Study on Mechanical and Structural Damage Characteristics of Concrete Corrosion by Acid Solution

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Abstract: Concrete has good plasticity and durability and is an important part of building construction. It is widely used in building structures. However, at present, concrete is applied in construction engineering, and there are still problems of corrosion and weathering, resulting in shortened use of the building structure. To this end, based on the durability of concrete and the theoretical basis of acid solution corrosion, this paper discusses the mechanism of corrosion degradation of concrete by acid solution. On this basis, the damage characteristics of concrete solution to concrete mechanics and structure are analyzed in detail, in order to supplement the research foundation of related fields, and provide reference for the effect of concrete to reduce the corrosion of acid solution.

1. Research background

1.1 Literature review

In recent years, many scholars have increased the research on the causes of concrete damage. Among them, many scholars have begun to take shape in the study of acid-eroded concrete. In order to study the damage evolution of concrete during compression and acid corrosion, the tensile test of concrete prism specimens was carried out with a mixture of nitric acid and sulfuric acid with a pH of 2.5 (Zhang et al, 2013). Nie Liangxue et al. used electron microscopy to explore the weakening law of sulfate on concrete strength. Studies have found that the sulphate environment can greatly impair the performance of concrete (Nie et al, 2016). Liu Juanhong et al. used environmental scanning electron microscopy and energy dispersive spectroscopy to observe the corrosive environment of concrete eroded by 10% sodium sulphate solution under the action of dry and wet cycle, and combined with X-ray diffraction test to analyze the different erosive periods of sulphate. The variation characteristics and damage mechanism of axial compression (Liu et al, 2016). Liu Hao et al. compared the changes of compressive strength, corrosion resistance and mass change rate of concrete under the coupling corrosion of single sulfate and sulfate-chlorine salt, and analyzed the corrosion of concrete under different corrosive environments. Characteristics (Liu et al, 2016). Han Tielin et al. soaked sandstone samples in neutral Na_2SO_4 solution, acidic Na_2SO_4 solution and alkaline NaOH solution, and observed the changes of physical and mechanical characteristics of sandstone freeze-thaw cycles and the degree of damage degradation under different chemical corrosion. The experimental results show that the increase of the number of freeze-thaw cycles will increase the damage degree of sandstone by different chemical solutions. Among them, sandstone immersed in acidic solution has the greatest damage (Han et al, 2017).

1.2 Purposes of research

Concrete is the most commonly used type of structure in building structures. The durability of concrete structures can directly affect the safety and service life of building structures, so it has long been the focus of the community. Compared with general building materials, concrete structures have good durability and are therefore widely used in the construction industry. However, with the prolonged use time, the concrete structures of many buildings have been damaged to varying degrees by extreme natural environments, such as acid corrosion, chloride ion corrosion and low temperature freezing. Among them, the concrete structures located in the eastern coastal areas and

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the high salinized soil areas in the south, such as bridges across rivers, building buildings and offshore working platforms, are often eroded by acid salts, resulting in significant degradation of the mechanical properties of concrete and internal structures. Destruction severely weakens the durability of the building (Xuan et al, 2017). At present, domestic scholars have conducted research and experiments in this area, hoping to find out the rules and characteristics of acid corrosion on the structural damage of concrete, but these studies are still few, and there are certain deficiencies. To this end, this paper focuses on the mechanical and structural damage characteristics of concrete solution corrosion, and hopes to supplement the research foundation of related fields, and provide reference and ideas for the durability of concrete structures.

2. Durability of concrete and corrosion of acid solution

2.1 Durability

Concrete is more convenient, cheaper, and relatively strong, so it is commonly used in engineering structures such as infrastructure, transportation, logistics, building construction and water conservancy. At present, concrete has become an important building material in the field of civil engineering. However, at present, many buildings have experienced concrete durability problems during their use. This not only makes the building structure difficult to operate normally, but also brings huge economic burden to the country. For example, Sweden spends more than $30 million annually on bridge repairs; the amount of maintenance investment in construction concrete used in the United States in early years accounted for 50% of total construction investment. In the sulphate-rich areas of China's coastal areas, North China, Northwest China and Southwest China, the concrete structure suffers from strong acid erosion, which will cause serious damage to the concrete structure of the building. Therefore, analyzing the factors affecting the durability of concrete structures and exploring ways to systematically improve the performance of concrete has important practical significance for promoting the healthy and sustainable development of the construction industry.

2.2 Acid solution corrosion

There are hydration products in the concrete. When these substances come into contact with acidic substances in the external environment, a certain chemical reaction occurs and an intumescent substance is produced. If these swelling materials accumulate and become larger, the original structure of the concrete will be destroyed, thereby reducing the durability of the concrete. This is the so-called chemical erosion effect of concrete. Among the chemical erosion effects of concrete, sulfate attack beyond the general concentration line is the most common form. At the same time, sulfate attack in soil or groundwater is one of the main factors causing failure of concrete materials. In areas with high concentrations of sulfate, this erosion has seriously affected the normal operation of construction projects. Statistics from experts in the former Soviet Union show that the loss of domestic concrete structures due to erosion damage accounts for about 1.3% of GDP. Japan is an island country and is surrounded by the sea. A large number of domestic buildings are located in coastal areas and are eroded by seawater all the year round, so the working years are relatively low. Therefore, further systematic studies on the corrosive action of acid solutions are necessary.

3. Mechanism of corrosion degradation of concrete by acid solution

3.1 Calcium gangue corrosion

The hydration products $4CaO \cdot Al_2O_3 \cdot 19H_2O$ and $3CaO \cdot Al_2O_3 \cdot CaSO_4 18H_2O$ of cement C_3A can react with $CaSO_4 \cdot 2H_2O$ and produce larger ettringite:

$$(4CaO\cdot Al_2O_3\cdot 19H_2O)+3CaSO_4+14H_2O\rightarrow \\ (3CaO\cdot Al_2O_3\cdot 3CaSO_4\cdot 32H_2O)+Ca(OH)_2 \quad (1)$$

$$(3CaO\cdot Al_2O_3\cdot CaSO_4\cdot 18H_2O)+2CaSO_4+14H_2O\rightarrow \\ (3CaO\cdot Al_2O_3\cdot 3CaSO_4\cdot 32H_2O) \quad (2)$$

Among them, the solubility of $3CaO\cdot Al_2O_3\cdot 3CaSO_4 32H_2O$ is relatively low. The volume of the product ettringite precipitated in the solution is about 10 times that of the reactants $4CaO\cdot Al_2O_3\cdot 19H_2O$ and $3CaO\cdot Al_2O_3\cdot CaSO_4 18H_2O$, and thus the damage to the concrete structure is relatively strong.

3.2 Gypsum corrosion

The medium $Ca(OH)_2$ of the cement stone reacts with the sulfate in the solution to form gypsum:

$$Ca(OH)_2+NaSO_4\cdot 10H_2O\rightarrow CaSO_4\cdot 2H_2O+2NaOH+8H_2O \quad (3)$$

In the circulating solution, this chemical reaction is continuously carried out until $Ca(OH)_2$ is fully reacted; in the non-circulating solution, the gradual accumulation of $NaOH$ causes the two to reach equilibrium, thereby precipitating a portion of the gypsum exceeding the solubility. The gypsum volume will increase by a factor of three, destroying the concrete.

3.3 Magnesium sulfate corrosion

$$(3CaO\cdot 2SiO_2\cdot 3H_2O)+3MgSO_4+10H_2O\rightarrow \\ 3(CaSO_4 2H_2O)+3Mg(OH)_2+3(2SiO_2 4H_2O) \quad (4)$$

It can be seen from the formula (4) that in addition to the corrosive action of sulfate, in the non-flowing magnesium sulfate solution, the magnesium ion can destroy the gelation property of the concrete and further reduce the strength to the concrete.

3.4 Calcareous corrosion

Sulfate generates calcium silica $CaCO_3\cdot CaSO_4\cdot CaSiO_2\cdot 15H_2O$ during the corrosion process. Moreover, under low temperature conditions, $Ca(OH)_2$, $CaCO_3$, amorphous SiO_2 and gypsum will chemically react to form wollastonite. Calcium silica causes the concrete to burst and become brittle, resulting in loss of quality.

4. Damage characteristics of concrete mechanics and structure caused by acid solution corrosion

In this test, a prism of 90 mm × 90 mm × 280 mm was used as a concrete test piece. In order to minimize the dispersion caused by the concrete pouring process, the same batch of C45 commodity, the factory slump of 170mm concrete, the Dashahe medium sand, the ordinary 42.5R grade cement, and the 5-25mm continuous grade green gravel are used. . A mixture of sulfuric acid and nitric acid having a corrosive medium of pH 2.5 was used, and the molar ratio was 9:1. The test pieces are divided into 4 groups, which are group A, group B, group C and group D. Among them, the acid solution corrosion test was performed only for group B and group D, and the experimental period was 90 days; corrosion of group A and group C was not performed. And in the process of etching Group B and Group D, the pH value of the mixed acid solution was measured every 2d, and sulfuric acid was added in time. The load loading scheme is shown in Figure 1.

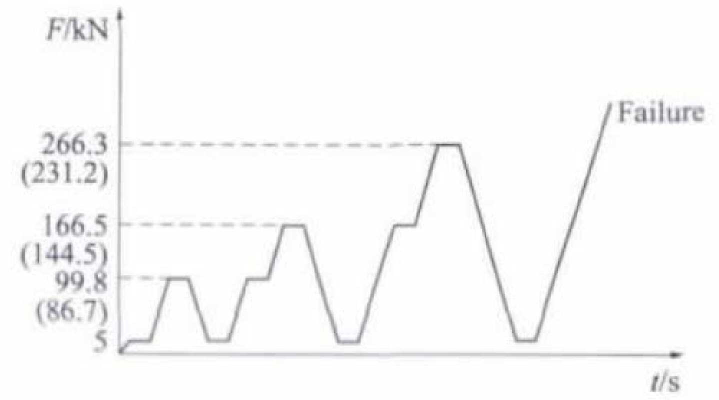

Figure 1. Loading Scheme

Through experimental data and results analysis, it can be found that the compressive strength of concrete specimens decreased significantly after 90 days of corrosion cycle; the mixture of sulfuric acid and nitric acid with pH value of 2.5 used in the experiment significantly reduced the corrosion effect of concrete structures. It can be seen that the corrosion of the acid solution can change the chemical composition and the mesostructure of the concrete, thereby causing damage to the concrete material and structure.

After being eroded by the acid solution, the strength of the concrete structure will mainly undergo two stages of evolution. At the beginning of the corrosion of the acid solution, the crystals of the newly formed acid solution gradually expand to form an expanded product. However, this kind of expansion is relatively small, which not only increases the compactness of the concrete structure, but also improves the quality and strength of the concrete.

In the late stage of acid solution corrosion, a large amount of expansion is produced, and the mention is increasing. This causes the expansion stress in the concrete pore structure to gradually exceed the concrete strength. Under the secondary action, the internal micro-cracks of the concrete structure are continuously widened, thereby reducing the strength, dynamic modulus and quality of the concrete structure.

In general, under the erosion of the acid solution, the concrete structure is subject to expansion, and the interior of the concrete begins to rupture due to the force. At the same time as the expansion force increases, the cracks on the concrete surface begin to appear gradually, and the material of the structural surface gradually peels off. Therefore, the concrete gradually shows a relatively fragile state.

To reduce the damage to the mechanics and structure of concrete by acid solution corrosion, or to improve the quality of the eroded concrete, construction companies can add fly ash to the concrete. With the advantages of fly ash structure, chemical composition and particle shape, the fly ash effect is formed in the concrete to improve the corrosion resistance of the concrete.

5. Conclusion

With the development of social economy and the improvement of people's material needs, China's construction industry has developed rapidly. As an important part of the building structure, concrete plays an important role in improving the durability of the building structure. However, acid solutions are common in water and soil in many parts of China. The corrosion of these acid solutions causes great damage to the mechanics and structure of the concrete, which greatly reduces the length of use of the building and brings great safety risks. To this end, construction companies should fully understand the characteristics of acid solution corrosion on concrete mechanics and structural damage, and accordingly give corresponding optimization strategies to improve the use value of concrete building structures.

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