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Investigating the Performance of Nano-Modified Asphalt Binders Incorporated with Warm Mix Additives

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Abstract: The current investigation presents a laboratory assessment of the physical and rheological properties of control and nanosilica-modified asphalt binders incorporated with warm mix additives (WMAs). Nanosilica can be produced from rice husk and silica fumes and therefore is a cost-effective and environment-friendly asphalt modifier. Fisher-Tropsch wax (FT wax) and organosilane additive were the two WMAs utilized in the current study. The study utilized three concentrations for each additive. Rutting evaluation of the asphalt binders was done through Superpave rutting and the multiple stress creep and recovery (MSCR) test. The fatigue performance was evaluated utilizing the Superpave fatigue test and the linear amplitude sweep (LAS) test. The results of this study revealed that adding WMAs decreased the viscosity of the control and nanosilica-modified asphalt binders. The asphalt binder showed an improved elevated temperature performance after the incorporation of WMA additives. The incorporation of WMA additives enhanced the resistance against fatigue cracking as revealed by the LAS test. The resistance to aging was enhanced after the addition of warm mix additives. **DOI: 10.1061/(ASCE)MT.1943-5533.0003943.** *© 2021 American Society of Civil Engineers.*

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Introduction

Exposure to arduous environmental conditions and varying kinds of axle loads affect the performance of pavements. Pavement engineers are faced with the challenge of designing pavements that are safe and durable. Diverse forms of modifiers are utilized to enhance and improve multiple characteristics of asphalt binders and, thereby, the asphalt pavements. Some of these materials include polymers, fibers, crumb rubber, sulfur, and different chemical agents (Behnood and Modiri Gharehveran 2019; Bhanuprasad et al. 2021; Isacsson and Xiaohu 1997; Oliviero Rossi et al. 2015; Palit et al. 2004; Lo Presti 2013; Yildirim 2007; Zhu et al. 2014). Polymers are extensively used for asphalt modification. Polymer modification of asphalt binders enhances high-, intermediate-, and low-temperature performance (Gama et al. 2016; Gordon 2002; Jahanbakhsh et al. 2017; Kim et al. 2019; Rahi et al. 2014; Saboo and Kumar 2016; Wang et al. 2017; Zhang et al. 2018; Zhou et al. 2019). However, asphalt binders modified with polymers suffer from oxidative aging and phase separation problems while being stored, which can affect their performance (Zhu et al. 2014).

As of late, the utilization of nanotechnology in various fields is gaining prominence. Carbon nanotubes, nanoclay, nanosilica, nanoalumina, and carbon fibers are a few of the nanomaterials used in asphalt modification (Castillo 2014; Li et al. 2017; Steyn 2011; Yang and Tighe 2013; You 2013). Multiple studies have shown that nano-modified asphalt binders exhibit improved performances (Ashish et al. 2017; Bhat and Mir 2020; de Melo et al. 2018; de Melo and Trichês 2016; Shu et al. 2017; Vargas et al. 2017; Wu et al. 2010; You et al. 2011). Using nanomaterials for asphalt modification purposes has been limited, owing to the high cost of nanomaterials. The raw materials, the equipment used, and the production techniques for the manufacturing of nanomaterials make them expensive additives. However, in the past few decades, the cost of nanomaterials has decreased significantly (Steyn 2009). Studies have shown it is possible to manufacture nanosilica from waste products such as rice husk and silica fumes (Ezzat et al. 2016; Hassan et al. 2014; Jafari and Allahverdi 2014; Phoohinkong and Kitthawee 2014; Yuvakkumar et al. 2014). Owing to the higher viscosities, nano-modified asphalt binder and mix preparation consume more energy at production, mixing, and compaction stages. Higher handling temperatures of nano-modified binders can be reduced by the incorporation of WMA additives. WMA modifiers reduce the viscosity of different unmodified and modified asphalt binders, thus lowering mixing and compaction temperatures (Biro et al. 2009; D'Angelo et al. 2008; Din and Mir 2021; Iwański et al. 2017; Kataware and Singh 2017, 2019; Kim et al. 2010, 2012; Mazumder et al. 2016; Oliveira et al. 2013; Wasiuddin et al. 1997; Ziari et al. 2018). The asphalt binders containing nanomaterials can also be expected to show similar behavior.

The performance of asphalt binders improves when nanomaterials and WMA additives are individually added to the asphalt binders. There is a need to study the synergized effect of nanomaterials and WMA additives on different properties of asphalt binders. Previous research has shown that the combined use of nanomaterials and WMA additives can improve the performance of the asphalt binder and mixes. Diab et al. (2013, 2014) found that the incorporation of nano hydrated lime and Advera improved the rutting resistance of the modified binders. A decrease in the nonrecoverable creep compliance and improvement in the recovery response of the asphalt binders was observed. Intermediate- and low-temperature properties did not show any significant improvement. However, the obtained results were within the specification limits. Zhu et al. (2019) evaluated the performance of hot mix asphalt modified with graphene oxide, Sasobit, and waste cooking

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