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Enhancing Sustainability and Durability in Asphalt Pavements: Evaluating the Impact of Low-Carbon Sulfur Polymer Modifiers and Reclaimed Asphalt Pavement

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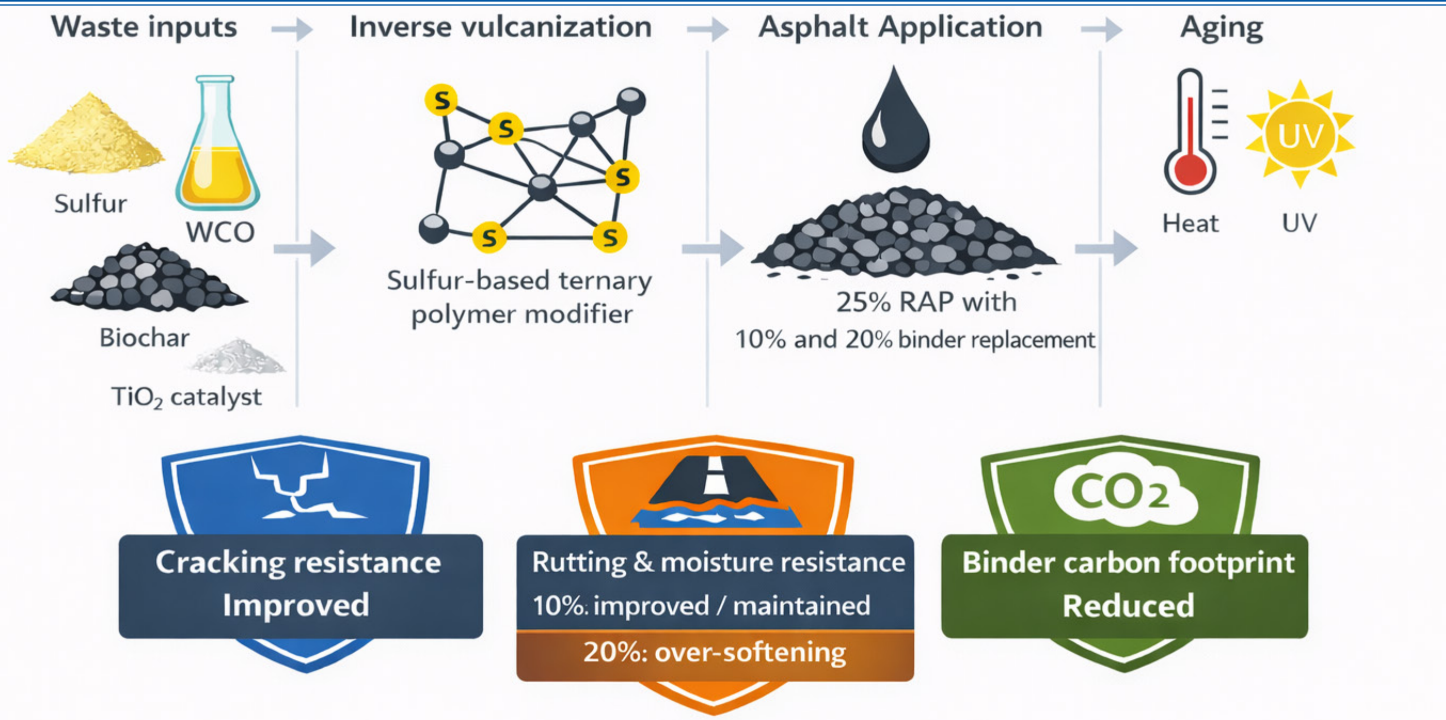

Introduction

Growing efforts in the asphalt industry are focused on minimizing asphalt's carbon footprint while extending the life of pavement through the introduction of a new generation of asphalt modifiers. This study evaluates asphalt mixtures containing low-carbon sulfur polymer modifier and reclaimed asphalt pavement (RAP) as a means to improving durability while reducing reliance on virgin materials. Low carbon sulfur-modified, RAP-rich mixtures were examined to understand if the modifier enhanced the strength properties of hot mix asphalt subjected to extended thermal and UV aging, conditions that simulate long-term real aging.

Study Methods

A control asphalt mix with 25% RAP was compared with mixtures modified using 10% and 20% sulfur polymer modifier by binder weight. The modifier system consisted of biochar, waste cooking oil, sulfur, and TiO2 formulated to enhance mixture properties. The mixtures were tested with oven long-term aging under 95° heat for 3, 5, and 7 days, following national guidance (NCHRP 973), and UV exposure. Performance was evaluated through the Indirect Tensile Cracking Test (IDEAL-CT) for cracking resistance and Hamburg Wheel Tracking (HWT) for rutting and moisture susceptibility. Data analysis covered comparison on CT index and rut depth across mixes and aging conditions. The team also performed a statistical analysis to verify the results.

Findings

Results show sulfur-modified RAP mixtures can better resist aging effects than the control mix. CT Index decreased with aging for all mixes, yet the 10%

sulfur mix consistently retained a higher CT Index, particularly under UV, indicating improved long-term cracking resistance. HWT results indicated lower rut depths for sulfur-modified mixes; the 10% sulfur dosage offered the best balance of cracking and rutting performance, while 20% showed diminishing returns in cracking. Overall, combining RAP with sulfur polymer and bio-based additives reduces virgin binder demand and offers potential life-cycle benefits alongside performance gains.

Sulfur-polymer-modified hot asphalt mixture with RAP improved cracking and rutting resistance, offering a practical path to longer-lasting, lower-carbon pavements.

Policy/Practice Recommendations

This study shows that sulfur-polymer-modified RAP mixtures can be a practical step toward more sustainable and longer-lasting pavements. Policymakers should encourage pilot projects using these mixes in place of conventional hot-mix asphalt. If the pilots perform as expected, the technology can be scaled into regular production. Updating specifications to allow sulfur-polymer additives will reduce reliance on virgin binder, lower greenhouse gas emissions, and extend pavement service life. This is an opportunity to move the industry toward materials that not only recycle more but also perform better, offering long-term cost savings and environmental benefits.

Summary of tests results by level of aging

	CT_{index}			HWT		
	CM	10%	20%	CM	10%	20%
Without Aging	125.1	158.6	128.4	-1.74	-1.26	N/A
3 Days	40.4	59.3	97.1	-1.36	-1.61	-1.16
5 Days	56.7	17.6	50	-0.8	-0.96	-1.25
7 Days	37.6	41.1	65.3	-1.36	-1.12	-1.08
UV	63.8	70.2	51	-1.42	-1.15	-2.27

N/A: Values for the 20%-WA mixture are not reported due to the observed significant rut depth after only 6,000 passes.

About the Authors

Mohammad Doroudgar earned his M.S. in Civil Engineering at California State University, Long Beach (CSULB); his work focuses on sustainable pavement materials and durability.

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Dr. Elham Fini is a Professor of civil engineering and an internationally recognized expert in sustainable asphalt materials, focusing on low-carbon binders, bio-based modifiers, and pavement durability.

To Learn More

For more details about the study, download the full report at https://transweb.sjsu.edu/research/2522

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