Analysis of Road Performance of Direct Cast High Modulus Modified

Guojun Zhu [1,*], Hui He [2]

[1] Wuhan Engineering Construction Engineering Co., Ltd., Hubei, China
[2] Chengdu Huachuan Highway Construction Group Co., Ltd., Sichuan, China
* Corresponding author: Guojun Zhu

Abstract: This paper studies the performance changes of asphalt after adding direct-cast high modulus materials and the pavement performance changes of asphalt concrete after adding direct-cast high modulus materials. The comprehensive road performance is analyzed through indoor test of simulated construction technology. The test includes high and low temperature performance and water loss performance test. The analysis results show that the high modulus modified asphalt concrete with high modulus material added during the preparation of asphalt concrete and its proportion controlled has better high temperature stability. At the same time, its low temperature performance is not impaired. Increase water damage resistance; It indicates that high modulus material extends the temperature suitability of asphalt concrete.

Keywords: high modulus materials; asphalt concrete; high temperature performance; road performance

1. Introduction

Asphalt pavement is becoming more and more popular and its performance requirements are becoming more and more stringent. With the increase of heavy-duty vehicles and the use of high-pressure tyres, channelization of traffic flow and persistent high temperature in summer, rutting of asphalt pavement is an important factor affecting its comfort, safety and economy. Ruts cause structural deformation of the pavement, resulting in damage to the pavement and consequent diseases. On highways in mountainous and hilly areas with long steep slopes and limited turning radius, heavy vehicles travel slowly, and rut damage is likely to occur and aggravate other diseases when the vehicle load acting on the road surface is longer than that designed. The potential safety hazards brought by rut diseases to drivers can't be ignored. When high-speed vehicles encounter ruts, they will slip and the direction is difficult to control. At the same time, water accumulates in the rut groove on rainy days, which makes it easier for the vehicle to drift and increases the risk of driving [1-3].

Under heavy-load traffic conditions, to improve the modulus of asphalt pavement, firstly, SBS/SBR and other materials are used to directly improve the asphalt material before concrete production. Secondly, high modulus particle material is added into the production process of base asphalt concrete. Third, adding fiber material to form the structure of physical reinforcement; Different methods have different advantages and disadvantages [4-5]. In recent years, more and more attention has been paid to the method of directly putting high modulus materials into the production of asphalt concrete with modified asphalt materials and then adding fiber materials to improve the modulus of asphalt pavement [6-7]. Direct feeding into asphalt concrete is mainly used for the middle and lower layers of road pavement and also for the surface of road pavement. High modulus of asphalt concrete can be significantly increased to improve the rutting resistance of asphalt concrete high temperature stability and fatigue resistance [8-9].

2. Raw Material Performance

2.1. High Modulus Materials

High modulus materials are supplied by Hubei manufacturers. Material components are granular black substances made of various polymers and resins. See Table 1 and Table 2 for performance indicators.

Table 1. Physical and technical index of high modulus materials

Project	Technical indicators	Test method
Appearance	Black solid particles	Visual inspection
Density（kg/m3）	910-980	GB/T13377-1992
Softening point（℃）	≥160	T0606-2000
Particle size（mm）	≤3.0	Filter screen
Addition amount（%）	≤6.0	

Table 2. Chemical composition of high modulus materials

Number	Component	Percentage by weight
1	Polyethylene（PE）	90%
2	Polypropylene（PP）	5%
3	Ethylene vinyl acetate copolymer（EVA）	2%
4	Ultrafine nano carbon black	0.8%
5	Maleic anhydride	2%
6	Antioxidant（RD）	0.2%

2.2. Asphalt

70 base asphalt is used as base asphalt to prepare asphalt concrete, while SBS modified asphalt is used for comparative study. All of them are Sinopec asphalt. The main technical indexes are shown in Table 3 and Table 4.

Table 3. 70 technical indexes of matrix asphalt

Test project		Technical standard	Test result
25℃ Penetration /0.1 mm		60~80	68.2
10℃ Ductility /cm		≥20	27.0
Softening point /℃		≥46	50.0
60℃ Dynamic viscosity /（Pa s）		≥180	219.4
TFOT after	Quality change /%	-0.8~0.8	0.036
	25℃ Penetration ratio /%	≥61	65.0
	10℃ Ductility /cm	≥6	7.0

Table 4. Technical index of SBS modified asphalt

Project		Technical standard	Test result
25℃ Penetration /0.1 mm		40－60	51
5℃ Ductility 5cm/min		≥20	33
Softening point ℃		≥75	84
135℃ Dynamic viscosity /（Pa s）		≤3	2.8
TFOT After	Quality change %	≤±0.3	0.01
	25℃ Penetration ratio %	≥65	85
	5℃ Ductility 5cm/min	≥15	24

2.3. Aggregate

The aggregate is basalt, the fine aggregate is machine-made sand, and the mineral powder is limestone mineral powder. The performance indexes meet the specification requirements.

3. Preparation Process

AC-20I grading is adopted, and j represents 70 matrix asphalt; S stands for SBS modified asphalt; X stands for fiber material; G stands for high modulus material; The dosage of high modulus material is 0.45% - 0.60% of asphalt mixture. Add the aggregate preheated to 185 ℃ - 190 ℃ to the Laboratory mixing pot, then add a certain weight proportion of high modulus materials to the mixing pot, dry mix the aggregate and high modulus materials in the mixing pot for 180 seconds, and then add 165 ℃ asphalt and fiber materials in proportion for 180 seconds; After holding the mixture for 30 minutes, take it out of the oven to prepare rutting test piece, Marshall test piece and low-temperature small beam test piece.

4. Road Performance Test of High Strength Asphalt

4.1. High Temperature Rutting Performance

Table 5. Rutting test results of AC-20I mixture

Project	60 ℃ dynamic stability (times / mm)	70 ℃ dynamic stability (times / mm)
AC-20I+J	2380	620
AC-20I+S	3159	874
AC-20I+S +X	3461	975
AC-20I+J+0.3%G	7220	1366
AC-20I+J +0.5%G	10986	2875
AC-20I+S+0.3%G	8754	1973
AC-20I+S +0.5%G	10392	2541
AC-20I+S+X +0.3%G	12454	3516
AC-20I+S+X +0.5%G	14726	3957

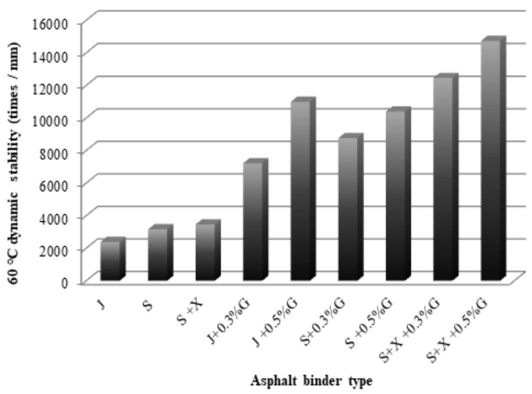

Fig. 1 Rutting test of AC-20I compound cement at 60 ℃

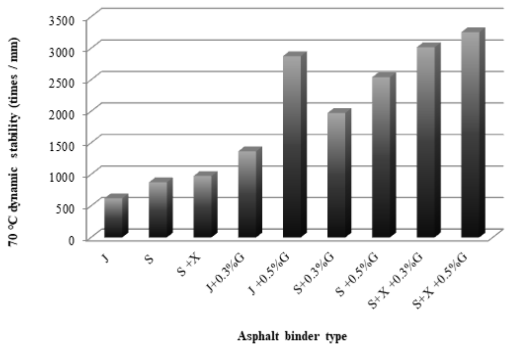

Fig. 2 Rutting test of AC-20I compound cement at 70 ℃

It can be seen from the test data in table 5, Fig. 1 and Fig. 2 above that in the conventional AC-20I medium surface structure grading, the high temperature stability of concrete composed of different cementitious materials is different; The matrix asphalt is the lowest, the performance of SBS modified asphalt with fiber and high modulus material asphalt concrete is the best, and the rutting resistance of asphalt concrete is significantly improved. It shows that it is an effective means to select the composite addition of asphalt cementitious materials in the simulation of real paving; In areas with limited economic conditions, the contribution of materials to high temperature stability can be considered for selection; The analysis shows that high modulus material contributes the most to high temperature stability, followed by SBS modified asphalt; Again, it is fiber material. After adding 0.3% and 0.5% high modulus materials, the dynamic stability can reach more than 12000 times / mm under the condition of 60 ℃ 0.7MPa and SBS modified asphalt plus fiber; It shows that its performance is stable and can effectively resist rutting; Even under the high temperature test temperature of 70 ℃, when the dosage is 0.5%, the dynamic stability index is more than 3500 times / mm, and the rutting resistance is improved. It shows that when the temperature and loading rate are constant, increasing the asphalt viscosity will enhance the viscoelasticity of the asphalt binder, and then enhance the deformation resistance of the asphalt mixture. The stronger the shear deformation resistance of asphalt concrete, the better the high temperature stability of rutting resistance.

4.2. Water Damage Resistance

Table 6. Freeze thaw splitting test results of AC-20I mixture

Project	Splitting strength before freezing and thawing R1（Mpa）	Splitting strength before freezing and thawing R2（Mpa）	R2/R1（%）
AC-20I+J	1.00	0.80	80
AC-20I+S	1.09	0.92	84.4
AC-20I+S +X	1.14	0.97	85.1
AC-20I+J+0.3%G	1.40	1.21	86.4
AC-20I+J +0.5%G	1.58	1.47	93.0
AC-20I+S+0.3%G	1.48	1.34	90.5
AC-20I+S +0.5%G	1.71	1.55	90.6
AC-20I+S+X +0.3%G	1.53	1.40	91.5
AC-20I+S+X +0.5%G	1.77	1.67	94.3

According to the requirements of jtgf40-2017 standard of the Ministry of transport, the water stability of asphalt concrete is verified by the splitting strength ratio before and after freeze-thaw. It can be seen from table 6 above that the absolute value of splitting strength and freeze-thaw splitting residual strength ratio of asphalt concrete mixed with high modulus materials have been improved to a certain extent, indicating that the addition of materials can better block the structural voids, improve the overall material performance, and then optimize the water damage resistance of asphalt concrete.

4.3. Low Temperature Crack Resistance

The low-temperature performance of asphalt concrete refers to the ability of asphalt mixture to resist low-temperature shrinkage cracks under low-temperature conditions in winter. China's code is characterized by the failure strain obtained from low-temperature bending test. According to the standard experimental method of the Ministry of transport.

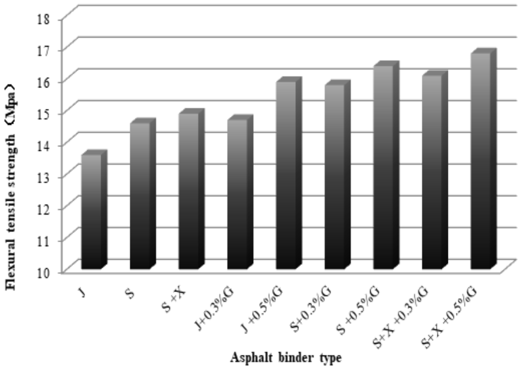

Fig. 3 Bending tensile strength of AC-20I compound cement

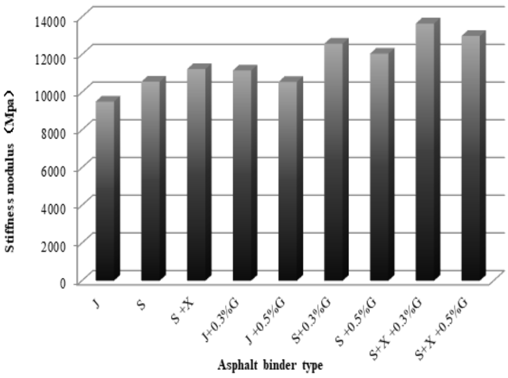

Fig. 4 Stiffness modulus of AC-20I compound cement

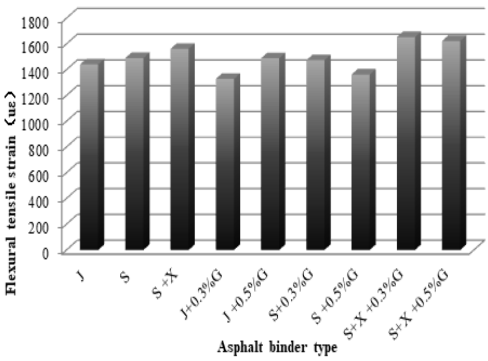

Fig. 5 Bending tensile strain of AC-20I compound cement

It can be seen from Fig. 3, Fig. 4 and Fig. 5 that after adding high modulus material asphalt, the flexural tensile strength and stiffness modulus indexes are improved, but the range is small, and the flexural tensile strain and other indexes change little, indicating that high modulus material asphalt has no adverse effect on the low-temperature performance of asphalt mixture. The high modulus material is first mixed with the aggregate dry, which is used to melt on the surface of the aggregate, improve the adhesion, and play a transitional phase between inorganic and organic; During the mixing and transportation of high modulus materials with modified asphalt, under the action of temperature effect; Partially dissolved and swelled in asphalt, mixed with modified asphalt to form a new binder, improve the performance of modified asphalt, improve softening temperature, increase viscosity and expand temperature adaptability. Fiber reinforcement has a certain degree of stiffness in the polymer microcrystalline area. During the construction process, with the weakening of temperature effect, during the curing process of binder, part of the binder is wrapped with fibers in the aggregate, which is bridged and crosslinked in the aggregate skeleton to form fiber reinforcement. When the high modulus material pavement is at a higher temperature, the internal elastic component can restore the elasticity of the deformed part of the pavement.

The research results show that when asphalt concrete produces the same deformation, the external force work required by high modulus materials is greater than that of low modulus materials, that is, the wheel load pressure under high modulus materials is greater or the load time of high modulus materials is longer under the same wheel load; The modulus of asphalt concrete is directly proportional to the high-temperature performance of pavement. The higher the modulus of concrete, the better the high-temperature stability of pavement. Under the same conditions, the rutting depth of high modulus asphalt concrete is significantly lower than that of low modulus asphalt concrete. Especially under high temperature, the stability of high modulus asphalt concrete is better.

5. Conclusion

Compared with matrix asphalt, SBS modified asphalt and fiber material asphalt mixture, the high-temperature performance of asphalt binder under the compound of direct cast high modulus materials is improved significantly at the addition of 0.3% and 0.5%, and the low-temperature performance and water damage resistance meet the road performance. The results show that the high temperature stability of high modulus modified asphalt concrete formed by adding high modulus materials in the preparation of asphalt concrete and controlling its addition ratio becomes better; At the same time, it did not damage its low temperature performance; Enhance water damage resistance; It shows that high modulus materials expand the temperature adaptability of asphalt concrete; It is helpful to guide the design and selection of materials.

Reference

[1] Zheng Xiaoping, Rutting analysis and treatment of asphalt concrete pavement; Highway Traffic Technology (Application Technology Edition); May 2009.

[2] John E. Haddock, Adam J. T. Hand, Hongbing Fang et al. Determining Layer Contributions to Rutting by Surface Profile Analysis, Journal of Transportation Engineering, 2005, 131(2): 131-139.

[3] Fan Zhiqiang, Causes and preventive measures of rutting on Asphalt Pavement; Traffic standardization; Issue 18, 2011.

[4] Atakan Aksoy, Kurtulus Samlioglu, Sureyya Tayfur, Effects of various Additives on the moisture damage sensitivity of asphalt mixture, Construction and Building Materials, 2005, 19(1):11-18.

[5] Ran Xubo; Causes and control measures of rutting disease on Asphalt Pavement of high-grade highway; Scientific and technological information; Issue 20, 2011.

[6] Bian Jianmin, Treatment of serious rutting disease of asphalt pavement; Transportation world (transportation vehicles); June 2011.

[7] Okan Sirin, Hong-Joong Kim, Mang Tia, Bouzid Choubane. Comparison of rutting resistance of unmodified and SBS-modified Superpave mixtures by accelerated pavement testing, Construction and Building Materials, 2008, 22: 286-294.

[8] Zhang Jun, Qi Jilu, Wang Heng, Research on Application of high modulus asphalt mixture, highway, June 2012.

[9] Huang Huaxi, Effect of dosage of direct injection high modulus modifier on road performance of asphalt mixture, transportation world, Issue 21, 2021, 4-6.