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Effect of mineral filler on properties of warm asphalt mastic containing Sasobit

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HIGHLIGHTS

- The relationship of complex shear modulus to *F*/*A* ratio of warm asphalt–mineral filler mastic is obtained.
- The effect of different type filler on the properties of warm asphalt–mineral filler mastics is evaluated.
- The high-temperature and low-temperature properties of different warm asphalt–mineral filler mastic are investigated.
- A 0.9–1.4 optimal range of *F*/*A* ratio is recommended for warm asphalt–mineral filler mastics.

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ABSTRACT

The dynamic shear rheometer (DSR) and bending beam rheometer (BBR) were used to characterize the high-temperature properties and low-temperature properties of different Sasobit warm asphalt–mineral filler mastics. The Limestone fillers (LM), Portland cement (PC), and Hydrated lime (HL) were selected as mineral fillers. Eight fill-to-binder (*F*/*A*) ratios for each type of mineral fillers were considered in this study: 0 (without filler), 0.3, 0.6, 0.9, 1.2, 1.5, 1.8 and 2.1 by the weight of asphalt binder. The effects of *F*/*A* ratio on the complex shear modulus (G^*), phase angle (δ), $G^*/\sin\delta$ and creep stiffness (S) of various kinds of warm asphalt-mastics were studied. Results of the study showed that the filler type and the *F*/*A* ratio had significant effects on the complex shear modulus (G^*) and $G^*/\sin\delta$, but had slight effects on the phase angle (δ). The *F*/*A* ratio had significant effects on the creep stiffness *S*, while the filler type had insignificant effects on it. It was also shown that the best function that described the relationship between each of G^*, $G^*/\sin\delta$ and S and the *F*/*A* ratio was the exponential function. Based on the rate of rheological curve, the optimum range of *F*/*A* ratios were obtained to balance the high-temperature and low-temperature properties.

1. Introduction

Mineral filler, the fraction of fine aggregate passing No. 200 (75 μm) sieve, has commonly been used in asphalt mixtures and plays an important role in the behavior of the asphalt mixture and the performance of the asphalt pavement [1]. It has an important effect on stabilizing the hot mix asphalt (HMA) by filling the voids within the larger aggregate particles, and improving the consistency of the binder that cements the larger aggregate particles. Furthermore, it can improve the workability, moisture sensitivity, stiffness and ageing characteristics of HMA. There are large varieties of mineral fillers. Natural limestone is processed into mineral filler used in asphalt mixture traditionally. Recently, recycled waste lime [2], phosphate waste filler [3], municipal solid waste incineration ash [4] and waste ceramic materials [5] have been investigated as filler used in asphalt mixture. The effect of mineral fillers on the behavior of asphalt mastics has been extensively studied in the literature. Harris and Stuart presented several means of testing a wide range of mineral fillers and asphalt mastics in an effort to relate performance to laboratory measured properties [6]. Shashidhar and Romero used rheology-based model, the Nielsen model, to study the dynamic mechanical behavior of asphalt mastics [7]. Chen and Peng used the direct tension tester (DTT) to study the effect of mineral fillers on asphalt behavior at low temperatures [8]. Kim and Little studied the rheology-based models in characterizing the dynamic mechanical behavior of asphalt mastics [9]. Abbas et al. used the discrete element method (DEM) to simulate the dynamic mechanical behavior of asphalt mastics [10]. Liu et al. investigated the low-temperature rheological performance (LTRP) of asphalt mastic [11]. Tan et al. studied the high- and low-temperature properties of asphalt–mineral filler mastic [12]. Al-Khateeb and Al-Akhras investigated the effect of cement additive on some properties of asphalt binder using Superpave

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Table 1
Properties of the base asphalt.

Properties	Units	Results	Specification limits
Penetration (100 g, 5 s, 25 °C)	0.1 mm	70	60–80
Penetration index	–	−0.58	−1.5–1.0
softening point	°C	47.1	⩾45
Ductility (5 cm/min, 5 °C)	cm	6.9	–

testing methods [13]. From literature review, it can be found that the previous studies about the effect of mineral fillers on the behavior of asphalt mastics are based on hot asphalt.

Recently, the utilization of warm mix asphalt (WMA) as a substitute for hot mix asphalt (HMA) has been widely increased. The use of WMA technologies reduces mix production and paving temperatures, decreases energy consumption to produce HMA, reduce emissions and odors or green house gases from plants, and make the better working conditions at the plant and paving sites [14–16]. In present, the WMA technology can be divided into four categories: organic additives, chemical additives, water-bearing additives, and water-based processes [17]. With increasing awareness of the WMA technology in pavement engineering, there is a need to investigate several properties of warm asphalt. Several studies have been conducted to investigate the performance of warm asphalt mixtures [18–20] and warm-mix asphalt (WMA) binder properties [18,21]. However, the test data are significantly lacking in terms of rheological properties of warm asphalt mastic as well as performance-related properties of the mix.

From the discussion on the mineral filler and asphalt mastic, it can be seen that the mineral filler also plays an important role in affecting the performance of warm asphalt mixture. But so far, little work has been done to study the properties of warm asphalt–mineral filler mastics. This paper presents the results of some rheological tests conducted on warm asphalt–mineral filler mastics. The objective of the research presented in this paper is, (1) evaluate the high-temperature and low-temperature properties of different warm asphalt mastic using dynamic shear rheometer (DSR) and bending beam rheometer (BBR); (2) study the effect of filler contents on the properties of warm asphalt–mineral filler mastics; and (3) determine the optimal *F*/*A* in order to optimize the high-temperature and low-temperature properties of warm asphalt–mineral filler mixtures containing Sasobit.

2. Preparation of material and laboratory testing

A typical petroleum asphalt used in heavy traffics was used in this research. Its properties are listed in Table 1. The bitumen was modified (adding 3% by weight) using Sasobit. Three types of mineral filler, Limestone filler (LM), Portland cement (PC), and Hydrated lime (HL), were used for preparing the warm asphalt mastic. The Portland cement and Hydrated lime are often utilized as anti-stripping agents to improve the resistance of asphalt mixture to moisture damage [22]. They are also used as mineral filler, functioning as both anti-stripping agents and mineral filler in asphalt mixture. All three types of mineral filler met the requirements in ASTM D242, Standard Specification for Mineral Filler for Bituminous Paving Mixtures. Each of the mineral filler was dry sieved on a No. 200 sieve, and only the minus No. 200 fraction was used in mixing with the asphalt binder. The fillers were conditioned in a 105 °C oven for 24 h to ensure moisture-free particle surfaces. Warm asphalt binders were transferred to the mixing container maintained at 120 °C. The mixer used was maintained at a constant mixing speed such that no voids were created during mixing. Filler was slowly added into the bitumen while stirring was maintained at 500 rpm for approximately 10 min. The dust-to-binder ratio, defined as the ratio of the mass of dust to the mass of binder in this study, is an important variable. When applicable, eight dust-to-binder ratios were considered in this study [i.e., 0 (without filler), 0.3, 0.6, 0.9, 1.2, 1.5, 1.8 and 2.1].

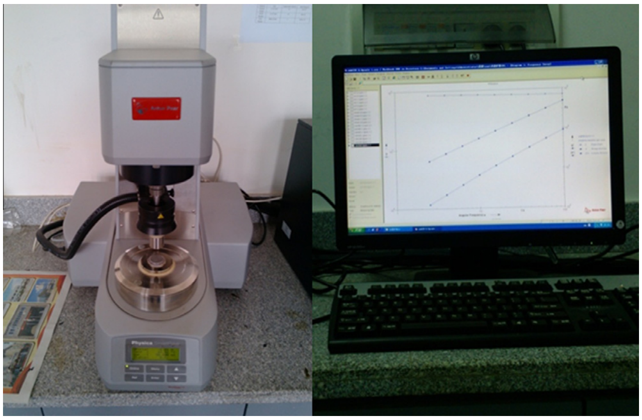

Fig. 1. DSR test machine.

Fig. 2. BBR test machine.

The DSR and BBR were used in this study to determine the rheological properties of warm asphalt–mineral filler mastics. DSR test samples were prepared according to the procedures described in Ref. [22]. The DSR test machine is shown in Fig. 1. The asphalt mastics were heated until it became sufficiently fluid to pour. Then they were poured into the silicone mold to get the required DSR test sample. The test was carried out with 25 mm diameter, 1 mm gap geometry between 30 °C and 80 °C. The BBR (Fig. 2) was applied to measure the creep response of mastics for a loading time from 8 s to 240 s at different temperatures. By loading the beam and measuring the deflection at the center of the beam continuously, the creep stiffness can be calculated as a function of the loading time and temperature.

3. Results and discussion

3.1. Evaluation of high-temperature performance

The DSR test was conducted to evaluation the high-temperature properties of the warm asphalt–mineral filler mastics at a frequency of 10 rad/s (1.59 Hz) and at a temperature of 60 °C. The values of the complex shear modulus (G^*) and the phase angle

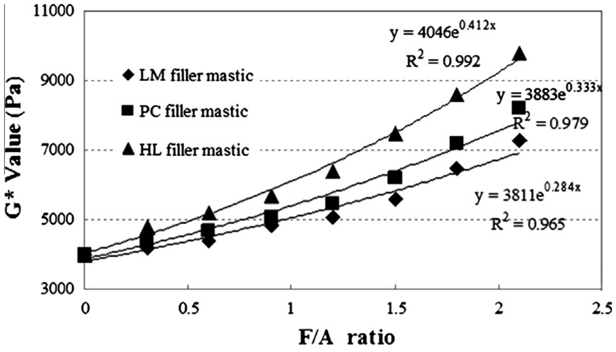

Fig. 3. G^* value versus *F*/*A* ratio by different fillers.