Construction and Building Materials 65 (2014) 330–337

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Analysing the effects of the mesoscopic characteristics of mineral powder fillers on the cohesive strength of asphalt mortars at low temperatures

Lv Dan [a,1], Zheng Chuanfeng [a,b,*], Qin Yong [a,1], Bi Heng [a,1], Li Keyao [a,1], Huang Junfei [a,1]

[a] College of Construction Engineering, Jilin University, Changchun 130026, China
[b] College of Traffic, Jilin University, Changchun 130021, China

HIGHLIGHTS

- The mineral powder fillers have influence on cohesive strength of asphalt mortars.
- Mesoscopic void have direct correlation with cohesive strength of asphalt mortars.
- Mesoscopic void can be tested by using infiltrating free-pressure water.

ARTICLE INFO

Article history:
Received 17 March 2014
Received in revised form 22 April 2014
Accepted 24 April 2014
Available online 23 May 2014

Keywords:
Asphalt mortar
Mineral powder filler
Mesoscopic characteristics
Cohesive strength

ABSTRACT

The mesoscopic characteristics of mineral powder fillers were tested, and their effects on the cohesive strength of asphalt mortars at low temperatures were analysed. The BT-1600 image particle analysis system was employed to test the mesoscopic grading, length-to-diameter ratio and circular degree of mineral powder fillers. Infiltrating free-pressure water was used to test mesoscopic void characteristics. Three kinds of asphalt mortars were prepared with different mineral powder fillers. Their low-temperature cohesive strengths were tested quantitatively according to a technology for testing tensile cohesive strength. Results showed that the differences in the mesoscopic characteristics of the three kinds of mineral powder fillers led to different low-temperature cohesive strengths of the three asphalt mortars, although their preliminary screening results were nearly the same. The mesoscopic void characteristics of mineral powder fillers can result from the combined effects of mesoscopic grading, length-to-diameter ratio, specific surface area and circular degree, among others. And it can also estimate the proportions of fixed and free asphalts. By using the mesoscopic void characteristics of mineral powder fillers as intermediaries based on the proportions of fixed and free asphalts, we can identify the effects of these characteristics on the low-temperature cohesive strength of asphalt mortars.

1. Introduction

Mineral powder fillers added to asphalt mixtures mainly include mineral powder, cement, lime and fly ash. Among these, conventional mineral powder is the most common [1,2]. Mineral powder fillers can be part of aggregates, filling in the space between mineral aggregates to enhance the mixture. Mineral powder fillers are currently combined with asphalt, thus resulting in the high continuity of asphalt mortar with mineral aggregates. Mineral powder fillers also increase the consistency of hot melting asphalt in cases of migration and leakage [3,4]. Thus, adding mineral powder fillers to conventional asphalt mixtures is necessary. Mineral powder has been used as an inert filling material in engineering. The amount of mineral powder is 6–8% in mineral aggregates, but its surface area accounts for 70–90% of the total mineral aggregates. Hence, adding mineral powder fillers influences the pavement performance of asphalt mortars. In recent years, numerous scholars have been studying the effects of mineral powder on the mechanical properties of asphalt mortar, such as rheological and creep properties [5–9].

Cracking of asphalt mixtures at low temperatures is among the main damages in road engineering [10]. The ultimate form of

* Corresponding author at: College of Construction Engineering, Jilin University, Changchun 130026, China. Tel.: +86 431 88502352; fax: +86 431 88502370.

E-mail addresses: lvdan@jlu.edu.cn (L. Dan), cfzheng0527@hotmail.com (Z. Chuanfeng), qinyong@jlu.edu.cn (Q. Yong), 903005116@qq.com (B. Heng), 398993084@qq.com (L. Keyao), 1959990401@qq.com (H. Junfei).

[1] Tel.: +86 431 88502352; fax: +86 431 88562370.

http://dx.doi.org/10.1016/j.conbuildmat.2014.04.123
0950-0618/

cracking in asphalt mixtures is the separation of mineral aggregate particles. Recent studies have shown that two failure modes occur on mineral aggregate contact surfaces during the separation of mineral aggregate particles. The first mode is the separation between the asphalt binder and the mineral aggregates, which is called adhesion failure destruction. The second mode is the destruction in the asphalt binder itself, which is called asphalt binder cohesion failure destruction [11–13]. The low-temperature cohesive strength of asphalt mortars significantly influences the low-temperature anti-cracking capability of asphalt mixtures.

With respect to using filling materials such as mineral powder, many countries have set certain requirements on the size distribution of mineral powder particles. For example, the cumulative passing rates of three sieve size measuring 0.075, 0.3 and 0.6 mm were determined. Our previous research showed that although the cumulative passing rates of mineral powder particles for the three sieve size measuring 0.075, 0.3 and 0.6 mm were the same, differences were found in the cohesive strength of asphalt mortars. Thus, we can conclude that the mesoscopic characteristics of mineral powder fillers influence the cohesive strength of asphalt mortars. The mesoscopic characteristics of filling materials, such as mineral powder, include mesoscopic grading, length-to-diameter ratio, specific surface area, circular degree and mesoscopic void characteristics. The effects of these parameters on the cohesive strength of asphalt mortars were evaluated in the present study.

2. Test materials and methods

2.1. Test materials

We selected three kinds of mineral powders from different workyards and called them Mineral powders I, II and III. All three mineral powders were limestone. After blending twice, we made the cumulative passing rates of the three kinds of mineral powders the same for the three sieve size measuring 0.075, 0.3 and 0.6 mm. The appearance of the mineral powders is shown in Fig. 1. Panjin 70# matrix asphalt and SBS-modified asphalt were used for the test. The fundamental performance parameters are listed in Table 1.

2.2. Test methods

The mesoscopic characteristics of the three kinds of mineral powders were analysed by the BT-1600 image particle analysis system (Fig. 2). The test parameters included the mesoscopic grading of the mineral powder filler, length-to-diameter ratio, specific surface area and the circular degree of particles. Before the test, we used a sampler for multipoint sampling in the container to make the sample representative. We made a suspension liquid with a certain concentration by mixing mineral powder samples with distilled water. In case of powder clusters, we used sodium pyrophosphate as dispersing agent and exposed the mineral powder suspension liquid to ultrasonic wave decentralised processing. We then collected samples and completed the test. The mesoscopic analysis images of the three kinds of mineral powder particles are shown in Fig. 3.

Existing studies have shown that we can describe the mesoscopic void characteristics of mineral powder fillers by using the technology for testing Rigden void fraction. For example, in European Norms (EN 1097-4), control parameters (Table 2) are used to test the mesoscopic voids of mineral powder fillers [14,15]. In this study, we chose infiltrating free-pressure water to test the mesoscopic void characteristics of the three kinds of mineral powders. Mineral powder sample (10 g) was placed in a 25 ml graduated cylinder after dry processing, and the initial volume was determined. Distilled water (10 ml) was placed in another graduated cylinder. The mineral powder sample was infiltrated by free-pressure water by using a dropper. When an unchanging water film formed on the surface of the mineral powder sample, we obtained the mesoscopic void characteristics of the mineral powder sample by measuring the reduced volume of distilled water. The test process is illustrated in Fig. 4. The effect of the mesoscopic characteristic parameters, including the mesoscopic grading of the mineral powder filler and the circular degree of the particles, resulted in different initial volumes of various kinds of mineral powders with the same mass. Given a 10 g mineral powder sample, the initial volume of Mineral powder I was 13.5 ml, that of Mineral powder II was 8.5 ml and that of Mineral powder III was 9.7 ml. Thus, we used the ratio of mineral powder void volume to mineral powder quality to describe the mesoscopic void characteristics of the mineral powders, i.e., the void in mineral powder per unit mass, which is denoted as V_m.

We designed and conducted a quantitative test for the low-temperature cohesive strength of asphalt mortars [16]. The test temperature was −15 °C, the asphalt film thickness was 1 mm and the geometric size of the mineral aggregate contact surface was 2.0 cm × 1.8 cm. An HC-40 force measuring device was used to measure failure load, F, when cohesion failure destruction occurred in asphalt mortars. According to the corresponding relation among the cohesive strength of asphalt mortar (R_c), cohesion failure zone area (S_c) and failure load (F) [refer to Formula (1)], we could obtain the low-temperature cohesive strength of different types of asphalt mortars at −15 °C. The test process is shown in Fig. 5.

$$R_c \times S_c = F \tag{1}$$

In the formula, R_c is the cohesive strength of the asphalt binder, S_c is the cohesion failure zone area of the asphalt binder (when asphalt film thickness was 1 mm, the failure destruction of asphalt film was the total cohesion failure destruction; both S_c and the mineral aggregate contact surface area were 3.6 cm^2) and F is the tensile failure load.

Table 1
Technical parameters of asphalt.

Asphalt	Penetration (0.1 mm)		15 °C Ductility (cm)	Softening point (°C)	Standard viscosity (Pa s)	
	5 °C	25 °C			60 °C	90 °C
Panjin 70# asphalt	6.8	75.3	>15	42.6	960	600
SBS-modified asphalt	7.5	97.2	>15	44.7	6246	3820

3. The test results

3.1. The test results for mesoscopic grading, specific surface area, length-to-diameter ratio and circular degree

Using the BT-1600 image particle analysis system, tests were conducted for the mesoscopic characteristic parameters of Mineral powders I, II and III. The tests included mesoscopic grading of mineral powders, length-to-diameter ratio of the particles, specific surface area of mineral powders and circular degree of the particles. In Mineral powder I, the number of particles was 3163, the largest grain size was 131.94 μm and the smallest grain size was 9.55 μm. In Mineral powder II, the number of particles was 3705, the largest grain size was 141.99 μm and the smallest grain size

Fig. 1. Mineral powders I, II and III.