Steel Post Splash Zone

with Inorganic Rust Prevention Material

Construction Method Manual

（Mighty CF-SP）

Mighty Chemical Co., Ltd.

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Steel Post Splash Zone with Inorganic Rust Prevention Materials Construction Method（Mighty CF-CP Method）

Chapter 1 Current Rust Prevention Construction Method

1-1 Inorganic Materials Lining Construction Method

a) Mortar Lining Construction Method

This is a general name for a construction method which covers steel pillars surfaces with cement mortar. Set the form around the post, and inject cement milk or resin mortar in between. Forms can be removed after cement or mortar harden, or can be left as protection cover. In the industrial method that leaves the formwork as a protection material, the formwork protects against impacts and saltwater intrusion. Mighty CF-SP Construction Method falls into this category.

In the mortar lining industrial method, alkalinity in mortar forms a passive film on the surface of steel posts, which creates rust control, the length of time the protection exists is dependent on the thickness of the mortar.

b) Metal Lining Construction Method

This construction method covers the steel pillar surfaces with titanium clad metal sheet or stainless steel sheet. This method provides ease of maintenance and repair, reinforcement, and impact resistance. You can also obtain electric anti-corrosion by utilizing forced current, depending to the kind of the metal.

However, it is necessary to note that corrosion might be promoted when utilizing the forced current method, depending on the type of metal land reactions created. Moreover, there is a problem that an external electric power source is always necessary which increases ongoing costs associated with this method.

c) Other Inorganic Materials Lining Construction Method

One of the Inorganic Materials Lining Construction Methods is to set the electrode and the steel pipe pile in seawater for direct current. That way, an inorganic quality of calcium or magnesium in seawater is electro-deposited and deposited on the surface of the steel pipe pile; it would create a precise film to prevent salt water penetrating into the structure.

However, this construction method applies to areas which are always under the

seawater, not in the splash zone which tends to rust much more easily.

1 – 2 Rust Prevention Paint Construction Method

This is a very general method of rust prevention utilizing paint or coatings. This method forms a paint film on the steel material face to prevent corrosion caused from elements infiltrating the steel. Except for some zinc rich paints, this method is widely used because it is easy to apply. The coated film is thin and light, the finished appearance good, and it can be applied to complex surfaces.

Generally, materials used as painting material are organic materials and pigments. The organism that contributes to the film formation is weather resistant, but is deteriorated by exposure to ultraviolet rays. Re-painting is needed from five to seven years after original application. Even with fluorine system painting, which provides excellent weather resistance, it is generally believed that re-painting is necessary in approximately 10 years.

1 – 3 Organic Lining Construction Method

This method forms film and plate structure with thick organisms on the surface of the metal. There are several variations of organic lining construction methods, including: a petrolatum industrial method that covers petrolatum that is oil system wax paste; a polyethylene lining industrial method that is polyethylene lining on the surface of steel pipe; a resin mortar; a petrolatum industrial method utilizing a underwater resin paint film; a method using fiber reinforced composite material (FRP) board materials covered with the resin mortar; and others. These methods have excellent anti-corrosion properties, and can be impact and abrasion resistant. These methods have been used for chemical plants and underground piping, but recently have been used for harbor structures, as well.

1 – 4 Current Heavy Anti-Rusting Industrial Method

The polyethylene lining industrial method excels in durability, and is excellent in seawater and weather resistance, but it is limited in application to new structures. The petrolatum lining industrial method is an industrial method to which the steel material is covered with a paste anti-corrosion material of which the principal ingredient is an oil

system wax.

Although it is very economical, it is vulnerable to impact and can rust easily at damaged sites. Moreover, the petrolatum tape can be infiltrated by seawater, making petrolatum flow out, and causing the corrosion of the entire steel pipe in the splash zone, as well as in locations.

Diagram 1 Secular distortion of construction by petrolatum industrial method

1 – 5 RC Lining Anti-Rusting Industrial Method with steel material formwork (CRUS Method)

Among the harbor's steel structures, this method aims at anti-corrosion in the steel pipe pile, sheet piles, and the steel pipe sheet piles. After welding the reinforced concrete with an underwater stud welding on the surface of the metal, and setting up the steel board on the surface of the outside instead of the formwork, it is necessary to pour the cement mortar between the steel board and the steel structure, which reinforces the structural integrity.

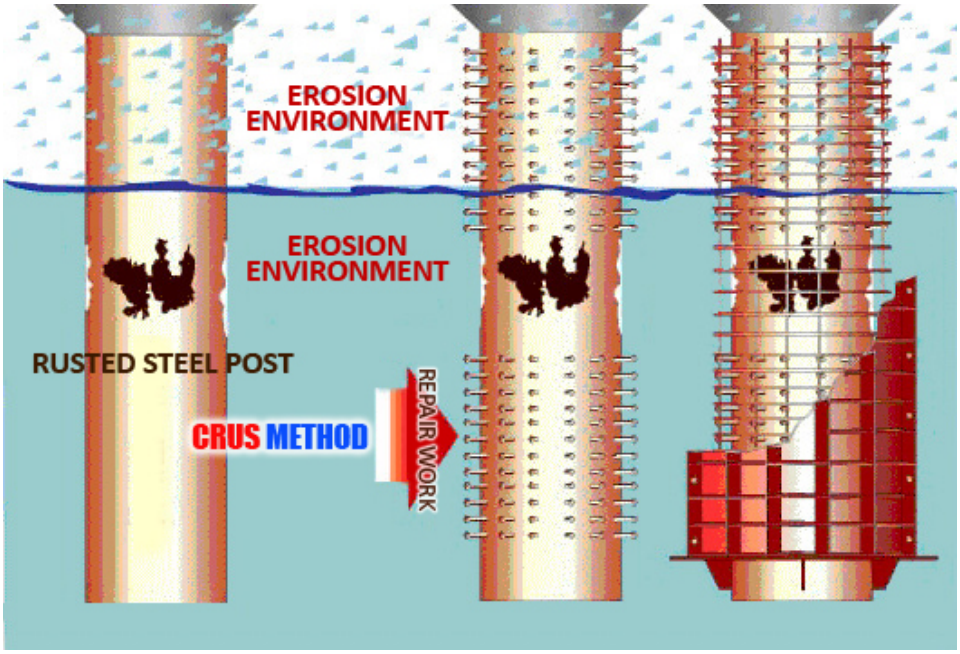


Diagram 2 CRUS Method Concept Chart

Chapter 2 Summary of Mighty CF-SP Construction Method

Steel pipe piles are often used as bases for structures such as piers, sea bridges, and foundation piles for harbor structures. However, it is clear that it is very difficult to figure in the maintenance and repair of the steel pipe piles, under a severe corrosive environment as illustrated in diagram 3. In general, the corrosive environment of the marine structure is greatly different based on varying conditions of placement in tides, under water, in the splash zone, and/or areas which are not impacted by seawater. Though the electrolytic protection demonstrates some effect in the anti-corrosion in the underwater parts, the splash zone is the area you would see most rusting because there is an ample supply of oxygen.

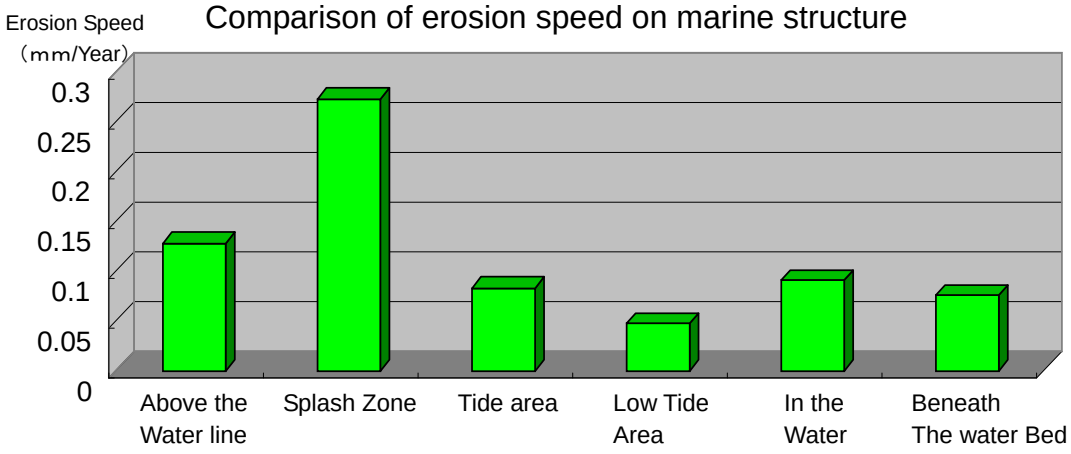


Diagram 3 Corrosion speed comparison in oceanic steel pipe stake

The corrosion rating is very high, especially around splash zone. The speed or rusting at splash zone is six times faster than at the tidal area and three times than the area under water. There many corrosion problems even though the splash zone is protected by heavy corrosion protection paint or Organic Material Lining Construction method.

Mighty CF-CP Construction Method was developed to solve these problems. Specifically, with Mighty CF-CP, formwork is set around the post pillars after sanding down and removing the existing rust. Then, inject Mighty CF-CP Inorganic Rust Prevention Material with special salinity adsorbent into the gap between the formwork and the steel pillars. The special salinity adsorbent material adsorbs and adheres to the remaining chloride ions, and prevents rust on the steel structures, through the positively discharged sub-nitrate ion.

Diagram 4 Injection of Mighty CF-CP

Diagram 5 Confirmation of exhaust at top vent holes

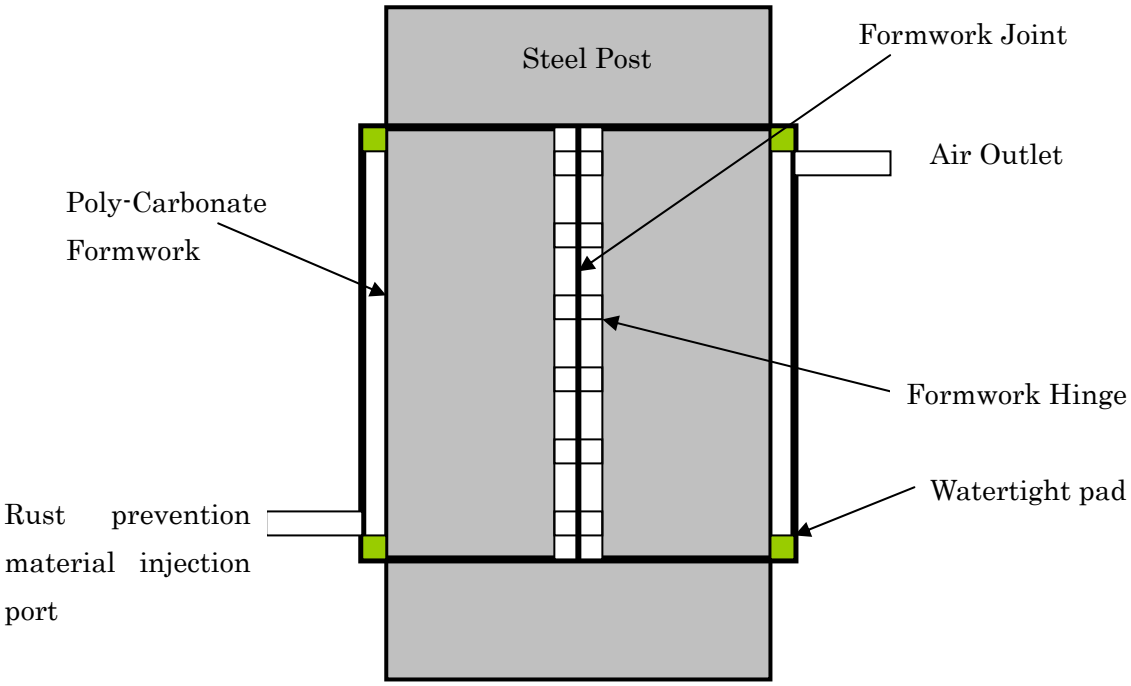


Diagram 6 Summary of Mighty CF-CP Construction Method

Mighty CF-CP is inorganic rust prevention material which promises long term rust prevention performance capability. Injecting this compound into the gap between the formwork and pillar posts prevents those steel pillars from rusting for more than 30 to 50 years. This is an innovative new steel post rust prevention construction method.

For the formwork, Mighty CF-CP has adopted formwork made of polycarbonate resin (PC), which is excellent for weather resistance and transparent. There is the pad,

reinforcement, the anti-rust injection port, and the air outlet to maintain the water-tightness of the formwork. The formwork was set around the splash zone of the steel pillars. Inject Mighty CF-CP containing rust prevention paste with salinity absorbent through the lower injection port. Mighty CF-CP is designed to protect the steel structure from corrosion by maintaining a strong alkaline level.

Chapter 3 Details of Mighty CF-SP Method

3 – 1 Reasons for Usage of Polycarbonate formwork

Polycarbonate is a kind of engineered plastic which has excellent weather resistance, is transparent, and highly durable to impacts. This polycarbonate resin is often used for walls in highways, for these reasons. These properties make it highly desirable for the formwork material for Mighty CF-CP.

If transparency is the sole consideration, the vinyl chloride resin (PVC) could be used. But it contains chlorine in the chemical structure, which poses a significant environmental hazard. Moreover, the plasticizer is considered carcinogenic, which could negatively impact the aquatic environment.

Alternatively, acrylic resin could be considered for the formwork material because of transparency. But it is not impact-proof, so that it is not recommended for use in areas which have a high probability of collision with floating debris and vessels. FRP (Fiberglass Reinforced Plastic) could also be considered, but it would be more costly.

These are among the reasons that we have chosen to use polycarbonate resin for the formwork material.

Kind of Resin	Gravity	Bending strength (Kgf/c ㎡)	Stretch rate (%)	Impact strength (Kgf/c ㎡)	Combustibility
Acrylic	1.17～1.20	840	2.0	1.6	N/A
PVC	1.25～2.30	700	40.0	2.2	N/A
FRP	1.35～2.30	700	0.5	13.5	N/A
PC	1.20	950	90.0	75.0	Flammability

Diagram 1 Characteristics of various materials

3 – 2 Characteristics of Rust Prevention Material Mighty CF-CP

Rust Prevention Material Mighty CF-CP is a strong alkali cement mortar. Moreover, in order to improve crack traceability, it contains carbon fiber in the compound. To unite and to solidify this compound, Urethane Acrylic Resin base water emulsion, which is excellent in stability and adhesion, is adopted. Mighty CF-CP also passed JWWA standards for the quality of drinking water by Japan Food Analyzing Center. This product is harmless to the environment and marine orgasms.

Mighty CF-CP is composed of a water emulsion of a compound and an acrylic fiber

system resin that gives it alkalinity. Please see the following chart showing the roles and effects of improvements to components such as white cement, silica sand, carbon fiber, alkali additives, acrylic esters, bond strength improvement material, and high temperature durability additives. Mighty CF-CP has more than 20 years of history of rust prevention projects all over Japan, and it is highly regarded as a durable and inorganic rust prevention paint material.

<table>
<tr><td colspan="2">Components of Mighty CF-CP</td><td colspan="3">Characteristic improved by the material</td></tr>
<tr><td rowspan="4">Compound</td><td>White Cement</td><td>Alkaline</td><td colspan="2">Improvement of physical characteristic</td></tr>
<tr><td>Silica Sand</td><td>Tight Layer</td><td>Adhesion improvement</td><td>Waterproof improvement</td></tr>
<tr><td>Carbon Fiber</td><td>Improvement of coating film</td><td>Crack prevention</td><td>Bending strength improvement</td></tr>
<tr><td>Calcium Alkali Additive</td><td>Alkaline</td><td colspan="2">Formation of passive film (black rust)</td></tr>
<tr><td rowspan="3">Emulsion</td><td>Acrylic Ester Co-Polymer</td><td>Adhesion improvement</td><td colspan="2">Uniting power strengthening between particles</td></tr>
<tr><td>Bond Strength Improvement Additive</td><td colspan="3">Adhesion improvement</td></tr>
<tr><td>High Temperature Durability Additive</td><td colspan="3">High temperature durability (200 degrees or more)</td></tr>
</table>

Diagram 2 Property of Mighty CF-CP and Effect of Improvement

3 – 3 Rust prevention paste using salinity absorbent

The rust prevention paste that uses the salinity absorbent is the salt damage control material developed by Railway Technical Research Institute Foundation. This material contains an absorbent that adsorbs salinity, and is the protective coating material with rust prevention performance by discharging the sub-nitrate ion through absorption. When the chlorine ion is absorbed by the salinity adsorbent additive, the sub-nitrate ion that has been adsorbed gets discharged. Subsequently, the iron exchange reaction occurs between the chlorine ion and the sub-nitrate ion. Therefore, after the remaining salinity is reduced, the sub-nitrate ion is discharged, and supplied. In the Mighty CF-CP Construction method, sea water is removed during the setting up of the formworks, but there is a possibility that water can remain. To reduce this remaining salinity, this salinity absorbent rust prevention paste, is used for Mighty CF-CP rust prevention material to improve rust prevention

performance.

3 – 4 Physical Characteristics of Mighty CF-CP

See the physical Properties of Mighty CF-CP in Diagram 3 below.

Test Items	Test Standard	Test Result	Unit/Condition
Compressive strength	JIS A1108	375	kg/cm^2
Tensile strength	ASTMC190	41.3	kg/cm^2
Bonding strength	JISK5400	20.3	kg/cm^2
Impact strength	JISK5400	Normal	Drop over 50 cm
Freezing and Thaw	JISK5209	JISK5400	10 Cycle
Compound cycle test of salt water, moist, and dry	JIS A5622	Normal	36 Cycle
Humidity test on steel board painted side	JIS A6909	Normal	20 Cycle

Diagram 3 Physical Property Test Result of Mighty CF-CP

Judging from the test results above, Mighty CF-CP has strong physical properties and is extremely durability. Further detailed information is available on request.

3 – 5 Current conditions of exposed areas of fishing piers which were coated with Mighty CF-CP 23 years ago

3Fishing Park was constructed by the City of Shimonoseki for fishing in 1984. As you can see from Diagram 7, it consists of 300m long straight pier stretched out to the water and 100m deck portion from the tip of pier. The water depth at the deck portion reaches over 10m deep. There is a long handrail running along the pier, and people can walk to the deck area from the land. Mighty CF-CP was applied to this structure as a Heavy Rust Prevention Coating material in 1984. 1.5 kg/m^2 of Mighty CF-CP was applied on the beams and girders of pier, and then a chlorinated rubber top coat was applied up to 300 μm of thickness. The pier subfloor slab and the guardrails consist of expanded metal which was galvanized with zinc. However, those structures corroded severely, and were re-painted with Mighty CF-CP.

Diagram-7 Shimonoseki Fishing Park

Following is information on the Mighty CF-CP Heavy Rust Prevention Project for this facility. The Rust Prevention material coating on the Pier structure was applied on land in September 1984. Mighty CF-CP was applied on the surface of steel structure, covering even any remaining red rust. After a simple cleaning procedure, Mighty CF-CP was sprayed over the surface where red rust remained (see Diagram 8, 9, and 10).You can see the light red color surface after the first coat of Mighty CF-CP over the red rust. Following the initial application, a paint spray gun was used to apply Mighty CF. After the two coats of Mighty CF dried completely, two coats of Chlorinated rubber paint were applied to complete this project.

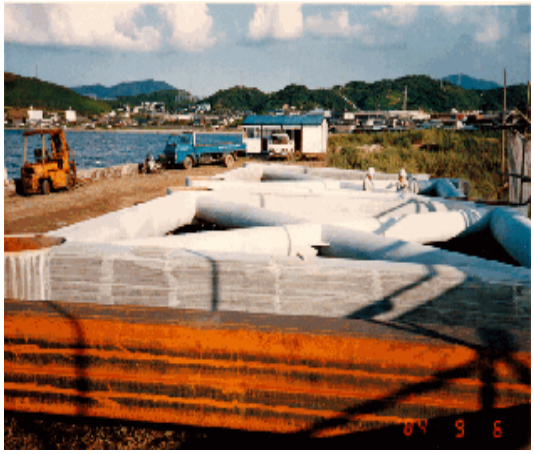


Diagram 8 Coating on joint part

Diagram 9 Setting subfloor slab of beam and pier

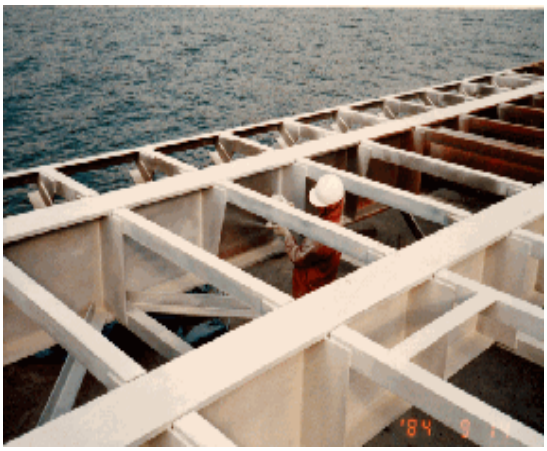


Diagram 10 Applied by Spray Gun

Shimonoseki Fishing Park was built in a very severe environment. There has been no major repair work done over 24 years since it was constructed In September 1984, due to the rust prevention performance of Mighty CF-CP. However, some problems have been found, and those were taken care.

The first repair work occurred just under the leading edge of the fishing pier deck. Some floating materials collided against the pier under-deck and the coated layer was damaged 4 years later during new construction. Rust was observed on this part, so Mighty CF-CP was reapplied at this location. A similar accident occurred on 1990 as well.

The second repair work was in 1991 on the hollow steel piles. These pier piles were originally coated with epoxy resin paint, but after 6 to 7 years exposure in severe conditions, they were completely corroded. Where this corrosion damage occurred, the area of the pile surface up to 60cm below from the deck was repainted with Mighty CF-CP instead of epoxy resin paint. After cleaning the remaining epoxy resin paint, Mighty CF-CP was applied. In total, 120 of the piers were re-coated with Mighty CF-CP between 1992 and 1994.

The third repair work was on guardrail on the pier. It was painted with normal resin paint, but was corroded by wind and salt. The guardrail was also re-coated by Mighty CF-CP. In 2002, deterioration of the top coating was observed and it was re-painted with urethane paint for aesthetic purposes.

As mentioned above, three major repairs have been performed in the 24 year history. However, the majority of repair was in areas where Mighty CF-CP was not originally applied or where something collided with the structure and damaged the coatings. This is evidence that Mighty CF-CP has very good durability and anti-corrosion performance even under severe conditions.

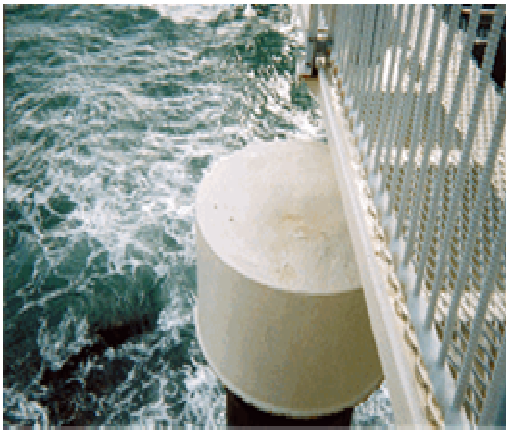


Diagram 11 Top of the pillar post

Diagram 12 Removing Top Coat

In order to confirm that Mighty CF-CP has the ability to change red rust to black, some objective tests were conducted at the top head of the steel piles in September 2006 by COSMO Engineering Co. Diagram 11 shows the top of the steel pile used for this test. At first, the top coat was lightly sanded down using a sander disk, to check the condition underneath (see diagram 12). It was confirmed that the condition of Mighty CF-CP is still healthy, and the bonding strength testing measured 1.4N, even 23 years after construction. Diagram 13 shows the top coat removed further to expose the steel surface of the pillar. According to this test, it shows the red rust shown in photo 8 was changed to a stable black rust. This is evidence that the red rust will be changed to the black stable rust through the high alkaline nature of Mighty CF-CP.

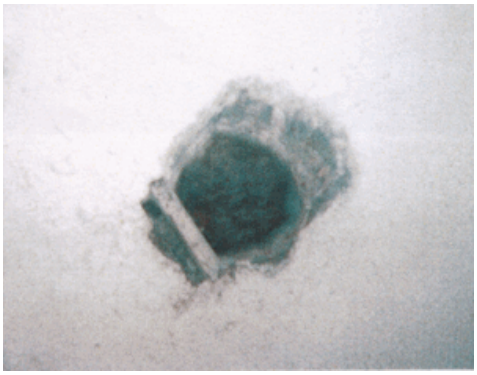
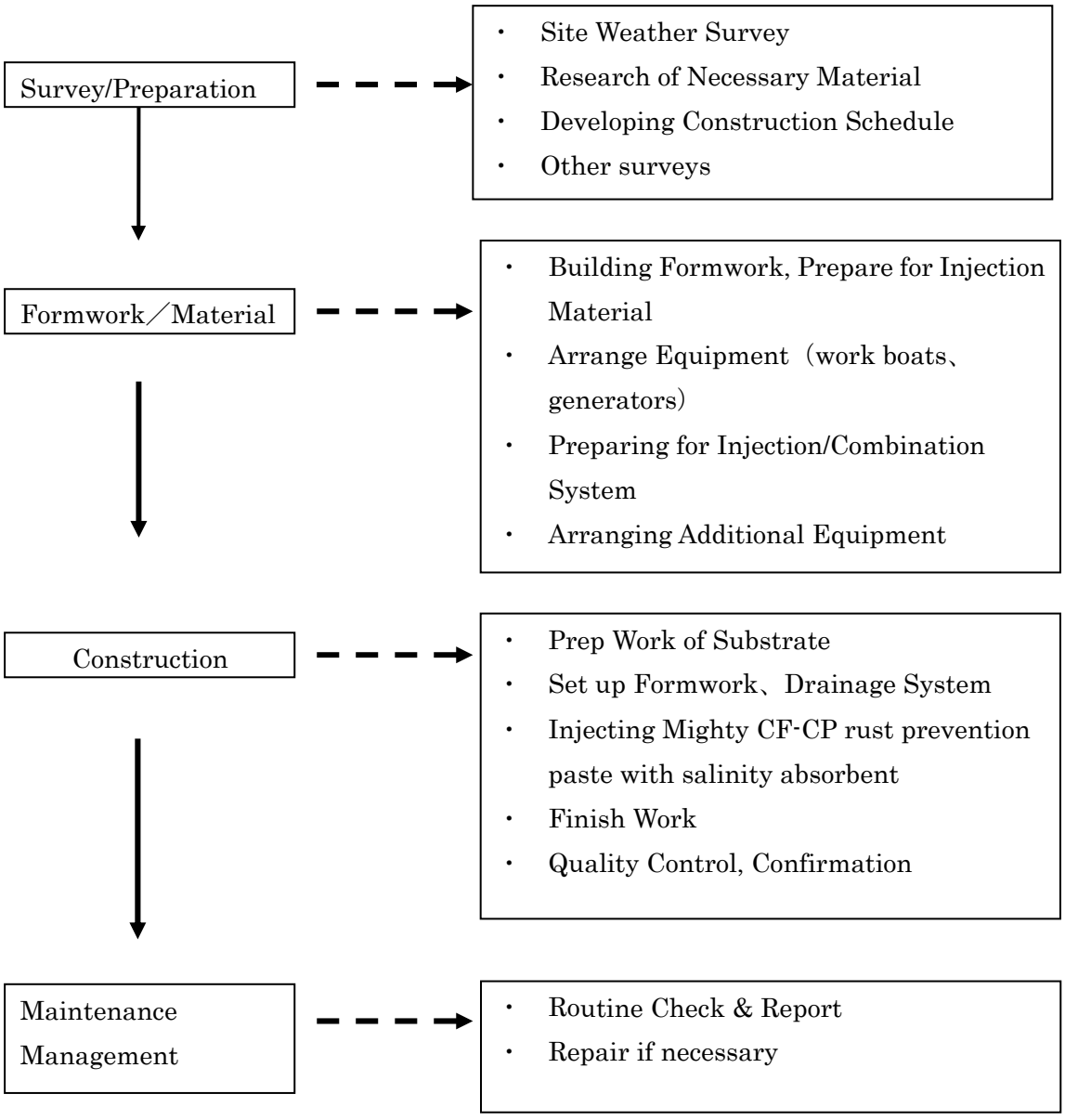


Photo 13 Removed Mighty CF-CP

Chapter 4 Construction Method

4 – 1 Construction Flow

Here is a general construction flow of Mighty CF-CP.



4 – 2 Construction Preparation

Construction Preparation requires research of necessary materials for the project and development of the construction schedule. Moreover, data on weather conditions and tide schedules are necessary to be collected and analyzed to coordinate with the

construction schedule. It is very important to determine the correct timing for the construction. It is important to time the construction when it is clear that there are no imminent typhoons or low pressure fronts, and during low tide. Staging area and stock yard for materials and workers is also necessary in case weather or tide conditions deteriorate. The sizes of pillars need to be confirmed by the job site and design offices. It would be ideal to test set the formwork around the pillar on the land before hand.

Additional necessary preparations:

1. Sea level timetable
2. Survey of wind velocity and direction by year
3. Investigation of waves, conditions and weather
4. Research on currents
5. Accurate measurement and confirmation of size of steel pipe and construction area at site and by design
6. Other Information

Necessary staff:

1. Site Manger: site management
2. Painters: Paint work on the steel pillars above the water
3. Divers: Prep Work, formwork, and injection work of rust prevention materials under the water.
4. Assistants: Mixing injection materials, setting up formwork, injection work, removing formwork

Acceptable work conditions include wave height under 60 cm, temperature between 5 ～40 ℃; ideal conditions are dry weather with breeze and temperature between 15～25 ℃. Since Mighty CF-CP is a waterborne emulsion material, the surface temperature of steel pipes should be over 5 ℃.

Mighty CF-CP emulsion needs be stored where it cannot freeze in the winter and out of direct sunlight and high temperatures in the summer. (The emulsion will separate under high temperatures). Mighty CF-CP Compound is a cement inorganic material so it needs to be stored in a dry area to avoid excess moisture.

4 – 3 Prep work and Formwork Set Up

Steel pillars have been exposed to severe conditions under water, which include rust, encrustation with shellfish and seaweed on the surface. The pillars need to be cleaned completely and cleared of all debris with high pressure wash. Oil inhibits

Mighty CF-CP from adhering to the steel pillars. The formwork needs to be set up after any oil is also completely removed from the surface of the steel pillars.

Polycarbonate formworks have 2 to 3 air vent holes at the upper part, and 3 to 4 injection holes for Mighty CF-CP at lower part. There are reinforcement sheets, bolts, and water pads at the joint. Water pads are 10 mm thick before installation, and become 3mm to 5 mm thick after they are installed. They are attached to the steel pillar tightly, and create 3mm to 5mm gap between formwork and Steel Pillar.

Once the formwork is installed, water must be removed. To remove water while the top air vents are open, water can be pumped out from the lower part of pillars, through the injection holes for Mighty CF-CP. After the water is completely removed, confirm there are no leaks in joint areas and top and bottom water pads. This completes the set up of the formwork.

Formwork and set up conditions for the formwork:

Diagram 14 Before set up

Diagram 15 Closing formwork on land

Diagram 16 Setting up the up formwork around the pillar

Diagram 17 Removing water from the formwork

4 – 4 Injecting Mighty CF-CP

Mighty CF-CP is an inorganic rust prevention material which consists of a waterborne Emulsion (E),and Carbon Fiber Cement Compound(C). The Emulsion and Compound are delivered to the jobsite in separate containers. The Rust Prevention Paste with Salinity Adsorbent is added to the Emulsion and Compound, and needs to be mixed well until it becomes uniformly distributed. The mix ratio of Emulsion and Compound is following:

Emulsion(E) : Compound (C) = 1.0 : 2.3

It is acceptable to change the mix ratio up to the following if necessary:

Emulsion(E) : Compound (C) = 1.0 : 2.0 to 2.5

Measure the Emulsion, and pour into the necessary container, and add the appropriate amount of Compound gradually and mix with mixer. Then, add the Rust Prevention Paste with Salinity Adsorbent. After the Emulsion and Compound are thoroughly mixed, confirm that it is up to 1 to 2.3 ratio. Mixing needs to be done immediately prior to injecting the rust prevention material right into the formwork, so should not be done until the formwork set up is complete. Injection needs to be done as soon as the mixing is finished.

Injection of Mighty CF-CP needs to be performed carefully; closely monitor that Mighty CF-CP is being filled through transparent polycarbonate formwork while the material is pumped in from the injection hole at lower part of pillars. After you confirm that Mighty CF-CP is pouring out from air vent at upper part of pillars, the

air vent holes need to be closed.

If pillars are not completely filled with Mighty CF-CP, the color of the transparent polycarbonate formwork is not white. Continue injecting Mighty CF-CP until all the formwork turns white and Mighty CF-CP is pouring out from the vent hole. The work needs to be re-checked after 48 hour,, and any excess materials around the vent holes needs to be removed.

Diagram 18 upper left area needs to be filled

Diagram 19 completion of injection

4 – 5 Management after completion

After completion of the work, the project owner needs to be apprised of the status and timing for site surveys. At the minimum, a site survey and work survey has to be done three months after the completion. Cost for this should be included in the proposal. Regular site checks should be conducted, due to the possibility of floating debris damage. A report with photo documentation should be submitted after each regularly scheduled check is conducted.