Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 263-283
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

Research on Service Performance of Buton Rock Asphalt and Rubber Powder Composite Modified Asphalt Pavement

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Abstract:

The performance of road surface has received more attention due to the increase of vehicle axle load caused by the growth of national economy. The polymer-modified asphalt represented by SBS is limited in use due to its high preparation cost, complex modification process, and weak low-temperature performance. Therefore, new modified asphalt materials are the key research directions of scholars from all over the world. In this paper, the matrix asphalt was modified with different dosage combinations of Buton rock asphalt and rubber powder, in order to obtain the composite modified asphalt with higher high and low temperature performance than SBS. From a theoretical point of view, it is feasible to demonstrate that the pavement performance of Buton rock asphalt and rubber powder composite modified asphalt is greatly improved compared with matrix asphalt; The content of Buton rock asphalt and rubber powder has different degrees of influence. The optimal combination of various factors is selected as 20% BRA+22% rubber powder. It provides a basis for further research on the road performance of the asphalt mixture, and provides a reference for further research on composite modified asphalt.

Keywords*: Buton Rock Asphalt, rubber powder, Compound modification, road performance*

I. INTRODUCTION

With the rapid increase in traffic in recent years, the phenomenon of early damage to the road surface has become more and more serious. It has become more and more important to improve the performance of the road surface and extend the service life of the road surface.

High molecular polymer modified asphalt represented by SBS modified asphalt can improve pavement performance to a certain extent[1], but there are also inevitable shortcomings: matrix asphalt is difficult to interact with due to the non-polar nature of high molecular polymer modifiers. High molecular polymer modified asphalt compatible.

Buton asphalt (BRA) has excellent performance, namely: (1) Buton asphalt has a high softening point (2) Buton asphalt has good compatibility with base asphalt (3) Buton Asphalt pavement has strong anti-water damage performance (4) Buton asphalt has good anti-aging performance[2]. Used rubber tire

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powder as a modifier can significantly improve the low-temperature performance, fatigue resistance and aging resistance of asphalt, and it can also improve the performance of asphalt pavement. To reduce noise, delay reflection cracks, and extend service life[3]. Buton asphalt can make up for the lack of adhesion between waste rubber powder modified asphalt and aggregates and the ability to resist water damage[4]. The content of this research expects that their respective advantages will break through the predecessors' restrictions on the research and use of Buton asphalt and waste rubber powder, and further explore and understand the performance advantages and disadvantages of the composite modified asphalt and its mixture to improve the high temperature and high temperature of the asphalt mixture. With low performance and fatigue resistance, the research on modifiers by domestic and foreign researchers has developed from unilateral modifiers to the current new composite modifications such as SBS-PE and SBS-SBR[5]. The research results show that: Modification The combined use of the agent can retain the advantages and improve the shortcomings of a single modifier, and significantly improve the multi-faceted road performance of the asphalt mixture.

Domestic Liu Li [6] proposed to mix domestic Qingchuan rock asphalt and rubber powder as a composite modifier for base asphalt in "Research on Performance of Qingchuan Rock Asphalt and Rubber Powder Composite Modified Asphalt Mixture". Experimental data shows that when the rubber powder blending amount is 18% + Qingchuan rock asphalt 10%, the high temperature stability and low temperature performance of the composite modified asphalt are better than SBS modified asphalt, and the low temperature performance is different from that of SBS modified asphalt. Not too big, but also has excellent fatigue resistance.

Zhang Jingfeng of the Second Highway Engineering Bureau of China Communications Second Highway Engineering Bureau Co., Ltd. [7] proposed to use domestic Qingchuan rock asphalt and rubber powder as a composite modifier in the "Rock Asphalt-Rubber Powder Composite Modified Asphalt Mixture Performance Test Study". The experimental results show that the best composite modification ratio is 7.5% Qingchuan rock asphalt + 15% rubber powder + 77.5% matrix asphalt.

However, at present, it is obvious that Buton asphalt and waste rubber powder are compounded modified asphalt and the performance research of the mixture. This article considers the compound modification of Buton bitumen and waste tire rubber powder as the research object to study the performance of the modified bitumen and the pavement performance of its mixture, enrich the relevant information in this respect, and do more in-depth research in the future. References and lessons learned.

In this paper, the composite modified asphalt with different contents of 15%, 20%, 25% of Buton rock asphalt and 16%, 19%, 22% of waste rubber powder is the research object. Conduct research on the performance of compound modified asphalt, the road performance of BRA-rubber powder compound modified asphalt mixture, and the economic and social benefits of BRA-rubber powder compound modified asphalt mixture. The performance of high temperature, low temperature, temperature sensitivity and anti-aging properties of powder composite modified asphalt, comprehensively select the best composite modified asphalt.

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II. MATERIALS AND METHODS

2.1 Test raw materials

2.1.1 Buton Rock Asphalt (BRA)

Through the extraction test, it is obtained that the asphalt content in the Buton rock asphalt selected in this study is 26.6%, and the mineral (ash) content is 73.4%. All technical indicators meet the requirements of Table I.

Table I. Indonesian Buton Rock Asphalt National Standard

Index	Unit	Min	Max	BRA IN STUDY
Asphalt content	%	18	-	26.7
Trichloroethylene Solubility	%	18	-	26.5
Flash point	℃	230	-	239
Heat loss	%	-	2.0	1.1
Water content	%	-	2.0	0.5

Asphaltene is the main component in Butonite bitumen, which is a molecular group of compounds with high molecular hydrocarbons and heteroatoms, of which the main chemical elements are carbon (C), hydrogen (H), oxygen (O), nitrogen (N) , sulfur (S), aluminum (Al), silicon (Si), and other metal elements, Table II is the value obtained by analysis.

Table II. Phase composition of minerals in asphalt

Composition of Buton Asphalt	Unit	Percentage
$CaCO_3$	%	73.5
$CaSO_3$	%	9.1
SiO_2	%	8.9
$MgCO_3$	%	2.3
Al_2O_3+Fe_2O_3	%	4.4
Na_2O+K_2O	%	0.67
Other residues	%	1.13

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2.1.2 Rubber powder

In this study, waste rubber powder produced by Sichuan Zhongneng Company was used as one of the modifiers for compound modified asphalt. The particle size of the rubber powder was 40 meshes. Table III is the technical index of the rubber powder used.

Table III Rubber powder technical indicators

Projects	Index	Results
Iron (%)	＜0.01	0
Fiber (%)	＜0.05	0
Ash (%)	＜8	7
Acetone Extract (%)	6～16	6.3
Carbon black (%)	28～38	29
Rubber hydrocarbons (%)	≥42	58

2.1.3 Base asphalt

The base asphalt used in this study is the 70#-A grade road petroleum asphalt produced by Foshan Chuangxin Chemical Co., Ltd. The specific parameters of the material is shown in Table IV.

Table IV 70#-A Base Asphalt Performance Index

Index	Unit	Skills requirement	Results
Penetration (25℃, 100g, 5s)	0.1mm	60-80	68.4
Penetration Index(PI)	-	-1.5-1.0	-1.28
Softening Point (Ring and Ball Method)	℃	≥46	47.8
Dynamic viscosity (60℃)	Pa•s	≥180	305
Ductility (10℃, 5cm/min)	cm	≥25	70.7
Ductility (15℃, 5cm/min)	cm	≥100	＞150
Wax content	%	≤2.2	1.71
Flash point (opening)	℃	≥260	277
Solubility	%	≥99.5	99.98
Density (15℃)	g/cm^3	Measured record	1.048

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Film oven test (163℃, 5h)	Quality change	%	-0.8-0.8	-0.195
	Penetration ratio	%	≥61	63.9
	Ductility 10℃	cm	--	55.5
	Ductility 15℃	cm	≥6	7.2

2.1.4 SBS modified asphalt

The SBS I-D modified asphalt produced by Foshan Chuangxin Chemical Co., Ltd. as a comparison. The specific parameters of the material is shown in Table V.

Table V SBS Modified Asphalt Performance Index

Index		Unit	SBS I-D	Measured value
Penetration (25℃, 100g, 5s)		0.1mm	40-60	52
Penetration Index (PI)		-	≥0	0.29
Ductility (5℃, 5cm/min)		cm	≥20	28.2
Softening Point (Ring and Ball Method)		℃	≥60	78.5
Dynamic viscosity (135℃)		Pa•s	≤3	1.7
Flash point		℃	≥230	295
Solubility		%	≥99	99.6
Elastic recovery		%	≥75	87
Storage Stability Isolation 48h softening point difference		℃	≤2.5	1.6
RTFOT Residual	Quality change	%	-0.1-0.1	-0.54
	Penetration ratio	%	65	71
	Ductility 5℃	cm	15	18

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2.2 Experimental scheme and preparation method of BRA-rubber powder compound modified asphalt

According to the previous research results of Buton rock asphalt and rubber powder, this experiment adopts the external mixing method, that is, the mixing ratio is the ratio of the quality of Buton rock asphalt and rubber powder to the quality of the matrix asphalt, respectively. The performance test of the compound modified asphalt and the modified asphalt mixture with the mixing amount of 15%, 20%, 25% and the rubber powder with the mixing amount of 16%, 19% and 22%, as shown in Table VI.

Table VI Experiment plan

Sample number	1	2	3	4	5	6	7	8	9
BRA Dosage (%)	15%			20%			25%		
Rubber powder dosage (%)	16%	19%	22%	16%	19%	22%	16%	19%	22%

Before preparing the BRA-rubber powder compound modified asphalt, the particle size of the Buton rock asphalt was processed first, and then sieved with a 1.18 mm square-hole sieve, which was the final powdered Buton rock asphalt.

When preparing BRA-rubber powder compound modified asphalt, the base asphalt is heated to the design temperature of 150-160 ℃ according to the test plan, and the Buton rock asphalt is first added according to the predetermined mixing ratio, and the high-speed shearing machine is used at 13000r/min. Heating and shearing at a high speed to achieve the design shearing time of 30min, to make it evenly mixed, then increase the temperature of the oil bath to 180℃ to make it co-heat to the same temperature inside and outside, and then slowly add it in several times according to the predetermined blending ratio rubber powder until shearing is complete[8]. It should be noted that since the BRA-rubber powder compound modified asphalt contains a large amount of limestone minerals and rubber powder particles of Buton rock asphalt, it is necessary to uniformly stir the BRA-rubber powder compound modified asphalt before starting each test. , in order to reduce the adverse effect of particle settlement on the performance of BRA-rubber powder composite modified asphalt. In addition, the overall temperature during the preparation of BRA-rubber powder composite modified asphalt needs to be controlled below 180 °C to reduce the effect of aging of the matrix asphalt caused by high temperature[9].

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Ⅲ. RESULTS

3.1 High temperature performance of composite modified asphalt

3.1.1 Softening point test

The softening point is an index reflecting the thermal stability of asphalt at high temperature[10]. The higher the softening point, the stronger the ability of asphalt to resist high temperature deformation. The softening point test of the nine groups of samples in this experiment is shown in Fig 1. The test results are shown in Fig 2, Fig 3, and Figure 4.

Fig 1 Asphalt softening point test

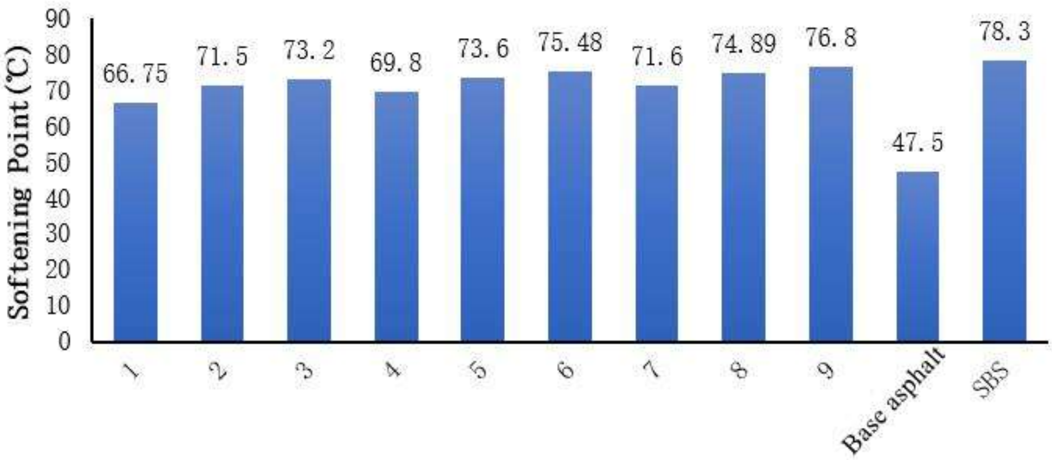

Fig 2 BRA-rubber powder different dosage combination

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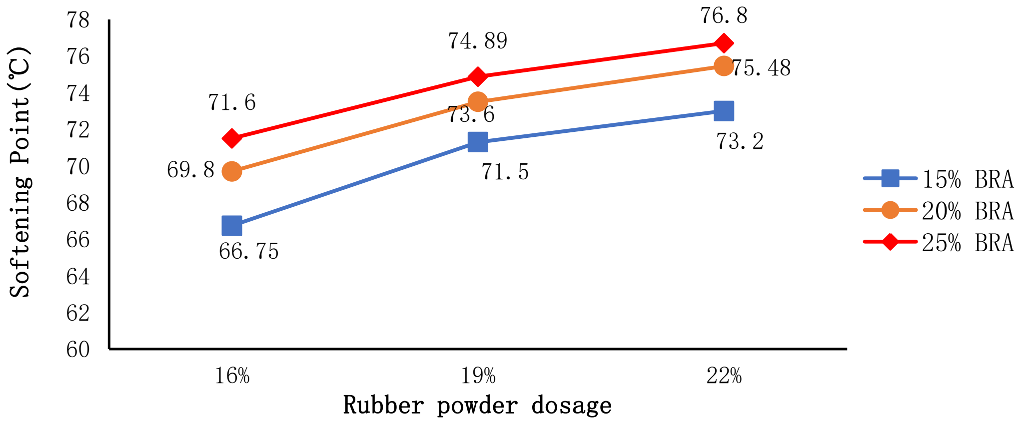

Fig 3 Comparison of the same amount of BRA

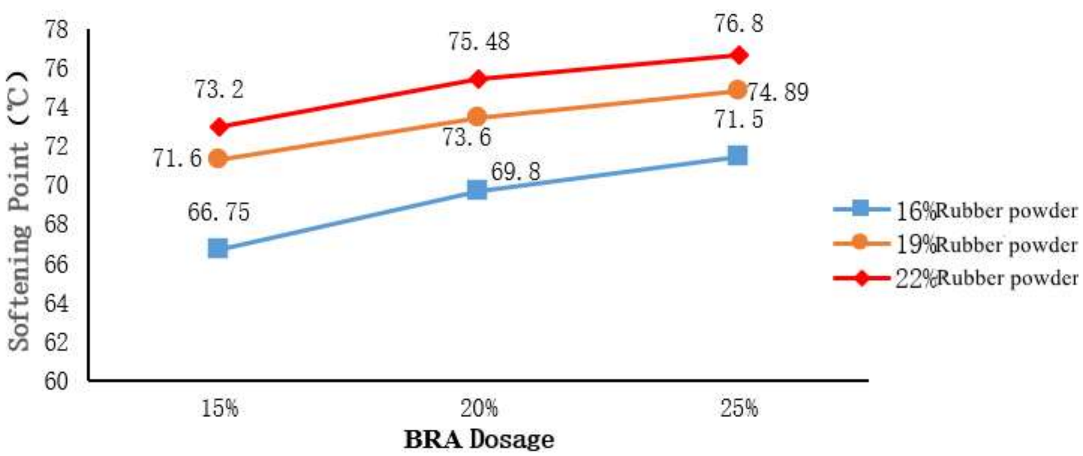

Fig 4 Comparison chart of the same amount of rubber powder

3.1.2 Equivalent softening point T_{800}

Penetration test is widely used internationally as a method for measuring asphalt consistency, which can reflect the ability of asphalt to resist deformation under load. Compared with the softening point index, the equivalent softening point T800 obtained from the test results is more accurate and more reasonable[11].

According to the current standards in my country, the penetration test of BRA-rubber powder composite modified asphalt, matrix asphalt and SBS at 15°C, 25°C and 30°C with different dosage combinations are shown in Fig 5, Fig 6

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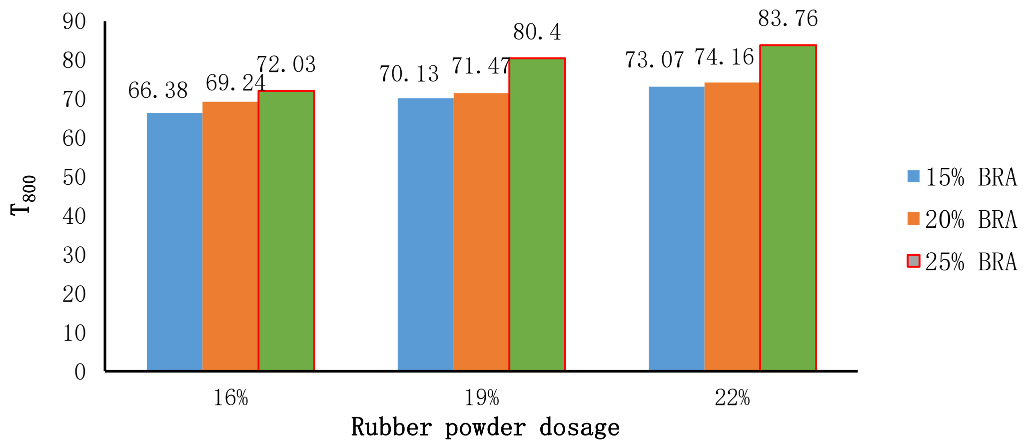

Fig 5 Comparison chart of the same amount of rubber powder

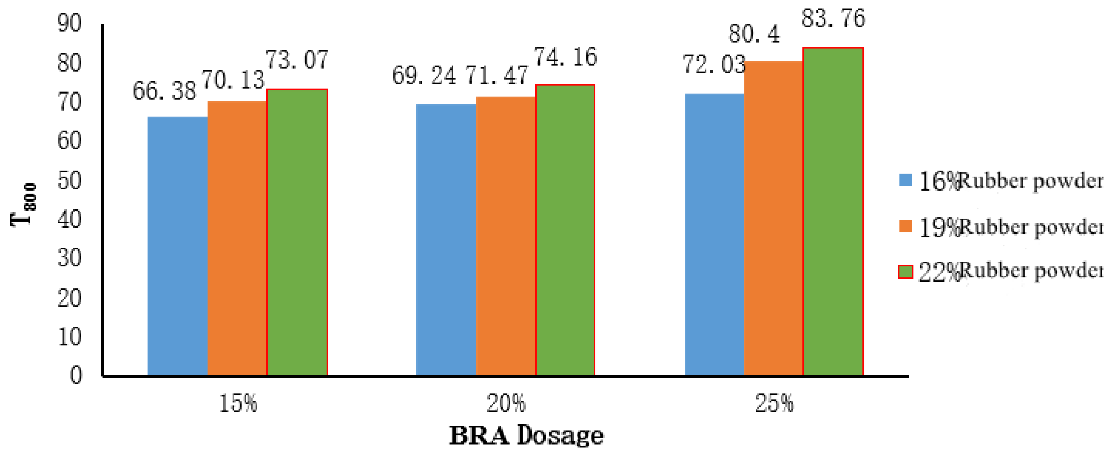

Fig 6 Comparison of the same amount of BRA

3.1.3 Dynamic Shear Rheological Test (DSR)

The indexes of evaluating asphalt performance by dynamic shear rheological test are complex modulus G*, phase angle δ, anti-rutting factor G*/sinδ[12].

The complex modulus G* and phase angle δ measured by the test are used to convert the rutting factor G*/sinδ as an index to evaluate the high temperature performance of the asphalt binder[13]. Test in accordance with the requirements of AASHTO T313-09 test procedures, the test adopts the strain control mode, and the test temperature is 64 ℃. The asphalt is made into a sample with a diameter of 25mm and a thickness of 1mm. The test results are shown in Fig 7, Fig 8, Fig 9:

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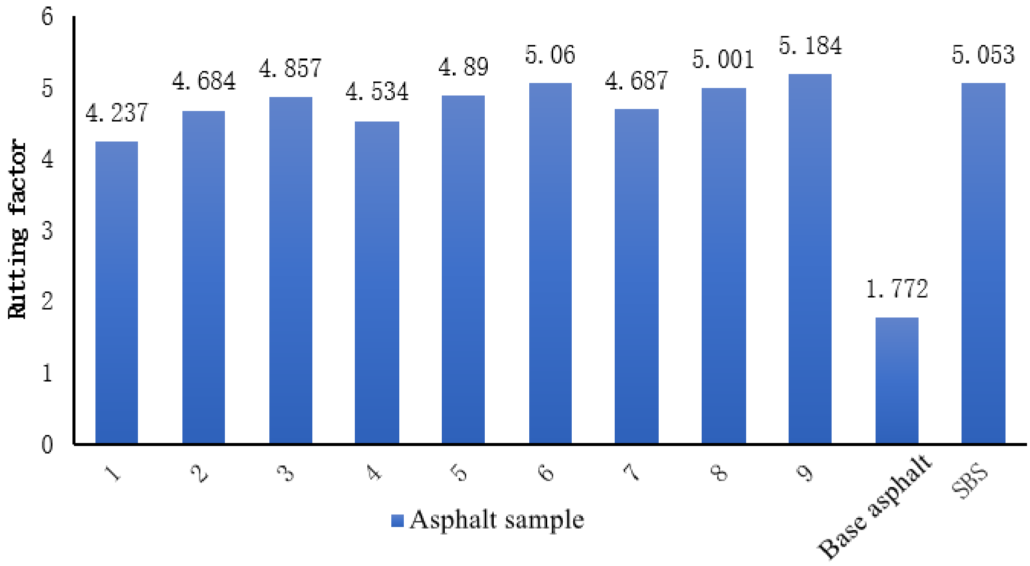

Fig 7 Comparison of rutting factors of different asphalt samples

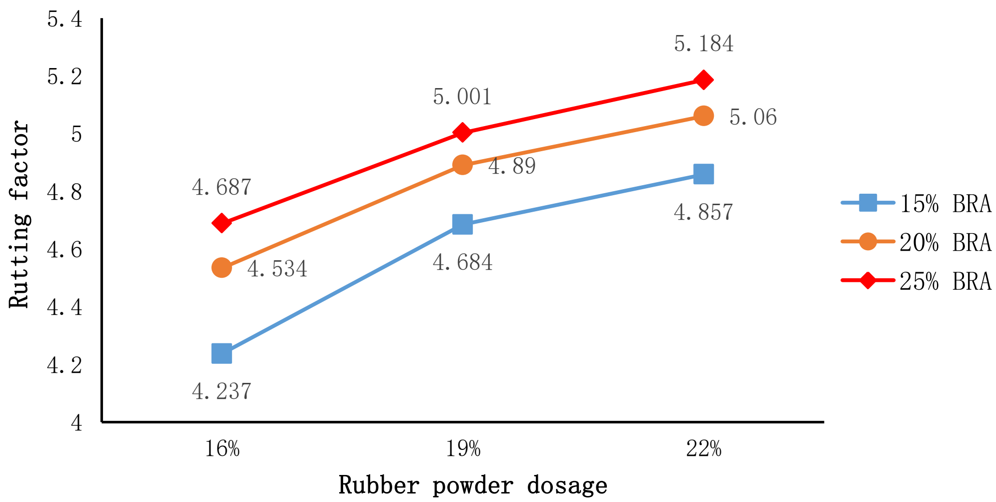

Fig 8 Comparison of the same amount of BRA

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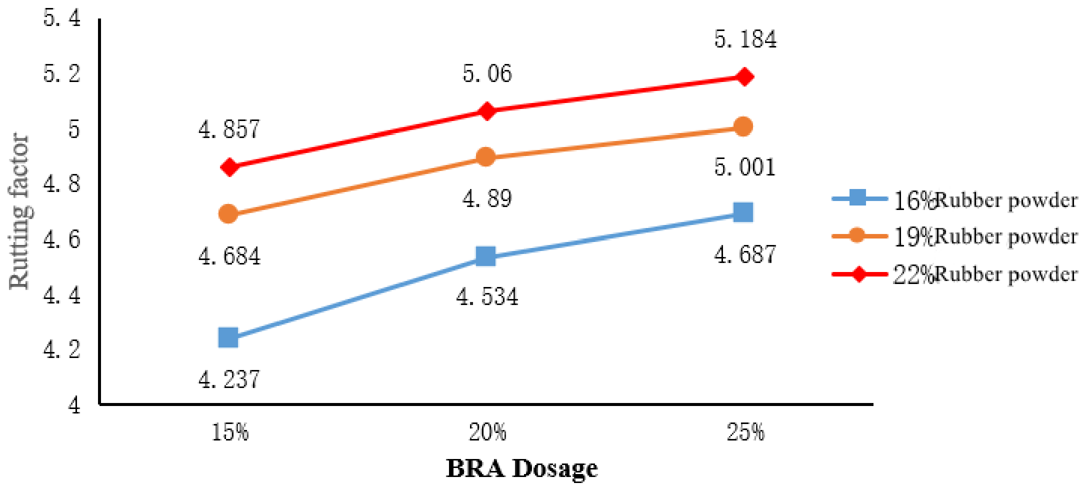

Fig 9 Comparison chart of the same amount of rubber powder

3.2 Low temperature performance of composite modified asphalt

3.2.1 Equivalent brittle point $T_{1.2}$

The emergence of the equivalent brittle point $T_{1.2}$ makes up for the fact that most of the asphalt used in my country has a high wax content and that the measured brittle point of asphalt binders used in practical engineering applications is not ideal for characterizing low-temperature crack resistance[14]. The results are shown in Fig 10, Fig 11, Fig 12

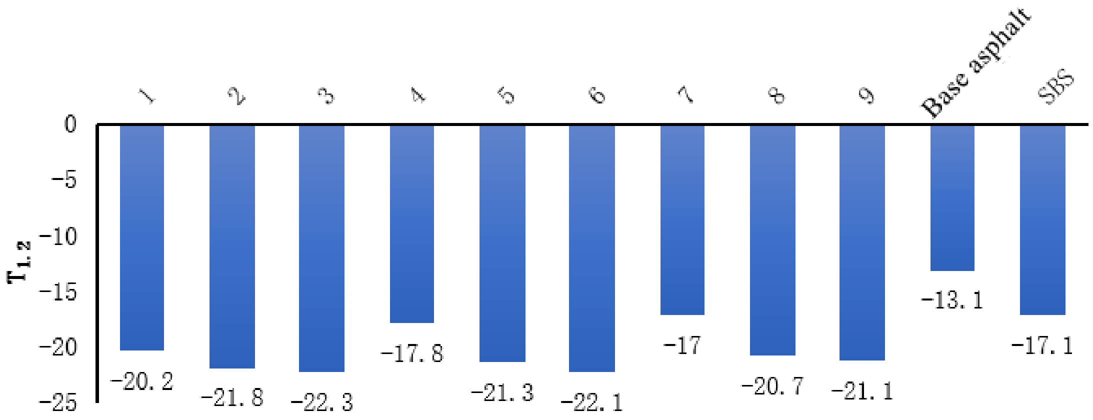

Fig 10 Comparison chart of different asphalt equivalent brittle point $T_{1.2}$

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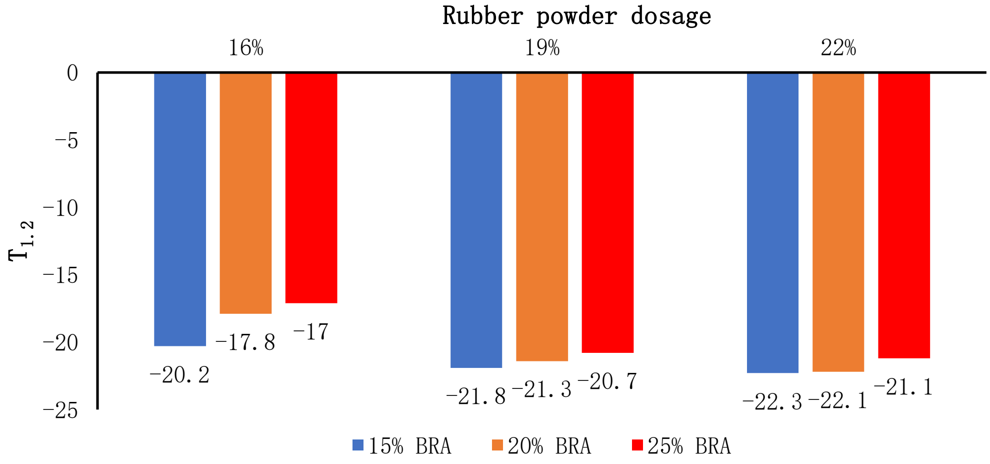

Fig 11 Comparison chart of the equivalent brittle point $T_{1.2}$ of different asphalts in the same amount of rubber powder

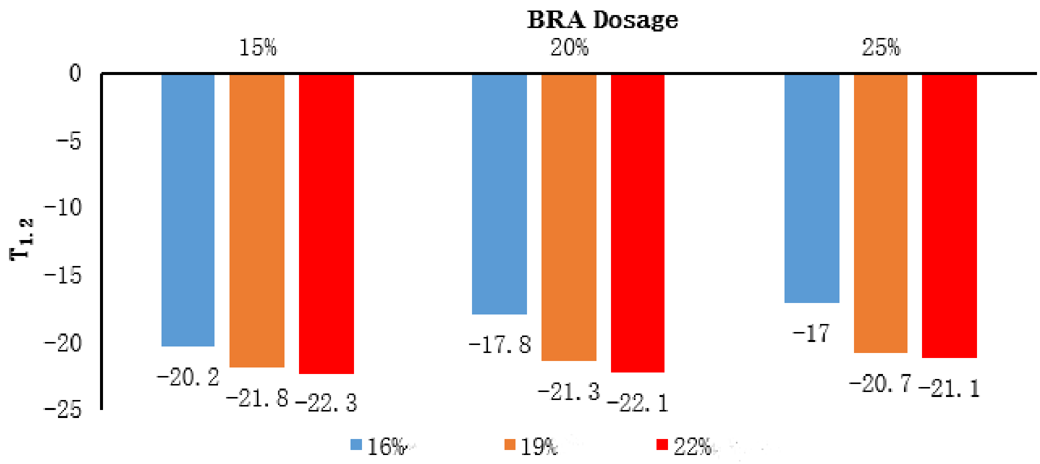

Fig 12 The comparison chart of the equivalent brittle point $T_{1.2}$ of different asphalts with the same BRA content

3.3 Thermal performance of composite modified asphalt

The evaluation index of temperature sensing performance is the penetration index. It is generally believed that the larger the penetration index PI value, the lower the sensitivity of asphalt to temperature[15]. Penetration index PI calculated from the linear regression of the penetration of BRA-rubber powder modified composite modified asphalt with different dosage combinations at different test temperatures. The PI value of each sample is shown in the Table VII and Fig 13.

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Table VII Penetration index results of composite modified asphalt

Sample	1	2	3	4	5	6	7	8	9	Base asphalt	SBS
PI	1.42	1.84	2.12	1.46	1.91	2.19	1.63	2.54	2.8	-1.28	0.29

Since the 21st century, Beijing, Hebei, Hubei and many other regions have successively developed their own Buton Rock Asphalt construction regulations, but my country has not yet issued formal industry standards for Buton Rock Asphalt, and waste rubber powder modified asphalt is the same. [16]For industry conditions, refer to the Hebei Provincial Standard on Buton Rock Modified Asphalt "Technical Guidelines for the Application of Buton Rock Modified Asphalt Mixtures" (DB13/T 2511-2017) and Sinopec's Standard on Waste Rubber Powder Modified Asphalt " "Waste Rubber Powder Modified Road Asphalt" Comprehensive Evaluation of Thermal Performance of BRA-Rubber Powder Compound Modified Asphalt. For specific requirements, see Table VIII and Table IX.

Table VIII Hebei Province "Technical Guide for the Application of Butun Rock Modified Asphalt Mixtures"

Technical indicators	Unit	Asphalt type		
		BRMA-70	BRMA-50	BRMA-30
Penetration 25℃	0.1 mm	60～80	40～60	20～40
PI，不小于	-	-1.0	-0.8	-0.6
Softening point, ≥	℃	45	50	55

Table IX Sinopec "Waste Rubber Powder Modified Road Asphalt"

Indicator name	Class I	Class II	Class III
Softening point ℃, ≥	60	55	50
Penetration 25℃/0.1mm	25～75	25～75	50～100

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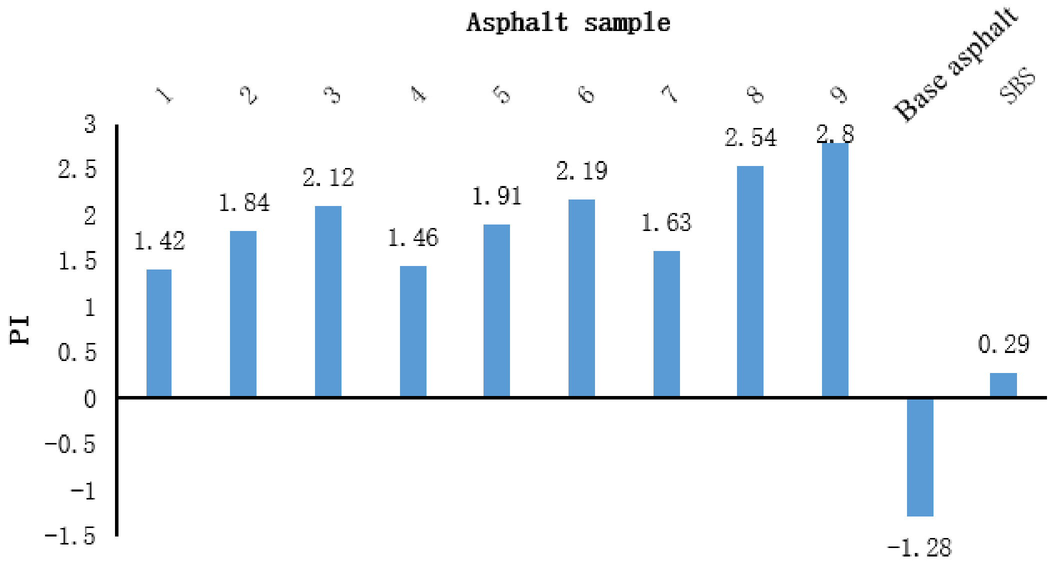

Fig 13 Comparison of Different Asphalt Penetration Index PI Results

3.4 Anti-aging properties of composite modified asphalt

The thin film heating test (TFOT) is used to simulate the long-term aging process of asphalt[17]. Figure 14 shows the thin film oven of the test instrument. The evaluation indicators are the penetration ratio and mass loss ratio after aging at 25 °C before and after aging. The test results are are shown in Fig 15-Fig 20.

Fig 14 Thin-film oven asphalt aging test

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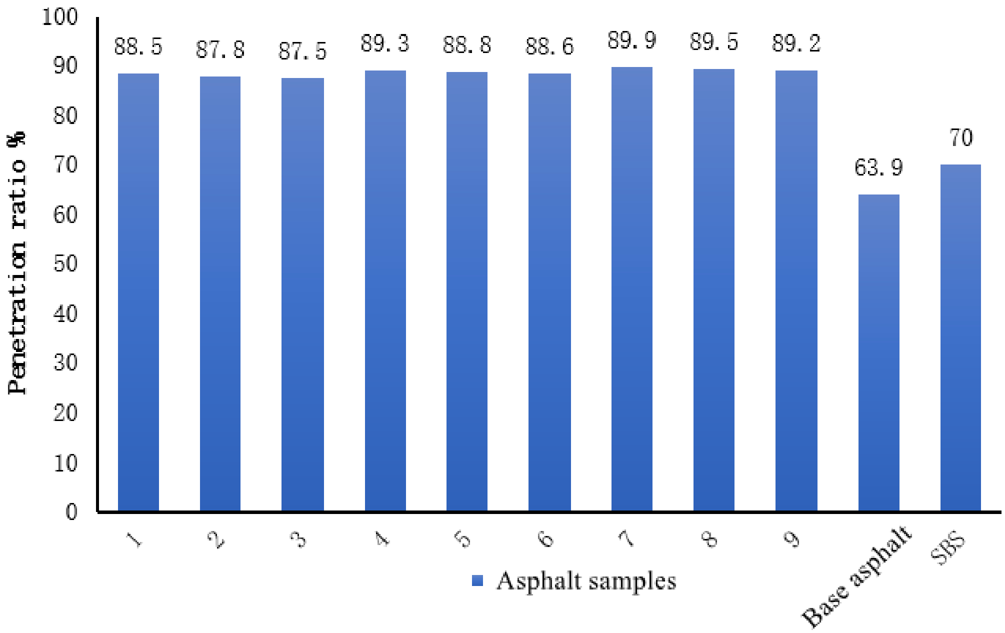

Fig 15 Comparison chart of penetration ratio of different asphalts

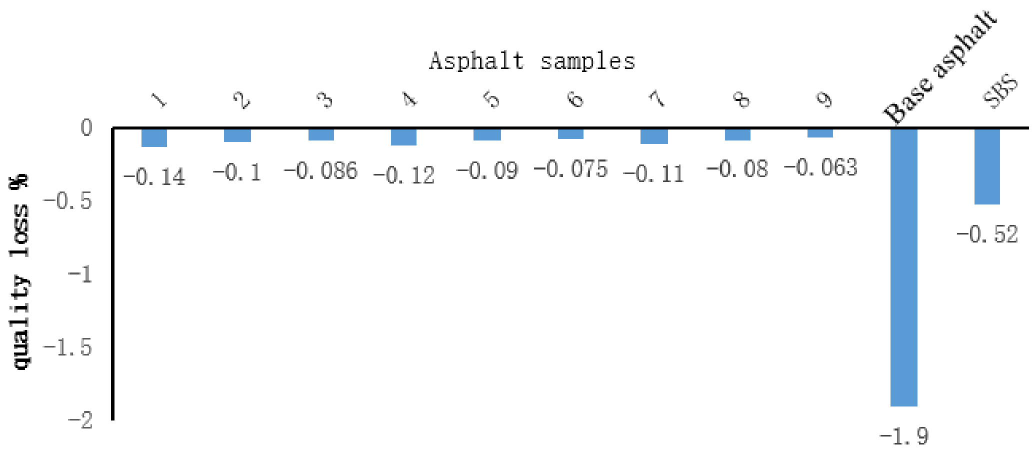

Fig 16 Comparison of mass loss of different asphalts after aging

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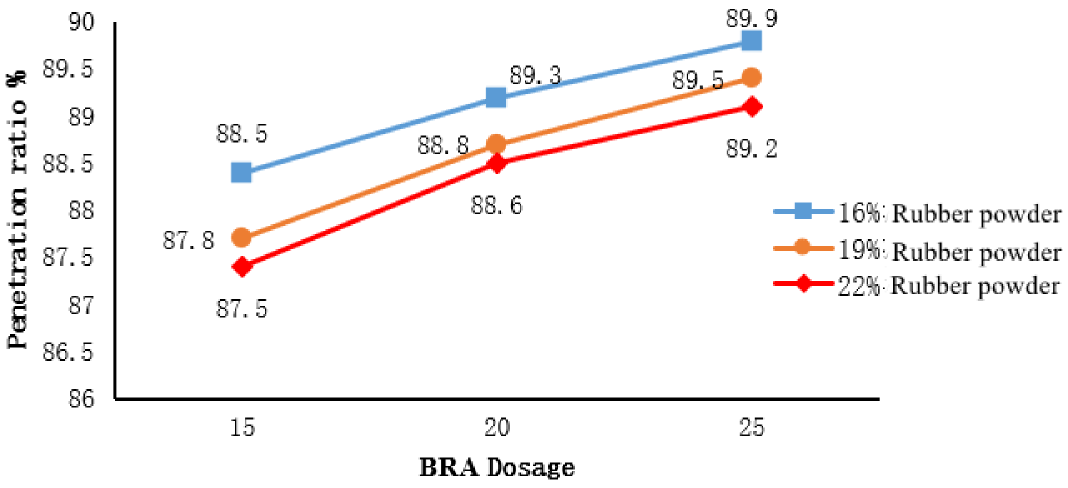

Fig 17 Comparison of different asphalts with the same amount of rubber powder

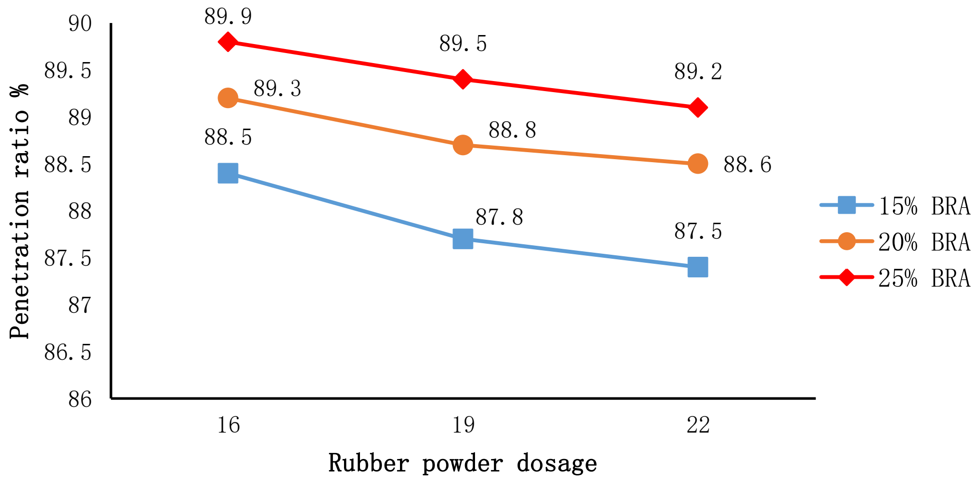

Fig 18 Comparison chart of penetration ratio of different asphalts with the same BRA content

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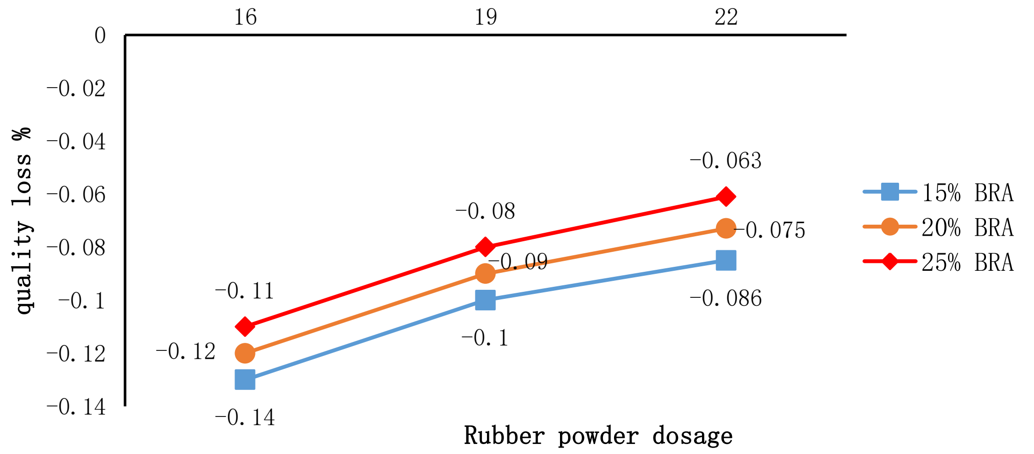

Fig 19 Comparison of mass loss ratios of different asphalts with the same BRA content

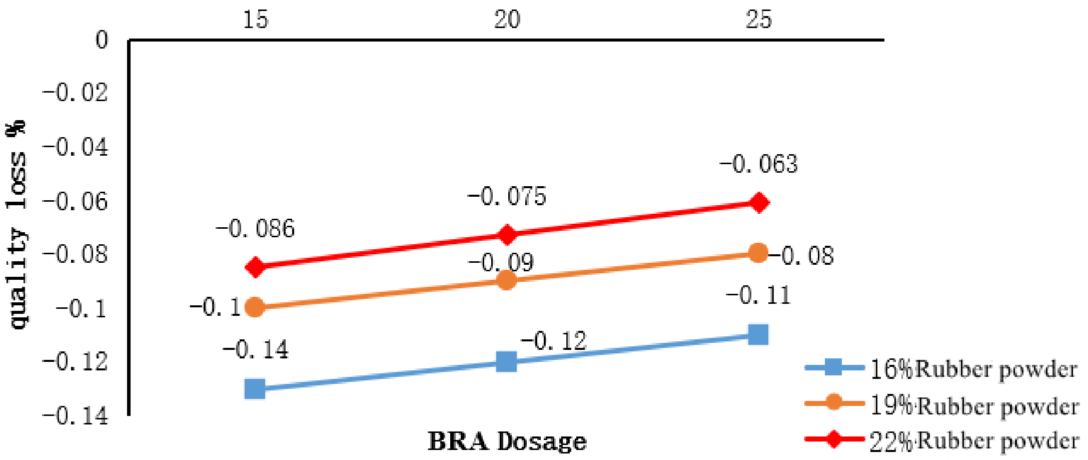

Fig 20 Comparison chart of mass loss of different asphalts with the same amount of rubber powder

Ⅳ. DISCUSSION

The four-component method is usually used to divide the chemical composition of asphalt, which are: saturated (S), aromatic (Ar), gum (R), and asphaltene (As). For specific parameters, see Table X.

Table X Buton asphalt composition table

Analysis Project	70# Matrix Asphalt	BRA extraction of asphalt
Saturation point S (%)	12.72	13.87
Aromatic Ar (%)	35.34	38.72

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Gum R (%)	33.40	13.18
Asphaltene As (%)	18.54	34.23

According to the relevant data in Table 10, it can be seen that the content of asphaltene (As), aromatic content (Ar), and saturated content (S) in the asphalt in BRA is higher than that of 70# matrix asphalt used in this study. It explains that the stability, high temperature performance and adhesion of Buton asphalt are better than those of base asphalt. [18]

Buton has a large molecular modulus and a high degree of polymerization, forming a well-developed network structure[19]. When it is added to the base asphalt and under the conditions of high-speed shearing and high temperature, the micelles of the network structure are broken, and the formed fracture will attract the substances with small molecular modulus in the base asphalt, and gradually form a cloth with a small molecular modulus. A new network structure molecular group with the macromolecule of Dunyan bitumen as the core. At the same time, the original four-component content in the base asphalt and the proportional relationship between them were changed, so that the ratio of asphaltenes and colloids also increased when the four-component content increased to different degrees at the same time[20]. The active groups in petroleum asphalt are cross-linked through organic chains in natural asphalt, which greatly improves the cohesion of asphalt, enhances adhesion, and reduces temperature sensitivity. Due to the excellent oxidation resistance and nitrogen content of rock asphalt itself The strong wettability brought about by polar functional groups is continued when added to the base asphalt, which improves the overall performance of the asphalt. According to the analysis of differential scanning calorimetry (DSC) results, the properties of asphalt affect the aggregate state of asphalt and the heat absorbed by asphalt in the process of state transition. The reduction of α and the narrowing of the endothermic peak width are the essence of natural asphalt improving the temperature sensitivity of petroleum-based asphalt. The test results of gel permeation chromatography (GPC) show that after adding rock asphalt, the endothermic heat decreases, the endothermic peak area becomes smaller, and the high temperature stability is obviously improved[21].

Mix the rubber powder with the base asphalt and place it in a high temperature environment. The rubber powder particles dispersed in the base asphalt absorb some of the light components (aromatic and colloid) and oil in the asphalt, and the volume becomes larger and the swelling phenomenon occurs[22]. A layer of gel film formed on the surface of the particles has a certain viscosity. Under the action of the high-speed shearing machine, the rubber powder particles are uniformly dispersed in the asphalt, so that the asphalt changes from a continuous phase to a semi-continuous phase, and the asphalt is filled between the rubber powder particles to form a skeleton - a dense structure that enhances the stability of the system. The tight connection between the particles constitutes the flocculent structure of the asphalt and increases the viscosity of the asphalt. Since the physical properties of the rubber powder particles and the base asphalt are different, after the blend is formed, the rubber powder particles and the Asphalt will produce different deformations. Stress concentration occurs at the interface between rubber powder particles and asphalt, which consumes a lot of energy. The low temperature performance of asphalt is improved, and the low temperature crack resistance of asphalt added with rubber powder particles is enhanced.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 263-283
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

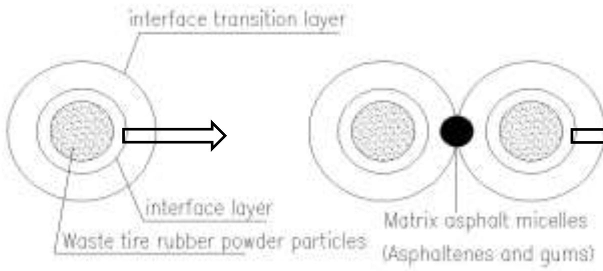

Fig 21 Buton asphalt and rubber powder composite modified asphalt model

The Buton rock asphalt and rubber powder are added to the base asphalt according to a certain mixing ratio, and the content of the four components of the base asphalt and the proportional relationship between them are readjusted. When the rubber powder particles are added to the base asphalt, a rubber Particles with viscous interface layer and interface transition layer with powder particles as the core. The particles are connected by the original matrix asphalt micelles[23]. The addition of Buton rock asphalt absorbs the original asphalt and turns it into macromolecules of Buton rock asphalt. The larger volume of micelles as the core acts as the connection point of the rubber particles, which changes the colloidal connection structure of the original matrix asphalt and jointly enhances the stability of the asphalt structure, and transforms to a sol-gel structure, as shown in Fig 21. Conceptual model of composite modified asphalt. On the basis of retaining or increasing the viscosity, plasticity and fluidity of the original asphalt, the inherent properties of the modifier are used to improve the temperature stability and elasticity of the asphalt.

Ⅴ. CONCLUSION

This study firstly analyzed the composition of Buton rock asphalt components and rubber powder, and then analyzed the performance of BRA-rubber powder composite modified asphalt, and compared the road performance of the composite modified asphalt mixture with the matrix asphalt and SBS modified asphalt. The experimental research and analysis of the comparison of the mixture and the discussion of the modification mechanism have led to the following conclusions:

(1) Through the research on the properties of BRA-rubber powder compound modified asphalt, it is shown that Buton rock asphalt and rubber powder can significantly improve the high temperature performance of asphalt, enhance the anti-aging performance and improve the temperature sensing performance.

(2) The high temperature performance increases with the increase of the rubber powder content when the content of Buton rock asphalt is the same, but when the rubber powder content exceeds 19%, the growth rate slows down; when the rubber powder content is the same The decrease rate increases with the increase of the Buton rock asphalt content, but the growth rate slows down when the Buton rock asphalt content exceeds 20%.

(3) The anti-aging performance increases with the increase of the amount of rubber powder when the

amount of Buton rock asphalt is the same, but when the amount of rubber powder exceeds 19%, the growth rate slows down; when the amount of rubber powder is the same However, when the content of buton rock asphalt exceeds 20%, the growth rate slows down.

(4) The temperature-sensing performance increases gradually with the increase of the combined dosage.

(5) In terms of low temperature performance, the absolute value of equivalent brittle point T1.2 is greater than that of SBS modified asphalt, indicating that composite modification has a positive effect on improving the low temperature performance of asphalt.

(6) Comprehensively considering the performance of the composite modified asphalt with different dosage combinations and the degree of performance improvement under the change of dosage, the combined dosage of 20% BRA + 22% rubber powder is recommended.

ACKNOWLEDGEMENTS

This research was assisted by China Municipal Engineering Zhongnan Design and Research Institute Co., Ltd.(Funded project: Research on key technology of UHPC wet joint in the negative bending moment area of hybrid composite small box girder KY-N-L-2018-004).

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Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 263-283
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