Designation: D8381/D8381M – 21

Standard Test Methods for Measuring the Depth of Deep Foundations by Parallel Seismic Logging[1]

This standard is issued under the fixed designation D8381/D8381M; 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 The test Methods described in this standard are used to measure the depth of vertical deep foundation elements including micropiles, driven piles (prefabricated or cast in-situ), bored piles, secant or tangent pile walls, caissons, barrettes, diaphragm walls and sheet pile walls. It is applicable where the top of the said foundation element (in the following also named "pile") cannot be exposed for testing and other testing methods such as ASTM D5882 or D6760 cannot be used.

1.2 This standard provides minimum requirements for measuring the depth of deep foundations. Plans, specifications, and/or provisions may provide additional requirements and methods as needed to satisfy the objectives of a particular test program.

1.3 This standard provides the following test methods:

1.3.1 Method "A" using a vertical access tube adjacent to the deep foundation.

1.3.2 Method "B" using a seismic cone inserted into the ground adjacent to the deep foundation.

1.4 Apparati and Methods herein designated "optional" may produce different a different kind of test results or additional information and may be used only when approved by the engineer responsible for the test.

1.5 The text of this standard references notes and footnotes that 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 either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.7 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.8 The methods 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 methods 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 be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis.

1.9 This standard offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this standard may be applicable under all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document only means that the document has been approved through the ASTM consensus process.

1.10 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.11 on Deep Foundations.

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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

D4428/D4428M Test Methods for Crosshole Seismic Testing

D5882 Test Method for Low Strain Impact Integrity Testing of Deep Foundations

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

D6760 Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing

D7400/D7400M Test Methods for Downhole Seismic Testing

D8232 Test Procedures for Measuring the Inclination of Deep Foundations

2.2 *Other Standards:*

AFNOR NF P94-160-3 Auscultation d'un élément de fondation, partie 3: Méthode sismique parallèle

3. Terminology

3.1 *Definitions:*

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *depth interval, n*—the vertical spacing between two stops.

3.2.2 *seismic sensor, n*—an instrument to measure the ground motion when it is shaken by a perturbation, including geophones or accelerometers.

3.2.3 *stop, n*—the level at which the hydrophone or seismic sensor is stopped for taking a measurement.

3.2.4 *trace, n*—the time history of the seismic sensor output at any given depth.

4. Summary of Test Method

4.1 *Method A:*

4.1.1 In this method, a vertical access tube is installed in a borehole drilled proximate to the deep foundation and filled with water. A hydrophone, connected to a depth measuring device, is lowered into the access tube. After a brief pause at each stop to stabilize the hydrophone reading, the pile or superstructure are hit at least once with a trigger-equipped hammer. A portable digital recording device and a (separate or integrated) display device that are connected to the trigger, depth meter and the hydrophone via data cables or wireless connections, record and plot the hydrophone output trace for each blow against the respective depth below the reference level.

4.1.2 The method can also be performed using a seismic sensor instead of a hydrophone. In this case , water is not required and the sensor is clamped to its sidewall by an appropriate device. The sensor might provide additional information due to registration of several wave types and components, but has no advantage to a hydrophone for the Method described above.[3] Chains of hydrophones or seismic sensors (a set of sensors mounted in fixed intervals along a multicore cable and used for simultaneous recording at several depths) can be used to speed up the investigation. In the following, just the term probe is used for both devices.

NOTE 1—When striking the superstructure is undesirable because of the potential for physical damage (such as decorative or historic finishes), or it appears that there is no connection between the superstructure and supporting pile, the side of the pile may be exposed by digging an access pit. As the test quality may improve by applying axial blows, this can be achieved by cutting a notch in the side of the pile or attaching a sturdy bracket to it.

4.2 *Method B:*

4.2.1 In this method, a seismic cone, conforming to the requirements of Test Method D7400/D7400M, is inserted into the ground proximate to the deep foundation, stopping after each depth interval. At each stop the pile or superstructure above the deep foundation are hit at least once with a trigger-equipped hammer. A portable digital recording device and a (separate or integrated) display device that are connected to the seismic cone via a data cable or a wireless connection, record the output trace for each blow and then plot the results against the respective depth.

NOTE 2—Method B may be inapplicable for testing the depth of foundations that penetrate into bedrock (such as rock sockets) or other hard or very dense strata due to inability to push the seismic cone to the required depth.

5. Significance and Use

5.1 It is often necessary to determine the depth of deep foundation elements supporting existing structures, such as buildings and bridges, for which neither drawings nor as-built records are available. Such situations occur when the foundation loads have to be increased or when it is intended to excavate near, or even under, the structure. When the top of the foundation is inaccessible, as is the case with underwater bridge piers, the Parallel Seismic method can be used to determine the deep foundations' depth. The method is also applicable in cases where the foundation top can be reached, but the foundation element is not testable by the Low Strain Impact Integrity Testing Method (ASTM D5882) due to the foundation type (such as diaphragm and secant-pile walls, H-piles and sheet piles) or excessive foundation slenderness.

5.2 Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing and inspection. However, users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results since the proper conduct and evaluation of parallel seismic tests requires training, special

[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] Niederleithinger, E., "Improvement and Extension of the Parallel Seismic Method for Foundation Depth Measurement," *Soils and Foundations*, Vol. 52 Nr. 6, 2012, pp. 1093-1101.

knowledge and experience. A suitably qualified engineer shall plan and supervise the acquisition of field data and the interpretation of the test results.

6. Apparatus

6.1 *Method A:*

6.1.1 *Pressure-sensitive probe (hydrophone or seismic sensor),* pressure-rated to withstand penetration depths prescribed in 9.1.1 and 9.2.2, respectively.

6.1.2 *Signal Transmission Cable (optional)*—The cable shall be sufficiently robust to carry the probe and abrasion resistant to allow repeated field use and maintain flexibility in the range of expected temperatures. The cable itself, as well as all connectors, shall be waterproof to at least 150 % of the maximum testing depth. Alternatively, a wireless connection between the probe and the data recording and display unit may be established.

6.1.3 *Depth Measuring Device*—The cable shall be marked at regular intervals to assess depth of probe. Alternatively, a pulley over which the cable is deployed may be instrumented with a depth-encoding device to monitor the depth to the location of the probe throughout the test. The design of the pulley and cable reel shall be such that cable slippage shall not occur. Alternatively, a flexible tape measure may be affixed to the transducer/cable such that it measures the transducer centerline depth but does not interfere with signal transmission to the transducer. Depth data may also be obtained from any source as long as it meets the requirements of 8.1.

6.1.4 Triggering is done with a hand-held hammer, equipped with a piezo shock switch or instrumented hammer head that can record the impact signal. Alternatively, a suitable receiver (such as an accelerometer) may be mounted to the structure being impacted within 0.3 m [1 ft] of the impact location and used as a trigger in response to impacts on the structure by a non-instrumented hammer.

NOTE 3—An offset in time (for example, caused by a delay in the triggering mechanism) does not change the final test result, if it is the same for all measurements.

6.1.5 *Recording and Display Device*—The signals from the triggering hammer or trigger accelerometer, the probe and the depth-measuring device shall be transmitted to a portable digital recording device and a (separate or integrated) display device for handling the data. Alternatively, the data may be transmitted offsite from the probe to any location where the signals can be viewed and recorded remotely. The device shall be capable of digitizing the data with a resolution of not less than 16 bit and a sampling rate of not less than 25,000 samples per second. The device may be equipped with a portable printer to produce hard copies of the results on site.

6.1.6 The probe and data collection system together must have adequate sensitivity to collect clear, lownoise waveforms for the entire testing depth range. A typical schematic arrangement of the testing apparatus is illustrated in Fig. 1.

6.2 *Method B:*

6.2.1 *CPT (Cone Penetration Testing) Rig,* equipped with a seismic cone attached to the end of rigid rods.[4] The CPT rig design should allow positioning close enough to the tested element.

6.2.2 *Data Logger,* equipped with an accurate clock and able to simultaneously record the depth of the seismic cone and the pulse reaching the seismic cone.

6.2.3 *Control Box,* equipped with an accurate clock and recording the time of each trigger pulse.

6.2.4 *Digital recording and display device.*

6.2.5 *Triggering Hand-Held Hammer,*—equipped with a piezo shock switch. A typical schematic arrangement of the testing apparatus is illustrated in Fig. 2.

7. Hazards

7.1 The test is often carried out over water or on construction sites with traffic of mechanical equipment such as tractors or drilling rigs, and used heavy, mobile equipment, potentially overhead. This standard does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health and environmental practices and determine the applicability of regulatory limitations prior to use.

7.2 Before penetrating the ground to prepare for the test the engineer in charge shall verify that no buried utilities will be affected during the process.

8. Calibration

8.1 The depth encoder wheel (if used) shall be field-calibrated at least once every six months to an accuracy of 1 % of the maximum testing depth or 0.1 m [4 in.], whichever is larger, according to the manufacturer's instructions.

8.2 The whole system shall be regularly calibrated following the manufacturer's instruction and checked for functionality before starting field work.

9. Procedure

9.1 *Method A:*

9.1.1 The distance b from the axis of the borehole to the side of the deep foundation shall be as small as practicable, preferably between 0.5 m [1.5 ft] and 1.5 m [5 ft]. However, a larger distance is allowed if dictated by local conditions. The borehole shall be as vertical as possible with an inclination not exceeding two percent of the depth. If in doubt, the inclination of the tube shall be measured according to ASTM standard D8232 (Method A).

9.1.2 The depth of the borehole shall exceed the assumed pile length by at least 5 m [16 ft] or five times the spacing b between the pile and the access tube, whichever is larger (Fig. 1). Where solid bedrock is encountered, the engineer may terminate drilling at a shallower depth.

9.1.3 The assumed pile length may be determined from existing documents (for example, pile design drawings), data from previous investigations (for example, investigation of

[4] Sack, D.A., Olson, L.D., Combined Parallel Seismic and Cone Penetrometer Testing of Existing Foundations for Foundation Length and Capacity Evaluation, *Geocongress Proceedings*, 2008