for Transportation Research The University of Texas at Austin 1616 Guadalupe, Suite 4.202 Austin, Texas 78701	Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080
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Center for Transportation Research
The University of Texas at Austin
1616 Guadalupe St, Suite 4.202
Austin, TX 78701

www.utexas.edu/research/ctr

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Research Supervisor: Amit Bhasin

Recommendations and Guidelines for the Use of WMA Mixtures

Conclusions and Recommendations

The main objective of this research study was to evaluate the influence of warm mix additives on the rheology and performance characteristics of asphalt binders with emphasis on the affects of long-term aging and use of recycled asphalt binder. In order to achieve this objective the asphalt binders were first screened based on their chemical makeup. The selected asphalt binders were combined with different WMA additives and evaluated for their mechanical properties. Subsets of these binders were also used to evaluate the affect of long-term aging and the affect of using recycled asphalt binder on performance characteristics. Tests were also conducted using a limited number of sand-asphalt mortars and full asphalt mixtures to further corroborate the findings from the binder study.

1.1 Conclusions

Some of the findings from this study are as follows.

Workability

- Viscosities of the un-aged binder modified using the warm mix additives were similar to, or in most cases, less than the viscosities of the control binders.

- Warm mix additives were very beneficial in reducing the viscosity of binders that were aged for twice the duration of conventional RTFO aging. This was particularly significant for binders with high natural wax content (these are typically binders with a high temperature grade of 70 or 76). These tests simulate a scenario where loose mix is stored in a heated silo for prolonged duration of time and/or transported over long distances.

Rutting resistance

- For three of the four binders modified using Sasobit, the $G^*/\sin\delta$ parameter was similar to the control. For 22 out of 24 combinations of binder and warm mix additives other than Sasobit that were tested, the $G^*/\sin\delta$ was reduced to 80% of the $G^*/\sin\delta$ for the control binder or less. Results based on the non-recoverable compliance using the multiple stress creep recovery test were also consistent with those based on the $G^*/\sin\delta$ parameter. These results were also consistent with the results based on the Hamburg wheel-tracking test (HWTT) conducted on full asphalt mixtures using some of the same binder-WMA additive pairs.

- Comparison with the control binders with reduced aging revealed that Sasobit compensated for the effect of reduced aging on early age stiffness and rutting resistance. However, certain other warm mix additives further aggravated the effect of reduced aging on early age stiffness and rutting resistance. In other words, for about half the binder-warm mix additive combinations, there was stiffness loss that was due to the presence of the additive itself. This was in addition to the stiffness loss that was due to reduced aging.

Stiffness and fatigue cracking resistance at intermediate temperatures

- Binders modified using the warm mix additive and long-term aged using the pressure aging vessel had similar or lower values of $G^*\sin\delta$ compared to their respective controls. It must be noted that this finding does not necessarily imply that the fatigue cracking resistance of warm mix binders is similar to or better than the control. This is in light of the recent research studies that have shown that the $G^*\sin\delta$ may not be an effective parameter to characterize binder fatigue.

- A subset of long-term aged binders was evaluated using a thin film fracture test. For 10 out of 16 combinations of binder and warm mix additives that were tested, the fracture energy was reduced to 80% of the fracture energy of the control binder or less. Tests on long-term aged asphalt mortar specimens using some of the same binder-WMA additive combinations also indicated that certain binder-WMA additives could reduce the fatigue cracking resistance of the asphalt composite. For example, presence of the WMA additives significantly affected the fatigue cracking resistance of asphalt mortars with the PG64-22 binder but there was no significant difference in the fatigue cracking life of asphalt mortars with the same WMA additives and the PG76-28 binder.

- The dynamic modulus of WMA mixtures was in most cases similar to or slightly less than that of a similar HMA. The difference in the dynamic modulus was more exaggerated at slower rates of loading (which can also be interpreted as higher temperatures).

Moisture-induced damage

- Based on the results from the HWTT, six out of eight mixtures with different binder-WMA additive combinations resulted in a reduced resistance to moisture-induced damage compared to the HMA control. This was also the case when the resistance to moisture-induced damage was quantified as the ratio of fatigue cracking life of moisture conditioned specimens to dry specimen in the mortar specimens.

Rate of aging

- Binders modified using the warm mix additive were RTFO aged (control at 163°C / 325°F and warm mix at 143°C / 289°F) and subsequently aged in an environmental room at 60°C / 140°F for a period of 132 days. Binder samples were analyzed and tested intermittently as they were being aged in the environmental room. Spectroscopic analysis of these binders indicated that the binders modified using the warm mix additive and RTFO aged at lower temperatures had significantly lower oxidative aging compared to the control initially. However, after 132 days, the extent of oxidative aging in the modified binders was not very different from that of the control.

Influence of recycled asphalt binder

- One of the questions related to the use of WMA is whether a combination of the RAP binder and WMA can help mitigate the risk of fatigue and thermal cracking after long-term aging. To this end, warm mix additives were combined with virgin binder and laboratory produced recycled binder. This blend, along with a control, was further subjected to RTFO and PAV aging and evaluated (control was RTFO aged at 163°C / 325°F and warm mix at 143°C / 289°F). Results indicate that based on the stiffness at 60 seconds and the "m" parameter, the low temperature cracking resistance of a combination of warm mix binders with recycled asphalt was in most cases similar to that of the control hot mix binder with recycled asphalt. These results are for the best-case scenario when the recycled binder has the same chemical makeup (other than extent of oxidation) and is fully blended with the virgin binder.

1.2 Recommendations

The following recommendations are made based on the findings from this study:

- Each binder-WMA additive pair must be treated as a modified binder that is likely to have performance related properties very different from the original binder.

- It is well recognized that the rutting resistance of WMA is relatively lower than the rutting resistance of a similar HMA. This is primarily attributed to reduced aging and addressed using RAP in the mixture. However, neither the cause nor the remedy is universally applicable. For example, findings from this study indicate that most WMA additives exacerbate the reduced rutting resistance that is due to reduced aging. Findings from this study also indicate that wax based additives such as Sasobit can compensate for the reduced rutting resistance with certain (but not all) binders. In such cases, it may not be necessary to use RAP.

- To the extent possible, a proposed job mix formula for a WMA must be evaluated for its fatigue cracking resistance (with the mix incorporating the additive) prior to being approved for construction. Results from this and other studies have shown that the fatigue cracking resistance of asphalt mixtures can be affected depending on the type of asphalt binder and WMA additive used. In addition, the use of a "mode independent" parameter to evaluate fatigue-cracking resistance must also be considered. Simply put, the findings from this study in combination from other studies indicates that depending on the mode of loading for a fatigue test (load versus displacement controlled) one can achieve different rankings for the same set of asphalt mixtures. For example, a displacement controlled mode of loading to evaluate the fatigue cracking resistance of asphalt mixtures is likely to reflect more number of load cycles to failure for a softer mix compared to a stiffer mix.

- In the context of using WMA in combination with RAP, in most cases the use of RAP with WMA does not offer any significant improvement in the resistance to low temperature cracking after long-term aging as compared to the use of RAP with a conventional HMA. Certain, WMA additives may present limited advantages but these must be evaluated on a case-by-case basis. To the extent possible, a WMA with RAP must be treated as a HMA with RAP. In light of the increasing trend in the use of WMA with RAP as green mixes, it is important the future studies further investigate the interaction of RAP binder with the virgin binder and its impact on fatigue and thermal cracking resistance.

Results indicate that most WMA mixtures tend to be relatively more moisture sensitive as compared to a similar HMA mixture. Increased moisture sensitivity compared to a control does not necessarily imply that a mixture cannot be used, because the moisture sensitivity of a WMA can still be within allowable limits. However, if a HMA is known to have moisture sensitivity issues then the use of a WMA based on the HMA design must be used with caution or avoided.