0-6009: Evaluation of Binder Aging and Its Influence in Aging of Hot Mix Asphalt Concrete

Background

Asphalt binders oxidize in pavements, even well below the pavement surface. This oxidation is ongoing throughout the life of the pavement and leads to ever-increasing binder embrittlement and reduced pavement durability. Understanding how best to design pavement mixtures in a way that takes this binder oxidation and embrittlement into account is a very complex but important issue. Additionally, maintenance treatments are believed to extend pavement service life, and data have been needed to confirm and quantify improvements. This project provided information on these issues in an effort to achieve significant improvements to pavement durability with significant life-cycle cost savings to the Texas Department of Transportation (TxDOT).

What the Researchers Did

Researchers conducted an extensive laboratory, field, and pavement oxidation modeling program carefully designed to provide a fundamental understanding of binder oxidation in pavements and the impact of this oxidation on pavement durability. They developed a fatigue analysis software user interface that assists design engineers in comparing asphalt materials' oxidative hardening in pavements in a way that is specific to pavement location. They also addressed the seemingly intractable problem of developing an accelerated binder aging test and conducted mixture experiments to provide an improved understanding of the decline of mixture durability that occurs due to binder hardening.

What They Found

This project provided the capability of predicting changes to binder properties in pavements due to oxidative hardening and the impact of this oxidative hardening on mixture durability, which is important to long-term pavement performance. This effort resulted in many interrelated *research and development products*:

- Pavement binder oxidation model that includes:
    - An ***improved pavement temperature model*** that provides the temperature of the pavement as a function of time and depth, and specific to the climate and hourly weather of interest.
    - ***Binder oxidation kinetics parameters*** for fast-rate and constant-rate portions of the oxidation reactions for 24 binders used by TxDOT, including their characteristic changes in binder rheology in response to the oxidation.
    - An improved fundamental understanding of ***binder diffusion coefficients*** for both unmodified and polymer-modified binders.
    - A transport and computational ***model for predicting binder oxidation in pavements***

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as it evolves over time and as a function of depth below the pavement surface, a model that incorporates each of the above elements and can be applied to specific climate and hourly weather of interest.

- Mixture test and measurements that include:
  - A test device and ***method for testing prismatic specimens cut from pavement cores*** that are applicable to determining the rheological properties of at least 3-inch pavement lifts.
  - ***Measurements of binder oxidation in pavements***, over the course of the project and the impact of these changes on mixture properties.
  - ***Measurements of binder oxidation in laboratory mixtures*** and the impact of these changes on the laboratory mixture properties.
  - An ***evaluation of seal coat effectiveness***.
- A hot mix asphalt (HMA) mixture design approach using binder oxidation that includes:
  - An ***accelerated binder aging test*** for comparing binders with respect to their oxidative hardening durability.
  - Initial development of a ***mixture design and analysis system*** that incorporates binder oxidative aging in pavements and the accompanying increased stiffness of mixtures that results in a deterioration of mixture durability.
  - The development of an executable ***software user interface*** that incorporates the various elements described above in an HMA mix design component to provide insight into binder oxidative hardening and mixture durability in pavements.

What This Means

Researchers recommend the following implementation and future work activities:

- Implementation activities:
  - Introduce the software user interface to TxDOT engineers as a pavement mixture design tool through a workshop with TxDOT personnel conducted by project researchers.
  - Adopt the accelerated aging test as a means of comparing binders in their expected oxidation and hardening in pavements and on a climate-by-climate basis.
  - Implement a strategy for evaluating existing pavements by testing recovered binders for their oxidation and hardening kinetics parameters, and projecting future hardening and mixture durability changes for the purpose of optimizing maintenance resources.
- Future work:
  - Incorporate the pavement transport and thermal oxidation model into a new pavement design guide.
  - Continue to evaluate the effectiveness of maintenance treatments.
  - Continue to validate the pavement oxidation and hardening model with data from field pavements.
  - Improve fundamental understanding of oxidation kinetics chemistry and reaction kinetics, including both the fast-rate and constant-rate reactions and the correlations between their several parameters.
  - Improve fundamental understanding of the correlation between reaction kinetics parameters at 20 atm and determinations at 1 atm.

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