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Engineering behavior of aged polypropylene-modified asphalt pavements

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HIGHLIGHTS

- Effect of aging on the properties of control and PPMCM mixes was determined.
- Two aging levels namely: 48 and 96 h at 100 °C were used.
- PPMCMs indicate a longer life than the control asphalt mixtures.
- PPMCMs achieve the ASTM and SCRB limits.
- PPMCMs reveal superior durability with resistance to rutting and moisture damage.

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ABSTRACT

An investigation was executed to determine the influence of laboratory aging on the engineering characteristics of polypropylene-modified concrete mixtures (PPMCMs) utilizing different experiments. The design bitumen content was obtained for dense mixture by the Marshall method using aggregate blends which conformed to the American Standard for Testing and Materials, ASTM (D-3515). Marshall stability, Marshall modulus of stiffness, indirect tensile strength, tensile strength ratio, resilient moduli, aging index, cracking index, and extensional viscosity of the aged PPMCMs at temperature of 100 °C and at two aging levels between 48 and 96 h are used to evaluate the performance change of PPMCMs. The PPMCMs achieve the ASTM specified limits; they reveal superior durability, elasticity, and adhesive characteristics with higher resistance to permanent deformation and moisture damage.

1. Introduction

Work on polymers-modified asphalt/mixtures has been proceeding at an increasing rate over the last years. The use of polypropylene (PP)-polymer modifiers change the bitumen/mixes performance, as illustrated by Al-Hadidy and Tan [1]. The PP is usually loaded in concentrations of about 3–5% by weight with respect to the asphalt [1].

However, neither of the researchers was documented the aging of PP-modified asphalt binders and mixtures. Aging considered as one of the other pavement problems. It increases pavement stiffness and affects pavement recycling [2].

Several researches reported aging effects on binders characteristics following ASTM and SuperPave testing procedures, so these procedures were relatively simple and require little time [3–9]. In contrast, studies on polymer-modified asphalt mixtures age-hardening need much more time and efforts. The assessment of the mixtures properties under aging effects may be a useful approaches than for binders.

For asphalt mixtures, the recommended laboratory procedure for short-term oven aging (STOA) is to heat the loose mix in a forced draft oven for 4 h at a temperature of 135 C [3], while for the stiffer mixes, short term aging of 2 h at 154 C is commonly used. Whereas, the laboratory procedure for long-term aging (LTA) is to place the samples in a forced draft oven for 4 to 8 days at 85 °C or 2 to 4 days at 100 °C. The LTA conditions representative of older than 3 years mixtures in the field as reported by Bell [4].

Mansour and Amin [5] determined aging and environmental effects on fracture strength of recycled paving asphalt (RPA) and steel slag aggregate (SSA) under freeze and thaw (FT) cycles and LTA. It was found that aging enhances fracture strength of RPA/SSA-mixtures.

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Shifeng et al. [6] reported that aging changed the physiochemical characteristics of crumb/terminal rubber-bitumen blends. The stiffness of the rubber-bitumen blends is also increases under aging effects.

MinBai [7] studied aging effects on the low temperature characteristics of SBS-modified bitumen with and without rejuvenators using conventional methods (penetration and ductility at 5 °C), Fraass breaking point test, dynamic shear rehometer (DSR), force ductility test and bending beam rehometer (BBR) testing procedures. It was found SBS-modified bitumen with rejuvenators achieve superior elasticity.

Zhang et al., [8] studied aging effects on the rheological property, physical characteristics and chemical composition of SBS-70 and SBS-90 modified asphalts using thin film oven test (TFOT), pressure aging vessel (PAV), and ultraviolet (UV) radiation procedures. It was found SBS-90 is more susceptible to aging than SBS-70.

Lee et al. [9] evaluated the effects of STOA on asphalt mixtures using the gel-permeation chromatography (GPC) procedure. Nine asphalt mixtures, using three different binder sources, were prepared and five STOA methods were used to evaluate these mixes. For comparison, the rolling thin film oven (RTFO) aging was also conducted for nine asphalt binders. The aging of a binder within asphalt mixtures, including polymer-modified mixtures, could be identified under various STOA conditions. Statistical analysis of the GPC test results indicated that two commonly used STOA methods in the laboratory, a 154 °C oven aging for 2 h and a 135 °C oven aging for 4 h, are not significantly different, based on the increase in the large molecular size (LMS) ratios. The RTFO aging method was found to have less effect on binder aging than the STOA methods of asphalt mixtures.

This research attends to determine the influence of aging process (100 °C for 48 h and 100 °C for 96 h) on the engineering properties (Marshall stability (MS), Marshall modulus of stiffness (MMS), indirect tensile strength (ITS) at 25 °C and 60 °C, tensile strength ratio (TSR), resilient modulus (MR) at 25 °C, aging index (AI), cracking index (CI), and extensional viscosity) of polypropylene-modified concrete mixtures (PPMCMs) at temperature of 100 °C and at two aging levels between 48 and 96 h, and compare the obtained results with control mixtures.

2. Materials

2.1. Asphalts

Iraqi penetration grade asphalt (AC-50) was used to prepare dense graded asphalt mixture (DGAM). Table 1 presents the basic asphalt properties.

2.2. Mineral aggregate

Aggregate selected for used in this investigation included crushed coarse aggregate and river sand. The gradation as illustrated in Fig. 1, conform to the ASTM (D-3515) limits [10]. The quality tests of the aggregate were also evaluated and summarized in Table 2. Portland cement with specific gravity of 3.15 was used as a mineral filler.

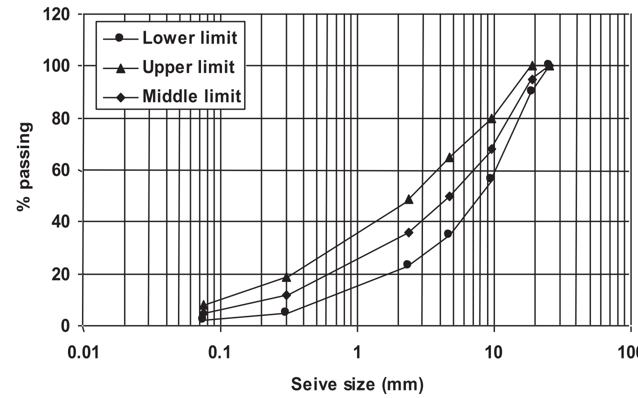

Fig. 1. Aggregates gradation limits.

2.3. Polypropylene modifier

The pyrolisis PP with an average density of 0.82 gm/cc and melting point between 156 and 161 °C was selected as a modifier for AC-50. 3% of PP was mixed with AC-50 for 7 ± 1 min at 150 ± 5 °C using a mixer of 500 rpm to obtain a homogeneous binder (Table 3).

2.4. Mixture design and test specimen preparation

Resistance to plastic flow of bituminous mixtures procedure documented in ASTM D-1559 [10] was executed to determine

Table 2
Aggregate quality tests.

Property	Coarse Agg	Fine Agg	ASTM limits [10]
Toughness, %	18.10	–	40 max.
water absorption, %	0.290	1.51	4.0 max.
Bulk sp.gr.	2.704	2.675	–
Apparent sp.gr.	2.744	2.696	–
Apparent sp. gr. Filler	–	3.15	–

Table 3
Properties of PPMAC50.

Property	Result
Penetration: (25 °C, 100 g, 5s, 1/10 mm)	31.5
Softening point, °C	59
Penetration index	−0.118
Ductility (25 °C, cm)	115
%loss wt of heat	0.15

Table 1
Physical properties of AC50.

Property	ASTM Designation No. [7]	Test Condition & units	Result	SCRB limits [11]
Penetration	D-5	(25 °C, 100 g, 5 s, 0.1 mm)	42	40–50
Softening point	D-36	Ring & ball	54	51–62
Ductility	D-113	(25 °C, 5 cm/min)	150+	100+
Specific gravity	D-70	(25 °C/25 °C)	1.053	–
Flash point	D-92	Cleveland open cup, °C	263	>232
Loss on heat	D-1754	5 h, 163 °C, %	0.25	–
Asphaltene	D-2006	%	32.65	–