Road performance of tourmaline/rubber powder modified asphalt mixture

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Abstract. To study the effects of tourmaline type and content on the road performance of rubber powder modified asphalt mixture, different types of tourmaline rubber powder modified asphalt mixtures were prepared by adding tourmaline powder instead of equal weight mineral filler into the mixtures. Based on indoor simulation test, the high temperature stability, low temperature crack resistance and water stability of rubber powder modified asphalt mixture under different tourmaline type and content were systematically analyzed. The results show that with the increase of tourmaline powder content, the road performance of asphalt mixtures show an overall growth trend. The 60 ℃ of rutting test dynamic stability, the -10 ℃ of bending test flexural-tensile strain, immersion residual Marshall stability and freeze-thaw splitting tensile strength ratio of rubber powder modified asphalt mixtures with tourmaline powder increase by 12.5-19.6%, 7.5-12%, 1.8-4.7% and 1.7-4.3%, respectively.

1. Introduction
In recent years, studying on inorganic micro-powder modified asphalt mixture has been more and more popular. Inorganic modified asphalt pavement materials, such as diatomite, montmorillonite, glass fiber and wood fiber, have been studied at home and abroad. Inorganic material modifier can not only improve the interface between asphalt and aggregates and meet the requirements of asphalt pavement performance, but also has the characteristics of simple production process, low price, excellent performance and abundant reserves. The results show that [1-4], the inorganic material of tourmaline can not only improve the comprehensive performance of asphalt, but also has certain environmental effects. Tourmaline is a boron-containing ring-structured silicate mineral of aluminum, sodium, iron, magnesium and lithium. It has permanent spontaneous polarization effect, piezoelectric and pyroelectric properties. At present, it has been widely used in environmental protection, medical care, acoustic and electrical functions, water activation and modification, electromagnetic shielding and other fields [5,6]. Kang et al. [7-10] investigated and studied the application of tourmaline in the above-mentioned fields, and concluded that the environmental characteristics of tourmaline, such as releasing negative ions and pyroelectricity, had been well utilized. However, there are few reports about the application of tourmaline in road field at home and abroad, and there is a lack of study on the road performance of tourmaline rubber powder modified asphalt mixture.

In this study, different types of tourmaline rubber powder modified asphalt mixtures are prepared by adding tourmaline powder instead of equal weight mineral filler into the mixtures. Based on high temperature rutting test, low temperature bending test, immersion Marshall stability test and freeze-thaw splitting test, the effects of tourmaline powder type and content on high temperature stability, low temperature cracking resistance and water stability of rubber powder modified asphalt mixture are
systematically studied. It lays a solid foundation for the popularization and application of tourmaline rubber powder modified asphalt mixture.

2. Raw materials and mix proportion design

2.1. Raw materials
The Korean AH-70 matrix asphalt (MA) and rubber powder modified asphalt (RA) are used in the test. The fineness of rubber powder in modified asphalt is 60 meshes with 17.5% (internal mixing, m(rubber powder): m(matrix asphalt) = 17.5:82.5). In this study, two kinds of tourmaline are selected to study, ordinary tourmaline powder (TP) with fineness of 600 meshes and tourmaline negative ion powder (TAP) with negative ion release of 8000 ions. The main technical indicators of each material are shown in Table 1.

| Materials | Basic performance indices |
|-----------|---------------------------|
| MA        | Penetration, 73 (0.1 mm, 25℃, 100 g and 5 s); Ductility, 138 cm (15 ℃); Softening point, 69 ℃ |
| RA        | Penetration, 47 (0.1 mm, 25 ℃, 100 g and 5 s); Ductility, 67 cm (15 ℃); Softening point, 86 ℃ |
| TP        | Black; Fineness, 600 mesh; Negative ion release, 2000-3000 number/cm³; Density, 3.05 g/cm³; Infrared wavelength, 4-15; Emissivity, 86-92 |
| TAP       | Milky white; Fineness, 1000 mesh; Negative ion release, 8000-9000 number/cm³; Density, 3.06 g/cm³; Infrared wavelength, 4-15; Emissivity, > 90 |

2.2. The mix proportion design
The AC-13 gradation asphalt mixture is used in this study, as shown in Table 2.

| Sieve hole size /mm | 16 | 13.2 | 9.5 | 4.75 | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 |
|---------------------|----|------|-----|------|------|------|-----|-----|------|-------|
| Passing rate /%      | 100 | 92   | 70  | 40.3 | 31.5 | 25.4 | 19.2 | 12.7 | 9.2   | 6     |

Different types of tourmaline rubber powder modified asphalt mixtures were prepared by using 15%, 20% and 25% TP or TAP instead of equal weight mineral filler, respectively. According to Technical Specifications for Construction of Highway Asphalt Pavements (JTG F40-2004), China, and Standard test Methods of Bitumen and Bituminous Mixtures for Highway Engineering (JTG E20-2011), China, the optimal asphalt aggregate ratio is determined by the Marshall method. Based on previous study results, the optimal asphalt content for the asphalt mixtures with different content of TP or TAP are shown in Table 3.

| Mixture types | MA | 15% TP + RA | 15% TP + RA | 20% TP + RA | 25% TP + RA | 15% TAP + RA | 20% TAP + RA | 25% TAP + RA |
|---------------|----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Asphalt content | 4.5 | 4.7 | 4.68 | 4.72 | 4.79 | 4.84 | 4.77 | 4.81 | 4.86 |

3. High temperature stability
To systematically evaluate the influence of tourmaline type and content on road performance of rubber powder modified asphalt mixtures. According to the Standard JTG E20-2011, China, the 60 ℃ rutting test of asphalt mixtures with different tourmaline type and content were carried out. The dynamic stability of different asphalt mixtures were measured to evaluate their high temperature stability. The results are shown in figure 1.
Analysis of figure 1 shows that:

1. Adding 15% TP into matrix asphalt mixture, the dynamic stability of the asphalt mixture was improved by 9.6%. When TP and TAP were added into the rubber powder modified asphalt mixture, the dynamic stability of the asphalt mixtures were obviously higher than that of the ordinary rubber powder modified asphalt mixture, which increases by 12.5-19.6% and 13.7-19.4%, respectively. It shows that adding tourmaline powder can effectively improve the high temperature rutting resistance of rubber powder modified asphalt mixture.

2. The dynamic stability of TP and TAP rubber powder modified asphalt mixtures was consistent with the change of tourmaline content. Both of them increase first and then decrease with the increase of tourmaline content. With the replacement mass was 20%, the improvement effect of their high temperature performance was obvious. The dynamic stability was 19.6% and 19.4% higher than that of ordinary rubber powder modified asphalt mixtures, respectively.

3. Under the same tourmaline content, the 60 ℃ dynamic stability of TP rubber powder modified asphalt mixture is similar to that of TAP rubber powder modified asphalt mixture as a whole, indicating that tourmaline type has little influence on the improvement of high temperature stability of asphalt mixture.

4. Low temperature crack resistance

According to the Standard JTG E20-2011, China, the -10 ℃ low temperature bending test of different tourmaline rubber powder modified asphalt mixtures were carried out. The flexural-tensile strain of different asphalt mixtures was used to evaluate their low temperature tensile and crack resistance. The results are shown in figure 2.

Analysis of figure 2 shows that:

1. Adding 15% TP into matrix asphalt mixture, the flexural-tensile strain of the asphalt mixture increased by 3.7%. When TP and TAP were added to the rubber powder modified asphalt mixture, the flexural-tensile strain increased by about 7.5-13.5% and 8.6-15.1%, respectively, compared with the ordinary rubber powder modified asphalt mixture. It is significantly higher than that of the matrix asphalt mixture. It shows that the addition of tourmaline powder can improve the low temperature flexural-tensile properties of rubber powder modified asphalt mixture.

2. The low temperature flexural-tensile strain of two kinds of tourmaline rubber powder modified asphalt mixture increased with the increase of tourmaline content, but their growth rate decreased gradually. With the replacement mass was 25%, their flexural-tensile strain were 4469 με and 4532 με, respectively, which were 13.5% and 15.1% higher than that of ordinary rubber powder modified asphalt mixture.
(3) Under the same tourmaline content, the -10 °C flexural-tensile strain of the TAP rubber powder modified asphalt mixture was slightly higher than that of TP rubber powder modified asphalt mixture, and the increase range of the flexural-tensile strain was higher about 1.1-2.0%.

5. Water stability

According to the Standard JTG E20-2011, China, the water stability of different tourmaline rubber powder modified asphalt mixtures were evaluated comprehensively by immersion Marshall stability test and freeze-thaw splitting test. The effects of tourmaline type and content on the water stability of asphalt mixtures were studied. The results are shown in figures 3 and 4.

![Figure 3. Immersion residual Marshall Stability.](image1)

![Figure 4. Tensile strength ratio of freeze-thaw splitting.](image2)

Analysis of figures 3 and 4 show that:

1. Compared with ordinary matrix asphalt mixture, the immersion residual Marshall stability (IRMS) and freeze-thaw splitting tensile strength ratio (TSR) of TP modified asphalt mixture increased by 1.7% and 1.8%, respectively. Compared with ordinary rubber powder modified asphalt mixture, the IRMS of TP and TAP rubber powder modified asphalt mixtures increased by about 1.8-4.7% and 2.1-4.6%, and TSR increased by about 1.7-3.9% and 1.8-4.3%, respectively. The results show that tourmaline is helpful to improve the water stability of rubber powder modified asphalt mixture. With the increase of tourmaline content, the IRMS and TSR of TP and TAP rubber powder modified asphalt mixture increased, but the growth rate decreased gradually.

2. Under the same tourmaline content, the IRMS and TSR of different types of tourmaline modified asphalt mixtures have little difference. With the replacement mass were 15% and 20%, the IRMS and TSR of TAP modified asphalt mixtures were about 0.5% and 0.4% higher than TP modified asphalt mixtures, respectively. With the replacement mass was 25%, the IRMS and TSR of TP modified asphalt mixture was about 0.2% higher than that of TAP modified asphalt mixture. The results show that tourmaline type has little effect on the water stability of the mixture.

6. Conclusion

1. Adding TP and TAP into rubber powder modified asphalt mixture, the dynamic stability of them increased by 12.5-19.6% and 13.7-19.4% respectively. It was indicated that tourmaline could effectively improve the high temperature stability of rubber powder modified asphalt mixture. The type of tourmaline had little effect on the improvement of high temperature stability of asphalt mixture.

2. Compared with ordinary rubber powder modified asphalt mixture, the -10 °C flexural-tensile strain increases by 7.5-13.5% and 8.6-15.1% respectively after adding TP and TAP into asphalt mixture. It indicates that the addition of tourmaline can improve the low-temperature flexural-tensile properties of rubber powder modified asphalt mixture. The increase range of low-temperature flexural-tensile strain of TAP was about 1.1-2.2% higher than that of TP.
(3) Compared with ordinary rubber powder modified asphalt mixture, the IRMS of TP and TAP rubber powder modified asphalt mixture increased by 1.8-4.7% and 2.1-4.6% respectively, and the TSR increased by 1.7-3.9% and 1.8-4.3%, respectively. The results show that the addition of TP can improve the water stability of rubber powder modified asphalt mixture, but the type of tourmaline has little effect on the water stability of the mixture.

Acknowledgments
This work is supported by Scientific Innovation Practice Project of Postgraduates of Chang’an University (No. 300103002039).

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