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EFFECT OF DEICING AGENTS ON THE LOW-TEMPERATURE PERFORMANCE OF ASPHALT CONCRETE UNDER FREEZE-THAW CYCLING CONDITIONS

ВПЛИВ ПРОТИОЖЕЛЕДНИХ РЕЧОВИН НА НИЗЬКОТЕМПЕРАТУРНІ ХАРАКТЕРИСТИКИ АСФАЛЬТОБЕТОНУ В УМОВАХ ПОПЕРЕМІННОГО ЗАМОРОЖУВАННЯ-ВІДТАВАННЯ

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The wide application of asphalt concrete in road construction has brought convenience to human travel, but road icing requires the application of deicing agents to prevent traffic accidents. However, the use of a deicing agent will also cause damage to the pavement material, so this paper carries out the research on the low-temperature performance of asphalt concrete with different concentrations of deicing agent solutions through the freeze-thaw cycle test. The test results show that with the increase in the number of freeze-thaw cycles, the five concentrations of deicing agent solution corresponding to the flexural tensile strength and maximum flexural tensile strain are decreasing trend. Although the deicing agent solution has a certain effect on the flexural tensile strength and maximum flexural tensile strain, the main effect on the reduction of the low-temperature performance of asphalt concrete is the frost damage caused by the freeze-thaw cycle.

З постійним розвитком транспортної інфраструктури, широке застосування асфальтобетону в дорожньому будівництві принесло зручність для пересування людей. Проте взимку частка дорожньо-транспортних пригод, спричинених снігом та ожеледицею, серед усіх дорожньо-транспортних пригод досить висока, і ці ДТП часто призводять до людських жертв. Для усунення явища обледеніння доріг відділ управління дорожнім рухом зазвичай використовує протиожеледні речовини. Цей спосіб досягає чудових результатів, значно зменшуючи кількість дорожньо-транспортних пригод. Проте використання протиожеледних речовин спричиняє пошкодження асфальтобетону, а особливо надмірне і неправильне використання засобу, що в свою чергу значно знижує експлуатаційні властивості дорожнього покриття.

Для того, щоб з'ясувати вплив різних концентрацій розчину протиожеледної речовини на низькотемпературні характеристики асфальтобетону, в цій статті проведено дослідження низькотемпературних характеристик асфальтобетону з різними концентраціями розчину *протиожеледної речовини за допомогою випробування на поперемінне заморожування та відтавання.*

Результати випробувань показують, що зі збільшенням кількості циклів заморожування-відтавання п'яти концентрацій розчину протиожеледної суміші, що відповідають межі міцності на розтяг при згині та максимальній деформації на розтяг при згині, мають тенденцію до зменшення, що свідчить про значний вплив кількості циклів заморожування-відтавання на пошкодження асфальтобетону. Чим більша концентрація протиожеледного реагенту, тим очевиднішим є зниження межі міцності на розтяг при згині та максимальна деформація на розтяг при згині. Хоча концентрація розчину протиожеледної суміші має певний вплив на межу міцності на вигин і максимальну деформацію на розтяг при вигині, основний вплив на зниження низькотемпературних характеристик асфальтобетону має пошкодження від морозного здимання, спричинене циклами замерзання-відтавання, що може призвести до серйозних пошкоджень внаслідок розриву бітумної оболонки. Корозія асфальтобетону під впливом протиожеледних реагентів може бути вторинним фактором. Протиожеледні речовини можуть знижувати адгезію асфальтобетону, що призводить до зменшення зв'язку між бітумом і заповнювачем, а це, в свою чергу, знижує експлуатаційні характеристики асфальтобетону.

Keywords: asphalt concrete, deicing agent, low temperature performance, solution concentration, freeze-thaw cycle, road performance.

Ключові слова: асфальтобетон, протиожеледна речовина, низькотемпературні характеристики, концентрація розчину, цикл заморожування-відтавання, експлуатаційні характеристики асфальтобетону.

Introduction. With the continuous development of transportation infrastructure in cold regions, asphalt concrete is increasingly applied in road construction[1]. However, in the cold season, the icing phenomenon on the road surface becomes a non-negligible problem, which not only affects traffic safety but also puts higher requirements on the performance of road materials. To solve this problem, the use of deicing agents has become a common means[2].

However, when selecting deicing agents, their effects on asphalt concrete performance need to be considered, especially under freeze-thaw cycle conditions[3]. Freeze-thaw cycle refers to the process of alternating freezing and thawing experienced by the road surface during the cold season, which puts higher requirements on the mechanical properties and durability of asphalt concrete[4][5]. Therefore, an in-depth study of the effects of different concentrations of deicing agents on the low-temperature performance of asphalt concrete under freeze-thaw cycle conditions is of great significance for optimizing the use of deicing agents and improving the performance of road usage. This study aims to systematically investigate the effects of different concentrations of deicing agents on the low-temperature performance of asphalt concrete through experimental methods, to provide a scientific basis for road construction.

In this investigation, five concentrations of NaCl solutions, 1%, 2%, 3%, 4%, and 5%, were selected to conduct freeze-thaw cycle tests on beam specimens (250 mm ± 2.0 mm in length, 30 mm ± 2.0 mm in width, and 35 mm ± 2.0 mm in height) of AC-20 asphalt concrete. The test parameters for a single cycle were: freezing temperature of -20°C ± 1°C and freezing time of 24h ± 0.5h for the test, and thawing temperature of 20°C ± 1°C and thawing time of 24h ± 0.5h. A total of 28 cycles were carried out and the low-temperature crack resistance tests were performed at the end of 0, 4, 8, 12, 16, 20, 24, and 28 cycles, and the test parameters included flexural tensile strength and maximum flexural tensile strain.

Table 1

Flexural tensile strength of asphalt concrete after multiple freeze-thaw cycles

Number of freeze-thaw cycles	Flexural tensile strength, MPa				
	1%NaCl	2%NaCl	3%NaCl	4%NaCl	5%NaCl
0	11,32	11,32	11,32	11,32	11,32
4	11,14	11,12	11,05	10,95	10,91
8	11,05	11,02	10,88	10,71	10,62
12	10,83	10,74	10,52	10,33	10,21
16	10,40	10,27	10,14	9,74	9,54
20	9,86	9,81	9,72	9,23	9,02
24	9,45	9,31	9,17	8,62	8,42
28	9,03	8,86	8,65	8,17	7,91

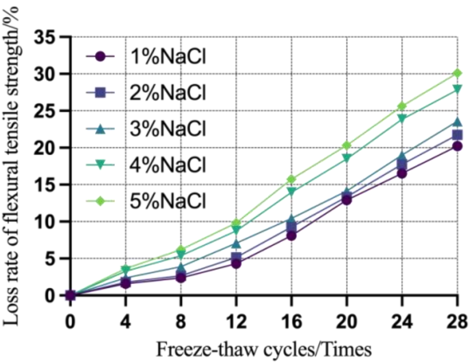

Fig. 1 Loss rate of flexural tensile strength of asphalt concrete after experiencing multiple freeze-thaw cycles

Test results. Low-temperature crack resistance test was performed on asphalt concrete after multiple freeze-thaw cycles, and the flexural tensile strength and maximum flexural tensile strain are shown in Tables 1 and 2, and their corresponding loss rates are shown in Figures 1 and 2.

As can be seen from Table 1, with the increase in the number of freeze-thaw cycles, the flexural tensile strength corresponding to the five concentrations of deicing agent solutions showed a decreasing trend, indicating that the damage of freeze-thaw cycles on asphalt concrete is extremely significant; meanwhile, it was observed that the larger the concentration of deicing agent corresponding to the flexural tensile strength decreases more obviously, at the end of the 28 times of freeze-thaw cycles, the flexural tensile strength corresponding to the five concentrations of deicing agent solutions were 9,03 MPa, 8.86 MPa, 8.65 MPa, 8,17 MPa and 7,91 MPa respectively, which shows that the deicing agent has a certain impact on the flexural tensile strength of asphalt concrete. Simultaneously, it can be observed from Fig. 1 that the loss rate for the first 12 freeze-thaw cycles is lower than the loss rate at 12-28 cycles. At the end of 28 cycles, the loss of flexural tensile strength corresponding to five concentrations of deicing agent solutions was 20.22%, 21.73%, 23.58%, 27.83%, and 30.12%, respectively.

Table 2

Maximum flexural tensile strain of asphalt concrete after multiple freeze-thaw cycles

Number of freeze-thaw cycles	Maximum flexural tensile strain, με				
	1%NaCl	2%NaCl	3%NaCl	4%NaCl	5%NaCl
0	2963	2963	2963	2963	2963
4	2915	2910	2901	2883	2871
8	2892	2884	2873	2842	2824
12	2835	2810	2799	2761	2741
16	2723	2689	2671	2614	2589
20	2627	2594	2578	2525	2493
24	2535	2508	2493	2437	2386
28	2463	2431	2417	2373	2307

As can be seen from Table 2, with the increase in the number of freeze-thaw cycles, the maximum flexural tensile strain corresponding to the five concentrations of deicing agent solutions showed a decreasing trend, indicating that the damage of freeze-thaw cycles on asphalt concrete is quite significant; simultaneously observed that the larger the concentration of the deicing agent corresponds to the maximum flexural tensile strain decreased more obviously, at the end of the 28 times of freeze-thaw cycles, the maximum flexural tensile strain corresponding to the five concentrations of deicing agent solutions were 2463 με, 2431 με, 2417 με, 2373 με and 2307 με, respectively, indicating that the deicing agent has a certain influence on the maximum flexural tensile strain of asphalt concrete. Meanwhile, it is observed from Fig. 2 that the loss rate in the first 12 freeze-thaw cycles is lower than the loss rate at 12-28 cycles. At the end of 28 cycles, the loss of maximum flexural tensile strain corresponding to five concentrations of deicing agent solutions was 16.85%, 17.95%, 18.43%, 19.91%, and 22.14%, respectively.

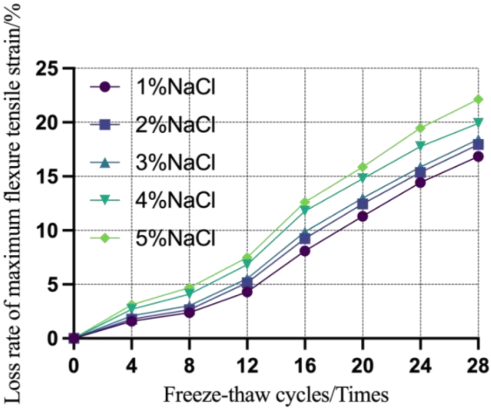

Fig. 2 Loss rate of maximum flexural tensile strain of asphalt concrete after experiencing multiple freeze-thaw cycles

Comprehensive analysis of the experimental results of flexural tensile strength and maximum flexural tensile strain shows that although the flexural tensile strength and maximum flexural tensile strain corresponding to the five concentrations of deicing agent solutions are different, the difference is not significant (at the end of 28 cycles, the loss rate of flexural tensile strength ranges from 20%-31%, and the loss of maximum flexural tensile strain ranges from 16% to 23%). Therefore, the greatest influence on the low-temperature performance reduction is the freezing and expansion damage of the freeze-thaw cycle, the freezing and expansion force caused by solution freezing will tear the asphalt membrane and cause serious damage; followed by the erosion damage of the deicing agent on the asphalt concrete, which may be due to the deicing agent reduces the adhesion of the asphalt, resulting in a decrease in the bonding force between asphalt and aggregates, which leads to a reduction in the performance of the asphalt concrete.

Conclusion. In this paper, by comparing and analyzing the experimental data of flexural tensile strength and maximum flexural tensile strain, the following conclusions can be drawn:

1. with the increase in the number of freeze-thaw cycles, the five concentrations of deicing agent solution corresponding to the flexural tensile strength and maximum flexural tensile strain have a decreasing trend, which

indicates that the freeze-thaw cycle on the asphalt concrete damage is significant.

2. The larger the concentration of deicing agent corresponding to the flexural tensile strength and maximum flexural tensile strain decreased more obviously.

3. From the loss rate of flexural tensile strength and maximum flexural tensile strain, it can be observed that the loss rate is low in the first 12 freeze-thaw cycles, while it increases in the 12-28 cycles. This may imply that asphalt concrete is relatively more resistant to freeze-thaw cycles in the initial stages, but the damage increases as the number of cycles increases.

4. Although the concentration of the deicing agent solution affects the flexural tensile strength and maximum flexural tensile strain, the main effect on the reduction in the low-temperature performance of the asphalt concrete is the frost heave damage induced by the freeze-thaw cycles. Freeze-up forces can cause tearing of the asphalt membrane, resulting in severe damage. Erosion damage to asphalt concrete by the deicing agent may be a secondary influence. Deicing agents may reduce the bonding of asphalt, resulting in a reduction in the bond between asphalt and aggregate, thus reducing the performance of asphalt concrete.

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