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Integration of nano Al_2O_3 and nano SiO_2 in asphalt mixes: A comprehensive performance and durability evaluation

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ABSTRACT

The current research work, examines efficacy of asphalt mixes prepared with varied proportions of nano SiO_2 and nano Al_2O_3. The study assessed the performance of modified asphalt mixes through Marshall stability, flow, indirect tensile strength, resilient modulus, Dynamic modulus, Flow number, and 4-Point bending tests. Elevated nanomaterial dosages notably enhanced high and intermediate temperature performance, nearly tripling rutting resistance, and augmenting fatigue resistance by approximately 130%. Elevated tensile strength ratios confirmed improved moisture resilience. The statistical analysis showed that nanomaterials had a significant influence on properties of asphalt mixes. Overall, diverse test approaches underscored the potential of nanomaterials in enhancing asphalt mix properties, promising durable and long-lasting pavements.

1. Introduction

The characteristics of asphalt binders influence the performance of asphalt mixes and, by extension, the durability and functionality of flexible pavements. The properties of asphalt binders play a critical role in influencing the performance characteristics of asphalt mixes across a spectrum of temperatures, encompassing high, intermediate, and low ranges. The failures associated with flexible pavements can be controlled to a large extent by implementing proper construction techniques and by using materials that have better performance in comparison with conventional materials. The high axle loads, increased number of vehicles on roads, and tire pressures have led to the early failure of pavements. which makes the use of conventional mixes unfeasible on these roads. This asks for the use of materials that can resist these distresses. Utilization of different modifiers is a prevalent approach in the pursuit of enhancing the characteristics of asphalt binders and thereby improving the characteristics of asphalt mixes. Various researchers have employed different modified asphalt binders to improve asphalt mixes' characteristics. The materials used as modifiers include polymers, Crumb rubber, nanomaterials, etc. These modifiers have successfully enhanced the permanent deformation characteristics, fatigue and low-temperature cracks, resistance to aging, and moisture-induced damage [1–3].

Nanomaterials have unique properties in terms of size, strain resistance, surface area, etc. They exhibit unique properties that are absent in their bulk counterparts, rendering the utilization of nanomaterials asphalt binder modification particularly attractive. Nanomaterials have shown considerable improvements when added to polymer modified asphalt binders, enhancing their storage stability and rheological properties [4,5]. Nanomaterials have a marked influence on the characteristics of asphalt binders at molecular levels. Consequently, nano-modified asphalt concrete exhibit higher resistance to permanent deformation, reduced fatigue cracking, higher aging resistance, lower moisture-induced damage and, improved compatibility between asphalt binder and aggregates. This results in development of durable and sustainable pavements [6,7].

Prior research has demonstrated that the utilization of nanomaterials enhances various performance properties of asphalt mixes. Findings of *Bach Le and Phuc Le* indicate that the addition of 0.1% of CNT enhanced the rutting and moisture resistance of asphalt mixes, the studied found

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