Quality Assurance for Deep Foundations

Pile Dynamics, Inc.

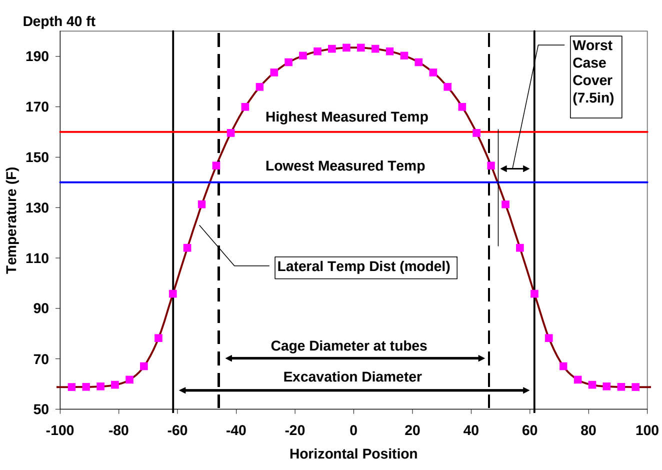
Thermal Integrity Profiler (TIP)

Overview

The Thermal Integrity Profiler uses the temperature generated by curing cement (hydration energy) to assess the quality of cast in place concrete foundations (i.e. drilled shafts or ACIP-CFA piles). Whereas other methods of integrity testing have limits in assessing the full cross-section or length (CSL: inside the reinforcing cage, or GGL: within a 3 inches (75mm) of access tube), TIP measurements evaluate the concrete quality from all portions of the cross-section along the entire length.

In general, a shortage of competent concrete is registered by relative cool regions (necks or inclusions); the presence of extra concrete is registered by relative warm regions (over-pour bulging into soft soil strata).

Anomalies both inside and outside the reinforcing cage not only disrupt the temperature signature near the anomaly, but also at more distant locations (at progressively less effect).

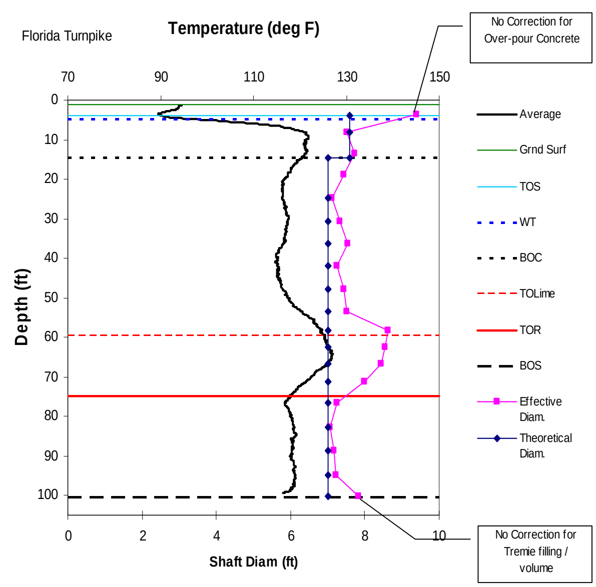


Temperature distribution for 10 ft diameter shaft (WSDOT). Lowest temperature measured corresponded to a 7.5 in cover

The shaft temperature is dependent on the shaft diameter, mix design, and the time of measurement.

As the temperature distribution within a shaft is bell-shaped with respect to radial position, the measurements are sensitive to cage eccentricity as well as the surrounding cover. A cage slightly closer to one side of the excavation exhibits cooler temperatures than average from the cage closest the soil and warmer temperatures from the cage closer the shaft center.

Since the diameter and temperature relationship is strongly linear in the region surrounding the cage, a plot of the average temperature of the entire cage versus depth mimics the actual shape of the shaft as determined from field concreting logs. Use of construction and concreting logs can be used in concert with the TIP data to better assess the overall quality of a given shaft.



Average shaft temp (blk) and concreting log (pnk)

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Data Collection

TIP data is obtained either using probes in access tubes or using embedded thermal wires. Thermal gradients can be obtained by either method to determine concrete cover.

Thermal Integrity Profiling for FDOT, Tampa (Probe version).

The TIP system (probe version) uses four orthogonally oriented infrared sensors within a single thermal probe to measure the inside wall temperature of standard 1.5 or 2.0 inch (38 or 50 mm) access tubes (plastic or steel). Four sensors provide redundancy and the capability of detecting thermal gradients.

5 in. long by 1.25 in. diameter Thermal Probe with four infrared sensors

A depth-encoder attached to the access tube tracks the probe location as it is lowered by the testing engineer for the entire length of each tube (access tubes must be empty during testing). The temperature and depth data are collected typically 12 to 48 hours after concrete casting. TIP results are insensitive to tube de-bonding.

The TIP embedded version uses wires (with thermal sensors) that are attached to the reinforcing cage. No access tubes are required. Data are automatically sampled every 15 minutes from each embedded thermal wire by a battery powered data acquisition unit, allowing the concrete curing process to be monitored. Data are collected on site at any time after casting for evaluation. A single embedded wire is attached to a center rebar for smaller augercast (CFA) piles.

Embedded Thermal wire attached to rebar cage (shown adjacent to CSL access tubes.)

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Should an anomaly be detected (local relatively cool spot) by either probes or embedded thermal wires, no additional field data is necessary to perform complete in-depth analyses.

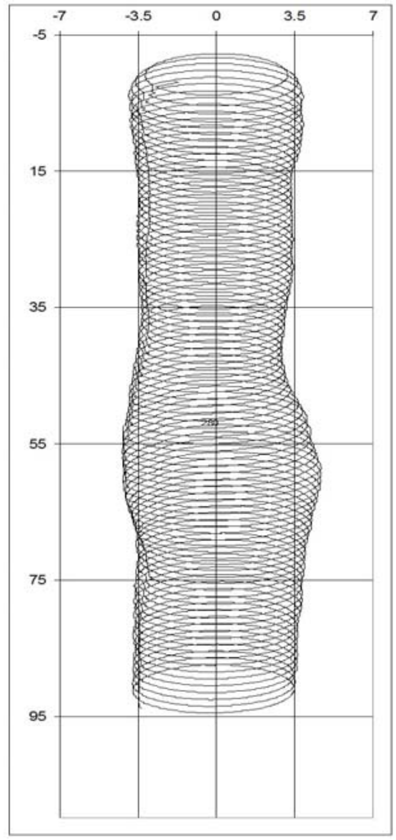
Data Analysis

Field measurements alone highlight glaring irregularities since the average temperature profile shows the general shaft shape. This level of review reveals cage alignment irregularities, casing location, locations of over-pour bulges or necking, and can easily alert the user or an owner of areas of concern.

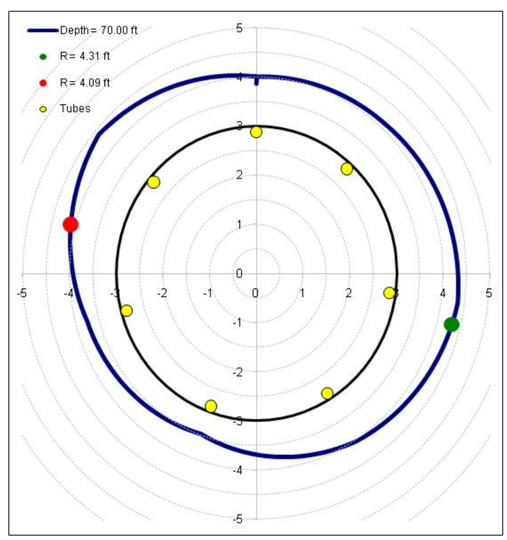
Superposition of construction and concreting logs can calibrate the average diameter with average temperature, particularly when multiple concrete trucks per pile are used.

The highest level of analysis uses thermal modeling to simulate the shaft, the surrounding soil, the climatic history and energy generated from the concrete mix design. Results from simulations can define the best testing time for probe data acquisition (data for embedded wires is evaluated at time of peak temperature), or match the field measurements to a probable concrete shape. These models define the slope of the temperature to radius relationship near the edge of shaft where the cage is located.

Finally, the measured temperatures when converted to radius can be used to provide a 3-D rendering of the as-built shaft as well as 2-D slices of the shaft cross section at any depths of interest and vertical slices through any radial orientation.



3-D rendering of 7 ft diameter shaft, Florida Turnpike Authority, Lake Worth, FL



2-D cross sectional slice of 7 ft diameter shaft (depth 70ft) Florida Turnpike Authority, Lake Worth, FL

References
Mullins, A. G., (2010), “Thermal Integrity Profiling of Drilled Shafts”, DFI Journal Vol 4, No.2, December.
Mullins, A. G. and Kranc, S. C., (2004), “Method for Testing the Integrity of Concrete Shafts,” **US Patent 6,783,273**.
Cotton, D., Ference, M., Piscsalko, G., and Rausche, F., (2010) “Pile Sensing Device and Method of Making and Using the Same”, **Patent Pending**.