0-6613: Evaluate Binder and Mixture Aging for Warm Mix Asphalt

Background

Warm mix asphalt (WMA) technologies employ reduced mixing and placement temperatures, thereby allowing reduced fuel consumption, enhanced compaction, increased haul distances, and an extended paving season. However, there have been issues of concern in WMA including binder oxidation, binder absorption, and the impact of both of these issues on pavement durability.

What the Researchers Did

Researchers used a wide range of methods, both new and new to asphalt materials, for assessing warm mix binder, mixture properties, and field performance. Laboratory work included characterizing asphalt oxidation kinetics, binder absorption (with estimates of precision) as a function of time and temperature, and measurements of mixture fatigue/durability, all for several common warm mix technologies. Researchers developed guidelines for specifications, suitable for unmodified and modified binders, which incorporate binder oxidative aging and its impact on WMA pavement durability. The research team also measured binder absorption in field loose mix materials and characterization of field warm mix specimens for both mixture rheology and recovered binder oxidation and rheological hardening. Two field projects employed the use of multiple WMA technologies.

What They Found

Absorption

A key finding is that absorption is directly related to aggregate void fraction. Other absorption key findings are:

- There is an effect of binder grade (viscosity).
- WMA absorption is somewhat less than hot mix asphalt (HMA) absorption.
- The density gradient column provides a reliable and relatively easy measure of absorption for an aggregate/binder pair.
- Standard (ASTM) methods for measuring absorption can be problematic, depending on the level of absorption.

Oxidation Kinetics

Binders modified using warm mix technologies were found to have similar oxidation kinetics to their base binders.

Mixture Fatigue

The overlay tester and viscoelastic characterization (VEC) measurements were successfully used to characterize mixture fatigue. Other mixture fatigue key findings are:

- Mixture fatigue resistance declines with binder oxidation.
- The VEC modulus varies over 1.5 inches of pavement depth due to the difference between the aging rate at the surface and the aging rate 1.5 inches below the pavement surface. The magnitude of the difference depends largely on average annual daily solar radiation.

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Project Completed:
8-31-2013

- Unaged binder properties, together with binder oxidation kinetics and climate data (primarily solar radiation), can be used to estimate pavement durability (fatigue resistance).
- From overlay tester data, it can be shown that there is an aging function that relates the Paris' law exponent to aging, a result that is omitted entirely from typical pavement design guides (e.g., the *Mechanistic Empirical Pavement Design Guide*).

WMA Curing at Early Pavement Lives

During the first summer of WMA's service life, oxidative aging, curing, and absorption have a significant beneficial effect on the performance of warm mixes. In particular, at early times warm mixes are more susceptible to moisture damage than hot mixes.

What This Means

Two procedures are recommended for developing into a durability specification for both warm mix and conventional hot mix binders.

Procedure 1

One of these procedures requires characterizing the oxidation kinetics and hardening susceptibility of a specific binder along with the climate for the specific pavement of interest. The approach then uses this information in a pavement oxidation model and couples the result to mixture characteristics (response to binder oxidative hardening and traffic loading) to predict pavement durability (fatigue resistance, for example) over time. Moisture damage is not included directly in the approach, although adjustments can be made to model parameters that would indirectly account for both fatigue and moisture damage.

Procedure 2

The second procedure incorporates the same factors mentioned above but is less specific to each binder type and climate and has the advantage of also including moisture susceptibility. Such a specification procedure would use a table that specifies the maximum allowable dynamic shear rate function value, according to mixture type, climate zone, and pavement target fatigue life.

Future Work

Key future work should combine results from this project with other recent Texas Department of Transportation (TxDOT) projects to develop a comprehensive and fundamentals-based mixture design and pavement performance prediction methodology. This new methodology should account for climate, traffic loading, pavement structural properties, and life-cycle cost analysis, and should be applicable to HMA, WMA, polymer-modified binders, and mixtures that incorporate recycled asphalt pavement (RAP) and recycled asphalt shingles (RAS). Such an effort would be a major contribution to pavement design and is a realistic goal. This effort should include the following:

- Use the pavement durability prediction software developed in Project 0-6009, Evaluation of Binder Aging and Its Influence in Aging of Hot Mix Asphalt Concrete, to make predictions about WMA materials.
- Continue to collect refinery products over time and characterize them with respect to binder oxidation kinetics and rheology to build a more extensive database of materials that TxDOT has used, with the caveat that there can be considerable variability in products caused by varying crude sources over time.
- Validate models and performance prediction with additional field data.
- Develop a specification that addresses the use of RAP and RAS. This development should take into account the oxidation/hardening state of the RAP or RAS binder. Additionally, the effectiveness of the blending of the RAP or RAS with new material should be evaluated.

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Keyword: Research