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Laboratory evaluation of long-term anti-icing performance and moisture susceptibility of chloride-based asphalt mixture

Mulian Zheng [a,*], Chongtao Wang [b,2], Lili Han [a,1], Yuqi Sun [c,1], Yifeng Li [d,1], Zonghui Ma [e,1]

[a] Key Laboratory for Special Area Highway Engineering of Ministry of Education, Chang'an University, South Erhuan Middle Section, Xi'an, Shaanxi 710064, China

[b] First Highway Consultants Co., Ltd., 63 Kejier Road Hi-Tech Industries Development Zone, Xi'an, Shaanxi 710075, China

[c] Yangling Vocational and Technical College, 24 Weihui Road Yangling Hi-Tech District, Xi'an, Shaanxi 712100, China

[d] Highway Administration Bureau of Rizhao City, 7 Yantai Road, Rizhao, Shandong 276826, China

[e] Highway Administration Bureau of Dezhou City, 1255 Mid Dongfeng Road Decheng District, Dezhou, Shandong 253006, China

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Abstract

The objective of this research is to investigate the long-term anti-icing performance and moisture susceptibility of chloride-based asphalt mixture. Two experiments (the natural and accelerated dissolving-out methods) were conducted on the Marshall samples and their salt releasing amount were determined based on the density measurement of the aqueous solution with a hydrometer. In addition, the impact of anti-icing agents (MFL) on the mixture water stability was also investigated. Results show that a similar tendency in both methods was observed and the salt dissolution history was generally divided into three phases. Most notably, compared with the natural dissolving-out experiment the accelerated test was more effective and time-saving. Moreover, asphalt concrete with MFL performed poorer water damage resistance than the conventional asphalt concrete and the residual stability of the former declined more dramatically than the later. Finally, based on the 60 °C dissolving-out experiment, a model to predict the effective working time of the anti-icing asphalt pavement was proposed subsequently.

Keywords: Asphalt mixture; Chloride; Long-term anti-icing performance; Moisture susceptibility

1. Introduction

Statistics show that approximately more than 30% of winter traffic accidents are associated with snow and ice on pavement surface [1,2]. The black ice on the pavement not only poses a great threat to the smooth and secure flow of traffic but also leads to high maintenance budgets [3]. Therefore, deicing and anti-icing technology has long been an central issue for pavement practitioners [4,5]. Anti-freezing asphalt pavement is a new pavement by adding certain anti-icing chemicals (usually chlorine salt) into asphalt mixture [6]. Originally applied in Europe in the 1960s, this pavement has been widely used in Switzerland, Japan, Germany and China [7–9]. The chemicals are crucial to melt snow and ice and primarily adopted chemical fillers are sodium chloride, calcium chloride and magnesium chloride [10]. When subjected to traffic loads these ingredients inside the pavement dissolve out

* Corresponding author. Tel./fax: +86 2982334846.
E-mail addresses: zhengml@chd.edu.cn (M. Zheng), chongtao0611@ 163.com (C. Wang), chdhanlili@yahoo.com (L. Han), 924207692@qq.com (Y. Sun), lyfrz@163.com (Y. Li), 18005348325@163.com (Z. Ma).
[1] Tel.: +86 2982334846.
[2] Tel.: +86 13609199920.
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gradually under capillary attraction and then deposit on the pavement surface, lowering the freezing point of melt water and restraining ice and snow from accumulation [10]. Many efforts have been made to promote the progress of this pavement. For example, in the 1990s researchers in Japan developed a new porous anti-icing filler known as MFL that was widely applied across the world [11,12]. Wang analyzed the influence of salt content, temperature and void ratio on the dissolving-out law by determining the conductivity of salt solution [13]. Liu et al. focused on the properties of asphalt mixtures containing anti-freeze fillers with the volume replacement method and investigated the void content, high and low temperature properties and the susceptibility to moisture damage by experimental method [14]. Zhang et al. adopted indoor simulating tester for anti-freeze pavement to verify the anti-freeze capability of MFL modified asphalt concrete and its snow melting function by observing the testing process [15]. On the whole, current investigations on the anti-icing asphalt mixtures primarily focused on the short-term snow melting performance by naked eye observation, and on the influence of anti-icing fillers on mixture performance. Little work has been reported about the long-term performance of chloride-based asphalt mixtures since there is no consistent method to evaluate the mixture long-term anti-icing property [16]. Moreover, when exploring the salt dissolving-out progression in the anti-icing mixtures, the conductivity test is widely used. However, it will be beyond range when the salt dissolving-out amount reaches a certain high value. Nevertheless, little work has been reported currently to overcome the limitation of this method.

In this view, this study aimed to evaluate the long-term anti-icing performance of the chloride-based asphalt mixture and to investigate the impact of chloride chemical on the mixture moisture susceptibility. In this study, the Marshall samples of asphalt concrete added with MFL powder were prepared and two experimental programs (natural dissolving-out experiment and accelerated dissolving-out experiment) were conducted. To avoid the aforementioned limitations of the conductivity test, the release amount of anti-icing salt was determined by measuring the solution density using a hydrometer in this research. In addition, the residual Marshall stability of asphalt concrete with or without MFL were compared and analyzed. Finally, a logarithm between the dissolving-out percentage and time was fitted and a model to predict the effective working time of the anti-icing pavement was then presented.

2. Materials and experiments

According to the current literature, there is no standard test method to evaluate the anti-icing performance of the snow melting asphalt mixture in the long run [16]. In this study two experiments were designed to assess the long-term anti-icing property based on the dissolving out amount of salts in the mixture. This section presents the basic materials and test methods included in this study.

2.1. Raw materials

2.1.1. Binder and aggregate

A Styrene Butadiene Styrene (SBS) modified asphalt binder from Wuhan was used in this experiment and its main technical properties are listed in Table 1.

The crushed basalt, long been regarded as the best choice for hot asphalt mixture in current China [17], was used as the coarse aggregate and the machine-made sand from the basalt stone was applied as the fine aggregate. In addition, the mineral filler included in this research was from the Jingshan stone plant. The physical and mechanical properties of the coarse and fine aggregates are shown in Tables 2 and 3. Based on the AC-13 gradation, three preliminary gradations were designed and then tested to select an optimal one leading to a mixture of appropriate void volume (VV), good high temperature stability and enough surface texture depth. The selected gradation is shown in Table 4.

2.1.2. Anti-icing additive

According to common practice, two types of anti-icing chemicals are predominantly used in the anti-icing asphalt pavement, which are the granular filler and the anti-icing powder. Generally their anti-freezing capabilities differ

Table 1
Properties of the binder.

Indicator	Test value	Requirement	Test method [18]
Penetration (0.1 mm)	58	40–60	T0604
Penetration index	0.126	⩾0	T0604
Softening point (°C)	84	⩾75	T0606
Ductility (cm)	22.7	⩾20	T0605
Viscosity (Pa s)	1.14	⩽3	T0625
Flash point (°C)	273	⩾230	T0611
Solubility (%)	99.4	⩾99	T0607
Elastic recovery (%)	89	⩾75	T0662
Softening point difference after 48h thermal storage (°C)	1.9	⩽2.5	T0661
Density (g/cm^3)	1.022	Test value	T0603
TFOT mass change (%)	0.06	⩽1.0	T0609
Penetration ratio (%)	75.9	⩾65	T0604