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Research and Application of ECC in Chloride Environment

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Abstract: In Marine environment and coastal areas, concrete structures often face chlorine salt erosion, which poses a severe challenge to the durability and mechanical properties of structural materials. Chlorine salts enter into concrete through osmosis, causing corrosion of steel bars and deterioration of concrete, resulting in a significant decline in structural bearing capacity and durability. As a new type of composite material, ECC shows great potential in strengthening and repairing RC structures due to its excellent corrosion resistance, high specific strength and good crack control effect. This paper introduces the mechanical properties and application of ECC in chlorine environment, and puts forward the optimization direction for the future application of ECC in chlorine environment.

Keywords: Application prospect; Chloride environment; ECC; Mechanical property.

1. Introduction

In the western part of China, there are a lot of saline soil and salt lakes, while the eastern and southern parts of China are rich in Marine resources[1] . With the development of resources, more and more salt lake projects, coastal and Marine projects are constructed. The concrete structures in these areas are in a dry-wet cycle environment, and the environment is rich in aggressive chloride ions[2]. The effect of chlorine salt environment can lead to durability and safety problems such as cracking of concrete structure and corrosion of steel bars, among which the coupling effect leads to durability failure of concrete structure and premature termination of service of concrete.

ECC's unique strain hardening properties and crack control capabilities give it significant advantages in harsh environments, such as chlorine salt environments. In recent years, the research of ECC in chlorine salt environment has been deepening, which provides a solid theoretical foundation for the wide application of ECC in bridge, harbor, underground engineering and other fields. Considering practical engineering application, the advantages and characteristics of ECC in chloride environment are described in this paper.

2. Basic Features and Advantages of ECC

In the 1990s, Professor Li VC et al., guided by micromechanics and fracture mechanics, analyzed the strain hardening phenomenon of flexible fibril reinforced quasi-brittle basic materials on the basis of the bond fracture model, taking into account the bridging effect of random random fibers, and proposed a new method based on cement, fly ash, fine sand and some admixtures. The product is made by mixing with PVA fiber in a certain proportion and adding a certain volume ratio, which will be named Engineering cementitious composites (ECC) for the first time [3]. As a new cement-based composite material, ECC has many unique properties. First, ECC has excellent strain hardening properties and can form multiple fine and evenly distributed cracks under tensile load, which significantly improves the toughness and durability of the material. Second, ECC's crack control capabilities are excellent, significantly reducing the width and number of cracks, reducing the risk of moisture and harmful substances penetrating. In addition, ECC also has good durability and impermeability, which can maintain good mechanical properties and stability in harsh environments.

In the chlorine environment, the advantages of ECC are particularly prominent. Chlorine salt erosion is one of the important factors leading to structural durability problems, and ECC's crack control ability and impermability can effectively reduce the penetration risk of chloride ions, thereby extending the service life of the structure. At the same time, the excellent toughness of ECC can also improve the overall stability of the structure in the chlorine salt environment.

3. Effect of Chloride Environment on ECC Performance

The influence of chloride environment on ECC performance is mainly reflected in the infiltration and erosion of chloride ions. The infiltration of chloride ions will lead to corrosion of the steel bars inside the ECC, which will lead to structural durability problems. Therefore, it is of great significance to study the influence of chlorine environment on ECC performance for evaluating the durability of ECC in chlorine environment and formulating corresponding protection measures. The permeability of chloride ions is a key indicator of the durability of ECC in chloride environment.

Sun Guowen et al.[4] through comparative analysis of the chloride ion diffusion coefficient of ECC and concrete specimens with different types, particle size distributions and volume fractions of aggregates, showed that aggregate changed the pore structure of the slurry in cement-based composite materials, and its dilution effect and zigzag effect reduced the chloride ion transport performance. The special microstructure of the interface region increases the transmission performance, and the effect of the interface region is greater than the tortuous and dilution effects.

Liu et al. [5]conducted a static mechanical property test on ECC under sulfate and chloride ion attack and found that ECC had durability in this environment, and ECC healed faster and more completely in this environment than in water. The durability was still maintained after 200 days, and the compressive and tensile strength of ECC increased with the increase of erosion time, while the tensile strain capacity decreased slightly.

Xu Shi-lang et al. [6]conducted a rapid chloride ion penetration test on ultra-high toughness cement-based composite (UHTCC). The results show that the permeability resistance of UHTCC is better than that of ordinary concrete of the same strength, and the advantages are more obvious with the growth of age. The permeability coefficient at 56 days of age is about 35% of that of contrast concrete. By measuring the free chloride ion content, the results show that UHTCC has significantly better chloride ion permeability resistance than ordinary concrete.

Zhong Junfei et al.[7] studied the influence of PVA fiber on the chloride ion permeability resistance of ECC, and the results show that PVA-ECC has obvious chloride ion permeability resistance compared with ordinary concrete.

Liu Peng et al.[8]carried out an experimental study on chloride ion erosion of ECC in order to explore the ability of ECC to resist chloride salt erosion under soaking conditions. The results show that the smaller the water-binder ratio, the smaller the chloride ion erosion depth; The greater the chloride concentration, the greater the erosion depth. With the increase of erosion time, the chloride ion erosion depth increased rapidly within 30 days of immersion, and the growth rate of chloride ion erosion depth decreased after 30 days.

Gao Shuling et al.[9]studied the freeze-resistance of PVA-ECC in fresh water and chlorine salts respectively based on the quick-freezing method, and the results showed that PVA-ECC had poor freeze-resistance and serious surface peeling in chlorine salt environment.

Wu Lili et al. [10]compared the differences in bond slip curves between GFRP bars and engineering cement-based composites (ECC) under normal environment, saline-alkali and freeze-thaw cycles. The results showed that the tensile and cracking properties of ECC specimens with fiber added were improved, and the specimens were mainly pulled out and broken with cracks: On the contrary, the tensile properties of ordinary concrete specimens are poor, and the splitting failure will occur. However, the freeze-thaw cycle makes the matrix loose, the encapsulation of GFRP bars becomes poor, and the mechanical biting force of the bonding interface is not enough to completely separate the cement, which changes the failure mode of the specimen.

4. Engineering Application of ECC in Chloride Environment

The engineering application of ECC in chlorine salt environment is mainly concentrated in the fields of bridge cold alternate infrastructure, harbor engineering, underground engineering and so on. These engineering structures are subjected to the erosion of sea wind and sea water for a long time, and the durability of materials and crack control ability are required. ECC is widely used in these fields because of its excellent durability and crack control ability. The following is a list of specific application scenarios:

Coastal transportation infrastructure: ECC has a wide range of application prospects in transportation infrastructure such as Bridges, roads and tunnels in coastal areas because of its excellent durability and crack control ability[11]. Especially in bridge structure, ECC can be used as bridge deck paving material to effectively reduce cracks caused by vehicle load and improve the flatness and service life of bridge deck. At the same time, ECC can also be used for bridge reinforcement and repair to improve the overall bearing capacity and durability of the structure.

Seaport and Marine engineering: Seaport and Marine engineering are in a high salinity and high humidity environment for a long time, which requires very high durability of materials. ECC's multi-fine crack characteristics can effectively prevent the penetration of seawater and protect the internal structure from corrosion. Therefore, ECC has a wide range of applications in the construction of seaports, offshore platforms and undersea tunnels.

Breakwaters and revetment works: Breakwaters and revetment works are an important part of Marine engineering, and they directly face the impact and erosion of the waves. Because of its high toughness and durability, ECC can effectively resist the impact and erosion of the waves and protect the coastline from damage.

Structural repair and reinforcement: ECC can also be used to repair and reinforce existing structures[12] .Especially in the chlorine salt environment, ECC can effectively prevent the penetration of chloride ions, prevent the corrosion of steel bars and damage to the structure. At the same time, ECC's high ductility and crack control ability can also improve the overall bearing capacity and seismic performance of the structure.

5. Challenges and Prospects of ECC Application in Chloride Environment

Although ECC has significant application advantages in chlorine environment, it still faces some challenges in practical application. First, the material and construction costs of ECC are relatively high, which limits its application in some low-cost projects. Secondly, the durability and long-term performance of ECC still need to be further studied and verified to ensure its stable performance under long-term loads and environmental erosion. In addition, the deterioration mechanism and protective measures of ECC in chlorine salt environment also need to be further studied in order to improve its service life in harsh environments. The future application of ECC may show the following trends:

the optimization and improvement of material properties, through further research and optimization of the material ratio and microstructure of ECC, can further improve its strength and toughness, reduce material costs, and improve construction efficiency. This will provide stronger support for the wide application of ECC in chloride environment.

To strengthen the research on the durability and long-term performance of ECC in chlorine salt environment, establish a more perfect evaluation system and prediction model, so as to accurately evaluate the service life and performance of ECC in practical engineering. This will provide a more reliable scientific basis for the wide application of ECC.

Research and development and application of protective measures, in view of the deterioration mechanism of ECC in chlorine salt environment, research and development of more effective protective measures, such as surface coating,

waterproof layer, etc., in order to improve the corrosion resistance and service life of ECC. At the same time, strengthen the maintenance and maintenance of ECC in the chlorine salt environment to ensure that it maintains stable performance under long-term load and environmental erosion.

6. Conclusion

As a new type of composite material, ECC has significant application advantages and potential in chlorine salt environment. Excellent durability and crack control under conditions of stress and environmental erosion. In the chlorine environment, the performance of ECC will be degraded to a certain extent, but through reasonable protective measures and maintenance, its service life can be extended. In the future, with the optimization of material properties, the deepening of durability and long-term performance research, as well as the development and application of protective measures, the application of ECC in chlorine salt environment will be more extensive and in-depth.

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