Study on High Viscoelastic Modified Modified Asphalt based on Alpine Region

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Abstract: In this paper, SBS and two kinds of high performance viscosity modifier SINTOPS and HVM-700 are used to modify the matrix asphalt, so as to prepare high viscosity modified asphalt which can be used to improve the pavement performance of asphalt pavement. According to the elastic recovery of each group of modified asphalt and 60 ℃ dynamic viscosity, as a viscoelastic properties of the contrast index. The results show that the modified asphalt with 6% SBS and 3% SINTOPS and 3% HVM-700 has better modification effect and road performance.

Keywords: Alpine Region;Viscoelastic property;Composite modified asphalt.

1. Introduction

With the rapid development of China's economy and the continuous expansion of the scale of expressway construction, the road quality standards are further improved, and the demand for modified asphalt, especially compound modified asphalt, is increasing. A large number of studies have shown that composite modified asphalt can prevent the early damage of pavement and improve the durability of pavement. Therefore, the composite modification technology of asphalt has been widely used in asphalt pavement design[1]. At present, under the general climate conditions, the asphalt composite modification technology has been improved, but in response to the extreme climate conditions in the alpine region, there are still some problems, which need to be further improved[2].

China's vast territory, from north to south across the Arctic, temperate and tropical zones, so that the natural factors in different regions of the country is very complex. Located in the southwest of China on the Tibetan Plateau and its surrounding areas mainly in alpine region with a total area of about 2400000 square kilometers, accounting for China's total land area of 1/6.The alpine region has the characteristics of plateau climate, which is characterized by low temperature, large diurnal temperature difference, low annual temperature difference, thin air, long sunshine, strong radiation and clear dry and wet seasons[3].Under the condition of the climate, not only high temperature stability of asphalt layer and freezing-thawing resisting ability put forward higher request, also need to consider the influence of the strong ultraviolet radiation aging of asphalt layer increased. Therefore, the performance requirements of composite modified asphalt should have high elastic recovery ability to prevent the degradation of asphalt, ruts and other diseases. On the other hand requirements of asphalt to aggregate have stronger bonding ability, to resist low temperature shrinkage crack, and reduce the porosity inside the asphalt road surface, in order to improve the asphalt water disasters and freezing-thawing resisting capacity [4].

Based on the background of Sichuan and Tibet, this paper has developed a composite modified asphalt which can be applied to the alpine high altitude climate condition, and mainly uses elastic recovery and 60 ℃ dynamic viscosity to evaluate the viscoelastic properties of modified asphalt.

2. Preparation and Performance Evaluation of Composite Modified Asphalt

In this paper, the study of composite modification of asphalt from the Maoming A grade 70 # road asphalt, Using the YH-791 type of SBS as the elastic group of modified asphalt, the suitable combination of the high viscosity asphalt modifier SINTOPS and hot plastic hvm-700 is used as the modification agent for viscosifying group. In view of the domestic and international research on the modification technology of SBS rubber composite, the content of SBS is 6% in the process of compound modification in this paper[5]. To ensure that the viscosity of compound during the preparation of modified asphalt mixing group modifier does not occur serious segregation, viscosity modifier set of content should be controlled in the range of 5-10% [6].

2.1. The Raw Materials

2.1.1. The Matrix Asphalt

The matrix asphalt is used in Maoming A grade 70 # road oil asphalt, performance indicator is shown in table 1.

Table 1. Maoming A level 70 # Road oil Asphalt Performance Indicators

Design specifications	Test results
Penetration(25 ℃, 100 g, 5 s)/(0.1 mm)	66.3
Softening Point(R&B)/ ℃	57.6
Extension(15 ℃, 5 cm/min)/cm	＞100
Density/(g/cm-3)	1.042
Quality loss/%	－0.10
RTFOT Residual ductility (15 ℃,5cm/min)/cm	53.6
Penetration than /%	69.3

2.1.2. SBS

SBS is the YH791 SBS produced by hunan yueyang baling petrochemical co., LTD. The main technical performance indicators are shown in Table 2.

Table 2. YH791 SBS Main Performance Indicators

Technical indicators	Test results
Structure type	Linear
Block than S/B	30/70
Volatile matter/%	0.5
Ash content/%	0.5
Elongation at break/%	750
Break permanent deformation /%	30

2.2. Preparation of Composite Modified Asphalt

The preparation of composite modified asphalt is as follows: first, the substrate asphalt heated to 160-170 ℃, with high-speed shearing machine under the speed of 3000-4000 r/min gradually add the SBS modifier, shear after 15 to 20 min, continue to add viscosity modifier and 3% of furfural extract oil as compatibilizers, keep the shear speed shearing 5 min, the viscous components can be distributed evenly in the asphalt.After the viscosifier is distributed evenly in bitumen, the speed of the shearing machine will be increased to 5,000 to 6000r/min continuously shearing 30 to 40min. Add 1% of transmitte PTS dicumyl peroxide as maintaining chemical crosslinking structure of the modified asphalt, and reduce the shear speed to 3000-4000 r/min under continuous shearing 30 min. After the completion of the above process, the prepared asphalt was incubated in a 135 ° C oven for 1 hour to test its performance [7].

2.3. Performance Test of Compound Modified Asphalt

For the preparation of high viscosity and high elastic composite modified asphalt, first by 6%SBS respectively with the viscosity modifier of asphalt is modified, and the composite modified asphalt elastic recovery and 60 degrees of dynamic viscosity test, to test the viscoelastic properties. The test data are shown in Figure 1 and Figure 2:

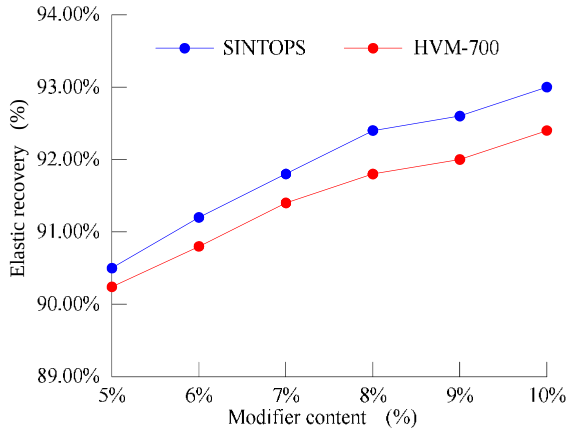

Figure 1. Elastic Recovery Test of Different Composite Modified Asphalt

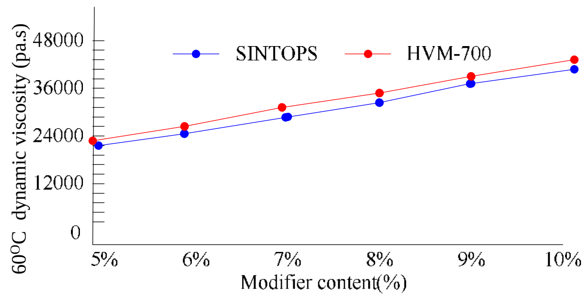

Figure 2. Dynamic Viscosity of Different Composite Modified Asphalt at 60° C

According to the test data and reference parameters of high viscoelastic composite modified asphalt requirements (i.e. elastic recovery of modified asphalt is greater than or equal to 90% DEG C, 60 viscosity more than 20000pa.s), can be found when the modifier content reached more than 5%, blending SINTOPS and HVM-7OO composite modified asphalt in the two aspects of elastic recovery and 60 ℃ dynamic viscosity properties achieved high viscoelastic modified asphalt standard.At the same time, the experimental data show that the elastic recovery ability of SINTOPS composite modified asphalt is obviously better than that of HVM-7OO compound modified asphalt, while the dynamic viscosity at 60 ℃ is HVM-7OO compound modified asphalt slightly better than SINTOPS Modified asphalt.
Although the basic parameter requirements tackifying modifier in the above content of 5% can meet the high viscoelastic asphalt, but the requirement of the standard high viscoelastic parameters of modified asphalt, did not

take into account the weather cold and high altitude effect. In addition, studies have shown that a class of modified rubber incorporation may produce a threshold effect of modification, according to test parameters before, combined with the performance advantages of SINTOPS and HVM-7OO both different, explore the incorporation of two kinds of rubber powder modified asphalt was again, and the detection performance. The test results of composite modified asphalt are shown in Figure 3 and Figure 4 below:

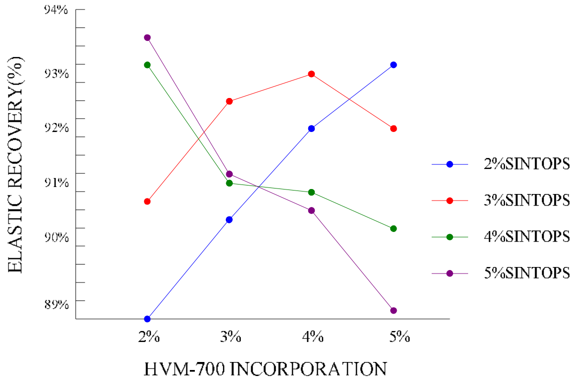

Figure 3 . Elastic Recovery Test of SINTOPS and HVM-700 Composite Modified Asphalt

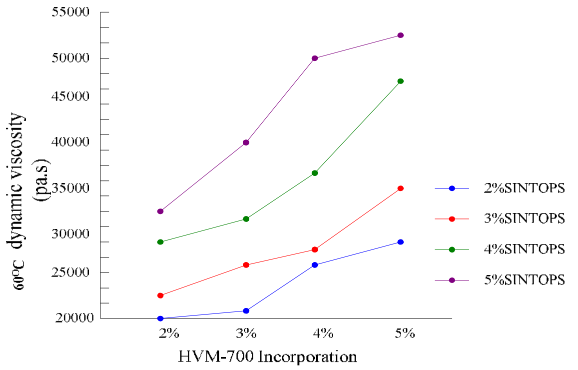

Figure 4 . Dynamic Viscosity of Modified Asphalt With SINTOPS and HVM-700

It can be found that when the content of composite modified asphalt SINTOPS is between 2% and 4%, the elastic recovery ability increases with the increase of HVM-7OO rubber content. When HVM-7OO content reached 4%, promotion effect is not obvious. When the content of SINTOPS is more than 4%, the elastic recovery ability decreases with the increase of HVM-7OO rubber content, which is not conducive to the improvement of the modification effect. In general, when the modified rubber content exceeds 7%, the modification effect of the elastic recovery ability is no longer significant, and even the elastic recovery ability is reduced. At 60 ℃ dynamic viscosity, the viscosity of the composite modified asphalt increases with the increase of SINTOPS and HVM-7OO. In addition, compared with Figure 1.1, 1.2, 1.3, 1.4, it can be seen: SINTOP and HVM-700 mixed with the modified modified asphalt in the same total amount of viscosity-modifying agent, whether it is elastic recovery capacity or 60 ℃ dynamic viscosity performance is better than the original mixed with modified asphalt.

In combination with the above analysis, for asphalt road surface design of alpine regions, the high viscoelastic composite modified asphalt can be used as the elastic group with 6% SBS, 3% SINTOPS and 3% HVM-700 rubber powder as the thickening group to obtain more good asphalt modification effect.

3. Modification Mechanism Analysis

The extent of SBS's modification of asphalt and its dispersion in asphalt are varied by the structure of SBS, the content of the SBS in asphalt and the composition of the substrate asphalt. Under the mechanical high shear force, the large molecular chain of the SBS polymer was cut off and produced the very active molecule free radicals. When the content of SBS is less than 5%, the particles of SBS asphalt in volume fraction of the small, although the SBS can absorb the oil content in asphalt and swelling, but less massive opportunity to contact with each other between particles, lively little radicals, only a small amount of combination between SBS particle of generating a short chain segment, with tiny particles dispersed in the asphalt. At this point, the SBS is the dispersed phase, and the pitch is continuous. When the SBS content in 5% ~ 5%, accounted for more of the particles of the SBS asphalt volume fraction increased gradually, the SBS radicals by polystyrene micro zone between physical relaxation "formed by the crosslinking network structure exists in asphalt matrix [8]. Due to the continuous network structure formed by SBS and asphalt, they run through each other. When the flow is dynamic, it is in a metastable state. With the decrease of the temperature, the asphalt and SBS become larger. The interpenetrating network structure is preserved, and the mobility of SBS molecules is increased, so the asphalt exhibits good elasticity and plasticity [9].

When the viscosity-increasing modifier is added to the matrix asphalt, the light component in the asphalt is absorbed and swollen in the environment of 150 ℃ or higher, and the partial degradation volume of the particles becomes larger after swelling. At the same time, a layer of gel film is formed between the modifier particles, and the whole modified asphalt becomes a semi-solid continuous phase system, so that the viscosity of the matrix asphalt increases. And when the matrix asphalt from the continuous phase into blending modifier particles and semi continuous phase, the powder particles can fill the gap between the matrix asphalt and plays a backbone role, make the powder particles in the matrix asphalt system plays an enhanced role. Under external force, due to the density and the modulus of rubber powder and asphalt is different , deformation of asphalt is greater than the powder, can produce stress concentration in the interface of rubber powder and asphalt, so that the low temperature properties of asphalt were improved, to improve the low temperature crack resistance of rubber powder modified asphalt [10].

The modification mechanism is known: because SBS and viscosifier compounds are similar to the light component solubility parameters of the matrix asphalt, under the reasonable blending ratio, which can play at the same time two kinds of physical and chemical properties of modified agents, and gradually formed in the asphalt loose network structure, eventually making modified asphalt to present good elasticity and plasticity.

4. Road Performance test of Compound Modified Asphalt Mixture

In order to be able to apply the composite modified asphalt to practical engineering, it is also necessary to verify the actual road performance of high viscoelastic composite modified asphalt. In this paper, the water stability, high temperature stability and low temperature crack resistance of the composite modified asphalt were tested. In this experiment, the road performance test was carried out with 5.6% best pitch ratio to prepare the target composite modified asphalt SMA-16 mixture, and the optimum asphalt SMA-16 mixture was used as reference.

4.1. Experimental Study on Water Stability

Water stability is one of the key road performance of asphalt mixture application, especially in the alpine region. Under the action of water and freeze-thaw cycle, the moisture gradually penetrates into the interface between asphalt and aggregate due to the dynamic load of automobile wheels , So that asphalt adhesion decreased, and gradually lose the bond force, asphalt film from the stone surface off, resulting in asphalt mixture dross, loose, the formation of pit [11]. This test according to the highway engineering and asphalt mixture test procedures (JTGE-20-2011), by immersing Marshall test and freeze-thaw splitting test to evaluate the water stability of asphalt mixture. Its results are shown in Table 3:

Table 3. Test Results of Mixed Water Stability Test

The mixture type	30min Stability (kN)	48h Stability(kN)	The residual stability (%)	The splitting strength before freezing (MPa)	The splitting strength after freezing (MPa)	Freeze - thaw splitting strength ratio(%)
Composite mod-ified asphalt mixture	6.86	5.92	86.3	1.11	1.01	91.6
Matrix asphalt mixture	6.75	5.15	76.3	1.04	0.88	84.6

From the above experimental results, the use of the composite compound modified asphalt mixture residual stability and freeze-thaw splitting strength ratio to meet the requirements of more than 80% of the standard value, and the use of matrix asphalt mixture does not meet the requirements. It is shown that the modified modified asphalt has a large viscosity, enhanced the asphalt on the aggregate bonding and bonding capacity, thus improving the water stability of asphalt mixture.

4.2. High Temperature Stability Test

Asphalt mixture of high temperature stability test is using rutting test to evaluate at different temperatures, test according to 《highway engineering asphalt and asphalt mixture test procedures》(JTGE－20—2011).

Table 4. High Temperature Rutting Test Results

The mixture type	Dynamic stability of temperature under test temperature (time /mm)		
	50℃	60℃	70℃
70# Matrix asphalt mixture	1651	958	—
Composite modified asphalt mixture	6653	4531	3374

According to the above experimental results, the composite modified asphalt mixture in the 50 ℃ environment dynamic stability value of more than 6000 times / mm specification requirements, and other temperature dynamic stability also meet more than 3000 times / mm standard requirements, The dynamic stability of the asphalt mixture is not satisfactory. This shows that the modified asphalt has a higher resilience in the resilience, the asphalt mixture also has a stronger high temperature anti-rutting ability.

4.3. Low Temperature Crack Resistance Test

The cracking of asphalt pavement is the main disease of asphalt pavement damage in cold region. The appearance of cracks will cause the water to enter the pavement structure, which leads to the reduction of the bearing capacity and service life of pavement structure [12]. In the experiment, the low temperature bending test method was used to evaluate the low temperature deformation of asphalt mixture, According to the relevant regulations of highway engineering asphalt and asphalt mixture test procedure (JTGe-20-2011). The wheeled specimen was cut into traversings of 30 mm × 35 mm × 250 mm with a test temperature of -10 ℃ and a loading rate of 50 mm / min. The test results are shown in Table 5.

Table 5. Low Temperature Beam Bending Test

The mixture type	Low temperature bending test destroys strain (με)		
70# Matrix asphalt mixture	1651	1674	1648
Composite modified asphalt mixture	4152	4198	4147

By a trabecular bending experimental results, the matrix asphalt mixture is far can not meet the requirement of the specification（>3000με）, and of the cold bending fracture strain of the composite modified asphalt mixture can meet the requirement of the standard value. At the same time, the compound modified asphalt compared with the matrix asphalt performance has improved considerably and it shows that compound modified asphalt with its high viscoelastic properties in improving the asphalt mixture on the low temperature crack resistance has greater advantages than the matrix asphalt, if applied in cold area highway asphalt pavement engineering can effectively improve the asphalt surface crack resistance at low temperature.

5. Conclusion

Based on the design of asphalt pavement in Sichuan and Tibet, this paper chooses SBS as the elastic group, SINTOPS and HVM-700 rubber powder for thickening group, The matrix asphalt is modified by high viscosity elastic composite, and the properties of asphalt and asphalt mixture are tested .

(1) By analyzing the different ratio of composite modified asphalt elastic resilience and 60 ℃ kinetic viscosity index ,It is recommended that the ratio of high viscoelastic composite modified asphalt in cold region is 6% SBS of elastic group,and 3 percent for viscosity-powder SINTOPS and HVM -700.
(2) High viscoelastic composite modified asphalt mixture has good road performance, compared with the matrix asphalt mixture water stability, high temperature stability and low temperature crack resistance are obviously improved.
(3) The application of this composite modified asphalt to the high freezing area will have good applicability, which will help improve the performance and durability of asphalt pavement.

References

[1] Liu Zhaohui, Liu Li, Shi Jin, etc. SBS / rubber powder composite modified asphalt preparation process and road performance [J]. China Science and Technology Papers, 2012 (11): 853-856.
[2] Liu Hua, Shuai Shaojun. Alpine area mountain expressway pavement design and disease prevention and control [J]. Journal of Highway and Transportation Research and Development, 2011 (9): 7-10 + 21.
[3] Bazan Dayton, Huang Xiaoming, Zhang Daode, et al. Analysis of common diseases and causes of asphalt pavement in southeastern Tibet [J]. Journal of Highway and Transportation Research and Development, 2006, 23 (11): 36-39.
[4] YANG Guang, SHEN Ai-qin, CHEN Zhi-guo, et al. Road performance and application technology of waste rubber powder and SBS composite modified asphalt mixture [J]. Journal of Highway and Transportation Research and Development, 2016, 33 (4): 25-31.
[5] Busset G, Sangely M, Montrejaud-Vignoles M, et al. Life cycle assessment of polychlorinated biphenyl contaminated soil remediation processes[J]. International Journal of Life Cycle Assessment, 2012, 17(17):325-336.
[6] Cai W, Mcdowell G R, Airey G D. Discrete element visco-elastic modelling of a realistic graded asphalt mixture[J]. Soils and Foundations -Tokyo-, 2014, 54(1):12-22.
[7] Ding Qingjun, Wei Liu, Ming Zhu, etc. A high viscosity and high elasticity asphalt modifier and its preparation method: CN 2009.
[8] Li Shuangrui, Lin Qing, Dong Shengxiong. Research progress of SBS modified asphalt mechanism [J]. Acta Metallurgica Sinica, 2008 (5): 14-19.
[9] Yang Guang, SHEN Ai-qin, CHEN Zhi-guo, et al.Characteristics and Modification Mechanism of Rubber Powder and SBS Compound Modified Asphalt Mixture in Seasonal Free Zone [J]. Journal of Chang'an University Natural Science Edition, 2015, 35 (6): 6- 15.
[10] Li Tinggang, Li Jinzhong, Li Wei. Micro-mechanism of rubber asphalt and its application in highway engineering [J]. Journal of Highway and Transportation Research and Development, 2011, 28 (1): 25-30.
[11] Tan Yiqiu, Guo Meng, Cao Liping.Effects of Common Modifiers on Viscoelastic Properties of Asphalt [J]. Journal of China Highway, 2013, 26 (4): 7-15.
[12] Xiao Chuan, Ling Tianqing. Application and research of waste rubber powder modified asphalt material in road engineering [J]. Journal of Highway Engineering, 2009, 34 (4): 49-53.