



Performance properties of polymer modified asphalt binders containing wax additives

Mithil Mazumder, Hyunhwan Kim, Soon-Jae Lee *

Texas State University, San Marcos, TX 78666, USA

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Abstract

The study presents an experimental evaluation of the rheological properties of control and polymer modified asphalt (PMA) binders containing wax additives and a comprehensive comparison between these two binder types. The control and PMA binders with the additives were produced using two of the available warm asphalt processes (i.e., LEADCAP and Sasobit) and then artificially short-term and long-term aged using the rolling thin film oven (RTFO) and pressure aging vessel (PAV) procedures. Superpave binder tests were carried out on the binders through the rotational viscometer (RV), the dynamic shear rheometer (DSR), and the bending beam rheometer (BBR). In general the results of this study indicated that (1) the addition of wax additives into the control and PMA binders decreases the viscosity, as expected; (2) the reduction rate of viscosity was quite similar for both the binders with wax additives; (3) the percentage increase of rutting resistance due to the additives was much higher for the control binder, compared to the PMA binder; (4) both the control and PMA binders showed the similar trends in terms of fatigue cracking and low temperature cracking behavior after the addition of wax additives.

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Keywords: PMA; Wax additives; Viscosity; Rutting; Fatigue cracking; Stiffness

1. Introduction

According to Environmental Protection Agency (EPA) in 2013, direct industrial greenhouse gas emissions accounted for approximately 21% of total emissions in the United States, making it the third largest contributor to this field, after the Electricity and Transportation sectors due to a rise in population, economic growth, the fluctuating price of energy, technological changes and many other factors. The paving industry has its own share of emission concerns with its use of hot mix asphalt (HMA), with the

major source coming from the production facility. HMA plants, regardless of its manufacturing technique (drum or batch) emit between 56,000 lbs/yr and 83,000 lbs/yr, depending on their fuel type (natural gas and oil, etc). As a result, warm mix asphalt (WMA) technologies have been introduced to reduce the mixing and compaction temperatures for asphalt mixtures as a means of reducing production cost, energy, and most importantly pollutant emissions.

In order to improve the quality of asphalt pavements, the asphalt industry incorporated polymers into asphalt as a way to mitigate the major causes for asphalt pavement failures, including permanent deformation at high temperatures and cracking at low temperatures [7,26]. When a polymer and virgin asphalt are blended, the polymer strands absorb part of the low molecular weight oil fraction of the virgin asphalt and become swollen. Of the polymer

* Corresponding author.

E-mail addresses: m_m624@txstate.edu (M. Mazumder), k_h82@txstate.edu (H. Kim), SL31@txstate.edu (S.-J. Lee).

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modifiers, styrene butadiene styrene (SBS) originally developed by Shell Chemical Co. is widely used in the majority of the asphalt binder industry and probably the most appropriate polymer for asphalt modification ([25,3]. SBS creates a three dimensional network within virgin asphalt phase resulting in excellent bonding strength to aggregates which leads to a durable and long lasting pavement [18,2]. According to [3], it is the most appropriate and used polymer for asphalt modification, followed by reclaimed tire rubber. It is the formation of critical network between the binder and SBS that increases the complex modulus, resulting the increase in rutting resistance. In 2004, Florida Department of Transportation and FHWA report that SBS benefited the cracking resistance by reducing the rate of micro-damage accumulation [30].

Due to high viscosity and improved binder coating, polymer modified asphalt (PMA) pavements have better pavement performance under high traffic applications. Polymer modifications are becoming important factors in paving industry due to their proven effects such as better resistance to rutting, fatigue damage, stripping, and thermal cracking in asphalt pavements [33,29,7]. However, there have been difficulties in workability of PMA because of high viscosity of the modified binders and concern about the health issues due to high level of toxic fumes and continuous exposure of workers to high temperatures during paving operations. Also, high temperature can thermally degrade the polymer as well as cause high economic cost due to the increased fuel consumption [30,4,35,27].

WMA technologies allow significant reduction of mixing and compaction temperatures of asphalt mixes using proprietary chemicals. In addition, the WMA provides better working condition based on reduction in emissions in asphalt plants and fields, and there are many other promising benefits including less fuel consumption, longer paving seasons, longer hauling distances, earlier traffic opening, reduced binder aging, and reduced cracking [1,6,8,12,13,24]. WMA technology can be used as a method of reducing the heat requirement for pavement operations while at the same time maintaining the integrity of the PMA binder. Several studies have been performed on the incorporation of wax additives into the PMA binder [11,5,15,14,17,16,20,19,21,32,13]. Most of the studies investigated the rheological properties of PMA binder by incorporating Sasobit into the binder. Based on this review, it appears that the addition of LEADCAP into the PMA binder and a comprehensive comparison between the two binder types (control and PMA) with two wax additives (LEADCAP and Sasobit) in terms of compatibility has not been reported in the previous study. This study can provide a substantial body of knowledge on such observations which may be of interest to the asphalt industry.

The objective of this study was to investigate the performance properties of PMA binders containing wax additives

through Superpave binder tests. Control binders with wax additives were used to compare with the PMA binders. The warm PMA binders were produced with two commercial wax additives, LEADCAP and Sasobit, and artificially aged using rolling thin film oven (RTFO) and pressure aging vessel (PAV) procedures. The viscosity properties for the binders were evaluated in the original state through rotational viscometer (RV) test using different testing temperatures (135 °C and 120 °C) and periods (30, 120, and 240 min). Rutting resistance properties in the original state and after RTFO aging as well as the fatigue cracking properties at intermediate temperature after RTFO + PAV aging methods were evaluated by dynamic shear rheometer (DSR) test. Low temperature cracking properties after RTFO + PAV procedures were evaluated by bending beam rheometer (BBR) test. Fig. 1 illustrates a flow chart of the experimental design used in this study.

2. Experimental design

2.1. Materials

Performance grade (PG) 64–22 asphalt base binder and PMA binders containing SBS (approximately 3% by the weight of binder) were used in this study. Table 1 shows the properties of base binder and PMA binder.

Two types of commercial wax additives were used in this study. The first one is an organic additive of a polyethylene wax-based composition that includes crystal controller and artificial materials known as LEADCAP. The wax used in LEADCAP additive has approximately 110 °C melting point [34]. It is to adjust crystalline degree of wax material at the low temperature [24]. The second one is a Fischer-Tropsch (FT) wax, Sasobit, manufactured by Sasol Wax. It is a long chain aliphatic hydrocarbon obtained from coal gasification using the Fischer-Tropsch process. It is completely melted into the asphalt binder at a temperature in excess of 115 °C which can reduce the binder viscosity. After crystallization, it forms a lattice structure in the binder which is the basis of the structure stability of the binder containing Sasobit [31]. Fig. 2 shows the images of the wax additives used in this study.

2.2. Production of warm asphalt binder containing wax additives

LEADCAP and Sasobit were used in this study for producing the warm binders. The process involved the addition of two wax additives at specified concentration (1.5% by weight of the binder) followed by hand mixing for 1 min at 170 °C in order to achieve consistent mixing. Table 2 explains the arrangement of binders with wax additives used in this study. Binder aging process were then conducted by rolling thin film oven (RTFO) for 85 minutes at 163 °C (ASTM D 2872) and pressure aging vessel (PAV) for 20 h at 100 °C (ASTM D 6251).

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