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Laboratory investigation of dynamic rheological properties of tourmaline modified bitumen

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HIGHLIGHTS

- The rutting resistance of bitumen is improved by the tourmaline.
- The tourmaline plays as a hardening agent in bitumen.
- The elasticity of bitumen is improved by tourmaline.

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ABSTRACT

Tourmaline modified bitumen was prepared by blending base bitumen with tourmaline powder. Effect of temperature, frequency as well as the content of tourmaline powder on the complex modulus and phase angle of the bitumen was investigated by dynamic shear rheometer (DSR). The results indicate that the complex modulus decreased whereas the phase angle increased with the increasing of temperature and frequency, the complex modulus of modified bitumen exhibit good linear relationship with the logarithmic value of loading frequency. Compared with base bitumen, the bitumen containing tourmaline powder exhibit higher rutting factor, indicating that the rutting resistance of bitumen at high temperature was improved by tourmaline, for the rigidity of bitumen was enhanced by tourmaline.

1. Introduction

With developing of low-carbon economy, the construction of low-carbon society has become the strategy emphasis of the world. In the road engineering, hot-mix bitumen mixture has been widely used for high-grade pavement, which has lots of disadvantage such as wasting energy, exhausting waste gas as well as causing other environmental pollution problems [1,2]. In 1995, people developed the warm-mix bitumen (WMA), which could decrease the discharge of waste gas and save energy by reducing the mixing temperature, but its road property cannot approach to the same level as the hot-mix bitumen [3,4].

Most of environmental modified bitumens are prepared by adding some functional materials into bitumen, and the function mainly attributes to the addictives. Among the inorganic additives, hydrated lime (HL) has been known as an additive for asphalt mixtures. It attracted a strong interest during the 1970s in the USA. Diatomaceous earth and montmorillonoid are also a hot research topic in recent years [5–10], but study about tourmaline is very few.

Tourmaline is a kind of inorganic material, which is of the functions of piezoelectricity, pyroelectricity, permanent spontaneous polarization, far infrared emission, water electrolysis, anion releasing [11–15]. The bitumen modified by tourmaline exhibits many new special low-carbon functions such as adsorbing dust and poisonous gas, saving energy and reducing the amount of smoke emission during the process of hot-mixing due to its functions of piezoelectricity, pyroelectricity and permanent spontaneous polarization. The application of tourmaline modified bitumen also can improve the environment, which attributes to the effect of tourmaline on air purification. Part of the thermal and mechanical energy stored in pavement can be converted into electrical energy, under the influence of the piezoelectricity and pyroelectricity of tourmaline, so the damage of vehicle load on pavement may be obviously reduced, and the service life of road is extended, meanwhile, the pavement temperature can be availably decreased, which will alleviate the urban heat island effect [16,17].

In this paper, tourmaline modified bitumen was prepared by blending base bitumen with tourmaline powder. Effect of

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Table 1
Physical properties of SK70.

Physical properties	Measured values
Penetration (25 °C, 100 g, 5 s, 0.1 mm)	71
Ductility (5 cm/min, 10 °C) (cm)	15
Softening point (°C)	45.7
Density (g/cm^3)	1.025
Solubility (trichloroethylene) (%)	99.7
RTFOT (163 °C, 85 min)	0.02
Mass loss (%)	

Table 2
Properties of tourmaline powder.

Colour	Appearance	Hardness	Density (g/cm^3)	Particle size (meshe numbers)	Purity
White	Powder	7	1.23	5000	99.2%

temperature, frequency as well as the content of tourmaline powder on the complex modulus and phase angle of the bitumen was investigated by dynamic shear rheometer (DSR).

2. Experimental

2.1. Materials

Bitumen, SK70 pave bitumen, supplied by SK Petroleum Bitumen Factory, Southern Korea, its physical properties was listed in Table 1. Tourmaline, supplied by Lingshou stone factory in Hebei Province, China, its properties was listed in Table 2.

2.2. Preparation of tourmaline modified bitumen

The modified bitumen was prepared using a high shear mixer. Bitumen heated to 150 ± 5 and tourmaline were poured into the mixer, the mixture was initially blended using a high shear mixer at a rotate speed of 1000 rpm for 10 min, and then the mixture was continuously blended at a rotation speed of 4000 rpm for 40 min, finally, the mixture was blended at the rotation speed of 1000 rpm for 10 min.

2.3. Rheogical properties testing

Dynamic rheological properties of the base and tourmaline modified bitumens were measured by DSR (MCR101, Anton Paar Company, USA). Frequency sweep test was carried out from 0.1 rad/s to 10 rad/s. The testing temperatures were set at 64 °C, 70 °C, 76 °C and 80 °C, respectively. The plate used for frequency sweep test was 8 mm in diameter and the gap between the parallel plates was 2 mm.

3. Results and discussion

3.1. Effect of frequency on the complex modulus and phase angle of tourmaline modified bitumen

The relationship between the complex modulus of tourmaline modified bitumen and loading frequency was shown in Fig. 1.

As could be seen in Fig. 2, the complex modulus of modified bitumen increased along with the increasing of loading frequency, there was a good linear relationship between the logarithmic value of complex modulus G^* and logarithmic value of loading frequency. The reason for this phenomenon was that bitumen material was a kind of visco-elastic materials, and its deformation generally included elastic deformation, renewable viscoelastic deformation and irreversible viscous deformation. The greater loading frequency was, the shorter time for external load contacted with bitumen, and then the complex modulus was increased. On the

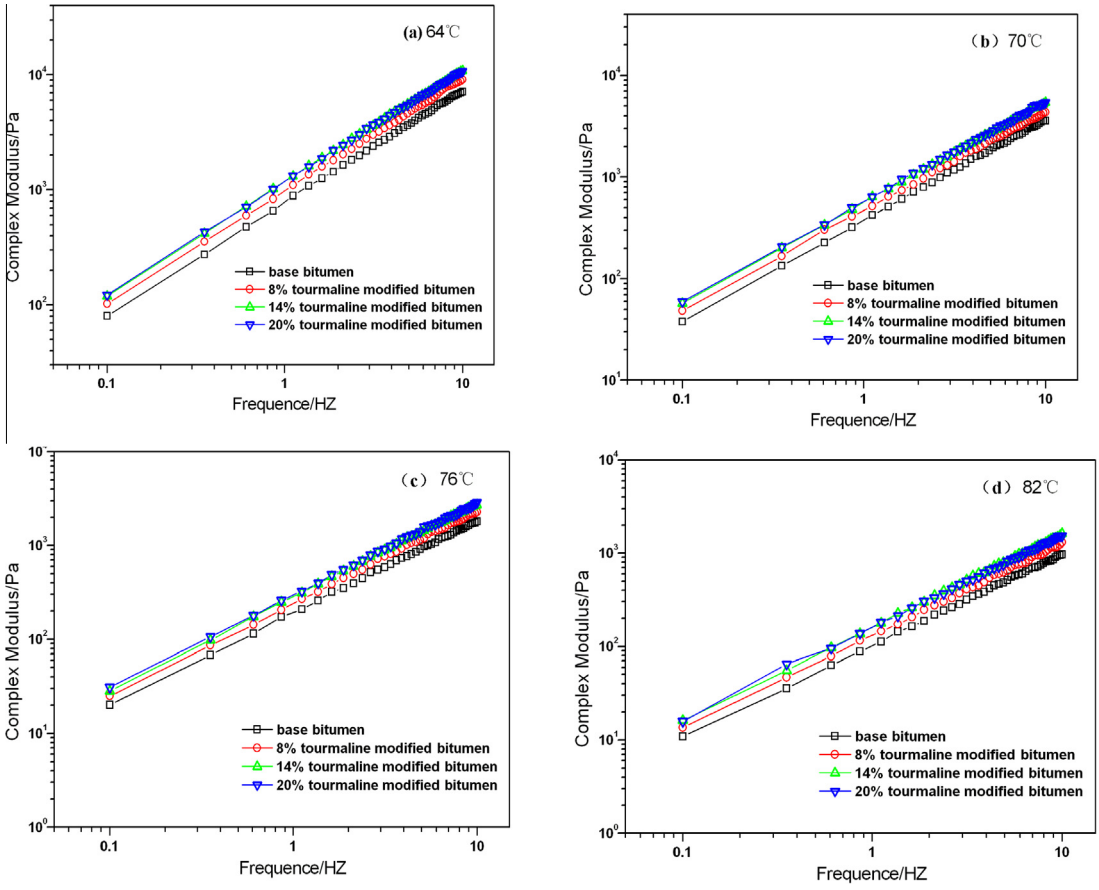

Fig. 1. Effect of loading frequency on complex modulus at different temperature.