Designation: D7949 – 14

Standard Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations[1]

This standard is issued under the fixed designation D7949; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods provide procedures for measuring the temperature profile within a deep foundation element constructed using cast-in-place concrete, such as bored piles, drilled shafts, augered piles, diaphragm walls, barrettes, and dams, and alike. The thermal profile induced by the curing concrete can be used to evaluate the homogeneity and integrity of the concrete mass within the deep foundation element.

1.2 Two alternative procedures are provided:

1.2.1 Method A uses a thermal probe lowered into access ducts installed in the deep foundation element during construction.

1.2.2 Method B uses multiple embedded thermal sensors attached to the reinforcing cage installed in the deep foundation element during construction.

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this standard.

1.3.1 The procedures used to specify how data are collected/recorded and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that should generally be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

1.4 This standard provides minimum requirements for thermal profiling of concrete deep foundation elements. Plans, specifications, and/or provisions prepared by a qualified engineer, and approved by the agency requiring the test, may provide additional requirements and procedures as needed to satisfy the objectives of a particular test program.

1.5 The text of this standard references notes and footnotes, which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

NOTE 1—ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

1.7 *Limitations*—Proper installation of the access ducts or thermal sensors is advised for effective testing and interpretation. If a flaw is detected, then the method does not give the exact type of flaw (for example, inclusion, bulge, honeycombing, lack of cement particles, and alike.) but rather only that a flaw exists. The method is limited primarily to testing the concrete during the early curing process.

1.8 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.11 on Deep Foundations.

Current edition approved Nov. 1, 2014. Published November 2014. DOI: 10.1520/D7949–14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *access ducts, n*—preformed steel pipes or plastic pipes (for example, PVC or equivalent) placed in the concrete to allow thermal probe entry to measure temperature in the concrete.

3.2.2 *access locations, n*—the plan view positions of either access ducts or longitudinally distributed groups of embedded thermal sensors.

3.2.3 *defect, n*—a flaw that, because of either size or location, may detract from the capacity or durability of the deep foundation element.

3.2.4 *depth interval, n*—the maximum incremental spacing along the deep foundation element between embedded thermal sensor levels or probe measurements.

3.2.5 *embedded thermal sensor, n*—a temperature measuring device cast in the concrete that meets the requirements of 6.3.5.

3.2.6 *effective radius, n*—the radius of intact uncompromised concrete that would result in the measured temperature to account for a change in concrete quality or change in section.

3.2.7 *flaw, n*—a deviation from the planned shape or material (or both) of the deep foundation element.

3.2.8 *measurement location, n*—the position of a temperature measurement as defined by depth (or elevation) and the access location.

3.2.9 *sensor level, n*—the depth or elevation where an embedded thermal device is located or where a temperature measurement is taken.

3.2.10 *thermal probe, n*—a slender device inserted into access ducts to measure temperature that meets the requirements of 6.3.1.

3.2.11 *thermal profile, n*—a temperature versus depth plot which can be prepared from a single access location or from the average temperature of all access locations versus depth.

4. Summary of Test Method

4.1 Exothermic chemical processes generate heat as concrete cures within a cast-in-place deep foundation element. The amount of heat generated and the rate of heat dissipation are strongly influenced by the concrete mix and by the size and shape of the deep foundation element. Therefore, temperature measurements within the deep foundation element provide a thermal profile from which to evaluate the consistency of the concrete and the regularity of its shape. Temperature measured at the reinforcing cage, typically near the perimeter, will be lower than the core temperature due to heat dissipation into the surroundings (for example, soil, rock, water or air). If the cage is not concentric within the foundation element, then the portions of the cage closer to the perimeter will be cooler during those times when elevated temperatures exist. Portions closer to the center will be warmer. A flaw in the form of a void, a neck, an inclusion, or poor quality concrete will generate less heat than the normal concrete around it, resulting in lower temperature near the flaw. Conversely, a bulge will have more effective concrete cover, resulting in higher temperature near the bulge. Temperature measurements at access locations equally spaced around the circumference of the reinforcement cage and at regular depth intervals allow the user to identify potentially weak zones of concrete, to estimate the effective size of the foundation, and to check concrete cover and cage alignment along the length of the foundation element.

4.2 Along the axis of a cast-in-place concrete deep foundation element and away from the ends, heat dissipates primarily in the radial direction. However, within approximately one diameter of the top and bottom of the deep foundation element, heat dissipates in both the axial and radial directions, resulting in more rapid cooling and reduced temperature. Analysis of the thermal profile near the bottom may help to evaluate the length of the deep foundation element and its shape at the bottom.

4.3 Cast-in-place piles with diameters less than 600 mm can be assessed by a single access location adjacent to the center reinforcing rod.

NOTE 2—During the initial concrete hydration period of a deep foundation element, heat production exceeds the rate of dissipation into the surrounding material, and thus it dominates the early thermal profile. Analysis also shows that the degree of saturation in the surrounding material has little effect on the early thermal profile. Interpretation of the thermal profile should consider any significant changes in the thermal diffusivity of the environment around the deep foundation element, for example, when it extends above the ground surface through air or water.

NOTE 3—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

5. Significance and Use

5.1 Temperature measurements taken from a thermal probe lowered into access ducts in the deep foundation element, or from embedded thermal sensors distributed along the length, can be used to assess the homogeneity and integrity of concrete both inside and outside the reinforcing cage, as well as placement of the cage relative to the center of the curing concrete.[3,4]

NOTE 4—If flaws are detected, then further evaluation and potential remediation may be warranted to determine if the flaw is a defect. Any interpretation is qualitative and possibly relative to the particular deep foundation element material, construction characteristics of the tested structure, and the apparatus used. Interpretation therefore should contain proper engineering judgment and experience.

6. Apparatus

6.1 *Method A: Apparatus for Internal Inspection (Access Ducts)*—To provide access for the thermal probe, access ducts made from pipe or round tube shall be installed during construction of the deep foundation element. Access ducts shall have a nominal inside diameter of 38 to 50 mm (38 mm is

[3] Mullins, G., "Thermal Integrity Profiler of Drilled Shafts," DFI Journal Vol 4. No. 2 December 2010: Deep Foundations Institute, Hawthorne, NJ, December, 2010, pp. 54-64.

[4] Mullins, G. and Kranc, S., "Thermal integrity testing of drilled shafts," Final Report, FDOT Project BD544-20, University of South Florida, May 2007.

preferred to reduce cage congestion) and shall be straight, rigid, and strong enough to withstand crushing from fluid concrete pressure. Ducts shall have a regular internal diameter, be free of obstructions, including duct joints, and shall permit the unobstructed passage of the probe. Ducts shall be water-tight. Ducts may be extended using external mechanical couplings.

6.2 *Apparatus for Determining Physical Test Parameters:*

6.2.1 *Weighted Measuring Tape*—A weighted measuring tape shall be used as a dummy probe to check free passage through and determine the unobstructed length of each access duct to the nearest 50 mm. The weight shall have a diameter equal to or greater than the probe and less than the inside diameter of the access duct.

6.2.2 *Magnetic Compass*—A magnetic compass accurate to within 10° shall be used to document the access location designations compared with the site layout plan. Alternately, access locations shall be labeled based on the site plan, structure orientation or other methods to document access location designations assigned and used for reporting test results.

6.3 *Apparatus for Obtaining Measurements:*

6.3.1 *Method A: Thermal Probe*—The thermal probe shall be equipped with a sufficient number of sensors (minimum two, oriented diagonally opposite) to obtain the average temperature around the perimeter of the access duct wall to within 1°C accuracy.

6.3.2 *Method A: Signal Transmission Cable*—The signal cable used to deploy the probe and transmit data from the probe shall be robust to support the probe weight. The cable shall be abrasion resistant to allow repeated field use and maintain flexibility in the range of anticipated temperatures.

6.3.3 *Method A: Probe Depth-Measuring Device*—The location of the probe in the access duct shall be tracked with a depth encoding device throughout the test; for example by engaging the signal cables over a pulley equipped with a depth-encoding device. The design of the depth-measuring device shall be such that cable slippage shall not occur. The depth-measuring device shall be accurate to within 1 % of the access duct length, or 0.15 m, whichever is larger. The depth sensors shall have a readability to the nearest 0.1 m.

6.3.4 *Method A: Container*—A container of sufficient size to hold the expected amount of water from the access tubes (for example, something like a bucket).

6.3.5 *Method B: Embedded Thermal Sensors*—When using Method B, embedded thermal sensors shall be installed at prescribed access locations defined by 3.2.2 and further specified by 7.3.1 where the sensor levels at one access location correspond to the same depth (or elevation) of the other access locations. The sensors may be installed individually or connected together in an array of sensors that may be individually polled to measure the temperature at each sensor. The thermal sensors shall have an accuracy of 1°C. The thermal sensors shall have a readability to the nearest 0.1°C. The wire(s) connected to the sensors shall be abrasion resistant and remain operational in the range of anticipated temperatures.

6.4 *Apparatus for Recording, Processing and Displaying Data:*

6.4.1 *Recording Apparatus*—The recording apparatus shall record depth and temperature data from each access duct or group of embedded thermal sensors at a depth interval no greater than 500 mm. Typical schematic arrangements for the test apparatus are illustrated in Figs. 1 and 2. For Method A, the apparatus shall read the depth-measuring device and assign a depth to each probe temperature reading. The apparatus shall store the temperature data versus depth from each access location (access duct or group of embedded thermal sensors). For either Procedure, all stored data (temperature versus depth) shall have identifying header information attached to it describing the test location, measurement location identifier, time/date stamp, and all pertinent information regarding the test.

6.4.2 *Processing and Display Apparatus*—The apparatus for processing the data shall be a computer or microprocessor capable of graphically displaying results as average temperature versus depth at each measurement location.

7. Procedures

7.1 *General*—The access ducts or embedded thermal sensors shall be installed during construction of the foundation element. Access ducts for probe-type testing equipment shall be spaced uniformly throughout the foundation cross-section, separated by no more than 1 m. For cylindrical foundation elements, the location plan shall provide in most cases one access duct for every 300 mm of diameter, with a preferred minimum of four access ducts for elements with diameters 1 m or larger. An even number of plan access locations is preferred to simplify interpretation. Access ducts shall be spread equally around the perimeter and spaced at an equal distance from the axis. Access locations for embedded thermal sensors shall conform to the same location plan requirements as access ducts, and the sensor levels shall be the same for all of the

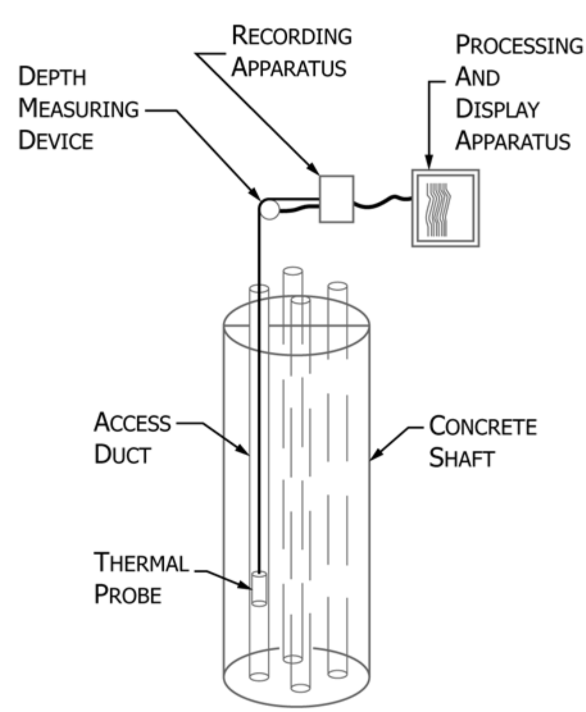

FIG. 1 Method A Test Schematic