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Performance Testing of Asphalt Binder Modified with Amine-Impregnated Zeolite and Plastic in Hot Mix Asphalt to Reduce Carbon Footprint

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Project 2323
March 2025

Introduction

Global temperature is rising continuously, and carbon dioxide emissions are responsible for this climate challenge. Asphalt paving materials for roads and infrastructure require an extremely high temperature, contributing to carbon emissions. In addition, asphalt often uses lime or liquid amine as an additive to reduce moisture damage. Lime production is another contributor to a significant amount of carbon emissions. Another conventional antistripping agent called "liquid amines" loses long-term efficacy of pavement service life due to weathering and UV radiation. In order to prolong the efficacy of amines and keep infrastructure strong against moisture damage and sustainable, zeolite can be used as a protector. Another related global crisis is plastic pollution, and this study also addresses this. In this study, the performance of PG 64-16 Low Carbon asphalt binder made with 10% post-consumer plastic is compared to conventional PG 64-16 asphalt binder. In addition, we investigated the effect of amine-impregnated zeolite (AIMZ) on asphalt mixture performance and compared it with a commercial amine based liquid antistrip (LAS) and with amine and zeolite separately (AZ). This research offers insights on using and promoting sustainable transportation infrastructure.

Study Methods

Three types of Hot Mix Asphalt (HMA) samples were prepared with aging levels of 3 days, 5 days, and 7 days. These aging periods are designed to simulate approximately 4, 8, and 10 years of field aging, respectively, based on the weather conditions in Southern California. This approach follows the guidelines from NCHRP Research Report 973. A durability indicator called the Tensile Strength Ratio (TSR) was used to evaluate the resistance to moisture-induced damage. Other tests were used to measure a variety of important factors in asphalt usefulness under the regular wear and tear of tires and loads that impact asphalt roads. The Hamburg Wheel Tracking (HWT) test was used to measure how well the asphalt resists rutting (wheel path deformation), while the IDEAL Cracking Test was used to assess its resistance to cracking. The susceptibility to moisture induced damage of both binder types were investigated using the Moisture-Induced Shear-Thinning Index (MISTI). The Multiple-Stress Creep Recovery (MSCR) test was used to assess how each binder would perform under loads and how well each binder can recover from repeated stress.

Findings

The Results from the tests described above indicate a number of important insights about which binders promote durability and sustainability. For example, rut depths measured using HWT tests showed no significant difference between low-carbon and conventional binders or among different additives, with depths consistently less than 3.1 mm. However, the aging level significantly impacted rut depth, with lower depths observed in aged mixtures.

Wet tensile strength, which is measured after one cycle of freeze-thaw conditioning, increased with aging but was lower for mixtures with a low-carbon binder. AIMZ significantly improved wet tensile strength compared to LAS in both binder types, especially at 3 and 5 days of aging. Dry tensile strength also increased with aging but was lower for the low-carbon binder. No significant differences were found between additives for dry tensile strength.

Tensile Strength Ratio (TSR), which is an indicator for moisture resistance, increased with aging for AIMZ mixtures. In contrast, the TSR for LAS mixtures decreased with aging. TSR values for AIMZ were higher than those for AZ and LAS at 5 and 7 days. These results indicate that AIMZ can provide better protection against weathering effects and gradually release amines over the pavement service life. As a result, it can improve the moisture resistance of asphalt mixtures in the long run. The CTindex values, which indicate cracking resistance, decreased as the asphalt aged. However, the low-carbon binder mixtures had higher CTindex values at 5 and 7 days, showing that they performed better in resisting cracking compared to the mixtures with a conventional binder. MISTI values indicated lower moisture susceptibility for the low-carbon binder. MSCR tests showed better performance for low-carbon binders under low stress but poorer performance under high stress, suggesting its suitability for low-load conditions. Overall, AIMZ and low-carbon binders demonstrated potential environmental and performance benefits, promoting sustainability in asphalt pavements. These tests reveal important information when considering the effectiveness of asphalt binders for transportation infrastructure.

Policy Recommendations

Amine impregnated zeolite can be an effective antistrip in terms of the long-term performance of an asphalt mixture. Incorporating plastics in asphalt binders results in higher cracking and moisture resistance, but it is only suitable for low-traffic-volume roads. This information can help transportation professionals make informed decisions about infrastructure development and implementation.

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