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Performance evaluation of high-elastic asphalt mixture containing deicing agent Mafilon

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HIGHLIGHTS

- The deicing performance of asphalt mixtures with/without agent Mafilon were evaluated.
- The rutting resistance, low temperature performance, and moisture damage resistance were evaluated.
- The high elastic asphalt (HEA) and deicing agent were used in combination to improve pavement performance.
- The HEA asphalt mixture containing Mafilon performed well in functional performance and deicing performance.

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ABSTRACT

Snow and ice on pavement surface in winter cause traffic safety issues due to the reduced skid resistance between tires and pavement surface. This study applies a high-elastic asphalt (HEA) mixture containing deicing agent Mafilon (MFL) to improve the snowmelt/deicing performance and the functional performance of asphalt pavement. The HEA was produced by adding a high-elastic modifier to the regular styrene–butadiene–styrene (SBS) modified asphalt. The asphalt mixtures containing MFL were produced by replacing 70% of the mineral fillers in regular asphalt mixture with MFL. Three types of asphalt mixtures were investigated to make a comparison study: the regular SBS asphalt mixture, SBS asphalt mixture containing MFL (SBS-MFL), and the HEA mixture containing MFL (HEA-MFL). The pavement functional performance and snowmelt/deicing performance were evaluated. The functional performance covered the rutting resistance, low temperature performance, and moisture damage resistance, which were evaluated through the dynamic stability test, three point beam bending test, and tensile strength ratio test, respectively. The snowmelt performance was evaluated through an outdoor snow melting observation and measurement. The deicing performance was evaluated through a sponge lift test and a mixture-ice bond shear strength test. The experimental results showed that the SBS-MFL mixture performed weaker than the regular SBS mixture in rutting resistance, low temperature cracking resistance, and moisture damage resistance. However, the HEA-MFL mixture showed remarkably better rutting resistance and low temperature performance than the regular SBS mixture, with only a slightly weaker moisture damage resistance. In terms of the snowmelt/deicing performance, the HEA-MFL mixture performed much better than the regular SBS mixture regards of the higher snow melting speed and lower mixture-ice bond strength. The findings in this study indicate that the HEA-MFL mixture has a great potential to be applied in asphalt pavement for the purposes of performance improving and snowmelt/deicing.

1. Introduction

Snow and ice on asphalt pavement surface can cause traffic safety issues in winter since they reduce the skid resistance between tire and pavement surface. Road agencies have been spending a large amount of money on snow removals and deicing. Nevertheless, economical losses and traffic accidents due to snow and ice are reported from time to time worldwide. Most of the countries in temperate zones are suffering from this problem in winter seasons. A regular practice of snow removal is to spread chlorine-based deicing materials on roads to melt the snow after the snow precipitation. In regions where snowfall is frequent in winter, deicing materials are often spread before the snow

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precipitation to produce a liquid layer between the pavement and snow. Snow removal by special vehicles are normally used in combination with deicing materials. Deicers spread on pavements become deicer solution, which may degrade pavement performance. Deicers were found to have hardening and plasticizing effects on asphalt binders [1]. Studies on pavement functional performance showed that deicer solutions such as formic acid, potassium acetate (KAc) and potassium formate (KFo) can increase the moisture susceptibility of asphalt pavements [2,3] and result in bleeding and raveling [4]. The main deterioration mechanism of deicer solutions on asphalt pavement is the asphalt emulsification per a small amount of asphalt soaked in deicer solutions [4]. Another study suggests that the greatest damage occurs when the deicer concentration is in the 1–2% range [2]. Additionally found in the same study, quartzite aggregate is more sensitive to deicer damage as compared to limestone. Recommendations to reduce the damage of deicer solutions include using stiffer asphalt and higher quality aggregates [4]. It has also been reported that the addition of microfiber or nanoclay can improve the moisture damage resistance of asphalt mixtures subjected to deicing solutions [3,5].

Since the traditional methods of pavement snow removal with salt spraying and snowplow machine induces potential traffic jams and is labor intensive and time-consuming, researchers have been seeking an alternative way by adding deicing materials into asphalt pavement. Calcium chloride chemical Verglimit was investigated as a deicing agents in hot mix asphalt in late 1980s [6–8]. In early 1990s, a handbook to evaluate chemical deicers was released by the Strategic Highway Research Program in the United States [9]. Recently other deicing agents such as sodium chloride chemical Mafilon and calcium–sodium based chemical IceBane have been investigated as well [10,11]. The deicing materials can release out to melt the snow when snow precipitation comes. Based on this concept, pavement materials containing deicing agents have been studied. Laboratory and filed investigations have showed that deicing or snow melting effects are remarkable for most of the asphalt mixtures containing deicers [10–12]. The literatures [10,11] mainly qualitatively investigate the deicing or snow melting performance through the survey of snow melting speed, while the literature [12] made a quantitative analysis through skid resistance measurements, freezing point determinations and mechanical abrasion. A deicing epoxy asphalt overlay was paved for a concrete bridge in the state of Colorado, USA, and a perceptible deicing performance was reported [13]. Another deicing approach for asphalt pavement is to add elastic particles to make the asphalt pavement more elastic in winter so that the large deformation can break the ice on pavement surface. Tan et al. [14] prepared the elastic asphalt mixture using granulated crumb to deice for pavements. The asphalt mixture using the granulated crumb can break ice layer on the pavement and improve the mixture performance to some extent [14]. However, the effect of anti-icing and snow-melting performance using crumb modified asphalt mixture is weaker than that using snow-melting chemical agents. Some other researchers installed conductive wires under concrete pavements and heat the pavement for the purpose of deicing [15,16]. High elastic asphalt (HEA), also known as high elastic modified asphalt, is a modified asphalt based on regular SBS asphalt using additional modifiers such as plasticizers and cross linkers [17]. Compared to regular SBS asphalt, HEA has higher elastic recovery, higher ductility and higher softening point. While no standard has been specified for an HEA, some suggested physical properties for an HEA has been reported [17]. These properties include softening point, penetration, ductility, etc. The performance evaluation has shown that HEA asphalt mixture has better high- and low-temperature performance, and better fatigue resistance [18].

Pavement engineers have been facing two concerns since the very beginning of the researches on deicing asphalt pavement. The first concern is that whether the pavement performance of deicing asphalt mixtures can be preserved. The other is the long-term deicing performance of such materials. The regular practices of producing deicing asphalt mixtures is to replace the mineral fillers with a certain amount of deicer agents. Some preliminary results have been obtained through laboratory and filed performance evaluations on pavement functional performance. Generally from existing literatures, the high temperature performance can be enhanced while the moisture damage resistance are compromised by adding deicing materials [10,11]. In regard of the low temperature performance, different deicing agents may have various influences. The study by Wang et al. [11] suggests that the deicing agent Mafilon has little effects on the low temperature performance of SBS modified asphalt mixtures through the thermal stress-restrained specimen test. On the other hand, Wang et al. [11] reported that the addition of deicing material IceBane would sacrifice the low temperature performance of SBS modified asphalt mixtures. The rutting resistance performance can be enhanced by the addition of deicing materials. Long-term deicing performance has been few reported due to limited long-term observations of road sections paved with deicing asphalt mixtures.

Considering the potential drawbacks of deicing asphalt mixtures in low temperature performance and moisture damage resistance, this study proposes a solution of combining deicing agents and high elastic asphalt binders with the aim of improving the deicing performance and functional performance of asphalt pavement. The deicing agent Mafilon (MFL) is used to partially replace the mineral fillers in asphalt mixture, and a high elastic modifier is added into the SBS modified asphalt to produce high elastic asphalt (HEA) binder. The deicing performance includes the snow melting performance and the ice de-bonding performance. The pavement functional performance covers the high temperature performance, low temperature performance, and moisture damage resistance.

2. Experimental plan

2.1. Material preparation and mix design

2.1.1. Asphalt binders

Two types of asphalt binders are used in this study: the SBS modified asphalt and the HEA. SBS modified asphalt is regarded as the control asphalt in this study considering it is a regular modified asphalt widely used around the world. The HEA is produced by adding a certain amount of high-elastic modifiers into the SBS asphalt. The high-elastic modifier used in this study is yellow colored granule, as shown in Fig. 1(a). The SBS asphalt and the high-elastic modifier are blended with a mass ratio of 92:8 using a high-shear mixer at 180 °C. The SBS asphalt and the modifier are firstly mixed at a mixing speed of 2000 RPM (rounds per minute) for 10 min to allow the modifier dissolved into asphalt. Then the mixing speed is increased to 4000 RPM for another 35 min. Some properties of the SBS asphalt and HEA were tested and shown in Table 1. It was observed that the HEA has higher softening point and lower penetration than the SBS asphalt, indicating a higher stiffness. Meanwhile, the HEA owns a higher ductility and elastic recovery, suggesting that the HEA is more elastic than the SBS asphalt. Normally, asphalt with a higher stiffness and higher elastic recovery is desirable for rutting resistance, while a higher ductility is preferable for a fracture resistance. Therefore, both the rutting resistance and fracture resistance of the SBS modified asphalt are enhanced by the high-elastic modifier.

2.1.2. Deicing agent

The de-icing agent used in this study is Mafilon, which is gray powders, as shown in Fig. 1(b). The main chemical components of the Mafilon are NaCl, SiO_2, MgO and CaO. The Mafilon is produced by soaking porous pyrolith in the salt solution for several days and then drying at the temperature of 120 °C until the weight is constant. Some basic properties and the particle gradation of the Mafilon are shown in Table 2. The specific gravity is 2.269, which is lower than typical mineral fillers. The salt content is about 55.9%, which is within the range of specification.