Effects Analysis of Super Surfacing Pavement Performance Using Epoxy Modified Emulsified Asphalt as Bonding Layer

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Abstract. A large number of studies have shown that emulsified epoxy asphalt has good cohesion and is an ideal choice for road surface treatment technology. However, after emulsification, epoxy resin needs to be emulsified and modified in a very special way to form a good combination with other structural layers in different binders. Based on super surfacing treatment technology, the combination of epoxy resin emulsification and different emulsification modification methods was discussed. Referring to the latest precision design, three bonding methods were used to bond the surface and the underlying layer. That is, no bonding layer, emulsified asphalt bonding layer and epoxy emulsified asphalt bonding layer. The pavement performance comparison test of super surface asphalt mixture was carried out. SBR-A modified emulsified asphalt and SBR-B modified emulsified asphalt were selected as the most commonly used fine surface binder. After comprehensive mix proportion design, three key indicators of wear resistance, water damage resistance and skid resistance are selected to evaluate road performance. The test process and research results show that the epoxy emulsified asphalt binder has excellent pavement performance under the design of test gradation, and has good compatibility with SBR-A modified emulsified asphalt.

1. Introduction
Super surfacing is one of pavement preventive maintenance with the layer thickness below 1 cm, mostly at 0.5-0.8 cm (structure as shown in Figure 1). It is composed of multi-component high-performance binder and fine aggregate[1]. It spreads to the original pavement through special construction equipment. Due to the addition of high-performance bonding layer, compared with the existing preventive maintenance technology such as fog seal and micro-surface, the super surfacing performs a stronger adhesion, more stable structure, better wear resistance and skid resistance[2], and it has no change in elevation and light weight, it therefore could be paved several times in maintenance.

![Figure 1. Typical Pavement Structure at Super surfacing.](image-url)
Super surfacing is a highly efficient maintenance technology in developed countries rather than in China. Because of its high price of emulsified epoxy asphalt, as a high-quality material, it is less used in pavement structure, only used in steel bridge deck bonding layer. With the improvement of road maintenance and the thermosetting resin chemical techniques in China, the research and application of super surfacing have been developed[2-3]. This research pioneered the use of epoxy emulsified asphalt in the bonding layer of cold pavement maintenance, in order to solve the problem of insufficient durability of super surfacing before[4]. At present, the most researchers are focused on gradation analysis and application introduction on super surfacing, and ignored the importance of its bonding layer. The purpose of this study is to analyze the pavement performance changes of 2 conventional refined surfaces after using epoxy emulsified asphalt as bonding layer through laboratory tests.

2. Materials and Tests

2.1. Materials

Epoxy asphalt contains Part A and B. Part A is epoxy resin, Bisphenol A epoxy resin typed E-51 accords to researchers’ prophase study[5]. Part B is a mixture of emulsified asphalt and the curing system. The basic properties of E-51 epoxy resin as Part A is shown in Table 1. Table 2 presents the basic properties of Part B and another bonding layer material (common emulsified asphalt) according to the ASTM specification[6]. Part B comprises amine curing agent, compatibilizer and additives[7].

| Chemical composition              | density (23°C)(g/cm³) | viscosity (mPa·s) | epoxy equivalent(g/eq) |
|-----------------------------------|-----------------------|-------------------|------------------------|
| 2,2-bis(4-(2,3-epoxpropoxy)phenyl)propane | ≤1.10                | 11000~14000       | 211~290                |

There are many kinds of binder innovated in pavement surfacing technology. At present, the most commonly used modified emulsified asphalt is the SBR modification technology[8,9]. In this study, the epoxy emulsified asphalt mixed with thermosetting resin and hardener is used as the bonding layer for the bonding between the lower bearing layer and the upper mixture on the super surfacing, and it actually will merge with the binder in upper mixtures and contribute to the pavement performance. Hence force, it is worth exploring which method can better integrate with the bonding layer (emulsified epoxy) system[10]. Therefore, two representative and innovative binders are selected: domestic SBR latex modified emulsified asphalt (SBR-A for short) and imported SBR latex modified emulsified asphalt (SBR-B for short) for fusion degree verification test.

| Items                        | Specification Requirements | Unit | Epoxy Emulsified Asphalt | Emulsified Asphalt |
|------------------------------|----------------------------|------|--------------------------|--------------------|
| Screen residual              | ≤0.1                       | %    | 0.04                     | 0.02               |
| Standard Viscosity of Asphalt| 12~60                      | S    | 18.4                     | 13                 |
| Evaporative residue content  | ≥60                        | %    | 62.1                     | 62.1               |
| Penetration (25 °C)          | 40~100                     | 0.1mm| 67.6                     | 71.4               |
| Softening point (R/B)        | ≥57                        | °C   | 63.2                     | 52.6               |
| Ductility (5 °C)             | ≥20                        | cm   | 35.8                     | 37.1               |
| 1days storage stability      | ≤1.0                       | %    | 0.43                     | 0.21               |
| 5 days storage stability     | ≤5.0                       | %    | 2.32                     | 1.32               |

The test grade is JB-5[11], as shown in Table 4. The oil-stone ratio of the two mixes are that: SBR-A: 9.5%, SBR-B: 8.0%, water content: SBR-A: 2.5%, SBR-B: 4.0%. On the basis of ultra-high performance and cost considerations, the amount of emulsified epoxy is uniformly 1.5%. Wet track abrasion test and pendulum tester friction pendulum were carried out to evaluate the pavement
performance of different modified emulsified asphalt. The aggregate are selected in strict accordance with the norms[1].

2.2. Test scheme and procedure
In the study tests, different bonding layers will be planned to undertake the two most common surface layers(SBR-A and SBR-B). Non-bonding layer, common emulsified asphalt bonding layer and epoxy emulsified asphalt bonding layer, respectively. Abbreviated as N/A, EA and EMEA respectively. The test orthogonal combinations are shown in Table 3.

| Bonding layer | N/A | Emulsified asphalt | Epoxy modified Emulsified asphalt |
|---------------|-----|--------------------|-----------------------------------|
| SBR-A modified emulsified asphalt | 1   | 2                  | 3                                 |
| SBR-B modified emulsified asphalt | 4   | 5                  | 6                                 |

There will be six groups of experiments and parallel experiments are conducted three times to remove data with coefficient of variation greater than 5%. The test specimens are shown in Fig. 2.

The forming steps of laboratory test specimens are as follows: 1. Clean the lower bearing layer (cement concrete surface or asphalt concrete surface); 2. Uniformly coat the bonding layer (0.8L/); 3. Spread out the mixtures on the fine surface and measure their average thickness by vernier caliper; 4. Stand at room temperature for 2 hours before testing. It is noteworthy that epoxy emulsified asphalt, as a bonding layer, must be sprayed almost simultaneously with the fine surface mixture, and the time interval is short. Therefore, synchronous construction should be carried out in the actual project.

3. Results and analysis

3.1. Abrasion resistance
The value of 1h wet track abrasion and loaded wheel test reflect the anti-wear property of the mixture to a certain extent[4]. Three kinds of bonding layer (including none bonding layer) in super surfaceing are used to tack the super surfacing mixture. Then the 1h Wet track abrasion test and the loaded wheel bonding test are carried out. The test results are shown in Fig. 2 and 3.

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Figure 2. Comparison of Anti-Water Resistance

Figure 3. Abrasion Resistance of three kinds of SBR-A super surfacing

Figure 4. Abrasion Resistance of three kinds of SBR-B super surfacing

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of bonding layer in Super surfacing(SBR-A), bonding layer in Super surfacing(SBR-B).

As shown in Figure 3 and 4, compared with the wear value of wet wheels for one hour, the performance of EMEA > EA > N/A shows that the wear resistance of SBR-A modified emulsified asphalt is better than that of SBR-B. This is mainly due to the use of rapid setting technology in this kind of domestic SBR, while SBR-B performs high viscous properties, but the strength increases slowly. The amount of adhering sand can reflect the adhesiveness of asphalt and aggregate after the strength of super surfacing mixtures is formed to a certain extent. However, it should be noted that the higher the amount of adhering sand is, the more likely the phenomenon of "sticking wheel" and "dust collection" will appear after open traffic. The order of the loaded wheel value is EMEA > EA > N/A.

3.2. Anti-water resistance

The results of 6-day wet track abrasion test (WTAT) on the precise surface of three modified emulsified asphalts are shown in Fig. 5 and 6.

In Figure 5 and 6, the data gap between 6d wet track abrasion value and 1h wet track abrasion value is more obvious. The order of 6d wet track abrasion value is EMEA > EA > N/A. Overall, the performance of SBR-A fine surface is better than SBR-B.

3.3. Skid resistance

As a friction layer directly serving the wheel load, the skid resistance of the finished surface is of particular concern. Pendulum BPN value is the most common and universal method to test the anti-skid ability of pavement. There are differences in the compatibility of different cements with gradation and aggregate at the finish surface, so it is necessary to analyze the anti-skid performance before implementation. Because different emulsified asphalt may have a great influence on the final strength formation of Super surfacing mixtures, this comparative test set up 60 for 2, 4 and 6 hours to analyze and compare the skid resistance of Super surfacing mixtures with different emulsified asphalt under different curing time. The experimental results are shown in Fig. 7 and 8.
bonding layer in Super surfacing(SBR-A).

From the test process and results shown in Fig. 7 and 8, it can be seen that combination of EMEA and SBR-B modified emulsified asphalt super surfacing shows the best anti-sliding performance. The reason is that its imported SBR polymer has poor compatibility with emulsified epoxy, and there is a lot of segregation, which results in the uneven distribution of modified substances in the binder, the uneven distribution of liquid and solid substances in the binder, and the waste of modifier. Meanwhile, it has brought negative impact on the anti-skid performance.

4. Conclusions
The pavement performance of four different emulsified asphalts was compared in order to study the advantages and disadvantages and evaluation effects of the currently used in integration with epoxy modified emulsified asphalt in super surfacing, and to compare the gradation and ring used in the test. The specific conclusions are as follows:
(1) The wear resistance of super surfacing used EMEA bonding layer is the best way. Bonding layer of epoxy modified emulsified asphalt is more completely wrapped between asphalt and aggregate than the other two ways, but it is easier to peel in blocks due to vehicle loads. It needs to prolong the sealing time properly and dry and clean the surface in time to improve its use effect.
(2) EMEA bonding layer greatly enhanced cohesion between asphalt and aggregate after demulsification in super surface, and in areas with complex water action, the combination of EMEA and SBR-A super surface is the best choice.
(3) With the passage of curing time, the anti-sliding ability of three bonding layer ways of super surfacing abrasive layers is increasing. Three kinds of emulsified asphalt surface can meet the requirements of open traffic within 6 hours of curing time (BPN > 60). After any curing time, the order of anti-skid performance is: EMEA>EA>N/A.

5. References
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