

Preparation and Mechanical Performance Study of High-Temperature Resistant Non-Sticking Emulsified Asphalt

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Abstract: In order to solve the problem that traditional emulsified asphalt is prone to insufficient bonding between the cohesion wheels and layers under high temperature conditions, TE hard asphalt, SBS modified asphalt, 70# matrix asphalt and interface separator were used to prepare non-stick wheel emulsified asphalt, and the content of TE hard asphalt and different interface separators was determined by the test of sticking wheel rate and storage stability. The performance of self-made non-stick wheel emulsified asphalt and commercially available ordinary and SBS modified non-stick wheel emulsified asphalt passed the non-stick wheel rate test, composite shear and pull-out test and adhesion pull-out test were compared. The results showed that when the ratio of the three asphalts was 65% matrix asphalt + 20% SBS + 15% TE hard asphalt, the sticking rate and storage stability were the most balanced. When the content of A-type nanointerface separator was 3%, the effect of reducing the sticking ring rate was the most significant, from 0.78% to 0.31%, and the effect on storage stability was minimal. By comparing the performance of ordinary and SBS modified non-stick wheel emulsified asphalt with commercially available products, the shear and pull-out strength of self-made non-stick wheel emulsified asphalt at 25°C and 40°C were the highest, the temperature sensitivity was the lowest, and the interlayer bonding performance was the most stable. Therefore, self-made non-stick wheel emulsified asphalt can effectively improve the sticking wheel phenomenon during high-temperature construction process, improve the bonding strength between layers, and reduce the maintenance cost in the later stage.

Keywords: non-stick wheel emulsified asphalt; sticky wheel performance; Interfacial sequesters; interlayer bond strength

1. Introduction

The adhesive layer is an important interface in the road structure that connects the old and new layers. Its function is to ensure the effective transmission of interlayer stress and maintain the collaborative performance of the overall pavement structure [1-2]. However, with the continuous increase of traffic load and the complexity of construction conditions in high temperature seasons, traditional emulsified asphalt is prone to problems such as tire adhesion, dragging and pulling film, and incomplete film formation under high temperature conditions [3-5]. Therefore, developing adhesive layer materials with good high-temperature non adhesive properties and considering interlayer bonding strength is of great significance for improving road service performance. In recent years, domestic and foreign researchers have attempted to improve non stick wheel performance by increasing the softening point of asphalt, introducing modifiers, optimizing emulsion systems, and other methods. Although ordinary SBS modified non stick wheel emulsified asphalt can improve the elasticity and shear resistance of the film layer, its high-temperature flowability is still significant, making it difficult to completely solve the problem of high-temperature wheel sticking [6-8]; Although ordinary hard asphalt has a high modulus, its film-forming toughness is insufficient, temperature sensitivity is strong, and it is easy to cause brittle cracking of the adhesive layer oil film. Moreover, the storage stability of simply emulsified hard asphalt is difficult to control [9-11]. In addition, existing research has mostly focused on regulating the performance of asphalt itself, with insufficient attention paid to the interface mechanism and the application of interface isolation agents in non stick wheel emulsified asphalt, and a lack of systematic process and formula optimization research.

In response to the above issues, this study constructed a ternary composite system consisting of TE hard asphalt, SBS modified asphalt, and 70 # matrix asphalt. By adjusting the content of TE hard asphalt and introducing different types of interface isolation agents, the influence of TE hard asphalt on high-temperature non stick wheel performance and storage stability was investigated. The optimal ratio scheme and isolation agent type were determined, and the interlayer shear and tensile strength of self-made non stick wheel emulsified asphalt was compared with commercially available ordinary and SBS modified non stick wheel emulsified asphalt to clarify the key mechanism of performance improvement. The self-made non stick emulsified asphalt can provide technical basis for engineering applications and have reference value for improving the quality of high-temperature construction.

2. Test methods and materials

2.1 Raw materials

This article uses 70 # matrix asphalt and SBS modified asphalt provided by Maoming Weilong Petrochemical Co., Ltd., and TE hard asphalt provided by Panjin Yutuo Chemical Co., Ltd. The performance indicators are shown in Table 1.

Table 1. Performance Indicators

Project	Unit	70# base asphalt	SBS modified asphalt	TE hard grades of bitumen	Technical method
Penetration depth at 25°C	0.1mm	63.6	51.4	25.7	T0604
Ductility at 15°C	cm	>100	>100	33.5	T0605
Softening point	°C	46.7	67.5	72.4	T0606
Solubility	%	99.9	99.5	99.6	T0607
Dynamic viscosity at 60°C	Pa·s	230	-	244	T0620

2.2 Emulsifier

Emulsifier A9DA is provided by Shengquan Group Co., Ltd. Its performance indicators are shown in Table 2.

Table 2. Performance Parameters of Emulsifiers

Emulsifier Name	Ion type	Demulsification speed	Surface	Active Ingredient
A9D A	Cation	Fast-reacting, fast-setting type	White paste-like solid	alkyl quaternary ammonium salts

2.3 Additives

Additives are composed of stabilizers, isolation agents, and pH regulators. The stabilizer is a mixture of calcium chloride and sodium carboxymethyl cellulose in a ratio of 1:2. The pH regulator is hydrochloric acid with a concentration of 38%. Type A isolation agent adopts nano interface isolation agent, provided by Beijing Dongfang Yuhong Waterproof Technology Co., Ltd. B-type isolation agent is provided by Haicheng Yongxiang New Materials Co., Ltd; Its performance indicators are shown in Table 3.

Table 3. Performance Specifications of Interface Isolating Agent

Project	Type A isolating agent	Type B isolating agent
Surface	Milk-white liquid	White fine powder
Active Ingredient	Nanopolymeric polymers	Calcium stearate
Density (25°C, g/cm ³)	1.02	1.08
pH	7~8	9~9.5
Contact angle (°)	>110	>100

3. Experimental methods

3.1 Preparation method of non stick wheel emulsified asphalt

Heat an appropriate amount of 70 # base asphalt, SBS modified asphalt, and TE hard asphalt in a (160 ± 3) °C oven to achieve a flowing state; Then place the three types of asphalt in a heating jacket at 165 °C in proportion, and mix with a mixer at a speed of 1000-2000rpm for 1.5 hours for later use; Dissolve a mixture of emulsifier, calcium chloride, and sodium carboxymethyl cellulose in water at 60-70 °C to make a soap solution, and adjust the pH to 0.8-3 with hydrochloric acid; Start the colloid mill and add soap solution, cut for 0.5 minutes; Slowly add the mixed asphalt (with a solid content of 62%) and shear for 2-3 minutes to obtain homemade non stick wheel emulsified asphalt.

3.2 Storage stability test

According to the T0655 storage stability test method in JTG E20-2011 "Test Code for Asphalt and Asphalt Mixtures in Highway Engineering", the storage stability is evaluated by the difference in solid content (SS) after standing for 5 and 7 days. The calculation formula is as follows:

$$S_s = |P_A - P_B| \quad (1)$$

In the formula: S_s - storage stability of the sample, unit: %, P_A - residual evaporation content of the sample in the upper branch after storage, unit:%, P_B - residual evaporation content of the sample in the lower branch after storage, unit:%.

3.3 Adhesive wheel performance test

This study adopts the rutting test method specified in T0719-2011 of the Test Code for Asphalt and Asphalt Mixtures in Highway Engineering (JTG E20). Using a wheel rut tester with temperature control function, the rubber skin coated with non stick wheel emulsified asphalt on the surface of the wheel rut plate is rolled by a roller. The non stick wheel emulsified asphalt characteristics at a specific temperature are evaluated based on the quality difference of the rubber skin before and after the test and the ratio of the non stick wheel emulsified asphalt mass covered by the rubber skin (δ). The calculation formula is shown in (2):

$$\delta = m/M \times 100\% \quad (2)$$

In the formula: δ - wheel adhesion rate (%); M - Poor quality of rubber skin (g); m - Mass of non stick wheel emulsified asphalt sample in the form of a belt (g).

3.4 Adhesion pull-out strength test

Firstly, the formed rutting specimen; Secondly, cut the rutting test piece into rectangular test blocks of 15cm×30cm×3cm, clean the cutting surface and apply 0.5kg/m² emulsified asphalt. After the surface is dry, use epoxy resin to bond the pull-out head. Leave it at room temperature for 6 hours until the epoxy resin is completely cured, and then keep it at the specified temperature for 4 hours. Finally, use a pull-out adhesion tester for pull-out testing, control the pull-out rate to 0.02MPa/s, and record the pull-out strength.

3.5 Composite drawing and shear tests

Apply a specified amount of non stick wheel emulsified asphalt to the surface of the rutting board, and let it stand at room temperature until it is completely emulsified. Place the specimen in a 300 mm×300 mm×100 mm test mold (with the coating facing upwards), spread commonly used AC-13 graded asphalt mixture with a thickness of 40-50 mm, cool to room temperature and cure for 24 hours. Use the core drilling method to obtain a cylindrical specimen with a diameter of 100 mm. After the specimen is insulated at the specified temperature for ≥ 4 hours, it is loaded into a universal testing machine, fixed with fixtures, and subjected to tensile or shear tests at a rate of 10 mm/min until the interlayer bonding layer is damaged.

4. Analysis of test results

4.1 Determination of TE hard asphalt content

The core function of TE hard asphalt in non stick wheel emulsified asphalt is to enhance the hardness of emulsified asphalt after emulsion breaking, so that it can maintain non stick wheel characteristics at higher road surface temperatures, while enhancing the interlayer adhesion of asphalt pavement. Therefore, this study appropriately increased the blending ratio of TE in the matrix asphalt, conducted non stick wheel performance and storage stability tests on different schemes, and selected the optimal blending amount of TE hard asphalt [12]. The specific experimental plan is shown in Table 4, and the test results are shown in Figure 1.

Table 4. Table of Various Asphalt Ratios for Non-Stick Wheels

scheme	Asphalt content (%)			
	Matrix asphalt	SBS modified asphalt	TE hard grades of bitumen	Amount to
1	75	20	5	100
2	70	20	10	100
3	65	20	15	100
4	60	20	20	100
5	80	15	5	100
6	80	10	10	100
7	80	5	15	100
8	80	0	20	100

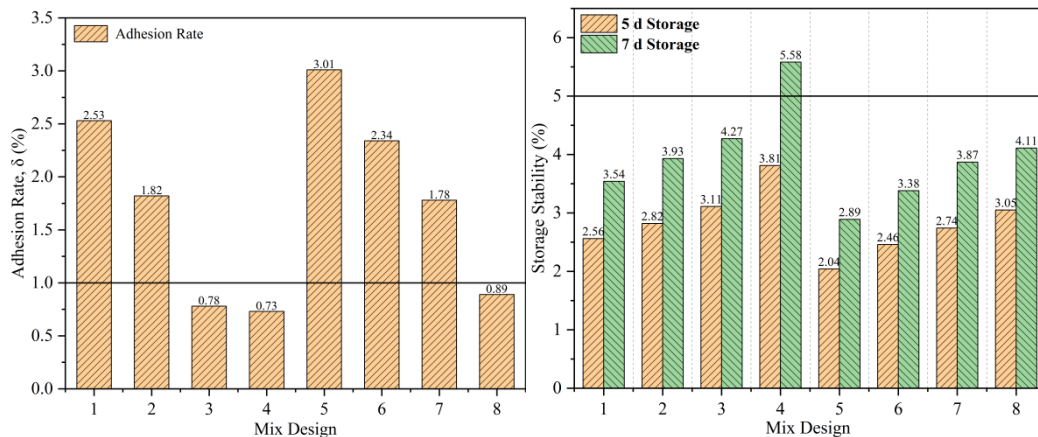


Figure 1. Test results of non-stick wheel performance and storage stability

As shown in Figure 1, with the increase of TE asphalt content, the non stick wheel performance shows an upward trend, but when the TE content increases, it will lead to a decrease in storage stability (SS). This is because TE hard asphalt itself belongs to the category of superhard high modulus modifiers, and the high rigidity components can improve the high-temperature modulus and shear deformation resistance of the film after demulsification and film formation. At the same time, the elastic phase and network structure provided by SBS modified asphalt can improve the extensibility and resilience of the film layer, improve peel toughness. In addition, 70 # matrix asphalt has relatively high penetration and low rigidity, which makes the system have better dispersibility and film-forming properties during emulsification and shear processes. It can form a compatible continuous phase with TE and SBS, thus reducing the viscosity and balancing storage stability. When the content of TE is too high, because the density and viscosity difference between asphalt particles increases, the elastic network structure of SBS is difficult to effectively buffer the heterogeneity of the system, resulting in lotion more prone to sedimentation and stratification [13]. Based on the test results of adhesion rate and storage stability, the optimal ratio of matrix asphalt, SBS modified asphalt, and TE hard asphalt is determined to be 65:20:15.

4.2 Selection of interface isolation agent types and determination of dosage

In the principle of preparing non stick wheel emulsified asphalt, it is considered to add interface isolation agent and investigate whether the addition of interface isolation agent can significantly improve

the non stick wheel characteristics [14]. Therefore, in this section, two different types of interface separators will be selected to investigate the degree of influence of each type of interface separator on the non stick characteristics of non stick emulsified asphalt. The test results are shown in Figure 2.

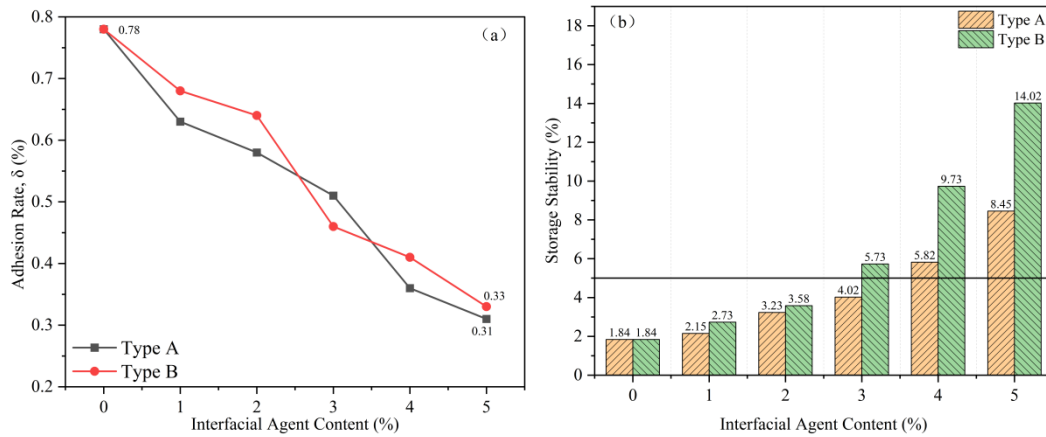
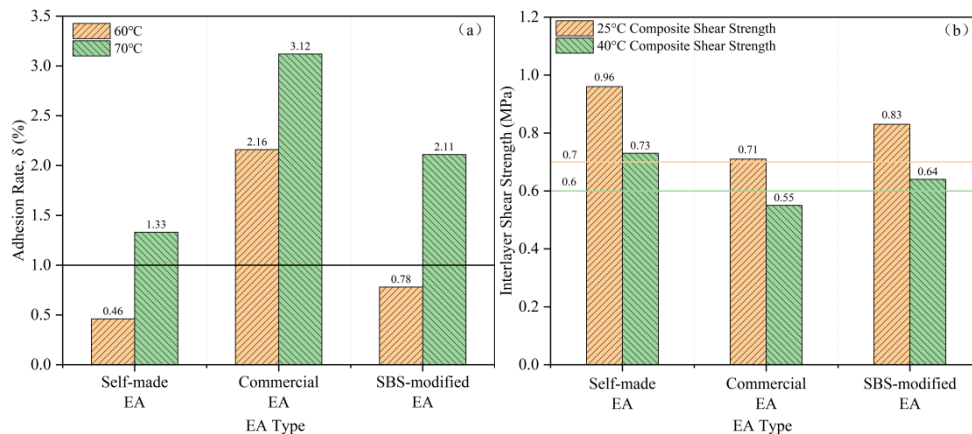


Figure 2. Effect of interface isolant dosage on the properties of non-stick wheel-emulsified asphalt

As shown in Figure 2 (a), the addition of interface isolation agent significantly improves the non stick wheel performance, while the stick wheel rate continues to decrease with increasing dosage. Among them, type A nano isolation agent can reduce the maximum adhesion rate from 0.78% to 0.31% (a decrease of 60.3%), and type B calcium stearate isolation agent can reduce it to 0.33% (a decrease of 57.7%). This is because the high specific surface area and surface activity of nanoparticles give the isolation membrane low surface energy, reducing the van der Waals forces and viscous interactions between the asphalt membrane and the rubber wheel [15]; And calcium stearate relies on hydrophobic long-chain physical coverage to form a film, reducing interfacial adhesion and improving non stick wheel performance. As shown in Figure 2 (b), the storage stability decreases with the increase of the amount of isolation agent added. When the dosage is less than 3%, both isolation agent systems meet the specification requirements; When the dosage is greater than or equal to 3%, obvious stratification or demulsification occurs. The storage stability of the lotion system is worse when the B-type interfacial spacer is added. This is because calcium stearate is a hydrophobic powder material, which is more likely to lead to particle enlargement and agglomeration, while the relatively uniform dispersion of A-type nano spacer and more stable chemical adsorption have little impact on the storage stability of the emulsion system. Based on the comprehensive effect of non sticking wheel and storage stability, 3% A-type nano spacer is finally selected as the best solution, which can greatly reduce the rate of sticking wheel and maintain the good stability of lotion.

4.3 Performance evaluation of non stick wheel emulsified asphalt

Conduct indoor tests on key indicators of non stick wheel characteristics, such as δ , for self-made non stick wheel emulsified asphalt, ordinary commercially available non stick wheel emulsified asphalt, and SBS modified non stick wheel emulsified asphalt at 60 °C and 70 °C, respectively. Conduct composite shear strength, composite tensile strength, and adhesion tensile strength tests at 25 °C and 40 °C. The test results are shown in Figure 3.



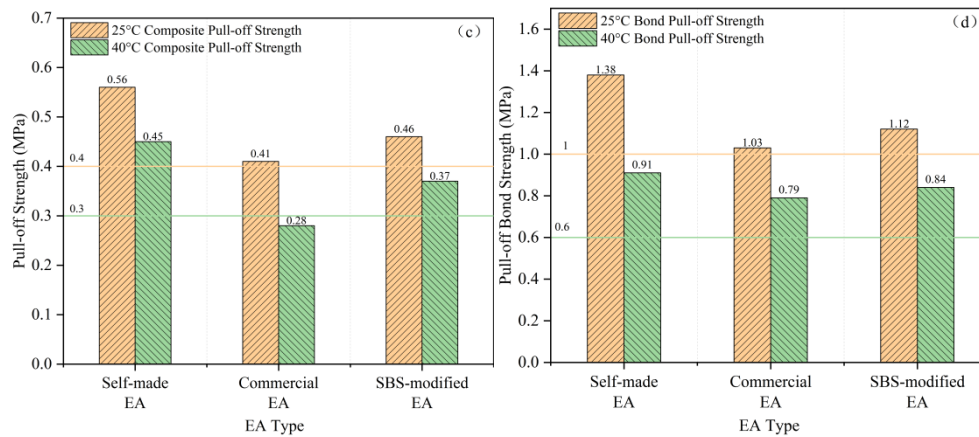


Figure 3. Non-stick wheel performance test

From Figure 3, it can be seen that the homemade non stick wheel emulsified asphalt has the lowest sticking rate at 60°C and 70°C, which is significantly better than the commercially available ordinary and SBS modified non stick wheel emulsified asphalt. And under the conditions of 25°C and 40°C, its adhesion, shear resistance, and interlayer bearing capacity have significant advantages. According to Figures 3 (b) and (c), at 25°C, the self-made non stick wheel emulsified asphalt showed an increase in tensile and shear strength of 21.7% and 15.7% respectively compared to SBS modified emulsified asphalt, and an increase of 35.2% and 15.7% compared to commercially available ordinary emulsified asphalt; Under high temperature conditions of 40°C, the improvement amplitude is further expanded, with an increase of 21.6% and 14.1% compared to SBS modified emulsified asphalt, and an increase of 60.7% and 32.7% compared to ordinary emulsified asphalt. According to Figure 3 (d), at 25 °C, the adhesion tensile strength of self-made non stick wheel emulsified asphalt is 34% and 23.2% higher than that of commercially available ordinary non stick wheel emulsified asphalt and SBS modified non stick wheel emulsified asphalt, respectively. At a high temperature of 40°C, compared to commercially available ordinary non stick wheel emulsified asphalt and SBS modified non stick wheel emulsified asphalt, the performance increased by 15.2% and 8.3%, respectively. This indicates that homemade non stick emulsified asphalt has weaker temperature sensitivity and more stable interfacial bonding performance. The performance improvement of homemade non stick wheel emulsified asphalt mainly comes from the high modulus skeleton provided by TE hard asphalt, which makes the demulsified film layer have a high softening point and shear resistance; SBS endows the film layer with elasticity and deformation recovery ability, reducing the risk of high-temperature tensile failure; 70 # asphalt, as a continuous phase, improves dispersibility and film uniformity, forming a composite structure with "high stiffness and moderate elasticity" as a whole, thereby maintaining high bearing capacity and shear resistance under both normal and high temperature conditions. In addition, the A-type interface isolation agent further enhances the non adhesion and interface stability of the film layer, resulting in a lower adhesion rate. In summary, the self-made non stick wheel emulsified asphalt relies on the structural advantages of three composite asphalt systems, combined with the synergistic effect of the interface isolation agent, to achieve comprehensive performance of high temperature low adhesion, high strength at room temperature and high temperature, and minimum temperature sensitivity. The overall performance is better than that of commercially available ordinary and SBS modified non stick wheel emulsified asphalt.

5. Conclusion

(1) When preparing non stick wheel emulsified asphalt, adding TE hard asphalt can significantly improve the high-temperature non adhesion performance of emulsified asphalt, but high dosage will weaken storage stability. When the content of AH70 matrix asphalt: SBS modified asphalt: TE hard asphalt is 65:20:15, a uniform membrane structure with both high modulus and moderate elasticity can be formed, ensuring a balance between wheel adhesion and storage stability.

(2) Both interface isolation agents can reduce the wheel sticking rate, among which type A nano isolation agent has the most significant effect, reducing the wheel sticking rate from 0.78% to 0.31%, and has the smallest impact on storage stability. Based on the results of the adhesion rate and storage stability tests, the optimal solution for A-type nanoisolation with a dosage of 3% was ultimately chosen.

(3) The homemade non stick emulsified asphalt has the lowest wheel sticking rate at 60°C and 70°C; At 25°C and 40°C, its shear, tensile, and adhesion strength are significantly better than those of

commercially available ordinary and SBS modified non stick wheel emulsified asphalt. At 25 °C, the tensile and shear strength of emulsified asphalt increased by 35.2% and 15.7% respectively compared to ordinary emulsified asphalt; At 40 °C, they increased by 36.6% and 32.7% respectively. This indicates that it has low temperature sensitivity and strong interface stability, and the self-made non stick wheel emulsified asphalt is significantly better than commercially available products in terms of high-temperature non stick wheel performance, interlayer strength, and temperature stability.

Acknowledgement

This work was supported by Shandong Provincial Department of Transportation Science and Technology Project (2022B101, 2023B92-03, 2025BAI14-02).

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