Recycled Micro Surfacing Based on RAP Refined Separation Process

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Abstract. To achieve high value utilization of reclaimed asphalt pavement materials (RAP), RAP with refined separation was applied to the recycled micro surfacing (the coarse and fine aggregates of micro surfacing coming from RAP), achieving efficient integration of RAP and micro surfacing. The gradation curves were designed based on MS-3 micro surfacing, and the influence of water consumption was explored on the mixing time of recycled micro surfacing mixture. In addition, the influence of modified emulsified asphalt dosage was analysed on the cohesion, wet-track abrasion loss, and sand adhesion of the recycled micro surfacing mixture. The results show that the mixing time of the recycled micro surfacing mixture gradually increases with increasing of water consumption, and the water consumption should not be less than 7%. The cohesion increases with the prolongation of curing time, and the initial setting time and open traffic time of the recycled micro surfacing mixture should be set at 60min and 90min, respectively. As the modified emulsified asphalt dosage increases, the wet-track abrasion loss of the recycled micro surfacing mixture gradually decreases, and the sand adhesion gradually increases. The dosage of modified emulsified asphalt for MS-3 micro surfacing mixture should be controlled between 6.3%-7.2%, and the optimal dosage of modified emulsified asphalt is 6.85%.

Keywords: asphalt pavement, micro surfacing, recycled asphalt pavement materials, refined separation

1 Introduction

According to calculations, China produces nearly 200 million tons of reclaimed asphalt pavement materials (RAP) annually only for major and medium maintenance projects on trunk highways. These waste materials not only occupy valuable land resources, but also cause damage and pollution to the surrounding ecological environment. [1-3] The country has promoted the recycling and comprehensive utilization of waste materials at the policy level, promoting the transformation of transportation development from pursuing speed and scale to paying more attention to quality and efficiency. [4]

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Micro surfacing has the advantages of fast construction, simple process, resource conservation, and low pollution. It can not only repair many road diseases, but also improve the skid resistance, wear resistance, and waterproof performance of the road surface. [5-6] Micro surfacing is suitable for preventive maintenance projects of various levels of highway pavement. [7-8] Recently, more and more scholars are paying attention to how to apply RAP to micro surfacing maintenance engineering with high quality. [9-10]

This article introduces a recycled micro surfacing based on refined separation process. The coarse and fine aggregates used in the recycled micro surfacing are all sourced from refined separation RAP. The refined separation RAP, modified emulsified asphalt, mineral powder, cement and other materials are used to prepare recycled micro surfacing according to the designed mix ratio, and the recycled micro surfacing mixtures meet the performance requirements of specifications. This study achieved efficient utilization of RAP and reduced the cost of micro surfacing engineering, which is beneficial for promoting the green development of highways.

2 Raw material

2.1 Refined separation RAP

The RAP was crushed and divided into three levels (0-3mm, 3-5mm, 5-10mm) through refined separation process. The refined separation RAP is shown in Figure 1. The refined separation RAP was screened and extracted to obtain the particle composition and asphalt content, and the test results are shown in Table 1.

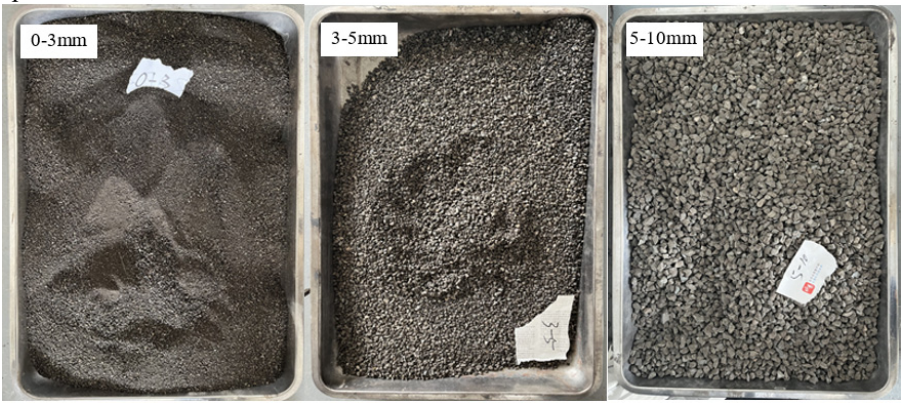

Fig. 1. Refined separation RAP.

Table 1. Results of sieve and extraction test for refined separation RAP.

Particle size/mm	Asphalt content /%	Percentage of sieve (mm) passing/%								
		13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
5-10	1.33	100	99.1	3.1	0.4	0.4	0.4	0.4	0.4	0.2
3-5	1.91	100	100	94.6	11.2	8.1	4.8	2.1	1.1	0.4
0-3	7.93	100.0	100.0	100.0	100.0	67.5	46.7	24.8	10.2	3.3

2.2 Modified emulsified asphalt

The modified emulsified asphalt was prepared in the laboratory. The emulsifier (63D) and SBR modifier (1469) are sourced from Ingevity Investment Co., Ltd. The test results of modified emulsified asphalt are shown in Table 2.

Table 2. Test results of modified emulsified asphalt.

Test items		Requirement	Test results
Residual on sieve（0.6mm）/%		≤0.1	0.02
Engler viscosity E_{25}		3~30	8.6
Storage stability 1d/%		≤1	0.4
Storage stability 5d/%		≤5	2.6
Residue content/%		≥60	62.1
Residue by evaporation	Penetration at 25℃/0.1mm	40~100	73
	Softening point/℃	≥53	57.3
	Ductility at 5℃/ cm	≥20	＞100
	Solubility/%	≥97.5	99.4

2.3 Cement and mineral powder

The cement (42.5 ordinary Portland cement) comes from Hebei Jinyu Dingxin Cement Co., Ltd. The mineral powder comes from Beijing Municipal Road and Bridge Building Materials Group Co., Ltd.

2.4 Rejuvenating agent

HRA-2 asphalt rejuvenating agent comes from Xi'an Huaze Road Materials Co., Ltd. Its technical indicators are shown in Table 3.

Table 3. Test results of asphalt rejuvenating agent.

Test items	Requirement	Test results
Appearance	—	Brown black viscous liquid
Flash point /℃	≥220	234
Saturation content /%	≤30	16.6
Aromatic content /%	≥60	63.7
Viscosity ratio before and after thin film oven test	≤3	1.59
Quality change after thin film oven test /%	≤4, ≥-4	1.8
Density 15℃/(g/m^3)	Test value	0.960

3 Recycled micro surfacing mixtures gradation

Based on the screening results of refined separation RAP and mineral powder, combined with the MS-3 gradation control range, composite gradation curves were obtained. Among them, the composite gradation 1 is the conventional gradation, and the composite gradation 2 is the extracted particle composition (sieve test results after 0-3mm RAP extraction). The composite gradation curves are shown in Figure 2, and the mix ratio of each material is shown in Table 4.

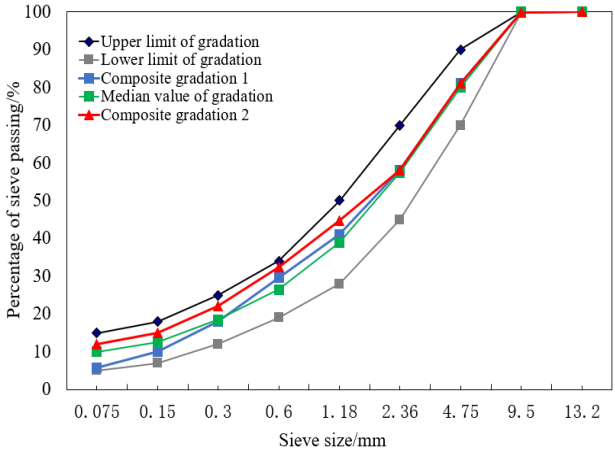

Fig. 2. Composite gradation of recycled micro surfacing mixture.

Table 4. Ratio of materials for recycled micro surfacing mixture.

Materials	RAP 5-10mm	RAP 3-5mm	RAP 0-3mm	Mineral powder	Cement	Rejuvenating agent
Ratio/%	18	27	50	5	2	0.4 (mixture)

As shown in Figure 2, the percentage passing of the smaller sieve in the composite gradation 1 is close to the lower limit of the MS-3 gradation range. When using the extracted particle composition of 0-3mm RAP for composite gradation 2, the percentage passing of the smaller sieve significantly increased, but it is still within the range of MS-3 gradation range. This is mainly due to the presence of a large number of fine particles in the 0-3mm refined separation RAP, which form "fake aggregates". In the gradation design, these fine particles cannot be completely equivalent to the new aggregates, but the presence of fine particles in the 0-3mm RAP cannot be ignored. Therefore, in the gradation design of recycled micro surfacing, the fine material of conventional gradation (without extracted) was kept close to the lower limit of the gradation range. When the composite gradation adopts the extracted particle composition from RAP (0-3mm), the composite gradation should be below the upper limit of gradation range.

4 Road performance of recycled micro surfacing mixture

4.1 Mixing time test

The mixing time of the micro surfacing mixture is influenced by multiple factors such as water consumption, emulsified asphalt dosage, and cement dosage. The water consumption has the greatest impact on mixing time. The experiment adjusted the water consumption to test the mixing time of the recycled micro surfacing mixture under the 7% modified emulsified asphalt dosage and 2% cement dosage. The test results are shown in Figure 3.

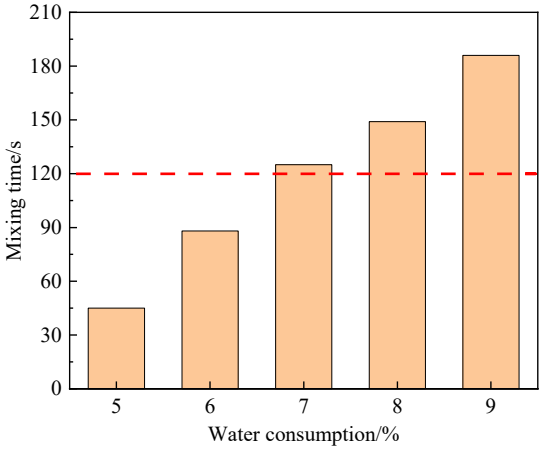

Fig. 3. Mixing time of mixture with different water consumption.

As shown in Figure 3, the mixing time of the micro surfacing mixture gradually increases with the increase of water consumption. When the water consumption reaches 7%, the mixing time of the micro surfacing mixture reaches 129s. In order to ensure sufficient mixing time for the micro surfacing mixture, the "technical specifications of micro surfacing for pavement" (T/CECS G: M53-02-2020) requires that the mixing time for Class B micro surfacing should not be less than 120s. Therefore, when the amount of modified emulsified asphalt and cement does not change significantly, the water consumption for the recycled micro surfacing should not be less than 7%.

4.2 Cohesion test

The cohesion test is mainly used to determine the initial setting time and open traffic time of the micro surfacing mixture. The experiment tested the cohesion of the micro surfacing mixture at different curing times, and the test results are shown in Figure 4.

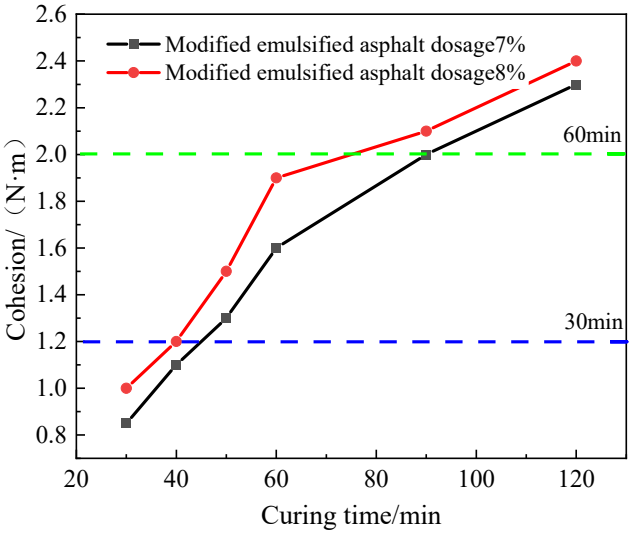

Fig. 4. Cohesive of recycled micro surfacing mixture.

As shown in Figure 4, with the extension of time, the cohesion of the micro surfacing mixture gradually increases. By comparing the cohesion of different modified emulsified asphalt dosages, it was found that increasing the modified emulsified asphalt dosages is beneficial for increasing the cohesion of micro surfacing mixtures. However, when the amount of modified emulsified asphalt reaches 8%, the cohesion at 30min and 60min are 1.0N·m and 1.9N·m, respectively. The test results still cannot meet the specification requirements of cohesion (not less than 1.2N·m (30min) and 2.0N·m (60min)). This is mainly due to the amount of modified emulsified asphalt significant decrease used in the recycled micro surfacing compared to the new aggregate micro surfacing. The amount of new asphalt has decreased, and the old asphalt has temporarily not played a binder role. But as the curing time is extended for 30min, the micro surfacing adhesion meets the specification requirements. Therefore, for recycled micro surfacing, it is advisable to adjust the cohesion testing time appropriately. It is recommended to set the initial setting time and open traffic time to 60min and 90min respectively.

4.3 Wet-track abrasion test

The wet-track abrasion test is mainly used to test the compatibility and water damage resistance of the formed micro surfacing mixture. The wet-track abrasion loss (1h and 6d) of micro surfacing mixture with different dosages of modified emulsified asphalt is shown in Figure 5.

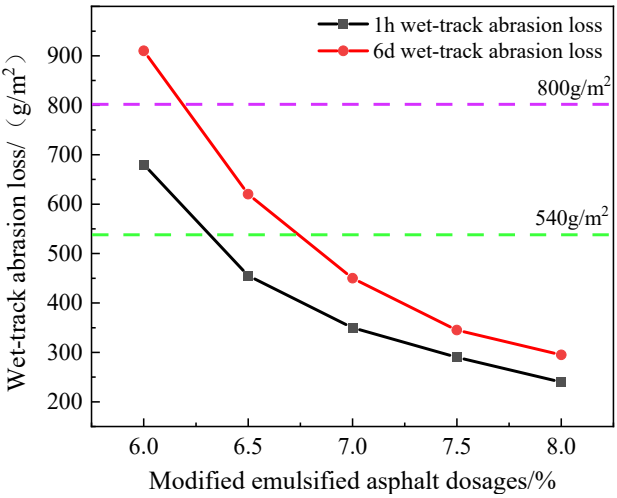

Fig. 5. Wet-track abrasion loss of micro surfacing mixture.

As shown in Figure 5, as the dosages of modified emulsified asphalt increases, the wet-track abrasion loss (1h and 6d) of the micro surfacing mixture gradually decreases. The "technical specifications of micro surfacing for pavement" (T/CECS G: M53-02-2020) requires that the wet-track abrasion loss of Class B micro surfacing for 1 hour and 6 days should not be less than 540g/m^2 and 800g/m^2, respectively. Therefore, the dosage of modified emulsified asphalt for recycled micro surfacing mixture should not be less than 6.3% (the modified emulsified asphalt evaporated residue content 62.1%).

4.4 Load wheel sand adhesion test

The load wheel sand adhesion test is mainly used to control the upper limit of asphalt content in the micro surfacing mixture. The results of the load wheel sand adhesion test are shown in Figure 6.

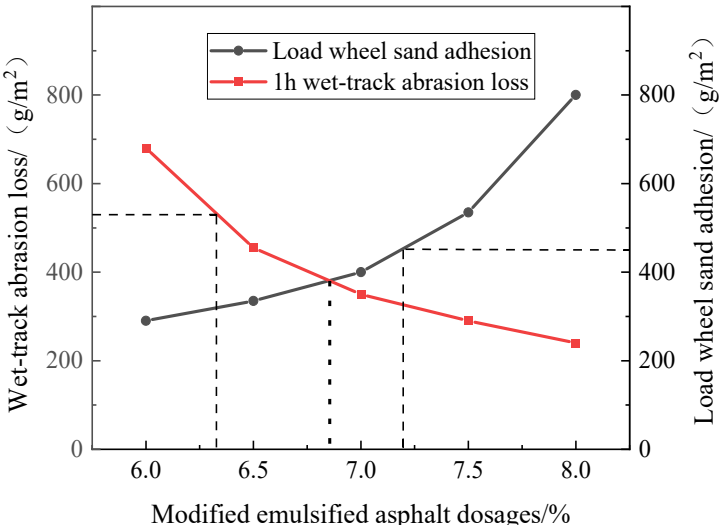

Fig. 6. Load wheel sand adhesion of micro surfacing mixture.

As shown in Figure 6, as the dosages of modified emulsified asphalt increases, the load wheel sand adhesion gradually increases. The "technical specifications of micro surfacing for pavement" (T/CECS G: M53-02-2020) requires that the sand adhesion of Class B micro surfacing should not exceed 450g/m^2. According to the specification requirements, the amount of modified emulsified asphalt should not exceed 7.2%. By combining the curve of the 1h wet-track abrasion loss, the dosages of modified emulsified asphalt in the micro surfacing mixture should be controlled between 6.3%-7.2%. According to the mix design method of the "technical specifications of micro surfacing for pavement" (T/CECS G: M53-02-2020), the optimal dosage of modified emulsified asphalt is 6.85% for recycled micro surfacing mixture.

5 Conclusion

(1) In the gradation design of recycled micro surfacing, the fine material of conventional gradation (without extracted) was kept close to the lower limit of the gradation range. When the composite gradation adopts the extracted particle composition from RAP (0-3mm), the composite gradation should be below the upper limit of gradation range.

(2) The mixing time of the recycled micro surfacing mixture gradually increases with the increase of water consumption, and the water consumption should not be less than 7%. The cohesion increases with the prolongation of curing time, and the initial setting time and open traffic time of the recycled micro surfacing mixture should be set at 60min and 90min, respectively.

(3) As the dosages of modified emulsified asphalt increases, the wet-track abrasion loss of the recycled micro surfacing mixture gradually decreases, and the load wheel

sand adhesion gradually increases. According to the results of wet-track abrasion test and load wheel sand adhesion test, the dosage of modified emulsified asphalt for MS-3 recycled micro surfacing mixture should be controlled between 6.3%-7.2%, and the optimal dosage of modified emulsified asphalt is 6.85%.

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