INNOVATIVE FRP PILING REPAIR WITHOUT THE USE OF COFFER DAMS

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ABSTRACT

Splash zone and underwater repair of concrete pilings using composites has traditionally been accomplished by utilizing coffer dams. This paper describes a splash zone installation using the Aquawrap® Repair System. The repair was successfully completed on two steel reinforced concrete pilings on a bridge over the North River located near Wilmington, North Carolina (Figure 1). This product uses a unique water activated urethane resin system coupled with a custom woven fabric that can easily be applied to round or rectangular pilings under water. The product is pre-impregnated at the factory and hermetically sealed in foil pouches. The pouches are opened at the jobsite just prior to application. The pilings were prepared with an underwater epoxy adhesive and then wrapped with this material. The river water activates the resin and cures the system. The particular system used has no VOC's and is approved for drinking water use, making it attractive for use in environmentally sensitive areas.

KEY WORDS: Composite Materials, Concrete Repair, Applications-Marine

1. INTRODUCTION

Steel reinforced concrete bridge and pier pilings are subject to splash zone damage in both fresh and salt water areas (Figure 2). The damage to the concrete is usually caused by abrasion or impacts by wave and tidal action, collisions with marine vessels, and normal spalling. In addition, oxygen and water penetration can cause corrosion of the reinforcing steel.

Figure 1. Bridge over the North River

Figure 2. Concrete deterioration

When this happens, the resulting expansion causes the concrete to fracture. The corrosion of steel in these structures is exacerbated in the splash zone due to the combination of salt-water and oxygen present in this area of the piling. The damage to the pilings may be cosmetic or structural. In either case, the repair system must restore the piling and reduce further deterioration.

Air Logistics Corporation and its distribution partner, Structural Composites Incorporated, have developed a method of infrastructure reinforcement using the Aquawrap® Repair System. These two companies conducted a demonstration program on several pier pilings for the North Carolina Department of Transportation on a bridge located over the North River. The installation was performed by staff members from Carolina Restorations & Waterproofing Services, who acted as the general contractor, and Watershed Services, who specialize in diving projects.

2. REVIEW OF THE PROBLEM AND TRADITIONAL SOLUTIONS

Restoration of splash zone damage to steel reinforced concrete pilings (Figure 3) has traditionally been accomplished by a variety of techniques. These include concrete encapsulation using steel or composite forms (Figure 4), wrapping with traditional composite systems, or simply patching the spalled concrete. The first two systems can be used for repairing cosmetic damage as well as structural damage (1). Patching is limited to cosmetic repairs only. Concrete patching materials do not work well in splash zone situations or in geographical areas subject to freeze thaw conditions. These environmental factors cause insufficient bonding to the base concrete which will result in premature failure of the repair. While encapsulation systems can be used without the use of coffer dams they are complicated and difficult to deal with (2). Conventional field-saturated composite systems using epoxy require that saturation equipment be brought on-site and that a highly trained staff perform the installation. This type of repair is generally not an environmentally friendly process either. This type of installation certainly requires the use of a coffer dam. The use of a water activated repair system avoids these difficulties. This type of system is moisture activated and cures normally when applied underwater or in the splash zone. The system can be installed at low tide with scaffolds or by divers in deeper water, thus eliminating the need for expensive coffer dams and the extended time necessary to complete the repair.

Figure 3. Typical Repair Situation

Figure 4. Concrete Encapsulation

3. PILING WRAP SYSTEM

This type of repair system consists of an adhesive, the pre-impregnated fabric, patching material, and various accessory items. An adhesive is used in the case of rectangular or hexagonal pilings. It is not required for round or oval pilings as the resin in the prepreg provides adequate bond strength on its own. The epoxy adhesive has been specially selected for its bond strength to old concrete and its ability to be applied under water.

The resin used in the prepreg is a specially formulated urethane system designed for installation in wet conditions. The fabrics are impregnated at the factory in a humidity controlled environment, cut to size, and packaged into sealed pouches. These pouches protect it from atmospheric moisture, which can cure the product over time. The package is opened just prior to application. When installed circumferentially, water is applied between each layer to activate and cure the resin. The system is NSF approved and has no VOC's, making it environmentally friendly. In the event the installation will not be painted, UV inhibitors can be added. This is usually added to the resin used in the final consolidating veil wrap. If requested, grey pigmentation can also be added to the resin to match the color of the concrete.

A variety of fabric styles and materials are available. Unidirectional and bi-axial fabrics are available with either glass or carbon inputs. This allows the best material to be selected depending upon the specific job requirements. A listing of the properties of popular materials is shown in Table 1.

Depending upon the condition of the piling, the cognizant engineer needs to determine if the remaining structure is sound and if the composite repair will be required to restore strength as well as cosmetic appearance. For most cosmetic repairs, the use of two or three layers of glass woven roving and one layer of glass tape are recommended. This technique has proven to provide good bonding to the base concrete, long term durability, and consolidation of the patching material. The usual structural issues are the restoration of hoop strength, bending moment, and compressive strength, or a combination thereof. The designer selects the materials and number of layers required to achieve the needed strength enhancement. Extensive properties and endurance testing including creep-rupture, alkaline and sea water exposure, cyclic load testing, impact testing, flame propagation, freeze thaw, etc. have been performed.

Table 1 - Mechanical Properties for Different Fabric Systems (3)

	TYPE G-03	**TYPE G-05**	**TYPE G-06**	**TYPE-C-14**
Reinforcement	woven glass bi-axial fabric	woven glass bi-axial fabric	woven glass uni-axial fabric	stitched carbon uni-axial fabric
Fabric Weight (g/m^2)	312	680	737	369
Nominal Thickness (mils)	.279	.686	.686	.686
Tensile Strength (MPa)	449	328	572	848
Tensile Modulus (GPa)	262	220	345	786
Tensile Load, per ply (kg)	324	581	1,016	1,506
Compressive Strength (MPa)	197	172	189	138
Interlaminar Shear (Mpa)	20	19	24	19

4. INSTALLATION

The pilings that were repaired support a roadway over the North River in North Carolina. There are over 125 pilings that support this bridge along its entire span. The nominal depth of the river is about 3.6 m. The bridge, located in a tidal zone, has been in service for many years and several of the pilings have suffered severe spalling. This has been caused by freeze/thaw cycles, splash zone water flow, and corrosion of the reinforcing steel. Inspection of the pilings that were to be rehabilitated indicated that the remaining structure had adequate strength and that only a cosmetic repair was required.

Two pilings, both 30.5 cm square, were repaired. The repair area on the first piling was 2.44 linear meters and the second was 1.83 linear meters. Engineers requested the repair extend below the water line at least 35 cm at low tide. The lay-up on this repair consisted of three layers of the WR 22/77 glass woven roving and one layer of tape (veil). The installation was done at high tide, which meant most of the work had to be done below the water line. The water temperature at the time of the installation was approximately 10° C.

The first piling was thoroughly cleaned and patched using a 100% solids epoxy-modified urethane (Figure 5). As a trial the second was only cleaned and marginally patched. A portion of a third piling was also prepared and wrapped. Diving mitts were used by the divers to apply the adhesive to a thickness of approximately .74 mm. Normal cure time in this case was around two hours. As soon as the adhesive was applied the pilings were wrapped with 20 cm wide woven roving material. This width was selected for ease of installation on this particular size piling. Widths of fabrics can vary depending on the specific application (Figure 6).

The wrap began at the top of the piling and proceeded as follows:

- One turn around the piling
- Spiral down with the pitch of the spiral set so that each successive wrap touches, but does not overlap, the previous wrap
- Continue this until the bottom of the wrap area is reached
- Take one turn and spiral back up
- Continue until the necessary three layers is achieved

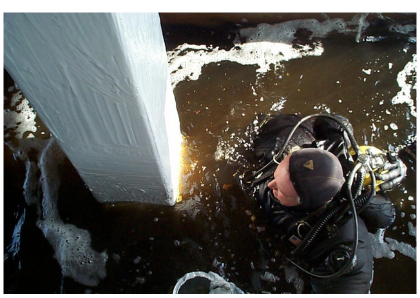

Figure 5. Epoxy adhesive installation

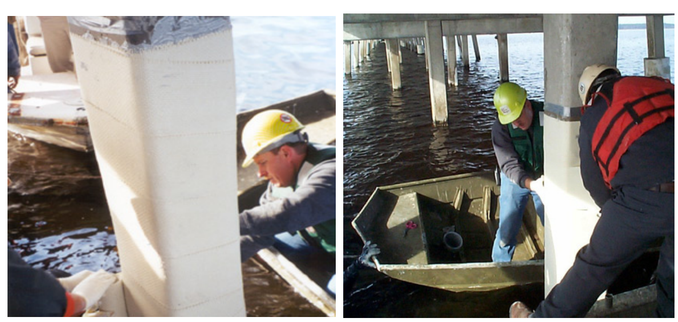

Figure 6. Aquawrap® installation

For installations completely above the water line, the application of water to the product is required between each layer. In splash zone installations, water need only be applied on material that is installed above the water line. When the woven roving wrap was completed a single layer of tape was applied. The purpose of this final layer is to consolidate the wrap during cure and provide an aesthetically pleasing appearance. The width of the tape was 25 cm and was spiral wrapped, beginning at the lower edge and continuing upwards to the top edge. The spiral wrap technique used a 5 cm overlap between layers so that it completely covered the woven roving. After the tape was installed, the entire wrap was secured with a special high tensile strength stretch film (Figure 7). The cure time for the finished composite was less than an hour.

After complete cure, the stretch film was removed and a layer of epoxy adhesive was applied as a protective coating. After completion, the installation was inspected for voids. None were located and the final appearance was excellent (Figure 8).

This was the first installation of this type for the construction crew, yet the entire operation of all three structures was completed in less than one day. The total time was about eighteen man-hours for the contractor staff and six man hours for the diving crew.

Figure 7. Stretch film application

Figure 8. Completed installation

5. CONCLUSIONS

This installation demonstrated that pier pilings located in a splash zone can be repaired without the use of coffer dams. Using FRP that is conducive with underwater installation can provide an economical solution for future repair and rehabilitation projects. Utilizing this type of repair can save money on labor and materials, while posing very little environmental impact or threat.

Care needs to be taken when designing this type of reinforcement to ensure the fabrics and resins used provide the strength and installation properties required to create a successful repair. As with any installation, good surface preparation is important. The surface of the piling needs to be patched and contoured to provide a smooth surface. It is essential to the performance of the system that there are no voids between the composite lay-up and the piling. Patching material and adhesives that are used should be part of the "system" and not a generic product. Installation methods and procedures should be strictly adhered to for consistency in performance, and all persons involved should be properly trained and/or have a qualified factory representative on site during the repair. Installation techniques are crucial in providing the required strength in the areas where it is needed.

The installation went exceedingly well and without incident. The crews were unfamiliar with traditional repair systems and were impressed with the ease of installation for the Aquawrap® system. The quality of the end product was excellent and aesthetically pleasing.

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