Research on Applicability of Anti-rutting Agent LY to Different Asphalt Mixtures

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Abstract—In order to study the applicability of anti-rutting agent LY to different asphalt mixtures, six asphalt mixtures, including AC-16, AC-16+0.4% anti-rutting agent, SBS modified asphalt AC-16, SBS modified asphalt AC-16+0.4% anti-rutting agent, SMA-16, SMA-16+0.4% anti-rutting agent, were tested for high temperature performance, low temperature performance and water stability performance. The test results show that the anti-rutting agent LY can improve the high temperature performance, low temperature performance and water stability of AC-16 and SMA-16 asphalt mixtures, and the effect is best when used with AC-16 asphalt mixtures. Compared with SBS modified asphalt mixture, although anti-rutting agent LY can improve its high-temperature performance, it has a negative impact on its low-temperature performance and water stability, so it is not recommended to use anti-rutting agent LY together with SBS modified asphalt mixture.

1. INTRODUCTION

With the increase of traffic axle load, the phenomenon of road rutting becomes more common. The occurrence of rutting has seriously affected the flatness of the road surface. Rutting reduces the service level and service life of the road, and at the same time increases the risk of driving.

In terms of improving road anti-rutting, the most researched by foreign scholars is the method of adding admixtures. There are many kinds of admixtures in asphalt pavement, some are directly added to asphalt to form modified asphalt to improve the road performance of the pavement, others are directly added to the mixture (waste rubber powder, fiber, polymer, resin, etc.) to improve the road performance of asphalt pavement[1]. Many European countries, including France, Italy, and Germany, have done a lot of research on admixtures in asphalt mixtures. The PR anti-rutting agent produced by a French company is representative. Because of its good high-temperature anti-rutting performance, it has been widely used on many highways in many European countries, which has improved the rutting phenomenon of asphalt pavements[2]. Yuan Wanjie, Wang Zhao and others studied the construction situation after adding PE anti-rutting agent to asphalt mixture. The results showed that the mixing time of mineral material and anti-rutting agent directly affected the interaction between mineral material and anti-rutting agent, and it also affected the overall quality and uniformity of asphalt mixture, mixing temperature and construction temperature will directly affect the rolling quality and construction quality of asphalt pavement after PE is added[3].

Although the research and application of anti-rutting agents in asphalt pavement have achieved certain results, due to the wide variety of anti-rutting agents, the construction quality after adding anti-rutting agents is uncertain. Some asphalt pavements have cracks and water damage after adding...
anti-rutting agent, although the anti-rutting performance of asphalt pavement has been improved. Therefore, how to determine that the anti-rutting agent is suitable for the pavement structure is particularly important. In order to study the effect of anti-rutting agent LY on the road performance of asphalt mixtures, a series of road performance tests were conducted on six asphalt mixtures, and the measured results were compared and analyzed to obtain the most suitable asphalt mixture type for anti-rutting agent LY.

2. RAW MATERIALS AND EXPERIMENT SCHEME

2.1. Asphalt

The asphalt used in this paper is Karamay 90# base asphalt and SBS modified asphalt. The performance indicators of the two asphalts are tested according to the specification "Test Procedures for Highway Asphalt and Asphalt Mixtures". The related technical indicators are shown in Table I.

2.2. Fiber, mineral powder and aggregate

The stone chosen in this paper is Basalt, which is the surface material for the reconstruction of the first-class highway from Erlianhot to Manzhou Latu. Fiber stabilizer of SMA is a polymer fiber produced by Xi'an Huaze. According to the "Highway Engineering Aggregate Experiment Regulations", the mineral powder and aggregate used in the test were tested separately. The technical indicators of the fibers are shown in Table II, the technical indicators of mineral powder are shown in Table III, and the technical indicators of aggregate are shown in Table IV and Table V.

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| Test item          | Measured value | Karamay 90# | SBS modified asphalt |
|--------------------|----------------|-------------|----------------------|
| Penetration        | 89.1           | 65.6        |
| Penetration Index  | -0.909         | -0.29       |
| Softening point    | 46.8           | 76.5        |
| Ductility          | 76.1           | 43.4        |
| Flash point        | 262            | 246         |
| Density            | 0.982          | 1.023       |
| Elastic recovery   | -              | 77.9        |
| Solubility         | 99.7           | 99.4        |
| Wax content        | 1.756          | -           |
| Quality loss%      | -0.435         | -0.283      |
| Penetration ratio% | 75.0           | 67.2        |
| Ductility 10°C/cm  | 10.4           | -           |
| Ductility 5°C/cm   | -              | 24          |

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| Test item          | Unit | Test results       | Test Standard                                      |
|--------------------|------|--------------------|---------------------------------------------------|
| Length             | mm   | All meet the      | ≤6mm                                              |
|                    |      | requirements       |                                                   |
| Oil absorption     |      | 5.3 times the fiber| Not less than 5 times the fiber mass               |
| rate               |      | quality            |                                                   |
| Heat resistance    | -    | No change in color | Color volume change is not obvious                |
|                    |      | and volume         |                                                   |
| Water content%     | %    | 2.3                | ≤5% (by mass)                                     |
### TABLE III. TECHNICAL INDICATORS OF MINERAL POWDER TESTING

| Test indicators                  | Unit     | Measured value |
|---------------------------------|----------|-----------------|
| Apparent density                | g/cm³    | 2.66            |
| Water content % 0.55            | %        | 0.55            |
| Grain size range                | %        |                 |
| 0.6                             |          | 100             |
| 0.15                            |          | 98.5            |
| 0.075                           |          | 86.3            |
| Appearance                      |          | No clumping     |
| Hydrophilic coefficient         |          | 0.5             |

### TABLE IV. TEST INDICATORS OF COARSE AGGREGATE

| Test item                          | Unit | Test results |
|------------------------------------|------|--------------|
| Gross volume relative density      | mm   |              |
| 16                                 |      | 2.753        |
| 13.2                               |      | 2.886        |
| 9.5                                |      | 2.895        |
| 4.75                               |      | 2.877        |
| Apparent relative density          | mm   |              |
| 16                                 |      | 2.760        |
| 13.2                               |      | 2.945        |
| 9.5                                |      | 2.989        |
| 4.75                               |      | 2.976        |
| Needle flake content               | %    |              |
| >9.5                               |      | 7.6          |
| <9.5                               |      | 9.3          |
| Water content                      | %    | 1.05         |
| Firmness                           | %    | 4.6          |
| Soft stone content                 | %    | 3.1          |
| Stone Polishing Value (PSV)        |      | 47           |
| Adhesion to asphalt (water immersion method) | level | 5 |
| Stone crushing value               | %    | 12.91        |
| Los Angeles abrasion loss          | %    | 11.45        |

### TABLE V. TECHNICAL INDICATORS OF FINE AGGREGATE

| Test item                          | Unit | Test results |
|------------------------------------|------|--------------|
| Apparent relative density 2.36mm 2.851 | mm | |
| 2.36                               |      | 2.851        |
| 1.18                               |      | 2.704        |
| 0.6                                |      | 2.711        |
| 0.3                                |      | 2.701        |
| 0.15                               |      | 2.697        |
| 0.075                              |      | 2.702        |
| Firmness                           | %    | 8.6          |
| Plasticity index                   | %    | 3.1          |
| Sand equivalent                    | %    | 69.0         |
| Mud content                        | %    | 2.67         |
2.3. Anti-rutting agent
The anti-rutting agent LY studied in this paper was developed by Beijing Zirui Tiancheng Technology Co., Ltd. It is a kind of granular high polymer additive, which is black and flat granular. It will deform to varying degrees under heating or external pressure changes. The specific measured technical indicators are shown in Table VI.

| Physical index | Unit | Test value |
|----------------|------|------------|
| Ingredients    | Polymer and cellulose | % | 95 |
| Other          | %    | 2          |
| Density        | g/cm³ | 0.97       |
| Granularity    | mm   | 4-6        |
| Melting temperature | ℃  | 155-165   |
| Water content  | %    | 2          |
| Color          | -    | black or brown |
| Exterior       | Solid granular |

2.4. Test methods
First, through marshall experiment, the optimum proportion of AC-16 asphalt mixture is 4.36%, the optimum proportion of SBS+AC-16 asphalt mixture is 4.63%, and the optimum proportion of SAM-16 asphalt mixture is 5.7%, the amount of fiber is 0.3%. Then according to the amount of anti-rutting agent LY and the test results of marshall test, rutting test, the cold bending rupture test, and immersion marshall test and freeze-thaw split test, the appropriate range of anti-rutting agent LY is 0.35%-0.5%. In order to compare the applicability of anti-rutting agent to different asphalt mixtures, the amount of anti-rutting agent LY is set to 0.4%. According to their respective mixture grading, AC-16, AC-16 + 0.4% anti-rutting agent LY, SBS modified asphalt AC-16, SBS modified asphalt AC-16 + 0.4% anti-rutting agent LY, SMA-16, SMA-16 + 0.4% anti-rutting agent LY six kinds of asphalt mixtures were made into test pieces required by the specification. It should be noted that in order to make SMA-16 and AC-16 asphalt mixtures have a better comparison, the SMA-16 asphalt mixture in this article uses base asphalt instead of modified asphalt. Then, the rutting test, the cold bending rupture test, immersion marshall test and freeze-thaw split test were carried out in strict accordance with the "Test Regulations for Highway Asphalt and Asphalt Mixtures".

3. ANALYSIS OF TEST RESULTS
3.1. Comparative analysis of high temperature performance
Rutting tests were carried out on six types of asphalt mixtures according to the requirements of the specification. The measured test results are shown in Table VII.

| Asphalt mixture type | Dynamic stability DS (Times/mm) |
|----------------------|---------------------------------|
| AC-16                | 1680.9                          |
| AC-16+0.4%LY         | 7342.5                          |
| SBS+AC-16            | 6220.8                          |
| SBS+AC-16+0.4%LY     | 8561.6                          |
| SMA-16               | 1965.3                          |
| SMA-16+0.4%LY        | 4520.2                          |
It can be seen from Table VII that adding the same amount of anti-rutting agent has different effects on the high-temperature performance of different types of asphalt mixtures. For AC-16 asphalt mixture, after adding 0.4% anti-rutting agent, its dynamic stability has increased from 1680.9 to 7342.5, and part of the increase was about 4.37 times of the original. After adding SBS modifier to AC-16 base asphalt mixture, the dynamic stability of SBS modified asphalt mixture which was generated was improved by 3.7 times. Then adding 0.4% anti-rutting agent, dynamically stable of the SBS modified asphalt has increased from the original 6220.8 to 8516.6, part of the increase is only 37.6%. It can be seen that the anti-rutting agent LY has a better high-temperature anti-rutting effect on the base asphalt mixture than the SBS modified asphalt mixture. Compared with SMA-16 asphalt mixture with better anti-rutting performance, it is found that its dynamic stability is not as good as expected. Although its dynamic stability is better than AC-16 asphalt mixture, it is not as good as SBS modified asphalt mixture, the reason may be that the base asphalt is used in the SMA-16 asphalt mixture, as a result, the high temperature performance of the pavement structure is not very outstanding. After adding 0.4% anti-rutting agent, the dynamic stability becomes 4520.2, which is about 2.3 times of the original SMA-16 asphalt mixture. Through comparison, it is found that adding the same amount of anti-rutting agent can increase the dynamic stability of AC asphalt mixture almost twice as much as SMA asphalt mixture. Although the nominal maximum size of the three types is the same, the sensitivity of LY to its high temperature performance is very different because of the different mineral structure.

The anti-rutting agent LY significantly improves the high-temperature performance of AC-16 asphalt mixture, which may be due to its continuous dense gradation, which enables the anti-rutting agent to be better dispersed in the asphalt, thereby improving the dynamic stability of the asphalt mixture. Compared with SMA asphalt mixture, the effect of anti-rutting agent is not very outstanding. It may be that the asphalt mixture of SMA-16 belongs to the discontinuous gradation, and there are more coarse aggregates in the mixture. The addition of the rutting agent makes the asphalt appear agglomerated and cannot be evenly dispersed in the asphalt, which limits the effect of the anti-rutting agent. As for the SBS modified asphalt mixture, it is least sensitive to anti-rutting agents. Because the anti-rutting agent will affect the structure of SBS modified asphalt to a certain extent, so it is found that the addition of anti-rutting agent does not significantly improve the high-temperature performance of this mixture. At the same time, it can be found through comparison that the anti-rutting agent can replace SBS modifier to a certain extent.

### 3.2. Comparative analysis of low temperature performance

The cold bending rupture test was carried out for six mixtures according to the specification. The flexural tensile strength, failure strain, and stiffness modulus were measured respectively. The specific test results are shown in Table VIII.

| Asphalt mixture type | Flexural tensile strength | Failure strain | Stiffness modulus |
|----------------------|--------------------------|----------------|------------------|
| AC-16                | 8.7                      | 2513.6         | 3461.2           |
| AC-16+0.4%LY         | 10.1                     | 2697.4         | 3744.3           |
| SBS+AC-16            | 9.3                      | 3217.8         | 2890.2           |
| SBS+AC-16+0.4%LY     | 10.4                     | 2916.5         | 3565.9           |
| SMA-16               | 7.9                      | 2342.8         | 3372.0           |
| SMA-16+0.4%LY        | 8.2                      | 2415.6         | 3394.6           |

It can be seen from Table VIII that when the same amount of anti-rutting agent is added, the changes in flexural tensile strength of different types of mixtures are different. For AC-16 asphalt mixture, after adding 0.4% of anti-rutting agent, the flexural tensile strength of the mixture has increased by 1.4Mpa on the original basis, an increase of 16.1%, and the increase is more obvious. However, for SBS modified asphalt, after adding the same amount of anti-rutting agent, the flexural tensile strength of the asphalt mixture increased by 1.1Mpa, which was only an increase of 11.8%. For
SMA asphalt mixture, the flexural tensile strength after adding anti-rutting agent also increased slightly, from the original 7.9 to 8.2, an increase of 0.3 Mpa. Through comparison, it can be found that the anti-rutting agent can only improve the low temperature performance of SMA asphalt mixture to a very limited extent. The increase in flexural tensile strength of AC-16 asphalt mixture is the most obvious. After adding anti-rutting agent, the flexural tensile strength under low temperature conditions is higher than the other two mixtures at the same content. This is also beneficial for areas with excessive temperature difference between day and night, can reduce the cracking of asphalt pavement caused by sudden temperature drop.

In terms of failure strain, when the same amount of anti-rutting agent is added, both AC-16 and SMA-16 asphalt mixtures have increased on the original basis. In terms of the growth rate, the AC-16 asphalt mixture is higher than the SMA asphalt mixture, but the scope of improvement for both is very limited. However, for the SBS modified asphalt mixture, it was found that its failure strain was reduced by 9.4% on the original basis, indicating that to a certain extent, the anti-rutting agent damaged the low temperature performance of the SBS modified asphalt mixture.

From the perspective of stiffness modulus, the growth rate of SBS modified asphalt is much larger than that of AC asphalt mixture and SMA asphalt mixture, indicating that SBS asphalt mixture has the greatest brittle failure risk under low temperature conditions. The reason may be that the anti-rutting agent has better compatibility with the base asphalt. On the contrary, the combination with the SBS modified asphalt mixture may destroy the fine structure of the modified asphalt itself, resulting in the stiffness of the SBS modified asphalt mixture. The phenomenon of excessive increase in volume.

3.3. Comparative analysis of water stability
The immersion marshall test and freeze-thaw split test were performed on six asphalt mixtures. The results of the immersion marshall test are shown in Table IX, and the results of the freeze-thaw split test are shown in Table X.

| Asphalt mixture type | 30min Stability | 48h Stability | Retained Marshall Stability |
|----------------------|-----------------|---------------|-----------------------------|
| AC-16                | 11.2            | 9.8           | 87.5                        |
| AC-16+0.4%LY         | 12.7            | 11.6          | 91.3                        |
| SBS+AC-16            | 12.3            | 11.5          | 93.5                        |
| SBS+AC-16+0.4%LY     | 12.9            | 11.7          | 90.7                        |
| SMA-16               | 6.2             | 5.1           | 82.3                        |
| SMA-16+0.4%LY        | 6.5             | 5.4           | 83.1                        |

It can be seen from Table IX that after the anti-rutting agent is added, the 30min stability and 48h stability of AC-16 asphalt mixture have the most obvious increase. The 30min stability has increased by 13.3%, and the 48h stability has increased by 18.4 %. For SMA asphalt mixture, after adding anti-rutting agent, the increase of 30min and 48h stability is 4.8% and 5.9% respectively. SBS modified asphalt mixture after adding anti-rutting agent 30min and 48h stability growth rate of 4.9% and 1.7% respectively. It can be seen that the anti-rutting agent has the best effect on the AC-16 asphalt mixture, and it also indirectly shows that the anti-rutting agent will be more uniformly dispersed in the AC-16 asphalt mixture and bring a greater effect.

Retained marshall stability is an indicator of water stability and anti-stripping performance. After adding 0.4% anti-rutting agent LY, the retained marshall stability of AC-16 asphalt mixture increased by 3.8%, which significantly improved the water damage resistance of asphalt mixture. For the SMA asphalt mixture, its retained marshall stability increased from 82.3% to 83.1%, an increase of only 0.8%, indicating that the anti-rutting agent has limited ability to improve the water spalling resistance of the SMA asphalt mixture. However, compared with the SBS modified mixture, its retained marshall stability has decreased by 3.2% on the original basis, indicating that the anti-rutting agent has caused a certain loss of the water spalling resistance of the SBS modified asphalt mixture. The reason may be
that the interaction between the SBS modified asphalt and the anti-rutting agent weakens the adhesion of the asphalt, as a result, the cohesive force between asphalt and aggregate decreases.

**TABLE X. SPLITTING STRENGTH TEST RESULTS**

| Asphalt mixture type | Unfreeze-thaw split strength (MPa) | Freeze-thaw split strength (MPa) | TSR (%) |
|----------------------|-----------------------------------|---------------------------------|---------|
| AC-16                | 1.01                              | 0.8                             | 79.2    |
| AC-16+0.4%LY         | 1.39                              | 1.22                            | 87.8    |
| SBS+AC-16            | 1.12                              | 1.05                            | 93.8    |
| SBS+AC-16+0.4%LY     | 1.19                              | 1.01                            | 84.9    |
| SMA-16               | 0.95                              | 0.74                            | 77.9    |
| SMA-16+0.4%LY        | 1.08                              | 0.92                            | 85.2    |

From the data analysis in Table X, after adding 0.4% anti-rutting agent LY, the unfrozen split strength of the three types of asphalt mixture increased to varying degrees. The AC-16 asphalt mixture increased the most, with an increase of 37.6%. SMA asphalt mixture increased by 13.7%, and SBS modified asphalt mixture increased the least, with an increase of only 6.25%. From the perspective of the splitting strength after freezing and thawing, the strength of AC-16 asphalt mixture increased by 52.5% after adding anti-rutting agent, and the strength of SMA asphalt mixture increased by 24.3% when 0.4% anti-rutting agent is added. It shows that the anti-rutting agent improves the ability of these two mixtures to resist water damage. It shows that the anti-rutting agent LY improves the adhesion force between the asphalt and the aggregate, and reduces the ability of water to peel off the asphalt. At the same time, it was also found that anti-rutting agent has a negative impact in the SBS modified asphalt mixture. Although the addition of rutting agent increased the split strength of the asphalt mixture before freezing and thawing by 0.07MPa, however, after freezing and thawing, the split strength of the mixture is reduced by 0.04MPa. Through the data analysis of TSR, it can be seen that the addition of 0.4% anti-rutting agent increases the split strength ratio of AC-16 asphalt mixture from 79.2% to 87.8%, an increase of 8.6%. The split strength ratio of SMA asphalt mixture increased by 7.3%. The split strength ratio of SBS modified asphalt mixture decreased from 93.8% to 84.9%, a decrease of 8.9%, which further shows that the water stability of SBS modified asphalt mixture after adding a certain amount of anti-rutting agent Cause a negative impact.

4. CONCLUSION

In order to study the applicability of the anti-rutting agent LY, the following conclusions were obtained by studying the high temperature performance, low temperature performance and water stability performance of 6 kinds of asphalt mixtures.

- The anti-rutting agent LY can effectively improve the high-temperature anti-rutting performance of AC-16, SBS+AC-16, and SMA-16 asphalt mixtures, and the effect is the most obvious when used with AC-16 asphalt mixture.
- The anti-rutting agent LY can improve the low temperature performance of AC-16 and SMA-16 asphalt mixtures, and it has the most significant effect on improving the low temperature performance of AC-16 asphalt mixture, but it has a negative impact on the low temperature brittleness of SBS modified asphalt mixture.
- The anti-rutting agent LY can improve the water stability of AC-16 and SMA-16 asphalt mixtures, and it has the best effect when combined with AC-16 asphalt mixtures, but it weakens the performance of Water stability of SBS modified asphalt mixtures.
- Based on the influence of anti-rut agent LY on different asphalt mixtures in high temperature, low temperature and water stability, it can be concluded that anti-rut agent LY has the best effect when used together with AC-16 asphalt mixture mixture. At the same time, it will not have a negative impact on the low temperature performance and water stability of the mixture.
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REFERENCES
[1] He Fengling. Application research of anti-rutting asphalt mixture [D]. Master's degree thesis of Southeast University, 2006.
[2] Gao L, Ni F, Charmot S, et al. High-temperature performance of multilayer pavement with cold in-place recycling mixtures[J]. Road Materials and Pavement Design, 2014, 15(4): 804-819.
[3] Yuan Wanjie, Wang Zhao, Sun Changxin. Research on application of PE anti-rutting agent asphalt mixture construction technology [C]. "Material Review" magazine: Material Review Editorial Office, 2007: 267-269.
[4] Zhang Zixian, Yang Wenhai, Liu Xiuping. Application of Rutting King Anti-rutting Agent in Asphalt Mixture[J]. Highway, 2010 (10): 186-188.
[5] Ma Suyue. Research on the application of PR anti-rutting agent in expressway[D]. Beijing Jiaotong University, 2008.
[6] Wang Wei, Zhang Xu, Zhao Yan. Experimental study on water stability of asphalt mixture with PE anti-rutting agent[J]. Highway and Transportation Technology, 2010 (4): 33-37.
[7] Li Zhiqiang. Research on road performance of anti-rutting asphalt mixture [D]. Chang'an University, 2012.
[8] Xiao Qingyi, Rui Shaoquan, Wang Hang, et al. Experimental study on asphalt mixture with PR PLASTS anti-rutting agent[J]. Journal of Wuhan University of Technology, 2006, 28(7): 36-39.
[9] Sun Guowei. Experimental study of anti-rutting agent and SBS modifier on asphalt mixture road performance [D]. Lanzhou: Master's Degree Thesis of Lanzhou University of Technology, 2014.