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Investigation of proper long-term laboratory aging temperature for performance testing of asphalt concrete

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HIGHLIGHTS

- A significant change in the relationship between asphalt binder rheology and chemistry occurs when the aging temperature is increased from 95 °C to 135 °C.
- Asphalt mixture performance can be negatively impacted by long-term aging at 135 °C.
- When the asphalt loose mix laboratory aging temperature is at or below 95 °C, the relationship between binder chemistry and rheology is unaffected by the aging temperature.

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ABSTRACT

The performance implications of laboratory asphalt loose mixture aging at 135 °C were evaluated by comparing the performance of mixtures subjected to long-term aging at 95 °C and 135 °C to yield the same rheology. Although the rheology of the mixtures aged at 135 °C and 95 °C matched, their chemistry differed. Performance test results suggest that the chemical changes induced by aging at 135 °C can negatively impact performance. The relationship between binder chemistry and rheology was unaffected by aging temperatures at or below 95 °C. The rate of oxidation increased with an increase in temperature, and thus, the optimal loose mixture aging temperature is 95 °C.

1. Introduction

The accurate characterization of asphalt mixture properties in terms of the service life of asphalt pavement is becoming more important as more powerful pavement design and performance prediction methods are implemented. Both an accurate aging model and an optimal laboratory conditioning procedure are required to simulate long-term aging for performance testing and prediction in order to integrate the effects of long-term aging into pavement prediction models and other mechanistic design and analysis methods. The standard method that is used to assess the long-term aging of asphalt mixtures in the United States is American Association of State Highway and Transportation Officials (AASHTO) R 30 [1]. In this method, compacted asphalt mixture specimens are conditioned at 85 °C ± 3 °C for 120 ± 0.5 h to represent five to ten years of aging in the field. However, the long-term oven aging of compacted specimens leads to both radial and vertical oxidation gradients, which is a concern for performance testing because the properties throughout the specimen can vary [2,3]. As an alternative, the long-term oven aging of loose (uncompacted) asphalt mixture has been gaining attention in recent years because it eliminates the oxidation gradient by promoting oxygen exposure to the mixture [4–10]. In addition, aging loose asphalt mixture is more efficient than aging compacted specimens at a given temperature [3]. Elwardany et al. (2016) demonstrated that long-term aged loose mixture can be compacted for performance testing and prediction.

The rate of oxidation increases as the temperature increases, and thus, laboratory aging at a higher temperature is more efficient than at a lower temperature [2,3]. This phenomenon has led several recent studies to propose loose mixture long-term aging at 135 °C as an efficient alternative to the aging procedure recommended in AASHTO R 30 [9–11]. Although increasing the aging temperature increases the rate of oxidation, which is a desirable attribute, it can also disrupt polar molecular associations and lead to the thermal decomposition of sulfoxides in asphalt binders.

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Thus, accelerated aging of asphalt binder at significantly high temperatures may lead to a fundamentally different aged asphalt binder than asphalt aged in the field (at a lower temperature) [12]. The literature indicates that the disruption of polar molecular associations and subsequent sulfoxide decomposition become critical at temperatures that exceed 100 °C [13–18]. However, past research efforts have not evaluated the implications of these chemical changes with regard to asphalt mixture performance. In addition, aging at temperatures above 100 °C can lead to asphalt mastic drain-down from the loose mix because asphalt binder has low viscosity values at elevated temperatures [9]. This study seeks to evaluate the performance implications of long-term laboratory aging of loose mixture at 135 °C.

2. Objectives

The objective of this study is to:

- Evaluate the performance implications of laboratory long-term aging temperature.

3. Materials and methods

For this study, comparative tests between loose mixtures aged at 95 °C and 135 °C were conducted to evaluate the implications of loose mix aging at 135 °C with regard to asphalt mixture performance using three mixtures, all prepared with the same Federal Highway Administration Accelerated Load Facility (FHWA ALF) aggregate, but with different binders: ALF styrene-butadienestyrene (SBS), SHRP AAD, and SHRP AAG. The SHRP AAD and SHRP AAG binders were selected due to their known differences in chemistry. SHRP AAD has high sulfur content (6.9%) and is highly structured (incompatible). Thus, SHRP AAD was expected to be especially susceptible to changes in oxidation kinetics and mechanics at 135 °C. SHRP AAG has low sulfur content (1.3%) and is less structured (more compatible) than SHRP AAD. Thus, SHRP AAG was expected to be less susceptible to changes in oxidation kinetics and mechanisms when the temperature for loose mixture aging was increased from 95 °C to 135 °C. The FHWA ALF SBS mixture was selected in order to include a common asphalt-modified asphalt binder in the study and because field core data were available for it. Fig. 1 presents a summary of the experimental plan implemented for each mixture to evaluate the implications of loose mixture aging at 135 °C. Table 1 presents the naming scheme for the samples subjected to different aging procedures. Loose mix aging at 70 °C and 85 °C was included to evaluate the comparison between effect of aging temperatures on the physiochemical properties of asphalt mixture, regarding the properties of the extracted and recovered asphalt binders. More details on this matter will be provided later in this paper. The designation of ‘UC’ (uncompacted) at the end of a sample’s identification indicates that the sample was extracted from the loose mix sample prior to reheating and compaction. The designation of ‘C’ (compacted) indicates that the sample was extracted from a specimen compacted after long-term loose mixture aging.

First, two batches of loose mix were aged separately at 95 °C and 135 °C for a prolonged duration. The loose mixtures were prepared using component materials in the laboratory and then subjected to short-term aging (4 h at 135 °C) in accordance with AASHTO R 30. These short-term aged loose mixtures then were spread in a single layer in aluminium pans and placed in a forced draft oven with lateral air-flow for long-term aging. Fig. 2 shows pans containing loose mix undergoing long-term aging in the oven. The pans were shifted frequently to compensate for air flow and temperature differences inside the oven.

Small samples of the loose mixture were taken from the pans at periodic intervals to assess the changes in the asphalt binder oxidation level versus the aging duration. These loose mixture samples were subjected to binder extraction and recovery in a rotary evaporator. Asphalt binder is the asphalt concrete constituent that undergoes oxidative aging. Therefore, the oxidation of pavements is best characterized using asphalt binder chemical and rheological properties, referred to as ‘aging index properties’ (AIPs) herein. The extracted and recovered binder samples were tested using a dynamic shear rheometer (DSR) and an attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectrometer to determine the chemical and rheological AIPs, respectively. The DSR tests included temperature and frequency sweeps, with temperatures ranging from 5 °C to 64 °C and frequencies ranging from 0.1 Hz to 30 Hz.

The primary oxidation products in asphalt binders are ketones and sulfoxides, detected by carbonyl and sulfoxide infrared absorption peaks. Ketone formation changes the polarity of the associated aromatic ring components, leading to an increase in the asphaltenes, which in turn increases viscosity [16,17]. Sulfoxides are polar and, hence, serve to increase asphalt binder viscosity [17]. The specific ketone and sulfoxides that are formed, combined with the physico-chemical interactions among the asphalt binder constituents, affect the binder rheology [16]. Therefore, the relationship between chemical and rheological AIPs can be used to detect changes in oxidation reaction mechanisms. The relationship between chem-

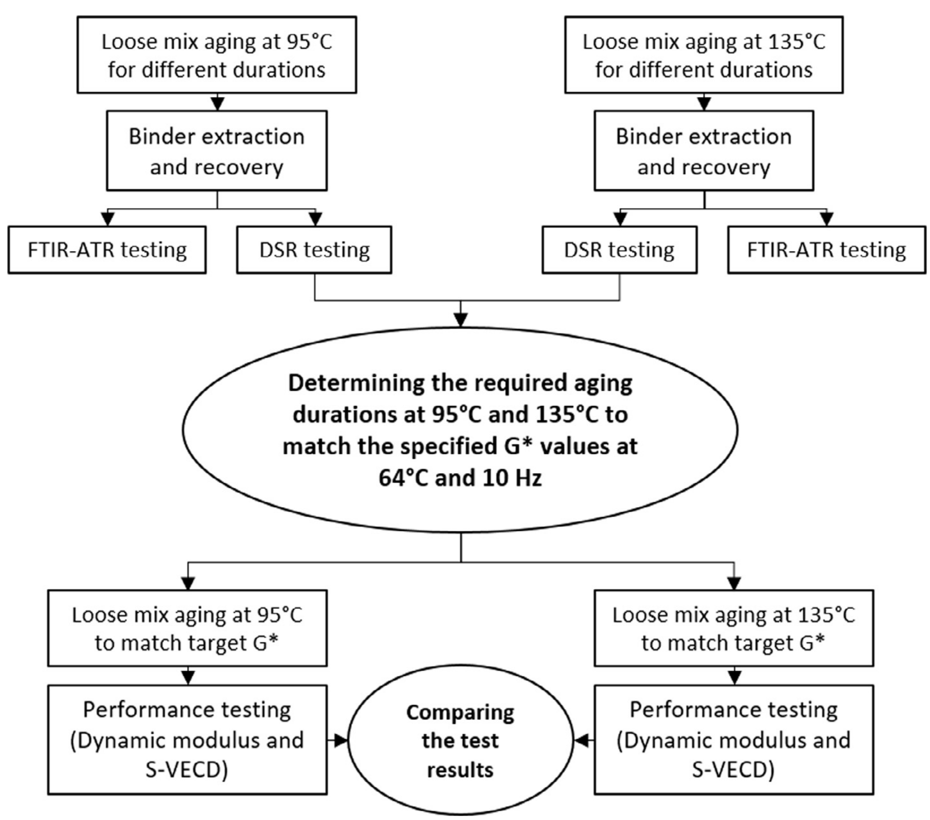

Fig. 1. Summary of experimental plan.