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

Use of Nanoclays as Alternatives of Polymers toward Improving Performance of Asphalt Binders

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PI: Dr. Zahid Hossain, Dr. Ashraf Elsayed (ASU)

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Evaluating the feasibility of nanoclays to enhance the performance of asphalt concrete

The main goal of this study is to assess the feasibility of the use of nanoclays as an alternative of commonly used polymers such as styrene-butadiene-styrene (SBS) or styrenebutadiene-rubber (SBR) to modify performance grade (PG) binders. To evaluate the effects of nanoclays on the mechanistic performance and rheological properties of the asphalt binders, PG 64-22 binders from two different sources are investigated in this project. Various percentages of three selected types of nanoclays (Cloisite 10A, Cloisite 11B, and Cloisite 15A) were selected to modify the neat binders. A blending protocol is being developed to mix the nanoclay with asphalt binder. The nanoclay modified asphalt binders were then tested using rotational viscosity, dynamic shear rheometer, atomic force microscopy, and chemical analysis. Rolling thin film oven and pressure aging vessel are being used to simulate short-term aging and long-term aging of the binders, respectively. Bending Beam Rheometer (BBR), Sessile Drop (SD), Texas Boiling test, Tensile Strength Ratio (TSR) and creep resistance at low temperatures will be performed to characterize the performance of the blended asphalt binders.

Problem Statement

Neat binders are usually modified by SBS and SBR to withstand increased load and extreme temperature events. The use of these polymers in modifying asphalt binders increases the overall cost of the binder. On the other hand, nanoclayis economical and naturally abundant. The use nanoclays instead of SBS or SBR will potentially reduce the cost of asphalt binders significantly.

Summary

Nanoclay is considered as an alternative of SBS and SBR to modify the asphalt binder. To evaluate the suitability of nanoclays, PG 64-22 binders from two crude sources and three types of nanoclay (Cloisite 10A, Cloisite 11B and Cloisite 15A) with different percentages (1%, 2% and 3%)were selected in this project. After differentials of temperature, time and rotational speed, a blending protocol was developed. Nanoclays were then blended with the unaged asphalt binders using a high shear mixer. The rotational viscosity test determined the viscosity of the neat asphalt binder. The dynamic shear rheometer test was used to quantify the viscous and elastic behavior of blended asphalt. In addition, an atomic force microscope (AFM) was used to evaluate the morphological and nanomechanical properties of the neat binder. SARA analysis was done for determining the percentages of certain families of chemical constituents.

Findings

After conducting a thorough literature review, unmodified PG 64-22 asphalt binders were collected from two different sources. One source was Ergon at Memphis and another source was Marathon at Catlessburg. Three different types of organic treated nanoclay named Cloisite 10A, Cloisite 11B and Cloisite 15A were collected from Southern Clay Products Inc. Based on the existing literature and manufacture? s recommendations, nanoclays at 1%, 2% and 3% by weight of asphalt were selected for blending with unaged asphalt binders.

Nanoclays were blended with the unaged asphalt binders using a high shear mixer (Figure 1). Nine different trials were conducted using different time (2h, 3h and 4h), rpm (1500 and 2000) and temperature (150 °C and 160 °C). Rotational Viscosity (RV) test, Dynamic Shear Rheometer (DSR) test and Atomic Force Microscope (AFM) tests were accomplished for every trial. From DSR test, complex shear modulus and phase angle were calculated and (G*/sinδ) versus temperature were plotted. From AFM test, the morphology, adhesion, DMT modulus and deformation values of the samples were observed and compared. From the output of these tests, a blending protocol (2h time, 2000 rpm and 150 °C temperature) was established to mix nanoclays with asphalt binders.

Figure 1. High Shear Mixer Used for Blending.

For evaluating the viscosity values, Brookfield Rotation Viscometer was used. The viscosity of the unmodified asphalt binders was determined according to AASHTO T 316. The test was done from 135°C to 180°C in 15°C interval. Complex shear modulus (G*) and phase angle (δ) were evaluated for unmodified asphalt binders and source one asphalt binders modified by three types of nanoclays of three different percentages. From the complex shear modulus (G*) and phase angle (δ), black diagram was plotted. Using the complex shear modulus (G*) and temperature, viscosity parameters A-VTS were evaluated and plotted (Figure 2).

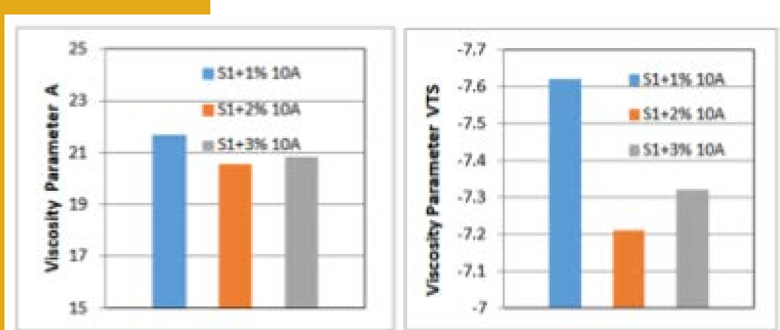

Figure 2. Viscosity Parameters A and VTS Calculated from DSR Values.

Morphological and nanomechanical properties such as DMT modulus, adhesion and deformation parameters were measured for unmodified asphalt binders (Figure 3). AFM test results are being analyzed by the research team. The SARA analysis was conducted for unmodified asphalt binders and source one binders modified by nanoclay Cloisite 10A. Results of SARA analysis are also being conducted by the research team.

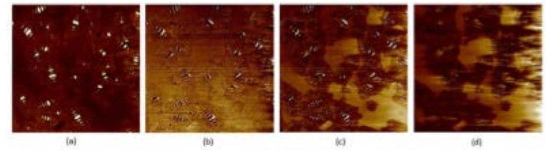

Figure 3. AFM Test Results of Unmodified PG 64-22 Binder from Source 1: (a) Surface Morphology, (b) DMT Modulus, (c) Adhesion, and (d) Deformation.

Impacts

This research is expected to lead the use of naturally occurring naoclays as alternatives of commonly used expensive polymers in enhancing the performance properties of asphalt binders. The cost of asphalt mixes will be reduced significantly. As a result, this will save taxpayers money. It will also help DOTs in the region to use eco-friendly and naturally abundant nanoclays in asphalt mixes that will be sustainable and preserve the environment. If implemented, the level of cost savings is expected to be hundreds of millions at the national level.

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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