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Detection of Voids, Soft Grout and Tendon Corrosion in Internal Bridge Post Tensioning Ducts

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Introduction

Bridge owners recognize voids and soft grout in internal post tensioning ducts of bridges as a potential cause of tendon corrosion and a serious issue that they need to address. Nondestructive sonic/ultrasonic testing complimented with a drilling and bore scope inspection program can provide engineers with the specific locations of voids and soft grout, approximate volume of voids and an assessment of tendon corrosion, information necessary to prepare a repair plan and bid documents. Sonic/ultrasonic testing can be conducted post repair for quality assurance. The testing of the internal bridge ducts could be considered an overwhelming task, as many bridges have tens of thousands of linear feet of post tensioning tendons, but a phased approach can determine how effective nondestructive testing can be and focus attention on a particular type or location where voiding may be occurring. NDT Corporation has demonstrated the accuracy and cost-effectiveness of nondestructive sonic/ultrasonic impact echo and pulse velocity testing in identifying open/air and water filled grout voids and soft grout areas within post tensioning ducts.

The testing procedure is a three-step process:

1) Accurately locate and mark PT duct locations with ground penetrating radar (GPR)
2) Evaluate grout conditions in the duct with nondestructive sonic/ultrasonic impact echo and pulse velocity measurements
3) Verify impact echo results and document tendon corrosion with video bore scope imaging

The results of these tests are reported on bridge plans or schematic drawings (along with video images of void size and tendon corrosion) and recorded as: PT ducts with voids or soft grout; location of the poor grout conditions; description of grout (soft/ hard discolored); estimated volume of void; and tendon corrosion assessment if any.

Nondestructive Testing Methods

It is necessary to use high-resolution ground penetrating radar (GPR) to accurately locate the centerline of the duct. Shop and as-built drawings typically are not accurate enough to locate the centerline. GPR data acquired with a high resolution 1500 Hz antenna (photo below) locates the centerline of the ducts. The high frequency GPR antenna enables the technicians to distinguish the signal representing the ducts from those of the reinforcement and mark their location on

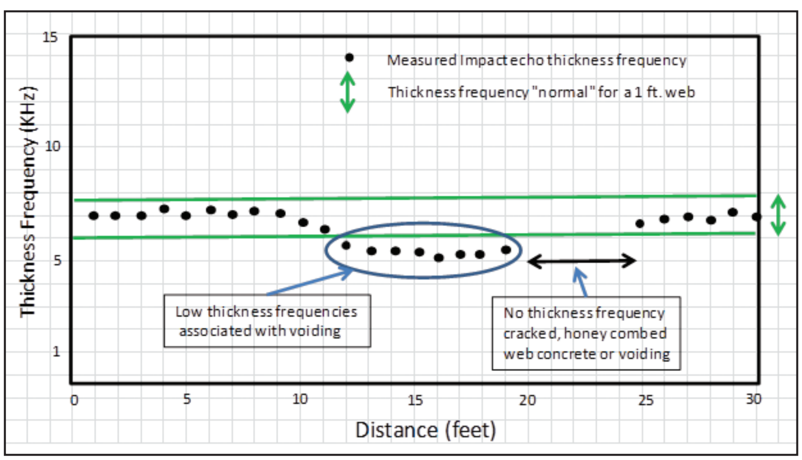
Using data from high frequency GPR technicians mark duct location on the surface of the concrete for further sonic/ultrasonic testing.

the surface of the concrete. The approximate centerline of each tendon duct is marked on the concrete surface with keel (wax crayon) for sonic/ultrasonic testing. Placement of the sonic receivers, as well as the position of the energy input, must be highly accurate – within one-half inch of the plane projected from the concrete surface through the duct center.

Sonic/ultrasonic testing acquires impact echo and pulse velocity data simultaneously. Technicians use impact echo data to identify areas of potential grout voids and soft grout, and pulse velocity data to assess the condition of concrete surrounding the duct and provide a complimentary data set to evaluate impact echo findings. It is important to have an evaluation of the concrete surrounding the duct since cracking in this concrete can produce false positive findings. The equipment components used for the sonic/ultrasonic testing are shown adjacent.

From top: GPR data acquired with a high resolution 1500 Hz antenna enables technicians to distinguish the signal representing the ducts from those of the reinforcement elements; Sonic/ultrasonic testing acquires impact echo data to identify areas of potential grout voids and soft grout, and pulse velocity data to assess the condition of concrete surrounding the duct.

The principal criterion for evaluating the tendon ducts is the thickness resonant frequency (impact echo testing) value of the concrete element (web, bottom slab, etc.). The concrete element, top slab, web or bottom slab that contains the tendon duct generally has two parallel faces. Energy input creates a compressional wave that propagates through the concrete in the horizontal direction and thickness directions. The compressional wave in the thickness direction sets up a resonance (multiple pulse-echoes). The reflected pulse-echo ray path time is a function of the compressional wave velocity and the element thickness. When the thickness and the compressional velocity remain constant, the thickness resonant frequency represents a fully grouted duct. When the resonant frequency is below (lower than) normal or is missing, then anomalies along the wave path such as an included air void (the velocity of air is 1,000 ft./sec; the velocity of the concrete is 13,500 ft./sec) results in a longer path time because the sonic ray path is diffracted around the void. A plot of the recorded thickness frequencies is used to determine suspect void/soft grout areas.

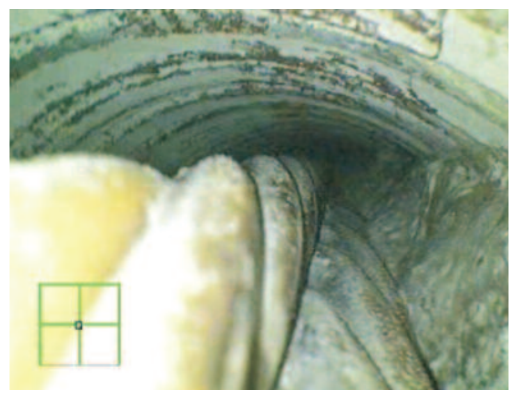


A plot of the recorded thickness frequencies determines suspect void/soft grout areas.

The resonant frequency for a fully grouted duct should represent the thickness of the concrete in which the tendon is located. If the duct is voided the wave will effectively travel (diffract) around the void along a longer travel time path than that for a fully grouted duct. If the duct is filled with soft grout (lower compressional velocity than hard grout), again there is a longer travel time path than that for a fully grouted duct. If the concrete surrounding the duct has cracking or honeycombed concrete, the reflected wave arrivals can destructively interfere with the normally reflected direct wave, resulting in no distinguishable thickness resonant frequency.

Verification and Documentation of Results

Technicians confirm nondestructive test results by carefully drilling a small diameter hole to the duct and using specially design tools to open the duct for visual observation and documentation with a video borescope. Technicians use GPR data to locate reinforcing to avoid drilling numerous holes to locate and access the PT duct. When they confirm and drill into a void, the technician inserts a borescope into the voided duct to document the size and length of the void, and the corrosion condition, if any, of the tendon. Voids that are several tens of feet long will require additional holes to the duct to verify void size, volume and tendon corrosion conditions. Technicians also drill at locations that impact echo results indicate no voiding or soft grout to verify these findings. Once testing is complete, the technician repairs all drill holes within a few hours. The technician permanently repairs locations with no voids. Locations with voids require a temporary repair that is airtight but can be easily re-opened for future repairs. All drill locations with voids are designated so that the repair contractor can easily find them in the future.



From top: video bore scope testing; and an internal duct image.

Nondestructive impact echo testing is very effective when web thickness are less than 2 feet. However, it is not possible to test 100 percent of every bridge PT duct. Locations where PT ducts cross over diaphragms or ducts that are below floor level or above ceiling level cannot be tested. Changing wall thickness can also be problematic, but this condition is usually observable or indicated on bridge plans and can be accounted for. This condition occurs at blisters where anchor heads are located. Potential voids within anchorages are evaluated by drilling and borescope inspection.

Drilling and borescope verification has confirmed in virtually every case that ducts with well-defined thickness resonant frequencies in a range considered normal for the web thickness have a duct filled with hard ("good") grout and those with thickness resonant frequencies lower than the normal wall thickness frequency have voids or soft grout. Our experience to date has been that usually 75 to 80 percent of the tendon areas tested fall into one of these two categories. The other 20 to 25 percent are locations where the technician is unable to detect well-defined thickness resonant frequencies. These locations are problematic because there is no information indicating if the duct is full or voided. In these cases, the technician acquires pulse velocity data from above or below these areas to determine if there is cracked or honeycombed (lower velocity) concrete conditions near the duct that could account for the loss of thickness resonant frequencies. If there is, no lower velocity the internal duct condition is determined with a drill hole and a bore scope inspection.

Technicians then record the results of these investigations on plans showing the location of voided PT ducts and tables listing:

- PT ducts with voids or soft grout
- Location of the poor grout conditions
- Description of grout (soft/hard discolored)
- Estimated volume of void
- Tendon corrosion assessment (if any)

This information allows the bridge engineer to prepare detailed bid specifications.

Nondestructive quality assurance (QA) testing is conducted on repaired PT ducts where the volume of grout used to fill the duct void is substantially lower than what is predicted by pre-repair measurements. This testing has been able to identify locations that are still voided and direct repairs to these locations.

Conclusion

Nondestructive sonic/ultrasonic impact echo and pulse velocity measurements can and have been successfully used to evaluate internal post tensioning ducts of bridges for grout voids and soft grout conditions. The results of this testing provides clients and bridge engineers with the data necessary to prepare repair bid documents that indicate specific locations to be repaired and approximate volume of the repair. As part of the nondestructive testing, the inspection holes used to identify void conditions are marked and labeled as voided with tendon identification to further assist the repair contractor efficiently locate duct to be repaired. Ultimately, this results in more accurate repair bids and potentially significant cost savings to bridge owners because contractors know what, where and the approximate volume of repairs they are bidding on. Nondestructive quality assurance (QA) testing can also be conducted on repaired PT ducts that grout takes are substantially lower than those predicted by pre-repair measurements. These measurements are used to verify that duct voids are filled and are able to identify locations that are still voided and direct repairs to these locations.

About NDT Corporation

In the last 14 years, NDT Corporation has completed numerous major projects: I-93 Bridges in Boston's Central Artery Project; Arrivals and Departures Bridges at Boston's Logan International Airport; Jamestown Verrazano Bridge in Rhode Island; and the Kellogg Bridge in Wichita KS. NDT Corporation uses nondestructive testing methods to identify specific locations within internal post tensioning ducts where grout voids and soft grout exist. Then verifies the nondestructive testing results by drilling a small hole to the duct, opening the duct with tools designed for this task, and verifying grout condition with probing and documenting tendon corrosion with video borescope imaging. The results of these investigations indicate where repair and remediation efforts should begin and are used to prepare repair bid documents.