

Influence of Expansive Agent on Concrete Performance in Northwest Cold Region

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Abstract: In this study, the effects of expansion agents on the compressive strength and frost resistance of concrete in the cold region of Northwest China were studied, and the effects of different amounts of expansion agents on the compressive strength and freeze-thaw cycle performance of concrete were analyzed experimentally, and the improvement mechanism of expansion agents on the frost resistance of concrete was revealed by combining the mass loss rate, relative dynamic elastic modulus attenuation and microstructure analysis. The results show that 10% expansion agent can improve the working properties of concrete, improve its compressive strength, and enhance the ability to resist freeze-thaw cycles. The expansion agent can effectively reduce freeze-thaw damage by compensating for shrinkage and optimizing the pore structure, thereby improving the frost resistance of concrete in the low temperature environment in the cold region of Northwest China.

Keywords: Bulking agent, Compressive strength, Freeze-thaw cycles, Pore structure.

1. Introduction

Under the harsh climatic conditions of the cold region of Northwest China, the concrete structure is faced with the combined effect of multiple unfavorable factors such as low temperature freeze-thaw cycle and drying shrinkage^[1], which seriously affects its durability and service life. As an important functional admixture, the expansion agent is expected to improve the comprehensive performance of concrete in cold areas by compensating for shrinkage and improving pore structure^{[2][3]}. At present, scholars at home and abroad have carried out a lot of research on the influence of expansion agents on the properties of concrete, but the systematic research on the special climatic conditions in the cold region of Northwest China is still insufficient, especially in the synergistic influence mechanism of expansion agents on the compressive strength and frost durability of concrete^[4]. In this study, the influence of expansion agent on the frost resistance of concrete in the cold region of Northwest China was systematically investigated by controlling the dosage of

expansion agent, and the mechanism of expansion agent in improving the frost resistance of concrete was clarified by combining microstructure analysis, aiming to provide theoretical basis and technical support for the durability design and material optimization of concrete engineering in the cold region of Northwest China^{[5][6]}.

2. Raw Materials and Test Methods

2.1. Raw materials

In this experiment, cement, water, fly ash and expansion agent were used as raw materials to prepare concrete. P·O 42.5 Portland cement grade II fly ash; The fine aggregate is natural river sand, the coarse aggregate is 5~31.6mm continuous granular gravel, the expansion agent is a high-efficiency expansion agent that meets the requirements of the national standard II type product index control, and the superplasticizer is a polycarboxylate acid superplasticizer. The chemical composition of cement, fly ash and expansion agent is shown in Table 1

Table 1. Chemical composition of cement, fly ash and expansion agent

raw materials	CaO	MgO	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂	SO ₃	Loss	Total
cement	64.09	1.35	4.62	4.34	19.26	3.08	2.28	99.02
Fly ash	1.81	0.36	5.02	30.16	59.79	0.51	1.73	99.38
Bulking agent	50.62	1.98	0.53	15.64	1.97	26.01	2.12	98.87

2.2. Mix ratio

The expansion agent is replaced by the internal doping

method, and the dosage of the expansion agent is the mass fraction of the total cementitious material, and the dosage is 0%, 8%, 10% and 12% respectively, as shown in Table 2.

Table 2. Cementitious material mix

numbering	water (kg/m ³)	cement (kg/m ³)	Fly ash (kg/m ³)	Bulking agent (kg/m ³)	Water reducer (kg/m ³)
J1	166	353	62	/	4.15
P1	166	319.8	62	33.20	4.15
P2	166	311.5	62	41.50	4.15
P3	166	303.2	62	49.80	4.15

The freeze-thaw test in this study uses the rapid freeze-

thaw method. The concrete rapid freeze-thaw testing machine

was used to freeze-thaw the drawing specimens, and the core temperature thawing temperature was 5 °C, and the freezing temperature was -18 °C. The single freeze-thaw cycle time is 3~4h, and the transition time between freezing and thawing is less than 10min.

3. Analysis of Test Results

3.1. Compressive strength varies

The compressive strength of concrete at different ages mixed with different amounts of expansion agents is shown in Fig 1 below.

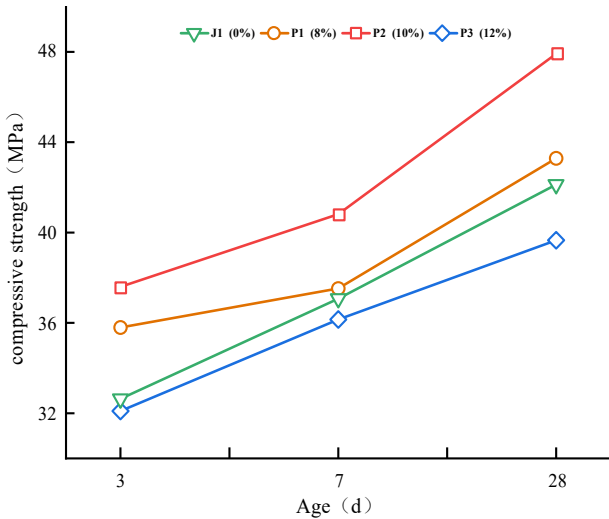


Figure 1. Effect of expansion agent dosage on compressive strength of concrete

The strength of concrete showed an increasing trend with the increase of age, but the strength of concrete increased first and then decreased with the amount of expansion agent, and the P2 group showed the highest compressive strength at all ages, indicating that the appropriate amount of expansion agent could effectively promote the hydration reaction of cement, generate an appropriate amount of aluminite crystals, and fill the capillary pores inside the concrete, thereby optimizing the microstructure of concrete and improving the mechanical properties. The compressive strength of the P3 group was lower at all ages, especially at the age of 28 days, and its strength of 39.66 MPa was significantly lower than that of the P2 group (47.92 MPa). This is because the hydration reaction caused by excessive expansion agents is too fast, and too many aluminite crystals are formed, which may trigger internal expansion stress concentrations, which in turn produce micro-cracks or increase porosity, weakening the overall compactness and mechanical properties of concrete.

3.2. Change in quality loss rate

The changes in the mass loss of concrete with different amounts of expansion agent in freeze-thaw cycles are shown in Fig 2.

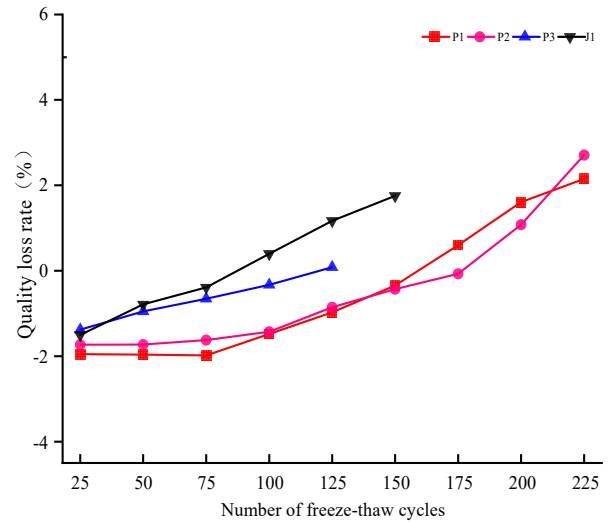


Figure 2. Diagram of the change law of concrete mass loss

The initial mass loss of the P2 specimen remained stable at about minus 1.9, and turned positive after 150 cycles, showing the best frost resistance. The P1 specimen remained stable before 125 cycles, and the mass loss was minus 0.43 at 150 cycles, showing moderate frost resistance. The P3 specimen was damaged after 125 cycles, and the mass loss reached 0.08, indicating that the excessive expansion agent would significantly reduce the frost resistance of concrete. The J1 specimen failed completely at 150 cycles, and the frost resistance performance was the worst. The test results show that the addition of expansion agent can effectively improve the frost resistance of concrete, but the frost resistance will be significantly reduced if the dosage is too high or no addition at all.

3.3. Change in relative dynamic modulus of elasticity

The relative dynamic modulus of elasticity of concrete changes with the increase of the number of freeze-thaw cycles, and the relative dynamic modulus of elasticity is shown in Figure 3 below:

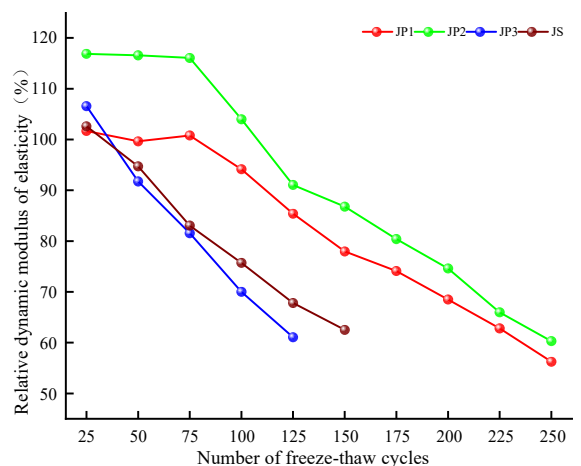


Figure 3. Diagram of the relative dynamic modulus of elasticity of concrete

According to the analysis in Figure 3, the relative dynamic elastic modulus of P1 gradually decreased from 41.85% at 0 times, to 99.65% after 50 freeze-thaw cycles, and then

continued to decrease under high freeze-thaw cycles to 56.25% at 250 times. During 25 to 50 freeze-thaw cycles, the relative dynamic elastic modulus of JP2 changed slightly, and at 250 cycles, the relative dynamic elastic modulus of JP2 decreased to 60.30%, which was improved compared with P1. The relative dynamic elastic modulus of P3 remained at a high level at the initial stage, which remained at 106.56% and 91.74% at 25 and 50 freeze-thaw cycles, respectively. However, after 100 cycles, the relative dynamic elastic modulus decreases sharply, showing obvious frost resistance attenuation, and damage occurs, and frost resistance is the worst. The relative dynamic elastic modulus of J1 was relatively stable at the initial stage of freeze-thaw, but decreased rapidly with the progress of freeze-thaw cycles. After 150 freeze-thaw cycles, the relative dynamic elastic modulus of JS decreased to 62.52%, showing poor frost resistance.

3.4. Changes in pore structure

As a key factor affecting its macroscopic properties, the concrete pore structure affects the mechanical properties and durability of concrete. The porosity of cement-based materials can be divided into gel pores, capillary pores and macropores according to the pore size, among which the capillary pores have the most significant impact on the performance of concrete. The swelling agent can effectively fill the capillary pores and improve the pore structure by participating in the hydration reaction to generate swelling products. However, excessive expansion agents can lead to overexpansion, which in turn can compromise the integrity of the internal structure of the concrete.

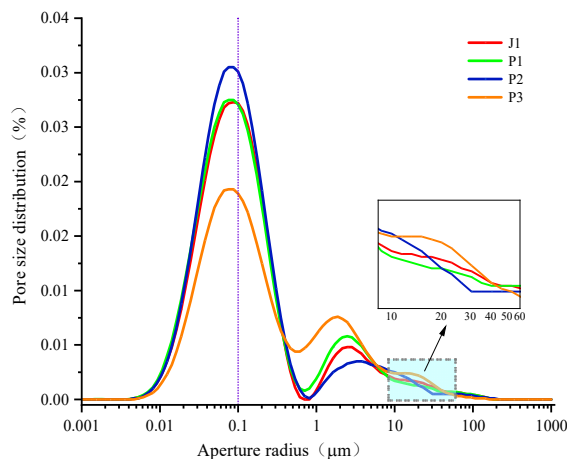


Figure 4. Concrete pore size distribution mappit

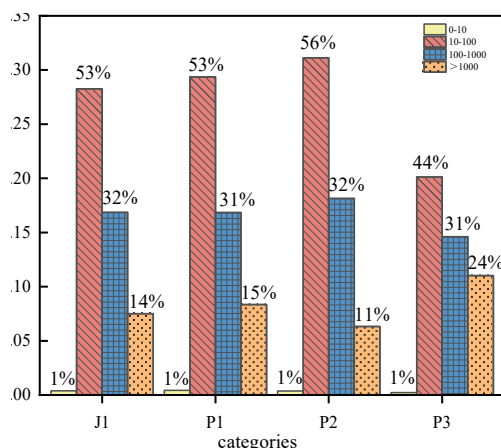


Figure 5. Concrete aperture percentage chart

Fig. 4 shows the distribution of concrete pore size, with the increase of expansion agent content from 0%, 8% and 10% to 12%, the most achievable pore size gradually shifts to the left, indicating that the larger pores in the concrete gradually change to the smaller pores, and the pore structure has been optimized to a certain extent. Through the pore size distribution curve, it can be found that in the first characteristic peak, the peak height is the P2 group > P1 group > J1 group, and the corresponding T2 spectrum shows that the first peak area of the P2 group is the largest, and the first peak area of the P1 group and the P3 group (12% dosage) gradually decreases, and the first peak area of the P3 group is the smallest. Among the second characteristic peaks, the P3 group had the highest peak, followed by the P1 group and the J1 group, and the P2 group had the lowest peak, and the corresponding T2 spectrum also showed that the second peak area of the P3 group was the largest, and the second peak area of the P2 group was the smallest. This indicates that the P3 group has a higher proportion of capillary pores and macropores and a poorer pore distribution, while the P2 group has a lower proportion of macropores and an optimized pore distribution.

Fig. 5 is the influence of the pore size proportion of concrete under different dosages of expansion agent, it can be seen from the figure that with the increase of expansion agent content, the proportion of transition holes in concrete increases first and then decreases, the proportion of capillary pores basically remains stable, and the proportion of large pores decreases first and then increases. When the expansion agent content is 10%, the proportion of transition holes in the P2 group reaches the maximum value of 56%, indicating that the P2 group has the optimal pore size distribution at 28 days of age, and its internal pore structure is dominated by small pores, which helps to improve the compressive strength of the concrete.

4. Conclusion

In this paper, the effects of different amounts of expansion agent on the mechanical properties, frost resistance and microporous structure of concrete are studied, and the following conclusions are obtained through relevant experiments and results analysis.

1. The compressive strength of concrete increases first and then decreases with the increase of expansion agent content. When the expansion agent content is 10%, the compressive strength of concrete at all ages is the highest.

2. The 8%, 10% and 12% dosages of the expander reduced the mass loss of concrete by 4.5%, 10.2% and -13.6%, respectively. The results show that the addition of 10% expansion agent can not only effectively reduce the mass loss of concrete and improve the dynamic elastic modulus of concrete, but also alleviate the adverse effects on concrete in the later stage of freeze-thaw cycle.

3. The 10% expander performed the best, and its relative dynamic elastic modulus decreased slightly under different freeze-thaw cycles, indicating that it had strong freeze-thaw resistance. The 12% expansion agent performed the worst, and the elastic modulus and relative dynamic elastic modulus decreased greatly after freeze-thaw cycles, and the frost resistance was poor.

4. The addition of 10% expansion agent can effectively optimize the pore size distribution of concrete, but when the dosage is increased to 12%, the pore structure of concrete deteriorates, which is manifested as the increase of macropore

proportion and uneven pore size distribution.

Acknowledgements

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