Experimental Study on Salt Freezing Damage of Cement Concrete by Chloride Deicing Agent

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Abstract. In winter, a large number of chloride deicing agents are spread in northern China. The damage effect of chloride deicing agent on concrete has attracted great attention in the industry. It is of great significance to study the mechanism of salt freezing to improve the service life and safety of roads and bridges in cold regions. In this paper, using C30 and C50 concrete specimens commonly used in highway engineering, using water bath box, oven, cut-201 ultrasonic instrument and other instruments and equipment, on the basis of a large number of indoor tests, the mode and degree of concrete salt freezing damage under freeze-thaw cycle environment are studied in depth, including the influence of concrete quality loss rate, appearance, dynamic elastic modulus and strength. The influence mode and degree of concrete salt frost damage are given, and the variation law of various performance parameters of concrete under salt freezing condition is analyzed, which provides the test basis for the proposal of relevant protection measures.

1. Introduction
In winter, chlorine salt deicing agent is widely distributed in the vast northern areas of China to melt ice and remove snow. The main components of chlorine salt snow melting agent are sodium chloride, calcium chloride, magnesium chloride, potassium chloride, etc. \cite{1}. The raw salt is crushed and sieved into particles with a certain particle size or dissolved in water to form salt water, and then sprayed on the road surface or other sites by machinery for snow melting operation. However, while melting road ice and snow to keep smooth and safe operation, chloride salt snow melting agent damages highway transportation infrastructure including concrete under the combined action of freeze-thaw cycle and traffic load, which seriously affects the normal use function and life of transportation infrastructure such as roads and bridges, pollutes the road environment, and is extremely harmful for long-term use. The destruction of concrete by chlorine salt deicing agent has attracted great attention in the industry. It is of great significance to study the mechanism of salt freezing for improving the service life and safety of roads and bridges in cold areas. In this paper, based on a large number of laboratory tests, the mechanism of salt freezing damage of concrete caused by chlorine salt deicing agents is deeply studied \cite{2}.

2. Test Scheme
The specimens of the freeze-thaw test of cement concrete are C30 and C50 concrete, which are commonly used in highway engineering. The mix proportion is shown in table 1. Three concentrations (mass fraction) of 3\%, 5\% and 20\% saline solution were selected. The concrete blocks with standard
curing time of 28 days were divided into two groups. One group was placed in A and B chloride solution with 3%, 5% and 20% concentration respectively (see table 2 for Cl\(^-\) content of each concentration) until the predetermined age (28 d, 60 d, 90 d and 180 d), and the other group was placed in the corresponding chloride solution to dry and wet cycle to the specified age. The dry wet cycle system was: soak in chlorine salt snow melting agent solution for 18 h and then it was dried in an oven at 60 \(^\circ\)C for 6 h.

### Table 1. Concrete mix ratio.

| Numbering | C30 | C50 |
|-----------|-----|-----|
| Cement   | 250 | 360 |
| Fly ash  | 30  | 40  |
| Silicafume| 0   | 0   |
| Water    | 165 | 145 |
| Sand     | 702 | 665 |
| Stone    | 1248| 1182|
| Water reducing agent/% | 0.90 | 1.60 |
| Air entraining agent/‰ | 3.8 | 3.8 |
| Rupture strength/MPa | |
| 7d       | 6.59 | 8.69 |
| 28d      | 8.17 | 9.91 |
| Compressive strength /MPa | |
| 7d       | 27.8 | 45.1 |
| 28d      | 37.3 | 66.1 |

Note: The air entraining agent is TS-AE.

### Table 2. Cl\(^-\) content of A and B chloride solutions with three concentrations.

| Projects | 3%  | 5%  | 20% |
|----------|-----|-----|-----|
| A        | 1.75% | 2.91% | 11.64% |
| B        | 1.61% | 2.68% | 10.72% |

3. Experimental Analysis of Chlorine Salt Deicing Agent on Cement Concrete.

3.1. Effect of Salt Freezing on Appearance of Concrete

3.1.1. Effect of Freeze-Thaw Cycles on Appearance of Concrete. Figure 1 shows the appearance of C30 concrete without freeze-thaw and after 75 and 200 freeze-thaw cycles in 3% snow melting agent a solution.

![Figure 1](image1.png)

(a) Before freezing and thawing (b) Freeze-thaw 75 times (c) Freeze-thaw 200 times

**Figure 1.** Appearance of C30 concrete after different freeze-thaw cycles in 3% solution.

Compared with the unfrozen concrete block in figure 1 (a), the laitance spalling on the surface of the test block after 75 freeze-thaw cycles is about 50% - 75%, and stones and sand particles in the concrete can be seen by naked eyes, some aggregates are exposed, and the corner of the test block is slightly damaged; a large number of concrete materials at one side corner of the test block after 200
freeze-thaw cycles collapse and fall, and the surface of the test block is fractured. The results show that the salt frost resistance of ordinary C30 concrete is poor due to its low strength and high porosity, and the surface of concrete is basically spalling after 75 times of freeze-thaw.

3.1.2. Effect of Chloride Concentration on Appearance of Concrete. The apparent morphology of C30 concrete after freezing and thawing 150 times in different solution is shown in figure 2.

![Figure 2](image)

Figure 2. Appearance of C30 concrete frozen and thawed 150 times in different concentrations of B snow melting agent solution.

It can be seen from figure 2 that the appearance of C30 concrete is different after 150 times of freezing and thawing in different concentrations of snow melting agent solution. After 150 freeze-thaw cycles in 3% chloride deicing agent solution, the surface of concrete is uneven, the paste is completely peeled off, and the aggregate is almost completely exposed; in 5% solution, the surface laitance of the test block falls off, and part of the corner material has collapsed and peeled off, the damage degree is the most serious; in 20% solution, the surface slurry of the test block has fallen off, but the overall structure of the test block remains intact. The results show that the damage degree of concrete is different with the concentration of chloride deicing agent, which is 5% > 3% > 20%.

3.2. The Quality Loss of Concrete

There is a certain corresponding relationship between the quality loss and the appearance and appearance. Figure 3 shows the quality loss of two kinds of concrete of A and B chloride deicer solutions, respectively [3-5]. It can be seen from figure 3 that the mass loss rate of C30 concrete is less than 5% after 100 cycles of salt freezing; the mass loss rate of concrete in 5% chloride deicing agent solution exceeds 5% after 100 times of salt freezing; the mass loss rate of concrete in 3% chlorine salt snow melting agent solution is more than 5% after 175 times of salt freezing; even if the salt freezing cycle is 200 times, the quality of concrete frozen in 20% chlorine salt snow melting agent solution is more than 5% The mass loss rates were 16.15%, 19.23%, 4.35%, 14.56%, 17.98% and 2.55% after 200 freeze-thaw cycles in A3%, a5%, A20%, B3%, B5% and B20% solutions, respectively.

![Figure 3](image)

Figure 3. Effect of chlorine salt variety and concrete mass loss rate.
Obviously, the loss rate of concrete quality is increasing gradually, and in the later stage of salt freezing, the increase range of mass loss rate is larger. This is mainly due to the cement paste peeling and a small amount of aggregate falling off at the early stage of freeze-thaw cycle, which leads to mass loss. In the later stage of freeze-thaw cycle, a large amount of aggregate and cement paste lose cohesion and fall off in large area, which can cause the whole concrete specimen to disintegrate seriously [6-10].

3.3. Dynamic Elastic Modulus of Concrete under Salt Freezing Condition

In this paper, cut-201 ultrasonic instrument is used to test the wave velocity of ultrasonic wave in concrete specimen, and then the dynamic elastic modulus of the specimen is calculated according to the formula. It can be seen from figure 4 that with the increase of freeze-thaw cycles, the relative dynamic elastic modulus of concrete decreases rapidly. The relative dynamic elastic modulus of C30 concrete is 57.34% after 100 times of freezing in A 5% solution, and it decreases to 66.24%, 74.32%, 81.43%, 90.68% and 92.83% in B 5%, A 3%, B 3%, A 20% and B20% solutions respectively, and still exceeds 60% after 200 times.

![Figure 4. Influence of variety and concentration.](image)

4. Conclusion

The conclusions are as follows:

1. The results show that the damage degree of concrete is different with the concentration of chloride deicing agent, which is 5% > 3% > 20%;
2. The concrete with higher strength has stronger salt frost resistance;
3. Chloride salt has double effects on the frost resistance of concrete, high concentration and low freezing point are beneficial to frost resistance, and high water saturation degree of concrete is not conducive to frost resistance;
4. The freeze-thaw cycle has a significant impact on the strength of concrete. With the increase of the number of freeze-thaw cycles, the strength of concrete decreases.

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