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Influence of different anti-stripping agents on the rheological properties of asphalt binder at high temperature

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HIGHLIGHTS

- The changes of rheological properties of ASA modified asphalt binders depend on the ASA types and its dosages.
- The high temperature performance grade of all ASA modified asphalt binders is the same as blank sample.
- Non-recoverable creep compliance susceptibility for stress level is weakened evidently by adding ASAs.
- ASAs can effectively improve the ability of asphalt binder to resist RTFO.

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ABSTRACT

Effects of different anti-stripping agents (ASAs) (M5000, M1 and LOF-6500) with various dosages (0.25%, 0.50% and 0.75% by weight of asphalt binder) on the rheological properties of asphalt binder before and after rolling thin film oven test (RTFO) at high temperature were investigated. The tested rheological properties included rotational viscosity, complex modulus (G*), phase angle (δ), rutting resistance factor (G*/sinδ), failure temperature, non-recoverable creep compliance (J_{nr}) and amplitude sweep. The results indicated that the rheological properties such as viscosity, G*, δ, G*/sinδ and failure temperature of ASA modified asphalt binders before aging depended on the ASA types and its dosages. After RTFO, all ASA modified asphalt binders showed the lower high temperature stability compared with blank sample, however, the high temperature performance grade maintained 64 °C unchanged. Besides, the J_{nr} susceptibility for stress level was weakened evidently by adding ASAs. As a result of the amplitude sweep test, compared with blank sample, all ASA modified asphalt binders after RTFO had the higher δ and G* values. Additionally, the introduction of ASAs could effectively improve the ability of asphalt binder to resist RTFO. Moreover, compared with M5000 and LOF-6500, the improvement degree of M1 was more apparent.

1. Introduction

Asphalt pavement has been widely applied for highway construction at present because of its excellent pavement performances. As two main components in asphalt pavement, the combination condition of asphalt binder and aggregate is primary responsible for realizing the excellent performances. However, some factors such as water penetration, traffic loading and the poor properties of asphalt binder and aggregate may lead to the breaking of the bond between asphalt binder and aggregate particles [1–5]. This phenomenon is also termed as stripping. Stripping can further cause some more serious distress such as rutting, corrugations, cracking etc., and finally the complete failure of asphalt pavement [6–9]. Therefore, it is significant to prevent stripping in asphalt pavement.

Many researchers found that adding antistripping agents (ASAs) could effectively enhance stripping resistance of asphalt pavement [10–12]. Arabani et al. [11] evaluated the influence of Zycosoil as an antistrip agent on the moisture sensitivity of warm mix asphalt (WMA) by means of surface free energy, and determined that adding Zycosoil increased the surface energy of adhesion between

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Table 1
Rheological properties and chemical compositions of base asphalt.

Rheological properties and chemical compositions		Measured values
Rheological properties	Viscosity (135 °C, mPa·s)	587
	Fail temperature (°C)	69.5
	$G^*/\sin\delta$ (64 °C, kPa)	1.93
Chemical compositions (%)	Saturates	20.80
	Aromatics	40.09
	Resins	29.24
	Asphaltenes	9.87

asphalt binder and aggregate in dry/wet condition. Xiao et al. [12] compared the influence of two liquid antistripping agents and hydrated lime on moisture susceptibility of WMA, and found that the liquid ASA additives could enhance indirect tensile strength of the mixtures but show a weak ability to resist moisture in contrast with the hydrate lime irrespective of WMA and aggregate type. Nazirizad et al. [13] also investigated the influence of hydrated lime and a liquid anti-stripping agent (Iterlene In/400-S)) on moisture susceptibilities of asphalt mixtures. The results indicated that, compared with the asphalt mixture containing hydrated lime, the asphalt mixture containing liquid anti-stripping additive had the better resistance to water damage. Park et al. [14] found that aliphatic amine type-developed liquid anti-stripping agents could improve the stripping and rutting resistance of the asphalt mixture. Zheng et al. [15] indicated that, after short-term and long-term aging, the adhesive strength enhancement effect was visibly weakened under the poor thermal stability of the anti-stripping agents. Besides, they pointed out that the compatibility between anti-stripping materials and asphalt binder required focused attention when an anti-stripping agent was chosen. Xiao et al. [16] further studied the rheology and moisture susceptibility of water bearing warm mixtures containing liquid antistrip additives, and found that although ASA leaded to a minor enhancement in rutting resistance of asphalt binder at high temperature, it had not obvious influence on the performance grade of asphalt binder. Selvaratnam et al. [17] found that anti-stripping additives (amine-based liquid anti-stripping additives) with various dosages caused more remarkable performance grade change for PG 70-28 and PG 76-28 polymer modified binders than that for PG 64-22. Hossain et al. [18–20] studied the influence of an amine-based liquid anti-stripping agent (AD-here® HP Plus) on the Advera®-modified binder, and drew a conclusion that 0.5% dosage anti-stripping agent could effectively enhance the fatigue and low temperature resistances of the Advera®-modified binder. However, the rutting factor of the binder decreased when the amount of ASA was increased.

From all above, most of researches focused on the influence of ASAs on the interaction between asphalt binder and aggregate or asphalt mixture, there were relatively few researches which reported on the influence of ASAs on the properties of asphalt binder. This work aimed to investigate the effect of different ASAs on the rheological properties of asphalt binder before and after RTFO at high temperature. Three types of ASAs (M5000, M1 and LOF-6500) with various dosages (0.25%, 0.50% and 0.75% by weight of asphalt binder) were chosen to prepare ASA modified asphalt binders. All binders were aged by RTFO. The tested rheological properties included rotational viscosity, complex modulus (G^*), phase angle (δ), $G^*/\sin\delta$, failure temperature, non-recoverable creep compliance (J_{nr}) and amplitude sweep.

2. Experimental materials and test procedure

2.1. Materials

In this research, Inman PG 64-22 was chosen as base asphalt, which was from southeast area of USA. The rheological properties and chemical compositions of base asphalt were listed in Table 1.

Three types of anti-stripping agents (ASAs), MORLIE 5000 (M5000), EVOTHERM M1 (M1), AD-here®LOF-65-00 (LOF-6500), were used to modify asphalt binder, and the basic information of the three ASAs was listed in Table 2.

2.2. Preparation of ASA modified asphalt binder

The preparation procedure of ASA modified asphalt binders was as follows: ASAs with various dosages (0.25%, 0.50% and 0.75% by weight of asphalt binder) (as recommended by the manufacturer) were added into base asphalt by using a paddle agitator, and the working conditions were 160 °C, 1000 rpm and 30 min. The same procedure was conducted on base asphalt to obtain blank sample. In addition, all prepared asphalt binders were aged by RTFO in accordance with ASTM D 2872.

2.3. Test procedure

The rotational viscosity test (60 °C) was performed by using Brookfield Viscometer according to ASTM D 4402.

Dynamic shear rheometer (DSR) was utilized to test the rheological properties of all binders according to ASTM D 7175. The change of complex modulus (G^*), phase angle (δ), rutting resistance factor ($G^*/\sin\delta$) and failure temperature as temperature was tested using temperature sweep mode. Meanwhile, the change of G^* and δ as shear strain was tested using amplitude sweep mode.

The Multiple Stress Creep and Recovery (MSCR) test was a creep and recovery test performed on the asphalt binders using the DSR according to ASTM D7405. Non-recoverable creep compliance (J_{nr}) was utilized to evaluate the rutting resistance of asphalt binder. The J_{nr} values for 0.1 kPa or 3.2 kPa stress level were used in this study. J_{nr} is computed as following formula (1). Three parallel tests for each binder were performed.

$$J_{nr} = \frac{Non\text{-}recoverable\ strain}{Stress\ level} \quad (1)$$

Table 2
Physical and chemical components of three types of ASAs.

Properties	M5000	M1	LOF-6500
Ingredients	Alkylamines; Alkanol amines; Alkylene amines	Fatty amines derivatives	Amidoamines
Physical state	Liquid	Liquid	Liquid
Color	Brown (dark)	Amber (dark)	Brown
Odor	Fishy	Amine-like	–
Specific gravity	1.09	0.97	–
Vapor density	4.6	–	–
pH values	11.9	10–12	–
Boiling point	255 °C	>200 °C	–
Flashpoint	Closed up: 146 °C	Closed up: >204.4 °C	>148.9 °C
Solubility in water	–	0.02 g/l	–