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Comparative Research on the Performance Grading of RPRS Modified Asphalt

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Abstract: This paper introduces a new preparation method of RPRS modified asphalt. Three kinds of matrix asphalts are modified through this method. Afterwards, the basic performances of RPRS modified asphalt are evaluated from the perspectives of Penetration, Ductility and Softening Point. Comparative study of performance grading of asphalts is performed through asphalt flexural creep stiffness test and asphalt rheological test. The experimental results show that RPRS modifier has good modification effects on these three asphalts, indicating that RPRS has universal applicability in different kinds of matrix asphalts. The DSR of RPRS modified asphalt can meet the requirements of all technical indicators of RPRS modified asphalt. The lowest temperature of RPRS modified asphalt is equal to the matrix asphalt; its performance at low temperature is the same to matrix asphalt. The highest temperature of RPRS modified asphalt is higher than that of the matrix asphalt by 2 to 3 degrees, and higher than SBS modified asphalt by 1 to 2 grades. The high temperature performances of RPRS modified asphalt are much better than the performances of matrix asphalt and SBS modified asphalt.

1. Introduction

RPRS modified asphalt is a kind of rubber resin modified asphalt. Because of the complicated production technology, it is not widely used in the world. [1] This paper studies the performances of a new type of self-made RPRS modified asphalt, and solve the problem of complicated production process. The rubber resin is pretreated in a special way, and mixed with a small amount of SBR. After the mechanical mixture of modifiers and asphalt, the RPRS modified asphalt is obtained [2, 3, 4]. It is a simple way to produce modified asphalt. It does not need high-speed shearing, and the finished products are not easy to segregate. It can use waste recycled rubber as raw materials; the production cost is lower than that of SBS modified asphalt. Thus, this method has application prospects [5, 6].

In this paper, a large number of experiments are carried out to test the performances of RPRS modified asphalt. In order to verify the applicability of RPRS modified asphalt, three kinds of asphalts are modified by RPRS. The basic performances of modified asphalts are analyzed comparatively; the PG Test is carried out to analyze the different performance indexes of RPRS modified asphalt compared with the matrix asphalt and SBS modified asphalt, and to provide certain technical parameters for the application this modification method.

2. Test Parameters

2.1 Sample preparation

The RPRS composite modified method is used to modify different asphalts; the modification effects are evaluated. Comparative analysis is carried out mainly based on three kinds of matrix asphalts and a kind of self-made SBS modified asphalt (I-C). The three kinds of matrix asphalts are: Maoming 70# A-grade petroleum asphalt (MM), Esso 70# A-grade petroleum asphalt (ESSO), Donghai 70# A-grade petroleum asphalt (DH).

The production method of RPRS composite modified asphalt goes as following. (1) The purchased waste plastic material is washed and crushed to get recycled plastics. (2) The recycled plastic is heated up to 470℃, then keeping at this temperature for 20 minutes without air. The recycling PEW is obtained after the material is cooled. (3) The recycling PEW is heated up to 260℃ and added with CRM. After stirring for 1 hour, the material is cooled and ultimately gets PR. The RPRS modifier is obtained after compounding PR with SBR. [7]

Above three kinds of asphalt are modified with RPRS modifier. In Table 1, three main kinds of RPRS modified asphalts and four kinds of contrasting asphalts are listed.

2.2 Test parameters

The CVOR-ADS type Dynamic Shear Rheometer made by Malvern and the TE-BBR type Bending Beam Rheometer produced by Cannon are used to test the rheological properties of asphalts at high and low temperature. Dynamic Shear Rheometer (DSR) is used to measue the performances of asphalts at high temperature, and to evaluate the performances of asphalts according to their rutting factors under different aging conditions. [8,9,10] Bending Beam Rheometer (BBR) is used to meaure the strength of asphalt beams at low temperature under the influence of creep load. [11] Creep load is used to simulate the gradual accumulation of stress in the pavement along with the lowering temperature. The computer data acquisition system is adopted to automatically acquire and calculate the creep stiffness S and the creep rate m.

3. Analysis of Experimental Results

Performance grading test. The dynamic rheological tests of matrix asphalt, RPRS modified asphalt, SBS modified asphalt and RTFOT remaining asphalt are carried out. The beginning temperature of the matrix asphalt is 58℃; the beginning temperature of the modified asphalt is 64℃. The highest temperature of matrix asphalt when $G^*/\sin\delta$(kPa) ≥1.0kPa is set as THE high temperature PG of matrix asphalt; the highest temperature of RTFOT remaining asphalt when $G^*/\sin\delta$(kPa)≥2.2kPa is selected as the high temperature PG of RTFOT remaining asphalt. After comparision, the lower figure will be taken as the high temperature PG.

As it can be seen from Figure 1, the $G^*/\sin\delta$(kPa) of all kinds of asphalts decreases with the rising test temperature, which is consistent with the rule of viscoelasticity of asphalts. Moreover, with the chaning temperature, the decreasing trend of $G^*/\sin\delta$(kPa) is different from the trend of penetration. The needle penetration classification system holds that; the penetration of asphalt has a linear relationship with temperature. While the relationship between $G^*/\sin\delta$(kPa) of asphalt and temperature is non-linear. Because of the concave curve character of parabola, the $G^*/\sin\delta$(kPa) of asphalt has great value at the beginning of the test, and decreases obviously with the rising temperature. When the temperature is relativley higher, the decscending range of $G^*/\sin\delta$(kPa) decreases. From the SHRP standard of $G^*/\sin\delta$(kPa) ≥1.0kPa it can be seen, all original asphalts of RPRS modified asphalts reach the high temperature PG at 82 degrees; SBS modified asphalt reaches at 76 degrees. The matrix asphalts of MM, DH and ESSO reach high temperature PG at 70 ℃, 64 ℃ and 70℃ respectively. It means that the high temperature PG of orignal asphalt of the SBS modified asphalt is higher than the high temperature PG of three kinds of matrix asphalts by about one grade; the high temperature PG of RPRS modified asphalt is higher than that of SBS modified asphalt by one grade, and higher than those of matrix asphalts by two grades.

As it can be seen from Figure 2, the $G^*/\sin\delta$(kPa) of all kinds of remaining asphalts after RTFOT decreases with the rising test temperature, which is consistent with the rule of viscoelasticity of asphalt. Moreover, the decreasing trend of $G^*/\sin\delta$(kPa) is different from the penetration trend of asphalt with the chaning temperature. The needle penetration classification system holds that; the penetration of asphalt has a linear relationship with the temperature. While the relationship between $G^*/\sin\delta$(kPa) of asphalt and temperature is non-linear. By drawing regression curves of $G^*/\sin\delta$(kPa) at different temperatures, the regression laws are be summarized in Table 2 and Table 3. The relationship between $G^*/\sin\delta$(kPa) and temperature can be drawn as a typical parabolic curve with good correlation. Because of the concave curve character of parabola, the $G^*/\sin\delta$(kPa) of asphalts has great values at the beginning of the test, and decreases obviously with the rising temperature.

When the temperature is relativley higher, the decscending range of G*/sinδ(kPa) also decreases.

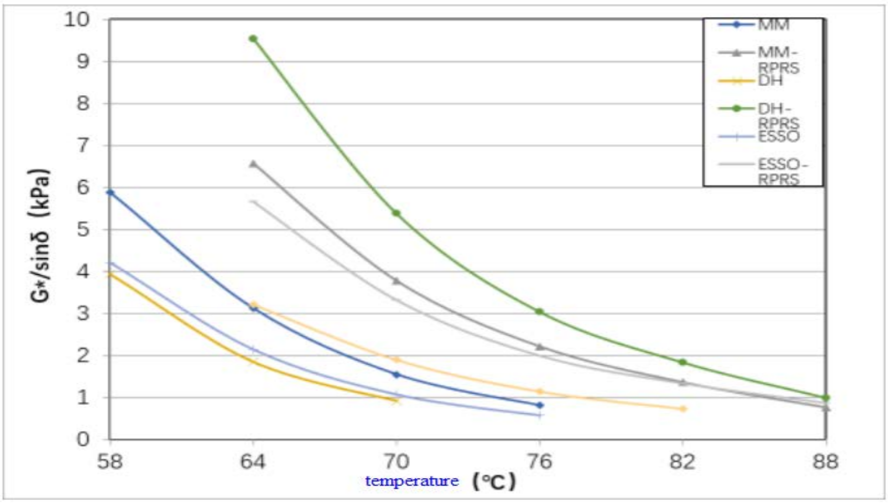

Figure 1. The results of dynamic rheological test of various asphalts

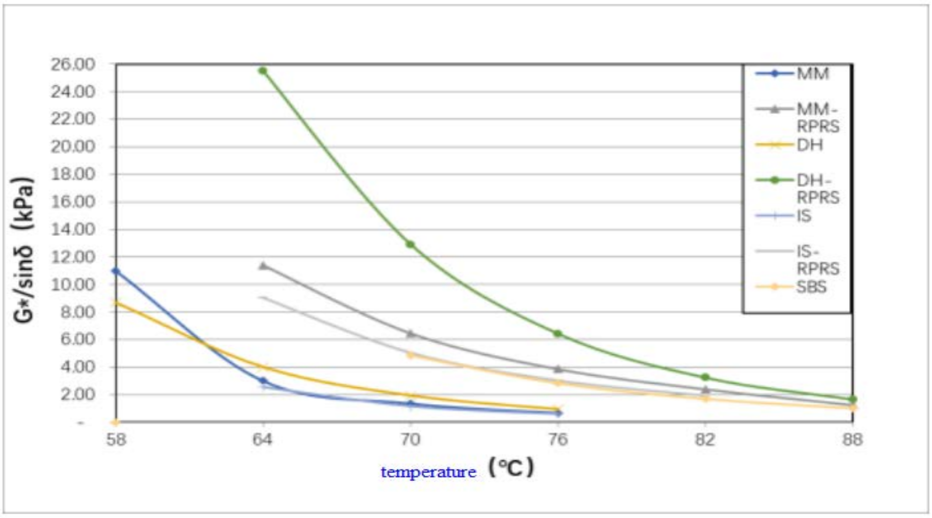

Figure 2. The results of dynamic rheological test of remaining asphalts after RTFOT

As far as one single RFTOF remaining asphalt is concerned, the values of G*/sinδ(kPa) of RPRS modified asphalt and SBS modified asphalt are much higher those of the matrix asphalts at the beginning of test. With the rising temperature, the descending ranges of RPRS modified asphalt and SBS modified asphalt are bigger than those of the matrix asphalts. From the SHRP standard of G*/sinδ(kPa)≥2.2 kPa it can be seen, the high temperature PG of several asphalts decreases. For instance, the high temperature PG of MM and ESSO drops from 70 degrees to 64 degrees; the high temperature PG of MM3283, ESSO3283 and ESSO4283 decreases from 82 degrees to 76 degrees; the high temperature PG of SBS modified asphalt decreases from 76 degrees to 70 degrees. This shows that the performances of some asphalts degrade after aging in rotated film aging oven.

The high temperature classification results of various asphalts are shown in Table 1. The SHRP specification stipulates that the lower figure in the high temperature PG values of the matrix asphalt and the RTFOT remaining asphalt should be selected as the final high temperature PG. From Table 1 it can be seen, the high temperature PG of several asphalt decreases. For instance, the high temperature PG of MM and ESSO drops from 70 degrees to 64 degrees; the high temperature PG of MM3283, ESSO3283 and ESSO4283 decreases from 82 degrees to 76 degrees; the high temperature PG of SBS modified asphalt decreases from 76 degrees to 70 degrees. According to above principle, the final high temperature PG of various kinds of asphalts is determined. Generally speaking, the high temperature PG of RPRS modified asphalt is higher than that of the SBS modified asphalt by two grades, and higher than those of the three matrix asphalts by three grades.

Table 1 High temperature PG classification of various asphalts

Type of asphalt	Matrix asphalt		RTFOT remaining asphalt		High temperature PG
	Test temperature	Test value (kpa)	Test temperature (centigrade)	Test value	
MM	70	1.542	64	3.006	PG64
MM-RPRS	82	1.360	82	2.403	PG82
DH	64	1.845	64	4.009	PG64
DH-RPRS	82	1.830	82	3.236	PG82
ESSO	70	1.070	64	2.537	PG64
ESSO-RPRS	82	1.327	76	3.005	PG76
SBS	76	1.142	70	2.832	PG70

RTFOT test for all kinds of asphalts is carried out before PAV test. After that, asphalt beams are tested in the flexural creep stiffness test at -6℃ and -12℃. The results are shown in Table 2.

RPRS contains SBR components. From the flexural creep stiffness tests, it can be concluded that SBR greatly improves the Ductility of asphalt at the temperature of 5℃, 10℃ and 15℃, but the improvement at the temperature of -12℃ is not significant.

Through above tests, it can be concluded that the low temperature PG of three kinds of matrix asphalts, MM, DH and ESSO is -16℃; the low temperature PG of six RPRS modified asphalt is -16 ℃; the low temperature PG of SBS modified asphalt is -22℃. SBS modified asphalt has obvious advantages in low temperature performances.

Table 2 Test Data on the Bending Creep Stiffness of Various Asphalts

Type of asphalt	Test temperature (-6℃)		Test temperature (-12℃)	
	bending creep stiffness (MPa)	creep slope (m)	bending creep stiffness (MPa)	creep slope (m)
MM	74.2	0.418	330	0.286
MM-RPRS	105	0.346	311	0.261
DH	68.4	0.437	243	0.266
DH-RPRS	104	0.312	283	0.257
ESSO	91.2	0.422	348	0.280
ESSO-RPRS	139	0.381	435	0.260
SBS	37.1	0.472	169	0.345

Table 3 Summary of Performance Grading Results of Various Asphalts

Type of asphalt	Matrix DSR		RTFOT Remaining DSR		PAV Remaining DSR		PG indicator
	Test temperature (centigrade)	Test value (kpa)	Test temperature (centigrade)	Test value (kpa)	Test temperature (centigrade)	**Test value (kpa)**	
MM	70	1.542	64	3.006	28	174.4	PG64-16
MM-RPRS	82	1.360	82	2.403	37	1390	PG82-16
DH	64	1.845	64	4.009	25	4075	PG64-16
DH-RPRS	82	1.830	82	3.236	37	1316	PG82-16
ESSO	70	1.070	64	2.537	28	476.6	PG64-16
ESSO-RPRS	82	13.27	76	3.005	34	1342	PG76-16
SBS	76	1.142	70	2.832	25	239.9	PG70-22

According to the high temperature PG and low temperature PG of all kinds of asphalts, the DSR test of all kinds of asphalt after RTFOT and PAV is carried out at the temperature of (high temperature PG+ low temperature PG) /2+4 ℃, so as to measure the fatigue resistance of all kinds of asphalt. The requirements of SHRP stipulate that $G^*/\sin\delta \leq 5000$kPa.

It can be seen from Table 3, at the temperature of fatigue, the shear modulus of asphalt after RTFOT and PAV can meet $G^*/\sin\delta \leq 5000$kPa.

Table 3 lists the different performance grading of asphalts. It can be found that 1) All the DSR of RPRS modified asphalt can meet the requirements of technical index. 2) The lowest temperature of RPRS modified asphalt is equal with the lowest temperature of matrix asphalts; its performances at low temperature are the same with matrix asphalts. 3) The highest temperature of RPRS modified asphalt is higher than the highest temperature of matrix asphalts by 2 to 3 degrees, and higher than SBS modified asphalt by 1 to 2 grades. The high temperature performances of RPRS modified asphalt are much better than those of matrix asphalts and SBS modified asphalt.

4. Conclusion

All the DSR of RPRS modified asphalt can meet the requirements of technical index.

The lowest temperature of RPRS modified asphalt is equal with the lowest temperature of matrix asphalts; its performances at low temperature are the same with matrix asphalts. The highest temperature of RPRS modified asphalt is higher than the highest temperature of matrix asphalts by 2 to 3 degrees, and higher than SBS modified asphalt by 1 to 2 grades. The high temperature performances of RPRS modified asphalt are much better than those of matrix asphalts and SBS modified asphalt.

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