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Laboratory investigation of andesite and limestone asphalt mixtures containing sodium chloride-based anti-icing filler

Ouming Xu [a,*], Sen Han [b], Caili Zhang [c], Yamin Liu [b], Feipeng Xiao [d], Jin Xu [b]

[a] School of Materials Science and Engineering, Chang'an University, Xi'an 710061, China
[b] Key Laboratory for Special Area Highway Engineering of Ministry of Education, Chang'an University, Xi'an 710064, China
[c] School of Civil Engineering, Hebei University of Technology, Tianjin 300132, China
[d] Key Laboratory of Road and Traffic Engineering of the Ministry of Education, Tongji University, Shanghai 201804, China

HIGHLIGHTS

- Asphalt mixtures containing anti-icing filler with different volume replacement were produced.
- Two aggregate sources were used to produce mixtures.
- Engineering properties, such as high- and low-temperature performance, and moisture susceptibility, were investigated.
- Anti-icing and deicer properties were evaluated by low temperature British Pendulum Number test and conductivity test.

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ABSTRACT

The research evaluates the effects and effectiveness of a sodium chloride-based anti-icing filler on andesite and limestone asphalt mixtures. The asphalt mixtures containing different amount of anti-icing fillers were designated based on the equivalent volume replacement method. In this study, the rutting susceptibility and low-temperature flexural properties, moisture susceptibility, anti-icing properties and snow melting capacity of mixtures were evaluated in the laboratory. The results showed that the specimens containing anti-icing fillers decreased their dynamic stability, flexural strain, residual Marshall stability ratio, and TSR values compared to those control ones. The mixtures made from two aggregate sources exhibit similar trends in general. It was also proved that the asphalt mixtures containing anti-icing fillers had anti-icing and snow melting capacity at a certain condition. In this research, it could be found that the replacement of anti-icing filler was 70% (by total volume) of mineral filler, providing a good anti-icing and snow melting capacity while the mixtures were still performed very well.

1. Introduction

There may be a layer of thin ice (black ice) on the road surface, when the road was covered with water and snow at a negative temperature in winter. It is very dangerous and easily result in drastically reducing the road skid resistance and increasing the risk of traffic accidents. So the maintenance of roads and airports at a low temperature to be kept running is a very important work for highway agencies of many countries [1].

At present, the prevention and limitation of ice formation on the road surface mainly depend on the deicer [2–4]. Conventionally, various salts, such as sodium chloride, calcium chloride and sodium acetate, are spread on the surface of road and other infrastructures before or after snowing in order to melt the snow and prevent the snow and/or snow water from freezing.

However, the application of the deicer not only demands a lot of deicers, workers and equipment, but also may lead to a high cost and low efficiency of snow clearing [4,5]. So some alternative solutions were presented, such as electrically conductive concrete, solar energy, geothermal energy, hydronics, heating cable, microwave heating, infrared heating, and self-ice-melting asphalt pavements [5–9].

In above solutions, the self-ice-melting asphalt pavement is an economical way and easily conducted by the contractors for snow and ice control. The self-ice-melting asphalt mixture, which was mainly mixed with chloride-base anti-icing filler, was already studied by Switzerland, Germany, and other European countries

* Corresponding author.
E-mail addresses: xuouming@yahoo.com (O. Xu), hyram_hs@aliyun.com (S. Han), 15438174@qq.com (C. Zhang), liu_yamin@yahoo.com (Y. Liu), fpxiao@gmail.com (F. Xiao), jinxu@yeah.net (J. Xu).

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Table 1
Engineering properties of asphalt binder.

Test items		Unit	Value	Specification
25 °C penetration		0.1 mm	75	ASTM D5
5 °C ductility		cm	44	ASTM D113
Softening point		°C	88.5	ASTM D36
135 °C viscosity		mPa s	207	ASTM D2196
Penetration index		–	0.036	ASTM D5
RTFOT	Mass loss	%	0.04	ASTM D2872
	25 °C penetration ratio	%	82	
	5 °C ductility	cm	28	

in 1960s [10,11].The chloride-based anti-icing filler was firstly applied in the field by Austria in 1975 [12]. Then, Japan introduced this technology and developed the corresponding products. Japanese engineering experience indicated that the road wearing course paved with mixtures containing anti-icing filler showed a higher level of anti-icing and snow melting capacity in winter condition, compared to conventional asphalt mixtures [13].

There are mainly two anti-icing filler types using in the asphalt pavement now. One is calcium chloride-based, and another is sodium chloride-based [14–16]. Recently, the driving safety in winter also aroused many concerns to use the anti-icing products on the surface of pavement in China. Sodium chloride-based anti-icing filler was firstly applied to the asphalt pavements nearby Xi'an City, China in 2008 [17]. As well known, the conventional filler, generally referred to as "limestone mineral filler", is directly mixed with aggregate and asphalt binder in the plant, providing a good stabilization and absorption with asphalt binder. Nevertheless, the anti-icing filler, typically consisting of chloride-based chemicals, is added during the production, which may inevitably affect interaction of the binder and the aggregate. How to well balance the pavement performance and anti-icing performance of mixtures containing chloride-based anti-icing filler is always challenging the researchers and is being investigated in this study. Asphalt mastics and mixtures produced with a sodium chloride-based anti-icing filler were tested to evaluate de-icing and anti-icing characteristics compared with specimens with a conventional calcareous filler by Felice et al. [18]. The anti-icing filler delays the formation of ice on the road surface and improves the ice-melting process and reduces the bond between ice and pavement surface. The high- and low-temperature properties and moisture susceptibility of asphalt mixtures containing anti-freeze filler were investigated [19]. The results showed that the asphalt mixtures containing a small particle had a better high- or low-temperature and moisture stability performance. Other researches focused on the engineering properties of asphalt mixtures exposed to deicer corrosive environments and freeze–thaw cycles [20,21]. Otherwise, few researchers studied the influence of sodium chloride-based anti-icing filler on the performance and anti-icing as well as snow melting capacity of andesite and limestone mixtures.

The objective of this study was to gain a more fundamental understanding of the influence of sodium chloride-based anti-icing filler on the performance of the andesite and limestone based mixtures by means of conventional testing procedures, such as wheel tracking test, low temperature flexural test, Marshall stability test, and tensile strength test. In addition, the anti-icing and snow melting properties were evaluated by anti-icing test and deicer precipitation test.

2. Materials and experimental program

2.1. Asphalt binder

Shell A-90 asphalt binder modified with SBS was used in this study. The properties of the asphalt binder were investigated, as shown in Table 1.

2.2. Aggregate

Two aggregate sources (A is andesite and B is limestone) were selected based on their engineering properties in accordance with Chinese corresponding specification [22]. The engineering properties of two aggregate sources were presented in Table 2.

2.3. Chloride-based anti-icing filler

The chloride-based anti-icing filler is a commercial powered material. Its shape and SEM image are shown in Fig. 1. In addition, the properties of chloride-based anti-icing filler were listed in Table 3.

The electron spectrum of the trial chloride-based anti-icing filler was obtained in this study (Fig. 2). It can be observed that main components of this anti-icing filler are silicon dioxide, sodium chloride, calcium chloride and calcium carbonate. Among of these components, the sodium chloride content is about 55% of the total mass.

2.4. Mix design

The mix design included the aggregates used for a 13-mm mixture, which was widely used as the wearing course in China, satisfied the specifications set forth by Chinese Ministry of Transportation (MOT). The gradations of the control mixtures (described as A0 and B0) were shown in Fig. 3. In addition, 35%, 70%, and 100% (described as A1, A2, A3 from A0, B1, B2, and B3 from B0) of total volume of the mineral filler were replaced by the anti-icing filler using equivalent volume displacement method. The replacement results of these mineral fillers were listed in Table 4.

2.5. Specimen preparation

Specimens were prepared by a Marshall Compactor according to the ASTM Specification [23]. Firstly, asphalt binder was heated and mixed with hot aggregates at 170–180 °C for about one and half minutes. Secondly, the mineral filler or the anti-icing filler was added into the mixture and blended another one and half minutes. Finally, mixtures were poured into hot mold and compacted with 75 blows each side at 160–170 °C to obtain a Marshall specimen with 101.6 mm in diameter and 63.5 mm in height.

Marshall mix designs were performed to obtain the optimum asphalt binders of the mixtures with various miller fillers and anti-icing fillers in this study. Specimens with different asphalt contents were carefully prepared and the optimum asphalt contents were determined by the volumetric properties and mechanics properties, as shown in Table 4.

After determined the optimum asphalt content of each mixture, the specimens were tested the following properties, such as high-temperature rutting susceptibility, low temperature flexural properties and water stability of mixtures with a selected gradation. The anti-icing and snow melting capacity were also investigated. A total of eight mix types and 224 specimens were investigated in this study.

Table 2
Engineering properties of aggregate sources.

Aggregate source	LA Abrasion loss (%)	Absorption (%)	Specific gravity								Sand equivalent (%)
			Bulk			Apparent					
			9.5–16 mm	4.75–9.5 mm	2.36–4.75 mm	9.5–16 mm	4.75–9.5 mm	2.36–4.75 mm	0–2.36 mm	Filler	
A	9	0.51	2.824	2.296	2.758	2.854	2.85	2.849	2.701	2.707	92.5
B	12	0.63	2.747	2.74	2.709	2.781	2.778	2.774	2.647	2.71	91.8