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Comparative study on the corrosion and freeze-thaw durability of aircraft deicer and airfield pavement deicer

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Abstract. During the corrosion cycle of 50 day, for the surface of OPC in the aircraft deicer it has net cracks, while in the airport pavement deicer it doesn't show a tendency to crack but having white matter. Under the coupling effect of corrosion and freeze-thaw, the surface properties of the aircraft deicer are better than that of the airport pavement deicer. Under the simple corrosion cycle or coupling action of corrosion and freeze-thaw for the deterioration degree of mechanical properties (compressive strength and flexural strength) of airport pavement concrete the airport pavement deicer is larger than the aircraft deicer. Finally, no matter whether the aircraft deicer or airfield pavement deicer, the coupling effect of corrosion and freeze-thaw has a significant influence on the concrete degradation of the airport deicing plateau.

Key words. Aircraft deicer, Airfield pavement deicer, Airport deicing plateau, Corrosion, Freeze-thaw.

1. Introduction

The snow and freezing rain in the northern cold regions bring great risks to the airport transportation safety. When the frost and snow attach to the fuselage, wings and control surfaces, it's easy to cause the body surface to be roughness and the gas dynamic efficiency and lift of wing will also likely be damaged, and it generates negative effect on the aircraft lift, resulting in serious aircraft stall. On the other hand, the ice and snow will decrease the friction coefficient of apron, taxiway and runway. Moreover, the ice and snow will cover road signs, taking-off and landing markers etc., posing a potential threat for the normal taking-off and landing. Even if there is a small amount of ice and snow on the airport road it will be dangerous to the aircraft landing. At home and abroad due to incomplete deicing it causes crash and events beyond count. Hence, in order to ensure the aircraft taking-off and landing safely it's a must to deice timely thorough aircraft deicer and airfield pavement deicer.

Airport deicing plateau involves two kinds of deicer including Aircraft Deicer referred to as AD and the Airfield Pavement Deicer referred to as APD. For both AD and APD at home and abroad how to impact airport pavement concrete still remains inconclusive. Therefore, the main purpose of this paper is aim at researching the durability especially the coupling action of corrosion and freeze-thaw damage of airport pavement concrete and furtherly getting a comparative analysis.

2. Experiment

In the paper, choosing aircraft deicer and airfield pavement deicer widely used is as comparing samples, and the concrete mix design parameters are shown in Table 1.

Table 1. Mixture Ratio Parameters of Concrete (kg/m^3)

Cement	Sand	Aggregate（mm）		Water	Admixtures
		5～20	20～40		
330	569.8	571.8	857.7	120.8	6.6

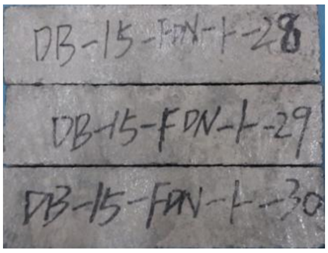
3. Results and discussion

3.1. Comparison of concrete apparent properties under deicers

3.1.1. Comparison of apparent properties of concrete with corrosion cycle

The apparent corrosion status of OPC in AD and APD with all concentration of 100% after corrosion cycle of 50 days is shown in Figure 1. OPC surface showing net cracks after undergoing corrosion cycle of 50 days in AD, while there is no tendency to appear continuous cracks but existing apparent white substances in APD. It means that in APD the airport pavement concrete might have taken chemical reaction. From the concrete surface corrosion resistance grade assessment standard, for the surface of OPC, the corrosion grade of AD and APD respectively are Grade 1 and Grade 0.

(a) AD



(b) APD

Figure 1. Apparent properties of OPC in AD and APD with corrosion cycle of 50 days

3.1.2. Comparison of apparent properties of concrete with coupling action of corrosion and freeze-thaw

The apparent corrosion status of OPC in AD and APD with all concentration of 100% after coupling action of corrosion of 50 days then freeze-thaw of 300 times is shown in Figure 2. Under the coupling action of corrosion of 50 days and freeze-thaw of 300 times, OPC surface presents punctate stripping but there is no aggregate exposed in AD, while it shows manifested peeling and some exposed aggregate in APD. Hence, from the concrete surface corrosion resistance grade assessment standard, for the surface of OPC, the corrosion grade of AD and APD respectively are Grade 3 and Grade 4.

(a)AD

(b) APD

Figure 2. Apparent properties of OPC in AD and APD with coupling action of corrosion of 50 days and freeze-thaw of 300 times

3.2. Comparison of concrete durability under action of deicer

3.2.1. Comparison of relative dynamic elastic modulus under corrosion cycle

The influence of two kinds of deicers on relative dynamic elastic modulus of OPC and the corresponding relative dynamic elastic modulus under the corrosion cycles of 50 days (one cycle per day) are unfolded in Figure 3 and Table 2. Except for under corrosion cycles of 15 days, in AD of KHF-1 the relative dynamic elastic modulus value of OPC is 95.28%, being lower than in the APD of Specialguard he corresponding value of 96.97%, the rest of each corrosion cycle for the test results, AD of KHF-1 is always higher than APD of Specialguard. At the end of entire corrosion cycles of 50 days for AD of KHF-1 and APD of Specialguard the relative dynamic elastic modulus of OPC respectively are 90.43% and 87.14%, namely AD of KHF-1 is still greater than APD of Specialguard.

However, from another point of view, with just corrosion cycles of 50 days， for AD of KHF-1 the relative dynamic elastic modulus is only of high values of about 3% than APD of Specialguard, illustrating that the two kinds of deicers themselves to concrete corrosion damage is not significant difference.

Hence, it is concluded that the corrosion action of AD is less than that of APD and the difference of their corrosion damage to concrete is not pretty distinct.

Table 2. Relative dynamic elastic modulus of OPC corresponding to deicers

		Times of freeze-thaw cycle										
		0	5	10	15	20	25	30	35	40	45	50
A	KHF-1	100	98.23	98.17	95.28	95.11	94.83	92.28	92.13	91.44	90.69	90.43
B	Specialguard	100	97.33	97.32	96.97	93.26	93	91.73	90.36	88.64	87.97	87.14

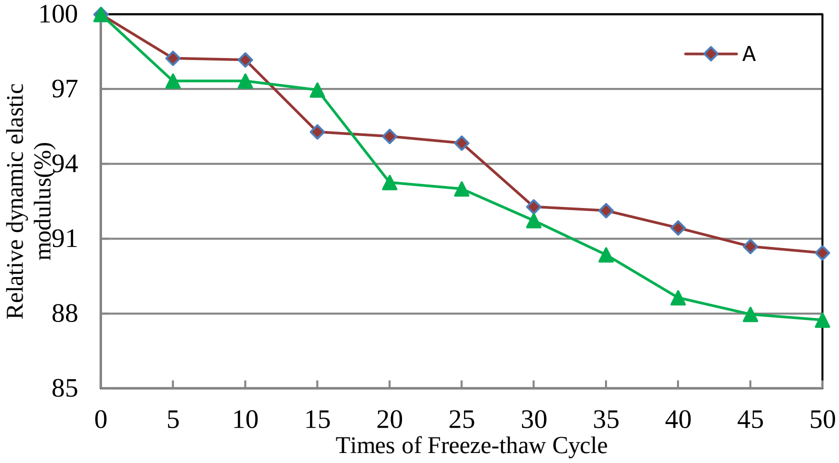


Figure 3. Influence of deicers on the relative dynamic elastic modulus of OPC

3.2.2. Comparison of relative dynamic elastic modulus under coupling action of corrosion and freeze-thaw cycle

The effect of deicers on the relative dynamic elastic modulus of OPC and the corresponding relative dynamic elastic modulus under the corrosion cycles of 50 days (one cycle per day) then freeze-thaw cycles of 300 times are presented in Figure 4 and Table 3. During the whole 300 freeze-thaw cycles, the relative dynamic elastic modulus of concrete corresponding to KHF-1 is higher than that of Specialguard. With the end of 300 times freeze-thaw cycles, for the relative dynamic elastic modulus of concrete the KHF-1 and Specialguard respectively are 52.68% and 47.26%, that is, at the end of coupling action of corrosion of 50 days and freeze-thaw of 300 times, the relative dynamic elastic modulus of concrete corresponding to KHF-1 is only greater about 5% than that of Specialguard. With respectively in the KHF-1 and Specialguard the corresponding freeze-thaw cycles being 225 and 175 times, for the relative dynamic elastic modulus they are both less than 60% (bottom line), which means that the two deicers under the coupling effect of corrosion and freeze-thaw cycles the durability of concrete shows pretty serious damage.

Thus, it is concluded that with the coupling effect of corrosion and freeze-thaw cycles it can cause extremely severe damage to the durability of concrete.

Table 3. Relative dynamic elastic modulus of OPC with the coupling effect of deicer corrosion and freeze-thaw cycles

		Times of Freeze-thaw Cycle												
		0	25	50	75	100	125	150	175	200	225	250	275	300
A	KHF-1	90.43	83.69	82.78	74.69	73.81	72.23	65.58	63.44	62.16	58.69	57.53	53.25	52.68
B	Specialguard	87.14	81.94	77.51	70.11	69.17	67.35	62.58	58.82	54.28	52.18	51.94	48.69	47.26

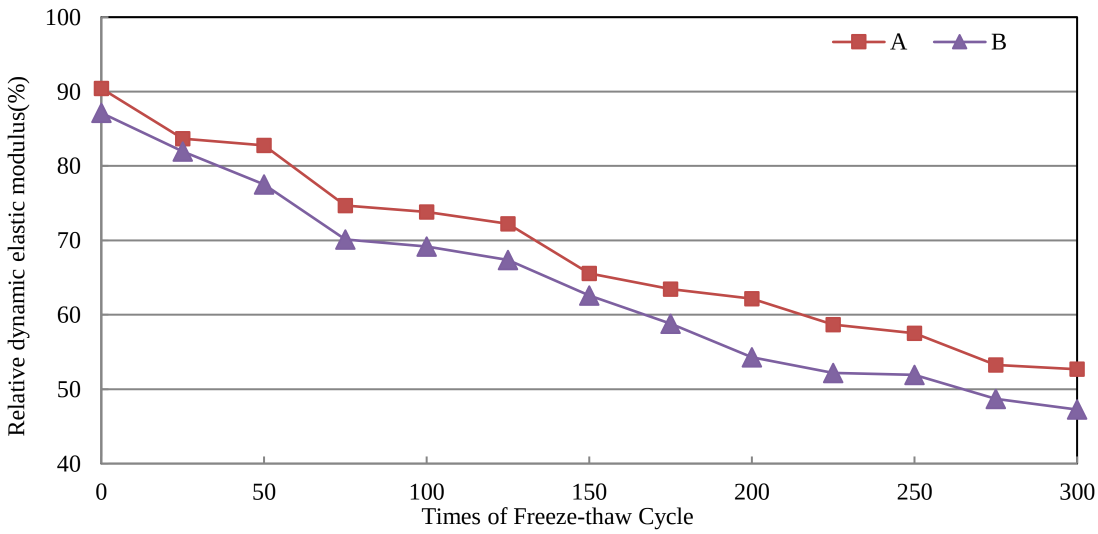


Figure 4. Influence of the coupling effect of deicer corrosion and freeze-thaw cycles on the relative dynamic elastic modulus of OPC

3.3. Comparison of mechanical properties of concrete with action of coupling action of corrosion and freeze-thaw cycles

The flexural strengths and its comparison in the different deicers under the effect of corrosion cycles or coupling action of corrosion and freeze-thaw cycles are shown in Figure 5 and Table 4. For the initial concrete the flexural strength of 28-day age is 5.59MPa, after corrosion cycle of 50 days in KHF-1 and Specialguard deicers the flexural strength values decline to 4.98MPa and 4.77MPa by themselves. With accomplishing freeze-thaw cycles of 300 times after corrosion cycles of 50 days the flexural strength are respectively 3.87 MPa and 3.62 MPa.

The compressive strengths and its comparison in the different deicers under the effect of corrosion cycles or coupling action of corrosion and freeze-thaw cycles are presented in Figure 6 and Table 5. For the initial concrete the compressive strength of 28-day age is 63.5MPa, after corrosion cycle of 50 days in KHF-1 and Specialguard deicers the compressive strength values decline to 56.5MPa and 48.1MPa by themselves. With accomplishing freeze-thaw cycles of 300 times after corrosion cycles of 50 days the compressive strength are respectively 44.4MPa and 41.1MPa.

Hence, under same conditions, AD of KHF-1 is smaller than APD of Specialguard for the compressive or flexural strength of concrete, and the corrosion action of KHF-1 to concrete is less than that of Specialguard. The coupling action of corrosion and freeze-thaw (firstly corrosion tests and then freeze-thaw cycles) has a significant effect on the deterioration of concrete. The flexural strength values are as follows: coupling action of low temperature corrosion cycle (Specialguard) and freeze-thaw cycle < coupling action of low temperature corrosion cycle (KHF-1) and freeze-thaw cycle < low temperature corrosion cycle (Specialguard) < low temperature corrosion cycle (KHF-1) < Control.

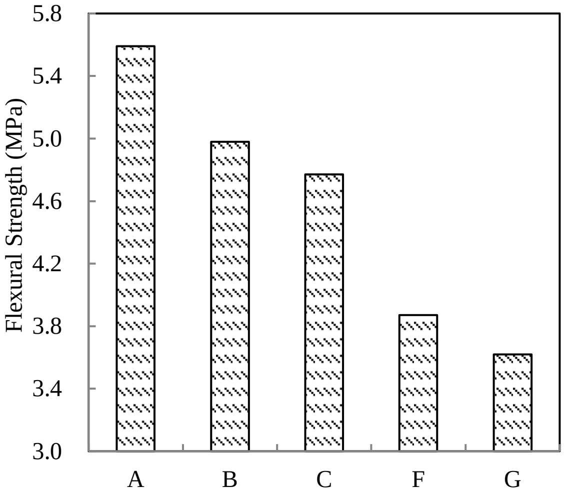


Figure 5. Comparison of flexural strength in the different deicers under the effect of corrosion cycles or coupling action of corrosion and freeze-thaw cycles

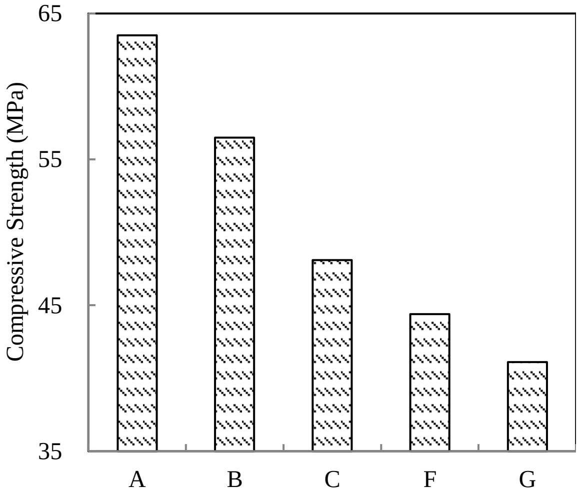


Figure 6. Comparison of compressive strength in the different deicers under the effect of corrosion cycles or coupling action of corrosion and freeze-thaw cycles

Table 4. Flexural strength in the different deicers under the effect of corrosion cycles or coupling action of corrosion and freeze-thaw cycles

NO.	Test condition	Flexural Strength（MPa）	Ratio of Flexural Strength
A	Control	5.59	100.00%
B	low temperature corrosion cycle (KHF-1)	4.98	89.09%
C	low temperature corrosion cycle (Special guard)	4.77	85.33%
F	coupling action of low temperature corrosion cycle (KHF-1) and freeze-thaw cycle	3.87	69.23%
G	coupling action of low temperature corrosion cycle (Specialguard) and freeze-thaw cycle	3.62	64.76%

Table 5. Compressive strength in the different deicers under the effect of corrosion cycles or coupling action of corrosion and freeze-thaw cycles

NO.	Test condition	Compressive strength（MPa）	Ratio of compressive strength
A	Control	63.5	100.00%
B	low temperature corrosion cycle (KHF-1)	56.5	89.00%
C	low temperature corrosion cycle (Specialguard)	48.1	75.80%
F	coupling action of low temperature corrosion cycle (KHF-1) and freeze-thaw cycle	44.4	69.91%
G	coupling action of low temperature corrosion cycle (Specialguard) and freeze-thaw cycle	41.1	64.78%

3.4. Mechanism analysis on the superposition and coupling effect of freeze-thaw and corrosion cycles on the airport deicing plateau

Concrete under low temperature corrosion environment conducting corrosion cycle and under the low temperature cycle environment carrying on freeze-thaw cycle are engendered to the surface damnification and internal structure damage which play a negative effect on the concrete durability. The main reasons for the surface spalling of concrete are as follows: on the one hand, the corrosive medium through micro pores and cracks on the surface of concrete penetrates into concrete, resulting in causing capillary pore tension in the pores of concrete to change, thus the pore walls being exerted a amount of stress, and the smaller the pore size is the greater the tension is. With the tension exceeding such cohesions as Van Edward force etc. of concrete, the surrounding of pores begins to damage; on the other hand, the invasion of external corrosive medium is a process from outside to inside, under the action of potential concentration field and capillary, the corrosion medium with ionic solution in the capillary of concrete occurs concentration exchange and the part of capillary solution in concrete begins to precipitate, under low temperature condition, there generates expansion in the surface of concrete, and it will produce surface damage when the crystallization force is more than the tensile strength of concrete itself. Thirdly, the corrosive medium is able to react with concrete, the formation of corrosion products and the crystal pressure caused by the crystal growth can also cause damage to concrete. APD of Specialguard with hydration products $Ca(OH)_2$ existing in the surface structure of concrete takes corrosion reaction resulting in white precipitates. The reaction occurs not only on the surface of concrete samples but also in the capillary solution of concrete, as the ion concentration achieving supersaturation condition, the crystal products start to precipitate, and with crystals growing to produce crystal stress, the capillary wall (hardened cement paste) will swell and crack finally resulting in concrete nearby surface spalling. Due to the specimen edges being two-dimensional and three-dimensional superimposition forces its crystallization pressure first reaches the tensile strength of concrete. So there are micro cracks, and these micro cracks further expand leading to corner spalling at last. The main components of white precipitates on the concrete surface may be Ca (CH3COO)2 · H2O and Mg (OH)2.

4. Conclusion

During the corrosion cycle of 50 day, for the surface of OPC in the aircraft deicer it has net cracks, while in the airport pavement deicer it doesn't show a tendency to crack but having white matter. Under the coupling effect of corrosion and freeze-thaw, the surface properties of the aircraft deicer are better than that of the airport pavement deicer.

Under the simple corrosion cycle or coupling action of corrosion and freeze-thaw for the deterioration degree of mechanical properties (compressive strength and flexural strength) of airport pavement concrete the airport pavement deicer is larger than the aircraft deicer. In addition, no matter whether the aircraft deicer or airfield pavement deicer, the coupling effect of corrosion and freeze-thaw has a significant influence on the concrete degradation of the airport deicing plateau.

The negative influence of different external environment on flexural strength values is as follows: coupling action of low temperature corrosion cycle (Specialguard) and freeze-thaw cycle ＞ coupling action of low temperature corrosion cycle (KHF-1) and freeze-thaw cycle ＞ low temperature corrosion cycle (Specialguard) ＞ low temperature corrosion cycle (KHF-1) ＞ Control.

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