Sample Specifications for Testing Foundations with the Thermal Integrity Profiler (TIP)

September 2016

Note: This sample specification contains recommended or typical quantities in parenthesis, in the format (quantity); the specifying Engineers can adapt these quantities for their particular construction projects. Contractual items are minimized since each agency has its own preferences and procedures. This document can be edited to satisfy the Specifier. "Notes" are provided (in indent and italics) which are Commentary to assist the Specifier and may easily be deleted from the actual specification.

Overview of Thermal Integrity Profiler (TIP) Testing Method The Thermal Integrity Profiler (TIP) uses the heat generated by curing cement (hydration energy) to assess the integrity or quality of cast in place concrete foundations such as drilled shafts, bored piles, micropiles, augered cast-in-place piles, continuous flight auger piles, and drilled displacement piles, herein referred to as "shafts". The expected temperature at any location is dependent on the shaft diameter, mix design, time of measurement, and the concrete "cover" thickness outside the reinforcing cage. TIP measurements may be used to estimate the actual shape of the shaft. These estimates may be compared with concreting logs to assess the overall quality of the shaft. Because the method relies on the heat of hydration, TIP testing is generally done between 8 and 24 hours of concrete placement (note the optimum TIP testing time is dependent on shaft size and concrete mix and could range from 4 to 72 hours). Smaller diameter shafts are tested earlier. Good communication between Contactor and TIP Consultant is therefore essential. Data is acquired with Thermal Wire® cables tied to the rebar cage or center reinforcing bar, and are installed prior to concreting.

TIP measurements that are colder than normal indicate a lack of sufficient cement which can be caused by necks, inclusions, or poor quality concrete, while warmer than normal measurements are indicative of bulges. Variations of temperatures between diagonally opposite pairs of cables or tubes reveal cage eccentricity.

Testing procedures and equipment shall conform to: ASTM D7949 – "Standard Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations".

(a) Equipment, Personnel, and Contractor assistance requirements for TIP

The qualifications of the Consultant and the specifications for the equipment used shall be submitted to the Engineer for approval prior to beginning shaft installation.

i) Equipment

Provide a Thermal Integrity Profiler (TIP) manufactured by Pile Dynamics, Inc., (30725 Aurora Rd., Cleveland Ohio 44139, USA, phone: +1 216-831-6131; www.pile.com/pdi). The equipment shall have the following minimum requirements:

(1) A computer based TIP data acquisition system to download and monitor temperature versus time after casting.

(2) Ability to collect data at user defined time intervals (typically 15 to 60 minutes).

ii) Qualifications of TIP Consultant

The TIP Consultant shall have a licensed professional engineer supervising the testing and interpretation of results. The TIP Consultant shall be an independent testing agency with documented and approved experience in TIP testing.

iii) Assistance by the shaft Contractor to the TIP testing consultant.

The Contractor shall provide cooperative assistance, suitable access to the site and shafts to be tested, and labor as required to assist the TIP Consultant in performing the required tests. The Contractor shall coordinate with TIP Consultant and install the necessary TIP instrumentation (cable method or access tubes) prior to concreting the shaft. Thermal Wire cable installation requirements are detailed elsewhere in this specification. Prior to TIP testing, the Contractor shall provide the shaft lengths, wire lengths, wire positions, the shaft construction date, shaft construction inspection record, and concrete placement details to the TIP Consultant.

(b) Shaft preparation for Thermal Wire cables

Install (number; typically a minimum of 4) evenly spaced cables in each (___m, ft) diameter shaft.

(Note: The actual number of cables installed is often selected as one cable for every 0.25m to 0.35m (10 to 14 inches) of shaft diameter, with a minimum of four Thermal Wire cables. Shafts with different diameters at the same site may require a different number of cables. The preferred even number of cables allows for direct comparison of temperatures on diagonally opposite cables to evaluate cage eccentricity.)

(Note: for small diameter shafts (typically less than 2 foot or 0.6 m) that lack a reinforcing cage, such as augercast or CFA piles, attaching a single Thermal Wire cable to the center reinforcing bar is recommended.)

Every shaft shall be equipped with Thermal Wire cables to permit possible integrity evaluation by TIP. The number of shafts to be tested by TIP is ([*number*] or [*percentage of all shafts*]). The shafts to be tested shall be chosen after installation by the Engineer. If significant defects are detected, the number of shafts tested may be increased by the Engineer.

(Note: Since the actual cost of the Thermal Wire cables and data collection is very low compared to the cost of the shaft, installing cables and collecting data in all shafts is highly recommended. For sensitive or critical structures, for foundations with minimal redundancy, or for shafts concreted using slurry, every shaft should be TIP tested.)

(Note: The cost of the cables is comparable to the cost of commonly used steel access tubes for CSL, so if access tubes are eliminated the cost to instrument the shafts is unchanged. Cables have a very small profile compared to the access tubes and do not restrict the concrete flow to the exterior outside the cage. The cost to collect the Thermal Wire cable data and process the results for every pile is less than the cost to acquire and process a percentage sample of CSL data, allowing every shaft to be inspected by TIP for about the same cost as only a sample of CSL data, and thus providing assurance that all elements of the foundation are satisfactory.)

Thermal Wire cables shall be aligned with the longitudinal reinforcement of the shaft. The cables shall be tied to the reinforcement at a location on the reinforcement that is 90^{o} to the line connecting the reinforcement to the center of the shaft using nylon zip-ties at 3.8 to 5 cm (1.5 to 2 inches) from the top and bottom of each node. Each Thermal Wire cable shall be attached to a **T**hermal **A**ccess **P**ort ("TAP" which is a mini data logger) and the TAP suspended on a protruding rebar well above the top of the concrete. If the cable is routed with a bend at any location, extra precautions on securing the cable with zip-ties on either side of each such node must be taken.

(c) When to perform the test, and evaluate the results

Thermal Wire cables should be monitored as soon as practical after concrete casting has begun and temperatures recorded over an extended time period. Two specific times are of interest: (a) The optimal time to evaluate the overall shaft shape is just prior to the core temperature reaching its peak, and this depends on the shaft diameter and concrete mix, and (b) the optimal time to inspect for local defects (e.g. necking or other weak concrete) is relatively early in the curing process, typically at half the time required to reach peak temperature.

(Note: for Thermal Wire cables, data is collected continuously and can be inspected for all times, so question of when to test is not relevant. The data can be searched in time for the above optimum times and both results should be reported.)

(Note: the duration of data acquisition is typically at least one day for smaller diameter shafts and at least two days for larger diameter shafts.)

(d) TIP Procedure

Prior to TIP testing, the Contractor shall provide the Engineer and TIP Consultant with a record of all shaft lengths with elevations of the top and bottom, field volume logs, cable serial numbers installed with corresponding location in the shaft, and installation date and times of all shafts.

Thermal Wire cables shall be connected to a Thermal Access Port (TAP) immediately (prior to or) following casting of concrete. Care shall be taken to record which cable is connected to which TAP. Data shall be collected by the TAP at intervals of time specified by the Engineer (typically every 15 minutes) for a duration of time specified by the Engineer (typically 12 to 48 hours, depending on shaft diameter; often 24 hours is sufficient to reach the peak temperature) or as recommended by the TIP Consultant. In the event peak temperature is not reached within the specified time period, the TAP units shall remain connected to the Thermal Wire cables for a longer duration as directed by the TIP Consultant. After completion of the data collection period, the TAP shall be connected to the main TIP data acquisition unit and the data files shall be downloaded for inspection of temperatures versus depth.

Potential local defects indicated by locally low temperatures relative to the average temperature at that depth, or average temperatures significantly lower than the average temperatures at other depths, shall be immediately reported to the Engineer.

(Note: In case defects are detected, additional TIP tests are not typically necessary. More detailed TIP analyses may be performed on the originally collected data.)

(e) TIP results

Results of the TIP testing shall be presented in a written report within (_[*number*]_) working days of completion of testing. The report shall present results of TIP tests by including:

1. Graphical displays of all temperature measurements (cables or probes) versus depth.

   (Note: If the temperature versus depth is relatively uniform, this presentation is generally sufficient to show that no significant defects are present.)

2. Indication of unusual temperatures at a time well before the peak temperature, particularly significantly cooler measurements of one or more Thermal Wire cables at any depth compared to the overall average temperature over the entire length. The "effective radius" of this deficiency can be computed if the total concrete volume is known.

3. (optional) The "effective radius" at any location can then be determined from the temperature at that location compared to the overall average temperature.

   (Note: The overall average temperature is proportional to the overall average radius computed from the actual total concrete volume installed, assuming a consistent concrete mix throughout.)

4. (optional) Where concrete volume is known (3. above), the cage alignment or offset from center could be noted based on variations in temperature between diagonally opposite Thermal Wire cables (at each depth).

(h) Basis of Payment

The completed TIP results and report shall be paid for at the contract bid price for "Thermal Integrity Profiling" (for each shaft, per linear meter or foot, or per day of testing). This shall constitute full compensation for all costs incurred and relating to the TIP testing including, but

not limited to procurement, preparation and installation, conducting the tests, and subsequent reporting of results.

(Note: A "per shaft tested" item should be included to cover the costs of the material and installation of Thermal Wire cables and for the processing and reporting of results. Payment for data collection for the Thermal Wire cable method depends on if the TIP Consultant is on site to personally collect data in which case the "per day of testing" basis is considered the most equitable, or if the data is sent electronically to the TIP Consultant by site personnel who collect the data in which case "per shaft tested" basis may be the most equitable.)