Study on the Effect of Anti-rutting Agent (NRP) on the Performance of Asphalt Mixture

Yantao Liu[1], Xiaoliang Tang[2*]

[1] Hebei Provincial Highway Development Center, Shijiazhuang 050000, China
[2] Guolu Gaoke Engineering Technology Institute Co., Ltd, Beijing 100083, China

*Corresponding author: 498716972@qq.com

Abstract. To improve the high-temperature performance of asphalt mixture and solve the problem of rutting disease in heavy traffic sections under repeated vehicle loads. The NRP anti-rutting agent was added to AC-13 asphalt mixture, and the influence of anti-rutting agent on the high-temperature, low-temperature, and water stability performance of asphalt mixture was analysed. The experimental results show that NRP anti-rutting agent is beneficial for improving the high-temperature performance and water stability of asphalt mixtures. However, the impact of the anti-rutting agent dosage on the high-temperature and water stability of asphalt mixtures is reduced, when the dosage of anti-rutting agent is large (>1%). When the dosage of NRP anti-rutting agent is low (<1%), it is beneficial to improve the low-temperature performance of asphalt mixtures, but when the dosage of anti-rutting agent is high (>1%), it has an adverse effect on the low-temperature performance of asphalt mixture. Based on AC-13 asphalt mixture, the optimal dosage of NRP anti-rutting agent is 1% (mass of the asphalt mixture).

Keywords: asphalt pavement; asphalt mixture; anti-rutting agent; high-temperature performance

1 Introduction

With the development economy, road traffic has significantly increased and the problem of vehicle overloading has gradually emerged. [1] In addition, due to the gradual rise of global temperature and frequent occurrence of extreme high temperature, the problem of rutting on asphalt pavement is becoming increasingly serious, especially in special sections such as long longitudinal slope, level crossing, traffic signal intersection, and bus stop. [2] In recent years, asphalt mixture anti-rutting agents have become a research focus, and some research results have been achieved. [2,3] Anti-rutting agent is an asphalt mixture additive composed of various polymer composites, mainly aimed at improving the anti-rutting performance (high-temperature) of asphalt pavement.

The existing anti-rutting agents are mainly composed of various polymer materials such as rubber powder, plastic, fibre, etc. In practice, some anti-rutting agents did not

Z. Ahmad et al. (eds.), *Proceedings of the 2023 5th International Conference on Structural Seismic and Civil Engineering Research (ICSSCER 2023)*, Atlantis Highlights in Engineering 24,
https://doi.org/10.2991/978-94-6463-312-2_17

significantly improve the asphalt mixture anti-rutting performance (high-temperature resistance). Moreover, some anti-rutting agents overemphasize anti-rutting performance (high-temperature resistance), which seriously affects the low temperature performance of asphalt mixture. [4] Therefore, it is very necessary to develop an anti-rutting agent that can improve the anti-rutting performance (high-temperature resistance) of asphalt mixture, while other performance of asphalt mixture does not decline significantly.

This study proposes a special anti-rutting agent, which combines SBS elastomer modifier with epoxy resin powder to form a "rigid-flexible community" (anti-rutting agent NRP). Through Marshall test, the influence of different anti-rutting agent dosages was analysed on the dynamic stability, bending tensile strain (low-temperature), splitting strength ratio (freeze-thaw) of asphalt mixture.

2 Raw materials and testing methods

2.1 Raw materials

Asphalt.

Asphalt comes from Qinhuangdao China Petroleum Fuel Asphalt Co., Ltd. (70# and A grade), with technical specifications shown in Table 1.

Table 1. Performance of 70# asphalt (A grade).

Test items		Results	Requirements
Penetration (25℃,0.1mm)		72	60~80
Ductility (15℃)/cm		> 100	≥100
Softening point/℃		47.6	≥46
Wax content/%		1.5	≤2
Solubility/%		99.8	≥97.5
Rolling thin film oven test (RTFOT)	Mass loss/%	-0.25	-0.8~0.8
	Penetration ratio (25℃)/%	62.7	≥61
	Ductility (10℃)/cm	11.8	≥8

Anti-rutting agent (NRP).

The test used NRP anti-rutting agent, with technical requirements shown in Table 2, and NRP anti-rutting agent is shown in Figure 1.

Table 2. Technical requirements for NRP anti-rutting agent.

Test items	Requirements	Test methods
Appearance	Uniform particles	—
Particles mass/g	⩽0.03	—
Density/(g/cm^3)	0.9~1.0	GB/T 1033-2008

Melt index(g/10min)	⩽2.0	GB/T 1033-2008
Ash content/%	⩽2.0	T 0614-2011

Fig. 1. NRP anti-rutting agent.

Aggregate and mineral powder.

The aggregate (coarse and fine) and mineral powder used in asphalt mixture meet the technical requirements of the JTG F40. [5]

2.2 Test methods

High-temperature performance test.

The rutting test specimen (300mm×300mm×50mm) was prepared according to the asphalt mixture preparation method of JTG E20 T 0703. The test method (JTG E20 T0719) was used to carry out the rutting test, with a test temperature of 70℃ and a load of 1.0MPa.

Low-temperature performance test.

This study used bending tests to verify the low-temperature performance of asphalt mixture with anti-rutting agent. The specimen size for bending test is 250mm×30mm×35mm. Before the experiment, place the small beam specimen in a constant temperature box with a temperature of -10℃±0.5℃ for 4 hours. The experiment adopted a mid-span loading mode with a loading rate of 50mm/min.

Water stability test.

The residual stability strength ratio and freeze-thaw splitting ratio are used as evaluation indicators for the water stability of asphalt mixture. The T0716 and T0729 (JTG E20) were utilized to perform the immersion Marshall test and freeze-thaw splitting test, respectively.

3 Marshall Mix Design

3.1 AC-13 asphalt mixture gradation design

This experiment used AC-13 asphalt mixture (key sieve size 2.36mm). The AC-13 mineral aggregate's gradation is displayed in Table 3.

Table 3. Gradation of mineral aggregate (AC-13).

Gradation	Percentage passing /%									
	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Lower limit	100	90	68	38	24	15	10	7	5	4
Upper limit	100	100	85	68	50	38	28	20	15	8
Median value	100	95	76.5	53	37	26.5	19	13.5	10	6
Composite value	100	92.4	79.1	53.5	37.6	25.3	17.6	10.2	7.4	6.1

3.2 Determination of the optimal asphalt-aggregate ratio

The Marshall test method was used for the design of asphalt mixture in the study. The optimal asphalt-aggregate ratio for AC-13 asphalt mixture is 4.8%, and Table 4 displays the test results for the AC-13 asphalt mixture.

Table 4. Indicators of AC-13 asphalt mixture.

Test items	Optimal asphalt-aggregate ratio/%	Void rate /%	Saturation/%	Voids in the mineral aggregate/%	Marshall Stability/kN	Flow value/mm
Value	4.8	3.5	75.1	14.1	13.6	3.9

4 Performance evaluation of asphalt mixture

The high-temperature, low-temperature, and water stability performance of asphalt mixtures were evaluated by rutting test (70℃，1.0MPa), low-temperature bending test(-10℃), freeze-thaw splitting test (25℃), and immersion Marshall test (60℃), respectively.

4.1 High temperature performance

The rutting test can effectively reflect the asphalt mixture high-temperature performance. The NRP anti-rutting agent dosage of the rutting test specimens is 0%, 0.4%, 0.7%, 1.0%, 1.3%, and 1.6% (mass of asphalt mixture) respectively. The rutting test uses dynamic stability (DS) as an indicator to evaluate the high-temperature performance of asphalt mixture. The high-temperature performance of asphalt mixture is

evaluated by the rutting test (dynamic stability). The dynamic stability results of different dosage of anti-rutting agent are shown in Table 5.

Table 5. Test results of dynamic stability of asphalt mixture.

Test items	NRP anti-rutting agent dosage/%					
	0	0.4	0.7	1.0	1.3	1.6
Dynamic stability/ (times/mm)	1880	7746	11434	13765	14661	15573

As shown in Table 5, the dynamic stability value of asphalt mixture rapidly increases and then tends to stabilize with the increase of NRP anti-rutting agent. The dynamic stability of asphalt mixture without adding anti-rutting agent is only 1880 times/mm. When the dosage of anti-rutting agent added reaches 1%, the dynamic stability of asphalt mixture is 13765 times/mm, which is 7.32 times higher than that of asphalt mixture (without anti-rutting agent). In addition, the dosage of anti-rutting agent increased from 1% to 1.6%, and the dynamic stability only increased 13.1%. When the dosage of anti-rutting agent exceeded 1%, the impact of the amount of anti-rutting agent on the dynamic stability of asphalt mixtures decreased. The rutting test shows that the best dosage of anti-rutting agent is 1% in asphalt mixture.

4.2 Low-temperature performance

The bending test can effectively evaluate the asphalt mixture low-temperature performance. The NRP anti-rutting agent dosage of the bending test small beam specimen is 0%, 0.4%, 0.7%, 1.0%, 1.3%, and 1.6%, respectively. The results of bending strain with different dosages (anti-rutting agent) are shown in Figure 2.

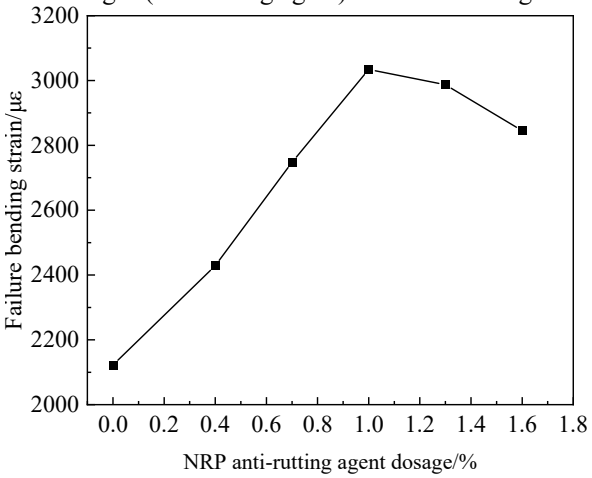

Fig. 2. Results of small beam failure bending strain.

As shown in Figure 2, the failure bending strain of the small beam rapidly increases and gradually decreases with the increase of NRP anti-rutting agent. The failure bend-

ing strain (maximum) occurs, when the anti-rutting agent dosage is 1%. The failure bending strain of the low-temperature small beam (without anti-rutting agent) is 2123με. The failure bending strain of the small beam specimen with 1% anti-rutting agent is 3034με, and the failure bending strain increases 42.9%, compared to the small beam (without anti-rutting agent). In addition, if the anti-rutting agent dosage exceeds 1%, as the dosage of anti-rutting agent continues to increase, the failure bending strain of the small beam shows a slow decreasing trend. When the anti-rutting agent dosage is 1.6%, the failure bending strain of the small beam decreases to 2845με. When the anti-rutting agent dosage is low (<1%), it is beneficial to improve the asphalt mixture low-temperature performance, but when the dosage of anti-rutting agent is high (>1%), it has a bad impact on the asphalt mixture performance (low-temperature). Through the low temperature bending test, it can be seen that the best dosage of anti-rutting agent is 1% in asphalt mixture.

4.3 Water stability

The Marshall (immersion) test and splitting test (freeze-thaw) are both effective in evaluating the water stability of asphalt mixture. The NRP anti-rutting agent dosage of Marshall specimens is 0%, 0.4%, 0.7%, 1.0%, 1.3%, and 1.6%, respectively. Residual stability strength ratio and freeze-thaw splitting ratio are used as indicators for evaluating water stability. The Figure 3 and Figure 4 display the residual stability strength ratio and splitting ratio (freeze-thaw) of asphalt mixture with varying dosages of anti-rutting agent.

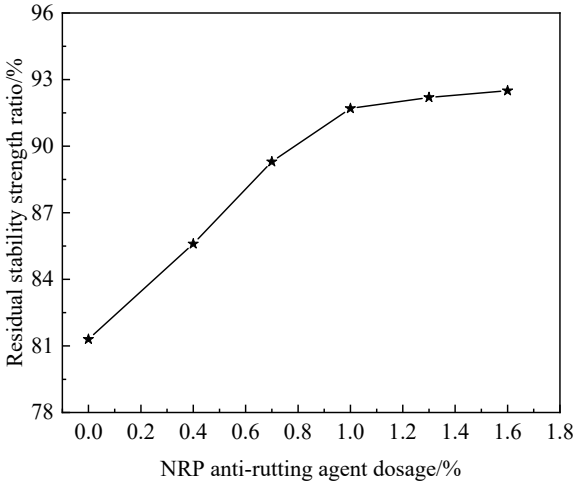

Fig. 3. Residual stability strength ratio of test specimens.

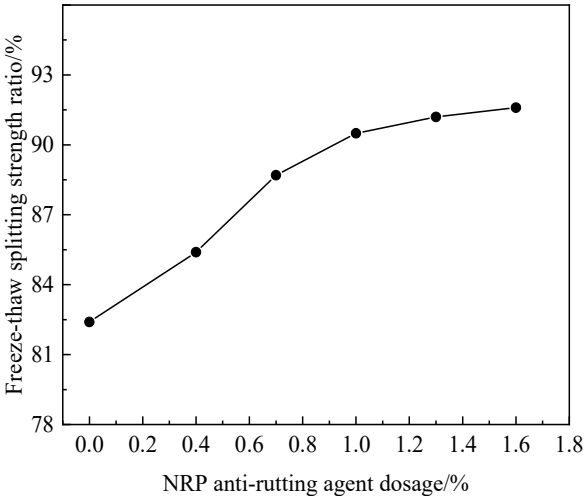

Fig. 4. Freeze-thaw splitting strength ratio of specimens.

As shown in Figure 3, the residual stability strength ratio of asphalt mixture after immersion gradually increases and then tends to stabilize, as the anti-rutting agent dosage increases. The residual stability strength ratio of asphalt mixture without anti-rutting agent is 81.3%. When the anti-rutting agent dosage reaches 1%, the asphalt mixture residual stability strength ratio is 91.7%, which is 12.8% higher than that of asphalt mixture without anti-rutting agent. As shown in Figure 4, the splitting strength ratio (freeze-thaw) of Marshall specimens shows a trend of increasing and then stabilizing with the increase of anti-rutting agent dosage. The change trend of freeze-thaw splitting strength ratio of asphalt mixtures with different anti-rutting agent dosages is basically consistent with the residual stability strength ratio. By adding anti-rutting agent, the strength ratio (immersion residual stability) and splitting ratio (freeze-thaw) of asphalt mixture can be improved, which is beneficial for improving the asphalt mixtures water stability performance. But when the anti-rutting agent dosage is large (>1%), the impact of anti-rutting agent on the water stability of asphalt mixture becomes smaller.

5 Conclusion

(1) NRP anti-rutting agent is beneficial for improving the high-temperature performance of asphalt mixture, but when the dosage of anti-rutting agent is large (>1%), the anti-rutting agent impact on the asphalt mixtures high-temperature performance is reduced.

(2) When the content of NRP anti-rutting agent is low (<1%), it is beneficial to improve the asphalt mixture low-temperature performance, but when the dosage of anti-rutting agent is high (>1%), it has a negative impact on the asphalt mixture low-temperature performance.

(3) NRP anti-rutting agent is beneficial for improving the asphalt mixture water stability performance. When the dosage of anti-rutting agent is large (>1%), the impact of anti-rutting agent on the water stability of asphalt mixture becomes smaller.

(4) The optimal dosage of NRP anti-rutting agent is 1% (mass of asphalt mixture).

References

1. Miao Q, Liu D R, Yang C, et al. (2015) Influence of anti-rutting additive on road performance of AC-16 asphalt mixture. Bulletin of the Chinese Ceramic Society, 34:2839-2844.
2. Song J. (2010) Study on the performance of asphalt concrete with HDPE anti-rut agent. Xian: Chang'an University.
3. Nie G, Cai X, Huang W, et al. (2022) Designing of an anti-rutting and high ductility asphalt mixture based on mortar performance. Construction and Building Materials, 316:125837.
4. Wang F C. (2011) Study of road performances of asphalt mixture with anti-rutting agent. Lanzhou: Lanzhou University of Technology.
5. Ministry of Transport. (2004) Technical Specifications for Construction of Highway Asphalt Pavements.