Rheological and Chemical properties of Asphalt Binder Modified by Cross-metathesized Crumb Rubber

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The high viscosity of crumb rubberized asphalt results in the higher mixing temperature and weakened storage stability as compared to base asphalt, therefore cause the significant hazardous emissions and energy consumption (Lo Presti 2013). Previous research indicates the degradation of crumb rubber may mitigate the drawbacks by improving its compatibility with base asphalt (Zheng et al. 2021). The current degradation methods is proven to break the S-S bonds and C-S bonds of crumb rubber (Zhou et al. 2020). Nevertheless, the content of C=C bonds in crumb rubber is much greater than S-S bonds or C-S bonds, indicating a great potential to furtherly reduce the molecular weight and release the three-dimensional grid (Akhlaghi et al. 2015). Herein, olefin metathesis catalyst was utilized to degrade crumb rubber, therefore decrease the viscosity of crumb rubberized asphalt. Fourier Infrared Spectroscopy (FTIR) and Scanning electron microscope (SEM) was used to characterize the chemical properties and micro morphology. Dynamic shear rheometer (DSR) and Brookfield rotational viscometer were used to evaluate the rheological properties of asphalt binder modified by cross-metathesized crumb rubber.

Asphalt binder 70/100 supplied by SK (Korea) was used as the base binder (BA). The crumb rubber (CR) was obtained from Tianjin Haitai Co., Ltd., with a rubber particle size ranging from 0.18-0.25 mm. To prepare the cross-metathesized rubber (MR), 1‰, 3‰, and 5‰ olefin metathesis catalyst (Grubb's second generation catalyst) was mixed with rubber particles and dichloromethane in a centrifuge test tube at ambient temperature. Then, the mixtures were placed in a shaker for 2, 4, 6, and 8 days and ventilated for 20 min to dry the rubber particles. To produce the rubberized asphalt (RA), 10% crumb rubber was mixed with base asphalt binder using an electric mixer at 450-600 rpm and the temperatures of 170 °C, 195 °C, and 210 °C for 0.5h, 1h, 2h, 3h.

Bruker Vertex 70 FTIR spectrophotometer was used to analyse the chemical changes. SU8010 Hitachi's scanning electron microscope was used to observe the micro morphology. Smart Pave 102 produced by Anton Parr was used to evaluate the rheological properties. A Brookfield rotational viscometer was used to determine the viscosity of the modified asphalt at the temperature of 95 °C, 115 °C, 135 °C, 155 °C and 175 °C.

Comparison of CR and MR shows the peaks related to N=C=O stretching, C≡C stretching, C=C stretching and =C-H disappeared in MR as shown in Fig. 1. It indicates the catalyst indeed broke carbon related bonds in rubber particles during olefin metathesis. Three new peaks related to N-H bonds, C=C bonds, and S=O bonds are observed in MR, which may attribute to the residual catalysts.

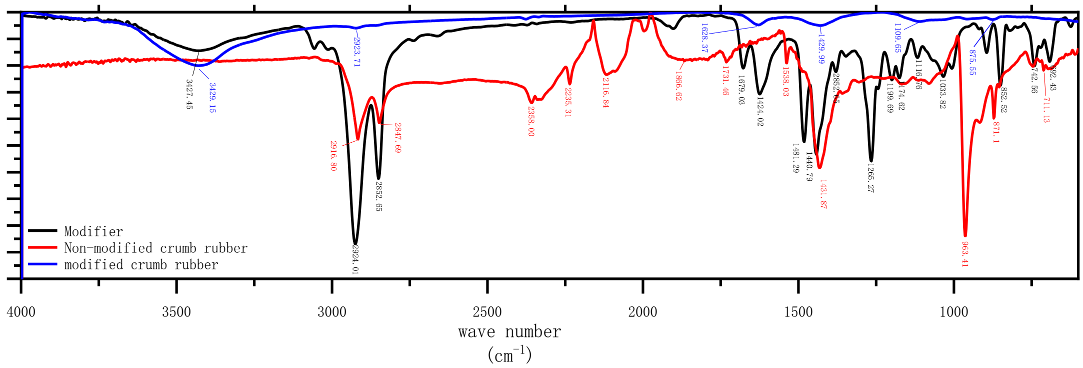


Fig.1 FTIR results of catalyst, CR, and MR.

SEM images shows the surface CR are dense with low void content. After olefin metathesis, the surface of BM has more fine prismatic bifurcations and higher voids contents, which is reported to enhance the interaction with asphalt binder (Wang et al. 2018).

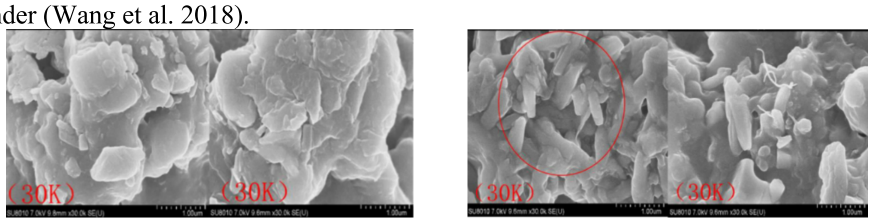
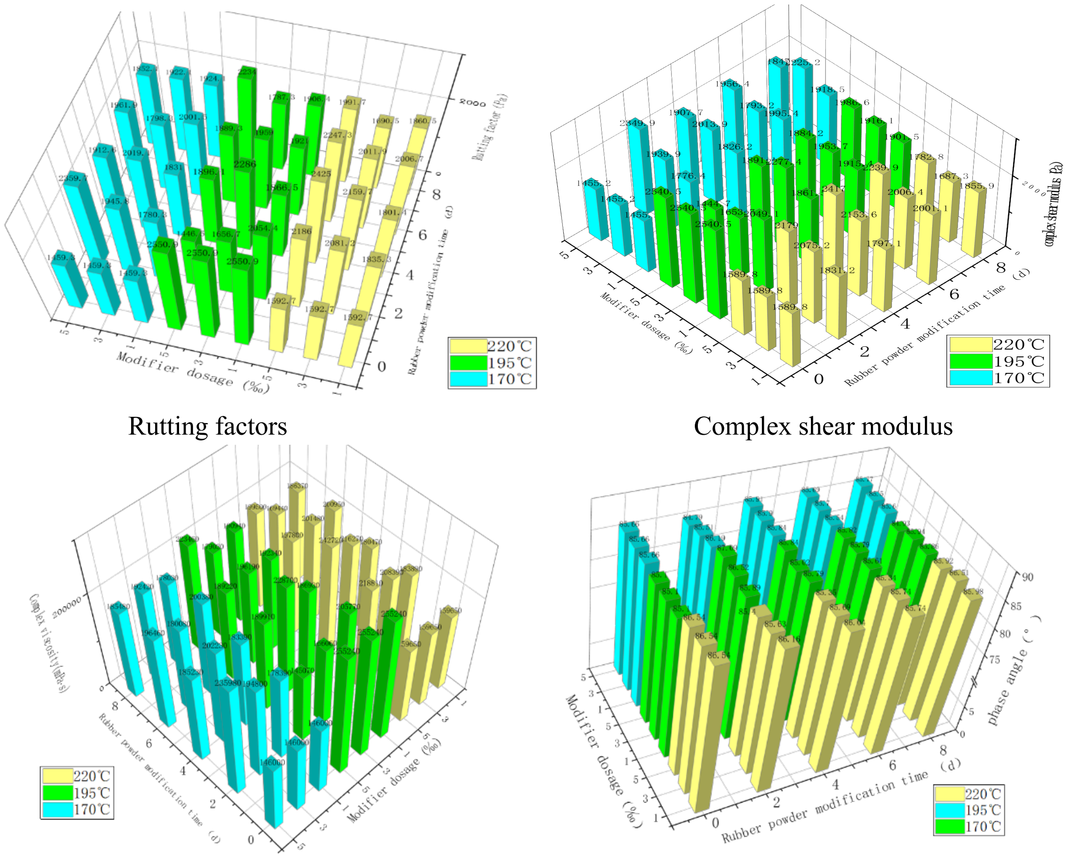


Fig.2 SEM images of CR (left) and MR (right).



Rutting factors Complex shear modulus

Complex viscosity Phase angle

Fig.3 Rheological properties of rubberize asphalt binder

Comparison of the rheological properties, the preparation producers and materials dosage can be optimized for different asphalt mixing temperatures and catalyst contents. The high temperature performance ranking is: 3‰ catalyst catalysing for 2 days and mixing at 195℃ > 1‰ catalyst catalysing for 8 days and mixing at 170℃ > 5 ‰ catalyst catalysing for 4 days and mixing at 170℃ > 3‰ catalyst catalysing for 8 days and mixing at 220℃ > 5‰ catalyst catalysing for 2 days and mixing at 195℃.

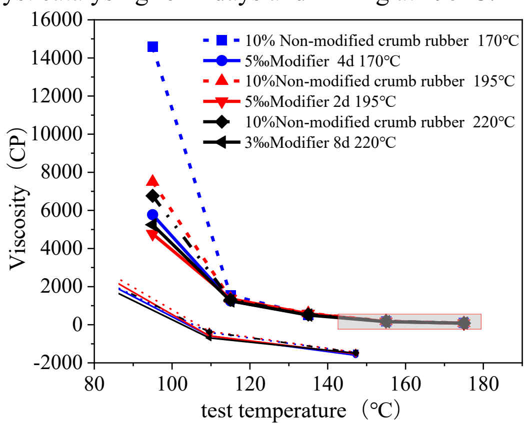


Fig.4 Viscosity of rubberize asphalt binder

Figure 4 shows the viscosity of various modified asphalts mixing for 1 h. It can be seen that as the temperature increases from 95 to 115 ℃, the viscosity of several modified asphalts decreases rapidly. The viscosity of the BR modified asphalt is even higher than that of the CR modified asphalt. Nevertheless, the viscosity values of BM modified asphalt are lower than that of the CR modified asphalt from 115 ℃ to 175 ℃, which is the temperature range for warm-mix and hot-mix asphalt mixtures. This indicates the olefin metathesis catalyst significantly decreased the viscosity of crumb rubberized asphalt in mixing temperatures, thereby enhancing the workability of rubberize asphalt mixtures.

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