Rheological Properties Evaluation and Microstructure Characterization of WMA Binder with Sasobit

Yi Pei¹, Kai Fang², Cunzhen Zhu³, Zhuang Hu⁴, Long Jin⁵

¹Research Assistant, School of Highway, Chang’an University, Xi’an, Shaanxi, China, 710064; peiyiCHD@foxmail.com
²Research Assistant, School of Highway, Chang’an University, Xi’an, Shaanxi, China, 710064; fangkai965073@foxmail.com
³Research Assistant, School of Highway, Chang’an University, Xi’an, Shaanxi, China, 710064; zhucunzhen@chd.edu.cn
⁴Research Assistant, School of Highway, Chang’an University, Xi’an, Shaanxi, China, 710064; huzhuang@chd.edu.cn
⁵Professional Engineer, Key Laboratory of Highway Construction and Maintenance Technology in Permafrost Region of Ministry of Transport, CCCC First Highway Consultants Co. Ltd., Xi’an, Shaanxi, China, 710075; jlcoolmail@163.com

ABSTRACT: Two matrix asphalt binders were selected and mixed with Sasobit in different proportion to prepare warm mix asphalt binders. The dynamic shear rheometer tests were conducted, and the microstructures were characterized. Test results indicate that both of the rutting factor $G^*/\sin \delta$ and fatigue factor $G^*\sin \delta$ exponentially decrease with the increasing temperature but linearly increase with the increasing Sasobit dosage. The four chemical components test, infrared spectrum test and nuclear magnetic resonance test were also conducted to characterize the microstructure. The test results indicate that the four contents of chemical components are slightly changed after adding Sasobit into matrix asphalt binder, there is no chemical reaction but similar physical dissolution between Sasobit and asphalt.

1. INTRODUCTION

Compared with the traditional hot mix asphalt (HMA), warm mix asphalt (WMA) can save energy and protect environmental due to the relatively lower mixing and compacting temperatures (Naisheng Guo et al., 2014). For the WMA technologies, Sasobit are widely applied because of its better high temperature stability than the other WMA technologies (Rui Zhang et al., 2007; Maowen Wang et al., 2009; Baha Vural Kok et al., 2014). Lots of researches have been conducted for Sasobit WMA. Chaofan Wu et al. (2012) studied the effects of warm-mix additive on penetration and high-temperature performance grade of asphalt binder. Yiqiu Tan et al. (2012) conducted a series of indoor tests of warm mix asphalt binder with Sasobit to evaluate the effect of the properties of the binder. Ali Tamshidi (2013) summarized the research and application progress of Sasobit WMA, and reported that Sasobit can increase the value of softening point, complex modulus, and anti-rutting factor, and reduce the value of the penetration and the phase angle. However, most of these researches were focused on the validation of road performance, determination of the additive dosage and the construction technologies.

In this paper, two matrix asphalt binders were selected and mixed with Sasobit in different proportion to prepare warm mix asphalt binders. The dynamic shear rheometer tests were conducted to indicate the rheological properties, and the microstructures were characterized to reveal the improvement mechanism of Sasobit WMA.
2. RAW MATERIALS AND EXPERIMENTAL METHODS

2.1 Raw Materials and WMA Fabrication

Two kinds of matrix asphalt binders were selected because of their wide application in China, which are Shell 90# asphalt and SK 70# asphalt. The technical properties of the two matrix asphalt binders meet the requirements in Chinese code, JTG F40-2004 (MOT, 2004). Sasobit were selected and added into the two matrix asphalt binders to prepare WMA binders with the dosage of 1%-5%. The matrix asphalt binder was heated at a temperature of 130°C for 60 minutes and then five different dosage of Sasobit (1-5%) were added the matrix asphalt to prepare the homogeneous WMA binder by using a glass rod to stir the mixture about 30min. The binder with 0% of Sasobit is used as the control group.

2.2 Dynamic Shear Rheometer and Microstructure Tests Methods

For conducting the Dynamic Shear Rheometer Tests (DSR), the asphalt binder was heated to have enough fluidity, put the heated asphalt binder into the silicone rubber mold to make the asphalt binder to be cooled to hard and then took the specimen out of the mold. Rheological measurements were performed with these samples by using dynamic shear rheometer, the dynamic shear modulus G* and phase angle δ were measured.

The four components analysis method was used for the component analysis of the asphalt binder according to the test procedure in Chinese code, JTG E20-2011 (MOT, 2011). The content of asphaltene, saturate, aromatic and resin can be obtained. The original and 3% additive dosage WMA binder of both two asphalts were obtained. The four beakers of asphalt binders were used to prepare the specimen by using the thin film method.

In addition, the asphalt was prepared onto a thickness of about 2~3mm film and then placed in the dryer cooling at room temperature to make the surface smooth. The samples were tested by the Fourier Transform Infrared Spectrometer. The infrared spectra test of these two kinds of matrix asphalt and WMA binder with 3% additive were preformed respectively.

3. RESULTS AND DISCUSSIONS

3.1 Rheological Properties at High Temperature

The results of DSR test at different temperatures for the two matrix asphalt binders and WMA binders are shown in Fig.1 and Fig.2.
As shown in Fig.1, the rutting factor \( \frac{G^*}{\sin \delta} \) decreases rapidly with the increasing temperature of WMA binders, which means the ability of asphalt binder to resist flow deformation has been reduced. And with the increasing additive dosages, the rutting factor increased gradually of both WMA binders at the same temperature. The results of both matrix asphalt binders and WMA binders have the same variation law which means the additive can improve the properties of asphalt at high temperature. As shown in Fig.2, the fatigue factor \( G^* \cdot \sin \delta \) decrease with the increasing temperature, namely the asphalt binder is easily to occur fatigue damage at a relatively low temperature. In Fig. 2(b), the fatigue factor exceeds the specific limits of both two WMA binders with 3% and 5% additives at 16\(^\circ\)C. In Fig.2 (a), the fatigue factor exceeds the specific limits of WMA binder with 1% additive at 16\(^\circ\)C, which means the effect of the additive on the property of sensitivity of 70# asphalt binder is larger than that of 90# asphalt binder. The fatigue factor increase gradually and the ability to resist fatigue declines gradually with the increasing additive dosages at the same temperature.

3.2 Analysis of Four Component

Asphalt contains different types of molecular species, which are classified (in terms of solubility in n-heptane) into two major fractions, maltenes and asphaltenes (Dong XG et al., 2005). Based on differences in solubility and polarity, the maltene fraction can be further divided into three groups: saturates (S), aromatics (A) and...
resins (R) (Redelius PG, 2000). Thus, bitumen physico-chemical and rheological properties strongly depend on both temperature and the relative proportion of those four SARAs fractions (A.A. Guadri et al., 2014). The results of the four component content of both two matrix asphalt binders and WMA binders with different additive dosages are shown in Fig. 3.

![Figure 3. The histogram of four component content of asphalt binder.](image)

As shown in Fig. 3, the composition proportion of the four component content are different of different kinds of asphalt, the difference is generally caused by different varieties of crude oil and refining process. For the same kind of asphalt, the four component content has been changed in a certain extent and the content of saturate increases with the increasing additive dosages while the rest component don’t show a clear rule of the variation. The increased content of saturate cause the improvement of complex modulus, rutting factor and fatigue factor.

3.3 Analysis of Infrared Spectrum

As observed in Fig.4, the –NH or –OH band (located in 3422cm$^{-1}$) is a broad and weak absorption band. The band at 2921cm$^{-1}$ is the stretching mode caused by -CH2-band. The absorption band of naphthenic and alkane C-H vibration is located at 2850cm$^{-1}$ and the band located at 1600cm$^{-1}$is the skeletal vibration of C=C of the benzene ring. The band at 1030cm$^{-1}$ is related to the oxidation of aromatic ethers. There is a big overlap in the infrared spectra of four components, but there is no absorption band at 1600cm$^{-1}$, which means there is no unsaturated double bond in the saturated.
Figure 4. The infra-red spectrogram of four components of asphalt.

The infra-red spectrograms of four components of two matrix asphalt binders and WMA binders with 3% dosage additive are shown in Fig.5.

(a) SK 70#

(b) SK 70# with 3% Sasobit
As shown in Fig. 5, the spectrum of functional group region of WMA binder is similar with that of its matrix asphalt binder. Also, it can be seen in Fig. 5(b), there is one more absorption band (located at 730.62 cm\(^{-1}\)) at fingerprint region where is always related to the bending vibration of alkyl and the value of n in \(-[\text{CH}_2]_n\) is \(\geq 3\). The variation of this part is probably caused by the additive which has been changed the four component of the original asphalt binder. And from Fig. 5(d), it could be found that there is an obvious change emerges at the fingerprint region which is located at the range from 650 to 810 cm\(^{-1}\). There is a strong absorption band at 771.22 cm\(^{-1}\) and a weak absorption band at 727.90 cm\(^{-1}\) while there is no strong absorption band at fingerprint region, just merged into a weak absorption band at 722.17 cm\(^{-1}\). It indicates that the four component of asphalt binder has not been changed with the additive, and there is no chemical reaction between additive and matrix asphalt.

4. CONCLUSIONS

In this paper, the dynamic shear rheometer tests were conducted to indicate the rheological properties, and the microstructures were characterized to reveal the
improvement mechanism of Sasobit WMA. The main conclusion are summarized as follows:

1. The rutting factor decreases rapidly with the increasing temperature and gradually increased with the increasing additive dosages at the same temperature. The fatigue factor decrease with the increasing temperature but increase with the increasing additive dosage. Sasobit improves the anti-rutting properties, but reduce the anti-fatigue properties.

2. The composition proportion of the four component content are different of different kinds of asphalt, which is due to the difference between crude oil and refining process. For the same kind of asphalt, the four component content has been changed in a certain extent, and the content of saturate increases with the increasing additive dosages.

3. The spectrum of functional group region of WMA binder is similar with that of its matrix asphalt binder, which means that there is no chemical reaction between additive and matrix asphalt, but similar physical dissolution.

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