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Nanoclay-modified asphalt materials: Preparation and characterization

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ABSTRACT

The objective of this study is to review existing literature in the area of nano-modification of asphalt and proceed to apply nano-materials to asphalt to improve the performance. This study integrates literature review, preparation, and characterization of nano-modified asphalt materials. In the experimental testing montmorillonite, nanoclay at 2% and 4% by weight of asphalt was blended in asphalt binder at a high temperature to exfoliate the nanoclay within the asphalt. The asphalt binder was then characterized using the Superpave™ rotational viscosity, dynamic shear modulus, and direct tension test. The rotational viscosity results indicate that the addition of the two types of nanoclay, Nanoclay A and Nanoclay B, increased the rotational viscosity by an average of 41% and 112%, respectively, across test temperatures 80, 100, 130, 135, 150 and 175 °C. It was found that the dynamic shear complex modulus (G^*) value increases significantly across a range of testing temperatures (from 13 to 70 °C) and loading frequencies (0.01–25 Hz). With 2% Nanoclay A reinforcement in the asphalt binder, the complex shear moduli generally increased by 66% while the 4% Nanoclay A reinforcement in the asphalt binder generally increased the shear complex moduli by 125%. The 2% and 4% Nanoclay B increased the shear complex moduli by 184% and 196%, respectively. In terms of direct tension strength, the use of Nanoclay A and Nanoclay B reduced the strain failure rate of the original binder while the secant or direct tension moduli showed increase with the addition of the nanoclays. In furtherance of this research, nanoclay-modified asphalt is being tested at percentages higher than 4% to underscore the fact that nanoclays may have the potential to reduce rutting and cracking.

1. Background and Introduction

1.1. Asphalt materials

In the United States, transportation infrastructure investments account for 7% of the Gross Domestic Product (GDP) according to the National Asphalt Pavement Association [1]. Over 550 million tons of hot-mix asphalt (HMA) is produced annually for construction projects. Increasing traffic loads and traffic volume, combined with the rising cost of asphalt, have led to an urgent need to improve the durability, safety and efficiency of asphalt pavements through asphalt modification.

Asphalt mixtures are composed of very irregular aggregates bound together with hydrocarbon-based asphalt, with a low volume fraction of voids dispersed within the matrix. Polymer-modified asphalts have increasingly been used over the last decade to minimize low-temperature cracking and high-temperature rutting while improving the fatigue cracking resistance of asphalt concrete [2,3]. Polymer modifiers fall into one of two major categories: (1) elastomeric (rubber/polymer) modifiers including styrene/butadiene polymers, natural rubber, and crumb rubbers (both virgin and recycled) [4–19] and (2) plastomeric modifiers such as polypropylene and polyethylene [20].

1.2. Nanotechnology and the current development in pavement materials

Nanotechnology is the creation of new materials, devices, and systems at the molecular level as phenomena associated with atomic and molecular interactions strongly influence macroscopic material properties [21]. Even though engineers are interested in material properties at the macro and meso scales, the nano and micro scales provide fundamental insight for the development of science and technology. Fig. 1 illustrates the evolution of length scales of an asphalt concrete material (in macro scale), to meso, micro [22], nano, and to quantum scales. Although improvements

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