Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Study on pavement performance of basalt fiber asphalt concrete under different pavement environment

Study on pavement performance of basalt fiber asphalt concrete under different pavement environment

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Abstract. In order to study the basalt fiber in the road with the performance, the test of matrix asphalt concrete, basalt fiber reinforced asphalt concrete and the SBS modified asphalt concrete applying ultraviolet aging, high and low temperature alternating cycle change, after the freeze-thaw cycle and salt freezing and thawing cycle road environment for rutting test, low-temperature bending test and immersion Marshall test. The test results show that basalt fiber plays an important role in improving the high-temperature stability, low-temperature crack resistance and water stability of asphalt concrete under different road conditions. The degree of influence of pavement environment on the deterioration of pavement performance of basalt fiber asphalt concrete is as follows: ultraviolet aging > high and low temperature alternating cycle > freeze-thaw cycle > salt freeze-thaw cycle.

1.Introduction

Road performance is an important index to evaluate roads. Serfass and Samanos [1] studied the influence of the modification of cellulose, rock wool, asbestos and glass cotton fibers on asphalt mixture. Jenq et al[2] used fracture mechanics method to evaluate the influence of fiber reinforcement on crack resistance performance. Simpson et al[3] evaluated the properties of polypropylene and polyester fibers. Chen et al [4] believe that the uniformity of fiber distribution in composite materials is a key factor affecting material properties. Putman et al [5] added carpet fibers to asphalt macadam gravel (SMA) to increase the toughness of SMA materials. Gao et al [6-8] studied the high and low temperature properties and water stability of basalt fiber asphalt concrete. Because of the excellent mechanical properties of the fiber, more and more researchers have done related researches. However, the pavement performance of basalt fiber asphalt concrete is less studied under different pavement conditions. Due to the above reasons, the rutting test, low temperature bending test and immersion Marshall test were carried out on the asphalt concrete, basalt fiber asphalt concrete and SBS modified asphalt concrete under the conditions of ultraviolet aging, high and low temperature alternating circulation, freeze-thaw cycle and salt freeze-thaw cycle.
1 test overview

1.1 test materials

Matrix asphalt and SBS modified asphalt were selected for this test asphalt. The asphalt indexes are shown in the table1.

Table 1 Basic indicators of asphalt

Material type	Penetration (0.1 mm)	Ductility (5cm / min) (cm)	Softening point (°C)
Base asphalt	86	86（10℃)	49
SBS modified asphalt 6	66	66(5℃)	79

The aggregate was selected basalt gravel in Zhuozi County, Inner Mongolia, and the ore powder was limestone ore powder. The basalt fiber is short-cut basalt fiber produced by Zhejiang Shijin basalt Fiber Co., LTD.

1.2 specimen preparation

The specimen is formed by using a shear compacting molding instrument, and then the shear compacting plate is cut into a trabecular specimen of 380mm×63.5mm×50mm by using a cutting machine.

1.3 Asphalt concrete mix ratio

By Marshall test, the optimum asphalt ratios of matrix asphalt concrete, basalt fiber asphalt concrete and SBS modified asphalt concrete are 4.3%, 4.5% and 4.9% respectively. The optimum value of basalt fiber content is 0.3% [9].

1.4 Circuit performance test

1.4.1 rutting test.

The specimen used in the rut test is a slab specimen with a length of 300mm, a width of 300mm and a thickness of 50mm. The specimen and the test mold are transferred together into a constant greenhouse at the test temperature for 5-12 hours. Then move it to the appropriate rolling position, lower the test wheel to the appropriate height, and start the test [10].

1.4.2 low temperature bending test

The UTM tester was used for the test, the test temperature was -10℃, and the loading rate was 50mm/min.A trabecular specimen with a length of 250mm, a width of 30mm and a height of 35mm [11].

1.4.3 immersion Marshall test

The standard Marshall specimen with a height of 63.5mm±1.3mm, the immersed specimen and the unimmersed specimen were each set. The immersed specimen was kept for 48h in the 60 ° C ±1 ° C constant temperature flume, and the unimmersed specimen was kept for 30min in the 60 ° C ±1 ° C constant temperature flume. The loading rate is 50mm/min [12].

1.5 test plan

The trabecular specimens were subjected to ultraviolet aging (UV), high and low temperature alternating cycle (HLTA), 10 freezing-thawing cycles (FT) and 10 salt freezing-thawing cycles (SF), respectively, and then rutting test, low-temperature bending test and immersion Marshall test were conducted. Three groups of parallel tests were set up, and the average value of the results was taken for analysis.

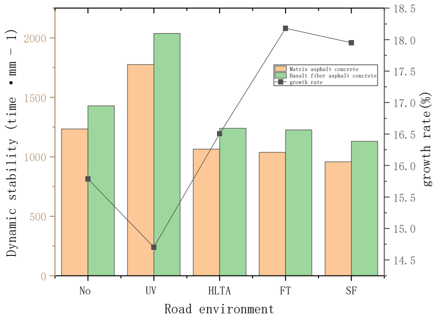
2. data and analysis

2.1 Study on high-temperature Stability of asphalt concrete

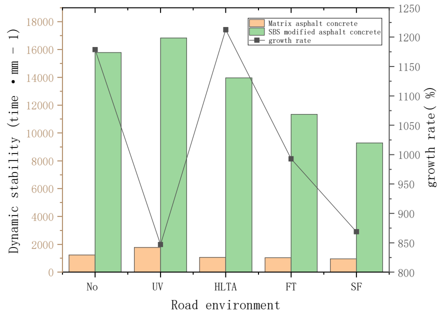
The high-temperature stability of asphalt concrete was determined by “Test Regulations for Asphalt and Asphalt Mixture for Highway Engineering” (JTGE20-2011). The experimental results are shown in Table 2

Table 2 AC-16 Asphalt mixture rutting test results

Type of mixture	Dynamic stability (time ·mm - 1)				
	No	UV	HLTA	FT	SF
Matrix asphalt concrete	1234.11	1776.93	1064.14	1037.64	957.79
Basalt fiber asphalt concrete	1428.93	2038.16	1239.78	1226.28	1129.72
SBS modified asphalt concrete	15781.19	16827.02	13967.2	11340.31	9279.17



(A) Basalt fiber asphalt concrete



(B) SBS modified asphalt concrete

Figure 1 Growth rate of dynamic stability of basalt fiber asphalt concrete and SBS modified asphalt concrete compared with matrix asphalt concrete

According to Figure 1, the dynamic stability of basalt fiber asphalt concrete is improved by 15.79%, 14.70%, 16.51%, 18.18% and 17.95%, respectively, compared with matrix asphalt concrete under the effects of no environment applied, ultraviolet aging, high and low temperature alternating cycle, freeze-thaw cycle and salt freeze-thaw cycle. This is because the addition of basalt fiber increases the thickness of asphalt film and the adhesion of asphalt mixture, effectively dispersing the external load. Compared with matrix asphalt concrete, the dynamic stability of SBS modified asphalt concrete increased by 1178.75%, 846.97%, 1212.53%, 992.89% and 868.81%, respectively. It can be seen that basalt fiber has a good improvement effect on the high-temperature performance of matrix asphalt concrete, but the improvement effect is far from that of SBS modified asphalt.

2.2 Research on anti-cracking performance of asphalt concrete at low temperature

According to "Testing Regulations for Asphalt and Asphalt Concrete for Highway Engineering" (JTG E20-2011), Low temperature bending test was selected for this test. The test temperature was -10℃ and the loading rate was 50mm/min. Three point bending test was carried out using UTM multifunctional tester. Calculating the bending tensile strength of the specimen is destroyed R_B.maximum bending strain $\varepsilon_B$and bending stiffness modulus S_B, calculation formula of type 1, 2, 3, the calculation results are shown in table 3.

$$R_B = \frac{3\times L\times P_B}{2\times b\times h^2} \tag{1}$$

$$\varepsilon_B = \frac{6\times h\times \mathrm{d}}{L^2} \tag{2}$$

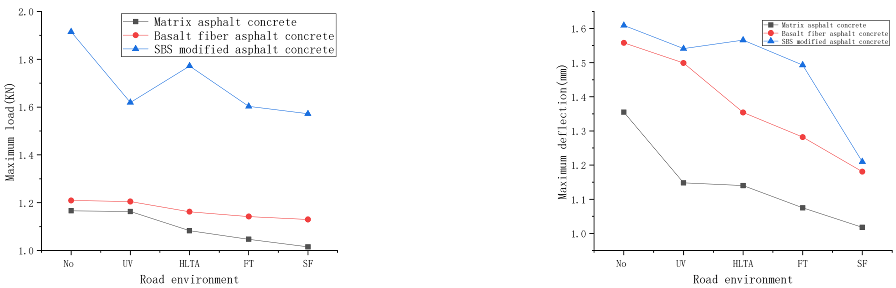
$$S_B = \frac{R_B}{\varepsilon_B} \tag{3}$$

Where: R_B-The flexural tensile strength of the specimen at failure / MPa; ε_B-The maximum bending and tensile strain of the specimen under failure/με; S_B-Bending stiffness modulus at failure / MPa; b - The width of cross break interview piece / mm; h-The height of cross interruption interview piece / mm;

L-The span of the specimen / mm; P_B-The maximum load when the specimen fails /N; d -Mid span deflection of specimen at failure / mm

Table 3 AC-16 Asphalt mixture trabecular bending test results

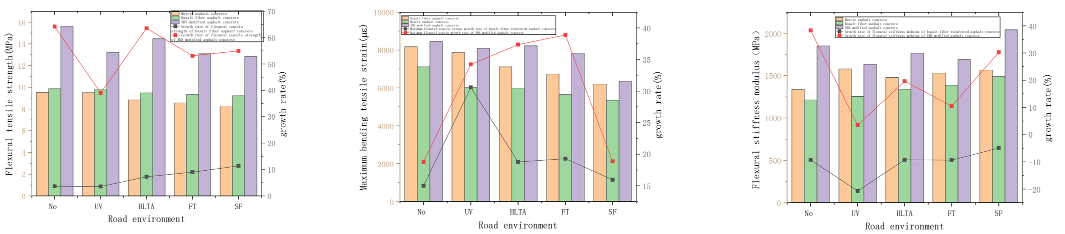
Material type	Road environment	Maximum load/KN	maximum deflection/mm	bending tensile strength/Mpa	maximum bending tensile strain/	bending stiffness modulus/Mpa
	No	1.166	1.355	9.52	7112	1338.52
	UV	1.163	1.148	9.5	6027	1579.94
Matrix asphalt concrete	HLTA	1.083	1.14	8.84	5986.75	1477.18
	FT	1.047	1.075	8.55	5642	1530.07
	SF	1.015	1.018	8.28	5346.25	1567.58
	No	1.209	1.558	9.87	8177.75	1214.03
	UV	1.205	1.499	9.84	7869.75	1252.84
Basalt fiber asphalt concrete	HLTA	1.162	1.354	9.48	7110.25	1340.47
	FT	1.142	1.282	9.32	6730.5	1386.88
	SF	1.13	1.181	9.22	6198.5	1490.99
	No	1.915	1.609	15.63	8447.25	1851.45
	UV	1.619	1.541	13.21	8090.25	1634.99
SBS modified asphalt concrete	HLTA	1.772	1.566	14.46	8223.25	1767.17
	FT	1.603	1.493	13.09	7836.5	1690.38
	SF	1.572	1.21	12.83	6354.25	2041.5



（A）Maximum load (B) Deflection

Figure 2 Low temperature test data

As can be seen from Figure 2, the maximum load of basalt fiber asphalt concrete under the action of no environment applied, ultraviolet aging, high and low temperature alternating cycle, freeze-thaw cycle and salt freeze-thaw cycle increased by 3.69%, 3.61%, 7.29%, 9.07% and 11.33% compared with that of matrix asphalt concrete. The maximum deflection of basalt fiber asphalt concrete is increased by 14.98%, 30.57%, 18.77%, 19.26% and 16.01% than that of matrix asphalt concrete without environment application, ultraviolet aging, high and low temperature alternating cycle, freeze-thaw cycle and salt freeze-thaw cycle.



(A) Flexural tensile strength (B) Maximum bending tensile strain (C) Bending stiffness modulus

Figure 3 Growth rate of low temperature index of basalt fiber asphalt concrete and SBS modified asphalt concrete compared with matrix asphalt concrete

It can be seen from Figure 3 that the flexural strength of basalt fiber asphalt concrete is higher than that of matrix asphalt concrete under each road service condition, among which, it increases the most under the action of salt freeze-thaw cycle, increasing by 11.35%.The reduction rates of bending-tensile strength of asphalt concrete under uv aging, high and low temperature alternating cycle, freeze-thaw cycle and salt freeze-thaw cycle were 0.21%, -7.14%, -10.19% and -13.03%, respectively. For basalt fiber, the reduction rates of flexural strength of asphalt concrete in ultraviolet aging, high and low temperature alternating cycle, freeze-thaw cycle and salt freeze-thaw cycle are -0.30%, -3.95%, 5.57% and -6.59%, respectively, compared with those without applied conditions. It can be seen that basalt can not only improve the flexural and tensile strength of asphalt concrete, but also slow down the decline of the flexural and tensile strength under the damage of road environment. Similarly, the maximum flexural and tensile strain of basalt fiber asphalt concrete can be improved compared with matrix asphalt concrete under different road conditions. Compared with matrix asphalt concrete under the conditions of no environment, ultraviolet aging, high and low temperature alternating cycle, freeze-thaw cycle and salt freeze-thaw cycle, the asphalt concrete increases 14.99%, 30.57%, 18.77%, 19.29% and 15.94%, respectively. The bending stiffness modulus of asphalt concrete is inversely proportional to its deformation resistance. It can be seen from Figure 3 that the bending stiffness modulus of basalt fiber asphalt concrete is the smallest among the three kinds of asphalt concrete, so the deformation resistance capacity of basalt fiber asphalt concrete is the strongest among the three kinds of asphalt. This is because the basalt fiber has the reinforcing function, which slows down the expansion of the micro-crack of asphalt concrete. Meanwhile, the basalt fiber forms a network structure inside the asphalt concrete, which further enhances the anti-cracking performance of asphalt concrete. According to the data analysis of the low temperature trabecular bending test, basalt fiber has a very good effect on the low temperature cracking resistance of asphalt concrete. Although the flexural tensile strength and maximum flexural strain are not as good as those of SBS asphalt concrete, the basalt fiber is better than SBS asphalt concrete in the deformation resistance.

2.3 Analysis of water stability of asphalt concrete

According to "Testing Regulations for Asphalt and Asphalt Concrete of Highway Engineering"(JTG E20-2011), the Immersion Marshall test was selected as the test method for determining the water stability of concrete. See Equation 4 for the calculation formula of the residual stability in immersion water. The test results are shown in Table 4.

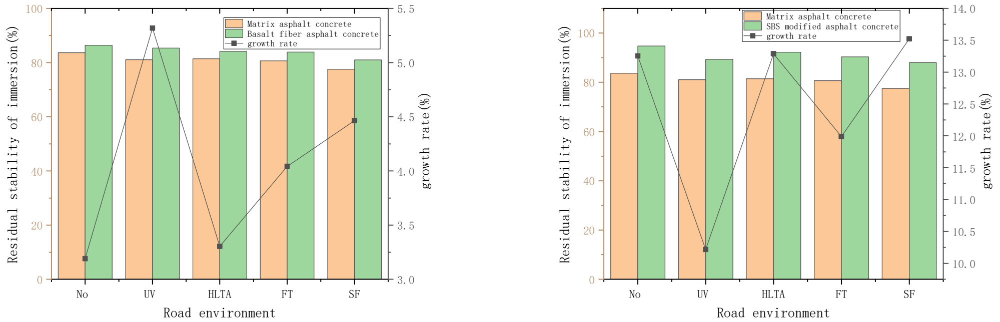
$$MS_0=\frac{MS_1}{MS}\times 100 \tag{4}$$

Where: MS_0 -the immersion residual stability of the specimen /%; MS_1 - stability of the specimen after being immersed in water for 48h /KN; MS -Marshall stability of the specimen /KN.

Table 4 AC-16 Asphalt concrete immersion Machel test results

Material type	Road environment	Stability of UN immersed specimens/KN	Stability of specimens after immersion in water for 48 h/KN	Residual stability of immersion/%	technical requirement/%
Matrix asphalt concrete	No	8.45	7.07	83.67	≥75
	UV	9.02	7.31	81.04	
	HLTA	7.59	6.18	81.42	
	FT	7.29	5.88	80.66	
	SF	6.71	5.2	77.5	
Basalt fiber asphalt concrete	No	11.57	9.99	86.34	
	UV	11.81	10.08	85.35	
	HLTA	8.81	7.41	84.11	
	FT	8.77	7.36	83.92	
	SF	8.3	6.72	80.96	
SBS modified	No	13.73	13.01	94.76	≥80
	UV	15.64	13.97	89.32	
	HLTA	12.89	11.89	92.24	

asphalt	FT	11.99	10.83	90.33
concrete	SF	11.23	9.88	87.98



(A) Basalt fiber asphalt concrete (B) SBS modified asphalt concrete

Figure 4 residual water content of basalt fiber asphalt concrete and SBS modified asphalt concrete compared with matrix asphalt concrete

It can be seen from Figure 4 that under the effects of unapplied environment, ultraviolet aging, high and low temperature alternating cycle, freeze-thaw cycle and salt freeze-thaw cycle, the stability of soaked residue of basalt fiber asphalt concrete is improved compared with that of matrix asphalt concrete, which increases by 3.19%, 5.32%, 3.30%, 4.04% and 4.46%, respectively. This is because the addition of basalt fiber can well reduce the void ratio of asphalt concrete and improve the material compactness. On the other hand, basalt fiber has poor hydrophilicity and can well reduce the spall of aggregate. Compared with the matrix asphalt concrete, the residual stability of SBS modified asphalt concrete increased by 13.25%, 10.22%, 13.29%, 11.99% and 13.52% respectively. Therefore, basalt fiber can effectively improve the water stability of asphalt concrete, but less than the improvement degree of SBS modified asphalt

2.4 Degree of influence of pavement environment on pavement performance of basalt fiber asphalt concrete

The high, low and water stability of basalt fiber asphalt concrete under different road conditions is compared with that under no environmental effect. The change rate of asphalt concrete pavement performance is calculated. The calculation formula is shown in Formula 5, and the calculation results are shown in the table 5.

$$Change\ rate = \frac{environmental\ impact\ asphalt\ concrete\ pavement\ performance}{asphalt\ concrete\ without\ environment} \quad (5)$$

Table 5 Performance change rate of basalt fiber reinforced concrete

Road performance		UV	HLTA	FT	SF
Dynamic stability		142.64%	86.76%	85.82%	79.06%
	Low temperature performance	99.70%	96.05%	94.43%	93.41%
Low temperature performance	Maximum bending tensile strain	96.23%	86.95%	82.30%	75.80%
	Flexural stiffness modulus	103.20%	110.41%	114.24%	122.81%
Residual stability of immersion		98.85%	97.42%	97.20%	93.77%

It can be seen from the table that the degree of influence of road environment on the high temperature stability, low temperature stability and water stability deterioration of basalt fiber asphalt concrete is in order as follows: salt freeze-thaw cycle > freeze-thaw cycle > high and low temperature alternating cycle > ultraviolet aging. Therefore, it can be seen that the northern regions that need to use snow melt agent in winter should pay more attention to the change of road performance during the use of basalt fiber asphalt concrete pavement, so as to prepare for the maintenance work.

3. Conclusion

1. Basalt fiber can effectively improve the high-temperature stability of asphalt concrete, and improve the most in freeze-thaw cycle compared with other pavement environments and matrix asphalt concrete.

2. The flexural strength and maximum flexural strain of basalt fiber asphalt concrete are generally greater than that of matrix asphalt concrete, and the flexural stiffness modulus is less than that of other two kinds of asphalt concrete, indicating that the low temperature anti-cracking performance of asphalt concrete can be well improved.

3 Basalt fiber has a good effect on the water stability of asphalt concrete, which is the most obvious in ultraviolet aging.

4 The order of influence degree of road environment on road performance deterioration is salt freeze-thaw cycle > freeze-thaw cycle > high and low temperature alternating cycle > ultraviolet aging.

References

[1] Serfass j Samanos-J. Fiber-modified asphalt concrete characteristics, applications and behavior[J]. J Assoc Asph Pav Tech, 1996, 65: 193-230.
[2] Jenq Yeou-Shang-Liaw-C-Pei-Liu. Analysis of crack resistance of asphalt concrete overlays A fracture mechanics approach[J]. Trans Res Rec, 1993, 1388: 160-166.
[3] Simpson Amy-L-Mahboub-C.Case study of modified bituminous mixtures[C]//Proceedings of the third materials engineering conference, somerset, kentucky: ASCE, 1994: 88-96.
[4] Chen, Pu-woei, Fu, et al. Microstructural and mechanical effects of latex, methylcellulose, and silica fume on carbon fiber reinforced cement[J]. ACI Materials Journal, 1997, 94(2): 147-155.
[5] Putman Bradley-J, Amirkhanian Serji-N. Utilization of waste fibers in stone matrix asphalt mixtures[J]. Elsevier B.V., 2004, 42(3): 265-274.
[6] Gao Chun-Mei, Zhang Qiang, Zhang Hu-Zhu. Research on Basalt Fiber Asphalt Concrete's Water Stability[J]. Trans Tech Publications Ltd, 2014, 2973(505): 117-120.
[7] Gao Chun-Mei, Han Shuo, Zhu Kai-Xuan, et al. Research on Basalt Fiber Asphalt Concrete's High Temperature Performance[J]. Trans Tech Publications Ltd, 2014, 2973(505): 39-42.
[8] Gao Chun-Mei, Han Shuo, Chen Shuang, et al. Research on Basalt Fiber Asphalt Concrete's Low Temperature Performance[J]. Trans Tech Publications Ltd, 2014, 2973(505): 35-38.
[9] Luo Guohu. Application of Mineral Compound Fiber Reinforced Asphalt Pavement in High-cold and High-altitude Area [D]. Xi’an: Chang’an University, 2014.
[10] CHENG X. Test Method for High Temperature Performance of Asphalt Mixture[J]. Engineering Construction and Design,2018(01):128-129.
[11] TANG W, SHENG XJ, SUN LJ. Pavement Performance of Fiber Reinforced Asphalt Mixture[J]. Journal of Building Materials,2008(05):612-615.
[12] YANG RH, XU ZH, LI YC. Research on Evaluation Method for Moisture Susceptibility of Asphalt Mixture[J]. Journal of Tongji University(Natural Science),2007(11):1486– 1491.