Comparative Analysis of Road Performance of TPE Modified Asphalt

Chenhui Yang¹, Rui Dong², Rongjie Du², Hengchang Yu² and Dongwei Cao¹,³*

¹ Research Institute of Highway Ministry of Transport, Beijing, 100088, China
² Qilu Transportation Development Group Co., Ltd. Jinan, Shandong Province, 250000, P.R. China
³ Research and Development Center of Transport Industry of New Materials, Technologies Application for Highway Construction and Maintenance, Beijing, 100088, China
Email: dw.cao@rioh.cn

Abstract. The paper tested conventional and Strategic Highway Research Program (SHRP) index performance of TPE and SBS modified asphalt. The test results show that TPE modified asphalt can effectively improve the high temperature performance, water stability and low temperature performance of asphalt mixture. Although the performance of TPE modified asphalt is inferior to SBS modified asphalt, the three major indexes all meet the specification requirements. The overall road performance of TPE modified asphalt mixture meets the technical requirements of modified asphalt, and even from the rut test and SPT test results, the high-temperature anti rut performance is higher than SBS asphalt mixture.

1. Introduction
Recently, with the large-scale construction of asphalt pavement, more modified asphalt, such as SBS modified asphalt and rubber asphalt, is needed. Although SBS modified asphalt has excellent physical properties and road performance, but SBS is expensive and requires more oil resources in production process. Rubber asphalt also has the disadvantages of high viscosity, irritating odor, poor storage stability, and difficult construction [1]. The asphalt modification with industrial and agricultural waste rubber materials can not only solve the problem of difficult degradation of waste rubber resources, but also save a lot of oil and energy resources [2].

The high-temperature melt processing of waste plastics and rubber powder into the thermoplastic elastomer (TPE) modifiers through a twin-screw extruder can significantly improve the high-temperature performance of asphalt, and improve the water stability and low-temperature performance to varying degrees [3]. This paper analyzes the applicability of TPE modified asphalt, SBS asphalt index and asphalt mixture road performance index, and analyzes the applicability of rubber-plastic alloy modified asphalt.

2. Comparison of TPE and SBS Modified Asphalt

2.1. Classical Tests.
The technical indicators and test date of the TPE modified asphalt and SBS modified asphalt are shown in Table 1. The selected matrix asphalt was SK-70, whose penetration at 25°C was 68.7 mm, softening point was 48.3°C, and ductility at 15°C was more than 100 cm. TPE modified asphalt and
SBS modified asphalt are produced from this matrix bitumen. The test results of the two modified asphalt indicators are shown in Table 1, and the asphalt modifier blending ratio is shown in Table 2.

### Table 1. Technical indicators and test date of modified asphalt.

| Sample ID | requirements | Test date (°C) |
|-----------|--------------|----------------|
| Penetration in dmm (25°C) | 30~60 | SBS: 52, TPE: 52 |
| Softening point | ≥60 | SBS: 80.8, TPE: 69 |
| Ductility in cm (5°C) | ≥20 | SBS: 35.1, TPE: 20.3 |

### Table 2. Modified asphalt modifier content ratio.

| Types          | Proportion of various additives/% |
|----------------|----------------------------------|
| SBS modified asphalt | SBS: 5, Waste rubber powder (80 mesh): 0, Waste plastic (PE): 0, Admixture: 0.5 |
| TPE modified asphalt | SBS: 3, Waste rubber powder (80 mesh): 8.85, Waste plastic (PE): 3.15, Admixture: 1.5 |

Penetration, softening point and ductility are the three most commonly used indexes of road asphalt in my country, which are intuitive and can reflect the high and low temperature performance of asphalt to a certain extent [4]. The following conclusions can be drawn from Table 1 and Table 2: The penetration of TPE and SBS modified asphalt is obviously smaller than that of base asphalt; The softening point of SBS and TPE modified asphalt is greatly improved compared with the matrix asphalt, indicating that the high temperature performance has been significantly improved; Judging from the 5°C ductility index, the low-temperature performance of SBS and TPE modified asphalt is greatly improved compared with matrix asphalt, and the performance of SBS modified asphalt is better. On the whole, although the performance of TPE modified asphalt is inferior to SBS modified asphalt, the three major indexes all meet the requirements of SBS I-D index.

2.2. Dynamic Shear Rheometer Test

A dynamic shear rheometer (Anton paar made in Austria, Type.H-PTD120) was used for dynamic mechanical analysis of asphalt binders [5]. In SHRP specification, the rheological parameter, G*/sinδ, was selected to represent the high temperature performance of asphalt binder. This value reflects the total resistance of a binder to deform under repeated loading(G*) and the relative amount of energy dissipated into nonrecoverable deformation(sinδ) during a loading cycle [6]. At high temperature, the larger G*/sinδ indicates that G* is larger and δ is smaller, indicating that the rutting resistance of asphalt is better.

It can be seen from figure 1 that the G*/sinδ value of modified asphalt decreases with the increase of temperature. According to Figure 1, the values of SBS modified asphalt and TPE modified asphalt are higher than those of matrix asphalt at the same temperature. Surprisingly, the G*/sinδ value of TPE modified asphalt is the highest among the three groups of asphalt at the same temperature, which indicates that TPE modified asphalt has excellent high temperature performance. From table 3, when G*/sin δ=1 kPa, the failure temperature data show that the high temperature performance of TPE modified asphalt and SBS modified asphalt can reach above PG 76.
The bending beam rheometer uses creep loads to simulate the stress gradually applied to the pavement as the temperature drops. Creep stiffness S is an index reflecting the ability of asphalt to resist fixed load, while creep rate m represents the change rate of asphalt stiffness after loading. Comparing the creep stiffness S and creep rate m of SBS and TPE modified asphalt in Table 3, it can be seen that SBS modified asphalt has relatively better low-temperature crack resistance. However, from the comparison of test data between base asphalt and TPE modified asphalt, we can find that the asphalt modified by TPE has better low-temperature crack resistance.

3. Comparison of TPE Asphalt and SBS Asphalt Mixture

3.1. Comparative Analysis of Road Performance of Asphalt Mixture
In order to analyze and compare the road performance difference between TPE asphalt and SBS asphalt mixture, this article uses the same mineral material and blending ratio to carry out AC-13C mixture mix design and road performance index test. The various asphalt mixture tests adopted in this paper meet the requirements of "Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering" (JTG E20-2011) and "Technical Specification for Construction of Highway Asphalt Pavement" (JTG F40-2004). And the test results are shown in the table below.
Table 4. Mix design of TPE asphalt and SBS asphalt mixture and test results of road performance indicators.

| Type       | OAC (%) | VV (%) | VMA (%) | VFA (%) | MS0 (%) | MS (%) | TSR (%) | DS (mm) | Failure strain (με) |
|------------|---------|--------|---------|---------|---------|--------|---------|---------|---------------------|
| AC-13C SBS | —       | —      | —       | —       | 12.5    | 94.6   | 95.3    | 4224.3  | 3231.84             |
| TPE        | 4.9     | 3.9    | 15.1    | 72.3    | 10.4    | 93.1   | 88.8    | 4565.2  | 2735.28             |
| requirements| —       | —      | —       | —       | ≥85     | ≥80    | ≥2800   | ≥2500   |                     |

According to the test data from Table 4, the road performance of TPE modified asphalt mixture meets the requirements of the current technical standards, and has significant advantages in some properties, which can be applied to the actual project. The Marshall stability and dynamic stability of TPE asphalt mixture are significantly higher than that of matrix asphalt mixture. At the same time, it is slightly higher than SBS asphalt mixture, indicating that TPE asphalt mixture has outstanding rutting resistance. In terms of residual stability, splitting strength ratio after freeze-thaw cycle and low-temperature bending failure strain, the water damage resistance and low-temperature cracking resistance of TPE asphalt mixture are slightly worse than SBS asphalt.

3.2. SPT Test of Dynamic Modulus of Asphalt Mixture

Asphalt mixture is a typical elastic, viscous and plastic complex. At low temperature, it has a small deformation range and presents the properties of linear elastomer, and, at high temperature, it has viscoplasticity and large deformation range. However, in the normal temperature environment, it reflects the general viscoelastic properties [7]. Therefore, the study of dynamic modulus of asphalt mixture is helpful to characterize the dynamic performance of asphalt pavement [8].

In order to simulate the ruts that may occur in summer and cracks that may occur in winter, the dynamic modulus test results of three asphalt mixtures at 50°C and 5°C are compared and analyzed, as shown in figure 2 and figure 3.

![Figure 2. Curves of dynamic modulus versus frequency at 5°C](image-url)
It is shown in figure 2 that the dynamic modulus of the base asphalt modified by SBS or TPE is significantly reduced at 5 °C, and the low-temperature deformation ability is better, which means the better low-temperature crack resistance. On the contrary, from Figure 3 the dynamic modulus of the modified asphalt at 50 °C is lower, which shows that the modified asphalt has good rutting resistance. In a word, the low-temperature crack resistance and high-temperature rutting resistance of asphalt mixture are obviously improved by SBS or TPE modifier. The cracking resistance of SBS modified asphalt mixture is better than that of TPE modified asphalt mixture at low temperature. However, corresponding to the previous test results, the high temperature rutting resistance of TPE modified asphalt mixture is better.

4. Conclusions

By comparing the properties of TPE and SBS modified asphalt, the following conclusions are drawn:

a. The thermoplastic elastomer (TPE) material, compounded of water rubber powder, SBS and additives, were successfully used to improve the matrix asphalt performance. Although the performance of TPE modified asphalt is inferior to SBS modified asphalt, the three major indexes all meet the requirements of SBS I-D index.

b. American SHRP test (mainly refers to DSR and BBR) also proved that TPE modified asphalt has better high-temperature performance than SBS modified asphalt, but its low-temperature performance is slightly worse.

c. Compared with matrix asphalt, TPE modified asphalt can improve the high temperature performance, water stability and low temperature performance of asphalt mixture to a certain extent. The overall road performance meets the technical requirements of modified asphalt, and even from the rut test and SPT test results, the high-temperature anti rut performance is higher than SBS asphalt mixture.

d. The comprehensive comparative analysis results show that TPS modified asphalt has some advantages over SBS asphalt in high temperature rutting resistance, and other road performance is not much different, and has significant environmental benefits.
5. References

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