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Evaluation of effect of curing time on mixture performance of Advera warm mix asphalt

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HIGHLIGHTS

- Three different curing time: 2 weeks, 1 month, and 2 months were tested.
- Material properties of the Advera mix changes with curing time.
- It is critical to evaluate the Advera mix at appropriate curing time.

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ABSTRACT

Foaming warm mix asphalt (WMA) is a green asphalt technology that has been widely used in recent years. This study evaluates the effect of curing time on the material properties of Advera foaming, as compared to hot mix asphalt (HMA) mix. Test specimens were tested at three different curing time: 2 weeks, 1 month, and 2 months after compaction. WMA performance tests, including dynamic modulus, flow number, moisture resistance, fatigue and thermal cracking resistance, were conducted for both HMA and Advera mixes. Based on the laboratory results it was found that the material properties of the Advera mix changes with curing time. As such, it is critical to evaluate the Advera mix at appropriate curing time.

1. Introduction

Warm mix asphalt (WMA) is a green technology that has been widely used in asphalt community. Many WMA types are available in the market. They are generally divided into three categories: organic additive, chemical additive, and asphalt foaming process by introducing moisture [1]. All of these WMA types aim in reducing viscosity of asphalt binder so as to reduce production temperature, and thus create a better working condition at asphalt plant and paving site [2–5]. The foaming technology can be further categorized depending on the water percentage: water-based and water-containing. The water-containing foaming, also called water-bearing [6], contains approximately 20% water in the additive, such as Aspha-min, Advera. When the water-containing additive is added into the hot asphalt, the water will be released and the foamed asphalt is created. The water-based foaming technology uses a small amount of water and inject it into the asphalt via a nozzle, such as Astec Double Barrel Green, Aquablack. The water turns into steam and expands the volume of asphalt, and thus reduce asphalt's viscosity and improves the compactability of mixes [7].

The foaming WMA technologies have received a lot of attention due to its low costs, effectiveness in reducing mixing and production temperature and easy implementation. Many properties of mixes could be measured in the laboratory to predict the performance of an asphalt pavement or for the purpose of quality control and quality assurance. However, in the reality, asphalt mixes, either loose or compacted, could be tested days or even weeks after the production. Therefore, it comes to a question that when the properties should be measured and how the curing time would affect these properties, such as rutting and cracking resistance.

Reinke et al. [8] studied the effect of curing time on the properties of Evotherm 3G WMA as compared to hot mix asphalt (HMA). They found that longer curing time help improve rutting resistance for both HMA and WMA mixes. The multiple stress creep recovery (MSCR) test performed on the recovered asphalt binder further

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indicated that a longer curing time resulted in a lower non-recoverable creep compliance, i.e., an improved rutting resistance.

Buecheet et al. [9] studied the curing time and conditioning method on the properties of HMA and WMA mixes. They cured the specimens for up to 12 weeks at room temperature, with sealing the specimens in bag or exposing them to the air. In their study, it was found that conditioning method (sealing or not) did not result in a statistically significant difference in material properties. However, as curing time increased, the rutting resistance of water-containing foaming WMA mix increased whereas no conclusion was reached for indirect tensile (IDT) strength or moisture susceptibility.

The long-term aging effect on the WMA's rutting and moisture resistance were evaluated by many researchers [2,10–12]. Mogawer et al. [2] found higher rutting resistance for HMA and Advera mix with increased aging time. Punith et al. [10] also found that long-term aging improved the moisture resistance of WMA. The addition of water-containing additive in the asphalt mix changes the rheological properties of binder and the material properties of asphalt mixes [2–4,13]. Al-Qadi et al. [14] concluded that a significantly longer curing time was needed before traffic open for WMA pavements. The literature review indicated that most researches have focused on the rutting and moisture resistance for the WMA as compared to HMA. There is a need to evaluate the effect of curing time on other properties, such as fatigue and thermal cracking. The storage condition and curing time further complicates the evolution of WMA.

As such, the objective of this study was to evaluate the effect of curing time on the material properties of Advera mix, as compared to HMA control mix. Three curing times were included: two weeks (2 W), one month (1 M) and 2 months (2 M). The material properties evaluated in this study included stiffness, moisture damage potential, rutting susceptibility, and fatigue and thermal cracking resistance.

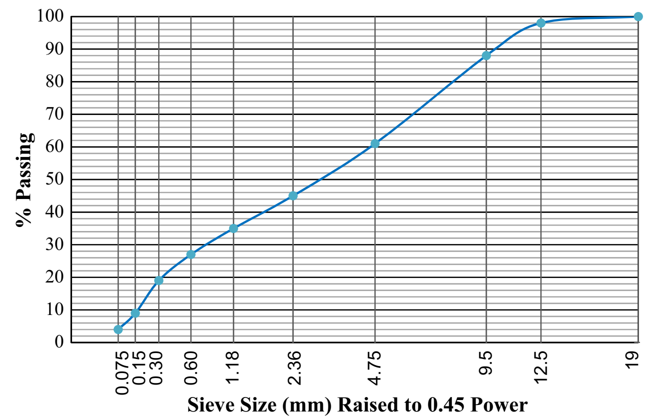

Fig. 1. Aggregate gradation in this study.

Table 1
Mix design for HMA and Advera mixes.

Volumetrics	HMA	Advera
Optimal AC, %	5.8	5.9
% G_{mm} @ $N_{initial}$	85.4	85.5
% G_{mm} @ N_{design}	96.0	96.0
VMA, %	14.2	14.4
Designed air void, %	4.0	4.0
VFA, %	71.9	72.1
Dust/asphalt ratio	0.92	0.9
Effective AC, %	4.3	4.4
G_{mm}	2.583	2.589
G_{mb}	2.486	2.485
G_{se}	2.848	2.846

Note: AC – asphalt content, G_{mm} – maximum specific gravity, VMA – void in the mineral aggregate, VFA – void filled with asphalt, G_{mb} – bulk specific gravity, G_{se} – Effective specific gravity.

2. Materials, mix design and experiment

2.1. Materials

Advera is a zeolite that consists of 20% water in the hydrocarbon compound. It is a product of Eurovia Services GmbH, Buttrop Germany. Previous study showed that it consists of hydrothermally crystallized synthetic zeolite which is sodium aluminum silicates [6]. By adding Advera in the heated asphalt, foaming occurs due to vaporization of water molecules which increases asphalt volume and reduces viscosity of binder [15]. Hossain et al. [6] found that the optimum dosage of Advera is 6% by the mass of the binder, which did not alter the base binder's PG. Handayaniet al. [16] found that 1% zeolite reduced mixing and compaction temperature on polymer modified asphalt by 30 °C. The manufacturer recommends the dosage of 0.3–0.9% by the weight of mix in order to reduce the production temperature by 10–20 °C. In this study, Advera additive was added at the dosage of 0.3% by the weight of mix. The aggregate used was basalt provided by POE Asphalt Inc. The asphalt binder type was PG 58-28 provided by Western State Asphalt.

2.2. Mix design

The mix design in this study was in accordance with Superpave mix design method [17]. The mix design kept the same for HMA and Advera mix, including aggregate gradation (Fig. 1), asphalt binder content, and aggregate type. Both mixes used 12.5-mm nominal maximum aggregate size (NMAS). Table 1 presents the volumetrics properties of HMA and Advera mixes, respectively. The mixing and compaction temperature of the Advera mix was 137 °C and 125 °C, respectively, which was 27 °C lower than the HMA production temperature, according to the manufacturer's recommendation. Both HMA and Advera mixes showed similar volumetric properties.

2.3. Laboratory experiments

The material properties of asphalt mixes were evaluated in terms of dynamic modulus, flow number, moisture damage, fatigue and thermal cracking resistance for both HMA and Advera mixes. The laboratory mixed laboratory compacted (LMLC) specimens were prepared at targeted air void using gyratory compactor following AASHTO T315 [18]. The specimens were placed in a sealed bag and stored in closet at controlled temperature (25 °C) and humidity (30%) without the exposure to light to minimize the effects of oxidization on the properties of mixes. The specimens were then tested after 2-week, 1-month and 2-month curing time.

2.3.1. Dynamic Modulus

Dynamic Modulus (|E*|) test is used to characterize the stiffness of asphalt mixture. It represents asphalt mixture stiffness in response to the application of haversine compressive load over different loading rates and temperatures. It is also a material property input in the Mechanistic-empirical Pavement Design Guide (MEPDG) design [19], to predict rutting, fatigue cracking and thermal cracking performance of asphalt pavement. Dynamic modulus is calculated as amplitude of cyclic peak-to-peak stress by cyclic recoverable strain in the linear visco-elastic range.