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Study on Performance of Epoxy Asphalt Concrete Applied in the Deck Pavement of Pingsheng Steel Bridge

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Abstract: As a fair deck pavement material of its kind used in steel bridge, the epoxy asphalt concrete is considered much more superior to ordinary asphalt concrete in terms of road performance, while still greatly subject to the level of design and construction. Starting from a practical case of the epoxy asphalt concrete that has been applied in the deck pavement of Pingsheng Steel Bridge, this paper centers on a comprehensive study and discussion of the epoxy asphalt mixture, specifically in aspects of physical and mechanical performance test of stability under high temperature, performance under low temperature, tortuosity, immersion stability, linear contraction performance, fatigue performance and oil-erosion resistance performance. This will provide positive instruction for future deck pavements on steel bridges.

Introduction

The technology used in the deck pavement of steel bridges has been a tough problem troubling experts around the world. Due to the fact that the stress and deformation undergone by deck pavement material that is paved directly on orthotropic steel plates on bridges are far more complicated than those applied in the case of highway pavement, stricter standards are required on the deck pavement material in terms of its stability under high temperature, fatigue and crack resistance performance, suitability for deformation of the surface plates of steel bridges and interlayer bonding.

One approach to deal with this problem is to add epoxy resin into the asphalt, and after a series of curing effect by mixing with the hardening agent, an inconvertible sort of condensate-the epoxy asphalt-will be engendered, which has fundamentally redefined the thermoplastic feature of the asphalt and therefore has rendered the asphalt a brand-new and fine physical and mechanical character. The road performance of the epoxy asphalt concrete has outperformed ordinary asphalt concretes with its major advantage of strong intensity and rigidity. Specifically, the bending stiffness modulus of the epoxy asphalt concrete under normal temperature condition such as 20℃ would be as high as 12,000 MPa. Meanwhile, it has strong resistance to plastic cracking and permanent deformation character under high temperature, and shows good crack-resistance performance under low temperature. With its outstanding anti-fatigue performance under a standard stress level, the epoxy asphalt concrete enjoys an enduring life of 10 or even 30 times as long as that of ordinary asphalt concrete. The epoxy asphalt concrete is also highly resistant to chemicals such as combustibles and oil-erosion.

An Overview of the Project

A single-pylon and single-span self-anchored suspension bridge with four cable planes, the Pingsheng Bridge extends 680.2 meters. Its main pylon stands 142.07 meters high and the main span measures 350.0 meters. Constructed in a three-column rectangle figure, the main pylon has a height and spanning length that top all the rest of its kind both domestically and internationally. The anchor span and the main span are made of concrete box girder and steel box girder respectively, and the bridge has twin-decks that are separated, allowing ten two-way traffic lanes to pass on. The steel box girder on the main span is paved with epoxy asphalt concrete and is constructed by thick wearing layer of 25mm, bonding material of leveling layer, thick leveling layer of 25mm and bonding material for the steel deck pavement.

Physical and Mechanical Performance Test of Epoxy Asphalt Mixture

(1)Test on Stability Under High Temperature

The stability performance under high temperature is evaluated by employing the rutting test, in which the specimens are created through natural processing and manufacturing. Specimens of the epoxy asphalt have been solidified and are sent through the rutting test after 12 hours of stabilization. The test is done under two levels of temperature: 60℃ and 70℃, and other materials are also used as comparison. Result of the rest is shown in Table 1.

Table 1 Result of the Rutting Test

Type of Mixture		Epoxy Asphalt Concrete	AC Modified Asphalt Concrete	SMA
Dynamic Stability /(times·mm^{-1})	60℃	Virtually no deformation	2209	2583
	70℃	5801	683	685

By comparing the test results, we can find that the dynamic stability of the epoxy asphalt concrete is far better than asphalt mixtures of other types, and the accumulated deformation is greatly less than others. This proves that the epoxy asphalt concrete is highly stabilized under high temperature and therefore is more suitable as a choice of deck pavement for steel bridges compared with other types of asphalt mixtures.

(2)Test on Performance Under Low Temperature

In the test of performance under low temperature, the Marshall Test specimens are adopted. For convenience, splitting tests at temperatures of 25℃、0℃ and -15℃ are separately carried through and the loading rates under these three temperatures are 50mm/min, 1mm/min and 1mm/min respectively. All specimens adopted are naturally solidified ones, and the test ends in a result as shown in Table 2.

Table 2 Result of Splitting Test

Temperature (℃)	Void Fraction (%)	Maximum Load (kN)	Intensity of Splitting (MPa)
15	2.77	61.1	6.08
0	2.84	92.6	9.01
-15	2.92	128.8	12.1

We can find from the test result illustrated in table 6 that the specimen's maximum load and splitting intensity have both increased when the temperature drops from 15℃ down to -15℃. Moreover, while the horizontal deformation at maximum load level tends to decrease, the degrees of horizontal deformation at 0℃ and -15℃ are basically the same. It can be concluded that the deck pavement is relatively stable under different temperatures, performs well under low temperatures and is strongly deformable. Meanwhile, by comparing the test results of specimens that have not been fully solidified in indoor laboratory test, we can see that the pavement material that has gone through natural stabilization has stronger Marshall intensity and splitting intensity. Therefore, it would be much better for the deck pavement made of epoxy asphalt mixture to be laid aside for some time before being used for public transport.

Bending Test

The small beam bending test, which is used to evaluate the characteristics of intensity and elasticity of tensile strength of the epoxy asphalt mixture, adopts the beam specimens which are sliced into a size of 30mm×35mm×250mm in the rutting test, and is carried through under temperatures of 15℃ and -15℃ separately. The employed test equipment is MTS810 Servo Hydraulic Material Test System. Result of the bending test on the asphalt mixture under temperatures of 15℃ and -15℃ is shown in table3.

Table3 Result of Bending Test on Bending Strength

Type of Mixture	Bending Strength（MPa）		Maximum Deformable Strength		Bending Stiffness Modulus /Gpa	
	15℃	-15℃	15℃	-15℃	15℃	-15℃
Epoxy Asphalt Concrete	16.37	21.0	6.342×10^{-3}	1.575×10^{-3}	2.554	13.377
AC Modified Asphalt Concrete	5.91	8.7	1.036×10^{-2}	8.303×10^{-4}	0.663	10.735
SMA	4.63	7.7	1.362×10^{-2}	7.437×10^{-4}	0.375	10.112

It can be drawn from the bending test result that the bending stiffness of epoxy asphalt concrete is far greater than that of the other two types of asphalt mixtures. In addition, while all of their deformable powers are close under normal temperature conditions, when the temperature drops low, the AC modified asphalt mixture and SMA tend to deform and shrink at a much faster rate. As a comparison, the epoxy asphalt concrete, though being deformed to some extent, is still at the same level of strength as under the normal conditions. Therefore, compared with AC modified asphalt mixture and SMA, the epoxy asphalt concrete is well deformable as well as having outstanding strength.

Immersion Stability Test

When soaked in water, the asphalt mixture has better immersion stability if its intensity does not drop that much. The immersion stability is measured by using Immersed Marshall Test. The soaking time of the specimen lasts for either 48 hours or 96 hours under two testing conditions. In this test, the specimen undergoes the same sort of criteria as in standard Marshall Test except that it needs to be placed in a basin under constant temperature for a long time. Specific data of the test result is shown in Table4.

Table 4 Test Result of Residual Stability

Immersion Time (h)	Stability（kN）	Flow Value （0.1mm）	Residual Stability （%）
48	44.54	42.5	95.5
96	42.17	44.2	90.2

It is not hard to find from the residual stability test on asphalt mixture that both the degree and value of residual stability of epoxy asphalt are much higher than other similar type of asphalt mixture, which shows that the former is well resistant to water erosion. Furthermore, by comparing the results of the two lasting periods, the residual stability of epoxy asphalt concrete does not change much when it is soaked for 48 hours and for 96 hours, meaning that the epoxy asphalt concrete is basically proof to water erosion.

Linear Contraction Performance

Due to the fact that contraction damage primarily occurs in low-temperature regions, the test is undertaken within the range of -15 to 5℃ to determine the linear contraction coefficient of the epoxy asphalt. Specific test result is shown in table 5.

Table5 Test Result of Linear Contraction Coefficient

Temperature Range（℃）	5~0	0~-5	-5~-10	-10~-15
Contraction Coefficient	2.50×10^{-5}	1.70×10^{-5}	1.49×10^{-5}	1.30×10^{-5}

The test result indicates that the linear contraction coefficient of epoxy asphalt concrete remains within $(1.3\sim2.5)\times10^{-5}$ under whatever range of temperature. The linear contraction coefficient of steel is around $(1.1\sim1.4)\times10^{-5}$, while that of epoxy asphalt concrete is very similar with no big difference, and is virtually the same under low temperature conditions.

Consequently, the shearing stress caused by temperature change that occurs between the deck pavement and steel plate of bridges is at its optimum when applying the epoxy asphalt mixture as the pavement material.

Fatigue Test

The fatigue test is performed on MTS. After the composite beam goes through cyclic loading with constant strain amplitude of 85,000 times at a maximum load of 12kN and minimum load of 0.05 kN, the asphalt concrete cracks at the middle of the span, and when the maximum load and minimum load changes to 10 kN and 0.05 kN respectively, the asphalt concrete cracks again at the middle of the span.

With the data acquired from the fatigue test on composite beam, we could draw a fitting curve by using the semilog coordinates to illustrate the fatigue life and fatigue load of the composite beam specimen. And the bending fatigue life formula of the composite beam when the asphalt mixture is in tension can be generated based on this fitting curve:

$$\log_{10}N = 5.229 - 0.356L \qquad (1)$$

In this formula: L and N represent the fatigue load (kN) and fatigue life (per 10,000 times) respectively.

It can be concluded from the fatigue test result that the properly designed bridge composition paved by epoxy asphalt concrete can meet the standard of Pingsheng Bridge in terms of its transportation and loading capacity within the designated 15 years of service life.

Capacity of Oil-Corrosion Resistance

In order to test the epoxy asphalt's ability to resist oil corrosion, a Marshall specimen made of epoxy asphalt concrete with 6.5 % of asphalt is selected to soak in diesel oil for 48 hours. Change of the specimen's formation is then observed, and Marshall residual stability as well as quality loss are assessed.

Table 6 Test Result of Marshall Residual Stability on Immersed Epoxy Asphalt Mixture

Test Conditions	Technical Properties						
	Bulk Density (g/cm^3)	Theoretical Maximum Density (g/cm^3)	Void Fraction (%)	Void Ratio of Mineral Aggregates (%)	Degree of Asphalt's Saturation (%)	Degree of Stability (kN)	Flow Value (mm)
60℃, 1h	2.575	2.610	1.324	10.66	87.58	62.6	41.8
60℃, 48h	2.574	2.610	1.395	10.72	86.99	65.7	43.4

After 48 hours of soaking in the diesel oil, the specimen of the epoxy asphalt concrete has a Marshall residual stability of 100%, and quality of the specimen has increased by 0.34%. This shows that the epoxy asphalt concrete can meet the standard of oil corrosion resistance.

After two weeks of soaking, edges of the specimen do not thresh or get loosened and are still hard and solid. The Marshall stability of the specimen is still measured at 30kN, which is three times that of the ordinary asphalt concrete.

Conclusions

Based on the practical project of epoxy asphalt concrete pavement applied in Pingsheng steel bridge, this paper is intended to make physical and mechanical experiments on the epoxy asphalt mixture regarding tests of stability under high temperature, performance under low temperature, bending capacity, immersion stability, linear contraction performance, anti-fatigue performance and oil-corrosion resistance. Results of these tests prove that the epoxy asphalt concrete pavement has shown excellent performances of stability under high temperature, anti-cracking feature under low temperature, immersion stability, resistance to deformation and fatigue, and oil-corrosion resistance. After nearly four years of heavy traffic flow since it is opened to public transport, the Pingsheng bridge is found to be in good working condition in terms of its deck pavement, which is composed of epoxy asphalt concrete. Therefore, this project proves to be of significant theoretical meaning and functional importance to the applied research on the deck pavement of steel suspension bridge with orthotropic steel box girder, and also to the exploring of new type of bridge deck pavement material and pavement structure that can adapt to the unique transportation load and climate condition in our country.

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