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Performance characteristics of Terminal Blend rubberized asphalt with SBS and polyphosphoric acid

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HIGHLIGHTS

- Comprehensive rheological evaluation of Terminal Blend hybrid asphalt.
- Additional SBS polymer led to formation of cross-linked network in TB binder.
- Further addition of PPA hinder the formation of cross-linked network.
- TB binder has advantage in inhibiting the formation of carbonyl and sulphoxides.
- TB + SBS asphalt mixture has good rutting resistance and fatigue performance.

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ABSTRACT

Terminal Blend (TB) rubberized asphalt is a promising technology in producing crumb rubber asphalt as it overcomes the shortcomings such as lack of storage stability and workability. However, the limitation of TB asphalt is that the high temperature property is drastically reduced compared to conventional rubberized asphalt binders due to the degradation of crumb rubber. Currently, the studies regarding to modification to improve its high temperature property is not adequate. The objective of this paper is to investigate the optimum modification formula of asphalt binders using styrene-butadienestyrene (SBS) and polyphosphoric acid (PPA) and explore their mechanism of modification. Firstly, dynamic shear rheometer (DSR) test and bending beam rheometer (BBR) test were conducted to evaluate the rheological properties at both high and low temperatures. Furthermore, Fourier transform infrared spectroscopy (FTIR) and gel permeation chromatography (GPC) test were conducted to detect the chemical changes of TB modified asphalt binders. Finally, the high temperature stability and fatigue property of TB modified asphalt mixtures were applied to verify the performance properties. Results indicates that 20T3S (20 wt% crumb rubber and 3 wt% SBS) used to produce the modified binders was the best modification formula considering both high and low temperature rheological properties. The modification mechanism was that SBS formed 3D cross-linking network structure in TB binder, which played an important role in enhancing high temperature properties of TB binders. Additionally, 20T3S asphalt mixture had better high temperature stability and fatigue performance comparing to 4.5S (4.5 wt% SBS) modified asphalt mixture.

1. Introduction

In China, more than 15 million tons of scrap tire rubbers are disposed on landfills every year, which creates drastically environmental problems and economic waste. Last decades, crumb rubber was recycled as a valuable polymeric material and was incorporated in asphalt modification. The crumb rubber modifier (CRM) not only improves the rutting resistance by increasing the stiffness and elasticity at a high temperature, but also increases the fatigue life of an asphalt mixture by increasing asphalt film around the surface of the aggregate [1,2]. In addition, CRM modification reduces the stiffness of an asphalt at a low temperature which improves the low temperature properties of CRM asphalt mixture [3,4].

The property improvement of CRM asphalt was due to the interaction between crumb rubber and base asphalt. In this aspect,

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Abdelrahman et al. investigated the interaction between asphalt and crumb rubber as well as its effect on the property development [5,6]. Fig. 1, developed from Abdelrahman's research [6], illustrated the relations between binder viscosity and particle size change, as well as the effect of further addition of polymer modifier. When the crumb rubber is fully mixed with asphalt (Case I in Fig. 1), rubber particles begin to absorb the oily phase of asphalt and finally are swollen to two or three times their original volume (Case II in Fig. 1). After crumb rubber reaches maximum swelling size in the asphalt, if the temperature is high enough or the mixing duration is long enough, the rubber particles start to degrade (Case III in Fig. 1). Crumb rubber has a reaction of devulcanization (defined as the cleavage of the sulfur cross-link bonds) and depolymerization (defined as the breaking of the backbone of the main chain) during curing process which cause a gradual reduction of high temperature property [7]. The depolymerization and devulcanization lead crumb rubber to dissolve in asphalt. Thus the binder become homogeneous with better storage stability compared to the original modified binder. If the crumb rubber is stored at a very high temperature for an extended time, full depolymerization can occur (Case IV in Fig. 1).

There are two technical routes in the production of crumb rubber modified asphalt (CRMA). The first type of production process was called "dry process", in which CRM was used as a substitute of 1% ~ 3% of weight of aggregates in the mixture. It was found that there was a limited interaction between CRM and asphalt during blending in the mix plant [8] (Case I in Fig. 1). The second one was called "wet process" which was developed by McDonald in the late 1960s [9]. CRM was added to base asphalt as modifier at 180 °C ~ 190 °C. The main interaction between CRM and asphalt was that the absorption of aromatic oils from asphalt cement into CRM occur (Case II in Fig. 1). As reported by Heitzman, it was not a chemical reaction, but a physical reaction [10]. The "wet process" has been used for a long history which can significantly improve

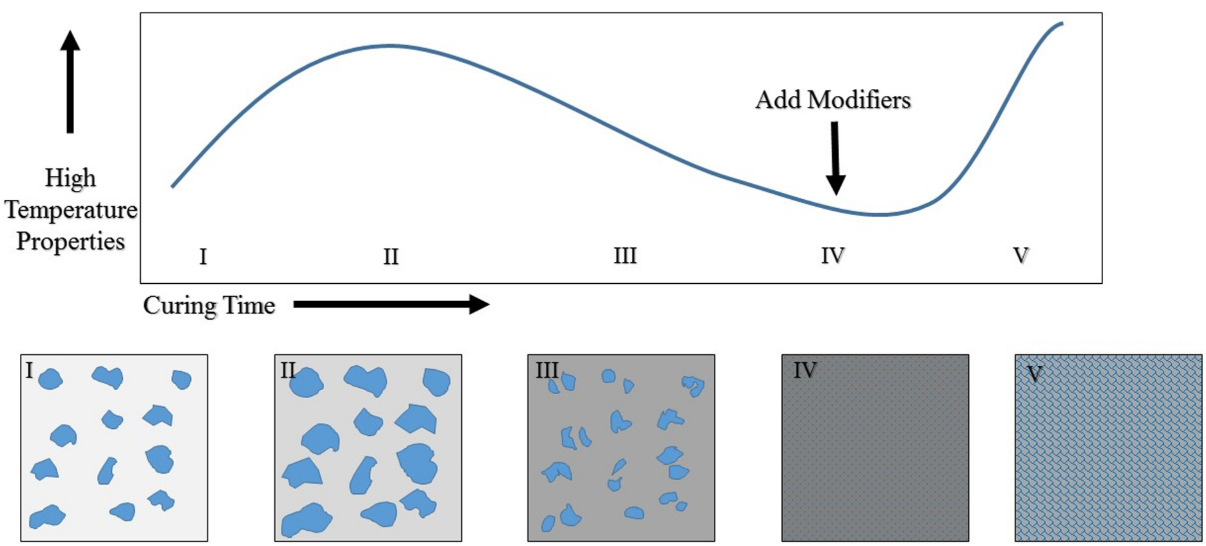

Fig. 1. Progression of asphalt-rubber-polymer interaction at high temperature (developed from [6]).

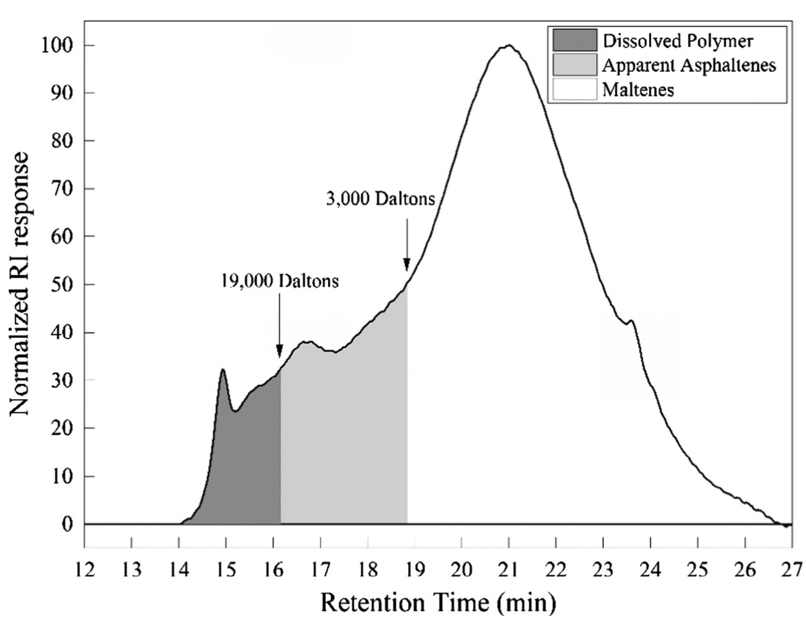

Fig. 2. Fractions of the chromatogram based on molecular weight.