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Impact of viscosity modifier on asphalt properties used for bus rapid transit lane in Chengdu

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Abstract In order to find the effect of different viscosity modifier dosages on asphalt binder's performance in bus rapid transit lanes in the city of Chengdu, three different viscosity modifiers were analyzed: TAFPACK-super (TPS), high-viscosity additive (HVA) and road-science-technology (RST), and four different asphalt binders were investigated through laboratory experiments. The percentages of the viscosity modifiers used were: TPS (0%, 8%, 10%, 12%, 14% and 16%) and RST and HVA (8% and 12%) depending on the type of asphalt binder. Technical indicators of modifier asphalt were tested through conventional and unconventional binder tests. It has been found out that only a percentage greater than or equal to 14% TPS is reasonable to achieve the requirement set by 20,000 Pa s for the 60 °C dynamic viscosity on local #70 grade asphalt. The results indicate that conventional binders did not meet the requirements of the 60 °C dynamic viscosity when 12% of TPS or HVA modifiers are used. In addition, the (B-type) styrene–butadienne–styrene (SBS) modified asphalt binder has better viscosity balance than the (A-type) (SBS) modified when 8% of each of the three different kinds of viscosity modifiers is used. Therefore, the (B-type) modified SBS thus appears to be a suitable choice in asphalt mixtures for bus rapid transit lane with the 60 °C dynamic viscosity.

Keywords High-viscosity modifier · Physical properties · 60 °C dynamic viscosity · Bus rapid transit lane

1 Introduction

With the rapid socioeconomic development and expansion of the urban scale of Chengdu, China, over recent years, the traffic in terms of both volume and weight has significantly increased. To that end, the Chengdu municipal government had put forward the use of bus rapid transit (BRT) that possesses modern technology with intelligent traffic and operation management. In Chengdu, BRT tire contact pressure is 0.9 Mpa, whereas for the conventional bus it is 0.7 Mpa.

The Corps of Engineers in the USA conducted some research related to the tire contact pressure and found that when it changes from 0.6 to 0.83 MPa, the life of pavement will be reduced by 38% [1]. Due to these special characteristics of forces, BRT lane requires that asphalt mixture should have excellent, high- and low-temperature performance, moisture stability and fatigue performance. Normal modified asphalt can only meet the requirements of one to two aspects. The overall performance of asphalt pavement should have higher requirements. Previous studies show that the high performance can be reached through a certain process by adding a certain content and type of modifier which can significantly improve the performance of some

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road asphalt [2–5]. Therefore, modifiers in the asphalt mixture can improve the performance of asphalt pavement and extend the life of the road surface [6].

Many efforts have been made in China to improve asphalt performance, such as the use of modifiers in the asphalt binders. The majority of modifiers are blended into the asphalt binder, aiming to enhance the binder properties so as to improve the performance of asphalt concrete mixtures.

In recent years, the high-viscosity modified asphalt pavement has proved to have a strong ability to resist shear flow and deformation, strong bonding strength and low-temperature extension of the material. In 2003, Shanxi Province in the North China region collaborated with a Japanese company to construct an 18-km drainage asphalt pavement in Xi'an airport highway. It was China's first large-scale use of drainage asphalt roadbed, and good engineering applications have been found. TPS was imported from a Japanese company [7]. China has widely used it in new and old Shanxi Expressway, Jiangsu-Yantong Expressway and Zhejiang-Ligong Expressway. In Chongqing, 12% (rate of mass of the designed asphalt) of TPS content has been used when mixed with the conventional asphalt, whereas only 8% was used in the styrene–butadienne–styrene (SBS) modified asphalt [8–11]. Long-term pavement performance test results showed that high-viscosity modifier TPS has many merits in pavement performance, such as enhancing adhesion of asphalt and aggregate, improving mix resist stripping and high temperature of the asphalt flow resistance and contributing to the resistance to mix rutting. TPS contains anti-aging ingredients, which improves the pavement durability and extends the pavement life [12].

In 2005, Shanghai Pudong Road and Bridge Construction Co. Ltd and Shanghai Jiaotong University independently researched and developed the high-viscosity asphalt modifier RST. They have currently formed industrial production and successfully applied it to the Expo exhibition area, Pudong outer ring road and other projects. Its application on highway projects considerably reduced the cost of porous asphalt pavement [13]. A study [14] showed the preparation of high-viscosity asphalt for drainage asphalt pavement in China by laboratory experiment to investigate the effect of TPS contents and kinds of base asphalt on the properties of modified asphalt. It is concluded that when the TPS content is between 14% and 16%, it has a significant influence on the viscosity of modified asphalt at 60 °C; the viscosity increases rapidly and can reach the specifications [15] for high-viscosity modified asphalt. At the same time, the high-temperature stability and cracking resistances at low temperature together with elastic recovery are increased. It was also observed [16] that 15% modifier mass percentage is reasonable to increase high-temperature heat stability, aging and cracking resistance at low temperature, dynamic stability, hydraulic stability and the low-temperature anti-crack ability of the porous asphalt mixture. The performances of new additive TPS on the matrix asphalt and SBS modified asphalt mixture [17] using the conventional evaluation method test and SHRP test have been investigated in order to evaluate its effects on the thermal, high- and low-temperature performance of asphalt mixtures. Experimental results showed that the performance of TPS additive can significantly improve the asphalt and asphalt mixture properties; with the increase in volume, the asphalt performance gradually improves at the same time. The experimental results also showed that the optimal dosage of TPS between 12% and 15% is recommended. In September 2008, a double-layer SMA with RST HV-PMB (polymer modifier asphalt) on RenMin Rd. Overpass Bridge in the Suzhou, China, was constructed [18]. Properties of RST PMB were studied by adding various contents of RST onto the ESSO straight asphalt 60/80. The content of RST by the rate of mass of the designed asphalt was 8%, 10%, 12% and 14%, respectively. The results showed that RST greatly improves the low-temperature properties of the binder, which endows mixture with good fatigue and anti-cracking properties. The 60 °C viscosity dramatically increases with RST addition. The proper content of RST from 10% to 12% has been adopted taking into account a comprehensive set of factors, such as construction and cost [18]. Research Institute of Highway Ministry of Communications Engineering Center developed HVA viscosity modifier and compound modification technology for highway drainage asphalt pavement. Its application in Yulin road test section was successful in 2011 [19]. Since there are special forces and high contact pressure along the BRT lane which can reduce the pavement life, high-viscosity modified asphalt pavement being able to withstand these forces is required. The current research aims to investigate the best modifier asphalt that can be used for asphalt mixtures in BRT lane in Chengdu by adding different high-viscosity modifiers (TPS, HVA, and RST) on asphalts.

2 Materials

2.1 Asphalt binders (conventional and modified)

Conventional asphalt binders used in this study were: #70 grade conventional asphalt binder (Chinese No. 70 conventional asphalt) and high rich #70 grade asphalt binder. Modified asphalt binders were (B-type) SBS asphalt binder and (A-type) SBS asphalt binder. The property of each type of SBS asphalt binder is listed in Table 1.

Table 1 Properties of the various types of SBS asphalt binders

Test items	A-type SBS	B-type SBS
25 °C penetration (0.1 mm)	49.9	48.3
5 °C ductility (cm)	21	32
Softening point (°C)	87	84
60 °C dynamic viscosity (Pa · s)	16,343	16,819
Sticky toughness (N · m)	30.8	38.1
Toughness (N · m)	19.5	30
Elastic recovery (25 °C)	93	95.6

2.2 High-viscosity asphalt binder modifiers

Three types of high-viscosity modifiers were studied in this research:

- Japan high-viscosity modifier TPS. It is a kind of asphalt viscosity modifier, which is the main component of asphalt pavement in Japan. The basic physical properties of TPS modifier are illustrated in Table 2 [20].
- RST is the second type of viscosity modifier used in this study. It is a kind of thermal plastic polymer, which is added to the plant mixer asphalt. Its properties are listed in Table 3 [18]. RST at about 170 °C can modify the straight asphalt and completely melt and be delivered directly to the aggregates and asphalt in the mix, in a relatively short period of time. Moreover, it can be uniformly distributed in the asphalt and its modified effect is significant. RST modifier asphalt has excellent high-temperature resistance and moisture damage resistance, also greatly reduces the cost and simplifies the operation process. It is also suitable for drainage pavement (RST-P), steel deck (RST-B), asphalt concrete pavement stress-absorbing structure layer (RST-G) and other pavement structures.

Table 2 Physical properties of TAFPACK-Super (TPS) asphalt modifier

Item	Properties
Shape	Granular (2–3 mm)
Color	Yellow
Proportion (specific gravity or specific weight)	0.98
Weight per volume	0.6 ton/m^3

Table 4 Properties of high-viscosity additive (HVA) asphalt modifier

Item	Technical requirements
Appearance	Granular, uniform, full
Unit particle quality (g)	$\ngtr$0.03
Density (g/cm^3)	0.90–1.00
Melt flow index (g/10 min)	$\nless$2.0

- HVA modifier is a comprehensive performance high-viscosity modifier and has laid a solid foundation for the high-viscosity asphalt brand localization. This product performance reaches the international advanced level of similar products and is significantly reduced by about 30% the cost of similar imported products. The basic physical properties of HVA modifier are illustrated in Table 4.

2.3 High-viscosity modified asphalt binder preparation method

Laboratory preparation of high-viscosity modified asphalt technology is as follows:

1. The matrix asphalt is heated to about 180 °C for ordinary asphalt or 190 °C for modified asphalt, then the desired content of the modifier is added, and the asphalt binder is stirred with a glass rod, as shown in Fig. 1.
2. The sample is dispersed in the high-speed cutting machine for 30 min at 5,000 rpm/min speed; during the manufacturing process, temperature control was between 180 and 190 °C with an increased range of 5–10 °C.
3. Finally, the shearing machine is closed and the modified asphalt is placed into an 180 °C oven about 30 min.

3 Test methods

The penetration grading system is used for this work. According to the technical requirement of high-viscosity modified asphalt of BRT asphalt pavement, the characteristics of high-viscosity asphalt's material component in the BRT asphalt pavement are analyzed. Using dynamic

Table 3 Properties of road-science-technology (RST) asphalt modifier

Item	Properties	Signification
Appearance	Well distributed size	Separating properties within mixture
Density (g/cm^3)	0.95–1.02	
Smell	No irritant smell	Environmental and safety properties
Melt index (g/10 min)	>10	Separation properties within mixture

Fig. 1 Preparation of high-viscosity modified asphalt

viscosity at 60 °C, toughness and sticky toughness as the most important evaluation indicators, combined with conventional asphalt indicators such as ductility, penetration, softening point, the indicators of high-viscosity modified asphalt influenced by the basic asphalt (local #70 grade asphalt and high rich #70 grade asphalt) and A- and B-type SBS are analyzed, so as to determine the optimum dosage of the modifier. The high-viscosity asphalt with high quality which is suitable to the BRT asphalt pavement is prepared in a particular process.

3.1 Sticky toughness and toughness test

The sticky toughness and toughness were done by allowing the sample containers to cool at room temperature for 60–90 min and then placing the sample containers in a water bath maintained at 25 °C for 60–90 min. The sticky toughness and toughness were recorded to the nearest 0.01 N · m (inch-pounds to the nearest whole number).

3.2 Elastic recovery test

The elastic recovery is measured by the percentage to which the asphalt cement residue will recover its original length after it has been elongated to a specific distance at a specified rate of speed and then cut in half. The distance to which the specimen contracts during a specified time was measured and the elastic recovery was calculated. The test was performed at the temperature of 25 °C with a speed of 50 mm/min.

Fig. 2 Dynamic viscosity test device

3.3 Dynamic viscosity test

The temperature of 60 °C is usually used as high-temperature performance index for asphalt pavement in the summer. For the high-viscosity modified asphalt, it is also one of the most important evaluation indexes, which can be used to characterize its high-temperature resistance to permanent deformation. During the test, the time required for the three asphalts to pass through the specified volume of the capillary viscometer under standard vacuum decompression conditions at 60 °C was calculated and the calculation formula for the 60° C viscosity was obtained by Eq. (1):

$$\eta = K \times T, \tag{1}$$

where η is the dynamic viscosity of a bituminous sample at 60 °C in Pa · s, K is viscometer constant in a unit of (Pa · s)/s and T is efflux time in s.

The dynamic viscosity test was obtained with the device as shown in Fig. 2.

The requirement of the penetration grading system is given in Table 5, and Table 6 shows the variables and levels of test design.

4 Results and analysis

4.1 Effect of different percentages of TPS on local #70 grade asphalt binder

Asphalt specimens of varying TPS contents: 0% TPS, 8% TPS, 10% TPS, 12% TPS, 14% TPS and 16% TPS with a

Table 5 Standard requirement of the penetration grading system of modified asphalt

Items	Unit	Test conditions	Target	Methods
Penetration	0.1 mm	25 °C, 100 g, 5 s	>40	T0604-2011
Softening point	°C		>80	T0606-2011
Ductility	cm	5 °C, 5 cm/min	≥30	T0605-2011
Film heat quality change rate	%		<0.6	T0609-2011
Sticky toughness	N · m	25 °C	>20	T0624-2011
Toughness	N · m	60 °C	>15	T0624-2011
Dynamic viscosity	Pa · s	60 °C	≥20,000	T0620-2000
Elastic recovery	(%)	25 °C		T0662-2000

Table 6 Variables and levels of test design

Variables	Level of each variable					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Asphalt type (A)	Local #70 grade asphalt	High rich #70 grade asphalt	A-type SBS	B-type SBS		
TPS percentage (B)	0	8	10	12	14	16
HVA percentage (C)	8	12	–	–	–	–
RST percentage (D)	8	12	–	–	–	

Table 7 Properties of local #70 grade asphalt with different contents of TPS

Test item	TPS content (%)					
	0	8	10	12	14	16
25 °C penetration (0.1 mm)	62	53.3	62.0	44.7	47.1	49.0
5 °C ductility (cm)	4	11	15	21	26	29
Softening point (°C)	48	54.5	71	78	87	91
60 °C dynamic viscosity (Pa · s)	248	721	1,695	10,592	21,599	30,914
Sticky toughness (N · m)	–	–	–	22.7	26.5	30.4
Toughness (N · m)	–	–	–	13.8	16.3	17.0
Elastic recovery 25 °C (%)	–	–	–	98	98.7	99.6
RTFOT residue						
Loss of mass (%)	–	–	–	–	0.24	0.25
Penetration 25 °C (0.1 mm)	–	–	–	–	37.0	41.4
Ductility (5 °C)	–	–	–	–	14.2	26.7
Softening point (°C)	–	–	–	–	72.1	89

"–" indicates tests were not conducted

base asphalt of local #70 grade were studied. The results of the physical property tests of the six specimens are presented in Table 7. As given in Table 7, there is a significant change from 10% to 12% in the penetration values, while there is a considerable increase in the softening point temperatures with the percentage of TPS content, respectively. The increase in softening point is favorable since asphalt with higher softening point may be less susceptible to permanent deformation (rutting). Compared with the virgin asphalt (local #70 grade asphalt), the increase in ductility of TPS modifier asphalt at 5 °C could be an indicator of the effect of TPS modifier on improving considerably the low-temperature properties of binders. As with the softening point and ductility results, the viscosities give an indication of the stiffening influence of TPS modification which can result in significant change in the resistance to deformation of asphalt mixture and modified asphalt binder.

Test results of the effect of different contents of TPS on local #70 grade asphalt are plotted in Fig. 3. Figure 3(a) clearly shows that with the increase in TPS modifier dosage, there is a significant change in asphalt 25 °C penetration from 10% to 12% when the portion of TPS is 12%. The 25 °C penetration has a minimum value of 44.7, which indicates 11.75% increase in the viscosity asphalts penetration standard value. From Fig. 3(b), it is deduced that with the increase in TPS content there is a corresponding increase in the 5 °C ductility of the high-viscosity modified asphalt. When the TPS content increased from 8% to 16%, 5 °C ductility increased from 11 to 29 cm, thus an increase of 1.64 times. In this case, the binder's low plastic deformation resistance has been greatly improved. Figure 3(e) illustrates that the softening point of modified asphalt is improved with the increase in

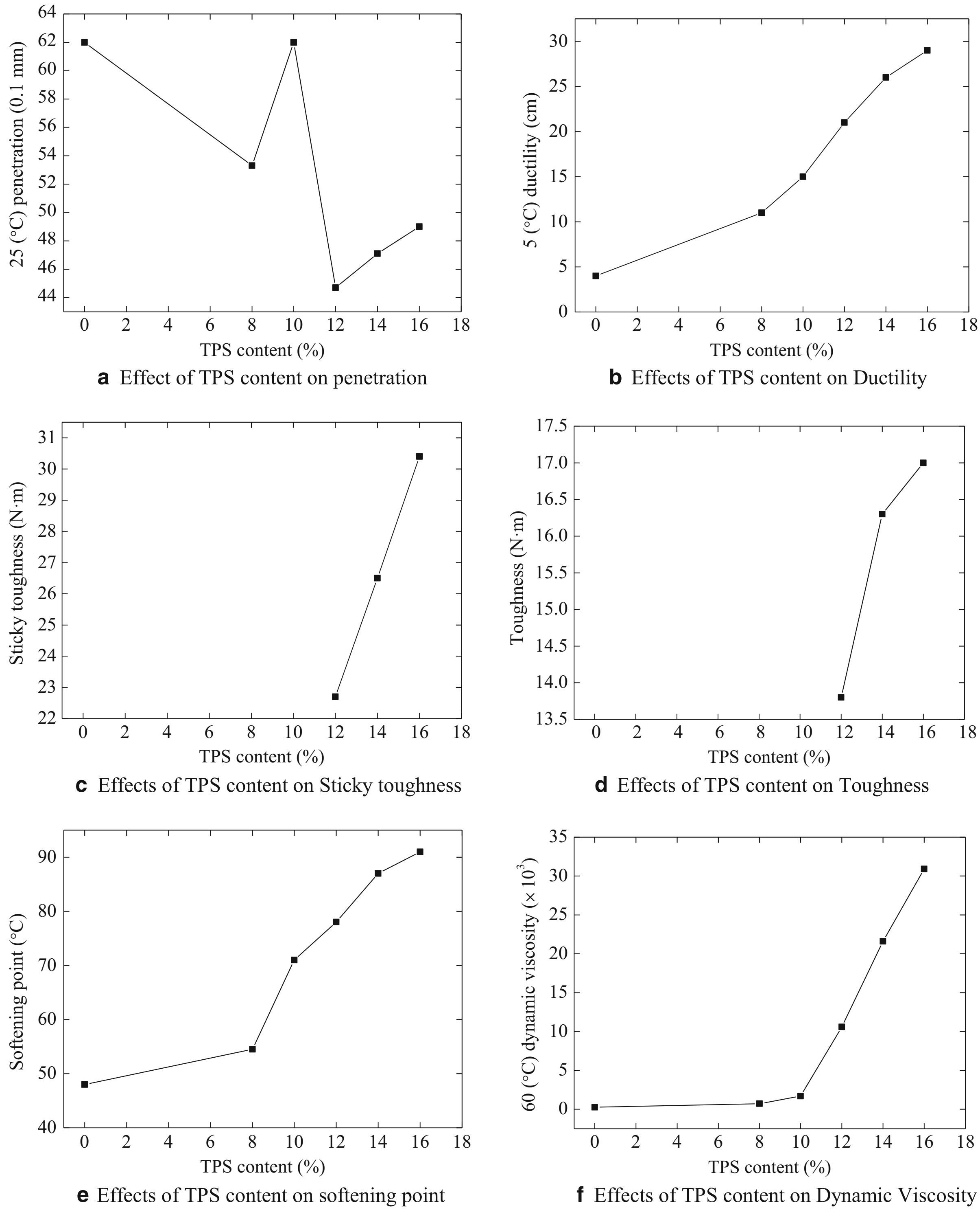

Fig. 3 Effects of different contents of TPS on local #70 grade asphalt binder. Individual plot of TPS content versus **a** penetration, **b** ductility, **c** sticky toughness, **d** toughness, **e** softening point, **f** dynamic viscosity

TPS content, and the high-temperature stability performance has been improved to some extent. At this time, the high-temperature performance of modified asphalt binder has a certain increase with the TPS content of less than 8%, but the increase in the matrix asphalt is small. The softening point of modified asphalt showed a trend of rapid increase when the content was more than 8%, and the softening point increased by 67% when the content was 16%. Furthermore, the high-temperature performance improved significantly. It is observed in Fig. 3(f) that when TPS content is less than 10%, the 60 °C dynamic viscosity of the modified asphalt increases slowly and the obtained value is far from the minimum requirement of 20,000 Pa · s. The 60 °C dynamic viscosity of the modified asphalt binder increased rapidly when the amount of TPS was over 10%, and at 14% the 60 °C dynamic viscosity was about 21,599 Pa · s, which meets the standard requirement of high-viscosity asphalt. Studies have shown that the 60 °C dynamic viscosity of asphalt and the dynamic stability of asphalt mixture have good correlation, so 60 °C viscosity asphalt is usually taken as high-performance control standards. According to [12], adding 12% of TPS to ordinary asphalt can meet the requirements, whereas, with local conventional #70 grade asphalt grade, it is shown that only a percentage greater than or equal to 14% TPS can achieve the 60 °C dynamic viscosity of 20,000 Pa · s, which is the standard requirement. It may be due to the fact that local #70 grade asphalt has a poor compatibility with TPS. Figure 3(c) and (d) shows that with an increase in TPS content of the local #70 grade asphalt, the toughness and sticky toughness improved gradually.

4.2 Effect of different percentages of viscosity modifier (HVA and TPS) on two conventional asphalt binders

In order to measure the performance of two types of conventional asphalt binders, two types of modifiers (HVA and TPS) at 12% each were used. The test results are summarized in Table 8.

Table 8 shows that under the same proportion, the effect of HVA modifier on local #70 grade asphalt viscosity is better compared with TPS effect on high rich #70 grade asphalt. However, both conventional asphalt binders have not met 20,000 Pa · s which is actually the requirement of 60 °C dynamic viscosity specification. At 12% of TPS modifier and using high enriched #70 asphalt viscosities, test result still does not reach 20,000 Pa · s and there have been varying degrees of decline in other physical properties compared with the same portion of HVA modifier on local #70 grade asphalt. It can be deduced that the two kinds of conventional #70 asphalt binders failed to meet the expected 60 °C dynamic viscosity requirement of 20,000 Pa.s.

4.3 Effect of different percentages of modifier viscosity (HVA, TPS and RST) modifiers on A-type and B-type modified SBS asphalt binders

Two types of modified asphalt binder SBS (PG76-22) were used: A-type SBS modified asphalt binder and B-type SBS modified asphalt binder. The goal was to see whether or not the effect of the three kinds of modifiers is significant and also to check the best high-viscosity modified asphalt

Table 8 Performance of different asphalt binders

Item	High rich #70 grade asphalt	High rich #70 grade asphalt +12% TPS	High rich #70 grade asphalt +12% HVA	Local #70 grade asphalt + 12% TPS	Local #70 grade asphalt + 12% HVA
25 °C penetration (0.1 mm)	65	54.4	43	44.7	38.1
5 °C ductility (cm)	3	10	14	21	21
Softening point (°C)	47	75	78	78	93
60 °C dynamic viscosity (Pa · s)	207	12,367	13,609	10,592	14,566
Sticky toughness (N · m)	–	17.4	25.6	22.7	39.7
Toughness (N · m)	–	0.2	16	13.8	26.1
Elastic recovery (25 °C)	–	95.1	94.8	98	99.5%

"–" indicates tests were not conducted

binder. Properties of A- and B-type SBS modified asphalt binders are, respectively, listed in Tables 9 and 10.

Table 9 shows that the addition of 8% of the three different kinds of viscosity modifiers into A-type SBS modified asphalt has a certain degree of improvement in its performance. The 60 °C dynamic viscosity reaches a value of 68,215 Pa · s for 8% TPS, while for the same percentage of HVA and RST modifiers, the 60 °C dynamic viscosity is less than 50,000 Pa · s. When 12% of RST modifier is added to A-type SBS modified asphalt binder, the value of dynamic viscosity at 60 °C is 142,854 Pa · s, which is almost three times the 60 °C dynamic viscosity at 8%.

Table 10 shows that when 8% of the three different kinds of viscosity modifiers are added to the B-type SBS modified asphalt; the physical property (25 °C penetration, 5 °C ductility and softening point) improvements are insignificant and there is no much difference with the A-type SBS modified asphalt. Their effect on B-type SBS modified asphalt sticky toughness and toughness is also insignificant. For the same percentage of modifiers, the 60 °C dynamic viscosity of SBS modified asphalt improved significantly and the difference is obvious. When the percentage of TPS content is 8%, the 60 °C dynamic viscosity of B-type SBS modified asphalt is 169,298 Pa · s, whereas for 8% of RST content the result is 291,057 Pa · s

Table 9 A-type SBS asphalt binder high-viscosity performance

Tests items	8% TPS	8% HVA	8% RST	12% RST
25 °C penetration (0.1 mm)	44	39.9	40.4	39.8
5 °C ductility (cm)	27	30	28	34
Softening point (°C)	93.5	95.5	96	95
60 °C dynamic viscosity (Pa · s)	68,215	45,683	48,599	142,854
Sticky toughness (N · m)	35.8	35.5	36.5	33.2
Toughness (N · m)	23.8	23.4	23.3	16.2
Elastic recovery (25 °C)	98.5	98.5	98	99.8

Table 10 B-type SBS asphalt binder high-viscosity performance

Tests items	8% TPS	8% HVA	8% RST	12% RST
25 °C penetration (0.1 mm)	44.9	42.9	41.3	46.7
5 °C ductility (cm)	42	37	37	47
Softening point (°C)	91.5	99	95.5	99
60 °C dynamic viscosity (Pa · s)	169,298	180,131	291,057	>360,000
Sticky toughness (N · m)	32.8	35.5	38	28.1
Toughness (N · m)	20.9	19.5	25.9	14.6
Elastic recovery (25 °C)	100	100	100	100

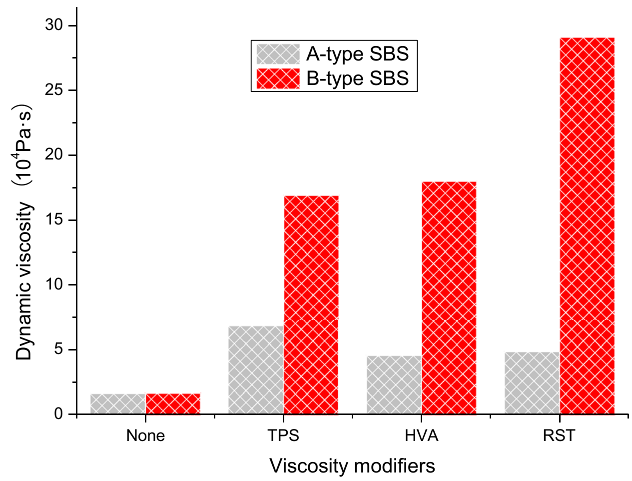

Fig. 4 Effects of different viscosity modifiers on SBS asphalt binders

almost twofold increase. In order to compare the two kinds of modified asphalt binders SBS (A and B types), Fig. 4 shows the effect of 8% of each modifier on 60 °C dynamic viscosity enhancement (none means there is no modifier used).

B-type modified SBS and A-type modified SBS asphalt binders have basically the same 60 °C dynamic viscosity test result when no viscosity modifier is added. Figure 4 shows that for both A-type and B-type modified asphalt binders, the effect on 60 °C dynamic viscosity of the modified asphalt is different for various kinds of viscosity modifiers. Using the same percentage of modifier, the 60 °C dynamic viscosity of B-type SBS modified asphalt binder is higher than that of the A-type SBS modified asphalt binder by 1.48, 1.64 and 3.26 times for TPS, HVA and RST modifiers, respectively. It can be concluded from above results analysis that B-type modified asphalt binder has better viscosity balance with the viscosity modifiers regarding 60 °C high dynamic viscosity.

5 Conclusion

The aim of this study was to compare the conventional and modified asphalt binders with different types of viscosity modifiers. The main conclusions drawn from the current research work are presented as follows:

- The results of physical properties test of local #70 asphalt binder with different contents of TPS showed that TPS modifier can significantly improve low-temperature properties of binders (ductility at 5 °C) and resistance to permanent deformation of asphalt mixes (softening point). The rate of increase in asphalt ductility at 5 °C and softening point gives an indication of the stiffening influence of TPS modification. Also, test results show that only a percentage greater or equal to 14% TPS can achieve the 60 °C dynamic viscosity of 20,000 Pa · s, which is the standard requirement. Furthermore, local #70 grade asphalt has a poor compatibility with TPS modifier.

- Both conventional asphalt binders have not met the requirements of the 60 °C dynamic viscosity which is 20,000 Pa · s, when 12% of TPS or HVA modifiers are used.
- The addition of 8% of the three different kinds of viscosity modifiers into A-type SBS modified asphalt resulted in a certain degree of improvement in its performance. The 60 °C dynamic viscosity is improved at the same percentage of different modifiers and meets the standard requirement of 20,000 Pa · s.
- When 8% of the three different kinds of viscosity modifiers are added into B-type SBS modified asphalt, the physical properties (25 °C penetration, 5 °C ductility and softening point) improvement is not significant. The same effect has been witnessed with its sticky toughness and toughness properties. Regarding the 60 °C dynamic viscosity, the B-type SBS modified asphalt binder has better viscosity balance than the A-type SBS modified one, and thus, it is a better option to use in the bus rapid transit asphalt mixture.

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