The Research on Performance of Double SBS Composite Modified Asphalt Based on High Temperature Characteristics in Hainan Province

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Abstract. In engineering application, a kind of SBS is often used to modify the matrix asphalt, but there is less research on the application of double SBS composite modified asphalt. This paper shows through indoor testing: 3.15% Dushanzi T161B Star SBS Modifier + 1.05% LCY3501 Linear SBS Modifier + 3.75% Stabilizer + Tipke 70# matrix asphalt can be made into composite modified asphalt, which the high-temperature performance, ductility and anti-aging properties can be well adapted to the high temperature characteristics of Hainan Province, and the commonly used single modified asphalt has obvious economic advantages and can be widely used in Hainan.

1. Introduction
Hainan Province is located in the tropical northern margin and belongs to the tropical monsoon climate. It has always been known as a “natural greenhouse” and has strong sunlight, high temperatures and long duration climate characteristics, coupled with vehicle overload, traffic channelization and construction quality control, etc. Due to the influence of the causes, early damages such as rutting and water damage on asphalt pavement have become increasingly prominent and have become key issues in the quality control of asphalt pavement in Hainan.

SBS modified asphalt is a widely used countermeasure for road rutting and cracking caused by the flow of heavy traffic road vehicles. Due to differences in the nature of different SBS, their modification effects on asphalt are often quite different, therefore, the composite modification of matrix asphalt by two kinds of SBS can exert their advantages. This kind of measure is of great significance to improving the performance of road asphalt and prolonging the service life of the road.

2. Raw material performance test

2.1 Raw material
(1) asphalt

The asphalt used in this research is commonly used in the construction of asphalt pavement in Hainan Province, Tipke 70# matrix asphalt, its main technical indicators are shown in Table 1.
Table 1  Test results of main technical indicators of Tipke 70# asphalt

| Test items and conditions | Unit  | Technique requirement | Test results |
|--------------------------|-------|-----------------------|--------------|
| Penetration 25℃, 100g, 5s | mm    | 60~80                 | 66           |
| Penetration index         |       | -1.5~+1.0             | -1.0         |
| Ductility 15℃, 5cm/min   | cm    | ≥100                  | >130         |
| Softening Point           | °C    | ≥45                   | 46           |
| Dynamic viscosity 60℃    | Pa.s  | ≥160                  | 205          |
| Flash point               | °C    | ≥230                  | 309          |
| Relative density 15℃     |       | —                     | 1.029        |
| RTFOT residue             | Weight change | %  | ≤±0.8                 | -0.1         |
| Penetration ratio 25℃    | %     | ≥61                   | 71           |
| Ductility 10℃            | cm    | ≥6                    | 29           |

From Table 1, it can be seen that the technical performance of Tipke 70# matrix asphalt meets the specification requirements.

(2) SBS modifier
In this paper, two brands of SBS modifiers are used, namely Dushanzi T161B SBS Modifier and LCY3501 SBS Modifier. Some of the modifier performance indicators are shown in Table 2.

Table 2  SBS modifier partial performance indicators

| Type   | Structure | S/B Block ratio | Specific gravity g/cm³ | Melt Flow Index g/10min | Hardness s | Volatility % | Tensile Strength MPa |
|--------|-----------|-----------------|-------------------------|--------------------------|------------|--------------|----------------------|
| T16B   | star      | 30/70           | 0.94                    | 0.5                      | 82         | 0.22         | 17.7                 |
| 3501   | linear    | 31/69           | 0.94                    | 0.5>0.5                  | 75         | 0.17         | 24.0                 |

2.2 Effect of SBS content on performance of modified asphalt
The T161B and 3501 SBS were selected to modify the Tipke 70# matrix asphalt with different dosages, the dosages were 3%, 4%, 5% and 6% respectively. The test results are shown in Tables 3.

Table 3  Test results of Tipke 70# modified by T161B and 3501SBS modifier dosage

| Test items and conditions | Unit  | 3%   | 4%   | 5%   | 6%   |
|--------------------------|-------|------|------|------|------|
| Penetration 25℃, 100g, 5s | 0.1mm | T161B| 53.2 | 55.2 | 50.6 | 51.0 | 47.3 | 50.1 | 46.2 | 48.7 |
| Penetration index        |       | T161B| -0.88| -0.94| -0.82| -0.71| -0.67| -0.74| -0.56| -0.80|
| Ductility 5℃            | cm    | T161B| 22.4 | 21.3 | 25.6 | 28.4 | 25.9 | 30.4 | 23.1 | 31.8|
| Softening Point          | °C    | T161B| 83.4 | 58.0 | 90.8 | 65.6 | 91.0 | 67.3 | 92.8 | 70.9|
| Viscosity 135℃          | Pa.s  | T161B| 1.583| 1.223| 2.125| 1.873| 2.862| 2.076| 3.017| 2.458|
| Elastic recovery 25℃     | %     | T161B| 92   | 80   | 97   | 87   | 98   | 89   | 98   | 90   |
| 48h softening point       | °C    | T161B| 1.3  | 1.6  | 1.3  | 1.5  | 0.8  | 1.0  | 0.7  | 0.7  |
| RTFOT residue             |       | T161B|      |      |      |      |      |      |      |      |
| Weight change             | %     | T161B| -0.3 | -0.6 | -0.1 | -0.3 | -0.1 | -0.1 | -0.1 | +0.1 |
From Table 3, it can be seen that within a certain range, the higher the SBS dosage, the better the asphalt high and low temperature performance, elastic recovery capacity, storage stability and aging resistance. However, the use of excessive amounts has no obvious effect and is not economical. According to the test results, when the SBS dosage is between 4% and 5%, the asphalt modification effect is best.

In order to improve the stability of modified asphalt, domestically, an appropriate amount of stabilizer is added to the production process of modified asphalt. In this test, a domestic company's HMD-1 stabilizer was used, and the modified asphalt was prepared from Tipke 70# matrix asphalt and T161B SBS modifier. The SBS dosage was 4.0%. The effect of stabilizer dosage on the performance of modified asphalt was studied. The specific test results are shown in Table 4.

| Test items and conditions | unit | 0%   | 0.05% | 0.10% | 0.15% | 0.20% |
|---------------------------|------|------|------|------|------|------|
| Penetration 25℃, 100g, 5s | 0.1mm | 50.6 | 50.7 | 51.5 | 50.2 | 51.3 |
| Penetration index         |      | -0.82| -0.91| -0.78| -0.73| -0.76|
| Ductility 5℃             | cm   | 25.6 | 25.7 | 26.2 | 24.8 | 24.9 |
| Softening Point           | °C   | 90.8 | 90.6 | 91.2 | 91.7 | 92.0 |
| Viscosity 135℃           | Pa.s | 2.125| 2.187| 2.372| 2.409| 2.532|
| Elastic recovery 25℃      | %    | 97   | 96   | 95   | 98   | 98   |
| 48h softening point difference | °C | 1.3  | 1.3  | 0.8  | 0.7  | 0.4  |
| RTFOT residue             |      |      |      |      |      |      |
| Ductility 5℃             | cm   | 15.4 | 17.2 | 16.8 | 14.4 | 14.3 |

It can be seen from Table 4 that with the increase in the amount of stabilizer, the softening point of asphalt increases, the viscosity significantly increases, the ductility slightly decreases, and the penetration does not change significantly. From the perspective of changes in many indicators, when the stabilizer content is between 0.15% and 0.20%, that is, between 3.75% and 5% of the SBS dosage, the modified asphalt can obtain better performance.

3. Modified asphalt test plan design and analysis evaluation

3.1 Modified asphalt test plan design

Due to the differences in the properties of different SBS modifiers, their modification effects on asphalt are often quite different. The composite modification of the matrix asphalts by the two SBS modifiers can exert their advantages, and at the same time, can reduce the cost to some extent. Through experimental analysis and combined with actual modified asphalt production experience, star SBS dosage can achieve asphalt performance and economic balance in 4% up and down, linear SBS is often greater than 4%. Therefore, the preferred Tipke 70# matrix asphalt, Dushanzi T161B star SBS modifier, LCY3501 linear SBS modifier, and HMD stabilizer were used as test materials, and the amount of SBS and stabilizing agent was changed. Design double SBS composite modification test plan. At the same time, in order to compare the performance of the prepared composite modified asphalt, another modified asphalt commonly used in Hainan is also prepared. The specific plan is designed as follows:

(1) Single modification plan

Tipke 70# matrix asphalt, Dushanzi T161B SBS, 3.6%~4.4% SBS dosage (based on mass percent of matrix asphalt, 0.1% apart, 9 groups in total), 3.75% and 5% of two stabilizers (Based on the percentage of SBS used), a total of 9 x 2 = 18 trials were performed.
(2) Composite modification plan
Tipke 70# matrix asphalt, Dushanzi T161B SBS and LCY3501 SBS, the two SBS blending combinations are shown in Table 5, 3.75% and 5% of two stabilizers (in percentage of SBS content), and a total of 3 x 3 x 2 = 18 trials.

| A+B/% | A:B | A+B/% | A:B | A+B/% | A:B |
|-------|-----|-------|-----|-------|-----|
| 4.0   | 1:1 | 4.2   | 2:1 | 4.4   | 2:1 |
| 3:1   |     |       |     | 3:1   |     |

A and B represent the dosage of T161B and 3501 respectively, %

3.2 Test data statistics
(1) Single modification plan test results
Eighteen trials were carried out according to the test plan. The results are shown in Table 6.

| T161B (%) | Stabilizers account for the percentage of SBS (%) | Penetration 25 ℃ (0.1mm) | Penetration index | Softening Point (℃) | Ductility 5 ℃ (cm) | Viscosity 135 ℃ (Pa.s) | RTFOT Weight change (%) | RTFOT Penetration ratio (%) | RTFOT Ductility 5 ℃ (cm) |
|-----------|-----------------------------------------------|--------------------------|------------------|---------------------|-------------------|-----------------------|------------------------|---------------------------|--------------------------|
| 3.6       | 3.75                                          | 52.2                     | -0.91            | 86.4                | 19.6              | 2.173                 | -0.5                   | 70                        | 12.3                     |
| 3.6       | 5.00                                          | 52.4                     | -1.01            | 86.4                | 20.8              | 2.264                 | +0.1                   | 71                        | 12.3                     |
| 3.7       | 3.75                                          | 52.1                     | -1.08            | 87.0                | 22.8              | 2.069                 | -0.3                   | 72                        | 13.2                     |
| 3.7       | 5.00                                          | 52.1                     | -0.84            | 88.4                | 21.9              | 2.238                 | 0                      | 72                        | 12.7                     |
| 3.8       | 3.75                                          | 51.4                     | -0.78            | 87.8                | 23.4              | 2.278                 | -0.3                   | 74                        | 12.1                     |
| 3.8       | 5.00                                          | 52.0                     | -0.93            | 89.6                | 22.8              | 2.333                 | +0.2                   | 74                        | 13.7                     |
| 3.9       | 3.75                                          | 51.7                     | -0.82            | 90.8                | 23.9              | 2.413                 | -0.2                   | 72                        | 13.9                     |
| 3.9       | 5.00                                          | 50.9                     | -0.77            | 91.0                | 24.2              | 2.468                 | -0.1                   | 73                        | 14.4                     |
| 4.0       | 3.75                                          | 51.2                     | -0.73            | 91.7                | 24.9              | 2.409                 | -0.1                   | 76                        | 14.4                     |
| 4.0       | 5.00                                          | 50.7                     | -0.76            | 92.0                | 24.9              | 2.532                 | -0.2                   | 75                        | 14.3                     |
| 4.1       | 3.75                                          | 49.0                     | -0.80            | 91.3                | 24.8              | 2.475                 | -0.1                   | 77                        | 16.4                     |
| 4.1       | 5.00                                          | 48.4                     | -0.74            | 91.8                | 25.7              | 2.463                 | 0                      | 77                        | 17.8                     |
| 4.2       | 3.75                                          | 49.7                     | -0.83            | 92.5                | 27.2              | 2.483                 | -0.1                   | 74                        | 16.2                     |
| 4.2       | 5.00                                          | 50.0                     | -0.62            | 92.5                | 26.7              | 2.577                 | -0.1                   | 73                        | 18.6                     |
| 4.3       | 3.75                                          | 50.1                     | -0.64            | 92.8                | 25.8              | 2.537                 | -0.2                   | 75                        | 17.3                     |
| 4.3       | 5.00                                          | 49.4                     | -0.68            | 93.4                | 25.5              | 2.618                 | 0                      | 76                        | 17.3                     |
| 4.4       | 3.75                                          | 49.1                     | -0.52            | 93.6                | 24.8              | 2.624                 | +0.1                   | 78                        | 19.0                     |
| 4.4       | 5.00                                          | 48.8                     | -0.53            | 94.3                | 25.2              | 2.656                 | -0.1                   | 79                        | 18.3                     |

(2) Composite modification plan test results
Eighteen trials were carried out according to the test plan. The results are shown in Table 7.

| T161B (%) | LCY3501 (%) | Stabilizers account for the percentage of SBS (%) | Penetration 25 ℃ (0.1mm) | Penetration index | Softening Point (℃) | Ductility 5 ℃ (cm) | Viscosity 135 ℃ (Pa.s) | RTFOT Weight change (%) | RTFOT Penetration ratio (%) | RTFOT Ductility 5 ℃ (cm) |
|-----------|-------------|-------------------------------------------------|--------------------------|------------------|---------------------|-------------------|------------------------|------------------------|---------------------------|-------------------------|
| 2.00      | 2.00        | 3.75                                            | 52.3                     | -0.74            | 78.5                | 28.4              | 1.923                  | -0.4                   | 69                        | 15.0                    |
| 2.00      | 5.00        | 3.75                                            | 52.6                     | -0.79            | 78.8                | 28.7              | 1.986                  | -0.4                   | 71                        | 16.2                    |
| 2.67      | 1.33        | 3.75                                            | 51.1                     | -0.68            | 83.6                | 26.8              | 2.136                  | -0.2                   | 76                        | 16.6                    |
| 2.67      | 5.00        | 3.75                                            | 50.6                     | -0.80            | 83.6                | 25.8              | 2.179                  | -0.3                   | 76                        | 16.4                    |
### 3.3 Test data analysis and plan determination

(1) Single modification plan test analysis

The comparative analysis of the changes in the four major indicators such as penetration, softening point, viscosity, and RTFOT residue ductility is shown in figures 1, 2, 3, and 4.

![Fig.1](image1.png)  
**Fig.1**  Change in penetration of single SBS modified asphalt

![Fig.2](image2.png)  
**Fig.2**  Change in softening point of single SBS modified asphalt
It can be seen from figure 1 to figure 4:

1) With the increase of SBS dosage, the penetration decreases, the softening point and the ductility increase, indicating that the high and low temperature performance of the modified asphalt are improved. The three above-mentioned indexes of 3.6%~4.4% SBS dosage basically meet the specification requirements, 4.1% is the critical point where the penetration is less than 50.

2) The more SBS dosage, the greater the viscosity of the modified asphalt, the dynamic viscosity of 3.6%~4.4% SBS modified asphalt meets the specification requirements. From the change of the three indicators of RTFOT residue, it can be seen that increasing the amount of SBS can improve the anti-aging performance of asphalt. When the SBS content is less than 4.1%, the RTFOT residue has a ductility of less than 15 cm and does not meet the specification requirements.

3) The effect of the stabilizer on the properties of modified asphalt was not very different from that account for 3.75% and 5% of SBS.

To sum up, for the single SBS modified test plan, taking into account the economic aspects and other reasons, to determine the best plan: 4.1% T161B + 3.75% stabilizer + Tipke 70 # matrix asphalt.

(2) Composite modification plan test analysis

The comparative analysis of the changes in the four major indicators such as penetration, softening point, viscosity, and RTFOT residue ductility is shown in figures 5, 6, 7, and 8.
Fig.5  Change in penetration of composite SBS modified asphalt

Fig.6  Change in softening point of composite SBS modified asphalt

Fig.7  Change in viscosity of composite SBS modified asphalt
Fig. 8  Change in RTFOT residue ductility of composite SBS modified asphalt

It can be seen from figure 5 to figure 8:

1) When the ratio of T161B to LCY3501 is 3:1, the penetration of modified asphalt is the smallest of the three in the same total amount of SBS, with a minimum penetration of 4.2%. That is to say when the total SBS content is 4.2% and the ratio of T161B to LCY3501 is 3:1, the high temperature performance of modified asphalt is the best.

2) When the ratio of T161B to LCY3501 is 1:1, the softening point of the modified asphalt is about 78°C. When the ratio is increased by 3:1, the softening point increases by more than 10°C.

3) The higher the proportion of T161B, the greater the viscosity and the penetration ratio of the modified asphalt, the smaller the weight change, indicating that the modified asphalt has better high temperature performance and aging resistance.

4) When the ratio of T161B to LCY3501 is 3:1 in the same total amount of SBS, the RTFOT residue of the modified asphalt is relatively large. When the total SBS content is 4.2%, the ratio of T161B to LCY3501 is 3:1, the RTFOT residue ductility of the modified asphalt is best.

To sum up, for the composite SBS modified test plan, according to the characteristics of long-term high temperature in Hainan Province, determine the best plan:

3.15% T161B + 1.05% LCY3501 + 3.75% stabilizer + Tipke 70# matrix asphalt.

3.4 Technical and Economic Evaluation of Modified Asphalt Test Plan

The optimal plans of the two groups are respectively represented by plan A and plan B, as shown in table 8.

| Table 8  selection plan |
|-------------------------|
| plan  matrix asphalt | T161B dosage/% | LCY3501 dosage/% | Stabilizer dosage/% |
| A   Tipke 70#         | 4.10           | 0               | 3.75               |
| B   Tipke 70#         | 3.15           | 1.05            | 3.75               |

(1) Technical performance comparative analysis

On the basis of the original experimental data, two indicators were tested for the elastic recovery and segregation of 48h softening point difference of plan A and plan B, and all the test data were shown in table 9.

| Table 9  comparison of the performance indicators of modified asphalt with plan A and plan B |
|-----------------------------------------------|
| Test items and conditions | unit | Plan A | Plan B |
| Penetration 25°C, 100g, 5s | 0.1mm | 49.0 | 48.0 |
| Ductility 5°C, 5cm/min | cm | 24.8 | 28.3 |
As can be seen from Table 9:
1) The indicators of both plan A and plan B meet the specification requirements.
2) The softening point, viscosity, elastic recovery and storage stability of plan A are better than that of plan B. The 5°C ductility and the ductility of RTFOT residue of plan B are greater than that of plan A, and the Weight change and penetration ratio of plan B are the same as those of plan A.

(2) Economic performance comparative analysis.
This paper collects the approximate prices of raw materials currently on the market and accounts for the production costs per ton of modified asphalt, as shown in Table 10.

Table 10  major raw materials costs

| materials                  | Tipke 70# matrix asphalt | T161B SBS | LCY3501 SBS | stabilizer |
|----------------------------|--------------------------|-----------|-------------|------------|
| price (yuan/ton)           | 3600                     | 16000     | 13000       | 13800      |

Calculated cost per ton of modified asphalt:
Plan A:
\[
\frac{1 \times 3600 + 4.1\% \times 16000 + 0.154\% \times 13000}{1 + 4.1\% + 0.154\%} = 4102.5 \text{ yuan/ton}
\]
Plan B:
\[
\frac{1 \times 3600 + 3.15\% \times 16000 + 1.05\% \times 13000 + 0.158\% \times 13800}{1 + 3.15\% + 1.05\% + 0.158\%} = 4082.7 \text{ yuan/ton}
\]

Therefore, from the economic performance comparative analysis, plan B is more advantageous.

4. conclusion
This paper relies on the G98 East Line Overhaul Project, combined with the high-temperature climate characteristics of Hainan Province, the experimental research on the performance of double SBS composite modified asphalt is carried out, and the following conclusions are obtained:

(1) In the single modification test plan, when the amount of T161B was 4.1%, and the stabilizer accounted for 3.75% of the amount of SBS, the technology and economic performance of the modified asphalt were all excellent.

(2) In the double SBS composite modification test plan, the ratio of T161B to LCY3501 is 3:1, the total SBS content is 4.2%, and the amount of stabilizer is 3.75% of SBS content is the best plan.

(3) plan A and B differ slightly in terms of high temperature performance and ductility, and plan B is more economically advantageous due to the use of lower cost SBS modifiers.

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