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A review of the effects of temperature on the durability of concrete structures in different environments

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ABSTRACT
Temperature, carbonization environment, chloride environment and sulfate environment are all important factors causing the failure of concrete structures, and the key to enhancing the safety and durability of concrete engineering is to make investigations of the impact of temperature on the durability failure of concrete structures under the condition of coupling temperature with carbonization environment, chloride environment and sulfate environment respectively. In this paper, the causes of concrete structure failure are summarized in the carbon-freeze-thaw coupling environment, chloride-freeze-thaw coupling environment, high temperature-sulfate coupling environment and low temperature freeze-thaw-sulfate catena environment, and the methods of reducing the degree of concrete failure and maintaining the durability of components are summarized, and the problems existing in the field of coupling temperature and different environments on concrete are discussed.

KEYWORDS
Temperature; carbonized environment; chloride environment; sulfate environment; failure of concrete structures; durability

1 Introduction

With the development of society, as a core material in modern engineering, concrete with good mechanical properties, high durability and plasticity, has become the preferred material for many infrastructure projects, such as bridge engineering, road engineering, tunnel engineering, and construction fields. Concrete is generally less cost and more cost-effective than other materials, making it an affordable choice for large-scale projects. Concrete is used in large-scale engineering projects to provide sufficient strength and stability for the project, to ensure the safety and durability of the building.

Global temperatures are rising and the climate is warming, resulting in higher summer temperatures and lower winter temperatures. And the temperature exacerbates the destruction of concrete buildings. Therefore, it is meaningful to study the effect of temperature on the durability of concrete structures in distinct environments, and at the same time, this research is also conducive to providing theoretical support for construction personnel to choose more durable concrete structures and types under different conditions in the actual construction process.

2 Overview of Research Status

Temperature, carbonization environment, chloride salt environment and sulfate environment all have different degrees of damage to concrete structures. Therefore, in order to understand the influence of temperature and different environments on the durability of concrete structures, scholars conducted experiments under the conditions of coupling temperature with carbonization environment, chloride environment and sulfate environment respectively, to explore the causes of concrete structure failure under coupled conditions and the methods to enhance the durability of concrete.

2.1 Carbon-freeze-thaw coupling environment

Low temperature freeze-thaw increases the internal compactness of concrete structures, which has an impact on carbonization. The icing pressure caused by freezing and thawing causes cracks in the concrete, providing a channel for CO2 to enter the structure, resulting in uneven distribution of stresses inside the material. Carbonization has a reparative effect on freeze-thaw damage, and in the meantime, the deterioration of concrete by the freeze-thaw environment impels CO2 to enter the concrete, so the two are coupled to each other [1].

QIAN Weimin [2] and other scholars studied the carbonization depth of concrete by controlling the temperature variable, and found that a phenomenon in which the depth of carbonization increases as the temperature decreases. Controling the temperature at 20~-80°C, the carbonization depth of UHTCC decreases slowly with the temperature. When the temperature drops to -160°C, the growth of carbonization depth slows down. They proposed that concrete exhibited the best resistance to carbonation when 1.5vol% fibers were incorporated into UHTCC.

Pan Dong et al. [3] carbonized the fiber-reinforced concrete test blocks and then freeze-thaw them with aqueous or salt solutions, and the test proved that the mixed fiber-reinforced concrete still has high durability under coupling even if serious carbonization occurs. Based on a similar test method, Huang et al. [4] incorporated BF fiber and steel fiber into expanded cement concrete, and the efflorescence evinced that the inclusion of fiber could reduce the carbonization depth and strength loss, meanwhile, BF fiber improved freeze-thaw resistance better than that of steel fiber.

Under the factor of carbonization-freeze-thaw coupling, for the sake of improving the durability of concrete structures, most experts and scholars have proposed a method of mixing fly ash to accumulate the internal products of concrete structures, fill the voids, and increase the compactness of the structure. Alternatively, a certain amount of fiber should be incorporated to ensure the durability of the concrete. However, the content of the incorporated fibers should be controlled within a certain range, and the unity effect and initial defects produced by excessive fibers will reduce the carbonization resistance of concrete. However, a small amount of fiber has little effect on improving the carbonization resistance of concrete, so that the durability of concrete structures can ' t be guaranteed to meet the requirements.

2.2 chloride-freeze-thaw coupling environment

The results show that the salt-freeze-thaw coupling is not the superposition of single factors, but the interaction effect. In the chloride-freeze-thaw interconnection environment, the hygroscopicity of the salt solution adds the moisture content of the concrete, which increases the internal icing of the concrete structure and produces ice pressure, bringing about on a decrease in the strength of the concrete and a decrease in the durability of the concrete component.

Yu Hongfa [6] obtained the correlation between freeze-thaw life and deterioration parameters, under freeze-thaw-brine corrosion coupling, indicating that the inclusion of fibers is beneficial to reduce damage. Subsequently, Ning Xiliang et al. [7] discovered that the incorporation of polypropylene staple fiber (PPFA) could ameliorate the frost resistance of concrete and reduce the loss rate of the bonding properties of concrete iron and concrete by changing the number of freeze-thaw cycles, fiber types and fiber content. Compared with the concrete specimens without fibers, the bond strength between the concrete and the GFRP bars was increased by 39.4% after the chloride-freeze-thaw cycle.

In the chloride-freeze-thaw environment, the addition of a single type of fiber has no obvious effect on improving the strength of concrete. However, the strength of the concrete structure can be significantly improved by using the method of mixing fibers, so in order to improve the durability of the concrete structure, the fibers should be mixed according to the actual construction conditions and levels, so as to limit the crack development of the concrete matrix and reduce the loss of cohesion caused by freeze-thaw cycles. Meanwhile, the BUS algorithm [8] of subset simulation should be used to establish a concrete durability model based on actual construction monitoring before the start of construction, so as to achieve better construction purposes.

2.3 Temperature and sulfate coupling environment

In the sulfate environment, the high temperature environment or low-temperature operation with freeze-thaw environment has significant damage to the concrete structure, and the wreck to concrete components caused by the high-temperature-sulfate coupling environment and the low-temperature freeze-thaw-sulfate coupling environment is common in daily life.

2.3.1 High-temperature-sulfate coupling environment

The high temperature environment accelerates the corrosion rate of sulfate on concrete, leading to an increase in the concentration of sulfate ions and a deepening of the corrosion degree. At the same time, high temperatures accelerate the rate of deterioration of concrete and reduce the durability of concrete components.

Studies have shown that [9] an increase in temperature promotes the rate at which sulfate corrodes concrete. It has also been suggested that although the increase in temperature can promote the deep etch rate of sulfate ions inside the concrete structure, the formation of corrosion products will be accelerated. However, as the temperature increases, the solubility of the corrosion products decreases. According to Fevziye [10], the temperature of the erosion solution is within 40 °C, and the rate of sulfate erosion of concrete changes when the temperature rises, which is generally favorable. Other studies [11] have also shown that the rate of sulfate corrosion of concrete increases with temperature at temperatures below a certain temperature, but decreases when the temperature reaches 70 ° C. This is only the effect of high temperatures on the sulfate environment.

Guo Jiaqing [12] and Nie Sifan [13] studied the sulfate erosion resistance of concrete with a constant temperature of 35 °C, and the results showed that the migration rate of sulfate ions is faster at 35°C compared to 20°C, the corrosion resistance coefficient of concrete was increased by 36.46%, and the concentration of sulfate ions was higher at the same depth. Yao et al. [14] compared and analyzed the damage law of mortar fully immersed in 5% sodium sulfate solution under Constant temperature (10°C, 20°C and 40°C, respectively) and variable temperature (from 10°C to 40°C) conditions, and found that the corrosion of sulfate on mortar was more destructive in the variable temperature environment, but the mortar had stronger resistance to sulfate erosion in the 40°C high temperature erosion environment. The above tests often set the temperature to a constant value, and all of them use full immersion to carry out sulfate erosion experiments, but the influence of sulfate physical erosion should also be considered in actual working conditions. Therefore, some scholars have begun to use the test conditions of semi-immersion and variable temperature environment to study the sulfate erosion resistance of concrete. In all of the above studies, the experimenters have used high temperature as a measure to accelerate sulfate erosion, and the high temperature for concrete in sulfate environment has not been fully studied.

Based on the above research status, Ding Yuqiao [15] and other scholars conducted experiments through self-made accelerated corrosion equipment, and the results showed that the morphology of the specimen under the coupling effect of thermal fatigue and sulfate erosion was seriously damaged, and serious crystallization and concrete spalling appeared. In addition, the mechanical properties of concrete are also greatly attenuated, and it is found that thermal fatigue under coupling action causes the deterioration of concrete from the early stage of erosion, while the coupling effect of sulfate action and thermal fatigue begins to accelerate the deterioration of concrete in the late stage of erosion. The effects of temperature and sulfate environment coupling on concrete deterioration are sequential.

According to the "Numerical Model of High Geothermal Tunnel" proposed by Chen Hao [16], innovation and development can be carried out on this basis in the fields where concrete materials are used a lot in bridges, roads, etc., and a prediction model for the durability of concrete structures in a high-temperature-sulfate linkage environment can be established in combination with the actual engineering construction background. At the same time, fiber or metal aggregate can be added to reduce the deterioration depth of concrete in the high-temperature-sulfate coupling environment. In addition, the use of high-temperature hot air drying process should be avoided as much as possible in the construction according to the actual conditions to reduce the affect on the durability of the concrete structure.

2.3.2 Low-temperature freeze-thaw-sulfate coupling environment

The main reason for the ruin of low-temperature freeze-thaw-sulfate environment to concrete structure is that the concrete pores are filled with erosion products and crystalline salts, which causes swelling stress, which acts on the pore structure, resulting in an addition in the number and size of harmful pores, and destroying the structural stability of the concrete.

More and more scholars at home and abroad have begun to study the deterioration of concrete under the coupling effect of multiple factors, and the reason is to get more real and reliable feedback on the actual use of local hydraulic concrete, among which the dual effects of sulfate erosion and freeze-thaw cycle have become the focus of research in recent years. Liu Hui [17] studied the durability of concrete by using three methods: freeze-thaw after drying-wetting, dry-wetting after freeze-thaw and dry-wet-freeze-thaw alternation, indicating that the dual factors of sulfate drying-wetting cycle and freeze-thaw cycle are not simply superimposed on each other, but the super-compound effects. Ge et al. [18] used the freeze-thaw-dry-wet alternate cycle method to deteriorate the durability of concrete in water and sulfate solution (Na2SO4) respectively, and showed that the freeze-thaw-dry-wet cycle in the Na2SO4 solution environment had a greater deterioration effect on concrete, and the deterioration effect increased with the increase of Na2SO4 solution concentration.

Wang et al. [19] found that salt freezing has both positive and negative effects on concrete, and replacing cement with 25% fly ash and 5%~8% silica fume can improve the salt freezing durability of concrete. Li et al. [20] found some clues of low and high fly ash on the salt freeze resistance durability of recycled concrete, and the results showed that low fly ash had beneficial erosion resistance. At the same time, [21] et al. proposed through experiments that concrete with different gas content has a destructive effect on the concrete structure when it undergoes freeze-thaw cycles in sulfate solution, and the amount of concrete surface erosion increases. However, with the increasing gas content, the amount of cyclic freeze-thaw denudation in the sulfate environment gradually decreases, indicating that the gas content in concrete can dramatically enhance the freeze-thaw resistance of concrete specimens in sulfate solution. In addition, Zhao [22] conducted sulfate solution-freeze-thaw studies on concrete doped with PVA fibers and geopolymer composites, and established a mathematical model of the stress level and damage relationship of the material based on acoustic emission parameters.

Under the condition of low-temperature freeze-thaw-sulfate coupling, concrete components can be mixed with fibers, mixed with low-amount fly ash, or air-entraining agents to enhance the durability of concrete structures. In addition, the actual conditions and damage model simulations of the concrete are carried out before the actual construction process to predict the degree and impact of concrete deterioration during construction.

3 Conclusion

In view of the effects of temperature and carbonization environment, chloride salt environment and sulfate environment on the durability of concrete structures, the causes of the failure of concrete structures and how to reduce the degree of concrete deterioration and improve the durability of concrete components were discussed. It is worth noting that: The coupling conditions of temperature and carbonization environment, chloride environment and sulfate environment are not a combination of the two single conditions, and the damage caused by the coupling conditions to the concrete structure is often more severe. The coupling of these two factors, their interaction and interaction will also have an impact on the durability of concrete structures. This paper only reviews the causes of concrete structure failure, the methods for reducing the degree of concrete failure and maintaining the durability of components in the carbon-freeze-thaw coupling environment, chloride-freeze-thaw coupling environment, high-temperature-sulfate coupling environment and low-temperature freeze-thaw coupling environment, but the conditions and conditions in the actual construction process are more complex, and there are many problems that need further research.

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