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The laboratory performance of asphalt mixture with Amorphous poly alpha olefins (APAO) modified asphalt binder

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HIGHLIGHTS

- 6% APAO was the optimal dosage in asphalt binder and asphalt mixture performance perspective.
- Asphalt mixture with 6% APAO had the best high temperature performance, moisture damage resistance.
- Negligible tensile strength differences occur between asphalt mixture with 4% APAO and 6% APAO.

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ABSTRACT

In this paper, asphalt binder was blended with 0%, 4%, 6%, and 8% Amorphous poly alpha olefins (APAO) to prepare modified asphalt binders. Based on the penetration, ductility, softening point, and Dynamic Shear Rheometer (DSR) test, 6% APAO was the optimal dosage in asphalt binder performance perspective. The dense graded aggregate was mixed with APAO modified asphalt binder to prepare the APAO modified asphalt mixture. The volumetric parameters of the asphalt mixture with APAO modified asphalt binder was tested. The standard Marshall stability test, immersion Marshall test, Freeze-thaw splitting test, and Marshall stability of aged asphalt mixtures test were conducted on asphalt mixtures with APAO modified asphalt binder. Based on the Marshall stability test, immersion Marshall test, and Freeze-thaw splitting test, asphalt mixture with 6% APAO possessed the best high temperature performance, the highest moisture damage resistance, and the least splitting tensile strength loss after the freeze-thaw conditions. The tensile strength decreased after the addition of APAO. There was only negligible tensile strength difference between asphalt mixture with 4% APAO and 6% APAO. Based on the Marshall stability and retained Marshall stability ratio (RMSR) of asphalt mixtures after aging, the optimal content of APAO was 6%. Therefore, 6% APAO was the optimal content for both modified asphalt binder and APAO modified asphalt mixture.

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1. Introduction

The pavement undertaken sustained increasing traffic volume, loads, and tire pressure in recent years, which put forward the modification of asphalt binders to meet certain conditions. The stiffness of asphalt binders at normal service temperatures need to be improved to enhance the rutting resistance property [1]. While, the stiffness of asphalt binders at low temperatures need to be decreased to improve the thermal cracking resistance [2]. The adhesion between asphalt binders and aggregates need to reduce striping and other moisture damage [3]. In extreme climatic regions, asphalt binder need modification to fulfill the asphalt binder specification. Using waste materials and industry byproducts as additive in asphalt binders can decrease their environmental and economic impacts [4,5]. The public agencies willing to fund projects with modified asphalt binder that had longer service life with lower maintenance costs.

Many different types of polymer modifiers are used to improve the performance of asphalt mixture pavement, which included plastomers (such as polyethylene) and thermoplastic elastomers (such as Styrene-Butadiene-Styrene (SBS)) [6]. Polymers are mainly used to increase the stiffness of asphalt binder at high temperatures to resist rutting, increase elasticity at intermediate temperatures to resist fatigue, and decrease the stiffness at low temperatures to resist thermal cracking [7–10]. During the modification procedure, the light components of asphalt binder were normally swollen by polymers, which produced two continuous

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phases [11]. The properties of polymer modified asphalt were normally influenced by the characteristics of asphalt binder and polymer, the polymer content, and the manufacture process. Segregation and the compatibility of polymer modified asphalt may be affected if inappropriate polymer content was adopted during polymer modification [12]. Polymer modified asphalt binder with optimum polymer content should possess overall performance improvement, which included storage stability, mechanical property, and cost effective. Researchers confronted inevitable challenges during the application of polymer modified asphalt binders, which included high cost, high temperature sensitivity, poor storage stability and limited aging resistance [13,14]. As the mostly used modifier, SBS modified asphalt binder increased the viscosity, complex modulus and elastic response of asphalt binder [15]. The aging resistance of SBS modified asphalt was restrained due to the asphalt binder oxidation, segregation, and the unsaturated property of SBS [16]. In some conditions, the low temperature performance of asphalt binders was sacrificed when enhancing the high temperature performance. Some researchers tried to modify the asphalt binder with two materials. Asphalt binder modified with polyethylene and organophilic montmorillonite had good high temperature stability and deformation resistance and low temperature cracking characteristics [17]. The combined modification of asphalt binder with rubber and polyethylene will increase the high temperature performance without sacrificing the low temperature property [4].

Amorphous poly alpha olefin (APAO) are low molecular weight and low crystallinity copolymers with atactic molecular structure, which is produced through the polymerization of propylene and ethylene [18,19]. APAO is milky white solid, with good tenacity, acid-resistance, alkali resistance and anti-oxidation. Besides, APAO can be used for the modification of asphalt binders for high grade highway pavement. The compatibility between APAO and asphalt binders is good, APAO can completely dissolved in the asphalt binders when mixed in the laboratory. APAO can significantly improve the high-temperature stability of asphalt binders [20]. The storage stability of APAO modified asphalt binders is highly related to the APAO content in modified asphalt binder. The short term aging performance of asphalt binders was increased after the addition of APAO. By adding APAO to waste tire rubber modified asphalt binder, the interaction between APAO and rubber modified asphalt improved the aging resistance of asphalt binder [21]. The APAO had good compatibility with asphalt binders when the APAO content is small (2%–6% wt.) [22]. When asphalt binders modified with APAO and Styrene Butadiene Styrene (SBS), the high-temperature stability and low-temperature anti-cracking performance were both improved. The high temperature characteristic of APAO and rubber modified asphalt was increased, while the low temperature rheology decreased [23]. Compared with SBS modified asphalt, APAO modified asphalt preparation process is simpler and the cost of production is lower. Wei et al made further systematic analyses on the APAO modified asphalt binders, which included conventional tests, rheological properties and morphology analysis [22]. The results showed that APAO improved the high temperature performance and reduced the temperature susceptibility of asphalt binders.

2. Objectives and motivations

Former researchers focused mainly on the characteristics of modified asphalt binders, while less analyzed the performance of asphalt mixtures with modified asphalt binders, not to mention asphalt mixture with APAO modified asphalt binder. The paper aims to study the Marshall stability, moisture susceptibility, and strength under different conditions of asphalt mixtures with APAO modified asphalt binders, as well as the conventional characteristics of APAO modified asphalt binders. Based on the penetration, ductility, softening point, and Dynamic Shear Rheometer (DSR) test, the characteristic of APAO modified asphalt binders were analyzed. The mixing temperature and compaction temperature of asphalt binder with different APAO content were determined with Rotational Viscometer (RV) test. The volumetric parameters, the Marshall stability test, the immersion Marshall test, Freeze-thaw splitting test and Marshall stability of aged asphalt mixture were conducted to evaluate the performance of asphalt mixture with APAO modified asphalt binder. The optimal dosage APAO in asphalt mixture with APAO modified asphalt binder was determined in asphalt binder and asphalt mixture performance perspective.

3. Materials

3.1. Material

SK-70# petroleum asphalt binders (penetration: 60–80) produced in South Korea was used as base asphalt binder in the study. The property tests of the asphalt binders were performed based on the ASTM D5, ASTM D113, ASTM D36, ASTM D4402, and ASTM D93, respectively. The basic properties of asphalt binders are shown in Table 1.

The APAO 2385, which was manufactured in the company of HUNTSMAN in America, was utilized in this study to modify asphalt binder. The main parameters of APAO were displayed as follows in Table 2.

The physical properties of aggregate and mineral filler had direct effect on how the aggregate performed in asphalt mixture and the interaction between asphalt binder and aggregate. The physical property of aggregate was measured based on standard test method. The basic performance of aggregate and mineral filler are displayed in Table 3.

In this study, dense-graded AC-13C type gradation was adopted as the aggregate gradation design of the asphalt mixture, which is widely used in the surface layer of pavement. The sieve analysis of aggregates was conduct based on the ASTM

Table 1
Basic properties of asphalt binders.

Parameters measured	Results
Penetration at 25 °C (100 g, 5 s) (0.1 mm)	64.6
Ductility at 15 °C (5 cm/min) (cm)	153.4
Softening point (R&B) (°C)	52.4
Viscosity at 135 °C (cp)	523.3
Flash point (°C)	265

Table 2
The physic characteristic of APAO.

Properties	Results
Density, g/cm^3	1.41
Tensile strength (23 °C), MPa	210
Bending modulus (23 °C), MPa	9000
Melting point, °C	295

Table 3
Basic performance of aggregate and mineral filler.

Parameters measured		Results
Aggregate	Crush. Value, %	20.7
	LA abrasion loss, %	16.7
	Apparent specific gravity	2.736
	Water absorption, %	0.5
	Soundness, %	4.0
	Moisture content, %	0.4
Mineral filler	Hydrophilic coefficient	0.79
	Plasticity index	2.9

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