Academic Education Publishing House

Research on Concrete Impermeability Lifting Method Under Marine Environment

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Abstract: With the development of Marine economy and the acceleration of offshore construction, the durability of concrete in Marine environment is becoming increasingly prominent. Based on a large number of domestic and foreign research data, this paper deeply discusses the methods and significance of enhancing concrete impermeability under Marine environment. Firstly, the challenges of concrete in Marine environment are summarized, especially the erosion of concrete structures by chloride ions. Then, the diffusion mechanism of chloride ions in concrete and its effect on the corrosion of steel bars are analyzed in detail. On this basis, this paper summarizes the research achievements of concrete impermeability technology at home and abroad, and points out the future research direction. Finally, the paper emphasizes the importance of improving concrete impermeability to promote the construction of ecological civilization and scientific and technological innovation.

Keywords: Marine Environment; Concrete; Impermeability; Chloride Ion; Reinforcement Corrosion

1. Introduction

Concrete, as a key construction material for many infrastructure projects, faces a severe test when it is used in Marine environments. Chloride ion is the most important erosion factor in seawater environment, it can enter the concrete through diffusion, cause structural damage and function reduction, and even affect the use of construction engineering safety. Therefore, improving the impermeability of concrete in the Marine environment has become the focus of the industry.

With the proposal of China's maritime Silk Road development strategy, Marine economy and Marine engineering construction will usher in rapid development, and coastal cities will build a large number of ports, cross-sea Bridges and other Marine engineering facilities. Concrete in seawater environment will face much greater tests during its actual service period than ordinary environment. The biggest feature of the seawater environment is that it contains chlorine salts, and chloride ions can easily penetrate into the concrete, causing structural damage, functional reduction and even affecting the safety of construction projects. The diffusion of chloride ions in concrete is mainly carried out through its corresponding surface and interface, that is, through various macroscopic cracks or large defects in concrete, concrete interfaces, various micro-cracks and relatively large pores such as transition holes and capillary pores. Therefore, in the seawater environment, how to reduce the impact of chloride ions on concrete, how to improve the permeability of concrete in the seawater environment is a problem that the industry has been concerned about. Based on this, the comprehensive application of concrete impermeability lifting method in Marine environment is studied in this paper. [1]

2. Chloride Ion Diffusion in Concrete and Reinforcement Corrosion

The diffusion of chloride ions in concrete is mainly carried out through macroscopic cracks, interfaces, micro-cracks and pores in concrete. When the chloride ions reach the surface of the steel bar, it will destroy the oxidation layer on the surface of the steel bar, resulting in corrosion of the steel bar. The anode and cathode regions formed during corrosion will accelerate the corrosion rate of steel bars and seriously affect the durability of concrete structures.

2.1 Diffusion of Chloride Ions in Concrete

The infiltration problem of chloride ions in cement concrete structures is becoming more and more serious in Marine environment, especially when the structures undergo dry and wet cycles. The transport of chloride ions will bring many problems to the reinforced concrete structure, the most important of which is the corrosion of steel bars. The chloride transport mechanism usually consists of two main components, namely capillary suction and diffusion. [2]

The diffusion of chloride ions in concrete is basically carried out through pore solution. Diffusion through liquids is much faster than through solids, and the diffusion rate of chloride ions is closely related to the nature and number of various pores and the degree of porosity. The diameter of chloride ions is about 0.2nm, and the chloride ions in solution cannot pass through the gel pores due to solvation, which binds a certain number of water molecules. Therefore, the diffusion of chloride ions in concrete is mainly carried out through its corresponding surface and interface, that is, through various macroscopic cracks or large defects in concrete, the interface of concrete, various micro-cracks and relatively large pores (such as transition holes and capillary pores). [3]

2.2 Physical and Chemical Changes of Concrete Caused by Seawater

The erosion of concrete by seawater containing SO42- and Cl- firstly results in the dissolution of CH and C4AH13 and the formation of AFt. With the dissolution of CH, the pH value decreases, and when the pH value reaches 11.6~10.6, gypsum is formed. When pH value is 10.6, AFt decomposing into silica gel, and when pH value is lower than 8.8, CSH decomposing into silica gel, resulting in expansive corrosion products of concrete, resulting in strength loss of cement hydration products and destruction of adhesive force, resulting in cracking of concrete, increased permeability, and accelerated deterioration of concrete. Secondly, the chlorine salt in the sea water accounts for more than 80% of the total salt, chloride ion is a strong anode activator, chloride ion and concrete steel bar surface Fe3O4-γFe2O3 passivation film action, resulting in steel bar corrosion caused by volume expansion, cracks in the protective layer, and ultimately lead to the destruction of concrete structure.

1.3 Corrosion of steel bars by chloride ions

Reinforced concrete is a composite material, the steel bar has a good tensile performance, and the concrete has a high compressive strength, the combination of the two can meet the resistance requirements required in the construction. For the steel bar alone, it does not have good corrosion resistance, but when it is combined with concrete, due to the hydration of concrete will produce hydroxide, the presence of a large number of hydroxide ions will turn the environment into a strong alkaline, the pH value can reach about 12.5, which will lead to the oxidation of the outer surface of the steel bar, so that it is in a passivation state. Thus, the anode electrolysis of the steel bar is prevented, and better corrosion resistance can be obtained. If the oxidation layer of the steel bar surface is destroyed, the durability of the reinforced concrete structure will be greatly reduced. When the oxide layer on the surface of the passivated steel bar is eroded by carbide or chloride, causing partial or total damage, it will cause the potential of the steel bar to change, forming the anode zone, and the part of the passivated layer that is not damaged will form the cathode zone, thus forming the galvanic cell and accelerating the corrosion of the steel bar. There are two ways for chloride ions to be mixed into concrete: one is doping, such as using chlorine-containing admixtures, sea sand, construction water containing chloride ions, and mixing and pouring concrete in a salt-containing environment; The second is infiltration, the molded concrete will have certain defects, and itself has characteristics such as porosity, chloride ions in the environment are easy to penetrate into the concrete, and reach the surface of the steel bar. [4]

3. Research Status at Home and Abroad

The durability of engineering structures under corrosive environment is a hot issue at home and abroad, and the impervious property of engineering materials is an important index to evaluate the durability and effective service life of materials. At present, domestic and foreign scholars have carried out more research on the standard environment of soil-soil, but the research on the seepage resistance of soil-soil in erosion environment is few.

3.1 Foreign Research Situation

Meng T et al. studied the development of cement strength and its impact on microstructure in Marine environment by adding composite nano-calcium carbonate. They believed that Marine environment had a great impact on the strength and durability of soil-cement and composite nano-materials, and the addition of calcium carbonate could effectively improve the compressive strength of soil-cement at early and late ages. In addition, the addition of composite nano-calcium carbonate is beneficial to reduce the corrosion rate of soil-cement in Marine environment and improve its compactness.

Fatahi B et al. mixed polypropylene, recycled carpet and steel fibers into soil-cement, studied the influence of fibers on its mechanical properties, and found that the addition of fibers can increase the residual strength of soil-cement, and make the brittle damage of soil-cement into the brittle behavior of ductile materials.

Tajdini M et al. compared and analyzed the properties of soil-cement by adding natural fibers and synthetic fibers, and concluded that fibers play an undeniable role in changing the fiber matrix from brittleness to ductility, which can greatly improve the properties of soil-cement. By using seawater mixing, Chen Jie deeply studied the comprehensive effect of fiber on reinforced soil-cement, and found that the expansion rate of soil-cement could be reduced after the addition of fiber, and the expansion rate decreased significantly with the increase of fiber content. It shows that fiber can not only effectively inhibit the expansion of solid matrix, but also enhance its compressive and flexion strength, so as to alleviate the erosion effect of seawater on soil-cement.

Mousavi S and Kalantari B et al. studied the curing mechanism of soil-cement and the influence of silica powder on the strength of soil-cement by studying the improvement properties of soil-cement with silica powder. However, Pei Xiangjun et al. further demonstrated the strengthening mechanism of nano-silica powder on soil-cement under Marine environment through laboratory tests, and found that silica powder particles can play a filling role between cement particles, and the products of secondary hydration can reduce the pores of soil-cement, indicating that nano-silica powder can also inhibit the expansion damage of soil-cement under Marine environment and improve its early strength. [5]

3.2 Domestic Research Results

Chu Chengfu et al. concluded that volcanic ash effect would occur when fly ash was added to soil-cement as an admixture through soil-cement reinforcement test of saline soil. When the amount of fly ash was 10%, the strength of the added solid could be increased by about 30%. [6]

Miao Jiale and Pei Xiangjun et al. also studied the influence of fly ash on soil-cement through a large number of tests, and the results showed that fly ash had a good effect on inhibiting the erosion and damage of soil-cement in the Marine environment, and had an obvious effect on improving the mechanical properties of soil-cement structure in the later stage. [7]

Based on the actual construction situation of deep mixing pile in the reclamation area of Shenzhen-Hong Kong Western Passage, Huang Hansheng et al. found that the groundwater and seawater had a certain degree of corrosion to soil-cement, and obtained a soil-cement formula with corrosion resistance. It can be seen from the study that the corrosion resistance of pure cement and cement made of cement as curing agent is relatively poor; The compression strength and durability of soil-cement can be greatly improved by adding proper amount of slag and fly ash into soil-cement instead of partial cement. Finally, the test also unlocked the corrosion resistant soil-cement formula required for site construction: that is, the quality of slag and fly ash accounted for 40%-60% of the curing agent, which can be used as a reference for similar projects. [8]

4. Methods for Improving the Impermeability of Concrete

4.1 Optimize the Concrete Mix Design to Improve the Compactness and Impermeability of Concrete

4.1.1 Selection Principle

The main properties of high performance concrete are high workability, high strength and high durability. High workability is that the slump of the concrete is controlled at 18~22cm, and the water retention and cohesion are good. The strength of concrete depends on the strength of coarse aggregate, the strength of cement stone and the bond strength of cement stone and aggregate. Among the three, the bond strength of cement stone and aggregate is the weakest, which is the key to improve the strength of concrete. The bond strength is related to the strength of cement stone, which increases with the strength of cement stone, so improving the strength of cement stone is an important factor to improve the strength of concrete [9]. The strength of cement is related to the grade of cement, the condition and structure of the void in cement. It is very important to improve the cement grade, especially the condition and structure of the void in the cement stone, to increase the strength of concrete. It can be seen that the selection of raw materials and the design of mix ratio of high performance concrete are particularly important [10].

4.1.2 Ratio principle.

The key of preparing high strength concrete is to improve the compactness of concrete. To improve the compactness of concrete, start with the grading of coarse aggregate, so that the gap between stones is the smallest, the total amount of cementing material is the smallest, the cement used is the least, the water consumption is the least, so that the organizational structure of concrete can achieve the purpose of uniform compactness. In this way, because the total amount of cementing material is the least, the plastic shrinkage settlement cracks are less, the water requirement is less, and the self-shrinkage cracks are less; The amount of cement is less, the hydration heat generated in the hydration process is less, and the temperature cracks are less; The amount of cement is less, the Ca(OH)2 precipitated by cement hydration is less, and the alkali-aggregate reaction is avoided. The amount of cement is less, the calcium aluminate hydrate generated by cement reaction is less, and the possibility of sulfate erosion of concrete swelling and cracking is reduced.

4.1.3 Selection and Ratio Requirements

In the selection of cement, it is first necessary to improve the grade of cement, and give priority to the selection of cement varieties with high strength and low hydration heat. For example, low-heat Portland cement, fly ash Portland cement, etc., the heat of hydration is relatively low, and the durability of impermeability is enhanced, which is the first choice for Marine engineering. However, the amount should be strictly controlled in use, if the amount is too much, the temperature stress generated inside the concrete will be too large, thus affecting its impermeability.

Secondly, the selection and ratio of aggregates should be strictly controlled. Coarse aggregate should be preferred with good grading, hard texture, rough surface and low porosity, and its maximum particle size should be moderate, which can not only ensure the strength of concrete, but also reduce the porosity and cracks inside the concrete. Medium sand should be used for fine aggregate, and its fineness modulus should be within a reasonable range, and the mud content and mud lump content should be as low as possible to reduce the weak links in concrete.

In addition, the water-cement ratio is one of the key factors affecting the concrete compactness and impermeability. Reducing the water-cement ratio can reduce the pores formed by the evaporation of excess water during the hardening process of concrete, thus improving its impermeability. However, too low water-cement ratio may affect the construction workability of concrete, so it is necessary to reduce the water-cement ratio as far as possible under the premise of ensuring the construction performance.

Finally, reasonable mixing, pouring and curing technology is also an important link to ensure the optimization effect of concrete mix ratio. Mixing should be fully uniform to ensure that the components are evenly distributed; When pouring, vibration and compaction should be avoided to avoid leakage or over-vibration; The maintenance should be timely and sufficient to keep the concrete hardened under appropriate temperature and humidity conditions and reduce the generation of shrinkage cracks.

4.2 Use of High-Performance Concrete Admixtures, Such as Silica Fume, Fly Ash, etc., to Improve the Microstructure of Concrete

4.2.1 Mechanism

In order to make the concrete fully hydrated, it is necessary to add mineral admixtures such as fly ash, slag and silica fume to effectively improve the performance of concrete. They can not only fill the pores in concrete, refine the pore structure, and improve the compactness of concrete. At the same time, it can also react with cement hydration products twice to further enhance the strength and impermeability of concrete.

4.2.1.1 Interface Transition Zone Enhancement

In high performance concrete, the interfacial transition zone between aggregate and cement slurry can be improved by adding mineral admixtures such as silica fume. This reinforced interfacial transition zone reduces the accumulation and penetration of water at the interface and improves the water resistance of the concrete as a whole. Because the interface is often a weak link in the concrete structure and is more sensitive to water penetration, improving the interface transition zone can significantly improve the water intolerance of concrete.

4.2.1.2 Secondary hydration reaction

Some mineral admixtures replace cement as micro-aggregate filling, which makes concrete more dense, improves concrete strength, and improves durability. The active component of some mineral admixtures (SiO2) and cement hydration product Ca(OH)2 undergo secondary hydration reaction to form C-S-H gel, which further increases the strength of cement and reduces the content of Ca(OH)2(low strength). If the Ca(OH)2 content in concrete is high, the concrete is easily corroded by various media. Through the secondary hydration reaction, the structure of cement-aggregate interface zone can be improved effectively. Active SiO2 and Al2O3 react with cement hydration products to produce hydrated calcium silicate and hydrated calcium aluminate. In addition to gelling and hardening, the resulting gel can also fill capillary pores, thereby improving the compactness of concrete. At the same time, the secondary hydration reaction also reduces the alkalinity of the liquid phase in concrete, further promotes the hydration of cement, and improves the later strength of concrete.

4.2.2 Synergistic effect

The combined use of silica fume and fly ash can play a synergistic effect and further improve the impermeability of concrete. Silica fume is a by-product of industrial furnace smelting industrial silicon and ferrosilicon alloy at high temperature. It is an ultra-fine powder with extremely high activity. The particles are extremely fine and can be filled into the void between the cement particles, making the microstructure of concrete more dense, reducing the pores and connecting channels, so as to improve the permeability resistance. In the later stage, the active ingredients in the fly ash will undergo secondary hydration reaction with the cement hydration products to produce hydration products with low calcium-silicon ratio, refine the pore structure and reduce the permeability. Fly ash is the fine ash collected from the flue gas after coal combustion, and is the main solid waste discharged from coal-fired power plants. Most of the particles are spherical, with good ball effect, which can improve the workability of concrete, make concrete more dense in the pouring process, and reduce the internal pores. It has high pozzolash activity and can react with calcium hydroxide produced by cement hydration to generate more hydrated calcium silicate gel, which enhances the interfacial transition zone between cement slurry and aggregate and reduces permeability. Silica fume mainly plays the role of filling and strengthening in the early stage, while fly ash continuously improves the microstructure of concrete through secondary hydration reaction in the later stage. The complementary effect of the two makes the concrete maintain good impermeability at different ages. Air entrainment agents can also be used to introduce tiny uniform bubbles to improve the workability of the concrete, while blocking the capillary channels inside the concrete to improve the impermeability. However, the amount of air entrainment agent should be strictly controlled to avoid excessive bubbles affecting the strength of concrete.

4.3 Use Admixtures Resistant to Chloride Ion Erosion to Reduce the Diffusion Rate of Chloride Ions in Concrete

4.3.1 Mechanism

The admixture resisting chloride ion attack can greatly improve the microstructure of concrete and enhance the physicochemical action. First, pore structure optimization. The admixture can refine the pore structure inside the concrete, reduce the connected pores, increase the compactness of the concrete, and thus hinder the transport channel of chloride ions. High performance concrete usually uses admixtures such as high efficiency water reducing agents, which can reduce the water consumption during the concrete mixing process, thereby reducing the porosity of the concrete. The lower porosity makes it more difficult for water to penetrate into the concrete. By reducing the number and size of pores, water transport channels are reduced. At the same time, the hydration process of the cement is more complete, making the microstructure inside the concrete more dense. Cement hydration products are filled in the pores, further refining the pore structure, and improving the resistance of concrete to water penetration. The second is chemical combination. Some components of the admixture can react with chloride ions to fix them inside the concrete and reduce their diffusion capacity. The third is adsorption. The admixture can adsorb chloride ions in the concrete pore solution, reduce the concentration of its free movement, and slow down the diffusion rate [11].

4.3.2 Types and characteristics

(1) organic rust inhibitor, through adsorption or film formation on the surface of the steel bar to form a protective layer to prevent chloride ions from contacting the steel bar.

(2) inorganic rust inhibitor, which chemically reacts with chloride ions to generate stable compounds and reduce the erosibility of chloride ions.

The experimental results show that the chloride ion diffusion coefficient of concrete can be significantly reduced by rational use of admixtures, and the effect of different admixtures is different. There is an optimal value of admixture content, beyond which the effect is not obvious or may have negative effects. At present, high efficiency water reducing agent is an important part of the preparation of high performance concrete. Under the condition of low water-binder ratio, the fluidity of concrete mix is mainly regulated by the amount of water-reducing agent. By adding a certain amount of high efficiency water reducer, the free water encapsulated by the agglomeration of fine particles is released. At the same time, due to the adsorption of surfactants on the surface of the particles, the dispersion of the particles is increased, which is more conducive to the increase of fluidity. The amount of superplasticizer is generally 0.5% to 1.5% of the cementing material, which can fully stimulate the workability of cement and mixture, and obtain high-performance and super-flowing concrete through careful mix design and reasonable mixing and production.

4.3.3 Influencing factors

(1) Concrete mix ratio. The compatibility and effect between admixtures and concrete are affected by the parameters of water-binder ratio, cement variety and dosage.

(2) Environmental conditions. Environmental factors such as temperature, humidity and exposure time have important effects on the diffusion rate of chloride ions and the performance of admixtures.

In practical application, it is necessary to consider the factors such as concrete mix ratio and environmental conditions, and choose the appropriate type and amount of admixtures. At present, the antichlorinated admixtures commonly used in Marine work in China are Muhu brand UNF-5 naphthalene series water reducing agent and Muhu brand AE2 air entraining agent. According to the different requirements of concrete strength grade and application range, the conventional dosage range of water reducer is 0.3~0.8%. If it is necessary to prepare high-strength and ultra-high-strength concrete, it can be selected within the dosage range of 0.8~1.8%. In the future, the admixtures with better performance and stronger adaptability should be further developed, and their long-term effects and synergies with other protective measures should be deeply studied to better meet the durability requirements of concrete in Marine engineering.

4.4 Strengthen the Waterproof Design of Concrete Structure, Such as Setting Waterproof Layer, Drainage System etc

Through reasonable design of waterproof layer and perfect design of drainage system, the impermeability of concrete structure in Marine engineering can be effectively improved, its service life can be extended, and the safety and stability of the project can be guaranteed.

4.4.1 Waterproof layer design

According to the harsh degree of Marine environment and service life requirements of the project, the waterproof material with seawater erosion resistance, strong weather resistance, good flexibility and strong adhesion with concrete is preferred in the material. For example, high performance polymer modified asphalt rolls, synthetic polymer waterproof rolls or waterproof coatings. In terms of laying position, it can be laid on the surface of the concrete structure in full or key parts. For the parts that are vulnerable to seawater erosion and erosion, such as the surface of the water, the splash area, etc., to ensure the integrity and continuity of the waterproof layer. In the joint treatment, the waterproof layer should be strengthened in the joint parts of the concrete structure such as Yin and Yang Angle, deformation joint and construction joint. Additional layers and sealing materials are used to ensure that no leakage occurs at the nodes. In terms of thickness control, the thickness of the waterproof layer is reasonably determined according to the actual situation to ensure its long-term effective waterproof performance.

4.4.2 Drainage System Design

On the surface drainage, the slope is set on the surface of the concrete structure, so that rainwater and seawater can be quickly discharged and the erosion of the water on the concrete can be reduced. It can adopt the way of slope drainage, setting drainage ditch and so on. In terms of internal drainage, drainage pipes or blind drainage ditches are set up inside the concrete structure to discharge the water penetrating into the concrete in time. The layout of drainage pipes should be reasonable to avoid blockage and water accumulation. In terms of water collection and discharge, water collection Wells or water collection tanks are set up to discharge the collected water away from the structure through drainage pumps and other devices to prevent water backflow from causing damage to the concrete. At the same time, attention should be paid to filtration and purification, and filtration devices should be set up in the drainage system to filter and purify the discharged water and reduce the pollution of the Marine environment.

4.4.3 Precautions

In the design of waterproof and drainage system, a variety of factors should be considered comprehensively to ensure the design effect.

Environmental factors to fully consider the Marine environment in the wind waves, tides, temperature changes, salt spray and other factors on the impact of the waterproof layer and drainage system, take appropriate protective measures.

Pay attention to the construction feasibility, the design scheme should be convenient for construction, ensure that the waterproof layer and drainage system can be accurately installed in accordance with the design requirements, and ensure the construction quality.

Pay attention to late maintenance and overhaul, and reserve maintenance and overhaul channels to facilitate regular inspection, maintenance and replacement of the waterproof layer and drainage system to ensure long-term stable operation.

4.5 Regular Maintenance and Testing of Concrete Structures, Timely Detection and Treatment of Potential Corrosion Problems

Through regular, comprehensive and scientific maintenance and testing work, the potential corrosion problems of concrete structures in Marine engineering can be found in time, and effective treatment measures can be taken to ensure the long-term stability of concrete impermeability and ensure the safety and reliability of Marine engineering.

4.5.1 Routine Maintenance.

First of all, it is necessary to regularly clean the surface of the concrete, regularly remove the attachment of Marine organisms, dirt, salt and other pollutants on the surface of the concrete, prevent the damage of the protective layer, prevent the accumulation of dirt and salt, otherwise it will accelerate the corrosion of the concrete. High pressure water gun flushing, chemical cleaning and other methods can be used, but attention should be paid to choosing the right cleaning agent to avoid damage to the concrete.

Secondly, the coating should be repaired regularly, the integrity of the coating should be checked regularly, and the damaged and spalling parts should be repaired in time. When repairing, ensure that the new coating is well combined with the old coating and has the same protective properties.

In addition, it is necessary to deal with cracks in the first time to ensure timely discovery and emergency disposal. For small cracks, the surface sealing method can be used to fill with special crack sealing materials; For wider cracks, it is necessary to perform pressure grouting to fill the cracks tightly and prevent the intrusion of moisture and corrosive media.

It is also necessary to protect the steel bars, regularly check the rust situation, remove rust from the corroded steel bars, and take protective measures, such as brushing anti-rust paint and increasing cathodic protection.

4.5.2 Periodic testing

Appearance inspection: By observing whether there are cracks, spalling, discoloration and other phenomena on the surface of the concrete with the naked eye, the health status of the concrete is initially judged.

Ultrasonic detection: The use of ultrasonic propagation speed and reflection characteristics in concrete to detect whether there are defects, porosity, holes and other problems in the concrete.

Rebound detection: By measuring the rebound value of the concrete surface, estimate the strength of the concrete and determine whether it meets the design requirements.

Steel corrosion detection: The use of electrochemical methods, such as half cell potential method, linear polarization method, etc., to detect the degree of corrosion and corrosion rate of steel bars.

Permeability test: Through water permeability test, chloride ion permeability test and other methods to evaluate the impermeability of concrete, timely find the decline in impermeability.

4.5.3 Detect and handle potential corrosion problems in a timely manner.

First of all, it is necessary to establish a monitoring system, install sensors and monitoring equipment, real-time monitoring of the temperature, humidity, corrosion potential and other parameters of the concrete structure, and timely detection of anomalies through data analysis. According to the test results, the health status of the concrete structure is regularly evaluated, and the corresponding maintenance and reinforcement programs are formulated. In addition, attention should be paid to emergency treatment, for serious corrosion problems found, emergency measures should be taken immediately, such as local reinforcement, replacement of damaged components, etc., to prevent further deterioration of the problem. Finally, it is necessary to analyze and forecast the data, analyze the long-term detection data, establish a mathematical model, predict the performance trend of the concrete structure, and take preventive measures in advance.

5. Economic Feasibility of Improving Concrete Impermeability in Marine Environment

In large-scale offshore engineering projects, the impermeability of concrete is the key factor to ensure the durability and safety of the structure, so the research on improving the impermeability of concrete has important economic feasibility significance.

5.1 Initial Construction Cost Reduction

Because of the need to use high-quality cement, and the addition of mineral admixtures and efficient admixtures, the raw material cost of high-performance concrete may be relatively high, but from the overall construction cost point of view, it still has a certain advantage. Due to its better water resistance, the thickness requirements of concrete structures can be reduced in Marine environments. For example, ordinary concrete in the Marine environment may require a larger thickness to resist seawater erosion, and high-performance concrete due to its superior performance, can be appropriately reduced thickness, thereby reducing the amount of concrete material. At the same time, the construction performance of high performance concrete is better, which can improve the construction efficiency, shorten the construction period, and reduce the indirect costs such as labor costs. In large-scale offshore engineering projects, the shortening of the construction period may bring significant economic benefits, such as reducing the cost of equipment rental and generating income from early use.

5.2 Reduced Maintenance and Repair Costs

In the Marine environment, concrete structures are easily damaged by factors such as seawater erosion, which requires frequent maintenance and restoration. High performance concrete can significantly reduce the frequency and cost of maintenance and repair due to its enhanced impermeability and greatly extended service life. In the long term, the use of high-performance concrete can reduce the loss of downtime due to structural damage, repair material costs and labor costs. Ordinary concrete structures may require large-scale restoration in a few years, while high-performance concrete structures require major maintenance in a decade or even decades, which has significant advantages in the life-cycle cost calculation of large-scale Marine engineering projects.

5.3 Sustainable and Long-Term Benefits

From the perspective of sustainable development, the durability of high performance concrete is improved, and the consumption of resources and the generation of waste are reduced. Especially in large Marine engineering projects, the frequent replacement and restoration of concrete structures has been greatly reduced, reducing the need for raw materials and meeting the requirements of environmental protection and sustainable development. At the same time, long-term stable concrete structures can provide a reliable guarantee for Marine engineering projects, reducing the potential economic losses caused by structural damage, such as damage to Marine facilities, damage to the Marine ecological environment, which may lead to huge compensation and repair costs.

6. Conclusion and Prospect

6.1 Conclusion

Improving the impermeability of concrete in the Marine environment is of great significance for ensuring the safety and stability of infrastructure. Focusing on the theme of improving the impermeability of concrete under Marine environment, this paper summarizes the principle and influence law of concrete's resistance to chloride ion penetration erosion, summarizes the research results of concrete's impermeability technology at home and abroad, and puts forward several mechanisms and methods for improving concrete's impermeability, and analyzes the economic feasibility of improving concrete's impermeability under Marine environment.

Through long-term exploration and practice, through the improvement of microstructure and the change of material properties, the improvement of concrete's impermeability has achieved certain results. However, with the continuous development of the field of Marine engineering, the requirements for concrete performance are also increasing. At present, there are still some limitations in the research, such as the lack of research on the long-term performance of concrete and the lack of in-depth research on new impermeable materials. In the future, the research and application of concrete impermeability technology should be further strengthened to promote the innovative development of related fields.

6.2 Outlook

Future research, there are many directions that can be worked on. First, the research of new materials. First, more new types of mineral admixtures, especially those with special chemical compositions and microstructure, can be explored to interact more effectively with cement hydration products. At the same time, the combination of mineral admixtures is optimized to achieve better synergistic effect and enhance the comprehensive performance of concrete. Secondly, an appropriate amount of polymer materials, such as polymer fibers, can be added to form a three-dimensional network structure inside the concrete to prevent water penetration and crack expansion, and enhance the permeability and crack resistance of the concrete. In addition, new polymer admixtures can be explored to further improve the microstructure and properties of concrete and improve its adaptability in complex Marine environments. The second is to strengthen the anti-seepage research under multi-factor coupling. At present, it mainly focuses on the influence of a single factor or a few factors. In the future, more attention should be paid to the complex Marine environment, including the change of concrete performance under the joint action of multiple factors such as sea water temperature, salinity, wave impact, and Marine biological erosion. Third, we should carry out special research on the deep-sea environment. The deep-sea environment has the characteristics of high water pressure, low water temperature and special chemical composition. With the expansion of Marine development to the deep-sea field, higher requirements are put forward for the impermeability of concrete. In the future, it is necessary to develop the mix ratio of high-performance concrete suitable for the deep-sea environment, study the microstructure evolution and performance change law of concrete under the conditions of deep-sea high pressure and low temperature, and explore effective protective measures to ensure the long-term stability and safety of concrete structures in the deep-sea environment.

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