

Corrosion Control with Induced Tension Piling Wrapping

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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 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 degrees 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 easy removal and replacement of the wrap to facilitate substrate inspection.

The elastic memory characteristics of the tough resilient outer coated 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 any irregularities.

in place for the rest of its operational life. Another example is the support created by an elastic bandage applied to a sporting injury.

The same concept applies in designing wraps for pilings, pipes, risers and other marine applications in locations from Flushing and Bowery Bays in New York to the North Sea or the Arabian Gulf.

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.

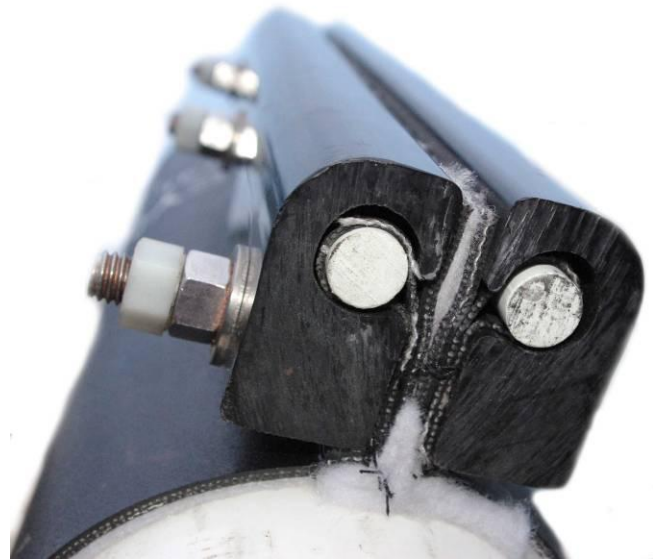
The degrees of stretch and consequent hoop tension have been derived over a period of 10 years development. Many projects have been conducted from northern waters to the tropics.

The required hoop tension is a function of the strength of wave suction forces the wrap has to overcome to maintain 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 tide 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 restraint and technical excellence for installation in diverse waters.

Design Criteria

The wrap design is based on a combination of materials with excellent performance records in some of the toughest environments. The components are in-line bonded to form the monocoque fabric, resistant to immersion in both seawater and freshwater 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 metal 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 develop a cold applied system that while fulfilling all the requirements once in service, would be quick and easy to install.

No labour 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.



The concept of using induced hoop tension within the elastic limits 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



Primary Fabric

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

Qualities of the primary fabric included...

- 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 polyimide woven textile scrim which supports, during manufacture a multilayer of coatings, selected for their long term record of excellent marine resistance throughout the system's design life of 15 to 20 years.



The multi layer construction method provided fabric of dedicated thickness selected to suit the operational environment. Conditions can vary from inland waterways, harbours and offshore deep water structures as well as northern regions, necessitating ice abrasion resistance. 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 242kg/m² to greater than 1,690kg/m², with tangential forces of up to 48.3kg/m².

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 -60 degreesC in northern regions to 54 degreesC in the Arabian Gulf.

Fabric Stress

To produce an inward pressure on a pile of 1.6m diameter equal to an approximate expected wave suction force of perhaps 724kg/m², the tension induced into the wrap must not be less than 608kg/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 25.4cm using draw bolts acting against the moulded plastic closure flanges.

Installation Requirements

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

Modular Units

The system is designed to be supplied in modular lengths up to 3 m. Each unit is 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 topside, with draw bolts fitted through the closure flange and driven by compressed air or a hydraulic impact wrench. After closure is achieved, draw bolts are removed and replaced with corrosion resistant monel or stainless steel bolts. Positive face to face closure simplifies inspection techniques.

Post Installation Inspection

Hoop Stress – Since induced 'hoop stress' is the principle operation, datum marks located around the circumference are permanently marked on the outer skin at predetermined point to point dimensions. Upon tensioning, a hoop tension is induced, determined by measuring the extended point to point dimension after installation and compared against a hoop stress graph. This determines if the required circumferential distribution is achieved.

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

Substrate Inspection – The system provides 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 is 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 biocide preservative can be substituted for the corrosion inhibitor.

Since the systems function 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 is all that is necessary. Shot blasting and the recovery of spent grit is not an expenditure, resulting in lower installation costs.

Typical Projects

LNG Deep Water Loading Jetty

Length: 12km

Pile Diameter: 137cm and 167cm)

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 0.6m below seabed to 1.5m above M.L.W. – a vertical distance of about 27m at deepwater end reducing to 6m at onshore termination.

Runway Extension L.G.A., New York

Pile diameter: 40.5 to 45.7cm)

Number of Piles: 3,500

Problem: Splash zone corrosion from M.L.W. to pile cap.

Solution: Wrap piles from pile cap to 1m below M.L.W. 3m

Bauxite Unloading and Alumina Loading Jetty, Western Ireland

Pile diameter: 2m plus 12 sided raked piles

Total number of Piles: 350

Problem: Splash zone corrosion from M.L.W. to pile cap.

Solution: Wrap piles from pile cap to 1m below M.L.W. (4m)

Special conditions to be considered:

Exceptionally high currents (7 knots) when tide coincides with river current.