Experimental Study about the Influence of Silane Impregnation on the Durability of Airport Pavement Concrete in Aircraft Deicing Fluid Environment

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Abstract. In order to study the influence of silane impregnation on the durability of airport pavement concrete in aircraft deicing fluid environment, corrosion resistance test, dynamic elastic modulus test, frost resistance test, and mechanical test (tensile strength) are adopted. The results show that (1) After 50 corrosion cycles, the surface of concrete without silane impregnation appears slight spalling, but the silane impregnated concrete does not, which indicates that silane impregnation effectively improves the corrosion resistance of concrete. (2) After the corrosion cycle and freeze-thaw cycle, the dynamic elastic modulus of the silane-impregnated concrete is nearly 1/4 higher than that of the untreated concrete, and the flexural strength is 19.88% higher, proving that silane impregnation has a good enhancement effect on the durability of concrete.

1. Introduction

The winter in northern China is long and cold, so aircraft deicing fluid is used to deice aircraft in airports. Under the corrosion and freeze-thaw coupling effect of aircraft deicing fluid, pavement peeling, spalling and other diseases occurs in airport concrete pavement, which not only affects the pavement performance, but also threatens the safety of aircraft[1-4]. As a concrete protection technology, silane impregnation has been applied in seaports, highways and other fields at home and abroad. In recent years, it has been gradually applied as a protection method of airport pavement concrete.

Li Hai Su, Yan Lv and Xun Gao Ji studied the influence of silane materials on the frost resistance of airport pavement concrete, and the research shows that silane materials can significantly improve the waterproof and frost resistance of airport pavement concrete [5].

Mao Jiang Zhu, Xing Zhong Weng and Rui Gao studied the influence of silane spraying on the frost resistance and abrasion resistance of airport concrete, and the results show that silane spraying can effectively improve the surface performance of airport pavement concrete, and it is suitable for the reinforcement and life extension of existing airport pavement [6]. Sang zhen Xu and Wei Sheng Chi studied the silane impregnation depth, chloride ion penetration resistance, water penetration resistance and frost resistance after silane impregnation, and the results show that the chloride ion penetration resistance, water penetration resistance and frost resistance are significantly improved when the silane impregnation depth is greater than 3mm [7]. Summarizing the relevant research, it is found that the research on the influence of silane impregnation on airport pavement concrete mainly focuses on waterproof and frost resistance at present, while there is little research on the influence of silane impregnation on the durability of airport pavement concrete in the environment of aircraft deicing fluid.
Therefore, this paper studies the influence law of silane impregnation on the durability of airport pavement concrete through relevant tests, which provides reference for the future research and practice.

2. Raw materials and specimen preparation

2.1 Raw materials
Cement: P·O42.5 cement.
Sand: fineness modulus 2.8, medium sand.
Stone: basalt gravel, basically 5-20mm, 20-40mm continuous grading.
Water: tap water, in line with national standards.
Aircraft deicing fluid: glycol aircraft deicing.
Silane impregnant: isobutene triethoxysilane protector.

2.2 Sample preparation
The sample is made according to mix proportion (mass ratio) as follow, cement: water: Sand: Crushed Stone (5 ~ 20mm): Crushed Stone (20 ~ 40mm) = 330:120.8:569.8, and then the surface of the sample is evenly coated with silane impregnant.

2.3 Test method
Corrosion resistance test and dynamic elastic modulus after corrosion test are used to evaluate the corrosion resistance durability of pavement concrete. Frost resistance test and mechanical test (bending tensile strength) are used to evaluate the durability of pavement concrete under the coupling action of corrosion and freeze-thaw. ASTM C 672c (m) - 2003 Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals is adopted for corrosion resistance test. Dynamic modulus of elasticity, mechanical test (flexural tensile strength) test and frost resistance test are conducted in accordance with relevant methods of Testing Methods of Cement and Concrete for Highway Engineering (JTG e30-2020).

3. Effect of silane impregnation on durability of airport pavement concrete

3.1 Effect of silane impregnation on corrosion resistance durability of airport pavement concrete
Figure 1 is a comparative diagram of concrete without silane impregnation and concrete with silane impregnation. In terms of the apparent properties, there is almost no obvious change in the surface of the silane impregnated concrete after 50 corrosion cycles, and the anti-corrosion grade is evaluated as 0; the surface of the concrete without silane impregnation appears whitening and slight peeling after 50 corrosion cycles, and the anti-corrosion grade is evaluated as 1. The results show that silane impregnation can effectively improve the corrosion resistance of concrete.

Figure 1. Comparison of apparent properties of concrete with and without silane impregnation after 50 corrosion cycles
3.2 Effect of silane impregnation on durability of airport pavement concrete under the coupling action of corrosion and freeze-thaw

3.2.1. Comparison of dynamic elastic modulus of untreated and silane impregnated concrete.
Table 1 and Figure 2 show the dynamic elastic modulus of concrete after 50 corrosion cycles and 300 freeze-thaw cycles in aircraft deicing fluid. The results show that: (1) at the end of 50 corrosion cycles, the difference of the relative dynamic elastic modulus between untreated concrete and silane impregnated concrete is only about 8%. With the advance of freeze-thaw cycle test, the relative dynamic modulus of elasticity of untreated concrete decreases rapidly. After 300 freeze-thaw cycles, the dynamic modulus of elasticity of untreated concrete is only 52.68%, which decreases by nearly 1/2. On the contrary, even after 300 freeze-thaw cycles, the relative dynamic elastic modulus of silane impregnated concrete is still 73.27%, which is about 21% higher than that of untreated concrete. (2) The results show that the elastic modulus of concrete treated with silane is better than that of concrete untreated, indicating that silane impregnation has a good protective effect on concrete.

| surface appearance | Freeze thaw times |
|--------------------|-----------------|
|                    | 0 25 50 75 100 125 150 175 200 225 250 275 300 |
| Untreated          | 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 |
| Silane impregnation| 98.72 97.86 97.45 97.12 96.87 92.16 85.35 84.12 80.27 78.66 77.98 74.19 73.24 |

Figure 2. Variation of dynamic elastic modulus after 50 corrosion cycles + 300 freeze-thaw cycles
3.2.2. Comparison of mechanical properties of untreated and silane impregnated concrete.

Table 2 and Figure 3 show the mechanical properties (flexural tensile strength) of untreated and silane impregnated concrete, which is in different conditions of no durability cycle damage, 50 corrosion cycles, 50 corrosion cycles + 300 freeze-thaw cycles. The results show that:

(1) the flexural strength of concrete is 5.59Mpa without any durability cycle failure. After corrosion cycle, the flexural strength of silane impregnated concrete is 4.98Mpa and the ratio of flexural strength is 96.24%. The flexural strength of untreated concrete is 5.38Mpa, the ratio of flexural strength is 86.76%, which proves that the flexural strength of silane impregnated concrete is increased by 9.48%.

(2) Freezing thawing cycle is carried out after corrosion test, when two tests are all finished, the flexural strength of silane impregnated concrete is 4.88mpa, and the ratio of flexural strength to tensile strength is 87.30%. The flexural strength of untreated concrete after corrosion cycle is 3.87Mpa, and the ratio of flexural strength to tensile strength is 67.42%. The flexural strength of silane impregnated concrete increases by 19.88%. (3) The flexural strength of silane impregnated concrete at different durability failure stages is higher than that of untreated concrete, which indicates that silane impregnation has a good effect on the durability of concrete.

Table 2. Comparison of mechanical properties (flexural strength) of untreated and silane-impregnated concrete.

| Number | Test conditions                                           | flexural strength (Mpa) | ratio of flexural strength (Compared with group A) |
|--------|----------------------------------------------------------|-------------------------|---------------------------------------------------|
|        |                                                          | Untreated | Silane impregnation | Untreated | Silane impregnation |
| A      | Without any durability cycle                            | 5.59      | 5.59                | 100.00%   | 100.00%             |
| B      | Corrosion cycle (50 times)                              | 4.98      | 5.38                | 86.76%    | 96.24%              |
| C      | Corrosion cycle (50 times) + freeze thaw cycle (90 times)| 3.87      | 4.88                | 67.42%    | 87.30%              |

Figure 3. Variation of mechanical properties (flexural strength) of untreated and silane-impregnated concrete
4. Conclusion
This paper studies the effect of silane impregnation on the durability of airport pavement concrete. The results are as follows.

(1) Silane impregnation can effectively improve the corrosion resistance of concrete. After 50 corrosion cycles, the corrosion resistance grade of silane impregnated concrete is evaluated as 0, and the dynamic modulus of elasticity is only decreased by 1.32%, which is far better than that of untreated concrete.

(2) Silane impregnation can effectively improve the freeze-thaw resistance of concrete. Under the coupling action of corrosion and freeze-thaw, the dynamic elastic modulus of untreated concrete is $1/4$ less than that of the concrete impregnated with silane, and the flexural tensile strength of the concrete impregnated with silane is 19.88% higher than that of the untreated concrete.

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