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RESEARCH ARTICLE

Evaluating the rheological, chemical and mechanical properties of hybrid asphalt binders and mixtures for enhanced performance

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Abstract
Waste materials in asphalt mixtures have garnered significant interest due to environmental concerns and the necessity for sustainable infrastructure. This study evaluated the performance of a waste material-based hybrid asphalt mixture, including palm oil fuel ash (POFA), garnet waste, and sawdust. Numerous physical tests were conducted to examine the hybrid asphalt mixture characteristics, such as penetration, softening point, and viscosity assessments. Rheological properties of the hybrid asphalt binders were analysed using a Dynamic Shear Rheometer (DSR), while microstructural characteristics were examined through scanning electron microscopy (SEM) and atomic force microscopy (AFM). A Marshall stability tests were then performed to evaluate the mechanical stability of the hybrid asphalt mixture under load-bearing conditions. Consequently, the hybrid asphalt mixture demonstrated favourable outcomes in improving the hot mix asphalt characteristics. These findings suggested that the hybrid contents (0% as control, 3%, 6%, and 9%) produced a significant performance impact on the hybrid asphalt mixture. DSR testing revealed that the 6% hybrid asphalt binder exhibited enhanced rutting resistance and elasticity, with higher complex modulus (G*) and lower phase angle (δ), indicating improved performance under high-temperature conditions. The 6% hybrid asphalt mixture demonstrated the highest stability, achieving a Marshall stability of 22.33 kN and showing enhanced resistance to aging, attributed to the binder's sensitivity to test temperatures. Additionally, SEM and AFM analyses revealed robust particle adhesion and interactions within the 6% hybrid asphalt mixture, indicating improved structural cohesion. This study effectively demonstrated that the waste materials (POFA, garnet waste, and sawdust) in the hybrid asphalt mixtures developed enhanced physical and mechanical characteristics.

Keywords Hybrid asphalt · Palm oil fuel ash · Garnet waste · Sawdust · Marshall stability · Rheology

1 Introduction

Asphalt pavements have been commonly employed in road construction due to their exceptional performance and durability. Nevertheless, the conventional manufacturing process of hot mix asphalt (HMA) depends on virgin aggregates and asphalt, contributing to environmental issues and depleting finite natural resources. Waste material incorporations into asphalt mixtures have revealed a growing interest in addressing these challenges and promoting sustainable infrastructure development in recent years [1–3]. These modifiers can enhance specific properties of the binder and mixture of the modified asphalt. Several studies have also explored different modifiers in asphalts, including industrial waste [4], agricultural waste [5], polymer-modified [6], waste cooking oil [7], and mineral fillers [8, 9].

This study evaluated the performance of a hybrid asphalt mixture utilising waste products as HMA modifiers, such as palm oil fuel ash (POFA), garnet waste, and sawdust. The POFA is a by-product produced in the agriculture industry. Similarly, garnet waste is generated in the blasting industry, while the widely accessible sawdust is made in the timber industry. These waste materials were selected to improve the HMA characteristics and mitigate the environmental consequences of traditional asphalt manufacturing processes.

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