Corrosion Control with Induced Tension Polymer Wraps

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The development of fabric and gel technology over the past 10 years has enabled wraps to be produced to cover pipe diameters from 1-1/2 to 120 in. (3.8 to 305 cm). Corrosion inhibitors and biocidal formulations contained within a range of gels provide "active" protection of steel, concrete, and timber substrates in the range of –40 to 130°C. Residual elasticity within the wrap fabric safely maintains the wrap in position and prevents leaching of the gel/inhibitor into the environment and enables the facility to remove and replace the wrap to facilitate substrate inspection.

The concept of using induced hoop tension within the elastic limit of materials to secure them in place has been practiced for many years within the clothing industry and in engineering applications. For example, the force induced into an article of clothing by stretching or tensioning during dressing is sufficient to retain a garment in place throughout the day, without undue discomfort. Similarly, the interference fit assembly of bearings onto a shaft is retained in place by hoop tension generated within the housing during installation. If designed correctly, this force should retain the bearing in place throughout its operational lifetime. Another example is the support provided by an elastic bandage to a sports injury.

The same concept applies in designing wraps for locations from Flushing and Bowery Bays in New York to the North Sea or Arabian Gulf. Examples of typical projects are given in Table 1. The elastic memory characteristics of the tough resilient coated outer fabric permanently retain the hoop tension forces which act upon a thixotropic gel containing a selection of corrosion inhibitors or biocidal preparations. This causes the gel to be exuded into the pile surface and into its irregularities.

Design Theory

Induced tension wrap systems afford both active and passive protection to marine and freshwater structural members. The wrap acts as a physical barrier to the environment, depriving the pile surface from oxygenated seawater while active corrosion inhibiting agents within the wrap arrest the corrosion process.

To maintain its position once installed, and provide a good association between the substrate and active components of the wrap, the membrane is stretched around the pile like an elastic band, generating hoop tension.

The degree of stretch and consequent hoop tension have been derived over a period of 10 years development. Many projects have been conducted from northern waters to the tropics.

The required hoop tension is a function of the strength of wave suction forces the wrap has to overcome to maintain its position, and hydrostatic pressure differential to prevent water ingress due to tidal fluctuations. Suction forces are primarily due to fluctuations in hydrostatic pressure resulting from natural wave motion. Larger waves produce larger wave suction forces and the hoop tension required to overcome these forces will be higher. Likewise, high tides ranges require higher hoop tension.

Experience in the field demonstrated that only two basic wrap designs are required to service most applications. By changing the physical properties of the material used, systems can be provided to function within the limits of both budgetary

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restraint and technical excellence for installation in diverse waters.

Design Criteria

The wrap design was based on a combination of materials with excellent performance records in some of the toughest operational environments. The components, which were in-line bonded to form the monocoque[A] fabric, were resistant to immersion in both seawater and fresh water and to biological and chemical attack. The system also withstood the degradative influences of environmental UV, ozone, and temperature variations.

The materials in the system were stressed below their operational elastic limits, ensuring a high safety factor in all parameters while in service. If accidentally punctured, the hoop tension causes the gel impregnated within the inner layer carrier to be exuded from the damaged area and then "self seal." The inhibitor within the gel serves to protect the base mtal underneath the damaged area. The design of the multilayer monocoque membrane and the hoop tensions involved, combine to ensure that in the extremely unlikely event of a tear to the wrap, it will not propagate.

The basic objective was to design a cold applied system that, while fulfilling all the requirements once in service, would be quick and easy to install.

No labor intensive ancillary materials such as tapes, sealants or adhesives were used to reduce the possibility of human error and/or noncompatibility of components in the installation system.

Primary Fabric

The following operational parameters, against a background of cost effectiveness were considered, in addition to design features necessary for the membrane to retain hoop tension throughout its projected operational life.

[A]Monocoque construction is where the stresses induced into the outer skin are shared with, and enhanced by other structural components of the multilayer construction.

TABLE 1
Typical Projects

LNG Deep Water Loading Jetty
Length: 8 miles (12 km)
Pile diameter: 54 and 66 in. (137 and 167 cm)
Pile construction: post stressed concrete
Problem: Rock boring mollusks attacked the calcium rich aggregate used within the concrete, creating bore holes which subsequently exposed post tensioned cables.
Solution: To wrap the piles from minus 2 ft (0.6 m) below seabed to 5 ft (1.5 m) above M.L.W.—a vertical distance of about 90 ft (27 m) at deepwater end reducing to 20 ft (6 m) at onshore termination.

Runway Extension LGA, New York
Pile diameter: 16 to 18 in. (40.5 to 45.7 cm)
Number of piles: 3,500
Problem: Splash zone corrosion from M.L.W. to pile cap.
Solution: Wrap piles from pile cap to 3 ft (1 m) below M.L.W. (10 ft [3 m]).

Bauxite Unloading and Alumina Loading Jetty, Western Ireland
Pile Diameter: 6.5 ft (2 m) plus 12 sided raker piles
Total number of Piles: 350
Problem: Splash zone corrosion from M.L.W. to pile cap
Solution: Wrap piles from pile cap to 3 ft below M.L.W. (4 m)
Special conditions to be considered: Exceptionally high currents (7 knots) when tide coincides with river current.

- toughness
- abrasion resistance
- good UV resistance
- good ozone resistance
- resistance to high climatic temperature
- proven long life under seawater
- resistance to hydrocarbon oil contamination
- resistance to degradation by any form of marine life
- oxidization resistance
- environmentally compatible.

The primary membrane of the wrap was polymide woven textile scrim which supports, during manufacture, a multilayer series of coatings, selected for their long term record of excellent marine resistance throughout the system's design life of 15 to 20 years.

The multilayer construction method provided fabric of dedicated thickness selected to suit the operational environment. Conditions can vary from inland waterways, harbors, and offshore deep water structures as well as northern regions, necessitating ice abrasion resistance (Figure 1). Simultaneous in-line bonding of the scrim to the inner face of a polyester absorbent felt enhanced the physical properties of the fabric and provided an absorbent carrier for the blend of corrosion inhibitors or biocides suspended in a thixotropic hydrophobic gel.

The finished fabric provided essential elastomeric memory and stretch retention characteristics together with the facility to be in-line welded into the finished design.

Design Load Assumptions

Wave transient suction forces result from waves, generated by the propeller wake of large vessels in rivers and estuaries and by "100-year" storms striking static objects such as piles, risers, or platform legs.

The resultant loads vary from as little as 50 lb/ft^2 (242 kg/m^2) to greater than 350 lb/ft^2 (1,690 kg/m^2) with tan-

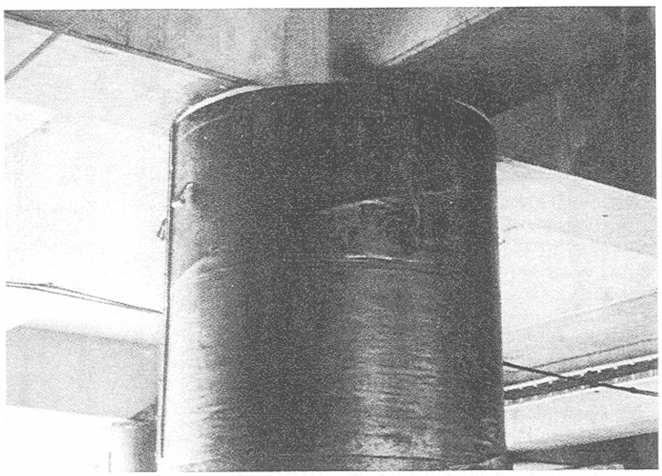

FIGURE 1
Induced tension wrap system underneath bridge piles.

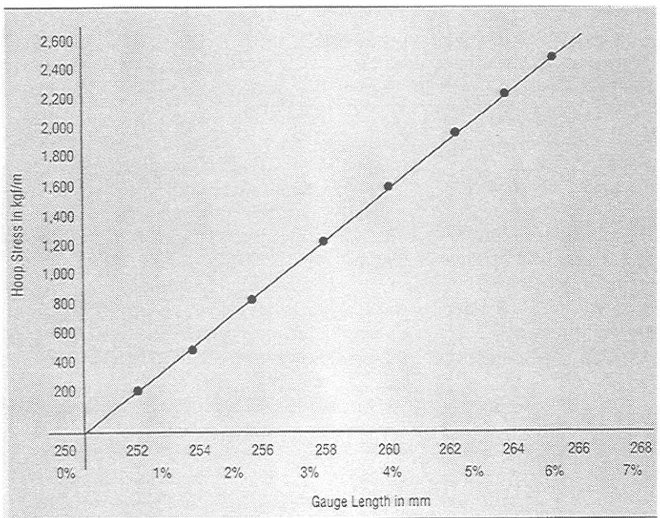

FIGURE 2
Retrowrap pile/riser cladding. Graph of hoop stress in km against gauge length in mm.

gential forces of up to 10 lb/ft^2 (48.3 kg/m^2).

The wraps should resist long-term immersion in seawater and nominal marine growth build up. If necessary, antifouling resistance can be added to the wraps during construction. Ambient temperatures can vary from –80°F (–62°C) in northern regions to 130°F (54°C) in the Arabian Gulf.

Fabric Stress

To produce an inward pressure on a pile of 5.5 ft (1.6 m) diameter equal to an approximate expected wave suction force of perhaps 150 lb/ft^2 (724 kg/m^2), the tension induced into the wrap must not be less than 412 lb/ft (608 kg/m) of vertical length, plus a safety factor and allowances for variations in water/air temperature. In practice, this required the fabric to be extended/stretched circumferentially during installation by approximately 10 in. (25.4 cm) using draw bolts acting against the molded plastic closure flanges.

Installation Requirements

Wrap systems should be as quick and cost effective to install as possible. The light wraparound modules were installed using relatively little manpower or trained supervision with the minimum of equipment and skill. Breakdowns and complications on-site were kept to a minimum. Temporary work, such as scaffolding around the riser or jacket leg was not required in many instances.

Modular Units

The system was designed to be supplied in modular lengths up to 3 m. Each unit was butt jointed and locked into place by a circumferential joining seal specially designed to induce additional hoop stress into the joint area. The units were tensioned in-situ, subsea or top side, with drawbolts fitted through the closure flange and driven by compressed air or a hydraulic impact wrench. After closure was achieved, drawbolts were removed and replaced with corrosion resistant monel or stainless steel bolts. Positive face to face closure simplified installation inspection techniques.

Installation Inspection

Post Installation Inspection

A. Hoop Stress—Since induced "hoop stress" was the principle operation, datum marks located around the circumference were permanently marked on the outer skin at predetermined point to point dimensions. Upon tensioning, a hoop tension was induced, determined by measuring the extended point to point dimension after installation and compared against a hoop stress graph (Figure

2). This determined if the required circumferential tension distribution was achieved.

B. Closure Seal—To determine if a satisfactory seal was achieved, after the marine resistant bolts were tightened and the flange seal faces were under compression, a slip gauge was used to inspect along the full length of the vertical seal.

C. Substrate Inspection—The system provided for easy systematic removal to carry out inspection of the substrate at predetermined intervals throughout the operational life. At this time, the inhibitor content of the inner gel layer can be monitored and, if necessary, recharged prior to replacement.

Conclusion

Induced tension wrap systems provide an effective retrofit method of corrosion or environmental protection of risers, piles, and certain specific sections of subsea pipe work. The principle of operation was such that the system could be used to become a retrofit carrier of the external antifouling system factory applied to the outer layer in quantities calculated to prevent marine growth build up for defined periods.

Within this technology package, the facility exists to provide specific shaped units for a variety of subsea or splash zone applications. In addition to concrete piles, the system accommodates square, multisided (H sections), together with wooden piles. In the case of wooden piles, a timber biocidal preservative was substituted for the corrosion inhibitor.

Since the systems' functions by active chemical inhibition provided by the corrosion inhibitor contained within the thixotropic gel, surface preparation was reduced to its simplest form. The mechanical removal of marine growth and delaminated iron oxide was all that was necessary. Shot blasting and the recovery of spent grit was not an expenditure, resulting in lower installed costs.