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Analysis of asphalt durability based on inherent and improved performance

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HIGHLIGHTS

- The improved high temperature durability of SBS and TPS modified asphalt is better than that of improved low temperature durability. Rubber modified asphalt has a significant ability to improve low temperature durability.
- The results show that microstructure of inherent performance is more easily affected by aging than that of improved performance.
- Comparison of durability between inherent and improved performance of modified asphalt shows that even different modified asphalt can improve high and low temperature performance, the modifier does not have the same ability to improve the performance due to different durability.

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ABSTRACT

The composite performance of modified asphalt is divided into inherent performance and improved performance. The inherent performance of asphalt refers to the original performance of the virgin asphalt. The performance obtained by modifying the virgin asphalt by different methods is referred to the improved performance of the asphalt. In most studies of modified asphalt, researchers pay more attention to how to improve the performance of virgin asphalt at high and low temperatures (i.e., rutting at high temperatures and cracking at low temperatures); however, little attention has been paid to the anti-aging durability of the improved performance. In this project, the macro and micro mechanisms of modified asphalt were compared and analyzed through a series of comparative experiments on the inherent and improved performance of modified asphalt to explore the anti-aging durability of the modified asphalt based on the inherent performance and improved performance at high and low temperatures.

1. Introduction

As an important binder for asphalt pavement construction [1], the selection and quality of asphalt determine the durability of asphalt pavement to a large degree and directly affect the service life and safety of asphalt pavement. Therefore, studying the durability of road asphalt, especially the durability of asphalt materials, is of great theoretical and practical value [2–4].

Zhang et al. [5] investigated the change in molecular weight during the aging process of asphalt and found some new functional groups that were produced inside the asphalt; they also found that the change in molecular structure will lead to changes in the morphology and performance of the asphalt. P. Chen's paper concluded that temperature has a great influence on the aging of asphalt. When the temperature was above 100 °C, a dehydrogenated chemical reaction of the asphalt was produced. When the temperature was below 100 °C, an oxidation reaction of the asphalt was produced, as well as some oxygenated compounds. The chemical reaction produced by asphalt aging has an important influence on the performance of the asphalt [6]. According to Zhu et al., as the aging time is increased, the residual needle penetration and residual ductility is decreased and the softening point is increased. This means that the high temperature performance of the asphalt is increased and the low temperature performance is decreased after aging [7]. Zhang et al. [8] indicated that the variation of the performance of the asphalt during the aging progress is mainly due to the change of its interior components. When asphalt is aging, the content of its lighter components is decreased, such as oil and gelatin, and the content of the heavier components is increased, such as asphaltene. This results in a harder asphalt, which is easily broken at low temperatures. Meanwhile, the aging of the asphalt threatens the safety of the road surface. In the aging process, the low temperature performance and water stability of the asphalt mixture is

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decreased. The asphalt pavement creates the risk of road fractures and the formation of a loose mixture of asphalt in cold and wet areas [9,10]. Therefore, it is of great significance to improve the service life and performance of asphalt pavement via improving the aging durability of asphalt.

Because virgin asphalt cannot meet the requirements of the durability required in asphalt pavement, when paving with high-grade asphalt pavement, modified asphalt is often used as a binder for the asphalt mixture [11]. The modified asphalt mixture greatly improves the properties of the virgin asphalt mixture. Rasool et al. [12] pointed out that adding highly reclaimed rubber and SBS modifiers into virgin asphalt can greatly improve its ductility and its ability to resist aging. R. Liang's paper reported that rubber powder can greatly improve the viscosity and rheology of the asphalt mixture; this finding was made by observing the viscosity of the rubber powder modified asphalt mixture after short-term aging and rheological tests. At the same time, the aging behavior and rheological performance of the asphalt mixture were found to have a certain linear relationship [13]. TPS and Sasobit modifiers have a significant effect on improving the mechanical performance and anti-aging ability of the asphalt mixture ability [14–16]. Therefore, adding modifiers to improve the performance of asphalt has a significant effect on improving its anti-aging durability.

The composite performance of modified asphalt is classified into improved performance and inherent performance. The existing research has done a great deal of analysis on the composite performance of modified asphalt during the aging process, but the formation mechanism and durability of asphalt modified by different admixtures have not been discussed [17]. The purpose of this study is to compare the inherent performance and improved performance of different mixtures of modified asphalt theoretically and experimentally. This paper will discuss the formation mechanism and durability of two properties of modified asphalt, and further analyze the technical characteristics of different modifiers. On the basis of this research, a new modified asphalt material based on composite modifiers is proposed to optimize the road performance of modified asphalt. Therefore, the research results have certain scientific significance for the evaluation of modified asphalt and for the development of future research directions.

2. Test materials and contents

2.1. Test materials

2.1.1. Asphalt

Asphalt 90# (25 °C penetration is about 80–100/0.1 mm) was selected in this test, and the indexes of the asphalt are shown in Table 1.

2.1.2. Modifiers

The modifiers of SBS, TPS, Rubber and Sasobit were selected in this test (Fig. 1), and the indexes of the modifiers are shown in Tables 2–5.

2.2. Preparation of asphalt specimens

Four kinds of asphalt specimens were prepared for the comparative test. They are 4% SBS asphalt (90#), 4% TPS asphalt (90#), 16% Rubber asphalt (90#) and 2% Sasobit asphalt (90#). The technical indicators of comparing the asphalt specimens are shown in Table 6.

2.3. Test content

The above asphalt samples were selected as the research objects to carry out aging tests (aging times were 0, 5, 20 h). Then, the macroscopic comparison and microcosmic demonstration of the durability of the asphalt, based on inherent durability and inherent performance, were carried out.

2.3.1. Macro-comparison

First, 4% SBS asphalt (90#), 4% TPS asphalt (90#), 16% Rubber asphalt (90#) and 2% Sasobit asphalt (90#) specimens were obtained by modifying skill. On the basis of this, RTFOT was used to heat these specimens for 0 h, 5 h and 20 h to determine the changes in the macro evaluation indexes, such as penetration, ductility, softening point and viscosity that occurred during the aging process. The regression curves of the modified asphalt index with aging times were all linear regressions. We then compared the speed of the performance index with the changing of the aging time (the absolute value of the linear slope), and we used this to evaluate durability based on the improved and inherent performance of the modified asphalt [18,19]. The larger the slope, the faster the asphalt performance index changed with the aging time, and the changes in the asphalt performance were more affected by aging. It means the larger the slope, the worse anti-aging durability is. Conversely, the smaller the slope, the better anti-aging durability is.

2.3.2. Micro-demonstration

According to the current standard tests, four components of the asphalt were measured by the four-component analysis method. The experimental principle of the analytical method is as follows: undissolved asphaltenes (As) in the bituminous samples were precipitated by the *n*-heptane after filtration (to remove the aromatics) using silica gel. The soluble fraction was adsorbed on the activated alumina adsorption column. Then, it was washed three times, and the solution of the remaining three components was obtained. For the first washing, *n*-heptane reagent was used to produce the saturated solution (S). For the second washing, toluene reagent was used to produce the aromatic fraction (Ar) solution. For the third washing, toluene, ethanol, toluene and ethanol were used to obtain the colloidal (R) solution. Finally, the solvent was recovered in a constant temperature tank; after solvent recovery, the content of each component can be obtained by vacuum drying (vacuum degree; 93 kPa ± 1 kPa, temperature: 105 °C ± 5 °C) [20–22]. The test process is shown in Fig. 2.

In microscopic verification, first, asphalt specimens were heated by RTFOT for 0 h, 5 h and 20 h. The changes in the four components of the asphalt samples in the aging process were recorded by the above component test method. Since the four components constituted a colloidal structure of bitumen in different proportions, we took the change in the colloidal instability index Ic (Ic = (S + As)/(R + Ar) of the asphalt as an index to explore the durability based on the inherent performance and improved performance of the different modified asphalt specimens from the microscopic components. Then, the macroscopic test results were verified.

Table 1
Technical indexes of virgin asphalt.

Asphalt	Penetration/25 °C/0.1 mm	PI	Ductility/cm		Softening point/°C	Viscosity/135 °C/Pa.s
			5 °C	15 °C		
90#	93	−0.77	9	165	44.5	0.328