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Microstructure of Virgin and Aged Asphalts by Small-Angle X-Ray Scattering

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Abstract : The study of the microstructure of asphalt is of great importance for the analysis of its macroscopic properties. However, the peculiarities of the chemical composition of the asphalt itself and the limitations of existing direct imaging techniques have caused researchers to face many obstacles in studying the microstructure of asphalt. The advantage of small-angle X-ray scattering (SAXS) is that it allows quantitative determination of the internal structure of opaque materials and is suitable for analyzing the microstructure of materials. Therefore, the SAXS technique was used to study the evolution of microstructures on the nanoscale during asphalt aging. And the reasons for the change in scattering contrast during asphalt aging were also explained with the help of Fourier transform infrared spectroscopy (FTIR). SAXS experimental results show that the SAXS curves of asphalt are similar to the scattering curves of scattering objects with two-level structures. The Porod curve for asphalt shows that there is no obvious interface between the micelles and the surrounding mediums, and there is only a fluctuation of the hot electron density between the two. The Beaucage model fit SAXS patterns shows that the scattering coefficient P of the asphaltene clusters as well as the size of the micelles, gradually increase with the aging of the asphalt. Furthermore, aggregation exists between the micelles of asphalt and becomes more pronounced with increasing aging. During asphalt aging, the electron density difference between the micelles and the surrounding mediums gradually increases, leading to an increase in the scattering contrast of the asphalt. Under long-term aging conditions due to the gradual transition from maltenes to asphaltenes, the electron density difference between the micelles and the surrounding mediums decreases, resulting in a decrease in the scattering contrast of asphalt SAXS. Finally, this paper correlates the macroscopic properties of asphalt with microstructural parameters, and the results show that the high-temperature rutting resistance of asphalt is enhanced and the low-temperature cracking resistance decreases due to the aggregation of micelles and the generation of new micelles. These results are useful for understanding the relationship between changes in microstructure and changes in properties during asphalt aging and provide theoretical guidance for the regeneration of aged asphalt.

Keywords : asphalt, Beaucage model, microstructure, SAXS
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