Research on the Influence of Microwave Filler on the Performance of Recycled Asphalt Mixture

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Abstract. In order to study the effect of different microwave fillers on the performance of microwave reclaimed asphalt mixture, carbon black with 10% by volume of asphalt and steel fiber with 6% volume fraction of asphalt were respectively formed by microwave induction method 30%, 40%, 50%. Recycled Asphalt Mixture (RAP) with water-immersed Marshall, uniaxial penetration, four-point bending fatigue for water stability, high temperature stability, fatigue resistance the study. The results show that the asphalt mixture test piece formed by microwave heating has better high temperature stability, water stability, fatigue resistance than the test piece formed by the conventional heating method. The microwave-induced reclaimed asphalt mixture with 40% RAP content has the best high temperature stability. For the performance of high temperature stability, it is better to add steel wool fiber as microwave filler, and the carbon black is used as microwave. Compared with steel fiber, the filler is superior to the water-stable and anti-fatigue of the recycled asphalt mixture under microwave induction.

1. Introduction

Asphalt mixture recycling (RAP) thermal recycling has received more and more attention. How to improve the performance of recycled asphalt mixture is the current research focus.

Al-Ohaly [1] and others carried out an experimental study on the effect of microwave heating on the performance of asphalt mixtures. The results show that the microwave-treated asphalt mixture has improved the adhesion between asphalt and aggregate, and has very good water damage resistance. Great improvement; Bian Tuo [2] and others used microwave heating to test the dehumidification effect of old asphalt mixtures. The results showed that microwave has excellent dehumidification ability and heating efficiency for old asphalt mixtures; Xue Liang et al. [3] analyzed the effects of microwave and infrared heating on high temperature deformation characteristics, low temperature crack resistance, water stability and fatigue resistance of asphalt mixtures. The results show that the asphalt asphalt mixtures have better road performance than infrared heated asphalt mixtures after microwave heating.

It is generally believed that the microwave heating characteristics of asphalt mixtures are weak, and materials with better microwave absorption properties need to be added to improve their performance. Carbon fiber [4], steel wool fiber [5], carbon black [6] and other materials are often used as external wave absorbing fillers in asphalt mixtures. In this paper, steel wool fibers and carbon black are used as microwave fillers. It is planned to use microwave heating to prepare recycled asphalt mixtures. The immersion Marshall test, uniaxial penetration test, four-point bending fatigue test, and ideal cracking
test (IDEAL-CT) are used. Investigate its water stability, high temperature stability, fatigue resistance and crack resistance.

2. Test materials

2.1. Asphalt Mixture Recycling Material

The used asphalt mixture recycled material (RAP) is derived from the physical engineering of the Yongjiang section of S356 (the highway along the river). In this project, the old pavement is crushed and milled in layers. The thickness of the upper layer of the milling is 5 cm. One RAP sample is selected every 500 meters, and a total of four RAPs are selected. After centrifugal extraction test of the RAP material, the average asphalt content is 4.28%, and the performance indicators are checked. The results are shown in Table 1. The ore materials after the asphalt extraction are sieved. The sieving results are shown in Table 2.

| Index test results of old asphalt |
|----------------------------------|
| 25°C Penetration/(0.1 mm) | Softening Point/°C | 135°C Rotational viscosity/(Pa · s) |
| 38.2 | 57.43 | 1.759 |

Table 2. Old aggregate screening results

| Sieve/mm | 16 | 13.2 | 9.5 | 4.75 | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 |
|----------|----|------|-----|------|------|-----|----|----|-----|------|
| Passing rate/% | 100 | 93.74 | 80.96 | 46.62 | 32.43 | 23.43 | 13.79 | 9.7 | 5.48 | 3.13 |

2.2. New aggregate and new asphalt

The new asphalt is I-C type SBS modified asphalt, and its relevant technical indicators meet the requirements of the specification after testing. The aggregate used in the experiments in this paper is limestone, and the filler is ground limestone. And use steel wool fiber and carbon black as microwave filler

2.3. Synthetic gradation

Adopt AC-13 as the design gradation of the recycled asphalt mixture, in which the RAP content is 30%, 40%, and 50%, respectively. Based on the sieving results of the new aggregate and the old aggregate in the RAP, the synthetic gradation is achieved to achieve The gradation design requirements of AC-13, the synthetic gradation curve is shown in Figure 1.

Figure 1. Gradation curve of recycled asphalt mixture

2.4. Best oil-stone ratio

The Marshall test design method was used to determine the optimal oil-stone ratio of AC-13 recycled asphalmine the oil-stone ratios a1, a2, a3, and a4 corresponding to the maximum gross volume relative density, the maximum Marshall stability maximum, the median porosity specification,
and the asphalt mixture. The test measures the flow value, porosity, asphalt saturation, gross volume density, and stability of standard compacted specimens under specified conditions of temperature and humidity, and plots the oil-stone ratio to the maximum gross volume relative density, Marshall stability, porosity, and pitch saturation curves. Then determine the median asphalt saturation specification, and determine OACmax, OACmin, OAC1, and OAC2. The optimal oil-stone ratio of OAC of the asphalt mixture is obtained. The test results are shown in Table 3.

| RAP Mixing ratio | a2  | a3  | a4  | OAC1 | OACmax | OACmin | OAC2 | OAC  |
|------------------|-----|-----|-----|------|--------|--------|------|------|
| 30%              | 5.00| 4.50| 5.00| 4.80 | 5.10   | 4.40   | 4.75 | 4.78 |
| 40%              | 4.90| 4.35| 4.20| 4.64 | 4.30   | 4.10   | 4.20 | 4.42 |
| 50%              | 4.40| 4.25| 4.00| 4.44 | 4.30   | 4.00   | 4.15 | 4.29 |

It can be known from Table 3 that the optimal oil-stone ratios of recycled asphalt mixtures with 30%, 40%, and 50% RAP content are 4.78%, 4.42%, and 4.29%, respectively. Steel wool fibers and carbon black have strong oil absorption capacity. For steel wool fiber recycled asphalt mixture, according to the research results in reference [7], the optimal oil-stone ratio needs to be adjusted upward by 0.2%; then adjust its optimal oil-stone ratio according to the method in reference [8].

### 2.5 Specimen preparation

1) Traditional hot recycled asphalt mixture

   Traditional heating method: pre-heat RAP, new aggregate and mineral powder in a constant temperature oven at 165 °C for 4 hours before mixing, and heat the SBS modified asphalt in a constant temperature oven to 165 °C. When mixing, first place the RAP in a 165 °C mixing pan and add steel wool fiber or carbon black and stir for 90s, then add new aggregate and mix for 90s, then add SBS modified asphalt and mix for 90s, and finally add ore powder for 90s. After taking out the asphalt mixture forming test piece.

2) Microwave-induced recycled asphalt mixture

   Microwave heating method: pre-heat the new aggregate and mineral powder in a constant temperature oven at 165 °C for 4 hours before mixing, and heat the SBS modified asphalt in a constant temperature oven to 165 °C. When mixing, first place the RAP in a custom microwave oven to 150 °C ~ 155 °C, put it into a 165 °C mixing pot and add steel wool fiber or carbon black for 90s, then add the new aggregate and mix for 90s, then add SBS The modified asphalt is mixed for 90s, and then the ore powder is added for 90s. Finally, the mixed recycled asphalt mixture is placed in a microwave oven for intermittent heating—after 3 minutes of heat preservation (microwave for 30s, pause for 30s), the asphalt mixture is formed into a test piece.

### 3 Test results and discussion

#### 3.1 High temperature stability

In this test, the uniaxial penetration strength was selected as the evaluation index of the high-temperature performance of the recycled asphalt mixture. The uniaxial penetration strength test is carried out in accordance with the method for testing the uniaxial penetration strength of asphalt mixtures in the "Code for Design of Highway Asphalt Pavements" (JTG D50-2017) (Appendix F). The test results are shown in Figure 2.
Figure 2. Uniaxial penetration strength test results

As shown in Figure 2 (a), no matter the steel wool fiber or carbon black is used as the microwave filler, the recycled asphalt mixture formed by microwave heating has a uniaxial penetration strength compared with the recycled asphalt mixture formed by traditional heating. It can be seen from Figure 2 (b) that no matter the externally added steel wool fiber or carbon black is used as the microwave filler, the microwave-induced recycled asphalt mixture with the 40% RAP content has the best high-temperature stability. According to the penetration strength results, at the same RAP content, the penetration strength of the recycled asphalt mixture formed from steel wool fibers as microwave filler is higher than that of recycled asphalt mixture formed from external carbon black, so it can be considered that for high temperature stability this in terms of performance, it is better to add steel wool fiber as microwave and microwave filler.

3.2. Water stability

An important index to evaluate the water stability of the recycled asphalt mixture by using the immersed Marshall residual stability. The test was carried out according to the method of "Testing Rules for Highway Engineering Asphalt and Asphalt Mixture" (JTG E20-2011) T0709. The results of the Marshall test of steel wool fibers and carbon black recycled asphalt mixtures with RAP content of 30%, 40%, and 50% are shown in Figure 3.
It can be seen from Fig. 3 (a) that under the 40% Rap content, the steel fiber recycled asphalt mixture and carbon black recycled asphalt mixture formed by microwave heating have higher residual stability than the recycled asphalt formed by traditional heating. The mixture means that the test piece formed by microwave heating has better water stability. As shown in Figure 3 (b), as the RAP content increases, the carbon black and steel wool fiber recycled asphalt are mixed by microwave induction molding. The immersion residual stability MS0 of the materials all showed a decline. This is due to the increase in the amount of old materials leading to an increase in the content of old asphalt. The aged asphalt has a poor resistance to deformation. In addition, the adhesion between the old asphalt and the aggregate is poor. Water penetrates the surface of asphalt and minerals more easily, and then appears as water damage. From the results of residual stability, it can be known that the water stability of recycled asphalt mixtures using carbon black as a microwave filler is better than that of microwave-induced steel fiber recycled asphalt mixtures.

3.3. Anti-fatigue performance

This paper uses a controlled strain mode to perform a four-point bending fatigue test. The test is performed in accordance with the provisions of the "Testing Rules for Highway Engineering Asphalt and Asphalt Mixtures" (JTG E20-2011) T0739. The test temperature is 15 $^\circ$C ± 0.5 $^\circ$C, the loading frequency is 10Hz ± 0.1Hz, and the test is terminated when the bending stiffness modulus of the test piece drops to half of the initial stiffness modulus. For SBS modified asphalt, the minimum tensile strain is 400 $\mu$ε, so the values of the strain control level selected in this study are 450$\mu$ε, 650$\mu$ε, and 850$\mu$ε. Take the experimental results at 450$\mu$ε as an example, as shown in Figure 4.

From Fig. 4 (a), it can be known that at 450$\mu$ε strain level, the RAP content of the steel wool fiber recycled asphalt mixture test piece formed by microwave heating is 40%. The ratio is increased by 31.3%, and the number of fatigue effects of carbon black recycled asphalt mixture specimens is increased by 108.1%. From Figure 4 (b), it can be seen that the fatigue life values of the microwave-induced recycled asphalt mixture with steel wool fiber and carbon black added have a decreasing trend with the increase of RAP content. As the content of asphalt increases, relatively speaking, the content of new asphalt continues to decrease, which in turn leads to a decrease in the bonding performance between asphalt and minerals. As the amount of RAP increases, the decline in fatigue resistance becomes more apparent. In addition, because the trabecular specimen cannot control the void ratio of the specimen, the data shows a certain degree of dispersion, but it is not difficult to see that the fatigue resistance of the recycled asphalt mixture formed with carbon black as the microwave filler is more excellent.
4. Conclusion

Compared with the test piece formed by the traditional heating method, the test piece of the asphalt mixture formed by the microwave heating method has better high temperature stability, water stability, fatigue resistance and crack resistance.

The microwave-induced recycled asphalt mixture with 40% RAP content has the best high-temperature stability. For the performance of high-temperature stability, it is better to add steel wool fibers as microwave and microwave filler.

Compared with steel wool fiber, externally added carbon black as microwave filler has more significant water stability, fatigue resistance, and moderate temperature for recycled asphalt mixtures under microwave induction.

Carbon black recycled asphalt mixture with 40% RAP content has the best road performance.

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