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Editorial: Asphalt pavement performance under complex service conditions

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Editorial on the Research Topic
Asphalt pavement performance under complex service conditions

Asphalt pavements often deteriorate under complex service conditions, as evidenced by reduced mechanical integrity, weakened interfacial bonding, and the emergence of secondary damage. These issues can significantly escalate maintenance costs and undermine operational safety and efficiency. While recent technological advances have improved the durability of asphalt materials, the combined effects of moisture, temperature variations, and traffic loading continue to present substantial challenges to long-term performance. Therefore, the development of advanced testing and characterization methods tailored to these multifactorial service conditions is essential to uncovering failure mechanisms and extending the service life of asphalt pavements.

"Frontiers in Materials" is an internationally recognized, high-visibility journal dedicated to publishing rigorously peer-reviewed studies that cover a wide spectrum of Research Topic in materials science and engineering. The Research Topic "Asphalt Pavement Performance under Complex Service Conditions" highlights recent advances and emerging technologies related to asphalt pavements. Specifically, this Research Topic addresses the multiscale investigation of asphalt pavement materials, performance evaluation under complex service conditions, and maintenance materials and schemes.

1. Multiscale investigation of asphalt materials: As a typical multiphase composite material, asphalt materials exhibit scale-dependent mechanical properties. Integrating investigations on these materials across multiple scales can provide valuable insights and explanations into their failure mechanisms. At the microscopic scale, the physical, chemical, and mechanical properties of the asphalt binder are governed by interactions among molecules of varying polarity and size. The effects of Sasobit and Evotherm warm mix agents on Karamay 90# asphalt and Tahe 90# asphalt in Xinjiang were evaluated by using Fourier transform infrared (FTIR) and molecular dynamics simulations. The results showed that Sasobit has good compatibility with Karamay 90# asphalt, while Evotherm has a good modification effect on Tahe 90# asphalt (Hu et al.). Rheological and microscale chemical indicators were proposed to evaluate the extent of aging of polymer-modified asphalt binder, including the complex shear modulus $|G^*|$ at 52°C, the derivative of

creep compliance J' at −18°C, and the carbonyl index I_{CA} (Chen et al.). At the mesoscopic scale, the adhesive property between aggregates and bitumen directly affects the performance of the asphalt mixture. The surface roughness, chemical composition, and surface adhesion properties of limestone were better than those of diabase, which resulted in limestone fine aggregate showing better adhesion performance with bitumen than diabase fine aggregate. It was recommended that diabase coarse aggregate and limestone fine aggregate be used to improve the asphalt-aggregate interface (Zeng et al.). In addition, an innovative asphalt mixture design method based on the binder film thickness (BFT) was developed, which, compared with the conventional Marshall and Superpave methods, may achieve superior rutting resistance and balanced durability while reducing binder content (Khan et al.). At the macroscopic scale, a new method of mineral aggregate gradation optimization based on the fuzzy analytic hierarchy process and a comprehensive evaluation method was proposed to obtain the optimal gradation for road performance (Zhu et al.). Polyacrylamide (PAM) can significantly enhance the mechanical properties of cement-stabilized construction waste slurry under varying moisture contents. An optimal PAM content of approximately 0.5% improves unconfined compressive strength, elastic modulus, and shear strength, and provides valuable insights for waste slurry resource utilization (Guo et al.). Overall, by integrating microscopic, mesoscopic, and macroscopic investigations, multiscale research not only deepens the fundamental understanding of the physical, chemical, and mechanical behaviors of asphalt materials but also provides practical guidance for material modification and mixture design, thereby improving pavement performance and durability.

2. Performance evaluation under complex service conditions: The effective determination of the working stress and service performance of asphalt pavements under complex service conditions is fundamental to analyzing their failure mechanism. The incorporation of recycled concrete aggregate (RCA) and freeze-thaw cycles was found to have a significant impact on the fatigue performance of asphalt concrete, where increasing freeze-thaw cycles accelerate fatigue damage, while an appropriate amount of recycled aggregate content was observed to mitigate strength loss and enhance durability under coupled environmental and mechanical loading conditions (Yan et al.). Salt erosion markedly deteriorated the mechanical strength and drying shrinkage resistance of cement-stabilized macadam. As salt solution concentration increased, the cement-stabilized macadam transitioned from shrinkage to expansion, thereby causing arching distress (Wang et al.). Furthermore, the temperature-load coupling effect had a significant influence on the permanent deformation behavior of steel-concrete composite beam bridge deck pavement, in which thermal stress and repeated loading jointly accelerate rutting development, thereby compromising structural durability and service performance (Yang et al.). In summary, the coupled effects of environmental and mechanical factors exert a critical influence on asphalt pavement performance and should be thoroughly addressed in durability-oriented pavement design.
3. Maintenance materials and schemes: For maintenance materials, SBS/CR-modified asphalt binder with C9 petroleum resin exhibited superior rheological properties and 3D printability, which enhanced its adaptability as a crack-filling material by providing improved deformation resistance at high temperatures and flexibility at low temperatures (Niu et al.). Regarding intelligent maintenance, a pavement dynamic monitoring data processing approach based on wavelet decomposition and reconfiguration was proposed, which effectively filters noise and enhances feature extraction, thereby improving the accuracy and reliability of pavement condition evaluation (Shang et al.). Overall, advances in maintenance material development and intelligent monitoring technologies offer promising approaches to improving the effectiveness, reliability, and efficiency of asphalt pavement maintenance.

A total of eleven manuscripts were submitted for possible publication in this Research Topic. Each manuscript underwent a rigorous, fair, and anonymous peer-review process. The quality and originality of every study were thoroughly evaluated. Ultimately, all eleven research articles were accepted for publication.

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