LOUISIANA TRANSPORTATION RESEARCH CENTER

Technical Summary

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Use of Innovative Recycling Agents for Improving the Sustainability and Durability of Asphalt Pavement

Introduction

The substitution of virgin asphalt binder with reclaimed asphalt pavement (RAP) has a number of environmental and economic benefits. However, cracking susceptibility arises due to the aged asphalt binder within RAP. The aged asphalt binder from RAP materials (subsequently referred to as RAP binder) generally cannot be used as a direct substitute for virgin asphalt binder because of its aging during service life and the resulting changes in its chemical composition and properties. The asphalt binder's chemical composition has a delicate balance of polar to non-polar molecules, small to large molecules, and aromatic to paraffinic compounds. Such an imbalance can originate from the aging of the asphalt binder.

RAP materials have been reused in new asphalt mixtures in Louisiana and across the country for decades, yet there are many concerns related to the cracking performance when a high RAP level (>25%) is used in asphalt mixtures. RAP binders include molecules with large molecular weights that raise issues with durability and cracking. Therefore, increased RAP contents in asphalt mixtures could negatively impact the cracking performance, which would raise the cost of pavement maintenance and repairs.

State Departments of Transportation and contractors are continually seeking effective ways to incorporate higher RAP content into asphalt mixtures without compromising pavement performance, particularly with respect to cracking. Various methods have been explored to rejuvenate aged RAP binders. Recent studies have evaluated the use of softer virgin binders, warm mix asphalt additives, and increased virgin binder content as potential solutions. The use of additives to restore the rheological properties of aged binders and enhance both short- and long-term performance is not a new concept. Since 2012, research has focused on identifying treatments that can break down asphaltene agglomerations in RAP binders.

Objective

The objectives of this study were to:

- Assess the effectiveness of using a reagent catalyst (Lewis acid type—$FeCl_3$) in improving the engineering performance of asphalt mixtures containing high RAP contents,;
- Develop a binder-blending tool for optimizing the dosages of RAs and increasing RBR up to 50%,; and
- Investigate the effectiveness of using innovative RAs (petroleum-based and bio-derived) to mitigate cracking susceptibility in asphalt mixtures containing 30% and 50% RAP.

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Scope & Methodology

Three 12.5 mm NMAS asphalt mixtures containing three levels of RAP were evaluated: 0%, 30%, and 50%. These RAP levels yielded RBRs of 0, 0.28, and 0.46, respectively. This study considered two approaches to mitigate concerns of hardened and oxidized aged RAP binders:

- **Approach 1: Reagent catalyst (Lewis acid type—$FeCl_3$) additive.** A total of four asphalt mixes were evaluated. Mix 1 was a control mixture (M76) that contained no RAP and SBS-modified PG 76-22. Mixes 2 and 3 were prepared with 30% RAP and PG 67-22 with and without $FeCl_3$ additive (M6730 and M6730F), respectively. Mix 4 contained 50%, PG 67-22 and $FeCl_3$ additive (M6750F).
- **Approach 2: Recycling agents (petroleum-derived aromatic oil, soy oil, and four types of tall-oil-derived phytosterol RAs).** A total of fourteen mixes were evaluated.

Two sets of laboratory experiments were conducted: (1) asphalt binder characterization and (2) asphalt mixture performance testing. The asphalt binder experiment included chemical characterization using Fourier Transform Infrared Spectroscopy (FTIR) and saturates / aromatics / resins / asphaltenes (SARA) analysis, as well as rheological evaluation using Superpave performance grading.

The asphalt mixture testing included a comprehensive suite of laboratory mechanical performance tests, including the dynamic modulus test for linear viscoelastic properties, Semi-circular Bend (SCB) test for intermediate temperature fracture resistance, Hamburg Wheel Tracking (HWT) test for rutting resistance, Moisture-induced Stress Tester conditioning method followed by HWT test for moisture susceptibility, Thermal Stress Restrained Specimen Test for low-temperature cracking resistance, and Cantabro abrasion test for assessing mixture durability.

A binder-blending tool was developed to optimize the required dosages of rejuvenating agents (RAs) in asphalt mixtures with high RAP content, based on the performance grades (PG) of the RAP binder, virgin asphalt binder, RAP content, and the target PG of the blended binder.

Conclusions

In general, rejuvenating agents (RAs) selected in this study effectively rejuvenated aged RAP binder and mitigated cracking concerns in asphalt mixtures with high RAP content. Based on the results, the following conclusions can be drawn:

- **Approach 1: Reagent catalyst (Lewis acid type—$FeCl_3$) additive.** The addition of $FeCl_3$ in the asphalt mixture containing 30% RAP (M6730F) enhanced cracking resistance as compared to the mixture without $FeCl_3$ (M6730). Further, the $FeCl_3$ additive reduced stiffness and abrasion loss without compromising the rutting or moisture damage resistance of asphalt mixtures containing high RAP content. As such, mixtures M76, M6730F, and M6750F complied with Louisiana's balanced mix design criteria. However, M6730 (30% RAP and no $FeCl_3$) did not meet the BMD criteria.
- **Approach 2: Recycling Agents.** The addition of RAs was effective in mitigating cracking susceptibility in asphalt mixtures containing 30% and 50% RAP, as measured by the SCB-J_c parameter, without compromising permanent deformation. As such, asphalt mixtures containing 30% and 50% RAP, and RAs at optimized dosages, complied with the Louisiana BMD criteria for both cracking and rutting resistance.
- A binder-blending tool for optimizing the RAs' dosages in asphalt mixtures containing high RAP contents was developed. Given the PG of RAP binder, RAP content, and target PG of the blended binder, the binder blending tool was able to estimate the PG of virgin binder and RA dosage.

Recommendations

- Conduct field performance trials to evaluate asphalt mixtures with high RAP content the and RAs that were evaluated in this project;
- Incorporate an assessment of the environmental impacts of asphalt mixtures containing high RAP content and RAs throughout their entire lifecycle, including the construction, use, and end-of-life phases; and
- Compare the cost-effectiveness of altering conventional asphalt mixtures with others containing high RAP content and the RAs utilized in this study by conducting a life-cycle cost analysis.