Study on synthesis and road performance of light-colored resin modified asphalt

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Abstract: To realize the color functionalization of road paving, this paper developed a light-colored resin modified asphalt, which can be added with toner to adjust different colors to realize the color paving of asphalt mixture. Fourier infrared spectroscopy (FT-IR) was used to analyze the difference between functional group composition of light-colored asphalt and 70# petroleum asphalt and to compare the conventional performance and road performance of light-colored asphalt with I-D grade modified asphalt. The road performance mainly includes high temperature performance, water stability performance and anti-skid performance. The test results showed that the light-colored asphalt and 70# petroleum asphalt had similar functional group composition, and the technical indicators of the light-colored asphalt could meet the requirements of I-D grade modified asphalt; the three road performances of the light-colored asphalt mixture met the specification requirements, which were even more excellent than the I-D grade modified asphalt mixture, indicating that the light-colored resin modified asphalt synthesized in this paper can meet the application of road engineering. Meanwhile, the light-colored resin modified asphalt has less smoke, lower carbon emissions, and superior performance than petroleum asphalt during use, which is beneficial to the sustainable development of road engineering.

1. Introduction
Colored asphalt paving has the effect of improving road beauty and architectural art. At present, colored asphalt is mainly obtained from light-colored cementitious materials through toning, and the light-colored cement mainly includes synthetic light-colored asphalt and decolorized asphalt. Decolorized bitumen is obtained by decolorizing petroleum bitumen, which is technically difficult and costly, and is currently less used. Synthetic light-colored asphalt has been used in relatively developed countries. European and American countries have carried out relevant research as early as the middle of the last century. In the 1960s, the Institute of Road Science of the former Soviet Union successively installed tens of thousands of square meters of colored asphalt concrete pavement in Moscow and other places, which achieved a wide range of applications [1]; in the 1980s, scholars in South Korea developed light yellow road cements and achieved successful applications [2]. The development of synthetic asphalt is comparatively late in China. At present, only a small amount of research and development of colored asphalt has been developed, and it has shown good road performance [3, 4]. In this paper, a color-adjustable light-colored resin modified asphalt binder was developed, and the three
road performances of the mixture, including high temperature, water stability, and anti-skidding, were evaluated, which can provide support for related research on road color paving.

2. Test

2.1. Materials
(1) Light-colored asphalt constituent materials: aromatic oil, Suzhou Hesen Specialty Oil Co., Ltd.; Petroleum resin (C5, C9 fraction), Qilu Petrochemical Co., Ltd.; Polymer modifier, Chongqing Zhixiang Paving Technology Project Co., Ltd.; Compatibilizer, Zhuhai Jieda Petrochemical Co., Ltd.; Polymer fluid filler (special plasticizing and toughening resin material), Chongqing Zhixiang Pudao Technology Engineering Co., Ltd.; SBS, China Petroleum & Chemical Corporation.

(2) Other materials: The coarse and fine aggregates used in the experiment were produced by Sichuan Hengtong Basalt Mining Co., Ltd., all of which were basalt crushed stone materials, and the ore powder was limestone ground ore powder, its various technical indicators meet the requirements of JTG F40-2004; The fiber was polyester, produced in Shandong Luxian Building Material Technology Co., Ltd.

2.2. Light-colored asphalt synthesis
Resin modified synthetic light-colored asphalt uses aromatic oil to replace aromatic components and partially saturated components, petroleum resins to replace partially saturated components and gums, and polymer modifiers to replace asphaltenes. Firstly, the aromatic oil was heated to 175 °C, then adding petroleum resin, stirring until it melts, adding polymer modifier and fluid filler, continuing stirring until the material is completely fused, and finally cutting for 30 minutes, and the light-colored asphalt can be obtained after discharge.

3. Performance evaluation of light-colored asphalt

3.1. Performance evaluation of cement
The performance indicators of the light-colored asphalt before and after rolling thin film oven test (RTFOT) were evaluated according to the JTG E20-2011 specification, and the results are shown in Table 1. From the test results, it can be found that the light-colored asphalt developed by this research institute can meet the index requirements of JTG F40-2004 for I-D grade modified asphalt (heavy traffic).

| Indicators                              | Unit     | Results | SBS I-D level technical index |
|-----------------------------------------|----------|---------|------------------------------|
| Penetration (25°C, 100g, 5s)           | 0.1mm    | 52      | 40–60                        |
| Softening Point                         | °C       | 62      | ≥60                          |
| Ductility (5°C, 5cm/min)                | cm       | 25      | ≥20                          |
| PI                                      | /        | 0.6     | ≥0                           |
| Kinematic viscosity (135°C)             | Pa.s     | 2.2     | ≤3                           |
| Flash point                             | °C       | 250     | ≥230                         |
| Solubility                              | %        | 99.8    | ≥99.0                        |
| Quality loss                            | %        | 0.5     | ±1.0                         |
| Residual penetration ratio (25°C)       | %        | 81      | ≥65                          |
| Ductility (5°C, 5cm/min)                | cm       | 18      | ≥15                          |

3.2. Infrared spectrum analysis
The functional group composition of light-colored asphalt and SK-70# base asphalt was analyzed by infrared spectroscopy. As can be seen from Figure 1, they have similar peak locations, so it can be
inferred that 3040 cm\(^{-1}\) is C-H bond stretching vibration on C=C bond of SBS in light-color asphalt, 2920 cm\(^{-1}\) and 2850 cm\(^{-1}\) is C-H stretching vibration of hydrocarbon substances, 1600 cm\(^{-1}\) is C=C skeleton vibration on benzene ring, 1450 cm\(^{-1}\) is C-H deformation vibration of hydrocarbon substances, and 700 cm\(^{-1}\) is C-H deformation vibration on carbon-carbon double bond [5]. The analysis results show that light-colored asphalt and petroleum asphalt are very similar in functional group composition, which provides theoretical support for the use of light-colored asphalt as road cementing materials.

![Infrared spectra of light-colored asphalt and base asphalt](image)

**Figure 1** Infrared spectra of light-colored asphalt and base asphalt

4. **Evaluation of road performance of asphalt mixture**

4.1. **High-temperature stability**

High-temperature rutting disease is one of the primary diseases of asphalt pavement in the early phase of its usage. Studying the high-temperature rutting performance of the bright-colored asphalt mixture can effectively prevent early diseases in the bright-colored paving of tunnels. The gradation of all asphalt mixture performance test specimens in this paper is SMA-13 gradation, and the content of mineral powder and fiber are 8% and 0.25% respectively. Taking dynamic stability as the evaluation index, the high-temperature stability performance of SMA-13 asphalt mixture of light-colored asphalt developed in this paper and I-D modified asphalt was compared through rutting tests.

| Asphalt type                        | Dynamic stability/(times/mm) | Specifications |
|-------------------------------------|-----------------------------|----------------|
| I-D grade SBS modified asphalt      | 3660                        | ≥3000          |
| Light-colored asphalt               | 4256                        |                |

Table 2 shows the test results of dynamic stability of two asphalt mixtures at 60 °C. It can be seen from the above table that the dynamic stability of the two asphalt mixtures meets the specification requirements, but the light-colored asphalt mixture has a significantly higher dynamic stability than the I-D grade modified asphalt mixture. The former increased by 16.3% compared to the latter. As the light-colored asphalt is added with toughened fluid fillers, it can improve the high-temperature elasticity of the light-colored asphalt mixture, thereby improving the high-temperature stability of the mixture.

4.2. **Water stability**

Water damage refers to the phenomenon of asphalt film peeling, loose aggregates, and structural layer damage in the asphalt mixture under the repeated action of rain and vehicle loads, which ultimately leads to the destruction of aggregates and pots on the road surface. For the evaluation of water stability
of asphalt mixtures, methods that have been widely used currently mainly include water immersion Marshall test, freeze-thaw splitting test, water immersion rutting test, etc.

Table 3 Marshall test results of immersion in water

| Asphalt type                  | Marshall stability/kN | Stability of immersed in water for 48h/kN | Residual stability in water/% |
|------------------------------|-----------------------|------------------------------------------|-------------------------------|
| I-D grade SBS modified asphalt | 6.2                   | 5.0                                      | 80.6                          |
| Light-colored asphalt        | 7.4                   | 6.6                                      | 89.2                          |

Table 4 Freeze-thaw split test

| Asphalt type                       | Splitting strength at 25℃/mpa | Freeze-thaw splitting strength/mpa | Freeze-thaw splitting strength ratio/% |
|------------------------------------|--------------------------------|----------------------------------|---------------------------------------|
| I-D grade SBS modified asphalt      | 1.09                           | 0.92                             | 84                                    |
| Light-colored asphalt              | 1.11                           | 0.99                             | 89                                    |

Table 5 Water-immersion rutting test

| Asphalt type                  | Dynamic stability/(times/mm) | Specifications |
|------------------------------|------------------------------|----------------|
| I-D grade SBS modified asphalt | 3144                         | ≥3000          |
| Light-colored asphalt         | 3856                         |                |

This paper selects the above three methods to evaluate the water stability of the two asphalts, and the test results are shown in Tables 3, 4, and 5 respectively. It can be seen from the results that the three indicators of the light-colored asphalt mixture are better than those of the I-D grade modified asphalt mixture, indicating that the light-colored asphalt mixture has the water loss resistance performance that can satisfy the road use. At the same time, the test results can indirectly show that light-colored asphalt has excellent bonding properties, which can form a dense overall structure with aggregates, prevent rain erosion, and make water stability better than I-D grade modified asphalt.

4.3. Anti-skid performance

The anti-skid performance of asphalt pavement affects the safety performance of road traffic. This paper uses a pendulum friction meter to test the British pendulum number (BPN) of two asphalt mixtures, and compares the anti-skid performance of the two asphalt mixtures.

Table 6 BPN test results

| Asphalt type                  | BPN test results | Specifications |
|------------------------------|------------------|----------------|
| I-D grade SBS modified asphalt | 61               | BPN≥45         |
| Light-colored asphalt         | 63               |                |

Table 6 shows the test results of the large anti-skid value of the two asphalt mixture samples. The results show that the light-colored asphalt mixture has excellent anti-skid performance, which meets the specification requirements (JTG F40-2004), and has similar anti-skid performance to the I-D grade modified asphalt mixture, indicating that the light-colored asphalt can meet the requirements of road skid resistance for driving safety.

5. Conclusion

(1) Based on the principle of simulating four components of petroleum asphalt, in this paper, light-colored asphalt was developed by simple preparation process with aromatic oil and petroleum resin as raw materials.
Comparing the three road performances of the light-colored asphalt mixture with the I-D grade SBS modified asphalt mixture, it is found that the three performances of the light-colored asphalt mixture are more excellent and they can meet the requirements of relevant specifications, in which the high temperature dynamic stability can be increased with 16.3%.

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