Road Performance and Application Analysis of Ultra-Thin Asphalt Coating Mixture with High Elastic Modification

WEI Jinfen[1], YANG Xundong[2], Zhou Qiwei[3], Wang Huoming[3], FANG Yunfei[1]

[1]China Merchants Road Guilin Company, Guilin Guangxi, 542100 China;
[2]China Merchants Road Network Technology Holding Co. LTD, Beijing, 100000, China;
[3]China Merchants Chongqing Communications Technology Research & Design Institute Co. LTD, Chongqing, 400000, China

Abstract: A kind of composite modified asphalt with high elasticity was prepared by SBS and high elasticity agent, and the asphalt mixture with easy compactness was applied. The high temperature, low temperature, water stability and fatigue properties of the mixture were evaluated by laboratory tests. The results show that the optimum content of high elasticity agent is about 6% for SBS modified asphalt. The pavement performance of the high-elasticity modified asphalt compacting mixture was improved to a certain extent. Compared with SBS modified asphalt SMA-13, the dynamic stability was increased by 13.5%. The water stability, low temperature crack resistance and fatigue resistance increased by 10.4%, 59.3% and 173%.

1 Introduction

In recent years, high elastic modified asphalt has been the hot research topic in the field of road modified asphalt. High elastic modified asphalt is generally used for steel bridge deck pavement. Chen et al. [1-2] carried out a study on high elastic modified asphalt mixture design for Nanjing Fourth Yangtze River Bridge and concluded that high elastic modified asphalt concrete is more often used in the upper courses of composite cast pavement for steel bridge decks because of its excellent performance. Hao et al. [3] analyzed the application of modified asphalt with high elasticity in steel bridge deck pavement and concluded that low temperature deformability of the high-elastic modified asphalt mixture has remarkably improved and low temperature bending strain of girders at -10°C is above 10,000 μξ; the fatigue life of modified asphalt mixture with high elasticity has greatly improved by 4-point bending beam test compared with common modified asphalt mixtures; the fatigue life at 1,000 μξ is about 1.9 million times, which is about 20 times longer than that of ordinary asphalt mixtures. Yang [4] took a research on road performance of high elastic modified asphalt SMA-10 and its application in bridge deck pavement, and concluded that the high elastic modified asphalt SMA-10 has better low temperature deformation performance, fatigue resistance and water resistance performance better than SBS asphalt SMA-10. The high elastic modified asphalt is also successively applied in the preventive maintenance of roads. Liu [5] studied the road performance of high elastic modified asphalt SMA-10 and concluded that the high elastic modified asphalt has higher cone penetration than ordinary modified asphalt, and the high elastic modified asphalt mixture has better low temperature performance and fatigue resistance than ordinary asphalt mixtures. Zhong et al. [6] studied the performance of high elastic SMA asphalt mixtures and concluded that the high-performance SMA asphalt mixture has superior strength, adhesion, water damage resistance, and better high temperature and fatigue performance than SBS modified asphalt concrete. Li et al. [7] applied high-elastic modified asphalt stress absorbing layer in major repair projects and concluded that the high elastic modified asphalt has excellent anti-crack and adhesion performance, Li et al. [8] studied the effect of different high elastic modifiers on high-elasticity modified asphalt performance and concluded that compared with normal SBS modified asphalt, the introduction of two high elastic modifiers dramatically improve the low temperature cracking resistance and fatigue property of modified asphalt. Shi [9] studied the response of rheological behavior of modified asphalt with high elasticity and concluded that the modified asphalt with high elasticity has relatively stable rutting resistance factor as the temperature changes; before and after aging, the low temperature ductility of the modified asphalt with high elasticity is 2 times and 1.4 times of those of SBS modified asphalt respectively; for PC grade, the former is 2 and 1 level lower than the latter respectively, with smaller creep strength degree and better low-temperature rheological behavior; the value of DSR fatigue property of modified asphalt with high elasticity is about 1/6 of that of SBS modified asphalt, with large strain and fine fatigue property. To sum up, the high elastic modified asphalt has better low temperature and fatigue performance than SBS modified asphalt.

In this paper, a kind of composite modified asphalt

Corresponding author: zqw041@163.com

with high elasticity was prepared by SBS and high elastic agent, the effect of different high elastic modifiers on high elastic modified asphalt performance was analyzed, and the pavement performance of the high elastic modified easy-compact asphalt (ECA) mixture was evaluated, making the test results the data reference for application and promotion of the high elastic modified asphalt.

2 Raw Materials and Mix Design

2.1 Asphalt

The asphalt referred in this paper was Maoming-70 matrix asphalt whose indicators were consistent with the relevant specifications.

2.2 Aggregate

Both coarse and fine aggregates were diabase from Longsheng, Guangxi. The mineral powder was fine limestone from Longsheng, Guangxi. All indicators of these materials were consistent with the relevant specifications.

2.3 High Elastic Agent

The high elastic agent used in this paper was rubber synthetic blends produced by Shandong Longsheng Chemical Company. The recommended dosing was 2 - 10%

2.4 Stabilizer

The stabilizer was the sulfur stabilizer produced by Guangdong Zhenjiang Sulfur Factory, and the recommended dosing was 0.3% of the matrix asphalt.

2.5 Gradation

Diabase and mineral powder with 0 ~ 3 mm, 3 ~ 6 mm and 6 ~ 11 mm were mixed for gradation design, and the final design results were shown in Table 1 below.

Table 1 Max Design Results

Sieve mesh (mm)	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Design value (%)	100.0	95.1	37.4	28.4	23.8	19.3	15.2	12.2	8.5
Gradation (%)	100	98.3	37.7	29.0	25.0	18.7	14.4	12.4	9.0

Based on the above gradation, a Marshall compaction test was carried out to determine that the optimal asphalt-aggregate ratio was 5.5%

3 Asphalt and Mixture Performance Analysis

3.1 Performance Analysis of Composite SBS + High Elastic Modified Asphalt

A composite SBS + high elastic modifier, with its specific mix ratio as shown in the following table 2, was used, and the performance analysis was carried out to determine the optimal dosing of the modifier, with the test results as shown in Table 3.

Table 2 Dosing of Composite Modifier

Group	SBS	High elastic	Stabilizer	Matrix asphalt
1	4	0	0.3	100
2	4	2	0.3	100
3	4	4	0.3	100
4	4	6	0.3	100
5	4	8	0.3	100
6	4	10	0.3	100

Table 3 Test Results of Composite Modified Asphalt

Group	Cone penetration (0.1 mm)	Softening point (°C)	Ductility/5°C (cm)	Recovery of elasticity (%)	Rotary viscosity @ 135 °C (mPa·s)
1	40.3	65.3	27.4	90.1	2857
2	50.8	67.7	30.2	92	2112
3	70.7	68.2	50.1	92.1	2028
4	80.4	72.1	67.2	100	1523
5	100.2	69.7	75.3	100	1120
6	130.2	63.9	79.8	100	908

From the analysis of the test results shown in Table 3, it was concluded that:

(1) The softening point of asphalt increased and then decreased with the increasing dosing of the high elastic agent. When the amount of the high elastic agent was 6%, the softening point reached to the peak, 72.1℃. The reason was that when the dosing of the high elastic agent increased to a certain amount, the rubber in its components interacted with SBS to form a good network

structure, and then increased the softening point of the asphalt.

(2) With constant dosing of SBS agent, the asphalt cone penetration increased with the amount of high elastic agent. This was because the increase of rubber material softened the asphalt and thus increased the cone penetration.

(3) With constant dosing of SBS agent, the asphalt ductility increased with the amount of high elastic agent. The ductility was above 100 cm at 5°C when the amount of high elastic agent was 6%. The reason was the rubber material in the high elastic agent improved the low temperature ductility of SBS modified asphalt, and the high elastic modified asphalt had excellent low temperature performance.

(4) With constant dosing of SBS agent, the asphalt's recovery of elasticity increased with the amount of high elastic agent. The recovery of elasticity was 100% when the amount of high elastic agent was 6%. The reason was the high elastic agent in the network composed by SBS and asphalt acted as the filler and improved the elastic recovery performance of the asphalt.

(5) With constant dosing of SBS agent, the asphalt's rotary viscosity at 135°C increased as the amount of high elastic agent decreased. This was because the high elastic agent in the SBS modified asphalt network structure acted as the adhesive to facilitate the workability of the asphalt mixture.

(6) Based on the above tests, the optimal dosing of high elastic agent was 6%.

3.2 Mixture Performance Analysis

3.2.1 High Temperature Stability

A rutting test was carried to evaluate the high temperature stability of mixtures. The complete specimen for the rutting test was upper 1.5 cm ECA mixture + lower 3.5 cm modified SMA-13 mixture. The control specimen was 5 cm SMA-13 mixture. Each group had 2 parallel specimens. The test results were average values, as shown in the following table 4.

Table 4 Rutting Test Results of Mixtures

Type	Dynamic stability (times/mm)	Required level (times/mm)
1.5 cm ECA mixture + 3.5 cm modified SMA-13 mixture	4782	≥3000
5 cm SBS modified SMA-13 asphalt	4213	

From Table 4 it was concluded that after adding the high elastic agent, the mixture's rutting resistance performance was improved to a certain extent, and compared with SBS modified asphalt mixture, its dynamic stability was improved by 13.5%. This was because the high elastic agent filled in the SBS + asphalt cemented network enhanced the network structure strength of the modified asphalt, and further improved the high temperature stability of the mixture.

3.2.2 Water Stability

The freeze-thaw splitting test was carried out to evaluate the water stability of high elastic modified asphalt ECA. Each group has 6 parallel specimens. The test results were average values, as shown in Table 5 below.

Table 5 Freeze-thaw Splitting Test Results of Mixtures

Type	Freeze-thaw splitting test strength ratio TSR (%)	Technical requirements (%)
High elastic modified ECA mixture	96.3	≥80
SBS modified SMA-13 asphalt	87.2	

From the analysis of Table 5, compared with SBS modified asphalt SMA-13 mixture, the water stability of the high elastic modified ECA mixture was improved by 10.4%, better than SBS modified asphalt SMA-13 mixture. The reason was that the high elastic agent contained many rubber components, further enhancing the adhesion between the asphalt and aggregates.

3.2.3 Low Temperature Cracking Resistance

The low temperature beam test was carried out to evaluate the low temperature cracking resistance of high elastic modified asphalt ECA. Each group has 6 parallel specimens. The test results were average values, as shown in Table 6 below.

Table 6 Low Temperature Bending Test Results of Mixtures

Type	Average bending strain (*10-3)	Required level (*10-3)
High elastic modified ECA mixture	4270	≥2500
SBS modified SMA-13 asphalt	2680	

From the test results in Table 6, compared with SBS modified asphalt SMA-13 mixture, the low temperature cracking resistance of the high elastic modified ECA mixture was improved by 59.3%, significantly better than SBS modified asphalt SMA-13 mixture. The reason was that the high elastic agent effectively improved the elasticity of the asphalt cement, further enhancing the low temperature cracking resistance of the mixture.

3.2.4 Anti-fatigue Performance

A UTM asphalt servo was used for comparative analysis of fatigue tests. During test, the strain level was 500 με, the test temperature was 15 ℃, and the load frequency was 10 Hz. When the stiffness modulus of the mixture decreased to 50% of its initial stiffness modulus, the test was stopped. The loading times was the fatigue life of the mixture. Each group has 4 parallel specimens. The test results were average values, as shown in Table 7 below

Table 7 Fatigue Test Results of Mixtures

Type	Fatigue life (times)	Required level (times)
High elastic modified ECA mixture	345910	None
SBS modified SMA-13 asphalt	126420	

From the test results in Table 7, compared with SBS modified asphalt SMA-13 mixture, the fatigue life of the high elastic modified ECA mixture was 340,000 times, an increase of 173%, remarkably better than SBS modified asphalt SMA-13 mixture. The reason was that the high elastic agent effectively improved the elastic adhesion of the asphalt cement, and its mixture had better recovery under the action of loads, further enhancing the anti-fatigue performance of the mixture.

4 Test Section Paving

Based on the above laboratory test results, an ultra-thin asphalt coating test section was built on the expressway from Yangsuo to Pingle, Guilin, Guangxi Zhuang Autonomous Region, with a length of 1 km. The specific construction processes included existing pavement treatment, spreading, compacting, and inspection after construction.

4.1 Existing Pavement Treatment

The existing pavement was milled with a fine milling process to a depth of 1.8 cm. The milled pavement was dedusted with a high-pressure suction pump, and then prayed with fast-crack type high viscosity emulsified asphalt by an automatic spraying machine at an amount of 0.5 kg/m^2.

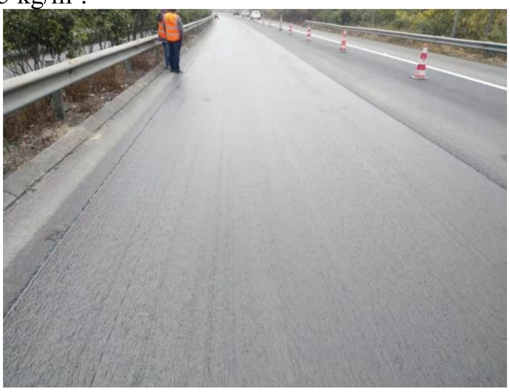

Figure 1 Existing Pavement Treatment

4.2 Spreading and Compacting

The ultra-thin asphalt coating was applied at the temperature between 165°C and 175°C at a rate of 6-9 m. The compacting machine combination was steel-rubber-steel, namely, 2 passes of initial compaction, 4 passes of secondary compaction by rubber wheel rubbing and kneading, and 2 passes of static compaction by steel wheel roller, to ensure an adequate degree of compaction.

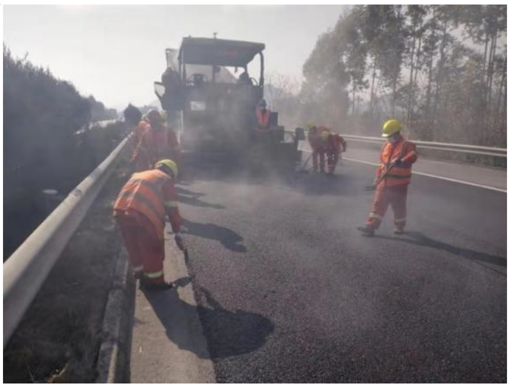

Figure 2 Spreading Process

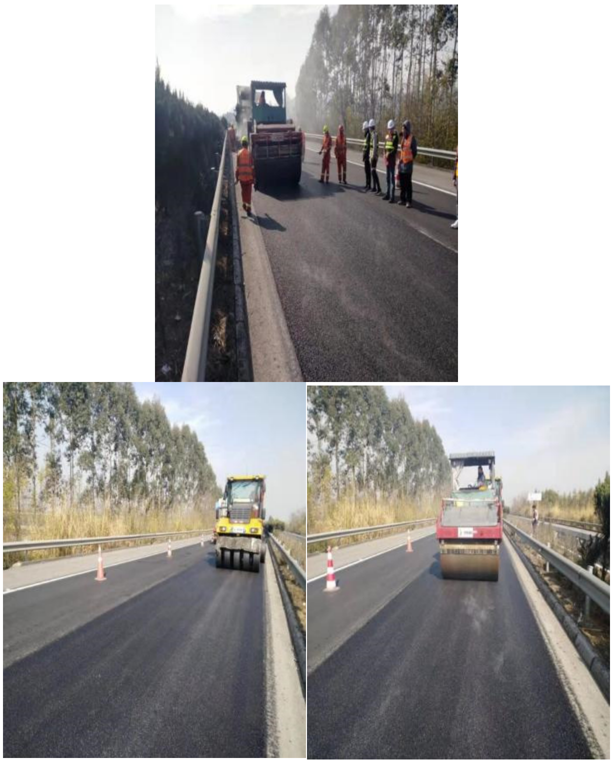

Figure 3 Combined Steel-Rubber-Steel Rolling Compaction Process

4.3 Construction Quality Test

The seepage and structural depth tests were carried out after construction, and cores were drilled and sampled to determine the thickness of the ultra-thin coating. The on-site test results of test agents were as shown in Table 8.

Table 8 On-site Test Results of Ultra-Thin Coating

No.	Voidage (%)	Water seepage (mL/min)	Structural depth (mm)	Thickness (mm)
1	4.2	37	0.75	19
2	4.7	52	0.80	18.5
3	4.5	49	0.70	19
Technical requirements	3~6	≤120	≥0.5	18

From the above test results, all pavement performance test results of the high elastic modified asphalt mixture met the design document and current technical specifications, indicating the pavement performance was good.

5 Conclusion

(1) For SBS modified asphalt, the optimal dosing of the high elastic agent was 6%.

(2) After adding the high elastic agent, the rutting resistance performance of the high elastic modified ECA mixture was improved to a certain extent, and compared with SBS modified asphalt mixture, its dynamic stability, water stability, low temperature cracking resistance and anti-fatigue performance were improved by 13.5%, 10.4%, 59.3%, and 173% respectively.

(3) Upon the verification at the test section, all pavement performance indicators of the high elastic modified ECA mixture met the specifications.

References

1.Chen CJ, Wang HC, ZuoHL, Li GF, Zhou K. Research on mix proportion design of Nanjing Siqiao high elastic modified asphalt concrete [J]. Journal of Liaoning Communications College, 2013,15 (4): 18-21

2.Tong Y, Guo CY, Li Z, Wang Z, Dong YM. Study on mix proportion design of Nanjing Siqiao high elastic modified asphalt concrete [J]. Journal of Liaoning Communications College, 2018,38 (1): 302-305

3.Hao ZH, Zhang XN, Sheng XY, Wang M. application of high elastic modified asphalt in steel bridge deck pavement [J]. Highway traffic science and technology, 2009,26 (4): 23-28

4.Yang ZF. Study on road performance of high elastic modified asphalt SMA-10 and its application in bridge deck pavement [J]. North Communications, 2019, (7): 36-39

5.Liu JB. Experimental study on the performance of SMA-10 high elastic modified asphalt and asphalt mixture [j]. Traffic world, 2015344 (1): 130-131

6.Zhong GW, Wang ZX. Performance evaluation and engineering application of high performance SMA asphalt mixture [j]. Highway traffic in Guangdong, 2018,44 (6): 1-6

7.Li M, Tang QX, Tang P, He WP, Huang SL. Application technology of high viscosity and high elasticity modified asphalt in Heyuan 205 national highway overhaul project [J]. Building Materials world, 2014,35 (4): 29-31

8.Li R, Liu WL, Li L, Sheng XY. Effect of different high elastic modifiers on properties of high elastic modified asphalt [J]. Petroleum asphalt, 2016,30 (4): 29-31

9.Shi SQ, Yang YJ, Gao L. rheological response of high elastic modified asphalt [J]. Highway transportation science and technology, 2012,30 (2): 15-17