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The Application of Carbon Fiber Reinforced Polymer in the Construction, Reinforcement and Restoration Project of High-piled Wharf

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Abstract

With the continuous development of China's economy, there are also fast changes in coastal port cities of our country, for the port facilities built in the early days, due to long-term erosion from the ocean, and because the design capacity at that time was too small to meet the existing demand for passing capacity, overloading operation is widespread in wharf of many old ports. Long-term overloading use and erosion from the sea have caused different levels of damage to the wharf structure; bring great safe hidden peril to production. Therefore, we can consider using carbon fiber reinforced polymer restore the damaged wharf, and consider using carbon fiber materials in the newly built wharfs.

Keywords

High-piled wharf, Erosion, Reinforcement, Carbon fiber.

1. Introduction

With the continuous deepening and development of reform and opening up, China's overall economy has developed by leaps and bounds; our country has also made not small breakthroughs in the level of science and technology that come with it. Against this big background, there are also fast changes in coastal port cities of our country, as important window for China's economic development and important channel for import and export of goods and materials, the construction and development of coastal ports have received increasing attention. At present, China has nine coastal provinces, one autonomous region, two municipalities directly under the central government, and fifty-three important coastal cities. China has the world's most port throughput and container throughput, and is also one of the fastest growing countries. All this should be credited to the construction of corresponding port infrastructure, since the reform and opening up, our country has built many ports, wharfs and cross-sea bridges. For the port facilities built in the early days, they look dilapidated due to long-term erosion from the ocean.

Due to the particularity of port buildings near the sea, the pile foundations of some buildings need to be exposed to sea water for a long time, and it is inevitable that they will be eroded from all aspects of the sea. Because there are many corrosive ions in sea water, such as chloride ions, sulfate ions, etc. Sulfate ions will corrode and destroy concrete, chloride ions will cause electrochemical corrosion inside the reinforced concrete, and corrode steel bars. The combined action of these two ions will cause concrete will be cracked, attenuation of the mechanical properties of reinforcing steel, and impact is not conducive to the buildings. For example, the wharf built in the southern coastal area in our country 50 years ago, after five years of use, the concrete on the wharf surface has been slightly corroded, in order to be able to use normally after 15 years, it is necessary to maintain and strengthen the wharf structure. It can be seen that the durability and reliability of ports and auxiliary facilities built by the sea are particularly important.

Carbon Fiber Reinforced Polymer (short for CFRP), due to its light weight, high strength, and corrosion resistance, therefore, it can be used in the construction and restoration project of the wharf.

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2. Carbon Fiber Reinforced Polymer

Carbon Fiber Reinforced Polymer (short for CFRP) is a composite material which takes carbon fiber or carbon fiber fabric as reinforcement body, and resin, ceramic, metal, cement, carbon or rubber as the matrix, etc. Among many lightweight materials, it has high specific strength and specific rigidity, and the lightweight effect is very obvious, it is 50% lighter than steel material and 30% lighter than aluminum material.

In recent years, the application of carbon fiber reinforced polymer in the marine field has become more and more extensive, corrosion in the marine environment, high pressure, and strong shear caused by underwater undercurrent flow have made strict demands on the corrosion resistance, strength and fatigue performance of the material. Carbon fiber reinforced polymer has excellent skin resistance and corrosion resistance, has advantages in the development and expansion of the marine field, nowadays, carbon fiber reinforced polymer is playing an increasingly important role in the marine field.

2.1 Historical applications of carbon fiber reinforced polymer

The carbon fiber reinforced polymer is used in marine project constructions; it mainly uses its light weight, high strength and corrosion resistance, it replaces traditional reinforced building materials with steel and structural components, solves the problem of seawater erosion of steel bars, long transportation routes and high transportation costs. It has been used in island and reef construction, wharfs, floating platforms, lighthouse towers abroad, etc. The use of carbon fiber c reinforced polymer which is used in restoration project began in the 1980s; Mitsubishi Chemical Corporation of Japan took the lead in studying the mechanical properties of carbon fiber reinforced polymer and its application in project reinforcement. The initial research focus was to use carbon fiber reinforced polymer to steel reinforced concrete beams, and later it developed to the strengthening and reinforcement of various civil project.

The restoration of carbon fiber reinforced polymer to marine oil platforms and ports is just one aspect of its applications. There are many related documents. It is worth mentioning that the US DFI company used carbon fiber rods restore the naval Pearl Harbor wharf, at that time, the technicians innovatively used carbon fiber rods for restoration and reinforcement, the wharf restored by carbon fiber rods can withstand 9t steel dropped from 2.5m high without damage, and the strengthening effect is obvious.

There is another category of restoration and reinforcement of submarine pipelines or tubular column on the application of carbon fiber reinforced polymer in marine project. Traditional maintenance methods such as welding, weld improvement, clamps, grouting and other methods have their own limitations, and the use of these methods is restricted in the marine environment. The restoration of carbon fiber reinforced polymer mainly uses carbon fiber cloth, epoxy and other high-strength and high-cohesive resin materials adhere to the restore surface, so it is thin and light, has high-strength, good durability and is convenient for construction, adapts to different shapes, and has significant advantages.

3. Application of Carbon Fiber Reinforced Polymer

At present, carbon fiber reinforced polymer has two applications in the construction and restoration project of wharf

One is to use carbon fiber reinforced polymer restore the damaged concrete pipe piles, and achieves the purpose of strengthening and restoring the old wharf structure to improve its bearing capacity. The conventional technical method for strengthening and restoring the structure of high-piled wharf is the pasting carbon fiber reinforced polymer reinforcement method of.

Carbon fiber cloth reinforcement and restore structure technology is also a new type of structure reinforcement technology that has been promoted and applied in recent years. It is widely used in bridge reinforcement and maintenance projects. This method pastes the carbon fiber cloth on the

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surface of concrete components by resin bonding material; the good tensile strength of carbon fiber materials is used to achieve the purpose of strengthening and storing the bearing capacity of the components.

The other is to directly use CFRP composite pipe pile when building the wharf; it is to replace the steel bars in the original ordinary reinforced concrete precast piles with carbon fiber reinforced polymer bar. Seawater contains a lot of chloride salts, and chloride ions are the main cause of corrosion of steel bars in reinforced concrete structures. The carbon fiber material will not be corroded by seawater, which will greatly extend the service life of composite pipe piles, and can improve the bending stiffness of composite pipe piles to a certain extent.

3.1 Reinforcement method of pasting carbon fiber reinforced polymer

Carbon fiber cloth reinforcement and restoration structure technology is also a new type of structure reinforcement technology, which has been promoted and applied in recent years. It is widely used in bridge reinforcement and maintenance project. This method is to use resin binding material to paste carbon fiber cloth on the surface of the concrete components, and uses good tensile strength of carbon fiber materials to achieve the purpose of strengthening and restoring the bearing capacity of components. Construction process of pasting carbon fiber reinforced polymer:

(1) Base course treatment, the concrete surface should be removed if there are peeling, honeycomb, corrosion and other deterioration phenomena, for larger areas of faulty layers, polymer cement mortar should be used for restoration after removal; if necessary, the cracks should be sealed first; concrete angle grinders, grinding wheels and other tools are used to remove impurities such as scum and oil on the concrete surface, the concrete on the component base surface should be polished smoothly, especially the protruding parts of the surface should be smoothed, the corner paste should be chamfered and polished into arc shape, and the hair dryer is used to clean the concrete surface and keep it dry.

(2) Apply base glue, the main agent and curing agent are put in the container in accordance with a certain proportion successively, and stir evenly with stirrer, the dosage is determined in accordance with the temperature, and the use time is strictly controlled; the roller brush or wool brush are used to evenly apply the glue on the surface of the concrete component, the thickness does not exceed 0.4 mm, and do not miss the brush, flow, bubbles, the next process can be carried out after the glue is cured. (The curing time depends on the on-site temperature, it is better to feel dry with the finger, generally not less than 2h).

(3) Use leveling glue to level out, the hollow parts of the concrete surface should be repaired and filled with scraper, and the parts with height differences such as formwork joints should be filled with leveling glue, minimize the height difference; corner treatment, apply leveling glue to restore it into smooth arc, the radius is not less than 20mm: the next process can be carried out after the leveling glue cured.

(4) Paste the carbon fiber cloth and cut the carbon fiber cloth in accordance with the size required by the design; configure, stir and paste the glue, and then use roller brush evenly apply it to the pasted part, and apply more on the corners; use the special smooth roller repeatedly roll along the same direction of carbon fiber cloth until the glue seeps out from the outer surface of carbon fiber cloth, remove bubbles, make the carbon fiber cloth fully soak the glue. Multi-layer paste should repeat the above steps, it is suitable to make the fiber surface feel dry, then the next layer of carbon fiber cloth can be pasted; a layer of paste glue is evenly applied on the outer surface of the outermost layer of carbon fiber cloth.

(5) Surface treatment, if we need to do surface treatment, we can evenly sprinkle quartz (or use yellow sand) when the glue on the surface is not dry, and when the glue is completely dry (usually after 48h), paint or do other base surface treatment as needed; if it is outdoors, when the anti-corrosion treatment is required, the anti-corrosion treatment should be done as needed after the surface glue is completely dry.

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3.1.1 The main technical advantages of strengthening and restoring reinforced concrete structure with CFRP

(1) High strength and high efficiency. The high strength and highly elastic modulus of CFRP can be fully used of two to improve the bearing capacity and ductility of reinforced concrete structures and components, improve its stress performance, and achieve the purpose of efficient reinforcement and restoration.

(2) Convenient construction. The construction efficiency is high; there is no wet work, large construction equipment is not needed, on-site fixed facilities are not needed and less construction space.

(3) Excellent corrosion resistance. There is no need for regular maintenance, and it can protect the internal concrete structure.

(4) Wide application. It can be widely used in the reinforcement and restoration of various structural types, structural shapes, and structural parts without changing the structural shape and affecting the structural appearance.

(5) The construction quality is easy to guarantee. Because the carbon fiber is flexible, even if the reinforced structural surface is not very flat, it can basically guarantee nearly 100% effective binding rate, in addition, even if the surface is found to have bubbles after curing, it is easy to restore, as long as the resin is injected into the air bubbles, the air is driven out.

(6) CFRP is light and thin, its weight after pasting is less than 1.0kg/m² (the single layer includes resin weight), and the thickness after single-layer paste is only about 1.0mm.

(7) Reinforcement construction operations are carried out under the wharf and above as usual, which avoid major losses caused by shutdown.

(8) Although the unit-price of CFRP is relatively high, the overall cost of reinforcement and maintenance is relatively low due to its small size and simple construction technology. It can be seen that the advantages of strengthening and restoring reinforced concrete structures with CFRP, especially marine hydraulic structures are very obvious.

3.2 CFRP composite pipe pile

CFRP composite pipe pile is a kind of composite pile obtained by replacing part or all of the steel bars in the reinforced concrete pipe pile with CFRP bars based on the traditional reinforced concrete pipe pile. Because the reinforcing steels in the traditional reinforced concrete pipe piles are susceptible to corrosion from the sea, CFRP materials have corrosion-resistant characteristics. Moreover, CFRP materials have higher strength and lighter weight than metal materials. This makes CFRP composite pipe piles have a longer service life than traditional reinforced concrete pipe piles.

When traditional reinforced concrete pipe piles are exposed to the marine environment, chloride ions from seawater will continue to corrode the reinforcing steels in the reinforced concrete pipe piles, cause the reinforcing steels in them to rust, thus slowly lead to the attenuation of the bearing capacity of pipe pile. If the reinforcing steels in the traditional reinforced concrete pipe pile are replaced with CFRP bar, it will greatly slow down attenuation speed of the bearing capacity of the pipe pile.

If all the reinforcing steels in the traditional reinforced concrete pipe pile are replaced with CFRP bars, although CFRP has corrosion-resistant characteristics, the bearing capacity of the pipe pile will hardly be attenuated, but the bearing capacity of the pipe pile will be much lower than that of the traditional reinforced concrete pipe pile.

4. Summary

For the moment, the overall development trend of CFRP in high-piled wharf applications is good. The two major aspects of help: economic, social and national policies will open up a new and broader situation for the application of CFRP in high-piled wharfs.

First of all, as the failure phenomena of port engineering under the long-term effect of the use environment become more and more prominent, the durability problem is becoming increasingly

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serious. Literatures show that the premature destruction of reinforced concrete structures caused by corrosion has become a big disaster which has received a lot of attention all around the world. The survey conducted by the American Bureau of Standards in 1975 showed that the corrosion of reinforcing steel in concrete has accounted for 40% of all corrosion in the United States. In China's early construction, due to the requirements for early strength or frost resistance, a large number of chloride-containing salt admixtures were used, which made reinforcing steel corrosion more serious. For a long time, the "prematurely old" phenomenon of concrete structures in complex environments has been formed; the durability is severely damaged and requires continuous maintenance and reinforcement in the later period, which brings great economic losses.

As a new type of composite material, CFRP has light weight, high strength, good corrosion resistance and other characteristics in comparison with existing reinforcing steel, due to the above characteristics; it has incomparable advantages over reinforcing steel in the design and construction, especially in the later maintenance and reinforcement. In short, as people have increasingly higher requirements for the durability and life cycle economy of high-piled wharfs, CFRP materials are increasingly used in engineering, and their advantages are increasingly recognized by the society, and the development prospects will be broader.

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