Study on high and low temperature performance of asphalt mixture modified by warm mixed tire rubber powder

Yanrong Liu

CCCC First Highway Consultants Co., Ltd., Xi'an Shaanxi 710075, China

Email:27279892@qq.com,Tel:13991265747

Abstract. For the problem about generating a large amount of smoke, poor environmental friendliness, asphalt aging when preparing rubber powder modified asphalt in high temperature environments, the study of warm mixed tire rubber powder composite modified asphalt mixing agent and the influence of the high and low temperature performance of asphalt mixture, the automobile tires, tire rubber powder preparation add asphalt quality were 5%, 7.5%, 10% respectively temperature mixing agent made of different dosage of warm mix rubber powder modified asphalt. Through dynamic shear rheological test (DSR), bending beam rheological test (BBR) tests to evaluate the temperature with high and low temperature performance of rubber powder modified asphalt. Experimental results show that temperature mixing agent made of waste tire rubber powder composite modified asphalt complex modulus and creep rate increases, phase Angle and creep stiffness modulus decreased, shows that temperature mixing agent has a beneficial effect on the high temperature performance, and can make its low temperature performance is obviously improved, when the temperature mixing agent is 7.5% the above effect the most obvious, but the higher dose (10%) or lower (5%), the effect will be dropped.

Keywords: Tire rubber powder; Warm mixing agent; DSR; BBR; High temperature performance; Low temperature performance.

1 Introduction

Rubber modified asphalt is a new type of high-quality composite material that is made by adding rubber powder made from waste tires as a modifier to the base asphalt, and through a series of actions such as high temperature, additives, and shear mixing in a special equipment[1]. Rubber powder as a modifier has the characteristics of economy, practicality, and environmental protection, which can improve the service life of the road surface, reduce noise, reduce vibration, improve thermal stability, and thermal cracking Improving anti icing performance[2-3], however, due to the fact that the preparation of rubber powder modified asphalt usually needs to be carried out in higher temperature environments, accompanied by the generation of large smoke, poor en-

G. Zhao et al. (eds.), *Proceedings of the 2023 5th International Conference on Civil Architecture and Urban Engineering (ICCAUE 2023)*, Atlantis Highlights in Engineering 25,
https://doi.org/10.2991/978-94-6463-372-6_8

vironmental friendliness, and easy aging of asphalt, sometimes asphalt containing a large amount of rubber powder is prone to ignition during the melting process[4]. Usually, under thermal aging conditions, the trend of asphalt change is to become harder, manifested by a decrease in penetration, Under the action of thermal oxygen aging, changes in the internal structure of asphalt usually cause changes in its microstructure and morphology[5]. Both polymers and asphalt in modified asphalt undergo oxidation reactions, resulting in an increase in oxygen-containing functional groups in the modified asphalt[6]. This increases the cost of asphalt by using rubber powder, and the addition of rubber powder to asphalt makes the asphalt mixture more difficult to treat (easy to bond), increasing the operating time[7]. Therefore, this study combines warm mixing agents with rubber powder to prepare warm mixing rubber powder modified asphalt, effectively avoiding unsafe events such as asphalt aging, significant performance degradation, generation of a large amount of smoke, and even fire during the preparation process of rubber powder modified asphalt[8], thereby achieving the goal of improving asphalt performance and environmental protection.

At present, scholars at home and abroad have conducted extensive research on polymer modified asphalt mixtures. Ma Feng, Dai Jiasheng[9] studied a nonlinear prediction model based on the main impact of the anti rutting performance index - anti rutting factor - of rubber powder and SBS double modified asphalt. Yang Jun[10] tested the creep characteristics of mixtures under different temperatures and confining pressures through uniaxial static compression tests, and studied the mechanical properties of warm mixed rubber modified asphalt mixture based on the viscoelastic Burgers model. The high-temperature deformation development process of rubber SMA asphalt mixture (ARSMA-13 type) mixed with warm mixed additives was studied, and the anti rutting performance of rubber modified asphalt pavement was explored. Cui Xiaopan, Cong Peiliang[11] conducted experiments on five types of asphalt, including matrix asphalt, rubber modified asphalt, and composite modified asphalt with different amounts of polyphosphate, using dynamic shear rheometer, bending beam creep stiffness test, and routine test. The effect of polyphosphate on the high and low temperature performance of rubber modified asphalt was analyzed. Liu Zhongming [12] using rheological evaluation indicators to analyze the high- temperature deformation resistance of biological asphalt and rubber powder modified biological asphalt, evaluated the effect of thermal oxygen aging on the performance of rubber powder modified biological asphalt, established aging dynamic models of rubber powder modified biological asphalt under different aging temperatures and times based on rheological evaluation indicators, and found that the aging resistance of rubber powder modified biological asphalt was significantly better than that of biological asphalt, and the larger the rubber particles were, The stronger the anti-aging ability is.

Since the existing research achievements involve less research on the high- temperature and low-temperature performance of warm mixed rubber powder composite modified asphalt and asphalt mixture, and the rubber composite modified asphalt prepared by mixing rubber powder into asphalt has good fatigue resistance and aging resistance, therefore, the warm mixed asphalt prepared by adding warm mixed agent into asphalt in this study can effectively reduce the viscosity of rubber asphalt and slow down the aging of rubber asphalt. At the same time, this study systematically studied the influence of warm mixing agent dosage on the high and low temperature properties of tire rubber powder composite modified asphalt through dynamic shear rheological test and bending beam rheological test (Dynamic shear Rheometer measurement method for asphalt rheological properties of AASHTO T315/ASTM D7175), and conducted triaxial repeated creep test.

2 Material characteristics and experimental methods

2.1 Material performance

(1)Asphalt.

The base asphalt used in the experiment is SK-90 heavy duty asphalt, and its basic performance indicators are shown in Table 1.

Table 1. Heavy duty asphalt performance

Technical Index		Unit	Technical standard	Inspection results	Inspection method
Penetration(25℃,100g,5s)		0.1mm	80-100	89.3	T0604-2000
Penetration Index(PI)		/	-1.5～+1.0	-0.73	
Softening point(TR&B)		℃	≮44	46	T0606-2000
Ductility 10℃,5cm/min		cm	≮20	74.9	T0605-1993
Ductility 15℃,5cm/min		cm	≮100	>100	
Solubility		%wt	≮99.5	99.5	T0607-1993
Density	15℃	g/cm^3	Actual measurement records	1.061	T0603-1993
Rotating thin film heating test 163℃ 85min	Mass loss	%	≯±0.8	0.507	T0610-1993
	Penetration ratio	%	≮57	61	T0604-2000
	Ductility 10℃	cm	≮8	8.35	T0605-1993

(2) Rubber powder.

The waste tire rubber powder (referred to as rubber powder) required for this experiment was prepared using car tires, with a mesh size of 40 and 80, respectively. The chemical composition test results of the rubber powder are shown in Table 2.

Table 2. Chemical Components of Small Car Tire Rubber Powder

No.	Test category	Results
1	Rubber hydrocarbon mass fraction,%	60.1
2	Carbon black mass fraction,%	27.4
3	Ash mass fraction,%	8.1
4	Mass fraction of acetone extract,%	4.2
5	Identification of rubber seed	Polyisoprene+polybutadiene rubber (cis-1,4-polybutadiene rubber)

(3) Warm mixing agent.

Using a surface active agent (light black emulsion solid-liquid mixture) independently developed and produced by a company in Chengdu, the recommended dosage of the warm mix agent is 5%, 7.5%, and 10% of the mass of the base asphalt.

2.2 Preparation of Warm Mix Rubber Powder Modified Asphalt

Place the prepared base asphalt in an oven with a temperature not higher than 130 °C for 2 hours, add the designed proportion of rubber powder to the base asphalt (the amount of rubber powder in the text is 18% of the asphalt mass), and use a glass rod to stir until evenly mixed; Place the mixed rubber powder modified asphalt in a 150 °C oven for 3 hours, and stir it with a glass rod every half hour during the development period. After development, use a high-speed shear emulsification machine to shear for 30 minutes, with a speed control of 7500 r/min and a temperature control of 180-185 ° C. After the shearing is completed, three different dosages of warm mix agents of 5%, 7.5%, and 10% of the asphalt mass are added to prepare modified asphalt with different dosages of warm mix rubber powder. To ensure uniform mixing, continue shearing at a speed of 3000 r/min for 30 minutes to ensure uniform mixing of the warm mix agent in the rubber powder modified asphalt.

2.3 Introduction to Test Plan

2.3.1 Asphalt High and Low Temperature Performance Evaluation Test.

(1) The dynamic shear rheological test, also known as DSR test, uses a dynamic shear rheometer (Bohlin DSRII type), with a temperature scanning test temperature of 28~82 ° C and a temperature interval of 6 ° C, strain control mode, load frequency of 10 rad/s, and strain of 12%. During frequency scanning, the scanning frequency is between 0.1rad/s and 100rad/s, and the temperature is 64 °C.

(2) The bending beam rheological test, also known as the BBR test, uses the ATS RHE-102 bending rheometer with test temperatures of -12 °C, -18 °C, -24 °C, -30 °C, and a load action time of 60 seconds.

2.3.2 Preparation of test specimens.

The warm mix agent uses a surface active agent produced by a company in Chengdu. The asphalt mixture has a gradation of AC-13, and the mineral aggregate gradation is shown in Table 3. The oil stone ratio is 4.9%.

Table 3. Mix proportions of AC-13 rubber powder modified asphalt mixture

Mesh size (mm)	16	13.2	9.5	4.75	2.36	1.18	0.60	0.30	0.15	0.075
Passing rate (%)	99.8	94.1	79.4	43.3	33.8	24.4	17.4	11.5	7.5	5.3

Referring to relevant literature, a compaction temperature of 140 °C is used for warm mix asphalt mixture, and a compaction temperature of 165 °C is used for hot mix asphalt mixture. According to the specifications, Marshall specimens are formed indoors.

2.3.3 Evaluation Test of High and Low Temperature Performance of Warm Mix Rubber Powder Modified Asphalt Mixture.

(1) The triaxial repeated creep test was conducted using a UTM-100 material testing machine at a temperature of 60 ℃ and a bias stress of 0.7MPa. The test was loaded using a half sine wave method of loading for 0.1s and unloading for 0.9s. When the strain reached 5000 microstrain or the number of cycles reached 10000, the test stopped.

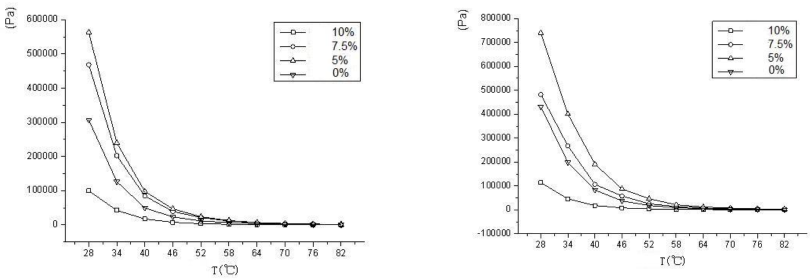
(2) According to JTG E20-2011 "Test Specification for Asphalt and Asphalt Mixtures in Highway Engineering", the low temperature bending test of the small beam of asphalt mixture is designed. The rubber powder modified asphalt mixture used in the test is obtained by soaking the rubber powder asphalt in a certain concentration of salt water for a corresponding time. The salt water conditions are achieved by adding a certain amount of NaCl to a certain amount of water, with salt concentrations of 0%, 5%, 10%, and 15%, respectively. The current small beam bending test is divided into two modes: multi-point loading and single point loading. In this experiment, the single point loading mode is used, and the small beam specimen is loaded to failure at a temperature of -10 ℃ and a loading rate of 50mm/min. Calculate the bending tensile strength RB and maximum bending tensile strain according to the specifications ε B. The calculation of bending stiffness modulus SB and the calculation of strain energy density refer to the material damage criterion.

3 Performance Analysis of Warm Mix Rubber Powder Modified Asphalt

3.1 High temperature performance

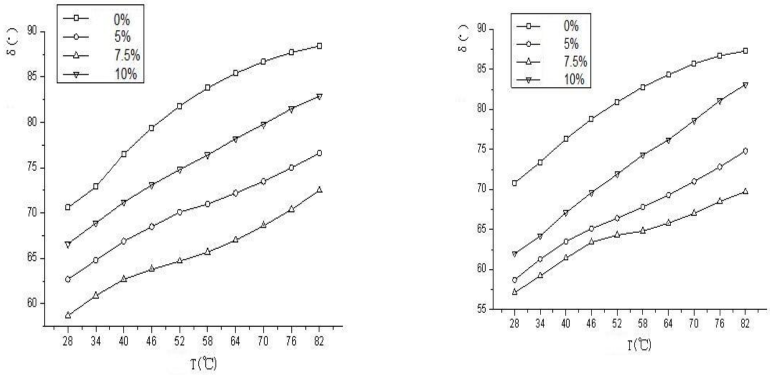
3.1.1 Temperature scanning.

During the experiment, temperature scanning was performed on the prepared 40 mesh warm mix rubber powder modified asphalt (CR40) and 80 mesh warm mix rubber powder modified asphalt (CR80) under a load frequency of 10 rad/s, and the corresponding data were obtained. The complex shear modulus G * and phase angle were calculated δ Plot the variation pattern with temperature as Figure 1.



(a)Relationship between 40 mesh temperature and complex modulus

(b)Relationship between 80 mesh temperature and complex modulus



(c)Relationship between 40 mesh temperature and phase angle

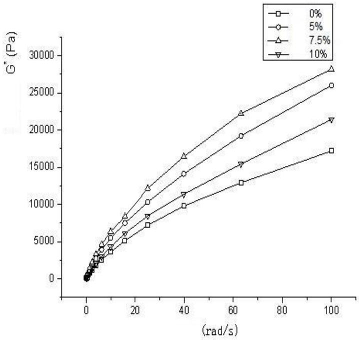
(d)Relationship between 80 mesh temperature and phase angle

Fig. 1. The variation of complex shear modulus and phase angle with temperature

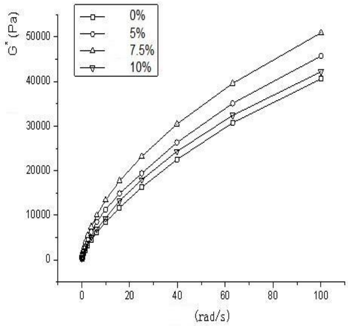
From Figure 1, it can be seen that the larger the fineness of warm mixed rubber powder modified asphalt, the better its high-temperature stability. The complex modulus of warm mixed rubber powder modified asphalt decreases with the increase of temperature, while the phase angle increases with the increase of temperature, Within a certain dosage range, the warm mix agent can increase the complex modulus of rubber powder modified asphalt, but the increase gradually decreases with the increase of dosage. When the dosage reaches 10%, it will cause the complex modulus to be lower than that without the addition of warm mix. It indicates that within the appropriate dosage range, the warm mixing agent has a beneficial effect on the high-temperature deformation resistance and recovery ability of rubber powder modified asphalt.

3.1.2 Frequency scanning.

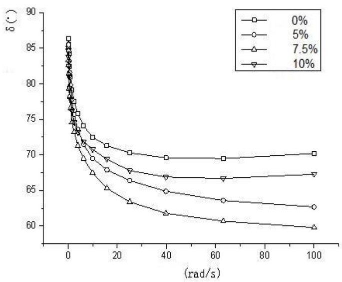
During the experiment, 40 mesh warm mix rubber powder modified asphalt (CR40) and 80 mesh warm mix rubber powder modified asphalt (CR80) were scanned at a frequency of 0.1rad/s-100rad/s at a scanning temperature of 64 ℃ to obtain data and plot the complex shear modulus G * and phase angle δ With frequency ω The change curve of is shown in Figure 2.



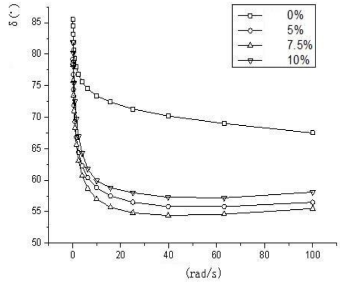
(a)Relationship between 40 mesh scanning frequency and complex modulus



(b)Relationship between 80 mesh scanning frequency and complex modulus



(c)Relationship between 40 mesh temperature and phase angle



(d)Relationship between 80 mesh temperature and phase angle

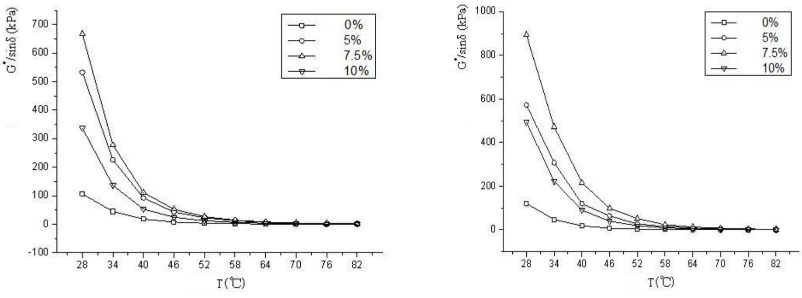
Fig. 2. Variation of complex shear modulus and phase angle with frequency

From Figure 2, it can be seen that the complex modulus of warm mixed rubber powder modified asphalt increases with the increase of scanning frequency, while the phase angle decreases with the increase of scanning frequency. Within a certain dosage range, the warm mixing agent can increase the complex modulus of rubber powder modified asphalt, and the increase gradually increases with the increase of dosage. However, when the dosage reaches 10%, the increase in complex modulus will actually decrease. It indicates that within the appropriate dosage range, the warm mixing agent has a beneficial effect on the high-temperature deformation resistance of rubber powder modified asphalt.

3.1.3 Rutting factor.

In the specification of "Superpave", the rutting factor (G */sin) is proposed δ), It is used to characterize the ability of asphalt binder to resist high-temperature deformation. The larger the rutting factor, the stronger the ability of asphalt to resist high-temperature deformation, and the better its high-temperature performance.

Through a 10 rad/s temperature scanning test, corresponding data were obtained and the curve of the rutting factor of warm mixed modified asphalt with temperature was plotted, as shown in Figure 3.



(a)Relationship between 40 mesh temperature and rutting factor

(b)Relationship between 80 mesh temperature and rutting factor

Fig. 3. Changes in Rutting Factor with Temperature

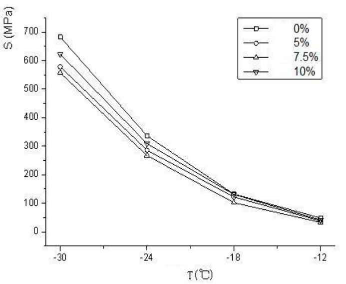
From Figure 3, it can be seen that the rutting factor of warm mixed rubber powder modified asphalt shows a decreasing trend with increasing temperature. Within a certain dosage range, the warm mixing agent can increase the rutting factor of rubber powder modified asphalt, and its amplitude gradually increases with the increase of dosage. However, when the dosage reaches 10%, the increase in rutting factor will actually decrease. It indicates that within the appropriate dosage range, the warm mixing agent has a beneficial effect on the high-temperature deformation resistance of rubber powder modified asphalt.

3.2 Low temperature performance

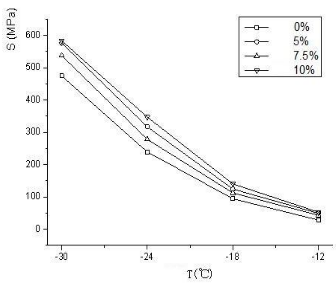
3.2.1 Creep stiffness modulus S and creep rate m.

The determination of creep stiffness modulus S and creep rate m is based on the bending beam creep principle, which is used to evaluate the low-temperature crack resistance of asphalt. The value of m is the tangent slope of the curve between creep stiffness modulus and time. The smaller the creep stiffness S, the greater the creep rate m value, and the better the low-temperature crack resistance of asphalt.

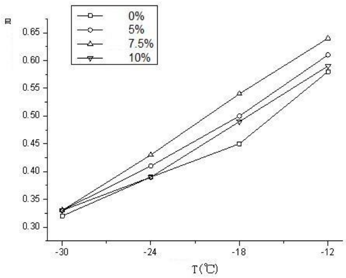
The creep stiffness modulus S and creep stiffness m of warm mixed rubber powder modified asphalt were measured using BBR test at four temperatures: -12 ℃, -18 ℃, -24 ℃, and -30 ℃. The data were obtained and a line graph of the creep stiffness modulus S and creep rate m with temperature was plotted, as shown in Figure 4.



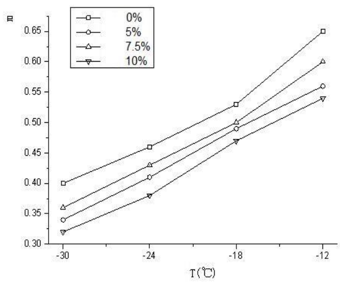
(a)Relationship between 40 mesh temperature and creep stiffness modulus



(b)Relationship between 80 mesh temperature and creep stiffness modulus



(c)Relationship between 40 mesh temperature and creep stiffness rate



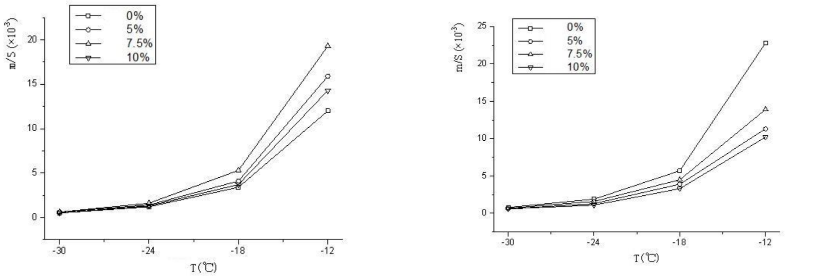
(d)Relationship between 80 mesh temperature and creep stiffness rate

Fig. 4. The variation of creep stiffness modulus and creep rate with temperature

Figure 4 shows that the larger the fineness of the modified asphalt with warm mix rubber powder, the better its low-temperature deformation ability. The creep stiffness modulus of warm mixed rubber powder modified asphalt decreases with the increase of temperature, while the creep rate increases with the increase of temperature. Within a certain dosage range, the warm mix agent can reduce the creep stiffness modulus of rubber powder modified asphalt, and the decrease gradually increases with the increase of dosage. However, when the dosage reaches 10%, the decrease in creep stiffness modulus will actually decrease. It indicates that within the appropriate dosage range, the warm mixing agent can help improve the low-temperature deformation ability and low-temperature crack resistance of rubber powder modified asphalt.

3.2.2 Low temperature crack resistance performance indicators.

The low-temperature crack resistance performance of asphalt can also be analyzed using low-temperature crack resistance performance indicators. The low-temperature crack resistance performance indicator is the ratio of creep rate m and creep stiffness modulus S. The larger the m/S value, the better the low-temperature performance. Obtain data and draw a line graph of m/S as a function of temperature, as shown in Figure 5.



(a)The relationship between 40 mesh temperature and m/S

(b)The relationship between 80 mesh temperature and m/S

Fig. 5. Variation of m/S with temperature

4 Main conclusions

This article combines different dosages of warm mix agents with rubber powder to prepare warm mix rubber powder composite modified asphalt. A asphalt mixture with a gradation of AC-13 and an oil stone ratio of 4.9% is used to study the high-temperature and low-temperature performance of warm mix rubber powder composite modified asphalt and asphalt mixture through dynamic shear rheological test (DSR), bending beam rheological test (BBR), triaxial repeated creep test, and small beam bending test. The results are summarized as follows:

(1) The larger the fineness of warm mixed rubber powder modified asphalt, the better its high-temperature and low-temperature performance. The increase in temperature will lead to an increase in the low-temperature cracking resistance of modified asphalt, but a decrease in high-temperature stability.

(2) The addition of warm mixing agent has a favorable positive effect on the high-temperature and low-temperature performance of rubber powder modified asphalt. But when the temperature is too high (greater than 60 °C) or the frequency is low (less than 10rad/s), the improvement effect of the warm mixing agent is no longer significant. After comparative analysis, adding a 7.5% dosage of warm mix asphalt to rubber powder modified asphalt can prepare warm mix rubber powder modified asphalt with relatively good high-temperature and low-temperature performance. Therefore, this dosage is recommended.

References

1. SANTUCCI L. Rubber roads: waste tires find a home[J]. Pavement Technology pdate, 2009,1(2):2-5.
2. PERALTA E JF. Micro-analysis of physicochemical interaction between the components of asphalt mixtures with rubber [DJ. Ames: Iowa State University , 2013.
3. PWS INC. Green book, Standard specifications for public works construction[S]. The City of San Diego,2015.

4. Lu Enguang, Yang Qun. Research on the Performance and Engineering Application of Rubber Asphalt Mixture [J]. Shanghai Highway, 2020 (04): 71-74+150.
5. Huang Peng, Lv Weimin, Zhang Fuqing, Wei Xiaojing. Research on the performance and process technology of rubber powder modified asphalt mixture [J]. Journal of China Highway Engineering, 2001 (S1): 6-9.
6. Wang Lan, Shan Mingyu, Chang Chunqing. Study on the low-temperature crack resistance of warm mixed rubber powder modified asphalt slurry under aging based on DIC technology [J]. Journal of China Highway Engineering, 2020,33 (10): 265-275.
7. Huang Bin, Ma Liping, Xu Wenjuan. Research progress on modified asphalt [J]. Materials Introduction, 2010,24 (1): 137-141.
8. Chen Wensheng. Preparation of stable rubber powder/SBS composite modified asphalt and study on its mixture performance [J]. New Building Materials, 2020,47 (10): 103-107.
9. Ma Feng, Dai Jiasheng, Fu Zhen, Li Chen, Wang Mengmeng, Dong Wenhao. Research on the Road Performance of SBS Modified Asphalt [J]. Journal of Guangxi University (Natural Science Edition), 2020,45 (01): 38-45.
10. Yang Jun. Research on anti-aging ability of high temperature and low temperature performance of polyphosphoric acid/SBR composite modified asphalt [J]. Zhongwai Highway, 2019, 39 (06): 249-254.
11. Cui Xiaopan, Cong Peiliang, Ye Huan, et al. Study on the Performance of Different Fiber Modified Asphalt [J]. New Building Materials, 2015,42 (2): 21-24.
12. Liu Zhongming. Study on the Rheological Properties and Microscopic Mechanism of Warm Mix Rubber Asphalt [J]. New Building Materials, 2020,47 (12): 163-167+172.