Research on influencing factors of high temperature performance of new type noise reduction micro-surfacing

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Abstract. The micro-surfacing has received widespread attention with its excellent anti-skid performance, waterproof performance, construction characteristics and significant cost advantages. However, the problem of the conventional micro surfacing high driving noise has been criticized. The new noise reduction micro-surfacing has appeared to greatly reduce the traffic noise to a considerable extent and solve the main bottleneck of the further promotion to the micro-surfacing. The noise reduction micro-surfacing proposed in this study has a special binder and gradation, as well as a specific rubber powder filler. Guided by the change rate of the wheel rut width, focused on the four key variables of oil-stone ratio, cement, mineral powder and rubber powder content, the high-temperature performance of the noise reduction micro-surfacing mixture is studied. The research shows: based on the special noise reduction gradation proposed in this article, in order to obtain a new type of noise reduction micro-surfacing with the best anti-rutting performance, the best oil-stone ratio is 10.5%, the best cement content is 1%, and the rubber powder should not exceed 2%.

1. Introduction
The highways and urban roads that have been opened to traffic in China have entered the peak period of maintenance on a large scale. The maintenance of asphalt pavements of various levels of highways and urban roads has received more and more attention. As a maintenance method with excellent cost-effectiveness and wide practicability, the micro-surfacing area is favored by many engineers [1]. For a long time, the noise caused by vehicles walking on the road surface of the micro-surfacing is higher than that of the ordinary road surface, which troubles the researchers and users. The birth of the noise reduction micro-surfacing (it only reduces the noise on the basis of conventional micro surfacing) after grading and composition reconstruction has brought a new look to this maintenance measure, but due to the adjustment of the gradation and the replacement of the binder, the increase of the asphalt-aggregate ratio will inevitably impact the density and the reduction of the clearance rate on the internal structure of the micro-surfacing, impact resistance to shear stress, among them, the most critical impact on the road performance is the high temperature performance. Considering that the change in the amount of coarse aggregate in the gradation will affect the high temperature performance of the mixture [2-3], the influence factors of the high temperature performance of the noise reduction micro-surfacing are studied, in order to provide an important reference for the design of the mix ratio composition of the noise reduction micro-surfacing during construction.
2. Experimental

2.1. Material

In order to make the research object representative, the wide-area type EM520 slow-cracking quick-setting emulsifier was used, which has a high tolerance for aggregate types and processing levels [4]. The technical indicators of modified emulsified asphalt emulsified by EM520 are shown in Table 1.

| Test items                          | Unit | Result | Standard requirement | Test method |
|-------------------------------------|------|--------|----------------------|-------------|
| sieve residue (1.18mm)              | %    | 0.04   | ≤0.1                 | T 0652      |
| charge                              |      | +      | +                    | T 0653      |
| standard viscosity C25,3            | S    | 19.2   | 12~60                | T 0621      |
| asphalt evaporation residue margin  | %    | 64.2   | ≥60                  | T 0651      |
| Properties of asphalt evaporation residue | %   | 64.2   | ≥60                  | T 0651      |
| penetration (25°C)                  | 0.1mm| 70.1   | 40~100               | T 0604      |
| softening point (R/B)               | °C   | 64.3   | ≥53                  | T 0606      |
| ductility (5°C)                     | cm   | 35.1   | ≥20                  | T 0605      |
| Storage                             |      | %      | 0.41                 | ≤1          | T 0655      |
| stability                           | 5d   | %      | 2.53                 | ≤5          |

The coarse aggregates used in the test are basalt produced in Jiangsu and the fine aggregates are limestone produced in Jiangsu. According to the noise reduction grading design, the aggregates are sieved into 0-3, 3-5 and 5-10 grades for the synthesis of the target gradation. Mineral powder will not participate in the noise reduction micro-surfacing gradation design, but it will be used as an external additive. The screening results of aggregate are shown in Table 2.

| Material name | project | requirement | Test method |
|---------------|---------|-------------|-------------|
| Coarse aggregates | crushing value (%) , ≤ | 28 | T 0316 |
|                | Los Angeles abrasion loss (%) , ≤ | 30 | T 0317 |
|                | burnish value (BPN) | 42 | T 0321 |
|                | sturdiness (%) | 12 | T 0314 |
|                | acicular content (%) | 15 | T 0312 |
| Fine aggregates | sturdiness (%) | 12 | T 0340 |
| Mineral        | sand equivalent (%) | 60 | T 0334 |

Cement is added as a filler into the mixture, should be dry, loose, without agglomeration, and should meet the relevant requirements in the "Technical Specification for Construction of Highway Asphalt Pavements" (JTG F40). The amount of cement added must be determined through a mixture design test.

| Technical index | Measured value | quality requirement |
|-----------------|----------------|---------------------|
| Fiber content (%) , ≤ | 0.3 | 1 |
| Metal content (%) , ≤ | 0 | 0.05 |
| Relative density | 1.17 | 1.1~1.3 |
| Other impurities content (%) | 0 | 0 |
| Acetone extract, ≤ | 10 | 22 |
| Carbon black, ≥ | 40 | 28 |
| Rubber hydrocarbons, ≥ | 51 | 42 |
The low noise effect of the micro-surfacing mixture used in this study mainly comes from two aspects, the special gradation design and rubber powder. The addition of appropriate rubber is one of the key elements to reduce noise [5]. The rubber powder should be made by normal temperature grinding or granulation method [6]. The technical indicators and measured values of rubber powder used in the research are shown in Table 3.

2.2. Grading
Aggregate grading has an important impact on the road performance of the micro-surfacing, and it is also another key to driving noise. Appropriately reducing the use of coarse aggregate, adding the medium-grain aggregate (3-5mm) with higher Los Angeles abrasion value, strengthening the squeezing effect between aggregates, reducing the difference between the laying thickness and the maximum particle size of the aggregate, using discontinuous grading to increase the proportion of coarse aggregate are the design principle of noise reduction gradation. However, the noise reduction treatment from the gradation point of view has an impact on the road performance, and the asphalt-aggregate ratio decreases with the increase of the coarse aggregate, which will lead to a decrease in durability. Increasing the asphalt-aggregate ratio helps to improve the durability of the micro-surfacing, but it will cause oil flooding and sticking to the surface structure of the micro-surfacing [7]. Table 4 shows the gradation of noise reduction micro-surfacing.

| Mesh size /mm | 9.5 | 4.75 | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 |
|---------------|-----|------|------|------|-----|-----|------|-------|
| Passing rate /% | 100.0 | 85.5 | 60.2 | 36.4 | 28.9 | 18.8 | 15.2 | 7.0 |

2.3. Test methods
According to the requirements of the performance indicators at the micro-surfacing in the construction technical specifications, the rutting deformation test is carried out in accordance with the designated test T0756 in the "Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering" (JTG E20-2011).

3. Rutting resistance
3.1. Asphalt-aggregate ratio
The test uses the gradation of noise reduction micro-surfacing from 9.0% to 12.0% of the asphalt-aggregate ratio. Making the test pieces according to test specifications, used the load wheel tester to simulate the wheel rolling on the mixed material at the micro-surfacing after forming, after the specified number of actions, the rutting depth and width deformation of the sample were measured, and the rutting depth per unit thickness of the sample and the lateral deformation per unit width were used to evaluate the anti-rutting ability of the mixture. The test results are shown in Table 5.

| Gradation of noise reduction micro-surfacing | Asphalt-aggregate ratio /% |
|--------------------------------------------|----------------------------|
|                                            | 9.0 | 9.5 | 10.0 | 10.5 | 11.0 | 11.5 | 12.0 |
| Deformation rate of wheel track width /%    | 8.02 | 7.33 | 6.45 | 4.57 | 4.83 | 5.48 | 6.52 |
For the noise reduction micro-surfacing mixture proposed by the new design method, the difference from the conventional micro-surfacing is that with the increase of the asphalt-aggregate ratio, the change rate of the wheel track width decreases first and then increases. This is reflected in the test results in Figure 1. There is an optimal asphalt-aggregate ratio to optimize the anti-rutting ability of the mixture at the low noise micro-surfacing. Based on the test results, this study recommends 10.5% as the best asphalt-aggregate ratio.

Generally, for hot-mix asphalt, the anti-rutting ability has a great relationship with factors such as mineral clearance ratio, asphalt-aggregate ratio, and mixture void ratio. The rut depth will gradually decrease with the increase of the void ratio of the mixture, and the void ratio is the main factor affecting the rutting resistance. However, due to the thin paving thickness at the micro-surfacing, it is mostly resistant to moderate and mild rutting. It is not enough to simply adjust the gradation to improve the high temperature performance. The appropriate material composition should be comprehensively determined by adjusting the asphalt-aggregate ratio, changing the types of additives, and combining actual engineering experience and construction environment conditions to improve the high temperature performance of the micro-surfacing mixture. The recommended value of 110.5% of the best asphalt-aggregate ratio here can be used as the initial value of the design and construction mix ratio at the noise reduction micro-surfacing.

3.2. Cement and mineral powder
Selected the special gradation to determine the best asphalt-aggregate ratio (10.5%) and the corresponding best content (2.0%), added different proportions of cement and mineral powder to conduct wheel rutting test to study the effect of additive types and content on high temperature performance. The test results are shown in Table 6 and Table 7.

**Table 6.** Wheel rutting test results under different cement content.

| Cement content /% | 0   | 0.5 | 1   | 1.5 | 2   |
|-------------------|-----|-----|-----|-----|-----|
| Deformation rate of wheel track width /% | 4.57 | 4.01 | 2.67 | 2.53 | 2.49 |

**Table 7.** Wheel rutting test results under different mineral powder content.

| Mineral powder content /% | 0 | 1 | 2 | 3 | 4 |
|---------------------------|---|---|---|---|---|
| Deformation rate of wheel track width /% | 4.57 | 4.32 | 3.79 | 3.71 | 3.53 |
The curve in Figure 2 shows that the addition of a small amount of cement can effectively improve the rutting resistance of the micro-surfacing. When the addition amount is 0.5% and 1.0%, the change rate of the rut width of the mixture at the micro-surfacing is 12.3% and 41.5% higher than that of no cement. However, when the cement content is greater than 1.0%, the change rate of the wheel track width tends to be stable and no longer changes with the increase of the cement content. It can be considered that for the high temperature performance of graded noise reduction micro-surfacing, 1.0% cement content is the best value. Too much cement cannot further improve the ability of the mixture to resist rutting deformation at the micro-surfacing.

It can be seen from Figure 3 that the addition of mineral powder does not significantly improve the rutting resistance of the micro-surfacing. When the mixing amount of mineral powder is 1% and 2%, the wheel rut width deformation rate of the mixture is only increased by 5.5% and 17.1% respectively compared with that without mineral powder. After that, adding mineral powder has no significant effect on improving the anti-rutting ability of the micro-surfacing. The reason is that the addition of mineral powder changes the gradation of the mixture and increases the number of fine aggregates. Although reducing the porosity of the mixture can improve rutting resistance, the mineral powder will absorb more modified emulsified asphalt. If the asphalt-aggregate ratio is not increased, the mixing property at the micro-surfacing will be reduced to a certain extent, the aggregate cannot be fully coated by the asphalt, and the ability of the mixture to resist rutting after emulsification will be
weakened. In the whole, it is not significant to increase the amount of mineral powder alone to improve the high temperature performance of the micro-surfacing.

### 3.3. Rubber powder

Rubber powder has the effect of absorbing and weakening noise. Its addition can make the mixture at the micro-surfacing further reduce noise after paving is completed, and appropriately increase the elastic modulus of the micro-surfacing. The noise reduction gradation is still used, the best asphalt-aggregate ratio (10.5%) determined in the previous section is used, and the water content (2.0%) is mixed with rubber powder at intervals of 0.5% and 1.0% by mass to carry out wheel rutting deformation. Experiment to study the effect of different amounts of rubber powder on the high temperature performance of the micro-surfacing. The test results are shown in Figure 4.

**Figure 4.** Change curve of wet wheel wear value with rubber powder content.

It can be seen from Figure 4 that adding rubber powder can also improve the high temperature performance of the micro-surfacing. 2.0% of rubber powder is a critical value. Between 0-2.0%, the high temperature performance increases significantly. After the critical range of 2.0%, the high temperature performance tends to be stable. More rubber powder cannot bring better road performance. Therefore, from the perspective of anti-rutting, 2.0% is the standard addition of rubber powder.

### 4. Conclusions

Based on the proprietary gradation proposed in this article, according to factors such as asphalt-aggregate ratio, cement, mineral powder and rubber powder, the effects of them on the high temperature performance of noise reduction micro-surfacing mixtures were studied. The main conclusions are as follows.

1. On the basis of the noise reduction micro-surfacing gradation proposed in this article, by adjusting the ratio of oil-stone, the amount of water, the content of cement, mineral powder and rubber powder, a micro-surfacing mixture with better high-temperature performance can be produced.

2. With the increase of the asphalt-aggregate ratio, the rate of change of the rut width at the noise reduction micro-surfacing decreases first and then increases. There is an optimal asphalt-aggregate ratio to optimize the rutting resistance of the mixture at the micro-surfacing. It is recommended to use 10.5% as the best asphalt-aggregate ratio at the noise reduction micro-surfacing, which can be used as the initial design value of the asphalt-aggregate ratio in actual construction.

3. A small amount of cement can effectively improve the rutting resistance of the micro-surfacing, but when the cement content exceeds 1.0%, the lifting effect tends to be stable. The addition of mineral powder can also improve the rutting resistance of the micro-surfacing, but the affection is not obvious, because the mineral powder will absorb more modified emulsified asphalt. If the asphalt-
aggregate ratio is not increased, the aggregate will not be fully coated by the asphalt. The mixture will
be demulsified, and the ability to resist rutting performance will be weakened.

(4) Adding rubber powder can improve the high-temperature stability of the micro-surfacing. According to the content and high-temperature performance curve, the performance tends to be stable after the rubber powder content exceeds 2.0%. From the perspective of anti-rutting, it is recommended 2.0% is the standard rubber powder addition amount for the noise reduction micro-surfacing.

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