Enhancing the Durability and the Service Life of Asphalt Pavements through Innovative Light-Induced Self-Healing Material

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A novel self-healing asphalt technology is presented, using UV light-induced polymers to close and delay the propagation of microcrack

Age hardening of asphalt pavements, not only leads to the appearance of micro-cracks but also eventually leads to pavement failure. To address this problem, the concept of selfhealing is introduced as a solution to cracking of asphalt pavement. Self-healing properties are defined as the recovery of original asphalt properties, repairing the damaged area by closing the cracks, stopping crack propagation, and eventually enhancing the performance of asphalt pavement. In this study, a new generation of UV light-induced selfhealing polymers is evaluated to enhance the elastic recovery of the binder and increase the self-healing capabilities of asphalt mixtures at the same time. The propagation of microcracks, due to aging and excessive loading, causes the chemical breakage of polymer bonds, which in turn produces free radicals. The produced free radicals subsequently recombine through UV light exposure and thus close the micro-cracks.

Problem Statement

Utilization of recycled asphalt materials such as RAS and RAP in asphalt pavement is a costeffective approach to reduce the use of virgin material consumptions and negative environmental impacts associated with paving construction.Yet,the challenge that the industry is facing is the oxidation and brittleness of the recycled binder. Age hardening of the recycled binder can also reduce pavement durability and eventually lead to premature failure. Self-healing agents were recently proposed to enhance the self-healing capabilities of asphalt binder, delay crack propagation at early stages, and therefore extend the service life of the pavement.

An innovative smart self-healing agent, which is being evaluated in the present study, is Ultra-Violet (UV) activated self-healing polymer. This new class of polymer can enhance elastic recovery of the binder and to increase the self-repairing ability of the polymer. The appearance of micro-cracks because of aging and excessive loading would cause the chemical breakage of polymer bonds and consequently producing free radicals. The produced free radicals would recombine through UV light exposure and close the micro-cracks. Based on this mechanism, it is expected that the new self-healing polymer can be useful in reducing the cost of maintenance and repair of asphalt pavements.

Summary

Light-activated self-healing polymer (SHP) used in this study can self-repair upon exposure to UV light, through the remodeling of the damaged network. After production of the self-healing polymer in the material laboratory, they were characterized by comparing obtained Fourier Transform Infrared (FT-IR) spectra of self-healing polymer's components. Later, the thermal stability of self-healing polymer was examined using Thermogravimetric Analysis (TGA). To evaluate the effect of self-healing polymer on the performance of asphalt binder, three different percentage of self-healing polymer (1%, 3% and 5%) were added to two different binders; (an unmodified binder 67-22 and a polymer modified binder 70-22 M), with or without recycled asphalt materials (RAP/RAS). Different binder blends were prepared and tested using fundamental rheological tests such as rotational viscometer, the dynamic shear rheometer, bending beam rheometer and multiple stress creep recovery.

Findings

Fourier Transform Infrared (FT-IR) Spectroscopy

The reaction of OXE with CHI in the oxetane-substituted chitosan (OXE-CHI) and the reaction of OXE-CHI with HDI and PEG in OXE-CHI-PUR were confirmed using the FTIR spectra obtained for CHI and OXE-CHI, spectra obtained for OXE-CHI and OXE-CHI-PUR, respectively. The results demonstrated that self-healing polymer was produced in laboratory with the desired chemical structure (see Figure 1).

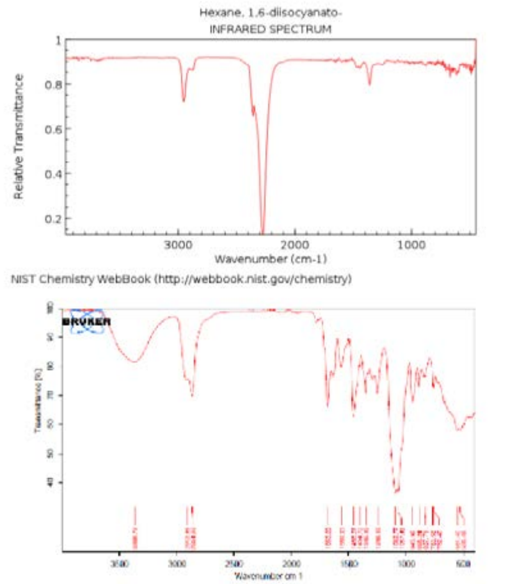

Figure 1. Wavenumber characteristics of the produced self-healing polymer.

Thermal Stability

Based on the result obtained from the Thermogravimetric Analysis of produced OXE-CHI-PUR cross-linked networks, the weight loss of sample was less than 10% in the first 200°C. Based on the result, it was concluded that produced self-healing polymer has the ability to resist high temperature of asphalt pavement mixing process (163°C).

Effect of Light-Activated Self-Healing Polymer on Rheological Properties of Asphalt Binder

Performance Grade (PG): The final performance grade result shows that the addition of recycled asphalt material (RAP/RAS) caused an increase in the high-temperature grade of the binder blend, which is an indication of a stiffer binder.Furthermore, changes in high-temperature grade and low-temperature grade caused by the addition of recycled asphalt material (RAP/RAS) and self-healing polymer were not significant enough to alter the low-temperature grade of the binder blends.The results from tests performed on binder blends exposed to UV light demonstrated an increase in the continuous high-temperature grade of the blends with increasing UV exposure.

Low temperature cracking performance of asphalt binders were evaluated using delta Tc, which can be defined as the difference between the critical stiffness temperature and critical relaxation temperature of binder blends. As a result of recycled asphalt material (RAP/RAS) addition, loss of relaxation of asphalt binders and increase in delta Tc was observed. However, the addition of self-healing polymer showed a decrease in delta Tc and therefore improvement in low temperature cracking performance. These values were further reduced with UV light exposure.

Multiple Stress Creep Recovery (MSCR): The percent recovery and the non-recoverable creep compliance (Jnr) of the samples were measured with MSCR, to evaluate the rutting susceptibility of the prepared binder blends at high temperature. These values were increased for 67-22 binder blends by increasing the percentage of self-healing polymers. However, these values were decreased for 70-22 M binder blends with the addition of SHP . Therefore, the addition of self-healing polymer to unmodified binder (67-22) containing recycled asphalt material showed an improvement in the rutting resistance of the binder blends.

Impacts

UV-light induced polymer has the potential to enhance the durability of asphalt pavement, and at the same time, delay crack propagation at the early stages of crack appearance. This technology can also be used to increase the allowable percentage of recycled materials application in asphalt pavement. This will support the construction of more durable asphalt pavements in Region 6 and will 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".

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