DID YOU **KNOW?**

Driven monopiles for offshore wind turbines reach 6m in diameter?

Pile Dynamics, Inc.

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THERMAL INTEGRITY PROFILER

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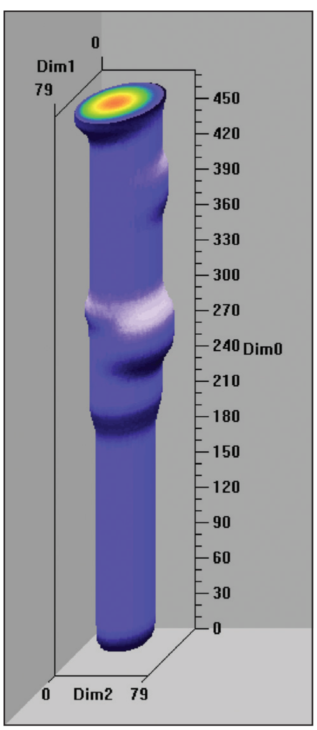
The integrity of drilled shafts (bored piles) is of vital importance. Low strain integrity testing (also called PIT and Pulse Echo), Cross Hole Sonic Logging (CSL) and Gamma-Gamma logging (GGL) are known integrity assessment methods, and each has its unique advantages. Each of these methods also has limits in evaluating the quality of the foundation: CSL assessments are restricted to the area inside the reinforcing cage, GGL assesses only the area within a few inches of access tube, and PIT results may be limited by shaft length and difficult data interpretation below major non-uniformities.

The Thermal Testing Method has been developed in response to these challenges. It uses the heat generated by the curing cement to assess the quality of cast-in-place concrete foundations such as drilled shafts, augered cast-in-place (ACIP) or continuous flight auger (CFA) piles. The Thermal Integrity Profiler (TIP) incorporates the Thermal Testing Method to evaluate concrete quality over the entire cross-section and shaft length.

TIP measures temperature either by an *Infrared Probe*[i] containing 4 orthogonal sensors and inserted into access tubes, or by *Thermal Wires*[ii] that have uniformly spaced sensors and are tied to the rebar cage. The recommended number of tubes or thermal wires is the same as for CSL or GGL applications. A single thermal wire is attached to a center rebar to test smaller diameter ACIP or CFA piles.

With the Probe Method, temperature data are collected typically 24 to 48 hours after concrete casting. With the Thermal Wire Method data are automatically (and, if possible, remotely) sampled at user defined intervals (e.g. 15 minutes), thereby continuously monitoring the concrete curing process. Thermal Testing by either method provides concrete quality data at a very early time, allowing construction to progress more quickly, because engineers no longer need to wait for the concrete to fully cure to assess shaft integrity.

In general, a shortage of competent concrete is registered by relatively cool regions (necks, inclusions or poor concrete); extra concrete (over-pour bulging into soft soil strata) is registered by relatively warm regions. The average temperature at any depth is proportional to the shaft diameter.



3D rendering of shaft generated by Thermal Modeling

Thermal testing by probe method, coutesy FGE

Temperature measurements at the cage, obtained by either the Probe or Thermal Wire method, may also be used to evaluate concrete cover and cage alignment. The measured temperatures have an almost linear relationship to the concrete cover: if the cage is closer to one side of the excavation (less cover) its temperature is lower than average while sections closer to the shaft center will exhibit higher than average temperatures.

Field measurements alone already highlight significant foundation problems, since a plot of the average temperature versus depth is an approximate image of the shaft geometry. This level of review may reveal cage alignment irregularities, casing or rock socket location, and locations of over-pour bulges or necking. Further refinement of concrete cover location is possible by measuring the gradient between 2 thermal sensors offset over a known, radial distance. Thermal Modeling is the highest level of analysis, estimating temperatures of the entire shaft based on the surrounding soil type, climatic history and specific heat generation for a particular concrete mix. Simulated temperatures are matched to field measurements, generating a probable concrete shape, a 3-D rendering of the as-built shaft, 2-D slices of the shaft cross section at any depths of interest and vertical slices through any radial orientation.

The Thermal Testing Method was developed at the University of South Florida under the direction of the first author, who also directed its practical implementation by Foundation & Geotechnical Engineering (FGE) of Plant City, FL. Further research and development is a joint effort of FGE and Pile Dynamics, Inc.

This article is partially based on Mullins, G., "Thermal Integrity Profiling of Drilled Shafts", DFI Journal Vol. 4, No.2, December 2010, available at www.pile.com/references.

i Mullins, A. G. and Kranc, S. C., (2004), "Method for Testing the Integrity of Concrete Shafts," US Patent 6,783,273

ii Cotton, D., Ference, M., Piscsalko, G., and Rausche, F., (2010) "Pile Sensing Device and Method of Making and Using the Same" Patent Pending