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# Editorial: Recent advances in testing and modeling of performance-related mechanical properties of asphalt mixtures

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Editorial on the Research Topic
Recent advances in testing and modeling of performance-related mechanical properties of asphalt mixtures

The field of road engineering is constantly evolving, propelled by a commitment to create pavement infrastructure more resilient, sustainable, and cost-effective. One key area that has seen significant advancements in recent years is the testing and modeling of performance-related mechanical properties of asphalt mixtures. The innovations in this sphere have profound implications for the durability, safety, and efficiency of our roads and highways.

Asphalt mixture, as a staple material in road construction, has always been subjected to rigorous testing and modeling to enhance its performance. However, the traditional methods often fell short of accurately predicting the long-term behavior of asphalt mixtures under various loading and environmental conditions. Thankfully, recent advances in technology, computation, and material science have ushered in a new era of improved testing and modeling techniques. One such innovation is the advent of performance-based testing. Unlike the conventional empirical tests that emphasize material characterization, performance-based tests focus on the behavior of asphalt mixtures under real-world conditions. By replicating the loading and environmental effects, these tests offer a more accurate prediction of pavement performance and its lifespan. This advancement aids in the selection of more durable mix designs and allows engineers to resolve potential issues related to rutting, fatigue damage, and temperature shrinkage of asphalt pavement in a more efficient way.

The new testing methodologies are anticipated to stem from the development of the new-age computational models. They use the morphology and mechanics of mixtures and integrate them with complex mathematical relationships to simulate the behavior of asphalt mixtures at macro and micro levels. With the help of these models, engineers can now assess how different factors such as inner structure distribution, temperature, loading frequency, and aging affect the performance of the pavements. One such example is using the compressible packing model to simulate the compression behavior of asphalt mixture under traffic loading so as to optimize the aggregate gradation. Another is the application of complex mechanics and digital learning algorithms to predict the performance of asphalt mixtures. Large data sets gathered from experimental tests can be used to deliver highly accurate predictions on the performance of the mixture under various conditions. Moreover, the use of advanced material characterization techniques, including Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD), has provided deeper insights into the microstructure of asphalt mixtures. Understanding the microstructure is crucial as it significantly influences the performance properties of asphalt mixtures. This knowledge has enabled researchers to enhance the performance-related mechanical properties of asphalt from the perspective of microstructure. The future of mixture testing and modeling is exciting. Scientists and engineers are exploring the potential of nanotechnology in asphalt mixtures to improve their performance. With nano-sized particles, it is hoped that the mechanical properties of the asphalt can be tweaked to an unprecedented level of precision. Furthermore, the rise of digital twin technology, which creates a virtual replica of a physical model, could revolutionize how we test and predict the performance of asphalt mixtures. By marrying the physical and virtual worlds, engineers can run simulations to predict the performance of asphalt mixtures in real-world conditions with remarkable accuracy.

In conclusion, the recent advances in testing and modeling of performance-related mechanical properties of asphalt mixtures are a testament to the relentless pursuit of excellence in the field of civil engineering. These innovations are conducive to not only improving the quality of our roads and highways but also contributing to the creation of more sustainable, efficient, and resilient infrastructure for the future. It is a promising trajectory, one that will continue to reshape our infrastructure landscape in the years to come.

"Frontiers in Materials" is an esteemed international journal that publishes meticulously peer-reviewed research in the fields of materials science and engineering. This Research Topic, titled "*Recent advances in testing and modeling of performance-related mechanical properties of asphalt mixtures*" focuses on the recent developments in measuring and evaluating the mechanical properties of asphalt mixtures. Specifically, it delves into advanced design methods and computational models of asphalt mixtures, advanced asphalt pavement additives and their reinforcements.

1) Advanced design methods and computational models of asphalt mixtures: The advanced asphalt mixture design based on the compressible packing model was proposed by Muhadeer et al. with promising prospects for practical application. The influence of the modified compressible model on pavement performance was investigated by selecting different matrix compaction indexes (η) and compaction indexes (K). Comparative analysis of design methods based on a 4% air void and minimum voids in mineral aggregate was conducted, considering volumetric parameters and pavement performance according to the modified compressible packing model. The performance of asphalt mixtures with three gradations was also evaluated. Test results demonstrated that decreasing the matrix compaction index (η) led to an increase in the optimum asphalt content for both methods, while the VMA decreased.
2) Advanced asphalt pavement additives and their reinforcements: The modification mechanism of modified ground calcium carbonate (GCC) mineral powder was investigated that was incorporated into the asphalt concrete (Zhang and Yan). Two types of Titanate coupling agents, TCA-K38S and TCA-201, as well as sodium stearate coupling agents, were used to modify GCC. Two selected modified GCC samples were then used in the preparation of asphalt concrete, and their performance was analyzed at both macro and micro levels. Results showed that the TCA-201 and sodium stearate exhibited better coating properties compared to TCA-K38S. The contact angles of TCA-201 and sodium stearate-modified GCC were larger than that of TCA-K38S modified GCC. The in-service performance of AC-13C asphalt concrete modified with sodium stearate was found to be superior to that of TCA-201 modified AC-13C asphalt concrete. Basalt fiber can be used as an addictive in the asphalt mixture to improve the engineering properties of asphalt pavement and prolong the service life of the road. The effects of fiber content, filler-asphalt ratio, and asphalt viscosity on the properties of fiber asphalt mastic were investigated by orthogonal experiments to quantify the reinforcement effect of basalt fiber on asphalt mastic (Shi et al.). The results showed that FBF was the most effective fiber in improving the high-temperature rheological properties and low-temperature tensile properties of asphalt mastic when compared to other fibers. FBF asphalt mastic significantly improved the asphalt rutting factor by more than four times, while the tensile fracture energy of fiber asphalt mastic was over three times higher than that of regular asphalt. However, BBF had poor reinforcement effects and it was recommended to be broken up before use. Besides, efficient demulsification is vital for the application of emulsified asphalt in road construction. The effects of the main chemical components of the aggregates ($CaCO_3$, MgO, $Fe_2O_3$, $SiO_2$, $Al_2O_3$) on the demulsification process of emulsified asphalt were studied by experiments and simulations using a Gompertz model (Tan et al.). The study findings suggested that the demulsification speed of emulsified asphalt is primarily influenced by the surface energy, specific surface area, and pH of the chemical components present in the aggregates. It was also observed that selecting specific chemical components for the aggregates can significantly accelerate the demulsification speed. For instance, the addition of $Al_2O_3$ to anionic (SDBS) emulsified asphalt and MgO to cationic (STAC) emulsified asphalt resulted in a remarkable acceleration effect, with both reaching up to 60%.
3) Advanced temperature-based performance characterization: The temperature shrinkage of materials primarily causes transverse cracking. The research work focused on analyzing the impact of structural combinations on temperature shrinkage (Jiangcai et al.). The temperature rise method was discussed as an alternative to the traditional temperature drop method in measuring the shrinkage coefficient. The findings revealed that there was a relatively small difference between the shrinkage coefficients obtained through the temperature rise and drop methods. Consequently, the temperature rise method can be effectively employed for measuring the temperature shrinkage coefficient. Furthermore, it was observed

that lime-fly ash-stabilized macadam with suspended dense gradation or higher lime-fly ash content exhibited the highest temperature shrinkage strain. In the case of asphalt mixtures, the temperature shrinkage strain increased as the nominal maximum aggregate size decreased. Therefore, it was recommended to prioritize controlling temperature shrinkage in asphalt mixtures with larger nominal maximum aggregate sizes.

Five manuscripts were invited and received for potential publication in the Research Topic. Each manuscript underwent a rigorous, fair, and anonymous review process, where careful examination was conducted to assess the quality and originality of the papers. Ultimately, all five research articles were approved and accepted for publication.

## Author contributions

YZ: Conceptualization, Writing–original draft. DZ: Conceptualization, Writing–review and editing.

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## Conflict of interest

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