DID YOU KNOW? *Newsletter No. 104 - December 2022*

The APPLE drop weight system can be used in certain situations to determine if existing concrete piles are reusable.

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Using Thermal Integrity Profiling (TIP) to Detect Defects of Drilled Foundations

By George Piscsalko and Danny Belardo

Thermal Integrity Profiling (TIP) is a non-destructive quality assurance method for evaluating concreted drilled deep foundation integrity and geometry. To implement TIP on a project, one Thermal Wire® cable is attached to the reinforcing cage for every one foot (305mm) of shaft diameter. For small diameter ACIP/CFA piles with no full-length cage, a single wire can be attached to the center reinforcing bar. The Thermal Wire cables contain digital temperature sensors spaced every one foot (305mm) along the cable length.

The data acquisition process in accordance with (ASTM D7949) commences when data loggers are connected to the cables. This generally occurs either before or just following the concrete placement process. This method utilizes the heat generated during the concrete/grout curing process to assess deep foundation integrity over the evaluated length. Temperature measurements vs. depth (thermal profiles) are recorded every 15 minutes until peak temperature is achieved. The thermal data is processed in conjunction with the installation records to generate a plot of the effective average radius versus depth.

Analysis results include both qualitative and quantitative assessments. Qualitatively, variations or sharp reductions in temperature profiles indicate potential defects. Quantitatively, temperatures measured at the time with peak temperature are correlated to estimated effective local radii for subsequent integrity evaluation. Considering most defects identified in drilled foundations occur within the upper two diameters and the lower two diameters, it is critical that any QA/QC method effectively assesses the upper and lower portions of the drilled foundation element.

For a perfectly cylindrical shaft, the temperature distribution is uniform over a majority of its length. The exception is near the top of shaft "TOS" and bottom of shaft "BOS" where there is a distinct region of decreasing temperatures. The decreasing temperatures at the shaft ends, referred to as "roll-off" zones, are caused by additional heat dissipation to the air above the shaft or soil/rock beneath a shaft. As part of the TIP analysis, TOS and BOS roll-off adjustments are applied to normalize the thermal profile. Differences between the measured and hyperbolic tangent TOS and BOS curve indicate variations from a perfect cylinder shape. Presented in the following examples are cases where anomalies were detected in the roll-off regions.

Figure 1 illustrates a temperature vs. depth plot for a 7 foot (2.1m) diameter drilled shaft with 7 Thermal Wire cables installed. The shaft is approximately 40 feet (12.2m) in length. The temperature versus depth plot shows the temperatures of all seven cables along with the average temperature of these seven cables. The plot indicates a local reduction near cables 1 and 7 in the top roll-off zone, and an early roll-off in cables 3 through 5 at the bottom of the shaft. After making the TOS and BOS adjustments and entering the shaft concrete volume, the effective radius and concrete cover versus depth plot are seen in **Figure 2**. The vertical red line represents the cage radius (and point of zero concrete cover). When the radius data appears to the left of the red vertical cage radius line, this indicates that the local effective shaft radius in this region is inside the reinforcing cage and thus with no concrete cover present. **Figure 2** also illustrates a localized effective radius reduction in the TOS roll-off region where cables 1 and 7 model as less than nominal near a depth of 2 feet (0.6m). Additionally, there is a significant reduction in the BOS nearest to cables 3 through 5 locations where the effective shaft radius is inside the reinforcing cage in these locations.

Figure 3 illustrates the 3-D model of the TIP measurements showing the reductions in both the TOS and BOS roll-off zones, including several regions where the anomalies extend inside the reinforcing cage.

On a Department of Transportation (DOT) project in the Midwestern United States, TIP was used for integrity evaluation on 12 drilled shafts that were approximately 26 feet (7.9m) in length. The shafts were all installed using similar installation techniques and contained an oversized 54 inch (1370mm) temporary casing down to rock which was approximately 16 feet (4.9m) below the top of concrete. In the rock below the casing, the shaft was 48 inches (1220mm) in diameter. Four Thermal Wire cables were installed along the full length of the 43.5 inch (1100mm) diameter reinforcing cage.

The temperature profile for a typical shaft installed on this project is shown in **Figure 4**. In

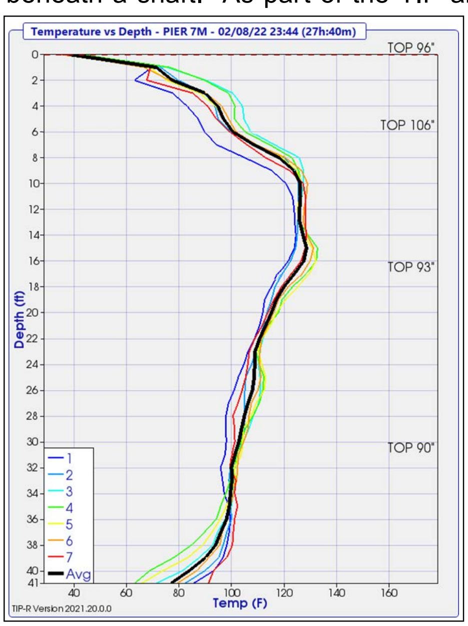

Figure 1.

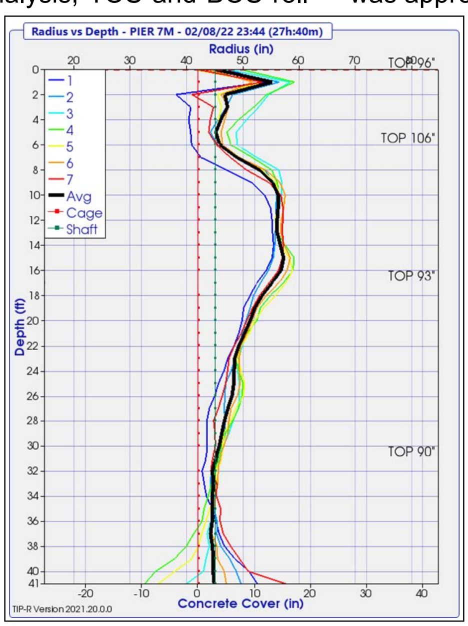

Figure 2.

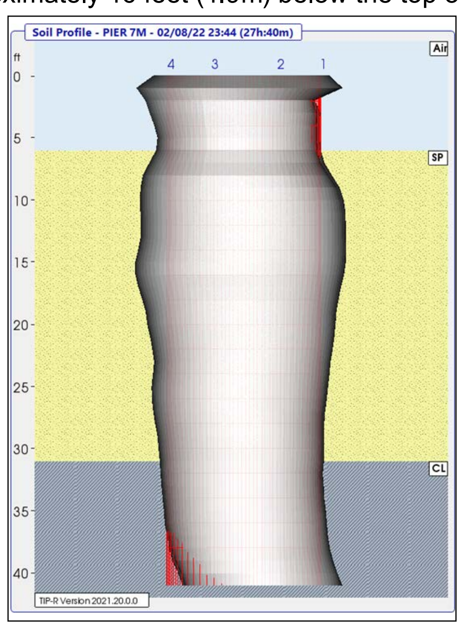

Figure 3.

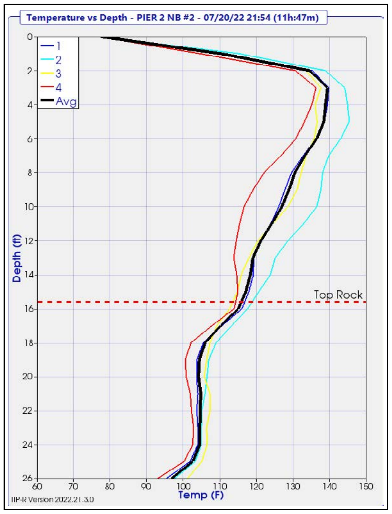

Figure 4.

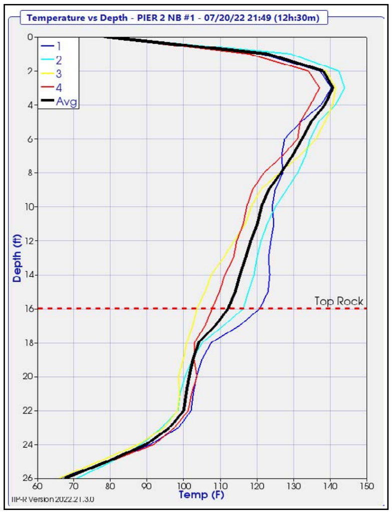

Figure 5.

Figure 5 the thermal profile for a shaft is presented where an early roll-off in temperature is observed near the shaft base. The characteristics of the bottom roll-off are different in both shape and temperature from other typical shafts. After applying the BOS roll-off adjustment to the data, a significant reduction in the effective average radius was indicated from 22 to 26 feet (6.7 – 7.9m). **Figure 6** displays the 3-D rendering of the shaft where a significant cover reduction extends well inside the reinforcing cage. Since all cable locations show evidence of a reduction, this may be a cross-sectional quality reduction.

Further investigation was recommended to confirm the presence of the defect. The shaft was cored and core results are presented in **Figure 7**. The left-most core in Figure 7 was extracted from a depth of 24 to 26 feet (7.3 - 7.9m). The anomalous zone was confirmed as segregated material encountered near the shaft base.

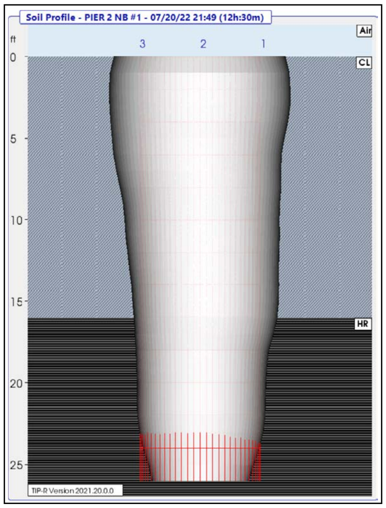

Figure 6.

Figure 7.

Thermal Integrity Profiling is rapidly becoming the primary integrity method for drilled foundations. The TIP method overcomes many of the limitations associated with other traditional methods and in addition can assess the concrete cover outside the reinforcing cage along the entire instrumented length of the foundation elements. TIP testing is typically completed within 24 to 48 hours after casting, and the data is typically transmitted offsite via the PDI-Cloud to expedite reporting and eliminate costly site visits. The TIP method is effective at assessing anomalies present over the entire instrumented length, including both the upper and lower roll-off zones. This integrity testing method is becoming an industry standard in the transportation, electric transmission line, and private construction sectors.

For additional information on Thermal Integrity Profiling, visit **https://www.pile.com/products/tip/.**

Upcoming Events

Jan 8-12 **Conference: TRB Annual Meeting**
Washington, D.C.
Learn More

Jan 22-25 **Conference: ASTM Committee Week**
San Antonio, TX
Learn More

Jan 30-31 **Conference: ADSC Annual**
Colorado Springs, CO
Learn More

Feb 7-9 **Conference: PDCA Annual**
San Diego, CA
Learn More

Feb 9-10 **Conference: GeoOmaha**
Omaha, NE
Learn More

Feb 16-17 **Conference: Pfahl Symposium**
Braunschweig, Germany
Learn More

Feb 27 **Seminar: Deep Foundation Integrity Testing and Wave Equation Analysis Seminar**
Orlando, FL
Register Today

Feb 28 - Mar 1 **Workshop: High Strain Dynamic Foundation Testing Workshop & Proficiency Test**
Orlando, FL
Register Today

Mar 13-15 **Conference: Design Build in Transportation and Aviation - Seattle, WA**
Learn More

Mar 26-29 **Conference: GeoCongress**
Los Angeles, CA
Learn More

Mar 28-30 **Conference: IPF Wind**
Baltimore, MD
Learn More

A complete list of PDI/GRL events can be found on pile.com or grlengineers.com

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