Project Summary

Texas Department of Transportation

0-4688: Development of a Long-Term Durability Specification for Modified Asphalt

Background

Polymer modification is used in asphalt concrete, primarily for control of permanent deformation early in a pavement's service life. By adding polymer to a conventional asphalt, the Superpave performance grade span can be increased by raising the upper grade without significantly affecting the lower grade. Polymer modification typically improves binder ductility. There is also evidence that polymer modifiers may improve the aging characteristics of a binder, leading to a more durable pavement.

While these characteristics benefit the durability of polymer-modified pavements, there is a need to quantify these improvements and their duration in the presence of oxidative aging. Such an improved understanding will lead to better modified binder selection, and to a better cost-benefit analysis, thereby leading to more efficient use of Texas highway construction dollars.

What the Researchers Did

This project evaluated polymer modified asphalt (PMA) durability including original binder characterization, pavement-aged binder characterization (in both Texas and Minnesota), and laboratory mixture characterization, for both modified and unmodified binders. The measurements were extensive, but necessary to provide a comprehensive view of PMA durability in pavements. Measurements included:

- original binder measurements such as rheology, composition, and changes to these properties with oxidative aging;
- laboratory-compacted mixture measurements and changes to properties due to oxidative aging; and
- pavement measurements of recovered binder properties and air voids levels.

What They Found

- Compositions of both modified and unmodified binders change with aging. Most of the modified binders showed a hardening rate that was less than that for the unmodified binder. This result suggests that the polymer degradation that occurs due to oxidation may serve to moderate the hardening that occurs due to base asphalt composition changes.

- Oxidative aging of asphalt materials causes an embrittlement, and thus a loss of ductility, of both unmodified and modified binders. Polymer modification in this project typically resulted in ductility improvements to the base binder, but oxidative aging degraded this improvement significantly over the life of the pavement. The primary cause of this degradation is base binder stiffening. A secondary cause is polymer degradation.

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- Asphalt materials and typical polymer modifiers self-fluoresce, thereby providing a mechanism for imaging black asphalt materials. Images showed an increase in the level of fluorescence with polymer modification but a decrease with oxidative aging. Apparent inhomogeneity (polymer-rich regions versus asphalt-rich regions) tends to become less distinctive with increased oxidative aging.
- A simple heat conduction model works surprisingly well for describing the temperature response of pavements to daily and annual thermal cycles. This temperature model, coupled with binder reaction kinetics parameters and rheological data, can be used to calculate the hardening of binders in pavements over time and well below the surface. The agreement to actual binder aging in pavements is surprisingly good and suggests that normal air voids in pavements are sufficient to oxidize binders almost as though there is no diffusion resistance, even well below the surface of the pavement. Low accessible air voids result in significantly slower rates of hardening of the binder, which can very significantly benefit pavement durability.
- Under strain-controlled conditions, mixture fatigue data showed that hot-mix asphalt concrete (HMAC) fatigue life declines significantly with oxidative aging. There can be widely different fatigue performance between different mixture designs and between different polymer modified binders. As a general observation — with all other mixture parameters such as gradation, asphalt content, aggregate type constant — softer asphalt binders produce better HMAC mixture performance in terms of fatigue resistance.

What This Means

Although this project identified some methods that will significantly improve pavement durability if implemented, other implementation issues were discovered that are not so easily controlled or determined. The project's final report (0-4688-1) lists these implementation issues.

Some methods and factors for improving pavement durability call for further research and development. High-priority efforts include:

- Determine parameters that govern the decline of mixture fatigue life with binder hardening.
- Develop a database of mixture design fatigue parameters and use these parameters in mix design optimization and selection.
- Determine high-reliability, low-risk methods to achieve very low accessible air voids.
- Develop a binder pavement-aging model that includes oxygen transport as a function of accessible air voids.
- Develop and implement major changes to the Mechanistic-Empirical Pavement Design Guide with respect to binder oxidative aging.

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