A Case Study of Asphalt Pavement Overlay for Beijing West Chang'an Avenue Using Modified Bitumen of High Viscosity and Elasticity

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Abstract: Beijing West Chang'an Avenue was re-overlaid in 2014 to improve its service condition due to serious reflection cracks . The existed structure of pavement is a combination of 8~10 cm bituminous surface based on cement concrete layer. In this case study, the cracked bituminous layers were removed and a stress absorbing layer was applied to improve the cohesion between road base and surface layer. A high temperature and traffic loading standard (70˚C, 1.0MPa) was adopted in according to the real project conditions. A series of performance laboratory test was conducted to optimize materials design and evaluate the characteristic of the materials. The laboratory test results shown that the modified bitumen has a excellent performance with higher resistance of fatigue and deformation. This project has been open to traffic for nearly one year and the stress absorbing layer were approved to effective reduce the reflection cracks and moisture damage of
pavement structure in the light of the satisfactory pavement service indexes.

Introduction

For traffic management support for APEC summit in 2014, the municipal government decided to make overhaul of West Chang'an Avenue with serious diseases and poor road conditions and so surveyed its disease characteristics and repair work conditions. The main road pavement structure of West Chang'an Avenue is the cement concrete high-strength anti-explosion layer of metro line and the bituminous pavement is of rigid base structure. Reflection crack treatment is the controlling factor and technical difficulty of overhaul design. Meanwhile, the pavement overhaul of Chang'an Avenue has the following characteristics:

Current West Chang'an Avenue (South Lishi Road-Wukesong Bridge) has serious equidistant reflection cracks on the asphalt surface course, serious concrete slab cracks under the surface course, as shown below, obvious driving bumpiness and poor comfort.

Under Chang'an Avenue is the earliest metro line 1 in Beijing and the asphalt surface course with the anti-explosion layer as the pavement base course is constructed above the subway tunnel anti-explosion layer in West Chang'an Avenue. On the anti-explosion layer is 8-10cm asphalt surface course. Crashing the cement concrete slab is an effective method to prevent reflection cracks, but the anti-explosion layer cannot be destroyed or excavated, so only other methods can be used to prevent reflection cracks.

There are many passenger foot-bridges in West Chang'an Avenue. Due to road clearance restriction, the elevation in the road overhaul process of West Chang'an Avenue may not be increased greatly. The elevation may be greatly increased by setting a thick layer of open-graded anti-crack mixture with large particle size between the cement concrete anti-explosion layer and the asphalt surface course, so this scheme is not adoptive. The pavements of many bus lanes and bus bays and large intersections in West Chang'an Avenue bear great shear stress and many rutting and fatigue crack diseases have appeared.

Objective and scope

There are mainly three following problems to be solved in terms of direct additional pavement of asphalt surface course in old cement concrete structure: (1) Prevention of reflection crack[1-3](2) Bonding between surface course and cement concrete slabs[4-5](3) Water infiltration of pavement surface[6-11].

Prevention measures of reflection crack research results show that International technical exchange with Europe and America and China’s engineering experience in recent years show that the stress absorbing layer technology has obvious advantages technologically and economically[12-13]. The special modified asphalt can solve interlayer bonding between the cement concrete pavement slabs and the asphalt surface course[14].The modified asphalt mixture with the design air voids less than 1.5% and asphalt content greater than 8% is used for the stress absorbing layer between the old cement concrete slab and the asphalt surface course for good water sealing function and excellent anti-crack effect[15]. Many professional bus lanes and bus bays in West Chang’an Avenue propose higher requirements for high-temperature performance of the bituminous pavement. The mixture grading, cementing material and additive may be considered comprehensively.

Test and analysis of results

Treatment measuresof reflection crack

High-viscosity and high-elasticity asphalt

The asphalt with high viscosity can ensure bonding effect between the bituminous mixture particles, enhance the bonding between the asphalt surface course and the cement concrete slabs, reduce the peeling, displacement and upheaval caused by shear deformation of the asphalt surface course under the role of vehicle load and improve the pavement comfort and durability.

With good elastic recovery, the bituminous mixture can recover quickly after load in case of pavement deformation under role of load, so as to reduce the residual strain and show good micro-crack self-healing. The most significant characteristic of the bituminous mixture at the stress absorbing layer is high elastic recovery performance, so as to possess good deformation recovery capability after large deformation. For the bituminous mixture at the stress absorbing layer, its deformation recovery ability mainly depends on the elastic recovery capability of the bituminous mixture.

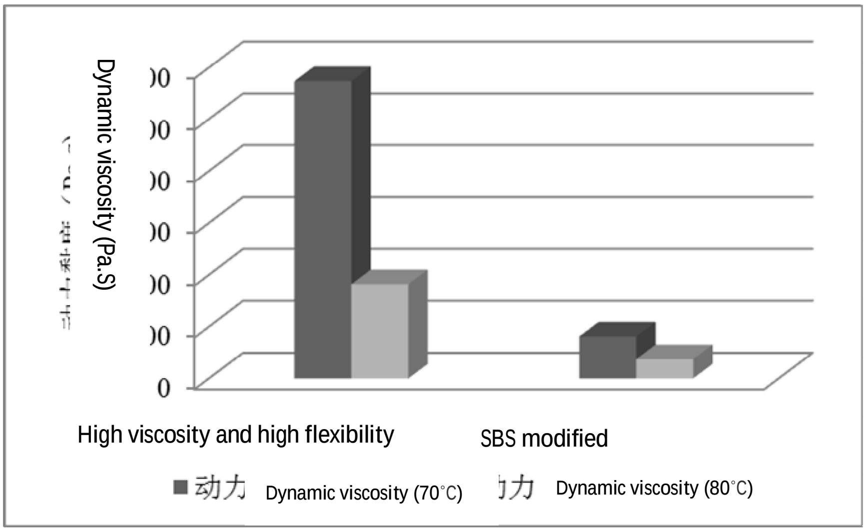

Figure 3-1 Viscosity of Two Asphalts at 70˚C and 80˚C

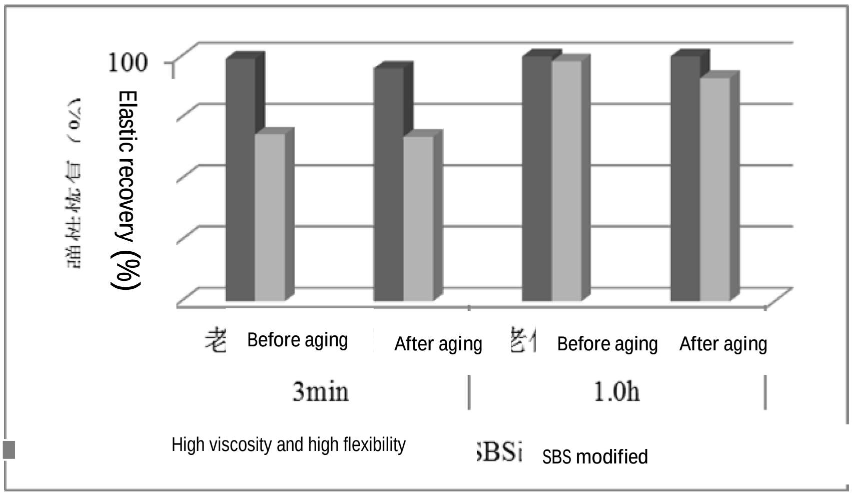

Figure 3-2 Elastic Recovery Performance of Two Asphalts 3min and 1h before and after Aging

Figure 3-1 shows that the dynamic viscosity of the modified asphalt mixture with high viscosity and high elasticity is 28680Pa·s at 70˚C, far above that (4057Pa·s) of the conventional SBS modified asphalt, indicating that its anti-deforming capability is far above that of the conventional SBSmodified asphalt. The same rule appearing in the dynamic viscosity at 80˚C, indicating high viscosity characteristic of such asphalt.

Figure 3-2 shows the elastic recovery performance of two asphalts 3min and 1h before and after aging. It can be known from Figure 2-2 that the elastic recovery of the modified asphalt mixture with high viscosity and high elasticity 3min before and after aging is far above that of the conventional SBSmodified asphalt, indicating that the quick recovery capability of the modified asphalt mixture with high viscosity and high elasticity after deformation is strong and far above that of the conventional SBSmodified asphalt. Such quick recovery capability after deformation is very beneficial to preventing or delaying generation of the reflection cracks; the 1h elastic recovery performance difference between the two asphalts is not obvious, indicating that the standard test method has no longer been able to effectively distinguish the elastic recovery capabilities of the modified asphalt mixture with high viscosity and high elasticity and the conventional SBSmodified asphalt.

Anti-fatigue property of asphalt mixture

The test data shows that the fatigue life of the mixture at the ordinary and enhanced stress absorbing layer meets the technical requirements under the test temperature of 20˚C and the strain level of 2000 me ; the fatigue life of the mixture at the mixture at the ordinary stress absorbing layer is 250280 times and at the enhanced stress absorbing layer is 328510 times. The fatigue rupture resistance ability of the mixture with fiber is more excellent.。

Meanwhile, the accumulative dissipated energy of the mixture at the enhanced stress absorbing layer is 833.902 MJ/m^3 and at the ordinary layer is 710.028 MJ/m^3. The former is 1.17 times the latter. The greater the accumulative dissipated energy, the stronger the fatigue rupture resistance ability of the mixture, that is, more energy shall be dissipated for eventual failure under the same conditions.

Phase angle represents the energy loss of each cycle and characterizes flexibility of high-polymer molecular chain, the greater the phase angle, the greater energy loss in joist, and the stronger the elastic recovery capability, the better the anti-fatigue performance. The data shows that the phase angle of the mixture at the enhanced stress absorbing layer is 46.2 and at ordinary level is 45.8, indicating that the fiber addition is contributive to improving the anti-fatigue performance of the mixture.

Treatment measures in high-temperature and high-pressure area of bus lane

Characterized by heavy traffic, many heavy duty automobiles, large longitudinal gradient, many curves and slow vehicle speed in some areas, this section is prone to rutting diseases under high air temperature in summer, thus affecting the pavement driving safety and comfort. Therefore, we conduct systematic high-temperature stability research for the overhaul project for current rutting diseases to avoid and delay the rutting diseases in the bituminous pavement and improve the service quality and life of the pavement.

Table 3-1 Anti-rutting bituminous mixture performance indexes

Inspection item	Unit	KAC-20	ATB-25	Technical requirement
Dynamic stability of rutting test (60˚C)	times/mm	11847	4590	≥5000*
Retained Marshall stability	%	95.2	94.2	≥85
residual strength ratio	%	84.3	90.4	≥80
Low-temperature bending (-10˚C) failure strain	με	2589	—	≥2500
Water permeability coefficient	ml/min	37	99	≤120

Three structures are used to simulate the actual structure of the cement concrete pavement slab paved with asphalt surface course. The specific structural grouping is as shown in Table 3-2:

Table 3-2 Structural Grouping

Structure A	25mmstress absorbing layer+60mmmodified asphalt KAC-20+40mm composite modified SMA-13
Structure B	80mmmodified asphalt ATB-25+40mm composite modified SMA-13
Structure C	60mmmodified asphalt AC-20+40mm composite modified SMA-13

Hamburg rutting is the ability to simulate the pavement deformation characteristics under the role of overload vehicle and record the deformation development and accumulation through repeated role of the steel wheels on the test piece to characterize the anti-load role of the pavement materials. Severe water bath with the test temperature of 50˚C is used to investigate the anti-rutting ability of the pavement measures under high temperature and dynamic water pressure. After grinding for 20000 times, the corresponding rutting depth is obtained and the test data is shown in the following table:

Table 3-3 Hamburg rutting test results (50˚C water bath)

Structure type	Structure A	Structure B	Structure C
Rutting depth (0.01mm)	233	272	295

The table shows that the rutting depth of structure A is smallest, followed by structure B and then structure C. The changes in the rutting depth with the grinding times are shown in Figure 3-2:

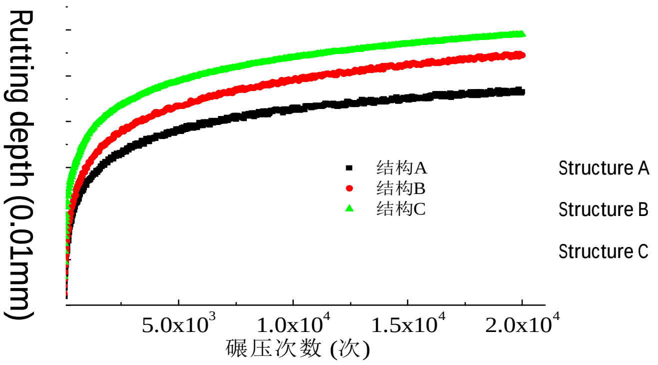

Figure 3-3 Hamburg rutting test results

Under general conditions, the rutting test curve covering the creep stage and peeling stage. The linear growth in the rutting depth at the creep stage is the plastic flow of the mixture after initial compaction and the peeling stage is the deformation acceleration stage triggered by mixture peeling. It can be seen from the figure that three structures enter the stable creep stage after initial compaction and deformation and do not enter the deformation acceleration stage, i.e. peeling stage yet after 20000 grinding times. In general, the rutting depth of three structures in the Hamburg rutting test under 50˚C water bath is within 3mm, indicating excellent anti-rutting ability of the structures.

Treatment measures of interlayer bonding

In the bituminous pavement overhaul project of West Chang'an Avenue, SBS modified emulsified asphalt as dedicated tack coat oil is sprayed with the amount of 0.2~0.3kg/m2 between the old cement concrete pavement and the stress absorbing layer and between the base course and the surface coat, as shown in Table 3-4.

Table 3-4 Technical Indexes of Modified Emulsified Asphalt

Test item		Unit	Technical specification	Test method
emulsification type		—	Rapid setting	T0658
Electric charge		—	(+) Cation	T0653
Surplus on sieve (1.18mm sieve)		%	≤0.1	T0652
Angler viscosity E25		—	1-15	T0622
Evaporated residue	Residue content	%	≥63	T0651
	Needle penetration (25˚C,100g,5s)	0.1mm	60-120	T0604
	Softening point (R&B)	˚C	≥60	T0606
	Ductility (5˚C)	cm	≥20	T0605
	Dynamic viscosity (60˚C)	Pa·s	≥1500	T0620
	Elastic recovery (25˚C, 1h)	%	≥60	T0662
	Solubility (trichloro ethylene)	%	≥97.5	T0607
Adhesiveness and wrapping area with mineral aggregate		—	≥2/3	T0654
Storage stability at ambient temperature	1d	%	≤1	T0655
	5d	%	≤5	

Thoroughly clean the base course before spraying, clean the pavement with much dust by efficient sweeping machines to ensure clean and dry base level and strengthen protection of the curb and structures. Timely spray the base level thoroughly cleaned and dried and don't spray when the air temperature is blow 10˚C or the pavement is wet. After demulsification, timely pave the asphalt layer to prevent the tact coat from being polluted. Ensure stable spraying speed and spraying amount during spraying and ensure uniform spraying to evenly distribute into a thin layer within the full width of the pavement without open or strip spraying or stacking. In case of insufficient or excessive spraying, the skilled technical worker has supplemented or scraped timely to avoid pollution of curb, traffic engineering and other finished products or semi-finished products; the spraying amount of PCR-SBS modified tack coat oil is controlled at 0.5±0.1kg/m^2.

Conclusion

In this paper, we analyze the disease characteristics and engineering characteristics of West Chang'an Avenue, find reflection crack treatment as the controlling factor and technical difficulty of the overhaul design, propose the stress absorbing layer technique to solve reflection cracks in the cement concrete base, the modified emulsified asphalt tack coat oil to solve the interlayer bonding, the rubber asphalt waterproof bonding layer technique to solve pavement waterproof problem and the anti-rutting bituminous mixture technique to solve high-temperature stability of the bituminous pavement in special sections.

The core of the stress absorbing layer is modified asphalt mixture with high viscosity and high elasticity. The high viscosity and high elasticity characteristics of the modified asphalt mixture with high viscosity and high elasticity for the modified bituminous mixture at the stress absorbing layer are researched; for current rutting diseases, the overhaul project has been subject to the pavement anti-rutting performance research based on high-temperature and high-pressure area; the dedicated modified emulsified asphalt modified asphalt mixture with high viscosity and high elasticity tack coat oil is used between the old cement concrete pavement and the stress absorbing layer and between the base course and the surface coat. These measures have effectively solved reflection cracks in the old cement concrete pavement paved with bituminous pavement. The use effect is good through the engineering application for nearly one year.

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