Transportation Consortium of South-Central States (Tran-SET)

Development of a Self-Healing and Rejuvenating Mechanisms for Asphalt Mixture Containing Recycled Asphalt Shingles

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Developing an innovative approach to address the aging of asphalt binders and to improve the performance of the mixture against cracking and rutting

The objective of this project is to test the hypothesis that hollow-fibers containing a rejuvenator product can improve both selfhealing, rejuvenation and mechanical properties of asphalt mixtures. The hollow-fibers containing a rejuvenator product will be synthesized via a wet-spinning procedure with a sodium-alginate polymer as the encapsulating material. The encapsulated rejuvenator product will be commercially-available synthetic oil. An optimization procedure will be performed by varying parameters such as the percentage of emulsifier, percentage of plasticizer, and ratio of rejuvenator to polymer used. The thermal stability and tensile strength of the developed fibers will be tested in a controlled laboratory environment to determine their resistance to asphalt production processes. The optimum fiber percentage will be assessed based on the performance of asphalt blends with different percentages of fibers (i.e., 1%, 3%, and 5%). Furthermore, the healing efficiency of asphalt mixtures containing fibers in two environmental conditions will be quantified by measuring the crack width before healing (day 0) and at different healing periods (i.e., day 2). Finally, a relationship between undamaged, damaged, and healed stiffness will be evaluated to determine the stiffness recovery at the end of the healing period.

Problem Statement

Recycled materials such as reclaimed asphalt pavements (RAP) and recycled asphalt shingles (RAS) have been incorporated into hot mix asphalt (HMA) to reduce virgin materials' consumption and to alleviate the environmental effects of paving operations. However, the aged binder in these recycled materials may affect the cracking performance of HMA prepared with RAS or RAP. Asphalt rejuvenators have emerged as a promising solution to address the issues related to the aged binder. This project presents an innovative approach to incorporate these rejuvenators products by encapsulating them in sodium-alginate hollow fibers. The sodium-alginate fibers are expected to enhance the cracking resistance of the mixtures; increase the service life of the pavement; and increase the use of recycled materials in asphalt pavements.

Summary

The study developed a procedure to produce sodium-alginate fibers containing a green biooil as the core material. An optimization process of the production parameters to enhance thermal stability and tensile strength of the fibers was performed. The rheological properties of the asphalt binder blends containing recycled materials and fibers were evaluated by performing a Performance Grading (PG Grading). The permanent deformation of the binder blends was characterized by performing a Multiple Stress Creep Recovery (MSCR) test.In addition, the complex modulus, G*, of the binder blends was evaluated by performing a frequency sweep test. Hot-mix Asphalt (HMA) mixtures were designed and evaluated to assess the reinforcement effect of the fibers in asphalt mixtures. The evaluated HMA mixtures were tested by performing laboratory tests in order to characterize their performance against distresses such as thermal cracking, fatigue cracking and permanent deformation.

Findings

Synthesis and Optimization of Production Parameters for Sodium-Alginate Fibers

The study developed a procedure to synthesize hollowfibers containing a rejuvenator product. The optimum production parameters were determined to be a rejuvenator to shell material of 1:1.5, an emulsifier content of 30% by weight of rejuvenator, and a plasticizer content of 40% by weight of rejuvenator based on TGA and tensile test results.

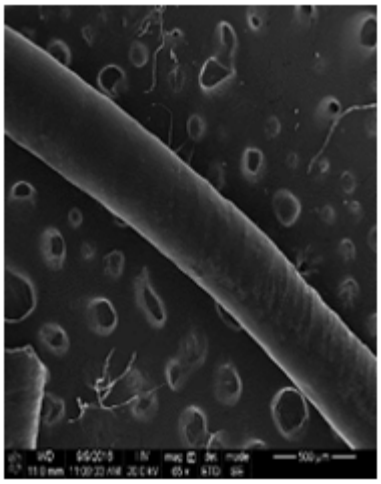

Figure 1. Scanning Electron Microscope of the developed Sodium-Alginate Fibers.

Evaluation of the Rheological Properties of Asphalt Binder Blends with Fibers

Performance Grading (PG Grading)

The Continuous PG grading results show that a decreased in both high-temperature grading and low-temperature grading was observed with the addition of the developed fibers. Therefore, less stiff binders at high-temperatures are obtained with the addition of fibers, with an improvement in the elasticity properties at low-temperatures.

Multiple Stress Creep Recovery (MSCR)

The permanent deformation of asphalt binder blends improved with the addition of recycled materials and fibers. This enhancement was confirmed in the increased in G* of binder blends at low-frequencies observed in the frequency sweep test.

Figure 2. Tensile strength test for the fibers.

Reinforcement of HMA Mixtures with Sodium-Alginate Fibers

Rutting Performance

The permanent deformation of asphalt mixtures was characterized by performing a Loaded Wheel Tracking (LWT) test. Based on the test results, the addition of recycled materials and fibers improved the permanent deformation resistance of HMA mixtures by lowering the rut depth from 3.82 mm (i.e.control mixture) to 2.49 mm.

Intermediate-Temperature Cracking

The negative effects of adding recycled materials in the intermediate fracture properties of the evaluated mixtures was reversed with the addition of fibers as the critical strain energy release rate increased from 0.45 kJ /m2 to 0.55 kJ /m2.

Low-Temperature Cracking

The thermal cracking resistance of the evaluated mixtures was improved with the addition of fibers as it showed to resist higher load at lower temperatures compared to the virgin asphalt mixture.

Impacts

In the proposed study, a new self-healing mechanism technology is being developed with a new class of rejuvenator products that may extend the service life of asphalt pavements. The addition of the proposed fibers will also enhance the use of recycled materials such as RAS resulting in more sustainable and low-cost pavements. The fibers will restore the properties of the aged binder through the release of the rejuvenator product in two different ways: (i) breaking when cracks initiate and (ii) self-degradation with time. This will improve the durability of asphalt pavements in Region 6 and will also address regional priorities by providing solutions to the deteriorating state of our existing and new road infrastructure.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

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