Designation: D6760 – 16

Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing[1]

This standard is issued under the fixed designation D6760; 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 This test method covers procedures for checking the homogeneity and integrity of concrete in deep foundation such as bored piles, drilled shafts, concrete piles or augercast piles. This method can also be extended to diaphragm walls, barrettes, dams etc. In this test method, all the above will be designated "deep foundation elements." The test measures the propagation time and relative energy of an ultrasonic pulse between parallel access ducts (crosshole) or in a single tube (single hole) installed in the deep foundation element. This method is most applicable when performed in tubes that are installed during construction.

1.2 Similar techniques with different excitation sources exist, but these techniques are outside the scope of this test method.

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

1.4 The method used to specify how data are collected, calculated, or recorded in this test method is not directly related to the accuracy to which data can be applied in design or other uses, or both. How one applies the results obtained using this standard is beyond its scope.

1.5 This standard provides minimum requirements for crosshole (or single hole) testing of concrete deep foundation elements. Plans, specifications, provisions, or combinations thereof prepared by a qualified engineer, and approved by the agency requiring the test(s), may provide additional requirements and procedures as needed to satisfy the objectives of a particular test program.

1.6 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.

1.7 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 *Limitations*—Proper installation of the access ducts is essential for effective testing and interpretation. The method does not give the exact type of flaw (for example, inclusion, honeycombing, lack of cement particles, etc.) but rather only that a flaw exists.

1.9 *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
D1143 Test Method for Piles Under Static Axial Compressive Load (Withdrawn 2005)[3]
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4945 Test Method for High-Strain Dynamic Testing of Deep Foundations
D5882 Test Method for Low Strain Impact Integrity Testing of Deep Foundations
D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *access ducts, n*—preformed steel tubes, plastic tubes (for example, PVC or equivalent), or drilled boreholes, placed in the concrete to allow probe entry in pairs to measure pulse transmission in the concrete between the probes.

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[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.

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[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] The last approved version of this historical standard is referenced on www.astm.org.

3.1.2 *anomaly, n*—irregularity or series of irregularities observed in an ultrasonic profile indicating a possible flaw.

3.1.3 *defect, n*—a flaw that, because of either size or location, may significantly detract from the element's capacity or durability.

3.1.4 *depth interval, n*—the maximum incremental spacing along the pile shaft between ultrasonic pulses.

3.1.5 *flaw, n*—any deviation from the planned shape or material (or both) of the element.

3.1.6 *integrity evaluation, n*—the qualitative or quantitative evaluation of the concrete continuity and consistency between the access ducts or boreholes.

3.1.7 *ultrasonic profile, n*—a combined graphical output of a series of measured or processed ultrasonic pulses with depth.

3.1.8 *ultrasonic pulse, n*—data for one specific depth of a short duration generated by a transmitter probe and sensed by the receiver probe.

4. Principle of the Test Method

4.1 The actual speed of sound wave propagation in concrete is dependent on the concrete material properties, geometry of the element and wavelength of the sound waves. When ultrasonic frequencies (for example, >20,000 Hz) are generated, Pressure (P) waves and Shear (S) waves travel though the concrete. Because S waves are relatively slow, they are of no further interest in this method. In good quality concrete the P-wave speed would typically range between 3600 to 4400 m/s. Poor quality concrete containing defects (for example, soil inclusion, gravel, water, drilling mud, bentonite, voids, contaminated concrete, or excessive segregation of the constituent particles) has a comparatively lower P-wave speed. By measuring the transit time of an ultrasonic P-wave signal between an ultrasonic transmitter and receiver in two parallel water-filled access ducts cast into the concrete during construction and spaced at a known distance apart, such anomalies may be detected. Usually the transmitter and receiver are maintained at equal elevations as they are moved up or down the access ducts. In some cases and for special processing the probes may be deliberately offset in relative elevation and the use of multiple receivers either in the same access duct or in multiple access ducts can also be allowed. Testing of the concrete in the vicinity of the access duct can also be made with both probes installed in a single access duct.

4.2 Two ultrasonic probes, one a transmitter and the other a receiver, are lowered to the bottom of their respective water-filled access duct(s) to test the full shaft length from bottom to top. The transmitter probe generates ultrasonic pulses at frequent and regular intervals during the probes' controlled travel rate. The probe depth and receiver probe's output (timed relative to the transmitter probe's ultrasonic pulse generation) are recorded for each pulse. The receiver's output signals are sampled and saved as voltage versus time (see Fig. 1) for each sampled depth. These signals can be then nested to produce a "waterfall" diagram (see right side of Fig. 2).

4.3 The data are further processed and presented to show the First Arrival Time (FAT) of the ultrasonic pulse and its Relative Energy (RE) to aid interpretation. The processed data are plotted versus depth as a graphical representation of the ultrasonic profile of the tested structure (see Fig. 2 left). Special test methods to further investigate anomalies are employed where the probes are not raised together.

5. Significance and Use

5.1 This method uses data from ultrasonic probes lowered into parallel access ducts, or in a single access duct, in the deep foundation element to assess the homogeneity and integrity of concrete between the probes. The data are used to confirm adequate concrete quality or identify zones of poor quality. If defects are detected, then further investigations should be made by excavation or coring the concrete as appropriate, or by other testing such as Test Method D1143, D4945 or D5882, and measures taken to remediate the structure if a defect is confirmed.

5.2 *Limitations:*

5.2.1 For crosshole tests, the access ducts should preferably be made of steel to prevent debonding of the access duct from the concrete resulting in an anomaly. This test can assess to the integrity of the concrete mainly in the area bounded by the access ducts, which means typically inside the reinforcement cage.

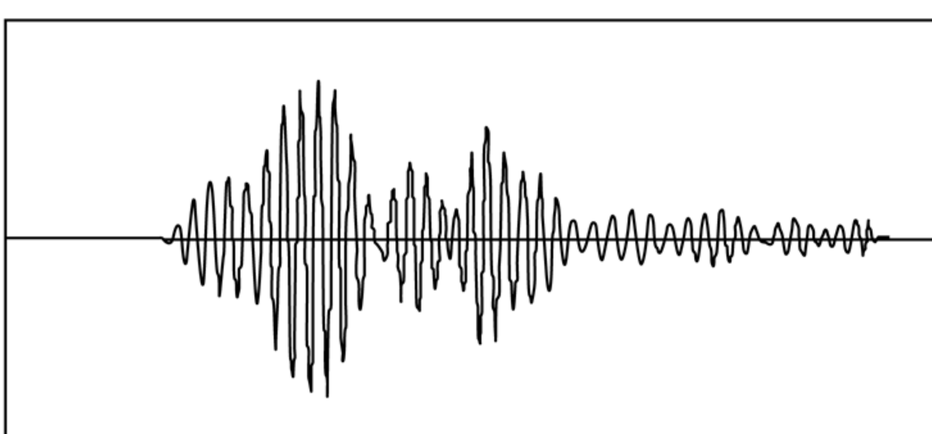

FIG. 1 An Ultrasonic Pulse from Receiver

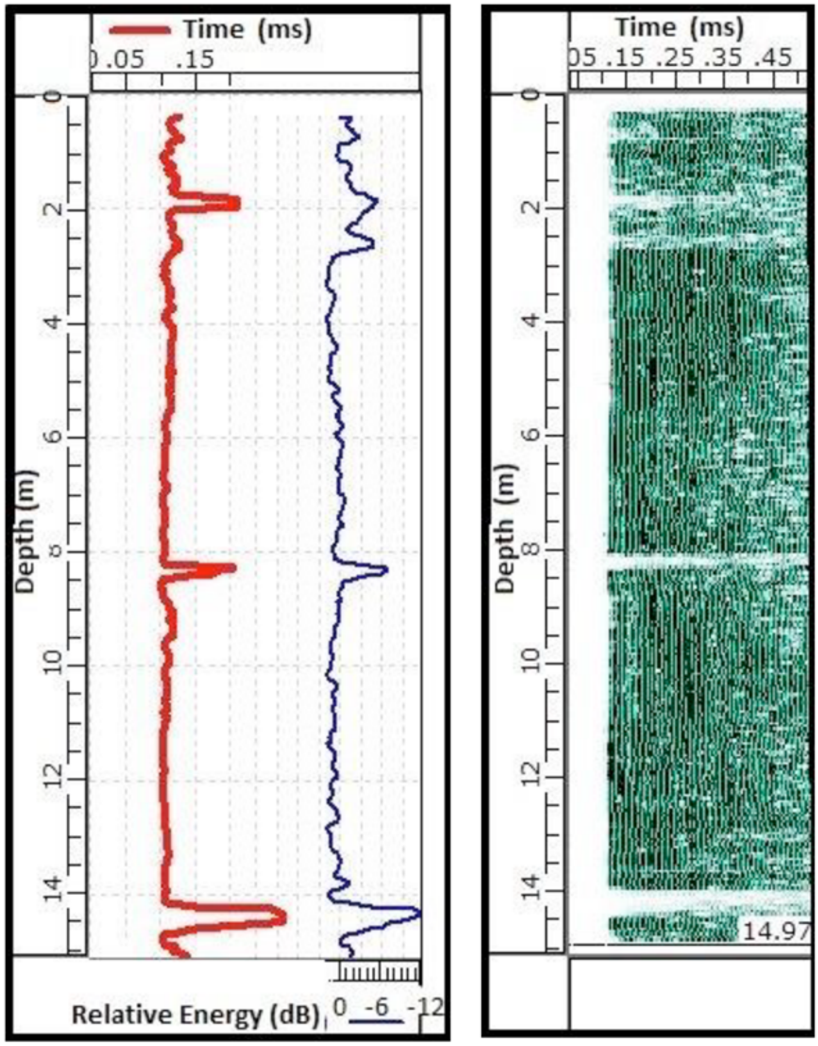

FIG. 2 Typical Ultrasonic Profile

5.2.2 For single hole tests the access tubes must be plastic tubes. Testing should therefore be performed as soon as practical in order to avoid debonding issues. Since the generated waves travel through the concrete around the access duct, unless a flaw is massive enough and very near to the access duct it may not be detected by this method.

NOTE 1—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 and inspection. 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.

6. Apparatus

6.1 *Apparatus for Allowing Internal Inspection (Access Ducts)*—To provide access for the probes, access ducts can be preformed tubes, which are preferably installed during the deep foundation element installation. The tubes shall preferably be mild steel for crosshole testing, and are required to be PVC or equivalent for single hole testing. Plastic tubes, while not preferred for crosshole testing, can be used in special circumstances if approved by the specifier but require more frequent attachment to the reinforcing cage to maintain alignment. The plastic material must not deform during the high temperatures of concrete curing. If no tubes are installed during construction, boreholes drilled into the pile or structure can be installed after installation. The internal diameter of the access ducts shall be sufficient to allow the easy passage of the ultrasonic probes over the entire access duct length. If the access duct diameter is too large it influences the precision of arrival time and calculated concrete wave speed. Access ducts typically have an internal diameter from 38 to 50 mm.

6.2 *Apparatus for Determining Physical Test Parameters:*

6.2.1 *Weighted Measuring Tape*—A plumb bob connected to a 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 100 mm. The plumb bob shall have a diameter similar to the diameter of the probes.

6.2.2 *Magnetic Compass*—A magnetic compass accurate to within 10° shall be used to document the access duct designations compared with the site layout plan. Alternately, access