Investigating Existing Grouted Tendons

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Post-tensioning (PT) tendons enable designers to build large, economical concrete bridges with low maintenance costs. PT tendons are the primary reinforcement relied on for the bridge's structural integrity. Tendons are typically grouted for two reasons: the grout protects the strand against corrosion, and it provides the bond with the surrounding concrete that achieves strain compatibility in design.

Owners' Concerns

Given the significance of the grouted tendons, we need to ensure adequate durability to satisfy the design expectations. Although the vast majority of grouted tendons perform as designed, there have been limited cases of tendon corrosion due to grout defects or entry of contaminants. The observed grout defects included voids in the tendons and soft grout. Both can lead to reduced protection of the strands as well as local corrosion that can lead to strand breakage or, in extreme cases, tendon failure.

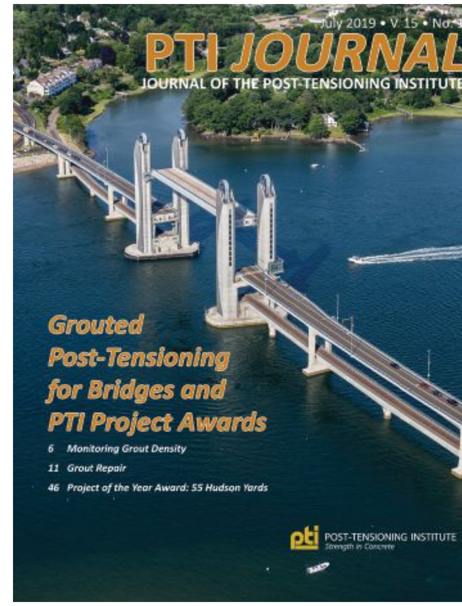
The owners of major PT bridges have two main concerns about grouted tendons, which the industry has been striving to address. First, owners want to be assured that quality grouting can be consistently achieved. Great progress has been made in this direction (see the Concrete Bridge Technology articles in the Winter 2017 issue of *ASPIRE®*). The fourth edition of *PTI M55.1-19: Specification for Grouting of Post-Tensioned Structures*,[1] was issued in 2019. This document includes requirements for the design, testing, and installation of grout, along with detailed grouting procedures. When the specification is followed in its entirety, good results are achieved. Also, the PT industry has moved to prepackaged grout mixtures that achieve consistent results when mixed and handled properly.

Impact-echo testing. See Reference 2.

Second, owners want to know how to detect grout defects in an already installed tendon. To address this concern, three papers on the subject have been recently published in the *PTI Journal*. The articles are available for download on the Post-Tensioning Institute website using the links provided in the references.

Nondestructive Tests to Detect Defects

The most recent of the three *PTI Journal* articles is "Nondestructive Testing for Voided and Soft Grout in Internal Post-Tensioning Ducts," by Paul Fisk and Benson Armitage.[2] This July 2019 article investigates the use of two nondestructive testing methods that can be used in detecting grout defects in tendons. The ground-penetrating radar (GPR) method is used to accurately locate the internal ducts to a precision of ½ in. Then, sonic/ultrasonic impact-echo testing can be used to detect voids or soft grout. Once a defect location is identified, workers can drill into the duct and use a borescope to document the tendon condition. The impact-echo system uses a projectile impact-energy source, a sensor array, and a computer to achieve quality display of data. If a



Cover of the July issue of 2019 *PTI Journal*, which featured grouted post-tensioning for bridges. All Photos and Figures: *PTI Journal*.

duct is fully grouted, the compression wave velocity generated and recorded by the impact-echo system remains constant. When voids or soft grout exist in the tendon, the resonant frequency is significantly lower or not measurable, indicating anomalies along the wave path.

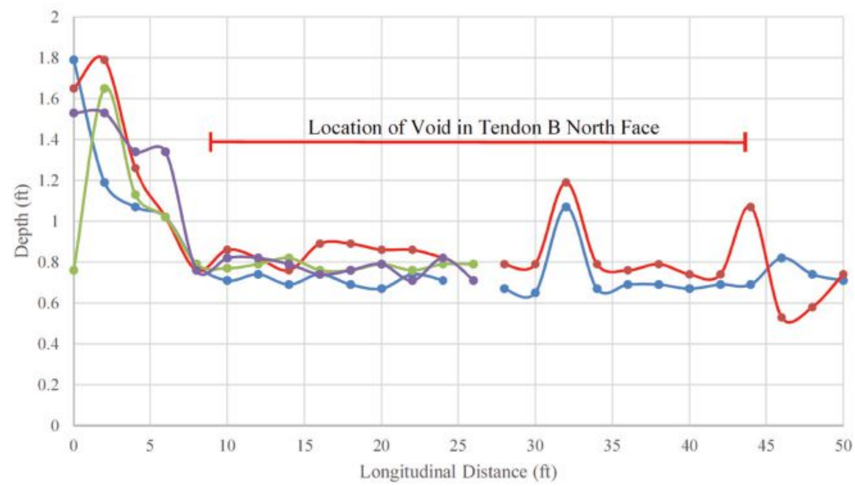
There are limits to the effectiveness of these testing methods related to the thickness of the concrete member. Most of the time, these limitations are not an issue when evaluating a typical thin-walled segmental or box-girder bridge. However, GPR and impact-echo methods have limited accuracy in thicker areas, such as tendon high points. Even with the limitations, the impact-echo system is a promising method that can help identify issues in existing tendons.

The second article is "NDT Investigation of PT Ducts," by David Corbett.[3] This December 2018 article also describes how GPR is used to locate tendons; once they are located, potential grouting defects are identified through an ultrasonic pulse and echo (UPE) method. Objects in concrete are detected through reflections that occur at the boundary between two materials with different properties. GPR works with reflections occurring when the two materials have different dielectric properties, whereas UPE works with reflections occurring when the two materials have differing acoustic impedance. GPR waves are totally reflected at a concrete-steel boundary and partially reflected at an air or plastic boundary. UPE waves are totally

Pulse echo instrumentation includes a transducer and an indicating device (upper photo). The lower photo shows the transducer directly above a duct. See Reference 3.

reflected at a concrete-air boundary and partially reflected at a steel or plastic boundary. Because of that, UPE enables PT duct detection through reinforcing bar configurations that would limit GPR. More significantly, the total reflection from air may make detection of voids in the duct possible. A comprehensive evaluation using the amplitude and phase analysis techniques of the pulse-echo technology is now possible as three-dimensional imaging is available in commercial equipment used on site.

The third article of note is "Grouted Post-Tensioning Tendon Evaluation," by Liao Haixue.[4] This December 2017 article discusses the causes of corrosion in tendons and describes evaluation techniques (GPR for locating tendons and sonic/ultrasonic impact echo for detecting grout voids or soft grout). Additionally, the paper discusses a case study of a bridge evaluation in British Columbia. Two possible voids, approximately 25 to 30 ft long, were identified using GPR and the impact-echo method. Subsequent drilling into the duct and borescope investigation confirmed the voids to be 28 to 33 ft in length, demonstrating that the nondestructive testing method identified the voids with good accuracy. Once the issues are located and evaluated, corrosion mitigation and repair solutions can be designed.



Sonic/ultrasonic impact-echo testing identified potential voids and soft grout areas. See Reference 4.

These three *PTI Journal* articles highlight how GPR can be used for locating tendons and the impact-echo method can be used to locate tendons in congested areas and to detect potential voids or soft grout in ducts. Together, these methods have been used to successfully identify grouting deficiencies, typically voids but sometimes also soft grout. Subsequent drilling into the ducts of those areas and the use of a borescope gives the investigators sufficient information to devise an effective repair.

Conclusion

As always, the best defense against corrosion of the tendons is to do the job right the first time. This starts with the owner and the designer using the state-of-the-art specifications *PTI/ASBI M50.3-19: Specification for Multistrand and Grouted Post-Tensioning*[5] and *PTI M55.1-19: Specification for Grouting of Post-Tensioned Structures*[1] (see the Summer 2019 issue of *ASPIRE* for an article discussing these specifications). These specifications are intended to be used together and should both be referenced in their entirety in the project specifications. Doing the job right the first time also means specifying and enforcing the field personnel certification requirements as outlined in the M50.3 specification. A properly trained workforce is much less likely to make errors in the installation and grouting processes. The grouting plan, as required in the M55.1 specification, should be followed from the beginning to the end, including any contingencies that are part of the plan. With all parties pulling together, tendon grouting deficiencies can be largely avoided.

References

1. Post-Tensioning Institute (PTI). 2019. *PTI M55.1-19: Specification for Grouting of Post-Tensioned Structures*. Farmington Hills, MI: PTI.
2. Fisk, P., and B. Armitage. 2019. "Nondestructive Testing for Voided and Soft Grout in Internal Post-Tensioning Ducts." *PTI Journal* 15 (1): 31–35. https://www.post-tensioning.org/Portals/13/Files/PDFs/Publications/Reprints/PTIJOURNALFisk-Armitage.pdf.
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5. PTI and American Segmental Bridge Institute (ASBI). 2019. *PTI/ASBI M50.3-19: Specification for Multistrand and Grouted Post-Tensioning*. Farmington Hills, MI: PTI.

EDITOR'S NOTE

The editors thank the Post-Tensioning Institute for making links available for the three articles discussed so that readers can obtain them at no charge.