**Preparation of color modified emulsified asphalt and performance analysis of micro surface mixture in cold area**

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**Abstract.** In order to determine the color modified emulsified asphalt and its preparation process in cold areas represented by Hulunbuir, Inner Mongolia, a variety of materials such as saturated hydrocarbon A, petroleum resin B, copolymer C, copolymer D, and plasticizer E were selected to simulate four components of asphalt are used to prepare colored asphalt, and a colored modified emulsified asphalt suitable for cold regions is developed by the preparation process of emulsified asphalt emulsifying and modifying. The performance of the prepared colored modified emulsified asphalt was analyzed, and the optimal dosage range of modifier, emulsifier, stabilizer, and pH adjuster was determined, and the high and low temperature performance of colored modified emulsified asphalt was improved to adapt to environment of cold areas. Through the colored micro-surfacing mix design to determined the optimal emulsified asphalt dosage, and the test compares the surface performance and durability of the ordinary micro-surfacing mixture and the colored micro-surfacing mixture, which proves that the CMS-3 type mixture has good water sealing effect, anti-slip performance and ability of water damage resistance.

**1. Introduction**

The color asphalt pavement has the advantages of high brightness at night, good lighting effect, easy identification of the road surface and low temperature of the road surface in summer. Its mixture has excellent performance and can meet the requirements of road use [1, 2]. Many research results have been made on the performance of color micrometers at home and abroad. Pasetto et al. alternately used mortar, colored oxides, and synthetic resins for color asphalt modification, and empirically evaluated the drainage and skid resistance of the colored micro-surface [3]. Ning Aimin and others have researched and developed the color pavement binder—FC-I series color paving material (FC-I for short). This FC-I color mixture has good high temperature stability and low temperature resistance to deformation, and is economical. Good benefits, bright colors can alleviate visual fatigue and other advantages [4, 5]. Alne James et al. found that the use of phosphoric acid as a pH regulator can develop a better index of cohesion of the mixture [6]. Research by Mu Mingren et al. found that the domestically developed colored asphalt can not only meet the requirements of heavy traffic petroleum asphalt on the road surface, but also draw various colored LOGO patterns according to actual needs.
This domestic colored asphalt has a lower cost than imported colored asphalt, has a strong competitive advantage [7]. In most areas of Hulunbuir, Inner Mongolia, due to the hot summer and severe cold and dry climate environment, the driving safety of asphalt pavement and road performance, especially low temperature performance, have put forward stringent requirements [8-11]. When surface diseases such as reduced anti-skid performance and excessive water seepage coefficient appear on pavement in cold areas, special modified emulsified asphalt needs to be selected for the environment of the area in order to improve the low temperature performance and sealing water effect of the layer [12, 13]. In this paper, through a large number of indoor tests, a colored asphalt with superior low-temperature performance was developed. The colored modified emulsified asphalt was prepared from the developed colored asphalt, and its performance was evaluated on the basis of meeting the requirements of cold regions. The research on the design and performance of the mixture ratio has laid the foundation for the color micrometer to be located in different public places, especially cold areas.

2. Preparation of colored asphalt in cold areas

In order to meet the application requirements in cold areas, priority is given to the low-temperature performance of asphalt, while ensuring its high-temperature performance, taking into account the workability and temperature sensitivity of asphalt, in which the colorless asphalt is prepared by simulating a four-component colloidal system of asphalt, in which the aromatic and saturated components are replaced by small molecular weight saturated hydrocarbon A components, and the asphaltenes and gums are replaced by petroleum resin B, copolymer C, and copolymer D, and choose the plasticizer E to reconcile the colloidal system of the colorless asphalt, finally, use the shearing method to melt the color pigments into the colorless asphalt to develop the colored asphalt. The composition ratio and main indicators of colorless asphalt are shown in Tables 1 and 2.

| Colorless asphalt composition | Saturated hydrocarbon A | Petroleum resin B | Copolymer C | Copolymer D | Plasticizer E |
|------------------------------|-------------------------|------------------|-------------|-------------|---------------|
| Blending ratio (%)           | 26                      | 58               | 6           | 2           | 8             |

| Main indicators                  | Detection result |
|----------------------------------|------------------|
| Penetration (0.1mm)              | 30℃, 100g, 5s   | 148              |
| Softening point                  | 5℃/min           | 55.6             |
| Ductility (cm)                   | 15℃, 50mm/min   | ≥100             |
|                                  | 10℃, 50mm/min   | ≥100             |
| After RTFOT                      | Penetration ratio, % | 94.6            |
|                                  | Quality change, % | 0.3              |
| Flash point                      | 250℃             |                  |
| Kinematic viscosity              | 135℃, mpaꞏs     | 181.4            |
| Dynamic viscosity                | 60℃, paꞏs       | 282              |

3. Preparation and performance analysis of colored modified emulsified asphalt

3.1 Preparation of colored modified emulsified asphalt

This paper adopts the method of emulsifying and modifying to prepare colored modified emulsified asphalt. First, add a certain amount of stabilizer CaCl2 and emulsifier to the vessel, then add a proper
amount of hydrochloric acid to adjust the pH of the solution to 2.0~3.0, and then add a certain amount of SBR modified latex. During each addition of admixture, it must be evenly stirred for 30s, and always pay attention to the temperature control operation, the temperature should not be too high or too low, the temperature should be controlled at 60~65°C. Finally, the mixture is poured into the colloid mill and discharged after running for 3 minutes.

Preheat the colloid mill with hot water for 1 minute and then pour it out. Pour the prepared soap liquid into the colloid mill and cut for 1 minute. During shearing, measure and pay attention to the temperature of the soap liquid, and then pour the 140~145°C colored asphalt into the colloid mill and continue shearing for 3~4 minutes to mix and emulsify the bitumen and soap completely, and then pour it out. When the temperature of the emulsion drops to room temperature, sieve and seal it for storage.

3.2 Test and performance analysis of colored modified emulsified asphalt

Based on experience and the recommended blending amount of emulsifiers and modifiers, the initial ratio is initially determined, and the emulsifier, modifier, stabilizer, and pH regulator ratio are determined by the external blending method to develop colored modified emulsified asphalt. In order to comprehensively study the factors affecting the performance of colored modified emulsified asphalt, a single factor control variable method was used to analyze the impact of four factors of soap pH, stabilizer content, emulsifier content, and modifier content on the performance of colored modified emulsified asphalt. The specific blending ratio is shown in Table 3.

| Components          | Modifier (%) | pH regulator proper amount | Emulsifier (%) | Stabilizer (%) | Water (%) | Colored asphalt (%) |
|---------------------|--------------|----------------------------|----------------|----------------|-----------|---------------------|
| Mixture ratio (%)   | 3.0          | 2.5                        | 0.4            | 32.0           | 68.0      |                     |

Fix other components, change a single factor to analyze its impact on the performance of colored modified emulsified asphalt: (1) Modifier content is 0, 2.0%, 3.0%, 4.0%, 5.0%; (2) soap pH is 1.0, 2.0, 2.5, 3.0, 4.0; (3) The emulsifier content is 1.0%, 1.5%, 2.0%, 2.5%, and 3.0%; (4) The stabilizer content is 0, 0.2%, 0.4%, 0.6%, 0.8%.

Test and analyze the remaining amount on the sieve of the colored modified emulsified asphalt after the evaporation residue, the 25°C penetration, the 5°C ductility, the softening point, and the asphalt standard viscosity C25,3 and 1d storage stability indicators to determine the optimum dosage range of modifiers, pH regulators, emulsifiers and stabilizers when developing colored modified emulsified asphalt See Figure 1-6 for details.

![Figure 1. Demaining amount on the sieve of colored modified emulsified asphalt with different factors](image1)

![Figure 2. 25°C Penetration of colored modified emulsified asphalt with different factors](image2)
Figure 3. 5°C Ductility of colored modified emulsified asphalt with different factors

Figure 4. Softening point of colored modified emulsified asphalt with different factors

Figure 5. Standard viscosity of colored modified emulsified asphalt with different factors

Figure 6. 1d Storage stability of colored modified emulsified asphalt with different factors

Combined with the analysis of the broken line trend chart in Figure 1-6, the following conclusions can be drawn:

(1) With the increase of the pH of the soap solution, the influence of the 25°C penetration and softening point of the colored modified emulsified asphalt after evaporation remains are insignificant; while the standard viscosity of the asphalt gradually becomes rough that the fluidity of the emulsion becomes worse, to ensure a good emulsifying environment, the pH of the soap should not be too large or too small; while the remaining amount on the sieve and the storage stability of 1d all show the same law of first decreasing and then increasing, the 5°C ductility also increases first and then decreases. Considering that the colored modified emulsified asphalt has to adapt to the environment in cold regions, the performance of the soap liquid is optimal when the pH is near the median value. It can be concluded that there is the best soap pH of color modified emulsified asphalt should be controlled around 2.5.

(2) With the increase of stabilizer content, the remaining amount on the sieve of the colored modified emulsified asphalt and the 25°C penetration and softening point after evaporation remains less affected; while the standard viscosity of the asphalt continues to decrease and the decrease
amplitude gradually becomes smaller. In order to ensure its performance, the amount of stabilizer should not be too large or too small; while the 5°C ductility and the 1d storage stability show a decreasing trend, which is unfavorable for its ductility but beneficial for 1d storage stability, when the stabilizer content exceeds 0.25%, its 1d storage stability is less than 1.0%, when the stabilizer content exceeds 0.4%, its 5°C ductility is significantly reduced. It is difficult to ensure the performance of colored modified emulsified asphalt in cold regions. Considering comprehensively the stabilizer content of colored modified emulsified asphalt should be controlled within 0.25%~0.4%.

(3) With the increase of the emulsifier content, it has little effect on the 25°C penetration and softening point of the colored modified emulsified asphalt after the evaporation remains; while the remaining amount on the sieve and 1d storage stability gradually decrease so that color modified emulsified asphalt has better performance. When the emulsifier content exceeds 2.0%, the remaining amount on the sieve is less than 0.1%, and the 1d storage stability is less than 1.0%. When the emulsifier content exceeds 2.5%, the standard viscosity of asphalt keeps dropping to less than 21s, therefore the emulsifier content should not be too large or too small; the 5°C ductility show the tends of increase first and then decrease. When the content of emulsifier is around 2.0%, its 5°C ductility reaches the maximum, and the colored modified emulsified asphalt can meet the requirements of cold regions. It can be concluded that the emulsifier content of colored modified emulsified asphalt should be controlled at 2.0%~2.5%.

(4) With the increase of the content of modifier, the 5°C ductility, softening point, and standard viscosity of the colored modified emulsified asphalt after the evaporation residue gradually increase. When the content of the modifier is 3.0%, the 5°C ductility reaches 48cm, the softening point exceeds 55°C, and the standard asphalt viscosity is 21s, which better improves the high and low temperature performance of the asphalt; its 25°C penetration continues to decrease, when the modifier content is 4.0%, the 25°C penetration is less than 80; the remaining amount on the sieve and the 1d storage stability gradually increase, and the stability of the emulsion gradually deteriorates, when the modifier content is 4.0%, the remaining amount on the sieve is 0.11%, and the 1d storage stability is 1.1%, both of which do not meet the specification requirements. In summary, it can be seen that the modifiers content of colored modified emulsified asphalt should be controlled at 3.0%~3.5%.

4. Research on the Design and Performance of the colored micro-surfacing mix design

4.1 Mix design

Color pigments are inorganic oxides, with the advantages of uniform particle size, complete chromatogram, strong coloring power, good dispersibility, light fastness, non-toxicity and low cost. Refer to the specification 《Technical guide for micro-surface and slurry seal》 [14] to conduct mixing test, wet wheel abrasion test and load wheel adhesion test of the color micro-surface mixture to determine the mineral grade and the best oil-stone ratio at the color micro-surface.

The best oil-stone ratio range of the CMS-3 type mixture determined according to the wet wheel abrasion test and the load wheel adhesion test is 6.31%–6.84%, which is 10.2%–11.0% when converted into colored modified emulsified asphalt.

Therefore, this paper finally determines that 6.6% of the allowable oil-stone ratio range is selected as the best oil-stone ratio for the subsequent performance study of the CMS-3 type mixture. The ratio of each raw material of the CMS-3 type mixture is shown in Table 4.

| Raw material | Aggregate | Pigment content | Cement content | Water | Colored modified emulsified asphalt |
|--------------|-----------|-----------------|----------------|-------|------------------------------------|
| Proportion (%) | 96.0      | 3.0             | 1.0            | 7.0   | 10.6                               |

4.2 Surface performance

The surface performance of the color micro-surface is mainly studied by comparing the water permeability and anti-slip performance of the mixture of ordinary and color micro-surface. The water
permeability of the color micro-surface is characterized by the water seepage coefficient, which can be measured by the water seepage test with a pavement water seepage meter; the anti-slip performance is generally characterized by the structural depth TD, according to the relevant regulations in the 《Field Test Regulations for Highway Subgrade and Pavement》 [15], the structure depth TD can be obtained through the manual sand-laying test to judge the surface roughness at the color micro-surface. The test results are shown in Table 5.

Table 5. Test results of structural depth TD and water permeability coefficient of micro surface

| Type of mixture         | Water permeability coefficient (mL/min) | Inspection standard (mL/min) | Water seepage               | Structural depth TD (mm) | Inspection requirements |
|-------------------------|----------------------------------------|-----------------------------|-----------------------------|--------------------------|-------------------------|
| Colored micro surface   | 1.8                                    | ≤10                         | Basically impermeable       | 0.84                     | ≥0.50                   |
| Ordinary micro surface  | 2.5                                    |                             | Basically impermeable       | 0.88                     | ≥0.60                   |

It can be seen from the test results in Table 5 that the water permeability coefficient and the structural depth TD of the mixture of the ordinary and color micro-surface all meet the standard inspection requirements in the specification, and the water permeability coefficient is far lower than the inspection standard requirements, and the structural depth is almost the same, which shows color pigments have little effect on the water permeability and structural depth of the mixture of the micro-surface. This is because the particle size of the color pigment is less than 0.075mm and the content is low, it acts as a fine aggregate in the color micro-surface mixture, can fill in the excess gaps and make it denser, so that the color micro-surface has good water sealing performance and anti-slip performance.

4.3 Durability

The durability of the color micro-surface mixture is mainly studied by comparing the abrasion resistance and water damage resistance of ordinary and color micro-surface mixture. The abrasion resistance of the mixture at the color micro-surface can be characterized by the wet wheel abrasion value after immersion in water for 1 hour, and its water damage resistance can be characterized by the 6d wet wheel abrasion value. In order to evaluate the water damage resistance and compatibility of the color micro-surface mixture from various aspects, a rotating bottle test was carried out in this paper. The test results are shown in Figure 7, Figure 8.
Analysis of the wet wheel abrasion test in Figure 7 shows that the 1h and 6d water immersion wet wheel abrasion values of the mixture of ordinary and color micro-surface meet the requirements of the specification. Compared with the ordinary micro-surface mixture, the wet wheel abrasion value of the color micro-surface mixture for 1h and 6d wet-wheel abrasion values are smaller. It can be seen that the color micro-surface mixture has better abrasion resistance and anti-water damage performance.

Analyzing the rotating bottle test in Figure 8, the compatibility grade value at the color micro-surface is the sum of the three average values of abrasion loss, entrapment rate, and integrity rate, which is 11.25 ≥ 11, which meets the specification requirements. This shows that the color micro-surface mixture has good water damage resistance and compatibility.

5. Main conclusions
In this paper, on the basis of proposing colored asphalt, the colored modified emulsified asphalt was prepared by emulsification and modification process, and the optimal dosage range and performance of modifier, pH regulator, emulsifier and stabilizer were explored. Concluded as follow:

(1) When preparing colored modified emulsified asphalt, the content of modifier should be controlled at 3.0%~3.5%, the content of emulsifier should be controlled at 2.0%~2.5%, and the content of stabilizer should be controlled at 0.25%~0.4%, The pH of the soap solution should be controlled at around 2.5, at this time, the overall performance is optimal, which can better adapt to the environment of cold regions and improve the high and low temperature performance of asphalt.

(2) The test determined that the best mineral gradation and the best oil-stone ratio of the CMS-3 colored micro-surface mixture is 6.6%, and the water permeability coefficient and structural depth TD of the mixture meet the standard inspection requirements in the specification. It shows that it has good anti-slip performance and water sealing performance.

(3) The test shows that the CMS-3 colored micro-surface has better water damage resistance and compatibility. Taking into account the special climate environment in the cold area of Hulunbuir, Inner Mongolia, the surface performance and durability have been improved and can be used in road maintenance projects for colored asphalt concrete pavements in cold areas.

References
[1] Chengqin Chen. Research on Road Performance of Colored Asphalt and Its Mixture[D]. Chang'an University, 2012.
[2] Shaoying Ren, Liu Xiaodan. Application and prospect of colored asphalt concrete pavement[J]. Journal of Inner Mongolia Agricultural University (Natural Science Edition), 2006(04):176-179.
[3] Pasetto, Marco, et al. "Preliminary Investigation of Mechanical and Functional Properties of Colored Asphalt Pavement Surfaces." Proceedings of the International Conference on Road and Rail Infrastructure CETRA. 2018.
[4] FC-1 color pavement cementitious material[J]. Petroleum Refining and Chemical Industry, 1993(08): 12.
[5] Aimin Ning, Jie Chen. The main performance evaluation of FC-1 color pavement cement[J]. Petroleum Refining and Chemical Industry, 1996(04): 21-25.
[6] Alan James Phosphoric Acid in emulsions [R]. 2006 ISSA World Congress.
[7] Mingren Mou, Yanjun Lu, Feng Wei, Weiping He, Jie Zhang, Haibo Liu. Research and application of colored cements[J]. Journal of Dalian Nationalities University, 2005(03): 73-75+80.
[8] Feng Lin. Research on preventive maintenance technology of asphalt pavement in cold area[D]. Hunan University, 2011.
[9] Stavitskiy VD. Construction of Colored Coatings [Minsk: Higher School, 1979.
[10] Tetsuya Shimoda. Decolorization Vine Taichi [J]. (Sun) Cloth, 1993, 28 (11): 37.
[11] Masato Kuriyama, Akira Kawai, Takeshi Yamamori. Riki-Ichi-Sho with a thermosetting coloring mixture [J]. (Sun) Cloth, 1994, 29 (11): 13-17.
[12] Yulong Tian. Causes of Asphalt Pavement Diseases in Cold Areas and Engineering Countermeasures[J]. Transportation Technology and Economy, 2008(06): 23-24.

[13] Qingfeng Wang, Mingqing Liu, Yubo Teng. The application of emulsified asphalt in road maintenance in cold areas[J]. Heilongjiang Transportation Science and Technology, 1998(01): 3-5.

[14] Songchang Huang, et al. "Technical Guidelines for Micro-surface and Slurry Sealing [M]." (2005).

[15] 2019, JTG 3450. Field Test Regulations for Highway Subgrade and Pavement [S]. Diss. 2019.