Study on the performance of new TPS high viscosity modifier on its modified asphalt

Yiluo Zhang¹,a, Yinglun Cheng¹,b*, Xuechao Dong¹,c, Ning Li¹,d

¹Key Laboratory of Highway Engineering in Special Region of Ministry of Education Chang’an University Xi’an, China
a zhangyiluo@163.com, c 1186056063@qq.com, d 784038457@qq.com
b* Corresponding author: 27634004@qq.com,

Abstract—In order to study the effect of a new TPS high viscosity modifier on the performance of its modified asphalt, a new type of TPS high viscosity modified asphalt with 3%, 8%, 13% and 18% content will be prepared, SBS modified asphalt and Japanese TPS modified asphalt were selected for comparison, high temperature and low temperature indexes were tested respectively, and the modification effect of the new TPS high viscosity modifier was verified through comparative analysis, and the more suitable dosage was determined. The results show that with the increase of the new TPS content, the performance of asphalt has been improved. When the content of the new TPS reaches 13%, the indicators of high-viscosity asphalt have fully met the requirements of the specification; By comparing the performance of each high-viscosity asphalt, and combining the requirements of high-viscosity asphalt and Japanese TPS. For the comparison between high-viscosity modifiers, the recommended dosage of this new TPS is between 13% and 18%.

1. INTRODUCTION
High-viscosity asphalt is the basic material for the construction of drainage pavement. High-viscosity asphalt has higher viscosity, toughness and softening point, which forms a strong bond between the aggregates and is wrapped in the form of asphalt film. The surface of the aggregate, and the increased viscosity of the asphalt will have good wettability and contain many polar components, which can effectively improve the resistance to water replacement. In addition, the high viscosity modifier contains anti-aging components, so the high viscosity Asphalt can effectively solve the durability problem of drainage asphalt pavement. High-viscosity asphalt can also effectively prevent the flow of asphalt from blocking the voids of the pavement due to the melt flow of the asphalt at high temperature and affecting the use of the pavement. However, most of the high-viscosity modified asphalt currently used in China's drainage pavement is imported modified asphalt. The import price of the modifier is generally tens of thousands of yuan/ton[1], especially the Japanese TPS high-viscosity modifier has a better Performance, while bringing good use effect to the pavement, also increases the cost of road construction. The high price has become a key factor restricting the promotion and development of China's drainage asphalt pavement. To study the new domestic TPS high viscosity modifier, and compare the asphalt performance with SBS modified asphalt and Japanese TPS modified asphalt. The purpose is to study the modification effect of the new TPS modifier and determine the best modifier range. The price of this kind of domestic high-viscosity modifier is much lower than that of imported
high-viscosity modifier, so this new type of TPS high-viscosity modifier has a very broad application prospect.

Perform basic index tests on materials required for testing, including asphalt, aggregates, modifiers, and mineral powders. Take SBS as an example\(^2\), use leak test and Kentucky Fort fly test to fully determine the range of asphalt content. And the determination of the amount of asphalt with different viscosity is carried out according to this method. The high-speed shear machine is used to prepare new TPS and Japanese TPS high-viscosity modified asphalt. The new TPS modifier uses different dosages to carry out indicators including high temperature and low temperature. Performance test and comparison with other asphalts, combined with the high-viscosity asphalt in the specification, analyze its modification effect, and determine the appropriate amount of new TPS modifier.

2. INTRODUCTION OF HIGH VISCOSITY MODIFIED ASPHALT

The composition of the new TPS is similar to that of the Japanese TPS material\(^3\). The components are thermoplastic rubber and resin, and contain a small amount of plasticizers and anti-aging components. They are also high-viscosity modifiers. \(^4\)Due to the large voids and easy flaking of the OGFC pavement, the main Used in drainage asphalt pavement, comparative analysis of all tests with Japanese TPS material\(^5\)the basic physical indicators are shown in Table 1 and Figure 1.

| Index   | Japan TPS | Domestic new TPS |
|---------|-----------|------------------|
| Colour  | Light yellow | Bright black     |
| Shape   | Granular  | Granular         |
| Density (g/cm³) | 0.6       | 0.54             |
| Particle size (mm) | 2 ~ 3      | 3 ~ 5            |

Figure 1. TPS appearance

The principle of modifier on asphalt:

Although TPS is not a clear polymer modifier like SBS, TPS contains similar thermoplastic rubbers and resins, so the mechanism should be similar to SBS modifiers, where the thermoplastic rubber component is stable to high temperatures and cracks at low temperatures. Both the performance and the fatigue resistance have been greatly improved, and the increase of the viscosity of the resin to the asphalt is also very obvious.
① TPS modifier will swell in the process of high temperature fusion and mixing with asphalt, and absorb the light components in the asphalt, so that the relative content of the heavy components of the asphalt increases, showing an increase in viscosity, softening point, and asphalt changes. thick.

② When the modifier absorbs the light components in the asphalt and swells, it will also diffuse into the asphalt. The modifier is dispersed into the asphalt in a filamentous form. The polymer and the asphalt each form a continuous network structure that penetrates each other. In a metastable state, the network structure will also dampen the flow of free asphalt, thereby increasing the viscosity of the asphalt.

3. PERFORMANCE STUDY OF NEW TPS MODIFIED ASPHALT

3.1. Preparation of TPS high viscosity modified asphalt

Select 70# two kinds of matrix asphalt for the preparation of TPS modified asphalt. According to the preparation process of high-viscosity asphalt, a high-speed shearing machine is used for shear preparation.

![Figure 2](image)

**Figure 2** Preparation process of high-viscosity modified asphalt

① According to the number of bitumen preparations, weigh 500g for each bitumen;
② According to the blending ratio, calculate the quality of each new TPS required;
③ When heating the base asphalt to about 170℃, gradually add new TPS and stir with glass rod. Because TPS has good compatibility with asphalt, it can be sheared by high-speed shearing machine when TPS has no obvious granularity. The asphalt temperature should be kept at about 170 ℃ throughout.
④ When the modifier is completely melted, due to its relatively high viscosity, the speed of the shear should be gradually increased to 3000 rpm, and the shear should be continued for 15-30 minutes according to the amount of TPS.

The preparation of Japanese TPS still uses the above steps for preparation, because Japanese TPS has been extensively studied, and its optimal dosage is generally set at 12%, so the amount of Japanese TPS high viscosity modifier used for comparison in this article is Choose 12%.

3.2. Index analysis of high viscosity modified asphalt

3.2.1. High-temperature performance of high-viscosity modified asphalt

For the high-temperature performance study of high-viscosity modified asphalt, two test indexes were selected: softening point and 60℃ dynamic viscosity. The softening point of high-viscosity asphalt is required to be higher than 80℃, and the dynamic viscosity at 60℃ is not to be less than 20,000 Pa·s. For the requirements of various indicators for high-viscosity asphalt in Table 2.
TABLE II. Technical requirements for high-viscosity modified asphalt

| Pilot projects            | unit   | skills requirement |
|--------------------------|--------|--------------------|
| Penetration (25°C, 100g, 5s) | 0.1mm | ≥40                |
| Softening Point          | ºC     | ≥80                |
| Elongation (15°C)        | cm     | ≥50                |
| Flash point              | ºC     | ≥260               |
| TFOT                     | %      | ≥0.6               |
| Viscosity (25°C)         | N·m    | ≥20                |
| toughness (25°C)         | N·m    | ≥15                |
| 60°C dynamic viscosity   | Pa·s   | ≥20000             |

The high viscosity asphalt obtained by modifying two No. 70 matrix asphalts was tested for dynamic viscosity at 60°C. The test results are shown in Table 3 and Figures 3 and 4.

TABLE III. Dynamic viscosity

| Test object                  | dynamic viscosity (Pa·s) | Test object                  | dynamic viscosity (Pa·s) |
|------------------------------|--------------------------|------------------------------|--------------------------|
| Shell matrix asphalt         | 246                      | Ganji base asphalt           | 238                      |
| 3% TPS                       | 3157                     | 3% TPS                      | 5883                     |
| 8% TPS                       | 14682                    | 8% TPS                      | 19914                    |
| 13% TPS                      | 25432                    | 13% TPS                     | 37734                    |
| 18% TPS                      | 54891                    | 18% TPS                     | 60097                    |
| 12% Japan TPS                | 61475                    | 12% TPS                     | 63769                    |
With the addition of the new TPS, the dynamic viscosity of the two base asphalts has been greatly improved. The dynamic viscosity of the selected SBS asphalt is between 3% and 8% of the new TPS. The dynamic viscosity of SBS asphalt at 60°C is 8837 Pa·s. When the dosage is 13%, the 60°C dynamic viscosity of the two base asphalts has exceeded 20,000 Pa·s, which meets the requirements of the specification for high-viscosity asphalt. Due to the difference between oil sources, the modification effect of different types of matrix asphalts with the same label is also different. In the process of TPS content from 3% to 18%, the viscosity of Gansu mechanization has always been higher than that of Shell asphalt. The relatively small amount of asphaltenes makes the compatibility of asphalt and TPS modifiers better. At 18%, the determination of asphalt viscosity is already very difficult. The viscosity reaches 50,000–60,000 Pa·s, compared with Japan. The TPS modifier, the new TPS, has a difference in viscosity. The kinematic viscosity at 60°C when its content reaches 18% is second only to the kinematic viscosity of 12% in Japan. However, if the viscosity is too high, it will increase too much. The construction temperature is also difficult to pump, so the recommended dosage is from 13% to 18% in terms of viscosity. The test results of the softening point of each asphalt are shown in Figure 5 and Figure 6.
With the increase of the amount of new TPS, the softening point gradually rises. When the amount of doping increases to 8%, the softening point has reached 80 °C, when the amount of 18%, the softening point is as high as 95.6 °C; SBS softening point is at 68 °C, it is between 3% and 8% of the new TPS content. Asphalt with 12% Japanese TPS content does not exceed the new TPS content of 18% as the 60°C dynamic viscosity, but it is between 13% and Between 18%, overall, from the softening point, the addition of the new TPS significantly improves the softening point of asphalt.

3.2.2. Low-temperature performance of high-viscosity modified asphalt

Drainage pavement also faces the problem of low-temperature cracking, coupled with its large porosity, so the low-temperature performance of asphalt is also crucial, and the low-temperature ductility is selected to study the low-temperature performance of the new TPS high-viscosity modified asphalt. The low-temperature ductility of the matrix asphalt is generally 10°C, and the modified asphalt is generally 5°C. These two temperatures are selected for the ductility test of TPS modified asphalt with different mixing ratios. The test results are shown in Figures 7 and 8.
Both the 5°C ductility and 10°C ductility of asphalt will increase with the increase of the new TPS content, but the change range is very small, even if the content reaches 18%, the increase rate is relative to the base asphalt Within 20cm; the ductility of SBS at 5°C and 10°C is significantly higher than that of the new TPS high-viscosity modified asphalt, which is about twice as high. The ductility of 12% Japanese TPS modified asphalt is also higher than that of the new model The ductility of TPS high-viscosity asphalt is greater, and the reason for analysis should be the composition of the TPS, which contains some resinous substances.

3.2.3. Aging properties of high viscosity modified asphalt
Asphalt should go through many processes from the factory to the construction site. It will be affected and influenced by various natural factors such as air and temperature, which will cause short-term aging; and after paving the road, in the long-term car load and external environment Under the combined action, it will also cause long-term aging. At 90min intervals, five action times of 85min, 180min, 270min, 360min and 450min were selected as the delay time test points to test the three major indexes of asphalt at different time points.
It can be seen that with the increase of the aging time, the penetration of each amount of asphalt is decreasing, and the magnitude of the decrease gradually tends to be gentle with the increase of the aging time. At 360 min, the change is not too large. The volatilization of light components is close to stop. During the aging process, with the addition of the new TPS, the decrease in the penetration of asphalt will gradually become gentle. When the delayed aging time reaches more than 180 min, the residual penetration of the high-viscosity asphalt exceeds the base asphalt. The residual penetration indicates that the addition of TPS has retarded the aging of asphalt to a certain extent. In order to compare its anti-delay aging performance more clearly, the penetration ratios of various blended asphalts under different delayed aging times are drawn as polylines. As shown in Figure 10, the penetration ratio gradually increases with the increase of the TPS content. Although the penetration of SBS has been at the maximum during the entire delayed aging process, the decrease in penetration through the penetration ratio is not the smallest, and its penetration ratio is equivalent to 13% of the high-viscosity modified asphalt. The penetration ratio reflects the degree of influence of asphalt on high temperature aging, and the addition of new TPS reduces this degree of influence. In the process of penetration decrease with aging time, 12% Japanese TPS high viscosity asphalt has been at the same level as 18% of the new TPS high viscosity asphalt, but from the perspective of penetration ratio, after 270 min, Japan high viscosity Asphalt becomes the gentlest. From the perspective of penetration ratio, the addition of TPS can significantly reduce the effect of delayed high temperature on asphalt and suppress the volatilization of components in the asphalt.
As shown in Figure 11, the overall performance trend is that the size of the softening point continues to rise with the increase of the delay time. During the entire process of aging delay, the overall amplitude of the softening point change is not large, and the addition of the new TPS makes the overall The softening point rises very slowly. When the dosage increases to 8% and 13%, the softening point curve is very smooth and tends to be stable after 360 min. This also reflects that the addition of TPS delays the occurrence of aging.

Figure 11 Aging time-softening point change

Figure 12 Aging time-ductility change graph

Figure 13 Comparison chart of aging time-ductility
According to Fig. 12 and Fig. 13, it can be seen that the addition of the new TPS has not increased much for the original asphalt at 10°C. The difference between its ductility and 13% is about 10 cm, which increases with the aging delay time. The difference will become larger and larger, and can reach about 20 cm. When the aging delay reaches 270 min, the 10°C ductility of the matrix asphalt is already 0, and with the increase of the TPS content, each delay point ductility also gradually increases. In summary, the comparison of indicators before and after aging in the test shows that the three indicators can show that the addition of new TPS to different degrees inhibits and delays the occurrence of aging to a certain extent, and has a more obvious anti-aging effect.

4. CONCLUSION

- Through testing the indicators of each high-viscosity asphalt, it is concluded that with the increase in the amount of new TPS, various properties of asphalt have been improved. When the content of the new TPS reaches 13%, the indicators of the high-viscosity asphalt have fully met the specifications; when the content of the new TPS reaches 8%, the high-temperature indicators are equivalent to SBS asphalt; The various properties of 12% Japanese TPS modified asphalt are between 13% and 18% of the new TPS content, and are close to 18% TPS high viscosity asphalt;
- With the addition of the new type of TPS, the dynamic viscosity of both base asphalts has been improved, and the dynamic viscosity at 60°C when its content reaches 18% is second only to the dynamic viscosity of 12% in Japan. And the softening point is gradually increased, when the dosage is increased to 8%, the softening point has reached 80 °C, when the dosage is 18%, the softening point is as high as 95.6 °C.
- Both the low-temperature ductility of asphalt at 5°C and the low-temperature ductility of 10°C will increase with the increase of the new TPS content, but the change range is very small.
- When the delayed aging time reaches more than 180 min, the residual penetration of high-viscosity asphalt exceeds the residual penetration of matrix asphalt, indicating that the addition of TPS delays the aging of asphalt to a certain extent.
- Through the above comparison of the performance of each content of high-viscosity asphalt, combined with the requirements for high-viscosity asphalt index and the comparison with the Japanese TPS high-viscosity modifier, this paper recommends that the new TPS dosage is 13 %~18%.

REFERENCES

[1] Zhu Man. Evaluation method and application of high viscosity modified asphalt performance [D]. South China University of Technology, 2015.
[2] Cao Tingwei. Performance study of drainage asphalt mixture with high viscosity asphalt additives [D]. Wuhan: Wuhan University of Technology, 2008.
[3] JTG F40-2004, Technical Specification for Highway Asphalt Pavement Construction [S]. Beijing: People’s Communications Press, 2004.
[4] Liu Xueliang. Preparation and properties of high-viscosity modified asphalt [D]. Wuhan: Wuhan University of Technology, 2008.
[5] Zhang Yiluo. Construction technology and quality control of asphalt pavement [M]. Beijing: People’s Communications Press, 2011.
[6] Tan Ruimei. Application of high viscosity modifier in OGFC asphalt mixture [D]. Changan University, 2011.