Repairing and Protecting Concrete Piles with Galvanic Jackets

by J. Christopher Ball, Vector Corrosion Services

From small county roads to major highways, a significant number of bridges are built over coastal waters. With exposure to the seawater environment, these structures are at risk of premature corrosion of the reinforcing steel. In particular, conventionally reinforced and prestressed concrete piles in seawater are subjected to high levels of chloride contamination leading to serious deterioration and on-going maintenance repairs.

Concrete Pile Corrosion

Concrete piles in seawater are exposed to three distinct exposure conditions:

- Atmospheric (Dry)—elevated sections of concrete piles are subject to airborne chloride deposition. Once critical concentrations of chloride are present on the steel surface, the passive oxide layer is defeated and corrosion initiates.
- Splash/tidal (Wet/Dry)—the splash and tidal zones are intermittently subjected to seawater saturation and are at high risk of corrosion due to wet-dry chloride exposure cycles.
- Submerged (Wet)—underwater sections of piles are less frequently affected by corrosion damage. This is due to seawater having low levels of dissolved oxygen, a precondition for corrosion because oxygen is necessary at the cathodic sites to facilitate the reduction reaction ($O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$).

Figure 1. Corrosion of prestressed pile in tidal/splash zone. All Photos and Figures: Vector Corrosion.

Figure 2. Fabric form jacket with concrete fill.

Pile Jacketing

In an effort to repair, protect, and extend the life of corroding concrete piles, damaged piles have been jacketed with

- an overbuilt layer of reinforced concrete,
- cement-grout-filled stay-in-place forms (fiber-reinforced polymer [FRP], corrugated steel, or fabric), or
- epoxy-grout-filled FRP jackets.

In the 1990s, it was documented that this type of jacketing was ineffective for chloride contaminated concrete piles as it allowed corrosion to continue and the jacketing concealed the pile damage from detection by visual inspection.

In 1998, research conducted for the Florida Department of Transportation concluded that only jacketing that included cathodic protection should be permitted and this was implemented as policy.[1] The Virginia Transportation Research Center also reported in 1999 that "Grout jacketing alone is an inadequate protection against corrosion and should be supplemented with cathodic protection (CP)."[2]

Cathodic Protection Jacketing

Cathodic protection jackets can employ impressed current cathodic protection (ICCP) or galvanic anodes. ICCP is effective but requires a permanently operating power supply and commitment to system monitoring. The importance of ICCP system monitoring cannot be overemphasized, especially when applied to prestressed concrete where overprotection can cause corrosion or hydrogen embrittlement of steel tendons.[3]

In the battle against pile corrosion, galvanic jackets are an effective, low-maintenance option for the bridge preservation engineer. Galvanic jackets are installed using zinc anodes that are directly connected to the steel or connected via an

Galvanic Jacket Anode Options

Exposure	Wetness	Wet Jacket	Dry Jacket
Atmospheric	Dry		AA
Splash /Tidal	Intermittent	BZ or AA	BZ or AA
Submerged	Wet	BA	BA

BA - Bulk Zinc Anode in Seawater
BZ - Bare Zinc Anode (Seawater Activated)
AA - Self-Activated Anode

Table 1. Galvanic jacket anode options.

exterior electrical junction box. Galvanic jackets can include additional reinforcing steel if structural strengthening is required to supplement corroded reinforcement.

Galvanic Jacketing

Wet Applications

Different types of galvanic jacket systems are available today (Table 1). Typical galvanic jackets that are appropriate for wet exposure in the splash/tidal and submerged zones (that is, wet jacket) contain high purity bare-zinc anodes (BZ) inside a stay-in-place FRP form with a bulk zinc anode (BA) attached to the submerged section of the pile (Fig. 3 and 4). Once the jacket is in place, the annulus containing the bare-zinc anodes is filled with portland cement grout or concrete. The FRP jacket, which is placed 1 ft below low tide, is continuously submerged in seawater. With an open-bottom design, seawater is allowed to penetrate inside the jacket through direct saturation and capillary diffusion. This keeps the concrete highly conductive and exposes the zinc anodes to chlorides thus keeping the zinc electrochemically active (chloride activation). The bulk zinc anode produces a small DC current that cathodically protects the submerged sections of the pile and supplements the zinc anodes inside the jacketed area.

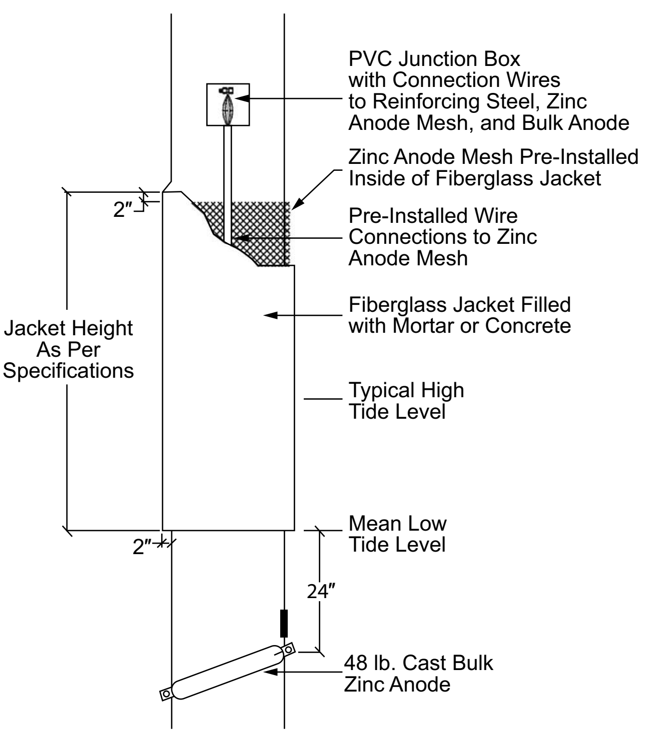

Figure 3. Schematic of wet jacket including bare zinc mesh anode, stay-in-place fiber-reinforced-polymer form, and submerged bulk zinc anode.

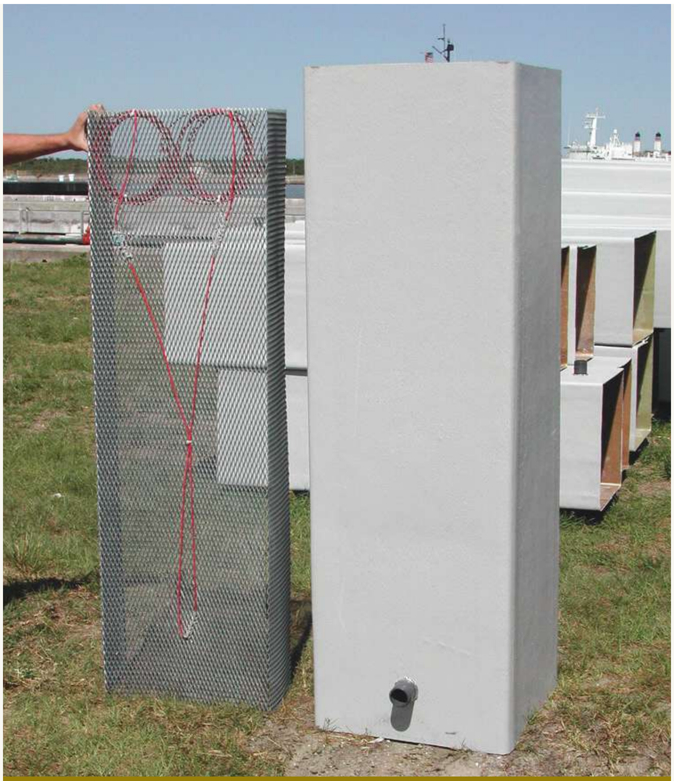

Figure 4. Wet jacket that includes a bare zinc mesh anode and stay-in-place fiber-reinforced-polymer form. (Bulk zinc anode not shown.)

Because bare-zinc jackets rely on saltwater saturation, they are less effective at protecting drier areas of concrete piles or piles exposed to low chloride water or freshwater. Bare-zinc jackets provide a high level of protection in the tidal and splash zones where the zinc anodes and grout infill are directly saturated in saltwater.

Dry Applications

A different type of galvanic jacket uses premanufactured self-activated anodes (AA) placed inside stay-in-place forms with portland cement grout or concrete infill. Self-activated anodes (that is, not saltwater/chloride activated) function by keeping the zinc in a highly alkaline environment that is corrosive to zinc but not to reinforcing steel. This technology facilitates anode operation independent of exposure to seawater or chloride saturation (Fig. 5) and can be used in dry applications (that is, dry jacket) such as severely damaged bridge columns or piles above high tide. If the concrete section to be protected is only in a dry, atmospherically exposed area, then a dry

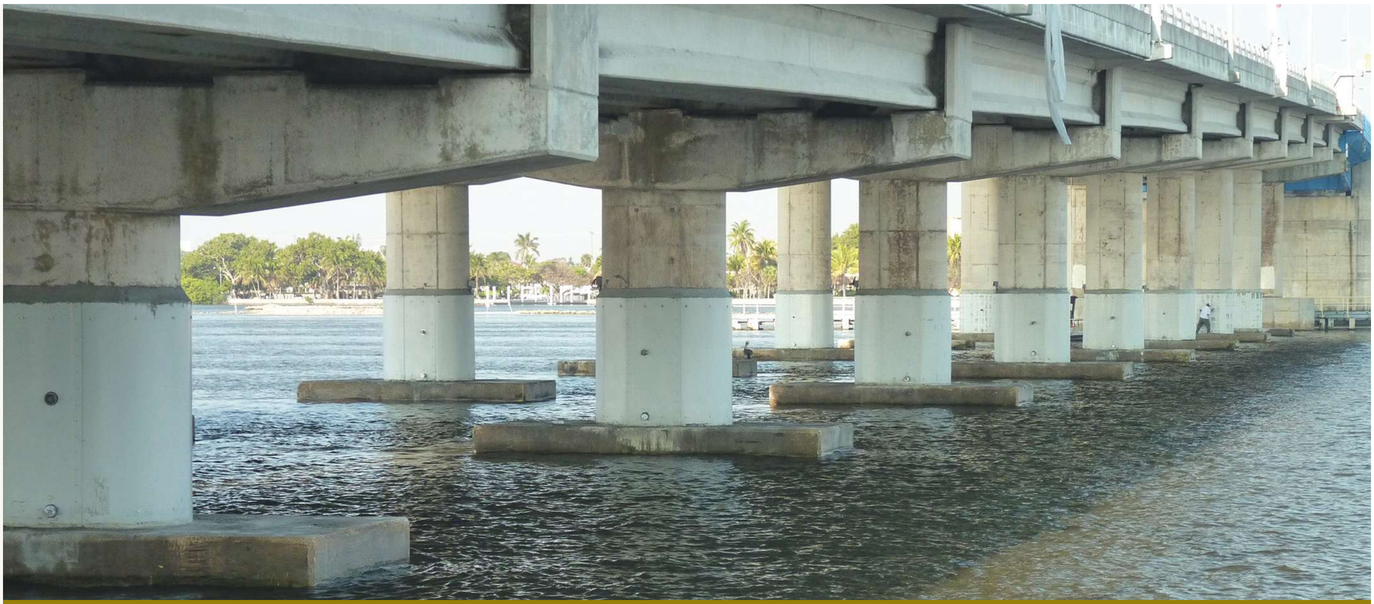

Figure 5. Installed dry jacket system that includes galvanic jackets with activated anodes (no bulk anodes).

Figure 6. Dry jacket that includes alkali-activated anodes on the pile prior to jacketing (bulk zinc anode not shown).

jacket with activated anodes is necessary but bulk zinc anodes are not required.

Alkali-activated distributed anodes are used in both wet conditions (including saltwater, brackish, and freshwater), and dry conditions. If the jacket is installed with the bottom of the form below low tide, then a submerged bulk zinc anode (BA) is used in addition to the alkali-activated anode in the jacketed area.

Galvanic jackets with alkali-activated distributed anodes are flexible in design. The anode size and spacing can be adjusted based on the desired service life. The anodes can be installed directly onto the pile or attached to stay-in-place formwork (Fig. 6). The anodes are used with a variety of formwork including removable concrete forms, stay-in-place FRP, or modular PVC forming systems that are assembled in the field (Fig. 7).

Figure 7. Self-activated anodes inside modular PVC formwork.

Conclusion

Galvanic jackets are a durable, low-maintenance cathodic protection solution to mitigate pile corrosion and can provide an estimated service life in the range of 20 to 50+ years without the need for external power or monitoring. To ensure the highest quality installation, galvanic jackets should be designed, inspected, and energized by a cathodic protection specialist experienced with concrete structures.

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References

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