Evaluation of Anti-Abrasion Performance for High-Performance Micro Surfacing Mixture

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Abstract. Methods to evaluate the anti-abrasion performance of a high-performance micro surfacing (HMS), including the wet-track abrasion test (WTAT) and initial curing abrasion test (ICAT), were studied, and the long-term and initial anti-abrasion performances of the HMS were evaluated. The ICAT is a new method, and the test results were used to evaluate the initial compaction properties of the HMS mixture. Specifically, this method simulates the contact state between the tire and road surface at the initial period when the road was opened for traffic after the micro surfacing treatment via the friction between a rubber tube and the mixture. Four typical modified emulsified asphalts were selected for the WTAT and ICAT. Based on the test results, two modified emulsified asphalts were selected to explore the effects of different amounts of added styrene butadiene rubber (SBR) modifiers on the wet-track abrasion loss and the effects of different abrasion times on the initial curing abrasion loss. Based on the results of the WTAT, it is recommended that the wet-track abrasion loss values of the HMS mixtures soaked in water for 1 h and 6 d are not higher than 360 and 480 g/m\textsuperscript{2}, respectively. The initial curing abrasion loss (ICAL) indicates that it is feasible to use the ICAT to evaluate the initial compaction properties of the micro surfacing and can be used to guide the HMS design. The results of the WTAT and ICAT showed that the HMS had a better initial compaction capability and durability than the conventional micro surfacing.

1. Introduction
Micro surfacing treatment, as an effective preventive maintenance measure for highways, has the characteristics of a simple construction process, low cost, low pollution, and fast construction speed [1-2]. Furthermore, it can improve the skid-resistance, anti-abrasion, and waterproofing properties, increase the road surface smoothness, and enhance the visual appearance of the road [3-5]. Therefore, micro surfacing treatment has been widely used in highway pavement preventive maintenance projects. However, in recent years, some issues have been found in the application process. Particularly in some special road sections and micro-surfaced roads built in special environments, severe peeling-off, cracking, raveling, and polishing have occurred in one year or less after project completion [6], limiting the promotion and application of micro surfacing technology to a certain extent.

To address this problem, researchers have conducted numerous studies to develop high-performance micro surfacing (HMS) with better anti-abrasion performances. Kuang prepared an HMS material, whose abrasion resistance and moisture damage resistance were about 60\% higher than that of conventional micro surfacing mixtures [7]. By adding modifiers, the skid resistance and abrasion resistance of the micro surfacing were greatly improved [8]. The addition of fibers to the micro surfacing
mix could improve the abrasion and skid resistances of the micro surfacing [9]. The road performance indicators of the developed high-performance rubber micro surfacing were considerably better than those of the conventional micro surfacing [10]. Many achievements have been made in the study of HMS, but the conventional micro surfacing test methods and technical requirements are still used in the evaluation of HMS, which do not reflect the advantages of HMS and are not conducive to the technical progress of micro surfacing. In addition, the initial compaction condition of the micro surfacing mixture directly affects the subsequent performance after the road is opened for traffic, and it is necessary to evaluate the anti-abrasion capability of HMS during the initial curing period. However, there have been few studies on methods for evaluating the abrasion resistance of HMS.

This article focuses on a method to evaluate the abrasion resistance of HMS. A wet-track abrasion test (WTAT) was used to study the moisture damage resistance and abrasion resistance of HMS. In addition, an innovative initial curing abrasion test (ICAT) for the micro surfacing was proposed, and the applicability of using this test method for evaluating the initial compaction and anti-abrasion capabilities of HMS was explored. These results can provide a reference for the development and application of HMS.

2. Experimental

2.1. Raw Materials and Equipment

2.1.1. Modified emulsified asphalt: Four typical modified emulsified asphalts were selected, and they were labelled WB-I, WB-II, WB-III, and WB-IV, of which WB-I and WB-II were used in the HMS and WB-III and WB-IV were used in the conventional micro surfacing. The properties of the four modified emulsified asphalts are shown in Tab. 1.

| Test item                                      | Unit   | WB-I         | WB-II         | WB-III        | WB-IV         | Test method [11] |
|-----------------------------------------------|--------|--------------|--------------|--------------|--------------|-----------------|
| Charge                                        | -      | Cation       | Cation       | Cation       | Cation       | T0653           |
| Engler viscosity E25                         | -      | 8.84         | 8.92         | 6.26         | 8.31         | T0622           |
| Content of evaporation residue %             | %      | 63.9         | 64.0         | 64.4         | 63.7         | T0651           |
| Penetration index of evaporation residue 25°C| 0.1 mm | 59.8         | 59.5         | 62.5         | 58.5         | T0604           |
| Softening point of evaporation residue °C    |        | 58.8         | 59.6         | 58.1         | 57.9         | T0606           |
| Ductility of evaporation residue 5°C         | cm     | >100         | >100         | 45           | >100         | T0605           |
| Storage stability 1 d %                      | %      | 0.6          | 0.7          | 0.7          | 0.5          | T0655           |
| Storage stability 5 d %                      | %      | 0.9          | 1.3          | 1.9          | 0.9          | T0655           |

2.1.2. Mineral aggregate gradation: Tab. 2 shows the mineral aggregate gradation used in the micro surfacing mixture.

| Sieve diameter | Mass fraction (%) passing through the following sieve holes (mm) |
|----------------|---------------------------------------------------------------|
| 9.5            | 4.75 2.36 1.18 0.6 0.3 0.15 0.075                              |
| Gradation range| 100 70–90 45–70 28–50 19–34 12–25 7–18 5–15                  |
| Median value of gradation | 100 80 57.5 39 26.5 18.5 12.5 10                              |
| Designed gradation | 100 75 56 36 26 19 14 11                                      |
2.1.3. Abrasion test equipment: The wet-track abrasion tester (TH98 model) used in the WTAT was manufactured by Tangshan Hongyuan Engineering Machinery Co. Ltd. The weight, revolution speed, and rotational speed of the abrasive head were 2270 g, 142 r/min, and 61 r/min, respectively. The raveling tester (HL-120) used in the ICAT was manufactured by Jiaxing Mide Machinery Co., Ltd. The weight, revolution speed, and rotational speed of the abrasive head were 616 g, 105 r/min, and 46 r/min, respectively.

2.2. Preparation of Abrasion Test Specimens

2.2.1. Preparation of WTAT specimens: The WTAT specimens were prepared in accordance with the T0752 preparation method in Testing Procedures for Asphalt and Asphalt Mixtures of Highway Engineering (JTG E20-2011) [11], which is similar to the ISSA TB-100 standard.

2.2.2. Preparation of ICAT specimens: The ICAT is a new test method for evaluating the initial compaction properties of the micro surfacing mixture. The sample preparation method was as follows. First, the mineral material was dried, and then the mineral material that met the gradation requirements (not necessary to pass 4.75 mm sieve) was placed in a mixing pot, following by adding water. After the mixture was evenly mixed, modified emulsified asphalt was added, the mixture was mixed evenly, and the mixed slurry was poured into a test mold (280-mm diameter and 13.5-mm thickness). After the excess material was quickly scraped off to obtain a flat surface, the mold was removed, and the specimen was immediately placed in a chamber with constant temperature (25°C) and humidity (70%) for curing. The mixing time did not exceed 30 s during the preparation process of the test specimen. The optimized ratio of each mineral component of the slurry mixture, modified emulsified asphalt, and water was 1500:97.5:156.

3. Test Methods

3.1. WTAT

The WTAT was performed in accordance with the T0752 test method described in the “Testing Procedures for Asphalt and Asphalt Mixtures of Highway Engineering” (JTG E20-2011) [11].

3.2. ICAT

The mixture test specimen cured for 1 or 2 h in the constant temperature and humidity chamber was removed, and the test specimen mass (mₐ) was obtained after weighing. The sample tray containing the test specimen was subsequently fixed on a raveling tester. The raveling tester was started, and the abrasive head rotated for 300 ± 2 s before it was stopped. The test specimen was then removed, the loose material was swept off with a soft bristle brush, and the cleaned test piece mass (mₐ) was obtained after weighing.

The initial curing abrasion loss was calculated as follows:

\[ \text{ICAL} = \frac{(mₐ - mₐ)}{S} \]  

where ICAL is the initial curing abrasion loss of the mixture (g/m²), mₐ is the specimen weight before abrasion (g), mₐ is the specimen weight after abrasion (g), and S is the abrasion area of the abrasive head hose (m²).

4. Results and Discussion

4.1. Wet-track Abrasion Performance of Micro surfacing

4.1.1. WTAT of different micro surfacing mixtures of modified emulsified asphalt

Fig. 1 shows the WTAT results of the four different micro surfacing mixtures of the modified emulsified asphalt. The wet-track abrasion loss values of the WB-I micro surfacing mixtures soaked in water for 1
h and 6 d were 118.9 and 279.3 g/m², respectively, and the wet-track abrasion loss values of the WB-IV micro surfacing mixtures soaked in water for 1 h and 6 d were 297.8 and 475.5 g/m², respectively. In comparison, the wet-track abrasion loss value of WB-I soaked in water for 1 h was 40% of that of WB-IV, and the wet-track abrasion loss value of WB-I soaked in water for 6 d was 62.6% of that of WB-IV. Apparently, the wet-track abrasion loss values of the WB-I and WB-II HMS specimens were both significantly lower than those of conventional WB-III and WB-IV micro surfacing specimens, and the HMS showed stronger resistances to abrasion and moisture damage.

4.1.2. Effect of different amounts of added styrene butadiene rubber (SBR) on wet-track abrasion loss

To further explore the pattern of change in the wet-track abrasion loss value of the HMS and conventional micro surfacing, the amount of SBR added to the modified emulsified asphalt for the micro surfacing was varied in the experiment. Fig. 2 shows the WTAT result of the micro surfacing mixture with different amounts of added SBR. As an asphalt modifier, SBR can significantly improve the mechanical properties of asphalt. Therefore, as the amount of SBR was increased, the wet-track abrasion loss values after soaking for 1 h and 6 d were reduced. By comparing the wet-track abrasion loss values of the HMS and conventional micro surfacing with the same amount of added SBR, the wet-track abrasion loss values of the HMS after soaking for 1 h and 6 d were lower than those of the conventional micro surfacing, indicating that HMS had better abrasion and moisture damage resistances.

Actual micro surfacing engineering requirements and relevant standards stipulate that the dosage of the modified emulsified asphalt used in micro surfacing should not be less than 3% [12]. When the SBR content was 3%, the wet-track abrasion loss values of the WB-I micro surfacing mixtures soaked for 1 h and 6 d were 136.3 and 356.5 g/m², respectively. The wet-track abrasion loss values of the WB-IV micro surfacing mixtures soaked for 1 h and 6 d were 401.7 and 703.5 g/m², respectively. Both met the standard technical requirements, which stipulate that the wet-track abrasion loss values of micro surfacing mixture soaked for 1 h and 6 d should not be more than 500 and 800 g/m², respectively [12].
However, for the HMS, the requirements for the wet-track abrasion loss values after soaking in water for 1 h and 6 d are not stringent enough, and this is not conducive to the advancement of the micro surfacing technique. Based on a large number of WTATs of HMS mixtures and engineering experience, it is recommended that the wet-track abrasion loss values of the HMS mixtures that are soaked for 1 h and 6 d are not more than 360 and 480 g/m², respectively.

4.2. Anti-Abrasion Performance of Micro surfacing at Initial Curing Stage

4.2.1. Anti-abrasion performance of different micro surfacing types at initial curing stage

Fig. 3 shows the ICAT results of four different micro surfacing mixtures of the modified emulsified asphalt. The initial curing abrasion loss value of the sample cured for 2 h was significantly lower than that of the sample cured for 1 h, and an increase in the initial curing time could distinctly improve the initial anti-abrasion performance of the micro surfacing mixture. The initial curing abrasion loss values of the WB-I micro surfacing mixtures cured for 1 and 2 h were 729.8 and 522.6 g/m², respectively. The initial curing abrasion loss values of the WB-IV micro surfacing mixtures cured for 1 and 2 h were 1935.3 and 963.3 g/m², respectively. Comparing the two types of micro surfacing mixtures, the initial curing abrasion loss value of WB-I cured for 1 h was 37.7% of that of WB-IV, and the initial curing abrasion loss value of WB-I cured for 2 h was 54.3% of that of WB-IV. The initial curing abrasion loss values of the WB-I and WB-II HMS samples were significantly lower than those of the two conventional WB-III and WB-IV micro surfacing samples. Compared with the conventional micro surfacing, the HMS could achieve a higher strength in a short time. As a new method to evaluate the initial performance of a micro surfacing, the ICAT can better guide the design of HMS mixtures and efficiently distinguish the HMS from conventional micro surfacing.

![Figure 3](image)

**Figure 3** INITIAL CURING ABRASION LOSS VALUES OF DIFFERENT MICRO SURFACING MIXTURES OF MODIFIED EMULSIFIED ASPHALT

4.2.2. Initial curing abrasion loss at different curing times

To better understand the abrasion process of this new test method (ICAT), during the test, the initial curing abrasion loss of the specimen was collected every other minute. Fig. 4 shows the ICAT results of the micro surfacing mixture at different abrasion times. Over time, the initial curing abrasion loss value gradually increased, and the rate of increase in the initial curing abrasion loss value gradually increased. Comparing the test results of WB-I and WB-IV with curing times of 1 h, the initial curing abrasion loss value of the HMS was considerably lower than that of conventional micro surfacing. When the abrasion time was 1 min, the initial curing abrasion loss values of the WB-I and WB-IV specimens with curing times of 1 h were 53.9 and 100.3 g/m², respectively, and the difference was 46.4 g/m². However, when the abrasion time was 5 min, the initial curing abrasion loss values of the WB-I and WB-IV specimens were 729.8 and 1935.3 g/m², respectively, and the difference reached 1205.5 g/m², indicating that with increasing abrasion time, the HMS exhibited better abrasion resistance. By comparing the initial curing abrasion loss curves of the WB-I and WB-IV specimens with curing times...
of 1 and 2 h, the initial curing abrasion loss of the conventional micro surfacing was considerably larger than that of HMS, further indicating that the HMS had a better initial compaction capacity.

![Initial Curing Abrasion Loss Values of the Micro Surfacing Mixtures with Different Abrasion Times](image)

Figure 4

5. Conclusions

The analysis of high-performance micro surfacing (HMS) and conventional micro surfacing mixtures showed that the anti-abrasion performance during the initial curing period, long-term anti-abrasion performance, and moisture damage resistance of the HMS mixture were better than those of the conventional micro surfacing mixture. The wet-track abrasion loss values of the HMS mixtures soaked in water for 1 h and 6 d should not be higher than 360 and 480 g/m², respectively. A new method for evaluating the initial micro surfacing compaction properties was proposed. This method can efficiently evaluate the initial compaction capacity of the micro surfacing and guide the design of the HMS slurry mixture.

Acknowledgment

This study was supported by National Key R&D Program of China (Grant Number: 2018YFB1600100).

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