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Study on Mechanical Properties of Concrete at Different Ages under Freeze-Thaw Cycles in Plateau

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Abstract: The purpose of this study is to explore the mechanical properties of concrete at different curing ages after freeze-thaw cycles in most areas of the plateau where freeze-thaw cycles exist. By comparing the compressive strength and splitting strength of concrete at different curing ages after different freeze-thaw cycles, the influence of curing age changes on the mechanical properties of concrete after freeze-thaw damage was analysed. The results show that the compressive strength and splitting strength of concrete can be significantly increased by increasing the curing days of concrete with the same number of freeze-thaw cycles, and sufficient curing age has a significant effect on reducing the influence of freeze-thaw cycles. Under the condition of the same curing days, with the increase of the number of freeze-thaw cycles, the compressive strength of concrete will first increase and strengthen at 50 cycles, and then start to weaken continuously. The splitting strength will continue to decrease with the increase of freeze-thaw cycles.

1. Introduction

Concrete is currently the most important construction material in modern engineering construction, and it is applied in engineering construction in various environments. However, in the Qinghai Plateau of China, due to the influence of monsoon and geographical environment, the climate is dry, alpine, and the temperature difference between day and night is large [1]. Severe freeze-thaw cycle damage often occurs in some areas, including civil buildings, highways, railway projects and other infrastructure. The damage of engineering construction facilities mainly occurs on the concrete materials with a large amount of use, which affects the overall durability of the concrete structure [2-3].

At present, the research on the durability of concrete at plateau mainly focuses on the mechanical properties test of new recycled concrete materials at plateau and the influence of complex coupling factors on the mechanical properties of concrete [4-5], and there are few studies on the influence of harsh construction environment conditions, construction technology and human factors on the mechanical properties of concrete at plateau [6-7]. This paper mainly studies the strength value of mechanical properties of concrete measured in different curing days after concrete pouring to compare the change trend of mechanical properties of concrete under different curing days during the freeze-thaw cycle, so as to reduce unnecessary losses caused by the schedule and human factors in actual engineering construction and improve the durability of concrete. It also provides a certain reference for the curing process after the completion of concrete construction [8].

2. Test

1) Purpose of the experiment

The concrete test blocks of different ages (0d, 1d, 7d, 14d, 28d) were formed by experiment. After the test blocks reached the corresponding age, they were put into the rapid freeze-thaw test chamber and subjected to freeze-thaw (0, 50, 100, 150, 200 times) respectively, and the compressive and splitting mechanical properties were tested to study the effects of freeze-thaw cycles. Effect of curing days on mechanical properties of concrete [9-10].

2) Test materials and mix proportion

Cement: using Gaozheng P.O.42.5 ordinary Portland cement.

Stone: Marble stone with a particle size of 6mm was screened out by aggregate size grading screening method.

Sand: fine sand

Water: Industrial tap water

Concrete mix as shown in Table 1:

Table 1: Concrete mix proportion

Cement (kg m^{-3})	Water (kg m^{-3})	Fine sand (kg m^{-3})	Crushed stone (kg m^{-3})	Water reducing admixture (kg m^{-3})
487	170	489	1211	45

3) Test method and design

In this paper, the freeze-thaw test of concrete test block adopts the fast freezing method. In this paper, the freeze-thaw cycle experiment is carried out by TDR-IiI concrete fast freeze-thaw testing machine. The rapid freeze-thawing device shall comply with the provisions of JG/T243 of the current industry standard "Concrete Frost Resistance Test Equipment" [11-12]. The test blocks that have reached the corresponding age are put into the rapid freeze-thaw testing machine in batches for testing. The specimens that meet the requirements of the number of freeze-thaw cycles are taken out immediately for subsequent tests [13].

Cubic compressive strength test, according to GBT 50081-2019 "concrete physical and mechanical properties of the test method standard" in the relevant requirements, for just after the freeze-thaw cycle test test specimen, immediately with a rag to wipe off the surface slag directly into the mechanical properties of the test instrument, the specimen will be levelled correctly placed, the use of the pressure testing machine on the different number of freeze-thaw cycles under the concrete cube specimen for the Compressive strength test. When testing the compressive and splitting strength of cubic concrete, the loading rate of compressive strength is controlled at 5-8Mpa, and the loading rate of splitting strength is controlled at 1-3Mpa [14-15].

Experimental design: According to GBT-50082-2009 ' Ordinary concrete long-term performance and durability test method standard ' forming test block,the size of the test mold is 100mm×100mm×100mm, the curing days are set to 1d, 7d, 14d, 28d, and the number of freeze-thaw cycles is designed to 200 times, including the initial weight measurement. After that, the weight test is carried out every 25 cycles, and the compressive (3 blocks) and splitting (3 blocks) strength tests are carried out every 50 cycles. A total of 90 blocks need to be formed [16]. After molding, they were immediately placed in a standard curing box (temperature 20 ±2 °C, relative humidity ≥ 95 %) for 24 hours and then demoulded. After demoulding, the test blocks that met the curing age of 1d were directly placed in a slow freezing test machine to start the freeze-thaw cycle test. One group of test blocks set to 0 freeze-thaw cycles was directly subjected to compression and splitting strength tests. After measuring the initial weight of the test blocks that met the curing days, they were all placed in a fast freezing test machine for freeze-thaw cycle tests. The compressive strength and splitting strength are taken as the final results with the average value of 3 blocks.

3. Analysis of Test Results

1) The change rule of concrete mass degree under freeze-thaw conditions at different ages in plateau.

Fig. 1 is the mass change diagram of concrete with different curing ages to increase the number of freeze-thaw cycles.

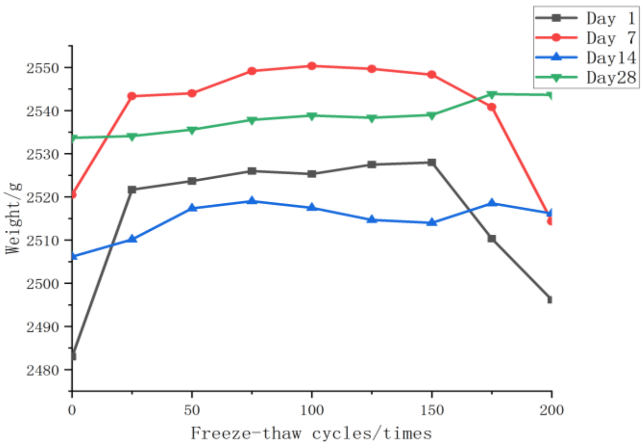
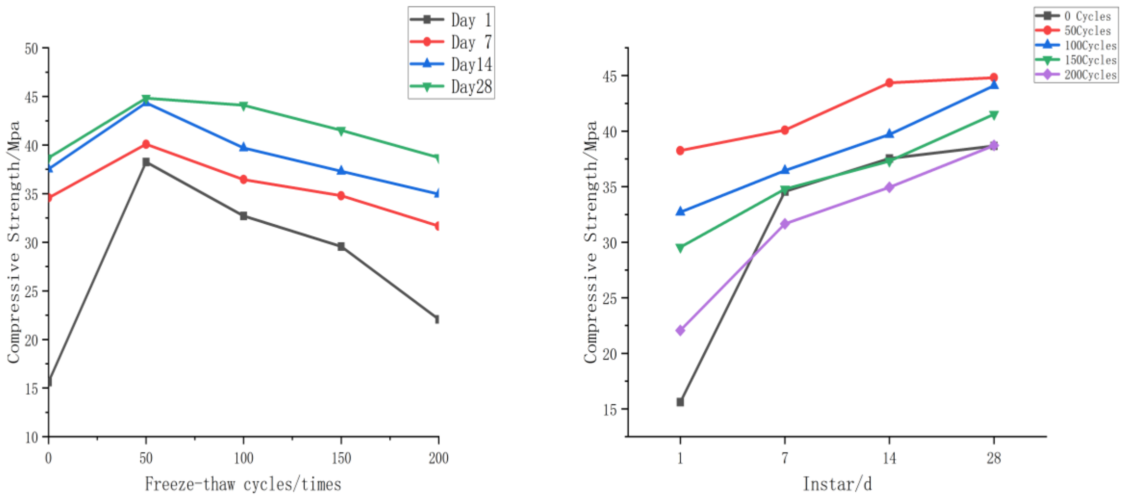


Figure 1: Quality change of each age

As can be seen from the figure, the quality change trend of concrete specimens at the curing age of 1d and 7d is roughly the same, showing a trend of first increasing, then stabilizing, and finally suddenly decreasing. While the quality change trend of concrete specimens at the curing age of 14d and 28d is basically unchanged, but with the increase of the number of freeze-thaw cycles, the quality change trend of concrete specimens at the curing age of 14D and 28D is basically unchanged. The quality of concrete specimens at each curing age will decline sharply, and the increase of curing age will slow down the time of rapid quality decline. The increase of curing age will slow down the time of sharp quality decline. It can be shown that the larger the curing age, the less likely the concrete specimens are to be destroyed. 0-25 freeze-thaw cycles, the quality of all ages have increased, which is manifested in the maximum change in the quality growth of age 1d, and the minimum change in the quality growth of age 28d, i.e., with the increase in the age of curing, the growth rate of the quality is getting smaller and smaller. With the increase in the number of freeze-thaw cycles, at 150 cycles, the quality of age 1d and 7d concrete showed the beginning of the decline, age 14d and 28d concrete quality showed growth. As the age of curing increases, the rate of change in quality becomes smaller.

2) The change law of compressive strength of concrete under freeze-thaw conditions at different ages in plateau.

According to the requirements of the test design, the compressive strength tests were carried out in batches of specimens at each age. The trends of the compressive strength of concrete with the number of freeze-thaw cycles under different curing age conditions were plotted, as shown in Fig. 2.



(a) (b)

Figure 2: Changes of compressive strength at different ages

As can be seen from Figure 2(a), the compressive strength increases with the increase of age when the freeze-thaw cycle is 0 times, and the growth rate of the compressive strength becomes smaller and smaller with the increase of age. At the age of 28d, the compressive strength of the specimen that has not been freeze-thaw is the largest, and the change of the compressive strength becomes smaller and smaller with the increase of age. With the increase of the number of freeze-thaw cycles, when 50 freeze-thaw cycles are reached, compared with 0 cycles, the compressive strength of each age presents a strengthening stage, and the strengthening amplitude of each age decreases with the increase of the age. The compressive strength difference between the two adjacent ages is basically the same, and the difference is small.

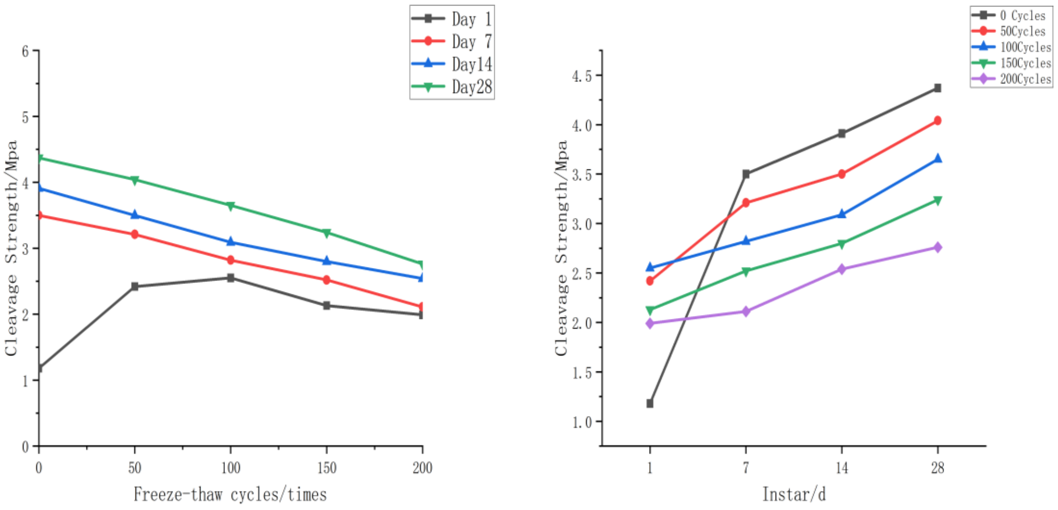
In the process of 50 to 200 freeze-thaw cycles, the compressive strength of concrete at each age shows a downward trend, showing that the decline rate of compressive strength of concrete at age 1d is the fastest, and that of concrete at age 28d is the slowest.

For visual observation, under the same number of freeze-thaw cycles, the change trend of compressive strength with age is drawn by changing the transverse and longitudinal coordinates. It can be clearly seen from Figure 2 (b) that the compressive strength of concrete for 50, 100, 150 and 200 freeze-thaw cycles all increases with age, and the growth trend is basically the same. However, the compressive strength of concrete with 0 freeze-thaw cycles has a large growth rate in the early stage of curing, and a small growth trend in the later stage with the increase of age, and the value remains basically unchanged. After 200 cycles, the compressive strength value of each age is greater than that after 0 cycles of freeze-thaw. We analyze the reasons and find that the decline rate is the fastest at age 1d and the slowest at age 28d. The compressive strength effect induced by the internal reaction of concrete is greater than the damage effect of freeze-thaw cycle on the compressive strength. It shows that the initial freeze-thaw cycle has a strengthening stage on the compressive strength of concrete. With the increase of the number of freeze-thaw cycles, the compressive strength of concrete at different ages will decrease rapidly until it is destroyed.

3) The variation law of splitting strength of concrete under freeze-thaw conditions at different ages in plateau.

After sorting out the test data of concrete splitting strength, the trend diagram of the splitting strength of concrete at different ages with the number of freeze-thaw cycles is drawn, as shown in

Figure 3.



(a) (b)

Figure 3: Change of splitting strength at different ages

It can be seen from Fig. 3(a) that the compressive strength of concrete at different ages decreases with the increase of the number of freeze-thaw cycles. The compressive strength of concrete at age 1d presents a trend of first increase and then decrease, while the compressive strength of concrete at age 7d, 14d and 28d presents a linear trend of decline, and the decline frequency is roughly the same. However, under the same number of freeze-thaw cycles, the splitting strength of concrete increases with the increase of age, and the increase range is as follows: The increasing amplitude of the splitting strength of concrete at age 7d, 14d and 28d is roughly the same, while the increasing amplitude of the splitting strength of concrete at age 1d is large under the initial number of freeze-thaw cycles, and the increasing amplitude tends to be stable with the increase of the number of freeze-thaw cycles. For visual observation, under the same number of freeze-thaw cycles, the change trend of splitting strength with the growth of age is plotted by changing the transverse and longitudinal coordinates, as shown in Figure 3.

It can be clearly seen from Fig. 3 (b) that the splitting strength of concrete for 50, 100, 150 and 200 freeze-thaw cycles all increases with the increase of age, and the growth trend is basically the same, while the splitting strength of concrete for 0 freeze-thaw cycles has a large growth rate in the early stage of curing, and a small growth trend in the later stage with the increase of age. The values remain basically the same. Instar 1d appears to have a local splitting strengthening stage within 100 cycles. Analysis of the reasons, due to the short curing age, the concrete itself is still in the self-reaction strengthening stage, the self-reaction strengthening stage is greater than the freeze-thaw damage on the reduction of splitting strength, there is a local strengthening stage. However, with the increasing number of freeze-thaw cycles, the splitting strength of each age showed a decreasing trend. When the number of freeze-thaw cycles is 200, the splitting strength of each age is the same as the compressive strength, and the splitting strength is greater than the splitting strength of 0 freeze-thaw cycles. It can be shown that the initial freeze-thaw cycle has a local strengthening stage on the compressive strength and splitting strength of concrete. With the increase of the number of freeze-thaw cycles, the mechanical properties of concrete will rapidly decline until it is destroyed.

4. Conclusion

1) Summarizing the experimental rules, it is found that when the freeze-thaw cycle reaches 50 times, the compressive strength of concrete at different ages has a strengthening stage relative to 0 freeze-thaw cycles, and the strengthening size decreases with the increase of age. The main reason for the strengthening stage is that the shorter the curing age of the concrete test block, because it has a rapid growth process of compressive strength in the early stage, the freeze-thaw cycle has an inhibitory effect on its compressive strength, but does not affect its entire growth trend. With the increase of curing age, the improvement of compressive strength by self-reaction began to weaken, and the damage of freeze-thaw cycle to its compressive strength gradually increased. The trend of self-growth of compressive strength was less than that of freeze-thaw cycle damage, and the overall compressive strength began to decrease. The decreasing trend of compressive strength decreases with the increase of curing age.

2) The difference between splitting strength and compressive strength is that the splitting strength of concrete at the age of 1d appears to be strengthened, while the splitting strength of concrete at the age of 7d, 14d and 28d decreases linearly. The main reason for the analysis is that the concrete is still in the strengthening stage in the early stage due to its own hydration heat. The effect of its own strength improvement is greater than that of the freeze-thaw cycle reduction, showing a short lifting stage. As the number of freeze-thaw cycles increase, this self-effect gradually decreases. The effect of freeze-thaw damage is greater than its own effect, and the splitting strength begins to strength.

3) Quality changes in the previous period all show an increase, and the growth rate decreases with the increase of curing age. The main reason is that the shorter the age of the concrete test block, the more voids it produces due to its own rapid reaction. When it is placed in a freeze-thaw testing machine with sufficient water conditions, a large amount of water is absorbed. After repeated freeze-thaw, a large amount of void volume begins to slowly become larger, and then more water is absorbed to reach the saturated water state, resulting in the largest change in quality. After 150 freeze-thaw cycles, a large amount of mortar began to fall off on the surface of the concrete test block with shorter age, resulting in the fastest decline in quality.

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