Available online at www.sciencedirect.com

ScienceDirect

International Journal of Pavement Research and Technology 9 (2016) 83–88

www.elsevier.com/locate/IJPRT

Investigation of two Warm Mix Asphalt additives

Isaac Omari, Vivek Aggarwal, Simon Hesp *

Department of Chemistry, Queen's University, Kingston, Ontario K7L 3N6, Canada

Received 29 October 2015; received in revised form 12 February 2016; accepted 13 February 2016
Available online 21 February 2016

Abstract

In order to address pertinent issues in relation to the use of Warm Mix Asphalt (WMA) in pavement construction, it is imperative to understand the effects that such additives have on rheological and failure properties in service. In this study, two commercial WMA additives, a proprietary siloxane-based compound and an oxidized polyethylene wax, were added to a soft Roofing Asphalt Flux (RAF), a soft Recycled Engine Oil Bottom (REOB) tainted binder, and a somewhat harder binder containing 20% oxidized asphalt derived from Recycled Asphalt Pavement (RAP). Binders were aged according to standard Rolling Thin Film Oven (RTFO) and Pressure Aging Vessel (PAV) protocols. Selected compositions were subjected to a period of extended PAV aging for 40 h. Standard and advanced rheological and failure tests were used to predict the performance of these binders in service. Dynamic Shear Rheometer (DSR) and Bending Beam Rheometer (BBR) tests according to Superpave™ protocols were done to determine performance grades. Extended BBR (EBBR) and Double-Edge-Notched Tension (DENT) tests were done to provide further insights into durability and strain tolerance, properties of utmost importance to assure long term pavement performance. The findings of this study show that the addition of the oxidized polyethylene wax WMA additive to REOB and/or RAP tainted systems can provide binders that are unstable and likely prone to premature and excessive low temperature failure in service. In contrast, the siloxane-based WMA additive appears to be a better choice to avoid premature low temperature and fatigue cracking distress.

Keywords: Asphalt cement; Warm mix additive; Failure; Performance grading; Durability

1. Introduction

In an effort to reduce energy consumption and support sustainability through the use of RAP, asphalt cement suppliers and construction companies have turned their attention over the last 10–15 years to the use of WMA additive technologies [1,2]. WMA technology involves three different types of approaches: direct foaming with steam, addition of porous inorganics that slowly release water vapor, and chemical modification with waxes and surfactants.

The foaming processes are able to significantly reduce high shear viscosity and vastly increase the bulk volume of an asphalt binder, allowing for improved wettability at reduced production and/or compaction temperatures. Similarly, inorganic additives are used to reduce mixing temperatures through the release of microbubbles that help reduce bulk viscosity. Finally, chemical processes utilize waxes, fatty acid amine type and siloxane type surfactants, typically decreasing compaction temperatures through a reduction in high shear viscosity and improved lubricity between aggregate particles.

The use of WMA was originally driven by efforts to reduce production and compaction temperatures in order to save on energy costs, reduce harmful emissions and mitigate safety risks associated with the handling of hot asphalt. However, an increasing number of construction

* Corresponding author. Tel.: +1 613 533 2615; fax: +1 613 533 6669.
E-mail address: simon@chem.queensu.ca (S. Hesp).
Peer review under responsibility of Chinese Society of Pavement Engineering.

http://dx.doi.org/10.1016/j.ijprt.2016.02.001
1996-6814/© 2016 Chinese Society of Pavement Engineering. Production and hosting by Elsevier B.V.

companies use WMA additives today as compaction aids at temperatures similar to those for Hot Mix Asphalt (HMA). This allows for the use of higher RAP contents while still reaching air void targets within a reasonable compaction effort.

Organic WMA have been categorized as surfactant and wax based [1,2]. The additives based on surfactants function by lowering the viscosity of the binder and also prevent moisture damage by facilitating the wetting of aggregates at construction and service temperatures. Wax based additives are designed to improve the flow properties of the asphalt by lowering its viscosity above the wax melting point and also increasing the binder's stiffness at a temperature below the melting point.

The objectives of this study were to investigate the effects of two commercial warm-mix additives, a proprietary siloxane-based surfactant and oxidized polyethylene wax, on the quality and durability of a superior quality asphalt and two lesser quality asphalts. The superior quality material used for this investigation was a soft RAF produced from Cold Lake crude oil. The lesser quality materials were obtained from a commercial source in northern Ontario and by blending 20% oxidized asphalt binder recovered from a local RAP source with the RAF base. The commercial source binder was found to be tainted with 10–15% by weight of REOB [3]. REOB is the residue left over from the recycling of used engine oil and contains a high amount of waste metals and degraded engine oil dispersants. The asphalt binders were mixed with one, two or four percent of the WMA additives prior to aging and performance based testing.

2. Materials and methods

2.1. Materials and sample preparation

The materials employed in this study were obtained from commercial sources. These materials comprised asphalt cements and two WMA additives. Commercial binder AC-1 was obtained during the reconstruction of a stretch of Highway 655 in northeastern Ontario [3]. RAF binder AC-2 was obtained from the Imperial Oil of Canada refinery in Nanticoke, Ontario. RAP-modified binder AC-3 was obtained by blending 20 weight percent of a binder recovered from a local RAP source with AC-2.

The two WMA additives used in this study were a siloxane-based surfactant sold under the TEGO® ADDIBIT tradename [4] and an oxidized polyethylene wax sold under the EE-2 grade [5]. TEGO® ADDIBIT was obtained from Evonik Industries of Piscataway, New Jersey in the United States of America [4]. This warm-mix additive is an organically-modified siloxane foam stabilizer which has a function of improving the wettability and foam stability of asphalt cements. TEGO® ADDIBIT is also characterized by its ability to control emissions of amines in the course of asphalt processing [4].

The oxidized polyethylene wax EE-2 was obtained from Westlake Chemicals of Houston, Texas in the United States of America [5]. This additive is reported to stabilize asphalt at high temperatures through the wax functionality in order to control rutting behavior in service. It has a remarkable effect on the construction of asphalt pavement due to its ability to lower high shear viscosity during compaction. Similar products are marketed under the Titan tradename by Honeywell of Morristown, New Jersey in the United States of America, and the Ceranovus tradename of Green Mantra Technologies of Brantford, Ontario, Canada.

The samples investigated, as shown in Table 1, were prepared by adding the two WMA additives to the hot asphalt cements (AC-1, 2 and 3) in a set of one gallon paint cans followed by vigorous stirring at 150 °C for at least 15 min. RAP derived binder was added to the modified RAF samples in a one liter can and mixed under similar intensity for equal duration for further investigation.

2.2. Superpave grading

All straight and modified binders were aged in both the RTFO and PAV according to American Association of State and Transportation Highway Officials standard procedures (AASHTO T240 [6] and AASHTO R28-09 [7]). In addition, the durability of modified binders G and H was evaluated in accordance with Ministry of Transportation of Ontario (MTO) laboratory standard LS-228 Modified Pressure Aging Vessel protocol [8]. The modified PAV protocol ages binders for a total of 40 h or for the normal 20 h in a reduced film thickness of 1 mm rather than the normal 3.2 mm. This study only investigated the effect of aging time in the PAV since it is known to provide a more realistic correlation with field aging for 8–10 years of service in Ontario's climate.

Properties were assessed according to Superpave protocols which comprise high temperature grading in a DSR [9], intermediate grading in a DSR [9], and low temperature grading in a BBR [10]. The high temperature grades of the unaged and RTFO residues and the intermediate temperature grades of the PAV residues were determined using a TA Instruments AR2000ex with parallel plate geometry.

Table 1
Pertinent information on asphalt binders evaluated in this study.

Sample	Binder type	Additive	Dose, weight%
A	AC-1	Siloxane	1
B	AC-1	Wax	2
C	AC-2	Siloxane	1
D	AC-2	Siloxane	2
E	AC-2	Wax	2
F	AC-2	Wax	4
G	AC-3	Siloxane	1
H	AC-3	Wax	2

AC-3 = AC-2 + 20% RAP derived binder.