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Road Performance of Fiber Reinforced Asphalt Concrete Bridge Deck Pavement

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Abstract: As the problem of asphalt concrete bridge deck pavement is becoming more and more serious, how to improve its road performance has become the focus of the study. Considering fiber is widely used in road engineering, wheel tracking test, flexural test, immersion marshall test and freeze-thaw splitting test were carried out to study road performance of asphalt mixture with different fiber contents, analyzing the function mechanism of fiber reinforced asphalt concrete. The test results show that polyester fiber can improve high-temperature stability, low-temperature crack resistance property and water stability of asphalt concrete and road performance improves with the fiber content increasing in a certain range.

Key words: Road engineering, fiber reinforced asphalt concrete, road performance, polyester fiber, bridge deck pavement

INTRODUCTION

As the diseases of asphalt concrete bridge deck pavement emerge, bridge deck pavement problem becomes a key technical problem in highway construction (Wang and Hu, 1998). Study on the problems of deck pavement structure stress, material properties, structure combination and waterproof processing has received growing attention, bridge on the highway has heavy traffic, more heavy vehicles, in the case of high temperature in summer, it's easy to cause high temperature instability disease, such as rutting, bleeding and so on, winter with low temperature is susceptible to case temperature shrinkage crack and temperature fatigue crack, under repeated vehicle load and seepage, loosening, pits and other damage on surface occur easily. Therefore, how to improve road performance of asphalt concrete bridge deck pavement has become the focus of the study. Considering the fact that fiber products are widely used in road engineering, putting forward the way to improve road performance of asphalt concrete bridge deck pavement by mixing fibers, which can provide reference for similar bridge deck pavement research.

MATERIALS AND METHODS

Asphalt: SBS modified asphalt from Panjin Liaohe was used in this experiment, properties of it are shown in Table 1.

Aggregate: Basalt from Xifeng forest farm Donglin quarry was used in this experiment, properties of it are shown in Table 2.

Mineral powder: Mineral powder is made by clean limestone, its degree of fineness meets the requirement, properties of it are shown in Table 3.

Fiber: Polyester fiber extracted from petroleum was used in this experiment, it has the advantages of high strength,

Table 1: Properties of asphalt

Property	Test result	Requirement
Penetration at 25°C/0.1mm	70	60-80
Softening point/□	81	≥55
Ductility at 5 □/cm	42	≥30
Softening point difference after segregation 48h/°C	1.5	≤2.5
Elastic recovery at 25°C%	98	≥65
Flashing point/□	285	≥230
Dynamic viscosity at 135°C/(Pa•s)	1.4	≤3
Solubility/%	99.7	≥99

Table 2: Properties of aggregate

Property	Test result	Requirement
Crushing value/%	13.3	≤26
Abrasion volume by Los Angeles rattler/%	7.7	≤28
Apparent relative density	2.978	≥2.6
Water absorption/%	0.5	≤2.0
Solidity/%	2.6	≤12
Elongated particle contents/%	8.2	≤15
Adhesion level	4	≥4

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insolubility, strong adsorption, stable chemical property and good dispersion, properties of it are shown in Table 4.

MIX DESIGN

Gradation: Gradation AC-16 is used in this experiment, mix design is performed according to Marshall Design Method. Based on gradation median, adjusting according to engineering practice and geography, climate of the eastern region of Heilongjiang Province, the final gradation is shown in Table 5.

Asphalt content: According to the determined gradation, the optimum asphalt contents of asphalt mixture with three different fiber contents were determined by Marshall test. The Marshall test result is shown in Table 6.

The Marshall test result shows that the optimum asphalt content improves significantly with fiber content increasing, because addition of polyester fiber increases the specific surface area of asphalt mixture, the same role as filler, thus more asphalt is needed to wrap. Density decreases with fiber content increasing, this is because fiber density is smaller than aggregate and the elastic effect of fiber makes it difficult to compact, so that the fiber reinforced asphalt mixture density decreases, therefore, in the construction process, more compaction energy is needed for fiber reinforced asphalt mixture to meet the requirements for its construction compacting standard. Because of the filling effect of fiber, void ratio decreases with fiber content increasing. In addition, because the bridge connection reinforcement and crack resistance effect of fiber, addition of fiber improves the Marshall stability (MS) and flow value (FL) of asphalt mixture.

Table 3: Properties of mineral powder

Property	Test result	Requirement
Water absorption/%	0.8	≤1
Apparent relative density	2.6	≥2.5
Appearance	No agglomeration	No agglomeration
Heat stability	No change in color	No change in color

Table 4: Properties of polyester fiber

Property	Test result	Property	Test result
Shape	Fasciculation	Color	White
Specific gravity/ ($g\ cm^{-3}$)	1.38	Ignition point/°C	560
Length/mm	6	Melting point/°C	249
Diameter/mm	0.015	Elongation at rupture/%	35
Tensile strength /MPa	960	Crimp property	Not curly
Safety	Yes	Heat resistance	Good

ROAD PERFORMANCE

High-temperature performance: Asphalt mixture is a kind of viscoelastic material, under the condition of high temperature in summer, asphalt will be soft and in flow state, so the stability of asphalt mixture becomes poor, prone to permanent deformation, such as rutting, translation, upheaval and so on, the rutting is one of the most harmful destructive forms of asphalt pavement. The wheel tracking test was carried out to evaluate high-temperature performance of asphalt mixture with different fiber contents. The wheel tracking test result is shown in Table 7.

The wheel tracking test result shows that asphalt mixture dynamic stability value increases with fiber content increasing, the greater the value of dynamic stability, the stronger the ability of asphalt mixture to resist deformation at high temperature, the better the high-temperature property. In the effect of load and temperature, permanent deformation of pavement is mainly caused by the shear flow deformation of asphalt mixture. Under high temperature condition, if the asphalt content is too low, resulting in asphalt mixture segregation; if the asphalt content is too high, resulting in rut due to larger high-temperature fluidity of asphalt mixture. After adding polyester fiber in asphalt mixture, on the one hand, due to good adhesion of fiber and asphalt, fiber will adsorb free asphalt and tiny particles; on the other hand, long fibers arrange in a crisscross pattern

Table 5: Mass passing percent of gradation AC-16 (unit: %)

	Sieve size/mm										
Gradation	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Upper limit	100	100	92	90	62	48	36	26	18	14	8
Lower limit	100	90	76	60	34	20	13	9	7	5	4
Median	100	95	84	75	48	34	24.5	17.5	12.5	9.5	6
Design	100	93.8	83	66	48.3	34.7	24.9	17.4	12.6	8.4	5.7

Table 6: Marshall test result

Fiber content/%	Asphalt content/%	Density/ ($g\ cm^{-3}$)	Void ratio/%	Marshall stability/kN	Flow value/0.1 mm
0	4.8	2.521	3.4	12.1	46
0.3	5.2	2.503	3.3	13.1	48
0.5	5.5	2.498	3.2	13.7	49

envelope in the aggregate external by overlapping action, forming fiber skeleton structure effectively (as shown in Fig. 1) and asphalt structure network, so as to improve the overall stability of asphalt mixture (Tang *et al*., 2008).

Low-temperature performance: There are a lot of test methods to study low-temperature performance of asphalt mixture at home and abroad, mainly including: destruction test with constant strain loading (indirect tensile test, flexural test and compression test), direct tensile test, flexural tensile creep test, thermal stress restrained specimen test, three point bending J integral test, C* integral test, contraction coefficient test, stress relaxation test and so on (Shen, 2006). Flexural test was used to evaluate low-temperature crack resistance performance of asphalt mixture. The test temperature in this experiment is -10, -20 and -30°C. Flexural test result of asphalt mixture with different fiber contents is shown in Table 8.

Table 7: Wheel tracking test result

Fiber content/%	0	0.3	0.5
Dynamic stability/ (Times/mm)	4483	4530	4783

Fig. 1: Polyester fiber in asphalt mixture (Chen and Lin, 2005)

According to low-temperature crack resistance technical requirements of modified asphalt mixture, three kinds of fiber reinforced asphalt mixture all meet the requirement of flexural test destruction micro strain at -10°C is not less than 3000. Test result shows that flexural tensile strength and flexural tensile strain of asphalt mixture increase significantly with fiber content increasing, which means low-temperature crack resistance performance of asphalt mixture improves significantly. Improvement of flexural tensile strength is mainly due to good adhesion between fiber and asphalt, tension caused by load is shared by the fiber asphalt colloid; improvement of flexural tensile strain is mainly due to good physical chemical properties of fiber, it don't be hard and brittle in low-temperature, fiber reinforced asphalt mixture has good flexibility, improving low-temperature strain value (Sun and Zhao, 2002; Peng, 2005; Liu *et al*., 2011). In addition, flexural tensile strength and flexural tensile strain of asphalt mixture decrease with temperature decreasing, which means the lower the temperature, the worse the low-temperature performance of asphalt mixture.

Water stability: Asphalt mixture will damage when submerged in water, due to reduction of adhesion between asphalt and aggregate, final performance is

Table 8: Flexural test result

		Test temperature/°C		
Fiber content/%	Property	-10	-20	-30
0	Flexural tensile strength/Mpa	9.3	8.4	7.6
	Flexural tensile strain/με	3498	2290	1789
	Flexural tensile modulus/Mpa	2659	3668	4248
0.3	Flexural tensile strength/Mpa	9.8	8.9	8.7
	Flexural tensile strain/με	3884	2658	2143
	Flexural tensile modulus/Mpa	2523	3348	4060
0.5	Flexural tensile strength/Mpa	10.2	9.1	8.9
	Flexural tensile strain/με	4028	2720	2204
	Flexural tensile modulus/Mpa	2532	3346	4038

Table 9: Immersion marshall test result

	Marshall stability/kN		
Fiber content/%	Before immersion	After immersion	Immersion residual stability/%
0	12.1	10.9	90.3
0.3	13.1	12.3	94.1
0.5	13.7	13.1	95.4

Table 10: Freeze-thaw splitting test result

	Splitting tensile strength/MPa		
Fiber content/%	Before freeze-thaw	After freeze-thaw	Freeze-thaw splitting strength ratio/%
0	0.943	0.850	90.1
0.3	0.971	0.915	94.2
0.5	0.992	0.938	94.6

reduction of overall mechanical strength, so the water stability of asphalt mixture is finally evaluated by degree of physical mechanical performance reduction in immersion condition. Immersion marshall test and freeze-thaw splitting test were carried out to evaluate water stability of asphalt mixture with different fiber contents. Immersion marshall test result is shown in Table 9 and freeze-thaw splitting test result is shown in Table 10.

The immersion marshall test result shows that immersion residual stability of asphalt mixture increases with fiber content increasing, this is mainly due to the adsorption and absorption of fiber, increasing film thickness of structure asphalt which has high viscosity and good heat resistance, fiber and structure asphalt wrap overlying the aggregate surface, the thicker asphalt film slows down asphalt aging rate, which can maintain its good adhesion for longer time, reducing the erosion damage effect of water on asphalt and aggregate (Li and Lv, 1998; Song *et al*., 2012; Zhao and Li, 2012), increasing immersion residual stability; the freeze-thaw splitting test result shows that freeze-thaw splitting strength ratio of asphalt mixture increases with fiber content increasing, this is mainly due to void ratio decreases with fiber content increasing, reducing frozen-heave stress of water on void wall in the freeze-thaw process, weakening spalling degree between asphalt and aggregate (Ma *et al*., 2006), improving splitting tensile strength after freeze-thaw. The above two experiments show that, addition of fibers increases the effective asphalt film thickness of aggregate surface, reducing void ratio, so the water stability of asphalt mixture is better.

CONCLUSION

- Marshall stability, flow value and optimum asphalt content of asphalt mixture increase with fiber content increasing, while density and void ratio decrease and the elastic effect of fiber makes it difficult to compact, so in the construction process, more compaction energy is needed for fiber reinforced asphalt concrete bridge deck pavement to meet the requirements for its construction compacting standard
- High-temperature performance, low-temperature performance and water stability of asphalt mixture improve significantly with fiber content increasing, thus the addition of fiber greatly prolongs the service life of asphalt concrete bridge deck pavement
- Practice shows that, polyester fiber content of asphalt concrete bridge deck pavement is appropriate in 3% in cold regions, if the fiber content is too high, it is easy to form voids for asphalt mixture in the mixing and compaction progress, reducing its road performance

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