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The influence of warm mix asphalt on binders in mixes that contain recycled asphalt materials

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HIGHLIGHTS

- Field production and evaluation of warm mix asphalt (WMA) using three technologies.
- Similar performance for HMA and WMA, with WMA having lower air voids on average.
- Evaluation of WMA/HMA using recycled asphalt materials via extraction and recovery.
- After recovery, no measurable long-term influences from WMA additives in binders.
- Reduced production temperatures do not show long term impacts on binder properties.

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ABSTRACT

Rheological effects of warm mix asphalt (WMA) additives have been carefully studied in the laboratory since their introduction. Research has shown that reduced plant temperatures decrease the aging of the asphalt binder. It is important to determine if the reduction in the asphalt binder grade is still detectable after in-service aging. Each pavement represents one of the three predominate types of WMA technologies: chemical modifiers, wax modifiers and a foaming process. All mixes in the study included RAP and some with recycled asphalt shingles (RAS). The performance grade (PG) was determined for virgin binders. Field-cores were measured for density. Binder from cores was extracted and recovered to compare between the HMA and WMA. Field performance surveys compared HMA and WMA test sections. Findings show little evidence to suggest WMA facilitates the incorporation of higher amounts of recycled asphalt materials. The recycled binder had a larger influence on binder properties compared to WMA additives. Performance surveys for HMA and WMA mixtures were comparable. Recovered binder from field cores showed similar performance in both HMA and WMA binders. All three mixtures comparing WMA and HMA mixes show evidence that the reduced production temperatures do not have long term impacts on the binder properties.

1. Introduction

Warm mix asphalt (WMA) technologies are being increasingly used to reduce mixing and compaction temperatures of hot mix asphalt (HMA). The WMA technologies are available in the form of additives or asphalt plant modifications. The use of warm mix asphalt with recycled asphalt materials has added another layer of complexity to quality control and quality assurance practices in the asphalt industry. During the introduction of WMA to the industry, multiple benefits were exhibited and discussed including the combined use of WMA and recycled asphalt material but little research has been done to investigate the influence of WMA binder on mixes containing recycled asphalt materials that have undergone some in situ aging. This research focuses on measuring the effect of using a warm mix asphalt additive in conjunction with recycled asphalt materials that include recycled asphalt pavement (RAP) and/or recycled asphalt shingles (RAS). WMA works in two ways that are synergistic to using recycled asphalt materials. First, the WMA reduces the mixing/compaction temperatures which will reduce aging of the virgin binder, creating an overall softer binder compared to a mix that is produced at a higher temperature. This effect is measured in this research by collecting virgin binder and

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field cores. The binder from the field cores is then extracted and recovered to compare WMA/HMA differences for both virgin and recovered binders. The second reason WMA works well in mixes using recycled asphalt materials is due to the improved compactability. Compaction improvements allow for a stiffer mixture, which is characteristic of mixes with recycled asphalt materials, to reach target density. In this research, field cores were collected after 2 years of traffic for WMA and HMA sections and comparing the densities of the field cores will determine if WMA and HMA show differences in the compactability.

The purpose of this paper is to measure the impact of WMA technologies on mixes with various amounts and types of recycled asphalt materials and measure the influence of WMA on the binder, compaction and pavement performance after 1 or 2 years of in situ aging in the field. This will evaluate the collective use of WMA with recycled asphalt materials. The detailed objectives are:

- to determine if any reduction in the continuous asphalt grade is still detectable after some in-service aging,
- determine the influence shingles have on WMA binder compared with RAP and show how the differences change with additional shingles added to the mixture,
- determine if there is evidence to support the premise that WMA may allow for additional RAP,
- observe pavement performance for two consecutive years, and
- compare field core density to determine if WMA binders play a role in the densification process of WMA.

2. Background

Within the last 15 years, a great deal of asphalt research has focused on sustainable practices and developing warm mix asphalt materials. The research of warm mix asphalt began in the 1950's with foamed asphalt [1]. Further studies on foamed asphalt were conducted in the 1980's and found that curing temperature, length and moisture conditions dramatically affect the strength of foamed asphalt mixtures that contain sand and RAP [2]. In addition to foaming asphalt with water via plant modifications, synthetic zeolite additives were also developed for the purpose of foaming asphalt. Chemical and wax modifiers were also developed as warm mix asphalt additives. Driving the development of the WMA technologies are the production benefits such as reduction in fuel cost, reduced emissions, improved compactability, a longer paving season, longer haul distances and the use of WMA with recycled asphalt materials [3–5].

The commercially available additives used in this study included a wax additive, a forestry products chemical additive, and a foaming plant modification. The wax additive is a Fischer–Tropsch paraffin wax. The Fischer–Tropsch (F–T) process produces the fine crystalline, long-chain aliphatic hydrocarbon that makes up the wax. The wax allows for a reduction in production temperatures of 10–30 °C and is added at 3% by weight of the mix to gain the desired temperature reduction but should not exceed 4% due to potential impact to the binder's low temperature properties [6]. The chemical additive used in this study is derived from the forest products industry and is commercially available. This additive contains surfactant properties that emulsify the asphalt [7,8]. A plant modification was used to produce foamed asphalt at reduced plant temperatures. The foaming of the asphalt is controlled by injecting water to the asphalt through nozzles that create small water droplets as the binder is being mixed with hot aggregates. Studying differences in the HMA and WMA field binders after in-service aging will help to detect long-term differences between HMA and WMA in the various WMA technologies.

Laboratory studies have shown that measureable differences do occur in mixture properties between WMA and HMA mixes [9,10]. A study which used laboratory aged binders demonstrated how certain WMA modifiers will significantly change the rheological and failure properties of the binders. Investigation of artificially aged binders helps to identify where potential changes in the field may occur as a result of using WMA technologies. Measuring the differences in viscosity between WMA and HMA in laboratory studies provides evidence for what will likely occur in the field. Another WMA study suggests some of the laboratory differences between binders may be due to variability in oxidative stability or due to viscosity effects [11]. A laboratory study focused on quantifying the long-term effects of WMA additives on binders aged in the laboratory at set time intervals. This study found that the WMA binder had the lower shear modulus which is likely due to the 20 °C reduction in rolling thing film oven (RTFO) aging [12]. As other variables in the field are added, such as recycled asphalt materials, it is important to investigate the impacts of WMA additives and processes on rheological properties, pavement density and performance.

In general, studies have shown good performance of WMA pavements and WMA technologies do achieve reduced mixing and compaction temperatures [13]. The incorporation of moderate to high amounts of RAP in WMA is hypothesized to work well because the reduction in temperature allows for less stiffening of the binder compared to a conventional mixture and a national study showed that using RAP with WMA exhibited adequate binder blending [5]. A study looking at high RAP mixes in Europe found no differences between a WMA and conventional mixture with the exception of a significant reduction in production temperature. The mixture performance test indicated that the WMA additive did not affect the stiffness nor the fatigue life [14]. In a WMA-high RAP field trial in Florida, mixture testing indicated a softer material response in WMA pavement with a high RAP content of 45%. Dynamic modulus values were similar but the Hirsh and Witczak models under estimated the E^* values. An explanation for the differences between the HMA and WMA test results presented in the study is the incomplete blending of virgin and recycled binder in the WMA mixture, due to the lower production temperatures [15]. Since differences were detectable, further studies are needed for mixes with both high and typical amounts of RAP. A synthesis review of WMA suggested selecting slightly higher temperatures when WMA is used with high RAP amounts [16].

Identifying differences in WMA and HMA mixes is complicated by the multiple technologies available. Some changes in mixture properties may exist with a particular additive where another additive may indicate no detectable difference between WMA and HMA properties. For example, studies have shown that a Fischer–Tropsch wax increases the viscosity of binders at 60 °C [17]. The variety of technologies can influence mixture properties in different ways. The focus of this research is to examine the influence of multiple WMA additive types in field projects that contain various amounts of recycled asphalt materials over time.

3. Mixture and material information

Three pavement projects were selected to be constructed with both hot mix asphalt and warm mix asphalt test sections. Each project used a different type of WMA technology and all three were constructed during the same construction season. The following construction season, three additional WMA projects were constructed. At the time of production, virgin binder was collected from the tank at the asphalt plant for each project. The virgin binder was tested to verify the performance grade (PG) and compare HMA and WMA binders. Testing of the virgin binder also established a baseline from which to compare recovered binder samples.