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Study on high temperature performance of coal based modified asphalt mixture

Quanjun Shen[1], Liang Fan[2] , Yaohui Yang[1], Hui Wei[2], Haifeng Xu[3] , Anzhen Cao[3] and Yan Zhang[2,*]

[1]Shandong Hi-Speed Group Co., Ltd. Innovation Research Institute, Shandong, China

[2]Shandong transportation research Institute, Shandong, China

[3]Shandong jianzhu university, Shandong, China

*Corresponding author e-mail: nongdazhangyan@163.com

Abstract. SHA, as a solid waste from direct coal liquefaction, has a certain application prospect. Based on the original concept and process of coal based clean asphalt preparation, this paper studies the performance of SHA coal based modified asphalt mixture, and draws the following conclusions: (1) SHA modified asphalt has the characteristics of hard asphalt (2) Compared with traditional SBS modified asphalt mixture, SHA modified asphalt mixture has good high temperature performance (3) SHA modified asphalt mixture has small rutting rolling depth, which can improve the rutting resistance of asphalt pavement.

Keywords: Coal based modified asphalt; Asphalt pavement; High temperature stability; Ruts; Rolling depth.

1. Introduction

Based on the research and analysis[1,2], it is feasible to use coal direct liquefaction residue as modifier in asphalt, and it can improve the high-temperature performance of asphalt to a certain extent. However, due to the difference between the standard system of the transportation industry and the coal chemical industry, the technical evaluation is not perfect. Only the basic performance indicators of SHA modified asphalt are studied, and the road performance of SHA modified asphalt and modified asphalt mixture is not systematically studied.

Therefore, based on the above research and performance analysis of coal based asphalt, this paper uses conventional means to evaluate the high temperature performance of SHA modified asphalt mixture, which has the most significant impact [3], so as to further carry out the performance characterization of SHA modified asphalt mixture and the evaluation of modification effect, provide reference data and optimization measures for its large-scale application, so as to achieve the double improvement of solid waste resource utilization and pavement quality.

2. Selection of raw materials and grading

2.1 SHA

The coal based super hard asphalt used in the test is from Shenhua Group Coal to Oil Co., Ltd., which is black flake, shiny on the surface, hard and brittle at room temperature, and easy to crush. During the processing, in order to improve the compatibility of SHA and petroleum asphalt and reduce the processing difficulty, sheet SHA needs to be mechanically crushed. At the same time, the density of SHA is larger than that of petroleum asphalt, which is equivalent to that of TLA.

Figure 1. SHA

The basic index test results and component contents of SHA are listed in the following table:

Table 1. SHA index and component content

Index	Soft point (℃)	Density 25℃	C/%	H/%	N/%	S/%	C/H
SHA	175	1.49	78.35	4.465	0.846	2.112	17.52

2.2 Raw material selection

The aggregate is limestone peculiar to Shandong, and the mineral powder is the fine powder ground by limestone in Shandong. The indicators of aggregate, mineral powder and asphalt shall comply with the relevant provisions of Technical Specifications for Construction of Highway Asphalt Pavement (JTG F40-2004). The following figure shows the relevant technical indicators of the raw materials used:

Table 2. Technical indexes of coarse aggregate

Index	unit	requirements	test result	test method
Crushing value of stone	%	≤26	22.3	T0316
Los Angeles abrasion loss	%	≤28	19.4	T0317
Soundness	%	≤12	5.2	T0314
Water absorption	%	≤2.0	0.3	T0304
Content of needle and flake particles	%	≤15	4.8	T0312
Soft particle content	%	≤3	0.4	T0320

Table 3. Technical indexes of fine aggregate

Index	unit	requirements	test result	test method
Apparent relative density	t/m3	≥2.500	2.732	T 0328
Sand equivalent	%	≥60	61	T 0334
Angularity (flow time)	s	≥30	36	T 0345

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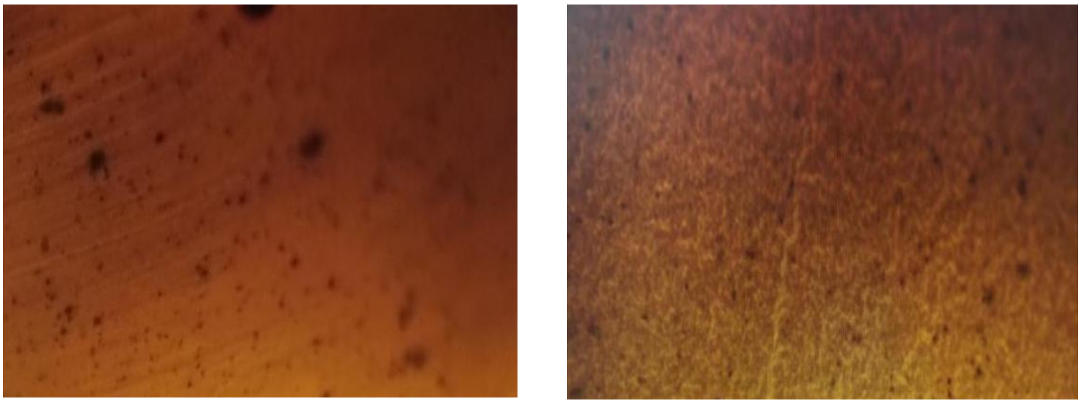
Table 4. Technical requirements for mineral powder

Index		unit	requirements	test method
Apparent relative density		t/m3	⩾2.50	T 0352
water content		%	⩽1	Drying method
Grain size range	<0.6mm	%	100	T 0351
	<0.15mm	%	90～100	
	<0.075mm	%	75～100	
appearance		-	No agglomeration	
Hydrophilicity coefficient		-	<1	T 0353
Plasticity index		%	<4	T 0354
Heating stability		-	Measured records	T 0355

The main research object of coal based asphalt is the composite asphalt studied in this project. Aiming at the asphalt state after mixing, microscopic analysis is conducted with fluorescence microscope, as shown in the figure:



(a) (b)

Figure 2. Micrograph of compound asphalt

The above is the fluorescence microscopic state of SHA asphalt at different multiples. The black spots shown in the picture are the state and distribution of SHA. It can be seen that the distribution of SHA is relatively uniform, but its melting ability is relatively poor with that of asphalt. The segregation test shows that the asphalt mixed with SHA is prone to segregation, that is, SHA sinks to the bottom. Therefore, if the asphalt is stored for a relatively long time, Considering that coal based asphalt is prone to large segregation, resulting in uneven performance of the binder in the mixture, which cannot ensure the accuracy of the test, it can be heated and fully mixed before use to ensure the uniformity of coal based asphalt.

2.3 Grading selection and determination

Based on the existing pavement structure and materials, this paper uses the AC-20 type grading of the middle surface course as an example, according to the conventional mix design and test analysis, to verify the road performance of the asphalt mixture under this grading.

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Gradation is determined through aggregate screening and Marshall grading design. During the test, specific temperatures such as heating, mixing and compaction of aggregate, asphalt and mixture are required. Relevant studies can be referred to, and the viscosity temperature curve method is used to analyze the rotational viscosity of SHA coal based composite asphalt, and the temperature during the production of mixture is determined based on engineering experience, as shown in the following table:

Table 5. Material heating temperature

Materials and processes	Aggregate	asphalt	Mixing	compaction
Temperature (℃)	180~190	180~175	175~185	120~140

Through the analysis and evaluation of mixture volume index and road use index, the final gradation is obtained as shown in the figure:

Table 6. Passing percentage of AC-20 grading

type	Percentage passing the following sieve openings (mm),%											
	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
upper limit	100	100	92	80	72	56	44	33	24	17	13	7
lower limit	100	90	78	62	50	26	16	12	8	5	4	3
Mediangradation	100	95	85	71	61	41	30	22.5	16	11	8.5	5
Composite gradation	100	91.7	82.7	73.7	63	43.7	26.8	19.6	13.7	9.3	8	5.5

Using different asphalt dosage, determine the best asphalt dosage for the mixture with determined gradation. Combined with the comprehensive analysis of test data and engineering experience, determine the best asphalt dosage under this gradation is 4.4%.

3. Performance and index verification

In this paper, the high-temperature stability of coal based modified asphalt mixture is studied, and the rutting test is conducted under standard test conditions, that is, under the condition of 60 ℃ temperature and 0.7MPa load, 42 times of reciprocating rolling per minute, totaling 60 minutes of rolling. Firstly, the rut test piece is molded, and the size of the test piece is 300mm * 300mm * 50mm, as shown in the figure:

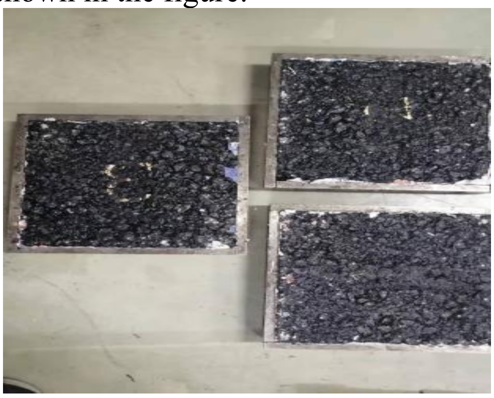

Figure 3. Rut test piece

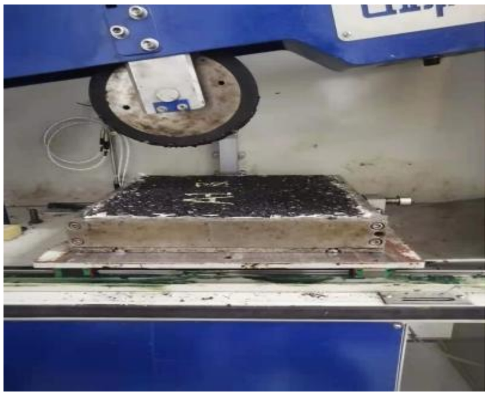

Figure 4.Wheel milling process

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Monitor and record the test temperature, time and rut rolling depth during rolling, sort out and analyze the test data after final rolling, and the calculation formula of dynamic stability (DS) is as follows:

$$DS = \frac{(t_2 - t_1) \times N}{d_2 - d_1} \times c_1 \times c_2 \qquad (1)$$

In the formula: DS -- dynamic stability, times/mm

t_1, t_2 -- Rolling time, generally 45min and 60min

d_1、d_2--t_1、t_2Rolling depth corresponding to time

N---1 min rolling times, generally 42

c_1, c_2 -- test coefficient, generally 1.0

Combining the calculation formula of the intermediate dynamic stability (DS) in formula (1), DS and the specific rolling depth are summarized as follows:

Table 7. Dynamic stability and rolling depth

Index	Coal based modification	SBS modification	70#
DS（times/mm）	5250	4500	1260
45minRolling depth（mm）	1.80	2.33	5.09
60minRolling depth（mm）	1.92	2.47	5.59

It can be seen from the table that among the rutting rolling depths under the same grading and different asphalt, the rolling depth of coal based asphalt mixture is the smallest, followed by SBS modified asphalt mixture, and the rolling depth of matrix asphalt mixture is the largest. Compared with the traditional SBS modified asphalt mixture and 70 # matrix asphalt mixture, the coal based composite asphalt mixture has low rolling depth and the highest dynamic stability at high temperature, which can better withstand the rolling of vehicle loads [4] and reduce the occurrence of rutting.

4. Conclusion

In this paper, the road performance of the composite SHA coal based modified asphalt mixture is systematically analyzed, and the AC-20 dense gradation is used as the test gradation. Through the rutting test, the high-temperature stability of the asphalt mixture is tested and studied, and it is concluded that all the indicators of the coal based asphalt mixture meet the requirements of the specification. At the same time, the feasibility of the mixture is verified, the following conclusions are also obtained:

(1) The rutting test shows that the dynamic stability of SHA coal based modified asphalt mixture is higher than that of conventional SBS, that is, the high temperature stability of SHA coal based modified asphalt is good.

(2) Compared with SBS modified asphalt and base asphalt mixture, SHA coal based modified asphalt mixture has the lowest rutting compaction depth, which indicates that SHA coal based modified asphalt mixture has strong rutting resistance and can improve the rutting resistance of asphalt pavement.

(3) The segregation effect of coal based modified asphalt is general, and it should be fully mixed before actual use to ensure the road performance of the mixture.

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