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Effect of phenolic resin on the performance of the styrene-butadiene rubber modified asphalt

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HIGHLIGHTS

- The SBR modified asphalt reinforcement with PF has improved the physical properties of asphalt.
- Using PF reduces the temperature susceptibility of SBR modified asphalt.
- The 4%SBR + 3%PF mixture has better Marshall stability and flow values.
- Resistance to permanent deformation and moisture damage increases significantly after addition of PF.

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ABSTRACT

To obtain the highest performance of styrene-butadiene rubber (SBR) modified asphalt, the phenolic resin (PF) was used. The changes on physical properties of asphalt binder such as penetration, softening points, storage stability, ductility, elastic recovery, and viscosity measurement with different content of SBR and PF (1–5%) were investigated. Fourier Transform Infrared Spectroscopy test was used to analyze the chemical and molecular changes on binders before and after aging. Wheel tracking (rutting) test, Moisture susceptibility test, and cracking resistance were also conducted to examine the high and low-temperature performance of the hot mix asphalt (HMA) mixture. Results indicated that PF enhanced the physical properties of SBR modified asphalt. Besides, the addition of PF would reduce the effect of temperature changes on asphalt performance. The high-temperature deformation resistance of HMA mixture was significantly increased by the addition of PF with opposed impact on the resistance of cracking.

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1. Introduction

Asphalt is widely used over the world to construct pavements because of its good viscoelastic property [1,2]. However, the asphalt is more sensitive to temperature, and a series of distress inflexible pavements will be caused by the increase of traffic loads, such as rutting in the high-temperature and cracking in the low-temperature [3]. These distresses influence the pavement life and increase the traffic safety hazard [4]. Hence, to improve the asphalt performance, the asphalt needs to be modified [5–7].

The main components of modifier include a thermoplastic elastomer, rubber, and resin [8]. Among them, styrene-butadiene rubber (SBR) can increase the base asphalt performance, such as the low-temperature cracking resistance, elastic recovery, adhesive and cohesive properties [9]. Compared with SBS modified asphalt, SBR has lower cost and better cracking resistance. So SBR is more suitable to be used in the cold regions than other modifiers [10]. However, the high-temperature rutting resistance of SBR is not enough [11]. While rutting is one of the significant issues related to the HMA mixtures used for road pavements and is usually manifested under heavy traffic loads [12,13]. Also, SBR is much easier to be oxidized, and then the loss of low-temperature ductility of SBR modified asphalt will be greatly evident after short-term aging [14]. In order to enhance the performance of SBR modified asphalt, the combination needs another modifier (either by chemical reaction or physical mixing) [15,16]. Liang et al. [17] investigated the effects of PPA and SBR composition on physical properties and viscoelastic behaviors. They found that the addition of PPA remarkably enhanced the adhesion, elasticity and anti-rutting ability of SBR modified asphalt. Zhu et al. [18] studied the influence of multi-dimensional nanomaterials on rheological characteristics of styrene-butadiene rubber modified asphalt. They reported that the addition of multi-dimensional nanomaterials could enhance

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the shear deformation resistance and elastic behavior of SBR modified asphalt.

Phenolic resin (PF) is one of the most common types of resin materials that began early to be popularized and used. PF has a relatively lower price and better resistance to high-temperature performance [19]. Under the condition of high-temperature, it can maintain the integrity of the structure and stability of the size which is usually regarded as refractory materials [20]. Qing Q I and You ping W U [21] found that PF could significantly improve the physical and mechanical properties of rubber. Akbar Shojaei and Morteza Faghihi [22] investigated the organoclay (OC) on the performance of SBR/PF blend prepared by two-roll mills. The results indicated that both PF and OC showed accelerating role on the cure rate of SBR and could increase the crosslinking density of the rubber phase. Babak Derakhshandeh [23] studied the thermal, mechanical, and microstructural characteristics of NBR/PF and SBR/PF blends. The results indicated that the glass-transition of the two kinds of rubbers was shifted slightly in various compositions of rubber/PF mixtures, in which the partial solubility of PF in the rubber phase could be shown. In the last decade, many researchers have reinforced rubber by PF [21–23]. However, the effect of PF on SBR modified asphalt has not been well studied.

The main objective of this study was to investigate the effect of PF on SBR modified asphalt and obtain high performance of SBR modified asphalt. The physical properties like penetration, softening point, and ductility were evaluated. The effect of PF and SBR as modifiers on the performance of HMA, including rutting resistance, moisture sensitivity and cracking resistance, were also investigated.

2. Materials and methods

2.1. Materials

Asphalt used in this study was AH-90 as a base asphalt, obtained from Liao He Asphalt Factory of Panjin, Liaoning, China. The physical properties of the base asphalt were shown in Table 1. The SBR modifier with 22.5–24.5 wt% styrene content was conducted by Zibo Petrochemical Co. Ltd., China. See Fig. 1. Phenolic resin powder was supplied by Jining Resin Factory, Shandong, China. Table 2 shows physical characteristics of PF. See Fig. 2.

The crushed coarse and fine aggregates used in this study were obtained from Harbin City in northeastern China. Properties of the aggregates are summarized in Table 3. With a nominal maximum aggregate size of 13.5 mm. Fig. 3 shows the aggregate gradation used in this study based on the JTG F40-2004 standard.

2.2. Methods

2.2.1. Asphalt binder preparations

Good dispersion is the key to display the effect of modifier. Firstly, base asphalt was heated until reached a molten state. Secondly, the different percentage of SBR (3%, 4% and 5% by total weight of asphalt) was gradually added at the low-speed mixer at 145 °C for 10 min, then used high shear mixer with 3000 rpm

Fig. 1. Styrene-Butadiene rubber.

Table 2
Physical characteristics of PF.

Property	Value
Moisture (%)	≤2.0
Fluidity (mm)	20–40
Polymerization speeds (150 °C)	45–85
Free phenol (%)	2.0–4.0
Fineness% (140 mesh)	≥95

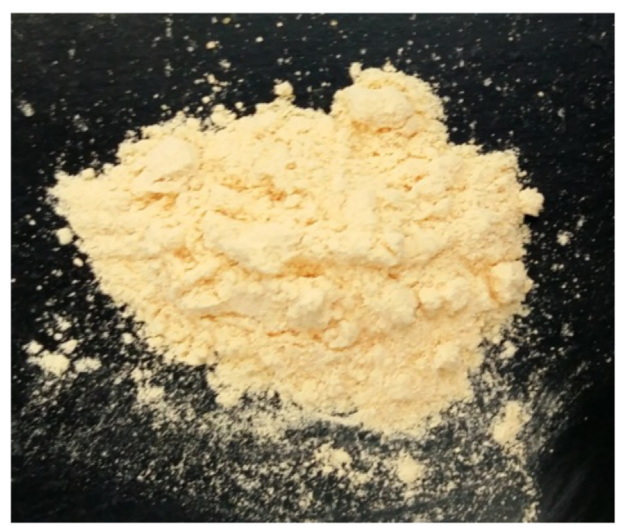

Fig. 2. Phenolic resin.

Table 1
Physical properties of base asphalt.

Physical properties	Standard	Result
Penetration (25 °C, 0.1 mm)	ASTM D5	87.0
Ductility (15 °C, 5 cm/min, cm)	ASTM D113	150+
Softening point (°C)	ASTM D36	47.4
Viscosity (135 °C, Pa s)	ASTM D4402	0.67
Penetration index (PI)		−0.49

Table 3
Properties of aggregates.

Aggregate property	Standard	Value
Crushing value (coarse aggregate) (%)	ASTM D6928	13.1
Los Angeles abrasion value (%)	ASTM C131	15.1
Apparent specific gravity	ASTM C128	2.78
Water absorption (%)	ASTM C70	0.39
Apparent specific gravity (fine aggregate)	ASTM C127	2.69
Sand equivalent (%)	ASTM D2419	93.7

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