Identifying Potential Damage to PT Ducts on the Theodore Roosevelt Bridge, Florida

Explore the non-destructive testing methods used to locate and inspect post-tension ducts and tendons in bridges

Overview

- The Florida Department of Transportation needed to pinpoint the specific location of potential post-tension (PT) damage in two box beam sections of the Theodore Roosevelt Bridge in Stuart, FL
- The Proceq GP8100 was used to identify the location of the tendons, while the Pundit PD8050 was used to determine the condition of the tendons.
- This project successfully identified potential PT duct failures and verified the integrity of good sections

The purpose of this project was to use non-destructive testing to locate PT tendon distresses identified with a permanent structural health monitoring system.

Challenge

The Roosevelt Bridge has experienced PT duct failures in the past, including improper grouting and cable breaks requiring repair. After these failures, a permanent acoustic and strain gauge structural health monitoring system was installed.

Data has been received that indicated potential PT damage in two box beam sections, but the current monitoring system is unable to determine the specific location. To avoid performing unnecessary work, a non-destructive method of pinpointing the damage is preferred.

Solution

Screening Eagle's Proceq Ground Penetrating Radar, GP8100 was used to locate the tendons, and the Pundit Ultrasonic Pulse Echo Linear Array, PD8050, was used together to assess condition of PT tendons. Both lower PT duct sections in the span of concern were scanned on the box beam floor between the anchorages. Most sections were acceptable, although there were several sections with potential defects.

Figure 1. PT tendon locations inside the box beam

Two technologies, ground penetrating radar (GPR) and ultrasonic pulse echo (UPE), were used to fully analyze the bridge; one to locate the tendons and the other to analyze their condition. Both are apt at mapping concrete embedments and anomalies, but each has their own specialties.

GPR devices emit electromagnetic waves into the concrete to create an image of objects up to 3 feet below the surface. A percentage of the wave is reflected at material boundaries depending on the dielectric constant of the materials. Metals, such as rebar and PT ducts, have an infinite dielectric constant which creates a strong reflection, clearly appearing in the scan. Air can also appear in the scan but has a weaker reflection because the difference in dielectric constant between concrete and air is smaller. However, since GPR waves are completely reflected at metallic surfaces, GPR devices are unable to assess the condition inside a metal duct, but are a great tool for locating PT tendons accurately.

Screening Eagle has three versions of concrete GPR, but the GP8100 was primarily used in this project. This device has 6 antennas for larger area coverage and single pass C-scans (called superline scans) that allow for easier interpretation (Figure 2). C-scans allow visuals through the concrete depth, starting at the surface and slicing through the thickness.

Figure 2. Proceq GP8100
GPR

The second device used was an Ultrasonic Pulse Echo Linear Array (UPE) device. This technology emits acoustic waves into the concrete to create an image of objects up to 5 feet below the surface. As with GPR, at material boundaries, there is a percentage of wave energy reflected to the device depending on the density, Elastic modulus, and Poisson's ratio of the materials. Since the difference in density between concrete and air is so large, there is nearly 100% reflection at concrete/air interfaces.

UPE excels at locating air-related defects such as delamination, honeycombing, and voids, including grouting voids within PT ducts. UPE is also able to locate metals but with less sensitivity. The difference in density between concrete and steel is smaller, so only about half the energy is reflected at metal interfaces.

Screening Eagle's UPE device, the Pundit PD8050, uses a linear array of transducers that enable detailed mapping with improved signal-to-noise ratios because it can intersect targets at different angles for better visuals.

Figure 3: Pundit PD8050

Key Findings

GPR Data

GPR data, like that shown in Figure 4, was taken at each scan location to locate each tendon. The six tendons on each side of the bridge are clearly visible. In addition, the rebar grid and concrete backwall are shown and tagged. The concrete backwall is only visible in between the rebar grid because the wave is unable to circumvent the PT tendons for a proper reflection. Using the lasers on the side of the device, tendon locations were marked on the concrete surface with red chalk.

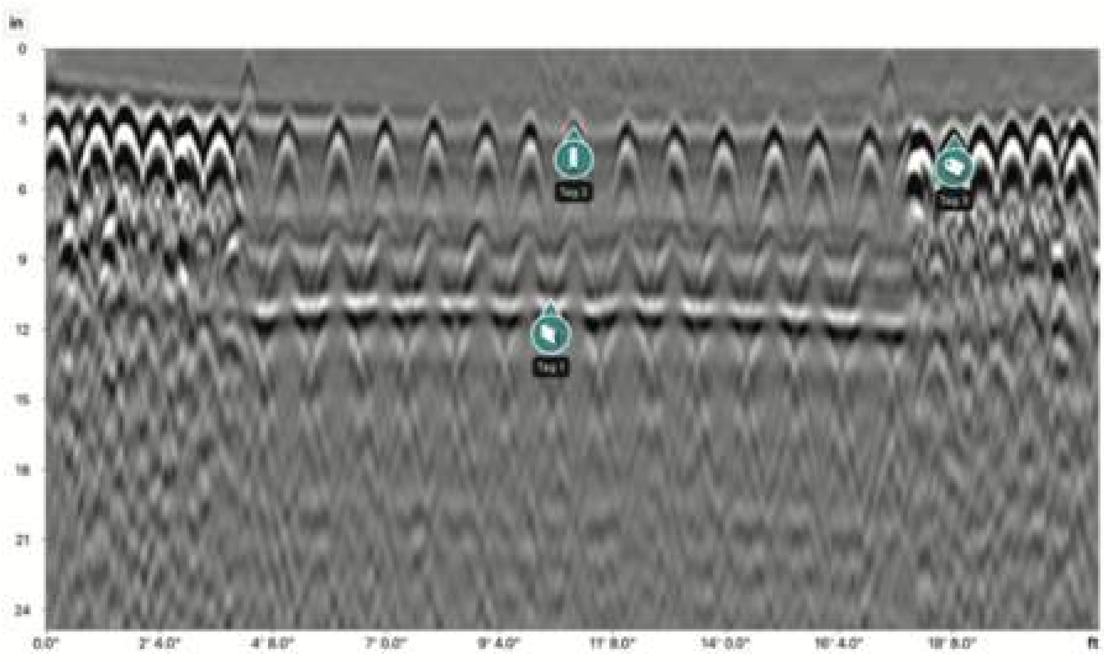
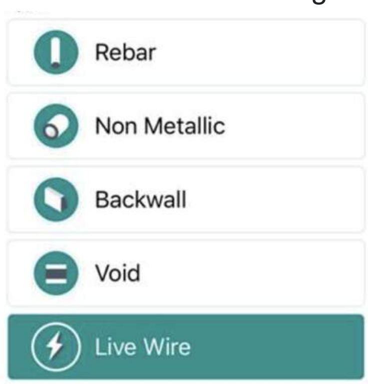


Figure 4: GPR scan across box girder width.



UPE Data

There is one line of snapshots per section composing the full scan and each scan is labeled on the top. The end of data snapshots corresponding to each tendon are identified with green markers (M1, M2, M3, etc.). In other words, the data for each tendon appears before the corresponding marker. Depending on surface conditions, a minimum of three snapshots were taken on each tendon at different locations.

Due to the overall surface roughness of the beam floor, the sixth tendon was not able to be scanned in all but one section. The x-axis can be used for distance measurement but in this instance, full gridding was disregarded in favor of inspection efficiency. The y-axis is the depth into the concrete with the surface being (0,0). There are many scans that identify the beam thickness at about 10 inches below the surface.

Figure 5

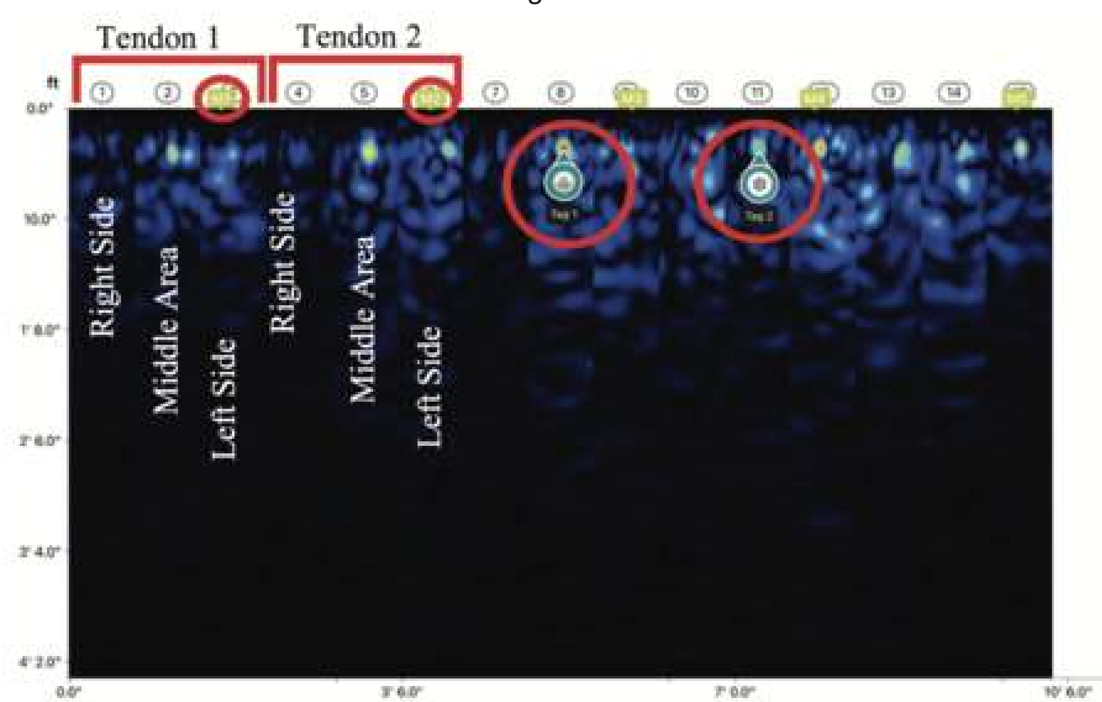


Figure 6

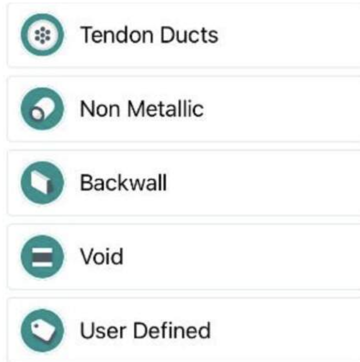


Figure 6 is a good example as there were 3 snapshots per tendon with 5 tendons able to be scanned. This section also had well grouted and poorly grouted sections of tendon, each labeled with proper tags. Areas in red indicate a strong reflection, typically an indicator of air. Areas in yellow or green indicate a weaker reflection, likely the metal and grout in the tendon or potentially minor honeycombing. Blue indicates solid concrete or a material so near to concrete in density the device does not register it.

Figure 7 showed a strong reflection in the third PT duct but it was only located in one snapshot. The rest of the tendon scans had reflections of a lower amplitude in comparison, indicating only a minor grouting concern in that centralized location. The other tendons in this section were deemed acceptable due to the low reflections.

There are many other sections that look like this example showing low amplitude reflections to indicate the tendon location and confirming proper grouting conditions. There were sections in each beam that had significant signs of distress. Figure 6 shows an area of delamination around tendon 3 and improper grouting in tendon 5. Delamination can be a lower amplitude reflection depending on the crack width but are easy to identify from the straight line of reflections. In this case, this delamination is underneath a patch.

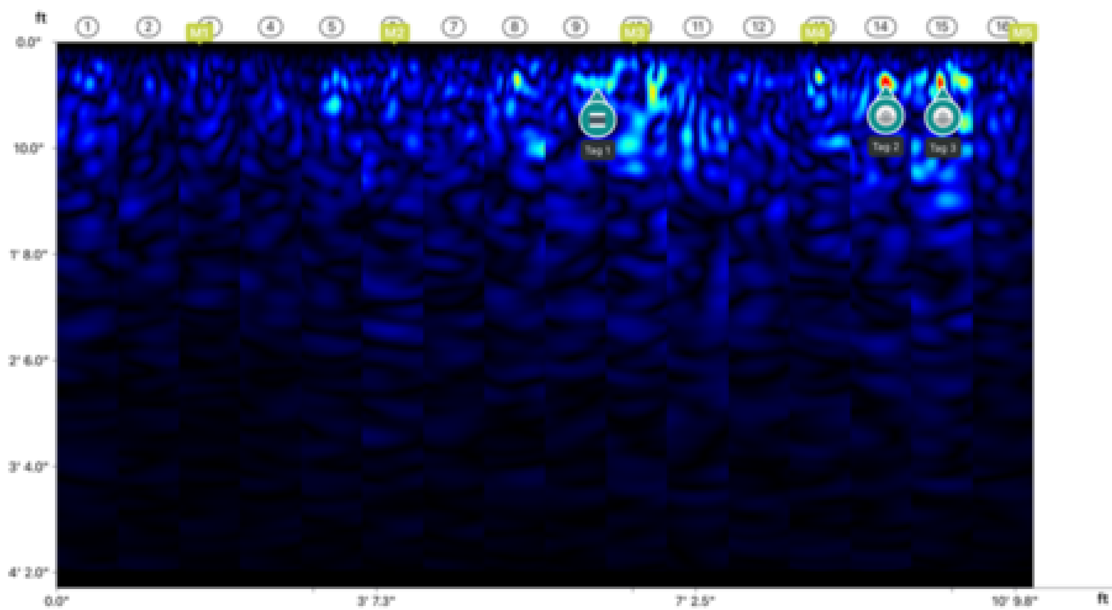


Figure 7: UPE scan

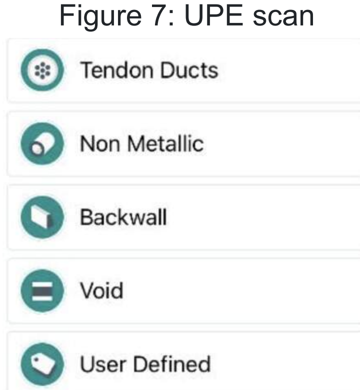


Figure 8 shows significant reflections with potential voiding occurring around the tendons as well as in the grout. Regardless, these strong reflections indicate a large presence of air voids in this area of the structure.

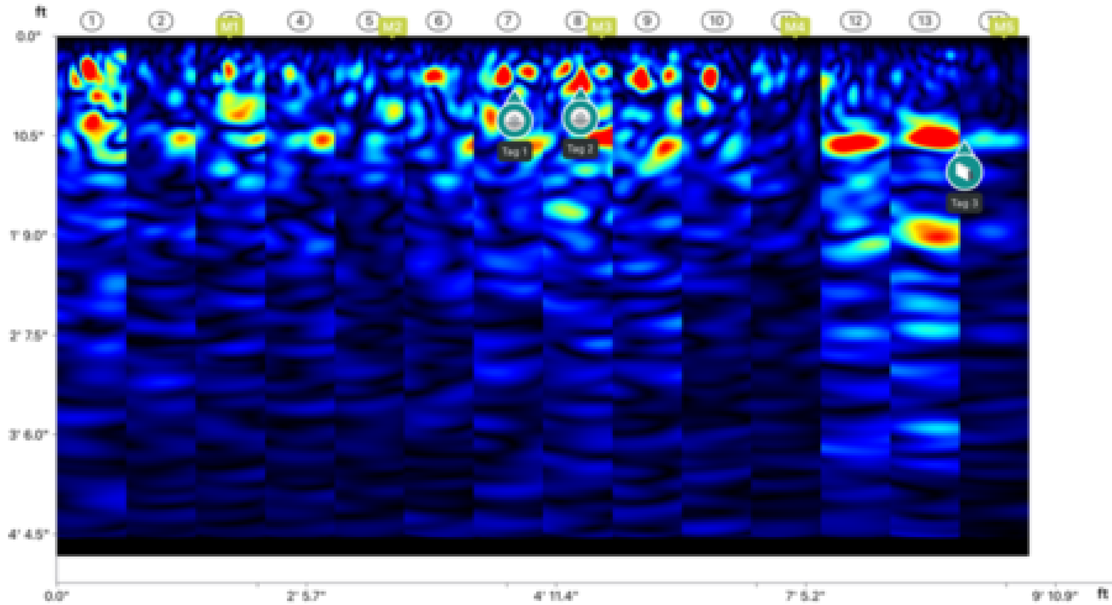
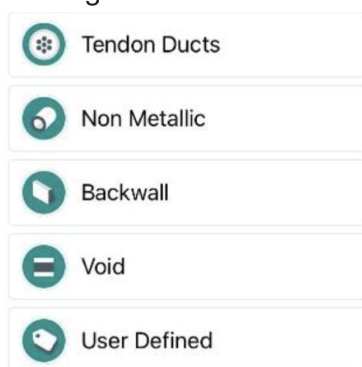


Figure 8: UPE scan



It is important to remember that not every strong reflection is harmful. This device is capable of imaging 5 feet into the concrete, so often there is a reflection from the other side of the concrete called the backwall. When the concrete is of good quality, there is a chance of a second backwall, an echo of the first trip the wave made through the concrete. This can be used to zero and calibrate the device for the best depth measurements.

In the 3-4 span of box beam, there was a consistent strong backwall under tendon 5 whereas everywhere else, only occasional hints of the backwall could be seen. The PT ducts can shadow the backwall even if it is in good condition due to the energy required to travel between the concrete/metal/grout interfaces. However, in tendon 5, the backwall could be seen the entire scan length. Whatever material interfaces the wave went through did not take the same energy as other locations scanned. This could be due to a change in concrete, grout, or duct material (maybe changing from metal to non-metallic sleeves).

The findings from this project show promise for precisely locating PT duct failures by identifying several instances of concern but also verifying the integrity of good sections. In this case, only a few snapshots were performed at each section but a C-scan of the complete tendon length between the deviation blocks is possible if there is a certain area of major concern. This is more time consuming, but if the detail and distance tracking is important, it can be done with the same device and app.

Destructive testing was performed on locations indicating a high degree of voids in the tendons by UPE. The official report has not yet been released, but initial reports indicate the presence of voids was confirmed at each location.

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