DID YOU KNOW? *Newsletter No. 109 - March 2024*

GRL's Tappan Zee Bridge Project was featured on the History Channel's "Project Impossible" series in 2018. Read the case study.

GRL Engineers, Inc. Pile Dynamics, Inc.

Drilled Shaft Base Quality Reductions Identified with Thermal Integrity Profiling

by Travis Coleman, P.E., and Daniel Belardo

Drilled shafts are a popular choice for deep foundations as they can support high axial and lateral loads and can be installed with limited disturbance to the surrounding area. Each project site presents unique challenges for installing drilled shafts. Ensuring that the method of drilled shaft installation is compatible with the subsurface conditions is critical, as the shaft performance and reliability is sensitive to the construction techniques and methods used during installation.

Since visual inspection of the completed drilled shaft is not possible, non-destructive test (NDT) methods are commonly specified. Prior to concrete placement, shaft designs including end bearing require the cleanout of debris that may have settled or sloughed into the shaft base. Project specifications often set limits for the allowable debris thickness that must be satisfied prior to placing concrete. Quality assurance tools, such as SQUID, allow for either visual inspection or direct measurements of the debris thickness.

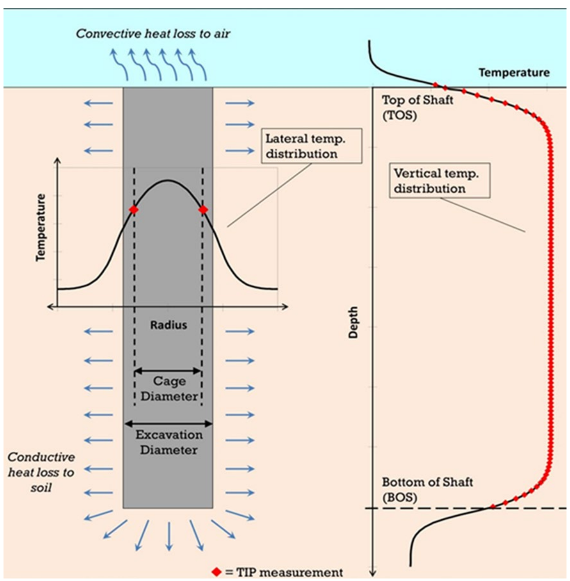

Figure 1. *Drilled Shaft Heat Dissipation and Resulting Theoretical Thermal Profile (Mullins 2016)*

Thermal Integrity Profiling (TIP) is a state-of-practice NDT method used for integrity and quality evaluation of drilled shafts, augered cast-in-place piles, diaphragm walls, and other concrete foundations. This method can be advantageous to both the contractor and owner based on the ease of installation of the instrumented cables, remote data collection, and early testing with results often within one day of concrete placement. TIP results and output models are dependent on proper selection of input parameters to normalize heat dissipation at the shaft ends. With proper understanding and application of shaft bottom analysis, the full length of a deep foundation element can be effectively evaluated.

Thermal Integrity Profiling utilizes heat generated during the concrete curing process to evaluate quality. Instrumented cables containing NIST traceable digital temperature sensors spaced every 1 foot (.3 m) are secured along the full length of the reinforcing cage. The cables are installed in accordance with ASTM D7949, which requires that they are installed equidistantly around the reinforcing cage with a quantity of one cable per 1 foot (.3m) of shaft diameter. Either before or soon after concrete placement is complete, each cable is connected to a data logger that records the temperature versus depth at 15-minute intervals. The data is transmitted remotely to a cloud-based network and to the TIP Engineer. The collected temperature data is combined with installation details to generate an effective radius plot along the shaft length and a 3D model.

Expected Thermal Profile

Temperature is recorded at each local cable position, as a function of time and depth, with the objective of capturing data from shortly after placement and up to or beyond the peak temperature. The temperature versus depth plots for all cables, also known as the thermal profile, provide the basis for qualitatively assessing drilled shaft integrity. The average temperature profile is generally a representation of the shaft shape, with the exception of the end conditions where the decreased temperature zone (i.e., temperature roll-off) is caused by 3D environmental transitions (Figure 1). At the bottom of shaft, or at the top of shaft, an inflection point in the temperature profile for a perfect shaft aligns with that of a hyperbolic tangent approximation. The observed temperature reductions at the end conditions must be adjusted and normalized prior to the generation of the effective shaft radius. A temperature to radius conversion factor is established using the overall average concrete temperature at the time selected for analysis and the concrete volume placed over the installed shaft length.

Case Study Example:

GRL conducted TIP testing on a Department of Transportation (DOT) project in the Midwest. TIP testing assessed the post-construction integrity of all 16 drilled shafts.

The shafts were designed with a 48 in (122 cm) diameter, transitioning to a 42 in (107 cm) rock socket. The contractor used 54 in (137 cm) temporary casings seated into weathered rock during installation. Subsurface conditions included hard sandy clay loam and sandy loam with sand seams up to 7 ft (2.1 m), followed by fine to coarse sand to the top of weathered rock at 12.3 ft (3.7 m). Groundwater was encountered at 11 ft (3.4 m).

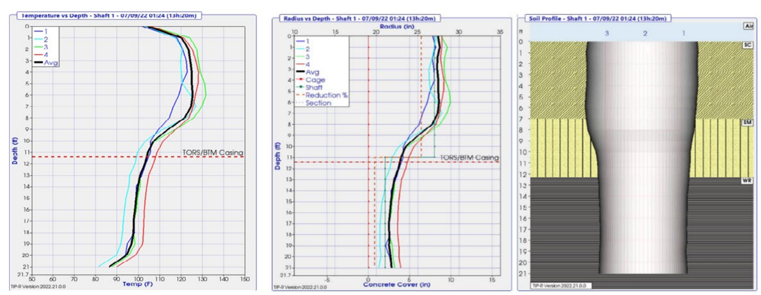

Figure 2. *Shaft 1: Temperature vs Depth Graph at Peak Temperature (left); Effective Radius Graph (middle); and 3D presentation (right)*

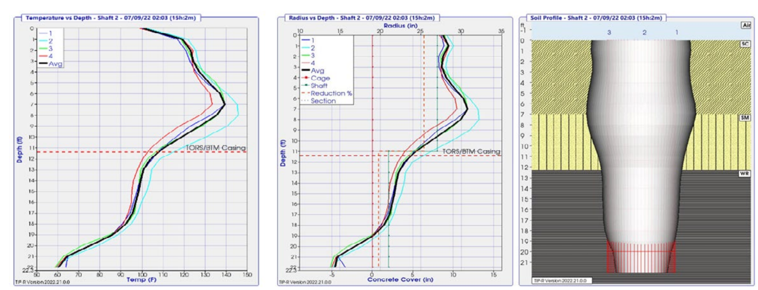

Figure 3. *Shaft 2: Temperature vs Depth Graph at Peak Temperature (left); Effective Radius Graph (middle); and 3D presentation (right)*

TIP data for Shaft 1 showed a thermal profile with normal temperature variations (Figure 2). The analysis included the standard Bottom of Shaft adjustment to normalize temperature data. Results indicated consistent effective radius and nominal shaft diameter alignment, with no anomalies.

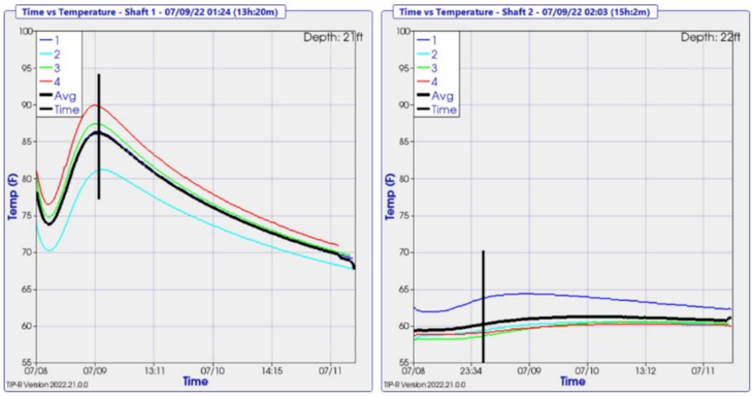

Figure 4. *Temperature vs Time Graph for Bottom Sensors Shaft 1 (left) and Shaft 2 (right)*

Figure 5. *Shaft 2 Retrieved Cores*

In Shaft 2, the TIP analysis revealed discrepancies in the expected temperature roll-off curve (Figure 3). Despite adjustments, the measured temperature remained below expectations, indicating a potential soft toe condition. Upon further examination of the bottom temperature (Figure 4), including exploratory coring, a soft toe was confirmed (Figure 5) prompting remediation efforts.

Conclusions

Thermal Integrity Profiling (TIP) is a widely used non-destructive testing method for assessing the integrity and quality of various concrete foundations. To properly evaluate the shaft bottom integrity, adjustments of the thermal profile are essential. This process involves a signal matching approach using near bottom shaft temperature, soil temperature, and bottom of shaft inflection point.

Additionally, qualitative assessment through the Time vs Temperature graph, alongside the Temperature vs Depth plot at the chosen analysis time, provides valuable insights. This comparative analysis is particularly beneficial for identifying regions of potential integrity concerns by contrasting "suspect" data with "normal" or "expected" temperature data.

The presented methods and case study demonstrate the efficacy of TIP in evaluating bottom conditions of concrete foundations. Furthermore, the **full reference paper** from which this article was derived, suggests that continued studies on temperature generation over time could assist in evaluating potential integrity issues. For additional reference information on Thermal Integrity Profiling, visit grlengineers.com or pile.com.

The Importance of Continuing Professional Development & State-of-Practice in Deep Foundations

by Mohamad Hussein, P.E.

Delving into the industry of Deep Foundations is to enter a realm where civil engineering and construction meet inherent uncertainties, posing challenges that demand careful understanding, evaluation, and management for project success. This specialized industry\ demands a blend of skills encompassing geotechnical site investigation, soil and rock mechanics, foundation engineering, quality assurance testing, and the complexities of constructability.

Designing deep foundations requires a multifaceted skill set:

- Geotechnical Expertise: Knowledge in site investigations and laboratory testing
- Mechanical Prowess: Mastery of soil and rock mechanics principles
- Holistic Approach: Understanding of constructability considerations, computer analyses, codes, specifications, costs, and local practices

Installation demands a different set of competencies:

- Strategic Planning: Proficiency in planning, logistics, and heavy equipment operations
- Local Insight: Knowledge of site conditions and adherence to local practices

Full Article

Upcoming Events

Apr 17	**Symposium: High Strain Dynamic Testing - Basic Principles, Data Analysis and Effective Applications, Washington DC** **Register**
Apr 22-25	IPF Wind, New Orleans, LA: Booth #1827; *Learn More*
May 6-10	IFCEE 2024, Dallas, TX: Booth #1226; *Learn More*
May 14	**Seminar: High Strain Dynamic Testing - Basic Principles, Data Analysis, and Effective Application, London** **Register**
May 16 & 17	**Workshop: Advanced High Strain Dynamic Testing Workshop & Proficiency Test, London** **Register**
May 21-23	Southwest Geotechnical Conference, Albuquerque, NM *Learn More*
Jun 3-5	IBC, San Antonio, TX; *Learn More*
Jun 12-14	SuperPile, San Francisco, CA: Booth 202; *Learn More*
Jun 15-18	International Transportation and Development Conference, Atlanta, GA; *Learn More*

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

GRL Engineers, Inc.
+1.216.831.6131
info@GRLengineers.com
www.GRLengineers.com
California • Colorado • Florida • Georgia • Hawaii
Illinois • Louisiana • Massachusetts • North Carolina
Ohio • Pennsylvania • Texas • Washington

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Pile Dynamics, Inc.
+1.216.831.6131
info@pile.com
www.pile.com
30725 Aurora Rd, Cleveland, OH 44139

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