Impregnation of Post-Tensioning Tendons

A solution for post-tensioning steel corrosion

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Post-tensioned concrete is a well-accepted construction technique that offers appreciable benefits in bridge design, construction, and appearance. Many signature structures across the country have been cost-effectively built with post-tensioned concrete. Post-tensioned bridge tendons are normally bonded with cementitious grout after tendon stressing. In addition to bonding the strands in place, the cementitious grout provides an important function in the durability of the structure by protecting the post-tensioning tendons from corrosion.

Grout quality for post-tensioning tendons has been an important consideration for many years because strand corrosion was noted in the presence of grout bleed water and bleed water voids. This concern prompted the development of proprietary cementitious grouts with anti-bleed characteristics.[1] Modern grouts have provided improved performance, but problems have been detected on recently constructed structures including grout voids, segregated grout, soft grout, presence of a high level of sulfates, and chloride-contaminated grout.[2]

In addition to the noted grout defects, an elevated level of relative humidity (RH) has been suggested as an environmental-condition factor that affects the risk of corrosion for post-tensioning systems, even without the presence of chlorides.[3] High RH influences the effectiveness of cementitious grout, particularly in the presence of voids, by reducing its electrical resistivity, an important material property for corrosion resistance. For example, RH levels in grouted post-tensioning tendons in Virginia have been measured as high as 94.4% as compared to ambient RH of 63.1%.[4]

According to the Federal Highway Administration, some post-tensioned concrete structures with multiple corrosion protection measures have experienced tendon failure within 6 to 17 years of service.[5] Due to the cost of inspection and the consequence of post-tensioning tendon failure, the Texas Transportation Institute states that ". . .bridge owners should do everything economically feasible to prevent the exposure of strands to high relative humidity levels, water, and/or chloride conditions."[3]

Example of a post-tensioned, box-girder bridge with external post-tensioning tendons. All Photos: Vector Corrosion Technologies Ltd.

Salt spray testing on untreated and impregnation-treated strands.

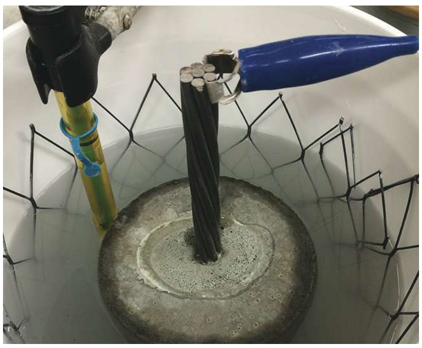
Segregation of grout (light tan is soft and grey is solid) and void at top of tendon.

Impregnation of post-tensioning tendons, a recent advancement in corrosion mitigation of grouted post-tensioning steel, offers a promising solution to protect both new and existing post-tensioning tendons from the effects of high RH levels, voids, water, sulfates, and chloride-induced corrosion. The system utilizes the naturally occurring interstitial spaces between the wires of seven-wire strands to transport a formulated low-viscosity, dual-acting, hydrocarbon-silicon-polymer resin that displaces moisture, forms a protective barrier on exposed steel surfaces, and impregnates the surrounding grout to form a barrier to moisture and oxygen.[6]

Access to the interior of the tendon is made at the grout caps or by an installed port at an intermediate tendon location. After the tendon is air tested and any leaks are

Corroded strands in a bonded post-tensioning tendon.

Impregnation of post-tensioning tendon from end anchorage.



Grouted post-tensioning strand sample undergoing potentiostatic testing.

Removal of grout reveals impregnation material present on steel surface and penetration into surrounding grout.

repaired, the impregnation process begins. The impregnation material has been shown to travel as far as 250 ft along the length of a tendon through the interstitial spaces.

Impregnation of post-tensioning steel has been utilized on post-tensioned bridges in Florida and Virginia. These projects have successfully demonstrated that the impregnation process allows the impregnation material to

- flow through the interstitial spaces in post-tensioned tendons up to 250 ft from the end or up to 100 ft from an intermediate location,
- leave a corrosion resistant film on exposed steel surfaces, and
- penetrate into the grout for an additional layer of protection surrounding the strands.

The post-tensioning-steel impregnation system has been subjected to a great amount of corrosion testing. Laboratory testing completed to date has focused on determining the qualitative and quantitative corrosion-resistance benefits of the impregnation process. For example, salt spray testing on treated and untreated post-tensioning strand dramatically reveals the substantial corrosion resistance provided by the impregnation material.

Potentiostatic testing is a method to produce direct quantitative comparisons between treated and untreated samples in a laboratory setting. The potentiostatic testing completed on impregnated samples produced positive results with a 94.7% reduction in corrosion current in samples with 4.5% grout voids and a 93.1% reduction in corrosion current in chloride-contaminated grout samples. Interestingly, potentiostatic testing on void-free grout samples with and without chlorides shows that the impregnation treated samples had an 81.4% reduction in corrosion current versus the untreated samples.[6]

This testing demonstrates that the impregnation treatment improves the corrosion resistance of post-tensioning tendons with grout voids and chloride contamination. In addition, the treatment improved the corrosion resistance of properly grouted post-tensioning strands, a result that demonstrates the benefit of the impregnation process as a proactive corrosion protection treatment for newly constructed post-tensioned bridges.

Test Objective	Sample Description	Treated vs Untreated Samples Reduction in Corrosion Current
Grout Void Test	Chloride-free Grout with 4.5% Grout Void	94.7%
Chloride-contaminated Grout Test	Chloride-contaminated (2%) and Void-Free Grout	93.1%
Control/ Properly Grouted Strand	Chloride-free and Void-free Grout	81.4%

Potentiostatic test matrix and results.

References

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