

Evolution Law of Frost Resistance of Fly Ash Concrete based on Large Temperature Difference between Freezing and Thawing Environment

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Abstract: In order to study the deterioration and damage process of fly ash concrete under the condition of freeze-thaw cycle with large temperature difference, we take the Ruoqiang area in Xinjiang, China as the research background (temperature difference: $-23.3^{\circ}\text{C}\sim 43.1^{\circ}\text{C}$), study the dynamic evolution process of corrosion resistance coefficients of the concrete specimens with fly ash dosage of 0, 10%, 20%, and 30%, and analyse the law of frost resistance decay of fly ash under the environment of freeze-thaw with large temperature difference; the results show that the addition of The results show that: adding 10%~20% of fly ash in concrete can slow down the deterioration of concrete frost resistance, and the frost resistance of concrete is the best under 20% of fly ash dosage.

Keywords: Large Temperature Difference; Freeze-thaw Cycle; Corrosion Resistance Coefficient; Fly Ash; Freezing Resistance.

1. Introduction

The presence of perennial and seasonal permafrost in cold regions, such as Northwest, North China, Northeast, and coastal areas, has a significant impact on concrete structures and infrastructure. The characteristics of these regions include a large temperature difference between day and night, and the two necessary conditions for freeze-thaw cycles, i.e., alternating freeze-thaw cycles and the concrete reaching a water retention state. As a result, freeze-thaw damage is common in railway, road and building projects in these regions, which has a serious impact on the frost service life of the structures. Concrete is susceptible to the effects of freeze-thaw cycling, which leads to damage due to internal stresses caused by the expansion of frozen water. In addition, long-term freeze-thaw cycles may also cause a decrease in concrete strength, which in turn affects the stability and durability of the structure. These effects seriously affect the service life and safety of engineering structures. Therefore, it is of great significance to study the evolution of concrete frost resistance in cold regions during long service life to improve the durability of concrete and prolong the service life of concrete structures under the condition of freeze-thaw cycles with large temperature difference [1-2].

To address this type of problem, domestic and foreign experts have conducted many related experimental studies, and more significant results have been achieved. In terms of low-temperature concrete durability damage, Li Zhongyu et al [3] studied the trend of concrete frost resistance by adjusting the proportion of different mineral admixtures, and it was pointed out that the introduction of mineral admixtures effectively improves the frost resistance of concrete; Woo Maoyin et al [4] investigated the effect of double mixing of fly ash and mineral powder and the proportion of double mixing on the frost resistance of concrete under the standard curing condition, and it was proved that the concrete with 40% of mineral admixture showed more excellent frost resistance than the concrete with 40% of mineral admixture. The

concrete showed more excellent frost resistance; Zhou Lu et al [5] studied the effect of mineral admixtures on the performance of permeable concrete, proved that fly ash, mineral powder, silica fume on the improvement of its frost resistance are improved, of which silica fume to improve the ability to improve the frost resistance of the weaker; Ma Xiaoyu [6] in his research to improve the performance of the concrete by the introduction of mineral admixtures and air-entraining agent, the results of the test showed that the use of 25% of the proportion of fly ash and 30% proportion of mineral powder, and add air-entraining agent, the resulting concrete shows excellent frost resistance; Li Jun [7] through the experimental investigation clearly points out that the introduction of fly ash in the concrete, its mixing should not be more than 25% can be obtained superior frost resistance, slag on the frost resistance of concrete has less impact; Zhang [8-9] proposed that fly ash has the effect of reducing the air content of the concrete, which will have an impact on its frost resistance. damage was predicted. However, there are fewer experimental studies on freeze-thaw in the context of large temperature difference in Northwest China, while there is a relative lack of research on fly ash concrete with large temperature difference freeze-thaw.

In this study, based on the experimental investigation of large temperature difference freeze-thaw environment in Northwest China, we try to use different fly ash admixture of concrete, based on the corrosion resistance coefficient of concrete under different number of freeze-thaw cycles, to improve the freeze-resistant and durable life of concrete for the large temperature difference area by quantitatively investigating the effect of different fly ash admixtures on the freeze-resistant performance of concrete.

2. Experimental Raw Materials and Methods

2.1. Experimental Raw Materials

In the test, Qilianshan brand P.O 42.5 ordinary silicate

cement was used, and the performance indexes are shown in Table 1; the coarse aggregate of concrete is 5-31.5mm continuous grained crushed stone, and its apparent density is 2670kg/m³; the fine aggregate adopts the natural sand with a fineness modulus of 2.9 and an apparent density of 2.60kg/m³ from sand type in Zone II; the water source used is the tap water of the laboratory; The water reducing agent is a high-performance polycarboxylic acid water reducing agent with a water reduction rate of 27%; the first-grade fly ash is used, and its relevant performance indexes are shown in Table 2.

Table 1. Performance indexes of P.O 42.5 ordinary Portland cement

Testing items	Loss on burning (%)	Water consumption for standard consistency of cement (%)	Specific surface area (m ² /Kg)
Measured value	3.05	27.4	349
normative value	≤5.0	/	300-350
Testing items	Sulphur trioxide content (%)	Chloride ion content (%)	Condensation time (min)
Measured value	2.56	0.023	95
normative value	≤3.5	≤0.06	≥45

Table 2. Performance indexes of fly ash

Testing items	Water content (%)	Sulphur oxide content (%)	Alkali content (%)
Performance Indicators	0.3	1.56	0.48
Testing items	Loss on burn (%)	Water requirement (%)	Density (g/cm ³)
Performance Indicators	4.5	91	1.5
Testing items	Calcium oxide content (%)		
Performance Indicators	0.13		

2.2. Test Programme

In order to compare the evolution of concrete corrosion resistance coefficient under large temperature difference freeze-thaw cycle conditions with different fly ash admixtures, three mixing ratios with fly ash admixtures of 0, 10%, 20% and 30% were set up respectively. The 100 mm×100 mm×100 mm concrete specimens were used as test specimens. The freeze-thaw cycle lifting mechanism was determined according to the actual climate of Ruoqiang area, the minimum temperature of the area is -23.3 °C, the maximum temperature is 43.1 °C, so the freeze-thaw temperature is set to -23.3 °C~43.1 °C; the freeze-thaw period and non-freeze-thaw period in this area in a year is 3:1, so it is set to be 24 hours as a cycle cycle, in which 6 hours of freezing, 18 hours of melting, a total of 100 A total of 100 cycles of freeze-thaw cycles were carried out, which reached 30 times, 60 times, 90 times, 120 times, 150 times, 180 times, 210 times, 240 times, 270 times, and 300 times to measure the change of compressive strength of the specimens to calculate the concrete corrosion resistance factor.

Freeze-thaw cycle test is based on the "Standard for Long-term Performance and Durability Test Methods of Ordinary Concrete" (GB/T 50082-2009) [10] in section 4 of the freeze-thaw cycle test related provisions, the specimen is soaked 4

days in advance for the concrete large temperature difference freeze-thaw cycle test, and the specimen is immersed in at least 20mm below the liquid surface; after reaching the specified age, the specimen surface is dried up and the initial data is measured, after which the specimen is Put the specimen box into the test box, the specimen box into the freeze-thaw cycle test box, the liquid surface is at least 5mm above the concrete; the temperature probe is placed in the centre of the freeze-thaw cycle test box; in order to ensure that the temperature stability of the freeze-thaw cycle test box for each freezing and thawing environment, the rest of the empty space is filled with the specimen box; to achieve the test critical period of the corrosion resistance coefficient, that is, the specimen compressive strength of the freeze-thaw cycle with the same batch of specimen test before the ratio of compressive strength, calculated as the ratio of compressive strength to compressive strength. Ratio of compressive strength after a certain freeze-thaw cycle to the compressive strength of the same batch of specimens before the test, the formula is as follows:

$$K_r = \frac{f_n}{f_0} \quad (1)$$

Where: Kr is the corrosion resistance coefficient; fn is the compressive strength of the specimen after n freeze-thaw cycles (MPa); f0 is the initial compressive strength (MPa). The freeze-thaw test chamber is shown in Figure 1.

2.3. Preparation and Curing of Test Specimens

To ensure that the fluidity of the concrete meets the specified requirements, tests were first carried out to determine the appropriate amount of water reducing agent. After determining the amount of material required for the concrete specimens of each mix ratio, the concrete materials were mixed. The number of materials per unit volume of each concrete mix is shown in Table 3. During the concrete mixing process, coarse and fine aggregates, cementitious materials, water and water reducing agent were added gradually in the order of 30 seconds after each addition of one material, followed by the addition of the next material. After the mixing was completed, the concrete was poured into 100mm×100mm×100mm moulds coated with release oil in advance, and then placed on the vibrating platform for vibration. The vibration was stopped when the concrete surface appeared floating slurry and no aggregate was exposed, and the surface was treated and then subjected to standard curing. The concrete casting process is shown in Fig. 2. 24 hours later, the specimens were demoulded, and after demoulding, the curing was continued until 28 days to carry out the freeze-thaw cycle test.



Fig 1. Freeze-thaw test chamber



Fig 2. The pouring process of the test block

Table 3. Concrete mix design

Water cement ratio	Water	Cement	Fly ash
0.30	153	510	837
0.30	153	459	837
0.30	153	408	837
0.30	153	357	837
Sand	Stone	Remarks	
837	944	0% Fly ash	
837	944	10% Fly ash	
837	944	20% Fly ash	
837	944	30% Fly ash	

3. Test Results and Analysis

Figure 3 shows the change curve of corrosion resistance coefficient. Based on the indoor large temperature difference freeze-thaw test to analyze the effect of different fly ash admixture on the corrosion resistance coefficient of concrete, Figure 3 shows that: in the corrosion resistance coefficient increase stage, 0%, 10%, 20% and 30% fly ash admixture concrete are in the 90th cycle to reach the maximum value of corrosion resistance coefficient, respectively, 1.12, 1.11, 1.15 and 1.17, increase in the range of 12.8%, 11.6 15.3% and 17.3%, and the development trend is 30%>20%>0%>10%; from the analysis of the peak corrosion resistance coefficient, it can be seen that: the concrete with 30% of fly ash has the largest corrosion resistance coefficient; from the analysis of the development trend, it can be seen that: the corrosion resistance coefficient grows more before 60 times of freeze-thaw cycles, and grows slower in the 60-90 times of cycles. The decay stage of the corrosion resistance coefficient can be divided into two stages: corrosion resistance coefficient greater than 1 stage and corrosion resistance coefficient less than 1 stage.

In the stage of corrosion resistance coefficient greater than 1, the concrete with 0% fly ash admixture decays from the peak value to 1 at 210-240 times of freeze-thaw cycles; the concrete with 10% fly ash admixture decays from the peak value to 1 at 240-270 times of freeze-thaw cycles; the concrete with 20% fly ash admixture decays from the peak value to 1 at 270-300 times of freeze-thaw cycles, and the concrete with 30% fly ash admixture decays from the peak value to 1 at From the analysis of the number of freeze-thaw cycles, it can be seen that the trend of corrosion resistance coefficient is: 20%>10%>0%>30%.

In the stage of corrosion resistance coefficient less than 1, the concrete with different fly ash admixture all reached the lowest point of decay value at 300 times of freeze-thaw cycle,

the lowest decay value of 0%, 10%, 20% and 30% fly ash admixture concrete were: 0.87, 0.89, 0.95 and 0.79, respectively, and the rate of decay was 13%, 11%, 5% and 21%. From the analysis of the change rule of the decline can be seen: corrosion resistance coefficient trend is: 0%>10%>0%>30%.

In summary, it can be seen that fly ash concrete corrosion resistance coefficient change law has the following two significant features: (1) with the growth of the number of freeze-thaw cycles, different fly ash dosage of concrete corrosion resistance coefficient has appeared to grow and then decline trend. (2) Different fly ash dosage on concrete corrosion resistance coefficient has different degree of influence, concrete corrosion resistance coefficient decline stage, 10%, 20% fly ash dosage corrosion resistance coefficient is greater than 0% dosage, 30% dosage corrosion resistance coefficient is lower than 0% dosage.

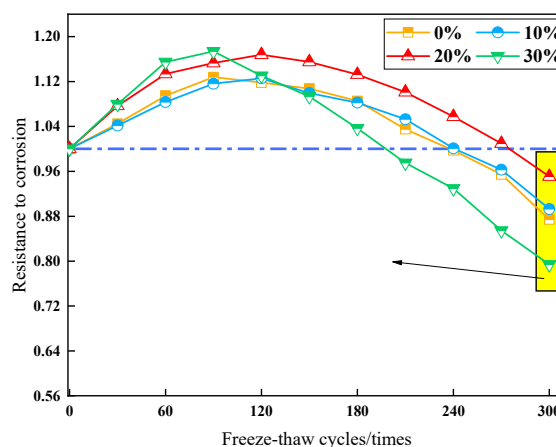


Fig 3. Variation of corrosion resistance coefficient

The reason for the above test phenomenon may be: in the process of concrete cementitious material reaction, cement began to hydrate, but fly ash play its activity slower, thus increasing the hydration reaction time of cementitious material, at the same time, fly ash particles are finer compared to cement particles, the pore space between cement particles have a certain filler effect, so that the concrete is more dense, resulting in the concrete corrosion resistance coefficient of the first upward trend; On the other hand, the increase of fly ash dosage makes the hydration reaction time prolonged, and the high dosage of fly ash makes in the process of freeze-thaw cycle, there is part of fly ash without hydration will be degraded, resulting in the corrosion resistance coefficient decline rate is large.

4. Conclusion

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