

Research on Fiber Micro-Surfacing Mixture Design and Pavement Performance in Interchange`s Connections

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Abstract: Now a large number of expressway enter the stage of repair and maintenance. But it's easy to overlook the pavement's performance, especially the skid resistance of the interchange at ramp exit and entrance during the repair and maintenance. Interchange ramp exit and entrance has always been the accident-prone sections. A lot of screeching halts happened in those sections which significantly reduce the pavement skid resistance and Micro-surfacing can significantly improve the performance of pavement. So it's meaningful that using the micro-surfacing to improve the performance of the pavement in the areas of the ramp exit and entrance, and especially the skid resistance of the pavement. But the existing micro-surfacing technology guide has some technical defects, which impede the application and development of micro-surfacing technology. In this paper, firstly the "graphical method" is used to determine the optimal dosage range of emulsified asphalt. Verified with laboratory tests, recommending the dosage of emulsified asphalt corresponding to the peak of flexural strain measured with low temperature bend test as OAC of micro-surfacing mixture showed superiority technically.

Introduction

Since the China's first expressway opened in October 1988, now a large number of these expressways need repair and maintenance. But it's easy to overlook the pavement's skid resistance of the interchange at ramp exit and entrance. Sometimes there is no obvious damage on the surface, but in fact these places have always been the accident-prone sections. Routine repair and maintenance of the interchange cannot solve the problem. So the use of micro-surfacing to improve the pavement skid resistance in this area and reduce the braking distance is important. Although this kind of material has been using in China for more than a decade, recently it has been found that micro-surfacing did not achieve the desired goals. There exist many problems in roads paved with micro-surfacing, such as poor resistance to crack and bad performance for heavy traffic, which result in a shorter service life of micro-surfacing pavement. When in application to fill thick ruts, micro-surfacing shows a lack of effective resistance to rutting deformation, which greatly limits the promotion and application of this technology in domestic preventive maintenance^[1-3].

Fiber has been widely used in highway engineering for its characteristics. It is well acknowledged that after adding fiber, micro-surfacing performance will be improved, but there is a lack of systematic design on fiber micro-surfacing mixture, especially on the new issues appeared in the application of domestic ordinary micro-surfacing technology. Therefore, it is necessary to carry

out specialized research and design reasonable ways to play the advantage of micro-surfacing technology in preventive maintenance and achieve a win-win situation of social and economic benefits.

Raw materials of fiber micro-surfacing

The main materials that Fiber Micro-surfacing Mix used are polymer modified asphalt emulsion, fiber, mineral aggregate, filler, water and additives. Their qualities directly affect the pavement performance of mixture^[4,5]. Therefore, when choosing materials, their various technical indicators should meet the requirements of the corresponding specification.

Modified Emulsified Asphalt

Emulsified asphalt used in this study is SBR modified asphalt emulsion, which consists of AH-70 asphalt, and is made by the modified and emulsified equipment.

Mineral Aggregate

At present, most of asphalt mixtures use limestone, basalt, diabase, etc. The basalt has good compression resistance, abrasion resistance and other properties, so we choose two different lithological stone as mineral aggregate. The test results show that the mineral aggregate various technical indicators can meet the standard requirements^[6].

Fiber

After adding fibers, the mechanical properties of asphalt mixture can be significantly improved. The micro-surfacing adopts KWS-A3 polypropylene fiber due to its good low temperature performance, low prices and wide application.

Water

Water is an important component of the slurry mixture, and its dosage determines the consistency, workability and construction operational time of the mixture. If the moisture is too low, the mixture will be too thick and not easy to be paved; if the moisture is too high, the slurry mixture will occur segregation, flowing, unstable, slow demulsification speed, and be very likely to produce the phenomenon of aggregate sinking and asphalt floating. This will lead to the result that the surface is a layer of oil-film, and the underneath is gray loose aggregate. Than the bond with the original road is not strong^[7].

Filler

This paper adopt 325 ordinary portland cement, limestone and mineral powder as filler. After tested, the filler various technical indicators can meet standard requirements.

Fiber Micro-surfacing Mix Design

Determination of Mineral Aggregate Gradation

Domestic micro-surfacing mineral aggregate gradation range was formulated in according with the relevant provisions of International Slurry Surfacing Association (ISSA) by Research Institute of Highway Ministry of Transport, in 2004. According to the mineral aggregate gradation, gradation can be divided into MS-2 and MS-3. The most common gradation type used in the micro-surfacing project is MS-3 in China^[8]. This paper adopt MS-3 type for research.

Mixing Test on Determining the Amount of Cement and Mixing Water

Mixing test is mainly used to determine the mixing time and slurred state of the micro-surfacing mix, so as to provide the basis for the choice of the optimal asphalt-aggregate ratio^[9]. In order to assess the effect of adding fiber on the amount of additional water, we choose the asphalt-aggregate

ratio of 7.5% and different fiber dosage to conduct the mixing test. The test results are shown in table 1.

Table 1 Mixing test results (Temperature 25 °C)

| Fiber Content (%) | Aggregate (g) | Additional Water (g) | Cement (%) | Mixing Time (s) | Requirement (s) |
|-------------------|---------------|----------------------|------------|-----------------|-----------------|
| 0.05 | 200 | 13 | 1.5 | 139 | ≥120 |
| | 200 | 14 | 2.0 | 135 | |
| | 200 | 15 | 2.5 | 130 | |
| 0.1 | 200 | 15 | 1.5 | 132 | |
| | 200 | 16 | 2.0 | 127 | |
| | 200 | 17 | 2.5 | 125 | |
| 0.15 | 200 | 16 | 1.5 | 127 | |
| | 200 | 17 | 2.0 | 125 | |
| | 200 | 17 | 2.5 | 122 | |
| 0.20 | 200 | 15 | 1.5 | 135 | |
| | 200 | 15 | 2.0 | 127 | |
| | 200 | 16 | 2.5 | 122 | |
| 0.25 | 200 | 15 | 1.5 | 138 | |
| | 200 | 16 | 2.0 | 127 | |
| | 200 | 17 | 2.5 | 124 | |

Table 1 shows the test results:

(1) When the fiber dosage is in the range of 0 to 0.1 percent, additional water consumption increases with the increase of fiber dosage. However, after the fiber dosage exceeds 0.1 percent, additional water consumption tends to be stable.

(2) Mixing water consumption increases with the increase of cement dosage. When the cement dosage is 2 percent, the mixing time is most appropriate.

In conclusion, combined with estimative engineering experience, materials ratio was preliminarily confirmed: the ratio of polyester fiber dosage, cement dosage, mixing water consumption and total fluid content (the sum of the emulsified asphalt dosage and the mixing water consumption) are 0.2%, 2%, 8% and 15.5%, respectively.

Determination of the Optimal Dosage Range of Emulsified Asphalt

In this paper, we use the "graphical method" to determine the optimal dosage range of emulsified asphalt. Keep the cement content 2% and fiber content 0.5% fixed respectively. Regarding the predicted optimum emulsified asphalt content 7% as median, change the emulsified asphalt content by interval 0.5%. In order to ensure the total fluid content remains the same, change the corresponding mixing water while changing the emulsified asphalt content. Wet track abrasion test, load wheel test, stability and resistance to compaction test, cohesion torque test were done to determine the optimal asphalt-aggregate ratio range of fiber micro-surfacing mixture^[9]. The test results are shown in table 2 and table 3.

Table 2 Results of wet track abrasion test and load wheel test

| Asphalt-aggregate ratio (%) | Wet-track abrasion loss of 1h (g/m ²) | Wet-track abrasion loss of 6d (g/m ²) | Sand adhesion amount (g/m ²) |
|-----------------------------|---|---|--|
| 6.0 | 645.3 | 835.7 | 317.6 |
| 6.5 | 526.5 | 789.3 | 367.3 |
| 7.0 | 429.4 | 673.0 | 392.9 |
| 7.5 | 342.8 | 557.2 | 403.5 |
| 8.0 | 238.3 | 524.5 | 437.3 |

Table 3 Results of stability and resistance to compaction test and cohesion torque test

| Asphalt-aggregate ratio (%) | Cohesion torque of 30min (N.m) | Cohesion torque of 60min (N.m) | Rate of width change (%) |
|-----------------------------|--------------------------------|--------------------------------|--------------------------|
| 6.0 | 1.21 | 2.1 | 4.1 |
| 6.5 | 1.24 | 2.4 | 3.4 |
| 7.0 | 1.27 | 2.4 | 3.1 |
| 7.5 | 1.30 | 2.3 | 3.4 |
| 8.0 | 1.29 | 2.4 | 4.0 |

Table 4 Micro-surfacing Mixture technical indicators

| Test | | Technical standard |
|-------------------------------------|----------------------|--------------------------------|
| Mixing Time (25°C) | | 120(s) Minimum |
| Cohesion Torque Test | 30min (Set Time) | 1.2(N.m) Maximum |
| | 60min (Traffic Time) | 2.0(N.m) Maximum |
| Excess Asphalt by LWT Sand Adhesion | | 450(g/m ²) Maximum |
| Wet-track Abrasion Loss | One-hour Soak | 540(g/m ²) Maximum |
| | Six-day Soak | 800(g/m ²) Maximum |
| Lateral Displacement | | 5% Maximum |
| Classification Compatibility | | 11 Minimum |

The test result shows that asphalt-aggregate ratio within the range of 6.5%~8% can meet the specification requirements of wet track abrasion test, load wheel test, stability and resistance to compaction test, cohesion torque test in table 4.

Determination of Optimal Dosage of Emulsified Asphalt Based On Bending Test of Small Beam

In this paper, within the scope of optimal asphalt-aggregate ratio determined by the conventional test method, introducing the bending test of small beam to accurately calculate the optimal asphalt-aggregate ratio of micro-surfacing mixture.

Combination of the range of optimal asphalt-aggregate ratio determined by graphical method, the preliminary emulsified asphalt content for small beam test is 6.5%, 7%, 7.5% and 8%. According to the requirements of flexural creep test in the "Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering", the flexural tensile strain of small beams with different emulsified asphalt content is tested under -10°C. The test results are shown in table 5.

Table 5 Low temperature flexural creep test results of fiber micro-surfacing mix

| Asphalt aggregate ratio | Flexural tensile strength (MPa) | Maximum flexural tensile strain ($\mu\epsilon$) | Bending stiffness modulus (MPa) |
|-------------------------|---------------------------------|---|---------------------------------|
| 6.5 | 6.78 | 2812.64 | 2410.55 |
| 7.0 | 7.10 | 3067.32 | 2314.72 |
| 7.5 | 7.37 | 3031.30 | 2431.30 |
| 8.0 | 7.22 | 2833.02 | 2548.52 |

From table 5, as the increase of asphalt-aggregate ratio, although the maximum flexural tensile strain of fiber micro-surfacing mix have little difference, there is still an obvious change rule. The maximum flexural tensile strain of -10°C shows a parabolic trend (increases at first then decreases) with the increase of asphalt-aggregate ratio. When asphalt-aggregate ratio is about 7.7%, the maximum flexural tensile strain has a maximum value.

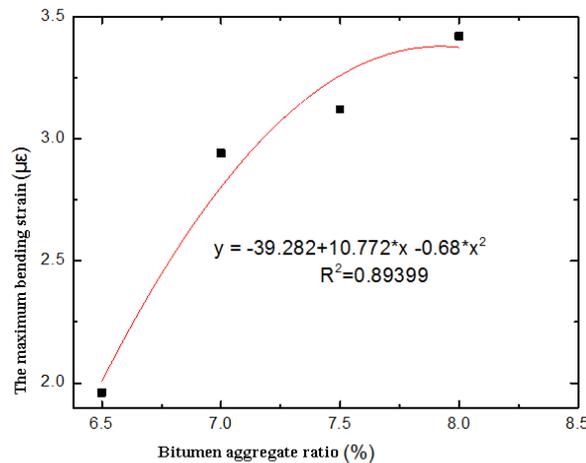


Figure 1 Flexural tensile strain variation with asphalt-aggregate ratio

In summary, in this paper, the fiber micro-surfacing mix optimal asphalt-aggregate ratio is 7.7%, the cement content is 2%, the optimal fluid content is 15.5% (mixing water consumption is 6.8%), the dosage of fiber is 0.2%.

The Rationality Verification of Optimal Dosage of Emulsified Asphalt

In this paper, in order to verify the rationality and applicability of the method for determining the optimal dosage of emulsified asphalt, indoor simulation experiment is carried out.

Verification of Construction Performance

The initial set time and traffic time of micro-surfacing mainly evaluated by the cohesion torque test, the value of which has great influence on whether the micro-surfacing can meet the requirements of quick traffic. When undertaking verification of construction performance, in the fiber micro-surfacing mix, the cement content is 2%, the fluid content is 15.5%, the dosage of fiber is 0.2%, and the emulsified asphalt content is 7.7%.

Table 6 Results of Construction Performance Test

| Type of micro-surfacing | Value of Cohesion Torque (N·m) | | | |
|-------------------------------------|-------------------------------------|----------------------|--------------|----------------------|
| | 30min | Specimen State | 60min | Specimen State |
| Polypropylene Fiber Micro-surfacing | 1.35 | Broken | 2.36 | Medium Molding |
| | Wet-track Abrasion Loss | | | |
| | 1h | Requirements | 6d | Requirements |
| | 320.5 | ≤540g/m ² | 530.1 | ≤800g/m ² |
| | Lateral Displacement | | | |
| | Measured Value | 3.2% | Requirements | ≤5% |
| | Excess Asphalt by LWT Sand Adhesion | | | |
| | Measured Value | 410 g/m ² | Requirements | ≤800g/m ² |

From the data listed in table 6, the optimal dosage of emulsified asphalt determined by the peak of flexural tensile strain can meet the requirements of micro-surfacing mix in quick traffic.

Verification of Pavement Performance

1. MMLS3 Accelerated Loading Test

Reference to the research results of Shen Aiqin^[11-14], test conditions of MMLS3 in this paper are as follows.

(1).Specimens preparation: the normal Marshall specimens, which are prepared with the fiber micro-surfacing mixture according to the test 2.3 and the diameter is 152.4mm and height is 95.3mm,are cured 2d on 60°C dryer. Then cut the middle 5cm section of specimens according to accelerated loading test model size;

(2).Standard axle load (0.7MPa);

(3).Loading frequency 6400(times·h⁻¹), equivalent to the speed 7km/h, simulate the real effect of heavy loading vehicle;

Load times. MMLS3 accelerated loading equipment can test and record each scene specimen’s rutting depth, and then the variation between the changes of each scene specimen with axle load times can be got (Fig. 2).

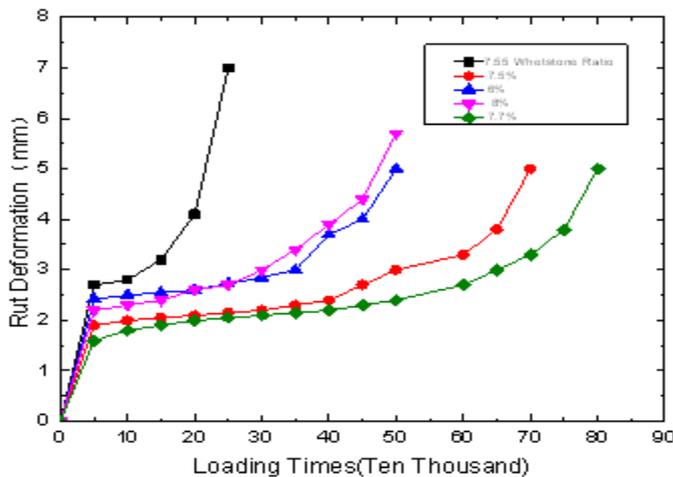


Figure 2 Accelerated loading test results

It can be found when comparing the load times of entering the destruction phase that joining fiber can improve the resistance to permanent deformation of micro-surfacing mixture apparently with the same asphalt aggregate ratio and the fatigue life of micro-surfacing mixture under the high temperature condition. From the prospective of the three-stage of the formation of rutting, the fiber micro-surfacing mixture's rutting deformation has slow development with the best emulsified asphalt content, and the rutting depth with 8% asphalt aggregate ratio < the one with 6% asphalt aggregate ratio < the one with 7.5% asphalt aggregate ratio < the one with 7.7% asphalt aggregate ratio. It shows that the best emulsified asphalt content which is determined by the maximum bending tensile strain can guarantee that micro-surfacing mixture will have good high-temperature resistance to deformation.

(4). Freeze-thaw splitting test. Water stability of asphalt mixture is usually evaluated by freeze-thaw splitting test [15, 16]. The ratio of average of splitting strength can be regarded as evaluation index [10]. The following are the results of test (Table 7).

Table 7 Thaw splitting test results

| Asphalt aggregate ratio (%) | R _{T1} (MPa) | R _{T2} (MPa) | TSR (%) |
|-----------------------------|-----------------------|-----------------------|---------|
| 6.5 | 0.754 | 0.624 | 82. 7 |
| 7.0 | 0.815 | 0.662 | 81. 27 |
| 7.5 | 0.903 | 0.782 | 86. 6 |
| 7.7 | 0.912 | 0.783 | 85. 9 |
| 8.0 | 0.920 | 0.749 | 81. 4 |

It can be concluded from the test results that the fiber micro-surfacing mixture's freeze-thaw splitting strength over the code value more than 80% when the emulsified asphalt content accounting for 7.7 percent. Micro-surfacing asphalt mixture's freeze-thaw splitting strength has the maximum value, and it means that emulsified asphalt with the maximum flexural tensile strain can guarantee that micro-surfacing asphalt mixture will have good water stability.

The superiority of confirming the best emulsified asphalt content by the low temperature bending test

Compared with the “graphical method”, this paper uses the maximum value to confirm the best emulsified asphalt content, it has many advantages as follows:

(1) The method mentioned in this paper confirms the best emulsified asphalt content of fiber micro-surfacing mixture on the basis of the low temperature bending test and “graphical method” and can give an accurately number value directly and reduces the dependency on the design experience when designing mix proportion of fiber micro-surfacing mixture.

(2) “Graphical method” is essentially a design method which just considers a single index of workability of micro-surfacing mixture and doesn't take pavement performance of micro-surfacing mixture into consideration when confirming the best emulsified asphalt content. The mix proportion

designing method of fiber micro-surfacing mixture mentioned in this paper based on the low temperature bending test and “Graphical method”. It not only can confirm the best emulsified asphalt content, but also takes low temperature cracking resistance into consideration. It is a dual-index design method essentially.

(3) The dramatic inner temperature stress is on the micro-surfacing, which directly beard the external temperature as the surface layer of pavement. In order to improve the low temperature crack resistance, the low temperature performance of mixture should be verified on the mix proportion design stage. It is beneficial to improve the pavement performance of fiber micro-surfacing mixture that the low temperature crack resistance indicator is used in design.

(4) The low temperature bending test is easy to get the evaluation indicator with the normal testing procedures.

Conclusions

The test results showed that the optimum asphalt-aggregate ratio of micro-surfacing was determined with the peak value of flexural tensile strain, on the range of graphic method results, to improve the pavement performance and reducing braking distance.

Combine with the result and the design experience, the track plate specimens with 4 asphalt-aggregate ratios which are on the range of graphic method $P_{bmin} \sim P_{bmax}$, were cured 2 days on 60°C and then were cut into small beams, 250mm×30mm×35mm. the asphalt-aggregate ratio was determined on -10°C low temperature bending test with the beam cracking resistance indicator.

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