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Effects of aging on rheological properties of asphalt materials and asphalt-filler interaction ability

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HIGHLIGHTS

- The aging effects can enhance the cohesion of asphalt binders and mastics.
- The indices *K-B-G** and *K-B-δ* have the consistency to evaluate asphalt-filler interaction ability.
- The deeper aging degree of asphalt binders is, the worse asphalt-filler interaction ability is.

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ABSTRACT

The rheological properties of asphalt mastics and asphalt-filler interaction play key roles on the performances of asphalt mixtures. However, the rheological properties of asphalt mastics and asphalt-filler interaction are significantly influenced by aging which exists in the compaction stage of asphalt mixtures. In order to analyze the effects of aging on rheological properties of asphalt binders, asphalt mastics and asphalt-filler interaction, the Dynamic Shear Rheometer (DSR) tests and Bending Beam Rheometer (BBR) tests were conducted for unaged and aged specimens. Results indicate that the aging can enhance the cohesion properties of asphalt binders and mastics, and so the rutting resistance of asphalt binders and mastics is better with an increase in aging degree. However, the low temperature properties of asphalt binders and mastics are worse with an increase in aging degree. The two indices *K-B-G** and *K-B-δ* were selected to evaluate asphalt-filler interaction ability. Results show that these two indices have the consistency to evaluate asphalt-filler interaction ability. And also the two indices can reflect the difference of interaction ability of different aged asphalt binders and fillers. The deeper aging degree of asphalt binders is, the worse asphalt-filler interaction ability is. Within the same aging degree, the interaction ability of asphalt 70# with higher asphaltene and resins contents is stronger than asphalt 90#. Therefore, the aging affects the asphalt-filler interaction ability via changes of asphalt active components.

1. Introduction

It has been long recognized that the aging plays a key role on overall performances of asphalt mixtures. And the coarse and fine aggregates in asphalt mixtures are effectively coated by asphalt mastics which are formed by the interaction between asphalt binder and filler [1]. Ample researches have been conducted on asphalt mastics and mixtures, and finding that the asphalt mastic is the weak phase in asphalt mixture [2–5]. However, there are still few studies about the effects of aging on asphalt-filler interaction ability at present. Therefore, deeply analyzing the effects of aging on rheological properties of asphalt mastic and asphalt-filler interaction ability have great significance to improve the asphalt mixture performances and reduce the diseases occurrence effectively.

Due to the limited test conditions, originally, researchers designed simple adhesion tests, such as boiling water test and static immersion test, to evaluate the asphalt-filler interaction ability. However, these tests can only reflect the anti-striping properties of asphalt binders and mineral aggregates to some extent, and cannot quantitatively characterize the asphalt-filler interaction ability [6,7]. As more research studies going on, ЛI *A Repintyuter* found that the 'free asphalt' and 'structural asphalt' that have different rheological properties would be formed in asphalt mastics when the asphalt-filler interaction occurred [8]. The fillers are coated by 'structural asphalt' that has thin film, high viscosity and strong adhesive force, and the 'free asphalt' maintains initial cohesion, as shown in Fig. 1. Zhang et al. [9] analyzed the effects of various

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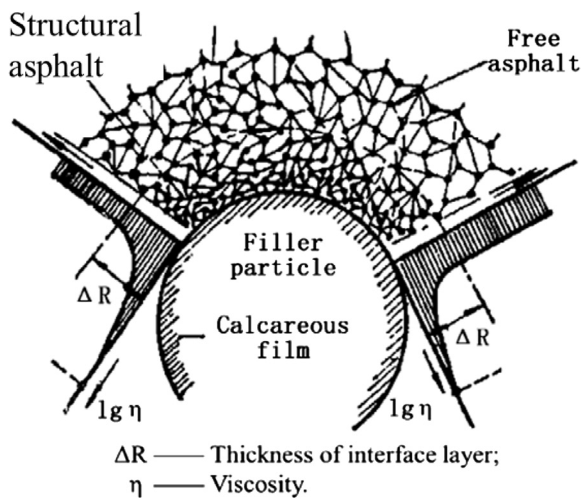

Fig. 1. 'Free asphalt' and 'structural asphalt' (cited by Hesami et al. [8]).

material properties of asphalt binder and filler, including filler particle size, SiO_2 content and asphalt components on asphalt-filler interaction ability, and finding that the relative proportion between 'free asphalt' and 'structural asphalt' is significantly influenced by filler particle size. These research studies show that although the asphalt and filler interaction is a complex process of physico-chemical interaction, the asphalt-filler interaction ability can be evaluated quantitatively by the rheological properties of asphalt binders and mastics.

As mentioned above, the asphalt-filler interaction ability can be evaluated quantitatively via the rheological properties of asphalt binders and mastics. Therefore, numerous researchers tentatively proposed evaluation indices based on rheological properties, such as complex modulus G^*, phase angle δ and complex viscosity η^*. Guo [10] evaluated asphalt-filler interaction ability by the intrinsic viscosity $[\eta]$. These results indicate that the intrinsic viscosity $[\eta]$ can only reflect the irregularity and dispersion of mineral filler in asphalt mastic to some extent. However, the intrinsic viscosity $[\eta]$ cannot evaluate the asphalt-filler interaction ability quantitatively. Zhang et al. [11,12] measured the Einstein coefficient K_E of Nielsen's model to evaluate asphalt-filler interaction ability. Nevertheless, the Einstein coefficient K_E is determined by non-linear regression fitting methods, and it cannot compare the ability of asphalt-filler interaction under different filler concentrations. In order to overcome the deficiencies of these evaluation indices, Tan et al. [13] firstly introduced the coefficients K-B-δ and L-A-δ, which were proposed by Ziegel [14] and Ibrarra [15] respectively, and established the complex shear modulus coefficient $\triangle G^*$ and complex viscosity coefficient $\triangle\eta^*$ to characterize the interaction ability between asphalt binders and aggregate fillers. And the results reveal that all four evaluation indices can capture the interaction ability of asphalt binders and aggregate fillers. Zhang et al. [16] analyzed the effects of temperature and loading frequency on asphalt-filler interaction based on the coefficient K-B-G^*. And Liu et al. [17] further compared the sensitivity of coefficients K-B-δ, L-A-δ and complex shear modulus $\triangle G^*$, and finding that the coefficient K-B-δ has higher sensitivity than other evaluation indices.

Besides the evaluation indices, materials characteristics are also studied. Tan et al. [18] analyzed the effects of internal factors on asphalt-filler interaction ability by coefficient K-B-δ. These results indicate that the asphalt properties, especially resins and asphaltenes contents, have significant influence on asphalt-filler interaction ability. The asphalt-filler interaction mainly occurs in the compaction stage of asphalt mixtures, and asphalt binders will experience the thermos-oxidative aging effects [19]. The thermos-oxidative aging has an impact on asphalt properties, such as rheological properties of asphalt binders and mastics, and then has a great influence on asphalt-filler interaction ability. The above studies show that the evaluation of asphalt and filler interaction ability based on rheological properties has become a research hotspot. However, there is lacking study about the effects of aging on asphalt-filler interaction ability via rheological properties. Therefore, the effects of aging on rheological properties of asphalt binders, mastics and asphalt-filler interaction ability are investigated in this study.

2. Objective and scope

The objectives of this study are to analyze the effects of aging on rheological properties of asphalt binders and mastics and reveal the effects of aging on asphalt-filler interaction ability. In order to achieve this goal, the two main elements are the following:

(1) To analyze the effects of aging on rheological properties of asphalt binders and mastics, such as high and low temperature performances et al.
(2) To analyze the effects of aging on the asphalt components, and reveal the effects of aging on asphalt-filler interaction ability based on the indices K-B-G^* and K-B-δ respectively.

3. Experiments

3.1. Raw materials and technical properties

Two virgin asphalt binders, whose penetration grades are 70# and 90# respectively, were used as base material. 70 means the penetration of the asphalt binder at 25 °C ranges from 60 to 80 (units in 0.1 mm), and 90 means ranges from 80 to 100 according to the Chinese specification, JTG F40-2004 [20]. The properties of asphalt binders were measured according to the test methods of specification Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering, JTG E20-2011 [21], as shown in Table 1. Limestone filler was selected to prepare asphalt mastics, and the properties of limestone filler are shown in Table 2.

Table 1
Properties of the virgin asphalt binders used.

Property indices	Test results 70#	Test methods 90#	Test methods
Penetration (25 °C, 5 s, 100 g)/0.1 mm	72	93	T0604—2011
Softening point/°C	48.2	49.8	T0606—2011
Ductility (5cm/min, 15 °C)/cm	140	150	T0605—2011
Dynamic viscosity (60 °C)	183	239.7	T0625—2011
Density (25 °C)/(g/cm^3)	1.03	1.01	T0603—2011