

Research on the Influence of Rainwater Erosion on Reinforced Concrete Structures and its Protection Methods

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Abstract. Today, global temperature warming and industrialization have exacerbated the problem of acid rain, resulting in severe erosion risks of reinforced concrete structures. Reinforced concrete structures are widely used in daily life, especially in bridges, buildings, water conservancy and other infrastructure. Studying the erosion principle of reinforced concrete structures by rainwater and the protective precautions of the structure can reduce the maintenance cost of reinforced concrete structures, put forward suggestions for modern protective measures, more rational use of resources, maximize the realization of green buildings, and reduce energy consumption. This paper analyzes and summarizes the erosion principle of reinforced concrete structures by rain: The acidic substance in the acid rain will undergo an acid-base neutralization reaction with the cement, thus increasing the porosity. In addition, cement stone and carbon dioxide undergo a carbonization reaction, thus reducing the pH value of the internal environment of the structure, resulting in corrosion of the steel bars. Thus, affecting the bonding performance of the reinforced concrete interface, and further affecting the overall bending and compressive resistance.

Keywords: Reinforced concrete Acid rain Erosion principle.

1. Introduction

China is the region with the most reinforced concrete structures in the world, and with the rapid development of China's infrastructure, reinforced concrete buildings are widely used in daily life. With the acceleration of the world's industrialization process and global warming, the scope and degree of acid rain pollution are gradually expanding, this greatly reduces the service life of reinforced concrete structures and has a great impact on their economic value and social benefits, and China is no exception, so it is particularly important to pay attention to the later detection and protection of reinforced concrete structures, timely and efficient, scientific and reasonable protection and repair of reinforced concrete structures, to ensure the safe operation of infrastructure, and to extend the service life of the construction is of great significance.

To slow down the impact of rainwater erosion, the research on protection technology at home and abroad mainly focuses on improving the compactness of concrete by adding anti-corrosion admixtures (such as silica fume and slag powder) to enhance its anti-erosion ability. For example, Yue Qi of Southeast University studied the preparation and performance of bridge ultra-high-performance concrete, explored the influence of silicon powder admixture on the mechanical properties, working properties, etc. of UHPC of coarse aggregates, and found that the mixing of cement, fly ash, silica and microbeads with a certain mass ratio in coarse aggregates can significantly improve the compressive and refractive strength of concrete and reduce the production cost. In addition, in recent years, high-performance protective coatings, such as silicone coatings, and high-durability composite materials have attracted a lot of attention.

This paper focuses on the impact of rainwater erosion on reinforced concrete structures and the later detection and protection measures. By collating relevant scientific research data and literature, the corrosion mechanism and damage effect of acidic compounds in rainwater on reinforced concrete were comprehensively analyzed, and the degradation law of mechanical properties of reinforced

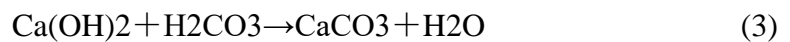
concrete in an acid rain environment was deeply discussed. Furthermore, combined with the latest technology, the detection methods and effective protective measures of reinforced concrete structures were evaluated.

2. Rainwater erosion of reinforced concrete

Many components of global rainwater contain acidic oxides, which will slowly expand and destroy the inside of reinforced concrete after contact with reinforced concrete, resulting in the rust of steel bars.

2.1. The principle of erosion of reinforced concrete by acidic compounds in rainwater

Rainwater contains SO₂ and NO₂ and other substances, these acidic oxides react with water vapor in the atmosphere to form sulfuric acid (H₂SO₄) nitric acid (HNO₃), which makes rainwater acidic, and rainwater will slowly dissolve and expand with the interior after contacting reinforced concrete buildings, and the cement stone in reinforced concrete carbonizes carbon dioxide[1]:



At the same time, carbon dioxide concentration(CO₂) plays a central role in the erosion of acid rain. The carbonization of concrete is a key link in the erosion of acid rain. After the carbon dioxide in the acid rain penetrates into the interior of the concrete, it reacts with calcium hydroxide to produce calcium carbonate, which reduces the strength of the concrete. At the same time, the higher the concentration of carbon dioxide, the faster the carbonization process. The study found that in an environment with high carbon dioxide concentration, the relationship between carbonization depth and time can be described by the following formula[2]:

$$D = xtb \quad (4)$$

Where: D - carbonization depth x - carbonization speed coefficient (including concrete water-cement ratio, cement variety, construction quality and other comprehensive influence coefficients) t-carbonization age (years) b-time index constant (generally 0.4~0.6).The carbonization will reduce the internal PH of the reinforced concrete, which will cause the steel bar to corrode [1].And these reactions will lead to the deterioration of the mechanical properties in the reinforced concrete structure, and will also cause the concrete to crack due to the expansion of the bonding properties of the steel-concrete interface and the volume of corrosion products.

In addition, hydrogen ions in acid rain can also undergo acid-base neutralization reactions with alkaline cement hydration products in multi-porous composite concrete, dissolving alkaline components and generating calcareous compounds and losing them, increasing porosity and damaging the internal structure of reinforced concrete [3]. Although the reaction process of rainwater to reinforced concrete is slow, these erosion mechanisms can cause irreversible damage, so buildings in areas severely affected by acid rain can cause serious structural damage and economic losses.

2.2. Degradation of mechanical properties of reinforced concrete in acid rain environment

The mechanical properties of reinforced concrete structures due to rainwater erosion are mainly reflected in the decline of the bonding properties of the steel corrosion and the steel-concrete interface, which leads to the decline and decline of the overall mechanical properties of reinforced concrete structures

As the erosion continues, the products of the acid-base neutralization reaction increase, and a large number of them enter the internal pores and microcracks, so that the internal expansion stress is generated, and the expansion stress increases to a certain extent will lead to the increase of the internal structure pores , resulting in the dissolution and expansion of the internal structure, thereby reducing

the overall strength of the reinforced concrete[4]. Therefore, the compressive performance of reinforced concrete structures in the environment of acid rain for a long time will be significantly reduced.

In addition, acid rain also has a significant impact on the flexural performance of reinforced concrete structures, The accelerated erosion experiment of simulated acid rain PH value of 3.0 on reinforced concrete frame beams with shear span ratios of 5.0, 4.2 and 3.4 respectively, and a quasi-static force test study was carried out on the beam, and it was found that when the acidification depth of reinforced concrete beams with different shear-span ratios is less than the thickness of the concrete protective layer, the bearing capacity and ductility of the frame beams increase slightly, but with the aggravation of corrosion, the failure of reinforced concrete beams will change from flexural failure to shear failure, and with the increase of longitudinal bar corrosion rate, the bearing capacity and ductility of reinforced concrete structures will decrease to varying degrees [5].

Regarding the research on the bonding properties of reinforced concrete under the effect of acid rain erosion, Chen Mengcheng and four other students from the School of Civil and Civil Engineering of East China Jiaotong University conducted experiments such as pouring and drawing of reinforced concrete specimens by simulating Jiangxi acid rain and configuration, and found that when the corrosion rate of steel bars is low, the maximum bond strength of corroded reinforced concrete will be higher than that of uncorroded reinforced concrete. However, as the corrosion rate increases, the bond strength decreases significantly, especially the maximum bond strength [6]. Therefore, the significant influence of acid rain erosion on the bond strength of the reinforcing steel-concrete interface is also one of the important factors for the degradation of its mechanical properties.

3. Research on the protection method of reinforced concrete structure

The protective measures of reinforced concrete are mainly from the aspects of rainwater anti-corrosion prevention measures, quality inspection technology of reinforced concrete structures, and construction and restoration. It is especially important to combine these traditional methods of protection methods with modern technology to protect reinforced concrete.

3.1. Rainwater antiseptic precautions

Reinforced concrete components are widely used, from the above content, it can be seen that the preventive measures of reinforced concrete components against rainwater erosion are particularly important. On the one hand, it can prevent rebar rust and concrete peeling, maintain structural strength and stability, and ensure building safety; on the other hand, it can extend the service life of components, reduce maintenance costs, and avoid the impact of frequent repair on use. The protection of rebar corrosion and concrete surface in concrete mainly starts from three aspects: first, to prevent or delay the destructive effect of erosion sources; second, to improve the anti-corrosion performance of rebar, and third, to protect the concrete surface through painting [7].

Use external coating technology. The strong ultraviolet irradiation of the high field is prone to aging and cracking, which makes the coating invalid. In addition, there are certain limitations. For example, the infusion paint cannot be applied externally and the effective time is short, with a maximum service life of 100 years; (2) Increase the protective layer and improve the concrete strength level, which can delay corrosion, but the engineering cost is high; (3) Use anti-sulfur Salt cement, however, the supply of sulfate-resistant cement is limited and the price is expensive. More importantly, the anti-sulfate cement has poor CL-corrosion resistance. In the environment where CL- and SO₄²⁻ coexist, the anti-corrosion effect is not good, which seriously affects the durability of reinforced concrete structures in the erosion area [8].

At present, the prevention of rebar corrosion at home and abroad can be roughly divided into the following four categories: (1) reduce the permeability of concrete; such as optimize the ratio or add water reducer. (2) coating protection on the surface of the condensate; (3) coating protection of the surface of the rebar; (4) corrosion-resistant rebar; (5) rust inhibitor of rebar [8].

In view of the mechanism of corrosion and destruction of concrete, the research progress and evaluation methods of protective measures in anti-corrosion and rust prevention of reinforced concrete are discussed. Adopting effective protective technology for concrete structures to prevent environmental erosion of concrete and maintain the performance of concrete is of great practical significance to ensure and improve the durability and service life of concrete structures, and greatly improve the safety of buildings during their service life [9].

3.2. Post-inspection and repair of reinforced concrete structures under rainwater erosion

Under the continuous erosion and destruction of reinforced concrete structures by acid rain, it becomes extremely important to learn to use modern means to detect and repair the structure.

3.2.1 Evaluation of the application of quality inspection technology for reinforced concrete structures

In order to deeply study the impact of reinforced concrete structures under rainwater erosion, quality inspection technology is particularly important. The key is to review the quality of concrete, covering the evaluation of its waterproofness, hardness, compactness, endurance and other main characteristics. The quality inspection methods of reinforced concrete can be roughly divided into concrete quality non-destructive detection technology and concrete quality destructive detection technology.

Non-destructive detection technologies such as sound waves, electromagnetic waves and ultrasound can evaluate the quality and structural condition of concrete and ensure engineering safety and durability. Destructive detection techniques such as cross-sectional analysis, internal defect detection and mechanical property testing can understand the strength and performance of concrete and provide reference for engineering design and construction. [10] The comprehensive use of these technologies can accurately grasp the quality of reinforced concrete structures after being eroded by rainwater, so as to take timely repair and reinforcement measures to ensure the safety and durability of the structure.

However, these detection methods still have technical limitations. The accuracy of detection may not be accurate enough and the scope of detection is also limited. A combination of multiple technologies can be used to upgrade testing instruments and apply new materials to solve these problems.

3.2.2 Rehabilitation of reinforced concrete components

Reinforced concrete components will be damaged under the erosion of rainwater, and the mechanical properties will decline as a whole. The products produced by the acid-base neutralization reaction will cause the structure to dissolve and expand and destroy from the inside, resulting in cracks, broken plates and other damage. Although there are many measures to prevent rainwater damage in most cases, when damage is encountered, the components can continue to be used through repair measures.

Nowadays, the repair methods of reinforced concrete include chemical repair, biological repair, electrochemical repair, etc. Epoxy resin can be used to repair the fracture of concrete cracks, and the glue injection repair technology can effectively delay the recurrence of the cracks and improve the fracture performance of concrete. In addition, scholar Li Peihao and others proposed the method of biodeposition to repair concrete cracks, and electrodeposition repair method of cracked reinforced concrete based on electrochemical technology [11]. MPC material can also be used, which has good durability and adhesion, which can meet the needs of road surface disease repair. In the process of disease repair, it is necessary to master the relevant construction technology and optimize the repair method to ensure that the quality meets the standard [12].

Future research on rain erosion of reinforced concrete structures can dig deeper. At the microscopic level, with the help of advanced equipment, this study can analyze the molecular mechanism of erosion reaction and clarify the root cause of damage. At the macro level, the construction of multi-

factor coupling model, and accurate prediction of life expectancy. Interdisciplinary integration of innovative protective materials to improve durability and ensure the long-term stability of the building.

4. Conclusion

This paper summarizes the erosion principle and protection methods of reinforced concrete by acidic compounds in rainwater. This is the basis for studying the impact of rainwater erosion on the structure. The cement stone in the structure and carbon dioxide produce carbonization, and the alkaline substances in the structure will undergo acid-base neutralization reaction with the acidic compounds in the rainwater, thus destroying the original substances of the structure, and the products of the reaction will cause the structure to expand and destroy from the inside, which is the most essential reason for the impact of rainwater erosion on the reinforced concrete structure.

In the acid rain environment, the mechanical properties of reinforced concrete will decline as a whole. The products produced by the acid-base neutralization reaction will cause the structure to dissolve and expand and destroy from the inside, reducing the compressive and bending resistance of the structure. The bonding performance of reinforced concrete structures will increase first and then significantly decrease under the gradual deepening of rain erosion.

In summary, after revealing the erosion mechanism of reinforced concrete by acid rain, that can change the selection of materials in different regions in a more targeted manner to better improve and innovate. Improve the endurance, sustainability, socio-economic benefits, etc. of reinforced concrete buildings to varying degrees.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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