Experimental Research on the Influence of Dry-Wet Cycle on Concrete Compressive Strength

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Abstract. In order to study the change of compressive strength of concrete under dry and wet cycle environment, the method of 60°C constant temperature drying and liquid water immersion is used to simulate the dry and wet cycle environment of concrete, and the concrete test pieces of different ages are subjected to compression test. The test results show that with the increase of the number of dry and wet cycles, the compressive strength of concrete generally increases first and then decreases. During the dry and wet cycle, the compressive strength of concrete specimens and the number of cycles showed a significant secondary correlation, and the number of cycles in which the compressive strength of concrete specimens of different ages reached the peak was basically the same. With the increase of the age of concrete specimens, the trend of the impact of the dry and wet cycle environment is basically the same.

Keywords: concrete; dry and wet cycle; concrete age; compressive strength.

1. Introduction
With the country's massive investment in infrastructure construction, concrete has become the most economical and most used structural material, and its engineering performance has also become a concern. However, when designing a structure, people usually only consider the effects of loads but ignore the effects of environmental conditions. The non-loading factors that affect the durability of concrete or structural damage are mainly caused by changes in the internal moisture or temperature of the structure. At present, the dry and wet cycle is considered to be the harshest, most typical, and most likely the external environment to cause damage to the concrete structure.

In recent years, domestic and foreign experts and scholars have done a lot of research on the destruction mechanism of concrete materials under the action of dry and wet cycles and have achieved some research results. Sahmaran and GongXin found in their respective studies that the compressive strength and flexural strength of concrete tend to increase firstly and then decrease under the action of
wet and dry cycles. Lu Jingzhou studied the change trend of the uniaxial compressive performance of concrete under the load history and sulfate dry-wet cycle erosion. The result showed that both of compressive strength and elastic modulus of concrete decreased, but the peak strain increased. Liang Yongning mainly studied the decay performance of concrete materials under the combined action of sulfate and dry-wet cycles. The results of the study showed that the compressive strength increased firstly and then decreased. Zhao Luyue mainly studied the attenuation law of the strength of fly ash concrete under different acidic environments. The result of the study showed that as the number of wet and dry cycles increases, its strength generally shows a decreasing trend.

To sum up, the change law of concrete performance under dry and wet cycle environment has always been a key subject of research by experts and scholars. Researchers mostly formulate corresponding test systems according to their respective test needs, so there is currently no unified dry and wet cycle standard. At the same time, there is no specific study on the influence of the number of dry and wet cycles on the strength of concrete materials. Therefore, this article will start with focusing on the number of wet and dry cycles. It will study the changing laws of concrete strength under different cycles by making a large number of concrete specimens, understand the shrinkage characteristics of concrete under dry and wet cycles, find a way to describe the law of the concrete compressive strength under different dry and wet cycles, and then establish the correlation equation between the number of wet and dry cycles and the compressive strength of concrete, find the correlation peak between the number of wet and dry cycles and concrete compressive strength and obtain the point which the strength of concrete decreases under wet and dry cycles.

2. Experimental method

2.1. Raw Materials Needed for the Test

The cement used in the test is PO42.5 ordinary Portland cement which is produced by Jiangxi Ganjiang Conch Cement Co. Ltd. The coarse aggregate is crushed limestone with particle size of 525 mm, and the fine aggregate is natural river sand with fine modulus of 2.6. The mixing water is ordinary city tap water. The design strength grade of concrete is C25, and the mixing ratio of concrete raw materials is shown in Table 1.

| Ingredient | Water | Cement | Gravel | Fine Sand |
|------------|-------|--------|--------|-----------|
| Quality    | 590   | 1343   | 1910   | 4256      |

2.2. Specimen Preparation

The concrete is mixed according to the mix ratio shown in Table 1. In order to obtain the mechanical properties of concrete of different ages under different numbers of wet and dry cycles, three ages (7d, 14d, 28d) concrete specimens are made in this experiment. Plastic molds is used to make ordinary concrete standard samples whose size is 150mm×150mm×150mm, and the mold will be removed after 24 hours. In order to simulate the actual curing environment of concrete, the specimen adopts indoor natural curing.

2.3. Specific Method of the Test

In order to obtain the influence of the dry-wet cycle on the strength of ordinary concrete, the dry and wet alternate cycles is started after the curing of the specimen is completed. The specimen is set in a digital display blast drying box with temperature of 60℃, dried for 24 hours, and then soaked in ordinary city tap water for 24 hours, and this 48 hours is a dry and wet cycle. A total of 15 groups of concrete specimens were prepared for the test, each of which consists of 3 parallel specimens, and each group of
specimens was subjected to N=1, 2, 3...15 times of dry and wet cycles. After the corresponding number of cycles is completed, the microcomputer-controlled constant-loading pressure testing machine is used to perform a loading test to measure its compressive strength and compressive value.

3. Test results and data analysis

3.1. The change law of concrete compressive strength under different numbers of wet and dry cycles

The internal damage of the concrete specimens is different under different numbers of wet and dry cycles. The compressive strength changes of the concrete specimens at different ages are shown in Table 2. It can be seen from Table 2 that the compressive strength of the three different ages concrete changes basically the same with different numbers of dry and wet cycles. The compressive strength of the same age concrete specimens shows a trend of firstly increasing and then decreasing as the number of wet and dry cycles increases.

| Age Cycles | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 7d         | 27.86 | 30.4 | 32.63 | 34.4 | 36.4 | 37.9 | 39.08 | 40.1 | 40.75 | 41.2 | 41.4 | 41.32 | 40.9 | 40.2 | 39.4 |
| 14d        | 33.37 | 33.9 | 35.17 | 36.5 | 37.95 | 38.2 | 40.08 | 40.1 | 41.05 | 41.6 | 42.5 | 41.9 | 41.26 | 41.2 | 41.13 |
| 28d        | 33.43 | 34.2 | 36.2 | 37.4 | 40.53 | 40.9 | 41.97 | 42.6 | 44.17 | 44.7 | 44.5 | 45.97 | 45.2 | 45.03 |

During the pre-soaking process of concrete, liquefied water enters the interior of the concrete to continuously hydrate it, which increases the compactness of the concrete and leads to the increase of strength. As the dry-wet cycle continues, the internal damage of the concrete increases, which causes the expansion of micro-cracks and the decrease of strength.

According to the data obtained from the test, the relationship between the concrete compressive strength and the specific number of wet and dry cycles are drawn respectively as it shown in Figure 1.

![Figure 1. Relation curves of different numbers of dry and wet cycles and compressive strength of three ages concrete](image-url)
From Figure 1, it can be seen that the compressive strength of different ages concrete changes basically the same under different numbers of wet and dry cycles, which shows increasing firstly and then decreasing. And the number of dry and wet cycles in which the compressive strength reaches its peak is basically the same. The performance of the concrete at the age of 14d and 28d is more obvious.

For the concrete specimen at the age of 7d, its compressive strength peaked in the 11th dry and wet cycle, and then decrease. According to the compressive strength of the specimen measured in the test, the correlation equation of compressive strength of 7d concrete and different numbers of dry and wet cycles were obtained and as follows:

$$y = -0.1317x^2 + 2.9355x + 25$$ (1)

The compressive strength of the concrete specimens at the age of 14d and 28d is basically the same, and the peak appears at the 13th time of the dry and wet cycle. The correlation equation is as follows:

$$y = -0.071x^2 + 1.7491x + 30.937$$ (2)
$$y = -0.0789x^2 + 2.1301x + 30.83$$ (3)

3.2. Comparison of the influence of age on the strength of concrete specimens under dry and wet cycles

Comparing the compressive strength curves of the three age concretes, it can be clearly seen that the compressive strength growth rate of the concrete specimens under the dry and wet cycle environment is an obvious process from fast to slow, and the compressive strength decreases slowly after reaching the peak. The concrete specimen at the age of 7d has the earliest peak compressive strength whose number of the dry and wet cycle is 11th. The compressive strength of the concrete specimen at the age of 14d and 28d is not much different during the front 5 times of dry and wet cycles, and the growth rate is similar. After the 6th time of dry and wet cycle, the compressive strength of the 14d concrete specimen is slower than 28d. After the 9th time of dry and wet cycle, the rate of compressive strength of the 28d concrete specimen growth is significantly reduced. Both of the compressive strength of 14d and 28d concrete specimen peaked at 13th time of dry and wet cycle.

It can be seen that the compressive strength of the three different age concretes is basically the same under dry and wet cycles. For the concrete specimens at the same age, during the pre-soaking process, liquefied water enters the interior of the concretes to make it continuously hydrated, which increases the compactness of the concretes and leads to the increase of strength. However, As the dry-wet cycle continues, the internal damage of the concretes increases, and micro-cracks expand, which causes the strength of concrete decreases.

From the above results, it can be seen that the age has a certain influence on the strength of the concrete mechanical properties under the dry and wet cycle environment: The concrete specimens at the age of 7d is not fully formed due to the short curing time, so the internal structure of concrete will be affect by the dry and wet cycle and strength of the concrete specimens is low. Therefore, the dry and wet cycle has a great influence on the structural stability of concrete specimens at the age of 7d, which causes the strength of 7d concrete specimens to reach its peak earliest. Due to the strength growth rate of the concrete specimens slowed down after 14th days of natural curing, the preliminary strength of the 14d concrete specimens is not much different from the 28d concrete specimens. However, after multiple dry and wet cycles, the internal structure of the 14d concrete specimens is damaged more obviously, and its strength growth rate and the peak strength was significantly lower than that of the 28d concrete specimens.
3.3. *The law of crack expansion and change of concrete under dry and wet cycles*

Compressive tests were carried out on the concrete specimens after the dry and wet cycle, and it was found that the concrete specimens had obvious oblique cracks. Comparing the development of oblique cracks in the three age concrete specimens, it is shown in Figures 2, Figures 3 and Figures 4.

*Figure 2.* Surface Characteristics of 7d Concrete Specimens after Compression Failure

*Figure 3.* Surface Characteristics of 14d Concrete Specimens after Compression Failure

*Figure 4.* Surface Characteristics of 28d Concrete Specimens after Compression Failure

It can be seen that the expansion law of oblique cracks on the surface of the three age concrete specimens after compression is basically the same. When the concrete specimens are compressed, firstly, small initial cracks appear at the edge of the compression surface, and then small cracks aggregate, form relatively obvious diagonal cracks, expand to both sides of the edge in a "tree-like" form, and even penetrate the surface of the concrete specimen. Due to the difference in the uniformity of coarse and fine aggregates and the degree of compaction of concrete specimens, when the internal structure of concrete specimens is damaged, there are differences in its surface characteristics. Some concrete specimens have large areas of fracture, while some concrete specimens have several on the surface crack but the structure keeps intact.
4. Conclusion
The uniaxial compression test was carried out with standard cubic concrete specimens, and the mechanical properties of ordinary concrete under different number of dry and wet cycles were studied. The preliminary conclusions after analysis are as follows.

(1) The compressive strength of ordinary concrete specimens firstly increases and then decreases under the overall process of the dry and wet cycle. The peak compressive strength generally occurs at the 12th to 14th times of the dry and wet cycle. The compressive strength of the concrete specimens does not decrease significantly after reaching the peak. The experiment established the relationship equations between the compressive strength of three age concrete and the specific number of dry and wet cycles in the early stage, and obtained the corresponding laws, which can be used as a preliminary reference for studying the relationship between concrete strength and dry and wet cycles.

(2) The compressive strength change process of the specimens of different ages in the dry and wet cycle environment all increase firstly and then decrease. It can be found in the test that the compressive strength of the 7d concrete specimens is obviously affected by the dry and wet cycle, and the peak appears the earliest and the compressive strength is the lowest. The initial compressive strength of the 14d and 28d concrete specimens is not significantly different until the 14d concrete specimens close to the peak strength. Combined with engineering design, it can provide a certain theoretical basis for the study of the influence of age on concrete.

(3) Obvious oblique cracks appeared on the surface of the three age concrete specimens under compression. When the load gradually increased, several micro cracks appeared near the edge of the concrete specimen from the compression surface, and then continued to expand and showed a certain inclination angle.

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