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Evaluation of a highly-modified asphalt binder for field performance

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HIGHLIGHTS

- We characterize the engineering properties of a highly-modified asphalt binder.
- We analyze the mechanic behavior of highly-modified asphalt mixtures.
- We evaluate the field performance of a test section with highly-modified asphalt.

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ABSTRACT

This paper deals with laboratory and field evaluation of pure and polymer-modified asphalts (PMAs), in which one bitumen and one polymer type of different contents were used. Styrene-butadiene-styrene (SBS) modified asphalts were selected to evaluate which polymer concentration could offer cost-effective solutions on heavily trafficked highways. Polymer concentrations used were 0%, 3%, and 6% SBS by weight of binder. Asphalt cement containing 6% SBS was referred to as a highly-modified binder in this study. An in-service test road was constructed in 2012 to compare the performance of asphalt pavements built with PMAs while all other variables were held constant as possible. The results of laboratory testing indicated that the morphology of SBS modified binders was influenced by storage temperature and polymer content. The formation of an interlocked continuous network was shown to enhance the rheological properties of PMAs. Significant differences in resistance to rutting and cracking were noted between highly-modified and control asphalt mixtures. This observation was attributed to increased modulus and enhanced critical strain energy release rate of polymer-modified asphalt mixtures. Preliminary performance evaluations showed that none of the test sections evaluated exhibited obvious rutting. Notable differences were, however, observed in the cracking behavior. The test section with the highly-modified binder had a much better resistance to cracking. The field measurements on cracking corresponded well with the test results of the semi-circular bend test in the laboratory. The experimental results of the highly-modified asphalt were in good agreement with field performance. Future monitoring is needed to evaluate long-term trends in performance.

1. Introduction

The increase of traffic frequencies and pavement loadings and the reduction of agency budgets drive the need for better materials with a lower life cycle cost. Polymer-modified asphalts (PMAs) are widely used for paving roads to provide improved service performance. It has been shown that the presence of polymer in PMAs improves the performance of asphalt pavements subject to heavy traffic loading over a wide range of temperatures [1–5]. In general, polymer-modified binders display improved properties with respect to neat bitumen, and increase resistance to permanent deformation at relatively high temperatures without leading to deterioration of their properties at low temperatures [6–8].

Different polymer modifiers for asphalt cement have been developed to help improve both the rutting and cracking problems of hot-mix asphalt (HMA) mixtures by altering the properties of the asphalt cement binder [9–17]. The most commonly used polymer in asphalt production today is styrene–butadiene–styrene (SBS) [4–6]. SBS is considered as a type of thermoplastic elastomers because the linking process between the rubber molecules is reversible through temperature change. Past studies indicated that the increased durability and rutting resistance displayed by surface mixtures containing SBS [9,10]. Manufacturers of polymer modifiers claim the incorporation of their product with the asphalt cement in the manufacture of HMA mixtures can significantly extend the service life of asphalt pavements. If additional service

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life can be achieved, then life cycle costs can be lowered, thereby allowing overall savings to the cost of maintaining pavements.

Most PMAs tend to be used at polymer concentrations of about 3% by mass of binder for highway applications. In Taiwan, the concentration of SBS across the various grades covers a range from 3% to greater than 6% depending on specifications. Asphalt cement containing 6% SBS polymers can be defined as a highly-modified binder relative to conventional 3% SBS. However, the application of PMAs to asphalt paving has been limited in some areas due to relatively high initial costs and uncertainty about the performance of polymer modifier. There are concerns with the difficulties of maintaining good compatibility for PMAs, particularly at high polymer concentrations. In addition, increasing the stiffness of highly-modified binders to resist rutting might make asphalt pavements more prone to cracking. From a performance perspective, a test road is needed to understand whether PMAs are cost-effective and to assess their sustainable benefits on heavily trafficked highways. It is, therefore, essential to characterize the highly-modified binder and evaluate its field performance. The objectives of this study are as follows:

- Evaluate the effect of polymer concentrations on the engineering properties of PMAs in the laboratory,
- Analyze the mechanical behavior of plant-produced and laboratory-compacted specimens mixed with highly-modified asphalt, and
- Compare the performance of the test section constructed with highly-modified asphalt with that of test sections with other binders.

2. Testing plan

The experimental design is shown in Fig. 1. The testing plan included three binders, one mix type, and four aging levels. One type of traditional asphalt and two commercially available SBS modified binders were used in this study. Plant-produced, laboratory compacted specimens were used to evaluate the engineering properties of asphalt mixtures. The performance evaluation of asphalt pavements included cracking and rutting.

3. Polymer-modified binders

3.1. Asphalt binders

One conventional binder and two commercially produced PMAs, intended to cover the range of asphalt cements used in the paving industry, were selected for testing. Polymer contents used in this study were 0%, 3% and 6% by weight of binder, and identified as 0% SBS, 3% SBS, and 6% SBS, respectively. The three asphalts represented reference bitumen, conventionally-modified bitumen, and highly-modified bitumen. Commercially available PMAs containing linear SBS polymers were incorporated in binders and mixtures that were placed on a test road in 2012. The 0% SBS binder is AC-20 graded asphalt cement selected as the control bitumen because this is traditional asphalt used for flexible pavements in Taiwan. The use of a highly polymer-modified binder (i.e., 6% SBS) was compared with a typically-modified binder (i.e., 3% SBS).

3.2. Morphology

An optical microscope was used to study the morphology of SBS modified binders stored at different temperatures. The sample container of binder was first heated in an oven at 200 °C for one hour. The container was removed from the oven, stirred with a metal spatula and samples taken using the spatula. The container was then returned to the oven which had been set to 200 °C. After a period of one hour, samples were taken. The process of oven storage and sampling was repeated at 20 °C intervals until a temperature of 120 °C was reached.

Samples were dropped into a rubber mold which was immediately immersed in a container of icy water to provide rapid cooling and to keep the morphology. These specimens were then placed on a metal plate sprayed with silicon to prevent sticking. This plate was placed in a freezer at −10 °C and the sample removed when frozen. The binder sample was detached and shattered, and a suitable piece placed on a microscope cover slip. Once the piece had adhered to the slip, the cover slip was inverted and placed in the microscope. The sample was then viewed through the cover slip. The instrument (Olympus, BX61) was equipped with a digital cam-

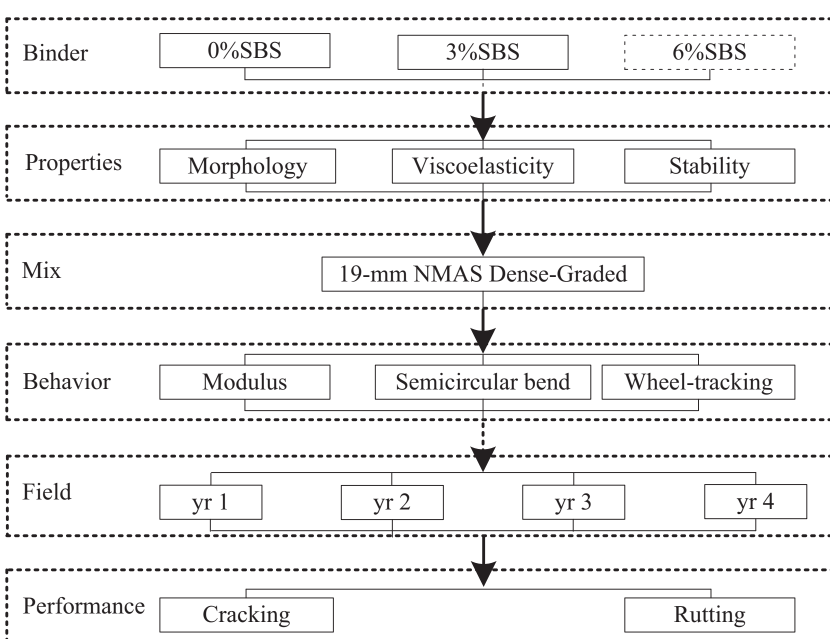

Fig. 1. Experimental design (yr = year).