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A Review of Mechanical Properties of Ordinary Concrete after High Temperature

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Abstract

Ordinary concrete is a widely used material in construction and infrastructure works. The study of mechanical properties of plain concrete after high temperature is of great importance for the safety of people's property and life. The aim of this review is to summarize the recent progress in the study of mechanical properties of concrete after high temperature, especially compressive strength, flexural strength and modulus of elasticity. Problems and future research directions in the study of high-temperature properties of ordinary concrete are pointed out. This will provide a reference for further research on the properties of ordinary concrete at high temperatures.

Keywords

Ordinary concrete, high temperature, mechanical properties, compressive strength.

1. Introduction

Fire is one of the disasters with high frequency and serious loss in nature, the main types are forest fires, building fires, traffic fires, etc., among which building fires are the highest frequency among all fire types, after the construction fire, the bearing capacity of the concrete structure decreases sharply, and the high temperature of the fire makes the cement slurry and aggregate inside the concrete be damaged to a certain extent. The bearing capacity of the building is reduced and the use performance is reduced, which seriously threatens personal safety and public property safety. With the frequent occurrence of building fire accidents and people's increasing attention to building fire safety, improving the fire resistance of concrete structures has become one of the current research hotspots. Therefore, it is essential to study the mechanical properties of concrete after high temperature to ensure the safety and reliability of the structure. For the study of mechanical properties of concrete after high temperature, compressive strength, tensile strength and elastic modulus are one of the most critical indicators. These indexes directly reflect the mechanical behavior of concrete under stress, which is of great significance for the design, construction and use of structures. The study of compressive strength mainly focuses on the stress-strain relationship of concrete under compression, that is, the deformation and failure process of concrete after being stressed. By studying the stress-strain relationship of concrete, we can better understand the mechanical behavior of concrete and provide a scientific basis for the design and construction of structures.

2. Change in compressive strength

Zhang et al. [1] found that the compressive strength of concrete decreases to varying degrees with the increase of temperature after high temperature, and the decreasing trend of compressive strength is slow before the fire temperature reaches 400°C. The decreasing rate of compressive strength increases after the fire temperature reaches 400°C, and the compressive strength of concrete is basically lost after the fire temperature reaches 800°C, and

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the loss degree is as high as 85.4% compared with normal temperature. According to the research results of Guo Qiang et al. [2], the composition of aggregate has an impact on the high temperature resistance of concrete. As the temperature increases, the compressive strength of concrete decreases. In addition, the study of Lufeng et al. [3] found that the substitution rate of manufactured sand has a significant effect on the compressive strength of concrete specimens after high temperature. When the temperature is 200°C and 400°C, the compressive strength loss rate of the specimen gradually decreases with the increase of the substitution rate of manufactured sand, while the compressive strength of the specimen increases at 80% and 100% substitution rates. When the temperature is 800°C, with the increase of the substitution rate of manufactured sand, the compressive strength loss of the specimen first increases and then decreases. Finally, at the temperatures of 800°C and 1000°C, the specimens with 20% of the machine-made sand substitution rate showed the maximum compressive strength loss rate. Wang Weiwei et al. [4] studied the change law of mass loss and compressive strength of concrete with different iron tailings sand content after high temperature, and the results showed that under the same substitution rate, the cubic residual compressive strength of iron tailings concrete decreased with the increase of temperature, and the strength of 100% iron tailings concrete decreased by 7.2MPa from 33.2MPa at room temperature to 7.2MPa at 800°C, a decrease of 78%.

After the concrete undergoes the same temperature, the damage and deterioration of the concrete is more serious with the extension of the constant temperature time. Shao Wei et al. [5] studied the influence of heating time on the compressive strength of concrete, and found that the longer the heating time of concrete at the same temperature, the greater the loss of mechanical properties of concrete, but the extension of heating time without temperature increase has a significant effect on the mechanical properties of concrete. Niu Zixuan [6] carried out the effect test of constant temperature time on the mechanical properties of concrete after high temperature, and the results showed that the ignition loss rate of ordinary concrete also increased when the temperature increased, and the temperature had a great influence on the damage degree of concrete, but the effect of constant temperature time was not significant but could not be ignored. Zhang Keqiang et al. [7] studied the influence of different constant temperature times on the compressive strength of concrete after high temperature, and the results showed that with the extension of constant temperature time, the compressive strength of concrete gradually decreased after high temperature, and the compressive strength decreased greatly after 1 h of constant temperature, and after 2 h and 5 h of constant temperature, the dehydration of the test block was small, and the strength decreased slowly.

ABADEL A et al. [8] found that when the temperature increased from 400°C to 600°C, the reduction rate of compressive strength was significantly accelerated. Cooling in water is conducive to the rehydration of cement in concrete, and the residual strength is greater than that of air-cooled concrete. Liang et al. [9] showed that the cooling method had a significant effect on the strength of concrete in the high temperature area above 550°C, and with the increase of static time, the compressive strength of concrete increased after water spray cooling, while the strength decreased after natural cooling. Zhuang Zhikai et al. [10] studied the effects of air-cooled, water-cooled, and semi-water-cooled cooling methods on the deterioration damage of concrete after high temperature, and the results showed that the damage of concrete test blocks with semi-water cooling after high temperature was the most serious. Wang et al. [11] conducted experiments on the effects of aggregate, strength grade and cooling method on the high-temperature performance of concrete, and the results showed that the relationship between the compressive strength of concrete after high temperature was natural cooling after high temperature> natural cooling after high temperature> watering cooling after high temperature.

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3. Change in tensile strength

After experiencing high temperature and constant temperature for different times, the mechanical strength of concrete decreases to varying degrees. The effect of the maximum constant temperature on the splitting tensile strength of the ordinary concrete test block after high temperature is obvious, and the tensile strength of ordinary concrete decreases with the increase of the maximum constant temperature duration [6]. Bian Rui et al. [12] studied the relationship between the tensile strength of concrete, the heating temperature and the heating time, and the results showed that the temperature change had a significant effect on the reduction of the tensile strength of concrete, and the sharp decrease in tensile strength occurred after the temperature was 300°C. The deterioration effect of heating time on the mechanical properties of concrete cannot be ignored, and the tensile strength gradually decreases with the increase of heating time. Jia Yandong [13] and Shao Wei [5] studied the influence of temperature and fire time on the tensile strength and elastic modulus of concrete, and found that the longer the fire time of concrete at the same temperature, the greater the loss of concrete mechanical properties, but the longer the fire time did not have the obvious effect of temperature increase on the mechanical properties of concrete. Existing studies show that after the concrete undergoes the same temperature, with the extension of the constant temperature time, the damage and deterioration of concrete is more serious, and the tensile strength gradually decreases.

Zhou Jianchao et al. [14] carried out fire experiments under different working conditions of ordinary concrete after high temperature and standing for 1 day and 14 days, and the results showed that the residual rate of tensile strength of the test block cooled by water spray increased with the increase of standing time, which was due to the reaction of calcium oxide produced after high temperature with water in the air and the free water in the test block after water spray cooling to form calcium hydroxide, thus repairing the cracks. Zhai Yue et al. [15] studied the effects of cooling method and high temperature on the splitting tensile strength of concrete, and after using water cooling and natural cooling, they were allowed to stand for more than 3 weeks under natural ventilation conditions, and the results showed that with the increase of temperature, the splitting tensile strength of water-sprayed concrete material decreased, and the decrease increased significantly.

4. Change in modulus of elasticity

The regularity of the elastic modulus of concrete with temperature is obvious. Shao Wei [5] and Jia Yandong [13] found that with the continuous increase of temperature, the elastic modulus of ordinary concrete decreases sharply, and the longer the constant temperature time, the smaller the elastic modulus of concrete. Zhuang et al. [10] analyzed the effects of different cooling methods on the mechanical properties and damage evolution of concrete after high temperature, and showed that the specimen became brittle and the bearing capacity was reduced under semi-water cooling, and the elastic modulus of concrete deteriorated most seriously under semi-water cooling conditions than under natural cooling conditions and full water cooling conditions. Wang et al. [11] studied the experimental study of the mechanical properties of concrete after high temperature cooling, and the results showed that; After high temperature natural cooling, the elastic modulus of concrete decreases continuously with the increase of temperature, and the reduction rate is faster than that of the corresponding compressive strength, especially when the temperature is greater than 600 °C, the elastic modulus decreases more rapidly, and the compressive deformation ability is basically lost.

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5. Stress vs. strain relationship

Li Yan et al. [17] studied the effects of different cooling methods on the relationship between stress and strain in concrete after high temperature, and the results showed that. The curve of watering cooling is slightly steeper than that of natural cooling in the descending section, and the shape of the curve is generally similar, and the change law is roughly the same. Shao Wei [5] and Chen Zongping [17] and others have shown that; With the increase of temperature, the shape of the stress-strain curve of concrete is obviously different, and the peak stress of concrete becomes smaller and smaller, and the curve gradually flattens. With the increase of constant temperature time, the shape of the curve is roughly the same, and the longer the heating time, the smaller the peak stress of the concrete, and the greater the peak strain.

6. Conclusion and Outlook

(1) After the high temperature of ordinary concrete, with the increase of action temperature and constant temperature time, the compressive strength, tensile strength and elastic modulus of concrete decrease to varying degrees.

(2) The damage of water spray cooling after high temperature of concrete is more serious than that of natural cooling. Under the same conditions, the compressive strength, tensile strength and elastic modulus of water spray cooled concrete after high temperature are lower than those under natural cooling.

(3) The change law of the stress-strain relationship of concrete after high temperature is not greatly affected by the cooling mode, but with the increase of temperature, the curve shape gradually slows down, and the peak value becomes smaller and smaller.

Under high temperature conditions, ordinary concrete has the disadvantages of high brittleness and low tensile strength, which restricts its application in engineering. Researchers can explore ways to repair and reinforce concrete after high temperatures, or use fiber-reinforced materials, refractories, etc., to improve the mechanical and refractory properties of concrete. Finally, the law and mechanism of mechanical properties of concrete in high-temperature environment can be studied in depth, so as to more accurately predict the performance of concrete in high-temperature environment.

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