Post-Tensioned Concrete: An Inherently Durable System

by Dr. Andrea Schokker, University of Minnesota Duluth

I teach courses in prestressed concrete and bridge design, and I am freshly reminded each semester about the inherent durability we have in our post-tensioned (PT) concrete bridge elements. While the phrase "belt-and-suspenders approach" may be overused, I think it truly defines a PT system. The steel strand is separated from aggressive agents, such as moisture and chloride, by the concrete, the PT duct, and grout (or other material or coating). Additionally, we have seen active development in each of these areas over the past 15 years, particularly in PT bridge systems. I've outlined the progression of each component below with a focus on a grouted PT system.

Concrete and Steel

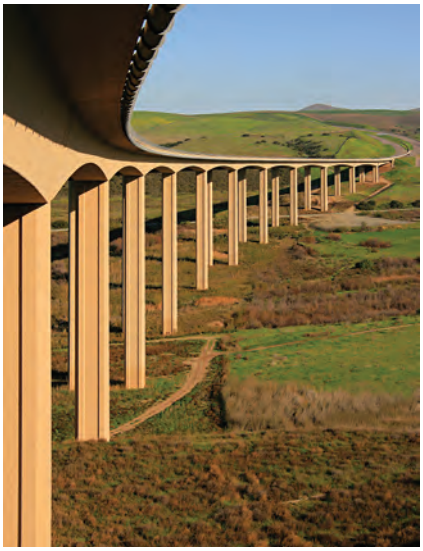
Low-permeability concrete with high-quality placement has become far more common, particularly in the quality-controlled, tight-tolerance environment of a bridge casting operation. We know far more about concrete materials and admixtures than we did a decade ago and the knowledge base continues to expand each year.

Quality concrete, combined with the active prestressing force from the steel PT tendon, provides the foundation for a highly durable structure. With today's low-permeability concrete, cracks are the primary path for corrosive agents to reach the steel. The precompression of PT concrete keeps cracks from forming under service loads and forces any cracks that might form to close after an overload is removed. This combination of high-strength steel strand and concrete brings the best out in both materials for a solution that is customized (through PT tendon layout) to the expected loads.

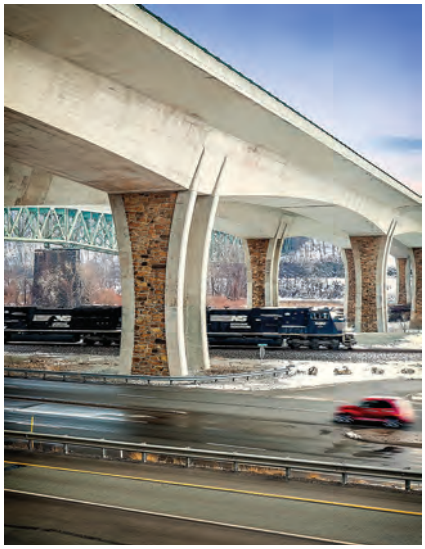
Duct and Anchor Protection

The PT duct and anchorage protection system has been revolutionized over the past 15 years. As a PhD student with Dr. Jack Breen at the University of Texas at Austin in the late 1990s, I was part of a team studying a wide array of options for improving durability of PT systems, including duct types, grout types, anchor protection, strand coatings, galvanized strands, and prestress level.[1–3] Most of the specimens contained the standard system at the time: a galvanized duct with duct-taped splices and attachments to the end trumpet, no end cap, and a nonshrink grout pourback in the anchor recess.

The Putnam Bridge in Washington County, Ohio, is a testament to the timeless aesthetic of concrete bridges. Photo: Julia David, Barr & Prevost.



Otay River Bridge, San Diego County, Calif. Photo: Mike Palhegyi.



Walsh Group built the Allegheny River Bridge, which features twin cast-in-place concrete segmental bridges with 532-ft-long main spans. Photo: FIGG.

Grouting was often done through an empty strand hole in the anchor head and venting, when done, was not always sealed with durable details. None of these would be considered good practice today in a PT bridge.

The PT system manufacturers responded quickly to the need for a more robust system to protect the tendon. In the concrete industry, change is often slow, but in this case we quickly saw the introduction of a number of new systems: watertight robust plastic duct, watertight mechanical duct and trumpet connections, leave-in-place plastic end caps, positive shut-off vents, and trumpets designed with a grout port that would also be accessible for inspection.

PT Grout

PT grout has come a long way in the past 15 years. The standard grout at the time of my PhD research was a 0.45 water–cement ratio, plain-cement-and-water grout that sometimes included an expansive admixture intended to help fill potential void areas (but was found to cause more issues than it helped[4]). We recognized the need for a high-performance material that had appropriate antibleed characteristics and a thixotropic (thick when static, less viscous when agitated) nature along with tests to measure antibleed properties. These early thixotropic grouts coming out of our research were water, cement and a thixotropic (gelling) agent suspended in a superplasticizer. The industry then moved to prepackaged versions for wider distribution that contained additional additives.

While the grouting material was changing, the Post-Tensioning Institute was also updating its grouting specifications to include state-of-the-art testing and implementation methods, and the American Segmental Bridge Institute started its grouting certification training course in 2001. Specifications, training, and materials have continued to develop since that time—all three of which are necessary for a quality end product. A cementitious grout when properly mixed and injected (including proper venting and low-point injection when possible), provides a compatible material for a PT concrete element including a high-pH environment for protection of the prestressing steel.

Summary

The PT system is inherently a multilayer protective environment that utilizes steel and concrete to their maximum potential for strength, ductility, crack control, durability, and overall resiliency. For this reason, many PT structures are in excellent condition today that were built prior to the advancements in PT durability that have been implemented over the last 15 years.[5]

We need to continue to train the workers who place the systems and continue to develop tests that are field friendly to ensure consistent quality. With today's improved materials, systems, and training, PT bridges are a robust, state-of-the-art solution for durable, high-performance bridges.

References

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